



Bees, flowers and honey



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On the cover, bee visiting a sunflower. Note the pollen accumulated on the hind legs. Photograph by the author.

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Introduction

Bees and flowers have a very intimate relationship. Bees depend on flowers to obtain the nectar and pollen they use as food, while many flowers depend on bees to carry pollen to another flower that will produce seeds. Honey is the product of this relationship.

My interest in bees originated early in the 1970s, when during an animal behavior course I made a project about their ability to distinguish colors and shapes. The interest in flowers dates back to the botany courses I took in those days and resurfaced strongly decades later during the preparation of *Flores de Puerto Rico* (edicionesdigitales.info). The interest in honey dates from childhood, when my paternal grandmother used it to flavor desserts and home remedies.

This work follows the old format of the catechism: a work that, frequently written in questions and answers, contains the succinct exposition of some science or art. True to this format, the questions are answered briefly and in general terms; the reader who wishes to learn more will find information in books, magazines, the Internet and YouTube. After all, *Apis mellifera*, the common bee or honeybee, is the most studied and best-known insect. There is a short list of references at the end of the work. Although the questions can be read in any order, it is better to follow the presented sequence because sometimes to understand an answer it is preferable to have read the preceding one.

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Bees

When did the bees originate? Entomologists (insect specialists) suspect that bees originated some 125 million years ago, shortly after the first flowering plants. Since then bees and plants have coevolved to produce the large diversity of species we have today.

What characteristics distinguish them? Bees are distinguished from their closest relatives, wasps, by the presence of many hairs on the body (important for collecting pollen) and because both adults and larvae feed on honey and pollen. An intermediate condition is the Mexican honeywasp (*Brachygastra mellifica*), which like bees builds combs and produces honey, but like wasps the adults feed on insects. Bees, wasps and ants compose the order Hymenoptera, one of the largest groups of insects.

How many bee species are there in Puerto Rico? The island has some 40 species, the largest being the Carpenter bee (*Xylocopa mordax*), which nests in dry trunks and pollinates the common passion flower (*Passiflora edulis*); the female is black and the male is golden. The smallest native bees are the size of fire ants.

Are all bees social? No, the vast majority of the 20 thousand species of bees are solitary. These bees construct nests composed of few cells, supply them with food, deposit one or more eggs near or on the food and leave. The only social bee present in Puerto Rico is the common, domestic honeybee (*Apis mellifera*), native bees are solitary or at most congregate to nest.

Which bees produce the honey we consume? Almost all the honey consumed by human beings is produced by *Apis mellifera* (literally bee with honey).

In the East there are six other species of *Apis*, the most productive being *A. cerana*, which is also kept in boxes. *Apis dorsata* is migratory and nests high in tree branches or under stone ledges, its enormous combs are harvested by villagers who climb using rope and rope ladders. The small hives that *A. florea* builds in vegetation are sold in open markets of Southeast Asia. In Australia, Brazil, southern Mexico and Cuba honey is harvested from melipone or stingless bees. *Melipona beecheii* was cultivated by the ancient Mayans and still produces honey for their descendants; this species was introduced from Mexico to Cuba, where it is also kept for honey production. The cultivation of melipones (literally honey workers) is called meliponiculture, the cultivation of bees of the genus *Apis* is called apiculture.

When did the honeybee arrive in Puerto Rico? According to a publication about local agriculture before 1898, the honeybee was brought from Cuba around 1780 and to Cuba it arrived some 20 years earlier from Florida. Shortly after arriving in Puerto Rico, the honeybee colonized the island and people began harvesting wild combs. It is said that the first honeybees arrived in the New World in 1662, taken by the English to the east coast of North America.

When did beekeeping start in Puerto Rico? The exact date is unknown, but at a fair held in 1867 a beekeeper exhibited honey and other products from his hives. In 1897 Puerto Rico exported 1350 liters of honey to the United States. The Agricultural Experimental Station at Mayagüez began in 1908 a project to establish the beekeeping industry using Italian bees brought from the United States; apiculture expanded rapidly in the Mayagüez coffee region and spread gradually throughout the island. In 1914 some 518,000 liters of honey were exported to the United States.

Where did the honeybee originate? *Apis mellifera* originated in Africa and migrated to Europe and the Middle East hundreds of thousands of years ago. A drawing made 8000 years ago in a Spanish cave shows people climbing a tree to collect honey. The Egyptians kept bees and transported hives along the Nile to flowering fields. The honeybee bee is found today in all continents except Antarctica.

Is there only one type of honeybee? No, geographic isolation before humans began to domesticate it produced some 30 subspecies. The subspecies that predominates in Europe, Canada, most of the United States and the temperate areas of South America is the Italian honeybee, *Apis mellifera ligustica*. The bee that predominates in tropical areas of South America, in Central America, Mexico, the southern United States and the Caribbean, is the hybrid between *A. m. ligustica* and *A. m. scutellata*, native to southern Africa and known as the African honeybee; these hybrids are called Africanized bees.

How did the Africanized honeybee originate and when did it arrive in Puerto Rico? Twenty-six African queens were imported in 1956 to Brazil with the intention producing a honeybee better adapted to the tropics. A year later several swarms were accidentally released which settled in the forest and crossed with wild Italian bees; the hybrids dispersed throughout the tropics of South America, crossed Central America and arrived in the United States in 1990. In 1994 they arrived in eastern Puerto Rico and in a year had crossed the island. Although local beekeepers have imported other subspecies, including *A. mellifera mellifera*, *A. m. carniola* and *A. m. caucasica*, the bee that predominates among beekeepers and which lives wild on the island is the Africanized honeybee.

Why is the African honeybee so defensive? It is said that *Apis mellifera scutellata* is very defensive because it has many enemies in its natural habitat. These bees respond promptly, joining in the attack numerous individuals who pursue the aggressor insistently and at greater distances. Hybrids (Africanized bees) are less defensive but attack more frequently than Italian bees. Beekeepers select queens from less defensive hives to replace the more defensive ones and thus gradually mitigate the problem.

What distinguishes the African bee from the Italian bee? Apart from the greater willingness to defend itself, the African bee is somewhat smaller, swarms more frequently, its hives are smaller, it tends to store less honey, and faced with unfavorable conditions leaves the nest more frequently. The Italian bee is slightly larger, swarms once or twice a year, its hives are larger, stores a greater amount of honey (necessary to survive the winter) and rarely leaves the nest when facing

unfavorable conditions. The hybrid (Africanized bee) combines characteristics of both subspecies.

