

# **Biosciences in the 21st century**

Lecture 1: Neurons, Synapses, and Signaling

Dr. Michael Burger

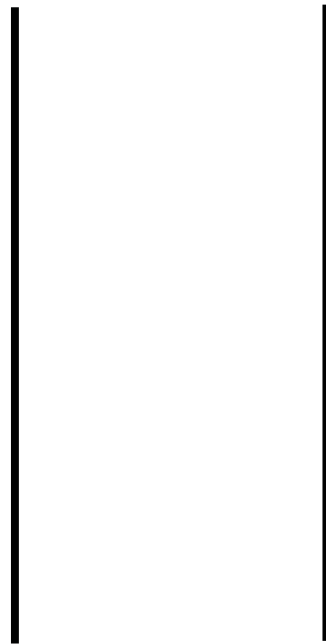
## Outline:

1. Why neuroscience?
2. The neuron
3. Action potentials
4. Synapses
5. Organization of the nervous system
6. Clinical approaches of today and tomorrow

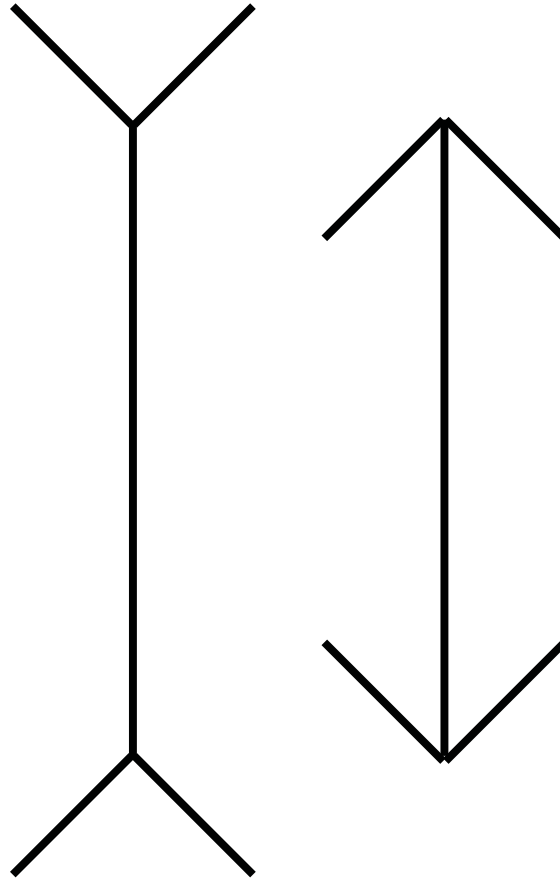
Figure-ground illusions are well known for visual stimuli



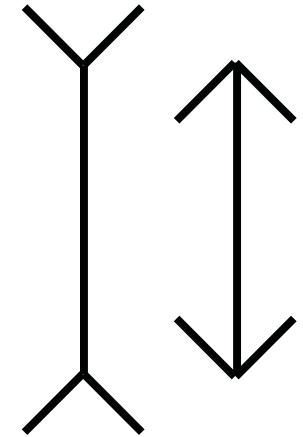
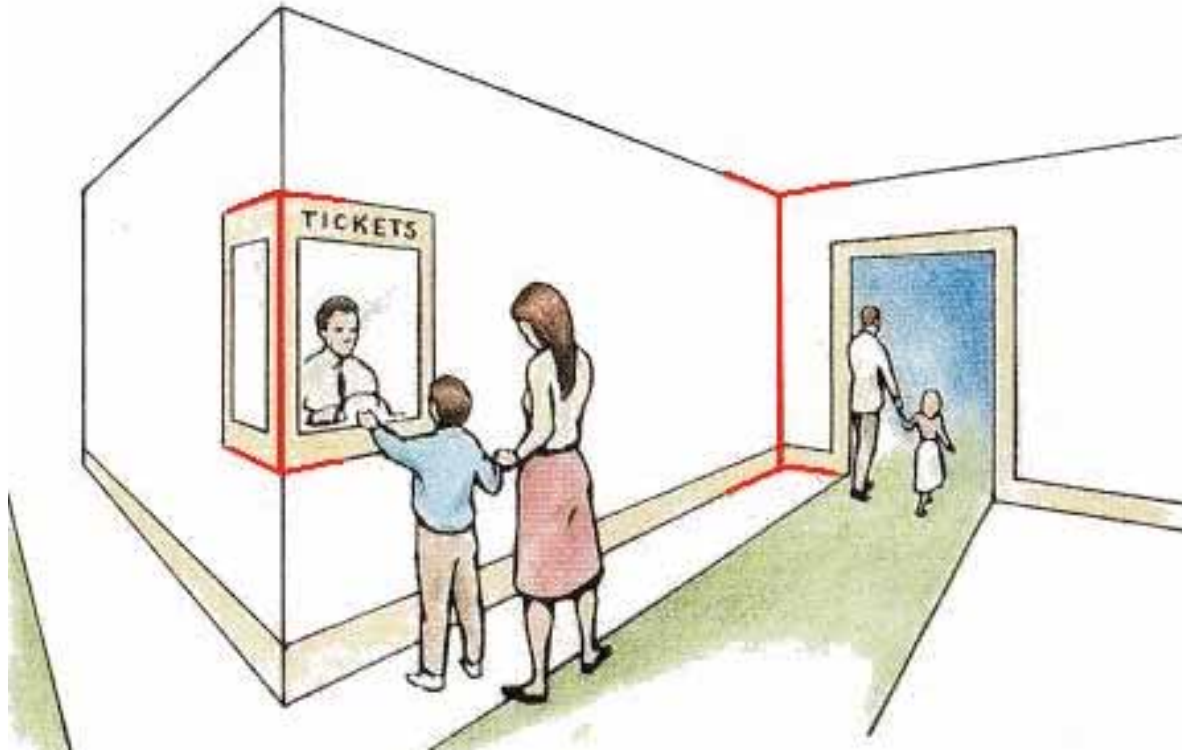
# The Müller-Lyer Illusion

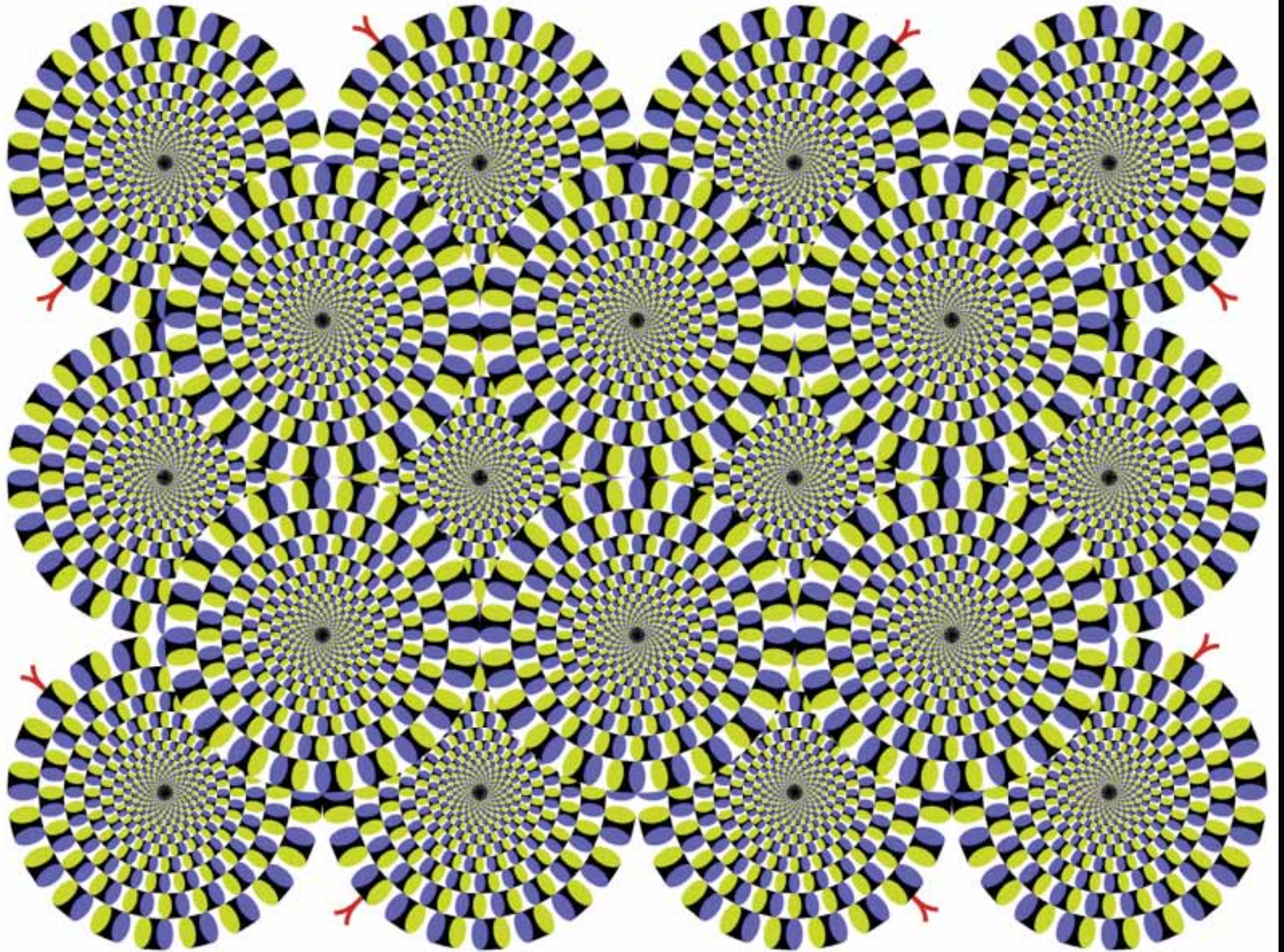


# The Müller-Lyer Illusion



# The Müller-Lyer Illusion





What did he say?



What did he say?

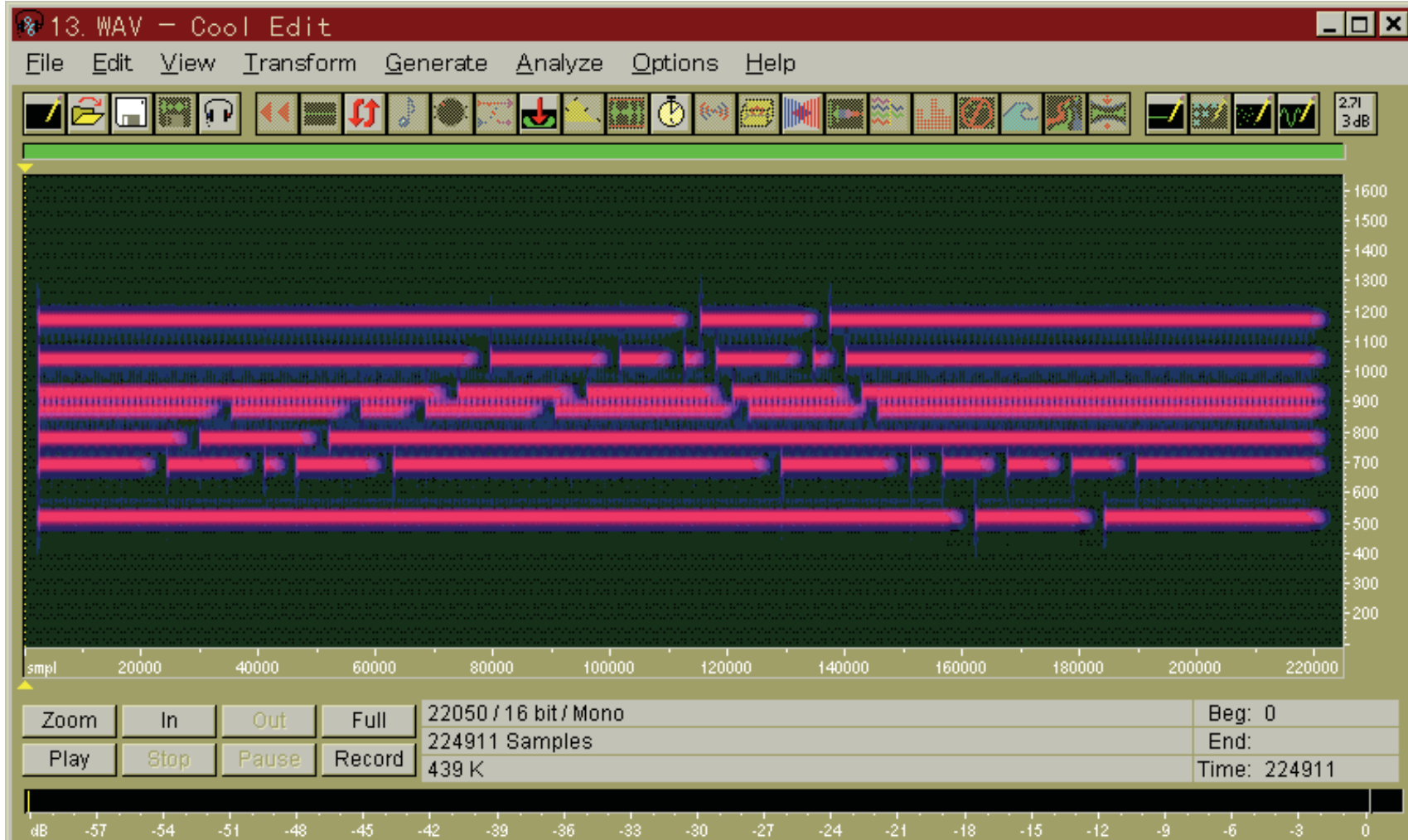


Now close your eyes!



