1

— FRIENDSHIPS —

YEARS AGO, I stumbled across a patch of strange-looking mossy stones in one of the preserves of old beech trees that grows in the forest I manage. Casting my mind back, I realized I had passed by them many times before without paying them any heed. But that day, I stopped and bent down to take a good look. The stones were an unusual shape: they were gently curved with hollowed-out areas. Carefully, I lifted the moss on one of the stones. What I found underneath was tree bark. So, these were not stones, after all, but old wood. I was surprised at how hard the "stone" was, because it usually takes only a few years for beechwood lying on damp ground to decompose. But what surprised me most was that I couldn't lift the wood. It was obviously attached to the ground in some way.

I took out my pocketknife and carefully scraped away some of the bark until I got down to a greenish layer. Green?

This color is found only in chlorophyll, which makes new leaves green; reserves of chlorophyll are also stored in the trunks of living trees. That could mean only one thing: this piece of wood was still alive! I suddenly noticed that the remaining “stones” formed a distinct pattern: they were arranged in a circle with a diameter of about 5 feet. What I had stumbled upon were the gnarled remains of an enormous ancient tree stump. All that was left were vestiges of the outermost edge. The interior had completely rotted into humus long ago—a clear indication that the tree must have been felled at least four or five hundred years earlier. But how could the remains have clung onto life for so long?

Living cells must have food in the form of sugar, they must breathe, and they must grow, at least a little. But without leaves—and therefore without photosynthesis—that’s impossible. No being on our planet can maintain a centuries-long fast, not even the remains of a tree, and certainly not a stump that has had to survive on its own. It was clear that something else was happening with this stump. It must be getting assistance from neighboring trees, specifically from their roots. Scientists investigating similar situations have discovered that assistance may either be delivered remotely by fungal networks around the root tips—which facilitate nutrient exchange between trees[1]—or the roots themselves may be interconnected.[2] In the case of the stump I had stumbled upon, I couldn’t find out what was going on, because I didn’t want to injure the old stump by digging around it, but one thing was clear: the surrounding beeches were pumping sugar to the stump to keep it alive.

If you look at roadside embankments, you might be able to see how trees connect with each other through their root systems. On these slopes, rain often washes away the soil, leaving the underground networks exposed. Scientists in the Harz mountains in Germany have discovered that this really is a case of interdependence, and most individual trees of the same species growing in the same stand are connected to each other through their root systems. It appears that nutrient exchange and helping neighbors in times of need is the rule, and this leads to the conclusion that forests are superorganisms with interconnections much like ant colonies.

Of course, it makes sense to ask whether tree roots are simply wandering around aimlessly underground and connecting up when they happen to bump into roots of their own kind. Once connected, they have no choice but to exchange nutrients. They create what looks like a social network, but what they are experiencing is nothing more than a purely accidental give and take. In this scenario, chance encounters replace the more emotionally charged image of active support, though even chance encounters offer benefits for the forest ecosystem. But Nature is more complicated than that. According to Massimo Maffei from the University of Turin, plants—and that includes trees—are perfectly capable of distinguishing their own roots from the roots of other species and even from the roots of related individuals.[3]

But why are trees such social beings? Why do they share food with their own species and sometimes even go so far as to nourish their competitors? The reasons are the same as for human communities: there are advantages to working together. A tree is not a forest. On its own, a tree cannot establish a consistent local climate. It is at the mercy of wind and weather. But together, many trees create an ecosystem that moderates extremes of heat and cold, stores a great deal of water, and generates a great deal of humidity. And in this protected environment, trees can live to be very old. To get to this point, the community must remain intact no matter what. If every tree were looking out only for itself, then quite a few of them would never reach old age. Regular fatalities would result in many large gaps in the tree canopy, which would make it easier for storms to get inside the forest and uproot more trees. The heat of summer would reach the forest floor and dry it out. Every tree would suffer.

Every tree, therefore, is valuable to the community and worth keeping around for as long as possible. And that is why even sick individuals are supported and nourished until they recover. Next time, perhaps it will be the other way round, and the supporting tree might be the one in need of assistance. When thick silver-gray beeches behave like this, they remind me of a herd of elephants. Like the herd, they, too, look after their own, and they help their sick and weak back up onto their feet. They are even reluctant to abandon their dead.

