**APPENDIX B**

# Honeybees in Agriculture & the Natural World

## An Illustrated STEAM Learning Book for Extension Educators Teaching 5th-7th grade Youth

Written & Illustrated by
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Illustration 1: Beekeeper checking on bees in apiary.

# Foreword

Hello! I hope you enjoy the following illustrated learning book, Honeybees in Agriculture & the Natural World. This project is the result of the combination of the popularity of pollinators (honeybees in particular) and my education and experiences. As an Extension educator, I am asked to teach about honeybees frequently. Teaching about bees is definitely one of the highlights of my job. I am a beekeeper and a graduate of the University of Montana's Master Beekeeper program. This book explains the basic science of apiculture, and paves the way to quick learning through activities and illustrations.

I painted the illustrations myself. Illustrations can explain concepts and ideas where words fail, and where photos are unclear. I wrote and illustrated this book for Extension educators and other youth leaders who want to learn the basics of apiculture and about the importance of honeybees to both agriculture and natural world without having to commit much time to research, and without having to gain a formal education in apiculture, like I did. After working through the book, you will be more prepared to answer basic questions about apiculture, and to teach basic lessons in apiculture, agriculture, and natural resources to youth.

The book provides a couple of ways to engage the 5-7th grade age group. Activities are provided to strengthen learning and develop STEAM (science, technology, engineering, art and mathematics) skills. The eight topics list learning objectives and there is one suggested activity at the end of each section. The book has 15 watercolor illustrations. Many of the learning activities refer to the illustrations.

This book can be useful to those new to apiculture and to those who already keep or know about bees. Extension educators can use the illustrations to show youth visual differences between queen bees, worker bees, and drone bees as well as what different kinds of bee hives look like rather than relying on verbal or written descriptions alone. The incorporation of STEAM activities can offer another element of development and learning to curious youth. For educators looking to expand their knowledge and explore, a list of resources is included at the end.

Happy learning!

Dominique Woodham

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Illustration 2: Pollinator planting in corn rows creates habitat, biodiversity and forage.

**1. Queen, Drone and Worker Bee.**

Youth Learning Objectives:

- Youth will distinguish and describe physical differences between worker, queen and drone bees
- Youth will recall two jobs for each of three honeybee social orders (worker, queen, drone)

Did you know there are thousands of kinds of bees in the U.S.? Honeybees are just one of the thousands of bee species in America. Honeybees also have a scientific name in the Latin language: Apis mellifera. Most of us just call them by their common name, honeybees. There were no honeybees in the U.S. until they were introduced from Europe a long time ago. European honeybees are really good at producing honey and can be cared for and managed like livestock by beekeepers. A rancher has to care for their cows; give them shelter, pasture, safety, and medicine when they're sick. Beekeepers do the same for their honeybees.

Honeybees are an amazing insect. A group of honeybees that live together in a hive are called a colony. You can think of each colony as its own village. A honeybee colony operates as a super organism. This means the bees in the colony can only survive as a colony, not as individuals. All the bees within a colony play a very important role in their colony's success and survival. Within the colony, there are three social orders of bees: queens, workers and drones. Bees within each order have very specific jobs. The queen, the workers, and the drones each have important responsibilities and are necessary for the colony to survive.

All worker bees in a colony are female and they do ALL the work in the colony. Worker bees are short, skinny, and small compared to other bees in a colony. The jobs of worker bees change as they mature. Worker bees start with simple jobs like caring for young bees and keeping the hive clean. They eventually mature to collecting food, caring for the queen, and guarding the hive. As the worker bees age, they return to jobs such as caring for young and sick bees, and keeping the colony clean and healthy.

During the summer, most worker bees live for about 6-8 weeks because flying and looking for food wears them out. Worker bees that are born in the fall maintain a honeybee colony through winter. These bees may live many months because they are not being worn out by foraging. They will not wear out as rapidly over the winter because they are clustered in a ball around the queen bee within the hive, trying to keep the colony warm. They don't fly in cold temperatures.

There is only one queen bee in each colony. Queen bees are long and skinny compared to the other bees in a colony. They have a distinct space between their large eyes similar to worker bees and are often followed by a group of worker bees. Queen bees are the only female bee within a honeybee colony that breed and lay eggs to produce young honeybees. A queen bee lives between 2-8 years. Within 3-5 days of a young queen bee hatching, she can fly up to 8 miles away breeding with 8-15 male bees before returning to her colony and beginning to lay eggs. The queen bee determines whether she will lay eggs destined to be female or male bees.

Speaking of male bees, they are referred to as drones in a bee colony. Drones are very large and blocky shaped compared to the other bees in the hive, and they have very large compound eyes. The one job of drones is to breed with a queen bee so she

can produce fertilized eggs. Upon successfully breeding with a queen bee, they die. Drones that never breed with a queen bee serve no purpose within a colony. If drones don’t die of old age (8 weeks) or any other natural and unnatural causes, the worker bees will kick them out of the hive in the fall. As non-producers within a colony, the drones are removed prior to the onset of winter so precious food and energy is not wasted on keeping drones alive throughout the winter.

Biology Questions:

Ask students to select a social order of honeybee they would like to illustrate. Ask them to describe the features that distinguish the illustrated bee and what it’s job is within the colony. Ask students if they know what a bee's job is in agriculture and nature.

Remember:

- Worker bee physical description and job: short, skinny and relatively small compared to other bees in a colony. Worker bees take care of the entire colony! They feed the colony, clean the hive, guard the hive, collect pollen and nectar, and convert nectar collected from flowers into honey.
- Queen bee physical description and job: long, skinny, space between large eyes and is often followed by an entourage of worker bees. Her job is to lay eggs which will grow into future queens, workers or drones.
- Drone bee physical description and job: These are the male bees in a colony. Their only job is to breed with a queen bee so she can lay eggs to produce baby bees. Drones are very large and blocky shaped compared to the other bees in the hive, and they have very large compound eyes.
- The job of bees in the world is as pollinators- a valuable ecosystem service.

