# 生物策略表

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| **類別** | 生物策略 (Strategy) |
| **生物策略**<br>STRATEGY | 獨特的抗凍劑抵擋極端寒冷<br>(Unique antifreeze protects from extreme cold) |
| **生物系統**<br>LIVING SYSTEM | 阿拉斯加擬步行蟲 *Upis ceramboides*<br>(Darkling beetles) |
| **功能類別**<br>FUNCTIONS | #保護免受冰危害 #保護免受溫度危害<br>#Protect from ice #Protect from temperature |
| **作用機制標題** | 由阿拉斯加擬步行蟲產生的糖基聚合物透過附著在細胞膜上來防止細胞內成分在極冷的溫度下結凍<br>(A sugar-based polymer produced by an Alaskan darkling beetle keeps cell contents from freezing in extreme cold temperatures by attaching to the cell membrane.) |
| **生物系統/作用機制示意圖** |  |

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

在仲冬之際，阿拉斯加擬步行蟲 (Alaskan darkling beetle, *Upis ceramboides*) 的居住處溫度可降至華氏零下 76 度（攝氏零下 60 度），但這種甲蟲仍能防止其體內液態的細胞成分免於災難性的凍結。有別於其他使用蛋白質作為抗凍劑的極端冷棲生物 (cold-dwelling organism)，包括植物、動物、魚類、真菌和細菌，這種阿拉斯加擬步行蟲產生一種稱為木甘聚醣 (xylomannan) 的糖基抗凍劑（由木糖 xylose 和甘露糖 mannose 交替連接而成的聚合物）。在某些油性化合物的幫助下，木甘聚醣附著在細胞膜外，其功能可能是防止細胞外的冰晶進入細胞內、防止冰晶在細胞內形成、以及促進膜的穩定性。

In midwinter, temperatures at the home of an Alaskan darkling beetle (*Upis ceramboides*) can drop to -76 degrees F (-60 degrees C), yet this beetle species is able to keep its internal, watery cell contents from catastrophically freezing. Unlike most other extreme cold-dwelling organisms, including plants, animals, fish, fungi, and bacteria that use proteins as antifreeze agents, this Alaskan beetle produces a sugar-based antifreeze called xylomannan (a polymer of alternating xylose and mannose sugars). With the help of certain oily compounds, xylomannan attaches to the outer cell membrane where it likely functions to prevent the entry of extracellular ice into the cell, keep ice from forming inside the cell, and promote membrane stability.

**文獻引用** (REFERENCES)

「在極北方的氣候下，例如阿拉斯加內陸地區，仲冬的氣溫可降至華氏零下 60 度，積雪和零度以下的溫度甚至可以持續到五月。在這些極端溫度下，大多數昆蟲都是凍結休眠蟲 (bugsicles)。舉例來說，阿拉斯加擬步行蟲會在華氏零下 19 度左右凍結。但驚人的是，牠可以在低至華氏零下 100 度的溫度下存活…來自聖母大學 (University of Notre Dame) 和阿拉斯加費爾班克斯大學 (University of Alaska-Fairbanks) 的研究團隊最近從阿拉斯加擬步行蟲中發現了一種新型抗凍劑。有別於其他甲蟲、雪蚤 (snow flea) 和飛蛾的蛋白質抗凍劑，阿拉斯加擬步行蟲的抗凍劑是一種叫做木甘聚糖的複合醣類，它可以有效地抑制冰晶形成，與活性最好的昆蟲蛋白質抗凍劑一樣有效。」(Carroll 2010)。

「儘管先前描述的所有產生熱遲滯 (thermal hysteresis, TH) 的生物分子都是蛋白質，但大多數熱遲滯因子 (thermal hysteresis factor, THF) 的結構尚未被描述…我們從阿拉斯加擬步行蟲 (*Upis ceramboides*) 中分離出一種高度活性的 THF…該 THF 中幾乎不含蛋白質，但它在濃度為 5 mg/ml 時可以產生 3.7 ± 0.3˚C 的熱遲滯，與最具活性的昆蟲抗凍蛋白相當…這種抗凍劑含有甘露糖和木糖 (β-mannopyranosyl-(1->4) β-xylopyranose) 主鏈以及一種脂肪酸成分，儘管脂質可能不與與醣類以共價鍵連接…這種木甘聚糖是第一種從耐凍 (freeze-tolerant) 動物中分離出來的熱遲滯產生型抗凍劑 (TH-producing antifreeze)，同時也是只含少量甚至無蛋白質的全新類別高活性熱遲滯因子。我們調查了來自阿拉斯加州內陸的擬步行蟲，因為牠在仲冬時可以忍受冷凍到攝氏零下 60 度。」(Walters et al. 2009: 20210)。

「…脂肪酸成分可能將 THF 錨定在細胞膜上。然而，脂質與醣的連接模式尚未被確立，脂質仍有可能不透過共價鍵方式連接醣類組成分。」 (Walters et al. 2009: 20211)。

