Biophysics I (BPHS 4080)

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Website: http://www.yorku.ca/cberge/4080W2018.html

York University
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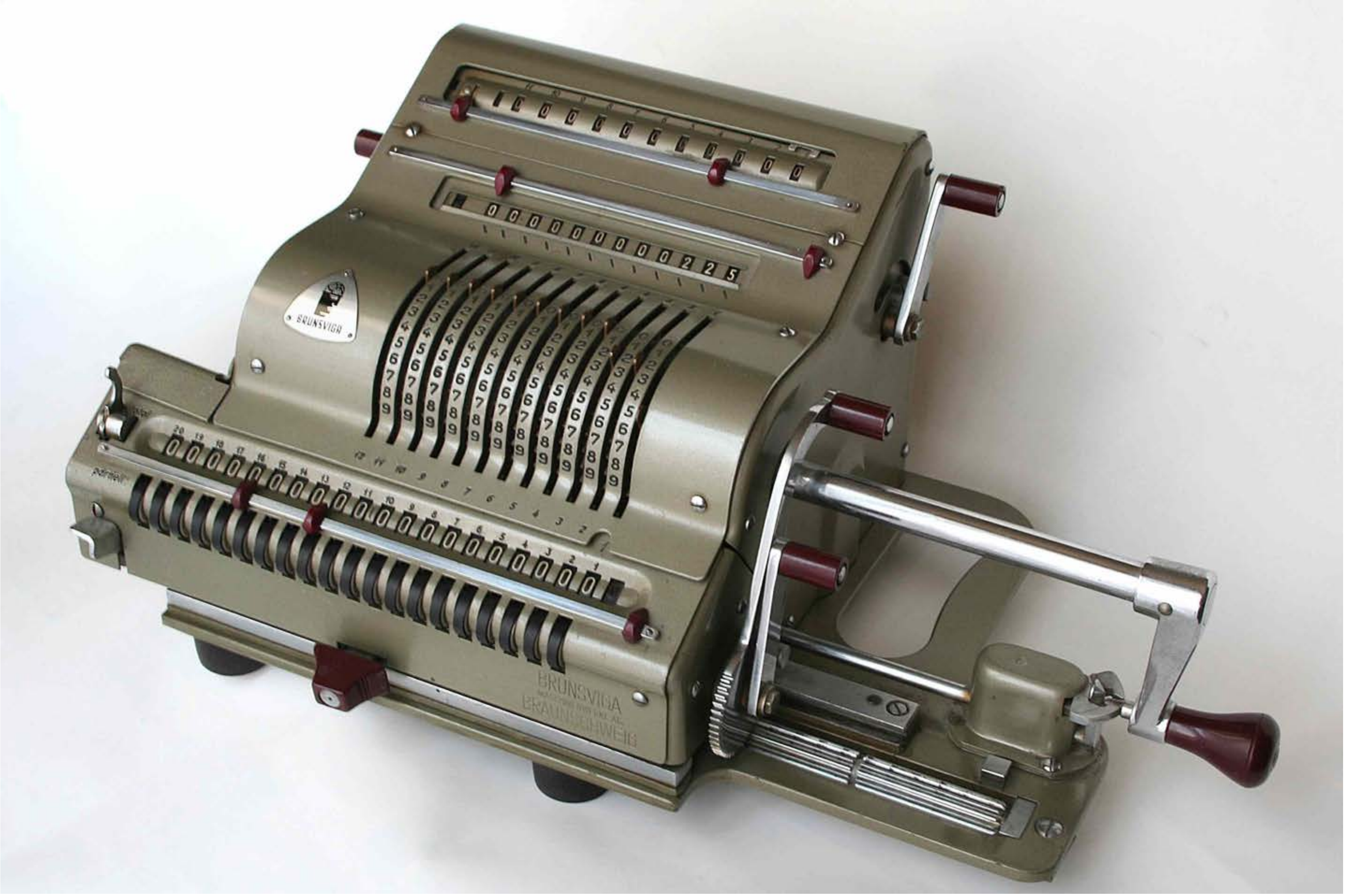
Lecture 22

Reference/Acknowledgement:
- TF Weiss (Cellular Biophysics)
- D Freeman



https://de.wikipedia.org/wiki/Brunsviga_Maschinenwerke

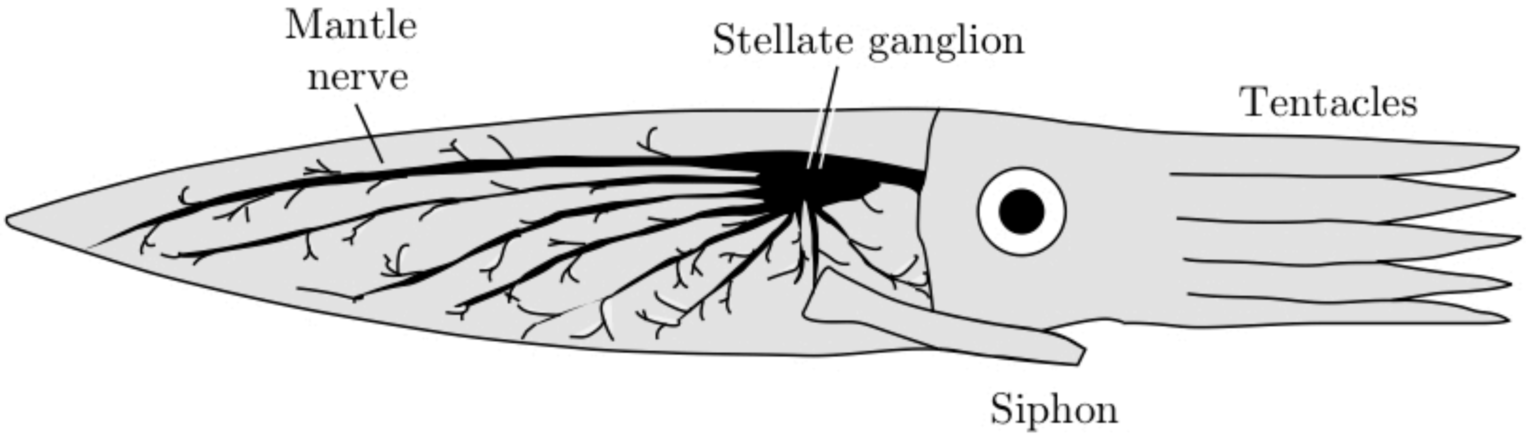


Figure 1.28

Some key observations...

