Bioscience in the 21st century

Neurons, Synapses, and Signaling

Dr. Michael Burger

Outline:

1. Why neuroscience?

2. The neuron

3. Action potentials

4. Synapses

5. How is information represented in neurons

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1. Why neuroscience?

2. The neuron

3. Action potentials

4. Synapses

5. How is information represented in neurons

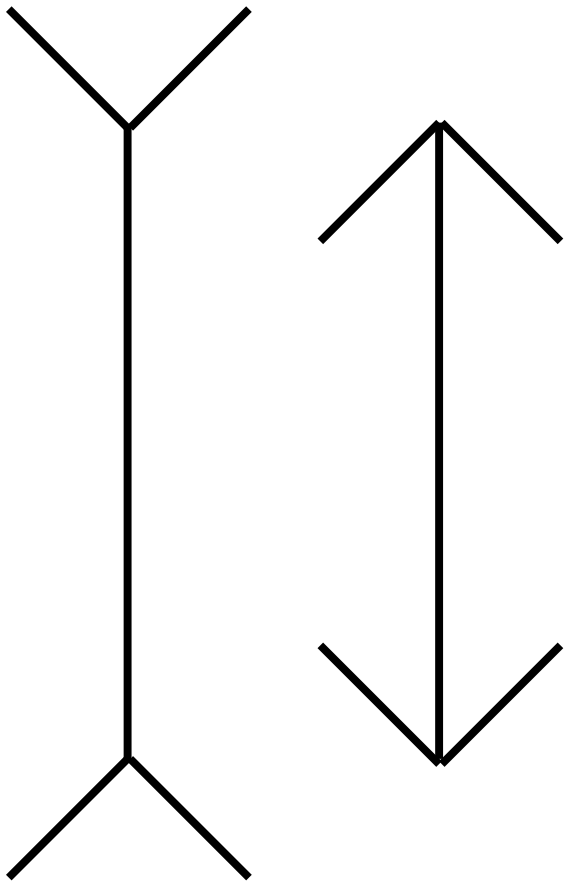
Why Neuroscience: reason 1

Everything you ever think, feel, or do depends on your (amazingly complex and normally functioning) brain.

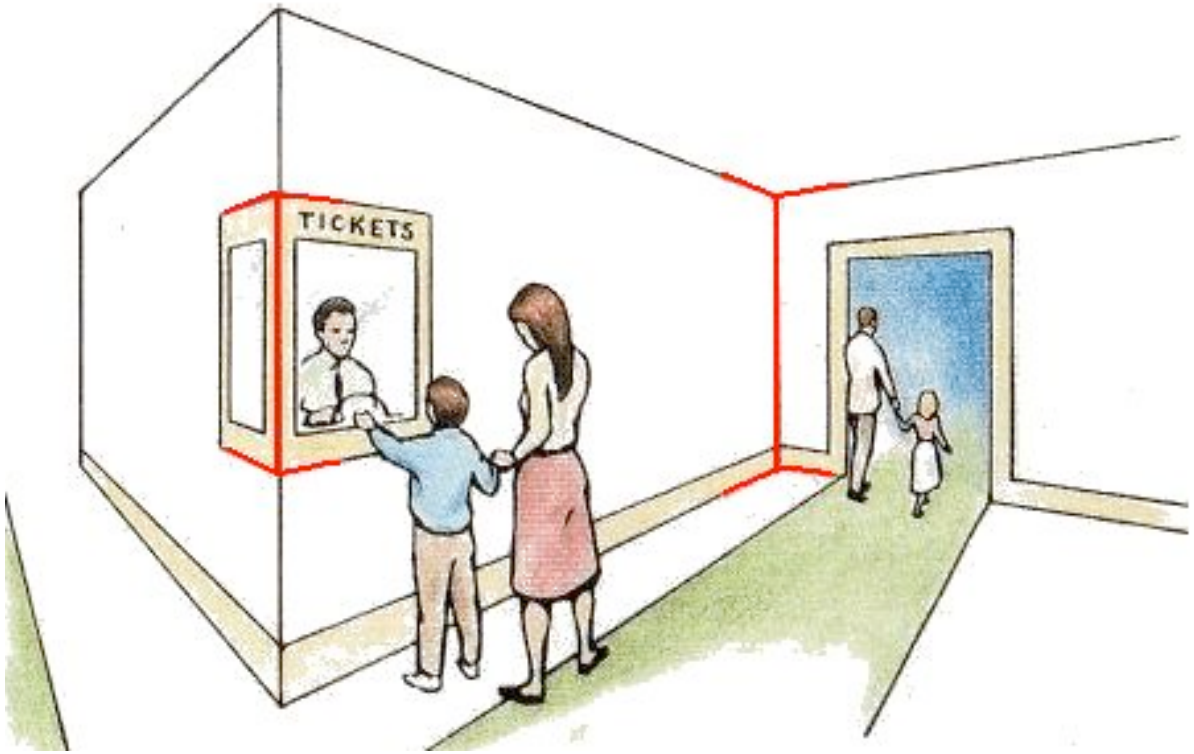
...In fact, from one perspective
"you" are your brain

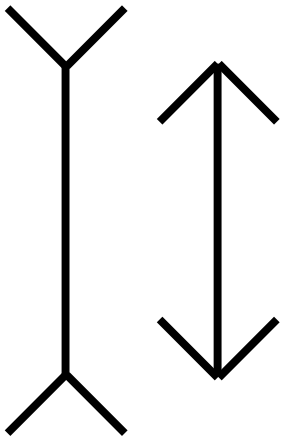
Figure-ground illusions are well known for visual stimuli