Where does the honeybee build its hive? Wild bees nest in hollow trees, caves, between walls, under eaves of buildings, under branches and in other places sheltered from rain. Beekeepers replace the natural nest with a box that can be opened to examine the hive and harvest honey.

What is a typical bee box like? The bee box is approximately 20 inches long by 16 inches wide and 9.5 inches tall. It is built of wood and rests on a bottom board that serves as the entrance. The board is placed on a stand to separate it from the ground. The box contains ten removable rectangular frames where bees build combs; this first box is called a deep super or brood chamber because its combs are used to produce bees. On top of the brood chamber sits a lower box called a shallow or honey super because its frames contain the honey harvested by the beekeeper. To keep the queen from laying eggs in the honey super, a grid or queen excluder is placed between the two boxes. The complex typically consists of one brood chamber and one or two honey supers. The box was patented in 1852 by Lorenzo L. Langstroth (1810-1895) and is known as the Langstroth box.

How are combs built? Bees construct a double comb of wax in each frame of the box. Each side or face of the comb is composed of several thousand hexagonal cells measuring about a quarter of an inch wide by half an inch deep, just enough to accommodate a bee inside. Adjacent combs are separated by three-eighths of an inch, the distance needed for bees to walk and work between the combs. Cells are slightly tilted back so that honey does not escape.

Why are the cells hexagonal? Bees build the cells using their body as a pattern and are therefore initially circular. Once the cell is finished, the bee vibrates its thoracic muscles to heat the wax until it melts; then, as the wax cools, the walls of the cell are flattened and the hexagonal pattern generates automatically. A similar effect can be observed with soap bubbles on a surface; solitary bubbles are circular, but when they touch the contact area changes to a straight line.

How are cells distributed in the comb? Brood cells occupy the central area of the comb, around them are cells that store pollen and beyond are those that

store honey. Cells for raising males (drones) are larger and are built towards a corner of the comb. Cells for raising queens are much larger, peanut-shaped and are built in various places of the comb.

How is wax obtained? Wax is secreted by eight glands that discharge between the abdominal segments of workers dedicated to building comb. Wax is initially liquid, but on the surface of the abdomen turns solid and forms thin sheets or flakes that are used to build, expand and repair comb. Wax is initially white, but turns yellow and eventually brown.

Why do bees store honey and pollen? Honey and pollen are the food of the bees; both are stored for daily use and as a reserve for periods of scarcity, such as winter for bees living in temperate zones and drought or prolonged rain for those living in the tropics. As a safety measure, bees store more honey than they usually need and we harvest the surplus.

What is honey used for? Honey is the main source of carbohydrates and therefore energy. The cells of the body degrade carbohydrates (sugars) through a process called cellular respiration, which breaks down chemical bonds to release the energy needed to walk, fly and work. Honey is also the raw material for wax production; bees consume eight pounds of honey for every pound of wax produced, and with this amount of wax build some 35,000 cells.

What is pollen used for? Pollen is the main source of proteins, fatty acids, minerals and vitamins. Proteins are digested to produce the amino acids that the bees need to make their own proteins. The same happens with fats to produce the fatty acids that they require to make their own fats. Minerals and vitamins are needed to carry out many metabolic reactions. Each worker larva receives about 135 milligrams of pollen during its development.

What is bee bread? During the process of packing pollen into storage cells, bees add to it honey, saliva and other enzymes that, combined with the action of microorganisms, modify it chemically and also conserve it. Pollen thus stored is known as bee bread.

How many bees live in a hive? This depends on the variety of bee, the age of the hive, the fecundity of the queen and the amount of food available. A mature and healthy hive contains about 50,000 bees: one queen, 500 to 2000 drones and the rest workers.

How does the hive grow? The hive grows by producing more bees, particularly workers. The queen inserts its abdomen into a cell and deposits at the bottom an elongated white egg. Three days later a white larva is born that will be fed royal jelly: a white secretion, rich in proteins and produced by the cephalic glands of workers laboring as nurses. Three days later the diet changes to honey and bee bread. Drone larvae receive the same diet but develop into males because their cells have 16 instead of 32 chromosomes (to produce a drone the queen lays an unfertilized egg, to produce a worker she lays a fertilized egg). After growing and molting the exoskeleton five times, larvae become pupae and a few days later emerge from the cells as adult bees. The cycle lasts about 21 days for workers and 24 for drones.

How are queens produced? Queens are produced like workers but eggs are laid in larger cells and the diet of the larvae consists exclusively of royal jelly (which will be the queen's food throughout her life). The cycle for queens lasts about 16 days. The hive only produces new queens when the current queen grows old or dies, and when the hive produces a swarm.

How long do bees live? The queen usually lives three to five years, but many beekeepers replace it annually to maintain high egg production and increase the size of the hive. Workers live about 45 days, but this varies with work load: when nectar is plentiful they fly a lot and live less than a month. Drones live up to three months or until they mate. In temperate areas, drones are expelled from the hive during autumn and none survive winter.

How does the queen differ from the workers? The queen is considerably larger, the dorsal surface of its thorax is bald instead of hairy and its stinger is smooth (the workers' is serrated). The queen's abdomen is much larger because the ovaries are developed.

Which are the queen's tasks? The main task of the queen is to lay eggs, approximately one per minute (1500 a day) when food is abundant and the colony grows fast. The queen also secretes a compound (pheromone) that keeps workers from developing sexually.

How do drones differ and what tasks do they have? Males are more robust, lack a stinger and their eyes are noticeably larger, touching at the top of the head. Their only task is to mate with queens. Drones of neighboring colonies fly daily to places where they congregate and wait for virgin queens coming from hives that have replaced their queen or have produced swarms.

What tasks do workers have? Workers perform all the tasks of the hive except producing more bees. They spend approximately the first half of their life inside the nest or box and fly during the second half. Inside the hive they clean and disinfect cells, remove dead larvae and bees, feed and groom the queen, feed larvae and drones, produce wax, build and repair cells, maintain a stable temperature in the brooding area, process and store food, and defend the entrance to the hive. Outside they collect nectar, pollen, water and vegetable resin; in addition, when a swarm is formed they choose the location of the new nest and when the colony migrates they lead the search for a better location. The tasks follow an order during the life of a worker, but if necessary any worker can repeat tasks she had done before. Bees that collect food are called foragers.

