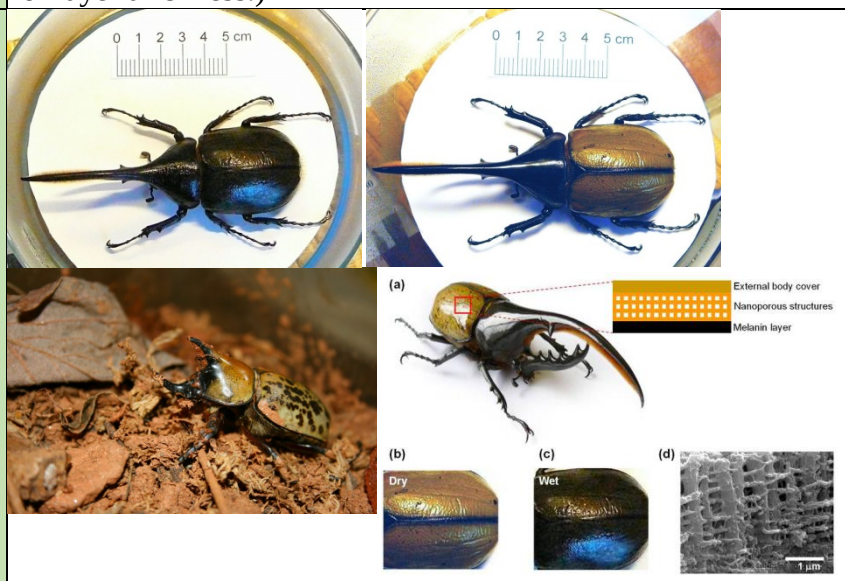
生物策略格式

2019/12/28

類別	生物策略 (Strategy)
生物策略 STRATEGY	濕度造成外骨骼顏色改變 (Humidity changes exoskeleton color)
生物系統 LIVING SYSTEM	赫克力士長戟大兜蟲 *Dynastes hercules*
功能類別 FUNCTIONS	#改變光線/顏色 #感應大氣條件 #Modify light/color #Sensing atmospheric conditions
作用機制標題	赫克力士長戟大兜蟲的外骨骼隨著濕度增加，外骨骼之層狀構造可逆的厚度變化造成薄膜干涉，使其從綠色轉為黑色 (The exoskeleton of the Hercules beetle changes from green to black with increasing humidity using thin film interference by reversible modification of layer thickness.)
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)

「從赫克力士長戟大兜蟲的乾燥標本可發現其翅鞘 (elytra) 在乾燥環境下呈卡其綠色，當濕度提高時則被動地轉為黑色。目前已使用新的掃描式電子影像 (scanning electron image)、分光光度法 (spectrophotometric measurement) 的測量以及實體模型建構 (physical modelling) 的方式來研究赫克力士長戟大兜蟲翅鞘的變色機制。在乾燥狀態下所見的綠色源自於角質層 (cuticle) 下方 3 μm 的多孔層。此多孔層為細絲狀網絡構成的立體結構，平行分佈於角質層下，強化了垂直於角質層表面的柱狀陣列結構。出乎意料的是，乾燥狀態的角質層中，光線繞射在寬頻 (帶) 色彩 (broadband colouration) 上具重要影響。當水分滲入多孔結構時折射率的差異會減小，使此層結構原本會造成的背向散射 (backscatter) 現象消失。」(Rassart et al. 2008: 1)

「在乾燥狀態下所見的綠色源自於角質層下方 3 μm 的多孔層。此層具有三維的光子晶體 (photonic crystal) 結構，為細絲狀網絡所構成，平行且呈層狀分佈於角質層下[圖.1d]。在乾燥狀態下，多孔層中奈米級的孔洞充滿空氣（折射率=1），但在高濕度環境下水會填滿這些孔洞 (折射率=1.33)。因濕度造成的折射率改變減少了可見色彩的變化。」(Kim et al. 2010: 103701-1)

