THE ARISTOTELIAN CONCEPT OF *PSYCHÉ TROPHICA* AND CONTEMPORARY ATTEMPTS TO CONCEPTUALIZE THE FUNCTIONING OF PLANTS HOLISTICALLY

Dariusz A. SZKUTNIK[1]
Rafał KUPCZAK[2]

ABSTRACT: *The first attempts to scientifically systematize plants and animals come from the ancient times. Observing the external features of organisms Aristotle created the first animal systematics. His student, Theophrastus, stated the basic differences between plant and animal worlds. The Stagirite, on the basis of scientific observation and philosophical generalizations, created the concept of soul, whose vegetative power was equipped with the eternal ability to organisms' reproduction and nutrition. The uptake of food by plants as well as their high reproductive capability were perceived by the researcher as phenomena in which particular dynamic processes occur, such as metabolism, the process of recovery, etc. These astounding phenomena, discovered by Aristotle as early as in antiquity, are the base for the development of contemporary, bio-botanical research. They also inspire contemporary researchers to intensify their philosophical and scientific speculations. This article is an attempt to present more holistic view of complex processes and behavior found in plants, which are more and more often presented as part of intelligent attitudes understood as general (unconscious) behavior adapting plants to variable external environment.*

KEYWORDS*: Aristotle, vegetative soul, holism, plant intelligence*

Contents

Introduction

It is not easy to clearly separate empirical claims from those which are the result of theoretical reflection on empirical data in Aristotle's biological writings (4th Century B.C.). In his texts Aristotle postulated the existence of a so-called "vegetative soul" psyche trofica (*De Anima*, I, 411 b 15 – 411 b 30). This indivisible

[1] Jagiellonian University in Krakow and University of Warsaw, POLAND.
[2] *University of Silesia in Katowice and Jesuit University Ignatianum in Krakow, POLAND.*

and unquantitative factor was to be able to shape the matter (consisting of four elements: air, water, fire and earth) into perfect form corresponding to reproductive form of an organism.

According to Aristotle all living organisms, that is plants, animals and humans had a vegetative soul. It can be assumed that in the case of plants it was something independent. Vegetative soul is the most basic principle of life and is in control of the most elementary phenomena of life: birthing, eating and growing (*De Anima*, II, 414a 14 – 414b 10). It should be emphasized here that a vegetative soul – as Aristotle used to formulate – had nothing to do with consciousness.

Until recently, the knowledge about plant was mostly based on descriptive research with little use of physiological and biochemical experiments. Nowadays, science was significantly enriched by empirical data concerning elementary phenomena of plant life. The ability of using new techniques enables to conduct research using non-invasive methods. At the end of 20th century the attempts to explain the mechanisms of regulation and coordination of life processes on specific levels of organization: genetic, molecular and organismic, being the attempt to perceive plant functioning from holistic perspective were made the centre of attention (see e.g. Taiz & Zeiger 1998, Kopcewicz & Lewak 2002, Trivedi 2006).

The aim of this article is to present some general theoretical assumptions concerning the Aristotelian concept of vegetative soul in relation to more recent attempts to recognizing life processes of plant as holistic.

1. Aspects of the Aristotelian concept of vegetative soul

Aristotle was conducting pioneering research, focusing on discovering the specificity of animals and plants. When making the attempts to explain these specificities the Stagirite used the theory of souls, which was attributed by him to many hierarchically systematized functions. And so, the researcher distinguished vegetative soul, attributed to plants which were to be responsible for growth and nutrition. The aspect of vegetative soul will be the most interesting for us at this point, because it is directly connected with the topic of this article, thus providing a reference point to more modern reflections on the issue which is the essence of plants' functioning. Let us emphasize that Aristotle, beside vegetative soul, also distinguished the aspect of a sensitive souls (animals) and a rational soul given exclusively to humans. It should be kept in mind that this specific rational element associated with human contained all three substantial layers within itself: rational soul, sensitive soul and vegetative soul (*De Anima*, II, 414b II – 415a 7).

Although the Aristotelian concept of vegetative soul generally referred to plants and used to be an attempt to explain their development, now, for many researchers is only a historical value. For nowadays, in botany far broader and more precise basis of empirical data is used to explain the courses of life processes, which is possible thanks to a tremendous progress of civilization as a result of which many new research techniques were created (confocal microscopy, controlling the mutagenesis, genetic manipulations, etc.). Nowadays we can examine plants at all levels of

biological organization, both molecular and cellular, as well as at the level of whole organs, or finally by putting the plant as a complex, integral whole.

