EDITORIAL

Planet of the microorganisms

This Focus issue on biogeochemistry highlights the metabolic versatility in microbial communities and the significance of microbial contributions to the flow of elements in Earth's biogeochemical cycles.

Microbial metabolic activity lies at the heart of the myriad of interactions between the environment and microorganisms that shape the dynamics of ecosystems. Earth is a closed system with a finite amount of matter that cycles between the lithosphere (rocky surface), atmosphere, hydrosphere and biosphere, and microbial metabolism drives biogeochemical cycling between these spheres. This Focus issue explores microbial metabolism in the context of wider ecosystems. It comprises Reviews that discuss the microbial nitrogen cycling network, the role that bacterial microcompartments (BMCs) have in atmospheric carbon fixation, the symbiotic exchange of nitrogen and carbon compounds between rhizobia and legumes, and the function of hopanoid lipids, which are important components of bacterial membranes and affect interactions with other organisms.

The six most common elements that are found in organic molecules — carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur — exist in various chemical forms, and the redox cycling of these elements by microorganisms substantially influences biogeochemical cycling and the functions of ecosystems on a global scale. Nitrogen is the most abundant element in the atmosphere and is essential for all life on Earth. A complex network of nitrogen-transforming microorganisms facilitates the interconversion between organic and inorganic forms of nitrogen while it cycles between the atmosphere and terrestrial and marine ecosystems. On page 263, Kuypers and colleagues take us on a journey through the microbial nitrogen cycle, highlighting new pathways and the vast diversity of nitrogen-transforming microorganisms and their enzymes. They discuss how these microorganisms form complex nitrogen cycling networks in different environments and posit on heretofore undiscovered nitrogen-transforming reactions that are thermodynamically feasible.

The fixation of atmospheric N_2 by rhizobia that live in symbiosis with leguminous plants such as alfalfa, beans and soy provides a substantial proportion of nitrogen to the biosphere. During the transition from free-living soil microbiota to plant-associated endosymbionts, rhizobia undergo drastic lifestyle and developmental changes to become bacteroids — the N_2-fixing form of rhizobia. Historically, rhizobia research has focused on specific interactions with legumes, without considering the complexity of the microbial communities that exist in the rhizosphere. On page 291, Poole et al. explore the changes that underlie this transition and the associated plant–bacteria interactions.

Bacteria contribute to the fixation of CO_2 to provide organic carbon that is necessary to support heterotrophic life, and BMCs have a role in this fixation. BMCs are self-assembling organelles (consisting of an enzymatic core that is encapsulated by a selectively permeable protein shell) that enhance metabolic flux and protect bacteria from potentially toxic metabolites. The first BMC that was isolated was found to enclose Rubisco — an enzyme that catalyses the first major step in carbon fixation and is the most abundant enzyme on Earth. Since then, numerous BMCs that are involved in various metabolic pathways have been identified, revealing their functional diversity in the biosphere. On page 277, Kerfeld and colleagues review our understanding of the role of BMCs in microbial metabolism, their structure, assembly and functional diversity. They discuss applications for engineered BMCs in biotechnology and propose that they could be used to program the metabolism of microbial communities in an approach known as synthetic ecology.

Finally, on page 304, Newman and colleagues discuss hopanoids — a class of bacterial membrane lipids that resemble eukaryotic sterols. They were first discovered by petroleum geologists in ancient sedimentary rocks, but since then they have been found in numerous environments. In this Review, the authors explore the biology and biochemistry of hopanoids and discuss how they may promote beneficial interactions between bacteria, in particular nitrogen-fixing species, and plants.

This Focus issue highlights the metabolic diversity on Earth and the significance of microbial contributions to biogeochemical cycles. An important future consideration is how the impact of changes in climate and land use will influence the relationship between microbial communities and the environment. Could increasing temperatures, greenhouse gas emissions or changing soil humidity impact microbial ecosystems, for example, by accelerating human-caused climate change, with broad implications for geological systems and human health? For now, this remains an open question. Nevertheless, providing evidence of the microbial regulation of biogeochemical cycles is vital for predicting ecosystem functions under current and future climate scenarios.

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