Title: Temperature sensitivity of soil bacterial networks from the Arctic to the Tropics

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Project Goals: The work proposed here will integrate genomics- and isotope-enabled measurements of **G**rowth **R**ate, growth **E**fficiency, and the stoichiometry of **E**ssential **N**utrients during growth, an integration we call GREEN 'omics. Our **overarching objective** is to develop and apply 'omics approaches to investigate microbial community processes involved in nutrient cycling. The specific objectives of our proposed work are 1) to evaluate the microbial ecology of nutrient uptake, testing hypotheses about nutrient assimilation in response to temperature variation; 2) to evaluate the ecology of nutrient-use efficiency for soil microorganisms within a framework of ecological theory, and 3) to develop new isotope-enabled genomics and transcriptomics techniques that probe the microbial ecology of nutrient dissimilation. This work will push the frontier of isotope-enabled genomics by connecting quantitative stable-isotope probing to ecological theory about nutrient assimilation, nutrient-use efficiency, metabolic efficiency, and by applying these tools to understand the basic biology and ecology of soil microorganisms and how they transform nutrients in the environment.

Abstract text:
Temperature changes can have dramatic effects on the structure and function of soil microbial communities[1–4], though uncertainty exists as to the magnitude and predictability of carbon loss across different spatial and temporal extents[2,5]. Complex multi-species interactions which underpin the ecological functioning of a community can be summarized through network analysis[6,7]. We examined the soil bacteria from wide diversity of biomes representing Arctic, boreal, temperate, and tropical ecosystems in response to 5, 15, 25, and 35 °C temperatures. Network analyses typically infer interactions among taxa by detecting simultaneous changes in their relative abundances[8]. In ecological theory, interactions among taxa also alter rates of growth. Here, we constructed interaction networks using enrichment of ^{18}O in bacterial DNA – added via isotope-heavy water—as a measure of growth[9,10]. Previous analysis of these data indicated that the growth and respiration (i.e., the ecological functioning) of bacteria in these soils was most sensitive to changes from 5 to 15 °C[11]. By contrast, network size and composition was most severely altered at 35 °C in Arctic and boreal soils. At 35 °C, Arctic and boreal networks lost nearly all diversity except those bacteria that were present and active across all temperatures, forming a consistent, temperature-invariant core microbiome, and aligning with

patterns of lower sensitivity of growth and respiration at the community level at higher temperature[11]. Networks from temperate and tropical soils were composed of fewer temperature-sensitive bacteria. The temperature-invariant taxa remaining in Arctic and boreal networks at higher temperatures maintained less interactions per taxon leading to lower network density. With regard to the type of interactions, we saw an increase in the proportion of positive interactions from 5 to 15 °C, an indicator of stress and network instability via increased interdependency between bacterial taxa[12]. Community cohesion, a measure of total ecological connectivity[13], was highest at intermediate temperatures in all ecosystems and lowest at 5 and 15 °C. Taken together, these results help explain the sensitivity of different soils to warming conditions and demonstrate the strong links between ecological dynamics and soil carbon cycling.

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