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Conversations on Plant Sensing: Notes from the Field

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Introduction

"If you are here to talk to me about "plant feeling," you can leave now. I will not speak to you." This was not the response I expected. Her voice got quiet and she slid her chair back. The atmosphere chilled. My presence was suddenly suspect. How to proceed? How to salvage this interview? I figured I had to stick it out. I ought to stay with the trouble.[1]

Of course I was there to talk about *plant feeling*. Though I had no intention of engaging this molecular biologist in a conversation on vegetal emotions. That was a conversation I knew better to reserve for other contexts. I was there to learn the ways *plants feel out their worlds*; that is, how they sense, perceive and respond to their environments. Plant sensing is a widely studied phenomenon, and falls under the purview of mainstream plant science in molecular biology, biochemistry, plant physiology, and ecology. I contacted this researcher a couple of weeks earlier hoping I would learn how her lab was contributing to the field. This was the one in a series of exploratory visits to laboratories at institutions on the west coast of the US and Canada, and in Jena, Germany. I had been engaged in the literature on environmental sensing in plants and the chemical ecology of plant/insect interactions since I was a graduate student conducting research on plant development in a molecular biology lab in the late 1990s. I had recently returned to this literature as an anthropologist (Hustak and Myers, 2012). It was time to start talking with a wide range of practitioners to get a multidimensional view of the field. I wanted to hear them tell stories about the ways plants *sense and make sense of* their worlds. This was my first attempt to compose a field in which to explore what plant scientists made the phenomena of plant sensing mean.

On these laboratory visits I met with scientists and their students in the fields of molecular biology and biochemistry, chemical ecology, behavioral ecology and evolutionary biology, biomechanics, environmental sensing, and circadian rhythms. These researchers worked on a range of different species, including *Arabidopsis thaliana* (a common weed and one of the best studied model organism in plant science[2]), tomato, sunflower, wild tobacco, and orchids. Their questions were wide ranging. One lab was trying to figure out the molecular mechanisms by which plants can perceive when another plant is shading their leaves. Tomato plants can apparently discriminate between the kinds of light generated by cloud cover, shade from buildings, and the light that

[1] See Donna Haraway (2010).
[2] See Leonelli (2007).

reaches them through the leaves of other plants. An adjacent lab had several researchers developing sunflower as a model system to learn about what they call "anticipatory" behaviours in plants. Sunflowers, it turns out, not only track the sun during the day, they also move through the night in order to be in the right place to greet the sun the next morning. Another lab delved deep into the ways orchids and insects get involved in acts of pollination. A postdoc I interviewed had studied the evolution of pollination mechanisms in one species of orchid which has figured out how to catapult its massive pollen bearing organs with great force at visiting bees. Reeling from the force of such blows the bees quickly learn to visit the harmless female flowers of the species, and in so doing participate in the act of pollination. Conversations with these researchers made it clear that plants have incredible sensory dexterities, and that they can *make sense* of and actively intervene in their worlds.

The conversations that unfolded over the course of these encounters were riveting. I learned a great deal, and was full of inspiration for the next phase of research. And so I arrived in this molecular biology laboratory primed for more. I was here to learn more about plasmodesmata, those microscopic structures unique to plants that link all cells in a plant to one another. These tiny structures were, I anticipated, crucial to story of plant sensing. Plasmodesmata are channels that connect the internal cellular membranes – the endoplasmic reticulum – of all cells in a plant and allow for the rapid and systemic movement of large molecules like proteins, DNA, RNA, and viruses throughout a plant's tissues. These structures transform what it means for a plant to be multicellular. Indeed, connected cells form a "symplasm" that can extend through an entire plant (see for example Marzec and Kurczynska 2014). Plants, which can grow, move and sense from so many distributed nodes -- from each root tip and from the apex of each growing branch or bud -- have no nervous system to connect up the filigreed multiplicity that is a plant body. I had long imagined these inter-cellular channels were what made it possible for a plant to perceive and propagate sensations through its widely distributed tissues, forming a network that could connect its multitude *centres of indetermination* (see Deleuze, 1986).

Depending on how one looks at it, I arrived in this office either too late, or just in time. In December of 2013, Michael Pollan, that eminent popularizer of plant agencies and author of *The Botany of Desire* and *The Omnivores Dilemma*, published an article he called "The Intelligent Plant" in *The New Yorker* magazine. That story was still flaming amazement across the Internet in April 2014.[3] Pollan was reporting on ideas about "plant intelligence" that had been circulating through the scientific literature under the banner of "plant neurobiology" for nearly a decade.[4] The researchers Pollan interviewed were inquiring into the homologies between plant and animal physiology, conducting experiments to show that, like animals, plants demonstrate intelligent behaviours, they have memory, they can anticipate events, and can communicate with other plants and with animals.

[3] Thanks to Naisargi Dave for pointing me to Ariel's remarkable line "I flamed amazement," in Shakespeare's *The Tempest*.

[4] See for example, Trewavas (2003, 2005), Brenner et al. (2006), V.A. Shepherd (2009), and Stahlberg (2006).

The molecular biologist sitting across from me was infuriated with Pollan's article. She explained that she used to love his work. She even assigned his essays in her courses. But this *New Yorker* essay was propagating bad science and misinformation. Plants don't have neurons or brains. And they certainly don't have *feelings*. She was not the only researcher who took exception to Pollan's story. Others I spoke with were also frustrated with his account. What seemed to be so troubling was the audacity of an approach that engaged human and animal models of intelligence and behaviour to structure inquiry into plants. Even though Pollan reported on conversations with both supporters and detractors of plant neurobiology, his article seemed to some readers to sediment the very anthropomorphisms that are anathema to science. For them it was blasphemous to suggest that plants had nervous tissues or that neurobiological approaches were appropriate for inquiry into plant physiology. Some even saw this move as a denigration of plants. For them, plant intelligence will never measure up to animal or human intelligence, and thus plants will always be rendered as "lesser us." The concern is that if people get distracted comparing plants' and animals' cognitive powers, they will forget about all of the marvelous things that plants can do that animals cannot. They reminded me about plants' aptitude for harnessing sunlight to pull matter out of thin air, and their alacrity for synthesizing chemical compounds like caffeine and nicotine.

I tried to save the situation. Having come all the way here, at least I wanted to learn something about this biologist's research on plasmodesmata. I had to negotiate this carefully. I assured her I was not promoting the idea that plants had feelings, and that I agreed the very concept was problematic. I admitted that as an anthropologist I was interested in what journalists like Pollan and wider publics made "plant feeling" mean. It took some effort to convince her that I was committed to communicating the research "correctly." I mobilized my expertise and credentials. I emphasized that I had graduate training in the plant sciences and molecular biology. I wasn't a journalist out for a sensational story, but a tenured professor on a full-year sabbatical, and soon to be a director of a research institute at my university.

She reluctantly agreed to tell me about the findings of her laboratory. She let me sit near her at the computer, but I felt her keep a cautious distance. She spoke under her breath as she walked me through a set of power point slides illustrating her research. I took notes like a dutiful student, letting her instruct me as if I was in a lecture, only occasionally reaching out with a question to see if I understood her correctly. It took a lot of effort to constrain my comportment and contain my line of inquiry. Unable to probe deeper, I was left underwhelmed by her lab's research. Exhausted and unnerved, I stepped out of the building an hour later into a bright California afternoon.

