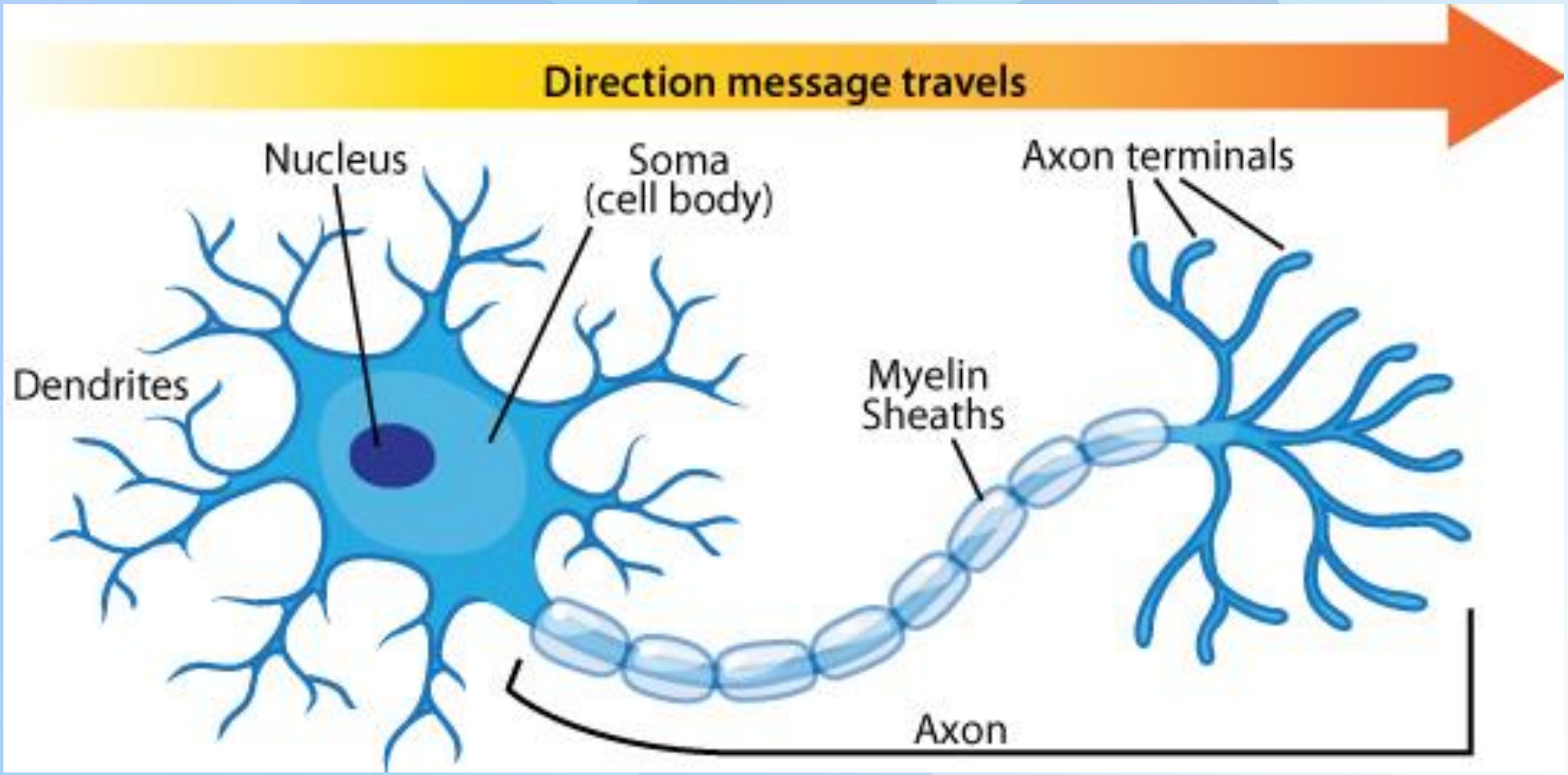
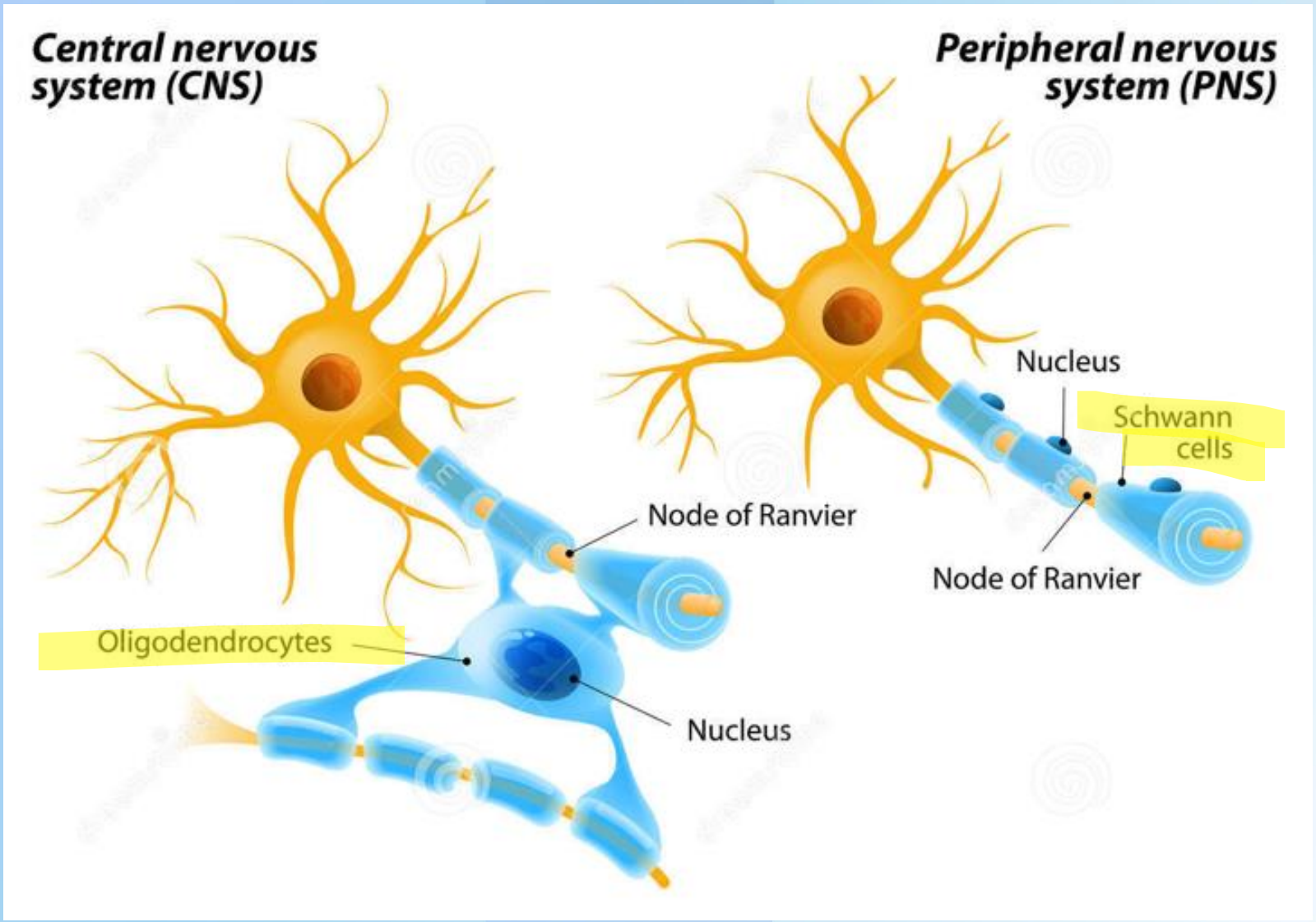
ACTION POTENTIAL

