Advances in the neural bases of orientation and navigation

Murray J.A., Estepp J., Cain S.D.

Department of Biology, 156 Lewis Science Center, University of Central Arkansas, Conway, AR 72035, United States; Friday Harbor Labs., 620 University Road, Friday Harbor, WA 98250, United States

Abstract: The ability to locomote in one direction (oriented movement), and the ability to navigate toward a distant goal are related behaviors that are phylogenetically widespread. Orientation behaviors include finding the source of an odor or acoustic signal, using a sun-compass for guidance, and moving relative to fluid-dynamic cues. Such abilities might require little more than directionally selective sensors coupled to a turning mechanism. This type of behavior, therefore, can be implemented by relatively simple circuits. In contrast, navigation involves both the ability to detect direction, as well as a map-sense that provides position. Navigation is less common and arguably requires greater brain computation than does simple orientation, but may be present in arthropods as well as in vertebrates. Great progress has been made in exploring the biophysical and sensory bases for these behaviors, and in recent years the locations and the identity of the cellular transducers of the sensory stimuli (for example, geomagnetic fields) have been narrowed in some taxa. Similarly, neurons within the central nervous that most likely function in higher order computational processes have been identified. For example, direction-selective and position-responsive brain cells have been located in the brains of mammals and birds, and these cells might contribute to a cognitive map that can enable navigation. One model organism in which orientation and navigation has been extensively studied is the sea slug Tritonia diomedea. This animal orients its crawling to chemical, hydrodynamic, and geomagnetic cues. The brain of Tritonia has 7000 relatively large neurons that facilitate circuit analysis. Recent work has characterized both peripheral and central neural correlates of orientation signals, as well as the control of thrust and turning, and studies of their field behavior have suggested how these disparate orientation systems may be integrated. These findings provide the basis for future studies to determine how the nervous system combines multiple sensory cues into a complex hierarchy of signals that can direct motor output and therefore guide navigational tasks.

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Authors with affiliations:

1. Murray, J.A., Department of Biology, 156 Lewis Science Center, University of Central Arkansas, Conway, AR 72035, United States, Friday Harbor Labs., 620 University Road, Friday Harbor, WA 98250, United States
2. Estepp, J., Department of Biology, 156 Lewis Science Center, University of Central Arkansas, Conway, AR 72035, United States
3. Cain, S.D., Friday Harbor Labs., 620 University Road, Friday Harbor, WA 98250, United States