Diversity of *Flavobacterium* spp. in polar aquatic environments

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Abstract

The polar regions suffer from extreme environmental conditions such as low temperatures, freezing-thawing cycli, high UV-irradiation, desiccation and varying light conditions, salinities and nutrient concentrations, and as such these areas are some of the most inhospitable places on earth. However, the poles harbour a wide variety of different terrestrial and aquatic biotopes ranging from the surrounding oceans, sea-ice and marine sediments to continental lakes, the ice sheet, soils and rocks, where microorganisms are the most abundant and often the only form of life.

Antarctica is characterised by its geographical and climatic isolation and most of the continent is covered by ice. However, desert like ice-free areas exist, often located near the costs and in these areas the Antarctic lakes are situated. Most of the Antarctic non-marine biomass is found in the lakes, which are dominated by a planktonic microbial loop community and benthic microbial mats. Polar oceans are cold and oligotrophic habitats, where most of the microorganisms are found in the water column and in sediments. The annual cycle of sea-ice formation and melting, the exclusion of salts during ice formation and the absence of wind mixing, result in a very stable and highly stratified water column. The sea-ice itself harbours a unique community dominated by microorganisms, often referred to as the SIMCO (sea-ice microbial community).

The organisms living under these harsh conditions have been under a high selection pressure and are potentially belonging to endogenous, as yet undescribed new taxa. During the last years, several studies were performed exploring the bacterial diversity of different polar habitats and overall the diversity in these extreme and cold environments is surprisingly high with taxa belonging to the *Bacteroidetes* as one of the dominant lineages. In the last decade, several novel *Flavobacterium* species isolated from different polar habitats such as soil samples, microbial mats, marine sediment, sea-ice and freshwater lakes were described. To date, there are 55 validly described *Flavobacterium* spp. of which 14 were isolated from polar habitats. An overview is given in Table 1.

Table 1: Overview of *Flavobacterium* spp. from polar habitats.

Flavobacterium spp.	Isolation source	Reference
F. antarcticum	soil sample from a penguin habitat, Antarctica	Yi *et al.*, 2005
F. degerlachei	microbial mat, Antarctica	Van Trappen *et al.*, 2004
F. frigidarium	marine sediment, Antarctica	Humphry *et al.*, 2001
F. frigoris	microbial mat, Antarctica	Van Trappen *et al.*, 2004
F. fryxellicola	microbial mat, Antarctica	Van Trappen *et al.*, 2005
F. gelidilacus	microbial mat, Antarctica	Van Trappen *et al.*, 2003
F. gillisiae	sea-ice, Antarctica	McCammon & Bowman, 2000
F. hibernum	freshwater lakes, Antarctica	McCammon *et al.*, 1998
F. micromati	microbial mat, Antarctica	Van Trappen *et al.*, 2004
F. psychrolimnae	microbial mat, Antarctica	Van Trappen *et al.*, 2005
F. segetis	soil sample from a penguin habitat, Antarctica	Yi & Chun, 2006
F. tegetincola	microbial mat, Antarctica	McCammon & Bowman, 2000
F. weaverense	soil sample, Antarctica	Yi & Chun, 2006
F. xanthum	pool mud, Antarctica	McCammon & Bowman, 2000

With the MICROMAT-project (http://www.nerc-bas.ac.uk/public/mlsd/micromat/), the bacterial diversity in microbial mats from 10 Antarctic lakes located in the Vestfold Hills, McMurdo Dry Valleys and Larsemann Hills was studied. In total 6 different *Flavobacterium* species could be described and some of them derived from lakes in different Antarctic regions, suggesting that they might be more or less ubiquitous on the Antarctic continent (*F. gelidilacus, F. degerlachei, F. micromati* and *F. frigoris*).

Surprisingly the polar *Flavobacterium* spp. were all isolated from Antarctica, of which 10 originated from aquatic habitats and 4 from terrestrial environments, suggesting an endogenous nature of this genus. However, to have a better view on the biogeography and bipolar distribution of this taxon, future studies should focus on both the Arctic and Antarctic region and much more samples of different polar habitats need to be investigated.

A phylogenetic tree was constructed using almost complete 16S rRNA gene sequences of all validly described *Flavobacterium* spp. (see Figure 1 on next page). Invalid species are also included (indicated between quotes). Most of the polar species (indicated in blue) cluster together on different branches.

Polar *Flavobacterium* spp. are well adapted to the cold resulting in a psychrophilic or psychrotolerant nature and the production of poly-unsaturated fatty acids, cold-adapted enzymes, anti-freeze proteins or pigments. In a study of β-galactosidase-producing strains from Antarctic lakes, McCammon *et al*. (1998) described a novel psychrotolerant species, *Flavobacterium hibernum*, showing gliding motility and the ability to lyse Gram-negative cells, indicating a bacteriovorous role for this species in its environment. Additionally, *F. hibernum* forms a gelatinous colony at low temperatures which may be an adaptation to desiccation during freezing.

Furthermore, *Flavobacterium* spp. may have a specialized role in the uptake and degradation of the high-molecular-mass fraction of organic matter in cold, aquatic environments, demonstrated by the capability of several species to hydrolyse organic polymers such as proteins and complex polysaccharides. In 2001, Humphry *et al*. isolated a psychrophilic and halotolerant strain from Antarctic marine sediment, exhibiting a xylanolytic and laminarinolytic activity and described it as a novel species, *Flavobacterium frigidarium*. Xylan and laminarin are important plant and algal cell wall polysaccharides and relatively few psychrophilic xylanolytic organisms have been described.

References

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Figure 1: Neighbour joining tree based on 16S rRNA gene sequences of *Flavobacterium* spp.