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. The scientist sitting across from me slid her chair back and lowered her voice. 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’. At the same time, 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 in her office 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 first got engaged in the literature on environmental sensing in plants and the chemical ecology of plant/insect interactions in the late 1990s, when I was a graduate student conducting research on plant development in a molecular biology lab (Myers n.d.). I returned to this literature more recently as an anthropologist (Hustak & Myers 2012). And was now just beginning ethnographic fieldwork

[1] See Donna Haraway (2010).

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with a wide range of practitioners to get a more multidimensional view of approaches to the sciences of plant sensing. I had contacted this researcher a couple of weeks earlier hoping I would learn how her lab was contributing to this research. This was 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 wanted to talk with researchers about the ways plants *sense and make sense of* their worlds. This was my first attempt to compose an ethnographic 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 with a range of different species, including *Arabidopsis thaliana* (a common weed, and one of the most closely studied model organisms 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 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 deeply into the ways orchids and insects get involved in acts of pollination. One postdoctoral researcher I interviewed studied the evolution of pollination mechanisms in a family of orchids that have figured out how to catapult their massive pollen bearing organs with great force at visiting bees. Reeling from the force of such blows, apparently 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 about plasmodesmata, those microscopic structures unique to plants that link all cells in a plant to one another. Plasmodesmata are channels that traverse internal cellular membranes—the endoplasmic reticulum—of all cells in a

[2] See Leonelli (2007).

plant and allow for the rapid and systemic movement of proteins, DNA, RNA, viruses, and other large molecules throughout a plant's tissues. These tiny structures were, I anticipated, crucial to the story of plant sensing. Plants have no nervous system to connect up their widely dispersed tissues, including the roots, shoots, stems, leaves, flowers, and fruits that make up their complex and filigreed bodies. Plasmodesmata transform what it means for a plant to be multicellular. Indeed, connected cells form what is known as a symplasm, a continuous cellular connection that extends through a plant (see for example Marzec & Kurczynska 2014). I had long imagined that these inter-cellular channels were what made it possible for a plant to perceive and propagate sensations through its widely distributed tissues. A remarkable feature of plants is that even as they can grow, move, and sense from so many distributed nodes, they cohere in a way that suggests that each root tip is connected to the meristem of each growing branch or bud. I had come to see a plant's manifold meristems, its million-fold nodes of growth, as 'centres of indetermination', each an ongoing experiment in and with the world, materializing what comes to matter for that branch or leaf or bud, now, and now, and now (see Deleuze 1986; Myers 2014b). Could plasmodesmata be the cellular structure that enables such a widely distributed and multiply interested body to cohere, to hang together? Did plasmodesmata endow plants with a nerve-like network to propagate energies, intensities, and affects throughout its body? But perhaps I was getting ahead of myself. Perhaps my own near numinous mediations on plants were getting in the way of me listening to what the scientists were actually saying.[3]

[3] Some biographical context is perhaps helpful here. In the midst of my training in plant molecular and developmental biology in the late 1990s, I was lured into new ways of thinking about plants by apprenticing with practitioners at the margins of mainstream science. Within weeks of completing my undergraduate degree in biology at McGill University, and just before I started a doctoral degree investigating the molecular genetics of flower development, I signed up for a course at Schumacher College in Devon, U.K. with Brian Goodwin (1994), Margaret Colquhoun (1996), and Henri Bortoft (1996). They introduced me to works by others, including Craig Holdrege (1996) and Lynn Margulis and Dorion Sagan (1995). In very little time, my thinking about life and science were utterly transformed. My connection to plants was also intensified through dance. I was a life-long dancer and a choreographer, and I found myself spending a lot of time outside the laboratory creating moving meditations and choreographies to explore plant movements, tropisms, rhythms, and temporalities. I enjoyed trying on plant movements to see how they felt propagating through my tissues. I visualized plant movement to explore how such imaginings could alter the contours of my morphological imaginary. Approaching dance as experimental inquiry, I explored ways of using my own body to help puzzle through chemical communication between the layered tissues of developing flowers and fruits. It was by playing through the possibilities of vegetal growth, propagation, photosynthesis, tropisms, and movements that I became sensitized to the wiles of plant life. *Becoming with and alongside plants*, I kept acquiring newly vegetalized sensory dexterities. I particularly enjoyed visualizing how communities of supracellular plants might form enmeshed subterranean rhizomes. I imagined these as excitable networks that could hum with an electric charge. Years later my

Depending on how one looks at it, I arrived in her 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*, had published an article in *The New Yorker* magazine entitled 'The intelligent plant'. That story was still flaming amazement across the Internet when I found myself sitting across from this scientist in April 2014.[4] Pollan was reporting on ideas about 'plant intelligence' that had already been circulating through the scientific literature under the banner of 'plant neurobiology' for nearly a decade.[5] The researchers Pollan had interviewed were investigating homologies between plant and animal physiology, and conducting experiments which suggested that, like animals, plants demonstrate intelligent behaviours, that they have memory, that they can anticipate events, and that they can communicate with other plants and with animals.

