Plant Intelligence & Consciousness

# **Introduction**

Plant intelligence – the capacity of plants to sense, learn, remember, and respond to their environment in complex ways – has become a topic of growing scientific interest. Unlike animals, plants lack a central nervous system, yet they exhibit remarkable behaviors such as rapid movement, inter-plant communication, and even forms of learning. Recent research in *plant electrophysiology* and *plant-fungal symbiosis* has revealed sophisticated signaling networks within and between plants, prompting scientists to reconsider the boundaries of intelligence and even consciousness. This report provides an in-depth analysis of these findings. We review how carnivorous and sensitive plants use electrical signals much like nerve impulses, how mycorrhizal fungal networks connect plant communities in a manner analogous to neural networks, and what these phenomena imply for our definitions of consciousness. We will discuss whether plants’ abilities – such as signal integration, habituation (learning), resource sharing, and communication – meet criteria for a form of awareness or “proto-consciousness.” The goal is to integrate recent experimental evidence with a broader literature perspective, examining both the excitement and skepticism in this emerging field.

# **Methodologies**

Research into plant intelligence spans laboratory electrophysiology, greenhouse experiments, field ecology, and theoretical modeling. Key approaches include:

* **Electrophysiological Recording:** Scientists measure electrical potentials in plants using microelectrodes or novel sensors. For example, Venus flytraps have been instrumented with thin-film electrode arrays to map the propagation of action potentials across their leaves ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=To%20measure%20and%20map%20these,recording%20the%20electrical%20impulses%20generated)) ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=The%20recordings%20reveal%20how%20electrical,twice%20within%20about%2030%20seconds)) on *Mimosa pudica* (the sensitive plant) detect voltage changes as the plant responds to touch. These methods reveal the speed and patterns of plant electrical signaling.
* **Behavioral Experiments on Plant Learning:** To test learning and memory, researchers design stimuli and observe plant responses over time. In one setup, potted *Mimosa pudica* plants were repeatedly dropped a short distance to induce their leaf-closing defense. Over repeated trials, scientists recorded whether the plants habituated – i.e. stopped closing their leaves when the stimulus proved harmless. Such experiments, com ([Experience teaches plants to learn faster and forget slower in environments where it matters - PubMed](https://pubmed.ncbi.nlm.nih.gov/24390479/#:~:text=animal%20learning%20research%2C%20we%20show,effects%20observed%20in%20many%20animals)) ropriate controls, probe the capacity for non-associative learning in plants. Other studies have attempted classical conditioning (for instance, pairing light and airflow stimuli in pea plants) to see if plants can form associations, though these remain controversial and not easily replicated.
* \*\*Mycorrhizal Network Experime ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=integrate%20different%20aspects%20of%20experience,their%20leaves%20after%20being%20touched)) ne communication and resource sharing via fungal networks, ecologists use both lab and field methods. In controlled greenhouse studies, plants are grown in pairs with their roots either connected by mycorrhizal fungi or separated by barriers. Researchers then introduce a treatment to one plant – for example, infecting it with aphids or altering its nutrients – and observe any response in the neighboring plant. Using such setups, a landmark study showed that when an aphid infests one plant, neighboring plants connected by a common mycelial network initiate defensive chemical production *before* they themselves are attacked. This indicates signal transmission through the f ([Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack - PubMed](https://pubmed.ncbi.nlm.nih.gov/23656527/#:~:text=The%20roots%20of%20most%20land,Our%20findings)) ([Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack - PubMed](https://pubmed.ncbi.nlm.nih.gov/23656527/#:~:text=parasitoids,herbivores%20and%20their%20natural%20enemies)) ng is tested by labeling a donor plant’s carbon (e.g. with ^13^C isotope) and detecting its transfer to nearby receiver plants via the fungi. Field studies complement this by mapping fungal mycelium in soil and measuring natural nutrient flow between trees.
* **Network Mapping and Analysis:** Advances in molecular ecology allow identification of fungal genotypes linking different plants, essentially mapping the “wood-wide web.” Researchers have found that large “hub” trees (often older trees) can be connected to dozens of younger seedlings via mycorrhizal fungi. Network analysis tools (borrowed from graph theory) are applied to character ( [Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4497361/#:~:text=characteristic%20of%20a%20complex%20adaptive,Ferguson%20et%20al) ) nections. Notably, the topology of plant-fungal networks has been described as *scale-free* and *small-world*, meaning a few highly connected hubs link many nodes, a pattern also seen in neural networks. Comparing these structures helps scientists explore analogies between distributed ecolog ([0003420564 191..213 ++](https://boomwachtersgroningen.nl/wp-content/uploads/2019/04/Simard2018_Chapter_MycorrhizalNetworksFacilitateT-1.pdf#:~:text=fitness,world%20properties%20that%20are)) and brains.
* **Theoretical and Philosophical Analysis:** Since “intelligence” and “consciousness” are complex concepts, some researchers incorporate frameworks like cognitive science and philosophy of mind. For example, the **Integrated Information Theory (IIT)** from neuroscience – which quantifies consciousness as the integration of information – has been invoked to hypothesize how a non-neural organism might still have a form of experience. Researchers also carefully define terms (e.g. distinguishing *sentience*, *consciousness*, \*cognitio ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=,However)) and propose criteria that plants would need to meet. This interdisciplinary approach ensures that interpretations of plant behavior are grounded in rigorous definitions and not just metaphor.

Using these methodologies, scientists have gathered a wealth of data on plant signaling and behavior. Below, we present findings from recent studies and analyze their significance.

