ALLEN LANE

USA | Canada | UK | Ireland | Australia
New Zealand | India | South Africa | China

Allen Lane is part of the Penguin Random House group of companies
whose addresses can be found at global.penguinrandomhouse.com

Published by Penguin Random House India Pvt. Ltd
4th Floor, Capital Tower 1, MG Road,
Gurugram 122 002, Haryana, India

Penguin Random House India

Originally published in Germany as *Das geheime Leben der Bäume* by Ludwig
Verlag, a division of Verlagsgruppe Random House GmbH, Munich 2015
First published in English by Greystone Books Ltd, Vancouver, Canada 2016
First published in India in Allen Lane by Penguin Random House India 2016

26 25

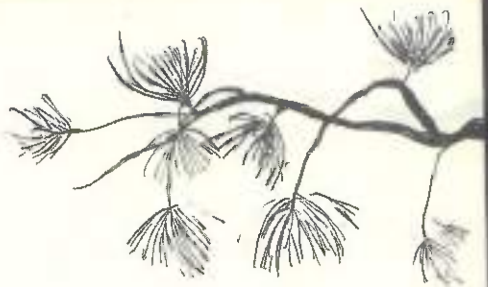
ISBN 9780670089345

For sale in the Indian Subcontinent only

Typeset in Cochin by Manipal Digital Systems, Manipal
Printed at Thomson Press India Ltd, New Delhi

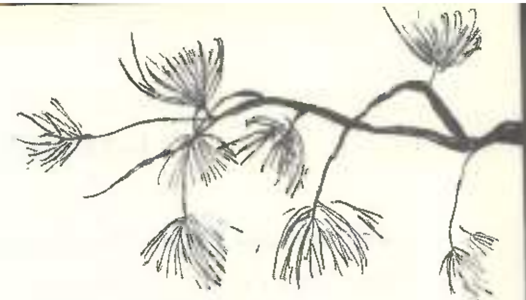
www.penguin.co.in

MIX
Paper
FSC FSC® C010615



Contents

CONTENTS



Introduction

What would you say if you met a man who told you that trees have feelings and experience pain? That they communicate with other members of their species and support their young? Chances are you'd smile indulgently and start patting your pockets for your car keys. What if he went on to say that trees have memory, hearing, language? That they can form circles of friends and 'see' colours . . . By now you'd have put on your quick, hard smile and said, 'Look, I'm sorry, but I *really* have to run.'

Right?

Wrong! You'd be a fool to go away! Here's a book written by a woodsman that will disarm you with its gentle explanations and blow you away with new insights into the world of trees. Seeing, feeling, hearing—these are sensory abilities that we find hard to think about differently from the way humans or animals use them. But break them down into basic neural/molecular components and it's not hard to accept, for example, that leaf tissue sends out electrical signals when it is nibbled, just like human tissue does when it is hurt. And that this constitutes a signalling system, not just to summon up defensive compounds in the hurt plant but also to release chemical signals—molecules of scent—to warn other plants nearby of the danger so that they too can put up defences.

Is this the same as 'language'? No, but it is in every sense of the word a 'communication' from one plant to its fellows and Peter Wohlleben is an engaging storyteller who draws you into his world of new discoveries persuasively and with consummate skill, drawing on impeccable scientific research.

There is an unfortunate sense in which this book is bound to provoke associations with Peter Tomkins's *The Secret Life of Plants* (1973), not least because of the similarity of their titles. Any resemblance is unfortunate and misleading. Tomkins's book became immensely popular as a New Age testimonial but it is difficult to escape a feeling that his account of plants responding to music and communicating with humans verged more on psychobotany than hard science. Peter Wohlleben's book suffers from no such defect. You don't need to be

a superannuated hippie to enjoy it thoroughly and it's a complete delight if you are seriously interested in trees, forests, and ecology.

