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PASSING THE WAND

Hannah slapped a mosquito the size of a B-52 bomber against her neck. As she stepped over the frayed plastic fringe encircling the roots of the Douglas-fir sapling, I said, "Touch her bark first, sweetie pie, to show your respect." She placed her hands on the young fir's smooth surface, then wrapped measuring tape around the trunk and called out the diameter—"Eight centimeters!"—the girth of a softball. Then she shouted "two"—code for "a wanting condition," yellowish needles a sign of root disease. Jean jotted the numbers on the data sheet. My niece Kelly Rose pointed the pocket-sized laser hypsometer at the roots and then at the terminal bud. "Seven meters tall," she called out. Nava and I were measuring a birch neighbor half the size of the fir, her base decorated with honey mushrooms.

We had returned to Adams Lake, one of the original sites where in 1993 I'd dug the grid of meter-deep trenches between fir and birch and wrapped plastic around the individual cylinders of roots to sever the mycorrhizal network that connected the trees. Twenty-one years later, in July 2014, we could see that the trees cut off from one another were suffering, their immune systems weak, their vitality bridled. Only thirty meters away was the thrifty control where I'd left the hyphal linkages intact.

It had been just over a year since I'd finished chemo, and Jean and I had brought Nava, Hannah, and Kelly Rose, fourteen, sixteen, and eighteen years old, to learn the ways of the forest and to see if the ecosystem really was a place where all were connected as one, the spe-

cies wholly interdependent as my research had been showing me for decades, wisdom long held by Aboriginal peoples the world over. This was my chance to show all this to my girls while we spent a summer's day in the bush.

"Here, put on these bug nets," said Jean. She took green beekeeper hats from her work vest and showed the girls how to pull them over their twisted-up ponytails. "These are great," Kelly Rose said, her relief instant.

The site contained some of my oldest experiments. We finished measuring the fifty-nine trees in the trenched plot before moving into the untrenched control area, the understory lush with thimbleberry and huckleberry bushes. "At least it's cool under this birch," Nava said. She had shot up to five foot seven, as tall as Robyn, towering over Hannah and Kelly Rose, who'd settled in at the height of Grannie Winnie, five feet one and a half inches. All three girls had Grannie Winnie's quiet toughness—getting on with the job, not making much fuss, quick to laugh, kind and gentle, watching over one another. Not batting an eye at climbing a tree, swinging from a branch, grabbing the highest apple, landing on their feet, making an apple pie. Nava peeled a strand of the paper-thin bark and measured the tree's girth. "What made these?" she asked, pointing to tiny holes drilled in six perfect rows around the circumference.

"Sapsuckers," I said. "They peck into the bark to drink the sap and feed on the insects." Nava swerved as a real-live snitch vibrated toward her red vest, chirping *chu-chu-chu.* "Oh," I said, laughing, "hummingbirds like it too." The rufous jewel darted to a nest made with seed wings and spiderwebs, four tiny beaks stretching open. The next birch had been bent over by a moose who'd munched its tender shoots. On the banks of the Adams River, half a kilometer east, where the birches were thirty meters tall, the elk and deer and snowshoe hares ate the branches and buds too, and beavers built lodges with the waterproof stems, and grouse nested in the leaves, and sapsuckers and woodpeckers carved out cavities, later used by owls and hawks. The roots of these distinguished birches drank the water of the glacial-fed river, the water turning red with spawning salmon in the fall.

I'd been wondering if the birches were also nourished by the fish carcasses seeping back into the riverbanks.

Within a few hours, we discovered that the birch trees whose roots ran freely and connected with the firs were almost twice the size of those in the trenched plots, and they were free of disease. Compared to the birches we'd thinned alongside the creek nearby two decades ago, these were smaller, but they were healthy, the papery bark thick, lenticels (eyelets) compact, branches few, valuable for making baskets. The bigger birches were especially the kind that Mary Thomas, an elder of the Secwepemc Nation, said would be good for harvesting bark. Mary Thomas's grandmother Macrit showed her how to peel the bark so as not to hurt the tree, as her grandmother had shown her, and as Mary would show her own grandchildren. Teaching them how to leave the pulpy cambium intact so it would be primed to heal over, to ensure the tree seeded new generations. They used the bark to make baskets of all sizes, some for thimbleberries, cranberries, and strawberries. The impermeable bark of the bigger birches down by the river would be perfect for canoes, the luxuriant leaves for soap and shampoo, the sap for tonics and medicines, the best wood for bowls and toboggans. With care—planted in rich soil, with good neighbors, in proper numbers, and with roots unrestrained—even these upland birches could become prominent providers in the forest.

Woven among the birches, the firs were also a little bigger than where we'd trenched between them, and they were in prime condition. In the early years, the mycorrhizal connections with birch had helped the fir saplings grow taller, and in adulthood, this head start still mattered. Two decades later, firs performed better in the neighborhood of birches than where they'd been cut off from their neighbors or where they'd grown only among other firs. They had better nutrition—the rich birch leaves building the soil—and less *Armillaria* root disease, the bacteria along the birch roots providing a bundle of nitrogen and immunity with a potent mix of antibiotics and other inhibitory compounds. Grown intimately together, this forest had almost twice the productivity of the stands where we'd trenched between the species two decades earlier. This was the opposite of the usual foresters' expectations. They figured that fir roots free of birch interference would obtain more of the resource pie, as though the ecosystem worked as a zero-sum game—the adamant belief that greater total productivity cannot possibly emerge from species interactions.

Even more surprising to me was that birch benefited from fir too. Not only did birches likewise grow at twice the rate when intimately connected with firs than when alone, but they also had fewer root infections. The birches that had delivered food and good health to the firs when they were young were now being helped in reciprocity by the bigger firs as adults. Although the birches were retreating as the firs grew skyward, as happens naturally with the aging of these forests, their roots were still deep in the soil, their legacy of fungi and bacteria intact, lifeblood painted indelibly into the canvas. At the next major disturbance—a fire or an insect outbreak or a pathogenic infection—the roots and stumps would sprout again, bringing a new generation of birches, as much a part of the cycle as fir.

