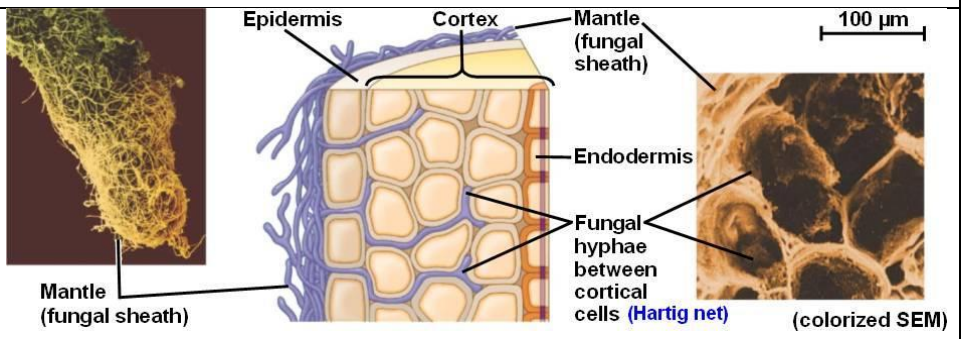
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	地下網路分配資源 (Underground Network Distributes Resources)
生物系統 LIVING SYSTEM	菌根菌 (Mycorrhizal fungi)
功能類別 FUNCTIONS	#分配固體 #分配液體 #保護免受動物危害 #傳遞化學信號（氣味、味道等） #不同物種之間合作/競爭 #Distribute Solids #Distribute Liquids #Protect From Animals #Send Chemical Signals (Odor, Taste, Etc.) #Cooperate/Compete Between Different Species
作用機制標題	菌根網路透過運輸養分和水分來維持森林裡的多樣性 (Mycorrhizal network sustains diversity in a forest by transporting nutrients and water.)
生物系統/作用機制示意圖	

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

在北美的花旗松 (Douglas-fir) 和松樹林中有各種年齡的樹木，從小的幼苗到幾百年的參天巨木。隱藏在土壤中的是一個龐大的網路，該網絡由數百萬英里、稱為菌絲體 (mycelium) 的細絲所組成。該森林中遍佈的菌絲體大多都是菌根菌 (mycorrhizal fungi)。這些是生活於與樹木及其它植物的互利共生關係 (mutualistic partnership) 中的真菌。

菌絲體的作用就像一個互聯網網路，但它們不會到處流動電子資訊，而是輸送水分和化學物質以使樹木存活並相互交流。這個網路已被稱為「樹木資訊網 (Wood Wide Web) 」。

在網路上，節點 (node) 是個人電腦，網路在它們之間流動訊息。中心 (hub) 是將許多節點連接在一起的地方，並且有大量信息通過它們，例如 Google。樹木資訊網的節點都是森林中的所有樹木個體。最古老的樹木，通常也是最高和最大的，擔當「中心」，因為它們擁有最多通過它們的連接。

菌絲體形成樹木資訊網中所有節點之間的連接。菌絲體纏繞在中心樹和其他植被的細根周圍，依附緊密以致於水分、養分和其它化學物質可以在根部和真菌的細胞之間移動。由於中心樹的大小，它相較於較小的樹木能接觸更多的陽光。這有時導致中心樹透過光合作用產生過多的醣類 (sugar)。當這種情況發生時，它將醣類通過菌絲體網路發送出去，提供自己的幼苗甚至其它樹種使用。醣類在樹木之間傳遞時，真菌會吸收一些供自己使用。

水分也在網路中的真菌和植物之間共享。水分和養分促進幼苗生長並幫助其它樹木存活。在另一種情況下，如果中心樹遭遇逆境並且需要水分或養分，菌絲體和其他樹木可以將它們送回中心樹。

但這不僅關於一棵中心樹。這是關於一棵中心樹連接到樹苗、連接到幼樹、連接到另一棵中心樹，依此類推。加拿大某研究地點的研究人員發現一棵樹透過此網路與其它 47 棵樹相連。世界上有百分之六十的樹種與這些菌根菌合作。大多數樹木與多種真菌種類（多於 5000 種）形成共生關係 (symbiosis)，每種真菌都可以與多種樹木建立關係。