The single discovery that changed the way scientists began to understand trees and plants has to do with things that happen unseen, below ground, but on an unimaginably colossal scale. Sometime in 1990 or so, an American doctoral researcher—Suzanne Simard—was the first to discover intricate underground networks of mycelium that we now know as 'mycorrhizae', essentially symbiotic fungi that bind to the roots of plants. Simard mapped and measured the degree to which mycorrhizae play a role in the cycling of nutrients and found a vast network of carbon and nutrient exchange. Two different species—paper birches and Douglas firs—were bound together in Pacific forests in North America and exchanging carbon in a dynamic mutualism made possible by an immense network of fungal threads underground. The journal *Nature* cleverly dubbed it the 'wood wide web' and, in the years since, the fungal web has been intensively studied and scientists have gone on to find all sorts of surprising ways in which it functions. It works in all kinds of ecological milieu—in cool, moist, temperate biomes; in crusty, dry deserts. Sometimes the wood wide web works *best* in the most difficult, stressed environments where fungi lap minerals from rocks that are otherwise unavailable to plants, in return for the sugars and carbohydrates that the plants provide. It is an amazing underground system, made all the more incredible by the fact that it escaped attention for so long. The wood wide web has completely transformed our understanding of how trees communicate with one another and regulate and influence the forest community. It is hard to overestimate its importance or even the insights it will provide that still await discovery. Clearly mycorrhizae are to ecosystems what genomes are to heredity. Or something like that!

* * *

It is a little ironic for us that a man who writes about trees in a simpatico vein is German, because we owe our stern forestry plantation system in India to German foresters who first organized and instituted the forest department and its policies in India and Burma in the mid-nineteenth century. Britain had no tradition of 'scientific forestry' in the nineteenth century. France and Germany did, and it would have been too much to expect that Britain would ask the French to come in to advise them about anything! It was German

foresters who were invited in and taught us that the ideal scientific forest was an even-aged forest, felled by rotation, stocked only with 'desirable' species, with everything else cut out as dross. It is a silvicultural system and a plantation mindset that caused enormous damage to our mixed forests and, in many ways, we still have not been able to shake off the worst aspects of thinking of forests as commercial plantations.

So it is wholly balancing that it is a German forester who shows us a way out of the ethos of plantation forestry. Peter Wohlleben makes no bones about the fact that he learnt and recognized very little about the hidden life of trees in the first years of his work as a woodsman:

> When I began my professional career as a forester, I knew about as much about the hidden life of trees as a butcher knows about the emotional life of animals . . . Because it was my job to look at hundreds of trees every day—spruce, beeches, oaks, and pines—to assess their suitability for the lumber mill and their market value, my appreciation of trees was also restricted to this narrow point of view.

Slowly, over the years, Peter began to connect with scientific research to learn about deep processes of regeneration and mutualism in his native forests, about which he had no previous idea. As he delved deeper, especially after news of the underground mycorrhizal web started to disseminate more widely, Peter began to think of the forest and its trees in very different terms.

Wohlleben's book is about his native beeches and oaks in the forests of the Eifel mountains near Germany's border with Belgium. He writes interestingly about commercially planted conifers too—spruce, fir and pines. But even though his book is about species foreign to India—we have spruce, fir and pines in the Himalaya too, but they are different kinds—Wohlleben's method and tone are inspiring and offer us leads and modes of inquiry that could help us with conundrums surrounding Indian trees and forests for which we have never found convincing answers.

Take the puzzle about the sal tree (*Shorea robusta*), for example, and its unswerving devotion to a particular swathe of country as its native habitat. Sal is—perhaps I should say 'was'—one of the great commercial timbers of India with a home range running all along the base of the Himalayas from western Uttar Pradesh to Bengal and then curving like the handle of an umbrella through Orissa into a corner of north-eastern Madhya Pradesh. For the great enterprise of the British Indian

railways, sal was the timber most in demand (for railway sleepers) and all through the second half of the nineteenth century and beyond, the Indian forest department tried with conspicuous lack of success to grow sal in new areas outside its native range. They surmised that failure had to do perhaps with minerals in the soil. Or moisture retentiveness. They failed again and again, and could not understand why.

Reams of paper in silvicultural and forestry journals were devoted to trying to understand, explain, and argue against competing ideas about why sal refused to prosper outside its native range. I suppose no one had the tools to peer below the topsoil to investigate what lay underneath, though various aspects of the soil itself—tilth, aggregate, moisture, pH, biochemistry—were invoked as explanation. It remains an unsolved mystery but I suspect the tools to understand it are now at hand.

