Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.27556

Tracing the molecular evolution of oxygenic photosynthesis in Archaean green-light environments

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Photosynthesis is among the most important biological innovations that enabled life to utilize the vast amount of light energy. In particular, oxygenic photosynthesis perpetually altered the Earth's environment and the evolutionary direction of life, which culminated in the emergence of organismally complex aerobic organisms. However, the early steps towards the establishment of oxygenic photosynthesis remains enigmatic. It is generally thought that first oxygenic photosynthesis evolved in cyanobacteria. Cyanobacterial photosynthesis consists of two distinct molecular complexes – reaction center and phycobilisome. These complexes have different evolutionary origins and also absorb different wavelengths of light. We recently proposed that the emergence of these two complexes was linked to the Archaean underwater light environments at different geological times, through combining numerical simulations of ancient aquatic environments, phylogenomic analyses of relevant biosynthetic pathways and growth experiments of genetically engineered cyanobacteria under reconstructed selective pressures in the Archaean [1]. Our presentation summarizes the inferred relationship between the Archaean environment and the evolutionary trajectory of cyanobacterial photosynthesis. We ultimately aim to build a general theory of photosynthesis evolution under various environments of host planets.

[1] Matsuo et al., Archaean green-light environments drove the evolution of cyanobacteria's light-harvesting system. Nature Ecology and Evolution (2025) https://doi.org/10.1038/s41559-025-02637-3

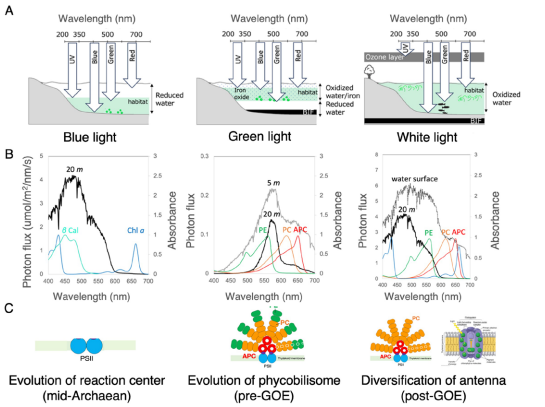

Figure: Light windows (light environments in underwater habitats) at different geological times. A, light selection in different aquatic settings. **B**, Light spectra for each light window at different water depths. **C**, associated photosynthesis systems. Reaction center = β-carotene (β Car) + chlorophyll *a* (Chl *a*); phycobilisome = phycoerythrin (PE) + phycocyanin (PC) + allophycocyanin (APC); GOE = Great Oxidation Event (~2.4 billion years ago).