Preface: *Seeing the World Through Moss-colored Glasses*

My first conscious memory of "science" (or was it religion?) comes from my kindergarten class, which met in the old Grange Hall. We all ran to press our noses to the frosty windows when the first intoxicating flakes of snow began to fall. Miss Hopkins was too wise a teacher to try and hold back the excitement of five-year-olds on the occasion of the first snow, and out we went. In boots and mittens, we gathered around her in the soft swirl of white. From the deep pocket of her coat she took a magnifying glass. I'll never forget my first look at snowflakes through that lens, spangling the wooly sleeve of her navy blue coat like stars in a midnight sky. Magnified tenfold, the complexity and detail of a single snowflake took me completely by surprise. How could something as small and ordinary as snow be so perfectly beautiful? I couldn't stop looking. Even now, I remember the sense of possibility, of mystery that accompanied that first glimpse. For the first time, but not the last, I had the sense that there was more to the world than immediately met the eye. I looked out at the snow falling softly on the branches and rooftops with a new understanding, that every drift was made up of a universe of starry crystals. I was dazzled by what seemed a secret knowledge of snow.The lens and the snowflake, were an awakening, the beginning of seeing. It's the time when I first had an inkling that the already gorgeous world becomes even more beautiful the closer you look.

Learning to see mosses mingles with my first memory of a snowflake. Just at the limits of ordinary perception lies another level in the hierarchy of beauty, of leaves as tiny and perfectly ordered as a snowflake, of unseen lives complex and beautiful. All it takes is attention and knowing how to look. I've found mosses to be a vehicle for intimacy with the landscape, like a secret knowledge of the forest. This book is an invitation into that landscape.

Three decades after my first look at mosses, I almost always have my hand lens around my neck. Its cord tangles with the leather thong of my medicine bag, in metaphor and in reality. The knowledge I have of plants has come from many sources, from the plants themselves, from my training as a scientist, and from an intuitive affinity for the traditional knowledge of my Potawatomi heritage. Long before I went to university to learn their scientific names, I regarded plants as my teachers. In college, the two perspectives on the life of plants, subject and object, spirit and matter, tangled like the two cords around my neck. The way I was taught plant science pushed my traditional knowledge of plants to the margins. Writing this book has been a process of reclaiming that understanding, of giving it its rightful place.

Our stories from the oldest days tell about the time when all beings shared a common language—thrushes, trees, mosses, and humans. But that language has been long forgotten. So we learn each other's stories by looking, by watching each other's way of living. I want to tell the mosses' story, since their voices are little heard and we have much to learn from them. They have messages of consequence that need to be heard, the perspectives of species other than our own. The scientist within me wants to know about the life of mosses and science offers one powerful way to tell their story. But it's not enough. The story is also about relationship. We've spent a long time knowing each other, mosses and I. In telling their story, I've come to see the world through moss-colored glasses.

In indigenous ways of knowing, we say that a thing cannot be understood until it is known by all four aspects of our being: mind, body, emotion, and spirit. The scientific way of knowing relies only on empirical information from the world, gathered by body and interpreted by mind. In order to tell the mosses' story I need both approaches, objective and subjective. These essays intentionally give voice to both ways of knowing, letting matter and spirit walk companionably side by side. And sometimes even dance.

The Advantages of Being Small: Life in the Boundary Layer

The wailing toddler attached to the end of my arm earns me a disapproving look from a sour-faced lady. My niece is inconsolable, because I made her hold my hand when we crossed the street. She is in full voice now, yelling, "I am not too little, I want to be big!" If she only knew how quickly her wish would come true. Back in the car, after she has whined through the ignominy of being buckled into her car seat, I try to have a reasonable talk with her, reminding her of the advantages of being small. She can fit in the secret fort under the lilac bush, and hide from her brother. What about stories in grandma's lap? But, she's not buying it. She falls asleep on the way home, clutching her new kite, a stubborn pout still on her face.

I brought a moss-covered rock to her pre-school for a science show and tell. I asked the kids at pre-school what a moss was. They skipped right over the question of animal, vegetable, or mineral and got directly to the most salient feature; mosses are small. Kids recognize that right away. This most obvious attribute has tremendous consequences for the way mosses inhabit the world.

