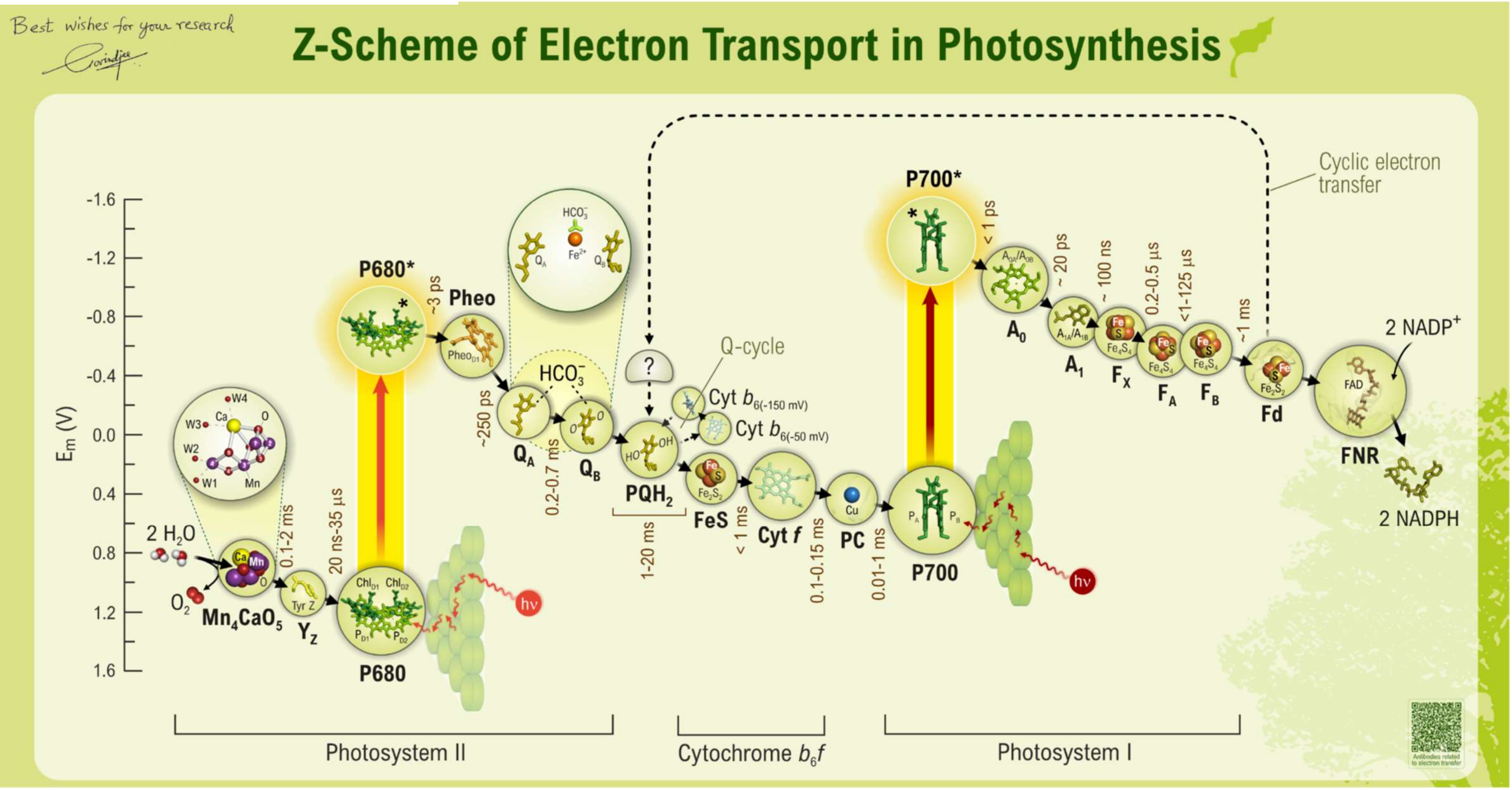
Periodic Table of the Elements

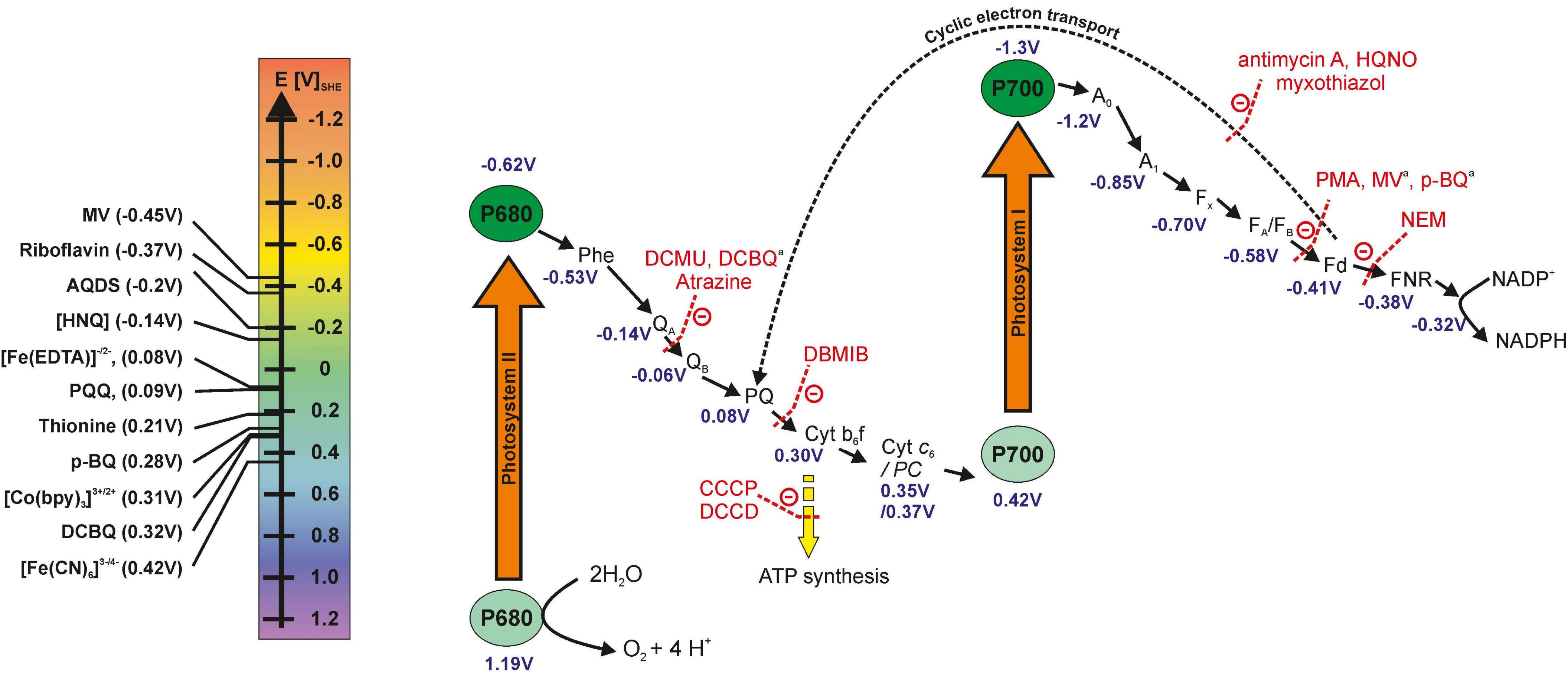
1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 **H** Hydrogen 1.008																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012											5 **B** Boron 10.811	6 **C** Carbon 12.011	7 **N** Nitrogen 14.007	8 **O** Oxygen 15.999	9 **F** Fluorine 18.998	10 **Ne** Neon 20.180
11 **Na** Sodium 22.990	12 **Mg** Magnesium 24.305											13 **Al** Aluminum 26.982	14 **Si** Silicon 28.086	15 **P** Phosphorus 30.974	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.948
19 **K** Potassium 39.098	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.956	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.942	24 **Cr** Chromium 51.996	25 **Mn** Manganese 54.938	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933	28 **Ni** Nickel 58.693	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.631	33 **As** Arsenic 74.922	34 **Se** Selenium 78.971	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.798
