

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.

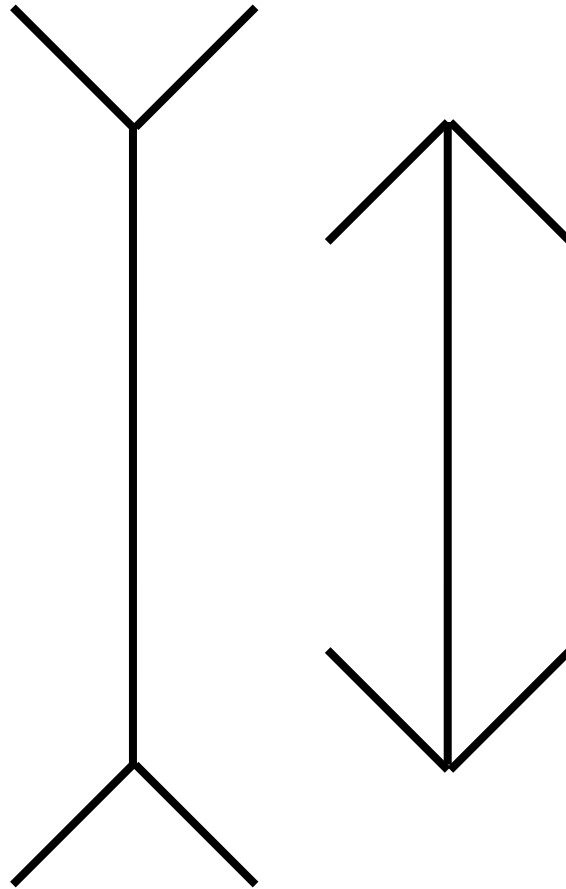
...In fact, from one perspective
“you” are your brain



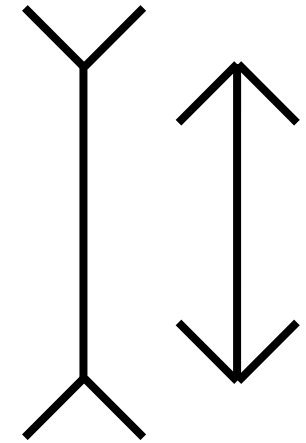
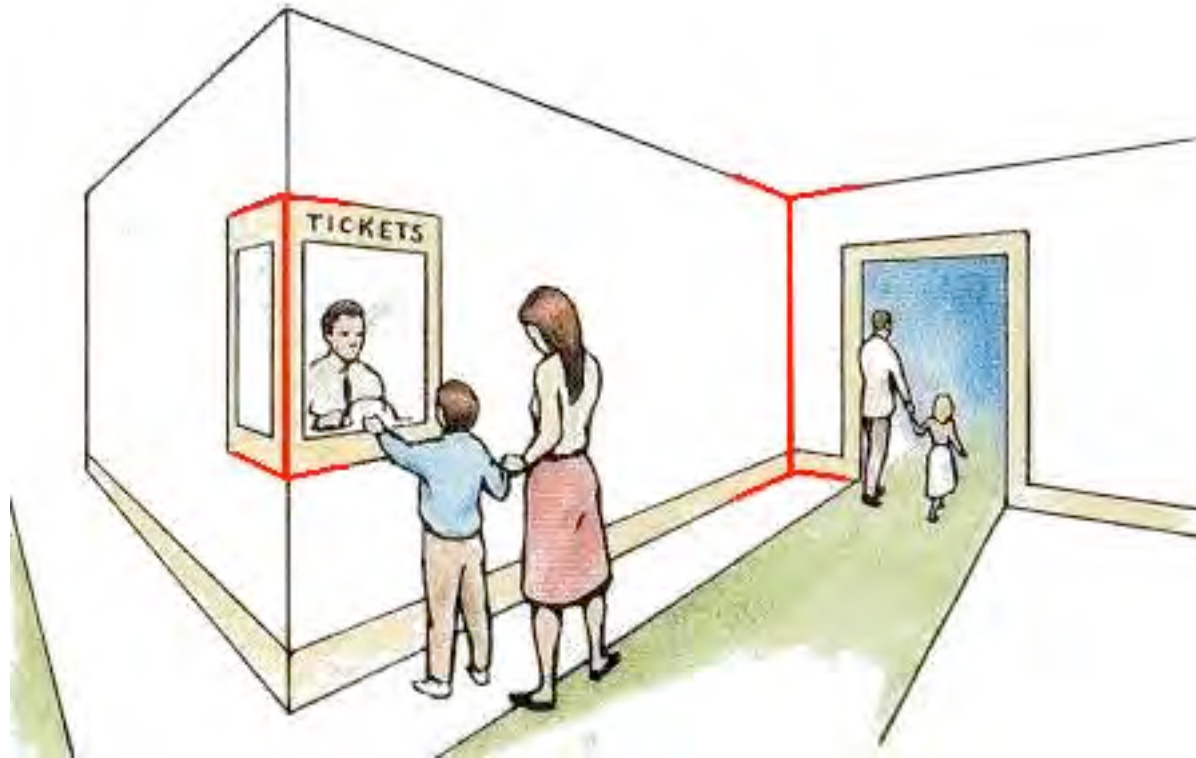
Figure-ground illusions are well known for visual stimuli

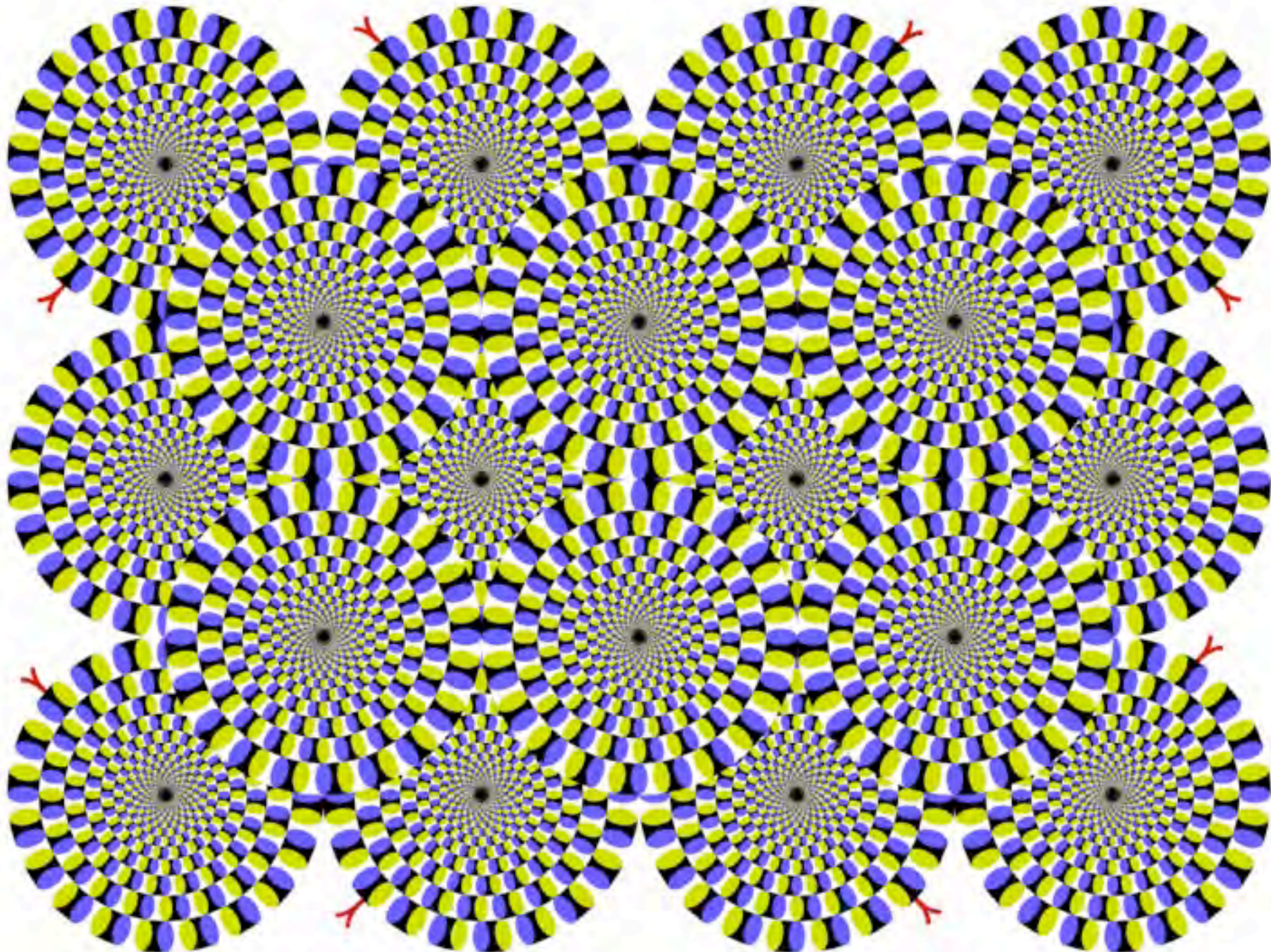


The Müller-Lyer Illusion



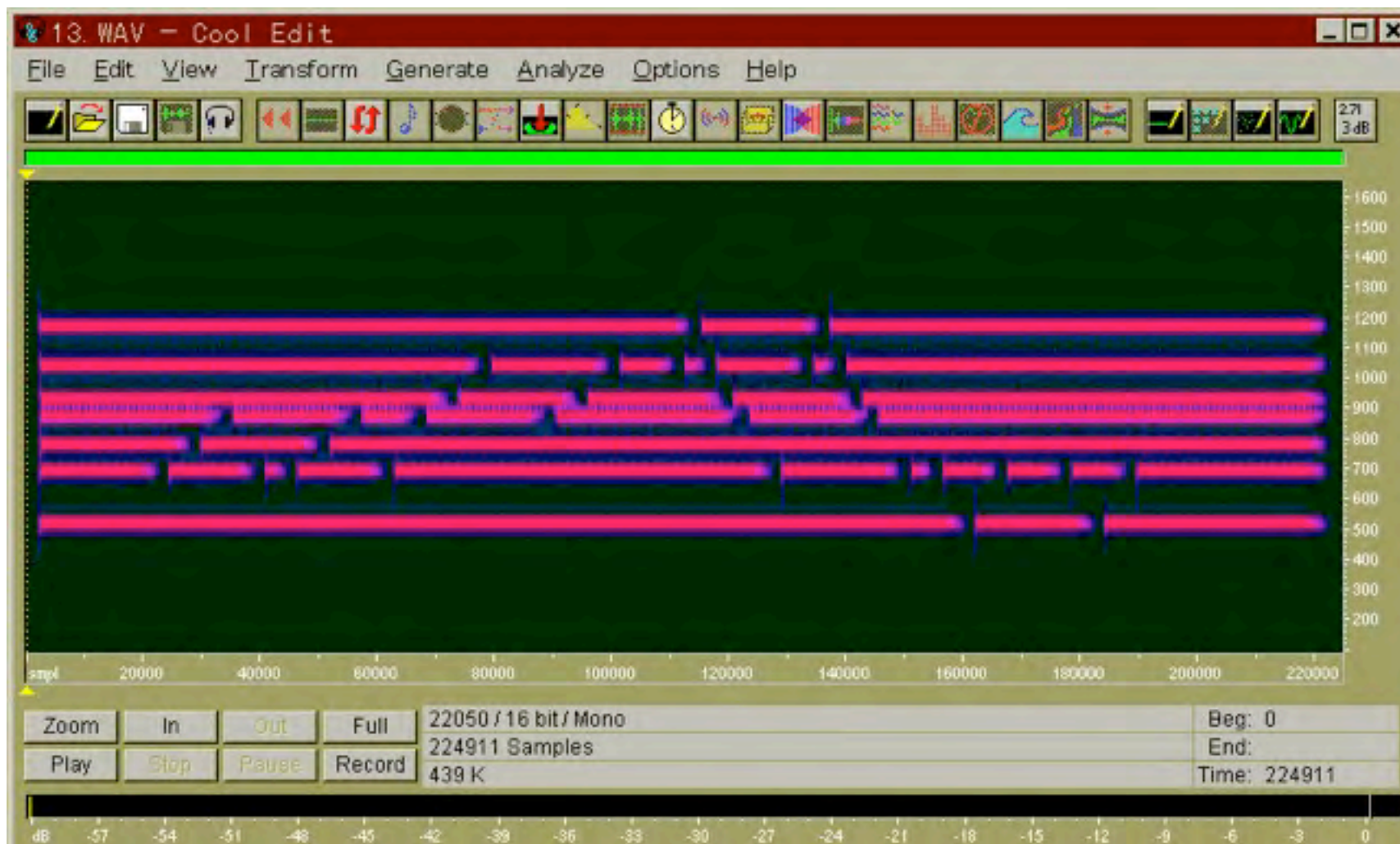
The Müller-Lyer Illusion





Hearing gaps

But they occur in the auditory system too!



