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CUSTOMIZED BEES

BEFORE WE DOMESTICATED bees a couple of thousand years ago, we encountered them in our role as hunter-gatherers. Although the point was not to hunt wild bees, gathering their honey was somehow linked to the dangers of hunting. Then we progressed to cultivating the land and rearing cattle, and also began to establish bee colonies near our dwellings. The oldest examples of beekeeping are probably from the Middle East; in Europe, beekeeping first really took off in the Middle Ages. It is difficult to say how and when the breeding of bees first had an impact on humans or even which bees were preferred. But these tended animals with a sting in their tails could be neither tethered nor confined when honey was harvested, so it is fairly safe to presume that beekeepers early on dreamed of how nice it would be if their honey producers could be a bit more cooperative.

A lot of things to do with beekeeping are unique—they cannot be transferred to other animals and cannot be compared to the breeding of other livestock. After all, a queen is not a huge mammal but a small insect, who in the course of its life has not half a dozen descendants (like a cow) or hundreds (like a sow) but millions of them. But still, a number of breeding principles apply, irrespective of the animal group.

In the professional rearing of bees, the term means more than just the breeding of offspring, it means controlled propagation in pursuit of quite specific breeding goals of genetic remodeling. Following the principles of genetic evaluation, the qualities that are nearest to our requirements should be targeted and reinforced by crossbreeding selected individuals and less favorable attributes should be suppressed accordingly.

The qualities that the beekeepers maintain or wish to improve can vary from country to country or from bee region to bee region. Three particular features, however, are consistent; honey yields, manageability, and health.

The honey yields are about the gathering capacities of a colony, about how much honey can be registered in one season—a busy bee is a good bee. Here, food consumption is significant: How much honey do the bees themselves consume or, as the case may be, how much supplementary foodstuff do they need? In this respect, the food source to brood graph presents an interesting picture. Ideally, a colony has its highest number and thus its strongest workforce when blossoms are peaking.

As far as manageability is concerned, bees get good marks for gentleness, consistency in the honeycomb, and a reluctance to swarm (the natural urge of bees to propagate by swarming should be minimal). They should react stoically and submissively to human encroachments and never defend aggressively. When a beekeeper accesses their living and working quarters they should remain peacefully on the honeycombs, on the frames where they have made their cells, and not leave them when they are removed from the hive or placed somewhere else for a short time. Beekeepers are also interested in how a colony handles propolis—the resin from buds that bees use as disinfectant in some areas of the hive and that is considered a nuisance as the frames become sticky and are difficult to move.

The third feature, the health of the bees, is mainly about resistance to diseases. Unfortunately, we know most about this factor when things are already bad and a disease or a parasite has already become established. This is becoming increasingly significant due to the current worldwide threat to honeybees. The resistance of a colony very much depends on its capacity for hygiene and, depending on the region, on the hardships of winter—how successful is the colony in overcoming up to six long, blossomless months of cold in the hive?

Evaluating the potential outcomes of breeding decisions is not a straightforward matter. The most important single factors are reckoned according to a point system, but there is no regional uniformity. Sound judgment and experience are called for in breeding evaluation as the factors cannot be precisely measured.

This is clearly exemplified by the assessment of hygiene. Swiss bee expert Ruedi Ritter explains:

> This impulse is important for the health of the colony. The colonies with the best marks are those that quickly clear the hive floor of debris and dead bees after the bad weather period. However, it is difficult to judge the cleaning instinct independently of the size of the colony because only a strong colony can warm the whole brood area during colder periods and in doing so keep the floor clean. Weaker colonies leave the dead bees and debris in the cooler, peripheral areas of the hive.[1]

In other words, as far as protection from germs is concerned, a numerically weak colony that cleans diligently is topped by a medium-strength colony of sloppy cleaners.

Uniform evaluation is also complicated by the fact that what is welcomed in some places is less appreciated elsewhere, if at all. So, rapid spring development—the ability of a colony to be ready to fly quickly and in significant numbers after the winter break—is most welcome at sites where early flowering plants need to be pollinated. This includes all rosaceous plants like apples, pears, cherries, and almonds. In areas where the food sources are in forests, it is better when a colony reaches full strength relatively late, in early summer.

They have to be later starters, because the aphids need to have developed enough for their secretions of honeydew to be harvested by the bees and processed into dark, strong honeydew honey.

