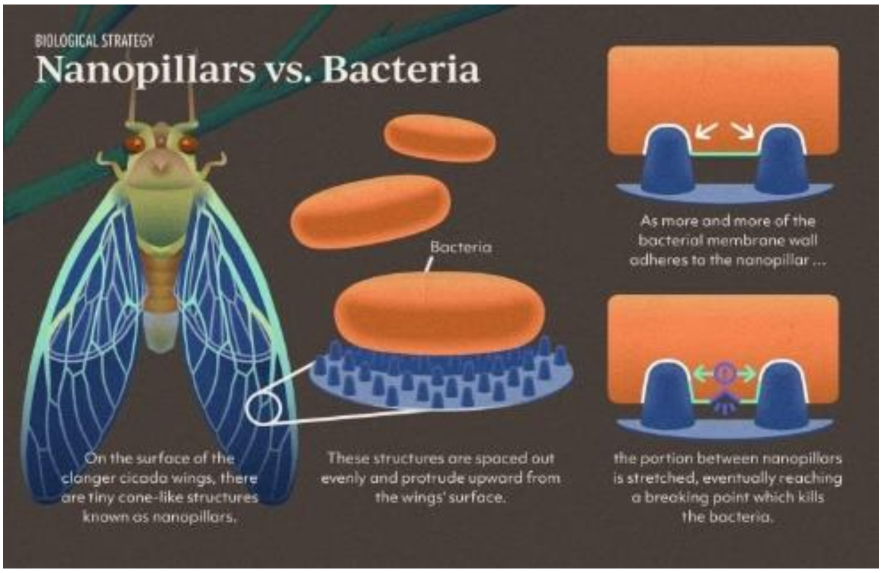
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	蟬的翅膀如何殺死細菌 How Cicada Wings Kill Bacteria
生物系統 LIVING SYSTEM	蟬(Cicadidae)
功能類別 FUNCTIONS	#免於其他動物危害 #Protect From Animals #免於微生物危害 #Protect From Microbes #防止過多的液體 #Protect From Excess Liquids #防止污垢或固體黏附 #Protect From Dirt/solids
作用機制標題	蟬翼的奈米柱錐體與細菌膜結合，將錐體之間的部分拉伸到破裂點 Nanopillar cones covering cicada wings bond with bacterial membranes, stretching the portion between the cones to the point of rupturing.

生物系統/作用機制示意圖
(確認版權、註明出處；畫質)



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

2012 年，科學家觀察到蟬的翅膀可以殺死幾種有害細菌，但尚不清楚它是如何工作的。是翅膀上塗了抗生素嗎？還是因為有快速的免疫反應？科學家們使用強大的顯微鏡對翅翼進行了極其近距離的觀察，觀察到稱為奈米柱的微小錐形凸起以六邊形排列覆蓋在蟬翼的兩面。

他們假設實際上是錐體本身殺死了細菌，他們用“the Midas touch”來證明這一點。他們在蟬翼上塗上一層超薄的金，以抑制任何生化反應。當暴露在鍍金的蟬翼下時，細菌仍然死亡，證明沒有化學殺手而是由獨特的奈米柱結構將細菌殺死的。

要了解錐體如何殺死細菌，可以將細菌細胞想像成水球。由於直徑比錐體之間的距離大幾倍，一個細胞位於許多奈米柱上。很容易將這些奈米柱想像成一個能簡單爆破水球的釘床。然而，在 2013 年，同一組科學家開發了一個模型，說明了不一樣的結果。

考慮兩個錐體之間發生的事情。水球會在兩個錐體周圍下垂，而中間的膜會像橋樑一樣延伸穿過間隙。然而，在奈米尺度上，細胞膜不只是下垂——它被物理地吸引到奈米柱的表面，粘在它們上面。隨著膜在兩個錐體上進一步向下粘附，跨越在錐體之間的膜持續伸展，最終像橡皮筋一樣折斷。

