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A Step toward Understanding Information Processing in Plants. Explaining the Complexity of Life Thanks to Plants' Physiology

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Abstract

This article argues that the complexity of life can be largely understood and explained by a somewhat "minor" field in biology, namely botany. The complexity of the plant's cell as well as the modularity of the organization of plants serves as conditions to the explanation of life on earth. Plants process information in a quite different way than animals, and the plant's anatomy and physiology are to be taken as the rationale for life on Earth.

Keywords Process information; Modularity; Complexity science; The weave of life

Introduction

The argument has been brought that the complexity of life consists in the way living beings process information [1]. More exactly, for living beings, processing information is a matter of death or life [2]. If so, then it becomes indispensable to understand such information processing.

To be sure, living beings do not process information in the way a Turing Machine (TM) does. The kind of processing of information by living beings has been named biological hyper computation [3].

This short essay aims at explaining how the processing of information occurs among the plants. Now, plants in particular are a domain that has not been entirely understood by complexologists, computer scientists or even biologists. Botany seems to remain a "minor" chapter in the broad framework of biology. Here, I shall claim that understanding the complexity of life in plants can provide a solid ground for further understanding the weave of life. My strategy here consists in bringing out directly the arguments in the text and leaving the support of some of these arguments for the references mentioned at the end.

Processing Information

The complexity of a living system can be seen to stem out of two different sources, thus: either from the genetic point of view or also from the standpoint of the cell. I shall leave aside here the first issue and focus on the second one. There has been, though, a traditional bias vis-à-vis the complexity of the cell, namely traditionally the studies on the plant cell have been superseded by the ones on the animal cell. Whence, the bias pertains also the development of the cell on to the organism. Two cases can be readily brought out as examples: on the one hand B McClintock (1983 Nobel Prize), regarding his contributions to the variations of the genome over the lifetime of a human being. On the other hand, A Fire and CC Mello (2006 Nobel Prize winners) for their work on animal cell, a research that was originally carried out on the plant cell by R Jorgensen. The subject here pertains the discovery of the RNA of the cell. Discussing the story and moral of these two cases remains the subject for another paper.

It goes without saying that the plant cell is more complex than the animal – regarding both the anatomy and the physiology. The chloroplast fulfills a most fundamental role for the story of life on Earth. Stomatal arrays do play a fundamental to, even though to-date they have been poorly understood [4]. Without it life could simply not be possible, as we know it. Moreover, the biological volatile organic compounds (BVOCs) play a most fundamental role in controlling the atmosphere and making thus life possible on earth [5]. The stomata play here a most fundamental role, and a primordial importance of plants for life on earth [4,6].

To be sure, thanks to its modular organization, plants process information throughout distributed, collective, emergent computation [7] throughout the various plants' centers that allow for a far more solid, secure and robust information processing. In contrast with animals, humans included, plants do not have a central processor unit. They process information in parallel and distributed processes. Even some quantum effects have been reported herein [1,8]

Now, from a computational point of view, life sustains herself by processing information. Indeed, the logics of life concerns in a twofold phenomenon, namely both processing information from the environment and at the same time creating new information as the organisms evolve and adapt –in and with the environment.

In contrast with animals – human beings included - the information processing in plants is not localized, but distributed. In quantum terms, it is a non-local phenomenon, a concept that has not been truly incorporated in biology; moreover, as it has been pointed out, plants process information in a quantum way: biological quantum computation [9]. This sends us back to what Einstein called the "spooky action" at a distance. Plants, it appears, do process information non-locally thanks to the modularity of its organization.
The information processing in plants invites us to moving from causation to correlations, a most significant shift that implies a different take on information, data, and the very processing. Plants do process information without brains [10]. A plant is a colony that thinks in terms of correlations and, therefore, both needs and develops more than the five basic senses we know [11,12].

Organization and Environment

A plant is a modular organization, i.e., organism. This means, it is not an individual. The modular organization of the plant is closely related to its relationship with the environment and to the way in which it processes information harnessing from as many circumstances as possible. Moreover, the modular organization helps explain the resilient strength of plants.

The modularity of plants means that they are a colony, or as an author has named, "a swarm". Millions of root tips, a number of branches, plenty of leaves, for instance, are so organized that the plant does not a have a center that is determinant, but a network of structures and processes that interact among themselves and with the environment in non-local terms. As a consequence, plants relate to the environment in a manifold of ways not so much following the conditions and constraints that physics imposes upon the living being, but, furthermore, to create its own environment and harness from it. Chloroplast, stomata, and the BVOCs molecules fulfill a most fundamental role hereafter [13].

