Research Results of the BCF presented at the COSYNE conference 2013

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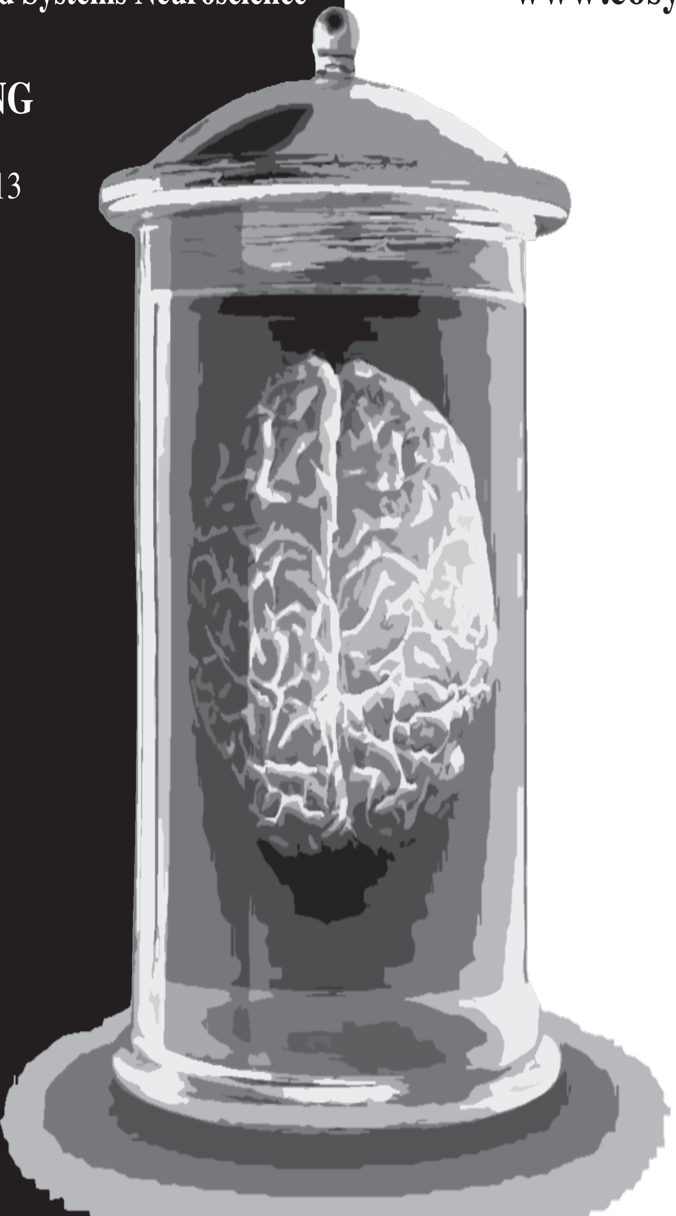

MAIN MEETING

Feb 28 - Mar 3, 2013
Salt Lake City, UT

(<1 Hz). These results are qualitatively similar in large-scale simulations of a network of excitatory and inhibitory neurons, operating at low rates. Our findings emphasise the role of synaptic bistability and of the extracellular calcium level for memory retention in cortical circuits in the presence of realistic background activity.

III-36. Dendritic subunits: the crucial role of input statistics and a lack of two-layer behavior

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Accumulating evidence suggests that dendritic trees play a crucial role in single-neuron information pro- cessing, yet there exists no simple, canonical formalization of dendritic computation. At one extreme, multi- compartmental models retain as much biophysical detail as possible, enabling them to exhibit the spatial and temporal dendritic nonlinearities observed in experiments, but sacrificing ease of fitting, mathematical tractabil- ity, and computational interpretability. At the opposite extreme, heuristic 'two-layer network' models [Poirazi et al., Neuron 2003, Polsky et al., Nat. Neuro. 2004], which assume that the somatic membrane potential is produced by passing the instantaneous synaptic inputs through a two-layer linear-nonlinear cascade, are easy to analyze mathematically and interpret computationally but were designed to work only with static inputs and out- puts, restricting their experimental application to artificial stimulus protocols involving brief, intense stimulation, rather than extended spike trains with realistic statistical properties. Moreover, because of this restriction, the associated metrics for judging nonlinear dendritic behavior were based only on either instantaneous firing rates or peaks/means of somatic membrane potentials, rather than predictiveness of dynamically changing firing rates or full membrane potential traces.

