生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	細菌表面菌毛有助於電子轉移 (Pili Direct Electron Transfer)
生物系統 LIVING SYSTEM	嗜乳酸桿菌 (L. acidophilus)、葡萄球菌屬 (Staphylococcus)
功能類別 FUNCTIONS	#形狀/材料最佳化 #轉導/轉換訊號 #對訊號反應 #Optimize shape/materials #Transduce/convert signals #Respond to signals
作用機制標題	細菌透過表面可導電的菌毛網路促進電子轉移。 (Surface of bacteria aids in direct electron transfer through use of network of nanofilaments(pili) that conduct electricity.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 https://www.shutterstock.com/zh/image-illustration/bacterium-pili-on-surface-isolated-dark-1757093456

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

先前認為細胞間透過表面的蛋白質(細胞色素)進行溝通與電子轉移。然而，近期研究表明細胞間的溝通方式亦可透過表面被稱為菌毛的奈米纖維進行。這些菌毛不僅是不同細胞型態的表現，它也參與了某些重要化合物的分解，例如三價鐵離子的氧化物。這些菌毛擔當著細胞間「橋梁」的角色，使電子能夠在細胞間更好地移動。當電子在細胞間移動時產生的電子流便會形成電荷。這將提供分解這些強鍵結化合物所需的能量。

(It was previously accepted that the surface of cells used a protein (cytochromes) to aid in communication and electron transfer between cells. This recent study suggests, however, that cell communication can extend beyond just the surface with nanofilaments known as pili. These pili aid in cell diversity but also in the breakdown of important compounds such as Iron (III) oxide (Fe(III)). They provide a type of "bridge" across which electrons can travel between cells. As the electrons move, a current is produced and a type of conductor is created. This electrical charge provides the energy and electricity needed to break down such strong compounds.)

文獻引用 (REFERENCES)

「能夠將電子轉移到如三價鐵離子氧化物等細胞外電子接受者的微生物，在降解土壤中有機物合養分循環扮演著重要的角色。過往對電子轉移至三價鐵離子的研究聚焦於細胞外的 c 型細胞色素。然而，某些還原三價鐵離子的細胞卻缺乏 c 型細胞色素。地桿菌屬在許多環境中都是主要的三價鐵離子的還原者。因其在還原三價鐵離子氧化物時須與其直接接觸，因此過往認為其生長出單邊的菌毛是為了更好的與化合物接觸。根據研究報告指出，缺乏菌毛的硫還原地桿菌突變體仍然能夠附著三價鐵離子氧化物但卻無法還原化合物。透過導電式原子力顯微鏡觀察發現其表面的菌毛是高度導電的。此觀察結果指出硫還原地桿菌的菌毛有如生物裡的電纜，將電子從細胞表面轉移至三價鐵離子氧化物

的表面。此種菌毛轉移電子的方式也揭示了其他細胞表面與細胞間的相互作用以及以生物工程創造新的導電材料的可能性。」 “Microbes that can transfer electrons to extracellular electron acceptors, such as Fe(III) oxides, are important in organic matter degradation and nutrient cycling in soils and sediments. Previous investigations on electron transfer to Fe(III) have focused on the role of outer-membrane c-type cytochromes. However, some Fe(III) reducers lack c-cytochromes. Geobacter species, which are the predominant Fe(III) reducers in many environments, must directly contact Fe(III) oxides to reduce them, and produce monolateral pili that were proposed, on the basis of the role of pili in other organisms, to aid in establishing contact with the Fe(III) oxides. Here we report that a pilus-deficient mutant of Geobacter sulfurreducens could not reduce Fe(III) oxides but could attach to them. Conducting-probe atomic force microscopy revealed that the pili were highly conductive. These results indicate that the pili of G. sulfurreducens might serve as biological nanowires, transferring electrons from the cell surface to the surface of Fe(III) oxides. Electron transfer through pili indicates possibilities for other unique cell-surface and cell–cell interactions, and for bioengineering of novel conductive materials.”
參考文獻清單與連結 (REFERENCE LIST) **Harvard 或 APA 格式**
Extracellular electron transfer via microbial nanowires *Nature* | 22/06/2005 | Gemma Reguera, Kevin D. McCarthy, Teena Mehta, Julie S. Nicoll, Mark T. Tuominen, Derek R. Lovley (https://www.nature.com/articles/nature03661)
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