What did he say?

What did he say?



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

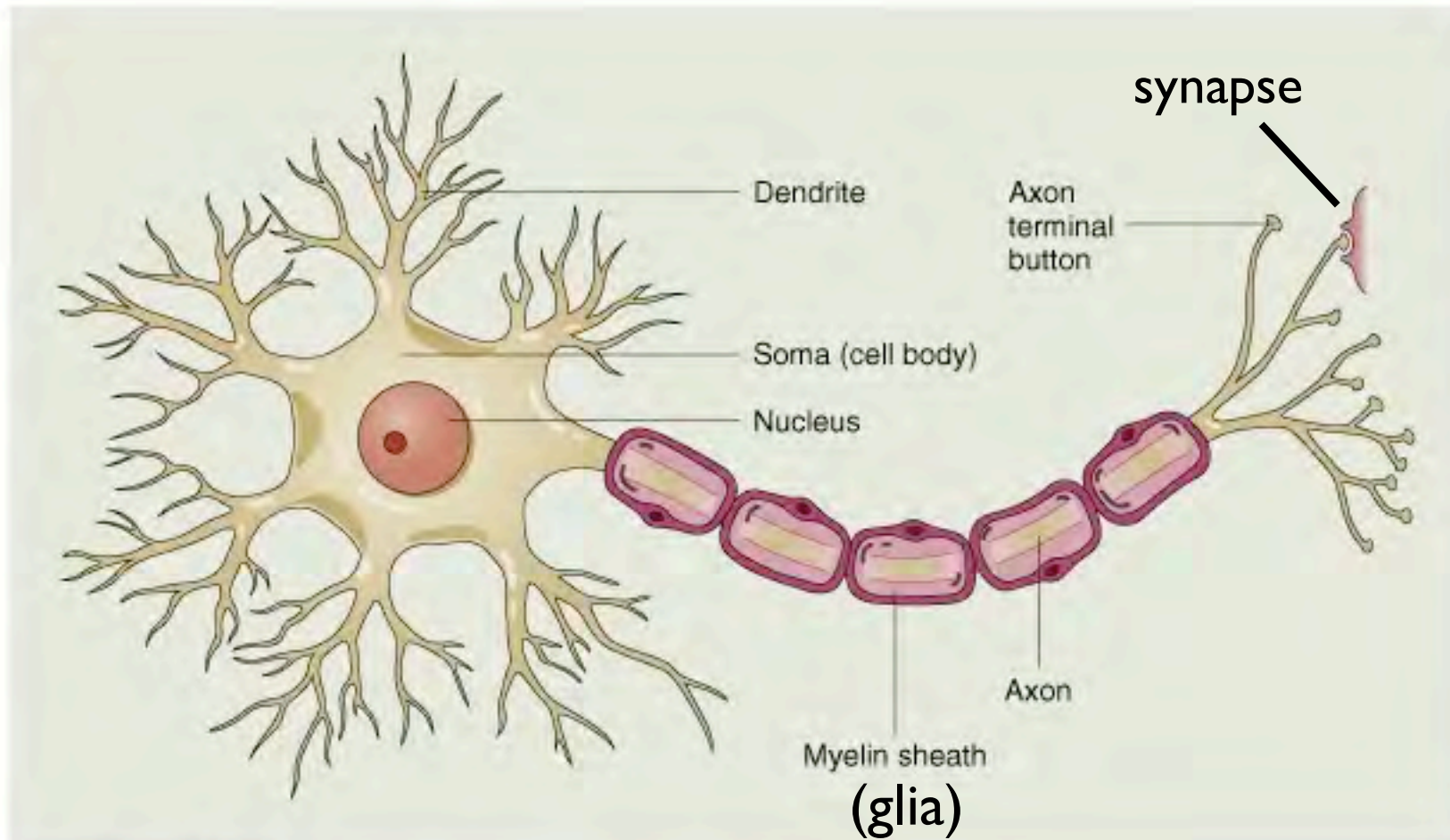
The **BIG THREE** topics for today:

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

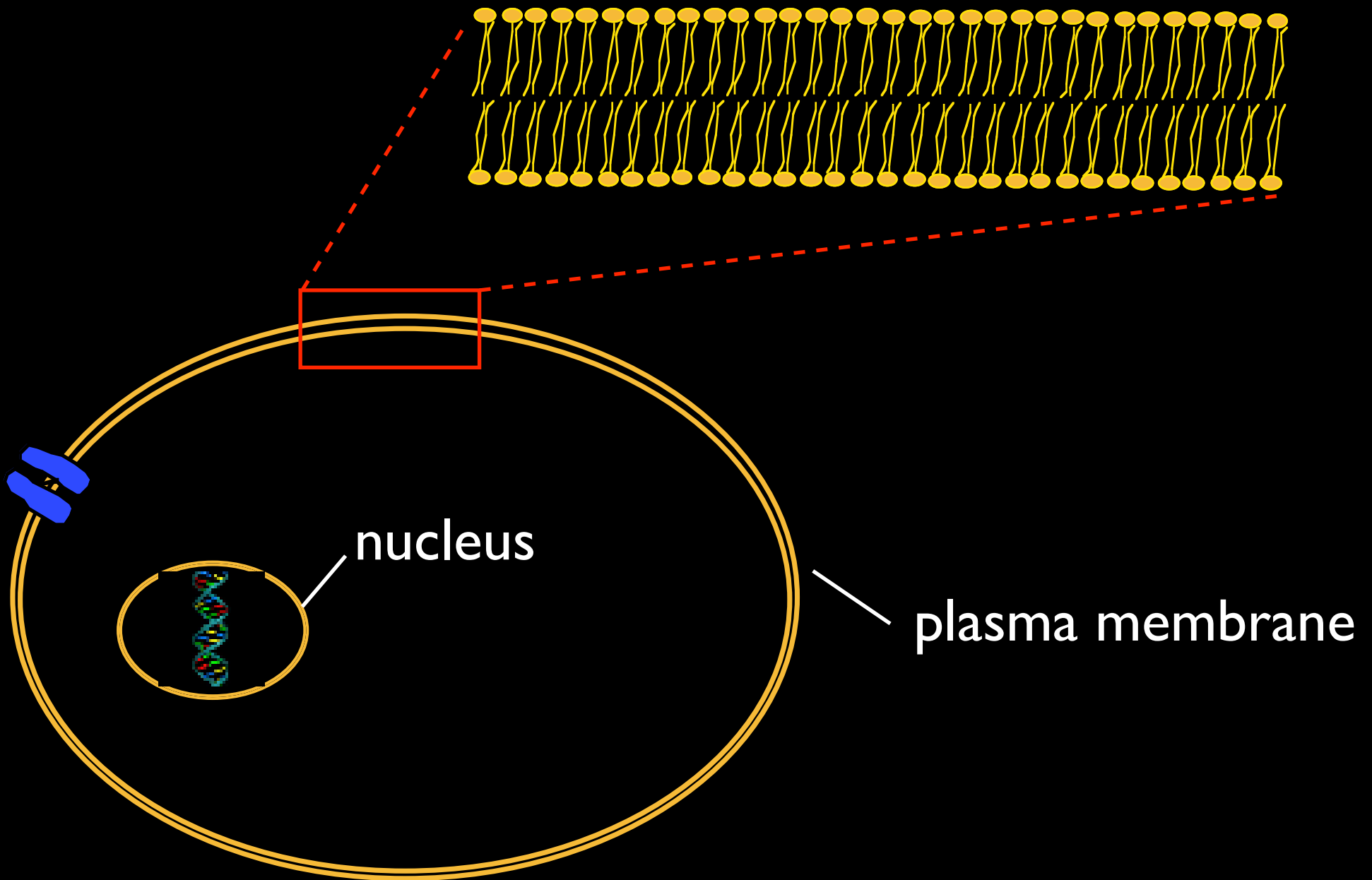
II. How do neurons “talk” to each other?

III. How do neurons encode information?

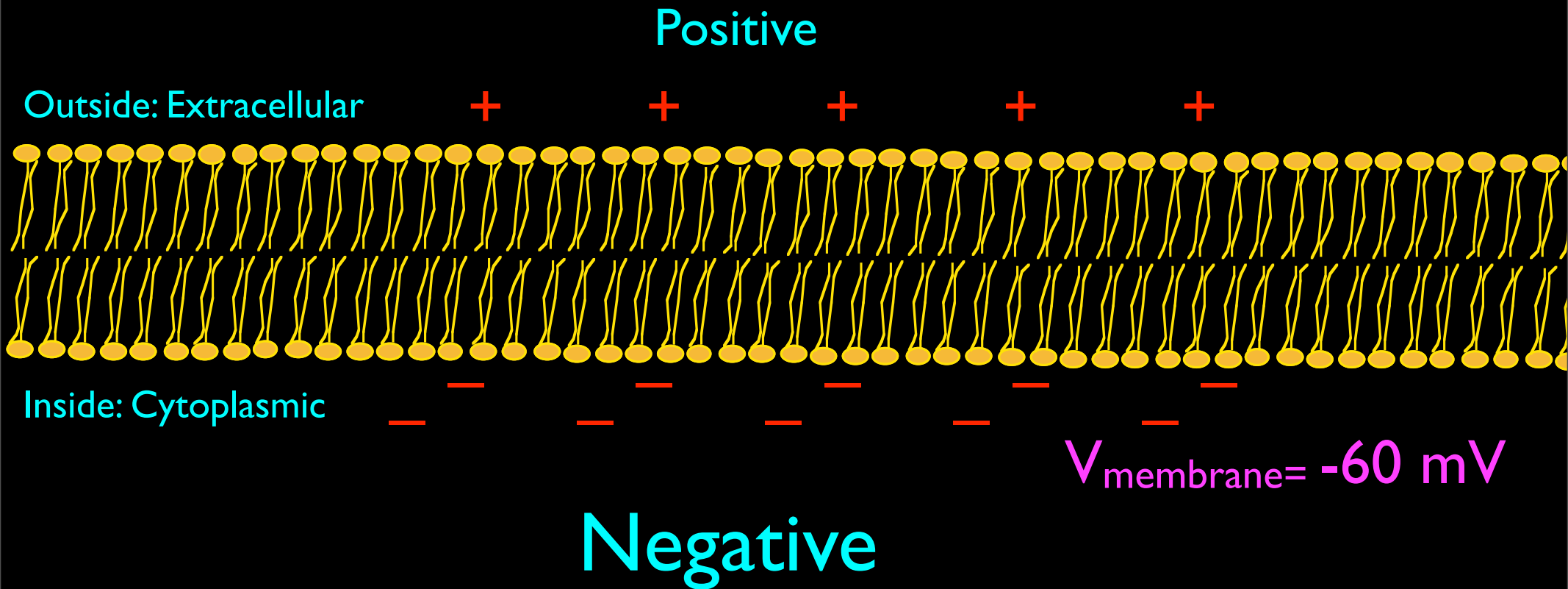
The neuron is the “unit of processing” for the nervous system