# **Findings and Analysis**

## **1. Plant Electrophysiology: Neural-Like Signaling in Plants**

Plants may not have nerves, but they can generate and propagate electrical signals remarkably similar to animal nerve impulses. In carnivorous plants like the Venus flytrap (*Dionaea muscipula*), mechanical stimulation of sensory hairs triggers an electrical *action potential* that races across the trap, causing it to snap shut on prey. These action potentials have characteristics analogous to neuronal signals. They are all-or-nothing voltage spikes ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=Like%20in%20human%20cells%2C%20an,of%20our%20nerve%20cells%20firing)) on flux (chiefly calcium, potassium, chloride ions) across cell membranes. The Venus flytrap’s signaling network is exceptionally fast by botanical standards – action potentials can spread at speeds u ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=Like%20in%20human%20cells%2C%20an,of%20our%20nerve%20cells%20firing)) in its tissue. This speed, while slower than the fastest animal neurons (which can exceed 100 m/s in large myelinated fibers), is still *fast enough* t ([Signaling in electrical networks of the Venus flytrap (Dionaea muscipula Ellis) - PubMed](https://pubmed.ncbi.nlm.nih.gov/30205235/#:~:text=chemical%20stimulation%20of%20a%20midrib,compared%20with%20equivalent%20electrical%20circuits)) apid movement. In fact, the Venus flytrap’s trap closure (one of the fastest movements in the plant kingdom) is enabled by this swift electrical wave and subsequent cell turgor changes.

Other plants also exhibit rapid electrical signaling. *Mimosa pudica*, the sensitive plant, folds its leaves when touched due to an electrical signal that travels from the stimulated leaflets to specialized motor organs (pulvini) at the leaf base. The conduction velocity in *Mimosa* is on the order of meters per second (some studies report ~1 cm/s in stems, while others find faster velocities up to several m/s depending on the pathway). The exact speed can vary with conditions and measurement method, but it is clear that *Mimosa’s* signal swiftly reaches distant parts of the plant to () () onse within a second or two. The electrical impulse triggers ion and water movements in pulvini cells, causing them to lose turgor and mechanically hinge the leaves closed. This sequence functionally parallels how an animal muscle contracts after neural stimulation – an impressive convergent strategy given plants evolved entirely different structur ( [Mechanical Signaling in the Sensitive Plant Mimosa pudica L - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC7284940/#:~:text=Mimosa%20pudica%20L,action%20potential%2C%20followed%20by%20water) ) ( [Mechanical Signaling in the Sensitive Plant Mimosa pudica L - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC7284940/#:~:text=potential%20in%20the%20pulvinar%20motor,step%20to%20enable%20rapid%20movement) ) nd Processing:\*\* Despite lacking a brain, plants like Venus flytrap show a rudimentary form of information processing. The flytrap does not snap shut upon a single accidental touch; it “counts” touches. Specifically, the plant requires two trigger hair stimulations within ~30 seconds to generate a full trap closure response. A first stimulus primes the trap (generating an electrical spike and a rise in internal Ca^2+ concentration), but a second consecutive spike is needed to cross the threshold for closure. This mechanism p ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=The%20recordings%20reveal%20how%20electrical,twice%20within%20about%2030%20seconds)) rap from wasting energy on false alarms (like rain droplets or wind). In essence, the flytrap integrates signals over a short time window – analogous to a simple short-term memory. Intriguingly, if a flytrap is stimulated once, and then stimulated again after a delay (e.g. ~1 minute), the second signal propagates faster than the first, as if the plant retains a “memory” of the recent event and is on alert. Such behavior implies the plant’s electrical network has a temporary excitability change (a form of facilitation), comparable to how neurons exhibit synaptic plasticity on short timescales.

*Mimosa pudica* also de ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=were%20touched%20twice%20within%20about,30%20seconds)) ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=If%20hairs%20were%20prodded%20more,plant%20was%20still%20on%20guard)) ion and learning. If repeatedly touched or dropped, *Mimosa* eventually stops closing its leaves – it becomes habituated. In an experimental study, Gagliano *et al.* (2014) showed that after many drops that caused no harm, *Mimosa* learned to keep its leaves open, seemingly recognizing the stimulus as benign. Remarkably, these plants “remembered” the habituation for weeks; even after a month of rest, previously trained plants resumed showing the learned non-response faster than naive plants. Habituation is a simple form of learning seen in animals – essentially, the plant filters out a repetitive, irrelevant stimulus. The electrical signaling in *Mimosa* is involved here as well: over repeated stimulation, the ionic changes in ([Experience teaches plants to learn faster and forget slower in environments where it matters - PubMed](https://pubmed.ncbi.nlm.nih.gov/24390479/#:~:text=animal%20learning%20research%2C%20we%20show,effects%20observed%20in%20many%20animals)) ([Experience teaches plants to learn faster and forget slower in environments where it matters - PubMed](https://pubmed.ncbi.nlm.nih.gov/24390479/#:~:text=environments,effects%20observed%20in%20many%20animals)) dampened, reflecting a physiological memory. Notably, if a different stimulus (e.g. a harsher shake) is applied, the plants respond again (dishabituation), indicating they specifically learned the original stimulus was not threatening. This experiment, while debated and awaiting further replication, provides evidence that plant electrophysiological responses can be modified by experience – a hallmark of learning.

