# First Order Processing of Complex Olfactory Information in the Moth Brain


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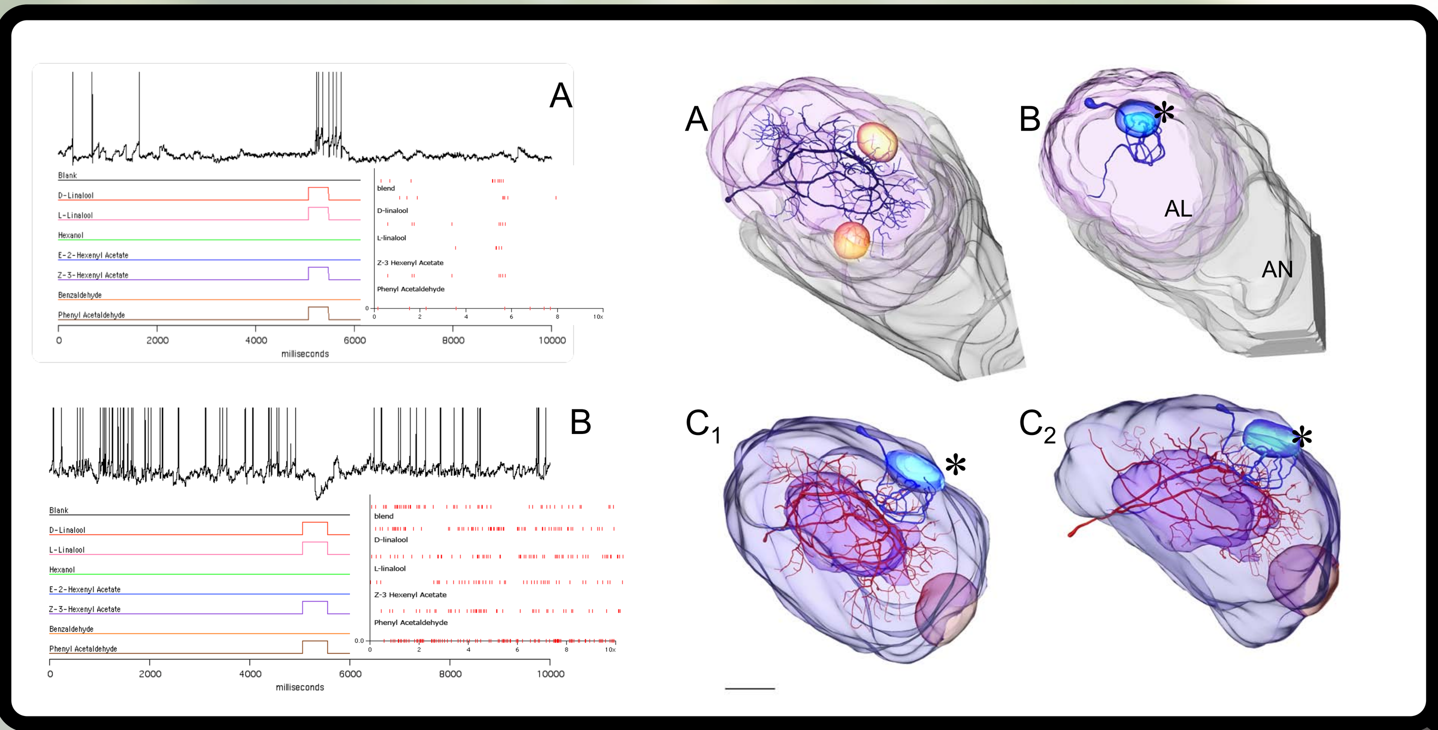
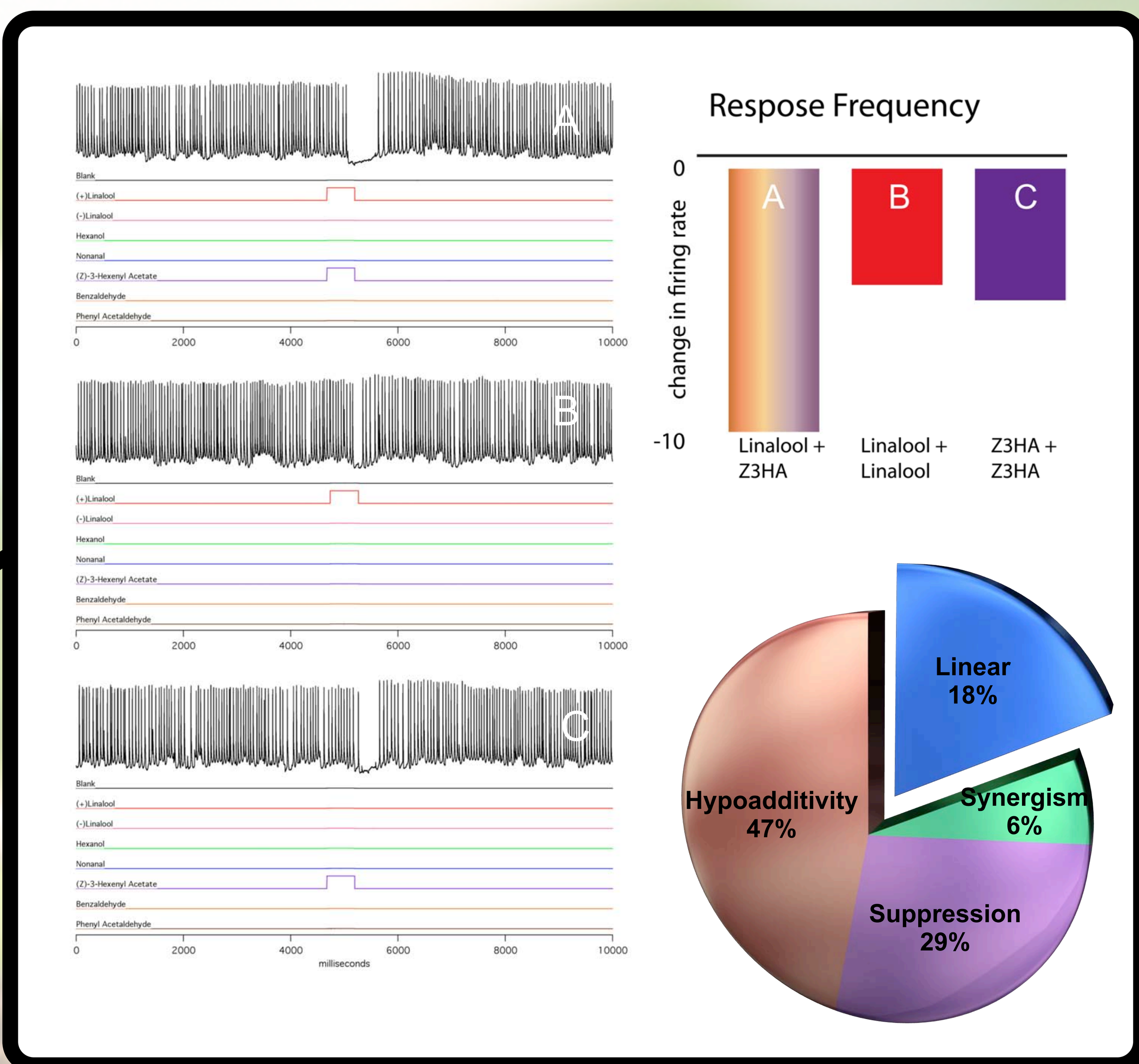
**Introduction:** The world is a cacophony of scent. What we perceive as a single scent is often several compounds acting in concert to form an unique odor percept. Yet how do animals decipher these complex mixtures from a noisy background to recognize a meaningful signal? As part of a project to develop a novel class of technology for infochemical communication, we investigated olfactory processing in the insect brain to form the basis for a multicomponent detector system able to recover ratiometric odor information deployed in the world. By unraveling neuronal network processing, we support the generation of a tuned detector capable of deciphering complex chemical signals produced by a biosynthetic chemoemmitter. This chemoemitter/receiver complex thus establishes an entirely new communication system based on the chemical signaling of insects. Our main challenge is to reveal how complex odor information is encoded in the insect olfactory system. In insects, the initial percept of odors detected by the antenna occurs in the first olfactory center of the brain, the antennal lobe (AL), the insect analog of the mammalian olfactory bulb. Using a novel multicomponent stimulus system, we performed intracellular recordings of projection (output) neurons traveling to higher brain centers and interneurons that provide neuronal connectivity within the moth AL. We then characterized host blend vs. single component representation and integration properties within individual neurons. To assess the network as a whole, optophysiological studies of the AL were used to monitor calcium activity patterns in response to these same stimuli. By comparing odor evoked activity patterns and response intensities between input and output processing levels, we could determine the relative contribution of the AL to odor blend processing within a single animal.



