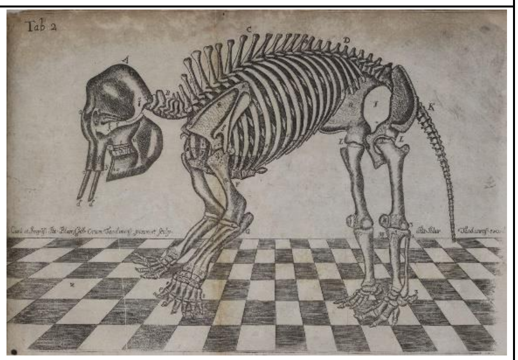
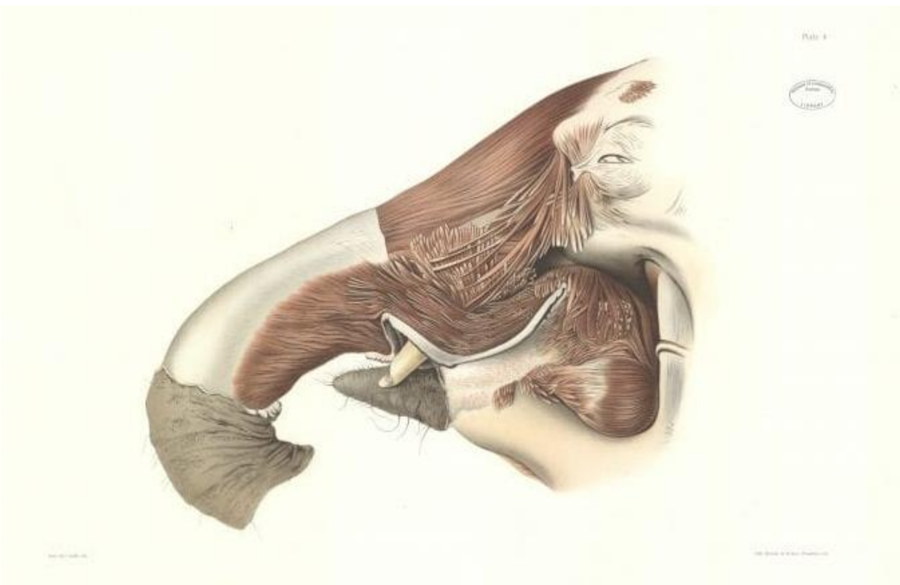
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	象鼻如何扭曲和旋轉 (How Elephant Trunks Twist and Twirl)
生物系統 LIVING SYSTEM	大象 (elephants)
功能類別 FUNCTIONS	每個纖維的形式都控制著特定的動作，或提供保持其整體形狀所需的支撐 (Each fiber pattern controls specific actions or provides the support required to preserve its overall shape)
作用機制標題	象鼻內的三種肌肉纖維模式共同作用，以提供極高的敏捷性彎曲和扭轉所需的力量、支撐和阻力。 (Three muscle fiber patterns inside trunks work together to provide the strength, support, and resistance needed to bend and twist with extreme agility.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	   出處:https://asknature.org/strategy/how-elephant-trunks-twist-and-twirl/

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

介紹

烈日下，一頭非洲象將扭曲的象鼻浸入水坑中，並啜飲泥漿。數以千計的肌肉引導著它宛如精緻的舞蹈，探索著每一個方向。滿滿的泥漿——高達 3 加侖（12 升），搖擺過大象的頭頂並向上捲曲，這樣他就能以用冷卻的混合物噴灑自己的背部。

在 1706 年，蘇格蘭外科醫生和解剖學家帕特里克·布萊爾 (Patrick Blair) 描述了大象象鼻的複雜肌肉組織，指出其肌肉纖維的複雜模式允許這種不同變化的運動。 “而且我認為我可以有充分的理由在它和舌頭之間做一個類比，” 他寫道，因為象鼻和舌頭都沒有骨頭，這使得這些器官幾乎可以向任何方向扭曲。

策略

大多數肌肉需要骨骼來支撐它們，需要關節來支撐它們的運動。為了從身體一側抬起你的前臂，你可以彎曲你的二頭肌 (biceps)，這會使前臂在肘部的鉸鏈 (hinge) 上旋轉。

沒有骨骼和關節的肌肉器官——如象鼻、蛇舌和章魚手臂——被稱為肌肉水壓器 (muscular hydrostat)。它們通過複雜的肌肉纖維排列來支持自己。水壓器最重要的特點，以及使它們能夠在沒有骨頭的情況下移動的原因是它們內部的水量保持不變。象鼻幾乎完全由水和肌肉組成（它本身主要是水）。因為這個水量保持不變，當大象向一個方向移動它的鼻子時，會自動在另一個方向發生補償變化。

控制這些運動的肌肉纖維以三種模式排列：與象鼻的長度平行，垂直於其長度，並像拐杖糖條紋一樣傾斜地纏繞在其長度上。在大象的象鼻中，每個纖維圖案都控制著特定的動作或提供保持其整體形狀所需的支撐。

