生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	養真菌螞蟻身上的細菌製造抗生素 (Bacteria on fungus farming ants produce antibiotics)
生物系統 LIVING SYSTEM	切葉蟻 Attini (Leaf Cutter Ant)
功能類別 FUNCTIONS	#生物性控制族群、蟲害、病害 #不同物種之間合作/競爭 #應付群落中的擾動 #保護免受微生物危害 #Biological control of population, pests, diseases #Cooperate/compete between different species #Manage disturbance in a community #Protect from microbes
作用機制標題	生長在螞蟻身上的細菌會持續地變換抗生素，使入侵的真菌無法產生抗性 (Bacteria growing on ants produce constantly changing antibiotics that invading fungi cannot develop resistance to.)
生物系統/作用機制示意圖	

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

在大自然中，物種透過與其他物種共同合作來建立長久的關係。其中一個例子就是養真菌螞蟻、真菌和細菌之間的關係。養真菌螞蟻會培養真菌菌圃，這種螞蟻會提供真菌食物及理想棲息地供其生長，而真菌則能做為螞蟻的食物來源。生長在螞蟻身上的特殊細菌能幫助保護螞蟻栽培的真菌免受外界威脅，例如其它入侵的真菌。這種三方的關係是互利得益 (mutually beneficial)，表示兩個物種或更多的物種共同合作來互相幫助對方，這樣的關係對所有參與者都能正面得益。

不良真菌 (bad fungi) 會不時地嘗試入侵螞蟻的真菌菌圃。然而，螞蟻由於無法食用這些入侵真菌，因此牠們並不會得益。兩種生長在螞蟻身上的細菌會從螞蟻身上獲得營養，並製造多種的抗生素化合物，用以抑制這些不良真菌的生長。這些細菌能利用它們 DNA 的不同部分來製造出多種抗生素，DNA 提供了明確指示，讓細胞知道該製造哪種化合物。細菌會持續利用不同部分的指示，因此製造出來的抗生素經常不一樣，。讓不良真菌無法快速地發展防禦能力。具體來說，想像一下，不良真菌需要製造一把完美的鑰匙來開啟螞蟻真菌菌圃的大門。為了阻止這件事發生，細菌只需要在鑰匙孔上進行微小的改變，就能阻止不良真菌開啟大門。因此，不良真菌很少能發展出對抗抗生素的防禦能力。

人類會被細菌所感染。為了治療這些感染，醫生給的處方只會使用含單一化合物的抗生素

來殺死細菌。經過一段時間，細菌就能學習保護自己，並對抗生素產生抗藥性。因此，人類或許可以運用養真菌螞蟻的策略，透過在抗生素上做出小改變，使其變得更難讓細菌發展出抗藥性。

In nature, species work with each other to build long-lasting relationships. One example is the relationship between a fungus-growing ant, fungi, and bacteria. Fungus-growing ants grow a garden of fungi. The ants provide the fungi with food and an ideal habitat to grow, and in turn the fungus is a food source for the ants. Special bacteria living on the ants help protect the fungi from outside threats, such as other invading fungi. This three-way relationship is mutually beneficial. This means that two or more species work together to help each other and that the relationship has a positive benefit for everyone.

From time to time, bad fungi will try to invade the ant's fungi garden. However, the ants cannot eat these fungi, so they would not benefit. Two species of bacteria live on the ant and receive food from the ant. In turn, they make a variety of antibiotic compounds that can stop the growth of these bad fungi. The bacteria can make a variety of different antibiotics by using different parts of their DNA. DNA provides instructions that tells the cells what kinds of compounds to make. The bacteria constantly use different parts of the instructions so that the antibiotic is always different. As a result, the bad fungi cannot develop a defense fast enough. To visualize this, imagine that the bad fungi need to produce a perfect key to open the gate to the ant's fungi garden. To stop this from happening, the bacteria only need to make small changes to the key slot to stop the bad fungi from opening the gate. As a result, the bad fungi are rarely able to develop a defense against the antibiotics.

Humans can develop infections caused by bacteria. To treat the infections, doctors give antibiotics consisting of only one compound to kill the bacteria. Over time, the bacteria can learn to protect themselves and become resistant to the antibiotic. Therefore, humans could apply fungus-farming ant's strategy by making small changes to the antibiotics that will make it more difficult for the bacteria to develop resistance.