We sat under a sprawling birch for lunch. Salmon sandwiches we'd made at our campsite, and berries picked along the way, and cookies bought at the Vavenby General Store. Kelly Rose ate the blood-red thimbleberries one by one, as if selecting chocolates from a box. "Why are the plants so sweet under the birches, Auntie Suzie?" she asked.

Their roots and fungi draw water from deep in the soil, I told her, and with it bring calcium, magnesium, and other minerals, and this feeds the leaves so they can make sugars. The birches, with their cables of fungi, knit the other trees and plants together, and through their web share the nutritious soup drawn from the soil and also the sugars and proteins made by their leaves. "In the fall, when the birch leaves drop, they nourish the soil in return," I said.

Mary Thomas's mother and grandmother Macrit had taught her to show gratitude for the birches, to take no more than she needed, to place an offering in thanks. Mary Thomas had even called the birches Mother Trees—long before I had stumbled onto that notion. Mary's people had known this of the birches for thousands of years, from living in the forest—their precious home—and learning from all living things, respecting them as equal partners. The word "equal" is where Western philosophy stumbles. It maintains that we are superior, having dominion over all that is nature.

"Remember how I said the birches and firs talk to each other underground through a fungal web?" I asked the girls, putting my hand to my ear and my finger to my lips. The girls listened, their ears filled with mosquito songs. I told them I wasn't the first person to figure

this out, that this was also the ancient wisdom of many Aboriginal people. The late Bruce "Subiyay" Miller of the Skokomish Nation, whose people live on the eastern Olympic Peninsula of Washington State, had told a story about the symbiotic nature and diversity of the forest, mentioning that under its floor "there is an intricate and vast system of roots and fungi that keeps the forest strong."

"This pancake mushroom is the fruit of the underground network," I said, handing an earthy bolete to Kelly Rose, who inspected its tiny pores and asked why it was taking so long for everyone to understand this.

I had been given a glimpse of these ideals—almost as a stroke of luck—through the rigid lens of western science. I'd been taught in the university to take apart the ecosystem, to reduce it into its parts, to study the trees and plants and soils in isolation, so that I could look at the forest *objectively.* This dissection, this control and categorization and cauterization, were supposed to bring clarity, credibility, and validation to any findings. When I followed these steps of taking the system apart to look at the pieces, I was able to publish my results, and I soon learned that it was almost impossible for a study of the diversity and connectivity of a whole ecosystem to get into print. *There's no control!* the reviewers cried at my early papers. Somehow with my Latin squares and factorial designs, my isotopes and mass spectrometers and scintillation counters, and my training to consider only sharp lines of statistically significant differences, I have come full circle to stumble onto some of the indigenous ideals: Diversity matters. And everything in the universe *is* connected—between the forests and prairies, the land and the water, the sky and the soil, the spirits and the living, the people and all other creatures.

We walked in the drizzle to where I'd planted conifers at different densities, to see how they liked growing in pure stands with few neighbors, or many. I knew every tree, every plot, every corner post. I knew where the larch was planted and the cedar. The fir and the birch. I showed the girls how this fir was planted too deep, that birch had been broken by a moose, this larch got pushed sideways by a black bear. I'd planted another spot every year for five years, but a tree would never take, and now it was a beautiful patch of lilies, what it was meant to be. In the mixed plots, cedars were luxuriant under

birches, needing their cover to protect the pigments in their delicate leaves. When I stopped chattering and looked up, Jean and the girls were grinning.

We settled into measuring the Douglas firs planted at different densities. Without birch neighbors, up to 20 percent had become infected by *Armillaria* disease, more where the firs were tightly clustered. Their roots had grown into infection pockets in the soil, and the pathogens had spread under their bark, strangling the phloem, no birch roots to stop them. Some of the infected firs were still alive—needles yellowing—and others were long dead, their bark gray and flaking. In their place, other plants grew, and even some birches had seeded in, inviting the warblers and bears and squirrels. Some mortality wasn't a bad thing. It made room for diversity, regeneration, complexity. It kept the bugs down and created firebreaks. A lot of death, though, could cause a cascade of changes, rippling through the landscape, upsetting the balance.

Jean showed the girls how to start the bit of the increment corer in the bark of a fir. "If the corer doesn't take, don't try more than twice, so you don't injure her," Jean told them. Kelly Rose asked if she could try. Within minutes, she hit the pith—bull's-eye—and Jean inserted the core sample into a red straw, sealed the ends with masking tape, and labeled it.

In the high-density plots—where the planted firs were only a few meters apart—the understory was dark. The floor looked bare except for rusty needles, their acidity slowing down the cycling of nutrients. Gray branches snapped off as we worked our way among the trees. I imagined the mycorrhizal network had taken on the pattern of the plantings, wiring trees together as if they were rows of telephone poles. It would become a little more complex as the bigger trees spread their limbs and roots, taking over the growing space where others had died.

Our shins scraped, we moved on to a plot where the firs were spaced farther apart, up to five meters, their girth a little more robust. Seed had dispersed into the openings between the plantings over the years, some probably their kin, others the descendants of those removed, still others from firs in the surrounding forest. Fertilized by pollen of neighbors, or by firs in other valleys, ensuring the population was resilient. Some of these new trees were toddlers, others kindergartners,

still others juniors, this patch of forest starting to look like a schoolhouse, with diversity and kinship. The mycorrhizal network, I imagined, was becoming more complex as the forest aged, the biggest trees becoming the hubs—the Mother Trees. Eventually it would look like the web we'd mapped a few years back in the old-growth Douglas-fir forest.

