生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	葉片具有彈性及形狀記憶 (Leaves have elasticity, shape memory)
生物系統 LIVING SYSTEM	復甦蕨 *Polypodium polypodioides* (Resurrection fern)
功能類別 FUNCTIONS	#獲取、吸收、或過濾液體 #改變大小/形狀/質量/體積 #儲存液體 #Capture, absorb, or filter liquids #Modify size/shape/mass/volume #Store liquids
作用機制標題	復甦蕨的葉片透過有層次的柵狀及海綿狀葉肉層在缺水過後能恢復形狀 (Leaves of the resurrection fern regain shape after dehydration due to hierarchical structure of palisade and spongy layers.)
生物系統/作用機制示意圖	 

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

文獻引用 (REFERENCES)

「復甦蕨 (*Polypodium polypodioides*) 有一個讓人印象深刻的彈性反應，就是這種蕨類在復水 (rehydration) 時，會隨著楊氏模數 (Young's modulus) 下降而快速吸收水分。在這裡我們會討論這種蕨類的彈性反應及提供模仿這種結構的想法，或可設計出有彈力特性的材質。」

「多年以來，植物一直是材料及仿生系統 (biomimetic systems) 設計及最佳化的一個豐富資料來源。舉個例子，蒼耳 (burdock) 直接影響了創新的魔鬼氈鉤子系統發明，荷葉則啟發了極疏水表面的創造。植物曝露在水分、光照等外界刺激的彈性反應也十分有趣，而新興的仿生材料或許能受惠於此。植物的葉片在完全充滿水分的狀態下通常是硬挺的，但在乾旱環境下則會變得萎縮及柔軟，如果完全乾燥的話，就只會剩下細胞基質 (cellular matrix)，葉片也就變得脆硬而易碎。不過，有些植物有著概念上相對單純的彈性反應，就是葉片在乾燥狀態下硬挺而濕潤狀態下柔軟。在這裡，我們研究了復甦蕨這種有著驚人能力的植物，在獲取水分的同時能夠改變其彈性，從柔軟的吸水狀態到堅挺的脫水狀態以渡過旱季。另外如同Ref. 6的報導，這種蕨類能夠在卷曲的乾燥狀態及完全展開的柔軟濕潤狀態之間重覆轉換，根本就是天然的形狀記憶 (shape-memory) 物料。」(Helseth 2008: 1)

「復甦蕨的結構是有層次 (hierarchical) 的（見Fig. 5及Ref. 6），最細小的彈性單位是排列成柵狀及海綿狀葉肉組織層 (palisade and spongy layers) 的細胞。水分因為毛細作用 (capillary pressure) 流進這些層狀結構，使細胞能吸收到水分。如果要製造出像蕨類般能反覆展示彈性反應的人工結構，就一定要模仿到這種植物的層次結構。」(Helseth 2008: 3)

「楊氏模數 (E)被定義為沿著測試樣本物料縱軸施加壓力，測量其縱軸變形或延長的比率，亦被稱為彈性模量。」

「當一個延展的力量（張力）施加到物件上時就會使其延展，這個現象可以用彈性變形區域中的應力-應變 (stress-strain) 曲線（也稱為虎克定律 Hooke;s Law）求得。施力所產生的延展程度不只取決於材質，也取決於其他因子如物件的維度（例如長度、厚度等）。」

"The resurrection fern *Polypodium polypodioides* has a remarkable elastic reponse, where the fast water uptake of the fern upon rehydration is accompanied by a significant reduction in its Young's modulus. In this letter, we discuss the fern's elastic response and suggest that by mimicking its structure, one should be able to design materials exhibiting interesting elastic behavior."

"For many years, plants have been a rich information source for designing and optimizing materials and biomimetic systems. For example, Burdock plants had a direct impact on the invention of a novel hooking system, while the lotus leaf has inspired the creation of very hydrophobic surfaces. The elastic response of plants when exposed to external stimuli water, light, etc. is also rather interesting,and emerging biomimetic materials may just take advantage of this. Plant leaves are often stiff while fully hydrated but loose turgor and become soft under dry conditions. If they dry completely up, only the cellular matrix remains, and the leaf appears to be hard and brittle. However, some plants have a conceptually simpler elastic response, where the plant leaf is stiff in the dry state and soft in the wet state. Here, we study the resurrection fern *Polypodium polypodioides*, which has an amazing ability to take up water while at the same time altering its elasticity from a soft hydrated state to a stiff dehydrated state in order to cope with drought. Moreover, as reported in Ref. 6, the fern can reproducibly switch between a curled-up dry state and a fully extended and soft wet state and is, therefore, a natural shape-memory material." (Helseth 2008: 1)

"The structure of the resurrection fern is hierarchical (see Fig. 5 in Ref. 6), where the smallest elastic units are the plant cells arranged into palisade and spongy layers. Water flows into the layered structures due to capillary pressure, allowing the cells to absorb water as well. An artificial structure aiming at reproducing the elastic reponse of the fern must display a hierarchical structure which mimics that of the plant." (Helseth 2008: 3)

"Young's modulus (E) is defined as the ratio of the stress applied to the material along the longitudinal axis of the specimen tested and the deformation or strain, measured on that same axis. Young's Modulus is also known as tensile modulus, elastic modulus or modulus of elasticity."

"When a stretching force (tensile force) is applied to an object, it extends, and its behavior can be obtained using stress-strain curve in the elastic deformation region (Known Hooke's Law). The extension that a force produces is not only dependent on the material but also on other factors like dimensions of the object (e.g. length, thickness etc.)"

參考文獻清單與連結 (REFERENCE LIST)

Helseth, L. E. (2008). Elastic response of the resurrection fern *Polypodium polypodioides* during rehydration. *Appl. Phys. Lett.* 92: 043902 1-3. (https://doi.org/10.1063/1.2838357)

SpecialChem SA. (n.d.). Young's modulus. *Polymer properties*. Retrieved April 10, 2020 from: (https://omnexus.specialchem.com/polymer-properties/properties/young-modulus)

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/Pleopeltis_polypodioides

撰寫/翻譯/編修者與日期

譚國鎏翻譯 (2020/04/07)；許秋容編修 (2020/11/25)；紀凱容編修 (2020/11/25)

AskNature原文連結

https://asknature.org/strategy/leaves-have-elasticity-shape-memory/