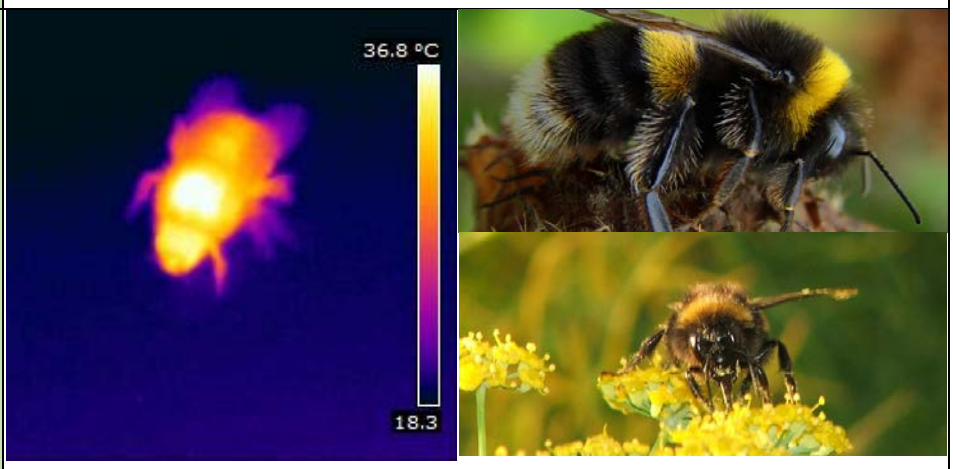
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	幫助調節體溫的機制 (Mechanisms help thermoregulation)
生物系統 LIVING SYSTEM	熊蜂 *Bombus fervidus* (Yellow bumble bee)
功能類別 FUNCTIONS	#維持體內平衡 #保護免受溫度危害 #Maintain homeostasis #Protect from temperature
作用機制標題	熊蜂的身體透過對流熱交換及熱分流機制維持恆溫 (The body of bumblebees maintains a regular temperature via counter-current heat exchange and a heat-shunting mechanism.)
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)

「1. 胸部和腹部間的腹柄 (petiole)，其內部之狹窄通道是解剖學上的結構，使得血液雖然在冷涼的腹部進出，但對流交換時仍能保存胸部內的熱能。

2. 然而，對流熱交換器的作用仍可在生理上被繞過。受到外在熱源的熊蜂會將熱量分流至腹部，以免胸部過熱。牠們也會反芻 (regurgitated) 液體，有助於降低頭部溫度，但對胸部溫度幾無影響。

3. 胸部腹面 (ventrum of the abdomen) 的升溫可能會與腹面膈膜 (ventral diaphragm) 的搏動同步，也會與腹部的「通氣」幫浦運動同步。當心臟停止時，將熱傳送至腹部防止胸部過熱的能力也會隨之消失。

4. 在低胸部溫度下，腹面膈膜以大範圍的速率和不同心搏間隔進行跳動，而心臟以相對於腹面隔膜的較高頻率跳動，但振幅非常小。然而，當任何一隻蜂的胸部溫度超過 43℃時，兩者的振幅皆很大，兩個脈動器官的心搏間隔以及搏動頻率都會變得相同。此外，

過熱的蜂會進行與心臟及腹面膈膜相同頻率的劇烈的腹部幫浦運動。

5. 此結果顯示透過將血流「切斷」成脈衝，在熱逆境中能減少或消除解剖上的對流熱交換器作用，並且透過開關機制交替的將血液脈衝通過腹柄進行分流。」(Heinrich 1976: 561)

"1. The narrow passage within the petiole between thorax and abdomen is anatomically constructed so that counter-current exchange should retain heat in the thorax despite blood flow to and from the cool abdomen.

2. However, the counter-current heat exchanger can be physiologically circumvented. Exogenously heated bumblebees prevented overheating of the thorax by shunting heat into the abdomen. They also regurgitated fluid, which helped to reduce head temperature but had little effect on thoracic temperature.

3. Temperature increases in the ventrum of the abdomen occurred in steps exactly coinciding with the beats of the ventral diaphragm, and with the abdominal 'ventilatory' pumping movements when these were present. The ability to prevent overheating of the thorax by transport of heat to the abdomen was abolished when the heart was made inoperative.

4. At low thoracic temperatures the ventral diaphragm beat at a wide range of rates and with varying interbeat intervals, while the heart beat at a high frequency relative to the ventral diaphragm, but at a very low amplitude. However, when thoracic temperature exceeded 43°C the amplitudes of both were high, and the interbeat intervals as well as the beating frequencies of the two pulsatile organs became identical in any one bee. Furthermore, heated bees engaged in vigorous abdominal pumping at the same frequency as that of their heart and ventral diaphragm pulsations.

5. The results indicate that the anatomical counter-current heat exchanger is reduced or eliminated during heat stress by 'chopping' the blood flow into pulses, and the blood pulses are shunted through the petiole alternately by way of a switch mechanism." (Heinrich 1976: 561)

參考文獻清單與連結 (REFERENCE LIST)

Heinrich, B. (1976). Heat exchange in relation to blood flow between thorax and abdomen in bumblebees. *Journal of Experimental Biology* 64: 561-585. (https://www.ncbi.nlm.nih.gov/pubmed/945321)

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延伸閱讀

AskNature Team. (October 1, 2016). CloudSolar. *AskNature*. Retrieved from: https://asknature.org/idea/cloudsolar/

生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)

https://en.wikipedia.org/wiki/Bombus_fervidus

撰寫/翻譯/編修者與日期

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AskNature 原文連結

https://asknature.org/strategy/mechanisms-help-thermoregulation/