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Department of Biomathematics Seminar Series:
Frontiers in Systems and Integrative Biology

Networks of Neurons Create Complex Dynamics: Statistical Physics and a Simple Model for the Control of Breathing

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ABSTRACT:

"Cogito ergo sum." There is a long history of physical scientists thinking about thinking, going back at least as far as Rene Descrates' famous pronouncement. Much more recently, a combination of neuroscientists and physicists realized that it is possible to explore the dynamics of interacting neurons using ideas borrowed from nonlinear dynamical systems and statistical mechanics. In particular the nervous systems contains many reasonably small collections of neurons that collectively generate well-defined pattern of electrical activity, which continue even when those collections of cells are removed from the animal. These functional groups of neurons are now termed central pattern generators. While understanding such restricted systems does not necessarily elucidate such sublime questions as those regarding the nature of consciousness, these studies do provide an intriguing example of a novel application of statistical mechanics to biology. They also admit quantitative comparisons to experiment!

In this talk I present a minimal model for one such central pattern generator based on the interaction of nonlinear dynamical systems interacting on a quenched random network. No neuroscience background will be assumed and, fortunately, very little will be required for exploring how a simple model of coupled excitatory neurons can produce collective and metronomic bursts of activity that controls the breathing rhythm in mammals. I will focus on how topological properties of the random network of neuronal connections controls the collective dynamical phase diagram of the system. I will conclude with some new extensions of this work to the building of similarly simple models of the global and rhythmic dynamics of the neocortex, the seat of consciousness and the paragon of complexity that produced "Cogito ergo sum."

Host: Tom Chou, Ph.D.

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