生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	卵殼防止微生物污損 (Egg shells prevent microbial fouling)
生物系統 LIVING SYSTEM	軌道岩螺 *Dicathais orbita* (White rock shell)
功能類別 FUNCTIONS	#保護免受微生物危害 #保護免受植物危害 #Protect from microbes #Protect from plants
作用機制標題	藉由一系列物理、機械和潛在性化學防禦，軌道岩螺的卵可避免微生物攻擊 (The eggs of the white rock shell snail ward off microbial attack with a series of physical, mechanical, and potentially chemical defenses)
生物系統/作用機制示意圖	

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

多細胞的海洋生物，面臨著微生物經常性的攻擊以及其他小型生物體在其身上尋找可附著的構造。無論這些生物為真菌、藻類、能形成生物膜 (biofilm) 的病原體，或其他生活形，都會導致該較大生物體表的生物污損，這可能造成嚴重的併發症。軌道岩螺 (*Dicathais orbita*) 之類的海螺，產下的卵具有特別防污損的適應。在發育早期，卵囊 (egg capsule) 外覆蓋著相隔一至五微米的同型稜脊。不同於其他海洋生物卵表面所觀察到的不規則奈米紋路，稜脊則是規律間隔開來，且彼此充分接近，相信可減少污損生物的潛在接觸點，使其更難以附著及定著。然而一段時間後，細菌仍會附著並深入卵囊表面。為了對抗此無可避免的生物污損，後期卵會完全脫去外殼，露出下方的新層。在外層脫落後，親脂性 (lipophilic) 的液滴會從卵表面的孔被擠出，且似乎有某種殺菌的作用。在卵發育成熟孵化前，這一系列防污損的步驟，可避免生物膜和寄生性微生物傷害牠。

Multicellular marine organisms face a constant onslaught of microbes and other small organisms seeking structures upon which to adhere. Whether they are fungi, algae, biofilm-forming pathogens, or other lifeforms, they lead to biofouling on the surface of the larger organism that can cause serious complications. The white rock shell (*Dicathais orbita*), a type of sea snail, produces eggs with remarkable anti-fouling adaptations. In early stages of development, the exterior of the egg capsule is covered in uniform ridges separated by 1 - 5 microns. Unlike irregular nano-textures observed on the surfaces of eggs from other marine organisms, ridges that are regularly-spaced sufficiently close together are believed to minimize potential contact points for fouling organisms, making it harder for them to attach and settle. Over time, however, bacteria will attach and take root on the surface of the egg capsules. To combat this inevitable biofouling, later stage eggs shed their exterior crust completely to reveal a fresh layer underneath. After this shedding of the outer layer, lipophilic (lipid-loving) droplets are extruded from pores on the egg surface and seem to exert some kind of antiseptic effect. This series of anti-fouling steps keeps biofilms and parasitic microbes from harming the egg until it is developed enough to hatch.

文獻引用 (REFERENCES)

「軌道岩螺（新腹足目 Neogastropoda）的早期卵囊，是相對地不會有表面微生物的。擔輪幼體期的卵囊，具有規則稜脊的微紋路，但當卵囊成熟時，可觀察到外壁會脫落，接著擠出不明液滴，然後相關細菌會累積在卵囊表面…軌道岩螺卵囊上有明顯較少的聚落形成…軌道岩螺似乎使用一種由物理、機械及可能化學防禦機制的組合，來減少卵囊的污損。」(Lim et al. 2007: 275)

「固著性無脊椎動物及藻類，會曝露在潛在有害微生物的持續攻擊之中。這些包括了能形成生物膜的細菌和單細胞矽藻，會在海洋環境的任何表面快速的定著、附著及形成聚落。微生物的生物膜形成，促使了藻類孢子、原生生物、藤壺腺介幼體及海洋真菌的附著，接著是其它海洋無脊椎動物幼體及大型藻類的定著…嚴重的表面污損可以導致有毒廢物的累積、氧氣及養分的可用性減少，以及增加拖曳負擔，這可能使固著生物在強流水中脫離底棲基質…卵囊似乎是有著高度彈性的多層生物材料…卵囊在海洋環境中能停留達數個月，所以也易受到表面污損。儘管如此，之前研究指出這些卵囊能維持無菌及顯著地無表面的大型生物污損…表面的組成及微紋路可影響生物污損的速率…對污損生物而言，同質性表面的可用空間是有限的，能夠阻礙其附著…比起其他類群的凝膠狀卵塊，包括軌道岩螺的新腹足目之卵囊，則有明顯更少的污損。」(Lim et al. 2007: 276)

「軌道岩螺在最外表面之細微表層的 (microtopographical) 結構上，還具有一層薄殼；此表面幾乎沒有任何細菌及藻類。當卵囊成熟後（1-3 週大），外殼開始崩解，露出細微表層的特徵。這殼層有著 1-5μm 間距的規則同質性稜脊 (ridge)…在第三週時，細菌的密度增加，其他例如絲狀藻的污損生物出現，形成一個混合的生物膜群聚。在發育後期（4 週以上的老面盤幼體），受污損的外壁構造開始與卵囊分離並掉落，留下無任何紋路的裸露卵囊…在大部分外壁分離後，在成熟的卵囊表面，會出現 8-20μm 的不明液滴。這些液滴為單獨的或成團的，伴隨著附著的細菌。」(Lim et al. 2007: 279)