Mosses are small because they lack any support system to hold them upright. Large mosses occur mostly in lakes and streams, where the water can support their weight. Trees stand tall and rigid because of their vascular tissue, the network of xylem, thick-walled tubular cells that conduct water within the plant like wooden plumbing. Mosses are the most primitive of plants and lack any such vascular tissue. Their slender stems couldn't support their weight if they were any taller. This same lack of xylem means that they can't conduct water from the soil to leaves at the top of the shoot. A plant more than a few centimeters high can't keep itself hydrated.

However, being small doesn't mean being unsuccessful. Mosses are successful by any biological measure—they inhabit nearly every ecosystem on earth and number as many as 22,000 species. Like my niece finding small places to hide, mosses can live in a great diversity of small microcommunities where being large would be a disadvantage. Between the cracks of the sidewalk, on the branches of an oak, on the back of a beetle, or on the ledge of a cliff, mosses can fill in the empty spaces left between the big plants. Beautifully adapted for life in miniature, mosses take full advantage of being small, and grow beyond their sphere at their peril.

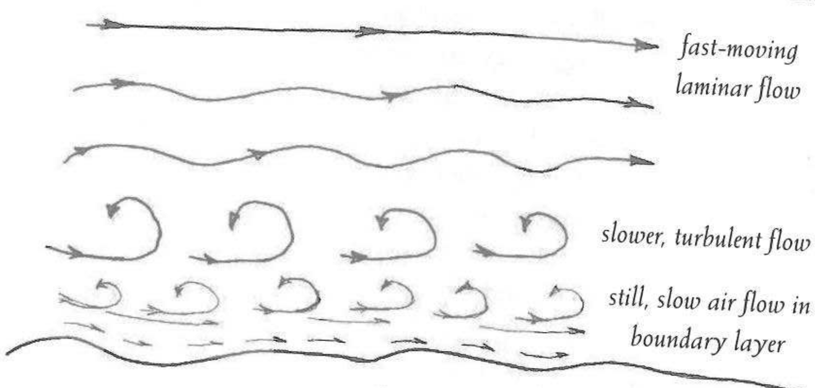
With extensive root systems and shading canopies, trees are the undisputed dominants of the forest. Their competitive superiority and heavy leaf fall are no match for mosses. One consequence of being small is that competing for sunlight is simply not possible—the trees will always win. So mosses are usually limited to life in the shade, and they flourish there. The type of chlorophyll in their leaves differs from their sun-loving counterparts, and is fine-tuned to absorb the wavelengths of light that filter through the forest canopy.

Mosses are prolific under the moist shaded canopy of evergreens, often creating a dense carpet of green. But in deciduous forests, autumn makes the forest floor virtually uninhabitable by mosses, smothering them under a dark wet blanket of falling leaves. Mosses find a refuge from the drifting leaves on logs and stumps which rise above the forest floor like buttes above the plain. Mosses succeed by inhabiting places that trees cannot, hard, impermeable substrates such as rocks and cliff faces and bark of trees. But with elegant adaptation, mosses don't suffer from this restriction; rather, they are the undisputed masters of their chosen environment.

Mosses inhabit surfaces: the surfaces of rocks, the bark of trees, the surface of a log, that small space where earth and atmosphere first make contact. This meeting ground between air and land is known as the boundary layer. Lying cheek to cheek with rocks and logs, mosses are intimate with the contours and textures of their substrate. Far from being a liability, the size of mosses allows them to take advantage of the unique microenvironment created within the boundary layer.

What is this interface between atmosphere and earth? Every surface, be it as small as a leaf or as large as a hill, possesses a boundary layer. We've all experienced it in very simple ways. When you lie on the ground on a sunny summer afternoon to look up and watch the clouds go by, you place yourself in the boundary layer of the Earth's surface. When you are flat on the ground, the wind speed is reduced; you can scarcely feel the breeze that would ruffle your hair if you were standing up. It's warm down there as well; the sun-warmed ground radiates heat back at you, and the lack of breeze at the surface lets the heat linger. The climate right next to the ground is different from the one six feet above. The effect that we feel lying on the ground is repeated over every surface, large and small.

