Magnetotactic bacteria: biological 1D magnetic nanostructure, biorobot for targeted therapies

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Magnetotactic bacteria (MTB) are aquatic microorganisms that synthesize magnetic nanoparticles called magnetosomes, which arrange in a chain along the cell's longitudinal axis, making them ideal models for studying magnetic properties and understanding self-assembled nanostructures. The ability of MTB to propel themselves with flagella and the presence of the magnetosome chain make them highly suited for targeted therapies. They can be manipulated by external magnetic fields and are naturally drawn to hypoxic areas, like tumour regions. The presence of magnetosomes also provides therapeutic benefits, such as the ability to generate heat under alternating magnetic fields, enabling their use in magnetic hyperthermia therapy. This review explores the latest advancements in using MTB as nanomagnetic systems and biorobots for targeted therapies.

Keywords: Magnetotactic bacteria; biomedical applications; 1D magnetic nanostructure

1. Introduction

Magnetotactic bacteria (MTB) are a group of mobile aquatic microorganisms that have the ability to align and orient themselves along the Earth's magnetic field, a phenomenon known as magnetotaxis [1]. This behaviour is possible thanks to the presence of magnetosomes, intracellular magnetic nanoparticles which the bacteria synthesize and organize forming a chain along the longitudinal axis of the cell. MTB exerts a strict genetic control on the composition, morphology, and size of the magnetosomes as well as on the organization of the chain. As a consequence, these factors are specific to each bacterial species. This results in a variety of diverse magnetic responses depending on the bacterial species being studied. The arrangement of magnetosomes in one-dimensional chains offers a unique opportunity to explore how morphology affects the magnetic characteristics of self-assembled nanostructures [2]. Furthermore, the high quality of these magnetosomes provides an excellent platform for studying nanoscale magnetic properties using emerging experimental techniques [2].

In addition to magnetotaxis, MTB also possess an oxygen sensory mechanism called aerotaxis, which allows them to navigate toward areas with optimal oxygen concentrations. This dual capability of magnetotaxis and aerotaxis, combined with the self-propulsion provided by their flagella, has led to the idea of using MTB as biorobots for various therapeutic and diagnostic applications. Specifically, MTB can be guided using external magnetic fields and are naturally attracted to hypoxic regions, such as those found in tumours. This has led to their investigation for use in applications such as magnetic resonance imaging (MRI), targeted drug delivery and magnetic hyperthermia [3].

This work presents recent research on MTB as model nanomagnetic systems for fundamental research and as biorobots in targeted therapies.

2. Results and discussion

Among all the MTB species, *Magnetospirillum gryphiswaldense* (MSR-1), *Magnetospirillum magneticum* (AMB-1), and *Magnetovibrio blakemorei* (MV-1), are easy to grow in the laboratory and all of them synthesize magnetite. MSR-1 and AMB-1, synthesize cube-octahedral shape magnetosomes with mean diameter of ~ 40 - 45 nm but different shape factor and magnetosome arrangement. On the other hand, MV-1 synthesize elongated magnetosomes with truncated hexa-octahedral morphology with a mean size of around 35 x 35 x 53 nm³. Using these species, we will explore how the morphology affect the magnetic anisotropy of the magnetosome and the arrangement of them in the chain given rise to different magnetic response [2].

We will demonstrate the capabilities of different bacterial species as hyperthermia agents and explore the effect of magnetic hyperthermia on tumour lung cancer cells using in vitro assays. We will also show how magnetosomes degrade over time in these cells. Finally, we will prove that it is possible to dope magnetosomes with other elements, such as Gd and Tb, which gives the bacteria new functionalities for biomedical applications [3].

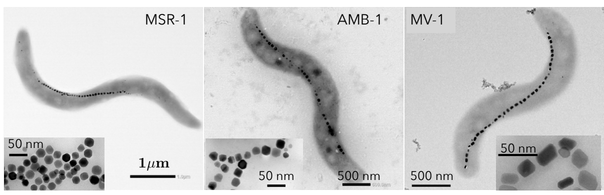

Figure 1. TEM images of a) *Magnetospirillum gryphiswaldense* (MSR-1); b) *Magnetospirillum magneticum* (AMB-1; *Magnetovibrio blakemorei* (MV-1). Insets: TEM images of magnetosomes for each bacteria species.

References

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