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Be mindful: Plant intelligence, art and patience

Sue Spaid

Intelligence is a property of life, something that even the humblest single-celled organism must possess. Every living being is continuously called upon to solve problems that essentially aren't so different from the problems we face.

Mancuso and Viola (2015: 130)

Since plants are the dominant form of life, their mechanisms of awareness are arguably superior to those of animals.

Trewavas (2021: 677)

In trying to imagine what the experiences of a plant would be like, we're a bit in the position, not of contemplating [Tom] Nagel's bat, but rather of [Frank] Jackson's (1982) Mary, the neuroscientist [who] knew everything there was to be known about colour, but just had not experienced it, having spent all [of] her life in a black and white room.

Calvo (2017: 220)

To anthropomorphize or not?

In retrospect, René Descartes' challenge to budding scientists to 'master and possess nature' propelled human beings to assume the privileged vantage that denies flora and fauna intelligence, agency and thus moral worth (Descartes 2006: 51). An unintended consequence of this Cartesian hierarchy has been the rampant destruction of the environment, engendering ecocide on a level that paradoxically jeopardizes human well-being (Naeem et al. 2016). Even

today, philosophers accuse scientists who claim that non-human animals think (and use language) of 'anthropomorphizing' animal behaviours. However, a recently published paper by philosopher Cameron Buckner, who conducts research alongside cognitive biologists, demonstrates that 'a wide range of animal species exhibit so-called executive control when it comes to making decisions, consciously considering their goals and ways to satisfy those goals before acting (Kever 2017). Let's just hope it doesn't take another five centuries for philosophers to appreciate 'plant intelligence'.

Ever since the forest ranger, Peter Wohlleben, authored two bestsellers *The Hidden Life of Trees* (2015) and *The Inner Life of Animals* (2017), critics have accused him (as well as the botanists Suzanne Simard, Monica Gagliano and Stefano Mancuso) of erroneously anthropomorphizing plants and animals, despite his referencing scientific research to explain his surprising observations. For him, trees feel, communicate, nurture and live communally, while some animals keep time, recognize old friends, exercise memory, point and experience emotions, empathy and pain, and so on. Neurobotanists keen to characterize plant intelligence (protein memristors), plant feelings (electrical signalling) or plant communication (plant squeals) have also borrowed from folk psychology, whose references to thoughts, beliefs, emotions, motivations and values stand in for 'actual' neuroscientific processes (Colin and Trestman 2020). Neurobotanists refer to cognition-specific cells as 'phytoneurones' and term this research area 'phytoneurology'.

Rather than defending scientists' appeals to folk psychology, this chapter reviews phytoneurological experiments and artworks whose results dispute prior 'plant beliefs' (due to perceptual fallacies caused by inapt perceptual apparatuses) and illuminate biological processes that reify plant intelligence. In drawing us closer to plants, these researchers and artists help us appreciate otherwise imperceptible events worthy of protection. Absent a greater esteem for plants, which provide food and habitat for some 60 per cent of all land and sea animals, ecocide will continue unabated.

Nearly three millennia ago, the Buddha sat under a *Ficus religiosa* for forty-nine days. During this meditation, he originated 'right mindfulness' by 'contemplating body as body, ardent, clearly aware and mindful, having put aside hankering and fretting for the world; he abides contemplating feelings as feelings … ; he abides contemplating mind as mind … ; he abides contemplating mind-objects as mind-objects' (Kessler 2016: 56). A discipline that must be learned and mastered, *abiding* guides the 'be mindful' imperative, and thus enhances environmental well-being.

When it comes to plants, contemplating bodies, feelings, minds and mind-objects (thoughts) *qua* bodies, feelings, minds and mind-objects not only requires vast reservoirs of patience, but an *abiding* spirit free from animal biases. Indicative of plant logistics, I first explore the 'relay race' whereby plants harness animals and natural forces. I next explain how the cognitive approach known as Enactivism accommodates all living beings, and point out some perceptual fallacies regarding plants. Lastly, I survey art projects that strive to compensate for these perceptual fallacies. By boosting our esteem for and protection of plants, 'being mindful' offers the most basic strategy for curbing the violent waves of ecocide that regularly destabilize ecosystems and engender environmental ill-being.

Contemplating minds as minds: The 'relay race'

The first thing that I want to stress is my 'non-binary' view of plants and animals. I accept that these are scientifically distinct kingdoms, but I don't think it's *philosophically* interesting to specify what it is to be a plant or 'plant-like', as philosophers since Aristotle have done. In extolling plants' capacity to perform functions associated with animals, Mancuso describes plants' affinity with animals despite their lacking brains.

