

# **Bioscience in the 21st century**

Neurons, Synapses, and Signaling

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## 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?

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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.

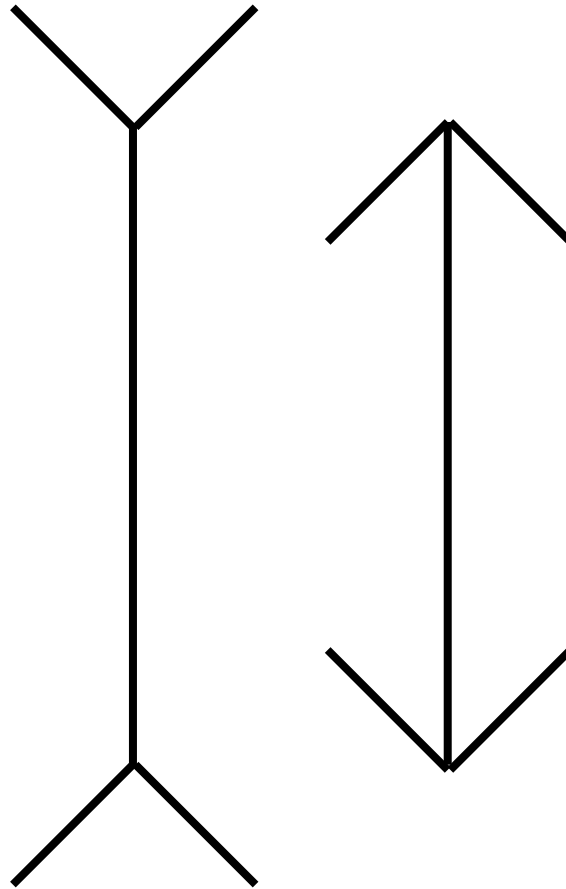
...In fact, from one perspective  
“you” are your brain



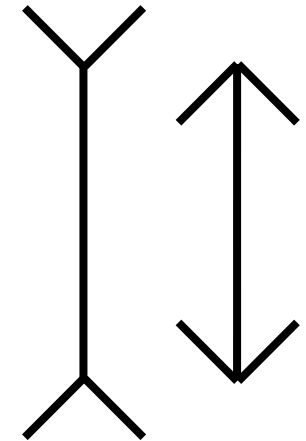
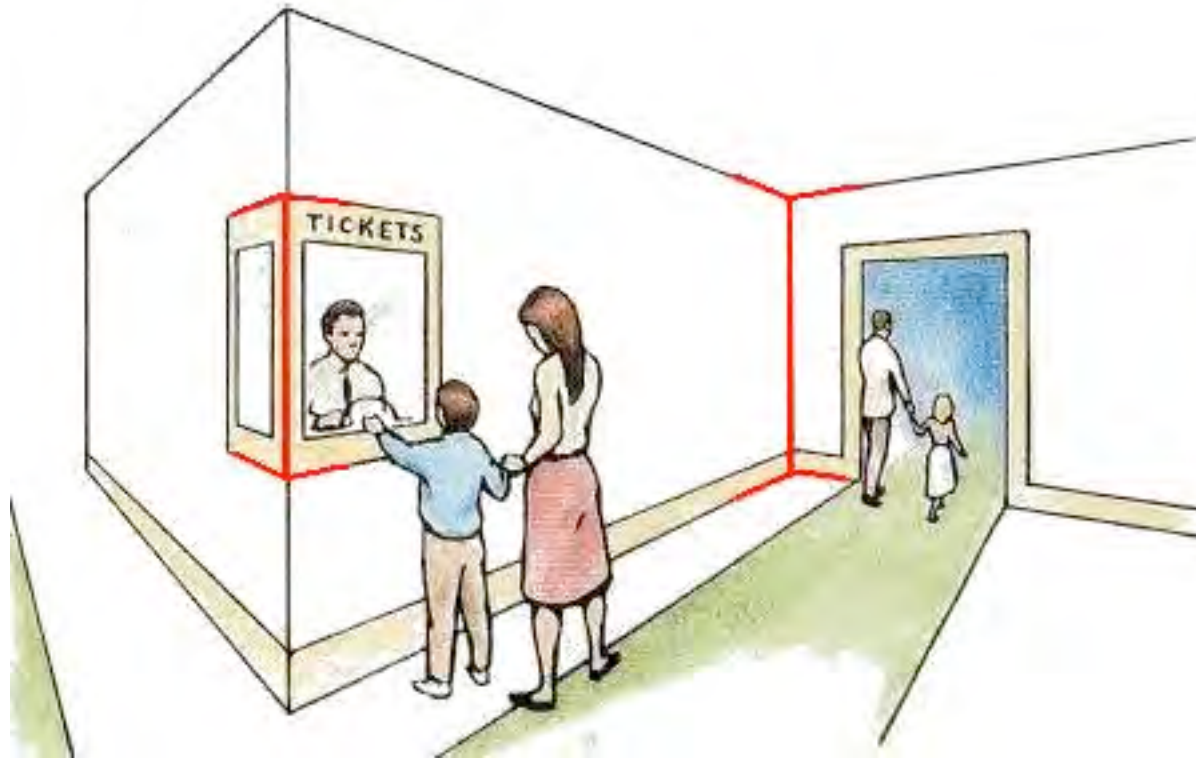
Figure-ground illusions are well known for visual stimuli