How far do they fly searching for food? Bees prefer nearby food sources in order to save energy but can fly long distances searching for nectar and pollen. Bees have been observed foraging 10 kilometers from the hive.

How do they collect nectar and produce honey? Bees suck flower nectar and store it in the crop (posterior portion of the esophagus). There they add enzymes that break sucrose (a double sugar) into glucose and fructose (simple sugars). At the hive they transfer the nectar to other workers who ingest it and repeat the process. Nectar is then deposited in storage cells, but its water content is still high and to reduce it the bees fan their wings over the cells. When the water concentration reaches 16 to 19% (the percentage depends on ambient humidity),

the cells are capped with a layer of wax called an operculum and the nectar is now called honey. Bees visit some 2 million flowers to produce a pound of honey.

How much honey can one hive produce? This depends on its size (number of bees), the abundance of flowers, the competition of other hives (including feral ones), the amount of honey bees consume to meet their needs, and the beekeeper's experience. A well-managed hive in southwestern Puerto Rico should produce yearly about 45 pounds of honey.

How do they collect and store pollen? Bees collect pollen with their front legs, pass it to the hind legs and pack it in a region called corbicula or pollen basket. At the hive, the bee places the pollen in a cell and other workers finish packing it. Unlike cells that store honey, those that store pollen are never capped with wax.

How do they collect resins and make propolis? Bees collect resins secreted by plants to protect their tissues. Like pollen, resin is collected with the front legs and transported to the hive on the hind legs. There other bees receive it and combine it with wax to form propolis. This dark-brown material is used mostly to reinforce the honeycomb and fill cracks.

How do they collect and use water? Bees suck water and store it in the crop; other workers receive it in the hive and use it immediately. When the need for water increases, some workers that receive water fill their crops and become living tanks. Bees do not use water to eliminate metabolic waste or to cool their bodies, like we do, instead they use a small amount for their metabolism and occasionally a larger one to cool the hive.

How do they regulate comb temperature? Nest temperature fluctuates with ambient temperature, but the brooding area is kept very close to 95°F (35°C). When the temperature drops, some workers stand over cells containing larvae or enter adjacent empty cells and vibrate their thoracic muscles to generate heat. When the temperature rises, they fan their wings over the cells and elsewhere in the hive to circulate the air. If the temperature keeps rising, they deposit a thin layer of water on the combs to cool them by evaporation. Bees that are not thermoregulating exit the nest or box and group outside.

How do they communicate? The most important senses in the dark interior of the hive are smell and touch, both perceived by thousands of sensors present on the antennae and the tips of the legs, which also perceive vibrations that propagate over the surface of the comb. Chemical communication occurs by way of compounds called pheromones, which modify the behavior of other bees.

Do they have good vision? Bees do not see as much detail as we do, but their eyes are very sensitive to movements such as the swaying of flowers in the wind. Each eye has several thousand tiny sensors called ommatidia that send information to the brain, where it is integrated to form a single image.

Do they see colors like us? Bees do not see red and thus for them a red flower is black. At the opposite end of the visual spectrum they see ultraviolet light which we cannot see. Some yellow flowers have on the base of the petals slightly darker areas that reflect ultraviolet light; we see the flower yellow but they see it yellow with dark blue stripes that point the way to the nectar deposit.

How do they know where the flowers are? When a foraging bee finds flowers rich in nectar and/or pollen, she returns to the hive carrying a sample and on one of the combs performs a display or dance. If the food source is close, she walks in circles, some to the left and others to the right, while vibrating the abdomen. If the food source is far, she walks in a straight line while quickly vibrating the abdomen from side to side, makes a turn to go back to the start, walks again in a straight line vibrating the abdomen and makes another turn in the opposite direction. The length of the straight line indicates the approximate distance to the flowers, and its angle on the vertical surface of the comb indicates the direction that her companions should follow with respect to the sun. In both cases, the duration of the dance and the intensity of the abdominal vibrations are proportional to food abundance and quality. Dancing bees stop occasionally to distribute food among their followers, as a hint of what they should find. Since the instructions are approximate, some dancers accompany their sisters during the first flights to the food source.

Do all bees visit the same flowers? No, while some bees dance to inform the location of certain flowers, others do it to inform about other flowers. If some

flowers provide more food than others, more bees advertise them and more bees visit them. If a source is very attractive, as would be a large tree, the vast majority of bees visit that source. When a bee begins to visit one type of flower, it continues doing so until food decreases; then, convinced by the dance of another bee, she begins to visit another type of flower.

How do they know where the hive is? Bees perform orientation or reconnaissance flights before straying far from the nest for the first time. During these flights they form progressively larger arcs while looking toward the nest to identify reference points that will allow them find it. Novice bees are often accompanied by experienced sisters during their first flights.

Do they visit flowers at night? No, but they visit them during twilight before sunrise and after sunset; this can be observed during the flowering of the ceiba tree, which starts opening its flowers when the sun sets. The bees remain in the flowers until shortly before it gets very dark and return as soon as there's some light in the morning.

Do the bees sleep? Foraging bees spend the night grouped in quiet areas of the comb while pointing their antennae down. Other workers sleep less and not necessarily at night. Some bees spend the night on vegetation, sometimes far from the nest.

Why are they afraid of smoke? Smoke indicates the proximity of fire and in response bees move to the interior of the nest in preparation for the possibility of having to flee. Smoke also apparently blocks the reception of alarm pheromones and calms the bees.

Who are their enemies? Bees have several enemies, including other bees that invade neighboring hives to steal food. Larvae of the moth *Achrosia grisella* destroy the combs. The mite *Varroa destructor* sucks their blood like a vampire. Bees are also attacked by bacteria, fungi and viruses that cause disease. Outside the hive they fall prey to spiders, wasps, praying mantises, toads, lizards and birds. Elsewhere, bears and honey badgers destroy the hive to eat honey, pollen and larvae. In Africa and Asia, birds called honey guides attract the attention of badgers and people to guide them to the proximity of a nest and feed later on the remains of the hive.

How do they defend themselves? The entrance to the hive is controlled by guard bees that only allow the entrance of bees identified by the particular smell of the hive. Intruders and other animals are rejected or attacked, other bees joining in the defense. The new defenders are alerted and attracted by an alarm pheromone produced by the first bees that sting.

What is in venom? Apitoxin or bee venom contains more than sixty ingredients, of which some eighteen proteins are considered active compounds; the main ones are adolpine, apamine and melitine. Each sting injects about 0.1 mg of venom.