37 **Rb** Rubidium 85.468	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.906	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.906	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium 98.907	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.906	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.868	48 **Cd** Cadmium 112.414	49 **In** Indium 114.818	50 **Sn** Tin 118.711	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.6	53 **I** Iodine 126.904	54 **Xe** Xenon 131.294
55 **Cs** Cesium 132.905	56 **Ba** Barium 137.328	57-71	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.948	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.085	79 **Au** Gold 196.967	80 **Hg** Mercury 200.592	81 **Tl** Thallium 204.383	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.980	84 **Po** Polonium [208.982]	85 **At** Astatine 209.987	86 **Rn** Radon 222.018
87 **Fr** Francium 223.020	88 **Ra** Radium 226.025	89-103	104 **Rf** Rutherfordium [261]	105 **Db** Dubnium [262]	106 **Sg** Seaborgium [266]	107 **Bh** Bohrium [264]	108 **Hs** Hassium [269]	109 **Mt** Meitnerium [278]	110 **Ds** Darmstadtium [281]	111 **Rg** Roentgenium [280]	112 **Cn** Copernicium [285]	113 **Nh** Nihonium [286]	114 **Fl** Flerovium [289]	115 **Mc** Moscovium [289]	116 **Lv** Livermorium [293]	117 **Ts** Tennessine [294]	118 **Og** Oganesson [294]

