Magnetic Bacteria

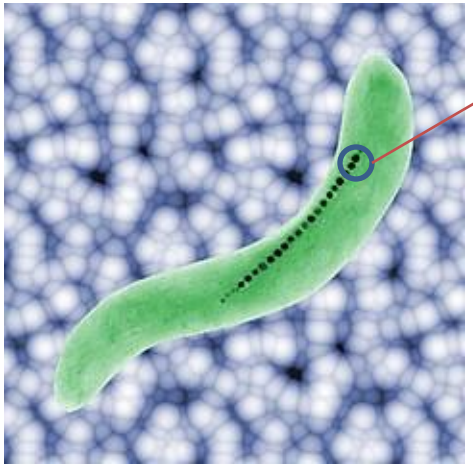
iGEM 2009 project canditate

What are Magnetic Bacteria

- Unicellular microorganisms of aquatic habitat
- They carry membrane bound organelles that surround a magnetic crystal
- The crystal is permanently magnetic
- Pseudogenus of “magnetotacticum”
- Polyphyletic evolution of magnetosomes
- Crystals used as a compass; Flagellin motility

Introduction to *Biologically Controlled Mineralisation*

An overview of the magnetic bacterium morphology



Magnetosome Membrane

Magnetic Particle

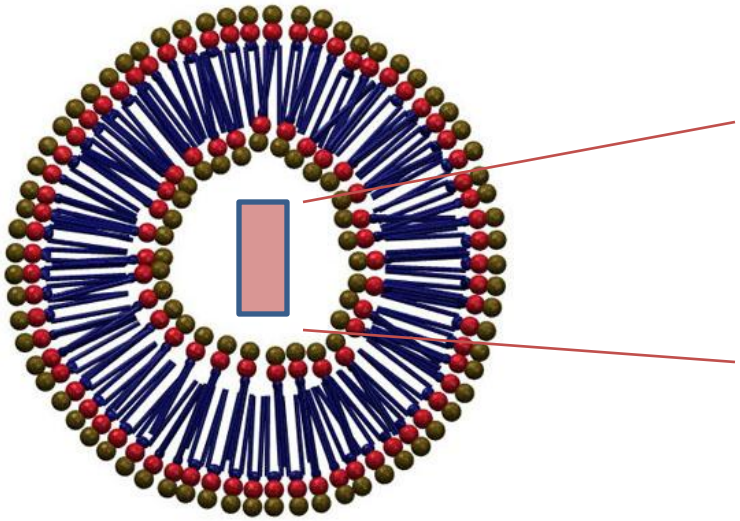
Cytoskeletal-like filament

2 types of Swimming;
Polar Swimming – Swim in one direction
Axial Swimming – Swim in both directions without flipping

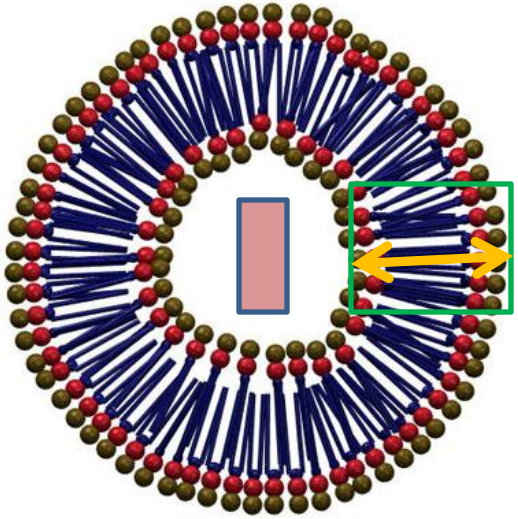
N.B. Swimming occurs by flagella and magnets only act as compass.

