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SCIENCE FOCUS 科言

Issue 029, 2025

School of Science 理學院

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Contents

Science Focus Issue 029, 2025

Message from the Editor-in-Chief 主編的話

Dear Readers,

We bring you a bonus issue as you return to school after the Lunar New Year. Hopefully, you will find interesting new topics to discuss with your teachers and classmates after a well-deserved break.

With smartphones being omnipresent, we provide a simple suggestion on how to prevent them from ruining your sleep. When you are not using them, how many of you charge your smartphones wirelessly? Have you wondered what wireless charging has in common with auroras, which were unusually common last year? A quick answer: magnetism. Moving on to animals, we challenge your prior knowledge on moth behavior and electric eels. Finally, we bring you the latest on our understanding of peanut allergy, and new therapeutic strategies that seem counterintuitive at first.

The School of Science will be organizing a couple of all day activities in the spring. Please watch out for promotional material in our social media feeds. We hope to see you on campus in the not-too-distant future!

Yours faithfully,
Prof. Ho Yi Mak
Editor-in-Chief

親愛的讀者：

我們很高興為你帶來農曆年假後額外出版的《科言》！希望你在悠悠長假後，能在此找到與老師同學閒談的有趣新話題。

在智能手機變得無處不在的同時，今期我們會向大家提供避免讓手機影響作息的小貼士。大家用完手機後會將它無線充電嗎？有想過無線充電與上年難得廣泛出現的極光有甚麼關係？簡短答案：磁性。然後我們會將話題轉向動物，挑戰你對飛蛾行為和電鰻的既有認知。最後，我們會為大家介紹科學界對花生過敏的新知，以及驟聽之下少許違反直覺的嶄新治療策略。

理學院在春季亦會舉辦多個全日活動，請密切留意我們在社交媒體的宣傳，期望在不久將來能與大家在科大校園相遇！

主編 麥晧怡教授
敬上

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What's Happening in Hong Kong? 香港科技活動

Fun in Spring Science Activities 春日科學好節目

Any plans for this spring? Check out the following events!
計劃好這個春天的課餘節目了嗎？不妨考慮以下活動！

Jane Goodall – Reasons for Hope 珍古德 — 信有希望

This documentary featuring Dr. Jane Goodall emphasizes her enduring optimism and commitment to raising environmental awareness. The show highlights successful restoration efforts, such as the transformation of polluted land in a Canadian mining town into a lush green oasis, and the reintroduction of the endangered American Bison by an indigenous North American tribe, the Blackfeet Nation. The show encourages viewers to embrace hope and take action for a sustainable future, particularly empowering youth to drive change.

Show period: Now – March 14, 2025
Time: 5:00 PM (Mon, Wed to Fri)
11:00 AM, 3:30 PM and 8:00 PM (Sat, Sun and public holiday)
Venue: Space Theatre, Hong Kong Space Museum
Admission fee: Standard admission: $40 (stalls), $30 (front stalls)
Concession admission: $20 (stalls), $15 (front stalls)

這套由 Jane Goodall 博士主持的紀錄片揭示了她對提高大眾保育意識的長期貢獻，以及堅定不移的樂觀態度。透過激勵人心的故事，節目展示了多個致力將環境復原的成功例子，例如將加拿大一個採礦小鎮受污染的土地轉化為綠洲，以及北美原住民「黑腳部族」幫助瀕臨絕種的美國野牛重新立足美洲大地的故事。電影鼓勵觀眾 — 尤其是青少年 — 抱持希望，並為締造可持續的未來出一分力。

放映日期： 現在至 2025 年 3 月 14 日
時間： 下午五時正（一、三至五）
上午十一時正、下午三時半及八時正（六、日及公眾假期）
地點： 香港太空館天象廳
入場費： 標準票：40 元（後座）；30 元（前座）
優惠票：20 元（後座）；15 元（前座）

The Sun, Our Living Star 太陽 — 生命之源

This Sky Show invites audiences to explore the deep fascination of humanity with the Sun, from ancient reverence to contemporary scientific insights. For billions of years, the Sun has been essential for life on Earth, influencing weather patterns and governing our daily rhythms. This show delves into the Sun's formation 4.6 billion years ago, its mechanism to generate energy, and its impact on our lives. Highlights include Galileo's groundbreaking observations of sunspots, the phenomena of solar flares and auroras, and the advanced telescopes that enhance our understanding of this vital star. Read the articles on circadian rhythm and auroras in this issue and watch the show!

Show period: Now – May 14, 2025
Time: 3:30 PM and 8:00 PM (Mon, Wed to Fri)
2:00 PM and 6:30 PM (Sat, Sun and public holiday)
Venue: Space Theatre, Hong Kong Space Museum
Admission fee: Standard admission: $40 (stalls), $30 (front stalls)
Concession admission: $20 (stalls), $15 (front stalls)
Remark: This show is not suitable for viewers sensitive to flashing lights.

由古代敬畏到現今科學發現，此天象節目邀請觀眾探索人類長久以來對太陽的著迷。數十億年以來太陽一直對地球上的生物至關重要，皆因它影響天氣規律，並掌管我們的晝夜節律。本片會闡述太陽在 46 億年前的形成過程、其產生能量的奧秘，以及對我們生活的影響。精彩內容包括伽利略對太陽黑子的突破性觀測、太陽閃焰和極光現象，還有使我們對這個生命之源有更深認識的先進望遠鏡。不妨閱讀今期關於晝夜節律及極光的文章，然後去看這套電影吧！

放映日期： 現在至 2025 年 5 月 14 日
時間： 下午三時半及八時正（一、三至五）
下午二時正及六時半（六、日及公眾假期）
地點： 香港太空館天象廳
入場費： 標準票：40 元（後座）；30 元（前座）
優惠票：20 元（後座）；15 元（前座）
備註： 本片不適宜對閃光敏感之人士觀看。

A New Explanation of "Like a Moth to a Flame"

「飛蛾撲火」新解

By Helen Wong 王思齊

If you ever lit a candle in the wilderness during nighttime, you would likely find moths (and other nocturnal insects) irresistibly drawn to the candle flame. This phenomenon is so common that there's a phrase for it, "like a moth to a flame."

For centuries, scientists wondered what attracts insects to flames [1]. Some believe insects mistake flame light for an indicator of gaps between leaves, or a celestial compass like the moon. Others propose that the heat of the light draws them in, or that the intense light blinds them, causing erratic flight patterns.

To answer this age-old question, researchers at Imperial College London recorded and analyzed high-resolution flight trajectories of insects under artificial lights. Surprisingly, their findings point to a new explanation: the dorsal light response (DLR) [1–3], a highly conserved behavior that keeps the dorsal side, or the back, of insects facing the brightest visual region.

Flying insects need to stay upright to maintain correct flight orientation. Throughout the long history of insect flight evolution, the sky has consistently been the brightest region in the visual field, making it a reliable cue for determining which way is up. Thus, by leveraging DLR, flying insects can adjust their flight orientation with reference to the sky. This capability is especially critical for small insects flying with a relatively low inertia because the gravitational force they experience can often be masked by other forces exerted by wind or turbulence, so unlike humans and plants, gravity cannot be used as a reliable cue of direction.

Let's take a closer look at how the researchers arrived at this unexpected conclusion of DLR.

The first clues for DLR emerged from initial field experiments in Costa Rica, where the team used infrared high-speed cameras (Footnote 1–2) to record insect flight under various lighting configurations. Upon analyzing the recordings, researchers observed three unusual behaviors that are common in conditions with light but not in complete darkness (Figure 1). When the insects are at the same horizontal level as the light source, they orbit around it. If the insects are above the light source, they inverse, or flip upside down, and crash onto the ground. While below the light source, the insects fly upward and then stall, or slow down. Most importantly, in all three scenarios, the insects tilted their backs toward the light source.

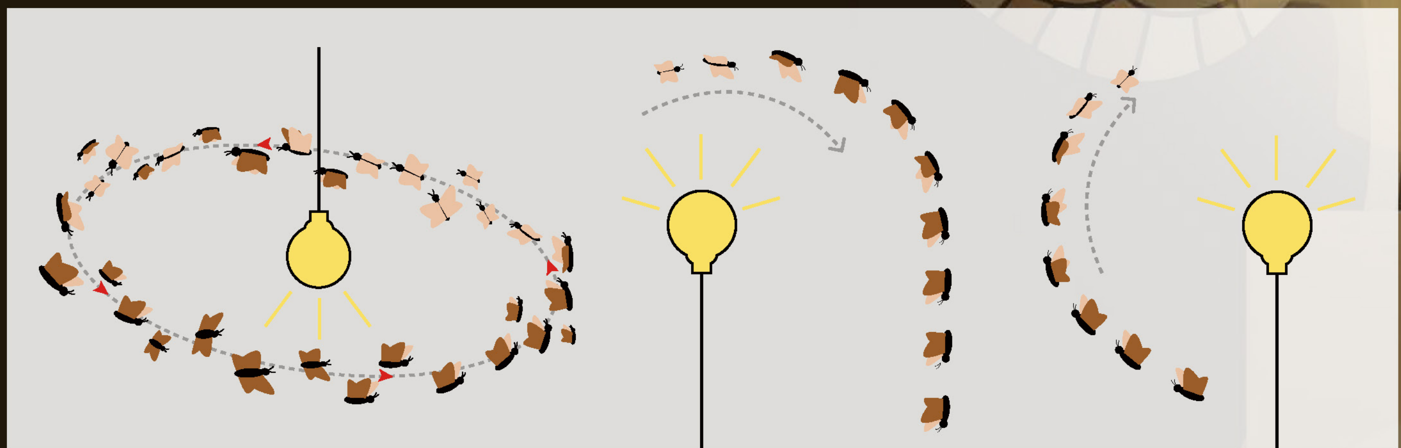


Figure 1 Insect flight trajectories demonstrating the three unusual behaviors observed during field experiments: orbiting (left), inverting (middle), and stalling (right).

