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Flash or Sniff: Testing the evolutionary divergence of firefly antennae due to sexual selection

Lindsay D. Waldrop[1,*], Shilpa Khatri[2]

[1] Chapman University, 1 Univ Dr Orange CA 92866, waldrop@chapman.edu, https://waldroplab.com
[2] University of California, 5200 Lake Rd, Merced, CA 95343, skhatri3@ucmerced.edu
* Corresponding author

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Unlike other beetles, many species within the family Lampyridae (fireflies or lightning bugs) produce a visual signal (abdomen flashing) instead of pheromones (chemical signaling) to attract mates from a distance. Once very nearby, fireflies use pheromones to complete mating behaviors. A number of species of lampyrids have secondarily lost abdominal flashing, reverting back to using pheromones for long-distance signaling. This sets up a natural experiment on the antennae, the location of many chemosensory structures involved in chemical signaling: did the use of flashing reduce aspects of antennal morphology involved in long-distance pheromone detection? And do these reductions lead to a decrease in odor-capture performance between flashers and non-flashers?

To investigate these questions, we photographed the antennae of a number of lampyrids from flashing and non-flashing species, as well as soldier beetles (an outgroup) using scanning electron microscopy to quantify morphological changes between species. Specimens were provided by the Natural History Museum of Los Angeles County and scanned at Chapman University. A variety of morphological features important for odor capture in air were measured: setae length, width, spacing, and angle to oncoming flow. Measurements were analyzed using phylogenetically aware methods to determine the effects of sexual selection on antennal features.

We also modeled odor capture using IB2d, an open-source implementation of the immersed boundary method in MATLAB. Select chemosensory setae were modeled as 2-dimensional odor sinks on a larger supportive antennae. Odor was then advected and diffused in several flow scenarios to quantify odor absorbed by setae. A variety of antennal morphologies reflecting the results in the morphometric study were tested that reflect flashers or non-flashing lampyrids.

In this study, we use a mixture of computational fluid dynamics modeling and morphometrics to investigate the evolution of odor-capture structures influenced by sexual selection.