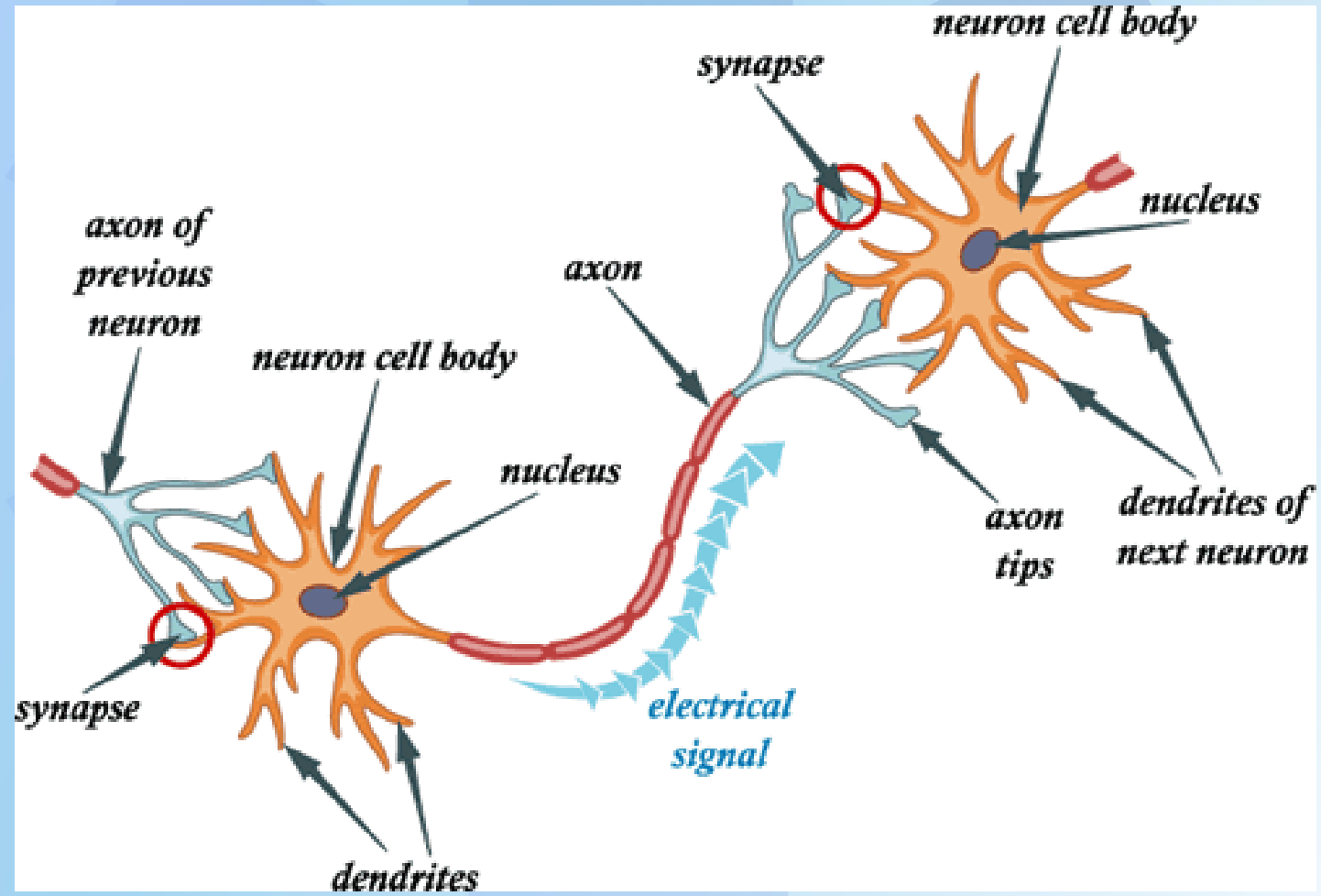
By Marte Rydland

Nerve anatomy




Central nervous system (CNS)
Peripheral nervous system (PNS)
Nucleus
Schwann cells
Node of Ranvier
Node of Ranvier
Oligodendrocytes
Nucleus

What is action potential?



Stages of action potential

- Resting stage
- Depolarization stage
  (“upstroke”)
- Repolarization stage
  (“downstroke”)

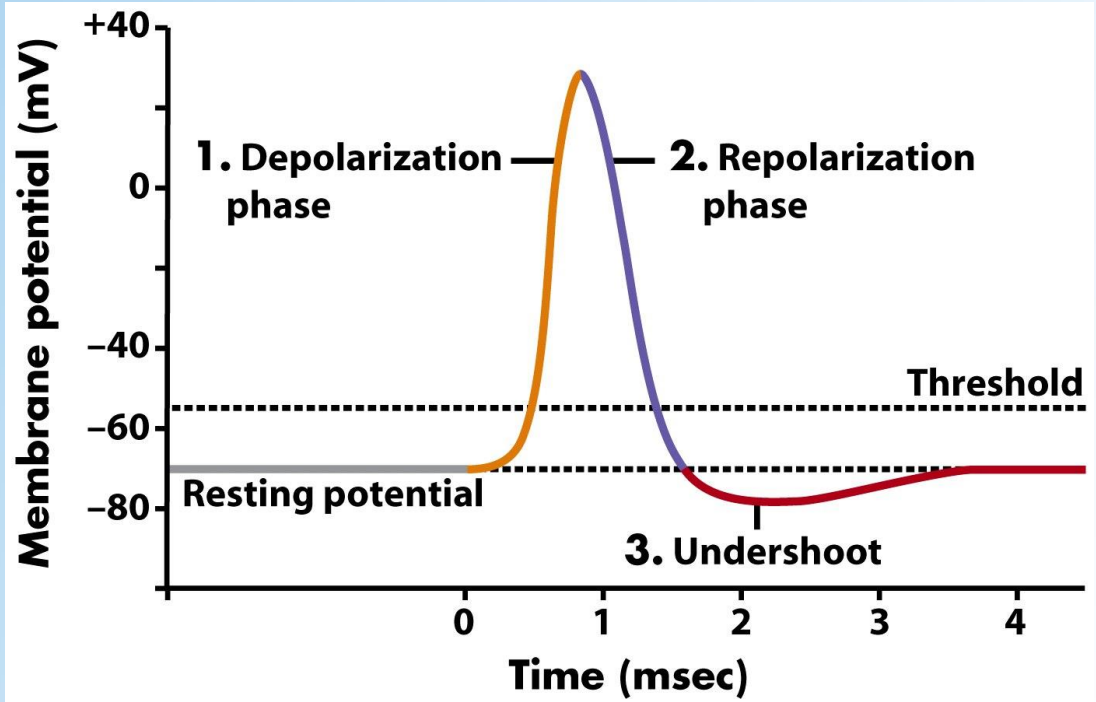
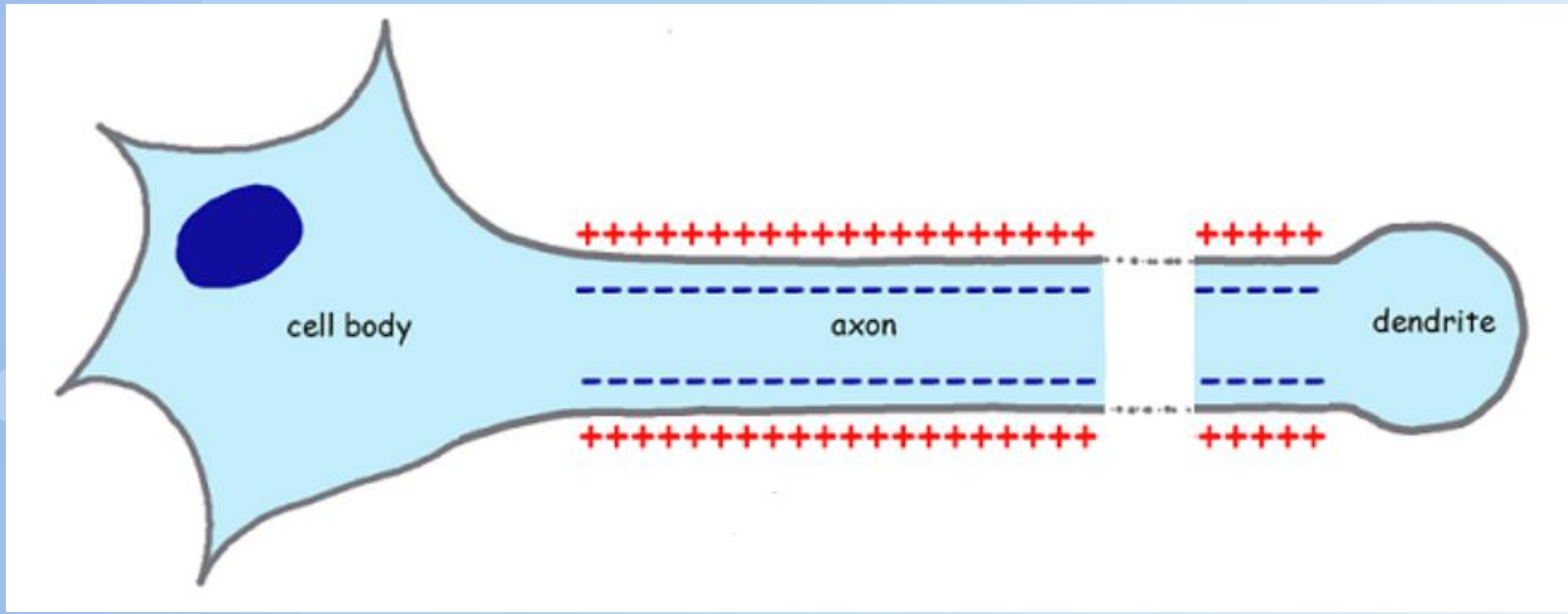


