# Neurophysiology and Computational Neuroscience
# Neurosci 613 Fall 2020
# Computer Lab 2

1. In the Neurons in Action tutorial "Na Action Potential", estimate the duration of the relative refractory period following an action potential. Follow the suggestions in the tutorial for adding a second IClamp applied current pulse of the same duration (0.15 ms) and amplitude (0.2 nA) as the first IClamp current pulse. Set the delay for the first pulse to 0 ms and vary the delay of the second pulse. Identify the time interval following an action potential where the second current pulse is not able to induce a second action potential (relative refractory period). Provide plots to support your answers.

For problems 2-4, use the following Matlab codes to numerically simulate the Hodgkin-Huxley model under current clamp protocols:

- run_HH.m: this script sets the parameters for the simulation, calls the Matlab function to compute the numerical simulation and analyzes/plots the output
- HHEquations.m: this function contains the equations for the Hodgkin-Huxley model and is called by run_HH.m

2. Numerically compute the frequency-current (f-I) relation for the Hodgkin-Huxley model for applied current density values $I_{app}$ between [0, 60] $\mu A/cm^2$. Run simulations for at least 1 sec and compute frequency in Hz from interspike interval times. Compute frequency for enough $I_{app}$ values so that the curve is smooth.
   a. A f-I relation is continuous if firing frequencies at firing threshold are arbitrarily low. The frequency-current relation for the Hodgkin-Huxley model is not continuous. To verify this, for $I_{app}$ values near firing threshold, run simulations taking small steps in $I_{app}$ to compute the firing threshold current to 1 decimal place. What is the frequency at firing threshold?
   b. The Hodgkin-Huxley model exhibits subthreshold oscillations at current values near firing threshold. Approximate the frequency of subthreshold oscillations for $I_{app}$ values just below firing threshold. How does this frequency compare to action potential firing frequency at firing threshold? Give an explanation for the difference between frequencies of action potential firing and subthreshold oscillations near firing threshold.
3. In the Hodgkin-Huxley model, what happens to action potential firing for applied current densities above 60 $\mu A/cm^2$? At what applied current density does the phenomenon known as "depolarization block" (when the membrane is too depolarized to support any sustained spiking or any oscillatory activity) occur? Provide plots to illustrate your results.
4. Consider the effect on action potential firing in the Hodgkin-Huxley model of shifting the activation of the $K^+$ delayed rectifier current to slightly depolarized levels. In the matlab code HHEquations.m, this is achieved by changing the following parameter values in the functions alphan and betan: anv = 53 and bnv = 63.
   a. Make a prediction about what depolarizing the activation of the $K^+$ delayed rectifier current will do to the current threshold for firing and the f-I curve.
   b. Numerically determine the current threshold for firing to 1 decimal place and compute the f-I curve as in problem #1
   c. Describe and explain the changes in firing behavior you observe. Provide plots to support your explanations.