Researchers investigate acidobacteria survival in extreme soil conditions

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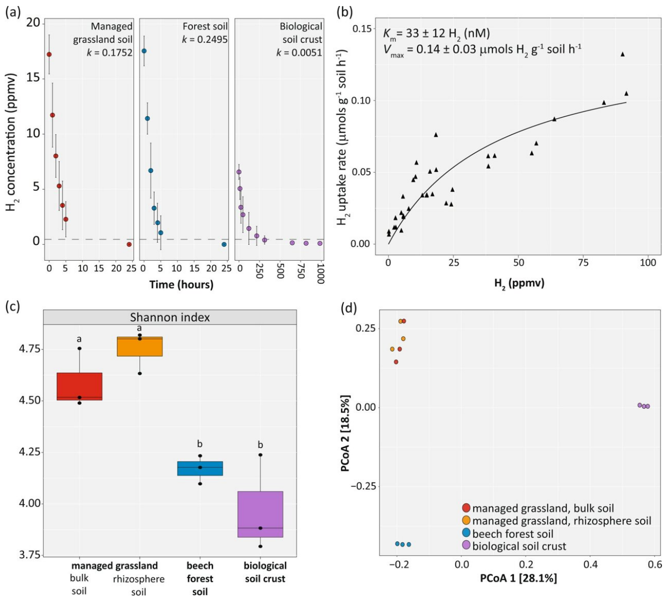

a Hydrogen consumption by soils collected from a beech forest, managed grassland and desert biological soil crust. Dotted lines represent atmospheric concentrations of H2 (~0.53 ppmv). Data points depict the mean ± standard deviation. b Michaelis–Menten kinetics of H2 oxidation by the beech forest soil. Best-fit curve was determined using a Michaelis–Menten non-linear regression model. c Alpha diversity (Shannon index) and d beta diversity (Bray–Curtis dissimilatory) of the group 1h [NiFe]-hydrogenase large subunit (hhyL) genes in the soils detected by long-read amplicon sequencing. Analysis of variance with a Tukey's HSD mean separation was performed across the soil types for the Shannon index; similar letters indicate that no significant difference was observed (p value > 0.05). Data were rarefied.

Soils are one of the most diverse habitats on the planet. There are more than thousand microbial species per gram that significantly influence numerous environmental processes. However, the majority of these organisms are believed to be in a state a state of "dormancy" due to environmental stress, such as nutrient-poor conditions.

An international team of scientists led by Dagmar Woebken and Stephanie A. Eichorst from the University of Vienna investigated how acidobacteria, which are widespread in soils, can survive under adverse conditions. Two recent studies published in *The ISME Journal* and *mSystems* describe these survival strategies.

The living conditions that microorganisms encounter in soils are unpredictable and challenging. Nutrients and oxygen are frequently scarce for long periods. Acidobacteria manage to defy these extreme conditions. They are found in an astonishing diversity in soils worldwide. "Since they are this widespread, we assume that Acidobacteria play a central role for the microbial community and thus also for the ecological balance in soils," explains Stephanie A. Eichorst, microbiologist at the Center for Microbiology and Environmental Systems Science (CMESS) at the University of Vienna. In a multi-year research project, a team around Eichorst and her colleague Dagmar Woebken, supported by international colleagues, have investigated the success strategies of these soil microbes.

Acidobacteria "breathing-in" low amounts of oxygen with unexpected enzymes

In their most recent study now published in *mSystems*, the researchers show that acidobacteria are surprisingly efficient in extracting energy from oxygen. In experiments, the microbiologists from the Universities of Vienna, Cádiz (Spain) and Aarhus (Denmark) and from the Joint Microbiome Facility—a joint venture of the University of Vienna and Medical University of Vienna—were able to demonstrate that the soil bacteria can use so-called low-affinity terminal oxidases to 'breathe' the smallest amounts of oxygen. Terminal oxidases are used for the generation of energy, which can be low-affinity (using higher concentrations of O_2) or high-affinity enzymes (using low concentrations of O_2). "Until now, it has been assumed that microorganisms need enzymes with a high affinity for oxygen in order to be able to breathe in environments with the lowest oxygen content," Daniela Trojan, first author of the study, reports. "In contrast, our experiments surprisingly showed that they can also use low-affinity enzymes for this purpose." As low-oxygen habitats are widely distributed on Earth, these findings have implications for other systems.

Acidobacteria scavenge atmospheric hydrogen to survive periods of starvation

The researchers have already deciphered a second survival strategy of these successful soil bacteria. A previous analysis—published in *The ISME Journal*—explored the ability of Acidobacteria to oxidize dihydrogen (H2), an atmospheric gas, at extremely low concentrations. "This is a mechanism that can be used to generate energy to survive periods of carbon limitation, i.e., nutrient shortage," explains Dagmar Woebken, who in a project funded by the European Research Council focuses on survival strategies in soil microorganisms. Surprisingly, it turns out that members of the Acidobacteria are the second most abundant group of microorganisms having this ability across different soils—a key finding in this study. In collaboration with other scientists from the University of Vienna and Monash University (Australia), the researchers were able to confirm this finding with acidobacterial strains in the lab. "Our data support the growing evidence that trace gases, such as hydrogen, are used as energy source for bacterial persistence," summarized Andrew Giguere, one of the co-first authors of the study.

Combining different methods for a more complete view and new insights

For both studies, the research team used an ambitious combination of several approaches to investigate a diverse, but challenging environment—soil and representative organisms from soil. In doing so, they were able to obtain a clearer picture about the flexibility and mechanisms soil microorganisms use to survive stressful conditions. "With just one approach, our findings would have been different. Rather the combination of these approaches, available both here at the University and with our collaboration partners, allowed to us to reach beyond our assumptions," says Eichorst. "Specifically, we found that acidobacteria can use low-affinity enzymes for respiration at low oxygen, which was surprising as it deviates from what one reads in the textbooks," recounts Woebken. As such, both advocate for combining molecular-based analyses with classical microbiology to address research questions. This way, it is possible to dig even deeper into the lifestyles of soil bacteria; and with this knowledge, it is possible to understand how the biodiversity of microorganisms in the soil is maintained.

More information: Andrew T. Giguere et al, Acidobacteria are active and abundant members of diverse atmospheric H2-oxidizing communities detected in temperate soils, *The ISME Journal* (2020). DOI: 10.1038/s41396-020-00750-8

Daniela Trojan et al, Microaerobic Lifestyle at Nanomolar O 2 Concentrations Mediated by Low-Affinity Terminal Oxidases in Abundant Soil Bacteria, *mSystems* (2021). DOI: 10.1128/mSystems.00250-21

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