Neurons and nerve impulses

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Objectives

- Outline the electrical and chemical changes during an action potential.
- Explain the role of neurotransmitters in signal transmission across a synapse.

Action Potential

Definition:

A **rapid change** in the membrane potential of a neuron.

Process:

1. **Resting Potential:**

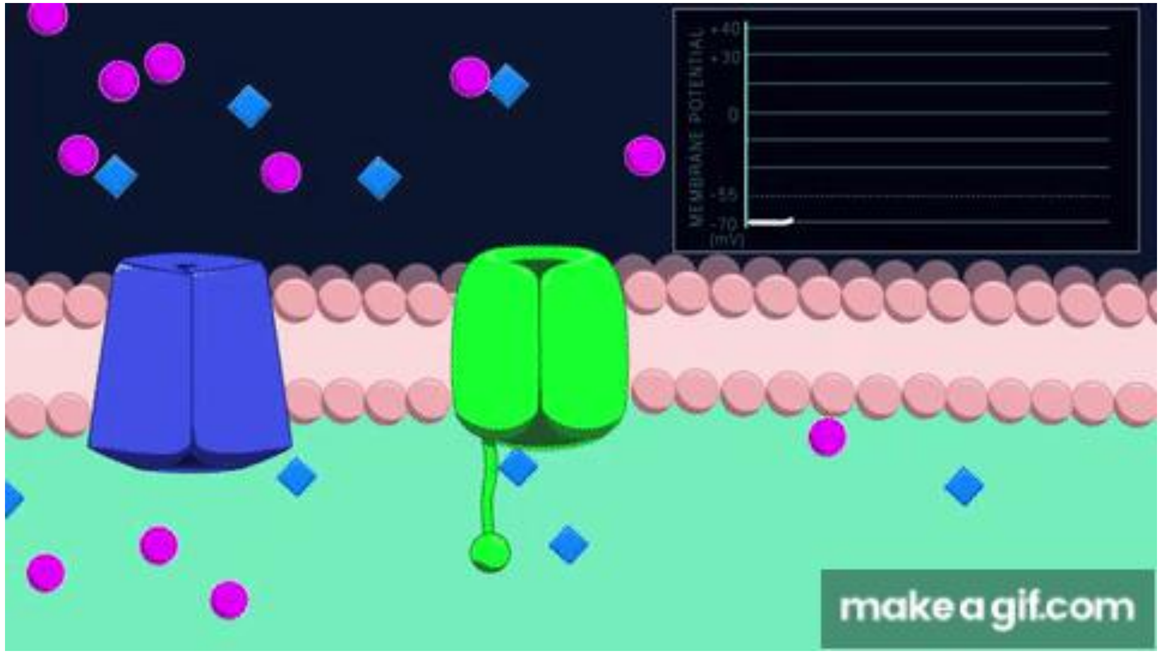
Neuron is polarized with a **negative charge inside** and **positive charge outside**.

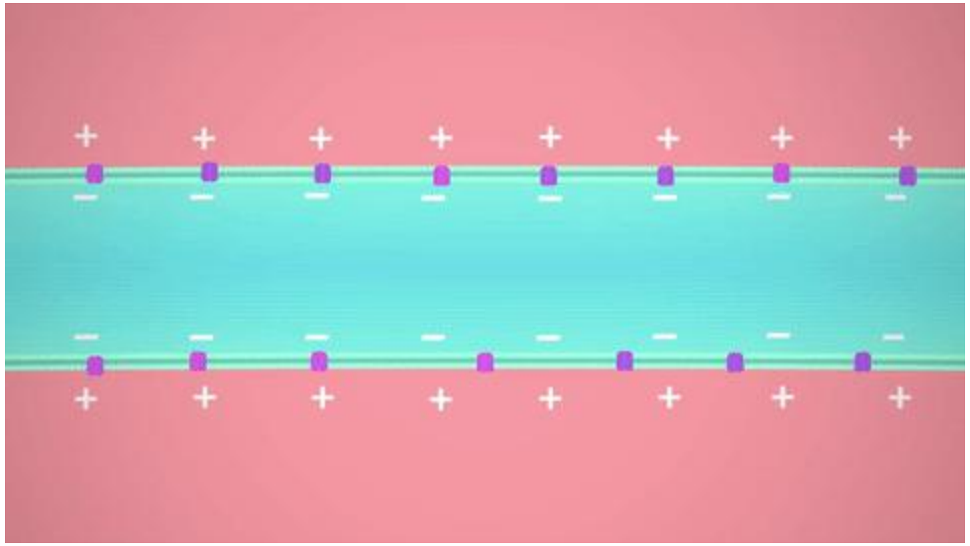
Voltage across the membrane: approximately **-70mV**.

2. **Depolarization:**

Stimulus triggers the **opening of voltage-gated sodium channels**.

Sodium ions rush into the cell, **making the interior more positive**.





Action Potential

3. Repolarization:

Voltage-gated **potassium channels open**.

Potassium ions exit the cell, **restoring the negative charge inside**.

4. Hyperpolarization:

Temporary overshoot of the resting potential.