For breeders who wish to optimize the qualities and talents of their animals, the question is: Which qualities are hereditary? That is, which ones can be influenced at all? Over the years, bee experts have developed a scale for "heritability," ranging from 0.0 (not hereditable) to 1.0 (entirely heritable). For example, a hereditary estimation could indicate a low value of 0.26 for honey yields, an average 0.41 for gentleness, and an impressive 0.91 for consistency in the honeycomb. But as the word "estimation" implies, although the values are given numbers they cannot be exactly defined mathematically.

Why the industriousness of *Apis mellifera*, of all things, cannot be genetically improved is, the experts say, to do with the fact that nature, over millions of years, has already carried out optimization through selection. Better foragers were always the enemies of the good foragers and they in turn were at some stage replaced by excellent ones. But as with top athletes, at a certain stage of perfection, a system, a creature, an organ can only be improved minimally because further progressions can only be made at the expense of losses elsewhere—which could cost nature dear.

It is easier to explain why the margins for gentleness are greater for beekeepers. Before we domesticated honeybees there was no selection pressure for placidity and humans could attempt to re-route priorities according to their needs. But as with all attempts at manipulation, as with all adjustments and readjustments, it is worth keeping an eye on the impact of mechanisms; a number of pieces of genetic information are often located at one control point. Dog breeders determined to breed Dalmatians with smaller black spots know now that this was only possible at the cost of impairing the dogs' hearing. It seems that the genetic factors that influence coat coloring are also associated with the development of hearing.

Breeders who select bees for winter hardiness, maybe to help them cope with northern winters, have to take into account a slight reduction in the colony strength. The advantage of a tolerance to the cold can only be achieved with this side effect. But because in colder climes spring arrives later, a well-populated colony would be burdened by a poor supply of blossoms anyway; for beekeepers in harsher climates, a moderate reduction in the size of a colony is not a damaging factor but really rather a positive one. Elsewhere there is a win-win situation for beekeepers. Tended colonies, in particular, inherit a low propensity to swarm, a factor highly rated by beekeepers.

How one attribute is encouraged while another is suppressed, how benefits can be developed without having to deal with significant drawbacks is the magic formula of beekeepers. There is both knowledge and a great amount of pseudo-knowledge. The beehive is always open to a world of esotericism and charlatans.

At the moment, great efforts are being geared toward *Varroa*-resistant or at least *Varroa*-tolerant honeybees. In densely populated regions of the world, purchasing the *Varroa*-hardened strains of Africanized bees—the "killer bees"—for breeding purposes is forbidden. They are easily provoked and aggressive, so the consequences would be unacceptable.

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What about other species of bees that over thousands of years have developed behavioral patterns that enable them to live with the mites? What about the Asian honeybees? It is well known that there is a species barrier between the Asian honeybee (*Apis cerana*) and the European honeybees (*Apis mellifera*) that cannot be crossed. Despite this, researchers are interested in learning what exactly it is that allows the *cerana* to co-exist with *Varroa*. It is striking, if not decisive, that the Asian worker bee broods develop in only eighteen days as opposed to the twenty-one days that the European ones need, or even twenty-four days until the actual hatching of the Asian drones. The *ceranas'* shorter development time makes it more difficult for the *Varroa* offspring, which thrive in the brood, to keep pace.

Can the European bees be induced to open the cell lids quicker? Not to date. As already stated, crossbreeding the species isn't an option. A genetic transfer of the *cerana* attributes would only be possible through genetic manipulation—if at all. Astonishingly, some committed environmentalists and beekeepers, who protest against agricultural genetic engineering, are willing to turn a blind eye to this modern magic if it could somehow help their bees.

Tentative steps that don't transgress the species' boundaries seem more promising. We know that bees that clean thoroughly make life difficult for the *Varroa* mites, and plans are already afoot to make very good cleaners from just good cleaners. There has been some success in observing cleaning bees with special infrared cameras and marking the particularly industrious ones. But how is it possible to pass on their traits when the workers in a colony are normally sterile females?

There is one exceptional circumstance in which the workers, to a limited extent, can reproduce, and that is when a colony loses the queen and the young brood, from which a new queen could develop, is not available. In this state of emergency a number of drones—laying worker bees—begin to lay eggs. As they are unfertilized eggs, only drones hatch from them and the colony will sooner or later perish, but their genes could still survive by being passed on to drones that leave the hive to mate.

