Intelligent Trees

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Recent assumptions about the nature and physiology of plant species threaten to revolutionise our perspectives on the world of plants. But orthodoxy is not easy to change.

The Leska Trail in the Risnjak National Park in Northern Croatia is a peaceful path through the beech and fir forest. A number of very clear information panels in Croatian and English illustrate its characteristics. One of them tells the story of the life of a tree stump and says, among other things, that the root systems of trees that grow close together sometimes merge, a phenomenon that becomes more intense after a tree is felled. In this way, the remaining stump derives its nutrients from another tree to which it is connected through its roots. The cambium [a plant tissue inside the trunk] continues to grow.
Science has actually proven this peculiar, curious statement to be true more than once. On the surface, this simple «fact» appears to be rather innocuous, but in recent decades, a veritable war has been waged over how trees behave, whether they are passive or not, or the extent to which phenomena like the passage of nutrients or even «messages» to and from the components of a forest are voluntary. Consequently, this has brought a revolutionary change of perspective in the image we have of trees and their ecosystems, and the narrative associated with them.

A New Perspective
That plants today do not at all correspond to the image that most of us have had of them is well established. They are not immobile, isolated beings engaged only in the difficult but indispensable task of photosynthesis or reproduction and nothing else, with little or no contact with their surroundings. In fact, the first inkling that there was something more is certainly not new, and even came from the father of modern biology, Charles Darwin. Together with his son Francis, he applied his acumen to plant movement in the book *The Power of Movement in Plants* (1880), and wrote this revealing sentence: «It is hardly an exaggeration to say that the tip of the radicle thus endowed,

and having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements».[1] (Despite its source, this idea was soon forgotten and quite a few decades passed before someone put it forward again. From Darwin onwards, however, the complexity of the plant world and its relationships with other living beings was revealed, becoming more and more intricate and, according to some, not dissimilar to what happens in the life forms we know best, animals. An important first step was to discover the relationships with other living beings, which helped to make our image of the plant world more complex. A classic example is that of *mycorrhizae*, the network of fungal *mycelia*, slender filaments that envelop the roots of many plant species. Or, on an even deeper level, the symbiosis between plants and very special bacteria which «help» plants by fixing atmospheric nitrogen in exchange for nutrients. A current researcher, Éva Kondorosi, who was awarded the Balzan Prize for Chemical Ecology in 2018, has been studying precisely this aspect of plant life for years, and she examines this very particular aspect in depth: «The presence of bacteria of the genus *Rhizobium* in the roots of plants (like leguminous plants) is an example of a non-compulsory symbiosis, because only when plants have little nitrogen do they choose to start their collaboration with bacteria, allowing them to penetrate into the roots and begin the exchange». The whole thing is therefore not a simple automatic exchange of favours. Kondorosi continues: «Between plants and bacteria there is also a continuous traffic of information, signals and other significant molecules».[2] We take our cue from these sentences (taken from a 2018 interview) to understand what the objects of contention are.

Bold Assumptions?

Throughout the world of communication and science, the use of words is important. Are terms such as *choice* and *decision* just metaphors, or are some botanists truly convinced that if every plant were to find itself

[1] Charles Darwin and Francis Darwin, *The Power of Movement in Plants*. London: John Murray, 1880, p. 573.

[2] Éva Kondorosi, Marco Ferrari, *Relazioni nascoste*, https://youtu.be/0_hl3sSm-gk?si=bO58WJ0mjfB1a6wH.

