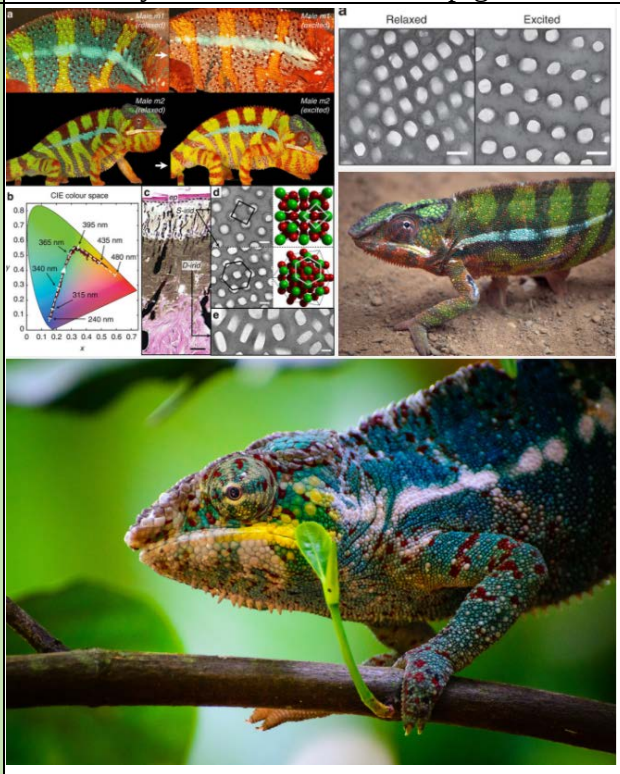
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	改變顏色的皮膚 (Skin changes color)
生物系統 LIVING SYSTEM	短角變色龍 *Calumma brevicorne* (Short-horned Chameleon)
功能類別 FUNCTIONS	#改變光線/顏色 #Modify light/color
作用機制標題	變色龍的皮膚透過主動調整色素細胞底下的奈米晶體結構迅速改變顏色 (The skin of the chameleon rapidly changes color via active adjustment of nanocrystal structures beneath pigment cells)
生物系統/作用機制示意圖	

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

變色龍所能展現的色彩變化是透過結合色素以及結構色 (structural colors) 來產生。變色龍皮膚包含不同類型的色素細胞（帶有顏色的細胞），在皮膚中以層狀排列著。皮膚的上層包含帶有黃色及紅色色素的細胞，而皮膚下層則包含帶有深沉顏色的黑色色素 (melanin) 的細胞，使其呈現黑色或褐色。緊貼在黃色及紅色色素細胞之下的，是由稱之為虹彩色素細胞 (iridophores) 所組成的細胞層，能產生結構色。虹彩色素細胞不具色素，而是具有透明、奈米尺寸晶體的有序陣列，能夠反射特定波長的光線。而這反射出來的光線被感知為顏色。

關於變色龍變色的最新研究揭示，牠們主要是透過主動調整這些奈米晶體之間的間距來改變顏色，這能導致不同波長的光線被反射。變色龍皮膚中的晶體結構和色素皆影

響皮膚的整體顏色。舉例來說，當藍光被晶體層反射而通過上層的黃色色素後，人類看到的色彩結果便是綠色。

研究人員仍在探討變色龍膚色變化的功能，但最新的研究表示，變色龍會在與其他個體進行社交互動時，藉由改變顏色來進行溝通。

The variety of colors that chameleons can display is produced through a combination of pigments and structural colors. Chameleon skin contains different types of chromatophore (color-bearing) cells organized in layers within the skin. The upper layer of skin contains cells with yellow and red pigments, while lower layers contain cells with dark melanin pigment, which appears black or brown. Just below the layer of yellow and red chromatophores is a layer of cells called iridophores (iridescent chromatophores) that produce structural color. Rather than containing pigment, iridophores contain an organized array of transparent, nano-sized crystals that reflect specific wavelengths of light. The reflected light is perceived as color.

The latest research on color-changing in chameleons reveals that they primarily change color by actively adjusting the spacing between these nanocrystals, which causes different wavelengths of light to be reflected. The crystal structures and pigments in chameleon skin both contribute to the overall color of the skin. For example, when blue light reflects off the crystal layer and travels through the yellow pigment above, the result humans see is the color green.

Researchers are still investigating the function of changing skin color in chameleons, but more recent research suggests that chameleons change color to communicate with one another during social interactions.

文獻引用 (REFERENCES)

「許多脊椎動物能夠迅速改變顏色來進行偽裝、溝通、以及溫度調節，但這些所謂的生理性變色通常是透過改變皮膚亮度（亦即漫射 diffuse 和/或鏡面反射 specular reflectivity）來達成，而這則是藉由真皮層色素細胞中含有色素的胞器（尤其是黑色素體 (melanosomes)）之分散/聚集所致。另一方面，迅速而主動調控皮膚彩度的能力僅在少數物種中被描述，而這通常涉及結構而非色素成分，亦即藉由高、低折射率交替的多層奈米反射構造來產生光波干涉…

…變色龍已經演化出兩群交疊、具有不同形態及功能的虹彩色素細胞：上方的多層細胞負責透過主動調節三角晶格 (triangular lattice) 中鳥嘌呤 (guanine) 奈米晶體的間距，以快速改變結構色，而較深層的細胞群則廣泛地反射光，尤其是在近紅外光譜範圍內。這兩種功能不同的虹彩色素細胞層組合構成了演化上的新穎性 (evolutionary novelty)，使某些變色龍物種能夠有效地結合偽裝與戲劇性的展示，同時亦可能減輕強烈太陽輻射帶來的熱效應。」(Teyssier et al. 2015: 2)

"Many vertebrates can rapidly change colour for camouflage, communication and thermoregulation[2, 4, 5, 6, 7], but these so-called physiological colour changes are generally mediated by modifications of skin brightness (that is, diffuse and/or specular reflectivity) through dispersion/aggregation of pigment-containing organelles, especially melanosomes, within dermal chromatophores[6, 7]. On the other hand, rapid active tuning of skin hue has been described in only a handful of species and generally involves structural, rather than pigmentary, components, that is, multilayer nano-reflectors with alternating high and low refractive indices that generate interference of light waves…

…chameleons have evolved two superimposed populations of iridophores with different morphologies and functions: the upper multilayer is responsible for rapid structural colour change through active tuning of guanine nanocrystal spacing in a triangular lattice, whereas the deeper population of cells broadly reflects light, especially in the near-infrared range. This combination of two functionally different layers of iridophores constitutes an evolutionary novelty that allows some species of chameleons to combine efficient camouflage and dramatic display, while potentially moderating the thermal consequences of intense solar radiations." (Teyssier et al. 2015: 2)

參考文獻清單與連結 (REFERENCE LIST)

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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/chameleon
https://www.onezoom.org/life/@chameleon
https://eol.org/pages/1056994

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https://asknature.org/strategy/skin-changes-color-2/