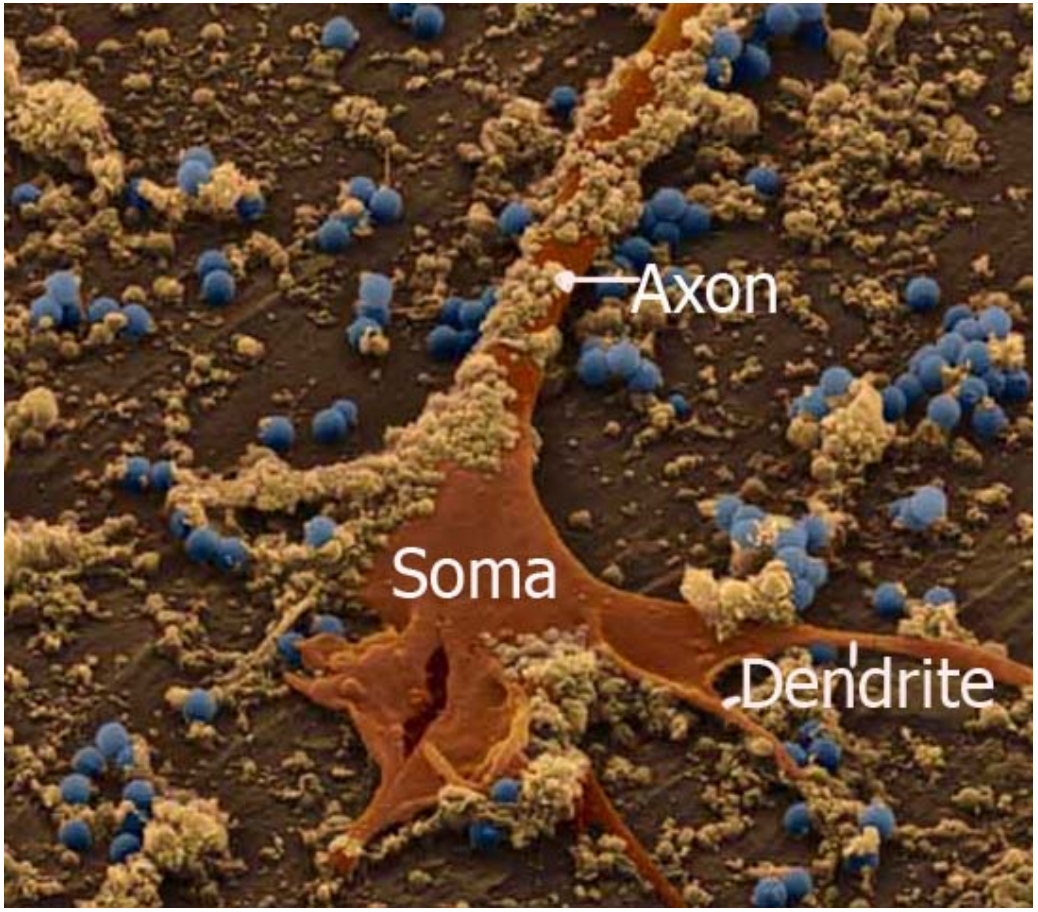
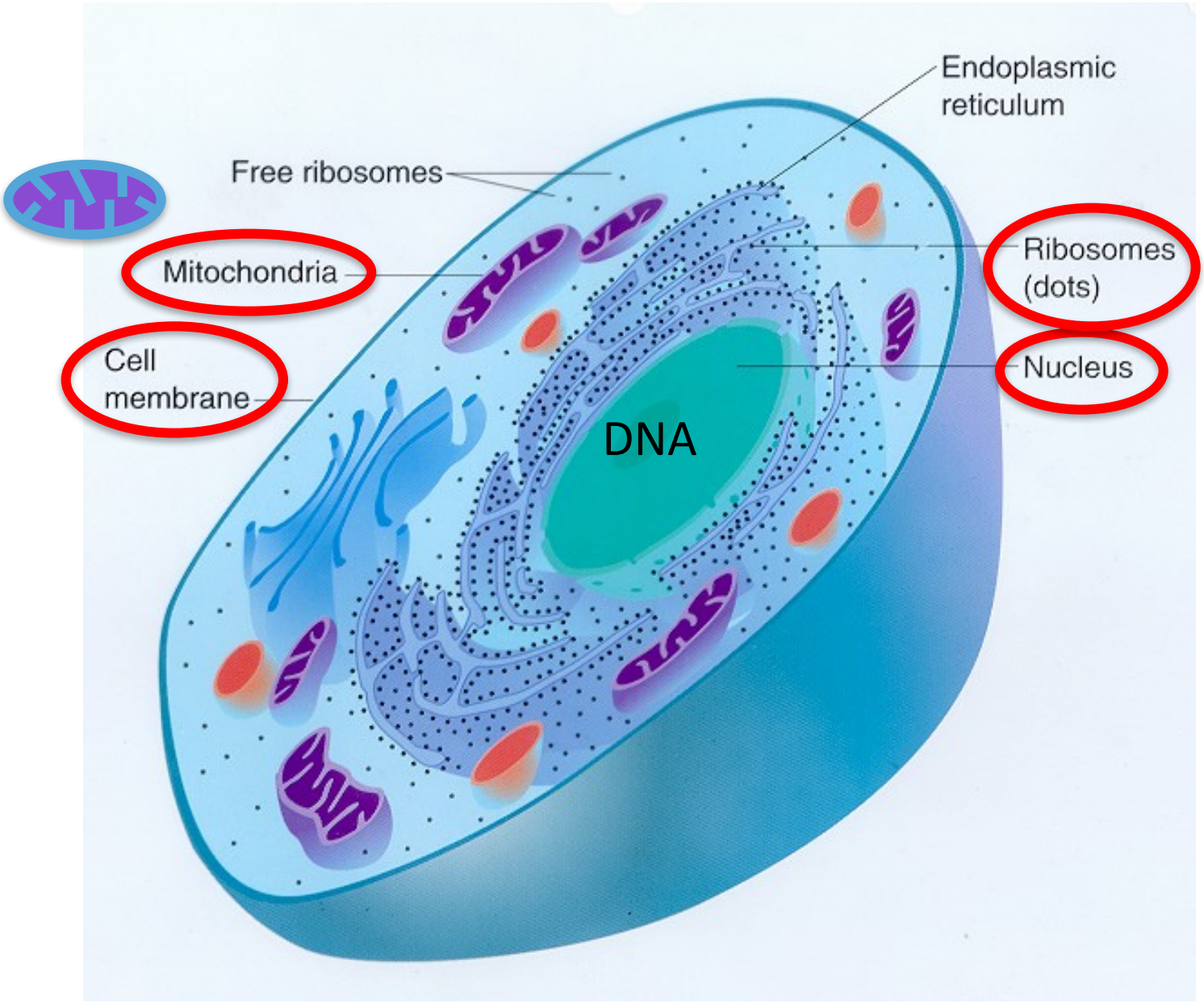
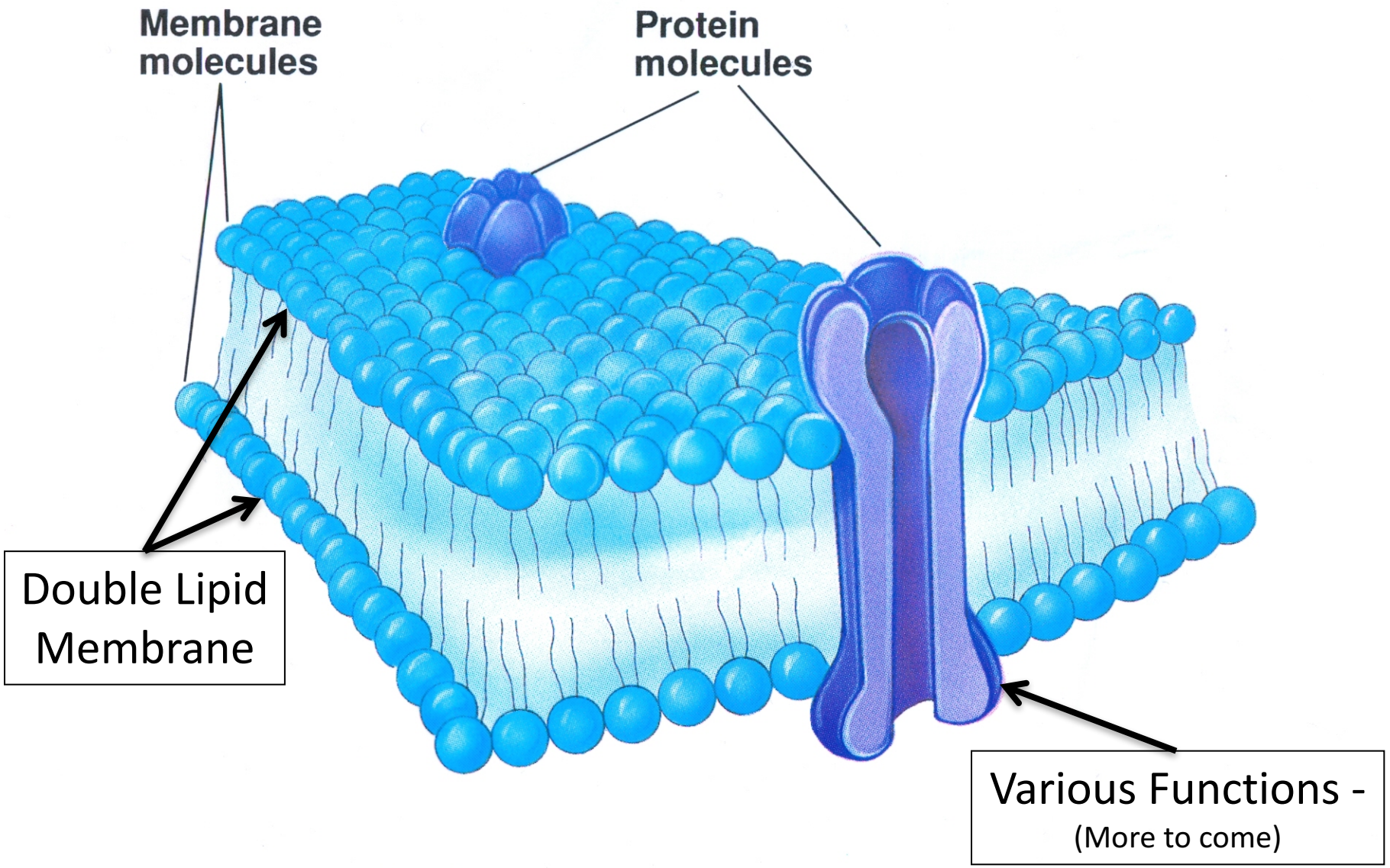
Lec 2a: Neural Functioning



Cogs 17 * Dept of Cognitive Science * UCSD

The Cell


Endoplasmic reticulum
Free ribosomes
Ribosomes (dots)
Mitochondria
Cell membrane
Nucleus
DNA

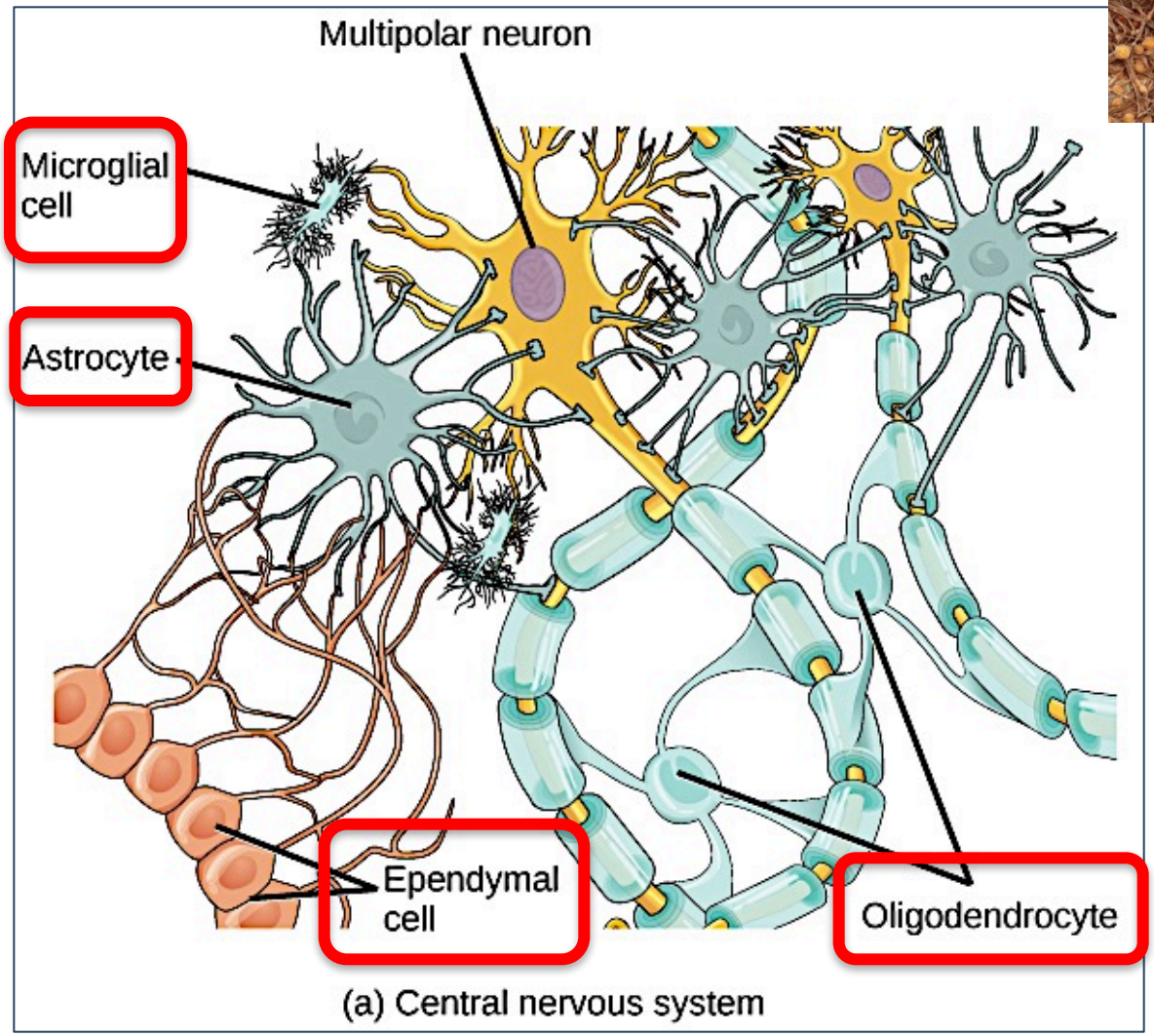


Neuron membrane

Neurons & Glia

Some of the many functions of

GLIA CELLS



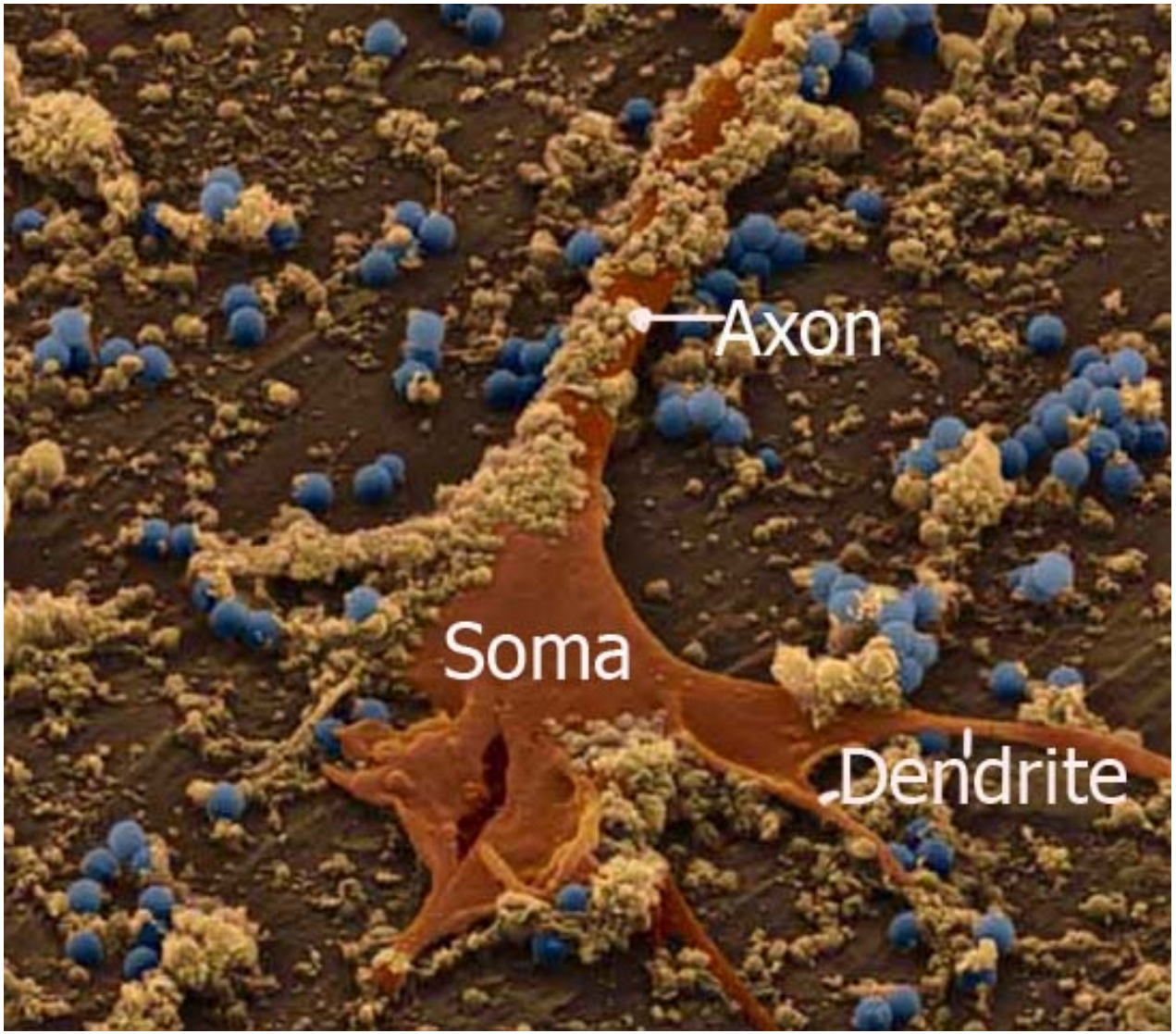
1/10 size of a neuron

10X as many

50% of brain by weight

< Myelinization

The Neuron



How small is a neuron?

Or, to think of it another way . . .

Suppose that **YOU** . . .

. . .were to shrink down to the size of a neuron,

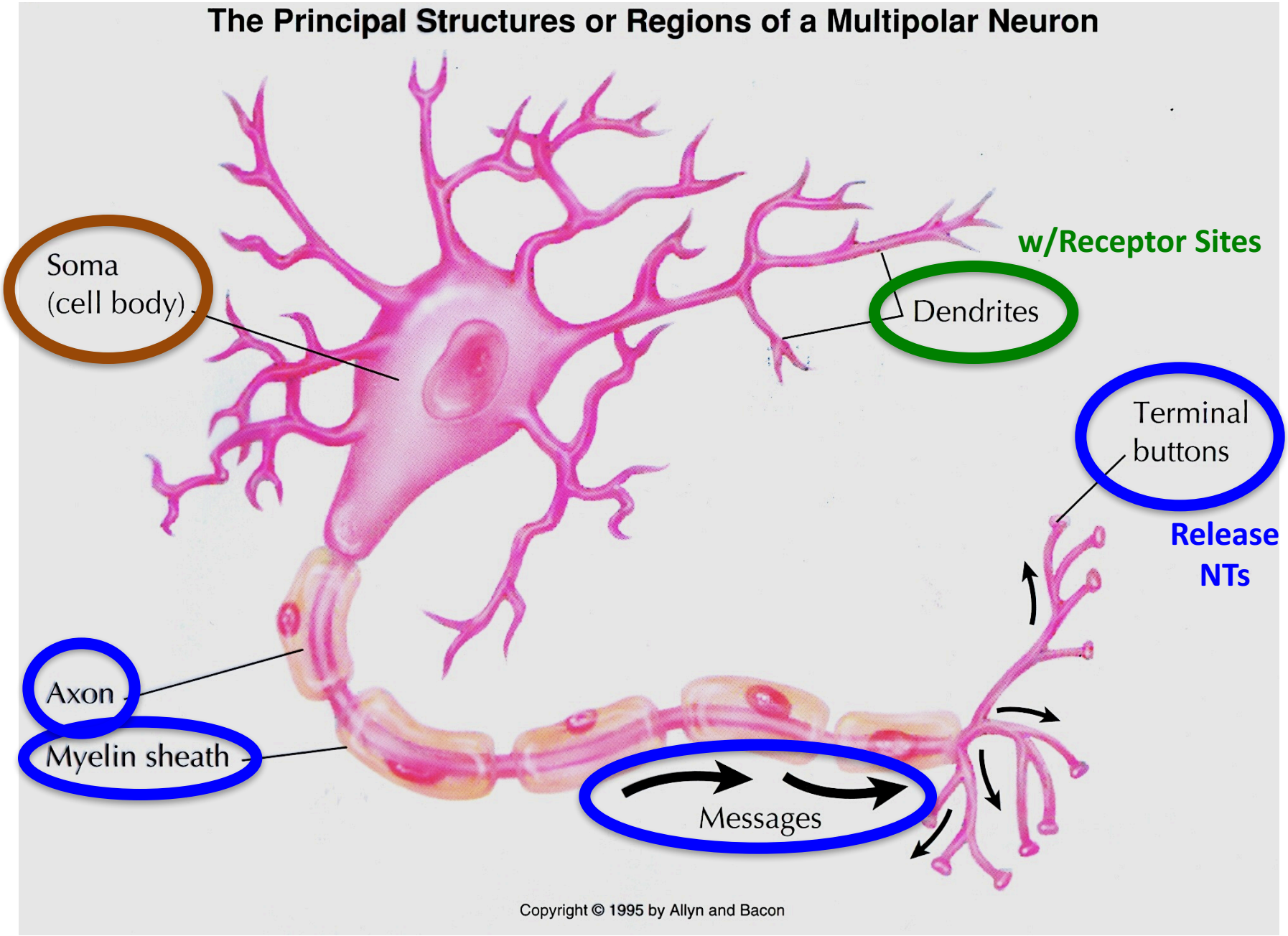
such that the neuron would seem to you as big as a car . . .

. . . the "real" Prius would look big enough to stretch from San Diego to New York!

BUT -- Neuron's branches can be 2m long!

A million times longer than their bodies.

Neuron cell-body diameters range from ~4 X 10^{-6}m


The Principal Structures or Regions of a Multipolar Neuron
Soma
(cell body)
Dendrites
w/Receptor Sites
Terminal
buttons
Release
NTs
Axon
Myelin sheath
Messages
Copyright © 1995 by Allyn and Bacon

The IONS

Charged particles
w/extra electrons (-) or fewer electrons (+)

Sodium

Potassium

Chloride

Calcium

The Nerve Impulse

To understand how Neurons "communicate"
we first need to recognize that

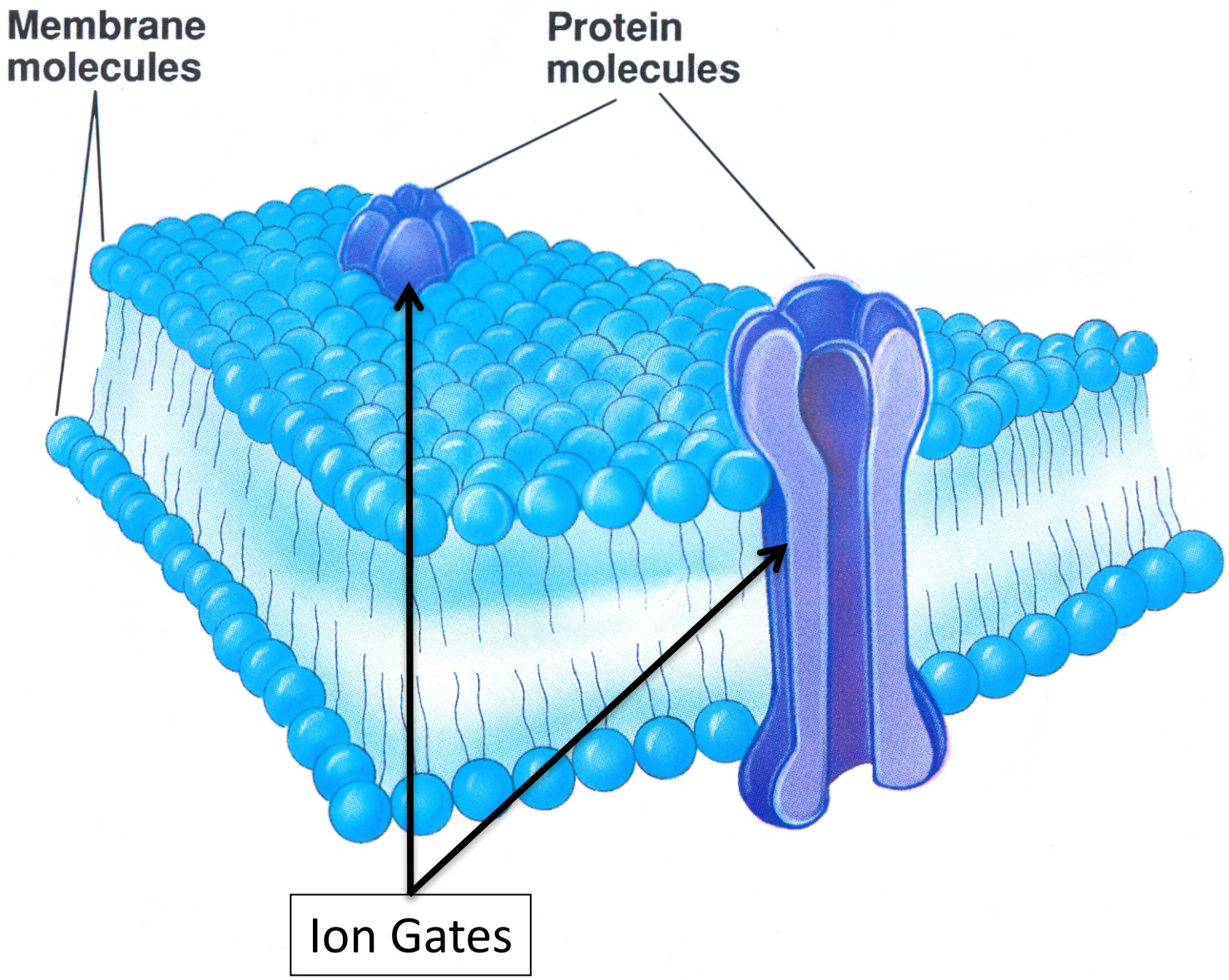
Nature seeks a Balance . . .

Any GRADIENT (inequality)
between chemicals inside vs. outside cell will,
if allowed, tend toward an equilibrium...

