Towards engineering magneto-receptive E. coli

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Abstract
Nanoparticles exhibit unique physical, mechanical, optical and electromagnetic properties owing to the increase in surface area to volume ratio as compared to the bulk material. The unique characteristics paves way to a wide array of applications such as detection of proteins, tumor destruction, tissue engineering and MRI contrast enhancement. Biological synthesis of these nanoparticles using bacterial hosts is being explored as an alternative to chemical synthesis as it is environmentally friendly. Protein nanocages, when employed as templates facilitate production of size controlled monodispersed nanoparticles. Cells harboring these protein nanocages could be engineered with surface ligands for tissue-specific accumulation for enhanced imaging for MRI applications.

Archaeoglobus fulgidus Ferritin (AfFtn) a self-assembling, 24-subunit iron storage protein which maintains iron homeostasis, is used as a template for iron nanoparticle synthesis in E. coli. To enhance iron uptake and reduce iron efflux, the E. coli has been further engineered to express iron influx transporter protein (feoB) while knocking out iron efflux protein (ΔfieF). Further protein engineering of AfFtn to exhibit magnetite forming ability was explored to enhance the magnetic properties. In vivo iron loading in AfFtn was achieved by incubating E. coli with excess iron in the growth medium. The bacterium which has been characterized for its magnetic properties exhibits ferromagnetic behaviour with a fast response to an external magnetic field.

The fast-developing field of synthetic biology enables broad applications of programmed microorganisms including the development of whole-cell biosensors, delivery vehicles for therapeutics, or diagnostic agents. However, the lack of spatial control required for localizing microbial functions could limit their use and induce their dilution leading to ineffective action or dissemination. To overcome this limitation, the integration of magnetic properties into living systems enables a contact-less and orthogonal method for spatiotemporal control. Here, we generated a magnetic-sensing Escherichia coli by driving the formation of iron-rich bodies into bacteria. We found that these bacteria could be spatially controlled by magnetic forces and sustained cell growth and division, by transmitting asymmetrically their magnetic properties to one daughter cell. We combined the spatial control of bacteria with genetically encoded-adhesion properties to achieve the magnetic capture of specific target bacteria as well as the spatial modulation of human cell invasions.

Except in bacteria, however, no one has seen magnetite crystals serving as a magnetic sensor. The crystals could be something Else—say, waste products of iron metabolism, or a way for the body to sequester carcinogenic heavy metals. In the early 2000s, scientists found magnetite-bearing cells in the beaks of pigeons. But a follow-up study found that the supposed magneto receptors were in fact scavenger immune cells that had nothing to do with the neural system. And because there is no unique stain or marker for magnetite, false sightings are easy to make.

High hydrostatic pressure (HHP) batch cultivation of a model extremophile, Archaeoglobus fulgidus type strain VC-16, was performed to explore how elevated pressures might affect microbial growth and physiology in the deep marine biosphere. Though commonly identified in high-temperature and high-pressure marine environments (up to 2–5 km below sea level, 20–50 MPa pressures), A. fulgidus growth at elevated pressure has not been characterized previously. Here, exponential growth of A. fulgidus was observed up to 60 MPa when supported by the heterotrophic metabolism of lactate oxidation coupled to sulfate reduction, and up to 40 MPa for autotrophic CO2 fixation coupled to thiosulfate reduction via H2. Maximum growth rates for this heterotrophic metabolism were observed at 20 MPa, suggesting that A. fulgidus is a moderate piezophile under these conditions. However, only piezotolerance was observed for autotrophy, as growth rates remained nearly constant from 0.3 to 40 MPa. Experiments described below show that A. fulgidus continues both heterotrophic sulfate reduction and autotrophic thiosulfate reduction nearly unaffected by increasing pressure up to 30 MPa and 40 MPa, respectively. As these pressures encompass a variety of subsurface marine environments, A. fulgidus serves as a model extremophile for exploring the effects of elevated pressure on microbial metabolisms in the deep subsurface. Further, these results exemplify the need for high-pressure cultivation of deep-sea and subsurface microorganisms to better reflect in situ physiological conditions.

Nanomaterials are at the leading edge of the rapidly developing field of nanotechnology. Their unique size-dependent properties make these materials superior and indispensable in many areas of human activity. This brief review tries to summarize the most recent developments in the field of applied Nanomaterials, in particular their application in biology and medicine, and discusses their commercialization prospects.

In terms of diameter, fine particles cover a range between 100 and 2500 nanometers, while ultrafine particles are sized between 1 and 100 nanometers. Nanoparticles may or may not exhibit size-related properties that are seen in fine particles.

Despite being the size of the ultrafine particles individual molecules are usually not referred to as nanoparticles.

Nanoclusters have at least one dimension between 1 and 10 nanometers and a narrow size distribution. Nano powders on the other hand are agglomerates of ultrafine particles, nanoparticles, or nanoclusters. Nano particle sized crystals are called nanocrystals.