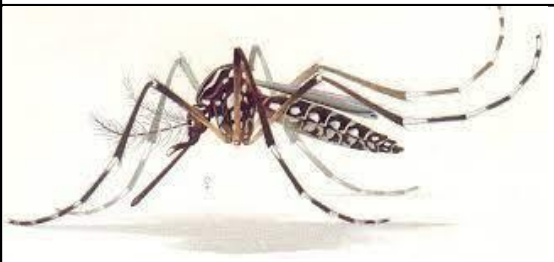
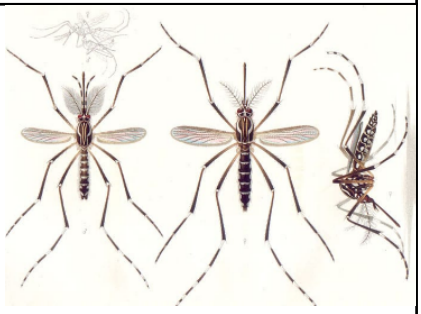
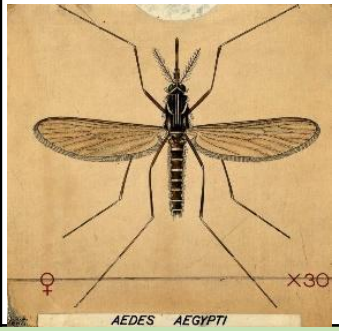
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	不需耳膜仍能擁有長距離聽覺 (Long-range Hearing Without an Eardrum)
生物系統 LIVING SYSTEM	蚊子 *Culicidae* (Mosquitoes)
功能類別 FUNCTIONS	#從環境中感應聲音或振動訊號 #Sense Sound and Other Vibrations From the Environment
作用機制標題	蚊子利用細毛能聽到遠達10公尺(32英尺)外的聲音 (Mosquitoes use fine hairs to hear sounds up to 10 meters (32 feet) away)
生物系統/作用機制 示意圖	  

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

昆蟲的觸角 (antennae) 是重要的非視覺感覺器官。蚊子將其觸角作為動作接收器，以對其周圍環境中的空氣粒子震盪 (oscillation) 做出反應。這屬於聽覺感知 (auditory sensing)，也稱為聽力。雄性蚊子的觸角特別適應於偵測聲音，以此作為尋找伴侶的手段。牠們可以特別地辨認出雌性蚊子在飛行中拍打翅膀的頻率。

從結構上來說，蚊子的眼睛下方有兩個觸角，每個觸角分成兩部分。在雄性中主要由「羽狀」桿 ('plumose' shaft) 所組成，這意味著它被細長羽毛狀的纖維或茸毛 (hair) 所包裹。在桿身末端的茸毛較短，而較後部分的長度則逐漸增加。主要部分直接與次要部分相連，次要部分有莊士敦氏器 (Johnston organ)。莊士敦氏器為球形的基部，佈滿著神經元 (neuron)。這束感覺受器 (sensory receptor) 對作用在桿毛上的力特別敏感。當毛髮被移動時，力量會立即被莊士敦氏器中敏感的神經元傳遞和識別。

以前認為生物需要耳膜 (ear drum) 才有遠距離聽覺(最遠距離可達幾米)。耳膜是透過吸收聲波的壓力並將該訊息作為聲音傳遞給大腦而作用。因為像埃及斑蚊 (*Aedes aegypti*) 這樣的蚊子只有觸角而沒有耳膜，所以以往人們認為蚊子只能聽到近距離(幾英寸或幾公分遠)的聲音。

現在知道蚊子可以聽到最遠達10公尺（32英尺）外的聲音。牠們對於150到500赫茲 (hertz)的頻率範圍內的聲音聽得最清楚，這與飛行中的雌性蚊子的頻率有著高重疊性。

蚊子的聽覺頻率範圍也與人類的聲音重疊。一個普通人的母音 (vowel) 能量最強的頻率在150到900赫茲的範圍內，因此技術上來說，牠們應該能夠聽到人們說話的聲音。但是，目前沒有證據表明牠們使用這個特點來定位及瞄準人類。蚊子已被認為會搜索例如二氧化碳、氣味和溫度之類的感官線索來定位人類。

這項研究為開發高靈敏度的定向麥克風和助聽器(hearing aid) 提供了參考。所有麥克風和聲音檢測設備都是基於通過偵測壓力差異來獲取聲音的，類似於耳膜。基於蚊子形成聽覺而設計的麥克風可以檢測到空氣流速的波動，並能設計成如細小的頭髮或纖維般來檢測聲音。

Insect antennae are important non-visual sensory organs. Mosquitoes use their antennae as movement receivers that respond to oscillations of air particles within the insects' surroundings. This is auditory sensing, also known as hearing. Male mosquito antennae are particularly well-adapted to detect sound as a means of finding mates. They can specifically recognize the frequency of female mosquitoes' wing beats while flying.

Structurally, mosquitoes have two antennae beneath their eyes, each with two segments. The primary segment in males is composed of a 'plumose' shaft, meaning it is coated in long, feather-like fibrils or hairs. These hairs are shorter at the tip of the shaft and increase in length toward the rear. The primary segment is connected directly to the secondary segment, which holds the Johnston organ. The Johnston organ is a spherical base, densely packed with neurons. This bundle of sensory receptors is extra sensitive to the forces acting on the shaft hairs. When the hairs are moved, the forces are immediately transmitted and recognized by the sensitive neurons in the Johnston organ.

It was previously believed that organisms required ear drums for long-range hearing (up to several meters away). Ear drums work by picking up pressure from sound waves and relaying that information to the brain as sound. Because mosquitos such as the *Aedes aegypti* have antennae instead of ear drums, it was thought that mosquitoes could only hear sounds at close distances (a few inches or several centimeters away).

It is now known that mosquitoes can hear sounds as far away as 10 meters (32 feet). They hear best in the frequency range between 150 to 500 hertz, which overlaps well with the frequencies of female mosquitoes in flight.

The mosquitoes' frequency range for hearing also overlapps with human speech. The most energetic frequencies of an average human vowel are in the range of 150 to 900 hertz, so they technically should be able to hear people speaking. However, there is currently no evidence that they use this to locate and hone in on people. It is well known that mosquitos pick up sensory cues such as carbon dioxide, odors and warmth to locate people.

This research offers the opportunity to develop highly sensitive directional microphones and hearing aids. All microphones and sound detection equipment are based on capturing sounds by detecting pressure differences, similar to ear drums. A microphone designed based on how a mosquito hears would detect fluctuations in air velocity, and could be designed as a fine hair or fiber for detecting sound.

文獻引用 (REFERENCES)

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生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)
https://asknature.org/system/insects?post-type=Biological%20Strategies
撰寫/翻譯/編修者與日期
黃柏凱翻譯 (2021/04/06)；譚國鋆編修 (2021/07/14)；林有駿編修 (2021/11/21)；陳柏宇編修 (2022/01/02)
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