Smithsonian Tropical Research Institute **News**

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TITAN Supercomputer Reveals How Microbes Cope With Scarcity

Neither plants nor animals can survive without phosphorus. But heavy rains wash this essential nutrient out of many tropical soils, creating the same conditions that could threaten world food supplies if phosphorus supplies run out. Two supercomputers analyzed the response of microbes collected from high- and low phosphorus tropical soils at the Smithsonian Tropical Research Institute (STRI), finding that microbes shift strategies for getting what they need depending on what is available.

"The results are remarkable for a number of reasons," said Ben Turner, co-author and STRI staff scientist. "First, they demonstrate that microbial communities shift their emphasis in acquiring nutrients depending on fertility, emphasizing phosphorus when it is in short supply, but switching to carbon, nitrogen and sulfur when phosphorus is plentiful. We also find that different groups of microbes specialize in obtaining phosphorus from different compounds in the soil, known as resource partitioning, promoting co-existence by sharing a limiting resource."

"Most surprising, however, is the enormous number of genes for phytase at low phosphorus," Turner said. "The phytase enzyme releases phosphate from inositol phosphates, a group of organic phosphorus compounds that are abundant in plant seeds, but are usually considered to be difficult for organisms to access. The extremely low-phosphorus availability in tropical soils must drive microbes to target these hard-to-get compounds to fulfill their nutritional needs, once again demonstrating the remarkable ability of tropical diversity to overcome challenges posed by their environment."

"Twenty years ago we set up a fertilization experiment to understand how soil nutrients influence the amazing biodiversity of tropical forests," said STRI staff scientist S. Joseph Wright. "Now, for the first time, several major U.S. government research centers—each able to take on huge, long-term experiments—joined forces to ask how microbial communities respond to nutrient scarcity."

Beginning in 1998, Wright's group applied 50 kilograms of phosphorus per hectare per year in the form of triple superphosphate fertilizer to phosphorus-deficient soils on Gigante Peninsula in the Barro Colorado Nature Monument, leaving other areas unfertilized.

A team from Oak Ridge National Labs (ORNL) collected soil from low- and high-phosphorus soils. Their colleagues from the U.S. Department of Energy Joint Genome Institute extracted DNA and proteins from the samples and then studied the DNA sequences on the Rhea supercomputer. In this first step of the analysis, they discovered 12 completely new genomes.

The huge data set—157 gigabase pairs of sequencing data from each of four soil samples—was then fed into the TITAN supercomputer to identify what proteins are in a sample by matching them up to a reference set of known proteins.

Genetic instructions for the assembly of each protein in a cell are like necklaces of differently colored beads in a specific order. In the reference collection at the National Center for Biotechnology Information there are "necklaces" representing the unique codes for proteins from more than 4,000 species of single-celled organism. The supercomputer matches unknown proteins in the samples to known proteins, identifying about 7,000 different proteins in four soil samples in 40 minutes.

Because phosphorus-bearing rock used for fertilizer is a finite resource, found only in five countries, understanding how microbes survive in phosphorus-limited soils may be especially relevant.

Co-authors include S. Joseph Wright and Benjamin L. Turner of STRI; Qiuming Yao, Zhou Li, Yang Song, Melanie A. Mayes and Chongle Pan of ORNL; Terry C. Hazen, University of Tennessee and ORNL; Xuan Guo, UT; Susannah G. Tringe of the DOE Joint Genome Institute; and Malak M. Tfaily and Ljiljana Paša-Tolic of Pacific Northwest National Laboratory.

The Smithsonian Tropical Research Institute, headquartered in Panama City, Panama, is a unit of the Smithsonian Institution. The Institute furthers the understanding of tropical biodiversity and its importance to human welfare, trains students to conduct research in the tropics and promotes conservation by increasing public awareness of the beauty and importance of tropical ecosystems. Website: http://www.stri.si.edu/. Promo video: https://www.youtube.com/watch?v=M9JDSIwBegk.

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Reference: Yao, Q, Li, Z., Song, Y et al. 2018. Community proeogenomics reveals the systemic impact of phosphorus availability on microbial functions in tropical soil. *Nature: Ecology and Evolution*. Doi: 10.1038/s41559-017-0463-5