FUNGAL PHYSIOLOGY

Ustilago takes control

In a recent *Nature* paper, a group of researchers from Germany demonstrate that the *Ustilago maydis* effector protein Cmu1 is a virulence factor that can move through plant cells, redirecting plant metabolic pathways to favour fungal infection.

As a biotrophic fungal pathogen, *U. maydis*, the causative agent of smut disease, invades living maize tissue. The *U. maydis* genome encodes a large number of secreted protein effectors. Interestingly, in addition to >380 effectors, many of which are required for the biotrophic interaction, *U. maydis* encodes an additional ~150 secreted enzymes that may be involved in accessory functions such as penetration of host cells.

Armin Djamei, Kerstin Schipper and colleagues investigated the function of one such *U. maydis* protein, Cmu1, which was predicted to encode a secreted chorismate mutase. Chorismate mutases are usually cytoplasmic proteins and are key enzymes at the branching point

of the shikimate pathway, which produces aromatic amino acids. The authors found that *U. maydis* *cmu1* complemented a *Saccharomyces cerevisiae* mutant (Δ aro7) in which the cytoplasmic chorismate mutase had been deleted; growth of the Δ aro7 mutant on medium lacking tyrosine and phenylalanine was restored by the presence of *cmu1*. That Cmu1 is produced and secreted by *U. maydis* and is highly expressed during infection of plants was confirmed by western blot detection of a Cmu1–haemagglutinin fusion protein in *U. maydis* culture supernatants and by proteomic analysis of apoplastic fluids isolated from *U. maydis*-infected maize. The disease symptoms displayed by plants infected with a *U. maydis* strain in which *cmu1* had been deleted (CL13 Δ cmu1) were substantially reduced compared with the symptoms associated with an infection by the progenitor strain, and virulence could be restored by reintroducing a single copy of *cmu1*. A Cmu1–haemagglutinin fusion protein was detected in the apoplast as well as in the plant cytoplasm, suggesting that Cmu1 is taken up

by plant cells. Furthermore, a Cmu1–mCherry fusion protein that was transiently expressed in plant cells was shown to spread to neighbouring cells.

What are the specific effects of Cmu1 on plant cell metabolism? Metabolic analysis showed that infection with CL13 Δ cmu1 led to a decrease in the constituents of

the phenylpropanoid pathway and a substantial increase in the amount of salicylic acid present. Salicylic acid is a key component of the plant defence response to infection and is thought to enhance resistance to *U. maydis*. The authors present a model in which *U. maydis* Cmu1 channels chorismate into the phenylpropanoid pathway, thus preventing it from being used for salicylic acid biosynthesis. The authors suggest that Cmu1 is just one component of an ‘effector cocktail’ that reprogrammes host cell metabolism and that such metabolic priming could be widely used by plant pathogens that rely on low salicylic acid levels to establish a compatible interaction.

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ORIGINAL RESEARCH PAPER Djamei, A. et al. Metabolic priming by a secreted fungal effector. *Nature* **478**, 395–398 (2011)

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