Figure 45-5 Biological Science, 2/e

Resting cell



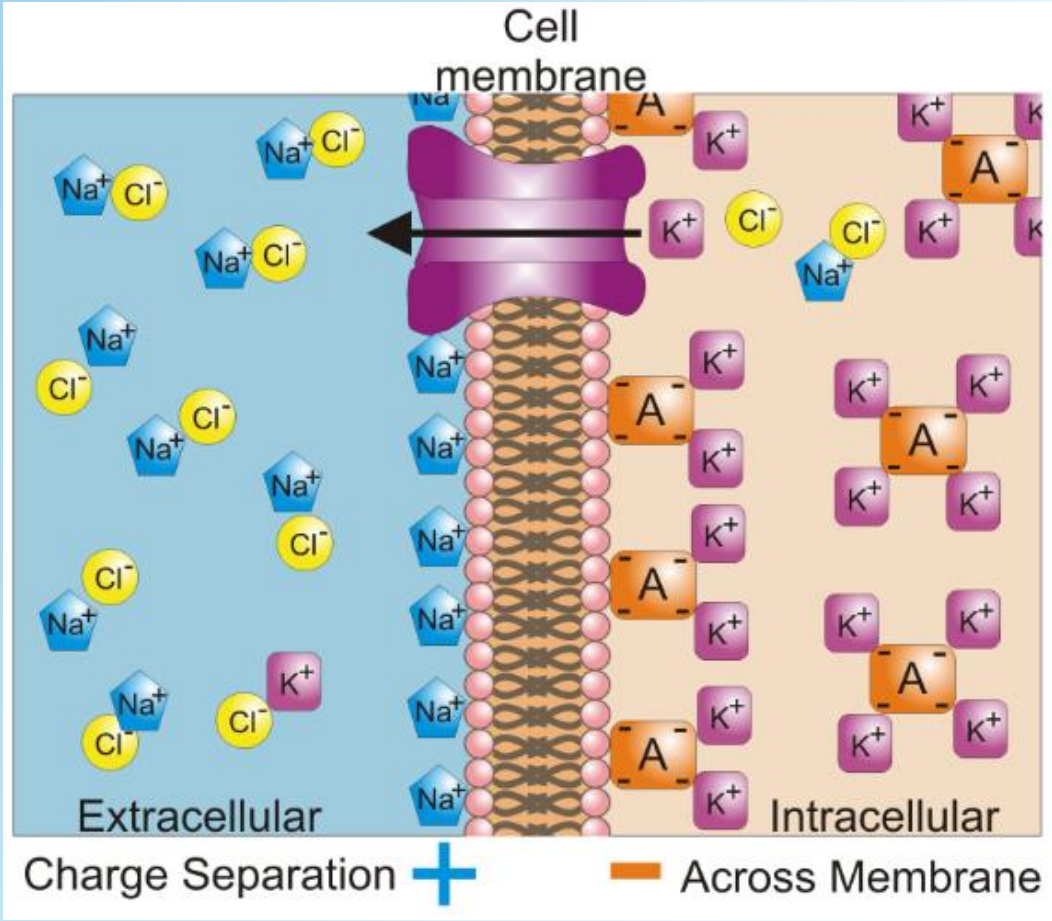
- Cell membrane potential
- Cation influx = more positive
- Cation efflux = less positive
- Na^+ and K^+ are cations!!

- More positive = less negative
- Less positive = more negative

Resting stage

Resting membrane potential: **-70 mV**

1. <u>K^+-Na^+ leak channels</u>
   - Passive
   - K^+ prime determinant
2. <u>Na^+-K^+ ATPase</u>
   - maintains negative charge
   - 3 Na^+ leave cell, 2 K^+ enter cell

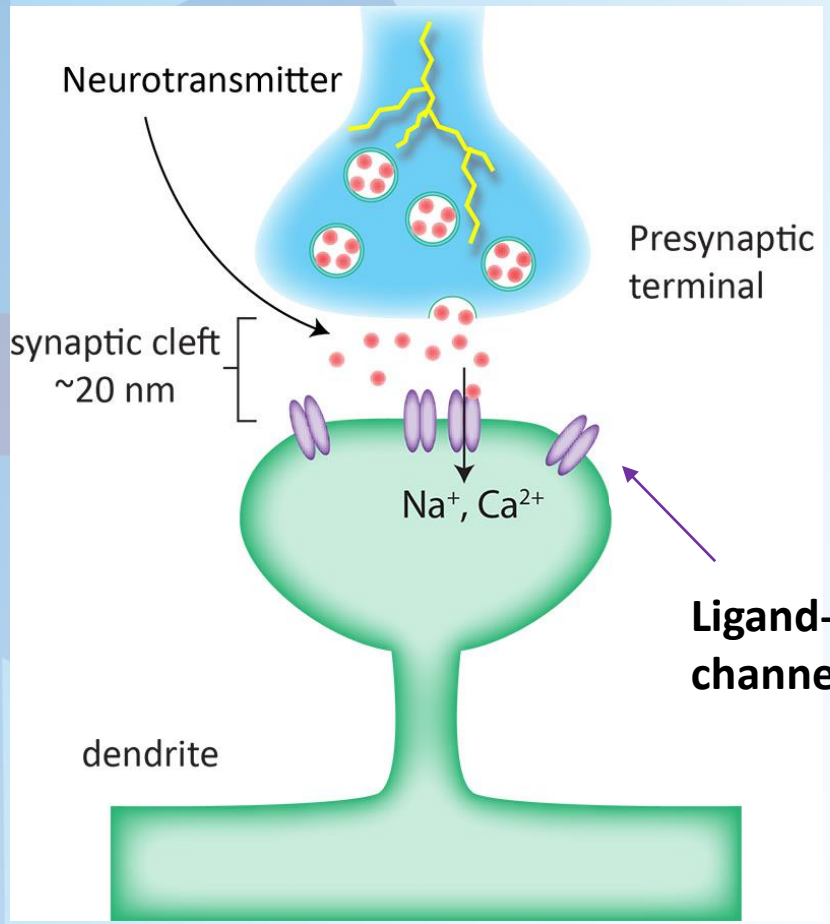


Equilibrium potentials:

$$E_{Na^+} = +65\ mV$$
$$E_{Ca^{2+}} = +120\ mV$$
$$E_{K^+} = -85\ mV$$
$$E_{Cl^-} = -90\ mV$$

