As I described in a previous column [1], Richard Blakemore of the Woods Hole Oceanographic Institution in Massachusetts found in 1975 that certain bacteria from Cape Cod marsh muds “harbored chains of magnetic crystals” that, “as swimming compass needles,” could follow the direction of the local geomagnetic field, which dips down at an angle of 70° toward the North Pole. Blakemore’s work inspired California Institute of Technology geologist Joe Kirschvink to study magnetic bacteria in the southern hemisphere (actually in a sewage treatment pond near Canberra, Australia), and he found that “sure enough, they swam down toward the South Pole” [1], [2].

Do magnetic bacteria have a potential role in medicine? Normally, one thinks of bacteria as a source of medical problems, e.g., infections, rather than a part of the solution. But, as a team of researchers from Montreal, Canada, has recently demonstrated [3], [4], swarms of specialized magnetic bacteria, the Magnetococcus marinus strain MC-1, may someday be harnessed in the battle against cancer.

The MC-1 bacteria, found in saltwater estuaries in the northern hemisphere, use their internal “compass needles” and the Earth’s geomagnetic field to point themselves toward deeper hypoxic (low-oxygen-concentration) water, their preferred habitat. It is this affinity for hypoxic environments that makes these bacteria particularly useful in targeting tumors. [3]

As cells of a solid tumor proliferate rapidly, they consume a large amount of oxygen, making some interior regions within the tumor hypoxic. It has been a challenge to deliver current...
pharmaceutical agents to these hypoxic regions in significant concentrations. The Canadian team has shown how MC-1 cells bearing drug-containing nanoparticles can penetrate these parts effectively. S. Martel, a member of the research team, explains [3],

We first produce a weak magnetic field pointing towards the tumor to guide drug-loaded bacteria and make them swim towards the tumor (a process called magnetotaxis). Once inside the tumor and sufficiently close to the hypoxic zones, we remove the magnetic field to allow the bacteria to use their internal oxygen sensors (aerotaxis) and follow the decreasing oxygen gradient in the tumor until they reach the 0.5% oxygen level.

Thus, the applied external magnetic field (slightly larger than the Earth’s magnetic field) serves two functions. First, it overcomes the random orientation of the MC-1 cells caused by thermal forces associated with Brownian motion. Second, it guides the aligned cells into the solid tumor from the surrounding region. Once the cells are within the tumor, magnetic guidance is no longer needed, and the internal oxygen sensors take over [4].

The researchers have demonstrated [4] the combined magnetotaxis and aerotaxis guidance of MC-1 cells in animal studies. They grafted colorectal tumors in mice, loaded each MC-1 cell with approximately 70 drug-bearing nanoparticles, and found that up to 55% of the MC-1 cells penetrated into the hypoxic regions of the tumor.

What comes next? The researchers plan to study the efficacy of various therapeutic agents using this technique, evaluate the safety of the protocol, and seek collaborations with other groups.

Stay tuned!

References

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