The molecular biologist sitting across from me was infuriated by 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, she insisted, 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 to them was his enchantment with an approach that so audaciously engaged human and animal models of intelligence and behaviour to structure inquiry into plants. Even though Pollan reported on the opinions of both supporters and detractors of plant neurobiology, to some readers, his article seemed to sediment the very anthropomorphisms that are anathema to science. For them it was blasphemous to suggest that plants had anything resembling nervous tissues or that neurobiological approaches were

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penchant for fabulating speculative fantasies about plants would be enflamed by Ursula Leguin's science fiction imaginaries (1990 [1987]), especially her short story 'Vaster than empires and more slow'. In that story she conjured a planet populated only by plants, and it was the interconnection among the roots of its vegetal inhabitants that rendered the entire planet conscious and empathic. Working between art and science, I crafted stories in which plants were protagonists in their life history. I engaged them as improvisers, practitioners, experimentalists, and chemical engineers. Plants were 'up to stuff', and I could feel it (Myers 2001; 2005).

And yet it was sitting in this molecular biologist's office that I realized that all of my predilections made me rather suspect. My commitments also made it hard to have a proper conversation. Under threat of expulsion from her office, I could not possibly reveal to her how I understood plant sensing. I was forced to dissimulate my views and intentions, and this generated significant strain in our interaction.

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

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

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, in the words of one researcher, 'lesser us'. The researchers I met were concerned that, distracted by comparing plant and animal cognitive powers, people would overlook all the marvelous things that plants can do that animals cannot. They reminded me about the remarkable ways that plants harness sunlight to pull matter out of thin air, and about plants' alacrity for synthesizing chemical compounds like caffeine and nicotine.

I tried to save the situation. Having made the journey all the way here, I at least wanted to learn more about her research on plasmodesmata. I had to negotiate carefully, as there was so much that I could not reveal (see note 3). 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 her research 'correctly'. I mobilized my expertise and credentials. I emphasized that I had graduate training in the plant sciences and molecular biology. I was not a journalist out for a sensational story, but a tenured professor on a full-year sabbatical doing serious anthropological research.

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 what they saw as the 'trap' of anthropomorphism at every turn. This conversation tuned me 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. In this process 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' research attentions, inspires new questions, and propels 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. Very recently, a suite of new works has appeared, 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, the most notable of which are Pollan's essay in *The New Yorker Magazine*, and a 2014 article in the *New York Review of Books* by Oliver Sacks, 'The Mental Life of Plants and Worms, Among Others'. Many of these texts encourage their readers to consider the extension of the concepts of intelligence, thought, communication, and cognition to plants, organisms that have hitherto seemed 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 with 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-plants up to electronic circuits. Some experiments attempted to use plants as living lie detectors, reading plants' excitable tissues as registering, in the form of electronic shudders, subtle shifts in human emotion. Unfortunately, the plants in many of those experiments merely became transducers for human affects and aspirations. In effect, the experiments generated deeper insight 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 as plants' ability to remember the precise timing of the last frost (e.g. Sung & Amasino 2004) and the discovery of a kind of 'swarm intelligence' in roots (Baluška et al. 2010), seem to promise so much for the radical reconfiguration of theories in philosophy, anthropology, and beyond. It is clear that plant sensing phenomena upend our thinking; they interrupt the order of things. The audiences reading these marvelous stories are transported and transformed. That innocuous patch of green lawn; those tree roots pushing up 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 genetic studies of maize. Accounts of her experience clue me in to the ways that people's perceptions of plants can deepen over time. As a maize geneticist she spent her summers running experiments on 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 the plants, she cultivated new modes of sensory perception and 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' (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 they catalyze with microbes, fungi, pollinators, herbivores, and other plants. 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. Through their instruments and experiments they get themselves thoroughly entangled with 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.[6] 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?

