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The Social Life of Forests

Trees appear to communicate and cooperate through subterranean networks of fungi. What are they sharing with one another?

By Ferris Jabr

Photographs by Brendan George Ko

As a child, Suzanne Simard often roamed Canada's old-growth forests with her siblings, building forts from fallen branches, foraging mushrooms and huckleberries and occasionally eating handfuls of dirt (she liked the taste). Her grandfather and uncles, meanwhile, worked nearby as horse loggers, using low-impact methods to selectively harvest cedar, Douglas fir and white pine. They took so few trees that Simard never noticed much of a difference. The forest seemed ageless and infinite, pillared with conifers, jeweled with raindrops and brimming with ferns and fairy bells. She experienced it as "nature in the raw" — a mythic realm, perfect as it was. When she began attending the University of British Columbia, she was elated to discover forestry: an entire field of science devoted to her beloved domain. It seemed like the natural choice.

By the time she was in grad school at Oregon State University, however, Simard understood that commercial clearcutting had largely superseded the sustainable logging practices of the past. Loggers were replacing diverse forests with homogeneous plantations, evenly spaced in upturned soil stripped of most underbrush. Without any competitors, the thinking went, the newly planted trees would thrive. Instead, they were frequently more vulnerable to disease and climatic stress than trees in old-growth forests. In particular, Simard noticed that up to 10 percent of newly planted Douglas fir were likely to get sick and die whenever nearby aspen, paper birch and cottonwood were removed. The reasons were unclear. The planted saplings had plenty of space, and they received more light and water than trees in old, dense forests. So why were they so frail?

Simard suspected that the answer was buried in the soil. Underground, trees and fungi form partnerships known as mycorrhizas: Threadlike fungi envelop and fuse with tree roots, helping them extract water and nutrients like phosphorus and nitrogen in exchange for some of the carbon-rich sugars the trees make through photosynthesis. Research had demonstrated that mycorrhizas also connected plants to one another and that these associations might be ecologically important, but most scientists had studied them in greenhouses and laboratories, not in the wild. For her doctoral thesis, Simard decided to investigate fungal links between Douglas fir and paper birch in the forests of British Columbia. Apart from her supervisor, she didn't receive much encouragement from her mostly male peers. "The old foresters were like, Why don't you just study growth and yield?" Simard told me. "I was more interested in how these plants interact. They thought it was all very girlie."

Now a professor of forest ecology at the University of British Columbia, Simard, who is 60, has studied webs of root and fungi in the Arctic, temperate and coastal forests of North America for nearly three decades. Her initial inklings about the importance of mycorrhizal networks were prescient, inspiring whole new lines of research that ultimately overturned longstanding misconceptions about forest ecosystems. By analyzing the DNA in root tips and tracing the movement of molecules through underground conduits, Simard has discovered that fungal threads link nearly every tree in a forest — even trees of different species. Carbon, water, nutrients, alarm signals and hormones can pass from tree to tree through these subterranean circuits. Resources tend to flow from the oldest and biggest trees to the youngest and smallest. Chemical alarm signals generated by one tree prepare nearby trees for danger. Seedlings severed from the forest's underground lifelines are much more likely to die than their networked counterparts. And if a tree is on the brink of death, it sometimes bequeaths a substantial share of its carbon to its neighbors.

Although Simard's peers were skeptical and sometimes even disparaging of her early work, they now generally regard her as one of the most rigorous and innovative scientists studying plant communication and behavior. David Janos, co-editor of the scientific journal Mycorrhiza, characterized her published research as "sophisticated, imaginative, cutting-edge." Jason Hoeksema, a University of Mississippi biology professor who has studied mycorrhizal networks, agreed: "I think she has really pushed the field forward." Some of Simard's studies now feature in textbooks and are widely taught in graduate-level classes on forestry and ecology. She was also a key inspiration for a central character in Richard Powers's 2019 Pulitzer Prize-winning novel, "The Overstory": the visionary botanist Patricia Westerford. In May, Knopf will publish Simard's own book, "Finding the Mother Tree," a vivid and compelling memoir of her lifelong quest to prove that "the forest was more than just a collection of trees."

Since Darwin, biologists have emphasized the perspective of the individual. They have stressed the perpetual contest among discrete species, the struggle of each organism to survive and reproduce within a given population and, underlying it all, the single-minded ambitions of selfish genes. Now and then, however, some scientists have advocated, sometimes controversially, for a greater focus on cooperation over self-interest and on the emergent properties of living systems rather than their units.

