Making magnets by bacteria: Biomineralization, functionalization, and application of biogenic magnetic nanoparticles

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Magnetotactic bacteria form specific intracellular structures, the magnetosomes, which are nanometer-sized, membrane-bounded magnetic particles of magnetite (Fe_3O_4). Unlike magnetite produced in inorganic systems, bacterial magnetosome particles display a variety of species-specific morphologies, have narrow size distributions and highly defined structural and magnetic characteristics. Magnetosomes within a bacterial cell are aligned within one or multiple straight chains, which are one of the most intriguing examples for the biogenic synthesis of a hierarchical self-assembled nanostructure. By interaction with the Earth's magnetic field magnetosome chains serve as navigational device for magnetic navigation in the aquatic habitats of the bacteria. The biomineralization of bacterial magnetosomes is controlled by a number of specific gene functions, which are encoded within a large genomic magnetosome island.

Because of their unique features, bacterial magnetosomes have the potential to yield biomaterials for use in number of applications, such as in immobilization of bioactive compounds, magnetic separation, and others. Magnetosomes can be produced and purified in larger quantitities from the magnetic bacterium *Magnetospirillum gryphiswaldense.* Biochemical analysis of the magnetosome membrane revealed a set of specific magnetosome-associated proteins, which are involved in the control of magnetite crystallization. Genetic *in vivo* techniques as well as biomimetic approaches can be used to control the physico-chemical and magnetic characteristics of particles. In addition to *in vitro* coupling, expression of fusion proteins with magnetosome constituents has been demonstrated using genetic technology. This approach is promising for the magnetosome-specific display of other bioactive compounds and biomolecular coupling groups in order to design functionalized magnetic particles. Potential applications of bacterial magnetosome particles will be discussed.