The Action Potential

By Jakub Staniszewski

Table of Contents

Star slides are for rapid review

studyaid

Where does it occur?

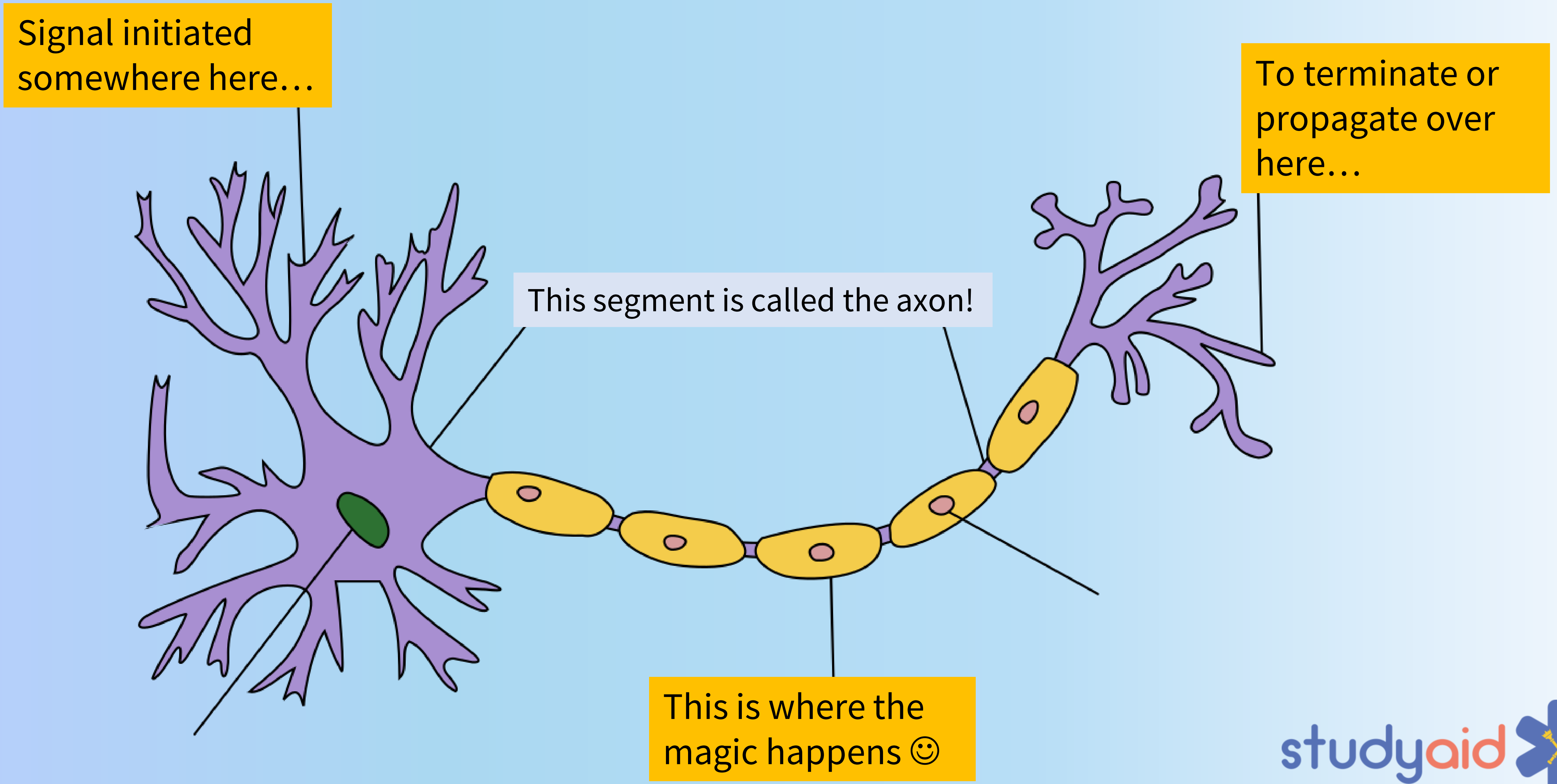
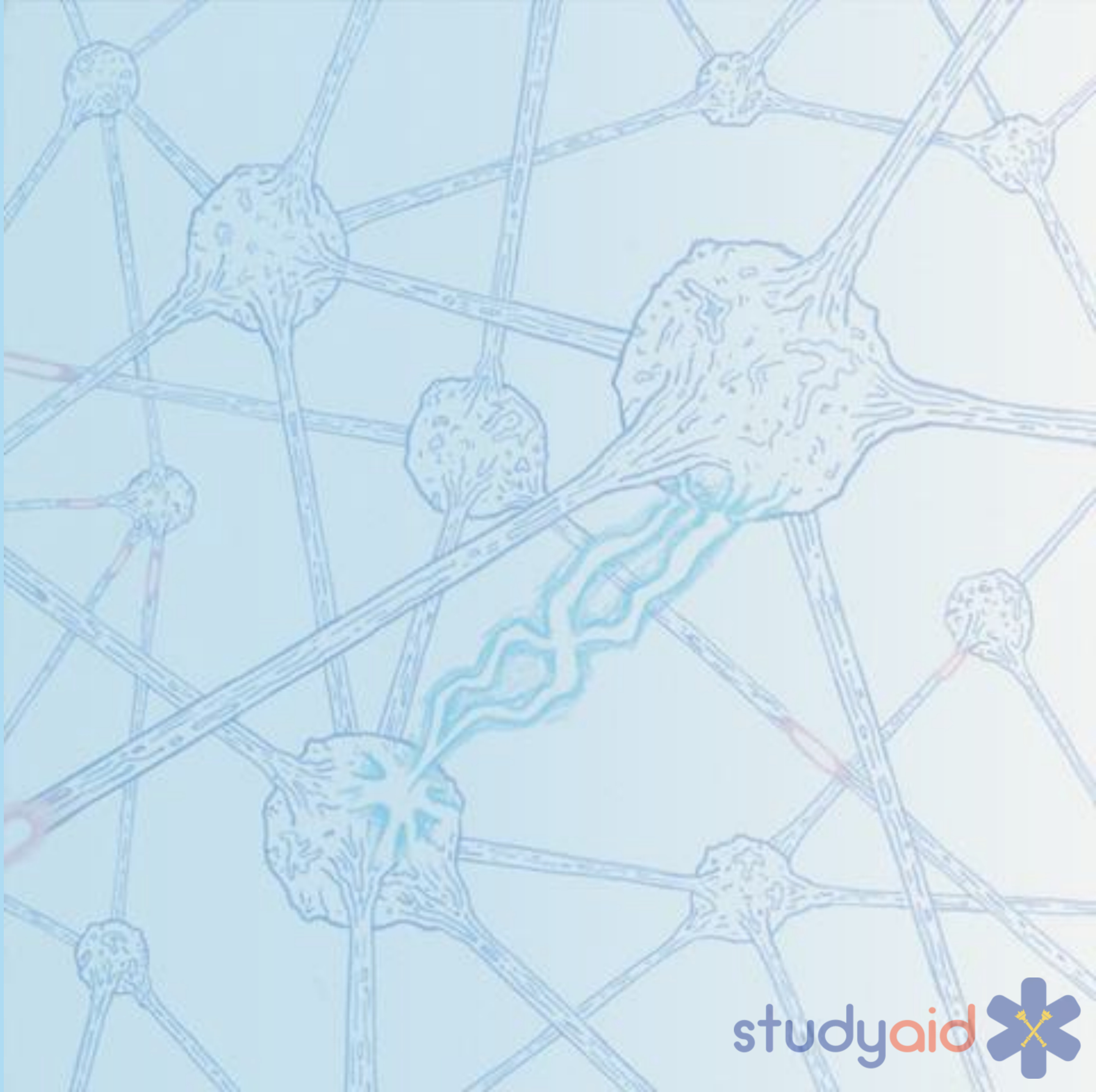