Suzanne Simard in Nelson, British Columbia, holding a Douglas fir seedling, right. She studies the way trees exchange carbon, water and nutrients through underground networks of fungus.

Before Simard and other ecologists revealed the extent and significance of mycorrhizal networks, foresters typically regarded trees as solitary individuals that competed for space and resources and were otherwise indifferent to one another. Simard and her peers have demonstrated that this framework is far too simplistic. An old-growth forest is neither an assemblage of stoic organisms tolerating one another's presence nor a merciless battle royale: It's a vast, ancient and intricate society. There is conflict in a forest, but there is also negotiation, reciprocity and perhaps even selflessness. The trees, understory plants, fungi and microbes in a forest are so thoroughly connected, communicative and codependent that some scientists have described them as superorganisms. Recent research suggests that mycorrhizal networks also perfuse prairies, grasslands, chaparral and Arctic tundra — essentially everywhere there is life on land. Together, these symbiotic partners knit Earth's soils into nearly contiguous living networks of unfathomable scale and complexity. "I was taught that you have a tree, and it's out there to find its own way," Simard told me. "It's not how a forest works, though."

In the summer of 2019, I met Simard in Nelson, a small mountain town not far from where she grew up in southern British Columbia. One morning we drove up a winding road to an old-growth forest and began to hike. The first thing I noticed was the aroma. The air was piquant and subtly sweet, like orange peel and cloves. Above our heads, great green plumes filtered the sunlight, which splashed generously onto the forest floor in some places and merely speckled it in others. Gnarled roots laced the trail beneath our feet, diving in and out of the soil like sea serpents. I was so preoccupied with my own experience of the forest that it did not even occur to me to consider how the forest might be experiencing us — until Simard brought it up.

"I think these trees are very perceptive," she said. "Very perceptive of who's growing around them. I'm really interested in whether they perceive us." I asked her to clarify what she meant. Simard explained that trees sense nearby plants and animals and alter their behavior accordingly: The gnashing mandibles of an insect might prompt the production of chemical defenses, for example. Some studies have even suggested that plant roots grow toward the sound of running water and that certain flowering plants sweeten their nectar when they detect a bee's wing beats. "Trees perceive lots of things," Simard said. "So why not us, too?"

I considered the possibility. We'd been walking through this forest for more than an hour. Our sweat glands had been wafting pungent chemical compounds. Our voices and footsteps were sending pressure waves through the air and soil. Our bodies brushed against trunks and displaced branches. Suddenly it seemed entirely plausible that the trees had noticed our presence.

A little farther along the trail, we found a sunny alcove where we stopped to rest and chat, laying our backpacks against a log plush with moss and lichen. A multitude of tiny plants sprouted from the log's green fleece. I asked Simard what they were. She bent her head for a closer look, tucking her frizzy blond hair behind her ears, and called out what she saw: queen's cup, a kind of lily; five-leaved bramble, a type of wild raspberry; and both cedar and hemlock seedlings. As she examined the log, part of it collapsed, revealing the decaying interior. Simard dug deeper with her thumbs, exposing a web of rubbery, mustard-yellow filaments embedded in the wood.

"That's a fungus!" she said. "That is Piloderma. It's a very common mycorrhizal fungus" — one she had encountered and studied many times before in circumstances exactly like these. "This mycorrhizal network is actually linked up to that tree." She gestured toward a nearby hemlock that stood at least a hundred feet tall. "That tree is feeding these seedlings."

The trees, plants, funghi and microbes in forests are so thoroughly connected some scientists describe them as superorganisms. Mycorrhizas in the soil, right, provide the network.

In some of her earliest and most famous experiments, Simard planted mixed groups of young Douglas fir and paper birch trees in forest plots and covered the trees with individual plastic bags. In each plot, she injected the bags surrounding one tree species with radioactive carbon dioxide and the bags covering the other species with a stable carbon isotope — a variant of carbon with an unusual number of neutrons. The trees absorbed the unique forms of carbon through their leaves. Later, she pulverized the trees and analyzed their chemistry to see if any carbon had passed from species to species underground. It had. In the summer, when the smaller Douglas fir trees were generally shaded, carbon mostly flowed from birch to fir. In the fall, when evergreen Douglas fir was still growing and deciduous birch was losing its leaves, the net flow reversed. As her earlier observations of failing Douglas fir had suggested, the two species appeared to depend on each other. No one had ever traced such a dynamic exchange of resources through mycorrhizal networks in the wild. In 1997, part of Simard's thesis was published in the prestigious scientific journal Nature — a rare feat for someone so green. Nature featured her research on its cover with the title "The Wood-Wide Web," a moniker that eventually proliferated through the pages of published studies and popular science writing alike.

