The Brain Behind the Jaws

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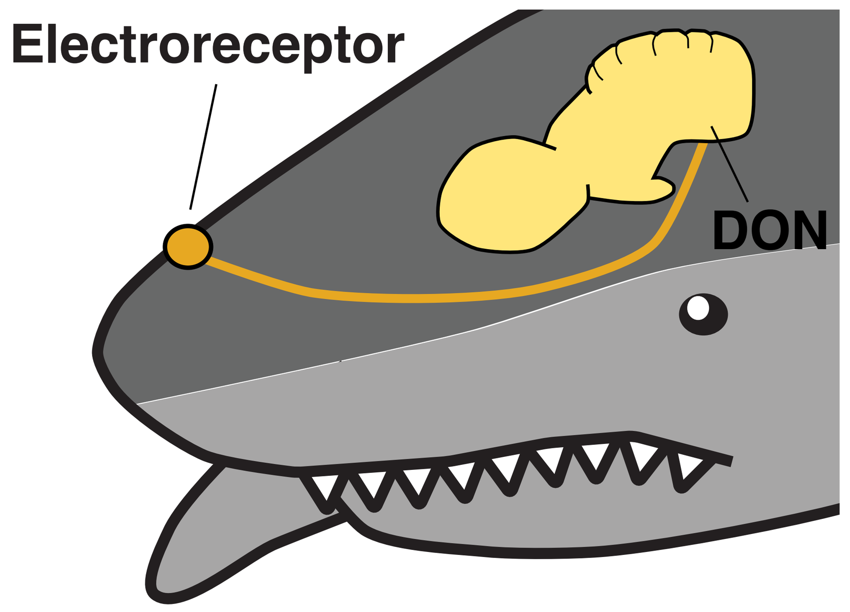
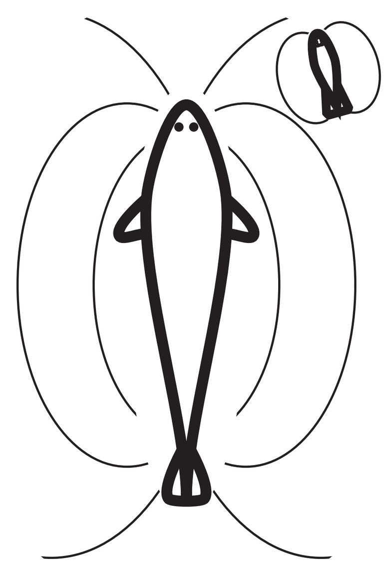
How does a shark distinguish the weak electric field of its prey from the much stronger field generated by its own body?

Background: the shark electrosense

Sharks locate their prey by detecting the electric field in the water.

Electroreceptors in the shark's skin detect the strength of the electric field. Neurons carry the signal to the **dorsal octavolateral nucleus** (**DON**).