> The plant breathes without lungs, feeds without a mouth, digests without a stomach, sees without eyes, hears without ears, and finally decides, communicates, competes, cooperates and solves problems without a brain. It is even able to remember and learn from experience. [It does all] this without a brain, or any similar structures to which such tasks can be assigned. Plants, in other words, do not have a centralized organization: everything in them is dispersed and not allotted to specific organs. (Mancuso 2018: 4–5)

That Mancuso's assessment seems surprising demonstrates how little we know about plants, let alone their intelligence. Since animals such as jellyfish have distributed nervous systems and lack centralized brains, 'intelligence is the ability to solve problems' (Mancuso 2018: 7).

Since time immemorial, people have considered plants immobile, since they're rooted in earth. I worry, however, that categorizing plants as sessile belies the dispersal of fertilized seeds by wind and animals; sometimes across vast distances (supposing they enter the right belly or beak, set sail on the sea, travel on the wind or cling to fur or feather). Not surprisingly, the heavier the

seed the quicker it hits the ground, where the 'relay race' begins as animals such as birds, ducks and squirrels scramble to hide their cache or drop it farther afield. Even Amazonian fish are known to deposit seeds dispersed by riverbank trees downstream (Kohn 2013: 162). That a species drops its seed, which gets transported by an animal, wind or water, enabling yet another force to disperse it elsewhere, strikes me as a relay race worthy of a gold medal.

All living organisms, whether rooted or ambulatory, partake in relay races; social practices on par with 'dating'. Such relays up the ante for mating, as seeds sown elsewhere augment biodiversity and animal intermingling produces DNA-rich offspring that are more likely to survive. Gilles Deleuze and Félix Guattari's notion of the *rhizome*, which has been abuzz in the artworld for nearly four decades, conveys a variant of my relay race that spurs dating and hastens mating. Regarding the wisdom of plants, they remarked, 'Even when they have roots, there is always an outside where they form a rhizome with something else – with the wind, an animal, human beings (and there is also an aspect under which animals themselves form rhizomes, as do people etc.)' (Deleuze and Guattari 1987:11). Unlike rhizomorphic mycelia, which transport nutrients and information long distances, rhizomes are plant stems that grow horizontally, mostly underground. They not only store nutrients, proteins and carbohydrates, but since new plants grow from them, they facilitate reproduction. Much more than a metaphor for conceptualizing the interconnectedness of all matter inhabiting the natural environment, Deleuze and Guattari's rhizome 'meme' proffers a material model on par with my *kinship model*, which views all living creatures as actively engaging one another, since nature provides for and sustains human life, and vice versa. With the kinship model, '[human] inaction risks immoral consequences, even as it grants nature mind-independence, but it also prevents human beings from exerting control or assuming jurisdiction' (Spaid 2016: 80).

In 1753, Linnaeus sparked a scandal over his classifying 7,000 plants in terms of their sexual reproduction. As Randy Moore points out, 'Opponents of Linnaeus' system, who were referred to as "anti-sexualists", described Linnaeus' system as "loathsome harlotry" since it was "obscene", "enough to shock female modesty" and "far beyond all decent limits"' (Moore 1997: 132). Despite the widespread acceptance of Linnaeus' taxonomic system, philosophers such as Georg Hegel, Martin Heidegger and Jacques Derrida mischaracterized plants as 'sexually indifferent', 'neutral' and even 'asexual' centuries later (Marder 2013: 87–8). Such a misunderstanding of plant sexuality effectively castrates their male and female reproductive organs and sexual proclivities, thus erasing/denying the crucial 'relay race' prevalent amongst social species.

Equally problematic is the approach of plant philosopher Michael Marder who considers plants oversexed for aimlessly flitting their seeds about. He views the 'seed's utter indifference' as extricated from 'the demands of productive or reproductive sexuality' (Marder 2013: 89). Even if copious copulation engenders excess seeds, such seeds, whether edible grains or young plants, give rise to life as they provide living organisms nutrients; land animals eat 18 per cent of plant biomass (equivalent to 400 times the biomass of animals), while ocean animals eat almost all of marine plant biomass. There's no such thing as 'wasted seed'. Moreover, animals routinely copulate for reasons other than goal-oriented reproductive strategies. Viewing plants as strategic beings (hardly dead logs) prepares us to explore what makes them tick.