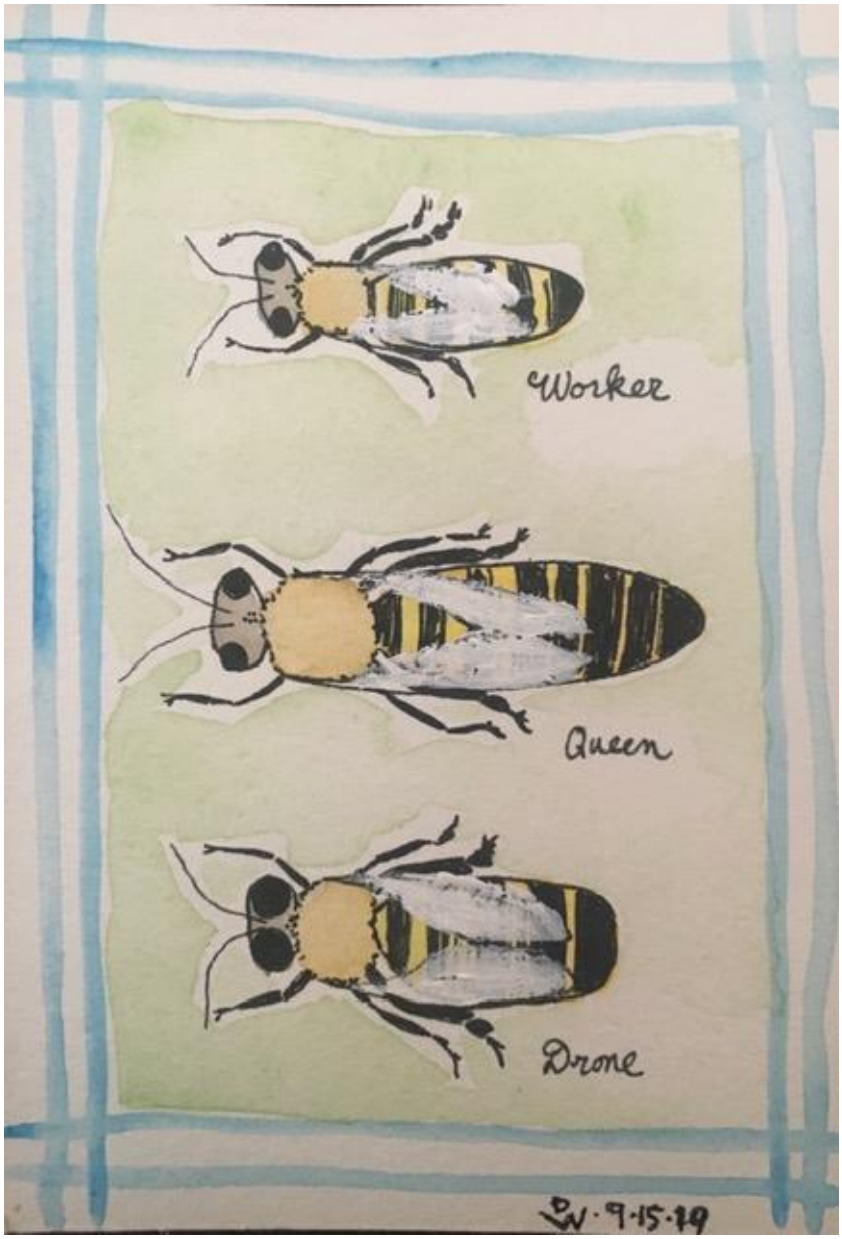


Illustration 3: Simplified illustration of a worker bee, queen bee and drone bee.

## 2. Honeybee Development and Anatomy

Youth Learning Objectives:

- Youth will identify food fed to the worker, queen and drone bees
- Youth will identify and count basic external anatomy of honeybees

Queen bees decide whether they will lay male or female bee eggs. Then once hatched, the food fed to the young larva (active but not yet developed honeybees) will determine how quickly the bees develop or grow. The four stages of honeybee development are: egg (unhatched developing young), larva (active, immature young), pupa (inactive, immature young) and adult (fully developed).

A queen bee will lay one egg per each hexagon shaped cell inside the honeycomb, laying up to 2,000 eggs a day within her beehive. The worker bees caring for young bees determine whether the female bees will become workers or future queens based on the food they feed the young larva. They eat royal jelly. This is the best food because royal jelly is very high in nutrients that bees need. Royal jelly is made by bees and if fed exclusively to female honeybee larva, will lead to the development of a future queen bee. A simple diet of honey and pollen fed to a female larva will lead to the development of a worker bee.

Queen bees emerge from their cells within 16 days of being laid due to their very nutrient and protein rich diet of royal jelly. Worker bees emerge within 21 days. Drone bees are fed a diet similar to that of a worker, but take longer to develop. Drones leave their cells within 24 days of being laid.

Honeybees are an insect so they have an exoskeleton, a hard external skeleton/shell instead of bones under skin like us. They are also fuzzy. Their

exoskeleton is made up of three main parts, the: head, thorax and abdomen. The exoskeleton plates on the underside of the honeybee's abdomen have wax glands. Wax comes out and honeybees use this wax to produce build honeycomb.

Honeybees have two sets of eyes; large compound eyes made up of many smaller optical units that see brightness and color, and five smaller eyes on top of their head called ocelli which see light and movement. Together, these sets of eyes help a honeybee travel by assessing distances and shapes. A honeybee also has two antennae on their head which are used to smell and feel.

The thorax is the middle part of the bee. The thorax is where all the legs and all the wings attach. Honeybees have six legs and four wings attached to their thorax. When viewed from above, bees have three legs on their left side, and three legs on their right, as well as two wings on their left and two wings on their right. The fore wing (front wing on both the left and right side closest to the head) and hind wing (back wing, closest to the abdomen) on each side of the thorax work together as one wing which is why it appears that honeybees only have two wings.

Anatomy and Math Questions:

Discuss symmetry with students- when one half of something is looks the same as the other half. Use a mirror to see how the left half of the following illustration of a honeybee is identical to the right half when viewed from above. Then identify and count parts of the bee (legs, wings, eyes, etc). What are other things that have symmetry (some types of flowers)? What are things that are asymmetrical (not symmetrical)? Discuss with students what the usefulness of each anatomy part is to the bee.

Remember:

- When viewed from above, the left half of the honeybee will be identical to the right half.
- Honeybees have a total of: 6 legs, 2 antennae, 4 wings (2 forewings, 2 hind wings), 2 compound eyes, and 5 ocelli. Legs help with landing and holding onto things. Antennae help with smell and interpreting through feel. Wings help bees to travel by flying. Eyes help bees to navigate with vision. These features all help a bee to seek and forage for nectar and pollen to eat.
- Things that have symmetry when comparing one half to another: squares, circles, an isosceles triangle, your face, a butterfly.
- Things that are asymmetrical: maybe a rock found on the ground, a book cover illustration, or chewed up gum.

