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Biophysics of Magnetic Orientation: Radical Pairs, Biogenic Magnetite, or both?

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Two major biophysical mechanisms for magnetoreception in terrestrial animals, one based on biogenic magnetite and another on radical-pair biochemical reactions, have been the subject of experiment and debate for the past 30 years. The magnetite hypothesis has stood the test of time: biogenic magnetite is synthesized biochemically in Bacteria, Protists, and numerous Animal phyla, as well as in some plants. Chains of single-domain crystals have been detected by clean-lab based SQUID magnetometry in animal tissues in all major phyla, followed by high-resolution TEM in selected model organisms, as well as by electrophysiological studies demonstrating the role of the ophthalmic branch of the trigeminal nerve in the magnetoreceptive process. Pulse-remagnetization - configured to uniquely flip the polarity of single-domain ferromagnets - has dramatic effects on the behavior of many birds, honeybees, mole rats, turtles, and bats, to cite a growing list. Magnetite-containing cells in the vicinity of these neurons in fish are now the subject of intense study by our consortium. The existence of a specialized class of magnetite-containing magnetoreceptor cells in animal tissues is no longer controversial. In contrast, less success has been achieved in gaining experimental support across a range of taxa for the radical-pair hypothesis. Although this mechanism was proposed to explain an early observation that birds would not respond to complete inversion of the magnetic vector, many organisms (even some birds) do indeed respond to the field polarity. We also note that few, if any, of these critical experiments have been done using fully double-blind methods. This is joint work with: M. M. Walker (University of Auckland, New Zealand) and M. Winklhofer (LMU Munich, Germany).