Appendix 1

Each neuron was represented as a conductance based calculation of membrane potential, with spikes determined by thresholds that varied according to recent spiking activity to implement the net effects of active conductances. Using 1 ms time steps, the change in membrane potential was calculated according to synaptic and leak conductances and to membrane capacitance. The probability of a simulated neuron firing is calculated at each time bin and approximated by the following sigmoid function of membrane potential (*V*):

$$P(V) = \frac{1}{1 + e^{-(V-\theta)}} \, .$$

Spikes were initiated when membrane potential exceeded threshold (random number from uniform distribution between 0 and 1).

if *P(V)* ≥ random number, *Spike* = 1

if *P(V)* < random number, *Spike* = 0

Threshold increased for each spike and returned exponentially to the baseline value. All synaptic conductances were based on time constants derived from *in vitro* studies, and the threshold properties (θ in each equation) of each representation was tuned to produce behavior that matches the *in vivo* characteristics of the target cell type.

	Activity Representation	Membrane Potential
Basket/Stellate cells:	$P_{b/s} = \frac{1}{1 + e^{-(V_{b/s}-\theta_{b/s})}}$	$V_{b/s} = \frac{\sum_{i=1}^{l} Spike_{gr}^{i} w_{gr}^{i}}{l}$
		l = number of granule cell inputs

Purkinje cells:

If climbing fiber spike, $P_{pkj} = 0$

$$V_{pkj} = \frac{\sum_{i=1}^{m} Spike_{gr}^{i} w_{gr}^{i}}{m} - \frac{\sum_{i=1}^{k} P_{b/s}}{k}$$

m = number of granule cell inputs

k = number of basket/stellate inputs

If no climbing fiber spike, $P_{pkj} = \frac{1}{1 + e^{-(V_{pkj} - \theta_{pkj})}}$

Nucleus cells: $P_{nuc} = \frac{1}{1 + e^{-(V_{nuc} - \theta_{nuc})}}$

$$V_{nuc} = \frac{\sum_{i=1}^{n} Spike_{mf}^{i} w_{mf}^{i}}{n} - \frac{\sum_{i=1}^{j} P_{pkj}}{j} + P_{cf}$$

n = total number of mossy fiber inputs

j = total number of Purkinje cell inputs

Climbing fibers: $P_{cf} = \frac{1}{1 + e^{-(V_{cf} - \theta_{cf})}}$

$$V_{cf} = E_{us} - K_{nuc} P_{nuc}$$

E_{US} = excitatory effect of US

$K_{nuc}P_{nuc}$ = nucleus inhibition of climbing fibers

Separate rules for plasticity were implemented at two types of synapses within the simulation: 1) the granule cell-to-PC synapses:

$$\Delta w_i^{gr} = \underbrace{\delta_{-}^{gr} \cdot Spike_i^{gr} \cdot Spike^{cf}}_{LTD} + \underbrace{\delta_{+}^{gr} \cdot Spike_i^{gr} \cdot (1 - Spike^{cf})}_{LTP};$$

and 2) the mossy fiber-to-DCN synapses:

$$\Delta w_i^{mf} = \underbrace{\delta_-^{mf} \cdot Spike_i^{mf} \cdot (1 - Spike^{nuc})}_{LTD} + \underbrace{\delta_+^{mf} \cdot Spike_i^{mf} \cdot Spike^{nuc}}_{LTP}$$

$$\Delta w_i^{mf} = \underbrace{\delta_-^{mf} \cdot Spike_i^{mf} \cdot (1 - Spike^{cf})}_{LTD} + \underbrace{\delta_+^{mf} \cdot Spike_i^{mf} \cdot Spike^{cf}}_{LTP} .$$

A granule cell-to-PC synapse underwent LTD or LTP every time it fired a threshold burst of spikes, LTD occurred when this burst fell within a window between 300 ms and 100 ms prior to a climbing fiber input to the PC, otherwise LTP occurred. Mossy fiber-to-DCN synapses active within a time window of an abrupt pause in Purkinje cell activity underwent LTD whereas those active during strong Purkinje activity underwent LTP.

After simulations were constructed pre-conditioning activity of each neuron type was checked to ensure a consistent activity baseline. Eyelid conditioning was simulated by presenting to the simulation mossy fiber and climbing fiber inputs based on empirical recordings during eyelid conditioning. Each mossy fiber was assigned a background firing rate between 1 and 40 Hz. To mimic activation of mossy fibers as a conditioned stimulus, a randomly selected 3% of the mossy fibers were designated phasic CS mossy fibers and were active for a brief 100 ms burst at CS onset. Another randomly selected 3% were designated tonic CS mossy fibers and were activate at a rate between 80 and 100 Hz throughout the duration of the CS. All mossy fiber activity was stochastic with the target firing rate for any given time used to determine the probability of activating an excitatory conductance in ways that made the actual activity noisy. The activation of an excitatory conductance for the four climbing fibers served to mimic the presentation of the US. The averaged and smoothed activity of the eight deep nucleus neurons was used to represent the output of the simulation and the predicted “eyelid response” of the simulation.