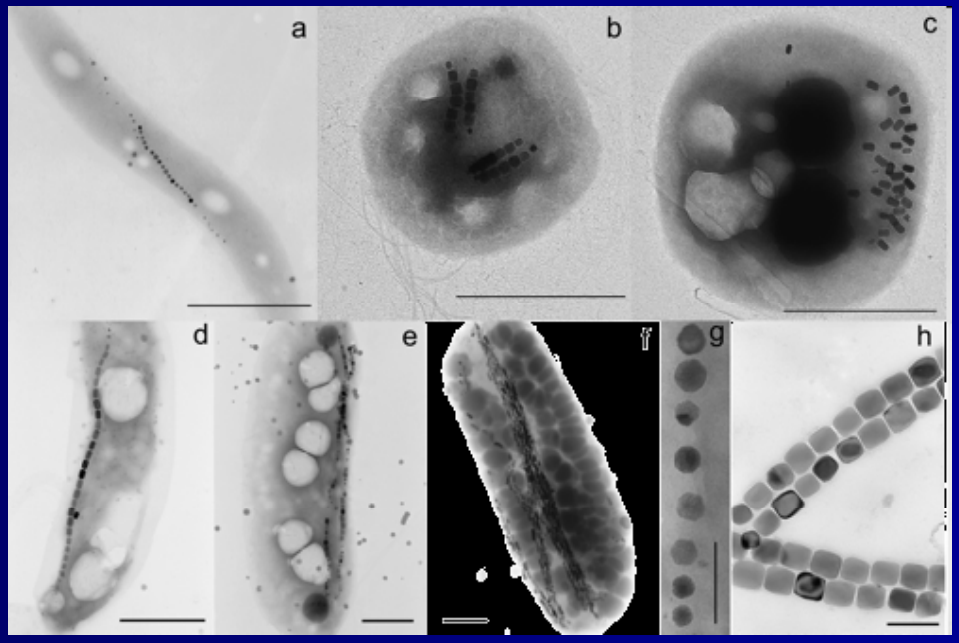
Magnetotactic Bacteria

Makers of Mini Magnets

Materials 265
11/5/08

Kristen Murphy



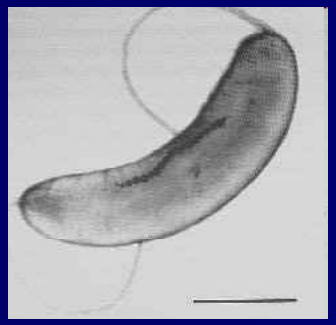
Background and Discovery

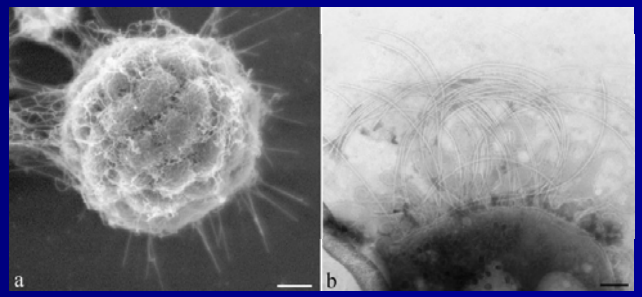
- Salvador Bellini first described the bacteria in 1963
- 1975 Richard Blakemore published in *Science* and called them "magnetotactic"
- Usually located in costal environments
- Have been found in the deep ocean as well
- Usually found in oxic-anoxic transition zones

Blakemore, R. P. *Science* **1975**, *190*, 377 Faivre, D.; Schüler, D. *Chem. Rev.* **2008**, ASAP Article

