
SPRINGS

THE RACHEL CARSON CENTER REVIEW

2022 | *Issue #1*

July 2022



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THE WORLD AS A WARDIAN CASE

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Springs
The Rachel Carson Center Review

2022 • 1

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In 1829, Nathaniel Bagshaw Ward, a London doctor, placed the pupa of a sphinx moth, some dirt, and a few leaves in a glass bottle and clamped on a lid. As Luke Keough describes in *The Wardian Case*, Ward watched as condensation formed inside and slid down the walls. In time, the moth hatched. As he reached in to retrieve it, the doctor noticed two fine slivers of green on the soil. He capped the bottle again and left it on a windowsill. Soon a sprig of grass and a tiny fern uncoiled. Ward was astounded. For years he had tried to grow ferns in his garden. Inside the bottle, the fern and grass created a tiny microcosm, generating their own atmosphere, recycling water, and drawing energy from light. The bottled plants, he reasoned, took root because they were sealed from the London soot that killed his outdoor plants.¹ Ward's London, heated by coal fires, suffered from a smog that generated lung disease, one of the chief causes of death in the city in the nineteenth century.



Photograph by Lucy Serafi. theurbanbotanist.co.uk. CC BY-SA 4.0. The image has been cropped.

In 1991, Biosphere-2 launched in the Arizona desert to great fanfare. Eight men and women wearing Star Trek-sleek uniforms stepped over the threshold into the 1.2-hectare glass dome erected to serve as a miniature replica of Earth. They waved to cameras before the wheel of a vault locked them in. The team vowed to remain inside the controlled environment for two years living almost entirely on food, water, and oxygen created by the structure's seven biomes: ocean, freshwater and saltwater marshes, rain forest, savanna, desert, farm, and human habitat.² Biosphere planners calculated how many plants were needed to produce enough oxygen for the eight humans plus farm animals, birds, and small fauna inside the glass—a total of 3,800 species. The lush vegetation would breathe in carbon dioxide and expel oxygen. The designers planned that once the seven biomes stabilized, the

living organisms would interact with inorganic matter to self-regulate and perpetuate conditions for life inside the Biosphere much as plants were thought to do on Earth or in Ward's closed bottle.

How did knowledge of Earth's atmosphere expand outward from these experiments? What can the history of controlled environments tell us about how we understand the planet today?

