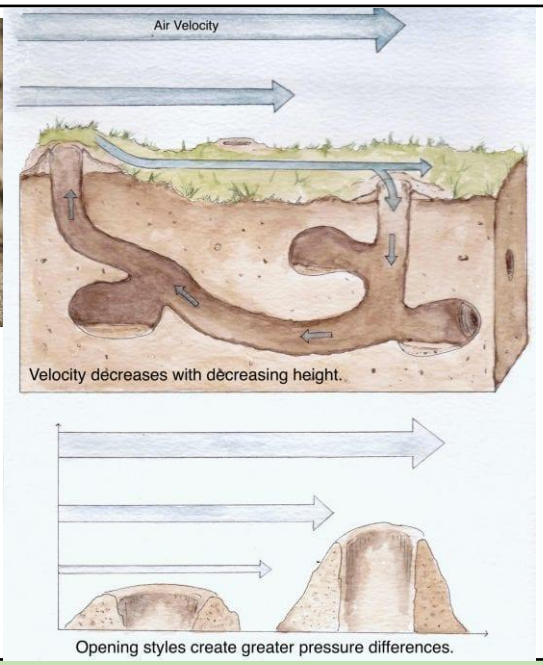
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	**不對稱的洞穴開口產生被動通風** (Asymmetric burrow openings create passive ventilation)
生物系統 LIVING SYSTEM	**黑尾草原犬鼠** *Cynomys ludovicianus* (Black-tailed prairie dog)
功能類別 FUNCTIONS	#分配氣體 #Distribute Gases
作用機制標題	**黑尾草原犬鼠巢穴洞口的位置和形狀差異使氣壓改變，透過風能產生被動性通氣** (Differences in position and shape of burrow openings of black-tailed prairie dogs create passive ventilation from wind energy by altering air pressure.)
生物系統/作用機制示意圖	 

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

草原犬鼠 (prairie dog) 是高度社交性的嚙齒動物 (rodent)，牠們在北美平原上建立廣大的地下洞穴 (burrow) 以供其族群居住。洞穴的長度可以達到10公尺（32英尺），巨大的洞穴意味著僅擴散作用 (diffusion) 並不足以讓新鮮空氣替換洞穴內使用過的空氣。然而，黑尾草原犬鼠建造洞穴開口的方式，有助於利用平原上的風能通過洞穴的地道 (tunnel)，產生被動性通風 (passive ventilation)。

當空氣流過一個表面時，會形成流速 (flow speed) 梯度，越靠近表面的空氣移動速度就越慢。草原犬鼠可以透過建立一個在高處有迎風 (upwind) 洞口的土丘 (mount)，和一個在低處有順風 (downwind) 洞口的土丘，利用這個梯度而得益。在較高開口的風速比較低開口的風速高，從而在局部區域形成了低壓與高壓（遵循伯努利原理 Bernoulli's principle）。兩個洞口之間壓力差導致空氣從較低的開口被吸入，並從較高的開口流出，造成單向的氣流通過洞穴。

洞穴開口周圍的土丘為草原犬鼠提供額外功能，例如可作為一個監視掠食者的棲息處 (perch)。其他生物也會使用類似的開口佈置來產生被動性流動，包括海綿 (sea sponge) 和帽貝 (limpet)。

Prairie dogs are highly social rodents that build extensive underground burrows in the plains of North America to house their family groups. The burrows can reach 10 m (32 ft) in length, and this size means that diffusion alone is not sufficient to replace used air inside the burrow with fresh air. The way that a prairie dog builds the openings to its burrow, however, helps to harness wind energy from the windy plains and create passive ventilation through the burrow's tunnels.

As air flows across a surface, a gradient in flow speed forms, where air moves slower the closer it is to the surface. The prairie dog is able to take advantage of this gradient by building a mound with an elevated opening upwind and a mound with a lower opening downwind. Over the elevated opening, wind velocity is faster than it is over the lower opening, creating a local region of low pressure (following Bernoulli's principle). The result of this difference in pressure between the two openings is one-way air flow through the burrow as air gets sucked into the lower opening and flows out the elevated one. This is the mechanism behind a Venturi tube.

The mounds around the burrow openings serve additional functions for the prairie dog, like providing a perch to watch for predators. Other organisms use a similar arrangement of openings to generate passive flow, including sea sponges and limpets.

文獻引用 (REFERENCES)

「在流體流過表面之處，例如風在地球上流動時，所產生的速度梯度會提供功 (work) 的潛在來源。此梯度被一隻穴居動物利用在狹長的洞穴中引起空氣流動。黑尾土撥鼠的洞穴構成了一個規模異常大的呼吸無效區 (respiratory dead-space)，擴散作用似乎不足以進行氣體交換。但是洞穴的排列方式適合風力驅動 (wind-induced) 的換氣，通常在洞穴的兩端有開口，而圍繞開口的土丘有兩種形式（圖3），兩端各為一種形式。當微風吹過土丘時，空氣通過較低的土丘進入洞穴，並通過較高的土丘離開。在風洞 (wind tunnel) 洞穴模型上的真實比例土丘模型 (scale model)，也有同樣明顯的單向氣流；洞穴內的氣流與穿過土丘的氣流幾乎能呈現線性函數（圖4）。洞穴模型中由風力驅動的通風也可以由不同形狀的土丘模型引起，但不同高度的土丘模型則不能。有較鋒利外緣的土丘比圓頂的土丘更有效地排出空氣；事實上這種形狀差異能補足高度差異。」(Vogel et al.1973: 1)

"Where a fluid flows across a surface, such as wind over the earth, the velocity gradient created provides a potential source of work. This gradient might be employed by one burrowing animal to induce air-flow in its long, narrow burrow. The burrow of the black-tailed prairie-dog constitutes a respiratory dead-space of extraordinary magnitude in which diffusion appears inadequate for gas exchange. But the burrow is arranged in a manner appropriate for wind-induced ventilation, typically with two openings at opposite ends and with mounds surrounding these openings of two forms (Fig. 3), with one form on each end. When a breeze crosses the mounds, air enters the burrow through the lower mound and leaves through the higher. The same unidirectional flow is evident with scale models of real mounds on a model burrow in a wind tunnel; flow inside the burrow is nearly a linear function of flow across the mounds (Fig. 4). Wind-induced ventilation in the model burrow could also be induced with model mounds differing in shape but not height. Mounds with sharp rims were more effective exits for air than mounds with rounded tops; in nature such shape differences complement the differences in height." (Vogel et al. 1973: 1)

參考文獻清單與連結 (REFERENCE LIST)

Vogel, S., C. P. Ellington, and D. L. Kilgore. (1973). Wind-induced ventilation of the burrow of the prairie-dog, *Cynomys ludovicianus*. *Journal of Comparative Physiology* 85: 1-14. (https://link.springer.com/article/10.1007%2FBF00694136)

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AskNature原文連結

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