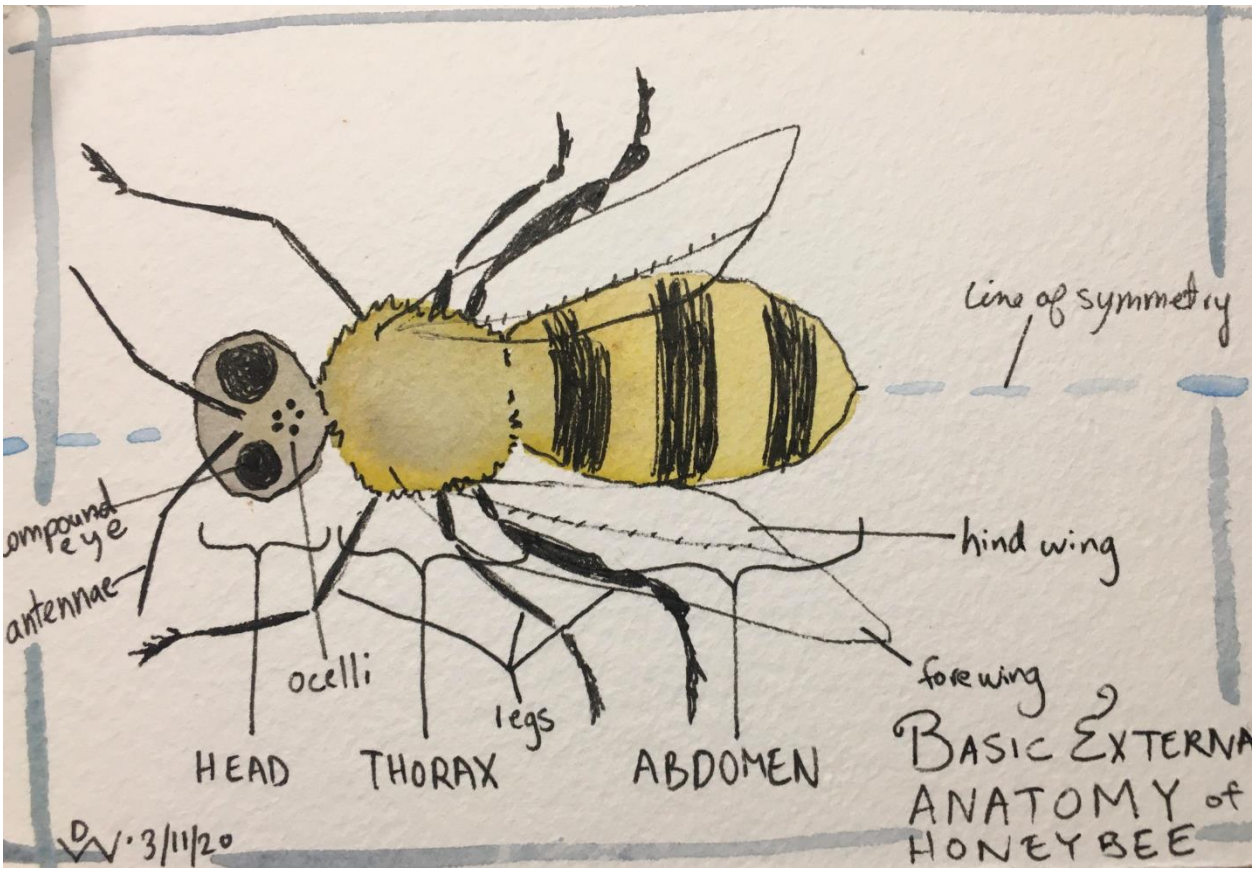


Illustration 4: Basic external anatomy of honeybee- see the symmetry?

### 3. Identifying Queen Bees

Youth Learning Objectives:

- Youth identify why honeybees sting, and why most can only sting once
- Youth recognize the vital role queen bees play in honeybee colony success

Queen bees are long and slender bees, typically longer than worker bees but not as fat as drones. Worker bees are the smaller bees in a colony, shorter than queens and smaller than drones. Drones are large in comparison to workers, and boxy when compared to queens. Their compound eyes are very large and touch each other whereas there is a space between the compound eyes of both worker bees and queens.

Queen bees and worker bees look similar but queens are long and skinny and worker bees are short and skinny. Drone bees are fatter and longer than workers, but shorter than queens. Drones are kind of blocky shaped and also have two very large compound eyes that touch on top of their head. There is a small group of worker bees that follow the queen bee everywhere, making sure she is fed, clean and well taken care of so she can focus on laying up to 200,000 eggs a day!

Queen bees are the only bees in a honeybee colony that could repetitively sting someone since their stinger is barbless, but since they only leave their colony once in their lifetime, it is unlikely to be stung by a queen bee. Worker bees will sting if they feel threatened, but can only sting once since their stingers have barbs. Barbed stingers remain stuck in the victim and as a bee pulls away, her intestines (which are attached to her stinger) are pulled outside her body, causing to her death. Drone bees lack stingers,

and instead of a stinger they have a male reproductive organ for mating with a queen bee.

Science Questions:

Ask students to identify and find the queen bee in the next picture. Can they identify the drones too? How did they tell the difference? Why should a beekeeper be able to identify which bee is the queen? What is the impact of honeybee colony losses to agriculture and the natural world?

Remember:

- Queen bees are slender and long. They are thinner than a drone and longer than a worker bee. Queens are surrounded by a group of worker bees that follow her and take care of her. If beekeepers can find and identify their queen bee, they know their colony is healthy. Without a queen bee, the whole colony will die.
- Drones are large, boxy in shape, fatter than queen bees and workers, and their compound eyes are so large they touch on top of their heads. The compound eyes of both queens and workers do not touch. If a beekeeper notices their hive is full of drone bees instead of workers, they know their colony is doomed because something happened to the queen and a worker bee started laying eggs (and worker bees can only lay male (unfertilized eggs).
- Worker bees are short and slender when compared to a queen bee or drones. Worker bees can only sting once. A worker bee’s barbed stinger will remain stuck in her victim and as she pulls away, pulling her intestines outside her body and killing her.
- Honeybees are valuable pollinators for both agricultural production and ecosystem services. Colony losses have both agricultural and environmental impacts as a result.


