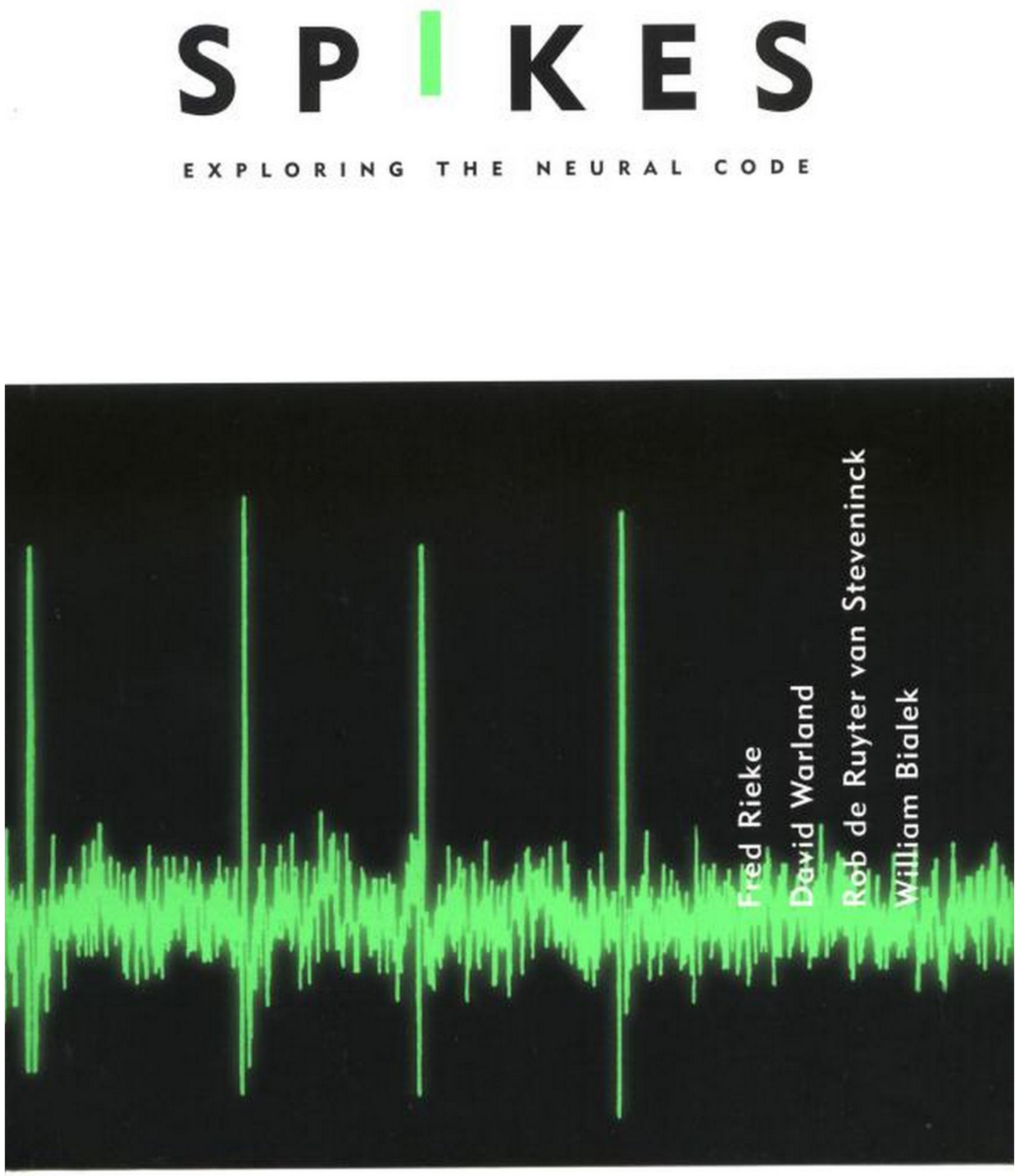
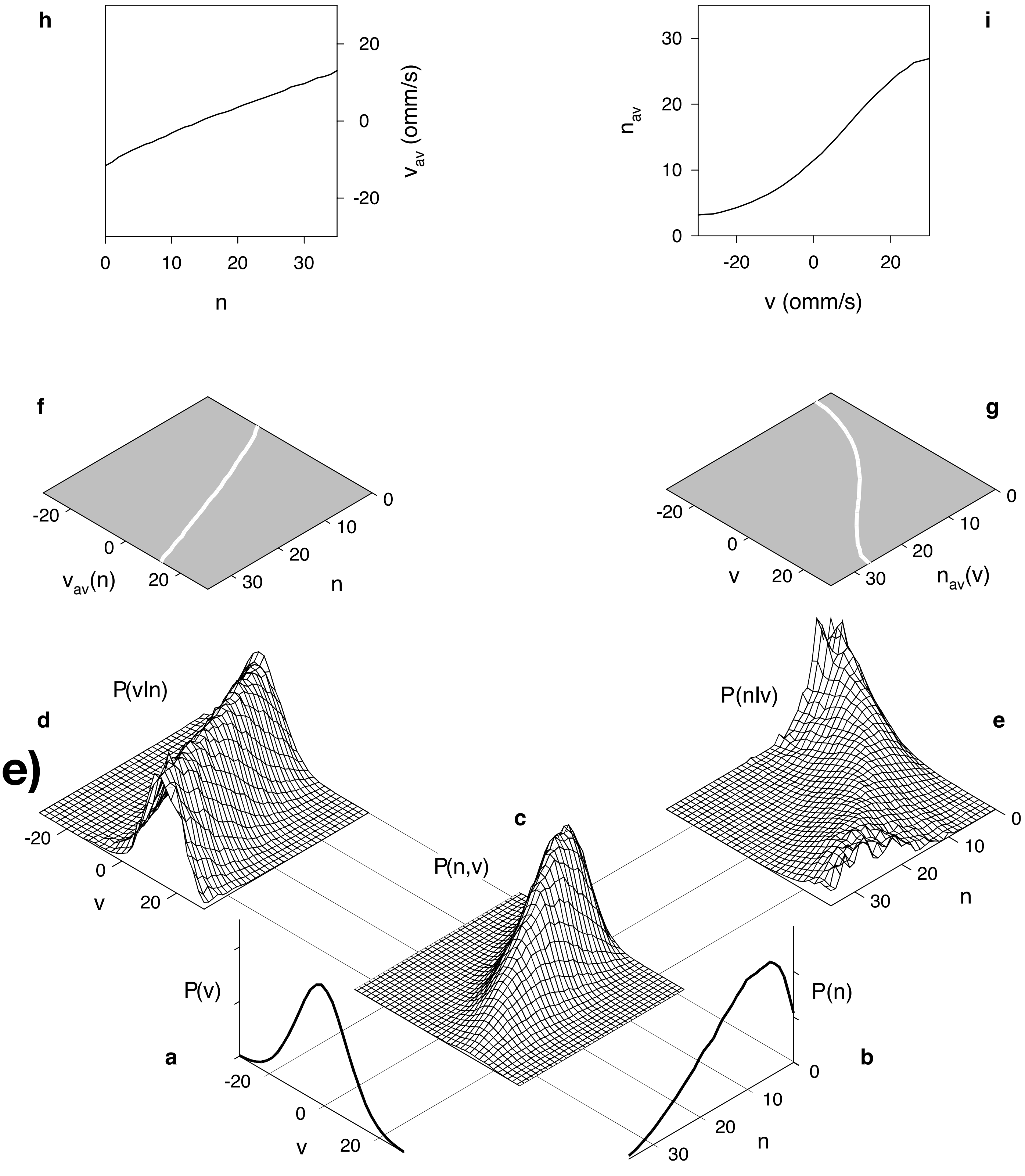


MIT Press (1997)

MIT Press (2002)