Sal is always labelled 'gregarious' because it grows in huge assemblies of its own kind, not quite in a monoculture but in massed stands in which it is, far and away, the predominant species. It has always been known that you can't grow a sal tree on its own. You won't find a sal tree growing in a park, for instance, nor will you encounter an avenue of sal trees. Foresters tell us that sal trees die of 'loneliness' when they are planted singly. This epithet was used in right earnest, completely without wry humour, by British foresters because they could find no other apt word to describe why sal trees died when they became isolated. Clearly, they *needed* to be in large groups and had some way by which they could tell when this condition was missing.

When the Wildlife Institute of India in Chandrabani, near Dehra Dun, was built in the early 1980s, its main building was situated in a cleared sal forest. One by one, the sal trees that became isolated started to die. These 'lonely' sal trees were clearly dying because they had lost communication with the rest of their group, but how on earth did they know or sense this? What was the mechanism that enabled a sal tree to keep in touch with the rest of its gang? Was it chemical—scent? Were they communicating underground, through their roots? Of course, no one knew about mycorrhizae then, but I'm willing to bet the answer lies not very deep underground, in the fine hairs of their root zone. That bit of last-mile conclusive proof remains to be clinched.

A similar sense of anticipated discovery awaits us with the dhok tree which forms impressive monocultures on steep rocky slopes in the Aravallis. Like the sal, it sticks stubbornly to a fixed home range and is not found

beyond the Aravalli hills and a few adjacent Vindhyan outliers. No one quite knows why. No one knows how dhok 'manages' to survive in its harsh habitat, because it doesn't have deep roots, bears no trace of succulence, and doesn't seem to be equipped in any special way for life in a rocky desert. But it manages exceedingly well and one of its attributes is an ability to form amazing 'clonal forests'—collectivities where a tree multiplies by sending out runners, so that in course of time it begins to *look* like a forest of separate trees, though in reality it remains just *one single giant organism*, because all the apparently separate trees bear identical DNA. Here again, I feel sure that we need to look under and between their roots to begin to find the explanations. It seems amazing that no one has tried so far.

These are just some aspects of Indian forest ecology that we haven't begun to explore or understand. In subtropical dry forests throughout much of the Indian subcontinent, we have 'large' seasonal events like the cascading flushes of new leaf at the height of summer and the dominance of red in the new leaves that have hardly been noticed, still less studied. I became more aware of this when I read *The Hidden Life of Trees* because Wohlleben writes so simply and engagingly about complicated things. Take this snippet, for example, about plant phenology—why plants do things when they do:

> Shedding leaves and growing new ones depends not only on temperature but also on how long the days are. Beeches, for example, don't start growing until it is light for at least thirteen hours a day. That in itself is astounding, because to do this, trees must have some kind of ability to see. It makes sense to look for this ability in the leaves. After all, they come with a kind of solar cell, which makes them well equipped to receive light waves. And this is just what they do in the summer months, but in April the leaves are not yet out. We don't yet understand the process completely, but it is probably the buds that are equipped with this ability. The folded leaves are resting peacefully in the buds, which are covered with brown scales to prevent them from drying out. Take a closer look at these scales when the leaves start to grow and hold them up to the light. Then you'll see it. They're transparent! It probably takes only the tiniest amount of light for the buds to register day length, as we already know from the seeds of some agricultural weeds. Out in the fields, all it takes is the weak light of the moon at night to

> trigger germination. And a tree trunk can register light as well. Most tree species have tiny dormant buds nestled in their bark.

It is sad but true that in India we live in a scientific backwater when it comes to ecological issues. Much of our plant life in India has been mapped and documented but very little of its ecology, the relationship between living things and their surroundings. Our forest departments are prime offenders because, far from learning about or teaching us about how things 'work' in our forests and wilderness areas, Indian forest departments have been notoriously inimical to independent scientific research. It seems such a shame.

Wohlleben's book is to be admired not just because he is a forester with important things to say but because he says them so wonderfully well. In a chapter called 'Immigrants' towards the end of his book, he looks at the issue of exotic plants and tells us what happened to the black cherry, imported into Germany from North America for its beautiful trunk and high-quality wood. In its new biome, the cherry trees grew crooked and lopsided and stunted, and in a remarkably short time became invasive.

Cut to India's foresters who have learnt no lessons from the depredations of invasive trees and shrubs that they are single-handedly responsible for introducing to the wild. Mexican mesquite and subabool have caused immense damage to large parts of the subcontinent. Israeli babool threatens sandy parts of the desert. Japanese cedar and Australian wattles have wreaked havoc in parts of the north-western Himalayas and the Nilgiris. And still the forest department shoos away scientists as dangerous interlopers.

