Microbial iron reduction in extreme environments

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As the fourth most abundant element on Earth, iron is harnessed by a diverse array of microorganisms for energy generation. Microorganisms able to harness energy from iron reduction reactions are widespread in time and space, with some occupying the deepest roots of the tree of life. Microbial iron reduction is also a plausible metabolism to support microbial life beyond Earth, particularly the iron-rich (red) planet Mars. In order to better understand habitability for life on other planetary bodies, it is essential to address the limits of life on Earth. Extremophilic iron reducers may also be useful in bioremediation and biotechnological ventures, such as high latitude oil spills and microbial fuel cells operating under non-standard conditions. However, little attention as been paid to the limits to the metabolism and its prevalence in extreme environments. In this talk I will present a comprehensive review of iron-reducing microorganisms from a previously undeveloped angle, focusing on iron reduction at extremes of temperature, pH, salinity and pressure. Drawing on a new database of all microorganisms capable of growth from iron reduction characterised to date (n=126), I will synthesise what is known about the most extremophilic (and in some cases polyextremophilic) iron-reducers in culture collections, including their growth conditions, electron donor preferences and biogeography, and place them into context of habitability on Earth and beyond. Gibbs free energy calculations of iron reduction reactions across the temperature and pH habitability space are used to identify conditions in which the metabolism is thermodynamically favourable, but no evidence of microbial iron reduction has been reported. Results indicate a strong preference among iron-reducing microorganisms for moderate growth conditions, and a lack of polyextremophily, despite thermodynamic favourability across a wide range of conditions. Possible explanations for this disparity between observed and theoretical limits is discussed, and next steps suggested to better investigate the limits to life sustained by microbial iron reduction.