Encoding and decoding are related through the joint distribution over *stimulus* (v) and *response* (n)



decoding

$$\hat{v} = g(n)$$

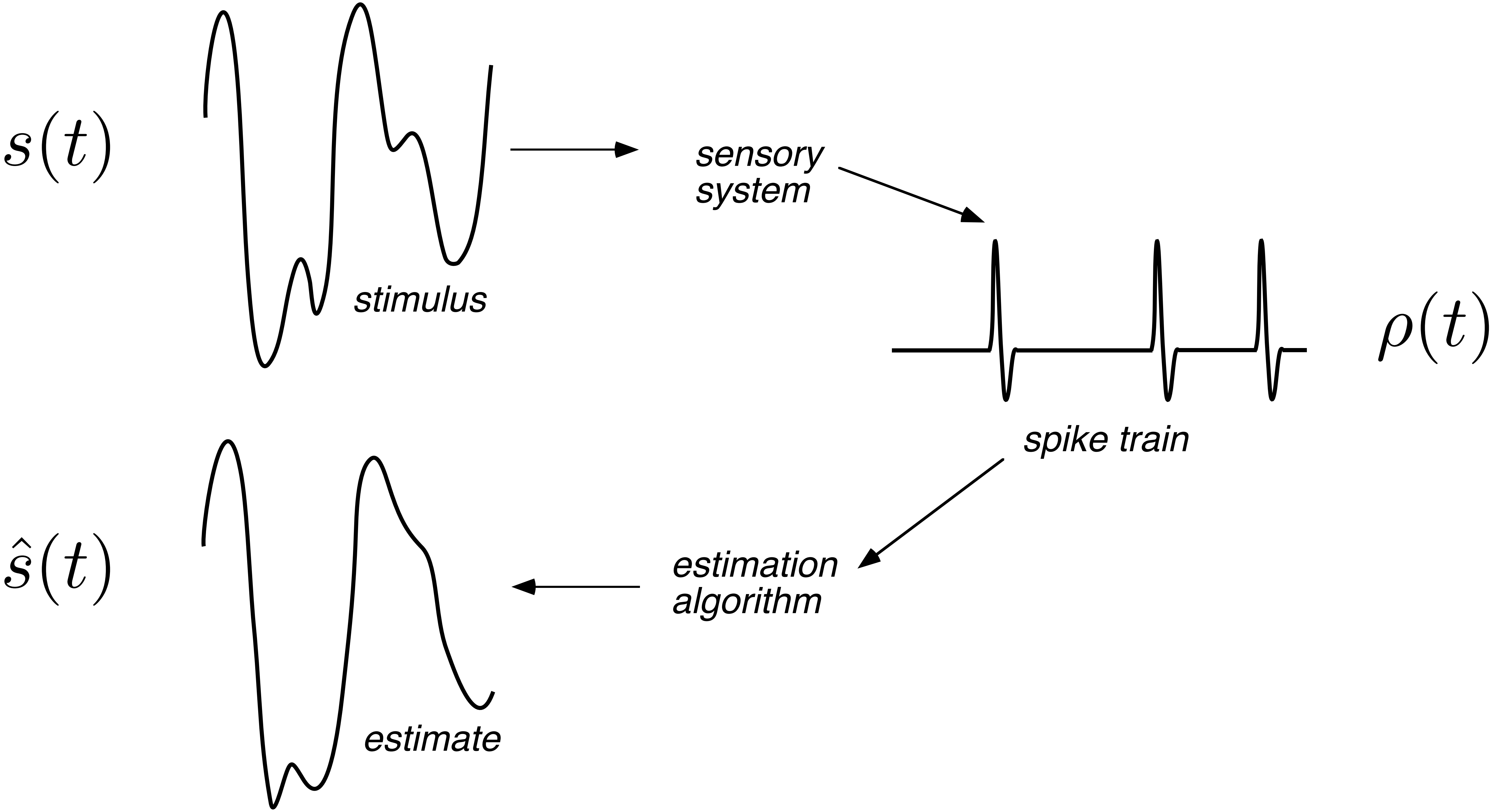
P(stimulus | response)

encoding

$$n = f(v)$$

P(response | stimulus)

From *Spikes*, by Rieke, Warland, de Ruyter, & Bialek



$s(t)$

stimulus

sensory
system

spike train

$\rho(t)$

estimation
algorithm

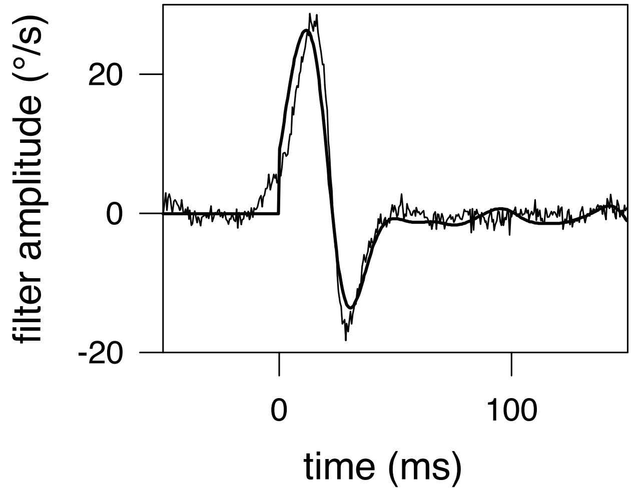
estimate

$\hat{s}(t)$

From *Spikes*, by Rieke, Warland, de Ruyter, & Bialek

Reconstruction kernel

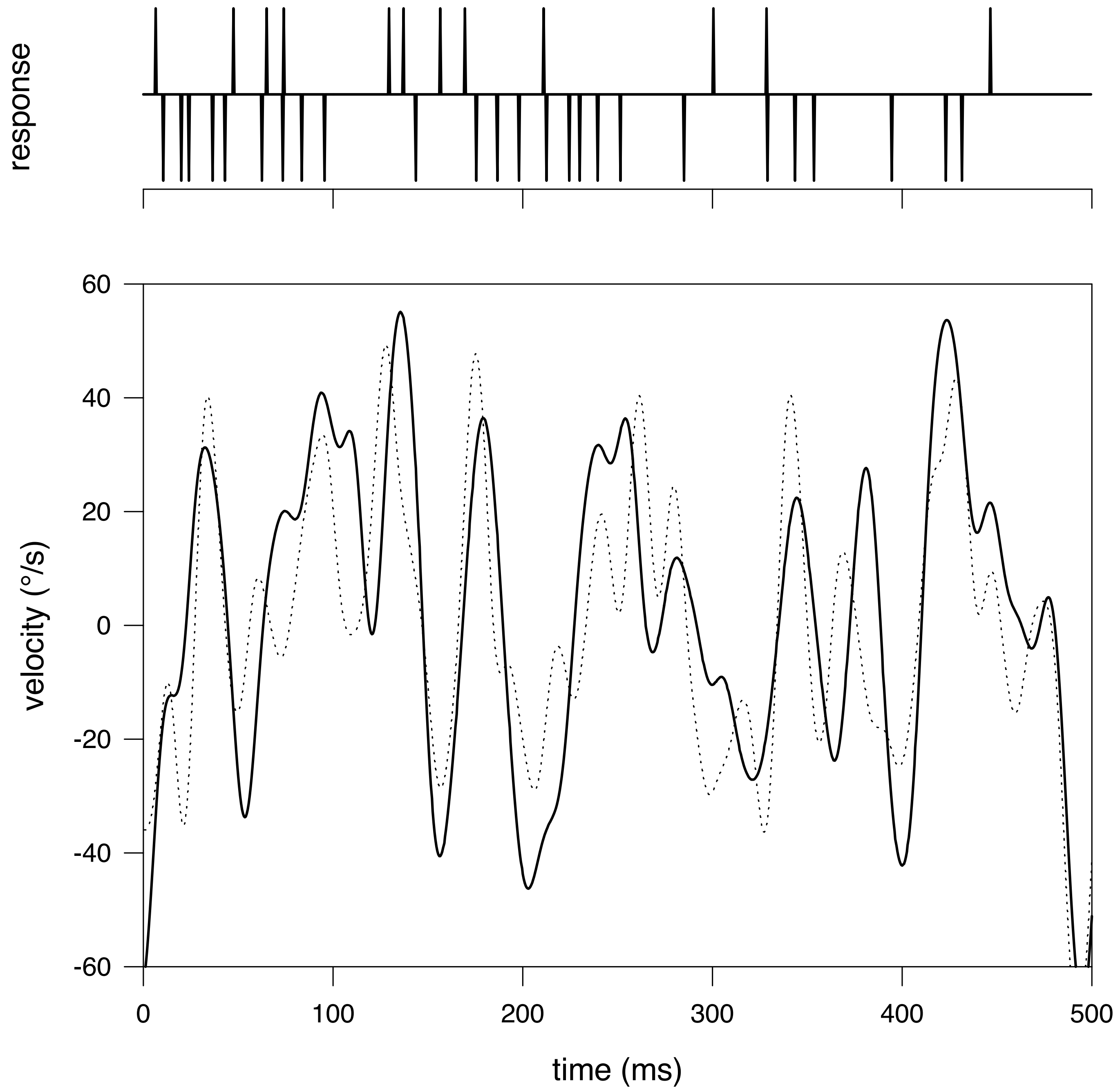
$k(t)$



Fly H1 neuron response

$\rho(t)$

Stimulus reconstruction



$$\hat{s}(t) = \rho(t) * k(t)$$

$$\hat{k}(t) = \arg\min_{k(t)} \left\langle \left[s(t) - \rho(t) * k(t) \right]^2 \right\rangle$$

From *Spikes*, by Rieke, Warland, de Ruyter, & Bialek

Strategy for estimating information rate

1. Estimate signal from spikes

$$\rho(t) \rightarrow \hat{s}(t)$$

2. Compute noise in estimate

$$\tilde{n}(\omega) = \tilde{s}(\omega) - \hat{\tilde{s}}(\omega)$$

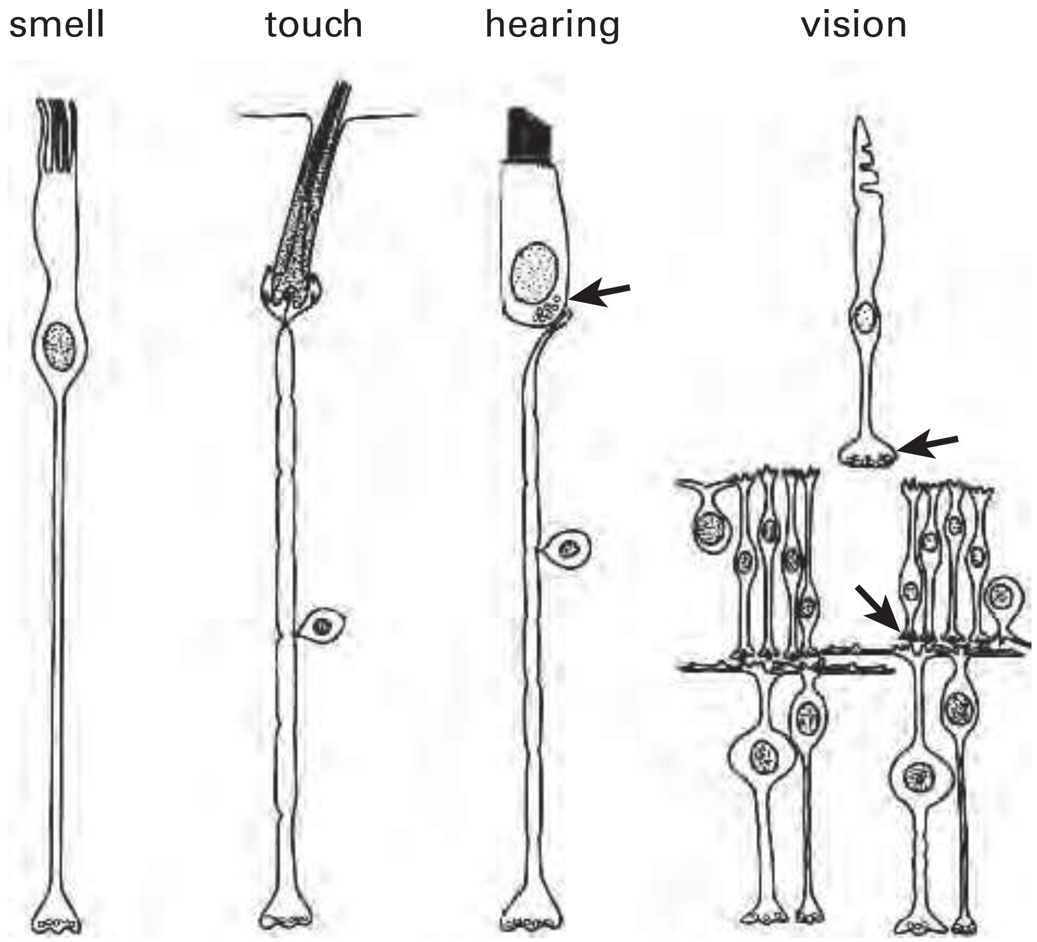
3. Compute SNR

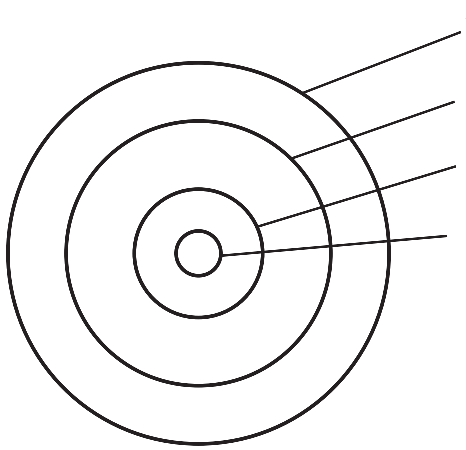
$$\mathrm{SNR}(\omega) = \frac{\langle |\tilde{s}(\omega)|^2 \rangle}{\langle |\tilde{n}(\omega)|^2 \rangle}$$

4. Calculate lower bound to information rate from SNR

$$R = \frac{1}{2} \int \frac{d\omega}{2\pi} \log_2[1 + \mathrm{SNR}(\omega)]$$

Adapted from *Spikes*, by Rieke, Warland, de Ruyter, & Bialek





axon diameter	number of axons
vestibular	10^4
auditory	5×10^4
optic	10^6
olfactory	10^7

From Sterling & Laughlin

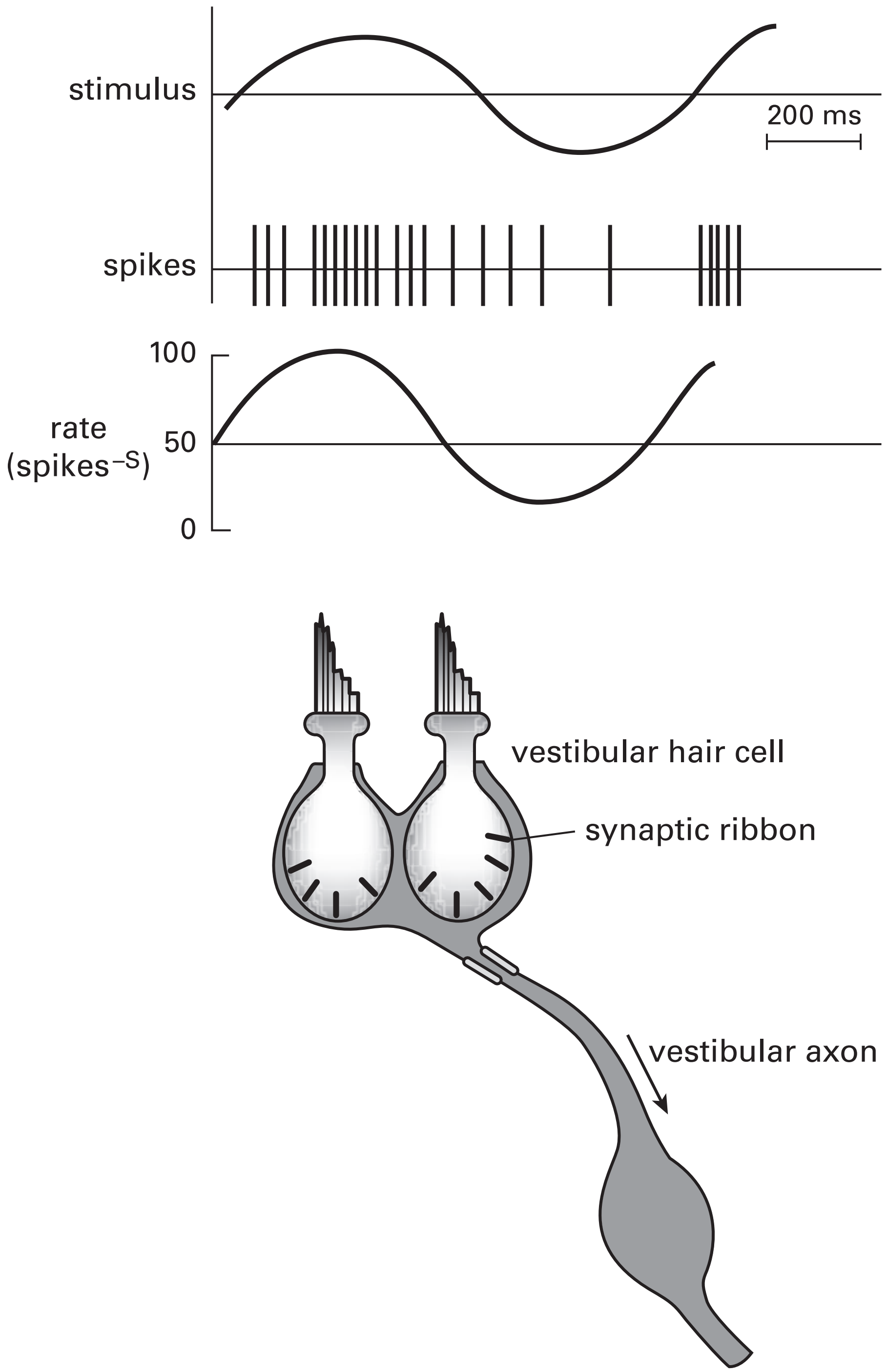
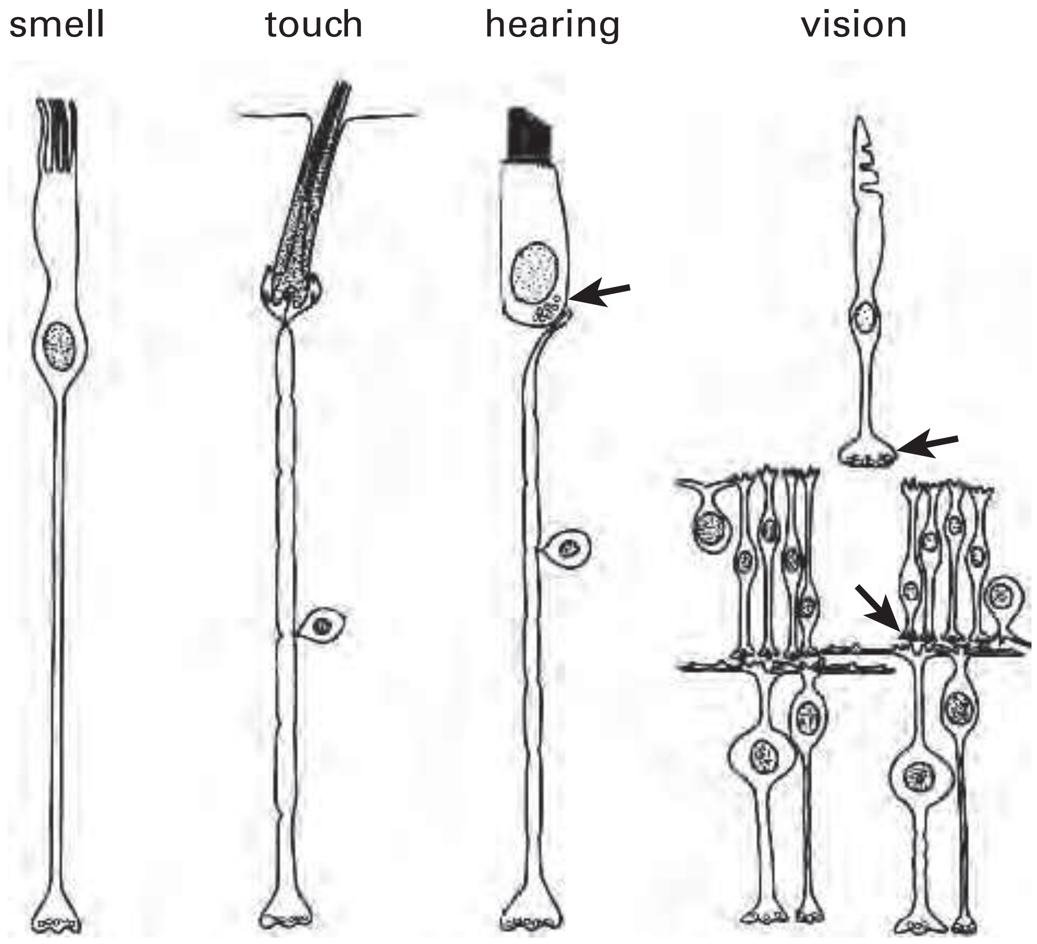
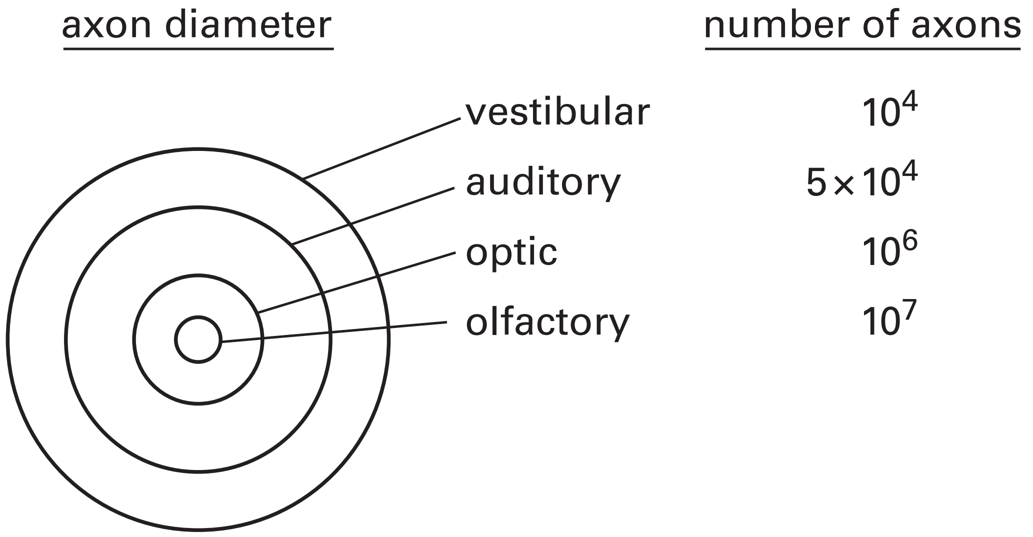


Figure 10.5

Vestibular hair cells, transducing low frequencies, can sum their analogue signals before recoding to spikes. Upper: Head rotates slowly (1 Hz). Spikes from second-order vestibular axon are modulated linearly through the full cycle around 50 spikes per second. **Lower:** Adjacent hair cells each converge multiple active zones onto single afferent fiber. Modified from Eatock et al. (2008).

From Sterling & Laughlin

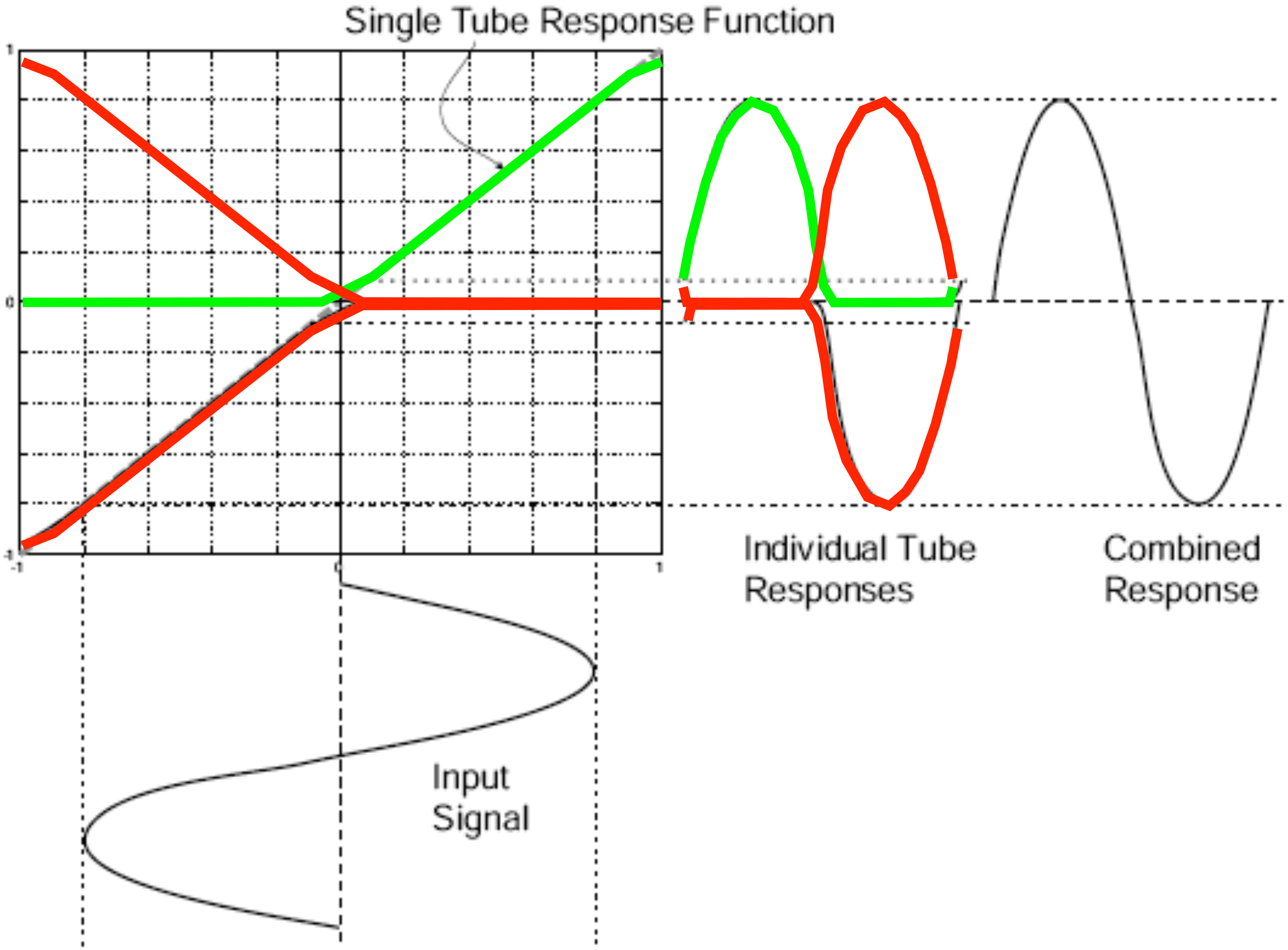




axon diameter	number of axons
vestibular	10^4
auditory	5×10^4
optic	10^6
olfactory	10^7

