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*Plant Sentience:  
Theoretical and  
Empirical Issues*

*Editorial Introduction*

A recurrent trend in philosophy and the sciences of the mind is to explore whether organisms and physical entities that, for different reasons, have been deemed as cognitively uninteresting at some point in history can now be characterized as cognitive agents. Chief examples of this trend are the earlier and contemporary studies on animal cognition after Descartes neglected its possibility and the fashionable contemporary field of artificial intelligence. A manifestation of the same trend is the corpus of works that have attributed some form of intelligent or cognitive abilities to plants since Charles Darwin's works on plant movement (1875; see also Darwin and Darwin, 1880). Current scientific literature has portrayed plants as not merely reactive organisms and has stressed the complex ways in which they interact with their environments. We know, for example, that plants do not react to environmental impingements on a one-by-one basis. Rather, they seem to be able to integrate information from multiple vectors, eliciting sophisticated responses (at the level of

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physiology, morphology, and phenotype) to maximize fitness (Trewavas, 2014). Plants also seem to be able to anticipate upcoming events (Novoplansky, 2016), to show some communicative skills (Falik *et al.*, 2012), and to be sensitive to relevant features of their environment as well as be able to organize their behaviour with respect to them (Raja *et al.*, 2020). Likewise, some plants seem to be able to memorize and learn from previous experiences, and researchers have found evidence of associative and non-associative learning in *Mimosa pudica* and garden pea, for instance (Gagliano *et al.*, 2014; 2016). This scientific evidence has garnered the attention of philosophers and cognitive scientists, among others, initiating the debate about whether plants can be considered intelligent in a proper, non-metaphorical way (Adams, 2018; Segundo-Ortín and Calvo, 2019) and if, for instance, they can serve as a model for some kinds of artificial systems (e.g. plant-inspired robots; see Frazier *et al.*, 2020).

In the context of the discussion of plants as cognitive and minded organisms, a much less explored issue is whether plants are conscious — namely, whether plants have subjective, phenomenal experience of the world (but see Segundo-Ortín and Calvo, under review). The debate about plant consciousness is framed into the broader debate concerning whether plants can be considered cognitive beings and, therefore, the former inherits some issues from the latter. One concrete issue has to do with anthropocentric assumptions. Take, for instance, Adams (2018). As a defender of the idea that sophisticated mental representations provide the ‘mark of the cognitive’, Adams has recently argued that only if plants can be demonstrated to have propositional states such as beliefs, desires, and so on can they be considered cognitive creatures. This is, of course, a non-starter for the debate regarding plant cognition but, at the same time, it is highly misled. This is so for two reasons (see Segundo-Ortín and Calvo, 2019). First, even if we agree that most human beings are capable of having propositional attitudes after appropriate developmental processes, we can wonder whether such capabilities are present in any other living being. By positing propositional attitudes as the hallmark of cognition we run the risk of limiting the domain of cognitive science to human beings exclusively, leaving out of consideration all sorts of sophisticated behaviours exerted by non-human creatures. Besides, there is no reason to believe that cognition depends on having such representational states. Assuming so, as Adams does, is simply to beg the question against non-representational and representational but not propositional theories of cognition. In this sense, Adams (2018)

not only sets an anthropocentric requirement impossible to meet, but also argues in no man's land.

However, despite our disagreement with Adams, we believe the structure of his argument is relevant. The argument goes, first, by setting up a requirement (or a series of requirements) for cognition and, second, by investigating whether plants meet the requirement(s). This structure is typical when studying plant cognition and has been inherited in the study of plant consciousness. For instance, Calvo (2017) defends the possibility that plants could be subjectively aware or conscious of the world. He rests his case upon a series of empirical findings gathered in the context of the field of plant signalling and behaviour. The rationale that underlies plant signalling and behaviour is that coordinated, goal-directed behaviour calls for the integration of information among different plant structures, and that uncovering the signalling mechanisms that give rise to this behaviour is the goal of part of plant (and cognitive) sciences (Brenner *et al.*, 2006; Calvo, 2016; Fromm and Lautner, 2007; Volkov, 2012). To that end, several disciplines are called upon, including biochemistry, electrophysiology, molecular biology, and plant ecology.

