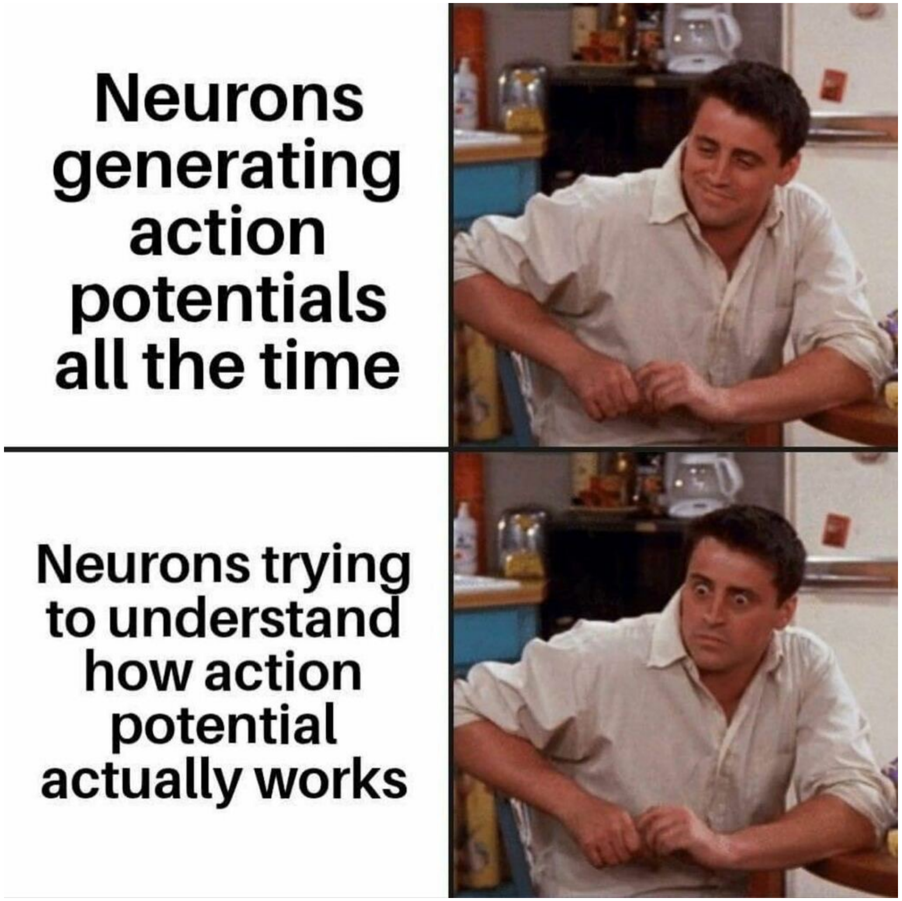
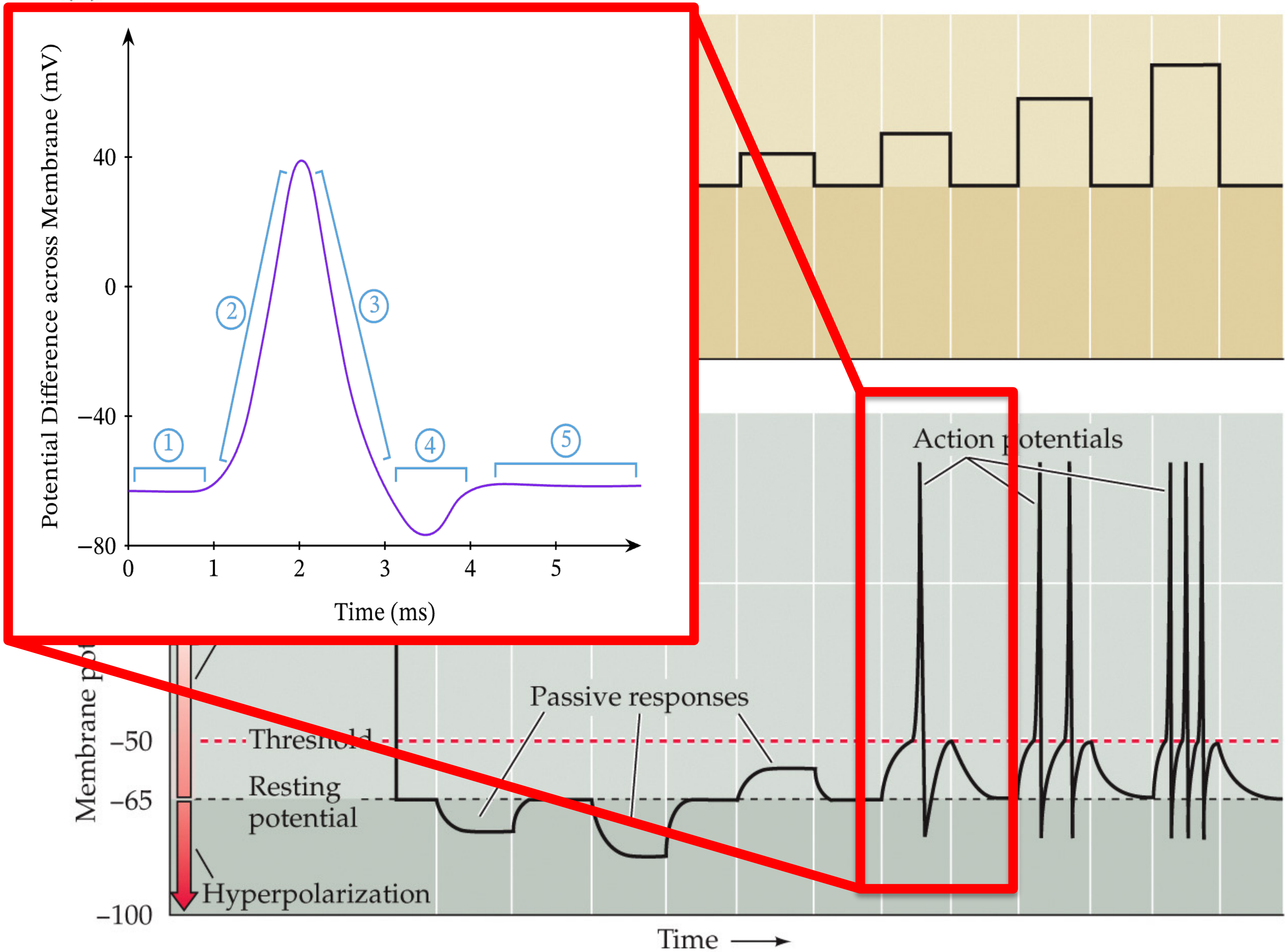
BMD ENG 301 Quantitative Systems Physiology (Nervous System)

Lecture 7: Action Potentials and Ionic Mechanisms

Emily Schafer

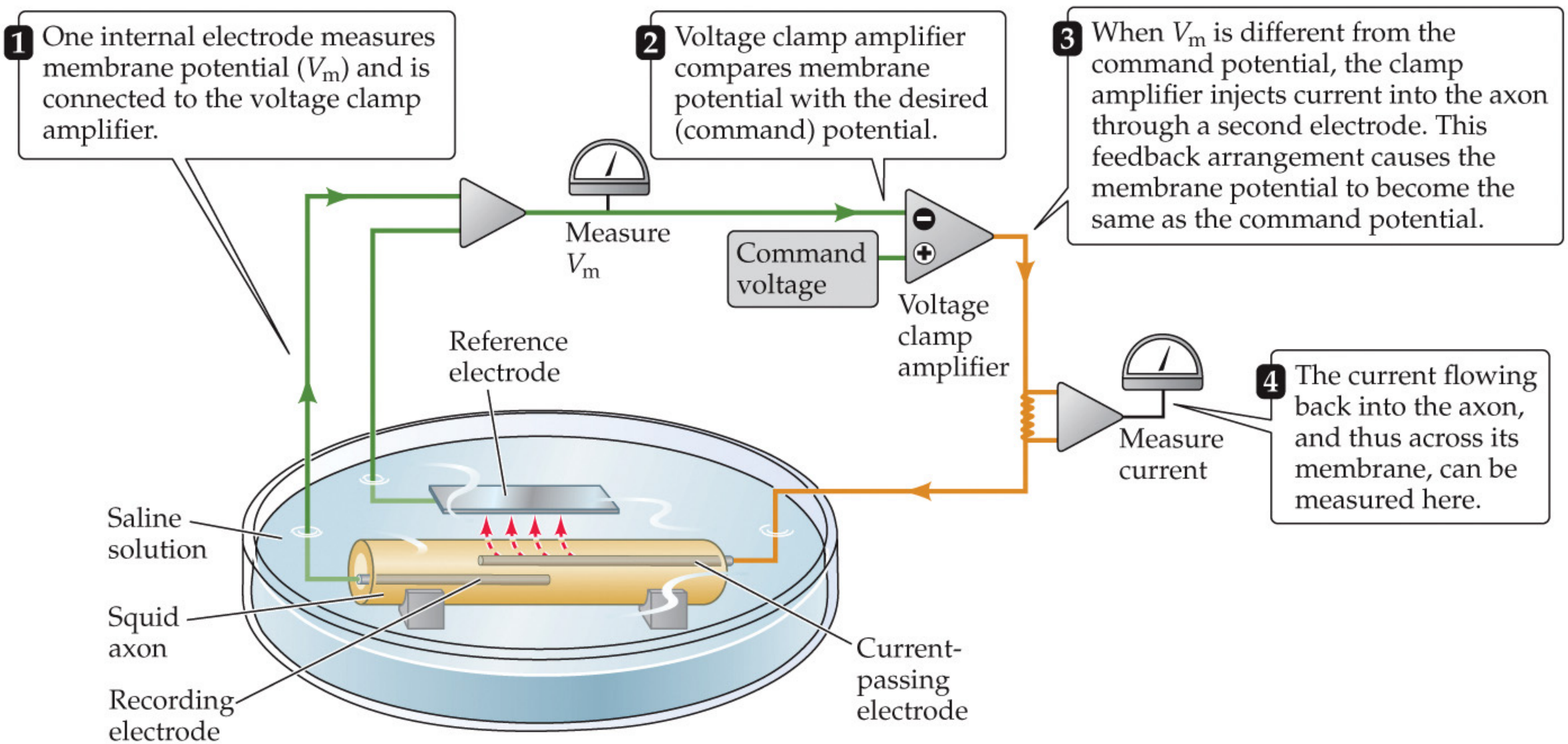


(B)



