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専門分野　地球生命科学

The Accidental Discovery of a Chemotactic Override on the Swimming Direction of Magnetotactic Bacteria (an Amusing Story)

Sometimes in Science a simple observation is made that reveals an underlying process of a fundamental nature, yet is difficult to publish in the peer-reviewed literature. Hence, I take great pleasure in being able to convey to the Japanese Geoscience Union an amusing story – and an important discovery about magnetotactic bacteria – that should have been published over 35 years ago, except for the unusual nature of the 'experiment'!

The magnetotactic bacteria are an amazing group of microbes that make an intracellular chain of magnetite (or greigite) crystals that turn the cells into swimming compass needles. Enough magnetite is present in these cells so that the magnetic orientation energy ($\mu \cdot B$) is greater than the thermal background energy (kT), so the cells rotate passively into alignment with the geomagnetic field despite Brownian motion. In all natural, marine and freshwater aquatic environments, these bacteria live at the aerobic/anaerobic interface and use the geomagnetic field inclination to control their up/down position within the sediments.

The first peer-reviewed report of these bacteria was published in *Science* in 1975, when I was a senior undergraduate at Caltech. I had been working with my mentor, Prof. Heinz Lowenstam, on magnetite biomineralization in molluscan teeth, so this new report of magnetite in these bacteria was very exciting. I spent the next several years looking for them. Surprisingly, in the first four years after their discovery no one had bothered to check in the southern hemisphere to see which direction the bacteria swam there. In 1979, an IAGA meeting was held in Canberra, Australia, preceded by a paleomagnetics field trip organized by the Director of the Canberra laboratory, Mike McElhinny. I took the opportunity on this field trip to test local streams and lakes for the presence of magnetic bacteria, carefully noting which way they swam. All went to the South (Kirschvink, 1980). The paleomagnetists on the trip were intrigued at these bugs, and McElhinny even provided me a portable microscope.

During the IAGA meeting, they had an evening party to celebrate the 25th anniversary of Ted Irving's founding of the Canberra Paleomagnetics lab. McElhinny asked me if I'd be willing to set up a demonstration of these new marvelous, magnetic bacteria. I'd found a wonderful source in the Canberra sewage treatment pond, and had a delightful time setting up a little coil system around the microscope so that you could flip the magnetic field direction. We could make a beautiful wave of magnetic bacteria swim back and forth. It was actually the hit of the party, as many of the guests were just fascinated by the ability to control billions of these little cells with the flip of a switch.

At one point during the night, a very famous Paleomagnetist – Sir Keith Runcorn – wandered up holding a glass of beer in his hand and asked me, "Joe – do your magnetic bacteria like beer?". A bit puzzled, I said well – this is easy to test. So we took a glass microscope slide and put a drop of the sewage water on it, and made the bacteria swim to one side. I put a drop of the beer on the other side, and gently used the pipette tip to merge the two droplets. Visually, it was easy to see the diffusion front between the amber-colored beer and the sewage pond water. When we turned the magnetic bacteria around and made them swim toward this interface, we saw an amazing reaction – as the bacteria approached the amber-colored beer, they abruptly changed their swimming direction and backed up! They started swimming madly to the North, away from the beer! Normally, if you suddenly change the magnetic field direction when these bacteria are swimming, you can clearly see a circular arc as they rotate around passively. In this case, they did a very sharp, sudden V-shaped 180° change in swimming direction. I had never seen that before. While Keith Runcorn was looking at this, Mike McElhinny secretly replaced the beer in his cup with some of the sewage water, and the elderly Runcorn wandered off carrying the bacterial sample thinking it was his beer. [I don't know if or when he discovered that prank!]

The next month, I tried the same experiment with bacteria extracted from a local pond in Phoenix, Arizona, using the same brand of Australian beer. Unlike the bacteria in Canberra, the American bacteria swam straight across the beer/water interface and slowly came to a stop within the beer. At first I concluded that the Australian bacteria could not handle their liquor well as American bacteria, but upon reflection it seemed that the Australian bacteria could detect the chemicals in the beer and reverse their swimming direction to avoid it. Over 20 years later a similar chemotactic response was discovered in other species of magnetic bacteria, and we now know that some of these bacteria actually have bundles of flagella at either end of the cell, enabling them to swim in either direction depending on what they 'sniff' in the water!

Reference

Kirschvink, J.L. (1980). "South-seeking magnetic bacteria." Journal of Experimental Biology 86: 345-347.