Air seems insubstantial, but it interacts in interesting ways with the things it touches, much as moving water interacts with the contours of the riverbed. As moving air passes over a surface like a rock, the surface changes the behavior of the air. Without obstacles, the air would tend to move smoothly in a linear path called *laminar flow*. If we could see it, it would look like water flowing freely in a smooth deep river. But as the air encounters a surface, friction tugs at the moving air and slows it down. You see this in the flow of water; when a river meets a rocky bottom or logs fallen in its path, the water slows. As the laminar flow is disrupted by the drag of the surface, the air stream becomes separated into layers of different speed. There is swiftly moving air aloft, flowing in a smooth sheet. Beneath it lies a zone of turbulence, where the air swirls and eddies as it encounters obstacles. Down toward the surface,

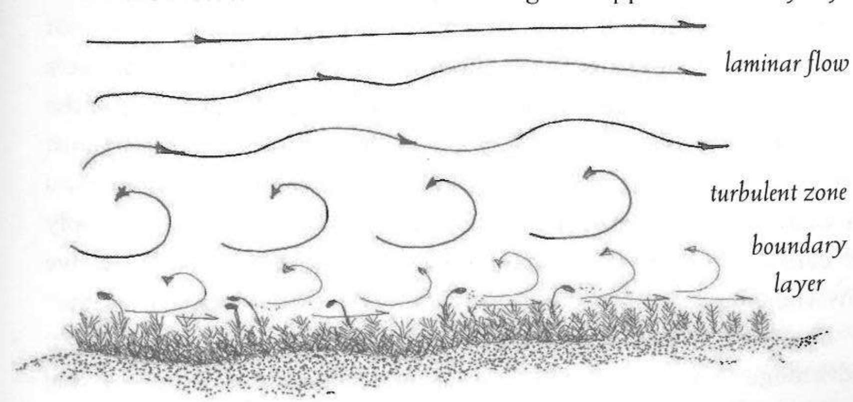


Air flow over a surface

the air becomes progressively slower and slower until, immediately adjacent to the surface, the air is perfectly still, captured by the friction with the surface itself. It is this layer of still air that you experience while lying on the ground.

At a larger scale, I encounter these layers of air every spring. On the first mild day in April, our beautiful kites that have been hanging draped with cobwebs on the porch all winter rustle in the breeze and remind us of blue sky. So, we take them out to play in the boundary layer. In our sheltered valley, the breezes are seldom strong enough to immediately catch the big dragon kites that the kids and I love. So we run crazily back and forth over the back pasture, dodging cow pies and trying to generate enough wind to carry the kite upward. Close to the surface of the earth, the winds are too slow to support the kites' weight. They are trapped, beyond the reach of the breeze. Only when our mad dashes loft one of the kites up to escape the layer of still air does it pull and dance on the string. Its wild pitches and threatened crashes show that it has ascended into the turbulent zone. And then at last, the kite's string pulls taut and the red and yellow dragon sails into the freely moving air above. Kites were made for the airy zone of laminar flow; mosses were made for the boundary layer.

Our pasture is littered with rocks left by the glacier, and I stop to sit on one and spool out the kite string, listening to meadowlarks. The rock is warm from the sun and softened by mosses. I can imagine the pattern of air, flowing smoothly around it until it encounters the surface, where the mosses live. The sun's warmth gets trapped in the tiny layer



Pattern of air flow over a moss carpet of still air. Since the air is nearly motionless, it acts as an insulating layer, much like the dead space in a storm window, which forms a barrier to heat exchange. The spring breeze around me is chilly, but the air right at the surface of the rock is much warmer. Even on a day when the temperature is below freezing, the mosses on a sunlit rock may be bathed in liquid water. By being small, mosses can live in that boundary layer, like a floating greenhouse hovering just above the rock surface.

The boundary layer traps not only heat, but water vapor, as well. Moisture evaporating from the surface of a damp log is captured in the boundary layer, creating a humid zone in which the mosses flourish. Mosses can grow only when they are moist. As soon as they dry out, photosynthesis must cease, and growth is halted. The right conditions for growth can be infrequent, and so mosses grow very slowly. Living within the confines of the boundary layer prolongs the window of opportunity for growth, by keeping the wind from stealing the moisture. Being small enough to live within the boundary layer allows the mosses to experience a warm, moist habitat unknown by the larger plants.

