Iron, sense, and neurotoxicity

It all began with the article "Giving Personal Magnetism a Whole New Meaning" published in Science back in 1992…15 years passed but my interest in this subject grew as the picture evolved.

That article was about JL Kirschvink, a geobiologist at the California Institute of Technology, who reported, in the Proceedings of the National Academy of Sciences, the first ever documentation of 50 nanometer-sized super-paramagnetic biogenic magnetites (Fe_3O_4) in human brain tissues. This work was inspired by the observation of aberrant dark spots in human magnetic resonance images. He demonstrated ferromagnetic materials in post-mortem brain tissues from patients with Alzheimer's disease using a Superconducting Quantum Interfering Device (SQUID), and the magnetite crystals by transmission electron microscopy. While the physiological implications of these findings warrant further exploration, other laboratories have confirmed their existence.

Actually the same researcher identified magnets in pigeons in 1979, a quarter of a century prior to his findings in human subjects. Recent delineation of superparamagnetic magnetite crystals in the trigeminal nerve terminals of the pigeon beak has led to the hypothesis that clusters of superparamagnetic crystals located in neurone membranes attract or repel each other, depending on the orientation of the external magnetic field, thus deforming the neurone membrane and potentially opening or closing ion channels.

Additional experimental proofs of an operational, biogenic magnetite-based navigation system, amidst other possible mechanisms like electromagnetic induction and chemical magnetoreception, have been nicely summarised by Johnsen and Lohmann. Other migrating animals may well be using such systems to draw guidance from the earth's electromagnetic field, underlying their amazing abilities to navigate across the world. This is arguably nature's version of the Global Positional Navigation System.

Interestingly, these electromagnetic sensory systems in animals have also been implicated in the seismic escape behaviour observed when wild animals relocate to safer terrains prior to earthquakes documented by human-invented technologies. Animal behaviour may be a more effective means of predicting an earthquake. Indeed, on 18 July 1969, an earthquake warning was issued at the Tientsin People's Park Zoo in China, 2 hours before the earthquake struck, based on observations of unusual behaviours of giant pandas, deer, yaks, loaches, tigers, and other animals.

The relevance of the effect of a change in the electromagnetic field to biologic behaviours is obviously not limited to these animals. Transcranial magnetic stimulation (TMS), besides being used to study neurophysiology, may be a possible treatment modality for depression, obsessive compulsive disorders, and spasticity. Recent use of functional magnetic resonance imaging to document specific brain regions activated by TMS provides a practical avenue for clinicians to explore benefits for our patients. On a more general scale, the mechanisms of electromagnetic sensing are just part of a spectrum of the refined temporal and spatial senses, fundamental yet intrinsic to the wide range of 'mysterious abilities' and functions we enjoy.

Finding complex iron compounds such as magnets in the human brain is not always welcome. Medical doctors have long been perplexed by observations of biomineral deposits in the brain tissues of people with Parkinson's, Alzheimer's, and Huntington's diseases. There are now data suggesting that strong local electromagnetic fields may promote the aggregation of such particles in plaques. More research is needed to determine whether environmental exposure to varying electromagnetic fields is detrimental to our health.

Finally, it is interesting to note that here in Hong Kong we have local experts in the field of iron induced–toxicity and neurodegenerative disorders, from the Laboratory of Brain Iron Metabolism in the Department of Applied Biology and Chemical Technology of the Hong Kong Polytechnic University.

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