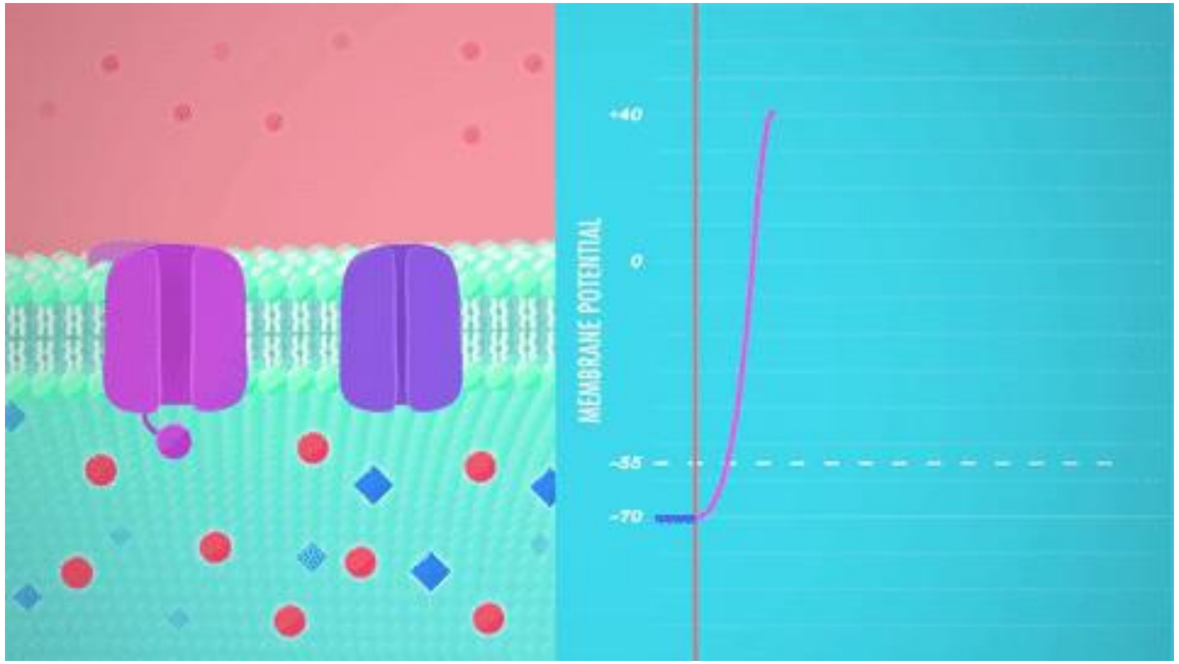
Excess potassium leaves the cell, making the **interior more negative than at rest**. Here Cl- also helps into the charging negatively of the interior of the cell.

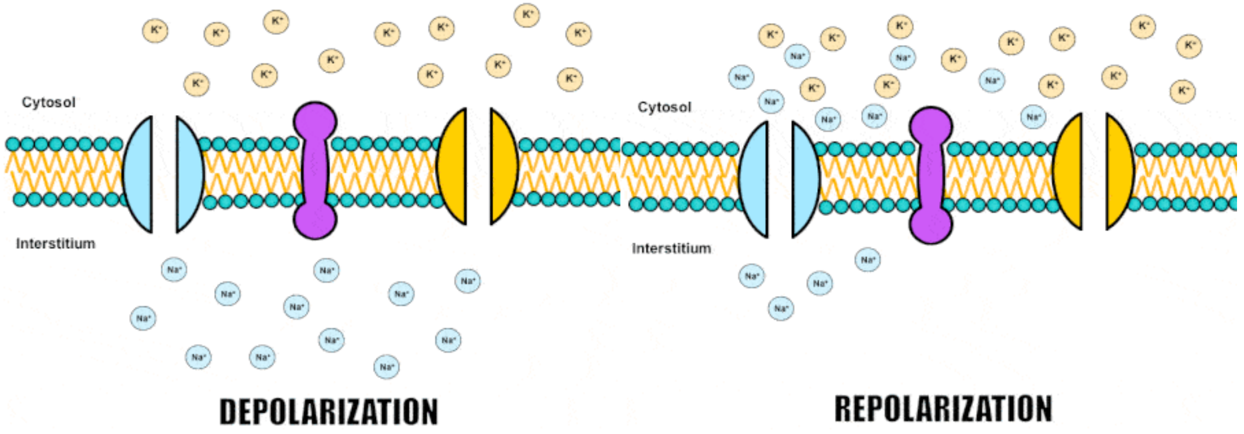
Key Points:

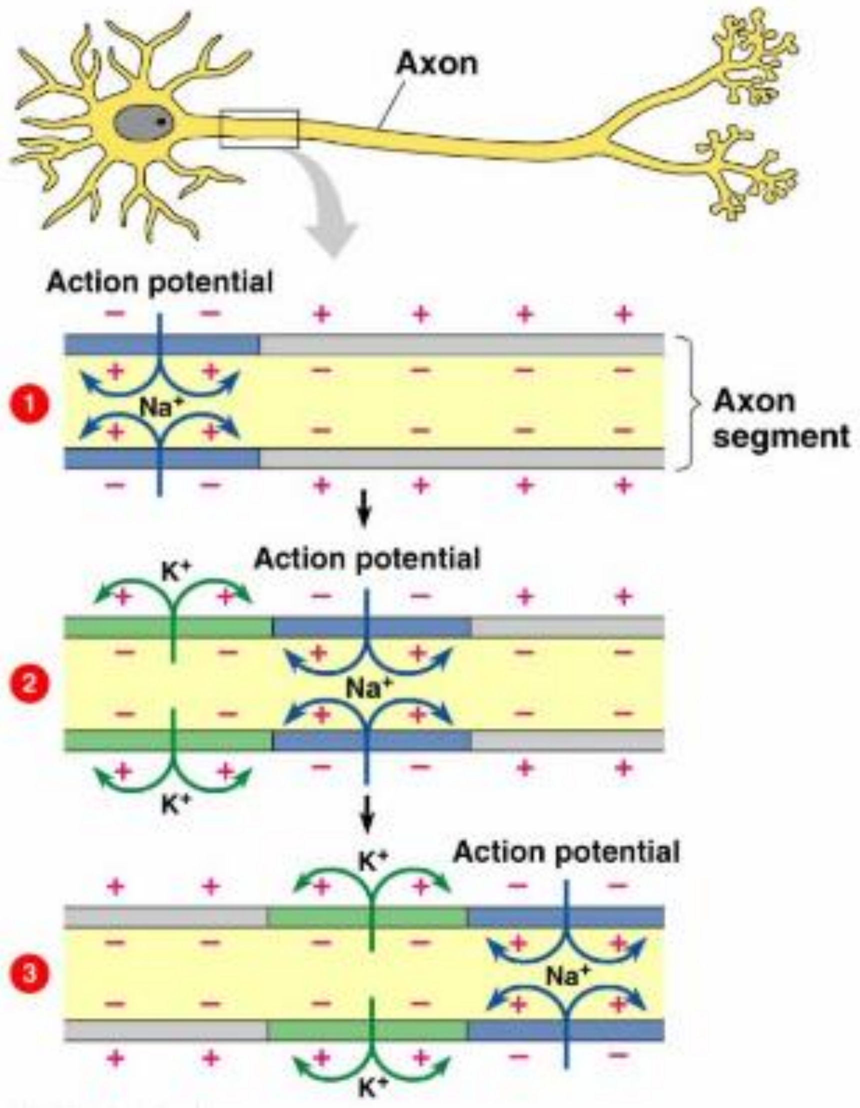
Action potential involves sequential changes in membrane potential.

