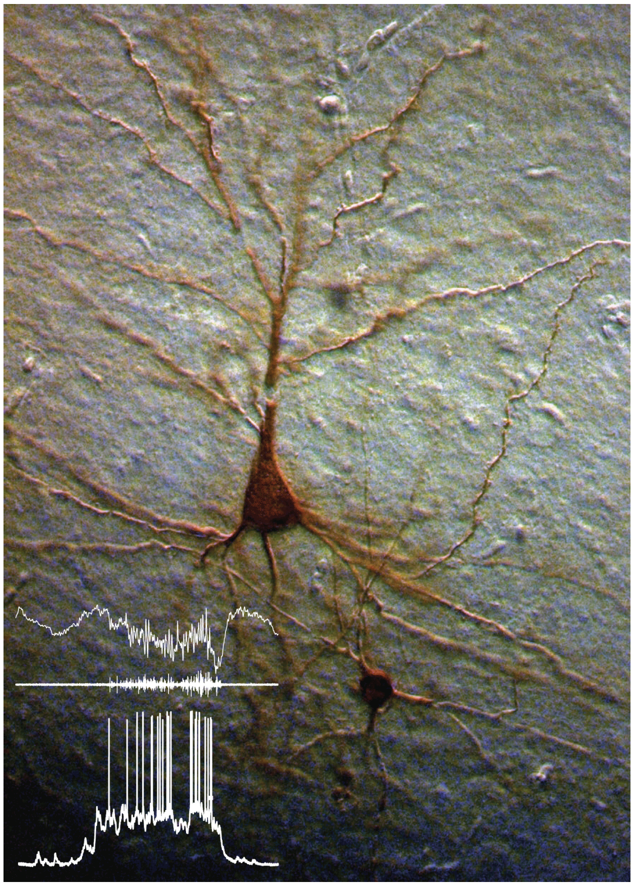
Cortical Dynamics are Controlled by Inhibition



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The cerebral cortex is a large sheet of massively interconnected neurons. The path that activity takes varies on a moment to moment basis, as determined by past experience, expectations, and context. The basic mechanism underlying the direction of this complex flow of neuronal activity is thought to be rapid gain control. Owing to its importance, we are investigating the mechanisms by which the neuronal activity and responsiveness may be rapidly modulated.

Intracellular recordings in vivo in naturally sleeping or anesthetized animals reveal the rhythmic recurrence of Up and Down states. During quiet waking, the membrane potential of cortical cells appears similar to that of a maintained Up state, with rapid variations around a steady level of depolarization. We examined here how changes in local neuronal network activity may influence the properties and responsiveness of cortical neurons, with the goal of obtaining clues on how gain modulation may occur during the wake, behaving state.

Our results indicate that recurrent networks in the cerebral cortex operate through a balance of re-entrant excitation and local inhibition. Rapid variations in this balance (e.g. excess excitation and withdrawal of inhibition) mediates rapid depolarizations and the initiation of action potentials. In the presence of this membrane potential variance, changes in the average membrane potential result in near multiplicative gain changes to sensory stimuli (e.g. visual stimuli of varying contrast). These changes in membrane potential can result either through the intracellular injection of current or spontaneously through variations in synaptic activity. The ability of changes in membrane potential to result in large multiplicative changes in neuronal gain indicates that the control of functional connectivity in the cortical sheet may occur through variations in membrane potential (as well as conductance and variance) mediated by rapid alterations in synaptic bombardment (as a consequence of variations in network activity).

Our results are consistent with the Hebbian view that cortical neurons interact in dynamically defined neuronal assembles, which are ever changing and evolving according to behavioral demands, past experience, and future goals. Rapid gain modulation is a major functional component to the operation of the cerebral cortex, giving it the flexibility it needs to perform complex computational tasks and behavior. Supported by NIH and the Kavli Foundation.

Host: Alison Barth, Ph.D.