生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	葉片構造在水中保留空氣層 (Leaf structure retains air layer underwater)
生物系統 LIVING SYSTEM	人厭槐葉蘋 *Salvinia molesta* (Giant *Salvinia*)
功能類別 FUNCTIONS	#獲得、吸收、或過濾空氣 #保護免受過多液體危害 #Capture, absorb, or filter gases #Protect from excess liquids
作用機制標題	水生蕨類槐葉萍葉表的疏水性毛茸之尖端帶有親水性，使沉在水中時可保留空氣層 (The leaf structure of the *Salvinia* water fern retains a layer of air when submerged in water due to water-resistant hairs that possess water-attracting tips.)
生物系統/作用機制示意圖	

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

漂浮的水生性蕨類植物，槐葉萍 (*Salvinia*) ，是一種在完全沉入水中時能夠保留著乾氣穴 (pockets of dry air) 的獨特植物。這種為提供植株浮力 (buoyancy) 的能力是來自於葉片的表面構造。

槐葉萍的葉子上佈滿了毛茸組合而成像小型打蛋器 (wire cooking whisk) 的構造。每根毛茸都從底部開始覆蓋著疏水性 (hydrophobic)（防水）蠟質晶體塗層，但不包含尖端。每根毛茸的最末端缺乏疏水性蠟質所以是親水性 (hydrophilic) 的，表示它會吸引水分子。就是這些親水性毛茸尖端幫助了沉入水中的植株可保留乾氣穴。它們使得在葉表和它們所吸引的水分之間困住一層空氣薄層。

打蛋器形狀使每根獨立毛茸之間的表面積達最大化，提供更多空間供水分子「就座」。這些水分子被釘在毛茸的頂端，因此減少了周圍水體不穩定性的影響。由於有大的親水性毛茸表面，水形成邊界，有助於減少在毛茸間的水體—植株的交互作用，進而減少植物在流體環境移動時的阻力。

這種親水性斑塊在疏水性表面上的組合被稱為「槐葉萍效應」(*Salvinia* effect) 。這導致氣泡層可以在水中的葉片上被維持好幾個星期。

這篇摘要是由 Ashley Meyers 所提供。

The floating water fern, *Salvinia*, is a unique plant in that it retains pockets of dry air when fully submerged in water. This capability, which provides the plant with buoyancy, is owed to the surface structure of its leaves.

The water fern's leaves are covered in tiny hairs grouped to look like miniature wire cooking whisks. Each hair is coated in hydrophobic (water-repelling) wax crystals from its base not quite to its tip. The very tip of each hair lacks hydrophobic wax and is hydrophilic, which means it attracts water molecules. It is these hydrophilic tips that help retain air pockets when the plant is submerged. They enable the trapping of a thin layer of air between the leaf surface and the water that they attract.

The whisk shape maximizes the surface area between individual hairs, providing more space for water molecules to "sit" upon. These water molecules are pinned on the tips of the hairs, thus reducing the impact of instabilities in the surrounding water. By having a large surface of hydrophilic hairs, water forms a boundary that aids in reducing drag as the plant moves in the fluid environment by creating less water-plant interaction between hairs.

This combination of hydrophilic patches on hydrophobic surfaces is known as the "*Salvinia* Effect." It is responsible for retaining an air layer underwater on the fern's leaves for up to several weeks.

This summary was contributed by Ashley Meyers.

文獻引用 (REFERENCES)

「一個關於長期性水中保留氣體的全新機制，在水生蕨類植物槐葉萍複雜的表面設計上被找到。槐葉萍的浮水葉片均勻地覆蓋著複雜的疏水性茸毛，當沉在水中時能保留一層空氣。令人驚訝的是細毛末端的細胞是親水性的。這些親水性的斑塊透過固定氣體—水分界面，對空氣層起了穩定作用。這種「槐葉萍效應」提供了革新的概念作仿生表面的發展，能在水中環境有長期保留空氣的能力。」(Barthlott et al. 2010: 2325)

「為了示範固定效應，單獨的打蛋器狀毛茸被浸入水中。當從水中拉出毛茸時，記錄從側面觀察到水分液面 (meniscus) 產生的形狀及大小…作為親水性的測量，我們量度了在液面消失的一剎那，毛茸的末端與水面的距離。這項實驗使用了未經處理的毛茸，以及沾上鐵氟龍（Teflon, 聚四氟乙烯 polytetra-fluoroethylene, PTFE）溶液而變成疏水性的毛茸。未經處理的毛茸可以拉起比鐵氟龍處理細毛高大約兩倍的液面…打蛋器狀毛茸的功能很明顯，它們促使在植株葉片表面及毛茸末端之間困住一層氣體薄層。如果要使水滲入到這個完整界定的區域，需要能量介入以使在水及疏水性毛茸之間產生更多的接觸面積。」

「這也解釋了這個特殊打蛋器形狀結構的由來。為了最有效率地穩定空氣—水界面，最理想的就是使水滲入細毛之間區域的能量最大化。因此毛茸被分成四臂狀，以產生每個高度差異下儘可能最多表面積的現象就變得很合理。」

「為了進一步增強這種效應，這四臂狀毛茸的末端彎曲在一起，將近是水平的角度。這導致水滲透入空氣保留區，意即使滲透至比毛茸最頂端更深的地方，所需要最大程度地水—毛茸每個高度差的接觸面積 (water-hair contact area per height difference) 得以最大化。」(Barthlott et al. 2010: 2327)

"A novel mechanism for long-term air retention under water is found in the sophisticated surface design of the water fern *Salvinia*. Its floating leaves are evenly covered with complex hydrophobic hairs retaining a layer of air when submerged under water. Surprisingly the terminal cells of the hairs are hydrophilic. These hydrophilic patches stabilize the air layer by pinning the air-water interface. This '*Salvinia* Effect' provides an innovative concept to develop biomimetic surfaces with long-term air-retention capabilities for under water applications." (Barthlott et al. 2010: 2325)

"To demonstrate the pinning effect, individual eggbeater hairs were dipped into water. From a lateral view the shape and size of the water meniscus created, when pulling the hairs out of the water was recorded…As a measure of the hydrophilicity we took the distance between the tip of the hairs and the water surface at the exact instant when the meniscus snapped off. This experiment was done with untreated hairs and hairs that were rendered hydrophobic by dipping them into a Teflon (polytetra-fluoroethylene, PTFE) solution. The water meniscus could be pulled roughly twice as high by the untreated hair…than by the Teflon coated hair…The function of the eggbeater hairs is obvious – they allow the trapping of a thin air layer reaching from the surface of the plant leaf to the top of the hairs. Penetration of water into this well-defined region requires energy for creating an increased contact area between the water and the hydrophobic hairs.

This also explains the special eggbeater shape of the structures. In order to stabilize the air–water interface most efficiently, it is desirable that the energy required for the water to penetrate into the region between the hairs is maximized. Therefore it makes sense that the hairs are split into four arms to create as much surface per height difference as possible.

To enhance this effect even more, these four arms are bent together at the terminal ends, approaching an almost horizontal angle. This leads to a maximization of the additional water-hair contact area per height difference required for the water to penetrate into the air retention area, i.e., to penetrate deeper than the topmost level of the hairs." (Barthlott et al. 2010: 2327).

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延伸閱讀

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

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https://asknature.org/strategy/leaf-structure-retains-air-layer-underwater/