Chapter 2

HOW THE HONEY BEE CONQUERED THE WORLD

IN THE COASTAL mountains of Mediterranean Spain, near Valencia, lies a cave known as Barranc Fondo. The cave has hosted modern man for thousands of years, and likely sheltered Neanderthals for tens of thousands of years before that. Festooned in black and ocher pictographs, it bears witness to that most basic of human preoccupations: food. In addition to game animals, Barranc Fondo depicts a dramatic honey hunt from more than 6,500 years ago. A half-dozen figures climb a rope ladder up a tall tree to a cavity buzzing with bees. As a crowd of onlookers cheers them on, one of the honey hunters has slipped from the ladder and, arms flailing, is plunging to earth.

Honey hunting has always been dangerous, yet that's never stopped human beings. In hundreds of pictographs across the planet, from Europe to Northern Africa, Zimbabwe and South Africa, India, throughout Indonesia, and even in Australia, the basics rarely change: a bee cavity in a cliff or tree, ropes, honey hunters, torches, gourds or baskets to catch the bounty, and around all, a cloud of furious bees.

It's an old, familiar story. The lure of a substance almost preter-

Barranc Fondo cave art

naturally pleasurable. The willingness to endure hardship, pain, and absurd risks, even death, if it means a chance to partake of the bliss. Some people view humans' fascination with honey as the first stirrings of the culinary imagination. I see it as proto-addiction.

With good reason. Put yourself in the mind of a hunter-gatherer in the new Iberian forests sprung in the wake of retreating glaciers of the dying ice age. You subsist on a diet of game, fibrous leaves and roots, and occasional fruit. Not fat, juicy cultivated apples, either. The sweetest thing you have ever tasted is a sort of wormy crab apple. And then you reach into a tree hollow and scoop out a handful of golden, liquid delight.

Well, I'd be hooked, too. If your idea of honey is the bland, cooked sugar alternative that comes in little plastic bears, then you might not understand. But taste a spoonful of raw, unfiltered wildflower honey and you'll get it right away. Plants have spent millions of years developing flowers, and the nectar at the base of flowers, to be as irresistible to animals as possible. It's part of the exchange of favors that is their reproductive strategy. Nectar averages about 16 percent sugar, as sweet as fruit juice, and it has no

purpose except to lure pollinators. Bees gather the nectar and concentrate it in the hive, evaporating water with their wings and bodies until it reaches about 70 percent sugar and has ripened into honey.[1] The honey carries some of the original plant flavors, as well as new ones formed by the bees' alchemy. The end-product of that original floral beckoning, honey is distilled desire. True, *Homo sapiens* was never the intended target, but throughout our evolution we've held on to that sweet tooth. It's a habit we've never kicked.

In fact, we can be pretty sure we know just what that honey hunt was like, because in isolated pockets of Indonesia and Malaysia, the honey hunt lives on virtually unchanged.

Honey hunters have many ways of finding "bee trees." The classic method is to capture a few bees in a box or hollow reed while they're at a flower or drinking from a spring. (Honey bait can be handy.) Then you let one go. It, presumably, makes a "beeline" for the hive, and you run like hell after it as long as you can, trying not to twist an ankle or smack into a tree. Once you lose sight of that one, you let another go, and once again the chase is on. If you have enough bees, and don't kill yourself, you'll make it to the hive. A more elegant variant requires just two bees and a compass. You let one bee go and mark its bearing. Then you move a few hundred yards away, in more or less a perpendicular line from the direction the bee flew, and let a second bee go, marking its bearing. The point where the two bearings intersect should mark the bee tree.

Most wonderfully, African honey hunters follow a bird known as the honeyguide. This sparrow-sized bird has the taste for honey-

1. Honey is to nectar as maple syrup is to sap.

comb but not the arsenal to plunder it. So it seeks out humans, chirps excitedly at them until they follow it, and leads them to the cache, feasting on the leftover spoils.

Because the same caves and trees host multiple generations of bees, ropes and ladders were erected long ago on the best bee trees. Still, picture yourself working an aerial trapeze with no net and a swarm of stinging insects intent on destroying you; honey hunting is not for the faint of heart. It would be impossible if not for smoke, the ancient ally of honey hunters and beekeepers alike. Smoke pacifies bees. No one is entirely sure why. It may prevent bees from detecting each other's alarm pheromones—messages transmitted via scent.

To drug the bees, honey hunters make a fire at the base of a bee tree, then, for safe measure, they carry torches up the ropes and smoke the bottom of the hive. This makes the difference between a lethal barrage of stings and only ten or twenty "love bites." Then, using a sharpened stick made of bamboo or some other lightweight material, they stab the hive and carve off the comb, lowering the chunks with rope to their assistants on the ground. A good hive can yield hundreds of pounds of honey.

Doesn't this destroy the hive as well? Yes. Bees can rebuild if they have the resources and the weather is gentle; if not, they're toast. And it's one reason why, in most places, Paleolithic honey hunting gave way to beekeeping as soon as humans decided to quit rambling and settle down.