The cell membrane is a phospholipid bilayer

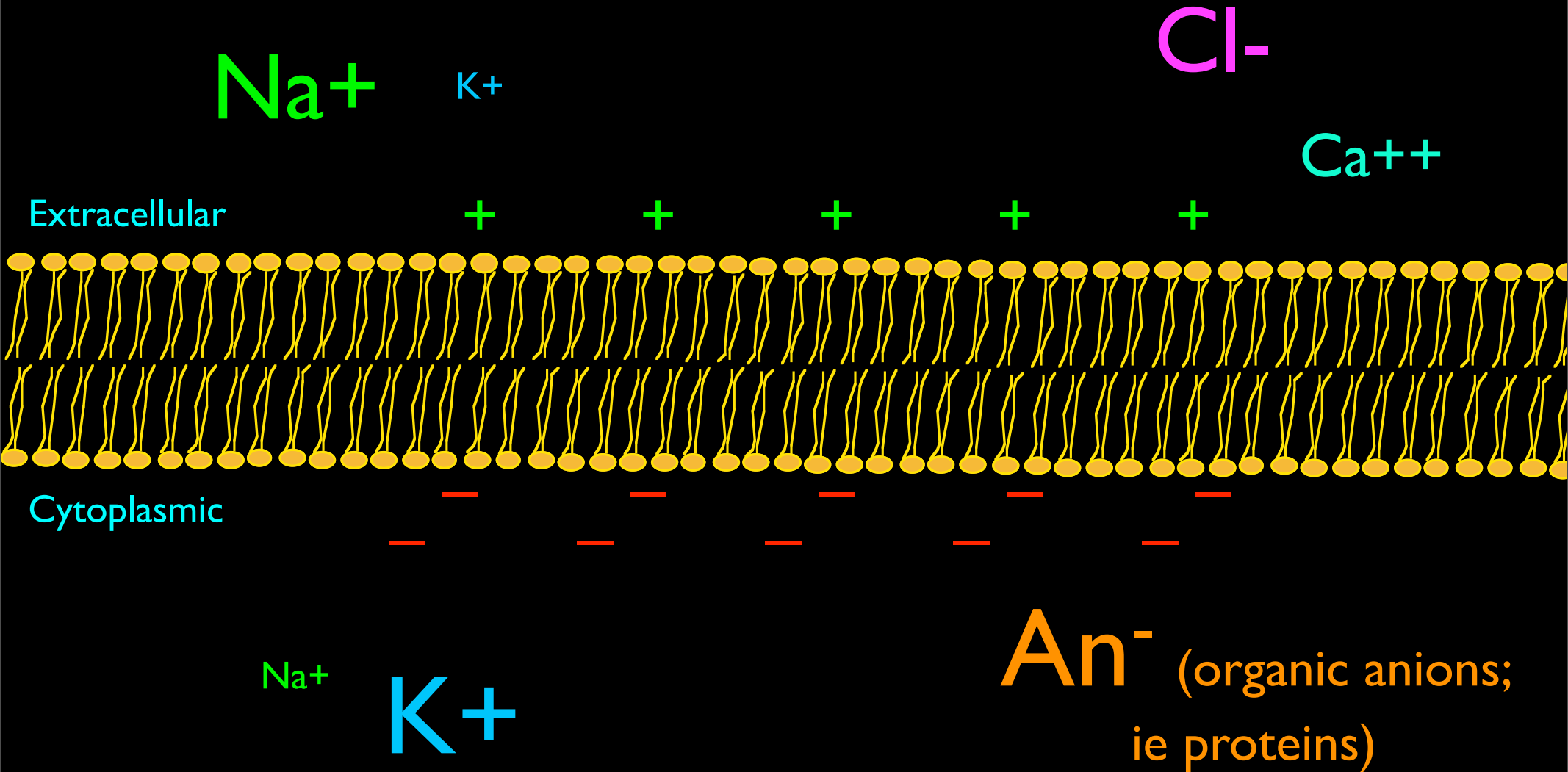


Cell membranes store Voltage

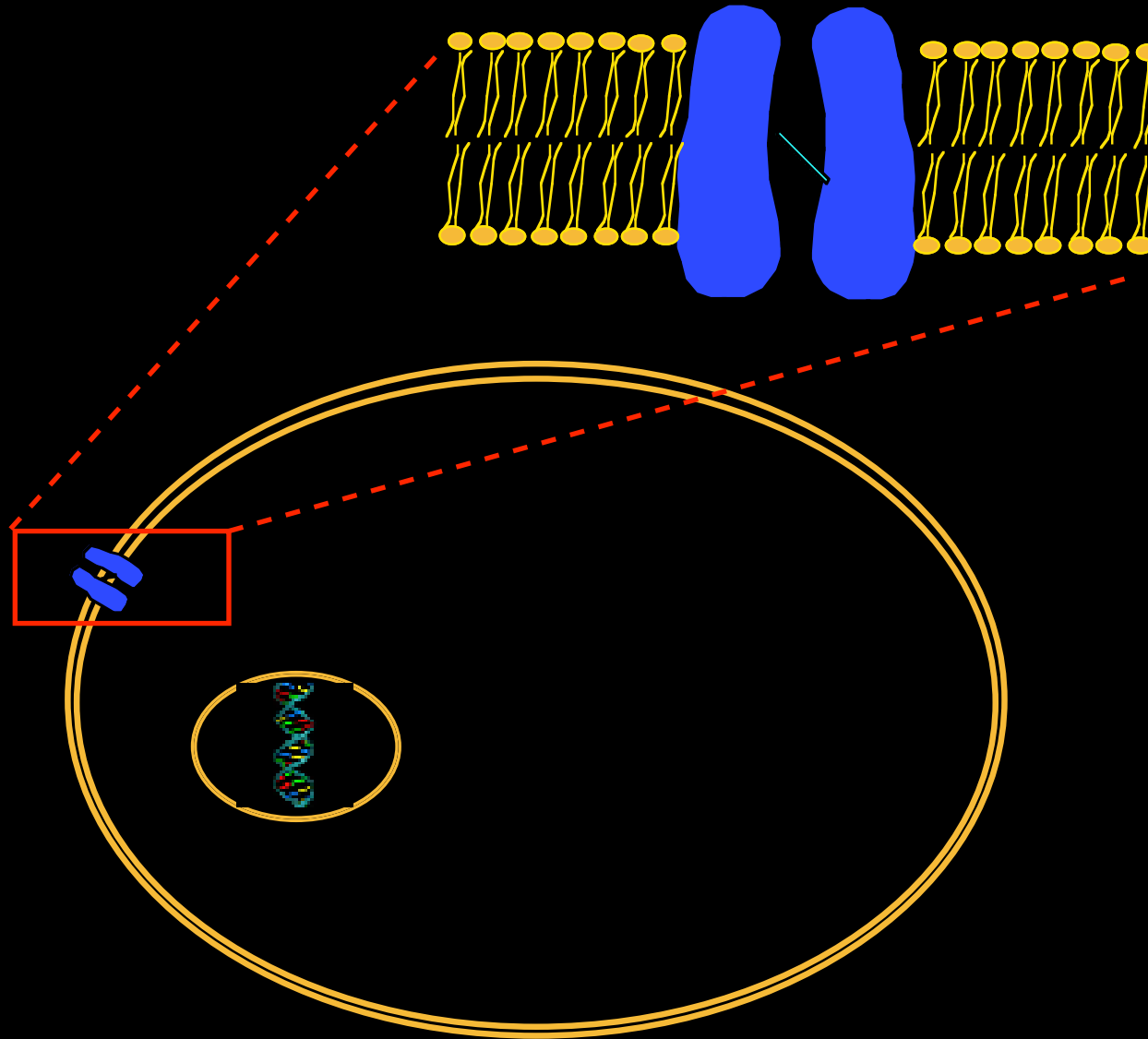


****The inside of the cell is usually more negative than the outside by about -60 mV**

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

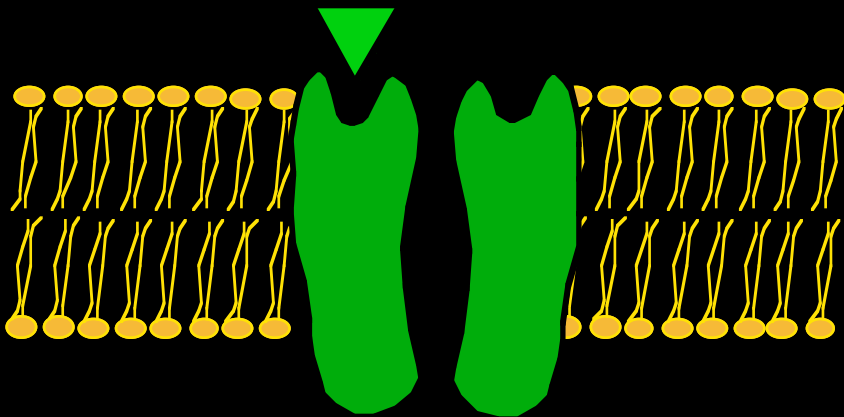


The cell membrane contains proteins, some of which are channels for charged particles

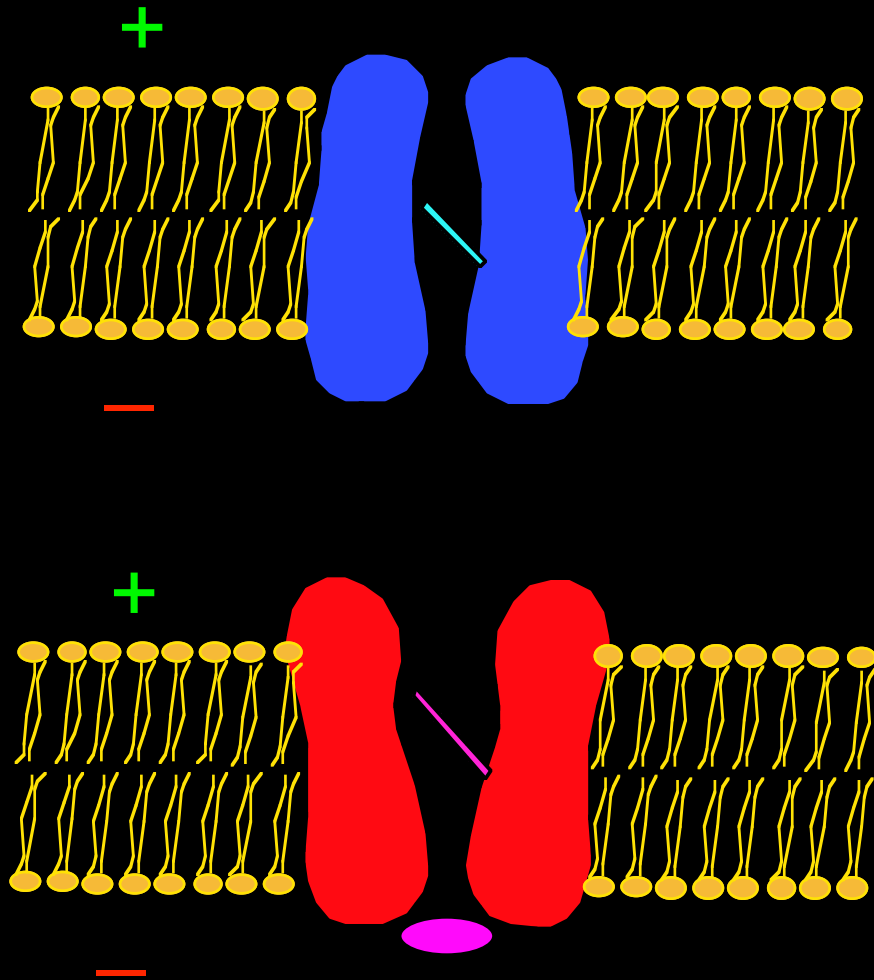


Two (of many) membrane protein types:

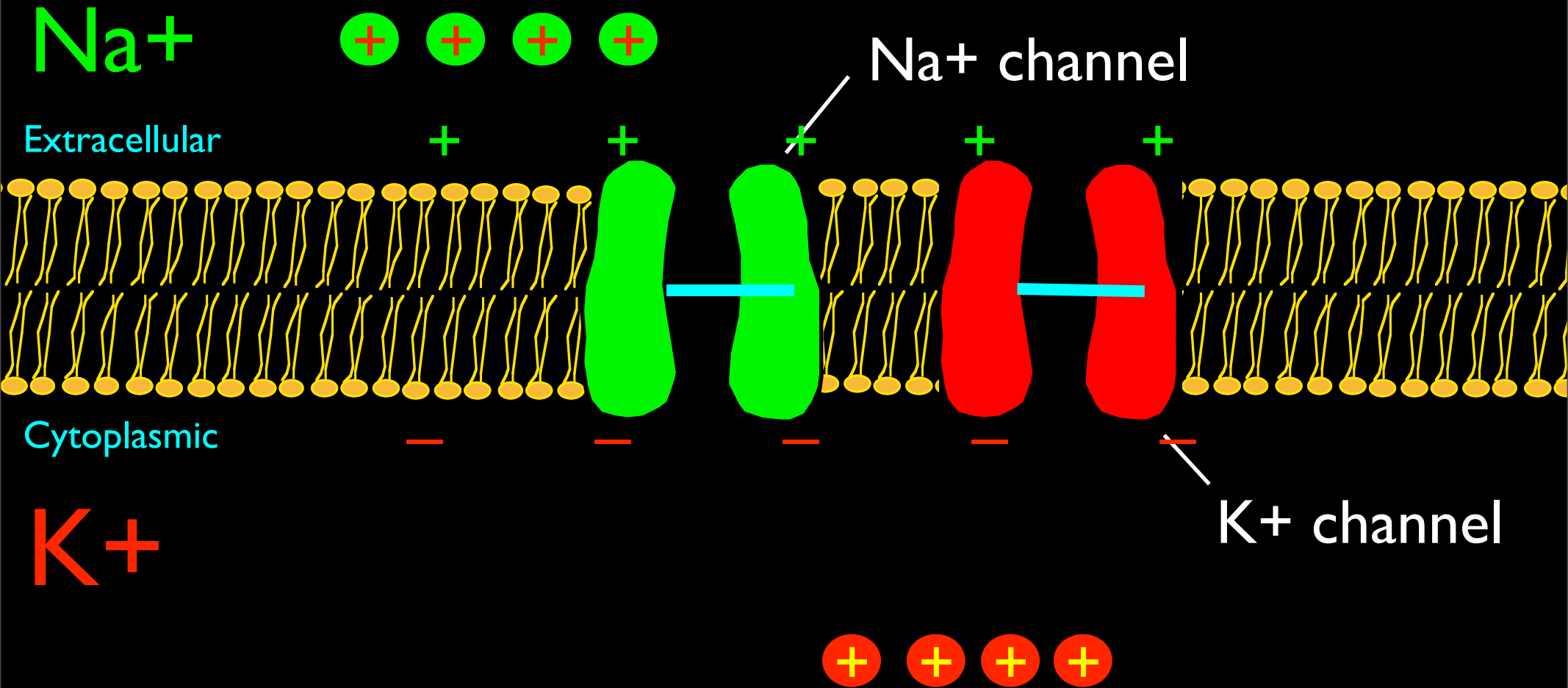
Ligand gated
(chemically gated)



Voltage gated



How does an electrical signal occur in a neuron?



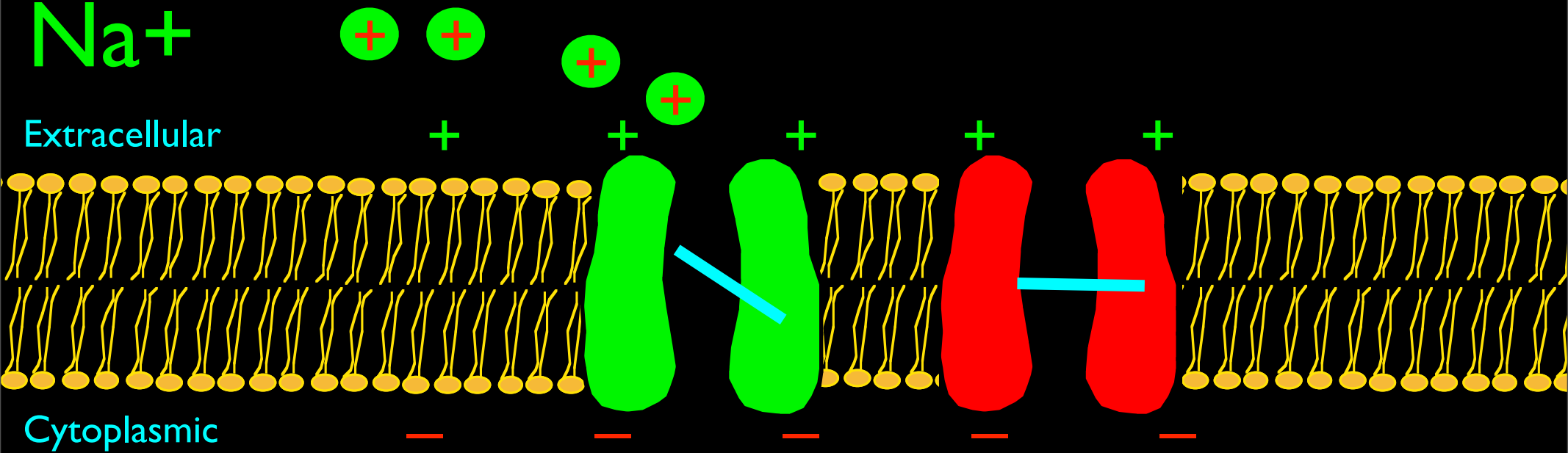
FIRST, WE GIVE THE Na⁺ CHANNEL A STIMULUS

Na+

Extracellular

Cytoplasmic

K+



Na⁺



Extracellular

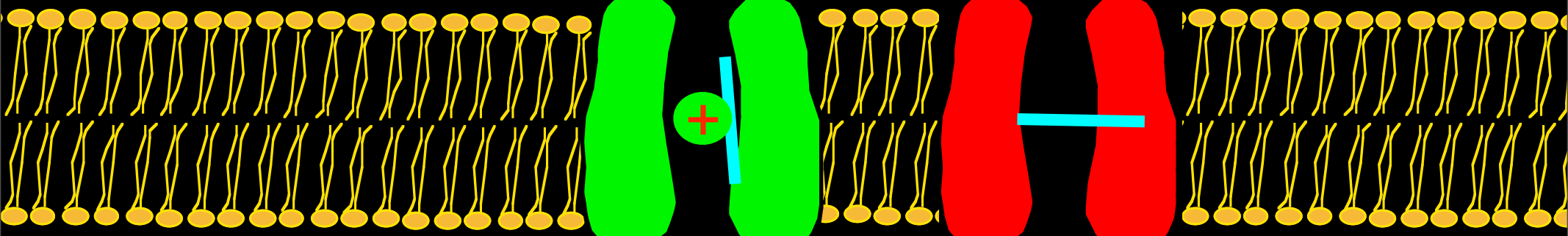
+

+

+

+

+



Cytoplasmic

-

-

-

-

-

K⁺



Na+



Extracellular

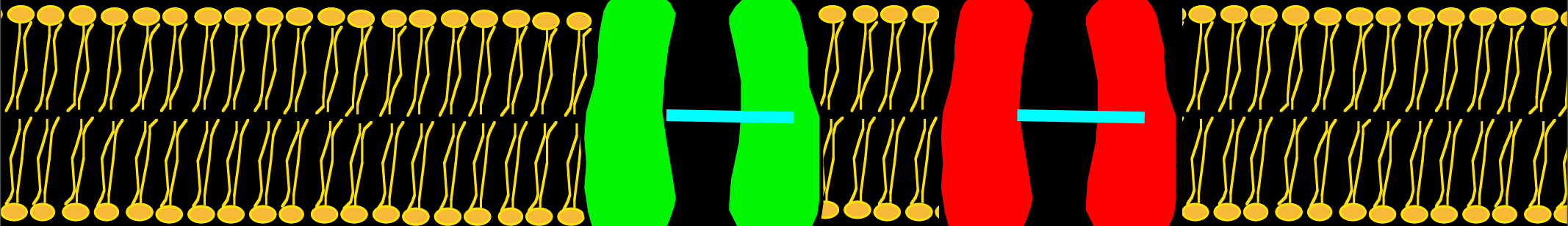
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Cytoplasmic