Table of Contents

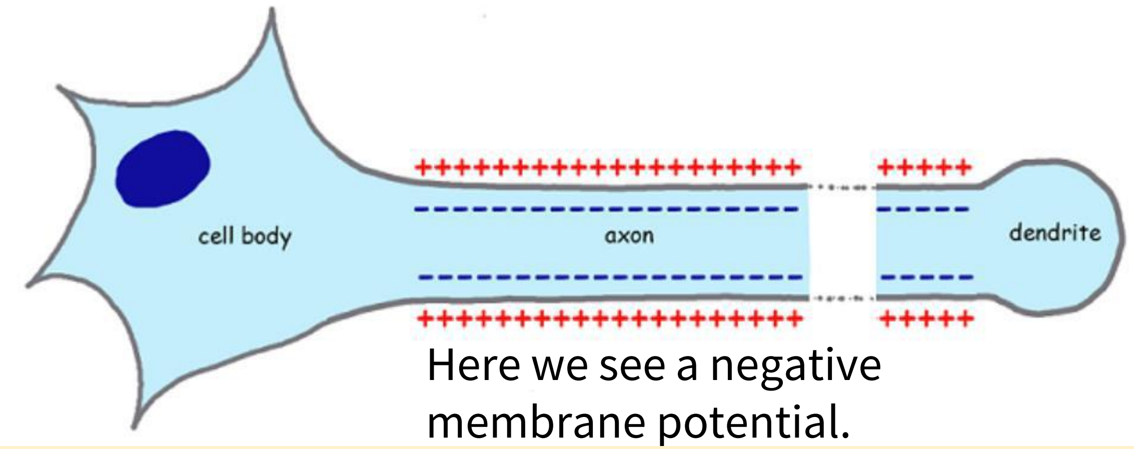


The science of potential

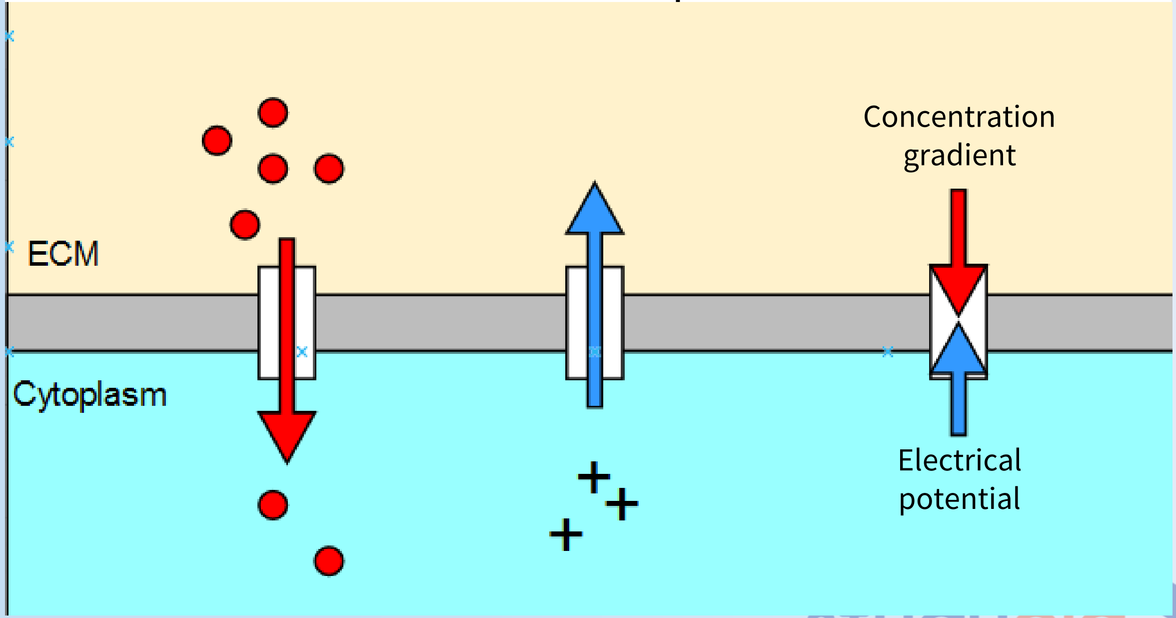
<u>Membrane potential</u>: separation of charge between interior *(cytoplasm)* and exterior *(ECM)* of cell, has *potential* to do work.

<u>Equilibrium potential</u>: the opposing forces of **concentration gradient** and **electrical potential** are equal for a given ion.

Many ions determine the potential, but the most important for the **action** potential are Na^+ and K^+.

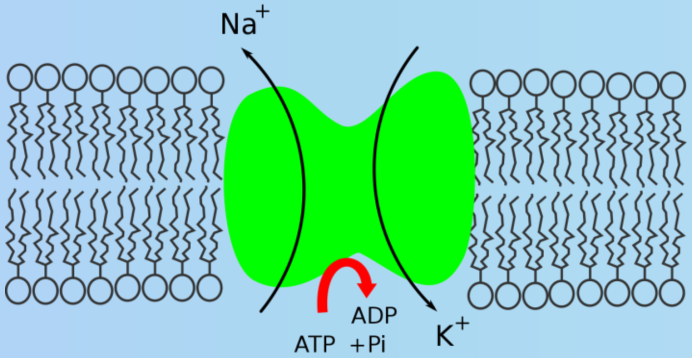


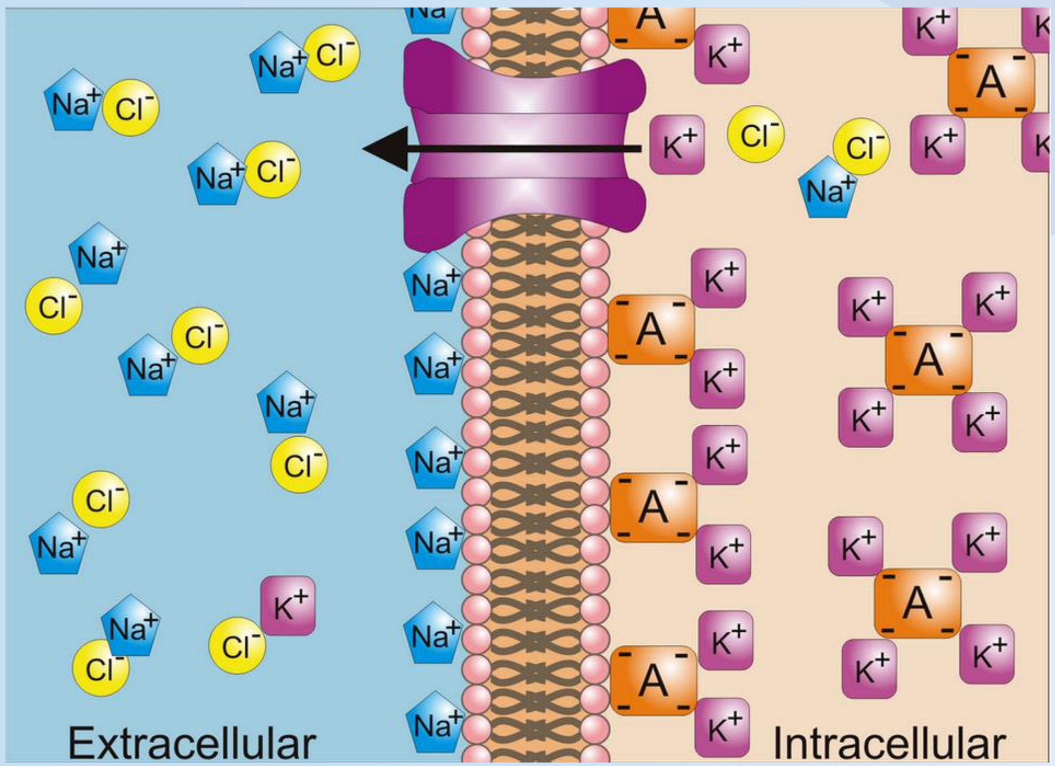
Here we see a negative membrane potential.

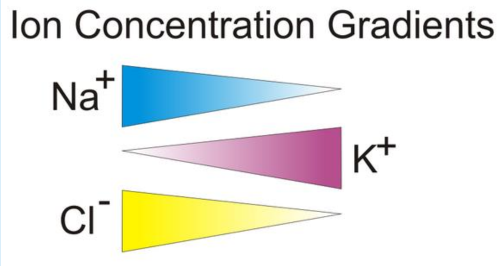


Resting potential

- All cells have a membrane potential.
- Na^+ is concentrated in the ECM and K^+ is concentrated in the cytoplasm.
- The **<u>Na^+-K^+ ATPase</u>** establishes this gradient using ATP as energy.
- $3Na^+$ are sent out of the cell, and $2K^+$ are brought in.
- This creates a negative membrane potential.



