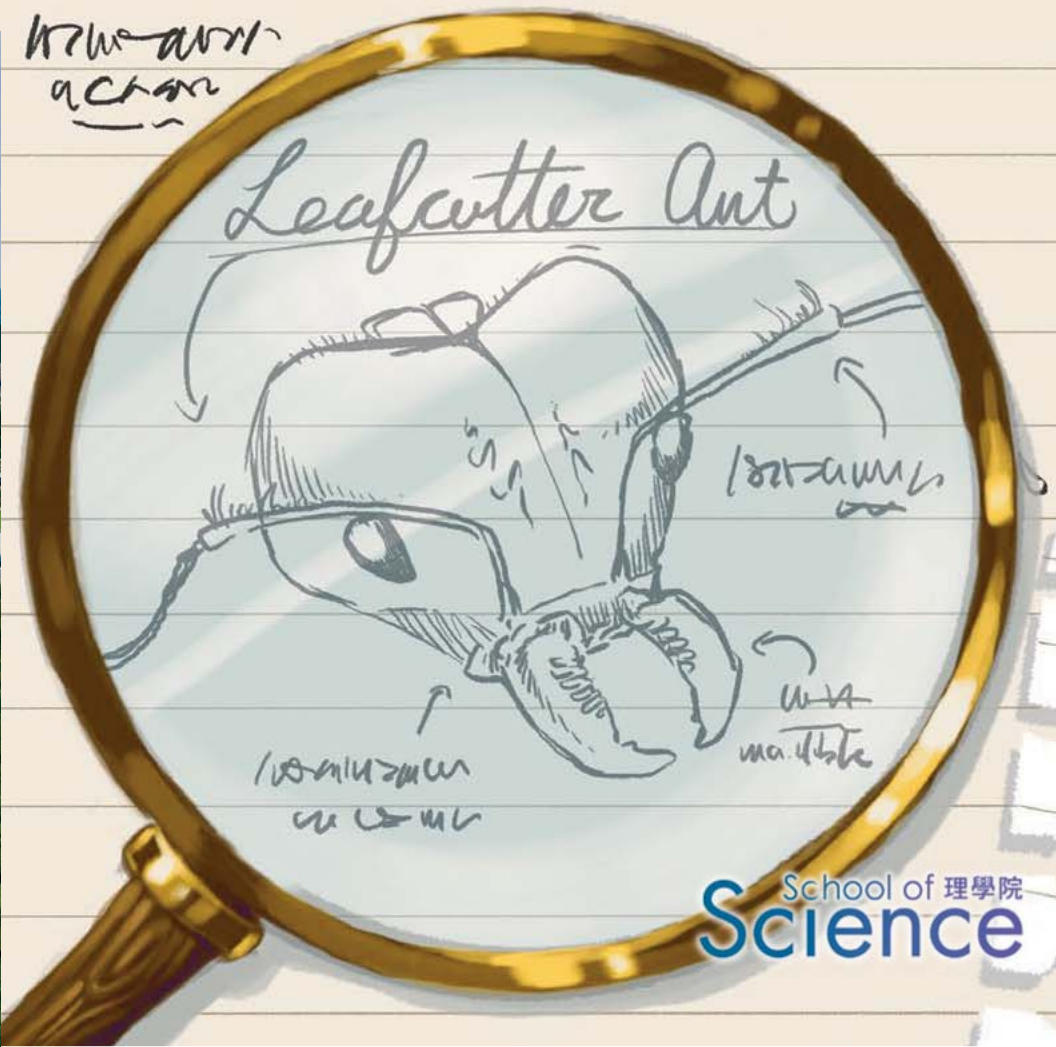
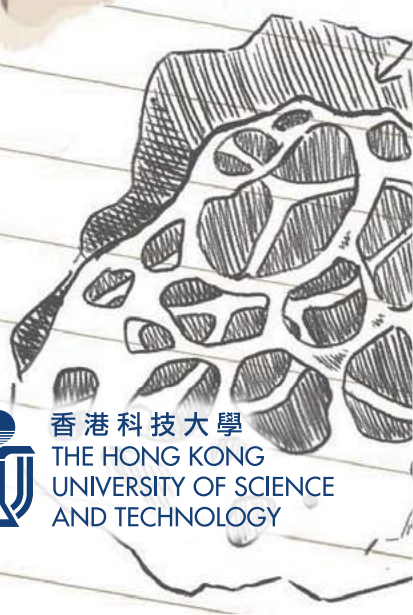
SCIENCE FOCUS 科言

Issue 018, 2020





School of 理學院 Science

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

Contents

Science Focus Issue 018, 2020

Message from the Editor-in-Chief 主編的話

Dear Readers,

After an extended stay-at-home period, I hope you are energized to return to school to resume some aspects of in-person learning. The road ahead remains challenging. For most science subjects, hands-on experiments are indispensable for in-depth learning. With the scaling back of school based assessments for those of you following the HKDSE curriculum, perhaps you will feel less pressured in school laboratories. As a result, I sincerely hope that you will be able to derive more pleasure from performing experiments.

Carefully planned experiments may not always yield expected results. But the courage to persevere can sometimes lead you to ground-breaking discoveries. The story of Barbara McClintock in this issue is an excellent example. The popularization of fiber optics by Charles Kao, further reinforces the idea that communication and cooperation among scientists are vital to turn brilliant ideas into something with lasting impact. Returning to the 21st century, we also bring you the latest on anti-cancer therapies, ice-cream induced headaches, and complex animal behaviors beyond the video game, *Animal Crossing*!

In addition to reading our regular issues, I invite you to visit our Facebook and Instagram pages where we post shorter articles, contributed by our dedicated team of student editors. We would be very pleased to see your comments and suggestions. Last but not least, I wish all of you the very best in the new school year.

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

親愛的讀者：

經過一再延長的在家學習安排後，希望您們能提起精神回到學校，重新展開面對面的學習。前路仍然充滿挑戰。要深入學習理科科目，很多時親身進行實驗都是不可或缺的寶貴經驗。對於修讀文憑試課程的同學，經過精簡的校本評核應該可以減少您進入實驗室時心驚膽顫的情況，希望您們因此更能享受做實驗的樂趣吧。

即使是經過精心策劃的實驗也未必時常會出現預期的結果，但鍥而不捨的勇氣卻有時能引導您作出一些突破性的發現。今期 Barbara McClintock 的故事是一個絕佳的例子，而高錕使光纖普及的故事就提醒了我們科學家之間的交流和合作，往往能把一些絕妙的想法轉化成對我們影響深遠的知識或發明。回到 21 世紀，我們會向您介紹抗癌療法的最新資訊、雪糕頭痛，以及從《動物森友會》延伸開去，探討一下動物的複雜行為。

除了閱讀我們的定期刊物外，我誠邀您瀏覽我們的 Facebook 和 Instagram 專頁，那裡上載了由我們學生編輯團隊所準備的短篇文章；我們亦非常樂意聆聽您的意見和建議。最後，祝您們在新學年一切順利。

主編 麥晧怡教授
敬上

E-mail: **sciencefocus@ust.hk**
Homepage: **http://sciencefocus.ust.hk**

Cover Design – The Fascinating World of Animal Behavior
封面設計 — 集合啦！超乎想像的動物行為學

The fungus garden of leaf-cutter ants 切葉蟻的真菌花園
Photo credit 相片來源: Austin Lynch

Inspired by the article *The Fascinating World of Animal Behavior* in this issue (P.22–25), the cover shows an elephant's trunk (upper right), a leaf-cutter ant (left) and the fungus garden of leaf-cutter ants (bottom right). In fact, animals behave in a way that is more complicated than we might think – they grow crops, perform complex courtship rituals, and mourn for their deceased family members. From this point of view, the anthropomorphic animal villagers in *Animal Crossing: New Horizons* don't actually sound that far-fetched...

取材自今期文章〈集合啦！超乎想像的動物行為學〉(第 22–25 頁)，封面展示的是象鼻 (右上)、切葉蟻 (左) 和切葉蟻的真菌花園 (右下)。動物行為其實比我們想像中複雜：牠們會種植農作物、進行複雜的求偶儀式，也會哀悼死去的家庭成員。由此可見，《集合啦！動物森友會》中以擬人形式登場的動物村民其實並不是完全天馬行空.....

What's Happening in Hong Kong? 香港科技活動

Are you bored of staying at home? You can have some fun in the following astronomical event. Stay safe and healthy!
你對足不出戶的日子厭倦了嗎？我們挑選了以下的天文現象讓你觀賞，安全和健康第一！

GEMINID METEOR SHOWER — DECEMBER 13–14, 2020

This year, the Geminids are expected to peak on the night between December 13 (Sun) and December 14 (Mon), and the best observation time will be around 03:00. You may also try the nights before or after. Theoretically, there could be up to 150 meteors per hour (subject to light pollution level, weather conditions, etc.). The Moon will be in a new moon phase so the moonlight won't affect our observation.

Q: Will there be an outburst like a fireworks display?

A: No, probably not. Sorry to disappoint you, but it won't be anything like the Japanese animation, *Your Name*. There may only be 20–30 meteors visible per hour even under ideal conditions, according to the Hong Kong Space Museum.

Q: What does a meteor shower look like?

A: The meteors appear to radiate from a point in the sky, called "radiant". The radiant this time is located within the constellation Gemini, so the meteor shower is named Geminids. We can observe the meteors more easily as the radiant moves towards the zenith, because they won't be blocked by the objects or haze near the horizon. But you don't have to stare at the radiant because the meteors will probably appear everywhere in the sky.

雙子座流星雨 — 2020年12月13至14日

今年雙子座流星雨的高峰期預計是 12 月 13 日 (日) 晚上至 12 月 14 日 (一) 凌晨，最佳觀賞時間是上午三時左右，你亦可以嘗試於前後一晚觀賞。理論上，每小時預計最多會有約 150 顆流星在夜空劃過 (亦受光害、天氣等因素影響)。當晚的月相是新月 (農曆三十)，因此觀測不會受月光影響。

問： 這次流星雨會不會像煙花匯演一樣如雨落下？

答： 恐怕不會，那大概只是日本動畫《你的名字》裡面的情景。香港太空館指出，即使在理想情況下，每小時也可能只有 20–30 顆可見的流星。

問： 流星雨看起來是怎樣的？

答： 流星會看似從天空上的一點從外散發，該點稱為「輻射點」。由於這次流星雨的輻射點位處於雙子座內，因此被命名為「雙子座流星雨」。隨著輻射點移向天頂，我們將能更容易觀測到流星，因為它們不再受地平線的物體或煙霞阻擋；但你亦不用只盯著輻射點，因為流星應該會在整個夜空出現。

Jumping Genes:

Barbara McClintock and Transposable DNA Elements

跳躍的基因：Barbara McClintock與DNA轉位子

By Chantelle Sullivan 蘇盈安

Have your friends ever shared with you a seemingly impossible scientific notion, and had you thinking "There's no way that's possible?" This was similar to what 1983 Nobel laureate in Physiology and Medicine Barbara McClintock faced when she came to her conclusion that some genes can move around the genome, and reinsert itself at other loci (positions of the DNA). McClintock had made her discovery even before the structure of DNA was elucidated. However, like Gregor Mendel, the first geneticist who is famous for his pea plant experiments, McClintock's discovery had not been accepted by her contemporaries but was rediscovered later.

In the 1940s, McClintock was working in the Cold Spring Harbor Laboratory and conducted studies focusing on the color patterns of *Zea mays* (maize). At the time, many geneticists were puzzled by the variation of kernel colors on the same corn cob, which can be white, purple or speckled. People assumed that the speckled kernels to be mutations of the white color gene and thought nothing more of it, as the assumption was too hard to prove true. McClintock took the problem into her own hands, and conducted experiments on maize, which entailed the endless breeding of these plants.

From her experiments, she obtained evidence that pointed towards the existence of transposable DNA elements[1] which inserted themselves into the color (C) gene to alter the abundance of the purple pigment in corn called anthocyanin. She called those transposable DNA elements *Ds*, for disassociation. When *Ds* jumped into *C*, the gene can be disrupted and the anthocyanin production is therefore halted. In this case, the kernel loses its purple pigmentation and becomes white.

