

# Periodicity of Benthic Photosynthesis in Lake Fryxell, Antarctica

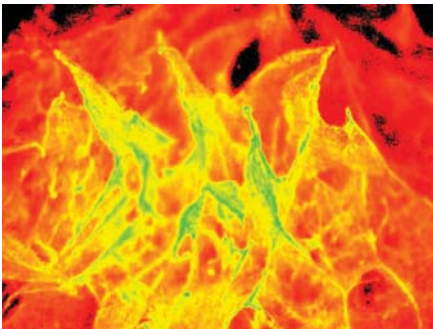
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**Figure 1.** Underwater photograph of a prostrate microbial mat at 8-m water depth. The surface of the mat is structured by pinnacles. Scale bar, 10 mm, applies to the center of the photograph. Vopel and Hawes (2006).



**Figure 2.** Chlorophyll fluorescence image showing the concentration of pigments associated with the small pinnacles (1–2 cm high). The false-color image shows low concentrations as red and higher concentrations as yellow, then green. Vopel and Hawes (2006).

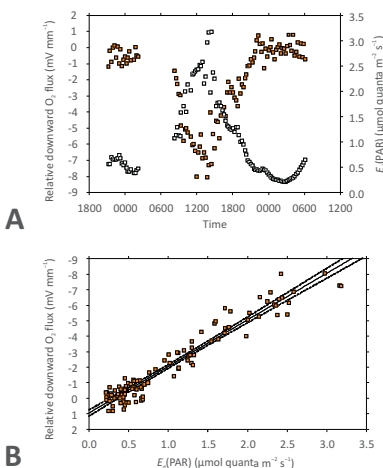
**INTRODUCTION:** Filamentous cyanobacteria, the earliest known oxygenic photosynthesising organisms, are the primary structuring agents in modern-day benthic microbial mats. Under conditions of low sedimentation rates and slow water flow, gliding and colliding of the filaments create peaked and ridged structures with regular centimeter-scale spacing (**Figures 1 and 2**).

Petroff et alii (2010) suggest that this spacing is set to minimise competition between individual structures. In support of this hypothesis they show that the spacing between structures corresponds to diffusive distances generated by a rhythmically fluctuating metabolism with a period of approximately 20 hours—the periodicity of photosynthesis.

Fossil stromatolites show similar structures and spacing, which supports the still-contentious view that they are evidence of early photosynthetic communities and provides constraints on the origin of phototrophic communities in the early evolution of life on earth.



**Figure 3.** Two photographs showing (A) a Unisense lander setup with 4 microelectrodes and (B) a dive hole in the ice cover of Lake Fryxell through which the tethered lander was lowered to the lake floor. A diver moved the lander away from the ice hole to a 9 m-deep site. After deployment, the lander measured time series of O<sub>2</sub> concentration microprofiles across the upper 2-mm layer of benthic cyanobacterial mats. (C) Two example O<sub>2</sub> concentration (electrode mV reading) microprofiles measured 10 Dec, 1345 h (open squares), and 11 Dec 2006, 0303 h. The solid line indicates a linear fit through the sub-peak profile. The slope of this fit was used as proxy for the downward O<sub>2</sub> flux (see **Figure 4**). The dashed line indicates the mat surface.



**Figure 4.** Lake Fryxell. (A) Time series of the relative downward flux of O<sub>2</sub> (negative values, orange squares) inside a benthic cyanobacterial mat and photosynthetically active radiation incident to the surface of the mat,  $E_0(\text{PAR})$ , at 9 m water depth. (B) Scatter plot showing a significant linear correlation between  $E_0(\text{PAR})$  and the relative downward O<sub>2</sub> flux. Solid and dashed lines indicate a linear fit and the 95% confidence limits.

**PROBLEM:** Ridge-peak microbial mats of the type and spacing considered by Petroff et alii are common in ice-covered Antarctic lakes. Such lakes provide a useful test of the diffusive mechanism of pinnacle spacing, since the weak diel variability in irradiance reaching the mats could be hypothesised as insufficient to generate metabolic periodicities. Centimetre-scale structures cannot relate to diffusive distances if metabolic cycles do not generate a marked diel pattern in resource availability in the water between structures, and the universal applicability of the Petroff model would be undermined.

**EXPERIMENTAL:** To test this model, we simultaneously measured, for the first time, a 30-hour time-series of in situ vertical O<sub>2</sub> concentration gradients in a pinnacle mat and incident irradiance in the perennially ice-covered Lake Fryxell (**Figure 3**).

**RESULTS:** We found that the O<sub>2</sub> concentration gradient and irradiance were significantly linearly correlated despite a diel irradiance change of only 3  $\mu\text{mol quanta m}^{-2} \text{s}^{-1}$  (**Figure 4**). This result supports the model by Petroff et alii and confirms our own previous conclusions regarding the mats photosynthetic competence.

Petroff AP, Sima MS, Maslov A, Krupenin M, Rothman DH, Bosak T (2010) Biophysical basis for the geometry of conical stromatolites. *Proceedings of the National Academy of Sciences* 107:9956–9961

Vopel K, Hawes I (2006) Photosynthetic performance of benthic microbial mats in Lake Hoare, Antarctica. *Limnology and Oceanography* 51:1801–1812

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