This situation was artificially induced in the case of the best cleaner bees under infrared light. The drones laid eggs as laying worker bees. The hatched drones, genetically identical clones of workers, inherited the cleaning gene of their mothers, and the female offspring of the queen, fertilized with their sperm, really did prove to be better cleaners.

While the goals for the breeding of queens have changed and continue to change, the basics and techniques for doing so have remained fixed for a long time. Nature only allows a certain amount of scope for human intervention, and those wishing to understand how controlling intervening can be must know what the bee colony does when left alone.

In natural circumstances a colony will only rear a new queen when it needs to increase its population through splitting or if the queen is getting too old. It knows exactly when the time is ripe for this and carries out specific arrangements. Special brood cells, round and cup-shaped rather than hexagonal, are prepared for the young queens. The eggs that the queen lays there are the same as other fertilized eggs, which later become workers, and in the early days the larvae develop identically. Only the subsequent diet of royal jelly makes the difference, eventually leading to the hatching of fertile, female reproductive creatures.

But before this happens, at the earliest when the first new queen cell is sealed, the pre-empting swarm moves on with the old queen. Roughly a week later, further swarms, each with a number of competing future queens, also begin swarming. After the strongest new queen has asserted itself in a swarm and a new habitation has been found, it makes a nuptial flight and starts establishing a new colony.

In the rare event of "efficient" queen supersedure—that is, when the old queen gives in to the new queen without a fight—there is no swarming. The old and ailing queen remains in the hive and waits until the incoming queen mates. Once the young queen has begun to lay eggs, the deposed queen leaves the colony of its own accord to die. In conventional beekeeping, however, very few queens reach an age in which this form of colony-initiated regeneration can occur. Just as ways are found to stop the bees from swarming, it is a widely accepted beekeeping practice to kill the queen before its laying capacities begin to wane. Those who don't wish to let their bees decide when to propagate but still want to make two colonies from one, split them and artificially produce the loss of a queen in one half of the colony. Then the workers of this offshoot colony seize the initiative and produce a queen from larvae that would normally have been other workers. After hatching, the queen goes on a nuptial flight. Alternatively, the colony gets a foreign "ready-made" queen, previously mated, from a breeder.

In order to breed queens you need a cultivated colony with the best queen, fertilized with the sperm of the best drones, and one or more carer colonies without queens but with nurse bees.

When the first fertilized eggs containing the genetic information of a particular queen in the breeding colony become larvae, delicate manual intrusion is required: grafting. Equipped with delicate instruments, a clockmaker-sized

magnifying glass, and maybe a headlamp, the beekeeper removes very young female larvae from the worker cells and implants every single one separately in queen cup cells either hand-made from wax or bought versions made from polystyrene or other substances. Whether Swiss- or Chinese-style grafting tools are used, how much sugar syrup is subsequently dabbed onto the tiny larvae, and a multitude of other details are the stuff of lessons given to the novice by the bee master.

The pre-filled queen cups, usually a couple of dozen, are then hung between brood combs in a queenless nursing colony. In order for a nursing colony to be enticed to care for the cultivated larvae that have been introduced from outside of the colony, it has to be without a queen, and so the queen has to be removed. In this situation breeders can directly intervene. A colony in which the queen is missing does everything it can to end this threatening situation. When a queen has gone, the tone is audibly different, as if the bees realize that in a month the colony will perish if they don't produce a substitute quickly. By taking away the young brood you prevent the nurse bees from feeding their own larvae to fertility on royal jelly and instead have them accept the foreign larvae that has been imposed upon them. When they adopt newcomers with their artificial queen cups they construct the typical queen brood cells, which look like coarsely crocheted thimbles, around them and they are pampered to become future queens.

In addition to the genetic provenance of the implanted larvae, the key to the success or failure of the breeders' efforts to find the best queen lies in the strength and health of the nursing colony. The customer has the choice of having the queen impregnated by selected drones or introducing it to the colony as a virgin queen.

In the summer, everywhere that honeybees are kept, groups of drones await the arrival of a queen bee that will allow a few of them to mate. The drones can have different backgrounds, can be from separate colonies of various beekeepers, and can belong to diverse races. Those who opt for this form of mating leave to chance which of the neighborhood drones mate with the freshly hatched queen on its nuptial flight and consequently the genetic makeup of the offspring.