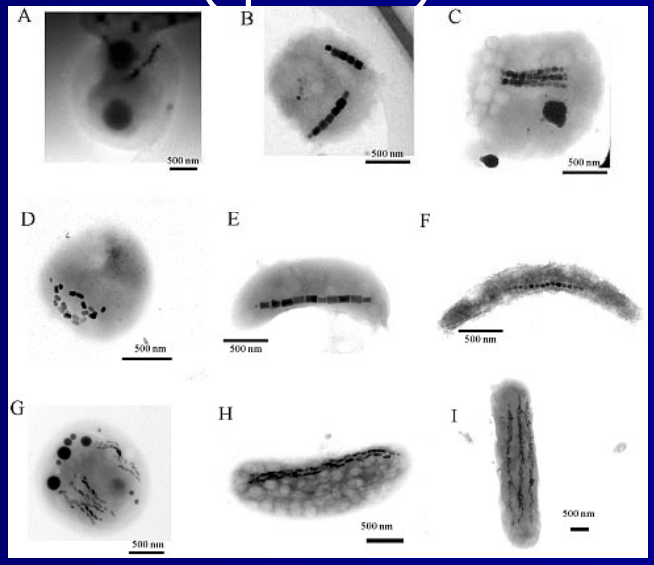
Anatomy

- Gram negative bacteria
- Can be single or multi-cellular





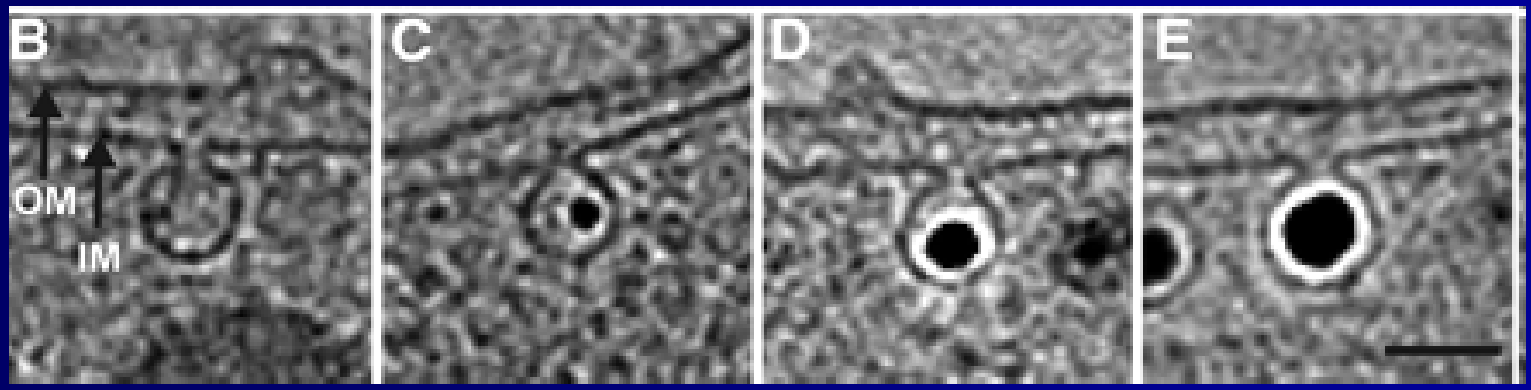
- Cell shapes include ovoid cells (cocci), rod-shaped (bacilli), curved bacteria (vibrio) and helical (spirillum)



