



Honey Bees as Pollinators, Their Habitats and Products

The European honey bee (*Apis mellifera*), also known as the common or western honeybee (Figure 1), is the most influential insect for humankind, both in history and in the honey and wax resources it provides. For example, beeswax was among the first plastics to be used, along with other natural polymers. It has been in use for thousands of years, being found in ancient Egyptian tombs, wrecked Viking ships, and Roman ruins. Records of honey use and production are even older. An 8,000-year-old cave painting in Valencia, Spain, depicts humans foraging for honey.



Figure 1. Honey bee (*Apis mellifera*).

Honey was the primary sweetener for humanity until production and extraction of sugar occurred in India and China around the seventh century. Sugar took another 500 years to gain much use in Europe. With the importance of wax and honey, it shouldn't be surprising that honey bees developed in association with humans, eventually being domesticated, somewhat like livestock, dogs and poultry. The information on honey bees is vast, with many books written annually, research programs conducted, college courses taught, conferences held, and thousands of beekeeping groups gathering regularly around the world.

The European honey bee was considered domesticated when it was brought to North America. However, it quickly established populations in the wild, thus becoming feral. As a nonnative pollinator, it assuredly influenced the ecological balance of other native pollinators and the floral resources. The ecological balance was further complicated as European settlers introduced new agricultural crops and cultivation methods, gradually moving across all of North America. Honey bees were likely more prized for their honey and wax than their pollination services, but it was understood they benefited the productivity of certain crops. Thus honey bees have coevolved with North American agriculture. In an interesting twist, in total the beekeeping industry now receives more income from a hive's pollination services than from honey. Honey bees are important in a typical Missouri garden, but native pollinators play an even more vital role. Estimates on how much pollination honey bees perform in a typical Midwest landscape, respective to all the other pollinators, vary widely, from 5 to 30 percent. However, as a single species, they are the most important pollinator.

Ask the average person to identify a pollinator insect, and the response will likely be "honey bees." In addition to knowing honey bees as pollinators, people are becoming increasingly aware of their plight, which was brought to the forefront with the colony declines led by the colony collapse disorder in 2006. So, the public knows the importance of the honey bee and would like to do something to help it. This desire creates an opportunity for conservation efforts on two fronts. First, gardeners can make a difference by increasing habitat favorable to pollinators and reducing insecticide use. Second, citizen efforts to make changes through local

Topics inside

Characteristics and life cycle of the honey bee	3
Natural habitats.	4
Artificial habitats.	5
Honey bee communication.	6
Which type of beehive is right for you?	11
Controlling bee pests.	13
Q&A on feral honey bees in the Midwest.	17
Value of pollination by honey bees.	19
Products from the hive	21
Should you keep bees?	23

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action or changes in public policy can be galvanized around efforts to save the honey bee. Iconic symbols such as the bald eagle and the polar bear have been used to push broader conservation efforts. In Missouri, the two insect symbols used to motivate the public are honey bees and monarch butterflies. Conservation efforts that benefit them will help all pollinators. This publication fully explores the honey bee, from its life cycle, to its various races, to its pest problems, the benefits it provides, and how we can aid its success.

Honey bee history

The honey bee (*Apis mellifera*) is the Missouri state insect and the only honey bee species native to Europe. The first hives sailed the Atlantic in 1622 with European settlers, along with their other livestock and few personal belongings. A source of wax for candles and weather stripping, and honey for mead (an alcoholic beverage created by fermenting honey with water), bees had a long-established history with Christian monasteries until Henry VIII closed them at the beginning of the Reformation.

Honey bees soon preceded white European settlers across the continent, earning themselves the Native American nickname “white man’s fly.”

In the North American colonies, honey bees were originally confined to wild hives in hollow trees. A 1641 court case in Massachusetts provides the first documented practice of controlled beekeeping. Honey hunting, or following a bee back to its hive, remained the most popular way of obtaining honey until the end of the 18th century.

Beeswax was the prevailing hive product. It was even accepted as currency in Tennessee to pay taxes in the late 1700s because of a money shortage.

Honey bees increased their range through swarming and by 1800 were reported in Missouri, Indiana, Iowa and Illinois. Hunting wild bees became a favorite late-summer pastime with campers, who were gone for days as they looked for trees with bees they could bait, cut down and harvest.

By 1839, Missouri’s and Iowa’s ragtag militias were mobilizing to fight each other over who owned a wild river bottom full of wild bee trees claimed by Missouri’s Franklin and Van Buren counties. By 1850, property markers were set every 10 miles, putting an end to the Honey War, a dispute dubbed the silliest war in U.S. history.

Rev. Lorenzo Lorraine Langstroth’s 1852 patent of a top-opening hive with removable frames hung $\frac{5}{16}$ inch apart launched beekeeping into an organized, commercial venture. Bees could be bred for temperament and production; wax could be easily collected and reused. The invention of wax comb foundation in 1857 and the centrifugal honey extractor in 1865 continued to develop beekeeping into a business opportunity.

About the same time, Italian queens were imported to the United States to improve the lineage of the original bee colonies, which were reportedly nervous, irritable and susceptible to European foulbrood disease. Large quantities of queen bee stock were imported until 1922, when imports were prohibited to try to stop the introduction of the acarine mite into North America. The first bee laws in the U.S. were enacted in 1883 to establish methods to control bee diseases.

By the early 1900s, Missouri was fourth in honey production nationwide and third in the number of bee hives on farms.

The Golden Age of Beekeeping ended at the beginning of World War I. Interest in bees became increasingly commercialized, and small farm apiaries declined. But beekeeping as a hobby was on the rise. After World War I, improved roads and more efficient cars led to the expansion of commercial beekeeping.

Major agricultural changes took place in the 1950s, shortly after World War II, when tractors replaced horses, chemical fertilizers replaced organic manure, aerial application of pesticides became commonplace, and farmers became increasingly

White man’s fly

Honey bees preceded white European settlers across the continent, earning themselves the Native American nickname “white man’s fly.” This term for honey bees, used by the Cherokee and other indigenous cultures, is attributed to John Eliot. Eliot, who was translating the Bible into Indian dialects, also discovered that these peoples had no words for honey or wax. As swarms of honey bees made their way across the continent, however, some tribes, such as the Cherokee in Georgia, quickly adapted to raiding their nests for the sweet liquid gold within.

conscious of business costs. These changes combined with demands to produce more on less acreage caused farmers to turn to pesticides to increase yields. The increased use of pesticides led to the requirement in 1972 that pesticide applicators be certified. The certification process was designed to ensure pesticide users used best practices, including minimizing exposure to bees.

A series of bee diseases that swept the U.S. encouraged most states to implement colony inspections programs. By 1998, most states required movable frames for bee hive inspections. Although basket-woven beehives, called skeps, are often used to represent beekeeping and are not illegal per se, movable frames don't fit in skeps, so skeps are no longer used in mainstream U.S. beekeeping (Figure 2).

During the winter of 2006–2007, bee colony losses jumped from an average of 10 percent to an average of 30 to 90 percent. First called the fall dwindle disease, the phenomena was renamed colony collapse disorder (CCD) because of two unusual characteristics: bees failing to return to hives, and rapid bee colony losses in uncharacteristic large numbers. Some 10 million hives were lost to CCD from 2006 to 2013.

Most of Missouri's feral bee colonies, once twice the population of domesticated bee colonies, were also wiped out in 2006. The feral bee colonies were survivor stock that bred with managed hive populations and helped to maintain the state's honey bee population's genetic diversity. The losses also impacted farmers, who once relied on feral bees for crop pollination but now had to seek pollination services or begin keeping bees themselves.

In 2008, the U.S. temporarily lifted import restrictions to introduce new bee genetics from Australia in an attempt to strengthen U.S. bee populations and provide bees to pollinate California almonds. By 2010, the importing of *Apis cerana*, an Australian bee species, was prohibited for fear of introducing exotic bee diseases and parasites.

By 2015, overuse of pesticides, poor nutrition, and viruses associated with the varroa mite were accepted as major CCD contributors.

In 2016, there were 125,000 beekeepers in the U.S. Of those, 1,600 were commercial beekeepers that were producing 60 percent of the honey while the rest was supplied by hobby (25 hives or less) and part-time (300 hives or less) beekeepers. Commercial beekeeping has evolved from keeping bees for products to raising bees for sale.

Characteristics and life cycle of the honey bee

The body color of *A. mellifera* subspecies varies from light brown to black. The body is covered with hair, with less on the abdomen. The abdomen has varying degrees of alternating black and orange-yellow rings. The legs are mostly dark brown to black.

Honey bees undergo complete metamorphosis and have four life stages: egg, larva, pupa and adult. A queen lays fertilized and unfertilized eggs. Each fertilized egg develops into a female and, based on diet, becomes either a sterile individual called a worker or a fertile individual called a queen. Unfertilized eggs develop into males, or drones. Adult honey bees vary slightly in size. The queen is largest, at 18 to 20 millimeters (mm) long.* The drones are 15 to 17 mm long. The workers are 10 to 15 mm long.

Some key morphological traits of a honey bee worker are corbiculae, wax glands and a stinger. Corbiculae, also called pollen baskets, are structures on a honey bee's hind legs that are specialized to carry large amounts of pollen back to the colony. On the underside of its abdomen, a honey bee has glands from which it produces wax scales that are used to make the colony's wax comb. Workers also possess a barbed stinger that is attached to a poison sac. When impaled into a person or animal, the stinger remains imbedded as the worker flies away, resulting in the bee's death.



Figure 2. A skep.

Metamorphosis and morphology

Metamorphosis refers to the physical change in form that occurs during an animal's development. Morphology deals with the form and structure of an organism or any of its parts.

* Measurements in this publication are given in millimeters because small measurements are more easily expressed in millimeters than in inches. One millimeter (mm) is less than four-hundredths of an inch (1 mm = 0.03937 inch).

Eusociality

A eusocial society is defined by three characteristics:

- Reproductive division of labor
- Overlapping generations
- Cooperative care of the young

Why bees make honey

Bees make and store honey for use during the winter, when they depend on it for survival. Bees in warmer climates do not need as much honey as those in cold climates, so they need fewer worker bees and thus have smaller colonies.

How many flowers?

Honey bees visit 2 million flowers and fly more than 55,000 miles to produce 1 pound of honey.

A worker bee produces one-twelfth of a teaspoon of honey in her six-week lifetime.

On average, each U.S. resident eats about 1.3 pounds of honey a year.

The abdomen of the queen is longer and larger than that of a worker. Also, the queen's stinger, or modified ovipositor, has no barbs or much smaller barbs, and she will not die after using it. Drones have a larger head and thorax than do workers and queens. The drone has large eyes that nearly meet at the top of its head, and a large abdomen with a blunt tip instead of a stinger. (See *Why bees sting* on page 9.)

