生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	葉片被觸碰後折合 (Leaves fold in response to touch)
生物系統 LIVING SYSTEM	含羞草 *Mimosa pudica* (Herbe sensible)
功能類別 FUNCTIONS	#改變大小/形狀/質量/體積 #保護免受動物危害 #Modify size/shape/mass/volume #Protect from animals
作用機制標題	含羞草以被觸碰後折合葉片的反應保護自己免受天敵及環境侵害 (Leaves of the sensitive plant protect themselves from predators and environmental conditions by folding in response to touch.)
生物系統/作用機制示意圖	 

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

當含羞草 (*Mimosa pudica*) 被其他生物所觸碰時，其葉子會自動折合及枝條會垂下。有假說認為這種迅速折合能威懾草食動物及昆蟲，使植株變小而避免牠們取食，同時亦能展露其枝條上的尖刺。含羞草亦會在晚上及非生物因子 (abiotic factor) 如過熱或下雨的環境下表現這種運動，保護植株免受物理傷害或缺水。

含羞草的每片葉子由一群沿著中肋 (mid rib) 生長的小葉 (leaflet) 所組成，通常每根中肋會有 15 到 20 對小葉。中肋跟每片小葉的葉脈夾角呈 25°到 85°，當小葉因為觸碰而有折合反應時，這個夾角角度會下降為 15°到 25°。

含羞草的葉片透過膨壓 (turgor pressure) 的改變來達到迅速折合，膨壓是細胞中水分推擠細胞壁的壓力現象。當有大量水分推擠細胞壁時即為高膨壓，細胞會是膨脹的狀態。當水分從細胞中移走時，膨壓下降而使細胞萎軟 (flaccid)，這種水分進出細胞的運動稱為滲透作用 (osmosis)。滲透作用會在膜兩側有不同濃度溶質如鈉離子或鉀離子時出現，在這個個案中膜的例子則是細胞壁。水分會從較低濃度溶質的溶液流向較高濃度溶質的溶液中，直到兩邊達到平衡點。

當含羞草的葉片被觸碰時，兩種細胞內的鉀離子及氯離子濃度梯度會被改變，這兩種細胞為屈折細胞 (flexor) 及伸展細胞 (extensor)，位於葉枕 (pulvinus) 之中。葉枕是植物

體小葉連接中肋、中肋連接莖的「關節」位置。水分從葉枕頂部的伸展細胞移動到底部的屈折細胞中。這種現象是來自鉀離子及氯離子的濃度變化，使伸展細胞中水分流走而變得萎軟，而水分流到屈折細胞使其膨脹，這些變化令小葉折合及中肋從枝幹上垂下來。

折合的過程大約需時 4 到 5 秒，當折合完成後，小葉會在數十秒到 10 分鐘內重新展開，有人認為展開時間取決於植株受到刺激的次數及種類而有習慣上的調整。草食生物通常偏好幼嫩的葉片，當含羞草較幼嫩的葉片重覆曝露在非傷害性的刺激下，幼葉會往常完全折合，但當經過一段時間後，重新展開葉片所需的時間會縮短。相反地，較老葉片只會部分折合而維持著一致的重新展開時間。這顯示植物可以調整其行為而有最高效率的保護、能量生產（光合作用），以及能量花費（折合及重新展開）。

When the *Mimosa pudica*, commonly known as the sensitive plant, is touched by another organism, its leaves fold in upon themselves and its stems droop. It is hypothesized that this rapid folding deters herbivores and insects from eating the plant by making the plant appear smaller, while simultaneously exposing the sharp spines on the plant stems. The Mimosa also exhibits this movement during the night and when it is exposed to abiotic factors such as excessive heat and rain, protecting the plant from physical damage or desiccation.

Each leaf of the Mimosa is a collection of small leaflets growing off of a midrib, usually with around 15 to 20 pairs of leaflets along each midrib. The angle between the midrib and the vein of each leaflet ranges from 25° to 85°. When the leaflets fold in response to touch, this angle decreases to between 15° to 25°.

The leaves of the *Mimosa* achieve this rapid folding by a change in turgor pressure. Turgor pressure is the amount of water pressure in the cell that is pushing up against the cell wall. When there is a lot of water pushing against the cell wall the turgor pressure is high, and cell is rigid. When water moves out of the cell, the turgor pressure decreases and the cell becomes flaccid. The movement of water into and out of the cell is known as osmosis. Osmosis occurs when there is an unequal concentration of solutes, such as sodium or potassium ions, on two sides of a membrane, in this case the cell wall. Water will flow from the solution with the higher concentration of solutes to the lower concentration, until an equilibrium between the two sides is reached.