First, let's see which life functions, for plants, were to serve as the aspect of vegetative soul in Aristotle's bio-philosophy:

> For plants do not grow upwards without growing downwards; they grow in both directions equally, in fact in all directions, as many as are constantly nourished and therefore continue to live, so long as they are capable of absorbing nutriment. This form of live can be separated from the others, though in mortal creatures the other cannot be separated from it. In the case of plants the fact is manifest; for they have no other faculty of soul at all (*De Anima*, II, 413 a 23 – 413 b 21).

From the passage above it can be assumed that Aristotle clearly noticed, that plants perform complex adaptive movements. They also have a specific capacity of foraging and reproducing, which is associated with living creatures. In this perspective, the researcher wondered how a plant seed when thrown on a fertile soil builds its roots and sprouts of stalks with time, how its builds leaves, which contain mechanisms of light energy absorption. Ancient researcher was clearly amazed by the fact in which plant's roots and sprouts are heading towards the sources of water by themselves and how do plants selectively absorb mineral salts from the soil.

Although Aristotle, intuitively, correctly recognized certain dynamic phenomena occurring, inter alia, inside plants, he was also looking for a proper base for explaining these processes (ability to grow, creating and reproducing specific structures and adapting to changes in the environment). Then, the level of science did not make it possible to examine the internal construction of plant's microstructure and all the more complicated precise communicative processes between the individual cells inside plants and animals.

> On the surface or inside the cells there are specific receptors of signal substances. The main condition of receiving information is to find a proper signal receptor and to form a complex molecule signaling receptor. They process those received signals to the "language understandable for the cell" which enables the organism to react. Transferring signals on the next molecules or signal ions, called the second messengers, causes their strengthening. In the case of light, there is a specific photoreceptor specialized in the reception of light of a specific wavelength and stimulation or inhibition of regulated processes, such as flowering growth, photosynthesis and their interaction (Starck 2011, p.11).

2. Philosophical reflections on the grounds of empirical research of plants' behavior

It is assumed that about 99% of the biomass of all living organisms are green plants (Rodin et al.1975). Still, for centuries plants were considered to be passive creatures. Their development was considered to be predetermined, only with

temporary interruptions, which were the answer for strong, external stimuli. Because plants are obviously lacking visible movement dynamics, for many people they seem to be devoid of any traces of behavior. Here there is a transparent conflict between the generally maintained picture of plants and their success among living organisms. Now we are able to show a significant complexity of plant behavior. Modern revolution in plants' research changes the picture of plants' passiveness and exchanges it for an exciting dynamics (see e.g. Trewavas 1999, 2002, 2003, 2004, 2005a, 2005b, Karpiński & Szechyńska-Hebda 2010, Starck 2011, Chamovitz 2012).

2.1. Genetic and molecular level

As noted by Trewavas (2002) a typical plant contains a web of millions of cell organized into tens of tissues and many meristems (tissues used for creation), which affect each other. There is no obvious, centralized tissue control and centralized control of behavior created as the attribute of all integrated cells and systems of tissues. Internally, plants' cells and tissues communicate using proteins, nucleic acids, many hormones, signals that are: mineral, chemical, hydraulic, mechanical, oxidative, electric, peptides, various lipids, sugars, fragments of walls and other complex hydrocarbons. The way in which plants' cells accumulate this great amount of information is not clear. Even anatomically homogeneous cells appear to give extremely various answers to a single signal. The huge reservoir of individual cells' behavior can be coordinated in production of various organism's behavior (see Starck 2011).

2.2. Organismic level

The problem of plant life is in any way simplified at the level of whole organism. Outside, growing sprouts sense their closest competing "neighbors", foreseeing consequences of their action and if necessary, they take evasive actions. The shape, height and direction of the stalk change in order to obtain the optimum position in relation to sunlight; position of leaves are adjusted to optimize the reception of light. When competitive neighbors approach the obtuse leaf, the whole plant backs away by diversification in supporting the growth of roots that support stems (Trewavas 2002, 2005a, 2005b, Starck 2011). Rootstock, which is a transformed stem growing underground (or underwater for aquatic plants) is able to choose its ingrowth and foraging habitat in places, which are free from competitors and/or are rich in resources.

It has been observed that many buds change their purpose and transform into leaves, not rhizomes, but the ability to search is maintained in other rhizomes of the same plant, which choose to develop in poorer soils where they are thinning, growing faster and spreading out. Roots are able to trace the humidity and concentration of minerals in the soil spatially and correspond rapidly by growing when they find rich resources, but take evasive oriented actions, when they approach competitors' roots (see Trewavas 2002, Baluska *et al.* 2004, Baluska *et al.* 2005, Starck 2011).

