Phytodynamics and Plant Difference
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"Common suddenly felt the firm tug of gravity. He felt glued to the spot, as if attached there. He was attached. Looking down, he was dismayed to find his feet lodged firmly in the ground – and himself a plant! Transformed into something soft and thin, greenish brown, neither tree nor grass." (Abe, 1992:44)

What is a plant?

A plant is generally regarded as a biological entity that is rooted to a particular location – an interesting coincidence of etymology and existential condition. Tugged by gravity from below and sunlight from above, being fixed to a particular place and environmental conditions that it is unable to choose or change by way of subsequent physical relocation, the plant seems like an excellent exemplar of adaptation – it has to learn to adapt to and/or manage the conditions as are rather than exercise the relatively simpler option of migration available to the more mobile animals. Its immobility is very often conceived to be the reason for its incapacity, and some like Aristotle argue, lack of necessity, to develop a complicated response system given the relative paucity of surprise and novelty in its immediate environment. However, these notions of immobility and a supposed lack of sensitivity have come to be attributed as natural to and constitutive characteristics of plants have been culturally constructed. This means that what one assumes to be essential and necessary qualities that differentiate the plant from other biological and non-organic matter alike, are merely qualities that they have come to be associated with *thus far* and which thus do not form exhaustive descriptions of what constitutes the plant. This also suggests that plants could be described and therefore encountered differently.

The Russian botanist, Kliment Timiryazev, presented one of the most radical critiques of the distinctions between plants and animals in his lecture, *The Plant and the Animal* (1878). He highlights the fact that the "absence of motion and outward activity is looked upon as the essential point of difference between plants and animals" in most conventional accounts of plants, both scientific and lay (Timiryazev, 1958: 306). However, he argues that it is problematic to define plants by their lack of movement as many plants display a wide range of movements. He suggests that the surprise and amazement elicited by first-time encounters with the movements of plants such as the mimosa (*Mimosa pudica*) are indicative of a deeper cultural bias that imputes *non-mobility* as a fundamental characteristic of plants.

Timiryazev argues that biologists and botanists have historically circumvented the need to adequately conceptualize the movements of plants when they encountered them. He notes that they desperately sought to safeguard the integrity and validity of their time-honoured categories of 'plant' and 'animal' by referring to them as anomalies, aberrant variants and sometimes even called such plants that display movements as *zoospores* (from *zoos*, 'animal'). Pointing to the fact that many of these movements seem to have "no apparent stimulus", Timiryazev asks if one is justified in wondering whether some of these movements are voluntary. He examines what other distinctions if any can be instantiated between plants and animals if movement itself is an inadequate distinguishing characteristic and after deliberating on the nutritional and respiratory habits of plants and animals shows that these form inadequate bases for differentiation. He follows with the question of whether plants have feelings and by logical extension, consciousness. He claims, "If we allow the response to stimulus, i.e., irritability, stimulation, to be a sign of feeling we are bound to recognize this faculty in the plant." (Timiryazev, 1958: 335) He states that insofar as there are plants that show sensitivity to and sometimes even discriminate between different stimuli, it is difficult to completely deny them the capacity to feel. In an extension of this argument about feeling, Timiryazev asks somewhat rhetorically, "Is the plant endowed with consciousness? …Are all animals endowed with it? If we do not deny it in the case of the lower animals, why should we deny it in the case of the plant?" (Timiryazev, 1958: 337) However, in a strategic turn, instead of deliberating further on whether plants have consciousness, Timiryazev chooses to draw his conclusion in terms of upsetting the very distinctions between plant and animal. He states, in what must surely rank as one of the most radical gestures in the history of systematic biology, "*the difference between plants and animals is not qualitative, but only quantitative*." (Timiryazev, 1958: 340) According to him, "As a matter of fact, there are no plants or animals as such, but a single undivided world. Plants and animals are only averages, typical conceptions that we form for ourselves, abstracting from certain characters of the organism, attributing special significance to some properties, and neglecting, almost ignoring the rest." (Timiryazev, 1958: 338).

