ALL WE CAN SAVE

Truth, Courage, and Solutions for the Climate Crisis

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Reciprocity

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Midway through my forestry degree, I found myself pointing a can of spray paint at the smooth bole of an ironwood tree. I was to mark it as part of a "release cut" in our experimental forest in New Jersey. The orange slash would tell loggers to fell, poison, or girdle anything that might compete with our sawtimber crop. We were taught that thinning would help the oaks and walnuts, freeing them to get more water, light, and nutrients. For many in our class, "opening up" a stand of trees was their favorite part. For me, it was an excruciating, empty choice.

I kept envisioning the historic forest right next to ours that hadn't been cut for two hundred years. I had seen overstory giants grouped in twos and threes and fours, a middle layer of hardwoods and conifers, and, at my feet, trilliums, fiddleheads, and rufous-sided towhees bursting from the duff. Nobody had released these trees from competition, yet all appeared well.

"The old forest is not nearly as open or regimented as this," I told my professor, "but it looks healthier. Do you think the trees might be grouped together for a reason? Do you think they might be benefiting one another in some way?"

He shook his head no, a bit alarmed. "Don't be so Clementsian," he said. "You'll never get into grad school." The reference was to Frederic Edward Clements, an ecologist from the early 1900s who had won and then lost the greatest debate in ecological history. Being compared to Clements was a well-known admonition, a sure sign of naïveté.

It was 1977, and ecologists were three decades deep into a paradigm shift that affected our experiments, our narratives about the wild, and, most powerfully, our maxims for managing forestlands, ranches, and farms. The precept that trees needed to be released from the struggle of competition was the fruit of a debate between Frederic Clements and his contemporary Henry Gleason. What they both endeavored to describe, in very different ways, was what constitutes a community of vegetation, what determines how plants grow together and why.

When Clements studied bayous, chaparrals, hardwood forests, and prairies, he saw distinct communities of plants reacting not just to soils and climate but also to one another. He proposed that plants were cooperators as well as competitors, facilitating one another in beneficial ways. Canopy trees "nursed" the saplings beneath their branches, creating more sheltered, nutritious conditions in a plant-helping-plant process later dubbed *facilitation*. They shaded seedlings from the drying sun, blocked the winds, and fertilized the soil with their leaves. As time passed, one community of plants prepared the way for another; annual plants built the soil for perennial shrubs, and those shrubs nourished saplings that grew into forests. Everywhere Clements looked, he saw communities so tightly interwoven, he called them organismic.

Gleason had a different take. What Clements called communities was simply happenstance, random individuals dispersed by chance and arranged according to how they adapted to water, light, and soil. There was no mutual aid; plants were merely competing for a spot in the struggle. The notion that there might be a connected, interdependent community to be studied as a whole was an illusion; examining the parts would do.

For the first half of the twentieth century, Clements's view prevailed—the ecological literature was full of studies on facilitation. Gleason's work was virtually forgotten until 1947, when a small group of researchers resurrected his individualist views and pitted them against Clements's holism. Ecologists in the throes of "physics envy" liked the fact that Gleason's view of plants allowed individuals to be studied with neat statistical precision, like atoms.

Within twelve short years, Clements's cooperative-community theory all but disappeared from the scientific literature, and the majority of ecologists rejected the idea of positive interactions as a driver of community assembly. Graduate students steered clear of the "unscientific aura" of Clements's ideas and instead focused their research on antagonistic interactions such as competition and predation. Given the times, we shouldn't be surprised. Clements's fall from grace coincided, to the year, with the release of the Truman Doctrine and the onset of the Cold War. For decades, communism was a third rail best avoided, even when talking about plants.

But here is what I love about the scientific method. Though culture seeps into science and sometimes holds its finger on the scale, it cannot stop the restless search for measurable truth. Un-American or not, the math has to work. When fifty years of wall-to-wall research into competition proved inconclusive, researchers went back to the field to find out what else was at play.

The same year I was pardoning an ironwood, ecologist Ray Callaway was in the foothills of the Sierra Nevada, rescuing blue oaks from bad practice. The prevailing wisdom, a gift from Gleason, was that the oaks dotting California's rangelands should be cut to release grasses from competition. Much to Callaway's dismay, thousands of acres of blue oaks were being bucked up for firewood.

The fact that grasses had thrived with blue oaks for eons nagged at him. How harmful could oaks be? For two and a half years, he measured the interaction between the oaks and the grasslands—his pans and buckets catching leaves, twigs, branches, and nutrient-laced rainfall dripping from oak canopies. His thesis showed that the nutrient totals under oaks were actually five to sixty times greater than in open grasslands. Those spreading trees, so artfully arranged in the California landscape, are nutrient pumps that lift minerals from the deep and scatter them in an annual leaf drop. Penetrating taproots loosen the dense soil, increasing water storage beneath the boughs and welcoming a profusion of plants. Today experts recommend protecting, not cutting, these "islands of fertility."

Callaway has gone on to become a leading light in facilitation research. His book *Positive Interactions and Interdependence in Plant Communities* reviews more than a thousand studies of how plants chaperone and enhance their neighbors' growth, survival, and reproduction. To read these strategies is to discover a manual for how life evolved on a challenging planet and how natural communities heal and overcome adversity—essential reading for a climate-changed world.