Illustration 5: Identify and locate the queen bee, worker bees and drone bees.

Illustration 6: Beekeeper catching a swarm of bees to rehome elsewhere.

**4. Bee Hives**

Youth Learning Objectives:

- Youth will distinguish between the homes of social and solitary bees
- Youth will be able to distinguish basic types of beehives and the bees they house

What type of beehive makes the best house for bees? When honeybees are looking for a suitable home, they really are just looking for a safe, dark space which they can begin to build wax honeycomb in and raise baby bees and store food for the winter. That dark space could be a hollow tree, inside the wall of a building, or even a dark corner of a barn. There are many different styles of human made beehives, each as functional as the next for honeybees, it just depends on a beekeeper's preference, goals and capabilities. Remember, honeybees are just one example of a type of bee. Most of the other bees in the world are solitary meaning they live by themselves instead of with other bees. As a result they need a much smaller house since they don't need to store lots of food or raise lots of baby bees like honeybees do.

Skep beehives were the original managed beehive. Skep beehives look like a basket made of grasses. Honeybees build honeycomb inside of these to raise baby bees and store food in. They are mobile, and transportable, but not convenient for close honeybee health monitoring.

The most common beehive used by beekeepers in the United States is the Langstroth hive. These are the hives people see most often in fields and in orchards. The Langstroth hive is made of stackable boxes, each of which is filled with 8-10 wooden frames. The frames are where honeybees build their honeycomb to house

developing bees and store food. These hives are easily managed by beekeepers and easy to transport which is why many professional beekeepers use them.

Warre hives are similar to Langstroth hives in many ways. They are vertically managed hives, but rather than adding empty boxes on top of the hive, the empty boxes are placed below the upper boxes. This works with the honeybee's natural tendency to build honeycomb in a downward direction.

Another popular style of hive is the Top Bar Hive. The Top Bar Hive is convenient for beekeepers not wanting to be lifting and hefting heavy boxes often. The Top Bar is essentially a long, elevated hollow space which has top bars placed inside that the honeybees will build wax comb from instead of filling in frames like in a Langstroth hive. All the hives described provide a safe dark place for an entire colony.

Engineering Questions:

Build a bee boarding house. They can be built by drilling holes into a block of wood, or by tying together a bundle of hollow reeds and straws. Talk through each step of the engineering process with students, making sure that everyone gets the opportunity to help with construction or at least external painting of the house. Explain that bee boarding houses are not built for honeybees, but solitary bees that can and like to live alone and need less space. A honeybee colony is a super organism and individual honeybees would not be able to survive alone. Bee boarding houses are built to provide shelter for any of the various other thousands of varieties of bees in the wild.

Remember:

- Honeybees are just one example of bee species in the United States. There are many species of bees in the wild- some live in holes in the ground, some live in hollow trees,

some might live in a junk pile! They are all just looking for a safe, dry place to build a nest.

- Unlike honeybees which depend on queens, workers and drones working together in a colony to survive, some kinds of bees in the wild like to live by themselves. Solitary bees are valuable pollinators just like honeybees, sometimes, they are even more efficient than honeybees!
- Bee boarding houses can be built and placed outside for bees that live by themselves.
- Remember to place the completed bee boarding houses in a sunny location and near water so they are appealing to wild bees looking for a home.


Illustration 7: Types of beehives for honeybees.

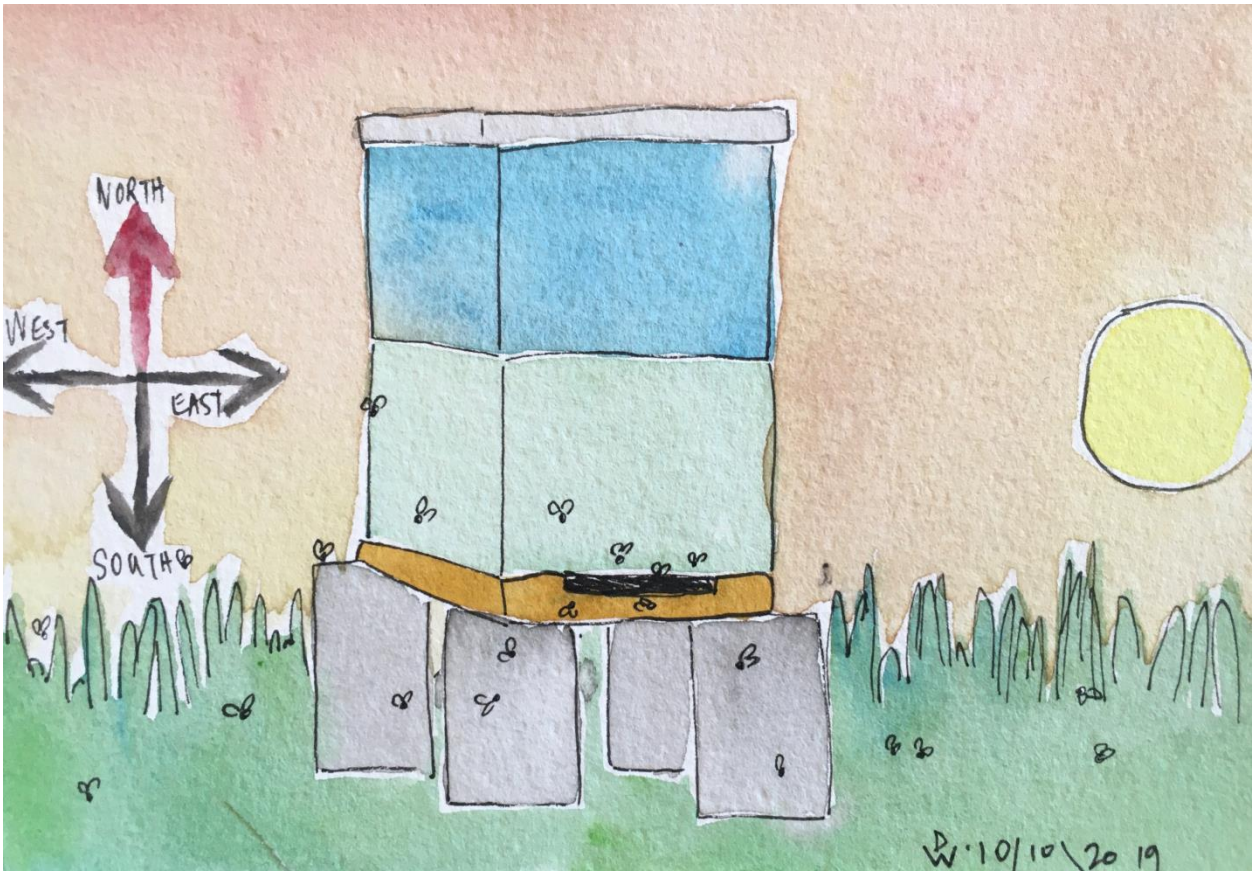


Illustration 8: Beehive positioning south east to maximize warming by sun.

