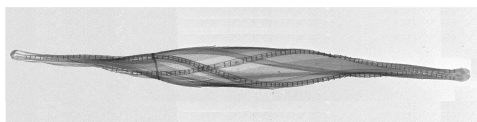


Miniature masonry

Vivienne Baillie Gerritsen

Ever heard of diatoms? Diatoms are phytoplanktonic unicellular algae that populate soil and seas around the globe. They are so small that many are indistinguishable under the light microscope – with dimensions ranging from a few micrometers to only a millimetre. Yet despite their microscopic size, diatoms are one of our primary sources of oxygen. Which just goes to show that minute can also spell merit. There has been a growing interest in diatoms – or their exoskeleton – in the past decade because they display the most intricate bioarchitecture ever seen...and in glass, if you please. The glass shells that surround the microalgae are nourishing the imagination of nanotechnologists. And diatomists are just beginning to decipher the molecular mechanisms underlying diatom shell masonry. One of the masons is called silaffin. Silaffins were discovered in the diatom *Cylindrotheca fusiformis*; they are an intimate part of the diatom glass matrix and are endowed with architectural talents.



Cylindrotheca fusiformis

Courtesy of Dr Nils Kroeger

Anton van Leeuwenhoek (1632-1723), the illustrious Dutch tradesman and pioneer of light microscopy was the first to discover diatoms in 1702. Leeuwenhoek described them as microscopic animals. But in the 1900s, they were shifted into the realm of plants, once their photosynthetic activity had been unveiled. Diatom-collecting became a fashionable pursuit and thousands of the microalgae were depicted...and almost as many names ascribed to them. As a result, it took the German microscopist Johann Dietrich Moller (1844-1907) the best part of 15 years to establish a diatom classification. And there is a famous slide, the size of a postage stamp, onto which Moller placed four thousand shells!

Over 70'000 species of diatom have been documented, all sporting different glass shell architectures. Van Leeuwenhoek could distinguish diatoms as a whole but could not see the detail on the shells' surface. This was

achieved in 1886 by the German optician Carl Freidrich Zeiss (1816-1888) who developed a microscope objective with which you could make out the miniature pores and slits on the cells' shell surface. In those days, diatoms were used to test novel microscope objectives. The objectives were sent to Belgium, to the laboratory of the diatomist Henri van Heurck (1838-1909), an authority on diatoms in the 19th century.

It took a further century to make out part of the molecular and chemical processes underlying diatom shell architecture. The shell is in fact a framework of silica, smeared with a number of organic molecules amongst which the silaffins ('affinity for silica') – discovered just before the turn of the last century. Silica formation – biosilica – takes place inside the cell's cytoplasm in a vesicle known as the silica deposition vesicle. This vesicle is believed to act as a mould in which the silica shell will grow. Silaffins have the ability to precipitate silica and form a kind of scaffolding onto which the biosilica will grow and arrange itself. They seem to do this by assembling into huge aggregates thanks to the existence of very specific side chains, which link to one another. *In vitro*, silaffin popped into a brew of monosilicic acid solution precipitates attractive nanospheres, which do not however resemble

the biosilica structures observed *in vivo*. What is the chemistry underlying silaffin structure?

Silaffins are small peptides (under 30 amino acids) – initially part of a longish protein sequence which is subsequently cleaved into three different active peptides. The silaffins sport side chains – polyamines – of different natures and lengths. The polyamine side chains are linked to lysine residues on the silaffin peptide backbones. For the knowledgeable and the curious, one type of silaffin known as silaffin-1A is actually the first peptide known to contain the polyamine ϵ -*N,N,N*-trimethyl- δ -hydroxylysine. In addition to the polyamine posttranslational modifications, a number of other chemical accessories are added such as phosphates, sulfates and various sugar molecules. Indeed, the silaffin peptide backbone just seems to be an excuse to append a certain number of chemical goodies, without which silaffins would lose their ability to act in biosilica morphogenesis. What is more, the different types of polyamine chains attached to the silaffins have their say in determining different designs of diatom architecture – and hence diatom speciation. However, despite the silaffins' seemingly major role in silica formation, it is becoming evident that other organic molecules are also needed to produce the final shell design. So closer scrutiny is needed.

Besides the aesthetics of diatom architecture, why bother delving into this microscopic world? For the sake of nanotechnology. The design of minute 3D structures is, not surprisingly, a challenge. So far, materials scientists have had to grow structures in painstaking and financially burdensome conditions. Diatoms can build 3D nanostructures at a speed and in physico-chemical conditions which make nanotechnologists dribble at the mouth. What is more, perhaps they could 'tame' diatoms to build structures with custom-sized pores, or with material other than silica to bestow new electrical or optical properties on them, or grow the silica hull devoid of the cellular algae itself! Diatoms could be used as miniature molds, or for creating novel optical devices, or as micro-gears in micro-robots, or as tiny diffraction gratings...the sky's the limit. There are drawbacks though – not much yet is known about diatom design and, as mentioned earlier, silaffins are far from the only organic molecule involved. The shell itself is also turning out to be a natural barrier to genetic hampering, which does not make things easier. While we await the feats of nanotechnology, why not pay a visit to the Van Heurck Museum in Antwerp, Belgium, to admire the very first photographic plate of a diatom taken with the Zeiss microscope – the Zeiss apochromat.

Cross-references to Swiss-Prot

Silaffin 1, *Cylindrotheca fusiformis* (Marine diatom) : Q9SE35

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