It is interesting though that while Timiryazev identifies non-mobility and lack of sensitivity as primary characteristics imputed to plants, he does not attempt, in this essay or subsequently, to systematically elaborate on the fact that this was historically enunciated and maintained in contradistinction to movement and sensitivity that are conceptualized to be fundamental characteristics of what constitutes the 'animal'. It is useful to state here, that just like the concept of the animal seems to have evolved in contradistinction to the 'human', the concept of the plant has been discursively elaborated in contradistinction to the 'animal'. And in articulating this contradistinction between plant and animal, the notion of movement has been central. How did movement become such a primary marker of animal status and the lack of it basis for assignment to plant status? And what if plants could move in ways that are not easily explained within the oft-cited, biological imperatives of nutrition, growth, procreation and survival imputed to them?

Rooting Plants

In the historical development of botany, the philosophical biases and methods of botanical speculation inherited from Aristotle had a discursive stranglehold in determining the way plants were conceptualized until the beginning of the last century. The contemporary notion of a plant as a biological entity that is fixed to a particular place and lacking in sensitivity has been inherited from Aristotelian botany. One of the foundational concepts in Aristotle's notion of the living thing is the concept of 'anima', conventionally translated as "soul", though most accurately conceptualized in relation to the notion of movement, as "that which moves". According to him, the living was distinct from the non-living by way of its capacity for movement, either by some innate capacity for self-movement or enabled to move by some peculiar vital principle.

Aristotle in Book II, chapter 3 of his '*De Partibus Animalium*', provides a fascinating example of the analogical reasoning that he used to make sense of plant and animal functions. In a discussion of the natural heat required for the nourishment needs of organisms, plants and animals alike, he first outlines the role of the mouth and stomach as part of a continuous system that concocts natural heat and nutrients for animals. And following this same logic of animal nutrition he speculates on that of plants thus: "For plants get their food from the earth by means of their roots; and this food is already elaborated when taken in; which is the reason that plants produce no excrement, the earth and its heat serving them in the stead of a stomach. But animals with scarcely no exception and notably all such animals as are capable of locomotion, are provided with a stomachal sac, which is as it were an internal substitute for the earth." (Aristotle, 1987: 29) Thus, for Aristotle, the earth and stomach become analogous organs of digestion – one serving the fixed plant, the other, the mobile animal. Aristotle continues this counterposing of movement of the animal with the fixity of the plant further in his description of the sponge. He claims that a sponge "completely resembles a plant" since "throughout its life it is attached to a rock and that when separated from this it dies." (Aristotle, 1987: 104) The fixity of the sponge is marked out as its primary characteristic and thus constitutive of its status as plant. He notes however that there are some problems in such classifications insofar as there are several exceptions to the principle of plant fixity. For example, he notes that the Holothuriae and Sealungs that are "free and unattached" still display plant-like qualities of being without feelings" and concludes that their life is simply that of a plant, separated from the ground." In a seeming acknowledgement of the difficulties of categorically differentiating animals and plants, Aristotle states in this section that "(S)ometimes it is a matter of doubt whether a given organism should be classed with plants or with animals." (Aristotle, 1987: 104)

Julian Sachs, in his excellent account of the histories of botany, suggests that the influence of the Greek authors like Aristotle and Theophrastus was particularly strong in the botanical literature insofar as every succeeding author felt obliged to refer to and build their own arguments from them. However, Sachs notes that the influence of these 'philosophical botanists' has "led to no important result" (Sachs, 1890: 17) and argues that these authors had seriously hampered the progress of the systematic and scientific enquiry into plants. Sachs claims that these authors "built their views on the philosophy of botany on very weak foundations; scarcely a plant was known to them exactly in all its parts; they derived much of their knowledge from the accounts of others, often from dealers in herbs." (Sachs, 1890: 16)

Andrea Cesalpino (1519-1603) wrote his botanical classic, '*De plantis libri XVI*' in 1583 which Sachs considers to be an important contribution to botanical history if not for its adherence to classical Aristotelian notions. Sachs claims that "the whole account is controlled by a teleology, the influence of which is the more pernicious because the purposes assumed are supposed to be acknowledged and self-evident, plants and vegetation being conceived of as in every respect *an imperfect imitation of the animal kingdom*" (Sachs, 1890: 43; emphases mine) Cesalpino's conception of the plant is no different from that of Aristotle despite the fact that the former had the advantage of several decades of scientific observation. In a manner that echoes Aristotle from '*De Anima*', Cesalpino begins his book thus: "As the nature of plants possesses only that kind of soul by which they are nourished, grow and produce their like and they are therefore without sensation and motion in which the nature of animals consists, plants have accordingly need of a much smaller apparatus of organs than animals." (Cesalpino cited in Sachs, 1890: 43)