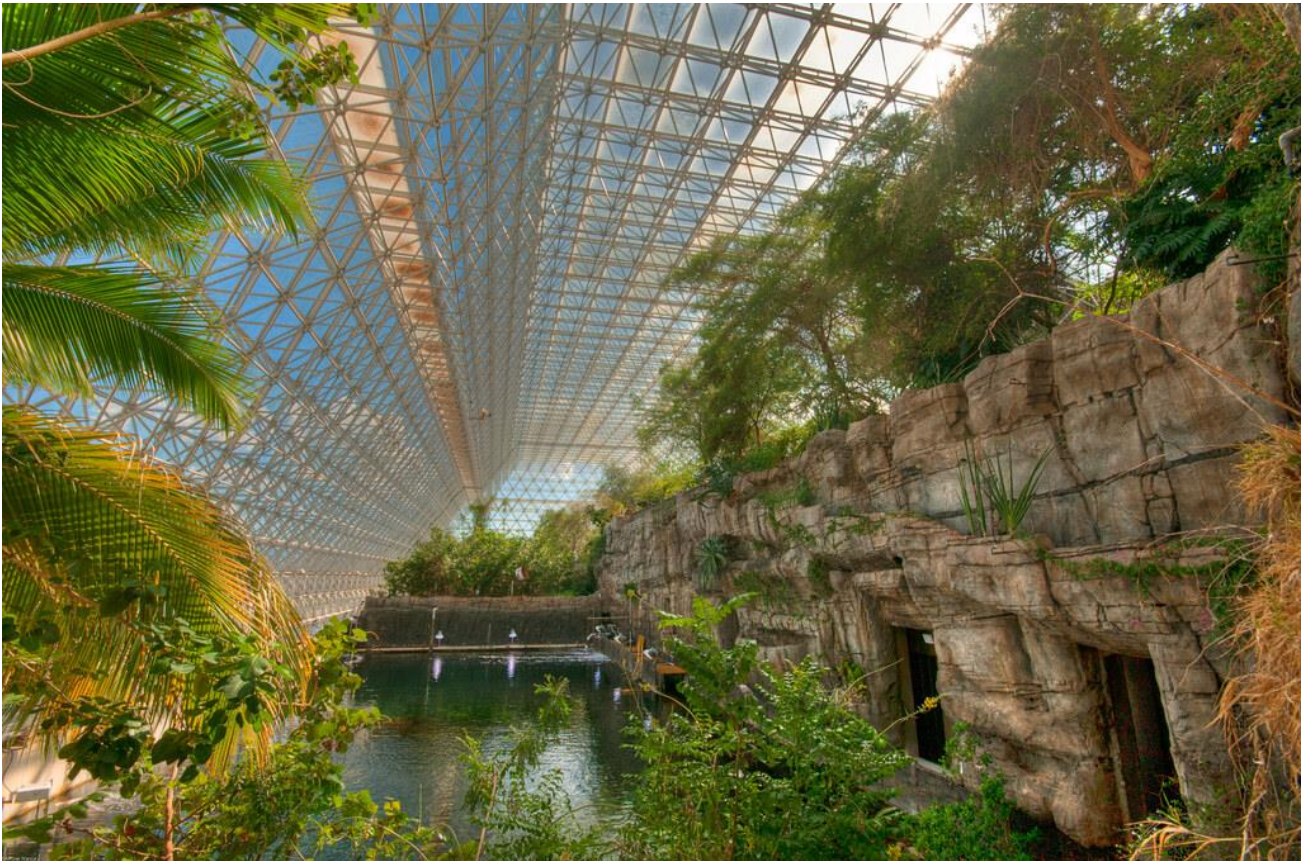
If a fern could dance, the small seed growing inside the capped bottle might have done a jig, free from killing smog as it extended upward in air of its own making. Certainly, Ward was delighted. In his workshop, he designed a wood-framed glass case to contain plants to grow in air innocent of London smog. The case worked. He experimented, using it to ship a number of ferns, mosses, and grasses to Australia. The plants survived the arduous journey comfortably in the "Wardian Case," as it became known.

Before Ward's invention, the majority of plants shipped on sailing vessels died. Ward's case broke a critical bottleneck in the establishment of monocrop plantations. By the end of the century, the profit-generating plants of colonialism—coffee, sugar, tea, quinine, cocoa, bananas, oil palm, rubber, cotton—suddenly grew legs. Rubber plants shipped from Brazil to Germany, where they were packed again to journey to Cameroon. Coffee from Ethiopia passed through Ceylon to land in East Africa. Live seedlings of cacao, pepper, Pará rubber, nutmeg, and vanilla orchid sailed from Madagascar to France. Tens of thousands of plants traveled in closed environments around the world. As settlers and plantation workers cultivated new ground, they lined up plants into row crops which radically changed their adopted landscapes, economies, and labor regimes.

Some plantation crops—bananas and corn—won entry into the Arizona biosphere, where the ship's crew carefully cultivated crops for their sustenance. Food was in short supply, but it was not the main problem. In film footage, the biospherians' faces are visible through the glass—drawn, tight grimaces. The camera catches the angry voices of two emaciated men, their belts pulled tight to hold up sagging pants. The men's chests heave as they struggle for air. Despite thousands of plants inside the biosphere, oxygen concentrations dropped. Plants breathed out oxygen as they photosynthesized, but once they expired, the decaying vegetal matter consumed oxygen and exuded carbon dioxide. The biosphere computers recorded a buildup of carbon and a net loss of oxygen. Biosphere designers had hoped for equilibrium. Instead, they got an unstable, shifting atmosphere.