It was only later that I realized that this encounter was a gift. That difficult hour in her office was the crucial event. This was the experience I needed to get me to slow me down and ensure that I listened very carefully to what these practitioners were trying to communicate. Her refusal to discuss "plant feeling" was an important clue that made me pay closer attention to the fraught politics of anthropomorphism in the plant sciences. She taught me how hard it is for these researchers to speak about their work on plant sensing

without stumbling into the *trap* of anthropomorphism at every turn. This conversation with her got me tuned in to what it was that these researchers wanted me to hear them saying, and what – in spite of what they actually said – they did not want me to hear them saying. It was in this process that I also had to confront what it was that I wanted to hear them say, and what I wanted to make their research mean. Moreover, these conversations helped me see that anthropomorphism is not always a trap; rather, in Isabelle Stengers' (2008) sense of the term, anthropomorphism can, in the right hands, also be a "lure," one that "vectorizes" researchers' attentions and questions and propels their inquiry.

The Plant Turn

This report from the field offers a contribution to what might be best called "the plant turn", a recent swerve in attention to the fascinating lives of plants among philosophers, anthropologists, popular science writers, and their widely distributed, electronically-mediated publics. A suite of new works have appeared very recently, including philosopher Michael Marder's *Plant Thinking: A Philosophy of Vegetal Life* (2013), philosopher Matthew Hall's, *Plants as Persons*: *A Philosophical Botany* (2011), scientist and educator Craig Holdrege's *Thinking Like a Plant: A Living Science for Life*, scientist Daniel Chamovitz's *What a Plant Knows: A Field Guide to the Senses* (2012), and anthropologist Eduardo Kohn's *How Forests Think: Toward an Anthropology Beyond the Human* (2013). These extraordinary texts have been followed up by articles such as the one by Michael Pollan in *The New Yorker Magazine*, as well as a 2014 *New York Times* book review by Oliver Sacks on the "Mental Life of Plants and Worms, Among Others." What many of these texts encourage their readers to consider is the extension of the concepts of intelligence, thought, communication, and cognition to plants, those organisms that have always appeared so passive, so mute, so still.

It is as if a kind of de-speciated orchid fever has swept people up in the fervent collection and circulation of stories of plant agency. Is this a twenty-first century return of the craze associated with that sensational 1973 publication, *The Secret Life of Plants*? Authored by Peter Tomkins and Christopher Bird, that text unearthed a bizarre array of experiments exploring the uncanny dimensions of plant memory, consciousness and intelligence. The follow-up documentary, released in 1979 and accompanied by a soundtrack by Stevie Wonder, was suffused with the textures and tones of a psychedelic culture attuned to occult practices and mystical experience. In these accounts, explorers in the realm of plant consciousness waver between the figures of the scientific rationalist and the paranoid whose suspicions link plant consciousness to extraterrestrial communications and secret military operations. Engineers-cum-plant whisperers invoke the rhetoric of cybernetics in experiments that wire their potted, pet plants up to electronic circuits. Some experiments aimed to turn plants into living lie detectors that could register, in the form of an electronic shudder, subtle shifts in human emotion. Unfortunately, the plants in many of these experiments merely became transducers for human affects and aspirations, with the effect that the experiments generated deeper insights into the people who designed them, rather than any profound knowledge about what it is that plants are up to.

Why now, long after the experiments in *The Secret Life of Plants* were debunked by skeptics and relegated to the detritus of New Age culture, are people again so compelled by stories of plant agency? Perhaps it is the tantalizing delight these new texts promise, and the ways they thrill with the revelation of new findings coming out of the mainstream – rather than the fringe – sciences. Astonishing phenomena such plants' ability to remember the precise timing of the last frost (e.g. Sung and Amasino, 2004) and the discovery of a kind of "swarm intelligence" in plant roots (Baluška et al., 2010), seem to promise so much for the radical reconfiguration of theories in philosophy, anthropology, and beyond. What is clear is that plant sensing phenomena upend our thinking; they interrupt the order of things. Consumers of these marvelous stories are transported and transformed. That innocuous patch of green lawn; those tree roots pushing through cracks in the concrete; the sweet aroma of that first spring bloom: these stories promise that your view of plants will be forever changed.

My contribution begins by turning to the very people who are so thoroughly caught in this tropic turn to plants. These are the scientists whose careful experiments have tuned them into the rich sensory worlds of plants. To do their work well they must commit themselves to the care, nourishment, and propagation of plants. They must observe plants' slow growth day by day in their laboratories, greenhouses, and fields. This is the kind of attention that Nobel Prize Laureate Barbara McClintock cultivated in her work on the genetics of maize. Her experience clues me in to the ways that peoples' perceptions of plants can shift and change over time. As a maize geneticist she spent her summers experimenting with corn in agricultural test fields. She recounted to her biographer, Evelyn Fox Keller, "I start with the seedling, and I don't want to leave it. I don't feel I really know the story if I don't watch the plant all the way along. So I know every plant in the field. I know them intimately, and I find it a great pleasure to know them" (Keller, 1983:198). McClintock felt compelled to keep pace with her plants as they grew in the hot summer sun. Her experiments demanded intensive labour, and as she worked closely with plants she cultivated new kinds of sensory perceptions and modes of attention. It was only by gearing her attentions and labours to the temporalities of her plants that she was able to cultivate her celebrated "feeling for the organism" (Keller 1983). Eventually she saw past the static forms we normally register and recognized plants as active agents: "Animals can walk around, but plants have to stay still to do the same things, with ingenious mechanisms." They can, she asserted, "do almost anything you can think of," and have immense capacity for movement in ways that are "fantastically beyond our wildest imaginations" (in Keller, 1983: 199-200).

In the process of their careful work plant scientists learn to pay attention to what it is that plants pay attention to: from the subtlest shift in the gradient of nutrients in the soil; to the most minute changes in the chemical bouquet of their surrounding atmosphere; to reconfigurations in the webs of relation that plants catalyze with microbes, fungi, pollinators, herbivoires, and their other affines. To do their work well, scientists must give themselves over to their inquiry. They must get entrained to plant behaviours, rhythms and temporalities, and they must learn to elicit and observe a range of phenomena that many others will never behold. Their instruments and experiments get them thoroughly entangled with the plants, and over time they come to learn remarkable

things. One researcher confided that that he "knows things" that he just can't publish yet; the data hasn't yet caught up with his intuitions, with what he has learned through his intimate and intensive work with plants.

One could approach these practitioners as vegetal epistemologists. After all these are the people who invest their efforts in figuring out what a plant can do, what a plant can know, and how plants get themselves involved in the lives of other organisms. Caught in the *affective and kinesthetic entanglements* of their inquiry into plant sensing, remarkable things start to happen to researchers' own perceptions.[5] Is it possible that practitioners' sensoria get *vegetalized* over the long duration of their experimental inquiry? If so, how might their vegetalized perceptions and imaginations shape the direction of their inquiry and the ways they think and talk about plants?

