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Bacterium reveals the crucible central to its metallurgical activity

An international consortium led by researchers from the CEA[1], in collaboration with the CNRS, has characterized the structure and function of a protein involved in the production of magnetite nanomagnets in so-called magnetotactic bacteria[2]. This protein, MamP, is central to the metallurgical activity of these bacteria as it gives magnetite its magnetic properties. This is an important advance in the understanding of these bacteria and their biomineralization of magnetite. This should widen the field of biotechnological applications of these nanomagnets, particularly in medical imaging and water pollution. These results were published on the Nature website on October 6th 2013.

Magnetotactic bacteria have the ability to synthesize nanocrystals of magnetite (Fe_3O_4), enabling them to align themselves with the Earth's magnetic field and find faster the position in the water the most favorable to their survival. The alignment of these nanomagnets is similar to a compass needle. However, the synthesis of these magnetite crystals is a complex process still poorly understood. Magnetite is a compound of oxygen and iron in two different oxidation-reduction states [$Fe(II)Fe(III)_2O_4$]. In this study, the researchers have shown how the bacteria produce these two forms of iron, one of which, Fe(III), is almost insoluble.

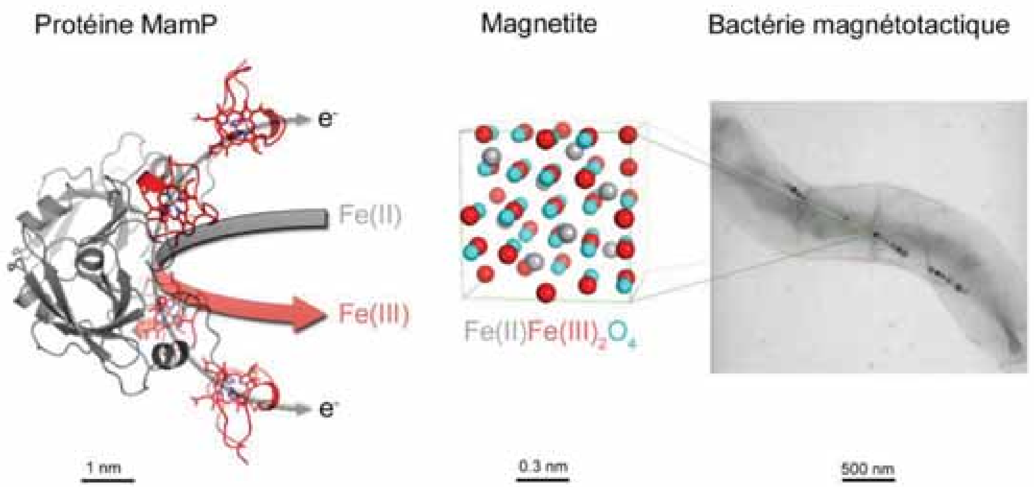
Determination of the structure of the MamP protein has shown for the first time that a section of this protein possesses a unique magnetochrome fold that was only found in magnetotactic bacteria. Moreover, this protein has a crucible-like shape capable of storing iron. Additional experiments showed that MamP has the ability to oxidize Fe (II) into Fe (III) and stabilize it in the crucible. Studies using site-directed mutagenesis and phenotypic variants of magnetotactic bacteria have subsequently confirmed the physiological importance of this crucible.

Finally, in vitro experiments have shown that MamP, incubated in the presence of Fe(II) alone can produce a precursor of magnetite, showing that the Fe(III) does indeed result from the activity of this protein.

[1] Researchers from the Institute of Environmental Biology and Biotechnology in the life sciences branch of Cadarache. The consortium also includes Aix-Marseille University (AMU) and the CNRS, SOLEIL synchrotron (Gif-sur-Yvette) and researchers from the Max Planck Institute (Potsdam, Germany) and the University of California (Berkeley, USA).

[2] Magnetotactic bacteria are aquatic bacteria that have the ability to orient themselves along the earth's magnetic field. This ability allows them to find the ideal depth where there is the optimal concentration of dissolved oxygen, which will vary depending on the water level and tide.

This fundamental study sheds light on part of the process of iron biomineralization and the synthesis of nanomagnets in a magnetotactic bacterium. The potential applications of these nanomagnets appear very promising. They could, for example, be used as contrast agents for MRI. Another possible application is depolluting water. Indeed, equipped with an enzyme that breaks down pollutants, magnetotactic bacteria could be used to treat effluent and could easily be recovered afterwards by magnetization.



Legend : The crucible of the MamP protein (structure colored in grey with its magnetochrome domains, in red) allows transformation of Fe(II) into Fe(III); those two redox states are necessary to make magnetite nanomagnets in so-called magnetotactic bacteria.

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Structural insight into magnetochrome-mediated magnetite biomineralization.
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