Faculty of Veterinary and Agricultural Sciences

Nerve Conduction I: The neuron, membrane potentials, and action potentials

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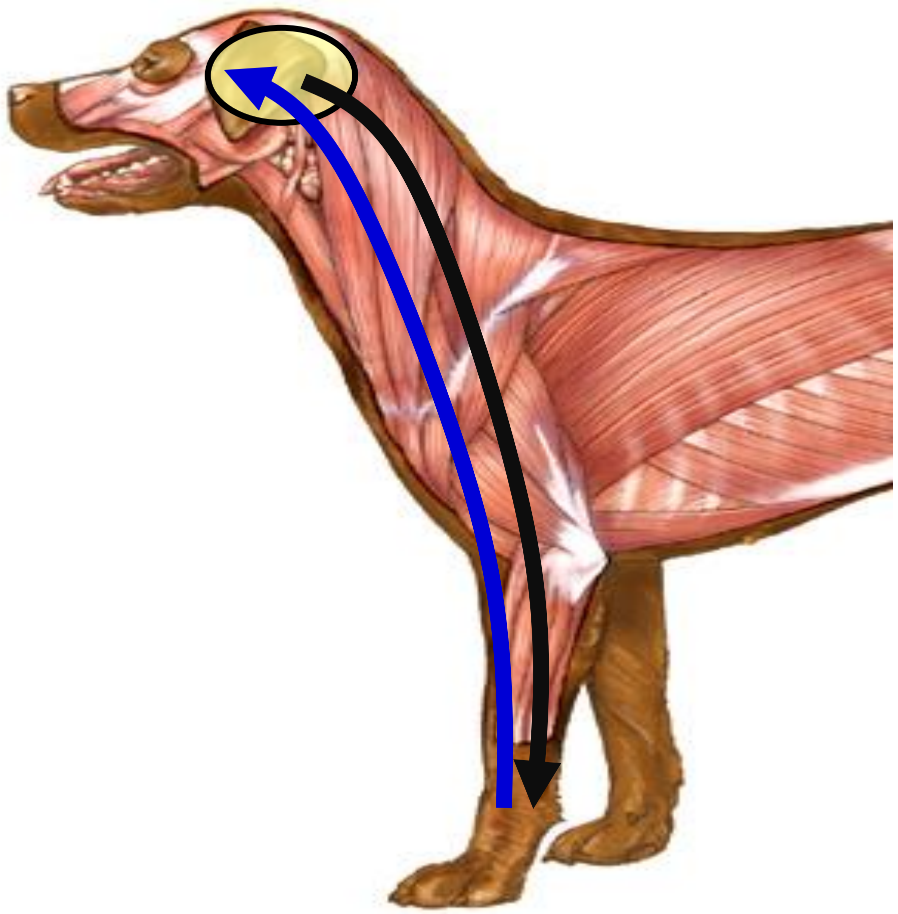
VETS30015 / VETS90121

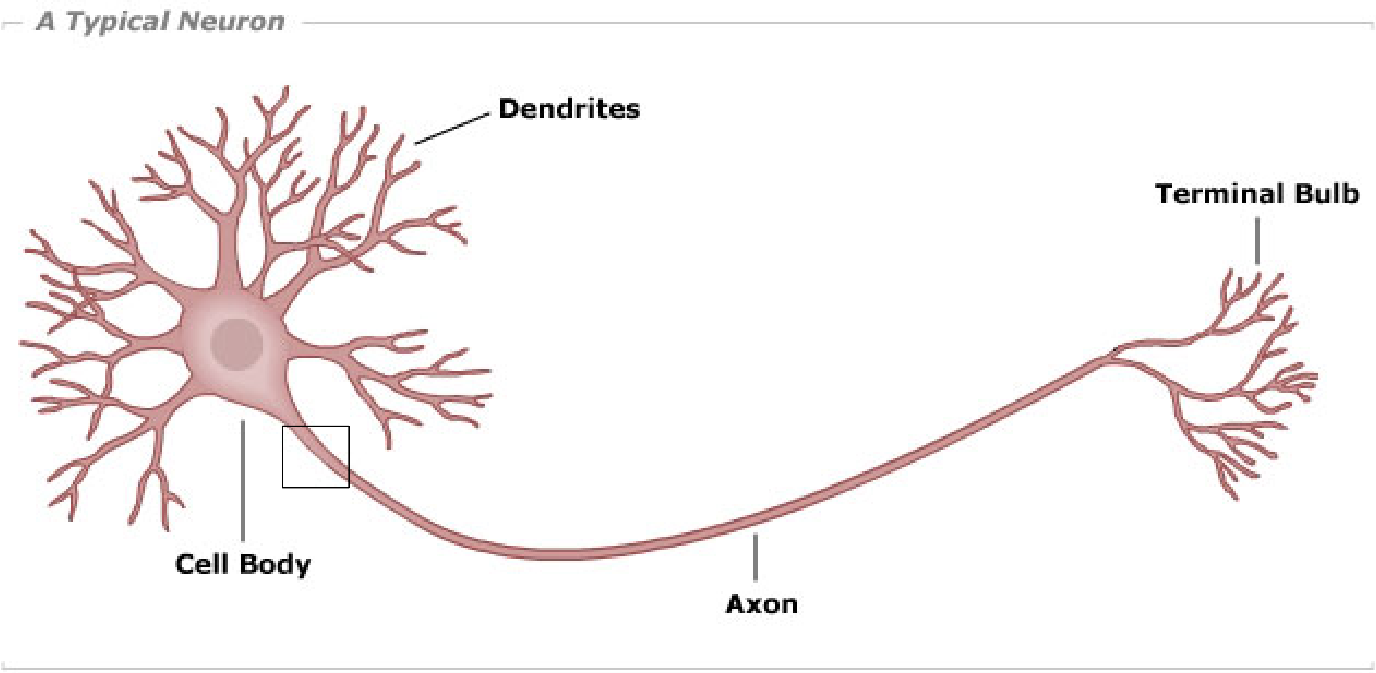
Nerves send discrete messages to and from the brain