After the last tree was measured, we followed a moose trail down to the river where we'd parked the truck. The forest was slowly taking over my experiment, the replicates filled with surprises—a dozen tree species naturally seeding in from the timber edge, moose eating the planted birches, honey mushrooms infecting the trees, firs helping birches, young cedars huddling under the broadleaved trees for protection from the sun. This forest naturally knew how to rejuvenate itself when allowed a proper start, seeding into soils that were receptive, killing my planted trees where they didn't belong, patiently waiting for me to hear what it was saying. *This data will be difficult to publish,* I thought to myself. Nature itself had blurred the rigidity of my experiment, my original hypotheses about species composition and density no longer testable due to the ingress of new trees. But I had learned so much more by listening instead of imposing my will and demanding answers.

As we drove the switchbacks over the mountain, the girls asleep in the back, Jean sorting the data sheets, I reflected on my good fortune with what the forest had shared with me over the course of so many years. In my first experiment testing whether birch transmitted carbon to fir through mycorrhizas, I thought I'd be lucky to see anything, but then I detected a pulse strong enough to fuel the setting of seeds. I saw fir giving back to birch the energy it needed to build new leaves in the spring. And my posse of students confirmed the findings of reciprocity, not just between birch and fir but among all sorts of trees.

In making the mycorrhizal-network map, I thought we might see a few links.

Instead we found a tapestry.

With Yuan Yuan, I figured it would be a long shot if dying Douglas firs transmitted messages to ponderosa pines. But they did. Another of my students confirmed it in a second study, as did others in labs around the world. Then I considered it a gamble that Douglas-fir

Mother Trees would recognize their own kin, never mind that the signals might move through the mycorrhizal network—and *mon Dieu!* The firs recognized their relatives! The Mother Trees not only sent carbon to help support their mycorrhizal fungal symbionts, they somehow enhanced the health of their kin. And not only their kin, but of strangers too, and other species, promoting the diversity of the community. Was this all luck?

I think the trees had been telling me something all along.

I'd had a hunch those little yellow spruce seedlings back in 1980—the ones who'd sent me on this long journey of a lifetime—were suffering because their bare roots couldn't connect with the soil. Now I knew they lacked mycorrhizal fungi, whose hyphae would not only have extracted nutrients from the forest floor but also connected the seedlings to the Mother Trees, providing them with carbon and nitrogen until they could stand on their own. But their roots had been confined to their plugs, isolated from the old trees. The subalpine fir that had naturally regenerated on the outskirts of the Mother Trees, though, had been lush with sustenance.

But that lingering question since my illness still haunted me: If we are equal to everything in nature, do we share the same goals in death? To pass the wand as best we can. Passing onward to children the most crucial material. Unless the essential energy went *directly* to a Mother Tree's offspring, stem, needles, buds, and all—not just into the underground network—I couldn't be sure that the connection increased their fitness beyond that of the fungus.

Monika, a new doctoral student, had added another link in this chain of knowledge. In the fall of 2015, she started a greenhouse experiment with 180 pots. In each pot, she planted three seedlings: two kin and one stranger, with one of the kin seedlings designated as her "Mother Tree." The idea was that, once injured, the Mother Tree would have a choice of where to send the last of her energy: to her kin, the stranger, or into the earth. Monika grew the seedlings in mesh bags with variously sized pores to allow or inhibit mycorrhizal connections, and she injured some of the Mother-Tree seedlings with shears or western budworms. She then pulse labeled the Mother Trees with carbon-13 to trace where the carbon went.

As if to remind us of the capricious nature of nature, a heat wave knocked out the greenhouse's ceiling fans, killing part of the experiment. The greenhouse cat, a fat orange tabby, flicked his tail while Monika and I knelt near the rows, testing the dry-as-a-bone soil in pot after pot. Most of the seedlings were still alive. We were lucky. Even in greenhouse experiments, many environmental factors are under our control, but things still can go wrong. This pales in comparison to the myriad calamities that can happen in even the most well-conceived field experiment, especially over the decades it takes to examine long-term patterns. *No wonder most scientists conduct their research in a lab,* I thought to myself.

But we didn't ditch the experiment. Besides, Monika's kin seedlings were many times the size of Amanda's, and I was burning to know whether they were robust enough sinks to draw the carbon released by the injured Mother Trees into their shoots. Using the survivors, the day came when Monika and I were scrolling through graphs of data as if watching a movie. All of the factors we tested were significant—whether the seedlings were related to the Mother Trees, whether they were connected, or whether they were injured.

Monika's Mother-Tree seedlings transmitted more carbon to kin than strangers, as Brian and Amanda had found. But unlike the earlier study, where we'd only detected carbon moving into the mycorrhizal fungi of the kin seedlings, Monika now found that *it went straight into their long leaders.* The Mother-Tree seedlings flooded the mycorrhizal network with their carbon energy, and it advanced into the needles of her kin, her sustenance soon within them. *Et voilà!* The data also showed that injury, whether by western spruce budworm or the shears, induced the Mother-Tree seedlings to transfer *even more carbon* to her kin. Facing an uncertain future, she was passing her life force straight to her offspring, helping them to prepare for changes ahead.

Dying enabled the living; the aged fueled their young.

I imagined the flow of energy from the Mother Trees as powerful as the ocean tide, as strong as the sun's rays, as irrepressible as the wind in the mountains, as unstoppable as a mother protecting her child. I knew that power in myself even before I'd uncovered these forest conversations. I'd felt it in the energy of the maple in my yard, flowing into me as I contemplated Dr. Malpass's wisdom about embracing the mystery of life, sensing that magical, emergent phenomena when we

work together, the synergy that reductionist science so often misses, leading us to mistakenly simplify our societies and ecosystems.

The trees of the next generation with genes most adaptable to change—whose parents have been shaped by a variety of climatic conditions, those attuned to the stresses of their parent, with robust defense arsenals and shots of energy—ought to be the most successful in rebounding from whatever tumult lies ahead. The practical application—what this might mean for forest management—is that elders that survived climate changes in the past ought to be kept around because they can spread their seed into the disturbed areas and pass their genes and energy and resilience into the future. Not only a few elders, but a range of species, of many genotypes, kin and strangers, a natural mix to ensure the forest is varied and adaptive.