Although we are far from gaining a thorough understanding of plant signalling and behaviour, we know that plants produce action potentials in response to many environmental factors, and that these electrical signals are transmitted in the membrane of plant cells through the whole plant body. In addition, neurotransmitters akin to those found in animals, such as dopamine, serotonin, and glutamate, are also present in plants. In light of these findings, Calvo (2017) argues that despite the fact that plants do not have neurons, properly speaking, they lack none of the functional structures supposedly needed to have phenomenal consciousness. Thus, Calvo (2017; see also Calvo, Sahi and Trewavas, 2017) claims that there is no solid reason to neglect such a possibility before serious engagement and investigation. Calvo's (2017) argument is already framed in terms of setting up some requirements (having functional structures for electrical and chemical transmission) and the proposal that plants actually meet these requirements.

By contrast, Taiz *et al.* (2019; 2020) argue that 'the capacity to process environmental information for adaptive behavior and subjective awareness of the environment are two different things' (2020, p. 219), and claim that the latter depends on having a complex nervous system. Therefore, they conclude that, while attributions of sentience to vertebrates, cephalopods, and arthropods are plausible, attributions to

plants are not. Furthermore, they argue that plants do not need consciousness, for their behaviour is ‘epigenetically determined by environmental factors’ (*ibid.*, p. 218). Hence, according to Taiz *et al.*, plants meet neither the functional nor the behavioural criteria for being considered conscious.

Some of the contributions to this special issue are framed within this same argumentative structure and therefore participate in the overall debate on whether plants meet the proper requirements to be conscious. **Simona Ginsburg** and **Eva Jablonka** argue against the attribution of pre-reflective, basic consciousness to plants on these grounds. According to them, claims that plants are conscious or sentient are supported by three main arguments. First, arguments for byopsychism — the idea that consciousness is an inherent feature of life itself. Second, arguments for the strong analogy between the vascular system of plants and the nervous system of animals. Third, arguments for the claim that plants exhibit roughly the same cognitive abilities as animals. To argue against these views, Ginsburg and Jablonka propose the following list of necessary and jointly sufficient conditions for sentience: percept unification and differentiation, temporal depth (or the integration of perceptual experiences over time), global accessibility and broadcast, flexible attribution and goal-directed behaviour, selective attention, intentionality, open-ended adaptability, and self–other distinction. Giving these conditions, the authors propose unlimited associative learning (UAL) as the evolutionary transition marker for sentience. Because all the capacities previously listed are required for UAL, the emergence of UAL in a species is a reliable indicator of sentience. Unfortunately, Ginsburg and Jablonka contend, there is no empirical evidence that any species of plants are capable of UAL. Finally, the authors consider the alleged ethical consequences of denying sentience to plants.

In an opposite flavour, **František Baluška** and **Arthur S. Reber** explore the biomolecular basis for plant sentience. Building upon the Cellular Basis of Consciousness model (CBC; Reber, 2019), they propose three principles to understand consciousness. First, that life and sentience are coextensive. Namely, that consciousness is an inherent feature of all life. Second, those functions of organisms that play an adaptive role always remain a part of the genome of a species and its descendants. And third, that cellular consciousness is generated by basic biomolecular processes. Concretely, senomic and ephaptic processes. Senomic processes refer to the full set of sensory events in a cell. Ephaptic processes refer to the functional relationships between a

cell and its adjacent ones. Baluška and Reber proceed by reviewing some evidence regarding the origin of these functions and how they can be understood as harnessing sentient processes in the cell. Then, the authors identify the anatomical structures that support the mentioned functions in eukaryotic cells: excitable membranes and cytoskeletal polymers. Finally, they extend these principles to multicellular organisms. If the proposal of Baluška and Reber is on the right track, consciousness would be a fundamental property of living systems and, actually, plants would have the anatomical and physiological resources to exhibit sentient behaviours.