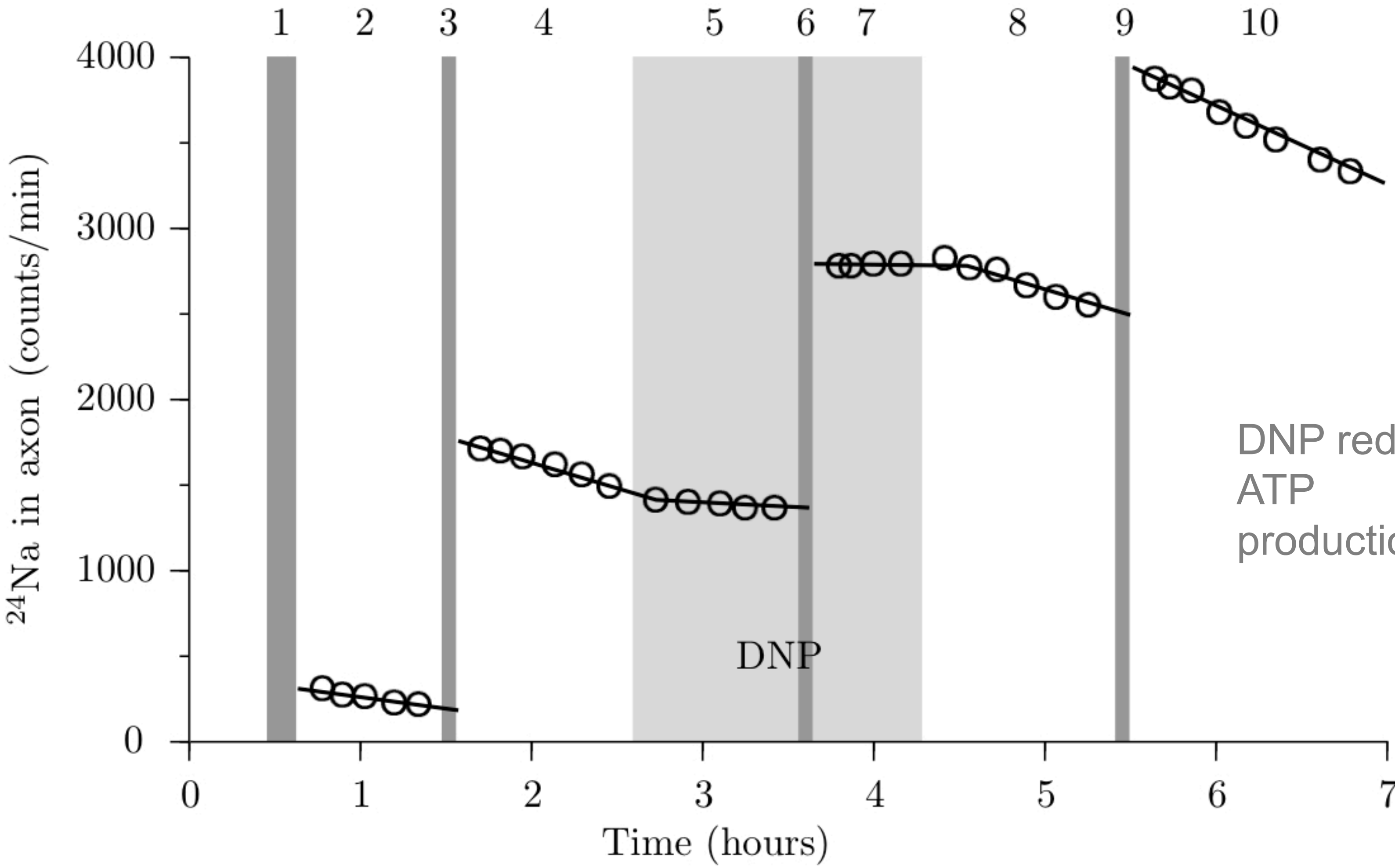


Figure 7.38

DNP reduces ATP production

Interrelationships between:
Na$^+$ flux, 'active' transport, & action potentials

→ Active transport not a priori required for AP generation

Some key observations...

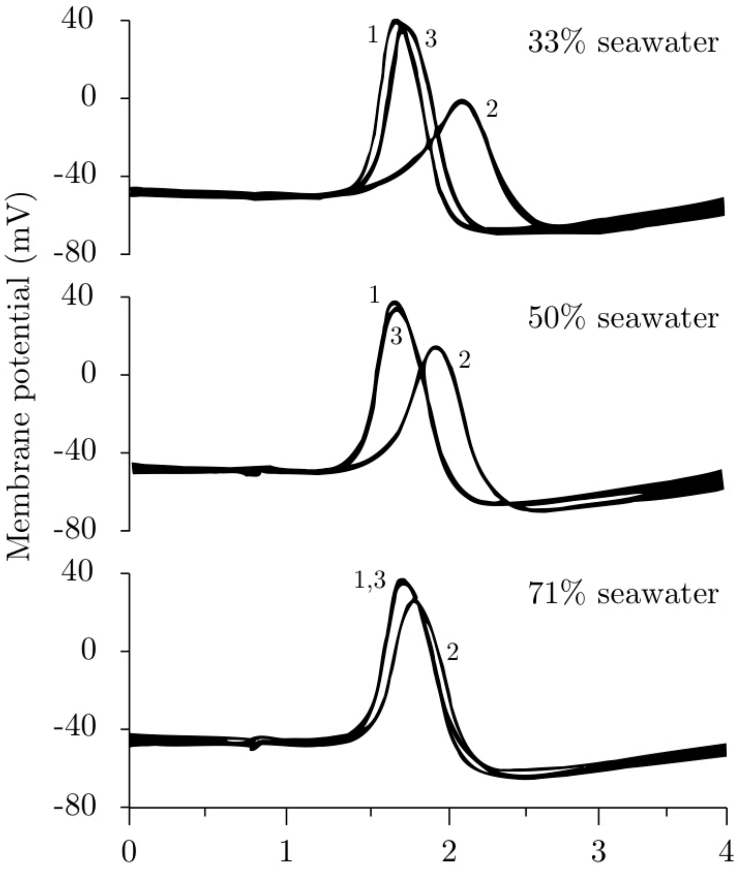


Figure 4.2

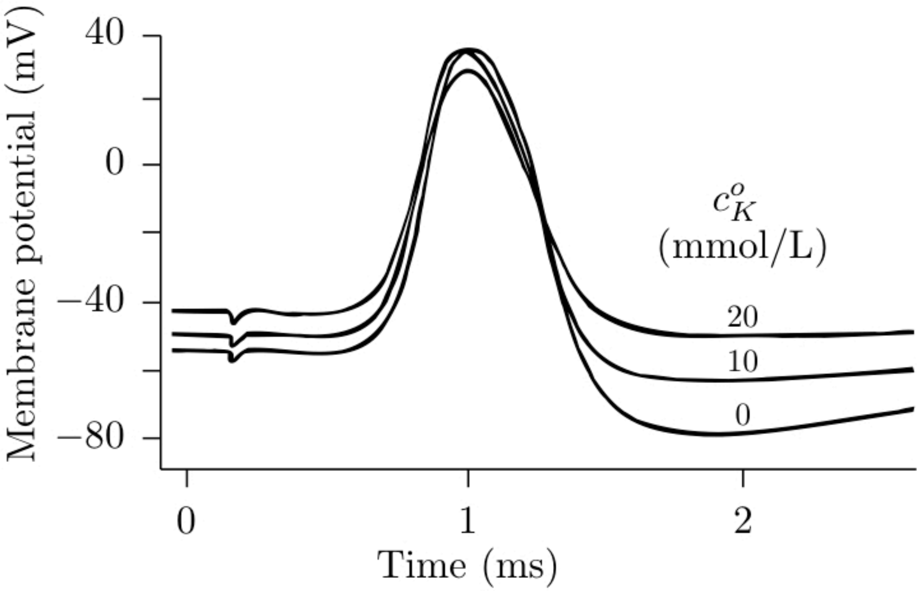


Figure 4.5

→ K^+ flux affects APs (*later on*)

