Bacterial proteins that transform iron and other minerals for energy and growth

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Growing crops for biofuels and cleaning up polluted soils benefit from a deeper understanding of how a specific microbial protein, known as multi-heme cytochromes, reduces iron, manganese, and other subsurface minerals. The review appears in Journal of the Royal Society Interfaces. Credit: Artwork by Nathan Johnson.

Cleaning up polluted soil and growing crops for biofuels benefit from a deeper understanding of how microbes alter subsurface minerals. Scientists at Pacific Northwest National Laboratory, University of East Anglia, and University College London assess the state of understanding of a key enzymatic pathway employed by bacteria in these transformations: chains of proteins called multi-heme cytochromes. The proteins perform a variety of tasks, primarily acting as electron conduits, and take multiple forms. The review, which focuses on the microbe Shewanella oneidensis, appears in Journal of the Royal Society Interfaces. The article covers more than 150 studies of the protein, spanning more than three decades.

"The proteins participate in electron transfer reactions that contribute to biogeochemical cycling of nitrogen, sulfur, and iron on the global scale," said Dr. Kevin Rosso, a PNNL geochemist and the review's co-corresponding author. "The properties of multi-heme cytochromes have attracted multidisciplinary interest and contribute beyond environmental sciences to advances in bioenergy and bioelectronic devices."

Called the subsurface environment by scientists, the soil, rocks, and water that stretch far beneath our feet are far from simple or static. Yet, scientists lack detailed knowledge of the complex processes that can cause local and regional fluxes to drive nutrients away from farms, or spread or immobilize uranium from nuclear waste sites. The review provides a one-stop shop of information on a key part of the complex, dynamic processes and highlights opportunities for additional research.

Another twist is that, one day, multi-heme cytochrome reactions could lead to bio-based batteries. The reason? When the microbes use iron, much like humans use oxygen, to burn fuel for energy, the associated flow of electrons can be captured and delivered to targets, such as electrodes in fuel cells. Lead researcher Professor Julea Butt at the University of East Anglia said, "these bacteria can generate electricity for us in the right environment."

In their 27-page review article, the four researchers discuss the structures, properties, and functions of the multi-heme cytochromes, especially how they channel their electrons. "This is an exciting advance in our understanding of how some bacterial species move electrons from the inside to the outside of a cell and helps us understand their behavior as robust electron transfer modules," said Butt.

While scientists have answered numerous questions about multi-heme cytochromes, just as many unanswered questions remain. "If we can unravel the relationships between encoding the protein and how it functions as an electron conduit, then we can start to think about customizing aspects of design for device purposes." said Rosso.

More information: Breuer M, KM Rosso, J Blumberger, and JN Butt. 2014. "Multi-haem Cytochromes in Shewanella Oneidensis MR-1: Structures, Functions and Opportunities." *Journal of the Royal Society Interfaces* 12: 20141117. DOI: 10.1098/rsif.2014.1117

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