# Hearing gaps

# But they occur in the auditory system too!



## **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:

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



The **BIG THREE** topics for today:

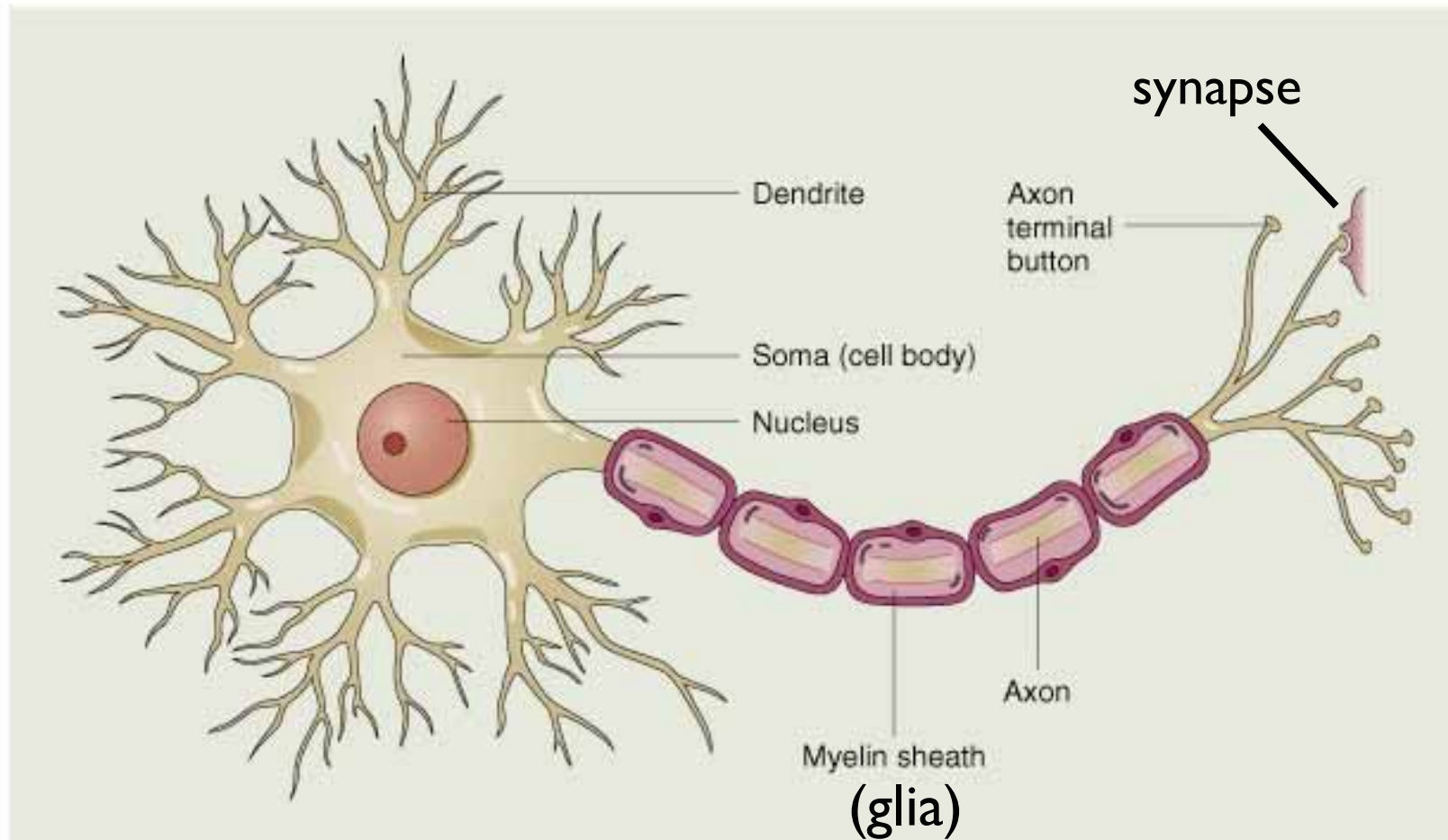
I. What is the basis of electrical signaling in neurons?

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

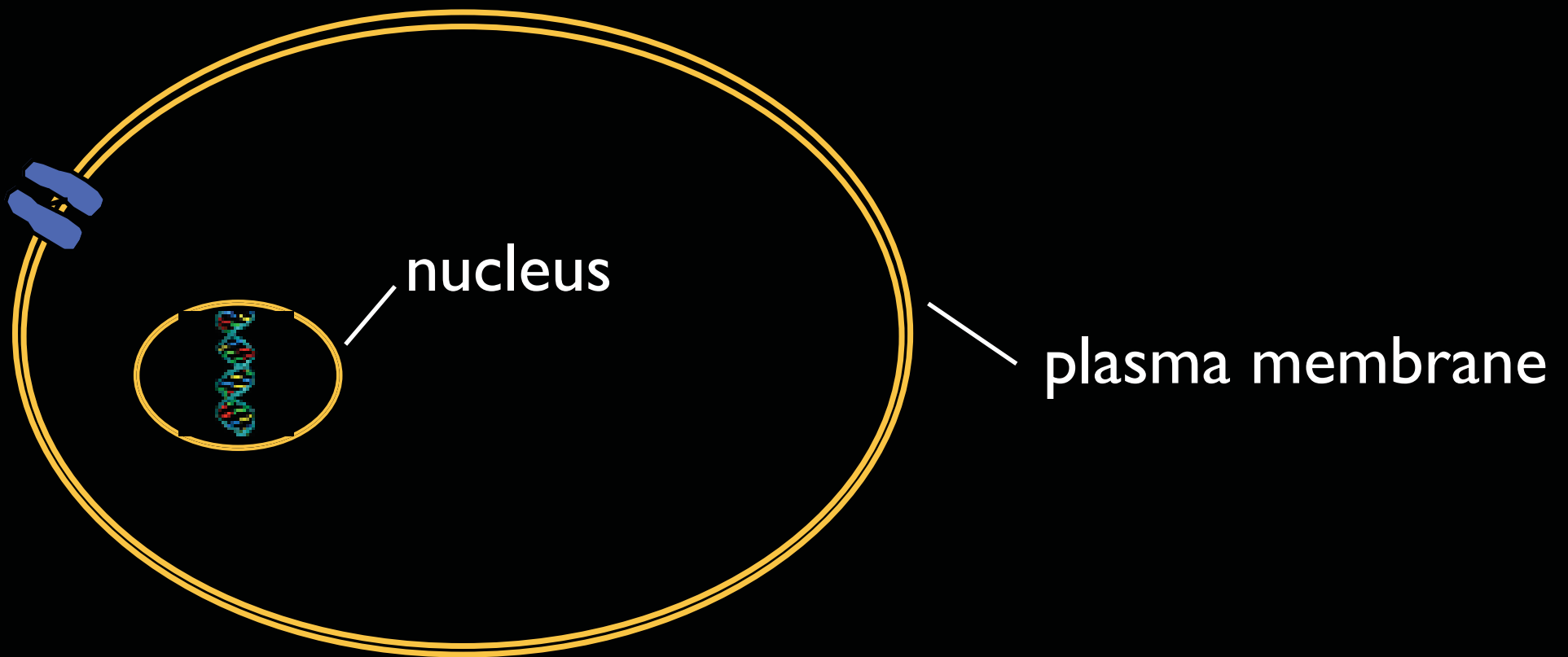
## The **BIG THREE** topics for today:

- I. What is the basis of electrical signaling in neurons?
- II. How do neurons “talk” to each other?
- III. How do neurons encode information?

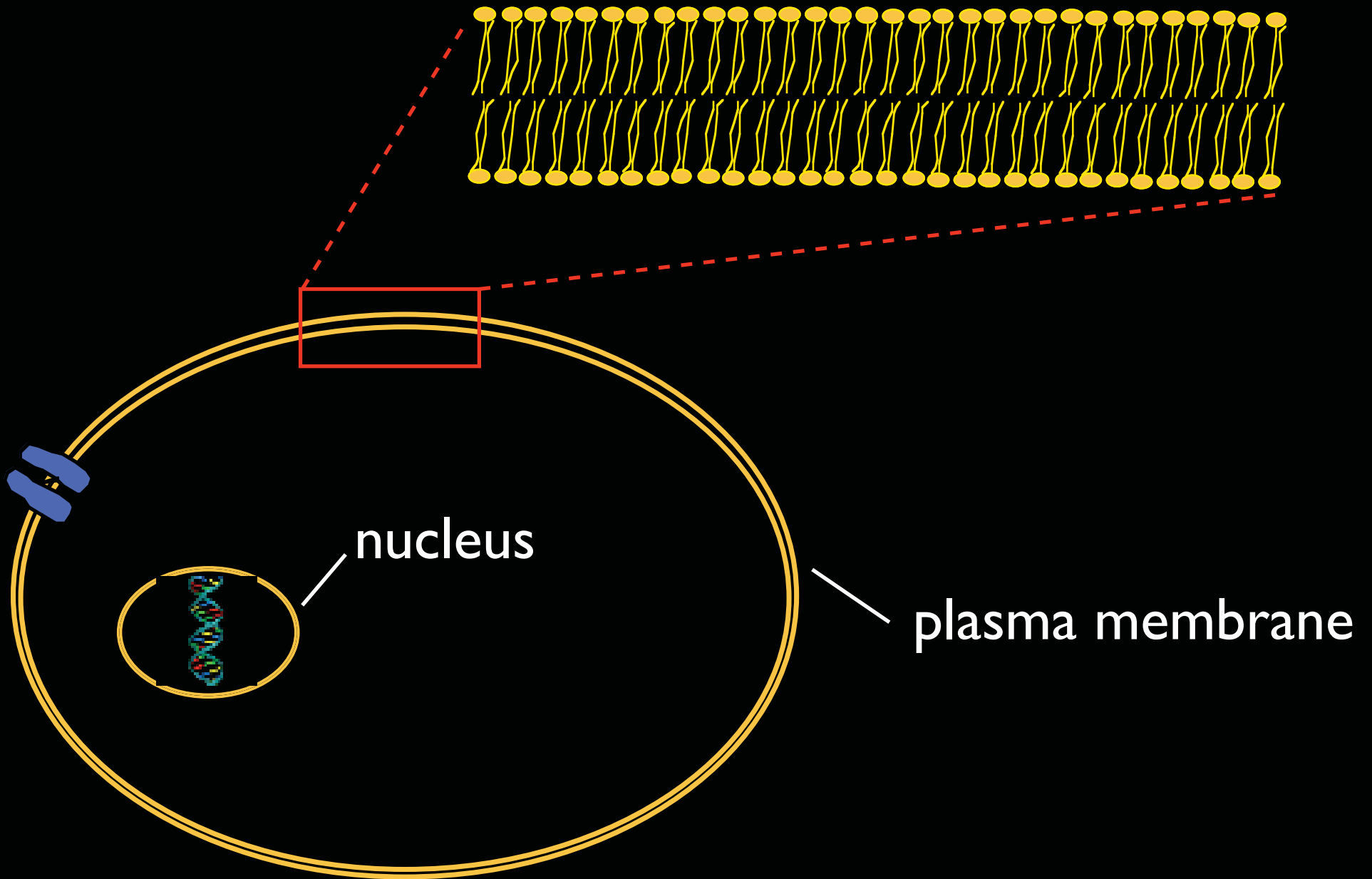
# The neuron is the “unit of processing” for the nervous system



# The cell membrane is a phospholipid bilayer



# The cell membrane is a phospholipid bilayer



# Cell membranes store Voltage

Positive

Outside: Extracellular

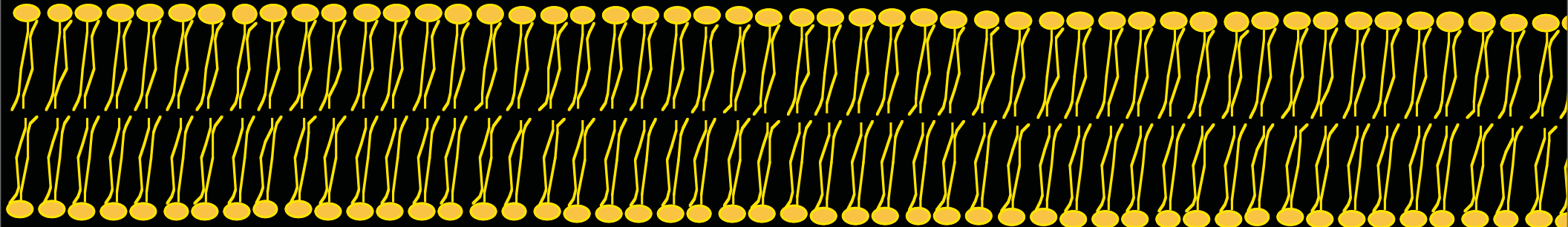
+

+

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Inside: Cytoplasmic

-

-

-

-

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-

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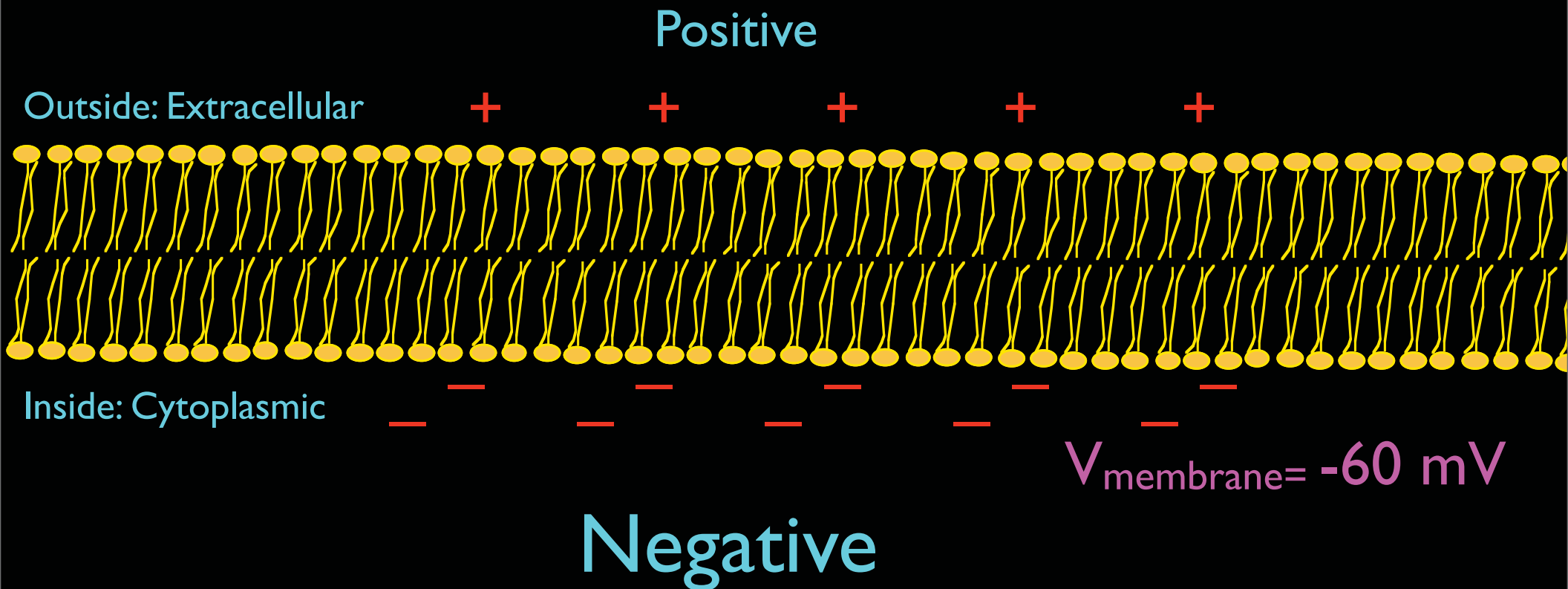
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$V_{\text{membrane}} = -60 \text{ mV}$