Still related to the different requirements needed to attribute cognition, awareness, and consciousness to plants, **Andrea Nani**, **Gabriele Volpara**, and **Andrea Faggio** propose a theoretical model to classify all those concepts. Overall, the authors defend that the complexity of plant physiology and behaviour should not lead to the temptation to interpret plants as having conscious experiences. First, Nani, Volpara, and Faggio review a number of works in the field of plant neurobiology and grant the possibility of attributing cognition to some plants. However, they argue that the presence of cognition in plants does not grant plant consciousness. The reason for this conclusion is well-known in the sciences of the mind: it is possible for different organisms to be undergoing events of unconscious cognition, so cognition and consciousness are not coextensive. The authors then proceed to propose their theoretical model for plant behaviour based on three dimensions: adaptiveness, sensitivity, and sentience. According to them, this model is adequate to characterize the different behavioural manifestations of all living organisms and, therefore, is adequate to characterize the behavioural manifestations of plants. Their conclusion is that, although plants exhibit interesting levels of adaptiveness, sensitivity, and sentience, these facts are not enough in order to predict conscious experience of plants as they are necessary but not sufficient conditions for consciousness.

**Pedro Mediano**, **Anthony Trewavas**, and **Paco Calvo** propose a theory-driven strategy to investigate plant consciousness based on integrated information theory (IIT). In a nutshell, the core idea behind IIT is that sentience has to do with a physical system's capacity, or some parts thereof, to integrate information (Tononi, 2008; Tononi *et al.*, 2016). Degrees of consciousness are measured as values of  $\Phi$ , which stands for the amount of causally efficacious information that is contained in the interaction between a subset of elements,  $C$ , belonging to the system. If the value of  $\Phi$  in  $C$  is higher than 0, the

system is conscious. Even though IIT has been primarily applied in the context of cognitive neuroscience, Mediano *et al.* argue that there is no reason to think that information integration cannot occur in plants.<sup>3</sup> In this sense, if plants can be described in terms of IIT and exhibit the same signatures as typically conscious organisms, they may be said to be conscious. The authors propose a series of physiological structures in the meristems and vascular system of higher plants allegedly capable of integrating information the way IIT requires. Moreover, coining the term ‘PLANT-IIT’, Mediano and colleagues propose a series of experiments that, according to them, could help us elucidate both how much information is integrated in plants and where such integration takes place. These experiments concern, for instance, the use of imaging techniques — such as MRI, positron emission tomography, and electrophytography — the use of anaesthetics, and the use of magnetic stimulation. According to the authors, if the PLANT-IIT research programme is successful, this would open the possibility of a much richer conception of consciousness as something that is not restricted to human beings and a few other animal species.

Not all the discussions regarding plant cognition and plant consciousness pivot on the idea that plants must meet a requirement in order to be considered cognitive or conscious systems. Other debates address more foundational questions regarding what consciousness is, how it is similar to or different from sentience, how it differs from cognition, etc. Within this framework, then, whether the notion of consciousness can be applied or not to plants is questioned. In his article in this special issue, **Quentin Hiernaux** claims that consciousness is a confusing term and cannot be adequately attributed to plants in the absence of a related theory of cognition. Such a theory of cognition must be able to bypass traditional anthropocentric biases while, at the same time, avoiding diluting cognitive faculties to the point that makes them overly cheap and uninteresting. Taking stock of this, Hiernaux proposes to understand consciousness as a type of cognitive activity and cognition as a type of behaviour — in this case, behaviour that is non-automatic, non-programmed, and that involves

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<sup>3</sup> The fact that information integration and sentience has been defended to occur in non-living systems (Tononi, 2008; Godfrey-Smith, 2016) shows that defenders of IIT do not exclude any physical system from being conscious *a priori*. The question of whether plants are conscious, according to IIT, depends on architectural and topological features — namely, whether any part of the vascular system takes the form of a re-entrant (non-feed-forward) circuitry.

decision over diverse alternatives. After having analysed different empirical findings concerning inhibitory behaviour and associative learning, Hiearnaux claims that attributions of minimal cognitive capacities to plants are sound. This is so despite the fact that plants lack the anatomical structures allegedly required to construct and manipulate mental or cognitive representations. Finally, based on related empirical findings concerning self–other distinction, foraging and competition, and proprioception, the author contends that plants are capable of minimal forms of consciousness, including immediate (non-reflective) awareness of the surrounding environment and self-recognition.

