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Sentient Plants: A Product of Nature or Human Imagination?

By Krissy Eliot

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Sentient Plants: A Product of Nature or Human Imagination?

By Krissy Eliot

Cover: Trees at Plaza San Martín in Buenos Aires, Argentina.
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A phenomenon called crown shyness describes the gaps that trees—usually of the same species—maintain between their top-most branches. This is one strategy trees have adopted to protect themselves and the collective forest from pests, diseases, and severe winds and storms. ("Trees Have Their Own Way of Social Distancing," by Zoe Baillargeon, *Atlas Obscura*, Sept. 8, 2020)

Krissy Eliot

SENTIENT PLANTS:
A Product of Nature or Human Imagination?

Monica Gagliano is lying in a hammock in the Amazon jungle. She has been consuming nothing but rice, vegetables, and mashed tree bark for weeks, and is having powerful dreams. She is on what the Shipibo people of the Amazon lowlands of Peru call a *dieta*, a practice of communing with a plant by ingesting it in isolation without the distraction of sex, friends, or tasty food. The bark is from the tropical Socoba tree, more commonly known as Bellaco-caspi (*Himatanthus sucuuba*), and through the dieta, the Socoba has been revealing powerful secrets to Gagliano—like how the plant is actually a "she," and how *she* can be used as a "blood cleanser."

In one of her dreams in the hammock, Socoba shows Gagliano a dark red image with thick black lines, and Gagliano awakes to write upon her notepad: *todas las cosas estan juntas* (all things are connected). "I suddenly understood what Socoba was saying—'it is through the blood that everything is connected,'" Gagliano writes in her book *Thus Spoke the Plant*, which chronicles her many plant dietas, as well as her scientific plant studies. "I knew without knowing that Socoba was a blood cleanser, the healer of conditions that affected the blood and the network of vessels that ensure the smooth flowing of blood inside the human body."

Upon Gagliano's return to her life as a scientist in Australia, she checked what she learned. The ideas Socoba had planted in her head are true according to the scientific literature, with decades of pharmacological research showing the benefits of Socoba for maintaining healthy blood pressure, preventing anemia, and dealing with inflammation-related diseases. Since Gagliano had no knowledge of this before meeting Socoba, this proved to her that "plants and nature can be heard," and that her role going forward would be to allow them to speak through her.[1]

After this, Gagliano became a self-proclaimed "custodian of the vegetal world," with a purpose of communicating the complex, subjective experience of plants through her writing and scientific research. Her book is about plants and by plants. "It is a phytobiography—a collection of stories, each written together with and on behalf of a plant person," writes Gagliano. "As such, these stories emerge out of a human-plant collaborative endeavor and a mixed writing style, which I think we can fittingly call plant-writing. Through plant-writing, this book transcends the view of plants as the objects of scientific materialism and empowers a new and yet timeless vision of the world…"[2]

While not every scientist is chewing the fat (or the bark, rather) with jungle trees, there is a scientific consensus that plants can receive and process information from the environment in complex ways. They have memory, are capable of decision-making, and even possess their own versions of all five human senses. Considering these findings, some scientists say that plants are not only *intelligent*—but even *conscious*—and that this should change how we understand and interact with plants forever.

Stefano Mancuso, a professor at the University of Florence and founder of the controversially named International Laboratory of Plant Neurobiology (LINV), supports the idea that plants may be sentient. According to the LINV website, plants are as sophisticated as animals. They are highly sensitive, intelligent, capable of cost-benefit analysis, and able to recognize their separateness from other things—the difference

David Maurice Smith

Evolutionary ecologist Monica Gagliano

Chaikuni Institute

What does Bellaco-caspi (*Himatanthus sucuuba*) know about blood cleansers?


Plant neurobiologist Stefano Mancuso

between self and non-self.[3]

"In the last several decades science has been showing that plants are endowed with feeling, weave complex social relations and can communicate with themselves and with animals," writes Mancuso and science journalist Alessandra Viola in the book *Brilliant Green*, which champions the concept of intelligent, sensitive plants. "How these brilliant creatures get information and process it in a way that results in consistent behavior is the focus of plant neurobiology."[4]

Scientists like Mancuso and Gagliano have a habit of using anthropomorphic terms to describe plant life, and also suggest that plants can do things like "eat," "sleep," and "choose." Many botanists find these comparisons problematic and confusing for the public, with the use of the term "plant neurobiology" being a particularly thorny issue.

But before we scurry down the rabbit hole of plant consciousness—let us first squirm down the wormhole of time to when the seeds of vegetal sentience started to sprout in America. It all started with a book.

The Secret Life of Plants

One night in the mid-1960s, Cleve Backster, interrogation specialist for the CIA and reputed founder of the agency's polygraph program, thought of lighting a plant on fire. Not at first, of course. Out of sheer curiosity, he had hooked the plant up to a polygraph machine, usually used to measure respiration rate, pulse, and skin perspiration in humans. He wanted to see if more moisture would enter the plant's leaves and produce a certain type of reading when watered. When he didn't get the reading he wanted, he decided to burn the plant to see what would happen.


Cleve Backster

But just as the thought of retrieving a match entered Backster's mind, the plant's reaction was "off the charts"—with the tracings from the needle of the polygraph going right off the top of the page. From this, he concluded, the plant had not only shown great fear of the pain that could be inflicted on it, but had demonstrated what he called "primary perception," telepathic abilities similar to what is more commonly known as extrasensory perception (ESP).[5] As the founder of New York's Backster School of Lie Detection, where he taught FBI agents and NYPD detectives how to sniff out the real story with polygraphs,[6] he was confident that his conclusions were correct. "I like to think of the polygraph," Backster once said, not as a lie detector, but "as a truth detector."[7]

Backster's experiment and a series of other controversial findings were featured in *The Secret Life of Plants*, a book that was eventually turned into a movie that was scored by Stevie Wonder. The book was written by author Christopher Bird and journalist Peter Tompkins, a former World War II Office of Strategic Services (OSS) spy.[8] Many of the experiments in *The Secret Life of Plants* were eventually discredited due to inadequate methods or an inability to reproduce results. The film version, for instance, suggested that plants are capable of learning human language, perceiving electronic signals better than machines, communicating with the stars, and even identifying which humans have hurt them in the past.[9]

Backster's experiment has been the subject of much scientific criticism, with plant scientists taking it upon themselves to do some "truth detecting" of their own. "The polygraph experiment is a stupid experiment because even with inhuman physiology, there's not a complete consensus on how valid polygraphs are," says plant geneticist Daniel Chamovitz, president of Ben-Gurion University of the Negev. He explains that polygraphs, like other machines, show physiological responses that don't have anything to do with stress, conscious perception, or even being alive. "You could also do an MRI on a dead salmon and get a response."[10]

It happened. In 2009, researchers published a study in the *Journal of Serendipitous and Unexpected Results* showing that fMRI machines, used for measuring changes in blood oxygenation levels in the brain, can produce red herrings. They used an fMRI machine to observe a salmon they picked up fresh from the store, and discovered "neural activation" in the little brain of a dead fish.[11]

If Backster's plant polygraph test were a legitimate scientific experiment, Chamovitz insists, it would have been repeated multiple times already by credible scientists. "This is such an easy experiment to do. Why are there no articles that use this?" Chamovitz asks. "Scientists are not always the most original people in the world. We want to publish! Anyone in any university throughout the world could be doing these experiments. Where's the data? It's not there."[12] At present, there's no scientific evidence that plants feel fear, as Backster surmised from the polygraph readings.


Dani Machlis/University Photographer

Plant geneticist Daniel Chamovitz

Plants don't have nocioreceptors, which are sensory neurons that alert the spinal cord and brain to potential threats. While plants can be mechanically stimulated to react, as far as scientists know, a frontal cortex is what defines and mediates emotional status—and plants don't have one. There also isn't adequate evidence to support that plants feel any pain to be afraid of. "In the absence of pain receptors, in the absence of a frontal cortex," Chamovitz says, "I think it's pretty clear that plants don't feel pain."

The urge for humans to attribute pain to plants comes from a false assumption that tissue damage results in a pain response, Chamovitz adds. "We have no pain receptors in our brains. You can cut the brain and you don't feel a thing, though obviously you're causing tissue damage. Damage does not equal pain."[13]

Which means all fruit lovers can mercilessly tear into the supple flesh of peaches without a hint of regret. Or is it possible you just can't hear their screams? Researchers at Tel Aviv University in Israel published a study in bioRxiv, an online archive of studies that have yet to be peer-reviewed, showing that tomato and tobacco plants emit ultrasonic sounds when under stress. Because plants emit sounds at a high frequency that people can't hear, the scientists set up microphones close to the plants and subjected one section of crops to drought, snipped the stems of another group, and left a third control group untouched. They found that each species of plant made different sounds at various rates depending on the stress they endured, an interesting finding that could help farmers determine what stressors are impacting their fields going forward.[14]

But a high frequency sound is not necessarily a "scream," just as an injury to a plant does not equate to pain. Plants respond to stress in myriad ways through habitual physiological responses—such as releasing chemical compounds or changing shape and color to ward off herbivores. The jury is still out on whether these are merely habitual physiological responses or "intentional" changes that require consciousness.