- **Sensory or afferent neurons**

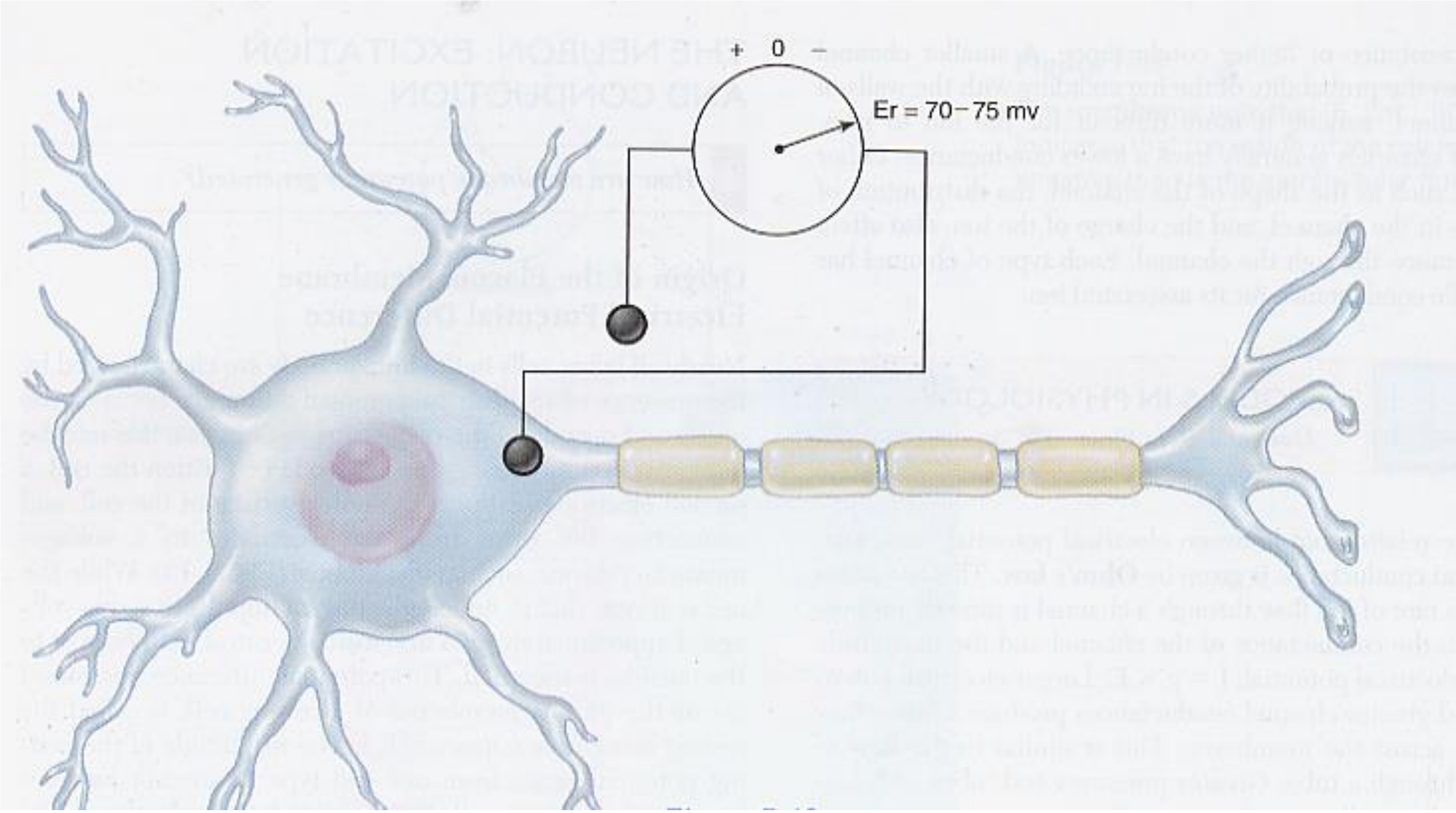
- **Motor neurons or efferent neurons**



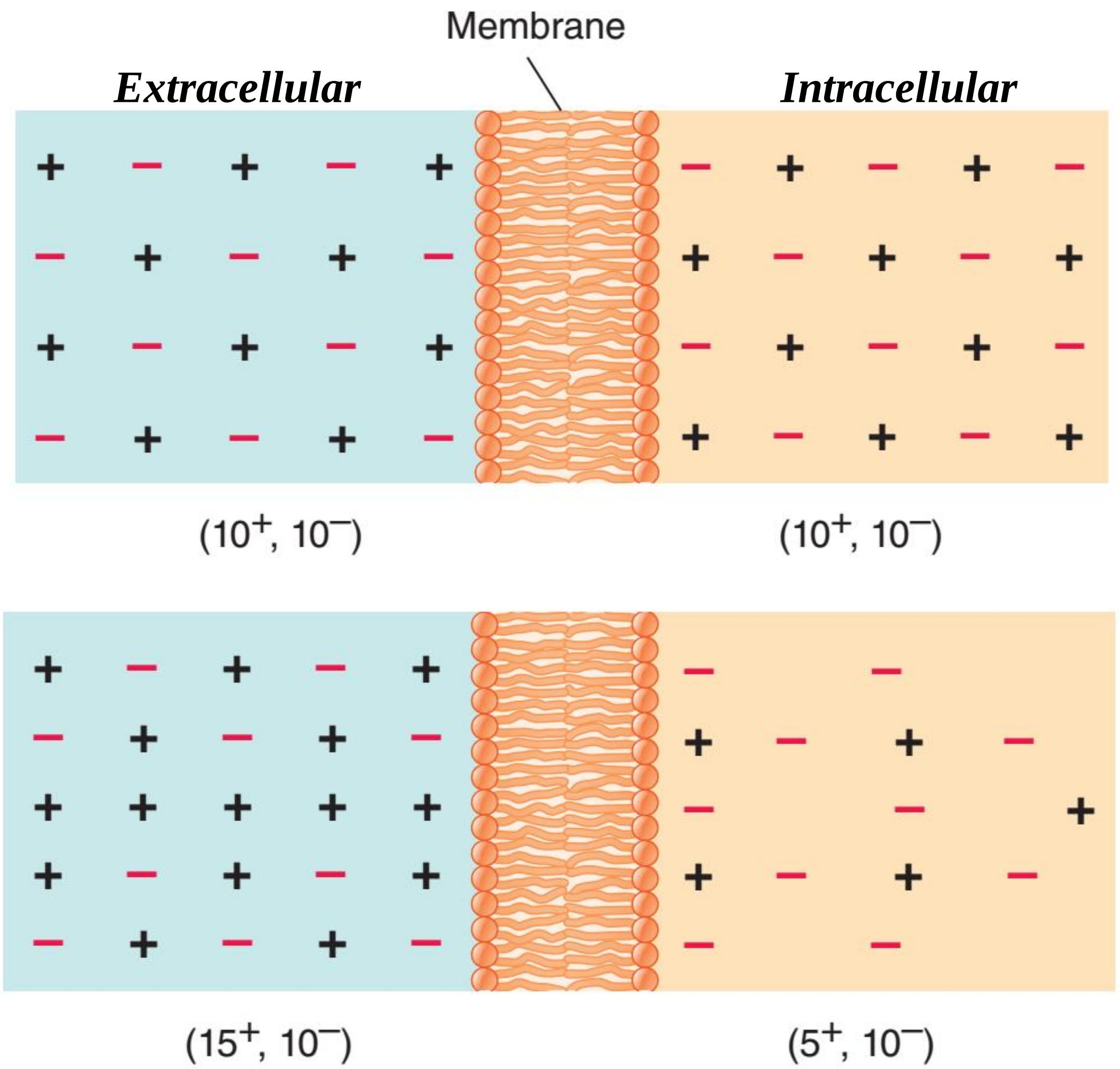
- How are signals transmitted by neurons?



Membrane potential

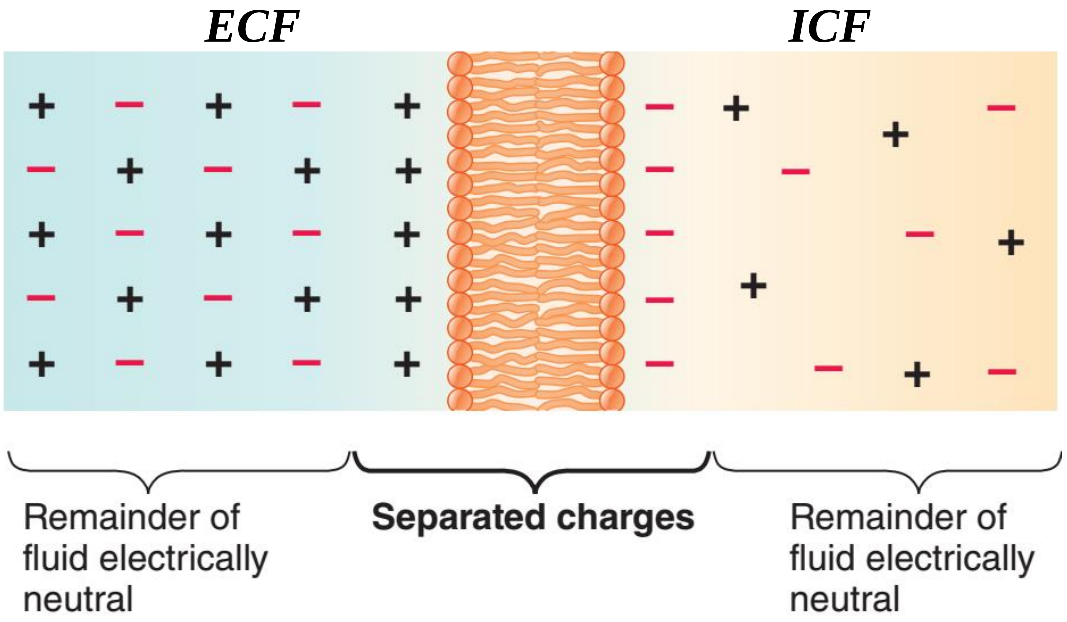


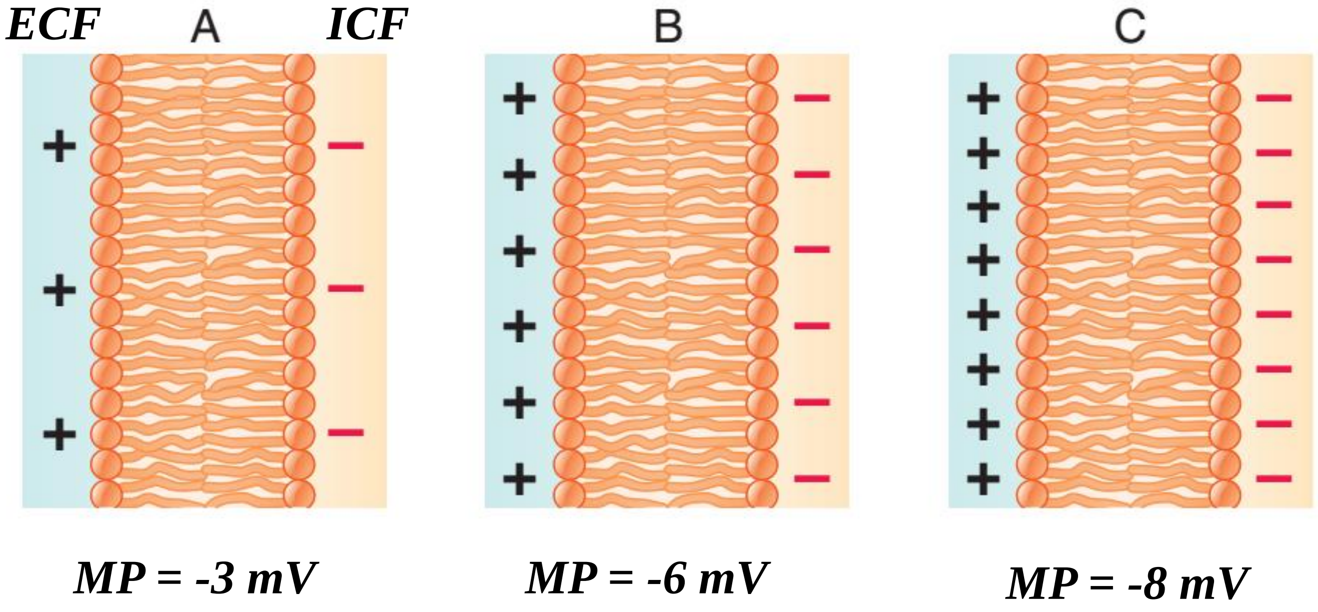
Ionic Basis of Membrane Potential



Neutral state
MP = 0 mV

Polarised state
MP = - mV


ECF
ICF
Remainder of fluid electrically neutral
Separated charges
Remainder of fluid electrically neutral

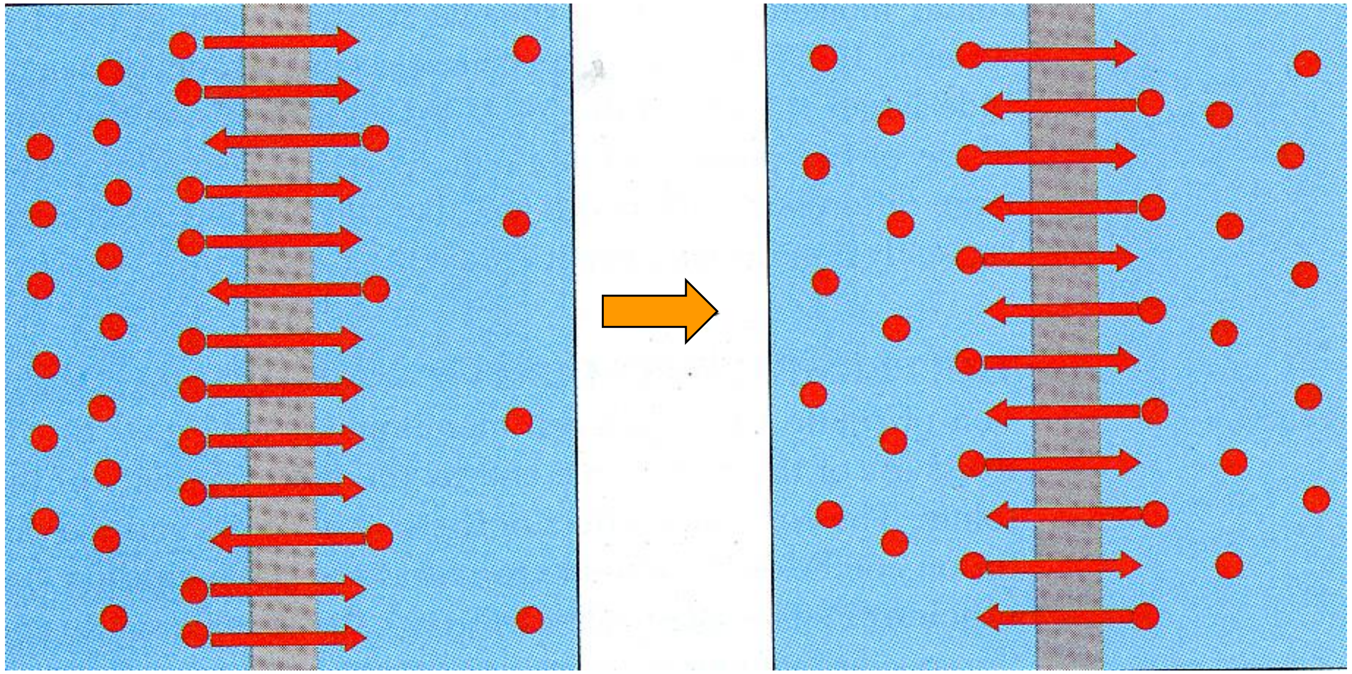

ECF
A
ICF
B
C
MP = -3 mV
MP = -6 mV
MP = -8 mV

Intra- and extracellular Ion concentrations

Ion	Extracellular Concentration*	Intracellular Concentration*
Na^+	150	15
K^+	5	150
A^-	0	65