This essay documents my conversations with a few of the plant scientists I met in this first foray into the field. In these encounters I feed on scientists' wonder, awe, and excitement about the marvelous worlds of plant sensing and behaviour, and explore how far they were willing to go with their stories of the "uncanny," "amazing," and "crazy" things plants can do. These conversations with practitioners reveal all kinds of productive ambiguities, slippages and ascriptions of agency to nonhuman organisms.
There is a remarkable wavering between enchantment and disenchantment in the stories they tell me. They seem to be pulled between near numinous stories of plants' marvelous sensory dexterities and the disenchantments of a reductionist and mechanistic "thought style" that resists imputing any agency to nonhuman organisms (see Fleck, 1979). The enchantments in their stories often show up when they extend their vocabularies and imaginations about forms of plant agency and intentionality. These are the very moments when they let down their guard against anthropomorphic descriptions of plants, when they revealed the promise of crafting analogies for generating new ways of thinking in the plant sciences. In spite of ardent attempts to constrain their language according to the conventions of their scientific publications, and push back against my provocations, the plants in their stories refused to be contained. Plants, as I learned have memory, and the capacity for learning and anticipation. They have the wherewithal to get interested and involved in worlds they actively make and unmake; they have a kind of intentionality, curiosity, and *interessement* that allows them to articulate their sensory dexterities as they learn how to articulate and register finer and finer differences in wordly phenomena.[6] Plants in these stories appeared to be more than mechanical bodies reacting automatically; these practitioners described the vegetal sensorium as open, responsive, excitable and attuned to a world full of other interested bodies. In the process, they taught me new things about the phenomena of sense, sensation, and sentience.

I treat the vacillations between enchantment and disenchantment in their stories as openings for ethnographic intervention. It is in these spaces that I test boundaries, push at conventions, and tug at the loose threads of the stories scientists hold dear. These moments offer a glimpse of the constraints that make it hard for these practitioners to

[5] See Myers (2015) on the affective and kinesthetic entanglements of inquiry in the life sciences.

[6] See Latour (2004) for a model of the senses grounded in the assumption that an organism's sensorium is articulated and so refined as they get interested in registering differences in the world's rich propositions.

think and talk about "plant feeling." Listening again and again to these recorded conversations I am attuned to the rhythms and tones of the interruptions and redirections each of us make in the course of a conversation. In some moments, I make attempts to destabilize how these scientists think about the plants they study. In other moments I get schooled, and have to confront the limits of my desires, predilections, and hopes for what plant feeling can be made to mean. These conversations help me to see that anthropomorphism is not what we thought it was. I got new opportunities to see how it is not just a one way imposition of human concepts and values on others. The stories they told me helped me understand that it is not only a trap, but also powerful "lure" for inquiry, "luring attention" and "vectorizing concrete experience" to "induce empirically felt variations" in what can be seen and known (see Stengers, 2008: 96).

The Vegetal Sensorium

Stacey Harmer's laboratory at UC Davis conducts detailed molecular and physiological studies of circadian rhythms in plants. Circadian rhythms play a significant role organisms behaviour and physiology, and these rhythms also contour their ecological relations (Hsu and Harmer, 2014, Harmer et al. 2000). Circadian rhythms are understood as a means for organisms to adapt themselves to the regular periodicity of "the geophysical world."[7] Stacey's lab investigates the ways that plants "keep time" through circadian clocks. Composed of complex networks of interacting genes and proteins, these clocks are conceived as "internal timers." Circadian clocks are sensitive to changing environmental signals, such as shifts in the number of hours of daylight over the course of a year, or to varying amounts of heat and cold, or humidity and dryness of each season. These clocks can also keep organisms on track "even in the absence of environmental cues," an especially useful skill for those organisms who never see the light of day.

Molecular clocks enable organisms to rhythmically modify their physiology and behaviour over the course of a day, a season, or a year. They play an especially central role in plants, which, given their reliance on the sun's energy, must adapt themselves to cycles of light and darkness, as well as to seasonal variations. Plants behave differently at different times of the day: they grow, move their organs, open their flowers and produce nectars at specific moments in order to stay in synch with the movements of the sun, and the activities of pollinating insects and herbivores. Research in Stacey's lab has shown that at least 30% of the genes expressed in a young plant are regulated according to circadian rhythms, and the activation of these genes appear to correspond to physiological phenomena such as rhythmic spurts in growth, and the periodicity of nectar production. These clocks seem to offer a means by which organisms get *involved* in their worlds.

> When you think about pollinators and plants, then obviously circadian rhythms are crucial to that relationship. So many plants have a circadian rhythm for when they emit odor, that scent that's going to attract the

[7] See URL: http://harmerlab.openwetware.org/Research.html

> pollinators. They have circadian rhythms for when they produce nectar. When they release their pollen. And of course insects have a circadian rhythm in that they know what time of day they should go to plants because that's when they know the plant is going to be making a reward for them. And with honeybees, it's of course that very famous dance they do to indicate where the other hive members should go to collect the good stuff. So they also have a time compensation in that. Because you know, that has to be part of it if they are migrating by the sun. You have to have a time compensation for that migration to be effective. So the pollinators absolutely have to use their circadian clocks to know where to go and to know when to go. And then plants to have their clocks to optimize when they are making their rewards to promote intercrossing within a species...

Melissa is a senior graduate student working on circadian clocks in *Arabidopsis thaliana* in another laboratory. Friendly, curious, and confident, she was quick to respond to my request for an interview. Born and raised in rural Wisconsin she grew up with access to acres of land she could explore. There was even a nature preserve across the road. "Trees, forests, grass, it was just...well that's where it started." Her mother was an avid gardener and Melissa spent a lot of time with her mom in the garden. She thinks its funny how, when she was a little kid, she used to think plants were boring. Her mom told her, "just wait, you will appreciate them one day." It was in a general biology class in her second year of college when she learned about the molecular mechanisms of photosynthesis that she awoke to a very deep appreciation of plants. She was keen to talk with me about the kinds of work that I do. She explained that she is working to develop her skills in the area of science communication. She is concerned that scientists aren't doing a good job at getting their insights across to wider publics. A conversation with an anthropologist seemed like a great opportunity for her to articulate what she saw as some of the major problems with recent popularizations of plant sensing. And so early on in our conversation, Michael Pollan's *New Yorker* article and the issue of anthropomorphism took centre stage.

We found a darkened conference room away from the bustle of her laboratory. Seeking more light we raised the blinds to reveal a good view of the courtyard below. After an hour-long interview, Melissa took me to the growth chambers in an adjacent building where she keeps her plants in controlled environments that regulate temperature and humidity. There she can entrain the plants to varying cycles of light and darkness. Though she had a lot of experience before arriving in this lab, this was the first time she had worked directly with plants and had to learn how to keep them alive and thriving. I reminisced with her about my own experiences caring for plants in growth chambers when I was a graduate student at McGill University. This was a much more impressive facility. On this visit she collected some leaves from an experimental strain of *Arabidopsis* that she had bred to carry multiple mutations in its circadian clock genes. Later she took me to the lab where I got to observe her lab-mate teach her a new technique for counting the number of cells in each leaf.

