Intracellular Recording
Voltage Clamp
Refractory period

Lab 3 Results
due tomorrow
Lab 2 final Friday by 11:59 PM
Save the date:
Weds, Friday (Feb 25/27)
BME lab exercise

Intracellular potentials
Action Potentials
Synaptic Potentials
Receptor Potentials
MRO stretch in TTX

Motor Network Example
Extracellular
Intracellular

Intracellular microelectrode filled with 3M KCl

Much more information in intracellular recording
Comparison of needle tips

Intracellular microelectrode filled with 3M KCl (conducting fluid)

How do we get KCl to the tip?

Replacing air with KCl in electrodes

Intracellular microelectrode

Properties 1:
Electrode resistance (10 to 30 Mohms with 3M KCl)
**RC response of electrode to current injection**

![Diagram of RC response]

**Properties 2:**
Electrode Capacitance

**Electrode capacitance**

**How do we get biological signal to electronics?**

- **Extracellular capacitative charge transfer**
- **Intracellular direct charge transfer**
- **DC charge transfer on electrode wire**

![Diagram of charge transfer]

**Current injection into cells**

![Diagram of current injection]
Problems analyzing conductances underlying AP?

Current across membrane - Race for the Prize
Nobel Prize Goal: understand the ionic conductances at each stage of the AP

\[ I_m = I_{Rm} + I_{Cm} \]

Introduction to Voltage Clamp:
Current across membrane
Goal to understand the ionic conductances at each stage of the AP

\[ I_m = I_{Rm} + I_{Cm} \]

Ohm’s law for V-Clamp

\[ I_{ion} = \frac{E_m - E_{ion}}{R_m} \]

constant clamped, constant...calculated from neuron

Ionic driving force

How was this practically done?
Fast thermostat-like feedback
Ionic driving force

\[ V_{ion} = \frac{C_m}{R_m} + \frac{C_{in}}{R_{in}} \]

Current across membrane with hyperpolarizations
\[ I_m = I_{K} + I_{Na} \]

Ion carrying this ohmic current?

Current across membrane with strong depolarizations
\[ I_{Na} \]
\[ I_{K} \]

Measure \( I_m \) for current flow with larger depolarizations

Allowed Hodgkin and Huxley to describe currents underlying the Action Potential.