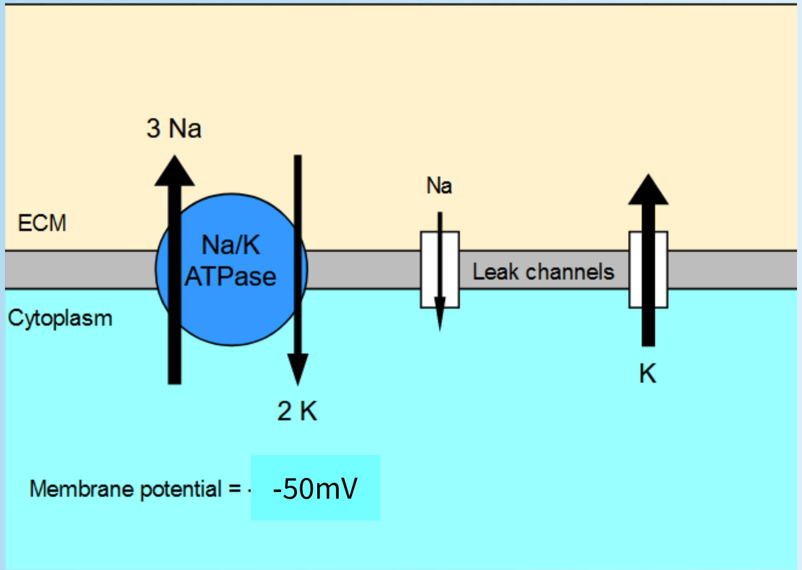


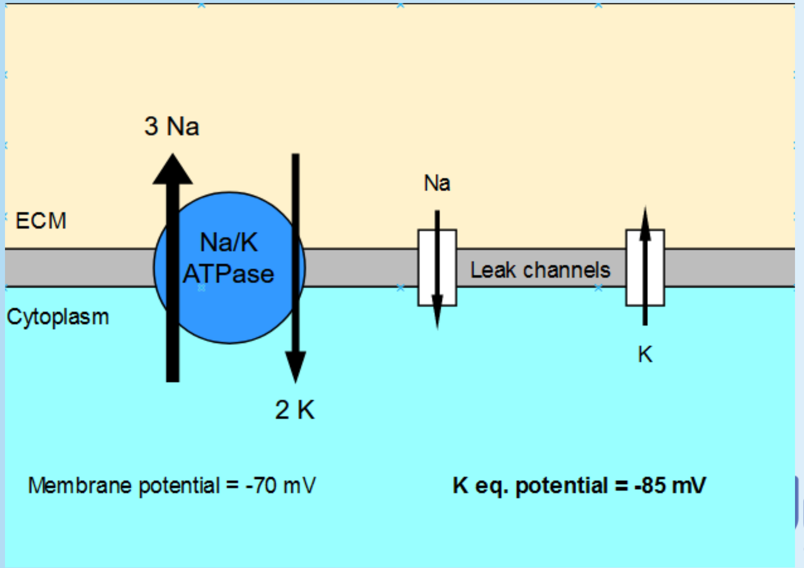


studyaid

Setting the resting potential

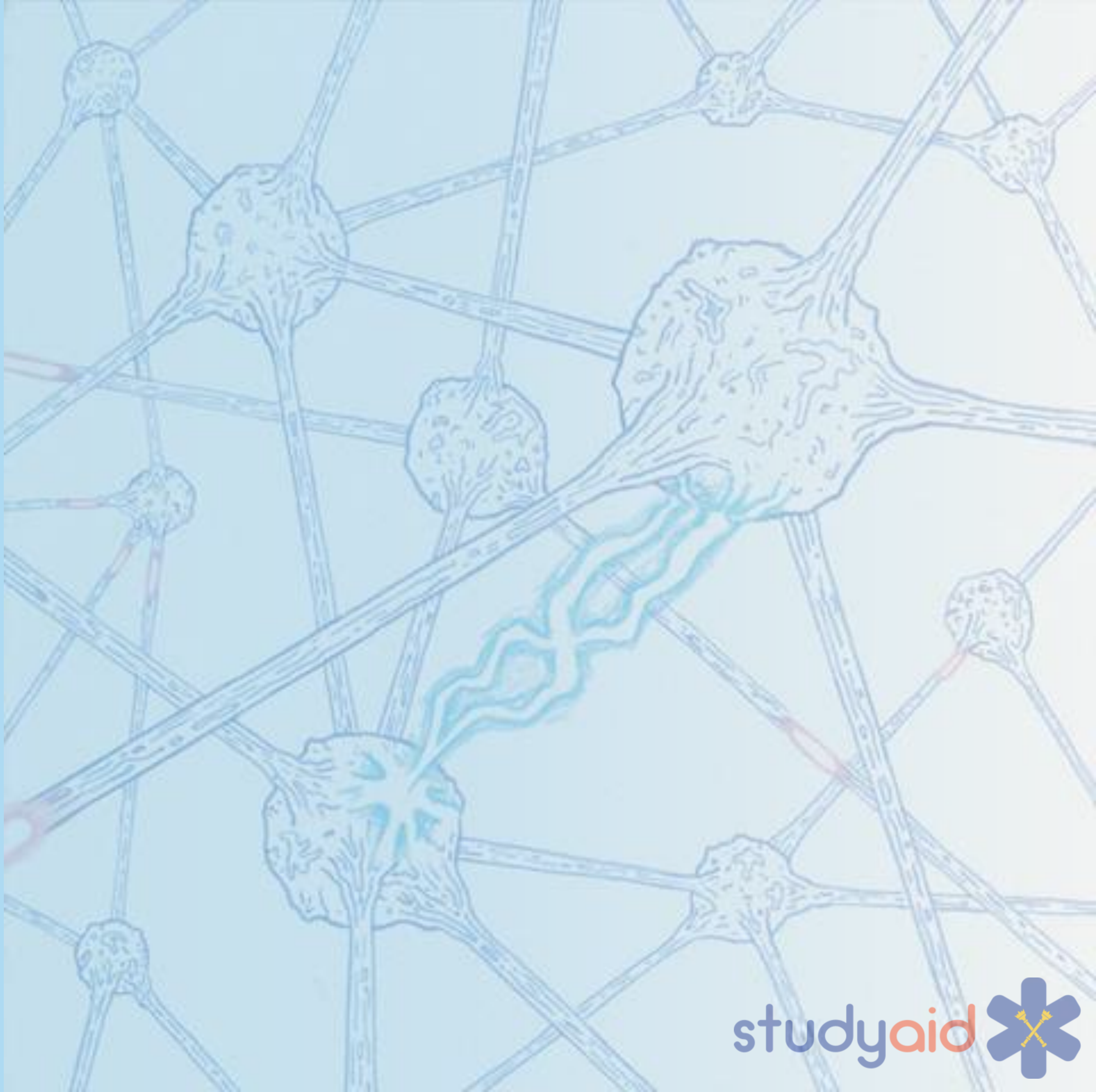
- If the Na^+-K^+ pump worked alone, memb. potential would go very low
- **<u>Na^+-K^+ leak channels</u>** are responsible for stabilizing the membrane potential.
- The K^+ leak channel has high conductance. Na^+ conductance is low.
- So, the resting potential is close to K^+'s equilibrium potential (but not quite the same!)
- A neuron has a resting potential of **<u>-70mV</u>**





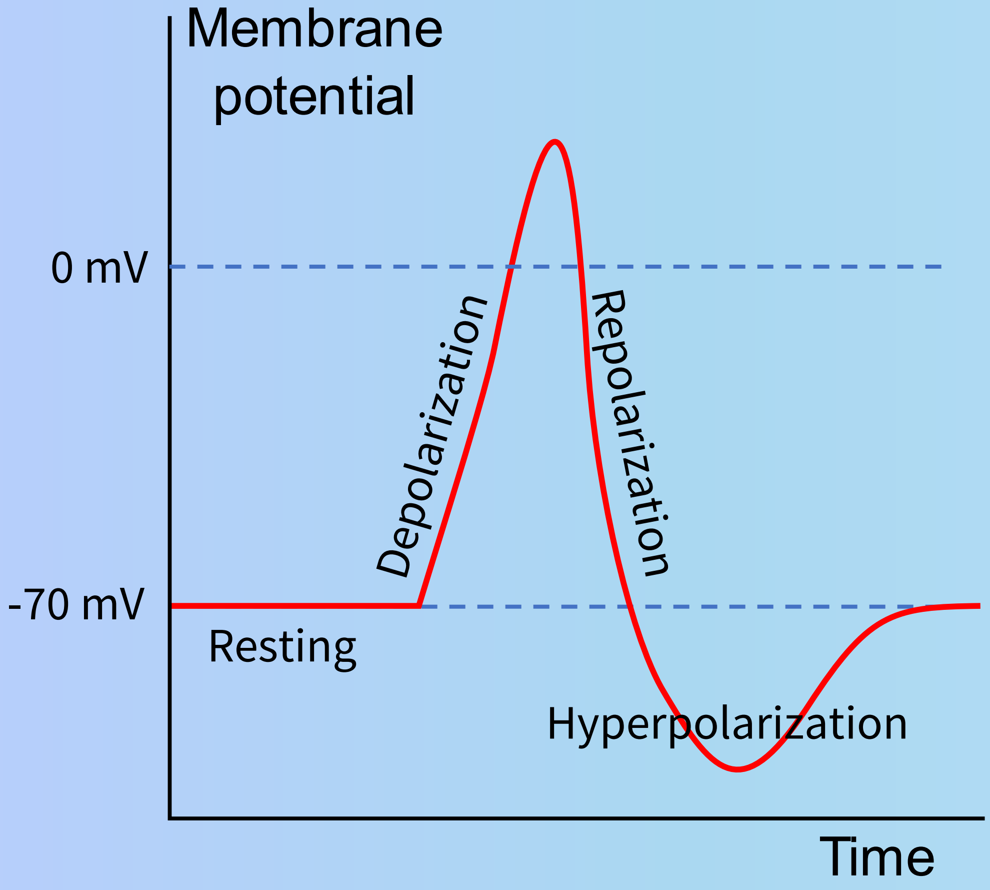
The Na^+ eq. potential is +70 mV

Table of Contents



studyaid

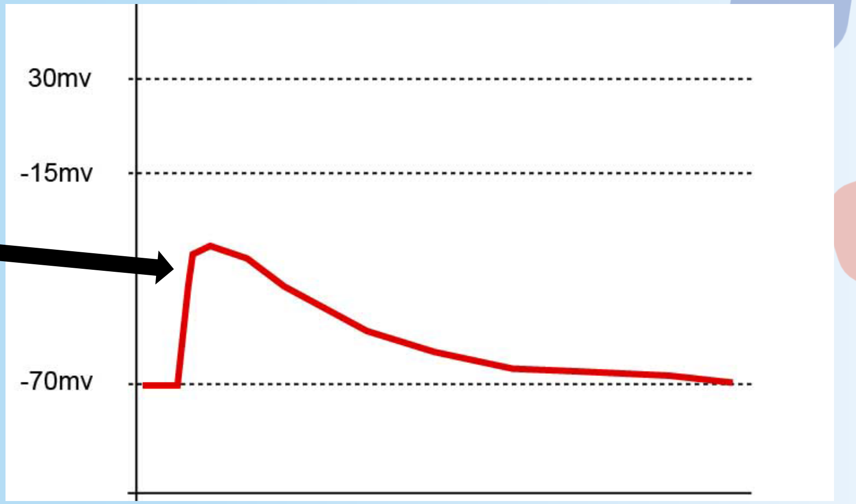
Phases of the action potential

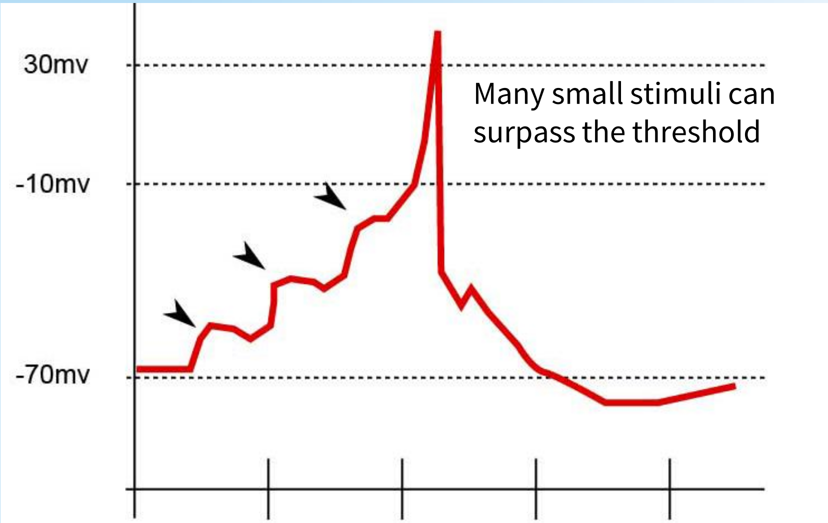


- **Resting phase:** membrane is polarized.
- **Depolarization:** loss of membrane potential; big Na^+ influx.
- **Repolarization:** the potential is restored; big K^+ efflux.
- **Hyperpolarization:** Too much, too much!
- Return to resting phase

How is an action potential initiated?

