Distinct anoxygenic phototrophic lifestyles on the Greenland Ice Sheet expand the light harvesting community during microbial summer blooms on ice surfaces

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Aerobic anoxygenic photosystems, identified within specific bacterial clades, have been described recently as pivotal components influencing the carbon cycle in ocean surface waters. These pigmented bacteria exhibit diverse life strategies, transitioning from anaerobic habitats, such as the sulfur cycle in purple sulfur bacteria, to harnessing sunlight for enhanced carbon assimilation efficiency through aerobic anoxygenic photosynthesis. Remarkably, these microbial entities have been found across varied environments, including soil, rivers, hypersaline waters, and thermal springs.

In cryospheric habitats like snow and ice, phototrophic organisms are predominantly represented by eukaryotic green algae, with Cyanobacteria confined to cryoconite habitats. However, bacterial phototrophy in these environments remains poorly understood. While recent studies have described anoxygenic phototrophy in ice samples, the ecological roles of these organisms remain elusive. In this study, we hypothesize that the ice surface and cryoconites provide suitable habitats for widespread aerobic and anaerobic anoxygenic photosynthesis.

Metagenomic analysis was performed on 21 samples collected from three distinct locations in east and south Greenland, representing sub-habitats of surface ice, snow, and cryoconites. Anoxygenic photosystem II genes were identified in 9 metagenome-assembled genomes (MAGs), primarily associated with surface ice and cryoconites, with no detection in the summer snowpack. Interestingly, three of these MAGs lacked genes for carbon fixation, a characteristic feature observed in aerobic anoxygenic phototrophs. Detection of the SOX complex in specific MAGs suggested a potential role in anaerobic photosynthetic reactions. The diverse phototrophic lifestyles did not exhibit clear associations with specific sub-habitats, although the majority of MAGs exhibited higher coverage in cryoconite samples, where anoxic microlayers are known to exist. A comprehensive meta-analysis utilizing 2000 metagenomes from various environments across the globe revealed that the identified MAGs from the GrIS are unique to cryospheric
habitats.

Our findings indicate the development of distinct bacterial photosynthetic lifestyles in glacial habitats within Arctic regions. This raises intriguing questions about the ecological roles of these microorganisms in cryoconites, where they coexist with cyanobacteria, and on glacial surface ice, where they may play a crucial role in the carbon cycle akin to their contributions surface water blooms in the ocean. Our findings suggest that the observed global biological darkening of ice surfaces may be influenced by a complex microbial community comprising pigmented bacteria alongside cryospheric algae. This interaction ultimately contributes to increased runoff from glacier surfaces, driven by the resulting increase in albedo.