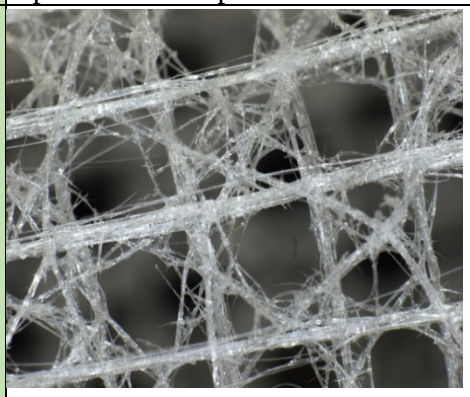
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	堅韌但具有彈性的玻璃骨架 (Glass skeletons are tough yet flexible)
生物系統 LIVING SYSTEM	玻璃海綿 *Euplectella aspergillum* (Venus's flower basket)
功能類別 FUNCTIONS	#應付擠壓 #Manage compression
作用機制標題	玻璃海綿的玻璃骨架既堅固又具彈性，是因為蛋白質媒介形成的奈米二氧化矽球層，乃由更小的奈米二氧化矽珠組成的。 (The glass skeleton of the Venus' flower basket is strong and flexible due to the protein-mediated formation of layers of nanoscale silica spheres made up of even smaller nanoscale silica beads.)
生物系統/作用機制示意圖	

作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)

此海綿的玻璃骨架由骨針 (spicule) 構成，骨針是不定形水合二氧化矽 (amorphous hydrated silica) 同心層的小管結構，由薄的有機層所分離，就像一片巴黎糕點 (Parisian pastry) 酥皮間的甜奶油。但是這些薄有機層對於骨針的強韌性有著很大的貢獻；甚至終其一生被困在玻璃海綿。與像是鮑魚的其他生物體之生物礦化 (biomineralization) 不同，玻璃海綿的礦物質部分並沒有規則的結晶形式。實驗指出二氧化矽層是由直徑約 50-200 nm 的膠體球 (colloidal sphere) 所組成，其又由直徑約 2.8 nm 的更小球體所組成。作為比較，海灘上最小的沙粒（通常也是二氧化矽）直徑約是 60 nm。

The sponge’s glass skeleton is made up of spicules, tubule structures of concentric layers of amorphous hydrated silica separated by thin organic layers, like a Parisian pastry with just a tease of sweet cream between flaky crusts. But these thin organic layers go a long way to impart the spicules with considerable toughness. Even the pair of symbiotic shrimp that live their lives trapped within each Venus’s woven glass basket can’t break out. Unlike biomineralization in other organisms such as the abalone, the mineral portion does not appear to have a regular crystalline pattern. Experiments suggests that the silica layers are made up of colloidal spheres of silica about 50 to 200 nm in diameter, which are in turn made up of smaller spheres about 2.8 nanometers in diameter. By comparison, the smallest sand grains on a beach (also usually silica)

are about 60 nm in diameter.

文獻引用 (REFERENCES)

「儘管其易碎性質，玻璃在生物界中被廣泛地當作建築材料。生物體已演化出加強此原本易碎材料的有效方式。跟具有相似長度等級的合成玻璃棒相比，矽質海綿的骨針表現出罕見的彈性和強韌性...綜合來說，奈米等級的二氧化矽球被排列在清晰的微觀同心環中，由有機基質黏合在一起而形成疊層 (laminated) 的骨針。藉由疊層狀二氧化矽基接合劑的作用，將這些骨針組裝成束，並以斜向脊紋 (diagonal ridge) 予以加強，因而形成宏觀的圓柱形方格 (square-lattice) 籠狀結構。接下來的設計克服了其構成材料玻璃的易碎性，並表現了出色的機械剛性和穩定性。」 (Aizenberg et al. 2005: 275)

"Glass is widely used as a building material in the biological world, despite its fragility. Organisms have evolved means to effectively reinforce this inherently brittle material. It has been shown that spicules in siliceous sponges exhibit exceptional flexibility and toughness compared with brittle synthetic glass rods of similar length scales… Consolidated, nanometer-scaled silica spheres are arranged in well-defined microscopic concentric rings glued together by organic matrix to form laminated spicules. The assembly of these spicules into bundles, effected by the laminated silica-based cement, results in the formation of a macroscopic cylindrical square-lattice cage-like structure reinforced by diagonal ridges. The ensuing design overcomes the brittleness of its constituent material, glass, and shows outstanding mechanical rigidity and stability." (Aizenberg et al. 2005: 275)

參考文獻清單與連結 (REFERENCE LIST)

Aizenberg J., J.C. Weaver, M. S. ThanawalaV. C. SundarD. E.Morse, and P. Fratzl. (2005). Skeleton of *Euplectella* sp.: structural hierarchy from the nanoscale to the macroscale. *Science* 309: 275-278. (https://science.sciencemag.org/content/309/5732/275)

延伸閱讀

生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)

https://en.wikipedia.org/wiki/Venus%27_flower_basket

撰寫/翻譯/編修者與日期

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AskNature 原文連結

https://asknature.org/strategy/glass-skeletons-are-tough-yet-flexible/