Here I offer preliminary thoughts on my conversations with a few of the many plant scientists I met in this first foray into the field. In these encounters, I found myself feeding on scientists' wonder, awe, and excitement about the marvelous worlds of plant sensing and behaviour, and exploring how far they were willing to go with their stories of the 'uncanny', 'amazing', and 'crazy' things plants can do. Conversations with these practitioners revealed all kinds of productive ambiguities, slippages and ascriptions of agency to nonhuman

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

organisms. There was a remarkable wavering between enchantment and disenchantment in the stories they told. They seemed to be pulled between near-numinous stories of the marvelous sensory dexterities of plants and the disenchantments enforced by a reductionist and mechanistic 'thought style' that resists imputing any agency to nonhuman organisms (see Fleck 1979). The enchantments in their stories often showed up when they extended their vocabularies and imaginations about forms of plant agency and intentionality. These were the moments when they let down their guard against anthropomorphic descriptions of plants and when they revealed the promise of crafting analogies for inspiring new ways of thinking. In spite of their ardent attempts to constrain their language and adhere to the conventions of their scientific publications, the plants in their stories refused to be contained. Plants, 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; and 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.[7] Plants in these stories appear to be more than mechanical bodies reacting automatically to external stimuli. These scientists described the vegetal sensorium as open, responsive, excitable, and attuned to a world full of other interested bodies. These conversations taught me new things about the phenomena of sense, sensation, and sentience.

I treat the vacillations between enchantment and disenchantment in these scientists' 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 that the scientists hold dear. These moments offer glimpses of the constraints that make it hard for these practitioners to think and talk about phenomena like 'plant feeling'. Listening again and again to the audio recordings of these conversations, I have become attuned to the rhythms and tones of the interruptions and redirections each of us make while talking. In some moments, it becomes clear that I am attempting to destabilize how the 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. Most importantly, these conversations helped me to see that anthropomorphism is not what we thought it was: they gave me new opportunities

[7] 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. Such a model of the sensorium, however, need not imply that sense experience or sense making is a progressive acquisition of cumulative experience. See A. Schrader (2015) for an astute critique that challenges progressivist models of learning and sensation.

to see how it is not just a one-way imposition of human concepts and values on others. The stories I heard helped me understand that while anthropomorphism can be a trap, it is also powerful 'lure' for inquiry, 'luring attention' and 'vectorizing concrete experience' in such a way that can '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 in organisms' behaviour and physiology, and shape their ecological relations (Hsu & Harmer, 2014, Harmer et al. 2000). Circadian rhythms are understood to be a means for organisms to adapt themselves to the regular periodicity of 'the geophysical world'.[8] Stacey's lab investigates the ways that plants 'keep time' using complex networks of interacting genes and proteins that are conceived as 'internal timers'. These 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 the 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 that 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, relying on the sun's energy, must adapt themselves to cycles of light and darkness, as well as to seasonal variations. To stay in sync with the movements of the sun, and the activities of their pollinating insects and herbivores, plants behave differently at different times of the day: they grow, move their organs, open their flowers, and produce nectar at specific moments. 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 seems to correspond with physiological phenomena such as rhythmic spurts in growth, and the periodicity of nectar production. Molecular clocks thus appear to offer a means by which organisms get 'involved' and keep time with 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

[8] See, http://harmerlab.openwetware.org/Research.html

> attract the 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 have their clocks to optimize when they are making their rewards to promote intercrossing within a species...

Stacey's laboratory contributes to a large body of research on circadian clocks in plants. Melissa is a senior graduate student working in a nearby laboratory where she studies circadian clocks in *Arabidopsis thaliana*. Friendly, curious, and confident, she was quick to respond to my request for an interview. She was working to develop her skills in the area of science communication, and so was eager to talk to me about the kinds of work that I do. She was concerned that scientists aren't doing a good job at getting their insights across to wider publics. She wanted an opportunity to discuss what she sees as serious problems with recent popularizations of the sciences of plant sensing. Early in our conversation, Mighael 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 tree-lined courtyard below. Over the course of our hour-long interview, I learned that Melissa had a strong connection to plants. She was born and raised in rural Wisconsin where 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 in the garden. She recalled 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 her second year of college, when she was in a biology course learning about the molecular mechanisms of photosynthesis, that she awoke to a very deep appreciation of plants.

In addition to our interview, I got the chance to spend time with Melissa in the laboratory. She took me to the growth chambers in an adjacent building where she keeps her plants in temperature- and humidity-controlled environments. There she can entrain the plants to varying cycles of light and darkness. Although she had acquired a lot of experience and skills before arriving in this lab, this was the first time she had an opportunity to work with living organisms, and so she faced some challenges trying to learn how to keep plants alive and thriving inside her experiments. I reminisced with her about my own experiences caring for plants in growth chambers when I was a graduate student at McGill University. Hers was a much more impressive facility, however. During our 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.