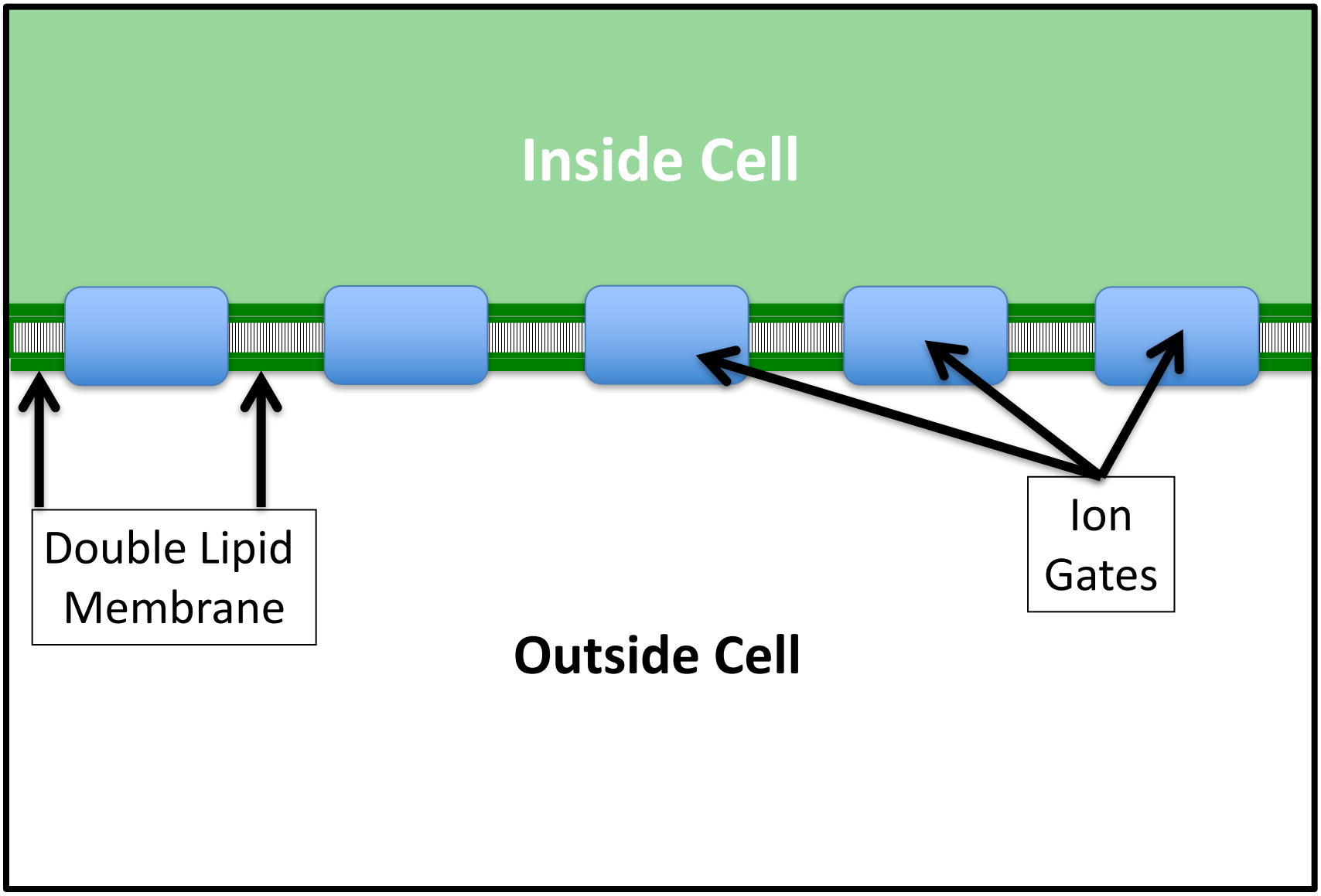
Concentration Gradient

Electrical Gradient

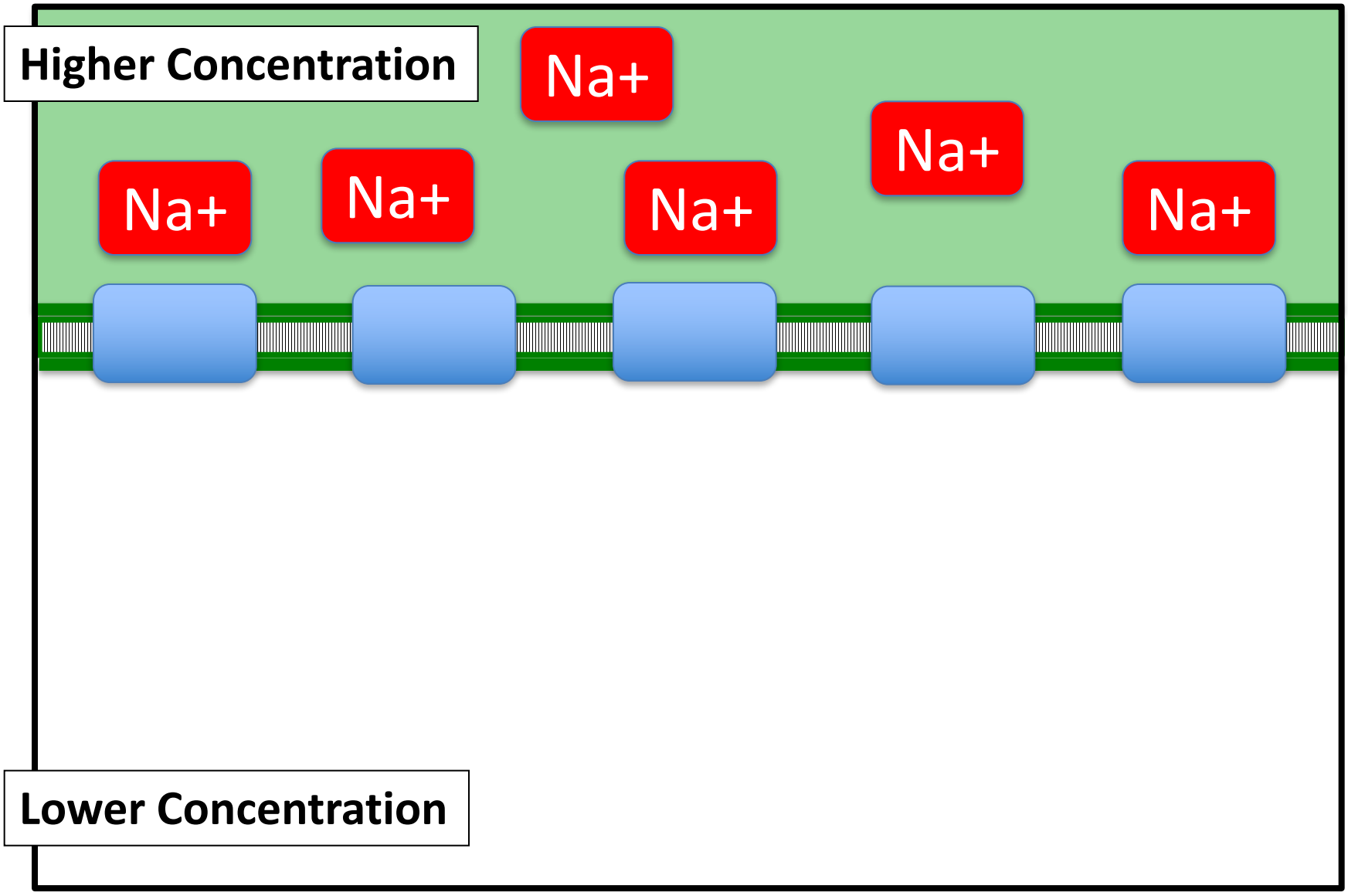
Concentration Gradient



Neuron membrane

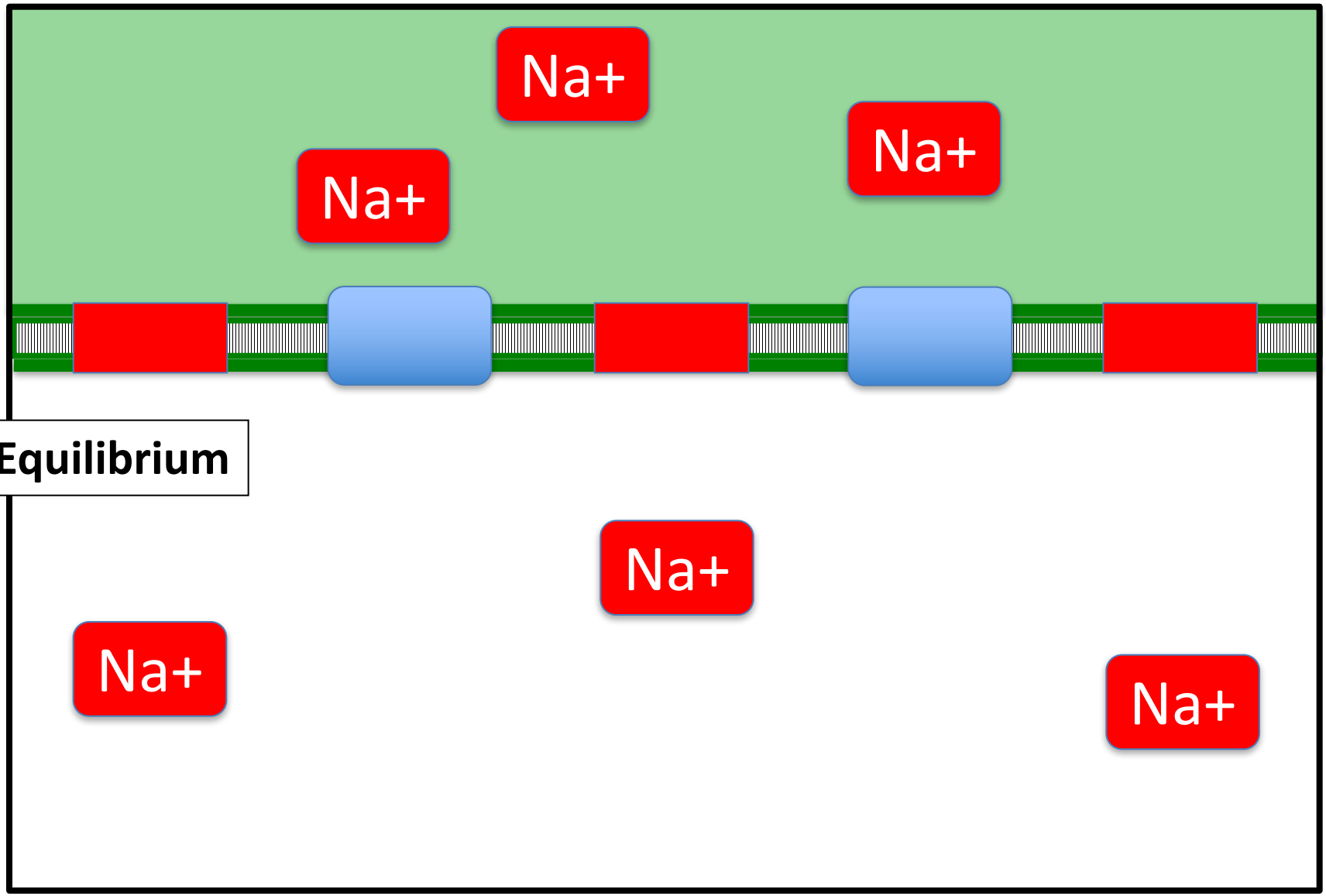

Inside Cell
Double Lipid Membrane
Ion Gates
Outside Cell

CONCENTRATION Gradient



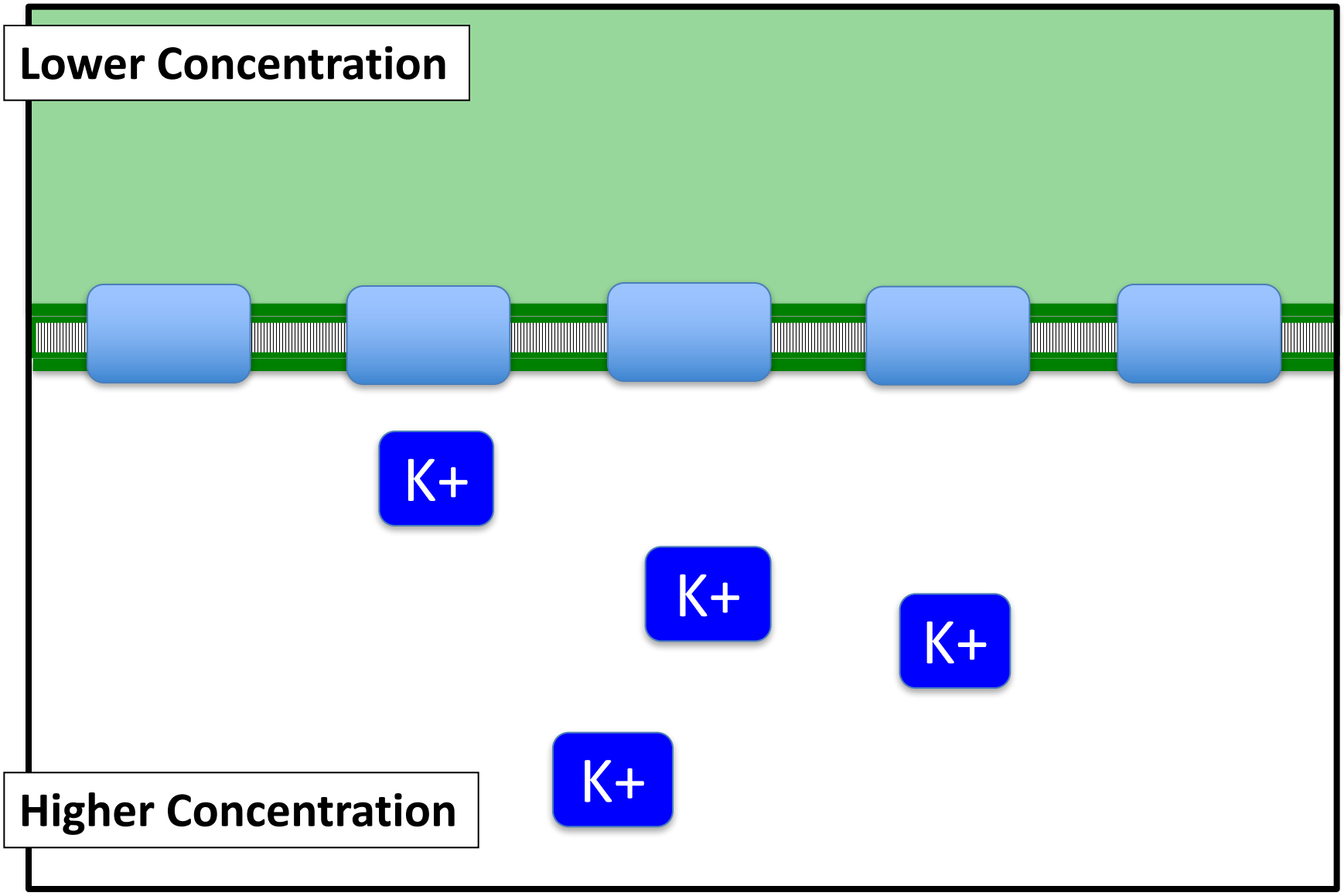
via Diffusion

CONCENTRATION Gradient



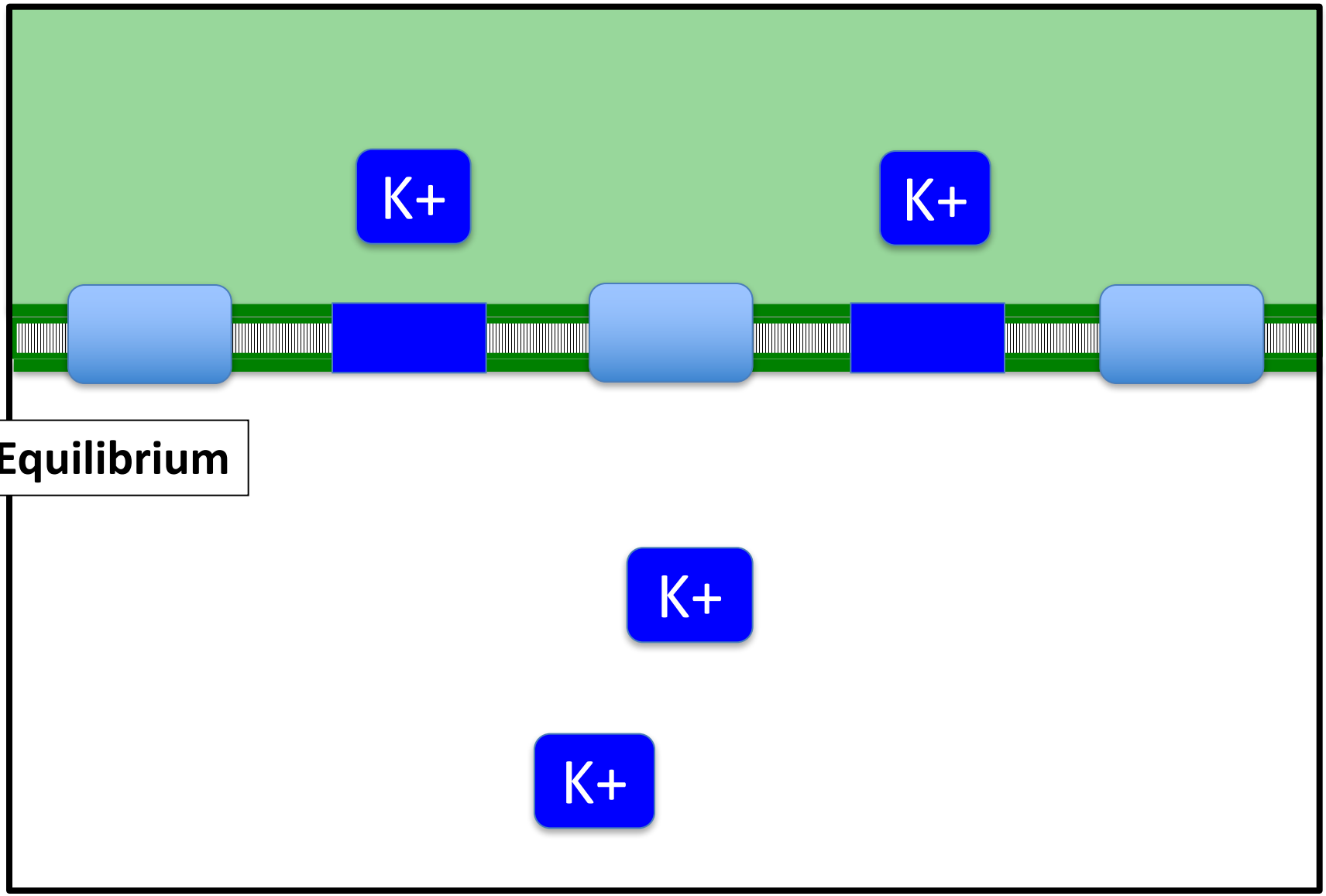
via Diffusion

CONCENTRATION Gradient



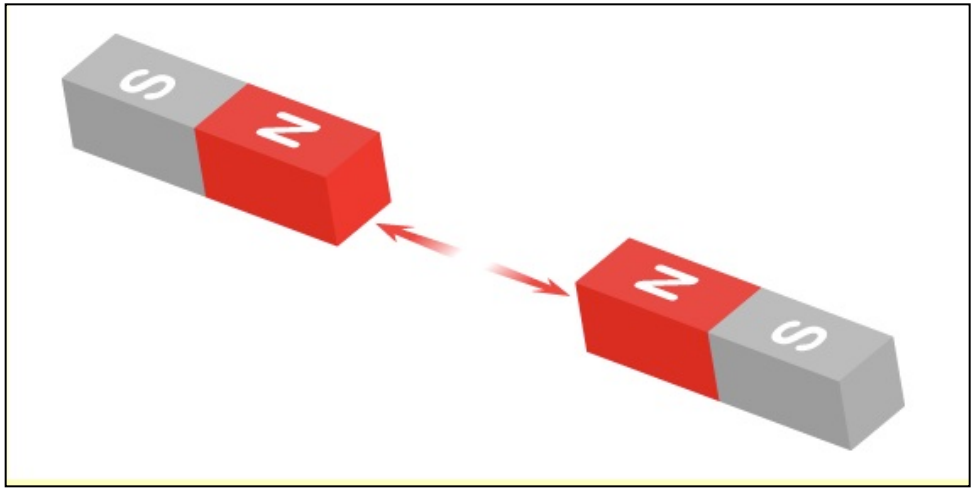
via Diffusion

CONCENTRATION Gradient



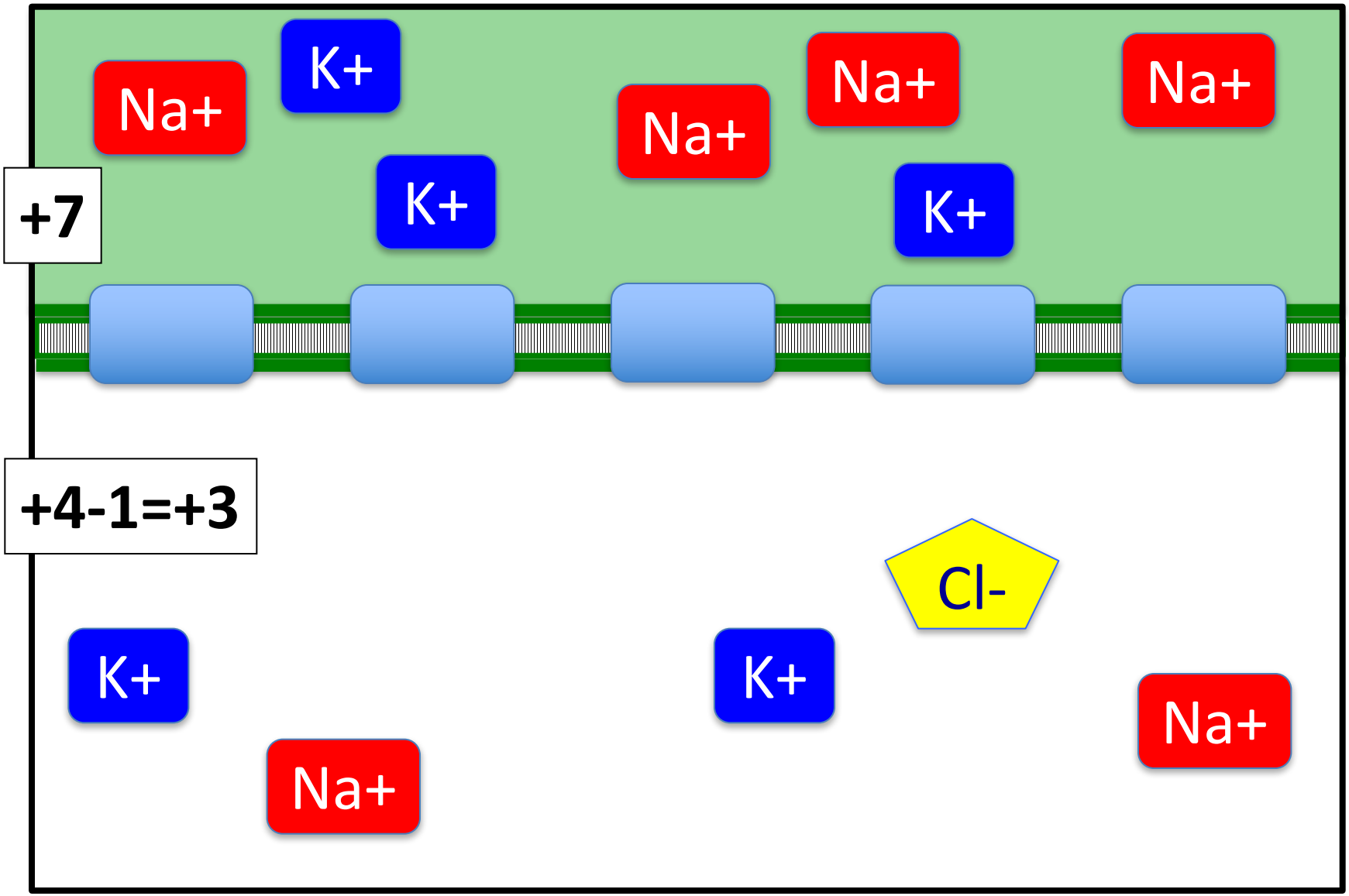
via Diffusion

Electrical Gradient



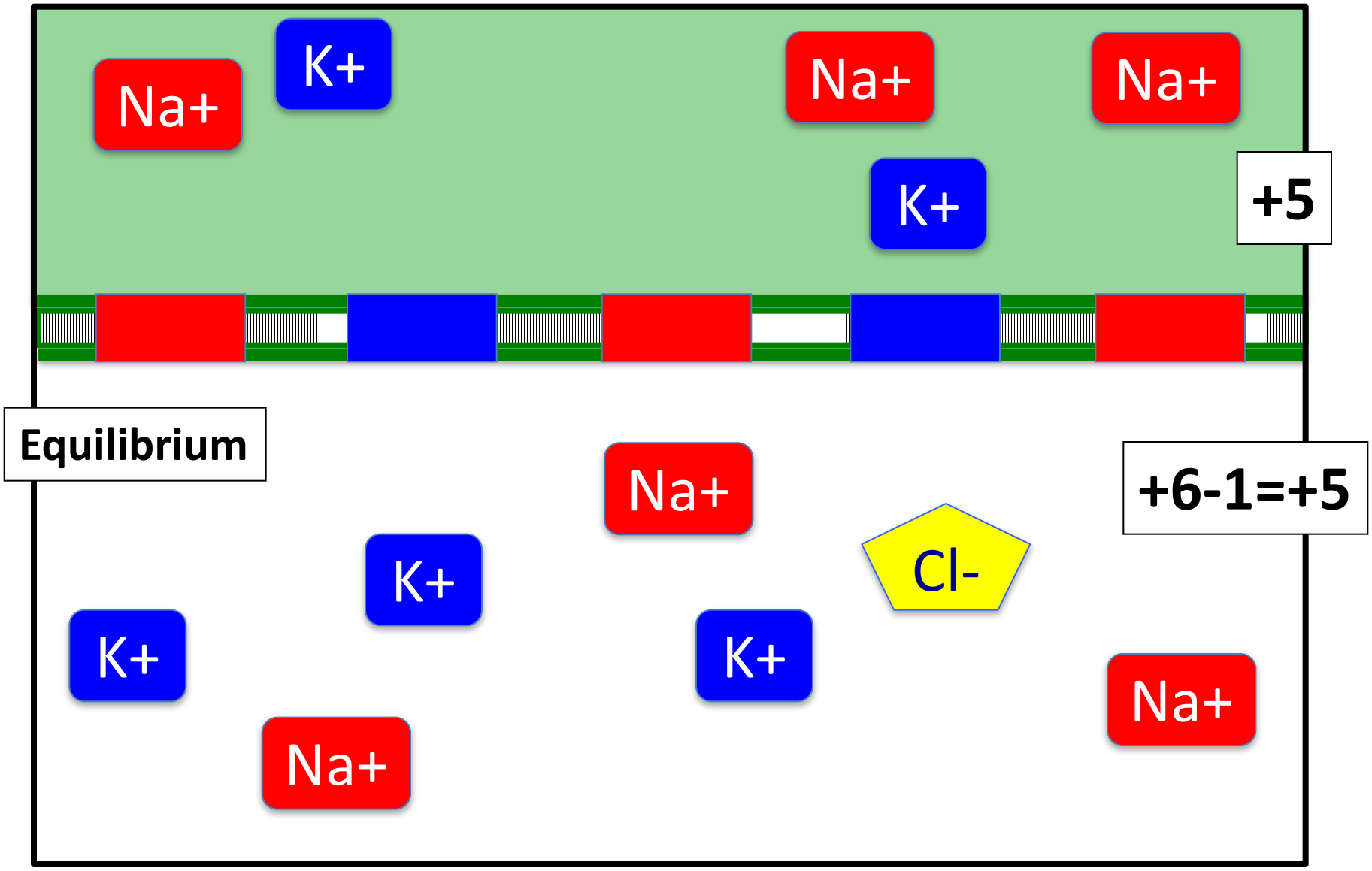
Identical charges
REPEL

ELECTRICAL Gradient



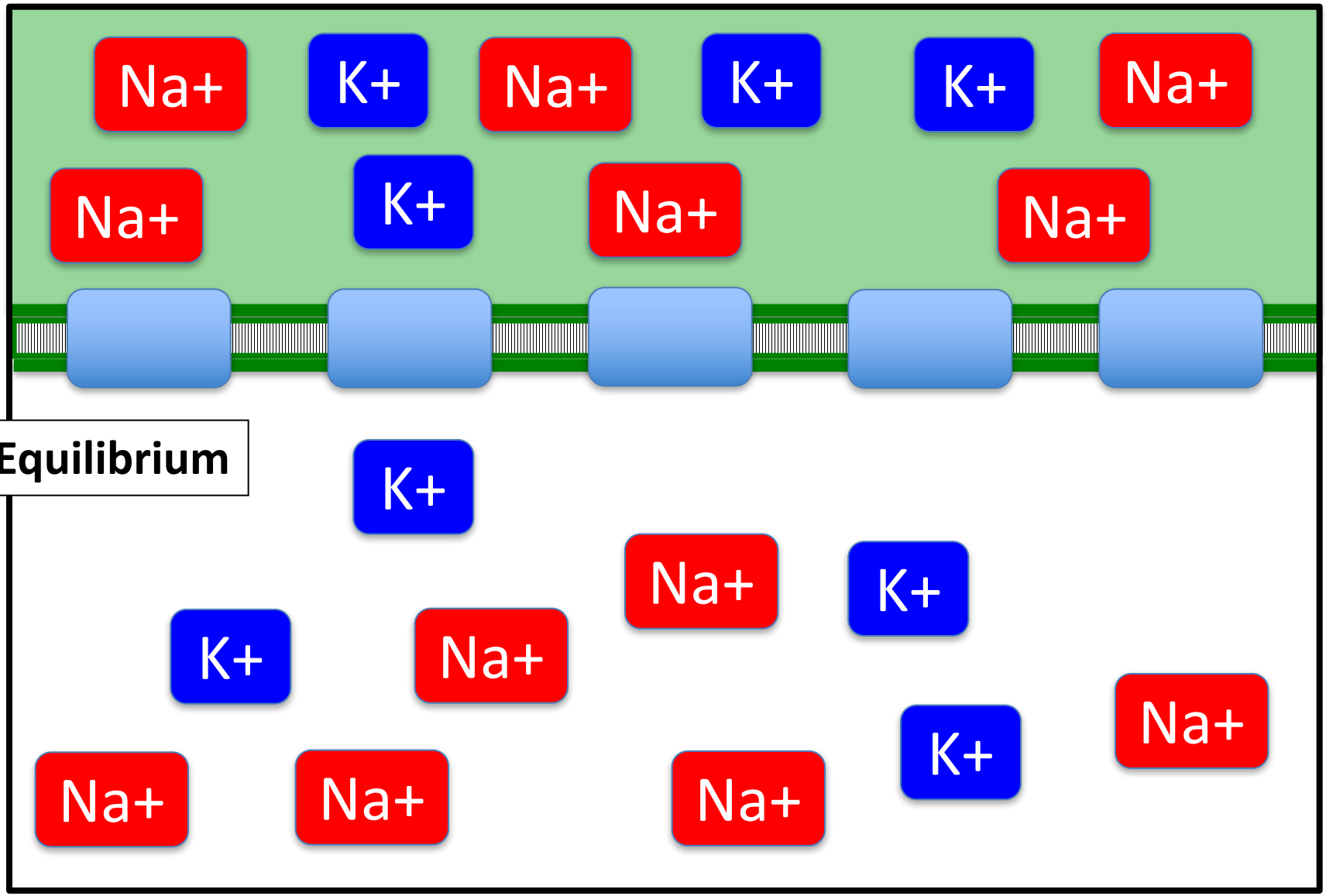
