

生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	結構分散壓力 (Structure Distributes Stress)
生物系統 LIVING SYSTEM	歐洲赤松 (Scots pine)
功能類別 FUNCTIONS	#管理緊張狀態 #管理壓縮 #管理剪應力 #Manage Tension #Manage Compression #Manage Shear
作用機制標題	樹幹和樹枝透過負載適應性生長承受外部壓力。 (Trunks and branches of trees withstand external stresses through load-adaptive growth.)
生物系統/作用機制示意圖 (確認版權、註明出處； 畫質)	 <p>出處：AskNature Team</p>
作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)	
<p>樹木和骨骼透過有效利用材料和適應性結構設計，來最佳化強度、彈性和材料以適應各種負載條件，從而實現機械張力的均勻分佈。例如，為了均勻分佈壓力，樹木會在機械負載壓力最大的位置上添加木材，而骨骼則會更進一步在不需要的地方去除材料，根據其結構的動態工作負載量使其結構輕量化。在細胞的尺度上，樹木會沿著力流方向或主應力軌跡來排列纖維，以最大限度地減少剪應力。工程師將從樹木和骨頭中學到的這些經驗及教訓納入軟體設計程式中，以優化纖維複合材料的重量和效能。例如，根據這些原則設計的汽車零件和整輛汽車已經帶來了新的車輛設計，這些新設計的碰撞安全性與傳統汽車一樣，但重量卻減輕了 30%。</p> <p>Trees and bones achieve an even distribution of mechanical tension through the efficient use of material and adaptive structural design, optimizing strength, resilience, and material for a wide variety of load conditions. For example, to distribute stress uniformly, trees add wood to points of greatest mechanical load, while bones go a step further, removing material where it is not needed, lightweighting their structure for their dynamic workloads. At the scale of the cell, trees arrange fibers in the direction of the flow of force, or principal stress trajectories, to minimize</p>	

shear stress. Engineers have incorporated these and other lessons learned from trees and bones into software design programs that optimize the weight and performance of fiber-composite materials. For example, car parts and entire cars designed with these principles have resulted in new vehicle designs that are as crash-safe as conventional cars, but up to 30% lighter.

文獻引用 (REFERENCES)

「不過，[Claus] Mattheck 想要追求的類比不是樹木和其他生物之間的比喻，而是樹木和工程製品之間的比喻。如果樹木實現了長壽和結構穩定性，那麼這些難道不是工程師想要設計成產品的可靠性和完整性的品質嗎？」

「關鍵在於 Mattheck 的論點，即樹木和其他自然結構（例如動物骨骼）的結構最佳化都是為了使整個結構的外部 and 內部壓力盡可能分配均勻。Mattheck 稱其為『均勻應力公理』，並補充說，儘管他可以舉出很多例子，但他無法證明它的存在……，Mattheck 的論點是，樹木通過在高壓處添加更多材料來不斷重新調整這種平衡。在低壓處或無壓力點則不添加任何材料。（他認為，骨骼比起樹木會更進一步的在低壓處實際收縮。）」

「例如，在樹木中，主幹和樹枝之間的連接處是壓力集中的地方。樹木通過在連接處添加更多材料來彌補這種額外的壓力。」（Pullin 1998：17-18）

“The analogy that [Claus] Mattheck wants to pursue, though, is not that between trees and other organisms, but between trees and engineered artefacts. If trees achieve longevity and structural stability, aren't these the qualities of reliability and integrity that engineers want to design into products?

“The key to this is Mattheck's contention that the structural optimisation in trees and apparent in other natural structures such as animal bones is all about making the external and internal stresses as uniform across the whole structure as possible. Mattheck calls this the 'axiom of uniform stress' and adds that, though he can cite plenty of examples of it, he cannot prove it exists...Mattheck's contention is that trees are constantly readjusting this balance by adding more material at points of high stress and adding no material at points of low or no stress. (Bones, he contends, go one stage further by actually shrinking at points of low stress.)

“In trees, junctions between main trunks and branches, for instance, are places of concentrated stresses. Trees compensate for this extra stress by adding more material to the shoulder.” (Pullin 1998:17-18)

參考文獻清單與連結 (REFERENCE LIST) Harvard 或 APA 格式

The author's reply to the discussion on “A survey of X-rays in engineering and industry”
Journal of the Institution of Electrical Engineers - Part I: General | 11/04/2014 | V.E. Pullin
(<https://digital-library.theiet.org/content/journals/10.1049/ji-1.1945.0103>)

Design in Nature: Learning from Trees

27/02/2004 | Claus Mattheck

([https://www.amazon.com/Design-Nature-Learning-Claus-](https://www.amazon.com/Design-Nature-Learning-Claus-Mattheck/dp/3540629378%3FSubscriptionId%3DAKIAIMGIS4T74NLTJ3Q%26tag%3Daskn)

[Mattheck/dp/3540629378%3FSubscriptionId%3DAKIAIMGIS4T74NLTJ3Q%26tag%3Daskn](https://www.amazon.com/Design-Nature-Learning-Claus-Mattheck/dp/3540629378%3FSubscriptionId%3DAKIAIMGIS4T74NLTJ3Q%26tag%3Daskn)

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[20%26linkCode%3Dxm2%26camp%3D2025%26creative%3D165953%26creativeASIN%3D3540629378](https://www.amazon.com/Design-Nature-Learning-Claus-Mattheck/dp/3540629378%3FSubscriptionId%3DAKIAIMGIS4T74NLTJ3Q%26tag%3Daskn))

Teacher tree: The evolution of notch shape optimization from complex to simple

Engineering Fracture Mechanics | 05/04/2006 | C. Mattheck

(<https://www.sciencedirect.com/science/article/pii/S0013794406000877?via%3Dihub>)

Talking to the trees

Pullin, John

延伸閱讀: Harvard 或 APA 格式（取自 AskNature 原文；若為翻譯者補充，請註明）
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曾苡晴翻譯 (2024/3/26)；陳柏宇編修 (2024/11/30)
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https://asknature.org/strategy/structure-distributes-stress/

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