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In 1869, the Suez Canal opened. Ships and trains powered by fossil fuels moved the vegetal cargo in the Wardian cases more quickly around the globe. In the wood and glass cases, tiny castaways—fungi, bacteria, and insects—also hitched a ride. In the United States, where nearly every commercial crop was non-native, most of the pests affecting farms and forests came from live-imported nursery stock. The chestnut blight (*cryphonectria*) arrived from Japan as auxiliary troops in the mass death of American chestnut forests. Liberian coffee rust set up a forward Atlantic post in Puerto Rico. In the 1920s, amidst mounting anxieties about epidemics and diseased migrants, seedlings of avocados, mangoes, pistachios, nectarines, and horseradish endured a vegetal quarantine before passing into the US.³ Plantation crops fueled European and North American economies. They powered invention, investment, industrialization, and urbanization. Plantation diseases triggered the abandonment of fields, farmers' bankruptcy, massive recurring famines, and the destruction of local and national economies. Meanwhile, native plants in newly-industrialized territories such as Pittsburgh or Cleveland lived under a ceiling of smog where plants struggled to transpire. Their growth slowed. Their leaves withered and turned yellow.



Inside Biosphere-2. Photograph by [Jasper Nance](#), 2010. [CC BY-NC-ND 2.0](#).

As oxygen levels sank, the biospherians' bodies transformed. Their hearts pumped faster. Their pulses increased. The men and women grew weak and thin. Seeking energy, their metabolisms slowed down.⁴ Food became scarce, and the team lost weight. Unable to breathe deeply, the biospherians suffered from sleep disorders. Short-circuit cameras showed them walking slowly, breathing heavily. They grew irritable. Arguments broke out. Finally, John Allen, Biosphere-2's research director, turned a valve that sent in a flush of oxygen. The response was immediate. The biospherians began to dance, leap, and run. The joy on their faces was broadcast widely.

Soviet engineers also experimented with regenerative life-support systems for space travel.⁵ In 1965 in the Siberian city of Krasnoyarsk, Evgenii Shepelev sealed himself in a 12-meter capsule connected through air vents to an 18-liter algal cultivator—his breathing machine.⁶ The job of the algae involved generating both oxygen and food for the cosmonaut. In this first attempt, Shepelev lasted 24 hours before stale air drove him to press the eject button. As Shepelev cracked open the sealed portal, his colleagues nearly swooned from the stench. Gases—methane, hydrogen sulfide, ammonia—produced by the algae had fouled the air (though Shepelev was oblivious to it).⁷ Shepelev kept working. He added more plants and systems to recycle water, stretching to many months the time he could remain in the tiny controlled environment.

A few years later, Soviet scientists attached a larger chamber to house plants more complex than algae. They renamed the larger vessel BIOS-3. Calculating that humans cannot live by algae alone, they included a wider range of crops—the hardy wheat and root vegetables, cucumbers, and dill of which Russians are fond. To tend their vegetal wards, the BIOS-3 cosmonauts passed through a sealed hatch from their chamber to the plant's quarters, called a phytotron. The psychological factor of having plants to care for lifted the scientists' spirits. The cosmonauts managed to live a full year

in the chamber with plant-supplied oxygen. BIOS-3 crops provided 80 percent of what they ate. This was a success until they realized one troubling fact. The vegetal co-travelers in BIOS-3 took in every small element around them, even those not in direct contact. Impurities in salts, soaps, and toothpaste (i.e., Ni, Cr, Al, Pb, Sn, and Ti) showed up in the edible plant matter. Plants absorbed other elements that came from construction materials, such as tiny amounts of lead in solder. A few harmful heavy metals, such as lead, chromium, and nickel, magnified in plants at rates 10 to 20 times higher at the end of the experiment than at the beginning.⁸ These toxins transferred from crops to the cosmonauts' bodies.

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The understanding that trace amounts of toxins in one part of a closed environment shift easily to other organisms rebounded around scientific institutions in the 1950s and 1960s. Tapping into deep pools of Cold War science funding, researchers acquired more sophisticated tools, such as phytotrons, chronographs, and radiation counters to follow molecules through biomes. In 1950, Caltech researchers imported Los Angeles smog into their phytotron, reversing Ward's experiment. They watched rows of spinach, endive, alfalfa, and oats wither from smog damage.