- A **subthreshold stimulus** increases the likelihood of an action potential *(positive deflection)*.
- An action potential will only occur if a **threshold stimulus** acts on the cell.
- The threshold potential in neurons is **-45mV**.
- A stimulus usually results in an influx of cations, like Na^+.





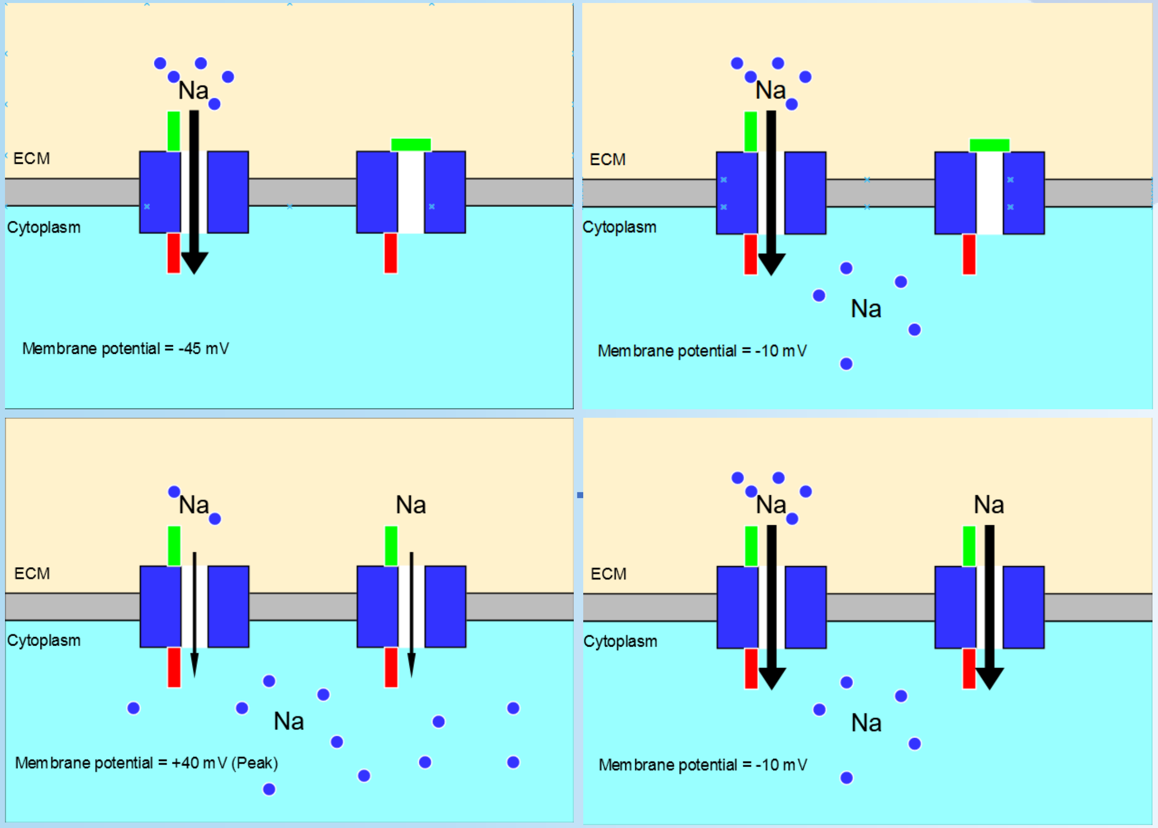
An influx of cations can be generated by:

- Chemical synapses (neurotransmitters)
- Sensory neurons (sensory transduction)
- Pacemaker potentials (*cardiac pacemaker cells*)

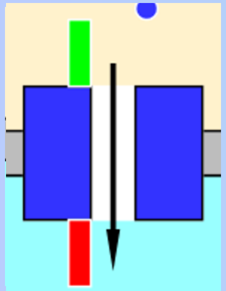
studyaid

Depolarization phase

1. The threshold potential is reached.
2. Voltage-gated Na^+ channels open/activate.
3. There is a massive influx of Na^+.
4. The membrane potential rises rapidly.
5. Even more Na^+ channels are opened.
6. This continues until all available Na^+ channels are open.
7. Na^+ influx slows because it is closer to equilibrium potential(+65 mV).

