Biomineralization

An Introduction

Inorganic materials can be artificially structured at different length-scales using biomineralization (1,2) and solution templating techniques.

1. Q. Huo, D. I. Margolese, U. Ciesla, P. Feng, T. E. Gier, P. Sieger, R. Leon, P. M. Petroff, F. Schuth, G. D. Stucky, *Nature* 1994, **368**, 317-321.
2. P. V. Braun, P. Osenar, S. I. Stupp, *Nature* 1996, **380**, 325-328.

- Examples include pioneering work on the use of liquid crystals and surfactants to template mesoporous silica (3–5).

3. G. S. Attard, P. N. Bartlett, N. R. B. Coleman, J. M. Elliott, J. R. Owen, J. H. Wang, *Science* 1997, **278**, 838–840. L. Addadi, S. Angew. Weiner, *Chem. Int. Ed. Engl.* 1992, **31**, 153–169.
4. S. Mann, *Biomineralization: Principles and Concepts in Bioinorganic Materials Chemistry*, Oxford University Press: Oxford, 2002
5. G. S. Attard, M. Edgar, C. G. Goltner, *Acta Materialia* 1998, **46**, 751–758.

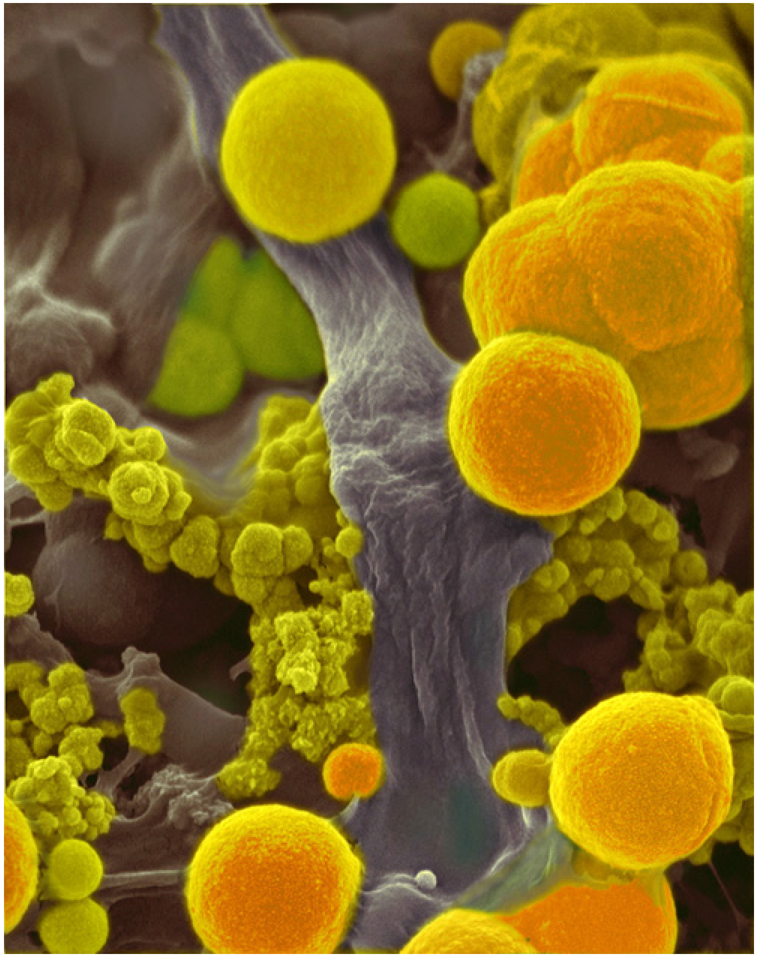
- Work on semiconductors (6), and metals, templating using bacterial S-layers (7), assembly of inorganics using peptide-based recognition (8), artificial mineralization using synthetic block copolypeptides (9), block copolymer lithography (10).

6. A. Monnier, F. Schuth, Q. Huo, D. Kumar, D. Margolese, R. S. Maxwell, G. D. Stucky, M. Krishnamurty, P. Petroff, A. Firouzi, M. Janicke, B. F. Chmelka, *Science* 1993, **261**, 1299–1303.
7. W. Shenton, D. Pum, U. B. Sleytr, S. Mann, *Nature* 1997, **389**, 585– 587.
8. S. R. Whaley, D. S. English, E. L. Hu, P. F. Barbara, A. M. Belcher, *Nature* 2000, **405**, 665–668.
9. J. N. Cha, G. D. Stucky, D. E. Morse, T. J. Deming, *Nature* 2000, **403**, 289–292.
10. M. Park, C. Harrison, P. M. Chaikin, R. A. Register, D. H. Adamson, *Science* 1997, **276**, 1401–1404.