My wish is that we might think twice about salvage harvesting the dying Mother Trees, might be compelled to leave a portion behind to take care of the young, not merely their own but those of their neighbors too. In the wake of diebacks from droughts, beetles, budworms, and fires, the timber industry has been cutting vast swaths of forest, the clear-cuts coalescing over whole watersheds, entire valleys mowed down. The dead trees have been considered a fire risk, but more likely a convenient commodity. Great numbers of healthy neighbors have also been captured for the mills as collateral damage. This salvage clear-cutting has been amplifying carbon emissions, changing the seasonal hydrology in watersheds and in some cases causing streams to flood their banks. With few trees left, the sediments are flowing down rivulets and into rivers already warming with climate change, harming the salmon runs even further.

Giving a TED walk in Stanley Park at TED Vancouver, 2017

This brings me to another adventure, one I'm still exploring because it speaks so graphically to the species connections we overlook. Scientists before me have discovered that the nitrogen from decayed salmon lives in the rings of trees along the rivers from where they came. I wanted to know whether salmon nitrogen was absorbed by mycorrhizal fungi of the Mother Trees and transmitted through their networks to other trees deeper in the forest. Even more, were the salmon nutrients in the trees declining with the reduction in salmon populations and habitat loss, causing the forests to suffer? If so, could this be remedied?

MONTHS AFTER MONIKA'S EXPERIMENTS, I was at Bella Bella on the midcoast of British Columbia, in the salmon forests of the Heiltsuk people. Our skiff glided into a pristine inlet, and our Heiltsuk guide, Ron, pointed to ochre pictographs marking a clan territory. Silken Pacific mist poured down the vertical rock wall and over the monumental trees. With me were Allen Larocque, my new doctoral student who would investigate the patterns of the fungal networks, and postdoctoral fellow Dr. Teresa "Sm'hayetsk" Ryan of the Tsimshian Nation, the people of the Skeena River to the north. Teresa was a traditional cedar basket weaver as well as a salmon-fisheries scientist on the Canada-U.S. Pacific Salmon Commission, Joint Chinook Technical Committee, among the many hats she wore. She wanted to know, as an Aboriginal person and a scientist, whether restoring the traditional fishing practices using tidal stone-trap technology could reinvigorate the salmon populations, perhaps to levels seen before the colonists took control of the fishery. This in turn might nourish the cedars from which she gathered bark.

We were in search of the bones of salmon carried into the forest by bears and wolves and eagles. The bones were all that were left once the flesh was eaten and the residual tissue decayed, nutrients seeping into the forest floor. In this inlet, Dr. Tom Reimchen of the Univer-

sity of Victoria and Dr. John Reynolds of Simon Fraser University had discovered salmon nitrogen in rings of cedars and Sitka spruces, and in the plants, insects, and soils. Allen would start our study of how mycorrhizal fungi might transmit the salmon into the trees, and possibly between trees, by determining how the mycorrhizal fungal communities differed alongside streams with various salmon population sizes. Could a difference in the fungi, in their ability to transmit the salmon nutrients, help account for the great fertility of these rain forests? I could barely contain my excitement as Allen, Teresa, and I jumped into the sedges with our hip waders and headed to shore.

"Bear path," said Teresa, pointing at a trail. "They've been here recently."

"Let's keep going." I was like a dog pulling on its leash.

We easily followed the trail into the wall of salmonberry along the shore, where the prickly canes stood thick. After half an hour of crawling on hands and knees in the humus, Teresa suddenly said, "You guys are nuts. You're asking for trouble with these fresh bear signs." She headed back to the boat to wait with Ron.

I looked at Allen to gauge his comfort level, and he didn't seem nervous. "If I were a bear, I'd take my salmon to where I wouldn't be disturbed," I said, thrilled he was up for the adventure. We kept crawling along, through a tunnel carved in the salmonberries, toward a fifty-meter-tall cedar on a high bench, her leader forked in a candelabrum, what the Heiltsuk called a Grandmother Tree.

Each bear preying on the spawning salmon transported some 150 fish per day into the forest, where the roots of the trees foraged for the decaying protein and nutrients, the salmon flesh providing more than three-quarters of the tree's nitrogen needs. The nitrogen in tree rings derived from salmon was distinguishable from the soil's nitrogen because fish at sea get enriched with the heavy isotope nitrogen-15, which serves as a natural tracer of salmon abundance in the wood. Scientists could use the year-by-year variation in tree-ring nitrogen to find correlations between salmon populations and changing climate, deforestation, and shifting fisheries practices. An old cedar tree could hold a thousand-year record of salmon runs.

I shouted *Yoohoo!* as we approached the ledge of the Grandmother cedar, despite my call being muffled by a wall of salmonberry leaves. A

grizzly out here would mean a quick death. Still, I felt peaceful. After chemo, this was bliss. And I was much calmer than I'd recently been on the big TED stage in Banff, where cameras and a thousand people had tracked my every move. I'd stepped into the bright lights thanking my lucky stars that Mary had made me wear a black coat over my blue shirt, an old favorite, because she'd spotted its missing button. I delivered my talk as though the audience were a sea of nodding cabbages. *I did it,* I thought as I walked off the stage, pride in overcoming my shyness, to speak from my heart, to unfurl what I've learned so that people could take what they needed, flooding me. "I've always known this about trees deep down inside of me," a woman wrote from Chicago after seeing the video. Robert Krulwich of *Radiolab* contacted me to create a podcast. *National Geographic* wanted to write an article and make a film. I received thousands of emails and letters. Kids, mothers, fathers, artists, lawyers, shamans, composers, students. People from every corner of the world expressing their own connections with trees through their stories, poems, paintings, films, books, music, dances, symphonies, festivals. "We'd like to design our city in a way that mimics the patterns of mycorrhizal connection," wrote a city planner from Vancouver. The concept of the Mother Tree and her connections to those around her had even made it into Hollywood, as a central concept to the tree in the film *Avatar.* How the film resonated with people reminded me how naturally crucial it is for people to connect to mothers, fathers, children, family—our own and the families of others—and to trees and animals and all of the creatures of nature, as one.