文獻引用 (REFERENCES)

養真菌螞蟻（切葉蟻族 Attini）栽培特定真菌做為食物已經有六千萬年歷史了。牠們共同演化的互相依賴性非常微妙，在很多切葉蟻族物種中，牠們的真菌栽培種 (cultivars) 並不會在共生關係之外找到。這些真菌需要螞蟻提供特定的微環境 (microclimates) 及營養，反過來，它們也成為螞蟻的唯一食物來源。來自 *Escovopsis* 屬的其它真菌能夠入侵到螞蟻栽培的真菌中，由於螞蟻完全依靠培養的真菌為食，因此這種寄生行為對螞蟻來說是不利的。為了對抗這些寄生性真菌，螞蟻演化出多重的策略。其中一種是三方互利共生關係 (tripartite mutualistic relationship)，螞蟻讓身體做為會製造抗真菌素的細菌之宿主，藉此保護牠們的真菌栽培種。很多的這類細菌會與宿主共同演化，製造抗微生物素來抑制寄生性真菌，反之，螞蟻也會提供細菌養分以及適合其生長的微環境。(Pathak et al. 2019: 974)

在這個共同演化的軍備競賽 (coevolutionary arms race) 中，新型的細菌性抗微生物化合物可以透過全新的基因簇重組 (gene cluster rearrangement) 或突變而形成。產生的新型化合物能達到較多或較少的演化成功率 (evolutionary success) 取決於不良真菌 *Escovopsis* 菌株對其抗微生物素的感受性 (antimicrobial susceptibility)。人類使用多種抗微生物素，但它們在結構上是分離的化合物，而不是像螞蟻和牠們互利共生夥伴所利用是範圍較廣泛的微細變異產物。人類的策略亦有不同，是使用單一化合物的抗微生物素做為快速消滅病原菌的手段，而不是以單方面進行長期逐步抑制的策略。(Pathak et al. 2019: 976)

"Fungus-growing ants (tribe: Attini) have cultivated specific fungi as food for 60 million years. Their coevolutionary interdependence is so refined that, for many attine species, their fungal cultivars are not found outside this symbiotic association. The fungi need specific microclimates and nutrition provided by the ants and, in turn, constitute the ants' sole food source. Other fungi, of the genus *Escovopsis*, can invade the cultivated fungus and, because the ants rely entirely on cultivated fungus for food, this parasitism is detrimental to the ants. To counteract these parasitic fungi, ants have evolved multiple strategies. One is a tripartite mutualistic relationship, within which the ants host antimicrobial-producing bacteria on their bodies to protect their fungal cultivar. Many of these bacteria have coevolved with their hosts, producing antimicrobials to inhibit the parasitic fungi, while in return, the ants provide them with nutrition and a microclimate suitable for growth." (Pathak et al. 2019: 974)

"In this coevolutionary arms race, novel bacterial antimicrobial compounds can be formed via novel gene cluster rearrangement or mutations. Novel compounds so generated achieve greater or lesser evolutionary success based upon the *Escovopsis* strain antimicrobial susceptibility… Humans use diverse antimicrobials, but they are structurally discrete compounds rather than the diverse range of subtle variants utilised by the ants and their mutualists. The humans' strategy is also different; use of discrete antimicrobials as means of rapid pathogen elimination rather than one facet of a long-term strategy of progressive inhibition." (Pathak et al. 2019: 976)

參考文獻清單與連結 (REFERENCE LIST)

Pathak, A., S. Kett, and M. Marvasi. (2019). Resisting antimicrobial resistance: lessons from fungus farming ants. *Trends in Ecology & Evolution* 34: 974-976. (https://doi.org/10.1016/j.tree.2019.08.007)

延伸閱讀

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

https://en.wikipedia.org/wiki/atta
https://www.onezoom.org/life/@atta

https://eol.org/pages/406378
撰寫/翻譯/編修者與日期
譚國鎏翻譯 (2021/03/22)；詹美鈴編修 (2021/04/26)
AskNature 原文連結
https://asknature.org/strategy/bacteria-on-fungus-farming-ants-produce-antibiotics/