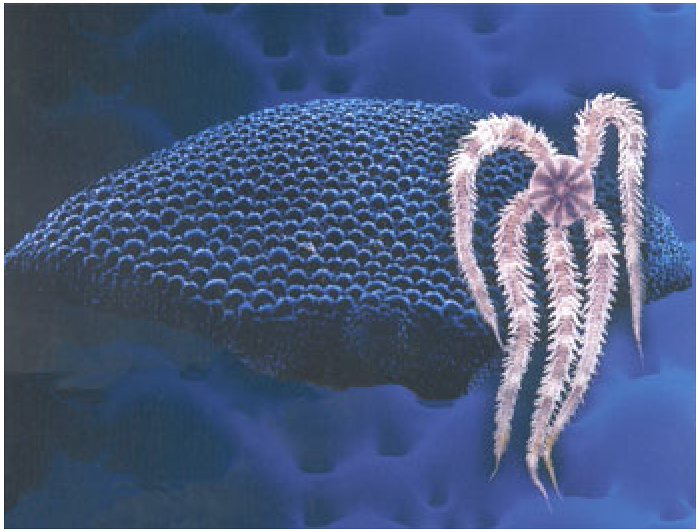
Work on mineralization of amphiphilic peptides (11), and biologically inspired micropatterned frameworks (12).

11. J. D. Hartgerink, E. Beniash, Stupp S. I. *Science* 2001, **294**, 1684–1688.
12. J. Aizenberg, D. A. Muller, J. L. Grazul, D. R. Hamann, *Science* 2003, **299**, 1205–1208.

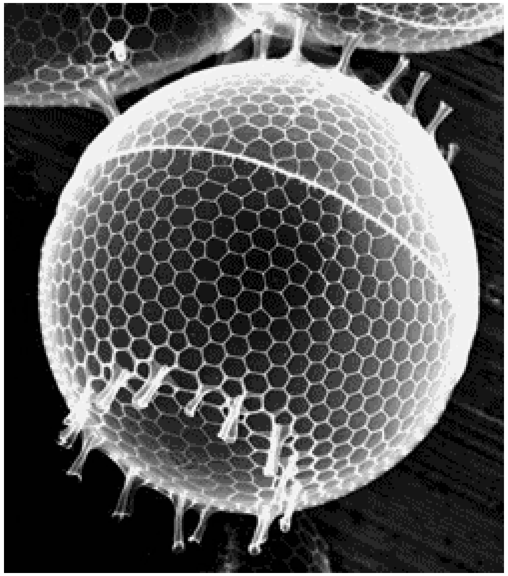
Biomineralization of ZnS (from Prof. J. Banfield, Geomicrobiology, UC. Berkeley).



CaCO3 produced by brittlestars (from Weizmann Institute Department of Chemistry).



SiO2 produced by diatoms, a type of eukaryotic algae (from Prof. M. Sumper, Biology, U. Regensburg



- One of the fundamental goals of this field of research is the technology to imitate the exquisite control over morphology and crystalline orientation possible in natural biomineralization.

- Impressive progress has been made in understanding the role of various polyanionic proteins used in such natural processes (13–14).

13. A. M. Belcher, X. H. Wu, R. J. Christensen, P. K. Hansma, G. D. Stucky, D. E. Morse, *Nature* 1996, **381**, 56–58.
14. K. Shimizu, J. Cha, G. D. Stucky, D. E. Morse, *Proc. Natl. Acad. Sci. U. S. A.* 1998, **95**, 6234–6238.

- The identification and isolation of these controlling peptides is difficult, and they are likely to be used together in synergistic combinations in many biomineralization processes.

- Simplified prototypical systems, by examining the mineralization behaviour of biomolecular templates with structures, charge distributions, phase behaviour and self-assembly characteristics that can be controlled precisely. These templates can be self-assembled, and consist of DNA, charged membranes, or artificial peptides with tailored properties.