In a 2013 interview for *The New Yorker*, Mancuso and cell biologist František Baluška told journalist Michael Pollan that it's possible that plants are conscious, and if they are, then pain would be a fundamental tool for staying alive. "If plants are conscious, then, yes, they should feel pain. If you don't feel pain, you ignore danger and you don't survive. Pain is adaptive," Baluška says. "That's a scary idea. We live in a world where we must eat other organisms."[15]

For a while, plants were thought to be extremely simple beings that couldn't hold a candle to animals and humans (and not just because they don't have opposable thumbs). Over the last century or so, it's become more accepted in the scientific community that plants have senses similar to ours. In their own plant way, they can touch, smell, see, taste, and hear what's around them. They also sense a lot of things that humans can't, like soil humidity, gravity and electromagnetic fields (which can influence how they grow), and chemicals in the soil and air.

And it makes sense that plants would evolve to have these senses, and then be able to take actions based on the information they receive. Without the ability to understand the environment and adapt, there's no way that plants would have been able to survive to dominate over 80 percent of the Earth.

But do these actions and behaviors, while appearing similar to ours, actually equate to those of human behavior? Do their abilities signal intelligence or consciousness? How much are plants really capable of, and how much do we really have in common?

Signs of Intelligent Life

Can Plants Sleep?

At the end of a long day, we humans are known to sag a little as we sink into our favorite chair or crawl into bed. But recent evidence shows that the end-of-the-day sag may not be unique to our species. Scientists from Austria, Finland, and Hungary used lasers to measure the movements of birch trees overnight, discovering that in darkness, the tree branches would actually start to droop by as much as four inches, suggesting the trees may be resting.[16] "It was a very clear effect and applied to the whole tree," says lead researcher Andras Zlinsky in an interview with *New Scientist.* "No one has observed this effect before at the scale of whole trees, and I was surprised by the extent of the changes."[17]

The researchers suggest that the drooping is possibly caused by something called turgor pressure, a phenomenon where internal water pressure changes within plant cells, and the branches and stems become a little less stiff. Since turgor pressure is caused by photosynthesis (the process of creating food from water, carbon dioxide, and sunlight), the trees appear to be "relaxing" at night when there's no sun to photosynthesize with.

Another explanation, the researchers say, is that the trees may be tuned to a kind of sleep-wake cycle. During the day, the leaves and branches use energy to reach toward the sunlight, but at night, they may just be chilling out, relaxing.[18] But whether this idea is actually true, Zlinsky says, "remains to be decided."[19]

Other studies have shown that plants assume different positions at night that vary depending on the species. When the moon rises, lupines turn their leaves down, spinach plants straighten their leaves toward the top of the stems, trefoils wrap their leaves around their flowers, the list goes on.

But just because plants are going through a process that appears similar to sleep, does that mean that they can be *unconscious*—and therefore, during the day, be *awake* and *conscious*?

Some plant neurobiologists say yes, pointing to the results of a study published in *Annals of Botany* showing that anesthetics cause *Mimosa pudica* plants, pea tendrils, Venus flytraps, and sundew traps to lose their autonomous and touch-induced movements, just like animals.[20] But other scientists take issue with this conclusion.

Noah Elhardt/ WC/ CC 2.5

What happens when a Venus Flytrap "goes under" with anesthesia?

Anesthesia is a chemical that blocks ion transporters that cause changes in the cell membranes. Those ion transporters are conserved among all organisms, so it makes sense that ion transport in both plants and animals stops when the chemical is administered. But this doesn't mean that plants are "going under" with anesthesia the way humans are.

"In the Venus flytrap, [anesthesia] stops it from closing," Chamovitz says. "It can no longer respond to the fly touching it, but it doesn't mean it's unconscious. It just means that it was given an anesthetic."[21]

Recognizing Friend or Foe

Whether they're conscious, awake, or just in a perpetual state of being plants in this wild, wild world, they definitely aren't just sitting around like bumps on a log (unless the plants are growing on a log, that is). They've got things to do, like reap nutrients from the soil, assess potential threats, and survive!

One of the ways they do this is by identifying their allies and enacting soil plots against their enemies. In 2007, Susan Dudley, a plant evolutionary ecologist at McMaster University, and researcher Amanda File tested if plants could recognize their kin, and if that recognition would lead to different behavior for the American searocket (*Cakile edentula*), a North American succulent. In the experiment, they grew 30 searocket seeds in one pot, and then grew 30 seeds from different plants in another pot. The plants in the "melting pot" decided that it wasn't big enough for the 30 of them, and each plant developed a great number of roots to disadvantage their adversaries and assure they'd get more water and nutrients. In the pot with the 30 members of the searocket clan, however, each plant produced much fewer roots, giving their family a better chance at aerial growth.

"Our results demonstrate that plants can discriminate kin in competitive interactions and indicate that the root interactions may provide the cue for kin recognition," the authors write in their study, published in The Royal Society journal *Biology Letters.* "If kin discrimination via root-root interactions proves widespread, it will profoundly change how we view competition in plants."[22]

A-P Drapeau Picard/WC/CC1.0

The American searocket (*Cakile edentula*) can recognize its kin.

Since then, more evidence has emerged that plants might recognize and cooperate with kin. In 2018, researchers at the University of Lausanne in Switzerland and the Spanish National Research Council placed more than 700 Spanish herb seedlings in pots with different configurations: some were in groups of unrelated plants, while others were in groups of the same mother but with different fathers. The results showed that plants grown with kin develop more flowers, with the presumed aim of wanting to attract more insects for pollination.

"Those growing with kin, particularly at high density, produced larger floral displays than those growing with non-kin," the study authors conclude in the journal *Nature Communications.* "Investment in attracting pollinators was thus moulded by the presence and relatedness of neighbours, exemplifying the importance of kin recognition in the evolution of plant reproductive strategies."

The researchers go on to suggest that the plants' behavior may be altruistic because they're making more flowers to help others with pollination at the expense of individual seedmaking.[23]

But just because plants may be communicating doesn't mean they're intentionally trying to help out their brothers and sisters in any way. "Here we're getting into a question of intention—and there are no plant psychologists," Chamovitz says. "We can't ask a plant, 'What do you mean?'"[24] (Though Gagliano and her friend Socoba may beg to differ.)

While a number of mathematical models show that altruism is an important strategy in biology, and plants may benefit from it, it's possible that plants are emitting chemicals into the air as a reactionary physiological response, and other plants are just listening because they happen to be in "earshot." "It's like when the National Security Agency is eavesdropping on your phone," Chamovitz says. "You're not meaning to communicate with them, but they're getting information from you."[25]

Or maybe there really is more to it.

Communicating on Purpose

Usually, plants pass information to one another through chemical molecules and herbivore-induced volatile organic compounds. These signals can alert other plants of predators and cause them to raise their chemical defenses. While it's been known over the last few decades that plants use chemical signaling to send messages to each other and to pollinators, the general understanding has been that, as Chamovitz suggests, anybody nearby can pick up on the transmissions.

But in 2013, researchers at University of California Davis, Kyoto University, and Niigata University discovered that it may not be so easy for anyone close by to "listen in." In fact, according to their study published in the *Proceedings of the Royal Society B*, plants may be able to send out chemical signals targeted to family members.

Researchers clipped sagebrush bushes (*Artemisia tridentata*) to mimic the experience of being nibbled on by predators like deer and caterpillars. Sagebrush bushes that received cues from closely related wounded relatives experienced less damage over the growing season than those who were exposed to


Peemus/WC/CC3.0

Sagebrush bushes (*Artemisia tridentata*) receive cues about predators from wounded relatives.

cues from wounded neighbors that were more distantly related.[26] "Why would plants emit these volatiles which become public information? Our results indicate that the volatile cues are not completely public, that related individuals responded more effectively to the volatiles than did strangers," says study co-author Richard Karban in an interview with UC Davis' *Entomology and Nematology News*. "This bias makes it less likely that emitters will aid strangers and more likely that receivers will respond to relatives."[27]

In 2014, the researchers did a follow-up study published in the journal *New Phytologist* showing that sagebrush volatiles can roughly be grouped into two chemotypes: thujone or camphor. They discovered that sagebrushes with the same chemotype communicated better and were eaten less by predators compared to nearby plants of differing chemotypes, showing that chemotypes may be a way for the plants to distinguish relatives from strangers.[28]

Moving forward, these kinds of insights could help agriculturalists devise more effective farming practices. "Ultimately, we would like to be able to understand the chemical nature of the volatile cues, how plants use them to communicate, and whether as agriculturalists, we can control host plant resistance to herbivores," Karban says.[29]

An even more surprising discovery regarding plant communication happened in the early 2010s, when Gagliano and a team of researchers found evidence that plants may be able to communicate even when all chemical signals are blocked. In a series of experiments, chili seeds were grown inside different cylindrical boxes for several months with all airborne chemical signals, light wavelengths, and direct contact blocked. Some of the chili plants grew on their own, while others were surrounded outside the box by basil or fennel—plants selected because of their opposing effects on chili. Fennel is a plant known to kill other plants in its vicinity by emitting aggressive chemicals, whereas basil is a companion plant that can act as a natural insecticide and keep the soil moist.