In the early 1960s, American biologists used human-made radioactive isotopes to track plant exchanges in a range of biomes indoors and out.⁹ Howard T. Odum wrapped a portion of a rain forest in Puerto Rico in plastic and dropped a radioactive cesium source into this closed environment. He and his team returned later to find the isotopes had traveled all over the forest. From trees to soils, soils to roots, and fungi to bacteria, radioactive cesium had entwined itself into organisms throughout the forest. Odum named the interconnections he traced with radioactivity "systems ecology."¹⁰ For biologists long used to isolating "individuals" or to circumscribing a local ecosystem, this realization was ground-breaking.

In short, during the postwar decades, Soviet and American scientists came to similar conclusions—the atmosphere worked like a vast ocean mixing whatever was in it. In a closed environment, minerals, elements, and pollutants zipped about like urban commuters on a Monday morning. They biomagnified efficiently to concentrate in the food chain. As this science became known in the 1970s, Peter Sloterdijk argues, the air humans so thoughtlessly breathed suddenly appeared fragile, destructible. That opened the door for what Sloterdijk calls a "greenhouse democracy"—a recognition of ecological interconnectedness. Like the biospherians struggling for breath in the Arizona desert, the air had to become unbreathable, he writes, "for people to learn to recognize themselves as guardians, reconstructors, and re-inventors of what had merely been taken for granted."¹¹

Scientists' grasp of interconnected ecosystems elicited a burst of environmental movements in the 1970s, but also some soothing notions that Earth could right itself. James Lovelock postulated that the Earth is a self-regulating system that would correct human-driven imbalances. He and Lynne Margulis named planetary homeostasis "Gaia." Leah Aronowsky shows how Shell Oil executives, worried about rising levels of CO₂, funded James Lovelock's Gaia research.¹² They rounded to the conclusions of Gaia—that if the Earth will right itself, there was no need for humans to take any corrective action. Perhaps for this reason despite new environmental movements and environmental protection agencies in the 1970s, the spread of toxins in subsequent decades magnified to historic heights around the planet.

These new threats came not as the result of violence or aggression but from ideas spawned in the name of a life-affirming optimism. American and European inventors and policymakers after two world wars fought valiantly to come to solutions to the longstanding problems of human society—war, famine, and mass poverty. They ingeniously devised manmade chemicals, radioactive isotopes, and anti-viral and anti-bacterial agents that promised to end infectious disease, while producing enough energy, food, housing stock, and consumer goods to feed and shelter everyone. New satellites circling the earth prospected for minerals and fossil fuels on a global scale.¹³ Powerful new machines dug them out and turned them into consumer goods at unimaginable volumes and speeds.

Consumption is totalizing and transformative. As humans consume, they eat the detritus of the technologies they have devised. They consume their own inventions, their own genius—literally. Pesticides, dioxins, glyphosate (Roundup), microplastics, antibiotics, cesium-137, and strontium-90 crowd into the corpus. No single body is pure. We have had a hard time seeing this obvious fact because one outcome of the twentieth century's cult of private property is a false impression that individual bodies are inviolable, discrete entities; that health, rather than a public affair, is a personal endeavor derived from one's lifestyle choices and genetic heritage. These ideas were useful because twentieth-century humans in the global north came to believe, as they consumed goods that poisoned the environments around them, that those with privilege and property could secure their well-being in controlled environments of dearly-purchased homeownership, automobiles, pension plans, and individualized health care. That myth shakes down, a tree shedding its leaves, as more and more people fall ill from "diseases of civilization."



Lead image, *Biospherians*, 1991. Photo by Deborah Snyder. Courtesy of the [Institute of Ecotechnics](#).