→ Na^+ flux affects APs (*early on*)

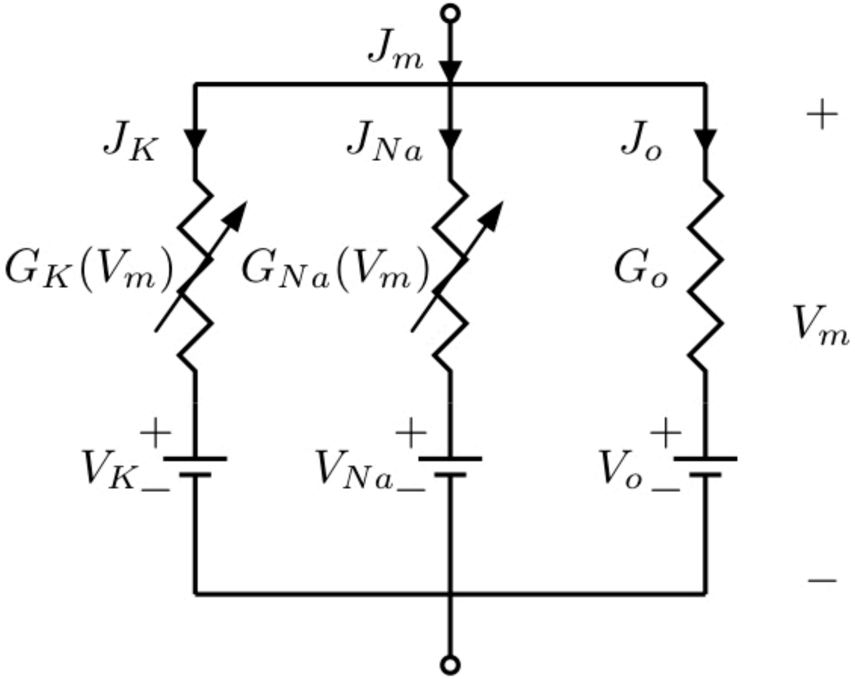
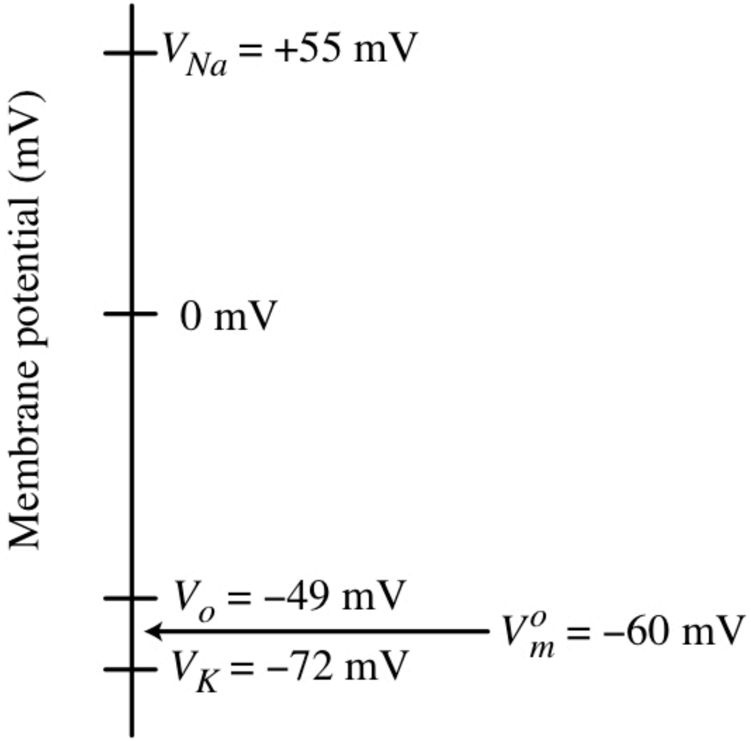


Figure 7.32



Idea 1 – Multiple permeant ions with different conductance (e.g., $G_k >> G_{Na}$)

Idea 2 – K+ and Na+ conductances can vary time

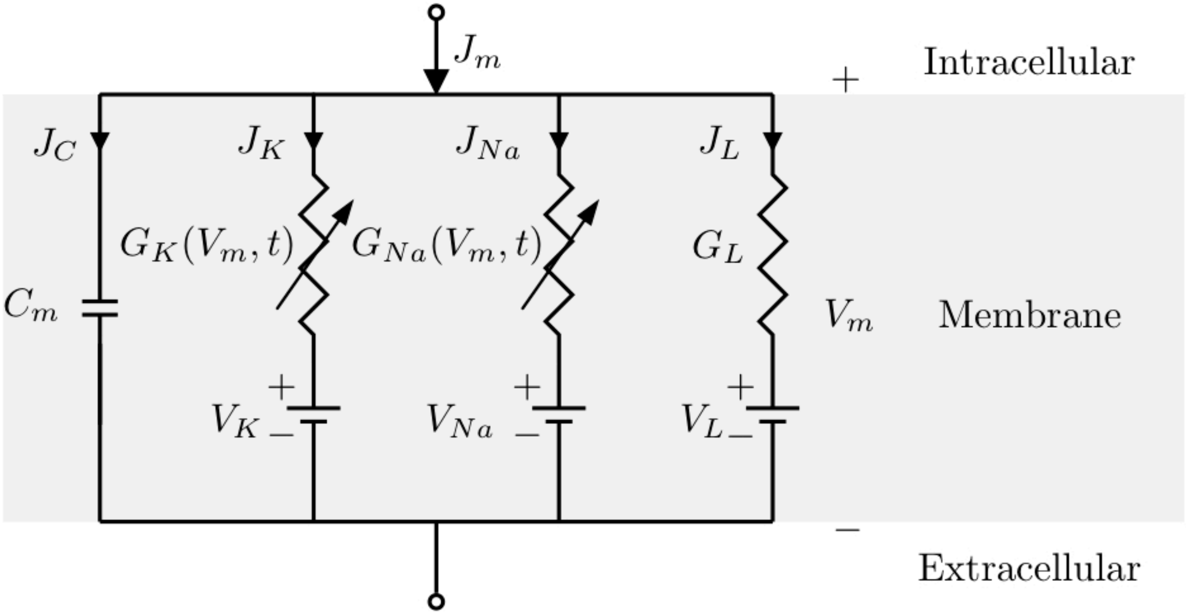


Figure 4.6

What are $G_K(V_m,t)$ and $G_{Na}(V_m,t)$?

