PLANT-MICROORGANISM INTERACTIONS

Synthetic symbiosis

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Plant biology embraced modern molecular engineering techniques decades ago. During these early and heroic times, when postdocs could choose a laboratory based on the purity of the EcoRI produced there, one project had already attracted a lot of attention. It was about correcting an evolutionary incongruity: most of the crops that feed us grow around immense quantities of nitrogen in the air, but cannot use it directly. We must compensate with vast amounts of synthetic fertilizer.

Legumes have adapted to this situation by partnering with symbiotic bacteria, sheltered inside root nodules, which fix the atmospheric dinitrogen so the plants can use it. In other crops, would it be possible today to engineer a new type of symbiotic relationship by modifying plant and microorganisms using synthetic biology? A new study led by Christopher Voigt at the Massachusetts Institute of Technology brings us one step closer to this goal by focusing first on the bacterial half of the symbiosis.

The team started with bacteria that are already natural mutualists of rice, maize and wheat. Some of them contain the clustered *nif* genes that permit nitrogen fixation, although they are not strongly expressed. These genes encode for the nitrogenase enzyme and other co-factors. Nitrogenase is a difficult enzyme to work with: it requires a high amount of

energy to produce ammonium and so must be conditionally expressed; in addition, it is irreversibly inactivated by oxygen and repressed by organic forms of nitrogen.

The authors of this study started with multiple combinations of natural *nif* clusters introduced into three bacterial hosts and selected the most promising ones. Then, they systematically modified and rewired the regulation of these clusters to be under synthetic control while eliminating the unwanted aspects. Given the flexibility of this synthetic biology approach, the gene clusters could finally be placed under the control of molecules that are produced by plant roots to make sure that nitrogenase is activated only when roots are close.

While not yet tested outside of a Petri dish, this bacterial engineering feat is a significant step in the long and winding road towards reducing nitrogen fertilizers. It could be associated with compatible modifications on the plant side to recreate, in the laboratory, a type of molecular dialogue similar to the one happening during natural symbiosis, obtained through millions of years of co-evolution.

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