Peter Wohlleben's book should be required reading for every forester in the subcontinent. And for anyone who is even remotely interested in plants and trees. And for policymakers who see trees only as lumber factories.

Wohlleben says:

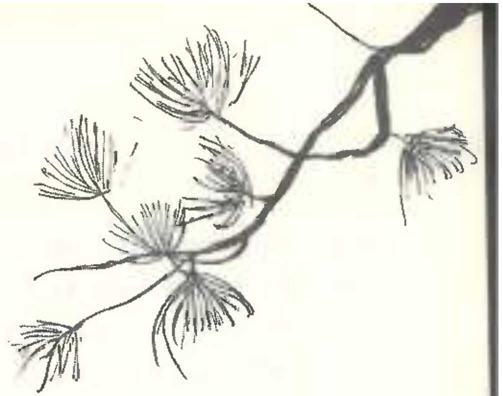
> The real question is whether we help ourselves only to what we need from the forest ecosystem, and—analogous to our treatment of animals—whether we spare the trees unnecessary suffering when we do this.
>
> That means it is okay to use wood as long as trees are allowed to live in a way that is appropriate to their species. And that means that they should be

> allowed to fulfil their social needs, to grow in a true forest environment on undisturbed ground, and to pass their knowledge on to the next generation. And at least some of them should be allowed to grow old with dignity and finally die a natural death.

Amen.

New Delhi
June 2016

Pradip Krishen



Foreword

We read in fairy tales of trees with human faces, trees that can talk, and sometimes walk. This enchanted forest is the kind of place, I feel sure, that Peter Wohlleben inhabits. His deep understanding of the lives of trees, reached through decades of careful observation and study, reveals a world so astonishing that if you read his book, I believe that forests will become magical places for you, too.

One reason that many of us fail to understand trees is that they live on a different timescale than us. One of the oldest trees on earth, a spruce in Sweden, is more than 9500 years old. That's 115 times longer than the average human lifetime. Creatures with such a luxury of time on their hands can afford to take things at a leisurely pace. The electrical impulses that pass through the roots of trees, for example, move at the slow rate of one third of an inch per second. But why, you might ask, do trees pass electrical impulses through their tissues at all?

The answer is that trees need to communicate, and electrical impulses are just one of their many means of communication. Trees also use the senses of smell and taste for communication. If a giraffe starts eating an African acacia, the tree releases a chemical into the air that signals that a threat is at hand. As the chemical drifts through the air and reaches other trees, they 'smell' it and are warned of the danger. Even before the giraffe reaches them, they begin producing toxic chemicals. Insect pests are dealt with slightly differently. The saliva of leaf-eating insects can be 'tasted' by the leaf being eaten. In response, the tree sends out a chemical signal that attracts predators that feed on that particular leaf-eating insect. Life in the slow lane is clearly not always dull.

But the most astonishing thing about trees is how social they are. The trees in a forest care for each other, sometimes even going so far as to nourish the stump of a felled tree for centuries after it was cut down, by feeding it sugars and other nutrients, and so keeping it alive. Only some stumps are thus nourished. Perhaps they are the parents of the trees that make up the forest of today. A tree's most important means of

staying connected to other trees is a 'wood wide web' of soil fungi that connects vegetation in an intimate network that allows the sharing of an enormous amount of information and goods. Scientific research aimed at understanding the astonishing abilities of this partnership between fungi and plant has only just begun.

The reason trees share food and communicate is that they need each other. It takes a forest to create a microclimate suitable for tree growth and sustenance. So it's not surprising that isolated trees have far shorter lives than those living connected together in forests. Perhaps the saddest plants of all are those we have enslaved in our agricultural systems. They seem to have lost the ability to communicate and, as Wohlleben says, are thus rendered deaf and dumb. 'Perhaps farmers can learn from the forests and breed a little more wildness back into their grain and potatoes,' he advocates, 'so that they'll be more talkative in the future.'

Opening this book, you are about to enter a wonderland. Enjoy it.