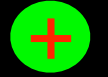
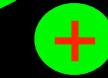
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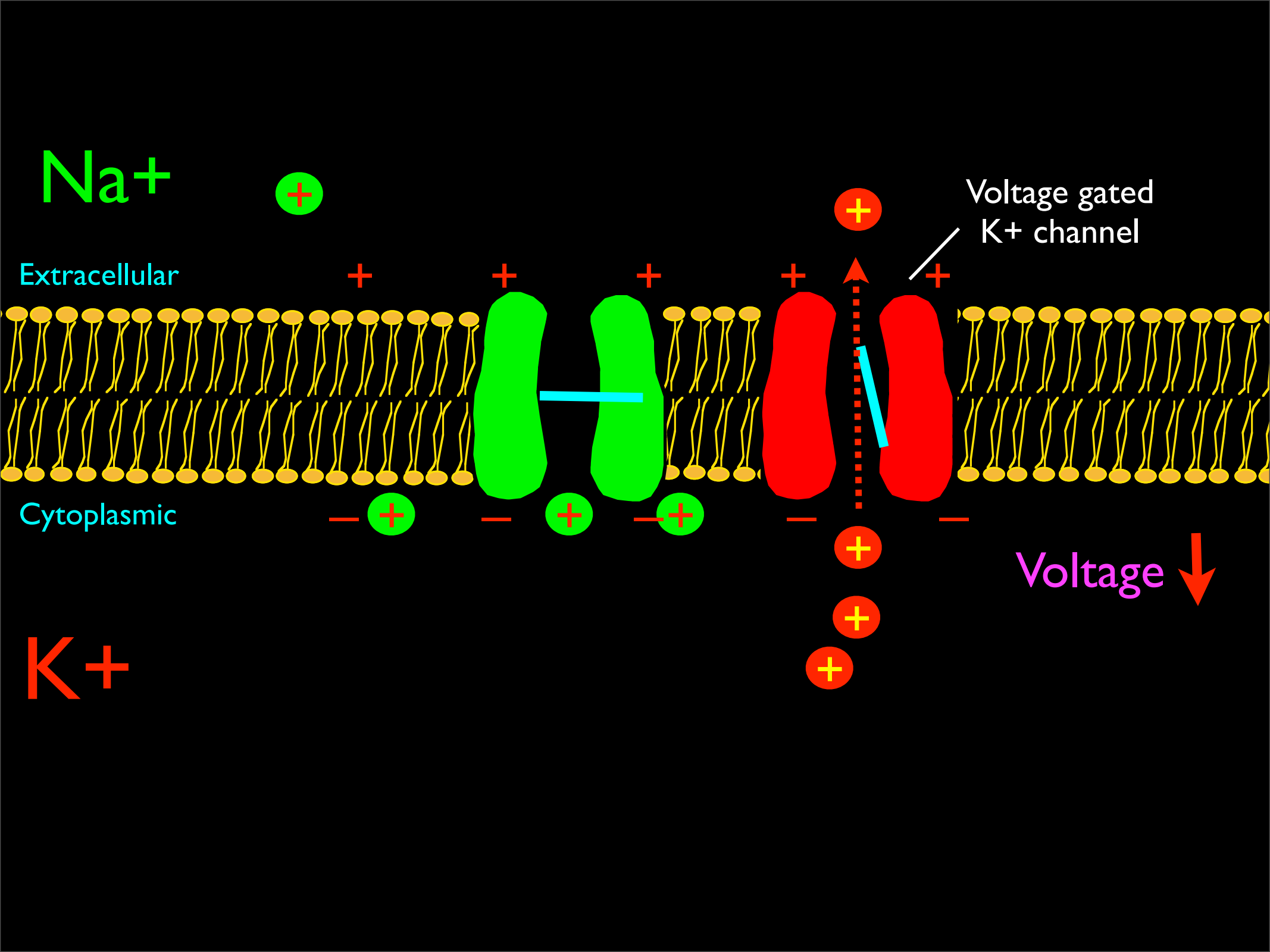
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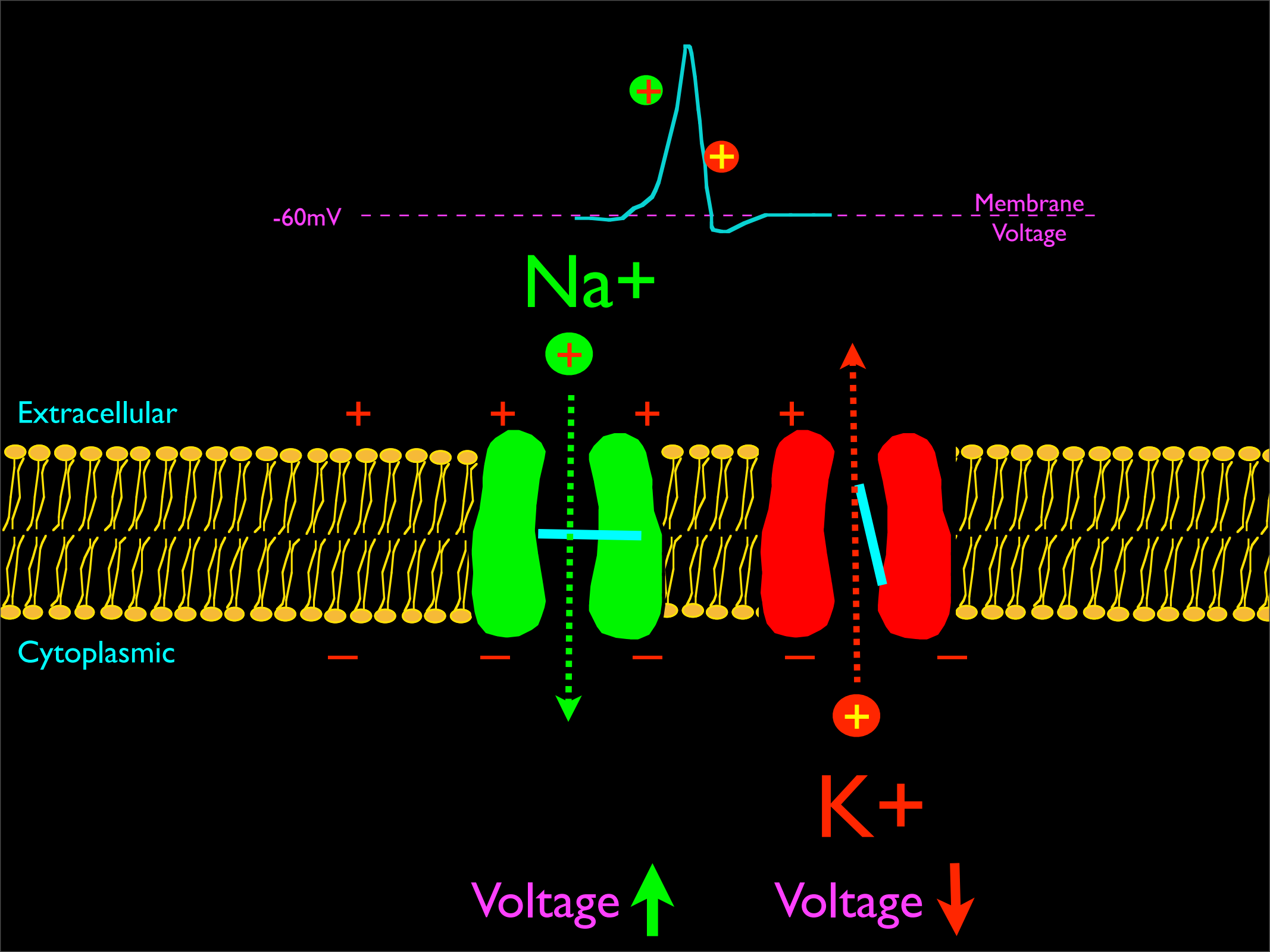


K+

Voltage ↑





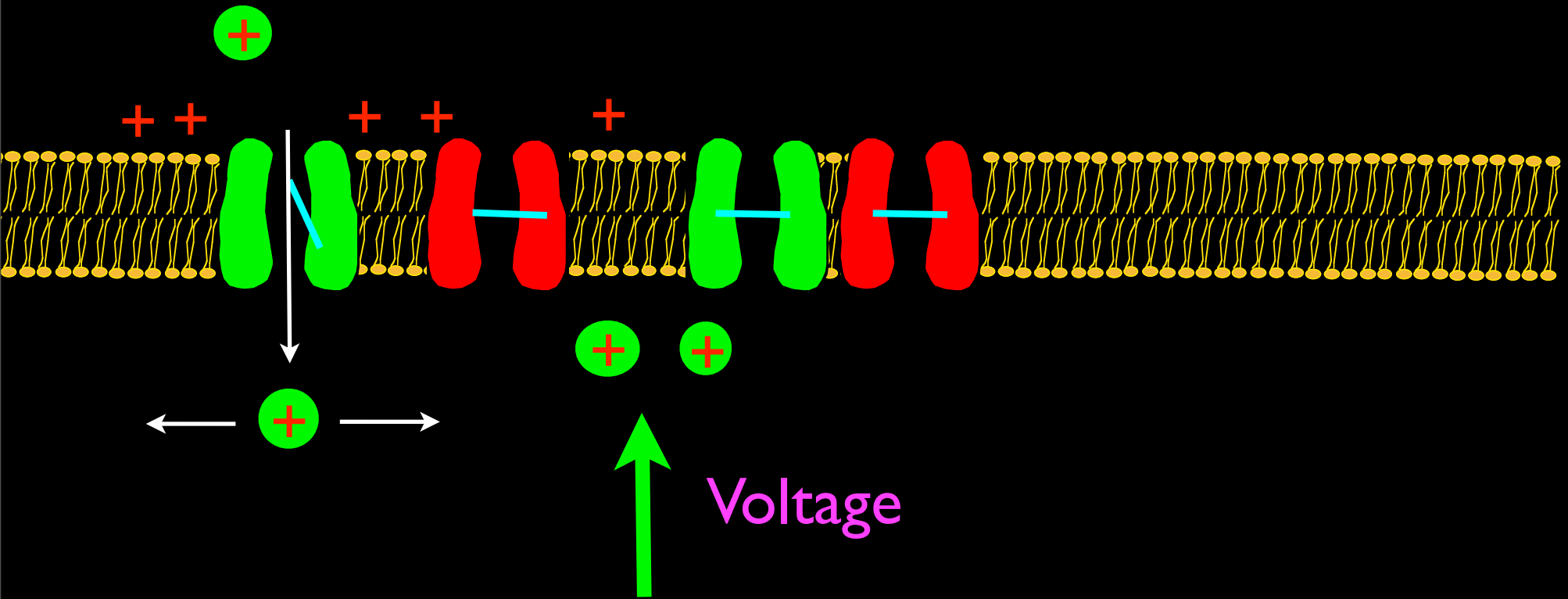


One more detail....

The voltage change travels...

Na⁺

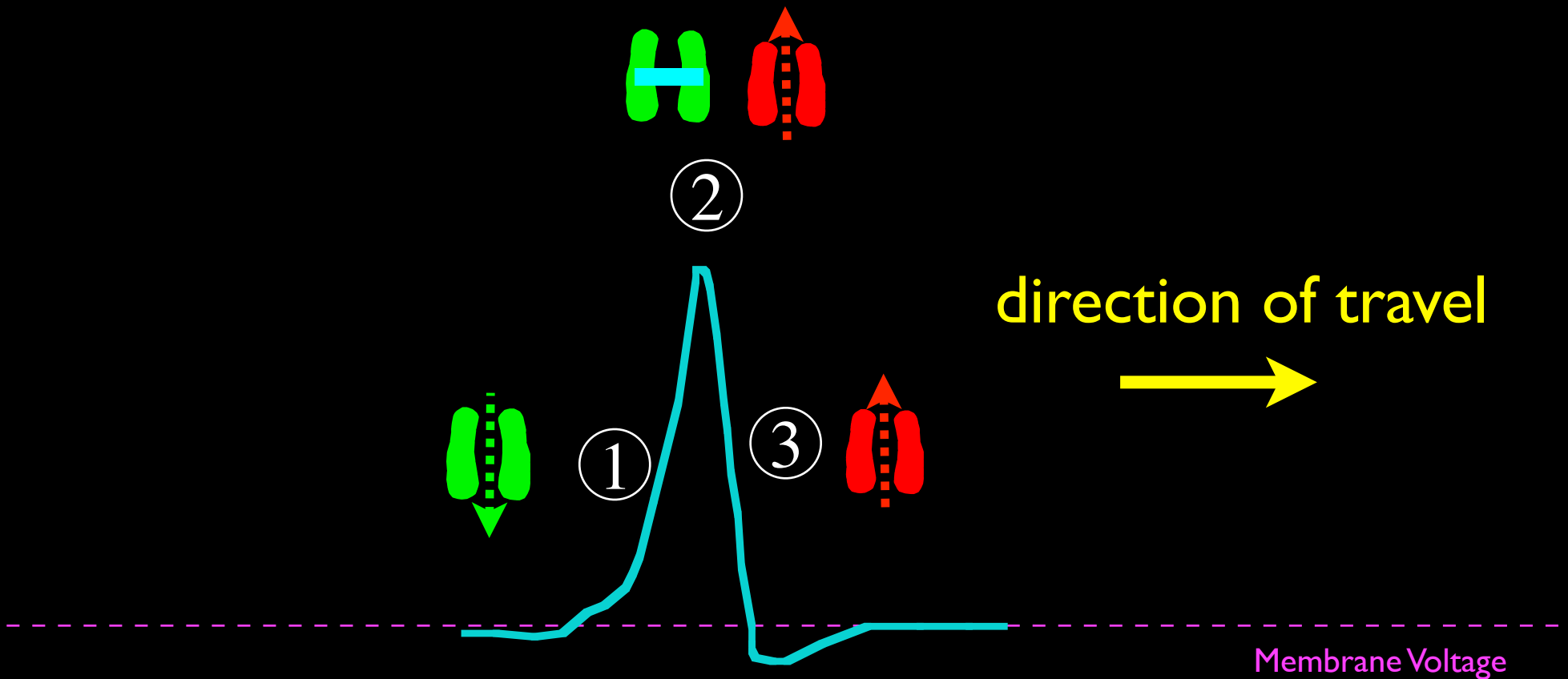
The basis of propagation...