The first attempts at beekeeping were probably as simple as relocating hives to a more convenient spot. Why bother trekking all the way to the bee tree when you could cut off the branch with the bees in it and bring it home? That's what people did. And they've been keeping bees, and moving bees, ever since.

The first human-constructed hives were variations on the

theme of the hollow tree. Dried mud or clay pots in India, wicker baskets covered in clay in Egypt, Greece, and Rome, coiled straw skeps insulated in cow dung in Medieval Europe.[2] In 2007, archaeologists in Israel unearthed the oldest beehives ever found. Thirty intact hives made of straw and clay were discovered in the center of the ruins of the city of Rehov, which thrived around 900 B.C. "Urban beekeeping" is not a new phenomenon. When the Bible refers to Israel as the "land of milk and honey," it isn't being figurative.

For the European honey bee, all went to hell for a while after the collapse of the Roman Empire, and throughout the Dark Ages the best beekeeping was practiced by monasteries. Northern Europe had a tradition of upright "log hives," in which the bees were often killed before honey and wax were extracted. Eastern Europe and Russia favored forest beekeeping (find a bee tree, mark it to stake your claim, pay off the local landowner, then deal harshly with any animals, human or otherwise, that try to muscle in on your territory).

All these beekeeping operations involved ripping apart the hive to get the honey, leaving the bees to put all their resources into building new comb. Even if they survived the winter, it would be a long time before they had excess honey again. Getting around that dilemma would fall to the Reverend Lorenzo Lorraine Langstroth, who on October 31, 1851, had one of the more jaw-dropping eureka moments in history. Nothing in beekeeping was the same after Langstroth's neurons fired off their thought bomb, but to fully appreciate the "Langstroth revolution," first we need to appreciate the genius of the hive.

2. These bell-shaped skeps, which were often built into niches in abbey walls and houses, remain iconic bee motifs.

Honey, I'm Home!

Of the twenty thousand species of bees on earth, only a handful make gobs of honey, because only a handful have complex urban societies. Most bees are solitary or, like bumble bees, live in simple underground "villages" of perhaps a hundred individuals. Bumble bees do make honey—a honey that nature writer Bernd Heinrich, for one, claims is superior to honey bee honey—but only enough to fill a few tiny "honeypots" in their grass-covered nests, which larvae feed from. They produce wax but use it only to build their honeypots and a few chambers for brood. They don't build comb, and almost all members of a bumble bee colony, including the old queen, die in the fall. Only the virgin queens disperse to mate and look for underground nests where they can hibernate through the winter before starting their own colonies in the spring.

Bumble bees are rugged frontier types, amazingly self-reliant and personally formidable, yet uncooperative. As soon as their colony reaches a certain size, workers will start eating the queen's new eggs unless she guards them. Honey bees are individually unimpressive but loyal and regimented. Conflict is exceedingly rare. Bumble bees are Gaulish villagers; honey bees are the Roman legions.

While bumble bees and some solitary bee species can fly at temperatures below freezing, honey bees don't like to fly when it's below 60 degrees Fahrenheit. Nor will they fly in rain. They start relatively late in the morning (compared with other bees) and stop early in the evening. A friend of mine who is an apple specialist refers to them as union workers—if several conditions aren't met, they'll shut it down for the day. However, like many a union, that team spirit has resulted in tremendous success.

That success begins with the hexagon—the building block of the hive. To make the leap to highly social insects who could live in groups of tens of thousands, bees needed efficient infrastructure: Instead of using their wax-making skills to form individual, artisanal honeypots and brood cells, why not combine forces to make factory-scale nurseries and warehouses? The hexagon proved the perfect form for this. Triangles and squares also fit together in endless repetition, but hexagons use less wax to cover the same area and better accommodate the round larvae. Hexagons are basically circles that fit together with no gaps.

A natural beehive consists of a hundred thousand or so wax hexagonal cylinders, constructed back-to-back and hung in panels facing each other, with aisles in between just wide enough for an adult bee to access them. Imagine library shelves laid out vertically instead of horizontally, where the patrons pull themselves up and down the shelves to get to the books they want. (This is easier if you have six legs and weigh a tenth of a gram.) These hexagonal cells are used to store not books but food and brood.

In the tropics, where honey bees evolved, there's little impetus to move this operation indoors. Just as humans in the Amazon or the Florida Keys will sometimes forgo walls on their dwellings, so bees in Africa, Malaysia, and other warm regions will hang their comb from exposed tree limbs, cloaked by a crawling veil of bees.