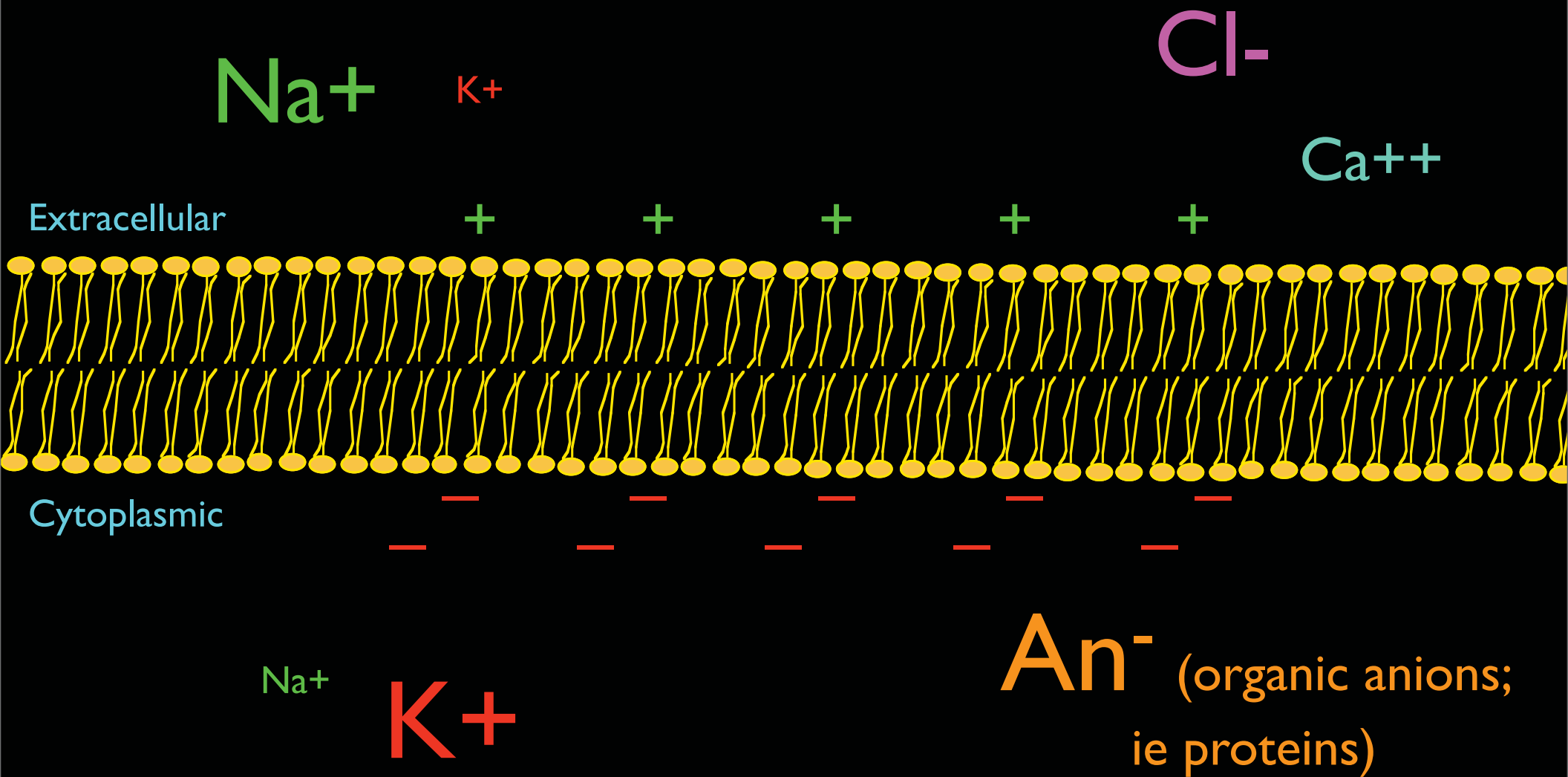
Negative

# Cell membranes store Voltage



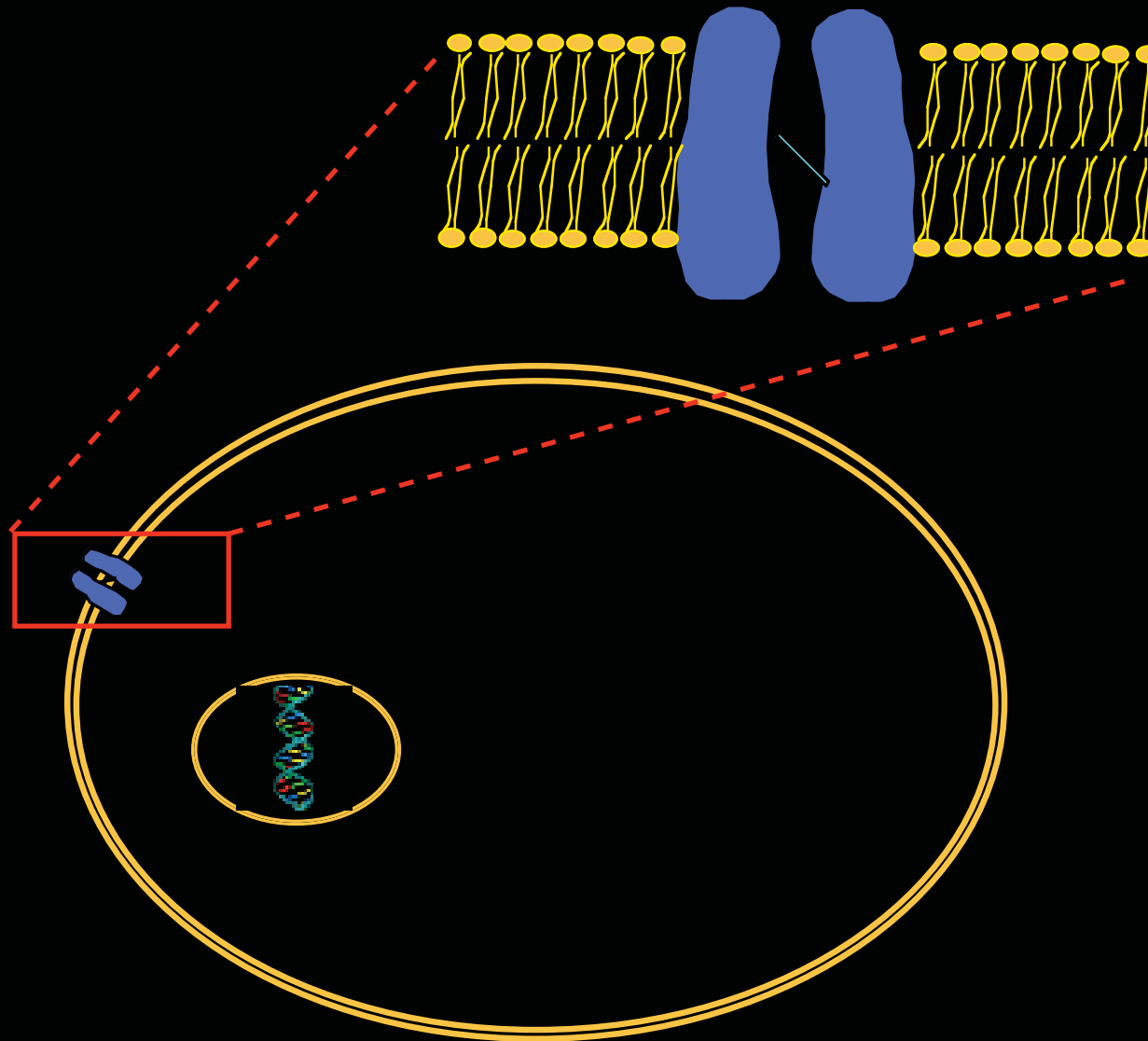
**\*\*The inside of the cell is usually more negative than the outside by about -60 mV**

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



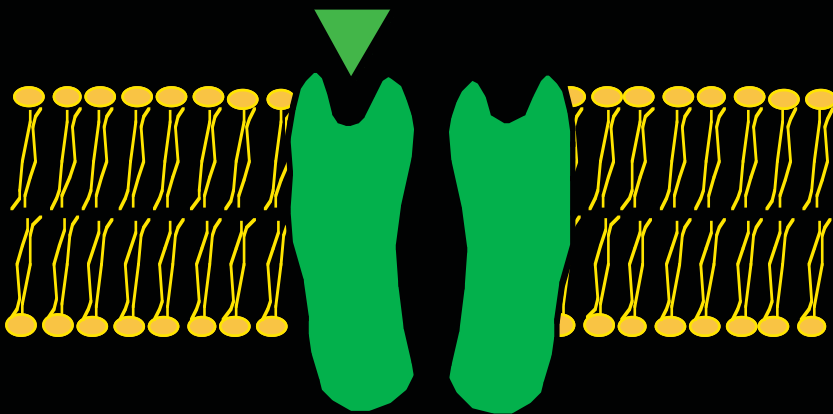


The cell membrane contains proteins, some of which are channels for charged particles

