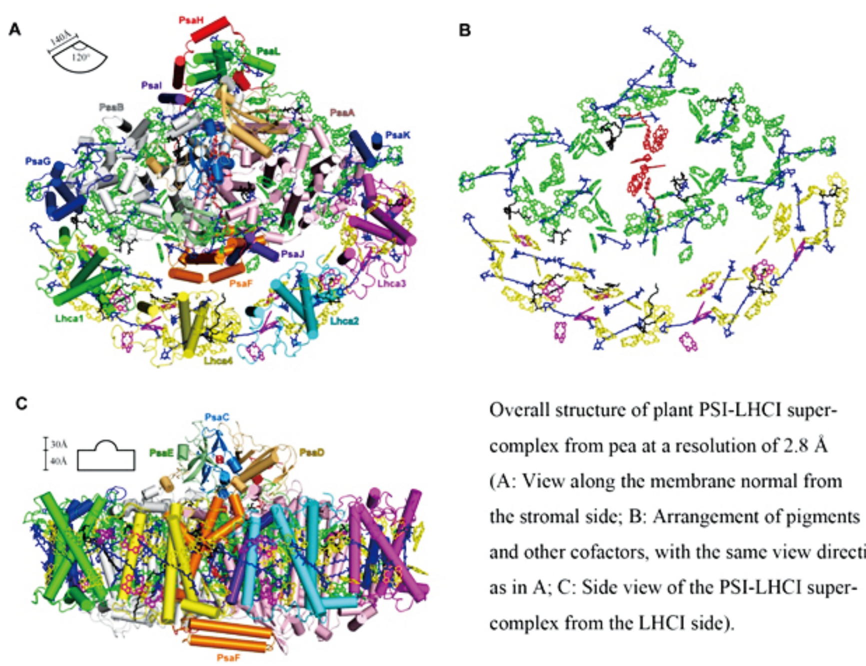
One Big Step Forward Towards Understanding Photosynthesis

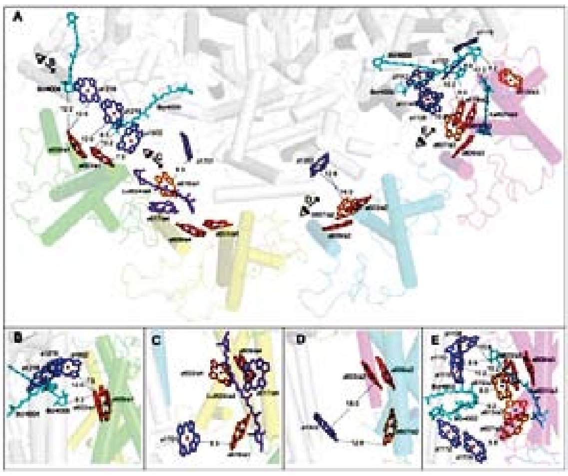
On May 29, 2015, a research team led by SHEN Jianren and KUANG Tingyun from the Institute of Botany, Chinese Academy of Sciences published their latest research results on the crystal structure of higher plant PSI-LHCI super-complex at a resolution of 2.8 angstroms in the distinguished journal *Science*. Their article, entitled "Structural basis for energy transfer pathways in the plant PSI-LHCI super-complex", revealed the first atomic view of PSI-LHCI.

Photosynthesis is the largest energy conversion process on earth. It utilizes light energy from the Sun to convert CO_2 and water into carbohydrates and oxygen, thus sustaining all aerobic life forms on the earth. Photosynthesis has been considered to be "the most important chemical reaction on Earth". The central problem of understanding photosynthesis is the molecular mechanisms underlying light-harvesting, energy transfer and conversion with high efficiencies.

The energy conversion in photosynthesis is carried out by two large pigment-protein complexes: photosystem I (PSI) and photosystem II (PSII), among which, PSI is an extremely efficient solar energy converter. The light energy absorbed by the PSI light-harvesting pigments is transferred to chlorophylls in the reaction center, where charge separation occurs, and this process produces one electron for nearly every photon absorbed. The high chlorophyll concentration in plant PSI maximizes light harvesting. Furthermore, light-harvesting complex I (LHCI) contain several chlorophylls with red shifted spectra, called red forms, which expand the light-harvesting capacity of plant PSI to the far-red region and allow energy transfer from high-energy to low-energy pigments. The excitation energy transfer in PSI is extremely fast, and the quantum efficiency is close to 100%, making PSI the most efficient energy transfer system. Therefore, the structure and function of PSI has received extensive interests in the field of



Overall structure of plant PSI-LHCI super-complex from pea at a resolution of 2.8 Å (A: View along the membrane normal from the stromal side; B: Arrangement of pigments and other cofactors, with the same view direction as in A; C: Side view of the PSI-LHCI super-complex from the LHCI side).



Plausible energy transfer pathways from LHCI to the PSI core (A: Overall location of pigments involved in energy transfer from LHCI to the PSI core; B-E: Pigment arrangement of 4 plausible energy transfer pathways deduced from this study).

photosynthesis research. However, the crystal structure of plant PSI-LHCI was solved to a medium resolution so far, therefore the structural basis for the high efficiency of light-harvesting, energy transfer and conversion within plant PSI remained to be elucidated.

The team led by SHEN and KUANG has been working on the structure and function of photosynthetic membrane proteins for many years. Their latest study revealed the detailed structure of plant PSI-LHCI with a total molecular mass of 600 kDa, which includes 16 subunits (12 core subunits and 4 Lhcas), 155 Chls (143 Chls a and 12 Chls b), 35 carotenoids [26 β-carotenes (BCRs), 5 luteins (Luts) and 4 violaxanthins (Vios)], 10 lipids [6 phosphatidylglycerols (PGs), 3 monogalactosyldiacylglycerols (MGDGs) and 1 digalactosyldiacylglycerol (DGDG)], 3 Fe_4S_4 clusters, 2 phylloquinones and several water molecules.

Based on the structure resolved, the chlorophyll a and b were differentiated in the 4 Lhca subunits for the first time, and the location and geometrical arrangement of each pigment were revolved, yielding a new pigment network of LHCI. Furthermore, the structure and organization of special chlorophylls - red Chls, in LHCI, were revealed, and 4 plausible energy transfer pathways from LHCI to the PSI core complex were deduced. In addition, detailed differences among the 4 Lhca subunits and their interactions, and the interactions between Lhca subunits and PSI core subunits, were elucidated.

This study provided a solid structural basis for understanding the highly efficient energy transfer within the PSI-LHCI super-complex, and thus will be a big step forward toward revealing the mechanisms of photosynthesis. The principles gained from the natural photosynthesis may prove useful for developing highly efficient solar energy utilization systems, which is important for fulfilling the increasing demand for energy as well as for solving the problems of food security and environment.

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