The boundary layer can also hold gases other than water vapor. The chemical composition of the atmosphere in the slim boundary layer of a log differs considerably from that of the surrounding forest. The decaying log is inhabited by a myriad of microorganisms. Fungi and bacteria are constantly at work degrading the log, with an outcome as sure as that of a wrecking ball. The continual work of the decomposers slowly turns the solid log to crumbling humus and releases vapors rich in carbon dioxide, which is also trapped in the boundary layer. The ambient atmosphere has a carbon dioxide concentration of approximately 380 parts per million. But the boundary layer above a log may contain up to ten times that amount. Carbon dioxide is the raw material of photosynthesis, and is readily absorbed into the moist leaves of the mosses. Thus, the boundary layer can provide not only a favorable microclimate for moss growth, but also an enhanced supply of carbon dioxide, the raw material for photosynthesis. Why live anywhere else?

Being small enough to live in the boundary layer is a distinct advantage. Mosses have found the microhabitats where their size becomes an asset. The growth of a moss would be sharply curtailed if the shoots grew too tall and into the drying air of the turbulent zone. We might predict therefore that all mosses are uniformly small, corresponding to the limits imposed by the boundary layer. However, mosses exhibit a tremendous range in height, equivalent to the height disparity between a blueberry bush and a redwood. They range from tiny crusts only a millimeter high to lush wefts that can be up to ten centimeters tall. These differences in stature can usually be traced to differences in the depth of the boundary layer in the particular habitat. The boundary layer on a rock face exposed to wind and full sun is quite thin. Hence, the mosses of such arid places must be very small in order to stay within the protective boundary layer. In contrast, mosses on a rock in a moist forest can grow much taller and still remain within a favorable microclimate, because the boundary layer of the rock is under the umbrella of the boundary layer of the forest itself. The trees slow the wind and their shade reduces evaporation, buffering the area against the drying atmosphere. In a humid rainforest, the mosses can be lush and tall. The larger the boundary layer, the larger the moss can be.

Mosses can also control the depth of their own boundary layers by changes in their shape. Any feature of a surface that increases friction with moving air can slow the air and create a thicker boundary layer. A roughened surface slows the passage of air more effectively than a smooth one. Imagine being caught in a fierce prairie blizzard with strong winds blasting sheets of snow against your face. To escape the force of the winds, you lie down, taking refuge in the shelter of the earth's boundary layer. Given a choice, would you be warmer lying in the open or in a field of tall grass? The projection of the tall grass into the moving air stream slows the air and makes a larger boundary layer, helping to conserve your body heat. Mosses utilize this same principle to enlarge the boundary layers above them. The surface textures of a moss itself can create resistance to airflow. The greater the resistance, the deeper the boundary layer. Like a tall grassy field in miniature, moss shoots exhibit adaptations that slow air movement. Many moss species have long narrow leaves held upright to slow the airflow around them. Moreover, the leaves of mosses in dry sites often possess dense hairs, long reflective leaf tips, or miniscule spines. These extensions from the leaf surface also slow the moving air and reduce evaporation of essential moisture by creating a thicker boundary layer.

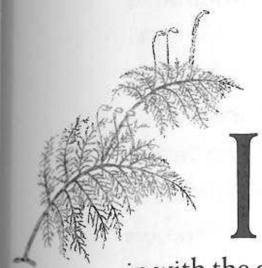
In arid zones, mosses often rely on dew for their daily ration of water. The interplay of the atmosphere and the rock surface creates the conditions for dew formation. At night, when the sun's heat dissipates, the temperature differential between the rock surface (which has retained some warmth) and the air may provide a site for condensation of water. A thin film of dew is created right at the air-rock interface, where it can be readily absorbed by the mosses. Only a very small being can take advantage of such a thin and evanescent supply of moisture in the desert, living on dew.

The safe and balmy realm of the boundary layer provides a secure refuge for mosses. But the very same nurturing environment that sustains growth to maturity poses a problem for the next generation. Like my niece, mosses eventually need to escape from protection by their elders and find their own places. Mosses reproduce by the formation of spores, tiny powdery propagules that require wind to carry them far afield. Most spores can't germinate in the leafy carpet of their own parents, so getting away is imperative. Air currents in the still air of the boundary layer are not sufficient to disperse them. So, to catch a breeze and help them leave the home territory, mosses elevate their spores on long setae, stalks that poke up above the boundary layer. The rapidly maturing sporophytes are thrust up through the boundary layer and into the turbulent zone like a kite on the wind. Here vortices of air swirl around the capsules, pulling out the spores and carrying them off to new habitats. Like the young of every species they escape the restrictions of their elders and seek out the freedom of the wide-open spaces.