Every tree is a member of this community, but there are different levels of membership. For example, most stumps rot away into humus and disappear within a couple of hundred years (which is not very long for a tree). Only a few individuals are kept alive over the centuries, like the mossy "stones" I've just described. What's the difference? Do tree societies have second-class citizens just like human societies? It seems they do, though the idea of "class" doesn't quite fit. It is rather the degree of connection—or maybe even affection—that decides how helpful a tree's colleagues will be.

You can check this out for yourself simply by looking up into the forest canopy. The average tree grows its branches out until it encounters the branch tips of a neighboring tree of the same height. It doesn't grow any wider because the air and better light in this space are already taken. However, it heavily reinforces the branches it has extended, so you get the impression that there's quite a shoving match going on up there. But a pair of true friends is careful right from the outset not to grow overly thick branches in each other's direction. The trees don't want to take anything away from each other, and so they develop sturdy branches only at the outer edges of their crowns, that is to say, only in the direction of "non-friends." Such partners are often so tightly connected at the roots that sometimes they even die together.

As a rule, friendships that extend to looking after stumps can only be established in undisturbed forests. It could well be that all trees do this and not just beeches. I myself have observed oak, fir, spruce, and Douglas fir stumps that were still alive long after the trees had been cut down. Planted forests, which is what most of the coniferous forests in Central Europe are, behave more like the street kids I describe in chapter 27. Because their roots are irreparably damaged when they are planted, they seem almost incapable of networking with one another. As a rule, trees in planted forests like these behave like loners and suffer from their isolation. Most of them never have the opportunity to grow old anyway. Depending on the species, these trees are considered ready to harvest when they are only about a hundred years old.

2

— THE LANGUAGE OF TREES —

According to the dictionary definition, language is what people use when we talk to each other. Looked at this way, we are the only beings who can use language, because the concept is limited to our species. But wouldn't it be interesting to know whether trees can also talk to each other? But how? They definitely don't produce sounds, so there's nothing we can hear. Branches creak as they rub against one another and leaves rustle, but these sounds are caused by the wind and the tree has no control over them. Trees, it turns out, have a completely different way of communicating: they use scent.

Scent as a means of communication? The concept is not totally unfamiliar to us. Why else would we use deodorants and perfumes? And even when we're not using these products, our own smell says something to other people, both consciously and subconsciously. There are some people who seem to have no smell at all; we are strongly attracted to others because of their aroma. Scientists believe pheromones in sweat are a decisive factor when we choose our partners—in other words, those with whom we wish to procreate. So it seems fair to say that we possess a secret language of scent, and trees have demonstrated that they do as well.

For example, four decades ago, scientists noticed something on the African savannah. The giraffes there were feeding on umbrella thorn acacias, and the trees didn't like this one bit. It took the acacias mere minutes to start pumping toxic substances into their leaves to rid themselves of the large herbivores. The giraffes got the message and moved on to other trees in the vicinity. But did they move on to trees close by? No, for the time being, they walked right by a few trees and resumed their meal only when they had moved about 100 yards away.

The reason for this behavior is astonishing. The acacia trees that were being eaten gave off a warning gas (specifically, ethylene) that signaled to neighboring trees of the same species that a crisis was at hand. Right away, all the forewarned trees also pumped toxins into their leaves to prepare themselves. The giraffes were wise to this game and therefore moved farther away to a part of the savannah where they could find trees that were oblivious to what was going on. Or else they moved upwind. For the scent messages are carried to nearby trees on the breeze, and if the animals walked upwind, they could find acacias close by that had no idea the giraffes were there.

Similar processes are at work in our forests here at home. Beeches, spruce, and oaks all register pain as soon as some creature starts nibbling on them. When a caterpillar takes a hearty bite out of a leaf, the tissue around the site of the damage changes. In addition, the leaf tissue sends out electrical signals, just as human tissue does when it is hurt. However, the signal is not transmitted in milliseconds, as human signals are; instead, the plant signal travels at the slow speed of a third of an inch per minute.[4] Accordingly, it takes an hour or so before defensive compounds reach the leaves to spoil the pest's meal. Trees live their lives in the really slow lane, even when they are in danger. But this slow tempo doesn't mean that a tree is not on top of what is happening in different parts of its structure. If the roots find themselves in trouble, this information is broadcast throughout the tree, which can trigger the leaves to release scent compounds. And not just any old scent compounds, but compounds that are specifically formulated for the task at hand.