The Müller-Lyer Illusion

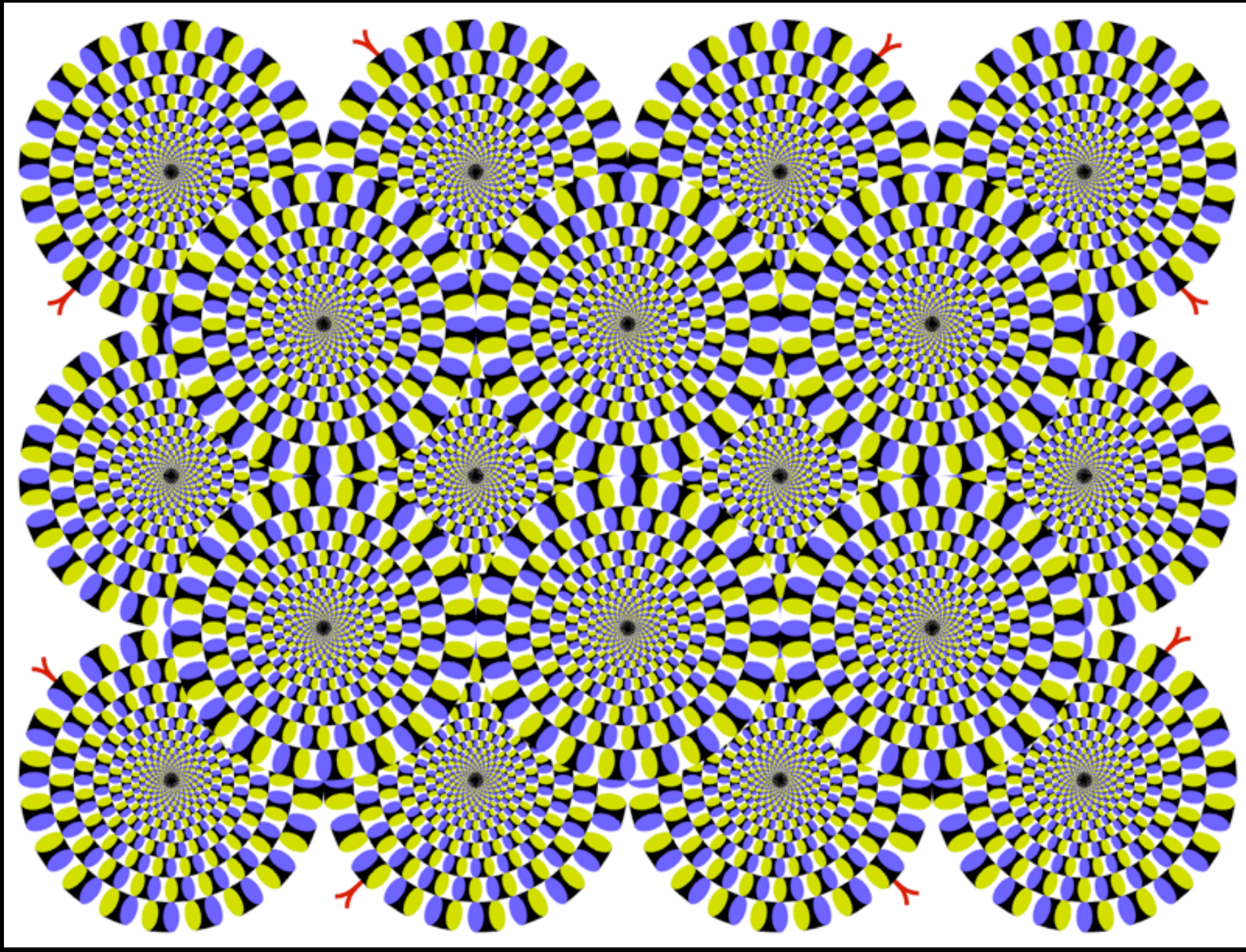


The Müller-Lyer Illusion





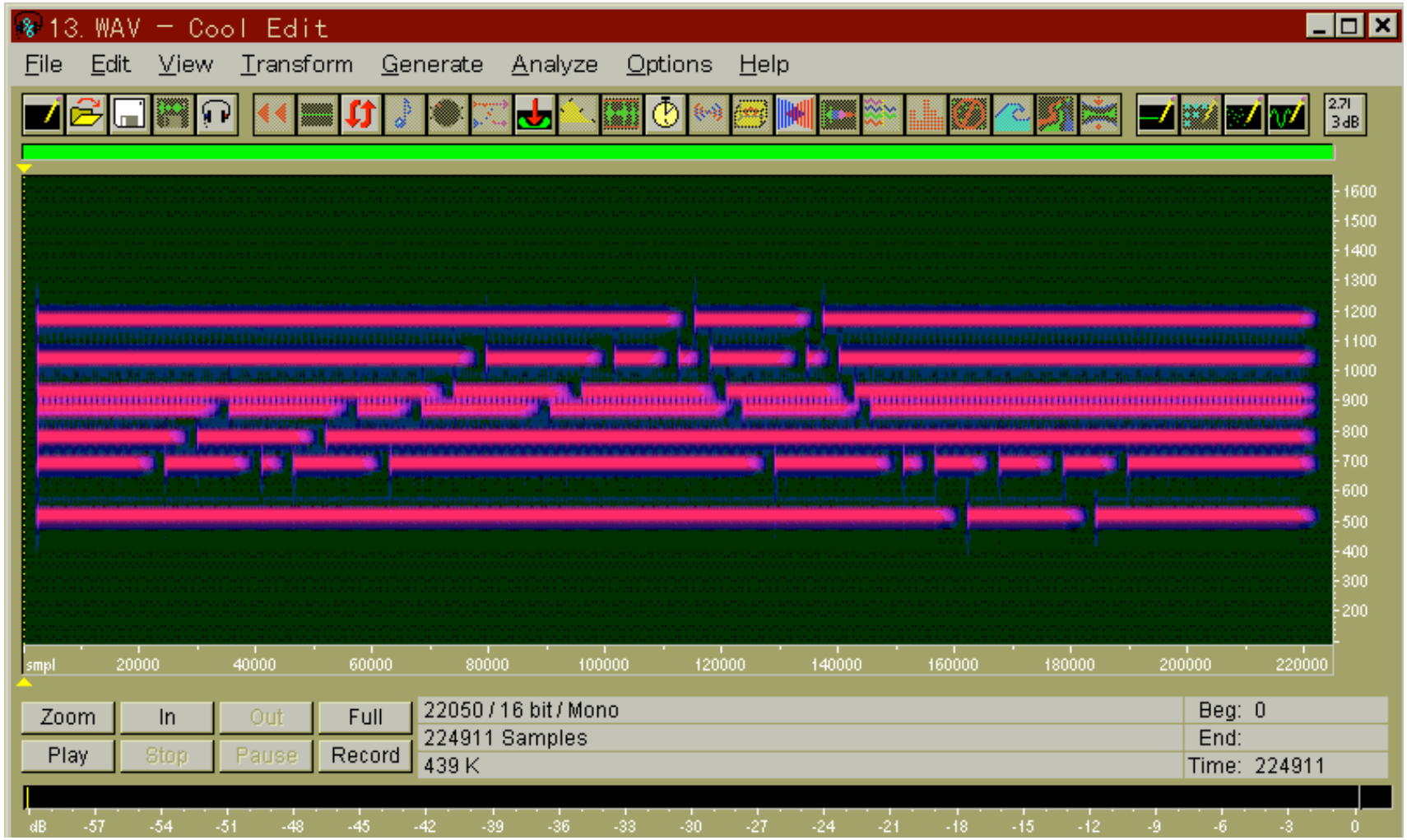
http://www.michaelbach.de/ot/sze_muelue/index.html



http://www.ritsumei.ac.jp/~akitaoka/index-e.html

Hearing gaps

But they occur in the auditory system too!



What did he say?

What did he say?

http://www.media.uio.no/personer/arntm/english.html

Now close your eyes!

Why Neuroscience: reason 2

We are going to need you to cure us

Alzheimer's Disease

more than 5 million people in the United States living with Alzheimer's.

The direct and indirect costs of Alzheimer's and other dementias amount to more than $148 billion annually.

Parkinson's disease:

3% of population over 65: 1.5 million patients

Hearing Impairment:

Approximately 28 million Americans have a hearing impairment

Approximately 314 in 1,000 people over age 65 have hearing loss and 40 to 50 percent of people 75 and older have a hearing loss.

Paralysis:

2.4 million Americans are paralyzed

Depression:

over 20 million Americans suffer from depression

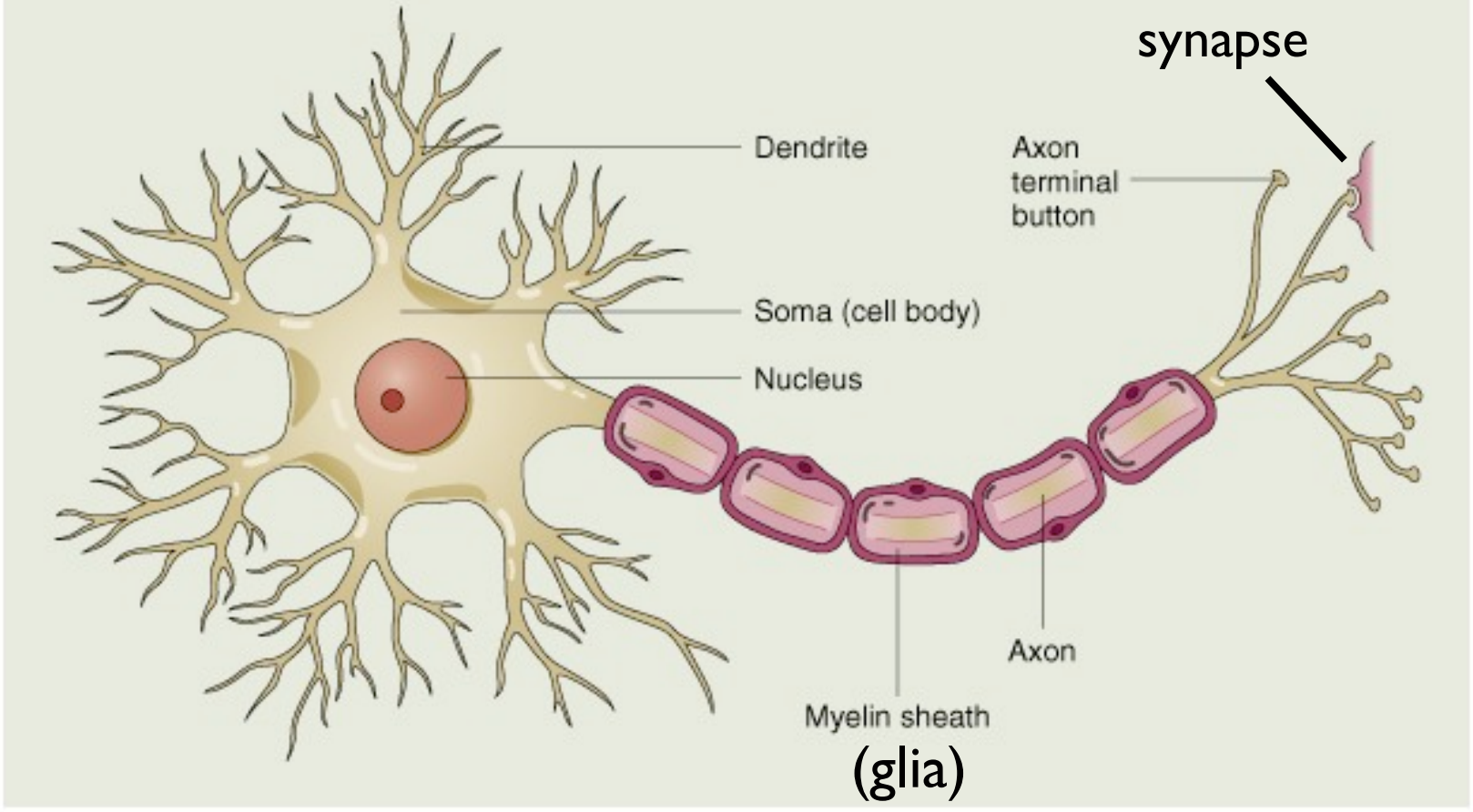
The BIG THREE topics for today:

I. What is the basis of electrical signaling in neurons?

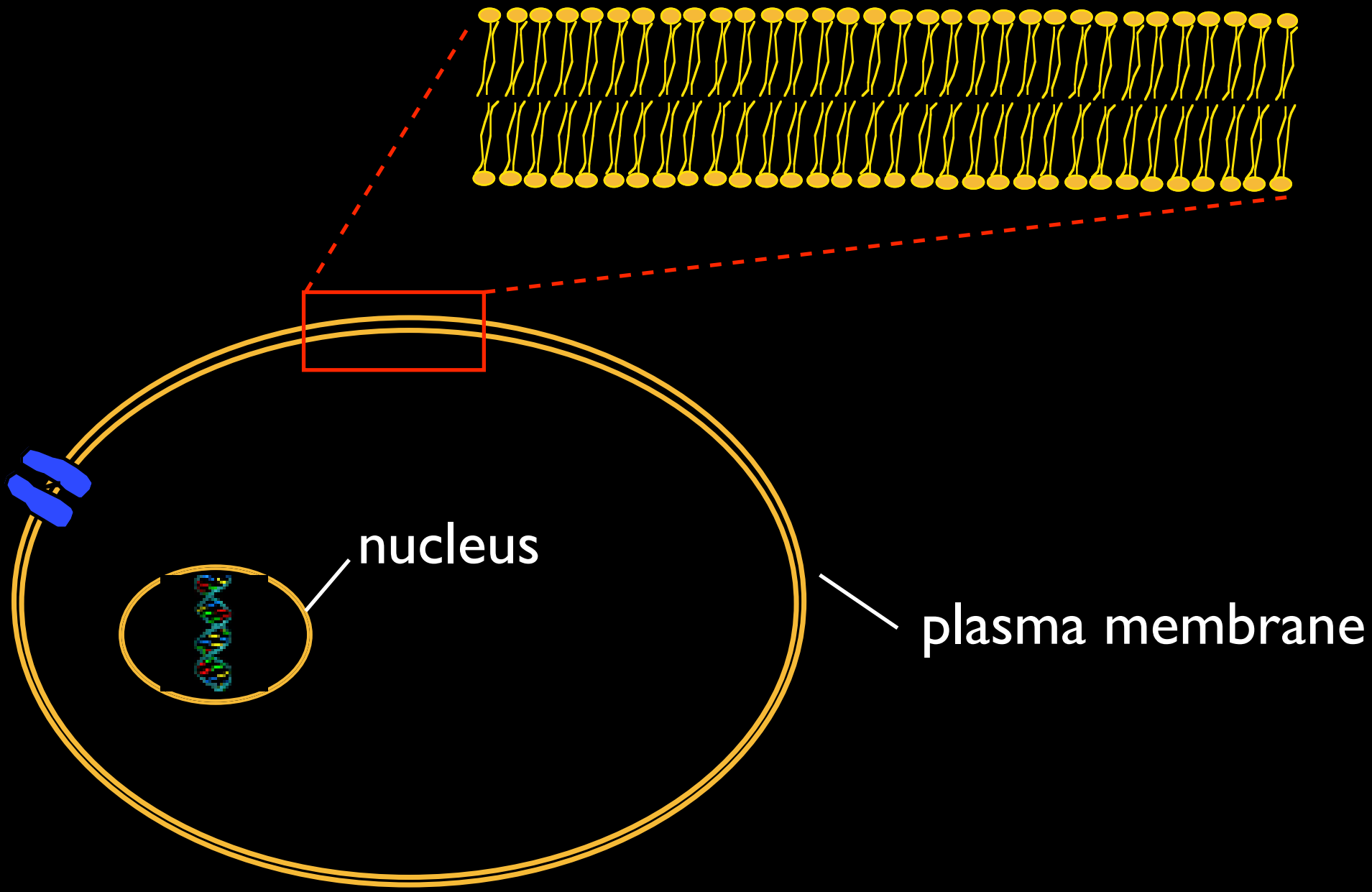
II. How do neurons "talk" to each other?