Breeders, and also ambitious beekeepers, select a different path at this stage and have their queens mated at remote locations, usually islands or secluded mountain regions where the breeders' interests in the mating partners of their queens are easier to control. Breeder associations and national agricultural organizations have set up "male hostels" with potential maters in such areas. These colonies have particularly high numbers of drones. These drones, according to the promises made to customers, have the desired good characteristics laid down in their genetic makeup. Beekeepers, sometimes from far away, arrive with their freshly hatched and still unfertilized queens, complete with a small entourage, and place their unmated queens in mini beehives in the vicinity of the "superdrones" and their supporting colonies. It is essential that the guests arrive without any drones and are only accompanied by worker bees. At these hostels it is almost impossible for unwanted competitors to interfere with the specially selected sperm donors. If all goes well, the beekeepers can return home with advantageously fertilized queens that have already begun laying eggs.

For those who want to take this a stage further, breeders can mail a queen that has already been fertilized by specially selected drones together with roughly ten nurse bees in attendance in a finger-sized, living animal transport cage. One end of the cage is sealed with a three-centimeter-thick (slightly thicker than an inch) plug of sugar mass; as soon as the new queen has been introduced to its new colony, the sugar plug is gnawed away from both sides. In the process the new queen and its attendants begin to take on the smell of the hive and what would otherwise have been a barrier to acceptance in a new colony then disappears.

As with horse and cattle breeding, there are top "studs" from which the owners promise miracles. Just as a horse-breeder might say, "My foal was sired by the wonder stallion Totilas," a *carnica* beekeeper might say, "My colony comes from a real Singer queen."

The Singers in the Ötschtal, Austria, are a true beekeeping dynasty. It seems somehow fitting that the family business is run today by two women, mother Liane and daughter Heidrun, as the queens from their breeding center are renowned. They have even registered Carnica-Singer, the race name together with their own surname, as a brand name. Under this name they offer a whole range of queens that can be ordered online and exported throughout the world. A pure-bred Carnica-Singer queen is priced at 60 euros (just over US$80), a previously mated high-quality Carnica-Singer breeding queen with provisions for the journey and attendants packed in special cases is on its way to you for 390 euros. A non-mated queen bee is to be had for just 16 euros and Singer worker bees sold as artificial swarms and *Varroa*-free bee material as a starter kit, for 38 euros per kilogram (almost US$24 per pound).

However, looking at the German honeybee scene as a whole, the majority of beekeepers continue to have their queens mated at their home locations. Comparatively few work with queens from professional pure-bred breeding centers, and although successful breeders are highly regarded, doubts are increasing about breeding approaches that narrow the gene pool, sometimes absurdly, even using outward appearances as a selection factor.

Ultimately, the breeders are working against the bees' own endeavors to avoid inbreeding. By nature, honeybees when mating try to affect a broad genetic mixture. Their drones fly quickly and far afield to spread their genetic makeup to other colonies. At a height of thirty meters (ninety feet) on every summer day between 1:30 PM and 4 PM, male bees from every possible direction meet at drone gathering areas to mate with queens from other colonies. They can then return with impunity to foreign colonies where they are fed and assimilated, something that the breeders would consider to be a disastrous scenario. People wanting to rear pure-bred queens would have to prevent these natural behavioral patterns.

Almost a hundred years ago, one breeder consciously and decisively pursued a different course, a course away from pure-breeding and toward a mixture of diverse hereditary factors. Karl Kehrle, born in 1898 in Mittelbiberach, Germany, was a pioneer, initially experiencing the loneliness of pioneering but eventually gaining widespread recognition.

He left his Upper Swabian home at a young age and while still in his teens joined the Benedictine monastery at Buckfast Abbey in Devon, England, where practical activities were encouraged on top of spiritual practices. The choice of activity was easy for Kehrle, as he had already fostered an interest in bees while in Germany. From 1919, under the name of Brother Adam, he took care of beekeeping. Southern England at that time had a major problem with serious bee plagues. The Isle of Wight disease, which we now know was a tracheal disease in which the mite *Acarapis woodi* penetrates the respiratory tracts, had wiped out almost all the country's colonies, including those of the monastery. The dark European honeybee *Apis mellifera mellifera* vanished from England.

