

[Biosemiotics](#)

December 2013, Volume 6, [Issue 3](#), pp 547-559

**Learning plants: Semiosis between the parts and the whole.**

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**Abstract**

10 In this article, I explore plant semiosis with a focus on plant learning. I distinguish between the scales and levels of learning conceivable in phytosemiosis, and identify organism-scale learning as the distinguishing question for plant semiosis. Since organism-scale learning depends on organism-scale semiosis, I critically review the arguments regarding whole-plant functional cycles. I conclude that they have largely relied on Uexküllian biases that have prevented an  
15 adequate interpretation of modern plant neurobiology. Through an examination of trophic growth in plant roots, I expose the conceptual difficulties in attributing functional cycles to whole-plants. I conclude that the mapping of resource areas in the root system is a learning activity requiring higher-scale sign activity than is possible at the cellular scale, strongly suggesting the presence of organism-scale functional cycles. I do however question whether all  
20 perception-action cycles in organisms are accompanied with organism-scale semiosis.

**Introduction**

Phytosemiotics is granted a passing nod in biosemiotic surveys but is not often given a careful examination (though see Krampen 1981, 2001; Kull, 2000; Barlow and Lück, 2007;  
25 Witzany 2008; Deely, 2009). In particular, plant learning has not featured explicitly as a topic of concern (for an exception, Cvrčková, et al. (2009). And yet, plant behaviour and communication is currently a hot topic, and learning is a useful semiotic concept. Learning is concerned with changes in sign activity, which may occur in either the sign, its object, or its interpretant.

Sign activity ushers in novelty, but the biological world operates on multiple scales and  
30 although the scales interact, the rate of semiotic changes on each scale is unequal. This leads to interesting dynamics. For example, since species-scale learning is much slower than organism-scale learning, signs inherited from a lineage appear as a contextual markers, constant and fixed, and perhaps less directly accessible to perception than those aspects available for direct modification by the organism. Thus, we find species-scale semiosis encoding sign aspects that  
35 are not possible in organism-scale semiosis, which is why we sometimes find that organisms have symbolic signs encoded in their lineage without being capable of forming new symbolic references during ontogenetic development. A typology of learning should be formalized, though it need not take on the form of the one suggested in this paper. Clarity on this distinction may bridge the divide between scholars who insist that all life forms have complex signifying  
40 capacities (such as Stjernfelt 2007; 2012) and those who maintain that broad semiotic divisions are evident across broad phylogenies (such as vegetable-animal-human) (such as Deacon 1997; Kull 2009).

This paper proceeds by a distinction between scales of learning and levels of learning. The former follows spatial and temporal dimensions, while the latter are Batesonian logical

45 types (1972). It is my conviction that different levels of learning are capable at different scales,  
but that there are invariably interactional effects such that the same learning activity at one scale  
may produce a different level of learning on another scale. I use this typology in order to narrow  
down on the notion that the most important questions regarding plant learning involve the  
organismic scale, because this scale would most likely reveal functional cycles in the whole  
50 plant organism -which is, arguably, the most important ontological question in phytosemiosis. I  
then review some cases from the plant neurobiology literature to assess whether we can  
reasonably presume the existence of functional cycles from the type of learning reported.

For the purposes of this paper, I take "learning" to mean changes in signification. This  
can occur through a modification in at least one of the three elements of semiosis, sign-object-  
55 interpretant. If no element changes no learning has occurred. All three elements cannot change  
simultaneously either because this would imply semiotic discontinuity. I assume that a change in  
any one of these elements can only come about as an interpretant of some prior semiosis. Thus, I  
assume that the learning process is made possible by the fact that prior semiosis enables the  
organism to participate in its environment in such a way that further significations become  
60 possible. Finally, I assume that learning occurs on a given scale if and only if semiosis occurs at  
that scale. Signification must be somehow evident that can only be made sense of by resorting  
to the scale that the learning is said to occur on, and not be compositional (i.e. a mere bi-product  
of a lower scale semiotic exchange).

## 65 **Scales of learning in plants**

By scales of learning, I refer to the different spatial and temporal ranges within which  
learning can be studied in plants. There are at least four major scales<sup>1</sup> in which it is conceivable  
that plants learn and each one gives us a different depth and understanding of changes in  
semiosis.