圖一 研究人員在野外實驗觀察到的三種不尋常昆蟲飛行軌跡：繞圈（左）、上下顛倒（中）和失速（右）。

Combining all lines of evidence, the most plausible explanation is that the insects are trying to align their backs to the light source under the influence of DLR. Nonetheless, these are just qualitative observations — can we possibly quantify this "dorsal tilting toward light" behavior?

An intuitive approach is to track the insects' flight paths and measure their body orientation as they fly. Back in the lab, the researchers conducted similar flight experiments, this time attaching position markers to several species of interest: Common Darter and Migrant Hawker dragonflies, as well as Yellow Underwing Moths and Lorquin's Atlas Moth. They then projected the velocity vectors of the insects onto the ground and compared them to the instantaneous direction of light. Results showed that the insects mostly moved at right angles to the direction of the light source (Figure 2) – a piece of strong evidence that the insects are not attracted to the light, but are instead caught in loops around it as they aligned their backs to it due to DLR. The team demonstrated, through simulated flight experiments, that DLR alone is sufficient to produce the observed behavior in both field and lab settings.

The significance of this study goes beyond merely answering a longstanding question; it also carries important implications for our use of artificial light. As human civilization progresses, we increasingly rely on artificial lighting at night for convenience, often not realizing that these lights could confuse insects. While many artificial light sources, like streetlamps, are essential, we can still make changes to help. By simply getting rid of unnecessary upward-facing lights that disorient insects and cause them to crash onto the ground (recall the inversion behavior!), we can seek a more harmonious coexistence with nature.

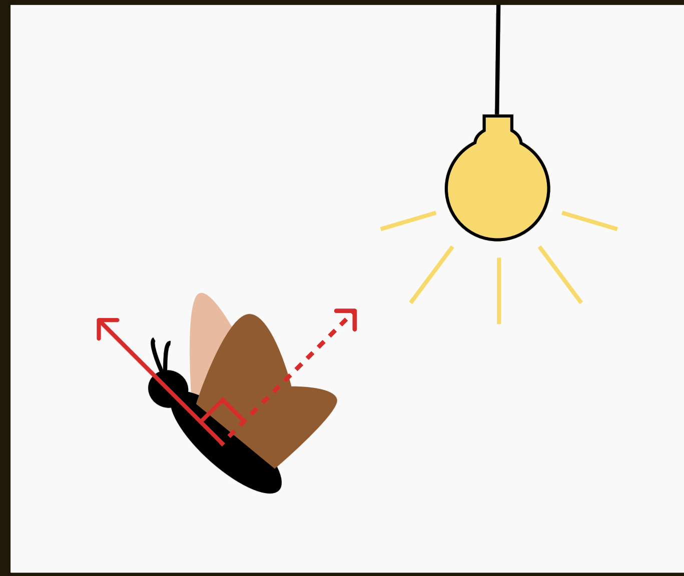


Figure 2 When insects tilt their backs toward the light source under DLR, their flight direction (solid arrow) will form a right angle to the direction of the light source (dashed arrow).

圖二 當昆蟲在背部光反應的影響下將背部朝向光源時，它們的飛行方向（實線箭頭）會與光源方向（虛線箭頭）形成直角。

1. Insect movements were captured using infrared illumination, as infrared light is assumed to be invisible to insects in this study [1]. This ensures their behavior remains unaffected during the flight experiments. In fact, none of the insects crashed into or interacted with the infrared lights set for videography purposes, which indirectly rejected the hypothesis that the heat of the light intervenes the flight of insects.
2. Videos in our daily life are filmed at 24, 25 or 30 frames per second (fps), while slow-motion videos are captured at 50 or 60 fps. In this study, they shot at an incredibly high frame rate of 500 fps.

如果你在夜間的荒野點起燭光，你很可能會看見飛蛾（和其他夜行昆蟲）出於本能反應撲向火焰。這種現象非常普遍，以至於古人創作了一個成語來形容它：飛蛾撲火。

數世紀以來，科學家一直希望找出火焰吸引昆蟲的原因 [1]。有人認為昆蟲誤將火焰當作樹葉間隙的線索，或是當成月亮等可用作導航的天體；又有人提出昆蟲是被火焰的熱力所吸引，又或是被火焰的強光致盲以致飛行路徑不穩。

為了回答這個長久以來的問題，倫敦帝國學院的研究人員記錄並分析了昆蟲在人工光源下的高解析度飛行軌跡。令人意想不到的是，研究結果指向一個全新的解釋：背部光反應（Dorsal Light Response / DLR）[1–3]，一種

普遍存在於多種昆蟲的高度保守（highly conserved）行為，使昆蟲背部始終朝向視野中最明亮的區域。

飛行中的昆蟲需要保持背部朝上以維持正確的飛行方向。在漫長的飛行進化史中，天空一直是視野中最明亮的區域，因此成為了昆蟲辨認上方的可靠線索。透過背部光反應，昆蟲就能以天空作參照來調整飛行方向。這對慣性較低的小型昆蟲尤為重要，因為它們感受的重力往往會被風或湍流施加的力所掩蓋，所以與人類和植物不同，這些昆蟲不能倚靠重力作為判斷方向的依據。

現在讓我們仔細看看研究人員如何得出背部光反應這個出乎意料的結論吧！

背部光反應的最初線索來自研究團隊在哥斯達黎加進行的野外實驗，他們使用紅外線高速攝影機（註一及二）記錄昆蟲在不同照明配置下的飛行軌跡。在分析影片後，研究人員觀察到三種在有光情況下出現，但在完全黑暗中沒有出現的不尋常行為（圖一）：當昆蟲與光源處於同一水平時，它們會圍繞光源飛行；如果昆蟲位於光源上方，它們就會上下顛倒，然後墜落地面；如果昆蟲位於光源下方，昆蟲則會改為向上飛行，漸漸失去前進的速度。最重要的一點是在全部三種情況中，昆蟲均會把背部朝向光源。

綜合所有發現，最合理的解釋便是昆蟲在背部光反應的影響下試圖將背部對準光源。可是，以上的結論只是基於定性觀測 —— 我們能否量化這種「將背部朝向光源」的行為呢？

一種直觀的方法是追蹤昆蟲的飛行路徑並測量它們飛行時的身體方向。回到實驗室後，研究人員進行了類似的飛行實驗，這次他們在以下數種昆蟲身上附加位置標記：條斑赤蜻、混合蜓、大黃夜蛾和蛇頭蛾。接著，他們將昆蟲的速度向量投影到地面，並將其與光的瞬時方向進行比較。結果顯示，昆蟲大多以與光源方向成直角的方式移動（圖二），證明昆蟲並非被光吸引，而是在試圖將背部朝向光源方向的情況下被迫繞著光源飛。團隊通過模擬飛行實驗進一步表明，單靠背部光反應就足以在野外和實驗室環境中產生觀察到的行為。

這項研究的意義不僅在於回答了這個長久以來的問題，亦為我們應如何設置燈光帶來重要的啓示。隨著人類文明進步，我們在夜間越發依賴人工照明的同時，往往沒有意識到這些燈光會干擾昆蟲飛行。儘管許多人工光源（例如路燈）已成為現代社會的必需品，但我們仍然有改善空間，例如我們可以避免使用向上照射的光源，因為它們會使昆蟲迷失方向並墜落地面（回想一下上下顛倒的行為！）。哪怕只是微小的改變，也能讓我們以更和諧的方式與大自然共存。

1. 在拍攝昆蟲移動時，選用紅外線照明的前設是昆蟲看不見紅外線，這樣才能確保它們的飛行路徑不受拍攝用的燈光影響。事實上，實驗中沒有任何一隻昆蟲撞上或飛向攝影用的紅外線燈具，這亦間接否定了光的熱力干擾昆蟲飛行這一假設。
2. 日常生活中的影片通常以每秒 24、25 或 30 幀拍攝，而慢動作影片則以每秒 50 或 60 幀拍攝。在這項研究中，研究人員以高達每秒 500 幀的速率進行拍攝。

References 參考資料：

[1] Fabian, S. T., Sondhi, Y., Allen, P. E., Theobald, J. C., & Lin, H. T. (2024). Why flying insects gather at artificial light. *Nature Communications, 15*(1), 689. *https://doi.org/10.1038/s41467-024-44785-3*

[2] nature video. (2024, January 31). *'Like a moth to a flame' - this strange insect behaviour is finally explained* [Video]. YouTube. *https://www.youtube.com/watch?v=i7awa_WGI_o*

[3] Ravate, B. (2024, February 2). *Flying insects become disorientated and trapped by artificial light*. Imperial News. *https://www.imperial.ac.uk/news/251217/flying-insects-become-disorientated-trapped-artificial/*

WIRELESS CHARGING 無線充電

Explained 大解構

By Daria Zaitseva

Wireless technology is the new black. Latest technological advances helped us ditch the hassle of cables and enjoy seamless use of devices with wireless charging pads and stands. Have you ever wondered how these chargers work? The answer is much simpler than you might think!