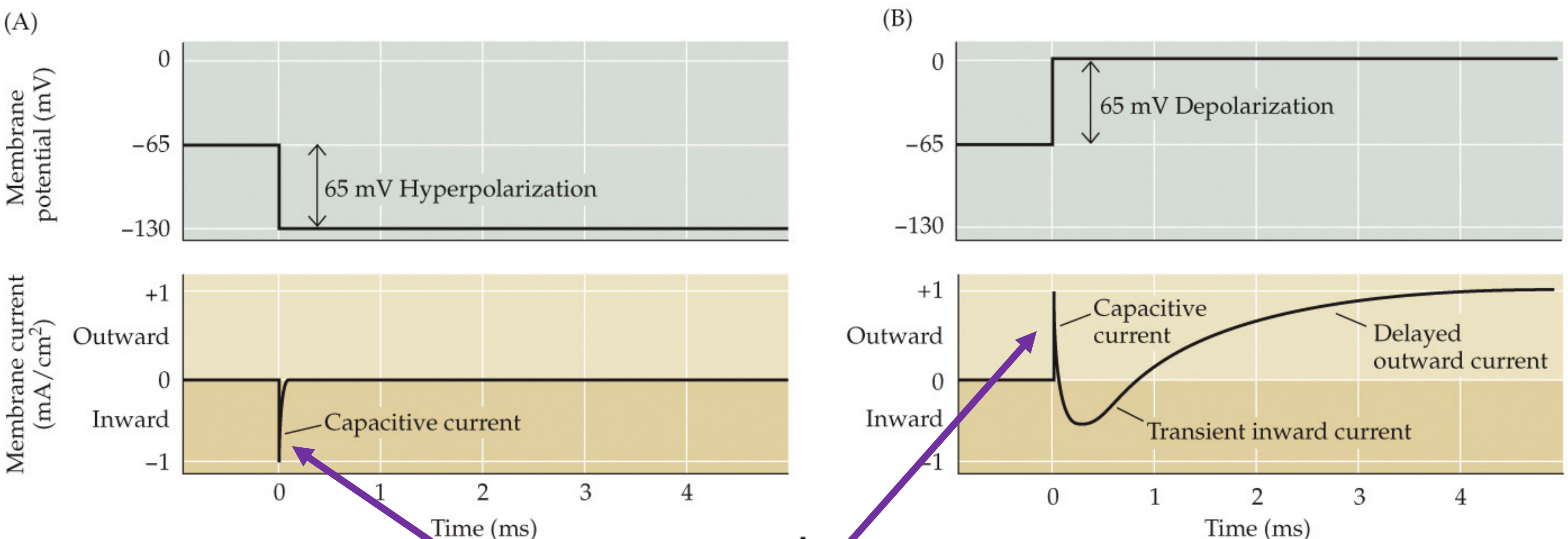
NEUROSCIENCE 6e, Figure 2.2 (Part 2)

The Voltage Clamp Method

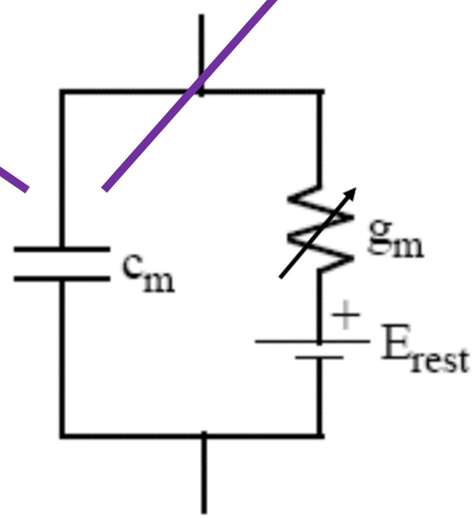


NEUROSCIENCE 6e, Box 3A

Voltage clamping allows us to discover the voltage dependence of different phenomena, like ion permeability

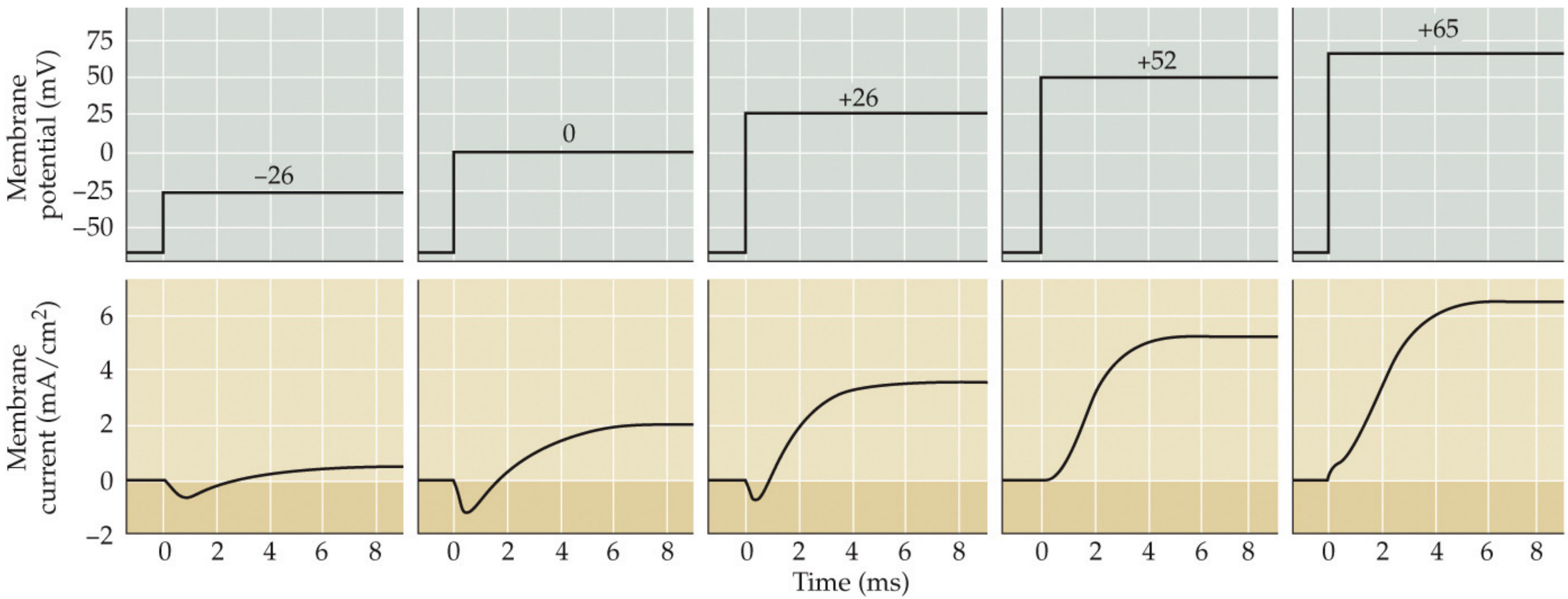


NEUROSCIENCE 6e, Figure 3.1

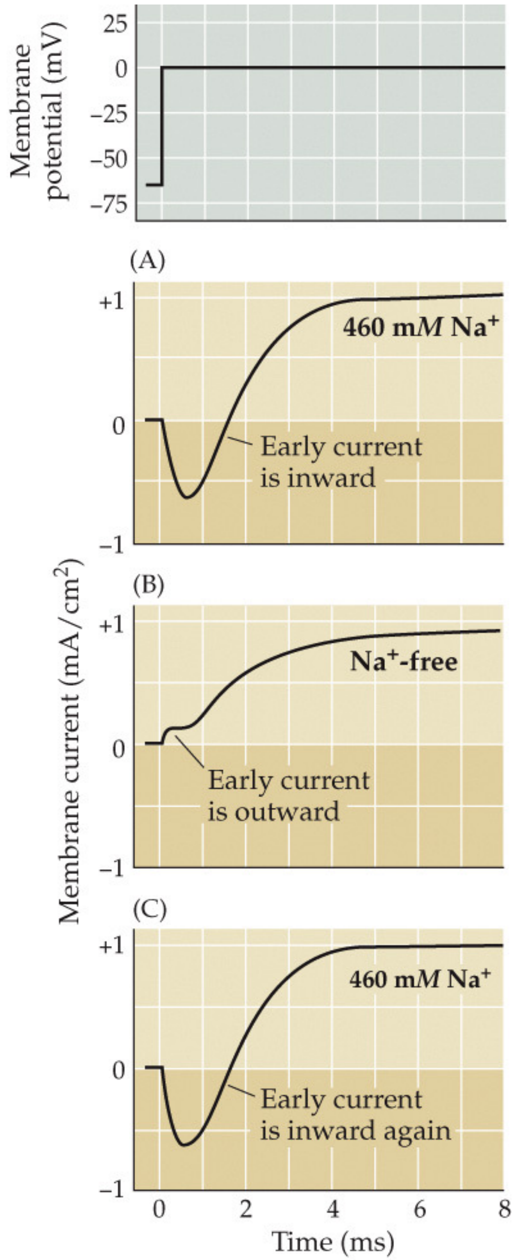


Remember – capacitors take time to charge and discharge!