Honey bee nests usually consist of several parallel layers of wax honeycomb. The combs are held vertical, and each consists of two layers of hexagonal wax cells laid back to back. These cells are used to rear young bees and to store honey and pollen. A wild, or feral, colony of *A. mellifera* usually has between 14,000 and 25,000 members, whereas a domesticated colony can have up to 60,000 members.

Honey bees display eusociality and live in colonies whose members are comprised into different adult castes — queen, drone, worker — based on a division of labor. The only purpose of the drones is to mate. They do no colony work and are fed by the workers. A colony usually has only one queen. After the queen takes her nuptial flight, during which she mates with several drones from other colonies, the only work she performs is egg-laying. The bulk of colony maintenance rests with the workers. At different ages, the workers perform different tasks. For example, newly emerged workers will usually clean out old brood cells and feed developing larvae. As they age, workers take on the tasks of building wax cells and honeycomb and attending to the queen by feeding and grooming her. The oldest of the workers are the ones seen leaving the nest to forage for nectar and pollen.

Honey bees form a new colony through the process of swarming. This behavior typically occurs only in the spring and early summer, when new queens and drones are produced. Before the adult virgin queens emerge, the original queen and about two-thirds of the workers leave the colony and establish a new nesting site, usually in an enclosed cavity or other protected location. At the original nesting site, the emerging virgin queens will fight until a single queen remains alive. After a short time, the remaining queen will leave the nest and go on several nuptial flights in which she mates with many drones. This is the only mating the queen will engage in for her entire life. The sperm she collects is nourished and kept viable in her spermatheca for two to three years. Once mated, the new queen begins laying eggs and building up the colony. Any virgin drones remaining in the nest are forced out of the nest and eventually starve.

During late-fall and winter, honey bees, unlike other insects, do not die or hibernate. They remain somewhat active inside the nest and keep warm by feeding on stored honey. If they run out of honey before the spring, however, they will starve to death.

Natural habitats

Honey bees nest inside large hollows, or cavities (Figure 3). These cavities may be found in trees, logs and rocky cliffs. Inside such a cavity, vertical rows of wax comb are suspended. The queen bee lays eggs, and worker bees store pollen and honey in these wax combs.

Honey bees visit a wide variety of flowering plants to obtain nectar and pollen as food for themselves and their colony. Natural habitats that provide nectar and pollen throughout spring and summer are particularly important for colonies to thrive and grow. In general, trees and shrubs provide early pollen and nectar, and



Figure 3. Wild honey bee colony in a tree.

herbaceous plants such as clover provide pollen and nectar later in the season. The most common nectar sources for honey bees in North America, from most to least common, are clovers, asters, lindens, berries, locust, cucurbits, dandelion, goldenrod, maples, mustards and ragweed. In addition to pollen and nectar, honey bees require a source of water nearby, within half a mile.

Artificial habitats

Humans have experimented for many generations to develop an abode for honey bee colonies where access to combs of stored honey was dependable and convenient. The earliest hives, developed in Europe and Africa, were essentially replicas of the honey bee's natural home. Hollow logs were used initially, but bark, wood slats, cork, rushes, pottery and coiled rope were used later to construct various kinds of transportable hollow spaces in which honey combs could be built. The main drawback of these early hives was that the bee colony had to be completely disrupted or even killed to harvest the honey. Hives that would allow harvesting of pure honey without destroying the colony still needed to be developed. In particular, a hive design was needed that would allow a beekeeper to easily open and close the hive and remove combs without disturbing the egg-laying queen.

The design that has become the modern global standard for keeping honey bees is the Langstroth hive. As previously mentioned, this hive design was patented in the United States in 1852 by L.L. Langstroth. The design includes many features that were developed through trial and error by 19th century gentleman-scholar-farmers in upstate New York. The Langstroth hive has allowed beekeepers to both harvest combs of pure honey and move honey bee colonies into areas where they are needed for pollination.

The Langstroth hive consists of the following elements: outer cover, inner cover, super, frames, excluder, hive body, bottom board and hive stand (Figure 4). Langstroth based the structure on the principle of bee space. Bee space is the space between hive elements that honey bees leave open for movement and work. It is equivalent to $\frac{5}{16}$ inch. Honey bees fill spaces in the hive that are larger than $\frac{3}{8}$ inch with wax comb, and spaces less than $\frac{1}{4}$ inch with propolis, which is a glue or sealant collected from tree sap. By using a $\frac{5}{16}$ -inch gap between the elements inside his hive, Langstroth was able to design an abode that featured easily removable combs and could be opened and closed with ease.

Each of the components of a Langstroth hive occupies a specific location and has an important function. The hive stand supports and elevates the hive off the ground and keeps the insides dry and away from ground-dwelling invaders. Above the

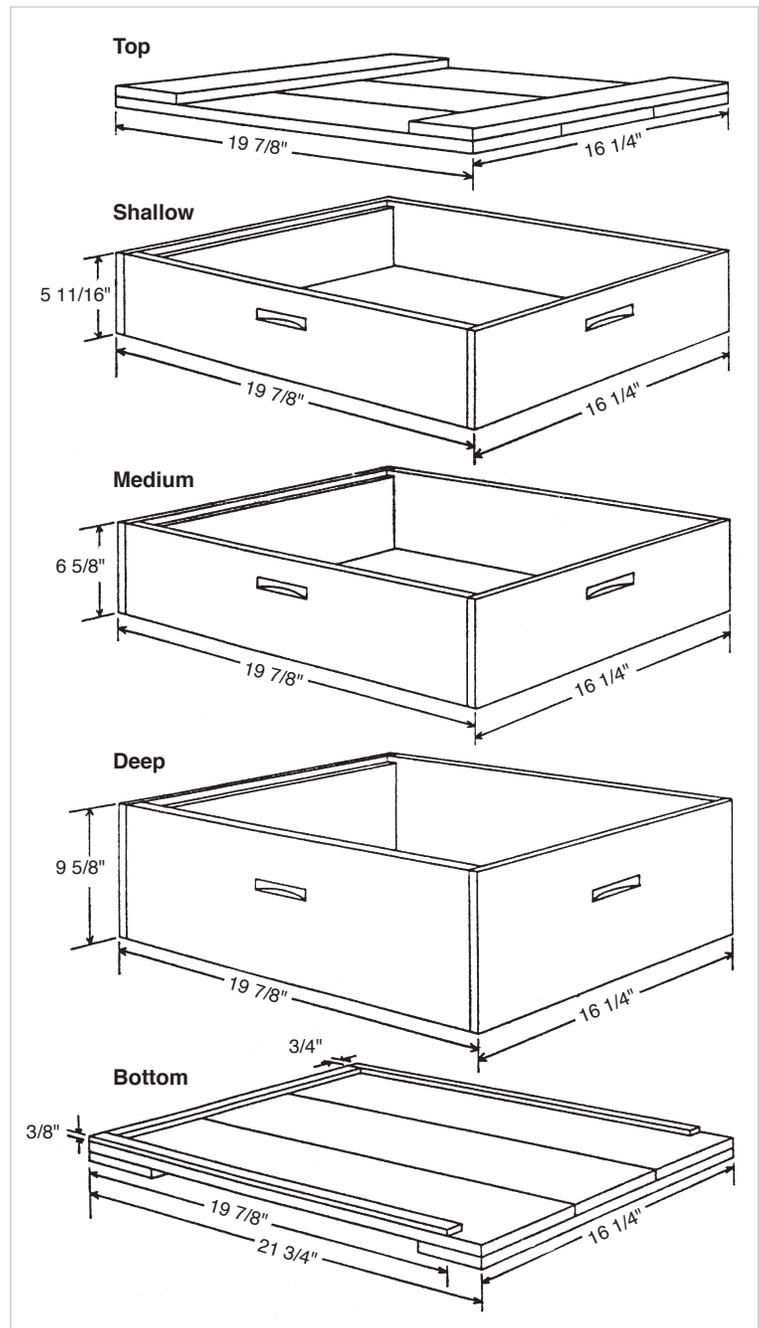


Figure 4. Some parts of a Langstroth hive.

Sharp eyesight, the honey bee's superpower

If honey bees had a superpower, it would be their eyesight. With their three simple eyes and two compound eyes, honey bees see farther along the color spectrum and see flowers differently than we do.

The two compound eyes have thousands of facets, or tiny lenses that respond to light, including polarized light. Polarized light gives bees a map in the sky, providing navigation even when the sun is not shining.

The three smaller eyes in the center-top of a bee's head are called ocelli, Latin for "little eyes." Those little eyes enable the bee to judge light intensity and stay oriented. Using these ocelli, bees can gather light and see ultraviolet (UV) light, helping them to detect UV flower colors.

Bees see a wider spectrum of UV light than people do. UV patterns on flower petals guide bees to the nectar and pollen. Studies have shown one of the reasons weeds are more successful than other plants in attracting pollinators is because of their distinct UV markers. Deprived of UV light, bees lose interest in foraging and will remain in the hive until they are forced out by starvation and severe food shortages.

hive stand is the bottom board. Three sides of the bottom board are 1½ inches tall, but the fourth side is divided to create a bee space-sized hive entrance between the hive stand and the lower edge of the hive body. The hive body sits on the bottom board. It is a 9½-inch-tall topless and bottomless box that serves as the chamber where the queen lives and lays eggs. An excluder sits on top of the hive body. The excluder is a wire, plastic or sheet metal grid that provides narrow spaces through which worker bees can pass, but excludes the larger drones and egg-laying queen from getting on the honey combs.

The honey combs are found inside the supers, which sit above the excluder. A super is a topless and bottomless box, similar to the hive body, in which honeycombs are produced and honey is stored. Several supers can be stacked on top of one another, if needed, to accommodate all of the honey produced by the colony. An inner cover sits above the highest super to create bee space there. This cover has openings to allow air circulation, which regulates moisture in the hive. On top of the hive sits an outer cover that is covered with sheet metal. It telescopes down over the inner cover and top few inches of super to protect the hive from the weather and elements.

Inside the supers and hive body are self-spacing frames made to hold the honeycombs and brood combs. The frames are thin wood rectangles. The width of these frames and the way they are suspended in the hollow boxes creates a space of ⅝ inch between them — the equivalent to bee space. Ten frames sit side by side within each super or hive body. Because of their spacing, each frame is removable and can be lifted from the super to allow honey to be extracted.

A group of hives in an area is called an apiary. Choosing an appropriate location for an apiary is important. Hives do best in relatively out-of-the-way locations that are near pollen, nectar and water sources. Bees forage on these resources in a very direct way; they literally make a beeline from these resources in the environment to the hive. This direct route minimizes the bees' expenditure of energy and increases their chances of beating nearby honey bee colonies to the resources. If pets, people or livestock are in this flight path, they might actually be hit by a bee that is following the beeline.

