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Preface

Magnetotactic bacteria and magnetoreception

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A broad range of organisms have evolved abilities to exploit the Earth's magnetic field for orientation and navigation—a behavior known as magnetoreception (Nordmann et al., 2017). Magnetotactic bacteria (MTB), diverse microbes with a patchy distribution across the bacterial tree of life, are the best known and most extensively studied magnetosensitive microorganisms. In order to efficiently achieve magnetotactic behavior, MTB biomineralize intracellular chain-arranged magnetic single-domain crystals of magnetite (Fe_3O_4) and/or greigite (Fe_3S_4) called magnetosomes, which are unique prokaryotic organelles that confer a magnetic moment to the cell and act as an internal compass needle (Bazylinski and Frankel, 2004).

Since the first discovery of MTB in the 1960s and 1970s (Blakemore, 1975; Bellini, 2009; Frankel, 2009), the field has seen tremendous advances in the diversity, ecology and ecophysiology of MTB, their magnetotactic behaviors, the magnetosome biomineralization mechanisms and the applications of entire MTB cells and isolated magnetosomal nanoparticles. MTB have a worldwide distribution across marine, brackish and freshwater environments, although their occurrence in waterlogged soils has also been noted (Lin et al., 2017). For many years, the known diversity of MTB was thought to fall into a few phyla (Amann et al., 2007; Kolinko et al., 2012); however, the development of culture-independent techniques has recently revealed an unexpected phylogenetic diversity of MTB across the bacterial tree of life (Lin et al., 2018, 2020; Uzun et al., 2020). Their global distribution and high diversity imply important roles of MTB in the global biogeochemical cycles in aquatic ecosystems (Lin et al., 2017; Amor et al., 2020). Biochemical and genetic studies using model MTB organisms including *Magnetospirillum magneticum* strain AMB-1, *M. gryphiswaldense* strain MSR-1 and *Desulfovibrio magneticus* strain RS-1 have led to important advances in understanding the underlying molecular mechanisms of magnetosomal biosynthesis and magnetoreception (Uebe and Schüler, 2016; McCausland and Komeili, 2020). Collectively, MTB represent a unique model system for the study of intracellular biomineralization, prokaryotic organelle biogenesis, and magnetoreception. For these reasons, MTB has become increasingly more attractive to researchers from a variety of different disciplines.

This special issue "Magnetotactic Bacteria and Magnetoreception" brings together a series of 11 peer-reviewed research, opinion, and review articles covering the breadth of research across MTB. Understanding the magnetotactic behavior of MTB and their diversity and distribution across different ecosystems is a crucial topic. Qian et al. (2021) reveal that UV radiation in combination with alternation of magnetic field direction in lab can trigger the reversal of magnetotactic swimming direction, from north-seeking to south-seeking, and initiated the unidirectional division of a multicellular magnetotactic prokaryote, which indicates a link between magnetic orientation of MTB and light. However, understanding the reaction time scale and

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mechanism governing such behavior requires integrated investigation. Chen et al. (2021b) examine the morphological and phylogenetic diversity of MTB in a mangrove environment and demonstrate the existence of a highly diverse group of MTB in this productive ecosystem at the transition between terrestrial and marine environments. Cui et al. (2021) extend the studies of MTB diversity and distribution to the Caroline Seamount located in the south of the Mariana Trench. Interestingly, the authors have revealed the occurrence of abundant living MTB cells in sediments at water depths >1 500 m. This finding, together with the previous studies (e.g., Petermann and Bleil, 1993; Liu et al., 2017), reinforces the widespread distribution of MTB in bathypelagic environments. MTB are generally considered as free-living microorganisms, but recently several studies have revealed that MTB could live as symbionts of marine bivalves (Dufour et al., 2014) and protists (Monteil et al., 2019), which have a remarkable impact on our understanding of MTB ecology and of magnetoreception evolution in other organisms. Metagenomic study considerably speeds up the progress of our understanding about diversity, distribution, and ecological significance of MTB. A preliminary study in this issue by Simon et al. (2021) indicates that several bacterial species closely related to known MTB exist in the human gut through a metagenomic analysis and these species appear to be related to magnetite-rich brain regions known to function in human orientation and navigation. It should be noted that magnetosome-associated genes are not found in these bacteria, thus further studies are necessary to confirm these findings. How MTB are transmitted into human gut and if they could maintain and reproduce there remain open questions.

Two papers in this issue explore the ecology of MTB and their impacts on iron cycling. Chen et al. (2021c) characterize a magnetically responsive ciliate (tentatively identified as *Uronemella parafilificum* HQ) collected from intertidal sediment of Huiquan Bay, Qingdao, China. The size and shape of magnetic particles within HQ are similar to those in MTB cells occurred in the same environment, which suggests that HQ has the ability to graze and digest MTB. This finding highlights the potential function of HQ in the release of iron back into the ecosystem. Taveira et al. (2021) in their opinion article propose that MTB infection by phages may play previously neglected roles in making iron available for the local microbial community and in the evolution of magnetosome biogenesis across different bacterial lineages, although further studies are required to confirm this hypothesis.

Three studies provide new insights into biology and magnetosomal biogenesis mechanisms of MTB. This includes a review paper that summarizes recent advances in redox modulation of magnetosome biosynthesis in model *Magnetospirillum* strains (Li, 2021). Through a combination of genetic approaches, transmission electron microscopy observations and rock magnetic measurements, Wu et al. (2021) identify an essential role of MamZ protein in magnetosomal maturation process of *M. gryphiswaldense* strain MSR-1. They also note the close relationship between *mamZ* and other magnetosome genes located in *mamXY* operon during the maturation process of magnetosomal crystals. Besides well-studied *Magnetospirillum* strains, Du et al. (2021) report the genomic analysis of a marine magnetotactic strain SH-1 belonging to the genus *Terasakiella* that was recently isolated, which offers several insights into metabolism and magnetosomal biosynthesis in this novel MTB strain.

Both entire MTB cells and isolated magnetosome nanoparticles have great application potentials in various fields of biotechnology and nanotechnology. Two papers in this issue assess the potential applications of MTB cells. Chen et al. (2021a) characterize the biocompatibility and safety of marine magnetotactic bacteria strain MO-1. They argue that cells of MO-1 could be potentially used in targeted clinical therapy. The magnetic hyperthermia properties of *M. gryphiswaldense* strain MSR-1 have been investigated by Zhang et al. (2021) using a combination of a commercial standard system and magnetic measurements. According to their findings, cells of MSR-1 exhibit excellent magnetic hyperthermia ability and their heat generation principle mainly follows the hysteresis loss mechanism.

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