*Concentration expressed in millimoles per liter, mM

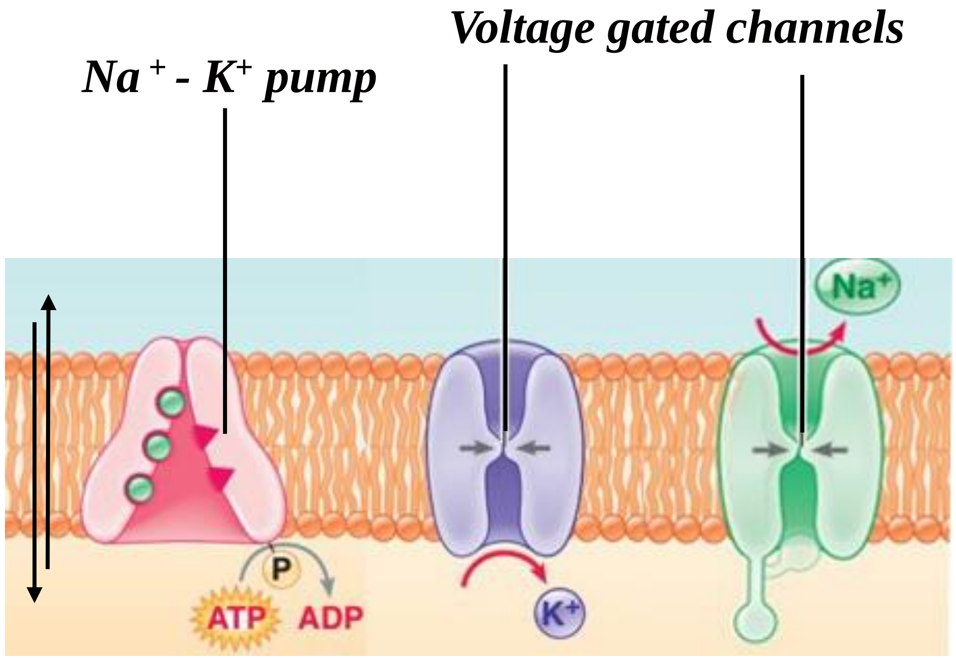
Diffusion of solutes across a biological membrane



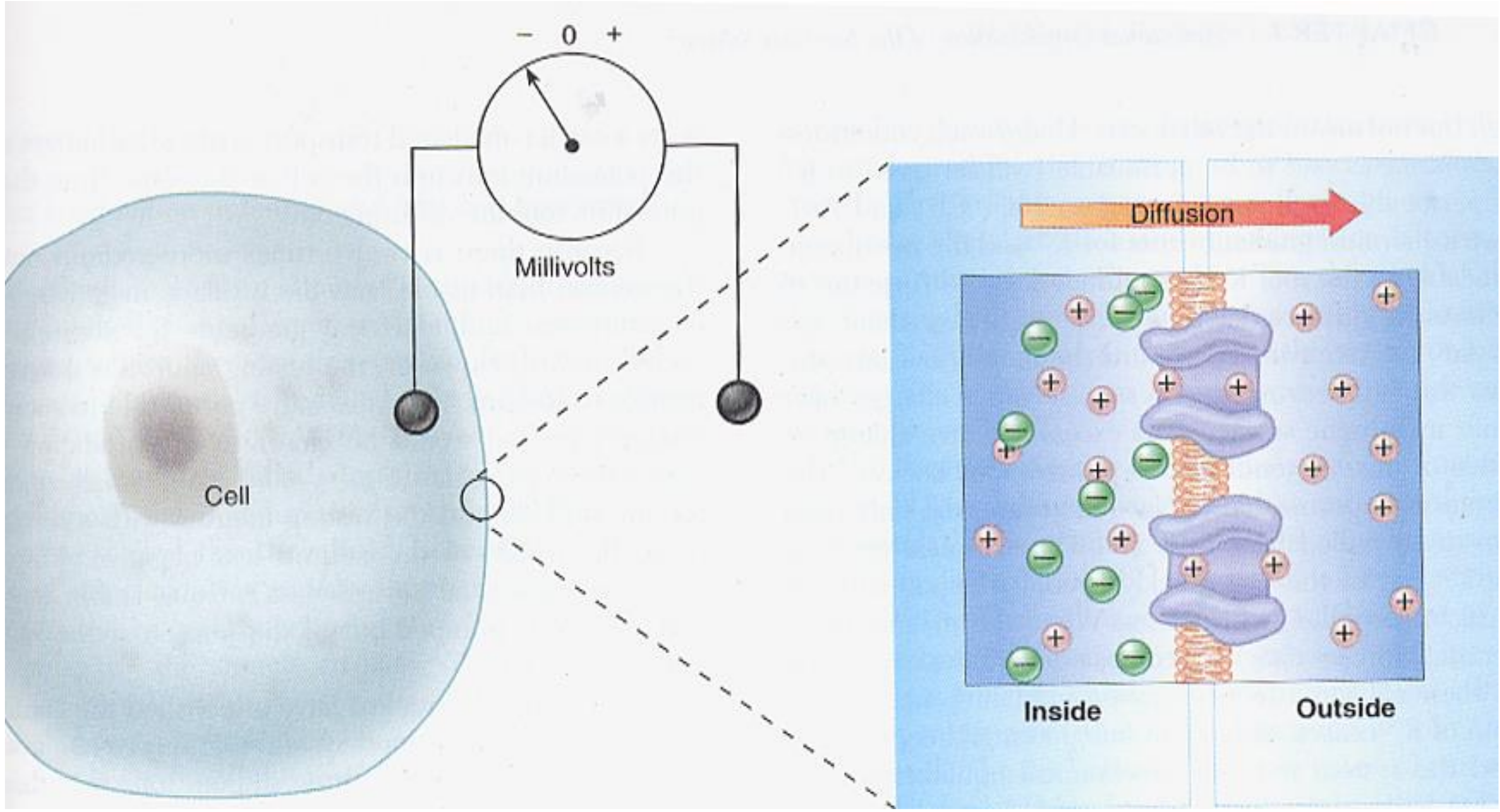
[High] [Low] Equilibrium

Permeability of cell membranes

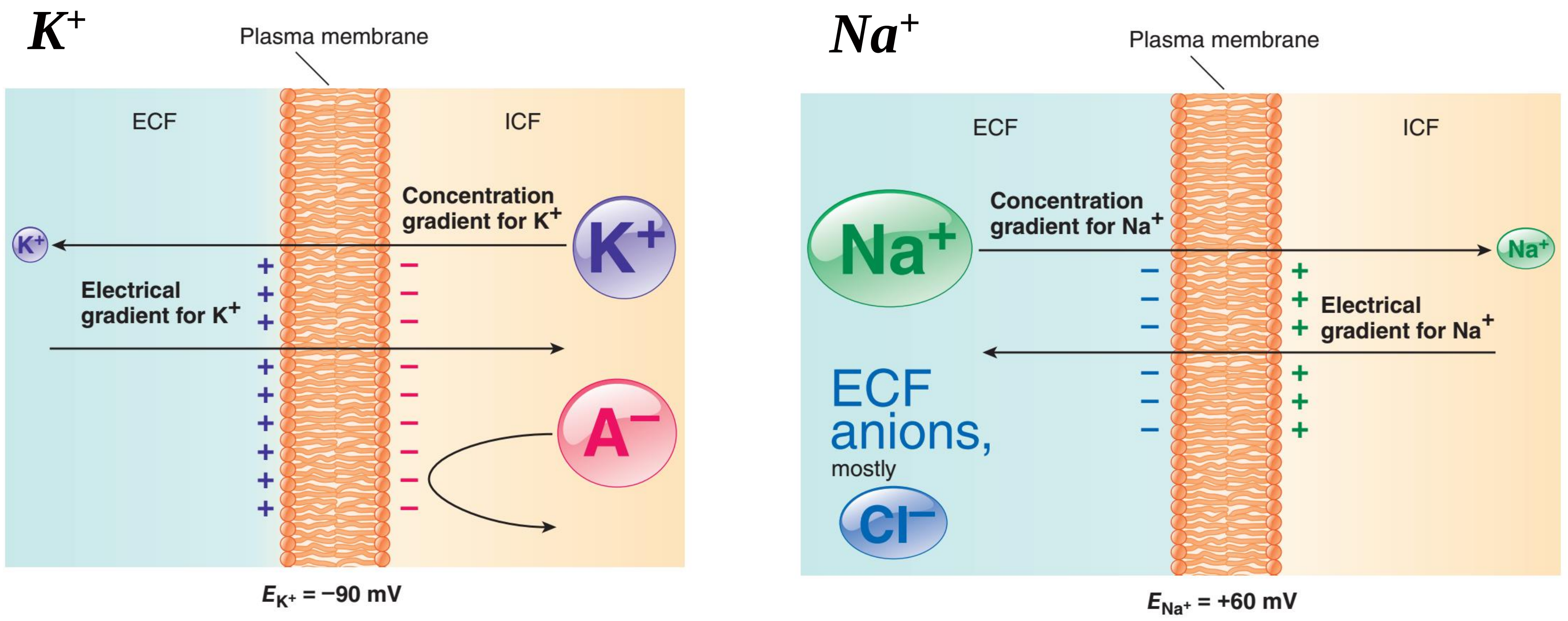
Ion	Relative Permeability
Na^+	1
K^+	25–30
A^-	0



