

BIOMINERALIZATION

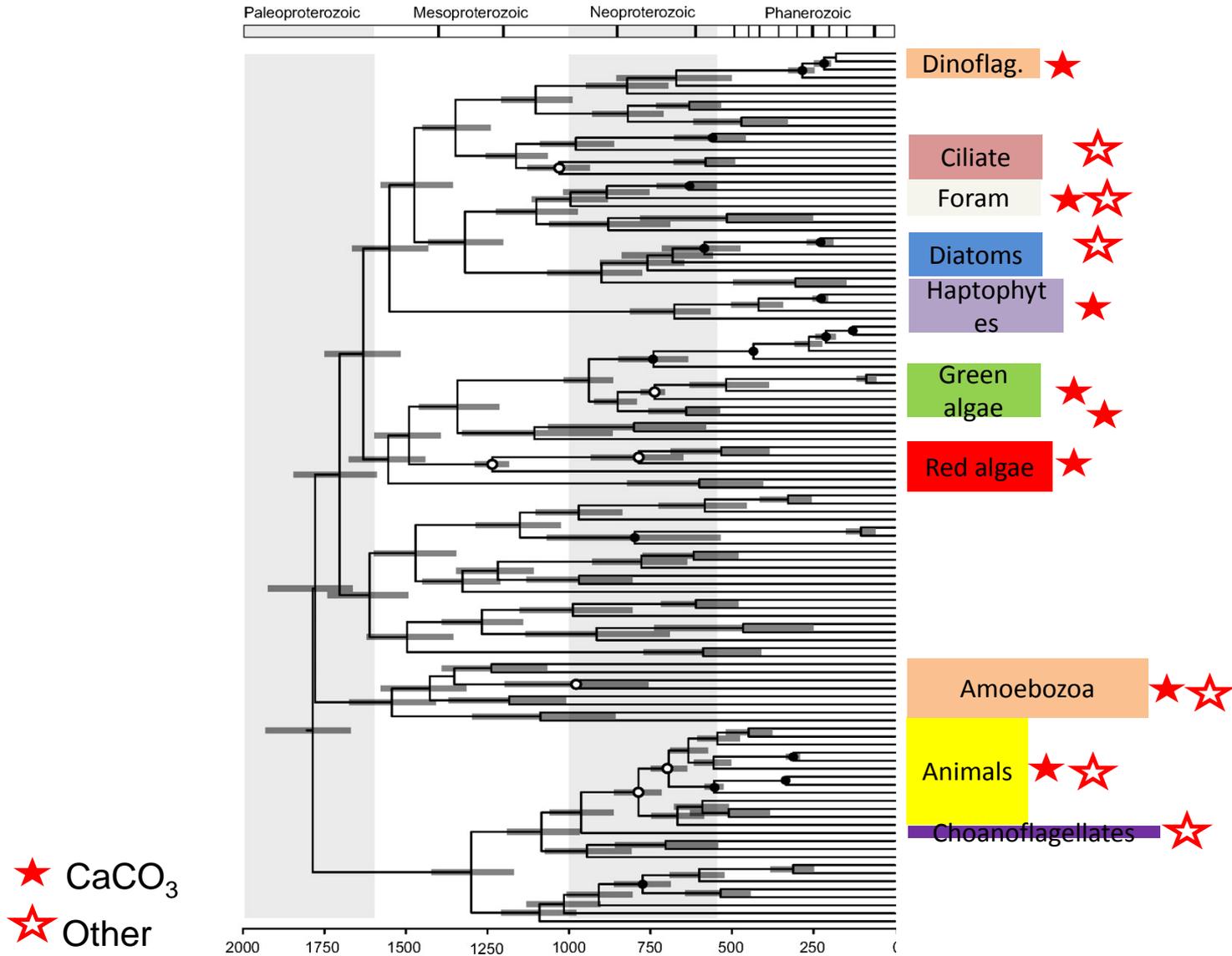
Concepts: biologically controlled and biologically induced biomineralization, the role of organic molecules in biologically controlled mineralization, phylogenetic distribution of biomineralizing organisms, composite materials

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.”

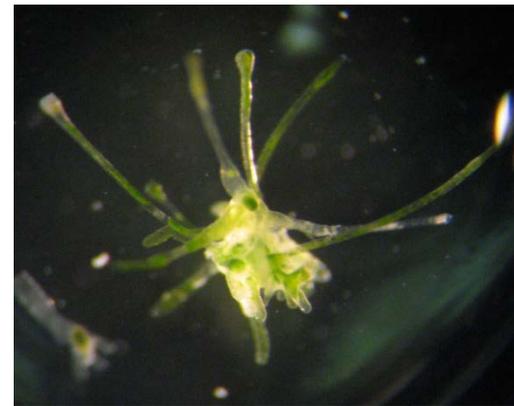
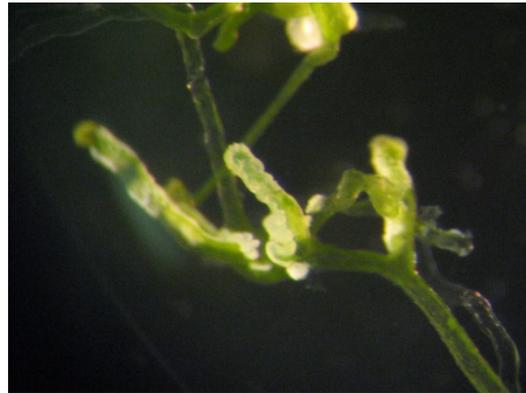
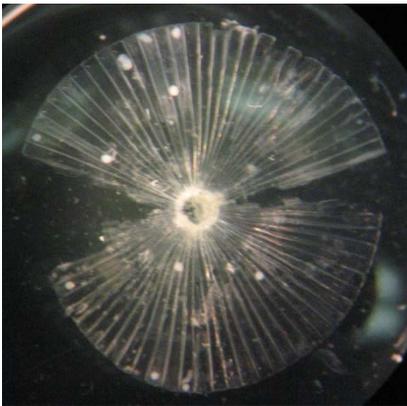
Charles Darwin

BIOMINERALIZATION IS WIDESPREAD AMONG EUKARYOTES



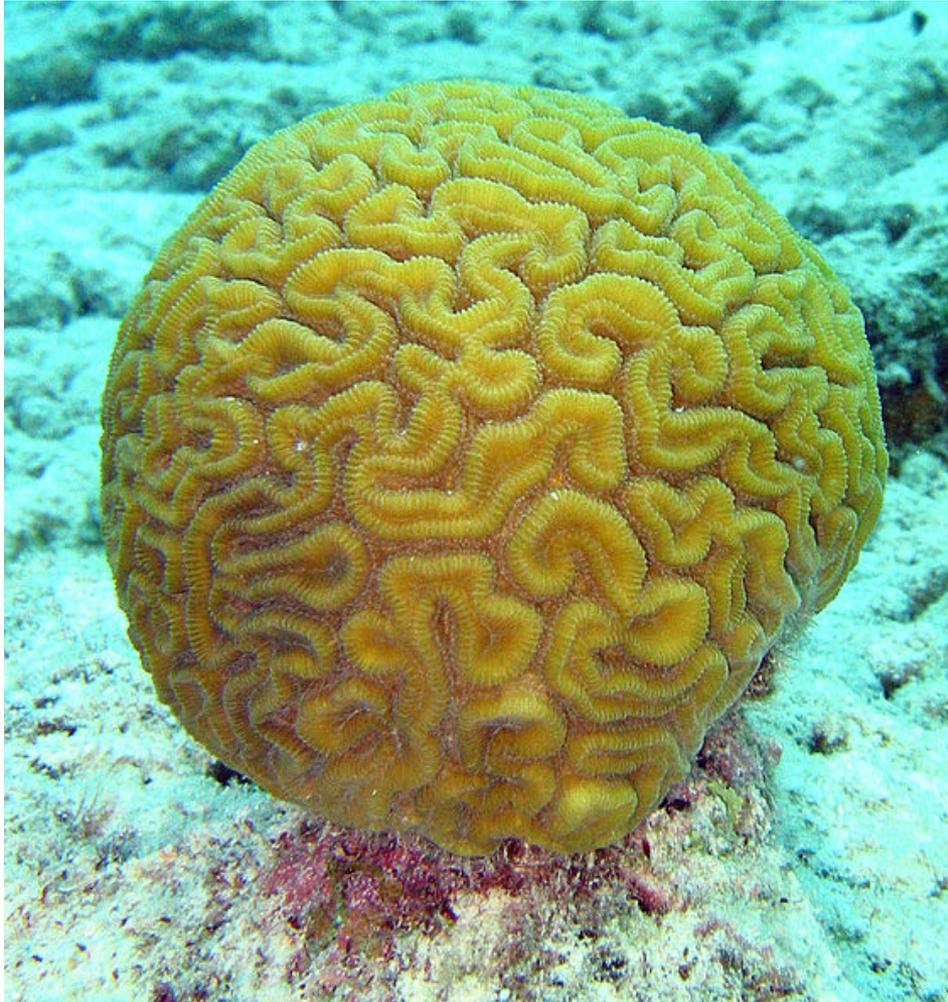
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 Source: Parfrey, L.W. et al. "Estimating the Timing of Early Eukaryotic Diversification with Multigene Molecular Clocks." *Proceedings of the National Academy of Sciences* 108, no. 33 (2011): 13624-9.

