Quantum Vision Allows Birds to "See" the Earth's Magnetic Field

It's accepted that our frequent-flyer feathered friends must be accessing the Earth's magnetic field somehow, but the little question of "How?" remained unanswered for a long time. A step towards answering that came forty years ago with the discovery of cryptochromes in bird eyes. Cryptochromes, as well as being terrific scorers in Scrabble, are a class of light sensitive chemicals which allow plants and animals to detect blue light. Of course, that just changes the question from "How?" to "How do the cryptochromes do it?" Recent research finally has some ideas for how this chemical not only allows you to see the wide blue sky, but the vast magnetic compass that runs through it.

Both the current theories are based on the reaction of cryptochromes to blue light. An incident photon creates a radical-ion pair in the bird's retina (one molecule with one too many electrons, and one too few, so both are electrically charged). Professor Hore of the University of Oxford proposes that these charged particles can be pulled apart by an applied magnetic field. While actual cryptochromes are quite hard to get hold of, a similar synthetic molecule known as a carotenoid-porphyrin-fullerene triad (or CPF for people who don't want to spend ten minutes saying its name) was examined by his team. By shining blue light on a chemical solution and applying a magnetic field, he was able to create different concentrations of radicals and ions in different parts of the solution. If birds can detect this chemical imbalance (and most of biology is just moving chemicals around), then they have their magnetic compass.

Professor Iannis Kominis of the University of Crete has a different idea. He argues that when the blue photon triggers the creation of radical-ion pairs, the orientation of the exchanged electrons are affected by the Earth's magnetic field. The reaction when the radical and ion recombine to form neutral molecules is thus affected by the direction of the applied field. One apparent flaw is that the time the radical-ion pair is separated is too short to allow the magnetic field to change things, but he answers this with a real-world example of quantum craziness - the Quantum Zeno effect. The very fact that the pair separation is constantly being checked by the bird prevents it from recombining as quickly as normal. This is a known quantum effect, an utterly scientific version of "a watched pot never boils" - the more you observe such a statistical quantum process, the slower it gets, because each time you check you redefine the particle as absolutely being where it is. It's like driving the family car, but every time a kid asks "Are we there yet?" you get teleported back to where you started.

Incredibly, this is exactly the effect used in the very latest atomic magnetometers, the pinnacle of humankind's ability to detect tiny magnetic fields. And it seems avians have had them in their eyeballs all along. Some would point out that finding such sophisticated systems inside an animal would be evidence of an intelligent creator. To which the answer is, of course, that if there is any such creator he went to a lot of effort creating things which could be decoded by scientific experiment and analysis. Instead of just putting all the answers in a book.

A new study at the University of Illinois shows that superoxide, a toxic molecule implicated in cell damage and disease, is a key player in the mysterious process that allows birds to 'see' Earth's magnetic field.

"Other researchers had found that cryptochrome, acting through its own molecular spins, recruits a reaction partner that operates at so-called zero spin. They suggested that molecular oxygen is that partner," Klaus Schulten, who holds the Swanlund Chair in Physics at Illinois, said. "We propose that the reaction partner is not the benign oxygen molecule that we all breathe, but its close cousin, superoxide, a negatively charged oxygen molecule." Although known primarily as an agent of aging and cellular damage, superoxide recently has been recognized for its role in cellular signaling.

Schulten was the first to propose that Cryptochrome was a key component of birds' geomagnetic sense. He made

this prediction after he and his colleagues discovered that magnetic fields can influence chemical reactions if the reactions occur quickly enough to be governed by pure quantum mechanics.

However, superoxide's toxicity may also explain why humans, who also have cryptochrome in their eyes, do not have the same ability to see Earth's electromagnetic field, Schulten said. "Our bodies try to play it safe," he said. "It might be that human evolution chose longevity over orientational ability."

Posted by Luke McKinney with Casey Kazan.

Cryptochrome eyes

Sources:

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