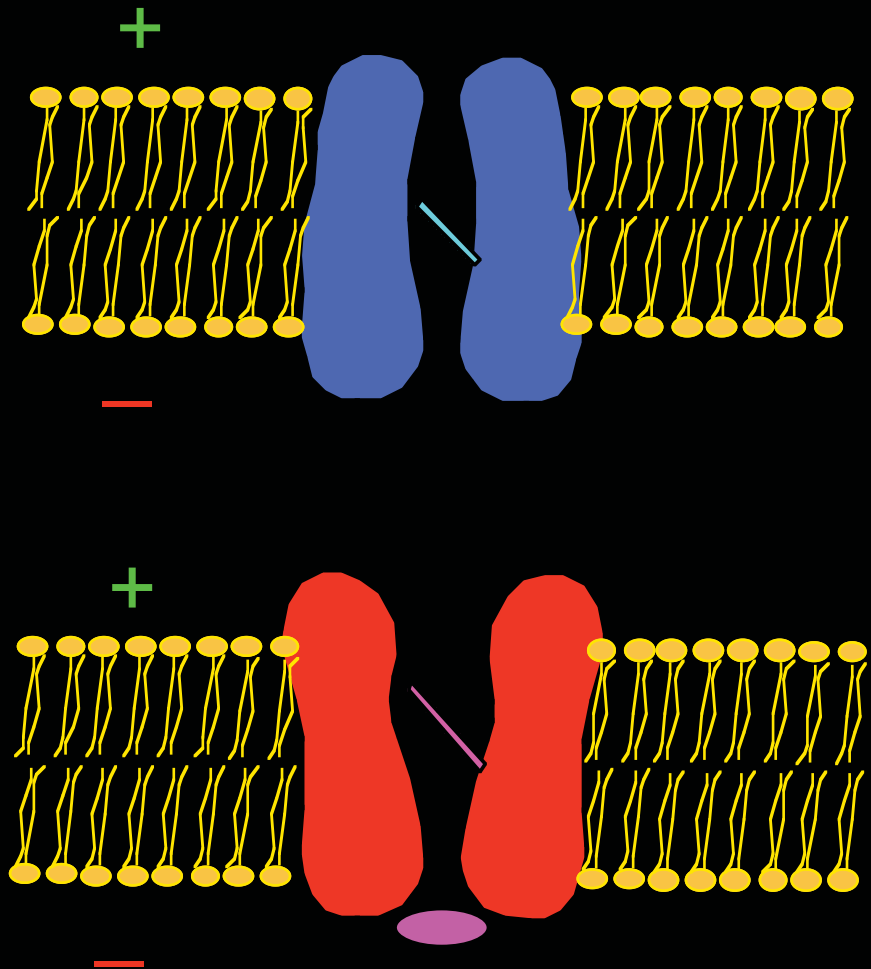


# Two (of many) membrane protein types:

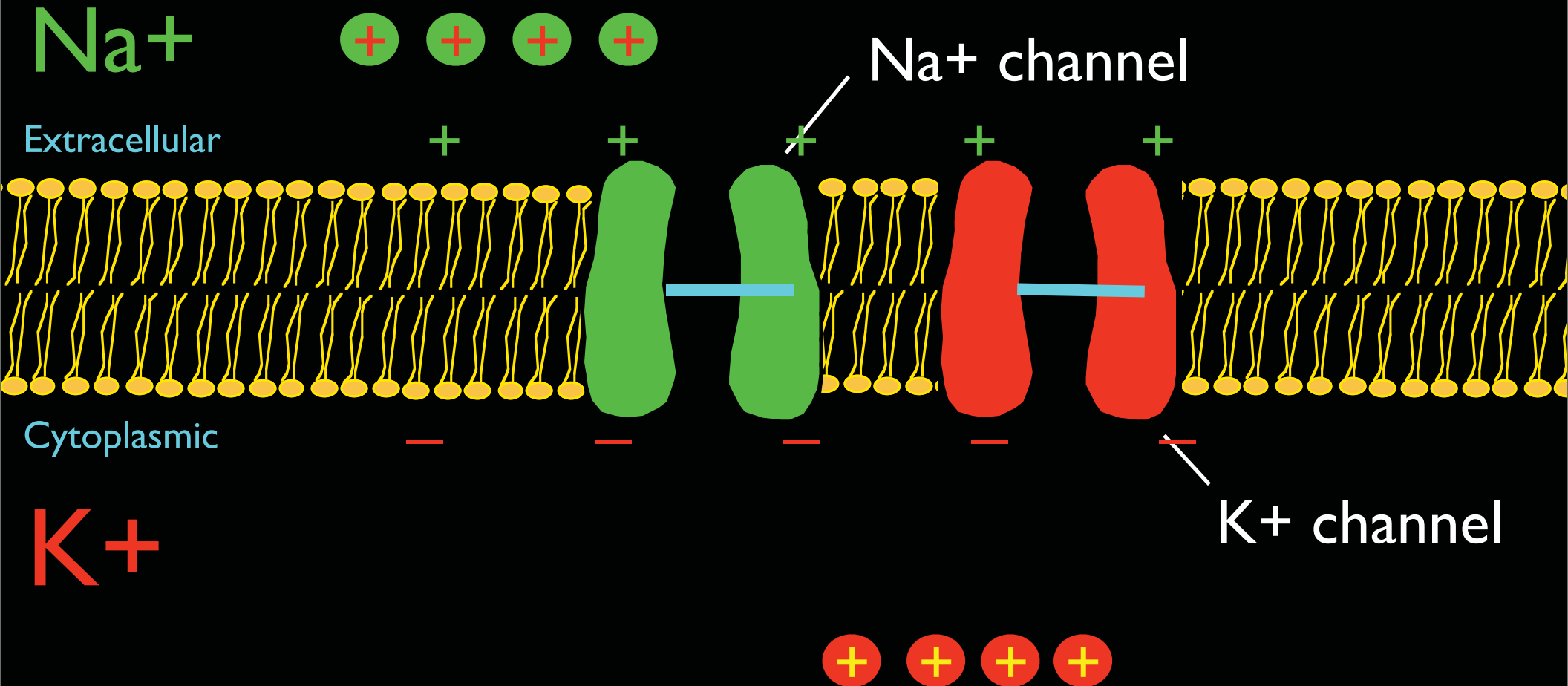
Ligand gated  
(chemically gated)



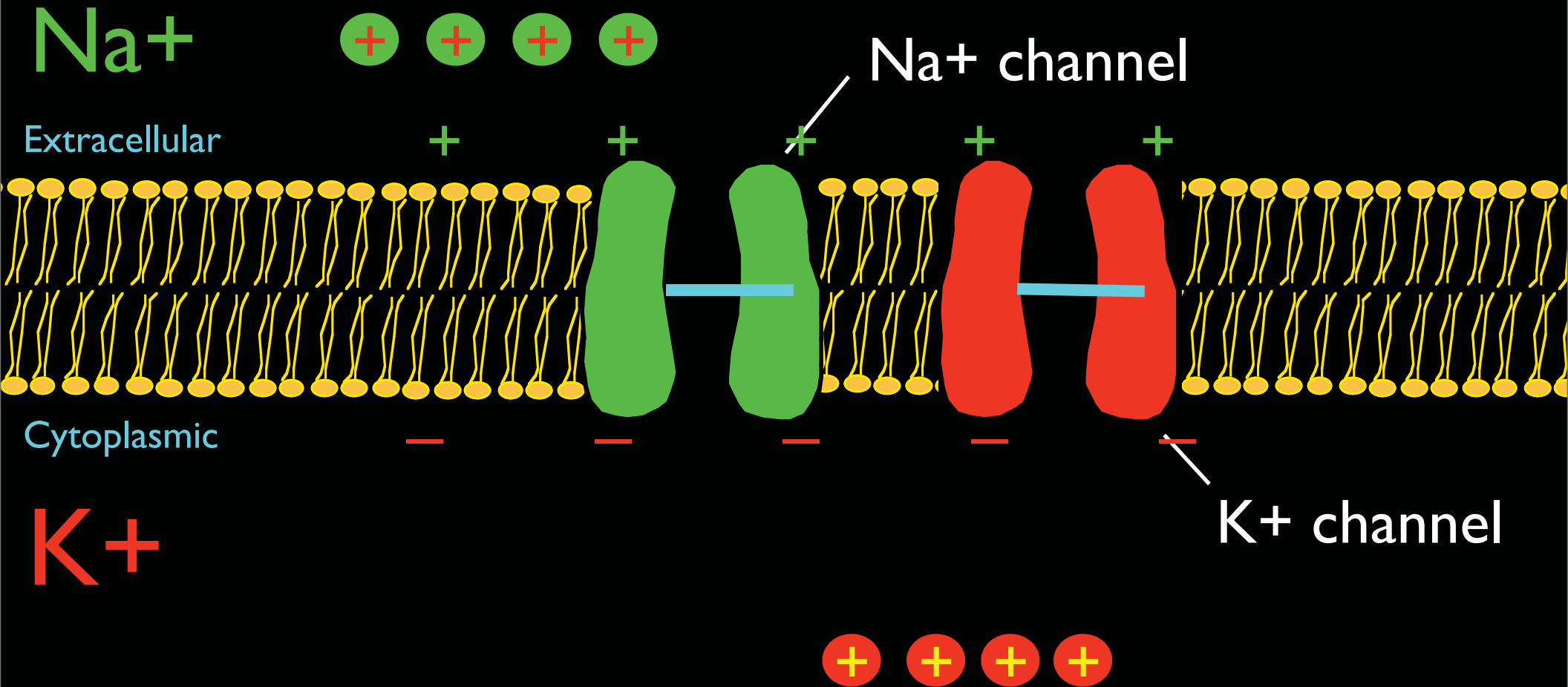
Voltage gated



# How does an electrical signal occur in a neuron?



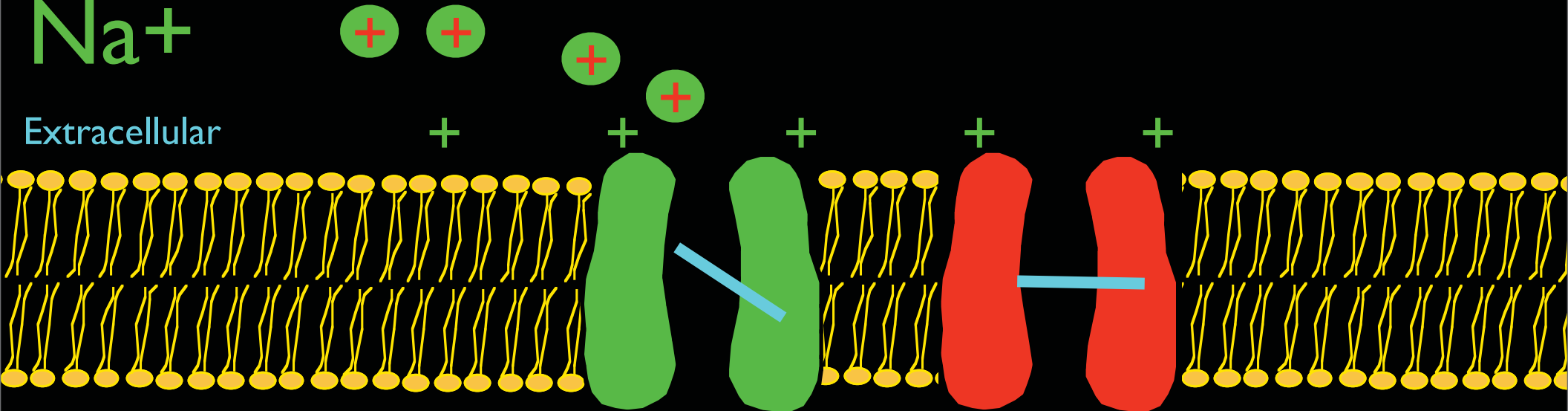
# How does an electrical signal occur in a neuron?



