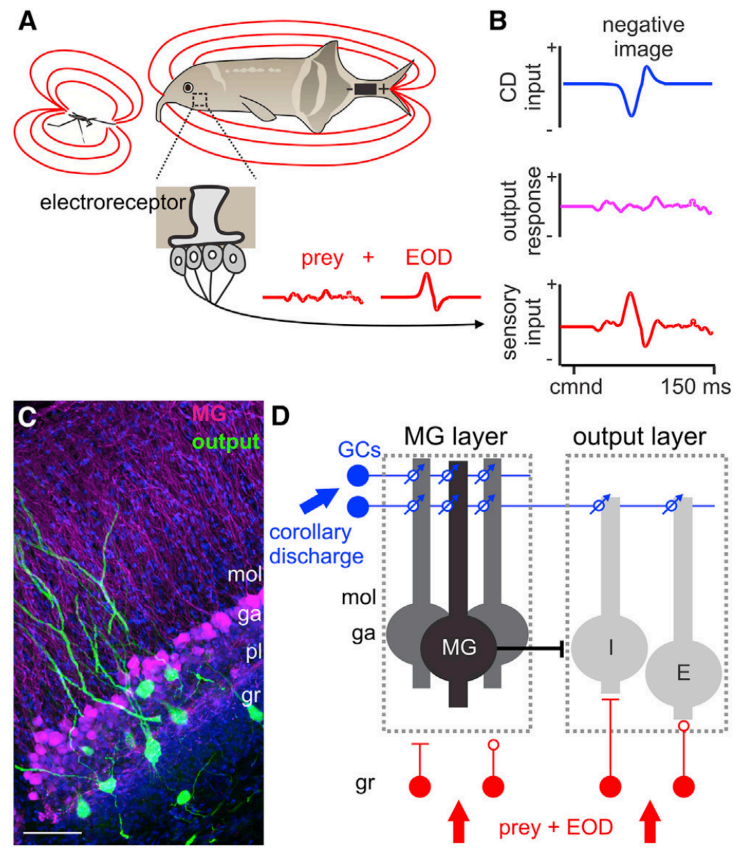
Learning and computing at the same time

Brabeeba Wang

4/25/2023

Electrical fish

- Mormyrid fish (electrical fish) uses electrosensing to detect prey.
- However, it self-generates electrical organ discharge (EOD) to do active sensing and it could mask the prey signal.
- Electrical fish is able to learn the negative image of EOD signals to cancel out the self-generated sensory inputs to detect prey