III. How do neurons encode information?

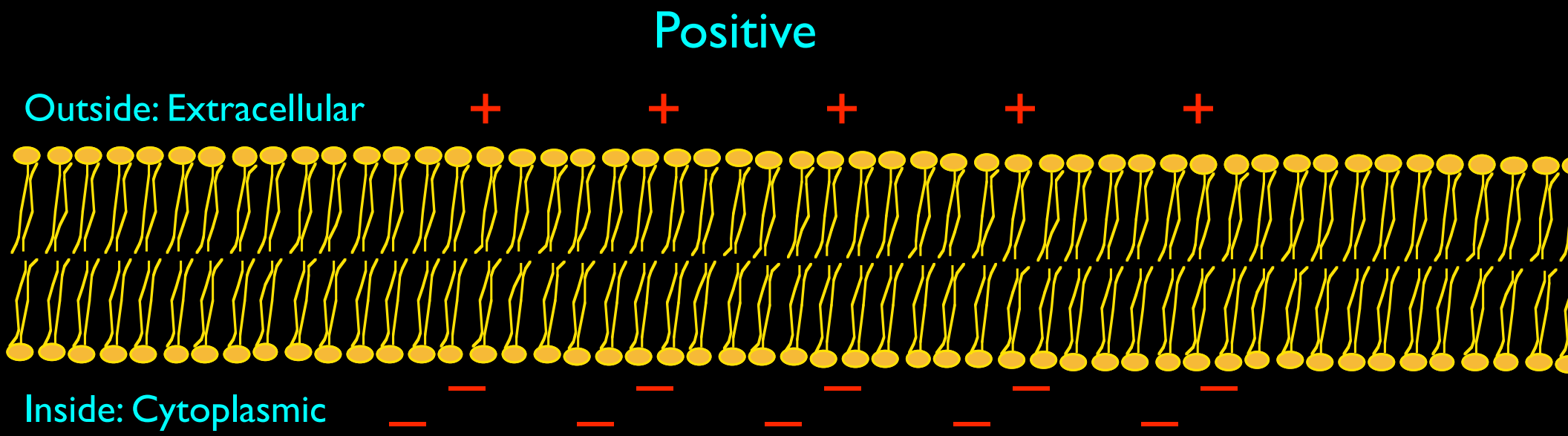
The neuron is the "unit of processing" for the nervous system



The cell membrane is a phospholipid bilayer



Cell membranes store Voltage

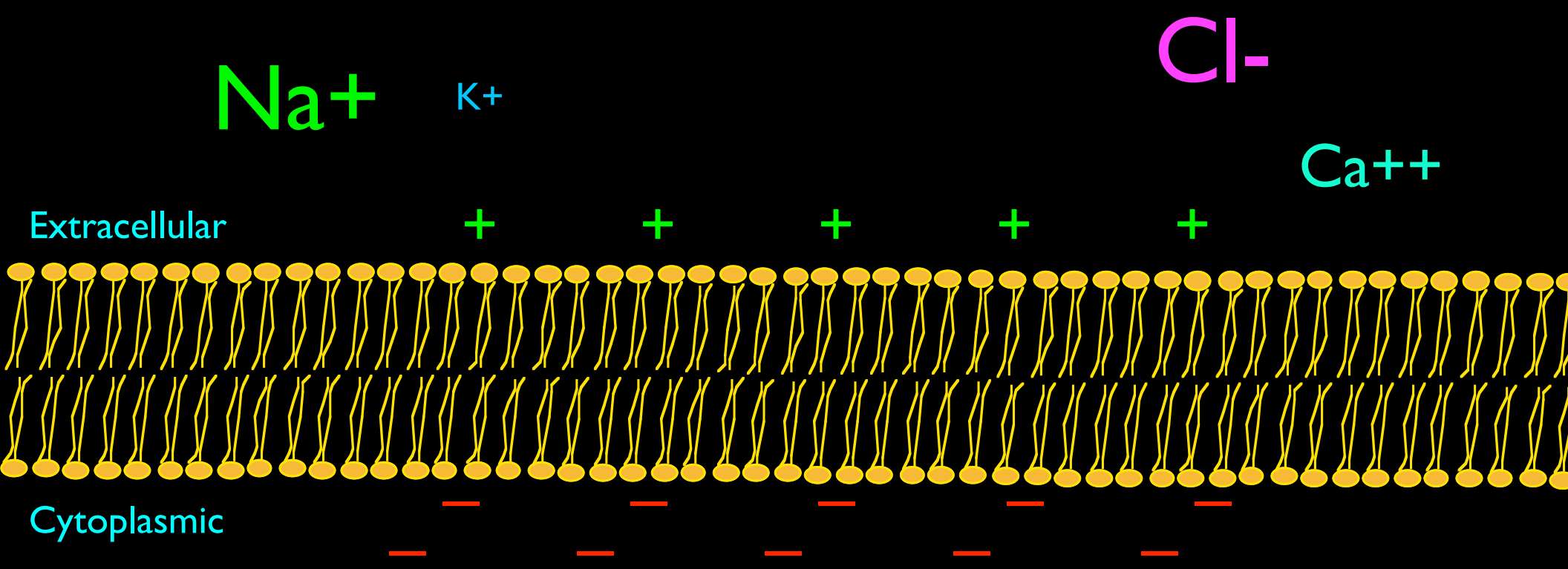


$V_{membrane}$= -60 mV

Negative

**The inside of the cell is usually more negative than the outside by about -60 mV

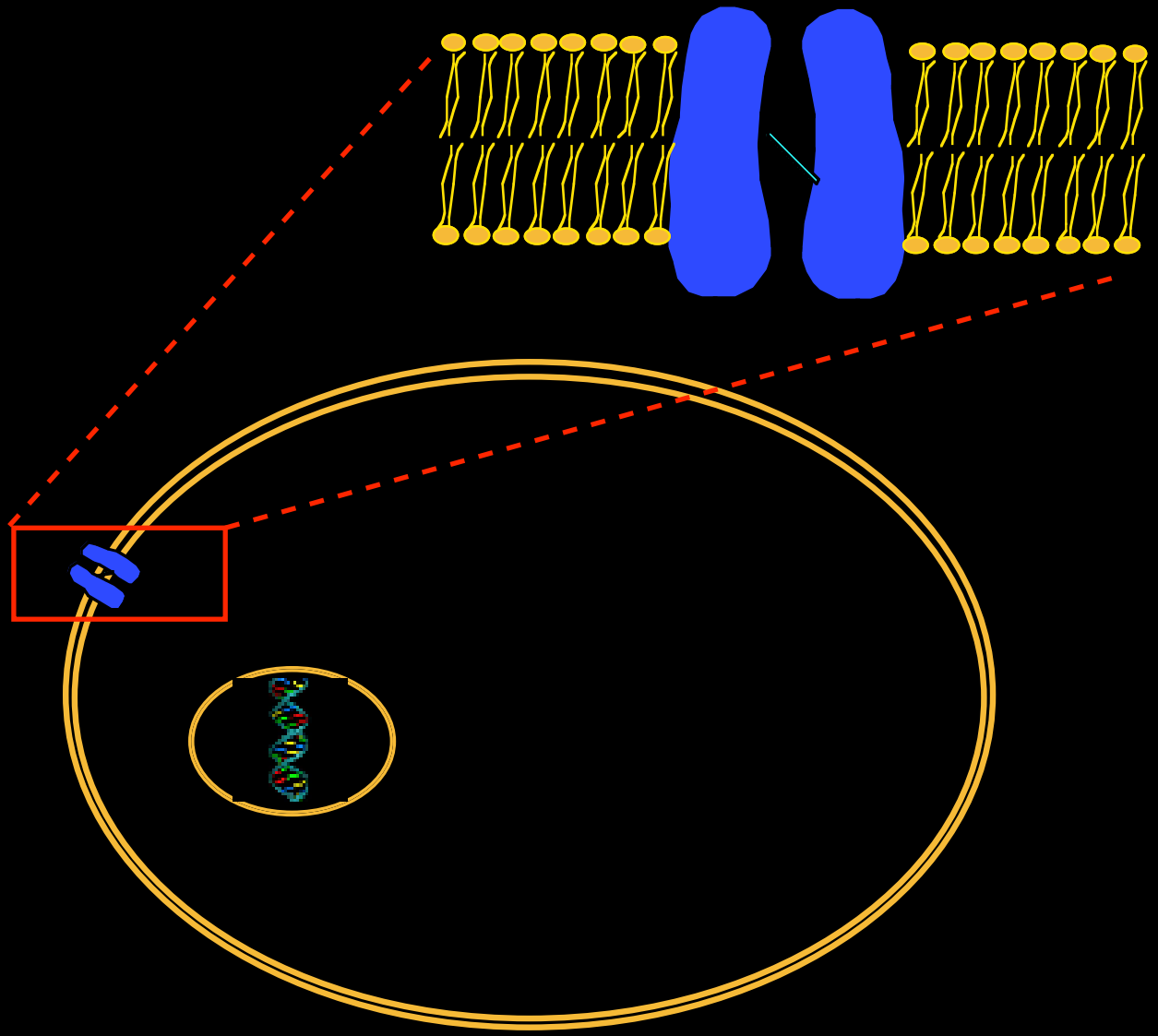
This "resting" voltage depends on ion distribution, and ions *in general* cannot cross the membrane