At one point, our conversation in the conference room turned to the nature of sensing mechanisms in plants. We were discussing prevailing views about the cellular and molecular mechanisms of sense perception. I told her that I though that plant sensing research is in a position to redefine what we mean when we use the terms "feeling" and "sensation": "We think we know what sensing is, but perhaps we just don't know." She nods in agreement as she reformats my statement, saying "We know what we think sensing is." I am particularly concerned with all of the inheritances of a cybernetic, militarized model of sensing and cognition that appears to be informing much of the plant sensing literature (see for example Baluška et al., 2010).

> N: Right...But it is also caught up in all these problematic assumptions. What if we started with the plants? Perhaps we would actually get somewhere really interesting. We'd multiply our understanding of what is possible, instead of overlaying the limitations of the human model on plants.
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> M: It is interesting though to think of plant sensing, if you talk to many scientists, they are going to say that it's through signal transduction and molecules interacting in a chain of molecular events.[8] And *that* response is sensing. So it is sort of analogous to that in humans, we have similar processes. But then [in the case of humans] we go on to say okay, "How does it make us feel?"

Melissa explained that she took issue with the attempt to make this same move in plants, "to go a step further," and try to make this chain of molecular events "equivalent to consciousness." I hear what she is concerned about, so I qualify what I mean. What I am fascinated with are forms of sensing that happen at the most minute scales of life, even at the level of individual cells. Thinking with recent work in cell biology and evolutionary biology that identifies cells as forms of "selves" with minimal forms of "sentience," I suggest that, "any organism, single cell or otherwise, that can change itself in response to its environment," could be considered sentient.[9] Melissa remained unconvinced by my plea:

> M: I think, I don't ... I guess sort of the general feel that I have is, scientists here, if they are going to consider sensing, umm ... I don't know really how to describe this... It is not umm...devalued? Or? It is not *just* stripped down. I mean there is a lot of respect there. And I guess, that's ... I think that that link is not being communicated.
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> N: Say more about that. When you say there is a lot of respect there...

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[8] Signal transduction is a term used to describe the ways that cells and tissues register environmental stimuli. It describes the chain of molecular events and energy transfers that transduce "information" from the outside to the inside of cells. It is a process that involves "cascades" of events, such as phosphorylation and dephosphorylation of protein and energy transfers between molecules.

[9] See for example, Margulis et al. (2011) and Shapiro (2011). For a philosophical perspective on minimal sentience and nonhuman ways of sense making, see also Thompson, (2011).

> M: Because I think that there is from what you were just saying ... It sounds a little bit like ... To assume that a plant is maybe passively, or responding in a way that is caused by a chain of biochemical reactions is to say it is less important than whatever a human is doing. And I think that is not true. Yeah! It is as if you are suggesting that to characterize it that way [at the molecular level] is to be completely insufficient. [It's as if there] has to be more there. And I think it is important and it's arguably sufficient the way it is. It is *so crazy* it is *so amazing*.

I really appreciate how she pushes back on me in this moment. She is concerned that to render these processes at the molecular level and leave it there is to denigrate it somehow. What she was telling me, what I finally heard her say, is "that the mechanism itself is so fascinating, rich, and amazing." Melissa was quick to affirm, "Yah! There doesn't have to be more." We were both laughing at this point. "Right," I affirm "There doesn't have to be a higher level cognition to make it interesting." I am with her on this, and I can hear the relief in her voice that we are getting each other: "Yeah! Yeah! Yeah! Exactly!" I keep going. "So perhaps, reducing it to a mechanism isn't actually so disenchanting." Melissa affirms, "Yah. That is, that is *exactly* how I feel."

> N: So I am curious if for you the world is more enchanted [Melissa interjects: Yes! Totally!] given you have this deep understanding of this chemistry. And not this disenchanted dead world of little machines bumping up against each other.
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> M: Definitely. Yeah but they are elaborately designed or produced machines. There is such a level of detail and complexity of molecules that can coordinate their actions and their interactions in time and space. There is just no way to explain that. It is really just ... it's totally enchanting.

Perhaps it is this wavering between enchantment and disenchantment in scientific stories that offers an important clue as to where there are openings to imagine plant sensing differently. Melissa is amazed at the ways that these complex and intersecting molecular processes hang together so robustly. At the same time she reminds me that my line of inquiry in our conversation is actually a little off. My research into mechanism in molecular biology and metaphors of "molecular machines" has shown that in the hands of practitioners, molecular mechanisms are anything but dead, disenchanted matter. Indeed, what I have been learning is that in spite of great effort, mechanism has failed to fully disenchant the life sciences. All kinds of enchantments, in the form of animisms and anthropomorphisms, keep bubbling up in practitioners' discourses and practices (see Myers, 2014 a, 2015). Indeed, these are the practitioners who taught me how to see processes of signal transduction not just as the traffic of information from the environment into a cell, but as a complex contact-dance between molecules propagating energies and intensities (see Myers, 2015). What if signal transduction was not just a way of moving "information" from the environment into the cell, but a way of transducing affects and energies through a body's excitable tissues? What if they were a way for

organisms to actively modify their biologies in response to their environments, and also a means for them to actively intervene in their worlds? What if this kind of responsive molecular affectivity were the most basic kind of "feeling"? Perhaps this is a molecular practice that gives cells both their sensitivity and their sensibility; perhaps it endows them with the kind of responsivity required not only for sensing but also making sense of their worlds (see also Thompson, 2011)? Some have proposed this process as the ground for a kind of cellular sentience and subjectivity (see also Margulis et al., 2011; Shapiro, 2011). Perhaps signal transduction is the place to begin shaping a model of plant sentience that is grounded in the very sensitivity of plant tissues. This would be a model that bypasses any reference to cognition or a central nervous system. It would be a model in which the specificity of bodies, tissues, and cells matters: plant tissues have unique sensibilities and transduce affects and sensations differently than animal or human bodies. Such a model would need to account for the specificity of vegetal sensoria and the peculiar kinds relations that each plant catalyzes with other organisms. Plant feeling would thus be a very different phenomenon than human feeling, and would require researchers to cultivate different modes of attention, distinct lines of inquiry, and new ways of telling stories about what plants do and what they know. Perhaps that is the place to begin conversations on plant sensing.

Disenchantments

I am early for my meeting with James, a postdoctoral fellow in Julin Maloof's plant shade laboratory at UC Davis. I wander down a long, gleaming white corridor that leads to a series of plant science labs. The walls are remarkably bare except for a few large posters from scientific meetings detailing recent research. A young man with a sleight build and short brown hair walks by me and gives me a curious look. No one wanders the halls reading these posters. I must be the person here to meet with him. He directs me to his office at the end of the corridor.

