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Trace metal availability at the crossroad between microbial functional diversity and the evolution of biogeochemistry

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Trace elements are fundamental for the growth of all life forms on this planet. They are used as cofactors in proteins and enzymes, playing key roles in energy conservation and redox chemistry [1]. Life uses selected trace elements to drive and control specific reactions. In particular, energy conserving reactions (redox reactions) require diverse elements as key catalytic centers to be tuned to the midpoint potential of their substrate [2,3]. Metals such as Fe, Co, Ni, Zn, Mo, W, V, and Cu are used in these proteins and constitute essential micronutrients for microbial growth [3]. While the control imposed on microbial metabolism by the scarcity of some of these metals in the environment is well known, for example for iron scarcity in the ocean controlling primary productivity, the relationship between trace element availability and microbial metabolic diversity has not been explored in detail [4]. Given that the availability of many of the essential trace elements has changed as a function of changing planetary conditions in deep time, unveiling the link between trace element availability and functional diversity might shed light on the evolution of metabolism and the emergence of biogeochemistry [3,4]. In geothermal environments, microbial communities rely on water:rock interactions to obtain necessary substrates and nutrients. Here, we will present recent data from field and laboratory experiments elucidating the impact of trace element availability on microbial functional diversity, showing that trace elements can be used to manipulate microbial metabolisms controlling the shift between diverse electron acceptors. We further show that this mechanism is widespread in the tree of life and that the scarcity of key trace elements imposes additional metabolic costs on the fitness of microorganisms.

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