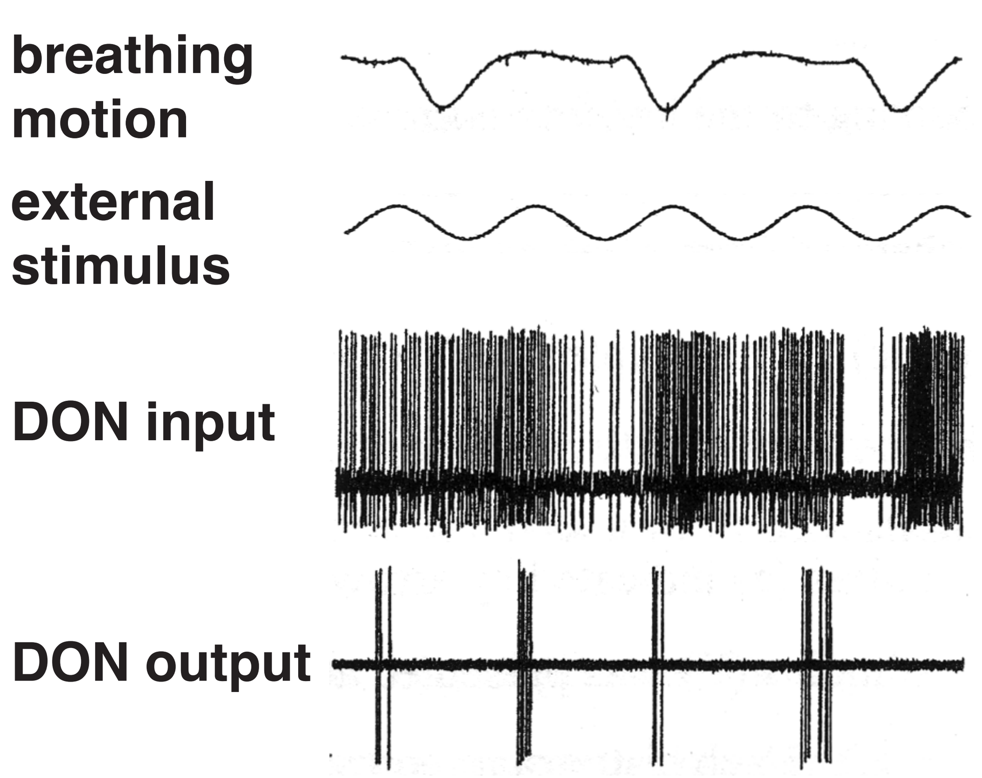


Electric fields generated by the movement of prey are superimposed on a much stronger field generated by the shark's breathing.

The resulting signal consists of weak external stimuli on top of a slowly varying breathing motion.

Background: adaptive noise filtering

Experiments show that the DON strips the breathing motion from the signal [1].



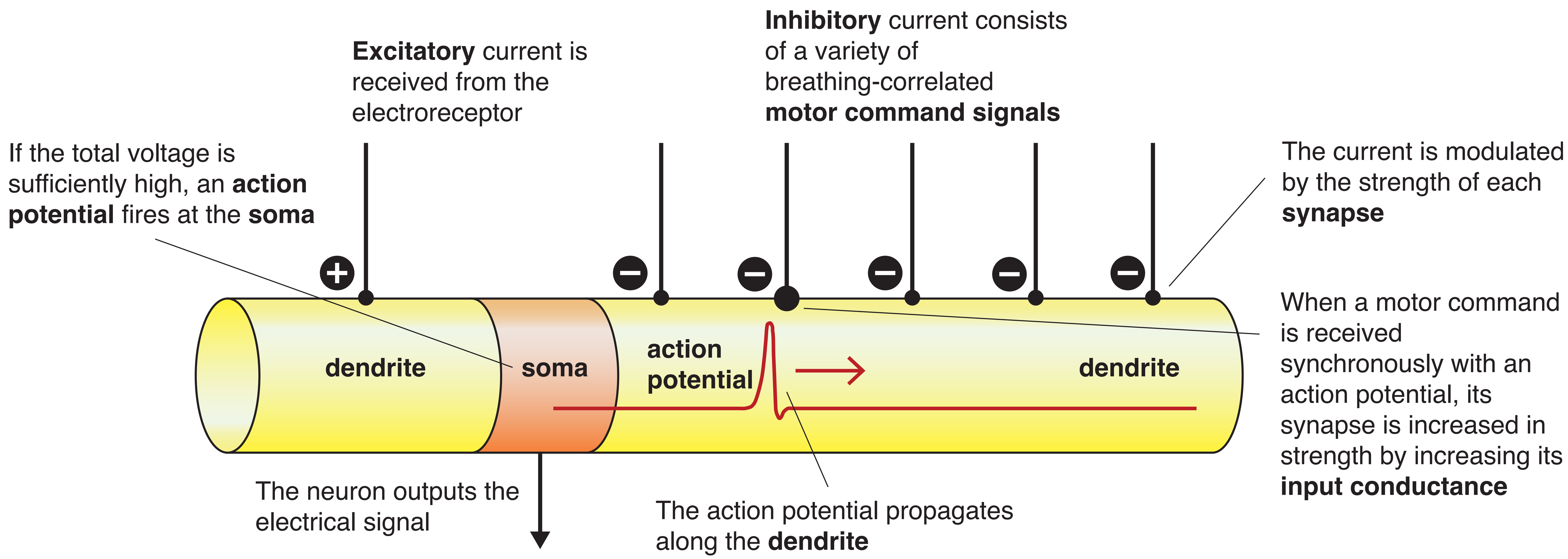
Over time the DON learns to suppress **any** field applied in time with the shark's breathing.

[1] Bodznick D, Montgomery JC, Carey M: Adaptive mechanisms in the elasmobranch hindbrain. J Exp Biol 1999, 202:1357-1364.