James is a recent PhD who made the move to UC Davis from Harvard to start a postdoc where he could extend research expertise to work on shade avoidance in tomato plants. He is from Caracas, Venezuela. He took a course during his Baccalaureate that led him from a world filled with "monotonous greenery" to a rich and varied landscape of diverse plant species that he learned how to name. He fell in love with plants. When he left Venezuela to study science at Cornell University he specialized in computational and mathematical modeling, combining the life sciences with physics and computer science. Plants fell into the background during that time. But when he started looking at opportunities for grad school he came back to them. He had an interest in biomechanics and a desire to expand his knowledge at the nexus of evolution and developmental biology, a branch of research now well known as "evo-devo." He was a vegetarian at the time and averse to working on animals in the lab. He found a lab at Harvard specializing in orchid evolution and became captivated by a project on the biomechanics of pollen dispersal in a fascinating family known as the Catasetum orchids. I thought we were going to talk about shade avoidance mechanisms in tomato plants. I was surprised and delighted to meet an expert on a family of orchids that I had recently been researching for another project (see Hustak and Myers, 2012).

James is a fan of Darwin, and he and Darwin share a love of orchids. I had recently been reading Darwin's accounts of his orchid pollination experiments, including those he had conducted on Catasetum orchids. Darwin, I had learned, loved orchids so much so that he confessed in a later letter to JD Hooker on October 13, 1861 that, "I never was more interested in my life in any subject than this of orchids." He was particularly in awe of stories he had heard about the propulsive power of male Catasetum flowers, which could fling their pollen sacs at visiting bees with magnificent force and simultaneously eject a long stream of glue that would ensure the pollinium would stick to the body of the insect. Indeed, in a letter to JD Hooker on June 9, 1861, detailing all of the British orchids he had examined, Darwin wrote, "I shall never rest till I see a Catasetum eject pollen-masses." Less than a year later some Catasetum specimens were sent to him by post, and he conducted an extensive series of experiments in his home laboratory (Darwin, 1862: 224-262; see also Hustak and Myers, 2012). He learned a great deal about the sensitivity of the triggering mechanism in the male flower that allowed it to propel its pollinium with such force at visiting insects. He reports: "Several persons have told me that, when touching the flowers of this genus in their hot-houses, the pollinia have struck their faces. I touched the antennæ of *C. callosum* whilst holding the flower at about a yard's distance from the window, and the pollinium hit the pane of glass, and adhered to the smooth vertical surface by its adhesive disc" (1862: 223-24). So bizarre was this phenomenon, that his attempts to relay his findings to his friend TH Huxley were met with disbelief: "I carefully described to Huxley the shooting of the pollinia in Catasetum, and received for an answer, 'Do you really think I can believe all that?'" The second chapter of James's dissertation opens with this very line from one of Darwin's letters to his friend Thomas Henry Farrer, dated May 7th, 1868. It seems to capture James's own awe and wonder over these marvelous plants.

During our conversation James told me "awesome", "crazy", and "uncanny" stories about the ways that as he put it, "the reproductive biology of the bees is intermingled with the reproductive biology of the orchid." He told me a story about an Australian plant, the Hammer orchid, known to perform an astonishing form of mimicry that can "deceive" male thynnine wasps into thinking that its flower is a female wasp. These plants synthesize bouquets of volatile chemicals that mimic the pheromones of their pollinators with incredible accuracy. Pseudocopulation names the form of mimicry through which a male bee "mistakes" a flower for a mate:

> What is so amazing about the pseudocopulation mechanisms is that they've evolved clearly many, many times in the Orchidacea. And you see them in Ophrys [a large family within the Orchidacea], and you see them in this really awesome Australian orchid [the *Drakaea*, or Hammer Orchid]. These orchids are pollinated by [thynnine] wasps, which have a sort of precopulatory behaviour. The males take females for a nuptial flight. And so they grab onto the orchid, which has this scent...And if you look in this particular case, this Australian orchid, if you look at it on a gas chromatography and mass spectrometry instrument, the chemical profile of the flower scent is practically identical to the pheromone of the female. So it's just *uncanny*, right? The bee is grabbing onto the labellum of the

> orchid, and trying to make off with it [for its nuptial flight]. And it can't [because the flower is attached to the plant]. And the labelleum is hinged at the bottom. When this wasp tries to fly off with a lot of force what it ends up doing, because of the hinge, is that it ends up butting its head against the column, the reproductive parts of the orchid, until it finally gets the pollinarium attached to it.

James story was full of enchantment and excitement at the discovery that the sensory dexterities of plants and insects were so intricately entangled. He used the term "uncanny" a couple times in our interview to express his fascination and near disbelief that these relations between plants and insects could even have evolved. I was relieved to hear so much awe in his voice. The literature on insect pollination in orchids I was reading was remarkably devoid of such sentiments. It is as if this wonder is stifled when scientists confront the conventions of scientific writing and publish their findings.

I make a couple of attempts to bring this issue up with James. I want to ask him why it is when researchers publish their accounts they remove all reference to the plants as active agents. I wanted to understand how and why pleasure, play, improvisation, and creativity are elided in published accounts of animal behaviour (see also Despret, 2013; Hustak and Myers, 2012). His response was telling:

> I think it is largely this skeptical attitude of scientists that we don't know if they have agency or not so we are not going to ascribe any. Frankly the jury is still obviously out on that, particularly in the case of mammals, which are quite intelligent. Nonhuman mammals are quite intelligent, like apes and ... I am not an animal behaviour scientist ... But ...

He admitted that his reluctance to "ascribe" agency to any organisms is part of what we had talked about earlier as a "scientific ethos" that requires investigators to maintain skepticism with regard to things they do not or cannot know. Though he wavers on nonhuman mammals, this ethos refuses to "grant" the capacity for awareness or even minimal sentience to other organisms. My concern is that this ethos of skepticism is bound up with a kind of refusal to inquire, a studied ignorance or nonknowledge around nonhuman life, with the effect that it maintains boundaries between human and nonhumans, and bolsters an exceptionalism towards human capacities and agencies.

Anthropologist David Graeber (2014) takes up this exceptionalism in how the behavioural sciences approach the phenomenon of animal play. He asks: "Why do animals play? Well, why shouldn't they? The real question is: Why does the existence of action carried out for the sheer pleasure of acting, the exertion of powers for the sheer pleasure of exerting them, strike us as mysterious? What does it tell us about ourselves that we instinctively assume that it is?" I tell James that I am interested in the ways that the scientific literature on plant/insect encounters "police pleasure." I relate a story about one researcher who in his scientific paper on insect mimicry among *Ophrys* orchids felt compelled to assure his readers that the male bees can actually discriminate between the flowers and their female mates. Though the bees do get aroused, he insists that,

"ejaculation does not occur at flowers": "Just enough rather than full sexual excitement is at play, a level that prevents pollinator exhaustion and sperm loss" (Nilsson, 1992: 257). The message: don't worry dear reader, the bees are not wasting their precious sperm on a nonviable sexual encounter. In the energetic economy figured in this account, *Ophrys* mimicry must not be too effective: if they were to trick all male bees, the orchids would "outcompete" female bees for mates, and the orchid's pollinator populations would decline (Nilsson, 1992; Vreecken and Sheistl, 2008). I didn't say this to James but the heteronormativity of compulsory and efficient reproduction seemed to me to be so out of place in the affectively charged space of this queer interspecies sex act that involves plants luring bees into intimate contact. What I found so troubling about this story is how it refused to entertain the possibility that the male bees might not just be "dupes" falling for "a sexual swindle." What if they were pleasuring themselves, and perhaps more to the point, pleasuring the flowers? Plant and flower tissues are, after all, incredibly sensitive to touch and tactile stimuli more generally (see for example Bose 1913, 1918; Darwin and Darwin, 1897; Braam, 2005). Recent studies attest to the importance of the microstructure of orchids' petals and their colorful displays and suggest that these features may entice males to "indulge" in the pleasures of pseudocopulation (see, for example, Bradshaw et al.).[10]

Fumbling with words, I found myself at the limits of language trying to communicate these ideas to James. His response to my rather cumbersome intervention spoke volumes:

> Nonscientists have interesting, very anthropomorphic, responses to these natural systems. But, it's just a bit fifth-grade sometimes.