→ Not easy to empirically distinguish, so new electrophysiological techniques were required

Space-Clamp

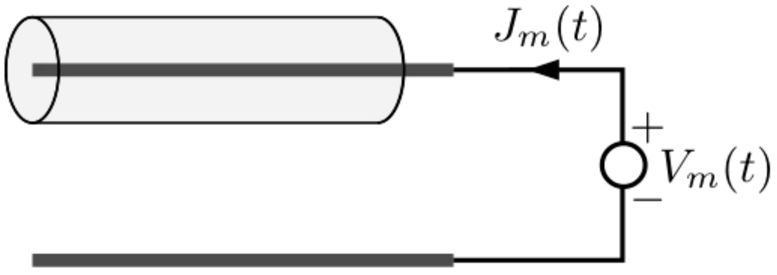


Figure 4.10

Kenneth Cole & George Marmont (1940s)

→ *Eliminates spatial dependence*
(i.e., make an electrically large cell a small one)

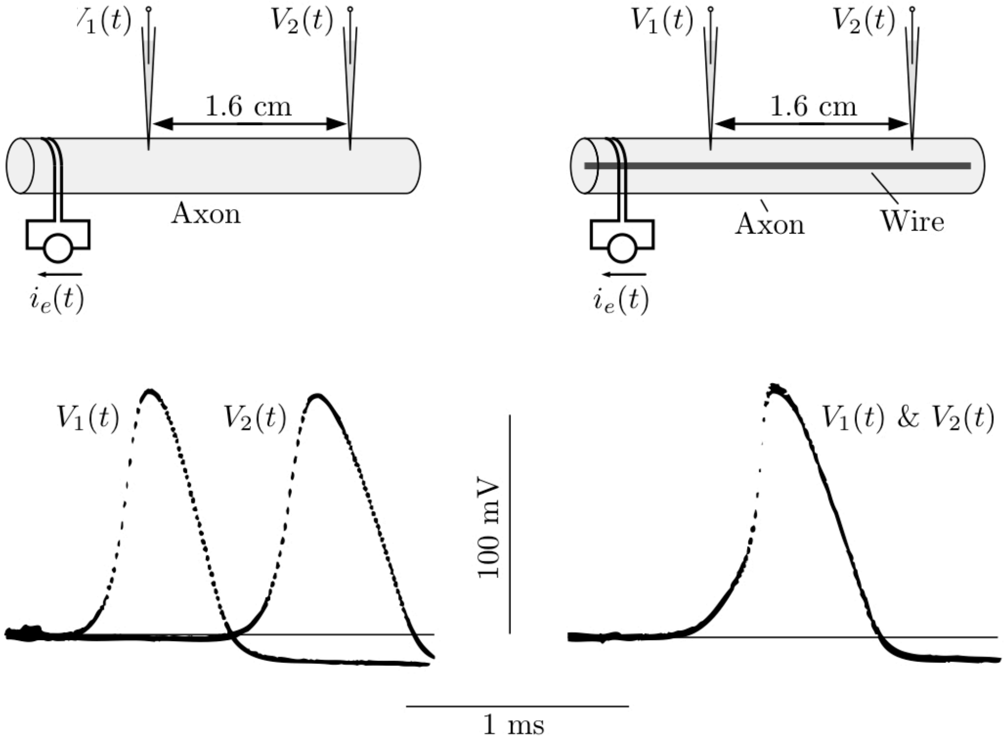


Figure 2.15

Conduction velocity
(Core-Conductor model)

$$r_i = \frac{\rho_i}{\pi a^2} \qquad \nu = \sqrt{\frac{K_m a}{2\rho_i}}$$

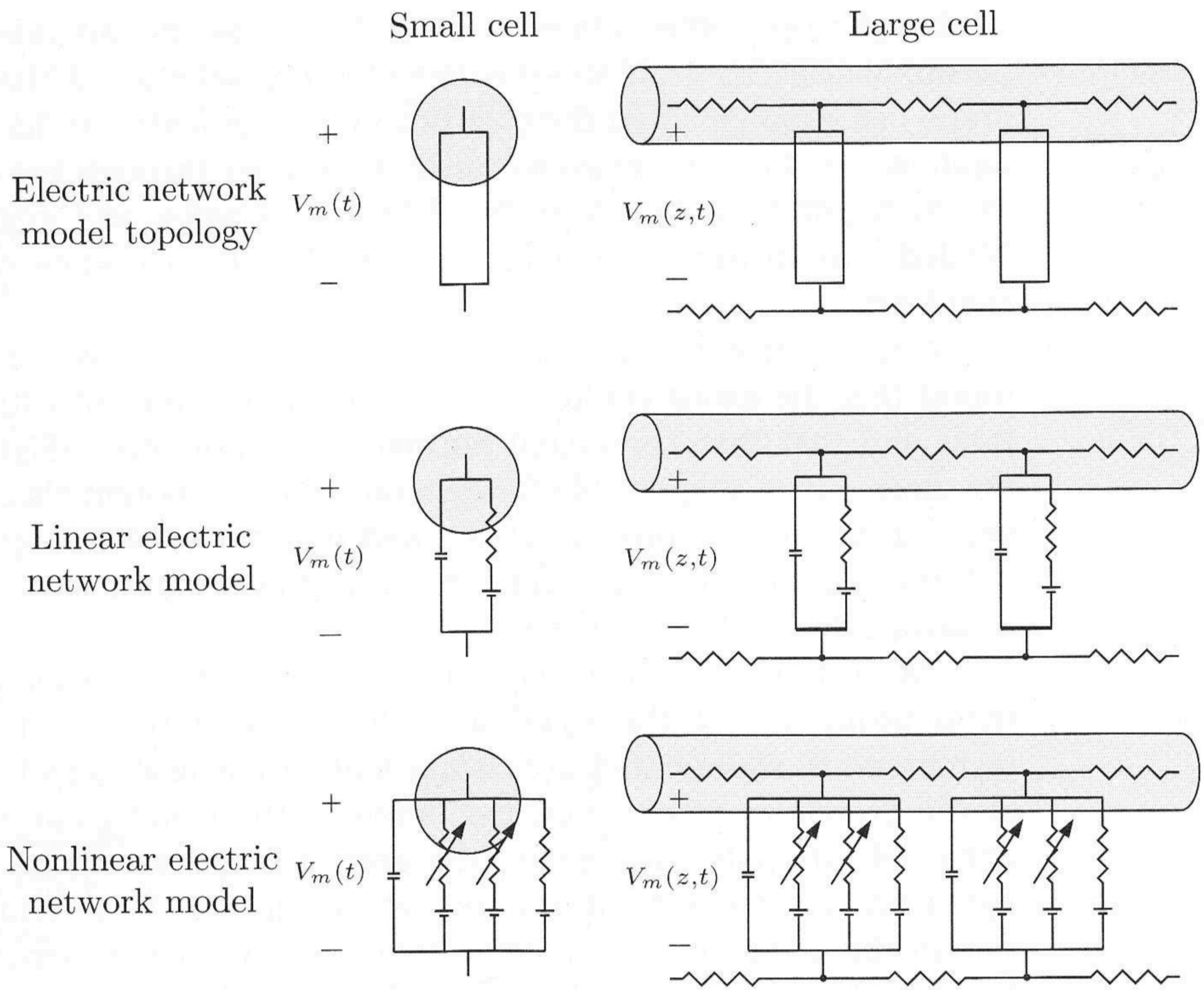
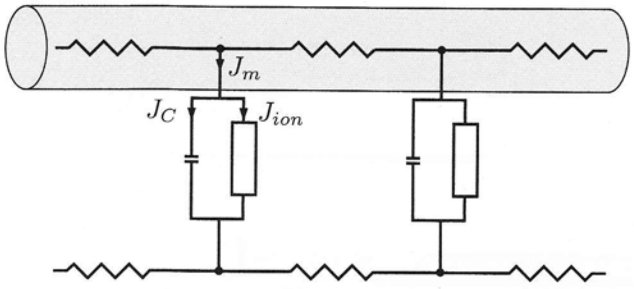


