Functional biological compass linked to light receptor protein

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Close up of a cockroach. Credit: Wikipedia/public domain

(Phys.org)—Many animals including birds and insects have been observed to perceive geomagnetic fields. Past studies have demonstrated that cryptochrome/photolyase family (CPF) light receptor proteins are involved in animal behavioral responses to the presence of geomagnetic fields, but so far, no studies have determined whether these proteins are linked with the direction of the magnetic field vector.

Recently, an international collaborative of researchers explored the possibility that CPF proteins provide directional magnetosensitivity in cockroaches. By combining behavioral and genetic approaches, they demonstrated the first evidence that animal-type cryptochrome (Cry2) proteins are sensitive to the direction of geomagnetic fields in two cockroach species. They've published their results in the *Proceedings of the National Academy of Sciences*.

In addition to their role in the detection of magnetic fields, Cryptochromes are also important in the regulation of the circadian cycle in many species, though they are likely not involved in the detection of light in mammals. At the outset of the research, the scientists developed an assay involving the American cockroach, Periplaneta americana, but when they realized that the species only expressed animal-type Cry2, they added Blatella germanica roaches, which express both Cry1 and Cry2.

During resting cycles, around noon, roaches generally display minimal behavior. But when the direction of the horizontal magnetic vector of the geomagnetic field is rotated periodically, the animals become more active, changing their resting positions more frequently. This magnetically induced restlessness (MIR) was one observational basis the researchers used in the experiment.

Observing no MIR when the roaches were in complete darkness, the researchers determined that photosensitive processes are involved with magnetosensitivity in P. americana roaches. To test the theory, they injected the roaches with double-stranded Cry2 RNA that significantly reduced the expression of Cry2, which completely abolished MIR behavior. While proving that MIR was not an endogenous activity of the roaches, this also knocked out their circadian rhythms. Other roaches tested in conditions of constant light developed arhythmic circadian cycles but did not demonstrate a loss of magnetoreception, proving the separation of geomagnetic field sensing and the circadian cycle. Thus, the researchers were able to associate the perception of geomagnetic fields with photoreception, separate from the circadian regulation.

They tested seven wavelengths of light under different intensities to determine the conditions under which the animals could detect magnetic fields. They found that the magnetoreception depends on light from UV wavelengths to cyan/green 505 nm. Then they attempted to localize the site of magnetoreception by painting the compound eyes of the animals with black enamel. These roaches stopped expressing MIR behaviors altogether, strongly suggesting that Cry2 within the compound eyes is responsible for magnetoreception.

The authors write, "Taken together, the results of our study establish the role of a mammalian-type Cry in light-dependent magnetoreception in two insect species phylogenetically distant to Drosophila. More important, our study delivers original evidence that the Cry2 protein is involved in the detection of geomagnetic field vector direction at natural intensities, which is a crucial feature of a biological receptor providing genuine compass bearings."

More information: Cryptochrome 2 mediates directional magnetoreception in cockroaches. *PNAS* 2016 ; published ahead of print January 25, 2016, DOI: 10.1073/pnas.1518622113

Abstract
The ability to perceive geomagnetic fields (GMFs) represents a fascinating biological phenomenon. Studies on transgenic flies have provided evidence that photosensitive Cryptochromes (Cry) are involved in the response to magnetic fields (MFs). However, none of the studies tackled the problem of whether the Cry-dependent magnetosensitivity is coupled to the sole MF presence or to the direction of MF vector. In this study, we used gene silencing and a directional MF to show that mammalian-like Cry2 is necessary for a genuine directional response to

periodic rotations of the GMF vector in two insect species. Longer wavelengths of light required higher photon fluxes for a detectable behavioral response, and a sharp detection border was present in the cyan/green spectral region. Both observations are consistent with involvement of the FADox, FAD•− and FADH− redox forms of flavin. The response was lost upon covering the eyes, demonstrating that the signal is perceived in the eye region. Immunohistochemical staining detected Cry2 in the hemispherical layer of laminal glia cells underneath the retina. Together, these findings identified the eye-localized Cry2 as an indispensable component and a likely photoreceptor of the directional GMF response. Our study is thus a clear step forward in deciphering the in vivo effects of GMF and supports the interaction of underlying mechanism with the visual system.

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