Dendritic voltage imaging maps biophysical basis of associative plasticity rules

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Neurons convert synaptic inputs arriving onto dendrites into action potentials that propagate outward along axons. Back-propagating action potentials (bAPs) also go from soma into dendrites and interact with synaptic inputs to strengthen or weaken individual synapses, a key process in learning and memory. However, our understanding of the molecular and biophysical mechanisms driving dendritic integration and synaptic plasticity remains limited. To bridge this gap, we developed molecular, optical, and computational tools for all-optical electrophysiology in dendrites. Our techniques have enabled us to map sub-millisecond voltage dynamics throughout the dendritic trees of CA1 pyramidal neurons in acute brain slices. In my talk, I will discuss our recent findings on history-dependent bAP propagation in distal dendrites, driven by locally generated Na^+ spikes (dSpikes). We observed that collisions of dSpikes with synaptic inputs can trigger N-methyl-D-aspartate receptor (NMDAR)-dependent plateau potentials, crucial elements in associative memory. These results, combined with numerical simulations, paint an intuitive picture connecting dendritic biophysics to associative plasticity rules.