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More Plant Biology in Philosophy Education

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Abstract

Philosophers usually tend to think of animals when they think about life, plants often only appear in their works as on the margins, in the background; they are rarely in the centre. However, plant life involves unique processes, including remarkable modes of interaction between plants and their environments. Needless to say, plants are vital parts of ecosystems. Serious attention to plants provides novel and interesting perspectives on many topics in philosophy of biology, including individuality, organisation and disease. Plant biology should have a substantial part in philosophy education. To support this assertion, this paper briefly describes three topics related to plant-environment interaction and explains some of their philosophical implications. These topics are growth, plant hormones and plant-plant microbiota interactions, all of which present crucial aspects related to some prevalent topics in philosophy of biology such as individuality, systems thinking, and holobiont.
Keywords**:** plant biology, hormones, individuality, holobiont, organism

Özet

Filozoflar yaşamla ilgili düşündüklerinde, bunu genellikle hayvanlar üzerinden yapmaya meyillidirler. Bitkiler, çalışmalarında çoğunlukla arka plandadır; nadiren çalışmaların merkezinde oldukları görülür. Oysa ki bitki yaşamı, bitki ve çevresi arasındaki etkileşimin çok ilginç halleri de dahil olmak üzere eşsiz süreçler içerir. Ayrıca tabii ki, bitkiler ekosistemlerin hayati derecede önemli parçalarıdır. Bitkilere yeterli ilgilinin gösterilmesi, biyoloji felsefesinde bireylik, organizasyon ve hastalık gibi birçok konuda yeni ve ilginç yaklaşımlar sağlayacaktır. Bitki biyolojisi, felsefe eğitiminde önemli bir yere sahip olmalıdır. Bu tezi desteklemek için, bitki-çevre etkileşimi ile ilgili üç konu örnek olarak ana hatlarıyla anlatılacak ve bu konuların felsefi yansımaları açıklanacaktır. Büyüme, bitki hormonları ve bitki-bitki mikrobiyom etkileşimleri konuları, bireylik, sistem düşüncesi ve holobiont tartışmaları gibi biyoloji felsefesindeki temel konulara önemli yaklaşımlar sunar.

Anahtar kelimeler**:** bitki biyolojisi, hormonlar, bireylik, holobiyont, organizma

Plant-Environment Interaction

An organism has a very dynamic and complex interaction with its environment. It constantly senses its surroundings, produces relevant responses and maintains itself through this interaction. Plants have a complex net of many signalling pathways that allows them to sense the environment, regulate their internal processes through these signals and produce relevant responses that maintain their physiology, enable their growth and affect their environment. Plant biology can provide great subjects for philosophy of biology education. Although the following sections are divided into growth, plant hormones and plant-plant microbiota interactions, these topics are of course intertwined; consequently, each section is also about the other two, and while the topics and their philosophical implications are only briefly described in this paper, further investigations into these topics can offer many more contributions to philosophy classes. Furthermore, these are only a few topics of plant biology which is, in fact, an extensively rich area and can provide many other interesting and beneficial perspectives in philosophy education.

Growth

Since there are various kinds of organisms and various kinds of life cycles, there are various kinds of organism-environment interactions. Because plants do not move around like animals do, they are usually and mistakenly thought to be inactive, only a passive subject to their environments. But, on the contrary, since they do not 'move' like animals, they have many other ways of interacting with their environments. Their movement is their growth which involves highly complex and intricate processes. According to Gorzelak and colleagues (2015), "plant behaviour is defined as a change in plant morphology or physiology in response to environmental stimuli" (Karban, 2008; Gorzelak et al., 2015). In other words, in addition to their growth and changes in their morphology, plants have many ways to change their environments, which are part of their physiological processes. Their active interaction with the environment involves many processes some of which significantly affect the environment causing it to become more suitable for plants. For example, root exudates have many roles in regulating the soil microbial community, initiating and modulating dialogue between roots and soil microbes, coping with herbivores, changing the chemical and physical properties of the soil, causing mineral nutrients to become more available for uptake and inhibiting the growth of competing plant species etc. (Badri & Vivanco, 2009; Walker et al., 2003; Haichar et al., 2014).

Arber (1950) says the morphology of plants may be thought to include something corresponding to behaviour in animals. Plants can grow in various kinds of ways depending on their specific context, in other words, their own interaction with their environment. Process philosophy (Dupré, 2012) provides crucial perspectives for understanding those. Recently, process philosophy in philosophy of biology is taking an important leap forward,[21] which is of course not independent of developments in biology. Plant-environment interaction and plant growth present perfect cases for illustrating the usefulness of processual thinking in biology. Rutishauser (2020) emphasises the process thinking and the continuum approach in plant morphology and points out that there is a need for a paradigm shift in the area of plant morphology which is "a valuable sub-discipline of EvoDevo"; this shift demands a processual thinking that involves taking plant morphology as a continuum rather than an assemblage of structural units (Rutishauser 2020). Baum's (2019) paper, which is about plant parts, also discusses the "process morphology approach". Baum (2019) argues that "depending on the context, parts are best understood sometimes as structures, sometimes as functions, and sometimes as processes". (Baum 2019).

