A Magnetite-Based Biophysical Hypothesis for the Radiowave Detector in Migrating and Homing Animals: Magnetoacoustic Transduction

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Two major biophysical theories have been proposed to explain how migrating and homing animals could make use of the geomagnetic field, including the presence of specialized receptor cells containing crystals of biologically-precipitated magnetite (*1*), or quantum-mechanical effects on electron spins in the photo-active pigment, cryptochrome (*2*). Evidence exists for both theories: Nearly 20 studies have shown that many animals change their behavior when subjected to a short magnetic impulse that exceeds the coercivity of biologically precipitated magnetite crystals, and proponents of the quantum compass idea argue that the disruption of magnetic behavior by radio frequency (Rf) waves in the mid-wave band (.1-5 MHz) can be explained by interference with the hyperfine transitions between singlet and triplet quantum states.

Two separate and unrelated studies now lead us to propose that biological magnetite might also be able to account for the radio wave effects, without the need for a cryptochrome sensor. First, Kellnberger et al. (*3*) demonstrated that energy absorbed in single-domain magnetite nanocrystals by the oscillating magnetic field vector in an incipient radio wave is converted to ultrasound at the second harmonic of the driving frequency (e.g., a 0.5 MHz signal produces ultrasound at 1 MHz); this ‘magnetoacoustic’ effect works, and they were able to measure ultrasound at double the Rf frequency in aqueous solutions containing SD nanophase magnetite when exposed to weak Rf radiation. Second and quite independently, Kubanek et al. (*4*) discovered a class of trans-membrane ion channels that were activated by ultrasound in this same frequency band. If those ion channels were expressed in the lipid-bilayer membranes surrounding magnetosomes, they could constitute the biological radio-wave receptor (*5*). Using scanning SQUID microscopy of bovine muscle tissue (‘wagu beef’), we have recently shown the common presence of common ferromagnetic clusters at ppb to ppm levels, with rock magnetic properties consistent with biological magnetite; some of these, if present in sensory cells, might be the radio wave detectors.

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