Follow electrons from water

The light-dependent stage uses thylakoid membranes and the thylakoid space. Light energy drives production of ATP and reduced NADP for the Calvin cycle.

1. NON-CYCLIC ELECTRON FLOW



Arrows track electrons, not proton movement. PSII acts before PSI; their numbers reflect discovery order. Carrier details are simplified.

2. PHOTOACTIVATE CHLOROPHYLL

Absorbed light energy excites reaction-centre electrons in photosystem II (PSII). Electrons pass to an acceptor and along carriers. Energy released during transfer supports proton pumping. Light excites electrons again in photosystem I (PSI).

3. REPLACE ELECTRONS BY PHOTOLYSIS

$$2H_2O \rightarrow 4H^+ + 4e^- + O_2$$

The oxygen-evolving complex associated with PSII catalyses water splitting. Electrons replace those lost by PSII, protons enter the thylakoid space, and oxygen is released. The oxygen comes from water, not carbon dioxide.

4. REDUCE NADP

After PSI, electrons are transferred to NADP. Together with a proton from the stroma, they form reduced NADP (NADPH), supplying reducing power for the Calvin cycle.

Photosystems, water splitting and NADP reduction: OpenStax, Biology 2e 8.2.
Electron transfer and photochemistry: Cooper, The Cell, Photosynthesis.

Scope: Cambridge Biology 9700, section 13.1, outcomes 2-3 and 7-10, pp. 35-36.

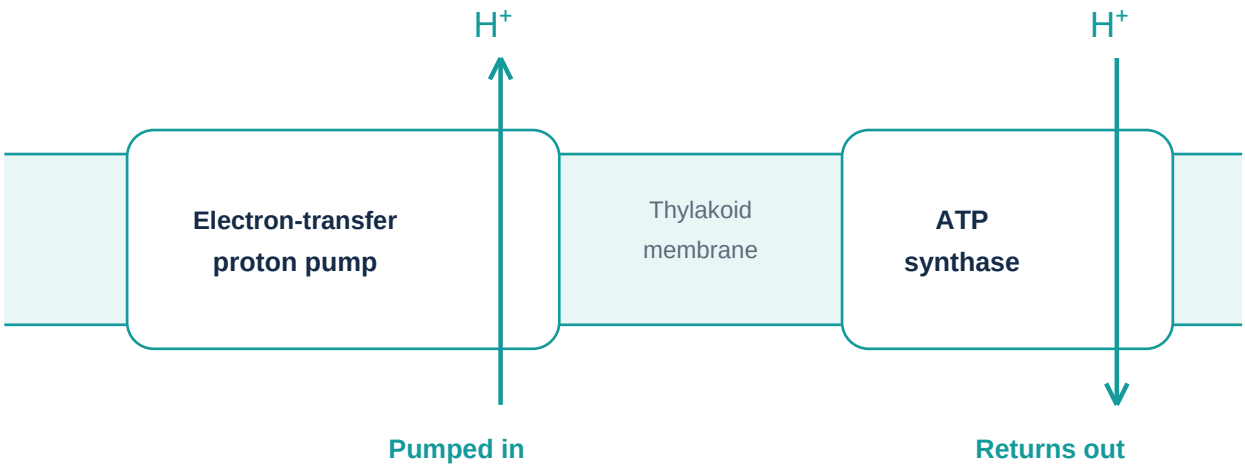
Use a proton gradient to make ATP

Photophosphorylation is ATP synthesis driven by light. Chemiosmosis couples proton flow through ATP synthase to phosphorylation of ADP.

1. KEEP THE TWO SIDES DISTINCT

THYLAKOID SPACE (LUMEN)

Higher proton concentration; lower pH



STROMA

$ADP + P_i \rightarrow ATP$

Arrows show proton flow only. The membrane is normally poorly permeable to protons, allowing the gradient to be maintained.

2. BUILD THE GRADIENT

Electron transport provides energy to move protons from the stroma into the lumen. Photolysis adds protons to the lumen, while NADP reduction consumes stromal protons. Together these processes help establish an electrochemical gradient.

3. HARNESS RETURN FLOW

Protons move down this gradient from lumen to stroma by facilitated diffusion through ATP synthase. The released energy drives ATP formation on the stromal side. Electrons do not flow through ATP synthase.

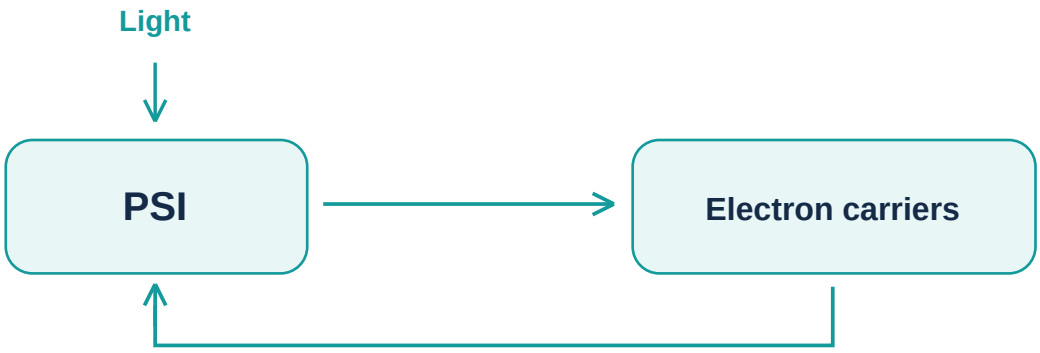
Thylakoid compartments and proton coupling: Alberts et al., Chloroplasts.
ATP synthase and photophosphorylation: Cooper, The Cell, Photosynthesis.

Scope: Cambridge Biology 9700, section 13.1, outcomes 2-3 and 7-10, pp. 35-36.

Two routes, different outputs

Both routes use light-excited electrons and electron transport to support ATP synthesis. Only non-cyclic flow transfers electrons from water to NADP.

1. CYCLIC FLOW RECYCLES ELECTRONS



Excited electrons return to PSI via carriers. This supports extra ATP production without net NADP reduction or water splitting.

2. COMPARE PHOTOPHOSPHORYLATION

Feature	Non-cyclic	Cyclic
Photosystems	PSII and PSI	PSI only
Electron destination	NADP	Return to PSI
ATP synthesised	Yes	Yes
Reduced NADP formed	Yes	No net formation
Oxygen released	Yes, from water	No

3. LINK TO THE CALVIN CYCLE

ATP supplies energy and reduced NADP supplies reducing power for forming organic molecules in the stroma. ADP, inorganic phosphate and NADP can be reused by the light-dependent stage. These reactions do not directly fix carbon dioxide or make glucose.

Cyclic electron flow and additional ATP: Alberts et al., Chloroplasts.
Light-reaction outputs and Calvin-cycle link: Cooper, The Cell, Photosynthesis.

Scope: Cambridge Biology 9700, section 13.1, outcomes 2-3 and 7-10, pp. 35-36.