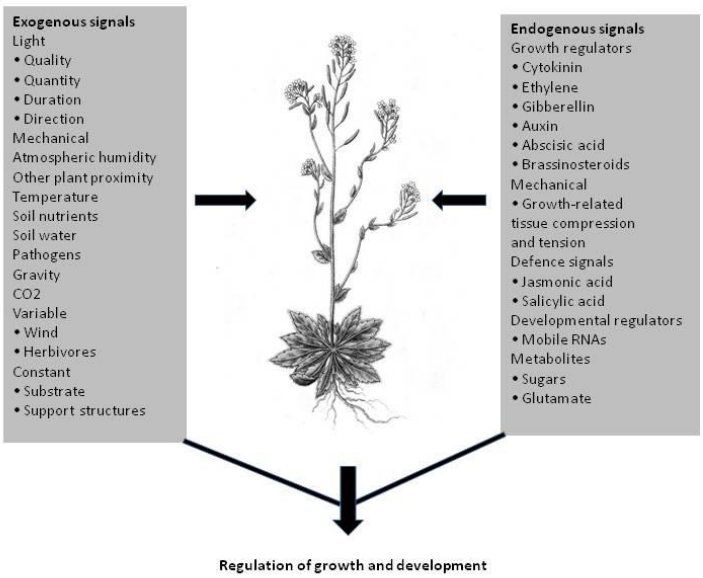
2.3. Holistic approach of plants' functioning

Plants' functioning refers to receiving signals from both external and internal environment and then to their acceptance or rejection. The whole picture of plants' functioning is obtained only after integrating the information retrieved from the knowledge of the specifics of processes on all the levels of organization, that is molecular, genetic and organismic (see Starck 2011, p.10). From this perspective, words formulated by Aristotle get more importance: "the whole is more than the sum of its parts". (*Metaphysica* 10f – 1045a)

The fundamental meaning of processes inside plants is to exchange information. It takes place at all level of organization from genes' expression, the course of biochemical reaction to cooperation of chloroplasts, mitochondria and other organelles as well as respiration and photosynthesis processes. The coordination of coexisting, interdependent processes –sometimes contradictory – such as an increase in water intake during drought, or increase in transpiration's intensity during plant's sinking, growth or rest, creation of new cells or programming their death depend on the content of the information. Coordination between processes is also essential between, for instance, photosynthesis and respiration, especially in the aspect of circadian rhythm (see picture 1). As noted by Starck:

> After a period of study in which molecular biology was dominating, now the problems of analyzing the whole organism's functioning, especially the interaction between processes and organs are in the centre of interest. (Starck 2011, p.21)

Holism is seen at the genetic and molecular level as clearly as at higher available to the naked eye level of dynamics and plants' structure.



Picture 1. Plants (for instance the model plant – thale cress Arabidopsis thaliana) record most of external and internal factors affecting their environment and having an impact on their growth and development (according to Gilroy and Trawavas 2001, p. 308 modified)

3. Modern researchers on the term of plant intelligence

The data described above, which come from observation and Aristotelian philosophical generalizations and modern data focusing around plants' life functioning force us to reflect on this important issue; they even provoke some biologists and philosophers to pose some fundamental questions directly.

> If a plant responds to stimuli quickly and efficiently what is the mechanism that enables it to make generally "good decisions" as far as the reaction to received signals is concerned? Does it possess the intelligence? Is it able to remember the content of received information and to predict changes in the conditions of the environment? (Starck 2011, p.19)

Therefore, let us look at more detailed reports regarding this serious matter. As indicated by Chmurzyński (2011) "intelligence" is figuratively described as ratiomorphic functioning of living organisms belonging not only to *Zoa* but even to plants, as in the titles of Maurice Maeterlinck's books *The Intelligence of Flowers*, J.H. Taylor's *The Sagacity & Morality of plants. A sketch of the Life and Conduct of the Vegetable Kingdom* (London 1884) and Adolf Wagner's *Die Vernunft der Pflanze* (Dresden 1925). This quite episodic, in a historic sense, relation between plants and the concept of intelligence seems to change before our eyes.

For a long time plants were regarded as living organisms with a limited ability to move and to make responses which properly formed part of limited ability to receive stimuli. As noticed by Stahlberg (2006) the research was focused mainly on plants which distinguish themselves by their mobility, such as: *Mimosa pudica* (also called the sensitive plant), *Drosera* (*sundews*), *Dionea muscipula* (*flytraps*). It was forgotten that local movement is only one type of "change", the weakest one. Speaking of behavior, other types of changes should be considered, their regularity, conditions and causes.