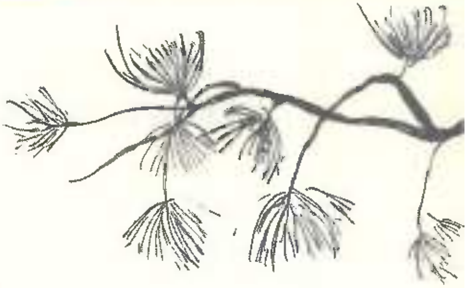
Tim Flannery

A for
by the
the ex
illustr
and ca

In *The*
draws
discov
human
with th
suppor
with th
even w

As a re
family
live to
like str
in most
in a gr

In this
shares
explain
and reg
unawar
of the d
readers
in the w



Preface to the English Edition

When I wrote this book, I wanted to describe my experiences in the forest I manage in the Eifel mountains in Germany and record what the trees had taught me. As soon as the German edition of the book was published, it was clear that the story I had to tell struck a chord with many, many people. My message, though grounded in a forest I interact with almost every day, is a message that applies to forests and woodlands around the world.

I am most familiar with the struggles and strategies of beeches and oaks, and with the contrast between deciduous forests that plan their own futures and coniferous forests planted for commercial gain. However, the struggles and strategies in forests left to their own devices, and the tension created when forests are planted instead of evolving at their own pace are issues that resonate far beyond my experiences in Hümmel.

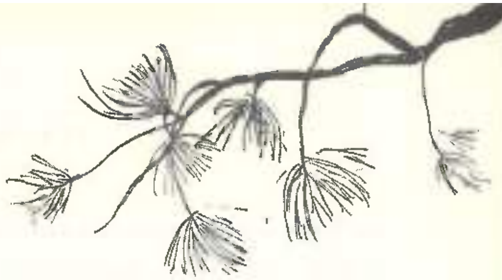
I encourage you to look around where you live. What dramas are being played out in wooded areas you can explore? How are commerce and survival balanced in the forests and woodlands you know? This book is a lens to help you take a closer look at what you might have taken for granted. Slow down, breathe deep, and look around. What can you hear? What do you see? How do you feel?

My story also explains why forests matter on a global scale. Trees are important, but when trees unite to create a fully functioning forest, you really can say that the whole is greater than its parts. Your trees may not function exactly as my trees do, and your forest might look a little different, but the underlying narrative is the same: forests matter at a more fundamental level than most of us realize.

Before you plunge into this book to find out what I have discovered just by stepping outside my back door, I want to tell you a story about Yellowstone National Park in the United States to show just how vital undisturbed forests and woodlands are to the future of our planet and how our appreciation for trees affects the way we interact with the world around us.

It all starts with the wolves. Wolves disappeared from Yellowstone, the world's first national park, in the 1920s. When they left, the entire ecosystem changed. Elk herds in the park increased their numbers and began to make quite a meal of the aspens, willows, and cottonwoods that lined the streams. Vegetation declined and animals that depended on the trees left. The wolves were absent for seventy years. When they returned, the elks' languorous browsing days were over. As the wolf packs kept the herds on the move, browsing diminished, and the trees sprang back. The roots of cottonwoods and willows once again stabilized stream banks and slowed the flow of water. This, in turn, created space for animals such as beavers to return. These industrious builders could now find the materials they needed to construct their lodges and raise their families. The animals that depended on the riparian meadows came back, as well. The wolves turned out to be better stewards of the land than people, creating conditions that allowed the trees to grow and exert their influence on the landscape.

My hope is that the wolves' stewardship of natural processes in Yellowstone will help people appreciate the complex ways in which trees interact with their environment, how our interactions with forests affect their success, and the role forests play in making our world the kind of place where we want to live. Apart from that, forests hide wonders that we are only just beginning to explore. I invite you to enter my world.



Preface

When I began my professional career as a forester, I knew about as much about the hidden life of trees as a butcher knows about the emotional life of animals. The modern forestry industry produces lumber. That is to say, it fells trees and then plants new seedlings. If you read the professional literature, you quickly get the impression that the well-being of the forest is only of interest insofar as it is necessary for optimizing the lumber industry. That is enough for what foresters do day to day, and eventually it distorts the way they look at trees. Because it was my job to look at hundreds of trees every day—spruce, beeches, oaks, and pines—to assess their suitability for the lumber mill and their market value, my appreciation of trees was also restricted to this narrow point of view.