Figure 1.32

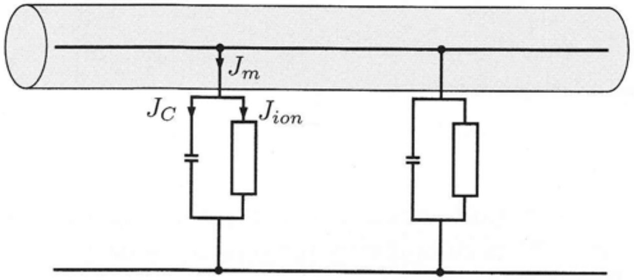
→ Electrically ‘small’ cell can still fire action potentials

Voltage-Clamp



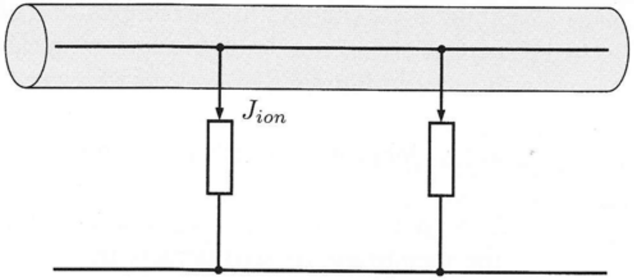
Space clamp

$$\frac{\partial V_m}{\partial z} = 0$$

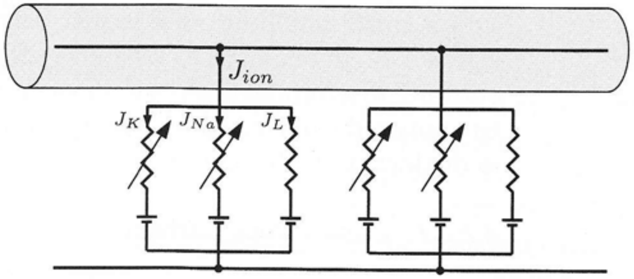


Step voltage clamp

$$\frac{\partial V_m}{\partial z} = \frac{\partial V_m}{\partial t} = 0$$



Separation of ionic currents



Separating Ionic Currents

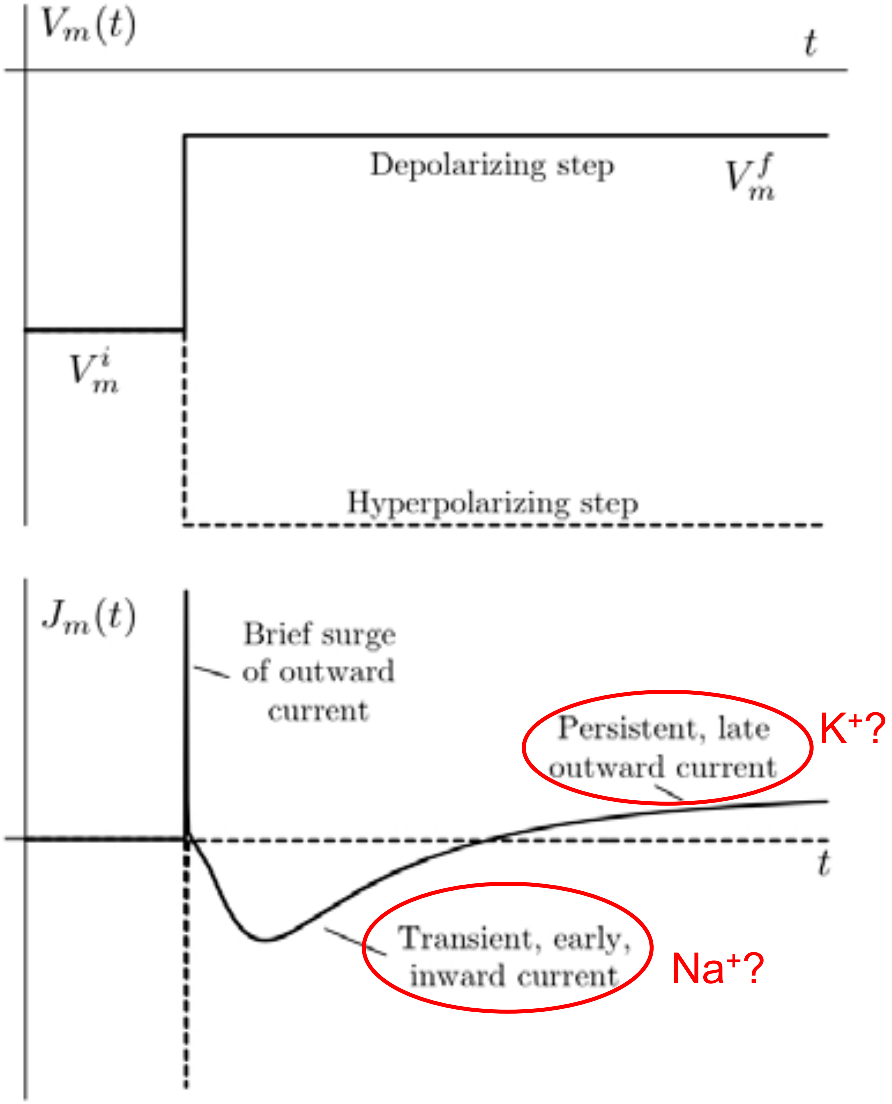


Figure 4.12

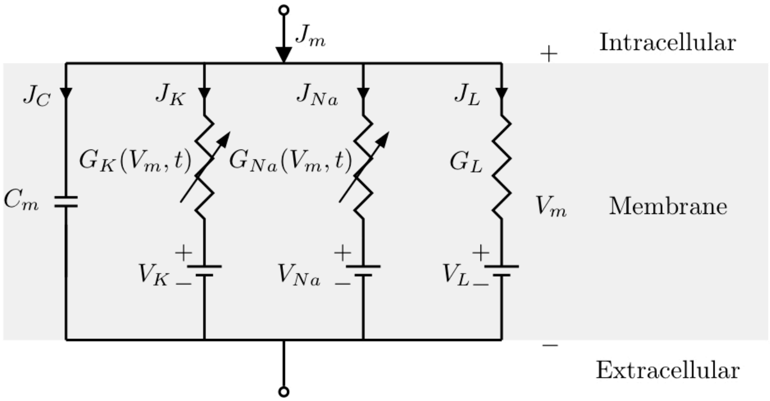


Figure 4.6

Capacitive Current

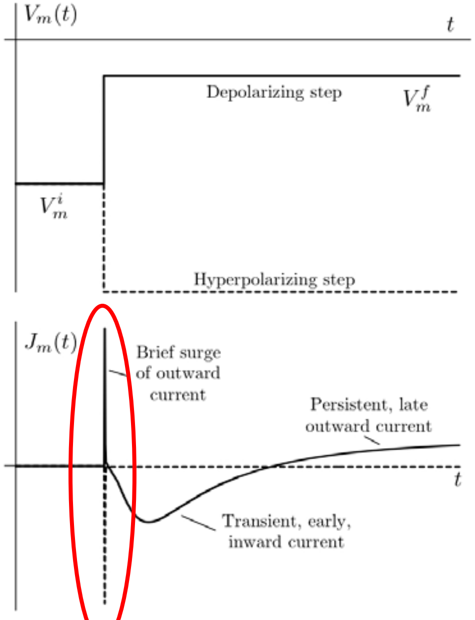
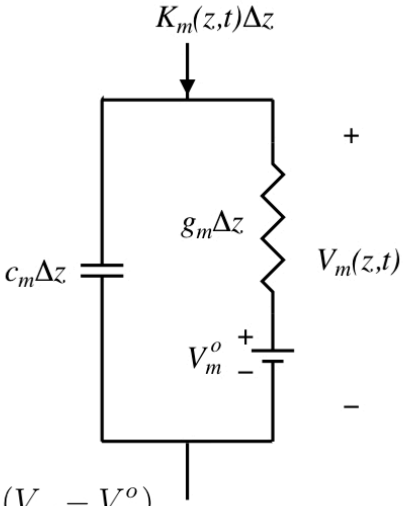