Na+ K+

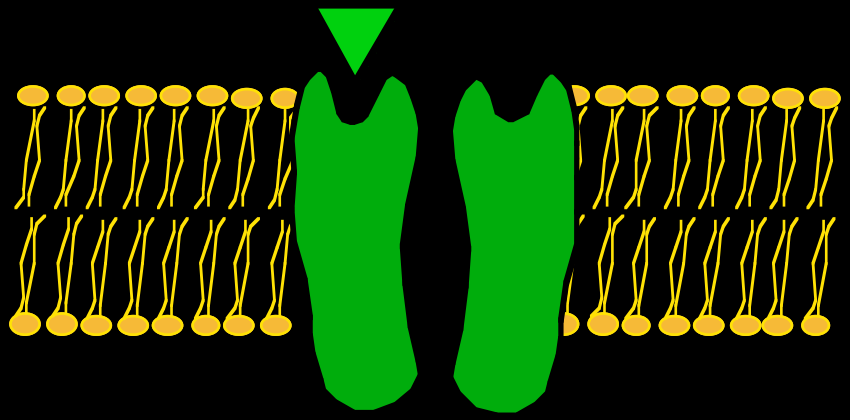
An- (organic anions; ie proteins)

The cell membrane contains proteins, some of which are channels for charged particles

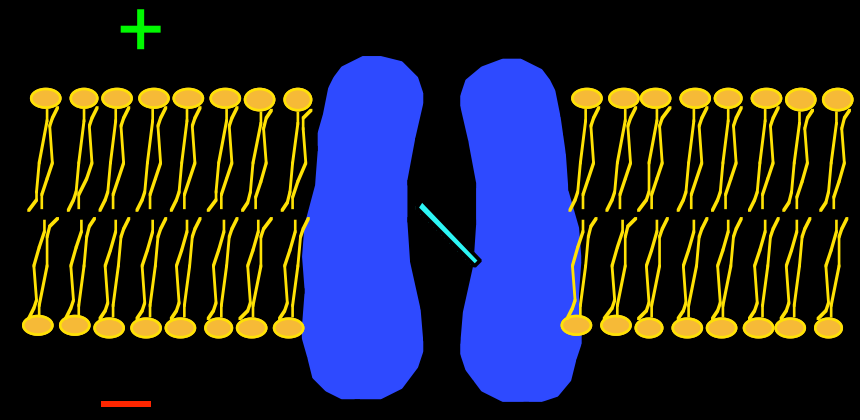


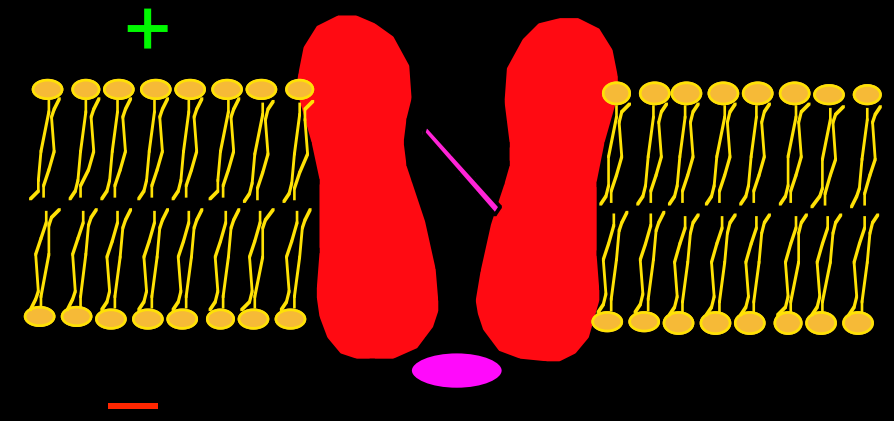
Two (of many) membrane protein types:

Ligand gated (chemically gated)