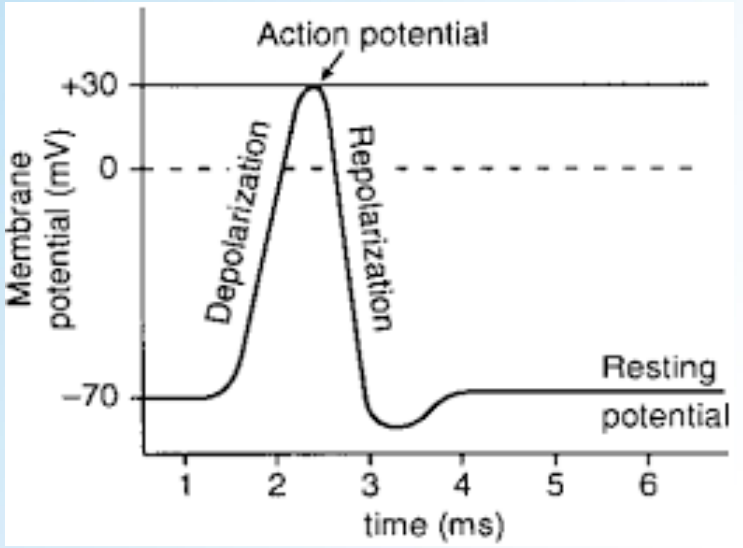
How is an action potential initiated?

- Synapse
- Neurotransmitters
- Chemical signal
- Receptors = ligand-gated ion channels
  - Na^+, Cl-, Ca^{2+}
  - K^+, A-
- Electrical signal
- Simultaneous stimulation of dendrites



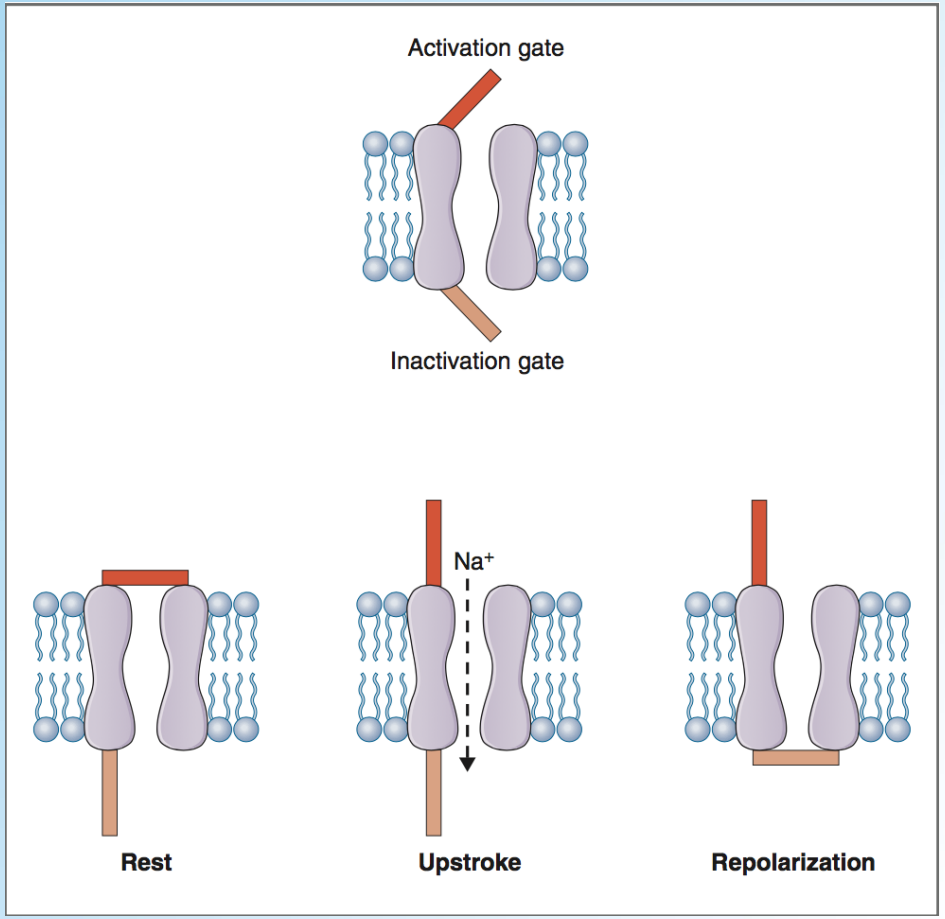
Depolarization stage

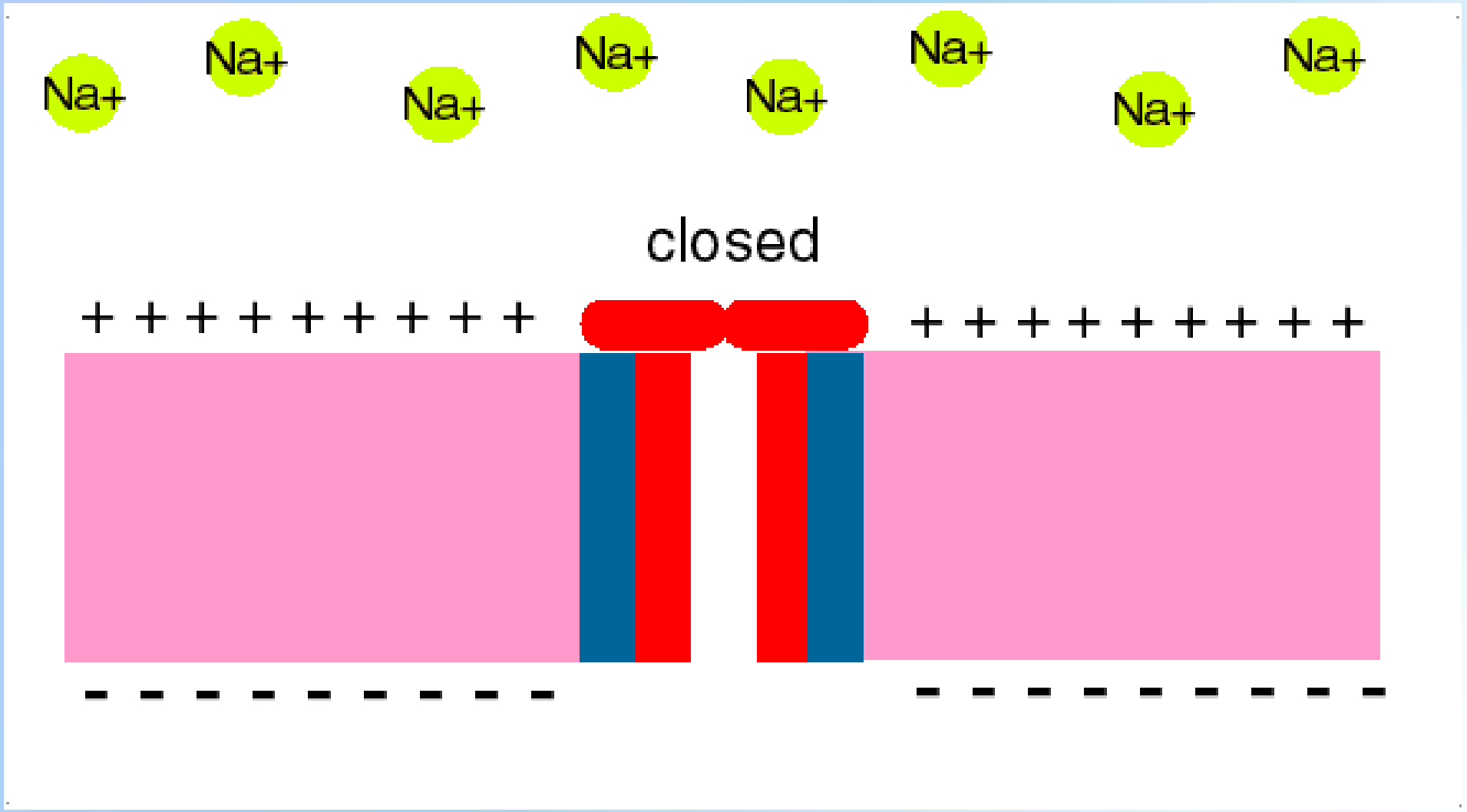
- "Upstroke" phase
- *Threshold potential* = **-55 mV**
- Na^+ prime determinant
- Na^+ rushes into the cell = membrane potential becomes <u>less negative</u>
- Voltage-gated Na^+ channels
  - Activated by change in voltage
  - Responsible for the main influx of Na^+ ions
  - Fast channels
- Peak at **+40 mV**
- All-or-nothing: Same amplitude always