In comparing plant electrical signaling to animal neurons, several points emerge. P ( [Learning in Plants: Lessons from Mimosa pudica - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4814444/#:~:text=by%20Gagliano%20et%20al,phenomena%20including%20short%20and%20long) ) n potentials are typically slower in both rise time and propagation, and plants lack specialized synapses; instead, their signals propagate cell-to-cell through junctions called plasmodesmata or via vascular tissues. The amplitude of plant action potentials can vary widely (14 to 200 mV in Venus flytrap, lasting milliseconds up to seconds), whereas animal neuron spikes are stereotypically ~100 mV and a few milliseconds in duration. Plants also use a mix of chemical and electrical signaling (e.g. the rapid electrical spike may be followed by slower hormone signals like jasmonates). Nonetheless, the *function* of ([Signaling in electrical networks of the Venus flytrap (Dionaea muscipula Ellis) - PubMed](https://pubmed.ncbi.nlm.nih.gov/30205235/#:~:text=electrical%20signals%20generated%20in%20the,3)) – to transmit information rapidly and coordinate distant organs – is analogous to nervous system function. Researchers have even noted that an excited Venus flytrap leaf generates a train of electrical oscillations with a high frequency, somewhat reminiscent of neuronal firing patterns.

In summary, plant electrophysiology shows that *intelligence-like processes* are not exclusive to brains. ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=Like%20in%20human%20cells%2C%20an,of%20our%20nerve%20cells%20firing)) ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=Although%20plants%20have%20no%20nervous,of%20our%20nerve%20cells%20firing)) y, signal integration (e.g. two-strike trigger mechanism, habituation), and rapid behavior (movement, secretion, etc.) are all present in plants. These findings challenge the notio ([Demystifying the Venus flytrap action potential - Wiley Online Library](https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.19113#:~:text=Library%20nph,of%20this%20carnivorous%20plant)) s as passive automatons and raise questions about how information processing in biology might occur in the absence of neurons.

## **2. Fungal Symbiosis and Mycorrhizal Networks: The “Wood-Wide Web”**

Beyond individual plants, intelligence-like complexity also arises on the ecosystem level through symbiosis. Mycorrhizal fungi form mutualistic associations with plant roots, creating vast underground networks that interconnect plants of multiple species. These networks, often dubbed the *“wood-wide web,”* facilitate both resource sharing and inter-plant communication. Recent research suggests that mycorrhizal networks exhibit emergent properties analogous to distributed decision-making or even a form of collective information processing in plant communities.

**Resource Sharing and Cooperative Behavior:** Mycorrhizal networks are known to transfer water, carbon, nitrogen, and other nutrients between plants. For example, in a shaded understory, small seedlings that receive too little light can be sustained by sugars translocated from larger, sunlit “mother” trees via fungal connections. Experiments with Douglas-fir and birch trees have shown bidirectional carbon exchange – a tree that is photosynthesizing well can send ex ([Underground Networking: The Amazing Connections Beneath Your Feet - National Forest Foundation](https://www.nationalforests.org/blog/underground-mycorrhizal-network#:~:text=a%20vast%20network%20of%20mycelium,%E2%80%9D)) ([Underground Networking: The Amazing Connections Beneath Your Feet - National Forest Foundation](https://www.nationalforests.org/blog/underground-mycorrhizal-network#:~:text=together%2C%20myecelium%20composes%20what%E2%80%99s%20called,%E2%80%9D)) hrough the fungi, and the flow can reverse seasonally depending on which tree needs it. In one study, researchers found that trees “recognize” kin: a tree will preferentially send r ([Underground Networking: The Amazing Connections Beneath Your Feet - National Forest Foundation](https://www.nationalforests.org/blog/underground-mycorrhizal-network#:~:text=In%20healthy%20forests%2C%20each%20tree,1)) earby seedling that is its own offspring or close relative, as opposed to an unrelated plant. Related pairs of trees were observed to favor each other with carbon sent through the mycorrhizal network. This implies a level of selective resource allocation that resembles cooperation or altruism. While the mechanism may be chemically mediated (roots and fungi may exude signals indicating genetic relatedness or health status), the outcome is a distributed system where organisms support one another. Such resource sharing could be seen as a decentralized decisio ([Do Trees Talk to Each Other? | Smithsonian](https://www.smithsonianmag.com/science-nature/the-whispering-trees-180968084/#:~:text=University%20of%20Reading%20was%20the,with%20carbon%20sent%20through%20the)) ocess – the network reallocates resources to where they are most needed, enhancing the survival of the whole community (and ultimately benefiting the fungi as well, which depend on healthy host plants). Ecologist Suzanne Simard has hypothesized that the fungus itself plays a managing role, redistributing nutrients to maintain its host network (ensuring its own steady carbon supply). In this view, the mycorrhizal network behaves like a collective entity optimizing the fitness of the system – an emergent property of many selfish interactions that produces an apparent co ([Underground Networking: The Amazing Connections Beneath Your Feet - National Forest Foundation](https://www.nationalforests.org/blog/underground-mycorrhizal-network#:~:text=Ecologist%20Suzanne%20Simard%20hypothesizes%20that,2%5D%20As%20a)) me.

