MECHANISMS OF EXPERIENCE-DEPENDENT NEURONAL COMPUTATIONS

The fundamental function of individual neurons is to produce an axonal output by integrating excitatory and inhibitory synaptic inputs.

My research sheds light on how changes in this input-output-transformation impact behaviorally relevant brain functions, especially in the context of tasks that require learning. Thus, I have been studying the mouse hippocampal area CA1, as this region is known to be involved in spatial learning. I found that broadly tuned synaptic inhibition is essential for producing the spatially localized firing fields of CA1 place cells (‘place fields’). Inhibition selectively counteracts out-of-field synaptic excitation, thus suppressing the firing of action potentials outside of the neuron’s place field and preserving the sparseness of the spatial code in CA1.

Furthermore, I co-discovered a new kind of plasticity, called behavioral timescale synaptic plasticity (BTSP), which is driven by a specific type of dendritic spike, Ca2+ plateau potentials (‘plateaus’), and produces place fields in CA1 neurons. BTSP provides a neural mechanism for one-trial learning as a single plateau is sufficient to modify synaptic strength. My most recent results point towards a fundamental role of BTSP in allowing experiences to shape CA1 representations and, thus, identify plateaus as a key signal that instructs CA1 neurons in how to represent an environment.

Taken together, my research provides a mechanistic understanding of how synaptic integration and plasticity shape feature-selective responses of neurons, mediate the formation of experience-dependent representations, and enable neural circuit computations to drive adaptive behaviors.