In 2002, Simard secured her current professorship at the University of British Columbia, where she continued to study interactions among trees, understory plants and fungi. In collaboration with students and colleagues around the world, she made a series of remarkable discoveries. Mycorrhizal networks were abundant in North America's forests. Most trees were generalists, forming symbioses with dozens to hundreds of fungal species. In one study of six Douglas fir stands measuring about 10,000 square feet each, almost all the trees were connected underground by no more than three degrees of separation; one especially large and old tree was linked to 47 other trees and projected to be connected to at least 250 more; and seedlings that had full access to the fungal network were 26 percent more likely to survive than those that did not.

Depending on the species involved, mycorrhizas supplied trees and other plants with up to 40 percent of the nitrogen they received from the environment and as much as 50 percent of the water they needed to survive. Below ground, trees traded between 10 and 40 percent of the carbon stored in their roots. When Douglas fir seedlings were stripped of their leaves and thus likely to die, they transferred stress signals and a substantial sum of carbon to nearby ponderosa pine, which subsequently accelerated their production of defensive enzymes. Simard also found that denuding a harvested forest of all trees, ferns, herbs and shrubs — a common forestry practice — did not always improve the survival and growth of newly planted trees. In some cases, it was harmful.

When Simard started publishing her provocative studies, some of her peers loudly disapproved. They questioned her novel methodology and disputed her conclusions. Many were perplexed as to why trees of different species would help one another at their own expense — an extraordinary level of altruism that seemed to contradict the core tenets of Darwinian evolution. Soon, most references to her studies were immediately followed by citations of published rebuttals. "A shadow was growing over my work," Simard writes in her book. By searching for hints of interdependence in the forest floor, she had inadvertently provoked one of the oldest and most intense debates in biology: Is cooperation as central to evolution as competition?

Simard is studying whether preserving some older trees in plots that are logged will improve the health of future saplings. Here, 60 percent of veteran trees in the foreground have been retained, while behind them a vast majority have been cut.

The question of whether plants possess some form of sentience or agency has a long and fraught history.

Although plants are obviously alive, they are rooted to the earth and mute, and they rarely move on a relatable time scale; they seem more like passive aspects of the environment than agents within it. Western culture, in particular, often consigns plants to a liminal space between object and organism. It is precisely this ambiguity that makes the possibility of plant intelligence and society so intriguing — and so contentious.

In a 1973 book titled “The Secret Life of Plants,” the journalists Peter Tompkins and Christopher Bird claimed that plants had souls, emotions and musical preferences, that they felt pain and psychically absorbed the thoughts of other creatures and that they could track the movement of the planets and predict earthquakes. To make their case, the authors indiscriminately mixed genuine scientific findings with the observations and supposed studies of quacks and mystics. Many scientists lambasted the book as nonsense. Nevertheless, it became a New York Times best seller and inspired cartoons in The New Yorker and Doonesbury. Ever since, botanists have been especially wary of anyone whose claims about plant behavior and communication verge too close to the pseudoscientific.

In most of her published studies, Simard, who considered becoming a writer before she discovered forestry, is careful to use conservative language, but when addressing the public, she embraces metaphor and reverie in a way that makes some scientists uncomfortable. In a TED Talk Simard gave in 2016, she describes “a world of infinite biological pathways,” species that are “interdependent like yin and yang” and veteran trees that “send messages of wisdom on to the next generation of seedlings.” She calls the oldest, largest and most interconnected trees in a forest “mother trees” — a phrase meant to evoke their capacity to nurture those around them, even when they aren’t literally their parents. In her book, she compares mycorrhizal networks to the human brain. And she has spoken openly of her spiritual connection to forests.

Some of the scientists I interviewed worry that Simard’s studies do not fully substantiate her boldest claims and that the popular writing related to her work sometimes misrepresents the true nature of plants and forests. For example, in his international best seller, “The Hidden Life of Trees,” the forester Peter Wohlleben writes that trees optimally divide nutrients and water among themselves, that they probably enjoy the feeling of fungi merging with their roots and that they even possess “maternal instincts.”

