Cryptic fleshy coat aids larvae in crawling on a moss carpet

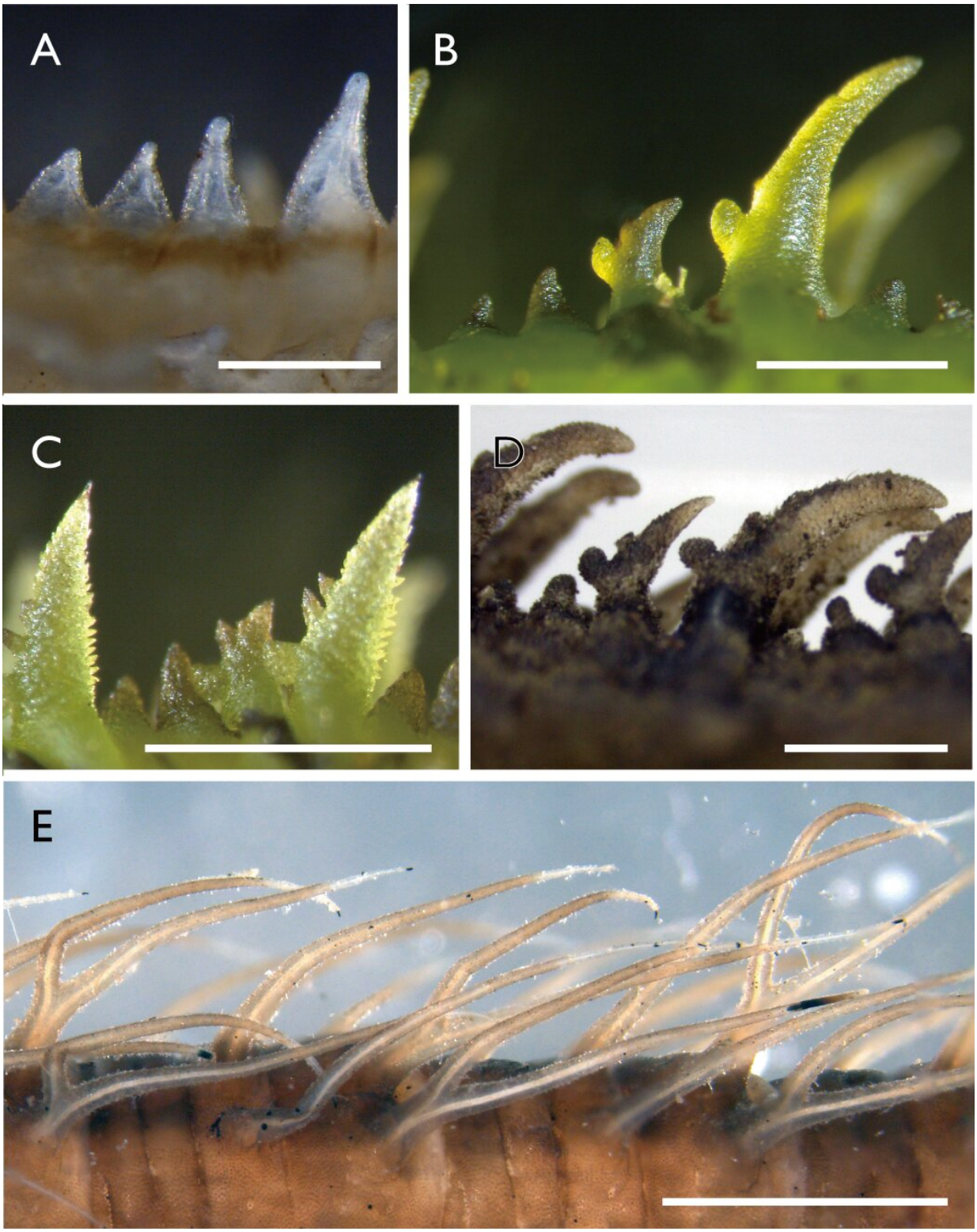
February 25 2021

(Upper) A larva of terrestrial moss-feeding crane fly, Liogma mikado, marvellously blended into a moss-laden habitat. Head on the left. (Lower) A larva of L. brevipecten, another moss-feeding species. The perfect protective resemblance is offered by three elements: green coloration, dorsal dark patterning, and numerous fleshy lobes. Head on the left. Credit: Yume Imada, Ehime University

The roles of physical structures in animal camouflage are not well known. This study illuminates an overlooked role of a mechanism for camouflage. Dr. Imada investigated how larvae of the long-bodied crane flies achieve uncanny resemblance to mosses, highlighting the functions of their special body armature, "fleshy lobes". The lobes on the lateral sides of the body had internal muscles, suggesting that they are not only for tricking enemy's eyes, but may also aid the larvae in crawling.

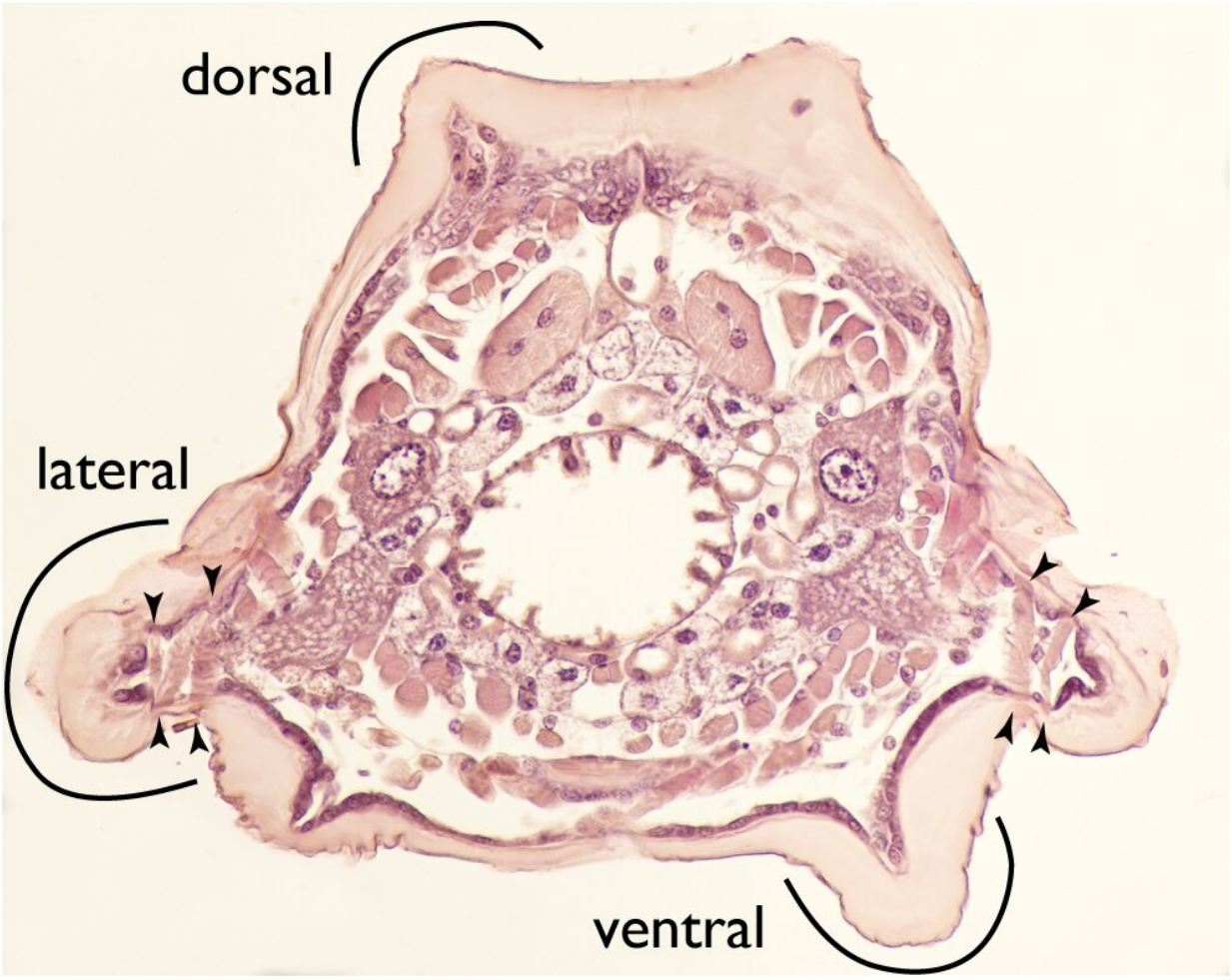
Different physical structures play an important role in animal camouflage; however, they are rarely studied compared to the camouflage colors and patterns. All known larvae of long-bodied crane flies (Cylindrotominae) are plant-feeders, feeding either on mosses or herbaceous plants. The terrestrial moss-feeding larvae resemble mosses to a remarkable degree (Fig. 1). The larvae not only have cryptic coloration and patterning, but also are cloaked with special armature; cryptic, fleshy lobes surround their body on dorsal, lateral, and ventral sides. These complex traits serve to trick potential predators by obfuscating typical caterpillar-like outlines.

The question is how a device for camouflage (fleshy lobes) can evolve simultaneously alongside physiological, mechanical, and behavioral functions? After a ten-year pursuit of the larvae, Dr. Imada discovered eight cylindrotomine species in Japan and North America. She explored the link between their ecological background (i.e. habitats and food-plants) and various larval forms. Furthermore, she challenged the conventional explanation of the function of the fleshy lobes, revealing their roles in respiration, attachment, and locomotion.



Lengths and forms of dorsal lobes are particularly diverse among species depending upon the species' habitats. The dorsal lobes tend to be more

complicated in moss-feeding species (B–D) than in herb-feeders, making their mimesis more successful among patches of mosses with delicate leaves. Aquatic moss-feeders have fine and the longest lobes. Terrestrial herb-feeder: (A) Cylindrotoma japonica ; terrestrial moss-feeder: (B) Diogma glabrata; (C) Liogma mikado; (D) Triogma kuwanai; aquatic moss-feeder: (E) Phalacrocera replicata. Credit: Yume Imada, Ehime University



Internal structure of the abdominal segment, in cross-section, has revealed that lateral lobes contain muscles (arrowheads), whereas dorsal and ventral lobes are simple thick cuticles. The muscles in the lateral lobes may assist larval locomotion when crawling on wet substrates (e.g. moss carpets). Credit: Yume

Major findings of this study are:

1. Larval morphological and behavioral (defensive behavior and locomotion) features are correlated with the species' habitats, varying from fully terrestrial, submerged, to fully aquatic environments, and their food plants. Notably, the fleshy lobes were longest in aquatic species and are more complex, often with auxiliary outgrowths, in terrestrial moss-feeding species (Fig. 2).
2. The fleshy lobes in aquatic species, which are among the longest, were previously hypothesized to be gills, by which the larvae absorb dissolved oxygen in water. However, this study did not support this view because they can take in oxygen through the spiracles, the same as terrestrial species, and examination of the ultrastructure of the lobe surface did not reveal evidence for respiration through the cuticles.
3. Serial cross-sections of the body revealed that the lobes on the lateral sides contained muscles, whereas the dorsal and ventral lobes were simply thickened cuticles (Fig. 3). The musculatures were comparable to those in the prolegs of caterpillars. The result thus cast a new light on the lobes' function as a mechanism for locomotion. The lateral lobes can assist the larvae in crawling.

Dr. Imada concluded that the cylindrotomine larvae live exposed on plants are more prone to predation than most crane flies living in organic mud. Also, the lobes may be adaptive for crawling slowly amongst wet, slippery moss carpets.

Two questions remain unanswered. First, soft, turgid appendages in larvae are curious structures which have evolved in many insect groups,

and yet their structures and functions are largely unexplored. Second, the evolution of camouflage in Cylindrotominae remains paradoxical because there seem to be no records of keen-sighted predators, but it is yet to be shown that ground moss patches are enemy-free spaces.

More information: Yume Imada. Moss mimesis par excellence: integrating previous and new data on the life history and larval ecomorphology of long-bodied craneflies (Diptera: Cylindrotomidae: Cylindrotominae), *Zoological Journal of the Linnean Society* (2020). DOI: 10.1093/zoolinnean/zlaa177