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Microbial electrical connections with minerals and their global impact

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The family *Geobacteraceae*, with its only valid genus *Geobacter*, comprises deltaproteobacteria ubiquitous in soil, sediments, and subsurface environments where metal reduction is an active process. Key to their global presence is the ability of *Geobacter* to wire the cell envelope respiratory chains to metal-bearing minerals, particularly abundant iron oxides, via conductive protein appendages. These microbial nanowires also bind soluble metals released during the reductive dissolution of minerals and reductively precipitate them extracellularly to prevent their permeation into the cell envelope and cytotoxicity. Such electrical adaptations maximize growth efficiency with electron donors derived from the decomposition of organic matter and contribute greatly to the sequestration of toxic metals and organic carbon into stable mineral sinks. The direct and indirect effects of *Geobacter* metal-reducing activities on the simultaneous mineralization of carbon and iron have been proposed to establish an iron mineral "mesh" that increases the porosity of the medium and further stimulates the metal-reducing metabolisms. As major drivers of metal mineralization, *Geobacter* also influence the mobility of oxidized species of nitrogen, promoting the retention of the essential element in reduced forms (ammonium) and attenuating the release of greenhouse gases such as nitrous oxide by competing organisms. These unique physiological traits make *Geobacter* attractive model organisms to investigate the biological reactions that electrically connect metals to biogeochemical processes contributing to the global sequestration of carbon and nitrogen.