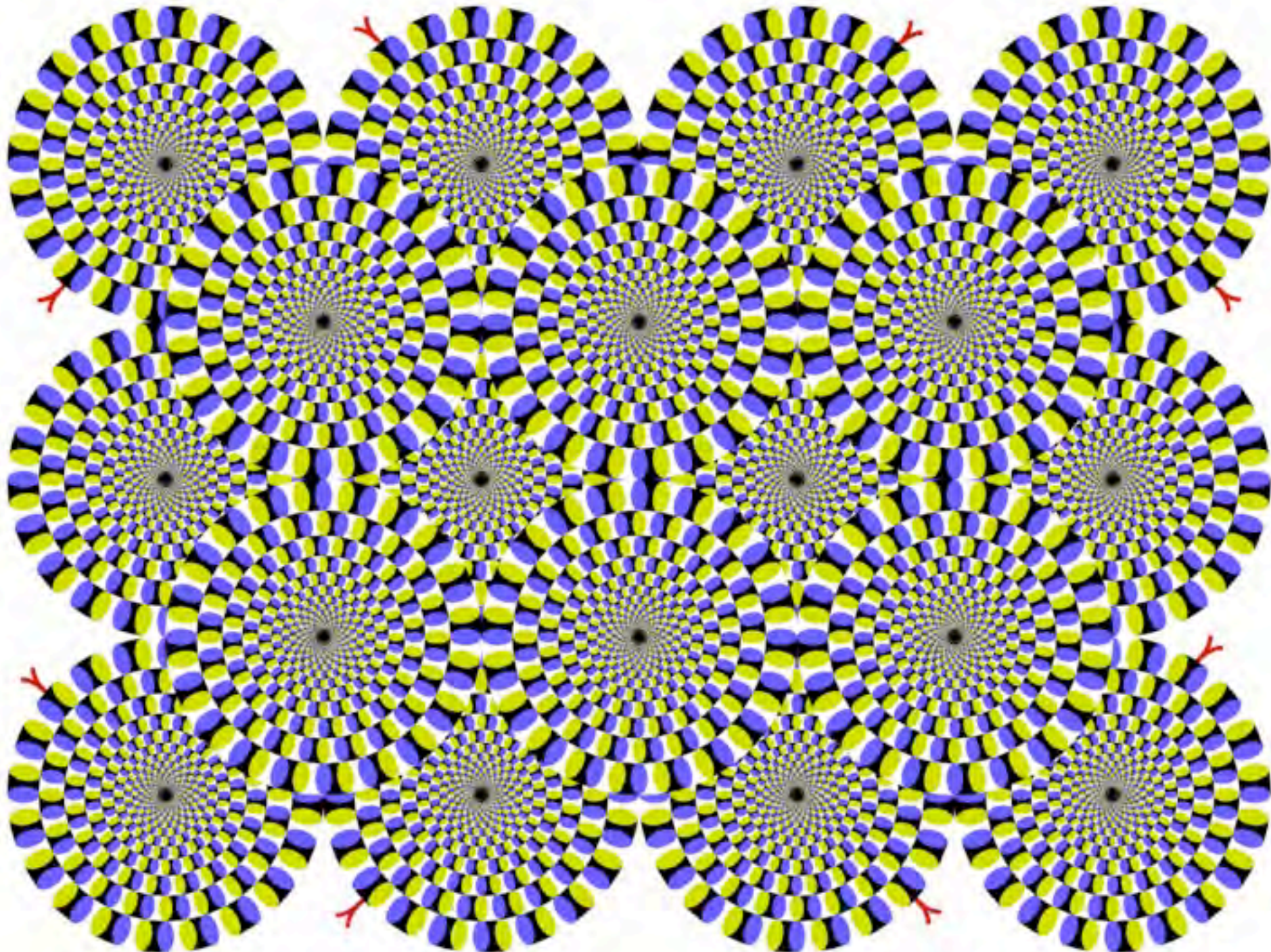
# The Müller-Lyer Illusion



# The Müller-Lyer Illusion



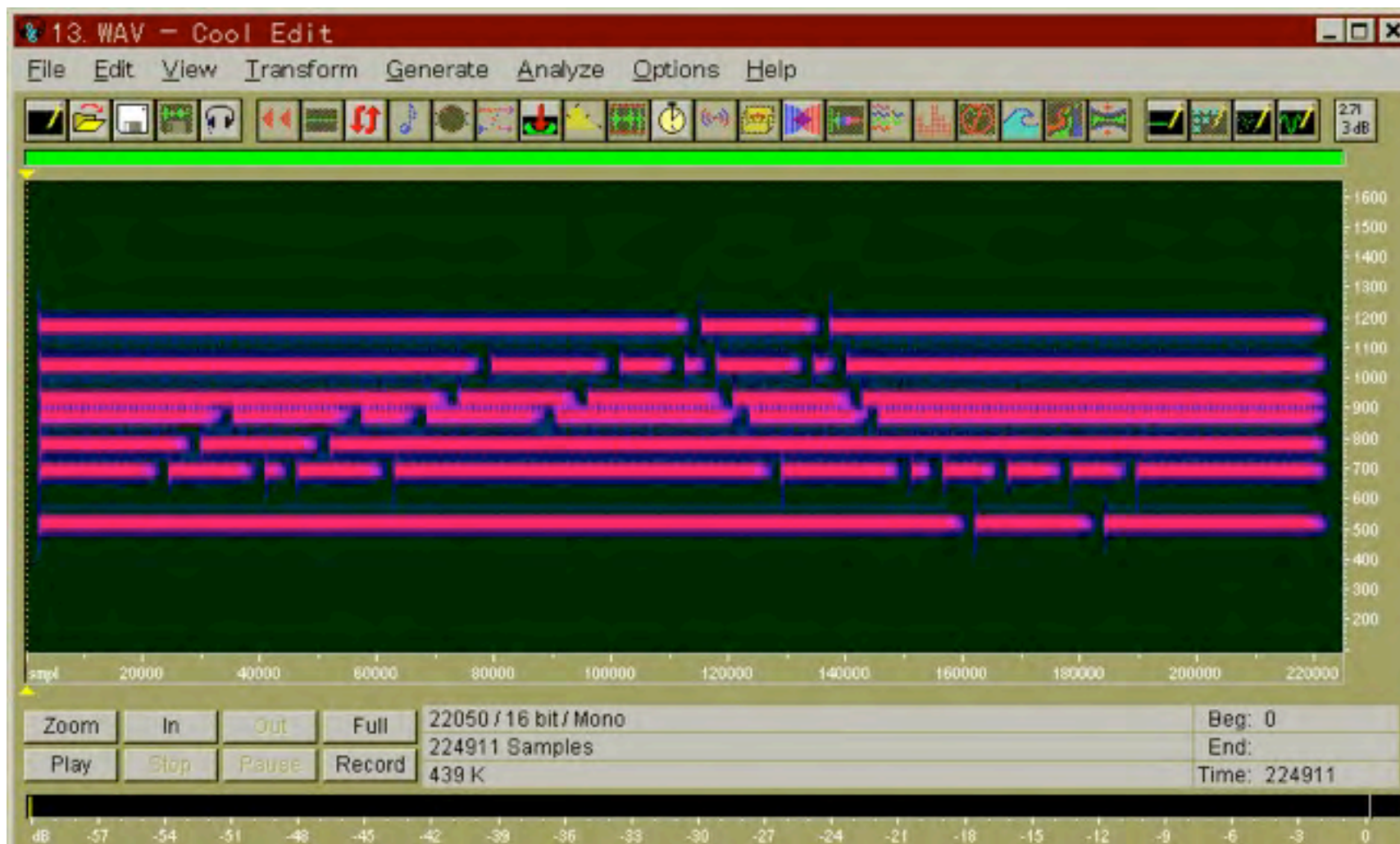






# Hearing gaps

# 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**

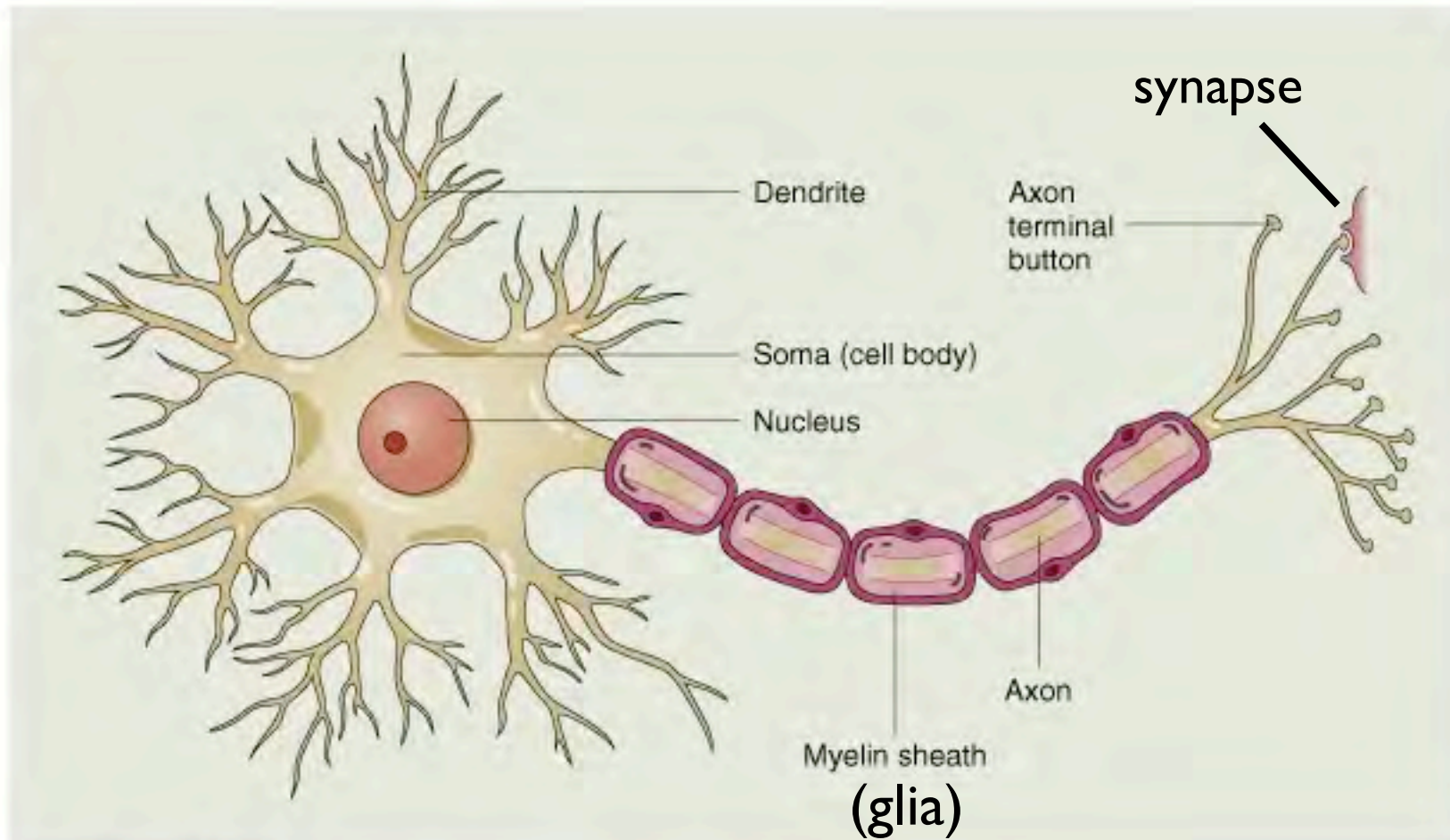
## The **BIG THREE** topics for today:

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

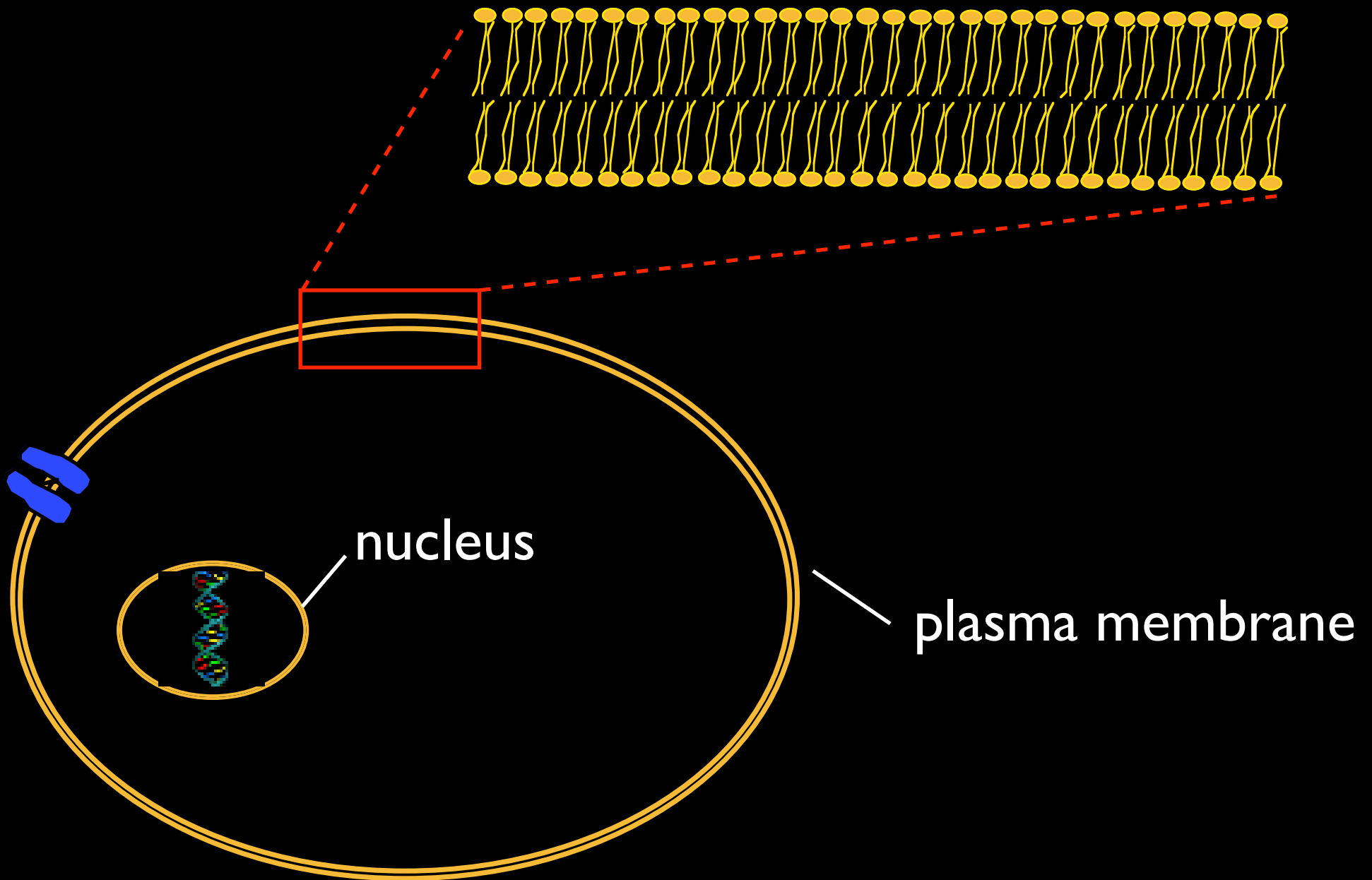
II. How do neurons “talk” to each other?

III. How do neurons encode information?

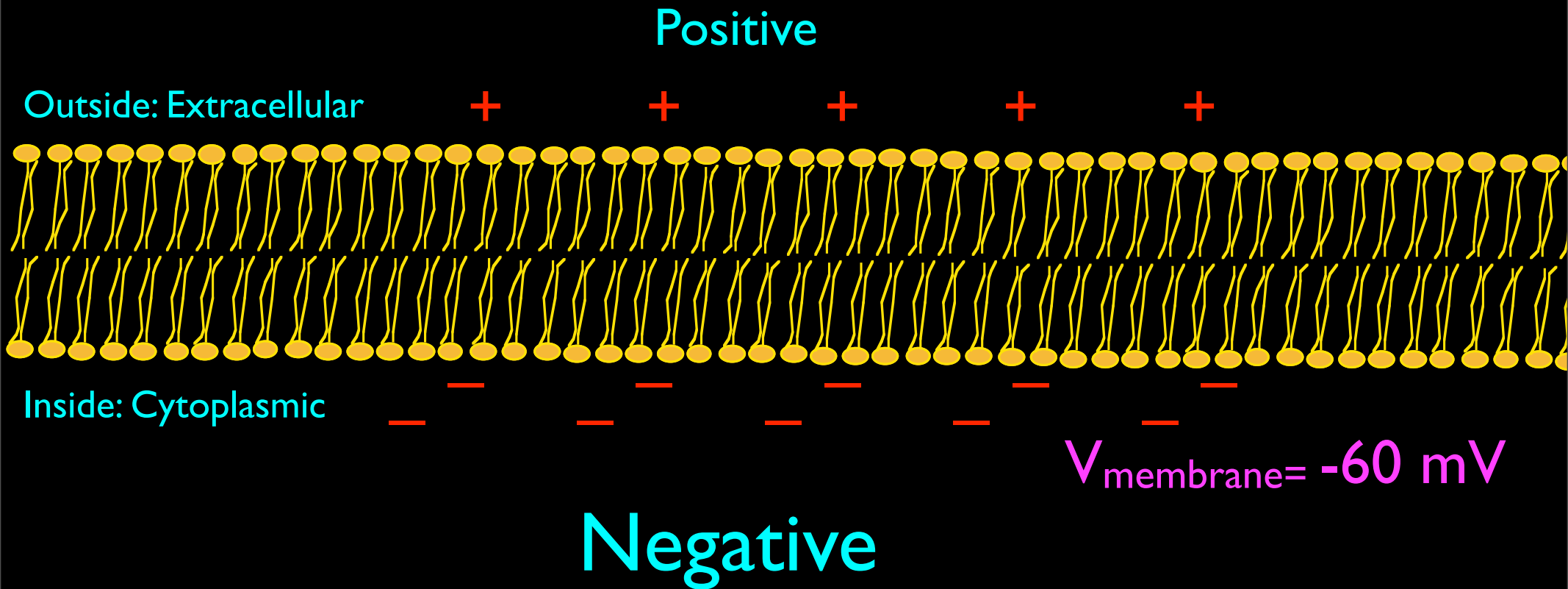
# The neuron is the “unit of processing” for the nervous system