Ascribing too much agency to the plants and their desires rendered my intervention childish, and therefore moot. The charge of childishness or immaturity is common among those who police against anthropomorphism in scientific discourse (see also Daston and Mitman, 2006). Here I get called out as a rather naughty little kid who hasn't yet gotten a handle on the function of sex. I am amused but also frustrated by how hard it is talk about these things and be taken seriously. I can feel the constraints on permissible and impermissible ways of speaking about organisms in the pauses and prevarications and elisions of my own speech.

This was not an issue James and I could work out in the course of our first meeting. But it was a crucial moment for me to begin to think through the politics of anthropomorphism in the plant sciences. Stacey, a well-recognized expert in her field didn't seem troubled by the invocation of terms like memory and anticipation. James's advisor, Julin Maloof, also a respected scientist, was like Stacey, not so concerned with imputing behaviours to plants. He referred to the ways that tomato plants avoid shading their own and others' leaves as part of their "foraging" behaviour. One could say that shade avoidance enables these plants to "eat" more sunlight. He thought it was fair to apply animal behaviour models to plants: "it's the same thing happening at a different speed," he explained. Where animals respond by movement, "plants respond by growing."

[10] See Hustak and Myers (2012) for a fuller treatment of this story.

So if Stacey and Julin could talk to me about plant behaviours in these ways, why was James so concerned? Why was he so careful with how we both used language in our conversation? Are there perhaps different consequences for a more junior scientist vying for recognition in the field? My conversations with Melissa helped me understand this predicament better.

Anthropomorphism meets Phytomorphism

Melissa's research project changed significantly over the years has been in her lab. Snags, unexpected challenges, and underwhelming results kept her shifting between projects. She was in the midst of describing her current research project, when our conversation took a swerve. She was telling me about a new phenotype she was observing in her plants that carry mutations in four circadian clock genes. The leaves of this plant were extraordinarily large. It was her job to figure out why. Was it because the mutations in the circadian clock made the plant process starch and sugar differently? She offers up one tentative hypothesis that she is considering pursuing in the lab:

> And so where it [the plant] is normally storing starch during the day, through photosynthesis, and then mobilizing throughout the night, maybe that process is confused, *if you will*. As if it [the plant] is just mobilizing sugars when it shouldn't be.

She ended her description with this caveat: "Well, that is really anthropomorphizing it." Anthropomorphism? Right. I had already heard several graduate students insert scare quotes around concepts, warning me that they were breaking the rules and anthropomorphizing the plants. I didn't skip a beat in my response. "Okay. Now say that for me in a non-anthropomorphic way. Tell me again what you were saying but this time try not to anthropomorphize it." I wanted to know the difference it would make to her account. How would the grammar change? Melissa hesitated for a moment. "Let me see. The... the...uh...the time of day of starch degradation, or the regulation of starch degradation is altered. Or, yeah, *is affected*." In her second rendition, the plant is a body that can be affected, but it does not have the power to affect its environment.

I pointed out that the main difference I could hear between the statements was that she posed the second version in the passive voice. It was no longer the plant mobilizing the sugars, it was a process happening to the plant. She agreed. She didn't want to be heard implying that the plant was deciding what it would do, or that there was any "intention in the plant." It was clear that it took some effort for her to articulate this process without ascribing any agency. Her caution and care, heard in the pauses, elisions, and prevarications in her speech, remind me of my faltering articulations of plant agency in my conversation with James.

As I learned in my long-term study of structural biology, pedagogical contexts are seen as particularly dangerous spaces for propagating anthropomorphisms. As a result experts are often much more careful about how they frame their stories when they are working with their students, and the students themselves are thus often more cautious about how they

use their language than their expert mentors. And yet, as I have observed so frequently in ethnographic research among a wide range of scientists, experts will anthropomorphize wildly, unabashedly, and without qualification (see Myers, 2015). I tell Melissa a bit about my research on anthropomorphism:

> N: I spent all this time with structural biologists who in their pedagogy with their undergraduates were really cautious about how they talked about their proteins. But then when they talk amongst themselves, they'd say things like "my molecule wants to do this."

Melissa laughs in recognition. She used to work in a protein biochemistry lab, and is familiar with the ways people anthropomorphize their proteins. Playfully we act out the anthropomorphisms that run rampant in the laboratory. "Right," Melissa confirms. "He [the protein] feels like he doesn't want to be degraded right now." I respond, "Oh! He's so unhappy. How do I make my proteins happy?" This acknowledgement shifts things for Melissa. "That's a really interesting point," she confirms. "It's how we talk in the lab." Like the protein crystallographers I interviewed, Melissa acknowledged that she and her labmates worry whether their plants are happy or unhappy, what they like or don't like.

In the midst of our conversation, James had also admitted that it is common for him and his colleagues to fall back on anthropomorphisms as a kind of shorthand. I shared with James my experience working with structural biologists who constrained their accounts for their students, but talk amongst themselves as if molecules were wily and desiring. Like Melissa, he was quick to confirm:

> J: Right! Because [amongst experts] it is easier and you are not going to be judged...A lot of my background is in phylogenetics, so I am very, very careful not to say "primitive," or "advanced." I don't say "basal." You know, I say it's an "early diverging lineage." But when I am talking to my peers, I am much less strict with the language, because they are not going to judge me. And they know what I am talking about. And they know that I am not ascribing directionality or you know...Yeah, especially the terms primitive and advanced. They are extremely loaded.

Melissa and James are both junior scientists, still learning the tacit and explicit rules put into play in the "thought collective" that constitutes their fields (see Fleck, 1979). There is a lot at stake for them. Where their advisors have the security of jobs and standing in the field, these younger researchers have to toe the line. They are not yet in a position to acknowledge the productivity of anthropomorphisms in their own thinking; for them it can only be a trap. Subjecting themselves to the charge of anthropomorphism is not a risk they are willing to take. They put a lot of effort into disciplining themselves, and their ethnographer, so that they are heard correctly.

Back in the conference room, I try to push Melissa to think with me on the implications of anthropomorphism. "So, what do you think the dangers are?" What are the risks in

talking about plants' intentions and desires? Her response brought us back to Michael Pollan.