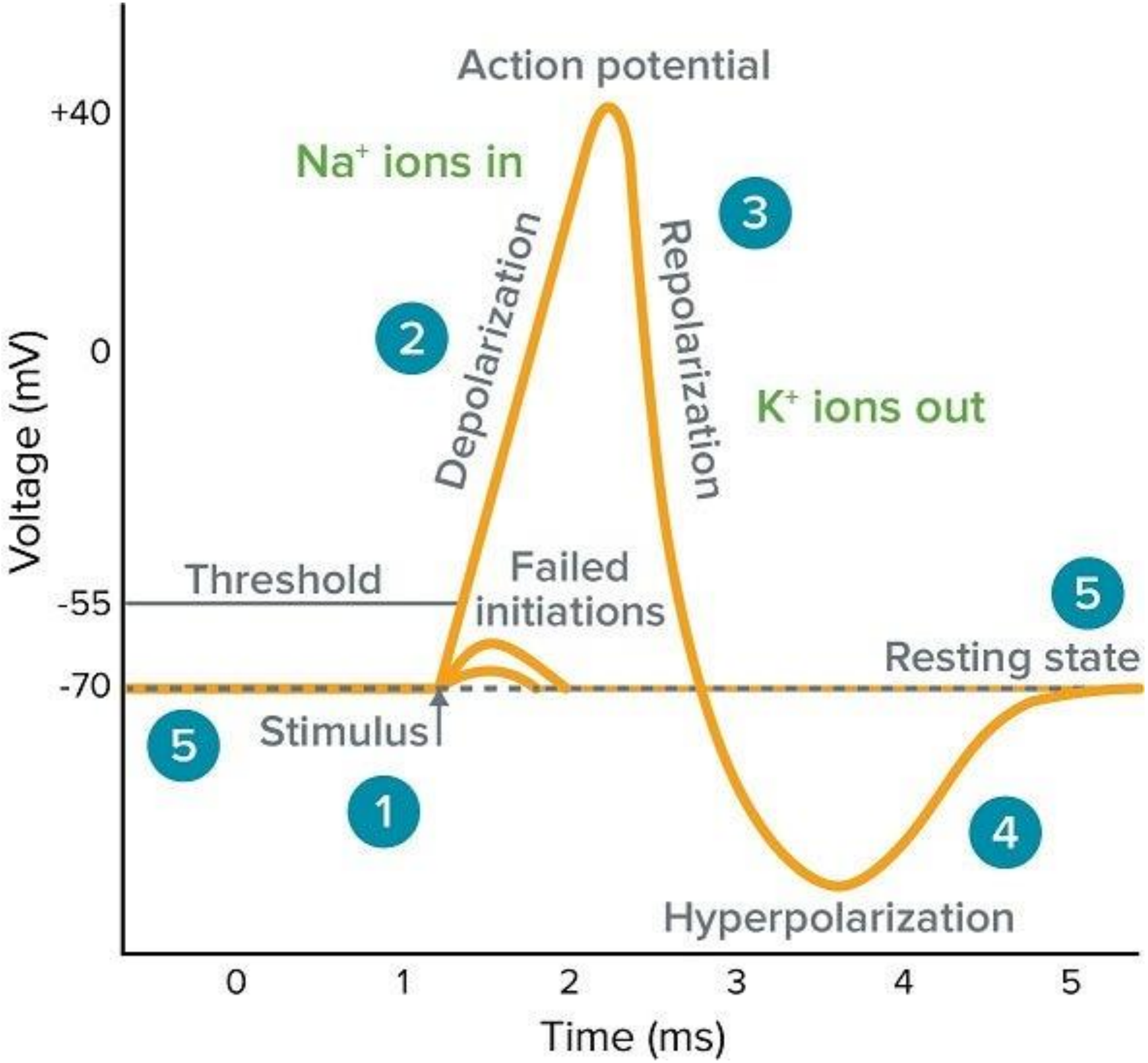
Depolarization allows for the transmission of the nerve impulse.