# The cell membrane is a phospholipid bilayer

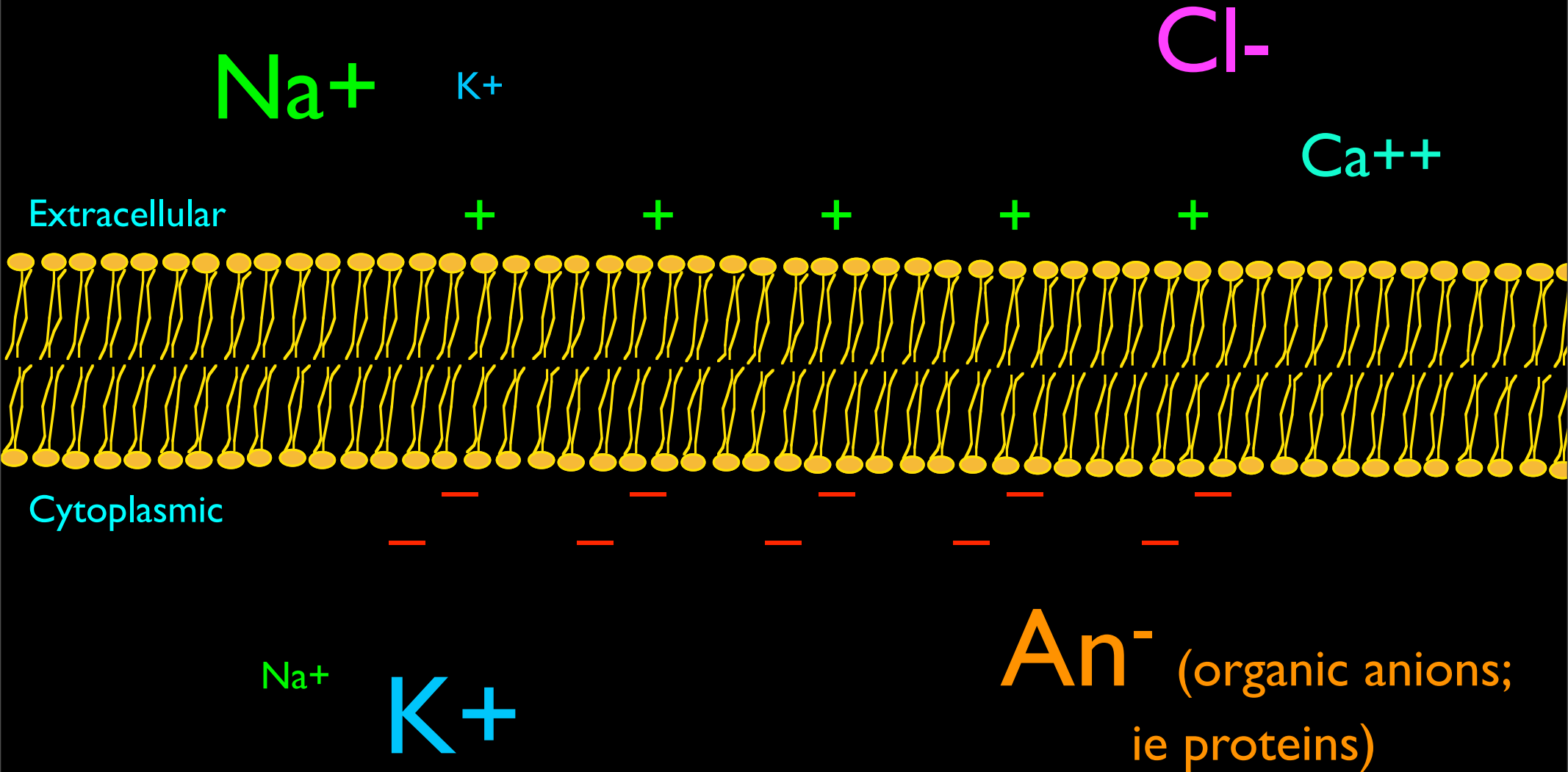


# Cell membranes store Voltage

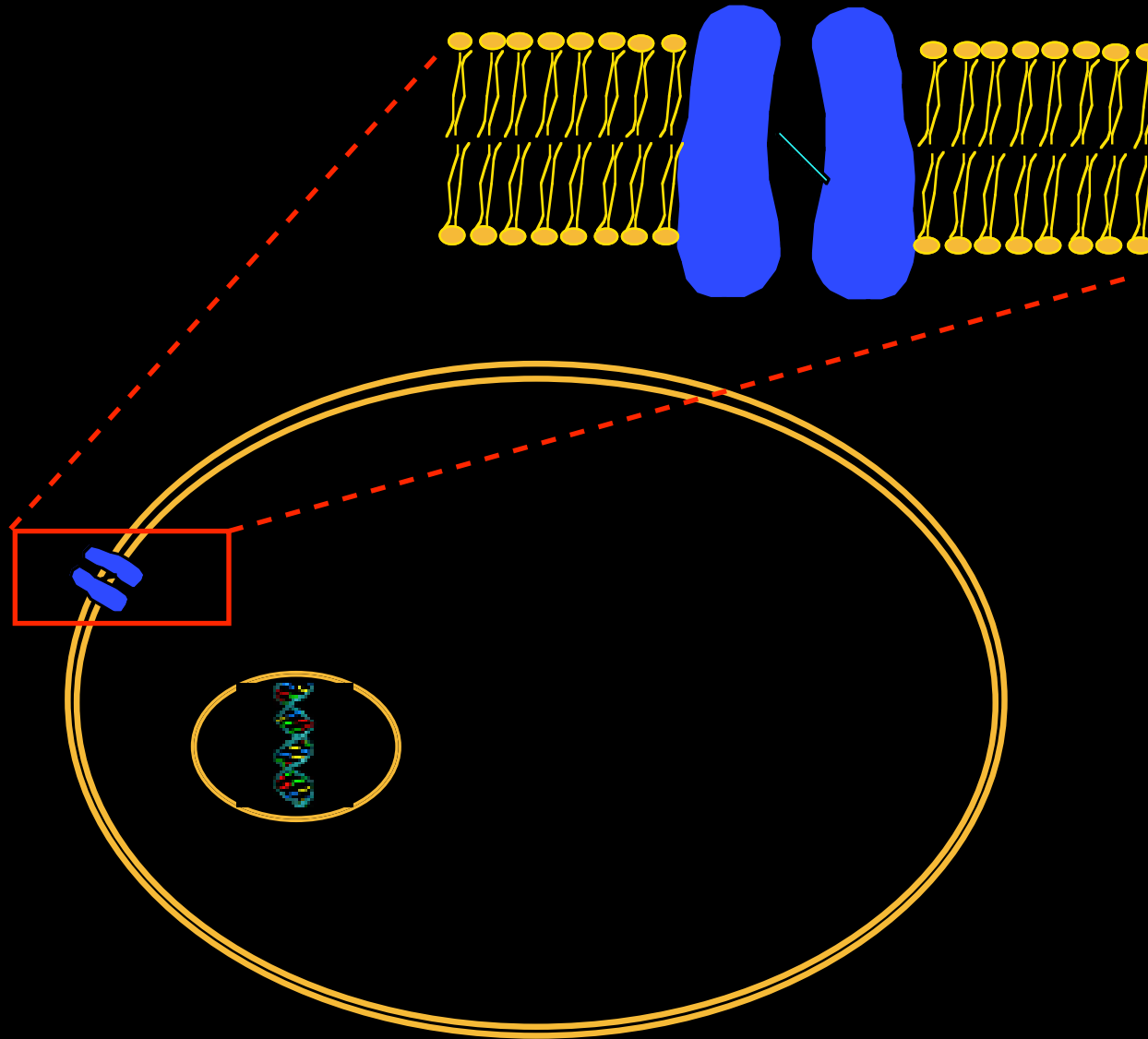


**\*\*The inside of the cell is usually more negative than the outside by about -60 mV**

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

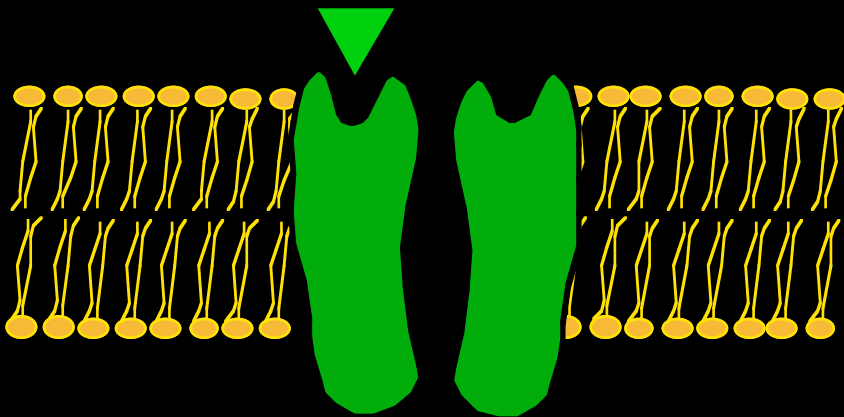


The cell membrane contains proteins, some of which are channels for charged particles

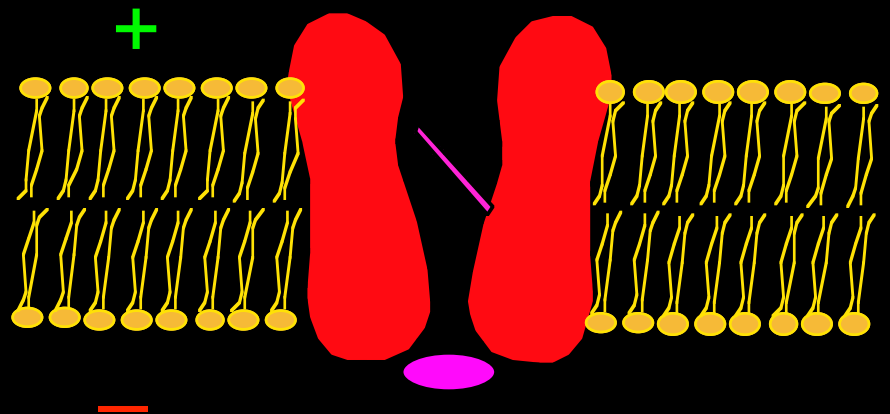
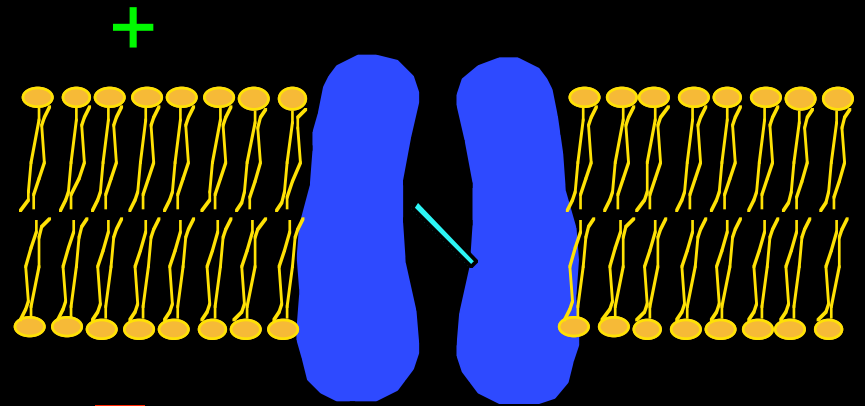