Intelligent behavior, even in humans, is an aspect of a complex adaptive behavior, which provides people with the ability to solve problems. Trewavas (1999, 2002, 2003, 2004, 2005a, 2005b, 2007) in his works tried to assess if plants have the ability to solve problems and because of that, can they be classified as intelligent organisms. Trawavas notes that despite many publications devoted to this topic, there is no generally accepted definition of intelligence. As a rule, dictionaries that define intelligence describe this phenomenon from anthropocentric perspective claiming that only humans are intelligent (Trewavas 2005a, 2005b). The additional controversy was aroused by – in already heated discussion on plant intelligence – the issue of constituting in 2005 a new field of science: "plant neurobiology", which quickly gained many supporters.

> Green plants are treated as intelligent organisms by neurobiologists, equipped with memory allowing them to learn and use stored facts in the realization of "life strategy" (Starck 2011, p.19).

Many scientists (e.g. Firn 2004, Alpi et al. 2007) expressed their critical approach towards the newly-constituted field of research and the promotion of – as they say – provocative ideas in sciences and plants. They considered claims suggesting that plants have nerves, synapsis or anything analogous to the brain placed somewhere in the roots to be invalid. They were also critical towards defining plants as intelligent. Firn (2004) asks why do we need a new term to define certain life processes of plants. According to Firn it is unnecessary and does not bring anything important, why using the term "intelligence" when you can describe it as "adaptive reaction of plants". The term "intelligence" may actually obscure our proper understanding of plant organisms' life processes.

Despite some criticism, it should be clearly mentioned, that the introduction of the term "intelligence" to the world of botany directed the attention of researchers to more holistic perception of phenomena linked with plant functioning. As we can read in a brochure from International Laboratory for Plant Neurobiology[3] numerous, research has proven that plants have a very well organized sensing system, which allows them to explore efficiently the environment and to react rapidly to potential dangerous circumstances. Below and above ground, plants are aware of the space surrounding them. Such responsiveness is, indeed, necessary to provide the appropriate actions in response to the environmental stimuli. Plants have memory, are able to learn, to solve problems and to make decisions. It is assumed that all the behaviors observed in plants, which look very much like learning, memory, decision-making, and intelligence observed in animals, deserve to be called by those same terms.

Fundamental questions relating to the organization of plant life concern the method of receiving signals both from external and internal environment and then their acceptance or rejection. The research that is ongoing nowadays, despite some major disagreements, illustrate the noticeable progress in the knowledge of plant biology. The term "plant intelligence" seems to be firmly established in the minds of scientists, but at the same time it still remains under constant observation of its critics (Brenner *et al*. 2006, 2007).

Conclusion

Comparing the ancient Aristotelian research to those in the field of modern biology (mainly botany) on the nature of the problem, it can be noticed to there are some similarities when it comes to the way of asking questions and differences in the proposed answers. Characterizing the category of the Aristotle's vegetative soul and taking advantage of modern conceptual apparatus, it should be indicated that it was responsible for the dynamic processes of morphogenesis, cytogenesis, organogenesis, embryogenesis and metabolism, constantly exchanging all structural elements of a living body. This broadly defined structure-making dynamics determines the formation of a complete set of anatomical organs allowing, for instance, to acquire food, to observe the surroundings etc. The very creation of monitoring structures,

[3] http://www.linv.org/wp-content/uploads/2014/10/brochure_linv.pdf (10.03.2015)

sensory organs, indicates the necessity for orienting and manipulating the structures. As an attempt to show, plants have the ability to adapt, regenerate and orient in a surrounding. It should, however, be remembered that before the possibility of orientation together with a selective manipulation of elements of the body or surrounding is created, first, the organs allowing to orient and manipulate have to be formed.

Finally, it should be indicated that there are some fundamental distortions in perceiving the concept of a vegetative soul. Some began to not notice the fact that Aristotle explained the vast majority of biological processes by a factor, however intangible, but also devoid of consciousness. Interpreters of philosophical and scientific views of the Stagirite often attributed some "psychological abilities" of conscious behavior manifested in the field of natural life to the concept of soul, which led to a fateful theoretical consequences and total distortion of the concept of vegetative soul, which was then dismissed as a figment of pure speculation.

Nowadays, the so-called "intelligent plant behavior" is not perceived as any kind of consciousness and certainly is not associated with the type of substantial awareness. Trewavas (2002), for instance, assumes that plants, as intelligent organisms, "manage" their organisms without having any mind – "mindless mastery" theory. Here there is some similarity to the Aristotelian concept of vegetative soul.

In the authors' opinion, holistic approach towards plant life enables to maintain some still relevant Aristotle's intuitions and at the same time, to cover the progressive changes in the assessment of dynamic processes taking place in plants, and exhibited by plans as well. Although, from the ancient times, the question about the cause has changed fundamentally, still the sense that may explain individual behavior of plants is being sought.

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