Inactivation of voltage-gated Na+ channels

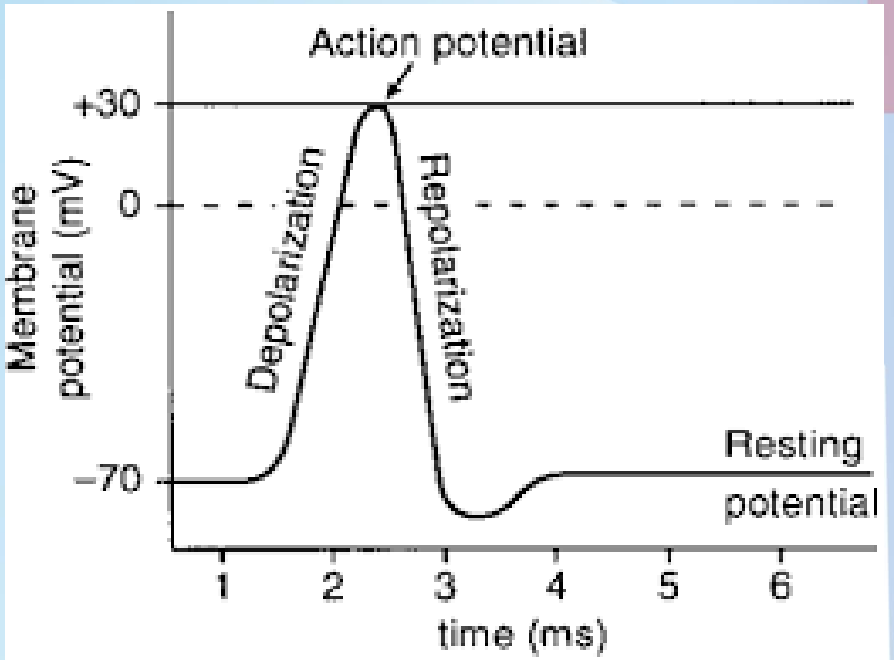
- At **+ 40mV**
- Activation gate – quick
- Inactivation gate – slow
- 3 states:
  1. Closed = rest
  2. Open = depolarization
  3. Inactivated = repolarization
     - No AP possible




Na+
Na+
Na+
Na+
Na+
Na+
Na+
closed
+ + + + + + + + + +
+ + + + + + + + + +
- - - - - - - - - -
- - - - - - - - - -

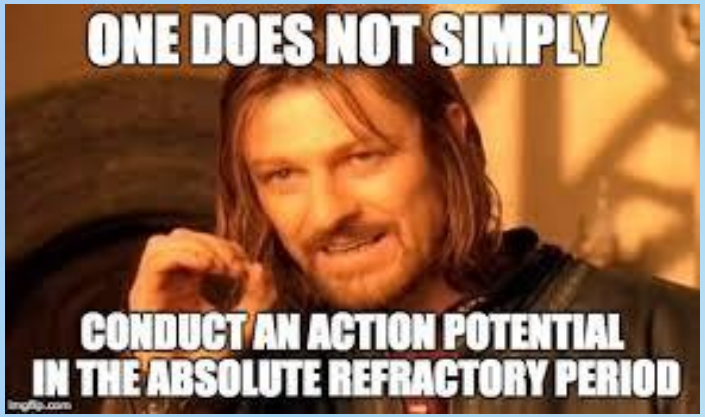
Repolarization stage

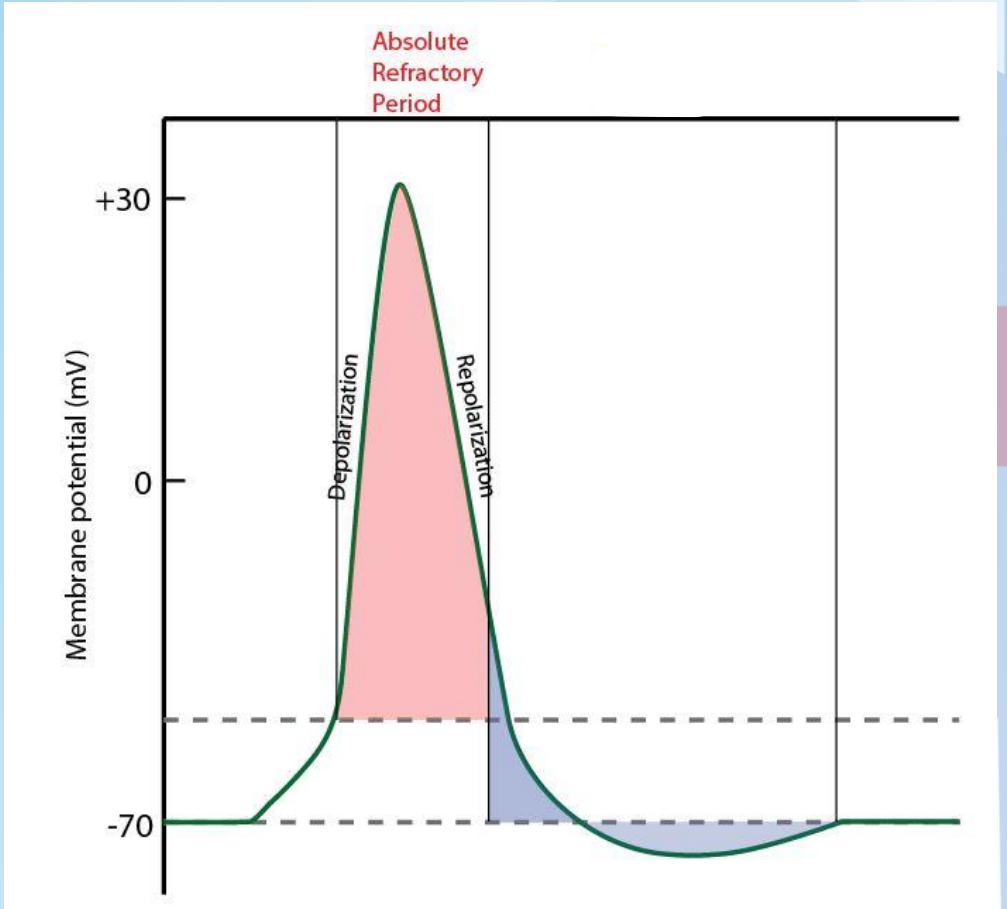
- “Downstroke” phase
- *Hyperpolarization:* decreased membrane potential
- Inactivated voltage-gated Na^+ channels
- Voltage-gated K^+ channels opens
  - Start **0 mV**
  - Peak **40 mV**
- Efflux of K^+ predominates
- Na^+/K^+ ATPase