# Two (of many) membrane protein types:

Ligand gated  
(chemically gated)

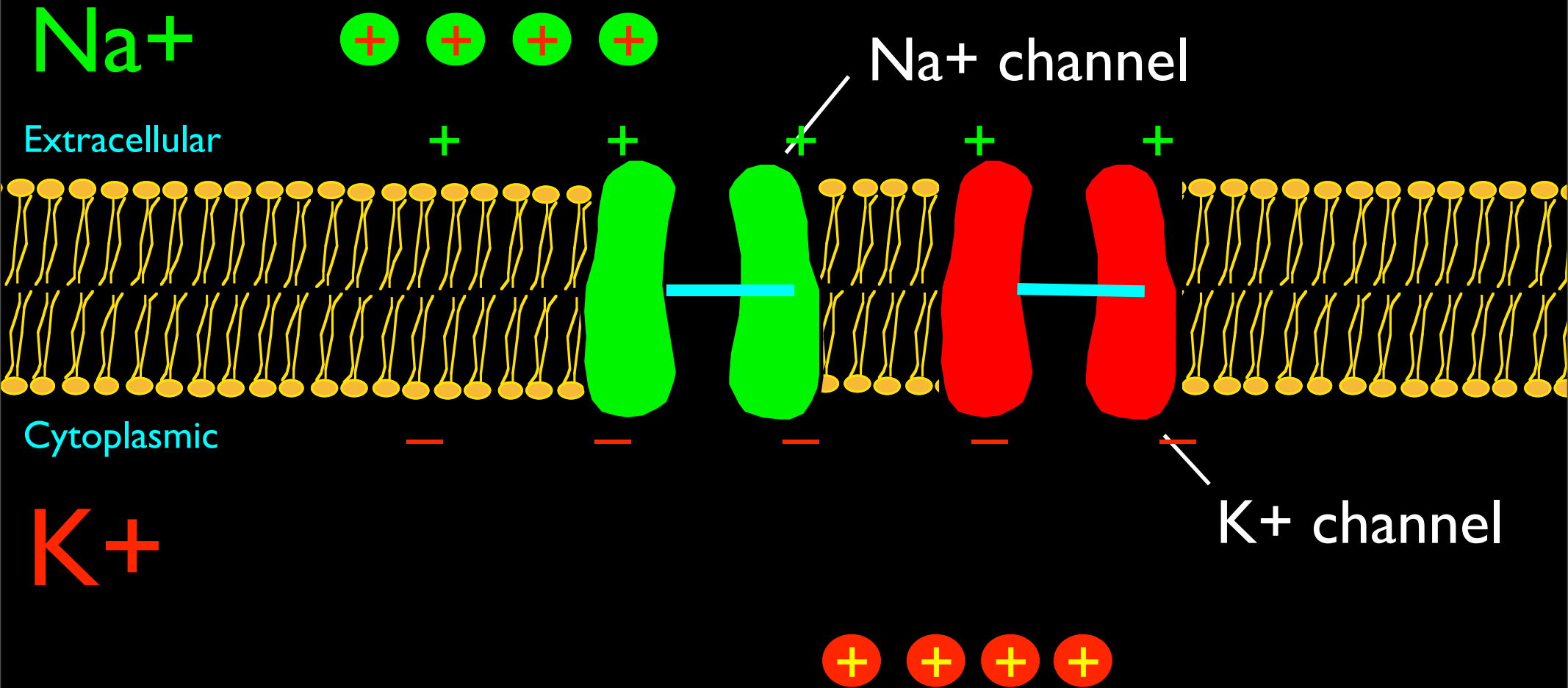


Voltage gated





# How does an electrical signal occur in a neuron?



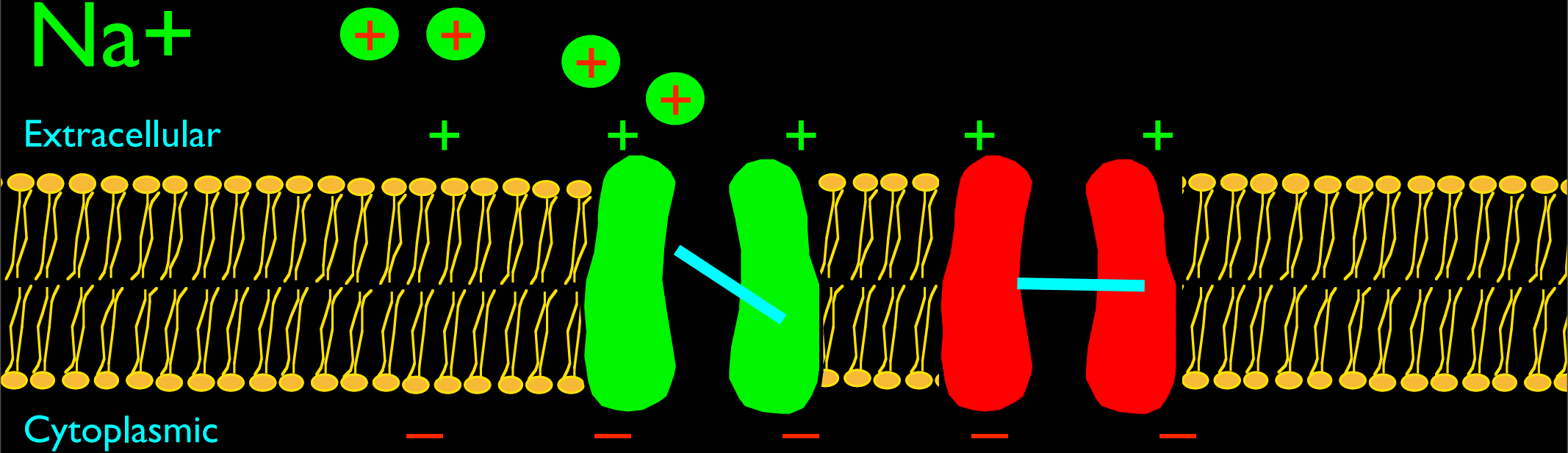
FIRST, WE GIVE THE Na<sup>+</sup> CHANNEL A STIMULUS