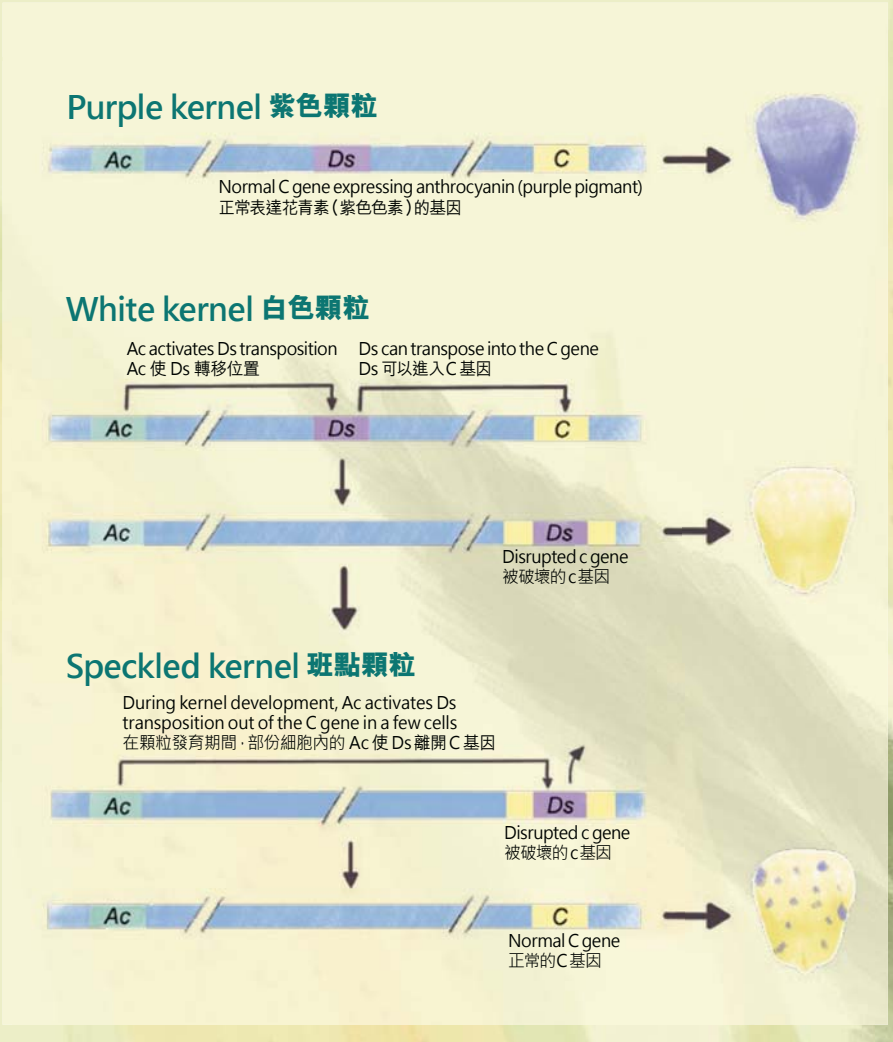
McClintock also found another element that controls the *Ds* transposon, which she named *Ac* for activator. *Ac* contains all the tools and enzymes needed for *Ds* to move around. She found that if *Ac* helps *Ds* move out of the color gene in cases where *Ds* was already lying in the *C* gene, the anthocyanin pigment production can be resumed. If this happens in one of the cells during kernel development where cell division continuously occurs, the resulting purple cell will divide and make clones of itself, and forms spots or streaks. As a result, the kernel will be speckled.

When McClintock shared her findings in the 1951 Annual Symposium at the Cold Spring Harbor Laboratory and in a publication in the same year, she received "puzzlement, even hostility" [1] since the concept was deemed conceptually difficult and seemingly unlikely to occur. In addition to transposable elements, she also presented her findings that genes can be silenced (i.e. gene expression can be halted) by enzymes, which also received ridicule and negative criticism. She subsequently stopped publishing more data regarding transposable elements, as she thought she "must await the right time for conceptual change." [2] McClintock and her research were ahead of her time.

It was only in the 1970s when her research resurfaced and was given a second look by other biologists in the community. This was due to the emergence of data from others who have also identified transposable elements in bacteria and viruses. Afterwards, Barbara McClintock gained the approval and acceptance of the scientific community, and was awarded the Nobel Prize in Physiology and Medicine in 1983. With her seminal discovery of transposable elements, McClintock was the pioneer of cytogenetics[2].

1 *Transposable element: A DNA sequence that can change its position in the genome*

2 *Cytogenetics: The study of the structure and function of chromosomes*



朋友有沒有給你分享過一些聽起來天馬行空的科學念頭,然後你在想:那絕對不可能吧?這正是 1983 年諾貝爾生理學或醫學獎得主 Barbara McClintock 在發現有些基因能在基因組內跳來跳去,把自己插在其他基因位點(基因的位置)後所面對的困窘。McClintock 甚至在 DNA 結構被發現前就有這樣的發現。可是,像以豌豆實驗聞名的史上第一位遺傳學家 – Gregor Mendel(孟德爾)一樣,McClintock 的發現並沒有被同期的科學家所接納,反而在之後被「重新發現」的。

在 1940 年代,McClintock 在冷泉港實驗室(Cold Spring Harbor Laboratory)工作,研究集中於玉米 *Zea mays* 的顏色樣式。當時,很多遺傳學者都對同一條玉米穗軸上能有著不同顏色的玉米顆粒感到困惑,而顆粒顏色可以是白色、紫色或是有斑點的。人們在假設有斑點的顆粒是由白色基因突變所導致後就沒有再進一步想下去了,反正這個假設在當時也很難被證實。McClintock 決定接手解決這個問題,她進行了很多玉米實驗,當中沒完沒了地把玉米雜交。

在實驗中,她取得了證明 DNA 轉位子(transposable DNA elements)存在的證據。轉位子可以通過進入顏色(*C*)基因,改變粟米內一種名為花青素的紫色色素的表達。她稱那些 DNA 轉位子為 *Ds*,解作「分離(disassociation)」。當 *Ds* 跳進 *C*,顏色基因便會受到破壞,花青素的合成會因而停止。在這個情況下,顆粒會失去其紫色色素而變成白色。

McClintock 亦發現另一種能控制 *Ds* 的部件,她稱之為 *Ac*,解作「啟動器(activator)」。*Ac* 包含了所有 *Ds* 移動所需的工具和酶。她發現當 *Ds* 已經進入 *C* 基因時,如果 *Ac* 協助 *Ds* 離開的話,花青素的合成便可以恢復。在顆粒發育時細胞會不停地分裂,如果此時其中一顆細胞出現花青素合成得以恢復的情況,而該細胞再繼續分裂來複製自身的話,就會形成斑點或條紋,使顆粒帶有斑點。

當 McClintock 在冷泉港實驗室 1951 年年度研討會和一份刊物分享她的發現時,她獲得了「疑惑,甚至是否定」的評價 [1],因為這概念在當時被認為是難以理解的,而且不太可能發生的。除了轉位子,她也發表了研究結果指出基因可以被酶靜默化(即使其不能表達),這同樣地亦引來了嘲諷和批評。McClintock 最終決定不再發表更多關於轉位子的研究結果,因為她認為「一定要等到人們有觀念上改變的一天」[2] — McClintock 和她的研究都比時代走得更前。

直至七十年代,她的研究才再一次浮現並且被其他生物學家重新檢視,那是因為其他科學家在細菌和病毒中亦發現了轉位子。此後,Barbara McClintock 得到了科學界的肯定和接納,並在 1983 年得到諾貝爾生理學或醫學獎。憑藉其具深遠影響力的發現,McClintock 可謂細胞遺傳學[2]的先鋒。

1 轉位子:一些能改變自己在基因組內位置的DNA 序列

2 細胞遺傳學:研究染色體結構和功能的範疇

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[1] McClintock B. *The discovery and characterization of transposable elements: the collected papers of Barbara McClintock*. New York, NY: Garland Pub.; 1987.

[2] Cornell University Graduate School. Barbara McClintock, M.S. '25, Ph.D. '27, Botany. https://gradschool.cornell.edu/about/history/notable-alumni/barbara-mcclintock-m-s-25-ph-d-27-botany/.

SIR CHARLES K. KAO – IGNITING THE FIRE OF MODERN TECHNOLOGY

高錕 — 現代科技的燎原之火

By Nicole Wu 胡欣蕾

On September 23, 2018, an 84-year-old gentleman passed away in Sha Tin, Hong Kong. At that time, you might have mourned his passing, like many others who deeply respected him. Although he is a household name in Hong Kong, do you actually know his contribution to our daily life? His research is crucial to the modern communication technology so that it could reach its current height and made our life much more convenient. This gentleman is the winner of the Nobel Prize in Physics 2009, the "Father of Fiber Optics," Prof. Sir Charles K. Kao.

Fiber optics (optical fiber), is a common term. But what does it really mean? Why was it such a breakthrough at the time of its development? Let's start from the very beginning, and consider the history of long-distance communication.

If we traveled back in time to a thousand years ago, it would be very difficult for us to contact our friends and family who were thousands of miles away. A famous Chinese poet, Du Fu (712–770), once said "a letter from home is worth ten-thousand pieces of gold," which reflects the difficulty for ancient soldiers to receive news from their families during a war. By the time a family letter arrived at the battlefield, the recipient might have already been a casualty of war. Thankfully, progress has been made. First, with the invention of telegraph, radio and telephone in the 19th century. Trans-continental communication has become much more convenient, but there were still limitations. It remained challenging to transmit a huge amount of information through a long distance at an affordable price. The scientists in the 20th century placed their hopes on a promising material, glass.

Fiber optics is a thin fiber which is usually made of glass or plastic to conduct light signal. The physical principle behind is simple. Light has different refractive indices when passing through different media. It is refracted to different extents depending on the angle of incidence ($n_1 \sin \theta_1 = n_2 \sin \theta_2$). When light passes from a medium with a higher refractive index to one with a lower refractive index, and if the incident angle is greater than a certain degree (i.e. the critical angle), the light will fully reflect back to the original medium. This phenomenon is called "total internal reflection (*Figure 1*)." Fiber optics harnesses this phenomenon – the core of the fiber is made by a medium with a higher refractive index and the cladding is composed of another material with a lower refractive index. By selecting an appropriate angle of incidence, the light that enters the fiber can be confined to the core and "bounces" towards the end of the fiber. Light signal can therefore be guided and transmitted.

在 2018 年 9 月 23 日，一位 84 歲的老人在香港沙田離世。在他離去之時，你或許與許多關心他、尊敬他的人一樣，哀悼他的離去；你或許對他的大名早有耳聞，卻不清楚他對我們今天的生活作出了多大的貢獻。現代通訊之所以獲得今日的發展水平，我們的生活之所以變得如此便捷，他的研究佔有舉足輕重的地位，值得我們去仔細了解並銘記。這位老人，便是 2009 年諾貝爾物理學獎得獎者，「光纖通訊之父」— 高錕教授。

光纖 — 一個在日常生活中經常聽得到，但卻不一定清楚理解的詞語。它有多厲害，足以獲得大名鼎鼎的諾貝爾獎？要理解光纖的偉大之處，首先要由遠距離通訊的演變歷史說起。

假如我們讓時光倒流一千年，要跟遠在千里外的親朋好友聯繫，可算是一波三折。杜甫 (712–770) 說「家書抵萬金」，就是指古代軍人在外征戰時跟家人聯繫有多麼困難。以古代的通訊速度，家書抵達軍人之處時，軍人可能已經陣亡一段時間了。這對於今天的社會來說，是難以想像的。經過漫長的探索後，自十九世紀開始，人類終於迎來了電報、電台和電話的時代，通訊一下子變得便捷，但仍然有其限制之處：成本、距離以及資訊量。要遠距離傳遞大量訊息，並且要將成本壓縮到一般人都付得起，實現起來並不容易。二十世紀的科學家寄望於一種潛力無限的材料：玻璃。

光纖全名光導纖維，原理是利用玻璃或塑膠等物料製成纖維以傳導光線訊號。當中的物理原理很簡單：光在穿越不同媒介時有不同的折射率，根據入射角度的變化，會產生大小不一的折射 ($n_1 \sin \theta_1 = n_2 \sin \theta_2$)。當光從折射率較高的媒介射向折射率較低的媒介時，如果入射角度大於某個值，即臨界角度 (critical angle)，所有光都會被反彈回來，而無法穿透到另一媒介，產生「全內反射 (total internal reflection)」的現象 (見圖一)。光纖利用這個特性：將折射率高的媒介 (例如玻璃) 作為纖維的核心，並由折射率低的媒介包裹著，調整好入射角度的話，射進光纖的光就會來回反射直到光纖的另一端，而不會逃走到光纖外，達到傳導光線訊號的效果。

可是事情並不是那麼簡單，在當時，以光來通訊實際上的面對著很多困難，最主要的問題是衰減率過大。光在介質中移動時，強度會隨著距離逐漸減弱，這使光不能被有效地傳遞。即使以當時最「透明」的玻璃作為介質，衰減系數