Biosphere-1

Cold War scientists scrolling the globe for research sites discovered that humans in the Anthropocene are located not in a human-made Biosphere-2, but in Biosphere-1 (Earth), a closed, controlled environment with limited resources, struggling in many different ways to breathe.¹⁴ Since 2014, the words "I can't breathe" have echoed across American cultural life. These were the last words uttered by Eric Garner, strangled in 2014 in a chokehold by a NYPD police officer, and by George Floyd in 2020, killed by Derek Chauvin's knee to his neck. Black Lives Matter protestors chanted "I can't breathe" at rallies. Firemen fighting California infernos and COVID-19 patients rushed to ventilators uttered the same short sentence. On 6 January 2021, as Rosanne Boyland lay crushed under a mob, Trump supporters besieging the US Capitol began to chant "I can't breathe!" in a cruel mimicry of Black Lives Matter protestors. Ross Gay's poem [*"A Small Needful Fact"*](#) remembers that Eric Garner worked as a gardener, placing plants into earth, plants that still might

be living, continuing to do what plants do “like converting sunlight / into food, like making it easier / for us to breathe.”¹⁵

Black Lives Matter protestors chanted “I can’t breathe” at rallies. Firemen fighting California infernos and COVID-19 patients rushed to ventilators uttered the same short sentence.

Of late, in many ways we are reminded that breathing is a human being’s primary act.¹⁶ And her last. Ross Gay’s poem points to how the act of breathing and of not suffocating is wrapped up in plants that give humans the oxygen we breathe and the worlds we inhabit. In fascinating ways, Cold War scientists came upon this insight as they imagined living on planets with no atmosphere. The Wardian cases designed to transport humans away from Earth led them back to a better understanding of Earth’s interwoven dependencies.



An “I Can’t Breathe” sign in Minneapolis, two days after the death of George Floyd. Photo by [Lorie Shaull](#). CC BY 2.0.

A New Imaginary

Humans understand the world by imagining it. Historians feed imaginations with stories of the past. If a historian follows humans, then history takes the shape of an escalator rising from the ground. Each century the edifice levitates in a narrative of progress. Aristotle started thinking of human history as an endeavor to be narrated separately from nonhuman history. According to philosopher Matthew Hall, Aristotle classified plants as without sense or intelligence, as dumb and vegetal.¹⁷

Women, slaves, and the colonized subsequently fell into the same vegetal or animal taxonomies, categorized as dull and without feeling. Anthropologist Eduardo Viveiros de Castro describes this trend as the colonization of anthropocentric reasoning.¹⁸ In time, European scientists looked to the plant world for inspiration and metaphors. They created a “tree of life,” a systematic way to exclude more humans and species as castaways from the escalator of progress. As social scientists fixed their understanding of “nature” into metaphors for living in the world, ideologies emerged to match them.¹⁹ Darwin’s proselytizers viewed species as being in competition with each other for scarce resources, a conceptual turn that influenced business and political leaders to see “survival of the fittest” as a motto for enterprise and diplomacy.²⁰



(Left) A microbe among *Arabidopsis* plant roots. Courtesy of [Pacific Northwest National Laboratory](#). [CC BY-NC-SA 2.0](#). The image has been cropped. (Right) The exterior of Biosphere-2. Photo by [CGP Grey](#). [CC BY 2.0](#).

If, however, a scholar follows plants, history becomes more interesting.²¹ Light travels from the sun to earth. Plant pigments fix solar rays, turning them into energy. The plants take off. The roots of some grasses can grow nearly one hundred kilometers of underground capillaries in one night. With each revolution of the earth, plants create vegetal structures. Humans use that architecture. On their path of growth, plants take light and shape it into the physical elements that become human memory.²² Following plants, history takes a different shape. It rides along wave-like, cycles back onto itself, reincarnates past living beings to make contemporary living organisms, and connects objects and organisms that western culture has been slow to see as interdependent. Plants create,

transduce, communicate, produce, resist, build up, and break down. Micheal Marder sees plants as the mediators between hard and soft realities—ground and gases, water and wavelengths, mineral and microbial.²³ From the perspective of the vegetal realm, history is a symphony to which every living being contributes.