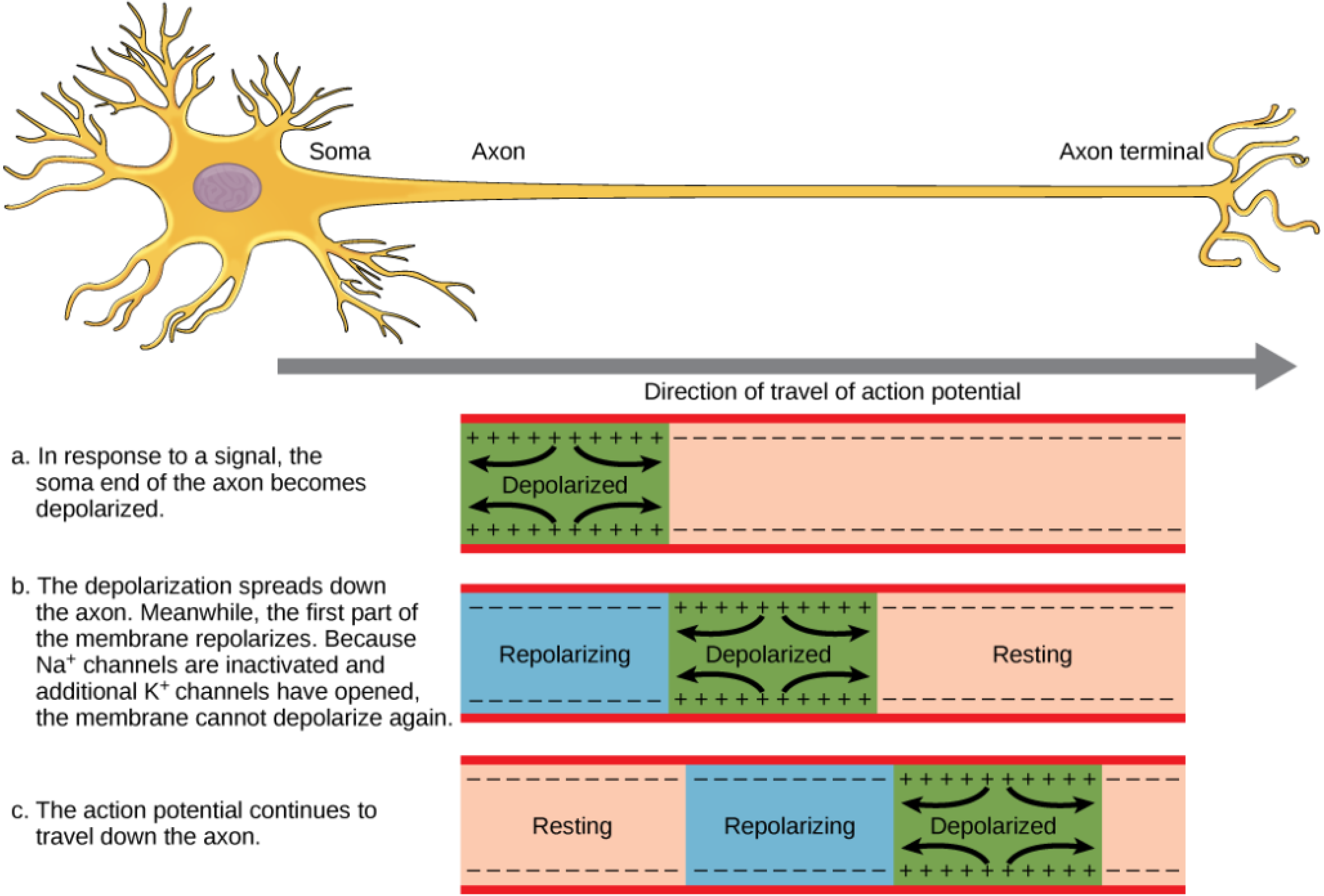
Repolarization and hyperpolarization restore the resting state of the neuron.






Axon
Action potential
Na+
Axon segment
K+
Action potential
Na+
K+
K+
Action potential
Na+
K+


Action potential
+40
Na+ ions in
3
2
Depolarization
Repolarization
0
K+ ions out
Voltage (mV)
Threshold
Failed initiations
5
-55
Resting state
-70
Stimulus
5
1
4
Hyperpolarization
0
1
2
3
4
5
Time (ms)



Soma
Axon
Axon terminal
Direction of travel of action potential
a. In response to a signal, the soma end of the axon becomes depolarized.
Depolarized
b. The depolarization spreads down the axon. Meanwhile, the first part of the membrane repolarizes. Because Na^+ channels are inactivated and additional K^+ channels have opened, the membrane cannot depolarize again.
Repolarizing
Depolarized
Resting
c. The action potential continues to travel down the axon.
Resting
Repolarizing
Depolarized

Synapse

Definition:

The synapse is the **junction** between two neurons or between a neuron and a target cell.

Components:

1.Presynaptic Neuron:

