Biological Magnetic Sensing Comes Close to Quantum Limit

Researchers find that two types of biological magnetic sensor can sense fields close to the quantum limit, a finding that could guide the design of lab-made devices.

By **Katherine Wright**

Canada geese, monarch butterflies, bonnethead sharks, and sockeye salmon are a few of the many animal species that navigate the globe by sensing small changes in Earth's magnetic field. Previous studies of these organisms have identified several types of sensors, such as magnetically sensitive chemical reactions and compass-like cellular structures, but it's been unclear how sensitive these so-called biological magnetoreceptors are. Now Iannis Kominis and Efthmis Ghoudinakis of the University of Crete, Greece, have calculated bounds on the sensing ability of three main types of biological magnetoreceptor, showing that two of them can likely sense magnetic fields with magnitudes close to the quantum limit for magnetic-field detection [**1**].

The performance of a magnetic sensor can be characterized by three parameters: its volume, its measurement time, and the uncertainty in its magnetic-field estimate. Each parameter can be made small, but there is a limit to their collective shrinking based on Planck's constant, a parameter that defines many quantum phenomena. All known lab-made magnetometers obey this quantum limit. Because of their small size and the small field changes they sense, biological magnetometers are thought to operate near this limit. But biologists have been unable to determine all the relevant parameters precisely.

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To get around this problem, Kominis and Ghoudinakis worked in reverse, using the quantum limit to put bounds on parameters that were unknown. They found that two biological magnetoreceptors that both involve magnetic-field-dependent chemical reactions can operate right at the limit, or close to it. Kominis says that the finding could help researchers design future magnetic-sensing devices. "If [scientists] want to make the most sensitive measurements, we have to go quantum. Mimicking biological magnetoreceptors can guide such quantum engineering," he says.

Katherine Wright is the Deputy Editor of *Physics Magazine.*

REFERENCES

1. I. K. Kominis and E. Gkoudinakis, "Approaching the quantum limit of energy resolution in animal magnetoreception," **PRX Life (2024).**