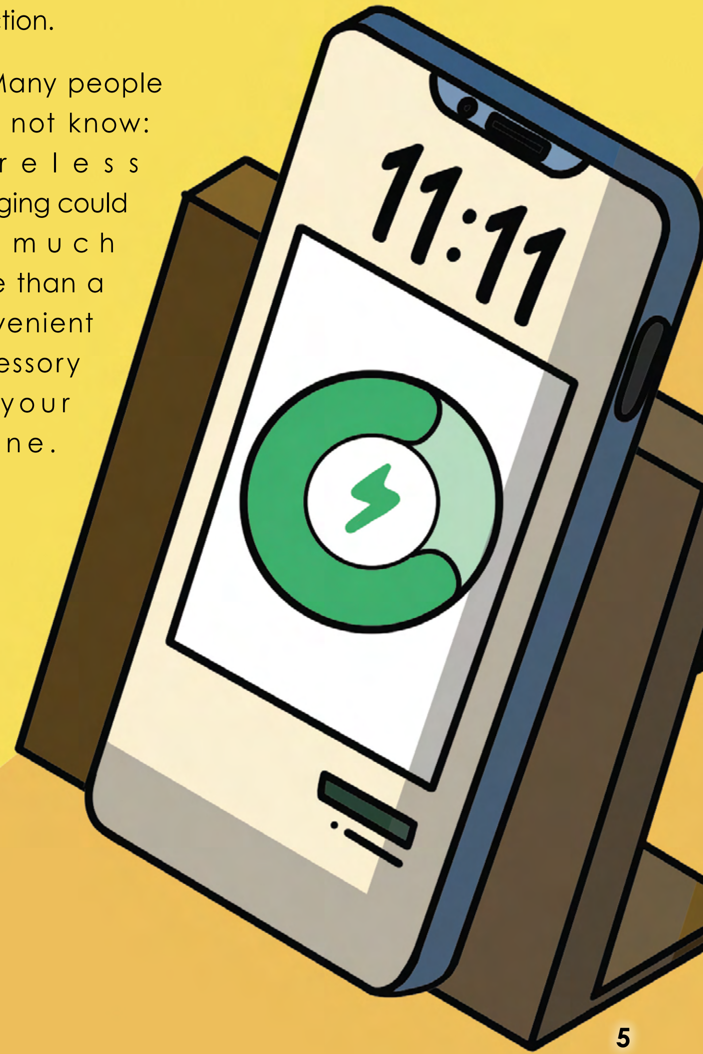
Wireless charging, also called inductive charging, is based on some physical principles of electromagnetism and electromagnetic induction. The first principle to know is Ampere's law, which implies that an electric current in a conductor generates a magnetic field with a strength proportional to the current. If we pass a current through a solenoid (a helical coil), the solenoid becomes an electromagnet with the north and south poles at either of its ends depending on the current direction.

This is the transmitter coil installed in the charging pad. When the transmitter is plugged in, a current runs through the coil and turns it to an electromagnet. An alternating current (a.c.) with the direction of electron flow reverses regularly can be supplied, so that we get an electromagnet with the two poles switching constantly, creating a changing magnetic field.

Then here comes the second principle: Faraday's law of electromagnetic induction. Discovered by Michael Faraday in 1831, this law states that a changing magnetic field can induce a voltage called an electromotive force (e.m.f.), which can drive a current to flow through a conductor.

Let's say we take advantage of this principle and install a receiver coil into the device we want to charge. The coil picks up the changing magnetic field and develop an e.m.f. across it, eventually inducing a current to flow through the device. Voilà, the current is now transmitted wirelessly. As smartphones and watches can only be charged by direct current (d.c.), there is an electrical device called a rectifier to convert the induced a.c. into d.c. by restricting the electron flow to only one direction.

Many people may not know: Wireless charging could be much more than a convenient accessory for your phone.



Researchers have long sought a wireless solution to power biomedical devices. Theoretically, magnetic fields can penetrate the skin to induce a current to charge the implanted device [1]. This capability could be a game-changer, eliminating the need of repeated surgeries to replace pacemaker batteries [2], and the infection risk associated with percutaneous wire insertion to power left ventricular assist devices (mechanical pumps for patients with advanced heart failure) [3]. Nevertheless, before the wireless charging technology can be commercialized in biomedical devices, some technical challenges still need to be overcome, such as misalignment between coils and burn injury caused by the high-power transmission [2, 4].

Wireless charging systems could be a future direction for electric cars as well. Mercedez-Benz has already been offering a wireless charging option in a car model back in 2017 [5]. Recently, the leading electric car company Tesla has also expressed interest in developing their own wireless charging technology [6]. However, infrastructural support, such as setting up charging stations with charging pads, is crucial to the promotion of the use of wireless charging. This may explain the general reluctance of car manufacturers to incorporate wireless technology into their products [6]. It is a chicken and egg situation: The motivation of car companies to invest in wireless technology is driven by the demand of electric cars, which, however, is now hindered by the accessibility to public charging.

Although a lot of development is still due, engineers have conceived some futuristic ideas in city planning. Detroit has built the first wireless charging road in the US with electromagnetic coils installed underground for pilot testing [7]. While driving down the 400-meter road, the car battery can be charged through inductive charging. This could be a solution to extend the range of electric vehicles.

This is just a glance at what wireless charging could do. In a desire to make technology better and smarter, developers take on the responsibility to make our lives easier without wires. From homes to high-tech endeavors, more and more devices go wireless. What's next?

無線技術是新潮流，科技進步使我們能擺脫電線的纏繞，讓我們享受到以無線充電座或支架為手機充電的便利體驗。你有想過無線充電器如何運作嗎？答案也許比你想像的簡單得多！

無線充電又稱為感應充電，運作原理基於電磁學和電磁感應範疇中一些物理學原理。我們第一個要了解的是安培定律，它表明導體中的電流會產生與其強度成正比的磁場。如果我們為一個螺線管（螺旋線圈）接上電源，螺線管就會變成一塊電磁鐵，兩端會根據電流方向一端成為南極，另一端成為北極。

這就是安裝在充電座裡的發射線圈。當發射線圈插上電源後，電流會通過線圈使其成為電磁鐵。如果接上交流電，電子的流動方向會不停改變，使電磁鐵的兩極不斷互換，從而產生不斷變化的磁場。

接下來是第二個原理：法拉第電磁感應定律。這個由米高・法拉第（Michael Faraday）於 1831 年發現的定律指出變化中的磁場可以感生出稱為電動勢的電壓，它可以驅使電流在導體內流動。

