Tales of Bitter Magnetism: Frog Eggs, Blood Cells, Pigeon Feet, Metal Shreds and a Sore Head

We enjoyed reading "Everyone's Magnetism" (PHYSICS TODAY, September, page 36), Andrey Geim's very clear and informative article on the history, principles and possible future of diamagnetic levitation as a microgravity tool. Unfortunately, part of his description of the results of our investigations into the tool's application for studying gravitational sensitivity in biological systems is inaccurate.

We did show[1] that diamagnetic levitation reduces the effective gravity acting on the constituents of eggs of the frog *Xenopus laevis* by a factor of more than 10. However, we did not observe any developmental abnormalities that we could attribute to this "low gravity" state—contrary to Geim's assertion but in agreement with observations of the development of *Xenopus laevis* eggs on the orbiting space shuttle.[2]

Levitation required placing our eggs in a region of a Bitter solenoid with a large (approximately 14 tesla), spatially varying (approximately 100 T/m) magnetic field. As a control to distinguish potential magnetic field effects from levitation ("low gravity") effects, we also placed eggs in the homogeneous, maximum field region (approximately 16 T) in the center of the solenoid, where they were not levitated. Eggs from the two regions exhibited similar, well-defined abnormalities in their development.

These unexpected magnetic field effects have proven to be interesting in their own right.[3] By appreciating and controlling for such effects, magnetic field gradient levitation can be a viable low-gravity simulator.

References

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Readers of Andrey Geim's article may be interested to know that various diamagnetic materials—such as red blood cells in water and plasma, aluminum hydroxide alumінum oxide[1] and aluminum itself[2] in paramagnetic manganese chloride solution—have been separated by the application of magnetic forces through the technique of high gradient magnetic separation (HGMS).[3] This technique employs microscopic magnetic wires to distort the field, rather than depending on the inhomogeneity of the field of the magnet to produce the field gradient. This way the gradients are local and hence very large. Also, more practical magnets can be used in applications because the high fields of Bitter magnets are not needed when high enough gradients are employed. The magnets can be iron bound and need only provide a uniform field.

References

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GEIM REPLIES: At this point, a word of caution seems to be appropriate regarding the use of magnetic fields for "low gravity" biophysics research. Efforts have been made for several decades to find evidence that static magnetic fields have any significant influence on animals, but all such efforts arguably have failed so far (see references 11 and 12 in my PHYSICS TODAY article).

The history of this research is full of amusing stories. The funniest one I have heard concerns the report of a magnetic field effect on a cockerel. The researchers determined that, above a certain field, the bird "felt discomfort." Eventually, this effect was shown to be an artifact caused by somewhat loose magnet poles that squeezed the cockerel's head an extra millimeter as the field increased. Another report (cited in reference 12 of my article) described what was called "the effect of cold feet in pigeons" and claimed it was due to a magnetic field's influence on body functioning. Later, though, the authors—to their credit—acknowledged that the effect was simply due to a field-induced draft of air.

On a more serious note, there exists a strong obscuring effect that, in my view, explains many of the earlier findings: Due to oxygen's paramagnetism, cold air accumulates in a magnet's center. The physics is similar to the well-known accumulation of cold air in low valleys, but the role of gravity is played by the magnetic field gradient exerting a force equivalent to tens of g's. The resulting redistribution of temperature and strong air turbulence could explain, among other things, the magnetically reduced body temperatures that have been reported in many studies.

David Kelland's letter invites a remark on the possible use of strong magnets in the recycling of so-called nonmagnetic waste. The global recycling industry produces an estimated million tons per year of small shreds of metals such as lead, zinc alloys and stainless steel, all mixed together. Currently, this refuse is exported to the third world for separation by hand. However, the industry is beginning to recognize that it is both technically straightforward and economically viable to employ superconducting magnets of moderate strength in the separation of at least part of this shredded refuse.

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