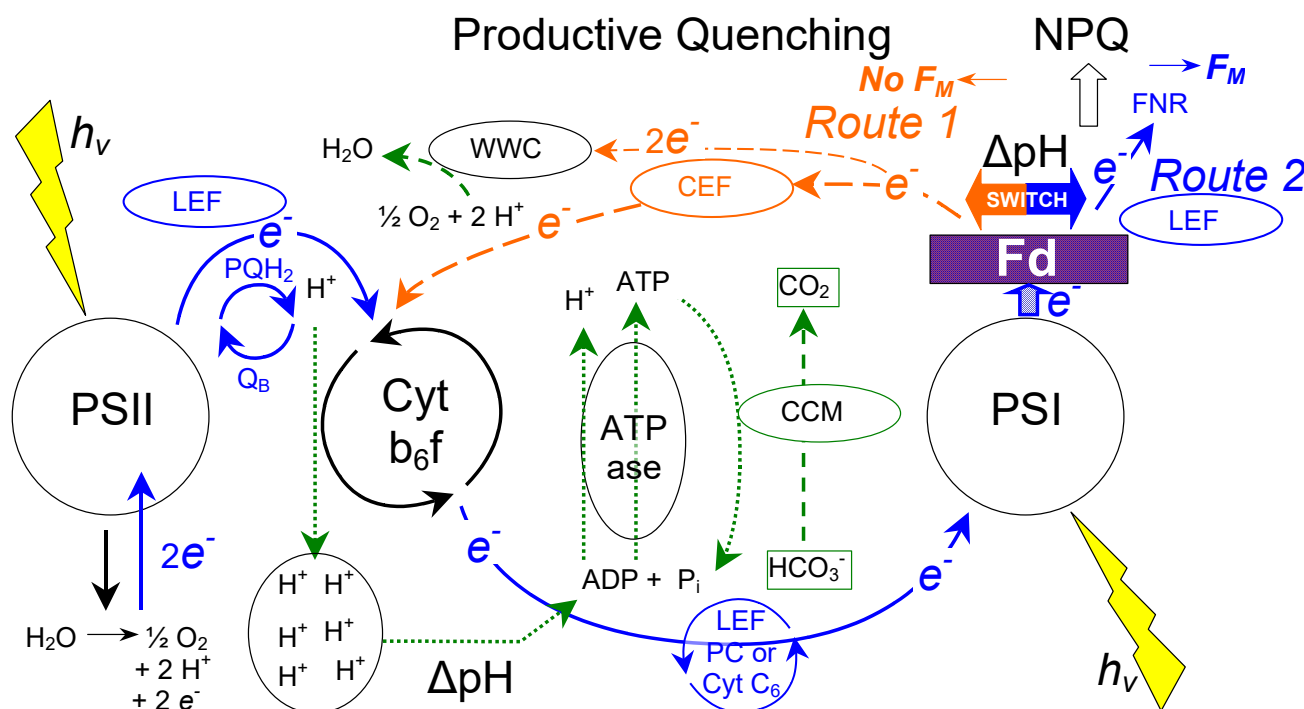


Online Resources. The missing P-step in red tide dinoflagellates: A productive quenching model for Form II RuBisCO bioenergetics. *Photosynthesis Research*. Hewes CD, Scripps Institution of Oceanography, UC San Diego, USA. chewes@ucsd.edu



Online Resource 1 Integrated Photosynthetic Energy and Carbon Flow Regulation. The interconnected pathways of electron (e^-) and proton (H^+) transport. Central to this process are the protein complexes PSII and PSI, which work in tandem with the cytochrome b_6f complex to shuttle electrons and generate a proton gradient (ΔpH). This gradient acts as a biological battery, powering ATP Synthase (ATPase) to produce ATP for the carbon concentrating mechanism (CCM) to generate CO_2 . A central ferredoxin (Fd) "switch", regulated by ΔpH , determines the routing between two distinct pathways: Route 1 (CEF), which facilitates the WWC, and the CCM and has no F_M ; or Route 2 (LEF), which leads to NADPH production, NPQ in PSII antennae and the familiar " F_M " of the OJIP signature. ATP is generated from ADP and P_i , which is subsequently consumed by the CCM to convert HCO_3^- into CO_2 , and consequently ADP and P_i recycled for ATP. Productive quenching serves as a specialized photoprotective mechanism within the CEF and WWC branch by converting "excessive" photons into production of ATP instead of NPQ

ADP: Adenosine diphosphate; ATP: Adenosine triphosphate; ATPase: ATP synthase; CCM: Carbon Concentrating Mechanism; CEF: Cyclic Electron Flow; CO_2 : Carbon dioxide; Cyt b_6f : Cytochrome b_6f complex; Cyt c_6 : Cytochrome c_6 ; ΔpH : Proton gradient; e^- : Electrons; Fd: Ferredoxin; F_M : Maximum fluorescence (produced via LEF); FNR: Ferredoxin-NADP $^+$ reductase; H^+ : Protons; H_2O : Water; HCO_3^- : Bicarbonate; $h\nu$: Light energy (photons); LEF: Linear Electron Flow; $No F_M$: State of no maximum fluorescence production (associated with CEF); NPQ: Non-Photochemical Quenching; O_2 : Oxygen; PC: Plastocyanin; P_i : Inorganic phosphate; PQH_2 : Plastoquinol; PSI: Photosystem I; PSII: Photosystem II; Q_B : Plastoquinone binding site; WWC: Water-Water Cycle