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Insect Navigation - en route to the goal

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Insect navigation refers to the ability of insects to find their way accurately to a specific location. Insects, just like many other moving animals, have evolved navigational abilities to move around their environment accurately and to exploit the resources available (Schultheiss et al., 2015). The three major navigational strategies recognized primarily in social insects are route following/visual piloting, path integration and map like spatial distribution.

Route following is the most straight forward mode of navigation found in the majority of ants, bees and termites, which follow a pheromone trail deposited on the surface by a conspecific and do not require previous knowledge on the path (Wolf, 2011). Similarly, they also employ terrestrial objects as navigational landmarks (Collett, 1996).

Path integration sums the vectors of distance and direction travelled from a starting point to calculate the current position and, thus, the path back to the start. Social insects such as bees, wasps and ants **employ different inputs like odometry, compass and optical flow to find their target in this strategy. In odometry, the insect calculates the distance travelled based on the number of steps taken to reach the target site. The compass input, on the other hand, includes celestial cues such as the sun, moon, magnetic field, and wind direction**. The honey bee uses sunlight to find food and communicate this information to other members of the hive through various dances and Karl von Frisch was awarded the Nobel Prize in Physiology and Medicine in 1973 for deciphering the bee dance. Fleishmann et al. (2018) demonstrated that in ants, a geomagnetic compass cue is both necessary and sufficient for accomplishing a well defined navigational task. Many insects use optic flow to measure the distance of objects from themselves based on the velocity of movements relative to nearby objects.

The assembly of landmarks, local and global, vectors into a two-dimensional spatial arrangement that yields a true map (mental map) in bees. Though location and mode of memory storage of maps remain elusive, the central complex of the brain in insects is considered to plays a vital role in forming the mental map (Menzel *et al*., 2005).

Insect navigation plays a significant role in insect survival such as to chart food bound routes, locate mate and ovipositional site, survive under adverse conditions, communicate among nestmates and escape from the predatory pressure (Cohen, 2019)). The basic information about navigational strategies in insect pests also helps to employ different pest management tactics such as trap crops, light traps, pheromone traps and repellents. Integrated Vector Management (IVM) programme proposed by WHO in 2020 uses semiochemicals to redirect the movement of mosquitoes from human habitation (Woodling et al., 2020). The navigational strategies in insects are also employed in modelling of robots used in surveillance programmes (Lambrinos *et al*., 2000).

The basic strategies of insect navigation is well explicitly studied in social insects, but their importance in the host plant selection process needs to be explored in detail. Though the navigational strategies in insects are employed in various fields, it is imperative to have a multi-dimensional understanding of navigation in insect pests to formulate various strategies to minimize their incidence.

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