Week 8 Review

What was covered:

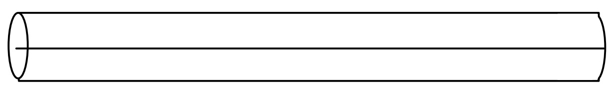
- Space clamp
- Current clamp
- Voltage clamp
- Hodgkin-Huxley Model

Review of last week:

Electrically small cell vs. electrically small cell
Graded potential vs. Action potential
Decrement conduction vs. Decrement-free conduction

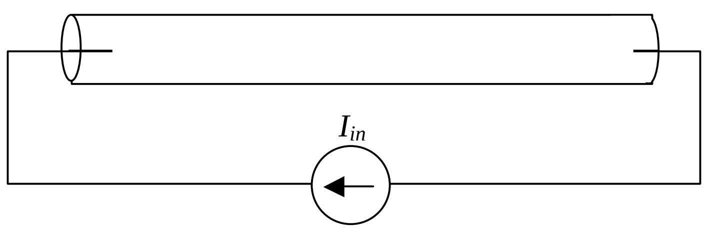
Space Clamp:

How to transform an electrically large cell into an electrically small cell?



Remember the core conductor model?
In an electrically small cell, the potential is everywhere (in space) the same. In a way this is the same as saying that the conduction velocity is infinite.
Conduction velocity is inversely proportional to the internal and external resistance, ri and ro. In most experiments, ro is very small (sea water). Therefore, if you make ri very small (by inserting a highly conducting wire into the cell), you can make the conduction velocity very very large (i.e. basically infinite on the length scale of the cell and the time scale of the experiment)

Current Clamp:

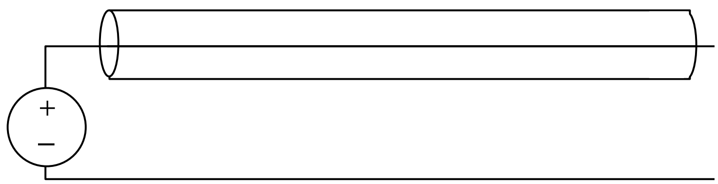


We can control the current across the membrane.
Therefore, we can stimulate with a current pulse and determine if the cell generates an ACTION POTENTIAL.
What did we learn from current clamp:

1. threshold
2. refractory
3. accommodation
4. all the other properties of AP

Voltage Clamp:

Try to understand how cell generates an action potential by control potential across the membrane.

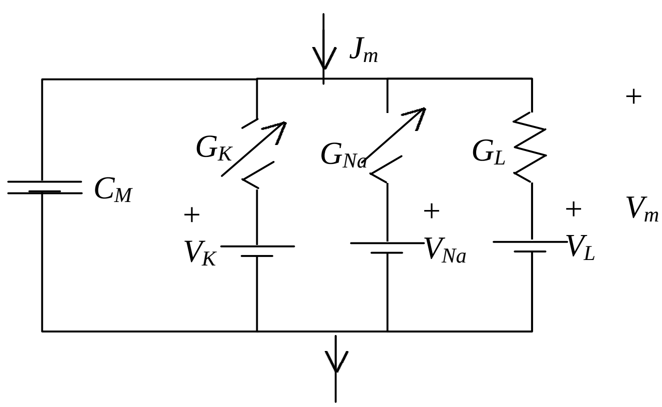


However, since you are controlling the membrane potential: there are **NO ACTION POTENTIALS** generated in voltage clamp.
But useful because we can study the current flow through membrane (Jm = Jc +Jion = Jc + Jna+Jk+J_L): So what did we learn from voltage clamp:

1. Assume G_L is ~constant.
2. initial current transient to Vm step is Jna (m has the fastest time constant)
3. direction of current flow depends on the “drive” (Vm-Vna)
4. after sometime inactivation (h) starts and Gna goes down → Jna goes down
5. at rest, Jk has the biggest effect (Gk is much bigger than others)