“There is value in getting the public excited about all of the amazing mechanisms by which forest ecosystems might be functioning, but sometimes the speculation goes too far,” Hoeksema said. “I think it will be really interesting to see how much experimental evidence emerges to support some of the big ideas we have been getting excited about.” At this point other researchers have replicated most of Simard’s major findings. It’s now well accepted that resources travel among trees and other plants connected by mycorrhizal networks. Most ecologists also agree that the amount of carbon exchanged among trees is sufficient to benefit seedlings, as well as older trees that are injured, entirely shaded or severely stressed, but researchers still debate whether shuttled carbon makes a meaningful difference to healthy adult trees. On a more fundamental level, it remains unclear exactly why resources are exchanged among trees in the first place, especially when those trees are not closely related.

In their autobiographies, Charles Darwin and Alfred Russel Wallace each credited Thomas Malthus as a key inspiration for their independent formulations of evolution by natural selection. Malthus’s 1798 essay on population helped the naturalists understand that all living creatures were locked into a ceaseless contest for limited natural resources. Darwin was also influenced by Adam Smith, who believed that societal order and efficiency could emerge from competition among inherently selfish individuals in a free market. Similarly, the planet’s dazzling diversity of species and their intricate relationships, Darwin would show, emerged from inevitable processes of competition and selection, rather than divine craftsmanship. “Darwin’s theory of evolution by natural selection is obviously 19th-century capitalism writ large,” wrote the evolutionary biologist Richard Lewontin.

As Darwin well knew, however, ruthless competition was not the only way that organisms interacted. Ants and bees died to protect their colonies. Vampire bats regurgitated blood to prevent one another from starving. Vervet monkeys and prairie dogs cried out to warn their peers of predators, even when doing so put them at risk. At one point Darwin worried that such selflessness would be “fatal” to his theory. In subsequent centuries, as evolutionary biology and genetics matured, scientists converged on a resolution to this paradox: Behavior that appeared to be altruistic was often just another manifestation of selfish genes — a phenomenon known as kin selection. Members of tight-knit social groups typically share large portions of their DNA, so when one individual sacrifices for another, it is still indirectly spreading its own genes.

Kin selection cannot account for the apparent interspecies selflessness of trees, however — a practice that verges on socialism. Some scientists have proposed a familiar alternative explanation: Perhaps what appears to be generosity among trees is actually selfish manipulation by fungi. Descriptions of Simard’s work sometimes give the impression that mycorrhizal networks are inert conduits that exist primarily for the mutual benefit of trees, but the thousands of species of fungi that link trees are living creatures with their own drives and needs. If a plant relinquishes carbon to fungi on its roots, why would those fungi passively transmit the carbon to another plant rather than using it for their own purposes? Maybe they don’t. Perhaps the fungi exert some control: What looks like one tree donating food to another may be a result of fungi redistributing accumulated resources to promote themselves and their favorite partners.

“Where some scientists see a big cooperative collective, I see reciprocal exploitation,” said Toby Kiers, a professor of evolutionary biology at Vrije Universiteit Amsterdam. “Both parties may benefit, but they also constantly struggle to maximize their individual payoff.” Kiers is one of several scientists whose recent studies have found that plants and symbiotic fungi reward and punish each other with what are essentially trade deals and embargoes, and that mycorrhizal networks can increase conflict among plants. In some experiments, fungi have withheld nutrients from stingy plants and strategically diverted phosphorous to resource-poor areas where they can demand high fees from desperate plants.

Several of the ecologists I interviewed agreed that regardless of why and how resources and chemical signals move among the various members of a forest’s symbiotic webs, the result is still the same: What one tree produces can feed, inform or rejuvenate another. Such reciprocity does not necessitate universal harmony, but it does undermine the dogma of individualism and temper the view of competition as the primary engine of evolution.

