Locusts Provide Clues to Insect Mushroom Body Function

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The 2 phases of the desert locust *Schistocerca gregaria* are very different beasts. Solitary individuals are slow-moving, nocturnal and cryptically colored, avoiding contact with conspecifics except for mating. But when crowded, sensory stimulation from the jostling bodies causes these formerly retiring creatures to transform into a gregarious phase characterized by flashy aposematic coloration, high locomotor activity and active aggregation into day-flying swarms numbering hundreds of millions of individuals [Simpson et al., 1999, 2001; Anstey et al., 2001]. A new study by Ott and Rogers [2010] demonstrates that the brains of the 2 phases are as different as their behaviors, with gregarious individuals having brains 30% larger than their solitary counterparts. Within the brain, higher brain centers such as the mushroom bodies are disproportionately larger in gregarious locusts, while in solitary locusts primary sensory neuropils such as the antennal lobes are larger. Solitary individuals thus seem to be geared towards lower-level sensory processing, perhaps increasing their sensitivity to visual and odor cues. Gregarious individuals on the other hand prioritize higher integration, perhaps necessitated by their extremely generalist feeding ecology and the intense intraspecific interactions they experience within the gregarious swarm.

The insect mushroom bodies are sensory integration and learning and memory centers that display morphological plasticity on both individual and evolutionary timescales; mushroom bodies and their intrinsic neurons restructure in response to individual behavioral experience [Withers et al., 1993; Seid and Wehner, 2009], while across the insects particular mushroom body morphologies are linked to species-specific behavioral ecologies [Farris, 2005]. It is therefore not surprising to see significant differences in mushroom body morphology associated with the dramatic behavioral differences of gregarious and solitary locusts. However, given the widely held belief that the mushroom bodies function predominantly as olfactory learning and memory centers [Davis, 2005], the disconnect between their size and that of the primary olfactory neuropils, the antennal lobes, seems somewhat anomalous. Rather, these results suggest that whatever functional demand the mushroom bodies of gregarious individuals have expanded to meet, it is unlikely to be solely associated with their role as olfactory processing centers.

Ott and Rogers suggest another challenge of life in the swarm that may impact mushroom body function: the need to extract salient sensory cues such as those produced by food sources and potential mates from the constant barrage of stimu-

li produced by millions of other locusts. That the mushroom bodies may be involved in such sensory filtering is supported by recent studies in the fruit fly *Drosophila melanogaster* that implicate these brain centers in tasks related to feature extraction and the ability to fixate on salient stimuli when faced with distractors [Tang and Guo, 2001; Peng et al., 2007; Zhang et al., 2007]. More provocatively, the insect mushroom bodies have long been noted for their striking architectural similarity with vertebrate cerebellum-like structures [Li and Strausfeld, 1997; Laurent, 2002; Yasuyama et al., 2002], for which an emerging body of work suggests an underlying role as adaptive sensory filters [Bell et al., 2008; Dean et al., 2009]. If the mushroom bodies indeed play a role as sensory filters, they may be expected to be enlarged in species with lifestyles like that of the gregarious locust, in which extracting sensory signal from background noise approximates finding the proverbial needle in the haystack. Future comparative studies of mushroom body morphological variation in relation to species-specific processing demands will likely continue to shed light on the underlying functional role of these higher brain centers.

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