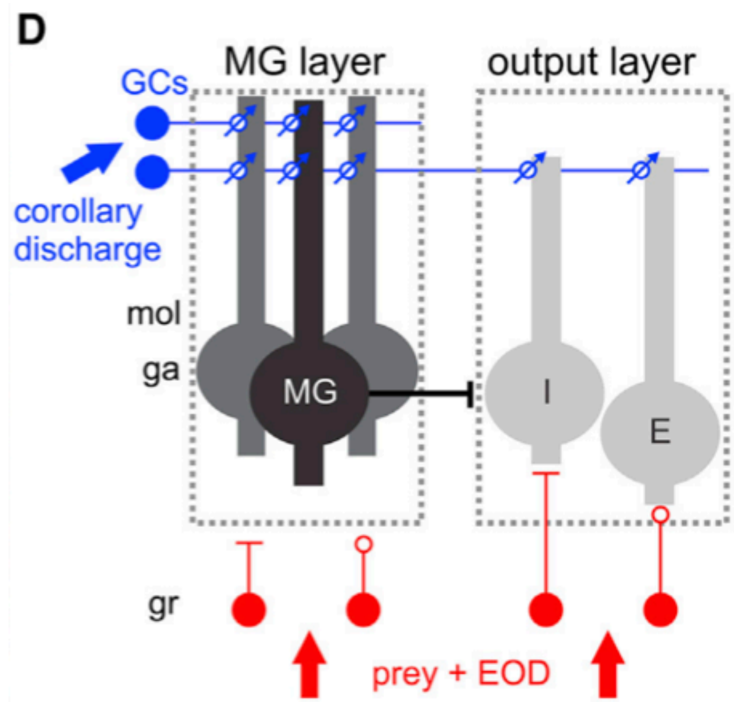


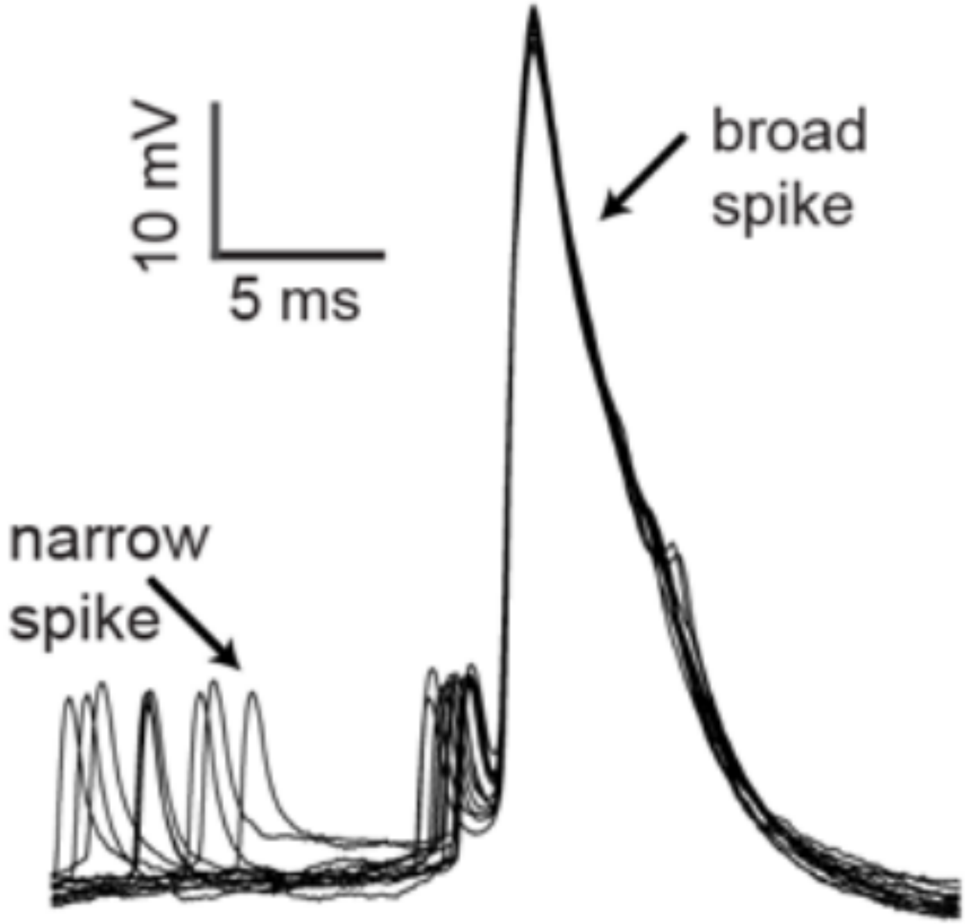
Cerebellum-like architecture

- MG cells receive corollary discharge from movement from granule cells at apical dendrites (this is like parallel fibers) and the