70 On the first scale, learning occurs by parts of the plant without being regulated by the  
activity of the plant as a whole. In this case, there is insufficient integration for what Maturana  
and Varela (1987) call "second-order autopoiesis" or what Uexküll calls a "functional cycle" to  
develop. Although not the most intuitive scale of learning from the point of view of naive  
consciousness, it is probably the least controversial one when botanists refer to plant response  
75 and adaptation. The modular character of a plant in distinction to an animal is well established  
(though animals do have modularity as well). Localized activities happen in individual cells and  
are mediated in multicellular locales<sup>2</sup>. For example, many studies now point to plant leaves  
dosing with allelopathic chemicals in locally-gauged response to insect predation. Trewavas  
(2003) notes that in some trees, every leaf can be seen at a slightly different stage or degree of  
80 responsivity to a stress. Because such examples suggest that each locale responds without being  
coordinated by centralization, Firm (2004) argues that plants should be primarily thought of as a  
confederacy of parts that only operate as a unit under exceptional circumstances. The prevalence  
of modularity lends weight to skepticism that plants have any unified perception-action cycles

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1 We shall ignore intracellular semiotics and signal transduction in this paper as this is a component of all life and therefore not essential to understanding phytosemiosis (or zoosemiosis). Mycosemiosis may be a different case, however, owing to the different role that cells play in fungi (see Hoffmeyer 2008, p. 224-225).

2 It may be that, in some cases, there are actually two scales here: the single cell scale and the organ scale. However, they shall be treated as a single ontological type for the purpose of this paper.

and therefore no *Umwelten*.

85           Nevertheless, the centralization hypothesis is growing in influence and in evidence. Plant  
neurobiologists have detailed descriptions of how plants utilize chemical and electrical  
signalling to centralize and coordinate sensory activity, movement, and tropisms (Trewavas  
2003; 2004; 2005; 2009; Karban, 2008; Brenner et al., 2006). Trewavas (2003) claims that  
90           globally mediated and regulated learning integrates signals from multiple body parts, combined  
with prior knowledge encoded in the phenotypic variation present in the different stages of the  
plant's growth. There is also growing evidence to support Darwin's (1880) controversial  
suggestion that centralization is localized in the plant's root systems, which has lent stronger  
legitimacy to whole-plant conceptions (Baluška et al. 2004; 2009a; Masi et al. 2009). Because  
learning, perception, and experience are thought to emerge through the structure of the whole in  
95           animals, the question of plant body unity is particularly interesting and will form the basis of this  
essay.

          Plant communities may also learn. "Signalling cascades" (Heil & Walters 2009) mediated  
through root signalling or through the release of volatile organic compounds (Baluška &  
Mancuso 2009b), gives rise to what I consider to be local or regional *phytodialects* of behaviour.  
100           Such learned behaviour can be passed to a plant's progeny as well (Mazer & Gorchoff 1996;  
Rossiter 1996). Though it is unclear how long such phenotypic communication and inheritance  
persists, this scale indicates the possibility of proto-enculturation, the transmission and  
perpetuation of learned behaviour through hereditary pathways that are neither genetic or  
epigenetic. The term "enculturation" is justified because the formal structure of the semiosis is  
105           the same as it is in human and animal cultures. In all cases, phylogenetic changes are circulated  
and re-circulated through pathways available as the result of phenotypic plasticity, creating  
enduring temporal patterns without being attached to causally efficacious genomic changes. That  
the particular sign types differ in human cultures to include arts, morals and religion, and are  
transmitted through processes such as language and imitation, is not relevant. The extent and  
110           ecological significance of this interactivity and its similarity and differences to cultural  
behaviour in animals is a great, unexamined field of inquiry.