Contemplating mind-objects as mind-objects: The enactivist turn

Plants represent only 16 per cent of all known species, yet they occupy some 82 per cent of all biomass. Considered expendable, plants suffer maltreatment. Moreover, people tend to associate animal faces and feelings with them deserving more rights than plants. That some 75 per cent of all land is substantially degraded reflects plant habitat neglect. However, recent phytoneurological research ranks plant awareness on par with that of most animals. Thanks to cognitive science's 'Enactivist Turn' (e.g. Varela and Maturana 1992; Hutchins 2010), cognitive capacities like perception, imagination and remembering are explicable without reference to mental representations. Related scientific evidence not only warrants treating plants with dignity and respect, but it also offers good reasons to protect plant life in order to thwart ecocide. For example, protected milkweed habitats boost monarch butterfly populations.

To frame cognition as 'enactive', neurophysiologists Francisco Varela and Humberto Maturana characterized 'the praxis of our living as coupled to a surrounding world which appears filled with regularities that are at every instant the result of our biological and social histories' (Varela and Maturana 1992: 241). Cognitive anthropologist Edwin Hutchins took this even further: 'Enactivism is the idea that organisms create their own experiences through their actions. Organisms are not passive receivers of inputs from the environment, but are actors in the environment such that what they experience is shaped by how they act' (Hutchins 2010: 428). If cognition is a feature of living organisms, then environments also play active roles. Thus, one could say that any system that is

open and exhibits 'autonomy, self-reference and self-construction' has cognitive capacities (Segundo-Ortin and Calvo 2019: 70). For our purposes, plants typically play a dual role as organisms and environments.

Even if animal brains coordinate limbs and organs, they are hardly 'command central' for perception given the environment's influence and inputs. According to Mog Stapleton, 'The enactivist project seeks to give a deeper explanation of perception-action coupling: deeper both in terms of approaching this at a variety of levels and perspectives (cellular-microenvironment, organism-environment, organism-organism) and in terms of grounding this agency in something intrinsic (autonomous) to the system rather than relying on … an external (heteronomous) perspective' (Stapleton 2016: 325). Moreover, all perceivers (all living organisms) are embodied, embedded, enacted and extended, so the notion of relay races taking place in time and space, as described earlier, is already in play. As Mancuso points out, plants pick out and appropriately respond to complex stimuli, 'biotic signals like the presence or absence of other plants in the vicinity and the identity of these plants, as well as competition, predation and disease' (Mancuso 2018: 8).

> In fact, plants respond electrically to many different environmental factors. Light, gravity, touch, sudden changes in temperature, water resources, salt stress, and many other sources can trigger an electrical response, allowing plants to switch on, for instance, turgor regulation for the sake of coordinating organ movement. Overall, cellular electric excitability underlies the ability of plants to respond in a fast and yet coordinated manner to environmental contingencies. (Calvo 2017: 214)

The philosophers, Miguel Segundo-Ortin and Paco Calvo, treat plant behaviour as analogous with animal behaviour. In their view, 'this renders plants suitable to be described as cognitive agents in a non-metaphorical way' (Segundo-Ortin and Calvo 2019: 65). Moreover, plants exhibit 'adaptive behaviors, decision-making, anticipating, as well as learning and memory' (Segundo-Ortin and Calvo 2019: 65). Such claims affirm my non-binary position.

> Whereas higher animals mainly use nervous mechanisms, brains and mental images for assessment, higher plants use molecular mechanisms: hormones, genomic changes and a complex system revolving around electrical changes and $[Ca^{2+}]i$ [intracellular calcium]. Learning, memory and intelligence also contribute to the process of assessment because they influence behaviour. Their contribution to assessment in plants has already been reported. (Trewavas 2021: 674)

The plant biochemist, Anthony Trewavas, whose life's research entailed contemplating plants' mind-objects, prefers the term awareness to consciousness, since consciousness is unique to human beings' linguistic skills. Additionally, he endorses assessing an organism's awareness, which is an 'operational version of consciousness based on behaviour and [is] thus potentially measurable … . Although the mechanisms of animal assessment are neural while molecular and electrical in plants' (Trewavas 2021: 674). That is, both plant and animal awareness are physical events with measurable outcomes. He recently proposed the Integrated Information Theory (IIT), which is blind to brains, nerves and synapses, to explain how plant awareness 'involves information of two kinds: (1) communicative, extrinsic information as a result of the perception of environmental changes and (2) integrated intrinsic information located in the shoot and root meristems and possibly cambium' (Trewavas 2021: 673), the tissue layer between the xylem and the phloem.

