Plant neurobiology: from stimulus perception to adaptive behavior of plants, via integrated chemical and electrical signaling.

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Editor's Corner

Plant neurobiology

From stimulus perception to adaptive behavior of plants, via integrated chemical and electrical signaling

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Motto:
"Most of us usually think of plants more as objects than as organisms."

This sentence from the stimulating and visionary review article by Jack C. Schultz entitled *Shared Signals and the Potential for Phylogenetic Espionage Between Plants and Animals*[1] is still very relevant. Although the sensory basis of plants, integrated signaling in plants, and the resulting adaptive behavior in plants, is accepted as legitimate areas for study in the plant sciences, these facts have not resulted in a general change of attitude towards plants, as evidenced by the recent letter signed by 36 plant scientists arguing that plant neurobiology inititative is not based on solid scientific grounds.[2] Our responses addressed this criticism[3-5] and made it clear that we do not take for granted animal brains and synapses in any dogmatic sense, but rather use terms such as 'brain-like plant command centre' and 'plant synapse' in plant-specific senses, in the context of plants and their organs solving their own plant-specific problems. It is quite obvious that plants are extremely sensitive and continually scan not any fewer environmental parameters than do animals and humans.[5-9] Moreover, it is also very obvious that plants communicate obtained information not only between the cells within the plant body but also, on an ecological scale, from plant-to-plant. In this latter context, they make use of a battery of volatile biomolecules, many of which are still not well characterized.[1,10] Plants also communicate with, and effectively manipulate, other organisms such as bacteria, fungi, insects, and animals.[9] Importantly, the intraorganismal communication is based on both chemical signals, such as auxin, exchanged between plant cells at F-actin and myosin-enriched cell-cell adhesion domains which we term plant synapses,[11] as well as electric signals which fullfil all the criteria that characterise action potentials.[12] The most active electric activity has been reported in the root apex zone[13] which shows also the most active polar auxin transport from cell-to-cell in vivo.[14,15] This so-called transition zone[16] shows numerous characteristics which indicate that it might act as a plant-specific, 'brain-like' command centre[17] which integrates and possibly memorizes numerous sensory experiences.[17,18] Because this specific root-apical zone initiates root tropisms,[17,18] it can be speculated that it also integrates the motor-like activity of growing root apices by which roots navigate through their complex environment.[19]

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Recently, issue 6 of *Plant Cell & Environment* focused on the emerging topic of the plant behavior.[19-24] It is nice to see that our plant neurobiology initiative, supported by *Plant Signaling & Behavior*, as well as by the plant neurobiology society, has contributed to the current rehabilitation of the word 'behavior' in the plant sciences.

Five years after its inaugural meeting, the international symposium on the Plant Neurobiology is returning to its 'birthplace' in Florence, Italy. We can only hope that plant sciences will accept our new view of sensitive plants, and that the three pillars of plant neurobiology—namely the sensory basis of plants, integrated signaling (both chemical and electrical), as well as adaptive problem-solving behavior of plants and their organs, will continue to develop under the umbrella of this newly emerging branch of plant sciences.

We started by mentioning the review article by Jack C. Schultz, and we would like to close with the first sentence of the last paragraph of Schultz's article which contains another important message:

It is time to stop dividing plants from animals in thinking about how organisms respond to their environments.[1]

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