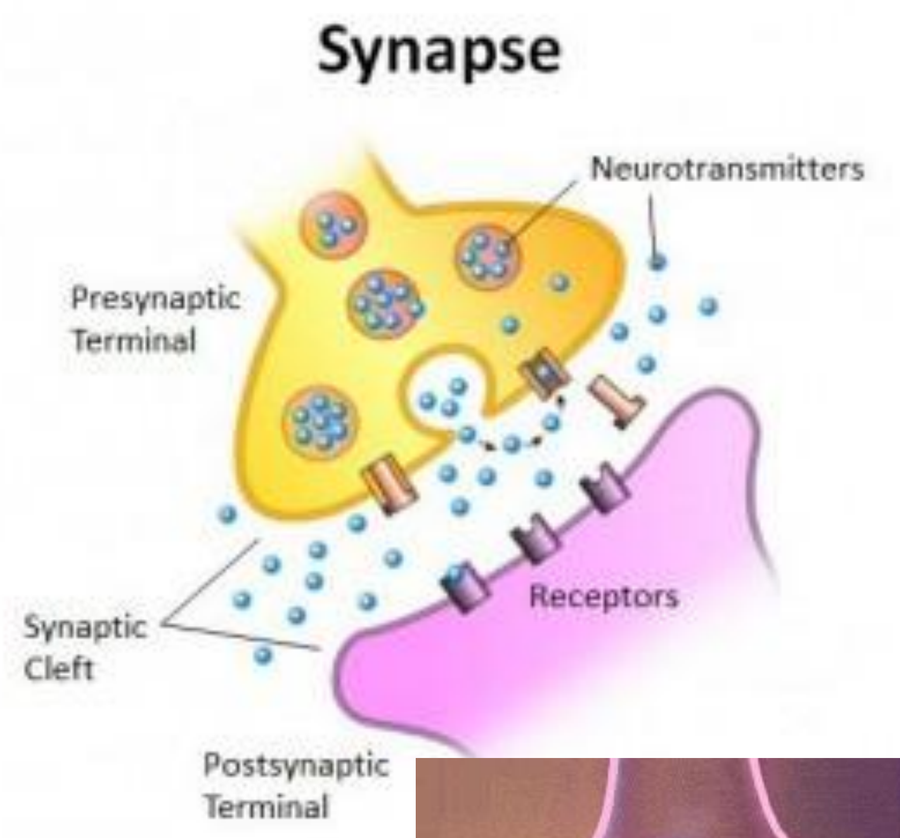
- The neuron sending the signal.
- Contains **synaptic vesicles** filled with **neurotransmitters**.

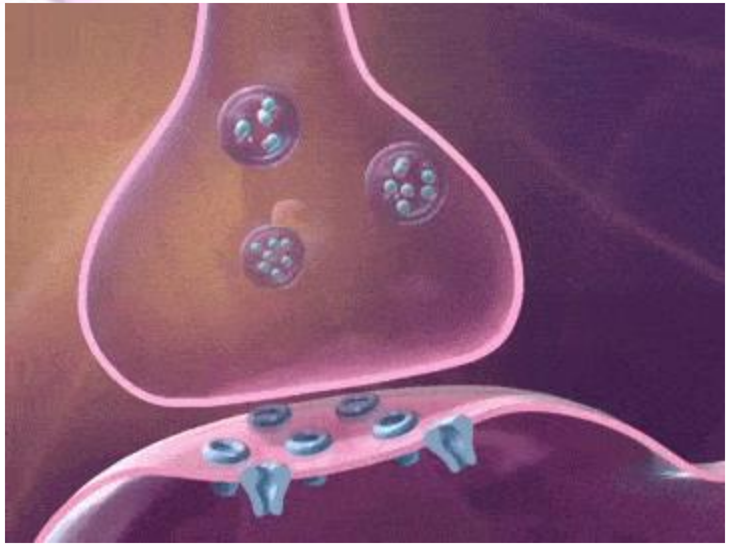
2.Synaptic Cleft:

- The **small gap** between the presynaptic and postsynaptic neurons.
- **Neurotransmitters** are released into this space.

3.Postsynaptic Neuron:

- The **neuron receiving the signal**.
- Contains **receptors for neurotransmitters.**