Ideally, hives should receive full sunlight in the morning because a sun-warmed hive will encourage the bees out for cleansing flights during which they clear their digestive system. In hot seasons, protect the colonies from excessive heat by placing the hives where they will be shaded during midday. Bees nest naturally in hollow trees or cliffs, so hives placed in an attic, a barn or the top of a garage do fine as long as they have plenty of air circulation and some shelter from the sun.

Orient the hives so that the entrances are away from human and animal activity and toward fields, orchards and areas that provide the major nectar and water supplies. If facing hive entrances away from all activity is impossible, place a 7-foot-high barrier about 10 feet out from the hive entrance to force the bees' flight path to rise high above the ground and make it less likely to intersect human and animal activity. In cooler climates, it is best to orient hives toward the south, if possible, especially during winter.

Honey bee communication

Honey bees are highly social animals. The basic requirement of social existence, for any animal, is effective communication. Without communication, an animal becomes solitary, and social structure begins to break down. Imagine 40,000 bees that weren't communicating with each other in a tight, enclosed place. It would be chaos. The basic modes of communication in bees are similar to those of humans. They use various stimuli (light, chemical and physical) that can be perceived by specific sensory organs. But honey bees do not have a humanlike intelligence, awareness or understanding of the messages being sent or received. Their communication is simply the transfer of stimuli to elicit behavioral or

physiological responses in receptive individuals. Although studied for decades, the ways honey bees communicate are not yet completely understood. For one, humans do not possess the same sensory perception as bees. Also, to study honey bee communication, the researcher must disturb a colony to some degree. This disturbance itself potentially affects the normal communication of honey bees. Two areas of honey bee communication about which science does know a great deal are dances and pheromones.

Dances

Although the description of bee dances may conjure up some visually interesting images, keep in mind that the inside of a colony is dark and the bees cannot actually see the dances. More than likely, they are using their antennae to detect air-particle movements caused by the dancing. Sound and smell may also play a role in effective communication through dancing.

Round dance. The round dance is used by forage or scout worker bees to communicate the location of food sources — nectar, pollen or both — that are relatively close to the colony, usually within less than 50 meters, or 55 yards. After unloading some of her new-found food, the worker bee will begin to run in small circles on the comb, changing direction often, for example, circling to the right and then to the left and then to the right again. After dancing for several seconds, the worker bee will move rapidly toward the entrance and fly out again. Foraging bees that were recruited by her dance will fly out of hive in all directions searching for this new food source. Although the round dance does not seem to indicate direction, newly recruited bees will typically find the food source because they are close to the hive, and the foraging bee that performed the dance likely marked the sources with a pheromone.

Sickle dance. The sickle, or crescent, dance is a variation of the round dance. It is used to indicate food sources that are a moderate distance, usually 50 to 150 meters (55 to 164 yards), from the colony. The sickle dance is similar to the round dance except that the shape of the dance is flattened like a crescent rather than circular. Some people refer to the dance shape as a figure 8 or as a waggle dance without the waggle.

Waggle dance. The waggle dance is a figure 8 with a waggle in the middle. It is used to communicate the distance and direction to food sources more than 150 meters (164 yards) from the hive (Figure 5). The waggle dance consists of two phases: the waggle phase and the return phase. A worker bee shakes its abdomen from side to side as it runs in a straight line across the comb at a certain angle — the waggle phase, and then it turns to the right and circles back to the starting point — the return phase. She then performs another waggle run, turns to the left and circles back, and so on. She may perform this dance 100 or more times. The number of waggles the worker makes indicates the distance to the resource. The angle of the path across the comb indicates the angle from the sun that is taken to find the resource. Unlike the round dance, the waggle dance communicates both the distance and direction of the food source to other foraging bees.

Grooming dance. A bee in need of cleaning will rapidly stamp its legs while rhythmically swinging its body from side to side. At the same time, the dancing bee will rapidly raise and lower its body and clean around the bases of its wings with its middle pair of legs. Usually, the bee nearest the dancer will sense the dance and begin to help clean the dancer.

Pheromones

Many animals — honey bees and humans included — produce chemical signals called pheromones. Pheromones affect the behavior of other individuals of the same species. Honey bees use pheromones in many aspects of daily life and to send key messages to the other members of their colony.

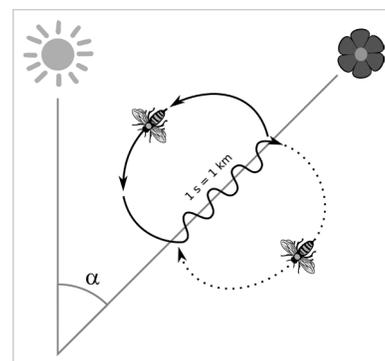


Figure 5. One way bees communicate is through dances such as the waggle dance, which is used to communicate the distance and direction from the hive to a food source.

Queen pheromone. The queen produces a pheromone that is fed to her attendants and then shared with the rest of the colony. This distribution of the queen pheromone lets the colony know that the queen is alive and healthy. The presence of this pheromone has a strong effect on the behavior of the colony. The absence of this pheromone will indicate to the worker bees that their current queen is dead or dying, and they need to produce a new queen. Outside the hive, a newly emerged queen uses this pheromone to attract drones for mating.

Orientation pheromone. The orientation pheromone is also known as the Nasonov pheromone. This pheromone is released by worker bees to communicate to returning forager bees how to get back to the colony. Worker bees will disperse this pheromone near the entrance of the colony by raising their abdomens and fanning their wings. This pheromone is also used during swarming. Swarms will send out scout bees to identify a new home. When a suitable location is identified, scout bees will release the Nasonov pheromone to guide the swarm to their new home.

Alarm pheromone. Two alarm pheromones are produced by worker bees. The first is produced by the mandibular glands and is used as a repellent to deter robber bees and other potential enemies. This pheromone also functions as an anesthetic and is used to paralyze intruders that are bitten by bees defending their colony. The second alarm pheromone is produced by a gland located near a honey bee's stinger and is released when a bee stings another animal. This pheromone tells other bees that a major threat is nearby and help is needed. It also induces the responding bees to behave in a defensive manner. Africanized honey bees are very sensitive to the alarm pheromone released by stinging and produce much more of it than do European honey bees. Smoke is effective at masking these alarm pheromones, which makes the use of a smoker necessary when a beekeeper is manipulating hives.

Only honey bees

Honey bees are the only insects that produce a food that humans eat — honey. And honey is the only food that includes all the substances necessary to sustain life, including water.

Races and other subsets of honey bees

Historically, the honey bees of the world have been classified as one of four species:

- Giant honey bee (*Apis dorsata*)
- Little honey bee (*Apis florea*)
- Eastern honey bee (*Apis cerana*)
- Western honey bee (*Apis mellifera*)

The species found in the United States, *Apis mellifera*, actually consists of numerous interbreeding subspecies, including *A. m. ligustica*, the Italian bee; and *A. m. mellifera*, the German dark bee. These subspecies, or races, can be differentiated from one another by morphological characteristics and often also by behavioral and ecological traits.

As stated earlier, the honey bee is not native to North America but was introduced by settlers and colonists in the early 1600s. The native range of *A. mellifera* includes Europe, the Middle East and Africa, but it is now distributed worldwide because of its high level of honey production and pollination behaviors.

Over time, both natural and controlled breeding have led to hybrids and other subsets of honey bees with unique characteristics compared to those of their ancestors. The most economically important races, hybrids and other subsets of honey bees in North America are described below.

German black bee (*Apis mellifera mellifera*)

The German black bee is known by many names, including the European dark bee and the English dark bee. This bee is native to northern Europe and was the first honey bee brought to North America by early settlers in the 17th century. German black bees tend to be black or dark brown, and they may be slightly larger than other varieties of honey bees. They are naturally acclimated to damp, cold climates, and overwinter exceptionally well. However, they are slow to build up in

Honey making is a specialty

Of the 20,000 bee species worldwide, only four produce honey.

the spring and are runny (that is, nervous or excitable on the combs). Pure strains of the German black bee are relatively docile, but hybrids with other subspecies vary from defensive to very aggressive. German black bees are not commercially available in the United States, and it is unlikely that pure strains of this race exist anywhere in North America.

Italian honey bee (*Apis mellifera ligustica*)

Italian honey bees, originally from the Italian peninsula south of the Alps, were introduced into the United States in 1859. Italian worker bees are pale yellow to light brown, with dark brown or black bands on the abdomen. Italian queen bees tend to be darker than the workers, making it easier to locate the queen in a colony. Although Italian honey bees are adaptable to a wide range of climates, they do not do well in areas with cold, harsh winters and cool, wet springs. Colonies will often continue to rear brood after the honey flow ceases, making them more likely to starve during long winters. Italian honey bees also have a stronger tendency to rob and are more prone to drifting than other races. If weather is favorable, they build up quickly in the spring and are excellent comb producers. They have only a moderate tendency to swarm and do not create excess propolis. Italian honey bees are relatively gentle and are strong honey producers, making them the most popular bee in the United States and an excellent choice for beginning beekeepers.

Carniolan honey bee (*Apis mellifera carnica*)

After the Italian bee, the Carniolan bee is probably the most widely distributed race of honey bee in the world. The Carniolan originated in the historical provinces of Carniola, Carinthia and Styria, which form parts of modern-day Austria and Slovenia. However, it is likely that Carniolans were found throughout the entire Danube Valley from Germany in the west to Romania and Bulgaria in the east. These bees have a slender gray to grayish-brown body. They also have a long tongue that enables them to collect nectar from flowers that other honey bees cannot access. These extremely docile bees are good comb producers that use very little propolis. Carniolans are able to forage on colder and wetter days, leading to explosive build-up in early spring. This rapid build-up, however, leads to an increased tendency to swarm. Strong honey production and gentleness are traits that make the Carniolan a good choice for beginning beekeepers.

Caucasian honey bee (*Apis mellifera caucasica*)

Caucasian honey bees are native to the Caucasus Mountains that form the border between Europe and Asia. As such, they are more tolerant of harsh winter environments than other races. These dark gray to black bees have the longest tongue of any race of honey bee. Their honey production is similar to that of Italians, although Caucasians tend to rob less. Caucasian honey bees are very gentle and have a low tendency to swarm. Despite their ability to forage in cooler, wetter weather, they are slow to build up in the spring. Caucasian honey bees are susceptible to *Nosema*, a disease spread by the spores of the microsporidia *Nosema apis* and *Nosema ceranae*. These bees produce excessive propolis, because of which they have been largely abandoned by beekeepers in the United States and availability of commercial stock is limited.