Earlier, during our interview in the conference room, our conversation 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 thought that plant sensing research was now in a position to redefine what we mean when we use the terms 'feeling' and 'sensation'. Reaching for the right words, I explained, 'We think we know what sensing is, but perhaps we just don't know'. Nodding in agreement, she reformatted my statement, 'We know what we think sensing is'. I was trying and yet somehow failing to communicate that I was 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 [our ideas about sensing are] 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 a human model of the senses 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.[9] 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

[9] 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.

'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 perhaps, 'any organism, single cell or otherwise, that can change itself in response to its environment', could be considered sentient.[10] 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... I don't know really how to describe this... It is not ... 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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> 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. For her, letting explanations rest at the molecular level does not denigrate plants. What she was telling me, what I finally heard her say, is 'that the mechanism itself is so fascinating, rich, and amazing'. When I finally got it, Melissa was quick to affirm, 'Yeah! There doesn't have to be more'. We were both laughing at this point. 'Right', I affirmed, '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!'

Buoyed by this shared understanding I try another tack: 'So perhaps, reducing it to a mechanism isn't actually so disenchanting'. Melissa affirms, 'Yeah. 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.

[10] 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: 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.

It is perhaps this wavering between enchantment and disenchantment in scientific stories that we can find clues to where there are openings that might enable us to imagine plant sensing differently. Melissa is amazed at the ways that these complex and intersecting molecular processes hang together and cohere so robustly. I am taken by her description of molecules as simultaneously 'elaborately designed or produced machines' and enchanted (see Myers 2014a; 2015). And here she reminds me that my line of inquiry in our conversation is actually a little off. My own research into mechanism in molecular biology and ubiquitous metaphors of molecular machines has shown that, in the hands of practitioners, molecular mechanisms are anything but dead, disenchanted matter. What I have been learning is that in spite of great effort, mechanism and mechanical analogies have failed to fully disenchant the life sciences. All kinds of enchantments, from animisms to anthropomorphisms, keep bubbling up (see Myers 2014 a; 2015).

Indeed, life scientists in the fields of molecular biology and protein modeling have taught me how to see processes of signal transduction, the very molecular phenomena Melissa and I were discussing, 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 within and among cells (see Myers 2015). What if signal transduction is not merely a way of transferring 'information' from the environment into the cell, but is also a way of 'transducing' affects and energies through a body's excitable cells and tissues? What if signal transduction allows organisms to actively modify their biologies in response to their environments, and also provides 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 remarkable 'molecular practice' endows cells with both sensitivity and sensibility; in other words, perhaps signal transduction achieves the responsivity required not only for cells to sense but also make 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). Might research on signal transduction open up a model of plant sentience that is grounded in the very sensitivity of plant tissues? Such a model would bypass 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. The 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 plants know. What I learned from Melissa, is that perhaps that is the place to begin conversations on plant sensing.

Disenchantments

I arrived early for my meeting with James, a postdoctoral fellow in Julin Maloof's plant shade laboratory at UC Davis. I wandered down a long, gleaming white corridor that led to a series of plant science labs. The walls were remarkably bare except for a few large posters from scientific meetings that detailed recent research. A young man with a slight build and short brown hair walked by me and gave me a curious look. No one just wanders the halls reading posters. I must be the anthropologist here to meet with him. He directed 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 post-doctoral research. He was there to extend his expertise in plant science by working on the topic of shade avoidance in tomato plants. He is from Caracas, Venezuela and 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 grad-school opportunities, plants again took centre stage. At that time, he was a vegetarian and averse to conducting experiments on laboratory animals. He was looking for a way to bring together his interest in biomechanics with research at the nexus of evolutionary and developmental biology, a branch of research fondly nicknamed 'evo-devo'. He found a lab at Harvard specializing in orchid evolution and was captivated by a project on the biomechanics of pollen dispersal in the genus *Catasetum*. I had arrived expecting 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 & Myers 2012).