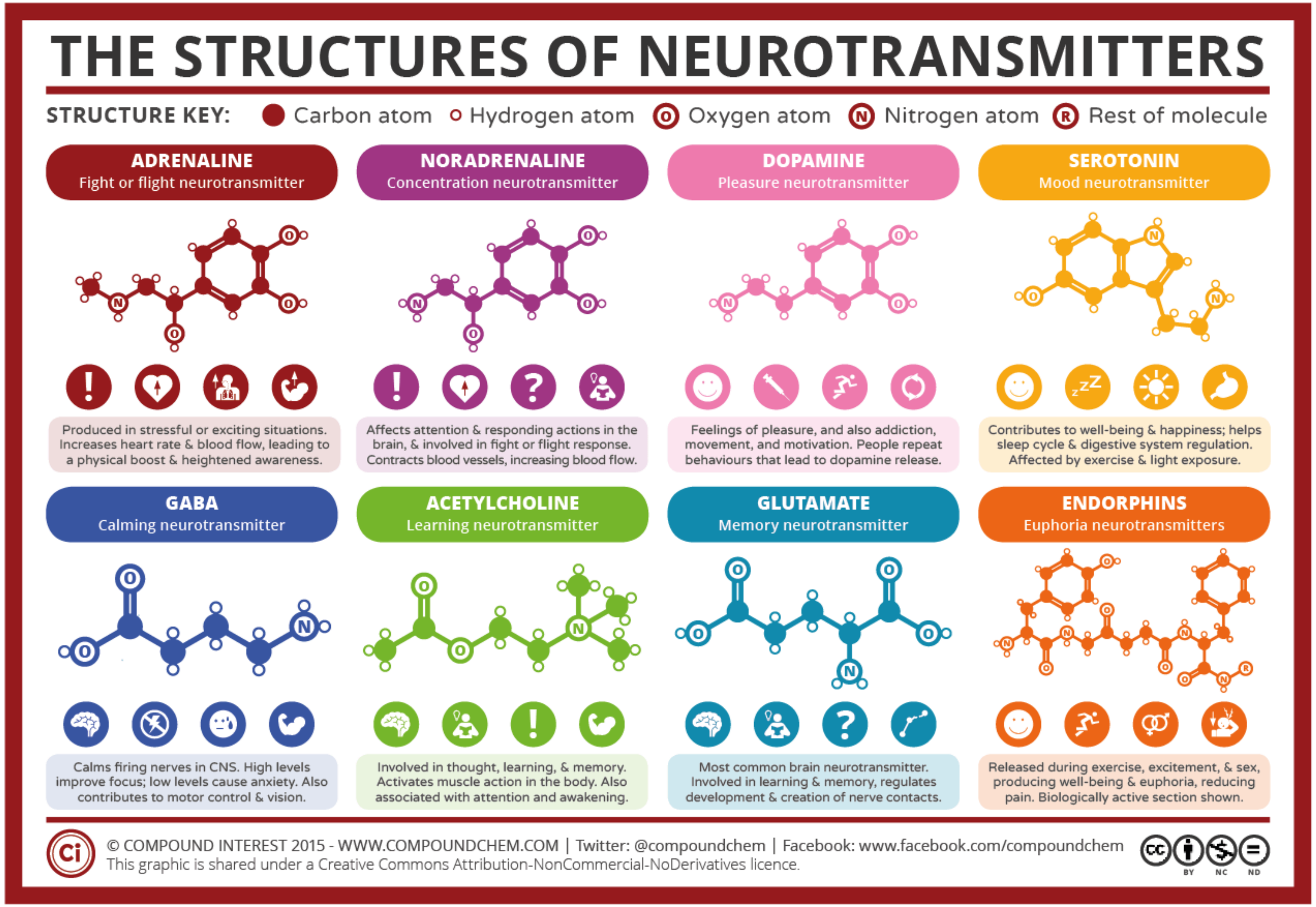
Neurotransmitters

Function:

Bind to receptors on the postsynaptic neuron.

Excite or **inhibit** its activity based on the **type of neurotransmitter** and receptor interaction.

Example: **Acetylcholine excites muscle cells**, while **GABA inhibits neural activity**.



Neurotransmitter Action

Excitatory Neurotransmitters:

Promote action potential generation in the postsynaptic neuron.

Inhibitory Neurotransmitters:

Prevent action potential generation in the postsynaptic neuron.

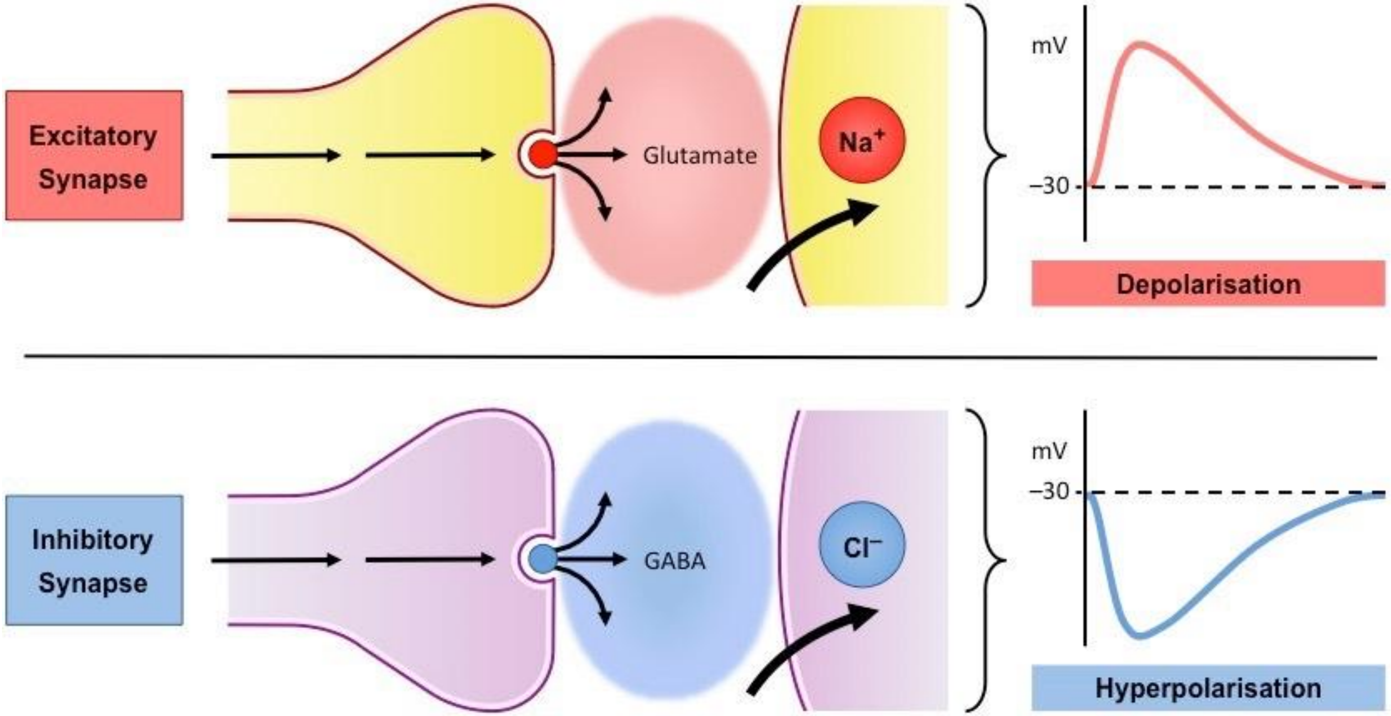
Balance of excitatory and inhibitory inputs determines whether an action potential is initiated.

Excitatory Neurotransmitters:

Promote action potential generation in the postsynaptic neuron.

Examples: **Glutamate, acetylcholine**.

Binding of excitatory neurotransmitters depolarizes the postsynaptic membrane, making it more likely to reach the threshold for action potential initiation.

