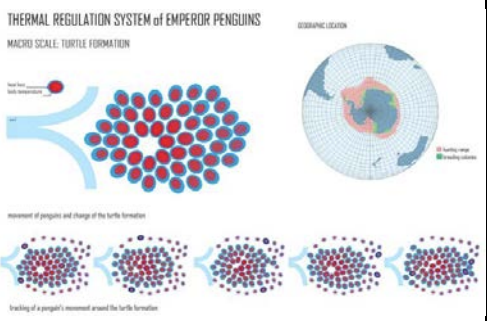
# 生物策略表

| | |
|---|---|
| **類別** | 生物策略 (Strategy) |
| **生物策略**<br>STRATEGY | 群體組織的禦寒<br>(Group organization protects from the cold) |
| **生物系統**<br>LIVING SYSTEM | 皇帝企鵝 *Aptenodytes forsteri*<br>(Emperor penguins) |
| **功能類別**<br>FUNCTIONS | #相同物種之間合作 #透過自我組織維持群落協調<br>#保護免受溫度危害<br>#Cooperate within the same species #Coordinate by self-organization<br>#Protect from temperature |
| **作用機制標題** | 皇帝企鵝群體藉由社會性緊靠行為以禦寒<br>(Groups of emperor penguins protect from the cold thanks to social huddling.) |
| **生物系統/作用機制示意圖** |  <br>  |

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

皇帝企鵝 (emperor penguin) 在南極洲的寒冬時期生殖，該地溫度會到-30°C甚至更低。為了保存能量並抵禦嚴寒，牠們採取在大群體中互相貼近緊靠 (huddling) 的行為策略。緊靠被認為是能在如此寒地中生活的關鍵能力。隨著不同的生殖階段，牠們會採用不同的緊靠模式，由於公企鵝在孵蛋期必須以禁食方式存活著，也要設法保持蛋的溫暖，因此此時企鵝緊靠的數量會最多隻。

在一個緊靠群中，皇帝企鵝會以波浪狀的動作 (wavelike movement) 改變其位置。每30-60 秒會有一隻企鵝移動，也使得相鄰的企鵝跟著移動。這些行動/反應會造成緊靠群中產生波浪狀移動，一段時間後，也引導著緊靠群有大幅度的移動。如此可容許較小的緊靠群得以加入，讓整個緊靠群的規模變得更大。這些小移動也影響了緊靠群的組織，當每隻企鵝尋找最佳位置時，可產生更有次序的排列，因而提升緊靠群的密度。

一段時間後，因為個別企鵝或其他緊靠群的加入，會使得緊靠群的企鵝太過擁擠，有時候會造成企鵝們的過熱。當他們需要散熱時，企鵝們會突然的脫離緊靠群。藉由速脫離會使得緊靠群大小的增加相對緩慢，此行為進一步讓牠們可以在不喜歡的溫度下調節其暴露程度。

想了解更多皇帝企鵝的社會性緊靠行為及此現象的研究探索，可觀看下列影片 “Lens

of Time: Huddle Masters” 由 Spine Films 提供。

Emperor penguins breed during the cold Antarctic winter, where temperatures can reach -30°C and below. To conserve energy and protect themselves from the cold, they adopt a behavioral strategy of huddling close together in large groups. Huddling is considered key to their ability to live in such a cold place. They have different huddling patterns across different breeding stages, with the largest number of penguins huddling during the egg incubation period, when the males must survive fasting while also trying to keep their eggs warm.

Within a huddle, emperor penguins shift their position in a wavelike movement. Every 30-60 seconds a penguin will move, triggering neighboring penguins to also move. These actions/reactions result in a wave of movements across the huddle, which over time leads to large scale movement of the huddle. This can increase the size of the huddle, by allowing smaller huddles to eventually join together. These small movements also affect the organization of the huddle by increasing the density, from creating a more orderly arrangement as each penguin finds their ideal position.

Over time, huddles grow larger as individual penguins join or other huddles join together, causing the penguins to be more tightly packed together, which can sometimes cause the penguins to get too hot. When they need to get rid of the excess heat, the penguins leave the huddle in an abrupt breakup. This relatively slow increase in huddle size followed by rapid separation is a behavior that further allows them to regulate their exposure to unwanted temperature.

To learn more about social huddling in emperor penguins and the research exploring this phenomenon, watch this bioGraphic video entitled, “Lens of Time: Huddle Masters” by Spine Films.

**文獻引用** (REFERENCES)

「對於皇帝企鵝來說，緊靠行為是牠們能在南極洲冬季存活的關鍵。企鵝們在緊靠群中相當緊密，不可能有個別的移動，令人想到在壓實膠體 (compacted colloid) 中的阻塞介面 (jamming transition)。然而重要的是相較於待在外圍的時間，緊靠結構能持續重組，使每隻企鵝都能有充份時間待在緊靠群內。這裡我們展示了皇帝企鵝以高度協調的方式集體移動，確保牠們的移動性，也同時維持著擁擠的緊靠群。每 30-60 秒，所有的企鵝會踏出小步伐，像波浪般傳遞於整個緊靠群。一段時間後，這些小移動會造成緊靠群的大規模重組。我們的資料顯示企鵝的緊靠行為是動態的，以間歇性模式操控著，與軟玻璃 (soft glass) 與膠體 (colloid) 等惰性非平衡系統的動態暫留 (kinetic arrest) 有著驚人的相似性。」(Zitterbart et al. 2011:e20260)