Is the sting dangerous? The sting is painful and the tissue becomes red and inflamed, but the pain usually lasts a short time and there are no other consequences. Some people are allergic to the venom and may suffer a reaction that includes swelling of the face, mouth and throat, dizziness, accelerated pulse, and difficulty in swallowing and breathing; such a reaction should be treated promptly. The purpose of the sting is to produce an intense pain that scares the predator and reminds him of the unpleasant experience.

Why do bees die after stinging? Because the stinger has minute teeth that become embedded in our skin and during the struggle to remove it part of the abdomen becomes detached. This does not happen when they sting spiders, bees from other hives and enemy insects.

How does the honeybee reproduce? The production of workers during most of the year only serves to increase the size of the hive. The bee reproduces when the hive generates a swarm composed of the queen, several thousand workers and some drones. Swarms form when food is plentiful and the population is high. Bees in temperate areas swarm once or twice annually, usually in spring and early summer; those living in the tropics may swarm several times during the year. Beekeepers take measures to insure that their hives grow and are productive without forming swarms, since they would lose part of the hive. To make a new hive, beekeepers divide an existing hive and introduce a new queen.

How is the swarm formed? Preparations for swarming begin with the queen laying eggs in much larger, peanut-like cells, which workers build specifically to raise queens. The workers that attend to the queen then place her on a diet so that

she stops laying eggs, reduces her weight and can fly. Workers who will be leaving fill their crops with enough honey for several days. The queen is led to the entrance of the nest or box and soon after, in the midst of a great commotion, she flies with many workers to a nearby place where the group congregates.

Are swarms dangerous? No, swarms are temporary groups and disappear when they find a place to build a new hive. The search for the future home may last hours or a couple of days. During this time the bees remain grouped around the queen and are not aggressive; therefore, there's no justification, other than irrational fear, to destroy the swarm.

How does a swarm differ from a hive? Swarms typically stop at unsuitable places to establish a hive, such as on a shrub, on power lines or on tree branches exposed to sun and rain. In addition, there's no comb under the bees.

How does the swarm find a new house? Foraging bees exit the swarm and fly in all directions looking for adequate places to establish a new hive. The scout bees return and dance on the surface of the swarm as they did when finding flowers. The dancers recruit other bees that leave to inspect the various places. A dance debate develops on the surface of the swarm, during which the least appropriate sites are eliminated and the best ones receive an increasing number of visitors. Eventually one place prevails and the scout bees, now very excited, fly about the swarm to activate their companions. Shortly, all the bees take flight and are guided by the explorers to the new house.

What criteria do scout bees evaluate? The most important criteria are the size of the shelter (large enough to build the needed number of combs, not so large that it is difficult to regulate the temperature), the size of the entrance (preferably small so that it is easily defended), whether the entrance is in the upper or lower part of the space (it is easier to regulate the temperature if the entrance is low), if there's comb from a previous hive (to reuse the wax) and the height of the entrance (important if there are large predators).

What happens in the hive when the queen leaves with the swarm? From the eggs she deposited before leaving, a queen emerges and kills the others by stinging them through the walls of their cells. If two or more queens emerge, they

fight until one remains. About a week later, the new queen makes one or more nuptial flights to mate with drones from other hives.

How does the queen mate? The queen and a group of workers leave the hive and fly in search of drones. The queen produces a pheromone that attracts the drones and they chase her. The male approaches from behind, grabs the queen, inserts his copulatory organ and transfers the semen; at the end of this process, which lasts a few seconds, part of the male's abdomen is detached and he falls dead. The queen mates with other males, if necessary during successive days, until she gathers enough semen to lay eggs during her whole life.

How long does a hive last? It could last indefinitely because workers are replaced regularly and when the queen becomes senile the workers raise a new queen. The duration of the hive, however, depends on the availability of food, enemy attacks, natural disasters and the incidence of parasites and diseases. In temperate areas many new hives fail to store enough food during the summer and die during their first winter.

What happens if the queen dies? Workers raise several newborn larvae to become queens, one of which will be the new queen. A hive without very young larvae will die because it cannot replace the workers. Beekeepers solve this situation by introducing a new queen into the hive; this is done gradually so that workers come to accept her, otherwise she would be immediately identified as a stranger and killed.

Why do bees migrate? Bees migrate when environmental conditions are very adverse; for example, when food or water is scarce, the temperature is too high, or after the attack of a predator. This behavior is known as absconding, and before it happens the queen typically stops laying eggs, workers wait for larvae to finish developing and all stored food is consumed. Only empty comb is left behind. The bees flies far, resting periodically, until they find an adequate place to settle. These groups resemble swarms but contain all the members of the hive.

How do hurricanes affect bees? Hurricanes have two main effects. First, they destroy hives by knocking down trees and bee boxes. Second, they create food shortage by destroying vegetation that takes time to recover and flower again.

During periods of need, beekeepers feed their bees with sugar water and/or with diets specifically developed for this purpose.

What is colony collapse? Colony collapse (CCD- colony collapse disorder) occurs when most worker bees disappear, leaving behind the queen, young workers, larvae and food. This affects mostly hives that are transported long distances to pollinate crops and which are therefore more exposed to stress factors, such as inadequate nutrition, diseases and pesticides. This phenomenon has not been observed in Puerto Rico.



Flowers

When did flowers originate? Botanists suspect that the first flowering plants (angiosperms) originated about 130 million years ago, shortly before the first bees. Before that, terrestrial ecosystems were dominated by ferns and gymnosperms (pines and cycads).

How did the relationship between flowers and bees originate? Experts believe that bees originated from wasps that began feeding their larvae with nectar and pollen, instead of spiders and insects. Ever since, flowers and bees have coevolved and modified each other. Wasps of the genus *Brachygastra* possibly illustrate a stage in the development of the relationship, since they feed their larvae with honey but adults eat insects.

How many species of angiosperms live in Puerto Rico? The island has approximately 3000 endemic, native and naturalized plants, of which some 2400 produce flowers. There are also hundreds of exotic plants cultivated for agricultural and ornamental purposes.

What factors determine plant distribution? Some plants tolerate diverse conditions and thus have a wide distribution, but most have special requirements of temperature, humidity, lighting and soil that limit them to particular places. Some plants grow only near the coast, in cloud forests, in dry zones or in serpentine soils.

When do the plants bloom? Some plants bloom throughout the year, others only during certain months; the length of the day, or rather of the night, is one of

the determining factors. Flowering can happen sooner or later than expected, due to factors such as excessive rainfall, drought, fires and hurricanes.