Despite all blocked signals, Gagliano discovered evidence that the chili plants understood whether basil or fennel was nearby and actually changed their behavior accordingly. The germination rates of the chili seeds were low when grown on their own, hindered when near fennel, and improved in the presence of adult chili plants and basil. "These results provide clear experimental evidence for the existence of communication channels between plants beyond those that have been recognized and studied thus far," the researchers conclude in their study, published in *PLOS One*.[30]

Of course, when it comes to communication and cooperation, we'd be remiss not to shine a light on those that have long cast a shadow over the plant kingdom in such matters: trees.

The Wood Wide Web

While trees have historically been considered statuesque loners, evidence indicates that they are a part of an underground collective that's constantly communicating, exchanging nutrients, and performing righteous acts of altruism. Their ability to do this is facilitated by a cooperative network of fungi and tree roots—what scientists are now referring to as the "wood wide web." In this network, fungi and trees have a symbiotic relationship. Trees provide fungi with about 30 percent of the sugar they photosynthesize from sunlight, and in exchange, the fungus provides messenger and delivery service between the trees' roots.

Like other plants, trees send chemical signals to warn neighbors to raise their defenses, and they use the fungal network for this purpose. But they also use the network to work together like a giant family unit, one that would seemingly do anything to keep its kin alive. Healthy trees will send a flow of radioactive-marked sugar molecules to sick trees to provide an equal measure of food and energy. Older, more dominate trees in a network, often called "mother trees," use the network to provide their seedlings with sugar and excess carbon to give them a better chance of survival. They also use it to sense their seedlings' location and adjust their roots for the greater benefit of their family.[31]

In 2016, German forester and author Peter Wohlleben caused quite a stir in the plant biology community with his book *The Hidden Life of Trees*. According to Wohlleben, trees have individual character, emotions, and experiences, and they are great altruistic healers. "Trees have just as much character as humans do. They also exercise independent judgments, which can differ," says Wohlleben in an interview with the Yale School of Environment. "Trees of the same species and age living right next to each other shed their leaves weeks before their neighbors. I'm not sure why some choose to do this earlier and others later, but it shows that there really are differences of character that we can't easily account for."[32]

Trees go to great lengths to see that their kin live long, even if said kin is nothing more than a stump. Wohlleben tells a particularly fascinating story of a beech tree that was cut

Forrester Peter Wohlleben

over four centuries ago. He found that it still had green chlorophyll under the thick bark. Without its own leaves to make sugar, Wohlleben surmised that the neighboring trees must have been working together to keep the chopped tree alive all this time. Why exactly they have done this, however, is a stumper.

Trees even show that they can possess what Wohlleben refers to as unique "friendships," distinguishing one tree from another, and not treating all trees the same. In his experience as a forester, he's noticed that tree pairs who take care of one another (adjusting their branches to make room for each other and consistently sharing nutrients) are connected the way human couples are—in that you could kill one and the other would die soon after.[33]

And trees don't only help others of the same species. While trees of varying species do compete and will try to sabotage one another if need be, they also cooperate and keep each other alive. Ecologist Suzanne W. Simard, who in 1997 helped spark the wood wide web craze with her discovery that Douglas fir trees use an underground network to interact, found that Douglas fir and paper birch trees will send nutrients and carbon back and forth to help each other. In a study published in *New Phytologist*, Simard and other researchers discovered that when a Douglas fir found itself in shade in the summer, any excess carbon from a paper birch was transferred to the Douglas fir. In autumn, as the paper birch began to shed its leaves, the Douglas fir had excess carbon from continuing to photosynthesize, so that excess carbon was sent to the birch.[34] Simard theorizes that the fungus in the network is amendable to helping with these transfers to maintain its livelihood.[35]

Walter Siegmund/WC/CC3.0

Douglas firs (*Pseudotsuga menziesii*) use an underground network to interact with paper birch trees.

Kevin Beiler, a PhD student working with Simard at the University of British Columbia in Canada, created a map of two related mycorrhizal fungi that link Douglas fir trees in a forest. Aside from a few exceptions, he found that all trees were linked, and those with the most connections were the oldest trees with the more established, large root systems—and they were responsible for helping to maintain the health of the network.[36]

The knowledge of this symbiotic, altruistic network of trees could help inform our forest management systems and even encourage us to change them, according to Wohlleben.[37] A common practice in forestry is to cut down trees to eliminate competition and encourage the growth of others. But when old trees are cut down, the young trees lose the network responsible for maintaining the health of the species. While young trees may grow at a more rapid rate when other trees are cut down from being exposed to more sunlight, growing too fast can actually sap their energy and make them more susceptible to illness and wounds—leading to rot and early death.

Wohlleben compares the practice of cutting down old trees to make room for new ones to shooting someone's parents to give kids more space to live in the house. "You slaughter their mother and the young trees will grow very fast," Wohlleben says, "but they will be unhealthy and have short lives."

In the forest he manages in the Eifel mountains in Germany, Wohlleben does not participate in clear-cutting, nor does he use heavy machinery or toxic chemicals that can kill beneficial microorganisms and insects. He suggests that foresters only grow tree species that are natural to the area they're managing and keep forest systems diverse, valuing trees both young and old.[38]

After all, if you were going to buy the idea that plants are capable of intelligent behavior and wisdom, who could be more wise than elder trees, some of the longest-living creatures on Earth?

Plant Memory: Not Your Mother's Memory

Memories are seen as a critical element of human consciousness. They can function as defining moments in our lives, shaping how we behave and driving our decision making. Philosopher Amos Bronson Alcott said it in the 19th century: "Memory marks the horizon of our consciousness, imagination its zenith,"[39] and the writers of the TV show *Westworld* said it through the character of Bernard Lowe in 2016: “Your memories are the first step to consciousness. How can you learn from your mistakes if you can’t remember them?”[40]

But memory isn’t just the privilege of humans and animals. Plants are capable of storing memory and recalling biological information, with recent evidence suggesting they may even be able to do so long term. In a 2014 study published in the journal *Oecologia*, Gagliano, Mancuso, and their colleagues placed *Mimosa pudica* (the sensitive plant) in cups alongside a vertical steel rail. When touched or disturbed, Mimosa plants close their leaves. Curious as to whether Mimosa plants could differentiate threats from non-threats and remember what they learned over time, they subjected Mimosa plants to a series of controlled drops along the steel rail, not fast enough to hurt the plants, but enough to “startle” them and cause their leaves to close. They repeatedly dropped the plants from a height of 15 centimeters every five seconds, for a total of 60 drops per session. Eventually, the Mimosa plants opened their leaves and learned that the drops weren’t actually a threat—and remembered this fact a full 28 days later.[41]

“[Mimosa plants] had the faculty of memory, and their behavior was not hard-wired in DNA, but learned!” Gagliano writes in her book *Thus Spoke the Plant*. “How amazing!”[42]

But not all memories are created equal.

Augustus Binu/flickr

Why is *Mimosa Pudica* known as the “sensitive” plant?

Endel Tulving, a Canadian and Estonian experimental psychologist and cognitive neuroscientist, has influenced generations of psychologists, neuroscientists, and clinicians with his research on human memory. His theory is that human memory can be broken up into three levels: procedural (based on external simulation, like typing on computer keys or riding a bike), semantic (memory of concepts), and episodic (remembering autobiographical emotional events, like the loss we feel when our dog dies).[43]

As far as we know, plants can only sense and react to external influences, so from Tulving’s perspective, they are only capable of procedural memory—the same type of memory the human immune system is capable of.

While plant memory may be considered more rudimentary than other types, that doesn’t make it any less important or handy. Plants use procedural memory to know how to respond to extreme weather conditions, as it helps them figure out the best time to produce flowers. They can remember when one of their leaves or stems has been repeatedly damaged and make the decision to devote energy to growing leaves on the side of their body that isn’t at risk, or they can grow in another direction. Armed with stored memories of past dehydration, when faced with lack of H_20 in the future, they can remember to store more water. They may even be able to recall the buzzing sounds of specific insect herbivores, which could help them recognize and respond to potential attacks.

“Plants obviously don’t have memories the way we do,” Chamovitz says. “You know, they don’t cower at the thought of a drought. They don’t dream about the sunbeams of summer. They don’t miss being encased inside the seedpod. They don’t feel anxious about premature pollen release. But plants clearly have the ability to retain past events, to remember them, and to recall this information at a later period for integration into their developmental network.”[44]

And with those memories, they can learn and act.