Absolute refractory period

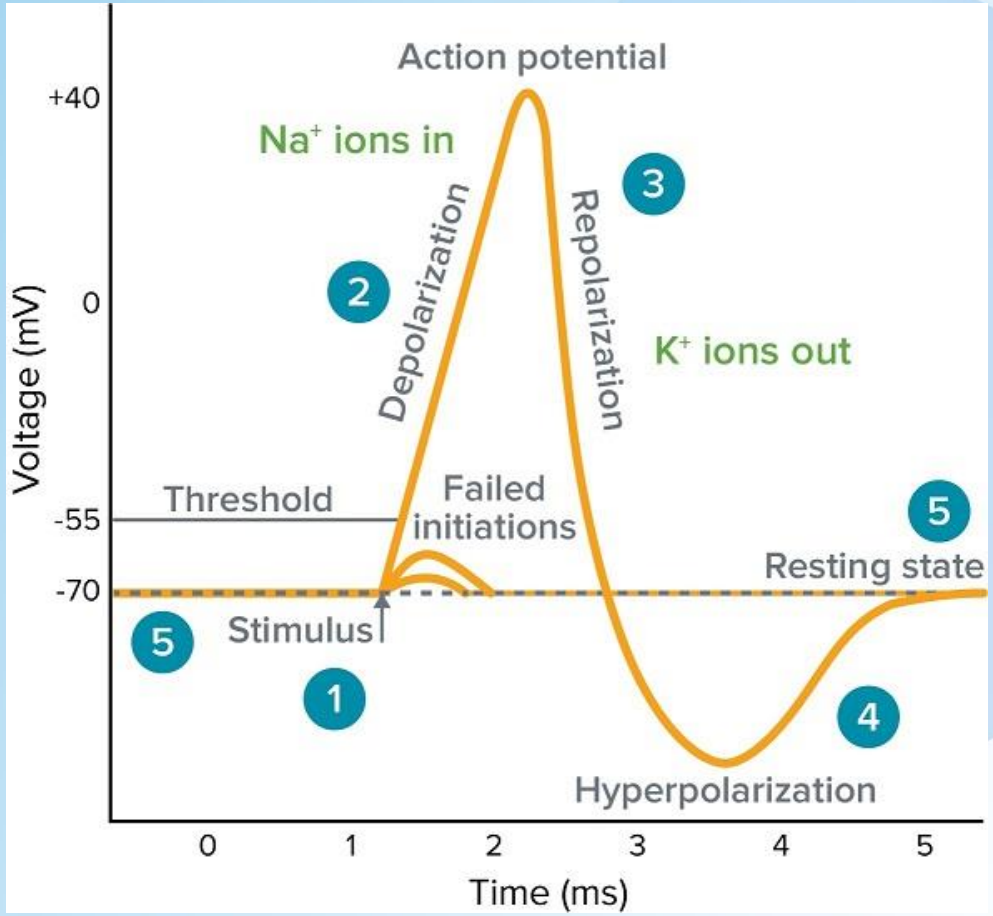
- No new depolarization
- From the start of depolarization
- Inactivated voltage-gated Na^+ channels
- Open voltage-gated K^+ channels





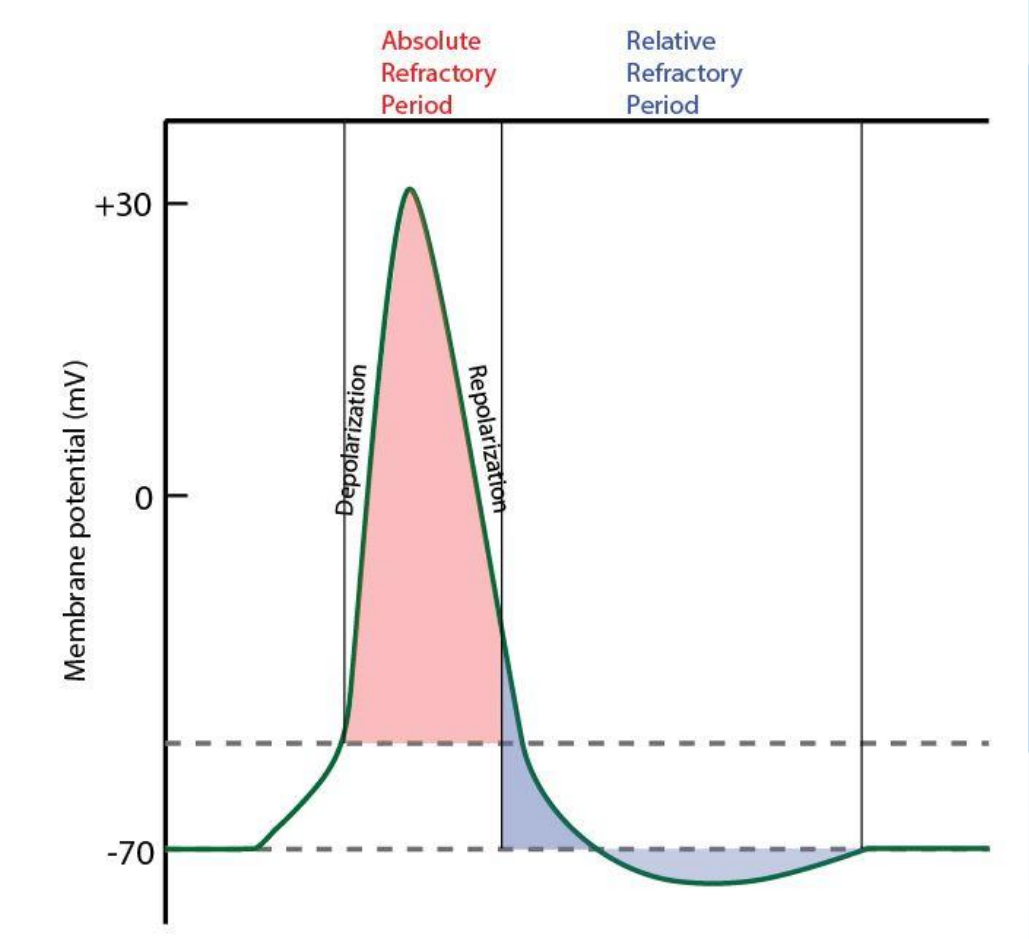
Hyperpolarizing afterpotential

- Undershoot
- No inactivation state of voltage-gated K^+ channels
- **-80 mV**
- Repolarization of inactivated Na^+ channels