K⁺

Voltage

Action Potential Summary:

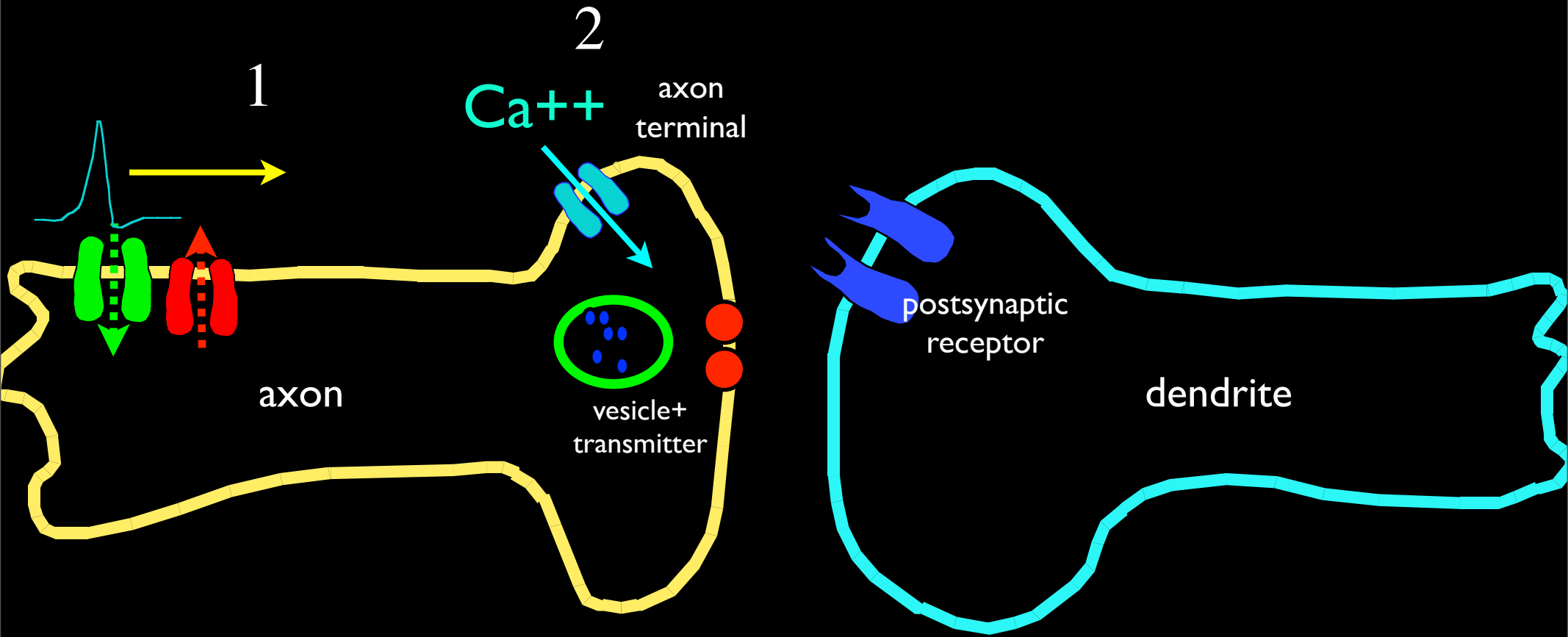


1. Na⁺ channels open/Na flows into the cell
2. Na⁺ channels close while K⁺ channels are opening
3. K⁺ flow out of the cell dominates

NEXT:

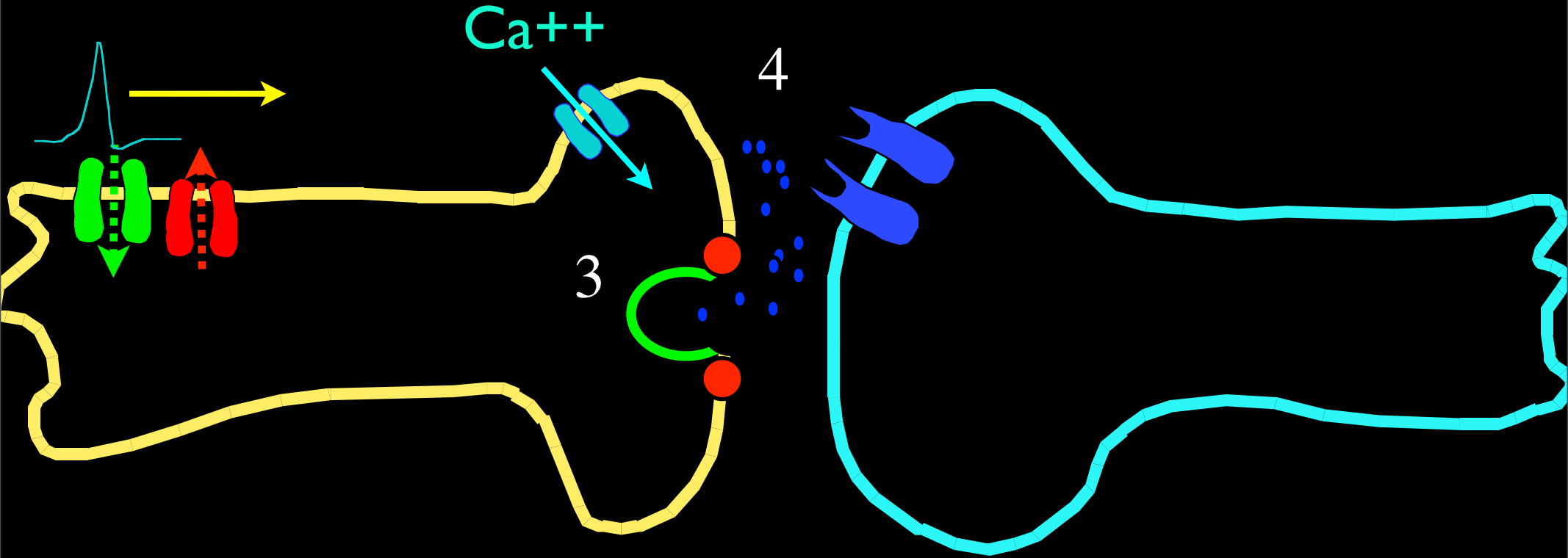
How do neurons “talk” to each other?