As became clear in our interview, 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. In a letter to JD Hooker on October 13, 1861, Darwin confided: '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, it was said, 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. In an earlier letter to JD Hooker on June 9, 1861, Darwin had detailed all of the British orchids he had examined, and exclaimed, 'I shall never rest till I see a *Catasetum* eject pollen-masses'. Less than a year later, he received some *Catasetum* specimens by post and conducted an extensive series of experiments in his home laboratory (Darwin 1862: 224–62; see also Hustak & Myers 2012). He learned a great deal about the sensitivity of the trigger mechanism in the male flower that enabled it to propel its pollinium with such force at visiting insects. He reported: '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: 223–4). 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?''[11] James opened the second chapter of his dissertation with this very quote. It seems to capture both his and Darwin's 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 can, with incredible accuracy, synthesize bouquets of volatile chemicals that mimic the pheromones of their pollinators. Male wasps are especially attracted to these chemical bouquets and they can be observed attempting to copulate with the flowers. Pseudocopulation names the form of mimicry through which a male wasps 'mistakes' a flower for a mate:

[11] See Darwin's letter to his friend Thomas Henry Farrer, dated May 7th, 1868.

> What is so amazing about the pseudocopulation mechanisms is that they've evolved clearly many, many times in the Orchidaceae. And you see them in *Ophrys* [a large family within Orchidaceae], and you see them in this really awesome Australian orchid [*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's 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 made a couple of attempts to bring this issue up with James. I wanted 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 the textual conventions of plant and animal behaviour researchers (see also Despret 2013; Hustak & 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 a 'scientific ethos' that requires investigators to maintain skepticism with regard to things they do not or cannot know. Though he wavered on nonhuman mammals, this ethos refuses to 'grant' the capacity for awareness or even minimal sentience to other organisms. James's assertion didn't do much to shake my conviction that this ethos of skepticism is bound up with a kind of refusal to inquire, a studied ignorance that in effect enforces a domain of nonknowledge around the capacities of nonhuman life. The outcome of this attitude and practice is the reinforcement of a boundary between human and nonhumans, and bolsters an exceptionalism towards human capacities and agencies.

Anthropologist David Graeber (2014) has taken up this issue of human exceptionalism in the behavioural sciences, troubling the ways researchers tend to 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?' In our conversation I told James that I was interested in the ways that the scientific literature on plant/insect encounters 'polices pleasure'. I relayed a story about how one researcher, in a scientific paper on *Ophrys* insect mimicry, 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, Nilsson insisted 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 nonviable sexual encounters. Indeed, bee and plant behaviours must not breach the dictates of efficiency in what this literature figures as an energetic economy governing reproductive strategies (Hustak & Myers 2012). *Ophrys* mimicry must not be too effective: were the orchids to trick all male bees, the orchids would 'outcompete' female bees for mates, and the orchid's pollinator populations would decline (Nilsson 1992; Vreecken & Sheistl, 2008).

Nilsson's worry is grounded in some of the core assumptions that guide evolutionary storytelling in this field. I did not find the words or space in the conversation with James to explain my concern with the heteronormativity of this account of compulsory and efficient sexual reproduction. Indeed, such anxieties about sperm loss seemed to me to be out of place in the affectively charged space of this undeniably queer interspecies sex act that involves plants luring wasps into intimate contact. What I found so troubling about this rendering of plant/insect encounters was its refusal to entertain the possibility that the male bees might not just be 'dupes' falling for 'a sexual swindle'. Could it be that the bees 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 (see for example Bose 1913; 1918; Darwin & 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. 2010).[12]

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. This is a familiar move. The charge of childishness or immaturity is common among those who police against anthropomorphism in scientific discourse (see also Daston & Mitman 2005). Here I get called out as a rather naughty little kid who does not yet have handle on the function of sex. I am amused but also frustrated by how hard it is talk about these things and still get 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, one where I could begin to think through the politics of anthropomorphism in the plant sciences. What I learned in this space was to think more carefully about where James, a postdoctoral fellow, was positioned in this conversation. Whereas Stacey, a well-recognized expert in her field, did not seem troubled by the invocation of terms like memory and anticipation during our conversation, James did not have the same stature or experience. James's advisor, Julin Maloof, also a respected and well-known 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',

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 anthropomorphisms 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.

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

Anthropomorphism Meets Phytomorphism

Over the course of her time in the lab, Melissa's research project changed significantly. Snags, unexpected challenges, and underwhelming results have kept her shifting between projects. She was in the midst of describing her current research project, when our conversation swerved. 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 time of day of starch degradation, or the regulation of starch degradation is altered. Or, yeah, *is affected'*. In her second rendition, the plant becomes 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; rather, 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 of her speech, remind me of my own 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 risky spaces for propagating anthropomorphisms. Instructors are particularly wary of the effects of anthropomorphisms on student understandings of molecular processes. They 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 shared 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 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.