via Electrostatic Pressure

ELECTRICAL Gradient

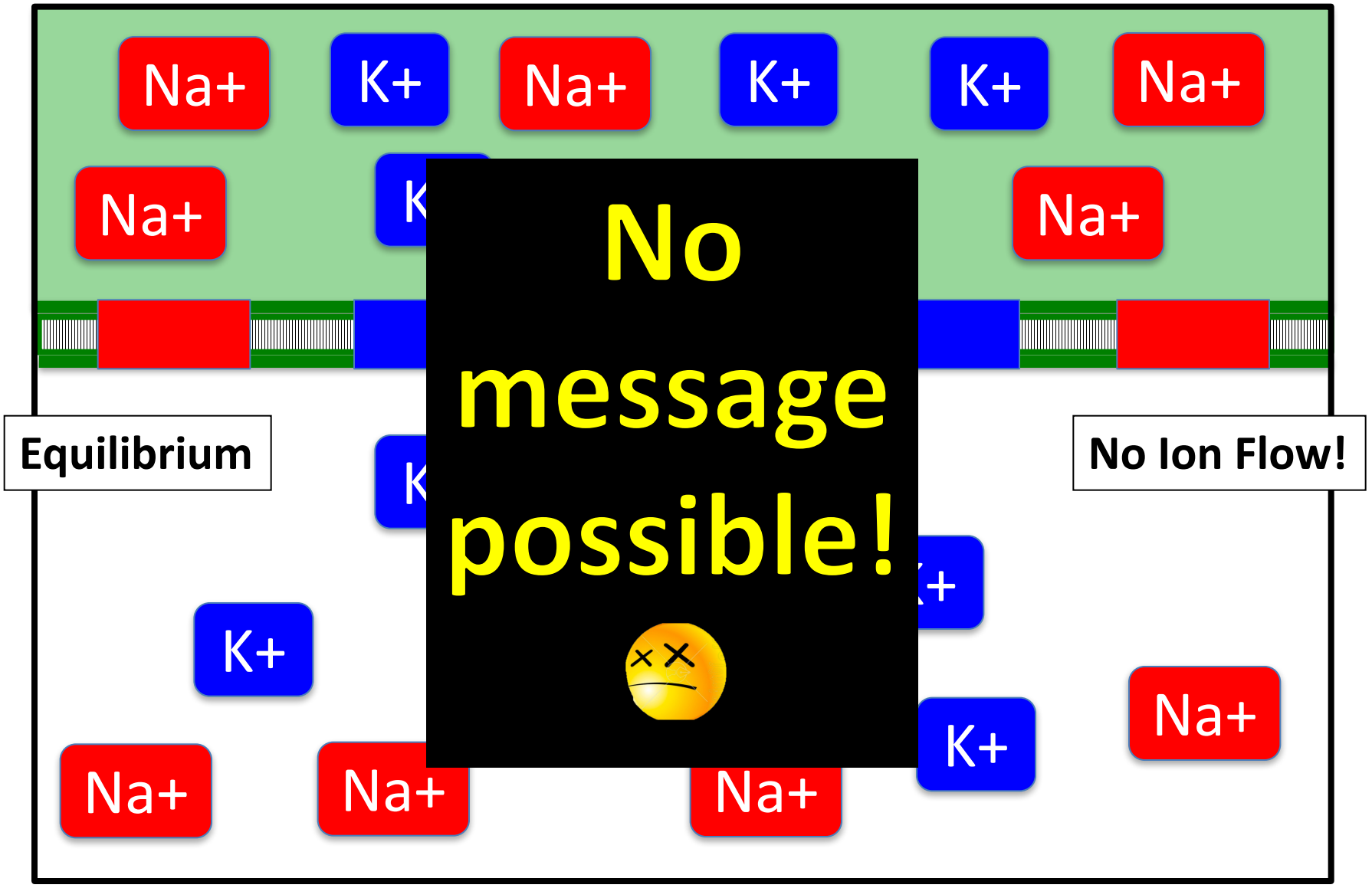


via Electrostatic Pressure

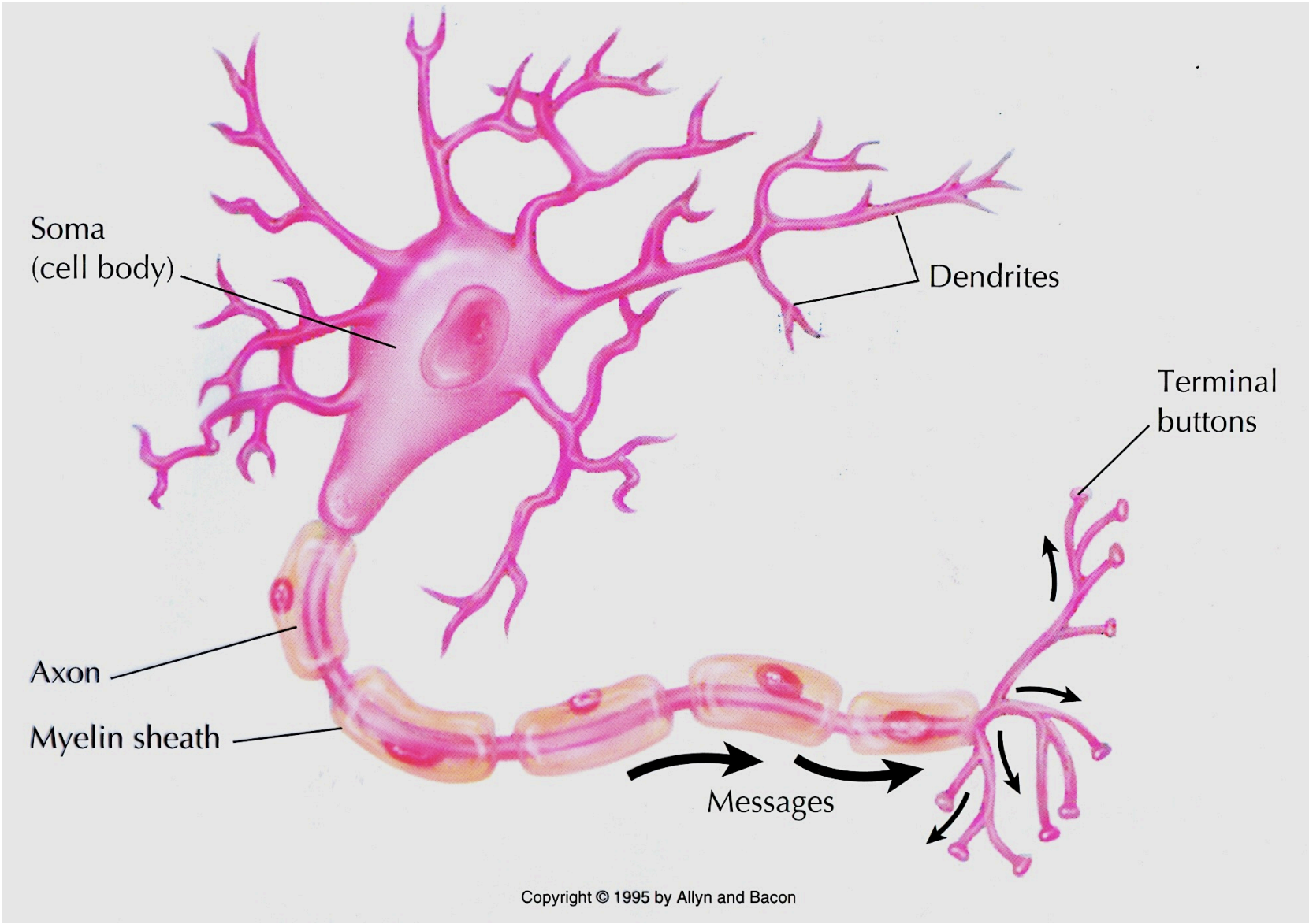
Equilibrium = NO Potential



Equilibrium = NO Potential

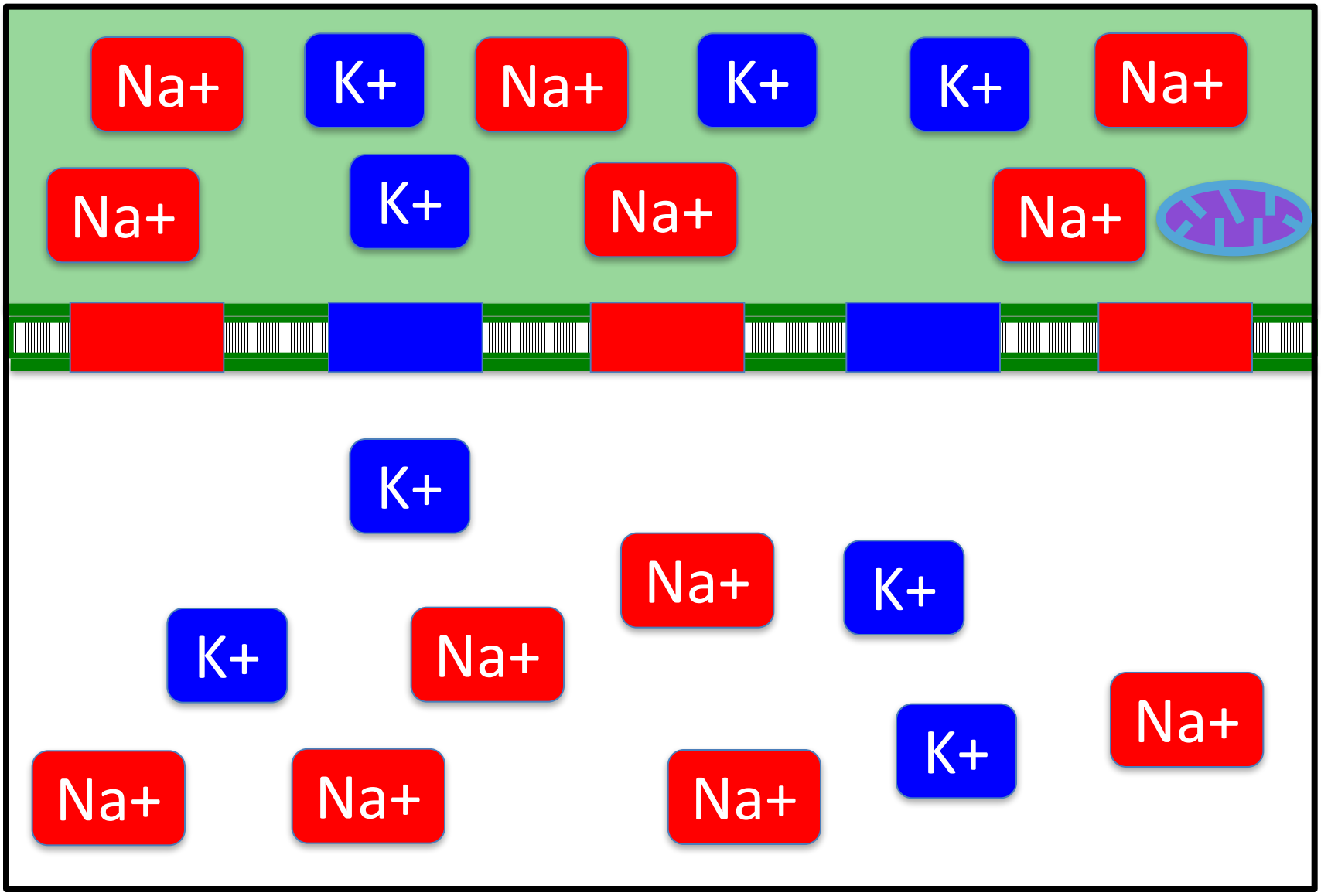


Let's look at ion conditions in an actual neuron...



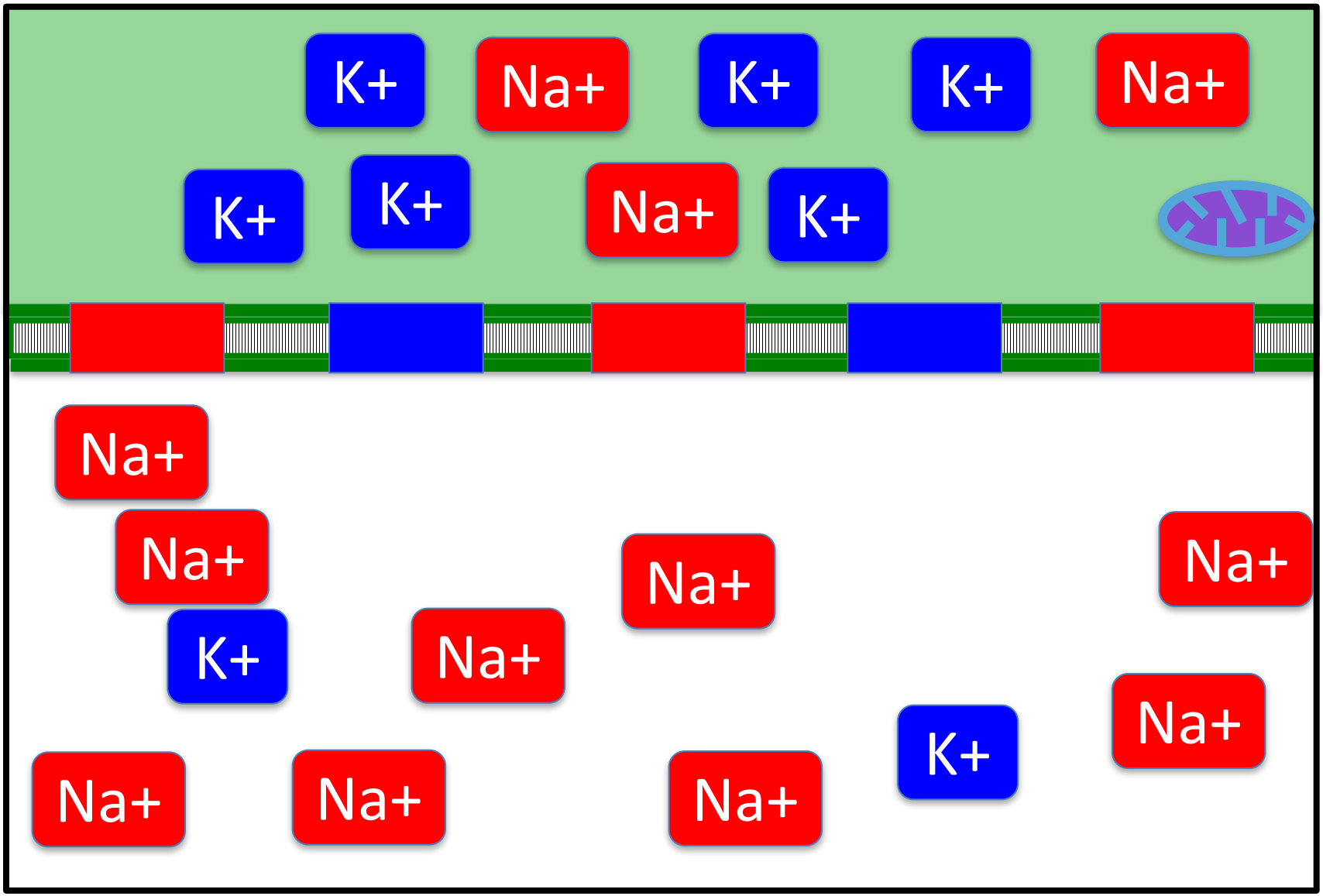
Instead of being at Equilibrium, a "Resting" Neuron is

HIGHLY POLARIZED



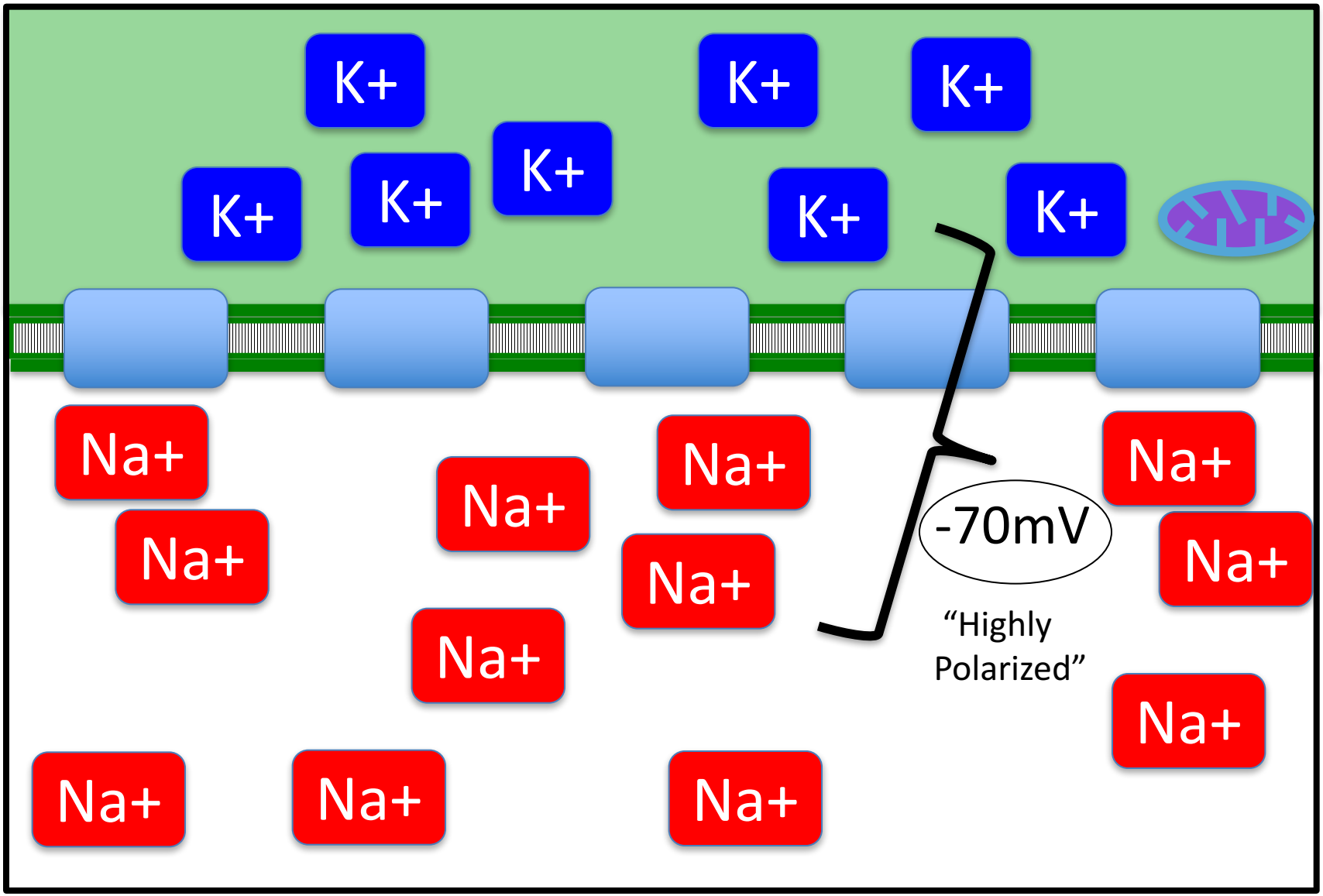
It reaches this HIGHLY POLARIZED state by moving

3 Na+ Out for every 2 K+ In

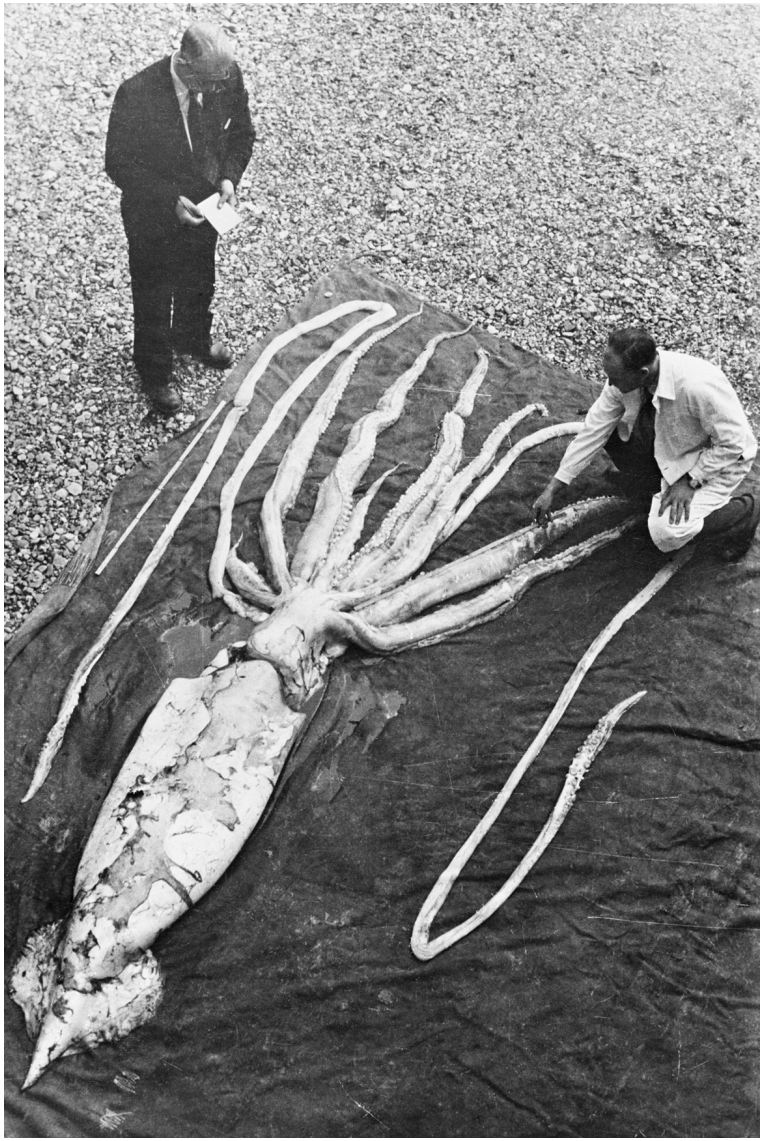


Accomplished by Energy-Requiring **Na+/K+ PUMP**

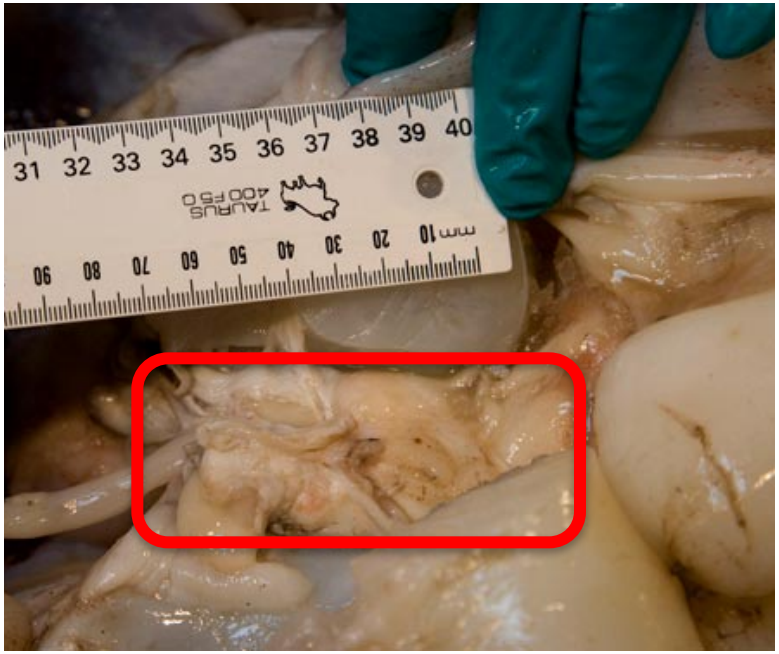
Then all gates are locked = "**Resting Potential**"