FIRST, WE GIVE THE  $\text{Na}^+$  CHANNEL A STIMULUS

Na<sup>+</sup>

Extracellular



Cytoplasmic

K<sup>+</sup>

Na<sup>+</sup>



Extracellular

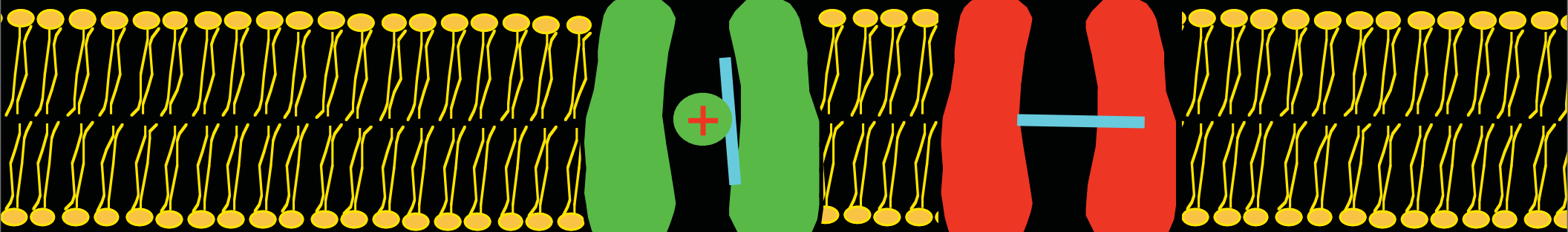
+

+

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Cytoplasmic

-

-

-

-

-

K<sup>+</sup>



Na<sup>+</sup>



Extracellular

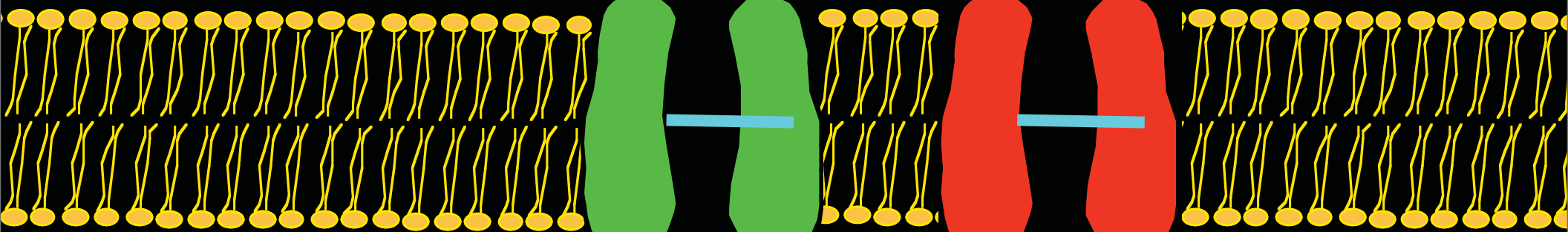
+

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Cytoplasmic

-

-



-

-

-

K<sup>+</sup>



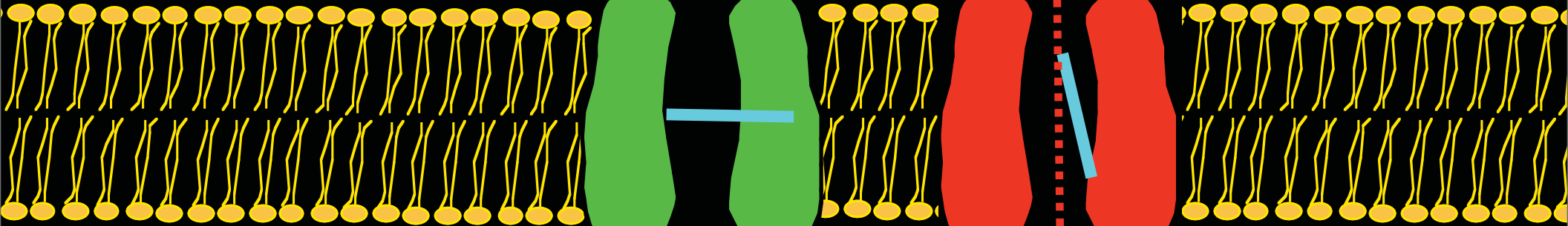
Voltage ↑



Na<sup>+</sup>



Extracellular

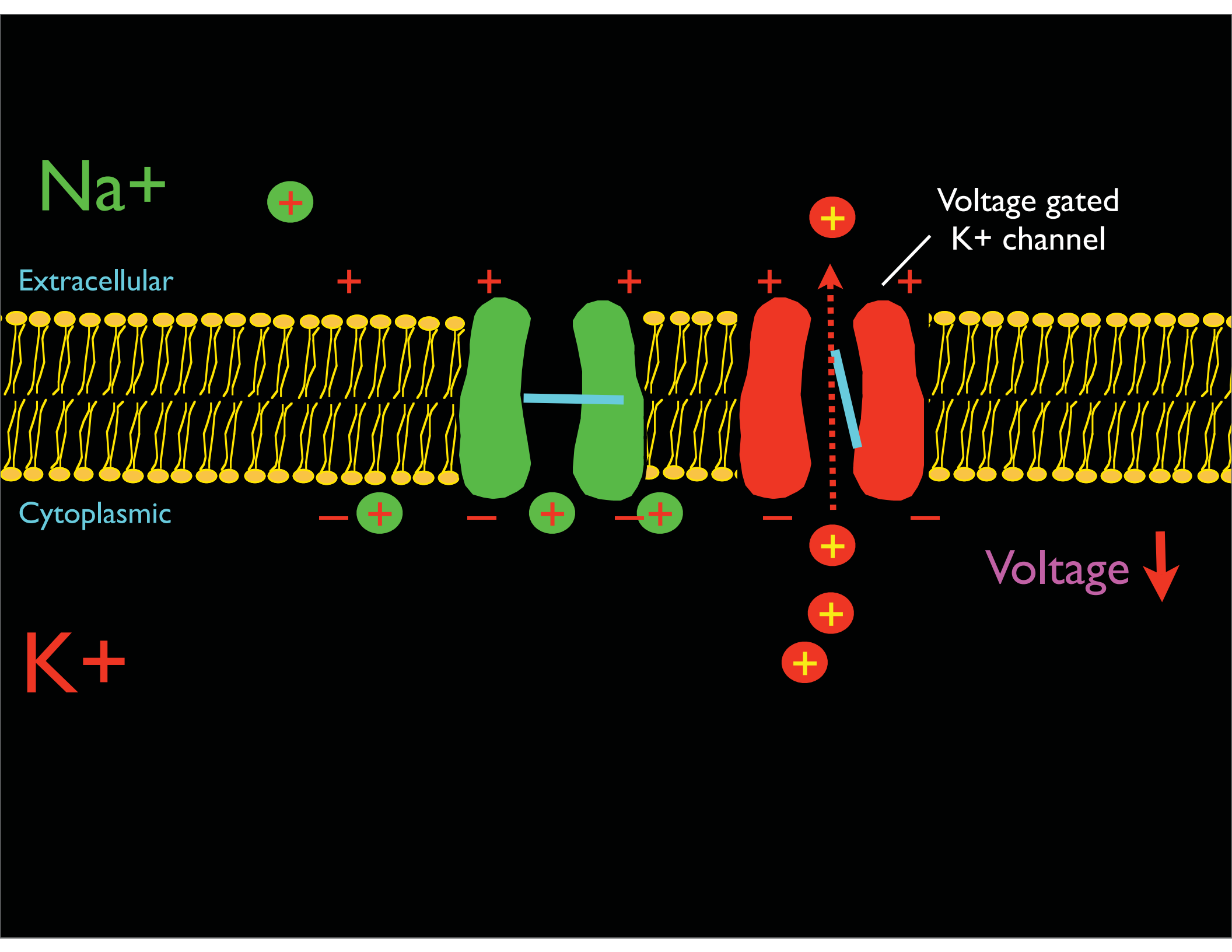


Cytoplasmic

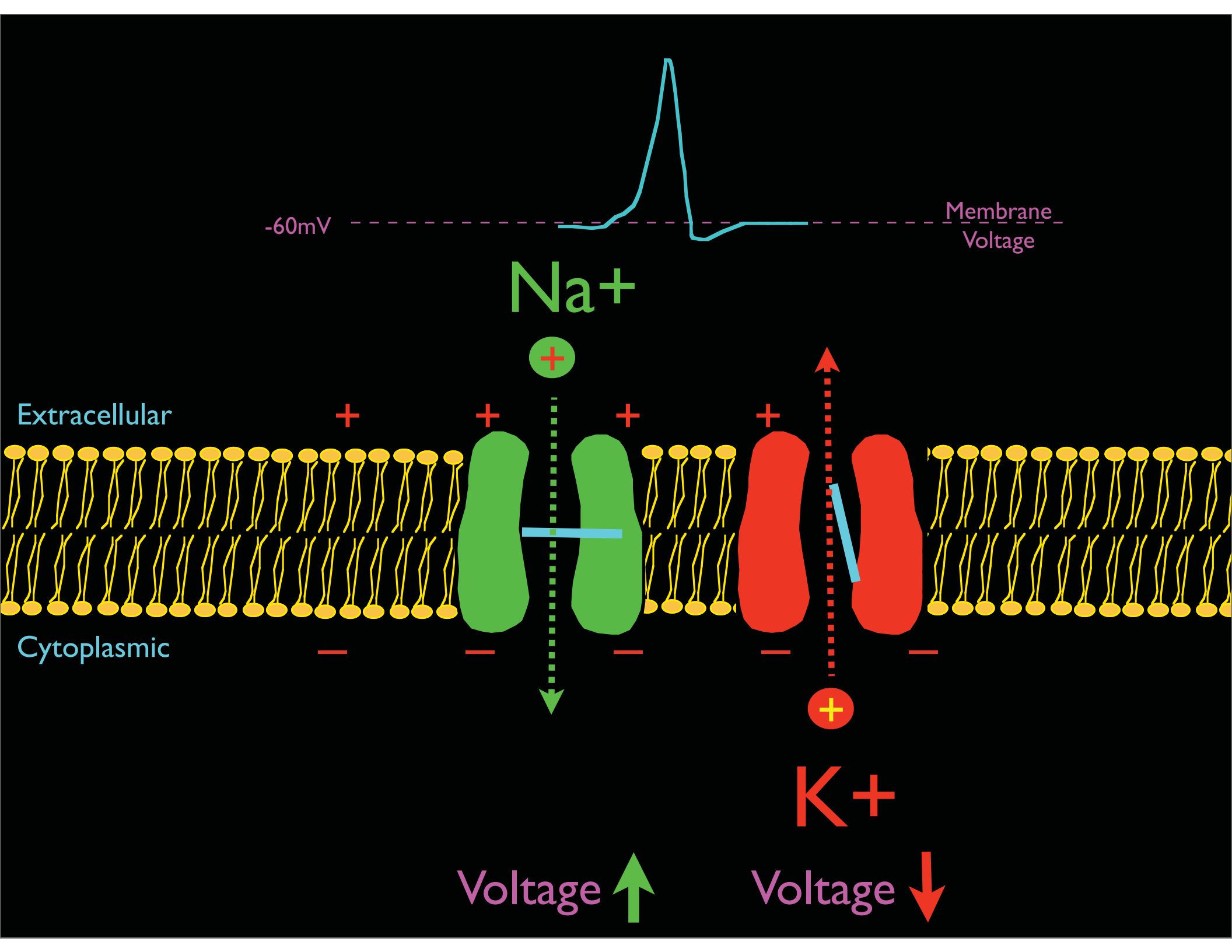
Voltage gated  
K<sup>+</sup> channel

K<sup>+</sup>

Voltage ↓





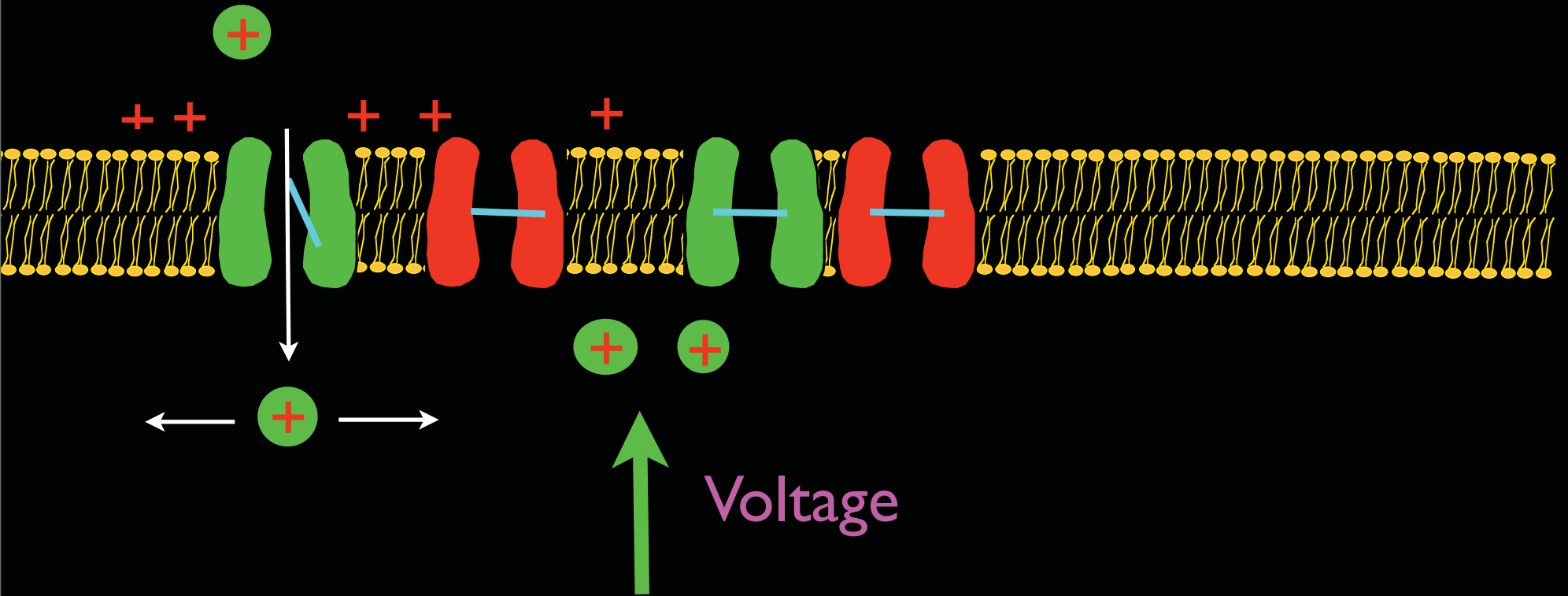


One more detail...

The voltage change travels...

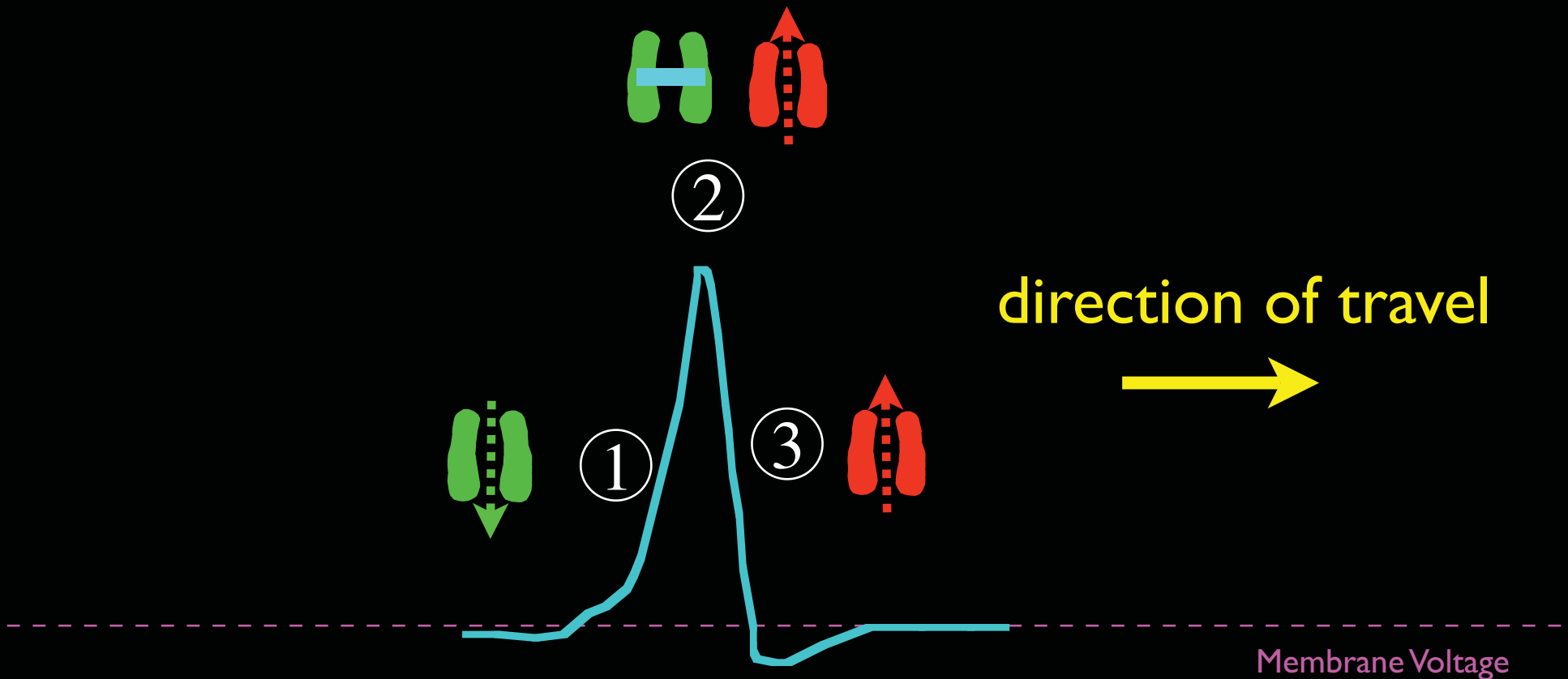
Na<sup>+</sup>

The basis of propagation...