Lanthanide Series	57 **La** Lanthanum 138.905	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.908	60 **Nd** Neodymium 144.243	61 **Pm** Promethium 144.913	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.925	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.930	68 **Er** Erbium 167.259	69 **Tm** Thulium 168.934	70 **Yb** Ytterbium 173.055	71 **Lu** Lutetium 174.967
Actinide Series	89 **Ac** Actinium 227.028	90 **Th** Thorium 232.038	91 **Pa** Protactinium 231.036	92 **U** Uranium 238.029	93 **Np** Neptunium 237.048	94 **Pu** Plutonium 244.064	95 **Am** Americium 243.061	96 **Cm** Curium 247.070	97 **Bk** Berkelium 247.070	98 **Cf** Californium 251.080	99 **Es** Einsteinium [254]	100 **Fm** Fermium 257.095	101 **Md** Mendelevium 258.1	102 **No** Nobelium 259.101	103 **Lr** Lawrencium [262]

Photosystem Z-Scheme



Photosystem Z-Scheme

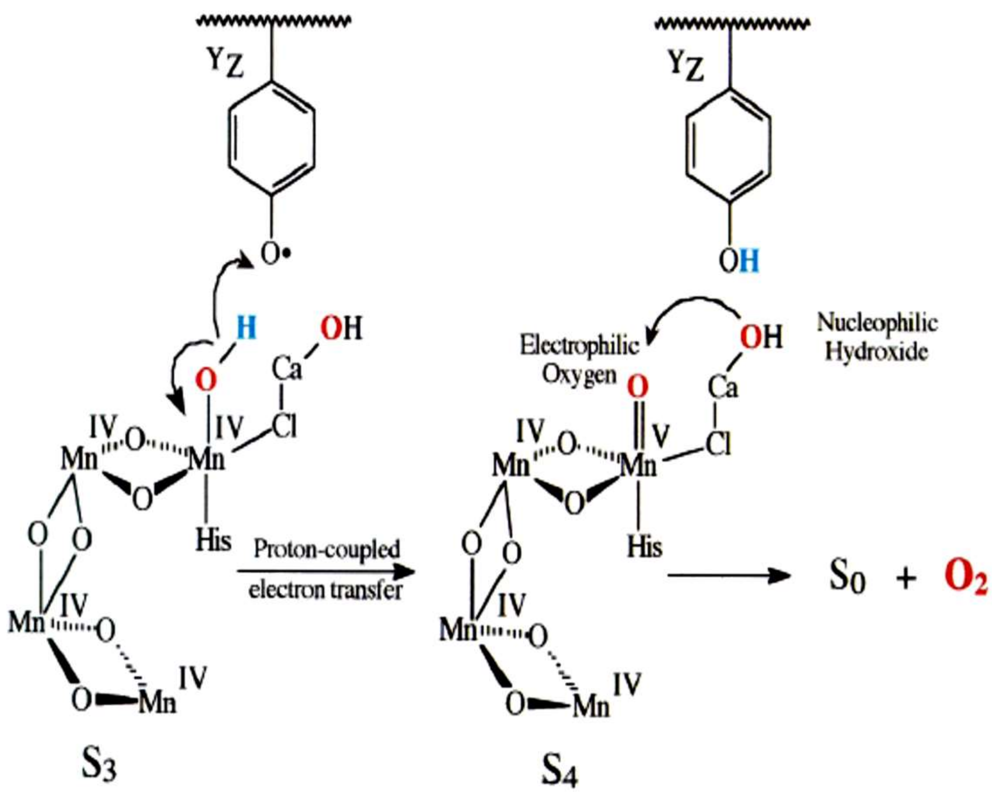


https://doi.org/10.3389/fmicb.2019.00866

Z-scheme of the photosynthetic electron transport chain (do not memorize please)

- the electron transfer inhibitors at specific sites and potential mediator molecules that could be used for withdrawing electrons.
- The redox potentials of photosystem I and II subunits are diverse in the literature and the values reported here are obtained from the following sources (Bottin and Lagoutte, 1992; Semenov et al., 2000; Cassan et al., 2005; Allakhverdiev et al., 2010, 2011; Kothe et al., 2013; Caffarri et al., 2014; Schuurmans et al., 2014).
- The redox potentials of mediators are taken for neutral aqueous conditions from Nivinskas et al. (2002),Schuurmans et al. (2014), Lai et al. (2016), and Emahi et al. (2017).
- **Abbreviations:** AQDS, 9,10-anthraquinone-2,6-disulfonate; CCCP, carbonyl cyanide m-chlorophenylhydrazone; DCMU, 3-(3,4-Dichlorophenyl)-1,1-dimethyl urea; DCBQ, 2,6-Dichloro-1,4-benzoquinone; DBMIB, 2,5-dibromo-3-methyl-6-isopropyl-P-benzoquinone; DCCD, N-N'-dicyclohexylcarbodiimide; HNQ, 2-hydroxy-1,4-naphthoquinone; HQNO, 2-heptyl-4-hydroxyquinoline n-oxide; MV, methyl-viologen; NEM, N-ethylmaleimide; PMA, phenylmercuric acetate; p-BQ, p-benzoquinone. aDCBQ, MV and p-BQ are performing more as competitors for the natural electron acceptor rather than inhibitors that bind and block the activities of specific sites (Ravenel et al., 1994).