When do flowers open? Some plants open their flowers early in the morning and keep them open throughout the day, others open them only in the morning, the afternoon or at night. Bees and other pollinators adjust their daily activity to this characteristic of the plants.

What is the role of the flower and its parts? The flower is the organ of reproduction. It has several parts but we are here interested in the petals, the stamens and the pistil. The petals attract pollinators and offer them a landing platform, those of some flowers have stripes that capture the attention of the pollinator and guide it to the nectar deposit. The stamens are composed of a filament and an apical section called the anther which contains the pollen grains. The pistil is composed of the ovary, a tube called the style and a thickened sticky tip called the stigma. Fertilized eggs become seeds, the wall of the ovary turns into the fruit and the surface of the ovary becomes the skin.

What produces the color of the flower? The color is due to the presence of pigments; yellow, orange and red are mostly due to the accumulation of carotenoids, while blue, violet, black and again red are due to the abundance of anthocyanins. Pale yellow is due to flavonoids. The combination of pigments produces the range of colors exhibited by flowers. Something similar happens with the color of the fruit, whose function is to attract the animal that eats it and disperses the seeds.

Are the terms pollination and fertilization synonyms? Although they are commonly used as synonyms, pollination refers to the arrival of pollen on the flower's stigma and fertilization to the fusion of the nucleus of a pollen grain with the nucleus of an ovule.

How does pollination happen? Pollination happens when pollen arrives from the anthers of the stamen to the stigma of the pistil. To be effective, pollination must occur during anthesis, when the surface of the stigma is ready to receive pollen, the secretion of nectar is high and the aroma of the flower reaches its highest intensity. Anthesis typically begins when the flower opens completely and

its duration varies between species. Bees visit a variety of flowers during the day, switching from one species to another according to the time when each has nectar and pollen available.

How does fertilization happen? Fertilization happens when the pollen grain germinates in the stigma, its nucleus travels to the ovary through the style and merges with the nucleus of an ovule. The number of ovules present in the ovary varies among plant species and for this reason fruits have from one to many seeds. Flowers that produce pollen and ovules are called perfect flowers.

Do perfect flowers self-fertilize? Some do, but the vast majority avoids it. Some flowers have the stigma very far from the stamens, in others pollen and ovules mature at different times of the day or are incompatible, and in some the flower opens and closes twice: first with fertile pollen and then with fertile ovules, or vice versa.

Why do so many plants with perfect flowers avoid self-fertilization? Because cross-fertilization (with pollen from another flower) increases genetic variability and the population is better adapted to survive environmental changes, such as a sustained increase in temperature, a prolonged drought or the arrival of a new predator.

Are all the flowers perfect? No, the flowers of some plants only produce pollen (male flowers) or ovules (female flowers) and are thus called imperfect. Depending on the species, imperfect flowers can occur on different plants or on the same plant; in some of the latter the pollen of male flowers can fertilize female flowers, in others the pollen must come from another plant.

Are all flowers pollinated by bees? No, many are pollinated by butterflies, moths, beetles, flies, wasps, hummingbirds and bats. Some pollinate themselves. Many flowers are wind-pollinated. Approximately 30% of crops and 90% of wild plants are pollinated by bees (including native species).

How do wind-pollinated and animal-pollinated flowers differ? Wind-pollinated flowers produce huge amounts of pollen, have very small petals, produce no aroma and secrete no nectar. Animal-pollinated flowers produce less

pollen, have larger and brightly-colored petals, produce scent to attract the pollinator and secrete nectar to reward its visit.

Can flowers pollinated by different animals be distinguished? Yes. Flowers that open during the day and have showy petals are pollinated mainly by bees and other insects; those that open during the day and have petals joined to form a long tube are pollinated mainly by hummingbirds and butterflies, whose long tongues reach the nectar accumulated at the base of the flower; flowers that have a long tube and open at night are pollinated by moths; and nocturnal ones that do not have a tube but have an intense aroma are pollinated by bats.

How specific are pollinators? Some flowers accept a variety of pollinators while others have very strict requirements. To the first group belong many daisies, to the second belong orchids pollinated by males of one species of bee.

Is the honeybee the best pollinator? The honeybee is an excellent pollinator because it visits a wide variety of flowers. Its importance in the pollination of almonds, blueberries, oranges and melons is such that many American beekeepers earn more money by renting their hives for pollination than by producing honey. Some native bees outperform the honeybee as pollinator for certain crops. Tomatoes and peppers, for example, are more efficiently pollinated by bees that intensely vibrate their bodies (buzzing) to dislodge pollen from the anthers, while the honeybee only shakes the anthers with its legs. The Carpenter bee (*Xylocopa mordax*) is the best pollinator of passionfruit because its back is taller rubs the anthers more frequently.

Is pollen consumption detrimental to plants? Pollen is used for reproduction and from this point of view it would be better for the plant if bees only feed on nectar. However, since bees consume pollen, plants compensate by producing a larger amount so that pollination still takes place. The flower of the cannonball tree produces two types of pollen: one sterile for consumption by bees and one fertile for pollination; the sterile pollen is located where the bee lands, the fertile pollen is located where her back rubs the flower.

Where is the flower scent produced? The aroma is produced in glandular cells called osmophores that are present in the petals and other parts of the flower.

Each flower has its own fragrance, product by tens or hundreds of organic compounds that evaporate as soon as they come into contact with air. The fragrance is intense while the flower is in anthesis and decreases after pollination. The aroma is not always pleasant, flowers pollinated by flies that lay eggs on dead animals stink of rotten flesh.

Where is nectar produced? Nectar is produced in glands called floral nectaries and accumulates near the base of the flower. The pollinator must pass near the stigma and the anthers in order to reach it, thus increasing the probability of pollen sticking to his body and reaching another flower.

How do nectar and honey compare? The exact composition of nectar varies among plant species, but its main ingredients are water, sugar (on average 55% sucrose, 25% glucose and 20% fructose) and small amounts of amino acids, proteins and minerals. Honey is essentially concentrated nectar, with almost all the sucrose digested into glucose and fructose.

What are honey plants? These are plants that produce nectar in abundance and therefore contribute more to honey production. The bee flora is the ensemble of honey plants present in a locality.

