Title: Neural circuits encoding wind direction in Drosophila
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Abstract

Wind direction provides a critical cue for navigation in many species. In particular, many organisms use wind direction cues to navigate towards attractive odors. However, little is known about the central neural circuits mediating orientation to wind. Here we used the genetic model organism Drosophila to investigate the circuit logic underlying wind direction orientation. Building on recent studies, we show that walking Drosophila differentially orient to wind in the absence and presence of odor. Using surgical manipulations, we show that this orientation relies on antennal mechanoreceptors, although odor can also elicit behavioral changes in the absence of wind direction signals. Next, we developed a novel recording preparation to investigate the neural encoding of wind direction. Using this preparation, we identify second- and third-order neurons downstream of antennal mechanoreceptors. We show that two populations of second-order neurons encode deflections of the ipsilateral antenna with opposing direction tuning, while third-order neurons combine information from both antennae to increase the dynamic range and discriminability of wind direction signals. Genetic silencing of one group of second-order neurons caused flies to preferentially travel upwind, rather than downwind, in the absence of odor. This result indicates that these neurons are causally involved in downwind orientation, and suggests that the fly brain contains parallel upwind-promoting, and downwind-promoting pathways that are normally in competition. Based on these data, we present a model of how wind orientation behavior could be implemented by neural circuits, and show that this model can successfully navigate in plume-like environments.