Figure 4.12



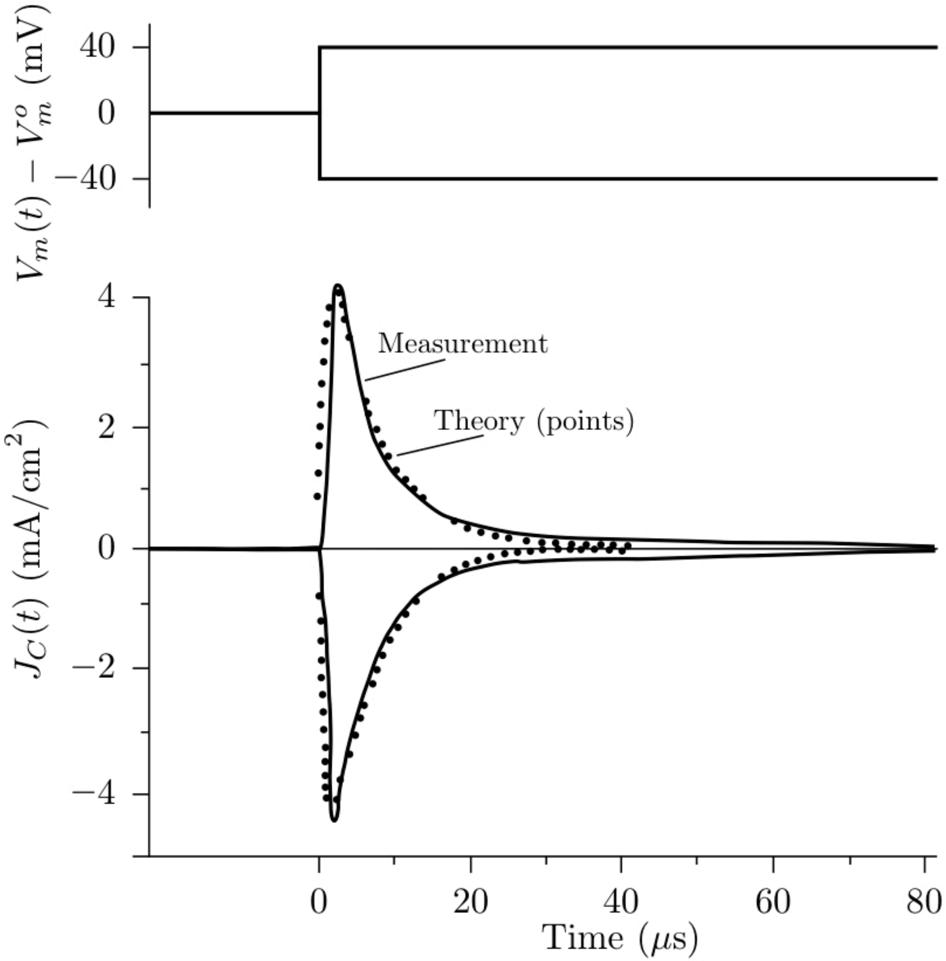


Figure 4.13

$$i_e(t) = AJ_m = AC_m\frac{dV_m}{dt} + AG_m(V_m - V_m^o)$$

$$\frac{AC_m}{AG_m}\frac{dV_m}{dt} + V_m = V_m^o + \frac{i_e(t)}{AG_m}$$

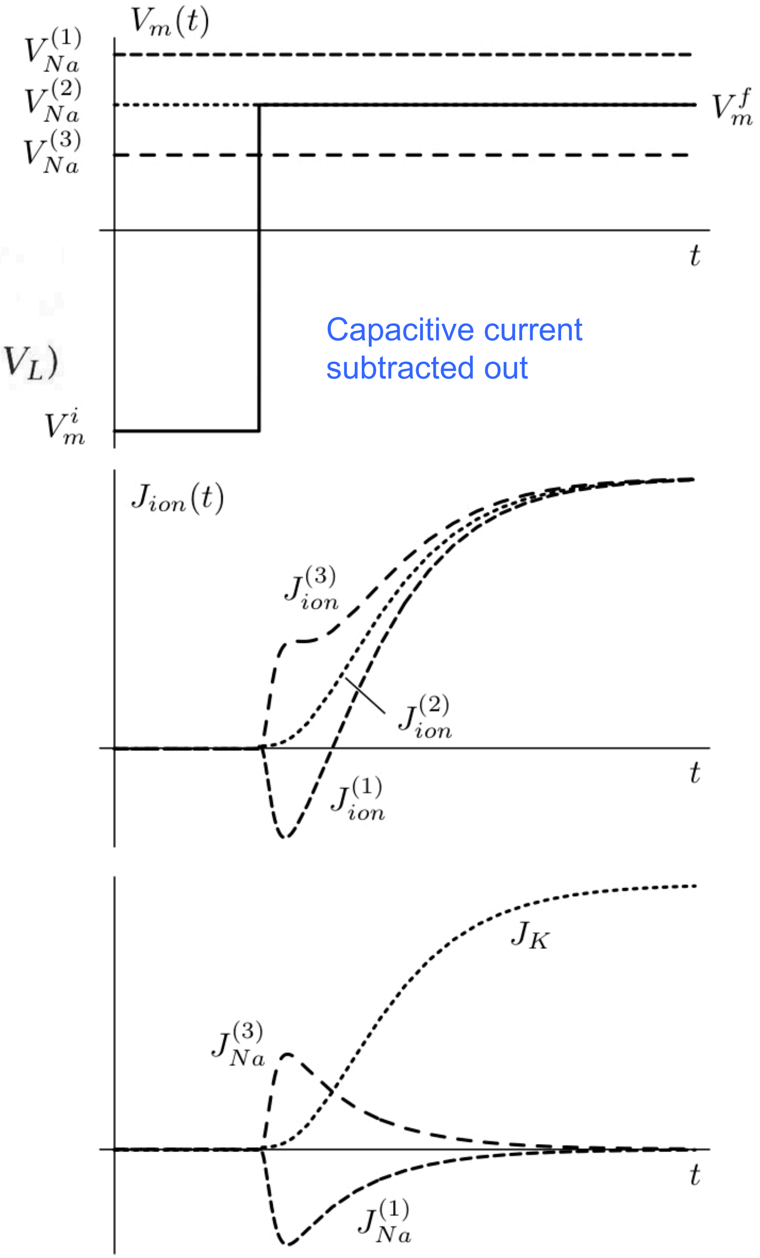
But what of the other ionic currents?

