PREFACE

It is widely known that two major organelles, plastid and mitochondrion, have evolved by integration of bacterial endosymbionts. Half a century since Lynn Margulis proposed the endosymbiotic theory, recent advance of molecular studies has revealed the complex evolution history of plastids. The common ancestor of Archaeplastida including land plants and several algae obtained a plastid by the uptake of a photosynthetic prokaryote related to extent cyanobacteria, and this event is termed "primary" endosymbiosis. After that, certain phagotrophic protists have engulfed plastid-bearing algae, which are named "secondary" endosymbioses. Those eukaryote-to-eukaryote endosymbioses have occurred multiple times in different lineages, which have led to the spread of complex plastids, the so-called secondary plastids, in diverse eukaryotes. Thus, it can be said that secondary endosymbioses have been a driving force for the diversification of complex life on Earth. To date, eight major groups (stramenopiles, dinoflagellates, apicomplexans, chromerids, haptophytes, cryptophytes, euglenophytes, and chlorarachniophytes) are known to possess secondary plastids. This volume entitled "Secondary Endosymbioses" consists of 10 chapters written by expert scientists for respective groups with secondary plastids.

The first chapter, written by Fabien Burki, provides the overview of secondary plastid evolution. He summarizes previous studies of molecular phylogeny and comparative genomics and explains several inferred models of plastid evolution. The second chapter (by David Smith) describes the primary endosymbiosis as an introduction for secondary endosymbioses. He illustrates the origin of primary endosymbiosis, plastid genome evolution, and loss of photosynthesis in some lineages of Archaeplastida. Chapter 3 (by Richard Dorrell and Chris Bowler) focuses on stramenopiles that is a supergroup including the popular microalgae diatoms. This chapter describes the morphology, biochemistry, genomic diversity, and endosymbiotic origin of stramenopile plastids. Chapter 4 (by Ross Waller and Luděk Kořený) summarizes dinoflagellates that possess extraordinary complicated plastids. They mainly describe some species of this group that replaced their original plastids by higher order endosymbioses with certain primary and secondary plastid-bearing algae. Chapter 5 (by Giel van Dooren and Sanduni Hapuarachchi) deals with apicomplexan parasites, some of which are known as the causative agents of malaria, that contain nonphotosynthetic secondary plastid, termed apicoplasts. They illustrate the membrane biology, biogenesis, and metabolic functions of the apicoplasts. Chapter 6 (by Zoltán Füssy and Miroslav Oborník) focuses on chromerids that are photosynthetic relatives of apicomplexans. They describe the morphology, phylogeny, and cellular biochemistry of chromerids, as well as the inferred tertiary origin of chromerid plastids. Chapter 7 (by Yoshinori Tsuji and Masaki Yoshida) describes haptophytes that are a dominant marine primary producer. They illustrate the morphological diversity of calcified scales and the unique carbon metabolisms in haptophytes. Chapter 8 (by Goro Tanifuji and Naoko Onodera) deals with cryptophytes whose plastids possess a vestigial endosymbiont's nucleus, termed nucleomorph, which presents the smoking gun of eukaryote-to-eukaryote secondary endosymbiosis. This chapter mainly illustrates the endosymbiotic evolution of nucleomorph genomes. Secondary plastids can be divided into red- and green-algal lineages based on integrated algal endosymbionts. Chapters 3–8 illustrate organisms with red-algal secondary plastids, whereas the last two chapters explain green-algal secondary plastids. Chapter 9 written by Vladimír Hampl and colleagues summarizes euglenophyte plastids in terms of their origin, genomes, and metabolisms. The last chapter describes chlorarachniophytes that are another organism possessing a nucleomorph. I summarize the current understanding of the evolutionary history of chlorarachniophytes in terms of morphology, phylogeny, and genomics.

As mentioned earlier, this volume covers current aspects of plastid evolution. I believe that this volume is useful to graduate students and researchers in a broad range of fields including plant physiology, cell biology, genomics, and evolutionary biology. Finally, I would like to thank all contributors for joining to produce this volume. I would also like to thank Kazuya Takahashi for providing a cover picture (dinoflagellate), and Takuro Nakayama and Yuji Inagaki for constructive comments on specific chapters of this volume.

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