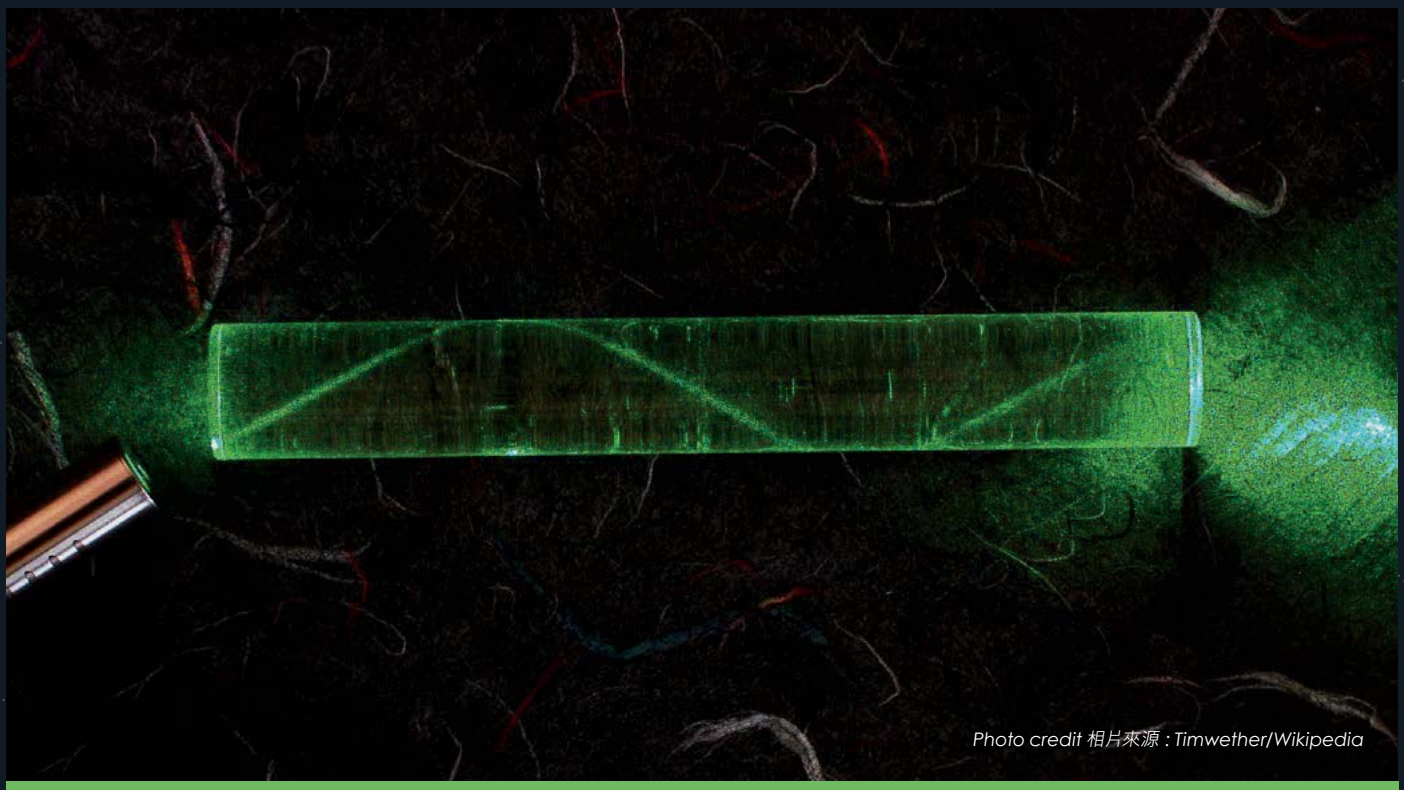

Figure 1. *Total internal reflection.*
圖一 *全內反射*

But it was easier said than done. At that time, there were many practical obstacles of using light for signal transmission. The main problem was the high attenuation rate. As light passes through a medium, its intensity is reduced, and hence cannot be transmitted effectively. Even when the "most transparent" glass at that time was used as the medium, the attenuation coefficient would have reached 200 decibels per kilometer (dB/km) [1] – that means, for every kilometer the light propagates, the intensity would reduce by 10^{20} times. This makes optical communication impossible.

One of the seminal papers that made Prof. Kao famous was entitled *Dielectric-fibre surface waveguides for optical frequencies*, which was co-authored by Prof. Kao's colleague, George Hockham. They postulated that if the attenuation coefficient of glass could be reduced to 20 dB/km, long-distance communication would become possible [2]. Simply put, if we can make glass that is "clean" enough, light should be able to propagate within it for a long distance without attenuating too much. Prof. Kao and his colleague attributed the high attenuation rate to the impurities within the glass – iron ions (Fe^{2+} and Fe^{3+} ions). Therefore, if they could purify the glass, they should be able to overcome this problem.

However, the paper in 1966 did not catch the attention of most others. Some groups even thought that it would not be useful to remove the impurities because it is the intrinsic properties of glass which make it unsuitable for being the material for light transmission. Fortunately, Prof. Kao did not give up. He traveled the globe to promote his idea, and successfully attracted many research groups to enter the field. In addition, Prof. Kao approached many glass manufacturers and persuaded them to develop the glass that fits the requirements mentioned in the paper. Finally in 1970, Corning successfully manufactured the glass with an attenuation coefficient of 17 dB/km, which allowed Prof. Kao's hypothesis to be confirmed. (Corning even reduced the attenuation coefficient to 0.4 dB/km two years later!) After that, the technology matured rapidly. Now, the attenuation coefficient of a modern optical fiber can be less than 0.1 dB/km [3], and every fiber can transmit a few tens of TB (10^{12} bytes) of data per second. This enables us to easily obtain a large amount of information.

The advancement of modern technology enables us to communicate instantly and conveniently. This changed our daily life and shortened the distance among people – the birth of the Internet, followed by the invention of social media and instant messaging apps. Prof. Kao refused to patent his invention on optical fiber, which in part accelerated its broad and rapid adoption around the world. If modern communication technology is a sprawling fire, then Prof. Kao must be the initial, indispensable sparks.

SIR CHARLES K. KAO – IGNITING THE FIRE OF MODERN TECHNOLOGY

高錕 — 現代科技的燎原之火

亦達到每公里 200 分貝 (dB/km) [1]，即是每前進一公里，光的強度就會衰減 10^{20} 倍，這使光通訊變得不可行。

使高教授享負盛名的有他和同事 George Hockham 在 1966 年發表、具預言性的《光頻率介質纖維表面波導 (*Dielectric-fibre surface waveguides for optical frequencies*)》論文。文中推論如果玻璃的衰減系數能減至每公里 20 分貝，遠距離通訊將會成功 [2]。簡單來說亦即是如果能製造出一種夠「清澈」的玻璃作為介質，光應該可以在當中前進一段極長的距離而不會減弱太多。高教授和同事認為當時玻璃的高衰減率主要是因為當中的雜質 — 鐵離子 (Fe^{2+} 和 Fe^{3+})，因此如果能把玻璃提純的話，應該就可以克服這個問題。

然而，1966 年的論文在當時並沒有引起太大的迴響，有人甚至覺得去除雜質並不會有用，因為正是玻璃這種材料本身內在的特性使它不適合用作傳遞光。幸好高教授沒有放棄自己的主張，並在之後數年孜孜不倦地到世界各地宣傳和游說，成功說服了更多的研究團隊投入這方面研究。另一方面，高教授嘗試聯絡不少的玻璃廠，游說它們協助研發符合論文中規格的玻璃。最後在 1970 年，美國康寧公司成功造出衰減系數為每公里 17 分貝玻璃光纖，令高教授在論文中的假設得以證實 (在兩年後他們更把衰減系數減至每公里 0.4 分貝！)。在此之後，光纖技術日益完善，到目前為止，現代光纖的衰減系數能低於每公里 0.1 分貝 [3]，亦能在每秒傳遞數十 TB (10^{12} 位元組) 的訊息，使我們能隨時隨地獲取大量訊息。

現代科技的進步使我們可以快捷方便地的通訊，改變了我們的日常生活：互聯網的誕生，然後是社交媒體、即時通訊軟件的出現，縮短了人與人之間的距離。正正是高教授放棄了專利，使這項通訊技術讓無數人受惠。如果現代科技是一團蔓延的火，那高錕教授便是那燎原的星星之火，閃爍在天上與人間。

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A Hidden Genius: The Life of Srinivasa Ramanujan

隱世傳奇：拉馬努金的故事

By Sonia Choy 蔡蒨珩

The normal path to becoming a mathematician is a very long one – you would go through close to 10 years of undergraduate and graduate education before you can begin looking for a full-time research position. Ramanujan is an exception. With no formal training, he rediscovered many contemporary results in mathematics (such as the Bernoulli numbers, a very important set of numbers that occurs frequently in number theory) all by himself. This makes Ramanujan's achievements all the more remarkable as an untrained mathematician.

Ramanujan was born in 1887 in Erode, India, a small village far from the state capital, Madras, and was raised in Kumbakonam, then a small town about 220 km east of Erode [1]. He first began studying mathematics from an outdated textbook while he was in high school, and attempted to enter university twice, but in vain because of sub-par performance in subjects other than mathematics. Instead he studied independently, also corresponding with mathematicians in Madras, and eventually found a job as a clerk to earn a pittance at the Accountant General's Office in 1912. In his spare time, he wrote letters to famous mathematicians in Europe to seek advice on his work.

One cannot tell Ramanujan's story without mentioning G. H. Hardy, his mentor, who was the first person to recognize Ramanujan's genius. Hardy was an accomplished number theorist himself, and yet he claimed that his biggest contribution to mathematics was the discovery of Ramanujan [2], and described his association with Ramanujan is the one romantic incident in his life [3].

Hardy corresponded with Ramanujan and welcomed the young mathematician to Cambridge with a scholarship in 1914; Ramanujan graduated in 1916 with what is now a PhD, his thesis being seven papers he published in England. Hardy and his collaborator, J. E. Littlewood, attempted to teach Ramanujan formal mathematics, but found it difficult as Ramanujan's brilliant intuition would often steer the conversation sideways. Nevertheless, the five years Ramanujan spent in Cambridge were fruitful, and his collaboration with Hardy is still remembered today. For his contributions, he was elected a fellow of both Trinity College Cambridge, and the Royal Society of London in 1918.

Throughout his life, Ramanujan had been plagued by health problems; he contracted smallpox as a child, and an operation had sent him fearing for his life in 1909. He fell sick again in 1917, but eventually recovered, and sailed home for India in 1919. However, his health deteriorated once he returned to India, and he died the following year, aged 32. Even in his last year, he made many discoveries, and wrote them without proof in what is known as *Ramanujan's Lost Notebook*. Although the notebook was not made available publicly until 1976, many of the results have since been proved by other mathematicians [4]. Still, the world had lost a genius far too early – one could only imagine what other discoveries he could have made, had he lived for a few more years.

Most of Ramanujan's discoveries are in number theory – the study of numbers themselves. He made discoveries in elliptic functions, modular forms, continued fractions, and a fun little phenomenon called "taxicab numbers" – the second taxicab number, 1729, was the number of the taxi Hardy took to visit Ramanujan in hospital once, and he remarked to Hardy on his bed that 1729 could be expressed as the sum of two distinct pairs of positive cubes

要成為一個數學家絕對不是一朝一夕的事情：一般來說，你必須經過大約 10 年的本科和研究生課程，才能開始找全職的研究工作。拉馬努金卻是例外：他沒有受過正式訓練，但是他單靠自己就重新發現不少當代的數學理論，例如數論之中經常出現而且十分重要的白努利數（Bernoulli numbers），這使他的成就更為引人注目。

拉馬努金在 1887 年出生於印度埃羅德（Erode），一個遠離邦首府馬德拉斯（Madras）的小鎮；並在埃羅德大約 220 公里以東的小市鎮貢伯戈訥姆（Kumbakonam）長大 [1]。在高中時期，他透過一本過時的數學教科書開始自修數學，及後兩次嘗試考入大學，但因數學以外科目的成績未如理想而未能成事。於是他選擇自己研究數學，並一直與在馬德拉斯的數學家聯絡，也在 1912 年於會計師行找到文員的工作以賺取微薄的工資過活。在工餘時間，他也有一直寫信給歐洲的著名數學家，希望從中得到對自己研究的一些建議。

談及拉馬努金的故事，就必須提到他的導師 — 哈代（G. H. Hardy），他可謂拉馬努金的伯樂，亦是注意到拉馬努金天賦的第一人。雖然哈代自己是造詣非凡的數論學家，但他本人卻認為自己對數學最大的貢獻是發掘了拉馬努金 [2]，並憶述道與拉馬努金的邂逅是在他生命中其中一件浪漫的事情 [3]。哈代一直透過書信與拉馬努金來往，並在 1914 年以獎學金歡迎這位年輕的數學家前往劍橋大學成為其學生。拉馬努金然後於 1916 年畢業，取得相等於現時博士學位的資歷，畢業論文為他在英國出版的七篇論文。哈代和同事李特爾伍德（J. E. Littlewood）一直嘗試教導拉馬努金正統數學，但這也有一定難度，因為拉馬努金過於敏銳的直覺總是把話題岔開。即使如此，拉馬努金在劍橋的五年總算碩果纍纍，而他與哈代的合作至今仍為人所津津樂道。對於拉馬努金的貢獻，他在 1918 年被選為劍橋聖三一學院和倫敦皇家學會院士。

拉馬努金一直受著到健康問題困擾。他小時候曾經染上天花，而 1909 年的手術則影響他其後的健康。他在 1917 年又得了重病，後來病癒，在 1919 年回到印度。但是當他一回到印度，健康便隨即惡化，並在翌年病逝，終年 32 歲。然而在臨終前的數年，他也作出了不少發現，並在沒有提出證明的情況下一一寫在筆記本上 — 該筆記本現在被稱為《拉馬努金的消失筆記（*Ramanujan' s Lost Notebook*）》。雖然該筆記直到 1976 年才被公開，在此之後，數學家已經可以證實當中的不少理論 [4]。儘管如此，一個數學天才如此英年早逝倒是令人惋惜，我們只可以想像如果他能延壽數年，定必能作出更多發現。

拉馬努金的發現主要是集中於數論方面，即是對數字本身的研究。他在橢圓函數、模形式和連分數上也有不少貢獻，亦發現了一個有趣的小現象，稱為「計程車數」的數列。第二個計程車數 1729，是有一次哈代到醫院探望拉馬努金時乘坐的士的號碼。在病床上的拉馬努金向哈代說道，1729 可以被寫成兩對不同數字的正三次方總和（$1729 = 1^3 + 12^3 = 9^3 + 10^3$）。而其他計程車數的定義亦是如此：第 n 個計程車數是能寫成 n 對數字的正三次方總和的最小數字 [5]。

($1729 = 1^3 + 12^3 = 9^3 + 10^3$). The rest of the taxicab numbers are defined similarly – the *n*th taxicab number is the smallest number that can be written as the sum of *n* distinct pairs of positive cubes [5].

