COMPUTATIONAL NEUROSCIENCE

# Electric dreams

Sleep is characterized by slow oscillations in cortical activity that can be measured by electroencephalogram (EEG). These oscillations depend on interactions between the thalamus and cortex. To investigate these interactions and the switch from wakefulness to sleep, Hill and Tononi have produced a computer model of the thalamocortical circuitry that can switch between waking and sleep modes.

The large-scale computer model contains 65,400 spiking neurons with almost 5 million connections. The neuronal properties were based on physiological data from the cat thalamocortical system, including firing properties and intracellular channel dynamics, and the model includes areas of primary and secondary visual cortex and regions of the dorsal and reticular thalamus. The simulated cortex consists of three layers — supragranular (layers 2/3), layer 4 and infragranular (layers 5/6) — and intracortical and thalamocortical connections are reproduced in detail. Importantly, the model also includes neuromodulation, modelled as widespread changes in conductances.

During wakefulness, the cerebral cortex shows patterns of spontaneous activity that are reflected in the EEG as fast, low-voltage activity, and individual neurons fire spontaneously and irregularly. Hill and Tononi's model reproduces this state, including aspects of its response to visual stimulation (for example, the evoked response shows gamma synchronization). In addition, like the cortex, the model can switch into a slow-wave sleep state that includes a bimodal membrane potential distribution with a depolarized up-state, during which neurons fire more rapidly, and a hyperpolarized, silent down-state.

The authors use the model to explore the initiation of slow oscillations, and find that the transition from wakefulness to sleep can be generated by an increase in potassium leak current. Physiologically, this could correspond to the effects of a reduction in acetylcholine or other neuromodulators. Hill and Tononi also use the model to investigate which neuronal conductances are necessary for the maintenance and termination of the sleep state, and show that corticocortical connections are responsible for synchronizing the slow oscillation.

The model incorporates aspects of the thalamocortical system from channel properties to global patterns of activity, and as such should allow researchers to investigate many aspects of slow-wave activity. For example, what effect does this activity have on neural plasticity? Hypotheses developed using models such as this can be tested in physiological systems and the results of such tests used to refine and improve the models. In this way, theoretical and experimental neuroscience can be exploited together to generate a better understanding of neural systems.

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## References and links

**ORIGINAL RESEARCH PAPER** Hill, S. & Tononi, G. Modeling sleep and wakefulness in the thalamocortical system. *J. Neurophysiol.* 10 November 2004 (10.1152/jn.00915.2004)
**FURTHER READING** Hobson, J. A. & Pace-Schott, E. F. The cognitive neuroscience of sleep: neuronal systems, consciousness and learning. *Nature Rev. Neurosci.* **3**, 679–693 (2002)