生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	高效率游泳 (Swimming efficiently)
生物系統 LIVING SYSTEM	鯊魚 (Sharks)
功能類別 FUNCTIONS	#改變位置 #改變大小/形狀/質量/體積 #在液體中/上/移動 #化學能轉型 #Modify position #Modify size/shape/mass/volume #Move in/on liquids #Transform mechanical energy
作用機制標題	鯊魚是高效的游泳者的部分原因來自他們複雜的靜水骨骼 (Sharks are efficient swimmers in part due to their complex hydroskeleton)
生物系統/作用機制示意圖	

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

文獻引用 (REFERENCES)

「當 Wainwright, Vosburgh, and Hebrank (1978) 提出鯊魚會使用水骨骼 (hydroskeleton) 的理論時，應該很令人感到驚訝。鯊魚擁有一般鈣化的骨骼，但是鈣化程度不如其他脊椎動物高。鯊魚皮比一般的魚皮更加堅韌，此外亦擁有可偵測靜水壓力的交錯螺旋纖維陣列。鯊魚的肌肉直接地附著在皮膚上，這樣牠們不僅能作為外部抗水壓的膜，還可以看作是全身性的外部肌腱，因為非彈性的皮膚能夠將肌肉產生的拉力傳送至至尾巴。在鯊魚活動時，鯊魚體內的壓力可高達 200 千帕 (kPa)，大約是大氣壓力的兩倍，因此鯊魚就像是一顆有牙齒的鯊魚形狀氣球一樣。

鯊魚的交錯螺旋纖維對於抵抗扭轉的力量有重要幫助。鯊魚缺少魚鰾的構造，所以在不活動時會下沉。鯊魚在游泳的過程除了產生推進力以外，也會有造成一股上升的力量，鯊魚藉由擺動上長下短的不對稱尾鰭，獲得向上的力量。不對稱尾鰭可能使鯊魚在每次擺動時，產生縱向的扭曲力，所幸鯊魚有個能承受彎曲、抵抗扭力的軀幹。」 (Vogel 2013: 415-416)

"It came as more of a surprise than it should have when Wainwright, Vosburgh, and Hebrank (1978) showed that sharks utilized a hydroskeleton. Sharks have conventional skeletons, but somewhat less calcified ones than that of most other vertebrates. Shark skin is sturdier stuff than fish skins generally and it has the crossed helical fiber array diagnostic of these hydrostatic arrangements. In sharks, muscles attach directly to the skin, which thus acts both as external, pressure-resisting membrane and as an external, whole-body tendon. The non-elastic skin must transmit the forces generated by the body musculature back toward the tail. During locomotion, the pressure inside the body of a shark rises to as much as 200 kilopascals, twice atmospheric, so sharks are just shark-shaped balloons with teeth.

In sharks, the peculiar resistance of crossed helical fibers to torsion may have functional significance. Sharks lack swim bladders and thus sink if inactive. Swimming must produce a little lift in addition to thrust, and a shark gets that lift, in part, by beating a tail fin that extends farther dorsally than ventrally. That asymmetry might make a shark uselessly twist lengthwise, reversing twist twice during each full tailbeat--were it not for a torso that, while flexible in bending, resists twisting." (Vogel 2013: 415-416)

參考文獻清單與連結 (REFERENCE LIST)

Vogel, S. (2013). *Comparative biomechanics: life's physical world*, 2nd ed. Arizona: Princeton University Press,2013.

Hebrank, J.H., Vosburgh, F. and S. A. Wainwright (2006). Shark skin: Function in Locomotion. *Science* 4369: 747-749. (https://science.sciencemag.org/content/202/4369/747/tab-article-info)

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

https://en.wikipedia.org/wiki/Shark

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AskNature 原文連結

https://asknature.org/strategy/swimming-efficiently/