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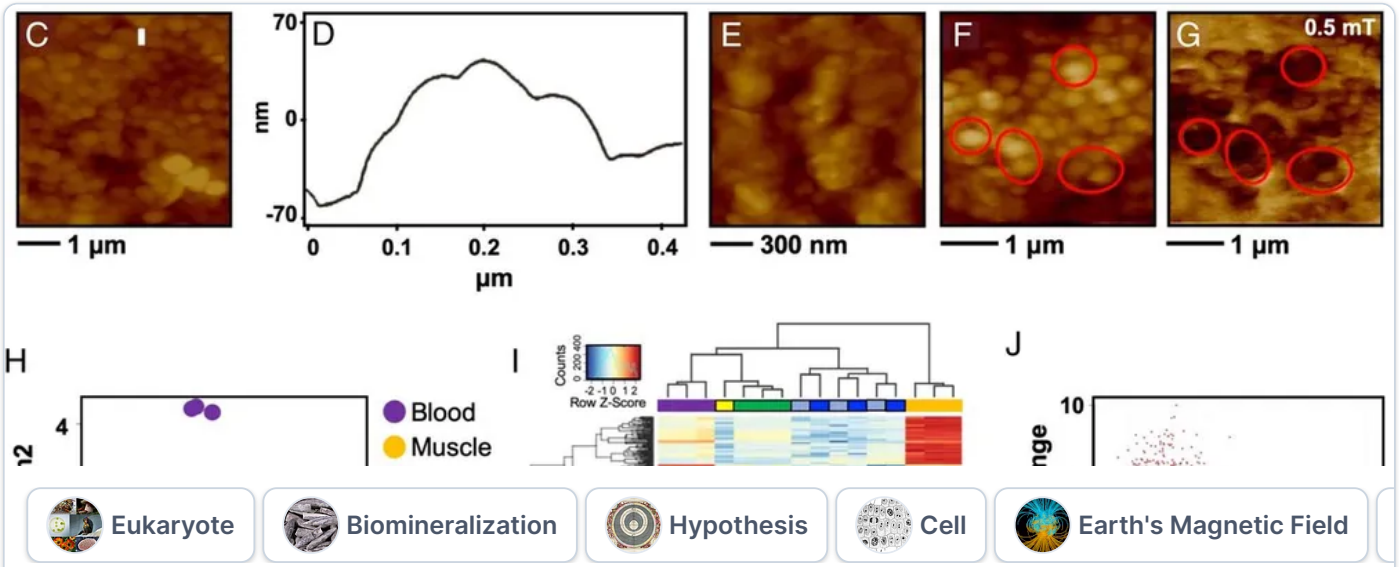

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Conservation of magnetite biomineralization genes in all domains of life and implications for magnetic sensing

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We present a model of biogenic magnetite formation in eukaryotes and hypothesize this genetic mechanism is used by broad forms of life for geomagnetic sensory perception. Countering previous assertions that salmon olfactory tissues lack biogenic magnetite, we determine that it is present in the form of compact crystal clusters and show that a subset of genes differentially expressed in candidate magnetoreceptor cells, compared to nonmagnetic olfactory cells, are distant homologs to a core suite of genes utilized by magnetotactic bacteria for magnetite biomineralization. This same core gene suite is common to a broad array of eukaryotes and the Asgard clade archaea Lokiarchaeta. Findings have implications for revising our understanding of eukaryote magnetite biomineralization, sensory perception of magnetic fields, and eukaryogenesis. The RNA sequencing data used for differential gene expression modeling are available through National Center for Biotechnology Information BioProject accession no. [PRJNA614978] [1]. All other data are available from [SI Appendix][2], [Datasets S1–S6][2], and public repositories as described within the text. [1]: https://www.ncbi.nlm.nih.gov/bioproject/PRJNA614978 [2]: https://www.pnas.org/lookup/suppl/doi:10.1073/pnas.2108655119/-/DCSupplemental

the Asgard clade archaea Lokiarchaeta. Findings have implications for revising our understanding of eukaryote magnetite biomineralization, sensory perception of magnetic fields, and eukaryogenesis.

Abstract Animals use geomagnetic fields for navigational cues, yet the sensory mechanism underlying magnetic perception remains poorly understood. One idea is that geomagnetic fields are physically transduced by magnetite crystals contained inside specialized receptor cells, but evidence for intracellular, biogenic magnetite in eukaryotes is scant. Certain bacteria produce magnetite crystals inside intracellular compartments, representing the most ancient form of biomineralization known and having evolved prior to emergence of the crown group of eukaryotes, raising the question of whether magnetite biomineralization in eukaryotes and prokaryotes might share a common evolutionary history. Here, we discover that salmonid olfactory epithelium contains magnetite crystals arranged in compact clusters and determine that genes differentially expressed in magnetic olfactory cells, contrasted to nonmagnetic olfactory cells, share ancestry with an ancient prokaryote magnetite biomineralization system, consistent with exaptation for use in eukaryotic magnetoreception. We also show that 11 prokaryote biomineralization genes are...

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