We know so much more about Biosphere-1 (Earth) thanks to Biosphere-2 and BIOS-3. Locked in closed chambers with oxygen-producing plants, scientists recognized a form of sentient life that western culture had long overlooked. Plants, it turns out, can communicate with one another and with other species. Plants make sounds, send chemical and aerosol signals. Plants “speak.” They have memory and can learn. Plants form communities with insects, microbes, fungi, and viruses. To be a “vegetable” is no longer to lay inert, unconscious, uncommunicative. Plants have relationships, intelligence, and even, some scientists venture to say, consciousness.²⁴ Working with microbes and fungi, they adapt to alterations in climate, pests, and other malevolent forces. Microbes are another underrated strata of life. They swap strands of DNA with each other to evolve continuously so they can live in extremely toxic environments. In this way, microbes are the mediators that help humans and other animals adjust to their environments. Increasingly, biologists have trouble distinguishing individual trees in a forest, so bound up are they with the lives of other plants, fungi, and microbes. All those creatures out there are not only in competition with one another. They flourish, thrive, and rejuvenate in concert. The forest is a commons. So is a savannah, so is my little garden across the street.

To be a “vegetable” is no longer to lay inert, unconscious, uncommunicative. Plants have relationships, intelligence, and even, some scientists venture to say, consciousness.

And that is good news. The commons lie within. There is no need to build a commons from scratch. Humans who are concerned can act to reconstruct the social imaginary to envision the pulsing webs between humans and plants, humans and animals, and the invisible yet sensible “dark matter” that inhabits us to create the extended body and extended, shared consciousness.

What good, you may ask, will that do?

The imaginary is a powerful tool. In the past, by imagining humans as elevated from other earthly creatures, elites armed with scientific thought rationalized hierarchies based on gender and race. Indigenous scientists and advocates of a new animism (that draws from Indigenous worldviews) point to a different imaginary. They note how Indigenous peoples, healers, peasants, farmers, scientists, and shamans work with plant life collaboratively. Coming to respect this knowledge can help decolonize history and treat the wounds of three centuries of exploitation.²⁵ People who were long seen as unreliable sources of information now appear to have wielded accurate knowledge on the sensitivity, plasticity, and vitality of plants and soils, while mid-century scientists promoting mass cloning of plants and chemical additives that sterilize soils and kill insect life appear to have been wrong in many basic assumptions. The plant imaginary might help release the fern from the bottle and humans from fears of their own environment closing in around them.

Notes

¹ Luke Keogh, *The Wardian Case: How a Simple Box Moved Plants and Changed the World* (Chicago: University of Chicago Press, 2020).

² Roy L. Walford, Dennis Mock, Roy Verdery, and Taber MacCallum, “Calorie Restriction in Biosphere 2: Alterations in Physiologic, Hematologic, Hormonal, and Biochemical Parameters in Humans Restricted for a 2-Year Period,” *The Journals of Gerontology: Series A* 57, no. 6 (June 2002): B211–B224.

³ Keogh, *The Wardian Case*: 168–69, 175, 190.

