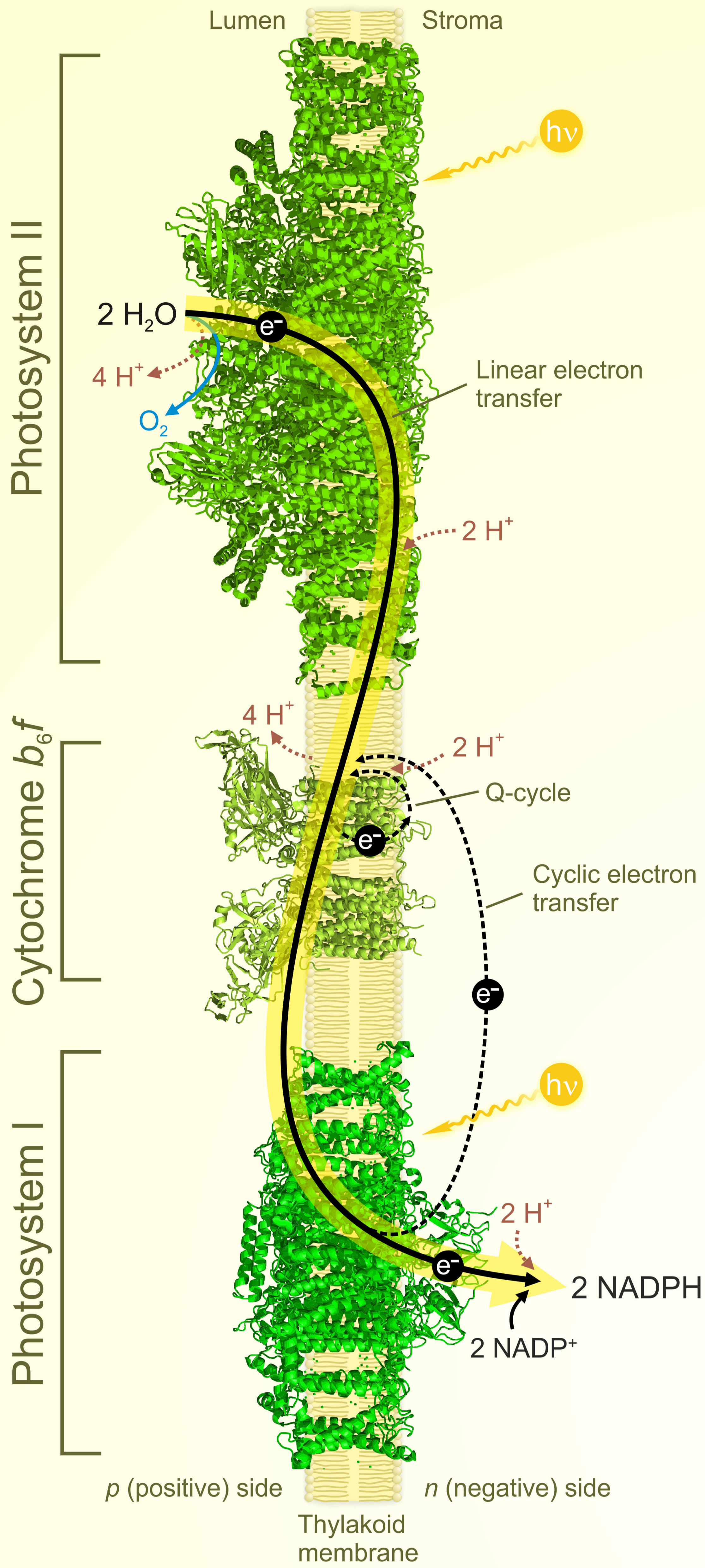


Z-Scheme of Electron Transport in Photosynthesis



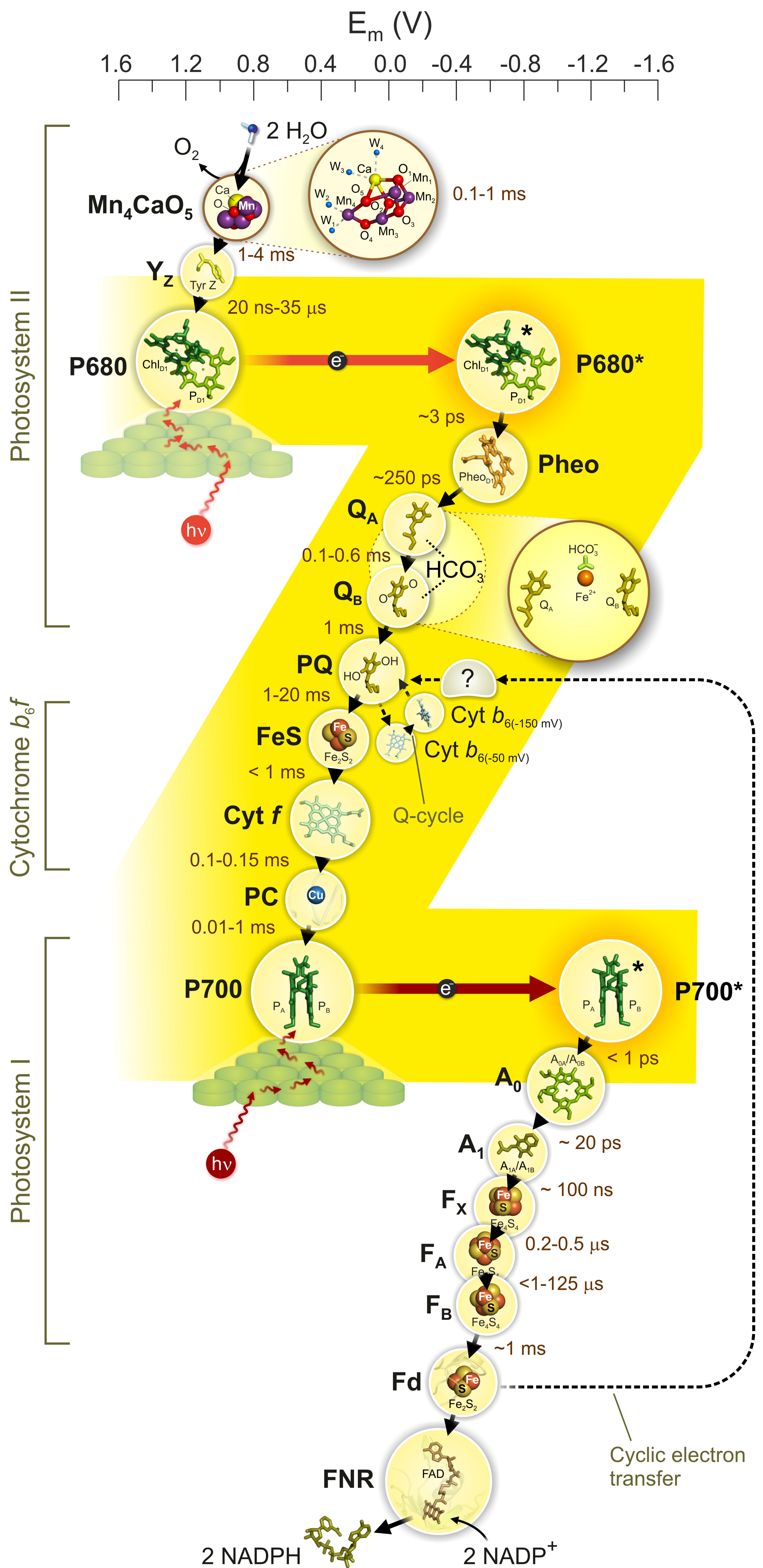
The Z-scheme
 A diagram for linear electron transfer from water to NADP⁺ plotted horizontally according to midpoint redox potentials at pH 7.0 (E_m , 7). For a historical review, see [1]. For further information, see [2]. For an earlier version of this scheme, see [3]. Send questions and comments to Govindjee (gov@illinois.edu).

[1] Govindjee, D. Shevela, L.O. Björn (2017) Evolution of the Z-Scheme of Photosynthesis. *Photosynth. Res.* 133: 5-15.
 [2] R.E. Blankenship (2014) *Molecular Mechanisms of Photosynthesis*, 2nd Edition, Wiley/Blackwell.
 [3] S. Demeter, Govindjee (1989) Thermoluminescence in plants. *Physiol. Plant.* 75: 121-130.

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 absorption maxima 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, which 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 phyloquinone (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
 All shown cofactors were generated using coordinates from available PDB entries: 3ARC (for cofactors of PSII and for PQ), 1VF5 (for cofactors of Cyt *b₆f*), 2GIM (for PC), 4Y28 (for cofactors of PSI), 2MH7 (for Fd), and 1SM4 (for FNR and NADPH). Phytol tails of Chls and Pheo, and the isoprenyl chains of the quinones have been cut for clarity.

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The above representation is not meant to imply that PSII, Cyt *b₆f* complex, and PSI are necessarily in 1:1:1 ratio. Further, these may be physically distant from each other in the thylakoid membrane, their functional connection accomplished by way of diffusible PQ (between PSII and Cyt *b₆f*) or PC (between Cyt *b₆f* and PSI). Several cyclic electron pathways, around PSI, have been suggested; for simplicity we present here only one, which may involve one or more proteins, shown with a question mark.