To end this article, here is a little problem, related to continued fractions, for you to solve:

> *"A street has between 50 and 500 houses in a row, numbered 1, 2, 3, 4, ... consecutively. There is a certain house on the street such that the sum of all the house numbers to the left side of it is equal to the sum of all the house numbers to its right. Find the number of this house and the total number of houses on the street. [6]"*
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> The story behind [7]: One of Ramanujan's contemporaries at Cambridge, P. C. Mahalanobis, read about this problem while visiting Ramanujan. After solving the problem, Mahalanobis turned to Ramanujan, who was cooking, and read the problem to him. While still stirring the vegetables in his pot, Ramanujan gave the answer right away – a continued fraction that expressed all the solutions to the problem, ignoring the constraint of 50 to 500 houses. So as a bonus problem, can you find the continued fraction that Ramanujan answered?

Answer: House number 204, on a street with 288 houses. In general, the continued fraction $3 - \cfrac{1}{6 - \cfrac{1}{6 - \cfrac{1}{6 - \cfrac{1}{6 - \ddots}}}}$ gives successively the fractions $\frac{3}{1}, \frac{17}{6}, \frac{99}{35}, \frac{577}{204}, \frac{3363}{1169}, \ldots$

The number of houses *n* and the house number *x* are expressed by the fractions as $\frac{2n+1}{x}$. A full explanation can be found in reference [7].

就讓我以一條與連分數相關的小問題作結吧，你能解答嗎？

> ***「在一條街上，有一列數目為50至500間的房屋，房屋號碼被順序編成1、2、3、4…… 在街上某一座房子，它左邊所有房屋號碼的總和，跟右邊號碼的總和是一樣的。到底這座房子的號碼和街上的房屋總數是甚麼？ [6] 」***
>
> **這條題目背後有著如此的一個故事 [7]：拉馬努金在劍橋的朋友馬哈拉諾比斯（P. C. Mahalanobis）在探望他時讀到這道問題。馬哈拉諾比斯自己嘗試解答後，便轉身把問題朗讀給正在做菜的拉馬努金聽。拉馬努金還在攪動鍋中蔬菜之際，就立刻道出了答案：他給的是一個能適用於所有情況的連分數（甚至可以忽略街道上有50到500間房子這個限制）。作為一道加分題，究竟拉馬努金給的連分數是甚麼呢？**

答案：204 號房屋、街上共有 288 間房子。簡單來說，連分數 $3 - \cfrac{1}{6 - \cfrac{1}{6 - \cfrac{1}{6 - \cfrac{1}{6 - \ddots}}}}$ 能給出以下的分數：$\frac{3}{1}, \frac{17}{6}, \frac{99}{35}, \frac{577}{204}, \frac{3363}{1169}, \ldots$

街上房屋總數 *n* 和該房屋的號碼 *x* 可以在那些分數中被表示為 $\frac{2n+1}{x}$。詳解可於參考資料 [7] 找到。

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A few miles from downtown Knoxville, Tennessee, in a wooden plot surrounded by barbed wires, cadavers are put inside wire cages, car trunks or even submerged underwater. Figures clad in gloves and water-repellent gowns work through the stench and the swarm of flies, jotting down observations of the decaying cadavers and scooping up soil samples into a jar. This is the University of Tennessee Anthropological Research Facility, better known by a macabre-sounding nickname: the Body Farm [1].

The Tennessee Body Farm was first conceived in 1971 as its founder, Dr. William M. Bass, realized the dearth of knowledge concerning the dead, having once incorrectly underestimated the age of a corpse by 113 years (The remains were thought to be only a few months old, but were in fact that of a 19th century Colonel William Shy, killed during the American Civil War and embalmed for preservation.) [2]. After appealing to the administration, he was granted a parcel of land that gradually expanded to what's now the 2.5-acre Forensic Anthropology Center, established in 1987. With around 100 donated bodies each year, the facility exposes them to a variety of settings: clothed or naked, exposed to scavengers or sheltered, subjected to summer heat or wintry blast. In each of these settings, the conditions of the bodies and environmental variables are periodically recorded. Once the person's remains become skeletal, they are deposited to the William M. Bass Donated Collection, the largest collection of skeletal remains from modern people in the U.S., consisting of over 1800 sets of skeletons. The collection helps researcher systematically study the effects of diseases such as diabetes and obesity on bones, as well as the difference in bone structure between different demographic groups. The facility accepts not only the freshly deceased, but also cremated remains, which also contain information, such as the sex of the former owners [3].

The Science of the DEAD

How Body Farm Aids Criminal Investigation

死人科學

人體農場和犯罪調查

By Terrence Tai 戴煒庭

在美國田納西州(Tennessee)城市諾克斯維爾(Knoxville)的數英里外，有一片受帶刺鐵絲網保護的空地，裡面屍橫遍野。屍體分別被放置於鐵絲籠、車尾箱、甚至被浸在水中。穿戴著手套和防水袍的身影在惡臭和蒼蠅中徘徊：他們觀察並記下腐屍的狀態之餘，又把土壤樣本舀起儲存於一個罐子裡。這是田納西大學人類學研究設施(University of Tennessee Anthropological Research Facility)，更廣為人知的是它另一個駭人聽聞的暱稱：人體農場(Body Farm)[1]。

田納西人體農場最初由 William M. Bass 博士於 1971 年構思，契機是一次判斷屍體死亡時間的工作，令他意識到當時對屍體知識的貧乏：在那次工作中，他推斷的死亡時間與真實的誤差足足為 113 年(他誤判那死者只在數月前去世，但其實遺體來自在十九世紀於美國內戰中戰死的 William Shy 上校，遺體經過防腐處理)[2]。在向相關行政部門爭取後，他獲得了一塊土地，及後逐步擴大並變成現在於 1987 年成立、面積達 2.5 英畝的法醫人類學中心。該機構每年收到約 100 具捐贈遺體後，會把它們放置於不同的條件和環境下作研究：身穿衣服或是全身赤裸、暴露於食腐動物或是放置於安全環境、放在夏日酷暑或是冬日寒風下。在每個設定下，屍體的狀態和環境參數都會定期被紀錄下來。當遺體腐化成骨之後，骨架會被送至 William M. Bass 遺骸收藏集(William M. Bass Donation Collection)。這套收藏集擁有超過 1800 套骨架，是美國最大的現代人類骨架收藏集，它除了能夠幫助學者研究糖尿病、肥胖症等疾病對人體骨骼的影響外，還能為比較不同族群骨骼結構的研究提供參考。機構不但接受剛去世的遺體，還接收已火化的遺體，因為骨灰也包含不少資訊，例如死者的性別等 [3]。

人類學研究設施的最大貢獻在於它促進了我們對於死後變化(post-mortem changes)的了解，亦即是死亡後身體會出現的各樣變化。如果你在炎炎夏日不慎把一隻豬

The biggest advancement the facility made is in our understanding of post-mortem changes, or the various processes that occur in a body after death. As anyone who has accidentally left a pork knuckle outside in a warm summer afternoon can testify, dead body tissues undergo a series of grisly changes that usually culminate in complete skeletonization[1]. The three most noticeable early changes after death are algor mortis, rigor mortis and livor mortis. Shortly after death, our bodies stop producing heat and gradually cool to the room temperature (algor mortis). A few hours later – the exact time depends on a variety of factors – once cellular energy (ATP) runs out, muscles could no longer return to a relaxed state, leading to the stiffening of limbs (rigor mortis). Gravity also causes blood to settle into the lower parts of the body, leading to reddish-blue discolorations[2] alternating with pallid areas where blood is drawn away (livor mortis).

What else could be going on? As organismal homeostasis fails, individual cells would begin to digest themselves. Microbes from the gut and outside the external orifices could also migrate and multiply throughout the corpse and digest bodily tissues (putrefaction). Combined, they lead to the liquefaction of body organs and the build-up of a cocktail of gases that lead to the characteristic stench of cadavers. The build-up of internal pressure leads to external changes including, among others, abdominal bloating, skin blisters, and discharge of liquid from body orifices. Scavengers such as blowflies, vultures and raccoons may be attracted by the stench to feast on the decaying body. Eventually, after the soft tissues have been decomposed, dried up or eaten, only skeletons remain.

These processes form a rough timeline which we may use to determine the post-mortem interval (PMI), or the time elapsed since an individual died. This is of great importance to criminal and archaeological investigations, but a precise estimation of the interval is confounded by a range of variables. The most important factor is temperature, which influences the rate of biochemical reactions and the activity level of microbes and scavengers. Humidity also plays an important role, as water serves as an essential medium for biochemical reactions and to sustain the survival and growth of microbes and scavengers. Using their database of hundreds of decompositional events of the human body, researchers at the Body Farm were able to derive an empirical formula that relates the extent of decomposition, temperature and humidity to PMI [4]. The formula is, however, incomplete: adjustment is needed if the formula is applied to other regions with different soil quality and climate. Researchers at the facility have also been investigating other methods, such as analyzing the chemical content of decomposing body tissues or the surrounding soil environment, to support the determination of the PMI [5]. The studies are also replicated in several other similar facilities in the US, Canada and other countries in order to improve our understanding in the difference in the decomposition process in different environments.

Other than serving as an active research site for post-mortem changes and human skeletal studies, the Body Farm also provides training courses on forensic recovery techniques for FBI investigators, law enforcement workers and forensic pathologists. The subject matter of the Body Farm, while unorthodox, is of great importance to us, and for its recent advancements, we must thank not only the researchers involved but also the contribution of the selfless donors who bequeathed their bodies to science.

1 The decomposition progress may be incomplete in rare circumstances. In 1991, hikers on the Ötztal Alps stumbled upon a frozen corpse which turned out to be over 5300 years old. The glacier mummy, who is now called "Ötzi" the iceman, was covered in ice shortly after his death, which halted the decomposition process such that his hair, organs and even his clothing and equipment were left intact [6]. (You may learn more about Ötzi from the cover story of *Science Focus* Issue 002.)

2 In cases of poisoning, the color might be different [7].

手放在戶外，就能見證身體組織在死後經歷一連串的駭人變化，通常直至完全化骨為止[1]。死後初期的三個明顯現象為:屍冷(algor mortis)、屍僵(rigor mortis)和屍斑(livor mortis)。死後，我們的身體會停止產生熱能，並慢慢冷卻至室溫(屍冷)。數小時後 — 具體時間受不同因數影響 — 當細胞剩餘的能量(ATP)被消耗殆盡後，肌肉再不能回到鬆弛的狀態，導致四肢僵硬化(屍僵)。受重力影響，血液會積聚在身體的低處，令皮膚出現紫紅色的斑痕(屍斑)[2]，當中又穿插著的一些因為血被抽走而變得蒼白的區域。

還會有甚麼事情發生？在身體不能維持體內平衡之時，個別細胞會開始分解自己。消化道內和身體孔竅外的微生物也能遷移至並在身體內外迅速繁殖，分解身體組織(腐爛)。這兩個過程導致器官液化，亦令體內累積不同氣體，形成腐屍獨特的惡臭氣味。內部壓力增加也會導致不同外部變化，例如腹脹、皮膚水泡、身體孔竅流出液體等。諸如綠頭蒼蠅、禿鷲和浣熊等的食腐動物可能會受屍臭吸引而前來享用腐屍。最終，當軟組織分解、乾涸，或被吃光後，所剩下的也只有骨骼。

這一連串過程可以被拼湊成一條粗略的時間線，讓我們可以窺探死後間隔時間(post-mortem interval/PMI)，也就是死者由死亡一刻距今的時間。PMI 對於刑事或是考古調查固然重要，但要準確預測 PMI 需要考慮許多變數。溫度是最重要的因數，它能夠控制生化反應的速率，以及微生物和食腐動物的活躍程度。濕度也是重要的變數，因為水是生化反應中不可或缺的介質，又是維持微生物和食腐動物生命和生長的必需物質。參考研究中心資料庫中數

百次人體腐化實驗的數據，人體農場的研究人員最終推導出一條實驗式（empirical formula），把腐爛程度、溫度和濕度與 PMI 連繫起來 [4]。但這條公式並不完整：如果要把這條公式應用至其他地區，我們還需要考慮當地土壤及氣候的差別來調整公式參數。除此之外，研究者還在尋找其他方法，例如分析腐爛身體組織或周圍土壤的化學物質，來佐證 PMI 的預測 [5]。在美國、加拿大和其他國家也有數個類似的機構重複相同的實驗，幫助我們了解不同環境下屍體腐化過程的差別。

人體農場除了是一所研究死後變化和人體骨骼的研究所之外，還為聯邦調查局調查人員、執法人員和法醫提供遺體挖掘的訓練課程。人體農場的工作範疇固然令人忌諱，但其重要性絕對不可輕視；對於近年的研究進展，我們除了要感謝研究者的付出外，更應該要對那些為科學無私地奉獻自己身軀的人致敬。