The length of the seta or stalk is strongly correlated with the depth of the boundary layer. The seta of a forest moss must be quite tall to escape the boundary layer and catch the light breeze that moves over the forest floor. In contrast, mosses of open sites where the boundary layer is thin typically have short setae.

Mosses take possession of spaces from which other plants are excluded by their size. Their ways of being are a celebration of smallness. They succeed by matching the unique properties of their form to the physical laws of interaction between air and earth. In being small, their limitation is their strength. Try telling that to my niece.

Back to the Pond

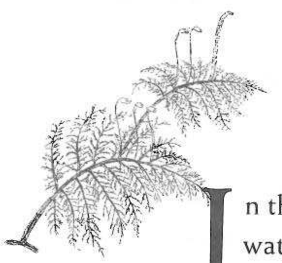


I shiver in the damp breeze, but I can't bring myself to close the window on this April night that is sliding off the cusp of winter into spring. The faint sound of the peepers flows in with the cold air, but it's not enough. I need more. So I go downstairs and slip my down jacket over my nightgown, slide bare feet into my Sorels and leave the woodstove's warmth behind in the kitchen. With bootlaces dragging through patches of remnant snow, I tromp up to the pond above the farmhouse, breathing in the scents of wet ground. I'm pulled by the sound. Coming closer feels like walking into a crescendo, rising with the chorus of voices. I shiver again. The air literally throbs with the massed calls of peepers, vibrating the nylon shell of my jacket. I wonder at the power of these calls, bringing me from sleep and bringing the peepers back to the pond. Do we share some common language that draws us both to this place? The peepers have their own plan. What is it that brings me here to stand like a rock in this river of sound?

Their ringing calls summon all the local peepers to this gathering place, for mass fertilization in the rites of spring. Females will squeeze their eggs out into the shallow water, where males cover them with milky drifts of sperm. Surrounded by a gelatinous mass, the eggs will mature to tadpoles and become adult frogs by summer's end, long after their parents have hopped back to the woods. Spring peepers spend most of their adult lives as solitary tree frogs, travelling the forest floor. As far afield as they may venture, they must all return to water to reproduce. All amphibians are tethered to the pond by their evolutionary history, the most primitive vertebrates to make the transition from the aquatic life of their ancestors to life on land.

Mosses are the amphibians of the plant world. They are the evolutionary first step toward a terrestrial existence, a halfway point between algae and higher land plants. They have evolved some

Binding up the Wounds: Mosses in Ecological Succession



In the after-lunch indolence that follows a good climb, I'm watching an ant haul a sesame seed from my sandwich crumbs across the bare rock. She carries it to a crevice in the rock which is filled with *Polytrichum*, a bristly moss that has taken hold in the tiny pocket of soil collected there. I doubt that next summer's hikers will find a sesame sprout, but the crack already holds a tiny spruce, started from a seed among the mosses. The ant, the seed, the moss, all bent on their own paths, are unwittingly working together, covering open ground, sowing a forest on this bare rock. The process of ecological succession is like a positive feedback loop, a magnet of life attracting more life.

From the dome of Cat Mountain, the Five Ponds Wilderness stretches out at my feet, the largest wilderness area east of the Mississippi, rolling green hills stretching to the horizon. This sun-warmed granite is some of the oldest rock on Earth, and yet the forest below is relatively new. Only a century ago the redtails would have ridden the thermals over charred ridgetops, cutover valleys, and isolated pockets of old-growth forest. The Adirondacks have been called "The Second Chance Wilderness." Today bears and eagles fish along the meandering course of the wild Oswegatchie River. Its logging scars healed by succession, it is an unbroken expanse of second-growth forest. Unbroken, save for one open wound. To the north, the green is interrupted by a gash, a treeless barren visible from ten miles away.

