Ecophysiology of Magnetotactic Bacteria

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Abstract Magnetotactic bacteria are a physiologically diverse group of prokaryotes whose main common features are the biomineralization of magnetosomes and magnetotaxis, the passive alignment and active motility along geomagnetic field lines. Magnetotactic bacteria exist in their highest numbers at or near the oxic–anoxic interfaces (OAI) of chemically stratified aquatic habitats that contain inverse concentration gradients of oxidants and reductants. Few species are in axenic culture and many have yet to be
well described. The physiology of those that have been described appears to dictate their local ecology. Known \( \text{Fe}_3\text{O}_4 \)-producing strains are microaerophiles that fix atmospheric nitrogen, a process mediated by the oxygen-sensitive enzyme nitrogenase. Marine \( \text{Fe}_3\text{O}_4 \)-producing strains oxidize reduced sulfur species to support autotrophy through the Calvin–Benson–Bassham or the reverse tricarboxylic acid cycle. These organisms must compete for reduced sulfur species with oxygen, which chemically oxidizes these compounds, and yet the organism still requires some oxygen to respire with to catalyze these geochemical reactions. Most \( \text{Fe}_3\text{O}_4 \)-producing strains utilize nitrogen oxides as alternate electron acceptors, the reductions of which are catalyzed by oxygen-sensitive enzymes. \( \text{Fe}_3\text{O}_4 \)-producing magnetotactic bacteria must solve several problems. They must find a location where both oxidant (oxygen) and reductants (e.g., reduced sulfur species) are available to the cell and therefore in close proximity. They must also mediate oxygen-sensitive, ancillary biochemical reactions (e.g., nitrogen fixation) important for survival. Thus, the OAI appears to be a perfect habitat for magnetotactic bacteria to thrive since microaerobic conditions are maintained and oxidant and reductant often overlap.

1 Introduction

1.1 General Features of Magnetotactic Bacteria

The magnetotactic bacteria are defined as mainly aquatic prokaryotes whose swimming direction is influenced by the Earth’s geomagnetic and other applied fields. The term “magnetotactic bacteria” has no taxonomic significance and represents a collection of morphologically, physiologically, and phylogenetically diverse prokaryotes (Bazylinski 1995; Bazylinski and Frankel 2004). Despite this diversity, these unique microorganisms have several traits in common. All known species or strains:

1. Are phylogenetically associated with the Domain Bacteria
2. Are motile by means of flagella
3. Are microaerophiles or anaerobes or both
4. Have a solely respiratory form of metabolism, with the exception of one species
5. Exhibit nitrogenase activity and presumably can fix atmospheric dinitrogen
6. Are mesophilic with respect to growth temperatures
7. All possess magnetosomes, which are intracellular membrane-bounded crystals of a magnetic mineral (Bazylinski and Frankel 2004)

The magnetosome is the most conspicuous feature of the magnetotactic bacteria and contains crystals of either the iron oxide magnetite (\( \text{Fe}_3\text{O}_4 \)) or the iron sulfide greigite (\( \text{Fe}_3\text{S}_4 \)). Almost all magnetotactic bacteria produce only one mineral compositional type (Bazylinski and Frankel 2004) although at least one uncultivated species is known to biomineralize both minerals