Knowing which plants are the chaperones in botanical communities will be important as droughts deepen in the coming years. For example, how and why do Amazonian rainforests create clouds even in the dry season? It turns out that 10 percent of the Amazon's annual rainfall is absorbed by certain trees and shrubs. Their shallow roots absorb the rainfall, and their deep taproots push it down deep into the soil bank. When the rainless months come, water rises up the taproots and gets distributed to the whole of the forest. Many species of plants throughout the world perform this hydraulic "lift," watering a multitude of plants under the forest canopy.

The more stressful the environment, the more likely you are to see plants working together to ensure mutual survival. On Chilean peaks, studies of mounded plants huddling together against harmful ultraviolet rays and cold, drying winds reveal complex interactions of support. A single six-foot-wide yareta, or cushion plant, can be thousands of years old and harbor dozens of different flowering species in its mound, tucked like colorful pins in a bright green cushion.

Downslope, tear-shaped "tree islands" show how facilitation can create the conditions conducive to community. If a tree can tough it out and get established on a rockfall, it creates a lee where winds calm and snows drift to water sheltered seedlings. Decaying leaves and needles create an organic sponge that collects and then releases moisture in the dog days of summer. Birds roost and mammals hide in the growing island, importing nutrients and seeds in their excrement. Over centuries, these tree islands migrate, the windward sentries succumbing while the leeward ranks march backward. Studies have shown that tree islands act as mobile soil builders, roaming back and forth, painting fertility across mountainsides.

Whether it comes in the form of shading, shielding, nourishing, or defending, facilitation allows plants to expand their niches, to thrive where they would normally wither. Landscapers, farmers, and foresters may want to mimic these moves by planting for partnership, including wind blockers, soil holders, water lifters, and nutrient boosters in their mixtures. As plants deal with shifting growing zones, a facilitation partner could make all the difference.

I admit it's counterintuitive to imagine plants increasing facilitation in the face of scarcity when our competition bias and our economic theories suggest otherwise. For years, careful experimenters tried to explain this as an anomaly, missing the beneficence in their search for the struggle. Now we know that it's not just one plant helping another; mutualisms—complex exchanges of goodness—are playing out above- and belowground in extraordinary ways.

While Callaway was measuring oaks in California, Suzanne Simard was a professional forester, wincing through British Columbia's mass clear-cuts. The management protocol of removing paper birch trees that grew in association with Douglas fir seemed strange to her—they had been companions for eons. Might they be helping each other in some way?

In a brilliant study, she exposed growing seedlings to two types of carbon dioxide—radioactive carbon-14 for birch and stable carbon-13 for Douglas fir. The seedlings would absorb the carbon dioxide and transform it into sugars. She followed the carbon to see if any would be exchanged. The first results came in an hour's time. She describes a sense of wonder bordering on euphoria when the Geiger counter popped and clicked—carbon-14 from the birch had traveled to the Douglas fir, while carbon-13 from the fir made its way to the birch.

How? Next time you're in a forest, dig into the duff, and you're bound to find white, cobwebby threads attached to roots. These are the underground parts of special fungi that deliver phosphorus to trees in return for carbon. Textbooks once described the exchange as exclusive, one tree to one fungus, until the data begged to differ. Simard's work was among the first to prove that fungi branch out from the roots of one tree to connect dozens of trees and shrubs and herbs—not only relatives but entirely different species. This "wood-wide web" is an underground Internet through which water, carbon, nitrogen, phosphorus, and even defense compounds are exchanged. When a pest troubles one tree, its alarm chemicals travel via fungi to the other members of the network, giving them time to beef up their defenses. Thanks to researchers like Simard, foresters are now encouraged to leave birch and large hub trees in the forest to give seedlings a fast connection to the network.

Discoveries about the connected nature of mutualists have vast implications for forestry, conservation, and agriculture in a warming world. Although 80 percent of all land plants have roots that grow in association with mycorrhizae fungi, it's rare to find thriving mycorrhizal networks in agricultural fields. Plowing disturbs the cobwebby network, and the year-on-year addition of artificial nitrogen and phosphorus fertilizers tell bacterial and fungal helpers that they are no longer needed—not needed for water transport or pest defense,

not needed to absorb the micronutrients our bodies long for. It's time to bring the wood-wide web to farmlands.

When communities of vegetation breathe in carbon dioxide, turn it into sugars, and feed it to microbial networks, they can sequester carbon deep in soils for centuries. But to do that, the communities need to be healthy, diverse, and amply partnered. If we're to encourage wild and working landscapes to recoup the 50 to 70 percent of soil carbon that has been lost to the atmosphere, we'll want to pause before plowing a field, opening a bag of fertilizer, or marking a sapling for removal. We wouldn't want to interrupt a vital conversation.

If humans are to help reverse global warming, we will need to step into the flow of the carbon cycle in new ways, stopping our excessive exhale of carbon dioxide and encouraging the winded ecosystems of the planet to take a good long inhale as they heal. It will mean learning to help the helpers, those microbes, plants, and animals that do the daily alchemy of turning carbon into life. This mutualistic role, this practice of reciprocity, will require a more nuanced understanding of how ecosystems actually work. The good news is that we're finally developing a feeling for the organismic, after years of wandering in the every-plant-for-itself paradigm.

One of the fallouts of our fifty-year focus on competition is that we came to view all organisms as consumers and competitors first, including ourselves. Now we're decades into a different understanding. By recognizing, at last, the ubiquity of sharing and chaperoning, by acknowledging the fact that communal traits are quite natural, we get to see ourselves anew. We can return to our role as nurturers, each a helper among helpers in this planetary story of collaborative healing.