Center for Soft Matter and Biological Physics

Discussion Meeting

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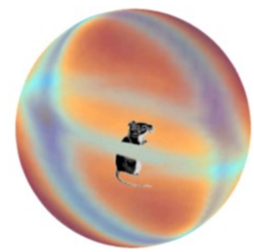
Quantum Biology meets Behavioral Biology (and a Behavioral Biologist): a new sensory system and a new class of sensory receptors in the mammalian retina

Friday, July 20, 2018

1:30 pm—2:30 pm

304 Robeson Hall



The ability of animals to detect the Earth's magnetic field remains the least understood of the major senses. Many vertebrates have two functionally distinct magnetoreception mechanisms: a light-dependent, photoreceptor-based mechanism that provides directional ('compass') information and a non-light-dependent, magnetite-based mechanism that provides positional ('map') information. The light-dependent magnetic compass (LDMC) is mediated by a manifestly quantum process thought to involve a light-dependent radical pair reaction that forms long-lived, spin-coordinated radical pair intermediates ("radical pair mechanism" or RPM). The most compelling evidence for the RPM is the finding that magnetic compass orientation in a variety of animals can be altered or abolished by exposure to low-level radio frequency (RF) fields ($\geq$ 1nT) that can alter the electron-spin dynamics of the radial pair. Interest in the RPM spans a wide range of disciplines, and has been a primary impetus for the emerging field of Quantum Biology.

Studies of murine rodents (mice, rats, etc.) have played a central role in both basic and applied (i.e., biomedical) research on mammalian spatial behavior and cognition. A number of well-characterized spatial cells (e.g., head direction cells, place cells, grid cells, boundary vector cells, and velocity cells; see 2014 Nobel Prize in Medicine) underlie a path integration system that encodes the animal's spatial position as it moves through the environment. However, the spatial circuitry characterized to date only provides accurate navigational information over distances of a few 10s of meters, falling well short of the 100s of meters routinely moved by even small rodents like deer mice (20g) under natural conditions. A magnetic compass sense can dramatically increase both the range and accuracy of a path integration system, as well as play important roles in many other aspects of spatial behavior and cognition. Nevertheless, the consensus of the literature is that murine rodents do not rely on magnetic cues, despite evidence that a magnetic compass is virtually ubiquitous in other animals, including some mammals (bats, mole rats, dolphins).

Contrary to the prevailing view in the literature, we have found that mice and rats have a well-developed magnetic compass. However, consistent behavioral and neurophysiological responses to magnetic cues can only be elicited reliably when the testing apparatus is shielded to screen out low-level RF noise. We have also identified photoreceptors in animals as different as flies, frogs, and mice that appear specialized for detection of the geomagnetic field. In this talk, I'll briefly discuss evidence: (1) that there are a specialized photoreceptors in which the response to light is dependent on the alignment of an earth-strength magnetic field, (2) that in animals where specialized photo-magnetoreceptors are located in the compound eye (flies) or retina (birds, mice), the magnetic field may be perceived as a 3-dimensional pattern of light intensity and/or color superimposed on the animal's surroundings, (3) that both behavioral and neurophysiological responses to magnetic cues can be altered or abolished by low-level radio frequency noise at intensities commonly found in laboratory environments, and (4) that the magnetic field plays multiple, previously unrecognized, roles in the spatial behavioral and cognition of murine rodents over a variety of spatial scales.