> M: It goes back to what I was saying earlier with the Pollan article. It speaks to us. It helps us understand. Because we are thinking of it in a way that *we know*. But plants are *not lesser us*. They are very different from us. They are their own entities.

Melissa wants us to be able to think about plants from "a plant's perspective," one not already biased by what we value in humans. Later in the conversation I bring up the issue of plant neurobiology again. I tell Melissa how excited I am to meet a researcher who is working on plasmodesmata. I tentatively reveal my speculative fabulation that maybe plasmodesmata turn the whole plant into a giant nerve. "It's not like plants have nerves. And of course a nerve doesn't feel on its own without a brain. But perhaps there is a system of connectivity that allows us to make the analogy..."[11] Melissa still pushes back in a way that teaches me new things about the kinds of human exceptionalism that these plant researchers are trying to work athwart.

"Again," she insists, "I think it cheapens plants." I ask her to say more. "It assumes we are the ultimate being," she explains. Rather than deploying humans as the measure of plants she wants us to see what would happen if we set plants as the measure of human capacities. "So," she asks, "what is the analogy we are making for our chemistry and the amazing *secondary metabolism* that we don't have, and the caffeine that we don't make.[12] These products that plants make that heal or defend." These are skills we don't have. She reminds me of Dorion Sagan's rant against human exceptionalism in a recent talk that lauded plants as "metabolically superior" to humans and animals. "We think we are so great," he chided his audience, what with our capacity to harness the power of mitochondria, those "latter-day bacteria" which enable the "the slow combustion of food molecules using atmospheric oxygen." Well plants are even better: "they have *both* chloroplasts and mitochondria" (Sagan, 2011).

> We learn in grade school that plants produce oxygen that we breathe, and breathe carbon dioxide that we exhale, suggesting an essential equivalence, and a nice ecological match between plants and animals. But plants not only photosynthesize, producing oxygen, they also use oxygen just like we do. They do it at night when sunlight is not available as a source of energy. They can do this because they also incorporate those former respiring bacteria, the mitochondria into their cells. Maybe aliens have detected life on Earth but, considering us parasites, have decided to communicate directly -- and chemically -- with plants, our metabolic superiors. (ibid)

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[11] On the question of how a nerve and a brain require different kinds of inquiries, see Dumit (2014) on what neurons care about.

[12] Secondary metabolism is a term that describes all the marvelous chemicals that plants are able to synthesize with the material products of photosynthesis.

Like Sagan, Melissa insisted that if you want to study chemistry, you should study plants. Plants are masters of chemical synthesis. Instead of measuring plant intelligence up against human intelligence, a contest that will always render plants "lesser us," then perhaps we should consider comparing our capacities to plants' remarkable skills at chemical engineering:

> So maybe it has to go both ways. Then that would be a little bit better if it went both ways. What's our homologous process to secondary metabolism? … If it goes that way it needs to go the other way too. [I agree, "Nice! Yay!"] But maybe then I'd feel more comfortable about that. But who wants to talk about that? All the things [like secondary metabolism and photosynthesis] that we don't have?

I was taken by her response, though I could see how easy it is for people to get caught up in contests that pit species and kingdoms against one another. In a larger ecological frame, such competitions seem quite beside the point. However, her insistence on asking "what is our homologous process" reminded me how our analogies move in unpredictable ways. Indeed, I had been learning that anthropomorphism doesn't operate as a one-directional process. This conversation with Melissa reminded me of Darwin's research with orchids. Reading through his orchid pollination experiments a couple of years earlier, I came across a striking passage, reproduced below. Here Darwin is attempting to communicate to his readers the precise form of several different species of Catasetum orchid:

> The position of the antennae in this *Catasetum* may be compared with that of a man with his left arm raised and bent so that his hand stands in front of his chest, and with his right arm crossing his body lower down so that the fingers project just beyond his left side. In *Catasetum callosum* both arms are held lower down, and are extended symmetrically. In *C. saccatum* the left arm is bowed and held in front, as in *C. tridentatum*, but rather lower down; whilst the right arm hangs downwards paralysed, with the hand turned a little outwards. In every case notice will be given in an admirable manner, when an insect visits the labellum, and the time has arrived for the ejection of the pollinium, so that it may be transported to the female plant. (1862: 235; see also Hustak and Myers, 2012: 92-93)

On first reading this statement appears like any other anthropomorphism that likens a plant in some way to a "man." But consider what it took for Darwin to make the analogy. Would he not have had to move his own body to figure out the distinctive forms of each plant? Here Darwin can be seen enacting a "body experiment." a kinesthetically and affectively charged twist on the well-known "thought experiment (Myers, 2015). He is demonstrating just how he has entrained his own body to the specificities of floral form. Darwin is mimetic entangled with the orchids, and his willingness to fold his around plant form produces a decentering and displacement that transforms his bodily contours at the same time as it reinscribes those of the orchids. Thus, we might first recognize as a

one-way imposition of human qualities on the plant, can be read, rather, as a process that generates infoldings in thought and in relation.

Darwin has helped me see that what we call anthropomorphism may actually be evidence of our capacity and willingness to open ourselves to others, to let other modes of embodiment inflect and transform our own. I tell Melissa about the protein modelers I have been working over the past ten years whose body experiments are resonant with Darwin's. They frequently animate and anthropomorphize their molecules as wily, desiring creatures. They have taught me how they articulate their sensoria to molecular forms and movements through their painstaking efforts to build atomic resolution models of otherwise imperceptible molecular structures. I have come to see this model building work as a process of attunement enables them to become responsive to the subtleties of molecular energies and movements. It is by giving themselves over to the labor of making models and animations they learn how to *move with and be moved by* molecular phenomena. In the process, they allow their bodies to be inhabited by their models. They draw on this embodied knowledge of molecules to make hypotheses about how molecules move and interact. They situate themselves inside molecular phenomena in order to reach towards insight (see Myers and Dumit, 2011). It is the molecular phenomena that set their bodies into motion, and in the process, they become proxies for their molecules. Indeed, protein modelers not only anthropomorphize their molecules, they also get *molecularized* in the process (see Myers, 2015).

Melissa was thrilled, "The people have been *molecularized*, Ah!" "Right," I explained, "These researchers have been so transformed in their intimate encounters with molecules. They learn to move their bodies around like molecules...And so perhaps there is also a kind of *plantification* of the human scientist going on in these labs."

> M: Ahh! Yeah! Yeah! That is a really, really good point!
>
> N: So I think anthropomorphism isn't a one way thing, there is that openness ....And I think the scientists are going to teach us about what it means to actually be taken into another world by another organism. That organism is going to teach us new things. I think it is wonderful when you say: "What is our homologous process and who are we to think that we are the ultimate being." There can be something so humble about scientific inquiry...
>
> M: ... It takes a level of open mindedness maybe.
>
> N: And maybe one day you will be *plantified*.
>
> M: If I am not already.