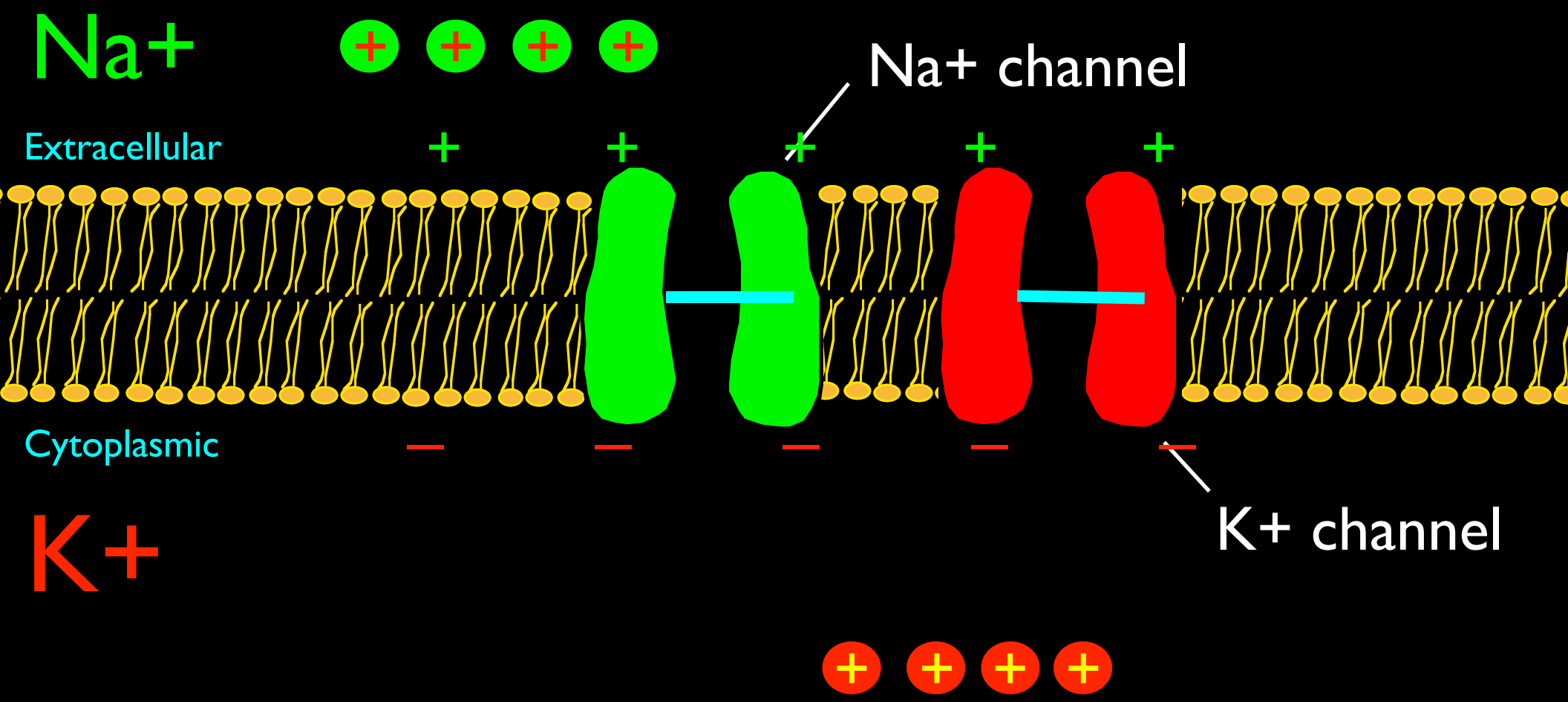


Voltage gated

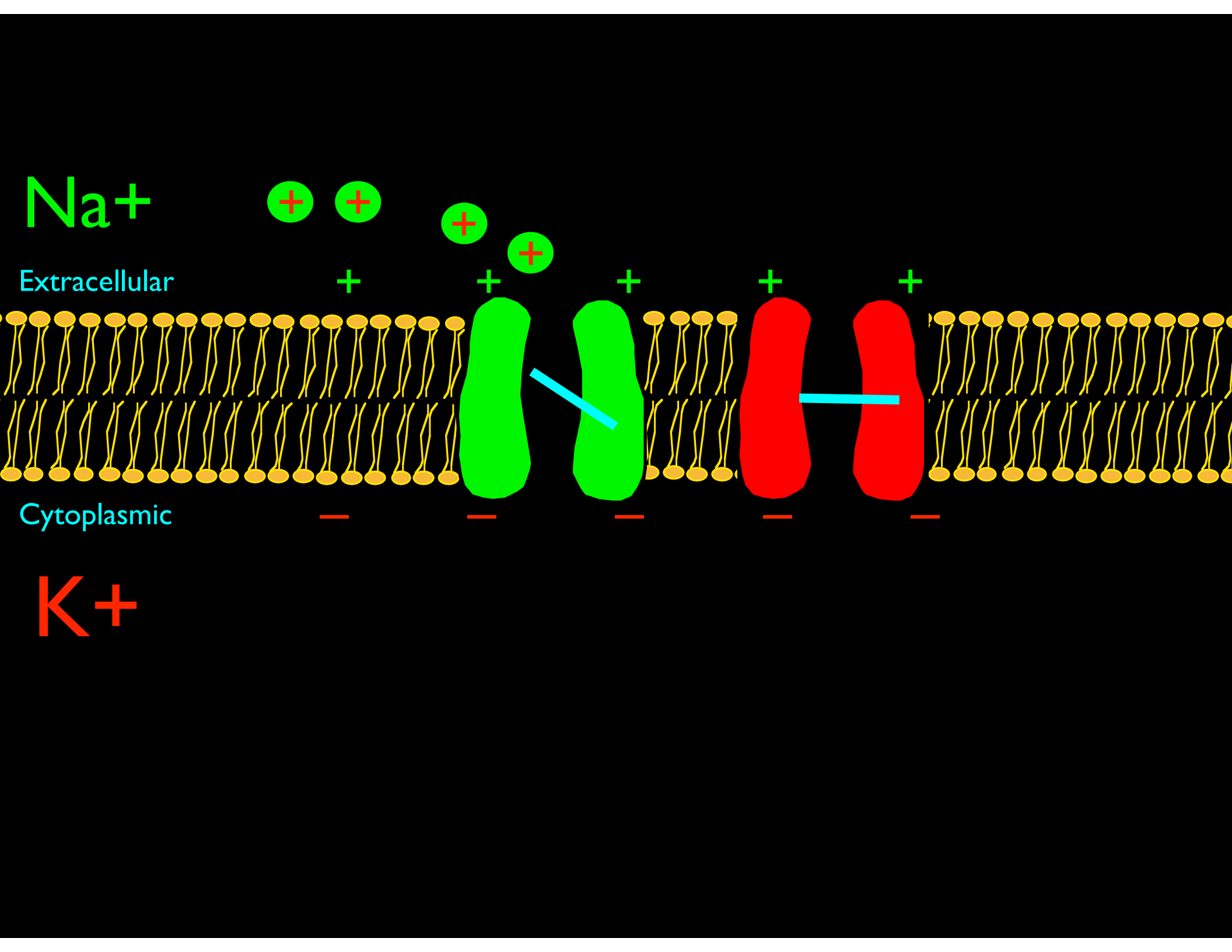


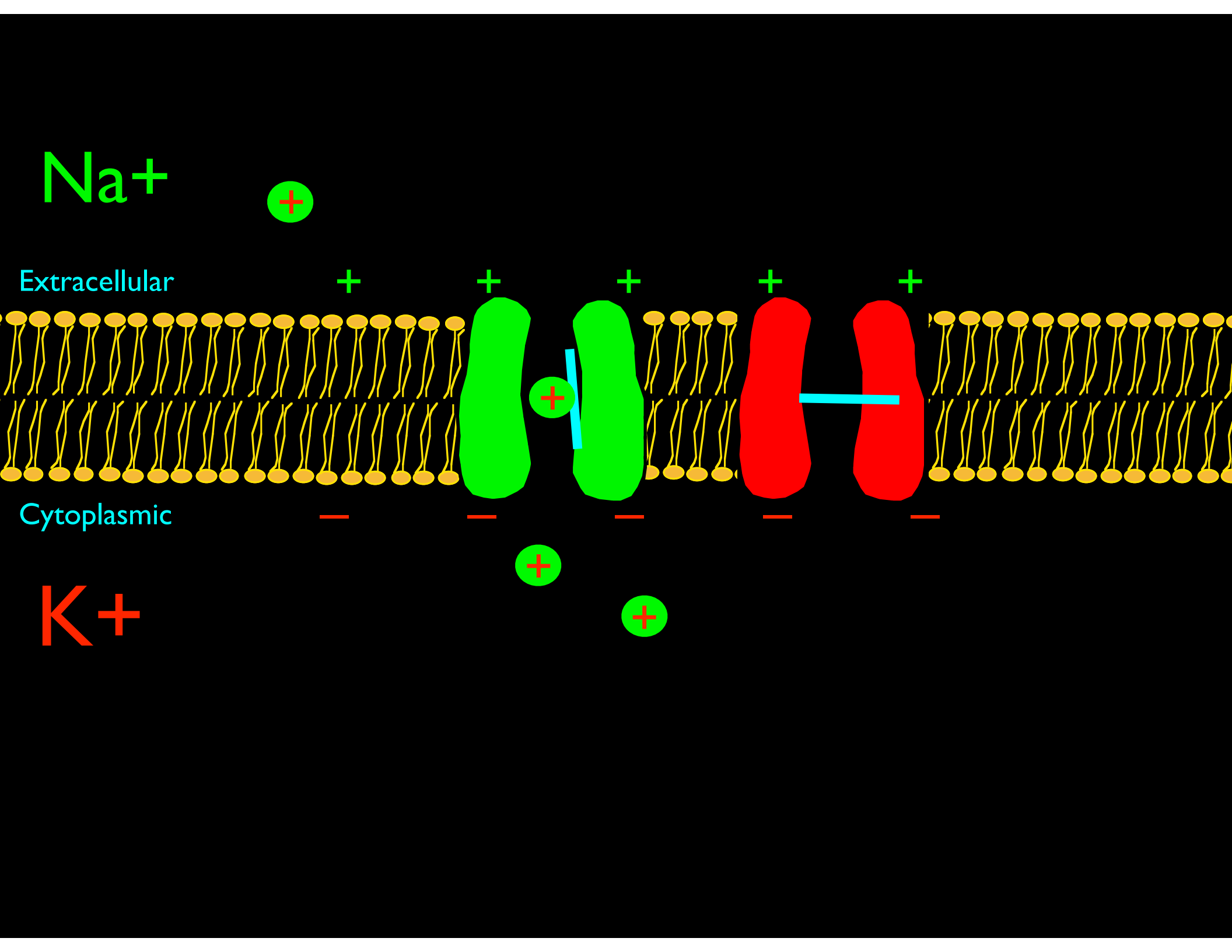


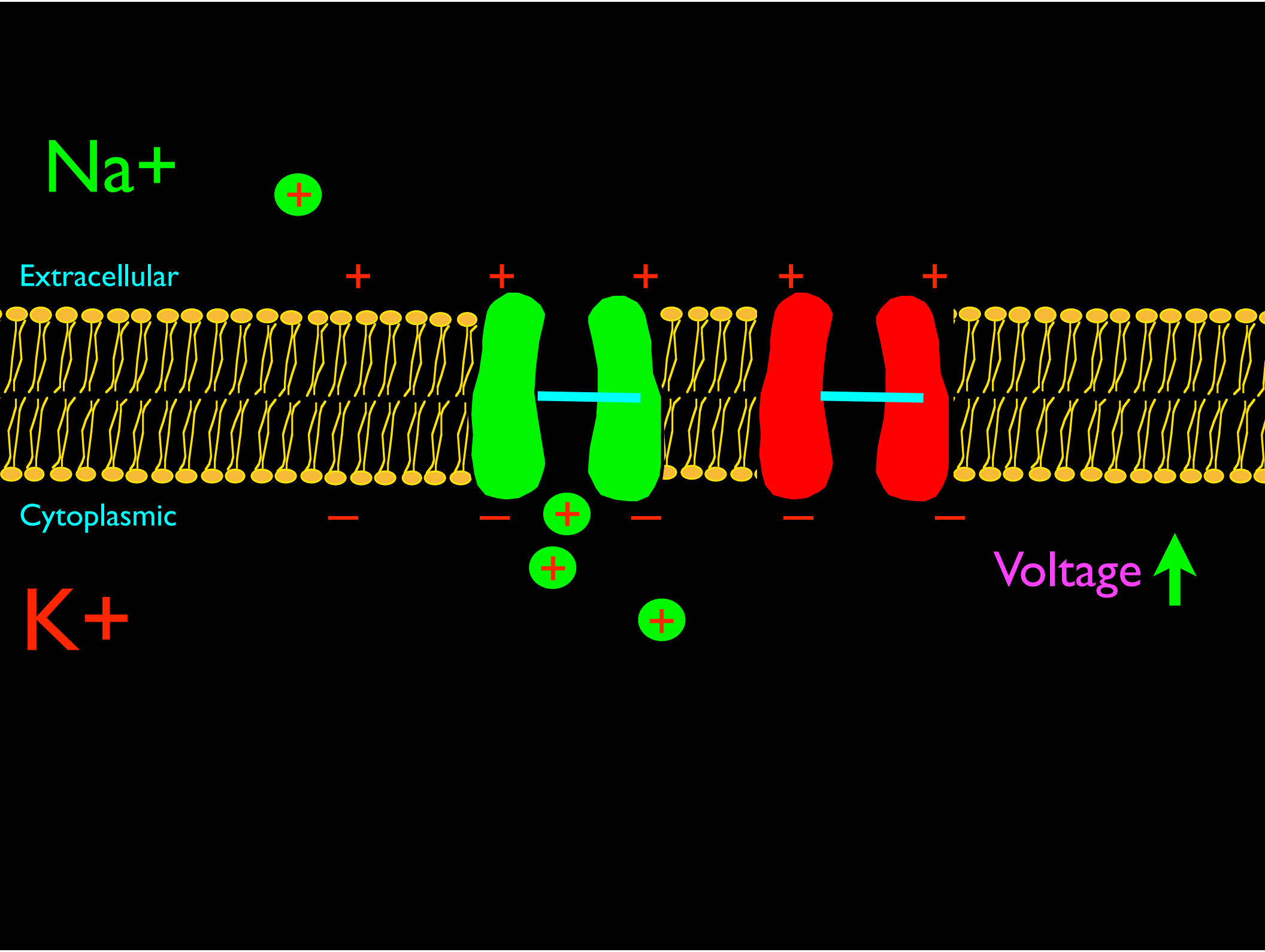
How does an electrical signal occur in a neuron?