One of the important concepts about plant-environment interaction and plant growth is phenotypic plasticity. Phenotypic plasticity, understood as the ability of plants to show a wide range of phenotypes in response to environment is one of the striking characteristics of plants. Since plants can show very plastic responses, they would provide excellent examples to show the plasticity of development of organisms. Sultan (2015) emphasises the importance of 'eco-devo' and niche construction perspectives and how these would require some specific kind of research (for example, allowing researchers to test the parent environment interaction too). Plant science has been producing a substantial amount of research on epigenetics, niche construction and developmental plasticity, all of which can present valuable examples in philosophy of biology syllabi and can help students grasp evolutionary processes in a more fulfilling way.

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[21] Two significant philosophy books in this trend are *Processes of Life* (Dupré, 2012) and *Everything Flows: Towards a Processual Philosophy of Biology* (Nicholson & Dupré, 2018).

One of the important aspects of plant growth and development is the regulation of source-sink balance. This regulation happens very dynamically through plant-environment interaction. Plants transport nutrients and photosynthates (products of photosynthesis) from source tissues to sink tissues. For example, the transport of photosynthates from leaves (sources) to roots or to newly developing leaves (sinks), or the transport of minerals from roots (sources) to shoots (sinks). Yu and colleagues (2015) examine these processes in cereals – in the germination-seedling development stage, in the vegetative stage and in the grain filling stage. Of course, since there are various kinds of plants and various kinds of life cycles, there are various kinds of source-sink transitions (e.g., an oak tree's source-sink transitions would be very different from a wheat plant's). Plant parts become sources, sinks or both in different stages of development and these transitions are dependent on environmental factors; not as simply determined by environmental factors, but as the outcome of constant plant-environment interaction. Source-sink balance is continuously regulated at every stage of development in the plant life cycle through this interaction. Many molecules, such as metabolites and hormones have roles in the source-sink balance regulation. This regulation is crucial for plant life and happens through a complex net of many processes and presents a very fruitful way to think about coordination and communication between the body parts of an organism.

Not only because of their microbiota, but also due to their modular nature and growth, plants have been constituting problematic examples of biological individuals and challenging the various conceptions of biological individuality (Dupré, 2010; Clarke, 2012; Gerber, 2018). Plants are modular organisms. Modules have meristem tissue in some parts of the shoots and roots, and this tissue contains undifferentiated cells which can grow to be any part of the plant. Modules in a plant's body are capable of growing themselves, they can be iterated to make up a larger unit, they can become a whole new individual, or they can make up a clone, for example, by root suckers (Dupré, 2010; Clarke, 2012). That is to say, some plants are clonal – a whole forest can be originated from a single zygote. Ramets and genets are key terms for distinguishing a clone (genet) and the 'individuals' (ramets) in the clone: a genet is a collection of modules or ramets, is developed from a single zygote and can be as big as a forest.[22] So, each tree in this clone is called a ramet. (Dupré, 2010; Clarke, 2012).

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[22] For example, Pando, a quaking aspen clone in USA (Mitton & Grant 1996).

Similar to animals, plants also challenge the monogenomic understanding of the individual organisms (Dupré, 2010, 2012). There can be many mutations as they grow and they have a very rich microbiome.

Plant hormones

Another interesting aspect of plant life – and another one that shows the benefits of using examples from biology to advance philosophical queries – is the plant hormone system, which has crucial roles in the regulation of many kinds of interactions between plants and their environment. These include development, growth, reproduction, abiotic stress responses, interactions with pathogenic and symbiotic fungi and other microorganisms (many plant hormones are also produced by fungi[23] [Chanclud & Morel, 2016; Eichmann, 2021]). The roles of plant hormones in these processes, of course, include regulation of source-sink balance too. For example, the ABA (abscisic acid) hormone, which is crucial in stomatal closure, also has roles in the transport of photosynthates towards developing seeds and the synthesis of storage protein in seeds (Davies, 1987).