Joachim Jung, a German botanist who was a contemporary of Kepler, Galileo, Vesalius, Bacon, Descartes and Gassendi, represented a key development in the botanical conception of the plant. His most important text, '*Isagoge Phytoscopica*' (1678) provides a fascinating thesis that both continues the Aristotelian logic of conceiving plants as existentially secondary to animals even as it breaks free from the Aristotelian notion of soul in making such a distinction. Sachs formulates Jung's basic arguments on the plant-animal distinction thus: "A plant is…a living but not a sentient body; or it is a body attached to a fixed spot or a fixed substratum, from which it can obtain immediate nourishment, grow and propagate itself." (Sachs, 1890: 60) The primary notion of Jung here, "*Plantes est corpus vivens non sentiens*" is worthy of some deliberation insofar as this consolidated the Aristotelian thesis of the plant's inability to sense based on his other thesis about its immobility. Jung's argument was that the immobile plant did not have a biological necessity for a complicated sensory apparatus given the fact that it was unlikely to encounter and respond in the wide range of stimuli that a mobile biological entity like an animal would. According to Jung, the plant was thought to live in a world where there were relatively little surprises insofar as it its immediate surroundings were relatively unchanging compared to that of an animal.

It is no surprise then that even the first botanist to systematically address the movements of plants, John Ray, in his '*Historia Plantarum*' (1693), explains away the movements as mechanical and physical phenomena without according them any significance to the physiological constitution and life of the plant. For example, he explains the movements of the mimosa by referring to them not as sensory responses but as a mechanical process triggered by the pressure applied by the touch of an animate creature or natural phenomena like wind and rain. The history of botany seems to have systematically circumvented dealing with the plant movement and its related issue of its sensitivity to external stimuli.Varro, the Greek philosopher, is the first to have noticed the heliotropic movement of certain flowers; Pliny notes the clove leaves closing in bad weather in his *Natural History*; Albertus Magnus (13th century) and Garcia del Huerto (16th century) recorded the leave movements of the Leguminosae; Cesalpino notes with some surprise the climbing movements of some plants; Borelli notes the irritability of the Centurae's stamens; and even Robert Hooke has a short excursus on the movements of the mimosa in his famous *Micrographia* in 1667 (See, Sachs, 1890: 535-562).

Following Ray, several botanists seemed to gain confidence in studying plant movements, a field which came to be categorized as **phytodynamics** by late 17th century (though the term itself, interestingly enough has fallen into disuse). Even within such studies of plant movements, there was greater emphasis on growth movements that were generally explained in terms of physical necessities as movement to sources of nourishment like light, water and nutrients. The serious study of the less regular, non-growth related plant movements, was relatively rare. Linnaeus studied the periodical movements of flowers in 1751 and of leaves in 1755, but was satisfied to have categorized them as 'sleep movements' not entirely dissimilar to those found in animals. This tendency to draw similarities to and differences from the movements of animals is also found in Du Hamel's '*Physique des arbres*' (1758) where he has a chapter entitled '*Movements of plants, which approximate to some extent the voluntary movements of animals*'. In this chapter, Du Hamel ventures a mechanical explanation for these movements based on the "direction of the vapours" inside the plants. This tendency to seek mechanical explanations was also coherent with a larger cultural climate in late 18th century Europe where a mechanized world-view was gaining currency. Sachs notes though that "the mechanical processes in plants were described much in the way in which a person with very indefinite ideas as to the nature of steam and the construction of the inside of the steam engine might speak of its movements." (Sachs, 1890: 540) These mechanical explanations ranged from Tournefort's speculation that the movements of plants were due to them possessing 'muscles' that acted similar those found in animals to those which postulated that there was a vital force that was gradually *unwinding* itself from within the plant as expressed movements.