- ⁴ Mark Nelson, a biospherian, notes that in the second year they became better farmers and grew two tons of food, regained some weight, and adapted to less oxygen and few calories. See Mark Nelson, *Pushing Our Limits: Insights from Biosphere 2* (Tucson: University of Arizona Press, 2018) and Abigail Alling, Mark Nelson, and Sally Silverstone, *Life Under Glass: Crucial Lessons in Planetary Stewardship from Two Years in Biosphere 2* (Santa Fe: Synergetic Press, 2020).
- ⁵ The decree to initiate biomedical studies on humans to withstand space flight dates from 1959. "On Strengthening Scientific-Research Work in the Field of Biomedical Support to Spaceflight," [Communist Party of the Soviet Union Central Committee \(CPSU CC\) Soviet Union. Council of Ministers](https://digitalarchive.wilsoncenter.org/document/208938), Wilson Center Digital Archive, accessed July 16, 2022, <https://digitalarchive.wilsoncenter.org/document/208938>.
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- ⁷ Kevin Kelly, *Out of Control* (London: 4th Estate 1994): 140, <https://kk.org/mt-files/outofcontrol/ch8-c.html> and Lydia Kallipoliti, *The Architecture of Closed Worlds: Or, What is the Power of Shut?* (Baden: Lars Müller Publishers, 2018).
- ⁸ Salisbury et al., "Bios-3: Siberian Experiments in Bioregenerative Life Support," 582.
- ⁹ Laura J. Martin, "Proving Grounds: Ecological Fieldwork in the Pacific and the Materialization of Ecosystems," *Environmental History* 23, no. 3 (2018): 567-92.
- ¹⁰ See Joel Bartholemew Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology* (New Brunswick, N.J.: Rutgers University Press, 1992): 103-17.
- ¹¹ Peter Sloterdijk and Wieland Hoban, *Foams. Spheres Volume III: Plural Spherology* (South Pasadena, CA: Semiotext(e), 2016).
- ¹² Leah Aronowsky, "Gas Guzzling Gaia, or: A Prehistory of Climate Change Denialism," *Critical Inquiry* 47, no. 2 (2021): 306-27.
- ¹³ Megan Black, *The Global Interior: Mineral Frontiers and American Power* (Cambridge, MA and London: Harvard University Press, 2018).
- ¹⁴ For an analysis of the Earth as a closed system in a technosphere, see P. K. Haff, "Technology as a Geological Phenomenon: Implications for Human Well-Being," *Geological Society, London, Special Publications* 395, no. 1 (2014): 301-9. For studies of closed environments, see David P. D. Munns, *Engineering the Environment: Phytotrons and the Quest for Climate Control in the Cold War* (Pittsburgh: University of Pittsburgh Press, 2017): xvii-135 and Kallipoliti, *The Architecture of Closed Worlds*.
- ¹⁵ Ross Gay, "A Small Needful Fact," Poets.org, <https://poets.org/poem/small-needful-fact>.
- ¹⁶ On this point, see Emanuele Coccia, *The Life of Plants: A Metaphysics of Mixture* (Medford, MA: Polity, 2018).
- ¹⁷ Matthew Hall, *Plants as Persons: A Philosophical Botany* (Albany: State University of New York Press, 2011). For the passage on the incorporation of Aristotle's tripartite division of nature into Christianity, see p. 42.
- ¹⁸ Eduardo Vivieros de Castro, *Cannibal Metaphysics* (Minneapolis: University of Minnesota Press, 2014).
- ¹⁹ For the power of these metaphors, see Rob Nixon, "The Less Selfish Gene: Forest Altruism, Neoliberalism and the Tree of Life," *Environmental Humanities* 13 (2021): 13.
- ²⁰ David Sepkoski, *Catastrophic Thinking: Extinction and the Value of Diversity from Darwin to the Anthropocene* (Chicago: The University of Chicago Press, 2020), 9-10.
- ²¹ See Catriona Sandilands' definition of critical plant studies and Indigenous ideas of plants as teachers in "Plants," (draft), https://www.academia.edu/50913305/Plants_Matter_draft_.
- ²² Kate Wright, "In the Shadow of a Willow Tree: A Community Garden Experiment in Decolonising, Multispecies Research," *Cultural Studies Review* 24, no. 1 (2018): 74-101.
- ²³ Michael Marder, *The Philosopher's Plant, An Intellectual Herbarium*, Part III, "Modern Plant Images" (New York: Columbia University Press, 2014).
- ²⁴ For a review of literature related to the "plant turn," see Teresa Castro, "The Mediated Plant," *e-flux Journal*, September 2019, <https://www.e-flux.com/journal/102/283819/the-mediated-plant/>.
- ²⁵ On new animism, see bethany oja-lehto mays, Rebecca Seligman, and Douglas L. Medin, "Cognition Beyond the Human: Cognitive Psychology and the New Animism," *ETHOS* 48, Issue 1 (2020): 50-73.



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