Photosynthesis involves a protein "piston"

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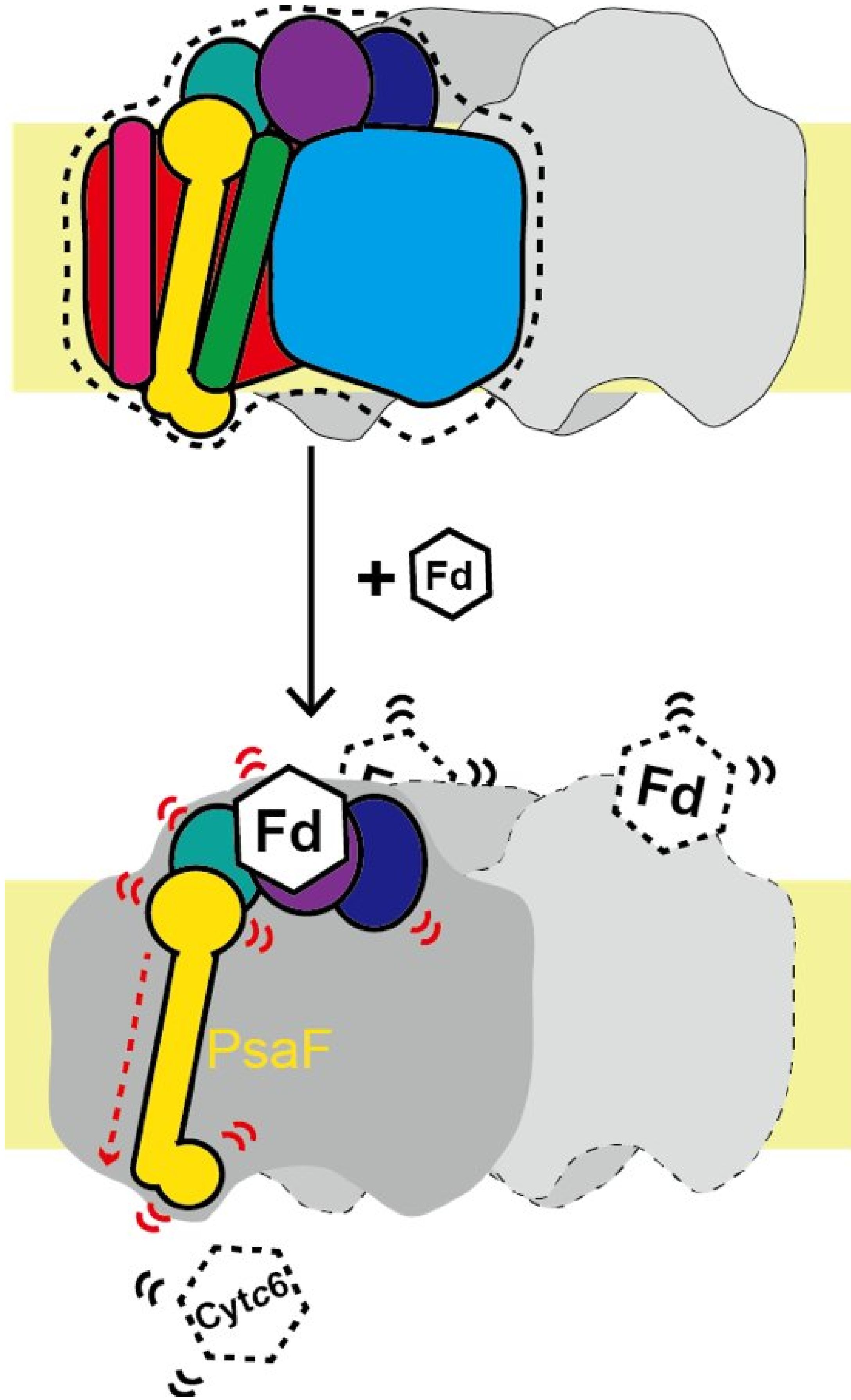
Fd
Fd
Fd
PsaF
Cytc6

Fig.1. The proposed mechanism underlying the function of cyanobacterial PSI. Upon binding of Fd, the vertical piston-like motion of PsaF may serve to couple sequential electron transfer from Cyt c6 to the PSI protomers in turn. Credit: Osaka University

Plants convert water and carbon dioxide into sugars and oxygen by photosynthesis. Photosynthesis is thus integral to life as we know it and has been investigated extensively by researchers around the globe.

