Evolution of phototrophy and carbon fixation in the Chloroflexi phylum

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The Chloroflexi are a metabolically diverse phylum of bacteria including filamentous anoxygenic phototrophs possessing the 3-hydroxypropionate bicycle for carbon fixation. It has been proposed that the Chloroflexi were among the earliest phototrophs, but recent discoveries of diverse new Chloroflexi—including aerobic and anaerobic heterotrophs, photoheterotrophs, and phototrophs using the Calvin cycle for carbon fixation—suggest a more complicated history for this phylum. We have integrated multiple approaches for understanding metabolic evolution in the Chloroflexi, including recovery of novel lineages from environmental metagenomes, phylogenetic analysis of phototrophy and carbon fixation genes, and cross-calibrated Bayesian relaxed molecular clock-based estimates for the age of Chloroflexi lineages. Our results suggest that the phototrophic Chloroflexi and the 3HP bicycle are relatively young, having evolved after the Great Oxygenation Event and the acquisition of aerobic respiration in this group. These data show that both phototrophy and carbon fixation have been exchanged within the Chloroflexi via horizontal gene transfer, including the replacement of the 3HP bicycle with the Calvin cycle in multiple lineages. Our analyses reveal a complex history of metabolic evolution in this phylum, and suggest it may never have been a substantial source of primary production prior to the evolution of oxygenic photosynthesis.