# 生物策略格式

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| **類別** | 生物策略 (Strategy) |
| **生物策略**<br>STRATEGY | 多重成分黏膠有助於水下附著<br>(Multiple component glue aids underwater adhesion) |
| **生物系統**<br>LIVING SYSTEM | 藤壺 *Megabalanus*<br>(Barnacle) |
| **功能類別**<br>FUNCTIONS | #永久性附著 #化學性組成聚合物 #改變材料特性<br>#Attach permanently #Chemically assemble polymers<br>#Modify material characteristics |
| **作用機制標題** | 由於四種接合蛋白的共同作用，藤壺產生之蛋白質的接合物質，具有強黏性的水下附著力<br>(The proteinaceous cement substance produced by barnacles allows tenacious underwater attachment due to cooperation of four cement proteins.) |
| **生物系統/作用機制示意圖** |  |

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

**文獻引用** (REFERENCES)

藤壺有著強黏性的水底表面附著能力，這有賴於一種由蛋白質的接合物質。在過往的研究中已經發現有三種主要的蛋白質，而本研究發現了第四種。推測在水下附著力中，每種接合蛋白都擔當不同且特定的角色，透過這些接合蛋白的合作而獲得牢固的藤壺附著力。理解每種接合蛋白的特定角色，將有助於提供較深入的了解藤壺之定著 (settlement) 及其合成聚合物之仿製，包括其水下附著力。（仿生協會提供）

對存活重要的酵素及生物化學機制，都是在嚴苛的天擇壓力下形成的，且在演化過程中是相當保守的。我們把這個演化概念應用到藤壺的接合聚合作用上，這是一個在藤壺適應性上的關鍵過程，牽涉到蛋白質的聚集作用及交叉鏈接。目前對接合聚合作用的生物化學機制仍有許多的未知。我們假設這種過程在生物化學上與凝血作用類似，這也是一個基於蛋白質聚集作用及交叉鏈接的關鍵生理反應。就像脊椎動物與無脊椎動物的凝血關鍵元素一樣，由藤壺的接合聚合作用中，顯示有酵素及結構前驅物的蛋白水解活化、轉麩醯胺酶的交叉鏈接及纖維蛋白的聚集之參與。結構蛋白的蛋白水解活化，可使其它蛋白質及表面的鍵結互動的潛能最大化。轉麩醯胺酶的交叉鏈接，則加強了接合的完整性。令人訝異地，以串聯式質譜法及/或西方墨點法，在藤壺的接合中，確認出與牛胰蛋白酶 (bovine trypsin) 和人類轉麩醯胺酶 (transglutaminase) 同源的抗原表位 (epitope) 以及基因序列。與凝血作用類似，蛋白水解活化中所產生的胜肽，具有訊號分子的功能，能將分子層面的事件（蛋白質聚集）連結至行為的反應（藤壺幼體定著）。我們的研究結果引起了對於高度保守蛋白質聚合機制的關注，並解開了此由來已久的生物化學謎題。我們提議藤壺接合聚合作用是一種傷口癒合的特化形式。藤壺接合與凝血之間，都具有相同的聚合作用機制，可能會是許多海洋動物黏膠的研究主題。(Dickinson et al. 2009: 3499)

“Barnacles have the capability for tenacious underwater adhesion to the surfaces by a proteinaceous cement substance. Three major proteins had been identified in a previous study and this study adds a fourth. It is suggested that each cement protein fulfills a distinct and specific role in underwater adhesion, and that firm barnacle adhesion is achieved cooperatively by these cement proteins. Understanding the specific role of each cement protein will help to provide a better understanding of barnacle settlement and of synthetic polymer mimics, including underwater adhesives.” (Courtesy of the Biomimicry Guild)

“Enzymes and biochemical mechanisms essential to survival are under extreme selective pressure and are highly conserved through evolutionary time. We applied this evolutionary concept to barnacle cement polymerization, a process critical to barnacle fitness that involves aggregation and cross-linking of proteins. The biochemical mechanisms of cement polymerization remain largely unknown. We hypothesized that this process is biochemically similar to blood clotting, a critical physiological response that is also based on aggregation and cross-linking of proteins. Like key elements of vertebrate and invertebrate blood clotting, barnacle cement polymerization was shown to involve proteolytic activation of enzymes and structural precursors, transglutaminase cross-linking and assembly of fibrous proteins. Proteolytic activation of structural proteins maximizes the potential for bonding interactions with other proteins and with the surface. Transglutaminase cross-linking reinforces cement integrity. Remarkably, epitopes and sequences homologous to bovine trypsin and human transglutaminase were identified in barnacle cement with tandem mass spectrometry and/or western blotting. Akin to blood clotting, the peptides generated during proteolytic activation functioned as signal molecules, linking a molecular level event (protein aggregation) to a behavioral response (barnacle larval settlement). Our results draw attention to a highly conserved protein polymerization mechanism and shed light on a long-standing biochemical puzzle. We suggest that barnacle cement polymerization is a specialized form of wound healing. The polymerization mechanism common between barnacle cement and blood may be a theme for many marine animal glues.” (Dickinson et al. 2009: 3499)

## 參考文獻清單與連結 (REFERENCE LIST)

Kamino, K. (2001). Novel barnacle underwater adhesive protein is a charged amino acid-rich protein constituted by a Cys-rich repetitive sequence. *Biochem. J.* 356: 503-507. (https://doi.org/10.1042/bj3560503)

Dickinson, G. H., I. E. Vega, K. J. Wahl, B. Orihuela, V. Beyley, E. N. Rodriguez, R. K. Everett, J. Bonaventura, and D. Rittschof. (2009). Barnacle cement: a polymerization model based on evolutionary concepts. *Journal of Experimental Biology* 212: 3499-3510.

(https://jeb.biologists.org/content/212/21/3499)

Knight, K. (2009). Barnacle glue cures like blood clots. *Journal of Experimental Biology* 212: i. (https://jeb.biologists.org/content/212/21/i.1)

| **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/megabalanus |
| **文章貢獻/編修者與日期:** |
| 李享翻譯 (2020/04/25)；譚國鎣翻譯/編修 (2020/05/27)；紀凱容編修 (2020/11/25)；施習德編修 (2020/12/27) |
| **AskNature 原文連結** |
| https://asknature.org/strategy/multiple-component-glue-aids-underwater-adhesion/ |