

Modeling Olfaction by Daniel P. Dougherty and his team of students

The process of smelling, called olfaction, requires reliable communication of information about chemical identity and concentration of odors from the environment to the brain. Many animals use olfaction to find food, locate mates, avoid danger and navigate their surroundings. The chemical reactions and neural processes required of olfaction involve several temporal and spatial scales which makes a detailed understanding of its functional basis quite challenging.



During the 2004 MBI Summer Program, a group of undergraduate and graduate students studied the issue. Their project focused on the dynamics of the olfactory receptor neuron (ORN). ORN are situated in the nasal epithelium and interface directly with odor molecules that become dissolved in the nasal mucosa. The response to these odorants requires the cooperation of two distinct processes within the ORN.

The first is an electro-chemical signal transduction cascade that occurs in the cilia of ORN upon binding of odor molecules to special receptors. The second is an action potential generation mechanism in the soma of ORN that allows neuro-electrical signals to be communicated to the olfactory bulb and higher processing centers in the brain. The students developed a mathematical model which synthesized a body of experimental data concerning the biochemical signaling and electrical spike generation processes of ORN.

Their model predicted that the total number of spikes per spiking episode is a non-monotonic function of log odorant concentration, first increasing then decreasing, in agreement with experimental observations. Their model was also able to explain why action potentials predominantly occur only during the activation phase of a response, not during the desensitization phase. In the future, their model of ORN spiking behavior will be used for a in-depth study of dose-response relations and coding capacity of these chemical-sensing cells.

Geraldine Wright and Daniel P. Dougherty are postdoctoral fellows at the Mathematical Biosciences Institute. This material is based upon work supported by the National Science Foundation under Agreement No. 0112050.

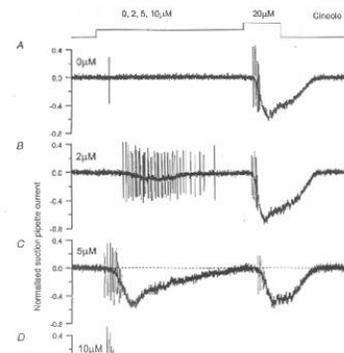


Figure 1: Response of a frog ORN to stimulation with a 4s conditioning pulse at concentrations, 0, 2, 5 or 10 μ M, followed by a 1s 20 μ M test pulse (Reisert & Matthews, 1999, Fig. 5).

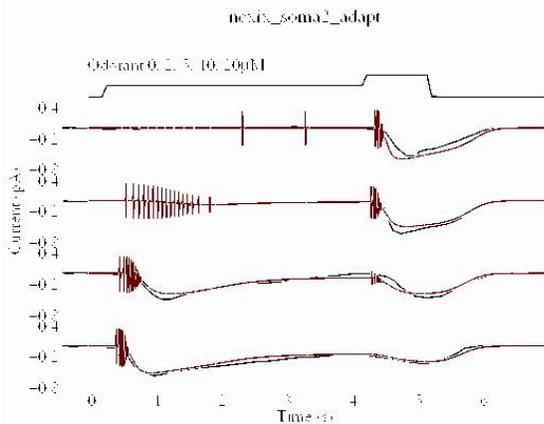


Figure 2: Model predictions (red traces) compared with the experimentally measured receptor current (black traces) taken from the data in Figure 1 (Dougherty et al., 2004).

References

- Reisert, J., & Matthews, H.R. (1999). *Journal of Physiology (London)*, 519, 801-813.
- Dougherty, D.P., Badamorzj, D., Carlton, M., Musielak, M., Wherity, L., & Yew, A.C. (2004). *Mathematical Biosciences Technical Report Series 27*.

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