About two million years ago, in Africa, a branch of honey bees decided to give up veranda living. *Apis mellifera* moved indoors, usually to a dry tree hollow or rock crevice, and weatherproofed the place by sealing off any cracks with propolis—caulking resin they gather from tree buds—leaving only a small entrance at the base of the hive. Initially, this probably offered more protection, but it had an unintended benefit: It allowed them to expand beyond the tropics. To colonize Europe, honey bees had to deal

with a little thing called winter. Instead of hibernation (the standard mammal and reptile solution), or migration (birds and butterflies), or generational death (most insects), they opted for a rather humanlike "keep the home fires burning" approach. They brought the tropics with them, staying metabolically active through the winter and leaning heavily on those honey stores.

When fall turns bleak and the last flowers disappear, a colony will stop raising brood, cluster together in the middle of the hive, shivering constantly, with the precious queen in the warm center, and wait out the dark days by eating sugar and snuggling together. (We Vermonters do much the same thing.) To make heat, they vibrate their wing muscles. A steady rotation from the inner cluster to the surface ensures that nobody freezes.

And it works. In the depth of a northern winter, when the outside temperature drops to 20 below, a honey bee cluster will maintain an Africanesque, honey-powered 95 degrees Fahrenheit in the center. Only about half the bees survive, the rest succumbing to old age and harsh conditions, but that's enough to keep the brood warm once the queen starts laying again in late winter as the colony gears up for the spring bloom.

With this move indoors, honey bees were at last primed for their partnership with humans: We give them more nesting cavities (in the form of beehives) than they could ever hope for in nature, and they give us more honey than our hunter-gatherer forebears could ever imagine. In the process, *Apis mellifera* became a more gentle and manageable creature as beekeepers chose to work with the most docile and productive colonies. The bee that helped Europe prosper was a far cry from its African roots. The wolf had become a collie. It's this agreeable European honey bee that convinced humans to transport it around the globe.

Of course bees aren't attempting a bribe when they convert

nectar into honey. They're simply condensing their food into the smallest, most shelf-stable form possible. Sugar draws moisture. Pack anything in sugar and it will dehydrate, as will the microorganisms that cause food to spoil. Corned beef and lox benefit from this curing process, and so does honey, which also contains a touch of hydrogen peroxide, a natural by-product of the ripening process. The jar of honey on your shelf is antiseptic and could outlast you. It makes a superb wound dressing and is useful for embalming the organs of mummies, should the need arise.

Millions of years before humans discovered how to make sugar syrups, bees had aced the test, inventing the ideal preserved, high-energy, vitamin-rich food. They store it in their honeycomb cells and cap it with wax, like jars of preserves in an endless pantry. A single hive can make hundreds of pounds of honey in a good season, yet the living occupants of that hive weigh only a combined ten pounds. They need those stores for the same reason we have grain silos—to get through the lean times, which, for a honey bee, can be long indeed.

How often, over the course of the year, are flowers blooming where you live? In New England or northern Europe, the window is depressingly short. A few tiny flowers in early April, then crocuses and daffodils, then in May the apple blossoms kick in and things really get rolling. By August, however, just three months later, the choices are already spotty: goldenrod, joe-pye weed, purple loosestrife (a recent invader), and not much else. Asters in September. From mid-October through March, nothing. For a bee, no flowers means no food. It's hard to believe bees could survive in such an environment, but they do. New England farmers need to make hay while the sun shines. Honey bees need to make honey—enough by August to power the entire colony all fall and winter.

Even in the tropics, *Apis mellifera*'s original home, the blooming isn't continuous; most flower species tend to bunch around cooler and moister seasons. It isn't unusual for blooms to be scarce for weeks at a time. In Florida, for example, once the Brazilian pepper is done in November, it's slim pickings until the citrus blooms in early spring. And even when blooms are plentiful, heavy rains can prevent bees from flying at all. Hives lose a little weight most days of the year.

And so they must gather nectar as fast as they can, whenever they can, and store it in staggering quantities. And that superconcentrated sugar, with its druglike ability to flood the human brain with dopamine, has spurred us into all sorts of creative endeavors.

Which brings us back to Lorenzo Langstroth.

Lorenzo Lorraine Langstroth, Yalie, Congregational minister, beekeeper, bipolar eccentric, sat in his Ohio study on October 31, 1851, "pondering," he wrote, "as I had so often done before, how I could get rid of the disagreeable necessity of cutting the attachments of the combs from the walls of the hives." If he could only make his combs more removable and his hives more reusable, Langstroth knew, he could stop destroying hives and bees every harvest and have a truly efficient enterprise on his hands. But how to do it? No matter what style of hive you presented to the bees, they quickly built out wax comb wherever possible and sealed up the small spaces with propolis, effectively gluing all parts of the hive together. Then it hit him:

"The almost self-evident idea of using the same bee space as in the shallow chambers came into my mind, and in a moment the suspended movable frames, kept at a suitable distance from each other and the case containing them, came into being. I

could scarcely refrain from shouting out my 'Eureka!' in the open streets."

