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FROM SINGLE CELLS & SINGLE COLUMNS to CORTICAL NETWORKS

Coincidence detection and synaptic transmission in brain slices and brains

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ABSTRACT

Initially patch pipettes were designed to record elementary current events from muscle and neuron membrane (Sakmann, 1992). Recording configurations designated as whole-cell and cell-attached recording proved to be useful to examine signaling within and between nerve cells embedded in their (almost) natural environment. In this Paton Lecture I will summarize work on electrical signaling within a neuron, involving communication between its dendritic compartments, soma and nerve terminals via forward and backward propagating dendritic action potentials. The newly discovered dendritic excitability endows neurons with the capacity for coincidence detection of spatially separated subthreshold inputs occurring during a time window of tens of milliseconds and the occurrence of coincidences is broadcasted in the cell by the initiation of bursts of action potentials (AP bursts). The occurrence of bursts critically impacts signaling between neurons. It revealed target cell specific transmitter release mechanisms in different terminals of the same neuron and the induction of synaptic plasticity mechanisms when AP bursts occur both presynaptically in terminals and postsynaptically in dendrites, within a short time window.

A fundamental question that arises from these findings is: "What are possible functions of active dendritic excitability with respect to network dynamics in the intact cortex of behaving animals?"
For this purpose, I will highlight in this review the anatomical and functional architectures of an averaged cortical column in the vibrissal field of somatosensory cortex (vS1), followed by a summary of the role of layer 5 thick tufted pyramids cells (L5tt) in the functional architecture of these very same cortical columns. Synaptic and unit responses of these major cortical output neurons to a whisker deflection are compared with responses of afferent neurons in primary somatosensory thalamus and of one of their efferent targets, secondary somatosensory thalamus (POm). Coincidence detection mechanisms appear to be implemented *in vivo* as judged from the occurrence of AP bursts. Three dimensional reconstructions of anatomical inputs that could

provide separated dendritic inputs suggest that inputs from several combinations of thalamo-cortical projections and intracolumar connections could generate AP bursts. Finally, recordings from the columns´ target cells reveal the importance of AP burst patterns for signal transfer to these cells.

The observations lead to the hypothesis that in vS1 cortex the sensory afferent rate code is transformed, at least partially, to an interval code that broadcasts sensory stimuli to different targets of L5tt cells. In addition, the occurrence of pre- and postsynaptic AP bursts may, on the long run, alter sensory representation in cortex.