          The fourth scale includes species scale, phylogenetic changes. Through natural selection,  
a species "learns" certain adaptive behaviours, makes novel semiotic distinctions and  
behavioural interpretants, as when a plant species co-evolves a flower morphology in tempo with  
115           the needs of a fellow co-evolving pollinator. Learning takes on a very different sense here as it is  
no longer associated with anything experiential or phenomenal. Phylogenetically evolved signs  
may be experienced in a species *Umwelt*, but the learning is unique in that it may be selected for  
and therefore not experienced. However, it should be noted that the ontogenetic and  
phylogenetic effects of different scales of learning are complex. When plants learn, they change  
120           their behaviour, which in turn shapes their environments. The changing environments modify the  
selection pressures on the plants in turn (Bateson 1979; Odling-Smee, Laland, & Feldman 2003).  
This sort of circular interaction between phenotype and genotype has seen some revival in  
renewed discussions by post-neo-Darwinist biologists (for overviews, see Weber & Depew  
2003; Jablonka & Lamb 2006; Oyama, 2000; Griffiths & Gray (1994)).

125           Note that Witzany's taxonomy of "levels of biocommunication in plants" (2008; 2012)  
(interpretation of abiotic influences, transorganismic communication, interorganismic  
communication, and intraorganismic communication (2012, p. 2)) are all instances of

cellular/modular semiosis. There is a crucial difference between plant semiosis having effects on organismic or ecological scales plant semiosis *occurring* on such scales. When considering the organism-scale, for example, the critical question is whether the unity of the organism is a necessary and sufficient condition for novel organism-scale sign activity. I would tend to agree that plants do not communicate with each other on the organism-scale, which suggests that communication and learning do not operate isomorphically, though this should be investigated further.

135 **Levels of learning**

Besides scales of learning, there are also levels of learning, corresponding to the logical typing of the semiosis (Bateson, 1972). Learning levels is a concept that Bateson draws on from set theory. The idea emerges from the fact that organisms can become responsive to patterns, but then recursively responsive to patterns within those patterns. Bateson identified likely levels of learnings as L0 through to L3.

Different levels of learning may theoretically exist at any scale. When discussing plant learning, then, it is necessary to distinguish what conceptual space is being considered with a general rubric. In fact, when talking about any semiotic activity, such specifications should also be of value. For the purposes of this paper, I shall confine my discussion to the level of the organism proper, as indicated by the cells marked with an "x" in the table below (Figure I).

	Learning 0 (L0)	Learning 1 (L1)	Learning 2 (L2)	Learning 3 (L3)
modular (subtypes include: intracellular, cellular, and modular)				
organismic	x	x		
cultural/ecological (subtypes include: social and cultural)				
evolutionary				

**Figure I: Scales of learning vs. Levels of Learning**

150 If a plant is capable of learning at an organismic scale, regardless of the learning level, the plant can be said to possess a functional cycle at the organism scale. Many examples illustrating plant adaptation and plasticity suggest higher levels of learning than learning 0, but do not adequately differentiate the scale. For example, plants are capable of producing novel and more efficient responses to droughts, salt, chemicals, frost, heat and water (Trewawas, 2003), but differences in what adaptation would look like from L1 and L2 are not considered.

155 Like any typology, there are of course problems with this one. For instance, it does not communicate intuitively to the user that there are often relationships between scales and levels, such that the same phenomena can function on different logical levels at different scales. In fact,

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160 in some sense, the different scales *are* different logical levels of one another, as higher scales  
make formal constraints on the learning process at lower scales. This is related to the problem of  
"punctuation" as discussed by Bateson. Be that as it may, it does not discount the fact that  
changes of logical typing also exist within each of these scales. The typology serves its purpose  
of differentiating plant learning in a way that forces precision on a discussion that has often  
otherwise lacked it. For example, when Cvrčková, et al. (2009) insist that learning requires  
165 "true" memory (which they define as stored information that is actively accessed rather than  
haphazardly imprinted), they insist that organism-scale memory and learning is the only real  
level, whereas the other levels are "metaphoric." I would prefer to ask, in the cases of imprinted  
information, what level of learning is occurring at each scale. If imprinting is a simple response,  
perhaps in these cases, we have L0 at the organismic scale, but L1 at the cellular and/or  
170 cultural/ecological scales. For a similar reason, differentiating levels and scales may assist in  
explaining how different sign aspects appear on in different ways in organisms, perhaps opening  
the way to combine Stjernfelt's (2007; 2012) "degenerative" (if I may call it that) biosemiotics  
with approaches favouring phylogenetic threshold zones (Deacon 1997; Kull 2009).

