生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	腳在水面上「划行」 (Legs 'row' Across Water)
生物系統 LIVING SYSTEM	狡蛛屬 *Dolomedes* (Fishing spider)
功能類別 FUNCTIONS	#能量轉型/轉換 #機械能轉型 #Transform/Convert Energy #Transform Mechanical Energy
作用機制標題	狡蛛藉由腳的拖行以及與「水渦」聯合產生的水平推力，使其能在水面上划行 (The legs of the fishing spider enable it to 'row' across the surface of water using the horizontal propulsive forces generated by the drag of the legs and their associated 'dimples.')
生物系統/作用機制示意圖	

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

「腳和水渦 (dimple)（後者從腳所轉移的下沉重量而來） 以一個單元 (unit) 產生作用。當蜘蛛推動時，兩者都會隨著蜘蛛推進而往後 (rearward) 移動，而這個單元往後的拖行 (drag) 產生向前的推力 (thrust)。（將水渦往後推會促使水往前移動，因此水渦這種非物體 (non-object) 擁有完美的普通阻力 (perfect ordinary drag)。）」 (Vogel 2003: 108)

「狡蛛 (fishing spider) 雖然在美國南方的數量特別豐富，但牠們在整個美國都有分佈。牠們會在池塘或溪流的水邊埋伏，當有昆蟲掉落至水面時，狡蛛便會衝過水面攻擊。牠們也能將腳伸進水中捕捉游泳中的蝌蚪 (tadpole) 或是小魚。

像狡蛛這種動物的生存方式，其第一要務為如何停留在水上。狡蛛善用表面張力 (surface tension) 來達成此目的。水分子之間的吸引力比空氣分子之間的還要強。這種分子拉力 (molecular pull) 使水的表面變得像橡膠薄層一樣。當蜘蛛將腳放在水面上，會在其周圍形成漣漪狀 (dimplet-like) 的凹陷，而水會往回推來回復成光滑的表面。

雖然表面張力能夠使狡蛛保持飄浮在水上，但這使牠們難以移動到別處。牠們在陸地上可以用腳對固體地面施力，產生相反的力使自己往前移動。然而牠們蠟質(waxy) 的腳沒辦法抓緊池塘的水面；水造成過滑的效果，使牠們沒辦法移動。

但狡蛛還是能夠移動，瓦薩學院 (Vassar College) 的生物學家 Robert Suter 已經研究狡蛛如何在水上移動好幾年。他發現狡蛛是利用腳在水中產生的水渦而在水面上划行。當狡蛛將其中一隻腳從前方移至後方時，也會將水渦移到後方。隨著水渦移動，它就像槳 (oar) 一樣推開周圍的水，產生一股力量將蜘蛛向前推進。

狡蛛以四對腳的中間兩對來划行。首先牠將第三對腳向後擺動，接著是第二對腳。當兩對腳都伸展到它們最遠時，狡蛛會將兩對腳從水面上抬起並重新往前。同時，狡蛛保持第一和第四對腳不動，讓牠在準備下一次划動時能利用表面張力保持浮在水上。

然而狡蛛以這種方式移動的速度會有限制。若要更快速移動，狡蛛可以製造更大的水渦（有更大的槳），或是將水渦以更快的速度後推。」(Zimmer 2000)

“What happens is that the leg and dimple (the latter from the downward weight transferred by the leg) act as a unit. Both move rearward as the animal pushes, and the rearward drag of the unit generates the forward thrust (fig. 5.8b). (Moving a dimple backwards forces water to move forwards, hence this non-object has perfect ordinary drag.)” (Vogel 2003: 108)

“Fishing spiders live throughout the United States, although they’re particularly abundant in the South. They lurk along the edges of ponds and streams, and when insects drop to the water, these spiders rush across the surface to attack. They can also dip their legs underwater and grab swimming tadpoles and small fish.

The first order of business for animals with this lifestyle is to stay on top of the water. Fishing spiders do so by taking advantage of surface tension. Water molecules are more attracted to one another than they are to molecules in the air. This molecular pull makes the surface of water act like a sheet of rubber. When a spider sets a leg on the water, a dimple-like depression forms around it, and the water pushes back up to regain a smooth surface.

Although surface tension can keep fishing spiders afloat, it makes it hard for them to go anywhere. On land they can push their legs against solid ground, generating an opposing force that carries them forward. Their waxy legs can’t get a purchase on the surface of the pond, however; the water is, in effect, too slippery to permit the spiders to move.

But move they do, and for the past few years Robert Suter, a biologist at Vassar College, has been studying just how they do it. What he has found is that the spiders row across the water’s surface by using the dimples their legs make in it. When a fishing spider moves one of its legs from front to back, it draws that dimple back with it. As the dimple moves, it acts like an oar, pushing against the surrounding water and creating a force that propels the spider forward.

A fishing spider rows with the middle two of its four pairs of legs. First it swings back its third pair, then the second pair, and when both pairs are extended as far back as they can go, the spider raises them from the water and brings them forward again. Meanwhile, it keeps its front and rear pairs of legs motionless, using their surface tension to keep itself afloat while it prepares for the next stroke.

There's a limit to how fast fishing spiders can travel this way, however. To speed up, a spider can either make deeper dimples (giving itself bigger oars) or push them back faster." (Zimmer 2000)

文獻引用 (REFERENCES)

參考文獻清單與連結 (REFERENCE LIST)

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Suter, R. B. (1999). Cheap transport for fishing spiders (Araneae, Pisauridae): The physics of sailing on the water surface. *Journal of Arachnology* 27: 489-496. (https://www.jstor.org/stable/3706047)

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