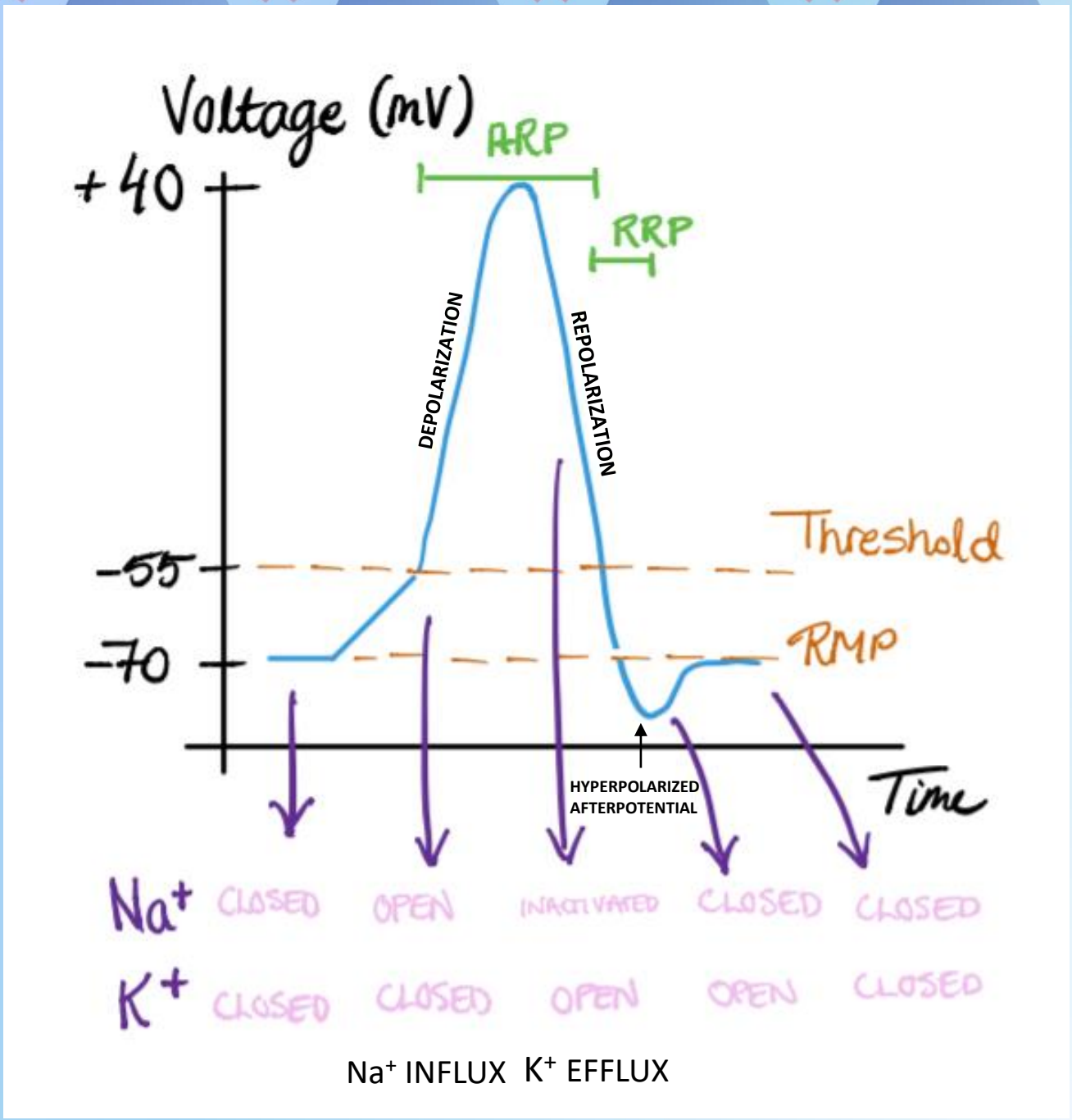


Relative refractory period

- End of *absolute refractory period*
- Closed voltage gated Na^+ channels
- Open voltage-gated K^+ channels
- Very strong stimuli only



Recap:

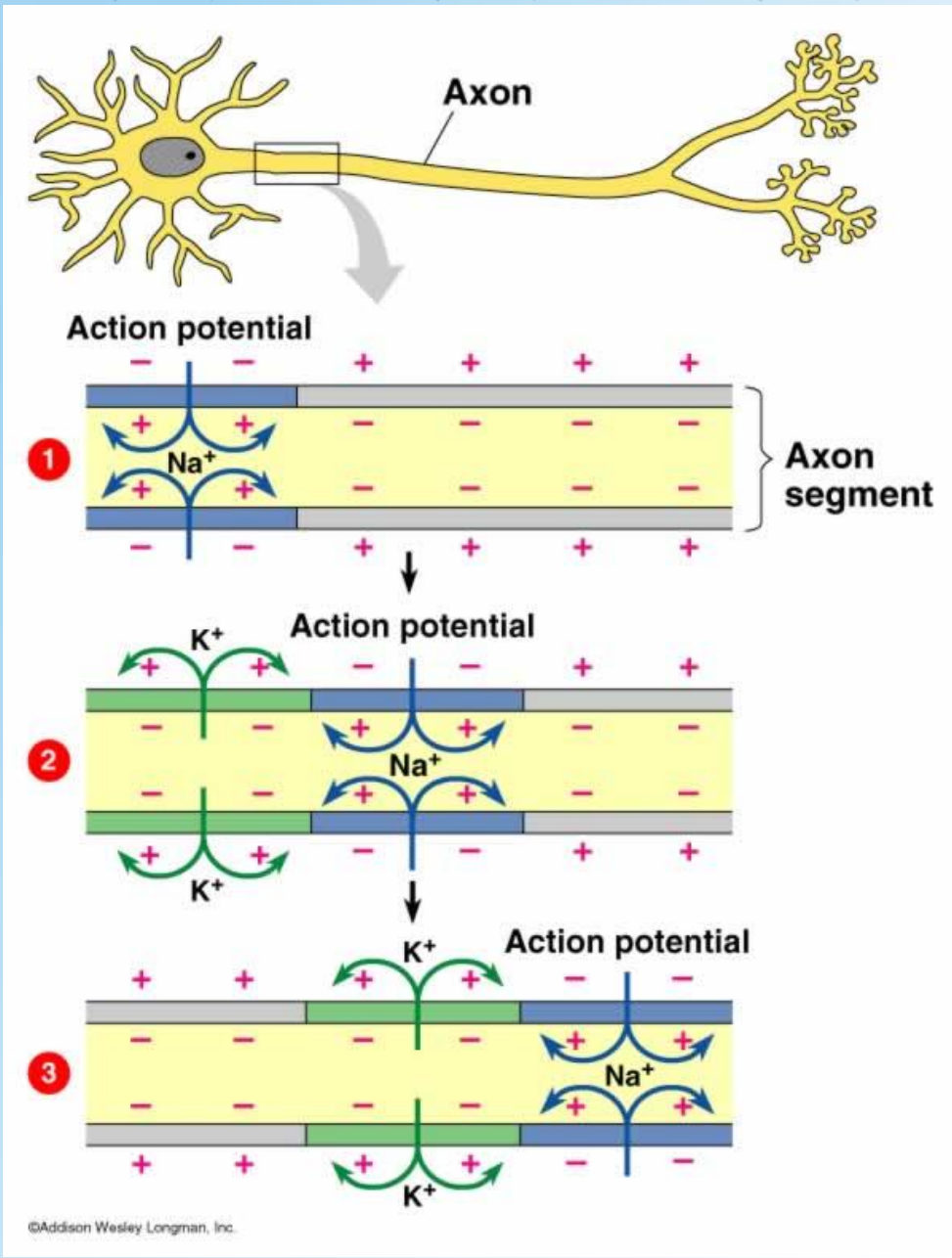


Na^+ INFLUX K^+ EFFLUX

How does action potential travel?

