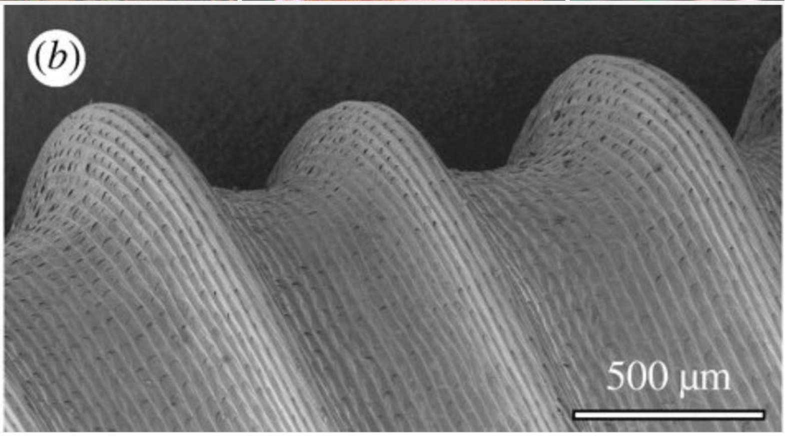
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	極度濕滑的捕蟲瓶邊緣 (Pitcher rims are extremely slippery)
生物系統 LIVING SYSTEM	豬籠草屬 *Nepenthes* (Tropical pitcher plants)
功能類別 FUNCTIONS	#獲得、吸收、或過濾生物 #在液體中/上移動 #Capture, absorb, or filter organisms #Move in/on liquids
作用機制標題	豬籠草的口緣因為一層液體薄膜覆蓋在微紋理表面上而變得極度濕滑 (Rims of the pitcher plant are extremely slippery due to a liquid film overlaying a microtextured surface.)
生物系統/作用機制示意圖	 

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

豬籠草屬 (*Nepenthes*) 是有著致命習性而令人驚嘆的熱帶植物。這種食蟲植物 (carnivorous plant) 的葉片特化成瓶子（捕蟲瓶），能誘捕昆蟲或其他細小的獵物，當其降落到捕蟲瓶邊緣後，使其失足掉落到一池的消化液中。圓形邊緣（稱為口緣或唇 peristome）的表面尤其光滑，使昆蟲掉入致命的捕蟲瓶中。是什麼使捕蟲瓶口緣如此危險？

科學家們發現了兩個不一樣但互相作用的因子，能使捕蟲瓶邊緣變成低摩擦力的表面：首先，捕蟲瓶邊緣裝飾著一系列微米尺寸的溝紋，並延伸進入捕蟲瓶。這些溝紋是由重疊的表皮細胞所組成，就像屋瓦一樣，給予表面方向性的紋理。這使得更容易滑落到捕蟲瓶中，而不能以相反方向逃走。第二，當出現液體的來源時，例如濕氣、雨水，或是植物本身的蜜汁，都會使捕蟲瓶邊緣的微紋理 (microtectured) 表面形成一層薄膜。這種「潤

濕過」的表面大大地降低植物與昆蟲腳之間的摩擦力，尤其是如果這個動作是住捕蟲瓶深處的方向。並不像很多有著微紋理的植物葉片表面般防水（疏水性），豬籠草的捕蟲瓶邊緣很容易沾濕，使其變成高效率的濕滑表面。

在豬籠草屬的很多物種中，附著在捕蟲瓶壁上的蠟質晶體在使表面變光滑上亦起了一定作用。晶體從植物表面脫落並堵塞昆蟲的足墊，使其不能黏附在表面上而逃脫。

豬籠草的濕滑表面啟發了部分研究人員發展出自潔表面，部分應用了保持永久濕潤來保持潔淨的嶄新概念。

Pitcher plants of the genus *Nepenthes* are stunning tropical plants with a deadly habit. Specialized leaves in this carnivorous plant form a tall pitcher that traps insects and other small prey when they land on the rim of the pitcher and fall in, ending up in a pool of digestive juices. The surface of the rounded rim (called the peristome) is especially slippery, causing insects to fall right into the fatal pitcher. What makes the pitcher rim such a precarious place?

Scientists have identified two different, interacting factors that make the rim a low-friction surface: first, it is patterned with a series of micron-sized ridges that run into the pitcher. The ridges are made of overlapping epidermal cells, like roof tiles, that give the surface texture directionality—it's easier to slide toward the inside of the pitcher than it is to slide the opposite way and escape. Second, when there's a source of liquid—for instance humidity, rain, or the plant's own nectar—a thin film forms on the rim's microtextured surface. This "wetted" surface drastically reduces friction between the plant and insect feet, particularly if movement is toward the inside of the pitcher. Unlike many microtextured plant leaf surfaces that are water repellent (hydrophobic), the pitcher plant rim appears to wet easily, making it a highly effective slippery surface.

