What came first, moth ears or bat sonar?

Adrish Dey

In the dead of the night occurs age-old aerial warfare between two parties- bats and moths. As this war occurs in hours of darkness, keen eyesight wouldn't prove to be a very convenient military asset. The bats, therefore, use echolocation which makes them exceptionally capable, predators. But insects are also not a rookie in this confrontation, they counter the bat's ultrasonic sonar with ears tuned to such high frequencies. In addition to this, they have evolved aerobatic evasive movements and anti-bat sounds. Such a sophisticated predator-prey interaction, significantly facilitated by an elegant paradigm of acoustic orientation, left the evolutionary biologists pondering when, why and how these moth-ears (tympanum Fig. 1) have evolved.

Until recently, predation by bats was hypothesized to be the driving force behind the evolution of hearing organs in moths, but the latest research confutes this proposition. The timing of when ears arose has remained untested because of a lack of a stable dated phylogenetic framework for the Lepidoptera. The studies conducted previously examining the macroevolutionary patterns of Lepidoptera did not have sufficient genetic data and carefully evaluated fossil sampling to confidently resolve the evolutionary history of the order.

In the recent study, first published in October 2019, a group of scientists sampled 186 extant species of moths and butterflies and constructed a dataset of 2,098 protein-coding genes. Then they conducted a phylogenetic analysis. The results were then calibrated using fossil data to obtain a dated tree which enabled the researchers to reconstruct the evolutionary history and determine the timing of ecological adaptations.

They found out that in four species-rich clades (Drepanoidea, Geometroidea, Notcuoidea, and Pyraloidea) ears evolved in the Late Cretaceous about 91.6 to 77.6 Ma; whereas, laryngeal echolocation in bats originated about 50 Ma. This suggests that

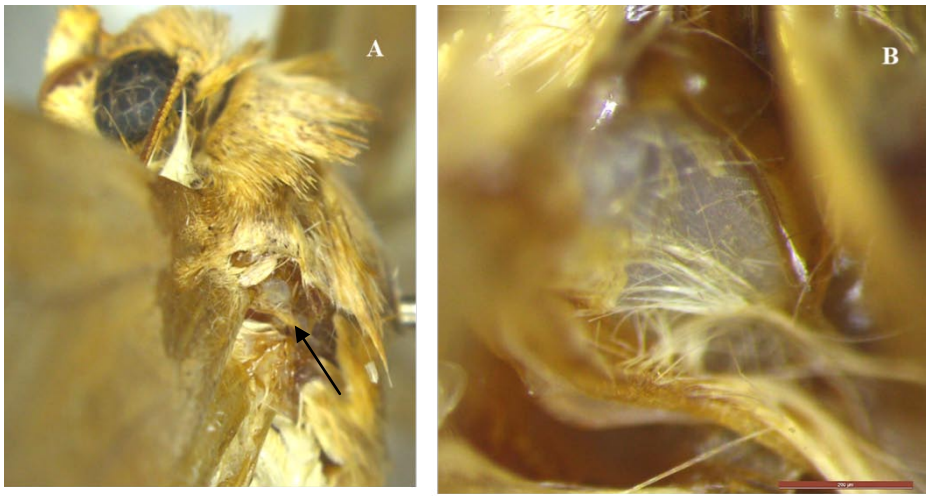

Fig. 1. Thoracic tympanum of noctuid moth. A: The arrow indicates tympanum of a Noctuid moth, B: The same tympanum at a higher magnification.

the evolution of moth hearing is not a consequence of selective pressure from bat predation. Then, what have these moths been listening to before the emergence of bats? The most probable explanation for the evolution of this trait is for detecting sounds of animal movement and general perception of the environment. In fact, the diurnal Lepidoptera and moths which were endemic to areas devoid of bats exhibited decreased responsiveness to high frequencies but were sensitive to low-frequency (caused by walking and wing beat of predatory birds). Thus, moth ears evolved primarily for auditory surveillance but were later co-opted for perceiving bat's position.

This study also disproves another hypothesis which states that butterflies became diurnal in order to escape bats. This trait of nocturnality in Lepidoptera existed in the Jurassic age, about 209.7 Ma, and the character can be traced back to at least the ancestor Heteroneura. The most notable event of switching to diurnality occurred in the ancestor of Papilionoidea about 98.3 Ma, which is again before bats evolved laryngeal echolocation (~50Ma). Therefore, some other factors, which may be the availability of nectar during the daytime, resulted in the evolution of this diurnal activity.

Now, returning to the original discussion on moth ears adapted to high frequencies; the most pertinent question that comes to the mind is haven't the bats developed counter adaptations? Turns out, that bats exhibit a multitude of phenomena from stealth echolocation (in which the calls are 10 to 100 times less in intensity when approaching an eared moth prey) to changing the timing parameters in call repetition rate (which prevents the insect to dodge the prey); thereby establishing the fact that an evolutionary arms race goes on between bats and moths ever since.

Such studies on evolutionary biology help us eavesdrop on the distant past, adding a new perspective to our perception of the prehistoric life and times.

Further reading:

Kawahara A Y, Plotkin D, Espeland M, Meusemann K, Toussaint E F, Donath A, Barber J R. 2019. Phylogenomics reveals the evolutionary timing and pattern of butterflies and moths. Proceedings of the National Academy of Sciences 116(45): 22657-22663.

Conner W E, Corcoran A J. 2012. Sound strategies: the 65-million-year-old battle between bats and insects. Annual Review of Entomology 57: 21-39.

Author: Adrish Dey (Corresponding author) – Division of Entomology, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi, India - 110012

Email: adrishdey1996@gmail.com