I'd taken my message and gone out with it, and a bracing surge of responses came in return. People cared about the forest and wanted to help.

"What we're doing isn't working," a government forester wrote. Music to my ears. We discussed how to leave Mother Trees to help heal the land following a harvest. Not enough foresters have embraced this yet, but at least there is a small beginning.

Allen and I crept up and peered along the bench. *"Putain de merde!"* I shouted. "Look!" Under the boughs of the old Mother Tree was a cozy, mossy bed large enough for a mama bear and her cub. Dozens of white salmon skeletons gleamed from the carpet, the flesh long

decayed, the vertebrae unhinged, the fine corsets of bones folded like butterfly wings, the scales and gills asunder, the essence of the fish slowly absorbed by the roots, transmitted into the wood of the tree, passed to the next life.

Tree bones.

Allen and I collected soil from under the bones and, for comparison, from places where there were no bones. We returned to Teresa and Ron, jumping onto the boat from the high-tide line and storing the samples on ice to prevent the degradation of the microbial DNA. Ron puttered away from the shore and skimmed over the stone wall that followed the contour of the shoreline, from one edge of the estuary to the next. The wall was one of hundreds of tidal traps built along the Pacific coastline by the Heiltsuk people, similar to those built by the Nuu-Chah-Nulth, Kwakwaka'wakw, Tsimshian, Haida, and Tlingit Nations—to harvest salmon passively, keep track of the populations, and adjust harvests accordingly. They collected the fish trapped at low tide, releasing the biggest egg-bearing females to continue up the river to spawn. They smoked, dried, or cooked the fish, buried the guts in the forest floor, and returned the bones to the waters to nourish the ecosystem. This practice enhanced the salmon populations and the productivity of the forests, rivers, and estuaries. The forests, rich with salmon, returned the favor by shading the rivers, shedding nutrients into the waters, and providing habitat for the bears, wolves, and eagles.

Teresa explained that when the colonists took jurisdiction of the waters and forests, they forbade use of the stone traps. The salmon were overfished within the first two decades and have yet to recover fully. Climate change and a warming Pacific Ocean have created new problems by exhausting the fish on their marathon from the ocean, reducing their success at reaching the natal spawning streams. It's part of a general pattern of destroying interconnecting habitats. To the north on Haida Gwaii, the last of the cedars, some more than a thousand years old, are being clear-cut on Graham Island, leaving the forest along the spawning rivers degraded and the Haida wondering what will happen to their way of life.

When will this stop, this unraveling?

As we sped out of the inlet toward Bella Bella, Ron pointed star-

board to a humpback surfacing a few hundred meters away. From out of nowhere, dozens of white-sided dolphins joined our boat, arcing over the water, somersaulting and whistling to one another. I was so astonished, so uplifted, that I stood, Allen and Teresa too, as the salt water splashed over us.

This study is ongoing, but our early data show that the mycorrhizal fungal community in the salmon forest differs depending on the number of salmon returning to their natal streams. We still don't know how far into the forest the mycorrhizal network is transporting the salmon nitrogen, and if—or how—restoration of the tidal stone traps might affect forest health, but we are starting new research and reconstructing some of the stone walls to find answers. I've been wondering too if we should check whether salmon also nourish the mainland forests from rivers that run inland. Do spawning salmon feed the cedars and birches and spruces along the rivers that run thousands of kilometers into the mountains? Such as along the Adams River running below my experiment. Salmon in this way connecting the ocean with the continent. The Secwepemc people knew how vital salmon was to the interior forests, and to their livelihoods, and they'd cared for the populations according to far-reaching principles of interconnectedness.

THANKSGIVING THAT YEAR found me driving home past clear-cuts as chain saws were bringing down the beetle-infested Mother Trees before their seeds had germinated in the turned-up duff. Slash piles of elders stood as tall as apartment buildings, access roads criss-crossed the valleys, and creeks were clogged with sediment. Planted seedlings stood encased in white plastic tubes like crosses.

The cracks are in plain view.

I come from a family of loggers, and I am not unmindful that we need trees for our livelihoods. But my salmon trip showed that with taking something comes the obligation to give back. Of late I've become increasingly enchanted by the story told by Subiyay, who talks of the trees as *people.* Not only with a sort of intelligence—akin to us humans—or even a spiritual quality perhaps not unlike ours.

Not merely as equivalent to people, with the same bearings.

They *are* people.

The Tree People.

I don't presume to grasp Aboriginal knowledge fully. It comes from a way of knowing the earth—an epistemology—different from that of my own culture. It speaks of being attuned to the blooming of the bitterroot, the running of the salmon, the cycles of the moon. Of knowing that we are tied to the land—the trees and animals and soil and water—and to one another, and that we have a responsibility to care for these connections and resources, ensuring the sustainability of these ecosystems for future generations and to honor those who came before. Of treading lightly, taking only what gifts we need, and giving back. Of showing humility toward and tolerance for all we are connected to in this circle of life. But what my years in the forestry profession have also shown me is that too many decision-makers dismiss this way of viewing nature and rely only on select parts of science. The impact has become too devastating to ignore. We can compare the condition of the land where it has been torn apart, each resource treated in isolation from the rest, to where it has been cared for according to the Secwepemc principal of *kwseltktnews* (translated as "we are all related") or the Salish concept of *nɁcaʔmat ct* ("we are one").

We must heed the answers we're being given.