「當外層卵囊分解後，液滴似乎是由壁上的孔洞分泌出來。這些液滴明顯地不是細胞組成的…它們似乎也不是膜結合的 (membrane-bound)…這顯示它們是疏水性的…它們可能含有親脂性化合物，例如吲哚二聚物泰爾維爾定 (tyriverdin)，前人研究這是一種有效的

抑菌劑，來自軌道岩螺卵囊中的萃取物。液滴會與細菌聚集在卵囊表面且…經常伴隨著死亡細菌，顯示它們可能具有抗微生物性質…所有這些防禦機制的組合用來防禦其卵囊，包括不適合細菌附著的表面紋路，然後是外層脫落以移除現存的微生物聚落，還有聚集不明化學成分液滴的滲出物，可能用以干擾細菌在卵囊表面的生長。」(Lim et al. 2007: 285)

"[E]arly stage egg capsules of *Dicathais orbita* (Neogastropoda) are relatively free of surface microorganisms. Egg capsules during the trocophore stage had a regularly ridged microtexture, but as capsules matured, shedding of the outer wall was observed, followed by the extrusion of unidentified droplets, which then accumulated on the capsule surface in association with bacteria...colonization was significantly less on *D. orbita* egg capsules... *D. orbita* appears to use a combination of physical, mechanical and possibly chemical defense mechanisms to reduce fouling on their egg capsules." (Lim et al. 2007: 275)

"[S]essile invertebrates and algae are exposed to a constant onslaught of potentially detrimental microbes. These include biofilm-forming bacteria along with single-cell diatoms that rapidly settle, attach and form colonies on any surface placed in the marine environment. The formation of a microbial biofilm promotes the attachment of algal spores, protozoa, barnacle cyprids and marine fungi, followed by the settlement of other marine invertebrate larvae and macro- algae...Heavy surface fouling could lead to the accumulation of toxic wastes, a reduction in oxygen and nutrient availability and increased drag, which can cause sessile organisms to become dislodged from benthic substrata in strong currents...egg capsules appear to be highly resilient multilaminate biomaterials...egg capsules can remain in the marine environment for several months, and thus would also be vulnerable to surface fouling. Nevertheless, previous studies indicate that these egg capsules remain axenic and remarkably free of surface macrofouling...surface composition and microtexture can influence the rate of biofouling...homogeneous surfaces are capable of deterring attachment by limiting space available for fouling organisms...egg capsules of neogastropods, including *D. orbita*, were significantly less fouled than a range of gelatinous egg masses." (Lim et al. 2007: 276)

"*Dicathais orbita* possessed a thin layer of crust over a microtopographical structure on the outer-most surface. The surface was almost free from any bacteria and algae. As the egg capsules matured (1 to 3 wk of age), the crust began to breakdown, exposing the microtopographical features. This layer has regular homogeneous ridges separated by 1 to 5 μm...during the third week, densities of these bacteria increased and other fouling organisms such as filamentous algae were observed, forming a mixed biofilm community. In the later stages of development (> 4 wk old veligers), the fouled outer wall structure began to dissociate and shed from the capsule, leaving behind a naked capsule without any texture...Unidentified droplets ranging from 8 to 20 μm appeared on the surface of mature egg capsules after the majority of the outer wall dissociated. These droplets were either solitary or clumped in association with attached bacteria." (Lim et al. 2007: 279)

"[D]roplets appeared to be secreted through pores in the wall as the outer capsule degrades. These droplets were clearly not cellular...They also did not appear to be membrane-bound...This suggests that they were hydrophobic...they may contain lipophilic compounds such as the indole dimer tyriverdin, which is a potent bacteriostatic agent previously reported from extracts of D. orbita egg capsules. The droplets were observed to aggregate with bacteria on the capsule surface and...were frequently associated with dead bacteria, suggesting that they may have antimicrobial properties...a combination of all these defense mechanisms to defend its egg capsules, including a surface texture not suitable for bacterial attachment, followed by shedding of the outer layer to remove existing microbial colonization and then exudation of unidentified chemical droplets that aggregate and possibly interfere with bacterial growth on the capsules' surface." (Lim et al. 2007: 285)

參考文獻清單與連結 (REFERENCE LIST)

Lim, N. S. H., K. J. Everuss, A. E. Goodman, and K. Benkendorff. (2007). Comparison of surface microfouling and bacterial attachment on the egg capsules of two molluscan species representing Cephalopoda and Neogastropoda. *Aquat. Microb. Ecol.* 47: 275-287. (http://www.int-res.com/abstracts/ame/v47/n3/p275-287/)

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/Dicathais

撰寫/翻譯/編修者與日期

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AskNature 原文連結

https://asknature.org/strategy/egg-shells-prevent-microbial-fouling/