One of Trewavas's experiments showed that plant and animal communications share several properties, though plants appear slower to respond. That the concentrations of Ca^{2+} (calcium ions) rise in response to physiological stimuli such as light, touch, plant hormones, pathogens and abiotic stresses such as salinity, temperature and drought is known as calcium signalling. Calvo describes how calcium signalling induces electronic impulses as follows:

> Although changes in behaviour to the signal were very much slower than the visible movement common in animal responses, the initial signal detection via Ca^{2+} was often at rates similar to those in animals (Trewavas 2011). Cytosolic Ca^{2+} signals are mediated by hundreds of proteins and protein kinases (Luan, 2011; van Bel et al. 2014). Many of the same signals inducing cytosolic Ca^{2+} transients also induce action potentials [electronic impulses] in plants; the two are probably intimately related. Likewise, what is more recent, at a higher level of description, is that plants prioritize between signals in the order of response. Animals prioritize their signal responses using sentience. (Calvo et al. 2017: 2858)

Despite the presence of Ca^{2+} and plants' capacity to prioritize signals, few scientists accept plant sentience (the capacity to feel).

As early as 1926, Sir J. C. Bose published *The Nervous Mechanism of Plants*, which claimed that plants have 'a system of nerves that are constituted as a single organized whole' (Bose 1926: 121). Such speculations were dismissed until the millennium when dozens of scientists initiated experiments to grasp both action potentials and variation potentials [intercellular electrical signals] in plants (Calvo et al. 2017: 2864–6). As Calvo et al. hypothesize,

> With time and experience, the developing phloem becomes increasingly cross-linked and memory could then reside in the electrical capabilities determined by numbers and characteristics of the cross linking. Local phenotypic changes to accommodate local environmental situations are characteristic of the behaviour of the self-organizing plant, and maybe, the bioelectric field coordinates with the electrical system to provide for the characteristics of self-organization. Both local and long-distance changes are characteristics of higher plants. (Calvo et al. 2017: 2866)

Researchers have found that touching a Venus Flytrap's hair generates an electrical signal that lasts twenty seconds. If a second hair is touched within twenty seconds, the trap quickly closes, enveloping its prey. Scientists call biological resistor proteins in the cell membrane that control cell-to-cell electrical signalling 'protein memristors'. Not only do protein memristors reflect the cell's electrical history, but plants and animals also have similar voltage gated K+ channels (Volkov et al. 2014). Although animal memory is typically described in physiological terms such that memories reflect synaptic connectivity, that is, the strength of connections between engram cells in the hippocampus, it has molecular components since potassium ion-channels (K+) intensify synaptic potentiation. Plant research conducted by Michel Thellier and Ulrich Lüttge indicates that signal or environmental cues prompt electrical signals, chemical concentrations, small RNAs, calcium waves or phytohormones that activate or deactivate genes associated with memory, thus facilitating processes such as store and recall, circadian rhythms, habituation and epigenetics (Thellier and Lüttge 2013: 1–12). Such genes' protein products eventually produce actions based on the memory of initial stimuli. The core of observable plant memory consists of proteins reacting to past stimuli.

It thus appears that 'plants are able to sample and integrate in real time many different biotic and abiotic parameters, not only nutrient patches and micro-organisms in the soil, but of course humidity, light, gravity, temperature, and many more. Plants also exhibit self-recognition and territoriality' (Schenk, Callaway and Mahall 1999), being able to tell apart their own from alien species, and exhibiting goal-directed behaviour (Gruntman and Novoplansky 2004). In addition, a very sophisticated sensorimotor system that includes proprioception (Bastien et al. 2013; Dumais 2013), with sensory information being transduced via a number of modalities, is found in plants (Trewavas 2009; Baluška and Mancuso 2013, Calvo 2017). Proprioception is an organism's knowledge of its movements and spatial coordinates, such that one automatically ducks one's head as one slips through a low doorway.

Calvo thinks that plants may even be able to perform 'predictive modelling' (Calvo 2017: 212). In light of 'phyto-nervous systems', phytoneurologists attribute choice to goal-directed behaviour that enables plants to exhibit efficient energy gains over expenditure (Trewavas 2021: 677). 'Crucially, if roots were given the possibility to choose the conditions in which to grow, they would develop greater biomasses in patches [of soil] perceived as having an increasing nutrient level, rather than a higher but not increasing one. As Novoplansky (2016) reports, this research shows that plants are sensitive to relative values of resource availability, and not to absolute values per se' (Calvo 2017: 215).