The 19^{th} century witnessed more systematic efforts to explain plant movements by careful experimentation. Andrew Knight experimentally showed that the vertical growth of the stem and primary roots are due to gravitation in 1806 while the Dutrochet showed that the movements of the mimosa were due to the alternating expansion of its pulvini in 1822. By the middle of the century, the field of phytodynamics had settled on differentiating between two kinds of movements – one that is related to growth and the other non-growth related movements of parts of the plant that had already ceased to grow (Sachs, 1890: 554-555). While the growth movements were usually explained by reference to nutrition-relevant stimuli, there was still some dispute as to the non-growth movements. For example, De Candolle speculates that the movements of mimosa constitute evidence for the 'excitability' of plants. The tendency to impute some mystical, primary sensitivity to plants was still current in these investigations. It was not until Brucke's 1848 study provided an experimentally founded explanation of the mimosa's movements in terms of alternating turgidity and relaxation of its pulvini that the mysticism that surrounded explanations of plant movements started to fade.

The extensive experimental work of Darwin on plant movements in his '*The Power of Movement in Plants*' in 1880 consolidated this transition from mystical explanations to scientific ones. Darwin concludes this study by noting that one cannot ignore the striking resemblances between plant movements and those of animals. He states "the most striking resemblance is the localization of their sensitiveness and the transmission of an influence from the excited part to another which consequently moves" but quickly clarifies that "plants do not *of course* possess nerves or a central nervous system; and we may infer that with animals such structures serve only for the perfect transmission of impressions, and for more complete intercommunication of the several parts." (Darwin, 1989: 571; emphasis mine) Despite citing the different ways in which the sensitivity and movements of plants and animals are similar, Darwin's conclusion that the plant's sensitivity and corresponding movements do not issue from their having some nervous system similar to animals, indicates that he follows the historical precedence of understanding the plant's capacities as 'reduced versions' of those found among animals.

A noteworthy development in research during this period was the discovery of electrical activity corresponding to plant movement and sensitivity. Becquerel discovered electrical activity in injured plants (1851) while Buff studied the direction of such activity in 1854. Burdon-Sanderson observed and recorded the electrical changes in a Venus' flytrap and in a *Dinoaea* plant in 1873, 1877, 1882 and 1888. He concluded that such electrical activity was similar to those issuing from stimulation of animal muscles – a phenomena that was being actively studied as bio-electricity. Kunkel was able to measure significant electrical activity from the stimulation of mimosa in 1878. Sachs (1887), Waller (1900), Ewart (1903), Pfeffer (1905) and Jost (1907) showed that such electrical activity is widely distributed in most plant physiology and that it usually corresponds to chemical reactions and changes in the plant (See, Potter, 1933: 3-36). The work of Indian botanist, Jagadis Chander Bose during the early part of the 20th century in the area of plant electricity is remarkable for its extensive recording of such electric activity under experimental conditions and using highly sensitive equipment designed by him. He established the existence of distinct action potentials of electric activity that could be measured with reasonable accuracy, reliability and expressive of the most subtle variations. His work primarily focused on the *Mimosa* and the *Biophytum sensitivum* showed that plant excitability shares many similarities to features of animal nerves specifically: "the plant becomes fatigued if exercised too frequently; stimuli too weak to cause movement on their own can build up into a sufficiently strong signal that eventually triggers movement; each movement has a waiting (latent) period before a response is apparent." (Simons, 1992: 100) It is noteworthy here that while botanists made the comparisons between plant and animal electricity, there is a surprising lack of interest in aligning or understanding the relationship between plants and machines through electricity. While there had been several interesting investigations on the implications of animal electricity with reference to mechanics and machines notably in the works of Benjamin Franklin, Felix Fontana, Luigi Galvani and A. von Haller, there was practically no attempt to think through how plant electricity and its corresponding movements and sensitivity related to machines.

The attempts to understand plant movements and sensitivity *vis a vis* parallel phenomena found in animals has been extremely unfruitful insofar as it has led to the generation of and reliance on somewhat clumsy and mystical concepts like 'soul of the plant', 'plant muscles' and 'plant nerves'. The possibility of such sensitivity and movements constituting *phenomena peculiar to plants* has seldom been articulated because of the discursive habits that define plants in contradistinction to animals. It seems a proper understanding of the difference of plant movement and sensitivity needs one to excise it from its relation to the animal.