Brother Adam was at a loss, but he did have a hunch about where to look for a remedy. A German "bee professor" named Ludwig Armbruster (1886–1973) had recently expressed well-founded, scientific doubts about the unconditional acceptance of pure-breeding—doubts that cost Armbruster his lectureship and university career and saw him denounced for "favoring foreign species" and "friendliness to Jews" when the Nazis took power. Armbruster steadfastly refused to distance himself from Jewish colleagues and their studies. His main denunciator, openly supportive of the Nazi regime, was rewarded with a step up the career ladder—an ascent that continued even after 1945, as he climbed toward the top of the German professional beekeeping hierarchy.

Armbruster used Mendel's laws of inheritance, which had been known for a while but were still not generally accepted, and applied them to bees in particular. His findings on the damaging effects of narrow pure-breeding and the importance of variety are, to a large extent, accepted today but are in no way followed in practice by all breeders.

Brother Adam, who all his life described himself as a student of Armbruster, set off to explore all the Mediterranean countries. *Auf der Suche nach den besten Bienenstämmen* (published in English as *In Search of the Best Strains of Bees*[2]) is the title of his scientific travelogue, which he dedicated to Armbruster. It became a classic in modern bee literature.

The Benedictine monk studied strains of bees in France, Switzerland, Austria, Italy, and Germany in 1950. In 1952 he turned his attentions to Algeria, Israel, and Jordan, and then to Cyprus, mainland Greece, and Crete; he also visited the Balkan countries and the Ligurian Alps, where he was particularly meticulous. In 1962 he was off again. This time his itinerary included Morocco, Turkey, Egypt, various Aegean Islands, and the Libyan Desert. Almost in passing he was able to prove that *sahariensis* was an independent type of bee, something that had been fiercely debated previously.

The practical result of his efforts—the gathering together of all the desirable bee traits—was a "new" bee which Kehrle named the Buckfast bee, in honor of his home monastery. He followed the crossbreeding methods of nature where two strains of bees impinge on each other geographically: the experimental mix. The Buckfast breeding practice, as it is still dynamically practiced, is based on the principle of continually crossbreeding with new strains. This process allows a pure-bred Buckfast line to be regularly replenished by the offspring of a parallel breeding line, with the parallel line consisting of a cross of Buckfast bees and various strains of European honeybees. Almost more important than what Brother Adam did is what he didn't do. He wasn't interested in the physical features of the various races, like hairiness, coloring, or the vein structures of the wings. He was only interested in characteristics beyond appearance.

The Buckfast bees were no flash in the pan. In England, Kehrle's adopted country, and also in other corners of the world, the Buckfast bees proved to be diligent foragers with a fairly strong constitution. Walter Haefeker, who works with Buckfast bees, however, warns about the creation of the bee-loving Brother being the be-all and end-all: "These bees only prove their worth in the hands of beekeepers who provide enough food, be it from moving locations or feeding in good time after harvesting the honey. If this is neglected, Buckfast bee colonies, with their high fertility rates, are in danger."

Brother Adam's credo, proclaimed in countless lectures and publications, is as follows: Create as broad a genetic basis as possible and maintain it! Particularly in times of faltering colonies worldwide, this could be an important precept if it comes down to strengthening the immune system of the superorganism bee colony. As the virologist, cancer researcher, and bee authority Professor Eberhard Bengsch says, "Germs are nothing, the immune system is everything!"

Nowadays, since Kehrle's death in 1996, the success of the Buckfast bees is in the hands of the few breeders who use targeted mating to deliver time and again the special vitality required by migratory beekeepers. Despite their benefits—and the various local strains combine a number of economically viable traits—the Buckfast bees are not as extensively prevalent beyond the British Isles as the *carnica* in Central Europe. The Adam bees are held in disrepute by many breeders and beekeepers. In Austria, where they are not considered a strain but mongrels, they are even officially forbidden, one of the main charges against them being that an undesirably strong brooding impulse results from the mating of *carnica* queens with Buckfast drones. Those Buckfast beekeepers that remain between Lake Constance and Lake Neusiedl on the Austrian-Hungarian borders report of threatening anonymous letters, poisoned stocks, and burned-down hives.

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Whether *carnica*, *nigra,* or Buckfast bees, honeybees on the whole fend for themselves. They are livestock that don't have to be enclosed or herded, their hives take up little space, they don't leave dung heaps behind, and for six months of the year they even provide nutrition without having to be fed. Nevertheless, the workaday life of a beekeeper, even if part-time or as a hobby, does require commitment, consistency, and nowadays also a certain understanding of chemistry to cope responsibly with the evaporation of acids.