**Communication and Signaling:** Beyond nutrients, mycorrhizal networks can transmit information. A striking example is the “early warning” system for herbivore attacks. In a 2 ([Underground Networking: The Amazing Connections Beneath Your Feet - National Forest Foundation](https://www.nationalforests.org/blog/underground-mycorrhizal-network#:~:text=Ecologist%20Suzanne%20Simard%20hypothesizes%20that,2%5D%20As%20a)) kova *et al.* found that when an aphid infestation began on bean plants, neighboring bean plants connected to the infested individual (via a common fungus) activated their chemical defenses *before* any aphids reached them. Signals (likely chemical messengers such as methyl salicylate or other stress compounds) passed through the fungal mycelium from the attacked plant to the unattacked neighbors. As a result, the forewarned neighbors produced aphid-repelling and parasitoid-attracting volatile chemicals, deterring the pest spread. This kind of inter-plant communication was only present when a mycorrhizal network lin ([Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack - PubMed](https://pubmed.ncbi.nlm.nih.gov/23656527/#:~:text=The%20roots%20of%20most%20land,Our%20findings)) – control plants without the fungal connection did not show the early defense response. The researchers called this an underground messaging system that “allows neighbouring plants to invoke herbivore defences before attack,” effectively functioning as a community immune system. Similar studies have shown mycor ([Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack - PubMed](https://pubmed.ncbi.nlm.nih.gov/23656527/#:~:text=can%20also%20act%20as%20a,communicating%20information%20on%20herbivore%20attack)) can transmit signals of other stresses, such as drought or disease, prompting connected plants to adjust their physiology.

The analogy to neural networks comes naturally: the fungal mycelium is a filamentous network akin to a web of “wires” connecting individual plant “nodes.” Indeed, scientists have explicitly likened mycorrhizal networks to information highways or biologic ([Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack - PubMed](https://pubmed.ncbi.nlm.nih.gov/23656527/#:~:text=parasitoids,herbivores%20and%20their%20natural%20enemies)) etworks in forests. Like a nervous system for the plant community, the network facilitates both *communication (signaling)* and *homeostasis (resource balance)* among the individual organisms. Recent reviews describe these fungal webs as having *complex adaptive system* properties, meaning the network can change and respond dynamically to environmental conditions and the needs of member plants. The structure of these networks often shows a pattern where cer ( [Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4497361/#:~:text=Trees%20can%20communicate%20with%20each,foundational%20process%20in%20forest%20ecosystems) ) are highly connected (analogous to highly connected neurons in a brain). This topology (often a scale-free network) provides both resilience and efficiency: signals or resources can quickly route through hubs to reach many points (short path lengths), but the network is vulnerable if a major hub is removed. Such parallels to neural network architecture have led to provocativ ( [Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4497361/#:~:text=match%20at%20L186%20comprise%20a,the%20survival%2C%20growth%2C%20physiology%2C%20health) ) ( [Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4497361/#:~:text=Complex%20Adaptive%20Systems) ) exhibit a form of “collective cognition.” Simard (2018) argues that the network’s modular hubs and links allow for information processing and memory in a way comparable to neural circuits, even using terms like “learning” and “memory” to describe how a forest adapts over time via its network. For instance, after a disturbance, the reconfiguration of fungal links and shifts in resour ( [Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4497361/#:~:text=match%20at%20L801%20al,hub%20trees%2C%20however%2C%20can%20cross) ) d be seen as the forest “remembering” and adjusting its growth pattern – a collective memory aiding survival.

It is important to note that these interpretations are not universally accepted, and some researchers urge caution in using cognitive metaphors for plant-fungal interactions. Nevertheless, the emergent behaviors are real: the community acts in a coordinated way that cannot b ([0003420564 191..213 ++](https://boomwachtersgroningen.nl/wp-content/uploads/2019/04/Simard2018_Chapter_MycorrhizalNetworksFacilitateT-1.pdf#:~:text=fitness,world%20properties%20that%20are)) ([0003420564 191..213 ++](https://boomwachtersgroningen.nl/wp-content/uploads/2019/04/Simard2018_Chapter_MycorrhizalNetworksFacilitateT-1.pdf#:~:text=The%20biochemical%20signals%20that%20transmit,communication%20through%20mycorrhizal%20networks%2C%20including)) e plant in isolation. In essence, the mycorrhizal network enables a form of *distributed decision-making*: decisions such as “which plant should get extra nutrients” or “when to activate defenses” are outcomes of network-integrated signals rather than a top-down command. One might say the “decision” emerges from the decentralized processing of information (nutrient gradients, chemical signals) by the fungus and the plants together. This distributed processing has been compared to how simple neural networks without a central brain can still exhibit learning and adaptive responses. In summary, mycorrhizal symbiosis transforms a collection of individual plants into a connected, interactive system – effectively, a super-organism with emergent capabilities for information sharing and resource optimization.

## **3. Redefining Consciousness: Do Plants Qualify as Aware?**

The findings above – electrical signaling akin to neural activity, learning and memory in plants, and distributed communication networks – naturally lead to a provocative question: could such phenomena constitute a rudimentary form of consciousness or awareness in organisms that lack brains? Traditionally, consciousness has been defined in terms of neural processes in animals, often tied to features like complex brains, centralized information inte ( [Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4497361/#:~:text=Trees%20can%20communicate%20with%20each,foundational%20process%20in%20forest%20ecosystems) ) ( [Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4497361/#:~:text=be%20sent%20between%20trees%20in,foundational%20process%20in%20forest%20ecosystems) ) r indicating sentience (the capacity to feel). Here we critically assess whether these definitions might be expanded to non-neural life forms, and what criteria would need to be met for plant consciousness or “proto-consciousness.” We also consider the arguments on both sides of this debate.

