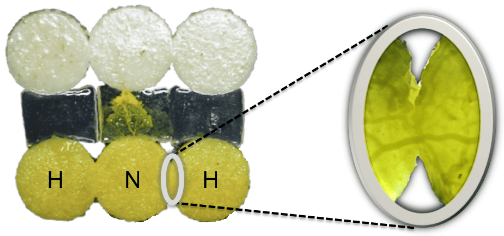
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	無須大腦的取得、儲存與傳輸知識 (Information Gained, Stored, and Transferred Without Brains)
生物系統 LIVING SYSTEM	多頭絨泡黏菌 (Physarum polycephalum slime mold)
功能類別 FUNCTIONS	#種內合作 #學習 #Cooperate Within the Same Species #Learn
作用機制標題	儘管缺乏神經系統，粘菌仍可以透過暫時結合來學習並與其他粘菌分享它們所學到的知識。 (Despite the lack of a nervous system, slime molds can learn and share what they learn with other slime molds by joining together for a time.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 (圖片來源：Asknature)  多頭絨泡黏菌沿著表面緩慢爬行，並沿途收集資訊。 (圖片來源：Asknature)  三個黏菌（下面三個圓圈）面臨跨越鹽橋以獲得飼料獎勵（上面三個圓圈）的挑戰。 外面的兩隻黏菌已經知道他們會在橋的另一邊找到美食。 中間的那個沒有，但無論如何他都會穿過，這要歸功於與鄰居融合所共享的信息。 (圖片來源：Audrey Dussutour CNR)



特寫鏡頭顯示有穿過鹽橋尋找獎勵經驗的黏菌 (H) 與沒有穿過鹽橋的經驗 (N) 之間的靜脈形成。
(圖片來源：Audrey Dussutour CNR)

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

導言

既非動物也非植物，屬於黏菌的多頭絨泡菌是一種住在潮濕森林裡的大型單細胞生物。乍看之下他可能像是一滴油漆，但耐心的觀察你會發現，他透過向前伸出指狀突起，在地面上爬行。

儘管沒有大腦，黏菌會根據過去的經驗改變自己的行為，展現出一種簡單的學習形式。透過與其他黏菌融合幾個小時，他們還可以將自己學習到的知識傳遞給另外一個黏菌。科學家們藉由給予不同黏菌機會爬過鹽製小橋（他們通常會避免這種行為）來獲取食物獎勵，發現這一點。

策略

實驗的設置很簡單：訓練一組黏菌通過未加鹽的橋。接著將一半的黏菌暴露於有鹽的橋上。剛開始他們會排斥，但最後還是會跨越過去。另一半黏菌則沒有接觸過鹽橋。

當兩組黏菌接下來都有機會穿過鹽橋時，有穿越鹽橋經驗的黏菌會比其他組更快通過令他們感到噁心的鹽橋去到有好吃食物的彼岸。然而，當一隻已經學會忍受鹽以獲得食物的黏菌與另一組的黏菌合併時，第二隻黏菌也能輕易的穿越鹽橋，只要兩者有在一起超過一個小時，且彼此之間形成一種聯繫結構，即使在與夥伴分開後，第二隻黏菌依然能輕易地跨越鹽橋。

潛力

黏菌如何學習和分享學問仍是一個謎。有些科學家認為這可能與基因的表達方式、靜脈的結構或化學物質在黏液中的相互作用有關。但即使我們不知道他是如何運作的，這種無需大腦的學習能力也為創新提供了寶貴的見解。研究人員借助黏菌解決困難的計算問題，像是尋找最短路徑和建立更好的網絡。而致力於設計人工智慧和機器學習系統的研究員可以利用這種聰明但無腦的生物作為靈感，開發無需中央樞紐就能學習與共享知識的新方法。

Introduction

Neither animal nor plant, the slime mold *Physarum polycephalum* is a large-scale single-celled organism that lives in damp forests. At a glance it may look like a splash of paint, but patient observation reveals it creeping across surfaces by oozing forward in fingerlike projections.

Even though it doesn’t have a brain, the slime mold exhibits a simple form of learning by changing its behavior based on past experience. It also can pass what it learns to another slime mold simply by fusing with it for a couple of hours. Scientists discovered this by giving different slime molds a chance to creep across a tiny bridge made of salt (which they usually avoid) to reach a food reward.

The Strategy

The setup of the experiment was simple: A group of slime molds was taught to cross a bridge without salt. Next, half of those slime molds were exposed to a bridge with salt. They were repelled at first, but eventually crossed anyway. The other half were not exposed to a salt bridge.

When both groups were later given a chance to cross a salt bridge, the slime molds that had experience with a salt bridge traveled across the “yuck” to get to the “yum” more quickly than the others. Then, when a slime mold that had learned to tolerate the salt in order to reach the treat merged with another slime mold, the second slime mold also readily crossed the salt bridge—even after being separated from its partner—as long as the two had been together longer than an hour and had formed a connecting structure between them.

The Potential

How slime molds learn and share learning is still a mystery. Some scientists think it might be related to how genes are expressed, to the structure of the veins, or to how chemicals interact within the slime. But even though we don’t know how it works, this ability to learn without a brain offers valuable insights for innovation. Researchers have turned to slime mold for help solving difficult computational problems such as finding shortest paths and building better networks. And efforts to design artificial intelligence and machine learning systems can use the bright but brainless creature as inspiration for developing new approaches to learning—and sharing knowledge—without the need for a central hub.

文獻引用 (REFERENCES)

隨著下一代網路的規模預計會變得非常龐大，通訊的集中控制變得不切實際。藉由分散式人工智能，絨毛黏泡菌屬可能為具有分散式控制系統的下一代—— 適應性強、穩健性佳的分布式基礎設施網路提供啟發。 (Sun, 2019:2)

As the scales of the next-generation networks are expected to be extremely large, centralized control of communication becomes impractical. With the distributed intelligence, Physarum may inform the design of next generation, adaptive, robust spatial infrastructure networks with decentralized control systems. (Sun, 2019:2)

參考文獻清單與連結 (REFERENCE LIST) **Harvard 或 APA 格式**

Yahui Sun. (2017, April 6). Physarum-Inspired Network Optimization: A Review. ArXiv. (https://arxiv.org/pdf/1712.02910.pdf)
David Vogel and Audrey Dussutour. (2016). Direct Transfer of Learned Behaviour via Cell Fusion in Non-Neural Organisms. Proceedings of the Royal Society B, 283(1845). (https://doi.org/10.1098/rspb.2016.2382)

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

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