Dasyclad algae



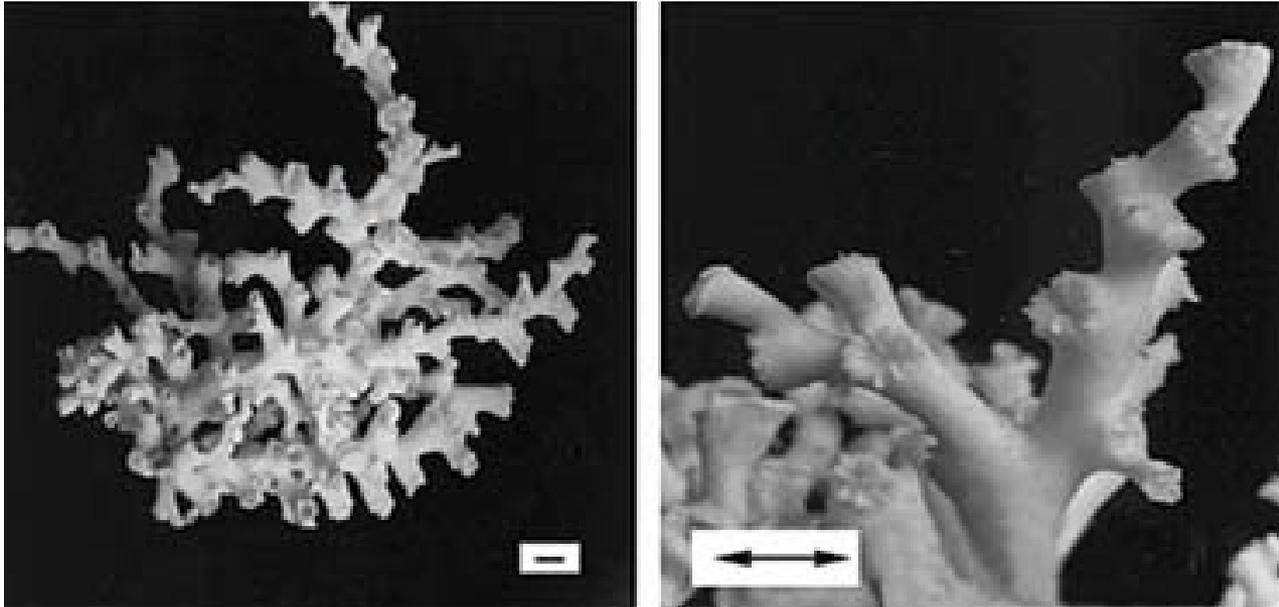
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Scleractinian corals



Courtesy of [Jan Derk](#) on wikipedia. Photograph in the public domain.

Deep water corals

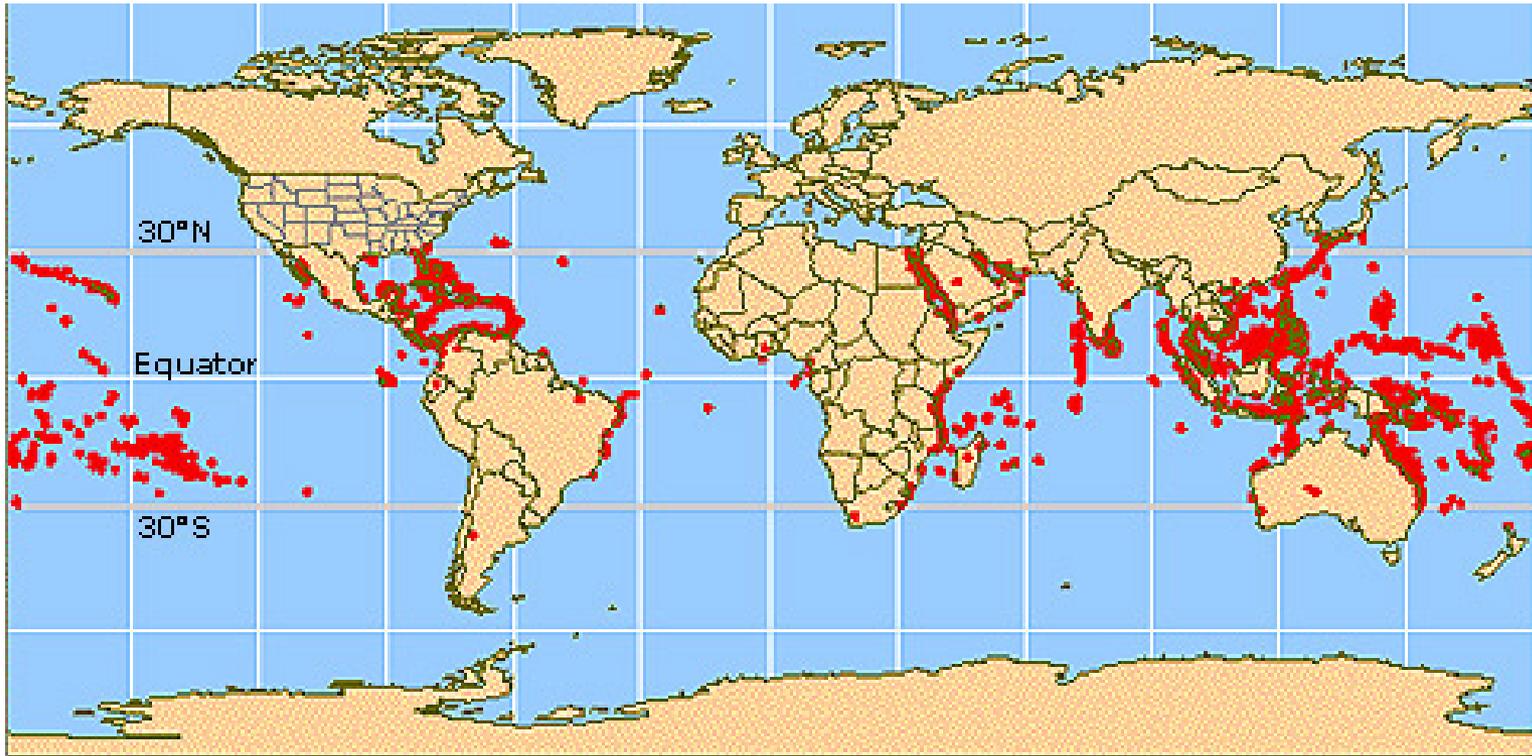


Lophelia pertusa

John Reed, 2002a.

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Source: Reed, J.K. "Comparison of Deep-Water Coral Reefs and Lithoherms Off Southeastern USA." *Hydrobiologia* 471, no. 1-3 (2002): 57-69.

Coral reef distribution



Courtesy of [National Oceanic and Atmospheric Administration](#). Image in the public domain.