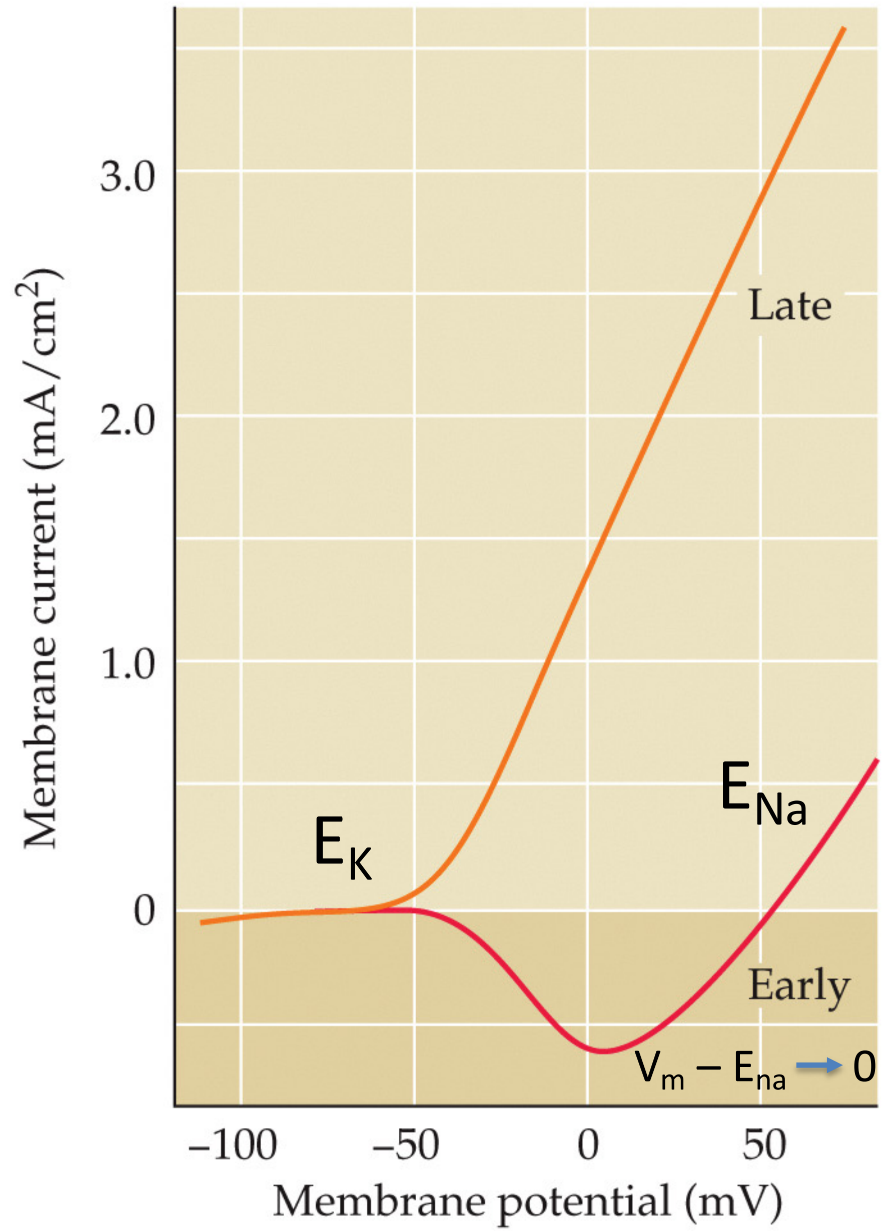
Voltage clamping allows us to discover the voltage dependence of different phenomena, like ion permeability



NEUROSCIENCE 6e, Figure 3.2

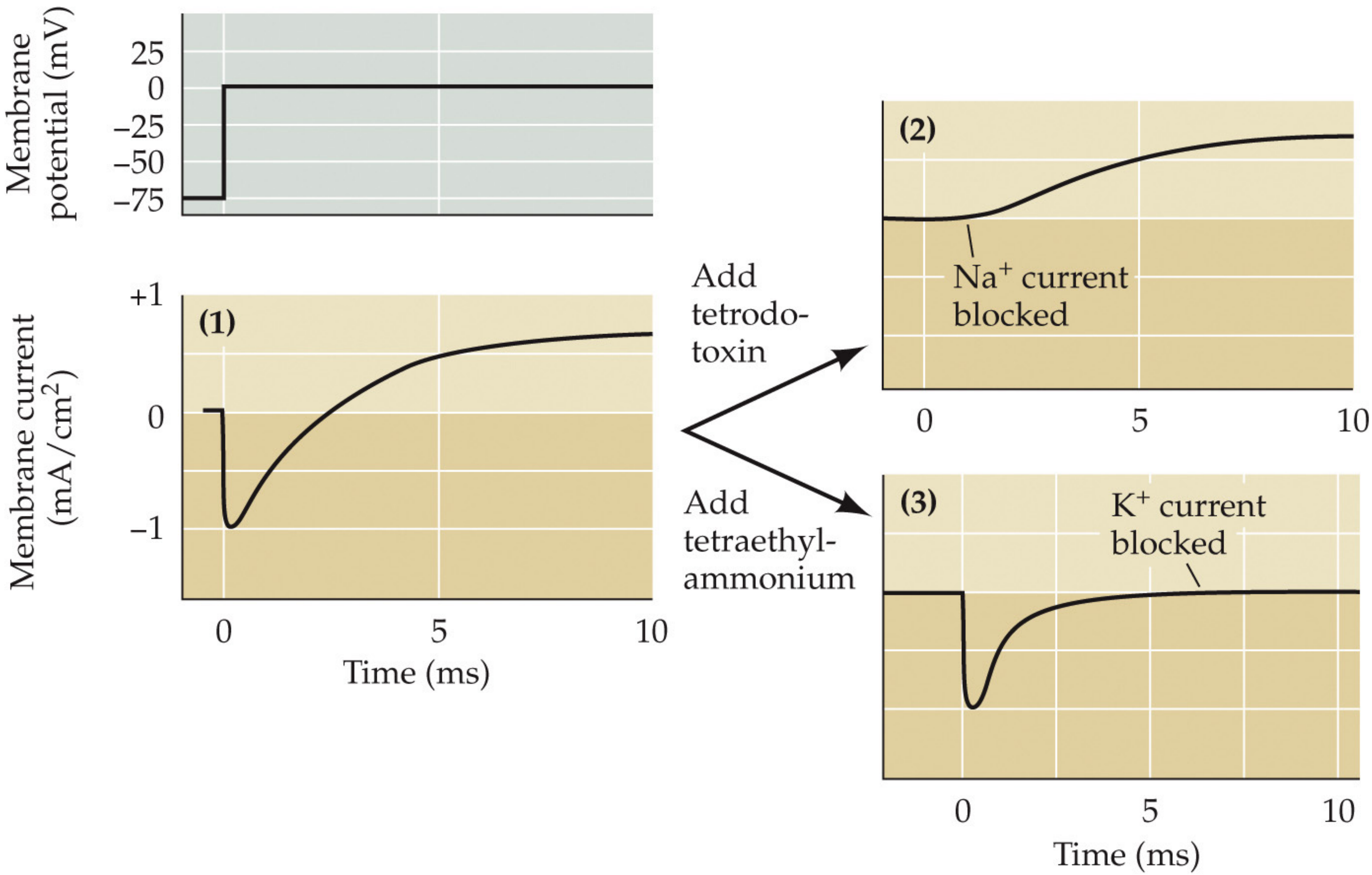


NEUROSCIENCE 6e, Figure 3.4



NEUROSCIENCE 6e, Figure 3.3

We can also pharmacologically prove which ion is responsible for which part of the current:



NEUROSCIENCE 6e, Figure 3.5

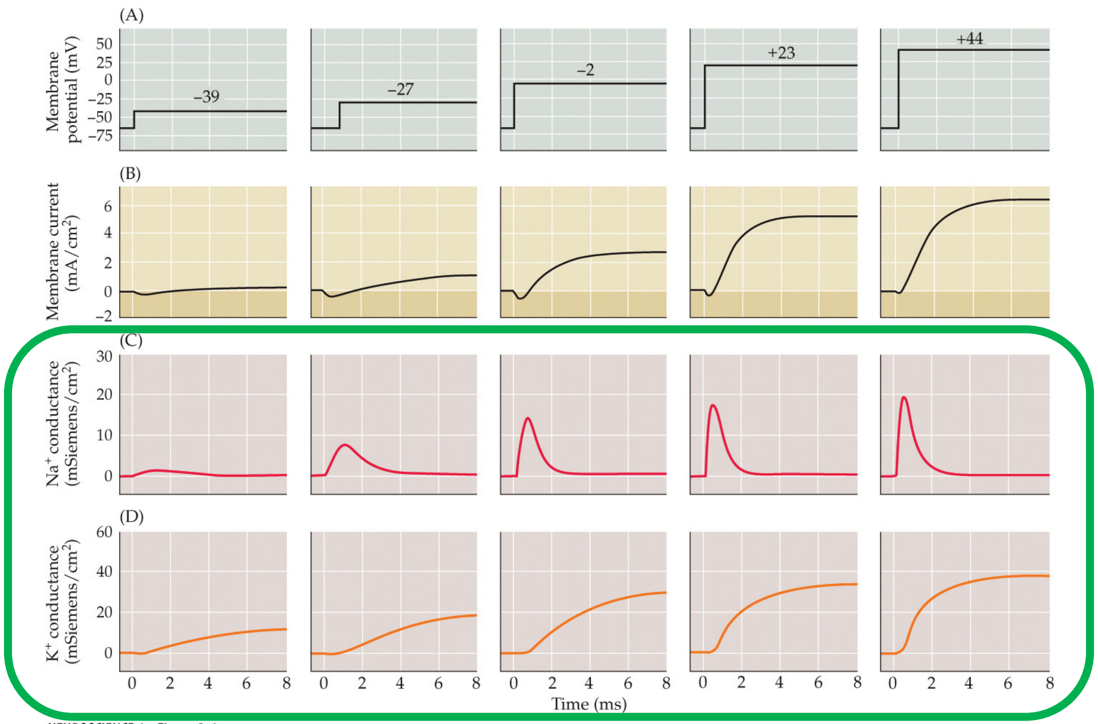
What does the conductance look like over **voltage** and **time**?

