生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	黏液降低阻力 (Slime Reduces Drag)
生物系統 LIVING SYSTEM	魚類 (Fish)
功能類別 FUNCTIONS	#在水中/上移動 #Move in/on Liquids
作用機制標題	魚類透過由複合蛋白、多醣以及細菌組成的黏膜層覆蓋於表皮上，以降低阻力 (Skin of fish reduces drag by being covered by a slime layer of complex proteins, polysaccharides, and bacteria.)
生物系統/作用機制示意圖	

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

「研究顯示魚類的黏液外層是用以減少阻力的聚合物 (polymer)。比較水流經虹鱒 (*Salmo gairdneri*) 與符合及不符合流體力學光滑表面的虹鱒蠟製模型 (wax model) 之速度資料，揭示了皮膚黏液分泌 (integumental mucous secretion) 能顯著降低通過邊界層的動量 (momentum) 傳遞率。動量傳遞的差異表示摩擦阻力 (friction drag) 的減小…」(Daniel 1981: 376)

「黏液作為減阻劑 (drag reducer) 和對實驗的速度梯度試驗有效，需要滿足幾個條件：(1) 黏液必須有一部分由水溶性、且分子量 (molecular weight) 超過50,000的聚合物所組成 (White and Hemmings, 1976)。(2) 魚類的周圍必須有湍流 (turbulent) 或規律且強力的層流 (pulsed laminar flow) (Driels and Ayyash, 1976)。以及 (3) 魚類表面外的流體密度與黏度 (viscosity) 須保持恆定。」(Daniel 1981: 380)

「利用黏液達到高游泳效率的機制包括轉態延遲 (transition delay)、減少湍流阻力，以及近期發現的減少聚合物溶液脈衝層流中的阻力。理論與實驗均顯示短暫的層流剪切流 (laminar shear flow) 在聚合物溶液中呈現出降低的壁面剪應力 (wall shear stress)。因此存在這樣的可能性，具低雷諾數 (Reynolds number) 的小魚可利用聚合物降低阻力，就如同具高雷諾數的大魚在湍流中一樣。」(Hoyt 1975: 653)

"The external layer of mucus on fish was investigated as a drag reducing polymer. Comparing velocity profiles for water flow over rainbow trout (*Salmo gairdneri*) and wax models

of trout with and without hydrodynamically smooth surfaces revealed that the integumental mucous secretion can significantly reduce the rate of momentum transfer through the boundary layer. The difference in momentum transfer is expressed as a reduction in friction drag…" (Daniel 1981: 376)

"Several conditions must be satisfied for mucus to act as a drag reducer and for my treatment of velocity gradients to be valid: (1) Mucus must consist, in part, of polymers soluble in water and with molecular weights exceeding 50,000 (White and Hemmings, 1976). (2) There must be turbulent or pulsed laminar flow about the fish (Driels and Ayyash, 1976). And (3) the density and viscosity of the fluid from the surface of the fish outwards must be constant." (Daniel 1981: 380)

"Mechanisms involved in utilizing the slime to achieve good swimming efficiency include transition delay, and turbulent flow drag reduction, in addition to the recently discovered drag reduction in pulsed laminar flow of polymer solutions…Both theory and experiment indicate the transient laminar shear flows show reduced wall shear stress in polymer solutions. Hence, the possibility exists that small fish with low length Reynolds numbers can utilize polymers to reduce drag, as well as the larger fish with high Reynolds numbers and turbulent flow." (Hoyt 1975: 653)

文獻引用 (REFERENCES)

參考文獻清單與連結 (REFERENCE LIST)

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Hoyt, J. W. (1975). Hydrodynamic drag reduction due to fish slimes. In *Swimming and flying in nature* (pp. 653-672). Springer, Boston, MA. (https://doi.org/10.1007/978-1-4757-1326-8_13)

延伸閱讀**:**

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

https://asknature.org/system/fish?post-type=Biological%20Strategies

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