connections are subject to synaptic modification.

- MG cells also gets sensory input at basal dendrites and inhibits the output layers

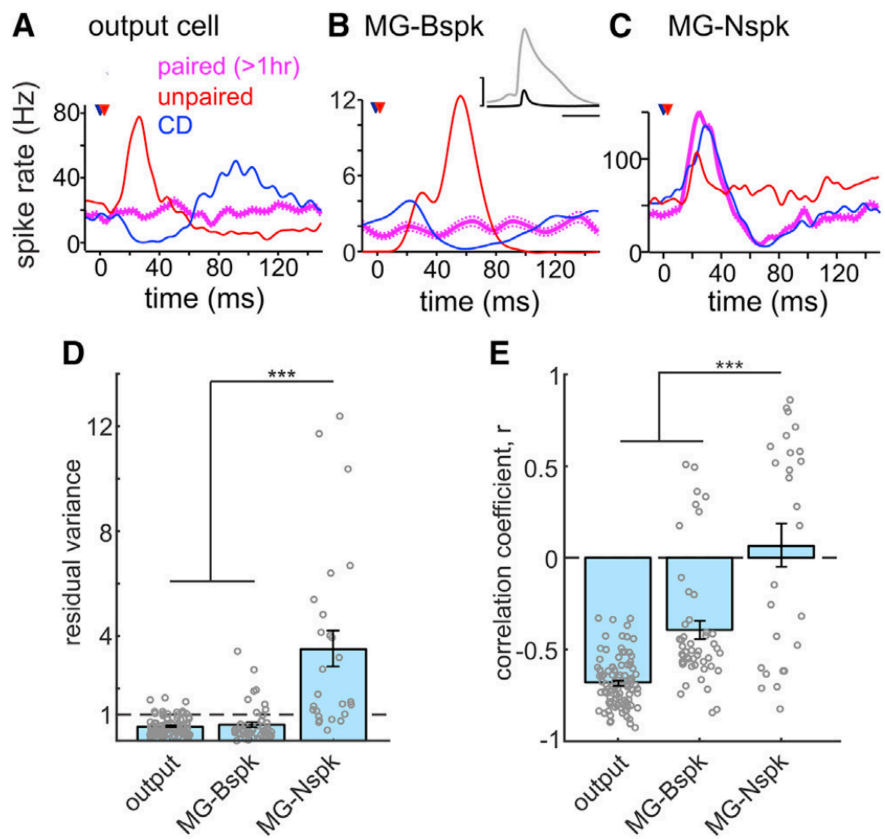
- MG cells fires narrow spikes (50Hz~) and broad spikes (2Hz~).



