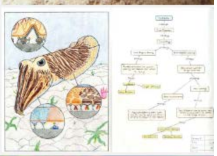
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	適應性偽裝幫助融入環境中 (Adaptive camouflage helps blend into the environment)
生物系統 LIVING SYSTEM	烏賊目 sepiida (Cuttlefish)
功能類別 FUNCTIONS	#改變光線/顏色 #保護免受動物危害 #傳遞光訊號（可見光譜） #Modify light/color #Protect from animals #Send light signals in the visible spectrum
作用機制標題	烏賊的皮膚利用稱為色表細胞的彈性色素囊袋迅速改變顏色，以躲避掠食者 (The skin of cuttlefish changes color rapidly using elastic pigment sacs called chromatophores, in order to evade predators.)
生物系統/作用機制示意圖	   

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

頭足綱 (cephalopod) 例如烏賊有時會使用適應性偽裝 (camouflage) 融入周圍環境中。牠們能夠透過調整皮膚的色素及虹彩效應，與周圍環境的顏色及表面質感匹配。

在皮膚表面，色素細胞 (chromatophores) （充滿紅、黃或褐色色素的小型囊袋）吸收不同波長的光線。當視覺訊號輸入完成，這種頭足綱會傳遞訊號到連接肌肉的神經纖維中。肌肉放鬆與收縮使色素細胞的大小及形狀改變。每種顏色的色素細胞都是被不同的神經所控制，當連接的肌肉收縮，它會變得扁平而使色素囊袋往外拉扯，使皮膚上的顏色擴展。當肌肉放鬆時，色素細胞回復緊密，使顏色消失。多達兩百個的色素細胞才可能填滿一塊橡皮擦大小的皮膚斑塊，就像一個閃爍的像素顯示器。

在皮膚的最內層是由白色素細胞 (leucophores) 所構成，能反射周圍的光線。這些波長寬廣的光線反射構造給予了頭足綱一層能幫助牠們與周圍匹配的「基底」(base coat)。

在色彩鮮艷的色素細胞跟散射光線的白色素細胞之間的是一由彩虹色素細胞 (iridophores) 形成的反射性皮膚層。這些反射的光線能製造粉紅、黃色、綠色、藍色或銀色色澤，而反射細胞（只有在章魚中發現）則能反射藍色或綠色。

Cephalopods such as cuttlefish often use adaptive camouflage to blend in with their surroundings. They are able to match colors and surface textures of their surrounding environments by adjusting the pigment and iridescence of their skin.

On the skin surface, chromatophores (tiny sacs filled with red, yellow, or brown pigment) absorb light of various wavelengths. Once visual input is processed, the cephalopod sends a signal to a nerve fiber, which is connected to a muscle. That muscle relaxes and contracts to change the size and shape of the chromatophore. Each color chromatophore is controlled by a different nerve, and when the attached muscle contracts, it flattens and stretches the pigment sack outward, expanding the color on the skin. When that muscle relaxes, the chromatophore closes back up, and the color disappears. As many as two hundred of these may fill a patch of skin the size of a pencil eraser, like a shimmering pixel display.

The innermost layer of skin, composed of leucophores, reflects ambient light. These broadband light reflectors give the cephalopods a ‘base coat’ that helps them match their surroundings.

Between the colorful chromatophores and the light-scattering leucophores is a reflective layer of skin made up of iridophores. These reflect light to create pink, yellow, green, blue, or silver coloration, while the reflector cells (found only in octopuses) reflect blue or green.

文獻引用 (REFERENCES)

「烏賊、章魚跟魷魚毫無疑問的是偽裝使用者中的冠軍⋯牠們可以即時調整自身的色彩、濃淡、斑塊、斑駁度或斑點、透明度、色溫，以及甚至是生物發光、偏振光 (light-polarity)，或是虹彩現象 (iridescence)⋯」(Woolley-Barker 2012: 12)

頭足綱有這種出色的偽裝，主要是因為牠們的色素細胞—皮膚中含有紅色、黃色或褐色色素的囊袋，它們周邊的肌肉使其變得可見（或不可見）。這些肌肉由腦部運動中心 (motor centres) 的神經元所控制，這就是為什麼牠們可以迅速融入背景中的原因。另一個協助形成偽裝的就是烏賊皮膚的質感可變性 (changeable texture)，其含有乳突狀細胞 (papillae)—成束的肌肉能夠改變皮膚的表面，從平滑變得帶有尖刺。這在牠需要躲藏在佈滿藤壺的岩石旁邊時相當有用。

關於烏賊偽裝資料的最後一部分來自於白色素細胞及彩虹色素細胞，為色素細胞底下非常關鍵的反射層。白色素細胞能反射多種波長的光線，因此在任何時候能反射當下周圍的光線—例如在淺水處反射白光，深水處反射藍光。彩虹色素細胞將稱為反射蛋白的蛋白質小板 (platelets)與多層的細胞質結合，產生像是蝴蝶翅膀的虹光反射。其他物種中的彩虹色素細胞，像是一些魚類及爬蟲類，能產生光學干涉放應 (optical interference effects)，反射出藍色到綠色的光澤。烏賊能在數秒到數分鐘內開關這些反射構造，控制小板的間距來選擇反射出的顏色。牠們亦能組合這些彩虹色素細胞與色素細胞的顏色來產生閃爍的色彩，例如紫色或橙色。(Brooks 2008: 28)

"The cuttlefish, octopus, and squid are the undisputed champions of camouflage… They can instantly modulate their color, shading, patchiness, mottling or stippling, transparency, heat, and even bioluminescence, light-polarity, or iridescence…" (Woolley-Barker 2012: 12)

"Cephalopods have such remarkable camouflage primarily because of their chromatophores – sacs of red, yellow or brown pigment in the skin made visible (or invisible) by muscles around their circumference. These muscles are under the direct control of neurons in the motor centres of the brain, which is why they can blend into the background so quickly. Another aid to camouflage is the changeable texture of cuttlefish skin, which contains papillae – bundles of muscles able to alter the surface of the animal from smooth to spiky. This comes in pretty useful if it needs to hide next to a barnacle-encrusted rock, for instance.

"The final part of the cuttlefish's camouflage portfolio comes from leucophores and iridophores, essentially reflecting plates that sit underneath the chromatophores. Leucophores reflect light across a wide range of wavelengths so can reflect whatever light is available at the time – white light in shallow waters and blue light at depth, for example. Iridophores combine platelets of a protein called reflectin with layers of cytoplasm to produce iridescent reflections rather like those of butterfly wings. Iridophores in other species, like some fish and reptiles, produce optical interference effects that shift the light towards blue and green wavelengths. Cuttlefish can turn these reflectors on or off in seconds to minutes, controlling the spacing of the platelets to select the colour. They can also combine these iridescent hues with those of the chromatophores to make shimmering purples and oranges, for example." (Brooks 2008: 28)

參考文獻清單與連結 (REFERENCE LIST)

Brooks, M. (2008). Do you speak cuttlefish? New Scientist 198: 28-31. (https://www.sciencedirect.com/science/article/abs/pii/S0262407908610416?via%3Dihub)

延伸閱讀

AskNature Team. (1 October, 2016). Optical metamaterials. *AskNature*. Retrieved from: https://asknature.org/idea/optical-metamaterials/

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

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