Cyclic electron flow – measurement and proposed proton-uncoupled pathway

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Experimental results. Cyclic electron transport around PSI was measured as difference between PSI electron flow (J_I, calculated from the post-illumination rate of 950 (810) nm transmittance change) and electron flow for PGA reduction (J_C, calculated from the net CO_2 uptake rate considering photosynthesis and photorespiration), $J_{Cyc} = J_I - J_C$.

Cyclic electron transport around PSI (CET) is absent (or very slow) during light limitation, but CET is fast during light-saturated (and CO_2-limited) photosynthesis. CET is also fast when PSI is excited by far-red light (FRL), but electron flow is rate-limited due to inactivation of ferredoxin-NADP reductase or by very low CO_2 and O_2 concentrations. CET donor pool on PSI acceptor side contains up to 4 e^- per PSI. CET acceptor on PSI donor side is not $P700^+$, but an electron carrier with more negative redox potential, most likely Cyt f. The first e^- is transferred with the rate constant of 30 s^{-1}, but the following e^- with the rate constant of 10 s^{-1}.

Interpretation. The absence of correlation between CET and photosynthetic rate suggests that CET is not always important for the maintenance of the necessary ATP/NADPH stoichiometry. Rather, under excess light CET is an energy-dissipating process protecting the photosynthetic machinery from the formation of reactive oxygen species under excess irradiation.

The fact that $P700^+$ is not an immediate CET acceptor rules out the possibility that the measured electron flow from PSI acceptor to its donor side is charge recombination. The following functional pathway of CET is suggested: Fd (or PSI-bound FeS e^- carriers) → FNR (?) → Cyt c_n → Cyt b_h → Cyt b_l → Rieske FeS → Cyt f → PC → P700 → (bound FeS) → Fd. The proton-uncoupled CET pathway activates when PQH_2 oxidation is restricted in the presence of high transthylakoid ΔpH. Then the absence of oxidized PQ in the inter-monomer quinone exchange cavity prevents reduction of PQ at the n-site of the Cyt b_6f complex, by this making CET uncoupled from H^+ translocation.

Not CET, but rather electron transport to alternative electron acceptors, mainly for nitrite and O_2 reduction, is the dominant mechanism for the precise control of ATP/NADPH stoichiometric ratio during photosynthesis.