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HIGHLIGHTS AND BREAKTHROUGHS

Biosilica: Structure, function, science, technology, inspiration

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Biomineralization is a complex ensemble of concomitant phenomena, driving the development of complex biological structures, associating highly organized organic matrices which function as templates for the nucleation and organization at the nanoscale of inorganic nanostructured phases (Sprio *et al.* 2014). These inorganic phases are called biominerals. They can be deposited within the tissues of living organisms (or in the immediate surroundings) as a result of the organism's metabolism (Skinner, 2000). These biomineral-forming organisms are known as biomineralizers. Their impressive diversity, recently reviewed by Ehrlich et al., (2008) boasts ~ 128,000 mollusk species, ~ 800 coral species, 5000 sponge species (including 550 species of glass sponges), 700 species of calcareous green, red and brown algae, more than 300 species of deep-sea benthic foraminifera and 200 000 diatom species (Mann and Droop 1996).

Among the plethora of biominerals, silicon dioxide (SiO_2, silica) in its various amorphous forms is undoubtedly one of the most intriguing and enigmatic, because it is the first and oldest natural bio-skeleton, it possesses unique mechanical properties, and it demonstrates high specific surface area and therefore, unique adsorption properties. Justifiably, these properties highlight silica as the most widely-distributed biomineral. It is worth-noting that silicic acid [$Si(OH)_4$], the "starting material" for biosilica synthesis, is found in very low concentrations in oceanic and fresh waters, with its levels in the range 10 - 180 μM (Sarmiento *et al.* 2007 and Marron *et al.* 2013). Nevertheless, species such as diatoms are able to pre-concentrate it up to concentrations of 19 - 340 mM (!) without any polycondensation (Martin-Jézéquel and Lopez 2003), whereas, *in vitro* we can only form silicic acid solutions in circumneutral pH of ~ 2 mM, before condensation starts (Demadis et al. 2014).

In the Review "Biosilica as Source of Inspiration in Biological Materials Science" by M. Wysokowski, T. Jesionowski, and H. Ehrlich (PLEASE ADD SPECIFIC CITATION), the authors set the ambitious goal to provide a thorough and comprehensive coverage of biosilicification as an interdisciplinary and multifaceted topic with controversial hypotheses and numerous open questions. Some of these refer to processes prior to biosilicification. Why do biosilicifiers select "Si" as the element of choice (in spite of its low levels in natural water systems)? Precisely, how is "Si" transported from the environment into the cell? How is it possible for silicifiers, such as diatoms, to "pre-concentrate" "Si" (in the form of silicic acid) up to concentrations of 340 mM (compared to a mere 8 mM in laboratory, ex vivo experiments), an achievement that would make any inorganic chemist jealous? Other unanswered issues concern the biosilcification process itself. How is biosilica formed in such a controlled manner, in intricate and awesome morphologies (compared to the almost unexceptional spherical silica particles that we make in the lab) and in a timely fashion? What are the biomacromolecules involved, and which is their precise function? Silaffins are well-known biological catalysts (Pamirsky and Golokhvast, 2013) that speed-up the biosilicification process, but what are precisely the chemical moieties that are involved and why?

The authors elegantly present the structural diversity of biosilica in some prokaryotes, and also in unicellular and multicellular eukaryotes with emphasis on biosilica of poriferan origin (sponges). They also illustrate strategies and approaches to ways in which the structural wealth and functions of biosilica formers can inspire new breakthroughs in artificial biomineralization and biomimetic technological advances.

The Review starts out with a concise description of biosilica of virus, bacteria and plant origin and its practical applications. Next, biosilicification in diatoms follows as source for bio-inspiration in materials and related scientific disciplines. Finally, the current state-of-the-art related to the unique siliceous structures in sponges is discussed, in light of recently-obtained experimental results. Silicofossils are also appropriately mentioned.

Based on the composition, morphology and physicochemical properties of a wide range of biosilicas, several bioinspired and miomimetic approaches have been launched. For example, whereas industrial production of glass requires very high temperatures, Nature has mastered the fabrication of extremely complex glass structures at low temperatures. As the Authors nicely put it, this is “a capacity that is far beyond the reach of current human technology”.

The Review discusses the interplay among flexibility, strength, hierarchical microstructure and unique optical properties of biosilica. Undoubtedly, these concepts already are, and will continue to be a source of inspiration for future structural and functional biomimetic approaches with the goal to discover the next-generation high performance composites materials. Although there are still several open questions and unsolved puzzles, as mentioned above, these can act as motives for further intense studies and discoveries in the scientific community of chemists, materials scientists, physicists and, of course, mineralogists. In the end, is it possible to mobilize a global and interdisciplinary effort to delineate biosilicification as a universal phenomenon, and utilize the tools of individual scientific and technical fields to advance our knowledge on why and how "Si" plays a vital role in the cycle of Life?

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