I am quick to laud James for his caution around the use of progressive language to describe evolutionary processes. After all, the effects of such metaphors have long plagued the history of anthropology, and anthropologists have spent considerable effort calling attention to the problems of such rhetoric in the human sciences. But are all anthropomorphisms so problematic? I wondered if James was being overly cautious. But then I had to remember that he and Melissa are both junior scientists, still learning the tacit and explicit rules that condition the 'thought collective' that constitutes their respective fields (see Fleck 1979). A lot is at stake for them and the risks are high. While their advisors have secure jobs and solid standing in the field, I can understand why these researchers feel compelled to toe the line. They are not yet in a position to acknowledge the productivity of anthropomorphisms in their own thinking; and so, 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...'[13] 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.[14] 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

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

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

'metabolically superior' to humans and animals. 'We think we are so great', he chided his audience, what with our animal 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, he insisted: '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. (Sagan 2011)

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 recently been learning that anthropomorphism does not operate in one direction. This conversation with Melissa reminded me of Darwin's research with orchids. Reading through Darwin's orchid pollination experiments a couple of years earlier, I had come across a striking passage, reproduced below. Here Darwin is attempting to communicate to his readers the precise form of several different species of *Catasetum*:

> 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 & Myers 2012: 92-3)

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 oft-encountered thought experiment (Myers 2015). In effect, he demonstrates just how he has entrained his own body to the specificities of floral form. Darwin shows his readers how he is mimetically entangled with the orchids. Willing to be moved by plant form, his human bodily contours are decentered and displaced in the same moment that he reinscribes those of the orchids. Thus, what might initially be seen as a one-way imposition of human qualities on the plant, can on second glance be read as a multi-directional process that generates infoldings in thought and in relation.

Darwin's example helps me understand 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 told Melissa about the protein modelers I had been working over the past ten years whose body experiments are resonant with Darwin's. I described how they would frequently animate and anthropomorphize their molecules as wily, desiring creatures. Close attention to their painstaking efforts to build atomic resolution models of molecular structures taught me how they continually refined their understanding of molecular forms and movements. I explained how I saw this as a process of attunement that enabled modelers to become responsive to the subtleties of molecular energies and movements. It was by giving themselves over to the labor of making models and animations that modelers learned how to 'move with and be moved by' molecular phenomena. In the process, they allowed their bodies to be inhabited by their models. They drew on this embodied knowledge to make hypotheses about how molecules move and interact. In the process, they situated themselves inside molecular phenomena in order to reach towards insight (see Myers & Dumit 2011). Molecular phenomena set their bodies into motion and, in the process, they became proxies for their molecules. Indeed, I explained, protein modelers not only anthropomorphized their molecules, they also got 'molecularized' in the process (see Myers 2015).

Melissa was thrilled, 'The people have been *molecularized*, Ah! Right'. And I elaborated, '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 the plant 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 a visit to Ian Baldwin's laboratory at the Institute for Chemical Ecology at the Max Planck in Jena, Germany a few months later. There, I encountered a new term for the phenomenon I had been calling 'plantification' or 'vegetalization' (see Myers 2014b). 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 plants and animals in its environment. Over dinner in a traditional Thuringian restaurant in Jena, Ian explained that he is not concerned about anthropomorphism. Rather, 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 in the space of these mimetic entanglements among scientists and their plants that it becomes increasingly unclear who is animating what, and what is animating whom (see also Stacey & 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.[15] What is also set into motion and transformed in this entanglement is the very meaning the terms used in the analogy. Thus, when researchers talk about plant sensing or plants' capacity for sentience, what these terms signify 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 stories she found fascinating. Sitting at her computer in her office, she showed me a time-lapse video produced by Roger Hangarter, a plant scientist at Indiana University. I was familiar with his work and the extensive collection of plant time-lapse movies he has archived online to demonstrate some of the incredible ways that plants move their bodies. She explained that she got the idea for working on this project on sunflowers from him.

> So this is a sunflower plant in Roger's backyard.[16] 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 at night though it goes back to neutral. [N: Wow!] And it keeps going.

[15] On the 'morphic' dimension of anthropomorphism see also Daston & Mitman (2005).
[16] The movie can be viewed at http://plantsinmotion.bio.indiana.edu/plantmotion/movements/tropism/tropisms.html

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 shy away from 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.

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 attention on the molecular mechanisms of plant sensing. Her rendering, however, is not disenchanted. 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 does not seem concerned about anthropomorphism in her storytelling. She does not 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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