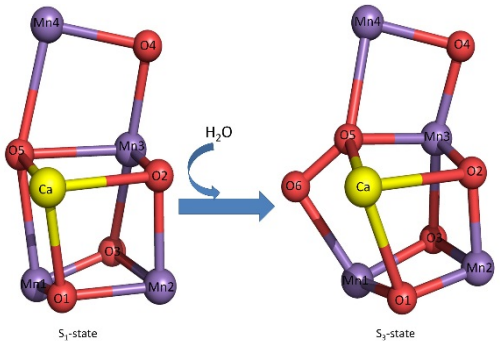
Research Highlights

Mechanism of photosynthetic water-splitting revealed by an X-ray free electron laser

Photosystem II (PSII) is a huge membrane-protein complex that catalyzes light-induced water-splitting, leading to the generation of protons and molecular oxygen. This reaction converts light-energy from the Sun into chemical energy that is required to sustain almost all living activities on Earth. The water-splitting reaction is catalyzed by a Mn4CaO5-cluster embedded within the protein matrix of PSII, and proceeds through five intermediate states called Si-states. The structures of PSII and the Mn4CaO5-cluster have been resolved with atomic resolution, however, mechanisms governing water-splitting are unclear due to the lack of intermediate structures of the enzyme.



Structural changes of the Mn4CaO5-cluster induced by two flashes illumination. S1-state: without illumination; S3-state: after two flashes illumination.

Now, Michihiro Suga, Fusamichi Akita, Jian-Ren Shen at Okayama University, and colleagues at institutes including Kyoto University, RIKEN, have clarified and resolved the structure of the Mn4CaO5-cluster at S3-state—an intermediate state that exists immediately before the formation of molecular oxygen, generated by two flashes of optical illumination. They employed a pump-probe method where two laser flashes were used to pump the enzyme to the intermediate state, and the X-ray diffraction data were collected by a serial-femtosecond crystallography method using femtosecond X-ray free electron lasers (XFEL) at SACLA, Japan.

The results showed the insertion of a new oxygen atom (water molecule) close to an already existing oxo-oxygen termed O5, enabling the formation of molecular oxygen between O5 and the newly inserted oxygen atom (O6). This clearly demonstrated the mechanism governing the water-splitting reaction catalyzed by PSII, and provided a blueprint for design and synthesis of efficient artificial catalysts that in the future could be utilized in artificial photosynthesis to produce clean and renewable energy from the Sun.

Reference:

Authors

Michihiro Suga, Fusamichi Akita, Michihiro Sugahara, Minoru Kubo,Yoshiki Nakajima, Takanori Nakane, Keitaro Yamashita, Yasufumi Umena, Makoto Nakabayashi, Takahiro Yamane, Takamitsu Nakano, Mamoru Suzuki, Tetsuya Masuda, Shigeyuki Inoue, Tetsunari Kimura, Takashi Nomura, Shinichiro Yonekura, Long-Jiang Yu, Tomohiro Sakamoto, Taiki Motomura, Jing-Hua Chen, Yuki Kato, Takumi Noguchi, Kensuke Tono, Yasumasa Joti, Takashi Kameshima, Takaki Hatsui, Eriko Nango, Rie Tanaka, Hisashi Naitow , Yoshinori Matsuura, Ayumi Yamashita, Masaki Yamamoto, Osamu Nureki, Makina Yabashi, Tetsuya, Ishikawa, So Iwata and Jian-Ren Shen.

Title of original paper

Light-induced structural changes and the site of O=O bond formation in PSII caught by XFEL.

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Reference (Okayama University e-Bulletin) : Jian-Ren Shen's team

e-Bulletin vol.1 :
Professor Jian-Ren Shen's research clarifying the mechanism governing plant photosynthesis is chosen as one of the runners-up for 'Breakthrough of the Year' by AAAS Science for 2011.
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Water splitting: Ultrahigh resolution data reveals reaction mechanisms
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Jian-Ren Shen is awarded the prestigious 2012 Asahi Prize
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