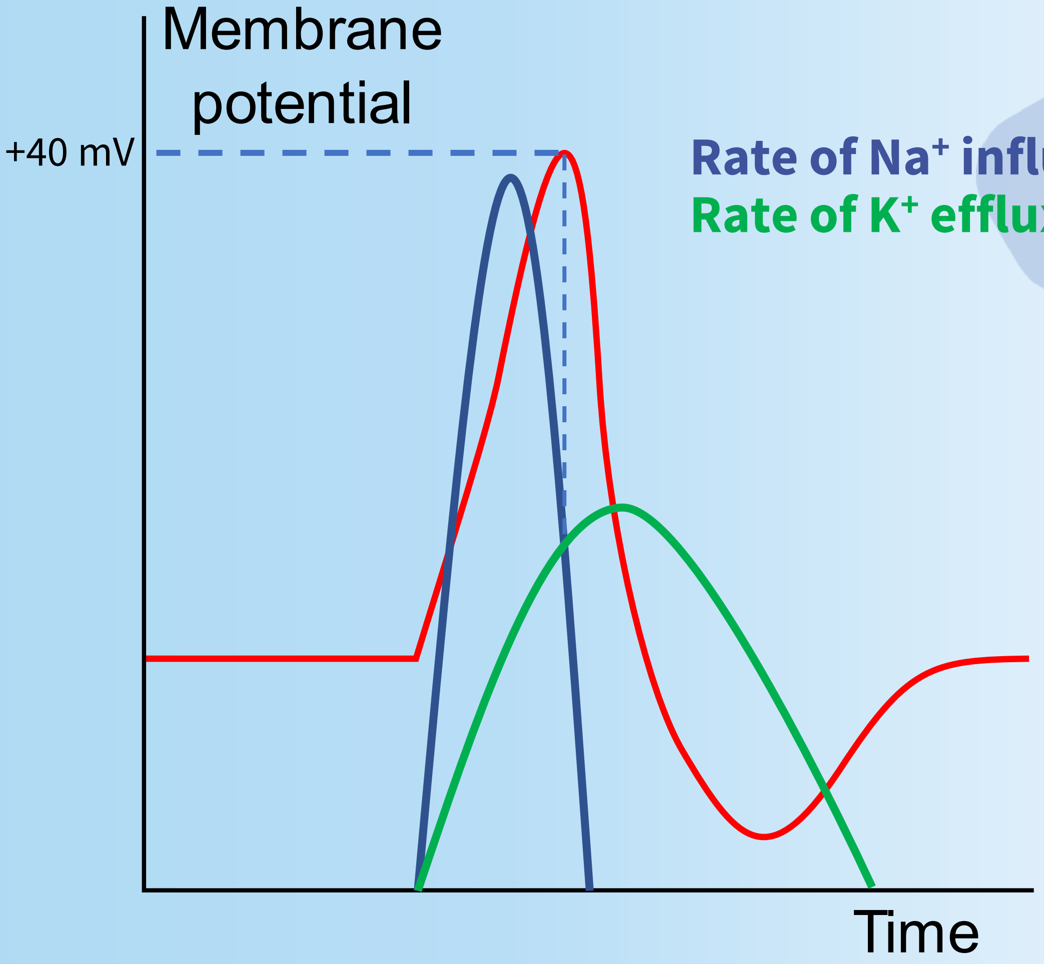


studyaid



The voltage-gated channel

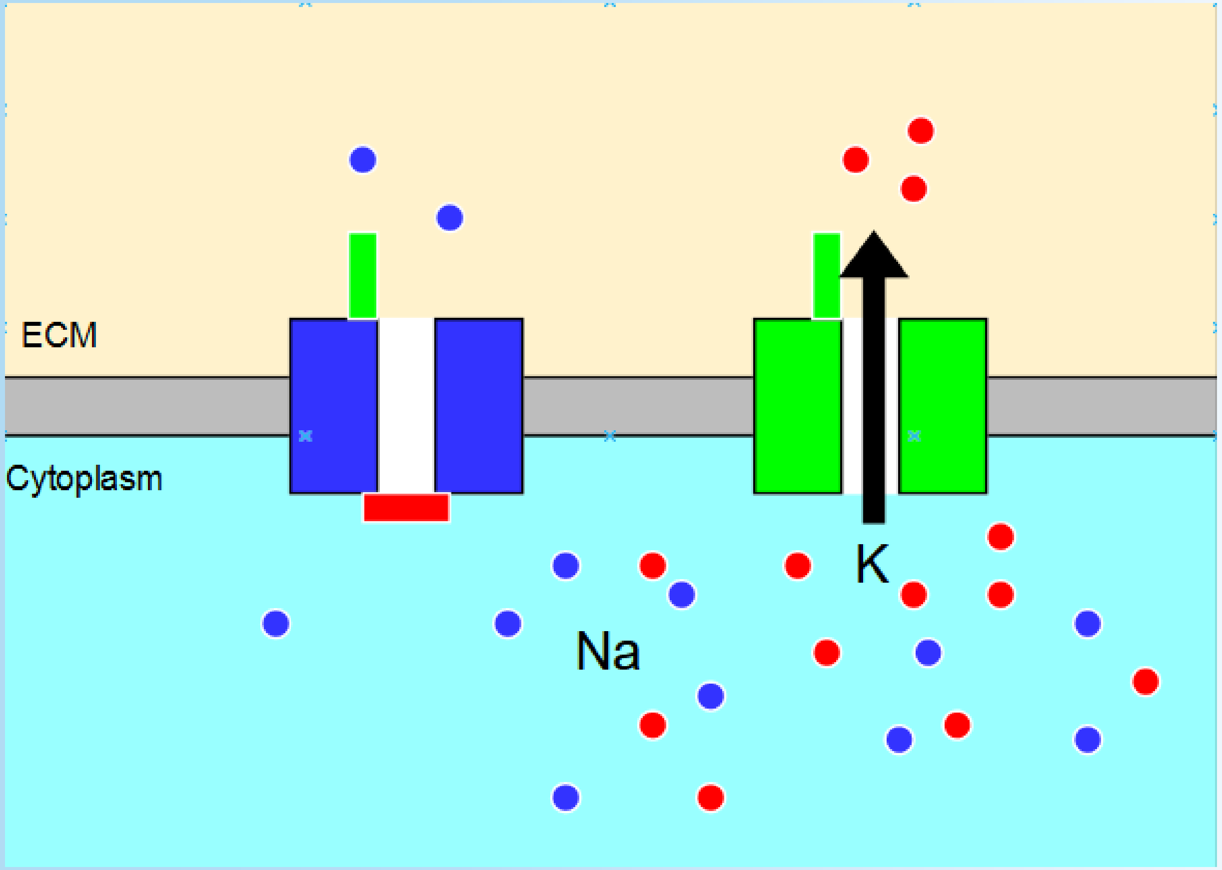
- The voltage-gated Na^+ channel lets through more ions than the leak channel (it has high conductance)
- At resting:
  - the activation gate (green) is closed
  - the inactivation gate (red) is open
- At threshold potential, the **activation gate** opens.
- The voltage-gated K^+ channel opens at a slower rate.
- At peak potential of +40 mV, K^+ efflux equals Na^+ influx.



studyaid

Repolarization phase

1. The inactivation gates of voltage-gated Na^+ channels close.
2. Voltage-gated K^+ channels are fully open.
3. Massive K^+ efflux → return to negative membrane potential.
4. The K^+ channel gate remains open for a long time.



At this point, the Na^+ channel cannot open, at any voltage.

Hyperpolarization

- The K^+ channels remain open for longer than necessary.
- Membrane potential falls below resting.
- It gets closer to the equilibrium potential of K^+ (-85mV).
- K^+ flow returns to normal when all K^+ channels close. They do not "inactivate" like Na^+ channels.

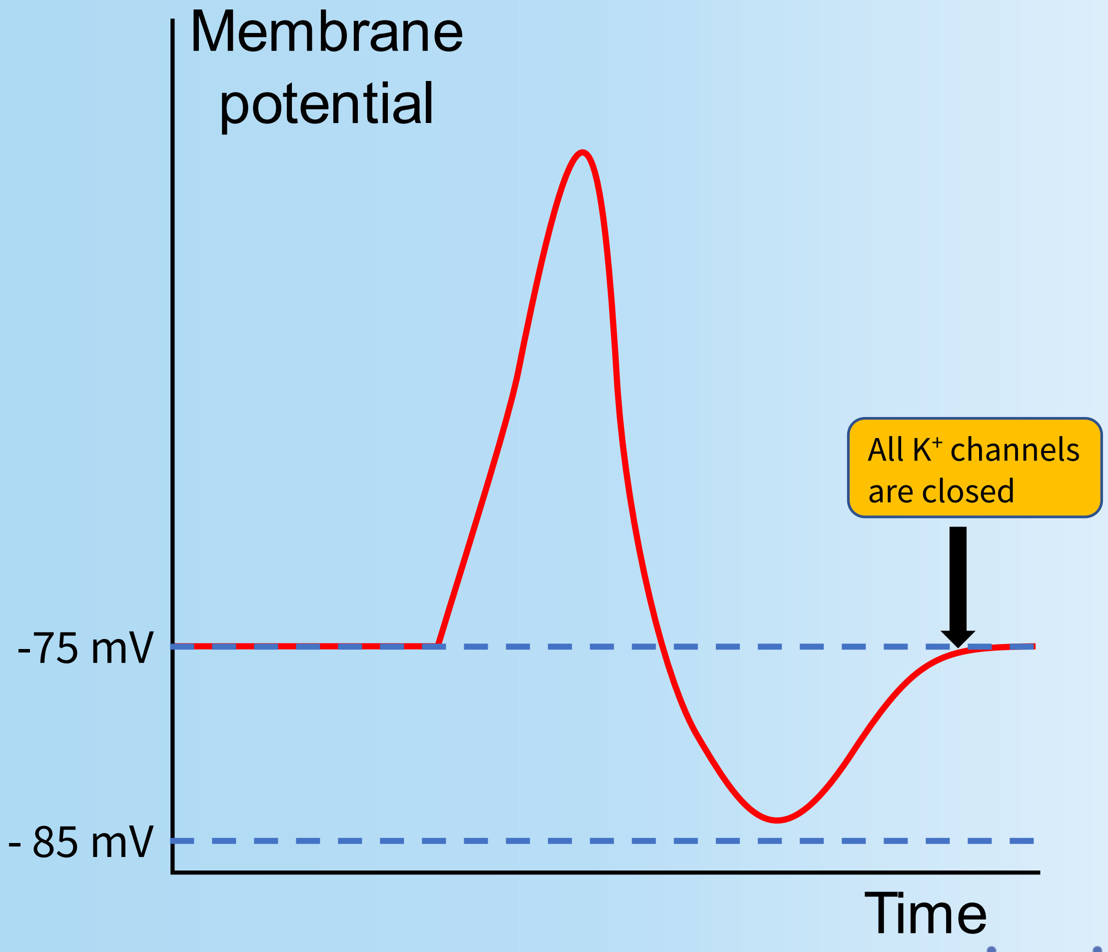
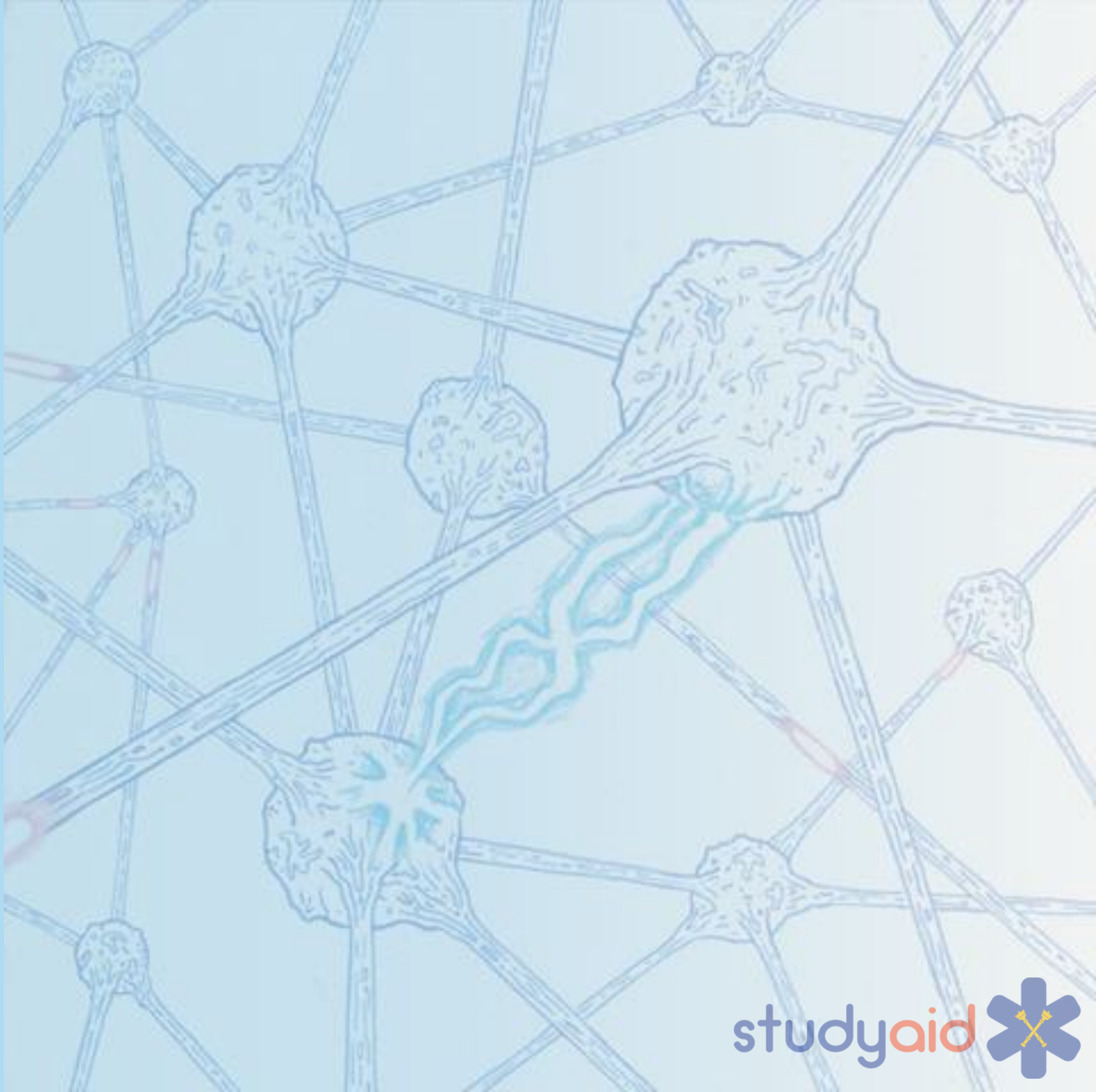


Table of Contents



Refractory periods

Absolute refractory period (ARP)

- When Na^+ channels close their inactivation gate, they cannot be opened by voltage.
- This prevents backwards propagation of the action potential.
- An action potential is impossible at this time.

