Local Connectivity in the Locust Antennal Lobe

Ron Jortner, Ofer Mazor and Gilles Laurent

Summary

The connectivity in a neural system, i.e. the number, pattern and strength of connections between its elements, is a fundamental property of the network architecture and underlies much of its dynamics. Here we present an experimental approach to studying functional connectivity in the insect antennal lobe, an intact, *in vivo* biological network, and its preliminary results.

The olfactory system uses synchronous oscillatory firing to encode odor information. In insects, such as the locust (S*chistocerca americana*), the antennal lobe (AL) forms the first relay of the olfactory system, analogous to the olfactory bulb in vertebrates. The AL receives its input from ~90,000 olfactory receptor neurons in the animal's antenna. The AL itself is a network consisting of two neuron types, ~830 excitatory projection neurons (PNs), and ~300 inhibitory, non-spiking local interneurons (LNs). This network forms a complex dynamical system, of an apparently highly recurrent nature. Through its input and internal dynamics, the AL generates a synchronous, oscillatory odor code, which is passed on to downstream networks via PN axons, forming the network's sole output node. LNs have extensive arbor which spans large portions of the AL (figure 1), implying wide reaching connections. This applies to LNs in all studied insects, including Drosophila. Functionally, LNs have been shown to be necessary for mediating synchrony between PNs. It has been demonstrated that downstream neurons are sensitive to PN-PN synchrony, and that it is behaviorally relevant.

Recordings were done from the antennal lobe of locusts, using experimental procedures of preparation, electrophysiology and odor stimulation as previously described. Simultaneous recordings of baseline activity were done from single LNs using intracellular sharp electrodes and from multiple (typically 5-20) PNs using tetrodes (figure 2). LN intracellular traces were then averaged based on triggers from action potentials of individual PNs. Averaging often reveals excitatory postsynaptic potentials (EPSPs) in the LN, triggered by the PN firing, indicative of a potentially direct synaptic connection from the PN to the LN. An example of spike triggered averages of LN traces indicating synaptic connections is shown in figure 3.

The results suggest a very dense connectivity of PNs to LNs. Over 80% of PN-LN pairs tested are consistent with direct synaptic connections, implying that the AL is a highly interconnected network. It should be noted that the EPSP can not be seen in individual LN traces (without averaging) due very high background activity, in accordance with such highly convergent architecture. Some of the findings were confirmed using dual intracellular recordings from PNs and LNs. This dense PN to LN connectivity may explain the high degree of correlation LN membrane potential exhibits with the local field potential (LFP) recorded in PN target areas(see fig 2). We are presently in the process of examining the connectivity between other elements of the AL network (e.g. within the PN population) using similar methods.

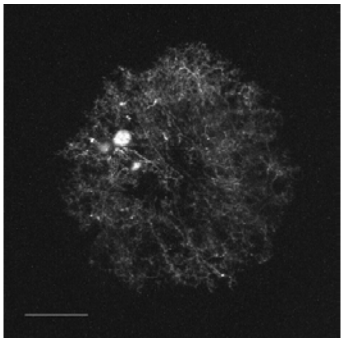

Figure 1

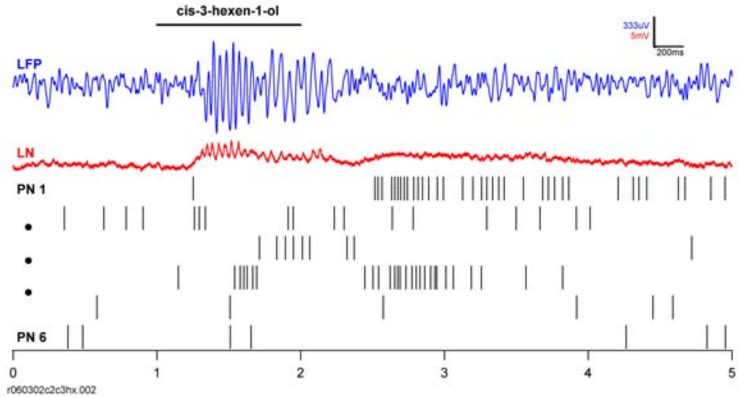

Figure 2

Figure 3

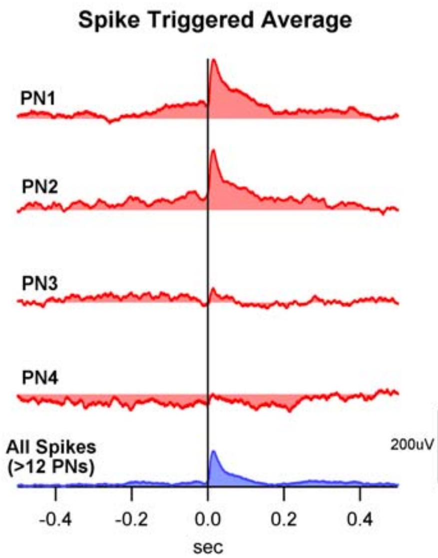

Figure 1: Confocal projection image of an LN, filled with Alexafluor 568. Scale bar 100µm.

Figure 2: Simultaneously recorded traces of an LN (red), six PNs (raster plots, black), and a local field potential (blue) in response to a 1 second odor pulse (black bar). LN recorded using an intracellular sharp electrode, PNs recorded using a silicon tetrode.

Figure 3: Spike triggered averages of the LN activity, each red trace is triggered on the spikes of a different PN. The blue trace is an average triggered on a total sum of all PN spikes (12 neurons, not all shown). Positive deflections immediately following the spike correspond to EPSPs, and are consistent with direct connections between the PN and the LN.