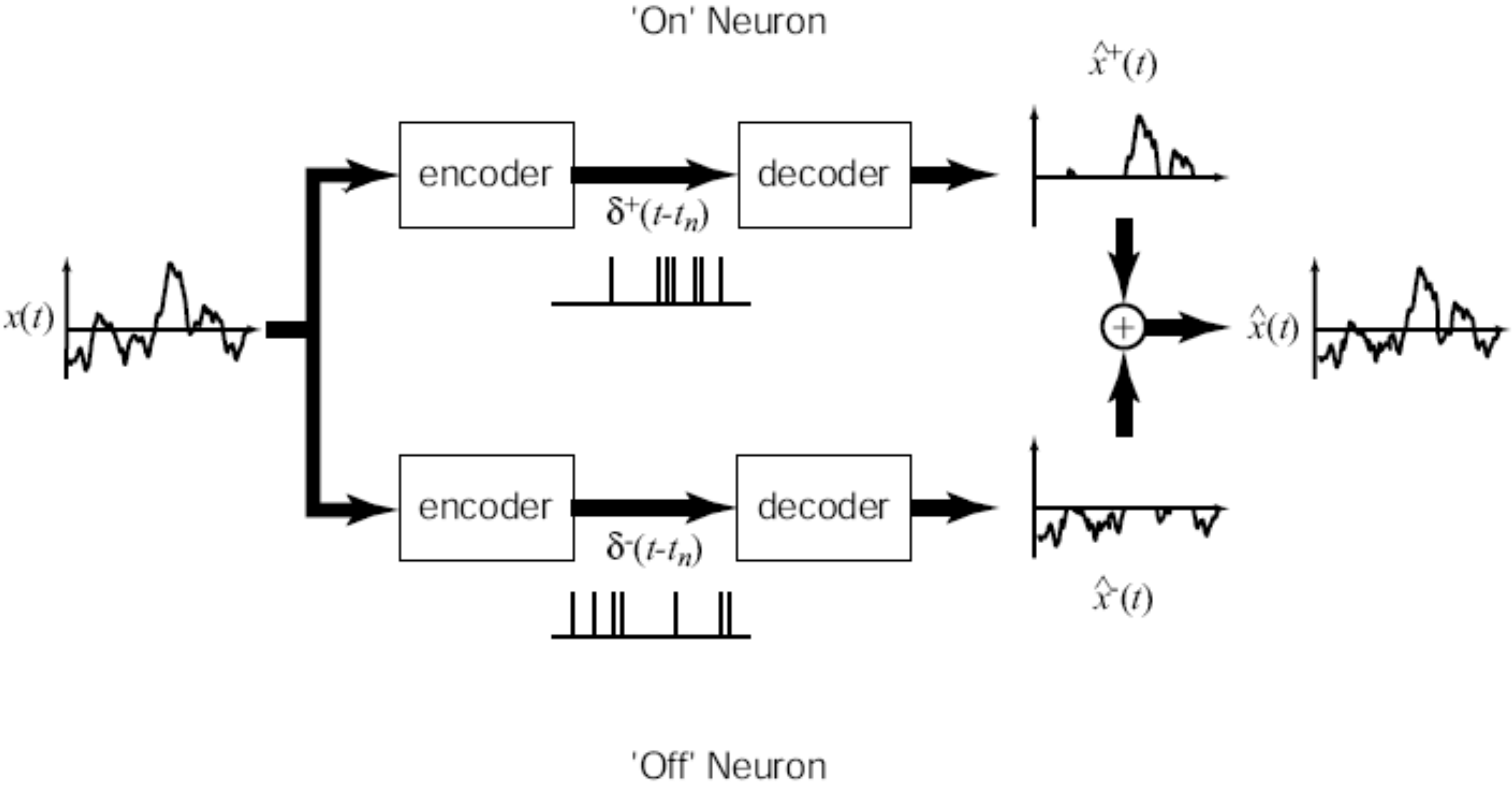
From Sterling & Laughlin

Neural responses are half-wave rectified (action potentials are positive-only). Signals are thus combined in a push-pull fashion, similar to push-pull amplifiers.



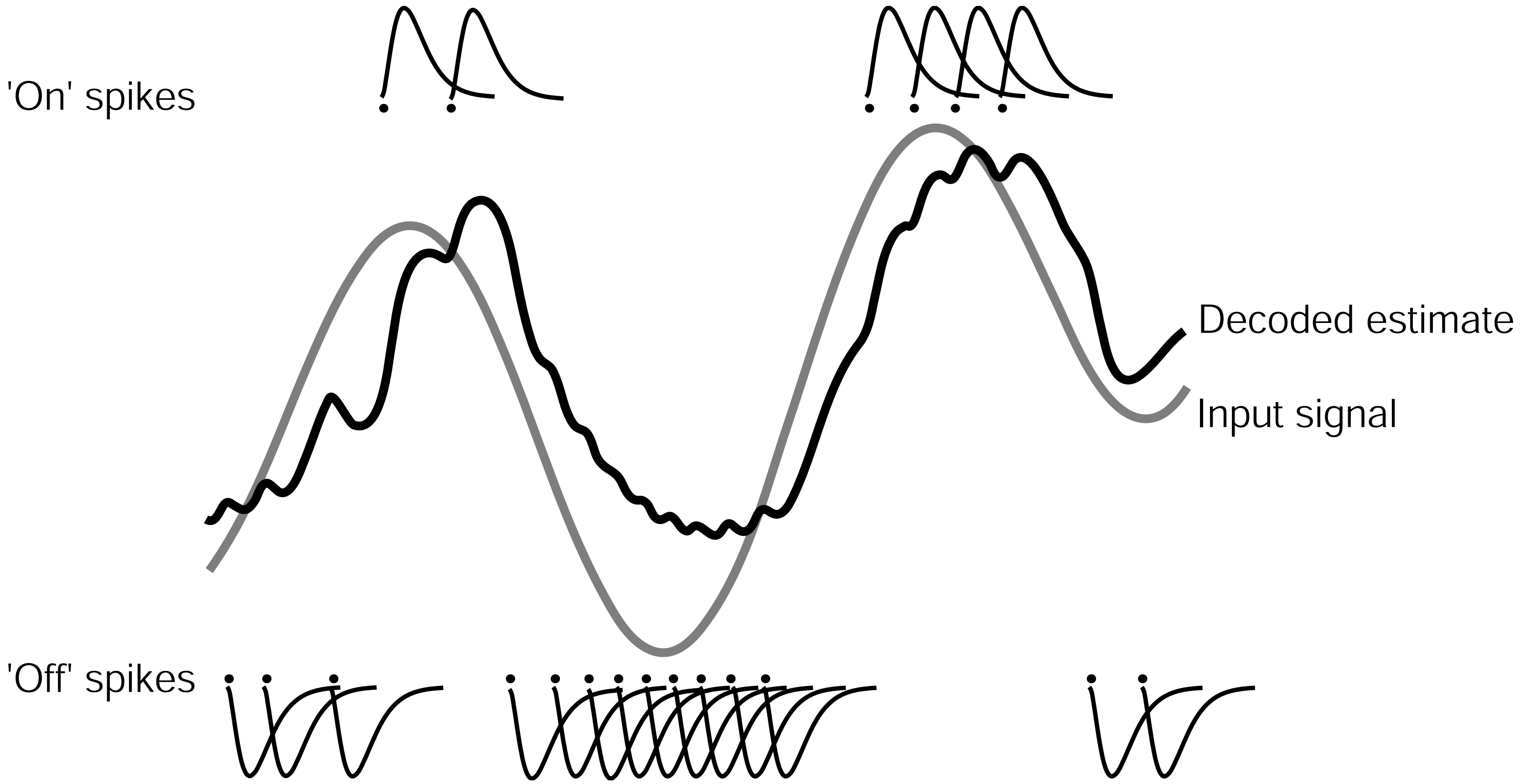
From: *Neural Engineering*, by Eliasmith & Anderson

Push-Pull decoding



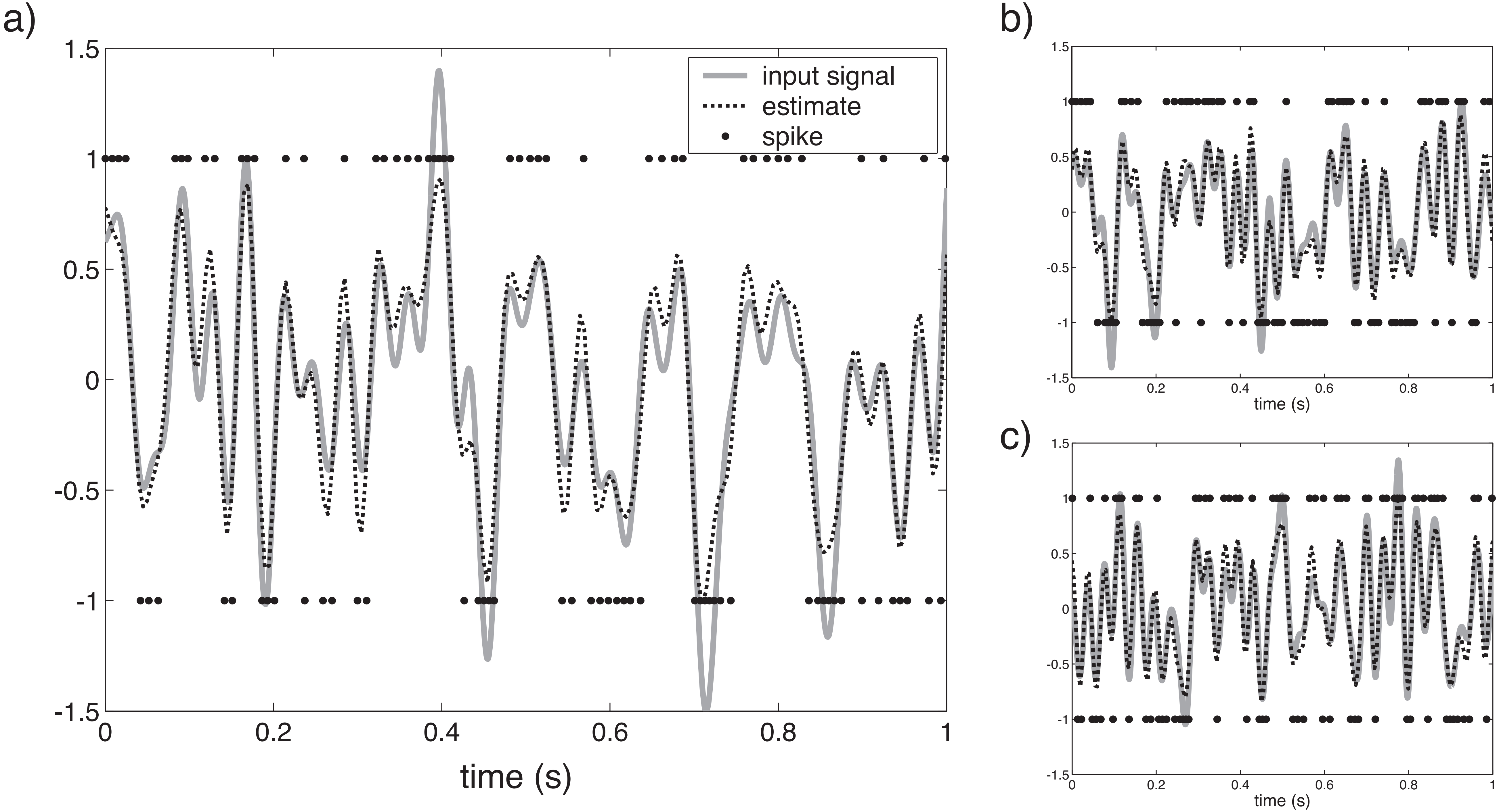
From: *Neural Engineering*, by Eliasmith & Anderson

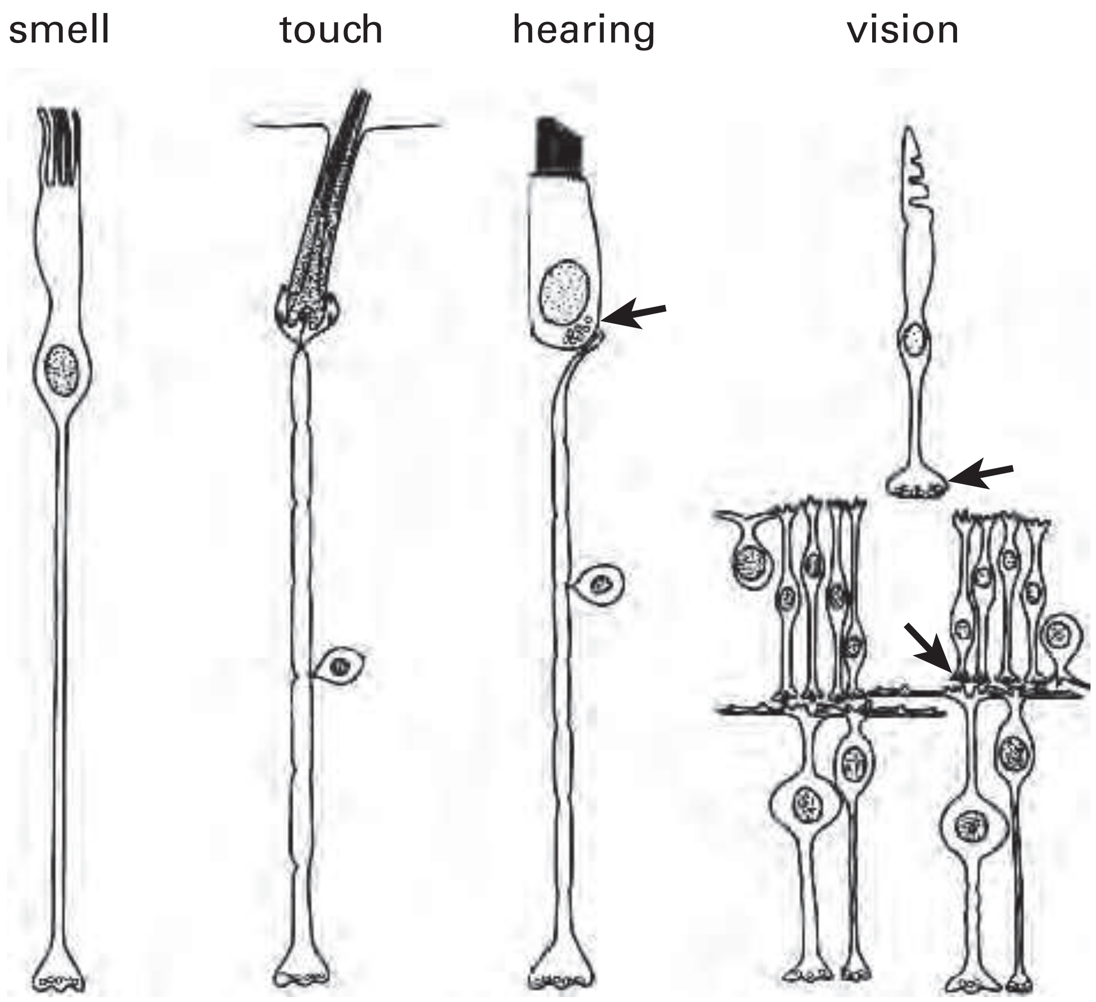
$$\begin{aligned}\hat{x}(t) &= \sum_{i,k}^{M} \phi_i \delta(t - t_{ik}) * h(t) \\ &= \sum_{i,k}^{M} \phi_i h(t - t_{ik}).\end{aligned}$$

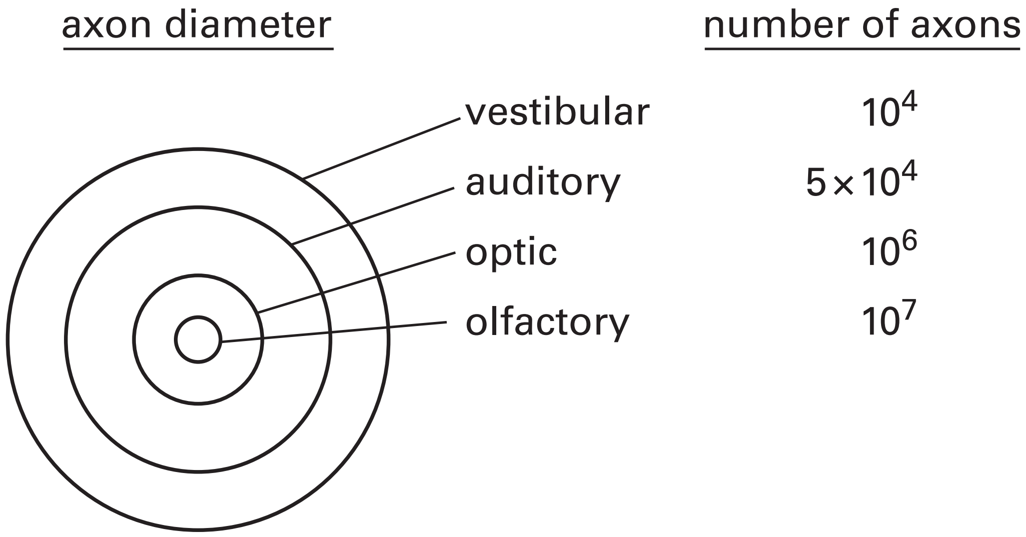


LIF encoding and decoding

(Eliasmith & Anderson, 2003)

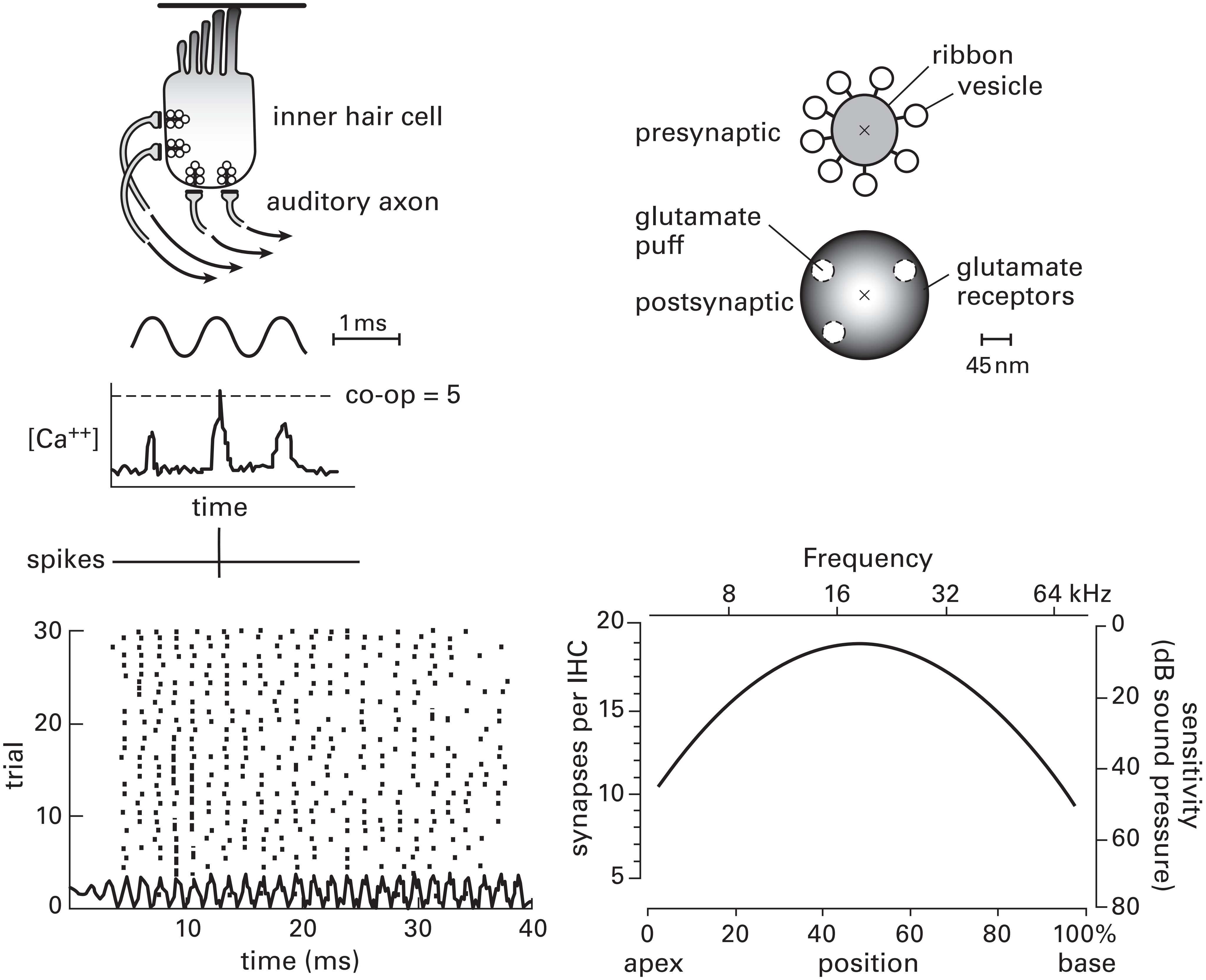






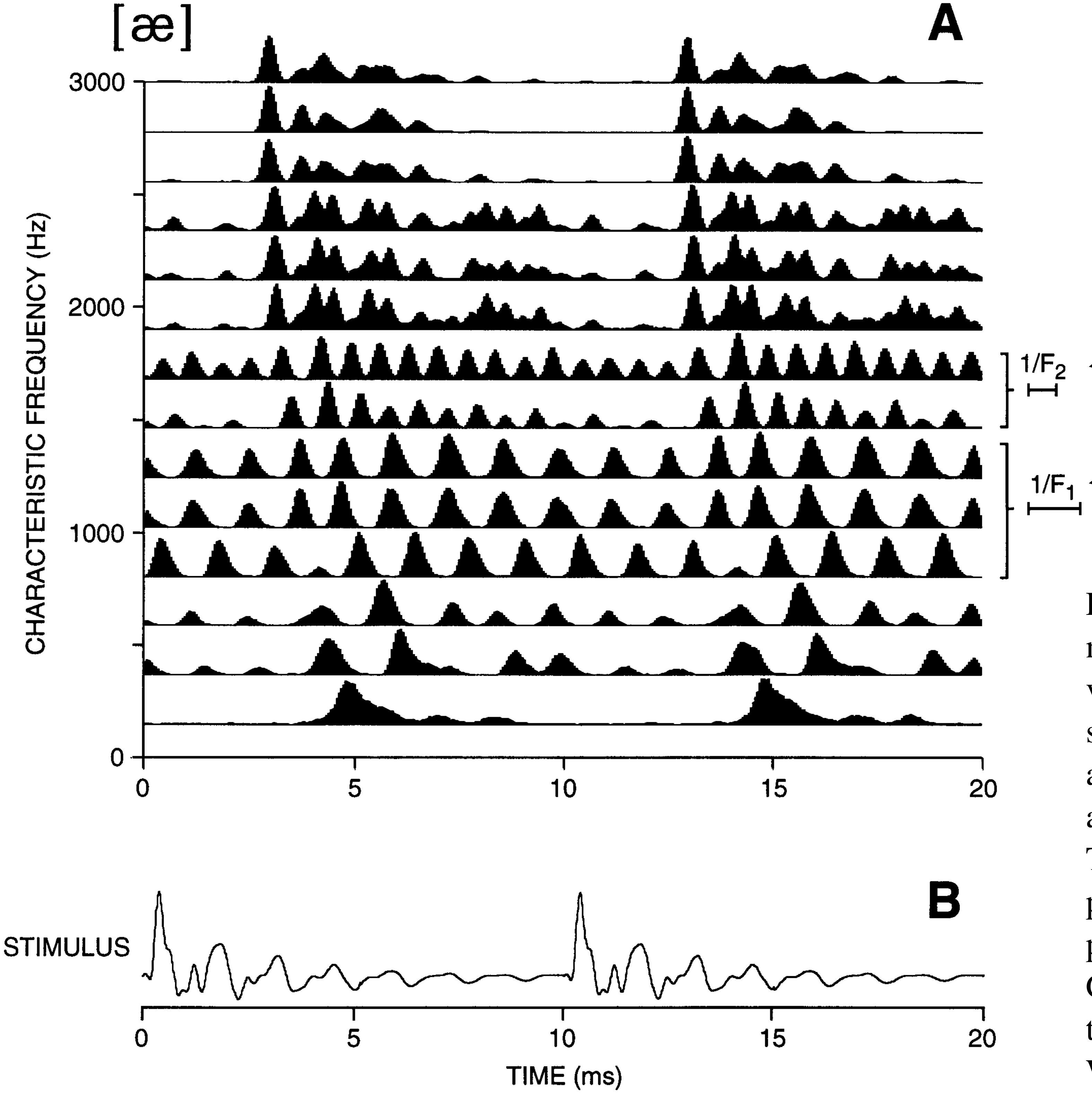
axon diameter	number of axons
vestibular	10^4
auditory	5×10^4
optic	10^6
olfactory	10^7

From: Sterling & Laughlin (2017)



From: Sterling & Laughlin (2017)

Spikes of auditory nerve fibers are phase-locked to components of sound waveform



Second formant

First formant

Fig. 3. A. Neurogram display of (cat) auditory-nerve activity in response to a synthetic [ae] vowel presented at 60 dB SPL. Each trace shows a smoothed period histogram for one auditory-nerve fiber whose CF was approximately equal to the vertical ordinate. The histogram bin width is 50 µsec, and its base period is 20 msec, corresponding to two pitch periods of the vowel stimulus. Brackets indicate CF regions in which ANFs phase-lock primarily to the first or second formant frequency. B. Waveform of two pitch periods of the [ae] stimulus, which had a 100-Hz fundamental.

