CHARACTERIZATION OF MAGNETIC NANOCRYSTALS FORMED BY MAGNETOTACTIC BACTERIA

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Many organisms are known to contain ferrimagnetic nanocrystals, whose magnetic properties are determined by their sizes, morphologies, crystallographic orientations and arrangements. However, in most cases the relationship between the presence of the crystals and navigation by the organism in magnetic fields remains poorly understood. Magnetotactic bacteria are the simplest organisms that use magnetite (Fe₃O₄) or greigite (Fe₃S₄) crystals for orienting themselves in the Earth’s magnetic field. We have used off-axis electron holography in the transmission electron microscope to characterize the magnetic fields of iron oxide and iron sulfide nanoparticles in magnetotactic bacteria in order to understand nanoparticle magnetism in the cells and to draw conclusions about possible mechanisms of magnetoreception in structurally more complex organisms.

We studied a variety of wild and cultured magnetotactic bacteria that contain magnetite nanocrystals of various sizes, shapes and arrangements, including single and double chains and disordered clusters. Electron holograms were used to construct magnetic induction maps, which showed that each crystal invariably contains a single magnetic domain and that in well-organized chains the magnetization directions of individual crystals are parallel to each other. Magnetic induction maps from magnetosomes with different sizes, morphologies, orientations and spacings suggest that shape anisotropy is the most important factor that controls the magnetic microstructure of chains of crystals, followed by interparticle interactions, with magnetocrystalline anisotropy being the least important. Some species of magnetotactic bacteria produce greigite magnetosomes. The morphologies and arrangements of iron sulfide magnetosomes are typically less strictly constrained than are those of magnetite magnetosomes, resulting in a lower magnetic moment per volume of magnetic material. The organism compensates for this reduced efficiency by synthesizing a correspondingly larger number of magnetosomes.

In all of the cells that were studied using electron holography, the magnetosomes were found to result collectively in a permanent magnetic dipole moment that is sufficient for effective alignment of the cell in the Earth’s magnetic field.