Plants may be sessile, but they are hardly inanimate, docile, thoughtless beings. Constantly on the move, plant seeds regularly adapt themselves to changing environmental conditions, whether water availability, lighting conditions, extreme temperatures and predators. And yet, although scientists increasingly highlight plant agency, most people (outside of indigenous traditions that have long recognized such agency) remain in doubt, largely because they lack 'evidence' of plant vitality. As the next section attests, ending forever ecocide might therefore require bringing plant activities into view, otherwise human beings will continue to neglect and dismiss plant life.

Contemplating bodies as bodies: Artworks that correct perceptual fallacies

Published in English in 2000, Guattari's *Les Trois Écologies* (1989) launched an 'ecological turn' in the art world, as elsewhere. Despite his prescience regarding rhizomes, this text mistakenly attributes tree verticality to forests' 'top-down hierarchy' (Marder 2013: 114 and 169). Philosopher of cognition, Patricia Churchland, claimed plants 'could afford to be stupid' since they're sessile (Churchland 1986: 13). However, the 'slowness' or *hidden* nature of plant activities actually parallels that of millions of invertebrates such as insects, especially ants, spiders, mollusks, crustaceans (some 97 per cent of *all* animals), whose profusion and daily proceedings are nearly impossible to track. The world's most *ubiquitous* organism is the virus HTVC010P, whose prevalence recently superseded its host, the marine bacteria known as *Pelagibacter ubique*, which until 2013 ranked first in abundance as conveyed by its species name 'ubique' (Eveleth 2013).

As already noted, plants remain the clear and outsized winner in terms of biomass (82.4 per cent as compared to bacteria [15 per cent] and animals [0.4 per

cent]), making plants climate change's first responders on a global scale. During photosynthesis, plants sequester carbon from the atmosphere, which they store in the soil as soil organic carbon (SOC). Meanwhile, their leaves, flowers and stems transpire, thus cooling warm climes and heating up colder ones (during winter). Slowness befits towering beings such as trees that burn a lot of their own energy to stay alive. Being 'in it for the long haul' (sometimes centuries), they do everything in their power to conserve their energy. Consider that Alaskan red cedars live 3,500 years, while Giant sequoias last 3,000 years and at least one Bristlecone pine is 5,000 years old (Bailey 2020).

Problematically, philosophers and poets sometimes make shortcuts that promote either indifference or misinformation. For example, Marder notes how the word 'vegetable' is used to describe people in comas, yet its Latin stem is either *vegetare*, which means 'to enliven or animate' or *vegere*, which means 'to be alive or active'. Vegetable is connotatively closer to the English word 'vegetation' (Marder 2013: 20). Despite the rooted nature of most vegetation, erroneous associations with the word vegetable not only erase the relay race, but they also ignore phytoneurology. For greater accuracy, grocery stores ought to replace 'vegetable' with terms that articulate plant's *vital* activities such as roots (anchorage, water absorption, food reserves), stems (water and nutrient conduction), leaves (photosynthesis and transpiration), flowers (reproduction), fruits (seed source) and seeds (fertilized offspring), whose edible status is species-dependent.

It's no wonder biodynamic gardeners and organic farmers follow 'moon sowing' which designates leaf, stem, fruit and flower days. According to 'The Old Farmer's Almanac', the ascending moon proves ideal for planting and harvesting leaves, stems and fruits, while its descent works best for roots. As noted on the 'Biodynamic Sowing and Planting Calendar', initiated by Rudolf Steiner acolyte, Maria Thun, 4 June 2021 was designated a leaf day until 6 June at 15:24 when it became a fruit day until 8 June when it became a root day through 11 June at 17:24 when it became a flower day through 13 June when it became a leaf day at 20:20. Although it seems rather random, the science behind this reflects the way the moon's gravitational pull affects soil moisture, enabling seeds to absorb more water during the full moon than the new moon. Moon sowing thus ties plants' already invisible activities to growth spurts occurring in the dead of night under moonlight, making the moon no less a player here than the sun's warmth, the rain's nourishment, while wind, animals and water dispense seeds hither and thither. Despite all that transpires under our watch, we human beings remain largely oblivious of plants' active routines.

