Are calcium signals coupled with cell nuclear movement during plant symbiosis with bacteria?

Teresa Vaz Martins[1]

[1]John Innes Centre, Norwich Research Park, Norwich, NR4 7UH, UK

When plant legumes encounter low nitrogen conditions, they release flavonoids as signals to soil bacteria [1]. In response, bacteria release Nod factors, marking the beginning of a symbiotic relationship. The nitrogen fixing bacteria provide the plant with ammonia, whilst the plant provides the bacteria with sugars.

Symbiosis occurs in the plants root hairs cells over the course of several hours. The root hair tip swells and curls to trap the bacteria, which then enters the cell upon the formation of an infection thread. The development of the infection thread is guided by the cell migrating nucleus [2].

In parallel with morphological changes, the generation and decoding of biochemical signals tells the plant what to do. A common hypothesis is that messages are encoded in the specific spatiotemporal patterns of calcium released by nucleus-localised ion channels.

We investigate the early stages of calcium oscillations within living root hair cells, following the addition of Nod factor, using time-lapse confocal microscopy with ratiometric fluorescent biosensors with two dyes [3]. Artefacts like bleaching, changes in focus, variations in laser intensity, etc, would affect both dyes equally. Only when calcium levels changes, are the variations in the fluorescence intensity of the two dyes anti-correlated. On the other hand, the inspection of the individual changes of the dyes intensity can provide clues into how the nucleus moves as calcium oscillates.

We present preliminary evidence that suggests that the timing of the calcium spikes is coupled with nuclear movements. However, it is not always straightforward to distinguish nucleus shape changes from movement. Additionally, nuclear movements seems to be related to other organelles movements, ranging from random kicks by floating small organelles, to the formation of vacuolar strands and cytoplasmic streaming.

Our results address the following key questions in the field. Does mechanical stretch affect the activation of the calcium-release channels? What is the role of active transport and random kicks in spatial calcium spreading? In what sense can the calcium patterns be fine-tuned to target specific decoding proteins if their timing depends on apparently randomly moving organelles? Are the observed early stages nuclear movements in anyway similar in origins to later nuclear migration at the time of the infection thread?

A complex systems framework can offer crucial insights in these problems. It may help interpret the type of synchronisation that occurs between nuclear movements and calcium oscillations, when both can be represented by typically noisy short time series. It can also provide insights into the generation of calcium spatio-temporal patterns, linking it to cytosolic streaming (which may take a variety of complex geometric flows), or to random kicks, or a combination of both.

[1] Giles E. D. Oldroyd, Nature Reviews Microbiology (April 2013) **11**, 252 (2013).

[2] Griffis Anna, Groves Norman, Zhou Xiao, Meier Iris, Front. Plant Sci. **5**, 129 (2014).

[3] Chidananda Nagamangala Kanchiswamy, Mickael Malnoy, Andrea Occhipinti, Massimo E. Maffei, Int J Mol Sci. **15 (3)**, 3842 (2014).