In many species of pitcher plant, waxy crystals lining the pitcher walls also play a role in making the surface slippery. The crystals detach from the plant's surface and clog the insect's foot pad, leaving it unable to stick to the surface and escape.

The pitcher plant's slippery surfaces are inspiring several researchers to develop self-cleaning surfaces, some of which apply the novel concept of staying permanently wet to stay clean.

文獻引用 (REFERENCES)

捕蟲瓶口緣的特性為有著規則的微結構，以及平滑的表皮細胞重疊而成的輻射狀溝紋，形成一系列的踏板導向捕蟲瓶深處。這種表面能夠被口緣內緣分泌的蜜汁以及雨水所完全潤濕，因此在潮濕氣候環境中能使表面被同質液體薄膜所覆蓋。只有在濕潤時，口緣表面對昆蟲來說才是濕滑的，因此大部分來訪的螞蟻都會被捕捉。透過測量編織蟻

(*Oecophylla smaragdina*) 在二齒豬籠草 (*Nepenthes bicalcarata*) 口緣表面上的摩擦力，我們證實了兩個因子能防止昆蟲附著在口緣上，即是水分潤滑以及各向異性表面形貌 (anisotropic surface topography)，在對抗昆蟲蹠足 (tsrsus) 的不同附著構造非常有效。」(Bohn and Federle 2004: 14138)

口緣表面有非常規則的一級和二級輻射狀溝紋微結構，由直排的表皮細胞所形成（圖 1D 及 E）。每個表皮細胞交疊在捕蟲瓶內的鄰近細胞，因此表面會有一系列的踏板通往捕蟲瓶深處並且為各向異性。(Bohn and Federle 2004: 14140)

口緣濕滑的機制是基於水分潤滑或蜜汁薄膜的存在，以及口緣的微結構表面。口緣表面的重疊表皮細胞之間含有微觀的空腔，可能會是提供昆蟲腳爪固著的適合尺寸 (26)，但只存在於往捕蟲瓶外部的方向。

"The peristome is characterized by a regular microstructure with radial ridges of smooth overlapping epidermal cells, which form a series of steps toward the pitcher inside. This surface is completely wettable by nectar secreted at the inner margin of the peristome and by rain water, so that homogenous liquid films cover the surface under humid weather conditions. Only when wet, the peristome surface is slippery for insects, so that most ant visitors become trapped. By measuring friction forces of weaver ants (*Oecophylla smaragdina*) on the peristome surface of *Nepenthes bicalcarata*, we demonstrate that the two factors preventing insect attachment to the peristome, i.e., water lubrication and anisotropic surface topography, are effective against different attachment structures of the insect tarsus." (Bohn and Federle 2004: 14138)

"The peristome surface has a very regular microstructure consisting of first- and second-order radial ridges formed by straight rows of epidermal cells (Fig. 1 D and E). Each epidermal cell overlaps the cell adjacent to the pitcher inside, so that the surface contains a series of steps toward the pitcher inside and is anisotropic." (Bohn and Federle 2004: 14140)

"The mechanism of peristome slipperiness is based on the presence of lubricating water or nectar films and on the microstructured surface of the peristome. The peristome surface contains microscopic cavities between overlapping epidermal cells that may be in the appropriate size range to provide anchorage for insect claws (26) but only in the direction toward the outside of the pitcher." (Bohn and Federle 2004: 14142)

參考文獻清單與連結 (REFERENCE LIST)

Bohn, H. F. and W. Federle. (2004). Insect aquaplaning: *Nepenthes* pitcher plants capture prey with the peristome, a fully wettable water-lubricated anisotropic surface. *PNAS* 101: 14138-14143. (https://doi.org/10.1073/pnas.0405885101)

Bauer, U. and W. Federle. (2009). The insect-trapping rim of *Nepenthes* pitchers. *Plant*

Signaling & Behavior 4: 1019-1023. (https://doi.org/10.4161/psb.4.11.9664)

Bauer, U., H. F. Bohn, and W. Federle. (2007). Harmless nectar source or deadly trap: *Nepenthes* pitchers are activated by rain, condensation and nectar. *Proc. R. Soc. B* 275: 259-265. (https://royalsocietypublishing.org/doi/pdf/10.1098/rspb.2007.1402)

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AskNature Team. (1 October, 2016). Slippery Liquid Infused Porous Surface SLIPS. *AskNature*. Retrieved from: https://asknature.org/idea/slippery-liquid-infused-porous-surface-slips/
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