現在考慮細胞接觸到的每一對錐體之間的破裂，細胞質內液會從破碎的膜中溢出導致細菌死亡。

這種機制僅對革蘭氏陰性細菌——那種容易引起感染的細菌類型有效。它無法對像革蘭氏陽性菌般的有益細菌起作用。與柔韌的水球不同，益菌更像是有堅硬膜的硬殼蛋。因為將它們的膜吸引到錐體表面的物理力不足以克服它們的剛度，免於受到奈米柱破裂效應，而得到保護。

In 2012, scientists observed that cicada wings kill several types of harmful bacteria, but it wasn't immediately clear how it worked. Were the wings coated in an antibiotic? Was there a rapid immune response? Using powerful microscopes to get an extremely close view of the wings, the scientists observed tiny cone-shaped bumps called nanopillars covering both sides in a hexagonal arrangement.

They hypothesized it was actually the cones themselves that were killing the bacteria, and they used "the Midas touch" to prove it. They coated cicada wings with a super thin layer of gold to inhibit any biochemical reactions. When exposed to the gold-plated cicada wings, bacteria still died, proving there was no chemical killer—the unique nanopillar structures were directly responsible.

To understand how the cones kill bacteria, think of a bacterial cell like a water balloon. With a diameter several times larger than the distance between cones, one cell rests on many nanopillars. It's tempting to think of these nanopillars as a bed of nails that simply pop the water balloon. However, in 2013, the same group of scientists developed a model that told a different story

Consider what's happening between just two of the cones. The water balloon would sag around both cones, while the membrane between would extend across the gap like a bridge. However, at the nanoscale, the cell membrane isn't just sagging—it is physically attracted to the nanopillars' surfaces, essentially sticking onto them. As the membrane adheres farther down on both cones, the membrane spanning between them stretches, eventually snapping like a rubber band.

Now consider ruptures ripping between every pair of cones the cell touches—cytoplasmic guts spilling out of a shredded membrane spells bacterial death.

This mechanism is only effective on gram-negative bacteria—the type of bacteria that tends to cause infections. It doesn't work on gram-positive bacteria, which tend to be beneficial "probiotic" bacteria. Instead of pliable water balloons, beneficial bacteria are more like hard-shelled eggs with rigid membranes. They are protected from the nanopillars' rupturing effect because the physical forces that attract their membranes to the cone surfaces aren't strong enough to overcome their stiffness.

文獻引用 (REFERENCES)
「Clanger 蟬（*Psaltoda claripennis*）翅膀表面的奈米圖樣代表了一類新的生物材料的第一個例子，它可以僅根據其物理表面結構在接觸時殺死細菌。翅翼為開發具有更高抗細菌污染和感染能力的新型功能表面提供了模型。我們提出了細菌細胞和蟬翼表面結構之間相互作用的生物物理模型，並表明機械性能，特別是細胞剛度，是確定細菌對翼表面殺菌性質的抗性/敏感性的關鍵因素。我們通過對細胞進行微波照射來降低表面抗性菌株的剛度，使它們容易受到翼效應的影響，而由此實驗確認這一點。我們的研究結果證明了將蟬翼奈米圖案納入抗菌奈米材料設計的潛在好處。」 "The nanopattern on the surface of Clanger cicada (Psaltoda claripennis) wings represents the first example of a new class of biomaterials that can kill bacteria on contact based solely on their physical surface structure. The wings provide a model for the development of novel functional surfaces that possess an increased resistance to bacterial contamination and infection. We propose a biophysical model of the interactions between bacterial cells and cicada wing surface structures, and show that mechanical properties, in particular cell rigidity, are key factors in determining bacterial resistance/sensitivity to the bactericidal nature of the wing surface. We confirmed this experimentally by decreasing the rigidity of surface-resistant strains through microwave irradiation of the cells, which renders them susceptible to the wing effects. Our findings demonstrate the potential benefits of incorporating cicada wing nanopatterns into the design of antibacterial nanomaterials." (Pogodin et al. 2013:835)
參考文獻清單與連結 (REFERENCE LIST) **Harvard 或 APA 格式**
Biophysical Model of Bacterial Cell Interactions with Nanopatterned Cicada Wing Surfaces
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