Fortunately, a number of artists' projects make plant life more perceptible to the human eye. The surrealist essayist and poet, Francis Ponge, relished tree leaves for their repeatable leaf iterations. Marder seems to endorse Ponge's erroneous observation that 'plants repeat the same expression, the same leaf, a million times' and 'burst out of themselves' to produce 'thousands of copies of copies of the same leaf' (Ponge 1994: 71). By contrast, conceptual artist, Sjoerd Buisman, went out of his way to demonstrate leaf variety within species. He assembled 'Sun and Shade' leaf studies for scores of plants, which rather capture the role played by sun and shade in orienting leaves, engendering tree-leaf diversity. His studies of oak leaves carried out over consecutive years (1974, 1975 and 1976) counter any notion of 'copies of copies', let alone 'repeat expressions'. His art rather demonstrates deciduous leaves' changing year to year as the tree ages. Several decades later, another artist, Hans de Vries, conducted leaf studies which similarly confirm the variety of leaves bursting from a single tree.

The forester, Michael Snyder, explains:

> But it's not just appearance. Sun leaves and shade leaves act differently, too. Leaves that emerge from budbreak into full sunlight tend to align themselves vertically, nearly parallel to the incoming sun rays. This orientation minimizes overheating and water loss, but because there is so much light available to sun leaves, it does not significantly reduce their ability to photosynthesize. Interior leaves, or shade leaves, on the other hand, typically hang from the branch in a horizontal fashion, more parallel with the ground, to maximize their exposure to incoming sun rays. It is said that for most species these leaf orientations are fixed; they do not change with changes in light conditions. However, there are a few species, such as some dry-site oaks, that can and do adjust leaf angle as the sun moves during the day. The smart money says others do it, too. (Snyder 2011)

Keen to co-create with plants, artist Rob Carter set up an art project whose drawing and video outputs depended on plants being actor-producers. Inspired by the description of plant movement studies by Charles Darwin and his son Francis in *The Power of Movement in Plants* (1880), Carter set up similar tracking experiments, first with kudzu plants and then with soybeans. He tracked the movements of various soybeans, including Big Fellow RR™ GMO soybeans, a mystery GMO bean swiped from a Nebraska field and two organic varieties, 'Agate' and 'Envy', granting us access to the *elan vital* of patented and unpatented life. To do so, he recorded their positions every fifteen minutes from three distinct perspectives over twenty-four- to thirty-six-hour periods under grow lights in an otherwise unlit room. Carter's system captures what scientists call

'circumnutation' of the stem, as the differential growth of plant cells causes them to sway in irregular 360° rotations (Calvo 2017: 219).

A tedious task, contemplating plant bodies as bodies required Carter's discipline to remain 'on schedule' for hours at a time, in order to accurately track the movements of the mystery GMO bean and 'Envy' at two-week intervals, enabling us to grasp their orbits at a larger scale. He claims not to have detected any measurable differences between these two varieties, yet he noticed how older (and therefore taller) plants appear to move faster, perhaps because their orbits' diameters are wider, so in fact their rotation speeds are probably more similar than they seem. From the video, it looks as though it takes seventy-five to ninety minutes for each plant to make a complete rotation. The artist also shared his raw footage of six plant movements with me. From this, I observed the GMO varieties having much more structured orbits than the organic varieties, which regularly reverse their orbits, perhaps because they're more sensitive to their environments. Carter doesn't necessarily agree here.

As briefly noted, philosophers, and especially Thomas Aquinas, have bemoaned that the 'life in plants is hidden [*vita in plantis est occulta*], since they lack sense and local motion, by which the animate and inanimate are chiefly discerned … . Soulless yet living, the plant seems to muddle conceptual distinctions and to defy all established indexes for discerning different classes of beings in keeping with the metaphysical logic of "either/or"' (Marder 2013: 27–8). By contrast, 431art (German artist duo, Haike Rausch and Torsten Grosch) imagine plants having dance parties in the dark, blasting ultrasound squeals in the 20khz–100khz range.

431art started noticing people's disrespect for plant life in 2006. Horrified that people didn't think twice about tossing still-alive plants in the trash, they initiated botanoadopt® (ongoing since 2009) to find plants homes. They initiated Empathy Training classes for people interested in living with, caring for and adopting one of the myriad plants accumulating in their studio, which they routinely reclaimed from neighbours' trash cans. Their book, *Urban Plants Bio-Biographies* (see botanoadopt.org) details the many plants adopted over the years.

431art's project, Plants and Aliens (2020), parallels Carter's effort to capture plant motion. For Plants and Aliens, 431art built a Fourier transformer that transcribes plants' ultrasonic squeals from their leaves to their roots into audible frequencies whose intensities are visualized as charts and flickering LED lights. That 431art amplifies sounds emitted by plant roots is significant, since the Darwins postulated 'root-tip brains' such that the plant's root functions like lower

animal's brains, enabling them to sense their environment (Mancuso 2018: 6). According to Mancuso, we now know, 'the root tip is able to sense and react to more than 20 different environmental parameters, including light, gravity, humidity, temperature, mineral content, and the mechanical resistance of the soil, discriminating between them, and deciding which are the most important for the survival of the plant' (Mancuso 2018: 7).