1 在很特殊的情況下，腐爛過程可能會中途停止。在1991年，一群遠足者在奧茨塔爾阿爾卑斯山脈（Ötztal Alps）偶然發現一具被凍結的遺體，其後該遺體被發現有超過5300年歷史。這具名為「冰人奧茨（"Ötzi" the iceman）」的冰封木乃伊在死後短時間內就被掩埋於冰雪之下，令腐爛過程被中止，使他的頭髮、器官，以至衣服、工具也完好無損 [6]。（想知道更多關於奧茨的故事，可以參考第二期《科言》的封面故事。）

2 在中毒的情況下，顏色可能會有所不同 [7]。

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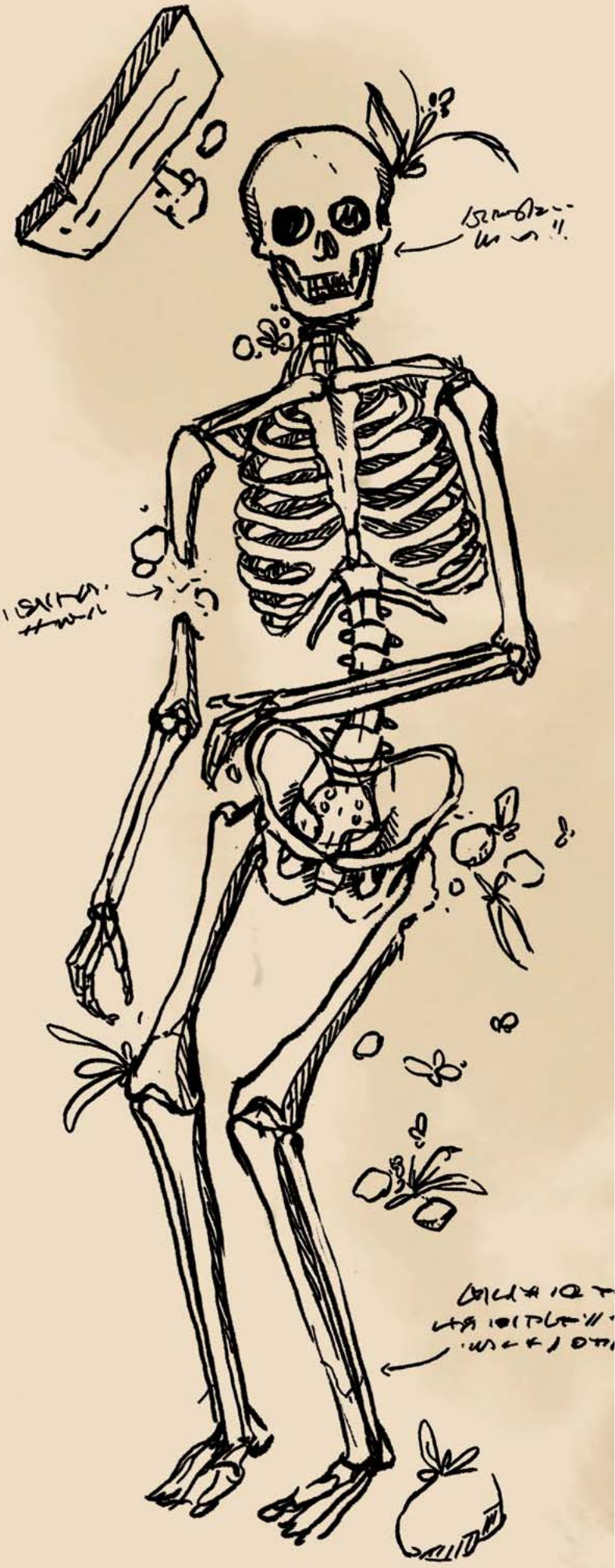


CAR-T Cells: The Programmed Cancer Killer

By Henry Lau 劉以軒

Enter the Chimera

Cancer is undoubtedly one of the most dreaded maladies known to humans. It is defined as a condition where cells proliferate uncontrollably [1]. Besides surgery, conventional cancer treatments include radiotherapy or chemotherapy that aims at selectively killing cancer cells. However, this is often accompanied by unwanted side effects, as these therapies tend to kill off healthy cells as well [2]. Fortunately, recent developments of immunotherapies allow us to fight cancer in a more precise manner, with our own immune system. Enter the Chimera – the renowned chimeric antigen receptor T cell (CAR-T cell) therapy, a man-made hybrid created for the sole purpose of eradicating cancer. The idea of this therapy is to extract a type of immune cell known as T cells from the patient, genetically engineer them into CAR-T cells *in vitro*, and infuse the transformed cells back into the patient's body. With the newly gained ability to recognize and attack cancer cells, CAR-T cells are almost like a "living drug" against cancer, fighting them off cell by cell!

Background Information – Immune Cells at Work!

CAR-T cells are constructed based on our current understanding of immune cells, which is a part of our natural defense mechanism for dealing with infections and diseases in our body. Here's some background information about our immune cells related to the therapy.

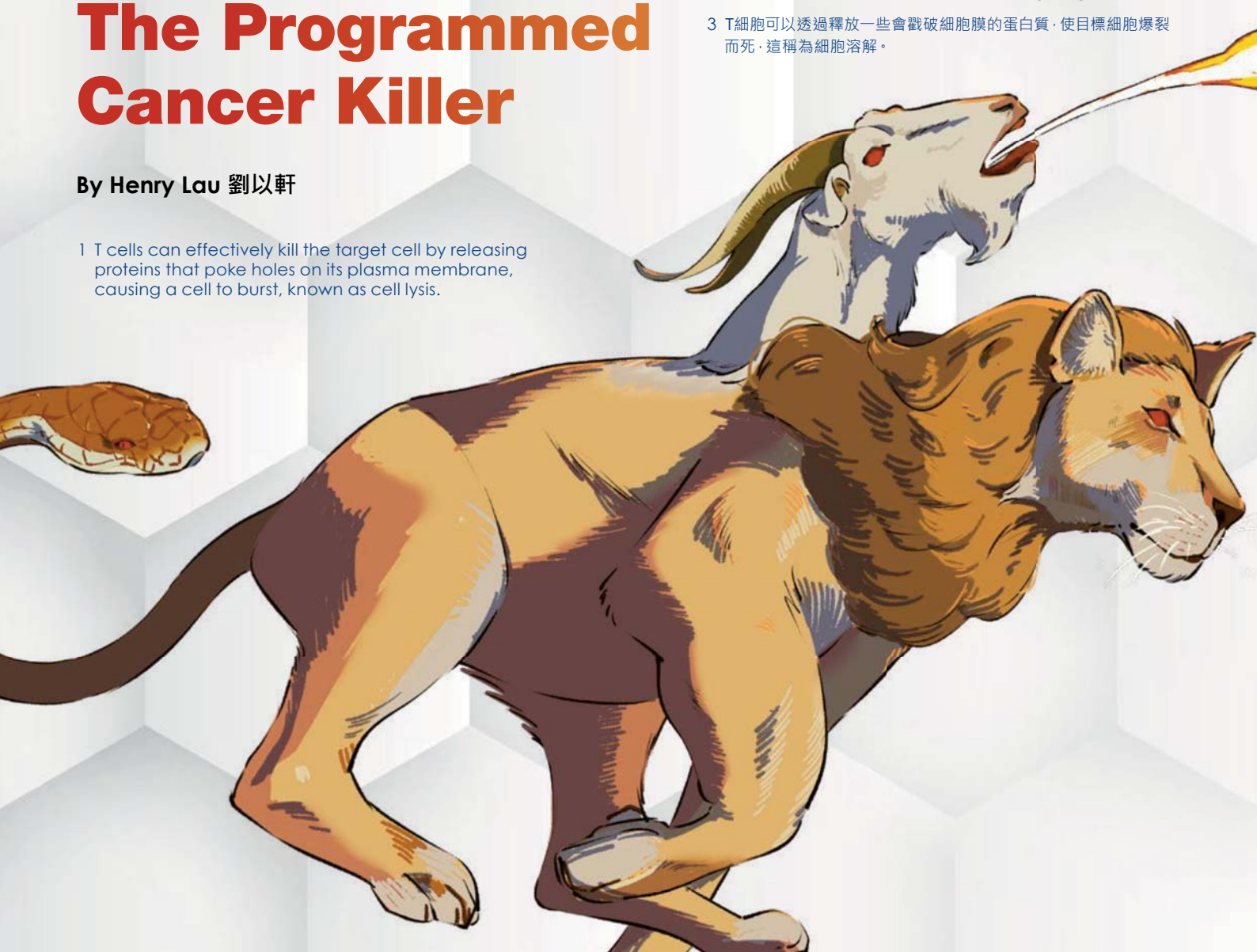
Fact Number 1: The T Cell Involved Is Known as Cytotoxic T Cell

Also known as killer T cells, one can infer from its name that this cell type kills other cells ("cyto-" meaning cell and "toxic" implying lethality). Cytotoxic T cells usually kill cells that are damaged, as their continued existence is undesirable for the body, such as virus-infected cells which are hijacked to shelter and replicate the pathogen. The major task of the T cell is to distinguish damaged cells from healthy cells,

1 編按：「Chimera」在英文有多重意思，原指希臘神話一隻會噴火、由獅子、山羊和蛇合成的怪獸，引伸義為「幻想、空想」，後來被借用至生物學上。作者在英文原文中用了語帶雙關的手法。

2 編按：CAR-T細胞在英文普遍被形容為「living drug」。

3 T細胞可以透過釋放一些會戳破細胞膜的蛋白質，使目標細胞爆裂而死，這稱為細胞溶解。



1 T cells can effectively kill the target cell by releasing proteins that poke holes on its plasma membrane, causing a cell to burst, known as cell lysis.

kill the former and spare the latter. The identification is enabled by a T-cell receptor (TCR), which recognizes an antigen presented on the surface of damaged cells but not healthy cells. When bound to an antigen, the TCR sends signals to activate the T cell so that it will be triggered to kill the damaged cell by inducing cell lysis[1].

Fact Number 2: Antibodies Are Produced By Another Class of Immune Cells Called B cells

Plasma cells, which are differentiated from B cells, produce proteins called antibodies. Shaped like a "Y", antibodies have the trademark function of being able to bind specifically to its corresponding antigen using the two tips of the "Y". Known as variable regions, the pairs of tips vary vastly among different antibodies, defining the target of an antibody and conferring an "identity" on it. On the contrary, the remaining part is known as the constant region; the same constant regions may be shared by different antibodies.

Upon being bound by antibodies, the antigen itself (sometimes toxins) or the unwanted entities with the antigen on surface (such as cancer cells or pathogens) will be recognized by other immune cells, which may swallow them whole in a process called phagocytosis. However, this system is not perfect. In the case of cancer cells, they are not always recognized as the enemies within our bodies.

CAR-T 細胞：程式控制癌症殺手

墮進幻想空間

癌症對人類來說無疑是其中一種最可怕的疾病，它被定義為一種細胞失控地進行分裂的病症 [1]。除了手術外，傳統的治療方法還包括放射治療及化學治療，原意是選擇性地殺死癌細胞，但是這兩種療法都有同時錯誤殺死健康細胞的可能，所以時常帶來不良的副作用 [2]。幸好，免疫療法（immunotherapy）近來的突破讓我們可以借用自身的免疫系統，更精確地對抗癌症。讓我們進入幻想世界，認識一下廣為人知的嵌合抗原受體 T 細胞療法（chimeric antigen receptor T cell (CAR-T cell) therapy）吧：那是一隻我們特意創造來消滅癌症的合成怪物[1]。這個療法的概念就是從病人身體提取一種叫 T 細胞的免疫細胞，然後在體外把它們基因改造成嵌合抗原受體 T 細胞（CAR-T 細胞），再把已轉化的細胞注射回病人的身體內。利用得來的新能力，CAR-T 細胞能辨認並攻擊癌細胞，因此將它們形容為活生生的藥物[2]也絕不誇張！

基本知識 — 工作中的免疫細胞！

CAR-T 細胞是基於我們現時對免疫細胞的認識而製成的。免疫細胞是身體對付感染和疾病自然防禦機制的一部分。以下是關於與療法相關的免疫細胞的一些基本知識。

事實一：療法所用到的 T 細胞為細胞毒性 T 細胞

又被稱為「殺手 T 細胞（killer T cells）」，我們可以從它的名字中猜想到其功能就是殺掉其他細胞（它對「細胞」有「毒性」）。細胞毒性 T 細胞通常會殺死受損的細胞，因為它們繼續存在對身體並不是一件好事，例如受病毒感染的細胞，它們很有可能被劫持而協助複製病毒。T 細胞的主要工作是要分辨出受損細胞和健康細胞，殺掉前者並放過後者。辨識工作全靠 T 細胞受體（T-cell receptor）負責，它能夠識別只出現在受損細胞表面、而不存在於健康細胞的抗原。當 T 細胞受體與抗原結合時，它會發送訊號活化 T 細胞，讓 T 細胞通過引發細胞溶解（cell lysis）[3] 來殺死受損細胞。

事實二：抗體由另一種免疫細胞 — B 細胞所製造

從 B 細胞分化而成的漿細胞會產生稱為抗體的蛋白質。抗體的形狀像英文字母「Y」，它擁有的標誌性的功能就是能用「Y」字的兩個尖端專一地與相應的抗原結合。那對尖端被稱為可變區，不同抗體之間的可變區差異很大，它決定了一個抗體的目標抗原，意義上可謂賦予了抗體一個「身份」。相比之下，餘下的部分被稱為恆定區；相同的恆定區可以出現在不同抗體中。

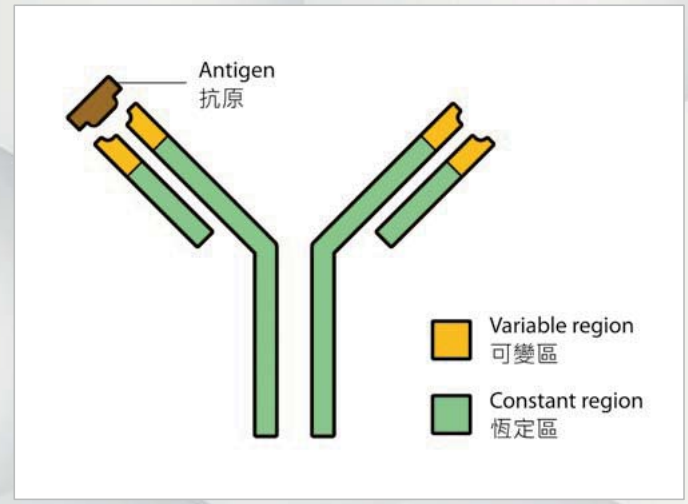


Figure 1 *Structure of an antibody.*
圖一 *抗體的結構*

The Powerful Chimera – CAR-T Cells

In fact, the CAR-T cell derives its name from the Chimera, a fire-breathing hybrid creature merged from a lion, a goat and a snake, in Greek mythology. The CAR-T cell is literally the merged form of cytotoxic T cells and antibodies. It utilizes a chimeric TCR to identify cancer cells. The word "chimeric" describes the fusion of several protein domains (parts of proteins) sourced from different proteins, that have distinct functions.