What does honey flow mean? This is a measure of nectar production by the bee flora. When nectar flow is high bees make a lot of honey, when it's low they produce little and when there's none they feed on stored honey. Beekeepers in temperate climates who extract too much honey from their hives inadvertently condemn them to die of hunger during the winter.

Which are our main honey plants? When the apiculture industry began developing during the first decade of the 20th century, the main honey plants were *guaba* and sweet pea trees planted for shade in coffee plantations. Other important honey plants were angelin, coffee, gooseberry, hogplum, orange, the royal palm and the coconut palm. The following trees are important today: angelin, avocado, coffee, *guara*, guava, Indian mulberry, lemon, lignum vitae, mahogany, mammee apple, mango, mesquite, muskwood, orange, padauk, papaya, pigeon pea, quickstick, seagrape, Spanish lime, sweet acacia and tamarind.

What other sources of food do bees use? Although bees prefer nectar and pollen, they also visit broken ripe fruits, freshly cut sugar cane, sap dripping from plant wounds, honeydew produced by insects that suck sap, hummingbird feeders, and discarded juice and soda containers. Bees have been observed carrying maize, soy and wheat flours instead of pollen.



Honey

What is honey made of? Honey is composed mostly of sugar (80 to 84%) and water (16 to 20%). The main sugars are fructose (30 to 44%), glucose (25 to 40%), maltose (two molecules of glucose, about 7%) and sucrose (one molecule of glucose and one of fructose, about 2%). Honey contains very small amounts of other sugars, organic acids, amino acids, proteins, lipids, minerals, hydrogen peroxide and vitamins. It also contains pollen, fungal spores, bits of wax and debris introduced accidentally.

Is pollen a natural component of honey? All honeys contain pollen, although the bees try to avoid it. Bees have a filter in their crop to remove pollen ingested with nectar and store both foods in separate cells, but their activity in the hive and the movement of air between the combs introduce a small amount of pollen into honey; the low concentration is evident when honey samples are examined with a microscope.

What is adulterated honey? This term has many meanings, including honey diluted with water, honey mixed with other substances, products sold as if they were honey, pasteurized and filtered honey, blends of different honeys, and imported honey sold as a local product.

Is honey syrup a type of adulterated honey? Yes when sold as pure honey, no when sold labeled as such. Honey syrup is a mixture of honey, corn syrup, water, sugar and citric acid. Its only virtue is its low price.

What products are sold as honey? Some stores sell an unlabeled sweet and very thick syrup, perhaps corn syrup, that resembles honey but neither smells or tastes like honey.

Is pasteurized and filtered honey a type of adulterated honey? Honey sold at low prices in supermarkets has been pasteurized to kill yeast spores and filtered to remove pollen, small crystals, wax bits and other debris. The purpose of the first processes is to keep honey from fermenting, that of the second is to keep it from crystallizing. To some people pasteurization and filtration constitute adulteration because the honey is heated and particles it contained are removed, to others the honey is still natural because heating is carefully controlled (as when pasteurizing milk) and the removed particles reached the honey by coincidence.

Are honey blends a type of adulteration? Large honey packers blend product from different sources in order to supply the large supermarket chains. Some consumers reject blended honey for the same reason they reject wine blends, but this does not mean that the final product has been adulterated.

How can I identify imported honey? Puerto Rico imports much honey from the Dominican Republic and some people sell it as local honey. This deception is very difficult to detect because the product is genuine honey and, since Puerto Rico and the Dominican Republic have a similar floras, both honeys naturally resemble each other. Read the label carefully, if it only says that the honey has been packaged locally, it may be imported. The same may happen if the label only reads product of Puerto Rico, because production can refer to nothing more than packaging and labeling.

How can I be sure of buying Puerto Rican honey? The only foolproof alternative is to buy it directly from a beekeeper. Another option is to buy it at agricultural markets and other places where it is sold labeled as Puerto Rican honey, including the producer's name, address and telephone number.

How can I be sure of buying honey and not another product? The best strategy is to know honey well; this is achieved by tasting different honeys until you recognize its essence and flavor. First, take note of the aroma. Then savor the honey while inhaling and exhaling. Try several local honeys, then Dominican

honey and if possible honey from other countries. Finally try honey syrup and corn syrup.

What is comb honey? This is honey sold in square or round sections of comb. The wax is chewed and usually discarded, although it does no harm to swallow it occasionally. Some packers include a piece of comb inside the honey jar.

What is natural or raw honey? This is honey sieved or gently filtered to remove particles of wax, fragments of dead bees and debris introduced during harvest and extraction, but allowing pollen, spores, and other very small particles to pass through. All honey produced locally is of this type..

How is honey extracted from the comb? Honey extraction begins with the removal of honey frames from the honey supers. Ideally, most cells will be capped, indicating that the honey is mature. In the processing area a long knife or another instrument is used to remove the cell caps and expose the honey. Then the frames are placed in the extractor, a kind of centrifuge that rotates them so that honey exits the combs and drips to the bottom of the unit. An old method is to press the combs, but then they cannot be reused by the bees; honey extracted this way is sold as pressed honey. Recently, a system called Flow Hive has become popular among amateur beekeepers, it is made of plastic combs that are opened from outside of the box and honey flows through a tube to a collection bottle; the combs are then closed and the bees fill them again.

How is honey processed before packaging? Honey passes from the extractor to a container covered by one or two sieves that trap pieces of wax, propolis and fragments of dead bees but let pass pollen, spores, and small particles of wax. Beekeepers and small packers transfer the honey to a storage tank and allow it to sit several days so that bubbles and wax particles rise to the surface, after which they pack the honey through a valve located at the base of the tank. Commercial packers pasteurize the honey and pass it through fine filters that remove pollen, spores and all other small particles.

Why are some honeys more transparent than others? The transparency or clarity of honey depends on the sieving or filtration it received. Some

consumers prefer perfectly transparent honey because they consider it purer, others for the same reason prefer it opaque.

What do small bubbles in honey mean? Small bubbles indicate that honey was bottled before all the air introduced during extraction rose to the surface of the storage tank; they are not a defect nor evidence of purity or quality.

Why are some honeys more viscous than others? This property depends mostly on water concentration. For example, a honey with 14% water is twenty times thicker than another with 20% water. Local honeys are relatively thin because humidity is frequently high and it is more difficult for bees to concentrate it. In addition, since honey is hygroscopic it absorbs moisture from the air during processing. Viscosity increases as temperature decreases, for this reason honey stored in the refrigerator is thicker. At room temperature local honey should be neither watery nor too thick.

