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Review Paper

Morphology and physiology of the olfactory system of blood-feeding insects

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A B S T R A C T

Several blood-feeding (hematophagous) insects are vectors of a number of diseases including dengue, Chagas disease and leishmaniasis which persistently affect public health throughout Latin America. The vectors of those diseases include mosquitoes, triatomine bugs and sandflies. As vector control is an efficient way to prevent these illnesses it is important to understand the sensory biology of those harmful insects. We study the physiology of the olfactory system of those insects and apply that knowledge on the development of methods to manipulate their behavior. Here we review some of the latest information on insect olfaction with emphasis on hematophagous insects. The insect olfactory sensory neurons are housed inside hair-like organs called sensilla which are mainly distributed on the antenna and mouthparts. The identity of many of the odor compounds that those neurons detect are already known in hematophagous insects. They include several constituents of host (vertebrate) odor, sex, aggregation and alarm pheromones, and compounds related to egg-deposition behavior. Recent work has contributed significant knowledge on how odor information is processed in the insect first odor-processing center in the brain, the antennal lobe. The quality, quantity, and temporal features of the odor stimuli are encoded by the neural networks of the antennal lobe. Information regarding odor mixtures is also encoded. While natural mixtures evoke strong responses, synthetic mixtures that deviate from their natural counterparts in terms of key constituents or proportions of those constituents evoke weaker responses. The processing of olfactory information is largely unexplored in hematophagous insects. However, many aspects of their olfactory behavior are known. As in other insects, responses to relevant single odor compounds are weak while natural mixtures evoke strong responses. Future challenges include studying how information about odor mixtures is processed in their brain. This could help develop highly attractive synthetic odor blends to lure them into traps.

Contents

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1. Introduction

Hundreds of millions of people suffer from insect-vector borne diseases every year. These diseases mainly include malaria, yellow fever, dengue, Chagas disease, African sleeping sickness and leishmaniasis, which are spread by parasite-infected blood-feeding (hematophagous) insects such as mosquitoes, triatomine bugs, tsetse flies, sandflies (van der Goes van Naters and Carlson, 2006). Many of these diseases, including leishmaniasis, Chagas disease and dengue seriously affect public health throughout Latin America, and according to the World Health Organization vector control is the most effective way to prevent some of these illnesses (WHO, 2010). Thus, an increasing number of research projects in this region focus on methods to monitor and control the insect vectors. In particular, our group is devoted to the study of the morphology and physiology of the olfactory system of these insects (see Guerenstein and Lazzari, 2010), and to the development of odor-baited insect traps (e.g., Guidobaldi and Guerenstein, 2013). Similar traps have already successfully helped fight harmful insects (Foster and Harris, 1997; Oehlschlager et al., 2002). However, to manipulate the behavior of the vector insects efficiently, more work on their sensory biology is necessary. The aim of this manuscript is to review some of the latest information on insect olfaction with emphasis on hematophagous insects, vectors of disease, and highlight future challenges.

2. The olfactory system

Insect vectors heavily rely on their sense of smell to locate hosts, find mates, and select egg-laying ('ovipositing') sites (e.g., Zwiebel and Takken, 2004). For example, *Anopheles gambiae* mosquitoes, vectors of malaria, may detect host volatiles from up to 70 m away the odor source (Kaufmann and Briegel, 2004) while domiciliated triatomine bugs, the vectors of Chagas disease, become activated to search for blood when they sense the CO_2 exhaled by their sleeping hosts (Guerenstein and Lazzari, 2009). Sex and alarm pheromones emitted by adults also play an important role in the biology of triatomine bugs (May-Concha et al., 2013; May-Concha, 2010; Minoli et al., 2013) whereas *Culex quinquefasciatus* mosquitoes, vectors of filariasis and West Nile Virus, are attracted to oviposition sites by a pheromone released from

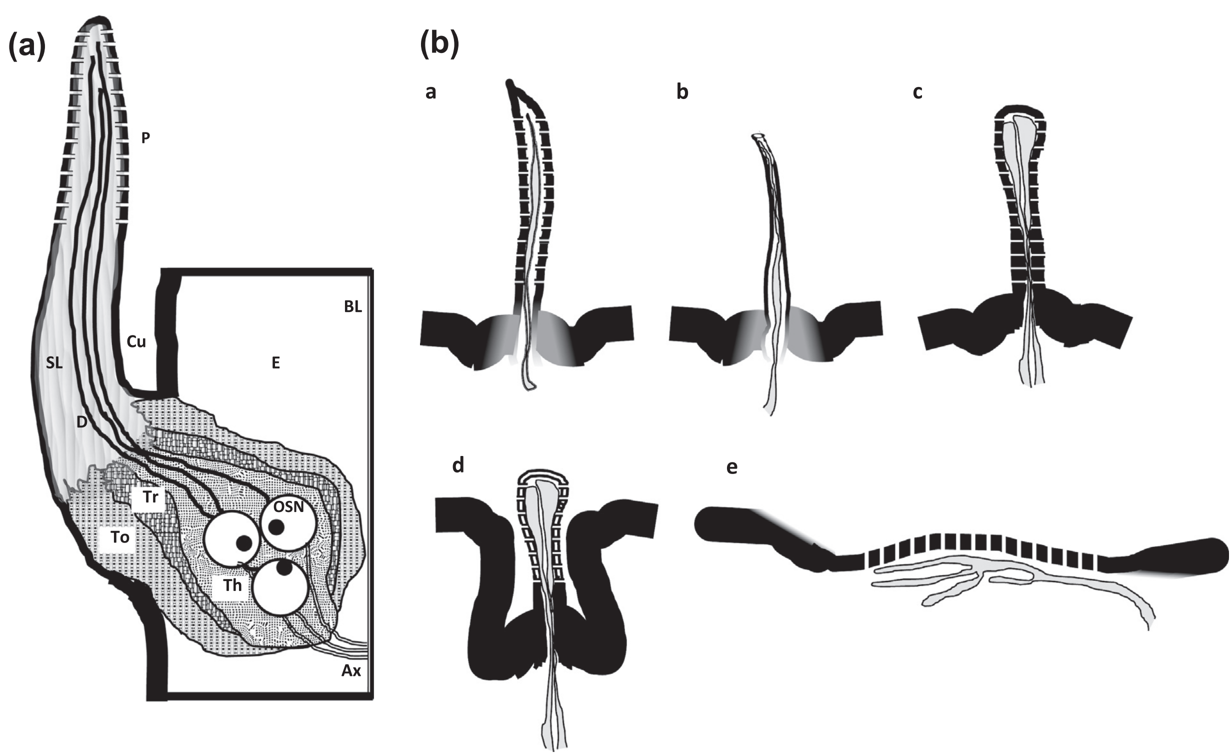

Fig. 1. (**a**) Internal structure of an olfactory sensillum. The sensillum contains one or more olfactory sensory neurons (OSNs) and three accessory cells: thechogen (Th), trichogen (Tr) and tormogen (To) cell.; P, pores; Cu, cuticule; D, dendrites; E, epidermic cell; Ax, axon; BL, basal lamine; SL, sensillum lymph. (**b**) Types of chemosensory sensilla. (a) Multiporous trichoid sensillum (olfactory), (b) uniporous trichoid sensillum (gustatory), (c) basiconical sensillum (olfactory) (d) coeloconical sensillum (olfactory) and (e) hair plate (olfactory).