除了共享養分和水分，網路也會發佈警告。如果一棵樹受到小蠹蟲 (bark beetle) 的攻擊，它會傳遞一種化學訊號，稱為防禦訊號 (defense signal)。菌絲體將此訊號傳遞到附近的其它樹木。當它們收到訊號就會增強化學防禦，這使它們在遭受攻擊時更容易作出抵抗。

In a Douglas-fir and pine forest in North America there are trees of all ages, ranging from tiny seedlings to giants that are hundreds of years old. Hidden in the soil is a vast network made up of millions of miles of thin threads called mycelium. Most of the mycelium spread throughout this forest are mycorrhizal fungi. These are fungi that live in a mutualistic partnership with trees and other plants.

The mycelium acts like an internet network but instead of moving electronic information around, they transport water and chemicals to keep the trees alive and communicating with each other. This network has been called the “Wood Wide Web”.

On the internet, nodes are individual computers and the network moves information among them. Hubs are places that connect lots of nodes together and have a lot of information traveling through them, such as Google. The nodes of the Wood Wide Web are all the individual trees in the forest. The oldest trees, which are often also the tallest and largest, are the ‘hubs’ because they have the most connections running through them.

Mycelia form the connections between all the nodes in the Wood Wide Web. The mycelia wrap around the fine roots of the hub tree and other vegetation, snuggling so close that water, nutrients, and other chemicals can move between the cells of the roots and fungi. A hub tree has more access to sunlight than smaller trees because of its size. Sometimes that results in it producing too much sugar through photosynthesis. When this happens, it sends the sugar out through the mycelium network to be used by its own seedlings and even other species of trees. The fungi take some of the sugar as it passes between trees and use it for themselves.

Water is also shared among the fungi and plants in the network. The water and nutrients increase seedling growth and help other trees survive. At another time, if the hub tree is stressed and needs water or nutrients, the mycelium and other trees can send them back to the hub tree.

But this isn’t just about one hub tree. It’s about a hub tree connected to a seedling connected to a sapling, connected to another hub tree, and so on. Researchers at a study site in Canada

discovered that one tree was connected to 47 others through this network. Sixty percent of the tree species in the world are associated with these mycorrhizal fungi. Most trees form symbioses with a wide variety of fungal species (there are more than 5000 of them) and each species of fungus can have relationships with a wide variety of trees.

Besides sharing nutrients and water, the network also sends warnings. If a tree is attacked by a bark beetle, it sends out a chemical signal, called a defense signal. The mycelium passes this signal along to other nearby trees. When they get the signal, they reinforce their chemical defenses, which makes it easier for them to fight off an attack when it comes.

文獻引用 (REFERENCES)

「當透過菌根網絡與鄰近植物連接時，植物的適應表現 (adaptive behavior) 可以被其改變，包含生理、基因調控和防禦反應的快速變化…這個現象與在森林生態系中更大規模的其它生物性網路之階級式整合，以及我們觀察到當它被中斷時的後果，都顯示地下的『樹語 (tree talk)』在森林生態系的複雜適應性中是一個基本過程。」(Gorzelak et al. 2015: 7)

"Adaptive behaviour of plants, including rapid changes in physiology, gene regulation and defence response, can be altered when linked to neighbouring plants by a mycorrhizal network... The hierarchical integration of this phenomenon with other biological networks at broader scales in forest ecosystems, and the consequences we have observed when it is interrupted, indicate that underground 'tree talk' is a foundational process in the complex adaptive nature of forest ecosystems." (Gorzelak et al. 2015: 7)

參考文獻清單與連結 (REFERENCE LIST)

Gorzelak, M. A., A. K. Asay, B. J. Pickles, and S. W. Simard. (2015). Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities. *AoB PLANTS* 7: plv050. (https://academic.oup.com/aobpla/article/doi/10.1093/aobpla/plv050/201398?searchresult=1)

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

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