



BIRCH



— 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?

2 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 trees¹—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.

3 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.



— 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 both-ersome 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. Isolated by their silence, 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.¹⁵ 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...



— 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 thron.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 crafts-person'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