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This Week in The Journal

Neurons in Zebrafish Brain that Sense Water Flow

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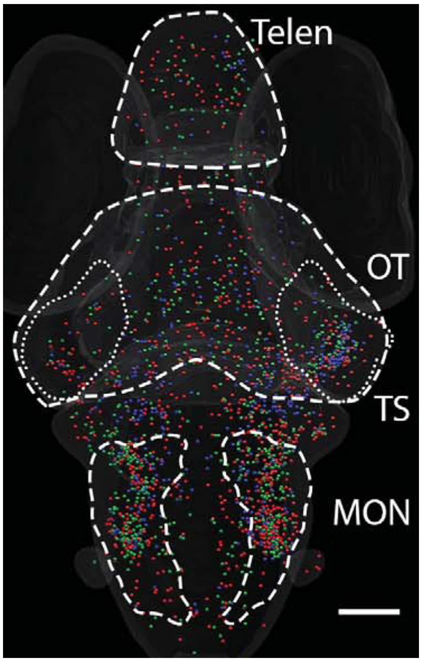
(see pages 4130–4144)

Fish detect water movement toward their head or tail with hair cells embedded in sensory structures arranged in a line along the body (the lateral line). Information provided by the lateral line guides essential behaviors such as avoiding obstacles, evading predators, and orienting the body with the current (rheotaxis). Lateral line afferents innervate subsets of hair cells that respond to either tail-to-head or head-to-tail deflection, and thus these afferents are direction selective. Centrally, lateral line ganglion neurons project to the medial octavolateral nucleus and eminentia granularis, which convey the information to higher brain regions. How this information is integrated to guide behavior is poorly understood, although fish are thought to compare the velocity of local flow on either side of the body to guide turns.

As a step toward unraveling the computations performed by the lateral line system, Vanwalleghem et al. used a fluorescent calcium indicator along with light-sheet microscopy to monitor activity in individual neurons across the entire brain of immobilized larval zebrafish as the fish were exposed to water moving at various speeds. Of the ~63,000 neurons examined, ~6,500 responded to changes in water flow. These neurons could be divided into three classes based on whether they were active only at the onset of water flow, fired fairly regularly throughout the duration of water flow, or showed increasing activity throughout the stimulus. Further analysis suggested some neurons encoded the speed of flow and some encoded a combination of flow speed and duration.

Most cells within each category responded only when flow was from head to tail, but some neurons responded selectively to tail-to-head flow, and some responded to flow in either direction. Neurons with different response properties were intermingled in many brain areas, including the optic tectum and torus semicircularis (the fish equivalents of the inferior and superior colliculi), the cerebellum, and the telencephalon. Using graph theoretical analysis, the authors clustered flow-sensitive cells into nodes and created a correlation matrix to assess how these nodes might be connected into networks. This lays the groundwork for future studies of how lateral line input is processed and integrated with visual and other sensory input to help fish navigate.



Locations of neurons in the zebrafish brain that respond to the onset of water flow from head to tail (red), from tail to head (green), or in either direction (blue). Dashed lines show borders of the telencephalon (Telen), optic tectum (OT), and medial octavolateralis nuclei (MON); dotted line shows outline of torus semicircularis (TS). See Vanwalleghem et al. for details.

Selection of Salient Stimuli by Owl Midbrain Neurons

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(see pages 4172–4184)

Nearly all environments contain far more sensory information than a brain can process fully. Therefore, the brain engages attention networks to select the most important stimuli and suppress neural responses to other stimuli. When an animal is engaged in a task to achieve a goal, forebrain circuits are especially important for directing attention; but attending to stimuli at a particular spatial location depends heavily on a circuit in the midbrain.

Studies in barn owls have revealed much about the midbrain selection network. The optic tectum represents visual, auditory, and other sensory information in a topographic map of space. A stimulus at a given spatial location excites tectal neurons that represent that location and inhibits neurons representing all other locations. This inhibition depends on reciprocal connections between the optic tectum and a group of inhibitory neurons in the nucleus isthmi pars magnocellularis (Imc) in the ventral tegmentum. Because highly salient stimuli greatly suppress activity evoked by competing stimuli, only neurons representing the most salient stimulus transmit information to downstream targets to enhance sensory processing and guide behavior (Knudsen, 2018, Trends Neurosci 41:789).

To better understand the midbrain selection network, Schryver et al. recorded responses of Imc neurons to visual stimuli in the presence or absence of competing stimuli. As expected, when a stimulus (S1) was positioned in the receptive field of an Imc neuron, the neuron's spiking increased. If a second stimulus (S2) was presented simultaneously outside the neuron's receptive field, the response to S1 decreased. Importantly, the magnitude of the suppression increased along with the strength of S2. Moreover, nearly 60% of Imc neurons showed switch-like responses to competitors: specifically, suppression was minimal until the strength of S2 exceeded that of S1, at which point the response to S1 was strongly suppressed.

These results indicate that neurons in Imc have response properties similar to those of neurons in the optic tectum. However, paired recordings in the two structures revealed that activity in Imc identified the stronger stimulus more quickly and precisely than neurons in the tectum. This suggests that Imc calculates the relative strengths of stimuli locally, rather than getting this information from the tectum.

This Week in The Journal was written by Teresa Esch, Ph.D.
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