The most radical interpretation of Simard’s findings is that a forest behaves “as though it’s a single organism,” as she says in her TED Talk. Some researchers have proposed that cooperation within or among species can evolve if it helps one population outcompete another — an altruistic forest community outlasting a selfish one, for example. The theory remains unpopular with most biologists, who regard natural selection above the level of the individual to be evolutionarily unstable and exceedingly rare. Recently, however, inspired by research on microbiomes, some scientists have argued that the traditional concept of an individual organism needs rethinking and that multicellular creatures and their symbiotic microbes should be regarded as cohesive units of natural selection. Even if the same exact set of microbial associates is not passed vertically from generation to generation, the functional relationships between an animal or plant species and its entourage of microorganisms persist — much like the mycorrhizal networks in an old-growth forest. Humans are not the only species that inherits the infrastructure of past communities.

The emerging understanding of trees as social creatures has urgent implications for how we manage forests.

Humans have relied on forests for food, medicine and building materials for many thousands of years. Forests have likewise provided sustenance and shelter for countless species over the eons. But they are important for more profound reasons too. Forests function as some of the planet's vital organs. The colonization of land by plants between 425 and 600 million years ago, and the eventual spread of forests, helped create a breathable atmosphere with the high level of oxygen we continue to enjoy today. Forests suffuse the air with water vapor, fungal spores and chemical compounds that seed clouds, cooling Earth by reflecting sunlight and providing much-needed precipitation to inland areas that might otherwise dry out. Researchers estimate that, collectively, forests store somewhere between 400 and 1,200 gigatons of carbon, potentially exceeding the atmospheric pool.

Crucially, a majority of this carbon resides in forest soils, anchored by networks of symbiotic roots, fungi and microbes. Each year, the world's forests capture more than 24 percent of global carbon emissions, but deforestation — by destroying and removing trees that would otherwise continue storing carbon — can substantially diminish that effect. When a mature forest is burned or clear-cut, the planet loses an invaluable ecosystem and one of its most effective systems of climate regulation. The razing of an old-growth forest is not just the destruction of magnificent individual trees — it's the collapse of an ancient republic whose interspecies covenant of reciprocation and compromise is essential for the survival of Earth as we've known it.

One bright morning, Simard and I climbed into her truck and drove up a forested mountain to a clearing that had been repeatedly logged. A large tract of bare soil surrounded us, punctuated by tree stumps, saplings and mounds of woody detritus. I asked Simard how old the trees that once stood here might have been. "We can actually figure that out," she said, stooping beside a cleanly cut Douglas fir stump. She began to count growth rings, explaining how the relative thickness reflected changing environmental conditions. A few minutes later, she reached the outermost rings: "102, 103, 104!" She added a few years to account for very early growth. This particular Douglas fir was most likely alive in 1912, the same year that the Titanic sank, Oreos debuted and the mayor of Tokyo gave Washington 3,020 ornamental cherry trees.

Looking at the mountains across the valley, we could see evidence of clearcutting throughout the past century. Dirt roads snaked up and down the incline. Some parts of the slopes were thickly furred with conifers. Others were treeless meadows, sparse shrubland or naked soil strewn with the remnants of sun-bleached trunks and branches. Viewed as a whole, the haphazardly sheared landscape called to mind a dog with mange.

When Europeans arrived on America's shores in the 1600s, forests covered one billion acres of the future United States — close to half the total land area. Between 1850 and 1900, U.S. timber production surged to more than 35 billion board feet from five billion. By 1907, nearly a third of the original expanse of forest — more than 260 million acres — was gone. Exploitative practices likewise ravaged Canada's forests throughout the 19th century. As growing cities drew people away from rural and agricultural areas, and lumber companies were forced to replant regions they had logged, trees began to reclaim their former habitats. As of 2012, the United States had more than 760 million forested acres. The age, health and composition of America's forests have changed significantly, however. Although forests now cover 80 percent of the Northeast, for example, less than 1 percent of its old-growth forest remains intact.

And though clearcutting is not as common as it once was, it is still practiced on about 40 percent of logged acres in the United States and 80 percent of them in Canada. In a thriving forest, a lush understory captures huge amounts of rainwater, and dense root networks enrich and stabilize the soil. Clearcutting removes these living sponges and disturbs the forest floor, increasing the chances of landslides and floods, stripping the soil of nutrients and potentially releasing stored carbon to the atmosphere. When sediment falls into nearby rivers and streams, it can kill fish and other aquatic creatures and pollute sources of drinking water. The abrupt felling of so many trees also harms and evicts countless species of birds, mammals, reptiles and insects.