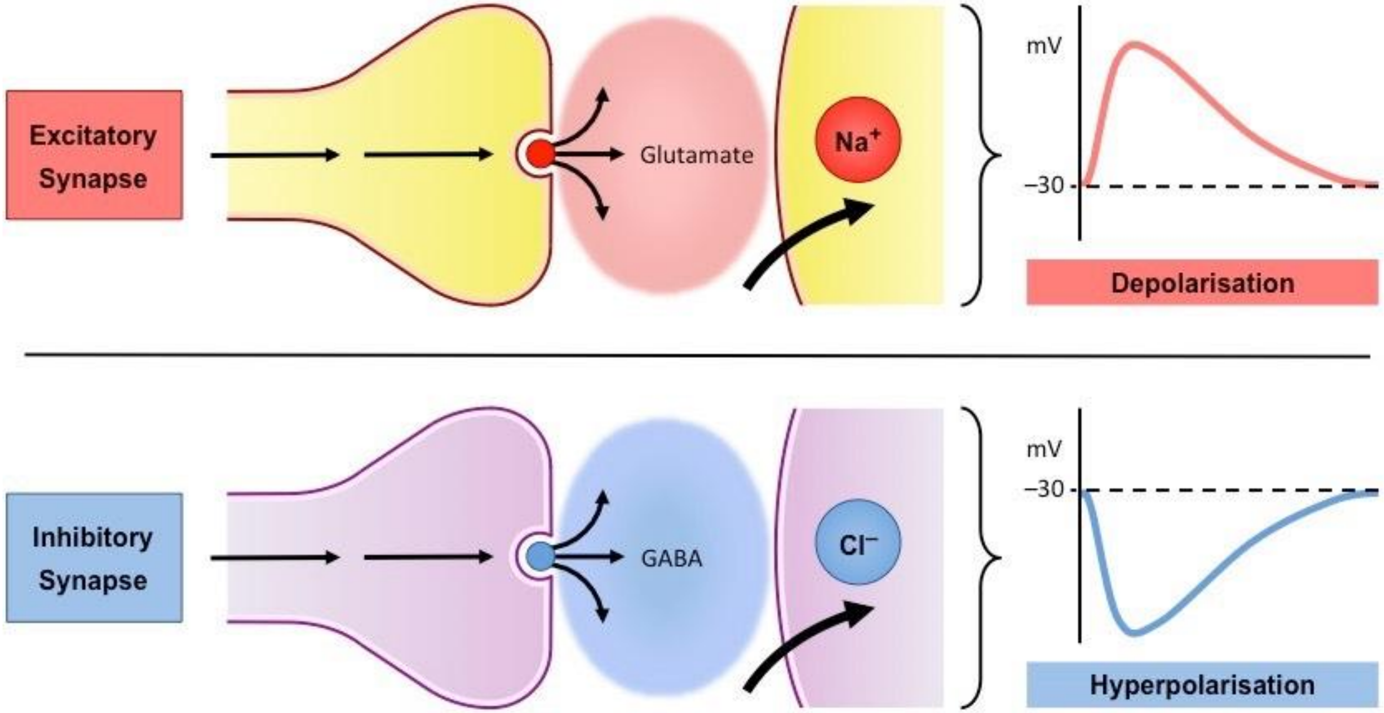


Inhibitory Neurotransmitters

Prevent action potential generation in the postsynaptic neuron.

Examples: **GABA, glycine.**

Binding of inhibitory neurotransmitters **hyperpolarizes the postsynaptic membrane**, making it less likely to reach the threshold for action potential initiation.



Everyday Life Example of EXCITATORY SYNAPSE: Imagine you're about to catch a ball thrown towards you.

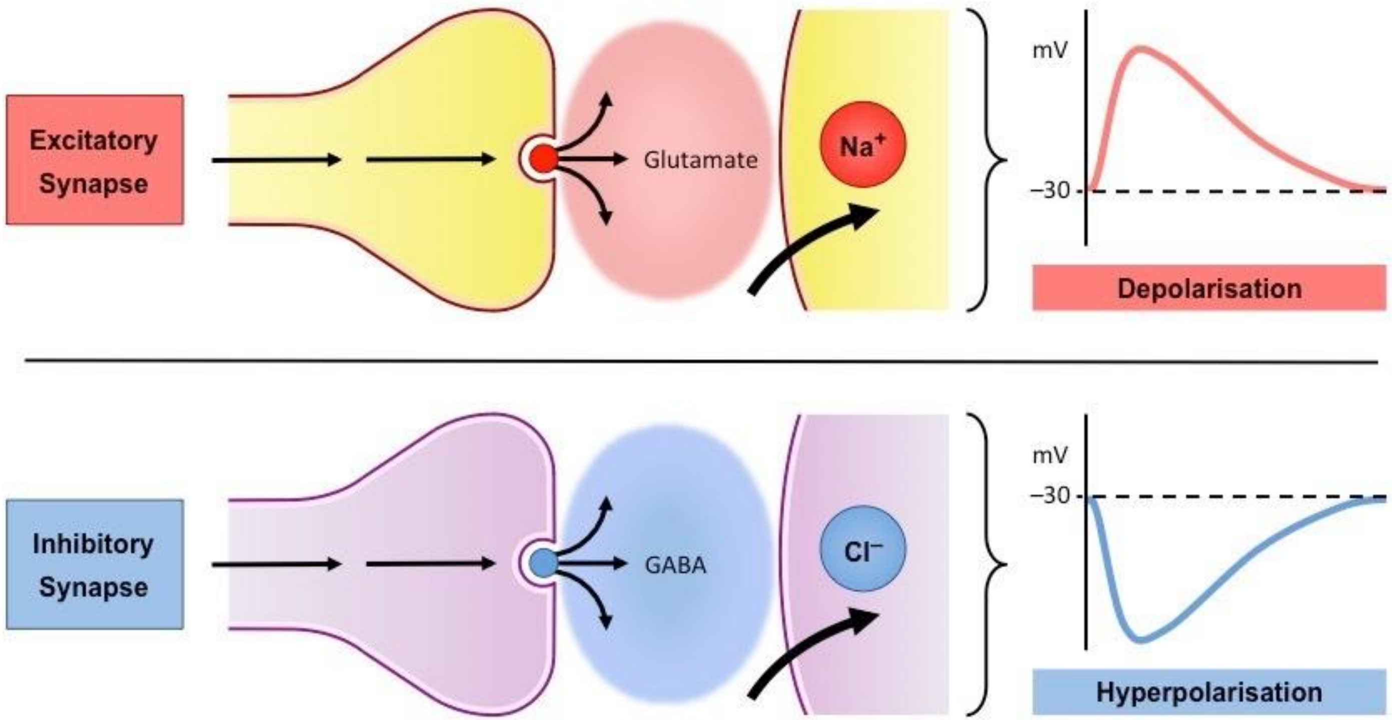
The visual information of the ball coming at you is processed by your brain.