Two arguments can be brought to enhance the understanding of life in the midst of catastrophes and extreme circumstances. Cockroaches have been mentioned as the conspicuous argument when surviving extreme conditions, such as a nuclear bomb or explosion (Hiroshima and Nagasaki, or also Chernobyl), or earthquakes. Plants should be also be taken into consideration and mentioned evenly along with those insects. Plants have been shown to be most resilient in the history of the planet and of human civilization.

The behavior of plants can be seen as very complex, provided that we do see and understand the very slow pace of their life. Plants have traditionally been said as passive – which is absolutely false – which in reality sheds new lights on the importance of a quite different lifetime. Plants are slow, therefore territorial, and open up the window for an understanding of life in terms of "longue durée". The dichotomy "nature-culture" that characterizes the Western civilization really concerns the tension between two quite different rhythms: the one of animals – speedy and quick – and the one of plants – slow, very slow.

And yet, it is the slow pace of plant's life that serves as ground for life on earth. Properly speaking, slow times-span and time-scale operate as the rationale for quick and speedy rhythms and processes. More radically said low entropy processes and structures stand out as the very foundation for life to be on this planet; this is something that has already been reckoned by thermodynamics, and specially non-equilibrium thermodynamics [14]. Plants serve as such low entropy systems that support and make possible high entropy systems and phenomena.

Adaptation and Learning

Plants have been highly successful in adapting to the environment, mainly thanks to the manipulation they make of other species, from plants to animals to humans. From predation to the production of fruits, for example, plants harness from natural conditions – the wind, for instance – from other plants, insects and relatively large mammals, to humans, to reproduce themselves in as many ways and in as many distances as possible. Such an adaptation makes up our planet as a green globe.

Whereas in mainstream science learning and adaptation have been taken as synonyms of parallel and interrelated processes, from the standpoint of complexity science, it is only the capacity of learning that entails, then, the capacity of adaptation. In other words, learning stands out as the condition for adaptation. A species that is not capable of learning will certainly be at odds in adapting – to new circumstances. Well, plants, I claim, learn far better than animals for one single reason: in nature learning implies the rhythm of long time scales. Humans seem to have forgotten this. If geology teaches us to think above the scale of a million years, plants teach as to think is terms of a truly "longue durée" vis-à-vis the short sighted view of time of animals and humans.

According to the biology of plants, learning can be seen as a slower process that allows for adaptation, which is characterized by the need to speed up and suit to variant conditions, unpredictable by definition. In other words, learning needs time, while adaptation demands speedy decisions and actions. To be sure, we can infer a better capacity for plants to learn, which explains their fundamental role in the weave of life [15].

Without being exhaustive, Table 1 summarizes the complexity of a plant in general. The aim here consists in providing a general frame that sheds some light on the complexity of a plant. Such complexity, we claim serves as the rationale for the further complexity of life on earth. A particular feature is mentioned and then the meaning or translation of it in the framework of a complexity study.

BVOCs molecules	**Play a vital role in the formation and removal of atmospheric molecules**
Autotrophic	Self-sufficient
Slow	Long time scale
Modular organization	Lack of a skeleton, a self-organized system
A colony	A plant is a swarm, whence it has a swarm intelligence
Territorial	A plant knows, defends, or moves away from a convenient territory
Photoreceptors	Phytochromes, cryptochromes, and phototropins: capture of quality and quantity of light
Chloroplast	The biological foundation of life
Stomata	Regulation of gazes
Numerous senses	A plant has more than 15 senses, whence it's complexity. A plant communicates not in waves but in molecules
Harnessing form other species	Plants can be predators, passive resistance, or harness from insects to large animals to humans

Table 1: A general view of the particular complexity of a plant.

Table 1 presents on the left the biological structures or processes that are translated on the right in terms of complexity science concepts or terms. One singular immediate conclusion pops up, thus: the complexity of plants can be seen as a greater one vis-à-vis the complexity of animals – at least from the standpoint of cell and developmental biology.

Finale Con Coda

In sharp contrast with the situation in physics, in biology we still are in an Aristotelian-Ptolemaic period [12], for the anthropological or anthropocentric point of view or relevance still prevails largely, it appears. Plant's anatomy and physiology can certainly help improve such a circumstance. From a theoretical and logical standpoint, biology is not less than physics. A sound and safe advancement of knowledge depends on the evenness, so to speak between physics and biology. One author has brought up the argument that biology can and should be seen as the proper ground for science in general – at large [16], over against the prevailing view that focuses on physics. If true, such a claim should by no means be taken as a reductionist one. After all, as the case of plants shows us, it is the complexity of plants' anatomy and physiology that transforms physics into biology. BVOCs, stomata, and chloroplast are three central processes that for such complexification.

There is no doubt about it: plants do transform energy and matter into the information processes that make life possible. Chlorophyll is but the name for such transformation [17]. If so, a fresh shift on to the cell and development biology of plants can shed new lights on the complexity of life on earth.

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