Synaptic Transmission



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

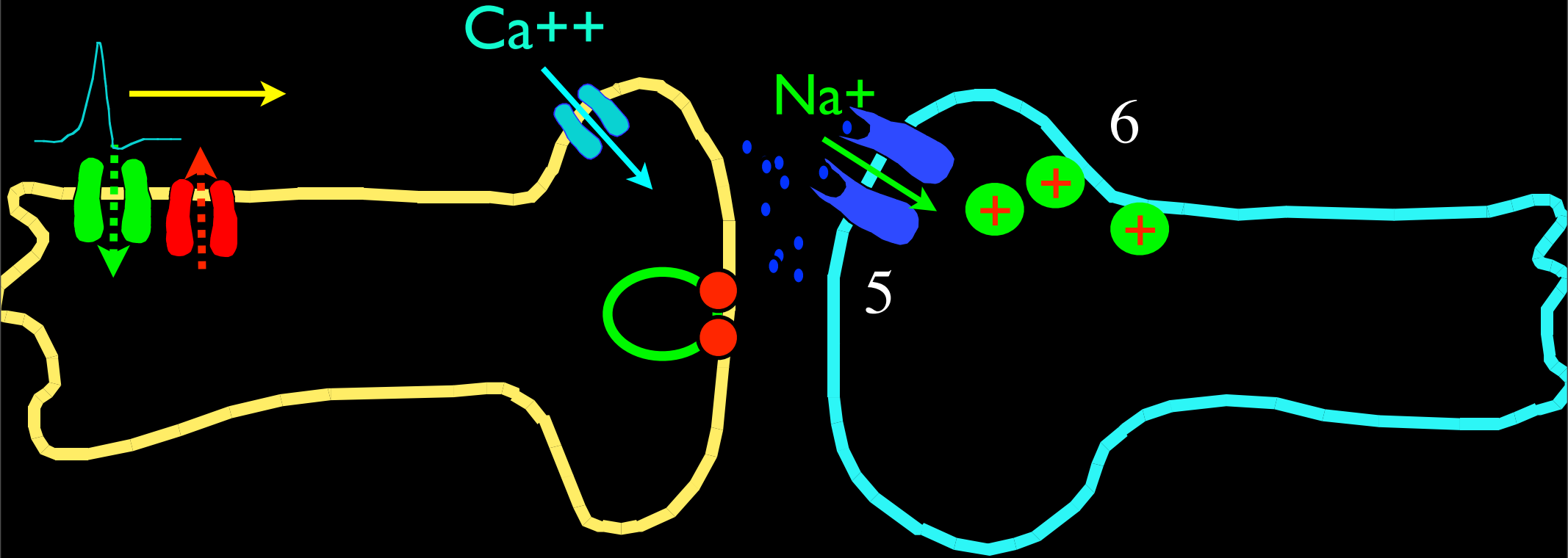
Synaptic Transmission



Step 3: Ca^{++} dependent vesicle fusion

Step 4: transmitter release

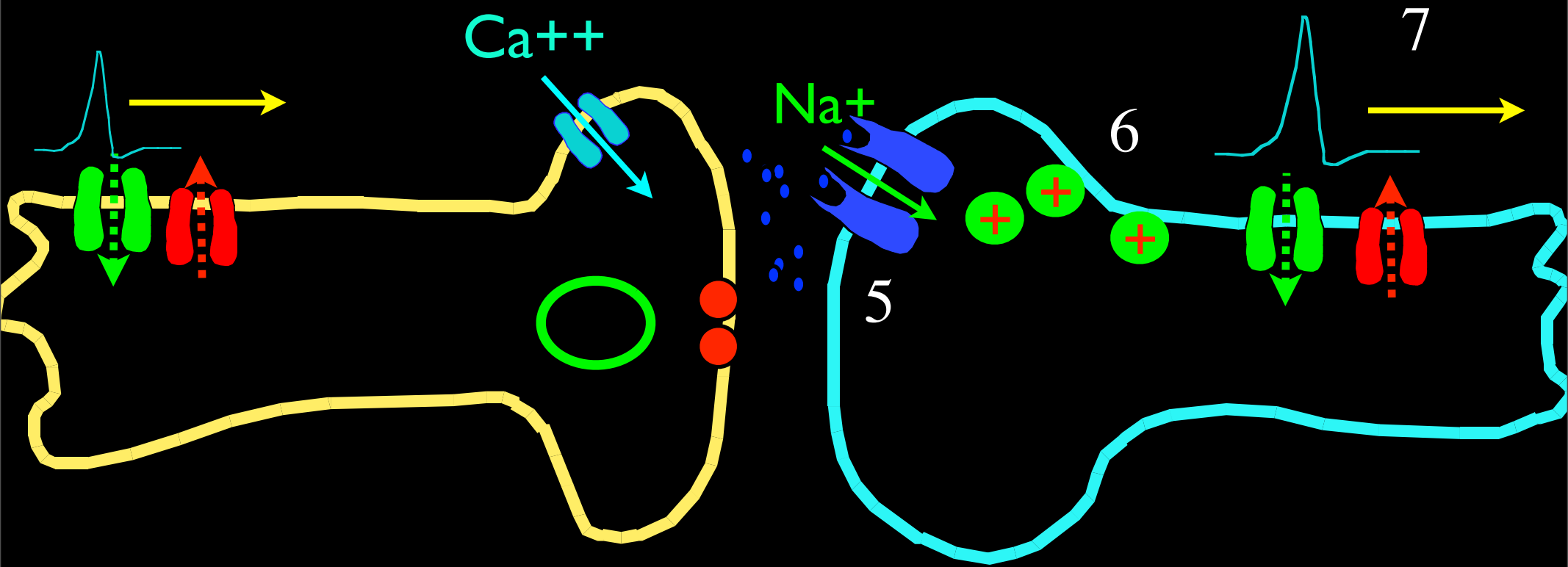
Synaptic Transmission



Step 5: Activation of ligand gated channel

Step 6: Na^+ flux/dendrite depolarization

Synaptic Transmission

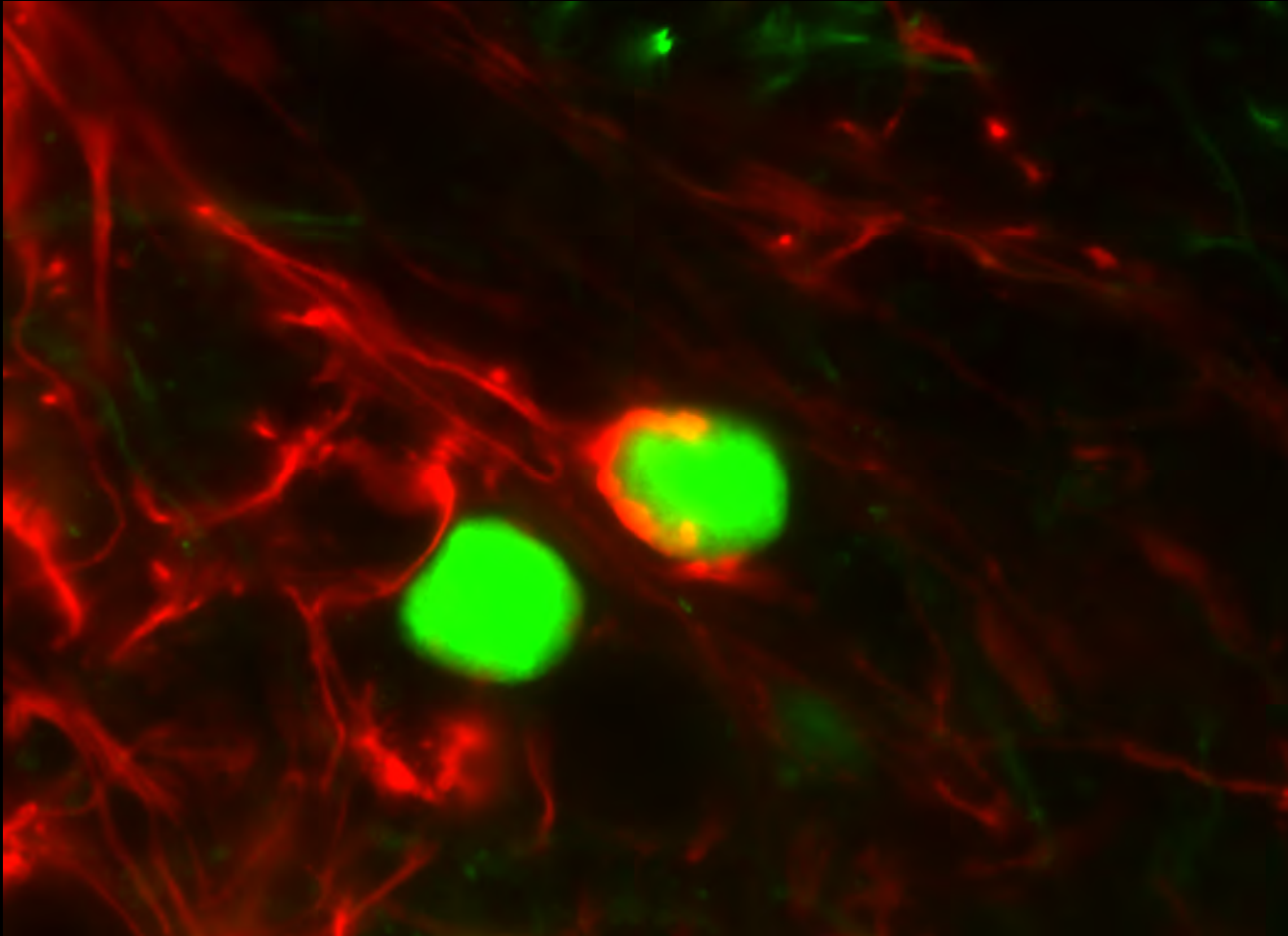


Step 5: Activation of ligand gated channel

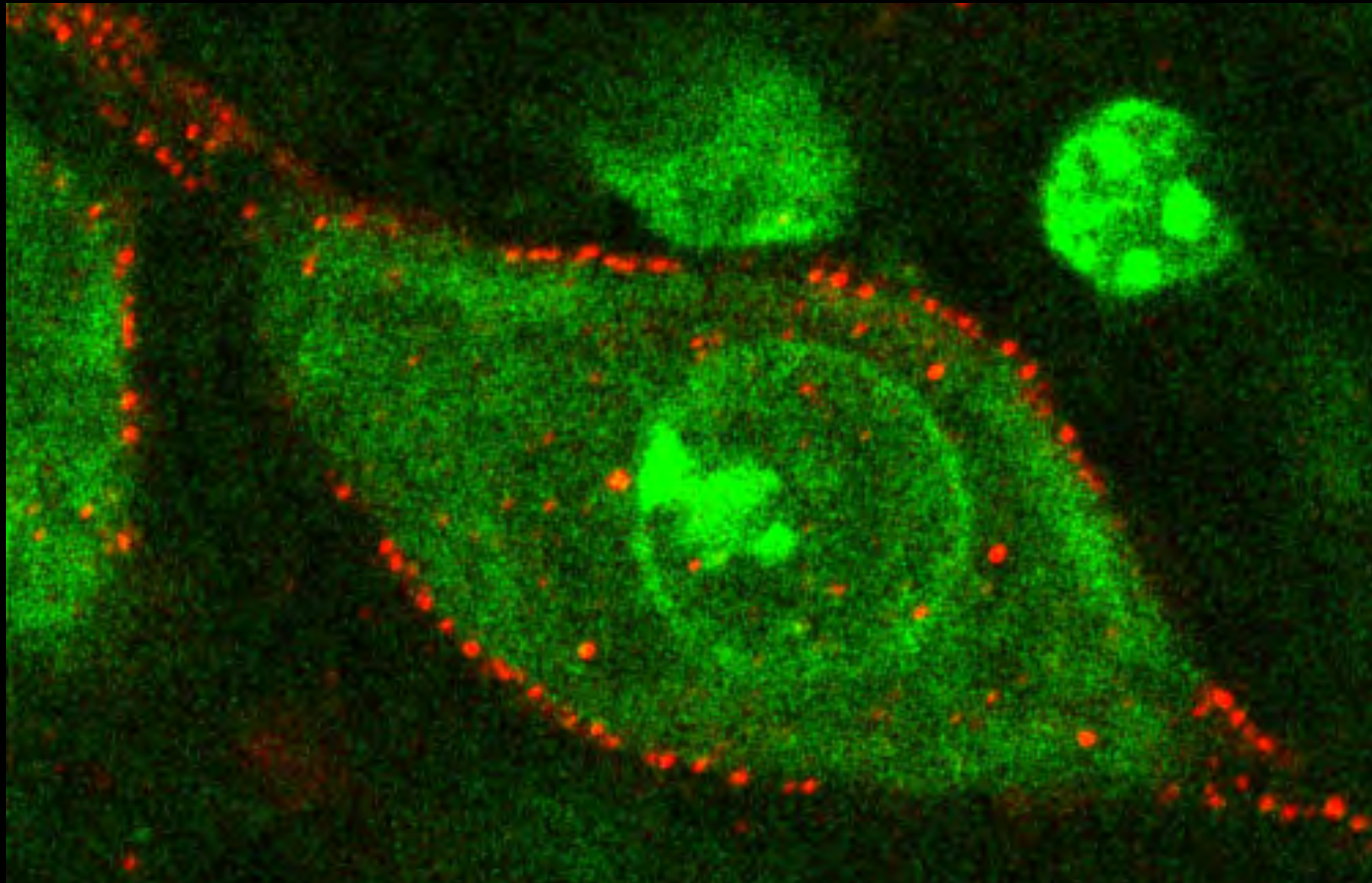
Step 6: Na^+ flux/dendrite depolarization