Coral symbionts - zooxanthellae



Courtesy of [Acropora](#) on wikipedia. CC-BY

Zooxanthellae

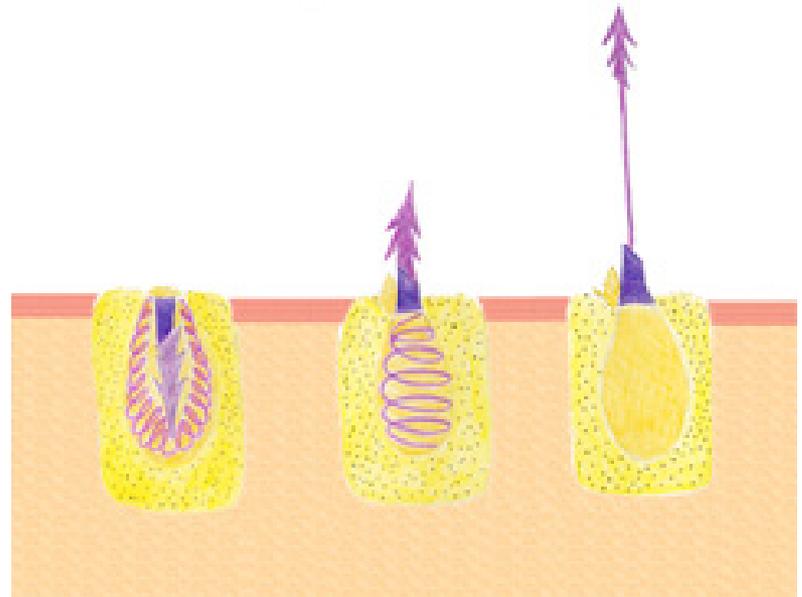
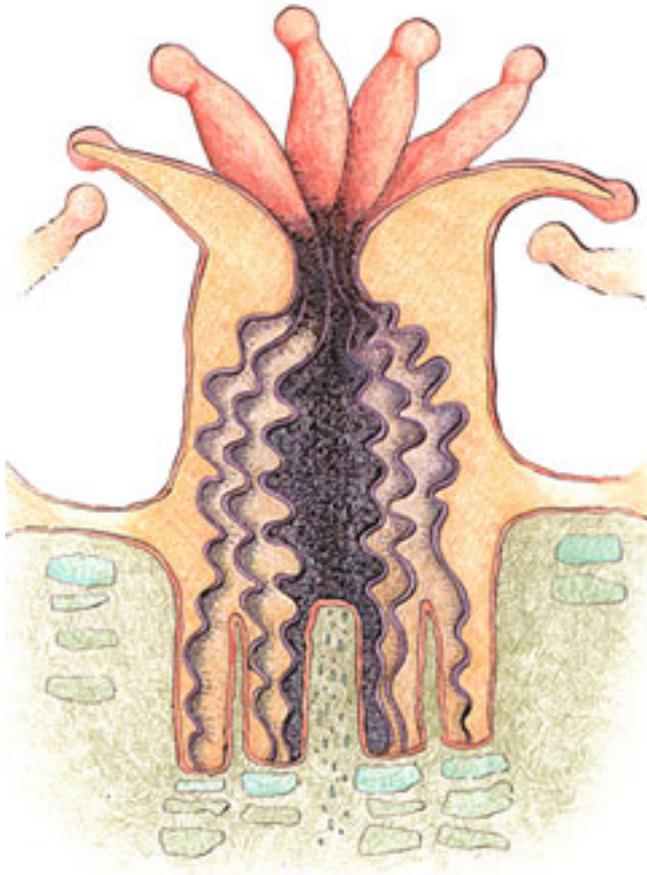


Courtesy of [Scott R. Santos](#). Used with permission.

Bleached coral

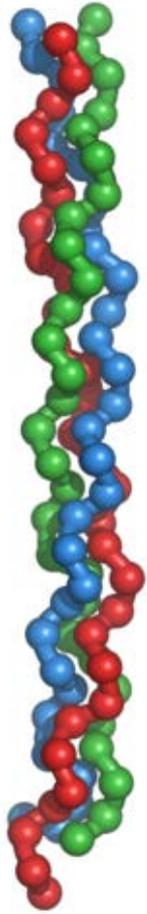
<http://oceanworld.tamu.edu/students/coral/coral5.htm>

How do corals calcify?

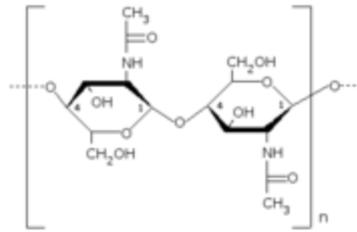


Courtesy of [National Oceanic and Atmospheric Administration](#). Image in the public domain.

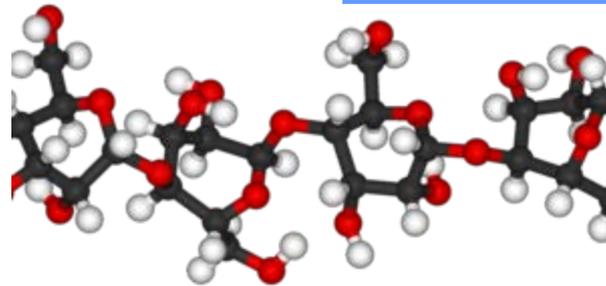
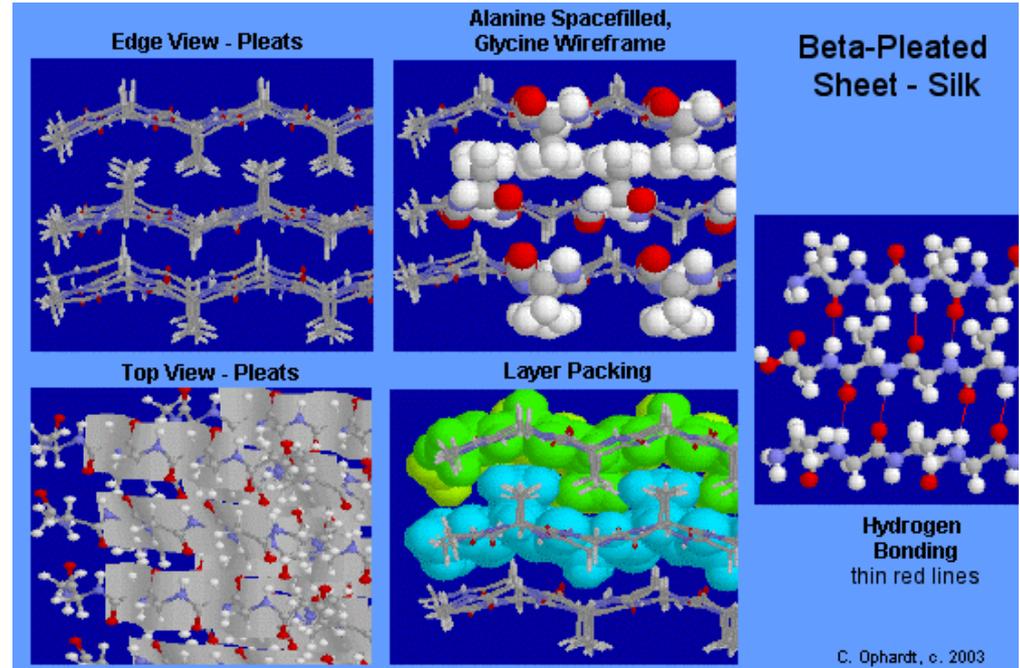
Framework macromolecules



collagen



chitin



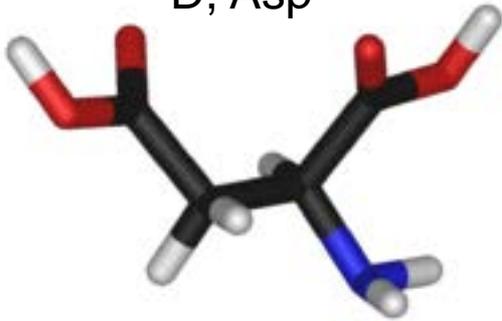
cellulose

Silk-like proteins

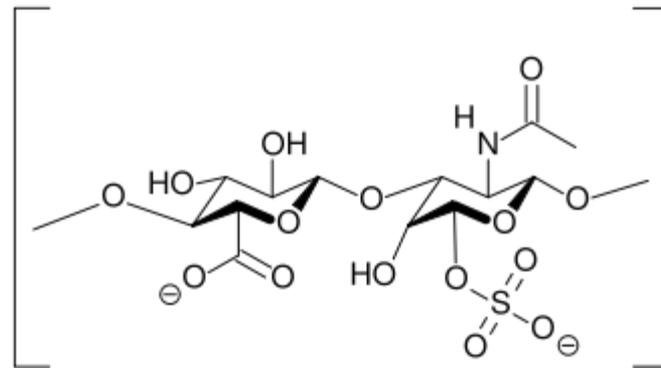
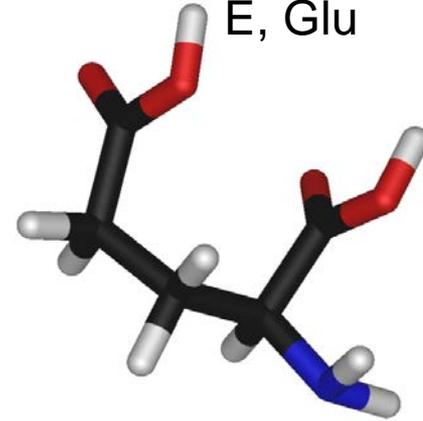
Courtesy of [Charles Ophardt](#), PhD, Professor of Chemistry, Elmhurst College, Elmhurst, IL. Used with permission.