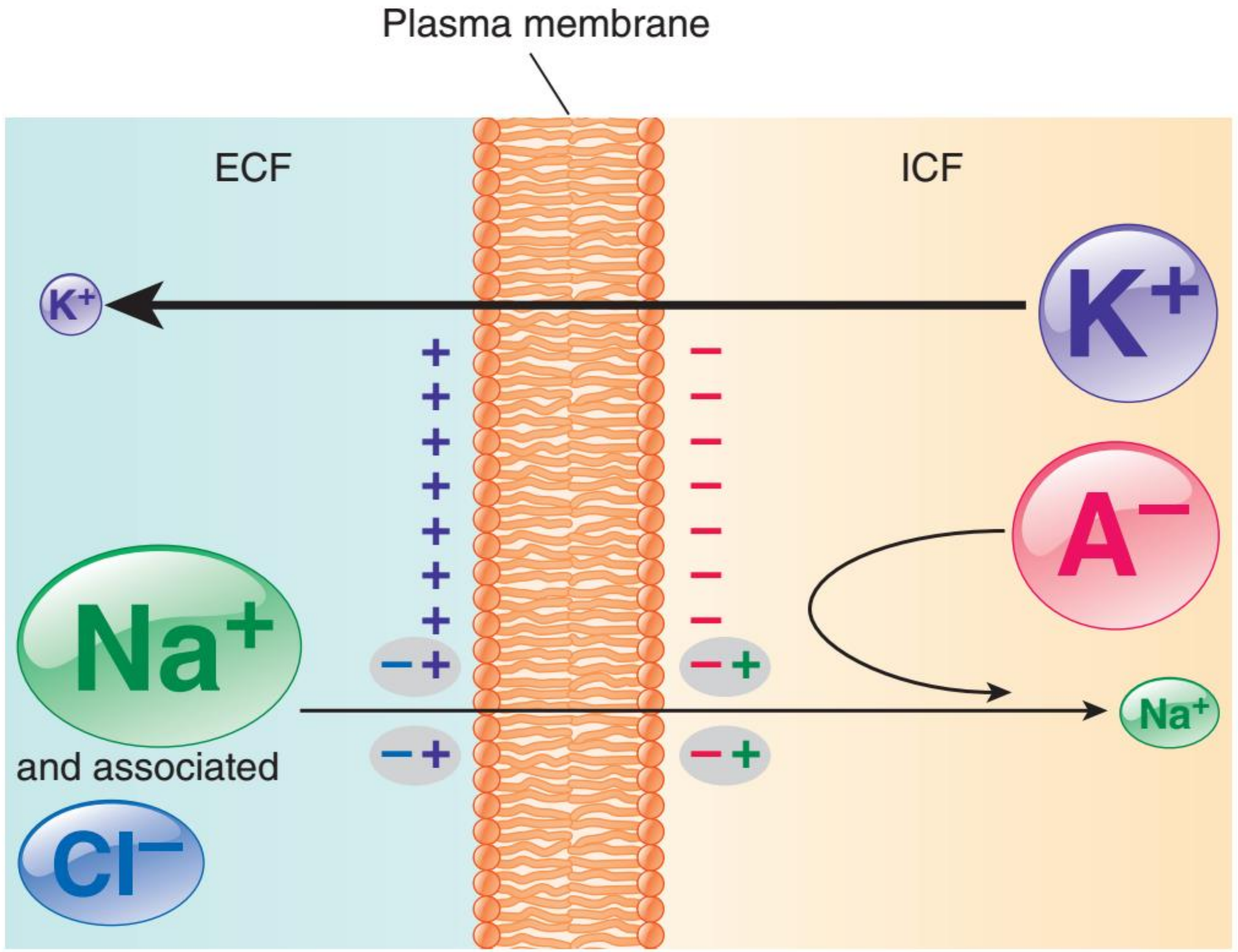
Developing membrane potential



Electrochemical equilibrium



Electrochemical equilibrium occurs when the chemical force of concentration gradient is equal to the opposing electrical force



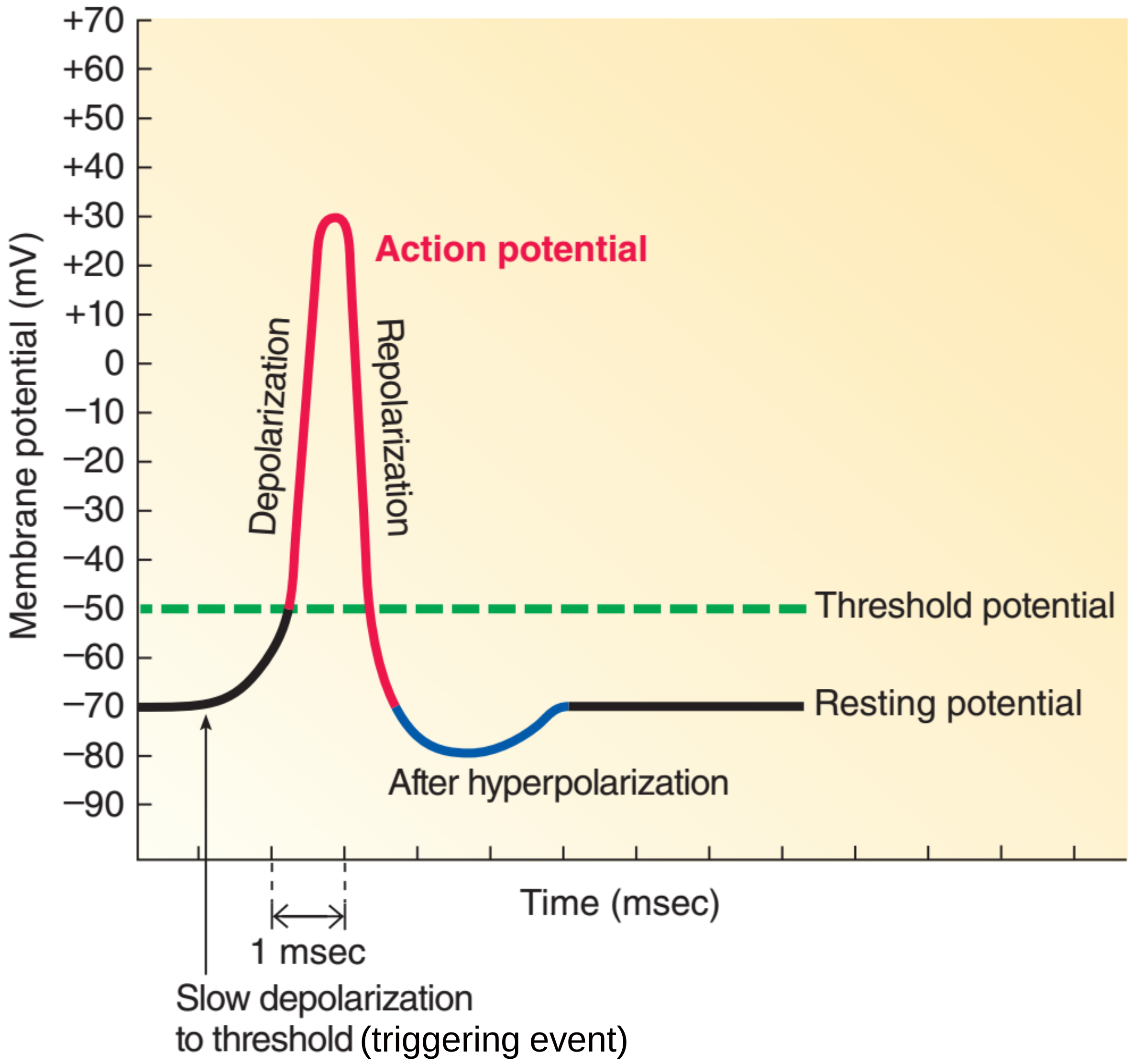
Resting membrane potential = −70 mV

Action potential

A rapid transient change in the membrane potential (electrical activity) of the cell membrane.

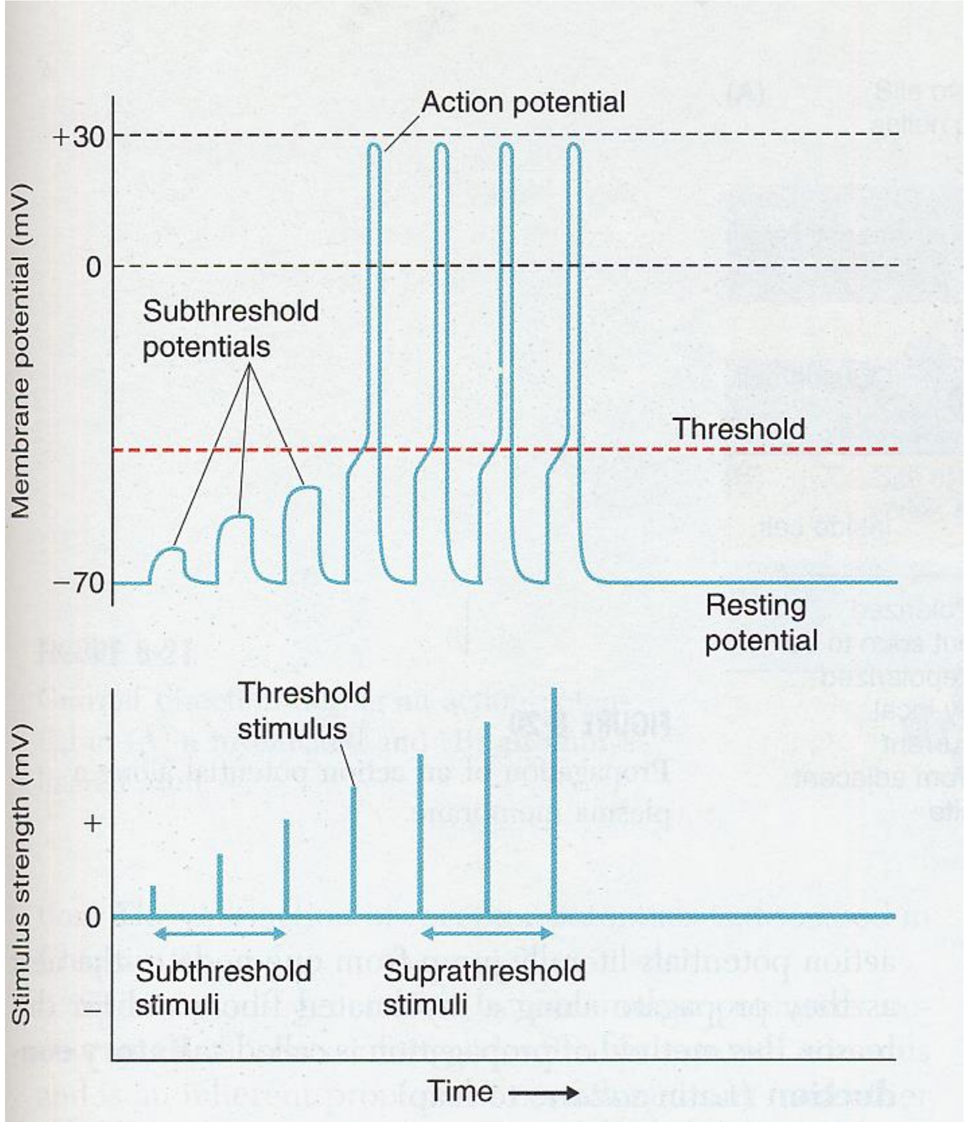
- Sudden
- Rapid
- All or none event
- Uniform amplitude.