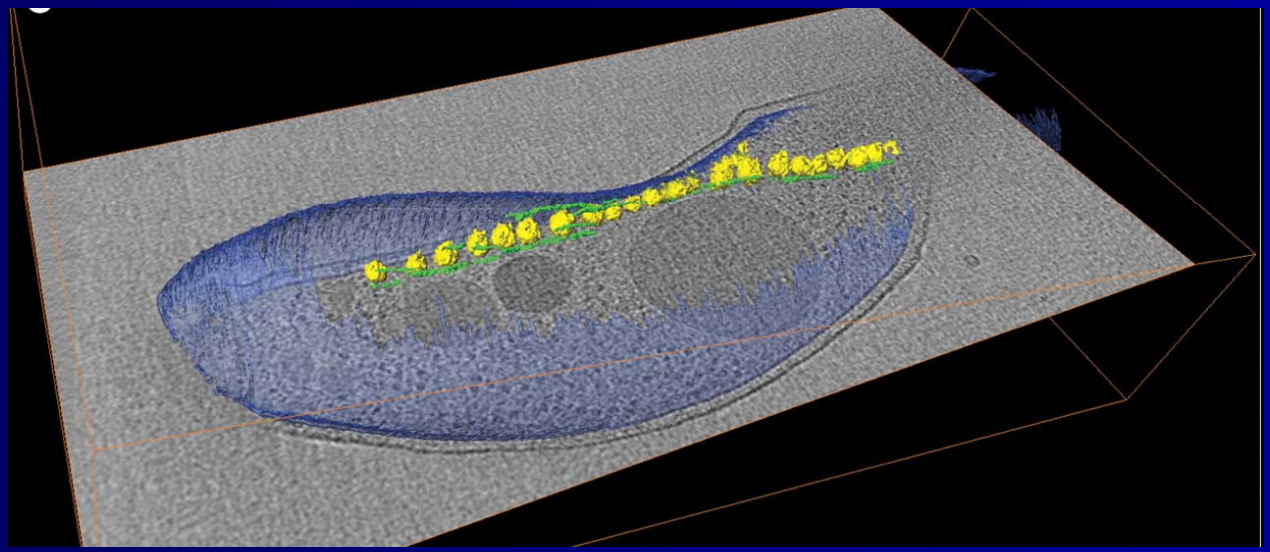
Rodgers FG, Blakemore RP, Blakemore NA, Frankel RB, Bazylinski DA Maratea D, Rodgers C, *Arch Microbiol* **1990** 154,18

Magnetosome

- Biomineralization occurs in the magnetosomes
- Small lipid bilayer sacks that are a part of the cell membrane



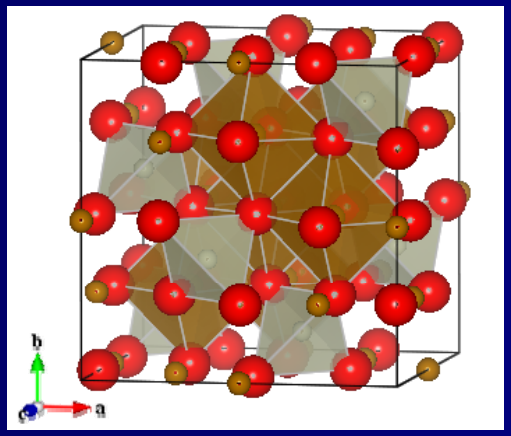
- Magnetosomes are flanked by cytoskeleton filaments



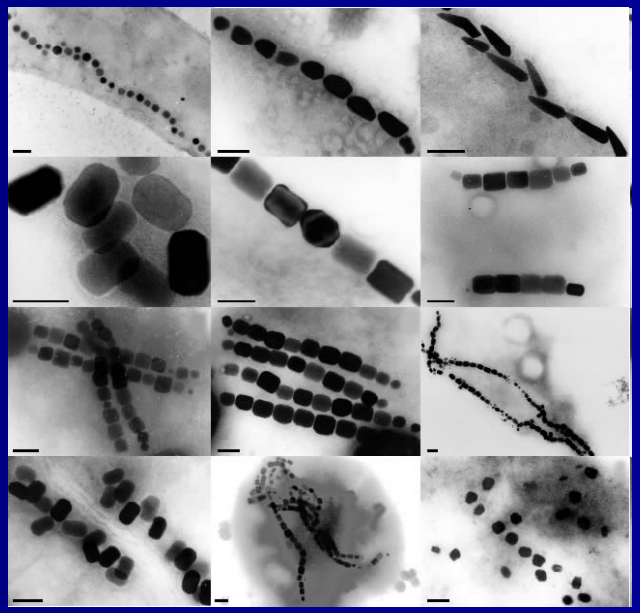
Komeili, A.; Li, Z.; Newman, D. K.; Jensen, G. J. *Science* **2006**, *311*, 242