### 175 **The Argument over Functional Cycles in Whole Plants**

Of course, it is natural that Cvrčková, et al. (2009) would like to make this distinction. As  
strongly individuated vertebrates, we have an especially strong interest in organism-scale  
semiosis. Since we identify our ability to have lived experience with our organism-scale  
experience, we also tend to look for evidence of lived experience in other creatures through their  
180 organism-scale perceptual faculties, information processing, and motor activities. With such a  
bias, I also consider plant organism unity as a fundamental ontological question for  
phytosemiosis.

This question has been approached in the literature through discussions of "functional  
cycles", where an organism's perception and action is recursively connected, integrating purpose,  
185 function and meaning through ever-reconstituting semiosis. Jakob von Uexküll took for granted  
that functional cycles were experiences subjectively by an organism in the form of *Umwelten*.  
Since they are more easily inferrable from physiology than *Umwelten*, they have formed the  
basis of much argumentation for organism *Umwelten*. Whether or not functional cycles are  
sufficient for *Umwelten* is a separate discussion (see below).

190 If plants can be said to learn as individuals and not merely as aggregates of parts, we  
would expect observable centralization of both sensory information and corresponding  
responsive activity. In other words, we would expect global functional cycles to emerge beyond  
specific locales such as cells or organs. Protosemiotician Jakob von Uexküll stated that plants do  
not have functional cycles, and Krampen (1981), who wrote the most often cited article on the  
subject, followed him in this assessment, reiterating many of his arguments, from claims that  
195 plants lack receptors or effectors, to the assertion that plants are structurally incapable of  
functional cycles because they are built as "casing" or "dwelling-shell" (*Wohnhülle*) (2010, p.  
146-150), i.e. a "living layer of cells" (147) around an abiotic core. Krampen connects  
Uexküllian semiotics with Peircean terminology, developing an early tripartite concept of  
200 threshold zones. Unlike later versions (such as Kull, 2009), Krampen associates plants with  
indexical semiosis and animals with the additional capacity for iconic semiosis, owing to the  
latter's capacity to form "images of objects".

205 There are many problems with both Uexküll and Krampen's characterization, which I will not repeat here but will refer the reader to Kull (2000), who has gone through Krampen's article point by point. I would, however, like to add several additional points to Kull's discussion. If we want to examine whether or not plants have functional cycles, I insist that Uexküll and Krampen both start from the wrong assumptions. **As we will see in the next section, I regard the possibility of organism-scale learning and hence functional cycles in plants as highly likely but remain doubtful as to whether this necessarily implies organism-scale experience unless accompanies with evidence of organism-scale signs.**

210 First of all, the claim that plants lack receptors or effectors (and for Krampen, that we call them "sensors" and "regulators" instead, in keeping with a cybernetic vocabulary that originated with the study of machines) is both arbitrary and mistaken. It assumes a difference and then reifies it through making a terminological distinction. Krampen does not use compelling biological evidence to make the distinction and it is unclear what such evidence would even look like. Further, this argument would seem to apply to plants at any level, including the cellular one, however most biosemioticians (including Uexküll) maintain that unicellular organisms do have functional cycles. In this case, he would have to show what is substantially different between a plant cell and a protist in this respect.

220 Second, the notion that plants are a "casing" or a "living layer of cells" seems unnecessarily arborocentric. There are obviously many instances in the plant kingdom of species that do not conform to the case or shell metaphor. Regardless, it is far from clear that those species that do have a casing architecture (at least in their trunk) are *a priori* denied functional cycles on this account. Communication and integration could feasibly operate either from within the casing itself (through auxin, other plant hormones, or through various neurotransmitters and ions (Baluška, 2004)), or laterally through the air and soil (as we find, with increasing evidence (Orians, 2005; Heil and Ton, 2008; Baluška, et al., 2009)). The fact that intercellular communication seems to be electrically mediated, with plant celling have action potentials (with the highest activity in the root apex) (Masi et al., 2009; Baluška, 2010), and even "adhesion domains" homologous to neural synapses (Baluška, Volkmann and Menzel, 2005) strongly suggests we should remain skeptical of denying functional cycles on the basis of the weight we place on anthropomorphically-valued structural differences.