at a crossroads, would it knowingly choose the best path for that moment in time and in those circumstances? Moreover, the question of plants as agents capable of choice is thus THE scientific dilemma that scholars have been confronted with in recent years.
After Darwin's vague suggestion, there have been episodic mentions of plants as intelligent agents, for example, in a provocative book of 1973 entitled *The Secret Life of Plants* by Peter Tompkins and Christopher Bird. The subtitle reads: *A fascinating account of the physical, emotional, and spiritual relations between plants and man*. Many of the «facts» presented in the book have been disproved, and it has provoked many negative reactions in the world of science, but the authors had thrown a stone in the pond, creating a ripple effect on the entire community. An important scientific turning point is considered to be an article of 2006 in which the authors, including the Italian Stefano Mancuso, proposed the birth of a new field of research, plant neurobiology. This time, the suggestion started from a series of observations and experiments that revealed how, first and foremost, plants also have a great ability to perceive environmental variations, which in many cases is superior to that of animals. Plants are obviously able to intercept the light and shadow cast by other plants, and «feel» gravity and humidity or the percentage of CO2 in the air. But they can also pick up subtle differences in the nutrients and molecules in the soil and in those emitted by other plants, as well as the gases of the bacteria that colonise the soil.

From Data to Intelligence

In the hypotheses of plant neurobiologists, the next step departed from perception to arrive at processing. Plants, it was said, were capable of integrating and developing all these signals, and use the result of this «manipulation» in everyday life to avoid or fight enemies, to protect themselves in difficult situations (drought, excessive salinity, etc.), or even to help their descendants. Each of these situations, say those who support these hypotheses, gives the plant two or more choices, based (precisely) on the myriad of data collected over its lifetime. As was pointed out more than a decade ago by the British botanist Anthony Trewavas, if a plant has to defend itself against stress from the environment and herbivores, it must face a choice as to which strategy is best to adopt. It must, for example, make a general decision on where and how to allocate its limited energy, metabolic, and biochemical resources. Meanwhile, other data collected speak of memory and

habituation (a *Mimosa pudica* no longer reacts by closing its leaves – as it usually does – after a continued stimulus has proved to be harmless), and the ability to transmit possible danger to other plants through small molecules emitted when an herbivore attacks the leaves. It has been noted how attacks by a caterpillar induce the release of substances that have the (apparent) dual function of blocking the metabolism of the herbivore and attracting parasites and parasitoids to the caterpillar itself. Numerous complex chemical signals are also exchanged in a continuous dialogue between the growing roots and the microflora in the soil, as well as with the fungi and bacteria colonising the roots themselves, as explained by Éva Kondorosi. As a result of these and other observations and experiments, say the «heretic» botanists, one cannot avoid talking about *plant intelligence*, and thus also plant neurobiology. In short, as stated in a scientific article published in the *Journal of Ethnobiology and Ethnomedicine* in 2022: «Evidence suggests that plants can behave intelligently by exhibiting the ability to learn, make associations between environmental cues, engage in complex decisions about resource acquisition, memorize and adapt in flexible ways».[3] However, just as happens in animals, the management and processing of signals also presupposes, according to official science, the presence of structures capable of performing this function. Again, following Darwin's suggestion, some have proposed the root tips as a kind of «plant brain». The hypothesis of a «choosing brain» and thus of what could be called *plant agency* would thus explain many plant behaviours in a simpler way. So far, what the «heretics» have to say has been covered.

Opposing Views

The response from the academic world was puzzled and sometimes hostile (scientifically). Although the evidence in favour of plant neurobiology (thinking of plants as beings capable of adopting what we might call «non-automatic» solutions) has gradually accumulated, not all of it was considered convincing, so much so that it gave rise to polemical clashes, sharp interventions and statements for or against plant neurobiology. The perplexities revolved around two aspects: the

[3] Khattar, J., Calvo, P., Vandebroek, I. *et al.* "Understanding interdisciplinary perspectives of plant intelligence: Is it a matter of science, language, or subjectivity?" *J Ethnobiology Ethnomedicine* **18**, 41 (2022). https://doi.org/10.1186/s13002-022-00539-3

