Biofuel, Biobattery, Algal engineering

Structural study and structure-based engineering of photosynthetic electron transfer in cyanobacteria

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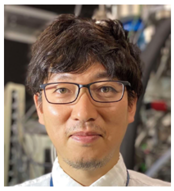


Abstract

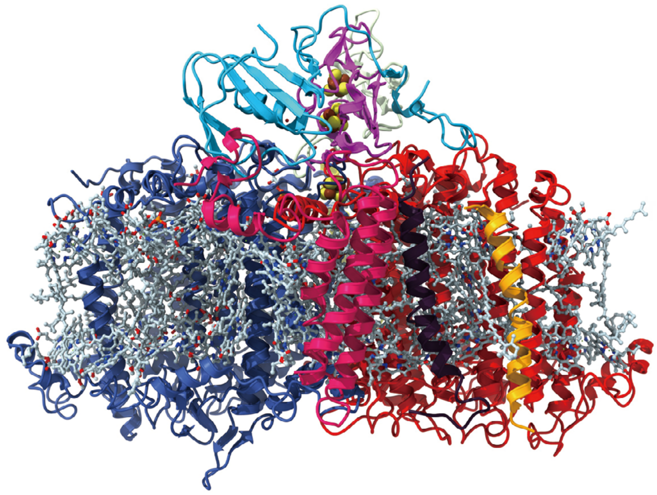
Photosynthetic electron transfer is a chemical reaction driven by light energy. The conversion from light energy to chemical energy is carried out by membrane protein complexes called photosystem I and II. The structure of the photosystem I complex from thermophilic cyanobacterium in its monomeric state was analyzed at high resolution, and a detailed mechanistic model was proposed to explain why the complex is monomerized and how the chlorophyll molecules in the complex enable the characteristic light absorption and drive the electron transfer.

Background & Results

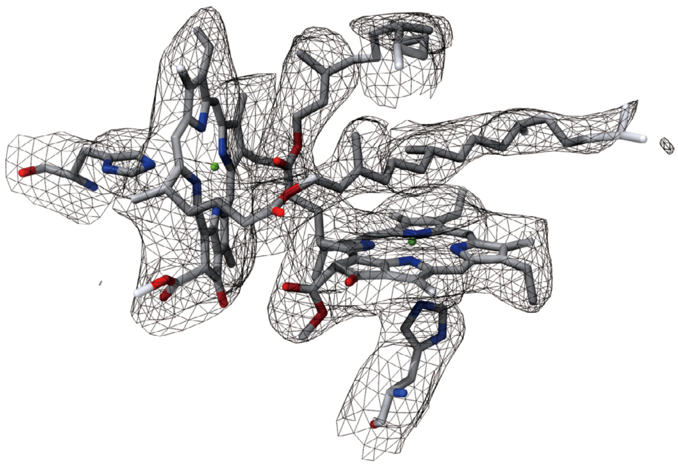
Plants and algae have changed the ancient Earth into a green planet by evolving photosynthetic functions, and they continue to support global environment on which our human societies fully depend. Photosynthetic reactions are like solar cells that generate electricity using light energy. The heart of this reaction is the generation of molecular oxygen by oxidizing water using excitation energy collected by light-harvesting antenna proteins composed of chlorophyll, as well as of reducing equivalent to fix carbon dioxide. The understanding and enhancement of photosynthetic function is an important research topic for the plant science, to stop global warming or climate change caused by fossil fuel consumption. If the detailed mechanisms of photosynthetic energy conversion, which are equivalent to solar cells, can be clarified, it would be possible to dramatically improve the photosynthetic functions of plants and algae by engineering the corresponding proteins, which had been thought to be impossible so far. Our group succeeded in obtaining a homogeneous membrane protein sample by improving the purification method of photosystem I in its monomeric state and analyzed successfully its three-dimensional structure of the complex at atomic resolution by high-quality cryo-electron micrographs using a state-of-the-art cryo-EM system (Cryo-ARM) (Figure).

Significance of the research and Future perspective

Our obtained resolution is good enough to discuss the atomic structure of proteins, pigments, and bound lipids, although the molecular size of photosystem I is larger than those of average protein molecules. In this analysis, comparison with the sample in the trimeric state allowed us to identify a cluster of red chlorophylls, whose absorption spectrum is red-shifted, and to understand how the bound chlorophyll molecules efficiently utilize the absorbed light energy. This might help to optimize the artificial photosynthesis and enhancement of photosynthetic functions.



Cryo-EM structure of monomeric photosystem I from thermophilic cyanobacterium *T. elongatus* BP-1



Chlorophyll molecules in the PSI structure with density map

Patent	
Treatise	Çoruh, Orkun; Frank, Anna; Tanaka, Hidaki et al. Cryo-EM structure of a functional monomeric Photosystem I from Thermosynechococcus elongatus reveals red chlorophyll cluster. Commun. Biol., 2021, 4, p.304, doi: 10.1038/s42003-021-01808-9
URL	http://www.protein.osaka-u.ac.jp/crystallography/LabHP/en/
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