- **Statistical and Nonlinear Physics of the Brain (E, Shew)**

Discovering the principles governing how the brain works is among the most exciting and challenging endeavors of modern science. This excitement is very attractive to undergraduate students as evidenced by the involvement of several undergraduates in our lab already. We are interested in how brain's marvelous abilities - computation, perception, turning thought into action - emerge from dynamic interactions among large networks of neurons. Understanding the collective behavior of large networks of neurons is a challenge ideally suited to statistical physics. Indeed, many ideas from statistical physics have direct analogs in real living neural networks. For example, a neural network can undergo a phase transition [73]. Recent experiments show that brain networks seem to regulate themselves such that they operate in a dynamic regime close to a phase transition [74-77]. And importantly, by operating near the phase transition, the network may optimize its ability to process information [76-79]. These phenomena and other work done in Shew lab lie at the exciting interface between physics and neuroscience, where new physics and new neuroscience are evolving together. Below, two projects that would benefit from contributions of undergraduate researchers are described.

Project 1. One of the current goals of the lab is to experimentally test predictions from statistical physics in real living neural networks, focusing on those that have implications for brain function. More specifically, we study how sensory dynamic range is optimized in the whisker system in rats [79-80]. Previous involvement of two undergraduate students has led to a new device for measuring whisker motion with unprecedented precision (Fig. 4 and ref [81]). Undergrads would also be well suited to analyzing data from these experiments.

Project 2. A second major research direction in our lab is to better understand how spontaneous, natural body movement is governed by neurons in motor cortex. And, importantly, we also seek to understand what goes wrong with this system in brain disorders that manifest with abnormal body movements, like autism, or motor dysfunction, like stroke. One way that undergrads can get involved with this research is recording and analyzing body movement data. We record rat body movements with high temporal and spatial resolution in three-dimensions using a multi-camera motion tracking system. Analyzing the data to identify motifs and fundamental components of body movements is one of the initial steps that an undergrad could help with.

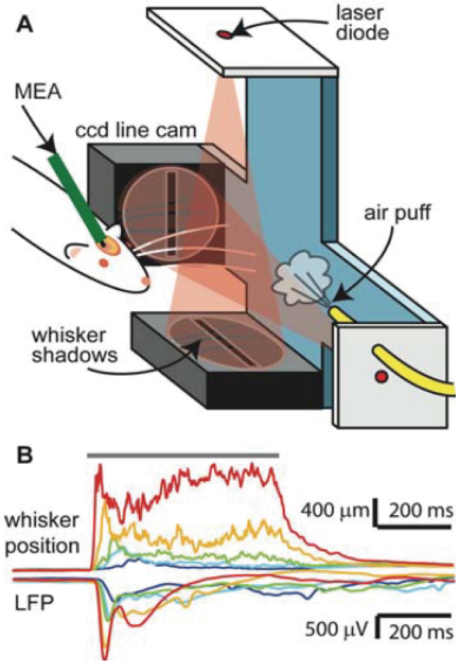

Fig. 4: Neural response (LFP) to whisker simulation

Skills and experience to be gained. In both these projects, the students will gain valuable expertise working in a research team and analyzing high-dimensional data using Matlab or similar technical computing software. These skills are in high demand for "big data" jobs across many industry and other private sector jobs.