Na+

Extracellular

Cytoplasmic

K+



Na<sup>+</sup>



Extracellular

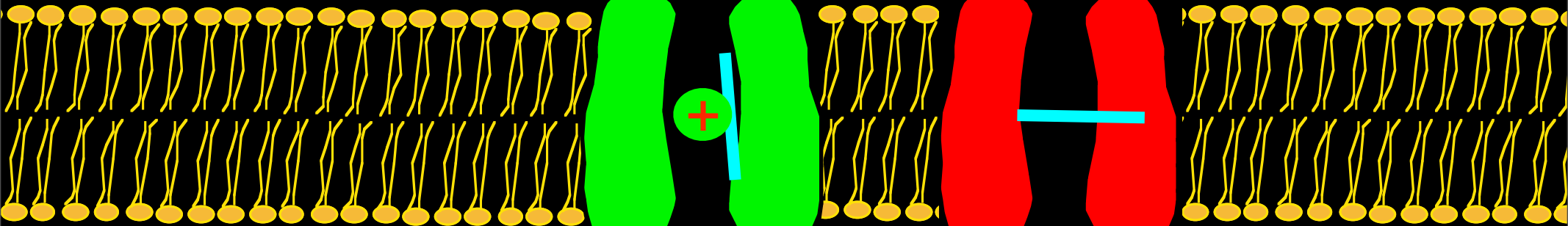
+

+

+

+

+



Cytoplasmic

-

-

-

-

-

K<sup>+</sup>



Na<sup>+</sup>



Extracellular

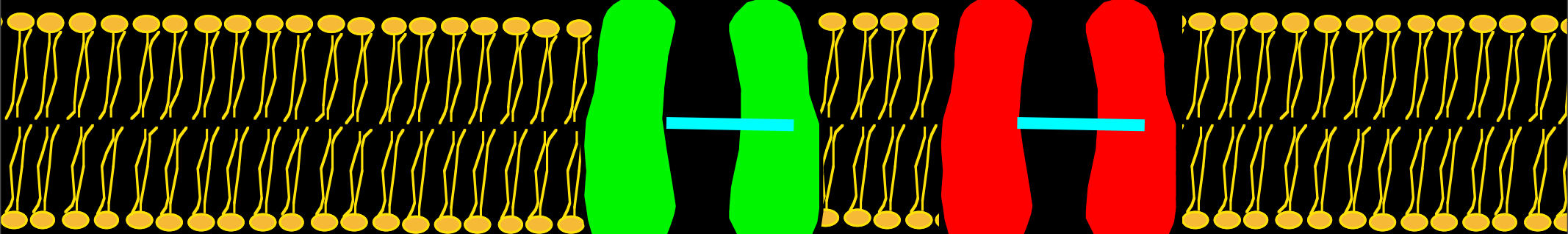
+

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Cytoplasmic

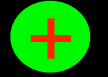
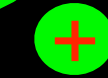
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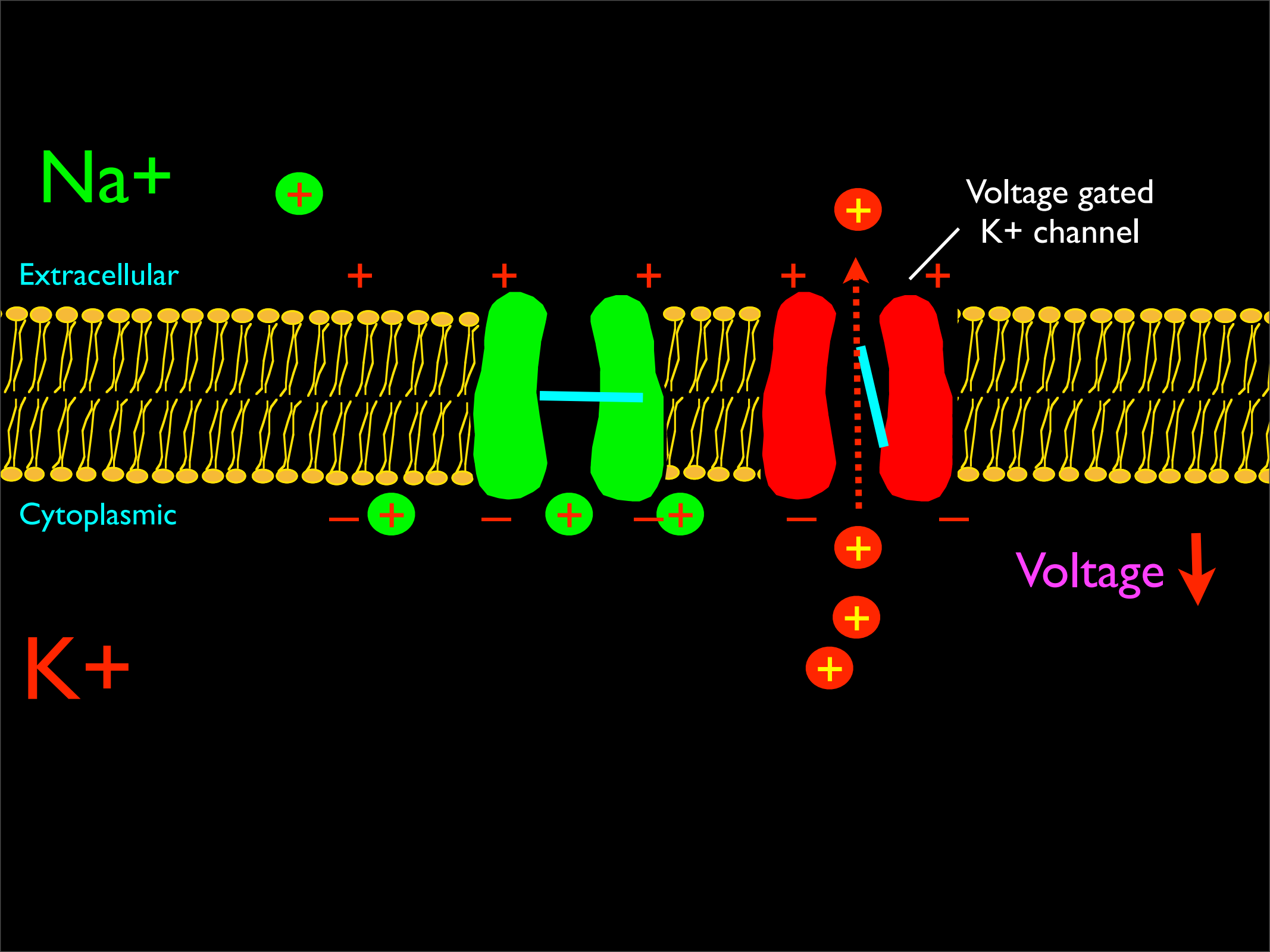
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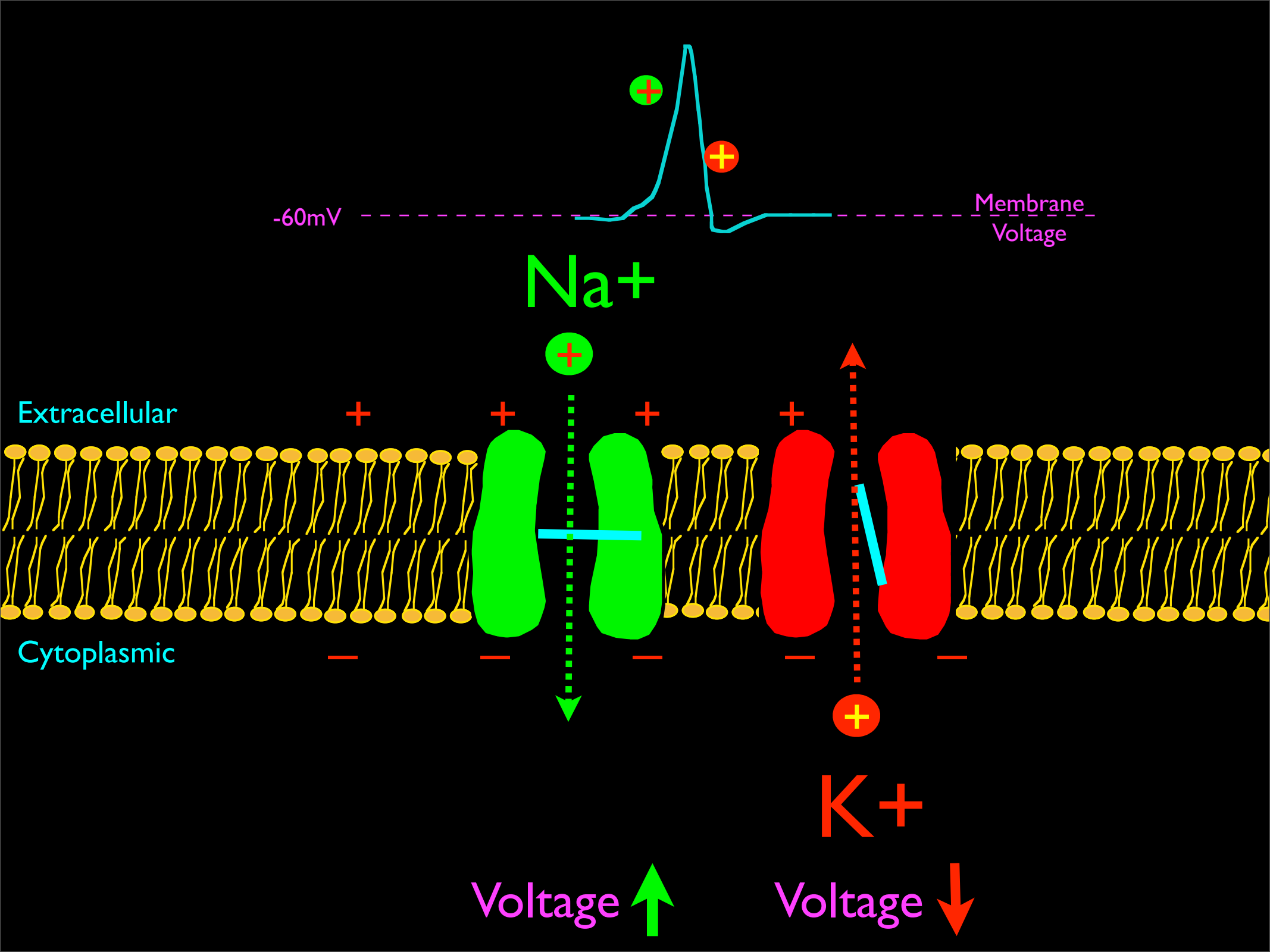


K<sup>+</sup>

Voltage ↑





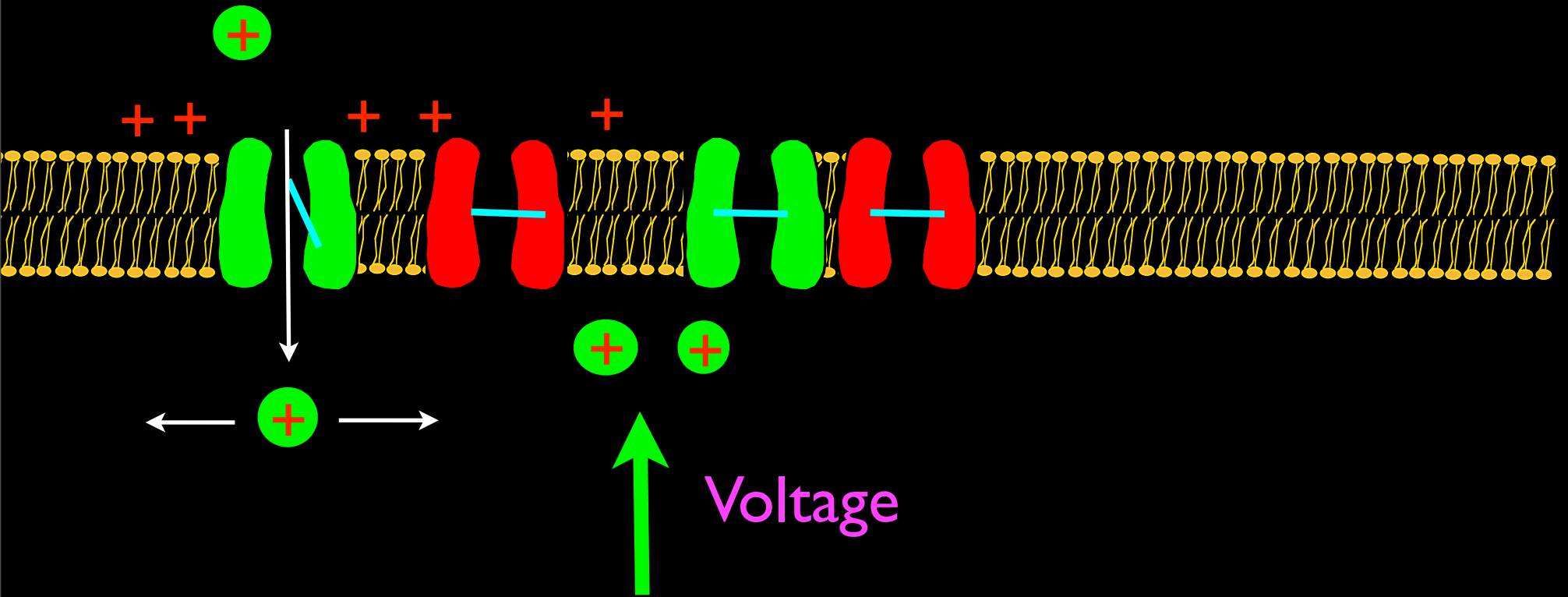


One more detail....

The voltage change travels...

Na<sup>+</sup>

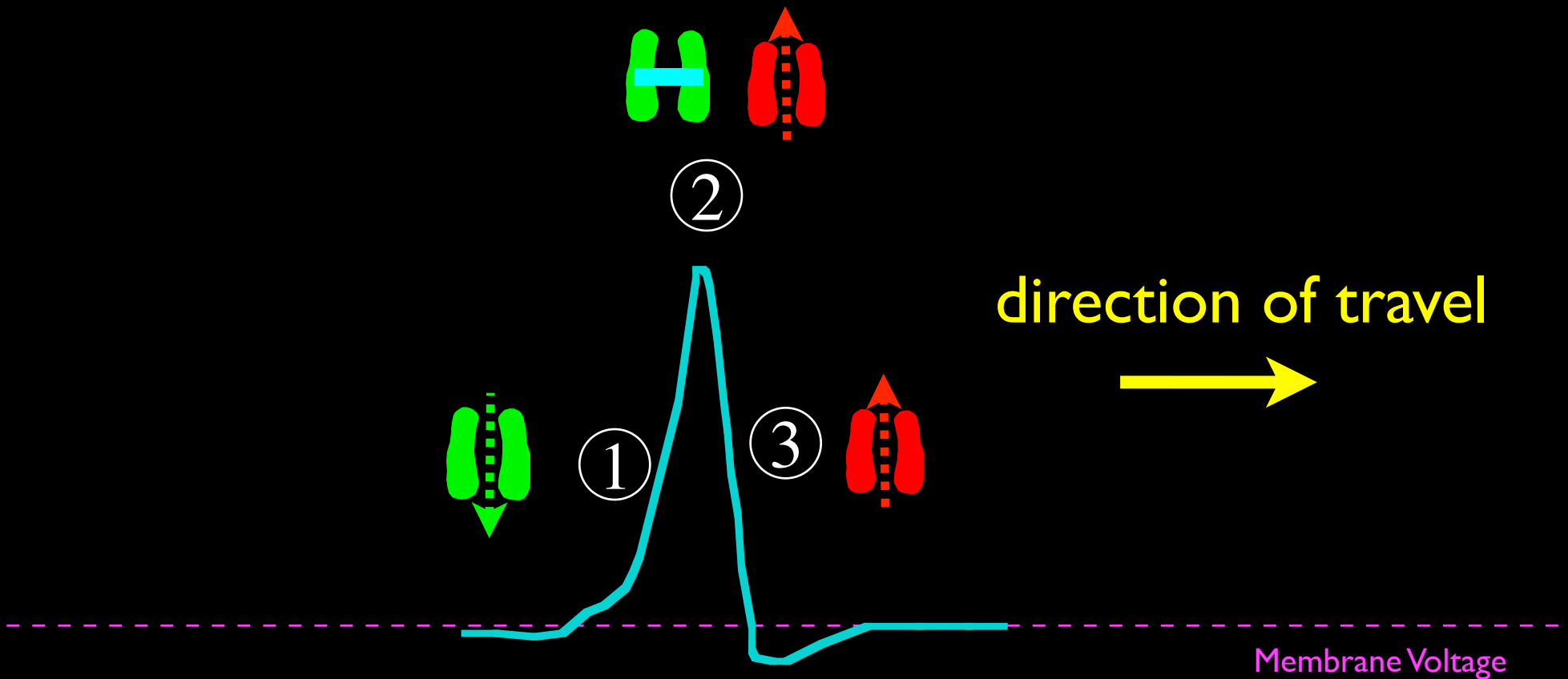
The basis of propagation...