The role of a distal tyrosine radical in electron transfer



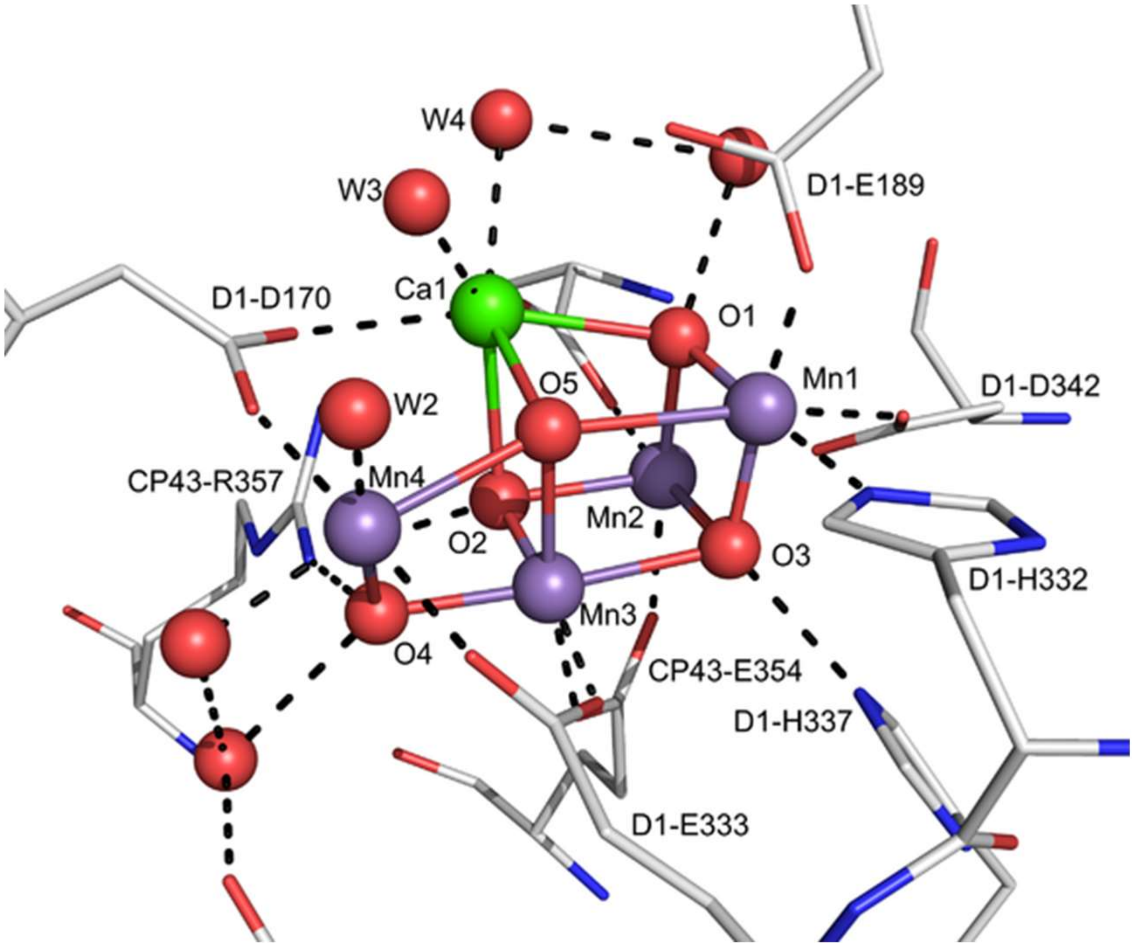
Why nature Chose Manganese in OEC?

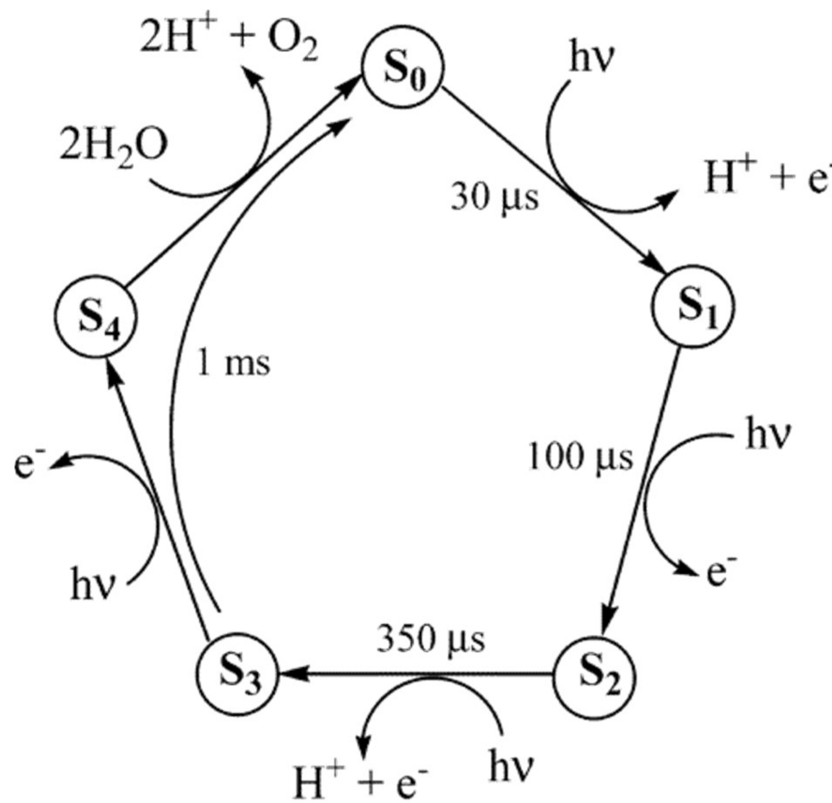
- ✓ highest oxidation state (Mn^{VII}), and the largest number of oxidation states (at least among those involved in plants)
- ✓ Mn carry five charges (from Mn^{II} to Mn^{VII}).
- ✓ Mn participates in many disproportionation reactions between two or multiple Mn ions.
- ✓ The unique redox chemistry of Mn makes it an ideal for building the OEC, in which accumulation of four charges is needed to oxidize two water molecules to molecular oxygen.