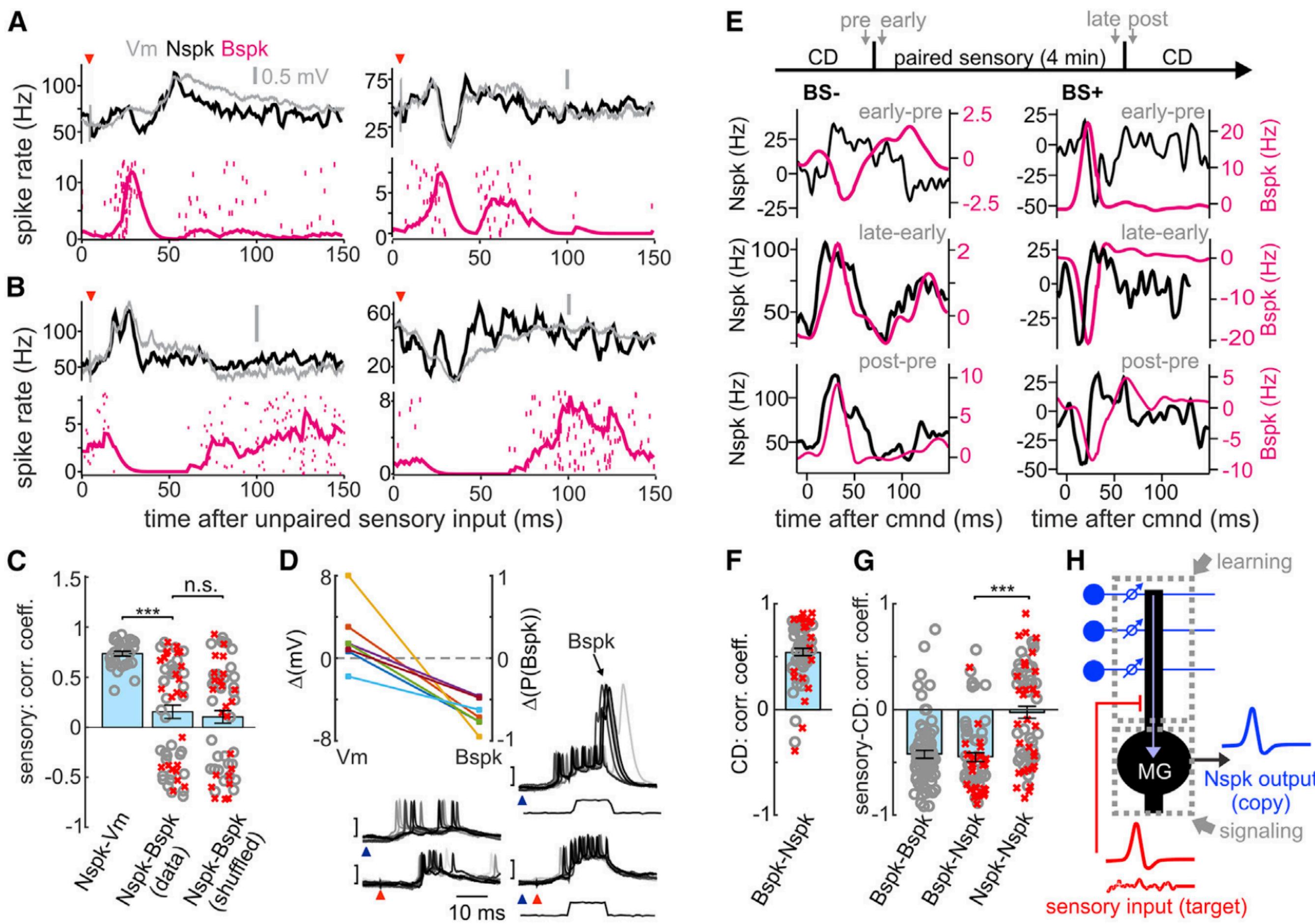


10 mV
5 ms
broad
spike
narrow
spike

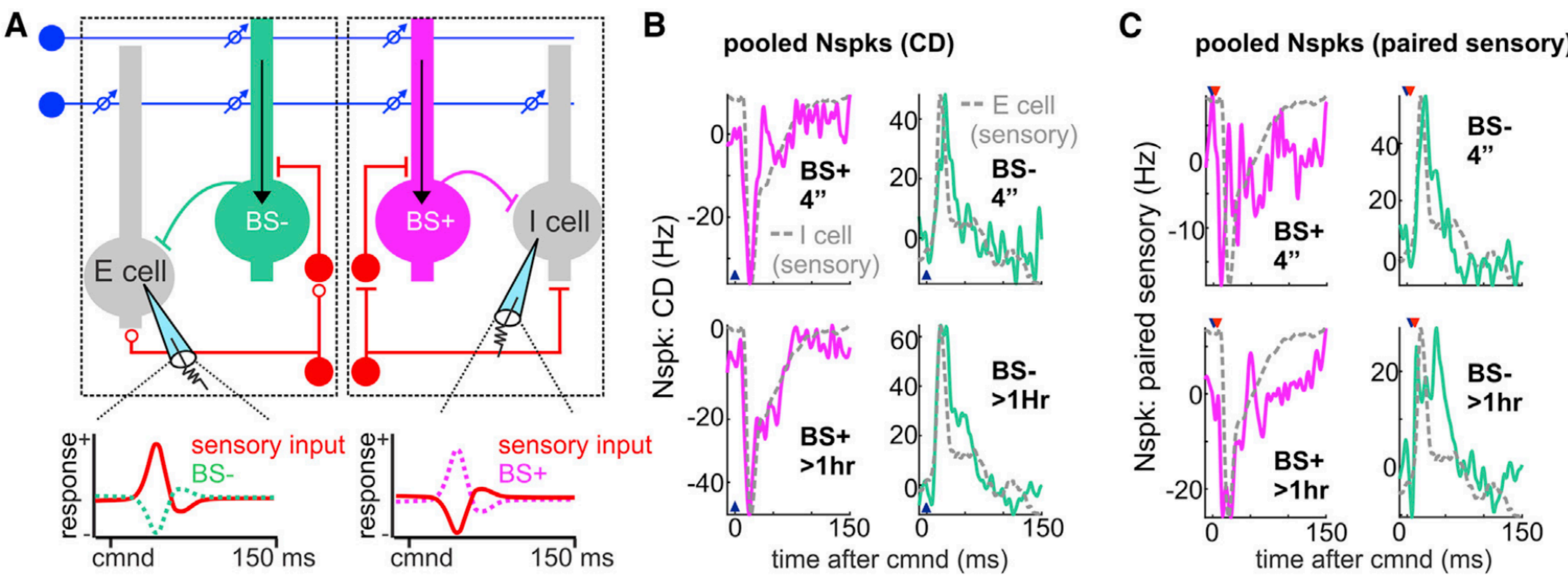
Broad spikes cancels while narrow spikes form negative image