This ability to produce different compounds is another feature that helps trees fend off attack for a while. When it comes to some species of insects, trees can accurately identify which bad guys they are up against. The saliva of each species is different, and trees can match the saliva to the insect. Indeed, the match can be so precise that trees can release pheromones that summon specific beneficial predators. The beneficial predators help trees by eagerly devouring the insects that are bothering them. For example, elms and pines call on small parasitic wasps that lay their eggs inside leaf-eating caterpillars.[5] As the wasp larvae develop, they devour the larger caterpillars bit by bit from the inside out. Not a nice way to die. The result, however, is that the trees are saved from bothersome pests and can keep growing with no further damage.

The fact trees can recognize saliva is, incidentally, evidence for yet another skill they must have. For if they can identify saliva, they must also have a sense of taste.

A drawback of scent compounds is that they disperse quickly in the air. Often they can be detected only within a range of about 100 yards. Quick dispersal, however, also has advantages. As the transmission of signals inside the tree is very slow, a tree can cover long distances much more quickly through the air if it wants to warn distant parts of its own structure that danger lurks. A specialized distress call is not always necessary when a tree needs to mount a defense against insects. The animal world simply registers the tree's basic chemical alarm call. It then knows some kind of attack is taking place and predatory species should mobilize. Whoever is hungry for the kinds of critters that attack trees just can't stay away.

Trees can also mount their own defense. Oaks, for example, carry bitter, toxic tannins in their bark and leaves. These either kill chewing insects outright or at least affect the leaves' taste to such an extent that instead of being deliciously crunchy, they become biliously bitter. Willows produce the defensive compound salicylic acid, which works in much the same way. But not on us. Salicylic acid is a precursor of aspirin, and tea made from willow bark can relieve headaches and bring down fevers. Such defense mechanisms, of course, take time. Therefore, a combined approach is crucially important for arboreal early-warning systems.

Trees don't rely exclusively on dispersal in the air, for if they did, some neighbors would not get wind of the danger. Dr. Suzanne Simard of the University of British Columbia in Vancouver has discovered that they also warn each other using chemical signals sent through the fungal networks around their root tips, which operate no matter what the weather.[6] Surprisingly, news bulletins are sent via the roots not only by means of chemical compounds but also by means of electrical impulses that travel at the speed of a third of an inch per second. In comparison with our bodies, it is, admittedly, extremely slow. However, there are species in the animal kingdom, such as jellyfish and worms, whose nervous systems conduct impulses at a similar speed.[7] Once the latest news has been broadcast, all oaks in the area promptly pump tannins through their veins.

Tree roots extend a long way, more than twice the spread of the crown. So the root systems of neighboring trees inevitably intersect and grow into one another—though there are always some exceptions. Even in a forest, there are loners, would-be hermits who want little to do with others. Can such antisocial trees block alarm calls simply by not participating? Luckily, they can't. For usually there are fungi present that act as intermediaries to guarantee quick dissemination of news. These fungi operate like fiber-optic Internet cables. Their thin filaments penetrate the ground, weaving through it in almost unbelievable density. One teaspoon of forest soil contains many miles of these "hyphae."[8] Over centuries, a single fungus can cover many square miles and network an entire forest. The fungal connections transmit signals from one tree to the next, helping the trees exchange news about insects, drought, and other dangers. Science has adopted a term first coined by the journal *Nature* for Dr. Simard's discovery of the “wood wide web” pervading our forests.[9] What and how much information is exchanged are subjects we have only just begun to research. For instance, Simard discovered that different tree species are in contact with one another, even when they regard each other as competitors.[10] And the fungi are pursuing their own agendas and appear to be very much in favor of conciliation and equitable distribution of information and resources.[11]

If trees are weakened, it could be that they lose their conversational skills along with their ability to defend themselves. Otherwise, it’s difficult to explain why insect pests specifically seek out trees whose health is already compromised. It’s conceivable that to do this, insects listen to trees’ urgent chemical warnings and then test trees that don’t pass the message on by taking a bite out of their leaves or bark. A tree’s silence could be because of a serious illness or, perhaps, the loss of its fungal network, which would leave the tree completely cut off from the latest news. The tree no longer registers approaching disaster, and the doors are open for the caterpillar and beetle buffet. The loners I just mentioned are similarly susceptible—they might look healthy, but they have no idea what is going on around them.