Hodgkin-Huxley Model:

Using what was learned from the voltage clamp, we get the HH model:



Potassium and Sodium conductance depend on the membrane voltage. Vk and Vna do not change with an AP since very little ions are actually transported…

$$J_m = C_m \frac{\partial V_m}{\partial t} + G_K(V_m,t)(V_m - V_K) + G_{Na}(V_m,t)(V_m - V_{Na}) + G_L(V_m - V_L)$$

And now we can fill in the black box in the Core Conductor with Hodgkin-Huxley models:

$$\frac{1}{2pa(r_i + r_o)v^2}\frac{\partial^2 V_m}{\partial t^2} = C_m \frac{\partial V_m}{\partial t} + G_K(V_m,t)(V_m - V_K) + G_{Na}(V_m,t)(V_m - V_{Na}) + G_L(V_m - V_L)$$

So how do the conductances (Gna and Gk), depend on Vm?

$G_K(V_m,t) = \overline{G}_K n^4(V_m,t)$

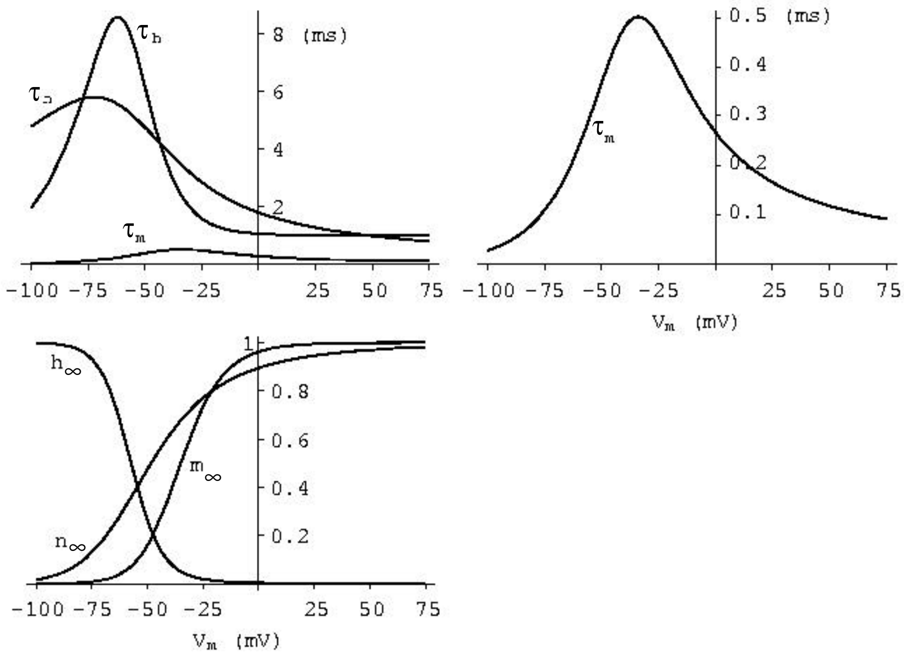
where $\overline{G}_K$ is a constant and only *n* depends on time and Vm.

$G_{Na}(V_m,t) = \overline{G}_{Na} m^3(V_m,t) h(V_m,t)$

where $\overline{G}_{Na}$ is a constant and *m* and *h* depends on time and Vm.

If Vm is kept constant (like in voltage clamp), n, m, and h are just exponential functions of time. Their final value and their time constants depend only on Vm.

n and m go up with Vm and h goes down with Vm. n has a much faster time constant.



$$n(V_m,t) + t_n(V_m)\frac{\partial n(V_m,t)}{\partial t} = n_\infty(V_m)$$

$$m(V_m,t) + t_m(V_m)\frac{\partial m(V_m,t)}{\partial t} = m_\infty(V_m)$$

$$h(V_m,t) + t_h(V_m)\frac{\partial h(V_m,t)}{\partial t} = h_\infty(V_m)$$