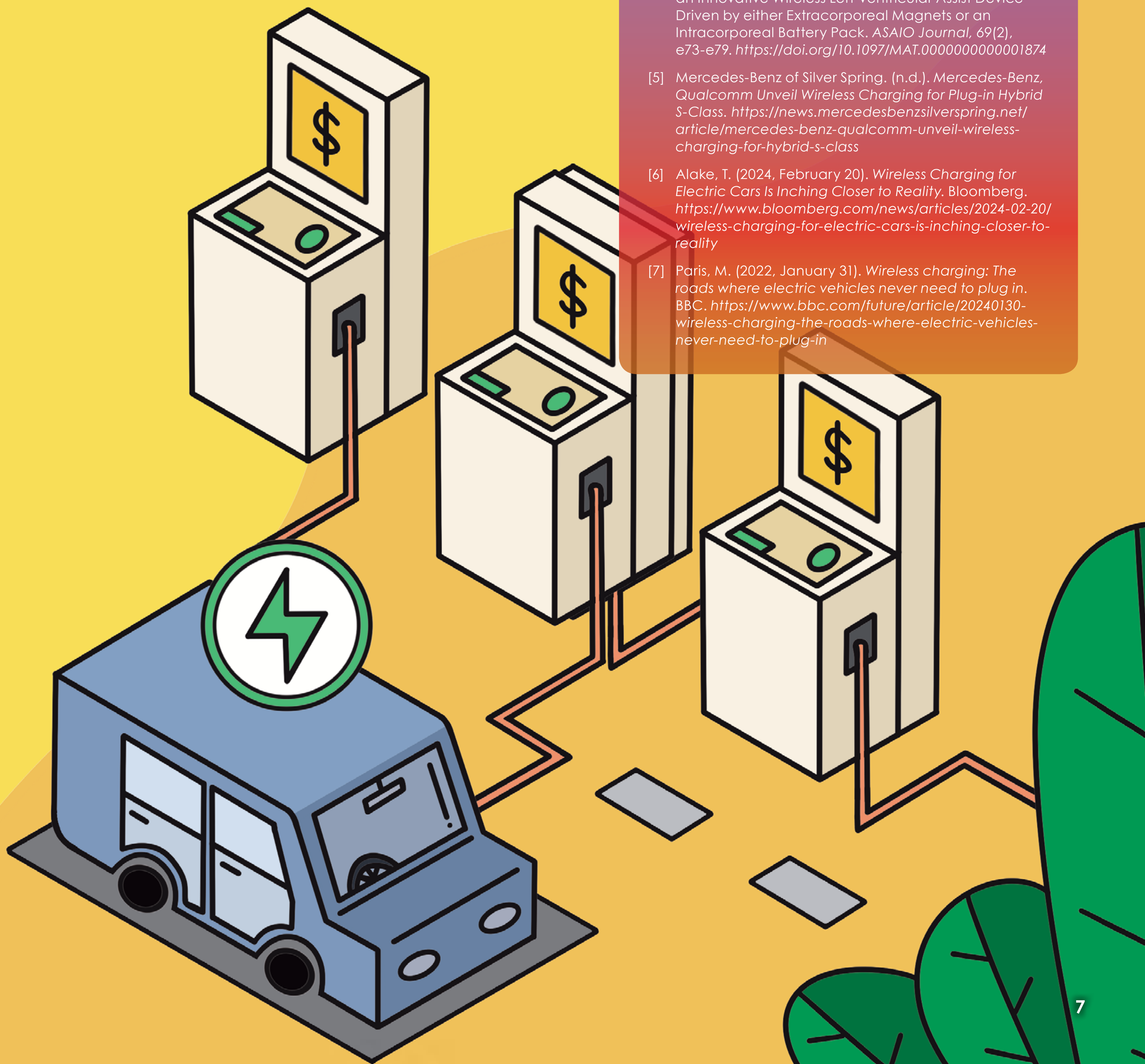
如果我們利用這個原理，將一個接收線圈安裝到我們想要充電的設備中，這個線圈就會接收到不斷變化的磁場，並產生電動勢，最終感生出電流通過設備。現在我們不就是能無線傳輸電流了嗎？由於智能手機和手錶只能用直流電充電，因此有種稱為整流器的電子零件可以透過限制電流方向，將感生而來的交流電轉換成直流電。

許多人可能不知道，無線充電並不僅被用於手機充電，研究人員亦一直尋求為醫療儀器無線供電的方案。理論上，磁場可以穿透皮膚並感生電流為已植入體內的儀器充電 [1]。這個原理未來可能會帶來革命性的改變，讓使用心臟起搏器的患者不再需要接受重複手術以更換電池 [2]，亦能使植入左心室輔助裝置（供末期心臟衰竭患者用的機械泵）的患者不再需要透過皮下導線供電，從而避免相關感染風險 [3]。然而，在應用無線充電技術的醫療儀器商品化之前，設計人員仍需克服一些技術挑戰，例如線圈之間的錯位問題和高功率傳輸造成的燒傷等 [2, 4]。

無線充電系統亦可能是電動車的未來方向。平治（Mercedez-Benz）早在 2017 年就已經為旗下一款汽車型號提供無線充電選項 [5]；最近電動車公司的領頭羊特斯拉（Tesla）也表示對開發自家無線充電技術感興趣 [6]。可是，建設基礎設施對推廣無線充電至關重要，例如設立更多設置充電板的充電站等，這某程度上解釋了汽車製造商普遍不願意將無線技術納入其產品的原因 [6]。這是個「先有雞還是先有蛋」的問題：驅使汽車公司投放資源於發展無線技術的誘因是電動車的需求，但目前這一需求又受制於公共充電設施的普及性。

儘管技術離發展成熟還有一段距離，但工程師們已經在城市規劃方面構想出一些具前瞻性的新穎想法。底特律就建造了美國第一條無線充電道路進行試點測試 [7]，在道路下方安裝了電磁線圈。當車輛駛過這條 400 米長的道路時，車輛電池就能夠進行感應充電。這方案有望在未來被用於延長電動車的續航力。

這只是無線充電在未來可行應用的數例。為了讓技術變得更智能和實用，開發者肩負起讓我們生活變得不受拘束的責任。從家居應用到高科技產業，越來越多設備走上無線化的道路，接下來的設備又會是哪個呢？



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Peanut Allergies Unshelled:

New Treatment and Preventive Measures

解密花生過敏：

新療法與預防措施

By Roshni Printer

Have you ever felt the craving for a warm peanut butter and condensed milk toast?

While most of us can probably relate, peanut allergy is one of the most common food allergies. It typically develops in early childhood and persist in around 80% of patients for life [1, 2]. In severe cases, life-threatening symptoms can occur after ingestion of even a small trace of peanut. The presence of these traces in everyday meals makes it challenging to avoid accidental ingestion. In the past, "treatment" of peanut allergy was largely limited to complete avoidance. However, recent studies have brought forward ways to prevent as well as manage this common condition: Let's delve into them and crack the peanut allergy!

In 2015, a landmark clinical trial published in the *New England Journal of Medicine* suggested that the introduction of peanuts in the diets of infants at risk could prevent the development of peanut allergy [3]. The mechanism is called desensitization: a treatment to increase the body's tolerance to peanuts by exposing the infant to an increasing amount of peanut antigen, the allergy-causing component in peanuts. Termed "oral immunotherapy," desensitization can modify the developing immune system of infants so that peanuts can be recognized by the body as a safe food instead of a threat.

In May 2017, after taking recent evidence into consideration, the United States National Institute of Allergy and Infectious Diseases (NIAID) recommended early introduction of peanuts to infants at risk, especially to those aged four to six months with severe eczema and/or egg allergy [4]. Preliminary immunological test should be conducted to infants with severe eczema and/or egg allergy to ensure safety and to determine the preferred method of the administration of dietary peanut. However, their recommendation for infants who had already been identified as allergic was avoidance.

In 2023, further data from a new study urged the promotion of this preventive intervention to the general population [5]. Compared to the marginal reduction of 4.6% by targeting only the highest-risk infants with severe eczema, extending the scope to all infants could lower the prevalence by 77%. The study also showed that the older a child grows, the less effective the intervention would become. This could explain the ten-fold lower rate of peanut allergy in the children in Israel, where peanut is frequently fed to infants in large quantities as snacks, when compared to the UK [6]. This prompted the National Health Service (NHS) of the UK to recommend introducing crushed or ground peanuts, or peanut butter to infants from the age of six months, after the infant is ready to ingest solid foods [7, 8].

The breakthroughs in the study of peanut allergy also came with the development of Palforzia, a novel drug for young patients already diagnosed with peanut allergy. Targeting patients aged from four to 17 years old, this drug was approved by the US Food and Drug Administration (FDA) in January 2020 [9]. It contains peanut allergens in powder form which can be ingested with a soft food [10]. By gradually escalating the dose until a limit is found, the patient can build up tolerance to small amounts of peanut protein. After the up-dosing stage, the patient will need to take a maintenance dose every day for the treatment to remain effective. This fact, combined with the high cost and the requirement of biweekly visits to doctors in the first six months of the treatment discouraged the widespread use by patients, especially during the pandemic shortly after its launch. These limitations eventually led to Palforzia's flop in sales – showing us how a medical breakthrough does not necessarily lead to a successful business [10, 11]!

The study of peanut allergy highlights the tentative nature of science – scientific theories are subject to change when new evidence arises. Therefore, it is crucial to be open-minded and keep abreast of the latest developments in scientific research. Before you share this article to those with peanut allergy, please make sure they understand that any attempt on the new therapeutic strategies should be closely supervised by medical professionals.