**Current Definitions and Criteria:** In neuroscience and philosophy, *primary consciousness* (or sentience) typically involves the ability to have subjective experiences – to feel sensations or emotions, to have an internal state of awareness. More concrete markers often include advanced learning (especially operant learning involving rewards/punishments), and internal representations of the environment (for example, a mental map or image in the brain). By these criteria, plants are a far cry from being conscious. A comprehensive critique by Taiz *et al.* (2021) argues that while plants are highly sensitive and can even learn in a basic sense, they do not show evidence of the *qualitative* aspects of consciousness seen in animals. Those authors emphasize that plant behaviors are stimulus-driven and reactive rather than driven by any internal subjective experience or goal. For instance, a venus flytrap’s snap is a reflexive action to touch, not a willful act, and a plant turning toward l ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=provide%20new%20arguments%20against%2012,Finally%2C%20we) ) ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=organisms%20possess%20consciousness,and%20lack%20sound%20scientific%20support) ) ed by hormonal gradients, not because it “wants” sunlight in any conscious sense. Taiz and colleagues specifically rebut the idea that plant electrophysiology indicates consciousness: they note that these signals serve immediate physiological functions (such as closing a trap or mo ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=provide%20new%20arguments%20against%2012,Finally%2C%20we) ) d do not involve the integrative, information-rich processing that animal brains perform. In other words, a plant’s electrical network, while sophisticated, isn’t assembling a complex picture of the world or making choices – it’s more akin to an automatic signal-response circuit. Moreover, even if plants can undergo simple learning like habituation or associative conditioning, those forms of learning *do not require* consciousness; they can be accomplished by unconscious neural networks as well (even simple robots can learn without awareness).

Another proposed criterion for consciousness is the presence of *affective* states – the ability to experience pain, pleasu ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=provide%20new%20arguments%20against%2012,Finally%2C%20we) ) . This is tightly linked to an organism’s ability to perform operant learning (actively behaving to seek reward or avoid punishment). Plants show no clear evidence of this sort of behavior. They do not run toward “pleasure” or flee “pain” – their behaviors are growth and development-mediated, not free-moving pursuit or escape. Additionally, consciousness in animals is often associated with having dedicated neural structures (like a brain with mapped senso ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=not%20been%20shown%20to%20perform,Finally%2C%20we) ) create an internal model of the environment. Plants lack any analogous structure; their information processing is decentralized and harder to compare to an animal’s unified conscious experience. Based on these arguments, many scientists maintain that while plants are *bio (* [*Debunking a myth: plant consciousness - PMC*](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=organisms%20possess%20consciousness,and%20lack%20sound%20scientific%20support) *) ex and even “smart” in an evolutionary sense*, they are not conscious. Claims of plant consciousness are viewed as speculative and not supported by current evidence.

**Expanding the Concept – Proto-Consciousness:** On the other hand, a number of researchers and philosophers have begun to question whether our definition of consciousness is too narrow and “neurocentric.” They point ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=organisms%20possess%20consciousness,and%20lack%20sound%20scientific%20support) ) ion has produced diverse forms of life with sophisticated behaviors, and it may be premature to assume that neurons are the only path to some form of awareness. Some propose that consciousness could be an emergent property of any sufficiently complex information-processing system – even a network of cells in a plant or fungi. The **Integrated Information Theory (IIT)** posits that consciousness correspon ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=organisms%20possess%20consciousness,and%20lack%20sound%20scientific%20support) ) e of integrated information in a system. By this theory, if a plant system (say, the signaling network within a plant, or a mycorrhizal network in a forest) integrates information from different sources into a unified state, it could possess a minimal subjective experience (“what it feels like” to be that system). Paco Calvo and colleagues, who advocate for the field of *plant neurobiology*, ([Consciousness and cognition in plants - Segundo‐Ortin - 2022 - WIREs Cognitive Science - Wiley Online Library](https://wires.onlinelibrary.wiley.com/doi/10.1002/wcs.1578#:~:text=conclude%2C%20we%20shall%20present%20a,phenomenal%20experience%20of%20the%20world)) ([Consciousness and cognition in plants - Segundo‐Ortin - 2022 - WIREs Cognitive Science - Wiley Online Library](https://wires.onlinelibrary.wiley.com/doi/10.1002/wcs.1578#:~:text=consciousness%20boils%20down%20to%20some,phenomenal%20experience%20of%20the%20world)) a priori\* exclude the possibility of plant sentience. They interpret the flexible, adaptive behaviors of plants – such as a bean plant’s strategic “foraging” movements as it climbs – as indicative that the plant is actively sensing and responding in a goal-directed manner, potentially accompanied by a basic awareness of its environment. For instance, when a climbing bean suddenly lunges towards a support stake after initially circling, it’s as if the plant *knows* the stake is there and decides to grab it. Calvo cautiously suggests this could hint at a “level of sentience” in brainless plants, though he emphasizes more research is needed and stops short of claiming proof of consciousness.

