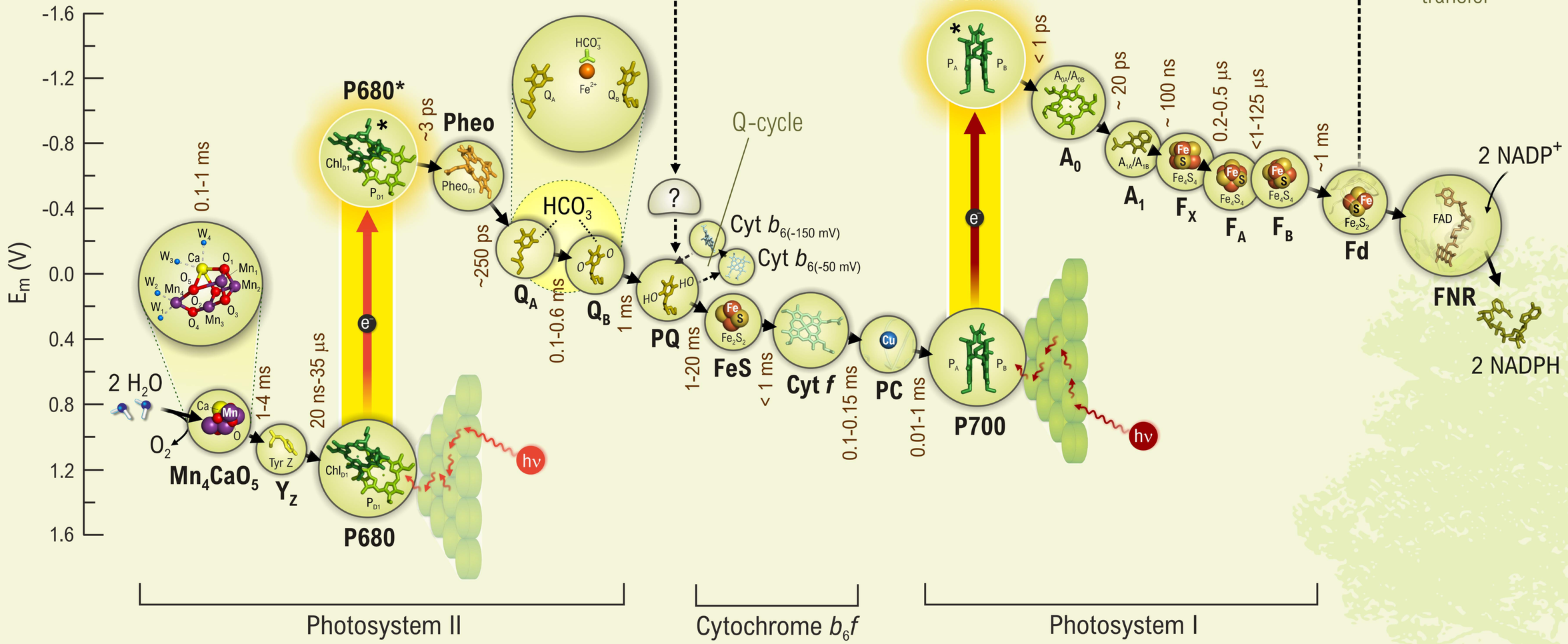
Best wishes for your research
Govindjee

Z-Scheme of Electron Transport in Photosynthesis



The Z-scheme: A diagram for linear electron transfer from water to $NADP^+$, plotted according to midpoint redox potentials at pH 7.0 (E_m, 7), based partly on a similar poster, printed horizontally in 2017. For a historical review, see [1]; for teaching basic versions of this scheme, see [2, 3]. In the diagram, shown in this poster, we have not included proton transport and the consequent formation of ATP; for further information on this part and all other aspects of photosynthesis, see [4, 5]. Send questions and comments to Govindjee (gov@illinois.edu).

References: **[1]** Govindjee, D. Shevela, L.O. Björn (2017) Evolution of the Z-Scheme of Photosynthesis. *Photosynth. Res.* 133: 5-15; **[2]** P.K. Mohapatra, N.R. Singh (2015) Teaching the Z-Scheme of electron transport in photosynthesis: a perspective. *Photosynth. Res.* 123: 105-114; **[3]** S. Jaiswal, M. Bansal, S. Roy, A. Bharati, B. Padhi (2017) Electron flow from water to $NADP^+$ with students acting as molecules in the chain: a Z-scheme drama in a classroom. *Photosynth. Res.* 131: 351-359; **[4]** R.E. Blankenship (2014) Molecular Mechanisms of Photosynthesis, 2nd Edition, Wiley/Blackwell; **[5]** D. Shevela, L.O. Björn, Govindjee (2018) Photosynthesis: Solar Energy for Life, World Scientific Publishing.

Abbreviations: Mn_4CaO_5, manganese-calcium-oxygen complex; Y_Z, redox-active tyrosine (Tyr Z); P680 and P700, primary electron donors of Photosystem II (PSII) and Photosystem I (PSI), 680 and 700 are wavelengths, in nanometers (nm), of the first excited states of special reaction center Chl *a* molecules. P680 includes an ensemble of Chl a molecules (P_{D1}, P_{D2}, Chl_{D1}, and Chl_{D2}, but only P_{D1} and Chl_{D1} are shown). P700 is a pair of Chls *a*, P_A and P_B); P680*and P700*, first singlet excited states of P680 and P700 (the first step after excitation is charge separation, conversion of excitonic energy into chemical energy); Pheo, pheophytin, primary electron acceptor of PSII, $Pheo_{D1}$; Q_A and Q_B, primary and secondary quinone (plastoquinone) electron acceptors (Q_A is tightly bound, whereas Q_B is loosely bound; the latter accepts two electrons and two protons; bicarbonate ion (HCO_3^-), bound to non-heme iron, located between Q_A and Q_B, plays an essential role here); PQ, mobile plastoquinone molecules; FeS, Rieske iron-sulfur protein; Cyt *f*, cytochrome *f*; PC, mobile copper protein, plastocyanin; A_0, primary electron acceptor of PSI (a special pair of Chl *a* molecules, A_{0A} and A_{0B}); A_1, pair of phylloquinone (vitamin K) molecules, A_{1A} and A_{1B}; F_X, F_A, and F_B, bound iron-sulfur clusters of PSI; Fd, ferredoxin; FNR, ferredoxin-NADP oxidoreductase.

Notes: The above representation is not meant to imply that PSII, Cyt b_6f complex, and PSI are necessary in 1:1:1 ratio. These may be physically distant from each other in the thylakoid membrane, their functional connection is accomplished through diffusible PQ (between PSII and Cyt b_6f) or PC (between Cyt b_6f and PSI). Several cyclic electron pathways, around PSI, have been suggested; for simplicity we show here only one, which may involve one or more proteins. All shown cofactors were generated using coordinates from available PDB entries: 3ARC (for cofactors of PSII and for PQ), 1VF5 (for cofactors of Cyt b_6f), 2GIM (for PC), 4Y28 (for cofactors of PSI), 2MH7 (for Fd), and 1SM4 (for FNR and NADPH). Phytyl tails of Chls and Pheo, and the isoprenyl chains of the quinones have been cut for clarity.

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