I believe this kind of transformative thinking is what will save us. It is a philosophy of treating the world's creatures, its gifts, as of equal importance to us. This begins by recognizing that trees and plants have agency. They perceive, relate, and communicate; they exercise various behaviors. They cooperate, make decisions, learn, and remember—qualities we normally ascribe to sentience, wisdom, intelligence. By noting how trees, animals, and even fungi—any and all nonhuman species—have this agency, we can acknowledge that they deserve as much regard as we accord ourselves. We can continue pushing our earth out of balance, with greenhouse gases accelerating each year, or we can regain balance by acknowledging that if we harm one species, one forest, one lake, this ripples through the entire complex web. Mistreatment of one species is mistreatment of all.

The rest of the planet has been waiting patiently for us to figure that out.

Making this transformation requires that humans reconnect with

Hannah, age twenty-one, working in the bush and eating huckleberries, July 2019

nature—the forests, the prairie, the oceans—instead of treating everything and everyone as objects for exploitation. It means expanding our modern ways, our epistemology and scientific methodologies, so that they complement, build on, and align with Aboriginal roots. Mowing down the forests and harvesting the waters to fulfill our wildest dreams of material wealth *just because we can* has caught up to us.

I crossed the Columbia River at Castlegar, only half an hour from home, anxious to see Hannah and Nava, grateful that Mary had made the trip north for the Canadian Thanksgiving. The river was low, the natural flow controlled by the Mica, Revelstoke, and Hugh Keenleyside Dams upstream—three of the sixty in the Columbia watershed. These dams meant the loss of salmon from the Arrow Lakes and the flooding of the villages, burial grounds, and trade routes of the Sinixt Nation, whose ancestral territory spans from the Monashee Mountains east to the Purcells and from the Columbia headwaters to Washington State. I wondered what this land looked like before the Canadian government declared the Sinixt Nation extinct, then dammed, clear-cut, and mined their landscape. The Sinixt people are resilient, though, continuing to uphold *whuplak'n*—the law of the land—joining together to help restore the Columbia watershed.

I arrived home, the moon high above snow-dusted mountains, where Mary and the whole family had converged. This Thanksgiving turned out particularly memorable because the tea-scented candles on the table tipped over, and flames licked around the turkey. I looked up from stirring the gravy as Don—his new girlfriend was off with her own kids—threw the pot of water for the brussels sprouts over the burning bird, and Robyn and Bill doused the napkins with their glasses of wine. Grannie Junebug carried her trifle past Oliver reading a Harry Potter book on the floor.

Family. In all its imperfection, and stumbles, and small fires. We were there for one another when it counted.

In spite of the clear-cuts, and my worries about work and climate change, and my health and my children, and everything else, including my precious trees, it was great, simply great, to be home, all of us together.

HANNAH FOLLOWED ME into the grove of hemlocks among the rockpiles below the black hole in the cliff—a portal leading to kilometers of tunnels blasted into the mountain a century ago by miners in search of copper and zinc. We dug a soil pit among the trees, some of the mineral grains green, others rust, our hands protected by surgical gloves, arms covered by long sleeves. Seepage from the portals was loaded with copper, lead, and other metals, and these had contaminated the forest floor. The metals combined with sulfides in the ore with the help of bacteria to form acid-rock drainage, which had leached from waste-rock piles deep into the soil. And yet trees were growing here, even if slowly, giving their all to fuel the recovery of the forest.

It was the summer of 2017. We were at the Britannia Mine—forty-five kilometers north of Vancouver on the shores of Howe Sound on the unceded territory of the Squamish Nation—the largest mine in the British Empire, opened in 1904 to extract the ore bodies that had formed when volcanic pyroclast flowed onto sedimentary rock and the metamorphosed result came into contact with plutonic intrusions. The miners had quarried the faults and fractures where the rich ore lay, boring right through Britannia Mountain, from Britannia Creek

on the northern flank to Furry Creek on the southern side, covering an area of about forty square kilometers. They left behind two dozen portals to 210 kilometers of tunnels and shafts, which stretched from 650 meters below sea level to 1,100 meters above.

The men had transported the ore from inside the mountain along rails that emerged into daylight at the portals, where they loaded it onto rail carts and tramways, leaving the waste rock in piles. Even after the mine closed in 1974, it remained one of the largest point sources of metal pollution to the marine environment in North America. Tailings and waste rock were used to fill in the shoreline, and Britannia Creek, containing kilograms of copper, flowed clear but devoid of life into Howe Sound, killing ocean life for at least two kilometers along the shore. Britannia Creek's water was so toxic at the mine's closing that Chinook salmon fry, when introduced, died within forty-eight hours. With years of remediation, salmon have returned to spawn successfully in Britannia Creek, and the shoreline at Britannia Beach is alive again, with plants and invertebrates on the rocks and dolphins and orcas in Howe Sound.

These are signs that the earth can be forgiving.

I'd come here with Hannah at the request of Trish Miller, an environmental toxicologist, to assess the impact on the surrounding forest from the waste-rock piles. The effects were not isolated to the creeks but had reached farther into the forest, and she wanted a broader assessment than is usually done. I had jumped at the chance to work with Trish, having listened to her talk of environmental remediation for many years as friends when our kids were small. I was curious to discover the capacity of the forest to heal a broken ecosystem, of the old trees to seed into the raw earth, of the fungal and microbial networks to mend the damage. How well were the trees growing in the halos of metal-contaminated forests around the waste-rock piles? Was the forest recovering? Should we do more, or could the forest slowly heal on its own?

How profound a wound could the forest suffer before healing became impossible?

Hannah and I found the portals hidden among the hemlocks, the shawls of the trees enveloping the yawning gateways to the caverns. Alders and birches lined the hand-carved mine roads and rail tracks

that led from the tunnels high in the crags to the separator mill at the shoreline below. Mosses and lichens covered the camps where the miners had slept, and the town sites where their families had lived were silent. The humus in the halo forest around the waste-rock piles was more barren than in the surrounding uncontaminated forests, but the roots of the trees had entwined the exposed stones, and a smattering of acid-loving false azaleas and black huckleberries and bracken ferns had found a foothold. As we stood under the hemlock branches dripping with rain, I felt that if there was anywhere that the earth held the power to heal, it would be here on the Pacific Coast in one of the most productive rain forests in the world.