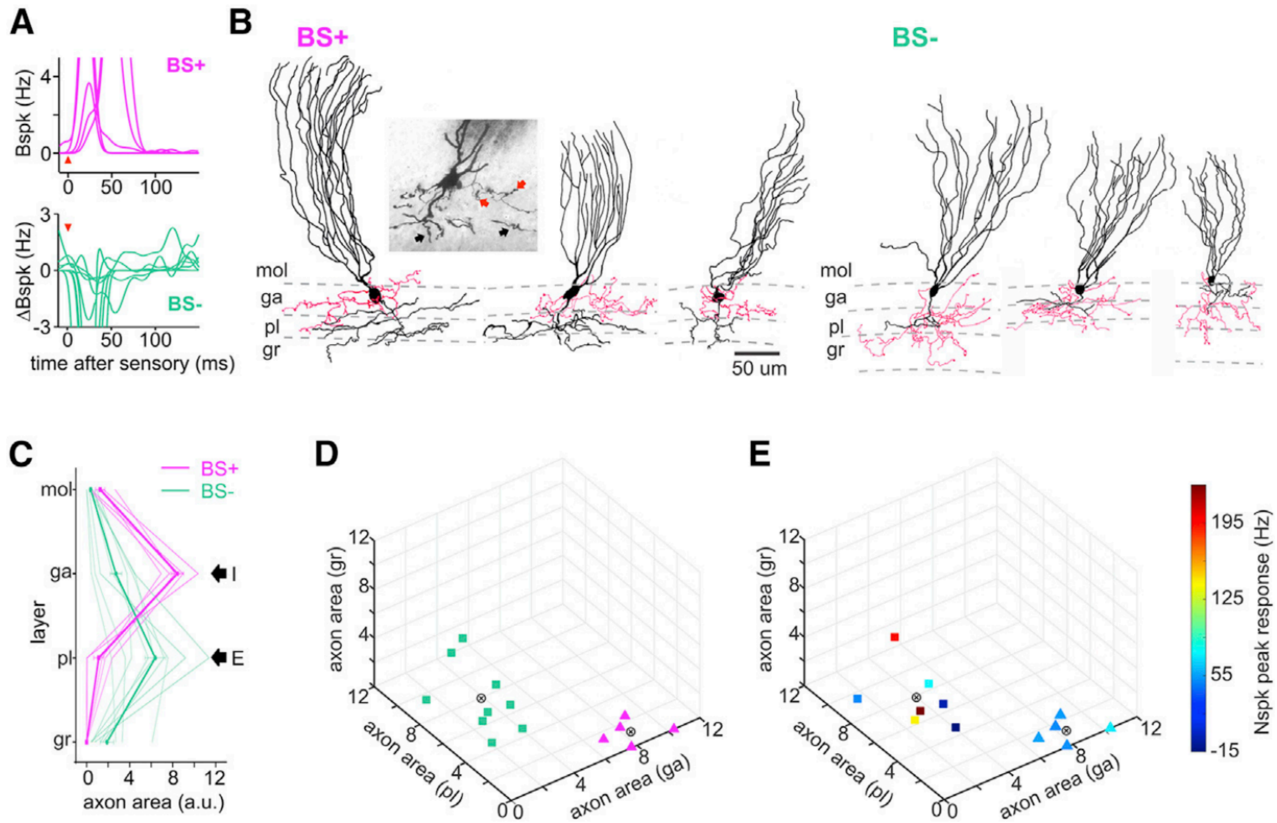
Differential effects on broad/narrow spikes



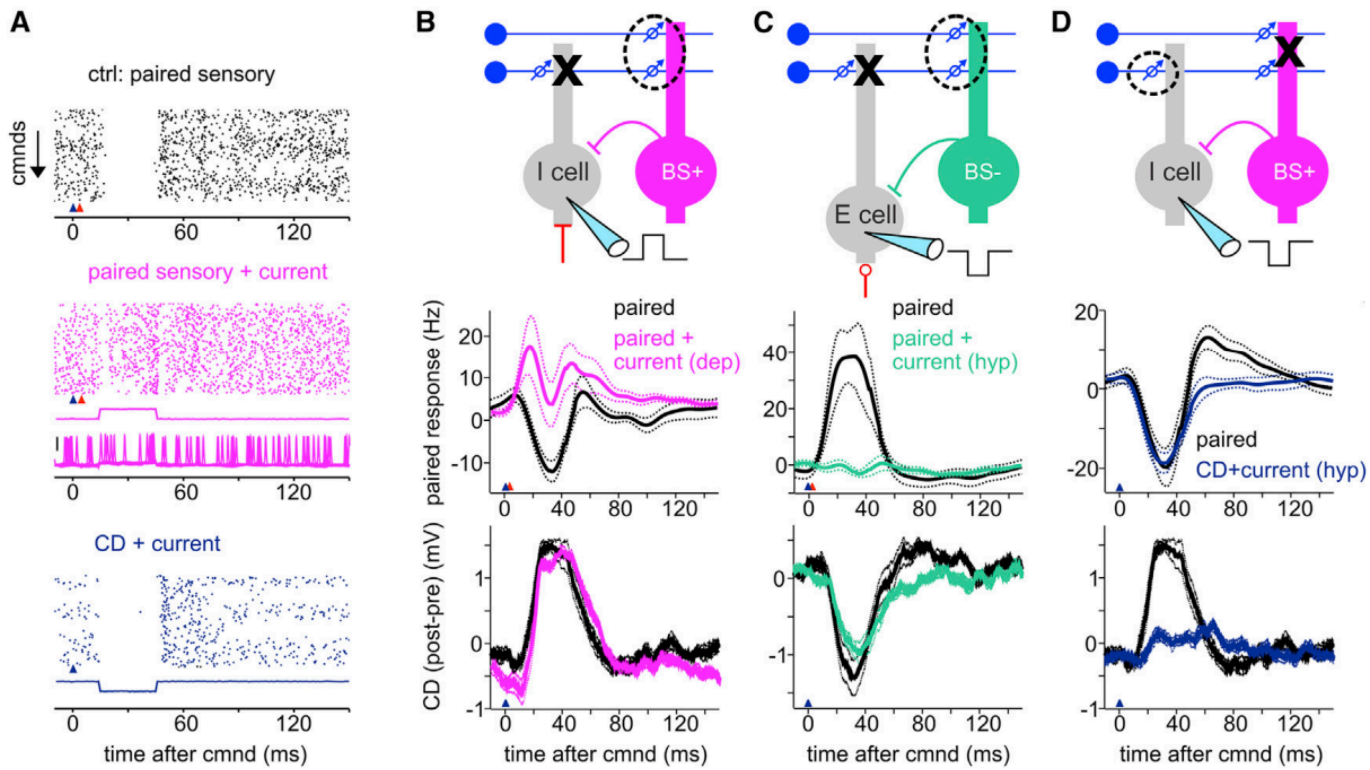
Broad spikes tuning leads to cell type grouping that predicts circuit function

