Scientists transfer genes required for formation of intracellular biocompass into a non-magnetic host

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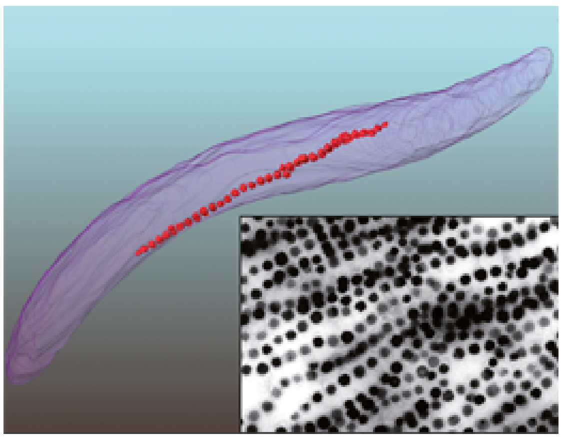

Magnetic bacteria navigate by means of an internal, biological compass. In a remarkable biotechnological feat, LMU scientists have succeeded in transferring the genes required for formation of the biocompass into a non-magnetic host.

Motile magnetosensitive bacteria found in the sediments at the bottom of lakes and ponds make use of Earth's magnetic field to tell which way is up, and to seek out environmental conditions optimal for their survival. Magnetotactic navigation is made possible by unique organelles called magnetosomes, which consist of minute magnetite crystals that are enclosed in a biological membrane. These crystals are organized into ordered linear chains, which act as a miniature compass needle, enabling cells to move along the Earth's magnetic field lines.

The magnetosome is one of the most intricate structures known in the bacterial world. It is assembled in a multistep process, which requires the products of many genes. "During the past several years, we have shown that at least 30 specific genes participate in the process, and that they are clustered together in a single region in the genome," says LMU microbiologist Dirk Schüler, whose research group has been studying magnetic bacteria for more than 15 years. "But it was not clear whether other, as yet unknown, gene functions, might be necessary for magnetosome formation."

Poor growth hampers biotechnological use

As magnetic nanoparticles with properties superior to anything that has yet been synthesized chemically, magnetosomes are of considerable biotechnological interest – for applications in biomedical imaging, for instance. Details of their biosynthesis, however, have been difficult to work out, because most naturally occurring magnetic bacteria are extremely difficult or even impossible to cultivate in the laboratory.

In principle the hurdle can be bypassed by transferring the genetic information for magnetosome formation into a host organism that can be grown in a conventional culture medium. It is therefore hardly surprising that many research teams have been pursuing this goal. "However, technically this is quite challenging, because the number of genes that have to be transferred is unusually high," as Isabel Kolinko, first author on the new study, explains. Moreover, correct assembly of the magnetosome requires numerous biosynthetic steps to happen in the proper order and at the right cellular localization – and that requires very precise regulation. And finally, it was not at all obvious that all gene functions essential for the process had actually been identified, which raised the question of whether the task could be accomplished at all. But the LMU team decided to make the attempt. In collaboration with colleagues from the Helmholtz Institute for Pharmaceutical Research Saarbrücken, Schüler's group successfully introduced all the genes known to be required for magnetosome assembly in the magnetic bacterium Magnetospirillum gryphiswaldense into the photosynthetic microorganism Rhodospirillum rubrum.

Nanomagnets from the bioreactor

And the experiment worked. "R. rubrum cells that had been transformed with this set of genes were indeed capable of forming chains of magnetic crystals like those found in M. gryphiswaldense, and the cells aligned themselves along with the Earth's magnetic field. These findings for the first time demonstrate that the transplantation of such a complex biosynthetic pathway into a different host organism is indeed possible," Schüler points out. In addition, the result proves that the 30 genes that had already been identified as necessary for magnetosome formation are in fact sufficient to program the whole process.

The researchers chose R. rubrum as their host organism because it is easier to grow in culture than the fastidious magnetic bacteria. In addition, the new strain with its newly acquired biochemical capabilities is already of considerable interest as it promises to facilitate the production of nano-magnets. It grows much faster than M. gryphiswaldense, yielding larger amounts of biomass, which should make the fabrication of the sought-after magnetic nanoparticles more efficient.

"Even more important is the fact that we can now use targeted manipulation of the transplanted genes to further improve the properties of the biogenic nano-magnets, in terms of controlling their size, number and form," Schüler explains. "If we can further reduce the number of genes required, and optimize or modify their functions, it might even become possible to introduce the blueprint for magnetosome construction into the cells of higher organisms – making them magnetosensitive. This would open up a wide range of potential applications, especially in basic research. For example, such nanomagnets could be used for the experimental manipulation of cellular processes, and as an intracellular reporter in procedures involving imaging techniques," says Schüler.

More information: "Biosynthesis of magnetic nanostructures in a foreign organism by transfer of bacterial magnetosome gene clusters." Isabel Kolinko, et al. *Nature Nanotechnology* (2014) DOI: 10.1038/nnano.2014.13.

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