「THFs 與蜈蚣的細胞膜的關連也出現在阿拉斯加擬步行蟲身上，這些觀察顯示這些分子可能會阻止細胞外的冰晶擴散到細胞質中（細胞內凍結普遍被認為是致命的）和/或在低溫下穩定原生質膜 (plasma membrane)。這項研究顯示從阿拉斯加擬步行蟲中分離出的（脂質）木甘聚糖是一種高度活性的 THF，其結構不同於迄今報導過的所有已知 AFPs 和抗凍醣蛋白 (antifreeze glycoprotein, AFGP)。與已知在質量上包含將近 39％胜肽 (peptide) 的 AFGPs 不同，從阿拉斯加擬步行蟲中分離出的 THF 則幾乎不含蛋白質。此外，β-Manp-(1->4) β-Xylp 主鏈與魚類 AFGPs 的醣類成分無關…這種木甘聚糖抗凍劑可透過防止細胞外冰的再結晶、防止細胞內凍結、和/或在低溫下穩定細胞膜來提升細胞的耐結凍性。」(Walters et al.，2009: 20214)。

"In the most northern climates, like the interior of Alaska, midwinter temperatures fall as low as minus 60 degrees Fahrenheit, and snow cover and subzero temperatures can last until May. At these extreme temperatures, most insects are bugsicles. The Alaskan *Upis* beetle, for example, freezes at around minus 19 degrees. But, remarkably, it can survive exposure to temperatures as low as about minus 100 degrees…a new kind of antifreeze was recently discovered in the *Upis* beetle by a team of researchers from the University of Notre Dame and the University of Alaska-Fairbanks. Unlike the protein antifreezes of other beetles, snow fleas and moths, the *Upis* antifreeze is a complex sugar called xylomannan that is as effective at suppressing ice growth as the most active insect protein antifreezes." (Carroll 2010).

"Although all previously described TH [Thermal hysteresis]-producing biomolecules are proteins, most thermal hysteresis factors (THFs) have not yet been structurally characterized…We isolated a highly active THF from the freeze-tolerant beetle, *Upis ceramboides*... the THF contained little or no protein, yet it produced 3.7 ± 0.3 °C of TH at 5 mg/ml, comparable to that of the most active insect antifreeze proteins…this antifreeze contains a β-mannopyranosyl-(1->4) β-xylopyranose backbone and a fatty acid component, although the lipid may not be covalently linked to the saccharide…This xylomannan is the first TH-producing antifreeze isolated from a freeze-tolerant animal and the first in a new class of highly active THFs that contain little or no protein…We investigated…*U. ceramboides*, from interior Alaska because they tolerate freezing to -60 °C in midwinter." (Walters et al. 2009: 20210).

"... The fatty acid component may anchor the THF to the cell membrane. However, the mode of lipid linkage to the saccharide has not been established, and it remains possible that the lipid is not covalently linked to the saccharide constituent." (Walters et al. 2009: 20211).

"The observation that THFs were associated with the cell membrane in the [a] centipede, as also appears to be the case for THFs from *U. ceramboides*, suggests that these molecules may prevent the spread of extracellular ice into the cytosol (intracellular freezing is typically thought to be lethal) and/or stabilize the plasma membrane at low temperature. This study shows that a (lipo) xylomannan isolated from *U. ceramboides* is a highly active THF that is structurally distinct from all known AFPs and antifreeze glycoprotein (AFGPs) reported to date. In contrast to known AFGPs, which comprise ~39% peptide by mass, THFs isolated from *U. ceramboides* contain little to no protein. In addition, the β-Manp-(1->4) β-Xylp backbone is unrelated to the saccharide component of fish AFGPs... This xylomannan antifreeze may contribute to freeze tolerance by preventing recrystallization of extracellular ice, preventing intracellular freezing and/or stabilizing cellular membranes at low temperature." (Walters et al. 2009: 20214).

## 參考文獻清單與連結 (REFERENCE LIST)

Carroll, S. B. (January 28, 2010). When built-in antifreeze beats a winter coat. *New York Times*. Retrieved from: https://www.nytimes.com/2010/01/19/science/19creatures.html

Walters, K. R., A. S. Serianni, T. Sformo, B. M. Barnes, and J. G. Duman. (2009). A nonprotein thermal hysteresis-producing xylomannan antifreeze in the freeze-tolerant Alaskan beetle *Upis ceramboides*. *PNAS* 106: 20210-20215. (https://doi.org/10.1073/pnas.0909872106)

## 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/Darkling_beetle |
| **撰寫/翻譯/編修者與日期** |
| 顏子傑翻譯 (2018/11/02)；譚國鋆編修 (2021/03/31)；紀凱容編修 (2021/07/01) |
| **AskNature 原文連結** |
| https://asknature.org/strategy/unique-antifreeze-protects-from-extreme-cold/ |