$$I_{\text{ion}} = \boxed{g_{\text{ion}}}(V_{\text{m}} - E_{\text{ion}})$$

Current
(measured)

Membrane voltage
(set during clamp)

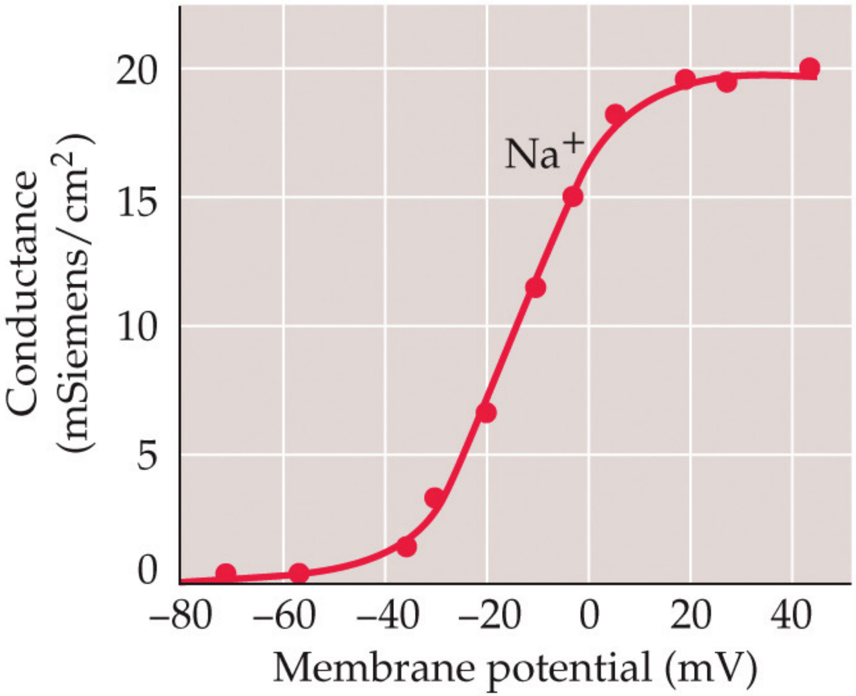
Reversal potential
(calculated based on measured concentrations)

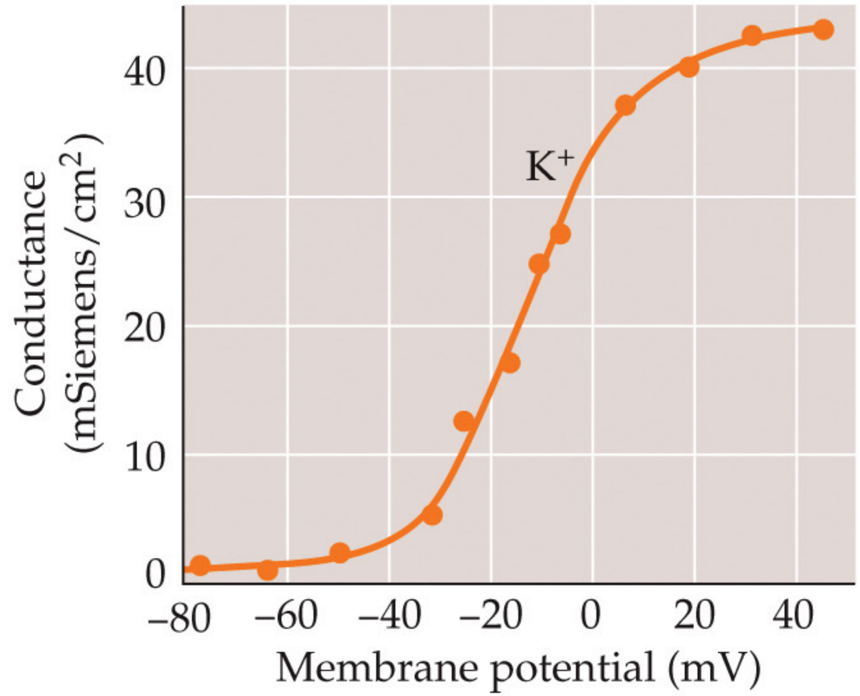


NEUROSCIENCE 6e, Figure 3.6

What does the conductance look like over **voltage** and **time**?