This was also a chance to show Hannah how to assess the disruption—to the trees and plants, soils, and mosses—and the capacity for nature to recover, even when her veins had been bled at the surface. These waste-rock piles were smaller in comparison to the hundreds of meters of a clear-cut, a thousand for the clear-cuts coalescing across valleys, and thousands in the open-pit copper mines around the world. The disturbance by clear-cutting is acute, but the forest can readily recover where its floor is left intact, whereas removing the soil and mining metals from deep inside the earth has a chronic effect on the forests and streams.

"It's good the trees are coming back," Hannah said, coring a small western hemlock. It was one of dozens—lined up like foot soldiers—that had found a niche in the decaying wood. Their seed had dispersed in from adjacent healthy forests, their roots finding purchase in rotting nurse logs where fungal symbionts absorbed scarce nutrients, spongy cellulose sopped up water, and light shafted in thinly from the overstory. Hannah's tree was growing at only half the rate of the nearby elders—her roots shallower, crown sparser—but I knew she would make it. My master's student Gabriel had found that even hemlock saplings like these, whose roots gripped old nurse logs, could also connect with nearby Mother Trees, and they received carbon from the powerful crowns until they themselves were self-sufficient providers. The plant community in this understory was recovering too, with half of the old-growth shrubs and herbs now present in small patches, most of them acid lovers like the hemlock, slowly changing the soil and speeding the cycle of nutrients. These feedbacks

were crucial in helping the trees regain their momentum. In the soil pit, I measured the depth of the forest floor—the litter, fermentation, and humus layers—and it was already about half that of the adjacent healthy areas.

When I peeled back the forest floor to look at the underlying mineral soil, a bronze centipede, big as a salamander, writhed onto my hand. "Ah!" I yelled, throwing the arthropod against a log, where it tumbled into some humus. The centipede was furious, wriggling so fast that the dirt churned. A sign—a stunning one—that the forest floor was in recovery. It burrowed out of sight to continue its day's work, eating the smaller bugs, them eating even smaller ones, and in eating and excreting, cycling the nutrients, a chain of actions to help the trees grow. Hannah and I ate our chocolate chip cookies before measuring and recording the depth and texture of the soil, the height and age of the trees, the species and cover of the plants, signs of birds and animals.

We drove five kilometers farther up the mountain and surveyed the plants and soils across a scree slope of waste rock, the 70 percent angle so steep that a rope had been strung to help workers rappel down. The talus was mostly bare in the middle, some lichens creeping over the rock shards, the odd grass rooted. The hemlock germinants that had found a grain of humus to root in were sickly pale—chlorotic—from insufficient nitrogen, reminding me of the little yellow seedlings in the Lillooet Mountains so long ago. Hannah kept pace behind me as we poked across the steep talus. The hemlocks seeded in from surrounding Mother Trees were increasingly robust as we approached the timberline. At the forest edge, shrouded in the mist, the saplings were bigger, their foliage brighter, mycorrhizas entwined with the minerals, building soil themselves. Bit by bit, with the help of the Mother Trees, the creatures—fungi and bacteria, plants and centipedes—were working together to heal the wounds of this exploited, majestic place.

"Bringing in soil from the old forest would also help," I said, recalling how Grannie Winnie built her garden with compost, burying at the base of the raspberry canes the guts of the fish that Grampa Bert caught, much as the Heiltsuk and the bears and wolves nurtured the Grandmother cedars with the bones of the salmon, giving back, completing cycles. I swear the berries were sweetest where Grannie

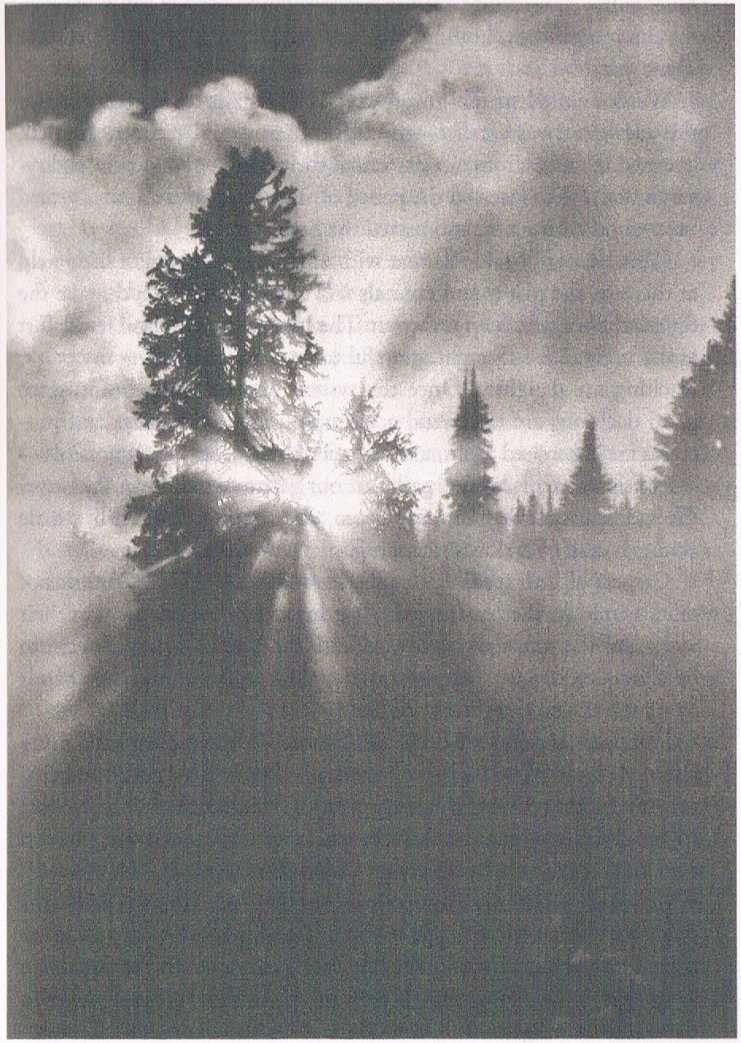
worked. I loved that Hannah was following me, just as I'd accompanied Grannie through her patches of corn and potatoes.