III-37. Physiology and impact of horizontal connections in rat neocortex

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Cortical information processing at the cellular level has predominantly been studied in networks with strong local connectivity, resulting in models displaying high noise correlations. However, recent studies suggest that the bulk of axons targeting pyramidal neurons most likely originate from outside the local volume. This opens interesting new possibilities to influence the input statistics of the neurons within the cortical network. For example, horizontal projections have been implicated to reduce noise correlations and improve the signal-to-noise ratio in reaction to external inputs. Unfortunately, no detailed data about physiology, numbers and spatial extent of horizontal connections is available to date. We, therefore, mapped the horizontal connectivity of L5B pyramidal neurons with photostimulation, identifying intact projections up to a lateral distance of 2mm. Our estimates of the spatial distribution of cells presynaptic to L5B pyramids support the idea that their majority is located outside the local volume. In addition, the synaptic physiology of distant horizontal connections does not differ markedly from that of local connections, while the layer and cell-type dependent pattern of innervation does. Implementing our data in a reduced model of a neocortical network shows that, indeed, the identified horizontal connections can promote robust asynchronous on-going activity states and reduce noise correlations in stimulus-induced activity and may,

thus, be a means for the neocortex to improve signal detection. More specifically, a new role for layer 6A emerges, since it provides a strong source of horizontal connections to L5B pyramids. In addition to its feedback projections to thalamus and its modulatory influence on the principal input layer of cortex (L4), L6A also seems to exert a strong influence on the principal output stage of cortical processing.

III-38. Gain-control via shunting-inhibition in a spiking-model of leech local-bend.

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It was originally theorized that shunting-inhibition could be playing a key role in gain-control by computing division. However, several studies have suggested that spiking dynamics interfere with the shunting mechanism and prevent divisive scaling. New hypotheses have emerged that suggest that division could be implemented via shunting-inhibition, but require synaptic noise. Other hypotheses suggest that non-shunting circuit mechanisms must be computing division. We describe implementations of both shunting and circuit-based neuronal gain-control in a model of leech local-bend. Much of the neural circuitry responsible for the local-bend behavior has been well worked-out, giving us a strong biological framework to test our hypotheses. The key experimental insight of the local-bend behavior is that the information necessary for the reflex is encoded by a population-code in the neural activity. Experimental work further shows that GABAergic inhibition has a divisive effect on neuronal responses. We describe the challenges of implementing division with a circuit mechanism, requiring overly complex and highly specific wiring to maintain the population-code. We derive a new implementation of shunting-inhibition as a mechanism for division in a multi-compartmental spiking neuron model. This mechanism enables us to implement gain-control without the need for noise, and build a complete spiking model of the local-bend behavior based on a population-code. We further explore the differences of feed-forward and feed-back inhibitory gain-control. This local-bend model has a direct correspondence to contrast-invariant orientation-selectivity as seen in V1 simple-cells and implicates soma-targeting inhibitory neurons as possibly controlling gain through this mechanism. This model is biologically plausible, computationally efficient, and, importantly, mathematically tractable. The model will allow for rate-coded theories of neural computation — especially those that depend on population codes or divisive normalization, to be translated into theories and simulations that include spiking dynamics.

III-39. Detecting and quantifying topographic order in neural maps

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Topographic maps are an often-encountered feature in the brains of many species. The degree and spatial scale of smooth topographic organisation in neural maps vary greatly, as do the sampling density and coverage of techniques used to measure maps. An objective method for quantifying topographic order would be valuable for evaluating differences between, e.g. experimental and control conditions, developmental stages, hemispheres, individuals or species; to date, no such method has been applied to experimentally-characterised maps. Neural maps are typically identified and described subjectively, but in cases where the scale of the map is close to the resolution limit of the measurement technique, just identifying the presence of a map can be a challenging sub-