Learning and Choice

Some time after her communion with Socoba, Gagliano once again found herself in the jungle, but this time a man was pouring a “soup” of crushed, stinky fruit from an Ayahuma tree over her naked body. When that was over, she drank a small glass filled with tree bits mixed into water. She went to bed and spent a day dry-fasting and drifting in and out of sleep while covered in tree goo. She was visited by the spirit of a cannonball tree (*Couroupita guianensis*), native to tropical forests of South and Central America. It was during this visit that the plant spirit, who Gagliano refers to as Ayahuma, gave her a complete set of instructions to test Pavlovian learning in plants—which, upon returning to Australia, Gagliano promptly followed.

Russian physiologist Ivan Pavlov showed that dogs can learn to associate the ringing of a bell with the arrival of food, so much so that every time a bell rings they will salivate. Guided by the instructions of her plant friend Ayahuma, Gagliano set out to test whether the associative learning Pavlov showed in dogs could also occur in plants, because up until that point, there had been no scientific evidence supporting this

Fotokannan/WC/CC4.0

Are Cannonball trees (*Couroupita guianensis*) experts on Pavlovian learning?

idea. So she put up a sign on her lab door at the Plant Growth Facilities at the University of Western Australia that read, "Plant learning in progress. Do not enter." And she got to it.[45]

Gagliano and her colleagues wanted to see if pea seedlings would associate the position of a small fan with the occurrence of light. The scientists created multiple Y-shaped structures from PVC pipes and put different seedlings in each of them, with 19 seedlings in a control group and 26 in the test groups. During an initial "training period" of three days, the seedlings were gently blown by a fan (the equivalent of Pavlov's bell), and then exposed to blue light (plant food). For some of the seedlings, both the light and breeze were delivered through the same tube of each Y-structure, while for others, the light and breeze came from opposite directions.

On day four, the peas began to grow close to the center of the Y—the fork in the road, if you will. That's when Gagliano and her colleagues left them in the dark and gave them a "choice" as to which tube to grow toward: the windy tube, or the windless one. Approximately 65 percent of the plants trained with wind and light grew toward the breezy tube, suggesting they learned to associate wind with food, while the plants that were trained with light and wind coming from different directions grew away from the wind, not making the association. The control group grew in seemingly random directions.[46]

This study, which was published in the journal *Scientific Reports* in 2016, rustled the leaves of the plant biology community. Up until that point, evidence suggested that plants could do basic forms of learning or information processing, but that associative learning could only occur in animals.

The findings of this study caused its authors to declare: "Our results show that associative learning is an essential component of plant behaviour. We conclude that associative learning represents a universal adaptive mechanism shared by both animals and plants."[47]

But alas, while the results are intriguing, in science, results need to be repeated to hold water. And when another scientist attempted to repeat the results last year, it didn't work. Kasey Markel, a plant biologist at the University of California, Davis, did virtually the same study that Gagliano and her colleagues did, but used a larger sample size and fully blinded analysis to make sure that the researchers recording the results weren't influenced by their expectations. He couldn't duplicate the findings.

Of course, this doesn't mean that more evidence for associative learning in plants won't surface. We just don't have the data right now. "A replication of [Gagliano's] protocol failed to demonstrate the same result," writes Markel in his study, published in the journal *eLife*, "calling for further verification and study before mainstream acceptance of this paradigm-shifting phenomenon."[48]

Speaking of shifting phenomena, if you've observed plants at all in your lifetime, you may have noticed that they learn to change position to grow toward light, moving their leaves to get as much of it as they can. Sometimes this process can be particularly difficult, especially if a smaller plant finds itself in the shade of a taller vegetal neighbor. That's when plants have to make a decision: do they let the other plant take over and accept their fate to die? Or do they take part in what scientists call "escape from shade?"

In an attempt to grow faster than a taller plant—a smaller plant will invest energy and materials to help intensify its growth and beat its competitor. But this behavior is risky: if the plant doesn't end up growing taller than its rival, the energy cost may be too high, and it won't survive. This calculation of risk and reward, followed by planning to act, proves that complex cognition is occurring, according to Mancuso. He even compares the plant's decision to escape from shade to an "entrepreneur investing for the future."[49]

Another example of plants "choosing" the best course of action for survival happens underground, with the roots. In soil, nutrients, water, oxygen, and mineral salts that plants need to survive can sometimes be far apart, and a plant must decide what resources are most important for its survival. The roots also must process information as to how to grow around rocks and rival plants, learning and making decisions as new obstacles arise. "Each root tip is a true 'data processing center,'" Mancuso says. "It has many tasks to perform and different needs to balance."[50]

While plants can make decisions about which direction to grow, and those kinds of decisions are easier to observe scientifically, you may have heard through the grapevine a less-than-scientific conclusion: that plants are choosy about what music they listen to.

Giancarlo Cignozzi, a wine-grower from Montalcino in Tuscany, collaborated with the International Lab of Plant Neurobiology and Bose, the audio corporation, to test if music could benefit the health of his grapevines. For a period of five years, he played Mozart's "Il Paradiso di Frassina" to some of his grapes, while he left others in silence. The result? The grapes that grooved not only saw more growth, but the vines ripened sooner and produced grapes richer in color, flavor, and polyphenols.[51]

While the media produced headlines such as "How Mozart's music is improving the grapes in one Italian vineyard," the most important finding from the experiment, according to Mancuso, had nothing to do with the actual song or musical genre. Instead, the music seems to have helped keep birds and insects away, with the noise likely disorientating them.[52]

While the grapevine experiment was fairly recent, the idea that plants have musical preferences has been around for centuries and is based on tenuous evidence. In 1973, an experiment was published with the conclusion that classical music benefits plant growth, while rock damages plant health and causes plants to grow away from the sound. These results were published in a book called *The Sound of Music and Plants*, written by Dorothy Retellack, a student majoring in music at Temple Buell College (now Colorado Women's College). She did the experiments for a biology class.[53]

"*The Sound of Music and Plants* has been cited by dozens of websites as solid scientific evidence," writes horticulturist and Washington State University professor Linda Chalker-Scott in an essay. "The research itself was never published in

> *"…if there can be an ever-growing list of types of intelligences, from emotional intelligence to machine intelligence, adding plants to the list would hardly be a stretch."*

a peer-reviewed journal, nor has any replication of the work appeared in this body of literature…The purpose of the book is to blend science with music, philosophy, and religion. This makes for an interesting read, but the reader must view the science in a more objective manner."

Retellack also consistently compares plant abilities to human abilities, Chalker-Scott points out, "ignoring the questionable logic in equating plants and humans."[54]

The results from others who have tried similar tests have provided mixed results. Hosts of the show *MythBusters* found that plants actually thrive off of rock music—particularly chaotic heavy metal.[55] Even Charles Darwin put on a concert for a sensitive Mimosa plant, having his son Francis play the bassoon to see if it would cause the Mimosa's leaves to close. The result? Nothing happened—other than the playing of some sweet bassoon tunes, of course. In his autobiography, Darwin refers to the whole thing as a "fool's experiment," and as far as we know, never tried to repeat it.[56]

It's more likely that it's not the genre of music that influences plants' growth, but rather the music's sound frequencies.

Scientists like Chamovitz are less interested in finding out the first date questions, like "What's your favorite band?" and are more interested in discovering the biological benefits plants may reap from exposure to certain sounds. Last year, Chamovitz and his colleagues at Tel-Aviv University in Israel discovered evidence that plants can not only "hear" noises, but their flowers may act as sound-sensing organs or "ears." Researchers exposed evening primrose (*Oenothera drummondii*) flowers to the sounds of buzzing bee wings and discovered that the sugar in the plants' nectar increased by over 20 percent, creating a better chance of cross pollination. The flowers even appeared able to tune out some common background noises like wind to pinpoint the sound of pollinators. In response to beating bee wings, the primrose flowers vibrated mechanically, indicating that the flower of a plant could be a sound-sensing organ—particularly in flowers with a "bowl" shape. They also did experiments where they removed the petals entirely and discovered that the presence of petals was crucial to plant vibration.[57]

"The response of plants to pollinators from a distance has never been demonstrated," the authors write in their study, published in *Ecology Letters.* "Our results document for the first time that plants can rapidly respond to pollinator sounds in an ecologically relevant way."

Plant response to sound could lower nectar waste and allow plants to pollinate more efficiently, the authors note. These results call for more experiments to test what kind of sounds affect pollination abilities, from sounds in the wild to those generated by humans.[58]

While Chamovitz says the results are exciting, he emphasizes that more research needs to be done. "We're really looking forward to someone trying to repeat our study," Chamovitz says. "At least it's a start!"[59]

So—Are Plants Intelligent or What?

While incredible discoveries like these have scientists excited to unearth new insights on plant capabilities, not all scientists are convinced that we can call plants intelligent, or that we ever should. "If you define intelligence as information processing, then plants are intelligent. And so are computers. So are bacteria," says Chamovitz.