The active site of OEC: Oxygen Evolving Centre

Chem. Rev. ***2004****, 104, 3981–4026*

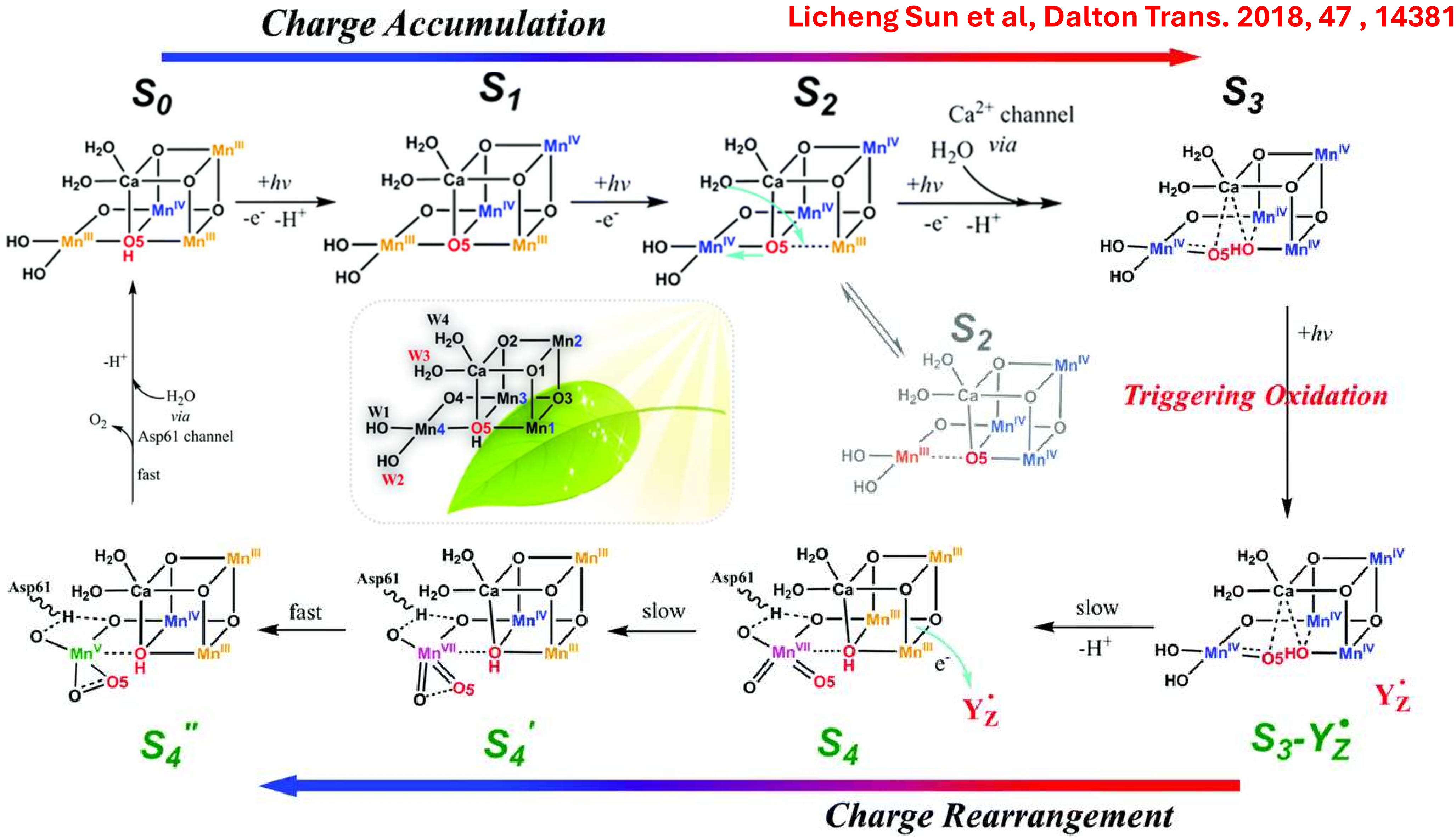
Science **2004**, *303*, 1831



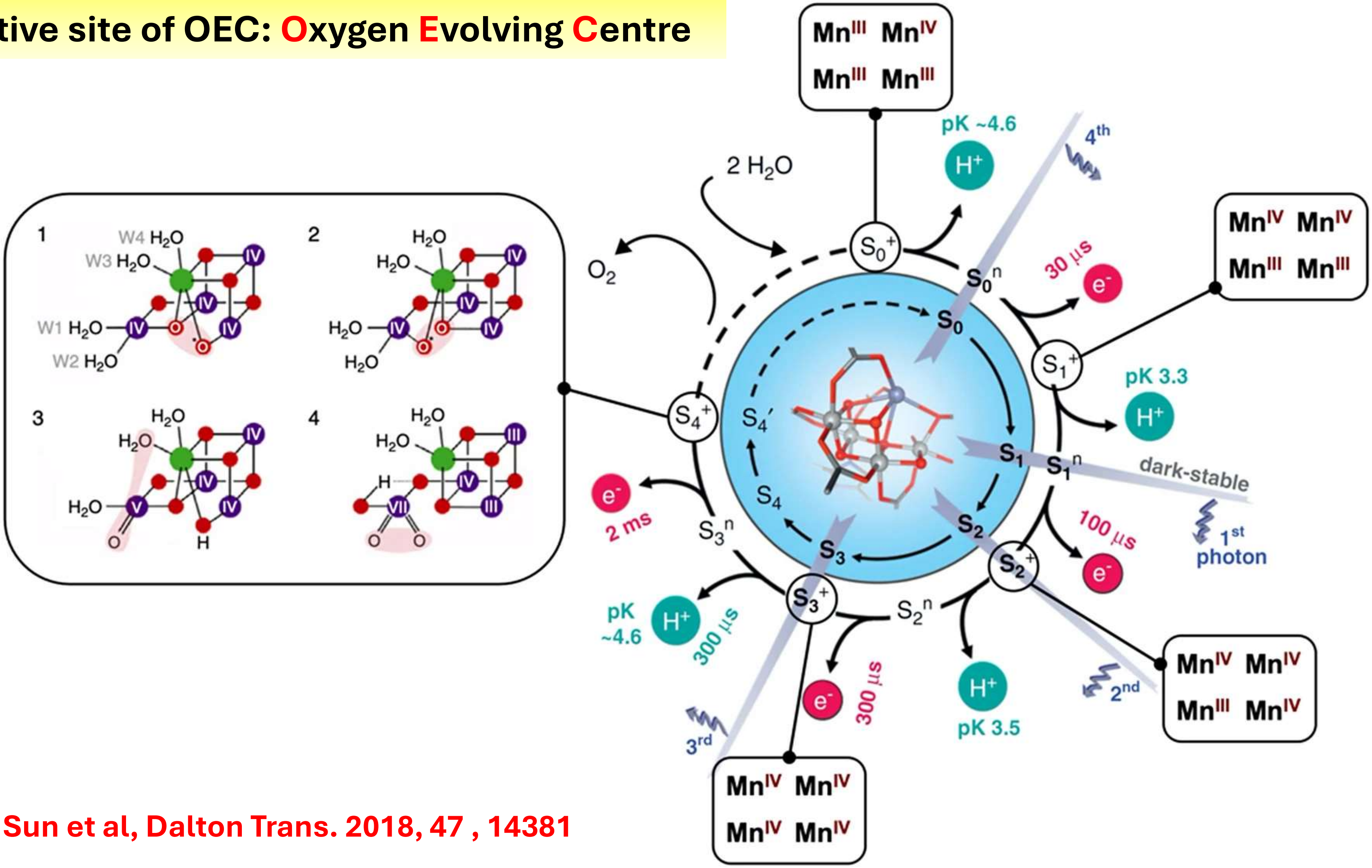


$$2H_2O \Longrightarrow O_2 + 4e^- + 4H^+$$

Licheng Sun et al, Dalton Trans. 2018, 47 , 14381



The active site of OEC: Oxygen Evolving Centre



Licheng Sun et al, Dalton Trans. 2018, 47 , 14381

- When the electron is rapidly transferred from P680* to 'pheophytin *a*', a positive charge is formed on the special pair, $P680^+$. $P680^+$ is an incredibly strong oxidant which extracts electrons from a tyrosine close to it which in turn leads to extraction of proton and electron from water molecules bound at the manganese center.