你試過突然想吃熱烘烘的花生醬煉乳多士嗎？

雖然我們大多數人都會有共鳴，但花生過敏是最常見的食物過敏之一。它通常從幼兒期開始出現，過敏情況在約八成患者中會持續終生 [1, 2]。在嚴重個案中，即使攝入微量花生也能導致危及生命的症狀，然而花生的蹤影在日常膳食中可謂無處不在，使過敏者難以完全避免攝入花生。在過去，花生過敏的「治療方法」僅限於避免進食花生，但近年研究提出了預防和減輕這種常見過敏的方法。讓我們深入了解，並嘗試破解花生過敏的難題吧！

2015 年，《新英格蘭醫學雜誌》（*New England Journal of Medicine*）發表了突破性的臨床試驗結果，指出在高風險嬰兒的膳食中加入花生有助預防花生過敏 [3]。當中原理稱為「脫敏法」（desensitization）：透過讓嬰兒攝取分量逐漸增加的花生抗原（花生的致敏成分），從而提高身體對花生的接受程度。這種被稱為「口服免疫療法」的脫敏治療能引導嬰兒發展中的免疫系統，使其將花生識別為可信賴的安全食物而非外來威脅。

2017 年 5 月，在考慮到最新證據後，美國國家過敏及傳染病研究所（United States National Institute of Allergy and Infectious Diseases / NIAID）建議在高風險嬰兒（四至六個月大患有嚴重濕疹或（及）雞蛋過敏）的膳食中引入花生 [4]，但此前應先進行初步免疫學測驗，以策安全並找出處方花生的最佳方法。儘管如此，研究所對已確診花生過敏兒的建議仍然是避免攝取花生。

2023 年，來自另一項研究的進一步數據建議將預防措施推廣至所有嬰兒 [5]。與僅針對患有嚴重濕疹的高風險嬰兒能帶來的 4.6% 些微減少相比，將範圍擴大到所有嬰兒能將花生過敏的患病率降低 77%。研究還指出措施成效會隨孩子年齡增長而減低。這些結果或許能解釋以色列兒童的花生過敏率比英國低十倍的原因，因為以色列家長會餵嬰兒進食大量含花生的零食 [6]。這促使英國國民保健署（National Health Service / NHS）建議從六個月起及在嬰兒能進食固體食物後，就應在其膳食中加入磨碎的花生或花生醬 [7, 8]。

花生過敏研究上的突破還促使一種新型藥物 Palforzia 的發展，這種藥物的對象是已被診斷為花生過敏的年輕患者。該藥物針對四至 17 歲的患者，於 2020 年 1 月獲美國食品藥物管理局（US Food and Drug Administration / FDA）批准使用 [9]。Palforzia 是含有花生過敏原的粉末，可混入流質食物進食 [10]。透過逐漸增加劑量直至找到上限，患者對花生蛋白的接受程度亦會漸漸增加，使其能接受少量花生。在增加劑量的階段完結後，患者需要每天服用維持劑量以維持療程效力。然而這一點，加上高昂的費用和療程首六個月每兩週就需要就診一次的要求成為了 Palforzia 未能普及的原因，尤其在推出後不久就爆發了新冠疫情，令銷情雪上加霜。這些缺點最終導致 Palforzia 銷情慘淡，因此故事告訴我們醫學上的突破未必等於商業上的成功 [10, 11]！

花生過敏的研究帶出了科學的暫時性 — 當新證據出現時，科學理論就會隨之變化。因此，保持開放和與時並進的心態至關重要。在你分享這篇文章給花生過敏者前，請確保他們明瞭任何新療法都應在專業醫療人員的密切監督下進行。

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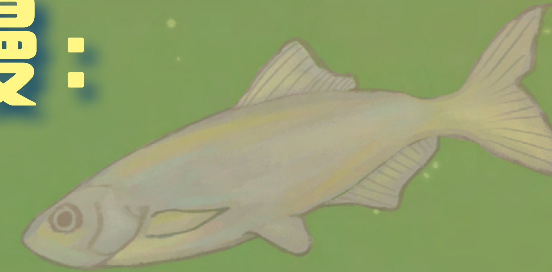
Electric Eels 電鰻：

Shock You in More Than One Way 水中的多重震撼



By Daria Zaitseva

In 1800, the Italian scientist Alessandro Volta drew inspiration from the electric eel to create the first ever battery [1, 2]. Despite their name, electric eels are not true eels but share a striking resemblance [2]. These fascinating fresh-water knifefish possess a unique ability to discharge electricity, which can stun or even kill some animals. But how does it work?

First, we should understand the concept of electric current, which is the flow of charged particles like electrons and ions. The difference in charges between two points generate a potential difference which results in a discharge when the circuit is complete, with the electric current inversely proportional to the resistance of the circuit.

In the nervous system of living organisms, signals are transmitted in the form of electrical impulses. Similar to how a battery has positive and negative terminals, our neurons actively maintain different ion concentrations across the cell membrane, resulting in a potential difference inside and outside the cell. By opening and closing the ion channels in the plasma membrane in an ordered fashion, ions are allowed to flow across the membrane down the concentration gradient. The flow of ions eventually generates a pulse of current that relays a message across a nerve.

Electric eels took it further. Up to 80% of their body consists of specialized organs involved in electricity generation [3]. The three organs, known as Sach's, Hunter's, and the main organ, are composed of modified flattened muscle cells called electrocytes. These tiny batteries are connected both in series and in parallel so the voltage and current add up respectively. When electrocytes receive a command to discharge, in the form of nerve signals, sodium channels in the plasma membrane will open, causing a flood of sodium ions (Na^+) into the cells. This results in the accumulation of positive charges within the stacks of electrocytes, turning the entire body of the electric eel into one long battery, with a positive end at the fish's head and a negative end at the tail. The voltage of this living battery can reach up to 600 V [1], which is almost three times of Hong Kong's standard electrical voltage!

To compensate for their weak eyesight, electric eels also set up low-voltage electric field to gauge their surroundings [4]. This feature enables them to live and hunt in the murky, slow-moving pools and swamps of the Amazon and Orinoco rivers of northern South America [2]. When an obstacle, prey, or a predator

comes close, the fish's electric field is disrupted. Even a tiny distortion, possibly as small as a microvolt per centimeter (10^{-6} V/cm) [4], can be detected by the electroreceptors distributed throughout the fish's body, alarming the knifefish.

Once the fish detects an object that resembles prey, it will enter a typical attack mode [5, 6]. It will first generate a doublet of high-voltage electric discharges which can cause a powerful involuntary twitch in the hidden prey. The ripples generated can be sensed by the knifefish and reveal the location of the prey. Then the fish will fire a volley of high-voltage pulses to paralyze the prey and then swallow it. To give an even harder shock, the electric eel sometimes seizes their prey in its mouth and curls its body to bring the prey closer to the tail, so that the prey can experience a much stronger electric field [5].

This fascinating ability comes with a mystery: How does a knifefish avoid shocking itself? A theory states that the relatively large size of electric eels (they can reach 2.5 meters in length!) helps them withstand the current that is unbearable to their much smaller prey [7, 8]. Meanwhile, the insulating fat layers surrounding the electric organs [8] and the dissipation of current into water [7] protect the fish's central nervous system and heart from being directly shocked by the strong current they just produce. Yet, there is indeed much more to be studied and discovered.

在 1800 年，意大利科學家 Alessandro Volta 受電鰻的啟發，創造了第一顆電池 [1, 2]。雖然名字中有個「鰻」字，但電鰻在分類上並不屬於鰻魚的一種 [2]，儘管兩者外形非常相似。這些有趣的淡水刀魚擁有獨特的放電能力，能使其他動物暈眩甚至死亡。到底箇中原理是甚麼呢？

首先，我們須了解電流這個概念，就是帶電粒子（例如電子或離子）的流動。兩點之間的電荷差異產生電勢差，當電路接通時就會導致放電現象，當中電流大小與電路的電阻成反比。

在生物的神經系統中，信號是以電脈衝的形式傳遞。類似於電池有正負極，我們的神經元會主動地維持細胞膜兩邊離子的不同濃度，使細胞內外有著電勢差。透過有秩序地開關細胞膜中的離子通道，離子就可以順濃度梯度穿越細胞膜。離子的流動最終產生一波電脈衝，將信息從神經一端傳遞至另一端。

然而電鰻將生物放電的潛能發揮到極致。牠們身體八成均由與放電相關的特化器官組成 [3]，這三個器官分別是石赫氏器官（Sach's organ）、亨特氏器官（Hunter's organ）和主器官（main organ），由稱為「發電細胞」的特化扁平肌肉細胞組成。這些微小的電池同時以串聯和並聯方式連接，分別使電壓和電流得以累加。當發電細胞接收到指示它們放電的神經信號時，細胞膜中的鈉通道會打開，使鈉離子（Na^+）湧入細胞。這使一群群堆疊的發電細胞內部積聚大量正電荷，將電鰻身體變成一條長長的電池 — 魚的頭部為正極，尾部為負極。這塊「活電池」的電壓可以高達 600 伏特 [1]，幾乎是香港標準電壓的三倍！

為了彌補視力上的不足，電鰻還能透過設置低電壓的電場以探測周圍環境 [4]，使牠們能在南美洲北部亞馬遜河和奧里諾高河一帶混濁的死水和沼澤中生活和捕獵 [2]。當障礙物、獵物或捕食者靠近時，魚的電場會受到干擾；而即使是細小至每厘米一微伏（10^{-6} V/cm）[4] 的電場扭曲，也能被散佈在電鰻身體上的電感受器偵測到，使電鰻能察覺四周。

一旦電鰻偵測到類似獵物的物體，就會進入典型的攻擊模式 [5, 6]。電鰻首先會以高電壓連續兩下放電，使躲藏的獵物不自主地強烈抽搐。泛起的漣漪能被電鰻感知，從而揭示獵物的位置。然後電鰻會以一連串高壓脈衝掃射獵物，使其麻痺再把其吞下。有時為了施以更強烈的電擊，電鰻會用口叼住獵物並捲曲身體，將獵物拉近尾部，把獵物扯進更強烈的電場 [5]。

這驚人能力背後還有一個不解謎團：電鰻如何在放電中保護自己免受電擊？有理論認為電鰻相對較大的體型（可達 2.5 米長！）能幫助牠們承受細小獵物無法忍受的電流 [7, 8]。與此同時，包圍著放電器官的絕緣脂肪層 [8] 和在水中散失的一部分電流 [7] 保護了電鰻的中樞神經系統和心臟，避免其受自己發出的強大電流直接衝擊。儘管如此，關於電鰻，確實還有許多東西需要進一步研究和發現。

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How to Regain Your Sleep from Your Smartphone?