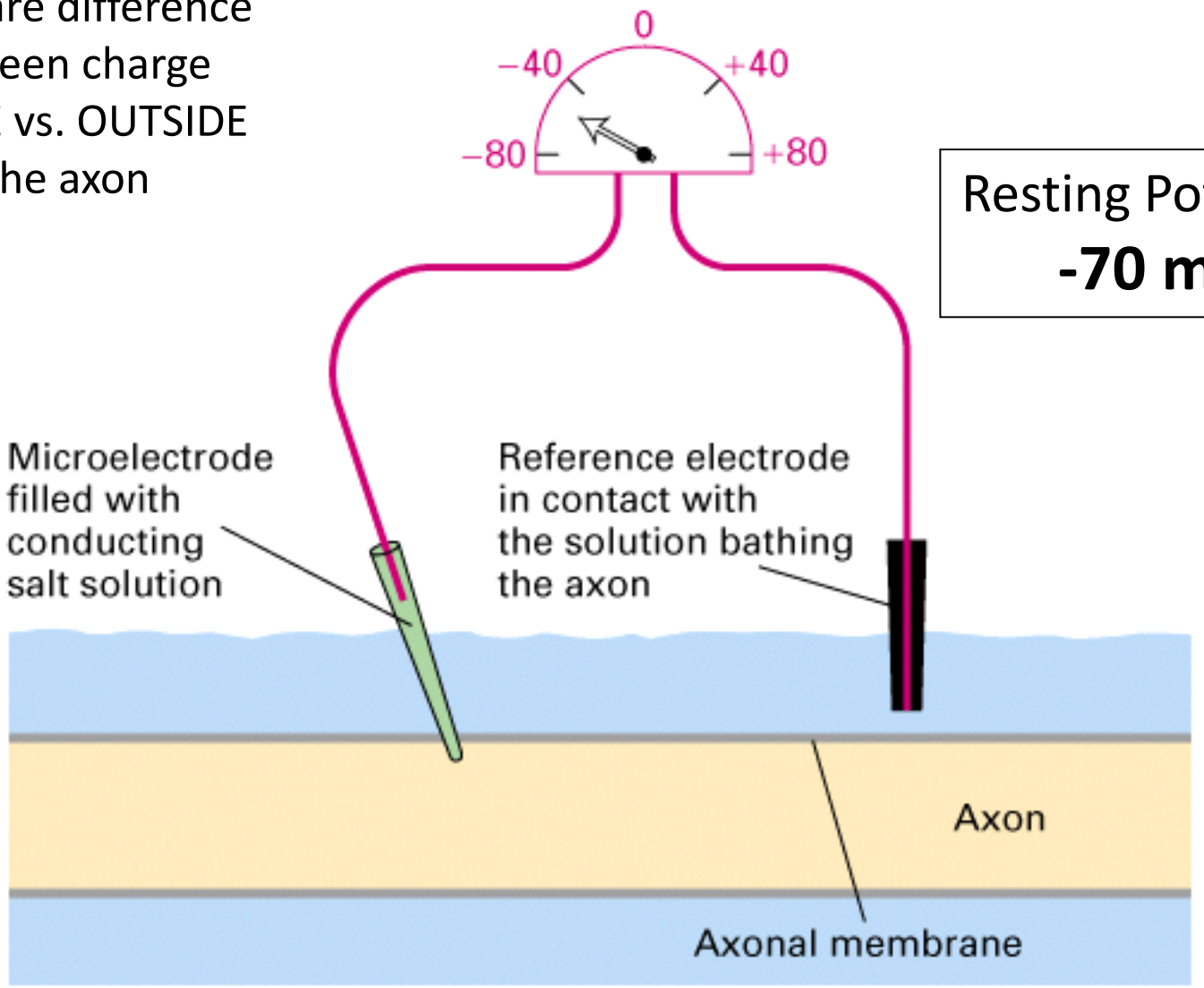
Giant Squid Axons



Unlike most neurons,
those of the Giant Squid are
actually visible



Compare difference between charge INSIDE vs. OUTSIDE the axon



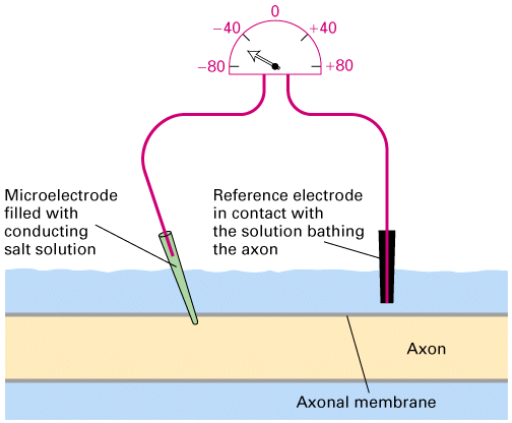
Resting Potential

-70 mV

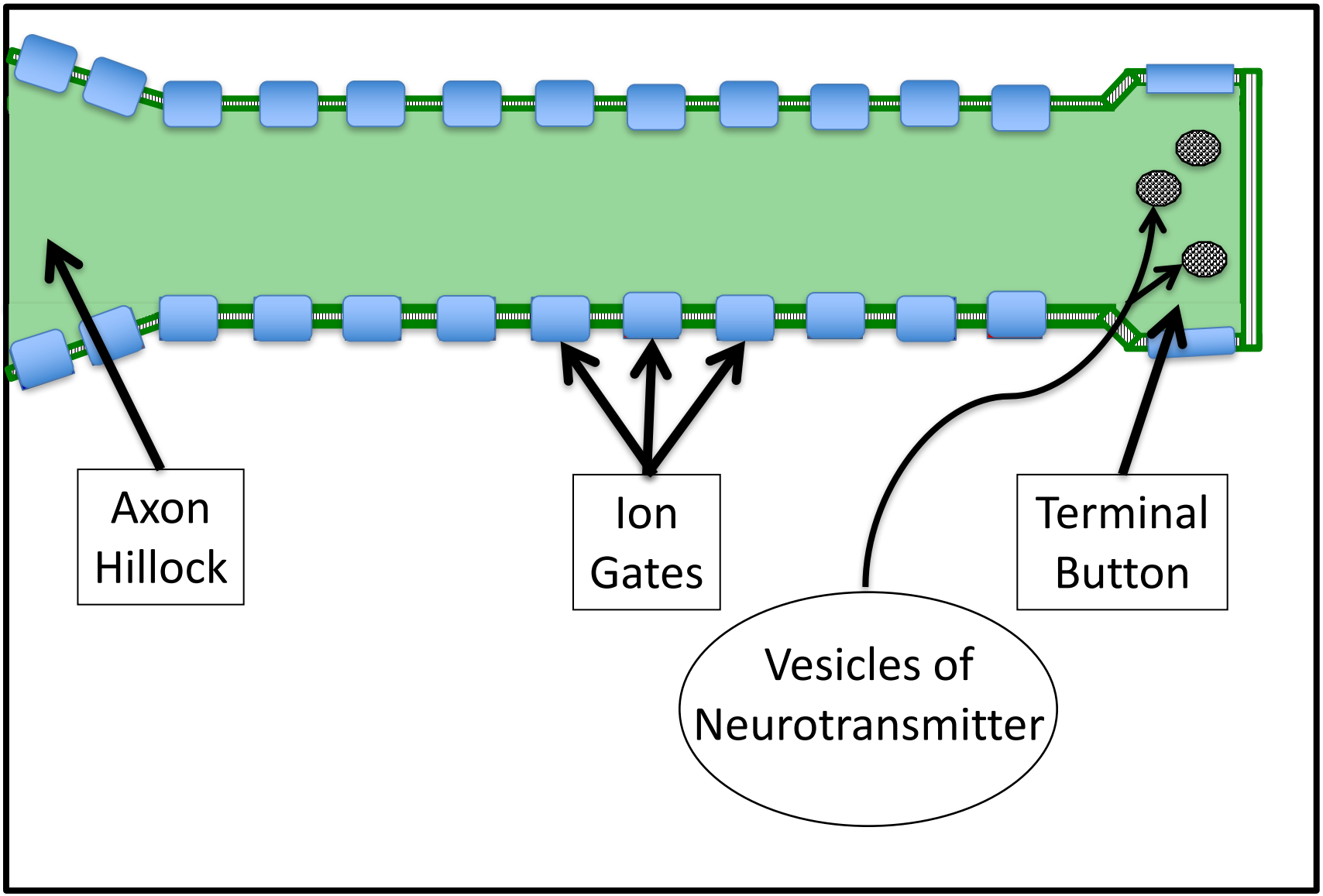
Resting Potential MNEMONIC

The Resting Cell
is Polarized,
more positive OUT
than it is INSIDE

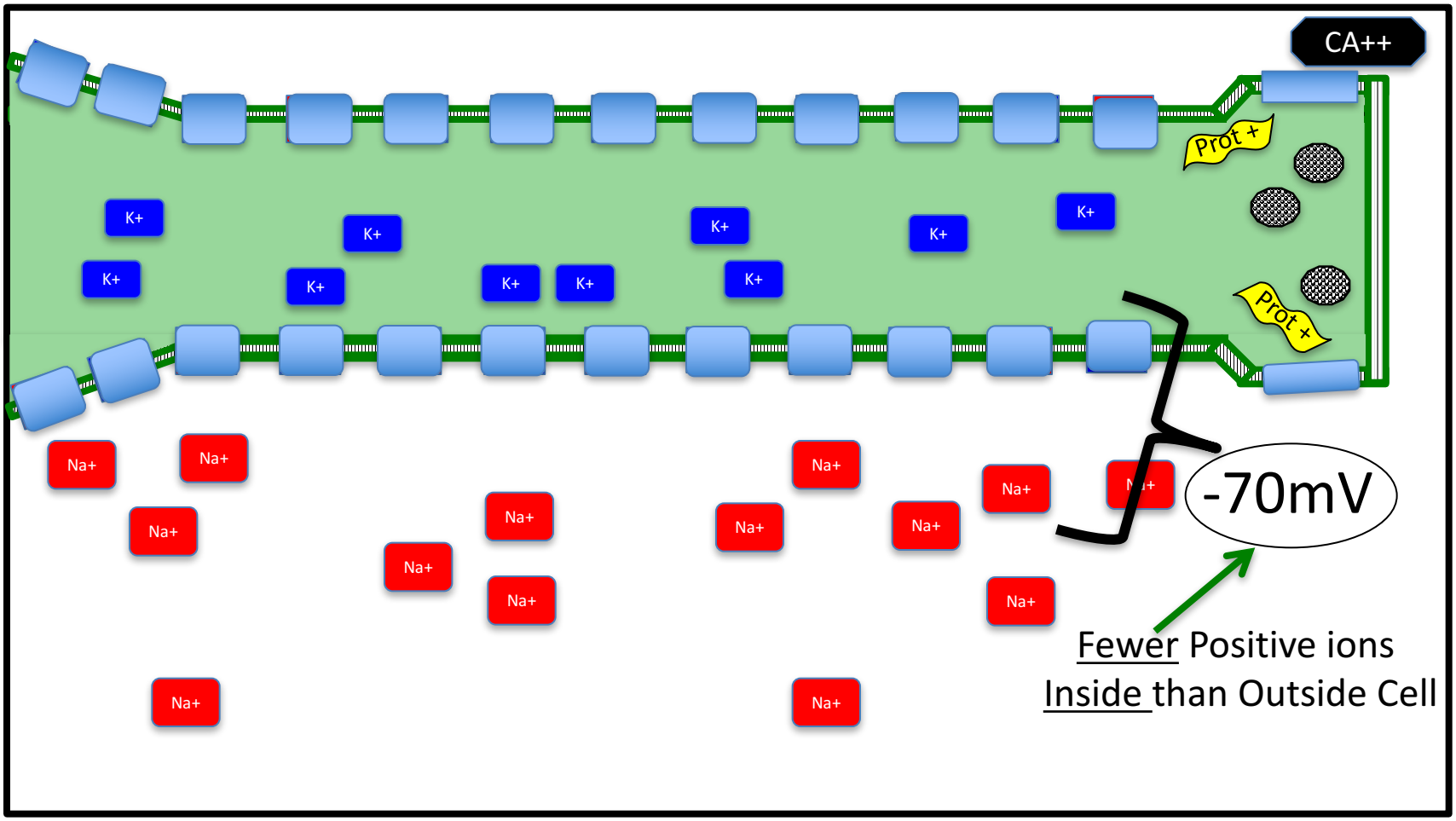
Resting Potential
-70 mV



The AXON

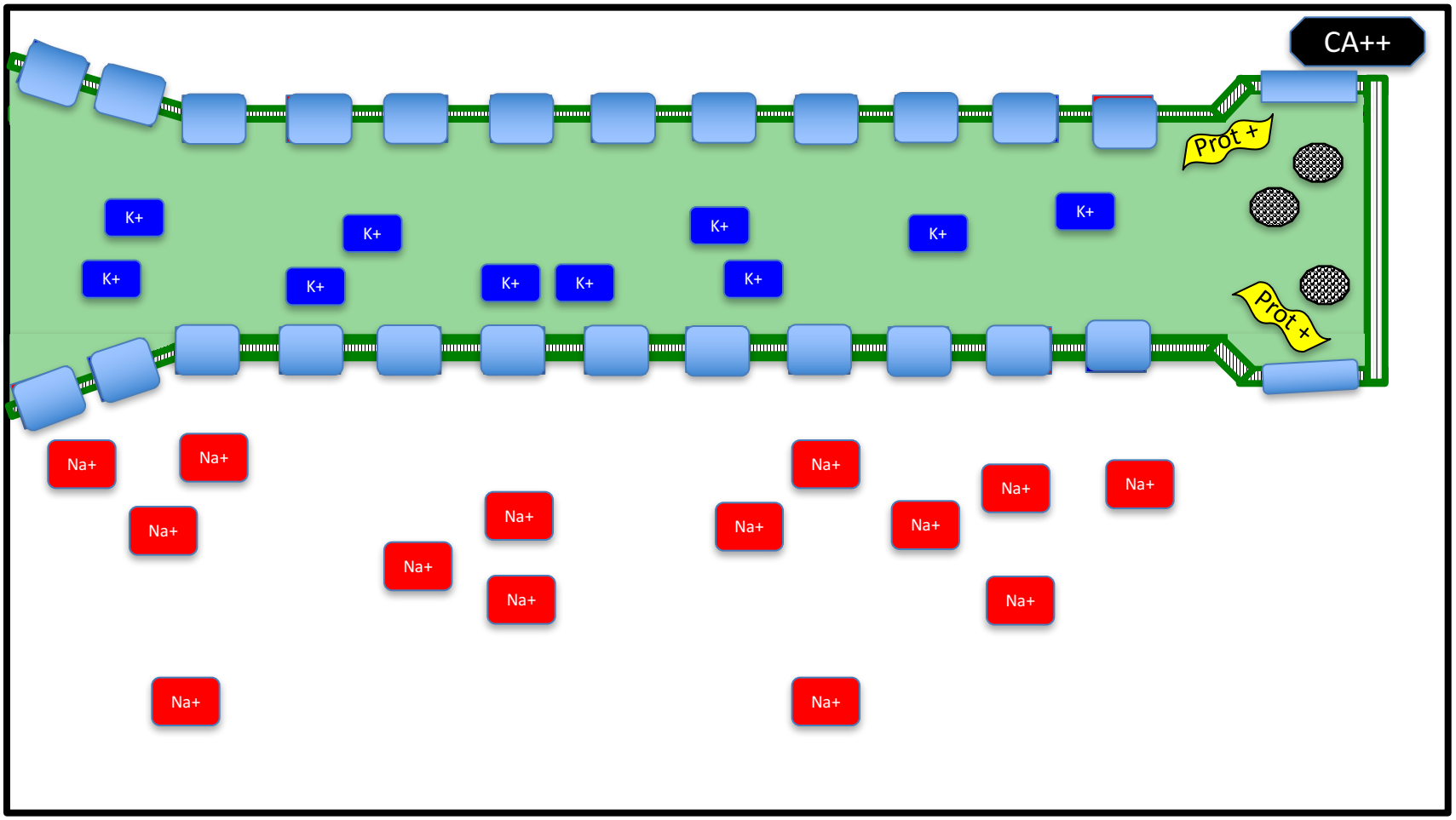

Axon Hillock
Ion Gates
Terminal Button
Vesicles of Neurotransmitter

The Resting Potential



Cell is ready to FIRE!

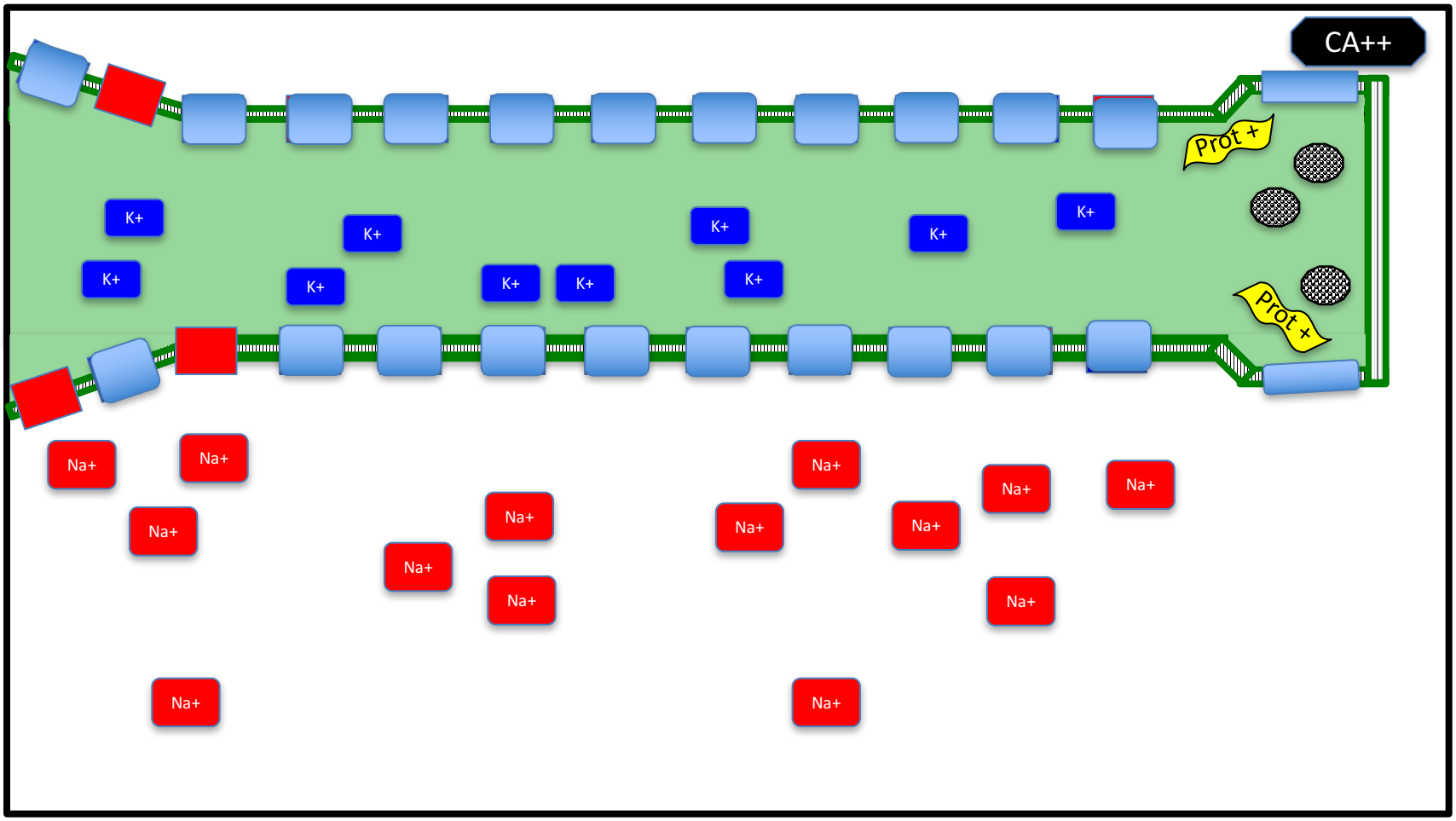
The Action Potential



A change in the polarity of the neuron
(we'll explain how, later) initiates an

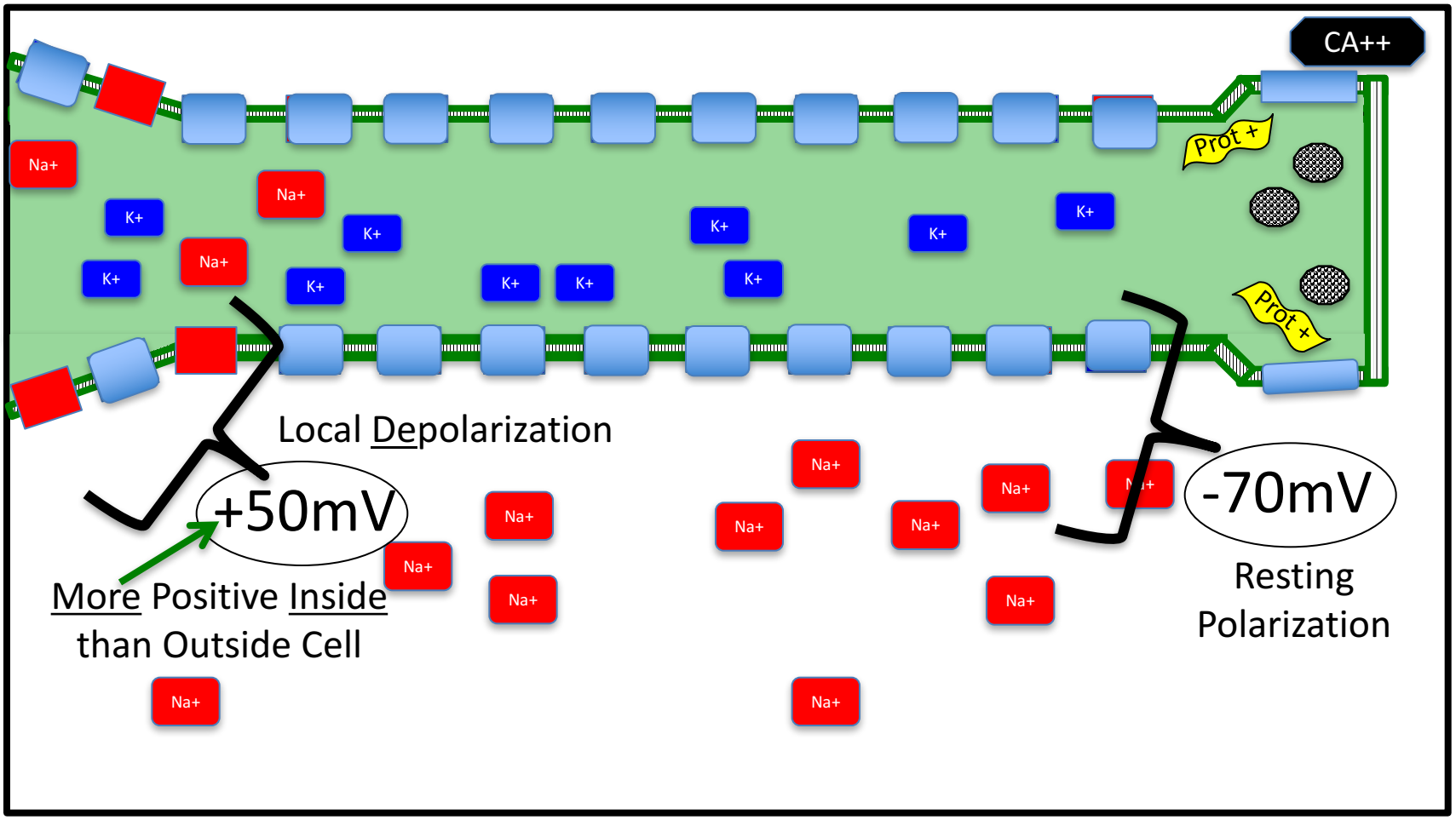
ACTION POTENTIAL

The Action Potential



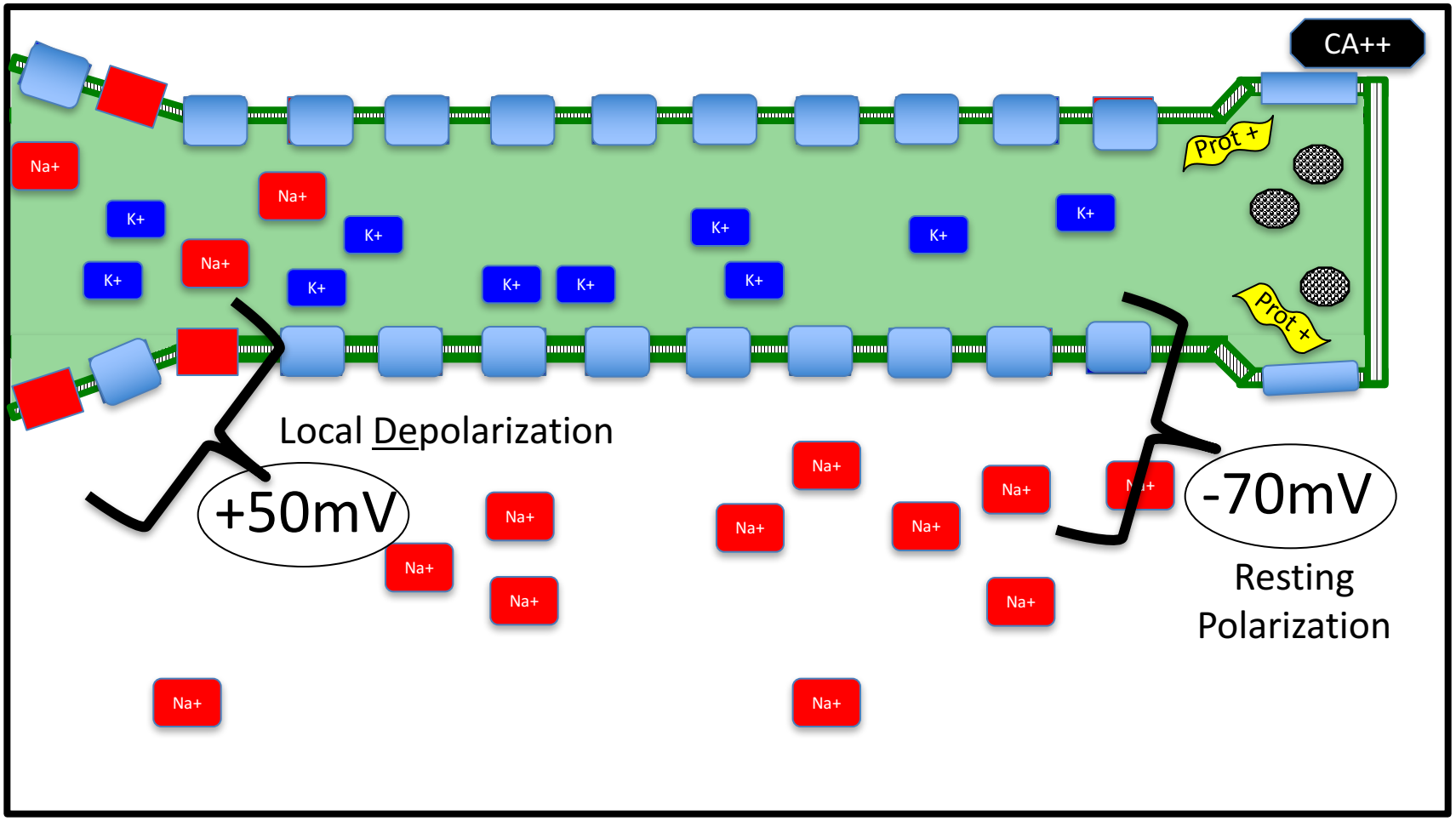
Na+ Gates at Hillock Open, Na+ Enters Cell

The Action Potential



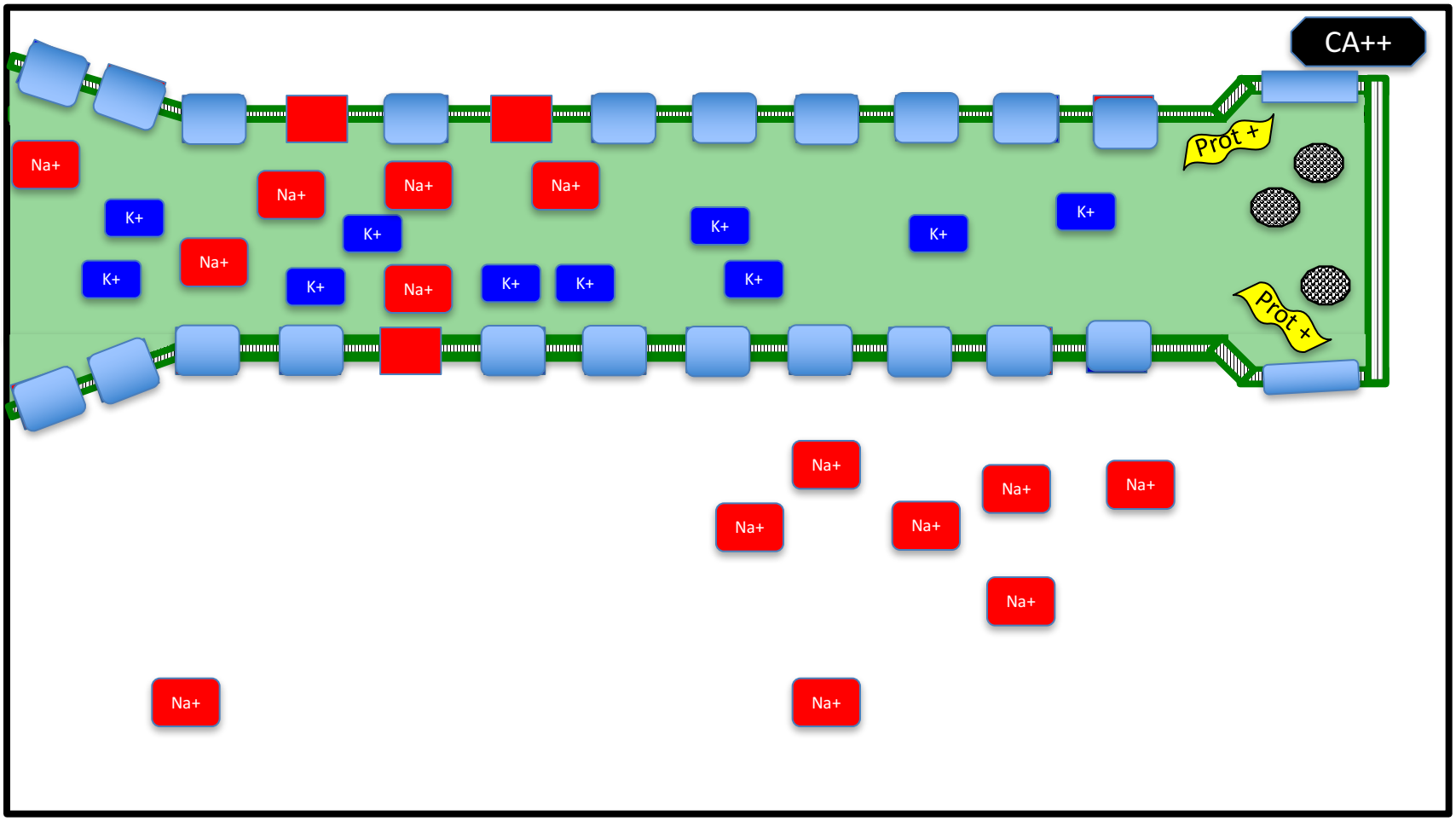
Na+ Gates at Hillock Open, Na+ Enters Cell

The Action Potential



This local polarity change causes the next Na+ Gates to open & Na+ Enters Cell

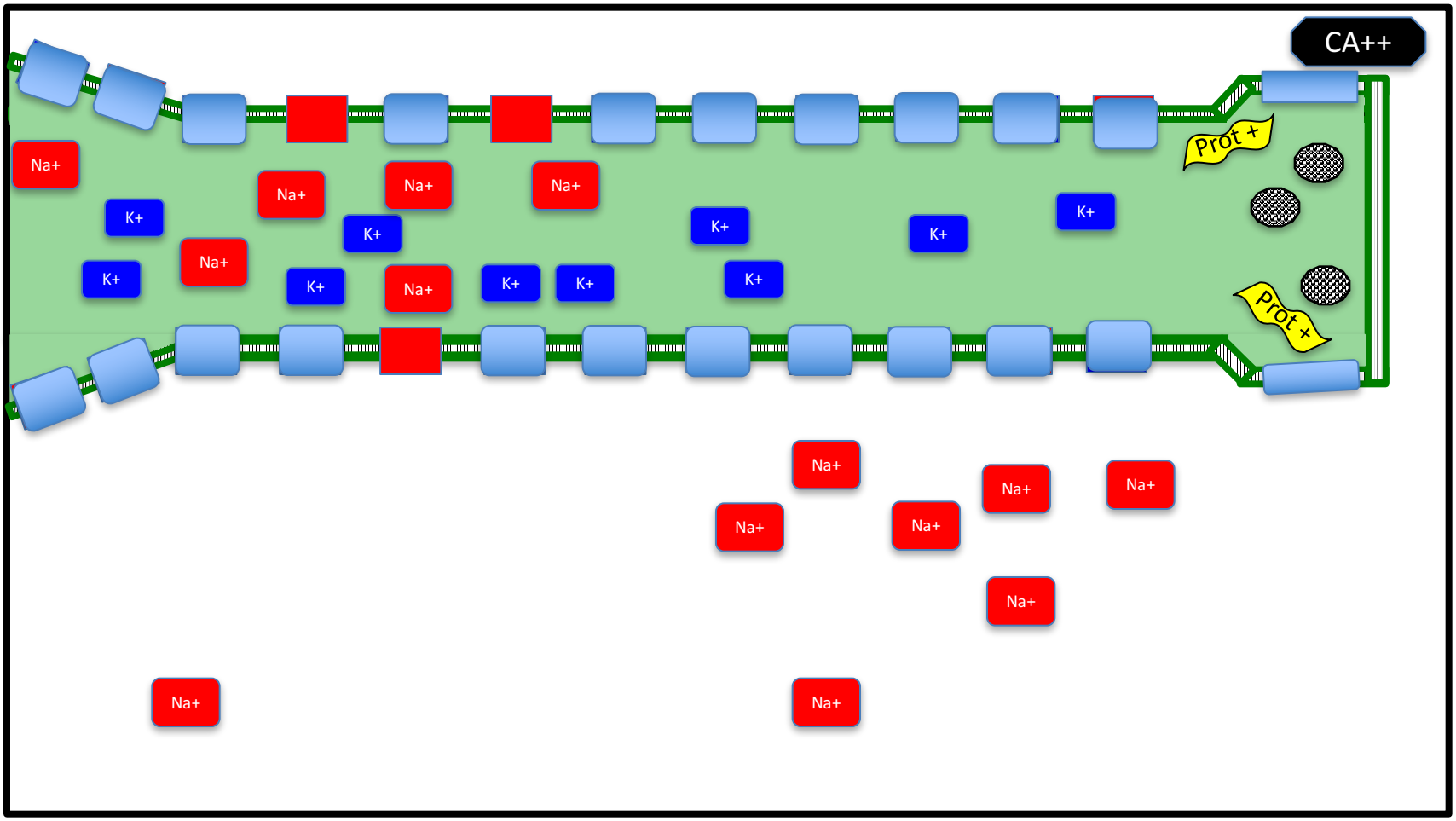
The Action Potential



This local polarity change causes the next Na+ Gates to open & Na+ Enters Cell . . .