Voltage dependence of conductance after a stimulus

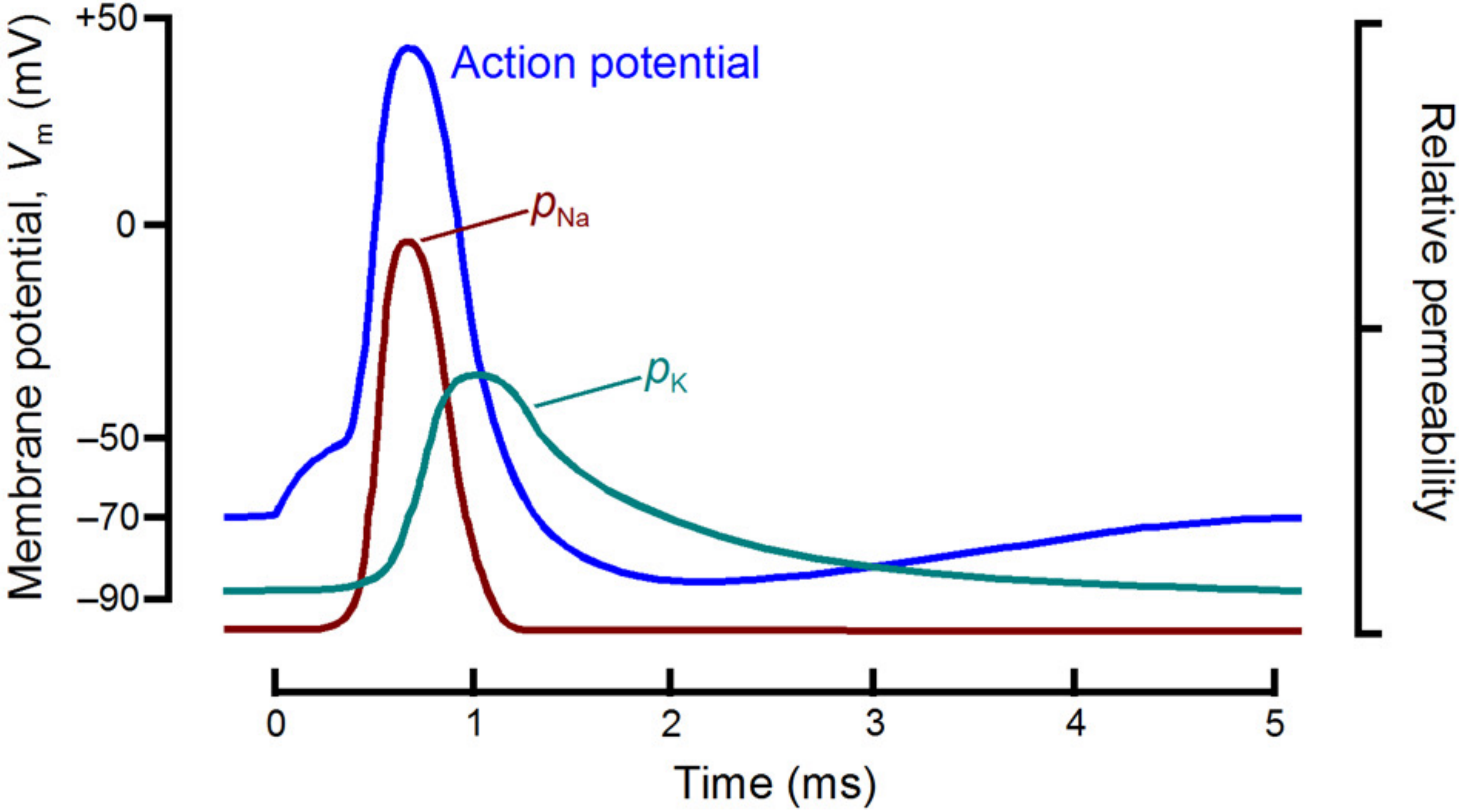




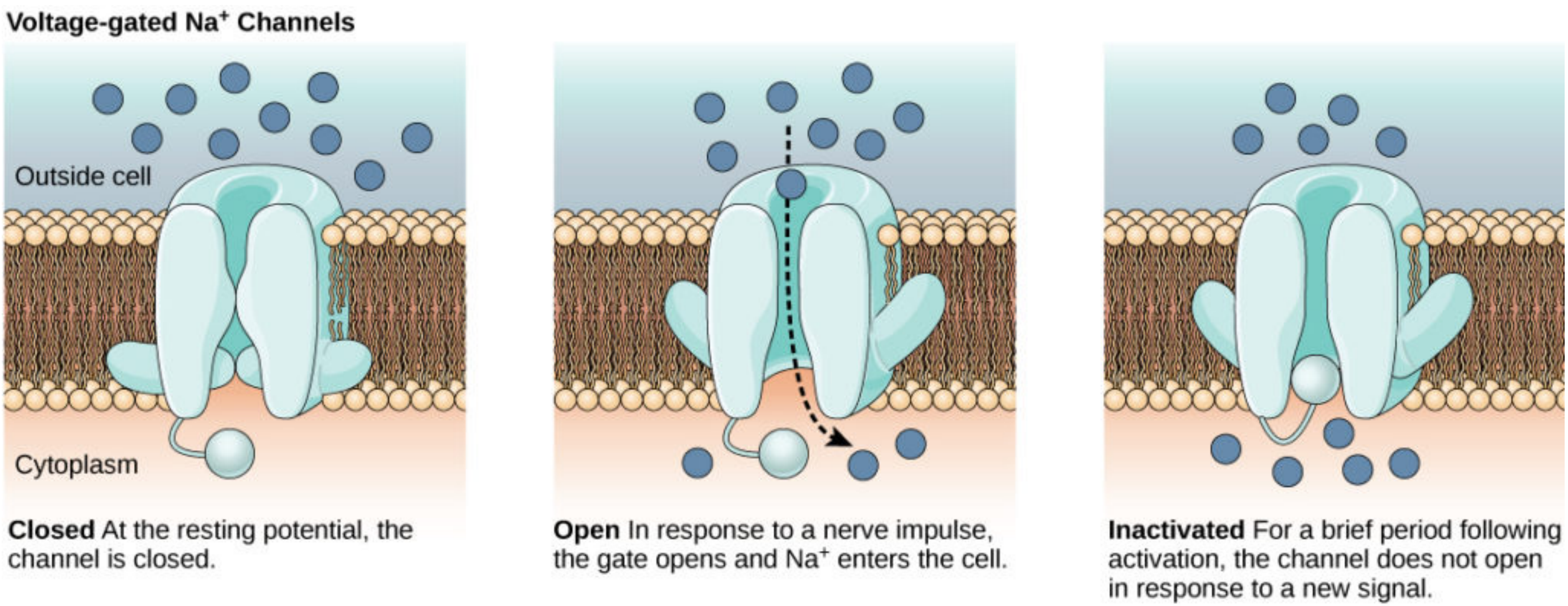
NEUROSCIENCE 6e, Figure 3.7

What does the conductance look like over **voltage** and **time**?