如何從智能手機搶回睡眠時間？

By Jane Yang 楊靜悠

In our modern, hyper-connected world, smartphones have become ubiquitous companions for many of us. However, the convenience and allure of these devices may come at a cost, particularly when it comes to our sleep habits. Do you find yourself habitually reaching for your smartphone as you wind down for the night, only to find yourself hours later still scrolling through endless social media feeds or watching video after video? If so, you're not alone. Let's explore the impact of bedtime smartphone use on our circadian rhythms — the body's internal clock that controls our sleep-and-wake cycles. Toward the end, we will provide some insights on how to regain a restful sleep.

Blue Light from Electronic Screens

Modern electronic screens, from smartphones to computer monitors, utilize the RGB color model to display a wide range of hues. This method relies on mixing varying intensities of the three primary colors — red, green, and blue. However, what many don't realize is that blue light has a profound impact on our circadian rhythms [1, 2].

Melatonin-Suppressing Effect of Blue Light

Our body's biological clock needs to be calibrated every day, so that our behavior and physiology can optimally adapt to the external day-night cycle [3]. Sunlight is composed of light waves of all the visible colors, of which retinal ganglion cells have been shown to play a key role in detecting blue light to synchronize our circadian rhythms [4]. Retinal ganglion cells are photoreceptors that do not contribute to our visual perception. However, in response to blue light, they will send signals to the suprachiasmatic nucleus (SCN) — a structure located in the anterior part of the hypothalamus [5] — to tell the brain that it is daytime. The SCN then regulates the release of melatonin by the pineal gland — stimulation in darkness and suppression in light — to modulate internal biological events, such as sleep-wake cycles and some energy metabolism functions (e.g. glycogen synthesis and daily phase of high insulin sensitivity) [6]. The blue light exposure in the evening hours, therefore, confuses our brain and disrupts our sleep-wake cycles, making us difficult to fall asleep.

The mechanism by which blue light from electronic screens disrupts our circadian rhythms is similar to jet lag. When we traverse multiple time zones, our internal clocks struggle to immediately adjust to the new daylight pattern of the destination. This mismatch between our body's internal clock and the local time confuses our body, leading to symptoms like fatigue and difficulty sleeping.

How to Resynchronize the Clocks?

So, what can we do to stay away from the negative effects of blue light? Many smartphones nowadays have eye protection mode and dark mode [7]. After switching to eye protection mode, the screen will turn yellowish because some of the blue light is filtered, so the red and green lights, which add up to yellow, become more prominent. Alternatively, dark mode features white text against a black background to minimize our exposure to the blue light in white backgrounds. Turning on these modes before sleep can reduce the melatonin-suppressing effect of blue light, potentially leading to a better sleep.

But these are just some long-term measures. What if I have an important event the following day but find myself unable to sleep due to the recent late-night use of smartphone? And what if I am suffering from jet lag? You can try taking melatonin as an emergency remedy under the instructions provided with the medicine or by your doctor [8, 9]. Taking melatonin two hours before the desired bedtime can promote sleep by putting you into a state of quiet wakefulness [8]. However, it is important to note that the effectiveness of melatonin can vary significantly between individuals [9]. We should always seek professional medical advice when in doubt.

After all, the best way to avoid blue light-induced insomnia and drowsiness at work or school is to stick to a healthy and responsible sleep routine, minimizing screen time in the hours before bed.

在現今高度互聯的世界中，智能手機已成為我們無處不在的搭檔。然而，尤其是在睡眠習慣方面，這些設備帶來的便利和誘惑卻可能叫我們付出沉重的代價。您有否發現自己在晚上休息時習慣性地拿起手機，數小時後仍在瀏覽社交媒體或觀看一條又一條的影片？如果你也是這樣，不用怕，你絕不是少數。讓我們探討睡前使用智能手機如何影響我們的晝夜節律，亦即是身體控制睡眠和覺醒週期的內部時鐘。最後，我們將提供一些重拾優質睡眠的方法。

電子螢幕發出的藍光

從智能手機到電腦顯示器，現代電子螢幕利用 RGB 顏色模型顯示不同顏色，這個方法透過混合不同強度紅、綠、藍三種原色的光來產生各種顏色。可是，許多人沒有意識到藍光會影響我們的晝夜節律 [1, 2]。

藍光抑制褪黑激素的作用

我們需要每天校準我們身體的生理時鐘，才能使我們的行為和生理適應外間的晝夜週期 [3]。陽光由所有可見顏色的光波組成，科學家已證明視網膜神經節細胞能透過偵測當中的藍光使我們的晝夜節律得以與外間同步 [4]。視網膜神經節細胞是一些沒有參與視覺形成的感光細胞，但它們在偵測到藍光後會向位於下丘腦前端的視交叉上核發送訊號 [5]，告訴大腦現在是白天。之後視交叉上核會透過調節機制：在黑暗中刺激松果體釋放褪黑激素，並在日間抑制褪黑激素的釋放，以調控體內的生理活動，例如睡眠覺醒週期和一些能量代謝活動（例如糖原合成和每日一次的胰島素高敏感度期）[6]。因此，晚間的藍光會使我們大腦誤以為現在是白晝，進而擾亂我們的睡眠覺醒週期，使我們難以入睡。

電子螢幕發出的藍光擾亂我們晝夜節律的機制類似於時差反應，在我們穿越多個時區後，我們的生理時鐘難以立即適應目的地的日照模式，生理時鐘與當地時間之間的不匹配使我們身體感到困惑，導致疲勞及難以進睡等症狀。

如何重新調較生理時鐘？

那麼，我們該怎樣做才能遠離藍光的負面影響呢？現在很多智能手機都有護眼模式和深色模式 [7]。切換到護眼模式後，螢幕顏色會因為部分藍光被過濾掉而變得偏黃，這是由於紅綠光加起來會變成黃光的緣故，使黃色更加突出。另一方面，深色模式是透過在黑色背景上顯示白色文字，避免我們接觸白色背景中的強烈藍光。在睡前打開這些模式能減少由藍光抑制褪黑激素所帶來的負面影響，有助我們進入更優質的睡眠。

但這些只是一些較長遠的方案，如果我明天就有一個重要活動，但發現自己因深夜使用智能手機而無法入睡，該怎麼辦？又或是說如果我正受時差反應所困擾呢？你可以嘗試按照包裝上的說明或醫生指示服用褪黑激素作為緊急補救措施 [8, 9]。在理想就寢時間前兩小時服用褪黑激素可以讓您進入寧靜的清醒狀態 [8]，有助睡眠。儘管如此，褪黑激素的效用因人而異 [9]。如有任何疑問，應尋求專業的醫療建議。

避免藍光導致的失眠及減少工作和上學時睡意的最佳方法，終究都是維持一個健康而有規律的睡眠習慣，並在睡覺前遠離螢幕！

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SCIENCE BEHIND AURORAS 極光的科學

By Minnie Soo 蘇慧音

Watching the light show of nature – auroras – may be on the bucket list of many people. The vibrant, magical colors were known to be mesmerizing, with green and red hues flickering and flowing gracefully like a river in the sky. This majestic natural phenomenon is particularly treasured by those of us who reside far from the poles, but have you ever wondered why do auroras mainly occur in polar regions? What is the science behind auroras? Taking a step back from the poetic imagination about auroras, you will find the formation process hardly as graceful as you might think, and underneath this beauty, lies a cascade of energetically violent events.

Solar Magnetic Field and Solar Wind

The Sun, like most stars, is a hot, fiery ball of plasma. Plasma is the fourth state of matter similar to gas, but with most of the particles ionized and moving at spectacular speeds [1]. Due to the extremely high temperature of the Sun, some particles possess sufficient kinetic energy to escape the Sun's gravity [2]. This stream of charged ions and electrons ejected from the Sun's surface forms what is known as the solar wind.