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

→ What are $G_K(V_m,t)$ and $G_{Na}(V_m,t)$?

$$V_{Na} = \frac{RT}{F}\log\frac{c^o_{Na}}{c^i_{Na}}$$

→ Separating ionic currents by subtraction
(assumes J_K unaffected by changes in [Na⁺])



Capacitive current subtracted out

Figure 4.17

Reversal Potential?

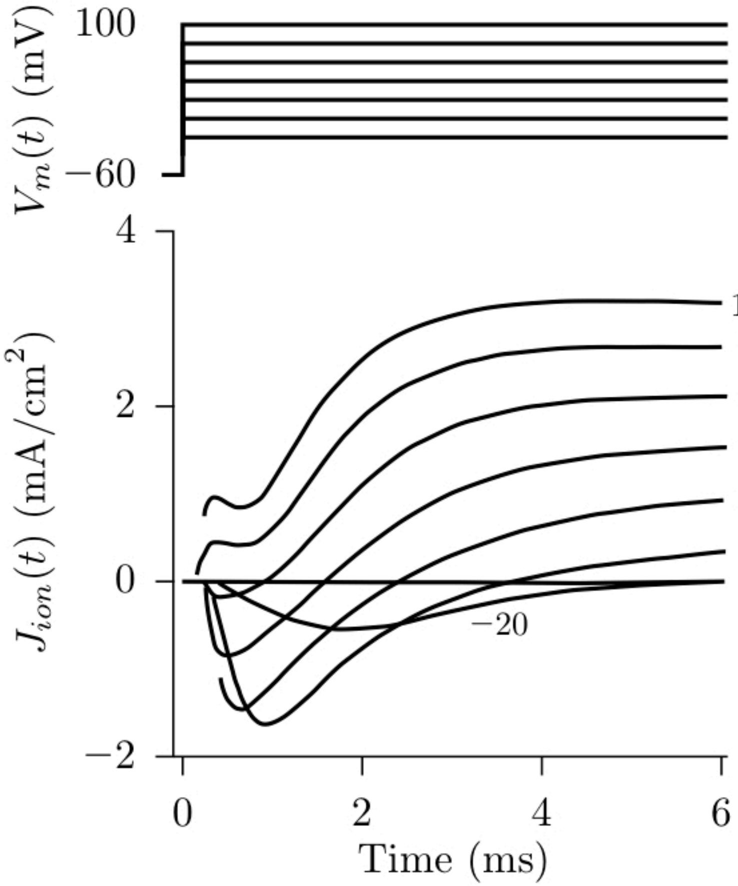


Figure 4.14

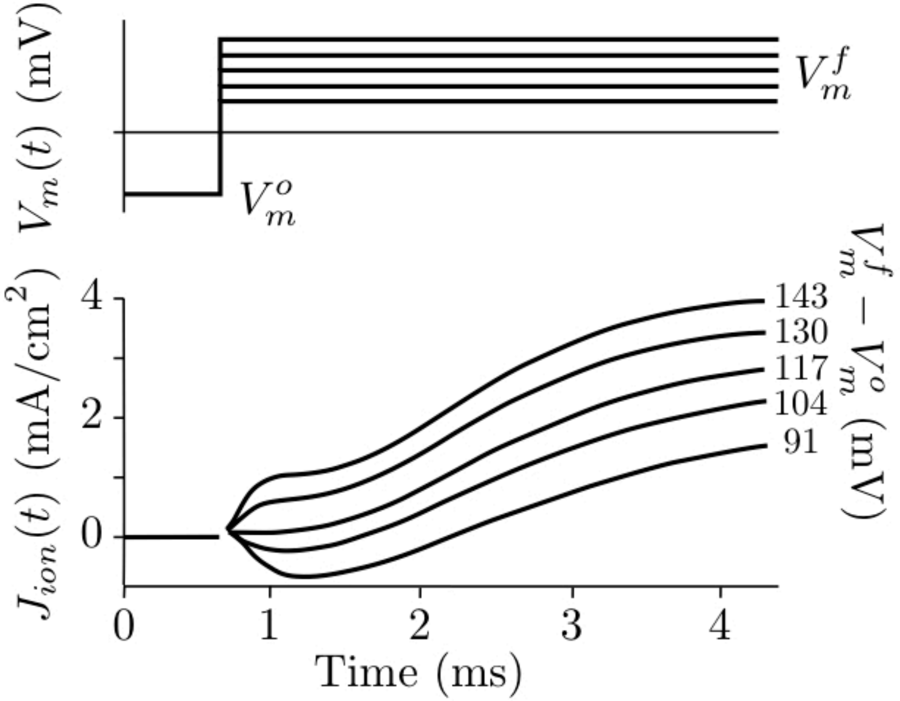
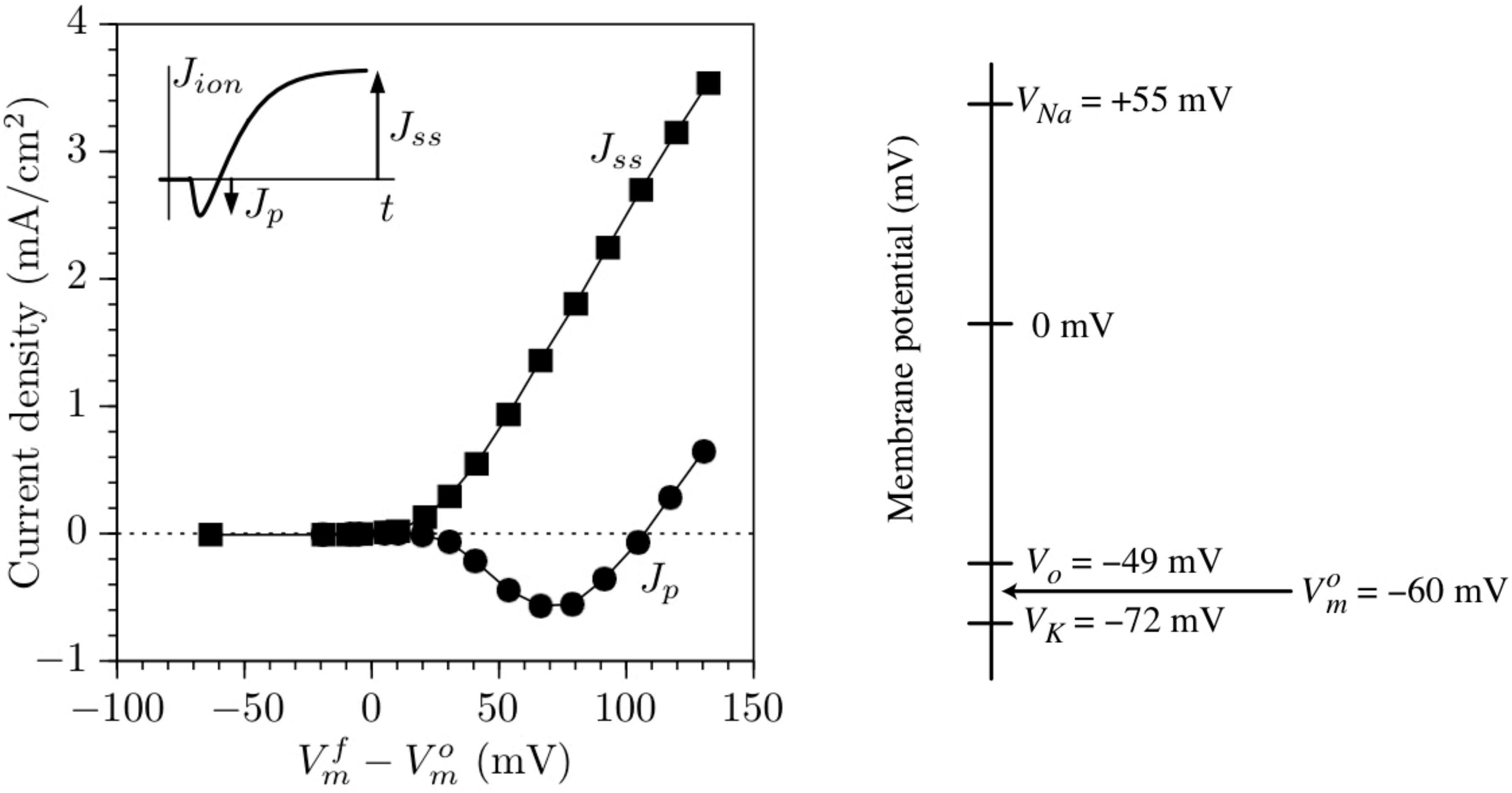