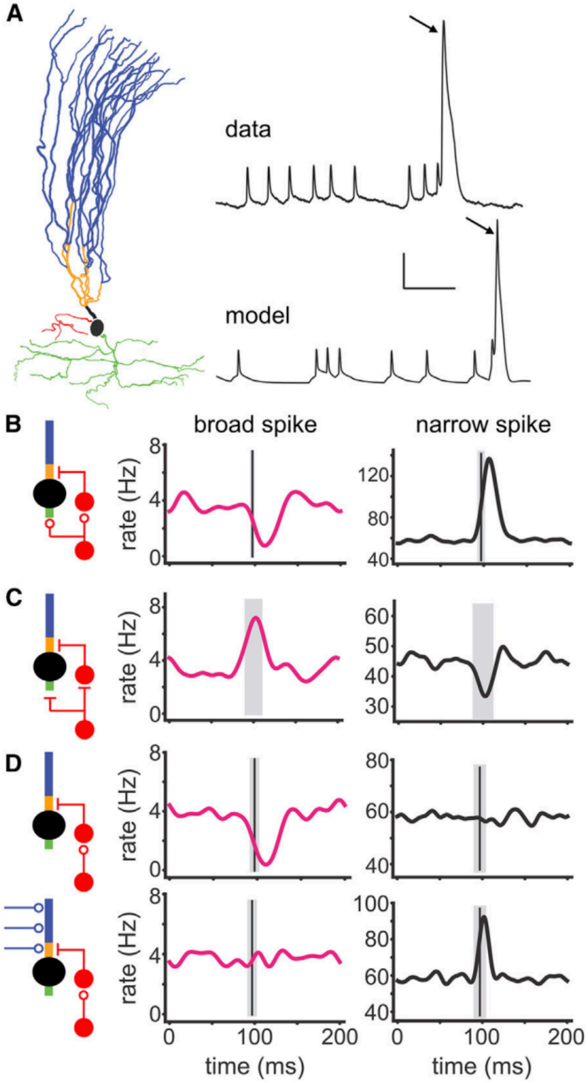


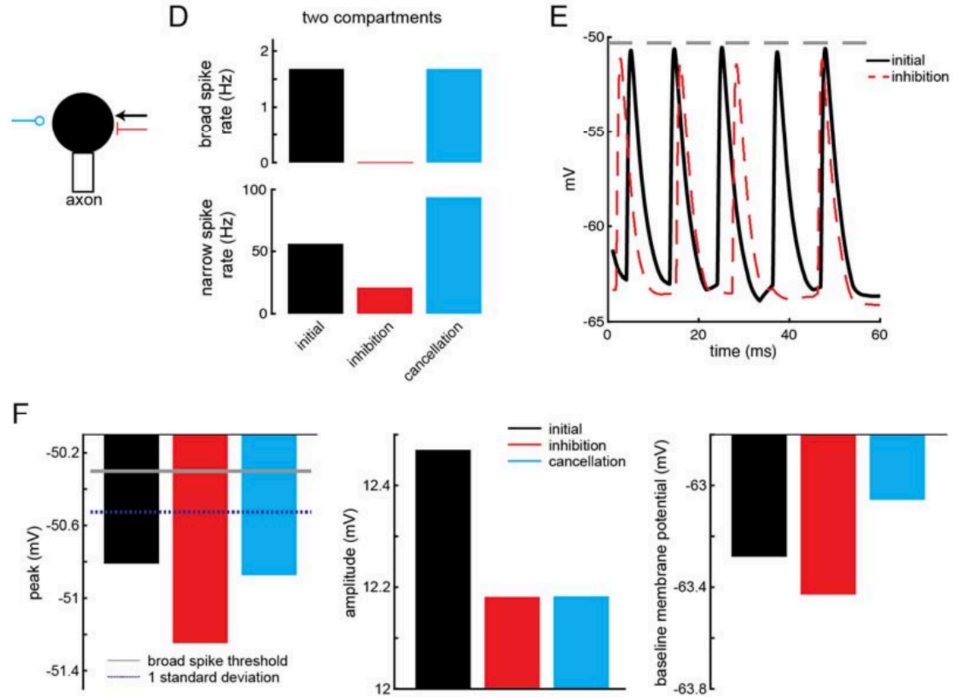
Anatomical evidence further affirm that broad spikes tuning categorize cell types



Majority of negative image happens at MG cells while output cell plasticity serves as cell-specific fine tuning



