Press Release

Tübingen researchers discover a nitrogen sensor widespread in the plant kingdom

Success story of an evolutionary invention

University of Tübingen
Public Relations Department

Dr. Karl Guido Rijkhoek
Director

Janna Eberhardt

Phone +49 7071 29-76788
+49 7071 29-77853
Fax +49 7071 29-5566
karl.rijkhoek[at]uni-tuebingen.de
janna.eberhardt[at]uni-tuebingen.de

www.uni-tuebingen.de/aktuell

Max Planck Institute for Developmental Biology
Public Relations Office

Nadja Winter
Press officer

Phone +49 7071 601-444
presse-eb[at]tuebingen.mpg.de

www.eb.mpg.de

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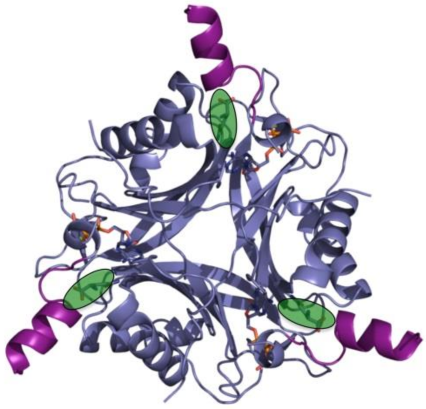
Subtropical rain forest in southern Brazil: all plants require nitrogen. Photograph: Karl Forchhammer

Quantitatively, nitrogen is one of the most important nutrients for the growth of plant organisms – from simple green algae to highly developed flowering plants. Nitrogen supply is essential for the development of all cell components, and as a good supply results in faster plant growth, it is commonly used as a fertiliser in agriculture. Nitrogen is assimilated in the chloroplasts of plant cells to produce the amino acid glutamine. This molecule serves as a storage form and central distributor that feeds nitrogen into various metabolic pathways. Scientists from the research group of Professor Karl Forchhammer at the Interfaculty Institute for Microbiology and Infection Medicine have investigated how plants keep track of their nitrogen supply. In cooperation with Dr. Marcus Hartmann at the Max Planck Institute for Developmental Biology and colleagues from the University of St. Petersburg, they discovered that plants possess a sophisticated glutamine sensor. So-called PII signalling proteins act as a “fuel gauge” for the amount of available nitrogen by measuring the glutamine concentration. This information is then used by the plants to precisely control their growth.

PII signalling proteins are central metabolic regulators that have been thoroughly investigated in bacteria by microbiologist Karl Forchhammer's team. However, investigations of this protein type in the green algae *Chlamydomonas* surprisingly revealed that an additional component is required to make the PII proteins work: their signalling function is tightly coupled to the glutamine level. The PII proteins stimulated the production of various other amino acids, the "building blocks" of proteins, but only at high glutamine concentrations. Together with Marcus Hartmann the microbiologists have now determined the three dimensional structure of PII proteins in these algae: in comparison to the bacterial PII proteins they have an additional small extension that the researchers termed the "Q-Loop". This small loop detects and wraps around free glutamine molecules. "Only when this extension is loaded with glutamine, the PII protein folds into the structure that is necessary to signal and initiate the subsequent metabolic steps", explains Dr. Vasuki Chellamuthu, the study's lead author.



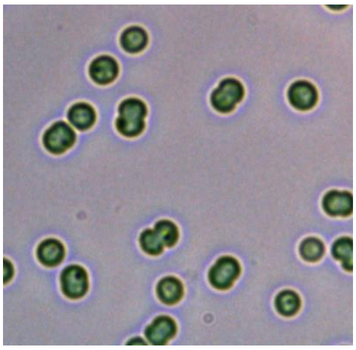
PII signalling protein from *Chlamydomonas reinhardtii*. The Q-Loop extensions are represented in violet, the glutamine binding sites in green. Image: Karl Forchhammer

Microscopic images of the single-cell green algae *Chlamydomonas reinhardtii. Images: Karl Forchhammer*

In a next step the researchers wanted to find out if this additional trait is unique to the green algae *Chlamydomonas*, or whether it is a common feature of plants. With bioinformatic methods, they analysed all available genetic blueprints of plant PII proteins. "It turned out that this small extension is present in all plant PII proteins, from green algae to mosses, and all the way to rice and other flowering plants", state Marcus Hartmann and Karl Forchhammer. The Q-Loop extension is degenerated in only one single plant family: the crucifers. "Curiously *Arabidopsis thaliana*, or thale cress, an important model organism in plant research, belongs to this family and thus to the exceptions", they add. The corresponding PII protein in thale cress is, in fact, not glutamine-dependent. However, when the researchers artificially appended the intact Q-loop extension from the algal protein to the thale cress protein in laboratory tests, the response to glutamine was restored – confirming the Q-Loop's functional role.

The moss *Physcomitrella* (left) has it, while thale cress, *Arabidopsis thaliana* (right), does not: the glutamine-dependent PII protein. Photographs: Karl Forchhammer

By altering the PII proteins in plants in a targeted manner, the formation of certain metabolic products could be influenced. “Whether the discovery of the nitrogen sensor will have a significant impact on plant breeding remains to be seen”, says Forchhammer. But the discovery has already taught us a lesson in evolution. The nitrogen sensor is an example of how new properties can emerge on the basis of existing components. Chloroplasts were originally cyanobacteria that migrated into cells. These bacteria possessed PII signalling proteins with no extension. However in the plant, it became necessary to directly measure the availability of nitrogen for metabolic control. Therefore, the extension was appended and the signal transmission was coupled to the glutamine level. This trait was so useful that it was passed on to all descendants in the plant kingdom and – with few exceptions – exists to this day.



Cyanobacteria: *Synechocystis* (left) and *Anabaena* sp. (right). Photographs: Karl Forchhammer

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Contact:

Prof. Dr. Karl Forchhammer
University of Tübingen
Faculty of Medicine and Faculty of Science
Interfaculty Institute of Microbiology and Infection Medicine
Phone +49 7071 29-72096
karl.forchhammer[at]uni-tuebingen.de

Dr. Marcus Hartmann
Max Planck Institute for Developmental Biology
Phone +49 7071 601-323
marcus.hartmann[at]tuebingen.mpg.de

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The Max Planck Institute for Developmental Biology

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