Time dependence of conductance after a stimulus



States of the Na^+ Channel

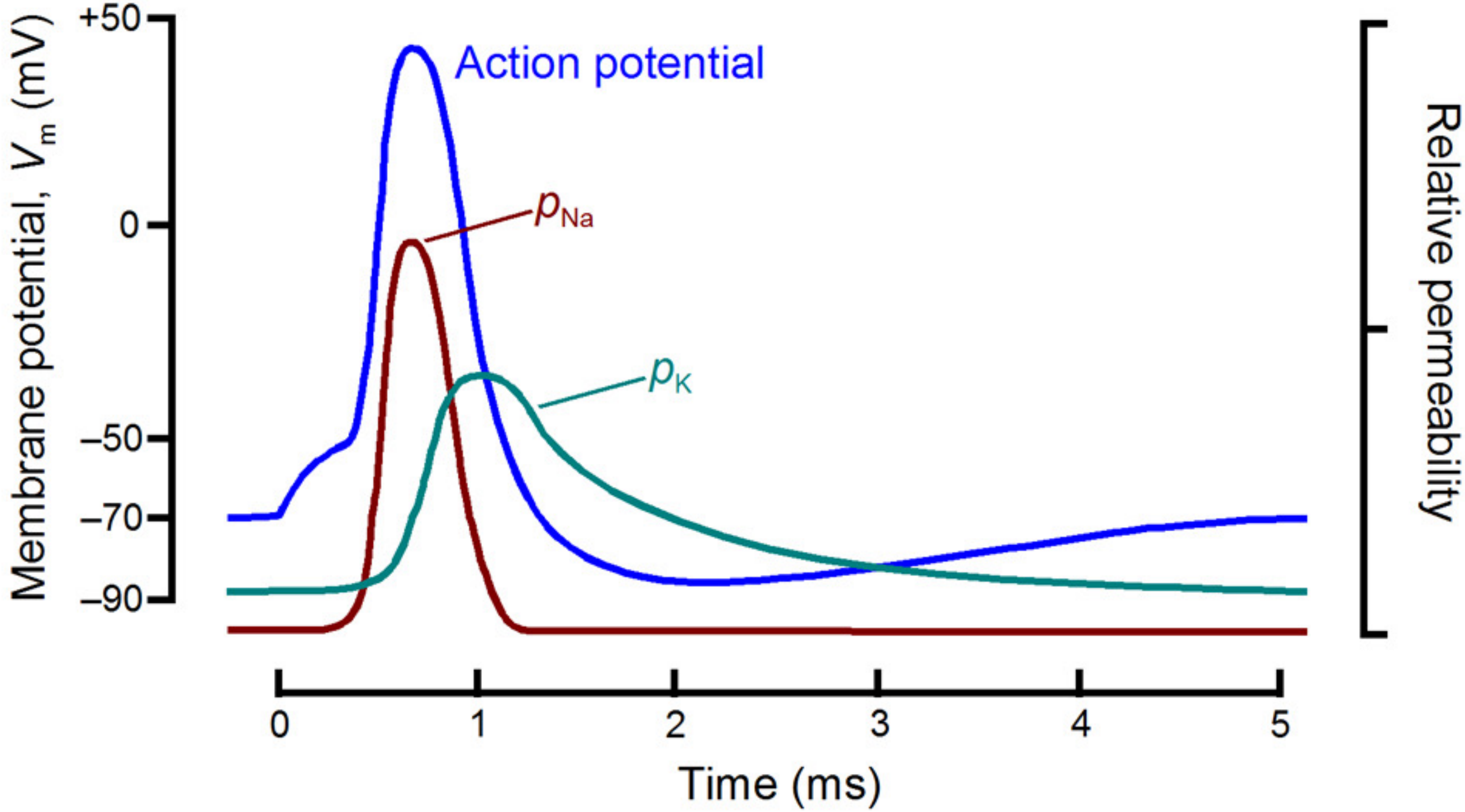


Remember: these are the states of a **single channel!**

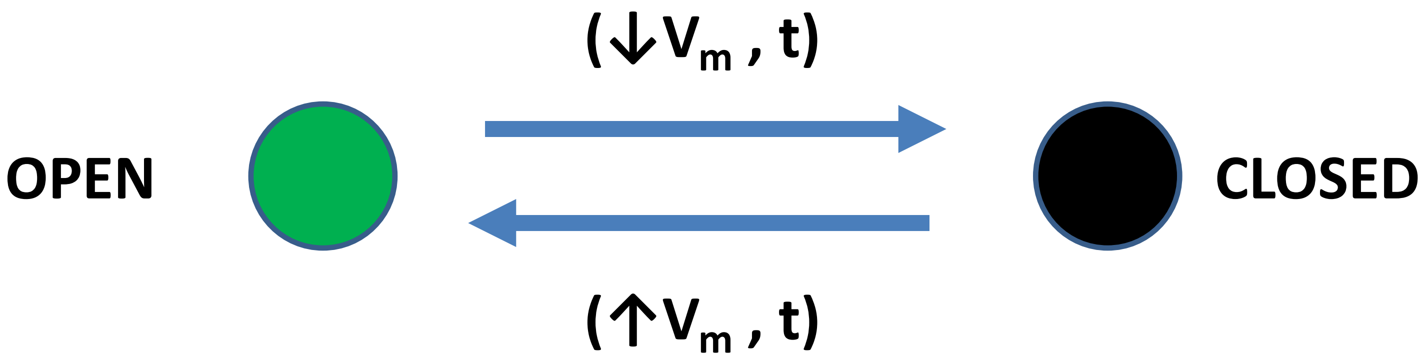
States of the Na^+ Channel

CLOSED **INACTIVATED** → **CLOSED**

OPEN

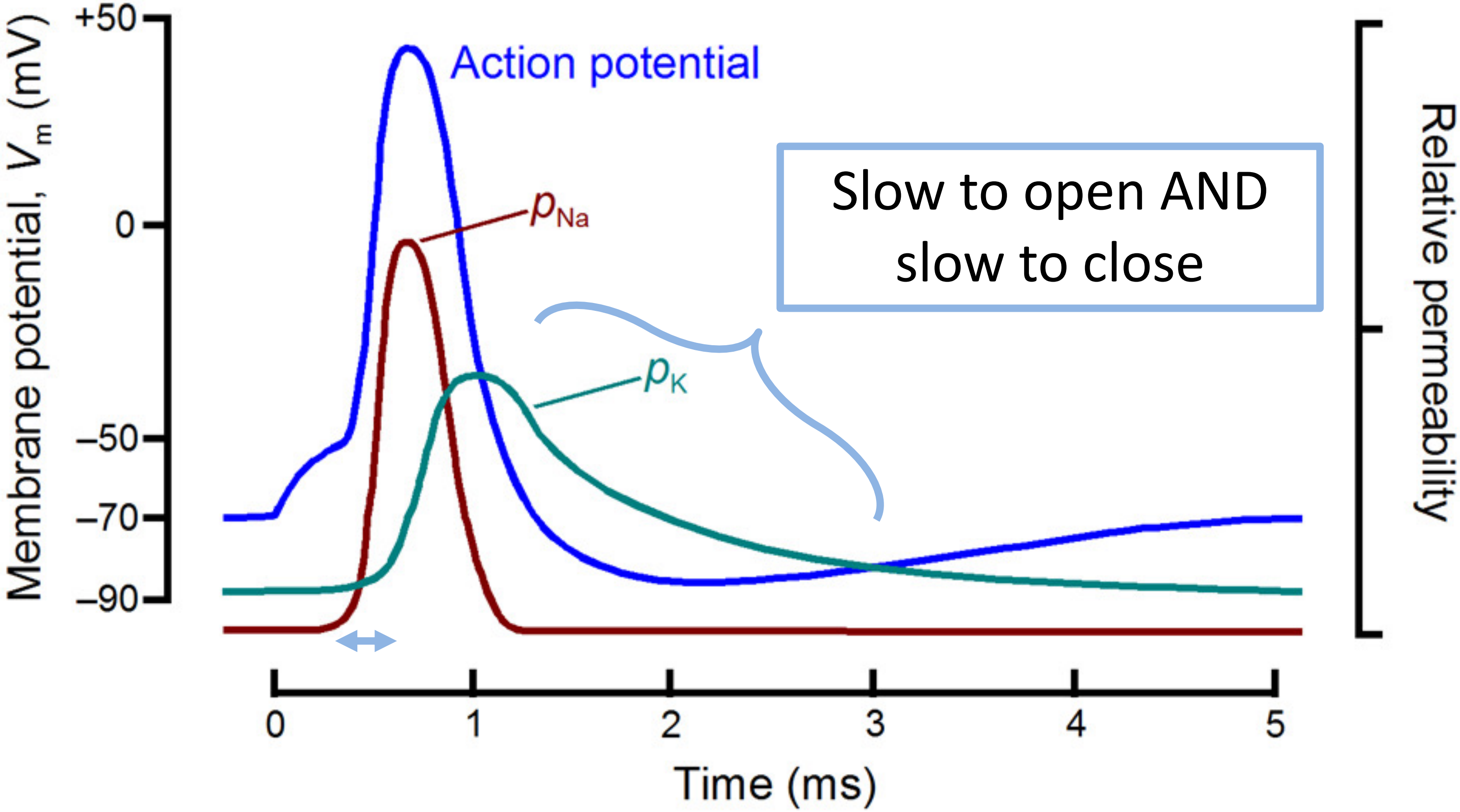


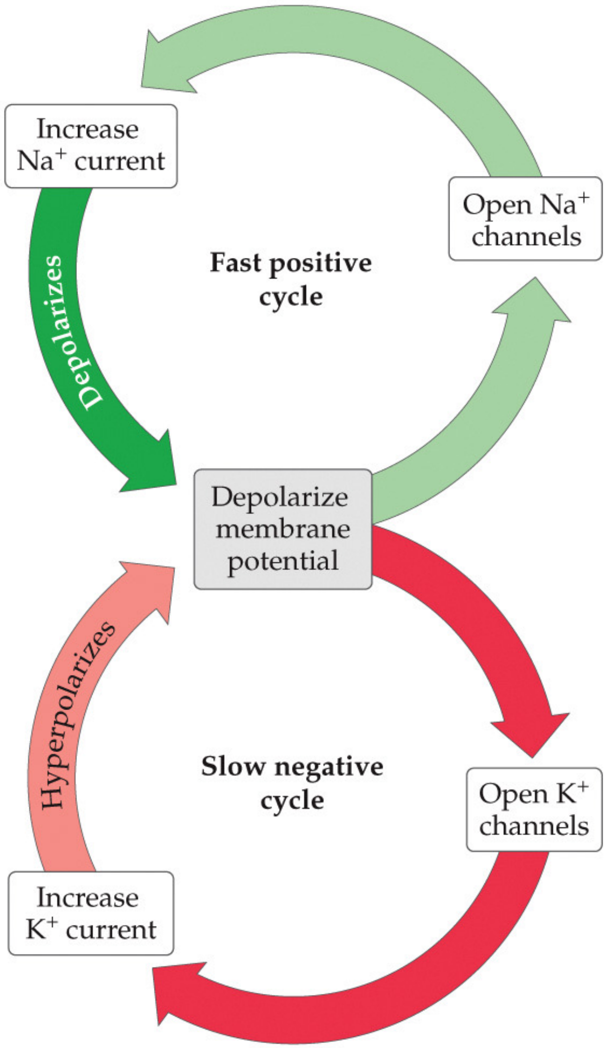
States of the Delayed Rectifier K^+ Channel



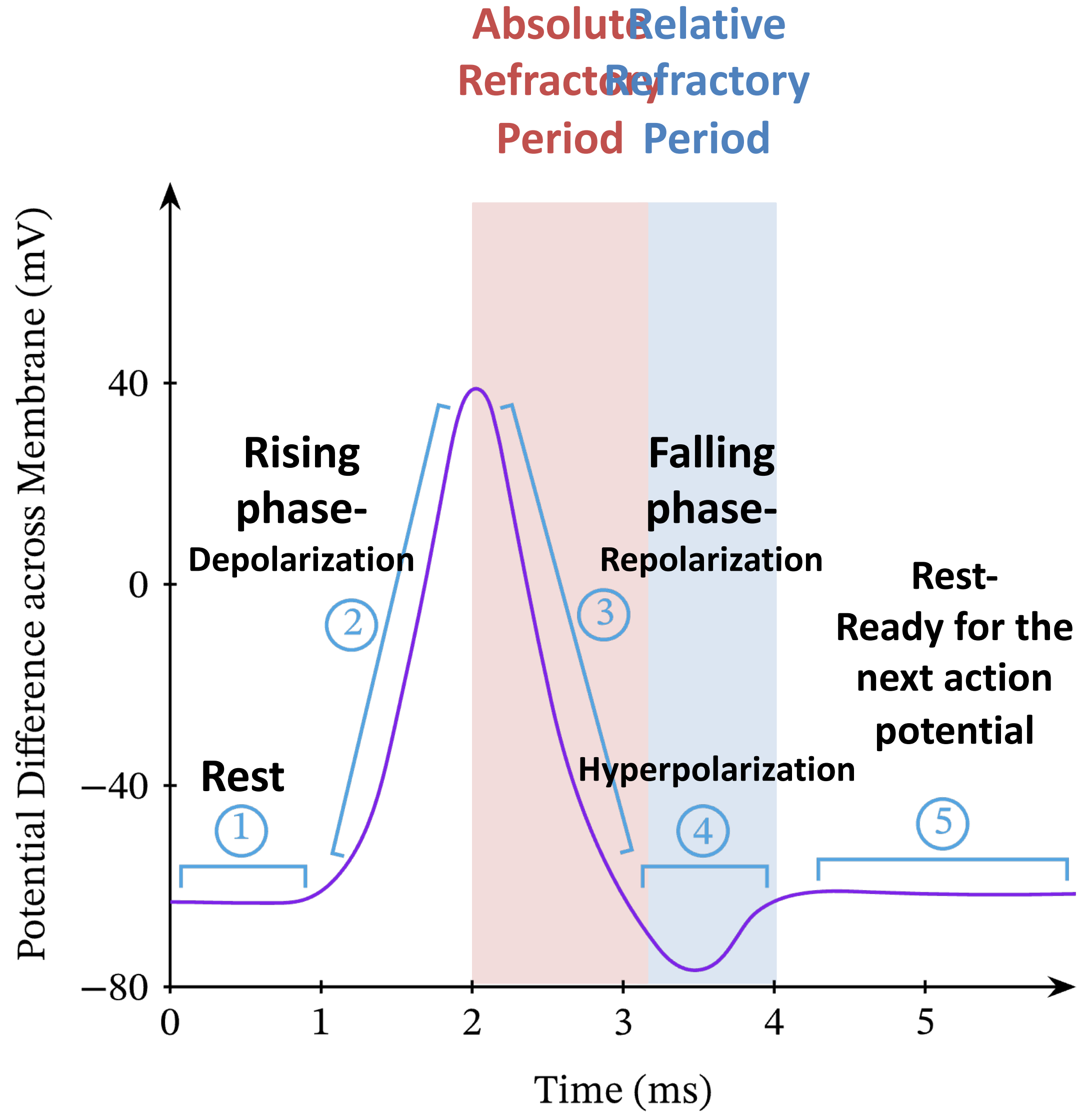
States of the Delayed Rectifier K^+ Channel