235 Third, Krampen maintains that plant systems are unable to fit together afferent and efferent signals to form the signifiers required to constitute "objects" in experience, and that this is a part of his general argument against functional cycles in plants. It is uncertain to me that object constitution is a necessary property of functional cycles, but this bias, again, seems rooted in his Uexküllian foundation. There are many stimuli that people react to that have semiotic significance but that do not appear as objects. It seems to indicate a distinct ocular-bias in his approach (in the abstract, he comments on a functional cycle needing to represent the "image" of objects (257, also 270), which recalls Jonas (1966), and has been critiqued by Sheets-Johnstone's (1999) approach emphasizing the primacy of movement over object constitution. Iconicity is less image-ruled than Krampen would have it. If a plant recognizes jasmonic acid as part of the same category of signification as methyl jasmonate itself, then this satisfies the requirements that the sign have aspects of iconicity, where a sign stands for something else on the basis of some similarity. This bears the same semiotic structure as an *E. coli* cell receptive to sugar but fooled by an artificial sweetener (Stjernfelt, 2007). It is not indexicality because the chemical relative is

in no way a necessary indicator of actual methyl jasmonate. Plants can also differentiate between roots that are their own and those that belong to plants, even to the point of differentiating their own roots from roots of vegetatively propagated clones that once came from them (Callaway, 2002; de Kroon, 2007; Callaway & Marshall, 2007; Dudley & File, 2007). Their competitiveness in foraging is correlated with the degree to which the other root is related to them (Gruntman & Novoplansky, 2004. This cannot be understood as purely indexical signification either because the self/other distinction is itself iconic (T. v. Uexküll, 1986, p. 211).

I shall not take sides in the debate as to whether or not plants semiosis is essentially indexical or iconic. I agree that a more complex picture of semiosis will emerge, recognizing that what aspect of a sign comes out depends on the level and scale it is being looked at, and the question of phylogenetic differences should always specify scale chosen for analysis prior to distinguishing threshold zones. Stjernfelt (2007; 2012) argues that complex Peircean sign aspects are distributed across the biological world in ways that do not fit neatly according to icon, index and symbol hypothesized phylogenetic threshold zones (such as Krampen 1981; Deacon 1997; Kull 2009). For Stjernfelt (2012) all the classes of signs are already in even the most primitive bacterial behavior because they are implicit in metabolism itself, and what differentiates complex from simple behavior is the capacity for the organism to explicitly articulate individual sign types from out of this originary unity, so as to increase plasticity. This occurs through "segmentation, articulation, autonomization, adaptation to further purposes, ... [and through] loosening semiotic structure still more from its causal basis" (p. 47). He likens this process of differentiation and distinction making to the emergence of semiotic freedom (Hoffmeyer, 1992). For Stjernfelt (and according to him, for Peirce) an argument is the basic fully-developed sign, and the question is how less-developed, degenerate sign aspects are made prominent in the semiosis and how such degenerate sign aspects assist the organism (Stjernfelt, 2007, p. 25). Thus, Krampen's borrowing of Marxian "subtraction" (Favareau 2010, p. 265) is not an adequate method by which to realize other species' semiotic capacities.

When Stjernfelt (2007) speaks of "hypostatic abstraction" he is referring to the capacity to form higher-level signs (via L2 and L3 level semiotic changes) within the organismic-scale. Hypostatic abstraction is already present in plants, but it is embedded and develops on the species scale. For example, "jasmonate-ness" occurs as evidenced by the fact that classification of various jasmonate derivatives is possible, but it is not possible within the learning level of semiosis for which the organism itself is responsible for.

### 280 **An examination of root growth**

Phenomenologist Hans Jonas (1966) attempted to connect temporality to spatiality through emotions, and can therefore provide a useful entry point into questions regarding plant semiosis and learning. He naturalized emotion by insisting that it provides a causal role in soliciting an animal towards (or away from) phenomena that is present to it at a distance. As space is established and a distance opens between what a creature needs and where it is located, there emerges the need to e-mote, literally to compel the creature into movement. A Peircean biosemiotician might prefer to say that the animal experiences some iconic sinsign (referring to a general class of problems denoted by a legisign<sup>3</sup>) to which its subsequent action is an emotional

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3 The capacity for a particular instance of some plant hormone or neurotransmitter to act as

interpretant. The experience of that which e-motes provides the incentive for an organism to  
290 pursue that which it needs but is not directly accessing. If there is some external object disclosed  
such that the organism acts with reference to it, Jonas suggests that this behaviour is therefore a  
clue into the phenomenal world of that being. It must be responding to something immediate that  
is internal to it but which is tied to the external, distant object. Plants have flushes of hormones,  
secondary metabolites and even neurotransmitters analogous to those in animals (Baluška &  
295 Mancuso 2009a), all of which direct or redirect the plant's activity, sometimes for spatially or  
temporally distant goals. Do they e-mote the plant into action? And if so, on what level or scale  
is this activity occurring?

