J. exp. Biol. (1981), 92, 333-335
With 1 *figure*
Printed in Great Britain

SHORT COMMUNICATIONS

FERROMAGNETIC CRYSTALS (MAGNETITE?) IN HUMAN TISSUE

BY JOSEPH L. KIRSCHVINK
Department of Geological and Geophysical Sciences, Princeton University

(*Received* 15 *August* 1980)

In recent years, a variety of animals have been found which are able to synthesize the ferromagnetic mineral magnetite (Fe_3O_4). Lowenstam (1962) originally recognized biogenic magnetite in the radular teeth of a primitive marine mollusc, the chiton (*Polyplacophora*), and since then it has been identified as a precipitate in several magnetically sensitive organisms, including honey bees (Gould, Kirschvink & Deffeyes, 1978), homing pigeons (Walcott, Gould & Kirschvink, 1979) and in magnetotactic bacteria (Frankel, Blakemore & Wolfe, 1979). Zoeger, Dunn & Fuller (1980) also report a localized concentration of magnetite in dolphin heads, although magnetosensory behavioural experiments have not as yet been done on them.

Magnetite is biologically unique because it is both ferromagnetic and conducts electricity like a metal; consequently it interacts strongly with magnetic and electric fields. Due to the numerous industrial and research environments which expose people to artificially intense electromagnetic conditions, it is of importance to know whether or not this material might exist in human tissue. Kirschvink & Gould (1980) have argued that there are probably one or more non-sensory metabolic functions for magnetite from which specialized magnetoreceptors could have evolved; consequently one might expect to find small amounts of magnetite in all animals, including humans.

In an attempt to partially answer this question, I searched for magnetic remanence in four intact human adrenal glands which had been removed during autopsy and were frozen quickly in non-magnetic containers. Results of this analysis are shown on Fig. 1. Indeed, there is a measurable amount of high-coercivity ferromagnetic material present which appears to be finely disseminated throughout the tissue. Between 1 and 10 million single-domain magnetite crystals per gram would be necessary to account for the observed magnetic remanence. Although these measurements do not uniquely identify the crystal phase as magnetite, no other ferromagnetic minerals have ever been observed as biologic precipitates. Positive identification, of course, awaits the development of magnetic separation techniques capable of isolating and purifying these submicroscopic crystals. Barnothy & Sümegi (1969) have shown that mouse adrenals are particularly prone to degeneration in moderately strong magnetic fields; this effect might be due to the presence of magnetite.

The presence of ferromagnetic material in human adrenal tissue suggests that it might be found in other organs as well. Indirect evidence for this comes from Presti & Pettigrew's (1980) work on the neck muscles of birds and a similar study on the

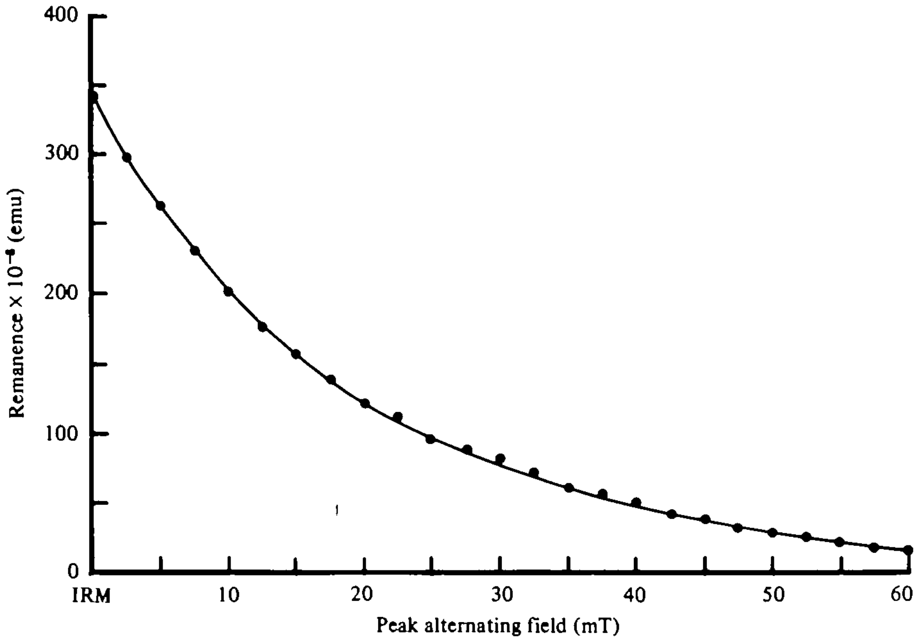

Fig. 1. Ferromagnetic remanence in human adrenal glands. The 2·9 g sample of adrenal tissue was frozen to about −20 °C and briefly exposed to a 0·3 tesla magnetic field. The resulting saturation Isothermal Remanent Moment (sIRM) measured in the zero-field environment of a super-conducting rock magnetometer was $3{\cdot}4 \times 10^{-9}$ joule/tesla (N.B.: 1 joule/tesla = 10^{3} emu) which could be produced by $7{\cdot}4 \times 10^{-8}$ g of single-domain magnetite 26 ppb by weight, or roughly 1–10 million single-domain crystals per gram). Demagnetization of the sIRM produced an exponential decrease in remanence with the peak alternating field which is consistent with the ferromagnetic material being dispersed single-domain magnetite of size similar to that found in pigeons, bacteria or chitons. Non-human control tissues (pigeon brain and kidney) dissected and measured at the same time and in the same fashion had no detectable remanence (e.g. less than 10^{-11} joule/tesla), suggesting that the ferromagnetic material was present in the tissues before the magnetic analysis. Surgical contamination during autopsy was unlikely as the gland was removed intact and the tissue for analysis dissected from the interior with non-magnetic tools. Three other human adrenal glands gave similar results (3·6, 4·5 and 8·0 nano-joules/tesla).

magnetic remanence distributed between and throughout the midbrain and corpus callosum of Rhesus monkeys (Kirschvink, in the Press). Unfortunately, it is currently far easier to detect the presence of magnetite than it is to determine what, if anything, it does. The biological function of this material needs to be understood in order to evaluate the merits of proposed human exposure guidelines to strong electromagnetic fields (recently reviewed by Salles-Chuna, Battocletti & Sances, 1980).

I thank C. Denham and V. Schmidt for use of their palaeomagnetic laboratories, and J. L. Gould, A. G. Fischer and M. E. Purucker for helpful comments on the manuscript. This work was supported by NSF grant SP 179–14845.

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