Photosystem I in Arabidopsis Thaliana

Part A. Photosystem I in Arabidopsis Thaliana

Arabidopsis thaliana is a small flowering plant related to the cabbage and mustard plants. Like all plants, Arabidopsis undergoes photosynthesis to generate oxygen and energy through electron flow. This electron flow begins in photosystem II and then travels to photosystem I. In photosystem II, water is oxidized and ADP is reduced to ATP. Specifically, in photosystem I, energy from sunlight is used to facilitate electron transfer in the center of the protein. Plastocyanin is oxidized and NADP$^+$ is reduced. This transfer ultimately leads to production of the high-energy molecule NADH$^+$. Overall, photosystem I transports electrons from the inner lumen to the outside stroma for energy conversion.\(^1\)

Part B. The Structure of the Active Site

The active site contains the chlorophyll ligands, the sulfur-iron clusters, the beta-carotene, and the phylloquinones.\(^1\) The beta-carotene is located close to the P700 to help with the electron transfer during the reaction. The essential structure of the active site is P700, a special pair of chlorophylls. A bond distance between these two molecules can be around 10 Å.\(^2\) The parallel arrangement shown in Figure 1 allow for the molecules to fit more densely inside of the structure and facilitate electron transfer.
Figure 1. Two perspectives of the P700 photoactive site of PDB 2O01. Figure A shows the two chlorophylls of the special pair P700. Figure B shows P700 surrounded by a large number of chlorophylls and in proximity to the sulfur-iron clusters (shown in orange and yellow).

Part C. Electron Flow in Photosystem I

The electron flow in photosystem I (PSI) of Arabidopsis thaliana starts with the acquisition of two electrons from photosystem II (Scheme 1). These two initial electrons are carried by a copper-containing protein called plastocyanin to the P700 site, a chlorophyll dimer. Although the electrons were previously excited in photosystem II, they lose all of their excitation energy during this transition, so they must be excited again. A photon of light is directed to the active site through chlorophyll and carotenoid molecules that act as antennas to funnel photons quickly to P700, which is named after its ability to absorb light at 700 nm. When a photon hits the P700 site, the electrons become excited and are concentrated by one of the chlorophylls. Phylloquinone oxidizes the chlorophyll to receive the electrons, and then reduces an iron-sulfur reaction center to pass off the electrons. Three iron-sulfur centers exist to direct the electrons to the ferredoxin complex. The last iron-sulfur center reduces ferredoxin to transfer the electrons. Ferredoxin transports the electrons to the NADP$^+$ reductase, where NADP$^+$ is reduced to NADPH, the energy-storing molecule.
Part D. The P700 Active Site

The photoactive site in photosystem I is a dimer of two identical, overlapping chlorophylls separated by a small gap. This pair of chlorophylls is referred to as a “special pair” because they work together to capture light energy and begin the process of converting this energy to sugar. One chlorophyll is hydrogen-bonded to the protein, and is therefore stabilized.
This hydrogen bonding also lowers the energy of this chlorophyll of the dimer.\textsuperscript{3} The other chlorophyll holds the unpaired electron, which is used for redox reactions.\textsuperscript{3} These two chlorophylls are observed to act like a heterojunction, where a gap forms on the hydrogen-bonded chlorophyll and the electron is excited on the non-bonded chlorophyll. As a result, this “special pair” is one of the strongest biological reducing agents.\textsuperscript{1} This photoactive site helps makes photosystem I demonstrate almost 100\% quantum efficiency in its use of light for energy.\textsuperscript{1} Figure 2 shows a model of one chlorophyll of the photoactive site.

\textbf{Figure 2.} Stick, ball-and-stick, and space-filling models of the special pair P700. The planes of the two chlorophylls are separated by an average distance of about 3.6 Å.
References