In the symbiotic community of the forest, not only trees but also shrubs and grasses—and possibly all plant species—exchange information this way. However, when we step into farm fields, the vegetation becomes very quiet. Thanks to selective breeding, our cultivated plants have, for the most part, lost their ability to communicate above or below ground—you could say they are deaf and dumb—and therefore they are easy prey for insect pests.[12] That is one reason why modern agriculture uses so many pesticides. Perhaps farmers can learn from the forests and breed a little more wildness back into their grain and potatoes so that they'll be more talkative in the future.

Communication between trees and insects doesn't have to be all about defense and illness. Thanks to your sense of smell, you've probably picked up on many feel-good messages exchanged between these distinctly different life-forms. I am referring to the pleasantly perfumed invitations sent out by tree blossoms. Blossoms do not release scent at random or to please us. Fruit trees, willows, and chestnuts use their olfactory missives to draw attention to themselves and invite passing bees to sate themselves. Sweet nectar, a sugar-rich liquid, is the reward the insects get in exchange for the incidental dusting they receive while they visit. The form and color of blossoms are signals, as well. They act somewhat like a billboard that stands out against the general green of the tree canopy and points the way to a snack.

So trees communicate by means of olfactory, visual, and electrical signals. (The electrical signals travel via a form of nerve cell at the tips of the roots.) What about sounds? Let's get back to hearing and speech. When I said at the beginning of this chapter that trees are definitely silent, the latest scientific research casts doubt even on this statement. Along with colleagues from Bristol and Florence, Dr. Monica Gagliano from the University of Western Australia has, quite literally, had her ear to the ground.[13] It's not practical to study trees in the laboratory; therefore, researchers substitute grain seedlings because they are easier to handle. They started listening, and it didn't take them long to discover that their measuring apparatus was registering roots crackling quietly at a frequency of 220 hertz. Crackling roots? That doesn't necessarily mean anything. After all, even dead wood crackles when it's burned in a stove. But the noises discovered in the laboratory caused the researchers to sit up and pay attention. For the roots of seedlings not directly involved in the experiment reacted. Whenever the seedlings' roots were exposed to a crackling at 220 hertz, they oriented their tips in that direction. That means the grasses were registering this frequency, so it makes sense to say they "heard" it.

Plants communicating by means of sound waves? That makes me curious to know more, because people also communicate using sound waves. Might this be a key to getting to know trees better? To say nothing of what it would mean if we could hear whether all was well with beeches, oaks, and pines, or whether something was up. Unfortunately, we are not that far advanced, and research in this field is just beginning. But if you hear a light crackling the next time you take a walk in the forest, perhaps it won't be just the wind . . .

3

— SOCIAL SECURITY —

Gardeners often ask me if their trees are growing too close together. Won't they deprive each other of light and water? This concern comes from the forestry industry. In commercial forests, trees are supposed to grow thick trunks and be harvest-ready as quickly as possible. And to do that, they need a lot of space and large, symmetrical, rounded crowns. In regular five-year cycles, any supposed competition is cut down so that the remaining trees are free to grow. Because these trees will never grow old—they are destined for the sawmill when they are only about a hundred—the negative effects of this management practice are barely noticeable.

What negative effects? Doesn't it sound logical that a tree will grow better if bothersome competitors are removed so that there's plenty of sunlight available for its crown and plenty of water for its roots? And for trees belonging to different species that is indeed the case. They really do struggle with each other for local resources. But it's different for trees of the same species. I've already mentioned that beeches are capable of friendship and go so far as to feed each other. It is obviously not in a forest's best interest to lose its weaker members. If that were to happen, it would leave gaps that would disrupt the forest's sensitive microclimate with its dim light and high humidity. If it weren't for the gap issue, every tree could develop freely and lead its own life. I say "could" because beeches, at least, seem to set a great deal of store by sharing resources.