Figure 4.15

→ Close to Na$^+$ Nernst potential!



J_{ion}
J_{ss}
J_p
t
J_{ss}
J_p
Current density (mA/cm^2)
4
3
2
1
0
−1
−100
−50
0
50
100
150
$V_m^f - V_m^o$ (mV)
Membrane potential (mV)
V_{Na} = +55 mV
0 mV
V_o = –49 mV
V_m^o = –60 mV
V_K = –72 mV

Figure 4.16

Separating Ionic Currents

NOTE: Other methods besides subtraction (e.g., TTX to block Na^+ current, replace K^+ w/ Cs^+, etc...)

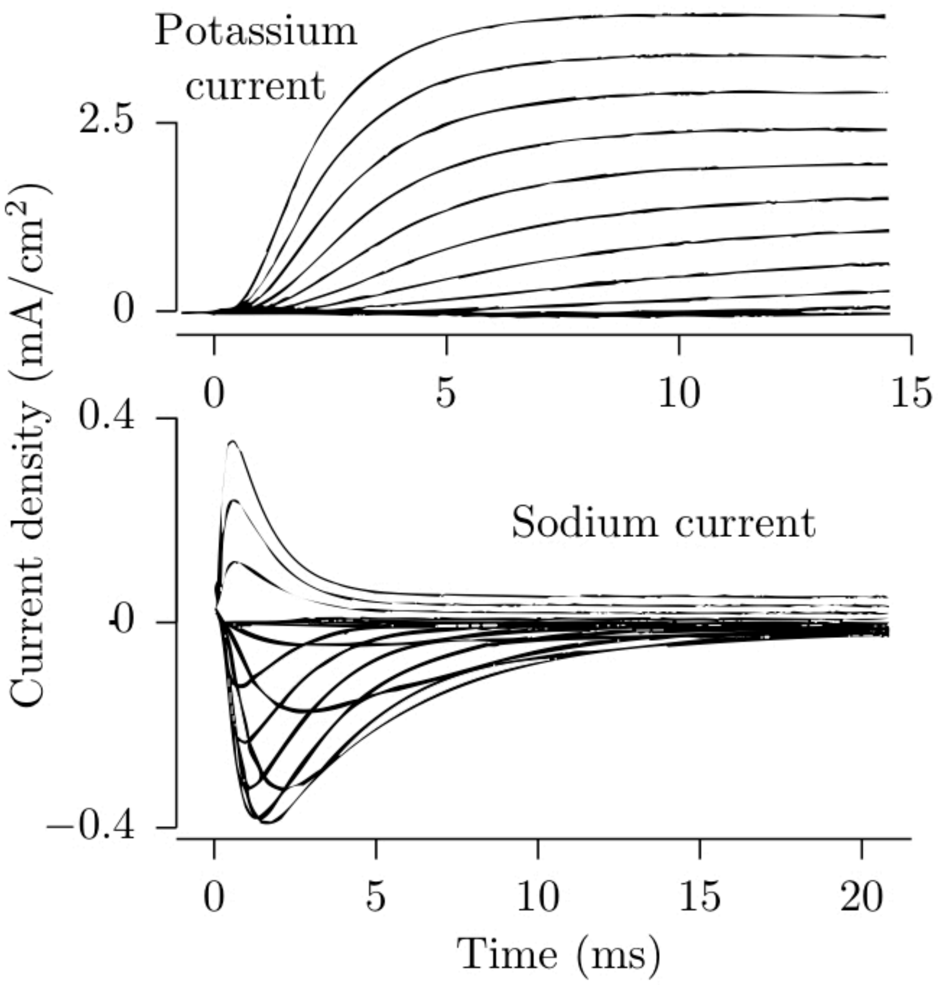


Figure 4.20

→ K^+ simply turns on
(with a bit of a slow start)

→ Na^+ more complex
(early 'activation', followed by 'inactivation)

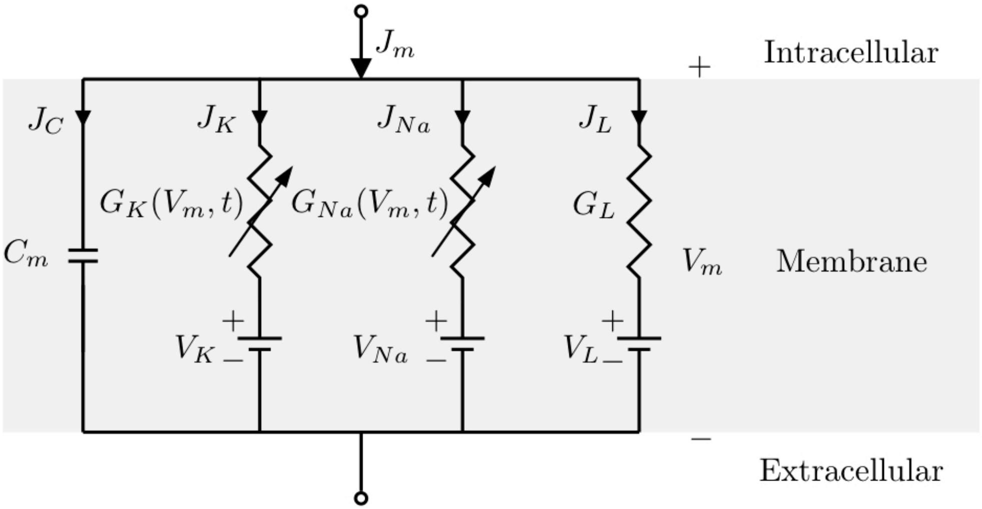


Figure 4.6

What are $G_K(V_m, t)$ and $G_{Na}(V_m, t)$?

→ Physiological data suggests Na^+ *activates* and then *inactivates* while K^+ simply *activates* (based upon V_m)