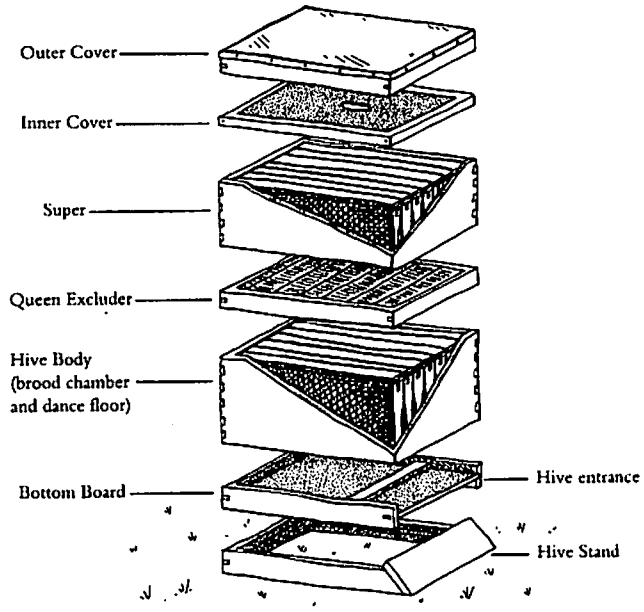
Bee space—the 0.3-inch-wide aisle bees leave between their combs—was Langstroth's epiphany. He knew that bees standardized this space, no matter what. He envisioned a file-cabinet-style hive, with each hanging file, or frame, being exactly wide enough for a two-sided sheet of honeycomb and exactly one bee space apart from the next frame and from the surrounding box.[3] Theoretically, the bees would build out their comb but leave a bee space so that any frame could be lifted out of the hive, the wax caps removed and the honey harvested, and the empty comb returned for restocking, without disturbing any of the other frames or ruining any comb.

He was right. And it changed everything. Within a decade, the Langstroth hive had swept the United States. In another decade, it was standard throughout the world. And it has endured with only minor improvements ever since.

It seems remarkable that not a single individual, in the previous eight thousand years of beekeeping history, hit upon this idea. It looks obvious in retrospect, but then so do a lot of revolutionary ideas. Langstroth's eureka moment saved an ungodly amount of honeycomb; and bees, freed from the torture of cranking out tons of wax every year to fix their comb, started cranking out unprecedented amounts of honey instead. Beekeeping became a more attractive profession.

One race of bee made things especially attractive. In the 1840s, a Swiss army captain noticed that the bees across the border in Italy were particularly gentle and industrious. They made tons of honey, rarely stung, and were prolific breeders. He acquired a

3. He used a wooden Champagne case for his prototype, a celebratory touch.



The modern Langstroth hive

colony and began spreading the word. Soon a book appeared—*The Italian Alp-Bee; or, The Gold Mine of Husbandry*—and the craze was on. Lorenzo Langstroth acquired his first colonies around 1861 and immediately began advertising "Italian Queens" in *American Bee Journal* (half price for "Ministers of the Gospel"). By 1900 the Italian honey bee was the bee of choice in Europe, the Americas, Australia, New Zealand, and even Japan. Breeders have continued to coax those desirable qualities out of the bee, and today's Italian bee, which dominates the industry, is as mellow and fruitful as any in history.

We humans are quick to pat ourselves on the back for our clever manipulation of nature, but, if you'll allow me a Michael Pollan moment, I'd say the manipulation goes both ways. I see the human–honey bee partnership as a classic example of coevolution.

The bees have benefited at least as much as we have. By "furnishing mankind with the two noblest of things, which are sweetness and light," as Jonathan Swift put it, they have bamboozled us into spreading their genes around the planet. And they did it fast. It took bees millions of years to hammer out the details of the pollination-for-nectar deal with flowers, but just a few thousand to get humans to break our backs building hives and hauling them around in exchange for a little sugar.

Sure, you can say that we were conscious of the relationship in a way that the bees weren't, but evolution doesn't care about consciousness or intention, only results, and the results are unequivocal: Honey bees have conquered the world with the help of their human general contractors.

Diary of a Young Bee

A honey bee colony is a bristling and formidable intelligence. Notice I use the singular. With honey bees, most of the intelligence lies in the colony, not the individual. So asking "How smart is a honey bee?" is like asking "How smart is one of my brain cells?" They don't live independently, and aren't meant to. Yet with its hive mind and evolutionary adaptations, a honey bee colony is capable of accomplishing sophisticated and complex tasks that put many "higher organisms" to shame.

Harvard University naturalist E. O. Wilson considers the social insects—bees, wasps, termites, ants—to be the most successful group of animals on earth. They're small, so we don't pay much attention, but Wilson points out that in some forests ant biomass alone is four times the biomass of all vertebrates put together. "This then is the circumstance with which the social

insects challenge our ingenuity: their attainment of a highly organized mode of colonial existence was rewarded by ecological dominance, leaving what must have been a deep imprint upon the evolution of the remainder of terrestrial life." They aren't just fascinating; they rule. "When reef organisms and human beings are added, social life is ecologically preeminent among animals in general."