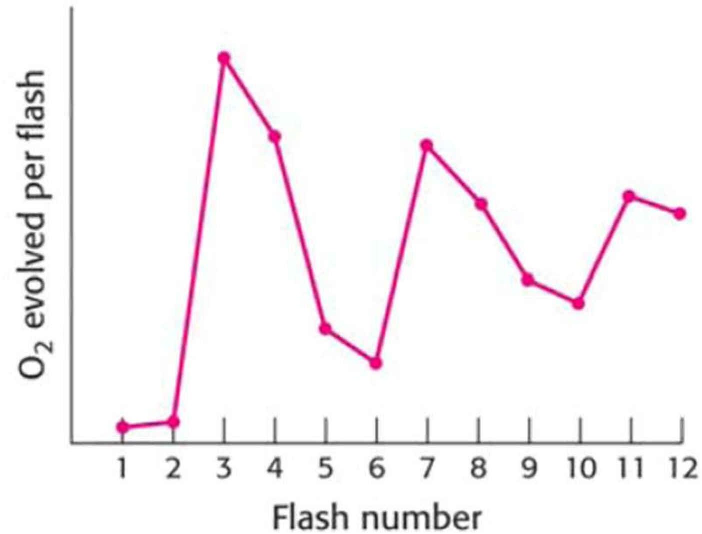
- The structure of this manganese center includes 4 Manganese ions, a calcium ion, a chloride ion, and a tyrosine radical. Manganese is the core of this redox center because it has four stable oxidation states (Mn^{2+}, Mn^{3+},Mn^{4+} and Mn^{5+}) and coordinates tightly to oxygen containing species.

- Each time the P680 is excited and an electron is kicked out, the positively charged special pair extracts an electron from the manganese center.

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

4 electrons must be transferred to two molecules of plastoquinone and water would oxidize to molecular oxygen. This requires 4 photochemical steps shown in the OEC.

When isolated chloroplasts are held in dark and then illuminated with very brief flashes of light, O_2 evolution reaches peak on the third flash and then every fourth flash. The oscillation in O_2 evolution dampens over repeated flashed and converges to an average value.



Probable Reason: *We know that the Mn-OEC exists is five different overall oxidation states numbered S_0 to S_4. One electron and a proton are removed during each photochemical step. When S_4 is attained and a O_2 molecule is released two new water molecules bind. The reason that the third pulse of light produces most O_2 is because the resting state of the OEC in the chloroplast while isolated may be S_1 not S_0*