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Biomineralization and biomimetic materials
Preface

*We mineralogists have much to learn from the biological world, as organisms have been mastering the art of making minerals for eons. As a result of evolution, organisms have developed a specialized biological machinery able to produce a number of minerals (mainly carbonates, phosphates, silica varieties, some oxides) in a wide array of morphologies and microstructures that they form at atmospheric conditions from readily available ingredients they take from the surrounding environment. They use these minerals to build highly sophisticated mineralized structures (*i.e.*, otoliths, bones, shells, teeth) specially adapted for specific functions (*i.e.*, sensing, structural support, protection, mastication). To control the precipitation of minerals, they create a microenvironment in which they can modify the solution chemistry (pH, temperature, ion activity) to reach supersaturation conditions with respect to the mineral phase they need to precipitate. To further control the mineralization processes, they use specific biomolecules that interact with the developing mineral surfaces and exert a comprehensive control on their nucleation and polymorphic selection, as well as on crystal size, morphology and orientation, producing minerals with defined textural properties which are species-specific. The formation, structure and properties of biominerals have been extensively studied in different animal and plant models using advanced analytical techniques, and as a result our understanding of certain aspects of biomineralization and even crystal-growth mechanisms has radically changed in the last decades. Understanding how organisms form minerals has far-reaching implications for many different scientific fields (mineralogy, biology, materials science, geo- and palaeobiology, archaeology) and ultimately can help us to reproduce these processes in the laboratory. In fact, biomineral structures such as bone or nacre, which have extraordinary mechanical properties, far superior to those of their constituting materials, have motivated the development of new, bioinspired ceramic composite materials.*

In this issue, a collection of articles by different research groups compiles recent advances in various aspects related to biological mineralization processes, from the study of the biominerals formed by unicellular organisms (bacteria, microalgae) and higher-phyla organisms (molluscs). It also includes in vitro *precipitation studies on how different biomolecules modify the precipitation of calcium carbonate, which are highly relevant to understanding the mechanisms by which organisms control mineral precipitation.*

Prozorov et al. *show that magnetosome single crystals from magnetotactic bacteria can incorporate foreign cations, although they have been thought to be chemically pure. These chemical modifications allow fine-tuning of the magnetic properties of magnetite nanoparticles to better serve specific applications.*

Hoffmann et al. *study the extraordinary structural complexity of algal coccospheres, which are built by submicrometre calcite crystals assembled in an ordered way. They show that the crystallographic arrangement of structural sub-units at the nano scale determines the growth and morphology of these assemblages.*

Dauphin et al. *studied in detail, using electron microprobe and X-ray absorption spectroscopy among other techniques, the composition and structure of the aragonite shell of* Neotrigonia *and show how the chemical composition of the organic matrix and mineral changes in different structural layers of the shell.*

Checa et al. *show the large variability in the crystallographic organization of the outer calcitic layer in* Mytilus galloprovincialis *and how the orientation of calcite crystals is conditioned by the moving inner-surface organic membrane. Their AFM experiments show how the membranes induce an oriented nucleation of calcite on {104} faces.*

Perez-Huerta et al. *introduce us to the fascinating world of natural pearls. Although pearls are generally made of aragonite, mineralogical modifications in the form of calcite or vaterite are common. The authors studied the crystallography of less well-known calcitic microstructures occurring in pearls and show how they relate to shell microstructures.*

Leemreize et al. *studied, using high-resolution X-ray diffraction, how the incorporation of biomolecules induces lattice deformations in the aragonite crystals making up the calcified attachment organ in* Anomia simplex *shell. The generated strains are anisotropic.*

Sancho-Tomas et al. *studied the* in vitro *precipitation of calcium carbonate in a gelling medium to reproduce the formation environment in which many different biomineralization processes occur. They used soluble organic matrix*

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extracts from nacre and sea-urchin spine and show how these extracts specifically modulate the precipitation of calcium carbonate.

Rao et al. *show how different carbohydrates influence the early stages of calcium carbonate precipitation by modifying the formation of pre-nucleation clusters and the subsequent nucleation and growth of the precipitates through specific interaction with sugars, which have an active role in many biological mineralization processes.*

This selection of papers provides examples for the diversity of biomineralogy studies and we hope it can serve as an incentive for further studies.

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