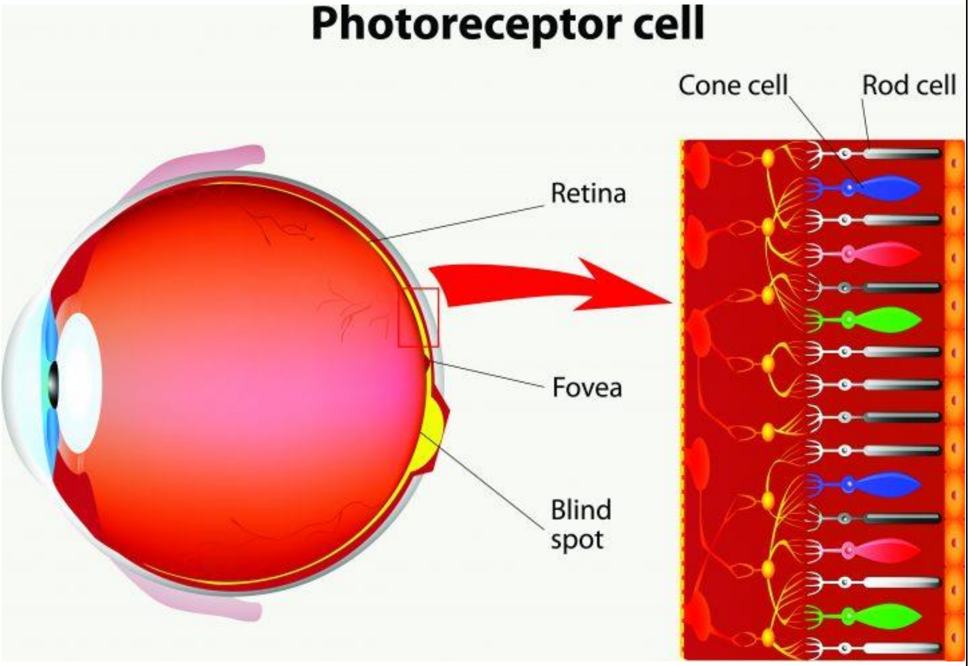
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	魚在黑暗中仍能看見東西 (The fish can see in the dark)
生物系統 LIVING SYSTEM	矛耙麗魚 (kribensis fish)
功能類別 FUNCTIONS	#感知環境中的光（不可見光譜） #Sense Light (Non-visible Spectrum) From the Environment
作用機制標題	一種酶可以將維生素 A1 轉化為維生素 A2（稱為脫氫視黃醇）。維生素 A2 似乎將紅視錐細胞的敏感性轉移到更長的波長，使具有這種特殊酶的魚能夠看到近紅外光。 An enzyme that converts vitamin A1 to vitamin A2 (called dehydroretinol). Vitamin A2 appears to shift the sensitivity of red cone cells to longer wavelengths, allowing fish that have this particular enzyme to see near-infrared light.
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 擷取自 ： https://asknature.org/strategy/the-fish-that-see-in-the-dark/#the-strategy
作用機制摘要說明	(SUMMARY OF FUNCTIONING MECHANISMS)

介紹

許多動物的視野超出了我們的視野。一些鳥類、蝴蝶和蜜蜂能看到紫外線 (UV)，它的波長比我們的視網膜可以檢測到的紫光短。科學家們之前認為紅外光不適合視覺感知，因為它的波長比紅色長，會產生過多的視覺噪音。但這原來只是一個古老的魚故事而已。幾種動物，包括矛耙麗魚 (kribensis fish, *Pelvicachromis taeniatus*），確實能夠很好地看到紅色以外的東西。

策略

要了解魚類如何看到如此長波長的光，我們需要了解一點關於使人類、魚類和其他脊椎動物能夠看到的過程——光轉導 (phototransduction)。在這個過程中，光線進入瞳孔，穿過眼睛的晶狀體聚焦，然後照射到視網膜上，視網膜上包含數億個感光細胞。與其他感知受體細胞一樣，這些細胞將信息轉換為大腦可以解釋的電信號。
感光細胞有兩種不同的形狀，每一種在視覺中都有不同的作用。桿狀感光器 (rod receptor)有助於提高光線對比度，讓我們能夠在較低的光照度下看到。穿過一個黑暗的房間，桿狀感受器可以幫助你導航，即使你無法區分顏色。在較高的光照水平下，三種類型的錐形感光器 (cone-shaped photoreceptor) ——紅色、綠色和藍色——幫助我們看到顏色，因為它們對不同波長的光敏感。

