Generation of electrical signals in mammalian cortex and their function in decision making

Lecture
May, 7th
2.00 p.m Room B107
Povo 2
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While patch pipettes were initially designed to record elementary current events from muscle and neuronal membrane (e.g. Sakmann, 1992) the whole-cell and cell-attached recording configurations proved to be useful tools for examining signaling within and between nerve cells. In this lecture I will summarize first work on electrical signaling within single neurons, describing communication between its dendritic compartments, soma and nerve terminals via forward and backward propagating action potentials. The newly discovered dendritic excitability endows neurons with the capacity for coincidence detection of spatially separated subthreshold inputs. When these are occurring during a time window of tens of milliseconds this information is broadcasted to other cells by the initiation of bursts of action potentials (AP-bursts). The occurrence of AP bursts critically impacts signaling between neurons that are controlled by target cell specific transmitter release mechanisms at downstream synapses even in different terminals of the same neuron. This can in turn determine the induction of synaptic plasticity mechanisms if 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 the possible functions of active dendritic excitability with respect to network dynamics in the intact cortex of behaving?"

To answer this question I will highlight in this review the functional and anatomical architectures of an averaged cortical column in the vibrissal (whisker) field of somatosensory cortex (vS1), with an emphasis on the role of layer 5 thick tufted cells (L5tt) embedded in this structure. 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 (VPM) and of one of their efferent targets, the 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 separate dendritic inputs suggest that inputs from several combinations of thalamocortical projections and intra-columnar connections could trigger the dendritic mechanisms that lead to the generation of AP-bursts. Finally, recordings from target cells of a column reveal the importance of AP bursts for signal transfer to these cells.

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