





**Figure 1.** *A*, Schematic of a fly brain highlights HS/VS cells and three descending neurons (adapted from Suver et al., 2016). *B*, A block diagram illustrates the functional connectivity of descending neurons with the visual system and the motor system.

the three DNs were separated by 120° from one another, suggesting that they reflect three descending channels with maximally distinct rotation information. Furthermore, the authors observed that visual responses of the DNs increased significantly during flight, akin to previous observations on HS and VS cells (Maimon et al., 2010; Schnell et al., 2014), suggesting that the entire flight visuomotor system is selectively “turned on” during flight.

To understand functional relationships between DNs and presynaptic visual neurons, Suver et al. (2016) measured visual responses of HS and VS cells in response to the same set of visual stimuli. They found that the response vectors of the DNs could be closely predicted by a weighted sum of HS and VS responses. Furthermore, the predictive ability of the model, as estimated in terms of residual prediction error with respect to the actual DN response vector, saturated after incorporating the two most significantly related HS/VS response vectors. Consequently, this analysis identified two HS/VS cells that are functionally associated with each DN, and this functional connectivity between HS/VS cells and DNs was consistent with the anatomical connectivity identified by the dye fill experiment.

Together, Suver et al. (2016) provide convincing evidence for the following model of the optomotor response. When an animal is caught by a gust of wind and rotated to a certain direction, the eyes of the fly will experience optic flow rotating to the opposite direction. This will depolarize or hyperpolarize a subset of HS and VS cells. The HS/VS cells will then collectively activate the neck motor system,

both directly via gap junctions and indirectly via the downstream DNs, so as to revert unexpected gaze changes. In particular, HS/VS cells would activate DNHS1 for yaw rotations, and DNOVS1/2 for roll-pitch rotations (Fig. 1). During flight, these DNs will additionally recruit wing and haltere motor systems to maintain the stable body orientation. Note, however, the HS/VS pathway may not represent the only neural circuit for the optomotor behavior. A recent study (Kim et al., 2017) showed that the functional inactivation of HS and VS cells impaired only the early component of wing optomotor responses for yaw optic flow stimuli. This is consistent with the lack of wing motor neuropil innervation by DNHS1 and strongly suggests the existence of optomotor circuits independent of HS/VS cells. Suver et al. (2016) also noted that the three DNs described here may not be the only DNs that pass optic flow information to the thoracic ganglion. In blowflies, two additional DNOVS cells have been reported (Strausfeld and Bassemir, 1985; Gronenberg and Strausfeld, 1990). Finally, the three DNs may carry sensory information above and beyond that conveyed by HS and VS cells, as suggested by the diffusive pattern of DN dendrites. Specifically, the three DNs may also integrate optic flow information encoded by the non-HS/VS optomotor circuits or even inputs from other sensory cues, such as visual inputs from ocelli and mechanosensory inputs from halteres (Sherman and Dickinson, 2003).

DNs in insects are in a unique position, as they connect the following two major brain structures: the central brain, which is specialized for sensory processing and

higher-order functions; and the thoracic ganglion, which generates motor programs (among other putative functions). In *Drosophila*, there are estimated to be ~1000 DNs in total, <1% of the total number of neurons in the nervous system (Hsu and Bhandawat, 2016). Thus, DNs may represent an information bottleneck between the brain and thoracic ganglion. Using whole-cell patch recordings in *Drosophila*, Suver et al. (2016) characterized the visual properties of three descending visual neurons downstream of well known visual neurons (HS and VS cells). This study not only is an important step toward understanding how optic flow stimuli lead to optomotor behaviors in *Drosophila*, but also provides a template for studying neurons bridging the gap between sensory and motor systems in this important model organism.

A primary function of the brain is to encode physical changes in the external world and generate appropriate behaviors. Because of the complexity of the brain, most neuroscience studies focus on either sensory or motor systems. Less common are studies on neurons that bridge the gap between the two. By identifying three DNs in *Drosophila*, Suver et al. (2016) opened a new avenue for understanding how visual neurons encoding self-motion information feed into motor centers in *Drosophila*. The numerical simplicity of the *Drosophila* brain, along with the advanced genetic and physiological tools available for this organism, may permit further advances. For example, one can test the hypothesis that the DNs show increased optic flow selectivity and robust self-rotation coding under variable surrounding texture, compared with HS and VS cells (Wertz et al., 2009a, 2009b). In addition, it

has been reported recently that HS/VS cells receive motor-related modulations during flight and walking (Kim et al., 2015, 2017; Fujiwara et al., 2017). It will be important to determine how these brief motor-related signals are reflected in the physiology of postsynaptic DNs.

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