Neurons in your motor cortex release glutamate onto other neurons controlling your arm muscles.

Sodium ions rush into those muscle-controlling neurons, depolarizing them.

This depolarization triggers muscle contraction (an action potential), allowing you to move your arm and catch the ball.

The "excitatory" part is the signal that *activates* your muscles, making you *do* something.



Everyday Life Example of INHIBITORY SYNAPSE: Imagine you're about to reach for a hot stove.

Sensory neurons in your fingertips detect the heat and send signals to your brain.

Your brain recognizes the danger and needs to *stop* you from touching the stove.

Neurons in your brain release GABA onto the neurons that would normally activate your arm muscles to reach.

Chloride ions rush into those muscle-controlling neurons, hyperpolarizing them.

This hyperpolarization prevents muscle contraction, stopping you from touching the stove.

The "inhibitory" part is the signal that *prevents* action, stopping you from *doing* something potentially harmful.

Balance of Excitatory and Inhibitory Inputs

Determines whether an action potential is initiated.

If excitatory inputs outweigh inhibitory inputs, the neuron is more likely to fire an action potential.

If inhibitory inputs outweigh excitatory inputs, the neuron is less likely to fire an action potential.

The formation of an action potential can be divided into five steps, which can be seen in Figure 1.

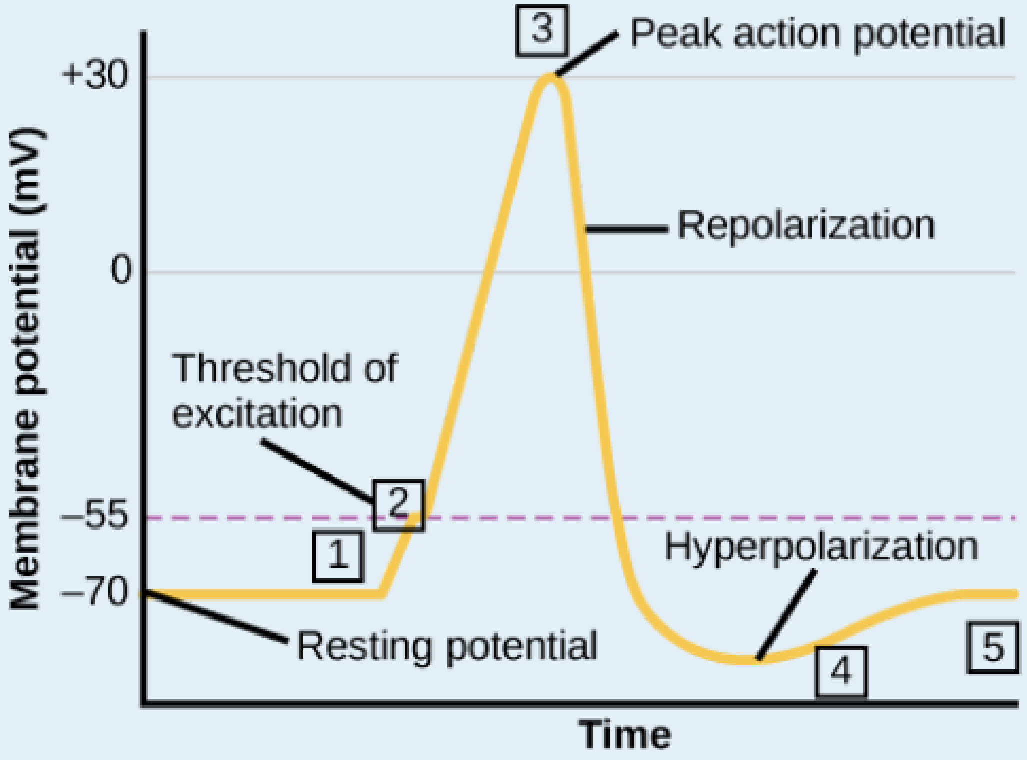


Figure 1. Action Potential

1. A stimulus from a sensory cell or another neuron causes the target cell to depolarize toward the threshold potential.
2. If the threshold of excitation is reached, all Na^+ channels open and the membrane depolarizes.
3. At the peak action potential, K^+ channels open and K^+ begins to leave the cell. At the same time, Na^+ channels close.
4. The membrane becomes hyperpolarized as K^+ ions continue to leave the cell. The hyperpolarized membrane is in a refractory period and cannot fire.
5. The K^+ channels close and the Na^+/K^+ transporter restores the resting potential.

How synapses communicate:

https://www.youtube.com/watch?v=hGDvvUNU-cw&t=57s

How addiction works:

https://www.youtube.com/watch?v=-RF9vg5tbpo&t=140s