The flow of these fast-moving charged particles are electric currents by definition, leading to the formation of the strong, chaotic magnetic field of the Sun (Footnote 1). The solar wind also filled the solar system with a magnetic field known as the heliospheric magnetic field or interplanetary magnetic field [3]. As visualized by imaginary magnetic field lines, some of the lines form closed loops with the Sun, while others extend far out into the solar system (Figure 1) [4].

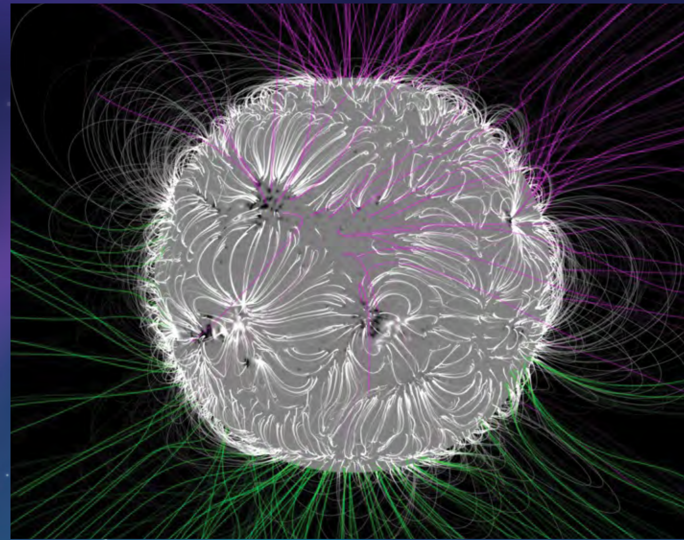


Figure 1 The solar magnetic field. White magnetic field lines are considered "closed", while magenta and green lines are "open" field lines extending far out into the solar system with opposite magnetic polarities [4].

Photo credit: NASA's Scientific Visualization Studio

The Earth originally possesses a toroidal (donut-shaped) magnetic field. However, due to the constant bombardment of the solar wind, the magnetic field lines on the side facing the Sun was squeezed and pushed, while the magnetic field lines on the opposite side was stretched into a long, tail-like shape (Figure 2) [3]. This dynamic interaction gives Earth's overall magnetic field a comet-like appearance. When the solar wind reaches the Earth, the charged particles are deflected by the Earth's magnetic field, so we are shielded from the bombardment of those harmful particles [3].

band stores elastic potential energy. When the two fields come so close that the reconnection finally occurs, the original field lines would break up and reconnect to form a new configuration. Like suddenly letting go of the stretched rubber band, the magnetic field releases a tremendous amount of energy, accelerating the plasma particles to extremely high speeds.

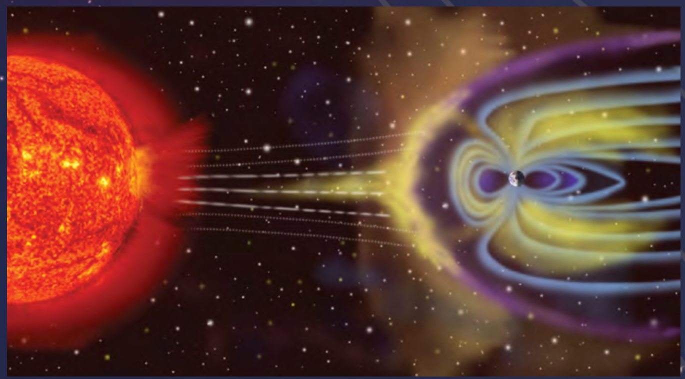


Figure 2 Artistic representation of the deflection of solar wind (greenish yellow) by the Earth's magnetic field (blue lines). The dayside (the side facing the Sun) of the Earth's magnetic field is compressed, while the nightside is elongated into a tail [5].

Photo credit: NASA

Magnetic Reconnection

When the Sun's magnetic field overlaps and interacts with that of the Earth, their field lines can align in different ways [6]. Imagine pushing two magnets with the same poles against each other with tremendous force. What will happen when the oppositely pointing field lines approach each other?

Based on the idea known as "magnetic reconnection", suggested by the Australian physicist Ronald Giovanelli in 1946, scientists discovered that misaligned magnetic fields could cause the field lines to break apart and reconnect in a whole new configuration [7, 8].

Before the reconnection occurs, as the solar wind permeated with the Sun's magnetic field approaches the Earth, our planet's magnetic field will be twisted, building up magnetic energy just as a stretched rubber band stores elastic potential energy. When the two fields come so close that the reconnection finally occurs, the original field lines would break up and reconnect to form a new configuration. Like suddenly letting go of the stretched rubber band, the magnetic field releases a tremendous amount of energy, accelerating the plasma particles to extremely high speeds.

Due to magnetic forces, the plasma particles travel toward the poles in helical motion along the magnetic field lines, and mirror back at the poles. They therefore bounce between the poles and are trapped in regions known as the Van Allen Radiation Belts [3, 9–11]. At the poles are two holes of the Earth's donut-shaped magnetic field, called the polar cusps, where the charged particles will be funneled downward (Figure 3) [12]. While most particles will be mirrored back at the poles, some highly energized particles will leak out of the magnetic field through the cusps and interact with molecules in the upper atmosphere of the Earth [9].

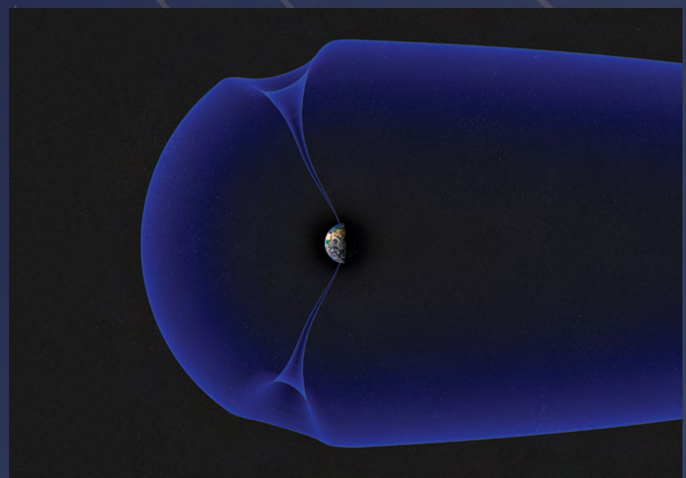


Figure 3 The Earth's donut-shaped magnetic field with the northern and southern polar cusps where the plasma particles are funneled downward toward the poles. [13].

Photo credit: Andøya Space Center/Trond Abrahamsen

Electron Transition and Aurora Colors

The plasma particles that have arrived at the poles can then interact with the gas particles present in the second-highest layer of Earth's atmosphere known as the thermosphere [3, 14]. While the lower part of the thermosphere is primarily composed of molecular nitrogen (N_2) and molecular oxygen (O_2), the upper part is dominated by monoatomic oxygen (O). Nitrogen and oxygen are crucial to the generation of auroras [3, 15].

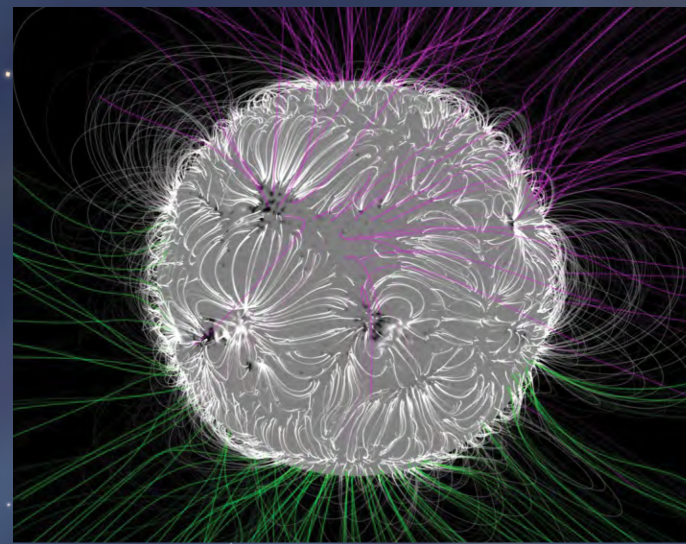
Before delving into the mechanism, it is important to note that electrons in an atom have discrete energy levels, much like the steps on a staircase. You can walk up integer steps such as 1, 2 or 5 steps, but you cannot walk 2.3 steps or anything in between with decimal parts. Electrons can only gain certain fixed amounts of energy to be excited and jump up to specific energy levels (or release some fixed amounts of energy and return to a lower energy state), and not anywhere in between. Each atom has its own unique set of energy levels, just as fingerprints are unique to each of us.