Magnetic particles

- Mineral is either inverse spinel magnetite (Fe_3O_4) or greigite (Fe_3S_4)

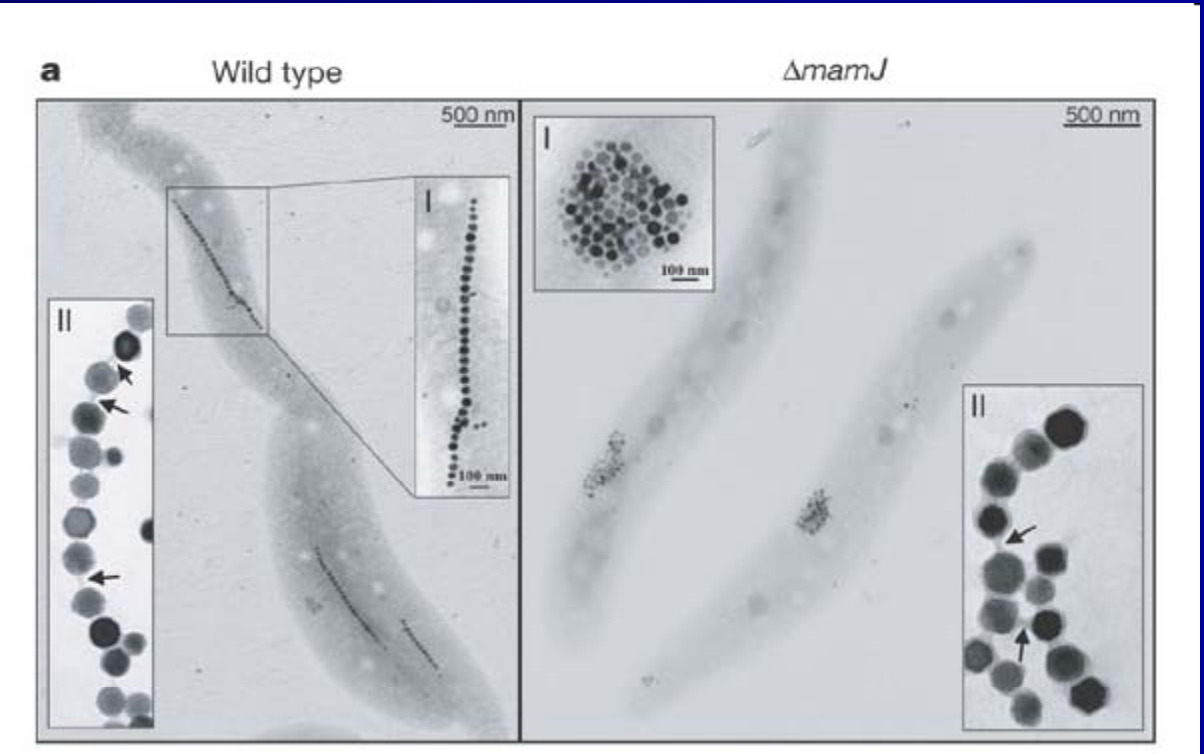


- Size and shape of vary between species or strain but the same amongst the same species
- Particles align in single or double chains
- Particles are free of internal defects



Lins, U.; Keim, C. N.; Evans, F. F.; Farina, M.; Buseck, P. R. *Geomicrobiol. J.* **2007**, *24*, 43

