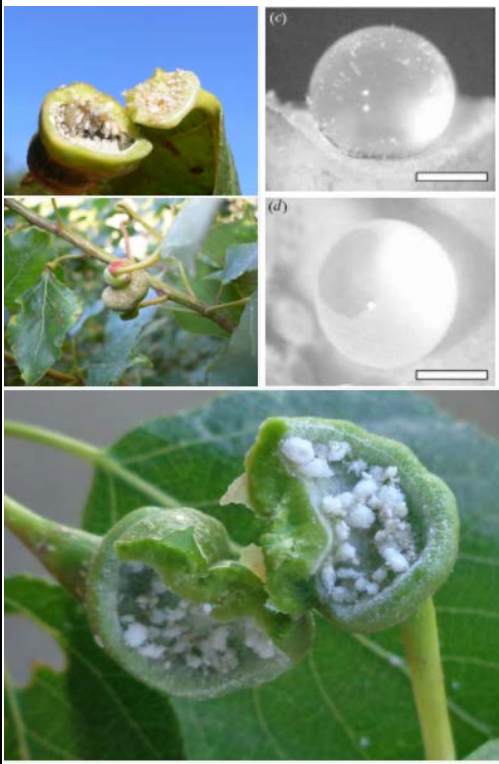


# 生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	粉狀蠟讓廢棄物有效地被移除 (Powdery wax allows for efficient waste removal)
生物系統 LIVING SYSTEM	楊樹螺旋癭蚜 <i>Pemphigus spyrothecae</i> (Poplar spiral gall aphid)
功能類別 FUNCTIONS	#分配液體 #保護免受過多液體危害 #Distribute liquids #Protect from excess liquids
作用機制標題	蚜蟲分泌的粉狀蠟透過將黏性蜜露包覆，產生非黏性的「液態水晶球」，使蜜露廢棄物變得容易處理 (Powdery wax secreted by aphids makes sticky honeydew waste manageable by coating it and creating non-stick “liquid marbles.”)
生物系統/作用機制 示意圖	
作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)	
<p>癭蚜 (Gall-dwelling aphids) 是一種可能讓其家裡變得黏答答的昆蟲。牠們居住在植物的蟲癭 (galls) 裡，蟲癭是植物枝條或葉片對蚜蟲引起的化學訊號反應而形成的膨大及中空增長產物 (outgrowth)。蟲癭提供蚜蟲食物及保護，但居住在密閉空間所帶來的獨特挑戰，是牠們居住在外的親戚們所無法經歷到的。</p> <p>蚜蟲從寄主植物吸食富含糖分的汁液，並排泄出黏稠的含糖液體，稱為蜜露 (honeydew)。他們必須將這些黏性的廢棄產物丟棄，否則將面臨被其淹沒的風險。蜜露在小尺度下由表面張力主導，變得特別難以處理。如果這些黏性物質散開的話，可能會淹死蚜蟲，或提供病原菌生長的理想環境。居住在外的蚜蟲可以將蜜露直接甩掉或是移到其它</p>	

地方，但癭蚜則需要另一種策略來處理牠們的廢棄物。

楊樹螺旋癭蚜 (poplar spiral gall aphid, *Pemphigus spyrothecae*) 是一種社會性蚜蟲，成群居住在黑楊樹 (black poplar) 的螺旋狀蟲癭中。這種蚜蟲會由位於腹部外面的特殊細胞分泌疏水性 (防水) 粉狀蠟質。這種蠟質最初會先分泌成細小長絲線並排列成直徑約 10-20  $\mu\text{m}$  的絞線，然後再裂解為微細絲狀粉末。這種物質尚未被完全確認，但是由類似蠟燭蠟質的混合化學物質組成。這種粉末覆蓋於蟲癭內壁，因其物理構造及化學組成而形成一個疏水性的微結構 (microtextured) 表面。當蚜蟲排出蜜露時，蜜露液滴 (droplets) 會被同時產生的蠟質絲線包覆，隨著液滴在蟲癭中來回移動，會被更多的粉狀蠟質包覆。被蠟質包裹的液滴不會黏附在蚜蟲蟲體上或蟲癭壁上，蚜蟲可以很容易地就將液滴滾動到蟲癭開口丟棄。

被蠟質包覆的蜜露液滴所形成的球狀液體稱為「液態水晶球」，很容易在光滑表面上來回滾動而不會弄濕。此外，因為蜜露液滴之間維持分離狀態，無法連結成為更大的液滴，因此能更快速滾動並以更少時間移動。綜合所述，蚜蟲群落製造了一個非黏性的微環境 (microhabitat)，以及既有效又具高效率的廢物棄置系統。

Gall-dwelling aphids are insects that make their home in a potentially sticky situation. They live inside plant galls, which are enlarged and hollow outgrowths on stems or leaves that form in response to chemical cues from the aphids. The gall provides both food and protection for the insect, but living in an enclosed space presents unique challenges that their free-living relatives don't experience.