Membrane potential during an action potential



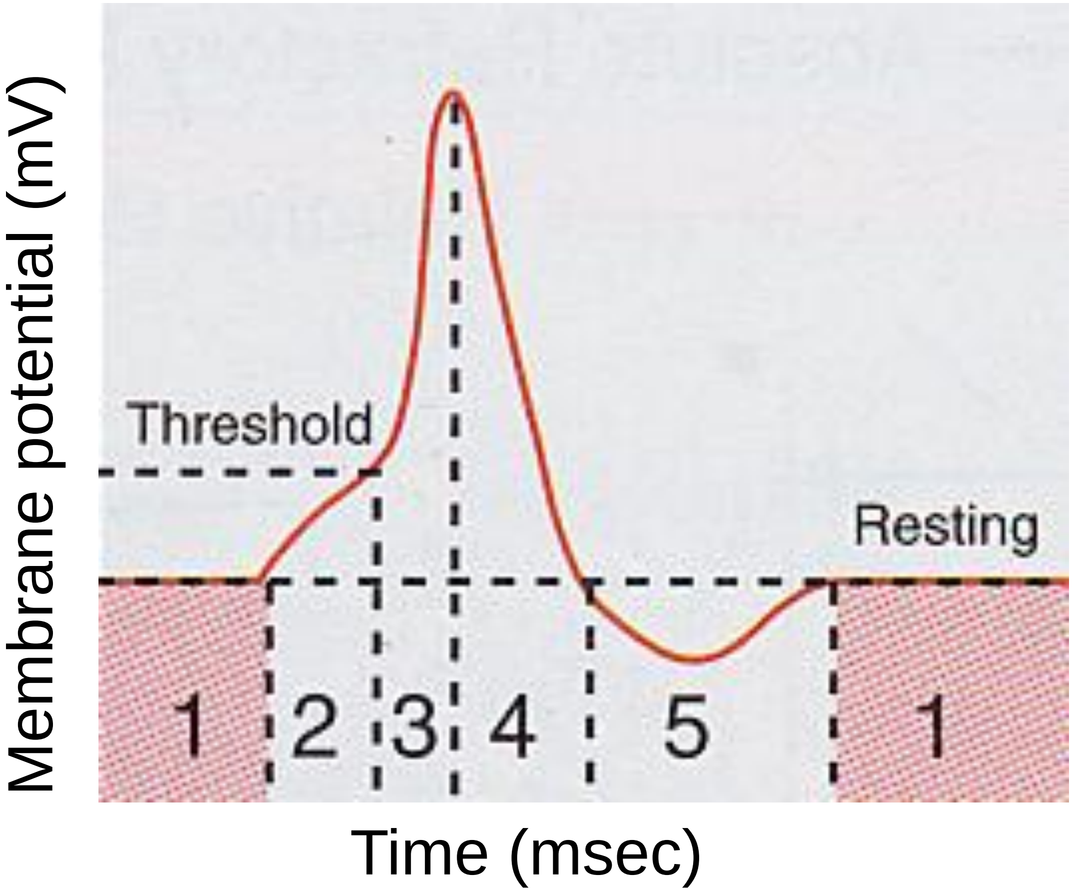
Sherwood p81

Threshold



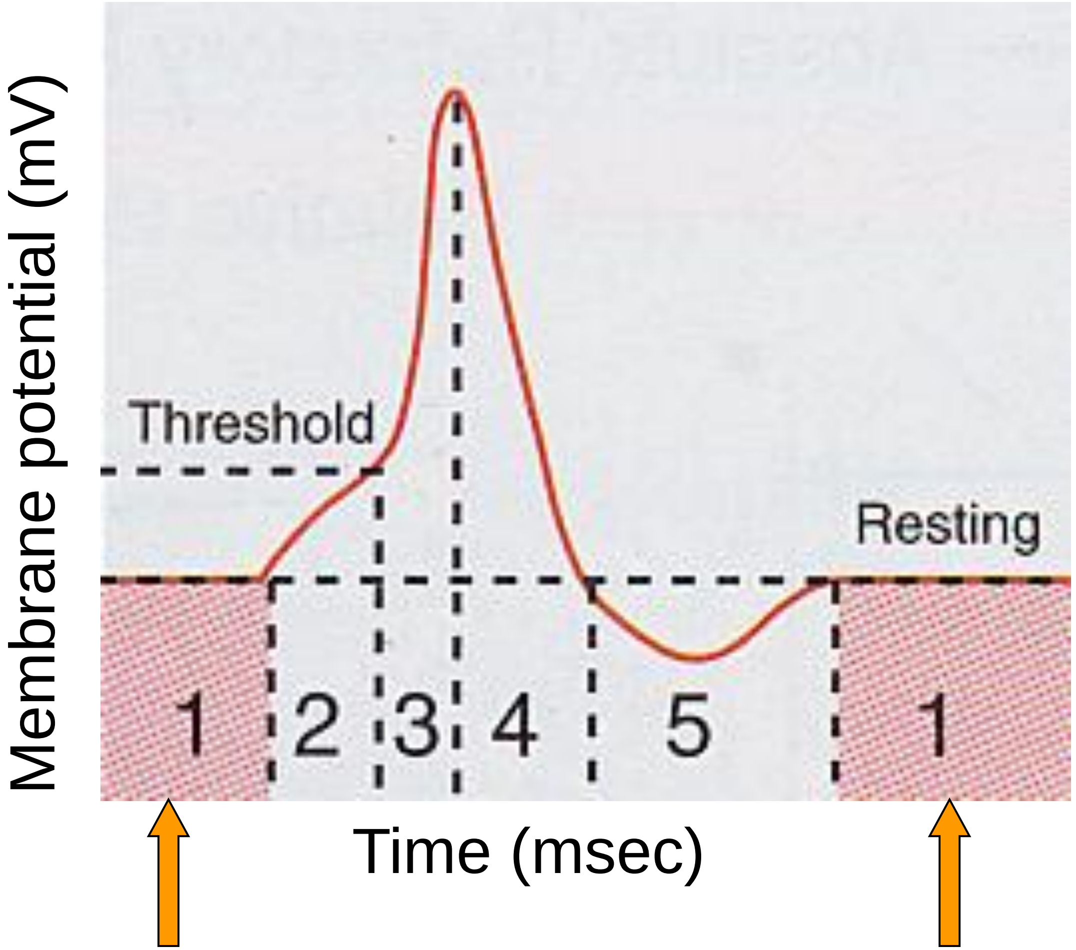
Vanda 197

Ionic basis of the action potential

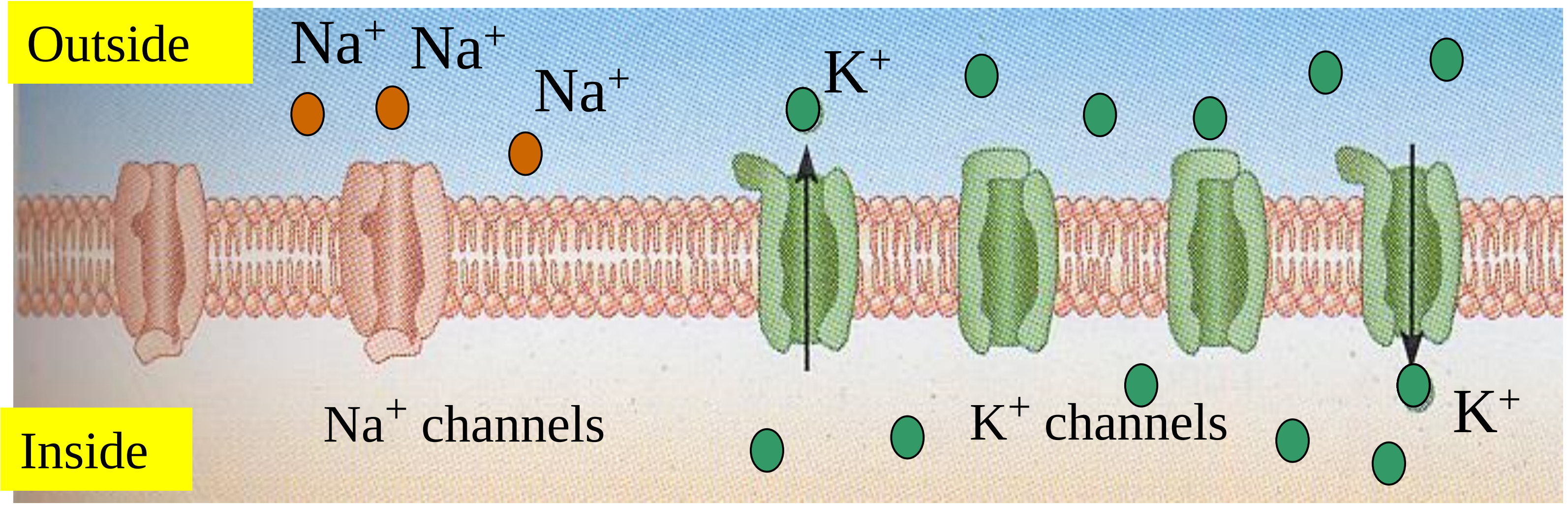


1. ***Resting potential***
2. ***Slow depolarisation***
3. ***Rapid depolarisation***
4. ***Repolarisation***
5. ***Hyperpolarisation***