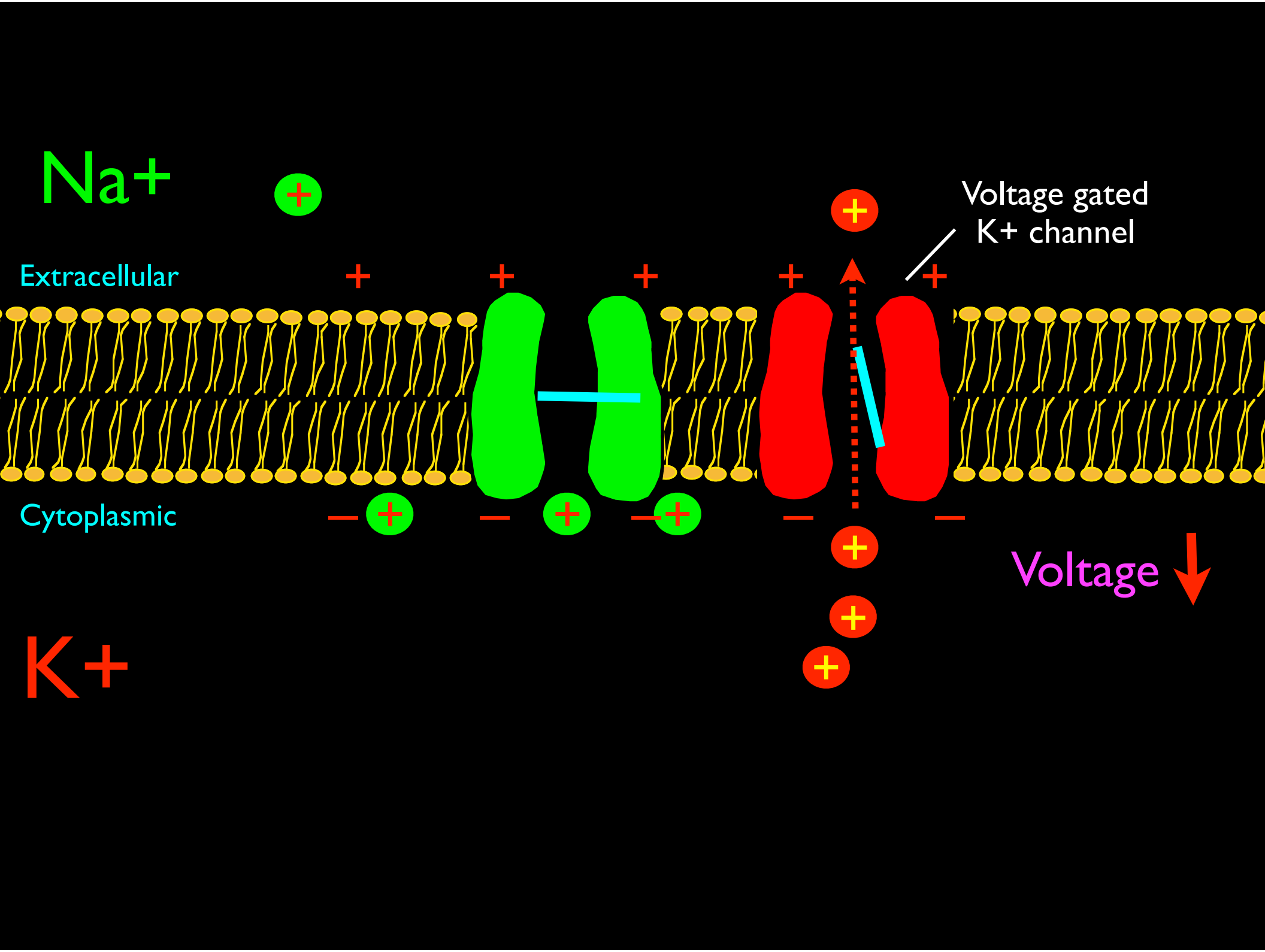


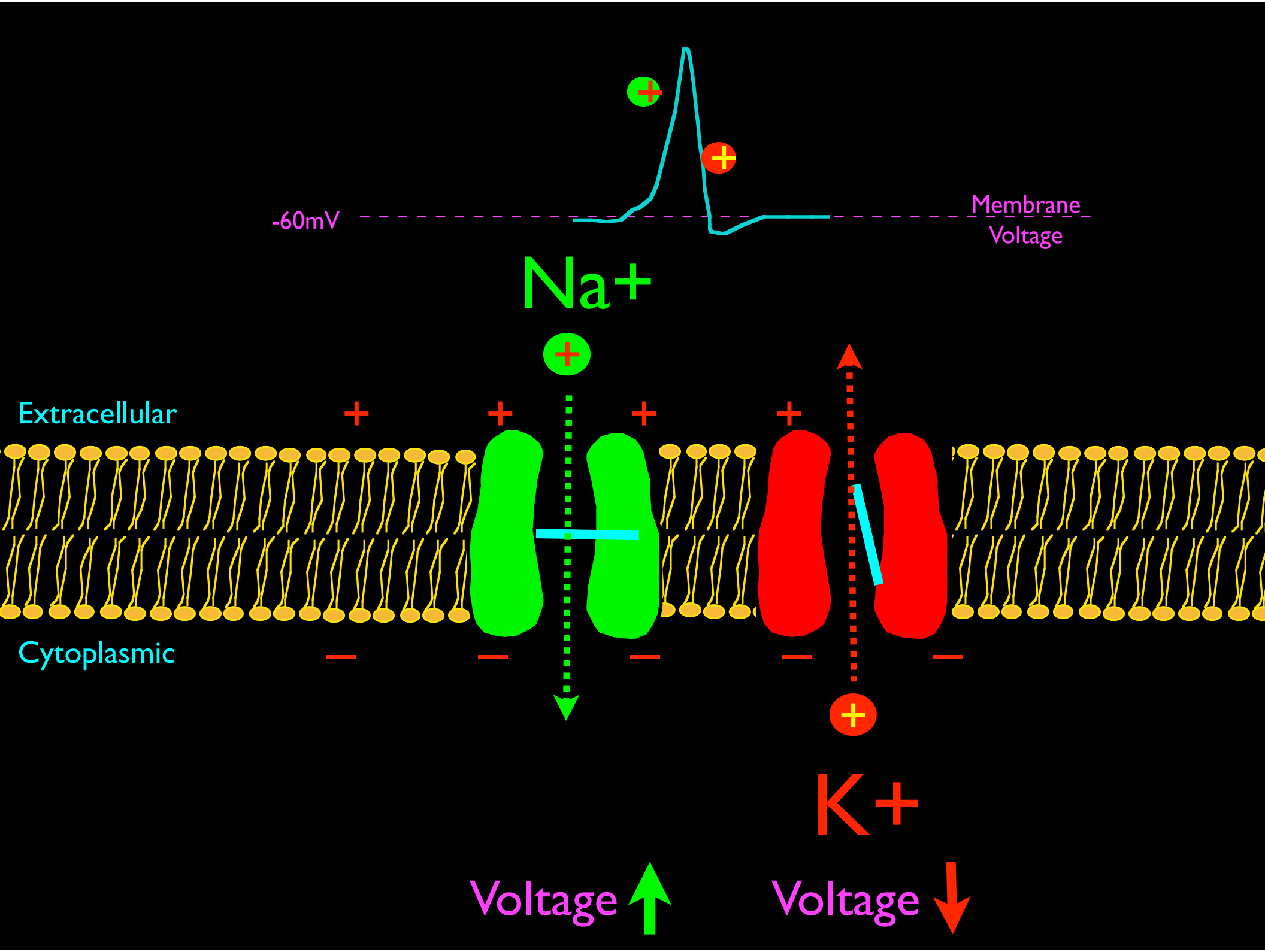
FIRST, WE GIVE THE Na+ CHANNEL A STIMULUS


Na+
Extracellular
Cytoplasmic
K+


Na+
Extracellular
Cytoplasmic
K+


Na+
Extracellular
Cytoplasmic
K+
Voltage


Na+
Extracellular
Cytoplasmic
Voltage gated
K+ channel
Voltage
K+

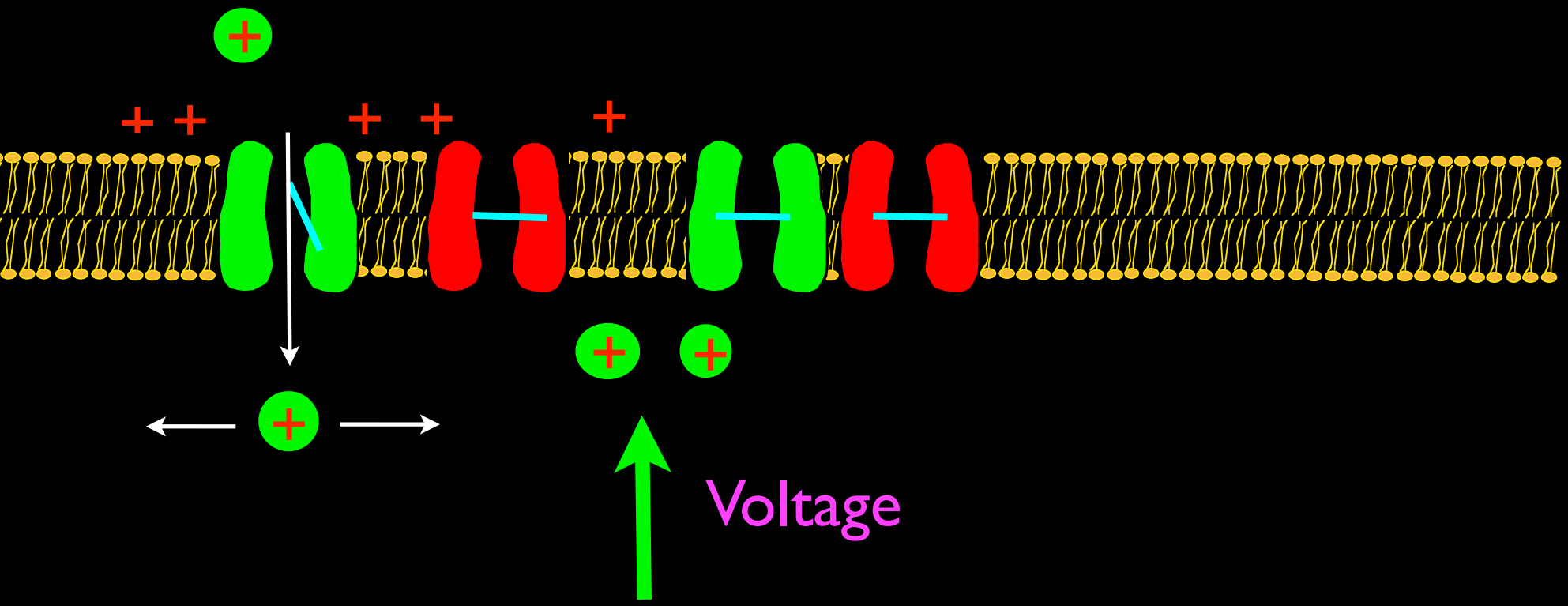

-60mV
Membrane
Voltage
Na+
Extracellular
Cytoplasmic
K+
Voltage
Voltage

One more detail....