Yet that social intelligence may be exactly what is being undermined by colony collapse disorder. Bear with me while I take you deep into the life of the hive and mind of the bee. To understand what's gone wrong with honey bees, it helps to appreciate how they interact when everything is going right.

Of the fifty thousand bees in a full hive, more than forty-nine thousand are sterile female "worker" bees. Well-named, they do all the work of the colony—foraging, comb construction, defense, nursing, you name it. The one thing they don't do is reproduce.[4] That's left to the queen bee, who lays her body weight in eggs each day (up to two thousand) and must be fed constantly. Because the queen mates with multiple males from other hives, most of the workers are half-sisters.

4. In a darkly poetic development, once it's clear that a bee larva isn't destined to become a queen, her ovaries produce a poison sac and stinger. Make love or war, but not both. One in ten thousand worker bees does manage to maintain a functioning ovary and lay eggs, but since she's never been fertilized, the eggs will be drones. In any case, the other workers, devoted to their queen, quickly notice the rogue eggs and destroy them. On the other hand, if the queen should die, and no new queens are on the way, suddenly those drone-laying workers come in handy. The colony is doomed, but at least the drones, carrying the colony's genetic uniqueness, can be sent far and wide like lifeboats leaving a sinking ship.

Occasionally the queen lays an unfertilized egg, which becomes a male, known as a drone. These few hundred members of the colony lead lives so much like a certain stereotypical human male that comparisons are irresistible. They have big heads and stout bodies. They hang around the hive all day doing essentially nothing. They don't forage, don't feed the kids, don't even build anything. They wait for the females to bring them food. And the females do. Other than grub, their only interest is sex. Every so often, they "go out for a while" to hang with males from other hives and chase after virgin queens. If they catch one, they don't come back.[5] If they don't catch one, they return to the hive and free food, but even the workers' philanthropy has limits. Drones are basically flying sperm, so once mating season is over, they're truly useless. When the weather cools in the fall and hive resources get scarce, the workers evict the drones from the hive, and they soon freeze.

All functioning societies place a premium on the next generation, and so it is with bees. Kids are raised in the safe lower center of the hive, pollen (baby food) conveniently at hand around them. Honey (adult food) is stored in the upper chambers. This is convenient for beekeepers, too, because it means that honey can be harvested from "supers"—the upper drawers of the file cabinet—without disturbing the brood in the lowest drawer. (To ensure this separation, beekeepers use a "queen excluder": a narrow passage dividing the lower chamber from the upper ones, through which worker bees can squeeze but not the larger queen, who must lay all her eggs below.)

Kid bees have things pretty cush. They begin life as white,

5. More on that gory story later.

pinhead-sized eggs, laid one per hexagonal cylinder by the queen. From the moment they hatch, they are lavished with protein-rich royal jelly—the bee equivalent of mother's milk—made from digested pollen by nurse bees, whose sole job is to staff the nursery. The crescent-shaped larvae grow quickly, doubling in size twice a day, and after six days they practically fill their chambers.[6] The nurses then seal the chambers with wax caps so the larvae can pupate in peace. The wax is fat from the nurses' own bodies, exuded from pores in little wafers. They soften up the wax wafers by chewing on them and adding saliva, much as you might soften a piece of gum, then molding them to cover the brood cell.

Alone inside her cell, the kid bee can get down to the serious business of transformation. She spins a cocoon around herself, like a butterfly, and three days later emerges as a fresh, fuzzy adult bee. Her first task is to chew through her nursery wax cap so she can join the hive. Once there, she gets no coming-out party. Instead she cleans herself up, has a snack, then gets to work.

Now, put yourself in the mind of this newly hatched "house bee." In many ways, her life is not so different from the life of the newly adult human. Day 1, you are ready to enter the workforce, but you have few skills. Your first job is to clean up the cell you just emerged from. After that you spend about half your time in the menial task of cleaning other cells. The rest of your day is spent eating, resting, and looking for a better job. Around Day 4, you find work: day care. You nurse the brood, squirting royal jelly from your head into their cribs. Your peers who show a building

6. Picture an 8-pound newborn growing to 16 pounds her first afternoon, 32 pounds the next morning, and 128 pounds the day after that. You can see why so many adult bees are involved in the food service profession.

aptitude may start constructing new wax comb. A few get assigned to the queen's retinue, charged with the precious tasks of bringing her food and carrying her waste out of the hive.

Around Day 10 things pick up. A wizened forager bee comes scrambling through your section of the hive, trembling all over and twitching her legs. "We need receivers!" she yells. "We've hit a clover gusher and there's no one to unload!" (The foragers don't store nectar themselves; they look for somebody in-house to hand it off to so they can get back out to the nectar flow ASAP.) It seems simple enough. You'll still be a house bee, but those days of cleaning and raising the little brats are finally over.