K<sup>+</sup>

# Action Potential Summary:



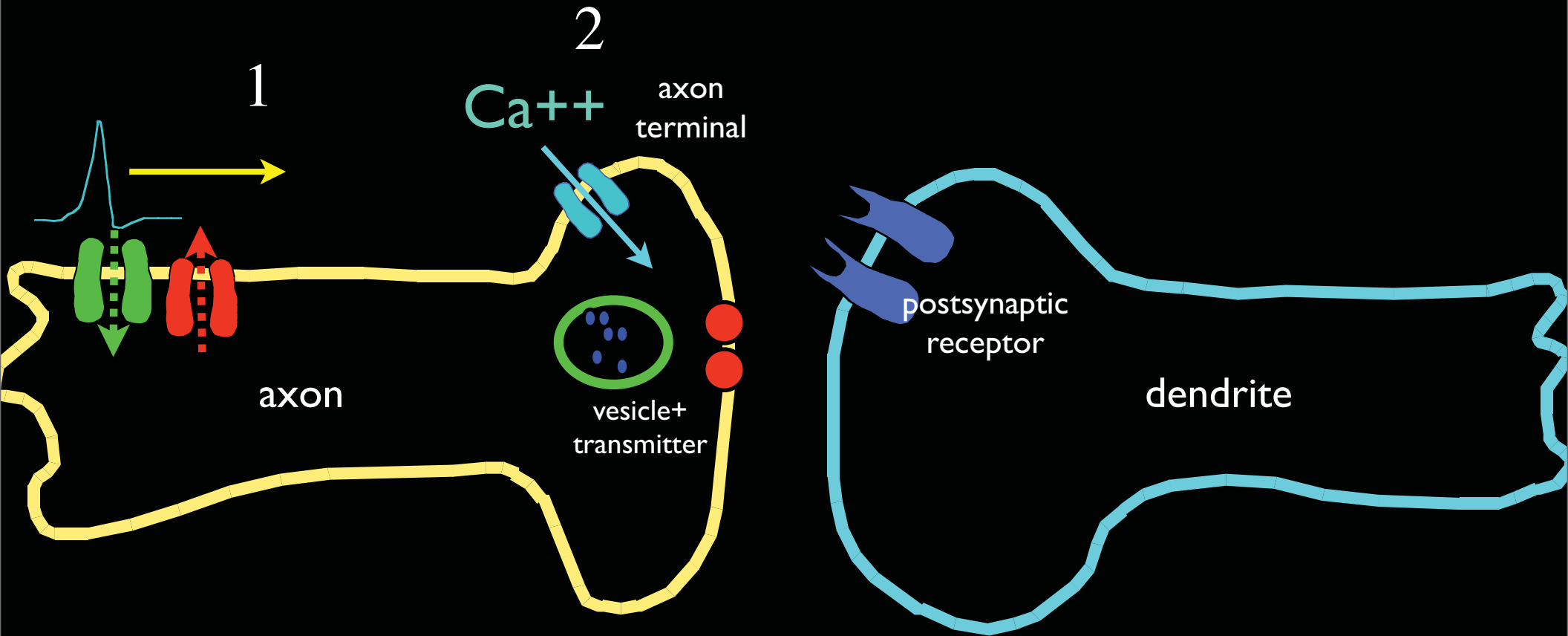
1. Na<sup>+</sup> channels open/Na flows into the cell
2. Na<sup>+</sup> channels close while K<sup>+</sup> channels are opening
3. K<sup>+</sup> flow out of the cell dominates

NEXT:

NEXT:

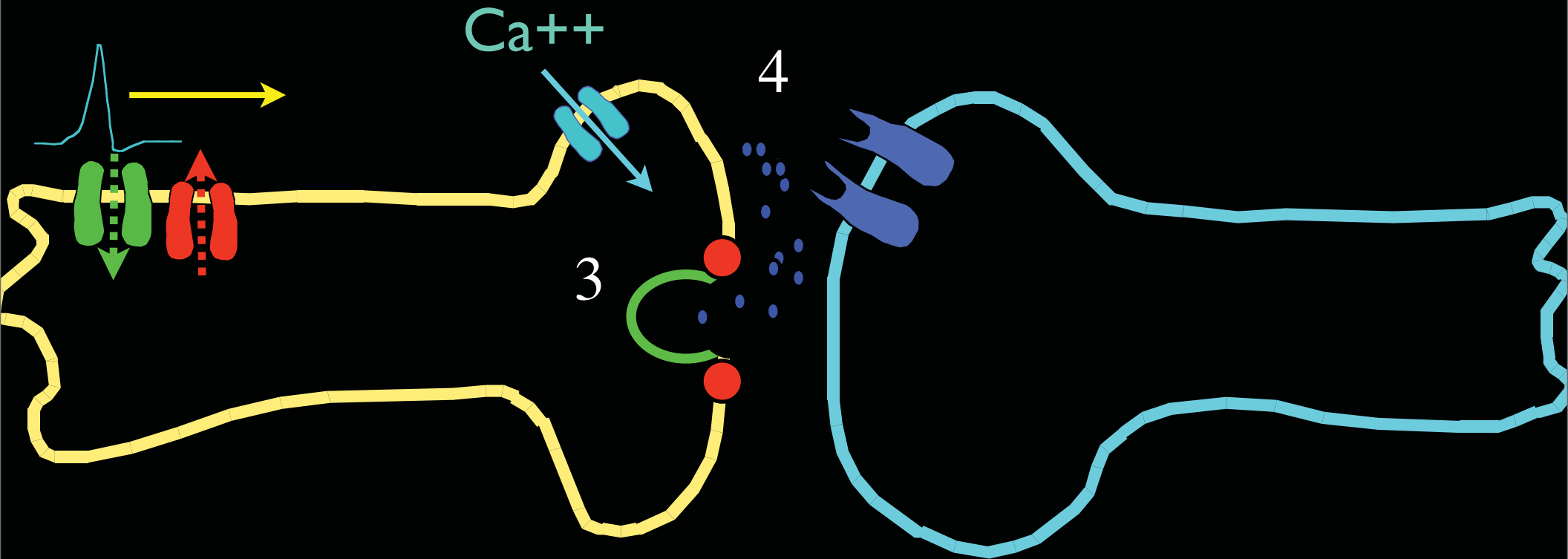
How do neurons “talk” to each other?