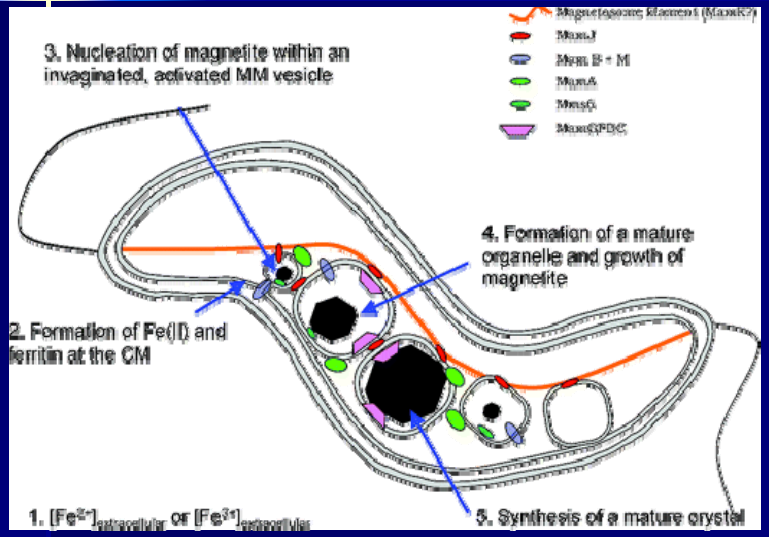
- Magnetosomes are anchored to the filaments with the protein *mamJ*

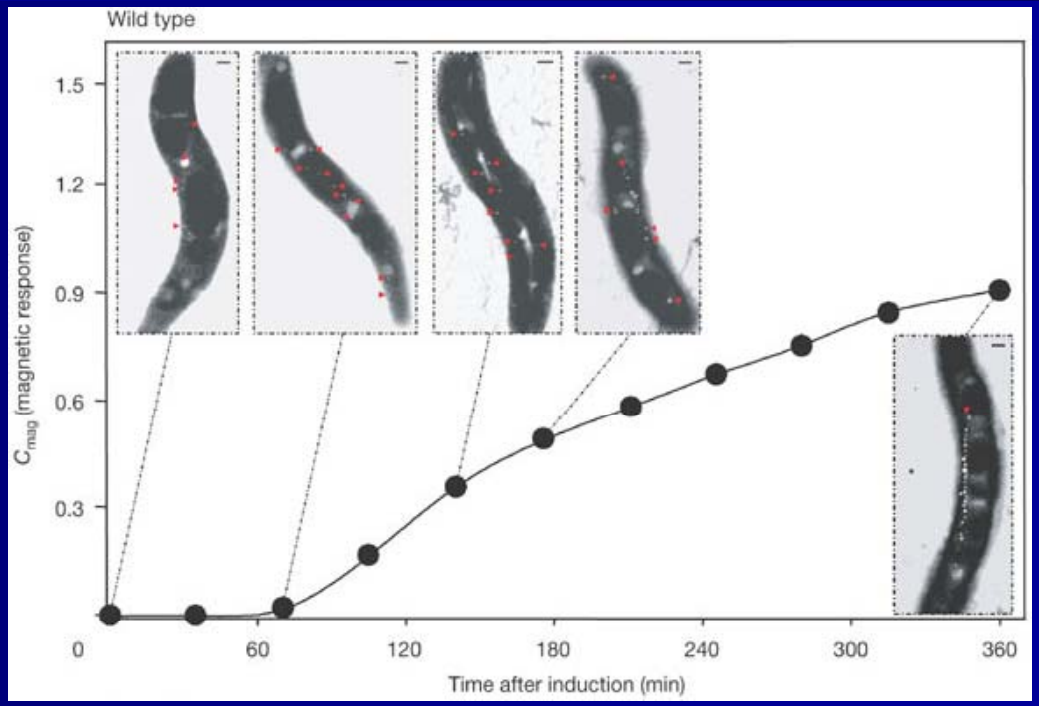


- Wildtype MTB form chains as expected, mamJ deficient form clumps of particles
- Filaments still present but magnetosomes are not anchored

Scheffel, A.; Gruska, M.; Faivre, D.; Linaroudis, A.; Graumann, P.; Plitzko, J. M.; Schüler, D. *Nature* **2006**, *440*,