You make your way to the excitement of the hive entrance, where forager bees are returning from all over the wide world with a steady stream of pollen, nectar, and water. As soon as they land, they bustle around, calling, "Somebody take this, somebody take this." You watch for a while, then work up your courage, approach a forager who's almost bursting at the seams with nectar, tap her with your antenna, and say, "Please, ma'am, I'll take it." Relieved, she unrolls her proboscis and drains her entire tank into you. You slosh back into the hive with your cargo, find an empty cell, unload your nectar into it, then spend the rest of the day pumping that nectar in and out of your mouth, evaporating its water in the process and adding enzymes that convert the sugar in the nectar from crystally sucrose to syrupy fructose. When the water content has dropped from the original 70 percent to about 40 percent, you and your colleagues start fanning your wings to pass maximum air over the nectar, reducing it like a good sauce. When the water content drops below 20 percent, it is honey. You cap it with a nice wax seal and go back to the entrance for another load.

A week later, you're still enjoying life as a receiver bee, but those tantalizing glimpses of the fields outside the hive have got

you curious. One day you work up your courage, walk out the hive entrance, and give your wings a practice buzz. Before you realize it, you're off the ground and floating around. This isn't so hard after all! You take some mental snapshots of your surroundings, then scoot right back inside where it's safe. Over the next few days, you take more orientation flights, each one a little farther out, memorizing the landmarks around the hive.

Then it happens. It's early morning, and things have been slow. It rained all day yesterday and no one was flying. You and your colleagues completely caught up on your honey ripening, so, with nothing to do, you rested to conserve energy. Suddenly, a forager has her legs on *your* shoulders and is shaking you awake! "The apple blossoms!" she shouts. "Nectar's coming fast and furious! All hands to the flight deck right now!"

"Me? But I've never foraged."

"Now's the time! Get going, kid."

So you head for the "dance floor," flustered with excitement. The dance floor is a section of comb, just inside the hive entrance, where the returning foragers do their waggle dances and other worker bees hang out, looking for a mission. You join the spectators, pushing your way through the crowd until—yes!—here comes a waggle dancer right past you, waggling her butt from side to side with urgency to tell everyone about her new find. You watch for a bit, noting the angle of her dance, which tells you what direction to head, and how long it lasts, which tells you how far to fly. There's no doubt what she found, because she is bloated like a water balloon and just reeking glorious apple perfume from every pore. "I've got it!" you shout, and you hop into the conga line behind her, shaking your butt, too. A few others join in as well, then you all scramble to the hive entrance.

The others set off, following the same angle from the sun as

the forager indicated in her dance, and you zip off right behind them. You count how long you're supposed to fly . . . should be about here . . . nothing at first . . . then there it is, like a big white-pink firework: an apple tree in full bloom. Your comrades are already there, so you fly in, single out a flower, and land on the petals. Ultraviolet lines on the petals point to a little well down at their base, from which an irresistible smell is emerging, so you follow the lines, unroll your proboscis, stick it into the well like a straw into a milkshake, and, *ahhhh* . . . sweet bliss.

You fill your "honey sac," a bladder in your abdomen that can be filled or unfilled using a special hydraulic pump in your head. But you don't digest all that nectar. It's all for one and one for all in the beehive, so once you've gorged on enough apple blossoms that you'd drip nectar if squeezed,[7] you fly, sputtering like an overloaded helicopter, back to the hive. At the entrance, you squirt the contents of your honey sac into the waiting mouths of receiver bees—young up-and-comers who remind you of you at that age, way back last week. Sometimes, after a great score, you're so excited about your awesome flower patch that, after unloading your nectar, you just can't contain yourself—you scoot over to the dance floor and waggle your butt. Sure enough, other bees leap into line behind you, following your dance, then zip off toward your flowers. Go team.

So it goes for about three weeks. Your twenty-one days of life in the hive as a house bee are mirrored by three weeks on the range, foraging. You get better and better at it, flying dawn to dusk, until changes start to set in. Those gossamer wings show more and more wear. You're feeling kind of creaky. Diseases are creeping through your gut. One day, you land on a fall aster, but

7. On slow days, bee researchers do this for fun.

your legs just don't seem to be working. You try to take off, but instead your wings fold, you fall to earth, and die.

Wise Beyond Their Years

That's the bee's-eye view of life in the hive. It gives a pretty fair account of the events in a typical bee's life, as well as the decisions she faces. Now let's pull back, look at the same events from the human's-eye view, and try to understand how remarkable coordination and intelligence—we might even say wisdom—can arise from thousands of individual bees making their own decisions with little knowledge about what's happening elsewhere in the hive. Think about it: fifty thousand individuals, and *no one is in charge.*[8] A human company of fifty thousand employees would be rife with territorial middle managers, each overseeing twenty employees and reporting to a supervisor, who reports to her supervisor, and on up the hierarchical tree all the way to the CEO. Pooling information and power in the hands of just a few people allows for quick, unilateral decisions, but it also means one incompetent executive can bring down the whole enterprise.

