OSCILLATIONS

Feel the rhythm

STOCKBYTE

> “…stimulating interneurons at 40 Hz had rhythmic inhibitory and permissive (or ‘gating’) effects on pyramidal neuron output.”

Gamma oscillations are thought to result from the synchronous spiking of interneurons and to enhance sensory processing and attention. Now, in two studies published in *Nature*, Deisseroth and colleagues provide direct evidence for this, showing that simultaneous activation of cortical interneurons can induce gamma oscillations and that this in turn affects sensory processing.

In the first study, the authors expressed the cation channel channelrhodopsin 2, which is activated by blue light, in parvalbumin-positive fast-spiking interneurons in the mouse barrel cortex. Stimulating fast-spiking interneurons with 1 ms blue light pulses at a 40 Hz frequency resulted in an amplification of the gamma band of the local field potential (LFP, a measure of synchronous local network activity), whereas stimulating them at lower frequencies did not alter LFP power. Thus, simultaneous, direct activation of fast-spiking interneurons at 40 Hz induced gamma oscillations.

In the second study Deisseroth and colleagues showed that, in mouse brain slices, using light to activate parvalbumin interneurons in a way that mimics feedback inhibition was able to elicit gamma oscillations in the spike trains of postsynaptic pyramidal cells. Conversely, light-driven inhibition of these interneurons suppressed LFP power in the gamma band *in vivo*.

Both papers also examined the functional relevance of gamma oscillations in the cortex. In the first paper the authors made single-cell *in vivo* recordings of pyramidal neurons in the barrel cortex. They showed that the magnitude and timing of the response of regular-spiking pyramidal neurons to a single whisker deflection depended on the phase of the (light-induced) gamma oscillation at which the stimulus occurred. Indeed, stimulating interneurons at 40 Hz had rhythmic inhibitory and permissive (or ‘gating’) effects on pyramidal neuron output. This indicated that gamma oscillations can synchronize the output of excitatory neurons.

In the second paper the authors investigated how indirectly induced gamma oscillations affect the output of pre- and infralimbic cortical pyramidal neurons to interneurons. First, pyramidal neurons were activated by injecting a range of simulated excitatory postsynaptic currents (sEPSCs) into the cells; this in turn drove interneurons, resulting in gamma oscillations. The subsequent output spike rate of the pyramidal neurons was then compared with the input sEPSC rate. The authors found that modulating input at gamma frequencies increased the gain and reduced noise in pyramidal neurons. Gamma-frequency modulation of pyramidal cell input also reduced noise in the responses of parvalbumin interneurons driven by pyramidal neurons, thus promoting signal transmission in the pyramidal neuron–interneuron circuit.

Together these studies demonstrate another application of using optogenetic manipulation to drive specific cells. This technique has provided direct evidence that network states characterized by gamma oscillations are induced by activation of fast-spiking interneurons, and that gamma oscillations improve information flow in cortical circuits. The findings might also explain how both abnormal gamma oscillations and altered sensory processing might contribute to disorders such as schizophrenia.

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ORIGINAL RESEARCH PAPERS Cardin, J. A. *et al.* Driving fast-spiking cells induces gamma rhythm and controls sensory responses. *Nature* Apr 26 2009 (doi:10.1038/nature08002) | Sohal, V. S. *et al.* Parvalbumin neurons and gamma rhythms enhance cortical circuit performance. *Nature* Apr 26 2009 (doi:10.1038/nature07991)
FURTHER READING Zhang, F. *et al.* Circuit-breakers: optical technologies for probing neural signals and systems. *Nature Rev. Neurosci.* **8**, 577–581 (2007)