By that definition, it makes sense that plants would be intelligent, Chamovitz says, because they're territorial organisms that have to sense their environment and adapt to survive. "The biggest difference between plants and animals is that they are sessile—rooted," says Chamovitz. "A plant doesn't have the ability to run away. It has to respond quickly to an ever-changing environment or it'll die. It has to be acutely aware of light, qualities, and directions. It has to be acutely aware of dangers. It has to be acutely aware of temperature. It has to be acutely aware of pathogens in order to survive."[60]

In his class offered on the educational online platform Coursera, Chamovitz breaks down the scientific evidence that plants can perceive and respond to their environments in intriguing ways. He reasons that if there can be an ever-growing list of types of intelligences, from emotional intelligence to machine intelligence, adding plants to the list would hardly be a stretch.[61]

But from Chamovitz's point of view, applying the question of plant intelligence to scientific inquiry is "a waste of time" because intelligence seems impossible to define. To demonstrate his point, he created a tongue-in-cheek VQ (vegetal quotient) test on his blog, *The Daily Plant*, calling attention to the absurdity of creating criteria to measure a plant's smarts.[62]

"While I, or any group of scientists, could develop a quantifiable metric of plant intelligence, this metric would be no more scientifically valid for measuring intelligence than claiming that college entrance exams are a comprehensive metric of human intelligence," Chamovitz writes in his *Nature Plants* essay "Plants Are Intelligent; Now What?" "Plants are wondrous life forms that integrate multiple external environmental and internal cues to yield a form of life exquisitely adapted for its environment. Is this integration of signals 'intelligence'? Whether yes or no, I am more interested in understanding how the signals are transmitted and integrated in real time, and how this leads to adaptation to an ever-changing environment and an amazing ability to survive. These and other emerging questions are the real challenges of plant biology."[63]

According to scientists like Mancuso, intelligence is simply "the ability to solve problems," and by that definition, plants definitely qualify.[64]

Evolutionary biologist Jon Mallatt, however, says intelligence is much more complicated than what Mancuso suggests. It involves a process of coding sensory information for complex learning and long-term memory. "I would say [plant neurobiologists] define intelligence so broadly that it almost loses all of its meaning. They define intelligence as any adaptive response to the environment that allows survival or any adaptive behavior that allows survival," Mallatt says. "[Intelligence] is more than just what would happen at a reflex level or maybe even at an unconscious level. If you accidentally put your hand on a hot stove and pull it back, that's not really intelligence."[65] The intelligent part, from Mallatt's point of view, would be the ability to predict that the stove was hot before putting your hand on it in the first place.

But to Mancuso's credit, he has another, more complicated theory on plant intelligence to share, which he presents this way: We humans get one body, and when a vital organ is damaged, we're pretty much S.O.L. Part of the reason plants are able to regenerate and grow back even when up to 95 percent of their bodies have been demolished, Mancuso says, is because they're composed of a variety of separate entities that can continue on and rebuild even when some parts are lost. From his point of view, plants possess a kind of *swarm intelligence*, typical of bees in a hive. Because we can cut a plant in half and the two parts can live independently, the plant isn't an individual, but more like a colony of bees or ants.[66] Also, as we discussed earlier, plant networks such as the wood wide web may show signs of swarm intelligence through the coordination of many individual roots in complex root systems.[67]

Despite compelling and tantalizing theories of intelligence like these, some scientists are still resistant to the idea of an "intelligent" plant. Not just because they feel like Mancuso's "ability to solve problems" definition of intelligence is oversimplified, but because plants are missing one very important organ.

If I Only Had a Brain

Plants have chemical and electrical signaling systems similar to those found in animal nervous systems, and they possess neurotransmitters like glutamate, serotonin, and dopamine, though it is unclear what the function of those neurotransmitters are in plants. Despite these similarities between us and them, plants are definitely not built like humans.

They don't have organs. No heart. No liver. No brain. You can chop off plant limbs and they'll grow right back. They can eat and breathe without a mouth, stand up without any bones. They also transmit information in their bodies differently than we do. Humans need all signals in the body, with few exceptions, processed by the brain, whereas plants can transmit information through different pathways, i.e. the roots can communicate with any leaf or limb without ever having to pass through the crown of a plant.

"A plant's internal communication pathways have a completely different architecture from those of an animal," Mancuso writes in *Brilliant Green*. "Plant organisms aren't equipped with biological structures normally devoted to the transmission of electrical *signals*, signals which in animals transmit information from the periphery to the central system. In other words, plants don't have nerves."[68]

Because Mancuso understands that plants don't have nerves, and neurobiology is the study of the nervous system, it was surprising to some scientists when, in 2005, Mancuso founded the International Laboratory of Plant Neurobiology (LINV) at the University of Florence in Italy.[69] Shortly after, a separate entity called the Society of Plant Neurobiology was also formed, with Mancuso as a member.[70]

Soon after the lab was founded, Mancuso and his colleagues published a paper in *Trends in Plant Science* defending their use of the term "plant neurobiology." They explain that because plant behavior is coordinated through neuron-like processes such as long-distance electrical signaling, action potentials, and vesicle-mediated transport of (neurotransmitter-like) auxin, that "plant neurobiology" is an appropriate term to use for the work they do. They also break down the etymological origin of the word neuron, pointing out that it is derived from "vegetal fibre."[71]

These arguments were and still are unsatisfying to some of the scientific community, so much so that a group of 36 plant scientists published a rebuttal piece in *Trends in Plant Science* condemning the use of the term. "The fact that the term 'neuron' is derived from a Greek word describing a 'vegetable fiber' is not a compelling argument to reclaim this term for plant biology," the authors write. They say that the comparisons of plant biology to neurobiology are "erroneous," that there isn't enough evidence to justify the arguments, and that the use of the term may create more confusion than good.

"New concepts and fields of research develop from the synthesis of creative thinking and cautious scientific analysis," they write. "True success is measured by the ability to foster new experimental approaches that are founded on the solid grounding of previous studies. We recognize the importance of a vigorous and healthy dialog and accept that, as a catch-phrase, 'plant neurobiology' has served a purpose as an initial forum for discussions on the mechanisms involved in plant signaling. We now urge the proponents of plant neurobiology to reevaluate critically the concept and to develop an intellectually rigorous foundation for it."[72]

And while their argument wasn't convincing enough for Mancuso to change the name of his lab, the Society of Plant Neurobiology changed its name to the Society for Plant Signaling and Behavior a few years ago—with a short explanation on their website saying that the society is "expanding its view."[73]

The same year that the society changed its name, Mancuso and others published a paper in the society's own journal, *Plant Signaling and Behavior*, to beef up their justification for using the word "intelligence" to describe plants. The article's hook? Charles Darwin.[74]

In 1880, Darwin published a book entitled *The Power of Movement in Plants*. It was hardly a bestseller and it certainly wasn't as sexy as *On the Origin of Species*.[75] But the book has made a big impact on plant biologists ever since, particularly those scientists founding edgy new plant neurobiology labs. One specific passage stood out to Mancuso, where Darwin suggests that a plant's radicle, the embryonic root of a plant that grows down into soil, holds some type of computing power. "It is hardly an exaggeration to say that the tip of the radicle thus endowed [with sensitivity] and having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals," Darwin writes. "The brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements."[76]

This sentence, Mancuso and others conclude, communicates that the root may be a "brain-like" organ.[77] Coming from one of the most influential scientists of all time, the idea packs a punch, particularly when Darwin is writing things in his autobiography like, "It has always pleased me to exalt plants in the scale of organized beings."[78]

But alas, "brain-like" does not a brain make. From Mancuso's point of view, however, if plants can function in brain-like ways, then the presence of an *actual* brain is irrelevant to their capacity for sentience. "A plant's functions are not related to organs—which means plants breathe without having lungs, nourish themselves without having a mouth or stomach, stand erect without having a skeleton, and as we will soon see, make decisions without having a brain," Mancuso writes in *Brilliant Green*.[79]

So, would it be possible that plants could possess consciousness without a brain?

To that, a group of scientists say: probably not.

A Feeling Plant is a Conscious Plant

Last year, some of the same scientists who rallied against the use of the term "plant neurobiology" published a paper in the journal *Cell* titled "Plants Neither Possess nor Require Consciousness." Their argument was based around the recent findings of neuroscientist Todd Feinberg and evolutionary biologist Jon Mallatt—who through a survey of brain anatomy, behaviors, and functional complexity across a wide variety of animals—determined that plants cannot be conscious. To claim that they could be would be denigrating the intricacies of the brain, the study authors say. "In claiming that plants have consciousness, 'plant neurobiologists' have consistently glossed over the remarkable degree of structural and functional complexity that the brain had to evolve for consciousness to emerge," they write. "We consider the likelihood that plants, with their relative organizational simplicity and lack of neurons and brains, have consciousness to be effectively nil."[80]

For Mallatt and Feinberg, feelings, or rather, emotions, seem to be the cornerstone of consciousness. By their definition, consciousness is the ability to have experiences of the sensed world and have feelings of good and bad. Plants cannot have feelings of good and bad, Mallatt says, because they don't have a brain to generate a first-person, emotionally subjective point of view.