「赫克力士長戟大兜蟲 (*Dynastes hercules* L.) 能夠改變其翅鞘(角質化前翅)的顏色，在黑色及黃綠色之間反覆變化，且過程只需數分鐘。在昆蟲之中，牠以前所未知的方式做到這一點。除了虹膜細胞中色素顆粒可逆的轉移現象外，快速且可逆的顏色變化在昆蟲中相當罕見。在甲蟲中，Coptocyclia、Aspidomorpha 及許多 Cassidinae 可因角質層中水分的變化改變他們翅鞘的顏色，並從而改變形成干涉色 (interference colour) 的薄層厚度。」(Hinton and Jarman 1972: 160)

"The elytra from dry specimens of the hercules beetle, *Dynastes hercules* appear khaki-green in a dry atmosphere and turn black passively under high humidity levels. New scanning electron images, spectrophotometric measurements and physical modelling are used to unveil the mechanism of this colouration switch. The visible dry-state greenish colouration originates from a widely open porous layer located 3μm below the cuticle surface. The structure of this layer is three-dimensional, with a network of filamentary strings, arranged in layers parallel to the cuticle surface and stiffening an array of strong cylindrical pillars oriented normal to the surface. Unexpectedly, diffraction plays a significant role in the broadband colouration of the cuticle in the dry state. The backscattering caused by this layer disappears when water infiltrates the structure and weakens the refractive index differences." (Rassart et al. 2008: 1)

"The visible dry-state greenish coloration originates from a open porous layer located at 3 μm below the cuticle surface. This layer has three-dimensional photonic crystal structures, which are a network of filamentary strings, arranged in layers parallel to the cuticle surface [Fig. 1d]. In dry state, nanosized holes in the layer are occupied with air (refractive index 1) but the empty holes are filled with water (refractive index 1.33) under high humidity. The change in refractive index with respect to the humidity level induces the variation in the visible color." (Kim et al. 2010: 103701-1)

"The Hercules beetle, *Dynastes hercules* [sic] L., can change the colour of its elytra—horny fore-wings—from black to greenish yellow and back again to black all within a few minutes. It does this in a way previously unknown among insects. Apart from the reversible migrations of pigment granules in the iris cells, physiological or rapidly reversible colour changes are very rare in insects. Among beetles, Coptocyclia, Aspidomorpha, and many other Cassidinae can change the colour of their elytra by varying the amount of water in the cuticle and thereby the thickness of the thin films responsible for the interference colours." (Hinton and Jarman 1972: 160)

參考文獻清單與連結 (REFERENCE LIST)

Hinton, H. E. and G. M. Jarman. (2003). Physiological colour change in the elytra of the Hercules beetle, *Dynastes hercules*. *Journal of Insect Physiology* 19: 533-539, 541-549. (https://doi.org/10.1016/0022-1910(73)90064-4)

Rassart, M., J. F. Colomer, T. Tabarrant, and J. P. Vigneron. (2008). Diffractive hygrochromic effect in the cuticle of the Hercules beetle *Dynastes hercules*. *New Journal of Physics* 10: 1-14. (https://dx.doi.org/10.1088/1367-2630/10/3/033014)

Kim, J. H., J. H. Moon, S. Y. Lee, and J. Park. (2010). Biologically inspired humidity sensor based on three-dimensional photonic crystals. *Appl. Phys. Lett.* 97: 103701-1-3. (https://doi.org/10.1063/1.3486115)

Hinton, H. E. and G. M. Jarman. (1972). Physiological Colour Change in the Hercules Beetle. *Nature* 238: 160-161. (https://www.nature.com/articles/238160a0)

延伸閱讀

AskNature Team. (October 1, 2016). Humidity sensor without electronics. *AskNature*. Retrieved from: https://asknature.org/idea/humidity-sensor/

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

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

文章貢獻/編修者與日期

周昀韋 (2019/04/25)；朱天愛編修 (2019/12/28)；吳晧編修 (2020/01/04)；
譚國鎏編修 (2020/04/01)；許秋容編修 (2020/11/25)；紀凱容編修 (2020/11/25)

AskNature 原文連結

https://asknature.org/strategy/humidity-changes-exoskeleton-color/