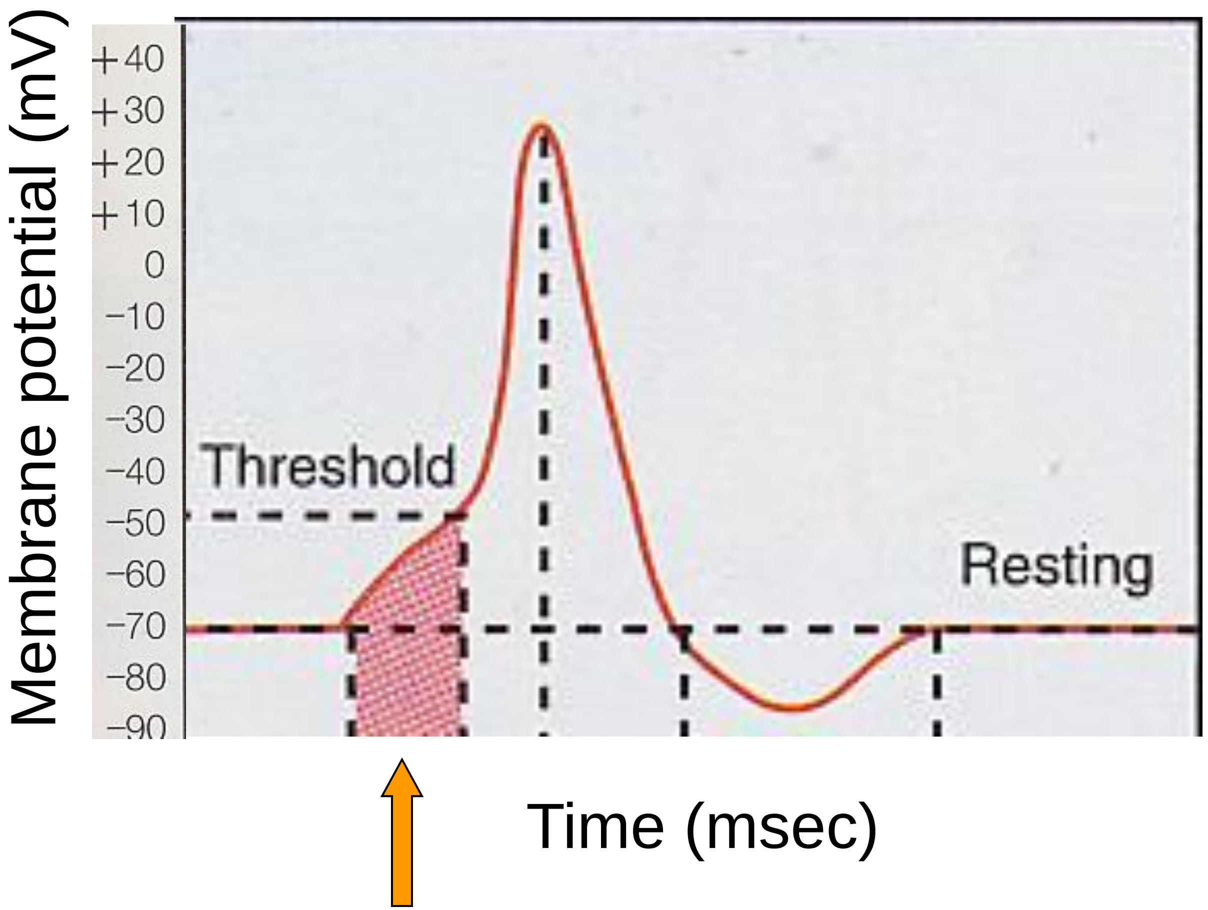
Resting membrane potential (pre-threshold)



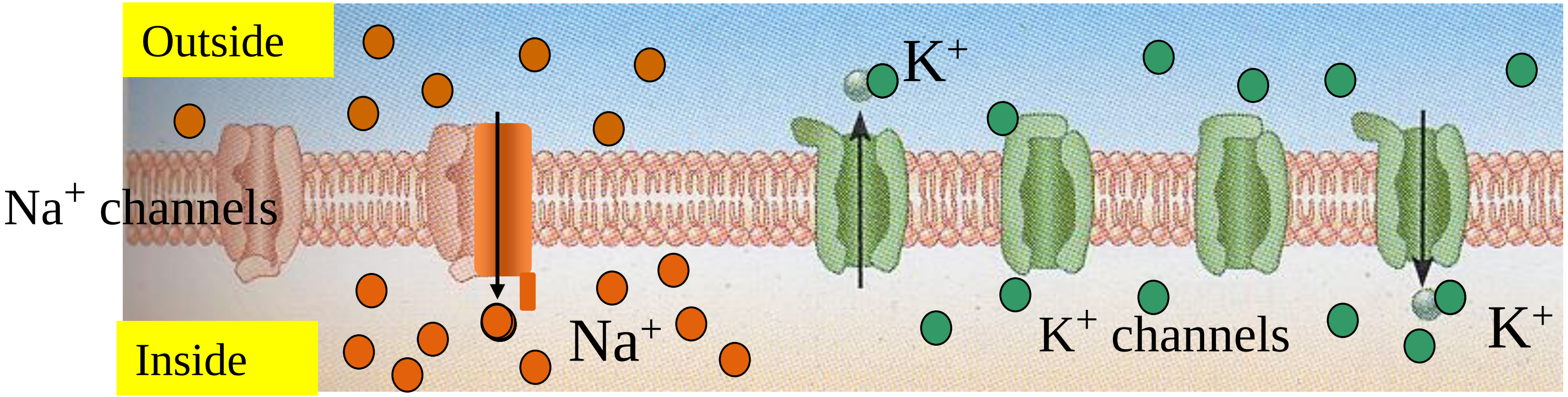
Resting state



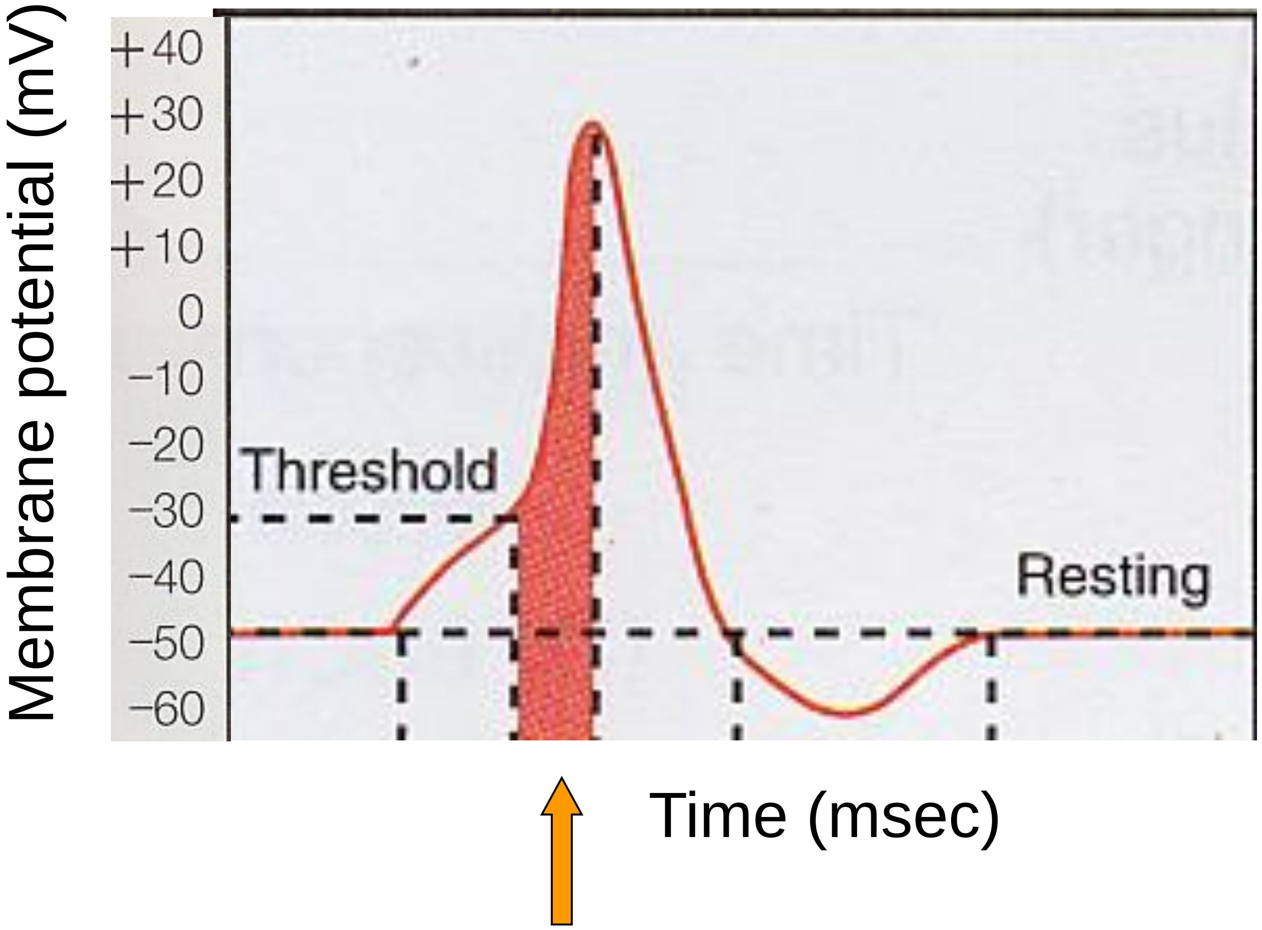
Membrane potential pre-threshold (slow depolarisation)



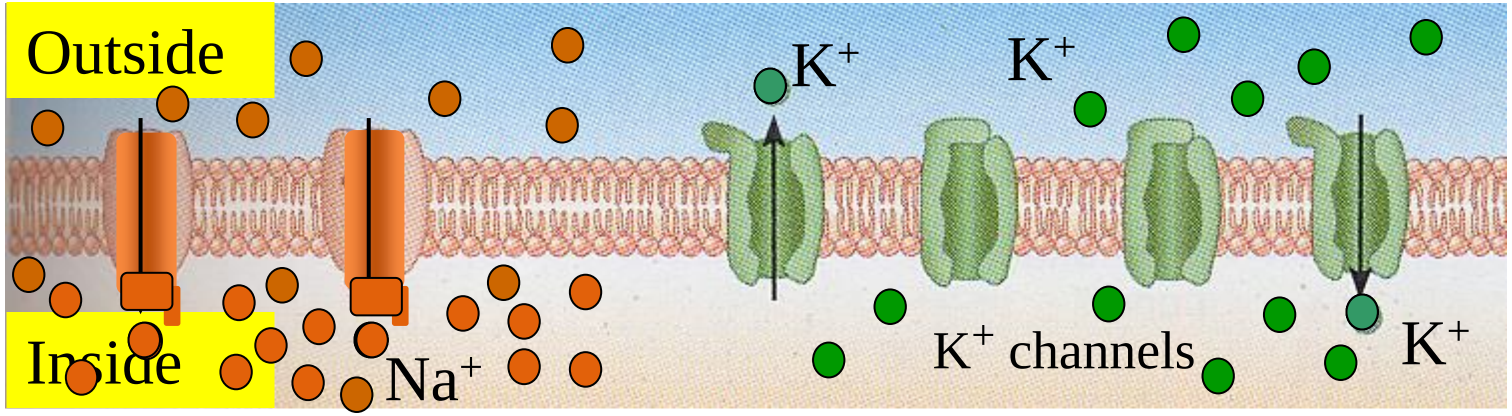
Slow depolarisation



Membrane potential post-threshold (depolarisation)