維生素 A 有兩種形式，是構成視桿細胞和視錐細胞的蛋白質複合物的一部分。在人類和大多數其他脊椎動物中，維生素 A1（通常稱為視黃醇）是主要形式。根據 2015 年的一項研究，一些魚可以看到更長波長的光，因為它們有一種酶可以將維生素 A1 轉化為維生素 A2（稱為脫氫視黃醇）。維生素 A2 似乎將紅視錐細胞的敏感性轉移到更長的波長，使具有這種特殊酶的魚能夠看到近紅外光。

潛力

基於魚眼的成像技術可以生產出多種更低耗能、更緊湊、多功能和可持續的紅外可視化設備。它可以幫助機器人在黑暗的水域中航行以清理漏油、研究難以接近的生態系統，並引導智能漁網避免捕獲受威脅的物種。

Introduction

Many animals see beyond what we see. Some birds, butterflies, and bees see ultraviolet (UV) light, which has wavelengths shorter than the violet light that our retinae can detect. Scientists previously thought that infrared light was unsuitable for visual perception because its longer-than-red wavelengths would produce too much visual noise. But that turns out just to be an old fish story. Several animals, including the striped kribensis fish (*Pelvicachromis taeniatus*), manage to see beyond red very well indeed.

The Strategy

To understand how fish see such long wavelengths of light, we need to understand a bit about the process that enables humans, fish, and other vertebrates to see at all—phototransduction. In this process, light passes into the pupil, focuses across the eye's lens, and strikes the retina, which contains hundreds of millions of photoreceptor cells. Like other sensing receptor cells, these cells convert information to electric signals that the brain can interpret. Photoreceptor cells come in two different shapes, each with a distinct role in vision. Rod-shaped photoreceptors help with light contrast and allow us to see at lower light levels. Walking through a dark room, rod receptors help you navigate even if you can't distinguish colors. At higher light levels, three types of cone-shaped photoreceptors—red, green, and blue—help us see colors because they're sensitive to different wavelengths of light.

Vitamin A, which comes in two forms, is part of the protein complexes that make up the rod and cone cells. In humans and most other vertebrates, vitamin A1, commonly called retinol, is the dominant form. According to a 2015 study, some fish can see longer wavelengths of light because they have an enzyme that converts vitamin A1 to vitamin A2 (called dehydroretinol). Vitamin A2 appears to shift the sensitivity of red cone cells to longer wavelengths, allowing fish that have this particular enzyme to see near-infrared light.

The Potential

Imaging technology based on fish eyes could produce lower-energy, more compact, versatile, and sustainable infrared visualization devices of many kinds. It could help robots navigate in dark waters to clean oil spills, study inaccessible ecosystems, and guide smart fishing nets to avoid capturing threatened species.

文獻引用 (REFERENCES)

"在這裡，我們通過實驗表明在僅單獨使用 NIR 照明下，慈鯛魚 (*Pelvicachromis taeniatus*) 對 NIR 反射獵物表現出明顯的覓食反應。 .. 這些結果為近紅外視覺敏感性的功能作用提供了第一個證據，並且挑戰了當前關於近紅外感知的觀點。"

"Here, we experimentally show that under exclusive NIR illumination, the cichlid fish *Pelvicachromis taeniatus* displays a clear foraging response towards NIR reflecting prey . . . These results give first evidence for NIR visual sensitivity in a functional context and thus challenge the current view about NIR perception."

JOURNAL ARTICLE

Visual prey detection by near-infrared cues in a fish

Naturwissenschaften | 2012 | Denis Meuthen, Ingolf P. Rick, Timo Thünken, Sebastian A. Baldauf

"尼羅河和莫桑比克羅非魚 (即吳郭，魚 tilapia) 對近紅外光譜靈敏度高，而斑馬魚、孔雀魚和綠劍尾魚 (green swordtail) 的近紅外光譜靈敏度低。 這些可觀察到的物種之間的差異可能是演化適應不同棲息地其主要光照 (prevailing illumination) 條件的結果。"

"Nile and Mozambique tilapia revealed high NIR sensitivities, while zebrafish, guppy and green swordtail were characterized by low NIR spectral sensitivities. The observed differences between species may be the result of evolutionary adaptation to the prevailing illumination conditions in the various habitats."

JOURNAL ARTICLE

Sensitivity Differences in Fish Offer Near-Infrared Vision as an Adaptable Evolutionary Trait

Plos One | 2013 | Denis Shcherbako, Alexandra Knörzer, Svenja Espenhahn, Reinhard Hilbig, Ulrich Haas, Martin Blum

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

撰寫/翻譯/編修者與日期
陳俊宇翻譯 (2022/3/19)；許秋容編修 (2022/5/14)
AskNature 原文連結
https://asknature.org/strategy/the-fish-that-see-in-the-dark/#the-strategy

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