K<sup>+</sup>



# Action Potential Summary:

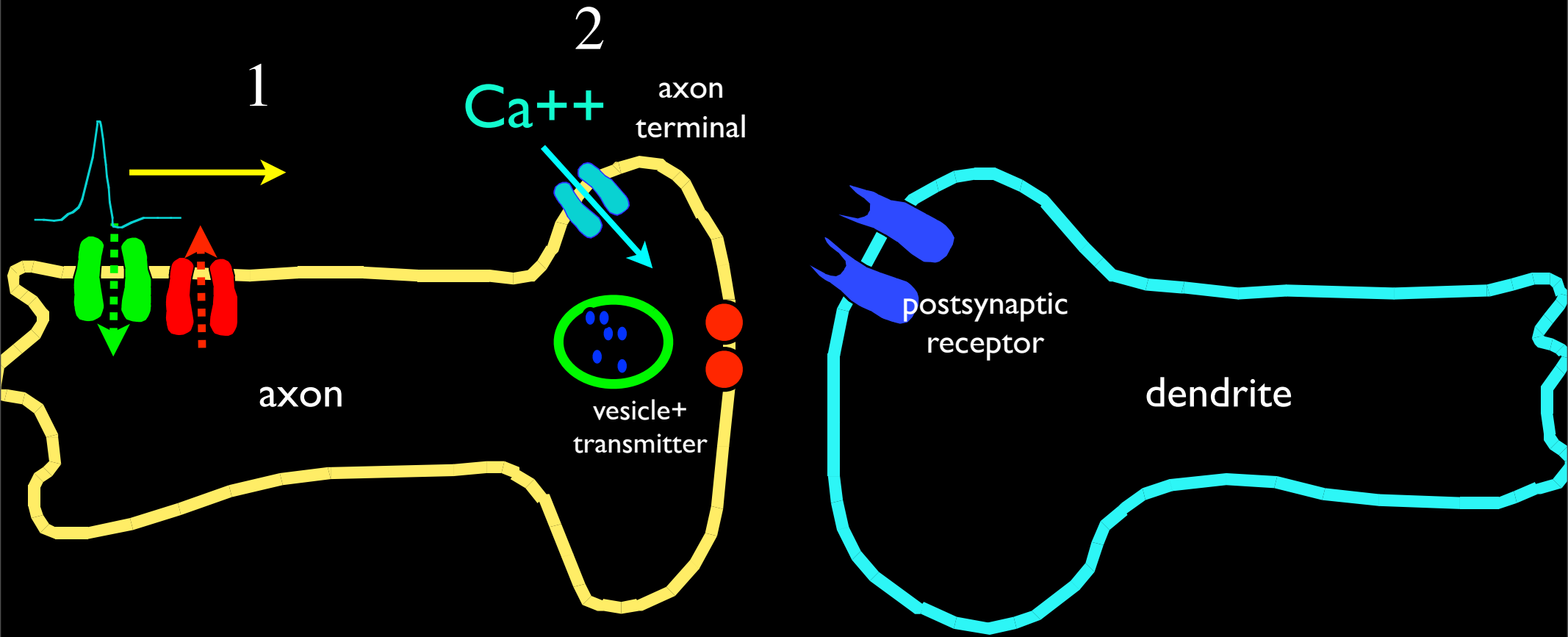


1. Na<sup>+</sup> channels open/Na flows into the cell
2. Na<sup>+</sup> channels close while K<sup>+</sup> channels are opening
3. K<sup>+</sup> flow out of the cell dominates

NEXT:

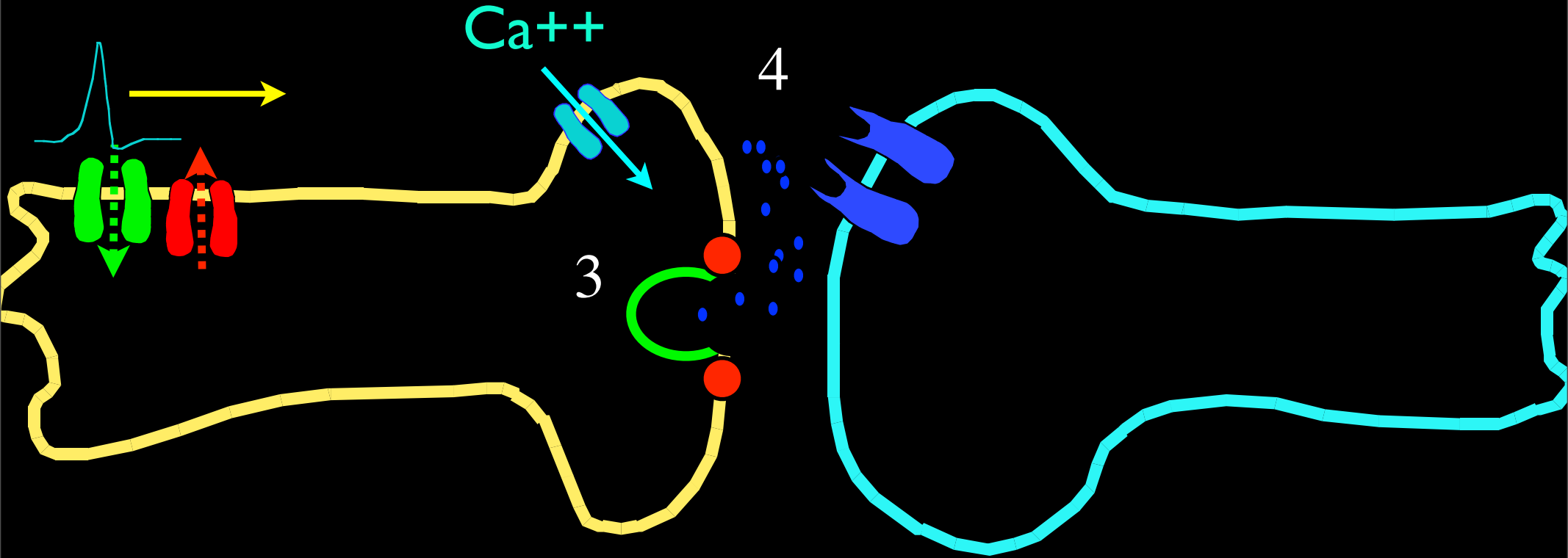
How do neurons “talk” to each other?

