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MINIMAL MODELS OF SPIKE ENCODING BY NEOCORTICAL NEURONS.

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We have previously shown that one important property of repetitive firing in neocortical neurons, the precision of spike timing, depends strongly on the presence of stimulus fluctuations [Mainen and Sejnowski (1995) Science, in press.] Thus, the use of complex current stimuli, more closely resembling natural synaptic input, can reveal features of spike generation that are difficult to extrapolate from data obtained by traditional protocols using simple dc stimuli. Here, we have used complex stimulus paradigms to build well-constrained minimal models of current-to-spike encoding in neocortical neurons.

Recordings (33-35 $^{\circ}$C) were made from visually identified pyramidal neurons in layer 5 of slices of rat visual cortex (P14-26) in the presence of synaptic transmission blockers (10 μm DNQX, 5 μm BMI, to eliminate spontaneous activity). Whole-cell as well as perforated patch methods, which minimize rundown, were used. Cells were stimulated in trials of up to 4 sec using computer-generated filtered Gaussian noise and responses digitized at 4 kHz.

"Leaky integrator" style models were fit to responses across a range of values for the mean and variance of stimulus fluctuations. Models were fit not only to the time-averaged firing rate and interspike interval variability, but also to the nonstationary response characteristics (e.g. bursting and adaptation) and the precise spike timing patterns evoked by individual stimuli. To do so it was necessary to augment the standard leaky integrator model with additional hidden variables corresponding to relevant intrinsic currents. Compared to complex Hodgkin-Huxley style compartmental models, which are severely underconstrained by available data and difficult to analyze, the simplified models studied here constitute a more compact and computationally tractable description of neural current-to-spike encoding that can be readily incorporated in large-scale network models involving temporally-based information processing. ZFM is an HHMI Predoctoral Fellow.