Project acronym: CAPTURE

Project title: Life in the shade: Diversity and distribution of chlorophyll-f containing cyanobacteria and infrared photosynthesis in the Arctic

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Discipline: Earth Sciences & Environment: Ecosystems & Biodiversity

Station(s): Czech Arctic Research Station (Svalbard/Czech Republic)

Significance of the proposed research nationally and internationally: Oxygenic photosynthesis in plants, algae and cyanobacteria converts light energy, CO2 and water into chemical energy that drives ecosystem function, carbon cycling and food webs on Earth. The majority of photosynthesis is based on chlorophyll a (chl a) which restricts its functionality to the visible range of the solar spectrum. However, recent findings have shown that some cyanobacteria use other types of chlorophylls, called chlorophyll d (chl d) (1) and chlorophyll f (chl f) (2), to expand their photosynthetic energy conversion into the near-infrared region of the solar spectrum. Chl f is the longest wavelength-chlorophyll known that still allows oxygenic photosynthesis and is widely distributed (3). It provides cyanobacteria with the selective advantage of growing in strongly shaded environments including microbial mats, soil layers and within rocks (4). The finding of chl f-driven photosynthesis in cyanobacteria is of particular importance for polar regions where energy sources are limited and cyanobacteria are an integral part of the biodiversity as key primary producers and drivers of carbon cycling in the absence of plants. The proposed research project will therefore investigate the abundance and the level of infrared photosynthesis using chl f in the Arctic for diversity, ecology and ecosystem processes. Understanding the range of photosynthesis in extreme environments such as polar deserts is also of interest for other research areas such as astrobiology as oxygenic photosynthesis is considered a signature for complex life and many otherwise potentially life-bearing planets are poor in visible light but rich in far-red/near infra-red light (5).

Previous research pertaining to the topic, how the research project links to it and is innovative:

Until recently, oxygenic photosynthesis was thought to be restricted to the visible range of the solar spectrum due to the absorption properties of its major pigment chl a. The discovery of the long-wavelength chl f (1) changed this perspective. Chl f is located in key positions in the photosynthetic machinery and enables cyanobacteria to grow in near-red light (2,6). The importance of chl f-photosynthesis in the environment is not well understood yet due to a lack of geographic coverage and availability of chl f-containing cyanobacteria strains (4). However, it is apparent from studies to date that they are likely widely distributed. The presence of chl f has been confirmed from stromatolites (Shark Bay, Australia; 1), beach rock (Heron Island, Australia; 7), endolithic communities within marine littoral carbonates (Isla de Mona, Puerto Rico; Menorca, Spain; 8) and microbial mats in hot springs (Nakabusa, Japan; 9). These environments provide a far-red light enriched niche, either by the properties of the rock or overlaying chl a-containing cyanobacteria and algae. To date there is no information available for terrestrial and freshwater environments in the polar regions. However, taxonomic studies on cyanobacteria from soil crusts, rocks and freshwater mats from Svalbard suggest the potential for chl f-containing cyanobacteria such as Chroococcidiopsis taxa (10). Our proposal aims to fill this lack of knowledge and provide a better understanding of richness and distribution of chl f-containing cyanobacteria as well as the requirement for near-infrared photosynthesis in the High Arctic to contribute to the primary production.

Research project links to research by the group leader and team: Dr. Jungblut's research focuses on the diversity, evolution and ecology of cyanobacteria, microbial mats and soil microbiology in the Polar Regions using a combination of sequencing, culturing and microscopy techniques (11-13). Her studies evaluate the relationship of diversity and environmental gradients, adaptation mechanisms to extreme conditions in permanently cold environments and climatic driven environmental change. The proposed CAPTURE project will contribute new data on the cyanobacteria distribution and adaptation in low light environments. It will furthermore provide insights into the potential importance of chl f-based photosynthesis by cyanobacteria for primary production in polar terrestrial and freshwater habitats. CAPTURE is directly linked to Dr. Nürnberg's research on chl f and identification of key positions in the photosynthetic machinery to allow efficient photosynthesis in infrared light (2). The proposed project will address key questions in his research about the importance of this new type of photosynthesis in the environment, and how cyanobacteria from different environments (hot versus cold) acclimate to infrared light at the photochemical, protein and genomic level. This is the first time for both Drs. Jungblut and Nürnberg applied for INTERACT TA, and none of them has carried out research in Svalbard.

Objectives

Research objectives: We propose to address the two hypotheses that richness and abundance of chl f-containing cyanobacteria will be different across habitat types, as a result of 1) environmental factors and/or 2) geographic distance. This project will provide the first comprehensive assessment of cyanobacteria able to use chl f-containing photosystems in Arctic terrestrial and freshwater environments. Our research objectives are 1) to determine the abundance of chl f in the environment by high-performance liquid chromatography (HPLC) and spectral imaging; 2) to map the diversity and richness of chl f-containing cyanobacteria across habitats (i.e. soil crusts, rocks, ponds and lakes), environmental, and geographic gradients using a combination of DNA high-throughput community sequencing and phylogenetic analyses based on specific near-red light and 16S rRNA genes; 3) to isolate chl f-containing cyanobacteria using infrared light selection, and 4) to characterise the properties of chl f-photosynthesis by fluorescence, absorbance and oxygen-electrode measurements.

References

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