OPEN **CLOSED**

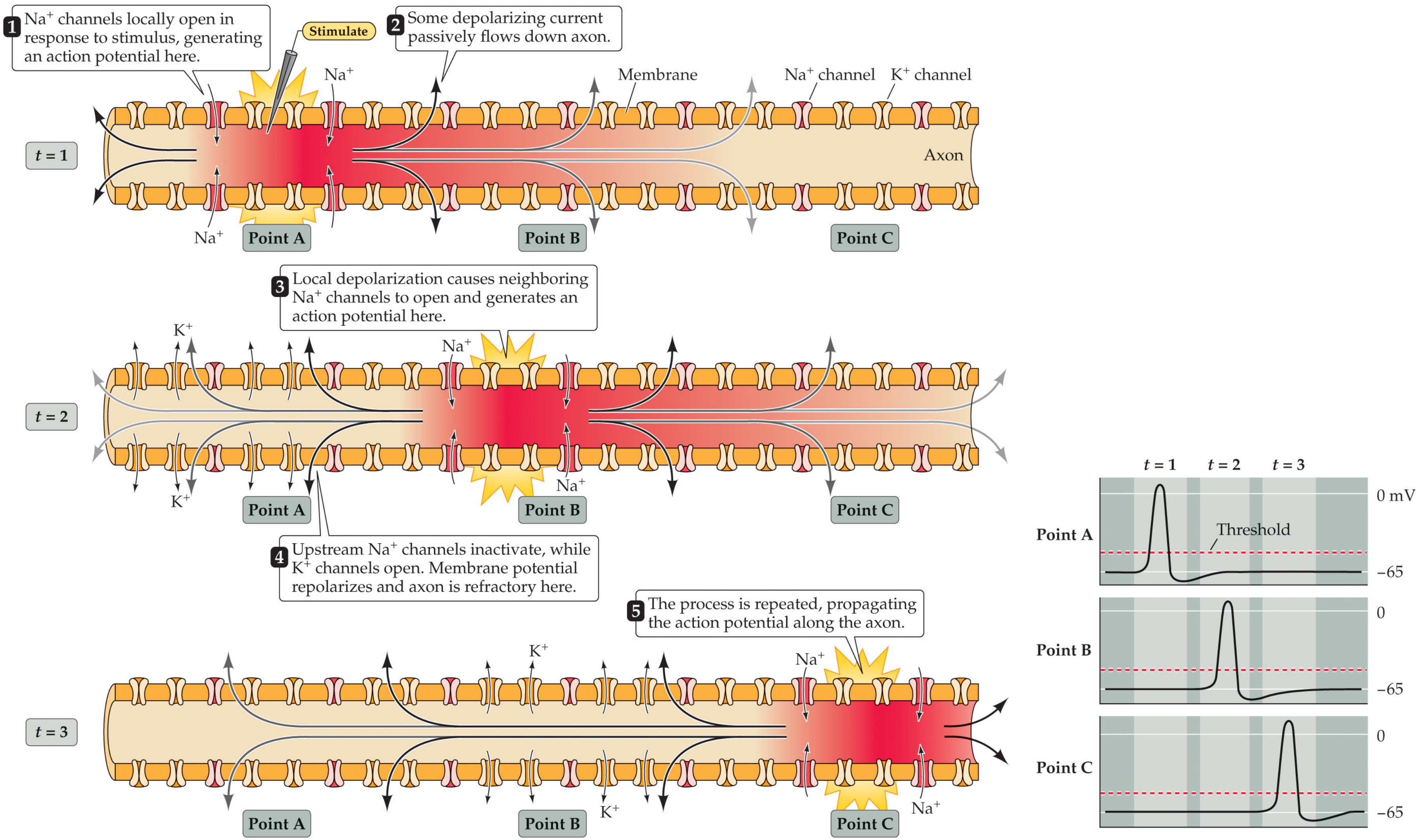




NEUROSCIENCE 6e, Figure 3.9



Action potential conduction requires **both active and passive** current flow



NEUROSCIENCE 6e, Figure 3.10

How do we make our action potentials **fast?**

TABLE 3.1 ■ Axon Conduction Velocities

Axon	Conduction velocity (m/s)	Diameter (μm)	Myelination
Squid giant axon	25	500	No
Human			
Motor axons			
Aα type	80–120	13–20	Yes
Aγ type	4–24	5–8	Yes
Sensory axons			
Aα type	80–120	13–20	Yes
Aβ type	35–75	6–12	Yes
Aδ type	3–35	1–5	Thin
C type	0.5–2.0	0.2–1.5	No
Autonomic			
preganglionic B type	3–15	1–5	Yes
postganglionic C type	0.5–2.0	0.2–1.5	No

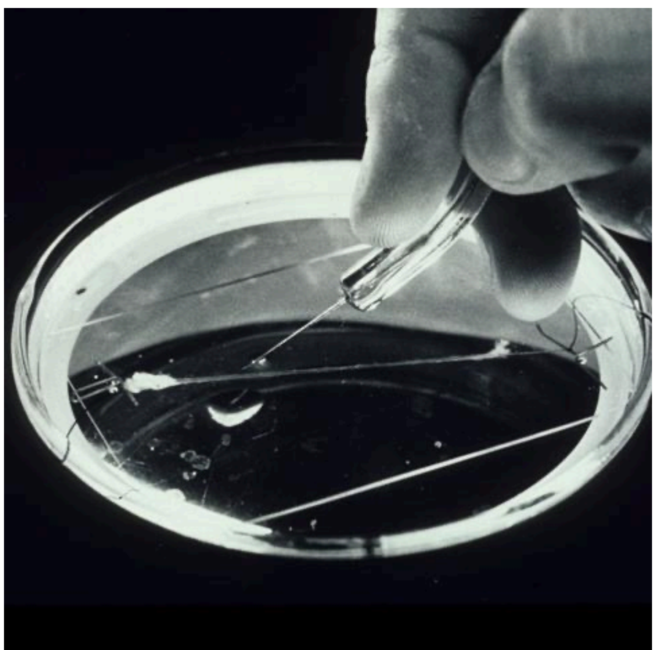
NEUROSCIENCE 6e, Table 3.1

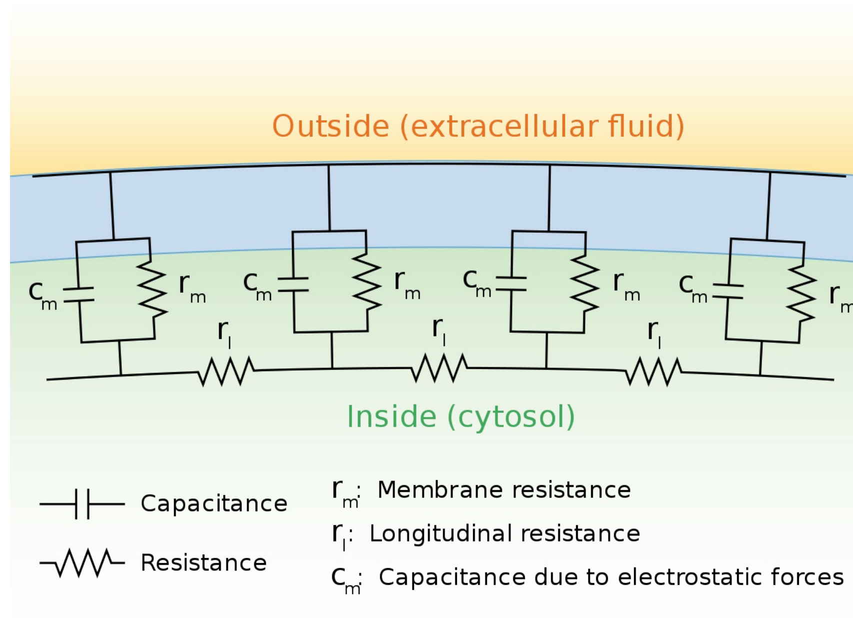
How do we make our action potentials **fast?**