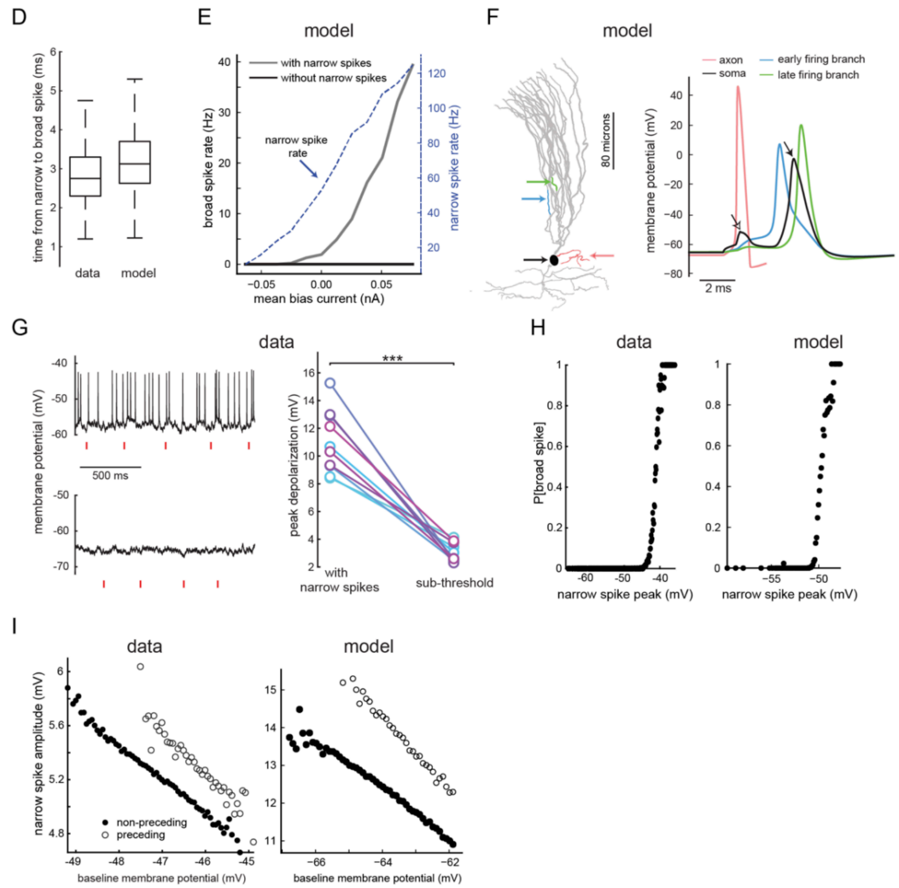


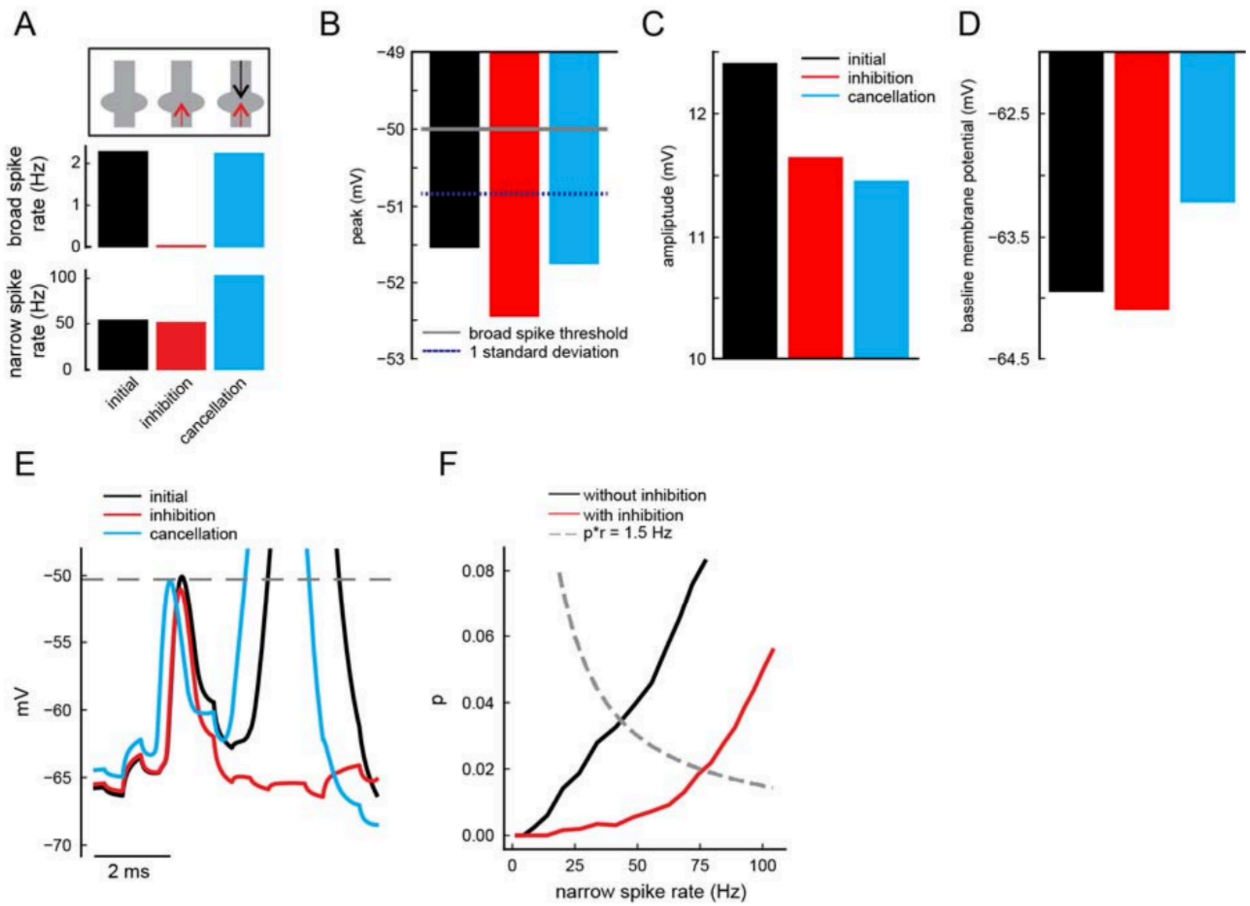


$$c_m \dot{v}_s = -g_l(v_s - E_l) - g_i(v_s - E_i) - g_e(v_s - E_e) - g_c\big(v_s - v_a(t)\big) + I_e$$

$$c_m \dot{v}_a = -g_l(v_a - E_l) - g_c(v_a - v_s(t))$$

Narrow spike backpropagates to generate the broad spikes





A
B
C
D
broad spike rate (Hz)
narrow spike rate (Hz)
initial
inhibition
cancellation
peak (mV)
broad spike threshold
1 standard deviation
ampliitude (mV)
baseline membrane potential (mV)
E
F
mV
2 ms
without inhibition
with inhibition
p*r = 1.5 Hz
p
narrow spike rate (Hz)

What is the mechanism?

- The basal dendrite sensory inhibitory inputs have reversal potential close to the threshold of narrow spikes so it does not influence narrow spike while broad spikes have higher threshold.

- Since the homeostatic plasticity changes the broad spikes to constant, narrow spike becomes the negative image.

- When narrow spikes become the negative image, the backpropagating potential is large enough to counter the sensory inhibition and thus causing broad spikes.