Simard's research suggests there is an even more fundamental reason not to deprive a logging site of every single tree. The day after viewing the clear-cuts, we took a cable ferry across Kootenay Lake and drove into the Harrop-Procter Community Forest: nearly 28,000 acres of mountainous terrain populated with Douglas fir, larch, cedar and hemlock. In the early 1900s, much of the forest near the lake was burned to make way for settlements, roads and mining operations. Today the land is managed by a local co-op that practices ecologically informed forestry.

The road up the mountain was rough, dusty and littered with obstacles. "Hold on to your nips and your nuts!" Simard said as she maneuvered her truck out of a ditch and over a series of large branches that jostled us in our seats. Eventually she parked beside a steep slope, climbed out of the driver's seat and began to skitter her way across a seemingly endless jumble of pine needles, stumps and splintered trunks. Simard was so quick and nimble that I had trouble keeping up until we traversed the bulk of the debris and entered a clearing. Most of the ground was barren and brown. Here and there, however, the mast of a century-old Douglas fir rose 150 feet into the air and unfurled its green banners. A line of blue paint ringed the trunk of every tree still standing. Simard explained that at her behest, Erik Leslie, the Harrop-Procter Forest Manager, marked the oldest, largest and healthiest trees on this site for preservation before it was logged.

When a seed germinates in an old-growth forest, it immediately taps into an extensive underground community of interspecies partnerships. Uniform plantations of young trees planted after a clear-cut are bereft of ancient roots and their symbiotic fungi. The trees in these surrogate forests are much more vulnerable to disease and death because, despite one another's company, they have been orphaned. Simard thinks that retaining some mother trees, which have the most robust and diverse mycorrhizal networks, will substantially improve the health and survival of future seedlings — both those planted by foresters and those that germinate on their own.

For the last several years, Simard has been working with scientists, North American timber companies and several of the First Nations to test this idea. She calls the ongoing experiment the Mother Tree Project. In 27 stands spread across nine different climatic regions in British Columbia, Simard and her collaborators have been comparing traditional clear-cuts with harvested areas that preserve varying ratios of veteran trees: 60 percent, 30 percent or as low as 10 percent — only around eight trees per acre. She directed my attention across Kootenay Lake to the opposing mountains, where there were several more experimental plots. Although they were sparsely vegetated, there was an order to the depilation. It looked as though a giant had meticulously plucked out particular trees one by one.

Since at least the late 1800s, North American foresters have devised and tested dozens of alternatives to standard clearcutting: strip cutting (removing only narrow bands of trees), shelterwood cutting (a multistage process that allows desirable seedlings to establish before most overstory trees are harvested) and the seed-tree method (leaving behind some adult trees to provide future seed), to name a few. These approaches are used throughout Canada and the United States for a variety of ecological reasons, often for the sake of wildlife, but mycorrhizal networks have rarely if ever factored into the reasoning.

Sm'hayetsk Teresa Ryan, a forest ecologist of Tsimshian heritage who completed her graduate studies with Simard, explained that research on mycorrhizal networks, and the forestry practices that follow from it, mirror aboriginal insights and traditions — knowledge that European settlers often dismissed or ignored. "Everything is connected, absolutely everything," she said. "There are many aboriginal groups that will tell you stories about how all the species in the forests are connected, and many will talk about below-ground networks."

Ryan told me about the 230,000-acre Menominee Forest in northeastern Wisconsin, which has been sustainably harvested for more than 150 years. Sustainability, the Menominee believe, means "thinking in terms of whole systems, with all their interconnections, consequences and feedback loops." They maintain a large, old and diverse growing stock, prioritizing the removal of low-quality and ailing trees over more vigorous ones and allowing trees to age 200 years or more — so they become what Simard might call grandmothers. Ecology, not economics, guides the management of the Menominee Forest, but it is still highly profitable. Since 1854, more than 2.3 billion board feet have been harvested — nearly twice the volume of the entire forest — yet there is now more standing timber than when logging began. "To many, our forest may seem pristine and untouched," the Menominee wrote in one report. "In reality, it is one of the most intensively managed tracts of forest in the Lake States."

On a mid-June afternoon, Simard and I drove 20 minutes outside Nelson to a bowl-shaped valley beneath the Selkirk Mountains, which houses an active ski resort in winter. We met one of her students and his friend, assembled some supplies — shovels, water bottles, bear spray — and started hiking up the scrubby slope toward a population of subalpine conifers. The goal was to characterize mycorrhizas on the roots of whitebark pine, an endangered species that feeds and houses numerous creatures, including grizzly bears, Clark's nutcracker and Douglas squirrels.

