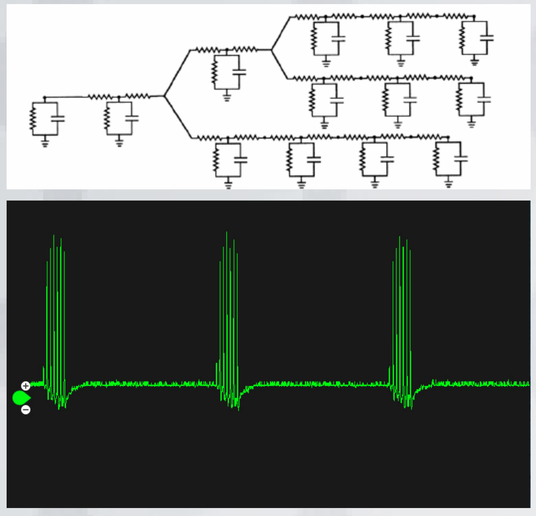
Virtual Neurophysiology Workbench

Alberto Fuentes, Christopher R. Butson PhD
Department of Bioengineering, Scientific Computing & Imaging (SCI) Institute

Can we use active learning tools to accelerate neuroscience education and brain research?

Computational Model Neurons

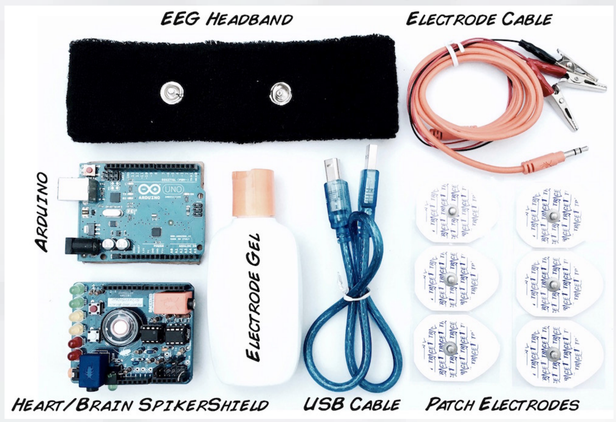


+

Gelatin Brain

+

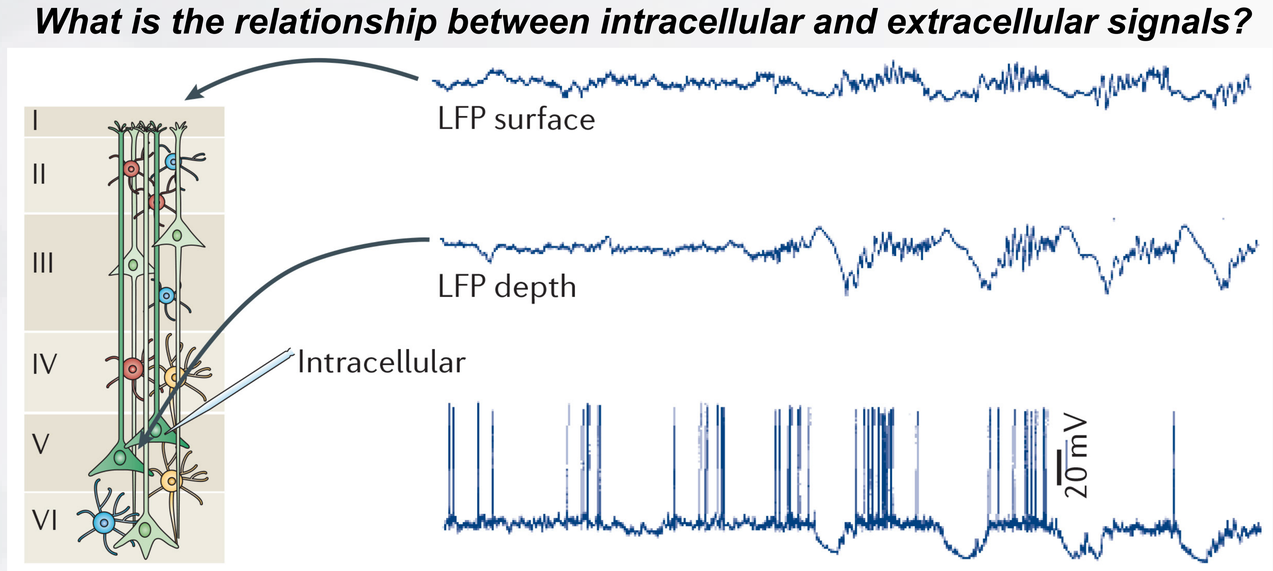
Low-Cost Recording System



= ***Virtual Neurophysiology Workbench***

Neurophysiology
Neurophysiology is a branch of physiology and neuroscience that studies how the nervous system functions. The primary tools of neurophysioloy research include electrophysiological recordings such as patch clamp, voltage clamp, extracellular single-unit recording and recording of local field potentials (LFPs). One of the goals of neurophysiology is to make inferences about intracellular activity from extracellular signals. Hence, one purpose of neurophysiology education is to enable students to learn the relationships between these signals. This is traditionally done using *in vivo* or *in vitro* experiments that require extensive training and skill, as well as expensive and specialized equipment (these equipment racks can cost over $100,000 each).

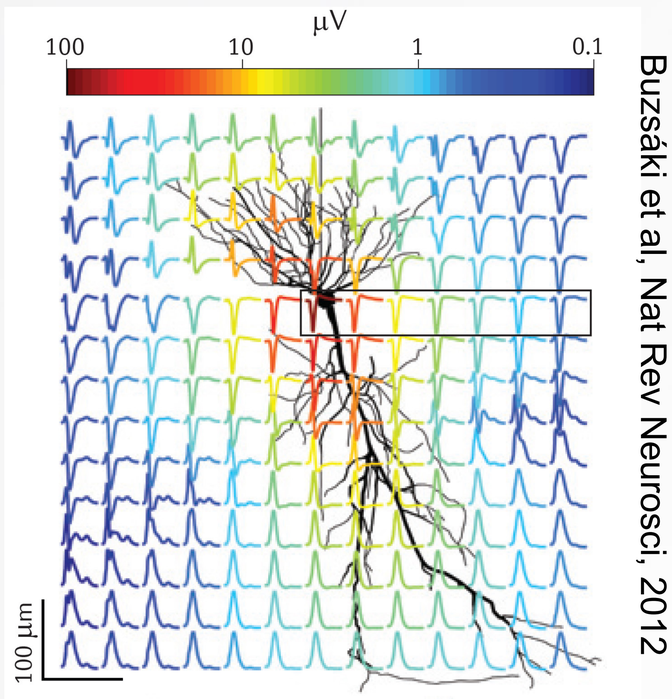
What is the relationship between intracellular and extracellular signals?



Novel Educational Approach
We have developed an alternative educational approach in which students can manipulate *in silico* neurons whose activity is measured using low cost recording systems such as the SpikerShield made by Backyard Brains, https://backyardbrains.com. Three advantages of this approach are:
1. There are many highly realistic computational models of neurons that are publicly available through websites such as ModelDB (https://senselab.med.yale.edu/modeldb)
2. Model neurons allow precise manipulation of biophysical properties, ion channels and cell morphology.
