BIOMINERALIZATION

Concepts: biologically controlled and biologically induced biomineralization, the role of organic molecules in biologically controlled mineralization, phylogenetic distribution of biomineralizing organisms, composite materials
Calcification Mechanisms

“The organic forces separate the atoms of carbonate of lime, one by one, from the foaming breakers, and unite them into a symmetrical structure. Let the hurricane tear up its thousand huge fragments; yet what will that tell against the accumulated labour of myriads of architects at work night and day, month after month. Thus do we see the soft and gelatinous body of polypus, through the agency of the vital laws, conquering the great mechanical power of the waves of an ocean, which neither the art of man nor the inanimate works of nature could successfully resist.”

Charles Darwin
BIOMINERALIZATION IS WIDESPREAD AMONG EUKARYOTES

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Dasyclad algae

http://coexploration.org/bbsr/coral/assets/images/acetabularia.jpg

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Scleractinian corals

Courtesy of Jan Derk on wikipedia. Photograph in the public domain.
Deep water corals

*Lophelia pertusa*

John Reed, 2002a.

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Coral reef distribution

Courtesy of National Oceanic and Atmospheric Administration. Image in the public domain.
Coral symbionts - zooxanthellae

Zooxanthellae

Bleached coral

http://oceanworld.tamu.edu/students/coral/coral5.htm
How do corals calcify?

Courtesy of National Oceanic and Atmospheric Administration. Image in the public domain.
Framework macromolecules

- Chitin
- Collagen
- Cellulose
- Silk-like proteins

Courtesy of Charles Ophardt, PhD, Professor of Chemistry, Elmhurst College, Elmhurst, IL. Used with permission.
Acidic macromolecules

D, Asp

E, Glu
Heinz Lowenstam

Courtesy of Joe Kirschvink. Used with permission.
Scrape Marks in Carbonate

Courtesy of Joe Kirschvink. Used with permission.
Chitons (cl. *Polyplacophora*) Eating Rock

Courtesy of Joe Kirschvink. Used with permission.
Typical Chitons from Palau

Courtesy of Joe Kirschvink. Used with permission.
Chiton radula (the tongue organ) have two rows of mineralized teeth

Heinz Lowenstam (1962) discovered that these teeth were capped with biologically-precipitated magnetite!

Courtesy of Joe Kirschvink. Used with permission.
All chiton teeth will stick strongly to a hand magnet! (They contain the mineral Magnetite, Fe$_3$O$_4$)

Courtesy of Joe Kirschvink. Used with permission.
Typical Bacterial Magnetosomes

(Courtesy of H. Vali)
Chiton teeth: biological control of mineral formation

The magnetite layer is ~ 10 um thick

From Kirschvink & Lowenstam (1979)

Sponge silicification

Maldonado and Riego 2007

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Silicatein – protein that condenses silicate

Silicatein is similar to cathepsin (protease)

Proposed mechanism for silicatein action


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Limpet teeth - goethite

Courtesy of Maine InterTidal Zone Investigation. Used with permission.

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Nacre – aragonite

Courtesy of P.U.P.A. Gilbert. Used with permission.

Courtesy of Antoni Tomsia. Used with permission.
Nacre – cross section

Image by MIT OpenCourseWare.
Silica in plants

Currie and Perry, 2007

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Avian egg shells

Calcite crystals

Keratin-like protein

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Silaffins – polyamines in diatoms that condense silica

Kroeger et al. 2002

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Courtesy of Proyecto Aqua on flickr. CC-BY-NC-SA.
ACANTHARIANS – SrSO$_4$

Low fossilization potential due to large celestite solubility

Courtesy of David Patterson, Linda Amaral Zettler, Mike Peglar, and Tom Nerad. CC-BY-NC-SA.
Bone growth

Courtesy of National Cancer Institute. Image in the public domain.