生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	葉片超累積砷(Fronds Hyperaccumulate Arsenic)
生物系統 LIVING SYSTEM	鱗蓋鳳尾蕨(Ladder brake fern)
功能類別 FUNCTIONS	#空氣/水/廢物的解毒/淨化 #Detoxification/Purification of Air/Water/Waste #防禦化學物質 #Protect From Chemicals #儲存化學實體 #Store Chemical Entities
作用機制標題	鱗蓋鳳尾蕨的葉子會利用一種特殊的轉運蛋白過度累積有毒的砷，這種蛋白質會在液泡中將化學物質空間隔離。Fronds of ladder brake ferns hyperaccumulate toxic arsenic using a special transporter protein that spatially isolates the chemical in vacuoles.
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 出處: https://asknature.org/strategy/fronds-hyperaccumulate-arsenic/

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

策略:

鱗蓋鳳尾蕨 (*Pteris vittata*) 具有極佳的砷耐受能力，能夠吸收並累積高濃度的有毒類金屬砷。它從土壤中攝取砷，並將其運輸至葉片內部。當砷進入植物根部後，砷酸鹽在運輸至葉片的過程中被還原為砷化物，並以游離砷化物的形式儲存在細胞內。該蕨類植物內含有兩個基因 ACR3 和 ACR3;1，其所編碼的蛋白與酵母中的 ACR3 砷化物外排蛋白具有相似性。

ACR3 在鱗蓋鳳尾蕨中扮演關鍵角色，能夠恢復 ACR3 缺失酵母的砷敏感表型，顯示其對砷耐受性的影響。此外，當孢子體的根部與配子體接觸砷時，ACR3 會被誘導並提升轉錄活性，而 ACR3;1 的表現則不受砷影響。當 ACR3 在配子體中受到抑制時，植物對砷化物的敏感性明顯增加，然而抑制 ACR3;1 並不會產生類似影響，顯示 ACR3 是配子體砷耐受性的重要因子。進一步研究發現 ACR3 定位於配子體的液泡膜上，可能透過將砷化物轉運至液泡內進行隔離，從而降低細胞內的砷毒性。

潛力:

這項發現可應用於植物修復砷污染土地，例如透過基因改造水稻，使其將砷累積於根部，而非轉運至稻粒，以降低食用風險。此外，ACR3 基因在蘚類、石松類、其他蕨類及裸子植物中均有發現，但在被子植物中完全缺失。因此，研究計劃將 *P. vittata* 的耐砷基因導入阿拉伯芥 (*Arabidopsis thaliana*)，以評估是否能賦予其他植物類似的砷耐受能力，為未來的環境修復提供新的可能性。

The Strategy:

The Chinese brake fern (*Pteris vittata*) exhibits exceptional arsenic tolerance, capable of absorbing and accumulating high concentrations of the toxic metalloid arsenic. It takes up arsenic from the soil and transports it to its leaves. Once arsenic enters the plant through the roots, arsenate is reduced to arsenite during transport to the leaf tissues and is stored in cells in its free arsenite form. This fern contains two genes, ACR3 and ACR3;1, whose encoded proteins share similarities with the ACR3 arsenite efflux protein found in yeast.

ACR3 plays a crucial role in arsenic tolerance in *P. vittata*, as it can restore the arsenic-sensitive phenotype of ACR3-deficient yeast, highlighting its importance in arsenic resistance. Additionally, ACR3 transcription is upregulated in the roots of the sporophyte and in the gametophyte when exposed to arsenic, as these tissues are in direct contact with the soil. In contrast, ACR3;1 expression remains unaffected by arsenic. When ACR3 expression is suppressed in the gametophyte, the plant exhibits increased sensitivity to arsenite, whereas inhibiting ACR3;1 does not have the same effect. This suggests that ACR3 is a key factor in arsenic tolerance in the gametophyte. Further research has revealed that ACR3 is localized to the vacuolar membrane in the gametophyte, where it likely sequesters arsenite by transporting it into vacuoles, thereby reducing cellular arsenic toxicity.