Like all receptors, the CAR[2] has three domains: an extracellular domain (outside the cell), a transmembrane domain (embedded in the plasma membrane) and an intracellular domain (inside the cell) [3]. In this case, the extracellular domain of the CAR is derived from the antigen-binding variable region of the antibody which specifically binds to tumor-associated antigens. Tumor-associated antigens tend to be more abundant on cancer cells, though they are not necessarily exclusive to them. It is hoped that the chosen extracellular domain can direct CAR-T cells to cancer cells. Then, there is the transmembrane domain, which is usually sourced from existing receptors. This structural domain serves to anchor the entire CAR onto the cell membrane. Lastly, there is the intracellular domain which contains the intracellular signaling domains of a regular TCR along with that of other co-stimulatory receptors. In simpler words, it can also activate the CAR-T cell when the extracellular domain binds to the tumor-associated antigen, enabling the lysis of cancer cells.

"Assembling" Our Weapon From Scratch

So, how do we actually create CAR-T cells? Once the desired protein domains have been chosen, we will fuse their respective DNA sequences together and integrate them into the genome of a T cell sourced from the patient's own body by some genetic engineering techniques in a lab. This brings CAR-T cells into existence because the cells will now be able to produce the customized weapon (the said chimeric receptor) with our lines of commands (the DNA sequences). The CAR-T cells are re-delivered back into the patients' body afterwards as a "living drug".

Efficacy and Challenges

Given its potential to cure cancer, CAR-T cells have undergone many clinical trials to test its effectiveness for various types of cancer. According to a study from the University of Chicago [4], the success rate of CAR-T cell therapy is currently at 30 to 40% for long-term remission of some cancers.

While potent, there are certainly many challenges in perfecting CAR-T cell therapy. One problem is on-target off-tumor toxicity. As mentioned, tumor-associated antigens are not exclusive to cancer cells and may be present on the surface of healthy cells. This sometimes leads to a safety issue, when CAR-T cell targets the antigen on a healthy cell by mistake. Other challenges presented lie in the tumor microenvironment (TME), where the cancer cells reside, that may suppress the function of CAR-T cells [5]. Even now, scientists are working hard to improve upon these weaknesses, with more advanced versions of CAR-T cells popping up frequently. Some of the notable improvements include adding logic gates[3] to CAR-T cells to increase specificity and safety [6], while some aim to counter the immunosuppressive TME with supplementary molecules such as immune checkpoint inhibitors, to avoid the cancer cells from circumventing the assault of CAR-T cells by "cheating" [7].

一旦與抗體結合，抗原本身（可能是毒素），或是表面帶有抗原的物體（多為不受歡迎的東西，例如癌細胞或病原體等）將被其他免疫細胞識別，然後免疫細胞可能透過吞噬作用（phagocytosis）把它們整個吞下。然而，這個系統並不完美；就癌細胞而言，免疫系統並不是時常能夠辨認出它們就是我們身體中的敵人。

強大的合成怪物 — CAR-T 細胞

事實上，CAR-T 細胞中「chimeric」一字源於希臘神話中一隻會噴火的混種怪物 — 凱美拉（Chimera）。牠是獅子、山羊與蛇的混合體，而 CAR-T 細胞亦名副其實是細胞毒性 T 細胞和抗體的混合體。CAR-T 細胞利用嵌合 T 細胞受體（chimeric T-cell receptor）來識別癌細胞，「嵌合」二字形容受體是由數個蛋白質結構域（蛋白質的構成部分）融合而成，當中的選用的結構域取自不同蛋白質，各有獨特的功能。

像其他受體（或感受器）一樣，嵌合抗原受體[4] 共有三個結構域：細胞外域（在細胞外）、跨膜域（嵌在細胞膜中）和細胞內域（在細胞內）[3]。在這樣的結構下，嵌合抗原受體的細胞外域來自抗體的可變區，它能專一地跟與腫瘤相關的抗原結合。在癌細胞表面往往有大量與腫瘤相關的抗原，儘管它們並不一定是癌細胞獨有的。科學家期望所選擇的細胞外域可以將 CAR-T 細胞引導至癌細胞。至於跨膜域，它通常來自現有的受體；這個結構域的作用是將整個嵌合抗原受體固定於細胞膜。最後還有細胞內域，當中包含普通 T 細胞受體的細胞內訊號傳導結構域（intracellular signaling domains），以及其他協同刺激受體的細胞內訊號傳導結構域。簡單而言，當細胞外域跟與腫瘤相關的抗原結合時，它還可以活化 CAR-T 細胞，從而令癌細胞溶解。

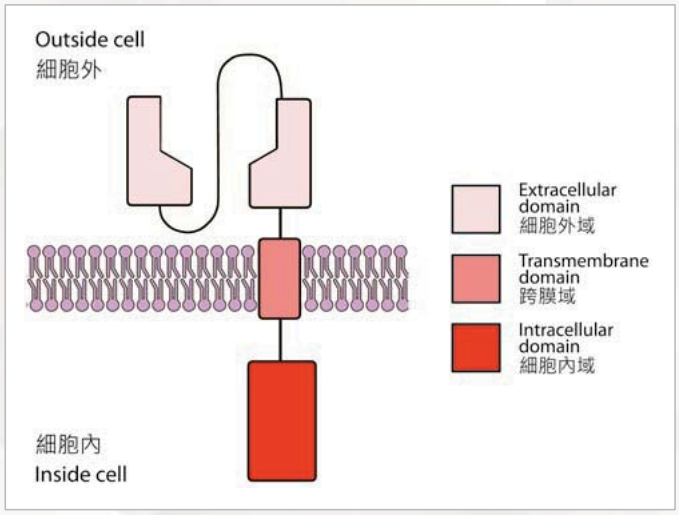


Figure 2 *Structure of a chimeric antigen receptor (CAR).*
圖二 *嵌合抗原受體的結構*

由零開始「組裝」我們的武器

那我們究竟是怎樣製造出 CAR-T 細胞的呢？當選定了合適的蛋白質結構域後，我們會在實驗室裡以基因工程技術，把這些結構域相應的基因序列串連起來，並將其合併到從患者身體抽取的 T 細胞當中的基因組內。這些細胞現在能夠根據我們輸入的「指令」（DNA 序列），生產出特別訂製的「武器」（之前提及的嵌合受體），製造出 CAR-T 細胞。此後 CAR-T 細胞會重新注射回患者體內，讓其發揮「活體藥物」的作用。

療效與未來挑戰

由於 CAR-T 細胞具有治療癌症的潛力，科學家已經進行了不少臨床試驗來測試其對各種類型癌症的效用。根據芝加哥大學的一項研究 [4]，對於部分癌症，以 CAR-T 細胞治療並達至長期緩解（remission）的成功率目前為 30% 至 40%。

儘管它功能強大，要使 CAR-T 細胞療法變得完善並非易事。CAR-T 細胞療法面對的其中一個挑戰就是「on-target off-tumor toxicity（擊中目標但並非腫瘤毒性）」。如前文所述，與腫瘤相關的抗原並非癌細胞獨有，它們亦可能存在於健康細胞表面。這有機會導致安全問題，因為 CAR-T 細胞可能錯誤地盯上健康細胞上的抗原。另一個挑戰在於癌細胞所在的腫瘤微環境（tumor microenvironment），它可能會抑制 CAR-T 細胞的功能 [5]。直到現在，科學家仍在努力克服這些弱點，而一些設計更先進的 CAR-T 細胞經常都會出現。一些顯著的改進包括在 CAR-T 細胞中加上邏輯閘（logic gate）[5] 以提高其專一性和安全性 [6]；亦有一些透過施以額外分子，例如免疫檢查點抑制劑（immune checkpoint inhibitor），來制衡免疫抑制的腫瘤微環境，從而防止癌細胞通過「欺騙」CAR-T 細胞而避過其攻擊 [7]。

什麼是免疫檢查點抑制劑？

從上文中，你會了解到抗原一旦與 T 細胞受體結合，T 細胞就會被活化而殺死癌細胞。然而，科家卻發現了一個名為「免疫檢查點（immune checkpoint）」的額外的調節器，它可以推翻上述的決定，而放生目標細胞；它是一個相反的機制，原意是避免免疫反應的過度激發 [8]。利用這一發現，嶄新的檢查點抑制劑免疫療法採用抑制劑來堵住癌細胞所表達的檢查點。在理想情況下，沒有癌細胞再能逃過 T 細胞的攻擊。這使其發現者贏得了 2018 年諾貝爾獎。

2 For the chimeric one, it is more often referred to as chimeric antigen receptor (CAR) instead of T-cell receptor. However, they refer to the same thing but just named from different perspectives – a receptor on T cells versus a receptor which binds to antigen.

3 Logic gates perform logical operations and produces outputs according to inputs it receives.

4 CAR-T細胞中的嵌合T細胞受體（chimeric T-cell receptor）更常被稱為嵌合抗原受體（chimeric antigen receptor/CAR）；兩者指的是同一樣東西，只是從不同角度命名而已 — T細胞上的受體，或是與抗原結合的受體。

5 邏輯閘執行邏輯運算，並根據其接收的輸入訊號產生相應的輸出訊號。

What is an immune checkpoint inhibitor?

From the passages above, you can learn that once the antigen is bound to the TCR, the T-cell will be triggered to kill the cancer cell. However, as a counter mechanism to prevent over-activation of an immune response, it was discovered that an additional regulator, immune checkpoint, can override this decision and spare the target cell [8]. Harnessing this discovery, the novel checkpoint inhibitor immunotherapy, which earned its discoverers a Nobel Prize in 2018, employs inhibitors to block the checkpoints expressed by cancer cells, so that ideally, they cannot be spared.

Summary

Owing to its reputation as the programmed cancer killer, CAR-T cells have garnered much attention in recent years. Where humans have traditionally relied on chemical drugs, CAR-T cells represent a new class of "living" drugs. Immunotherapy, which includes CAR-T cells, is set apart from other therapies because such treatments utilize our own immune system to fight against diseases. In truth, the immune system has always been a faithful guardian, defending our body from diseases all the time, sometimes even without us noticing; it is only fitting that, with the help of an innovative upgrade, it can be used to dispatch rebellious cells that turn cancerous. Hopefully, this will prove to be a more effective therapy, with substantially less side effects, bringing humans one step closer to curing cancer effectively!

總結

有著「程式控制癌症殺手(programmed cancer killer)」的美譽，CAR-T 細胞近年來受到廣泛關注。儘管我們以往都按照傳統地偏向使用化學性藥物，CAR-T 細胞卻向我們展示了一類嶄新的「活體」藥物。包括 CAR-T 細胞在內的免疫療法與其他療法不同之處，在於這類療法是利用我們自身的免疫系統來對抗疾病。事實上，免疫系統一直是我們的忠實守護者，不知不覺間全天候地保護著我們的身體。藉著把它們用創新方法升級，它可以用來殺死難以對付、叛變的癌細胞。希望這個療法在將來能變得更有效和副作用能大大減少，使人類可以更有效地治療癌症。

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BRAIN FREEZE「凍上腦」

The Signature Summer Pain

另類夏日風物詩

By Yasine Malki 馬建生

Brain freeze, the signature summer pain we experience when we are enthusiastically gulping down a large bowl of ice-cream, or slurping down a cup of refreshing slush...then you suddenly feel a sharp, searing pain in your forehead, almost like your brain has turned to ice!

Seeing that it is so common, and the fact that we have a massive repertoire of medication for headaches and migraines[1], you may expect that we would have a clear explanation for this. However, scientists are still not sure of the specific mechanism that causes brain freeze. Before exploring its possible causes, let's first talk about what brain freeze is!