In humans and animals, the body is set up to send signals to the brain to be processed in one place. It's the brain's job to build up a map of the external world, says Mallatt. The map creates a series of images, like a movie playing inside our minds 24-7, allowing us to plan and act. For example, let's say you've just encountered the legendary Bigfoot in the forests of Northern California. Contrary to popular belief, he's not timid and trying to hide, but instead, he's crazed! He lunges at you from behind a massive redwood, ready to attack. Your brain's map puts together all the information from the environment and your five senses, and in a fraction of a second, provides a prediction as to where the mad Bigfoot creature might go next so you can dodge him, hide, or run away. In other words, your brain can make logical assessments that predict future outcomes. With the map, Mallatt says, you're "not tied to the present anymore."

Plants have shown that they can make decisions based on present circumstances, says Mallatt, but he isn't convinced they can make detailed, predictive maps without a brain. "All the plant's electrical signals just tend to go one way and then signal some physiological or some body response right away. There's no brain for plants to tie all the electrical information together . . . No integration of electrical signals based on the sense of the environment," Mallatt says. "[Consciousness] is the ability to have an image of the outside environment that you simulate inside your head so that you can use that image to act in the environment. You're not just trying to act, blind. You have a simulation in your head about where to go, what to do, what's present in space."

So, because plants don't have a brain to do this supercomputing, Mallatt says, they can't be conscious.[81]

But what about the research showing that plants have decision-making abilities and memory? Does this not indicate at all that plants could have some form of impressive computing power?

"[Plants] do have tremendous abilities to process information and integrate information, but it is all just chemical, secreted chemicals in their fluids, almost like hormones," Mallatt says. "Every living independent cell can make decisions and even have a real short-term memory, even bacteria."

Notably, Mallatt says, we don't have adequate scientific evidence showing that plant behaviors indicate emotion, and emotions are a fundamental part of consciousness. An indicator of emotion would be *operant* or *instrumental learning*, which is learning from personal experience to change behavior. He gives examples of such learning, including *conditioned place preference* and *conditioned place aversion*, where the animal demonstrates she has a preference or aversion to certain stimuli. Like when a rat accidentally discovers that when she touches a button, she gets cheese, so she continues to press the button going forward. If plants could demonstrate that kind of complex learning and behavior, Mallatt says, "that might indicate they have some emotions."[82]

While Gagliano's Pavlovian pea experiment is a start to showing plants may be capable of classical Pavlovian learning, Mallatt says, that kind of learning is actually a lower form of learning than one might expect. The difference between operant learning and classical learning is that classical learning is based on involuntary responses (like dogs salivating), and operant learning is based on voluntary behavior and consequence (planning to get the cheese by pressing a button). Historically, classical learning has been considered nonconscious, says Mallatt, because it can be explained through simple changes in synaptic connectivity that cause basic reflexes. He gives the example of grisly experiments done on rats in the 1990s, where their spinal cords were cut from their brains, and yet they were still capable of associative Pavlovian learning.[83] "Most people wouldn't think that an isolated spinal cord is conscious or intelligent," Mallatt says.[84]

Needless to say, Mallatt and Feinberg are hardly the only scientists and academics with a theory of consciousness. There's been tens of thousands of papers published on the subject with no discernible consensus, and not everyone believes it is relegated to "higher animals." Nor is everyone bold enough to say, without a doubt, that plants simply cannot possess consciousness, particularly when we know so little about consciousness in humans.

While Michio Kaku, a theoretical physicist at the City College of New York, says he doesn't believe that plants have the ability to plan or predict the future like humans can, he asserts that consciousness exists on a spectrum—where even inanimate objects have a place. "I believe that even a lowly thermostat has one unit of consciousness, that is, it senses the temperature around it. Then we have a flower. A flower has maybe 10 units of consciousness. It has to understand the temperature, the weather, humidity, where gravity is pointing," Kaku explains. He breaks consciousness into different levels, including reptilian and monkey consciousness, and he places humans at the top, crediting their position in the hierarchy to the human brain's prefrontal cortex—responsible for personality, decision-making, and complex cognitive behavior. "Humans run simulations into the future," Kaku says. "Our brain is a prediction machine."[85]

But it's worth pointing out that we know tragically little about brain function. Neuroscientists are still perplexed by the brain of a worm, which has a few hundred neurons, while humans have 80 to 100 billion.[86] If we don't even have a clear picture of the whole brain and how it functions, can we confidently say the brain is responsible for revealing the whole picture of consciousness?

And, as plant pathologist Saskia von Diest points out, can we know for sure that consciousness is not something more complex than what can be housed inside our brains? Could consciousness be grander than us?

"I can't say for sure what [consciousness] is," says von Diest, a post-doctoral fellow at Stellenbosch University, South Africa, and at Coventry University in the UK. "What I can say is that there seems to be growing evidence for the fact that our consciousness is non-local, meaning it's not limited to the human brain, and it's not even limited to the human mind. It's pervasive in all of life, and even in those parts of the universe that don't seem to be alive. In an animistic perspective or a panpsychic perspective, consciousness is everywhere, and we have the ability to tap into consciousness with our minds as the receiver."[87]

William Parsons

Plant pathologist Saskia von Diest

Mallatt, who identifies as a "more traditional scientist," maintains that science can figure out everything, eventually, and that consciousness must lie in observable physical processes. "If you get a blow to your head that damages your brain, you're going to lose consciousness," Mallat says. "[Consciousness] is a whole complex series of neural reactions…[not] a magic psychic force in the universe. To me, that's the problem. So many people are saying there's got to be a magic ingredient so it's spirits or its panpsychism. There's no evidence for that. It's something super complicated that we don't understand yet."[88]

And that leads us to the hard problem.

Bridging the Explanatory Gap

The hard problem, or the explanatory gap, is our inability to connect the dots between the observable physical processes in the body to our subjective, felt experience of being alive. For instance, we know we have a brain, but how does the brain generate our conscious *mind*? Nobody really knows. "We just have no idea how the neurons could mechanically cause something like *mind*," Mallatt says, "except that it's got to have emerged somehow from a lot of complex neural interactions."[89]

One reason the gap is so hard to bridge is because in science, to prove something, you have to be able to observe it in the third person and prove it for *everybody*, and yet to study subjective experiences, you need to analyze first-person perspectives. It's a catch-22.

"The more you as a first-person try to think really hard about…what the neurons are doing in your own mind, the more you're getting into your own personal ideas and the less you're getting into the neuron," Mallatt says. "That's the problem."[90]

With our limited understanding of consciousness, could trying to seek it out with science be like trying to shove a square peg into a round hole? Or is there a way that the gap could be filled that we just haven't explored yet?

Gagliano says that not considering ideas of intelligence and consciousness in the study of plants is crippling, keeping scientists from filling chasms in our understanding of plant biology. "To forget to ask the question, in effect, dismisses any chance for the proof to emerge," Gagliano writes in her book *Thus Spoke the Plant*. "Scorning traditional knowledge as unsubstantiated and fanciful and erasing our ancestral memories that spoke of other possibilities, humanity has found itself locked inside the experimental box of a restraining sociocultural view."[91]

Gagliano isn't the only scientist who shares this perspective, nor is she the only scientist who talks to plants. Says von Diest: "By blocking the idea [that plants could be intelligent or conscious] to begin with, we're not even opening up the exploration."

Von Diest had her first conversation with a plant while she was grocery shopping. As she stepped through the doors of a store on a sunny afternoon, a voice spoke to her, commanding her: "Take me home with you." Von Diest halted and looked around, but nobody was near her, and the voice was loud and clear. "Okay, this is it. I'm going crazy," von Diest told herself. "I'm hearing voices."

That's when she realized that the voice was coming from a poinsettia sitting on an empty shelf at the front of the store, and it was trying to convince von Diest to take it home with her. Von Diest told the plant that she hadn't a clue how to take care of it. That's when it started telling her how often and how much she should water it, how and when to prune it, and more. Curious, she took the plant home and checked online to see how to take care of a poinsettia, realizing that all the information the plant had given her at the store was correct. She was shocked, and the poinsettia told her, "See? I told you so."

"Interspecies communication [is] something that's 'super natural,'" von Diest says. "Not because it's something that's limited to only a few people, but rather that it is *very* natural."

Von Diest says she believes that every person has an innate ability, a blueprint in our DNA, that allows us to communicate with plants. Accessing this natural ability is just a matter of keeping an open mind.[92] But some scientists seem worried that people's brains might fall out.

For scientists like Mallatt, the belief that plants are conscious is just too big of a leap. "To me, it sounds like creationism," Mallatt says. The idea that plants could have consciousness is not a simple hypothesis that you can test with the scientific method, Mallatt says, but rather, it's a "giant edifice with a billion details in it, no evidence."[93]

Von Diest argues that some traditional scientists may be the ones guilty of religious thinking. "Science is just a method of gaining knowledge. It's not a religion. It's not a dogma—although many scientists probably think of it that way. I know I used to when I was younger, and it took a lot for me to change that," von Diest says. "It took me having my own experience of communicating with nature to change the way that I saw science and the way that I saw the world."[94]

Regardless of the individual experiences scientists might have while connecting with plants, those experiences will be subjective and unique to each of them. The scientific method is rooted in observable and objective observations, Chamovitz says, not in subjective anecdotal experiences or opinions of what intelligence and consciousness are.