Bees, on the other hand, manage to precisely calibrate their food intake, nest construction, and other needs by following a "wisdom of the crowd" philosophy. There's no centralized decision making, just the order that naturally emerges from thousands of workers making unselfish decisions. "Unselfishness" is the key. If those forty-nine thousand sterile workers are to pass their genes onward, they have to do it through Mom. The "survival of the fittest" genetic competition that is a hallmark of

8. People used to think the queen was in charge, but she's more of an egg-laying slave.

most evolution doesn't quite apply to honey bees. Members of a hive don't compete with each other; they're all in the same boat.

This has allowed evolution to establish a network of communications and feedback loops enabling a honey bee colony to make enlightened decisions that couldn't be made by any one member. A lot of these abilities are explained in Thomas Seeley's brilliant and pellucid book *The Wisdom of the Hive.* The feedback loops are made possible because of the division of labor between forager bees and receiver bees. It would be a waste of the experienced foragers' time to have to take every load of nectar high into the hive, find an empty cell, and process the nectar into honey, so that labor falls to the receivers. To efficiently bring as much food into the hive as possible, a colony needs to maintain a perfect balance between foragers and receivers. Too many foragers creates a bottleneck at the hive entrance, with foragers waiting to unload their cargo. Too many receivers means bees hanging around the hive doing nothing when they could be out gathering food.

Bees calibrate this balance through their famous dances. The "waggle dance" recruits more fliers. The "tremble dance" recruits more receivers. A third signal, "shaking," encourages inactive bees to start foraging. Here's how it works:

Say a scouting forager hits an orange tree that is just pumping out nectar. She sucks up a full load and races back to the hive. Immediately she looks for a receiver bee to take her nectar. What she does next depends on how long this takes. If receivers are falling all over themselves to get her nectar, and she can unload in just a few seconds, then there must be a shortage of foragers. She heads to the dance floor and does her waggle dance for the spectators, running up and down the comb while wiggling her butt and buzzing. The angle she runs from the vertical (remember, all comb,

including the dance floor, is vertical) corresponds to the angle from the sun of the path that will lead straight to the orange tree.[9]

The duration of the waggle dance tells other bees how far to go—loosely, three quarters of a mile per second of waggling. Spectator bees aren't choosy about which waggle they'll follow; they usually jump right in with the first waggle dance they see, following in the conga line for a few rounds to make sure they've got the coordinates before heading out. So the more repetitions of a waggle dance, the more recruits a dancer will get, and sure enough, repetitions correspond to how valuable the find is. An orange tree will get more repetitions than a few tufts of clover, and a near orange tree will get more than a far orange tree. It's also relative; the same orange tree can be a front-page feature if it's the only thing blooming for miles, or a yawner if it's in the midst of a gallberry explosion. Waggle dance repetitions can vary from one (barely worth telling another bee) to one hundred (turn out the whole hive!), with anything over twenty being a real find.

You know the feeling. Say you are out for lunch alone and you blunder into the best Sri Lankan restaurant in Manhattan. You stuff yourself on curry and street hoppers, then hustle back to the office. You tell all your coworkers, write Zagat's, and soon the place is bustling with activity. If, on the other hand, the food is lukewarm and greasy, you might mention it to only a few people, or no one. This is Manhattan, after all, there are ten thousand

9. Brightness seems to play a role, too. The horizon is brightest directly below the sun and directly opposite it, and darkest in the two perpendicular directions. If you place a polarized filter over a hive entrance and rotate it, you can make the bees start off in the wrong direction for a particular waggle dance, though they'll quickly correct it once they leave the polarized zone.

restaurants to choose from. You can do better. Soon, the place has disappeared.

Now, in my town of Calais, Vermont, which has a grand sum of zero restaurants, things would be different. In the unlikely event that I'm hiking the back roads and chance upon a just-opened Sri Lankan restaurant, well, even if it's a little on the greasy side, I'm gonna waggle my ass off to everyone I meet.

Just like the restaurant scene in any city, honey bees find floral hot spots through word of mouth—a beautifully efficient barometer of quality.

But wait a minute. How can bees "know" how excited to get, especially those fairly new to foraging? Is that raspberry patch a once-in-a-lifetime find or a daily staple? Since they are genetically distinct, couldn't one bee get more excited, and thus do more waggle dances for goldenrod, while another waggles more for fall asters? And might one bee simply waggle more than another in general, and thus get more recruits to some sites that aren't all that good?

Well, yes. In one of the most charming experiments in *The Wisdom of the Hive*, Seeley tracked the waggling tendencies of ten individual bees. First the bees were given a feeder filled with weak sugar syrup, then Seeley swapped it for a feeder of concentrated syrup. The bees' individual responses were all over the map. One bee (labeled BB) accounted for a full 41 percent of the waggle dances produced by this group, while another (OG) contributed only 5 percent. OG, like a jaded restaurant critic, sometimes didn't bother waggling at all. Even the supersweet solution stirred OG to a mere thirty waggle runs of excitement—a number BB was doing for the lousy stuff. ("I had this Big Mac for lunch; it was *so good!*") The good stuff made BB completely lose her cool and waggle more than one hundred times.