Russian honey bee (*Apis mellifera hybrid*)

A strain of *Apis mellifera* originating in the Primorsky Krai region of Russia was found to be resistant to both varroa mites and tracheal mites, major pests of honey bees in the United States. This strain was brought into the United States in 1997 by the U.S. Department of Agriculture's Honey Breeding, Genetics and Physiology Laboratory in Baton Rouge, Louisiana. There, it was used to create a hybrid Russian-Italian strain of honey bee that is more resistant than the Italian to varroa and tracheal mites. The Russian hybrids look similar to Carniolans but are

Why bees sting

Honey bees sting if they are threatened or to protect their home. When nearing a hive, it is best not to approach it from the front or the guard bees will be challenged.

Only the queen and worker bees sting. Drones do not have stingers.

Queen honey bees have a smooth stinger. Virgin queens use their stingers to kill rival queens until there is only one. Then that queen begins mating. After mating, queens stay in their hives and thus rarely sting humans.

When a worker bee stings, barbs in the stinger firmly stick into the victim. When the bee pulls away or is removed, its venom sac and glands are pulled from its body, killing the bee. The venom sac left in the victim continues to pump venom, which is why you should never try to remove the venom sac by pinching it.

more similar to Caucasians in terms of cold weather tolerance and susceptibility to Nosema. Russian hybrids have an increased tendency to swarm, are highly sensitive to forage availability, and may be more aggressive than other races or hybrids. Although widely available, they are generally not recommended for new beekeepers.

Buckfast honey bee (*Apis mellifera* hybrid)

In the early 20th century, honey bee populations in the British Isles were decimated by tracheal mites. Brother Adam of Buckfast Abbey in the United Kingdom set out to develop a hybrid that was resistant to tracheal mites and yet maintained the positive traits of honey bees. The resultant Buckfast honey bee is highly tolerant of tracheal mites and is extremely gentle, with a weak instinct to sting. Buckfast honey bees are well suited to cool, wet climates; overwinter well; and have a low tendency to swarm. They are good honey producers but can be expensive and hard to find. Buckfast honey bees may become more aggressive if a colony is allowed to requeen naturally.

Minnesota hygienic honey bee (*Apis mellifera ligustica* subset)

In 1994, Marla Spivak and Gary Reuter at the University of Minnesota began breeding honey bees for resistance to varroa mites and various diseases. Their program focused on selecting for the hygienic trait found in Italian honey bees. The resultant bees resist diseases and mites by detecting diseased or mite-infested brood and quickly removing the infected brood from the nest. Because the hygienic trait was developed using Italian honey bees, Minnesota hygienic honey bees exhibit many of the characteristics and behaviors of standard Italian bees. The hygienic trait is recessive, meaning the gene has to be inherited from both parents. Therefore, a queen raised from a hygienic colony must mate with drones from other hygienic colonies for the colony to continue to express the trait. Minnesota hygienic honey bees are widely available from bee breeders throughout the U.S.

Africanized honey bee (*Apis mellifera* hybrid)

The Africanized honey bee is a hybrid of the African honey bee (*Apis mellifera scutella*) and a European honey bee, such as the Italian (*Apis mellifera ligustica*). African honey bees were brought to Brazil in an attempt to breed a strain of honey bees that produced more honey and were better adapted to tropical conditions. In 1957, 26 of these Africanized swarms escaped quarantine and quickly began to spread throughout South America. They have since spread throughout most of Central America and the southern parts of North America. Africanized honey bees are excellent honey producers, resistant to varroa mites, and well suited to tropical climates. They are highly defensive and aggressive, occasionally to the degree of being dangerous and potentially life-threatening. They readily swarm or completely abandon a nest, and they overwinter poorly in temperate climates. Although Africanized honey bees are the predominant bees used in beekeeping in Central and South America, under no circumstances should they be considered for use in the U.S.

Cordovan honey bee (*Apis mellifera* subset)

Cordovan refers not to a physical characteristic or behavior but to a color variation in a honey bee, which is expressed as a recessive trait (that is, it is inherited from both parents). As all honey bee races have this recessive trait, all races may have a subset that is Cordovan in color. The majority of Cordovan subsets, however, tend to come from the Italian race. Therefore, they tend to exhibit many of the behaviors and characteristics of Italian bees. The main difference is coloration, with Cordovan bees being a yellow to reddish-brown or

Stinger removal

To remove a honey bee stinger, scrape it off with a flat object. Don't try to pull it out; squeezing the stinger will push more venom under the skin.

After you have removed the stinger, wash the skin to remove pheromone that might attract other bees. Talcum powder will also mask the pheromone.

It has been estimated that it would take 1,100 bee stings to produce enough venom to be fatal.

How bees fly

In 1934, French entomologist Antoine Magnan and his assistant André Sainte-Lague calculated that bee flight was aerodynamically impossible, and ever since, science has been pondering how it is possible.

The answer was published in Proceedings of the National Academy of Science November 2005. Michael H. Dickinson, the Esther M. and Abe M. Zarem professor of bioengineering, and his postdoctoral student Douglas L. Altshuler and their colleagues at Caltech and the University of Nevada at Las Vegas, figured out honey bee flight using snap freeze-frame images of bees in motion and a giant bee wing robotic mock-up.

The researchers said the secret of honey bee flight is the unconventional combination of short, choppy wing strokes; a rapid rotation of the wing as it flops over and reverses direction; and a very fast wing-beat frequency.

“These animals are exploiting some of the most exotic flight mechanisms that are available to insects,” Dickinson said.

Generally the smaller the insect, the faster it flaps. Aerodynamic performance decreases with size, so to compensate, small animals have to flap their wings faster. Mosquitoes flap at a frequency of over 400 beats a second. Being relatively large insects, bees would be expected to beat their wings rather slowly, and to sweep them across the same wide arc as other flying bugs. They do neither. Their wings beat over a short arc of about 90 degrees, but absurdly fast, at around 230 beats a second. Fruit flies, which are 80 times smaller than honey bees, flap their wings only 200 times a second.

When bees want to generate more power, such as when they are carrying a load of pollen, they increase the wing stroke arc but keep flapping at the same rate.

“Bees have evolved flight muscles that are physiologically very different from those of other insects. One consequence is that the wings have to operate fast and at a constant frequency or the muscle doesn’t generate enough power,” Dickinson said.

purple color and lacking the black bands found on other bees. Cordovans bred from Italian bees may be slightly more gentle and more likely to rob than their counterparts. Because of their unique coloration, Cordovan honey bees are used extensively in open mating-based breeding programs. Cordovan bees are available commercially but, like Minnesota hygienic honey bees, queens produced by a colony must mate with drones from other Cordovan colonies to continue to express the recessive coloration trait.

Which type of beehive is right for you?

Choosing a beehive is an important decision. There are many beehive designs, and they all have different dimensions, thus components that work with one type of hive generally don’t work with another. Beehive equipment can be an expensive investment, and once you have begun to assemble equipment of a certain design, it can be problematic to switch to a different design. Fortunately, there is a lot of flexibility in hive design, giving a beekeeper the opportunity to select the system that best fits his or her needs. There are only two real requirements in the design of a beehive:

- The design allows for proper bee space.
- The hive has movable frames.

As previously mentioned, honey bees build excess comb in spaces larger than $\frac{3}{8}$ inch, making harvesting and extracting honey difficult. They also seal with propolis any space $\frac{1}{4}$ inch or less, making these spaces unusable. Therefore, properly designed and constructed hives ensure that bee space of about $\frac{5}{16}$ to $\frac{3}{8}$ inches between hive elements is found throughout.

Movable frames allow the beekeeper to manipulate the colony. Modern beehives feature movable frames, which are a requirement on hives used in the U.S. to allow examination of colonies by state apiary inspectors for pests and diseases. The use of bee gums (sections of a hollow tree, which were originally made from black gum trees) and skeps, both of which were common in the 19th century, is generally no longer allowed.

The following are the most commonly used beehives that feature movable frames and use proper bee space:

Bees’ knees?

“The bee’s knees” was a popular 1920s expression meaning something wonderful. But do bees actually have knees?

Bees have jointed antennae and legs, like most insects. They do not, however, have kneecaps, so technically they do not have knees.

10-frame Langstroth hive. The 10-frame Langstroth hive is the most common beehive in use in the U.S. today. It could be referred to as a modular system as hive bodies and supers can be added or removed as needed to fit the needs of the colony. It is easy to find commercially produced equipment of this particular design, and components are usually interchangeable with other hives of the same design. Components of this beehive can be heavy or bulky to handle and must be stored when not in use.

8-frame Langstroth hive. The eight-frame Langstroth hive is identical to the 10-frame variety except it is slightly smaller. The biggest benefit of the eight-frame over the 10-frame hive design is that components weigh less and are easier to handle. With the exception of the frames, most eight-frame hive components are not interchangeable with 10-frame hive components.

Top bar hive. Top bar hives are much more common in other parts of the world, especially in developing countries, than they are in the U.S., although they are becoming more popular here as well. Top bar hives are oriented more on a horizontal axis rather than a vertical axis as Langstroth hives are oriented. In top bar hives, beekeepers provide only the top part of a frame (hence the term top bar) and possibly a starter strip of wax for the bees, rather than providing a full frame and a sheet of foundation as in the Langstroth design. Top bar hives may be less expensive to establish than traditional hives, but they are usually considered to be stationary and are not easy to move.

Horizontal hive. A horizontal hive can best be described as a combination of a traditional Langstroth hive and a top bar hive. They feature the horizontal orientation of the top bar hive and the full frames and foundation of the Langstroth hive. They have been used for centuries in other parts of the world and are becoming more popular in the U.S.

Warre hive. A warre hive can also be described as a combination between a traditional Langstroth hive and a top bar hive, albeit a much different combination than the horizontal hive. Warre hives feature the vertical orientation, square boxes and modular nature of the Langstroth hive but feature the top bar foundationless frame design of the top bar hive. This design is usually recommended for people who simply wish to have bees but do not plan to harvest honey, as frame removal for honey extraction is difficult.

Flow hive. The flow hive is a relatively new design that allows beekeepers to harvest honey without disturbing the colony. Although this design appeals to many people, interested individuals should carefully consider its pros and cons to determine if this system is suitable for them. The biggest potential benefit is that this design makes harvesting honey less work. Potential drawbacks include the hive's cost, its plastic components (generally not recommended), and how it reduces the beekeeper's ability to inspect and assess the overall health of the colony.

Observation hive. Observation hives are used for short-term storage of colonies for educational display purposes. They are not intended to be used as a long-term home for a colony and are not used for productive beekeeping.

Other hives. Additional hive designs include the national hive, WBC hive, Catenary hive, Stewarton hive, Glen hive and many, many others. These other designs are not common, and their components are not commercially available. Nor are they recommended for beginners. Experienced beekeepers, however, may want to try them for a different beekeeping experience.