## 5. Apiary Positioning & Location

Youth Learning Objectives:

- Youth will recognize the importance of following rules for beekeeping
- Youth will recognize needs of bees and identify considerations for beekeeping in rural and urban areas

Many states have rules guiding beekeeping. It is best to check with your state's department of agriculture to learn about any beekeeping rules. We have beekeeping rules to help keep bees healthy and limit the transfer of sickness between bee colonies. Some cities also have beekeeping laws for public safety. If you want to keep bees in a city (urban beekeeping), check before you get started!

It is best to place beehives where they face the south or south east. This positioning takes full advantage of the rising sun to heat the hive entrance and encourage bee activity earlier in the day. Honeybees are poikilothermic, which means that their body temperature changes with surrounding air temperature. This means that they move slowly in colder temperatures, and are more active as temperatures rise. As long as temperatures are below 50 degree Fahrenheit, bees are typically not very active, but as temperatures increase, their activity will increase. This affects where we place their hives.

Hives should be off the ground and protected from scavenging animals such as raccoons and skunks that love to eat honeybees and honey, so an elevated hive can help to keep these pests from entering the hives. The elevation also allows air to circulate beneath the hives and can help prevent the hive from rotting.

Honeybees need food and water. Honeybees can and will fly up to three miles regularly from their hive in search of food and water, potentially further. Honeybees will forage on any pollen and nectar producing blossoms. As for water, they will collect water in the form of dew, from puddles, lakes and rivers, even stock tanks or swimming pools. Some beekeepers place dishes of water near hive entrances with rocks so that the bees do not fall into the water and drown.

Both urban (big cities) and rural (smaller towns or the countryside) areas can be good places for bees to find food. Honeybees within or near urban areas feed on flowering trees and shrubs in parks and along streets, flowers in pots and window boxes, and even in urban gardens. In rural areas, honeybees forage on both native flowering forbs, shrubs and trees, as well as agricultural crops that produce blossoms.

A concern in rural agricultural areas is the use of chemicals to control pests that damage crops. Some chemicals can negatively impact honeybee health or even kill them. All chemicals have a label that clearly states the appropriate time, amount and manner which the chemicals may be applied so that the negative impacts to honeybees and other pollinators are removed or lessened.

Science Questions:

Discuss the challenges and benefits of urban compared to rural beekeeping with students. What special considerations need to be taken into account in both situations with respect to hive locations (closeness to water, forage, potential for chemical contamination)? Ask students to draw a picture of where they live and where they would position a beehive or bee boarding house if they have one and why.

Remember:

- Discuss challenges of urban beekeeping: there might be rules to follow, neighbors may not like or be scared of bees, where can you place a beehive if you don’t have a yard or live in a small apartment?
- Discuss benefits of urban beekeeping: keeping bees can help to pollinate flowers growing in window boxes or plants growing in urban gardens, there is less likelihood the bees will be accidentally sprayed by agro-chemicals used to control pests.
- Discuss challenges of rural beekeeping: wild animals might break into your hives, drought conditions can impact availability of natural flowers, hives might accidentally be sprayed by agro-chemicals being applied to crops.
- Discuss benefits of rural beekeeping: potentially wide variety and diversity of flowering plants to forage on, more space to keep bees and less likely they will irritate neighbors.

Illustration 9: Beekeeping in rural and urban locations.


Illustration 10: A honeybee foraging and pollinating an almond blossom.

## 6. Pollination

Youth Learning Objectives:

- Youth will distinguish pollination from gathering nectar
- Youth will recognize the value of bees in pollination

Pollination benefits the natural world and humans. This makes it an ecosystem service, or a natural benefit to others by simply existing. Pollination is considered an ecosystem service provided by honeybees and other pollinators. Pollination is the act of fertilization. The transfer of male parts of a flowering plant to the female parts. As pollinators visit multiple flowers, seeking food, they often end up pollinating the flowers they visit as a result. About 80% of the flowering plants in the world rely on pollinators (like honeybees) for fertilization and plant growth.

Pollinators are organisms (like honeybees) that transfer pollen between flowers, helping to pollinate. There are thousands of pollinators; some examples include hummingbirds, bats, beetles, ants, bees and wasps. Honeybees are very efficient and effective at pollination due to their natural foraging behavior. A honeybee collects and consumes both nectar (juices produced by flowers) and pollen (powder from male parts of flowers) from flowering plants. Nectar is the carbohydrate energy source that honeybees convert into honey, and pollen is a protein energy source for honeybees. What is not consumed or fed to other bees is stored in cells within the wax comb inside a bee hive for later.

As honeybees forage on a flower for nectar and/or pollen, pollen granules will stick to the honeybee's body. Then when the honeybee leaves that flower and lands on another flower to feed, the pollen granules stuck to her body may come into contact with

the female parts of that next flower, thus fertilizing the flower. Honeybees are very efficient at pollination because they will fly between many flowers of the same variety on any one foraging trip outside the hive; spreading pollen granules between many flowers.

Science Questions:

Demonstrate pollination by using a cotton ball (which represents the honeybee) to transfer glitter sprinkled on one faux flower to another. Then ask students to illustrate the male and female parts of a flower, and describe where bees gather nectar and pollen from, place glue and glitter in the appropriate locations to indicate pollen (anthers of flowers, legs of bees, etc). Discuss why pollination is a valuable ecosystem service and if youth can identify any foods they enjoy that require pollination to produce a crop.

Remember:

- The cotton ball, glitter and faux flowers teach how the honeybee transfers pollen between flowers. To show how fertilization works, the illustration of the male and female parts of a flower is necessary.
- On the student's illustration of male and female parts, you as the instructor will place glue and glitter on the male pollen producing parts of the flower and glue a glitter covered cotton ball to the illustration to indicate how the honeybee transferred the pollen to the female part of a flower. This will help keep the associated mess with glitter and glue to a minimum.
- Pollination is a valuable ecosystem service because so many flowering plants in nature and agriculture could not produce reproduce without pollinators.