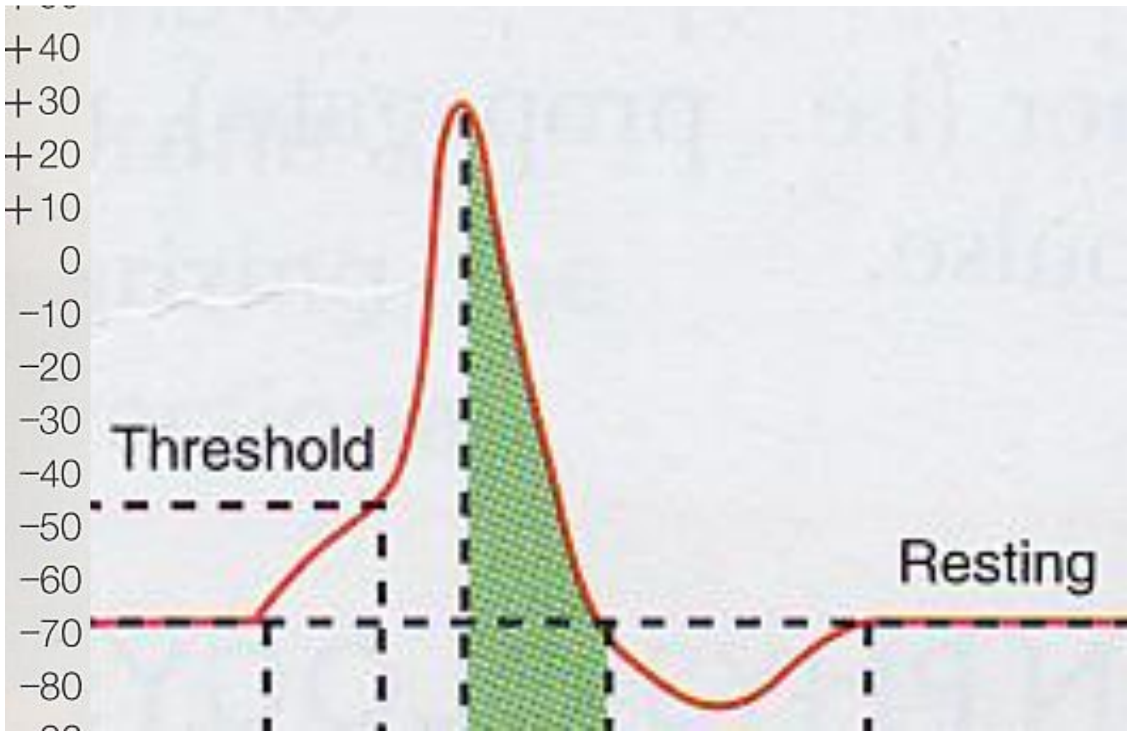
Depolarisation after threshold is reached



Cell Interior now more positive due to increased [Na^+]

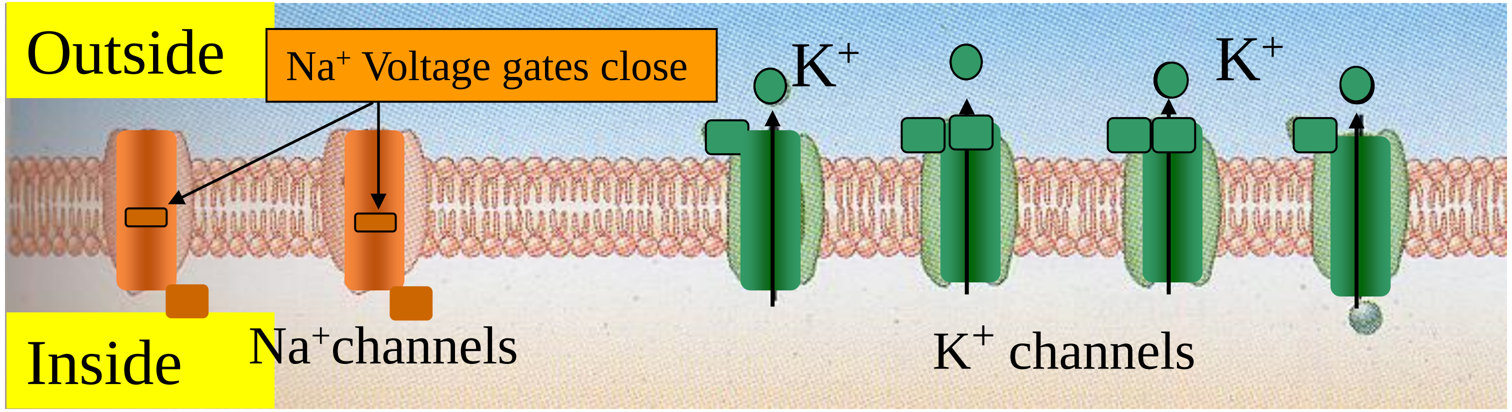
Membrane potential during repolarisation

Membrane potential (mV)



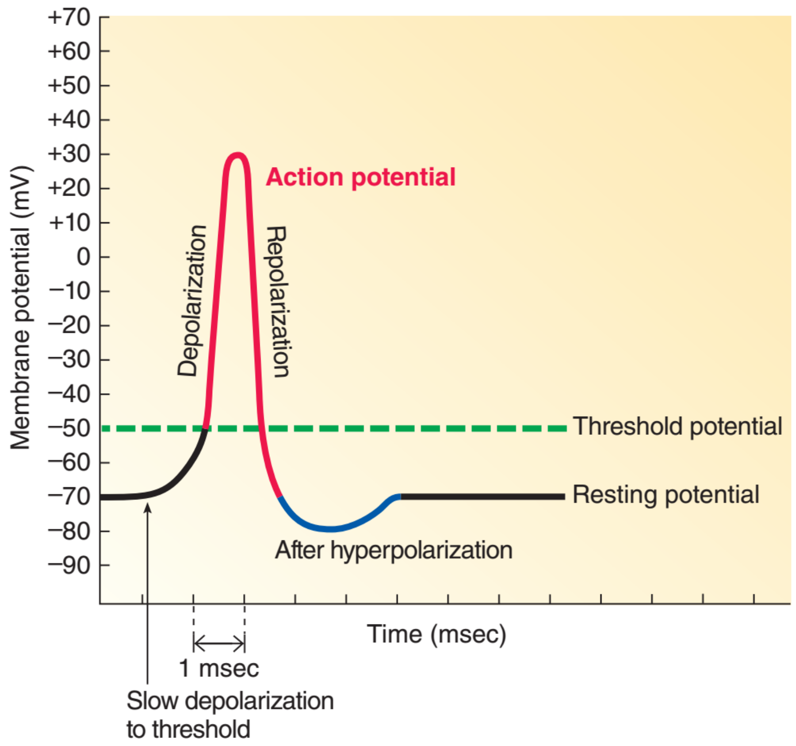
Time (msec)

Repolarization



The cell interior becomes more negative due to K^+ leaving the cell

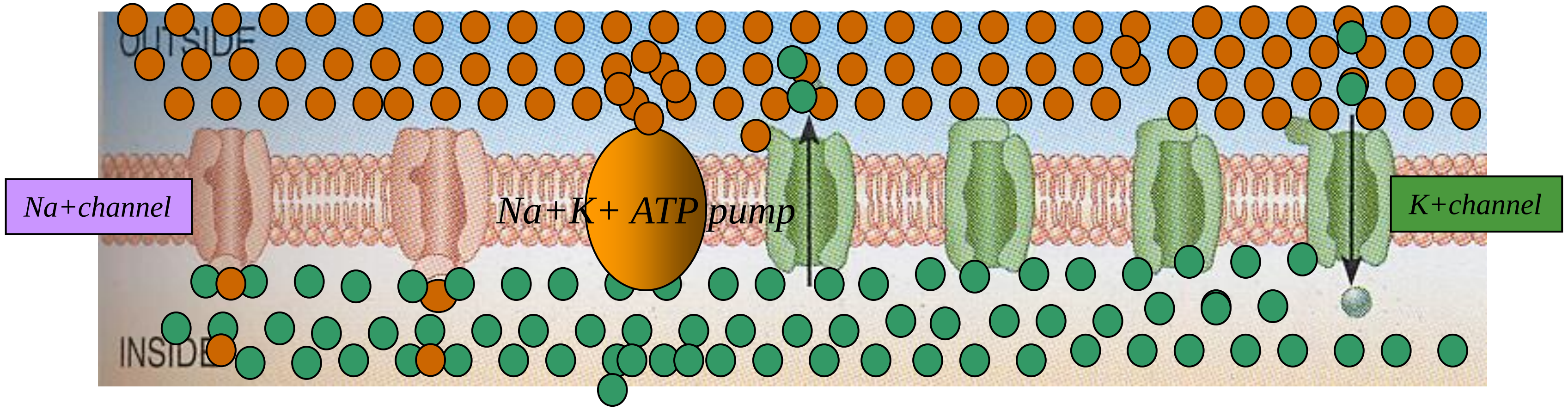
Membrane potential during hyperpolarisation



The voltage gated K+ channels close slowly causing hyperpolarisation of the membrane prior to returning to resting membrane potential by Na+ - K+ pump

