How to build a magnetic organelle: Engineering and transfer of the bacterial magnetosome pathway

Dirk Schüler, University of Bayreuth, Germany

Several bacteria synthesize magnetosomes, which are complex organelles dedicated to magnetic navigation of the cells in their aquatic habitats. In the alphaproteobacterium *Magnetospirillum gryphiswaldense* the stepwise biogenesis of magnetosomes involves the invagination of vesicles from the cytoplasmic membrane, the magnetosomal uptake of iron and redox-controlled biomineralization of magnetite crystals, as well as their assembly into nano-chains along a dedicated cytoskeletal structure to achieve one of the highest structural levels in a prokaryotic cell.
We previously discovered genes controlling magnetosome synthesis to be clustered within a larger genomic magnetosome island. Whereas numerous of those genes have accessory roles in biomineralization of properly sized and shaped crystals, we found only a part of the magnetosome island to encode factors essential for iron transport, magnetosome membrane biogenesis, and crystallization of magnetite particles. While deletion of single and multiple genes caused the biosynthesis of smaller, fewer, misshapen and ectopically positioned particles, genomic multiplication of magnetosome operons resulted in substantial magnetosome overproduction in the native host *M. gryphiswaldense*.
We also demonstrated that the ability to synthesize such a highly complex organelle can be reconstituted within foreign hosts. Transfer of 30 genes to the recipient *Rhodospirillum rubrum* resulted in biosynthesis of well organized magnetosomes and conferred magnetotactic behaviour to this photosynthetic bacterium. Expression of the magnetosome biosynthetic pathway from the fastidious donor bacteria within other foreign hosts may greatly expand the nanotechnological and biomedical applications of magnetosomes and enable the designed and production of tailored magnetic nanostructures by genetic engineering. In addition, this represents a step towards the endogenous magnetization of various organisms by synthetic biology approaches.