Many beekeepers are interested in building their own hives. For a person that is the least bit handy, building a hive will usually not be too difficult. However, a home-built hive must have proper bee spacing and moveable frames. Builders are advised to use a commercially produced hive for measurements or obtain hive plans from a reputable source. Although building a hive can be enjoyable for a handy beekeeper, once materials and time are taken into account, it is usually cheaper to buy a hive from a commercial source.

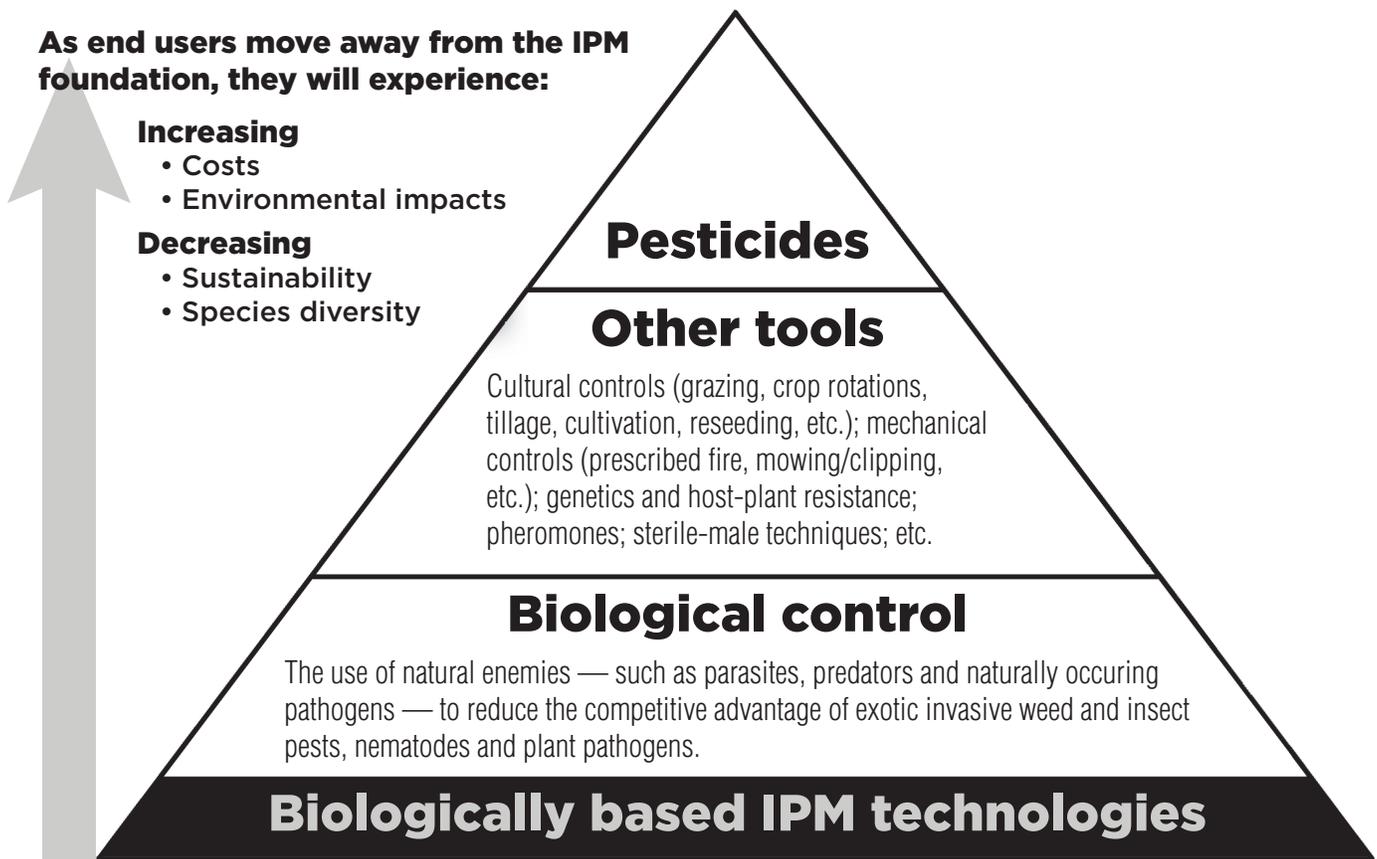


Figure 6. Integrated pest management.

Controlling bee pests

Bees are subject to a variety of insect and pathogen pests. At the time of this chapter's publication, no standard best management practices for controlling bee pests had been developed. Therefore, the best management practice for beekeepers is diligent monitoring of hives and aggressive action when a pest or disease is discovered. An integrated pest management approach is advised.

Integrated pest management

Integrated pest management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common sense practices. IPM uses physical, mechanical, cultural, genetic, biological and chemical tactics to control pests (Figure 6). The main goal of integrated pest management is to be more eco-friendly by reducing the use of pesticides while still maintaining pest control. **Physical** management tactics for a hive include locating it on a stand, tilted forward to shed water, with a screened bottom board. A **mechanical** tactic would be using a drone comb for mite reduction. **Cultural** management tactics include prompt removal and processing of honey to limit small hive beetles, and placing the hive in a quality location or moving it near better floral resources. A **genetic** tactic would be replacing poorly producing queens with more vigorous or locally adapted queens. **Biological** control includes supplemental feeding to maintain health, because healthier bees fight off diseases, insects and mites more effectively. **Chemical** approaches would be using softer chemical treatment products or rotating chemical treatments, both of which reduce pest resistance to chemicals.

IPM uses the concepts of economic injury levels and economic thresholds, where the pest numbers or injury needs to reach a certain level before treatment. An insecticide applied before it is needed is a waste of product, time and money. The goal is that the inputs, such as chemicals and labor, should always be less than the outputs, such as crop yield.

Keeping good scouting records that contain information about pests, treatments and yields will allow a beekeeper to determine minimum expenditures for acceptable economic yield. You need to know when to cut your losses if your colony or yield is going to be substandard in a given year.

Most common pests and diseases of bees

Colony collapse disorder (CCD) was given its name after the winter of 2006 when between 30 and 90 percent of all U.S. honey bee colonies died. Although this term represents a specific series of hive conditions to beekeepers, CCD has become the general term the public associates with the worldwide bee decline and its causes.

The following is a short summary of key pests and diseases currently challenging bees — and beekeepers.

Beekeepers should know the signs of good colony growth and of healthy brood. When you notice changes, check for the latest recommended treatments, as many are updated as new approaches are developed.

Varroa mites

Varroa destructor and *Varroa jacobsoni* are referred to as varroa mites. Varroa mites are currently the most severe beekeeping challenge faced by beekeepers (Figure 7). These parasitic mites feed off the bodily fluids of adult, pupal and larval honey bees, specifically *Apis cerana* and *Apis mellifera*.

Research has shown these parasitic mites carry and transfer about two dozen viruses harmful to honey bees. Due to the many viruses a large varroa mite population can introduce into a bee colony, a variety of disease symptoms may appear. Many of these symptoms — especially the appearance of stressed, dying or dead larvae — are similar to those of other, more traditional bee diseases. These symptoms, coupled with high varroa mite populations, have been named varroosis. Sometimes the terms varroosis and parasitic mite syndrome (PMS) are used interchangeably.

PMS has symptoms that appear to be a cross between sacbrood and foulbrood, and appear only in varroa mite-infested colonies. PMS may be suspected when entire colonies disappear from previously healthy hives in early fall.

Varroa mites are thought to have all but eliminated feral bee colonies in many areas and are present in most, if not all, apiaries. If mite populations are left unchecked, bee colonies will die from varroa parasitism within three years.

What you will see. During their mobile life cycle stage, these external pests are visible to the naked eye. They look like a red or brown spot on a bee's body and are easiest to see on the head or thorax. They can also be found feeding between bee abdomen segments. With a light infestation, the colony will show few symptoms. With a medium infestation, mites will be found on drone brood and on the thorax of adult bees. Signs of a heavy infestation include deformed bees, the wings of which are shriveled up or completely missing (a disease called deformed wing virus); and a dwindling bee colony population.

Treatment. Currently, complete removal of varroa mites from a colony is impossible. Using a combination of integrated pest management tactics, beekeepers should maintain varroa mite levels below the threshold affecting colony health, which changes depending on several factors. A number of mite management strategies, chemical controls and nonchemical treatments are available. Varroa mite recommendations are frequently updated based on the latest research findings. The

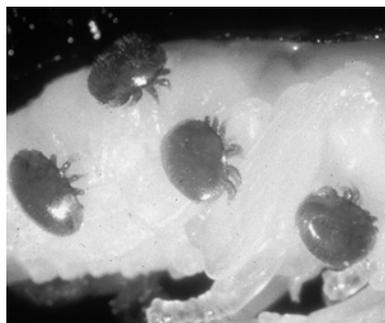


Figure 7. These varroa mites have matured while feeding on honey bee larvae and are ready to parasitize other honey bee larvae and adults.

most comprehensive source of varroa mite control recommendations is the Honey Bee Health Coalition's website.

American foulbrood

Before parasitic mites, American foulbrood (AFB) was the most serious bee disease (Figure 8). AFB is caused by the bacterium *Paenibacillus larvae*.

AFB is spread by spores that are consumed by larvae during their first couple of days in the cell. One dead larvae may contain as many as 100 million spores. As bees clean out the infected cells, they spread spores to other larvae. AFB spores are known to be viable for up to 40 years.

What you will see. The brood pattern will be spotty. Infected bee larvae will turn dull white to tan to brown. At the brown stage, when the cell is stirred with a toothpick and the toothpick is removed, the cell content will appear ropy. Cell cappings may appear greasy, and some will be perforated. The hive will have a chicken coop-like foul odor.

To confirm suspected AFB cases, you can send comb samples containing infected larvae to a diagnostic lab for testing. AFB field kits are also readily available from bee equipment suppliers.

Treatment. Burn all frames and comb; scorch boxes and other equipment. Kill bees with a water and dish soap solution.

If it is early in the season, an option is to kill the queen and shake all the bees onto new frames with new, undrawn foundation in a new hive. Introduce a new queen bred for hygienic behavior, and leave her caged for three days. Place the colony well away from others, and feed a 1-to-1 sugar-water syrup to encourage comb building. Monitor the colony closely to ensure brood rearing appears normal.

Prevention. Keep strong healthy colonies headed by young prolific queens. Varroa-sensitive hygiene (VSH) queens show some AFB resistance.

After working with colonies suspected of having AFB, sanitize hive tools and thoroughly wash hands and gloves before moving onto the next colony. Replace old combs on a regular basis; replace a third of all brood comb every year. Don't leave old comb accessible to foraging bees.

European foulbrood

European foulbrood (EFB) (Figure 9) is a disease caused by the bacteria *Melissococcus plutonius*. It affects a colony when the nectar flow is sporadic, usually in spring. Sometimes EFB signs will disappear during the onset of a good nectar flow, but infected colonies must be closely monitored.