「社會性體溫調節是一個反應環境低溫的合作策略，動物會主動聚集並由同種個體的體溫相互獲利。利用這種行為，皇帝企鵝可確保他們在南極洲冬季期間的存活與生殖。一

個皇帝企鵝群體，是由多個緊密區域 (即所謂的緊靠群) 以動態的鑲嵌結構所組成，屬於一個鬆散連結架構的個體群。為了最大限度的節能，鳥群會因應環境條件而調整其緊靠行為。這裡我們藉由照片及錄影紀錄，分析皇帝企鵝群聚動態和天氣因素間的關係。環境溫度、風以及太陽輻射是其緊靠群形成的主要因素。由個體動作的分析，顯示來自鬆散群體的鳥群會持續加入緊靠群。有時少數鳥群產生的移動會傳遞至整個緊靠群，導致其在兩分鐘內分裂，所釋出的鳥群則形成較鬆散的聚集。因此在群體中的不同部分，顯然會因應環境狀況而持續交換個體。可能的解釋是有溫暖需求的個體會加入緊靠群，而需要散熱的個體則使緊靠群分裂。隨者鳥群獲得、保存或散發熱能的不同，緊靠群則像是脈衝般的規律成長和消散。就皇帝企鵝實際的調節功能而言，最初曾提出減少能量散失的解釋，而社會性體溫調節的概念顯然更能涵蓋此一高度動態的現象。」(Ancel et al. 2015: 91)

"For Emperor penguins (*Aptenodytes forsteri*), huddling is the key to survival during the Antarctic winter. Penguins in a huddle are packed so tightly that individual movements become impossible, reminiscent of a jamming transition in compacted colloids. It is crucial, however, that the huddle structure is continuously reorganized to give each penguin a chance to spend sufficient time inside the huddle, compared with time spent on the periphery. Here we show that Emperor penguins move collectively in a highly coordinated manner to ensure mobility while at the same time keeping the huddle packed. Every 30-60 seconds, all penguins make small steps that travel as a wave through the entire huddle. Over time, these small movements lead to large-scale reorganization of the huddle. Our data show that the dynamics of penguin huddling is governed by intermittency and approach to kinetic arrest in striking analogy with inert non-equilibrium systems, including soft glasses and colloids." (Zitterbart et al. 2011: e20260)

"Social thermoregulation is a cooperative strategy in which animals actively aggregate to benefit from the warmth of conspecifics in response to low ambient temperatures. Emperor penguins, *Aptenodytes forsteri*, use this behavior to ensure their survival and reproduction during the Antarctic winter. An emperor penguin colony consists of a dynamic mosaic of compact zones, the so-called huddles, included in a looser network of individuals. To maximize energy savings, birds should adjust their huddling behavior according to environmental conditions. Here, we examined the dynamics of emperor penguin aggregations, based on photo and video records, in relation to climatic factors. Environmental temperature, wind and solar radiation were the main factors contributing to huddle formation. The analysis of individual movements showed that birds originating from loose aggregations continually joined huddles. Sometimes, a small number of birds induced a movement that propagated to the entire huddle, causing its breakup within 2 min and releasing birds, which then integrated into looser aggregations. Different parts of the colony therefore appeared to continually exchange individuals in response to environmental conditions. A likely explanation is that individuals in need of warmth join huddles, whereas individuals seeking to dissipate heat break huddles apart. The regular growth and decay of huddles operates as pulses through which birds gain, conserve or lose heat. Originally proposed to account for reducing energy expenditure, the concept of

social thermoregulation appears to cover a highly dynamic phenomenon that a genuine regulatory function in emperor penguins." (Ancel et al. 2015: 91)

**參考文獻清單與連結** (REFERENCE LIST)


Zitterbart, D. P., B. Wienecke, J. P. Butler, and B. Fabry. (2011). Coordinated movements prevent jamming in an emperor penguin huddle. *PLoS ONE* 6: e20260. (https://doi.org/10.1371/journal.pone.0020260)

Ancel, A., C. Gilbert, N. Poulin, M. Beaulieu, and B. Thierry. (2015). New insights into the huddling dynamics of emperor penguins. *Animal Behaviour* 110: 91-98. (https://doi.org/10.1016/j.anbehav.2015.09.019)

Gilbert, C., G. Robertson, Y. Lemaho, Y. Naito, and A. Ancel. (2006). Huddling behavior in emperor penguins: Dynamics of huddling. *Physiology & Behavior* 88: 479-488. (https://doi.org/10.1016/j.physbeh.2006.04.024)

Gerum, R. C., B. Fabry, C. Metzner, M. Beaulieu, A. Ancel, and D. P. Zitterbart. (2013). The origin of traveling waves in an emperor penguin huddle. *New Journal of Physics* 15: 125022. (http://iopscience.iop.org/article/10.1088/1367-2630/15/12/125022/meta#artAbst)


**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/Aptenodytes_forsteri

**撰寫/翻譯/編修者與日期**

陳默翻譯 (2019/04/28)；譚國鎏編修 (2020/04/16)；紀凱容編修 (2020/11/26)；施習德編修 (2020/12/20)

**AskNature 原文連結**

https://asknature.org/strategy/group-organization-protects-from-the-cold/