Small Things Considered

The Cold Side of Microbial Life
http://schaechter.asmblog.org/schaechter/2014/03/the-cold-side-of-microbial-life.html
by Gemma Reguera

The almost permanent frozen state of many northern soils—the permafrost—limits microbial activity and the turnover of organic matter, contributing to the storage of approximately 25% of all of the planet’s soil organic matter. But do not be fooled by the frozen state: the permafrost harbors a great diversity of metabolically active microbes. Just how active, we don’t know. As global warming continues to thaw large areas of permafrost, the activity of these microbes could be stimulated further, promoting the turnover of the organic matter trapped in the soils and the release of greenhouse gases into the atmosphere.

But how active are permafrost microbes? Microbial ecologists have many techniques to profile microbial communities and assess the abundance of specific phylogenetic groups. However, measuring the metabolic activity of specific phylogenetic groups and their contribution to carbon cycling and biomineralization is more challenging. In a recent paper, Tuorto et al. combined two powerful techniques to address both. They first used stable isotope probing with $^{13}$C to selectively label the DNA from metabolically active permafrost cells when they incubated permafrost soil microcosms with $^{13}$C-acetate at temperatures ranging from 0°C to -20°C C. The metabolically active, growing microbes incorporated $^{13}$C isotope into their newly replicated DNA, which could be separated from the original, lighter $^{12}$C-DNA of the nongrowing population. They then profiled the active and inactive microbial communities with techniques based on the 16S rDNA sequences present in the heavy and light DNA pools, respectively.

The profile of the permafrost communities revealed a great diversity of resident bacteria: 152 operational taxonomic units (OTUs). Most of them incorporated the $^{13}$C isotope; hence, they were able to grow with acetate (or by-products of its metabolism) at subzero temperatures. Furthermore, the permafrost community was active across a range of temperatures, but half of the active OTUs had very specific temperature preferences. Interestingly, the groups with a temperature preference contained the same phyla (Acidobacteria, Actinobacteria, Chloroflexi, Gemmatimonadetes and Proteobacteria); however, the types of active microbes within each phylum varied: these microbes had specialized their metabolism to grow within a narrow range of temperatures.

How could a microbe specialize to grow at a specific subzero temperature? Most likely, it has evolved strategies to meet its water needs at that particular temperature. In frozen soils, water is restricted to a very thin, salty layer of liquid surrounding the soil particles. The high concentration of solutes in this liquid layer prevents the water from freezing, but to access this water source microbes need to evolve mechanisms for both cold- and salt-adaptation. Some microbes, for example, synthesize extracellular polymeric substances (EPS) as cryoprotectants, but also to facilitate attachment to soil particles and promote water retention and nutrient absorption. In fact, increases in EPS synthesis and bacterial abundance in cold ecosystems correlate well with decreases in temperature. Changes in fatty acid composition have also been reported for these microbes, which modulate the stability and functioning of the lipid membrane to the low water activity in their surroundings.

Results from this study support the notion that the metabolic activity of permafrost communities is resilient to temperature variations. Although many of the metabolically active microbes were active within a narrow range of temperatures, the microbial community fluctuated with the changing temperatures to maintain its overall productivity. Hence, it is reasonable to think that they could continue to be active, and even be stimulated, if global temperatures continue to rise and permafrost soils continue to melt. These conditions may also “wake up” dormant microbes stimulating carbon turnover and gas emissions from these ecosystems in unpredictable ways. Given that permafrost soils occupy ~20% of the Earth’s land surface, changes in the activity of resident microbes are likely to impact the planet globally. Despite these being educated guesses, it is clear that permafrost microbial activities need to be accounted for in global climate models to improve their predictive value. But the real message here is that this is indeed a planet of microbes. Microbes are active everywhere we look, even in the coldest lands.

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