"You could plant birches and alders here too," said Hannah, suggesting we collect seed from the alder along the stream and from the birches along the old mining road.

"Good thinking," I said, "and in clusters, not in rows." Trees need to be near one another, to establish in receptive soil, to join together to build the ecosystem, mix with other species, relate in patterns that produce a wood-wide web, because the forest becomes resilient from this complexity. Scientists now are more willing to say that forests are complex adaptive systems, comprised of many species that adjust and learn, that include legacies such as old trees and seed banks and logs, and these parts interact in intricate dynamic networks, with information feedbacks and self-organization. Systems-level properties emerge from this that add up to more than the sum of the parts. The properties of an ecosystem breathe with health, productivity, beauty, spirit. Clean air, clean water, fertile soil. The forest is wired for healing in this way, and we can help if we follow her lead.

We reached the mound of waste rock at the top portal, the blasts having exposed a cavernous scar a few hundred meters high and just as wide, the waste rock in knuckled piles at the base. The air was thinner, the clouds billowing over the granite turrets, cold rain pelting us. The mountain hemlocks around the portal were still exuberant, their needles like velvet, branches ragged from the wind, tops curved by the tonnage of snow. Their roots spread under the forest floor like veins across old hands, cycling the granite into wood, feeding the plants and animals.

But then, at the scar, where the rock glinted with deep-earth metals, the roots stopped. Like the rails that stopped midair at the portal below, as though men had been hurtled into the river to their deaths. These gouges were too profound for the roots to continue, the unearthed rock too raw to offer nourishment, the water too acid to drink, the wounds impossible to knit. The metallic rock glistened under water seeping from the crags, the lichens and mosses still absent from the grains even after a century of peace. I could see Hannah's shock that the earth sometimes simply cannot bear—cannot recover from—too enormous an injury. There is only so much hurt it can



Mother Tree in the inland rain forest near Nelson, British Columbia

take. Some connections are too broken, the blood too drained, even for the magnificent, healing roots and tenacity of a powerful Mother Tree.

We descended to the lowest portal. The gash creating a mine at this elevation was smaller—the forest here would recover. Hannah counted the rings from our day's final coring and wrote down "eighty-seven years." She inserted the pencil of rings back into the tree, sealed the wound with pitch, and patted the bark.

"The beauty," I said, "is that with a little momentum, a little help at this site, the plants and animals will come back." They'd make the forest whole again, help it recover. The land wanted to heal itself. Just as my body did, I thought, grateful to be here, continuing my work, teaching my daughter. Once the system hits a tipping point, once good decisions are made and acted upon, and when parts and processes are enmeshed again, and the soil rebuilt, recovery is possible—at least in some places. We gathered our gear to wind down the slope, the soil still speckled coppery green, the seeping water still a little acidic, but all of it slowly changing.

Carpets of lush seedlings swished around our ankles. Columns of taller hemlocks marched down fallen logs, their leaders lusty in their search for the sun, roots entwined with the wood. "I think I want to be a forest ecologist, Mama," my daughter said, running her hands along the saplings' feathery needles.

I stopped and looked back. Silhouetted in the setting sun, rising above the others, rooted in the volcanic rocks that nourished her, was the Mother Tree of this wide swath of seedlings. Her limbs were spread like arms, gnarled from centuries of snow, scars long healed over, fingertips loaded with cones. I was calm, happy, but also in need of rest. A classroom in Virginia had sent me a poem entitled "Mama Tree," in which a Mother says to us all: *Goodnight, my loves; it's time to sleep*. This evening I would take the little trail down to the Squamish River and sit on the riverbank with the herons and close my eyes in the warm air.

Hannah took the camera and GPS unit from her vest pocket to snap a photo and log the location of the old Mother Tree and her brood of seedlings. "We can put this in our report," she said, her ability to *see* the forest growing boundlessly.

With the sun sinking behind the sprawling crown of the Mother Tree, a bald eagle landed on her highest branch, scattering her cones. He angled his white head to stare straight down at us. I exhaled sharply, my breath joining a rush of mountain air. I like to think it was carried up to the eagle, because right then he ruffled his prodigious wings. *Now I know why.* I know why these seedlings are healthy in spite of the damage and ravages, unlike the little yellow seedlings from so long ago in the Lillooet Mountains, the ones that received the promise of how I would dedicate my life. The seeds here had germinated in the vast mycorrhizal network of this parent.

Their nascent roots drank from the nutritious soup supplied through her web. The shoots received messages about her past struggles, giving them a head start.

Their response was this plumage of emerald.

The eagle suddenly lifted, caught an updraft, and vanished past the peaks. There is no moment too small in the world. Nothing should be lost. Everything has a purpose, and everything is in need of care. This is my creed. Let us embrace it. We can watch it rise. Just like that, at any time—all the time—wealth and grace will soar.

Hannah stuffed the soil samples in her pack. Ferns shuddered in the raindrops, and she pulled on her hood. She peeked out to see where the eagle had flown, then pointed to it joining a companion over the granite arêtes.

The wind whipped through the needles of the Mother Tree, but she stood steadfast. She had seen nature in countless forms: hot summer days when the mosquitoes swarmed; rain that came in sheets for weeks; snow so heavy some of her branches snapped; periods of drought followed by long damp spells. The sky turned scarlet, her limbs on fire, blood rising to a battle cry. She would be here for hundreds more years, guiding the recovery, giving it her all, long after I was gone. *Farewell, dear Mama.* Tired, I fumbled to do up my vest. Hannah slung her heavy pack over her shoulders, adjusting the load and cinching the buckles, barely noticing the weight.

She took my shovel to lighten my burden and gripped my hand to lead us back home.