# Synaptic Transmission



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

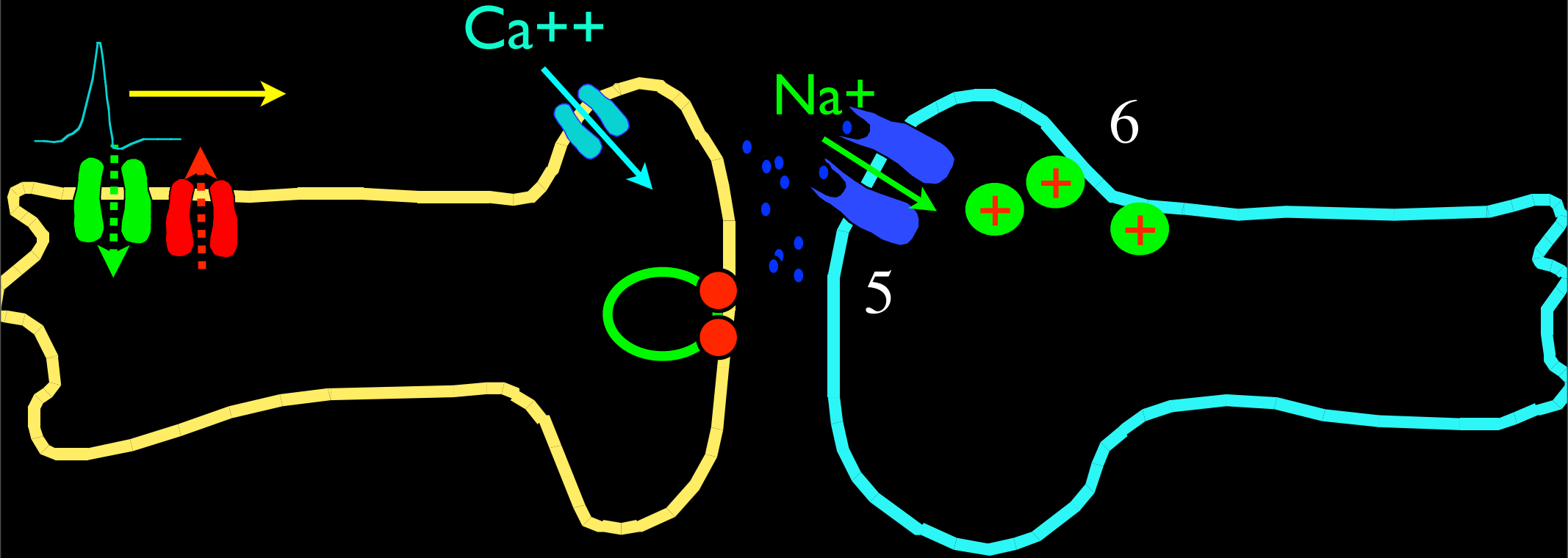
# Synaptic Transmission



Step 3:  $\text{Ca}^{++}$  dependent vesicle fusion

Step 4: transmitter release

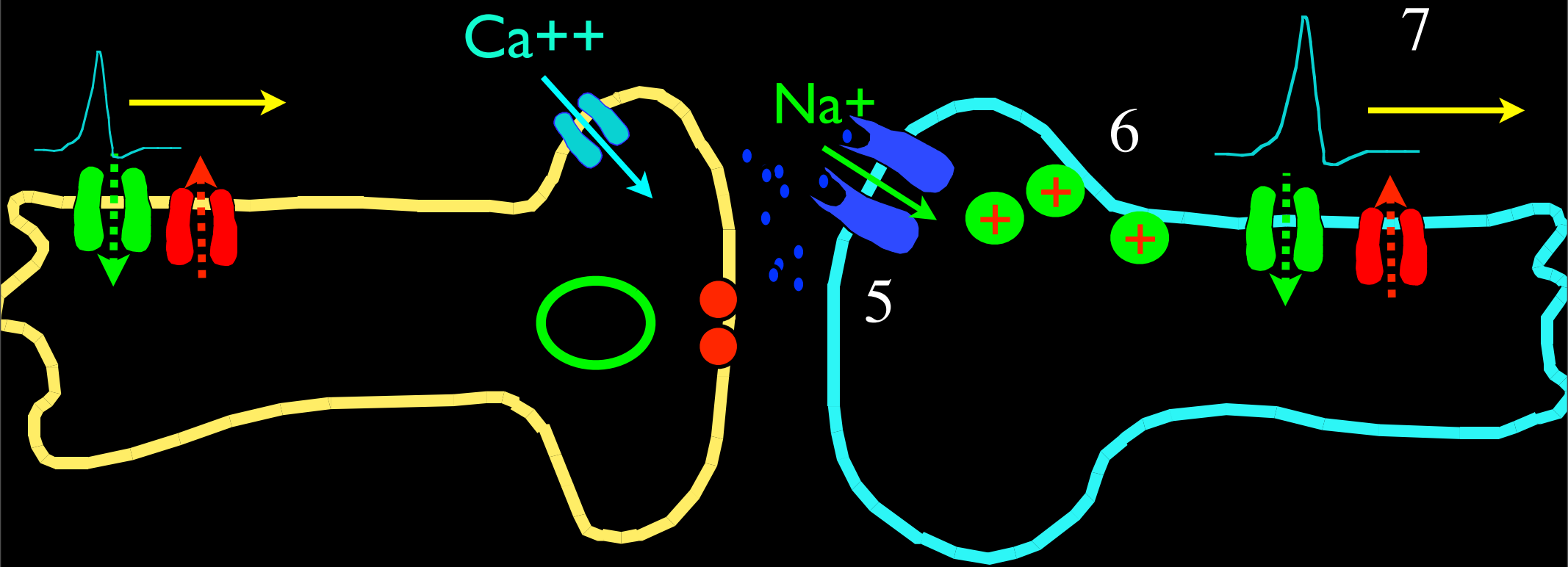
# Synaptic Transmission



Step 5: Activation of ligand gated channel

Step 6:  $Na^{+}$  flux/dendrite depolarization

# Synaptic Transmission

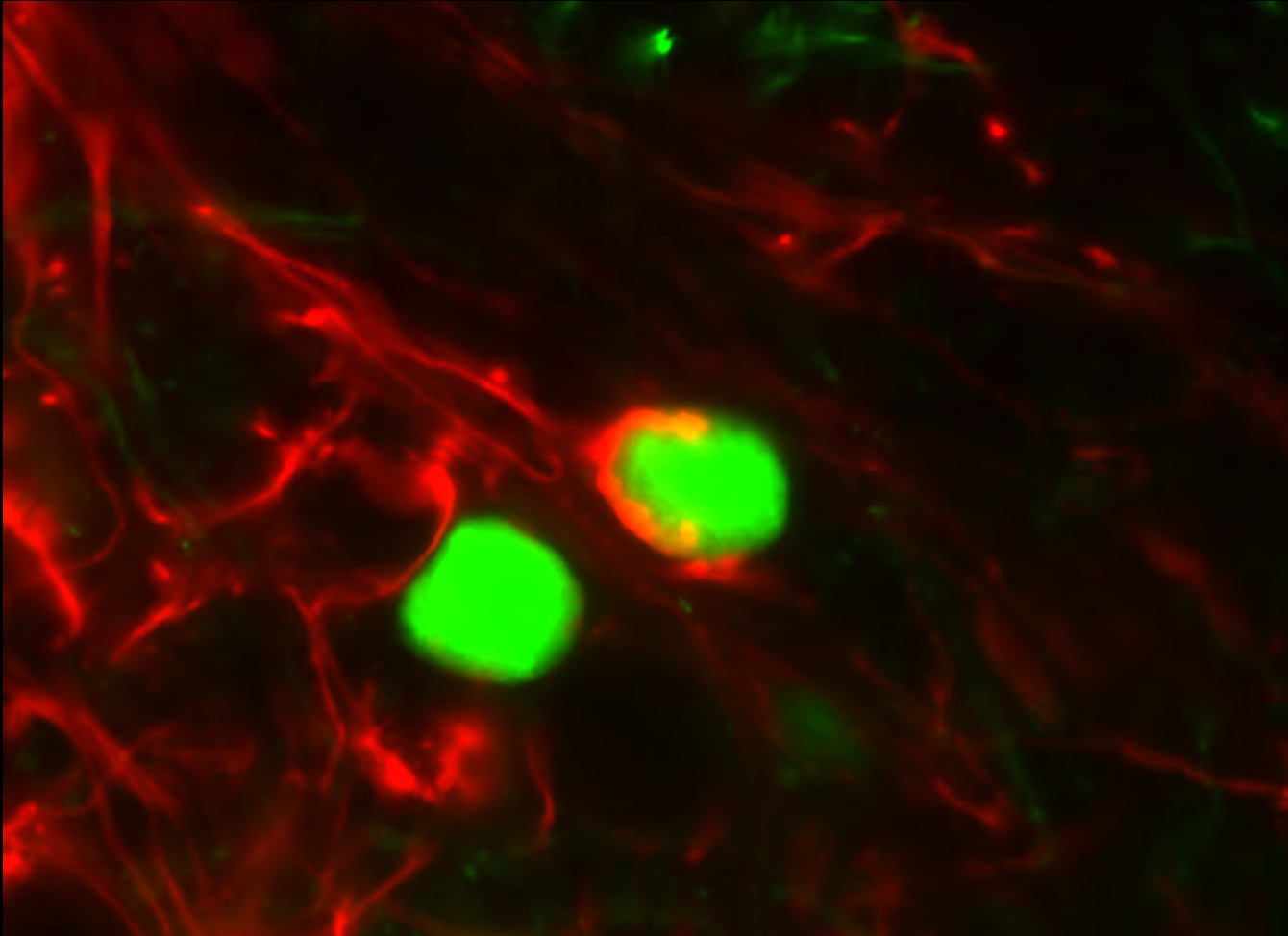


Step 5: Activation of ligand gated channel

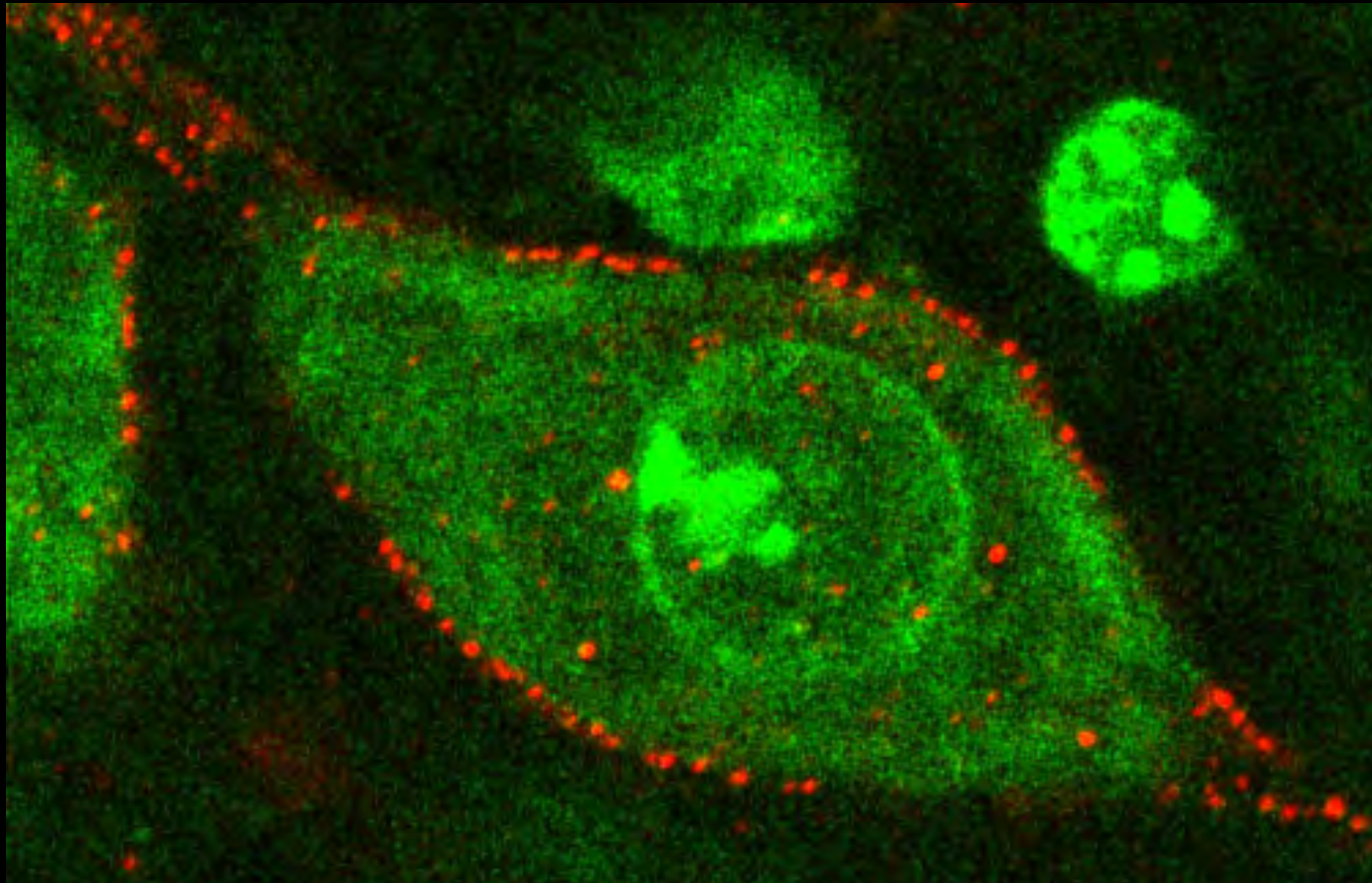
Step 6:  $Na^{+}$  flux/dendrite depolarization