As with every agricultural activity, beekeeping is a year-long project with bouts of intense activity and more sedate phases, but never periods of total inactivity. What has to be done is decided by the bees, the season, and the weather. Depending on the weather or maybe dramatic events (for example, the outbreak of a disease), the beekeepers' annual program may be delayed or may intensify.

At the beginning of the calendar year all is quiet in the bee colony. In January, a gentle, uniform buzzing can be heard from the hive. In early February, but at most sites somewhat earlier, the queen starts to lay the first eggs. Depending on the state of the bee population, this month is still a quiet period for beekeepers. The bees clean their winter quarters and their bodies. At temperatures above 10°C (50°F) and in favorable weather conditions the cleansing flights begin and they defecate, something that they never do in the confines of the hive. All around the hives are flecks of honey-colored snow. The first pollens (hazelnut, alder, crocus, and snowdrops) and some nectar can be gathered. If the winter was unusually mild the beekeeper will begin the monitoring process: Is the colony faltering? Are there enough supplies available? How serious are the *Varroa* infestations?

March is brooding time in the colony. Considerable amounts of food are brought back to the hive to build up the colony. The growing colony needs new combs for both the nectar and the brood. Left to their own devices, bees would make their own combs, but beekeepers now supply either empty combs from the previous year, complete with the risk that they may be carrying germs, or they accelerate the building of new combs with comb foundation sheets embossed with cell forms.

In April, young bees, both workers and drones, are reared. With good weather conditions the early blossoms arrive (apples, pears, and cherries). It is still necessary to check whether the colony has enough materials for the building and filling of the combs.

From May, the delivery of pollen to the hive is in full swing. Within the colony the need to reproduce is awakened. The bees prepare queen cells for rearing new queens. The time is right for expanding the hives by placing new frames in the hive. Beekeepers who don't enjoy climbing trees to retrieve swarms would be well advised to run regular swarm checks and remove queen cells. Countermeasures like decreasing the colony by manual splitting can also reduce the risks of swarming. From the end of May until mid-June, depending on the region, the first harvesting of honey takes place.

In June, the development of the colony has reached its peak, possibly comprising 500,000-plus individuals. Work for the beekeeper in June is similar to the work in May. The spring honey can be extracted, and for those engaged in the pollination business, June is the prime time for migratory beekeeping.

After the swarming times are over in July, peace and quiet returns to the colony. The bees harvest early summer supplies (raspberries, blackberries, lime trees, and dog roses). And the beekeepers also harvest—the summer honey! At heights above one thousand meters (three thousand feet) and in areas with harsher climates there is, as a rule, only one honey harvest per year, in high summer or slightly later. Beekeepers wanting to produce honeydew honey relocate their colonies to nearby forests.

From August into September the colonies prepare for winter. The queen lays fewer eggs, and the production of offspring diminishes noticeably. The bees now hatching will be winter bees and will live not for five weeks but for six months. Drones are driven out of the hives. The only pollen entering the hive is from late bloomers; building activities cease. After the last honey harvest, beekeepers take on the struggle against *Varroa*, with ecological beekeepers using formic acid. As the nectar inputs decline in late summer the then unemployed foraging bees are used by some beekeepers to make artificial swarms to increase the bee populations. Particularly strong colonies are split, and the colony without a queen either gets a pre-purchased one or a home-bred one; if needs be, two weaker colonies can be merged into one. After a cool summer it is possible that even at the end of August, once there are no more blossoms, additional feeding may be necessary. October is, from a beekeeping perspective, a month of leisure. The queen has almost completely stopped laying eggs.

In November and December, the bees settle in for winter. The bees form a cluster in the hive, and from time to time the bees on the outside move toward the center to warm up. During the bees' active phase, the temperature is kept at a constant 35°C (95°F). In winter, the bees at the center of the cluster keep the temperature in the hive at 25°C–28°C (77°F–82°F) by shivering—they vibrate their flight muscles but keep their wings still, raising their body temperatures. The queen has priority, and as VIP of the bees, resides in the middle of the cluster. Beekeepers can make use of the dark months for further education and training. There is time to attend beekeeping lectures, for reading, and for improving equipment and accessories. At the Christmas markets, honey and other beekeeping products like wax candles can be sold. All that needs to be done with the hive is to keep a wary eye out for *Varroa*, using whatever treatment is considered necessary.