The voltage change travels...

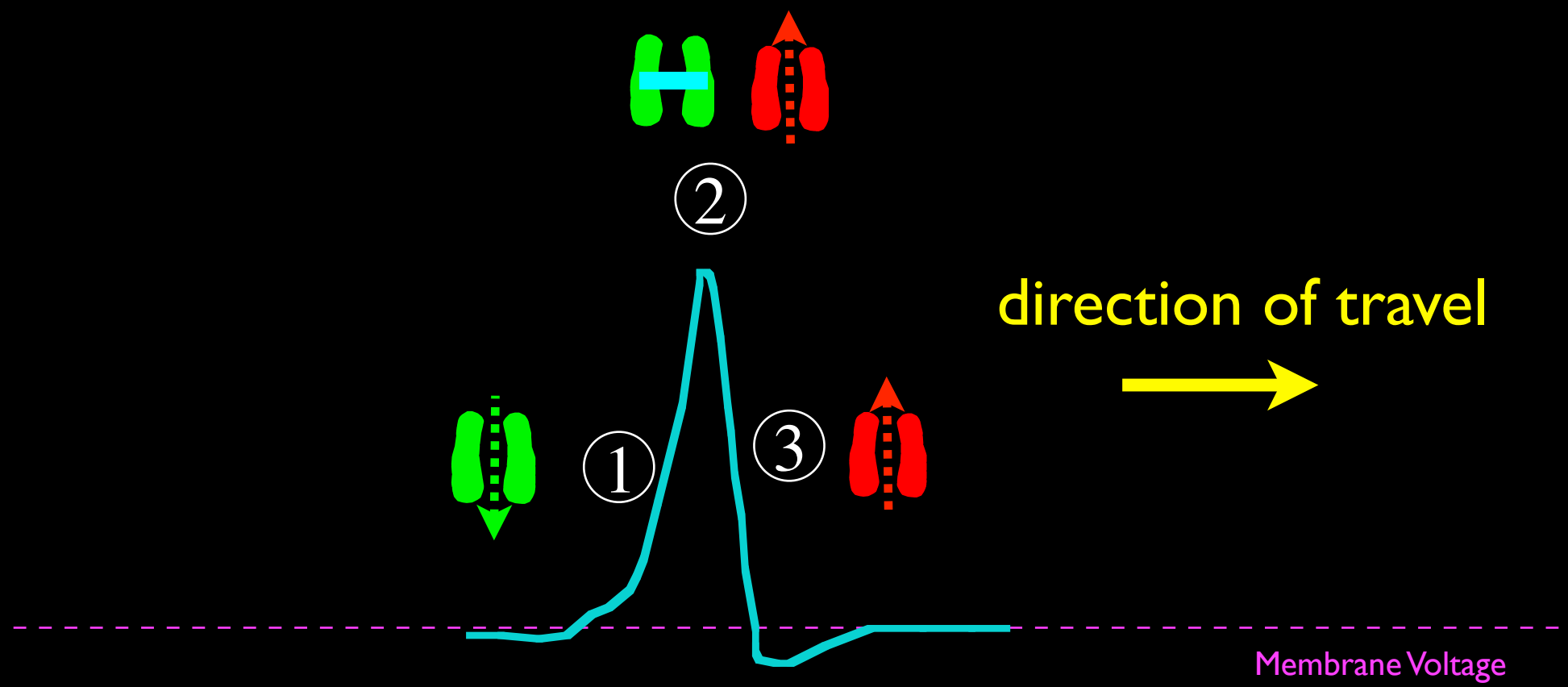
Na+

The basis of propagation....



K+

Action Potential Summary:

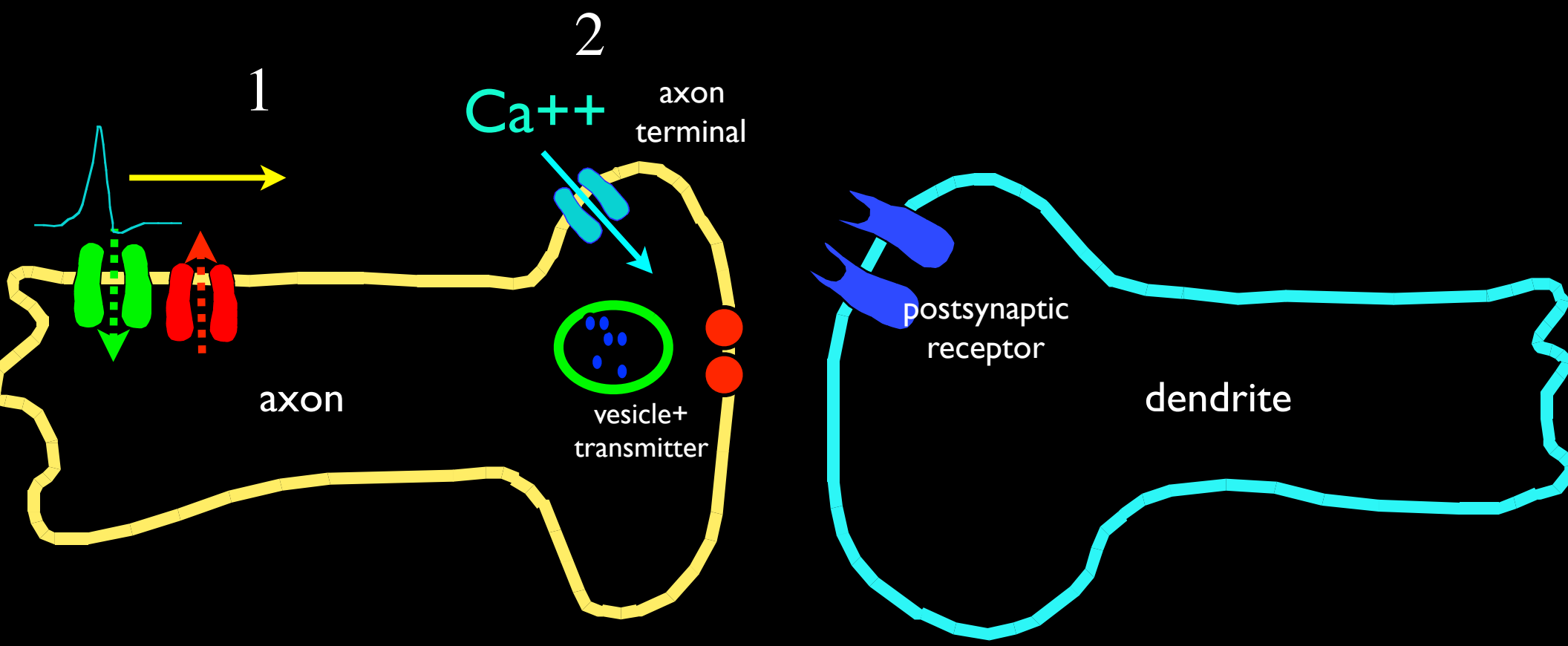


1. Na+ channels open/Na flows into the cell
2. Na+ channels close while K+ channels are opening
3. K+ flow out of the cell dominates

NEXT:

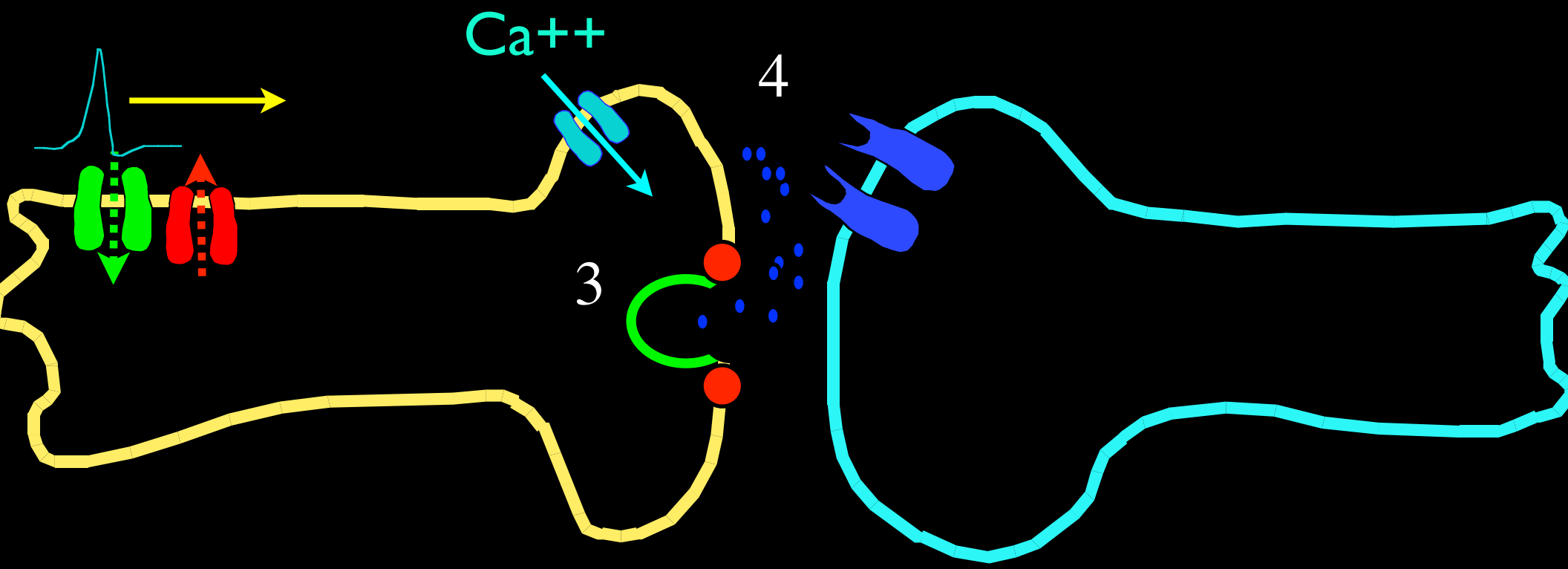
How do neurons "talk" to each other?