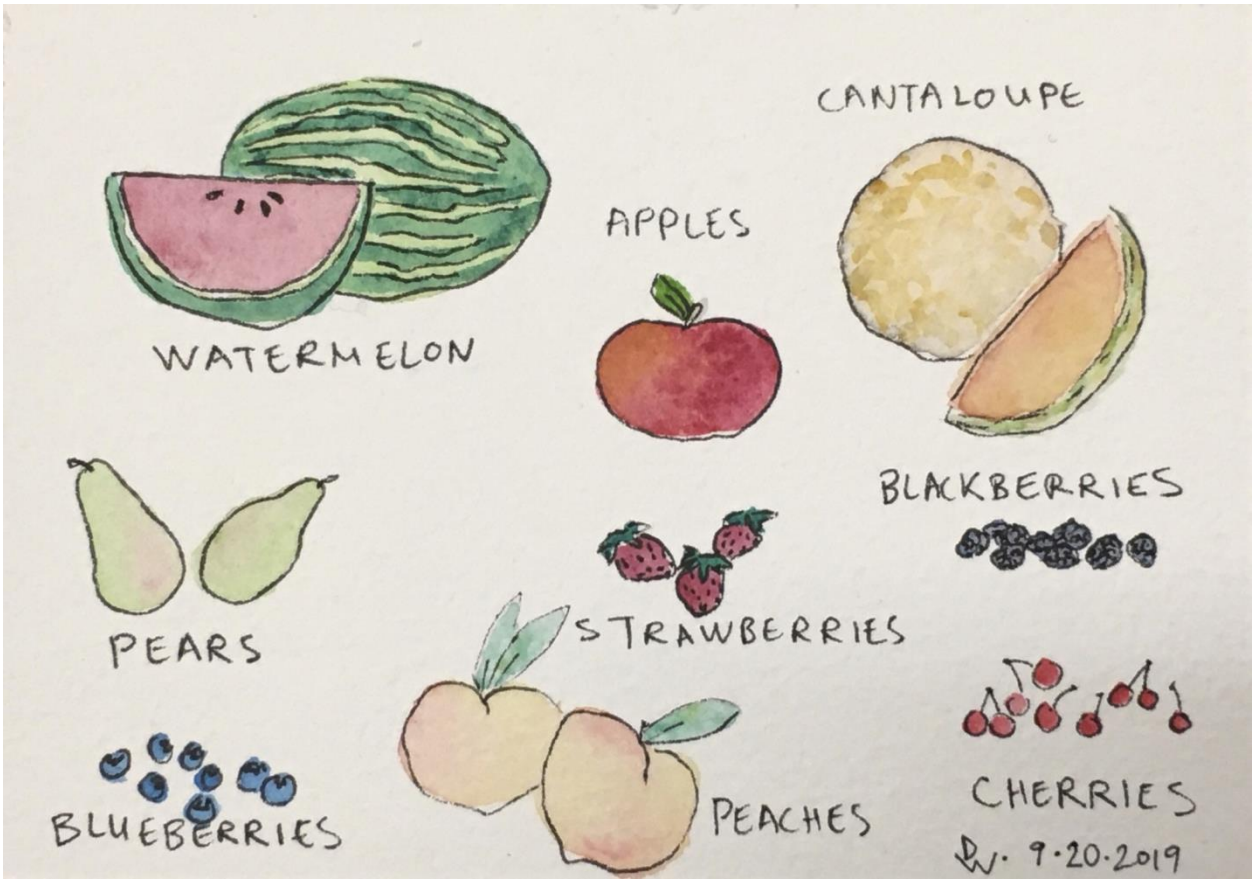


Illustration 11: Fruits dependent upon pollinators for pollination.

## 7. Migratory Beekeeping

Youth Learning Objectives:

- Youth will describe migratory beekeeping through the story of pollinator dependent crops and draw a possible beekeeper migration route for their geographic area
- Youth will describe how diverse diets help keep bees strong and healthy

One example of a pollinator dependent crop is the almond. Almonds grow on trees. To produce an almond, a flower blossoming on an almond tree must first be pollinated. 80% of the almonds grown in the world, are grown in California. When those almond trees bloom, over half of the honeybee colonies in the U.S. are transported to California for pollination services.

Managing honeybees for pollination services has become profitable. Pollination services are needed by certain farmers (like almond farmers) growing produce that is cross pollination dependent and cannot readily be open pollinated. Honeybee pollination services are a by-product of their natural foraging behavior. Beekeepers are able to make money on this behavior by transporting their honeybee colonies between different farms requesting pollination of their crop. The beekeepers then charge the farmer requesting pollination services a fee per each colony needed for pollinations.

The following calendar describes one example of a potential migratory beekeeping route. Not all migratory beekeepers follow this specific rotation or calendar. Some beekeepers travel to other states at different times, and have contracts to pollinate other crops. This just helps to describe when and where the bees are being moved, and why.

| Month | Where | Crop |
|---|---|---|
| February-March | California | Pollinating almonds |
| April-May | Oregon or Washington | Pollinating cranberry bogs, blueberry fields, apple and cherry orchards |
| June-September | Montana or North Dakota or South Dakota | Rest and recover; but will still pollinate anything they come into contact with |
| October-February | Texas or Southern Idaho | Texas for the winter where it is warmer, or kept in climate controlled storage facility like those used to store potatoes in southern Idaho |

Map and Science Questions:

Honeybees produce the most honey while they are, “resting and recovering,” from their migratory journey and contracted pollination services. Ask students why they think this is? Research migratory bee routes in the United States and ask students to draw a map illustrating the routes and the crops in each location that require pollination services from managed honeybee colonies (examples include almonds in California, blueberries in Maine, oranges in Florida, etc).

Remember:

- This activity can be strengthened with place based learning. Are there crops dependent upon pollination in your area? If so, emphasize this in your activity.

- Honeybees are stronger and healthier, and produce the most honey while they are resting and recovering from intense single crop pollination services. Why? They have a more diverse diet rather than feeding on a single source of food, and are healthier as a result. They are also expending much less energy to forage since they are not competing with as many other bees for forage.