(from Delgutte 1997)

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Information in the Zero Crossings of Bandpass Signals

By B. F. LOGAN, JR.

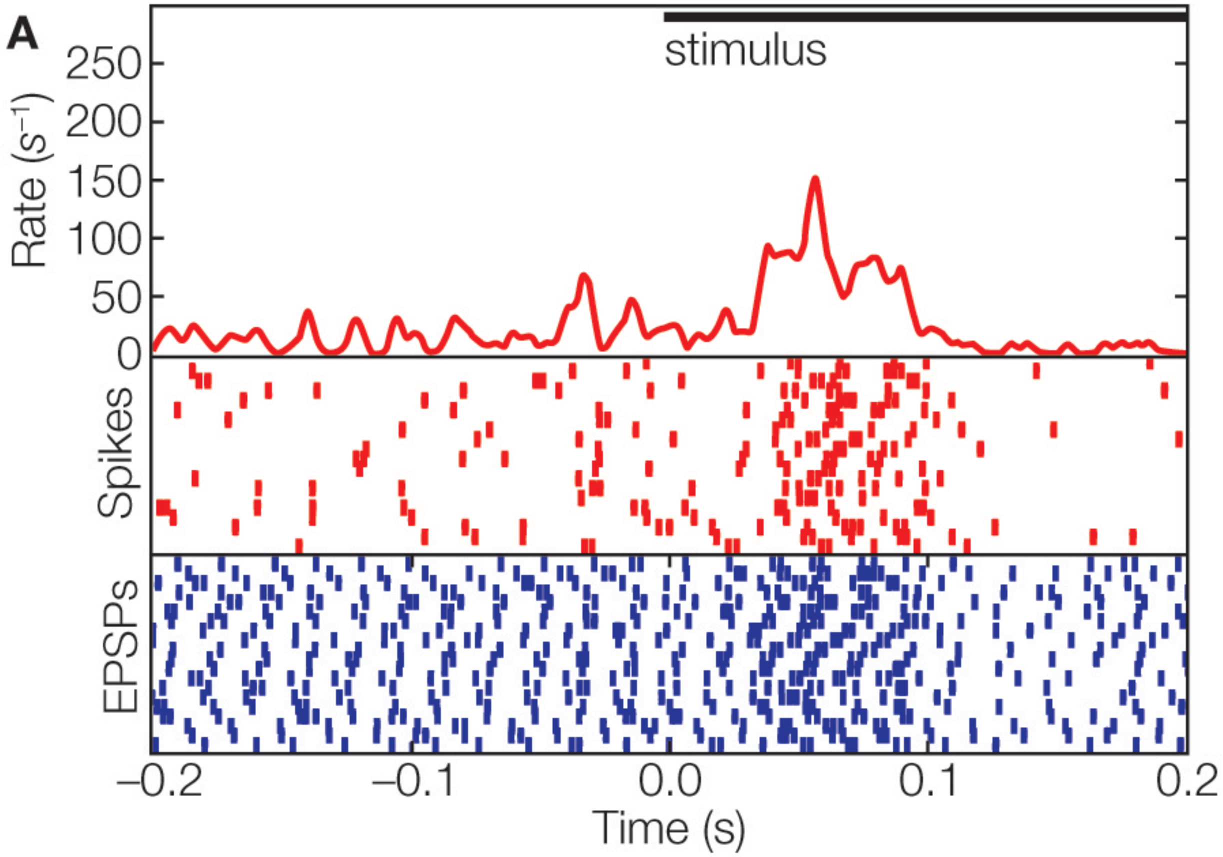
(Manuscript received October 4, 1976)

An interesting subclass of bandpass signals $\{h\}$ *is described wherein the zero crossings of* h *determine* h *within a multiplicative constant. The members may have complex zeros, but it is necessary that* h *should have no zeros in common with its Hilbert transform* $\hat{h}$ *other than real simple zeros. It is then sufficient that the band be less than an octave in width. The subclass is shown to include full-carrier upper-sideband signals (of less than an octave bandwidth). Also it is shown that full-carrier lower-sideband signals have only real simple zeros (for any ratio of upper and lower frequencies) and, hence, are readily identified by their zero crossings. However, under the most general conditions for uniqueness, the problem of actually recovering* h *from its sign changes appears to be very difficult and impractical.*

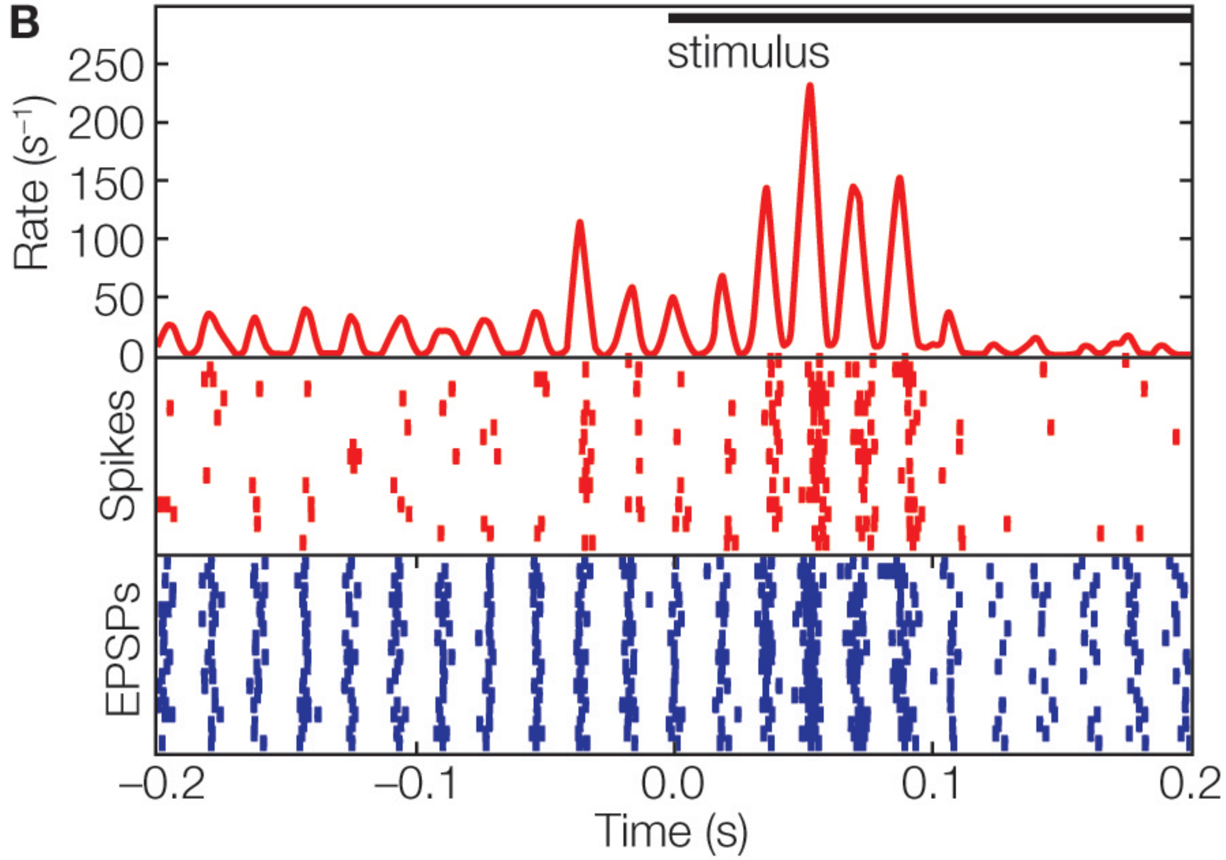
Retinal oscillations carry information to cortex

(Koepsell, Wang, Hirsch & Sommer 2009)

Locked to external stimulus onset



Locked to ongoing oscillation phase



See also Haider et al. (2023) Narrowband gamma oscillations propagate and synchronize throughout the mouse thalamocortical visual system. *Neuron, 111(7)*, 1076-1085.