Students at the Institute for Environmental Research at RWTH Aachen discovered something amazing about photosynthesis in undisturbed beech forests. Apparently, the trees synchronize their performance so that they are all equally successful. And that is not what one would expect. Each beech tree grows in a unique location, and conditions can vary greatly in just a few yards. The soil can be stony or loose. It can retain a great deal of water or almost no water. It can be full of nutrients or extremely barren. Accordingly, each tree experiences different growing conditions; therefore, each tree grows more quickly or more slowly and produces more or less sugar or wood, and thus you would expect every tree to be photosynthesizing at a different rate.

And that's what makes the research results so astounding. The rate of photosynthesis is the same for all the trees. The trees, it seems, are equalizing differences between the strong and the weak. Whether they are thick or thin, all members of the same species are using light to produce the same amount of sugar per leaf. This equalization is taking place underground through the roots. There's obviously a lively exchange going on down there. Whoever has an abundance of sugar hands some over; whoever is running short gets help. Once again, fungi are involved. Their enormous networks act as gigantic redistribution mechanisms. It's a bit like the way social security systems operate to ensure individual members of society don't fall too far behind.[14]

In such a system, it is not possible for the trees to grow too close to each other. Quite the opposite. Huddling together is desirable and the trunks are often spaced no more than 3 feet apart. Because of this, the crowns remain small and cramped, and even many foresters believe this is not good for the trees. Therefore, the trees are spaced out through felling, meaning that supposedly excess trees are removed. However, colleagues from Lübeck in northern Germany have discovered that a beech forest is more productive when the trees are packed together. A clear annual increase in biomass, above all wood, is proof of the health of the forest throng.[15]

When trees grow together, nutrients and water can be optimally divided among them all so that each tree can grow into the best tree it can be. If you "help" individual trees by getting rid of their supposed competition, the remaining trees are bereft. They send messages out to their neighbors in vain, because nothing remains but stumps. Every tree now muddles along on its own, giving rise to great differences in productivity. Some individuals photosynthesize like mad until sugar positively bubbles along their trunk. As a result, they are fit and grow better, but they aren't particularly long-lived. This is because a tree can be only as strong as the forest that surrounds it. And there are now a lot of losers in the forest. Weaker members, who would once have been supported by the stronger ones, suddenly fall behind. Whether the reason for their decline is their location and lack of nutrients, a passing malaise, or genetic makeup, they now fall prey to insects and fungi.

But isn't that how evolution works? you ask. The survival of the fittest? Trees would just shake their heads—or rather their crowns. Their well-being depends on their community, and when the supposedly feeble trees disappear, the others lose as well. When that happens, the forest is no longer a single closed unit. Hot sun and swirling winds can now penetrate to the forest floor and disrupt the moist, cool climate. Even strong trees get sick a lot over the course of their lives. When this happens, they depend on their weaker neighbors for support. If they are no longer there, then all it takes is what would once have been a harmless insect attack to seal the fate even of giants.

In former times, I myself instigated an exceptional case of assistance. In my first years as a forester, I had young trees girdled. In this process, a strip of bark 3 feet wide is removed all around the trunk to kill the tree. Basically, this is a method of thinning, where trees are not cut down, but desiccated trunks remain as standing deadwood in the forest. Even though the trees are still standing, they make more room for living trees, because their leafless crowns allow a great deal of light to reach their neighbors. Do you think this method sounds brutal? I think it does, because death comes slowly over a few years and, therefore, in the future, I wouldn't manage forests this way. I observed how hard the beeches fought and, amazingly enough, how some of them survive to this day.

In the normal course of events, such survival would not be possible, because without bark the tree cannot transport sugar from its leaves to its roots. As the roots starve, they shut down their pumping mechanisms, and because water no longer flows through the trunk up to the crown, the whole tree dries out. However, many of the trees I girdled continued to grow with more or less vigor. I know now that this was only possible with the help of intact neighboring trees. Thanks to the underground network, neighbors took over the disrupted task of provisioning the roots and thus made it possible for their buddies to survive. Some trees even managed to bridge the gap in their bark with new growth, and I'll admit it: I am always a bit ashamed when I see what I wrought back then. Nevertheless, I have learned from this just how powerful a community of trees can be. "A chain is only as strong as its weakest link." Trees could have come up with this old craftsperson's saying. And because they know this intuitively, they do not hesitate to help each other out.