Trophic growth in plants presents a subtle though commonplace sort of plant movement.  
Because many trophic movements in plants arise through responses to qualities contiguous on a  
300 gradient scale in the environment, it is often argued that any movement or growth towards a  
resource is better than none and therefore acting towards something and acquiring more of it are  
one and the same thing, requiring neither perception of a distance (nor, therefore some iconic  
sinsign) for solicitation. There simply would be no need to e-mote if the benefit is directly  
entwined in the action. A distance in space and in time need only be disclosed when *no* benefits  
305 at all are incurred until the organism has reached its goal. If we can show an instance where a  
plant's trophic growth acts toward anticipated objects such that no benefit occurs for some  
duration between the point that it begins acting and the point that it reaches its object, then the  
plant will have to fit Jonas' e-motion (and therefore distance) criterion. Keep in mind, however,  
what we would need to look for in reference to our discussion of plant learning. Suppose we do  
310 find internally generated sinsigns driving behaviour towards potential things. From the organism  
scale, there could be no changes in objects, signs or interpretants, and hence no learning, even if  
this turns out to be a veritable functional cycle. For learning, there must be some observable  
change in sign activity and semioticians must be able to decide on what scale it is occurring.

It is a common misconception that plants are autotrophic and animals are heterotrophic.  
315 This misconception is propagated by biologists themselves who discriminate between the two  
terms primarily on whether or not a given species is able to fix atmospheric carbon. However, if  
we consider both terms more etymologically, the identification of plants as autotrophic and  
animals as heterotrophic becomes unjustifiable. Plants do photosynthesize ATP and gain carbon  
directly from the air, but their nutrient needs are met through precarious soil foraging. By  
320 contrast, humans can be said to be autotrophic in certain senses (their access to oxygen and  
vitamin D is secured through a contiguous adjacency to the resources) while other nutrient needs  
are met through foraging their environments. In animal motility, an animal moves by using  
energy from broken down carbohydrates. In plant trophism, a plants moves (i.e. grows) by  
selecting where to put inflowing carbon. In both cases, a surplus of carbon-based molecules frees  
325 the organism to choose from a complex manifold of interacting variables that would not be open  
to it had it no stored energy<sup>4</sup>.

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a iconic sinsign e-moting the plant into an activity occurs on a different scale than the capacity  
of the plant to form a class of situations for which the iconic sinsign is but a replica. The class is  
a legisign, and it may be an evolutionarily inherited sign type that is not itself available to  
change during the course of somatic development.

4 To coordinate the movement of sugars, plants use action potentials along long tubules interspaced with



330 However, whether certain plant chemicals act as iconic sinsigns compelling plants into trophic activity does not necessarily imply the existence of organism-scale semiotic activity. Certain perceptual information is received, produces the sinsigns as an interpretant, which then becomes a sign for other cells, which in turn act so as to push trophic activity forward. This can easily be explained by cellular functional circles. There are similar ambiguities with Kull's (2000) double-slit experiment (with a bow to Thomas Young and Claus Jonsson). If we put a plant in a black box, with two holes in the top, through one of which is shone light at a wavelength unusable for photosynthesis, that plant certainly moves towards the hole with the  
335 light, but this does not illustrate the need for whole-organism functional cycles as an explanation either. On the contrary, this can easily be explained by the fact that the wavelength is interpreted as a sign by all of the cells that the light hits, triggering all of them into movement towards that hole in the box. Of course, we have a case of iconic sinsigns again, but the semiotic activity may be confined to the cellular scale and intercellular semiotic interactions. Such activity within the  
340 plant is a feedforward process just like resource foraging in animals. It is precisely internally significant signs that function as a surrogate stimuli when distal goals are required. But this may only mean that Kull's "biological need" (2000, p. 339) is confined to the plant cell.

