# 生物策略表

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| **類別** | 生物策略 (Strategy) |
| **生物策略**<br>STRATEGY | 翅膀減少熱量散失<br>(Wings Reduce Heat Loss) |
| **生物系統**<br>LIVING SYSTEM | 企鵝 (Spheniscidae) |
| **功能類別**<br>FUNCTIONS | #保護免受溫度影響<br>#Protect From Temperature |
| **作用機制標題** | 企鵝的翅膀通過血管設計形成逆流熱交換器，減少熱量的散失。<br>(Wings of penguins reduce heat loss by forming a countercurrent heat exchanger via the vascular design.) |
| **生物系統/作用機制示意圖**<br>(確認版權、註明出處；畫質) |  |

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

讓企鵝能在寒冷水域覓食的一項主要適應性特徵是肱動脈(plexus)，它是一種通過翅膀形成的血管逆流熱交換器（CCHE）。覓食使企鵝暴露於遠低於核心體溫的水中，並且面臨著持續的低溫症威脅，這種風險在一定程度上通過管理熱量在翅膀上的流動來避免。[在大多數鳥類中]血液通過一條主要血管供應到鳥類的翅膀中，該血管穿過肱骨並成為肱動脈。相比之下，企鵝的肱動脈分為三到五條主要血管，這些血管在肱骨上穿過並在肱骨-橈骨關節處交匯為兩條動脈。每條肱動脈都與兩條或更多的靜脈相關聯，形成一個逆流熱交換器（CCHE），即肱動脈。血液以核心體溫（38.5 攝氏度）供應到翅膀中，外出的動脈血在肱動脈處加熱較冷的來流靜脈血；因此，熱量得以保存並返回到體內核心，而不是沿著翅膀進一步流出並丟失到冰冷的水中。企鵝肱動脈作為 CCHE 機制的效能已通過測量企鵝肩部和翅尖之間高達 30 攝氏度的內部溫度差得到證明。

A major adaptation that allows penguins to forage in cold water is the humeral arterial plexus, a vascular counter-current heat exchanger (CCHE) through the flipper…Foraging exposes penguins to water well below core body temperature and presents a constant threat of hypothermia, a risk avoided in part by managing the flow of heat along the wing. [In most birds] Blood is supplied to the wings of birds through a single major vessel that traverses the humerus as the brachial artery…By contrast, the brachial artery of penguins splits into three to five major vessels that traverse the humerus before anastomosing to two arteries at the humerus–radius joint. Each humeral artery is associated with two or more veins to form a countercurrent heat exchanger (CCHE), the humeral arterial plexus. Blood is supplied to the wing at core body temperature (38.5 deg C), and outgoing arterial blood heats the cooler incoming venous blood at the plexus; heat is thus conserved and returned to the body core instead of travelling further out along the wing to become lost to cold water. The efficacy of the humeral plexus as a CCHE mechanism has been demonstrated by up to 30 deg C internal temperature differences measured between the shoulders and wingtips of penguins.

| 文獻引用 (REFERENCES) |
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| 「企鵝（Sphenisciformes）棲息在地球上一些最極端的環境中。企鵝的 60 多萬年化石記錄跨越了新生代海洋溫度和洋流發生劇烈變化的時期，表明企鵝的演化與環境變化之間存在著長期的相互作用。也許最值得讚揚的例子是王冠支序企鵝成功入侵冰川環境的晚新生代。一項主要適應性特徵是肱動脈 plexus，一種血管逆流熱交換器（CCHE），它通過翅膀限制熱量流失，使企鵝能夠在冰冷的水中覓食。化石證據顯示，肱動脈 plexus 至少在約 4900 萬年前的“溫室地球”時期出現。因此，CCHE 的演化與全球變冷或南極冰川的發展無關，但可能代表了對在溫帶緯度的水下覓食的適應。隨著全球氣候變冷，CCHE 成為入侵與南極冰川相關的溫度要求更高的環境的關鍵因素。」(D. B. Thomas, D. T. Ksepka, R. E. Fordyce 2010)<br><br>“Penguins (Sphenisciformes) inhabit some of the most extreme environments on Earth. The 60+ Myr fossil record of penguins spans an interval that witnessed dramatic shifts in Cenozoic ocean temperatures and currents, indicating a long interplay between penguin evolution and environmental change. Perhaps the most celebrated example is the successful Late Cenozoic invasion of glacial environments by crown clade penguins. A major adaptation that allows penguins to forage in cold water is the humeral arterial plexus, a vascular counter-current heat exchanger (CCHE) that limits heat loss through the flipper. Fossil evidence reveals that the humeral plexus arose at least 49 Ma during a ‘Greenhouse Earth’ interval. The evolution of the CCHE is therefore unrelated to global cooling or development of polar ice sheets, but probably represents an adaptation to foraging in subsurface waters at temperate latitudes. As global climate cooled, the CCHE was key to invasion of thermally more demanding environments associated with Antarctic ice sheets.” (D. B. Thomas, D. T. Ksepka, R. E. Fordyce 2010) |
| 參考文獻清單與連結 (REFERENCE LIST) **Harvard 或 APA 格式** |
| D. B. Thomas, D. T. Ksepka, R. E. Fordyce (2010). Penguin heat-retention structures evolved in a greenhouse Earth. Biology Letters. (https://royalsocietypublishing.org/doi/10.1098/rsbl.2010.0993) |
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| **生物系統延伸資訊連結** (LEARN MORE ABOUT THE LIVING SYSTEM/S) |
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| 王智斌翻譯 (2024/3/16)；陳柏宇編修 (2024/11/30) |
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