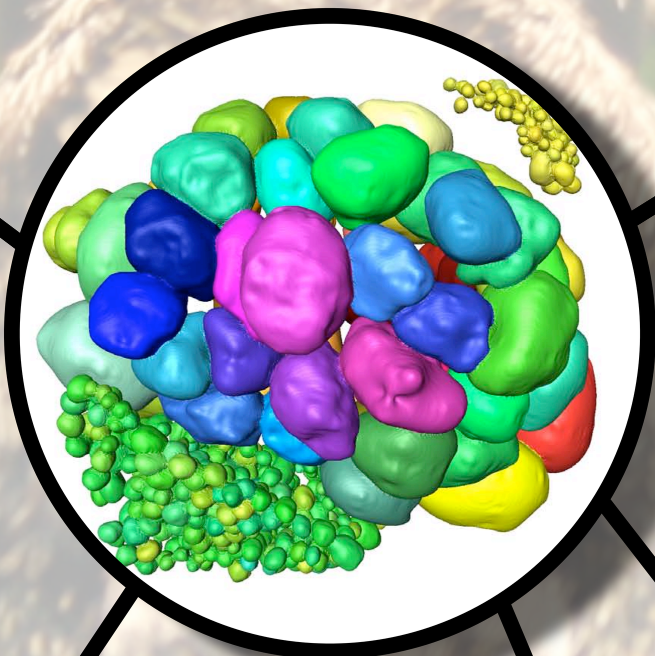


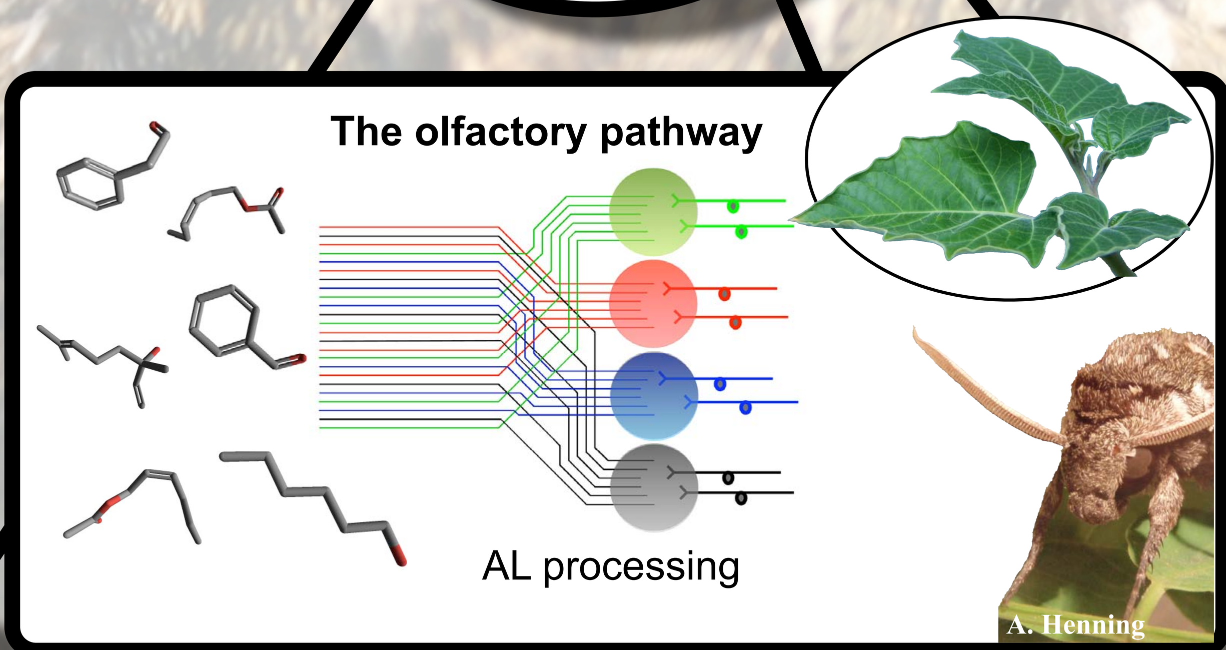
**Spatial relationship of single olfactory neurons in the AL of the hawkmoth *Manduca sexta*.**
**Left panel:** An example of two common morphological types of AL neurons traced with neurobiotin dye and visualized by 3D reconstruction. Neuron A (local interneuron, connecting neurons within the AL) exhibits an excitatory response to four components. Neuron B (projection neuron, leading to higher brain centers) responded to the very same blend with an inhibitory response.
**Right panel:** Fitting of a local interneuron (A) and uniglomerular projection neuron (B) into the antennal lobe (AL) using AMIRA software.
Digital template of the *Manduca sexta* AL (C).
The registration process reveals the relative position (asterisk) innervated by the projection neuron to the local interneuron. The local interneuron (red) does not connect to the projection neuron.
This shows that a blend signal can be perceived across the AL, rather than in a spatially-restricted region.
Registration by J. Rybak
($C_1$: anterior view, $C_2$: posterior view, scale 100µm)