345 Is there anything that makes plant foraging a better candidate for organism-scale functional cycles and the possibility of organism-scale learning? Having no resource directly gained through the activity, allocating resources to grow roots in certain areas and not others requires e-moting by iconic sinsigns (which, again are instantiations of legisigns, or there would be no generalizability as to the interpretants they generate). This is particularly true when the translocation of resources is not a passive process in plants, such as in "active transport," which works against chemical gradients and therefore requires energy input (see, for example,  
350 Servaites, Schrader & Jung 1979). However, the nature of the plant foraging suggests a semiotic activity beyond what is required for mere e-moting. In foraging for nutrients, a plant never spreads its roots out uniformly in all directions. Instead, the roots in the more nutrient-rich soil patches spread out more than the ones in the relatively barren areas. To accomplish this, the various roots' micro-environments need to be compared so that carbon resources can be best  
355 distributed. What is considered "nutrient dense" is *relative* to the particular context of a given plant so that nutrient-poor soil in one plant's environment may be interpreted as rich in a very infertile location. Now, here's the point: a sign is as big as it needs to be. If we see integrated whole-plant behaviour that shows that the various regions of the plant root system are being compared to one another and energy resources from other parts of the body translocated  
360 accordingly, it is reasonable to assume that a organism-scale mapping is occurring. The mapping is itself a sign activity, but one that functions on a higher scale than the modular scale for the simple reason that it is integrating information to rate multiple modular locales. In essence: whole-plant spatial behaviour that implies a global map also implies a global sign. If the organism is responsible for creating a sign that can only be interpreted by the whole-organism,  
365 then we have compelling evidence of a global functional cycle. Of course, the map is not "visual," but it is certainly spatial. That the mapping is continually changing as a result of the very trophic decisions that the plant makes while using it indicates that mapping is also a continuous learning process, occurring at least on the cellular and organismic level. What levels

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chemically mediated signalling across plasmodesmata, in a system that formally converges with animal neurotransmission (Baluška, Volkmann & Menzel 2005)

of learning are possible at each scale could be revealed through further plant research.

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### Conclusion/Discussion

There are rather complex sensorimotor activities that occur in humans that do not seem to clearly disclose an *Umwelt*. When sleeping, people can receive perceptual signals and respond to them in coordinated ways, sometimes including vocal responses, without being aware that they have done so. Are plants like sleeping animals? Of course, many plants experience nyctinasty, difference in plant growth (Nozue & Maloof, 2006), a reduction in nutrient translocation and assimilation (Lillo, 2008), stomatal closure (in non-CAM plants), as well as nighttime shifts in genomic activity (Schaffer et al., 2001). Though these studies indicate deep physiological differences that are undoubtedly accompanied by semiotic differences, they cannot provide evidence that the plant's daytime semiosis discloses a more vivid *Umwelt* than its nighttime activity. Nevertheless, studies that show that plant learning at the organism-scale depends on sign activity (such as mapping) that is itself at the organism-scale, are a more compelling reason to assume some sort of organism-scale experience. To really find out whether or not plants sleep, it is necessary to examine changes in organism-scale semiotic activity.

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I will this paper with four remarks. First, "functional cycles" are difficult to find in organisms that veer strongly from the paradigmatic cases. Second, there appear to be cases, even in humans, that satisfy Uexküll's criteria for functional cycles but that do not have tangible *Umwelt* experientiality. Both of these points, taken together, imply that the term functional cycle is unclear and should be fleshed out. The way it is often defined may be a necessary but not sufficient conditions for constituting phenomenal experience. Third, it seems that a stronger claim for organism-scale experience is the requirement that there are functional cycles organize perceptual and/or effector signs as single organism-scale signs, such as a maps, that cannot be conceivably "read" at the modular scale. Fourth, the typology of learning types along scales and levels can allow for a more precise discussion as to what sort of semiotic processes are active and changing and which ones are providing more static, contextual, and formal constraints. This is important for any discussion of semiotic classification along phylogenetic lineages, but is also likely useful for integrating richer Peircean semiotics into our understanding of biological systems.

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