What you will see. The brood pattern will be spotty. The chalk-like spores are fed to young larvae by nurse bees. The bacteria compete for nourishment inside the larvae, causing the larvae to starve to death, usually before the cell is capped. Infected larvae can appear deflated and turn yellow to brown or dirty gray. The spiracles of the tracheal system can appear as ribs on the discolored larvae. The bacteria consume the larval tissue until nothing is left but a twisted brown rubbery mess that is usually curled upward at the bottom of the cell. Sometimes there is a foul odor.

To confirm suspected EFB cases, you can send comb samples to a diagnostic lab for testing. EFB field test kits are also available from bee equipment suppliers.

Treatment. Simulate a nectar flow by feeding bees 1-to-1 sugar-water syrup for two to three weeks. If problems persist, kill the queen bee, and shake remaining bees onto new frames with undrawn foundation in a new hive. Then requeen.

Prevention. EFB can recur if contaminated frames and hardware are used. Get rid of all contaminated equipment. Keep strong bee colonies, requeen yearly, and replace worn woodenware. After working colonies suspected with EFB, sanitize hive tools and thoroughly wash hands and gloves before moving onto the next colony. Replace old comb on a regular basis, and don't leave old comb out where foraging bees can get to it.

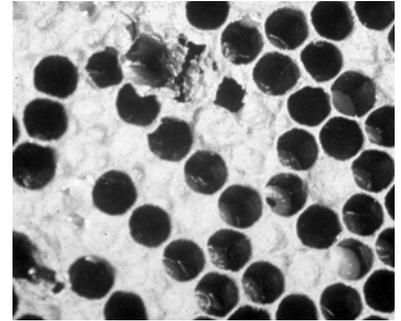


Figure 8. Sunken and perforated cell cappings are indicators of larval death due to American foulbrood.

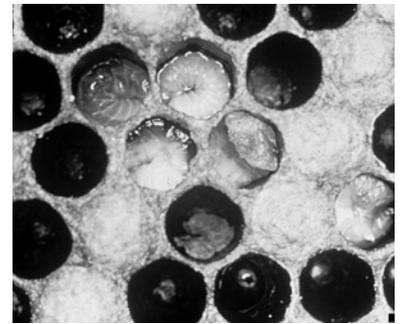


Figure 9. Honey bee larvae infected with European foulbrood turn darker colored, and some become deflated or shriveled. Normal larvae are white and plump.



Figure 10. Brownish streaks on the outside of a honey bee hive indicate nosema disease.



Figure 11. Small hive beetle adult.



Figure 12. Small hive beetle larva.

Nosema

Nosema is the most widespread adult bee disease (Figure 10). It is spread by spores of two microsporidia: *Nosema apis* and *Nosema ceranae*. *Nosema apis* is primarily a problem in winter and early spring. *Nosema ceranae* affects bees in summer and fall.

What you will see. Bees will be defecating inside the hive instead of taking a cleansing flight. Yellow to light brown streaks may be seen on the outside and possibly inside the hive. The colony may requeen for no apparent reason. The infection causes the queen's ovaries to degenerate, causing egg-laying issues.

Treatment. The current standard recommendation for nosema treatment is to use fumagillin, despite the movement in the past several years towards natural or treatment-free beekeeping. No research-based practical alternatives have been identified to replace fumagillin. Beekeepers are encouraged to stay current on scientific research concerning how best to deal with nosema.

Prevention. Ensure colonies have healthy diets of pollen and nectar. Control hive moisture by providing good ventilation. Help eliminate nosema spores by routinely culling old comb, which provides the infection source.

Small hive beetle

The small hive beetle (SHB) (*Aethina tumida*) can destroy a bee colony (Figure 11). The beetle larvae tunnel through the comb and leave excrement that causes fermented, runny honey. Clusters of eggs laid in areas where bees cannot reach lead to thousands of aggressive larvae seeking pollen and bee larvae and pupae to eat. SHB larvae look superficially like wax moth larvae but have three sets of larger, more pronounced legs located near the head (Figure 12). When the infestation becomes too great, the bees will abandon the hive.

SHB larvae burrow in soil below and around the hive, where they pupate into free-flying adults that can fly up to 7 miles.

What you will see. Adult black beetles will be moving over comb and inside the hive lid. Strong colonies are often able to keep adult SHBs trapped in cracks and crevices to the point where the beetles are unable to reproduce. Weaker, stressed colonies produce a pheromone that triggers female adult SHBs to lay eggs. Growing larvae can be found in hive debris in the bottom of the hive, along frame bottoms, and in any other dark, protected places. In severe cases, developing larvae can be found infesting honey stores and leaving a film of slime over honey frames. SHB reproduction produces a pungent, foul odor.

Treatment. Remove slimed individual honey and pollen frames. Put in a freezer overnight to kill existing SHB larvae and eggs. Scratch cappings; then, using a garden hose, gently flush out honey and dead brood without damaging the delicate comb. Shake excess water from comb, allow it to dry and reach the current air temperature, and then return it to the hive.

Prevention. Maintain a large, strong colony. Keep hives in direct sunlight; shaded colonies experience more SHBs because the beetles avoid light. Trap adult SHBs with SHB traps or unscented dryer sheets. Remove debris from the hive bottom, especially in spring, and freeze or burn it; do not toss it into soil. Research has shown SHB larvae will travel 50 feet or more. Freeman beetle traps, available from bee suppliers or homemade, have proven successful in reducing and preventing SHB infestations.

Wax moths

Two moths — the lesser wax moth (*Achroia gresella*) and the greater wax moth (*Galleria mellonella*) — do not directly harm bees but can destroy unoccupied comb and woodenware. Wax moth larvae are a secondary predator of bee larvae and pupae. They also feed on beeswax, pollen and honey unless bees catch and remove them.

What you will see. Evidence of white moths includes white cocoons on the side and bottom of the hive, and spiderlike webbing through comb (Figure 13). Before making the cocoons, the larvae bore scallops into the frames and woodenware. In early stages, wax moth larvae look similar to SHB larvae. However, SHB larvae have three sets of legs close to the head, whereas wax moth larvae have many small, fleshy, uniform legs along the length of the body.

Treatment. Freeze comb before storing. Store empty frames in cool conditions. Be careful moving comb; it is fragile. Para-Moth, with the active ingredient paradichlorobenzene, can be used in tightly-sealed woodenware to prevent wax moth damage.

Prevention. Wax moths are opportunistic; they move in when a colony is stressed and on the decline. Keep colonies strong and healthy, and the bees will prevent wax moths from moving in.

Chalkbrood

Chalkbrood is caused by the fungus *Ascosphaera apis*, which attacks honey bee larvae (Figure 14). It appears when a bee colony is in distress from food shortages and erratic temperatures, and spreads by spores from previous infections.

What you will see. The brood, both sealed and unsealed, will have a fuzzy, white growth that almost looks like wool or cotton. The larvae will then harden into gray mummies that will be visible on the hive floor or will be thrown out of the hive entrance.

Treatment. Chalkbrood is usually temporary and rarely fatal to a colony. Most colonies will recover without intervention. If the disease persists, requeen.

Prevention. Keep hives dry. If one colony has chalkbrood, sanitize hive tools before moving onto the next colony. Keep strong healthy colonies headed by young prolific queens. Replace one-third of your used comb each year.

Tracheal mites

The tracheal mite, *Acarapis woodi* (Rennie), is a small parasitic mite that infects a bee's airways, or tracheae. These mites eventually grow and may hamper the bee's ability to breathe (Figure 15).

Although significant in the 1990s and early 2000s, tracheal mite infestations in Missouri have sharply declined and symptoms are rarely reported.

Q&A on feral honey bees in the Midwest

If you see a honey bee on a flower, can you tell if it is from a managed hive or is feral?

No, you cannot tell by looking whether a bee is managed or feral.

What is the ratio of feral honey bees to managed honey bees?

The number of feral and managed honey bees is unknown. One bee expert estimates that for every one feral honey bee there would be 10 from managed hives. In remote areas where few or no managed hives are kept, the proportion of feral honey bees would be greater. Studies have shown that at least two feral honey bee colonies can be supported in a square mile of forest, but it is unknown how successful Missouri's feral honey bees are currently.

How common are feral honey bees in urban areas?

In urban areas, feral honey bees may be more common in neglected settings because these areas can provide excellent places to locate hives. Wall spaces in abandoned buildings are a good habitat, as are old cars and trucks. The bees would be limited by the floral resources in the area. If managed honey bees are kept nearby, the feral bees may be outcompeted by them for available floral resources, likely suppressing the feral honey bee population.

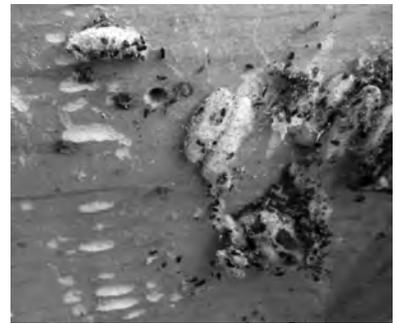


Figure 13. The presence of sticky white webbing, larvae, and physical damage to a hive are signs of a wax moth infestation.



Figure 14. Chalkbrood.



Figure 15. Mites inside a honey bee's tracheal tube.

Exaggerated public fear of Africanized honey bees

Arthur Herzog's 1974 book *The Swarm* seemed to kick off the horror film interest in the U.S. and fed the public fear of the Africanized honey bee (AHB). The geography in the movie *The Swarm* (1978, adapted from the novel) is truer to AHB territory than the book: The movie is set in Texas, the book in New York.

Herzog's book was preceded by a 1966 movie in Britain called *The Deadly Bees*, which was based on the 1941 H.F. Heard book *The Taste of Honey*.

Such movies and books have not only amplified the public's fear of the AHB but have also led to some misconceptions. The sting of an AHB is no more potent than that of any other honey bee, and these bees do not seek to attack humans. They are easier to provoke, however, and will attack more quickly and pursue a threat much farther than other honey bees.

Have feral honey bee populations in Missouri recovered from varroa mites and other factors?

Missouri's feral honey bee populations may have recovered from varroa mites and other factors that had diminished them last century. In the 1980s, feral honey bee populations began declining all across North America. Recently, there have been increasing reports of feral honey bee colonies surviving in several eastern and southern states. One noteworthy study took place in the Arnot Forest in central New York. This detailed study documented the population of feral honey bee colonies in the Arnot Forest in the 1970s and then again in 2002 and 2011. It found that by 2011, the feral honey bee population had recovered to its 1978 level.

If managed colonies die off when not managed for varroa mites, how do feral honey bees survive?