However, photosynthesis is a complex microscopic process and some of its aspects are still not well understood. For example, Photosystem I (PSI) is a complicated protein system involved in photosynthesis. PSI reversibly forms complexes with ferredoxin (Fd) that mediate transfer of electrons derived from water. The PSI–Fd complex has not been fully characterized and the atomic-level interactions between PSI and Fd in the complex remain unclear despite their importance as links in the photosynthetic chain. This is because it is difficult to analyze the weak interactions in such an intricate protein system, which is partly caused by the weak binding interactions in the complex making it challenging to crystallize.

An Osaka University-led international collaboration recently made a breakthrough in knowledge of the PSI–Fd complex by collecting X-ray structural data for this complex isolated from a type of hot spring cyanobacteria. Genji Kurisu and collaborators grew bacteria, purified the PSI–Fd complex, and then grew crystals of the complex. X-ray data for the crystals were subsequently collected and resolved. The X-ray data for the complex provided some interesting information; in particular, that not all PSI–Fd interactions were the same. The results were reported in *Nature Plants*.

"We found that the crystal structure of the PSI–Fd complex contained two PSI trimers and six bound Fds in each crystallographic asymmetric unit," Kurisu says. "The Fds were non-equivalent because they were located at different distances from PSI; that is, Fd had strong and weak binding states in the PSI–Fd complex."

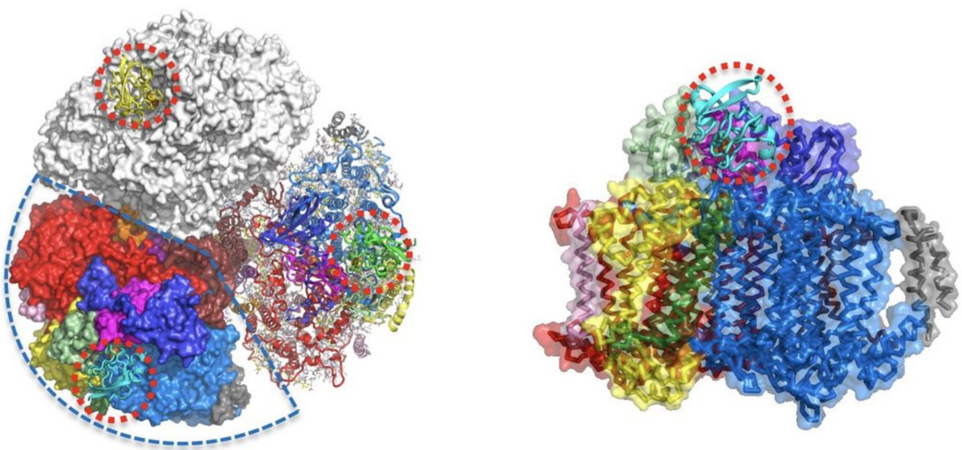

Fig. 2. Overall structure of the cyanobacterial PSI-Fd complex. (A) A cytosolic view of the PSI-Fd complex. Bound Fd are indicated by dotted red circle. (B) A side view of the PSI-Fd monomer depicted from the blue dotted line in the left panel. Credit: Osaka University

The group's findings were corroborated by the results of further characterization of the PSI–Fd complex by spectroscopic and chromatographic measurements, which also indicated that Fd had two different binding states in the complex. By considering all their experimental findings, the researchers developed a mechanism to explain the formation of two Fd binding states in the PSI–Fd complex.

"We propose that the binding of Fd to PSI lowers the symmetry of the three-dimensional structure of PSI," an associate professor, Hideaki Tanaka, in the team explains. "This induces a piston-like motion of one of the subunits of PSI to provide a complex that displays rapid electron transfer through PSI from the donor (Cyt c6) to the acceptor (Fd)."

The piston-like motion of the PSI subunit is thought to possibly act as a molecular signal across the cell membrane to stimulate rapid electron transfer.

The team's findings may provide clues to allow optimization of artificial photosynthesis to obtain complex chemicals from carbon dioxide, water, and light.

More information: Hisako Kubota-Kawai et al. X-ray structure of an asymmetrical trimeric ferredoxin–photosystem I complex, *Nature Plants* (2018). DOI: 10.1038/s41477-018-0130-0

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