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Tracing metal adventures from Earth to life

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Metals play a critical role in writing the history of life-environment interactions. Certain metals (e.g., Fe, Mn, Cu, Zn, Mo, Ni, Co) are essential to life as they mediate critical metabolic reactions by functioning as cofactors in vital enzymes. Yet, others (e.g., Hg, Pb, Cd, Cr) can act as mutagenic/genotoxic compounds to interrupt normal metabolism and hence are toxic. Since life can neither create or destroy metals and only obtain metals from the Earth, suffice it to say the historical availability of metals have shaped today's biological landscape. Conversely, the biogeochemical cycling processes contributed to metals' redistribution in the geosphere.

Throughout geological history, the availability of life-essential metals has echoed with the environment changes (e.g. the oxygenation of atmosphere and ocean) and may have directly influenced developmental biology such as metabolic pathways. Today, humanities are changing the environmental availability of metals through unprecedented scales of extraction and release, threatening the ecological system and causing unknown effects on future life. In a sense, metal availability may become a "planetary boundary" that constrains the sustainability of the Earth's biosphere.

Metal isotopes are powerful tracers widely applied to distinguish natural from anthropogenic processes and reconstruct the evolution of Earth's environment. Metal isotope fractionation is driven by mechanisms at the molecular level regardless of the inorganic or biological nature of the substrates, thus has the potential to elucidate interactions between geosphere and biosphere. In this talk, we trace the journey of metals from Earth to life using their isotopes. The journey starts from volcanism reconstruction using sedimentary record of Hg isotopes. The ensuing weathering process that releases metals will be then examined by novel weathering tracers such as Ga isotopes. After release, metals are transported and cycled between air, land and ocean, where multiple isotope tracers are applied to understand their source, fate and biological effects. The journey ends with our newest attempt to trace biological assimilation, trophic transfer, *in vivo* metabolism and even progression of disease using metal isotopes, highlighting the emerging frontier of metal isotope geochemistry in searching for answers concerning the future habitability of Earth.