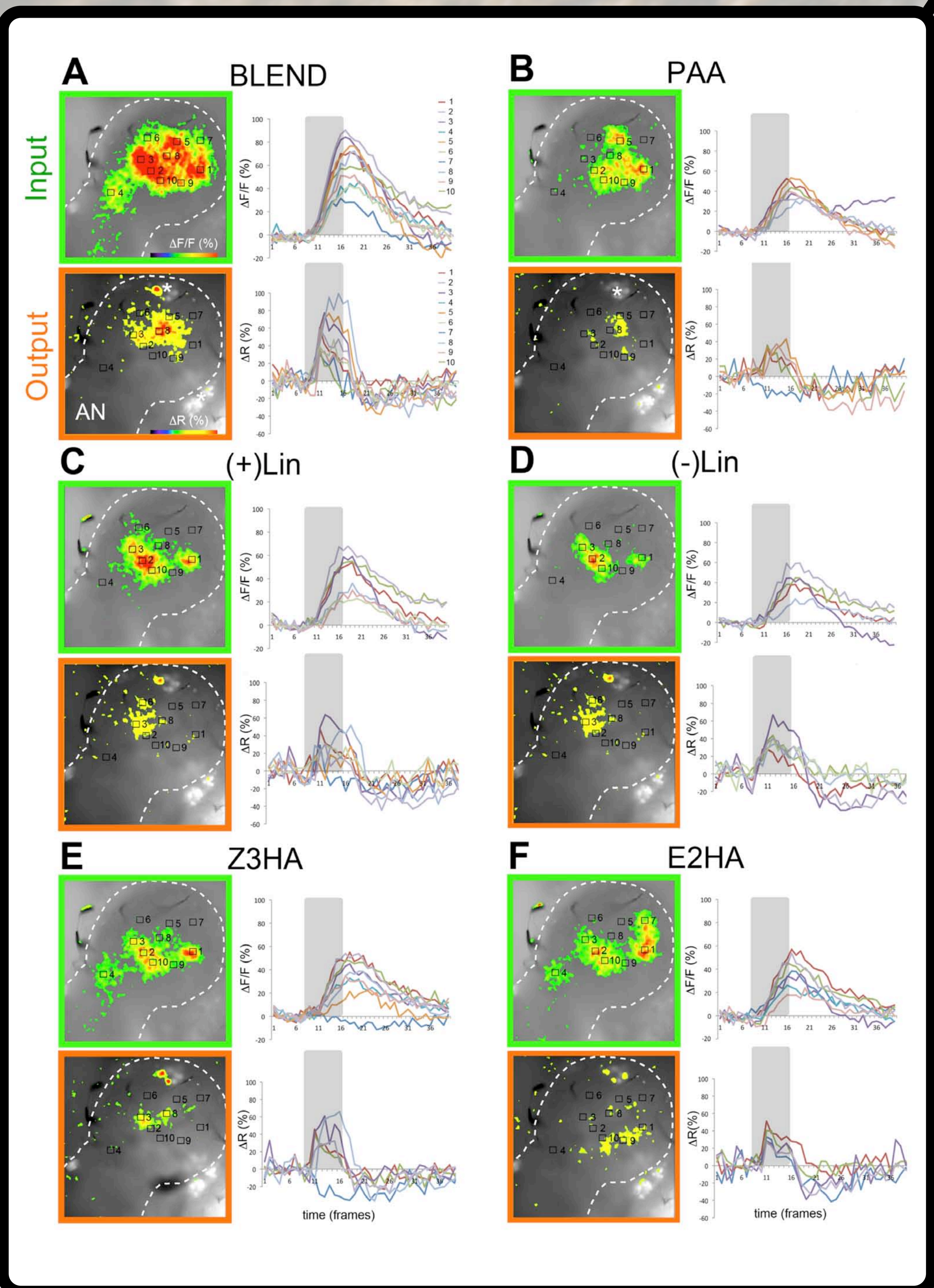


**Response profiles of a single AL neuron to a binary odor blend:**
Comparison of inhibitory responses of a single neuron to a binary odor mixture (A) and its single components (B,C) reveals a synergistic effect for the blend.
**Proportion of Blend Interactions.**
Inset pie graph. Percentage of linear vs. non-linear response frequencies (Hz) for blend vs. single component responses.
This shows that individual neurons generally produce unique, nonlinear temporal kinetics to the blend as compared to single components.
Thus, the blend percept is already present at the single unit level.