When the leaves of the *Mimosa* are touched, there is a change in the concentration gradient of potassium and chloride ions within two types of cells, the flexor and extensor cells, within the pulvinus of the plant. The pulvinus is the “hinge-like” area of the plant where the leaflet connects to the midrib, and the midrib connects to the stem. Water is channeled from the extensor cells, located on the top side, to the flexor cells, located on the bottom side of the pulvinus. This change is concentration of potassium and chloride ions causes water to flow out of the extensor cells, and they become flaccid, while water flows into the flexor cells, making them turgid. This causes the leaflets to fold and the midrib to droop from the stem.

The folding process takes between 4-5 seconds. After folding is complete, the unfolding of the leaflets can take anywhere from tens of seconds to up to 10 minutes. It is believed that the unfolding time is a result of behavioral adjustments that the plant makes over time in response to different kinds of stimuli. Herbivores prefer younger, tenderer leaves of plants. When younger leaves of the sensitive plant were repeatedly exposed to non-damaging stimuli, the younger leaves consistently folded completely, but over time, they decreased the time it took for them to unfold. Conversely, older leaves folded only partially while maintaining similar reopening times. This shows that the plant is able to modulate its behaviour to optimize protection, energy production (photosynthesis), and energy expenditure (folding and unfolding).

文獻引用 (REFERENCES)

「當葉片被觸碰時，小葉及羽片會快速折合及從葉柄接合處垂下…葉子在晚上、雨中及過熱時也會下垂，這種反應可能是對付草食動物、避免養分流失，或是缺水的防禦。不同葉子之間的折合反應是相連及相容的，整個結構可以從單一或多個驅動點開始折合。」(Patil 2007: 19-23)

「含羞草小葉的迅速折合是由機械性刺激所觸發，有假說指出幾個能制止草食生物的攻擊的原因：使葉子羽軸底下的尖刺能露出；葉片在昆蟲降落時閉合使其飛走；以及減少可見葉片或使變小的錯覺。」(Amador-Vargas 2014: 1446)

「在含羞草中有一個廣為人知、相似但比較快速的機制，當有外來刺激時會使葉片折合。葉枕一端的機動細胞（稱為伸展細胞）膨壓在受到刺激時下降，造成另一端的機動細胞（屈折細胞）延展，但沒有增加更多的膨壓，使細胞的硬度大大降低，結果整個關節不能維持其彎曲硬度，轉而觸發折合反應。」(Burgert and Fratzl 2009: 1543)

“When the leaf is touched, it quickly folds its leaflets and pinnae and droops downward at the petiole attachment⋯The leaves also droop at night, and when exposed to rain or excessive heat. This response may be defenses against herbivorous insects, leaching loss of nutrients, or desiccation. The folds of different leaves are interconnected and compatible with each other, and the whole structure can be folded and unfolded from a single or multiple driving points.” (Patil 2007: 19-23)

“The rapid folding of Mimosa leaflets is triggered by a mechanical stimulus and has been hypothesized to deter herbivore attack for several reasons: it exposes the spines located below the leaf raquis; the leaf moves when insects land on it causing them to move away; and it could decrease the visibility of the leaves or make them look smaller.” (Amador-Vargas 2014: 1446).

“A similar mechanism, but with rapid movement, is well known for mimosa, which folds

its leaves upon external stimuli. Motor cells on one side of the pulvinus (so-called extensor cells) lose their turgor pressure upon stimulation. As a result, the motor cells on the opposite side (flexor cells) are stretched, but without any further increase in turgor pressure, which reduces the cell stiffness dramatically. As a consequence, the entire hinge loses its bending stiffness, deflects and thereby triggers the folding movement" (Burgert and Fratzl 2009:1543).
參考文獻清單與連結 (REFERENCE LIST)
Patil, H.S. and S. Vaijapurkar. (2007). Study of the geometry and folding pattern of leaves of *Mimosa pudica*. *Journal of Bionic Engineering* 4: 19-23. (https://link.springer.com/article/10.1016/S1672-6529(07)60008-0) Amador-Vargas, S., M. Dominguez, G. León, B. Maldonado, J. Murillo, and G.L. Vides. (2014). Leaf-folding response of a sensitive plant shows context-dependent behavioral plasticity. *Plant Ecology*: 1445-1454. (https://link.springer.com/article/10.1007/s11258-014-0401-4) Burgert, I. and P. Fratzl. (2009). Actuation systems in plants as prototypes for bioinspired devices. *Phil. Trans. R. Soc. A* 367: 1541-1557. (https://doi.org/10.1098/rsta.2009.0003) Volkov A.G., J.C. Foster, T. A. Ashby, R. K. Walker, J. A. Johnson J.A., and V. S. Markin. (2010). *Mimosa pudica*: Electrical and mechanical stimulation of plant movements. *Plant, Cell and Environment* 33: 163-173. (https://doi.org/10.1111/j.1365-3040.2009.02066.x)
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/Mimosa_pudica
撰寫/翻譯/編修者與日期
譚國鋈翻譯 (2020/04/06)；林煜軒翻譯 (2020/04/18)；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-fold-in-response-to-touch/