Propagation

The spread of local currents from active regions of the axon to inactive regions



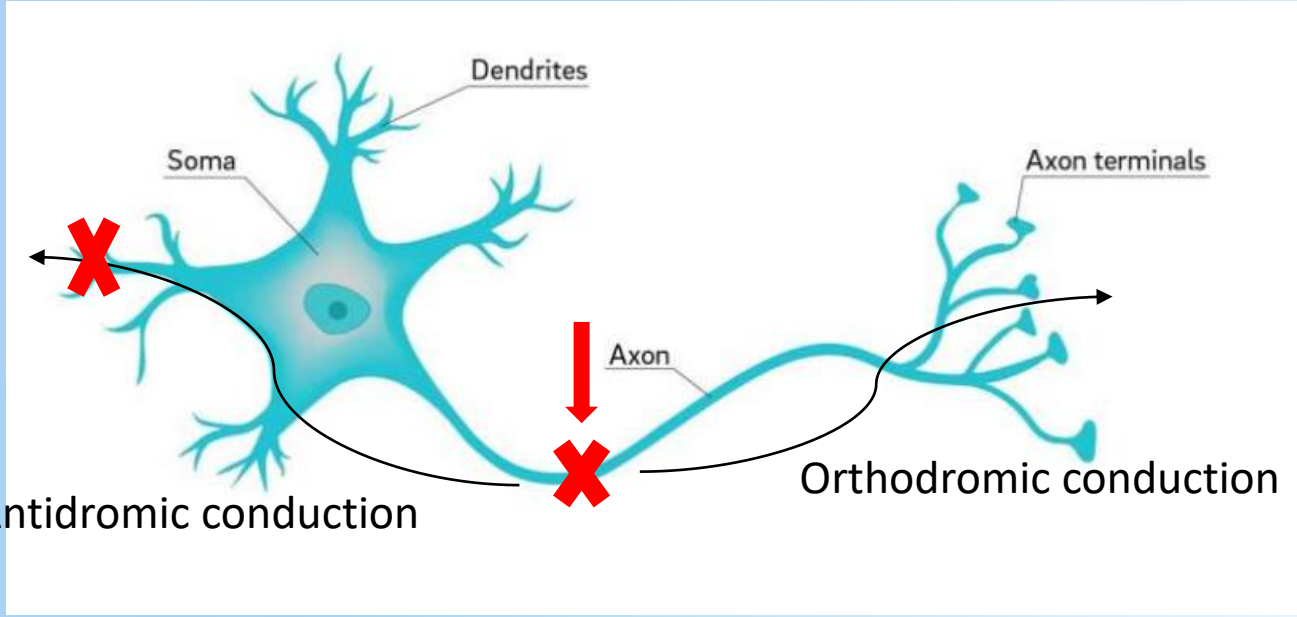
Conduction direction

Orthodromic

- From dendrite to axon terminal
- Normal

Antidromic

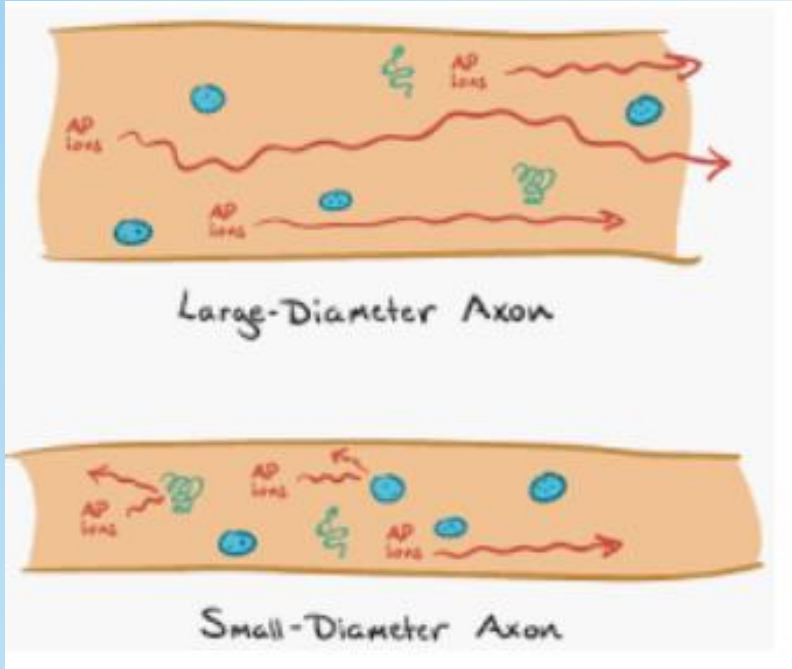
- Towards dendrite/synapse
- Abnormal
- Cancelled out



How can propagation be sped up?

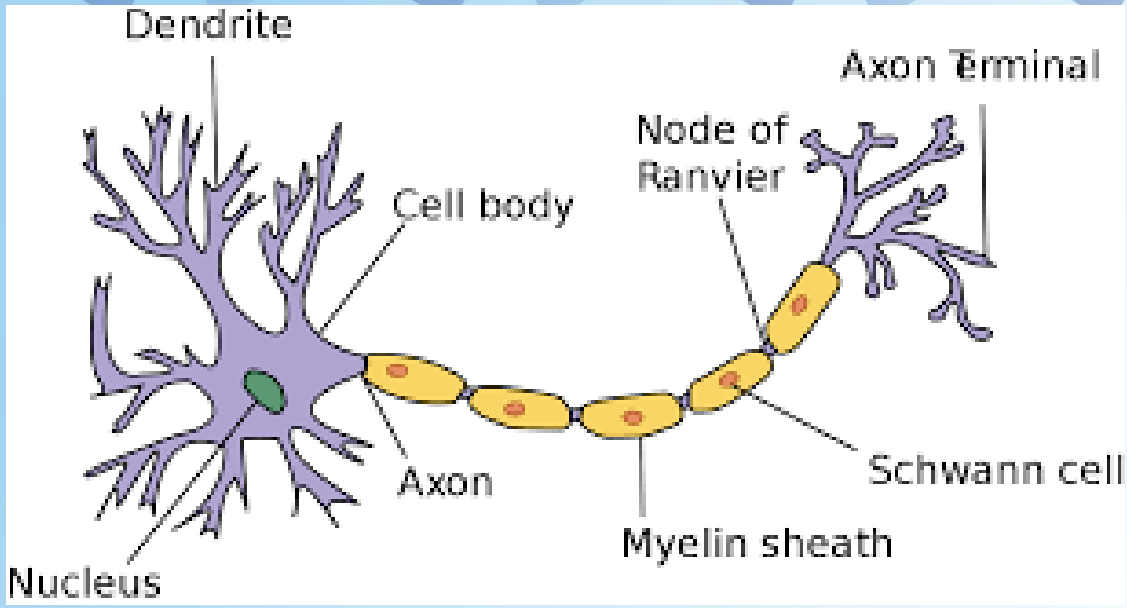
1. Nerve diameter
2. Internal resistance
3. Membrane resistance

Cable properties

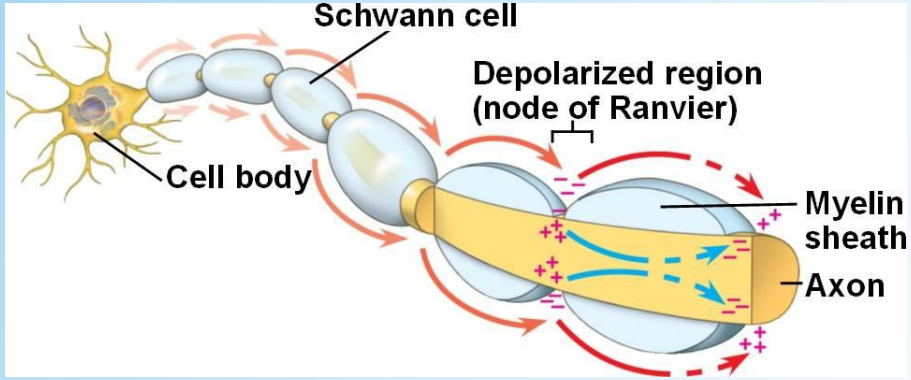


- Nerve diameter
  - Directly proportionate to velocity
  - The bigger, the faster
  - Anatomical restrictions on size
- Internal resistance
  - Inversely proportionate to diameter
  - The less internal resistance, the faster
- Membrane resistance
  - Makes impulse travel along axon interior rather than on membrane
  - The more membrane resistance, the faster
  - Myelin sheath

Myelination



- Increase membrane resistance
  - Increases conduction velocity
- Lipid sheaths
- Nodes of Ranvier
  - Non-myelinated areas of low membrane resistance
- Impulses “jump” from node to node
- *Saltatory conduction*
- Velocity x 50



Summary:

- Neurons & glial cells
- Neurotransmitters
  - Between neurons
  - chemical signal
- Action potential
  - Within neuron
  - Electrical signal

- RMP = **-70 mV** ⇨ **K^+** concentration gradient
- Threshold potential = **-55mV**
- Orthodromic conduction in stepwise fashion

	Initiation	Depolarization	Repolarization
Main determinant	Small Na+ influx	Rapid Na+ influx	K+ efflux
Main channel	Ligand-gated ion channels	Voltage-gated Na+ channels	Voltage-gated K+ channels
Activation of channel	Neurotransmitter	Depolarization	**0mV**
Membrane potential	From **-70mV** to **-55mV**	From **-55mV** to **+40mV**	From **+40mV** to **-70mV**

	Absolute refractory period	Relative refractory period
When	Depolarization + repolarization	Hyperpolarized afterpotential
Voltage-gated Na+ channels	Open + inactivated	Closed
Voltage gated K+ channels	Closed + open	Open
New AP conduction	No!!	Only with strong stimulus