In favor of an expanded view, propone ([Consciousness and cognition in plants - Segundo‐Ortin - 2022 - WIREs Cognitive Science - Wiley Online Library](https://wires.onlinelibrary.wiley.com/doi/10.1002/wcs.1578#:~:text=conclude%2C%20we%20shall%20present%20a,phenomenal%20experience%20of%20the%20world)) ([Consciousness and cognition in plants - Segundo‐Ortin - 2022 - WIREs Cognitive Science - Wiley Online Library](https://wires.onlinelibrary.wiley.com/doi/10.1002/wcs.1578#:~:text=consciousness%20boils%20down%20to%20some,phenomenal%20experience%20of%20the%20world)) indings: Plants can be rendered unconscious-like by anesthetics (for example, a bit of ether or lidocaine will “knock out” a Ve ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=encourage%20caterpillars%20to%20cannibalize%20one,that%20lunging%20by%20beans%20is)) *Mimosa*, preventing their movements). The fact that the same chemicals that block conscious experience and neural firing in animals also halt electrical activity in plants hints at common underlying biophysical processes. Additionally, plants possess a plethora of chemical signaling molecules analogous to neurotransmitters (gl ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=encourage%20caterpillars%20to%20cannibalize%20one,that%20lunging%20by%20beans%20is)) serotonin, etc.), raising the question of whether they might use these in ways that parallel neural signal processing. Those who entertain plant consciousness often use the term “proto- ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=running%20a%20pre,the%20fact%20they%20have%20electrical)) – suggesting that while a plant likely doesn’t experience the world as vividly as a dog or human, it may have *proto* subjective states or a basic integrated awareness that something is happening, akin to a very dim feeling or what philosopher Fein ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=,broad%2C%20circular%20sweeps%20of%20their)) t call “minimal consciousness” in simple animals. This remains hypothetical, but it is a provocative idea: consciousness not as an on/off property, but a spectrum that could extend into the botanical realm in rudimentary form.

**Balancing the Debate:** There is currently a healthy debate between the skeptical view (plants are insentient biological automata) and the more permissive view (plants might possess unconventi ([0003420564 191..213 ++](https://boomwachtersgroningen.nl/wp-content/uploads/2019/04/Simard2018_Chapter_MycorrhizalNetworksFacilitateT-1.pdf#:~:text=The%20biochemical%20signals%20that%20transmit,communication%20through%20mycorrhizal%20networks%2C%20including)) cognition or awareness). It is important to clarify that even the latter view does not claim plants have human-like or even animal-like consciousness, but rather asks whether *any* degree of sentience could emerge from non-neural processes. As one science writer put it, the recent radical experiments force us to confront our understanding of consciousness and acknowledge that “plants are incredibly complex” even if we ultimately decide they are not conscious in the strict sense. Practically, most scientists agree that much more evidence is needed to even begin to ([Consciousness and cognition in plants - Segundo‐Ortin - 2022 - WIREs Cognitive Science - Wiley Online Library](https://wires.onlinelibrary.wiley.com/doi/10.1002/wcs.1578#:~:text=conclude%2C%20we%20shall%20present%20a,phenomenal%20experience%20of%20the%20world)) consciousness. Proposed future approaches include looking for *behavioral choices* made by plants that are not strictly hardwired, searching for integrative “neural” correlates in plant electrical activity (do plants have something like brain waves or coordinated signal oscillations correlating with different states?), and perhaps applying mathematical measures of information integration to plant processes. Until such work yields positive results, the default position is that plants do *not* meet the standard criteria for consciousness as we define it in animals. However, the mere exercise of defining those criteria and testing them on plants is illuminating – it forces science to mor ([A debate over plant consciousness is forcing us to confront ... - Quartz](https://qz.com/1294941/a-debate-over-plant-consciousness-is-forcing-us-to-confront-the-limitations-of-the-human-mind#:~:text=A%20debate%20over%20plant%20consciousness,admits%20plants%20are%20incredibly%20complex)) ine what consciousness truly entails and what adaptive functions it serves.

# **Discussion**

The above findings challenge us to rethink some long-held assumptions about intelligence and consciousness. **Do these results reinforce current definitions, or do they push us to broaden them?** On one hand, one could argue the results *reinforce* a traditional view: they showcase how much can be accomplished *without* consciousness. A plant can learn, remember, communicate, and solve problems (like finding suppor ([Consciousness and cognition in plants - Segundo‐Ortin - 2022 - WIREs Cognitive Science - Wiley Online Library](https://wires.onlinelibrary.wiley.com/doi/10.1002/wcs.1578#:~:text=emerging%20field%20of%20plant%20neurobiology,phenomenal%20experience%20of%20the%20world)) haring resources) all through unconscious processes shaped by evolution. In this view, plant intelligence is real but fundamentally different from animal inte ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=organisms%20possess%20consciousness,and%20lack%20sound%20scientific%20support) ) oes not involve conscious thought, but rather clever biochemical and biophysical signaling networks. The complex behaviors of plants might then be seen as analogous to a sophisticated computer program: capable of remarkable feats, yet not accompanied by any inner life. This interpretation aligns with researchers who say none of the plant phenomena so far necessitate invoking consciousness. The burden of proof remains on showing something in plants that *cannot* be explained by mechanistic, unconscious processes.

On the other hand, these findings *challenge* us to consider whether our concept of consciousness is too tightly bound to a specific substrate (neurons) or a specific evolutionary pathway (animals). If we define consciousness in purely functional or behavioral terms (such as adaptability, signal integration, and response to stimuli), then the line between plant and animal starts to blur a bit. Plants exhibit *many* of the functional hallmarks of intelligence: they gather information from their environment, integrate it (a Venus flytrap effectively “computes” whether two touches happened within 30 seconds), make decisions (to close or not, to grow in one direction or another), and even communicate ( [Debunking a myth: plant consciousness - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC8052213/#:~:text=not%20been%20shown%20to%20perform,Finally%2C%20we) ) to other organisms. They also have internal states that change (a “primed” electrical state after one stimulus, a different state when habituated, etc.). If some of these processes were observed in an animal with a simple nervous system, we might readily associate them with primitive consciousness. For example, the way a sea slug habituates to a touch is often discussed in neuroscience as a model of implicit learning – we don’t assume the slug is self-aware, but we do attribute a basic form of neural processing that underlies learning. Plants achieve a similar outcome via different means. Perhaps *awareness* – if we use the term loosely – could emerge in any system that has to continually sense and respond to its environment in an integrated fashion. This is essentially the argument of those who propose consciousness could be present in diverse forms: they are suggesting a more inclusive definition that centers on the *process* (integrating information and using it to guide behavior) rather than the *structure* (having a brain or not).

