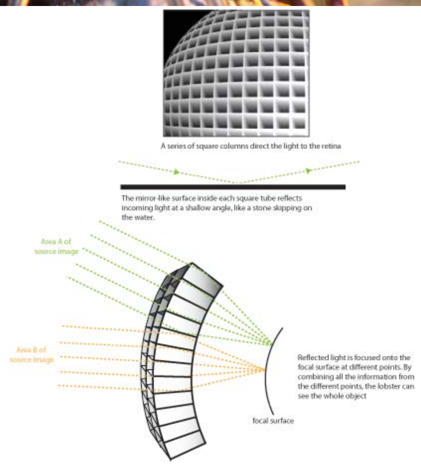
生物策略格式

KJC, 2019/10/21

類別	生物策略 (Strategy)
生物策略 STRATEGY	複合結構聚焦反射光 (Complex structures focus reflected light)
生物系統 LIVING SYSTEM	十足目 Decapoda (Decapoda order)
功能類別 FUNCTIONS	#獲取、吸收、或過濾能量 #改變光線/顏色 #Capture, absorb, or filter energy #Modify light/color
作用機制標題	龍蝦的眼睛以完美的幾何方形多管結構將反射光聚焦在視網膜上 (The eye of a lobster focuses reflected light onto the retina using a perfect geometric configuration of square tubes.)

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)

「蝦類及其近親的光學結構並不具有高折射率與徑向梯度的圓錐晶體，而是以大略同質的膠體所構成的低折射率方型結構。[1975 年 Klaus Vogt] 發現這些膠狀小球體根本不是晶體，而是多個銀面化 (silvered) 的鏡箱結構（圖 8.13b）...現今發現這種反射系統遍存於長體型的十足目甲殼類 (蝦類、龍蝦、螯蝦、異尾鎧甲蝦) 中...本質上這種反射疊置機制十分簡單。1975 年 Vogt 曾寫下：「由一目標點進入不同小面的光束，不是被如其他疊置型眼睛 (聚焦眼) 的折射系統所疊置，而是一個以圍繞的嘌呤層與晶錐側面所構成的正交反射面的徑向排列來疊置。」如圖 8.14 所示，多個鏡面導光至共同焦點。這些鏡面是反相

器，就像是望遠鏡中的折射疊置眼 (refracting superposition eye)，因此這兩種光學元件所形成的曲光束幾乎相同。然而，當有人試想光束沒有像圖 8.14b 聚焦在理想平面上會發生什麼時，問題就開始浮現。一般而言，光束在每一鏡箱的斜面上不會只接觸其中一面，而是兩面都會。這些光束發生了什麼事？難道它們全都可以像圖 8.14 的單獨反射光，全部抵達共同焦點上嗎？」

「其實這些小面排列的方格安排（幾乎是十足甲殼類獨有的）有其重要性。這個原則就是『邊角反射器』(corner reflector)，就像那些在商店一角發現的鏡子…從兩面鏡子反射的一束光必定會轉成總共兩種的正確角度，這意味著用這對鏡面，無論光最初從哪個角度來，它將轉為與原入射方向平行。換句話說，邊角鏡雖然只有單鏡，但它總是使除了反射光的些微橫向位移之外的入射光呈現正確的角度。這種特性其實非常有用，如船和浮標上的雷達反射器，它能使反射波疊置變為可能…。

「這些眼睛的其他特色對它們的功能很重要。鏡箱必須確實有總長兩至三倍寬度的深度，如此大多數的光束才得以從至多兩個面反射進來，不能再更多了。筆直穿過的光束被鏡箱的非銀面化尾端所截取，Vogt (1980) 指出它的折射率會以此方式降低，使得合適的臨界角反射在此淨區內持續通過。最後，螯蝦的角膜中有層薄弱晶體 (weak lens)。此晶體可『預先聚焦』進入鏡箱的光線，然後提供視網膜一束更窄的集束光。這些特點相當於提供一個折射疊光學置所產生的影像 (Bryceson and yre)」，然而似乎這些光束是以過多或過少的反射來提供視網膜影像中的雜散（耀）光之偵測 (Land and Nilsson 2002:172-174)。

“Instead of being lens cylinders with high refractive indices and a radial gradient, they [optical structures of shrimps and their relatives] were square structures of low refractive index, made of more or less homogeneous jelly." [Klaus Vogt in 1975] found that the jelly blobs were silvered, and they were not lenses at all, but mirror boxes (Fig. 8.13b)…it now appears that this reflecting system is the rule throughout the long-bodies [sic] decopod crustaceans–the shrimps, prawns, lobsters, crayfish, and the anomuran squat lobsters…In essence the reflecting superposition mechanism is extremely simple. In 1975 Vogt wrote: ‘Rays from an object point entering through different facets are superimposed not by refracting systems as in other superposition eyes, but by a radial arrangement of orthogonal reflecting planes which are formed by the sides of the crystalline cones and the purine layers surrounding them.’ As Fig. 8.14 shows, the mirrors direct light to a common focus. Mirrors are inverters, just like the telescopes in refracting superposition eyes (Fig. 8.3b), and so the ray-bending that the two kinds of optical element perform is almost identical. However, problems start to arise when one tries to work out what will happen to rays that are not in the idealized central plane shown in Fig. 8.14b. In general, rays in oblique planes will not encounter just one side of each mirror box, but two. What happens to such rays? Do they, like the singly reflected rays in Fig. 8.14, all reach a common focus?”

“It turns out that the square arrangement of the facet array (almost unique to the decapod crustaceans) is crucial here. The principle is that of the ‘corner reflector’ [like those mirrors found in corners of stores] ... A ray reflected from the two mirrors must be rotated through a total of two right angles, which means that it will return parallel to its original direction, no matter what angle the ray initially makes with the mirror pair. In other words, apart from a slight lateral displacement of the reflected ray, a corner mirror behaves as though it were a single mirror, but one that is always at right angles to the incoming ray. This property turns out to be very useful, for example in radar reflectors for ships and buoys, and it is also the property that makes reflecting superposition possible...

“Various other features of these eyes are important for their function. The mirror boxes must be the right depth, two to three times the width, so that most rays are reflected from two of the faces, but not more. Rays that pass straight through are intercepted by the unsilvered ‘tail’ of the mirror boxes, and Vogt (1980) showed that its refractive index decreases in such a way that appropriate critical angle reflexion continues to occur through the clear zone. Finally, there is the weak lens in the cornea of the crayfish. This lens ‘pre-focuses’ the light that enters the mirror box, thus given a narrower beam at the retina. All these features provide an image generally comparable in quality to that produced by refracting superposition optics (Bryceson and McIntyre), although it does seem that rays which make too many or too few reflections contribute to measurable stray light (glare) in the image of on the retina.” (Land and Nilsson 2002: 172-174)

參考文獻清單與連結 (REFERENCE LIST)

Vogt, K. (1980). Die spiegeloptik des flußkrebsauges. *J. Comp. Physiol.* 135: 1-19. (https://doi.org/10.1007/BF00660177)

Land, M. F. and. E. Nilsson. (2012). *Animal eyes.* Oxford University Press.

延伸閱讀: Harvard 或 APA 格式

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

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

文章貢獻/編修者與日期:

曾俊嘉翻譯 (2018/05/11)；吳晧編修 (2019/12/08)；譚國鋈編修 (2020/05/25)；紀凱容編修 (2020/11/26)；施習德編修 (2020/12/15)

AskNature 原文連結

https://asknature.org/strategy/complex-structures-focus-reflected-light/