# Synaptic Transmission



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

# Synaptic Transmission

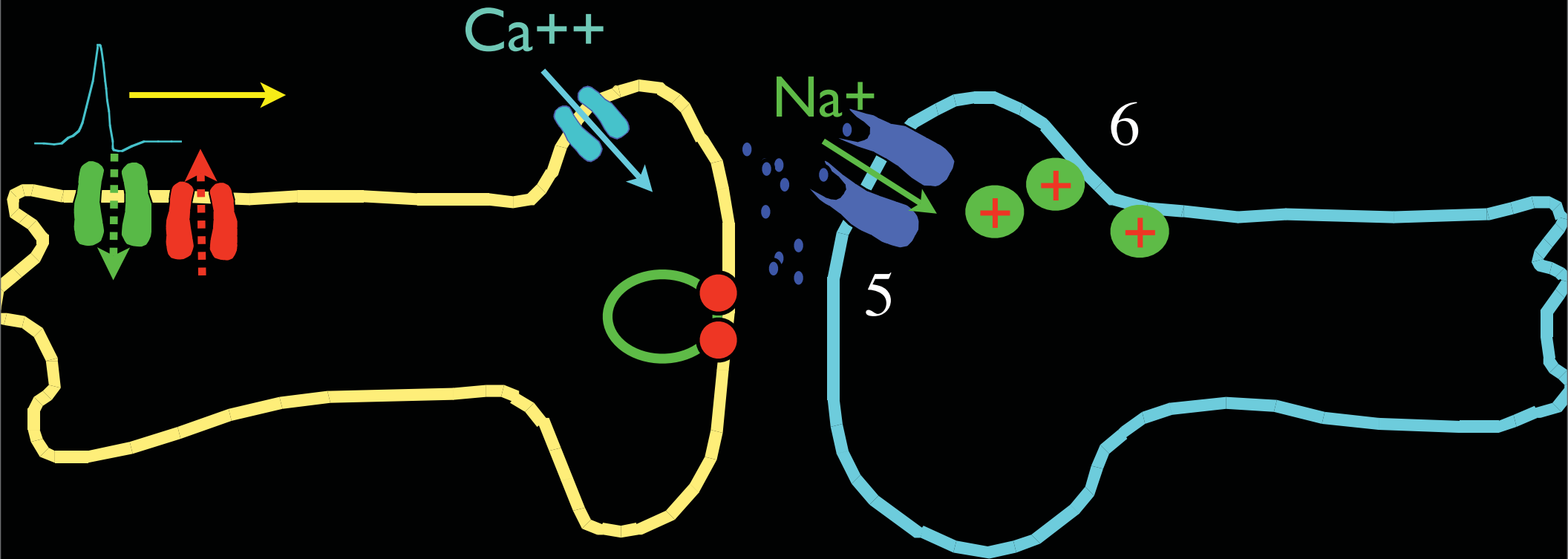


Step 3: Ca<sup>++</sup> dependent vesicle fusion

Step 4: transmitter release



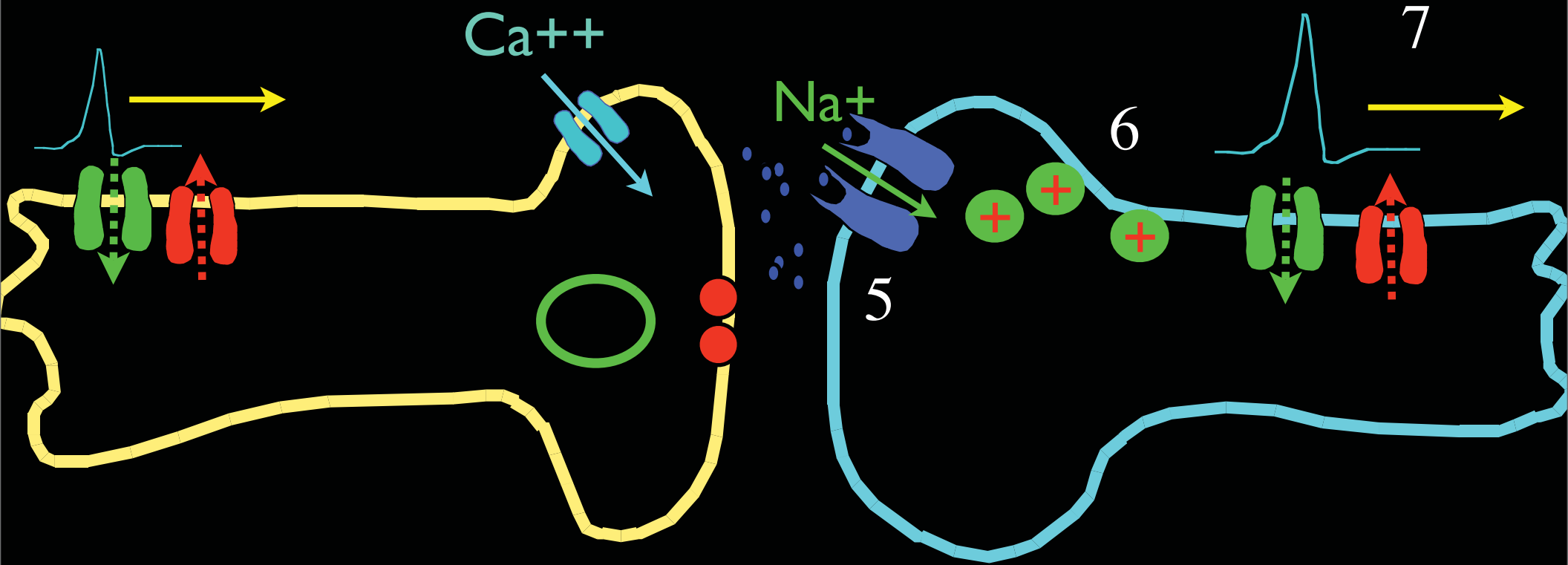
# Synaptic Transmission



Step 5: Activation of ligand gated channel

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

# Synaptic Transmission

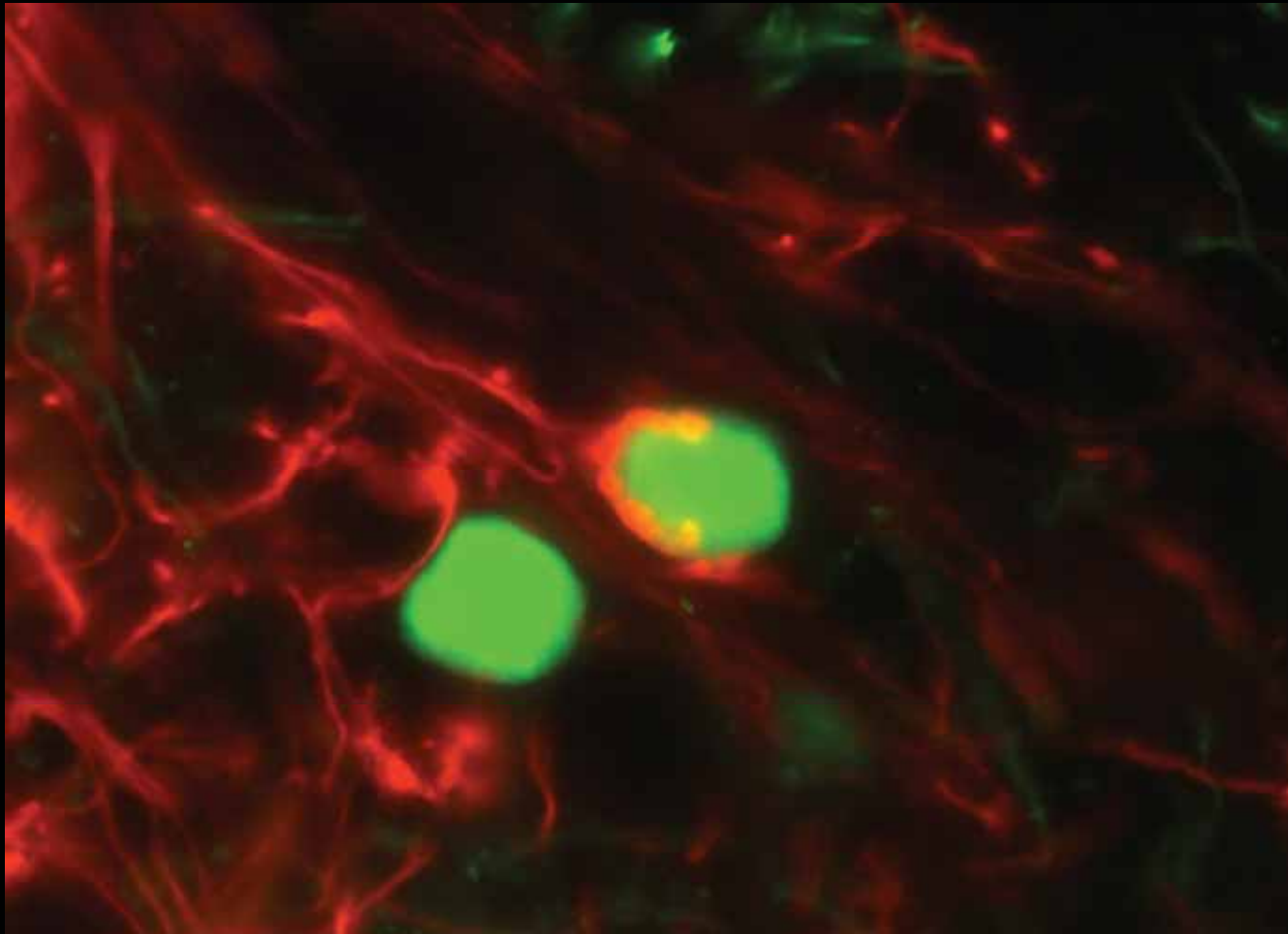


Step 5: Activation of ligand gated channel

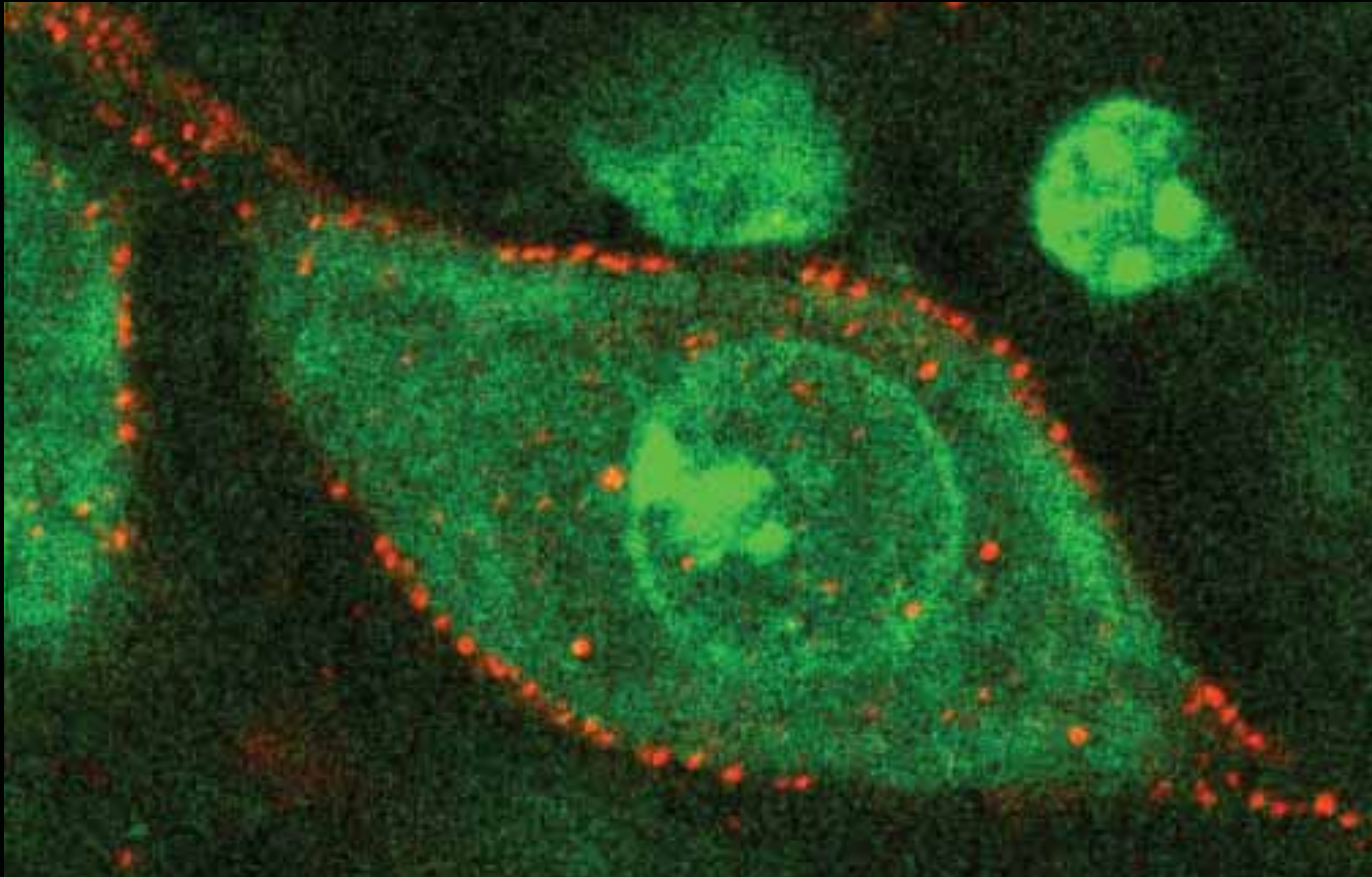
Step 6:  $\text{Na}^{+}$  flux/dendrite depolarization

Step 7: Action Potential is regenerated postsynaptically

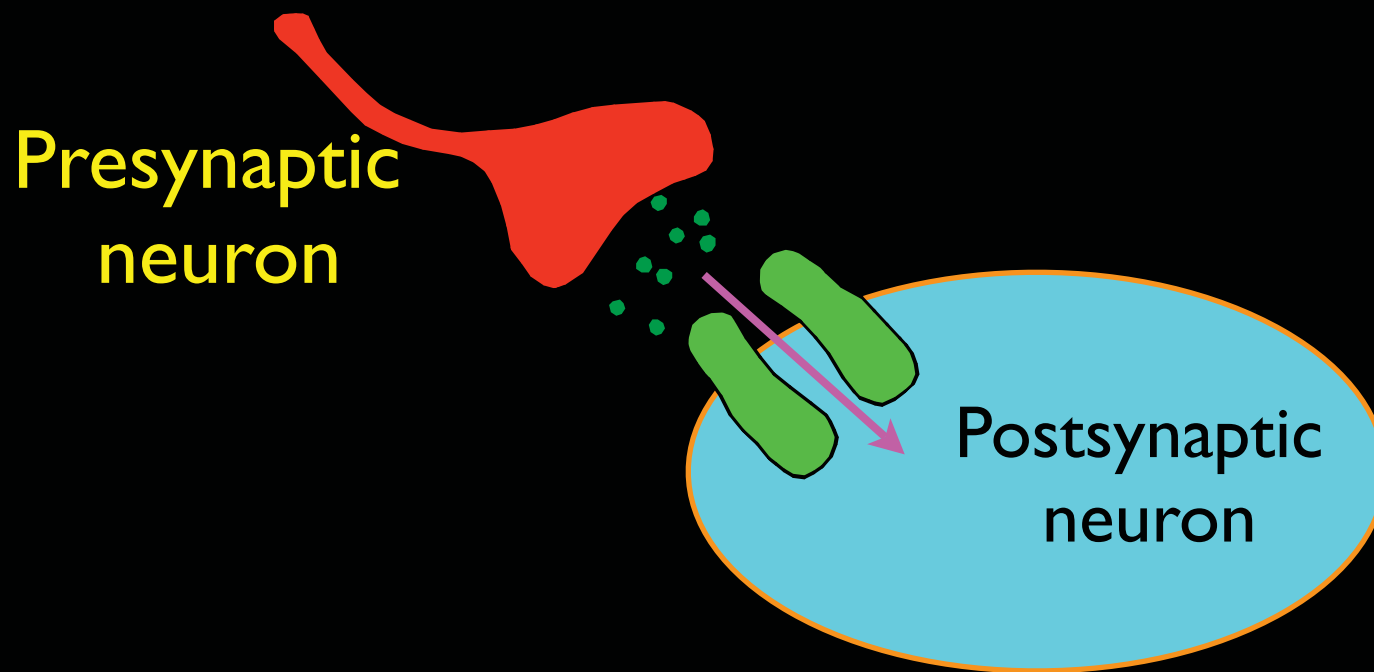
# Very large auditory synapse



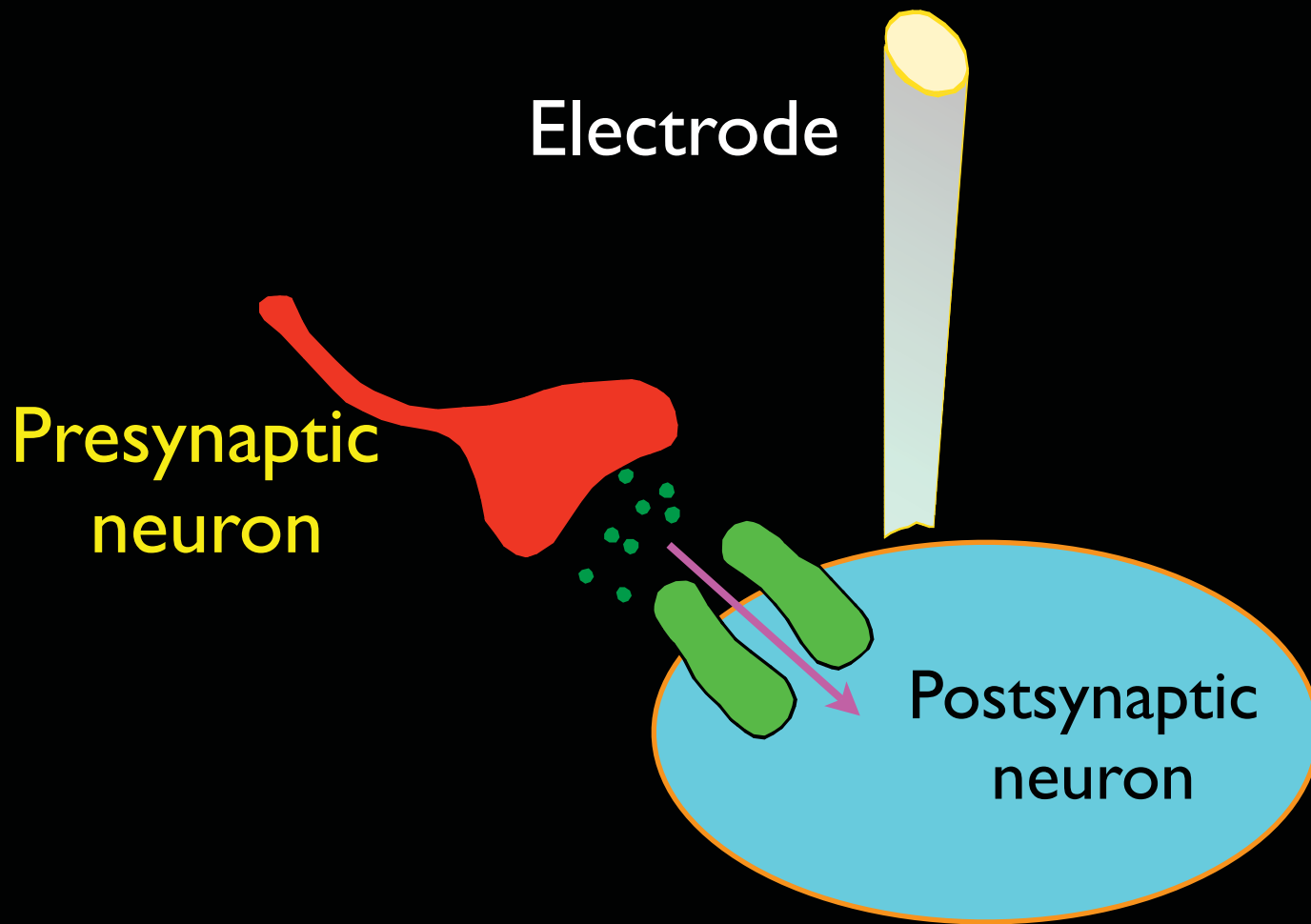
Stain in red marks postsynaptic receptors



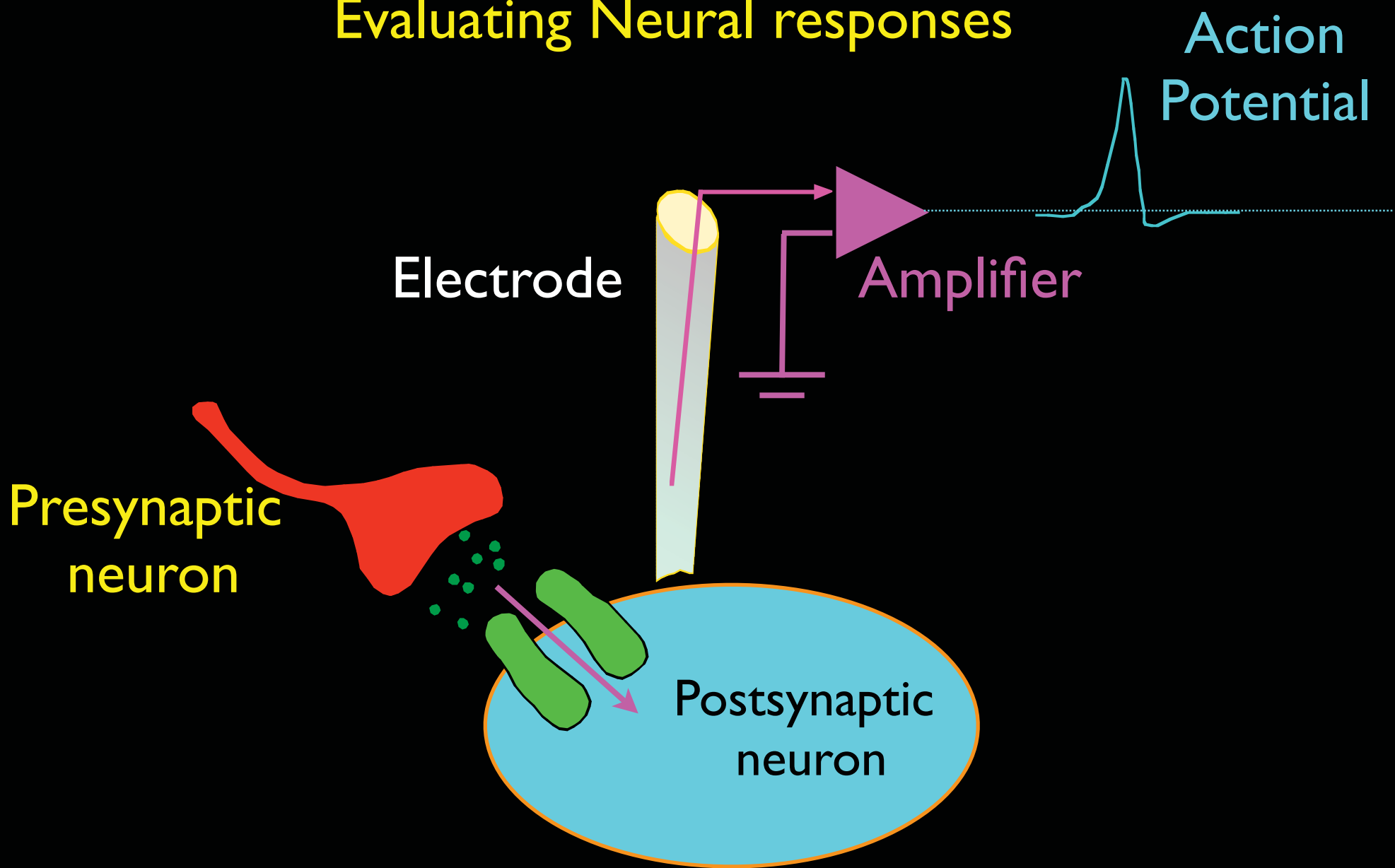
# Evaluating Neural responses



# Evaluating Neural responses



# Evaluating Neural responses



AND Finally,....