Still, even an expanded definition must grapple with the qualitative gap: we know what information processing in neurons feels like *from the inside* (at least in our own case – it produces feelings and experiences). We have no evidence that information processing in a plant produces anything like an experience. It may simply be a series of chemical reactions. A cautious stance in the discussion is to perhaps introduce intermediate concepts like **“sentience-lite”** or **“proto-cognition.”** These terms acknowledge plant sophistication without equating it to full consciousness. For instance, one might say plants have a form of *biological intelligence* – they solve problems and communicate – but this might be *acellular intelligence* or *hormonal-electrical intelligence* that lacks a subjective component. Another approach is to view consciousness on a continuum: plants could lie somewhere on a lower end of an awareness spectrum (with something like humans at the high end). This idea resonates with panpsychist philosophies or theories like IIT, which propose that even simple systems have a tiny glimmer of experience. While far from mainstream, such perspectives encourage interesting thought experiments and new research angles.

In discussing plant intelligence and consciousness, it is also important to avoid anthropomorphism while still appreciating the truly extraordinary capabilities that plants do have. Terms like “plant memory” or “plant communication” can be contentious – critics say these are metaphors that risk misinterpretation. Yet, these terms also serve as useful shorthand to compare plant functions with analogous animal functions. The discussion in the field is gradually finding a middle ground: acknowledging plant cognition (in the sense of information processing and behavior) as a legitimate scientific subject, while being careful about how we use terms like “consciousness” that carry philosophical weight. Ultimately, the study of plants is expanding our understanding of the necessary and sufficient conditions for intelligent behavior and might one day inform our understanding of how consciousness arises – by showing us what complex, life-directed activity looks like in the complete absence of a brain.

# **Implications**

If we accept that plants are intelligent in their own way – and even entertain the possibility of some primitive consciousness – the implications span ecological ethics, agriculture, and interdisciplinary science:

* **Ethical and Ecological Implications:** Our relationship with plants and ecosystems might need re-examination. Humans have traditionally viewed plants as insentient resources. However, evidence of plant communication, learning, and possible awareness invites questions about the moral consideration of plants. Should wanton destruction of old trees or forests be seen as more than just habitat loss – perhaps even as destruction of entities that have a kind of collective sentience? Some ethicists argue that even if plants do not suffer in the way animals do, recognizing their advanced capacities should foster greater respect and care for living plants. In practical terms, this could influence conservation policies, such as stronger protection for “mother trees” that are crucial hubs of forest networks. It also provokes the discussion: if someday science did confirm a form of plant sentience, would practices like clear-cutting forests or even industrial farming be viewed in a new ethical light? (Notably, certain cultures and indigenous traditions have long attributed spirit or consciousness to plants, leading to more sustainable harvesting prac ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=witnessed%20what%20they%20called%20learning%2C,it%20okay%20to%20eat%20them)) ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=Needless%20to%20say%2C%20there%20is,that%20need%20to%20be%20considered)) a way, coming full circle to those ideas but through empirical evidence.)
* **Agriculture and Horticulture:** Understanding plant intelligence can improve how we grow crops. For example, knowing that plants communicate pest attacks via mycorrhizal networks suggests that maintaining healthy soil fungal communities can make crops more resilient ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=Needless%20to%20say%2C%20there%20is,that%20need%20to%20be%20considered)) ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=be%20surprising%20if%20we%20learn,with%20bold%20or%20cautious%20violets)) g signals. Farmers and foresters might manage lands in a way that preserves network integrity (e.g., avoiding practices that kill mycorrhizal fungi). Additionally, if plants have forms of memory or anticipation, could farming techniques leverage that? There is research into “priming” plants – exposing them to mild stress so that they remember and respond stronger to future stress. An informed view of plant learning could refine such techniques. Moreover, acknowledging “personalities” or variability among plants (as studies suggest, some plants are bolder or more sensitive) might encourage biodiversity in planting, to balance traits in an ecosystem.
* **Interdisciplinary Research Opportunities:** The convergence of plant biology with neuroscience, computer science, and philoso ([Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack - PubMed](https://pubmed.ncbi.nlm.nih.gov/23656527/#:~:text=The%20roots%20of%20most%20land,Our%20findings)) rontiers. One exciting area is **bio-inspired computing**. The decentralized problem-solving of plant networks could inspire new algorithms for distributed computing or artificial intelligence that do not rely on a central processor. For instance, routing of resources in a mycorrhizal network has parallels to routing in communication networks; studying how the fungus optimizes resource distribution might inform network design. Likewise, the fact that plants can compute and make “decisions” with a very low-energy, widely distributed system is intriguing for sustainable computing – can we build machines that compute more like plants, less like power-hungry brains? On the philosophical si ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=failures%20to%20replicate%20the%20findings,When)) iousness debates force refinement of concepts in consciousness studies and may yield testable hypotheses (for example, if IIT predicts some level of consciousness in plants, experiments could be designed to detect correlates of that). This cross-pollination of fields (no pun intended) is already evident: plant scientists are teaming up with psychologists to apply learning theory to plants, and philosophers are joining botanists in experiments (as with the Minimal Intelligence Lab working on electrophysiology of bean plants). Such collaborations can only enrich our understanding of life’s cognitive spectrum.
* **Legal (**[**Underground Networking: The Amazing Connections Beneath Your Feet - National Forest Foundation**](https://www.nationalforests.org/blog/underground-mycorrhizal-network#:~:text=Ecologist%20Suzanne%20Simard%20hypothesizes%20that,2%5D%20As%20a)**) siderations:** If the notion of plant sentience gains traction, there could be policy implications. For example, some countries (like Switzerland) have at times considered the “dignity of plants” in their legal framework for biotech, reflecting an early acknowledgement that plants warrant ethical reflection. While it’s unlikely we would ever grant individual plants rights akin to animal rights, policies might emerge to encourage treating ancient trees or complex ecosystems as heritage entities deserving protection for more than just utilitarian reasons.