Synaptic Transmission



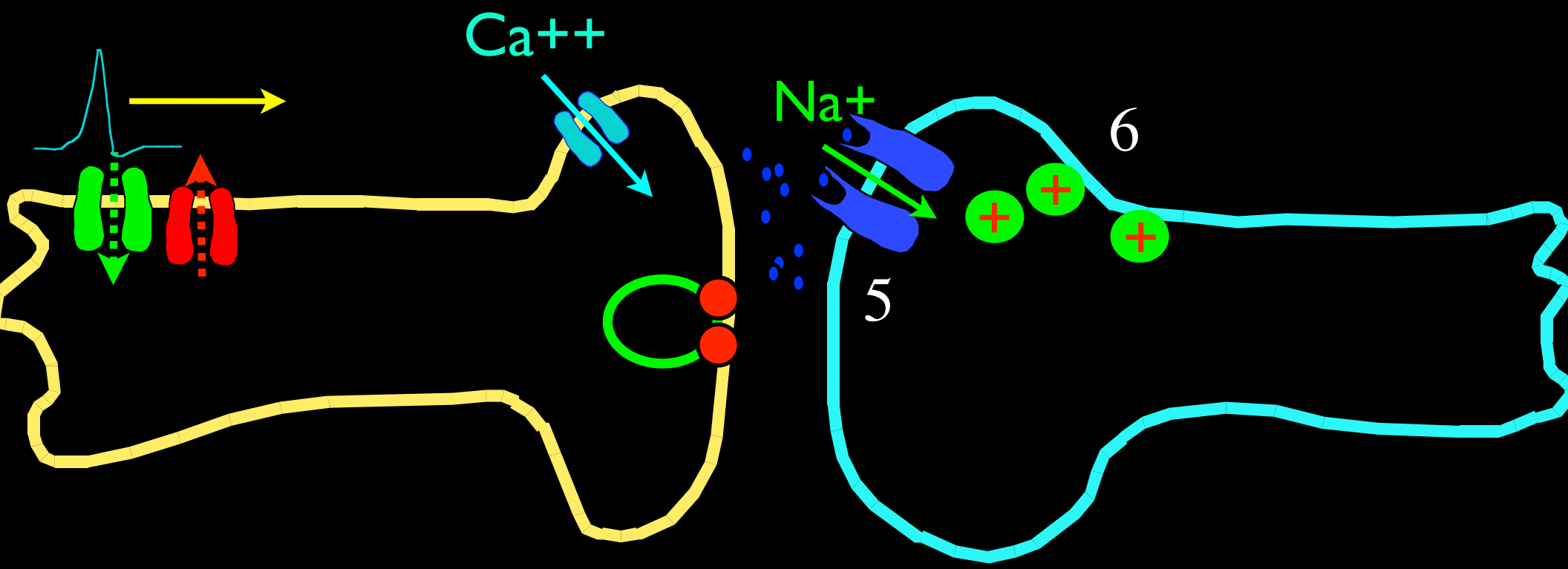
Step 1: Depolarization of the axon terminal
Step 2: Voltage dependent Ca++ entry

Synaptic Transmission



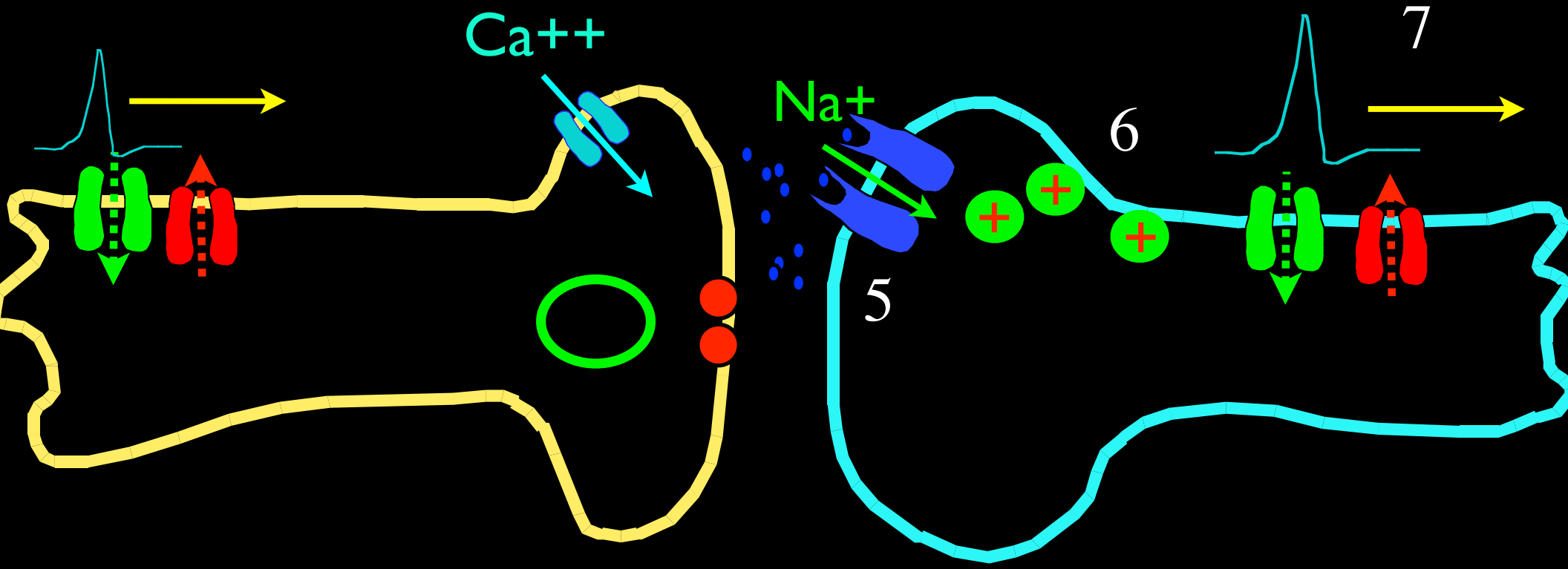
Step 3: Ca++ dependent vesicle fusion
Step 4: transmitter release

Synaptic Transmission



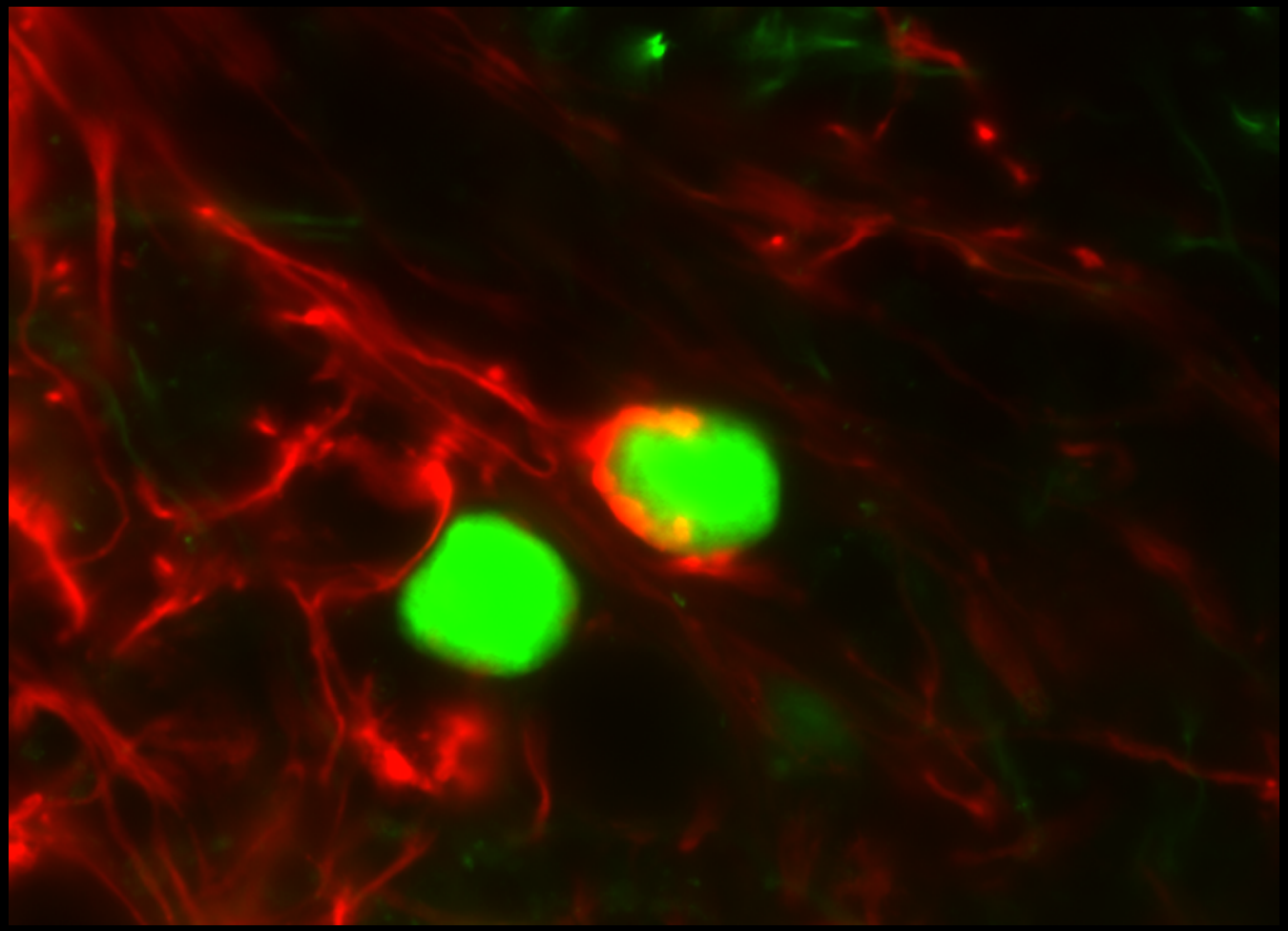
Step 5: Activation of ligand gated channel
Step 6: Na+ flux/dendrite depolarization

Synaptic Transmission



Step 5: Activation of ligand gated channel
Step 6: Na+ flux/dendrite depolarization
Step 7: Action Potential is regenerated postsynaptically

Very large auditory synapse



Stain in red marks postsynaptic receptors