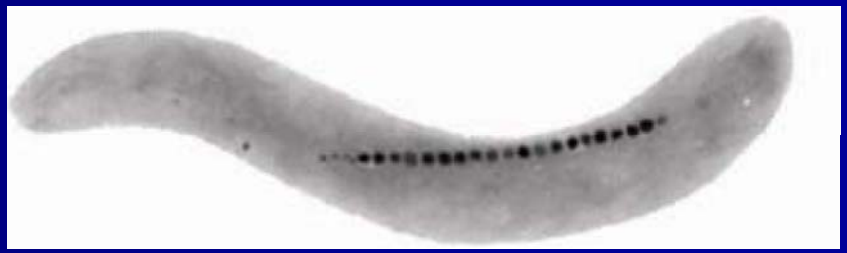
Biomineralization





- Vesicle forms before biomineralization
- Iron taken up by the cell, mineralization occurs at magnetozome membrane
- Formation at vesticles along entire chain length

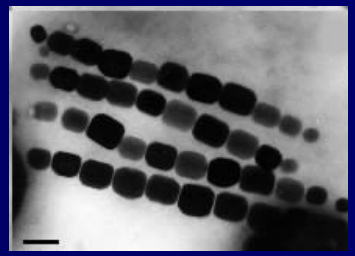
- Vesicle migrates as crystals form
- Mature crystals are at the center of the chain

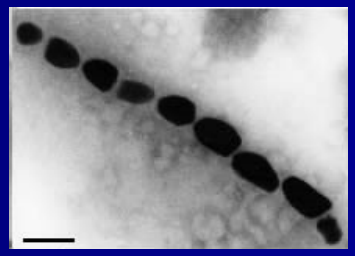


Faivre, D.; Menguy, N.; Guyot, F.; Lopez, O.; Zuddas, P. *Am. Mineral.* **2005**, *90*, 1793

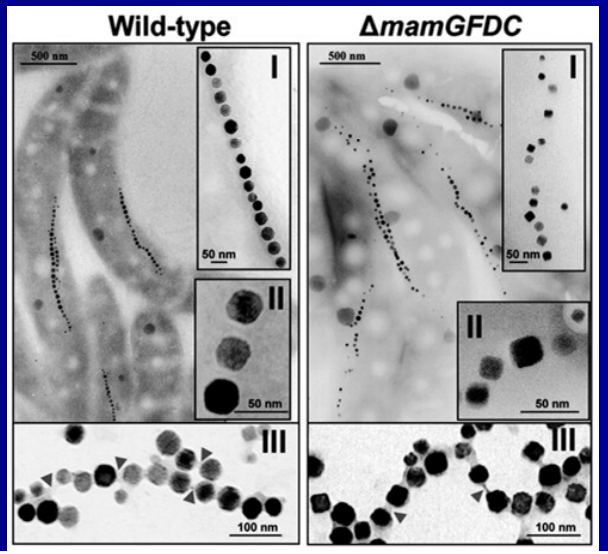
Size and Shape Control

- Unknown how the shape is controlled
- What affects shape includes:
  - Mms6 protein, Δ*mamA* and Δ*mamGFDC* genes, supersaturation state, iron supply direction, concentration of activation molecules/ions, iron uptake rate, oxygen partial pressures, pH, redox potential and temperature