Aim

To develop a biophysically-based computational simulation which demonstrates a mechanism for adaptive noise filtering in the dorsal octavolateral nucleus.

The neuron: an electrical learning machine



Simulating the neuron

Combining the **Hodgkin-Huxley equation** with the **cable equation** results in a mathematical model describing the propagation of action potentials along the dendrites.

$$\frac{\partial V}{\partial t} = \frac{\partial^2 V}{\partial x^2} + g_{\mathrm{Na}} m^3 h (V - V_{\mathrm{Na}}) + g_{\mathrm{K}} n^4 (V - V_{\mathrm{K}}) + g_{\mathrm{L}} (V - V_{\mathrm{L}})$$

$$\frac{dm}{dt} = \alpha_m (1-m) - \beta_m m$$

$$\frac{dn}{dt} = \alpha_n (1-n) - \beta_n n$$

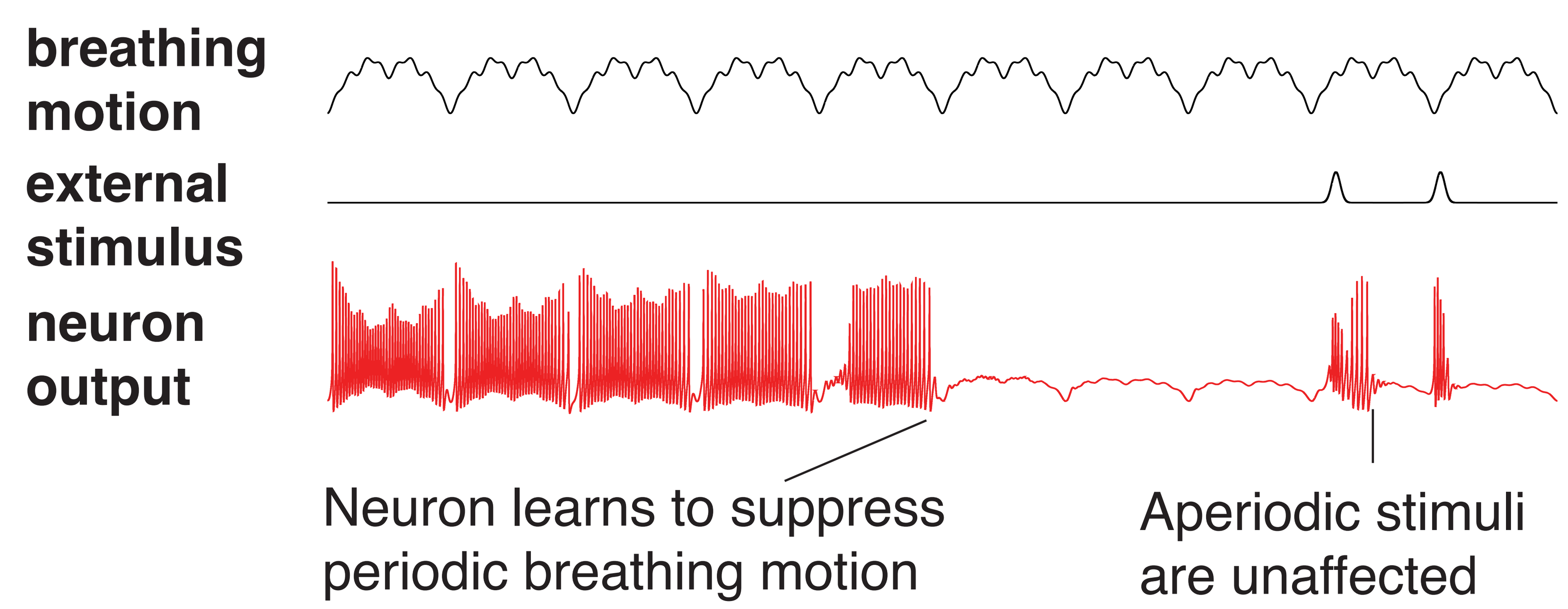
$$\frac{dh}{dt} = \alpha_h (1-h) - \beta_h h$$

Synapses are modelled as applied currents at varying positions along the dendrites.

Motor command signals are simulated by a set of sine waves of varying phase and period.

The resulting system of differential equations is then solved numerically.

Results of the simulation



Conclusions

It is possible for a single neuron to behave as an adaptive noise filter.
The adaptive noise filtering is not significantly affected by the spatially distributed nature of the model.