QUENTIN
HIERNAUX

FROM PLANT BEHAVIOR TO PLANT INTELLIGENCE?

Sciences en questions

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Quentin Hiernaux

From Plant Behavior to Plant Intelligence?

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The working group was set up at INRA –now INRAE– in 1994 on the initiative of the departments responsible for training and communication. Its objective is to promote critical reflection on research through contributions that shed light on philosophical, sociological and epistemological issues related to scientific activity in an accessible and attractive form.

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Preface

It has long been known that plants are regarded by the public as still life. While it is accepted that plants do germinate, grow and flower, it is not immediately obvious to us that they do much else. However we ourselves are animals and we impose specific animal requirements on everything else biological. Our requirement to detect movement, for example, is limited by the nature of our visual process. The retinal image lasts about a tenth of a second and numerous, vibratory movements of the eye (usually unperceived) are necessary to prevent retinal adaptation. If the movement is much slower than these visual limitations the description of still life is obvious – but from our perspective. Some bamboos grow a metre a day but at less than a mm/minute, it is still not obviously visible. The consequence is that whereas animal behaviour is easily seen and deductions made about both its instigation and likely consequences, plant behaviour has always had to rely on experimental circumstances with appropriate measuring devices to establish that plants do really behave. And even then the half below ground remains largely invisible. Only with the onset of time lapse can many plants now be easily seen to be doing something; to behave. And to a much wider public. While Jane Goodall could record chimpanzee behaviour with merely a pencil and notepad, only with special cameras or other complex experimental apparatus could plant behaviour in wild circumstances be recorded. Much of real plant behaviour in wild conditions still remains unreported.

Plants are among the only groups of organisms that use an external source of energy; the sun. The consequence is that they are the basis of all food chains and predation of one kind or another, threatening survival, was inevitable from the time some two billion years ago when plants first separated from their protozoan ancestors. The evolutionary solution

has been the construction of a plant body composed of repetitive elements, leaves plus subtended buds above ground and branch roots below. Inevitable loss of some simply leads to replacement by others. Growth takes place in embryogenic meristems in shoot and root tips. Furthermore predation and disease were tackled by the acquired ability to synthesize what is termed natural pesticides; substances that often flavour our food but do not kill us, because we are so much larger than any insect. The movement of plants to land some 500–700 million years ago subjected plants to additional environmental hazards. These are specifically sensed too and result in selective changes of the phenotype, often called plasticity. These changes are adaptive, designed specifically to potentially help survival, to continue growth of a kind and as far as possible reproduce. Plants are more sensitive to a much greater number of environmental signals that require adaptive change than the common roaming animal. Plants know about their environment because they respond to it; they are cognitive. Individuals control their own behaviour as cognitive agents to counter the hazards they perceive. Virtually all plant tissues are plastic. Plasticity is used to construct a phenotype with improved chances of survival, to fight over space and resources and construct a dynamic niche underground.

Biological intelligence is quite simply adaptive behaviour, improving survival probabilities as Dobzhansky indicated some 70 years ago. Easy to see when a zebra runs away from

a marauding lion or chooses to continue movement to find un-grazed food. Plants approach similar goals when they synthesize a chemical to kill off marauding insects or choose to search new soil by root proliferation when phosphate deficiency is sensed. Animals move, plants change structure and physiology; the goal is identical. For those that like simple analogies; there are two kinds of cars on European roads, those run by electricity and those using petrol. But the goal, transport of people or goods is the same despite the entirely different mechanisms.

However the choice of words to describe plant behaviour, intelligence, agency, cognition, consciousness (or better awareness) and incorrectly believed by some to require nervous systems, creates controversy. This book by a young Belgian philosopher of science deals with many of these issues. Intelligence, memory, learning, consciousness are discussed in the first part. The second part concentrates on biosemiotics, how meaning is created from the perceived signs and signals that plants experience and it creates a plant ethology. There is an ongoing debate among plant scientists that will continue until plant physiologists doff their white coats and decide to understand how plants do behave in the real world. A place of environmental uncertainty, extreme competition, battles over space and resources, disease, invasion, common death and real predation in the many ecosystems of the planet. This book should interest and educate any open-minded scientist who wants to understand better the current controversy and the increasing understanding of how complex, plant behaviour actually is.

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From Plant Behavior to Plant Intelligence?

Introduction

Behavior is a key concept in numerous fields of study: psychology, ethology, but also in the biology of organisms. It does not cause much surprise that dolphins, chimpanzees or rats display rational behavior – after all, they are not so different from us. But what about the organisms we deem "simpler"? Or even brainless organisms like plants? Do they display behavior at all? Is their behavior comparable to the behavior of animal species, or even to human behavior? Do plants give meaning to their environment? Do their activities result from a cognitive process? These questions are the starting point of recent controversies – of which the "plant intelligence" debate has received the widest coverage in mainstream media. But looking beyond controversies, we will see that it is essential to investigate plant behavior. According to the theory of evolution, life forms are continuous. Hence when we study behavior in biology, we cannot a priori, arbitrarily exclude some life forms from our investigation. We must bring forward and test justifications and arguments which will identify analogies in the behavior of distinct species, but which will also point to behavioral differences between them. Recent scientific experiments contribute to this inquiry. In philosophy, the study and interpretation of plant behavior will lead us to rethink concepts such as memory and consciousness, but also to reflect on the nature of the mind. Such a task will require subtle arbitration and a detailed examination of classical oppositions rather than catchphrases. Inquiring into how we use the notion of plant behavior will reveal a strained divide between reckless anthropomorphism and confirmed scientific reductionism – philosophy will allow us to examine

it properly. Yet, to think beyond the anthropomorphism-reductionism divide turns out to be complex. This is why this work acknowledges that anthropomorphism can sometimes be of use to draw the attention to neglected topics – but that, doing so, it may cause distortions, for instance when it grants plants human emotions and attitudes. By contrast, reductionism studies phenomena solely through its observable causes, thus minimizing the risk of anthropomorphism – but, doing so, it often avoids the epistemological, ethical and metaphysical problems that lie at the foundation of biology (Canguilhem, 2008; Myers, 2015).

Let us first investigate the nature of behavior. What do philosophers and biologists mean by that? And what are the specificities of plant behavior? How could we distinguish it from the activities of a stone or from those of an animal?

These questions lead us to look deeper into problems where science and philosophy go hand in hand. They also require us to examine the often-hidden historical context in which these problems arose. Indeed, at least since the development of modern botany, philosophers and naturalists have been concerned with the nature of movements in plants and with the possibility of sensibility, and even soul, in plants.

Such interrogations are actually the core of the recent controversies on communication, memory, learning, consciousness, cognition and mind[1] in plants. We must reassess these notions, starting from a critical, better-informed standpoint. The present study will then more specifically put forward an original biosemiotic view of plant behavior. Finally, what does the recent excitement about these issues tell us? And

[1] Cognition and mind are sometimes used like synonyms. The way we use them here roughly echoes the difference between "mind" as a term used to refer to some abstract or metaphysical thing more relevant to philosophy, and "cognition" as a term scientists generally favor to describe the mechanisms of information processing.

to what epistemological and ethical developments can they lead us?

General Considerations on Behavior

Behavior is often intuitively approached from a human perspective. Yet, one can distinguish three distinct levels of behavior: a psychic level (which, in our intellectual tradition, is a priori taken to be typically human, even though scientists now recognize it in vertebrates and some cephalopods), a biological level (which concerns physiology) and a physical level (which concerns stones and particles). The level of behavior most commonly used to understand plants as organisms is the biological level. This section aims to distinguish the behavior of a plant from the behavior of a molecule or a human being, with the controversies about the differences and analogies between plants and animals as a backdrop. A clarification may first be in order: despite its pedagogical usefulness, the tripartition of behavior sketched here remains open to discussion.

Let us first distinguish the behavior of living beings from the behavior of non-living things. A preliminary, very general definition circumscribes biological behavior (displayed by animals, plants and other living beings) as an active response of the organism:

> Here we use the term behavior to mean what a plant or animal does, in the course of an individual's lifetime, in response to some event or change in its environment (Silvertown and Gordon, 1989, p. 350).

How is the motion of a stone following a shock different from a similar motion performed by a living being? Stones and other physical entities can only undergo events – it cannot respond to them. The nature of living activity, *i.e.* a living thing's response, must be specified. All organisms, including plants and unicellular organisms, respond to their environment according to internal processes. Since they depend on

such internal mechanisms, the response is slightly delayed, unlike a stone's reaction to a shock, which is immediate. Internal processes are thus causes of behavioral responses (Dretske, 1988, p. 26–27).

Like stones, organisms can also undergo events. But, when they are sensible to them, when they process internally the information they obtain from stimulation and when they react to it in a delayed and observable manner, they display behavior. Thus, for there to be behavior, a reaction cannot follow uniquely from the stimulation without any mediation. But such a theoretical distinction is sometimes hazy when it comes to practice. Take this example. If I cut myself on a shard of glass and start bleeding, cutting myself is a behavior (since I wanted to pick up the shard of glass). By contrast, bleeding is not a behavior (since the wound is incurred without activity on my part). On another note, my organism's reaction to the wound and the coagulation of the blood following the wound does display a behavior. Furthermore, the activity or passivity of a behavior depends in part on one's perspective (Dretske, 1988). Take the following account of a miscellaneous news item: "Betsy was run over by a bus." Phrased in this way, it describes how someone underwent an event, and thus does not describe behavior. But if the account goes like this: "Carelessly attempting to cross the road outside designated crosswalks, Betsy was run over by a bus.", the tragic incident becomes the observable consequence of a behavior. Examples like this one show that behavior is relative: it always depends on an observer's point of view, on the context, as well as on the causal chain one takes into account. This aspect of behavior is crucial when we want to understand all the problems and controversies surrounding plant behavior. For what counts as behavior – even biological behavior – depends on an interpretation made within a specific theoretical framework.

Following the work of behaviorists and Tinbergen (1963), the methodology for the study and interpretation of biological behavior has primarily favored causes. It explains behavior