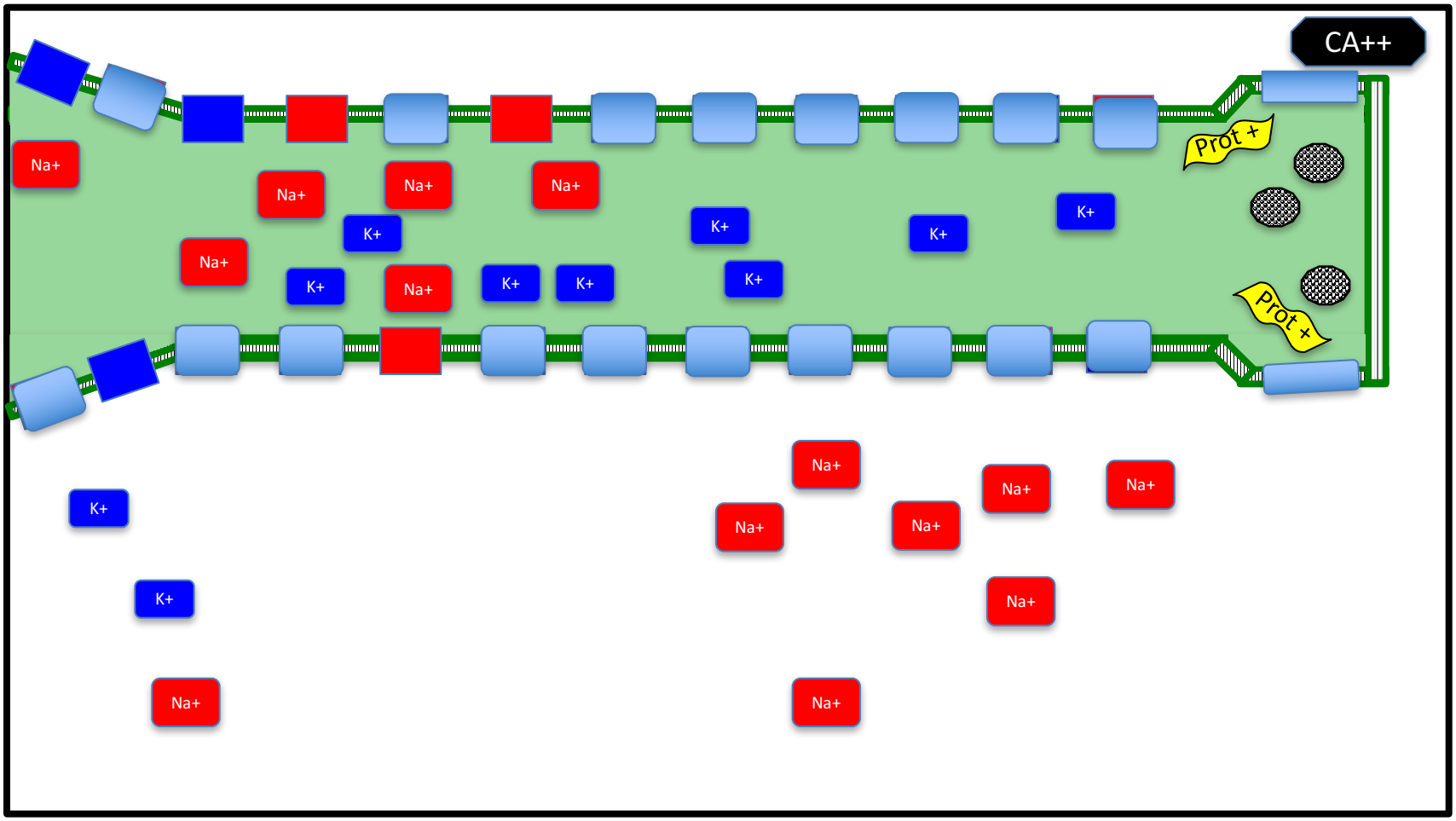
Then the previous Na+ Gates Close

The Action Potential



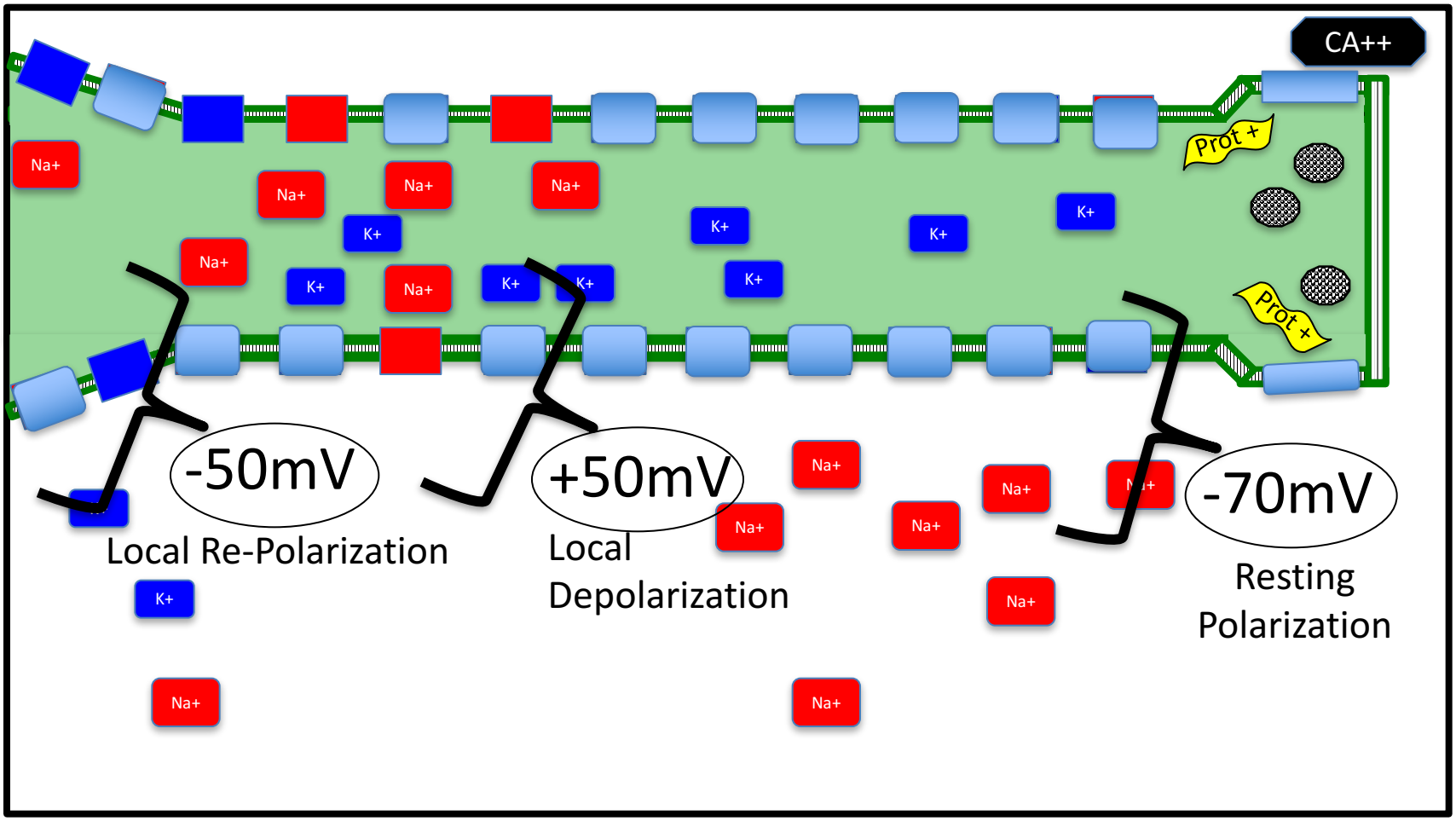
Then K+ Gates at Hillock Open, K+ Exits Cell

The Action Potential



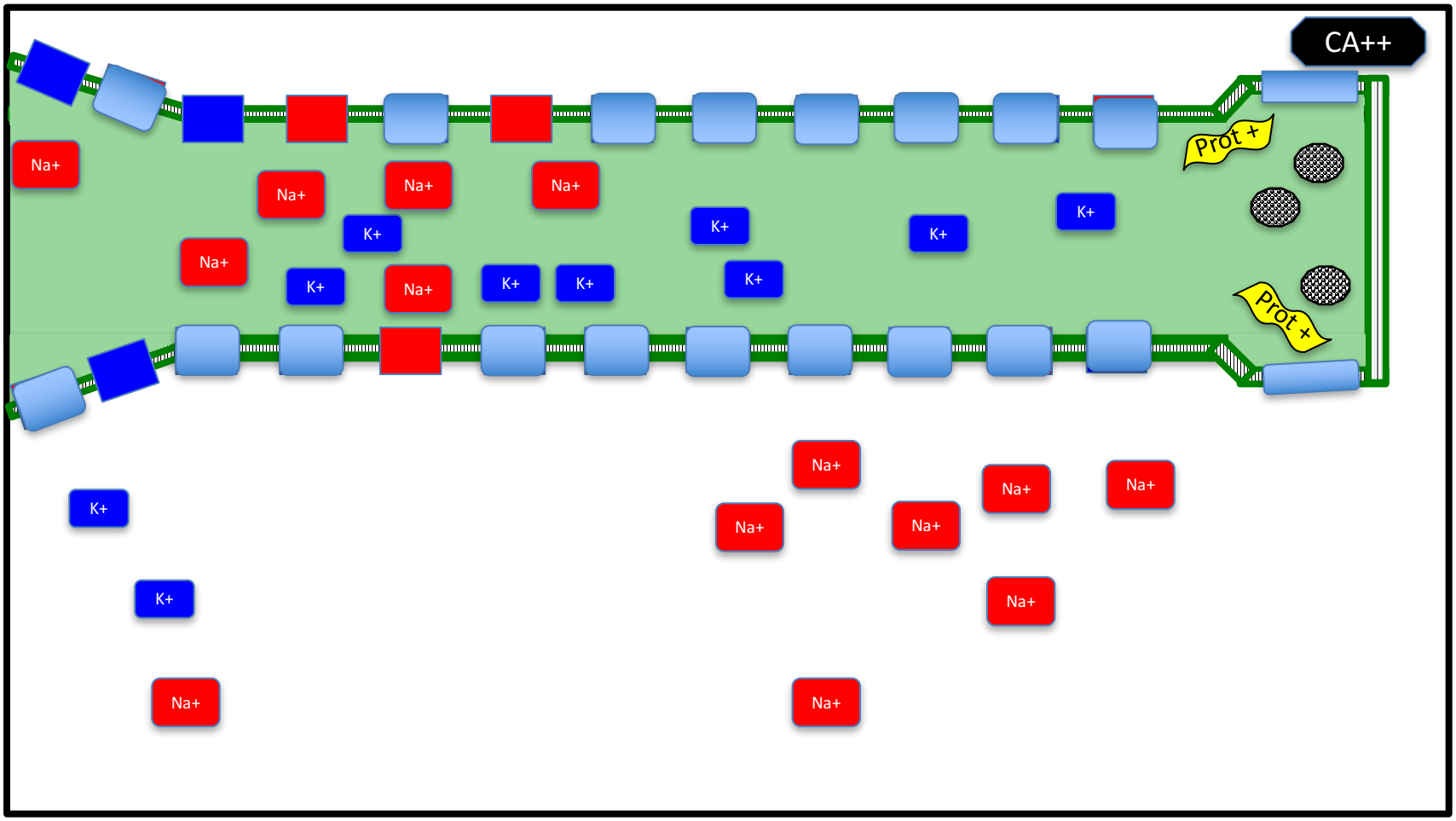
Then K+ Gates at Hillock Open, K+ Exits Cell

The Action Potential



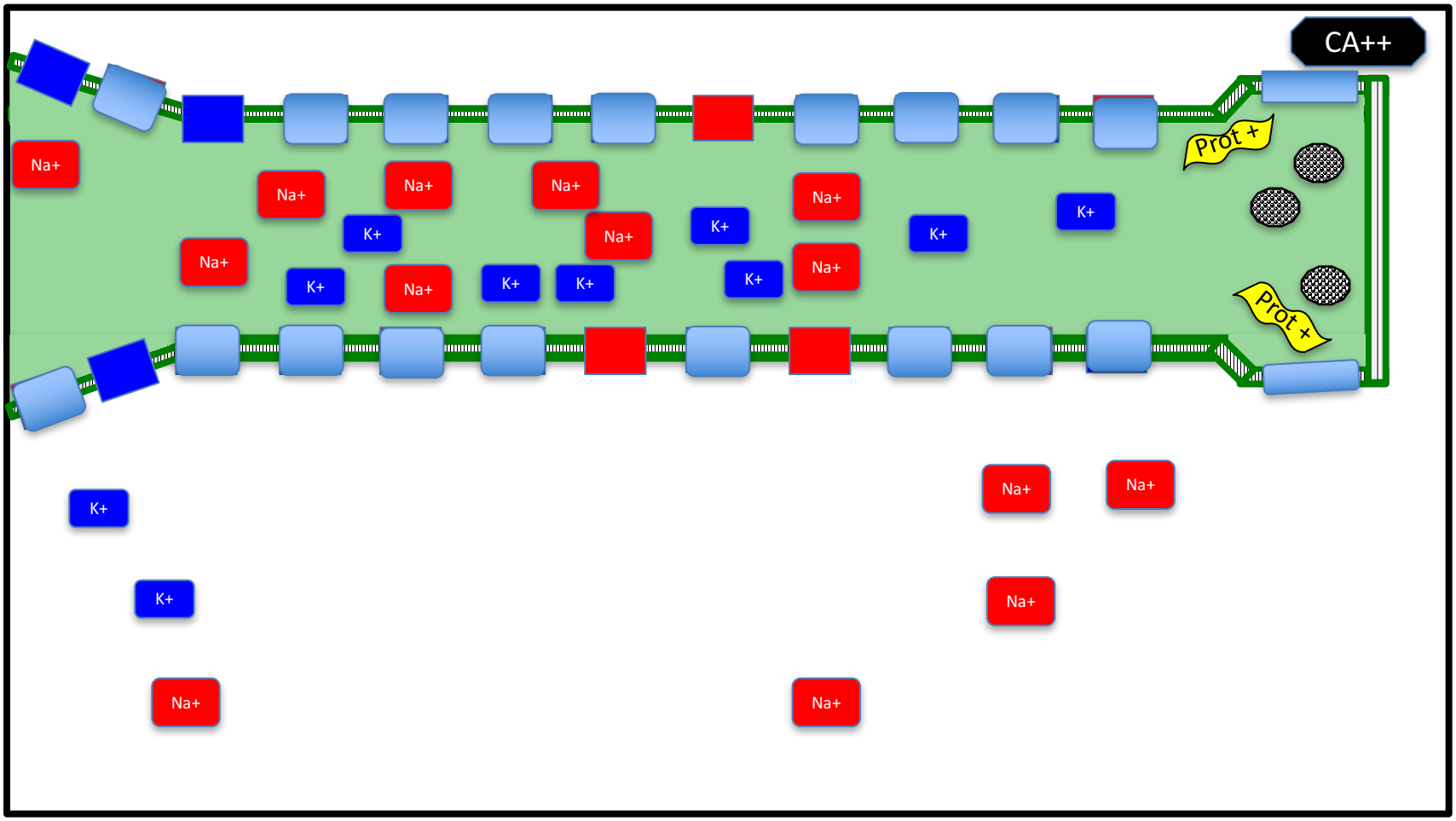
When K+ exits, creates a local re-polarization to –50mV
(once again, less positive inside)

The Action Potential



Next Na+ Gates Open, Na+ Enters Cell. . .

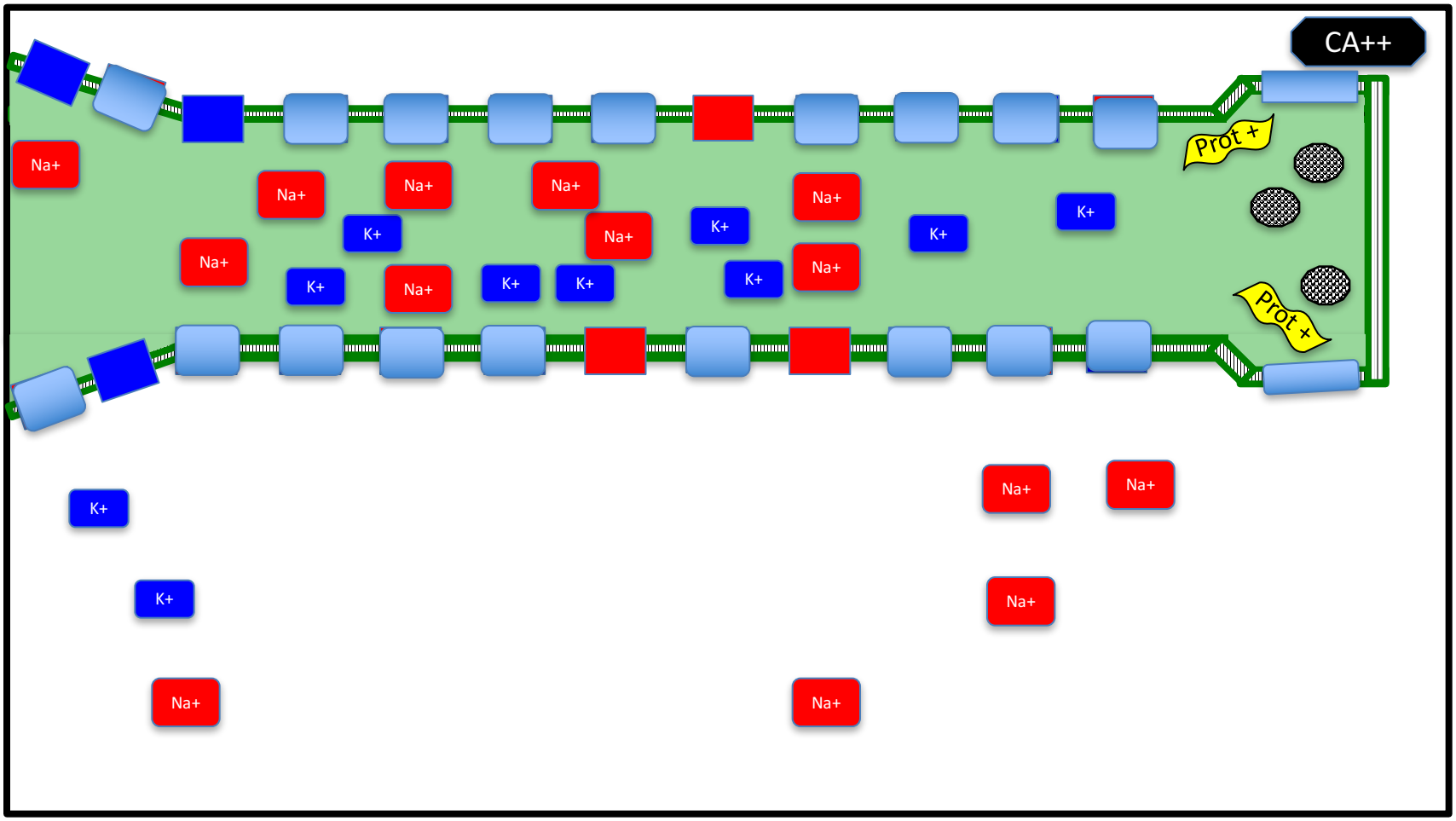
The Action Potential



Next Na+ Gates Open, Na+ Enters Cell. . .

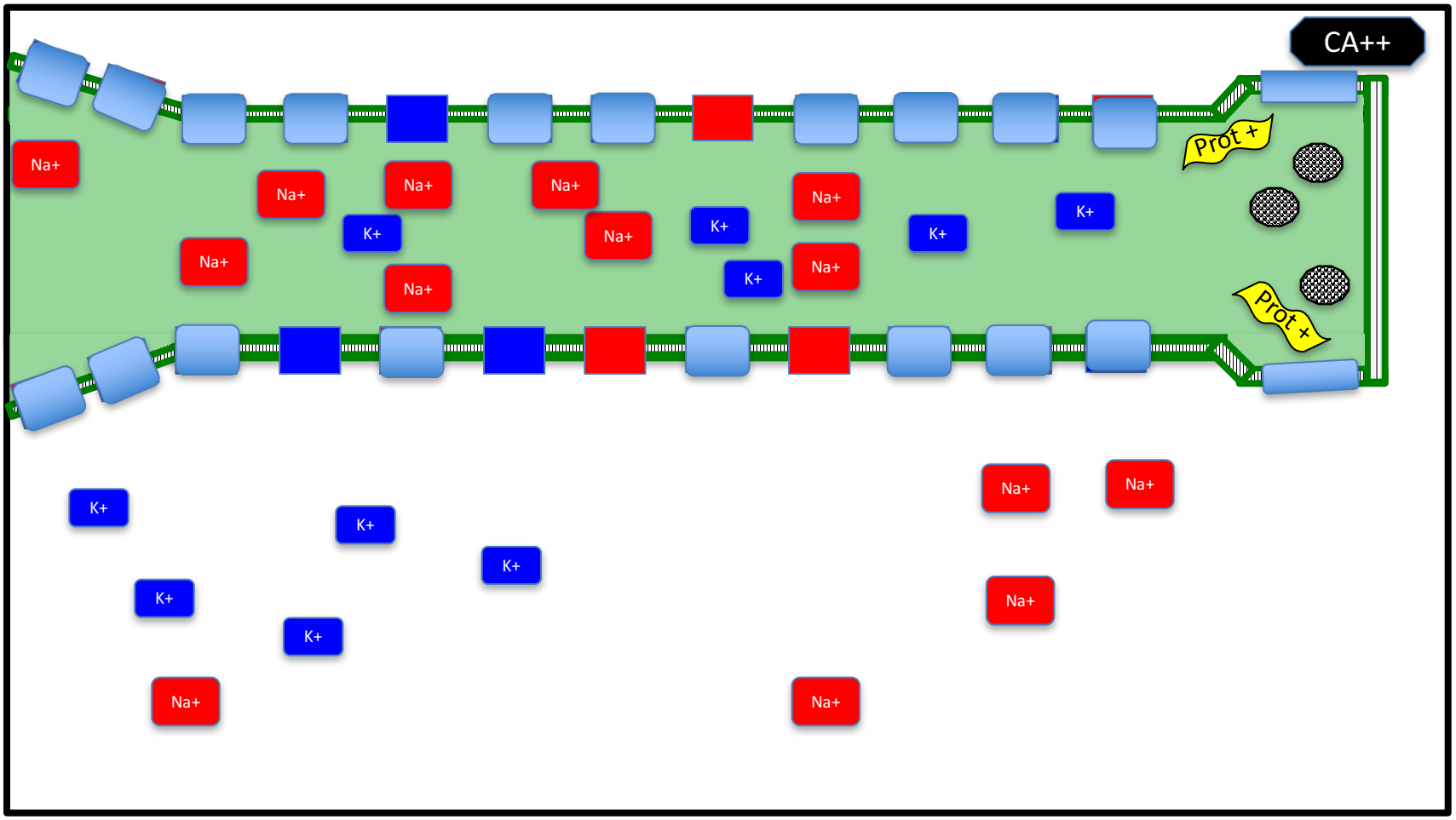
then previous Na+ Gates Close

The Action Potential



Then the next K+ Gates Open, K+ Exits Cell. . .

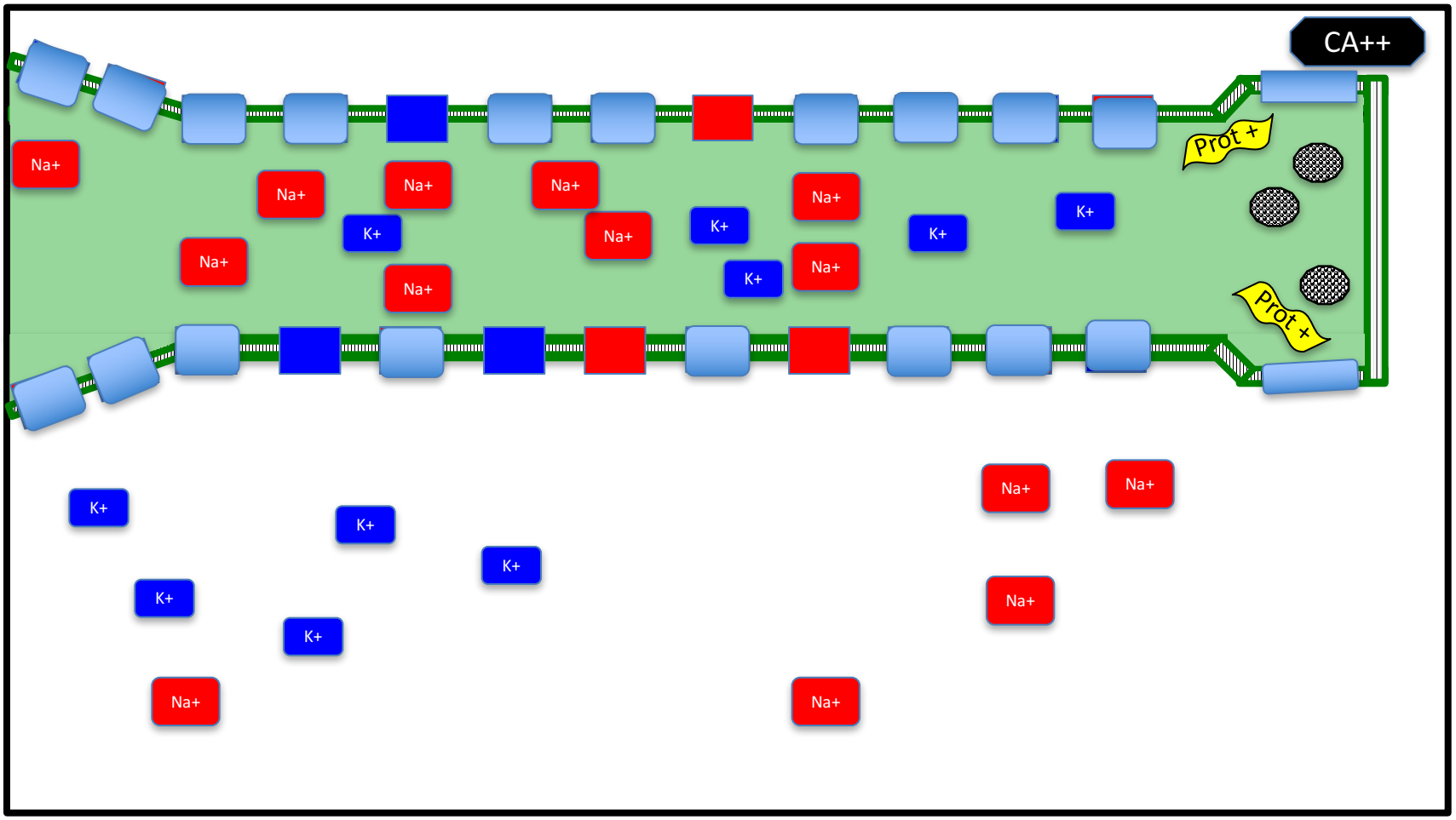
The Action Potential



Then the next K+ Gates Open, K+ Exits Cell. . .

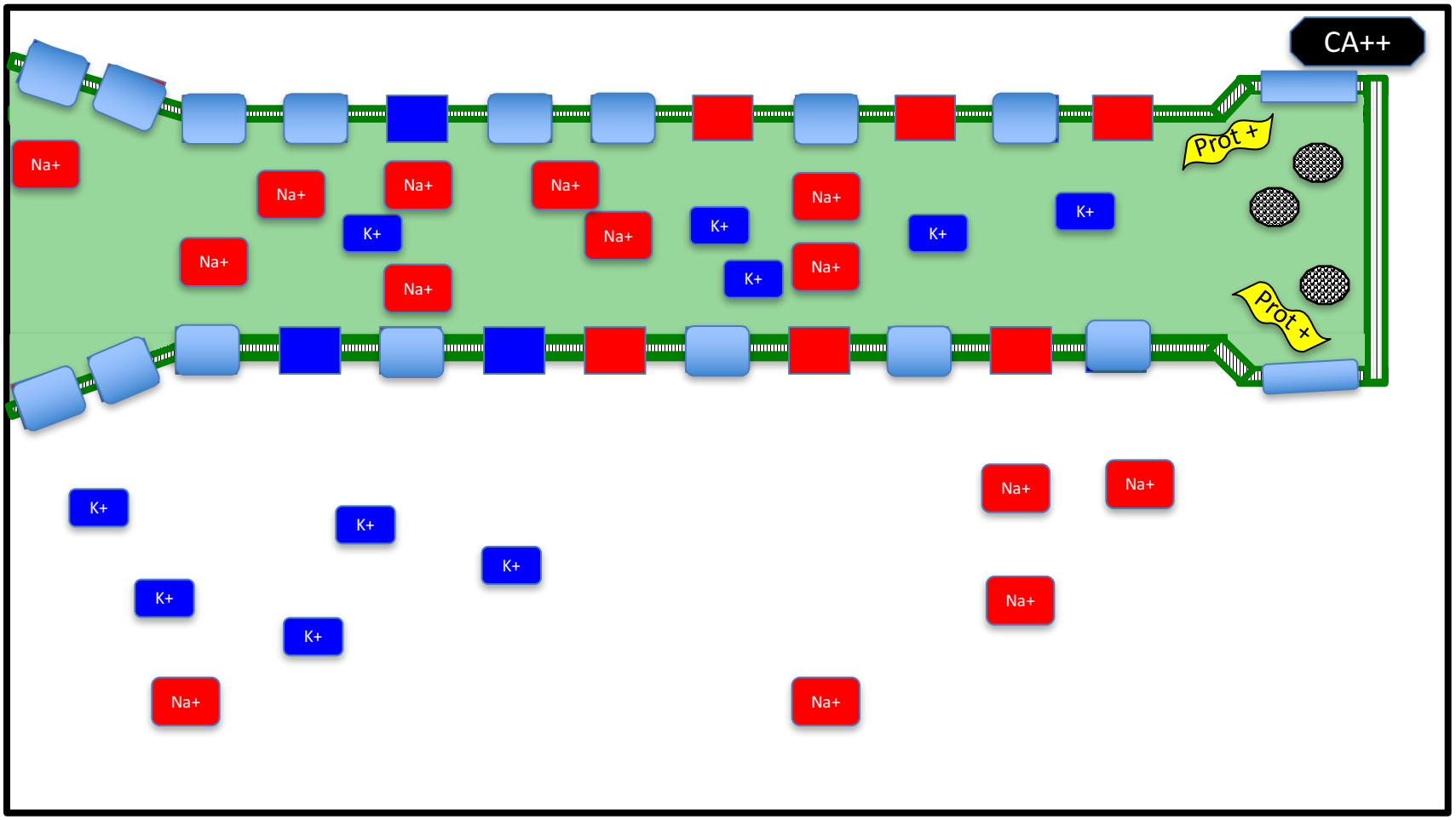
then previous K+ Gates Close

The Action Potential



Next Na+ Gates Open, Na+ Enters Cell . . .