What is pure honey? This is honey to which nothing has been added. Some people consider that pasteurized and filtered honey is not pure because it has been heated and the pollen has been removed, but since pollen reaches honey by accident and nothing has been added to the honey, producers consider it pure and as such label it.

What is organic honey? This is honey produced in fields where insecticides were not applied and antibiotics were not used to control bee diseases and parasites.

What is non-GMO honey? This is honey produced in fields free of plants containing genes from other organisms. GMO is the acronym for Genetically Modified Organism.

What is Grade A honey? The United States Department of Agriculture issues guides for honey quality but makes no inspections, the classification is therefore assigned by the producer. Grade A honey should have less than 18.6% water, the normal aroma and flavor of the dominant nectar, and should be free of caramelization, fermentation and smoke odor.

What does fancy mean in a honey label? The term fancy has no official definition related to honey and is thus an empty term used to sell the product.

Why do some jars have an expiration date? Honey does not expire and therefore requires no such date. Some jars have an expiration date because it is company policy to include it with all its products.

What is forest or mountain honey? The raw material for this honey, produced in temperate climates, is the honeydew eliminated by aphids and scale insects that feed on the sap of certain trees; these insects extract from sap the most important nutrients and eliminate through the anus most of the water and sugar. Bees collect the honeydew and use it to make honey. Some producers name the honey after the tree that produced the sap; for example, fir honey or pine honey. This honey is dark, almost never crystallizes, and has a strong flavor with shades of molasses, coffee or chocolate.

What is the pH of honey? The average pH of honey is 3.9, quite acidic and similar to that of orange juice. The sweetness of honey hides most of its acidity.

How many honey varieties are known? The United States produces some 300 varieties; in the world there are thousands, many more than wine varieties. Some aficionados travel the planet searching for the rarest honeys.

What determines honey's color, aroma and taste? These properties depend on the nectar collected by the bees, which in turn depends on the diversity of flowers visited. All honeys are composed mostly of sugar and water, but the proportions of sugars, minerals, organic acids, amino acids and other components vary among them.

Are honey color and taste related? Yes, pale honeys are usually sweeter than dark ones. European acacia honey is pale yellow and very sweet, while buckwheat honey is almost black and its strong taste is reminiscent of molasses. Local honey is typically brown and sweet.

Can a single hive produce different honeys? Yes, since the bee flora changes during the year, honey from early spring differs from that made in late summer. One same hive can produce simultaneously more than one variety of

honey, when bees in different parts of the hive visit different flowers and store honey in different combs.

What is multifloral or polyfloral honey? This is honey made from the nectar of an indeterminate variety of flowers. It is identified as such, as wildflower honey or simply as honey. If the label does not identify a type of flower, we may assume that the honey is multifloral.

What is monofloral or unifloral honey? This is honey in which at least 70% of the nectar comes from a single plant species. It is identified by the name of the dominant flower: acacia honey, avocado honey, orange honey, etc.

How is the percentage of nectar in honey calculated? This requires identifying and counting under the microscope the various types of pollen present in honey. The task is performed in specialized laboratories and thus the consumer has no choice but to rely on the label.

How is monofloral honey produced? When the desired flowers are about to open, the beekeeper brings his hives to the area, removes the honey supers and replaces them with empty ones. When flowering starts waning and the bees begin to visit other plants, the supers filled with honey are removed and replaced by empty ones. The honey is then extracted and packed.

Is monofloral honey produced in Puerto Rico? The large-scale production of this type of honey in the island is difficult because we have few large tracts of land dominated by a single plant. However, during certain months of the year some plants flower massively and honey contains so much nectar from that plant that it becomes monofloral. In this way some beekeepers produce modest amounts of coffee, mangrove, mesquite, angelin and Spanish lime honeys.

Should I store honey in the refrigerator? No, honey lasts months or even years at room temperature. Simply store it in a tightly-lidded container to protect it from ants. Honey stored in the refrigerator occupies space, turns very thick and the low temperature favors crystallization.

Why do some honeys crystallize? The main culprit of crystallization or granulation is glucose concentration, which varies from 25 to 40% in different

honeys. Some honeys with low glucose concentration never crystallize, while others with high concentration granulate soon after being extracted or even inside the comb. Air conditioning accelerates crystallization, for this reason raw honey frequently granulates in stores and supermarkets.

How does honey crystallize? The process begins with the formation of small crystals around pollen grains, spores, minute wax particles, dust or other debris present in honey; the crystals grow until all the glucose precipitates, leaving on top water and fructose. The amount of liquid and solid varies with the concentrations of glucose, fructose and water in the different honeys.

What does crystallization tell us about honey? First, that it has a high concentration of glucose. Second, that it is raw, since pasteurized and filtered honey does not crystallize.

Can granulation be avoided? To avoid crystallization, consume honey soon, don't store it in a cool place, and buy honey less susceptible to granulation. Inexpensive honey sold in large supermarkets does not crystallize because filtration removes the particles that serve as nuclei for crystal formation.

Can crystallization be reverted? Yes, the traditional method consists of placing the container in hot water until the crystals dissolve. The process can be accelerated with a microwave oven but the honey must be in a glass container (plastic deforms when heated this way). Begin with 15 seconds in high if the bottle is large or 10 seconds if it's small. Remove the jar, mix the honey and repeat until all the honey is liquid. Honey will crystallize again if you don't consume it within a reasonable time, if this happens simply repeat the process.

What is creamed honey? This is honey prone to crystallize that has been prepared to give it a creamy texture suitable for spreading on bread, toast and other foods. It should be consumed fairly soon because over time it may separate into the liquid and solid portions typical of crystallized honey.

How does honey last such a long time without spoiling? Honey does not spoil easily because its elevated sugar content makes it highly hygroscopic. Most

bacteria and fungi that spoil food dehydrate and die when they come in contact with honey.

Why does honey ferment? Honey contains yeast spores that remain dormant until the water concentration nears 20%, then they activate and begin to metabolize (ferment) sugar. Since honey is hygroscopic, its water concentration increases every time the jar is opened and especially when it is left open. Honey also ferments when beekeepers harvest combs rich in immature honey (watery honey that the bees had not finished condensing). As may be expected, honey diluted with water ferments readily. An early sign of fermentation is the escape of gas (carbon dioxide) when the jar is opened.

Can fermented honey be consumed? Yes, as long as its odor and taste are acceptable. Early in the process ethyl alcohol accumulates and honey acquires a pleasant smell and taste. Later, acetic acid accumulates and honey turns sour.