This genetic variability seems like it could screw up a hive's

ability to make good use of its resources, but it averages out over thousands of bees. Sure, BB may get a bunch of recruits to follow her to her supposed find, but then those underwhelmed recruits will come back and report that the place wasn't so exciting after all: They won't waggle. By then perhaps BB will be back in the hive, sleeping off her Big Mac attack, and the wildfire of overenthusiasm will have burned out.

Hives need a few BBs around, because when food is scarce, a Big Mac really is a great find; and they need a few skeptical OGs, who recruit only to the best joints, for when food is plentiful. A wide bell curve of excitement allows the hive to respond wisely to a constantly changing nectar supply.

Less than 10 percent of foragers dance at all when returning to the hive. It takes a pretty darned good nectar flow and an eager receiver. If the time to find a receiver is between twenty and fifty seconds, that means the troops must be well deployed. The forager will unload, clean up, maybe get a snack, then head back to her flower source alone. If the flower source was really lousy, she'll stop foraging altogether for a while and switch to some in-hive task instead. In the thousands of foraging returns that Seeley watched, he never saw a bee go straight from foraging to the dance floor to find a new target.

If it takes more than fifty seconds to find a receiver, this means a lot of nectar must be coming back to the hive and there aren't enough receivers to handle it. Our forager will give up on finding a receiver and instead plunge into the depths of the hive, doing a tremble dance. She jerks spastically from side to side, spinning in random directions, her two forelegs held aloft and shaking. She trembles for, on average, half an hour, covering a lot of territory inside the hive—which she needs to do, because the only way to get a message to another bee in those dark, con-

gested quarters is to be very close to it. It doesn't matter whether she knows she is sending a signal with her dance, or whether the stress of not finding a receiver triggers her spasms; either way, the message gets through loud and clear: NEED MORE RECEIVERS. Nurse bees and comb builders who have never received before heed the call and head for the hive entrance.

If our forager passes a waggle dancer, she'll buzz at her and sometimes even head-butt. *Stop recruiting flyers, you idiot! We've got too many already.* Sure enough, waggle dancers who hear a tremble dancer's buzz or get head-butted tend to stop dancing and return to foraging alone.

With these two built-in behaviors, the waggle dance and the tremble dance, a honey bee colony is able to constantly adjust its rates of nectar acquisition and processing to make best use of what the flowers are providing. When a scout bee finds a new nectar flow just beginning, she'll make a beeline for the hive, waggle her findings, and bring ten recruits back with her. If the flow is a gusher, those recruits will waggle when they return, each bringing a new posse. This is how one bee sniffing your peonies in the early morning turns into a hundred-bee orgy by noon. If those hundred foragers have trouble finding receivers, they'll tremble to produce new ones before returning to the peonies. On the other hand, as the peonies get Hoovered dry, those bees will first stop waggling up new recruits, then eventually quit that mission altogether. It takes only hours for a colony to abandon a weakening flow for an improving one.

But how do foragers know to start foraging in the first place? The answer is the third type of signal foragers send: the shake. If a honey bee returns from a great discovery and can't find anyone waiting on the dance floor, waggling would be pointless. Instead, she'll plunge into the hive, put her legs on resting bees, and shake

them into action. Sometimes she'll shake two hundred bees, many of them young bees that have never flown before. Any shaken bee is stirred to go to the dance floor and get her flight plan.

Seeley tracked one bee in a colony that had found no food for days. He then placed a feeder of sugar syrup nearby. The bee's first ten return trips from the feeder consisted of shaking signals to wake her comrades. Then, as more bees crowded the dance floor, she switched to a mixture of shaking signals and waggle runs for her next fifteen trips. After that, she did only waggle runs.

PROTEIN POWER

Ask a school kid "What do bees eat?" and she'll say, "Honey." She's right, but that's only half the story. Bees also collect pollen—the most vital food for the colony. Like nuts and seeds, pollen is full of complex, top-quality nutrients: mostly protein, plus fats, vitamins, and minerals. Honey is a doughnut for breakfast; pollen is a spinach and garlic omelet.[10]

The carbohydrates in honey make great fuel, which is why a forager bee eats little else. Like a marathoner, she needs to "carb load" so she can fly all day long. Protein is the building block for all animal bodies; once a worker bee is built, she needs much less. You and I need protein to repair damage to our bodies, but worker bees, who live only a few weeks, don't come with a maintenance plan; when they break, they don't get fixed.

A baby bee, on the other hand, needs lots of high-quality protein to grow. Famished from day one, it makes its needs known like babies everywhere—it cries. Only, being a bee, it doesn't use an auditory cry but instead an olfactory message using what's

10. It's also tasty stuff. Clover is my favorite.