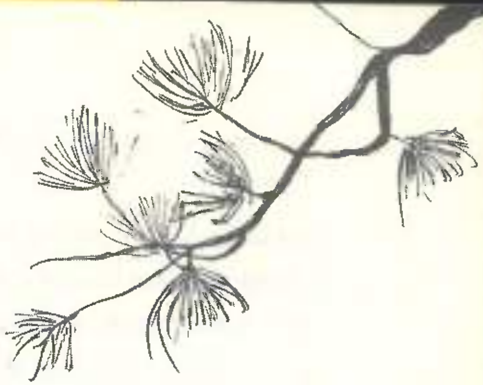
About twenty years ago, I began to organize survival training and log-cabin tours for tourists. Then I added a place in the forest where people can be buried as an alternative to traditional graveyards, and an ancient forest preserve. In conversations with the many visitors who came, my view of the forest changed once again. Visitors were enchanted by crooked, gnarled trees I would previously have dismissed because of their low commercial value. Walking with my visitors, I learned to pay attention to more than just the quality of the trees' trunks. I began to notice bizarre root shapes, peculiar growth patterns, and mossy cushions on bark. My love of nature—something I've had since I was six years old—was reignited. Suddenly, I was aware of countless wonders I could hardly explain even to myself. At the same time, Aachen University (RWTH Aachen) began conducting regular scientific research programmes in the forest I manage. During the course of this research, many questions were answered, but many more emerged.

Life as a forester became exciting once again. Every day in the forest was a day of discovery. This led me to unusual ways of managing the forest. When you know that trees experience pain and have memories and that tree parents live together with their children, then you can no longer just chop them down and disrupt their lives with large machines. Machines have been banned

from the forest for a couple of decades now, and if a few individual trees need to be harvested from time to time, the work is done with care by foresters using horses instead. A healthier—perhaps you could even say happier—forest is considerably more productive, and that means it is also more profitable.

This argument convinced my employer, the community of Hümmel, and now this tiny village in the Eifel mountains will not consider any other way of managing their forest. The trees are breathing a collective sigh of relief and revealing even more of their secrets, especially those stands growing in the newly established preserves, where they are left completely undisturbed. I will never stop learning from them, but even what I have learned so far under their leafy canopy exceeds anything I could ever have dreamed of.

I invite you to share with me the joy trees can bring us. And, who knows, perhaps on your next walk in the forest, you will discover for yourself wonders great and small.



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 colour 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 400 or 500 years earlier. But how could the remains have clung on to 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 neighbouring 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 neighbours 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.

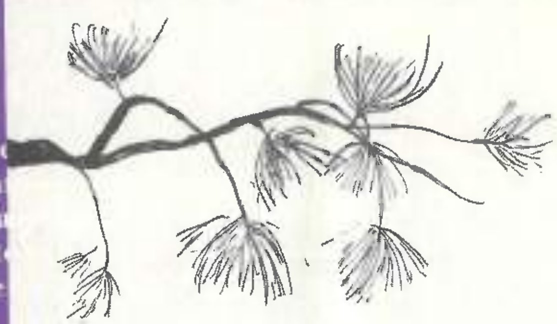
Every tree, therefore, is valuable to the community and worth keeping around for as long as possible. And that is why even sick individuals are supported and nourished until they recover. Next time, perhaps it will be the other way round, and the supporting tree might be the one in need of assistance. When thick, silver-grey 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 on to 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 neighbouring tree of the same height. It doesn't grow any wider because the air and better light in this space is 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, 'Street Kids'. 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 100 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 behaviour is astonishing. The acacia trees that were being eaten gave off a warning gas (specifically, ethylene) that signalled to neighbouring 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 were 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 the tree can match the saliva to the insect. Indeed, the match can be so precise that the tree can release pheromones that summon specific beneficial predators. The beneficial predators help the tree 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 that 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 only be detected 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 defence 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 defence. 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 defence 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 neighbours would not get wind of the danger. 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 neighbouring 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 fibre-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 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 favour 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 defence 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 colour 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. 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, 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 . . .

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 neighbours 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 only be 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 make-up, 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 neighbours 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 neighbours. 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 vigour. I know now that this was only possible with the help of intact neighbouring trees. Thanks to the underground network, neighbours 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 craftsman's saying. And because they know this intuitively, they do not hesitate to help each other out.