"What is intelligence? I think it's such a crazy subjective term," Chamovitz says. "Why even deal with it? The reason I don't want to deal with it is because it doesn't help me plan experiments. It's not something I can test. Clearly, we should not be testing that of which the definition is subjective."[95]

But Chamovitz says that plants are not just automatons. Science shows that plants are aware of their surroundings and can adapt their behaviors to the environment. But beyond that, Chamovitz won't extrapolate. "[If consciousness] is the ability to sense and respond to environmental changes then yes, plants have consciousness," he says. But based purely on scientific data, as far as we know, "Plants aren't aware of [us] talking about them."[96]

When asked if it's possible that traditional scientists are being close-minded about consciousness or intelligence in plants, Chamovitz says it's possible, but he's not worried. In science, he says, the truth ultimately wins out. "Yes, scientists can be recalcitrant to things that go against dogma. There are plenty of examples. Galileo was almost put to death for saying that the Earth was round. There are still some people in [the U.S.] who would agree that he was wrong, but most people don't," Chamovitz says. "If there's strong enough data from numerous labs, then scientists are always ready to change their minds. We see it happening again and again."[97]

The Root of the Problem: Clarity

Forester Wohlleben says that he uses anthropomorphic language to describe trees so people will make connections and be interested in their well-being. When scientists use only scientific terms, people just don't care, because the words are inaccessible. "I use words of emotion to connect with people's experience," Wohlleben says. "Science often takes these words out, but then you have a language people can't relate to, that they can't understand. That's one reason most scientific research has so little impact on people. If you only write technically about 'biochemical processes,' people would quickly get bored and stop reading. We have been viewing nature like a machine. That is a pity because trees are badly misunderstood."[98]

From von Diest's point of view, using words like intelligence and consciousness to describe plants could open up a new understanding of plants, and perhaps a new understanding of our own existence. "There's so many stigmas attached to certain words, and we've colonized those terms. For example, intelligence has historically only been associated with humans, and now it's vaguely being associated with animals," von Diest says. "If we expand what [intelligence] can be applied to, that becomes interesting. Then we can actually use science with a more open-minded approach. The methods that we have, the language that we have, are actually suitable, but it's how we apply it that becomes crucial."[99]

But right now, no one can agree on how to apply it—so determining which words to use to describe plants is a hard problem. Not *the* hard problem. But a hard problem nonetheless.

In order to help dispel some of the confusion and arguments regarding plant consciousness and intelligence, Chamovitz suggests doing away with the use of those two words all together when describing plants, and perhaps trying out others that don't carry so much weight. "The title of my book originally was not *What a Plant Knows*. It was the *Aware Plant*. But someone convinced me that that was too 'new agey,'" he says. He struggled with using the word "know" because it is more commonly associated with humans.

"A plant is definitely aware of its surroundings because we see it responding. Plants have multiple sensitivities. Multiple awarenesses." Then again, Chamovitz adds, his definition of awareness may not work for others.[100]

Like Mallatt, for example. "If you want to define awareness as just the sensory receptors being stimulated by sensory stimuli…[then plants] are definitely aware," Mallatt says. "But I would define awareness as perception and conscious experience."[101]

And around and around we go.

Ultimately, we're kind of stuck with our vocabulary, so we're going to have to use it. And that doesn't have to be bad. "We can use the language, as long as we understand that the language is limited. And that's why we always have to be clear," Chamovitz says.[102]

A lack of clarity on scientific information is what leads people to blow their money on expensive speakers to play classical music to their plants—who (which?), for all we know, just wanted to grow faster to get the experiment over with. If plants are like us, then having to listen to the same song on repeat for five years would be *pure torture.*

"What scientists are afraid of," says Chamovitz, "is that the statements taken out of context can lead to pseudoscience. For example, if I'm using a scientific method to come to the conclusion that I can call plants intelligent, or that they have the lowest level of consciousness, it doesn't mean that we need laws to protect plants. It's not like we need to emancipate our houseplants."[103]

Are Plant Rights Wrong?

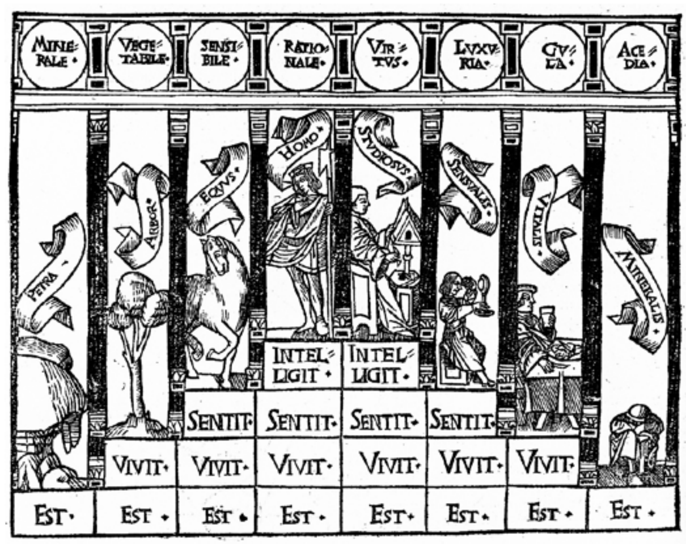
In 1509, a little book called the *Liber de sapiente* (*Book of Wisdom*) was published by French mathematician and philosopher Charles de Bovelles, and inside was something called the "Pyramid of Living Things." This pyramid functioned as a diagram, ordering living and nonliving species in order of their complexity. At the top of this pyramid sit humans, the only beings capable of intelligence, according to de Bovelles. Next are animals, which have senses but not intelligence; then plants, which are merely alive and nothing more; then rocks, which simply exist.[104]

According to Mancuso, the perspective that plants are a lower form of being continues to this day, and it's led to plants being subjected to unfair treatment, playing "second fiddle" to animals, unappreciated for their complexity.

A great example of this is Barbara McClintock, who in the 1940s did studies with corn to determine that pieces of DNA can move within the genome, going against the whole paradigm that the genome was immutable and unchangeable. She was ostracized by the scientific community for her research using plants, Mancuso says, because her "observations ran counter to academic orthodoxy." Forty years later, the importance of her work was finally recognized, and she was the first woman to win the Nobel Prize without a man's name attached to the prize at the same time. What she discovered then with corn is now fundamental in human cancer research today.[105]

While Mancuso seems to appreciate McClintock's work, he also cautions against experimentation on plants for the sole purpose of understanding and benefiting those of us stacked higher on the pyramid. He says it's considered ethical to subject plants to experiments for the benefit of animals because plants aren't seen as beings with dignity—and they should be. "Are we really sure that the ethical implications are inconsequential? We hope that reading this book will help plant some doubts on that score," Mancuso writes in *Brilliant Green.* "For centuries, animals, too, were considered unthinking machines. It is only in the past several decades that we've begun to guarantee them rights, dignity, and respect: animals are not things anymore. This change in perspective had led nearly all the most advanced nations to enact regulations designed to protect and defend animals' dignity. Nothing like this exists for plants. The discussion of their rights is only beginning, but it cannot be put off any longer."[106]

Wohlleben suggests that part of the reason we continue to label plants as lower beings is to justify our ruthless treatment of them. "This hierarchical ranking of living beings is totally unscientific. Plants process information just as animals do, but for the most part they do this much more slowly. Is life in the slow lane worth less than life on the fast track?" Wohlleben says. "Perhaps we create these artificial barriers between humans and animals, between animals and plants, so that we can use them indiscriminately and without care, without considering the suffering that we are subjecting them to."[107]



Charles de Bovelles

Pyramid of Living Things

In 2008, the Federal Ethics Committee on Non-Human Biotechnology (ECNH) published a document titled *The Dignity of Living Beings with Regard to Plants: Moral Consideration of Plants for Their Own Sake*, concluding that plants do have dignity, and recognizing this fact is the first step toward legitimizing their rights independent of human interests. In other words: we have a moral obligation to respect plants for their own sake, no matter what they do for us.[108]

Sound ridiculous? Biologist Florianne Koechlin, who was a part of the ECNH during the creation of the document, says that based on our current paradigm and understanding of plants, it makes sense that some of us may be resistant to the concept. "If we look at plants as living automatons following a set program and only satisfying our interest and demand, such a notion [of plant dignity] would be absurd, it doesn't make sense," Koechlin says in a 2015 TEDx talk. "But if we look at plants as excellent networkers even capable of subjective perceptions, having a life of their own, then it makes sense to say yes, they have dignity."[109]

While the committee agreed that plants have dignity, they struggled to come to a consensus on what a violation would look like. They have yet to reach an agreement about whether the mass industrialization of plants for commercial interests constitutes a violation, or whether plucking a daisy for your girlfriend could qualify as a critical offense. Regardless, Koechlin says, the conclusion they came to is that plants should have some degree of independence regarding the survival and adaptation of their own species. This doesn't mean that we need to stop eating, cutting, mowing, grafting, or researching plants, but rather, we have an obligation to think more carefully about how we do these things.[110]

In response to the plant dignity treatise, ENCH was awarded with the Ig Nobel Prize for improbable research, with the "Ig" in the name standing for "ignoble," or "low quality."[111] The award, given to scientists by scientists, was also bestowed upon Dr. Elena Bodnar in 2009 for her invention of the Emergency Bra, "which can convert into a set of protective facemasks in a pinch."[112] (Funny a decade ago, pre-pandemic, but who's laughing now?)