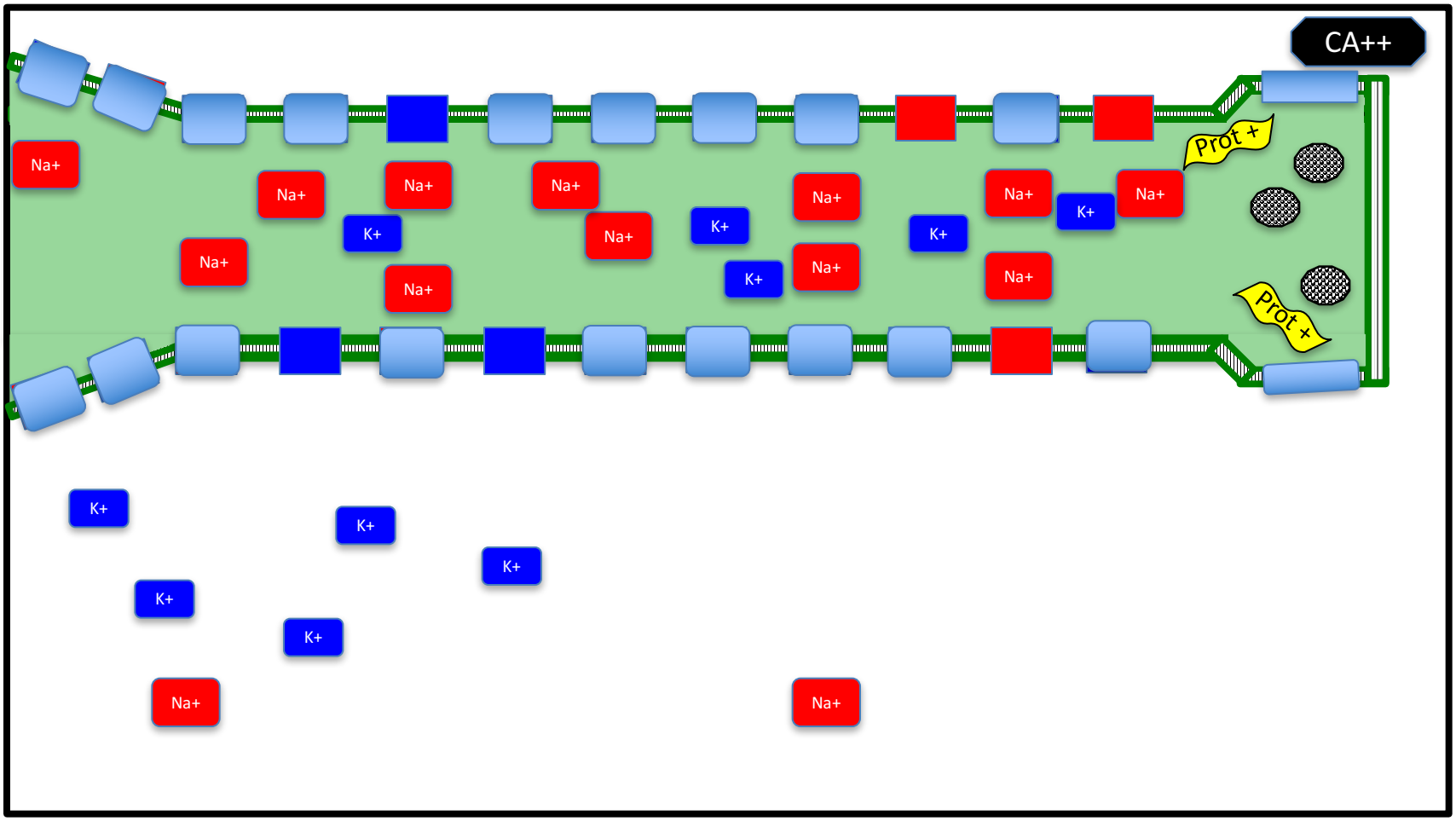
The Action Potential



Next Na+ Gates Open, Na+ Enters Cell . . .

then previous Na+ Gates Close

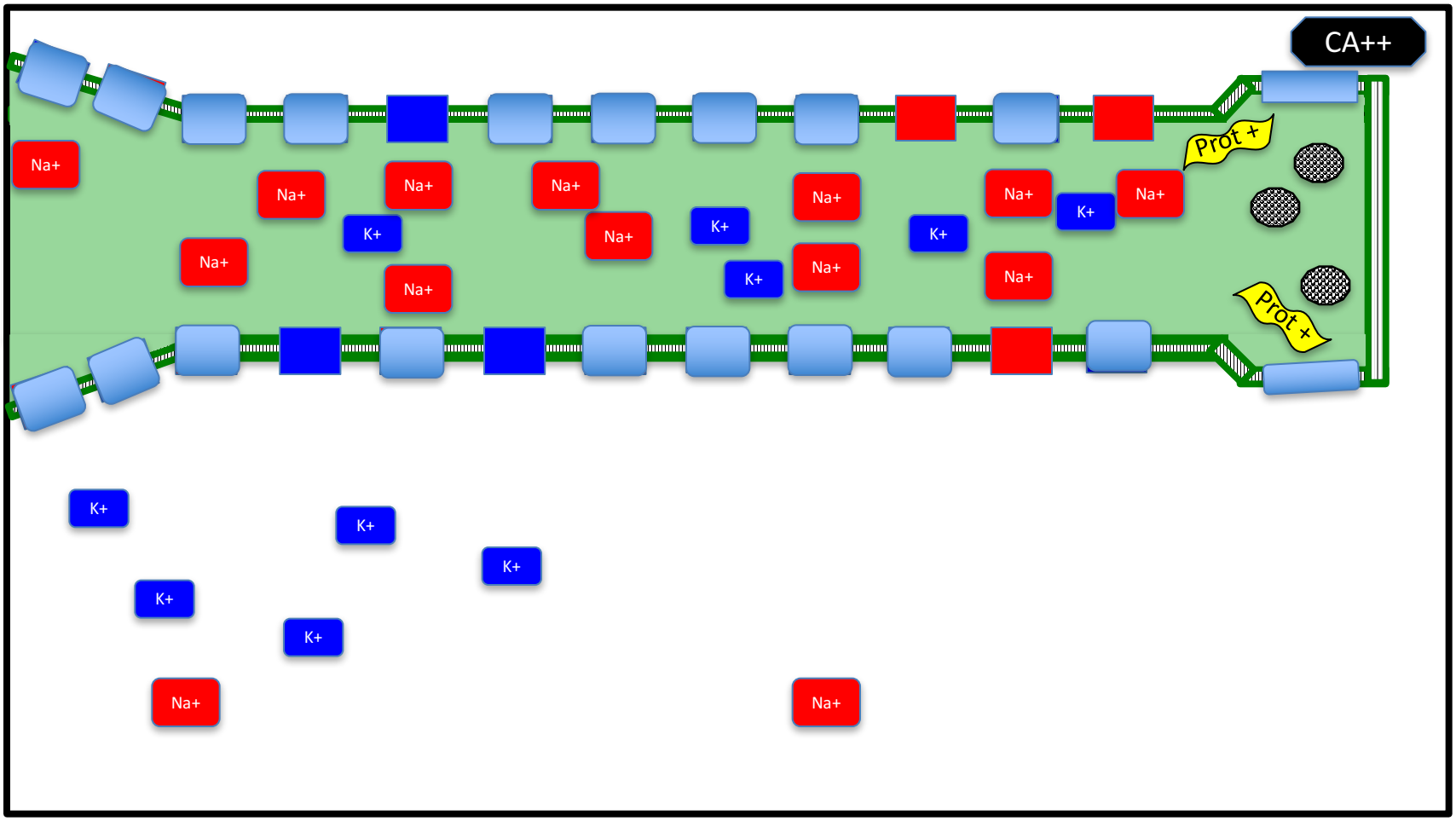
The Action Potential



Next Na+ Gates Open, Na+ Enters Cell . . .

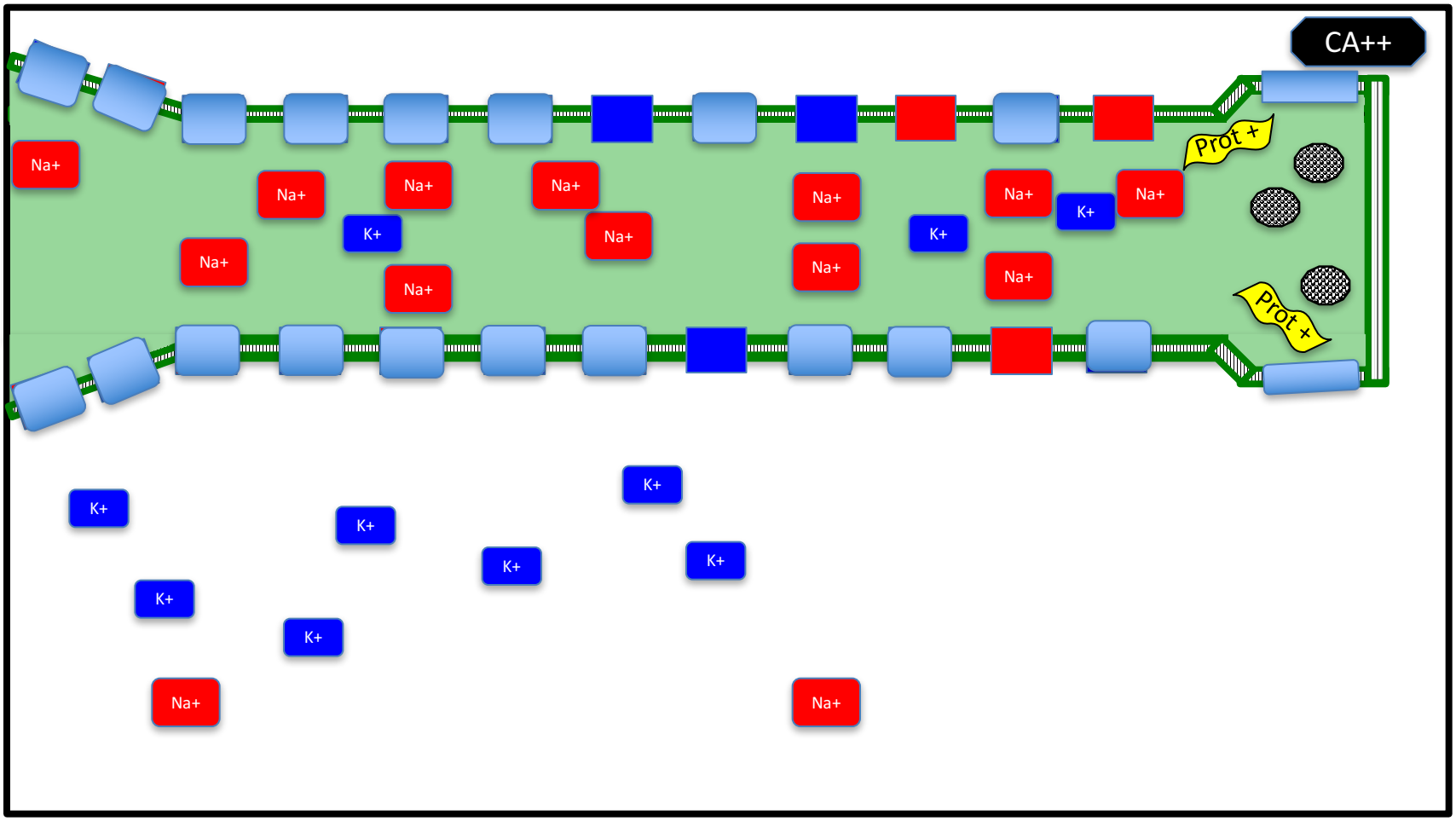
then previous Na+ Gates Close

The Action Potential



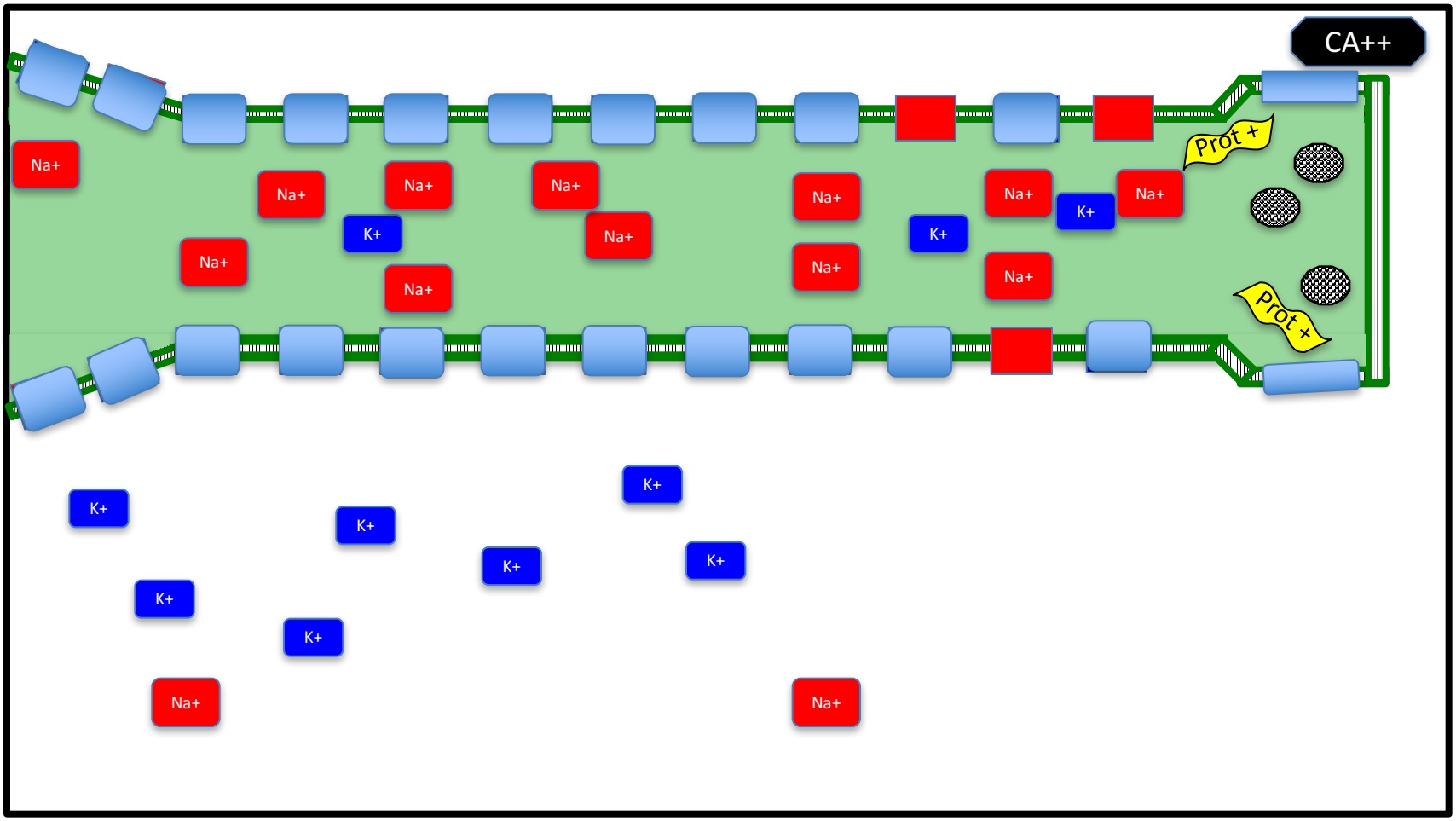
Next K+ Gates Open, K+ Exits Cell . . .

The Action Potential



Next K+ Gates Open, K+ Exits Cell . . .

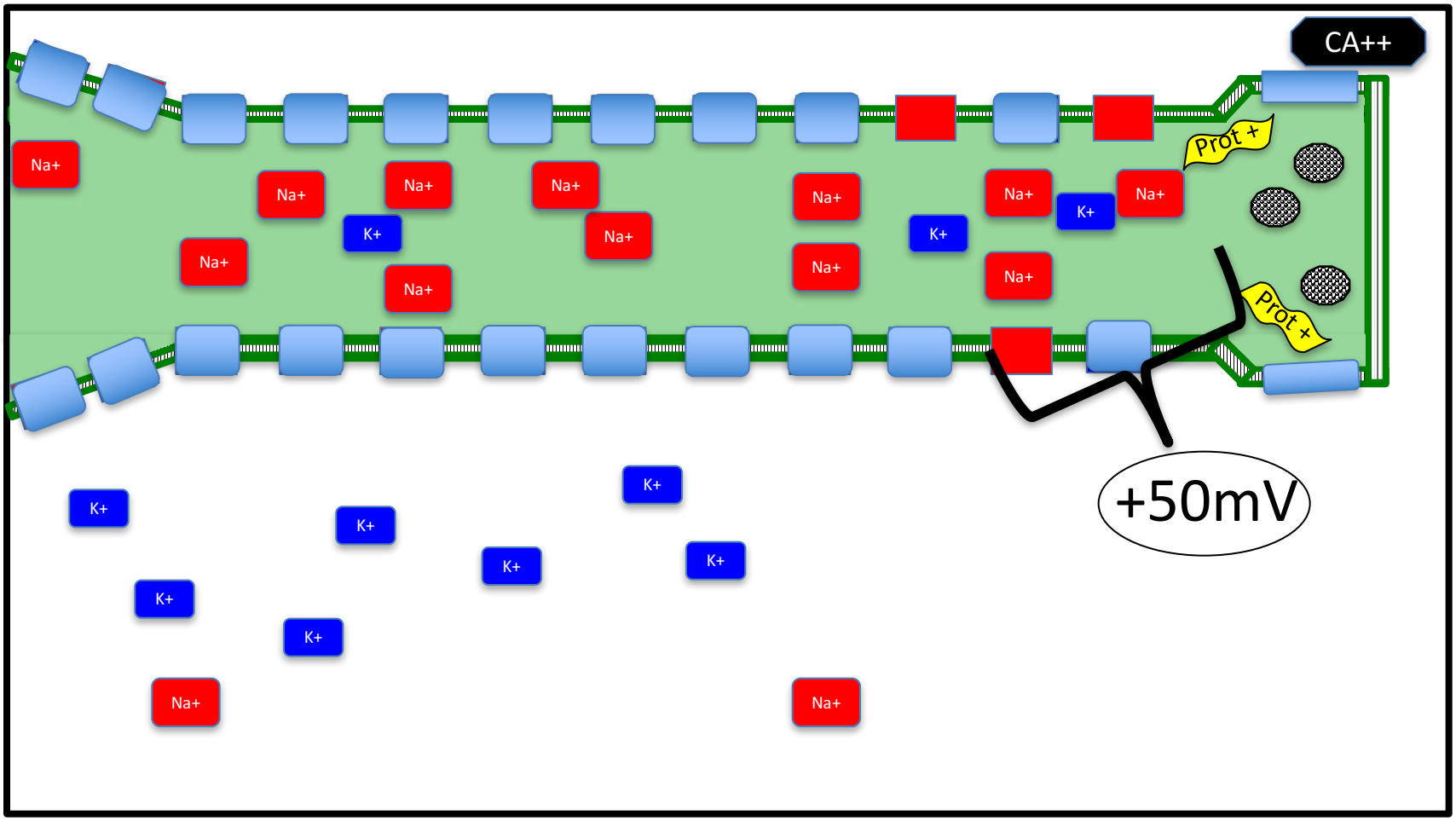
The Action Potential



Next K+ Gates Open, K+ Exits Cell . . .

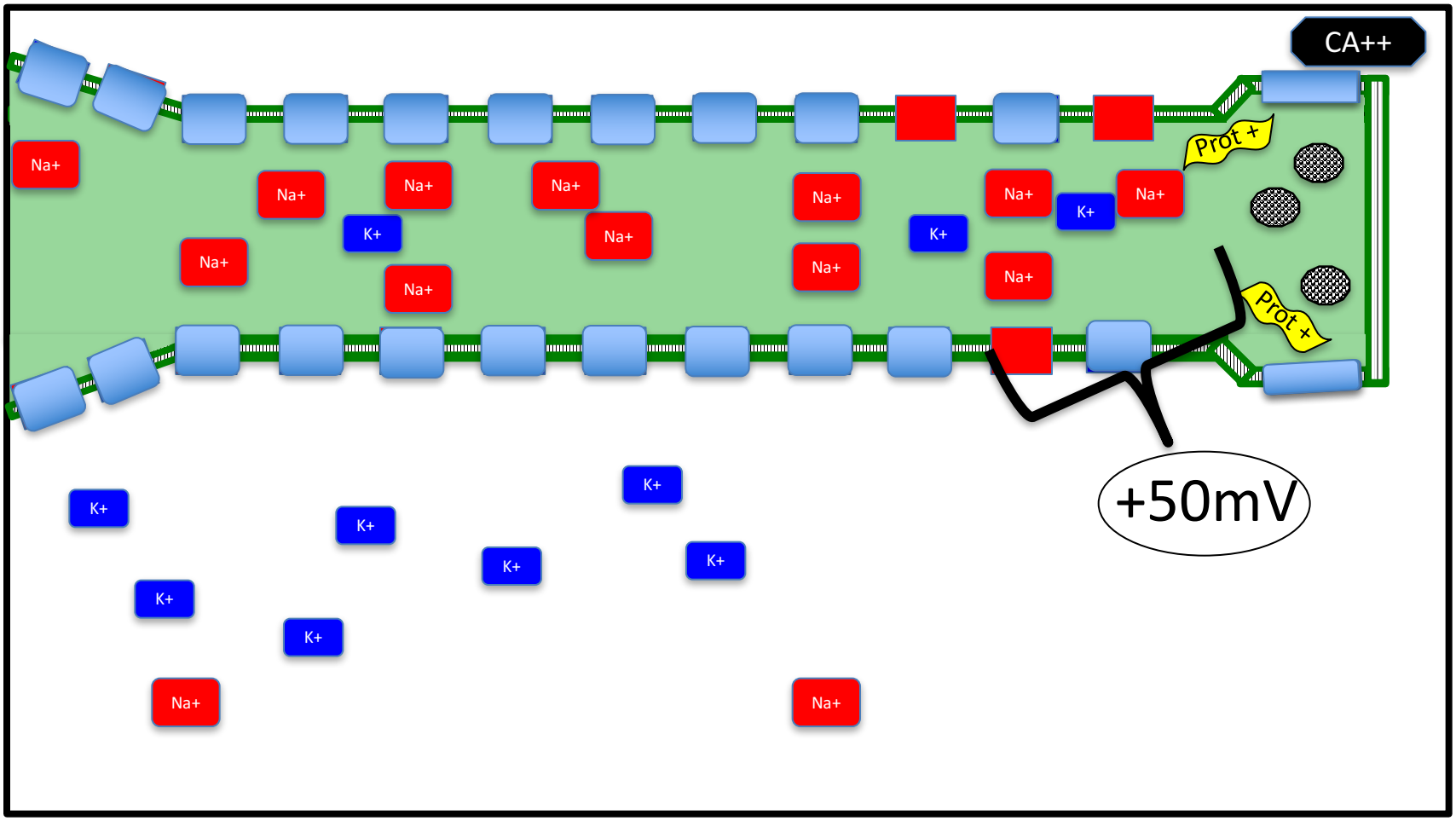
then previous K+ Gates Close

The Action Potential



When "Spike" of Depolarization reaches Terminal. . .

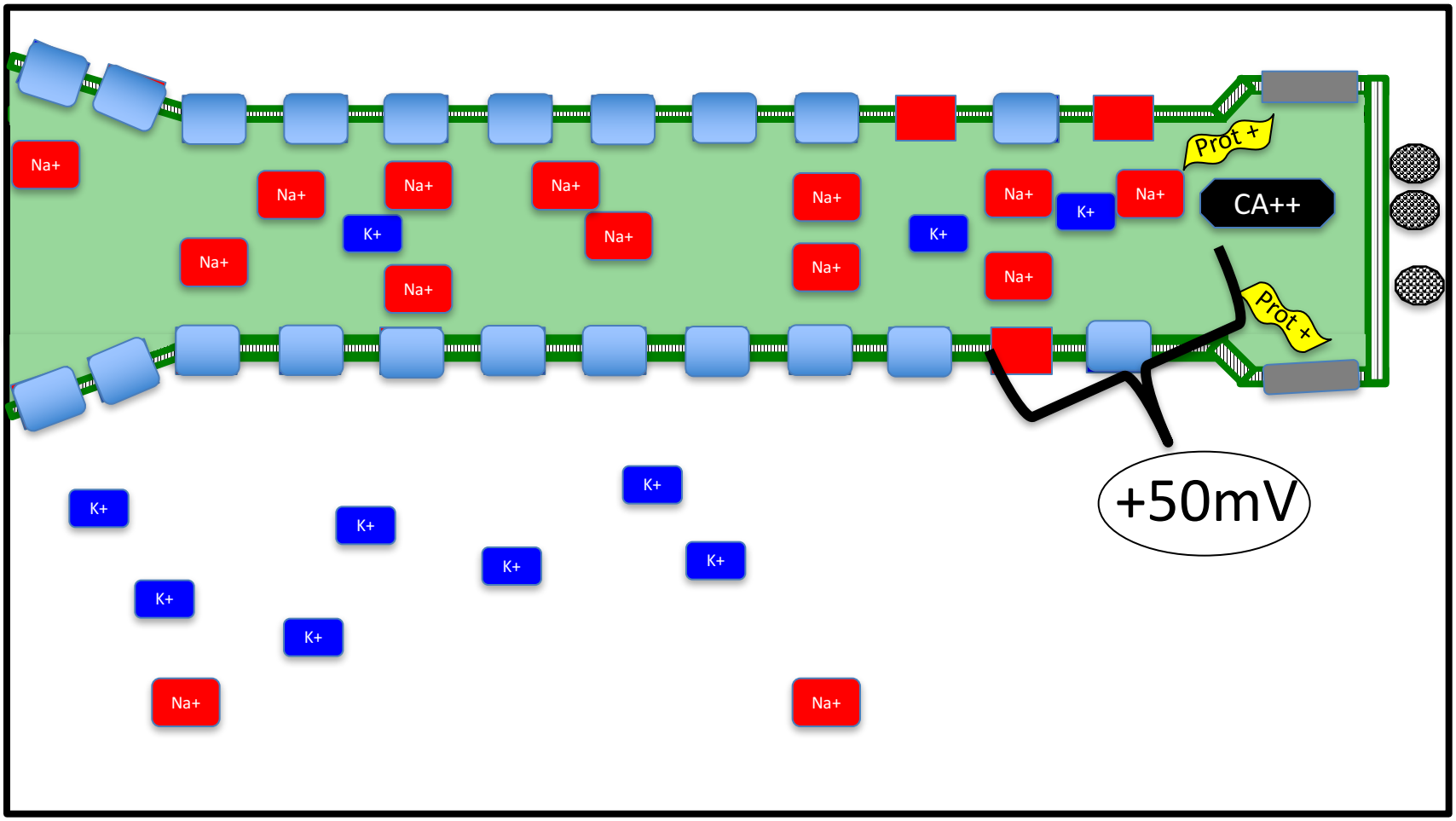
The Action Potential



When "Spike" of Depolarization reaches Terminal,

CA++ enters cell & Neurotransmitter released –

The Action Potential



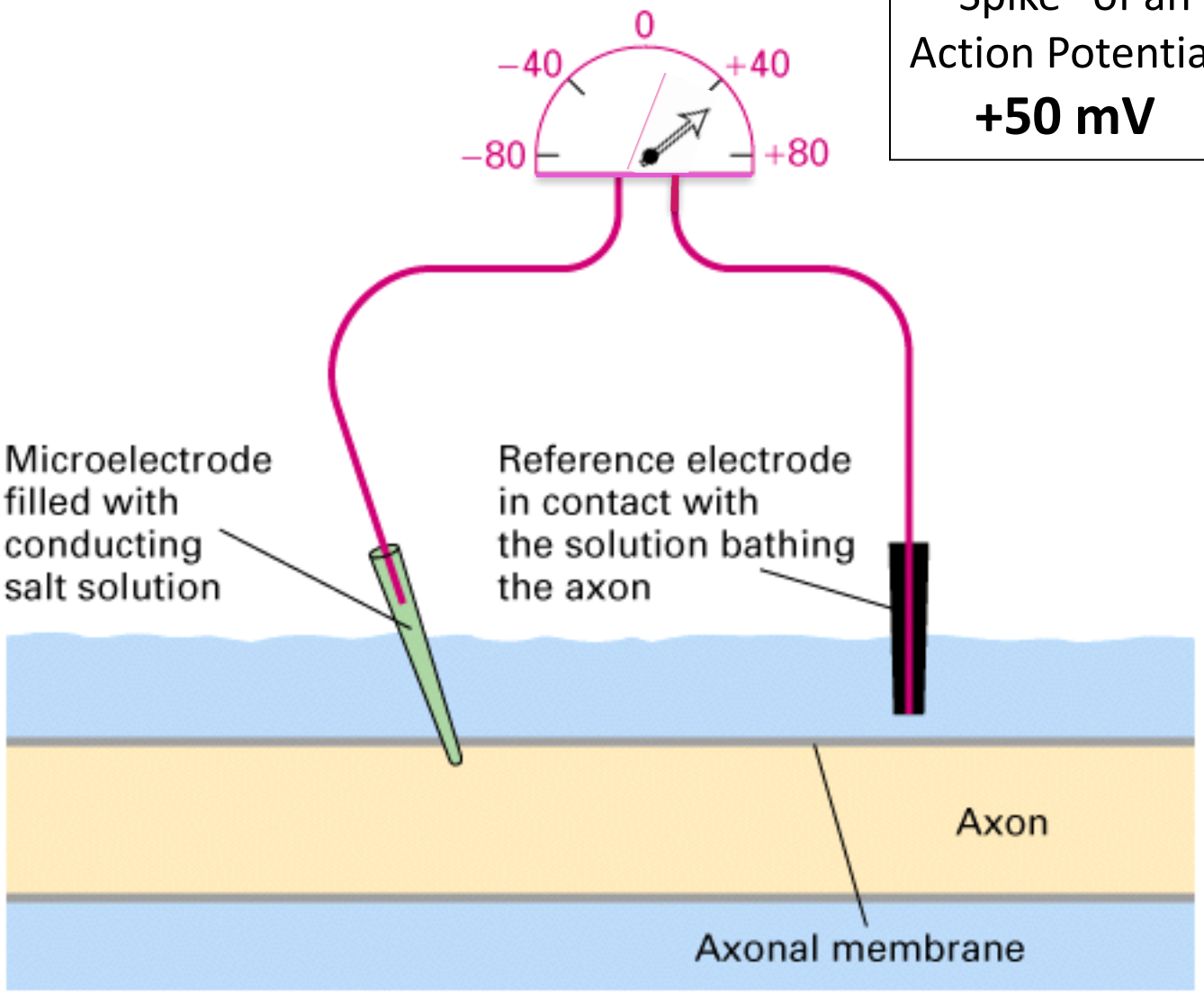
When "Spike" of Depolarization reaches Terminal,