Bazylinski et al. (2004) Magnetosome formation in prokaryotes, Nat. Rev. Microb. 2, 217-230

Taking a closer look…



35 – 120 nm
SD Crystals



3-4 nm in size

Size

Properties

Permanently Magnetic
Fe_3O_4/ Fe_3S_4

Morphologies dependent on species and environmental stress

The magnetic moment is a sum of all the magnetosomes aligned on a line

Cytoplasmic Membrane Composition (phospholipids,F.A.,Proteins all from Cytoplasmic membrane)

Probably arises by invagination

Synthesis of a magnetosome

- Occurs in 4 main steps

1. Hollow vesicle formation (Mms16)
2. Fe uptake from environment (CDF proteins)
3. Uptake of Fe into vesicle
4. Biomineralisation occurs in Vesicles

Bazylinski et al. (2004) Magnetosome formation in prokaryotes, Nat. Rev. Microb. 2, 217-230
Faivre et al. (2008) Magnetotactic Bacteria and magnetosomes, Chem. Rev. 108, 4875-4898

Envelope Proteins

- Mms16
  - GTPase protein essential for envelope formation.
  - Reminiscent of eukaryotic envelope formation
- magA - Fe Transport into vesicle
  - Fe(II)/H+ Antiporter
  - Homologous to KefC Cation Efflux Protein in E.Coli
  - Expressed in E.Coli !
- MamB/M – Cation Diffusion Facilitators

Okamura et.al (2001) A magnetosome specific GTPase from the magnetic bacterium Magnetospirillum magnetotacticum AMB-1, J. Biol. Chem 276, 48183-48188
Grunberg et.al (2001) A large gene cluster encoding several magnetosome proteins is conserved in different species of magnetotactic bacteria, Appl. Environ. Microbiol. 67, 4573-4582
Bazylinski et al. (2004) Magnetosome formation in prokaryotes, Nat. Rev. Microb. 2, 217-230

Biomineralisation in Vesicle

- Crystals are pure within their structure.
- Mms5/6/7/13
  - Bound to Fe_3O_4 Crystals
  - Membrane Proteins N-Hphob-Hphil-C
    - (LG)4 AWGPXXLGXXGXXGXAGA – Search for E.Coli homologs ?
- Mms6
  - important in homogeneous size crystal formation
  - Expressed in E.Coli !

Bazylinski et al. (2004) Magnetosome formation in prokaryotes, Nat. Rev. Microb. 2, 217-230

More on import

- ChpA protein to uptake Fe into cell
- MamB/M
  - CDF proteins in MamAB operon homologous to FieF CDF Transporter
  - Possibly remove FieF and translate MamB/M ?
- Mam22
  - TPR family homology for import proteins

Redox Processes & Cytoskeletal Processes

- Many cytochromes possibly involved
  - Cyt.c-550 involved can be expressed in E.Coli
- Cytoskeletal Filaments
  - mamK
    - N-Terminal FtsZ-like domain (Tubulin like)
    - C-Terminal Actin-like Protein
    - Expressed in E.Coli
  - mamJ
    - Important in chain assembly
    - Prevents Crystal Agglomeration

Allen et.al (2002) ,The *Escherichia coli Cytochrome c Maturation (Ccm) System* Does Not Detectably Attach Heme to Single Cysteine Variants of an Apocytochrome *c, J.Biol.Chem 37,* 33559–33563.
Jogler etl.al (2009), Toward Cloning of the Magnetotactic Metagenome: Identification of Magnetosome Island Gene Clusters in Uncultivated Magnetotactic Bacteria from Different Aquatic sediments, Applied & Environmental Microbiology, 3972-3979
Schuler etl.al(2008), Genetics and cell biologyofmagnetosomeformation in magnetotactic bacteria, FEMS Microbiol. Rev. 32, 654-672

Good News

- Magnetotaxis
  - A process that has a convergent rather than divergent evolution
  - Evidence of occurrence in many proteobacteria & nitrospira
- Horizontal Gene Trasnfer
  - Most of the genes are found on a genomic island
  - Genomic Island is able to transpose and self-insert
- Genomic Island isolated in Fosmid Libraries
  - FOS0001
  - FOS0002

Jogler etl.al (2009), Toward Cloning of the Magnetotactic Metagenome: Identification of Magnetosome Island Gene Clusters in Uncultivated Magnetotactic Bacteria from Different Aquatic sediments, Applied & Environmental Microbiology, 3972-3979

Some Considerations

- Time Limitation
- Need to have target goals
- Feasibility issues ?
- Oxygen concetrations of growing bacteria need to be limited.

- ADDITIONAL LITERATURE:
  - Matsunaga et.al (2005),Complete Genome Sequence of the Facultative Anaerobic Magnetotactic Bacterium Magnetospirillum sp. strain AMB-1, DNA Research 12, 157-166