As the plasma particles collide with the gas particles, they excite electrons within the atom. When the electron later drops back to a lower energy level, it releases energy in the form of light whose wavelength is decided by the amount of energy released. The relationship between the released energy E and the wavelength λ of emitted light is represented by the equation $E = \frac{hc}{\lambda}$, where h is the constant known as Planck's constant (6.63×10^{-34} J s) and c represents the speed of light (3.00×10^8 m s^{-1}). We can see that the energy released is inversely proportional to the wavelength, which determines the color of light we perceive.

Atomic oxygen (O) can emit green and red lights at the wavelengths of 558 nm and 630 nm respectively [3, 16]. Molecular nitrogen (N_2), on the other hand, can emit blue and red lights at multiple wavelengths which combine to form a hue of magenta at lower altitudes [3, 17]. Now you see why it matters that the energy levels are discrete: Instead of creating a continuum of all colors, only certain signature colors of auroras exist. They produce the mesmerizing display of the aurora borealis (northern lights) and aurora australis (southern lights).

1. Editor's note: By Ampere's law, an electric current always generates a magnetic field with a strength proportional to the current.

不少人的願望清單裡大概都有一項是觀賞極光 — 大自然的光影表演。那艷麗的幻彩令許多人為之著迷，當中紅、綠色兩種色調在空中搖曳，宛如河流般優雅地流淌。這種壯麗的自然現象尤其受我們這些居住在遠離兩極的人所珍視，但你有沒有想過為甚麼極光主要在極地出現？極光背後的科學原理又是甚麼呢？讓我們從對極光的詩意幻想中抽離，你會發現極光的形成過程並不如想像中婉約，美麗背後竟隱藏著一連串高能量的猛烈反應！



圖一 太陽磁場。白色是「閉合」的磁場線；而洋紅色和綠色則是各具相反磁極的「開放」磁場線，它們延伸到太陽系的遠處 [4]。

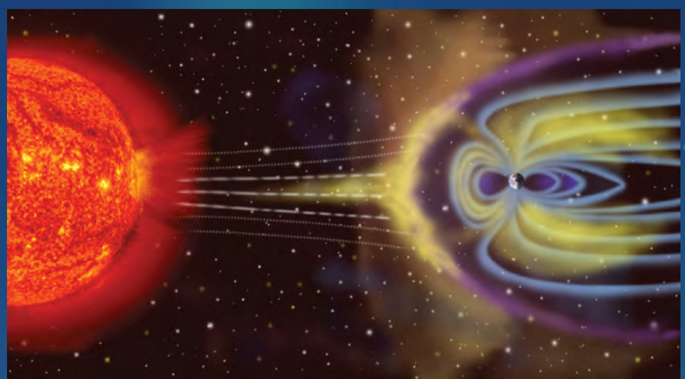
圖片來源：NASA's Scientific Visualization Studio

太陽磁場和太陽風

太陽和大多數恆星都是炙熱火紅的等離子球。等離子體是物質的第四種狀態，類似於氣體，但當中大部分粒子都已經離子化，並以極高速移動 [1]。由於太陽溫度極高，所以當中一些粒子擁有足夠的動能逃離太陽引力 [2]，這些從太陽表面噴發出的帶電離子和電子形成了太陽風。

這些高速流動的帶電粒子顧名思義就是電流，它們構成了太陽強力而混亂的磁場（註一）。太陽風使太陽系被太陽圈磁場（heliospheric magnetic field，又稱為行星際磁場，即 interplanetary magnetic field）覆蓋 [3]。正如假想的磁場線所示，有些磁場線在太陽內形成閉合的迴圈，有些則延伸到太陽系的遠處（圖一）[4]。

地球原本擁有環狀（toroidal，即甜甜圈狀）的磁場，可是在太陽風的猛烈轟擊下，令面對太陽一方的磁場線受到擠壓，而另一側的磁場線則被拉長成尾狀（圖二）[3]。這種動態的拉鋸讓地球的整體磁場呈彗星狀的外觀。當太陽風抵達地球時，地球磁場會使帶電粒子轉向，保護我們免受這些有害粒子的侵襲 [3]。

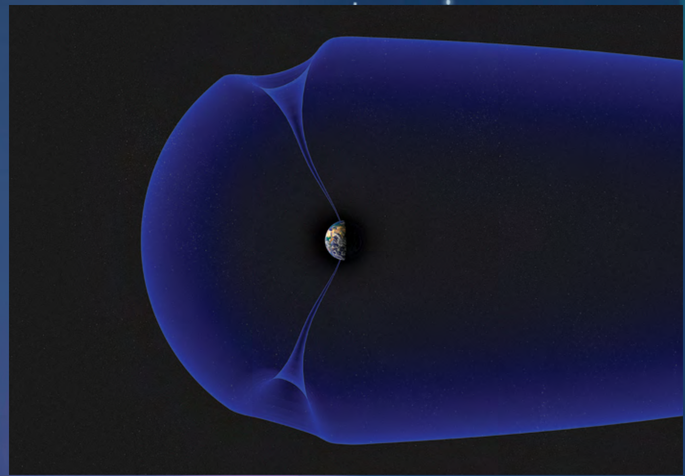


圖二 地球磁場（藍線）使太陽風（綠黃）偏轉的示意圖。地球磁場的晝側（面對太陽的一側）被壓縮，而夜側被拉長成尾狀 [5]。

圖片來源：NASA

磁重聯

當太陽磁場與地球磁場重疊並互相影響時，兩者的磁場線能以不同方式排列 [6]。試想像當用力將兩塊磁極相同的磁鐵推向對方，相反方向的磁場線互相接近時會發生甚麼事呢？



圖三 地球的甜甜圈狀磁場與南北極尖，等離子粒子會在極尖的漏斗形通道中被引導向下 [13]。

圖片來源：Andøya Space Center/Trond Abrahamsen

基於澳洲物理學家 Ronald Giovanelli 於 1946 年提出的「磁重聯」概念，科學家發現方向不一致的磁場能導致磁場線斷裂後以全新的方式連接 [7, 8]。

在磁重聯發生之前，當帶著太陽磁場的太陽風接近地球時，我們星球的磁場會被扭曲，就像拉長的橡皮筋儲存彈性勢能一樣累積磁能。當兩個磁場靠得太近最終觸發磁重聯時，原來的磁場線會斷裂並以全新方式重新連接。就像突然鬆開拉長了的橡皮筋一樣，磁場會釋放巨大的能量，使等離子粒子加速至極高速度。

在磁力影響下，等離子粒子會沿磁場線以螺旋運動的方式向兩極移動，並從兩極反射回來。因此它們會在兩極間穿梭，困在被稱為 Van Allen 輻射帶（Van Allen Radiation Belts）的區域 [3, 9–11]。兩極正是地球甜甜圈狀磁場兩個洞的所在位置，稱為極尖，帶電粒子循著這個漏斗形通道被引導向下（圖三）[12]。雖然大部分粒子都會在兩極被反射回去，但有些高能量粒子會透過極尖從磁場漏走，並與地球上層大氣中的分子產生作用 [9]。

電子躍遷與極光顏色

抵達兩極的等離子粒子可以與地球大氣層中第二高的熱成層裡的氣體粒子發生作用 [3, 14]。熱成層的底部主要由分子氮（N_2）和分子氧（O_2）組成，而頂部則主要為單原子氧（O）。氮和氧對於極光的形成至關重要 [3, 15]。

在探討極光原理前，我們必須記住原子中的電子就像樓梯一樣具有分立的能級。你可以走上整數的梯級，例如 1、2 或 5 級，但您無法走上 2.3 級或任何整數之間具小數點的梯級。電子只能透過獲取某些固定值的能量，而被激發並躍遷到特定能級（或釋放某些固定值的能量而回到較低能級），而不能停留於介乎兩個能級之間的位置。每個原子都有自己一套獨特的能級，就像我們每個人的指紋一樣都是獨一無二的。

等離子粒子與氣體粒子碰撞時會激發原子內的電子。當電子稍後回到較低能級時，它會以光的形式釋放能量，而光的波長由釋放的能量所決定。釋放的能量 E 與光的波長 λ 之間的關係可以用方程 $E = \frac{hc}{\lambda}$ 表示，當中 h 是普朗克常數（6.63×10^{-34} J s），c 則代表光速（3.00×10^{8} m s^{-1}）。由此可以得知釋放的能量與波長成反比，而波長決定了我們所感知到光的顏色。

原子氧（O）可以發出波長分別為 558 nm 和 630 nm 的綠光和紅光 [3, 16]。另一方面，分子氮（N_2）可發出多個波長的藍光和紅光，它們在較低的海拔高度會形成洋紅色調 [3, 17]。現在你能明白分立能級所帶來的結果：產生的極光顏色並不是一個連續而具有所有顏色的光譜，因此只存在特定顏色的極光。正是這個原理產生令人著迷的北極光（aurora borealis）和南極光（aurora australis）。

1. 編按：根據安培定律，電流會感生與其強度成正比的磁場。

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