ENCH took the award as a compliment. "It's a prize for particularly ridiculous research which makes people laugh—and then think," says Koechlin. "We were proud to receive this prize and a member of our commission flew to Harvard to get it."[113]

Scientists like Mancuso assert that to better tackle the environmental crises we face today, we must recognize and respect plants as dignified beings. In fact, we can't afford not to. "In life as in science, the common scale of values relegates plants to last place among living things," Mancuso says. "An entire realm, the plant world, is underappreciated, despite the fact that our survival on the planet and our future depend on it."[114]

But not everyone treats plants like dirt. In fact, there's a farming movement dedicated to acknowledging plants, and every other living thing on the farm, as the wonderous organisms they are.

A Leaf of Faith

Biodynamics is an agricultural practice and philosophy that sees an entire garden or farm as one living spiritual organism that can possess its own individuality. Biodynamic practitioners see themselves as responsible for nurturing every element of the farm or garden, including the fields, forests, plants, soil, compost, people, and even the land's spirit. They often listen to the land to guide harvest decisions, tune their farming practices to match the rhythms and cycles of the stars, and make things like "horn manure," where cow manure is buried inside a cow horn during the winter months to help increase plant immunity. Biodynamics requires a farm system to remain fertile on its own, composting and recycling its own nutrients as much as possible.[115]

"Biodynamics really promotes the idea that in order to approach nature, in order to learn from nature and to work *with* nature, not work on nature ... one needs to have a certain disposition," says von Diest. "One needs to be humble because you are made of the same earth as the soil below you."[116]

The biodynamics movement was made popular in 1924 by Austrian philosopher and scientist Rudolf Steiner, who believed that combining spiritual practices with science would lead us to new knowledge. He invented the philosophy of anthroposophy, meaning "wisdom of the human being," which asserts that humans are intellectually capable of fathoming and even contacting spiritual worlds. A symbol he described to represent his philosophy was an upside-down plant, rooted in the spiritual heavens, blossoming down toward the practical, intellectual Earth. He was very vocal about his devotion to God and saw anthroposophy as a way to better connect to Christianity—a religion he believed would guide us along the cosmic, universal path of evolution.[117]

Critics of biodynamics say that the practice is more philosophy than science, which is why its efficacy remains up for debate. "The movement is controversial because at its core it is a philosophy, not a science," says horticulturist and Washington State professor Linda Chalker-Scott, in an interview with *The Guardian*. "It is an entanglement of some good, science-based organic practices with alchemy, astrology, and homeopathy. As long as biodynamic preparations continue to be at the heart of the movement, it will continue to be questioned by the scientific community."[118]

Von Diest is a proponent of biodynamics and also practices *ecofluency*, the state of being relaxed and in tune with nature. When you're ecofluent, von Diest explains, you possess the ability to communicate and commune with nature directly—outside of agricultural practices and food growing. In other words, you can talk to a poinsettia in a grocery store. "You could have a conversation with your dog at home, you could have a conversation with your food," von Diest says. "It's the idea that all of nature is not just alive but is conscious and is also self-conscious."[119]

Accepting plants as intelligent, conscious beings is a step toward a smarter and more respectful existence on the planet, according to scientists like von Diest. With a new perspective on plant dignity, we could potentially champion ideas similar to those embodied in biodynamics.[120] We might rethink the use of genetic modification, which, according to Gagliano, treats plants as "unfeeling objects" merely existing to serve us. We also may reconsider the use of monocultures (the process of cultivating a single crop in a given area), says Gagliano, which has led to unstable agroecosystems, reducing phenotypic and genetic variability of plant species.[121]

"By constraining them as obligate annuals designed for uninhibited sex and early death, the process of converting wild species into tamed plants fit for human consumption has enfeebled them," Gagliano writes in *Thus Spoke the Plant*, "stripping them of their ability to communicate effectively to protect themselves from pests and diseases."[122]

While all of these biodynamic, respect-the-plants ideas may make some hearts skip a beet, there are only about 5,000 certified biodynamic farms worldwide today,[123] and the majority of the world's population doesn't recognize plants as sentient, dignified beings. And if the history of humankind is any indicator, even if we collectively decide that plants are complex, perceptive beings tomorrow, that doesn't mean we'll change our relationship with them.

"The fact that something is intelligent has absolutely, unfortunately, no bearing on how we treat it," says Chamovitz. To make a point, he asked me if I think people are intelligent.

"Some people," I replied.

"And how do we treat people around the world?"

"Pretty crappy."

"I rest my case."[124]

The good news is that scientists are gathering data that could lead to better agricultural practices even without the global recognition of plant consciousness or intelligence, and without everybody holding hands and singing kumbaya.

For example, Chamovitz's experiment showing that plants produce sweet nectar at the sound of buzzing bee wings could teach us how we might use sound to optimize pollination going forward.[125] In studies of how birch trees "sleep" at night, scientists can learn more about how trees budget the water they store, which could help climatologists better understand the effects forests can have on weather and global warming.[126] A study published in the *Journal of Integrated Agriculture* in 2014 shows that when certain plants are exposed to sound waves at different distances, sound pressure levels, and frequencies, it can increase yields and strengthen plant immune systems, sometimes decreasing plant viruses and disease by up to 50 percent.[127] Evidence also suggests that sound can cause a leaf's stomata (or plant pore) to open up, leading to an increase in the uptake of morning dew, fertilizers, and herbicides. With sound stimulation, it might be possible to dramatically reduce the amount of herbicides and biocides used in agriculture, as the plants will be more ready to "absorb" them.[128]

The Explanatory Canyon

Many of us will live our whole lives without having tripped with a tropical tree or shot the breeze with a poinsettia. Von Diest may be right that we all have an innate capacity to communicate telepathically with plants, but the fact is, not everyone will. So its seems that the job of the scientific method is to try to get at the core of what's true for everyone despite varying cultures and beliefs.

Right now, there are scientists who are extremely resistant to the concept of plant intelligence and consciousness. They condemn the possibility of plant sentience with a confidence that is arguably bewildering, considering the fact that we can barely unravel the mystery of human consciousness.

All science can reasonably show is that plants are aware, adaptable beings. The explanatory gap is like the Grand Canyon, and when it comes to belief in plant sentience, some scientists think it better to proceed with caution than to run over the edge.

Of course, if you personally can talk to plants, then maybe you know more than others; perhaps you're lucky and are tapped into the secrets of the universe. It's hard to deny that Gagliano is responsible for leading scientific studies that reaped astonishing results—and far be it from anyone (including the author of this piece) to tell her that a tree in Peru didn't give her the guidance to do the experiments. But do we want scientists to take stories of other people's subjective, anecdotal experiences on faith? Or do we want them to stick to the data? It's all just a matter of opinion, it seems. Like the definition of intelligence or consciousness.

In the film *The Secret Life of Plants*, Dr. Prem Chand of the International Plant Communication Society gave a speech to a crowd of sunhat-wearing, hoity-toity garden club members, challenging them to consider for a moment not how we see plants, but how they might see us. "Imagine receiving from plants, locked in their own dimensions of time and space, a view of our own chaotic world. We see them as static, unmoving objects. And to them perhaps, we are a hopelessly mechanical rush of activity," Chand says. "A flurry of the absurd."[129]

Maybe there's a grain of truth to Chand's idea. It would be exciting to believe that we're really getting somewhere with all this—that one day the movie running in our conscious minds will get a new ending. At some point we'll look back and laugh at our arrogance, our simple-minded perspective on the world. "Plants are sentient, exalted beings!" we'll cry, praying to Mother Nature whilst playing the harp to a bundle of grapes. But it's also possible that our science experiments and philosophical arguments over plant rights, behaviors, and abilities appear to plants as nothing more than a meaningless blur.

While there's difference of opinion among botanists as to how to study and treat our flora, the common ground seems to be a deep-rooted desire to know more. Indeed, plants are very different from us, and when it comes to complex questions of their behavior and existence, we still largely remain in the dark. But like plants, human beings have the capacity to adapt to changing information. And when the shade starts to creep in, we can try to learn, grow, and find the light.

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Kristine Lee

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