Metabolic engineering, Plant / Algal manipulation

Elucidation of molecular mechanisms of chloroplast protein import and its applications

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Abstract

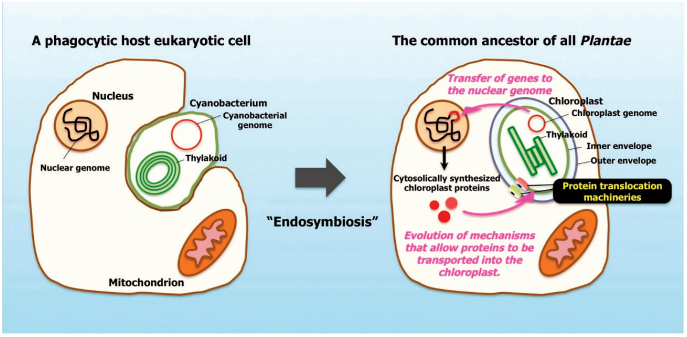
All life on earth depends on organic compounds which are produced by photosynthesis accompanied with carbon/sulfur/nitrogen assimilations. In green lineages, namely, green algae and plants, a specialized intracellular compartment – organelle - called chloroplast plays a key role on this task. To achieve this, chloroplast requires more than 2000 kinds of different proteins/enzymes , each of which are correctly localized in respective subornagellar compartment inside the chloroplast. Most of these chloroplast proteins are nuclear-encoded and synthesized in the cytosol, the outside of chloroplast, and therefore must be transported across the double envelope membranes which surround this organelle. In recent years, our molecular analyses have revealed mechanisms of chloroplast protein import in higher plants as well as in green algae.

Background & Results

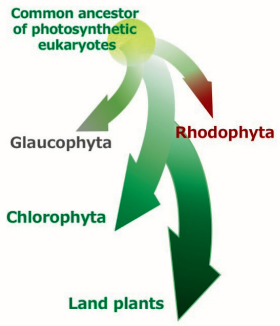
In general, since proteins cannot pass through lipid bilayers freely, protein translocation across biological membranes requires supramolecular machineries called translocons. Translocons are particularly important for eukaryotic cells which harbors various membraneous subcellular compartments- organelles including chloroplasts and thus have been established along with the evolution of those organelles. Chloroplasts of extant photosynthetic eukaryotes are assumed to derive from single endosymbiotic event between an eukaryotic ancestor and a cyanobacterium-like endosymbiont. How translocons, sophisticated molecular machineries, arose at the double envelope membranes of chloroplast during evolution of photosynthetic eukaryotes have attracted much attention over the years. My group has focused on elucidation of the molecular mechanisms of chloroplast protein import mainly using a model plant, Arabidopsis thaliana. In 2013, we discovered a genuine protein translocon at the chloroplast inner envelope membrane (TIC) and, in 2018, we further identified another completely novel protein complex (FtsHi/Ycf2 complex) at the inner envelope membrane which functions in concert with the TIC complex as an ATP-driven protein import motor. By international collaborative research, very recently in 2020, we determined the molecular components which play an important essential role in chloroplast protein import in a model green algae, Chlamydomonas reinhardtii. Our findings clearly indicate that the key molecular mechanisms of protein translocation across the chloroplast envelope membranes had already been established when green algae appeared on earth and has been inherited from green algal ancestor to green plants.

Significance of the research and Future perspective

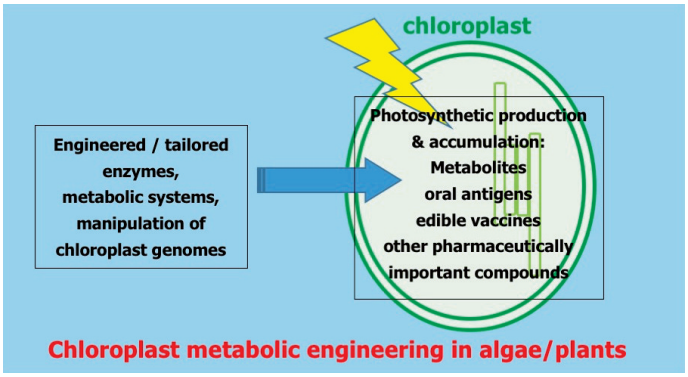
Our extensive research has revealed that molecular mechanisms of chloroplast protein import are highly and widely conserved among green lineages including green algae and green plants. Our future research efforts will clarify our understanding of protein transport systems in other chloroplast-containing organisms and, ultimately, will further enrich our knowledge of the evolution of this protein transport system as well as the evolution of various photosynthetic eukaryotes. Furthermore, as applicable tools, our studies on protein transport to chloroplast may help to utilize chloroplasts in green alga or in green plants as factories for foreign / recombinant proteins or compounds which might be used for the sources of drugs, vaccines or other therapeutic materials.



Chloroplasts of photosynthetic eukaryotes originated from cyanobacterial endosymbiosis.



Early divergences of photosynthetic eukaryotes.



The use of chloroplast engineering to produce foreign compounds such as pharmaceuticals.

Patent

Treatise Ramundo, Silvia; Asakura, Yukari; Nakai, Masato et al. Co-expressed subunits of dual genetic origin define a conserved supercomplex mediating essential protein import into chloroplasts. Proceedings of the National Academy of Sciences. 2020; 117(51): 32739-32749. doi: 10.1073/pnas.2014294117

URL http://www.protein.osaka-u.ac.jp/enzymology/nakaiJ.html

Keyword plant, chloroplast, protein, green algae, molecular evolution