Relative refractory period (RRP)

- After some time the inactivation gate on the Na^+ channel opens.
- The activation gate can open at the threshold potential.
- Some Na^+ channels take longer to re-activate.
- Open K^+ channels make it very difficult to reach the threshold.

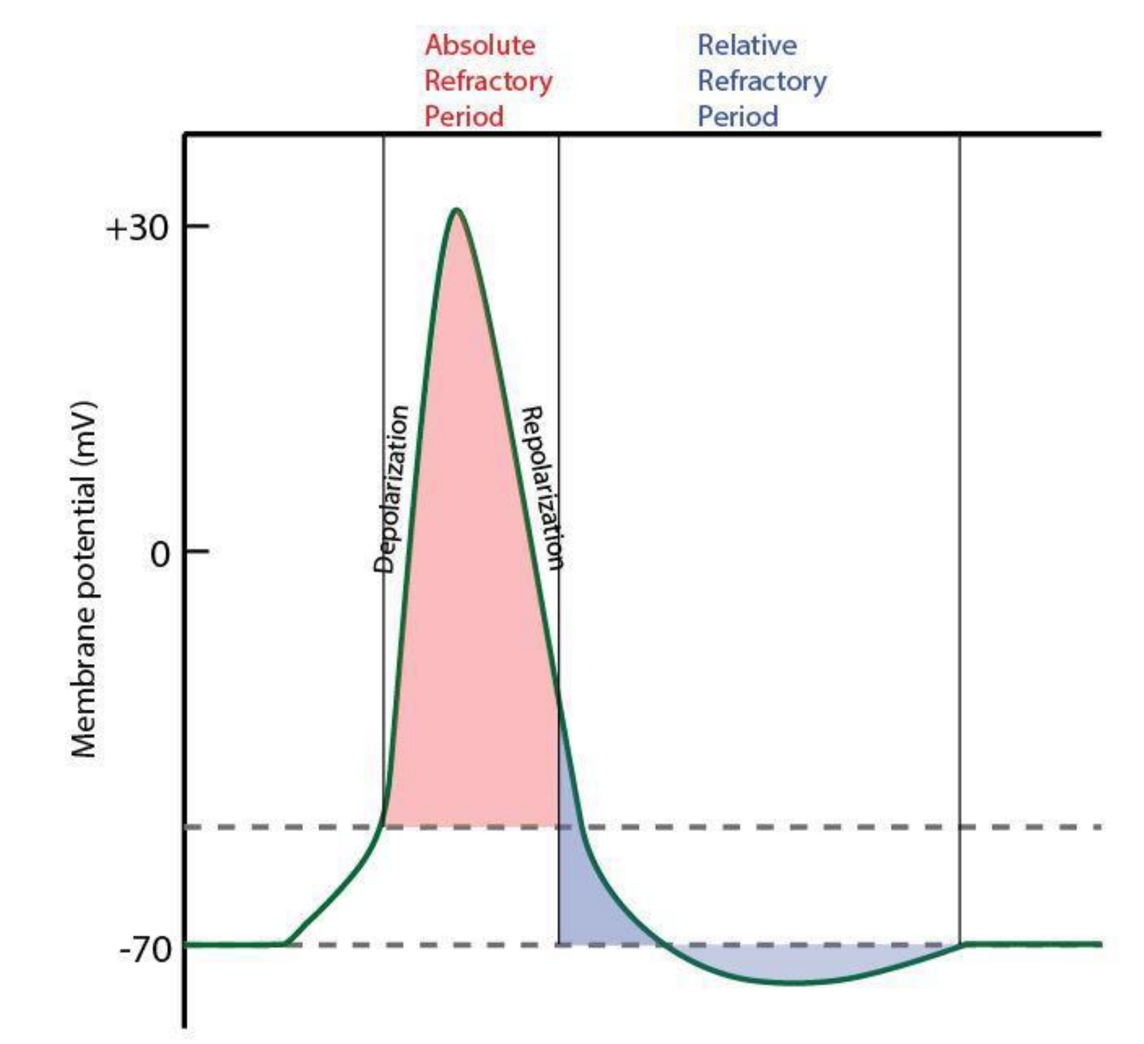
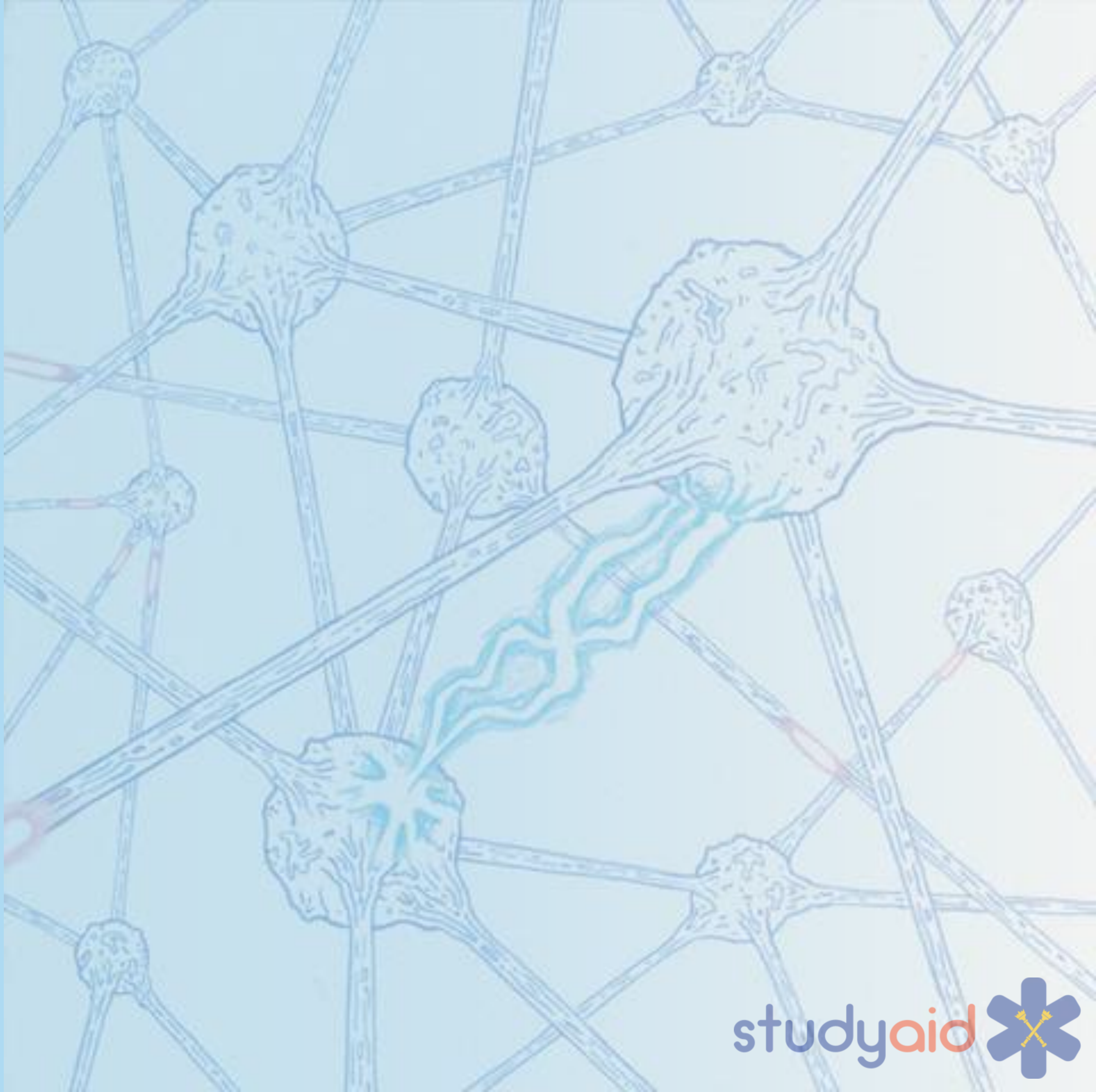