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If you ask beekeepers what the highlight of the year is, you won't get the same answer from everyone everywhere, but noticeably often the reply is that it is the moment after extraction when the kind and quality of the year's honey is revealed. Honey harvesting begins with an act of violence: Someone steals from the bees all that they have stockpiled for their feeding requirements, including their winter stores. But while in the olden days the harvesting of honey went hand in hand with the destruction of the colony, nowadays removal of the easy-to-handle frames holding the honeycomb has a comparatively minor impact. Before getting down to the sticky stuff, the beekeeper checks whether the honey is "ripe." This happens when the honeycombs are sealed or the honey in the non-sealed comb is so thick that even when the frame is banged against something solid nothing seeps out. Some people like to work scientifically and use a refractometer to measure the water content, which should not exceed 18 percent.

Bees remaining on the comb once the frames have been extracted can be dusted off with a bee brush. In modern beekeeping businesses, the brood combs are separate from the honeycombs so that the bees can be blasted from the honey supers (part of the commercial beehive) by compressed air—which is effective but can damage the wings—or by using repellants to drive the bees away from the honeycombs.

There are a variety of tools and techniques for uncapping, or removing the wax seal of the honeycomb. There is cold uncapping using a broad fork-like tool, and also warm uncapping with a spatula tool that has been warmed before use. Many beekeepers use a heat gun, which looks like a mini hairdryer. The uncapped honeycombs are then placed in an extractor, a centrifuge that slowly builds up speed and forces the honey out of the hexagonal wax cells. The honey accumulates at the bottom of the extractor and is drained into a honey tank where it remains sealed for a couple of days at room temperature. During this time, wax debris, which separated from the frames during the spinning process, floats to the surface where it can be easily skimmed off. Once the honey is free from particles it can be decanted into jars. In some honey regions, such as the northern Lüneburg Heide (often referred to in English as Lüneburg Heath) where there are still vast connected areas of heathland, portions of honeycomb are sold as a specialty product.

In addition to honey and wax, which bees secrete from special wax glands to build the honeycomb, bees produce other products. In specialized beekeeping businesses, the queen's diet of royal jelly is wrested from them and uses have been found for propolis, the substance that bees use as disinfectant. Propolis is a resinous mixture that bees collect from tree buds by taking the sticky cobwebby mass from the buds with their mandibles. Secretions that are released by the mandible glands in the process make the mass supple and the bees then stick it to pollen baskets on their back legs. Back at the hive, the gatherer remains almost motionless until its sister-bees have gnawed off the propolis-laden sacs.

Bees cover practically the whole honeycomb with a fine layer of propolis, and according to the classic bee text *Das Schweizerischen Bienenvater*, "They put propolis at the entrance like a doormat so that every arriving and departing bee comes into contact with it."[3]

At the time of the pharaohs, propolis served as an embalming agent. The ancient Egyptians possibly followed the lead of the bees. Small honey-robbing intruders that break into the hive and die there are coated in propolis, thus protecting the bees from the unwanted byproducts of decomposition that could contaminate their nest. Humans use the pleasant-smelling resin-like substance, which aids the healing of wounds, in ointments and creams.

China is the world's leading supplier of propolis, with annual yields of three hundred metric tons (just over 330 short tons)—an immense amount if you consider that a colony annually produces only 50–150 grams (two to five ounces). Very good foraging colonies like the Caucasian bees, however, can yield between 250 grams (8.8 ounces) and one kilogram (2.2 pounds). Depending on the region of origin, propolis can have a wide range of colors, from amber to anthracite. And somewhere hidden in this sticky substance—and yet to reveal itself—is the explanation for its marvelous sound qualities. Famous instrument makers such as Stradivari and Amati mixed propolis into their varnishes, but which kind, how exactly, and in what ratio to other substances remains their secret. The Singers, in Purgstall on the River Erlauf in Austria, not only breed queens but also sell other bee products—after all, the honey comes from an unspoiled nature reserve, free from pesticides and car fumes. The storage of the honey there well reflects the value of this precious natural product. In the cellar beneath the extraction room, the honey is stacked by the barrel, like liquid gold reserves in a safe.