Pheromone plumes provide optimal signal for the olfactory sensory neuron

Lubomir Kostal\textsuperscript{a} Petr Lansky\textsuperscript{a} Jean-Pierre Rospars\textsuperscript{b}

\textsuperscript{a}Institute of Physiology, CAS, Prague, kostal@biomed.cas.cz, lansky@biomed.cas.cz

\textsuperscript{b}INRA, Physiologie de l’Insecte, Versailles, France, rospars@versailles.inra.fr

KONTAKT, Barrande
INOVACE 2006, Prague, 7.12.2006
Efficient coding hypothesis

Barlow, 1961

The sensory neurons are adapted to the statistical properties of the signals to which they are exposed.

Formalized by Information theory (Shannon, 1948)

- Visual system: LMC in insect compound eye (Laughlin, 1981); review and details in Simoncelli and Olshausen (2001)
- Auditory system: reviewed in Lewicki, 2002; Smith and Lewicki, 2006
- Olfactory system: ?? (stimulus control, slow)
Efficient coding hypothesis

Barlow, 1961

The sensory neurons are adapted to the statistical properties of the signals to which they are exposed

Formalized by Information theory (Shannon, 1948)

- **Visual system**: LMC in insect compound eye (Laughlin, 1981); review and details in Simoncelli and Olshausen (2001)
- **Auditory system**: reviewed in Lewicki, 2002; Smith and Lewicki, 2006
- **Olfactory system**: ?? (stimulus control, slow)
Stimulus: the pheromone plume

- Pheromone plume at a time instant, plan view
- Meandering, undiluted patches of pheromone detected far from the source
- Universal physical laws
Stimulus: the pheromone plume

- Pheromone plume at a time instant, plan view
- Meandering, undiluted patches of pheromone detected far from the source
- Universal physical laws
ORN Model

- *Antheraea polyphemus*; ORN sensitive to the main component ((E,Z)-6,11-hexadecadienyl acetate)
- Peri-receptor and receptor events, deterministic
- Pheromone concentration in the air ($L_{air}$) $\Rightarrow$ concentration of activated receptors ($R^*$)


\[
\begin{align*}
L_{air} & \xrightarrow{k_i} L \\
L + R & \xleftarrow{k_{-3}} \xrightarrow{k_3} R_L \xleftarrow{k_{-4}} \xrightarrow{k_4} R^* \\
L + N & \xleftarrow{k_{-5}} \xrightarrow{k_5} N_L \xrightarrow{k_6} P + N
\end{align*}
\]
Experimental and predicted results I.

- Experimental measurements of odorant dispersion: ion sources (most often)

![Graph showing probability density function of L_{air} [µM] for exponential and log-normal fits](image)

Kostal, Lansky, Rospars

Efficient coding
Ion signal, averaged over 330 ms, distance up to 30 m from the source Murlis (1986)
Experimental and predicted results III.

- Propylene source, distance 67 m from the source (Mylne, 1988)
ORN studied is well adapted to the natural stimulus:
⇒ Parallel to the Laughlin’s (1981) approach to LMC
⇒ Stimulus reconstruction in time (comparison with experiments on odorant dispersion)

Technical analysis of efficiency of different encoding schemes: