Evidence that a diverse range of organisms can utilize the Earth’s magnetic field to orient and navigate has accumulated over a period of 50 years. Much of the evidence currently available is based on behavioral data, with the exact mechanistic basis of magnetoreception remaining one of the great unsolved mysteries in biology. Just as magnetotactic bacteria use magnetic iron oxide nanoparticles to take advantage of the Earth’s magnetic field for orientation, it has been hypothesized that a similar mechanism could be present inside specialized cells in higher animals. Future research on magnetoreception requires to complement behavioral studies by proximate approaches to identify the mechanistic basis of magnetic field detection at the cellular level. Novel correlative microscopic approaches that bridge a range of length scales now provide the necessary approaches to determine the location, structure and function of these elusive cells.

The honeybee Apis mellifera is known to exhibit magnetoreceptive behavior and represents an ideal model system for elucidating the cellular basis of this sense in animals. In theory, a magnetoreceptive system could function using only a small number of cells located virtually anywhere in the body, which has presented researchers with the problem of searching for a potentially rare cell type of unknown location and structure; the classic ‘needle in a haystack’ problem.

Here we used a broad range of imaging and analytical techniques to initially characterize the particulate composition of honeybee body parts. Using a specially developed filtration technique, the bulk particle fraction of the honeybee was isolated (Fig.1). The particles’ structure and composition have then been characterized using a variety of techniques. In parallel, 2D and 3D imaging techniques such as scanning electron microscopy (SEM), magnetic resonance imaging (MRI) and X-ray micro-computed tomography (micro-CT) were attempted in order to provide overall anatomical detail and potentially pinpoint the location of magnetoreceptor cells (Fig. 1). Our ultimate aim is to trace the location of the particles back to their original anatomical position and provide a detailed description of cell ultrastructure and function. This knowledge is crucial to guide future research to clarify the importance and function of magnetoreception in honeybees.

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Fig. 1: Anatomical information achievable by (A) Optical, (B) SEM and (C, D and E) MRI imaging in the honeybee. (E) An MRI section through the abdomen reveals the internal anatomy, including highly contrasting material beneath the cuticle (arrowheads). (F) SEM has also been used to image magnetically responsive particulates extracted from whole bees.