The rock hereabouts is rich in iron. There are places where your spinning compass makes you think you've wandered into the twilight zone. You can pick up the beach sand with a magnet. Iron mining came early to the Adirondacks and at Benson Mines they tore down the mountain and ground it up. The ore went all over the world, and the mountain came out of a pipe as a slurry of tailings, mine waste laid

thirty feet deep. Then the bottom dropped out of the market, jobs left, the mine closed and left behind hundreds of acres of sandy waste, a Sahara in the midst of the wet green Adirondacks.

Current law demands restoration of mined lands, but Benson Mines fell between the legal cracks and has not been reclaimed. There were some half-hearted attempts at revegetation, but they all failed. Midwestern prairie grasses were planted in some places, but they couldn't survive long without fertilizer and irrigation, which ran out about the same time that the business moved overseas. Someone planted trees; a few of the pines have persisted, yellow and stunted. I don't know whether these were planted as acts of contrition or a façade of responsibility, but there wasn't much sense to it, like painting a mural on a condemned building. It's not enough to put plants here; there has to be something to sustain them and the tailings are a far cry from the humus-rich soils that now lie buried under the sterile sand. Now it's officially classified as an "orphan mine." Rarely is official language so direct and evocative—this piece of land is indeed without anyone to care for it.

Driving the Adirondack roads, past glittering lakes and deep woods, you'll scarcely ever see roadside litter. People love this wild place and the care for its well-being is obvious. But where Route 3 cuts through the mined land, plastic bags are caught in the alders and beer cans float in the ditches full of rusty water. Disregard is also a positive feedback loop; garbage attracts garbage.

I turn in to the cemetery, an anomalous patch of green surrounded by the old mines. The company showed as little regard for the dead as for the living. Past the well-tended gravestones, the pavement ends and the tailings begin. The polished granite monuments give way to an idiosyncratic collection of homemade memorials: a rusty blade from the sawmill half-buried in the ground, rebar welded to form initials, an old-time TV aerial bent to the shape of a cross. There are stories here, buried in the tailings. The path to the mine runs through the cemetery junkpile, past old Christmas wreaths still on their stands, white plastic baskets of pink plastic flowers, the remains of mourning.

I walk up the tailings slope, slipping backwards in the loose sand, like walking on the beach. I don't mind my shoes filling with it; these dunes aren't toxic, just hostile in the way of most deserts. The sand can't hold water so any rains percolate quickly, leaving it dry again. Without vegetation, there's no organic matter to soak up water or build the foundation of a nutrient cycle. Without the shade of trees, the surface temperature can reach extremes—I've measured it at 127 degrees Fahrenheit, more than enough to wither a tender seedling. The slope is littered with spent shotgun cartridges, and cans shot full of holes. And here and there are odd little structures, pieces of fabric stretched between Popsicle sticks, like miniature tents. Pieces of old carpeting lie on the sand, like a strange demonstration from a zealous vacuum cleaner salesman.

Up ahead, I see Aimee kneeling in the tailings, cradling a clipboard, her red curls tucked underneath a broad-brimmed hat. She looks up, apprehensively at first, and then smiles. I know she'll be glad of the help today and relieved to have company. Last week, she found an ugly threat scrawled into the smooth surface of our research plots. Garbage attracts garbage. At least today she'll know that the sound of approaching footsteps is only me.

The role of mosses in ecological succession on the mines is Aimee's thesis project, and she has experiments set up all around. Together, we set off across the tailings to check on some research plots. Where the slope levels out there are tire tracks. Trucks with names like Sippin' Sue and the Honey Wagon painted on the tanks have been making illegal deliveries under the cover of darkness. The stink of septic tank contents lingers in the air. Items people thought they had "disposed of" with a flush now see the light of day again, in a pool of dried-up sewage sludge. The water and the nutrients might actually have done some good if there was soil to hold it. But it all drains away quickly, leaving behind a gray crust studded with cigarette butts and pink tampon applicators. Garbage attracts garbage.

On the other side of the pile, there is a place where the land is healing itself, without benefit of sewage effluent or exotic grasses. Here are clumps of bright hawkweed and clover and scattered evening primroses rooted in the tailings; they would be weeds in other situations, but their presence here is welcome. Especially to the butterflies that crowd around them, as if they were the only flowers around. They are.

