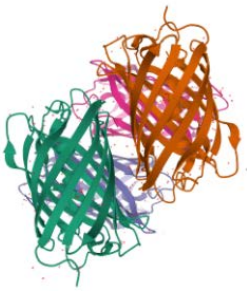
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	蛋白質將陽光轉變成鮮艷色彩 (A protein turns sunlight into vivid color)
生物系統 LIVING SYSTEM	刺胞動物門 Cnidaria (Cnidarians)
功能類別 FUNCTIONS	#改變光線/顏色 #保護免受化學物質危害 #傳遞光訊號（非可見光譜） #傳遞光訊號（可見光譜） #Modify light/color #Protect from chemicals #Send light signals in the non-visible spectrum #Send light signals in the visible spectrum
作用機制標題	圓盤海葵製造的蛋白質利用陽光的能量產生特定波長的光線來形成色彩 (A protein made by *Discosoma* corals produces color by using the sun's energy to generate specific wavelengths of light.)
生物系統/作用機制示意圖	 

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

把樸素的陽光轉變為鮮艷的色彩？這些在印度洋及太平洋發現的煎餅形長得像珊瑚的海葵正在這樣做。圓盤海葵屬 (*Discosoma*) 的成員，在照射光線之後口部周圍出現從螢光橘黃到鮮紅色的斑點，其顏色視物種而定。

這種能力是來自一種非常長的分子，稱為紅色螢光蛋白 (red fluorescent protein, RFP)，蛋白質被折疊成有點像一盤義大利麵的形狀，上方有兩根管狀的部分，稱為 beta cans。在每個 beta can 的裡面是一段稱為色素基 (chromophore) 的特殊蛋白。色素基的獨特結構使它能從陽光吸收光子的能量，並產生紅光。Beta cans 能保護色素基不會被其他分子奪取能量，使其能利用陽光產生 RFP 標誌性的發光。

RFP 是珊瑚或海葵產生的其中一種螢光蛋白。螢光蛋白的種類繁多而且非常相似，它們的顏色包括靛青、黃綠，以及藍紫色。儘管沒有人能確定，但科學家推測這些蛋白質可能是保護動物避免曬傷。它們也可能有助於珊瑚與海葵與藻類的互利關係，彼此共享藻類光合作用的產物。它們亦可能傳遞關於珊瑚的訊號給其他動物。它們更可能透過破壞有害分子的方式來幫助珊瑚渡過逆境。

圓盤海葵的發光能力亦為人類帶來潛在的益處。很多傳統紡織染料經常帶有劇毒或是致癌及致突變性。它們會污染環境，降低湖泊及河流的水質，並傷害植物及泥土中的有益微生物。相反地，像其它的蛋白質，RFP 可以經生物降解成簡單的分子，例如在所有生物中都可以找到的碳氫氧分子。

如果生產商能混合 RFP 到製造纖維的分子中，他們可以利用這些纖維來製造色彩鮮艷而不需使用有害染料的紡織品。多彩的蛋白質能被設計成在使用壽命結束時能快速降解成為對環境友善的分子。

隨著我們合成蛋白質及將其混合到其他分子的能力有所提升，現在有望使用圓盤海葵的設計，作為生產一系列特定顏色的環境友善紡織品之基礎。

[黃興倬附註：*Discosoma* spp. 中文學名為「圓盤海葵屬」，英文俗名為 mushroom anemone，不知為何原文使用 coral 稱之。可能是因為屬於擬珊瑚海葵目 Order Corallimorpharia。]

Turn plain sunlight into vibrant color? These pancake-shaped corals found in the Indian and Pacific oceans are on it. Members of the *Discosoma* genus, they have spots around their mouths that glow yellow-orange to bright red, depending on the species, after being exposed to light.

Behind this ability is an extremely long molecule known as red fluorescent protein (RFP) that is folded into a shape that looks a little like a plate of spaghetti with two tubelike sections, called beta cans, sitting on top of it. Inside each of the beta cans is a special stretch of protein called a chromophore. The chromophore's unique configuration allows it to absorb a photon — a packet of energy — from the sun and use that energy to produce a pulse of red light. The beta cans shield the chromophore from other molecules that could steal the energy before the chromophore can use it to create RFP's signature glow.

RFP is one of many very similar fluorescent proteins that corals produce, in colors that include cyan, green-yellow, and purple-blue. No one knows for sure, but scientists have speculated that the proteins might protect the corals from sunburn. They might help the corals contribute to a partnership with algae that capture light energy and share it with the coral. They might signal something about the coral to other animals. They also might help the corals deal with stress by destroying molecules that could harm them.

Discosoma's glowing reputation holds potential benefit for humans as well. Many conventional fabric dyes are toxic or cause cancer or mutations. They can pollute the environment, reducing water quality in lakes and streams and harming plants and beneficial

microbes in the soil. In contrast, like other proteins, RFP can biodegrade into simple molecules such as carbon, hydrogen, and oxygen found in all living things.

If manufacturers could incorporate RFP into the molecules that make fibers, they could use those fibers to make textiles that are colorful without requiring harmful dyes. The colorful proteins could be designed to readily degrade when their useful life is over into friendly molecules.

As our ability to synthesize proteins and incorporate them into other molecules has advanced, it is now possible to use *Discosoma*'s design as a basis for producing environmentally friendly textiles with a range of built-in colors.

文獻引用 (REFERENCES)

「珊瑚以牠們鮮艷的色彩聞名，而螢光蛋白 (FPs) 作出了大量貢獻。FPs 在珊瑚蟲綱種類中非常豐富及多樣，範圍包括四種基本色彩；靛青色 (CFP)、綠色 (GFP)、紅色 (RFP) 以及藍/紫色的非螢光色素蛋白。」

「螢光蛋白是唯一已知其顏色由單一基因序列所決定的天然色素。」

"Corals are renowned for their vivid coloration, for which fluorescent proteins (FPs) are largely responsible. FPs are abundant and diverse within anthozoans, ranging across four basic color types; cyan (CFP), green (GFP), red (RFP) and a blue/purple nonfluorescent chromoprotein."

"[Fluorescent proteins] are the only known natural pigments in which the color is determined by the sequence of a single gene."

參考文獻清單與連結 (REFERENCE LIST)

Palmer, C. V., C. K. Modi, and L. D. Mydlarz. (2009). Coral fluorescent proteins as antioxidants. *PLoS One* 4: e7298. (https://dx.doi.org/10.1371%2Fjournal.pone.0007298)

Alieva, N. O., K. A. Konzen, S. F. Field, E. A. Meleshkevitch, M. E. Hunt, V. Beltran-Ramirez, D. J. Miller, J. Wiedenmann, A. Salih, and M. V. Matz. (2008). Diversity and evolution of coral fluorescent proteins *PLoS One* 3: e2680. (https://dx.doi.org/10.1371%2Fjournal.pone.0002680)

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/cnidaria
https://www.onezoom.org/life/@cnidaria

https://eol.org/pages/1745
撰寫/翻譯/編修者與日期
譚國鎏翻譯 (2021/03/22)；黃興倬編修 (2021/04/12)
AskNature 原文連結
https://asknature.org/strategy/a-protein-turns-sunlight-into-vivid-color/