生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	翅膀表面的自潔作用 (Wing Surface Self-Cleans)
生物系統 LIVING SYSTEM	閃蝶屬 *Morpho* (Morpho butterfly)
功能類別 FUNCTIONS	#保護免受塵土/固體危害 #Protect From Dirt/solids
作用機制標題	閃蝶大片表面積的翅膀紋理透過疏水性微結構去除水和灰塵 (High surface-area wing texture of Morpho butterfly sheds water and dirt via hydrophobic microstructure.)
生物系統/作用機制 示意圖	 

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

就像某些植物，許多大翅昆蟲的翅膀保持無塵 (dirt-free)（例如蝴蝶、飛蛾、蜻蜓、草蛉 lace wing），這在飛行上有明顯優勢，而且牠們無需使用化學清潔劑或消耗能量。這是透過其翅膀表面上大片表面積的多尺度微米及奈米形貌 (multi-scale micro- and nano-topography) 與水分子物理特性之間的相互作用來實現的。

儘管在翅膀表面形貌中出現了不同的特定結構，但它們都在與超疏水性（superhydrophobicity，極度不潤濕性）相關凸起 (protrusion) 的大小和距離上共享著相似的數學比例。舉例來說，蝴蝶的翅膀顯示出兩個關鍵的重複結構：個別鱗片(aquama)（每枚鱗片約40×80微米）和覆蓋每個鱗片隆脊 (ridge) 的微浮雕 (micro-relief)，每個隆脊的寬度在1000-1500 nm之間。

因為水分和空氣的黏附力不如水和固體的黏附力強，所以粗糙和大片表面積的折疊紋理可以降低對水滴的附著力 (adhesive force)，粗糙表面間隙中的空氣會導致液態-固態接觸面積減小。這使水分極性分子 (polar molecule) 的自體吸引力能更充分地發揮功能，從而使其形成球體。翅膀表面的灰塵顆粒會黏附在這些液滴上，這是由於水分和固體之間的自然黏附，以及由於翅膀的微觀形貌減少了與翅膀表面接觸。翅膀表面的最小角度會導致水珠因重力而滑落，將附著的灰塵顆粒一同帶走，清潔翅膀而無需使用清潔劑或消耗能量。受到自潔 (self-cleaning) 生物性表面啟發而產生的微米和奈米表面拋光漆 (micro- and nano- surface finish) 現已應用於油漆、玻璃、紡織品等，從而減少了對劇毒化學物質和昂貴勞力的需求。

多尺度紋理化同時亦提供了一個模型，可以大大增加許多材料的表面積。

Like some plants, the wings of many large-winged insects remain dirt-free (e.g., butterflies, moths, dragonflies, lace wings), an obvious advantage for effective flight, and they do so without using chemical detergents or expending energy. This is accomplished by the interaction between the high surface-area multi-scale micro- and nano- topography on their wing surfaces and the physical properties of water molecules.

While a variety of specific structures appear in this wing surface topography, all share a similar mathematical set of proportions in the size and distance of protrusions that are associated with superhydrophobicity (extreme non-wettability). For example, butterfly wings show two key repeating structures: the individual scales or squama (roughly 40×80 microns each) and the micro-relief of raised ridges covering each scale, each between 1000-1500 nm wide.

Because water and air adhere less well than water and solids, rough, high surface-area folded textures can reduce adhesive force on water droplets, as trapped air in the interstitial spaces of the roughened surface result in a reduced liquid-to-solid contact area. This allows the self-attraction of the polar molecule of water to express more fully, causing it to form spheres. Dirt particles on the wing's surface stick to these droplets, both due to natural adhesion between water and solids and because contact with the wing surface is reduced by the wing's micro-topography. The slightest angle in the surface of the wing then cause the balls of water to roll off due to gravity, taking the attached dirt particles with them, cleaning the wing without using detergent or expending energy. Micro- and nano- surface finishes inspired by self-cleaning biological surfaces have now been applied to paints, glass, textiles, and more, reducing the need for toxic chemistries and costly labor.

Multi-scale texturing is also providing a model for dramatically increasing the surface area of many materials.

文獻引用 (REFERENCES)

「許多生物性表面是疏水性 (hydrophobic) 的，因為其複雜的組成及表面微結構。選擇蝴蝶作研究目標，並透過共軛焦光顯微鏡術 (Confocal Light Microscopy)、掃描式電子顯微鏡術 (Scanning electron Microscopy) 及 接觸角測量技術 (Contact Angle measurement) 來研究其特性。水滴在蝴蝶翅膀表面的接觸角被測量到維持在大於140度。當傾斜角 (inclining angle) 大於3度時，於表面上的灰塵能被移動中的球狀水滴所清除。可以總結為，蝴蝶翅膀的表面具有防水 (water-repellent)、自潔、或「蓮葉效應」(Lotus-effect) 之特性。(Collins 2004: 245)

"Many biological surfaces are hydrophobic because of their complicated composition and surface microstructure. Butterflies were selected to study their characteristics by Confocal Light Microscopy, Scanning electron Microscopy and Contact Angle measurement. The contact angle of the water droplets on the butterfly wings surface consistently measured to be more than 140 degrees. The dust on the surface can be easily cleaned by moving spherical droplets when the inclining angle is larger than 3 degrees. It can be concluded that the butterfly wing's surface possess a water-repellent, self-cleaning, or 'Lotus-effect' characteristic." (Collins 2004: 245)

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