Most of this slope is a carpet of *Polytrichum* moss, the same species I saw at the top of Cat Mountain. I admire its tenacity in enduring this place, where others would wither away in the span of a single day. In last year's field season, Aimee found that the wildflowers were almost never rooted in the bare tailings; they almost always occurred in the beds of *Polytrichum*. This summer we're trying to find out how that works. Do the mosses come in under the tiny island of shade produced by the flowers, or do the mosses create a safe place for the weed seeds to get started? How are they interacting to advance succession? She calls me over to a cluster of the little tents that I'd seen on the way up the slope. She erected these canopies to see if moss growth is increased or decreased by shade. Shade might help to explain the association between moss and wildflowers. We kneel and peer under the canopy: the moss beneath it is soft and green, while most of the rest of the slope is black and crisp. Walking over the dry moss sounds like walking over crackers as they break beneath your feet.

I pluck a shoot of *Polytrichum* from under the tent and look at it with my hand lens. The leaves are long and pointed, making the whole plant look like a tiny pine tree. All along the center of each leaf are wavy ridges of bright green cells, the *lamellae*. When the plant is wet, the lamellae are exposed to the sun like solar panels. Like other mosses, it can photosynthesize only when the leaf is both moist and illuminated. Otherwise, which is most of the time, growth is suspended and the moss just waits. It's no wonder that it has taken forty years to carpet this small patch of tailings.

The mossy slope changes color as we work through the day. In the morning light, it's a wash of blue green. The dew of the previous evening was intercepted by the stiff leaf points and funneled down to the leaf base. Moistened, the leaves open and take advantage of the cool morning sun. But when the *Polytrichum* starts to dry, the leaf folds inward to protect the lamellae from desiccation, and growth stops until the next time conditions are right. By lunchtime, the leaves have all flexed inward like a folded umbrella and the green is hidden. Only the dead leaves at the base of the plant are visible, giving the whole slope a black, crusty appearance. With the leaves all folded up, the surface of the tailings is exposed. You have to look closely to see it. When you are down on your knees, the tailings are almost too hot to touch. The surface between the shriveled moss stems is speckled with blackish green. This is a microbial crust, a community even tinier than the mosses, which seem to tower above it. It's made up of intertwined filaments of terrestrial algae, bacteria, and fungal hyphae, taking advantage of the shade provided by the mosses. The algae are nitrogen fixers, incrementally adding nutrients to the tailings.

We try to finish our work by mid-afternoon when its really gets scorching. We can retreat to the shade and get a glass of iced tea at the café in Star Lake, but the *Polytrichum* is stuck out on the tailings in the heat of the day. Its remarkable stress tolerance allows it to persist on this harsh site. It can endure a complete lack of water, while the grasses and wildflowers cannot. *Polytrichum*'s needs for minerals are met by rainwater alone, while the higher plants must extract them from the soil with roots that die in the drought.

The *Polytrichum* carpet is interrupted by small gullies and windswept bare spots. Anyplace the moss is absent, the tailings are subject to erosion. If you pick up a handful of bare tailings, it sifts away through your fingers like water and the wind scatters it as it falls. But under the mosses the tailings are bound firmly together, the sand braided by moss rhizoids. I can stick the blade of my Swiss Army knife into the turf and slice out a neat column of sand, several inches deep, with a cap of moss at the top. The sand below the moss is darkly tinted. This tiny amount of accumulated organic matter may slow the passage of water and subtly increase the pool of soil nutrients. The hair-like rhizoids of *Polytrichum* bind the tailings together and stabilize the surface. We think that this stability might be important as a factor for allowing other plants to get started and Aimee has set up a clever experiment to test that.

It's hard to track the fate of tiny wind-blown seeds that look just like grains of sand. So Aimee went to the bead store and bought vials of plastic beads in the brightest possible colors. Sometimes our kind of science needs more creativity than high-tech equipment. She carefully placed the beads in a grid pattern on different kinds of surfaces at the mine—the bare tailings, under shading vegetation, and on the moss carpet. Every day she would come back and count them. Within two

days, every bead on the bare tailings was gone, blown away and buried in the shifting sand. A few more persisted under the wildflowers, but the record setter was *Polytrichum*. The beads became lodged between the shoots, safe from the wind. Mosses might well advance succession simply by providing a safe site for germination. A few days later, a natural experiment confirmed her results. The aspens at the edge of the mine released their cottony cloud of seeds, which blew freely across the bare tailings but were trapped by the moss turf, caught like cat hair on a velvet sofa.