$$Velocity \;\alpha\; \frac{1}{C_m}\sqrt{\frac{d}{4R_mR_i}}$$

1. Large diameter axon

Resistance of a “wire” varies inversely with cross sectional area





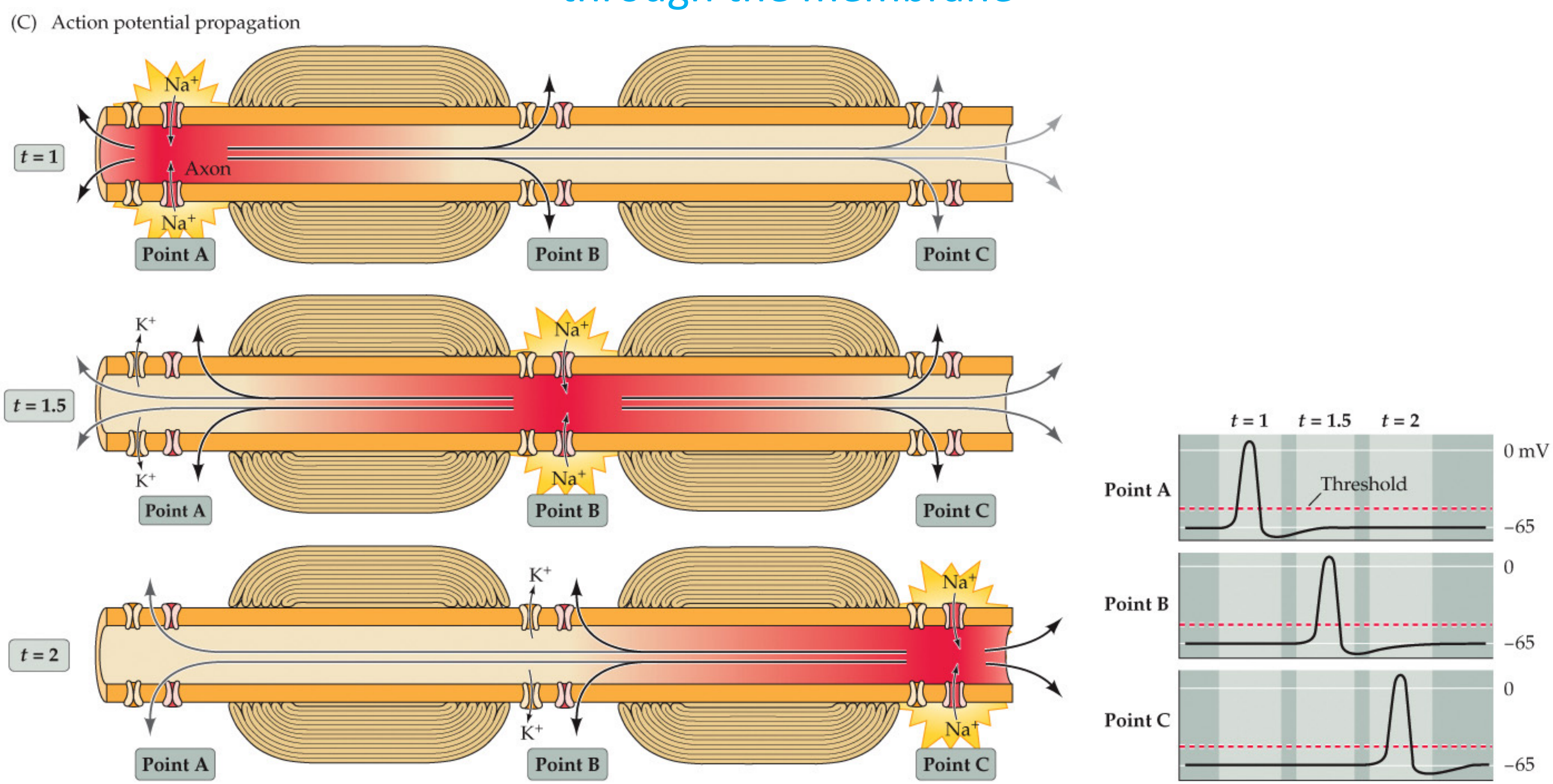
$$R = \frac{\rho L}{A}$$

ρ = resistivity
L = length
A = cross sectional area

$$Velocity \;\alpha\; \frac{1}{C_m}\sqrt{\frac{d}{4R_mR_i}}$$

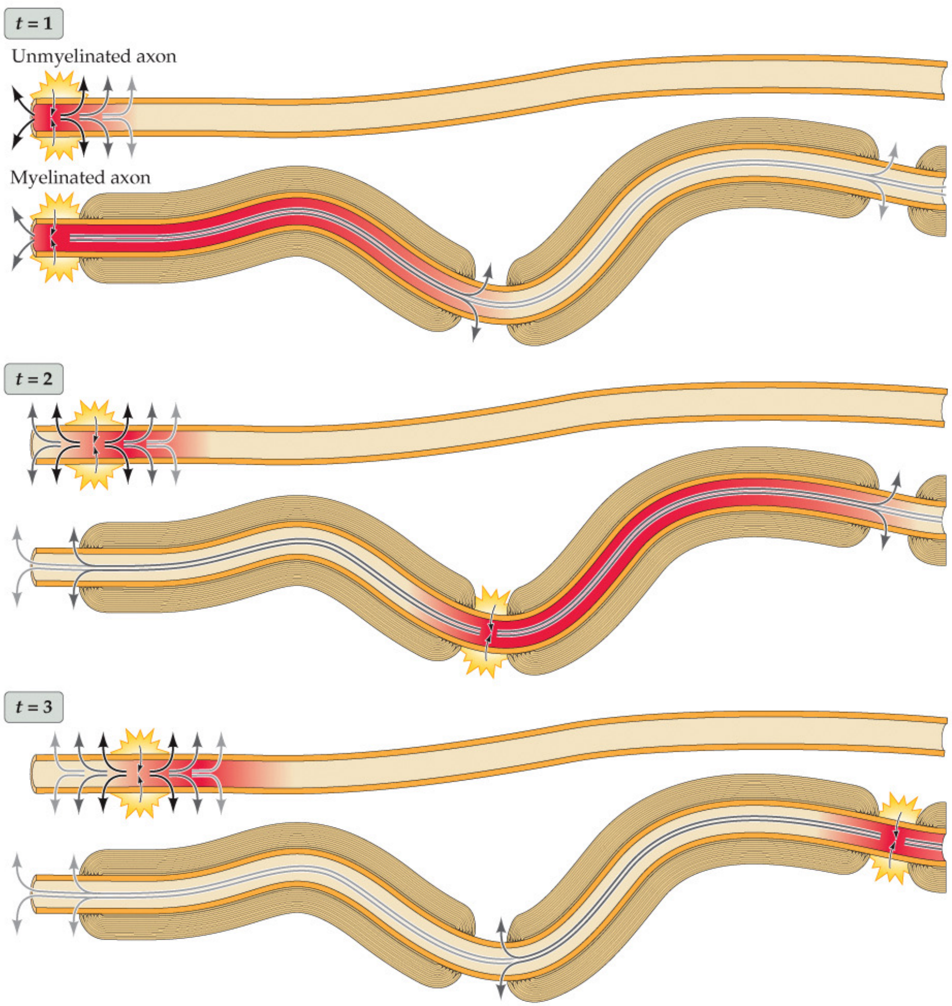
2. Saltatory conduction of action potentials

The myelin sheath increases conduction speed by reducing current loss through the membrane

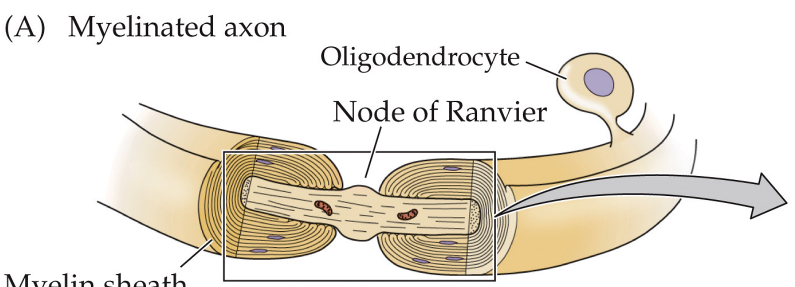


NEUROSCIENCE 6e, Figure 3.11 (Part 3)

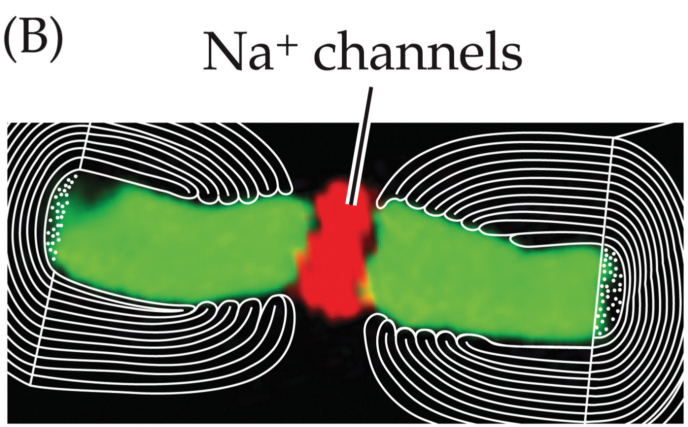
2. Saltatory conduction of action potentials

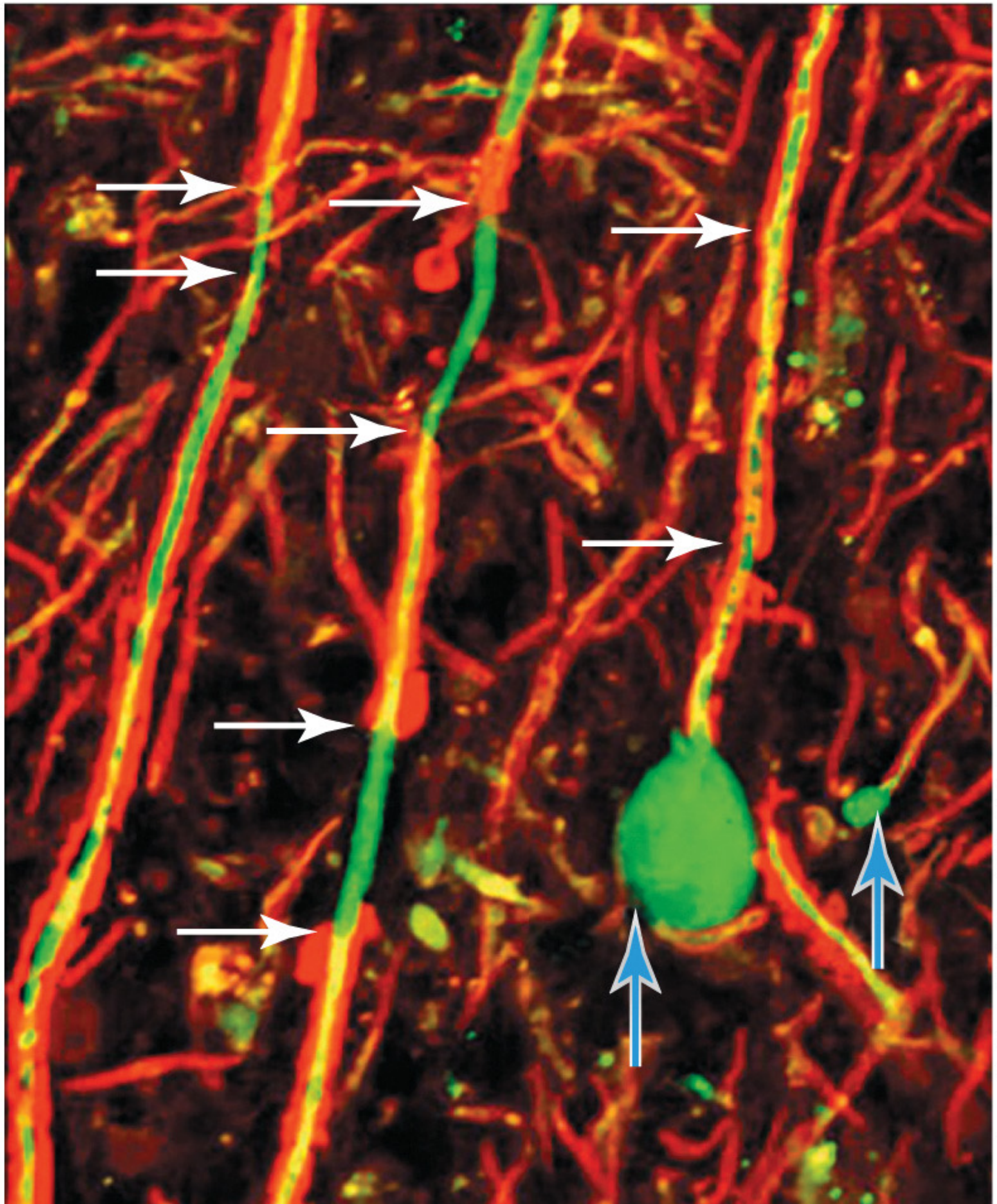


NEUROSCIENCE 6e, Figure 3.12



NEUROSCIENCE 6e, Figure 3.11 (Part 1)





From Trapp, B. D and P.K. Stys (2009) *Lancet Neurol.* 8: 280–291.

NEUROSCIENCE 6e, Clinical Applications 3

Multiple Sclerosis

- Inflammation and demyelination of the central nervous system
- Abnormal patterns in action potential conduction likely lead to most symptoms