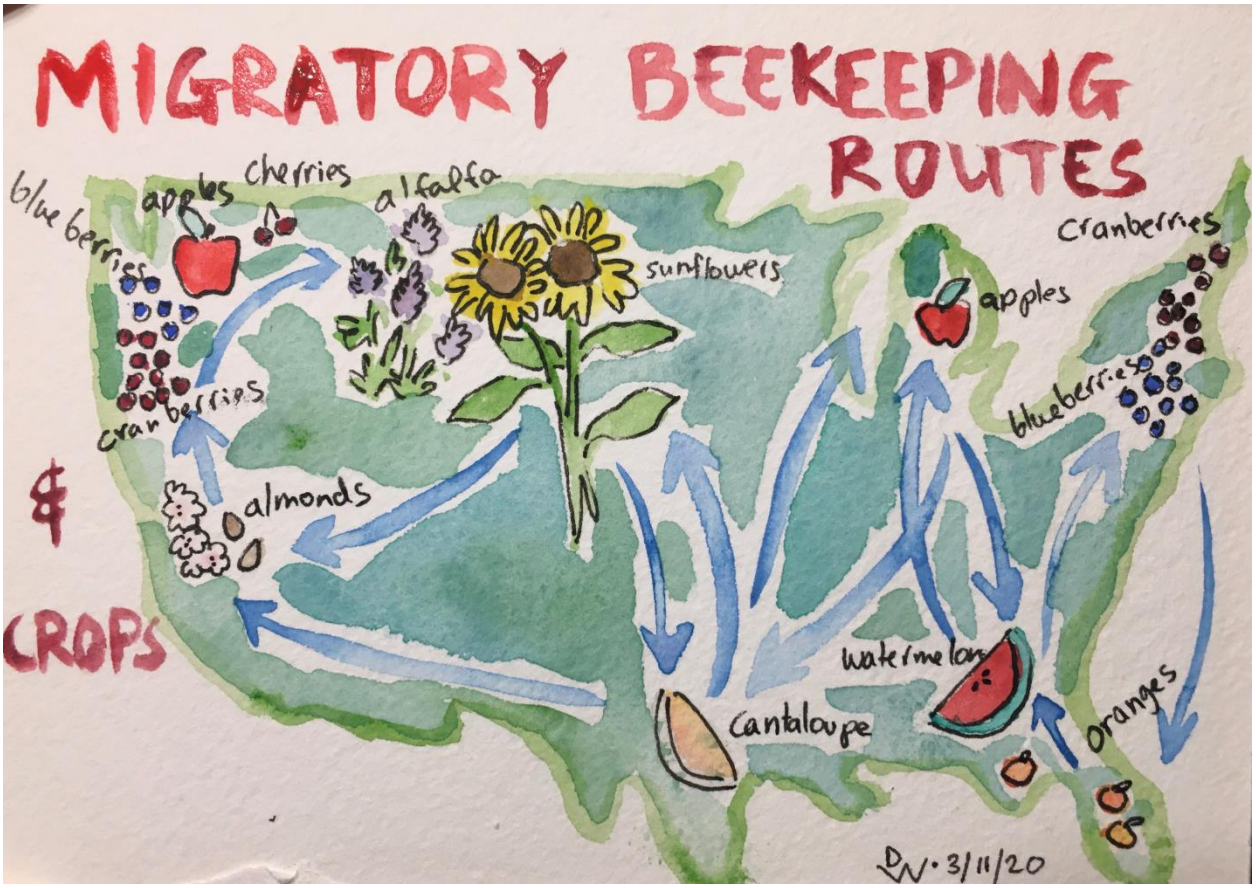


Illustration 12: Example map of migratory beekeeping routes in the U.S. and crops to be pollinated.

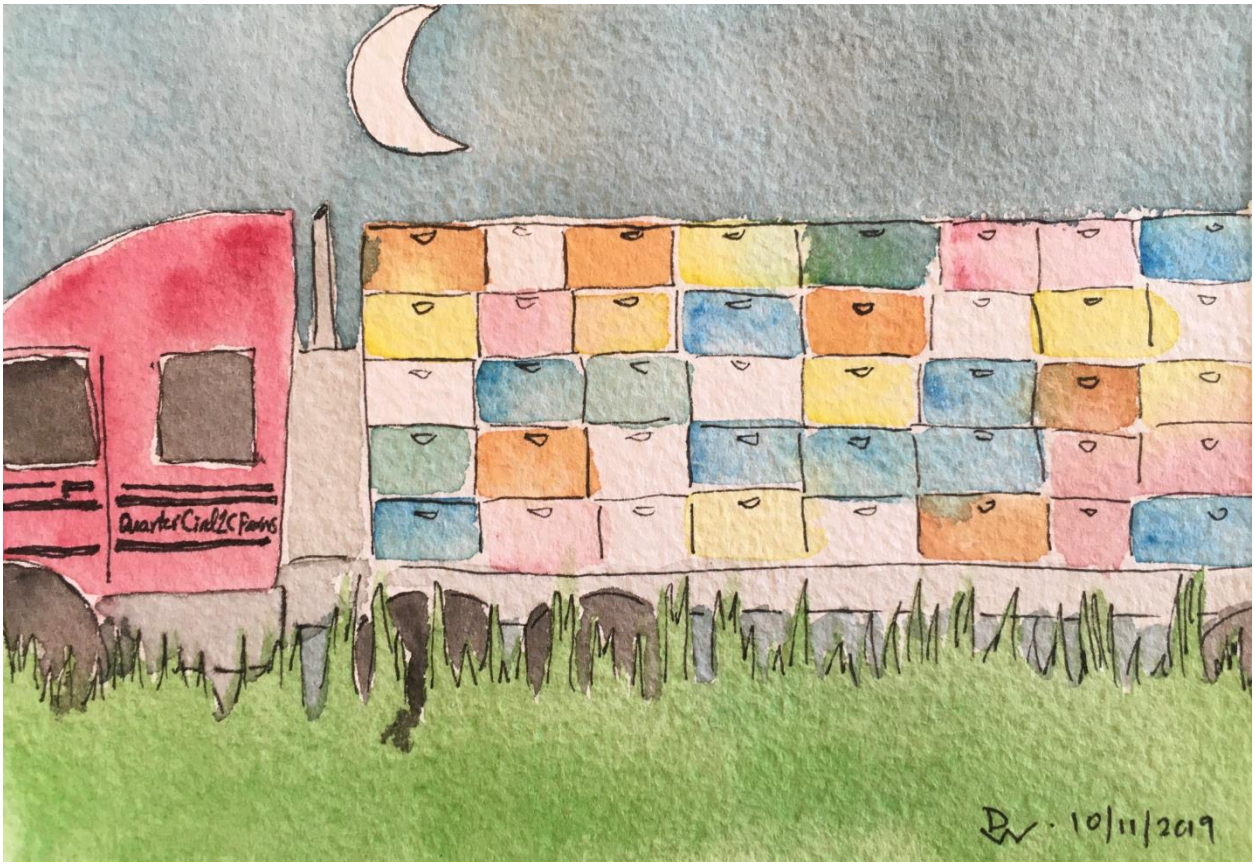


Illustration 13: How migratory beekeepers transport beehives across the U.S.