Contemplating feelings as feelings: Botany's latest frontier

Mancuso's lab has shown that the intense and coordinated exchange of electrical signals amongst root cells resembles electrical activity in neurons (Masi et al. 2009: 4051). 431art worry, however, that their Fourier transformer picks up far more environmental sounds than otherwise inaudible ultrasonic plant squeals. They are currently researching technologies for isolating plant sounds. I imagine them one day registering plant responses to car alarms, buzzing bees, snakes hissing and so on. They hope to capture more than stress signals, making plants' acoustic expressions – the basis for cross-species communication – humanly perceptible. Just as we humans attribute feelings to animal sounds, postures and gestures (myriad websites infer cat feelings from tail gestures), making plant sounds audible is perhaps the first step towards contemplating plant feelings as feelings.

Plants and Aliens also parallels a recent Tel Aviv University experiment which tested tomato and tobacco plant stress signals arising from thirst and cut stems. Apparently, tomatoes are noisier:

> On average, drought-stressed tomato plants made 35 sounds an hour, while tobacco plants made 11. When plant stems were cut, tomato plants made an average of 25 sounds in the following hour, and tobacco plants 15. Unstressed plants produce on average fewer than one sound per hour. It is even possible to distinguish the cause of the stress from the sounds they make. The researchers trained a machine-learning model to discriminate between plant sounds and the wind, rain and other greenhouse noises, correctly identifying in most cases whether the stress was caused by dryness or a cut, based on the sound's intensity and frequency. Water-hungry tobacco appears to make louder sounds than cut tobacco, for example. (Vaughan 2019)

These scientists imagine plants hearing other plants' cries for help, as well as some mammals and insects hearing them and opting not to lay eggs on stressed (thirsty) plants. While some scientists find such possibilities fascinating, others

consider them too speculative. Needless to say, ultrasonic plant squeals are a hot topic for artists and botanists alike.

In the 1970s, people regularly played music for their plants, but no one thought to understand what was actually going on. Wanting to know whether sound and music is stored in water in such a way that it affects plant growth, 431art carried out a preliminary experiment whereby they watered hundreds of bush bean (Marona) seedlings with four different sonic conditions: classical music, hip-hop, a mixture of both and 'non-sonicated' water. After spending seven days in the Frankfurt Palmengarten examining the germination time, growth levels and number of plants germinated, a Goethe University scientist found the number of germinations of bean seeds doused with 'classical water' and 'non-sonicated' water was roughly the same. However, water sonicated with hip-hop music (or mixed with classical music) caused significantly fewer plants to germinate. 431art thus conclude that watering plants with 'hip-hop water' reduces plant germination (Spaid 2017: 221). Similarly, researchers discovered that plants not only distinguish tomato and wheat volatiles (chemicals emitted by plants), but they prefer the former (Calvo 2017: 218).

Gagliano's scientific team trained pea plants to determine which direction plants would follow when rewarded with blue lights that simulate biosynthesis and cue plants' circadian rhythms. Similar in effect to Pavlov's dog, the wind (simulated by a fan) doubled as a prompt (similar in effect to the sound of the bell), while light proffered a reward much like food. In their experiment, plants trained to associate wind with light primarily responded to wind (the fans) as if they expected to be bathed in blue light. Gagliano found that 'all seedlings of the control group grew into the arm of the maze where the blue light had been presented in the last training sessions. This result corroborates the well-known innate phototropic response of seedlings to blue light' (Gagliano et al. 2016: 2). The majority of seedlings (62 per cent) trained to associate the fan with the light grew in the direction of the fan, whereas 69 per cent of the seedlings not subjected to the fan grew away from the light. 'Thus, the first experiment has shown that plants are able to form associations to enhance foraging success' (Gagliano et al. 2016: 2). Their second experiment showed that such training prevailed over innate positive tropism during periods of light, though not periods of partial and total darkness. Gagliano thus concludes that 'the ability of seedlings to anticipate both the imminent arrival of light ('when') and its direction ('where') based on the presence and position of the fan indicates that plants are able to encode both temporal and spatial information and modify their behaviour under the control of environmental cues' (Gagliano et al. 2016: 3).

