Structural analysis of the magnetosome-associated protein MamC by Chimeric Nanoreactor Design

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Biomineralization is mediated by specialized proteins that guide and control mineral sedimentation. Protein domains that directly interact with the minerals during nucleation and growth are often intrinsically disordered. High-resolution structures of these proteins, while interacting with minerals, are essential for understanding biomineralization processes and the function of intrinsically disordered proteins (IDPs). IDPs accommodate defined structures in many biomineralization systems when interacting with nucleation clusters or mineral surfaces. However, these structured protein fragments are distributed irregularly around the mineral and are often found in small proportions and thus raise a significant challenge for structural biology techniques. In this study, we designed a synthetic chimeric protein from an intrinsically disordered magnetite-interacting peptide (MIP) conjugated to ferritin to create a bio-nanoreactor. This innovative nanoreactor offers a controlled environment to explore the structure-function interplay between biomineralizing IDPs and minerals during their formation. Employing Cryo-Electron Microscopy (Cryo-EM) single-particle analysis, we visualized atypical mineral-nanoparticles formed inside the ferritin-MIP chimera and a direct interaction of MIPs with the mineral-nanoparticles. Our results also suggest consistent directional mineral growth inside the confined compartment. This study may pave the way for understanding how iron oxide biomineralization processes take place, how the crystallization of inorganic nanoparticles can be enhanced, inhibited, phase (polymorph) determined, or directed in vitro, and lay the basis for the rational design of synthetic molecules that could modify organization stages of different bioceramic materials.