Acidic macromolecules

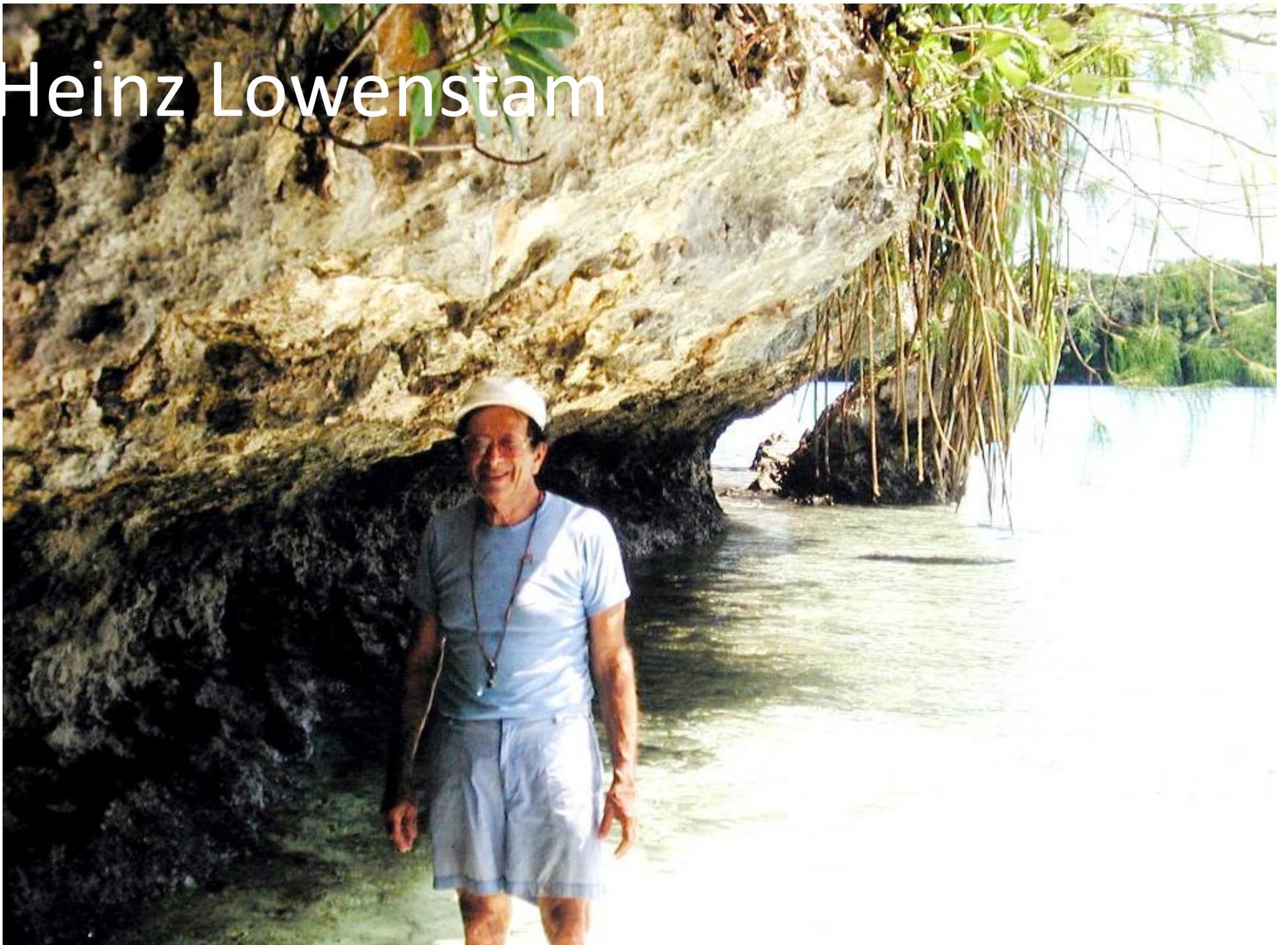
D, Asp



E, Glu



Heinz Lowenstam

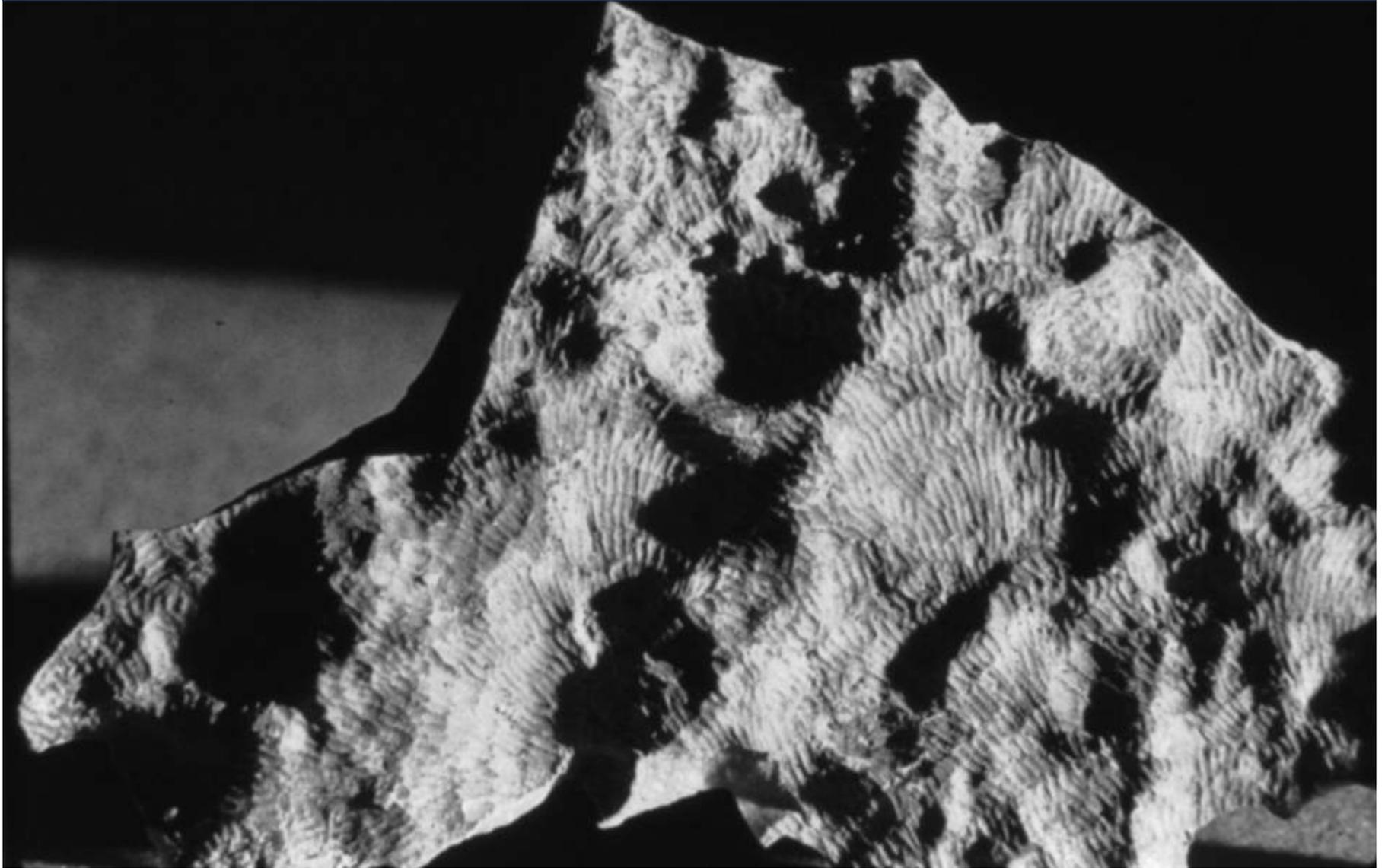


Courtesy of Joe Kirschvink. Used with permission.



Courtesy of Joe Kirschvink. Used with permission.

Scrape Marks in Carbonate



Courtesy of Joe Kirschvink. Used with permission.

Chitons (cl. *Polyplacophora*) Eating Rock



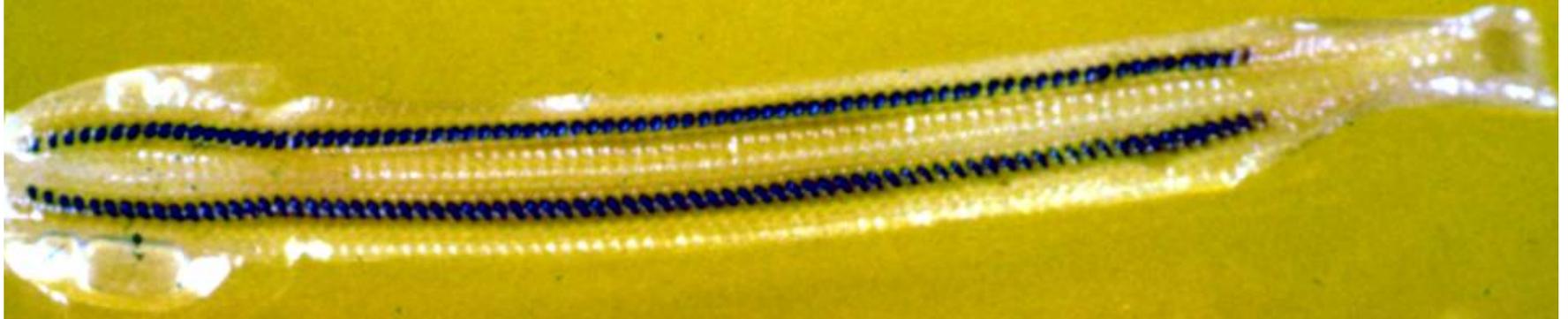
Courtesy of Joe Kirschvink. Used with permission.

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.