CA++ enters cell & Neurotransmitter released –

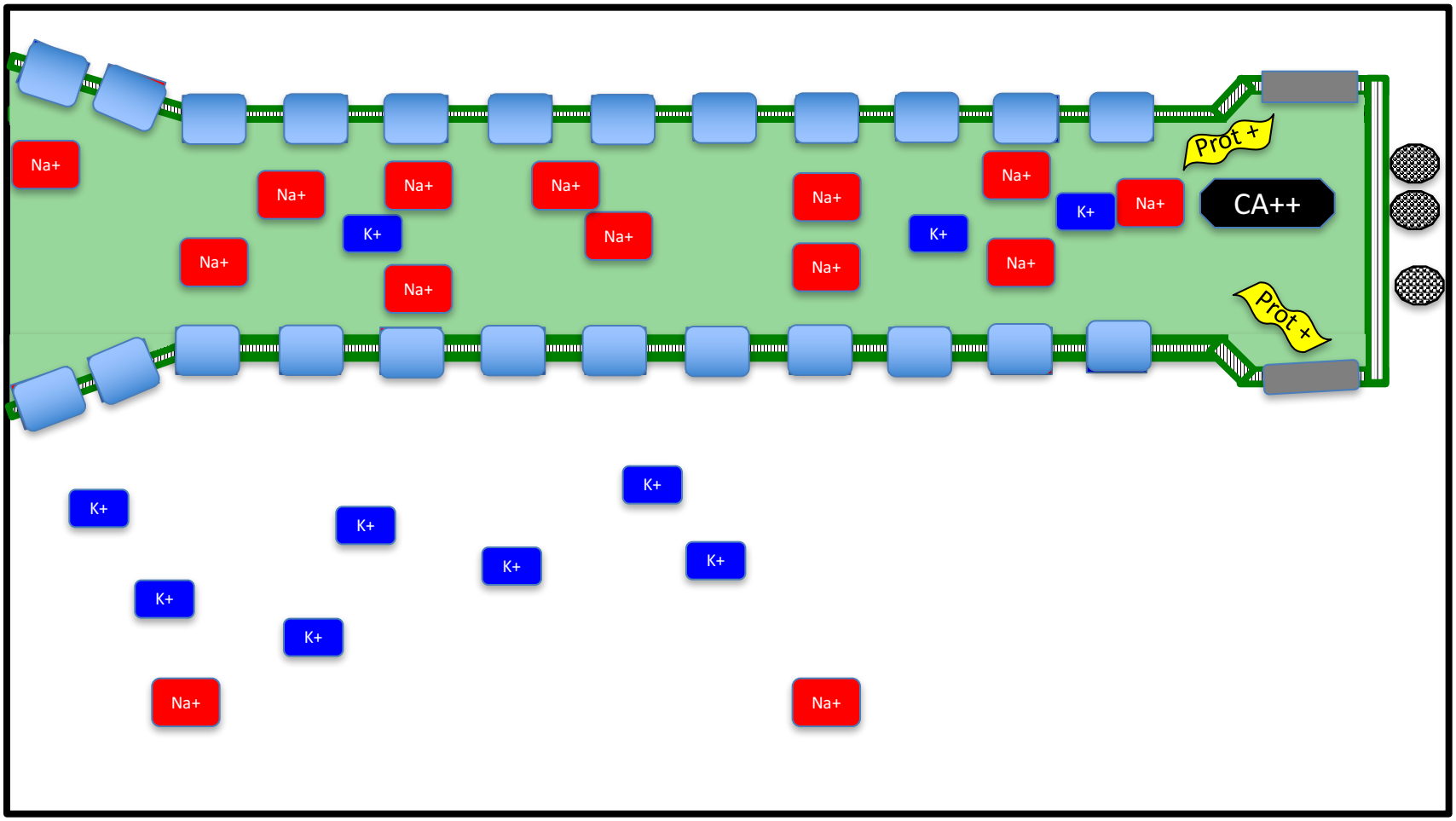
The Cell Fires!

"Spike" of an Action Potential

+50 mV

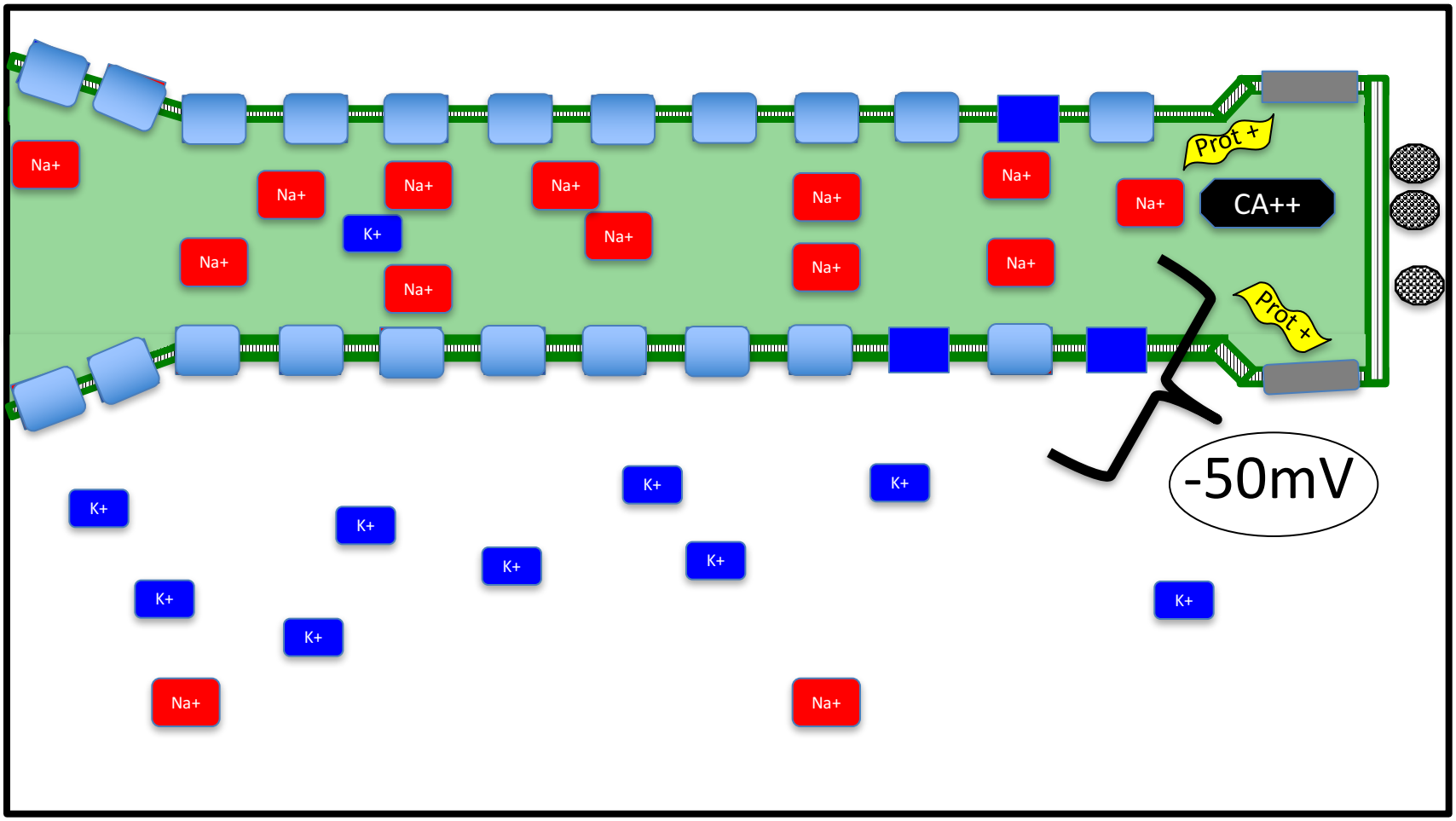


Restoring the Resting Potential



Final K+ gates open, and K+ exits cell

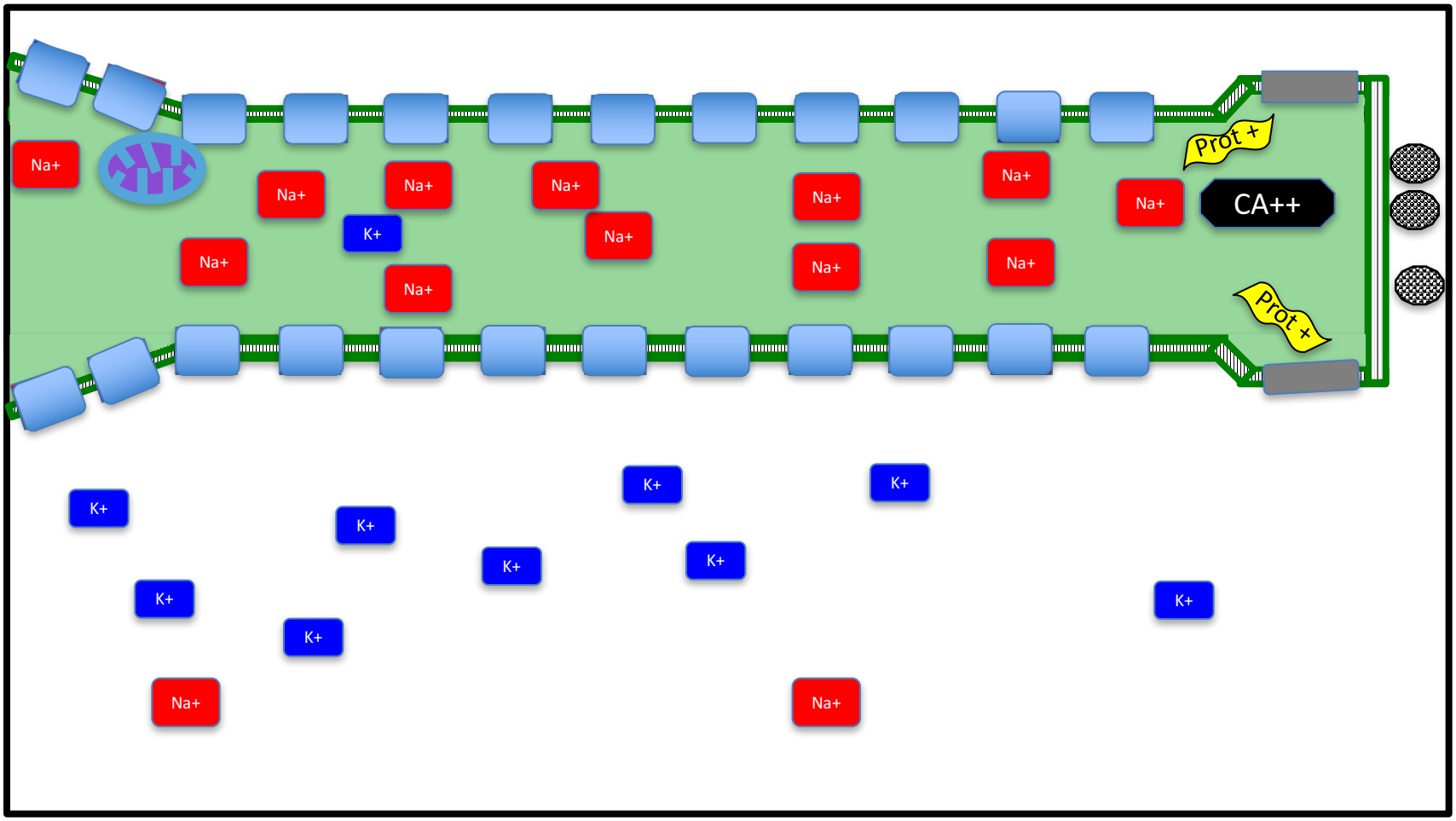
Restoring the Resting Potential



Polarity is back to negative, as it was initially, BUT - -

K+ and Na+ are are wrong side of membrane!

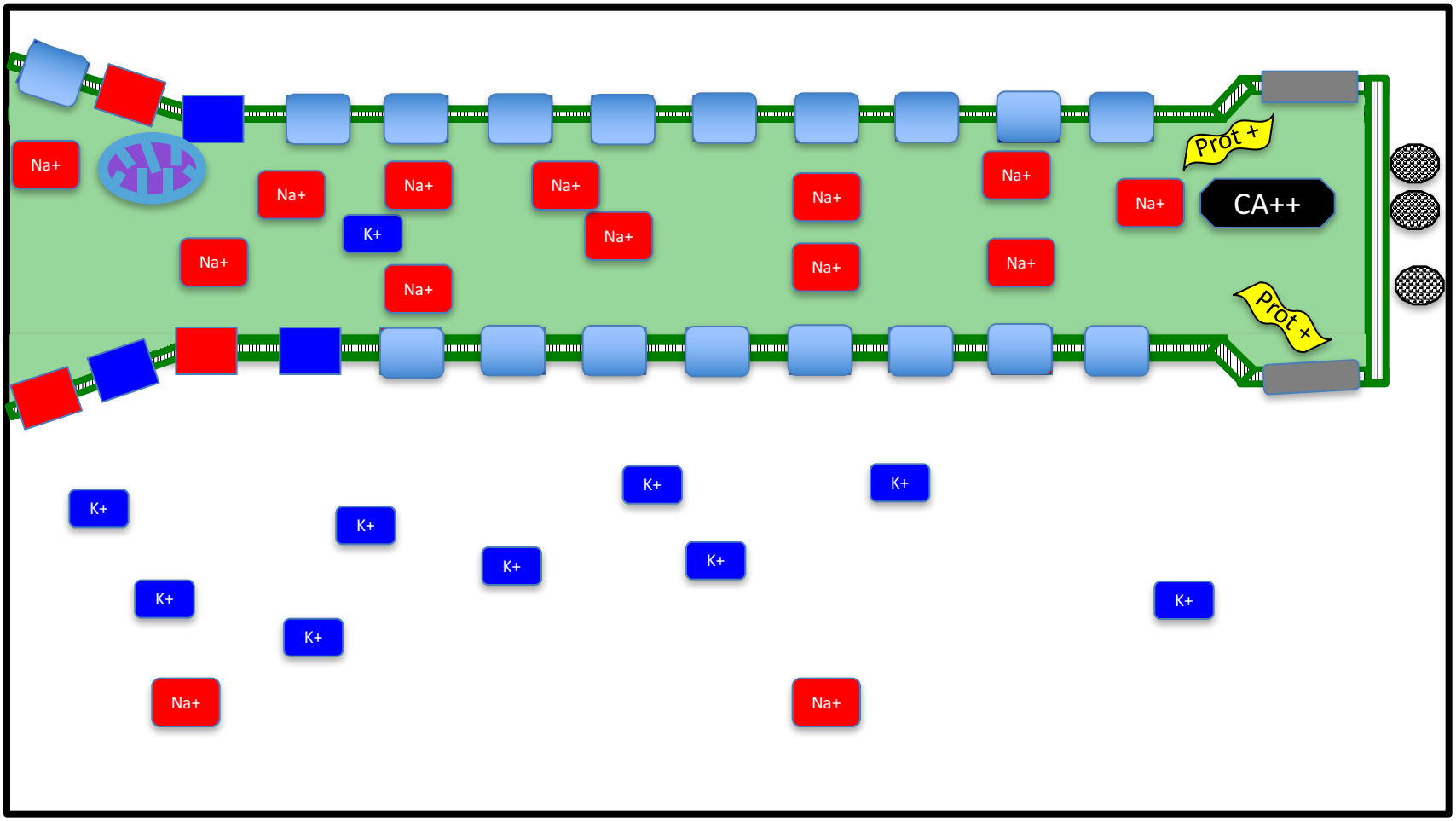
Restoring the Resting Potential



Energy requiring 

Sodium–Potassium Pump

Restoring the Resting Potential

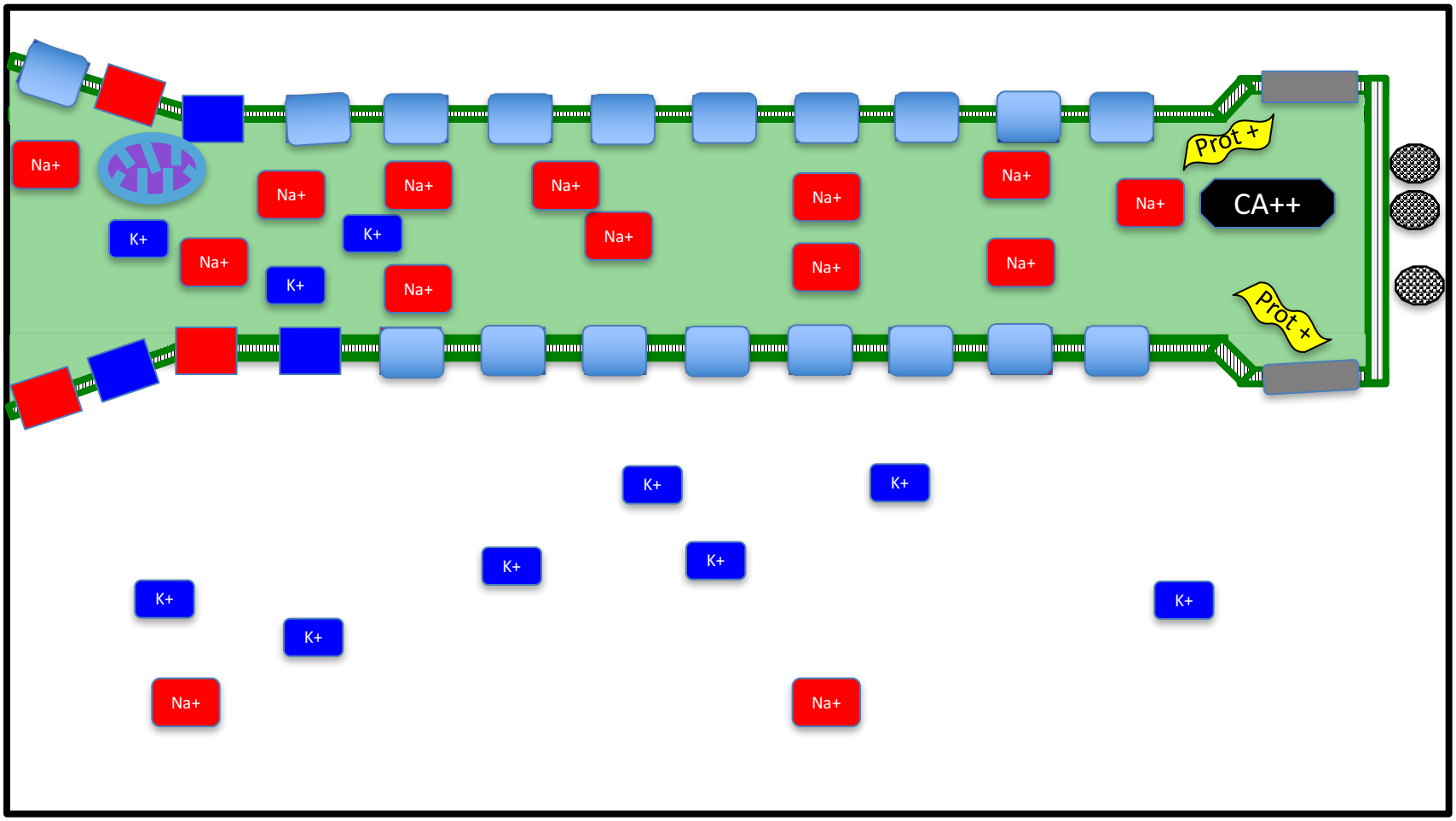


Energy requiring 

Sodium–Potassium Pump

Takes in 2K+ for every 3+ Na+ it puts out

Restoring the Resting Potential



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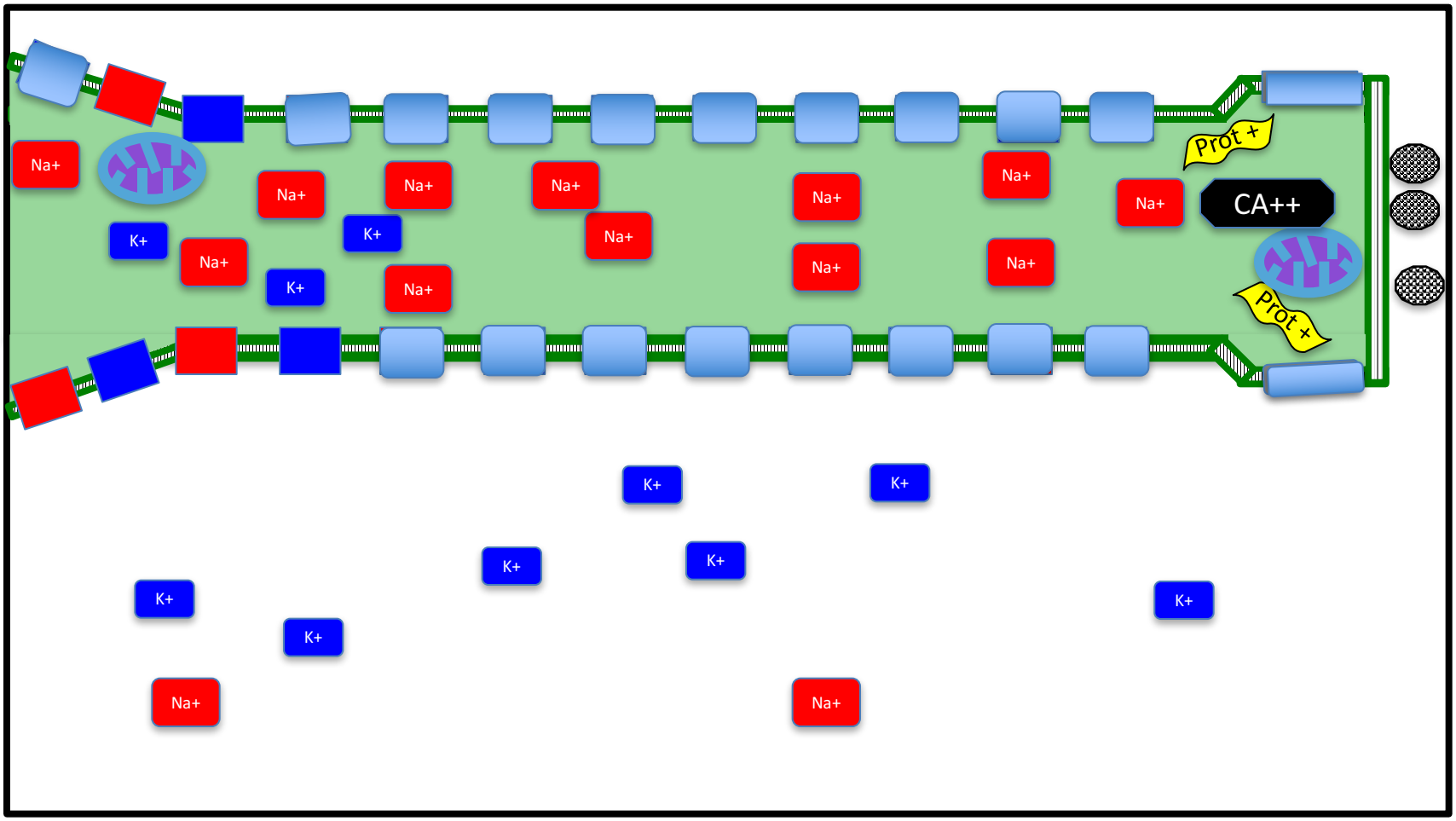