The scientific term for brain freeze is sphenopalatine ganglioneuralgia [1], or sometimes referred to as ice-cream headache or cold-stimulus headache. Induced by the consumption of a cold product, like an iced beverage or ice cream, at a very rapid rate, brain freeze is a short-term headache in the frontal and temporal (behind the eyes) regions of our head [2] that lasts for seconds, or sometimes up to one or two minutes. Not normally leaving any long-term effects, this phenomenon is suspected to be an evolutionary temperature regulator, telling the body to slow down the consumption of cold products [3].

The question is, given that food travels down our digestive tract, how does it connect with our head and cause brain freeze? Also, our brains are not equipped with sensory components to detect heat as we do in our skin, so how can it sense the cold in our mouth?

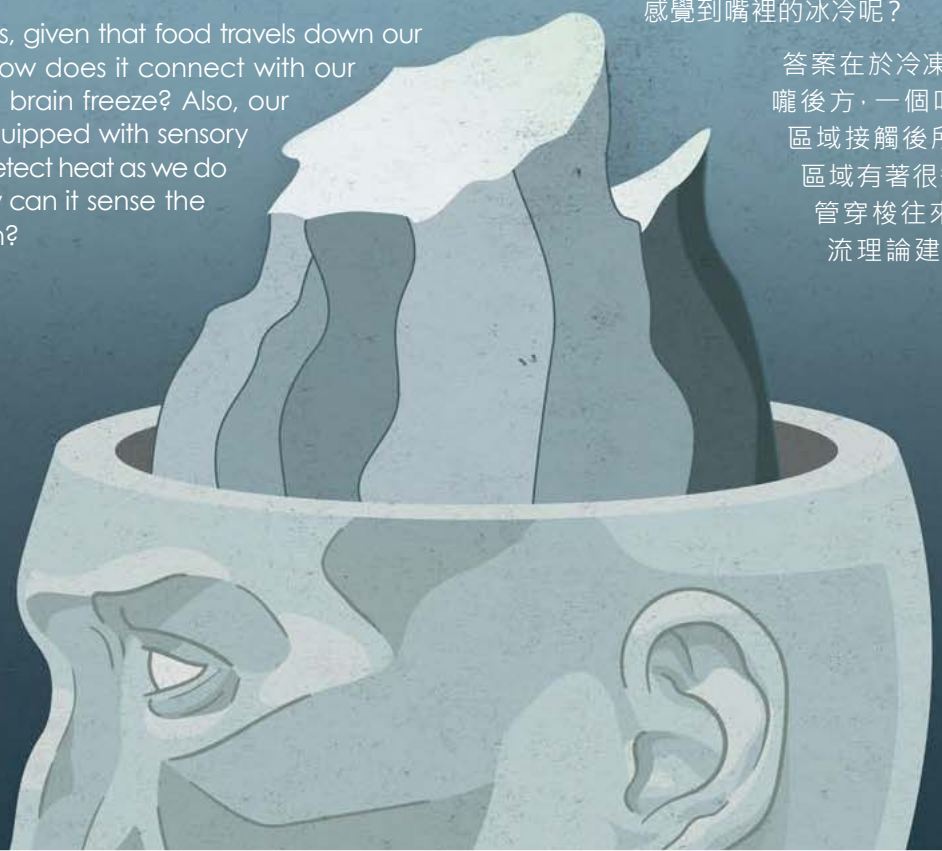
大腦凍結(brain freeze) — 亦即是廣東話裡的「凍上腦」,是一種夏日限定的頭痛。每當我們貪婪地吞下一碗雪糕,或是大口地啜飲一杯沙冰的時候 — 突然一陣刺痛侵襲你的前額,彷彿要把整個腦袋冰封!

眼見這個現象甚為普遍,而事實上我們亦齊備一系列治療頭痛和偏頭痛[1]的藥物,你可能會覺得我們對此會有一個清晰的解釋。可是,科學家卻不太肯定導致大腦凍結的詳細原因。在探討其可能原因之前,讓我先介紹甚麼是大腦凍結吧!

大腦凍結科學上叫「翼齶神經節疼痛(sphenopalatine ganglioneuralgia)」[1],有時又被稱為「雪糕頭痛(ice-cream headache)」或「冷刺激頭痛(cold-stimulus headache)」,它是出現在大腦額葉和顳葉(眼睛後面)區域的短暫性頭痛[2],持續時間為數秒至數十秒不等,有時更會長達一至兩分鐘,誘發的原因是因為我們狼吞虎嚥地吃或喝下冰凍飲料、雪糕等冷凍食品。這現象正常並不會為身體帶來長遠的影響,它被認為可能是從進化而來的機制,提醒我們要減慢進食冰凍食品的速度[3]。

那問題來了,既然食物是應該進入消化道的,那麼它跟頭部有著甚麼關係,可以引致大腦凍結?而且,我們的大腦並不像皮膚那樣具有能探測冷熱的結構,那麼它又怎樣能感覺到嘴裡的冰冷呢?

答案在於冷凍物與口腔頂部和喉嚨後方,一個叫「顎(palate)」的區域接觸後所觸發的反應。那個區域有著很多血管,高密度的血管穿梭往來該處。其中一個主流理論建基於喝下冰水後通

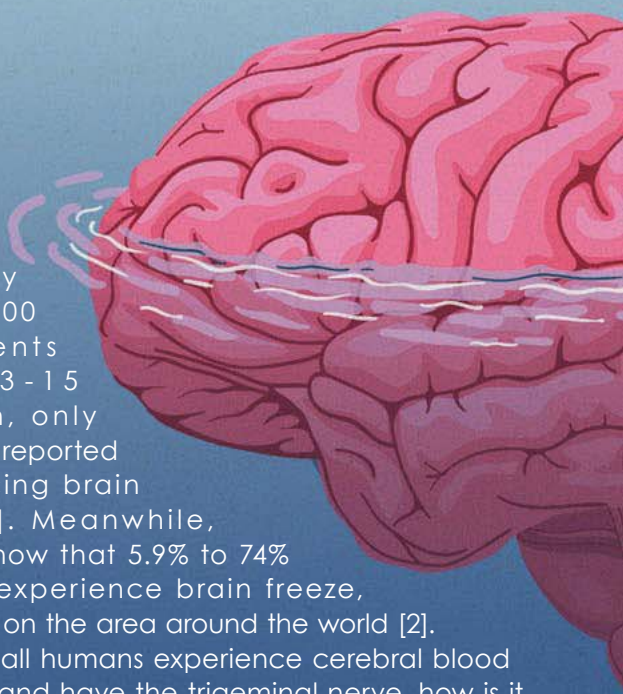


The answer is related to the response triggered when cold material comes into contact with the roof of the mouth and back of the throat, a region known as the palate. This area is highly vascularized, meaning that it has a high density of blood vessels that travel around it. One of the leading theories of brain freeze was based on measurements of blood flow to the brain during the consumption of ice-cold water. Researchers noticed a prominent increase in the blood flow in the anterior cerebral artery, a blood vessel that provides blood to the frontal lobe of the brain, which may be sufficient to trigger the sensation of pain [4]. The increase in blood flow is presumably facilitated by vasodilation, the widening of blood vessels. However, the underlying mechanisms that connect cold sensation with vasodilation awaits further investigations [3, 5].

In addition, the roof of the mouth is innervated by the trigeminal nerve, a major nerve that facilitates the communication between the forehead and face, with the frontal and temporal regions of the brain. Another plausible explanation of brain freeze is that the cold sensation leads to an over-stimulation of the trigeminal nerve [6], causing this widespread headache effect in which the brain is confused by the actual position of the cold sensation, and hence the pain perceived is also projected to other unrelated positions of the head covered by the trigeminal nerve [3].

However, there is still no consensus of what actually causes the pain, and how these two theories are connected – we don't know whether it is the abrupt blood pressure change that triggers the trigeminal nerve activations [5, 6], or the trigeminal nerve activation induces fluctuations in local blood pressure [7, 8] which leads to the pain. There are also possibilities that the two events are not linked, or either one of the processes – alternations in blood pressure or trigeminal nerve activation – doesn't involve in triggering brain freeze at all [1, 2, 4].

Seeing that we somewhat have an idea of what may cause this brain freeze effect, here comes the real mystery – not everyone experiences brain freeze!



In a study of over 8000 adolescents aged 13-15 in Taiwan, only about 40% reported experiencing brain freeze [9]. Meanwhile, statistics show that 5.9% to 74% of adults experience brain freeze, depending on the area around the world [2]. Given that all humans experience cerebral blood circulation and have the trigeminal nerve, how is it possible that some people experience brain freeze, but not others?

So far, scientists speculate that the trigeminal nerve may be less sensitive in certain individuals [6]. It is also revealed that the effect of brain freeze appears to be heritable, as children who experience brain freeze tend to have parents who also have it [2, 6]. Also, those who experience migraines and headaches seem to be more susceptible to brain freeze [5, 6, 9], which implies a similar mechanism between these conditions [5, 6].

Unless you are a lucky one who can eat as much ice-cream without experiencing brain freeze, the best way to prevent brain freeze is to eat your ice-cream slowly, and avoid touching the upper roof of your mouth with it. During a brain freeze, the best remedy is to drink some warm water. If that's not available, warm the upper roof of your month with your tongue. Both can raise the temperature of your palate, which should do the trick.

1 Migraines: A throbbing, pulsing pain in the head, normally in one specific area, and may be accompanied with nausea and sensitivity to light and sound.

往大腦的血流的量度結果：研究人員發現大腦前動脈（為大腦額葉提供血液的血管）的血流有顯著的增加，這可能足以引發疼痛的感覺 [4]。據推測，增加的血流可能是由血管舒張所促成的，然而凍結感和血管舒張之間的詳細關係卻有待進一步研究發現 [3, 5]。

此外，口腔上顎受三叉神經所支配；三叉神經是讓前額和面部與大腦額葉和顳葉溝通的主要神經。另一個大腦凍結的可能解釋是冰冷的感覺過度刺激三叉神經 [6]，令大腦也因混亂而搞不清楚冰冷感覺的實際位置，令痛楚感覺投射至其他受三叉神經覆蓋但不相關的位置，最終引起如此大範圍的頭痛 [3]。

可是，對於頭痛的實際原因，以及這兩個理論之間的關係，科學家並未能達成共識：我們不知道引發疼痛感是由於突然的血壓改變激發三叉神經 [5, 6]，還是三叉神經的激發導致局部的血壓改變 [7, 8]。也有可能兩者其實沒有關係，或者是其中一個過程（血壓改變或三叉神經的激發）並不參與其中 [1, 2, 4]。

正當我們以為對大腦凍結這個現象略知一二的時候，以下才是真正的疑團：原來並不是所有人都會經歷大腦凍結！在台灣一個超過 8000 個 13 至 15 歲青少年參與的研究中，只有約四成參加者回答曾經歷大腦凍結 [9]。另一方面，研究統計顯示在世界的不同地方，根據地域的不同，5.9% 到 74% 的成年人曾感受大腦凍結 [2]。既然所有人的血液也會流經大腦，大家都有三叉神經，那為甚麼有些人感受過大腦凍結，有些沒有？

到目前為止，科學家猜想某些人的三叉神經可能在相比之下沒有那麼敏感 [6]。研究亦反映大腦凍結的現象似乎是可以遺傳的，因為能感受到大腦凍結的小孩，它們的家長也傾向會出現大腦凍結的情況 [2, 6]。此外，出現頭痛或偏頭痛症狀的患者亦似乎更容易會出現大腦凍結 [5, 6, 9]，意味著這些症狀背後也可能有著相似的原理 [5, 6]。

除非你是大吃特吃雪糕也不會出現大腦凍結的幸運兒，否則最佳的預防方法還是從容地吃你那杯雪糕，同時避免讓雪糕接觸上顎。當出現大腦凍結時，最佳的補救方法是喝一些暖水；如果沒有暖水的話，用舌頭溫暖一下上顎吧。這兩個方法都能提高上顎的溫度，因此應該奏效。

1 偏頭痛：出現在頭部的一陣陣痛楚，通常集中於一個特定位置，可能伴隨著嘔心和對光線及聲音的過敏。

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The Fascinating World of Animal Behavior

集合啦！超乎想像的動物行為學

By Chantelle Sullivan 蘇盈安

Introduction

With the release of *Animal Crossing: New Horizons*, it is hard not to fall in love with the cute anthropomorphic animal villagers that you may have come across in the game. The game series is well known for their cute and colorful animal characters that you, as the main character, can befriend. Of course, one can argue that it is unrealistic and far-fetched for animals to act like humans – socializing, building their own furniture, getting married, etc. (*There is a pair of married alpacas in the game!*) However, as surprising as it may seem, many animals have complex behaviors that you may not have previously thought possible. Therefore, Animal Crossing may actually be more realistic than you think. In this article, we will look at animal behavior through multiple angles: social relationships between families and potential mates, and the way of living.

Animals can socialize and communicate via seven different ways: visual, olfactory, electric, auditory, touch, seismic and thermal. Different animals utilize a different combination of these ways to convey information to their own kind, their preys and predators!

Social Communication in Elephants

All elephant species are able to communicate with each other via seismic vibrations on the ground. These animals are constantly on the move and can travel up to 195 kilometers in a day [1]. Being able to communicate over a long distance is undoubtedly an advantage. When auditory or acoustic communication reaches its limits, elephants turn to using ground waves. When an elephant stomps the ground, the vibrations produced were estimated to be sensed up to 2.2 kilometers away [2]. Researchers are currently investigating the special receptors in their feet and trunks that allow them to detect such vibrations from their own kind.