But plastic beads are not seeds, and just because a seed is caught doesn't mean it will germinate and become an established plant. The moss turf is just as likely to hinder the seed as help it, as the two compete for water, space, and scarce nutrients. The moss turf might strand the seed high and dry above the soil and prevent it from ever sprouting or block the passage of tiny roots to the soil. So the next step in our investigation was to sow real seeds. Armed with patience and forceps, Aimee followed the fates of hundreds of seeds, marking each germination and recording its growth over the weeks. In every experiment, with every species, she found that seeds grew and survived best when living in partnership with the moss. The *Polytrichum* seemed to encourage the success of the seedlings. Life attracts life.

Or does it? With appropriate scientific skepticism, we wondered if all the seeds really need is a protective substrate. Maybe it doesn't need to be a living moss at all. The *Polytrichum* may be no more than a physical refuge. How could we see if the seeds were responding just to the protection and not to the moss itself? Can seeds differentiate between moss and a surrogate of the same structure? We puzzled over how to create an experimental substrate which simulated a moss, yet was not alive.

Language provided the key to our experiment. People often refer to mosses as "carpets." The metaphor is really very apt, so we headed for the carpet store. We found ourselves running our hands over Berbers and shags to find the most moss-like textures. Rugs are excellent mimics of the structure of moss colonies, with their closely packed upright shoots. Laughing down the display aisles, we began renaming the designs by their mossy look-alikes: Urban Sophisticate became *Ceratodon*, Country Tweed was clearly the synthetic kin of *Brachythecium*. We chose a shag carpet that most closely mimicked the *Polytrichum* turf, Deep Elegance. It was wool and so would hold water as well as provide protection. We also bought some remnants of an outdoor carpet, an Astroturf of water-repellent plastic fibers in a lurid shade of grass green. Each piece was subject to abuses never dreamed of in the sales warranty. We soaked it to remove chemicals and punched it full of holes to allow water to percolate through.

We installed the carpet squares out on the tailings with small stakes. Aimee sowed a variety of seeds on each carpet, as well as on the tailings and the living carpet of *Polytrichum*. Faced with a choice between the shag which provided water and shelter, the Astroturf which provided shelter but no water, the real moss, and the bare tailings, what would the seeds do?

Weeks later, the hot summer weather broke with a thunderstorm, echoing off the headwall of the old mine. The desert of the tailings was briefly cooled as the water poured through the sand like a sieve. Unsheltered seeds were washed down the bare gullies. *Polytrichum* unfurled its leaves and began to display resilient green. The Astroturf lay lifeless on the tailings; the shag was sodden and spattered with mud. Out of the carpet of living moss came a crowd of seedlings, the next step in binding up the wounds of the land, life attracting life.

Human communities aren't so different. Like ecological succession, one phase leads to the next. The village at Benson Mines was once a small settlement of loggers in a seemingly boundless forest. Maybe there was just a single house, like a pioneering clump of moss. More families followed, and children, and then a school, a growing population which brought a store and then a railroad and then the mine. It seems that people take as little responsibility for their incrementally evolving future as does a seedling landing on a moss. The corporation left them a legacy, life on the edge of a wasteland, burying their dead in mine tailings.

Aimee and I would rest on hot afternoons in a little grove of aspens that had somehow gotten started in this desolate place that everyone wanted to cover in garbage. We know now that these aspens originated from seeds caught on a patch of moss, and the whole island of shade began to grow from there. The trees brought birds and the birds brought

berries—raspberries, strawberries, blueberries—which now blossom around us. The center of the grove was cool and shady, and the leaf litter from the aspens had started to build up a thin layer of soil over the tailings. Sheltered from the harsh conditions of the mine, a few maple seedlings, migrants from the surrounding forest, were holding their own. Brushing aside the leaf litter, we uncovered the remnants of *Polytrichum*, the first plants to begin healing the land, making it possible for others to follow. In the deepening shade, they'll soon be replaced, having done their work. This island of trees is the legacy of mosses pioneering on the tailings.