I think back to this conversation with Melissa during my visit to Ian Baldwin's laboratory at the Institute for Chemical Ecology at the Max Planck in Jena, Germany. There I

learned a new term for this phenomenon that I had been calling "plantification" or "vegetalization" (see Myers, 2014 b). Ian, an American scientist who took up this post in Germany 17 years ago, runs a massive laboratory with over 70 graduate students, postdocs, and staff dedicated to the study of the chemical ecology of wild tobacco. His group examines of a range of chemicals that this plant synthesizes to lure pollinators, deflect predators, and communicate with other animals in its environment. Over dinner in a traditional Thuringian restaurant in Jena, Ian explained that when he is training his students he gets them to "phytomorphize." According to him, this is the best way for his students to get inside the problems that plants encounter in their environments. He wants his students to be able to morph their bodies in such a way that they can begin to appreciate the nature of the vegetal sensorium. This means that his students actually have to physicalize vegetal embodiments by moving their own bodies to act out plant behaviours and sensing phenomena. "Its kind of like those Dance Your PhD contests," he explained, not knowing that I had been researching the Dance Your PhD contests and other body experiments, and was writing a book explicitly on the ways that scientists move their bodies to help them to work out their hypotheses (see Myers, 2015, and also Myers, 2012). In this remarkable moment, Ian made explicit the multidirectionality of this mimetic and morphic practice that so readily in other contexts would be rebuked with the charge of anthropomorphism. Like Darwin's body experiments with orchids, phytomorphism is not a trap for Ian and his students, it is a lure: it allows them to "vectorize" their thinking, pulling and propelling them into new modes of inquiry, and new lines of flight (see Stengers, 2008 on lures).

It is precisely in the space of these mimetic entanglements among scientists and their plants that it becomes quite unclear who is animating what, and what is animating whom (see also Stacey and Suchman, 2012). These entanglements have a morphic effect, engendering larger-scale meta-morphoses that change the ways that practitioners think and feel about their objects as much as it changes how they think and feel about themselves.[13] What is also set into motion and transformed in this entanglement is the very meaning the terms used in the analogy. Thus, perhaps when researchers talk about plant sensing or plants' capacity for sentience, the very meanings of these terms is also set in motion. Perhaps we could begin to trace an entirely new genealogy of sense, sensibility, and sentience if we were to initiate inquiry among the plants.

Coda

Sitting across from Stacey Harmer in her office, I was treated to enchanting stories about anticipatory behaviours in sunflowers. Where her students used scare quotes around every mention of a concept like a plant "knowing" or "doing" something, Stacey just told me the stories that she found so fascinating. Sitting at her computer in her office she showed me a movie produced by Roger Hangarter, a plant scientist at Indiana University. I was familiar with his work and his extensive collection of plant time-lapse movies he

[13] On the "morphic" dimension of anthropomorphism see also Daston and Mitman (2006).

has archived online to demonstrate some of the incredible ways that plants move their bodies. She got the idea for working on this project on sunflowers from him.

> So this is a sunflower plant in Roger's backyard. [14] So it is tracking the sun. And it really moves. ... The leaves are fairly perpendicular to the sun. The apex is as well. As the sun sets, the leaves in the apex are both going to move towards the west. [N: Amazing!] And so that is pretty cool. And then night though it goes back to neutral. [N: Wow!] And it keeps going.

I am watching the film totally amazed. Roger was able to film with an infrared time-lapse camera through the night and I could see the plant continuing its movement even as its leaves dropped down to rest for the night. Stacey continues: "So this is all before dawn. You can see that the plant...It looks like it is *anticipating*." Right. I am amazed: "It is getting ready for where the sun comes up. Oh! That is just so unbelievable. Stunning!"

> S: Great! Yeah! That is really fascinating to me because that plant is *anticipating* the direction of dawn. And it is *anticipating* the timing of dawn. And anticipation is one strong argument for why circadian rhythms evolved. And so I thought ah, well, maybe we could study sunflower.

At no point does Stacey qualify what she means by anticipation. I push her a little.

> N: Now, anticipation suggests some kind of memory. And these are very human words. I love the idea that we could redefine them from the plant perspective. So how do you understand memory?

She doesn't shun my invitation to explore such aspects of plant sensing. Rather, she responds with another remarkable story:

> S: I'll just mention this. We didn't do this experiment but it is in the literature. You can take a plant in a pot in the field. And it's nighttime and its facing west. You can go in and manually rotate it 180 degrees so it is facing east. And in the morning it is facing west. Because it remembers that is where the sun should come up.
>
> N: You can mess with it and it still knows!
>
> S: You can mess with it, yeah. And so when you move this plant to a growth chamber with constant light. You can see that that motion continues for a number of days, though the amplitude is lower. You could argue that it is remembering the direction and the timing of the light conditions. Yeah. So it is a really good question.

[14] The movie can be viewed at http://plantsinmotion.bio.indiana.edu/plantmotion/movements/tropism/tropisms.html

She tells me how her lab is trying to bring this sunflower experiment indoors, into controlled conditions.

> We can do this in a growth chamber too. So we've got LED lights turned on sequentially to mimic the sun moving. And we have a camera that can monitor the plant, and then infrared lights so we can take pictures even in the dark. And you can see that ... Even during the dark period the plant is reorienting. So that is nice. It is that anticipation again. And that works nicely when the light/dark cycle is 24 hours. But we know for plants and animals that our clocks can't be entrained to non 24-hour cycles. Or they are very different ... So we did this to our plants. We ran the experiment on a 32-hour cycle, which is very nonnatural. But now you can see that at night it just sits there. It doesn't do anything. But that same plant, when we reprogram the lights ... it spends a couple days, I would say *learning*, being entrained by the new cycle, but then you see that *anticipation* again. So. Yeah. I think it is a really interesting question. Is it learning? I mean it doesn't have a brain, obviously. I don't think it is thinking about anything.

At the very end of the interview, Stacey qualifies this comment: "We seem to feel that if things don't have a brain then they can't be intelligent. But of course anything that survives is intelligent in some way." I interject, "It's figured something out!" Stacey agrees and adds, "They just don't reason things out the way we do." I think back to my conversation with Melissa. Perhaps thinking and reasoning are over rated. Perhaps there are things that plants can do that we can as yet barely imagine. I respond, "Well maybe they don't need to." "Right," Stacey agrees, "They don't need to."

Stacey homes her attentions on the molecular mechanisms of plant sensing. However, hers is not a disenchanted rendering. Plants in Stacey's account don't reason, but they certainly have *know how.* They have the wherewithal to anticipate; they can learn, and they can remember. I hear her as suggesting that plants are *up to stuff*, that they have a kind of agency, a kind of intentionality, and their own way of getting interested and involved in the thicket of entanglements that constitute their multispecies ecologies. She doesn't seem concerned about anthropomorphism in her storytelling. She doesn't police her use of human concepts to talk about plants. She is interested in how plants do the things they do and she uses available concepts to communicate her insights. These concepts are lures for Stacey. And yet, it is by bringing these concepts to bear on plant sensory phenomena that she is simultaneously changing the very meaning of these terms. In this sense, it could be said that she is *vegetalizing* the concepts of memory, anticipation, and learning. I can't help but wonder: What might happen if we were to germinate and grow these concepts from studies of plant sensing? What difference might a vegetal epistemology make to these otherwise human terms?

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