為了彎曲，象鼻外側的縱向纖維必須在一側收縮和縮短。但是為了防止象鼻像被夾住的軟管一樣折疊起來，在整個橫截面上徑向排列的垂直纖維必須張緊以抵抗彎曲的壓縮。

當彎曲時，這些徑向纖維形成一種“關節”，就像一個實心環，象鼻可以圍繞它彎曲，同時保持恆定的直徑。因為這些纖維的長度與象鼻一樣長，大象可以在許多點彎曲“環形”肌肉，有效地擁有一個可移動的關節，幾乎可以在任何位置彎曲。

大象也可以扭曲它們的象鼻，因為傾斜的纖維像螺旋一樣盤繞在它們周圍。如果你向下看象鼻的末端，一些螺旋會以左旋或逆時針方向盤繞，而另一些則為右旋。這些纖維的不同方向使大象能夠以向左和向右的動作扭轉他們的鼻子。

潛力

大象的象鼻包含超過 40,000 塊肌肉，而整個人體包含的肌肉少於 650 塊。象鼻可以舉起 770 磅（350 公斤）的重量，但可以在不破壞它的情況下拾取一個玉米片（如上面的影片所示）。

機器人技術領域對於強大、靈巧的運動有著無限的應用。已經開發出模仿象鼻的機器人來抓取易碎的物體或作為醫療應用的“第三手”。當人類探索火星和其他天體尋找外星生命的跡

象時，配備機械大象手臂的漫遊車可能足夠強大，可以清除路徑上的巨石，但又足夠靈活，可以小心翼翼地擦拭物體以尋找細菌。

Introduction

Under the scorching sun, an African elephant dips his twisting trunk into a waterhole and slurps up mud. Thousands of muscles guide its delicate dance as it probes every which way. Full of muddy water—up to 3 gallons (12 liters)—it swings above the elephant's head and curls upward so he can spray his own back with the cooling mixture.

In 1706, Scottish surgeon and anatomist Patrick Blair described the complex musculature of an elephant's trunk, noting intricate patterns of muscle fibers that permit such varied movement. "And I think I may with good reason make an analogy betwixt it and the tongue," he wrote, because both trunks and tongues lack bones, enabling these organs to contort in almost any direction.

Strategy

Most muscles require bones to support them and joints to cantilever their movements. To raise your forearm from your side, you flex your biceps, which rotates the forearm across the hinge of your elbow.

Muscular organs without bones and joints—like elephant trunks, snake tongues, and octopus arms—are called muscular hydrostats. They support themselves instead with a complex arrangement of muscle fibers. The most important feature of hydrostats, and what enables them to move without bones, is that the volume of water within them stays constant. An elephant trunk is composed almost entirely of water and muscle (which is itself mostly water). Because this volume of water stays constant, when the elephant moves its trunk in one direction, there will automatically be a compensating change in another direction.

The muscle fibers that control these movements are arranged in three patterns: parallel to the length of the organ, perpendicular to its length, and obliquely wrapped down its length like candy cane stripes. In an elephant's trunk, each fiber pattern controls specific actions or provides the support required to preserve its overall shape.

In order to bend, longitudinal fibers on the outside of a trunk must contract and shorten on one side. But to prevent the trunk from folding in like a pinched hose, perpendicular fibers that are arranged radially throughout the cross-section must tense up to resist the compression of bending.

When flexed, these radial fibers form a kind of "joint" like a solid ring around which the trunk can bend while maintaining a constant diameter. Because these fibers run the length of a trunk, an elephant can flex the "ring" muscles at many points, effectively having a movable joint that allows bending at nearly any location.

Elephants can also twist their trunks because the oblique fibers coil like helices around them. If you looked down the end of a trunk, some helices would coil in a left-handed or counter-clockwise direction while others would be right-handed. The different orientations of these fibers enable elephants to twist their trunks in both left- and right-handed motions.

The Potential

Elephant trunks contain more than 40,000 muscles while entire human bodies contain fewer than 650. Trunks can lift 770 pounds (350 kg) yet pick up a single tortilla chip without breaking it (as seen in the video above).

The field of robotics has infinite applications for strong, dexterous movements. Robots that mimic elephant trunks have already been developed to grip fragile objects or serve as a "third-hand" for medical applications. As humans explore Mars and other celestial bodies searching for signs of extraterrestrial life, rovers equipped with robotic elephant arms might be strong enough to clear boulders from pathways yet agile enough to gingerly swab objects for bacteria.

文獻引用 (REFERENCES)

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Trunks, Tongues, and Tentacles: Moving with Skeletons of Muscle

JOURNAL ARTICLE

A finite element simulation scheme for biological muscular hydrostats

Journal of Theoretical Biology | 01/04/2006 | Y. Liang, R.M. McMeeking, A.G. Evans

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