Although Kasey Markel failed to replicate Team Gagliano's pea plant preference experiment, he remarks:

> Many complex environmental responses have recently been discovered in plants, including luring in animal predators to attack herbivores in response to herbivory (De Moraes et al. 1998), production of toxins in response to distress signals from kin (Karban et al. 2013), and dose-dependent responses to insufficient water (Pandey et al. 2016) or excess salt (Julkowska and Testerink, 2015) in the soil (Markel 2020). These responses demonstrate an impressive capacity to detect a variety of environmental signals and respond accordingly. (Markel 2020)

Gagliano's use of Y-shaped mazes that double as decision-matrices, such that plants grow this direction or that, served as a precursor to The Florence Experiment (a collaboration between artist, Carsten Höller, and botanist, Stefano Mancuso), which involved two 'relay races': spectators rode slides with bean seedlings strapped to their bodies, which scientists tested to grasp the impact of human contact and movement on plant life (Murphy 2019), and visitors' body odours were piped across the building's façade as they watched scary and funny films. In general, seedlings riding alone transpired less and had lower photosynthetic capacities than those that didn't ride at all, but they transpired more and had higher photosynthetic capacities than those transported by human beings.

Following each ride, participants filled out basic questionnaires that gave scientists additional information to help them identify contributing factors. Females tend to boost transpiration, yet slow photosynthesis, while 'excited' non-smokers who are either young or in their golden years tend to enhance both. Höller and Mancuso produced five graphs that detail plant emissions of twenty-seven compounds. Initially, they look pretty similar, but the fifth graph demonstrates how being transported by humans substantially lowers the emission levels of six of the twenty-seven compounds, which coheres with transported plants' lower transpiration and photosynthetic rates.

After riding, spectators were invited to watch comedy and horror films. For this second part of the exhibit, Plant Decision-Making Based on Human Smell of Fear and Joy, laughing and frightened visitors' body odours were pumped through pipes and discharged outside above wisteria plants climbing Palazzo Strozzi's façade. Faced with 'y-shaped' tubes, each of the eight wisterias had to decide whether to grow towards odours aroused by comedy or horror (odours emitted by left and right y-tubes varied from maze to maze). Five out of eight plants (62.5

per cent), a number that exceeds chance, chose comedy, which resembles earlier outcomes, such that moths tend not to lay their eggs on stressed plants and 62 per cent of peas grew towards fans once they were trained to associate blowing air with light. Upon exiting the exhibition, participants were encouraged to adopt an already tested plant and thus continue their observations as citizen scientists.

Some concluding remarks: Contemplating patience as patience

These days, the internet grants us instant access to information, news, entertainment and international destinations. We thus lack patience more than ever, making it especially difficult to perceive, let alone appreciate, plants in real time. In 2020, 431art initiated the portable *Botanical Powwow: Micromuseum for the Future*. This intimate performance occurs inside a modest teepee, thus enabling participants to devote their complete attention to plants selected by the artists. During the pandemic, only four participants at a time could join the duo as they listened to songs, read 'cut-up' texts, used drawing to imagine plant roots and explored plants with their senses, slowing participants down enough to let them 'tune in' to plants, and thus feel more connected to life.

Calvo proffers one last salvo regarding our limited perceptual apparatus:

> We may very well end up realizing that, regardless of the amount of information that a complete plant neurobiology gathers, we simply cannot picture what it is like. But this would not [go] against the sense of awareness of plants, but only reveals our limitations to empathy, and relatedly, of introspection. To accomplish it in some cases, and not in others, may only point towards shared neural/computational mechanisms between the target organism and us. That may be one of the reasons we feel it easier to imagine the subjective experiences of mammals than that of insects, for instance. (Calvo 2017: 221)

No doubt, art-science research demonstrates that plant lives are often beyond our limited perceptual apparatus. Being mindful requires patience which, like abiding, is a discipline built on learning and mastery. This is especially the case when we're mindful of beings that live very different sorts of lives. Generating the necessary tools to overcome our perceptual fallacies requires admitting how little we know about plant intelligence.

Hardly a hipster slogan strewn across a t-shirt, 'Be mindful' captures the Buddha's survival recipe. It demands that we never stop contemplating living

beings' bodies, feelings, mind and mind-objects. Artists working alongside scientists can show us how to do this. Tending vegetables requires first nurturing the soil they inhabit. Mitigating climate change requires first protecting forests and planting ever more seeds. Eager to innovate sustainable materials, we must co-create with plants and fungi. Eradicating ecocide requires apprehending how plant logistics maximize plants' dual role as living organisms and environment. Human beings, too, must recognize our dual role as living organisms whose environments double as other species' habitats.

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