The common ancestor of cianobacteria and chloroplasts should have contained both chlorophyll b and phycobilins.

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What was the first oxygenic photosynthetic organisms? To reveal the early evolutionary history of photosynthetic organisms, we conducted molecular-phylogenetic analyses of chlorophyll b synthesis genes (CAO) from chlorophytes (land plants and green algae) and prochlorophytes. Prochlorophytes are an unusual group of oxygenic photosynthetic cyanobacteria because they use chlorophyll (Chl) b like chlorophytes, while cyanobacteria contain phycobilins but lack Chl b. There remained a question how chlorophyll b-containing oxygenic prokaryotes evolved. Our analyses showed that these CAOs shared a common evolutionary origin. This strongly suggested that the common ancestor of cyanobacteria and prochlorophytes was oxygenic photosynthetic prokaryote containing both Chlb and phycobilins.

Photosynthesis is the physico-chemical process in which plants, algae and photosynthetic bacteria use light energy to drive the synthesis of organic compounds. The provided energy and reduced carbon are required for the survival of virtually all life on the earth. Molecular oxygen is necessary not only for the survival of oxygen-consuming organisms, but also for all organisms for they have protected themselves from the UV damage by the ozone layer, which is a product of O2.

The ancestral oxygenic photosynthetic organisms had been considered to be cyanobacteria, for they were only identified bacteria performing oxygenic photosynthesis. Discovery of extant stromatolites in Hamelin Pool of Shark bay, northwestern part of Australia suggested that fossil stromatolites might have been produced by cyanobacterial activities in shallow water (Logan, 1961). Much efforts to reveal the roles of photosynthesis during the earth's history have been made in the field of paleontology and geology. The geological records, however, have been always accompanied by bad preservations, even though they were direct evidences for the ancient times. Therefore little was known about evolution of photosynthetic organisms. In the past few decades, spectacular progress has occurred in molecular biology, and molecular phylogeny has become a powerful tool in elucidating the evolutionary history of life, owing to the accumulated sequence data. Molecular phylogenetic analyses for the first time would allow us to approach the question about the history of photosynthesis and the role in earth's geo-biosphere from a biological point of views although we deal with data only from extant organisms. Photosynthetic organisms exhibit diversified accessory pigment compositions, on which their classification has been based. Here we isolated and analyzed chlorophyll b synthesis genes from chlorophytes (land plants and green algae) and from prochlorophytes, answering the question; 'What was the first oxygenic photosynthetic organisms?'

Prochlorophytes are prokaryotes which perform oxygenic photosynthesis using chlorophyll b like plants and green algae (Chlorophyta), and were proposed to be the origin of chlorophyte chloroplasts (Lewin, 1976). However, molecular-phylogenetic analyses showed that three known prochlorophytes were not on the lineage that led to chlorophyte chloroplasts but were related to different cyanobacterial species respectively (Palenik et al., 1992; Urbach et al.,1992). This means that prochlorophytes had polyphyletic origins among cyanobacteria. It was considered that the ability to synthesize chlorophyll b might have arisen at least four times independently in the lineages of three prochlorophytes and the ancestral eukaryote of chlorophytes.

Recently, we succeeded in isolation of a gene involved in chlorophyll b synthesis from of a green alga Chlamydomonas reihardtti by molecular-biological technique. We isolated and analyzed chlorophyll b synthesis genes from two prochlorophyte genera and from major groups of chlorophytes. The phylogenetic analyses showed that these CAO genes shared a common evolutionary origin. Taking into account multiple evolutionary origins of prochlorophytes among cyanobacterial radiation, it is strongly suggested that there should have existed hypothetical common ancestral prokaryotes of extant oxygenic cyanobacteria and prochlorophytes, which performed photosynthesis using both chlorophyll b and phycobilins. Subsequently cyanobacteria and prochlorophytes would have appeared by losing chlorophyll b or phycobilins respectively from the common ancestral photosynthetic prokaryotes.

This conclusion provides not only novel and profound knowledge about the early evolutionary history of photosynthetic organisms, but maybe also one of the clues to know the early history of the earth's biosphere.