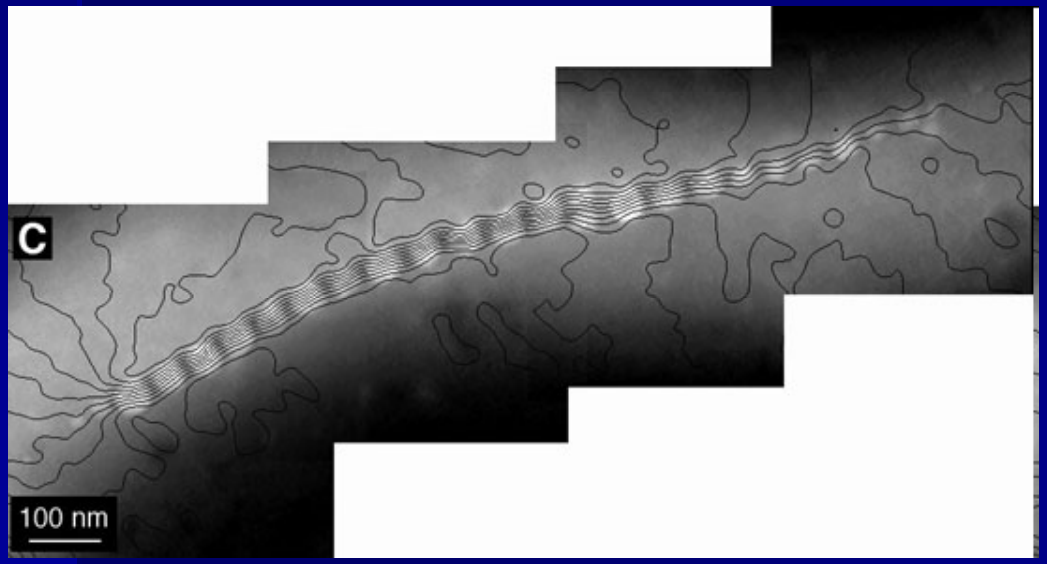

- Size controlled so they are single domain but above the superparamagnetic size
  - hydrophobic magnetosome proteins MamG, MamF, MamD, and MamC are involved in size control
  - Possible that magnetosome vesicle size constrains growth

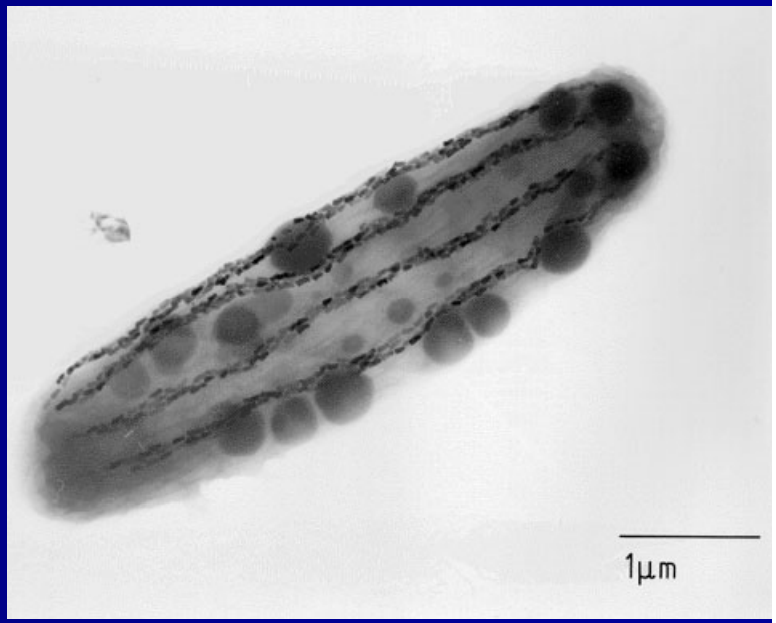


Scheffel, A.; Schüler, D. *J. Bacteriol.* **2007**, *189*, 6437

Fun Facts

- Magnetotaxis used to navigate oxygen gradients- swim from high to low/no oxygen
- North seeking in northern hemisphere, south seeking in southern hemisphere, equal numbers at the equator
- 1% in each hemisphere are opposite polarity
- Two types of magnetotactic bacteria: polar and axial
- Can't be demagnetized but polarity can be reversed





Simmons, S. L.; Bazylinski, D. A.; Edwards, K. J. *Science* **2006**, *311*, 371
Frankel, R. B.; Bazylinski, D. A.; Johnson, M. S.; Taylor, B. L. *Biophys. J.* **1997**, *73*, 994
Dunin-Borkowski, R. E.; McCartney, M. R.; Frankel, R. B.; Bazylinski, D. A.; Pósfai, M.; Buseck, P. R. *Science* **1998**, *282*, 1868