3. Simulation programs such as Neuron (https://www.neuron.yale.edu/neuron) allows virtually infinite instrumentation, whereas the number of type of measurements that can be made *in vivo* or *in vitro* is extremely limited.

How is the shape of the extracellular signal affected by the position of the recording electrode relative to the neuron?

How sensitive are extracellular recordings to changes in the properties of membrane ion channels?



Buzsáki et al, Nat Rev Neurosci, 2012

Key Components of the Virtual Neurophysiology Workbench
- Computational model neurons that accurately mimic neural activity. These can be synaptically connected or isolated neurons, and can reproduce a wide range of activity (action potentials, graded potentials, constant firing rates, bursting, etc). The compartmental transmembrane currents from these neurons are saved as audio files.
- A smartphone or laptop is used to play these audio files through modified headphone wires (the ear buds have been removed). These are meant to mimic neural sources.
- The wires are positioned in a conductive medium (in this case a human brain mold made from agar) to mimic the position of the neurons.
- A low-cost, portable recording system is used to record signals from surface electrodes or microelectrodes.

Conclusions
The Virtual Neurophysiology Workbench is a new direction in neurophysiology education. Using funds from a recent teaching grant we have developed experiments for two courses during the Fall 2016 semester: BIOEN 6440 Neural Engineering & BIOEN 6003 Cellular Biophysics & Electrophysiology. These experiments will be posted to our website to encourage others to try them and develop new ones. http://www.virtualneurophysiology.org/

Acknowledgements *University of Utah Teaching Grant, "Virtual Neurophysiology Workbench"*
Principal Investigator: Christopher R. Butson PhD