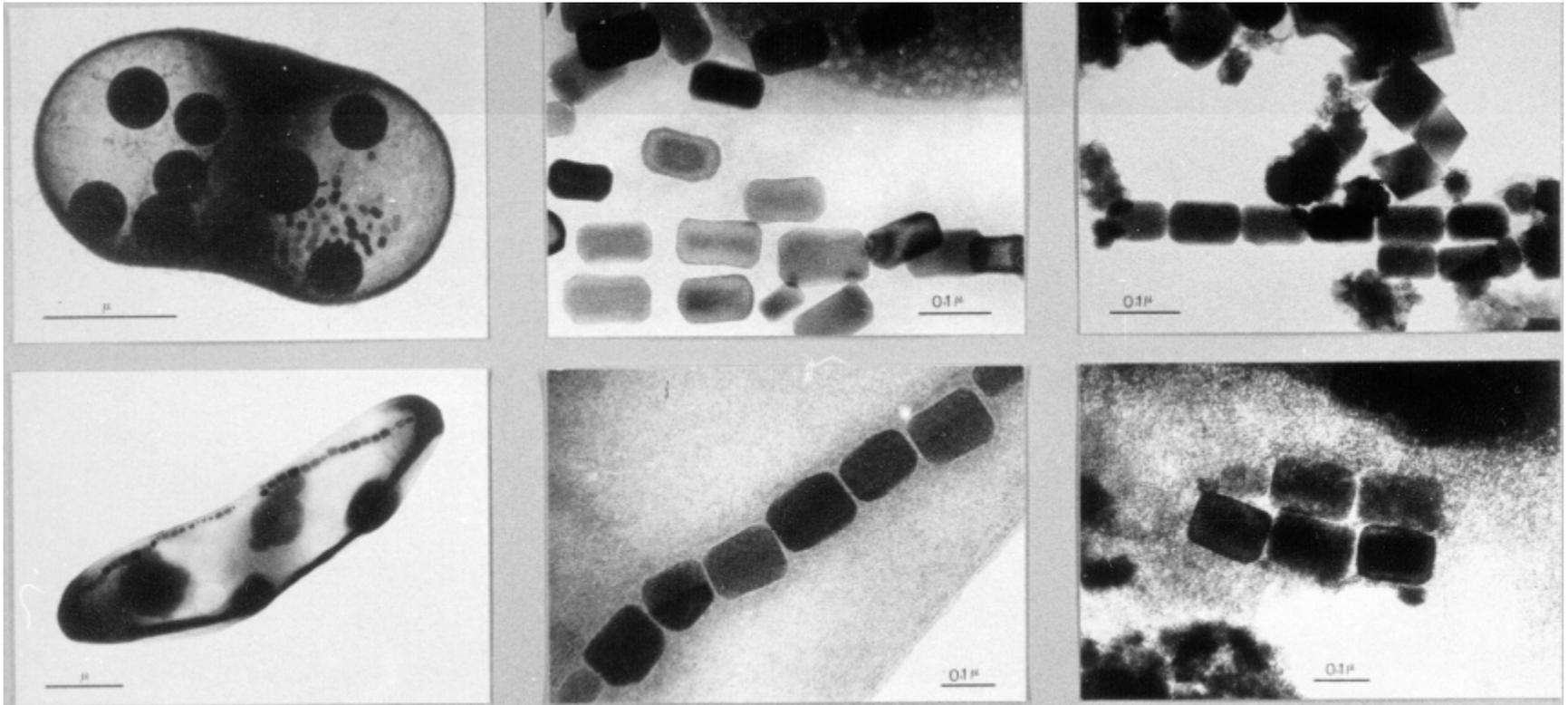


All chiton teeth will stick strongly to a hand magnet!
(They contain the mineral Magnetite, Fe_3O_4)

Courtesy of Joe Kirschvink. Used with permission.

Typical Bacterial Magnetosomes

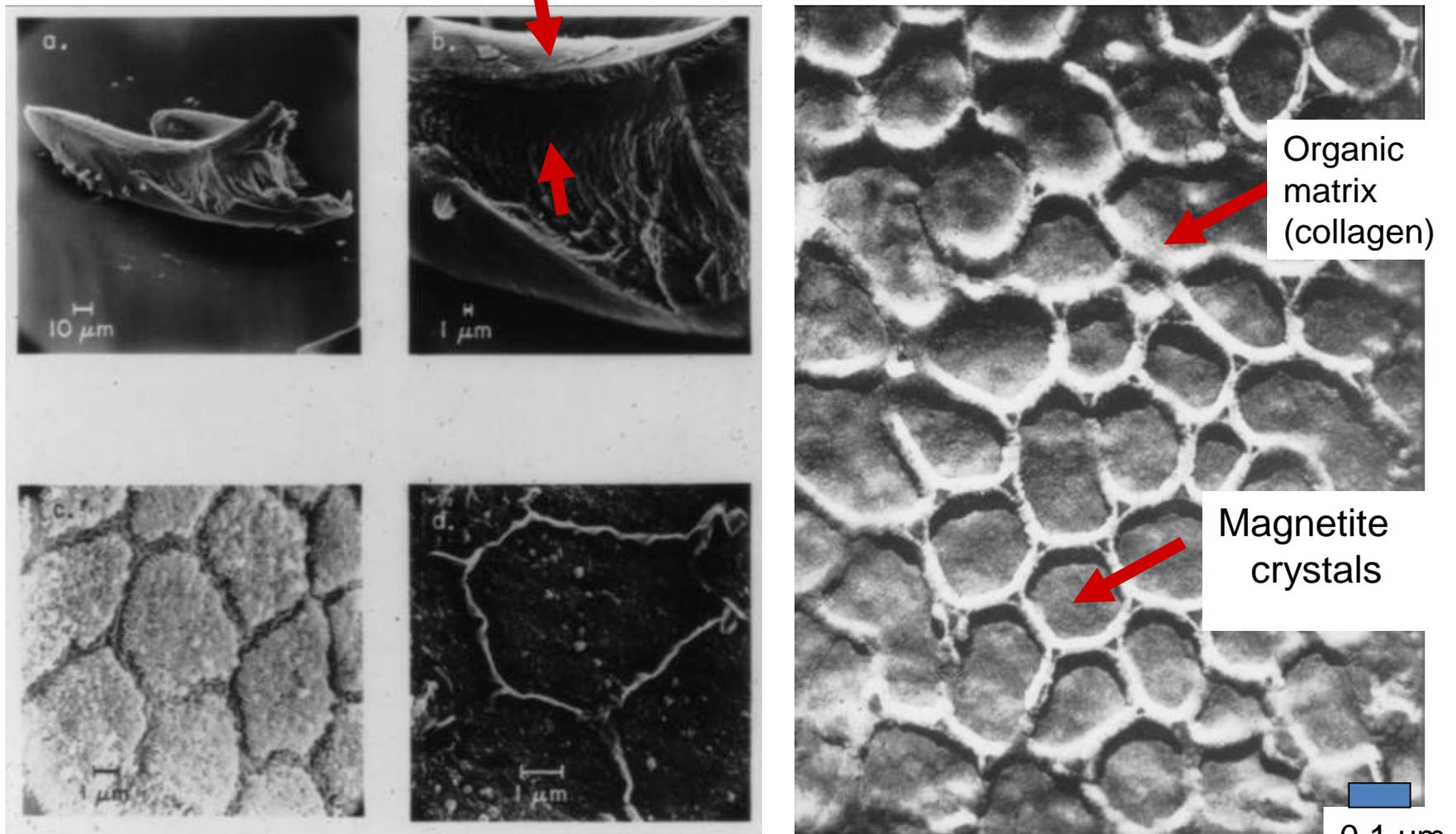
(Courtesy of H. Vali)



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Chiton teeth: biological control of mineral formation