Can fermentation be avoided? To avoid fermentation, keep the container tightly closed so that honey cannot absorb water vapor. When the volume decreases substantially, transfer the honey to a smaller jar or consume it soon. Large packers heat the honey to about 150°F for 30 minutes to kill the yeast spores, pasteurization is carefully controlled so that honey does not caramelize and change color and flavor.

Which are the culinary uses of honey? Honey was the main sweetener until sugar surpassed it during the 19th century. It is currently used in the preparation of cakes (including panettone), biscuits, cookies (Honey Maid Graham Crackers), cereals (Honey Nut Cheerios), dressings and sauces; it is also used to season coffee, tea, ice cream, yogurt, sweets and other desserts. Marzipan, nougat and local treats such as *polvorones*, *cucas*, *bombotó cookies*, *besitos de coco* and *mantecaditos* have (or originally had) honey among the ingredients. Honey can replace sugar, with the advantage of being just as sweet and adding its delicious flavor.

How else has honey been used? Honey was used to preserve food, including meat, fruits and nuts that were submerged in it until consumed. Due to its antiseptic property it was used during embalming and mummification in Egypt. Honey is fermented to produce mead (honey wine).

What is honey's nutritional value? Honey is mostly sugar. Although it contains amino acids, proteins, vitamins and minerals, the concentration of these nutrients is very small. For example, a spoonful of honey typically weighs 21 grams, 17 of which (81%) are sugar and the rest is almost all water; that same spoonful contains 0.5% (half of 1%) of the daily requirement for iron and riboflavin, the most abundant mineral and vitamin in honey. To obtain a significant amount of nutrients from honey, it would be necessary to consume amounts incompatible with a healthy diet. Honey is delicious and enjoying it is one of the pleasures of life, but it should be consumed with the same caution as sugar, pancake syrup, corn syrup, date syrup, agave nectar or any other product rich in sugar.

Is agave nectar healthier than honey? Agave nectar or syrup contains less glucose than honey and therefore its impact on blood sugar level is lower. However, agave nectar is richer in fructose, which the liver converts to fat and thus contributes to weight gain and the development of a fatty liver. All natural sweeteners should be consumed with equal care.

What is honey's medicinal value? Honey has been used for medicinal purposes since ancient times, but many of its benefits are supported by anecdotes and not by scientific evidence. Honey seems to be effective as an antiseptic to help heal wounds, burns and ulcers, and also as a cough suppressant for children. On this topic you should consult reliable sources and not follow blindly the opinion of people without adequate preparation, who may be more concerned with sales than with your health.

Why could honey be dangerous to babies? Spores of the bacterium that causes botulism (*Clostridium botulinum*) are common in the environment and may be present in honey. Infants less than 1 year old do not have robust defenses and may become very ill if the bacterium lodges in their intestine.

Are there poisonous honeys? The nectar of some poisonous plants is toxic and the honey causes dizziness and indigestion when consumed in excess. It is said that honey made from poppies cultivated to produce opium and heroin has narcotic effects.

What other products are obtained from bees? Beeswax candles were used for centuries to illuminate houses and temples because they burn without producing smoke or soot, today this wax is used in the manufacture of lubricants, certain foods, cosmetics and pharmaceutical products. Pollen collected by bees is intercepted at the entrance to the hive and sold as a food supplement, while propolis is used for its antiseptic properties. Bee venom is used as an anti-inflammatory in certain natural remedies. Royal jelly is used by the cosmetics industry.



References

- Bishop, H. 2005. *Robbing the Bees. A Biography of Honey, the Sweet Liquid that Seduced the World*. Free Press, 326 pp.
- Bryant, V. M. y G. D. Jones. 2001. The R-Values of Honey: Pollen Coefficients. *Palynology*, 24: 11-28. [http://entnemdept.ufl.edu/honeybee/extension/Honey%20Show%20and%20Judging/Bryant%20%20Jones%20\(2001\)%20The%20R-Values%20of%20Honey%20-%20Coefficients.pdf](http://entnemdept.ufl.edu/honeybee/extension/Honey%20Show%20and%20Judging/Bryant%20%20Jones%20(2001)%20The%20R-Values%20of%20Honey%20-%20Coefficients.pdf)
- Colón, E. D. 1930. *Datos sobre la agricultura de Puerto Rico antes de 1898*. Cantero, Fernández & Co., 302 pp.
- Genaro, J. A. y N. Franz. 2008. The Bees of Greater Puerto Rico (Hymenoptera: Apoidea: Anthophila). *Insecta Mundi*, Paper 569. <http://digitalcommons.unl.edu/insectamundi/569/>
- Marchese, C. M. y K. Flottum. 2013. *The Honey Connoisseur. Selecting, Tasting, and Pairing Honey, with a Guide to More than 30 Varietals*. Black Dog and Leventhal Publishers, Inc., 208 pp.
- Marson, A. 2013. *Bees. Knowing them to defend them, knowing them to improve our lives*. iTunes, 62 pp.
- O'Toole, C. 2013. *Bees: a Natural History*. Firefly Books, 240 pp.
- Phillips, E. F. 1914. *Porto Rican Beekeeping*. Porto Rico Agricultural Experiment Station, Bulletin No. 15, 24 pp. <http://ufdc.ufl.edu/AA00014641/00001/1j>

- Pundyk, G. 2010. *The Honey Trail*. In *Pursuit of Liquid Gold and Vanishing Bees*. St. Martin's Press, 337 pp.
- Readicker-Henderson, E. 2009. *A Short History of the Honeybee*. Humans, flowers, and Bees in the Eternal Chase for Honey. Timber Press, 163 pp.
- Roubik, D. W. 1989. *Ecology and Natural History of Tropical Bees*. Cambridge University Press, 514 pp.
- Seeley, T. D. 2010. *Honeybee Democracy*. Princeton University Press, 273 pp.
- Tautz, J. 2008. *The Buzz About Bees*. Biology of a Superorganism. 284 pp.
- Tower, M. N. 1911. Bees in Porto Rico. *Porto Rico Progress*, 2(1): 69-79. <https://ia700406.us.archive.org/0/items/cu31924003425521/cu31924003425521.pdf>
- Wilson-Rich, N. 2014. *The Bee, a Natural History*. Ivy Press, 224 pp.
- Winston, M. L. 1987. *The Biology of the Honeybee*. Harvard University Press, 281 pp.