SYMBIOSIS

Twin entry route

A paper just published in *Nature* reveals a new aspect of plastid biology — two plastid proteins have a role in symbioses with fungi and bacteria.

Most higher plant species can enter into a root symbiosis with arbuscular mycorrhizal (AM) fungi that is characterized by formation of arbuscules, which are branched structures in the host cell that enable plants to trade carbon for fungal phosphate. Nitrogen-fixing root nodules that contain rhizobia (nitrogen-fixing bacteria) are characteristic of a different symbiosis in which plant carbon is exchanged for bacterial fixed nitrogen. Plants perceive molecular signature molecules produced by rhizobia (Nod factors) and respond by genetically reprogramming root hair cells to allow microbial entry and to develop the specialized nodule organs that house the microbial symbionts. Nod factors immediately induce ion fluxes, specifically a rapid Ca^{2+} influx across the plasma membrane, followed by Ca^{2+} concentration oscillations around the nucleus that are known as Ca^{2+} spiking.

Imaizumi-Anraku and colleagues study symbiotic interactions of bacteria and fungi with the leguminous plant *Lotus japonicus*. In a research collaboration involving the laboratories of Makoto Hayashi, Shinji Kawasaki and Martin Parniske, a collection of *L. japonicus* mutants was screened for those unable to form nodules. Mutants in either the *CASTOR* or the *POLLUX* genes were not able to form either rhizobia nodules or arbuscular mycorrhizal symbioses. Despite some changes in root hair morphology, such as root hair branching, no infection threads were formed when mutant plants interacted with rhizobia, and neither bacteria nor fungi proceeded into symbioses. *castor* and *pollux* mutant root cells did not show Ca^{2+} spiking in response to Nod factors, so the early biochemical and developmental steps in symbiosis were uncoupled by these mutations.

Positional cloning of *CASTOR* and *POLLUX* genes showed that they are located on chromosomes 1 and 6, respectively. The high homology between these genes indicates that they arose through gene duplication, although adjacent sequences showed no synteny. *CASTOR* is expressed in all organs, but expression is increased in the roots, and *POLLUX* is preferentially expressed in nodules. Both CASTOR and POLLUX proteins were predicted to have a chloroplast transit peptide and GFP-tagging confirmed that these proteins co-localized with a plastid marker protein. Given the similarity of CASTOR and POLLUX and their inability to function alone, the authors speculate that these 'twin' proteins might form a heteromeric complex that is required for symbioses.

How might such a twin complex function? The authors uncovered structural features of CASTOR and POLLUX that match an archaeal multimeric calcium-gated potassium channel. It is possible that a twin channel might coordinate the ion fluxes that occur at the plasma membrane and around the root cell nucleus when the microorganism and plant interact in the early stages of symbiosis, but the ion transported and the mechanism now need to be experimentally confirmed.

This intriguing report reveals that an ancient endosymbiont controls how modern-day symbionts enter plants. Elucidating the mechanism of this control is an exciting challenge for the future.

Susan Jones

References and links

ORIGINAL RESEARCH PAPER

Imaizumi-Anraku, H. *et al.* Plastid proteins crucial for symbiotic fungal and bacterial entry into plant roots. *Nature* 22 December 2004 (doi:10.1038/nature03237)

WEB SITES

Makoto Hayashi's laboratory: http://www.p.chiba-u.ac.jp/lab/idenshi/crest-e.html
Shinji Kawasaki's laboratory: http://www.nodai.ac.jp/english/app/bios/lab.html
Martin Parniske's laboratory: http://www.sainsbury-laboratory.ac.uk/archive/mp/