About an hour into our hike, we found one: small and bright-leaved with an ashen trunk. Simard and her assistants knelt by its base and began using shovels and knives to expose its roots. The work was slow, tiring and messy. Mosquitoes and gnats relentlessly swarmed our limbs and necks. I craned over their shoulders, trying to get a better look, but for a long time there was not much to see. As the work progressed, however, the roots became darker, finer and more fragile. Suddenly Simard uncovered a gossamer web of tiny white threads embedded in the soil.

“Ho!” she cried out, grinning broadly. “It’s a [expletive] gold mine! Holy [expletive]!” It was the most excited I’d seen her the whole trip. “Sorry, I shouldn’t swear,” she added in a whisper. “Professors are not supposed to swear.”

“Is that a mycorrhiza?” I asked.

“It’s a mycorrhizal network!” she answered, laughing with delight. “So cool, heh? Here’s a mycorrhizal tip for sure.”

She handed me a thin strip of root the length of a pencil from which sprouted numerous rootlets still woolly with dirt. The rootlets branched into even thinner filaments. As I strained to see the fine details, I realized that the very tips of the smallest fibers looked as though they’d been capped with bits of wax. Those gummy white nodules, Simard explained, were mycorrhizal fungi that had colonized the pine’s roots. They were the hubs from which root and fungus cast their intertwined cables through the soil, opening channels for trade and communication, linking individual trees into federations. This was the very fabric of the forest — the foundation of some of the most populous and complex societies on Earth.

Trees have always been symbols of connection. In Mesoamerican mythology, an immense tree grows at the center of the universe, stretching its roots into the underworld and cradling earth and heaven in its trunk and branches. Norse cosmology features a similar tree called Yggdrasil. A popular Japanese Noh drama tells of wedded pines that are eternally bonded despite being separated by a great distance. Even before Darwin, naturalists used treelike diagrams to represent the lineages of different species. Yet for most of recorded history, living trees kept an astonishing secret: Their celebrated connectivity was more than metaphor — it had a material reality. As I knelt beneath that whitebark pine, staring at its root tips, it occurred to me that my whole life I had never really understood what a tree was. At best I’d been aware of just one half of a creature that appeared to be self-contained but was in fact legion — a chimera of bewildering proportions.

We, too, are composite creatures.

Diverse microbial communities inhabit our bodies, modulating our immune systems and helping us digest certain foods. The energy-producing organelles in our cells known as mitochondria were once free-swimming bacteria that were subsumed early in the evolution of multicellular life. Through a process called horizontal gene transfer, fungi, plants and animals — including humans — have continuously exchanged DNA with bacteria and viruses. From its skin, fur or bark right down to its genome, any multicellular creature is an amalgam of other life-forms. Wherever living things emerge, they find one another, mingle and meld.

Five hundred million years ago, as both plants and fungi continued oozing out of the sea and onto land, they encountered wide expanses of barren rock and impoverished soil. Plants could spin sunlight into sugar for energy, but they had trouble extracting mineral nutrients from the earth. Fungi were in the opposite predicament. Had they remained separate, their early attempts at colonization might have faltered or failed. Instead, these two castaways — members of entirely different kingdoms of life — formed an intimate partnership. Together they spread across the continents, transformed rock into rich soil and filled the atmosphere with oxygen.

Eventually, different types of plants and fungi evolved more specialized symbioses. Forests expanded and diversified, both above- and below ground. What one tree produced was no longer confined to itself and its symbiotic partners. Shuttled through buried networks of root and fungus, the water, food and information in a forest began traveling greater distances and in more complex patterns than ever before. Over the eons, through the compounded effects of symbiosis and coevolution, forests developed a kind of circulatory system. Trees and fungi were once small, unacquainted ocean expats, still slick with seawater, searching for new opportunities. Together, they became a collective life form of unprecedented might and magnanimity.

After a few hours of digging up roots and collecting samples, we began to hike back down the valley. In the distance, the granite peaks of the Selkirks bristled with clusters of conifers. A breeze flung the scent of pine toward us. To our right, a furtive squirrel buried something in the dirt and dashed off. Like a seed waiting for the right conditions, a passage from “The Overstory” suddenly sprouted in my consciousness: “There are no individuals. There aren’t even separate species. Everything in the forest is the forest.”

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