4.6D: Magnetosomes

LEARNING OBJECTIVES

- Illustrate the structure of magnetosomes and the advantages that they provide to magnetotactic bacteria

Magnetosomes are intracellular organelles found in magnetotactic bacteria that allow them to sense and align themselves along a magnetic field (magnetotaxis). They contain 15 to 20 magnetite crystals that together act like a compass needle to orient magnetotactic bacteria in geomagnetic fields, thereby simplifying their search for their preferred microaerophilic environments. Each magnetite crystal within a magnetosome is surrounded by a lipid bilayer. Specific soluble and transmembrane proteins are sorted to the membrane. Recent research has shown that magnetosomes are invaginations of the inner membrane and not freestanding vesicles. Magnetite-bearing magnetosomes have also been found in eukaryotic magnetotactic algae, with each cell containing several thousand crystals.

Magnetotactic bacteria usually mineralize either iron oxide magnetosomes, which contain crystals of magnetite (Fe$_3$O$_4$), or iron sulfide magnetosomes, which contain crystals of greigite (Fe$_3$S$_4$). Several other iron sulfide minerals have also been identified in iron sulfide magnetosomes — including mackinawite (tetragonal FeS) and a cubic FeS — which are thought to be precursors of Fe$_3$S$_4$. One type of magnetotactic bacterium present at the oxic-anoxic transition zone (OATZ) of the southern basin of the Pettaquamscutt River Estuary, Narragansett, Rhode Island is known to produce both iron oxide and iron sulfide magnetosomes.
Magnetospirilli with black magnetosome chains faintly visible: There is a broad range of shapes and groups of magnetic bacteria. However, cultivation of these organisms in the laboratory is often difficult. Only a few strains of magnetotactic bacteria have been isolated in pure culture, a tiny minority of the vast diversity of naturally occurring populations from largely unexplored natural habitats such as the marine environment.

The particle morphology of magnetosome crystals varies, but is consistent within cells of a single magnetotactic bacterial species or strain. Three general crystal morphologies have been reported in magnetotactic bacteria on the basis: roughly cuboidal, elongated prismatic (roughly rectangular), and tooth-, bullet-, or arrowhead-shaped. Magnetosome crystals are typically 35–120 nm long, which makes them single-domain. Single-domain crystals have the maximum possible magnetic moment per unit volume for a given composition. Smaller crystals are superparamagnetic—that is, not permanently magnetic at ambient temperature, and domain walls would form in larger crystals. In most magnetotactic bacteria, the magnetosomes are arranged in one or more chains.

Magnetic interactions between the magnetosome crystals in a chain cause their magnetic dipole moments to orientate parallel to each other along the length of the chain. The magnetic dipole moment of the cell is usually large enough so that its interaction with Earth’s magnetic field overcomes thermal forces that tend to randomize the orientation of the cell in its aqueous surroundings. Magnetotactic bacteria also use aerotaxis, a response to changes in oxygen concentration that favors swimming toward a zone of optimal oxygen concentration. In lakes or oceans the oxygen concentration is commonly dependent on depth. As long as the Earth’s magnetic field has a significant downward slant, the orientation along field lines aids the search for the optimal concentration. This process is called magneto-aerotaxis.

Key Points

- Magnetosomes contain 15 to 20 magnetite crystals that together act like a compass needle to orient magnetotactic bacteria in geomagnetic fields, thereby simplifying their search for their preferred microaerophilic environments.
- The particle morphology of magnetosome crystals varies, but is consistent within cells of a single magnetotactic bacterial species or strain.
- Each magnetite crystal within a magnetosome is surrounded by a lipid bilayer. Specific soluble and transmembrane proteins are sorted to the membrane.
Key Terms

- **magnetotaxis**: The supposed ability to sense a magnetic field and coordinate movement in response, later discovered to be natural magnetism: such creatures orient themselves magnetically even after death.

- **magnetosome**: A membranous prokaryotic organelle, containing mineral crystals, present in magnetotactic bacteria.