Step 7: Action Potential is regenerated postsynaptically

# Very large auditory synapse

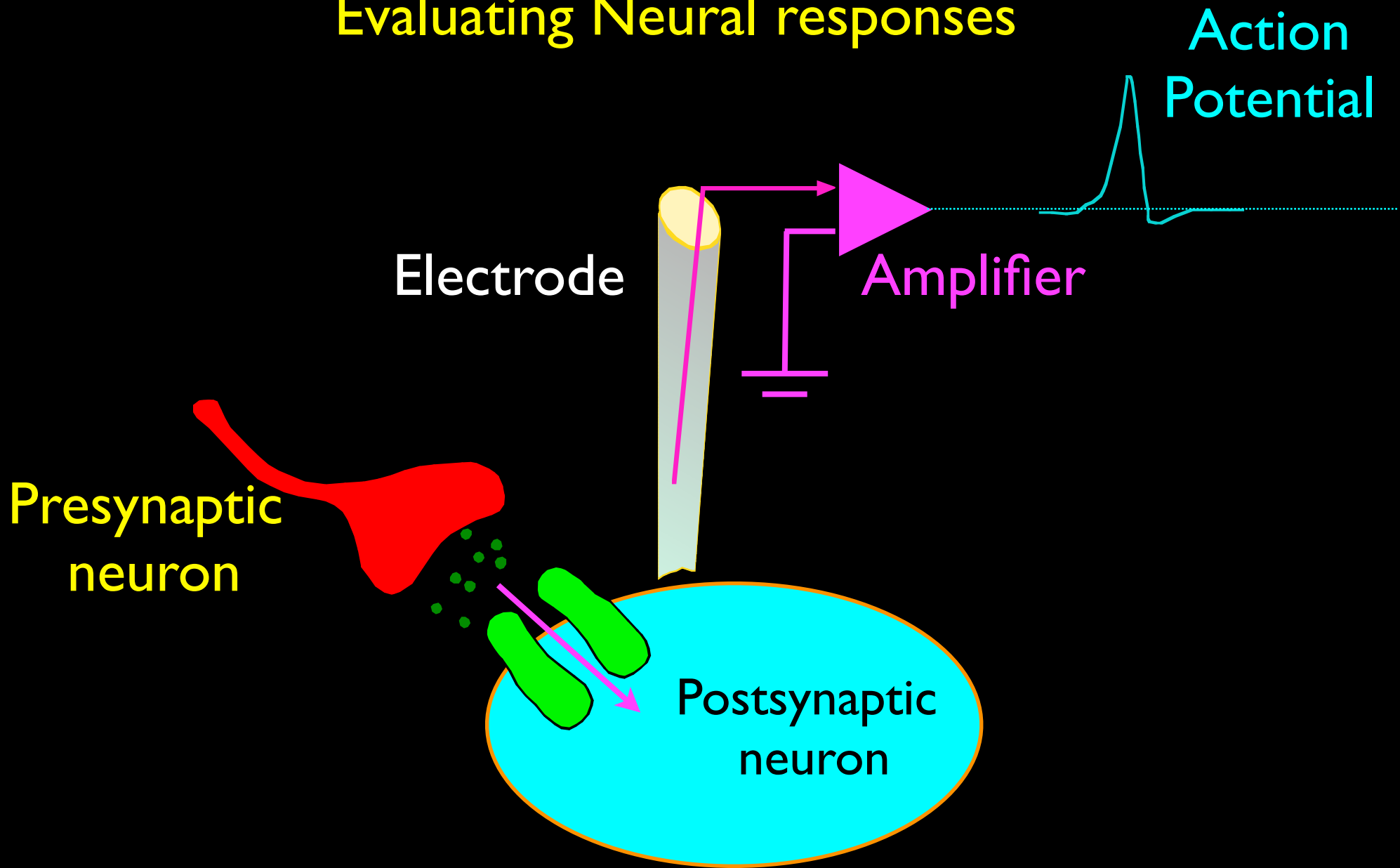


Stain in **red** marks postsynaptic receptors





# Evaluating Neural responses



AND Finally,....

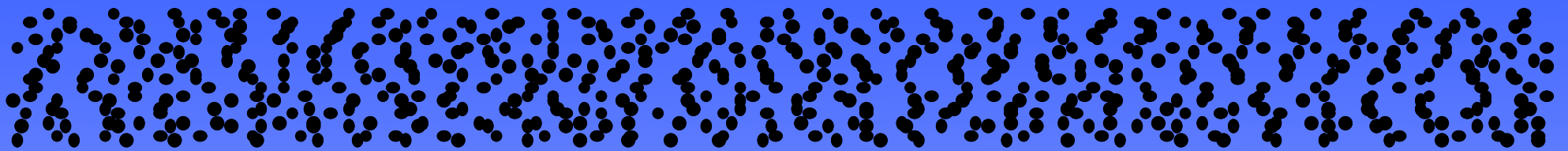
How do neurons encode information?

*there are two simple ways.....*

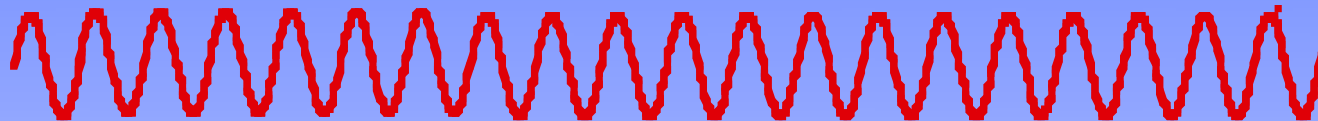
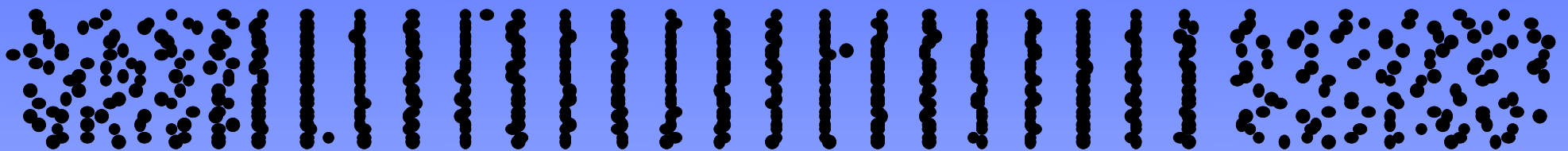
with action potential **TIMING**....

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no sound

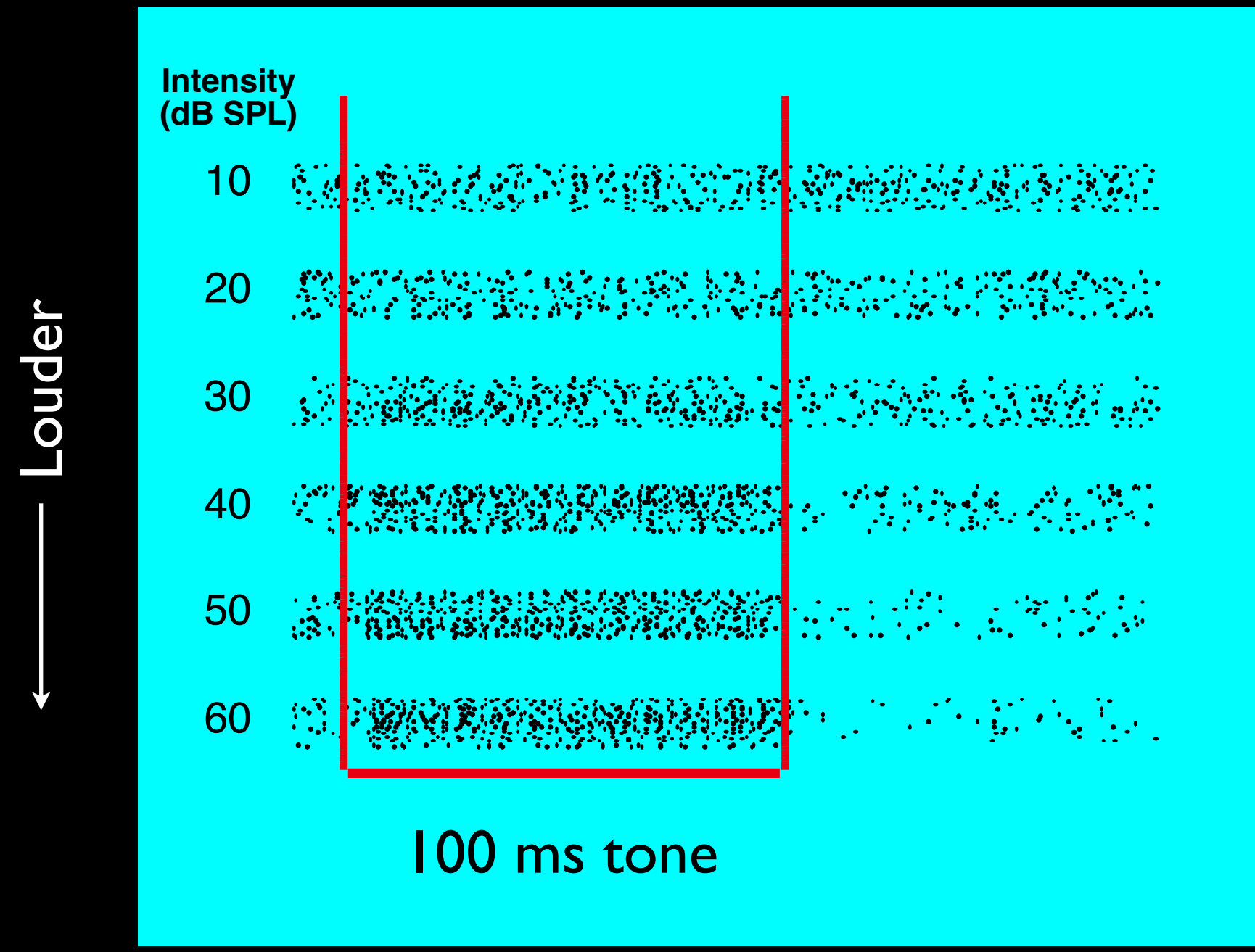


evoked

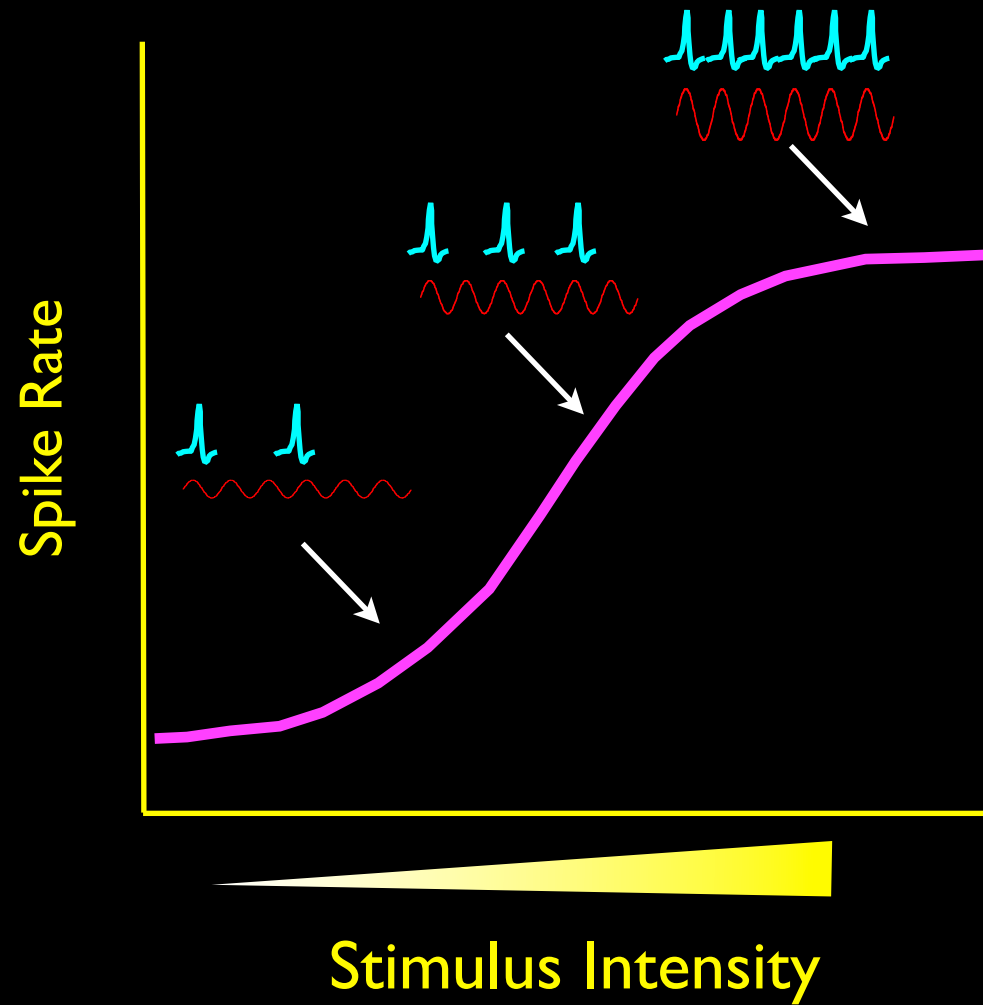


100 ms tone

...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