The feral honey bees that survive varroa mites might have developed some resistance, referred to as immunocompetence, but this has not been documented as being different from bees in managed hives. A key adaptation trait for feral honey bees is to swarm and move more often. The cavities in which they dwell are generally smaller than a managed hive, so frequent swarming is required. When they move, they leave some of their pest problems behind and get to start clean in a new hive.

Have feral honey bees adapted to a given area of the country over the years?

Yes, all honey bees, managed and feral, adapt to an area. Within any population of honey bees exists a tremendous amount of genetic diversity, termed intracolony genetic diversity. This diversity helps the colony adapt and survive.

Are feral Africanized bees a threat to Missouri?

Feral Africanized honey bees (AHB) have not been documented in Missouri. But as the climate changes, Missouri may see their arrival. Feral AHBs have been documented in several states south of Missouri, including Texas, Oklahoma and Arkansas, although the latter had only one AHB colony. Feral AHB colonies tend to fizzle out in areas with longer and colder winters. AHBs are quite prevalent in southern California but as of 2014 were not north of Sacramento or San Francisco.

How does one find feral honey bee colonies?

Bee lining is one method of bee hunting. It uses a combination of capture, feeding, timing and geometry. Online videos on bee lining can be entertaining and educational. For instance, one produced by Cornell University shows how bee expert Professor Tom Seeley catches and tracks feral bees. He catches them in a bee box as they forage, feeds them a concentrated sugar solution, and determines the direction they fly to return to their colony. He paints identifying marks on some of the bees so he can measure their round-trip time to estimate the distance to the colony. Once he knows the direction and distance, he moves closer and locates the colony.

If so much is unknown about feral honey bees, why aren't they studied more?

There is little economic benefit for studying feral honey bees because they don't provide honey, wax, or any pollination service income. Farmers with smaller fields that require bee pollination for their crops, such as apples, melons and blueberries, may feel confident that they have enough feral honey bees to rely on. These farmers receive a modest economic benefit because they don't have to spend money for pollination services.

What can I do to benefit feral honey bees?

You can help feral honey bees by planting and managing habitat to increase floral resources for them and other pollinators. The presence of honey bees in bird feeders may indicate they need additional food sources (Figure 16).

If you decide to try locating feral honey bee colonies, you can document them on Save the Hives, a website for hobbyist beekeepers, citizen scientists, and researchers. The site also gives tips for locating feral hives.

Value of pollination by honey bees

Even during ancient times, the value of honey bees for pollination was recognized. As agriculture evolved, an evolution that included domesticating honey bees, certain crops and honey bees became inextricably linked. Nevertheless, beekeeping was still more about producing honey than ensuring crops were pollinated. The design of modern orchards began around 1910 in the U.S., and with it, growers began to pay beekeepers for the service of their hives, now referred to as pollination services. The demand developed through the decades. In 1973, the economic paper “The Fable of Bees” reviewed the newly identified pollination services industry, focusing on the burgeoning apple production in Washington and Oregon. Feral honey bees and the native bees of North America could still be counted on in many areas for pollination, but reliance on them came under threat in the 1980s when their populations began to vanish. As the varroa mite swept across the country, feral honey bee populations declined, and even more demand was placed on managed hives in the 1990s and 2000s.

The U.S. crops that are currently highly dependent on honey bees are alfalfa (seed), almonds, apples, avocados, blueberries, blackberries, cherries, citrus (oranges, limes, etc.), cranberries, cucumbers, melons, raspberries, squash (including pumpkins and zucchini), strawberries and watermelons. For most commercial production of these crops, honey bee hives are introduced so pollination is predictable and sufficient, often for a few weeks to a couple of months. For many other crops (for example, lima beans, okra, peppers and sunflower), yield or quality would be reduced without honey bee pollination. A 2010 Cornell University study documented that the contribution made by managed honey bees hired by U.S. crop growers to pollinate crops amounted to over \$19 billion. No crop epitomizes pollinator dependency more than the almond, largely due to California’s dominance of the industry (about 70 percent of worldwide production). By the early 21st century, California almonds demanded more honey bees than any other crop. A 2013 *Scientific American* article reviewed the dizzying numbers: 31 billion honey bees were required for 810,000 acres of almond trees to produce 700 billion almonds. More than 1.5 million colonies are required, at a pollination service value of about \$240 million (in 2016, an average of \$167 per colony). The mass-produced crops that require pollination services are in flower for a short time, so once they have set their fruit, vegetable or nut, the hives are moved to other fields. Whether in large or small scale, this movement from field to field is the essence of the migratory beekeeping industry.

The practice of migratory beekeeping originated for better honey production. Nephi Miller (1873–1940) of Utah was a pioneer of this practice. Commercial operators use this practice most, many on a large scale. Hives are generally moved on trucks, and many factors determine where they go and when. The demand of the crop and moving to a warmer, more hospitable overwintering location are the primary factors (Figure 17). Some states see a great movement of migratory hives, whereas others, such as Missouri, see little. In Missouri, hives are primarily brought to the Bootheel for watermelons or the central area for apples. Across the U.S., many hives are moved around locally for pollination services, and a rental payment or other compensation arrangement is made. Recognizing the importance of this revenue, the National Agricultural Statistical Service (NASS) began



Figure 16. Honey bees will often seek alternative sources of food during pollen and nectar scarcity.

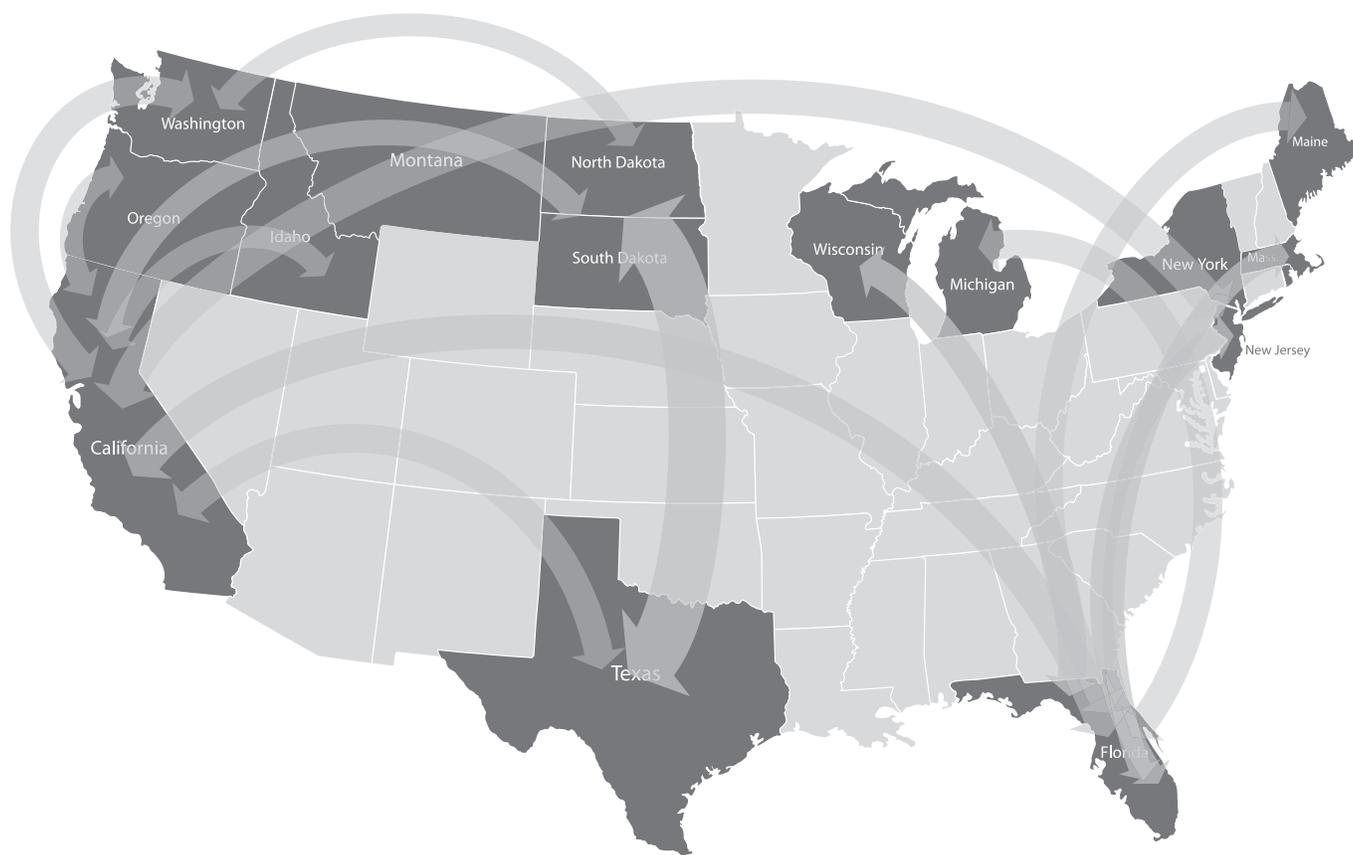


Figure 17. The arrows on this map indicate major movements of migratory beekeepers in the U.S. between February and November. Arrow width represents the relative number of bees being moved between the two locales.

capturing it, issuing their first “Cost of Pollination” report in 2016. It documents the value as \$354 million, with more than \$300 million attributed to California. In the U.S., the estimated value of honey bees for pollination services recently surpassed the value of honey produced. However, California accounts for over 80 percent of the pollination service value; for other states, honey is more important economically.

The cost for pollination service or hive rental varies in Missouri. Beekeepers report \$25 to \$75 as common. The 2016 NASS report cites an average of \$59 in Region 3, which comprises Arkansas, Florida, Louisiana, Missouri, Mississippi, New Mexico, Oklahoma and Texas. Watermelons led the crops for pollination value, requiring about one hive per acre. The exact number of honey bee hives needed to pollinate a crop depends on several factors: the strength and condition of the colonies, magnitude of the natural pollinator community, amount of wild flower material competing with the crop, attractiveness of the crop to bees, projected yield, and weather. For many crops, two to three hives per acre are required. Placing these hives requires some planning, as the crop may need pesticide applications, and floral resources will be limited until the crop flowers.

Recommendations for commercial growers

- Do not place hives in a field until the crop flowers. If the hives are placed too early, the bees will find forage resources in the surrounding area and may not forage sufficiently in the crop.
- Bees forage best within about 100 yards of the hive, so distribute hives in clusters around a large field.
- Bees require a source of clean water nearby. If none is available, set out a shallow container of fresh water.

