Evolution of anoxygenic phototrophy

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Geological evidence strongly suggests that anoxygenic phototrophy originated during Archean time and that oxygenic photosynthesis evolved later, sometime before the rise of atmospheric oxygen around 2.3 Ga. Previous work has shown that lateral gene transfer played an important role in the evolution of phototrophy, however the timing of the acquisition of phototrophy within extant anoxygenic phototrophic clades is currently unknown.

We used comparative genomics to show that the α, β, γ classes of Proteobacteria were ancestrally aerobic. Genes encoding for the molecular machinery of aerobic respiration (bc_1 complex and cytochrome oxidase) are congruent with the phylogeny of the Proteobacteria, demonstrating that they were present in the ancestor of this clade. However genes encoding for anoxygenic phototrophy are not congurent with the phylogeny of the Proteobacteria, suggesting that it was acquired later, after aerobic respiration. This is consistent with cross-calibrated molecular clocks that place the origin of the Proteobacteria at ~2.0 Ga, well after the rise of atmospheric oxygen. Similar analyses on other anoxygenic phototrophic clades (Chloroflexi, Chlorobi, Acidobacteria, and Gemmatimonadetes) strongly suggest that they also acquired the ability to perform phototrophy via lateral gene transfer after the rise of atmospheric oxygen.

This work shows that while anoxygenic phototrophy is a very old metabolism, the extant anoxygenic phototrophs acquired this ability after the rise of atmospheric oxygen. Therefore none of these clades could have been the progenitors of phototrophy, and other unknown organisms must have been performing anoxygenic phototrophy in the Archean.