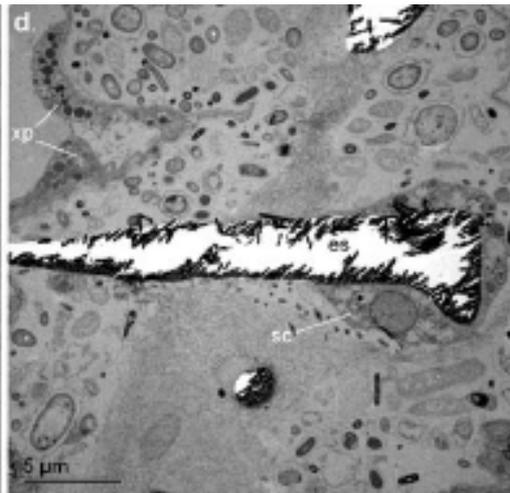
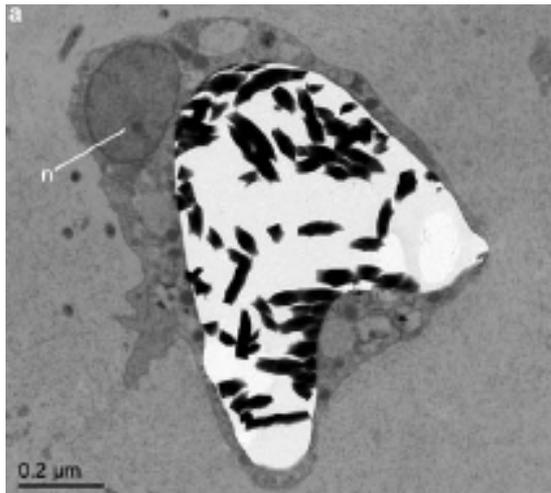
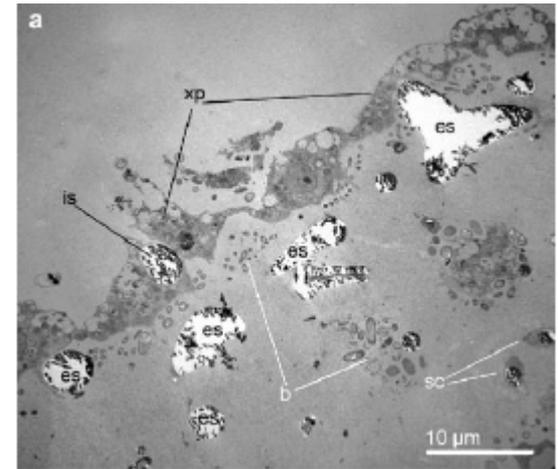
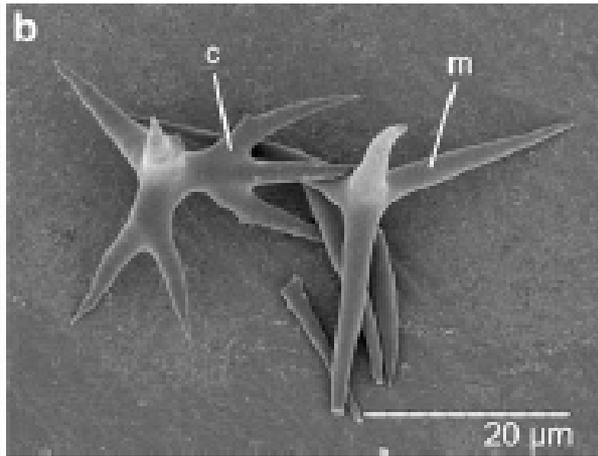
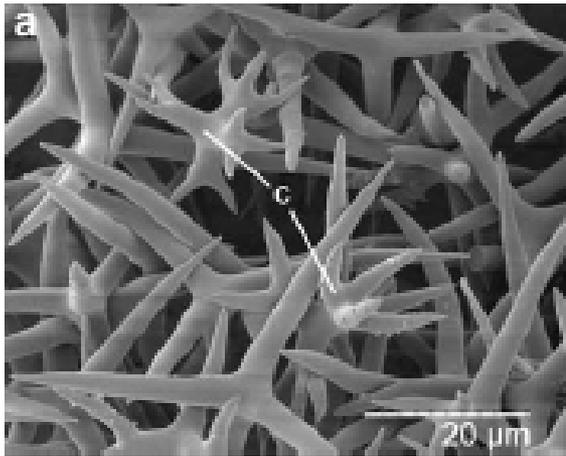
The magnetite layer is ~ 10 μm thick



From Kirschvink & Lowenstam (1979)

Courtesy of Elsevier. Used with permission. Source: Kirschvink, J. L., and H. A. Lowenstam. "Mineralization and Magnetization of Chiton Teeth: Paleomagnetic, Sedimentologic, and Biologic Implications of Organic Magnetite." *Earth and Planetary Science Letters* 44, no. 2 (1979): 193-204.

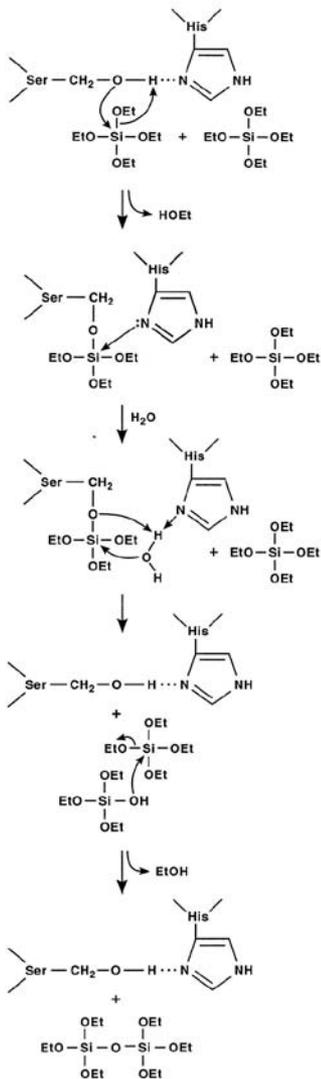
Sponge silicification



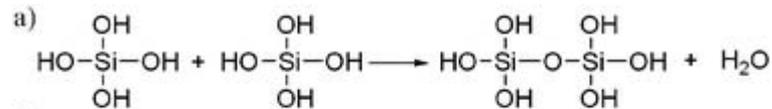
Maldonado and Riego 2007

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Silicatein – protein that condenses silicate



Cha et al. 1999



Fairhead et al. 2008

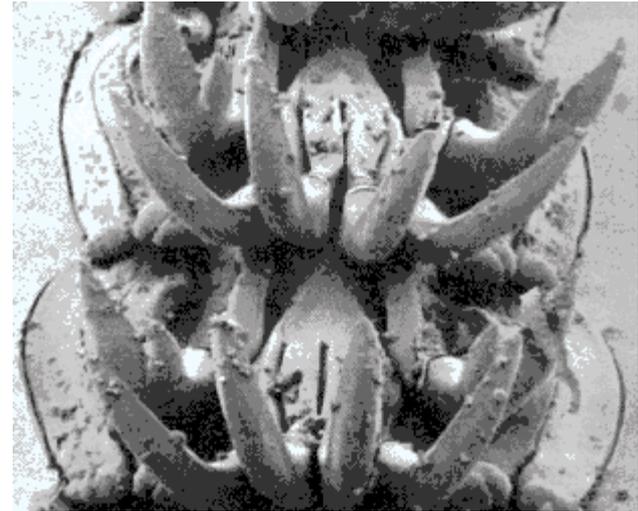
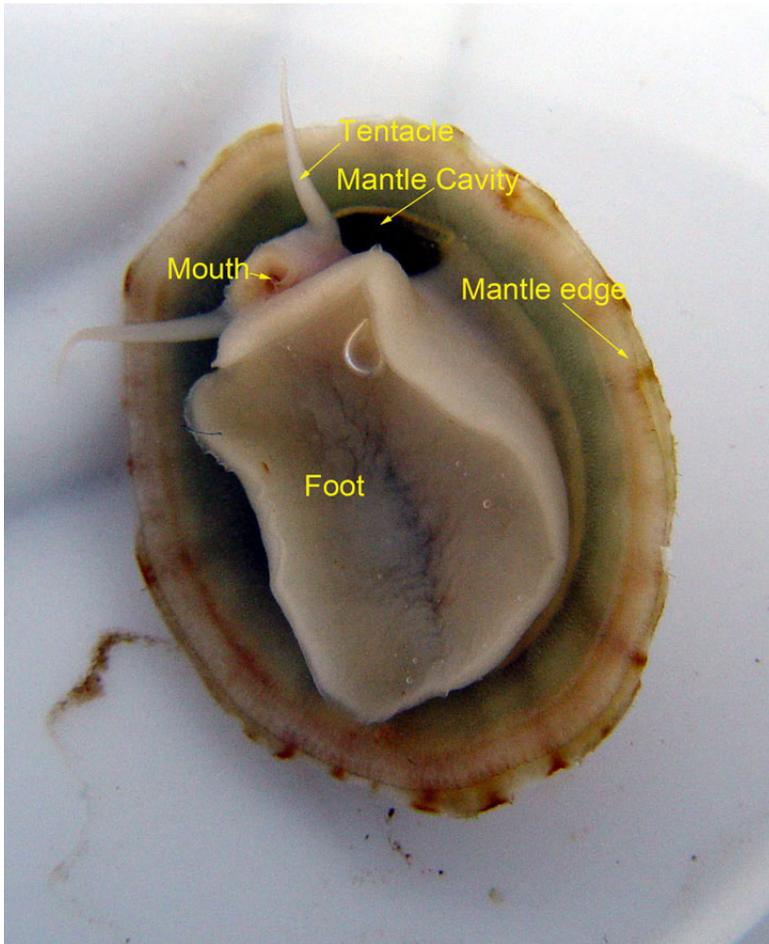
Silicatein is similar to cathepsin (protease)

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Source: Fairhead, M. et al. "Crystal Structure and Silica Condensing Activities of Silicatein α -Cathepsin L Chimeras." *Chemical Communications* 15 (2008): 1765-7.