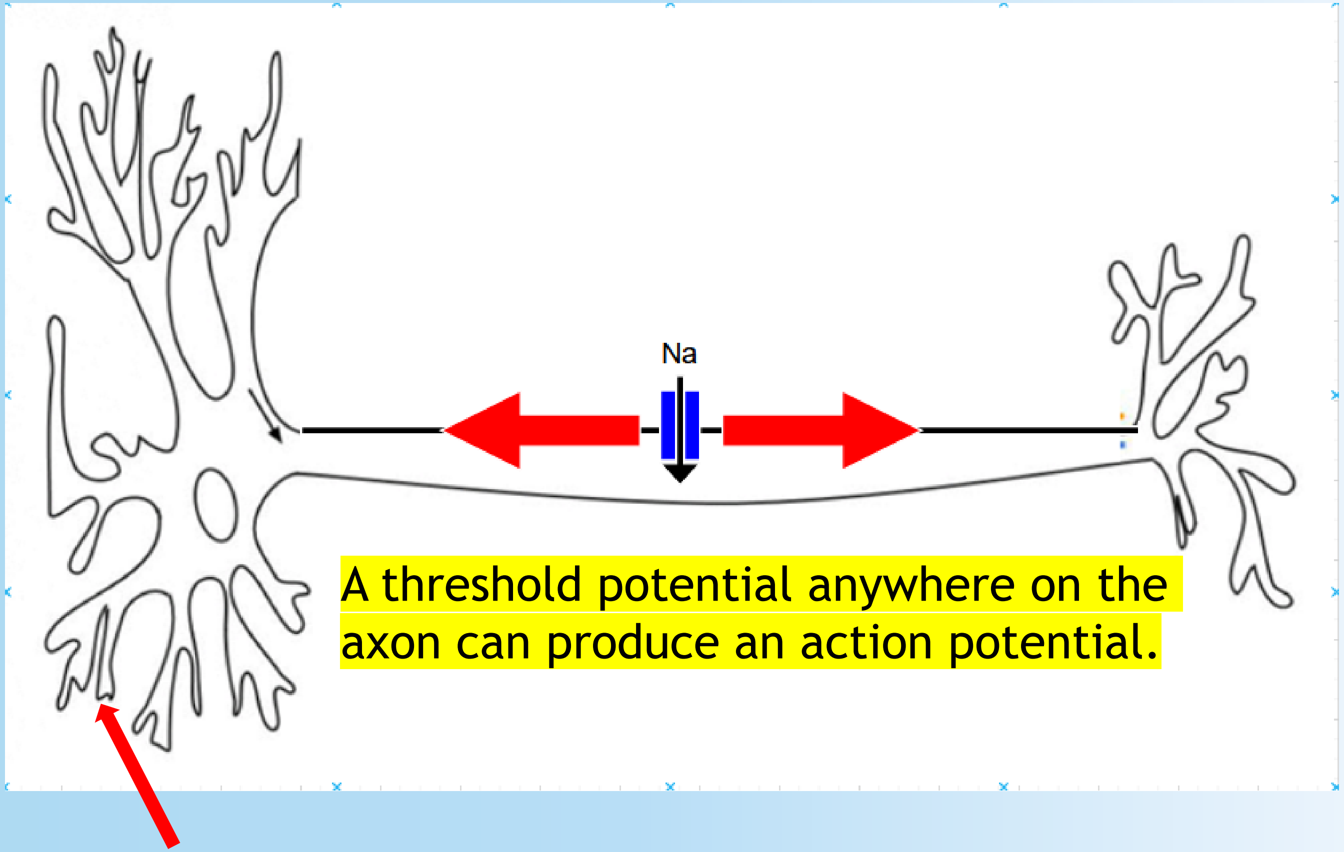
Table of Contents



studyaid

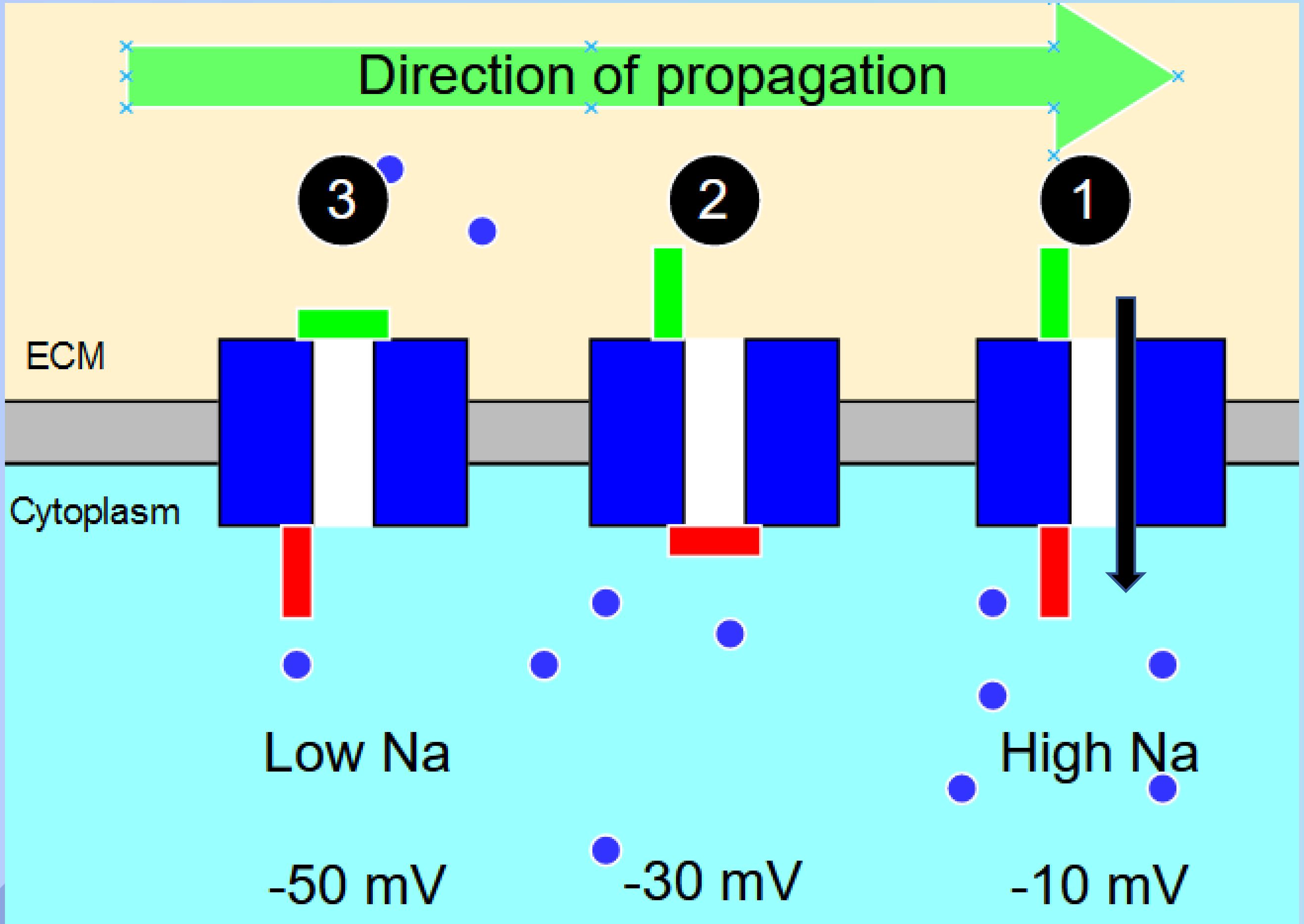
Propagation of the action potential

- The action potential is propagated by activation of V-gated Na^+ channels in order.
- The action potential propagates away from the point of initiation.
- Orthodromic conduction means in the "correct" direction. (dendrite → axon)



Physiologically, action potentials are initiated at the dendrites.

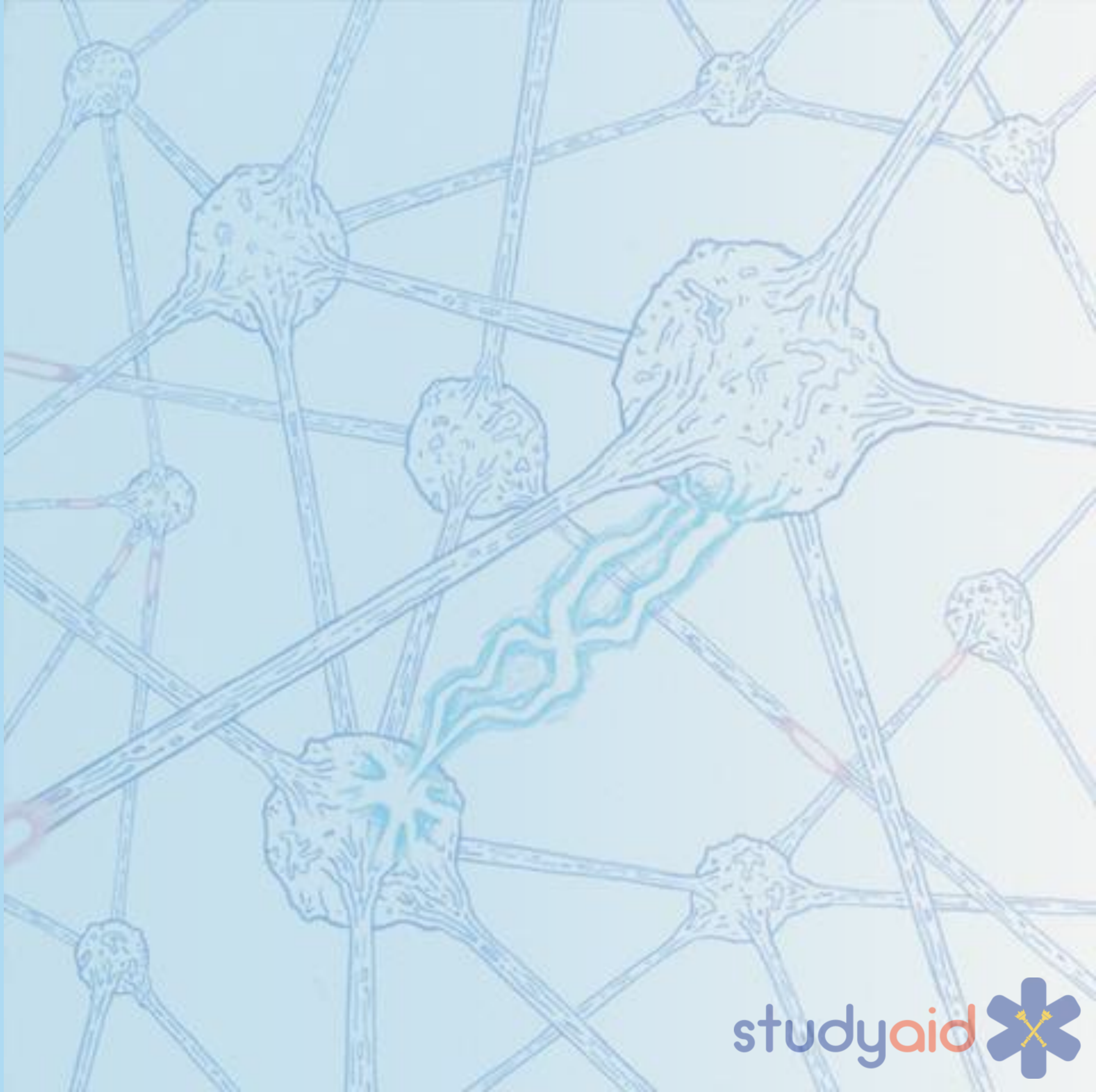
Why refractory periods are important



- 1 is open and 2 is inactivated
- This gives time for the membrane potential to be restored at 2 (by K^+ channels)
- By the time 3 reactivates, the membrane is repolarized