The Potential:

This discovery has promising applications in phytoremediation of arsenic-contaminated soil. For instance, genetically modifying rice to accumulate arsenic in its roots rather than in the grains could help reduce arsenic exposure through food consumption. Furthermore, the ACR3 gene is present in mosses, lycophytes, other ferns, and gymnosperms but is completely absent in angiosperms. To explore whether this gene can confer arsenic tolerance to other plants, researchers plan to introduce the *P. vittata* arsenic-resistance gene into *Arabidopsis thaliana*, providing new possibilities for environmental remediation.

文獻引用 (REFERENCES)

“ ACR3 is necessary for arsenic tolerance in *P. vittata*. ACR3 likely functions as an arsenite effluxer based upon its ability to suppress the arsenite sensitivity and arsenic hyperaccumulation phenotypes of Δacr3 yeast, which lack an endogenous arsenite effluxer. Furthermore, the abundance of the ACR3 transcripts in *P. vittata* increases in response to arsenic in gametophytes and the roots of sporophytes, organs, and structures that naturally come in direct contact with arsenic in the soil. Finally, reduction in ACR3 transcript levels in gametophytes by RNAi results in an arsenite sensitive phenotype, clearly establishing the role of this protein in arsenic tolerance in *P. vittata*. (Emily Indriolo, GunNam Na, Danielle Ellis, David E. Salt, Jo Ann Banks. 2010)

ACR3 是 *P. vittata* 耐受砷所必需的。ACR3 可能發揮亞砷酸鹽外排劑的作用，因為它能夠抑制缺乏內源性亞砷酸鹽外排劑的Δ acr3 酵母的亞砷酸鹽敏感性和砷過度累積表型。

此外，由於配子體和孢子體根部、器官和結構中的砷與土壤中的砷自然直接接觸，*P. vittata* 中 ACR3 轉錄本的豐度會增加。最後，透過 RNAi 降低配子體中的 ACR3 轉錄水平，產生亞砷酸鹽敏感表型，清楚地確立了這種蛋白質在 *P. vittata* 砷耐受性中的作用。(Emily Indriolo, GunNam Na, Danielle Ellis, David E. Salt, Jo Ann Banks. 2010)

Single ACR3 genes were found in bacteria, fungi, in the whole-genome sequences of the moss *Physcomitrella patens* and the lycophyte *Selaginella moellendorffii*, and in EST collections from the fern *Ceratopteris richardii* and the gymnosperms *Welwitschia milabilis* and *Picea sitchensis*. Interestingly, ACR3 genes were not found in angiosperms, including Arabidopsis, rice, black cottonwood (*Populus trichocarpa*), maize (*Zea mays*), grape (*Vitis vinifera*), and Sorghum bicolor (sorghum for which whole-genome sequences exist). (Emily Indriolo, GunNam Na, Danielle Ellis, David E. Salt, Jo Ann Banks. 2010)

細菌、真菌、苔蘚植物小立碗蘚 (*Physcomitrella patens*) 和石松植物異葉卷柏 (*Selaginella moellendorffii*) 的全基因組序列中以及蕨類植物水蕨 (*Ceratopteris richardii*)和裸子植物千歲蘭 (*Welwitschia milabilis*) 和北美雲杉 (*Picea sitchensis*)。有趣的是，在被子植物中沒有發現 ACR3 基因，包括擬南芥、水稻、黑楊 (*Populus trichocarpa*)、玉米 (*Zea mays*)、葡萄 (*Vitis vinifera*) 和高粱(高粱)，這些植物都有全基因組序列。(Emily Indriolo, GunNam Na, Danielle Ellis, David E. Salt, Jo Ann Banks. 2010)

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

A Vacuolar Arsenite Transporter Necessary for Arsenic Tolerance in the Arsenic Hyperaccumulating Fern Pteris vittata Is Missing in Flowering Plants

The Plant Cell | 09/06/2010 | Emily Indriolo, GunNam Na, Danielle Ellis, David E. Salt, Jo Ann Banks

https://academic.oup.com/plcell/article/22/6/2045/6095974?login=false

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撰寫/翻譯/編修者與日期

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AskNature 原文連結

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[注意：此圖才是正確的鱗蓋鳳尾蕨 (*Pteris vittata*)]