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Chemistry and neurobiology of perception of complex signals - study case of ant recognition pheromones

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Nestmate recognition is a hallmark trait of social insects. It not only protects the colony from nest invasion and robbery of conspecific and/or parasitic ants, but is also imperative for conserving colony cohesion. In all ants studied to date complex hydrocarbon mixtures appear to serve as the recognition pheromones. They also constitute an excellent example of evolutionary cooption of chemicals, from primarily serving as structural waterproof layer to their adoption as communicative chemicals.

Hydrocarbons, being very hydrophobic, provide a perfect water proof layer that protects insect from desiccation. This, however, is true for long chain linear alkanes, but considerably less efficient for branched, mono and dimethyl, alkanes, which are very abundant in ants. Moreover, branched alkanes, due to their molecular diversity, are excellent agents for communication. Finally, hydrocarbons are spread throughout the body, such that recognition can be attained upon contact, irrespective of the body part encountered. Evidence on the role of hydrocarbons as recognition pheromones arise from bioassays in which an ant that is applied with alien hydrocarbons is fiercely aggressed by its nestmate, whereas an alien ant smeared with odors origination from another colony is accepted a nestmate by members of that colony.

A premise of nestmate recognition pheromone is that all members of the society have the same odor, which is different from that of members of another colony. However, since members of a colony are often genetically heterogeneous, which may create odor heterogeneity, a mechanism for odor homogenization has evolved. This mechanism involves a special gland in the head that accumulates self-hydrocarbons, which are then exchanged between individuals to create a gestalt odor that is commonly applied onto the ants' bodies.

Studying the perception and neural deciphering of recognition pheromones is challenging, not only because they comprise complex mixture, but also because specificity is not embedded in the formation of new compounds but the relative proportion of qualitatively identical profiles. Two contrasting, but not mutually exclusive, alternative hypotheses for the neural mechanisms responsible information processing in recognition are proposed. The first classical hypothesis states that upon perception of recognition cues by the sensory system (the antennae) the information passes as is either to the antennal lobes, or even to a higher brain center, where the information is deciphered and compared to a neural template. Match or mismatch information is then transferred to some behavior switching or locomotion pattern generating centers where the appropriate response is elicited. The alternative hypothesis posits the existence of a "pre-filter mechanism" whereby the decision whether to pass on the information to the central nervous system takes place already at the peripheral sensory system. It further posits that through sensory adaptation only alien signals are passed on to the brain, specifically to an "aggression center" where the response is generated if the signal is above a certain threshold. Accordingly, nestmate odors, being very similar to each other are below the perception threshold and do not generate any peripheral neural activity, whereas alien ant odors are sufficiently different to elicit both peripheral neural response and activate the aggression center in the brain.