In summary, recognizing advanced capabilities in plants encourages a more holistic and ethical approach to how we interact with the livi ( [Learning in Plants: Lessons from Mimosa pudica - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4814444/#:~:text=Second%2C%20we%20will%20provide%20an,related%20to%20the%20terms%20cognition) ) ( [Learning in Plants: Lessons from Mimosa pudica - PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC4814444/#:~:text=stimulates%20collaboration%20between%20plant%20biologists,automated%20apparatus%2C%20and%20have%20much) ) p line humans often draw between the animal kingdom (considered sentient) and the plant kingdom (considered insentient), suggesting a co ([The Inner Lives of Plants: Cognition, Sentience, and Ethics | Psychology Today](https://www.psychologytoday.com/us/blog/animal-emotions/202209/the-inner-lives-plants-cognition-sentience-and-ethics#:~:text=running%20a%20pre,the%20fact%20they%20have%20electrical)) . The implications urge us to be better stewards of plant life and to continue probing the deep questions of intelligence and consciousness across all forms of life.

# **Conclusion**

The study of plant intelligence and the intriguing possibility of plant consciousness compel us to broaden our scientific imagination. This analysis has highlighted that plants, though brainless and rooted in place, have their own rich electrochemical language and a kind of hive-mind connectivity through fungal symbionts. **Key insights** include: (1) Plants like the Venus flytrap and *Mimosa* use rapid electrical signals for behavior, demonstrating signal integration, speed (up to several meters per second), and even learning-like habituation. These are processes once thought to require neurons, yet plants achieve them differently. (2) Mycorrhizal fungal networks connect plants into large communities where resources and information flow between individuals, producing emergent collective behaviors such as shared immune responses and cooperative nutrient distribution. This “wood-wide web” mirrors the architecture of neural networks in surprising ways, challenging our understanding of decision-making in nature. (3) When it comes to consciousness, current evidence does *not* confirm that plants are conscious in the way humans or animals are – there is no definitive sign of subjective experience. However, the phenomena of plant learning, memory, and communication force us to ask what minimal requirements for awareness might be, and whether our definitions should be adjusted to account for diverse biological architectures.

**Future research directions** are plentiful. Experimentally, scientists could search for mo ([Electrical Pulses That Trigger Venus Flytrap Mapped For The First Time : ScienceAlert](https://www.sciencealert.com/electrical-pulses-that-trigger-venus-flytrap-mapped-for-the-first-time#:~:text=The%20recordings%20reveal%20how%20electrical,twice%20within%20about%2030%20seconds)) ([Experience teaches plants to learn faster and forget slower in environments where it matters - PubMed](https://pubmed.ncbi.nlm.nih.gov/24390479/#:~:text=animal%20learning%20research%2C%20we%20show,effects%20observed%20in%20many%20animals)) nts, or attempts at choice-like experiments (can a plant “choose” between different actions in a way that isn’t pre-programmed?). Advancing technology in bioelectrics may allow detection of plant electrophysiological patterns analogous to brain waves, potentially revealing levels of signal coordination previously unknown. At t ([Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack - PubMed](https://pubmed.ncbi.nlm.nih.gov/23656527/#:~:text=The%20roots%20of%20most%20land,Our%20findings)) ([Do Trees Talk to Each Other? | Smithsonian](https://www.smithsonianmag.com/science-nature/the-whispering-trees-180968084/#:~:text=University%20of%20Reading%20was%20the,with%20carbon%20sent%20through%20the)) term studies of forests with intact vs. disrupted fungal networks could illuminate how information flow impacts ecosystem resilience and “memory” of past events. Theoretically, frameworks like IIT or others might be applied in modeling plant networks to estimate their potential level of integrated information. If such models suggest even a trace of consciousness, it would spur experimental tests for that prediction.

In closing, plants occupy a fascinating position in the study of mind in nature – they are complex enough to exhibit many traits of intelligent life, yet fundamentally alien in how they are organized. Whether or not one is convinced that plants have any consciousness, investigating these questions deepens our appreciation of life’s capacity for innovation. As one review noted, keeping an open mind about the “inner lives of plants” is scientifically warranted. By exploring plant intelligence and potential proto-consciousness, we not only learn about plants – we also gain fresh perspective on what consciousness itself might be, as a biological phenomenon. The coming years of research will continue to unravel how a being with no brain can nonetheless compute, remember, and perhaps, just maybe, feel something of its world.

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