生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	真菌如何淨化汙染 (How Fungi Can Clean Up Pollution)
生物系統 LIVING SYSTEM	真菌 (Fungi)
功能類別 FUNCTIONS	#催化化學性分解　#化學性分解聚合物 #從有機化合物中分離重金屬 #從有機化合物中分離鹵素 #化學性分解有機化合物 #Catalyze Chemical Breakdown　#Chemically Break Down Polymers #Cleave Heavy Metals From Organic Compounds #Cleave Halogens From Organic Compounds #Chemically Break Down Organic Compounds
作用機制標題	真菌有許多種特別令人印象深刻的酶，可被用來分解許多化學物質，以提取生存所需的能量及分子。 (Fungi have a particularly impressive variety of enzymes they can use to break down a wide variety of chemicals to extract the energy and molecules they need to live.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 出處: https://unsplash.com/photos/Y65sjGDJr18?utm_source=unsplash&utm_medium=referral&utm_content=creditShareLink
作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)	

導言

真菌利用很少有其他生物想要的資源——馬糞、落葉、動物屍體等——並將其中的天然化學物質分解成能滋養它們的能量及化合物之來源，以維持生命。有些真菌可利用相同的化合物來幫助它們獲得食物，同時分解人類所汙染環境中的人造化學物質。

策略

所有生物都含有酶，生物用來破壞或形成化學鍵的蛋白質。透過使兩個或更多的分子保持在靠近彼此且促進它們相互反應的位置上，酶使它的擁有者能夠將一種物質轉換成另一種物質，從而產生生物提供結構、製造能量等所需的分子。

作為專門分解其他生物 (或曾經活著的生物) 的生物，真菌擁有許多種特別令人印象深刻的酶，可被用來分解許多化學物質，以提取生存所需的能量及分子。正在尋找方法將人造汙染物從環境中移除的科學家們發現有些真菌可利用他們的酶來降解這些不受歡迎的化學物質。

已發現真菌可分解的汙染物包含多環芳烴 (polyaromatic hydrocarbons)（例如可在原油和汽油中被找到的那些）、重金屬、除草劑、殺蟲劑、藍藻毒素、藥物、抗生素、鄰苯二甲酸鹽、染料 (dyes) 和清潔劑。通常，他們(真菌)用來做這件事(分解汙染物)的酶也是他們平時用來分解木質素的酶，木質素是幫助植物形成堅固結構的分子。但其他酶似乎也參與其中。化學反應包括去除氧或氫、改變化學鍵的結構等。在某些情況下，這種變化可以將有毒物質變成無害的分子，例如碳水化合物、水和氧氣。

潛力

傳統用來從土地和水中去除工業廢物、油漆和殺蟲劑等污染物的方法成本高昂、耗能大且效果有限。有時甚至會在此過程中產生其他不受歡迎的分子。可以將正確種類的真菌引入受污染的地點獨自開始並完成這項工作嗎？這個過程被稱為真菌修復 (mycoremediation)，使用其他形式的生命直接完成任務（而不是將它們的經驗改進成新方法），因此是一種生物利用形式。為何我們通常不直接將真菌放入一個環境中並讓它們處理我們的汙染，有一個很好的原因: 很難擴大規模。真菌轉換已被創造之汙染物的速度遠低於我們製造汙染的速度。然而，基因改造 (genetic modification) 可提高一些降解汙染的真菌之效率，或者使它們能專門處理特定的汙染物。科學家們還在探索引入某些細菌或如纖維素等天然化學物質的方法，以使真菌的天然能力更有效。這項吸收有毒物質的能力亦可用於透過從電子廢物、廢水或天然沉積物中“收獲”貴重金屬來改善回收和減少採礦。

Introduction

They make their way through life by tapping into resources few if any others want—horse manure, fallen leaves, dead animals, and the like—and breaking down the natural chemicals they contain into a source of energy and molecules to nourish themselves. Some fungi can use the same molecules that help them obtain food to break down artificial chemicals with which we humans have contaminated the environment.