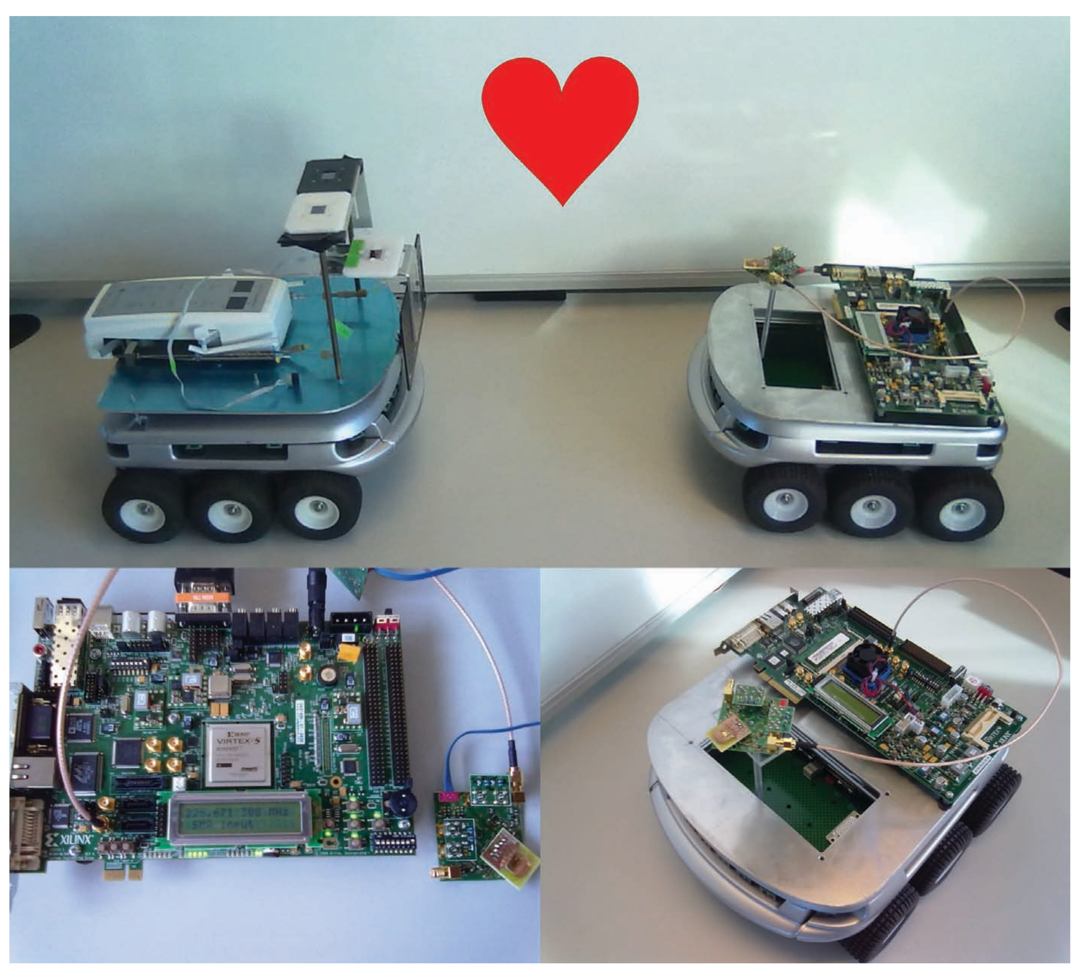






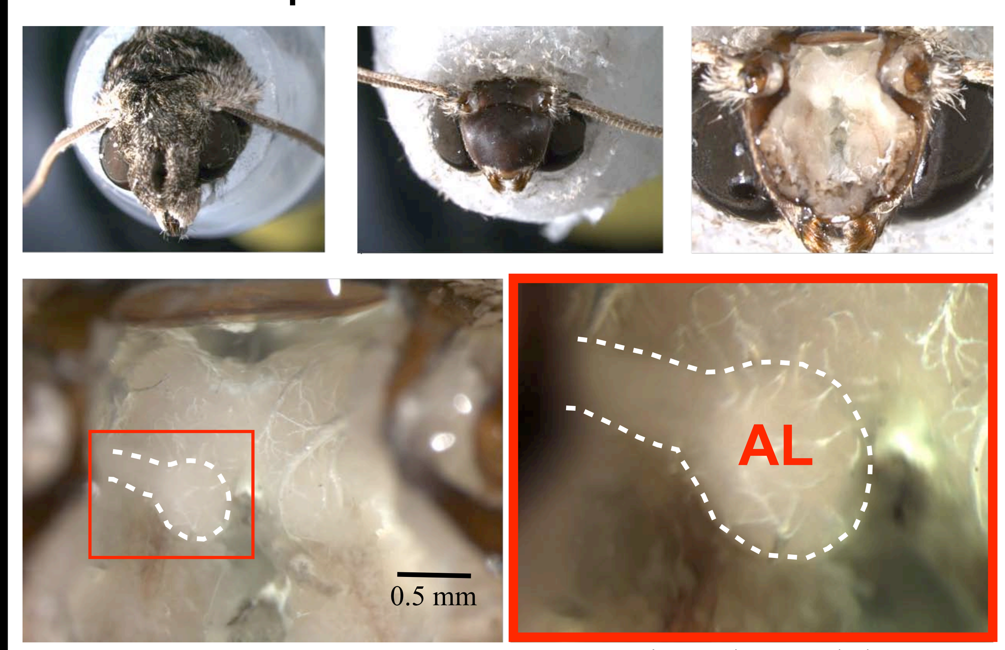


**Sample recordings of simultaneous imaging within a single *Manduca* female.**
Olfactory responses to a blend vs. its 5 single components monitored as spatially restricted activity regions of fluorescence change (ΔF) in the antennal lobe at two different processing levels (Input: sensory neurons, green frame and output: projection neurons, orange frame).
Strong interactions in PNs suggest network modulation, establishing a unique blend percept separate from monomolecular component input .



**The LoveBots**

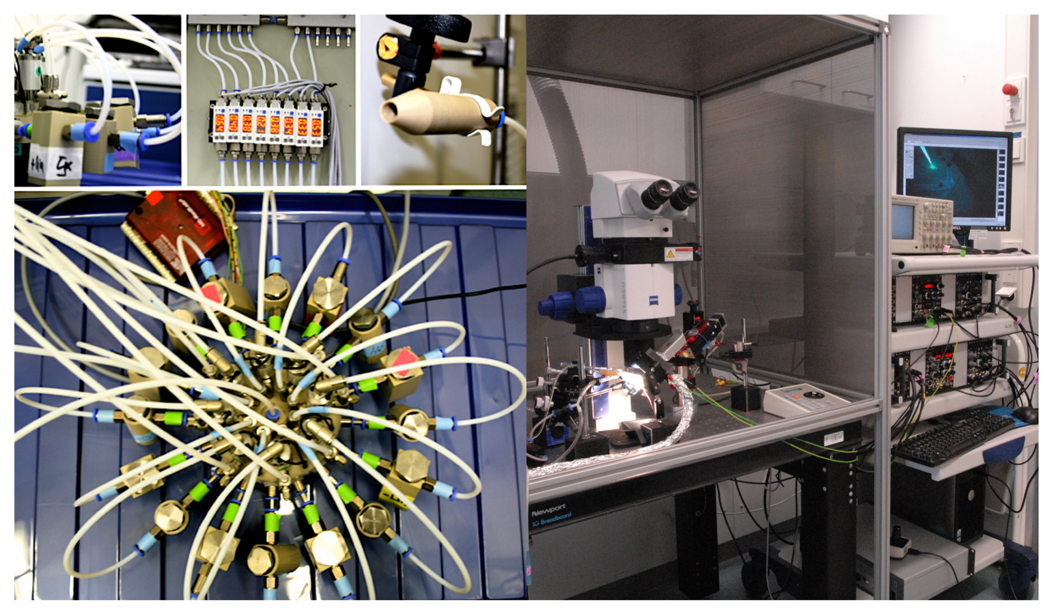
pictures by S.Karaout





**Preparation of the moth brain**

pictures by M. Schubert



**A new stimulus delivery system:**
("A novel multicomponent stimulus device for use in olfactory experiments"Shannon B. Olsson*, Linda S. Kuebler*, Daniel Veit, Kathrin Steck, Alexandra Schmidt, Markus Knaden & Bill S. Hansson. J Neurosci Methods. 2011 Jan 30;195(1):1-9. Epub 2010 Oct 7)

**CONCLUSIONS:**
**Our combined physiological approach reveals a highly combinatorial, non-linear process for coding complex host blends in the moth brain. Odor blends establish a unique blend feature separate from individual component identities as early as the first olfactory processing stage, the antennal lobe (AL). An olfactory system incorporating non-linear coding may be advantageous because it can process signals from a "noisy" periphery with input from both specific and broadly tuned receptors , as are found in the moth. Thus, the subsequent separation of molecular components as well as the generation of the novel blend percept must be established by the network. For a neuromorphic processor, this implies that a minimum of sensors with varying selectivity can already detect complex blends, increasing the processing power of the biosynthetic communication system.**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