Harvesting light

Reaction centres and antennae

The light absorbing pigments are a mixture of chlorophylls and accessory pigments, like carotenoids and xanthophyll. Photosynthetic pigments are normally bound to proteins. These hold them in position, so they face the right direction to trap light and to transfer energy between each other.

Light energy that has been absorbed by a pigment is used to transfer an electron. The pigment and the associated proteins involved in this electron transfer form a reaction centre.

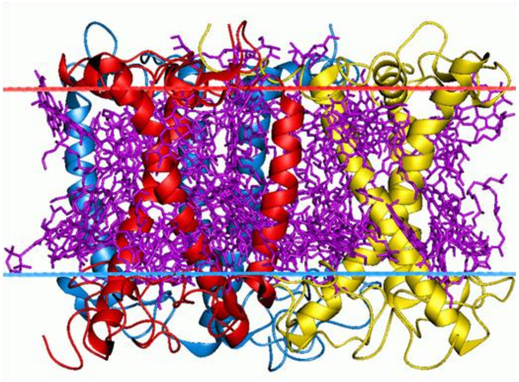

Figure 1 The structure of a light harvesting antenna.

Between about 100 to 5000 pigment molecules (depending on the type of plant) are arranged together in an 'antenna', which is used to harvest light and transfer the light energy to a single reaction centre. This ensures that there is a high rate of electron transfer in every reaction centre, even at lower light intensities.

Energy transfer through the antenna pigments must therefore be very efficient to avoid large energy losses. This is the job of the structural proteins. They hold the pigments close together in precise orientations, so that the molecular geometry is exactly right to ensure high energy transfer efficiency.

The excited electrons produced are passed to the electron transport chains of the Z-scheme.

Shade plants and sun plants

The light harvesting antennae vary in their structure to adapt plants to their environment. Plants which are adapted to grow in the shade, in low light conditions, generally have a larger number of antenna pigments transferring energy to each reaction centre. Plants found in full sunlight will tend to have antennae with fewer pigments. If the amount of light that is absorbed by plants exceeds their capacity for electron transfer, part of the photosynthetic electron transfer chain can be shut down, in a process called photoinhibition, and the excess light energy is converted to heat and dissipated.

Reaction centres: two photosystems and the Z-scheme

There are two kinds of reaction centres. The chlorophyll in photosynthetic organisms which generate oxygen is found in thylakoids, associated with antenna proteins which feed energy into PSII or PSI (photosystem II or photosystem I) (See *Photosynthesis*).

PSII is where water is split (photolysis) and oxygen is evolved. Light energy from the antenna causes an electron to gain energy and become excited. The reaction centre PSII undergoes photoionisation and loses the electron (is oxidised). This removes an electron from tyrosine, an amino acid in the surrounding protein. This in turn obtains a replacement electron from a water splitting complex, where water molecules are used to liberate oxygen molecules, hydrogen ions and electrons in photolysis.

The electrons from PSII flow to free electron carrier molecules, plastoquinone (PQ), from where they are transferred to a membrane bound cytochrome complex. Here they are used in proton pumps in the process of chemiosmosis (see below) to provide the energy needed to phosphorylate ATP (adenosine diphosphate) to give ATP (adenosine triphosphate) which can be used in carbon fixation in the light independent reactions of photosynthesis.

Electrons are transferred to plastocyanin (PC) and then into PSI to replace the electrons lost in photoionisation. In PSI, electrons are transferred to ferredoxin (Fd) and used to reduce $NADP^+$ (nicotinamide adenosine dinucleotide phosphate). Reduced NADP (NADPH) is used in carbon fixation.

Chemiosmosis and ATP synthesis

The components of the Z-scheme of non-cyclic phosphorylation – the chlorophyll molecules and proteins of the reaction centres (including enzymes), the electron acceptors and the electron transport chains – are found in the thylakoid membranes of the chloroplast. Electrons passing through the transport chain provide energy to pump H^+ ions from the stroma, across the thylakoid membrane into the thylakoid compartment. H^+ ions are more concentrated in the thylakoid compartment than in the stroma. We say there is an electrochemical gradient. H^+ ions diffuse from the high to the low regions of concentration. This drives the production of ATP.

The net effect of non-cyclic phosphorylation is to pass electrons from water to NADP. The energy released enables the production of ATP.

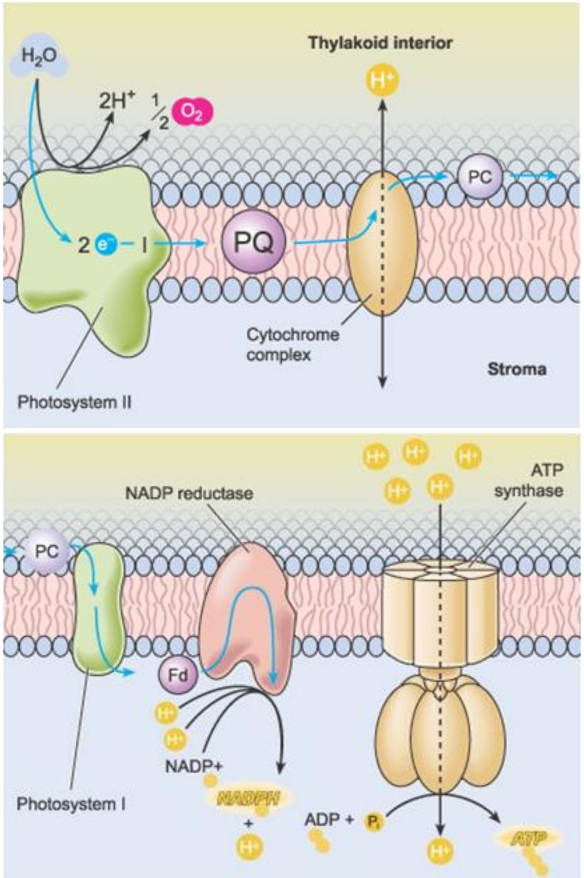

Figure 2 Chemiosmosis as it operates in photophosphorylation within a chloroplast.

Key: PQ = plastiquinone; PC = plastocyanin;

Fd = ferredoxin

Finding out

Pigments and dyes contain chromophores.

What is a chromopohore?

What is the difference between a pigment and a dye?