A local stimulus can cause a systemic response in the whole plant. For example, if we wound an *Arabidopsis thaliana* plant on one leaf, we would expect to observe an increase in the ROS molecules (reactive oxygen species), first in the wounded area and then quickly – in minutes or seconds – in the whole plant (Baxter et al. 2014). Plants produce systemic responses to many types of environmental stimuli including biotic (viruses, bacteria, fungi, insects) and abiotic (heat, high light, cold etc.) stressors and changes in sugars and other metabolites. Plant systemic responses consist of the crosstalk of many pathways that involves various kinds of molecules, including metabolic compounds, reactive oxygen species and hormones. Recently, Robischon (2019) advocated the usefulness of plant hormone examples in fostering systems thinking in education. Robischon points out how plant hormone signalling networks can perfectly illustrate nonlinear

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[23] "Hormones take a crucial role in contributing to the assembly of plant microbiomes, and plants and microbes often employ the same hormones with completely different intentions." (Eichmann, 2021).

effects and feedback loops in biological systems,[24] and having effects even beyond the plant system can help the student think about the nature of system borders (Robischon, 2019).

Plant-plant microbiota interactions

Plants live with various kinds of microorganisms including bacteria, viruses and fungi. Since all the plants and animals live in very close association with microorganisms, it is very important to consider these interactions for understanding organisms. *Holobiont*,[25] which is mostly understood as "a host macro-organism and all of its associated microbiota including bacteria, archaea, viruses, protists, fungi, and microscopic multicellular animals such as nematodes" (Skillings, 2016 citing others) is a very intriguing topic in natural sciences and also in the philosophy of natural sciences. Unsurprisingly, plants and their microbiota constitute a rich research subject both for scientists and philosophers. More and more research has been focusing on the importance of plant microbiota on plant growth, health and stress resilience (for example, Vandenkoornhuyse et al., 2015; Müller et al., 2016; Compant et al., 2019; Trivedi et al., 2020; Babalola et al., 2020; 22 articles on the research topic[26] of 'Plant Holobiont' in *Frontiers in Plant Science* and *Frontiers in Microbiology*, 2020).

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[24] An example study about this is the work of Aerts and colleagues (2021) where they examine the role of complex hormone networks in plant defence. They point out that such complex hormone networks are constituted by molecular pathways which are initiated by different hormones, and the aforementioned networks involve synergistic, antagonistic and additive interactions.

[25] "Holobiont: A plant and the members of its associated microbiota considered as a single entity; this represents the 'unit of selection' at which plant–microbiome interactions have probably co-evolved in order to maintain host functionality and fitness over ecological and even evolutionary timescales." (Trivedi et al., 2020).

[26] Editors of Volume I (*Microbiota as Part of the Holobiont; Challenges for Agriculture*): Patrizia Cesaro, Elisa Gamalero, Barbara Pivato and Junling Zhang.
Editors of Volume II (*Impacts of the Rhizosphere on Plant Health*): Nadia Lombardi, Roberta Marra, David Turra, Francesco Vinale and Sheridan Lois Woo.

One of the philosophical problems related to holobiont is about biological individuality: whether or not holobionts are biological individuals. Many philosophers have examined this problem (for example, Dupré & O'Malley, 2009; Dupré, 2010; Dupré, 2012; Skillings, 2016; Pradeu, 2016; Gilbert & Tauber, 2016; Chiu & Eberl, 2016; Suárez & Triviño, 2019; Molter, 2019). In the investigations of the concept of biological individuality one needs to consider the evolutionary individual, the ecological individual and the physiological individual, which, according to Pradeu (2016b), only partly overlaps. Skillings (2016) finds holobionts interesting because they have features of organisms and also of communities. It seems, depending on research questions and the part of the holobiont that is the subject of our investigation, we may be considering it as a community or as an individual. For example, Molter (2019) argues that a plant with its symbiotic fungi is a mycorrhizal collective that is an evolutionary individual; however, a mycorrhizal collective is not a holobiont, because of those fungi's macrobial nature and the fact that it has its own microbiota too. Furthermore, those fungi constitute a huge physiological individual since they are integrated networks[27] connecting trees and causing them to share nutrients and signalling molecules (Gorzelak et al., 2015; Molter, 2019). Reading about plant microbiota and holobiont would provide students with important benefits including learning about ecosystems, organisms' fuzzy boundaries, complex interactions between organisms and biological individuality.

Conclusion

Plant biology is a broad discipline that involves many areas researching various processes of plant life including physiology, ecology, evolution, morphology and more. Plant growth, plant hormones and plant-plant microbiota interactions are some of the striking aspects of plant life and present crucial examples for thinking about prevalent topics in philosophy of biology such as individuality, systems and holobiont. Even the few examples that are presented in this paper show the important benefits of including more plant biology in philosophy of biology education. Students can gain a broader perspective about life, understand ecosystems better, appreciate diversity, understand its importance and grasp organism-environment interaction in a much richer way.

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[27] "Mycorrhizal networks are composed of continuous fungal mycelia linking two or more plants of the same or different species." (Gorzelak et al., 2015).

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