

FUNDING PROGRAM FOR NEXT GENERATION WORLD-LEADING RESEARCHERS

Project Title: Exploring the basis of transcriptional regulation and uniparental inheritance of chloroplasts

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1. Background of research

In plants and algae, photosynthesis occurs in a specialized intracellular organelle- **the chloroplast**. Chloroplasts are thought to have arisen from ancestral endosymbiotic relationships between nucleated cells and free-living cyanobacteria. Reflecting their endosymbiotic origins, chloroplasts contain their own genome (chloroplast (cp) genome) and gene expression machineries that displays several prokaryotic features. The cp genome is crucial not only for sustaining photosynthesis but also as a target of chloroplast engineering.

2. Research objectives

In this research, we focus on **a unicellular green algae, *Chlamydomonas reinhardtii***, which is one of the ideal model organisms not only for chloroplast biology but also for biofuel production. Over the last few years, the research tools available for working with *C. reinhardtii* have rapidly improved; considerable genome information has accumulated, and techniques for systematic forward genetic analysis have been developed. By taking full advantage of these powerful technical advances, we would like to address compelling questions such as “How is the mRNA level controlled in chloroplasts?” or “What is the mechanism underlying the active digestion of the male cp genome to achieve uniparental inheritance?”.

3. Research characteristics (incl. originality and creativity)

The gene expression system in chloroplasts is unique, differing in many aspects from bacterial systems and using a variety of unusual posttranscriptional steps. The maintenance and inheritance of the cp genome is also intriguing as it is usually transmitted only from the maternal parent to the next generation. By understanding molecular mechanisms underlying these unique aspects of chloroplasts, it would be possible to establish a technology to manipulate gene expression machineries and inheritance of chloroplasts, which would realize the full potential of chloroplast engineering.

4. Anticipated effects and future applications of research

By understanding the molecular mechanisms to control transcription and inheritance of chloroplasts, it may be possible to convert chloroplasts into a “factory” for pharmaceutical proteins or useful metabolites. Also, a technology to control inheritance of chloroplasts or mitochondria would contribute to the regulation of male sterility or mitochondrial diseases, which would impact agricultural or medical sciences.

What are the mechanisms of
(A) regulation of the mRNA levels in chloroplasts
and (B) the uniparental inheritance of cpDNA?

Genetic analysis of mRNA
stability control in chloroplasts

Characterization of mutants
defective in uniparental
inheritance of chloroplast /
mitochondrial genes

Basic analysis using a model system,
unicellular green algae, *Chlamydomonas*.

Application to higher plants or ferns

Identification of genes and molecular
mechanisms that regulate mRNA levels
in chloroplasts

Identification of genes and molecular
mechanisms that govern inheritance of
chloroplast / mitochondrial DNA

Better regulation of chloroplast
functions by manipulating gene
expressions in chloroplasts

Development of technologies to control
inheritance of chloroplast or mitochondrial
traits, such as cytoplasmic male sterility or
mitochondrial diseases

Improvement of chloroplast functions and
chloroplast engineering that would lead to
“Green Innovation”