4

— LOVE —

The leisurely pace at which trees live their lives is also apparent when it comes to procreation. Reproduction is planned at least a year in advance. Whether tree love happens every spring depends on the species. Whereas conifers send their seeds out into the world at least once a year, deciduous trees have a completely different strategy. Before they bloom, they agree among themselves. Should they go for it next spring, or would it be better to wait a year or two? Trees in a forest prefer to bloom at the same time so that the genes of many individual trees can be well mixed. Conifers and deciduous trees agree on this, but deciduous trees have one other factor to consider: browsers such as wild boar and deer.

Boar and deer are extremely partial to beechnuts and acorns, both of which help them put on a protective layer of fat for winter. They seek out these nuts because they contain up to 50 percent oil and starch—more than any other food. Often whole areas of forest are picked clean down to the last morsel in the fall so that, come spring, hardly any beech and oak seedlings sprout. And that's why the trees agree in advance. If they don't bloom every year, then the herbivores cannot count on them. The next generation is kept in check because over the winter the pregnant animals must endure a long stretch with little food, and many of them will not survive. When the beeches or oaks finally all bloom at the same time and set fruit, then it is not possible for the few herbivores left to demolish everything, so there are always enough undiscovered seeds left over to sprout.

"Mast years" is an old term used to describe years when beeches and oaks set seed. In these years of plenty, wild boar can triple their birth rate because they find enough to eat in the forests over the winter. In earlier times, European peasants used the windfall for the wild boar's tame relatives, domestic pigs, which they herded into the woods. The idea was that the herds of domestic pigs would gorge on the wild nuts and fatten up nicely before they were slaughtered. The year following a mast year, wild boar numbers usually crash because the beeches and oaks are taking a time-out and the forest floor is bare once again.

When beeches and oaks put blooming on hold for a number of years, this has grave consequences for insects, as well—especially for bees. It's the same for bees as it is for wild boar: a multi-year hiatus causes their populations to collapse. Or, more accurately, could cause them to collapse, because bees never build up large populations in deciduous forests in the first place. The reason is that true forest trees couldn't care less about these little helpers. What use are the few pollinators left after barren years when you then unfurl millions upon millions of blossoms over hundreds of square miles? If you are a beech or an oak, you have to come up with a more reliable method of pollination, perhaps even one that doesn't exact payment. And what could be more natural than using the wind? Wind blows the powdery pollen out of the blossoms and carries it over to neighboring trees. The wind has a further advantage. It still blows when temperatures fall, even when they drop below 53 degrees Fahrenheit, which is when it gets too chilly for bees and they stay home.

Conifers bloom almost every year, which means bees are an option for pollination because they would always find food. However, conifers are native to northern forests, which are too chilly for bees to be out and about while the trees are blooming, and that is probably why conifers, like beeches and oaks, prefer to rely on the wind. Conifers don't need to worry about taking breaks from blooming, like beeches or oaks, because they have no reason to fear deer and wild boar. The small seeds inside the cones of Spruce & Co. just don't offer an attractive source of nutrition. True, there are birds such as red crossbills, which pick off cones with the tips of their powerful crossed bills and eat the seeds inside, but in general, birds don't seem to be a big problem. And because there is almost no animal that likes to store conifer seeds for winter food, the trees release their potential heirs into the world on tiny wings. Thus equipped, their seeds float slowly down from the tips of their branches and can easily be carried away on a breath of wind.

Spruce & Co. produce huge quantities of pollen, almost as though they wanted to outdo deciduous trees in the mating department. They produce such huge quantities that even in a light breeze, enormous dusty clouds billow over coniferous forests in bloom, giving the impression of a fire smoldering beneath the treetops. This raises the inevitable question about how inbreeding can be avoided in such chaotic conditions. Trees have survived until today only because there is a great deal of genetic diversity within each species. If they all release their pollen at the same time, then the tiny grains of pollen from all the trees mix together and drift through the canopy. And because a tree's own pollen is particularly concentrated around its own branches, there's a real danger its pollen will end up fertilizing its own female flowers. But, as I just mentioned, that is precisely what the trees want to avoid. To reduce this possibility, trees have come up with a number of different strategies.