- If the crop requires pesticides, apply them in the early morning or late evening, when bees are generally less active.
- See the pesticide label for information on the toxicity of the product to bees.
- Do not apply pesticides to flowering plants or weeds.
- Applying a single pesticide product may be less hazardous to bees than mixtures or combinations, which are sometimes more toxic to bees.
- When possible, use a pesticide formulation that is less harmful to bees. Systemic insecticides (applied as either granules or drenches to the soil or growing medium) are less toxic to bees than are foliar applications. Emulsifiable concentrate or water-soluble formulations are typically less hazardous to bees than are wettable powder formulations.
- Ideally, incorporate into pollination contracts a list of pesticides, application methods, and application timings on which the grower and beekeeper agree.
- Notify local beekeepers of your plans to apply pesticides. Some states require that applicators notify beekeepers 24 hours before applying a pesticide that is toxic to honey bees when (1) the treated crop is blooming, and (2) the field is greater than a half-acre and within half a mile from a registered apiary.

Products from the hive

Bees

Some beekeepers split their strong bee colonies to generate new colonies and raise queen bees for sale. Locally raised bees have become acclimatized to local conditions and reduce the introduction of pests and diseases.

Beeswax

Honey bees produce beeswax (Figure 18) from special wax glands in their underbelly. Facial creams, ointments, lotions, soaps and lipsticks use beeswax as an ingredient, making the cosmetic industry the largest user of beeswax. Of the industries that use beeswax, the cosmetic industry uses the most, about 40 percent; the pharmaceutical industry uses about 30 percent; and the candle industry about 20 percent. Beeswax is also used in car and furniture polish, ski wax, chewing gum, crayons, candy and other well-known products.



Figure 18. Large pieces of beeswax in varying shades of yellow and brown.

Bee bread

Bee bread is a mixture of honey, pollen and secretions from nurse bees (Figure 19). It is fed to developing larvae and newly emerged worker bees. Some beekeepers collect and sell bee bread as a health supplement or for use in pollen therapy.



Figure 19. Bee bread is sold as both a food and a nutritional supplement.

Bee venom

In Missouri, bee venom was traditionally administered with live bees that had been refrigerated and then stimulated to sting the area to be treated. Bee venom is available in other parts of the world as the active ingredient in medicines and products such as creams, liniments, ointments, salves or injections for treating different human complaints.

Honey

Twice as sweet as sugar, honey is flower nectar that bees beat their wings to evaporate to 18 percent of its original moisture content after adding beneficial enzymes. The color, flavor and aroma of honey varies depending on the types of flowers visited, time of year the nectar is collected, and length of time the honey is stored in the hive. Honey is the only sweetening material that requires no manipulation or processing to be ready to eat. Honey is available as it is made by the bees as raw, strained honey; still in the wax as comb honey; and as whipped or creamed honey.



Figure 20. Bee pollen is used in some natural dietary supplements.

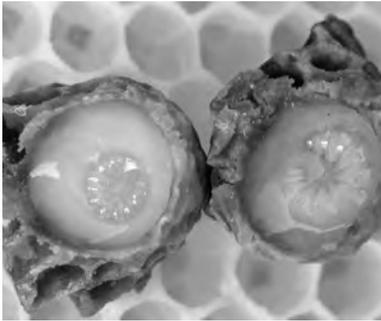


Figure 21. Royal jelly with queen larvae.

Pollen

Pollen, which is male reproductive cells of flowering plants, has a high content of trace minerals and vitamins (Figure 20). It is used as a human and animal food supplement.

Pollination

Beekeepers provide hives to property owners for crop pollination in exchange for a fee. Some communities have adopt-a-hive and similar management programs that involve providing hives in exchange for a fee and a portion of the extra honey produced.

Propolis

Propolis is a sticky resinous material honey bees collect from trees and plants. It that exhibits antibacterial and pharmacological properties. The potent antimicrobial activity of propolis is well studied and has a long history as a treatment in human health. Propolis is mainly used in natural supplements and herbal medicines.

Royal jelly

Royal jelly is a complete food worker bees produce that contains proteins, vitamins, minerals and fats. It provides queen bees all of their food requirements during their lifetime (Figure 21). The cosmetic industry and health food markets buy royal jelly for use in a range of products.

Waxworms

Waxworms are the larvae of the 1-inch greater wax moths (*Galleria mellonella*) that move into struggling honey bee colonies. Waxworms, a favorite snack of birds and reptiles, are sold at pet stores.

Economic value of hive products

All products from a hive have value. For some beekeepers, other products may be more valuable than honey, but overall, honey is the highest-value product from hives. It is the only product fully quantified (by the U.S. Census of Agriculture). Thus, honey serves as the best way to review the beekeeping industry economically. Since it began in the 1840s, the census has tracked honey. It later included beeswax. In 1850, Missouri produced over 1.3 million pounds of honey and beeswax. In 2016, just under a half million pounds of honey was produced from an estimated 10,000 hives, which is typical for the 2000s. Missouri likely produced more honey in the 1800s than it does today. The price of honey can fluctuate significantly. In 2015, the average national price was over \$3.50 per pound, but it fell to \$2.18 in 2016.

The U.S. produced almost 160 million pounds of honey in 2016, at a value of more than \$330 million, from just over 2.7 million hives. The top six honey-producing states were North Dakota, California, South Dakota, Florida, Montana and Texas. Missouri is in the bottom fourth of states in honey production, but has the land and floral resources to produce much more. In 2012, Missouri had almost 1,300 farms with honey bees and more than 14,000 colonies, but only 560 farms reported collecting honey. Most likely, many of these farms collected honey but didn't sell it, so chose not to report. Commercial operations with five or more hives sell the vast majority of honey. The Census of Agriculture reported that in 2016 less than 0.5 percent of honey sold came from farms with five or fewer colonies.

Whether the census accurately reflects the beekeeping industry in Missouri is questionable. On a commercial scale, because Missouri isn't a top producing state, its commercial honey operations are likely smaller scale. Beekeepers generally categorize themselves as commercial, sideliner or hobbyist. Commercial beekeepers consider beekeeping their primary source of income. For sideliners, beekeeping

is a secondary source of income, and for hobbyists, income from beekeeping is nil or insignificant. Beekeeping industry statistics based on honey sales don't reflect hobbyists and may miss some smaller farms that don't sell honey. The census includes only farms with hives, and beekeepers that have more than five hives and sell honey. There are certainly many more than 1,300 beekeepers in Missouri.

To better understand the diversity of beekeepers that make up Missouri's industry, consider attending a local beekeeping group or club. There are more than 40 scattered around the state, so one is somewhat nearby, no matter where you live. A list of groups can be found on the Missouri State Beekeepers Association website.

Should you keep bees?

If you are considering becoming a beekeeper, don't be surprised if you meet experienced beekeepers who don't share your enthusiasm. To become a successful beekeeper requires education, perseverance, information-sharing and the ability to manage several tasks at once to meet the needs of your honey bees. Although many people initially get into beekeeping with an interest in helping to save the bees, they soon find being an amateur biologist, managing constantly changing environmental and hive conditions, to be more challenging than they thought it would be.

Five mistakes of beginning beekeepers

They don't know why they want to keep bees

People keep bees for several reasons, and for every reason, a variety of techniques can be used. Before you become a beekeeper, consider why you want honey bees — for pollination, to have honey, to get more bees, as pets?

Knowing why you want to keep bees will help you know who to get advice from. How best to manage your bees depends on why you keep them. The value of the advice you get will depend on whether the person giving the advice keeps bees for the same reason you do. You will be frustrated if, for example, it turns out your mentor is teaching you how to keep bees for honey production when all you want them for is to pollinate your garden.

They think there is only one way to keep bees

Not only are there several ways to keep honey bees but, as stated above, how to keep them depends on why you keep them. Sometimes the equipment and techniques beekeepers use are based on how they first learned to keep bees, but these may not fit their later needs. Ask questions, be open to new techniques and concepts, and learn why one approach is used over another one. No two years of beekeeping are the same, so the more exposure you have to experienced beekeepers, the better prepared you will be.

They think they have to learn everything before they start.

Learn the basics — beekeeping terminology and a typical monthly beekeeping chore schedule. Then lift that hive lid for a closer look, and start to get to know your bees; they are your best teachers. Don't be surprised if they keep changing things. They have a tendency to do that, so do your best to keep up.

They want to try lots of different equipment.

You can try different hive equipment, but doing so can get expensive quickly. Before you buy any equipment, visit a couple of area apiaries and lift a super full of honey to see how heavy it is. That weight may help you decide what kind of hive equipment to use. Select manageable sizes with interchangeable parts, and make sure you know the correct terminology before you order.

Beneficial qualities of honey

Humans have used honey for its medicinal and nutritional benefits for millennia. Its antibacterial properties have been attributed to helping heal sore throats, gastric ulcers and acne. Honey's physical properties — its percentage of moisture and sugar, and its acidity — can impart medicinal benefits. Honey is hygroscopic, meaning it contains little water (its moisture is below 18 percent) and can absorb moisture from the surrounding environment. This property helps to dehydrate most bacteria. Honey's low pH, 3.2–4.5, makes it acidic enough to hinder the growth of many microorganisms. In addition, its high percentage of sugar deters growth of many organisms. Because of these physical traits, and some others, honey is valued as a treatment for wounds and burns and for use in cosmetics.

Nutritionally, honey has more calories than cane sugar, 64 versus 48 per tablespoon. But honey also contains a variety of vitamins, minerals, amino acids, and enzymes, and the monosaccharides (that is, simple forms for sugar) glucose and fructose. Raw honey is easiest to digest and provides immediately available glucose for the liver and the brain.

Ultrafiltering makes honey look clearer but can strip out beneficial traits, such as small amounts of pollen. Unpasteurized honey is considered better for you than pasteurized, but honey stores longer without crystallizing if pasteurized, so larger producers and retailers prefer it. For the maximum benefit, look for honey labeled as raw and buy it as directly as possible, from a farmers market or a retailer selling local products.

They want to keep bees cheaply.

To get into beekeeping costs \$700 to \$1,000, plus you will need an extra freezer. The first couple of years, you will not get much honey, so income from honey sales will not give you much of a return on the investment you will need to make to create a successful business. Keeping bees has many benefits, but, in general, making a lot of money is not one of them.

How can I help if I don't want to keep bees?

Keeping honey bees may not help the insect pollinator health crisis. Yes, hobby beekeepers add more net pollinating insects, but these bees compete with populations of native bees for the same floral resources, thus threatening populations of native bees. The best thing master pollinator stewards can do for the insect pollinator health crisis is to increase floral resources.

Resources

Bee Lining: The Craft of Bee Hunting (2016) — video featuring Professor Tom Seeley, Cornell University: <https://www.cornell.edu/video/bee-lining-finding-wild-beehives>

Honey Bee Health Coalition — comprehensive source of varroa mite control recommendations: <http://honeybeehealthcoalition.org>

Missouri State Beekeepers Association — Missouri's only statewide beekeeping association: <https://mostatebeekeepers.org>

Save the Hives — a website for mapping the location of honey bee colonies: <https://SaveTheHives.com>

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