The Strategy

All living things contain enzymes, proteins they use to break or make chemical bonds. By holding two or more molecules close to each other in a position that encourages them to react with each other, enzymes allow their owners to transform one substance into another, creating the molecules they need to provide structure, produce energy, and more.

As organisms that specialize in decomposing other living (or formerly living) things, fungi have a particularly impressive variety of enzymes they can use to break down a wide variety of chemicals to extract the energy and molecules they need to live. Scientists searching for ways to remove human-made pollutants from the environment have discovered that some fungi can use their enzymes to degrade these undesirable chemicals.

Contaminants that fungi have been found to break down include polyaromatic hydrocarbons (such as those found in crude oil and gasoline), heavy metals, herbicides, pesticides, cyanotoxins, pharmaceuticals, antibiotics, phthalates, dyes, and detergents. Often, the enzymes they use to do this are also ones they normally would use to break down lignin, the molecule that helps give plants their stiff structure. But other enzymes appear to be involved as well. The chemical reactions include removing oxygen or hydrogen, altering the configuration of chemical bonds, and more. Such changes, in some cases, can turn toxic substances into harmless molecules such as carbohydrates, water, and oxygen.

The Potential

Conventional processes for removing pollutants such as industrial waste, paints, and pesticides from land and water can be expensive, energy-demanding, and of limited effectiveness. Sometimes they even produce other undesirable molecules in the process. The right kinds of fungi could be introduced to a contaminated site though and begin to do the job themselves? This process, known as mycoremediation, uses other forms of life to accomplish tasks directly (as opposed to adapting lessons from them into new innovations) and so is a form of bioutilization.

There is a very good reason why we don't generally just put fungi into an environment to let them take care of our pollution: it is very difficult to scale. Fungi convert the pollution we have created at a much slower rate than we create it. Genetic modification could enhance the efficiency of some contaminant-degrading fungi though, or enable them to specialize in certain pollutants. Scientists are also exploring ways to introduce certain bacteria or natural chemicals such as cellulose to make fungi's natural abilities more effective. This ability to take up toxic substances could also be used to improve recycling and decrease mining by "harvesting" precious metals from e-waste, wastewater, or naturally occurring deposits.

文獻引用 (REFERENCES)

「真菌修復可作為一種經濟的、環保的且有效的策略，以應對日益嚴重的土壤及水污染問題。真菌生長旺盛、龐大的菌絲網絡、多種細胞外木質素分解酶的製造、高表面積體積比、對重金屬的抵抗力、對波動的 pH 值及溫度之適應性以及金屬結合蛋白的存在；真菌是個整治各種不同汙染物的理想候選者。它可被用於各種污染，像是各行業釋放的染料、除草劑、藥品等的原位修復」 (Akhtar 和 Mannan 2020:1)

"Mycoremediation can be an economical, eco-friendly, and effective strategy to combat the ever-increasing problem of soil and water pollution. Robust growth of fungus, vast hyphal network, production of versatile extracellular ligninolytic enzymes, high surface area to volume ratio, resistance to heavy metals, adaptability to fluctuating pH and temperature and presence of metal-binding proteins; fungi are an ideal candidate for the remediation of various pollutants. It can be used for the in-situ remediation of various pollutants such as dyes, herbicides and pharmaceutical drugs released by various industries." (Akhtar and Mannan 2020:1)

參考文獻清單與連結 (REFERENCE LIST)　Harvard 或 APA 格式

延伸閱讀: Harvard 或 APA 格式（取自 AskNature 原文；若為翻譯者補充，請註明）

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

撰寫/翻譯/編修者與日期

賴儷心翻譯 (2022/4/1)；許秋容編修 (2022/5/20)

AskNature 原文連結

https://asknature.org/strategy/the-fungi-that-clean-up-pollution/

更多補充的圖片 (1. 確認版權、註明出處　2. 品質: 盡量 72dpi 或 300K)