Some species—like spruce—rely on timing. Male and female blossoms open a few days apart so that, most of the time, the latter will be dusted with the foreign pollen of other spruce. This is not an option for trees like bird cherries, which rely on insects. Bird cherries produce male and female sex organs in the same blossom, and they are one of the few species of true forest trees that allow themselves to be pollinated by bees. As the bees make their way through the whole crown, they cannot help but spread the tree's own pollen. But the bird cherry is alert and senses when the danger of inbreeding looms. When a pollen grain lands on a stigma, its genes are activated and it grows a delicate tube down to the ovary in search of an egg. As it is doing this, the tree tests the genetic makeup of the pollen and, if it matches its own, blocks the tube, which then dries up. Only foreign genes, that is to say, genes that promise future success, are allowed entry to form seeds and fruit. How does the bird cherry distinguish between "mine" and "yours"? We don't know exactly. What we do know is that the genes must be activated, and they must pass the tree's test. You could say, the tree can "feel" them. You might say that we, too, experience the physical act of love as more than just the secretions of neurotransmitters that activate our bodies' secrets, though what mating feels like for trees is something that will remain in the realm of speculation for a long time to come.

Some species have a particularly effective way of avoiding inbreeding: each individual has only one gender. For example, there are both male and female willows, which means they can never mate with themselves but only procreate with other willows. But willows, it must be said, aren't true forest trees. They colonize pioneer sites, areas that are not yet forested. Because there are thousands of wild flowers and shrubs blooming in such places, and they attract bees, willows, like bird cherries, also rely on insects for pollination. But here a problem arises. The bees must first fly to the male willows, collect pollen there, and then transport the pollen to the female trees. If it was the other way around, there would be no fertilization. How does a tree manage this if both sexes have to bloom at the same time? Scientists have discovered that all willows secrete an alluring scent to attract bees. Once the insects arrive in the target area, the willows switch to visual signals. With this in mind, male willows put a lot of effort into their catkins and make them bright yellow. This attracts the bees to them first. Once the bees have had their first meal of sugary nectar, they leave and visit the inconspicuous greenish flowers of the female trees.[16]

Inbreeding as we know it in mammals—that is to say, breeding between populations that are related to one another—is, of course, still possible in all three cases I have mentioned. And here, wind and bees come into play equally. As both bridge large distances, they ensure that at least some of the trees receive pollen from distant relations, and so the local gene pool is constantly refreshed. However, completely isolated stands of rare species of trees, where only a few trees grow, can lose their genetic diversity. When they do, they weaken and, after a few centuries, they disappear altogether.

5

— THE TREE LOTTERY —

TREES MAINTAIN AN inner balance. They budget their strength carefully, and they must be economical with energy so that they can meet all their needs. They expend some energy growing. They must lengthen their branches and widen the diameter of their trunks to support their increasing weight. They also hold some energy in reserve so that they can react immediately and activate defensive compounds in their leaves and bark if insects or fungi attack. Finally, there is the question of propagation.

Species that blossom every year plan for this Herculean task by carefully calibrating their energy levels. However, species that blossom only every three to five years, such as beeches or oaks, are thrown off kilter by such events. Most of their energy has already been earmarked for other tasks, but they need to produce such enormous numbers of beechnuts and acorns that everything else must now take second place. The battle for the branches begins. There's not a speck of space for the blossoms, so a corresponding number of leaves must vacate their posts. In the years when the leaves shrivel and fall off, the trees look unusually bare, so it's no surprise that reports on the condition of forests where the affected trees are growing describe the tree canopy as being in a pitiful state. Because all the trees are going through this process at the same time, to a casual observer the forest looks sick. The forest is not sick, but it is vulnerable. The trees use the last of their energy reserves to produce the mass of blossoms, and to compound the problem, they are left with fewer leaves, so they produce less sugar than they normally do. Furthermore, most of the sugar they do produce is converted into oil and starch in the seeds, so there is hardly any left over for the trees' daily needs and winter stores—to say nothing of the energy reserves intended to defend against sickness.

Many insects have been waiting for just this moment. For example, the beech leaf-mining weevil lays millions upon millions of eggs in the fresh, defenseless foliage. Here, the tiny larvae eat away flat tunnels between the top and bottom surfaces of the leaves, leaving brown papery trails as they feed. The adult beetles chew holes in the leaves until they look as though a hunter has blasted them with a shotgun. Some years, the infestations are so severe that, from afar, the beeches look more brown than green. Normally, the trees would fight back by making the insects' meal extremely bitter—literally. But after producing all those blossoms, they are out of steam, and so this season they must endure the attack without responding.