Besides their unique form of communication, elephants also have very special social structures. One herd, led by a matriarch, is comprised of her daughters and grandchildren. Males depart from the herd when they reach 12–15 years of age to search for mates. Female members of the same family form the same herd usually stay together till death do them part. Members within the same herd have their own unique calls and greetings to each other. It has been reported that members even assign themselves a unique "name" to be called by.

Elephants are also one of the few kinds of animals that mourn the deaths of family and friends. Cynthia Moss, a researcher who investigates elephants in the Amboseli National Park in Kenya, brought a dead matriarch's jawbone to her camp. A few days later, she was visited by the matriarch's family. The elephants headed straight to the jawbone of the dead matriarch [3], surrounded it and caressed it lightly with their trunks. It was also found that one elephant – stayed particularly longer than the rest, stroke the jawbone and turned it around – was the dead leader's seven-year-old son.

Agricultural Practices in Ants

Since animals live in the wild may live under hostile environmental stresses, homes are crucial to them. This applies to leaf-cutter ants. It is easy to belittle the complexity of their lives – being such small and seemingly insignificant insects – whose only task in life seems

to be cutting and carrying leaves. Actually, these underground critters are pioneers of agriculture, practicing farming even before humans did [4]. Their underground nests are split into rooms for different activities and members of the hierarchy [5]. The "farming room" is where they bring their freshly-cut leaves to cultivate their fungal garden. They also protect their fungi from pests and other unwanted growth, and remove waste when necessary. One way they remove harmful bacteria and unwanted fungi is through secreting antimicrobials [4, 6]. The fungi, in return, act as food for the ants. This symbiotic relationship first arose 50 million years ago and has sustained both species' populations till now [4], showing that even simple animals such as ants are capable of forming and carrying out complex relationships and activities.

Mating Rituals in Birds and Spiders

One of the prime purposes for species to survive is to reproduce successfully and pass on their genes to the offspring. To achieve this, animals have many tricks up their sleeve to land them the partner they want.

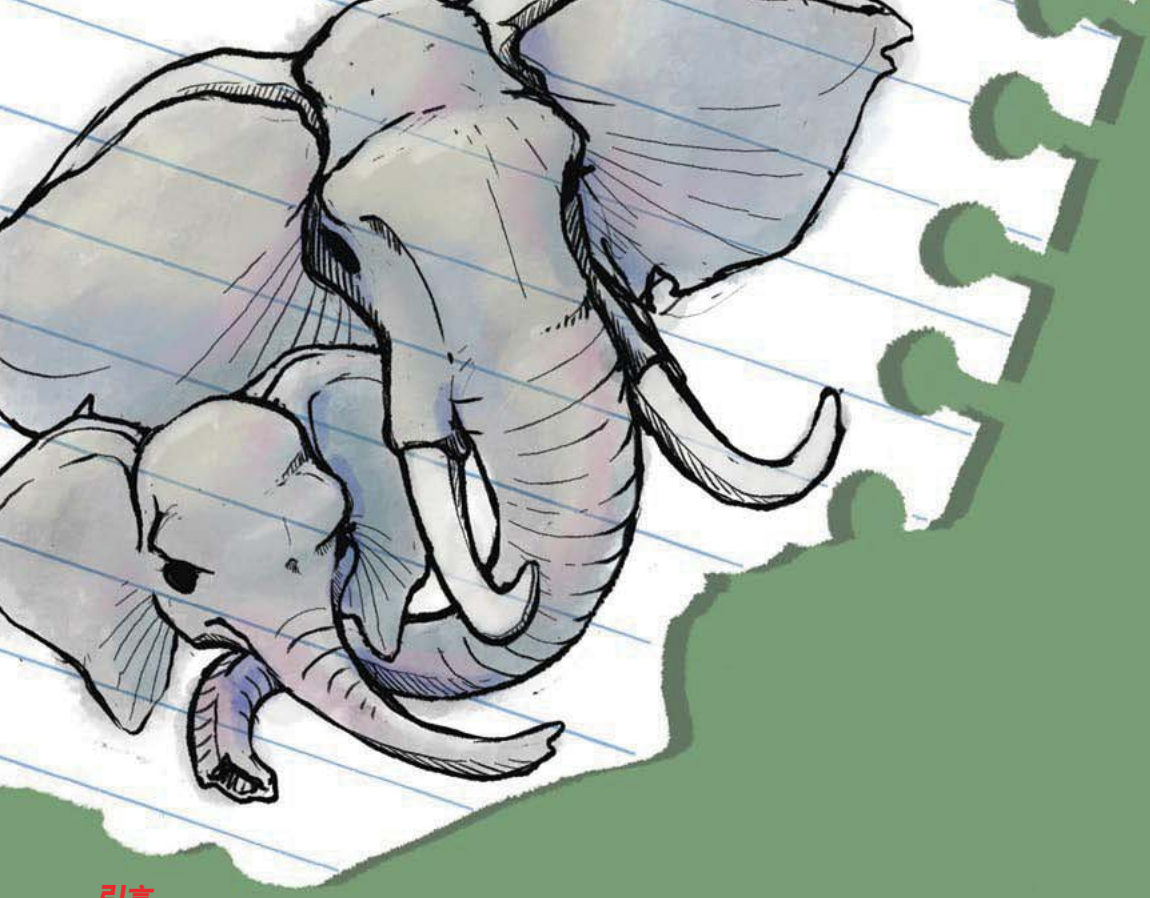
Like humans, some animals are selective in choosing their mates. For example, male birds-of-paradise, living in Papua New Guinea and eastern Australia, have elaborate courtship rituals where they dance to attract females [7]. The male Western Parotia (*Parotia sefilata*) is a black-colored bird with patches of iridescent yellow feathers by its neck. Before dancing for his mate, he first clears the ground of any fallen leaves and debris over a few days. At the open forest ground, females perch on the branches around to watch the show. Upon the females' arrival, the male performs on the "dance floor" with a polite bow, and with a flash of his blue eyes that momentarily turn yellow, followed by swaying, fancy footwork, head bobbing, and even a fancy move of spinning his body while holding it in a circular shape, as if it were a spinning black disk. Throughout the show, he flashes patches of bright-colored feathers alongside certain moves to show his fantastic dancing skills.

Other animals may adopt a lower profile in finding their mates. The nursery web spider is one example. To charm a female, males present food parcels that are wrapped with their own silk. The female usually prefers mating with the one that can provide high quality food in a nice package. It was found that males without a gift only had a 40% chance of successfully mating, whereas those with a gift had a 90% chance [8]. Interestingly, some sneaky males would eat the food within the silk and present an empty present to the female [9]. Females that are not vigilant might be tricked and only realized it after mating.

Fortunately, not all love stories in the animal world have sad endings. The albatross (a group of Antarctic birds) stay with one and only one mate for their lifetime. Spending most of their time in the open seas hunting for fish, they return to land once every year or every two years to reunite with their mate and reproduce [10].

Summary

Although most animals are not bipedal and cannot speak the same language as we do (as *Animal Crossing* may have wanted us to believe), they have a set of unique behaviors that demonstrate their intelligence and complexity. Besides knowing the differences between humans and other animals, we should also appreciate the wonder of their similarities and the complexity in the world of wild animals.



引言

隨著《集合啦！動物森友會》的推出，我們很難不愛上遊戲中那些逗人喜愛、以擬人形式出現的動物村民。這個遊戲系列以可愛和色彩豐富的動物角色見稱，作為主角的你可以成為他們的朋友。當然，有人對於在遊戲中動物的擬人行為，例如參與社交活動、製作家具、結婚（遊戲中甚至出現一對羊駝夫婦！）等，會覺得超乎現實和天馬行空；可是，現實卻可能會令你大吃一驚，因為許多動物都有著一些你從未想過的複雜行為。因此，《動物森友會》其實可能比你所想的更貼近現實。在這篇文章，我們會從多個角度探討動物行為：與家庭和潛在配偶之間的社會關係，以及動物的生活方式。

動物可以利用以下七種方法社交和溝通：視覺、嗅覺、電、聽覺、觸覺、地面震動和熱。不同動物會用不同組合來向同類、獵物和捕食者傳遞訊息。

大象的社交溝通

所有大象都能利用地面震動互相溝通。大象是不斷遷移的動物，一天可以移動多達 195 公里 [1]，因此能遠距離溝通無疑是個優勢。當溝通距離超越聽覺和聲音的極限時，大象會轉用地面波。當大象向地面蹬腿，製造的震動估計能傳遞到遠至 2.2 公里外而被感受到 [2]。研究人員正在調查在大象的腳和鼻中那些讓牠們可以感受到由同類引發的震動的特殊感受器。

除了與眾不同的溝通方式外，大象也有著非常特別的社會結構。每個象群由一個女族長帶領，並包含牠的女兒和孫兒們。雄性會在 12–15 歲時離開象群去尋找配偶，而同一個家族裡的雌性成員則會留在象群，直至生命終結。同一象群內的成員會以獨特的方式向對方鳴叫和問好，有研究指出成員甚至有著不同的「名字」給其他成員稱呼。

大象也是少數會哀悼家庭成員和朋友的動物。Cynthia Moss 是在肯亞安博塞利國家公園（Amboseli National Park）研究大象的學者，有天她把一塊死去大象女族長的顎骨帶到營裡。數天後，女族長的家庭前來拜訪，那群大象直接走向死去女族長的顎骨 [3]，把它圍住，然後用象鼻輕輕撫摸。有一隻大象被發現逗留得比其餘的久，又撫摸顎骨和把它反來覆去 — 原來牠是死去族長的七歲兒子。

螞蟻的農業活動

生活在野外的動物可能會面對各種不利的環境挑戰，家對牠們來說十分重要。切葉蟻也是一樣。牠們看上去只是一些微不足道的昆蟲，畢生的任務似乎就只有把葉片切開然後搬走，這使我們很容易輕視這些小生命的複雜性。事實上，這些居住在地下的小動物是農業先鋒，甚至比人類更早有務農的習慣 [4]。牠們的地下巢穴分成不同房間，供各類活動和不同階層的成員使用 [5]。

「種植室」是牠們的真菌花園所在的地方，切葉蟻會把剛切下的葉片帶到那裡用以種植真菌。牠們亦會透過防止害蟲和其他有害生物滋長來保護真菌，有需要時也會清理廢物。其中一種移除有害細菌和真菌的方法是分泌抗微生物劑 (antimicrobials) [4, 6]。作為回報，真菌將會成為切葉蟻的食物。這種共生關係最早出現在 5000 萬年前，使這兩個物種的種群到今天依然屹立不倒 [4]，亦展示了原來像蟻一樣的簡單動物也能結成複雜的關係和進行複雜的活動。

鳥類和蜘蛛的求偶儀式

物種生存的其中一個主要目標是要成功繁殖，把基因遺傳至後代。要達到這個目的，動物準備了各種各樣的招數，使牠們可以贏得心儀配偶的歡心。

像人類一樣，有些動物在選擇配偶方面都有一定要求。譬如居住在巴布亞新幾內亞和澳洲東面的雄性天堂鳥就有精心策劃的求偶儀式，牠們會以舞蹈取悅雌性 [7]。雄性的阿法六線風鳥 (*Parotia sefilata*) 是一種黑色的鳥，頸前有著一片片黃色虹彩羽毛。為異性跳舞之前，牠首先會一連數天清理地上的落葉和雜物。在森林中空曠的一隅，雌性會安坐於四周的樹枝上觀看這場表演。雌性到來後，「舞池」上的雄性會以一個風度翩翩的鞠躬揭開序幕，藍色的眼睛一閃之下頃刻地變成了黃色，伴隨著是身體的擺動、變化多端的舞步和頭部輕快的上下晃動；牠更會把身體展開成環形，然後花哨地旋轉，宛如一隻旋動的黑色圓盤。在表演途中，牠會藉著某些動作展示其鮮艷的羽毛斑塊來賣弄其超卓的舞藝。

其他動物在尋找配偶時也可能會採取低調。盜蛛是其中一個例子。為了博取雌性歡心，雄性會獻上自己用絲包好的食物包裹；而雌性通常會選擇與其交配的，是能奉上高質素食物，並以絲包得整整齊齊的雄性。研究發現沒有呈上禮物的雄性只有 40% 機會能成功交配，而有呈上禮物的則有 90% 機會 [8]。有趣的是，有些雄性會偷偷把絲裡面的食物吃光，然後呈上一份空空的禮物 [9]。沒有警剔的雌性可能因而受騙，直至交配後才意識到。

幸好，並不是所有愛情故事都會以悲傷結局告終。信天翁 (一種南極地區的鳥類) 終生只會與一個伴侶長相廝守。牠們幾乎窮盡大部分時間在遠離陸地的海域捕魚，每一至兩年才會回到陸地與配偶重逢和繁殖。

總結

儘管大部分動物都不是用兩隻腳走路，亦不是跟我們說著同一樣的語言 (《動物森友會》一直想我們相信這點！)，牠們也有一系列與眾不同的行為可以展示牠們的智慧和複雜性。除了了解人類和其他動物的相異之處外，我們亦應該欣賞動物之間那些令人不禁讚嘆的相似點，以及野生動物世界的複雜性。

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