Proposed mechanism for silicatein action

Courtesy of National Academies of Science. Used with permission. Source: Cha, J.N. et al. "Silicatein Filaments and Subunits from a Marine Sponge Direct the Polymerization of Silica and Silicones in Vitro." *Proceedings of the National Academy of Sciences* 96, no. 2 (1999): 361-5. Copyright (1999) National Academy of Sciences, U.S.A.

Limpet teeth - goethite



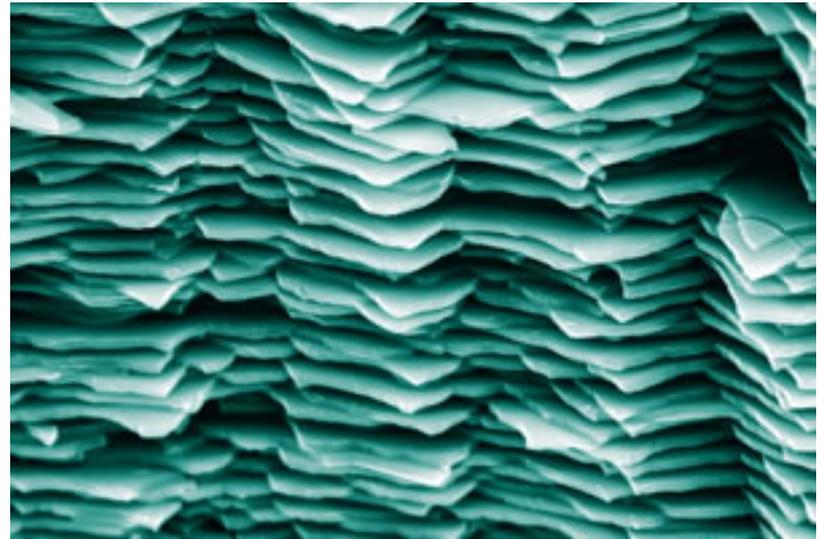
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Courtesy of [Maine InterTidal Zone Investigation](#). Used with permission.

Nacre – aragonite



Courtesy of [P.U.P.A. Gilbert](#). Used with permission.



Courtesy of [Antoni Tomsia](#). Used with permission.

Nacre – cross section

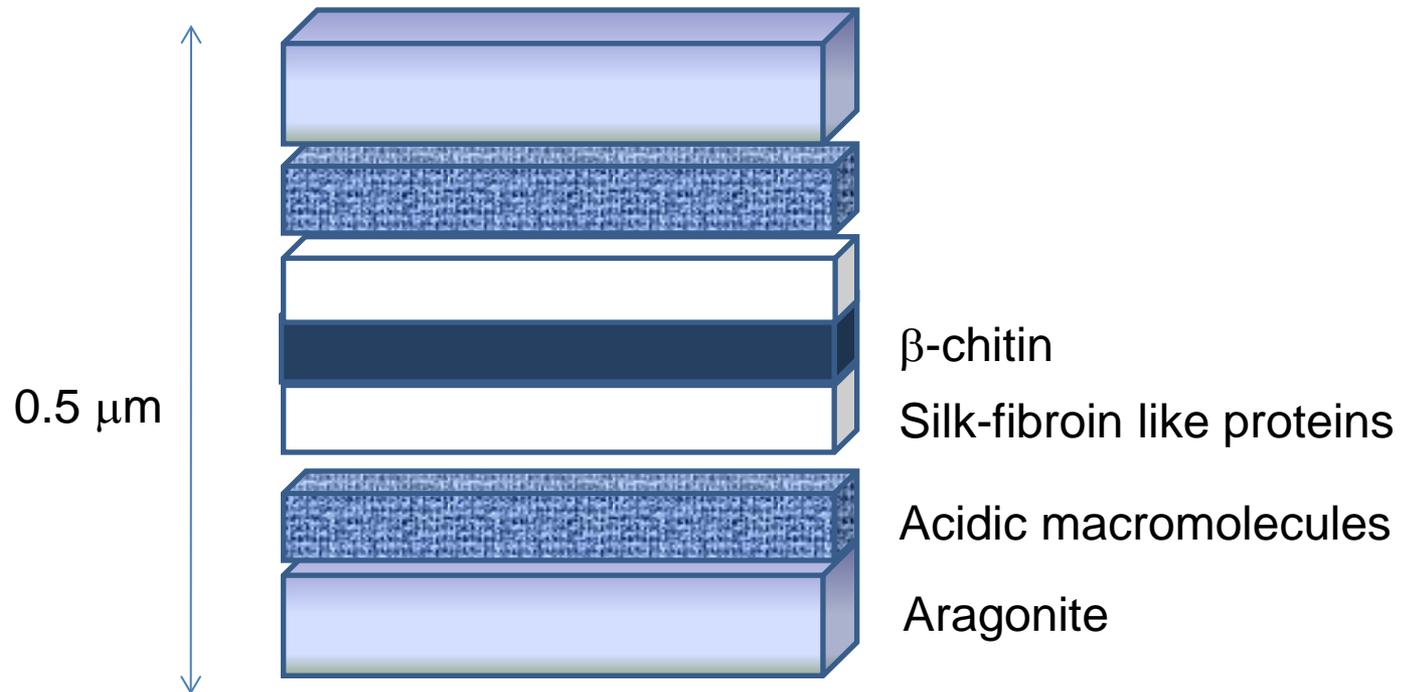
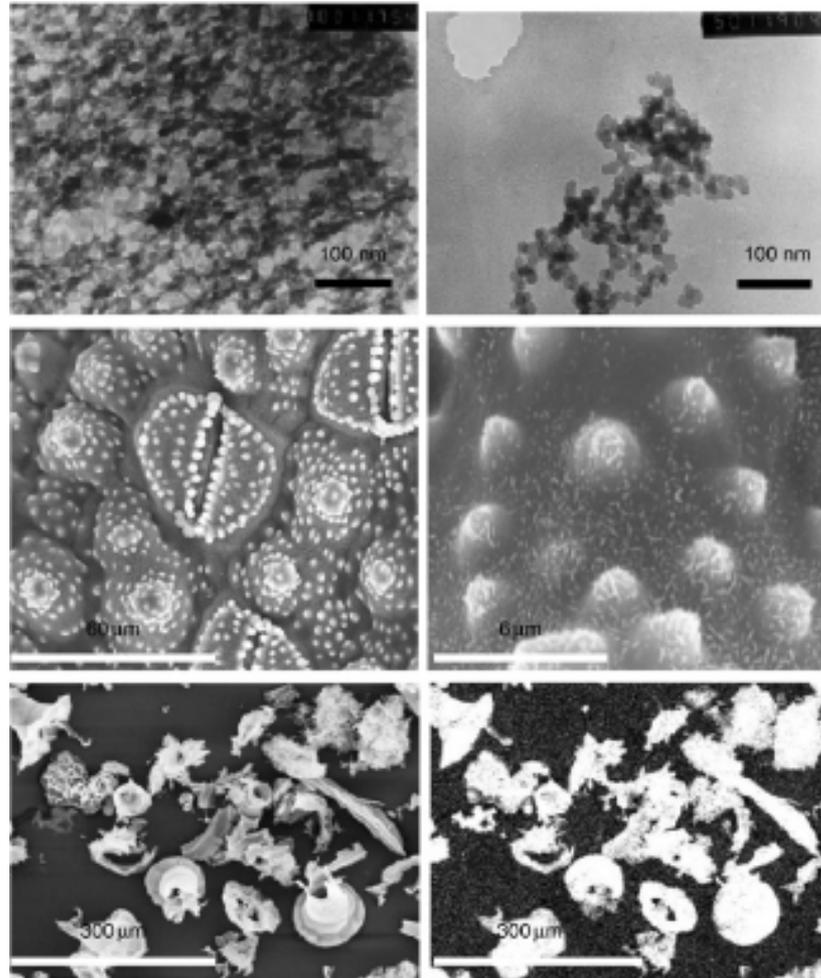