Healthy trees get over this, especially because afterward there will be a number of years for them to recover. However, if a beech tree is already sickly before the attack, then such an infestation can sound its death knell. Even if the tree knew this, it would not produce fewer blossoms. We know from times of high forest mortality that it is usually the particularly battered individuals that burst into bloom. If they die, their genetic legacy might disappear, and so they probably want to reproduce right away to make sure it continues. Something similar happens after unusually hot summers. After extreme droughts bring many trees to the brink of death, they all bloom together the following year, which goes to show that large quantities of beechnuts and acorns don't indicate that the next winter will be particularly harsh. As blossoms are set the summer before, the abundance of fruit reflects what happened the previous year and has nothing to do with what will happen in the future. The effect of weak defenses shows up again in the fall, this time in the seeds. The beech leaf miners bore into fruit buds as well as leaves. Consequently, although beechnuts form, they remain empty, and therefore, they are barren and worthless.

When a seed falls from a tree, each species has its own strategy as to when the seed sprouts. So how does that work? If a seed lands on soft, damp soil, it has no choice but to sprout as soon as it is warmed by the sun in the spring, for every day the embryonic tree lies around on the ground unprotected it is in great danger—come spring, wild boar and deer are always hungry. And this is just what the large seeds of species such as beeches and oaks do. The next generation emerges from beechnuts and acorns as quickly as it can so that it is less attractive to herbivores. And because this is their one and only plan, the seeds don't have long-term defense strategies against fungi and bacteria. The seeds slough off their protective casings, which lie around on the forest floor through the summer and rot away by the following spring.

Many other species, however, give their seeds the opportunity to wait one or more years until they start to grow. Of course, this means a higher risk of being eaten, but it also offers substantial advantages. For example, seedlings can die of thirst in a dry spring, and when that happens, all the energy put into the next generation is wasted. Or when a deer has its territory and main feeding ground in exactly the spot where the seed lands, it takes no more than a few days for the seedling's tasty new leaves to end up in the deer's stomach. In contrast, if some of the seeds do not germinate for a year or more, then the risk is spread out so that at least a few little trees are likely to make it.

Bird cherries adopt this strategy: their seeds can lie dormant for up to five years, waiting for the right time to sprout. This is a good strategy for this typical pioneer species. Beechnuts and acorns always fall under their mother trees, so the seedlings grow in a predictable, pleasant forest microclimate, but little bird cherries can end up anywhere. Birds that gobble the tart fruit make random deposits of seeds wrapped in their own little packages of fertilizer. If a package lands out in the open in a year when the weather is extreme, temperatures will be hotter and water supplies scarcer than in the cool, damp shadows of a mature forest. Then it's advantageous if at least some of the stowaways wait a few years before waking to their new life.

And after they wake? What are the youngsters' chances of growing up and producing another generation? That's a relatively easy calculation to make. Statistically speaking, each tree raises exactly one adult offspring to take its place. For those that don't make it, seeds may germinate and young seedlings may vegetate for a few years, or even for a few decades, in the shadows, but sooner or later, they run out of steam. They are not alone. Dozens of offspring from other years also stand at their mothers' feet, and by and by, most give up and return to humus. Eventually, a few of the lucky ones that have been carried to open spaces on the forest floor by the wind or by animals get a good start in life and grow to adulthood.

Back to the odds. Every five years, a beech tree produces at least thirty thousand beechnuts (thanks to climate change, it now does this as often as every two or three years, but we'll put that aside for the moment). It is sexually mature at about 80 to 150 years of age, depending on how much light it gets where it's growing. Assuming it grows to be 400 years old, it can fruit at least sixty times and produce a total of about 1.8 million beechnuts. From these, exactly one will develop into a full-grown tree—and in forest terms, that is a high rate of success, similar to winning the lottery. All the other hopeful embryos are either eaten by animals or broken down into humus by fungi or bacteria.

Using the same formula, let's calculate the odds that await tree offspring in the least favorable circumstances. Let's consider the poplar. The mother trees each produce up to 54 million seeds—every year.[17] How their little ones would love to change places with the beech tree youngsters. For until the old ones hand over the reins to the next generation, they produce more than a billion seeds. Wrapped in their fluffy packaging, these seeds strike out via airmail in search of new pastures. But even for them, based purely on statistics, there can be only one winner.