various behaviours can only be explained by genetic dynamics, fixed modules of action based on genetically determined, or «automatic» structures. Unlike animals, plants have a vast, continuous range of forms and thus behaviours expressed by the genome. This leads to a much broader spectrum of possible responses to stress and environmental conditions than that of animals. It is argued that the modular nature of the former thus permits most adaptations that could alter not only metabolic and biochemical, but above all behavioural, aspects. The release of substances to attract one's enemies would not be a choice, but a much more basic chemical reaction. And the apparent intricacy of plant behaviour is precisely due to the myriad of data collected by plants and biochemical pathways that intertwine in green cells and leaves. Therefore, choosing whether to send a signal or not does not depend on actual reasoning, but on automatic mechanisms born of millions of years of evolution. Plants, the botanists explain, cannot flee from danger like animals, but they react to threats biochemically. However, we ourselves, as animals, find it difficult to understand the reactions of plants, which are infinitely more complex, and so we ascribe them to reasoning and intelligence. According to Ivan Scotti, director of research at the National Research Institute for Agriculture, Food, and the Environment (INRAE) in Avignon, even the so-called «signals» are simply automatic reactions of plants, and there is no intention of, for example, attracting their enemies. «Even an unconscious person sends out the "help me" signal, but certainly not voluntarily». Added to this is that thinking of roots as a data processing centre brings with it other problems, such as the speed of the signal between cells and the connections, which, if there are any, are not very obvious.

The director of the botanical garden of the University of Pisa, Lorenzo Peruzzi, sums up the position of the greater part of the botanical community. He starts with a firm position: «If being intelligent means relating more than effectively to the environment, then plants are intelligent, indeed very intelligent! If having a nervous system means reacting to stimuli (vibrations, heat, light wavelengths, etc.) then plants have a nervous system and therefore a plant neurobiology makes sense!». But he continues: «It is clear, however, that the whole thing is played out on a misunderstanding of the semantics and definition of intelligence, not to mention on a cunning zoomorphisation of plants. Because while it is true that plants certainly interact in many ways with

their environment,» Peruzzi concludes «they have neither psychic and mental faculties nor auditory, visual or other apparatuses».

Far from Agreement

But the proponents of the «plant intelligence» hypothesis offer a rebuttal that it is also a question of perspective. Overturning Peruzzi's perspective, they accuse those who are unconvinced of reasoning from a point of view that could be defined as *zoocentric*. The brain and intelligence thus considered, they say, are organs and capacities that belong to animals, even quite complex ones, and consequently they cannot be present in plants. But what if these structures and properties are completely different in plants? If we judged a fish by its ability to climb trees, for example, wouldn't that be a mistake? The important thing would be the function, not the structure, which can also be, like so many characteristics of the plant world, completely alien, profoundly different, that is, from those we know in animals. Peruzzi is, paradoxically, in agreement, but his perspective is the opposite, and he reverses the accusation. Those who support the intelligence of plants treat them as very slow animals, with a finger also pointed at communication of the topic: «To lapse into these inappropriate comparisons in order to interest the general public in plants is, in the long run, only counterproductive to the cause. Plants are worthy of interest, study, and protection precisely because they are totally different organisms from us, and not because they "feel", "see" or "think".»

The debate on plant intelligence has also attracted the attention of other disciplines seemingly far removed from strict biology, such as philosophy. According to Vincenzo Crupi, professor of logic and philosophy of science at the University of Turin: «At first I was intrigued that one could analyse the behaviour of plants by postulating that it was analogous to that of other biological entities (such as animals)». The problem is, according to the philosopher, a different one: «Many characteristics are in humans (and in many animals) all intertwined: from consciousness to sentience to awareness to intelligence. But this intertwining is contingent, and these faculties could also be entirely independent». Crupi concludes: «If when we say intelligence we simply think of our experience and link it to the "faculties" of plants, we are making a big mistake».

We have reached a point where the two fields have not yet found a common point of discussion, or «negotiating table» at which to

exchange hypotheses that are in some way commensurable. It may be that an intermediate position will be found in the future (after all, as mentioned at the beginning of this article, our perspective on plants and the forest has changed profoundly over the past few years), but for now the two visions of the plant world are still quite far apart.