The contribution by **Chauncey Maher** shares this conceptual gloss. Based on the previous works by Mark Wilson (1982; 2006; 2017) on predicates and concepts, Maher argues that the question of whether plants are conscious cannot be answered, for we do not know what it means for plants to be conscious. For Maher, that the predicate ‘is conscious’ is indeterminate when applied to plants can be seen in the fact that current competent users of it disagree about the proper grounds for its application to non-human creatures. But, why is the meaning of the predicate ‘is conscious’ indeterminate in the case of non-human creatures? According to Maher, this indeterminacy has to do with our lack of knowledge of the implicit restrictions we rely upon when we apply the predicate correctly. Because we are unsure about the conditions that should be in place to attribute consciousness beyond human beings, we cannot know whether the sentence ‘plants are conscious’ is correct. If Maher’s argument is on the right track, then discussions about whether plants are conscious cannot be solved by appealing to any empirical findings. Rather, they require both conceptual analysis and conceptual engineering.

In a similar vein, **Deborah Brown** and **Brian Key** discuss two assumptions in the literature on plant intelligence: (i) the applicability of psychological predicates to many kinds of physical structures and (ii) the compatibility of grades of consciousness with Darwinian gradualism. First, Brown and Key analyse the conflation between the notions of nociception and pain in the literature on plant sentience. After that, they do the same with terms like ‘sentience’, ‘awareness’, or ‘consciousness’. The authors remain sceptical of the adequacy of the use of these notions with regard to plants and propose a focal/non-focal distinction in their use with Aristotelian reminiscences. The second part of the paper addresses the ‘emergentist dilemma’ (i.e. the idea of the emergence of consciousness in a gradual fashion) and the

relationship between awareness and complex systems. In this context they offer an analysis of the multiple levels of awareness in different systems. Nowadays, the authors claim, there is insufficient evidence that plants are sentient or subjectively aware of their environment. The analysis in their article, however, provides according to Brown and Key a better theoretical framework to try to understand the claims regarding plant awareness or plant consciousness in the literature on plant intelligence.

Finally, the paper by **Ethan C. Terrill** is the contribution from moral philosophy to the special issue. Terrill explores and analyses the plausibility for plants to bear some moral status if they are minded and/or sentient beings. To do so, Terrill first analyses the notion of moral status and proposes partial moral status as a form of moral worthiness for those organisms with rudimentary cognitive capacities like the ones attributed to plants in the literature on plant intelligence. In Section 3, Terrill reviews some of that literature. The latter part of the paper combines the previous work in order to answer two inter-related questions: if plants have minds, then do plants have some kind of moral status? If so, what kind of moral status they have? The paper ends up providing some tentative answers to these questions. The tentative answer to the first question addresses the extent of that moral status in terms of wide and narrow notions of it. The tentative answer to the second question takes the form of an outline of practical plant ethics in case of a positive answer to the previous question. Terrill does not aim to offer the final word regarding the moral status of plants, but the paper provides an exhaustive analysis of the logical space where the discussion regarding plant ethics given plant minds will develop in the future.

Our intention with this special issue was to offer a preface, and not coda, for the study of plant sentience. We didn't know whether plants are sentient or not. Indeed, we didn't even know whether posing the question made some sense. After reading all the contributions to the issue, we have gained some knowledge. Now we know the question regarding plant sentience actually makes sense. This special issue has engaged philosophers and scientists trying to make sense of it and trying to provide an answer. Their answer, however, is not unanimous. Besides, this special issue shows different theoretical, methodological, and empirical positions regarding plant sentience. And we think that this is great for a preface. By providing works that both deny and embrace plant sentience, the contributors to this special issue have settled up the coordinates of a whole field of philosophical and

scientific enquiry. Many different research directions towards plant sentience may be taken from this preface. Many adventures may be lived. And we think it is great. We hope the reader feels the same.

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