Aphids feed on sugar-rich sap from their host plant and excrete a viscous, sugary liquid called honeydew. They must dispose of this sticky waste product or risk becoming covered in it. Honeydew is particularly hard to handle at small length scales, where surface tension dominates over gravitational forces. If the sticky substance spreads, it can drown the aphid or present an ideal environment for the growth of harmful pathogens. Free-living aphids can fling the honeydew away or move to another location, but gall-dwelling aphids have to use another strategy to manage their waste.

The poplar spiral gall aphid (*Pemphigus spyrothecae*) is one species of social aphid that lives in colonies in spiral-shaped galls on black poplar. This aphid secretes a powdery, hydrophobic (water-repelling) wax from special cells on the outer surface of its abdomen. The wax is initially secreted as small threads that arrange into skeins about 10-20  $\mu\text{m}$  in diameter, which then break down into a fine filamentous powder. It has yet to be fully characterized, but comprises a mixture of compounds similar to candle wax. This powder coats the gall's interior walls, creating a microtextured surface that, due to its physical structure and chemical composition, is hydrophobic. When an aphid excretes honeydew, the droplet is coated in wax strands it produces at the same time. The droplets are then covered with additional powdery wax

as they get moved around inside the gall. Wax-coated droplets don't stick to the aphid or gall walls, and can be disposed of simply by rolling them out of the gall opening.

The wax-covered honeydew droplets form spheres of liquid called "liquid marbles" that can easily roll around on a smooth surface and not wet it. In addition, because the honeydew is kept in small discrete droplets and not allowed to coalesce into bigger drops, the marbles roll faster and take less time to move. Together, the aphid colony creates a non-stick microhabitat with an effective and efficient waste-removal system.

#### 文獻引用 (REFERENCES)

「利用蠟質分泌物來有效地包覆及運送牠們自己的排泄物，蚜蟲在 2 億年前就能解決這個問題了…分泌出來的粉狀蠟質具有三個不同的作用：(i) 它是疏水性，(ii) 它以不太緊實的針狀蠟質在蟲癭內部形成了一個微觀的粗糙表面，使蟲癭變得超疏水，以及 (iii) 它包覆蜜露液滴並將其變成液態水晶球，使其能夠迅速並有效率地移動。」 (Pike et al. 2002: 1211)

「癭蚜的蠟質是一種尚未被描述的混合物，包括了長碳鏈的酯類、醇類、醛類以及脂肪酸 (Brown 1975)，是由特化的表皮細胞所產生，這種細胞在腹部背板 (abdominal tergites) 上特別多 (Smith 1999)。」 (Pike et al. 2002: 1211)

“Using secreted wax to efficiently parcel and transport their own excrement, aphids were able to solve this problem 200 Myr ago...The secreted powdery wax has three distinct roles: (i) it is hydrophobic, (ii) it creates a microscopically rough inner gall surface made of weakly compacted wax needles making the gall ultra-hydrophobic, and (iii) it coats the honeydew droplets converting them into liquid marbles, that can be rapidly and efficiently moved.” (Pike et al. 2002: 1211)

“The wax of galling aphids, which is an, as yet, undescribed mixture of long-chained esters, alcohols, aldehydes and fatty acids (Brown 1975), is produced by specialized epidermal cells, which are particularly numerous on the abdominal tergites (Smith 1999).” (Pike et al. 2002: 1211)

#### 參考文獻清單與連結 (REFERENCE LIST)

Pike, N., D. Richard, W. Foster and L. Mahadevan. (2002). How aphids lose their marbles. *Proc. R. Soc. Lond. B* 269: 1211-1215. (<https://doi.org/10.1098/rspb.2002.1999>)

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#### 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/pemphigus\\_spyrothecae](https://en.wikipedia.org/wiki/pemphigus_spyrothecae)  
[https://www.onezoom.org/life/@pemphigus\\_spyrothecae](https://www.onezoom.org/life/@pemphigus_spyrothecae)

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<https://asknature.org/strategy/powdery-wax-allows-for-efficient-waste-removal/>