# Laboratory of Organelle Biology

## Institute for Protein Research


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The basic unit of the animal and plant body is the cell. Within these cells are intracellular organelles surrounded by biological membranes called organelles, such as the nucleus, mitochondria, peroxisomes, and chloroplasts, which are responsible for a variety of metabolic processes. How did eukaryotic cells with complex organelles arise from the first bacterial prokaryotic cells on earth, which were surrounded by a simple membrane structure? This is the result of a long evolutionary process in which bacteria symbiotic in the host cell, from which eukaryotic cells originated, became organelles. Our research focuses on chloroplasts of plants and algae, focusing on the protein transport systems that have been established in association with organelle formation.

### The Mystery of Chloroplast Evolution, which Started from Intracellular Symbiosis

Chloroplasts are the site of photosynthesis and support many forms of life on Earth. Chloroplasts originated about a billion years ago when photosynthetic prokaryotes such as cyanobacteria formed intracellular symbioses with eukaryotes, which have nuclei and mitochondria. Many of the endosymbiont genes have since been transferred to the nuclear genome of the host, and more than 2,000 chloroplast proteins, including newly added ones, are now encoded in the nuclear genome. Since the synthesis of these proteins takes place outside the chloroplast (in the cytosol), a system that specifically transports only chloroplast proteins had to be established in the membrane surrounding the chloroplast (Fig. 1). We succeeded in purifying the TIC translocon, a protein transport system of the chloroplast inner membrane, as a supramolecular complex with a molecular weight of 1 million for the first time in the world, and identified all of its components (Science, 2013).

This finding also suggests that changes in the chloroplast protein delivery system may have contributed to the evolution of green algae and land plants. We will explore the mysteries of chloroplast evolution, such as why a huge membrane permeabilizer with a molecular weight of 1 million was necessary and how it was established (PNAS, 2020).

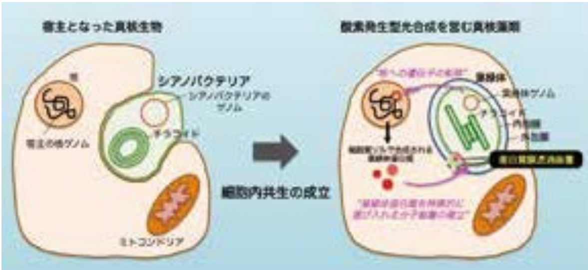


Figure 1. chloroplasts by endosymbiosis of cyanobacteria.

### Elaborate mechanism by which cells send only chloroplast proteins to chloroplasts

Transport of macromolecules such as proteins across biological membranes requires sophisticated molecular devices - translocons - that allow proteins to pass through the membrane while maintaining the membrane barrier. Life has produced several different types of translocons during the course of evolution. Because of the different membrane systems and evolutionary backgrounds in which they emerged, their components and transport mechanisms are quite different. The above-mentioned translocon TIC in the chloroplast inner envelope, the recently identified novel ATP-dependent transport motor complex with a molecular weight of 2 million that works in association with TIC (Plant Cell, 2018), and the translocon TOC in the outer envelope with a molecular weight of 10,000,100000, are all examples of the type of translocons that are being generated by these megacomplexes. We will reveal the elaborate mechanism of chloroplast protein transport through functional coordination, including plant genetic engineering (Fig. 2) and structural biology (Fig. 3). We are close to elucidating the principles of building


Figure 2. albino trait exhibited by an Arabidopsis mutant defective in the protein membrane permeabilizer of the chloroplast envelope.

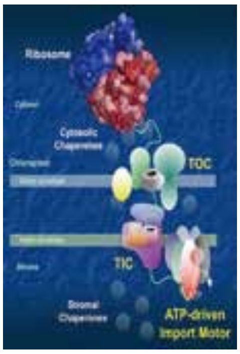


Figure 3. Megacomplexes involved in chloroplast protein transport

### References


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