Step 7: Action Potential is regenerated postsynaptically

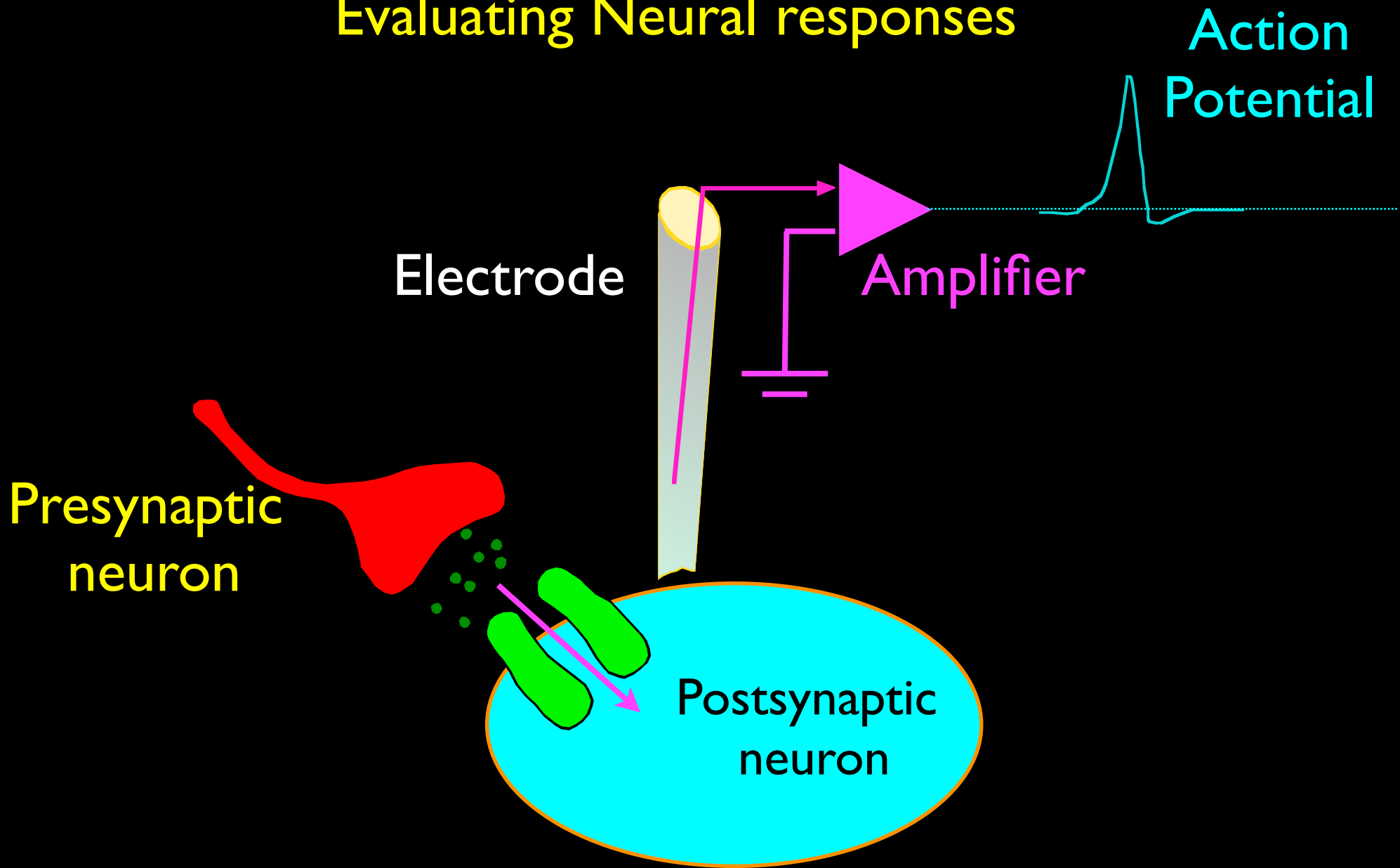
Very large auditory synapse



Stain in **red** marks postsynaptic receptors



Evaluating Neural responses



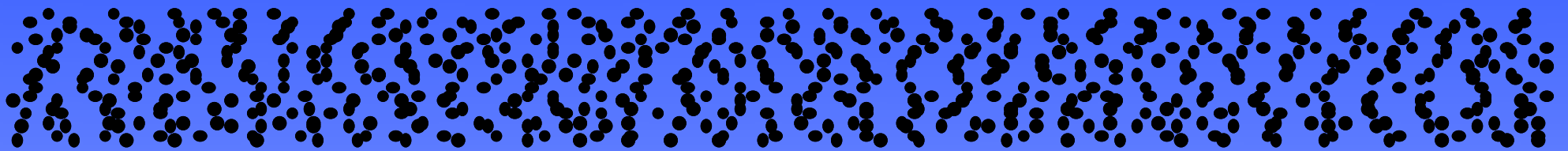
AND Finally,....

How do neurons encode information?

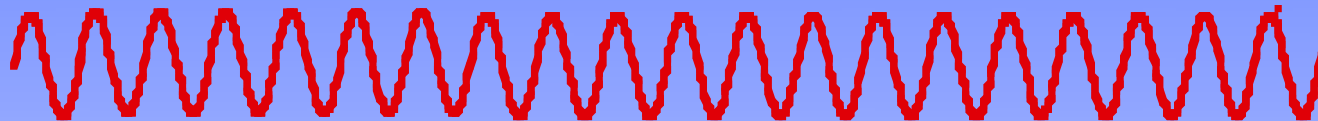
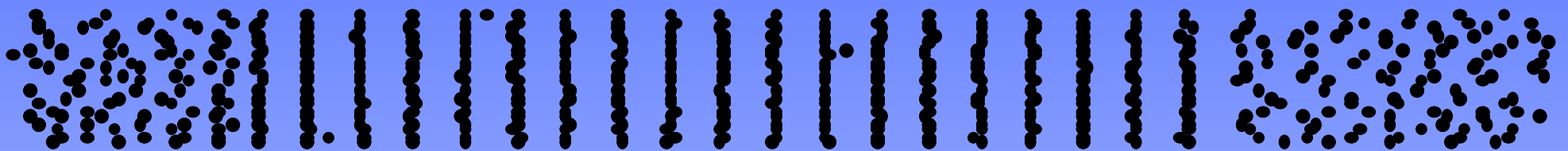
there are two simple ways.....

with action potential **TIMING**....

no sound

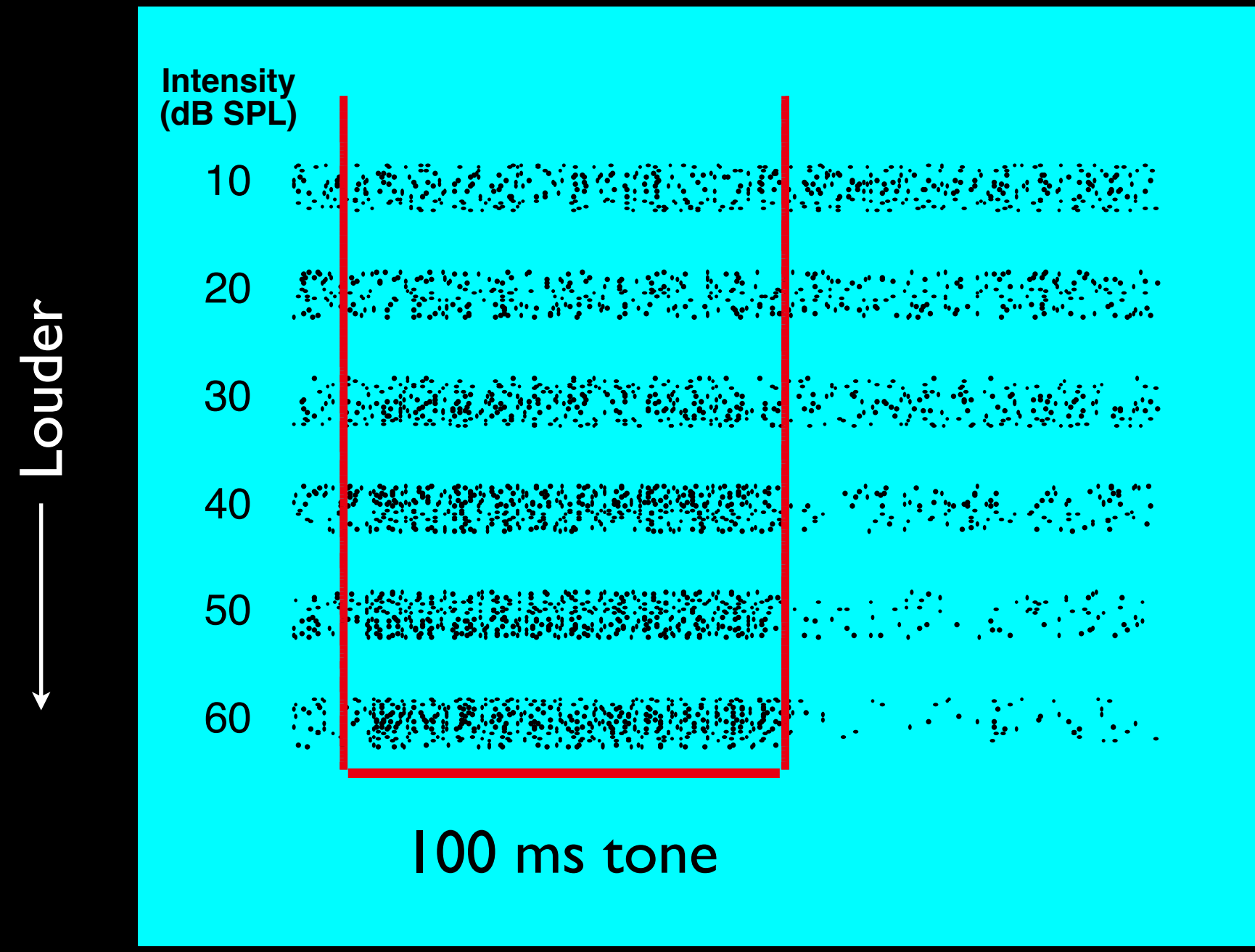


evoked

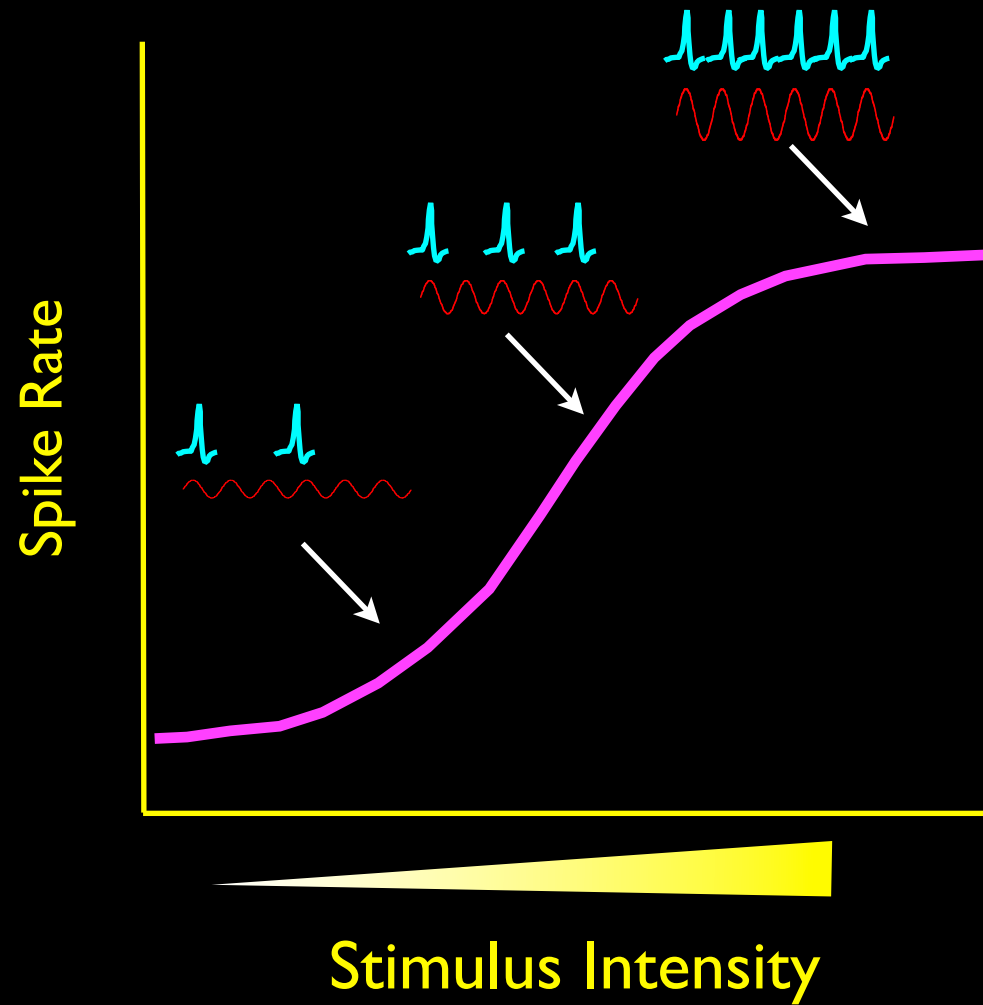


100 ms tone

...and Neurons signal by changing their firing rate



Spike Rate increases with Intensity



What we learned today:

1. Neurons and glia: characteristics and function
2. Ionic basis of electrical signaling
3. Basics of chemical synaptic signaling
4. How neural activity is recorded
5. How neural activity relates to information processing