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Silica in plants

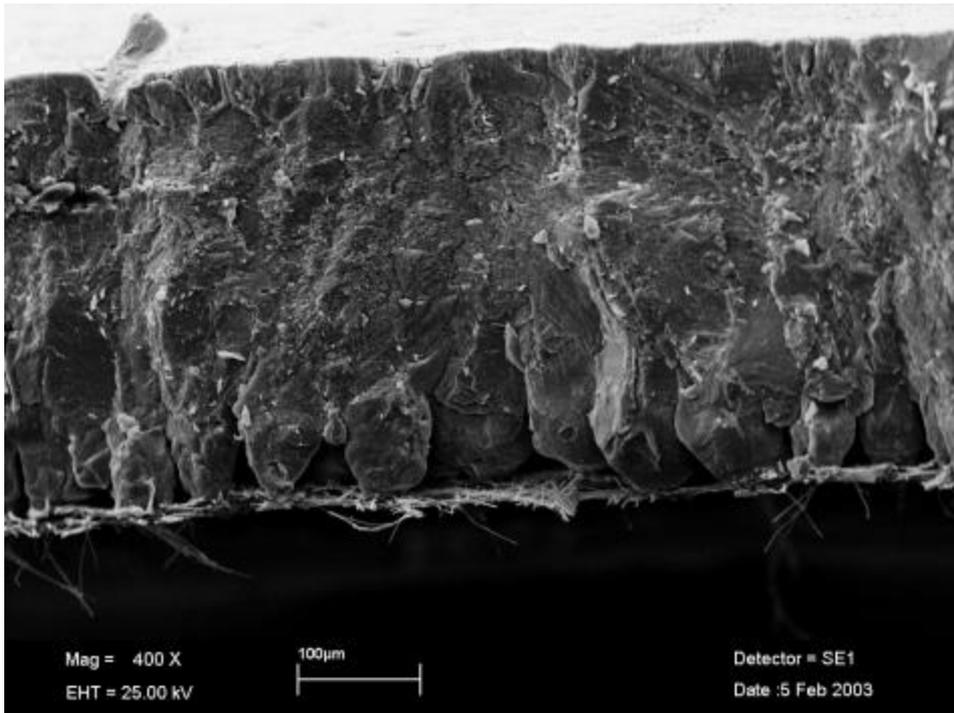


Currie and Perry, 2007

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Source: Currie, Heather A., and Carole C. Perry. "Silica in Plants: Biological, Biochemical and Chemical Studies." *Annals of Botany* 100, no. 7 (2007): 1383-9.

Avian egg shells



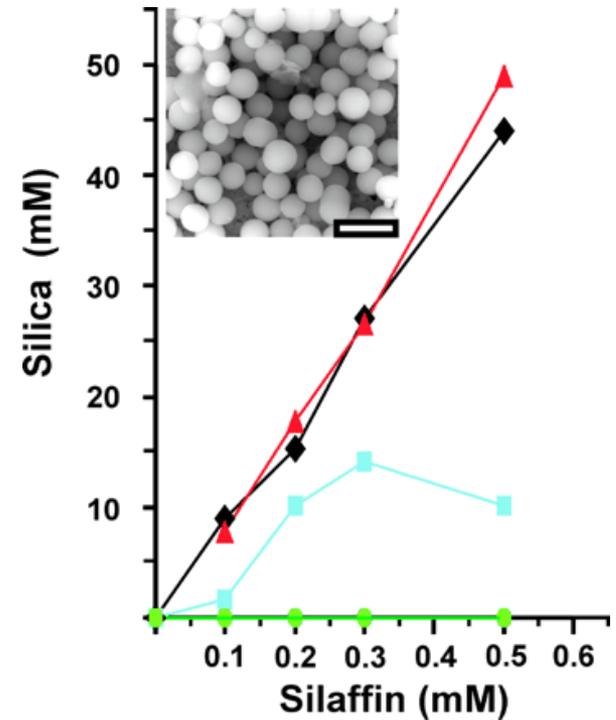
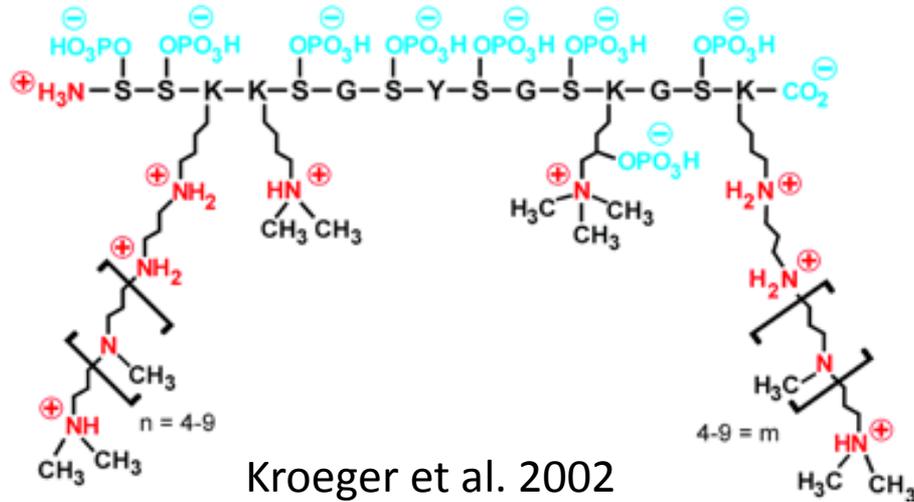
Calcite crystals

Keratin-like protein

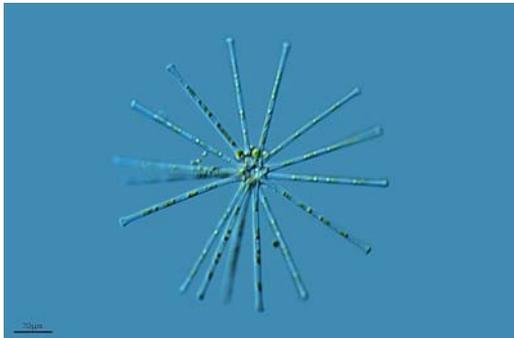
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Silaffins – polyamines in diatoms that condense silica

C



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Courtesy of [Proyecto Aqua](#) on flickr. CC-BY-NC-SA.

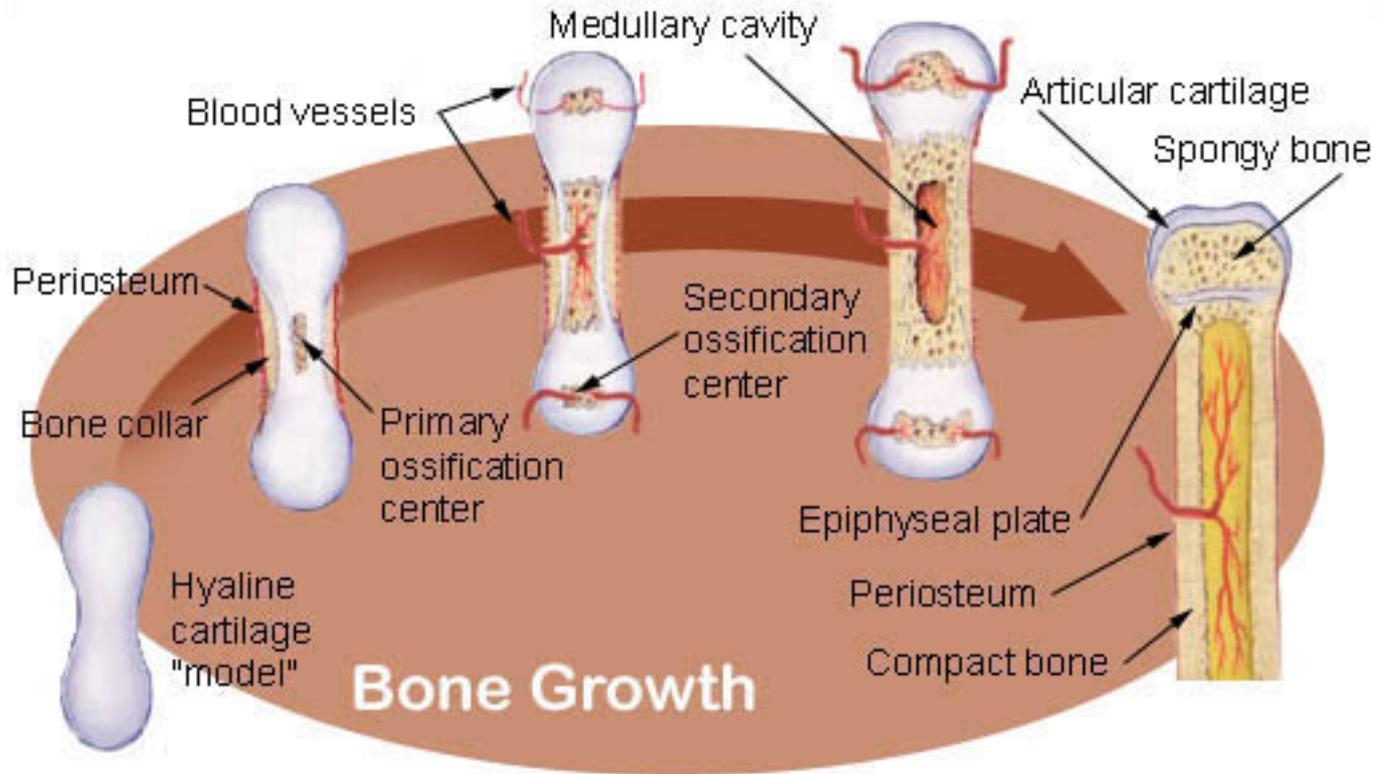
ACANTHARIANS – SrSO₄



Courtesy of [David Patterson](#), [Linda Amaral Zettler](#), [Mike Peglar](#), and [Tom Nerad](#). CC-BY-NC-SA.

Low fossilization potential due to large celestite solubility

Bone growth



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12.007 Geobiology
Spring 2013

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