Photosynthesis: Living laboratories

November 27 2019

In his laboratory in Martinsried, Professor Dario Leister investigates photosynthesis processes. Photo: ole/LMU

Ludwig-Maximilians-Universitaet (LMU) in Munich biologists Marcel Dann and Dario Leister have demonstrated for the first time that cyanobacteria and plants employ similar mechanisms and key proteins to regulate cyclic electron flow during photosynthesis.

Cyclic electron flow (CEF) is a crucial component of photosynthesis in both plants and cyanobacteria. However, up to now, it was not clear how

it differs from, and what components it shares with, the related electron-transport process of linear electron flow (LEF) or how it is regulated. LMU biologists Marcel Dann and Dario Leister have now shown that two specific proteins, called PGRL1 und PGR5, mediate the control of CEF in plants. These proteins had been identified as important elements in photosynthesis in recent years, both in Leister's laboratory and by a group of researchers in Japan. In plants, the amount of biologically useful energy (in the form of ATP) generated by the LEF pathway is insufficient for the synthesis of sugars from carbon dioxide. The ATP produced by cyclic electron flow makes up for this shortfall, and is vital for carbon fixation. This becomes obvious when plants are exposed to stress, have to repair damage caused by high light levels, or are confronted with other deleterious environmental changes. "When CEF is defective, plants very quickly get very sick," Leister says.

Since cyclic electron flow is extremely difficult to measure directly in plants, Dann and Leister turned to cyanobacteria, which also possess a CEF pathway. Cyanobacteria are a very useful model system because the organelles known as chloroplasts—the sites of photosynthesis in plants—were actually derived from them during evolution. The molecular mechanisms that regulate CEF in cyanobacteria are therefore similar to, but significantly less complex than those used by plants, Leister explains. "These are systems that utilize a simpler form of photosynthesis." In their study, which appears in the online journal *Nature Communications*, the authors introduced the genes that code for the two plant proteins PGRL1 und PGR5 into various mutant strains of these bacteria and analyzed their effects on photosynthesis. "We were quite surprised to find that we could in fact measure something that looked very like cyclic electron transport," says Leister. This finding clearly proves that these two proteins indeed play a key role in cyclic electron flow. In addition, it emerged that they are sufficient to re-establish CEF in mutant cyanobacteria.

This is particularly notable, because cyanobacteria lack PGRL1, although they do have a PGR5-like protein. For this reason, researchers have long wondered why these cells manage to implement CEF with the aid of this PGR5 homolog alone, while the plant pathway requires both PGR5 and PGRL1. The two researchers also found a possible answer to this riddle. They showed that cyanobacteria have a second protein, called Sll1217, which apparently has a function analogous to that of PGRL1 in plants. Although Sll1217 displays only a very low level of structural (i.e. amino-acid sequence) similarity to plant PGRL1, it interacts with PGR5 from both plants and cyanobacteria. Dann and Leister are the first to suggest a function in CEF for Sll1217.

Dario Leister plans to make practical use of these new insights. His latest project, "PhotoRedesign", for which he recently received a Synergy Grant from the European Research Council (ERC), sets out to improve photosynthetic performance and develop ways to enable plants to make better use of sunlight. "We are attempting to beat nature by combining the best elements of different systems of photosynthesis," says Leister. In this respect, the genetically altered cyanobacteria provide new opportunities for further experimentation. "In bacteria, we can experimentally alter the plant version of cyclic electron transport by genetic manipulation within a few weeks," Leister points out. "The altered cyanobacterial strain is like a living laboratory, which allows us to play around with the process of CEF. Such experiments would take years in plants."—And solutions that work in cyanobacteria can then be tried out in plants. "That not only saves lots of time, it allows us to carry out experiments that would be impossible to do in plants."

More information: Marcel Dann et al, Evidence that cyanobacterial Sll1217 functions analogously to PGRL1 in enhancing PGR5-dependent cyclic electron flow, *Nature Communications* (2019). DOI: 10.1038/s41467-019-13223-0

Provided by Ludwig Maximilian University of Munich