Plant Moves

In series of unconventional experiments, Cleve Backster, an American lie detector examiner, beginning in 1966, discovered that plants attached to a galvanometer, *Dracaena massangeana*, displayed a rich array of electrical activity that was related to different kinds of stimuli ranging from real threats to their lives to the life-threatening situations of other plants and animals (See, Tompkins and Bird, 1972: 17-26). Backster's experiments had interestingly enough caused a greater stir in the parapsychology community than in the regular scientific communities that remained relatively skeptical of his findings. The scientific community considered his experimental conditions to be flawed and problematic and most damagingly argued that these experiments were never repeated successfully under stricter experimental conditions (for a critical review of these experiments, see Simons, 1992: 202-203 and Galston and Slayman, 1979).

In a radio interview in 1972, Backster said cheekily, "But if you really want to make a psychologist sit up and take notice, you could instrument a plant to activate a small electric train, getting it to move back and forth on no other command than that of human emotion" (Backster, cited in Tompkins & Bird, 1974: 27) According to Backster, the abilities of the plant to sense and respond in synchrony to human emotions, could conceivably make it function as a sort of relay station for issuing signals to control non-animate machines and processes. Tompkins and Bird give an account of Pierre Paul Sauvin, an electronics enthusiast who keen on testing the feasibility of Backster's instrumentation, actually developed an experimental situation wherein he trained a plant to transmit his emotions to trigger and control a toy train. They also highlight the work of Ken Hashimoto, another researcher affected by Backster's experiments, who was able to transcode the electrical signals from a cactus into musical notes and simple graphical messages. (Tompkins & Bird, 1974: 34-5) While the authenticity of Backster's, Sauvin's, Hashimoto's experiments and developments have been rightfully challenged, the notion of aligning plant and machinic processes brims with aesthetic and critical possibilities. The machine, in being neither animal nor plant but historically defined in relation to both, represents a useful point of reference for articulating phytic difference as it has in defining animal difference.

Canguilhem argues that “a machine can be defined as a man-made artificial construction which essentially functions by virtue of mechanical operations” and identifying movement as a central aspect of mechanism as such, he stresses that “in every machine…, movement is a function, first, of the way the parts interact, and second, of the mechanical operations of the overall unit.” (Canguilhem, 1992:46) Drawing on movement as a central trope of the machinic and the phytic, where both are defined with reference to their differential capacities for movement, a series of artworks have been conceptualized over the last few years and are being developed by myself (in partnership with various technical collaborators) currently. In this concluding section, a brief description of one such work, *Moving Garden* is offered.

Moving Garden is an *anthorobotic* (Greek, *anthos,* ‘flower’) installation for an outdoor location. The work is part of a series of *phytorobots* (Greek, *phytos*, ‘plant’) being developed, where plants would control mobile robots through their natural tropisms and propensities for movement. This work has a group of mobile robots being controlled by the natural ‘suntracking motion’ of sunflowers that are connected to them. A combination of mechanical (gauge sensors) and electrophysiological (Galvanic Skin Response) sensors will be used to detect electrophysiological changes resulting from and accompanying the subtle movements of the flowers. A group of ten anthorobots would be deployed in an outdoor area where the sun’s movements would trigger the sunflower’s movements that in turn would trigger the solar-powered robots to also move. The sun thus becomes the choreographer of the complex dance movements of these anthorobots. This *solar choreography* binds the plant and robot thus in an intimate symbiotic relationship where their mutual nourishment is made possible by their ability to function as a single entity. In addition to this work, several other phytorobots drawing on various movements and electro-sensitive activities of plants are being developed, including a mimosa controlled robot that develops a rich contact avoidance repertoire.

Uprooting Plants

In a fascinating short story, *Dendrocacalia*, Kobo Abe tells of how a man, Common, suddenly finds himself being transformed into a plant. The transformations, which happen without any warning, are characterized by short intense spells where Common feels the strong tug of gravity that root his feet to the ground and where his body becomes stiff and unwieldy. Understandably, Common resists the transformations but finally decides to give in to it on the advice of a messenger who has guided other humans who have also been stricken by this imperative of becoming-plant. The story presents an interesting occasion to speculate on what constitutes the human in contradistinction to the horror of the vegetal state. The anxiety with which Common meets his transformation into a plant are indicative of a larger cultural conception where the plant and the vegetal are conceived to be states of inertia, insensitivity and immobility. Phytorobotics as an aesthetic strategy provides the possibility of technologically 'uprooting' the plant and the ways in which it is conceived so as to enable different encounters with it.

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