**8. Overwintering Bees**

Youth Learning Objectives:

- Youth will be able to list three ways that honeybees survive winter conditions
- Youth will describe what the infrared illustration shows in relation to monitoring overwintering hives

Bees live under cold conditions as long as they are healthy and have a food supply. Some beekeepers help their bees during cold winters by feeding them, providing wind breaks, and insulating the hives. The combination of cold and wet conditions can negatively affect honeybees, but cold conditions alone can be survived.

Honeybees survive cold temperatures by several ways. They can cluster into a ball for warmth. The queen is always positioned at the center of the cluster, while worker bees shiver to build heat and warmth, taking turns rotating from being on the outside of the cluster (colder) to the center (warmest). The colder it is, the tighter the cluster. As temperatures rise, the cluster loosens, eventually dissolving as bees begin to venture outside the hive.

Bee hives should not be opened for inspection unless temperatures are above 45 degrees Fahrenheit. With advances in technology, beekeepers can now monitor bee conditions throughout the winter without opening their hives and exposing their bees to the cooler temperatures.

Technology Questions:

Beekeepers can monitor their hives using infrared technology. Infrared technology allows us to see images of heat energy, something we can not visually see otherwise. This imagining can help search and rescue to find people they would not otherwise see

in the dark, or help firefighters to find hot spots on a fireline that do not have flames and are no longer producing smoke. Based on the illustration showing an infrared photo of a bee colony, ask students to describe observations and what the technology helps them to see. Ask the students to illustrate what they think might be happening within the hive from the infrared illustration.

Remember:

- During colder temperatures, such as in the fall or winter, bees cluster together for warmth. Worker bees form a ball with the queen at the center (the warmest part of the cluster) and the bees surrounding her shiver to produce heat. The workers take turns rotating from within the cluster, to the outside, so that each has a chance to be warm after being on the outside of the cluster where it is cooler.


Illustration 14: Illustration of a beehive viewed via thermal imaging.

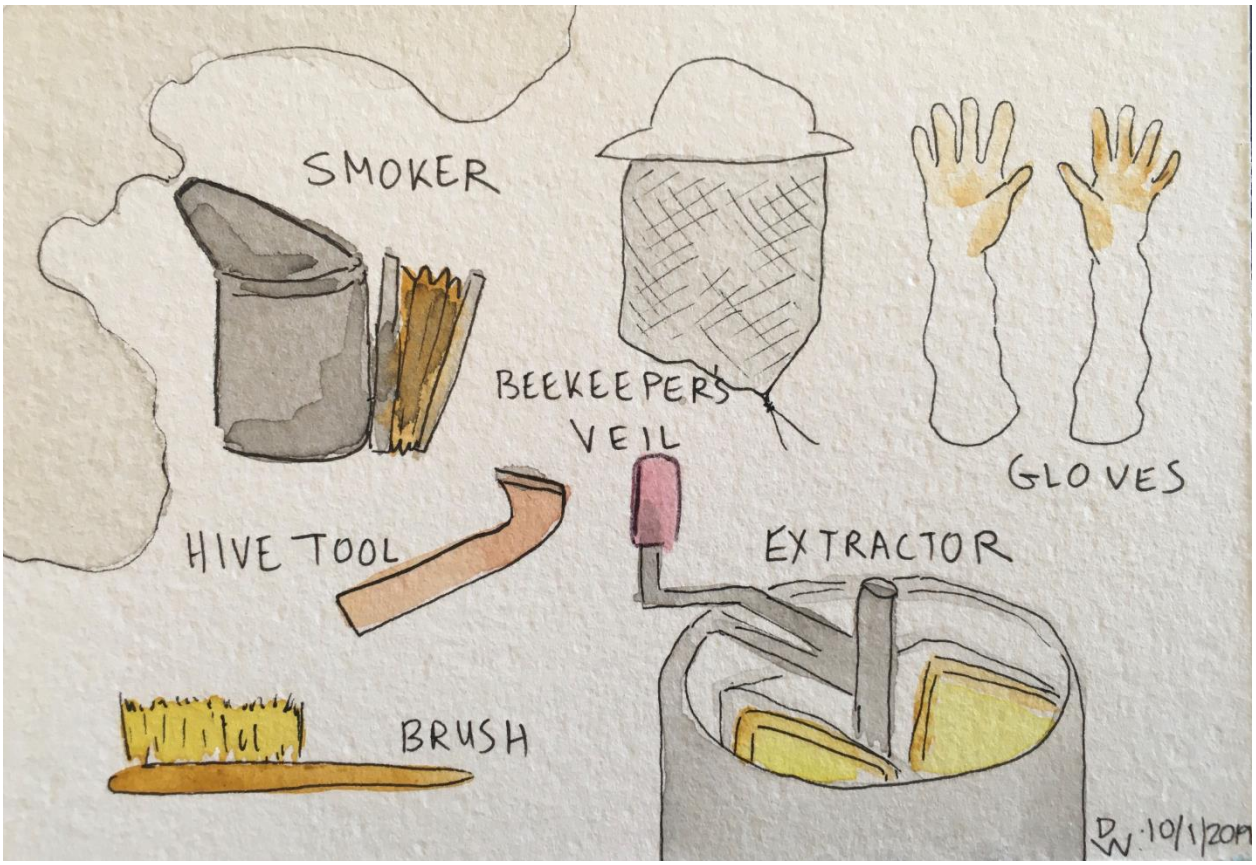


Illustration 15: The basic beekeeping tools needed to manage honeybees.