How do neurons encode information?

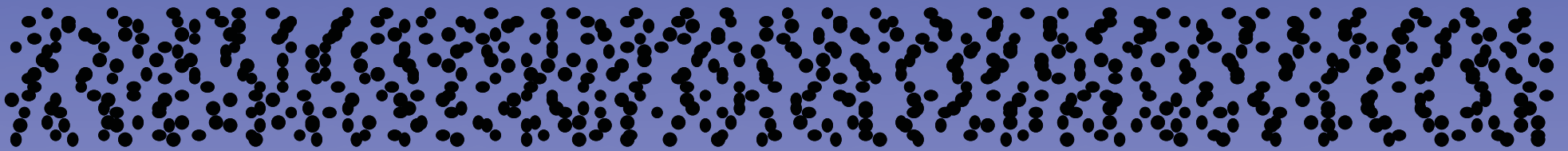
*there are two simple ways.....*



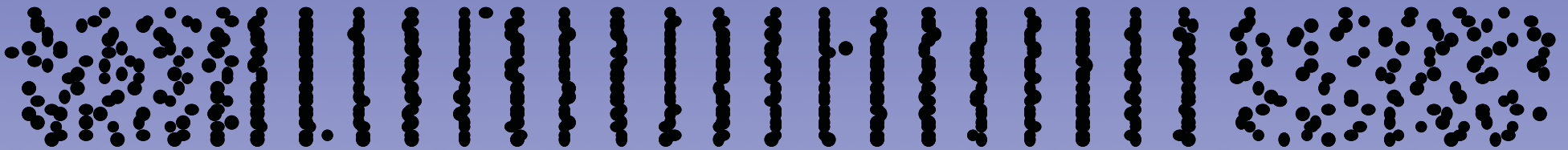
with action potential **TIMING**....

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no sound

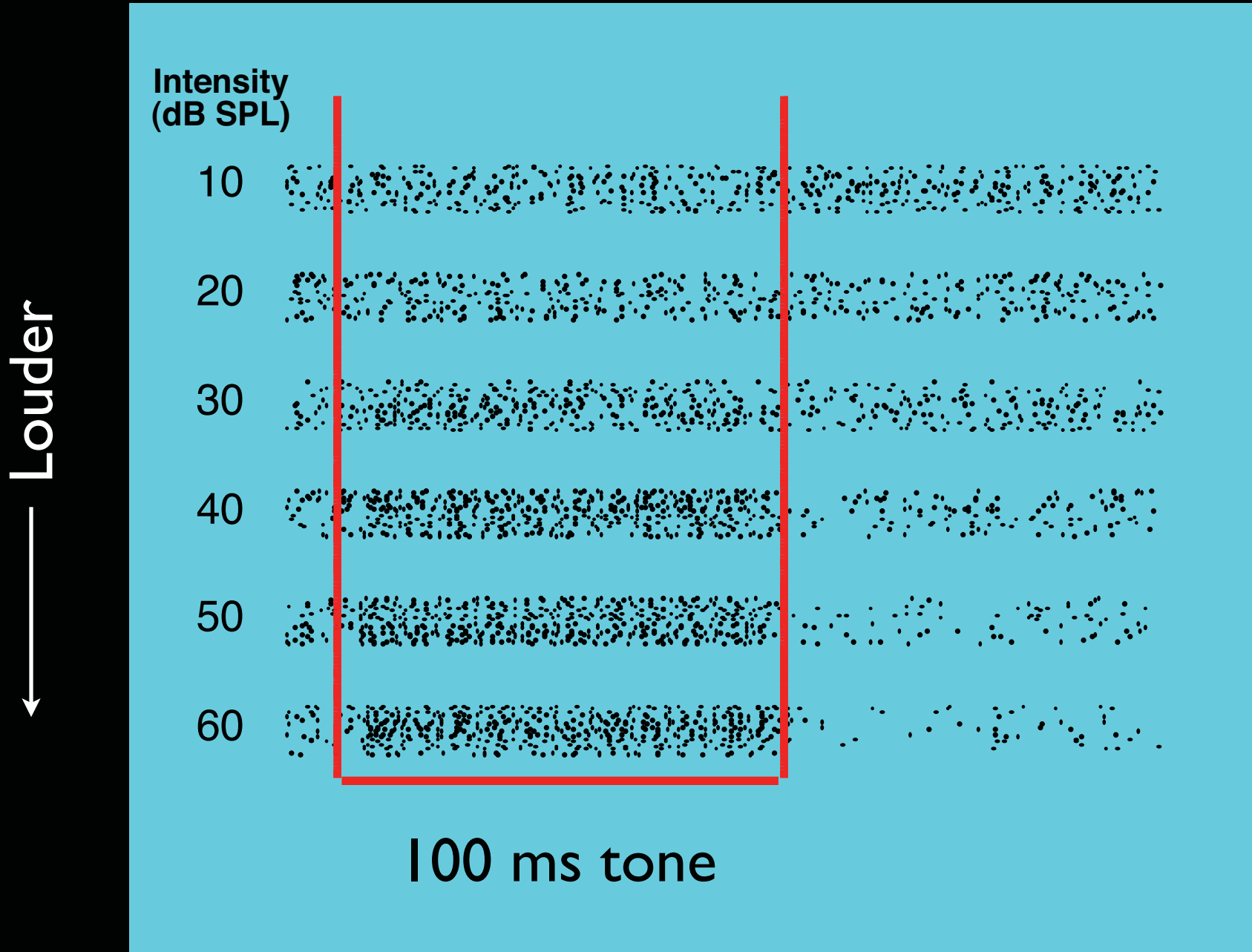


evoked

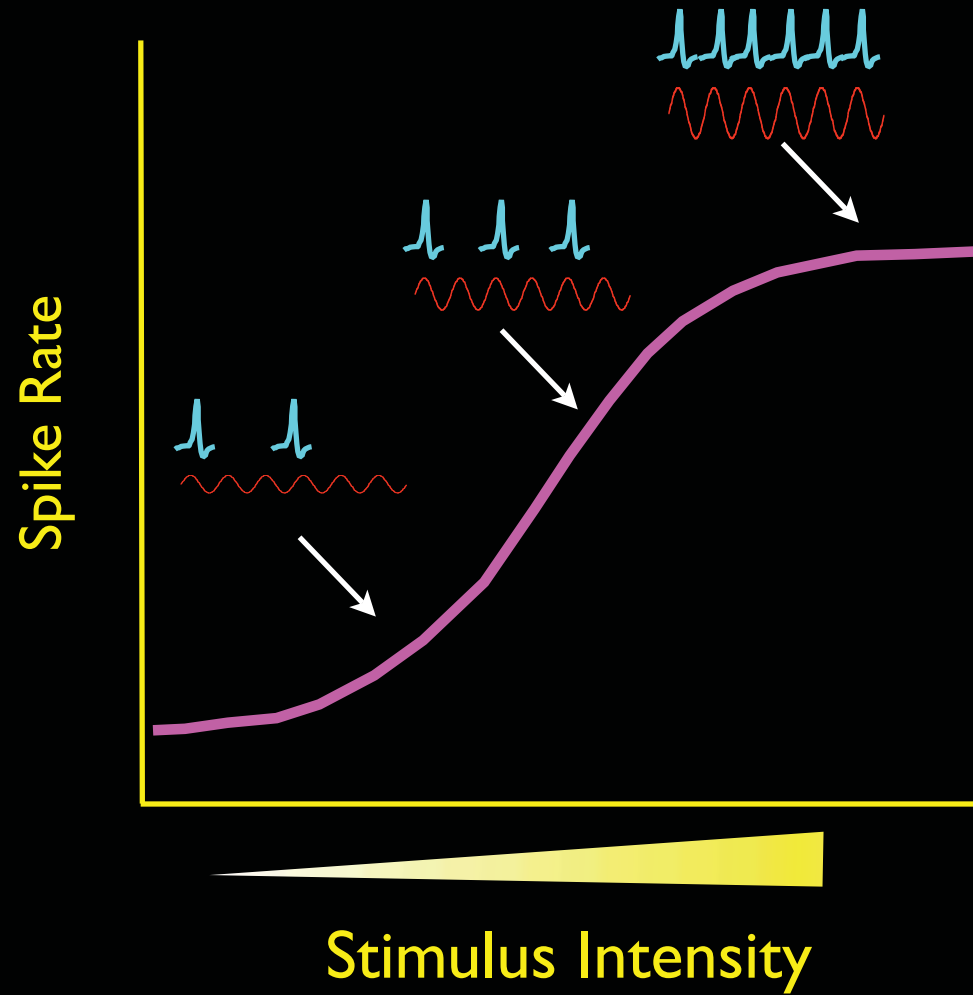


100 ms tone

...and Neurons signal by changing their firing rate



# Spike Rate increases with Intensity

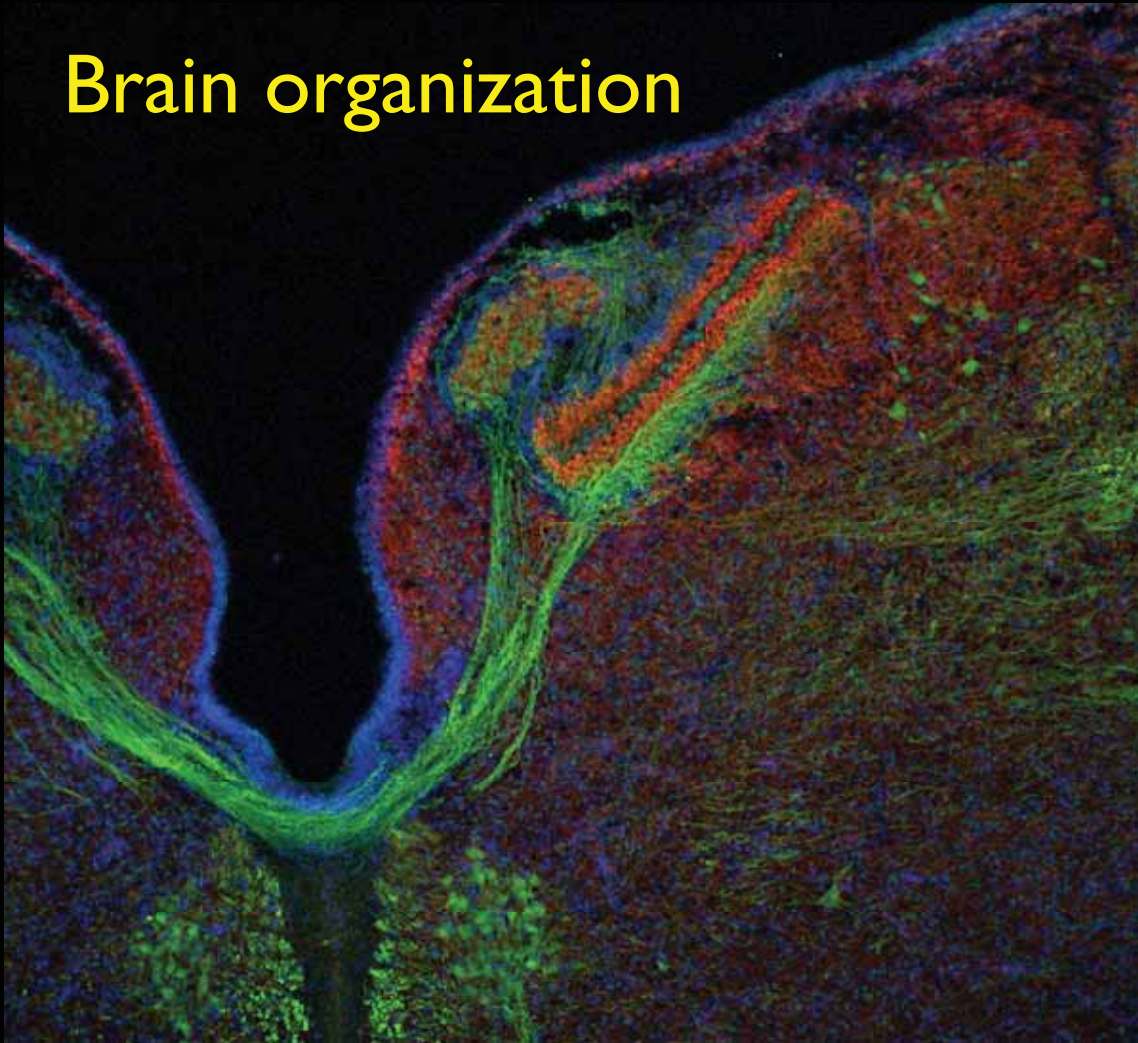


## What we learned today:

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

Next time....

## Brain organization



New technology  
for therapy