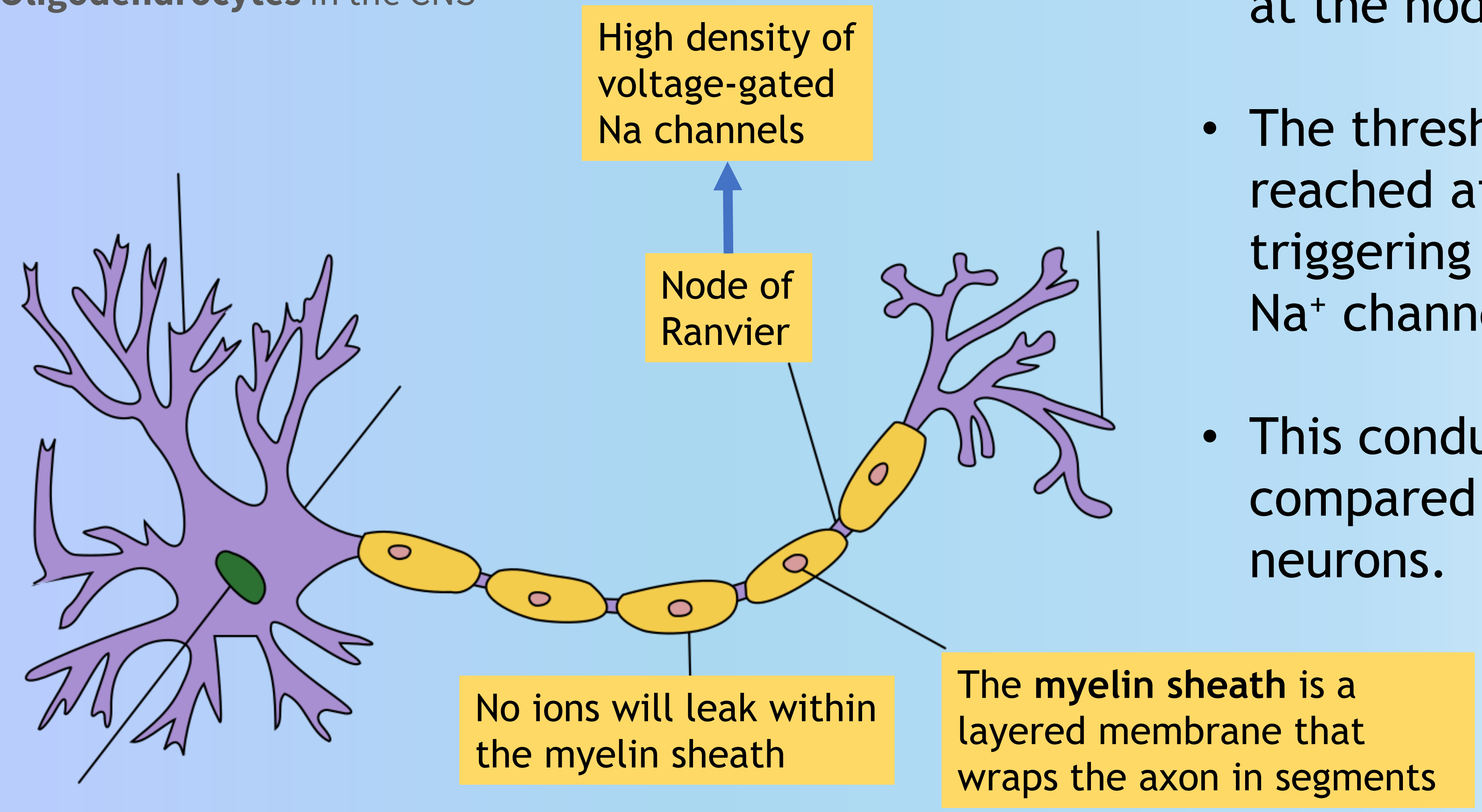
studyaid

Table of Contents



Myelin sheath and saltatory conduction

Schwann cells in the PNS
Oligodendrocytes in the CNS

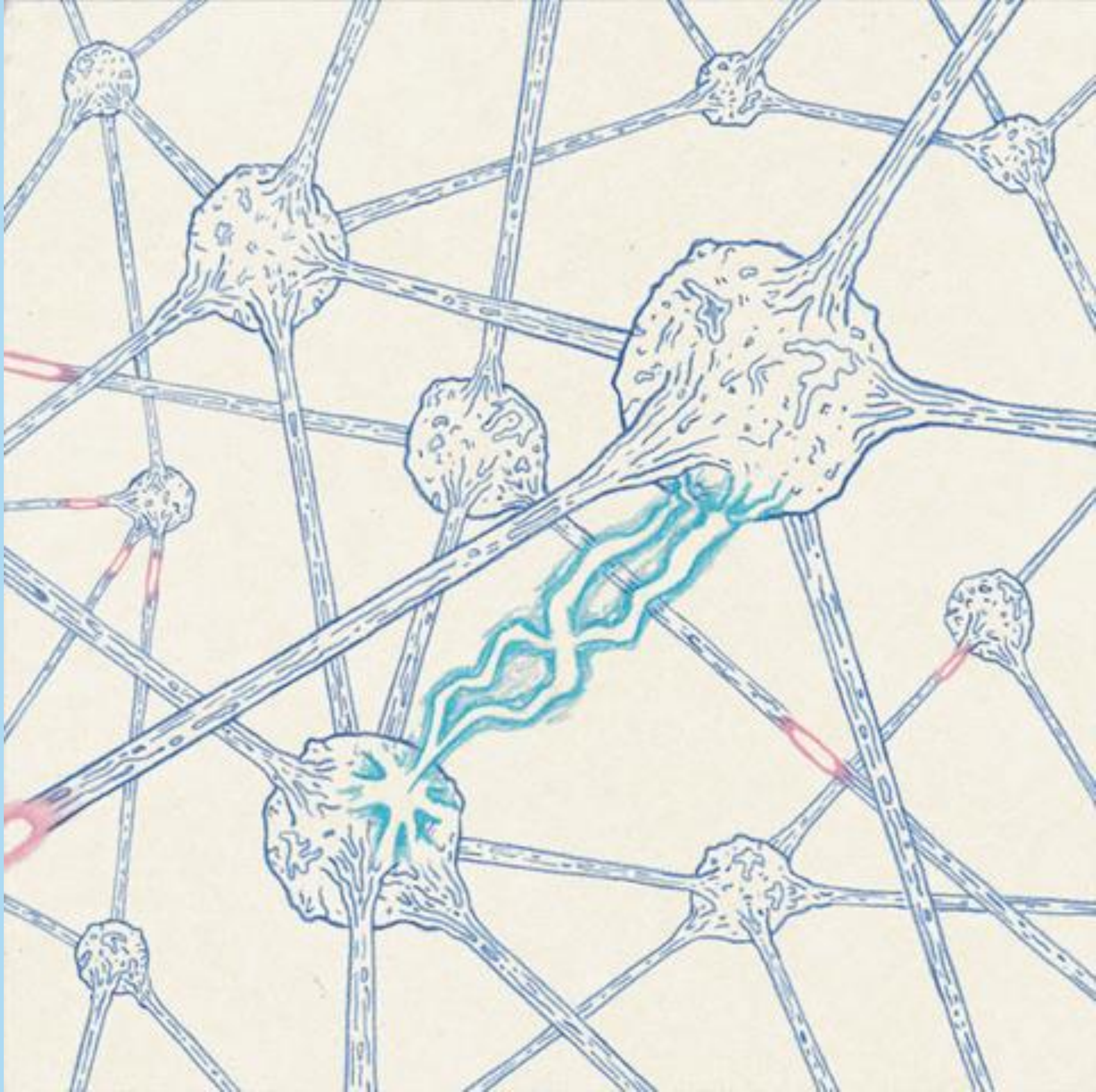


- A massive Na^+ influx occurs at the node of Ranvier.
- The threshold potential is reached at the next node, triggering the next group of Na^+ channels.
- This conduction is VERY FAST compared to unmyelinated neurons.

studyaid

Table of Contents

- Quick anatomy ✓
- Potentials ✓
  - Membrane
  - Equilibrium
  - Resting
- Phases of action potential ✓
  - [illegible]tion
  - Depolarization and voltage-gating
  - Repolarization
  - Hyperpolarization
- Refractory periods ✓
- Propagation ✓
- Myelin sheath ✓



Quiz time!

www.wooclap.com/POTENTIAL

studyaid