Energy requiring 

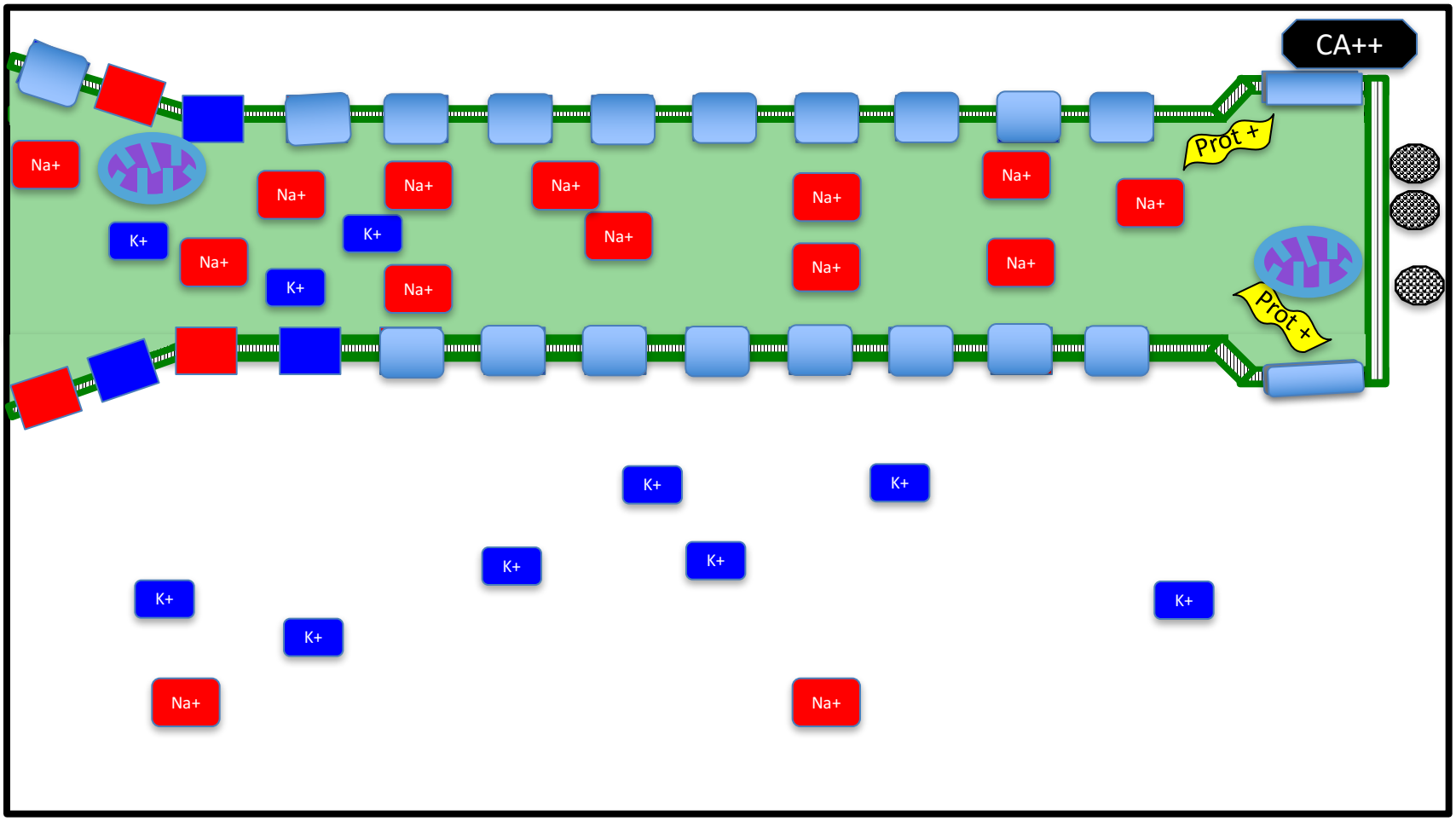
Sodium–Potassium Pump

Takes in 2K+ for every 3+ Na+ it puts out

Calcium Pump

Ejects Ca++ from Terminal

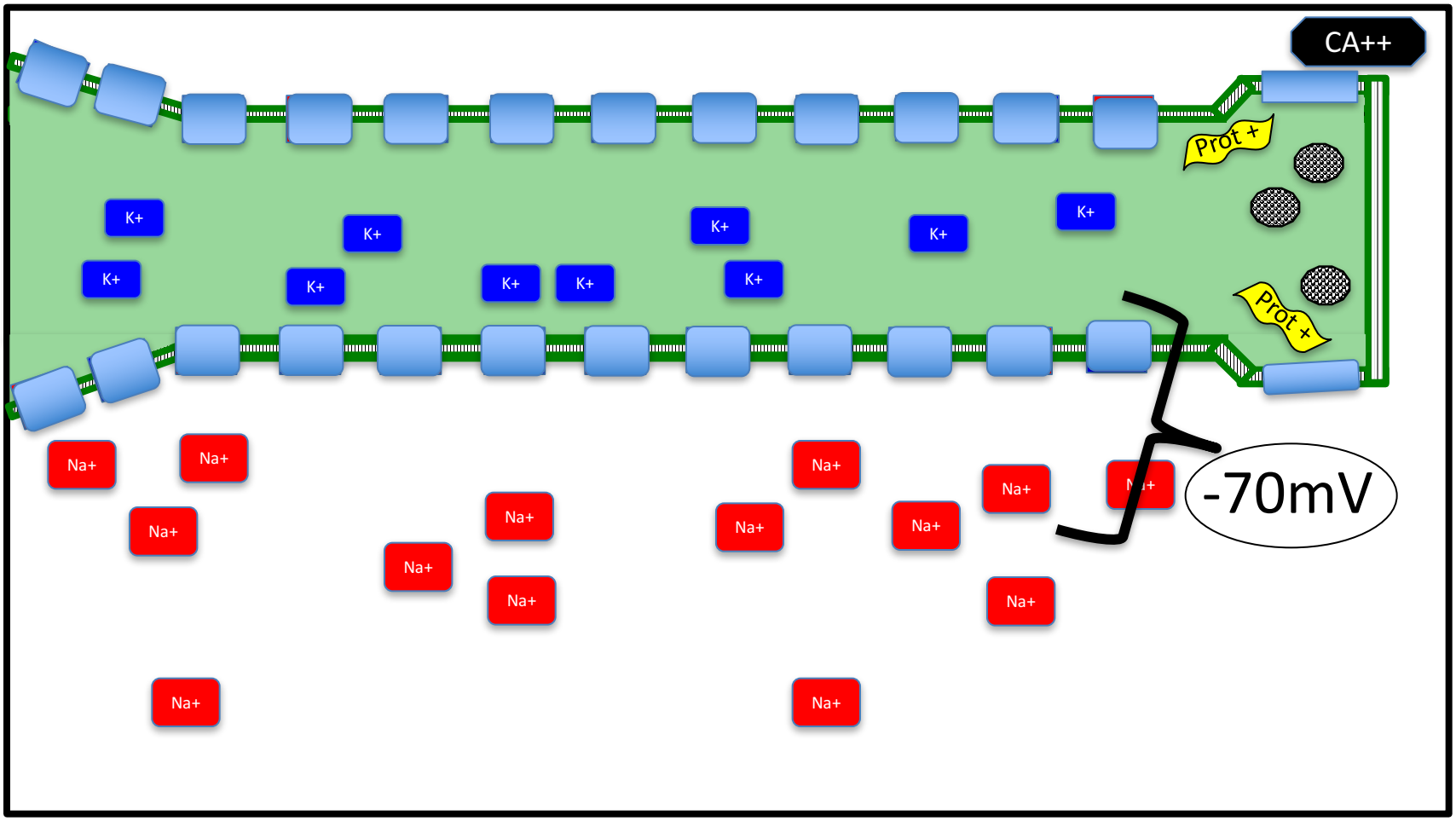
Restoring the Resting Potential



While Resting Potential is being restored,
cell can NOT fire

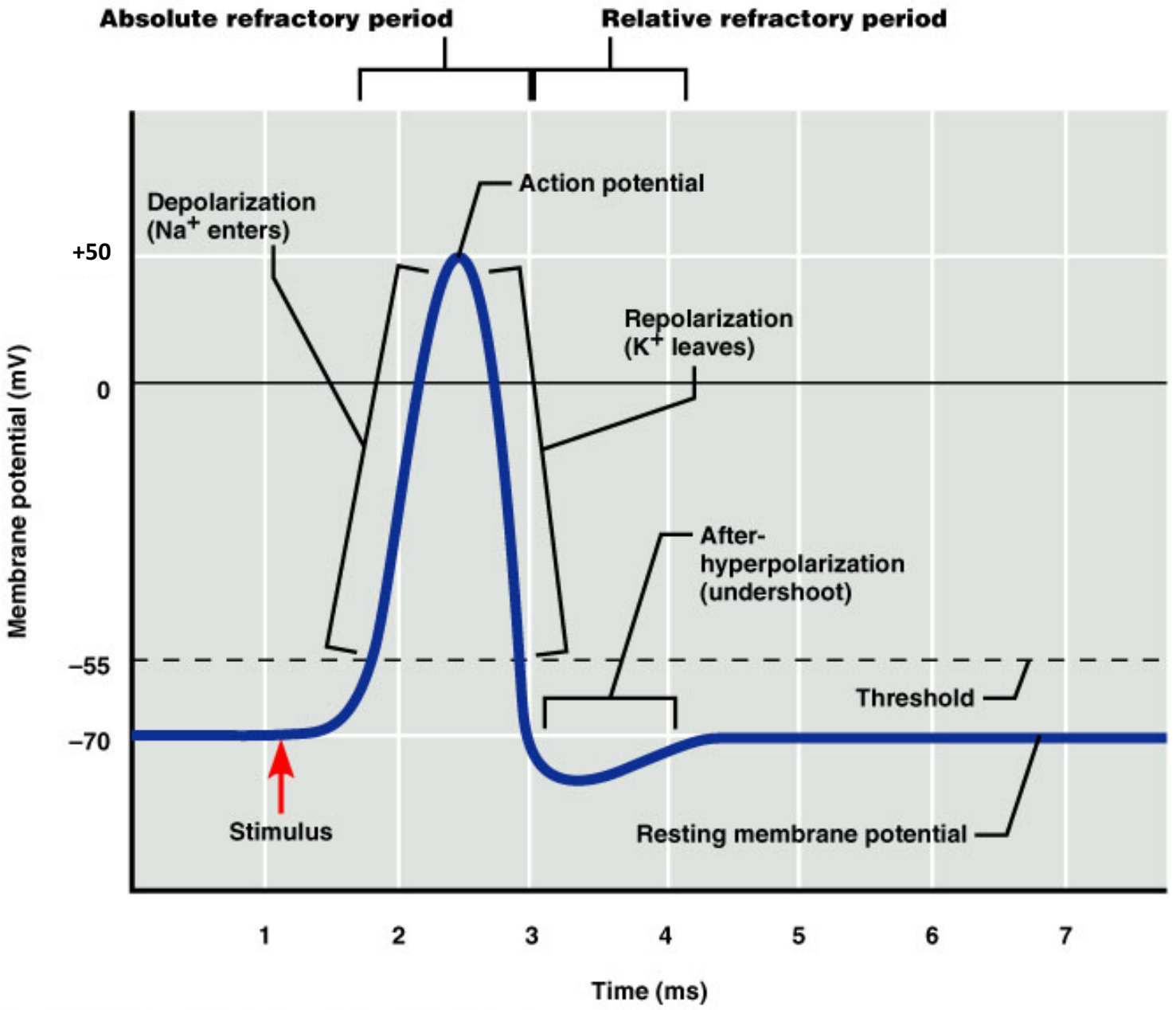
Refractory Period

Restoring the Resting Potential



Once Resting Potential is fully restored cell is

ready to FIRE!



MNEMONICS for Resting Potential

When Ions of Sodium want to come in,

what does the Resting Cell say?

Na+, Na+, Na+

This is because what minority is locked inside?

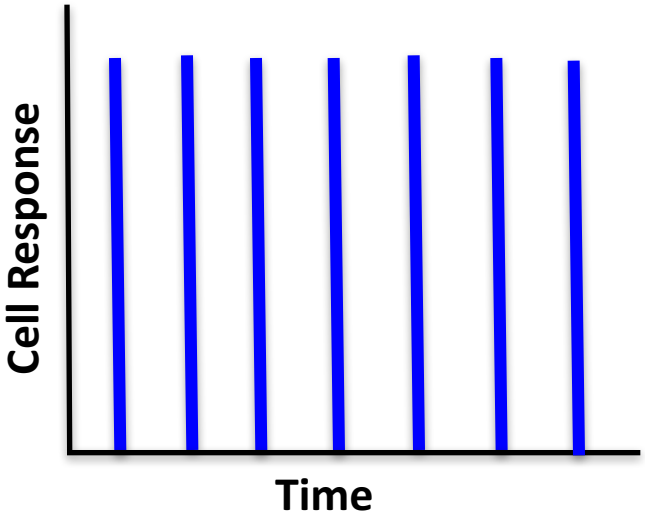
K+ K+ K+

(Actually **K+K+** for each **Na+Na+Na+**)

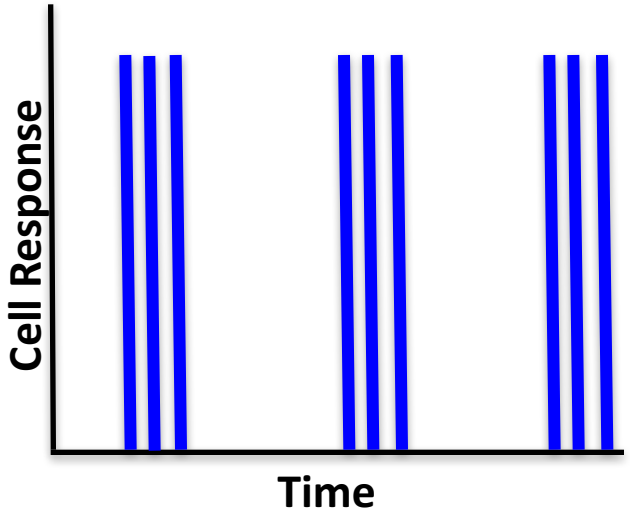
Action Potential = "**All or Nothing**"

Action Potential results is same release of NT
regardless of intensity of input

(as long as "Threshold for Firing" is crossed)



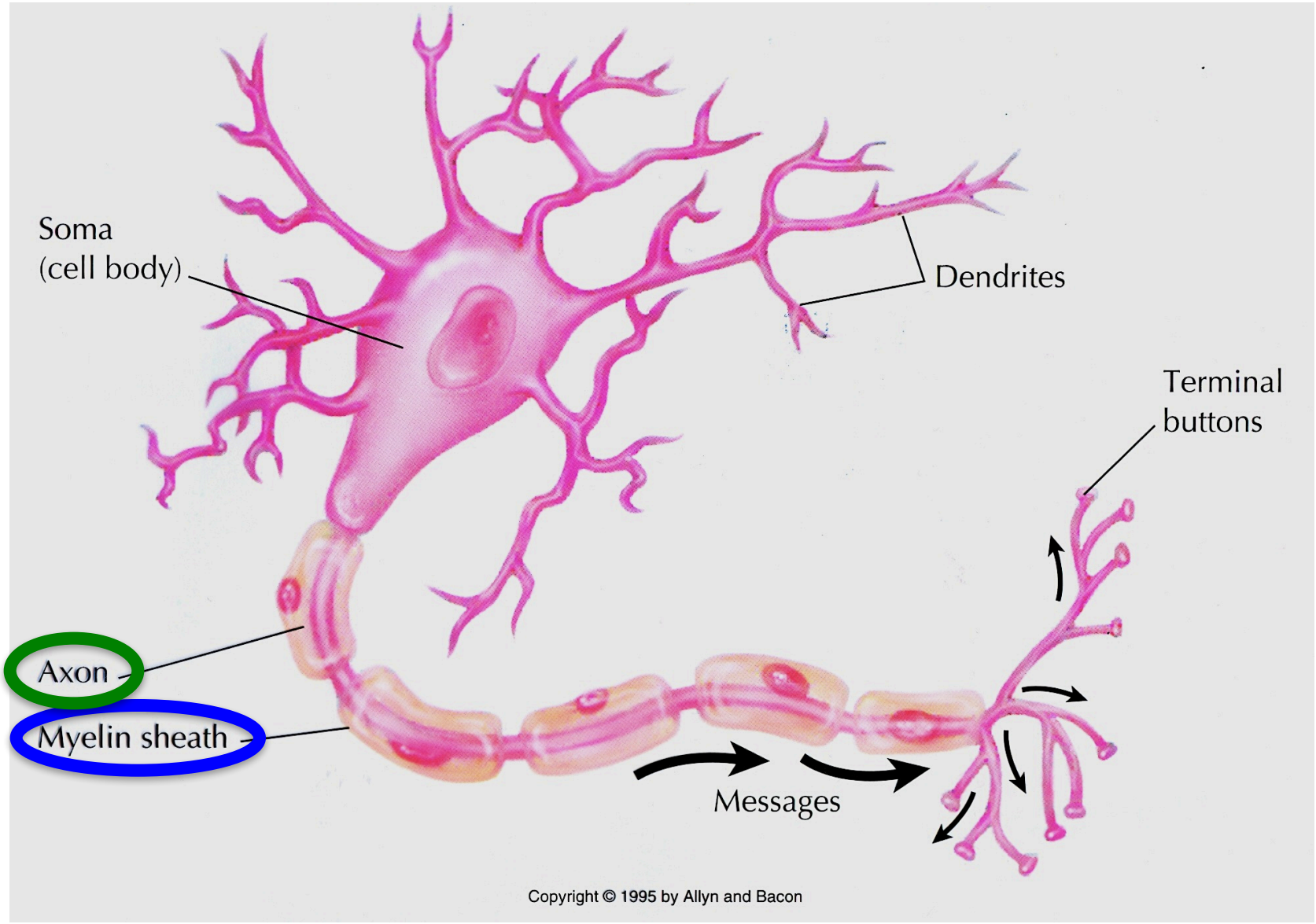
Every spike is the same



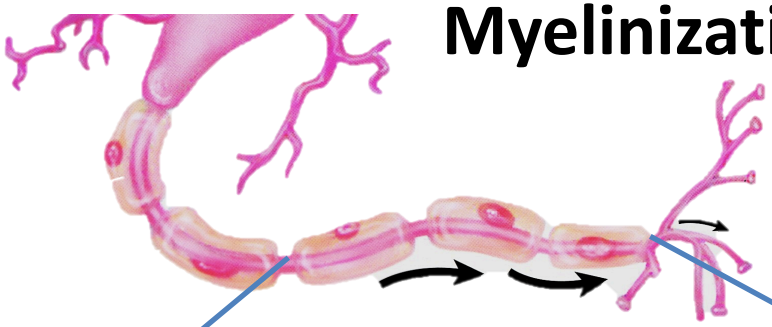
But message can vary

Temporally!

Myelinization



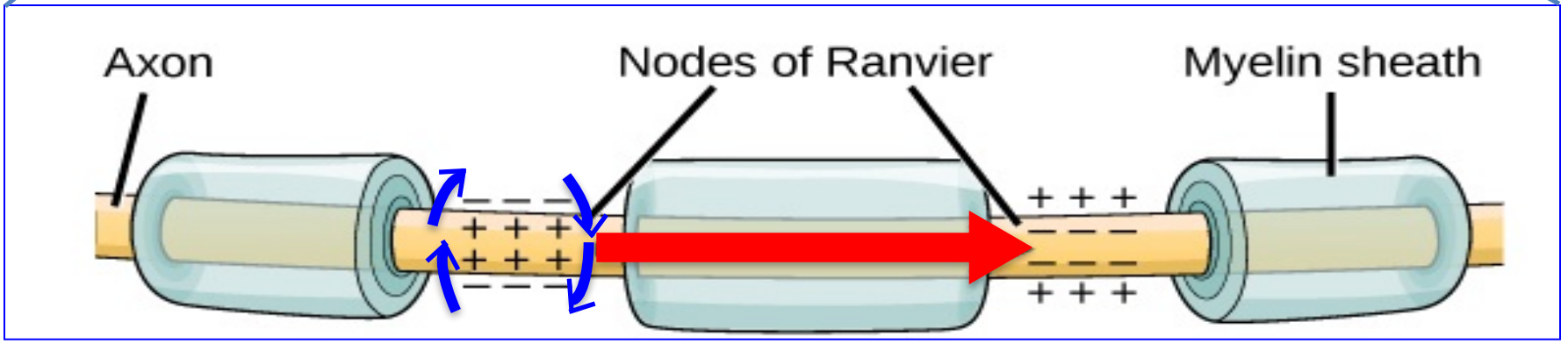
Myelinization



Glia Cells,
wrapped around the axon,
w/gaps between called
"Nodes of Ranvier"

Electrical Conduction
(Electricity flows thru axon
under "insulation")

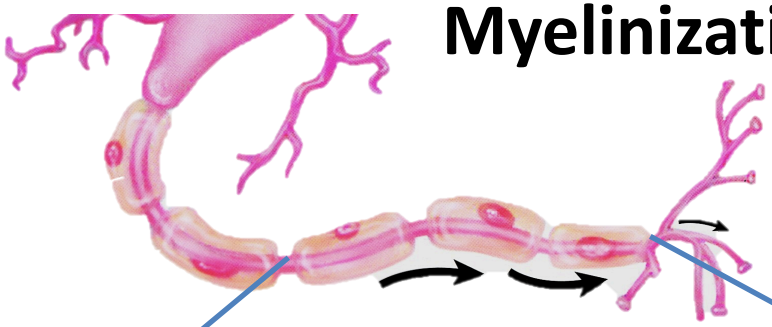
Ionic Conduction
(Ions flow across membrane)



Slow, but stays strong

VERY fast,
but decays over distance

Myelinization



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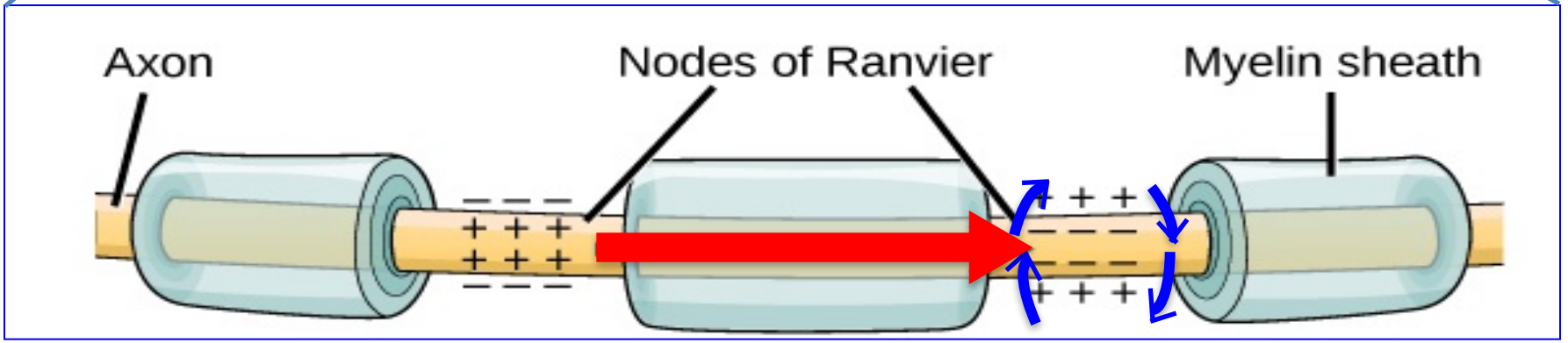
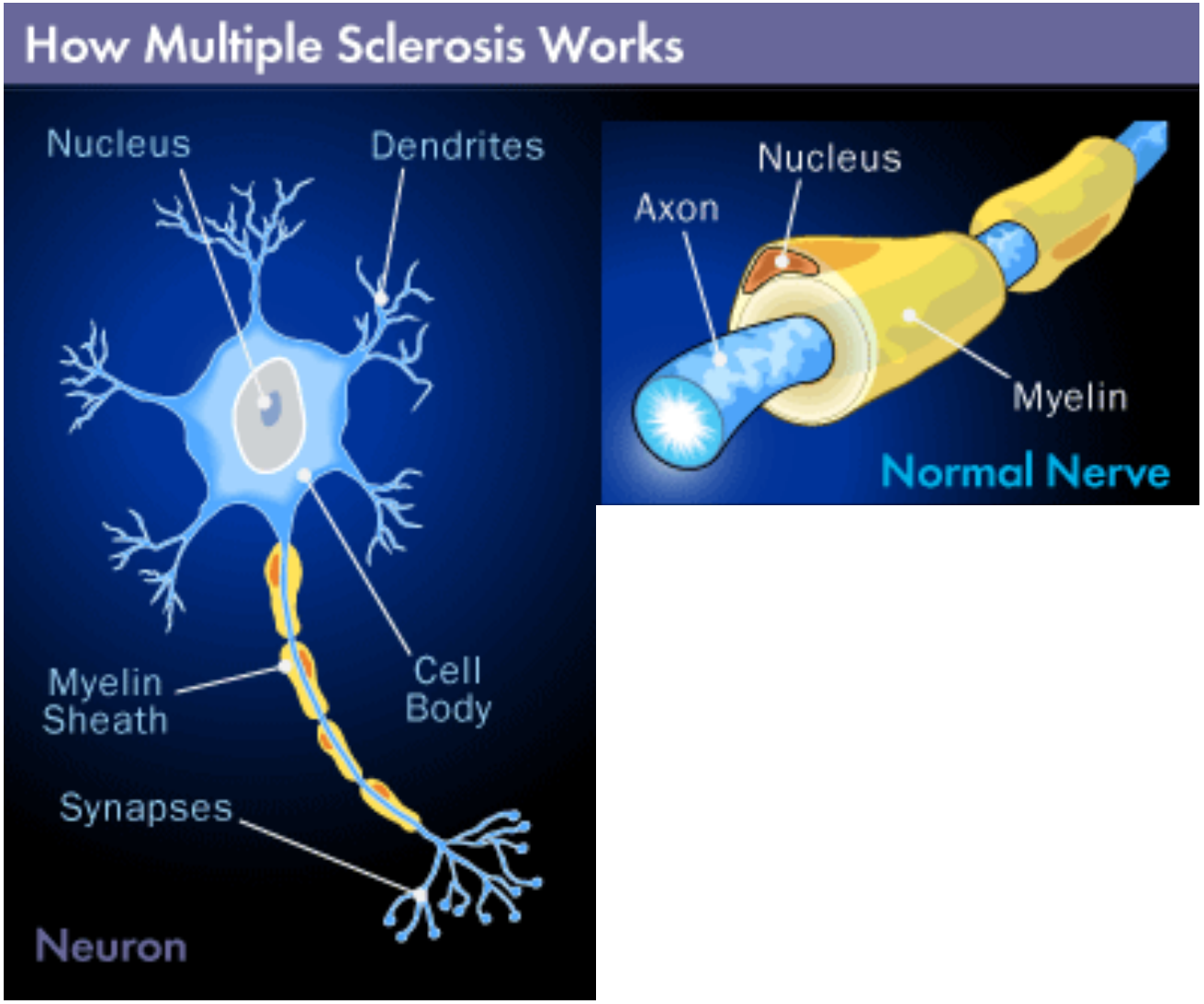


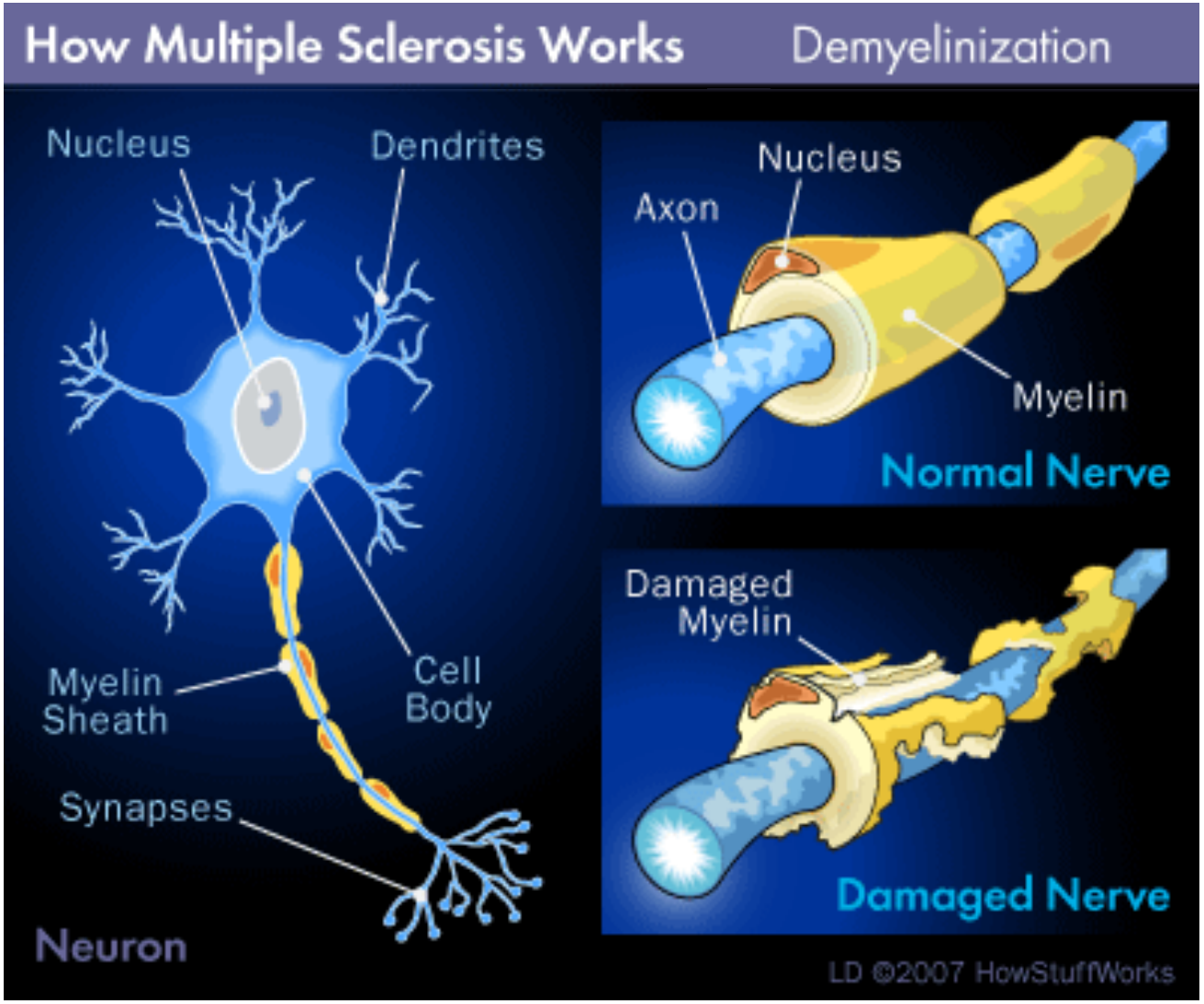
So, overall, myelinated axons show
"**Saltatory**" – or "jumping" - Conduction

Multiple Sclerosis

Multiple Sclerosis



Multiple Sclerosis



No ion gates under the myelin so signal does not propagate

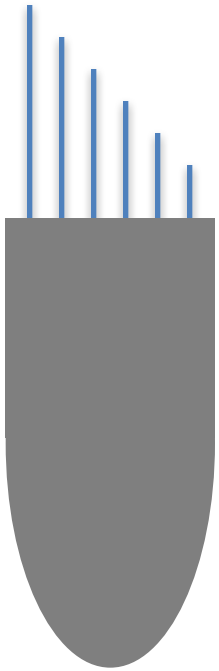
Graded Potentials

Not all Neurons show "Action Potentials"

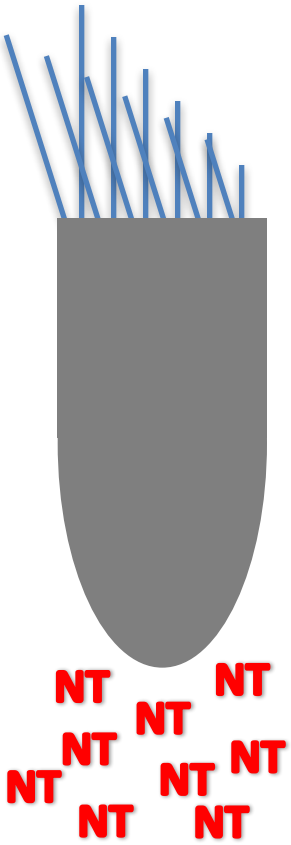
Cells that fire "Graded Potentials" may release **MORE** or **LESS** neurotransmitter

e.g. "Hair cells"
Auditory receptors

Soft sound, cilia move a little



A little neurotransmitter is released



Loud sound, cilia move a lot

A lot of neurotransmitter is released