生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	內壁防止昆蟲的腳附著 (Walls keep insect feet from sticking)
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 #Capture, absorb, or filter organisms
作用機制標題	豬籠草內壁透過以片狀、蠟質並會變硬的物質堵塞昆蟲的腳來防止其逃走 (The internal walls of pitcher plants prevent insects from escaping by clogging their feet with a flaky, waxy substance and being rough.)
生物系統/作用機制示意圖	 

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

「豬籠草吸引多種動物，從昆蟲到兩棲類再到鼠類甚至鳥類，使牠們掉入特化成碗形的葉子裡。給合顏色、蜜液及香氣而達成。」 (Zygote Quarterly)

“The plant lures animals, from insects to amphibians to rats and even birds, into a modified leaf that forms a bowl. It does this by a combination of color, nectar, and scent.” (Zygote Quarterly)

文獻引用 (REFERENCES)

「發展出最精巧的變成陷落式陷阱 (pit-fall traps) 葉片的植物，最廣為人知、淺顯、無疑就是豬籠草 (pitcher plants)…它們的陷阱捕捉能力與瓶子草 (trumpet pitchers) 相當。豬籠草以帶香氣的蜜液來引誘昆蟲。它們陷阱的內壁更為奸詐，其片狀蠟質表面可脫落而黏附昆蟲的腳，使牠們失去任何能附著的機會。隨著豬籠草的受害者墜落到水中並開始掙扎逃生，這種擾動刺激捕蟲瓶壁中的腺體釋放消化性酸液。這些酸液非常有效，一隻蒼蠅會在幾天內化為一個空殼，而一隻蠓更可以在數小時內完全消失。豬籠草的整個裝置非常有效，不僅能夠捕捉小型昆蟲，更能捕捉蟑螂、蜈蚣及蠍子。而馬來王豬籠草 (the rajah) 據說可以捕獲老鼠。 [趙怡姍補充：另一篇中提及馬來王豬籠草是消化糞便，而此處可能是舊研究]」(Attenborough 1995: 77-78)

「[摘要] 豬籠草屬 (*Nepenthes*) 的植物能以特化的葉片有效地捕捉及困住昆蟲獵物。除了光滑的捕蟲瓶開口 (peristome) 阻止昆蟲附著之外，它們在捕蟲瓶的傳導區域 (conductive zone) 內壁利用上表皮蠟質晶體，以妨礙昆蟲黏性物質的附著能力。推測捕蟲是由獨特晶體的脫落及其污染昆蟲的附著器官。然而，我們的結果提供支持其它機制的證據，主要是基於蠟質表面的穩定性及粗糙程度。首先，從翼狀豬籠草 (*Nepenthes alata*) 成熟捕蟲瓶滑落的昆蟲腳上並沒有找到大量的晶體碎片。第二，以聚焦離子束顯微鏡 (focused ion beam treatment) 觀察豬籠草，顯示蠟質晶體形成緊密的 3D 結構。第三，原子力顯微鏡 (atomic force microscopy) 的觀察顯示小板狀晶體是機械性穩定的 (mechanically stable)，因此難以置信這些晶體會因昆蟲的腳導致脫落。第四，蠟質層的表面參數與低粒度的拋光紙有顯著的相似度。透過測量昆蟲在人造表面上的摩擦力，我們說明了只靠微觀的粗糙度就足以減少昆蟲的附著力。理論性的模型證實了在一定尺寸規模的表面粗糙度下，依靠附著力的腳會因為太粗糙，腳爪則會因為不夠粗糙，而導致兩種方式皆無法附著。」[結論] 作為結論我們無法排除廣泛突出的單一蠟質晶體會有某程度的破碎而被發現作為殘餘物附著在蹠足 (tarsi) 上的可能性。推測這可能增加翼狀豬籠草表面的抗附著效果。另外，以晶體碎裂來捕捉獵物的現象可能會在某些情況或環境中出現在其它豬籠草屬物種或者甚至是翼狀豬籠草的其它個體中。然而，從結果中清楚地表明只靠機械性非常穩定的上表皮蠟質之結構特性，就已經足夠防止昆蟲附著在翼狀豬籠草的傳導區域。(Scholz et al. 2010: 1115, 1125)

“The most elaborate of all these leaves turned into pit-fall traps are developed by the plants that are known, simply and without qualification, as pitcher plants…Their trapping strategy is the same as the trumpet pitchers. They entice insects with fragrant nectar. The walls of their traps are made even more treacherous by a flaky waxy surface that peels off and clogs the feet of insects so that they lose all chance of adhesion. As their victims tumble into the water and start to struggle to save themselves, the disturbance stimulates glands in the pitcher walls which start to discharge a digestive acid. This is so powerful that a fly will be reduced to a hollow shell within days and a midge will disappear entirely within hours. The whole device is so effective that these pitchers can trap not just small insects, but cockroaches, centipedes and scorpions. The rajah is said to be able to consume mice.” (Attenborough 1995: 77-78)

“[Abstract] Pitcher plants of the genus Nepenthes efficiently trap and retain insect prey in highly specialized leaves. Besides a slippery peristome which inhibits adhesion of insects they employ epicuticular wax crystals on the inner walls of the conductive zone of the pitchers to hamper insect attachment by adhesive devices. It has been proposed that the detachment of individual crystals and the resulting contamination of adhesive organs is responsible for capturing insects. However, our results provide evidence in favour of a different mechanism, mainly based on the stability and the roughness of the waxy surface. First, we were unable to detect a large quantity of crystal fragments on the pads of insects detached from mature pitcher surfaces of *Nepenthes alata*. Second, investigation of the pitcher surface by focused ion beam treatment showed that the wax crystals form a compact 3D structure. Third, atomic force microscopy of the platelet-shaped crystals revealed that the crystals are mechanically stable, rendering crystal detachment by insect pads unlikely. Fourth, the surface profile parameters of the wax layer showed striking similarities to those of polishing paper with low grain size. By measuring friction forces of insects on this artificial surface we demonstrate that microscopic roughness alone is sufficient to minimize insect attachment. A theoretical model shows that surface roughness within a certain length scale will prevent adhesion by being too rough for adhesive pads but not rough enough for claws.” [from Conclusion] In conclusion we cannot rule out the possibility that to a certain degree breaking of extensively protruding single wax crystals may occur and consequently be found as residues attached to the tarsi. Presumably this would increase the anti-adhesive effect of the surface of *N. alata*. Furthermore, breaking of crystals for catching prey may occur in different species of pitcher plants or even individuals of *N. alata* under certain circumstances or environmental conditions. However, the results presented clearly indicate that the structural properties of the mechanically very stable epicuticular wax alone are sufficient to prevent insect adhesion to the conductive zone of *N. alata*. (Scholz et al. 2010: 1115,1125)

參考文獻清單與連結 (REFERENCE LIST)

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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)

https://en.wikipedia.org/wiki/nepenthes
https://www.onezoom.org/life/@nepenthes
https://eol.org/pages/60885

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譚國鋈翻譯 (2021/03/22)；趙怡姍編修 (2021/04/20)

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