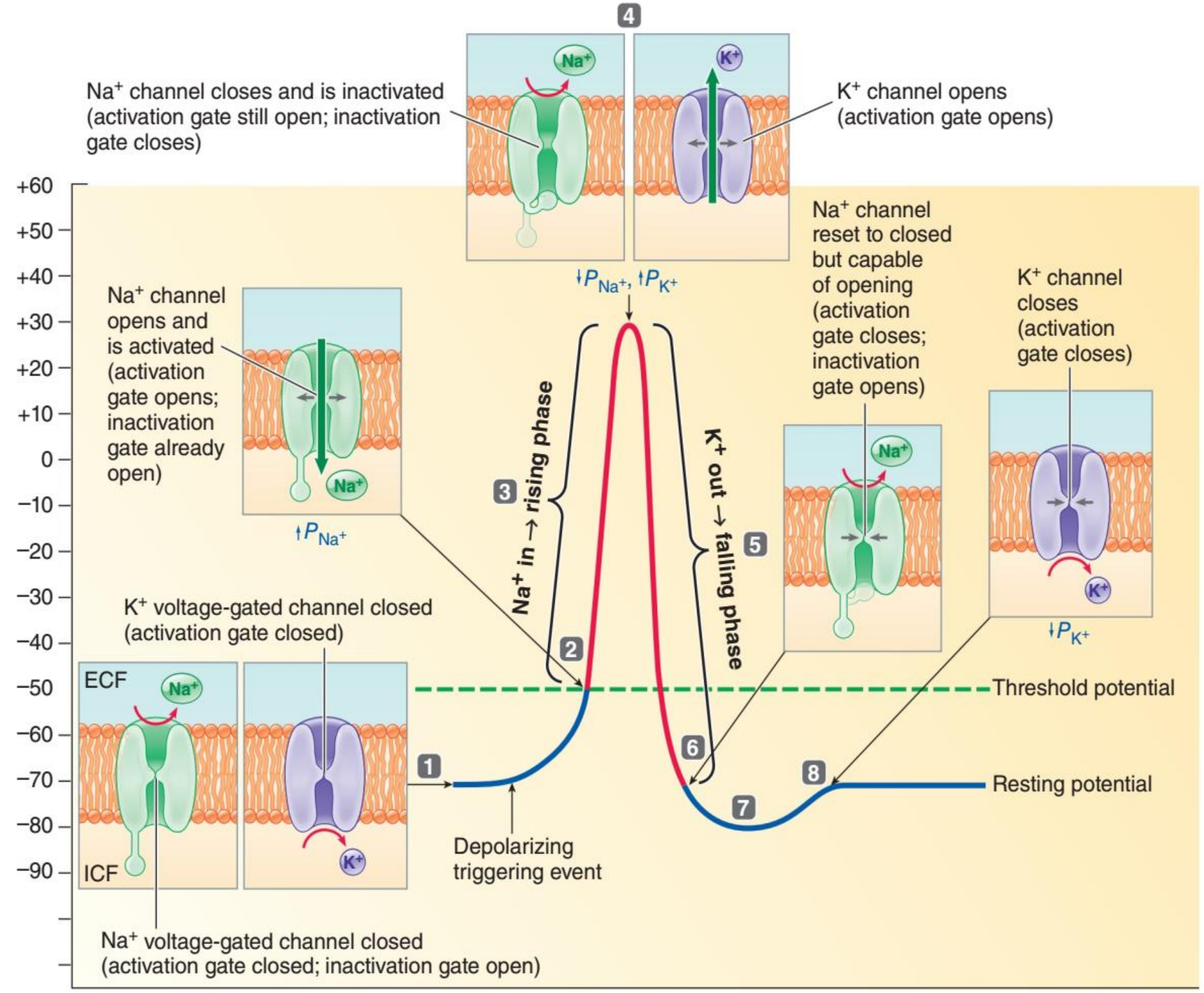
Na^+ - K^+ pump

Na+ 150 mM outside cell



K+ 150 mM inside cell

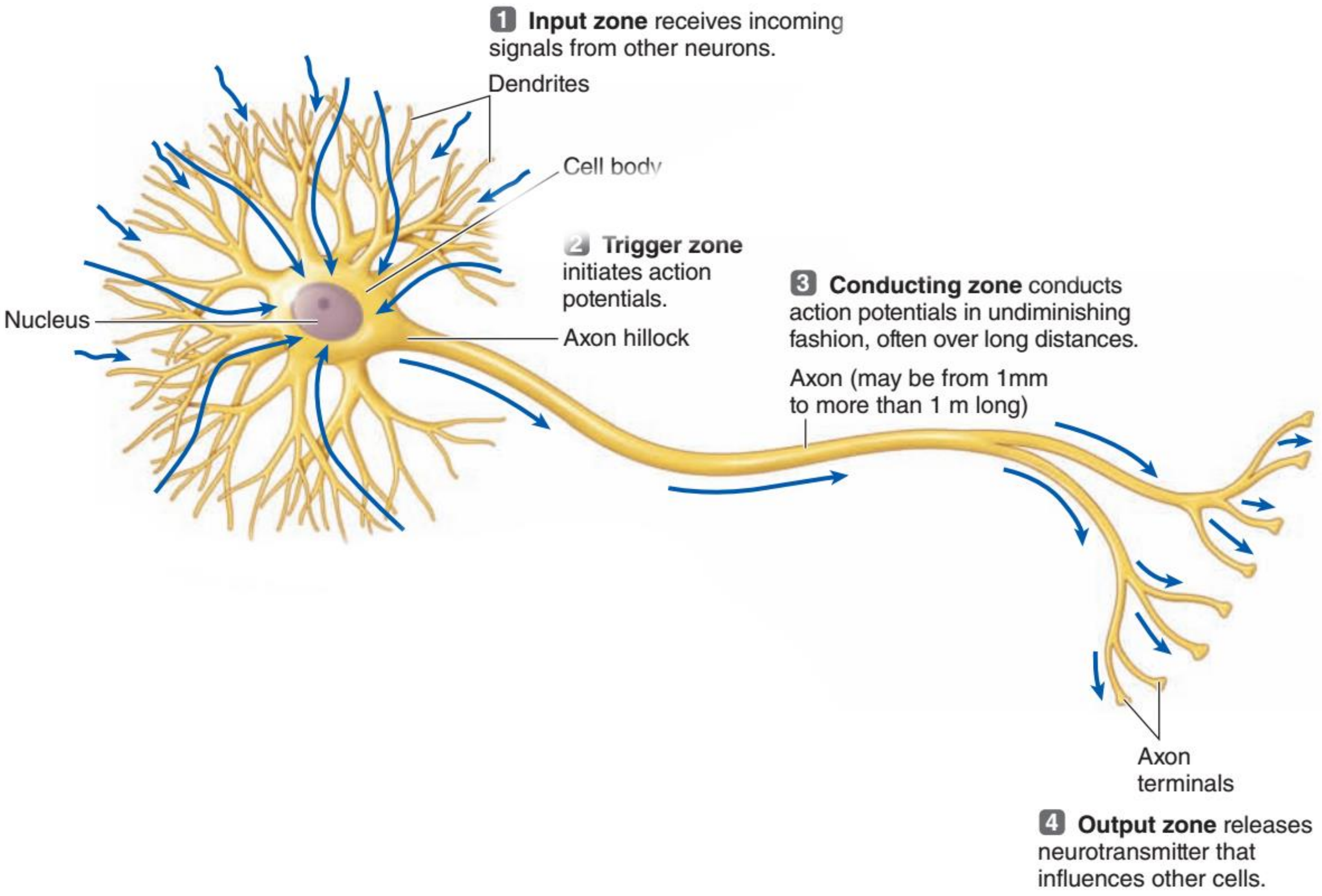
Action Potential (Summary)



Membrane potential (mV)

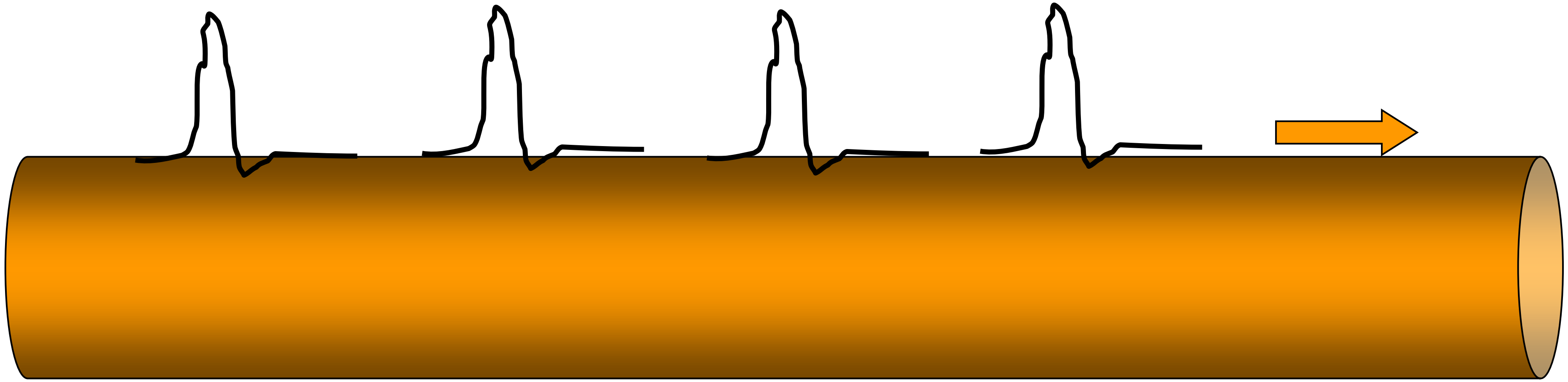
Time (msec)

The propagation of action potentials



Sherwood pg 95

Propagation of action potentials in one direction



Refractory period

- Minimum time during which the neuron is unresponsive to further stimulation

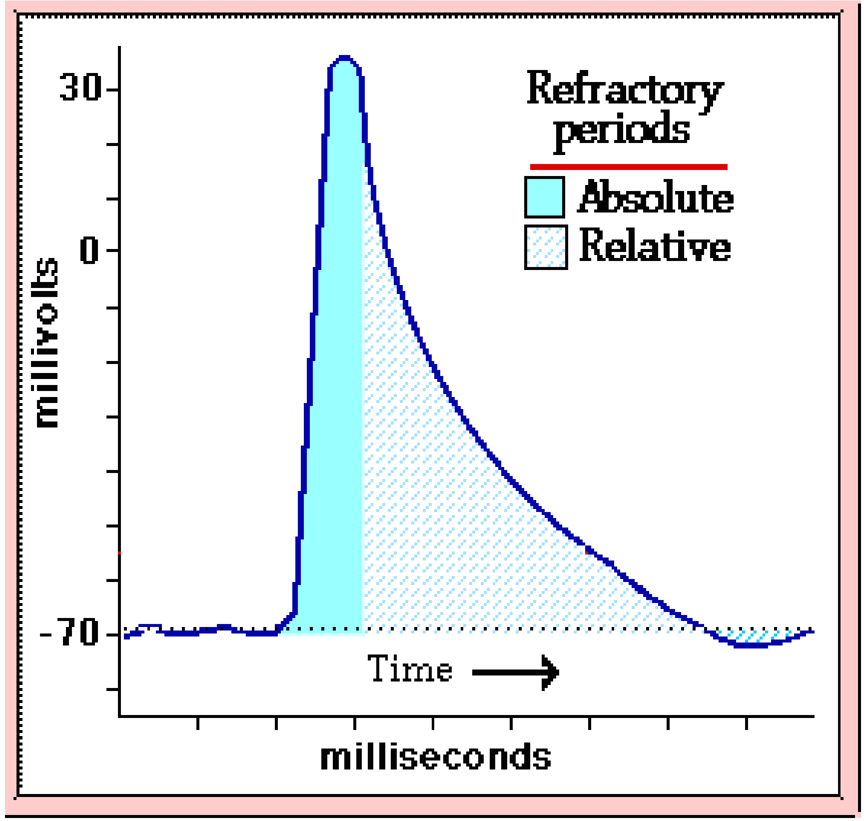
- 1st phase called absolute refractory period

  Voltage gated Na^+ channels have become inactivated and are incapable of being opened until resting membrane potential is reached

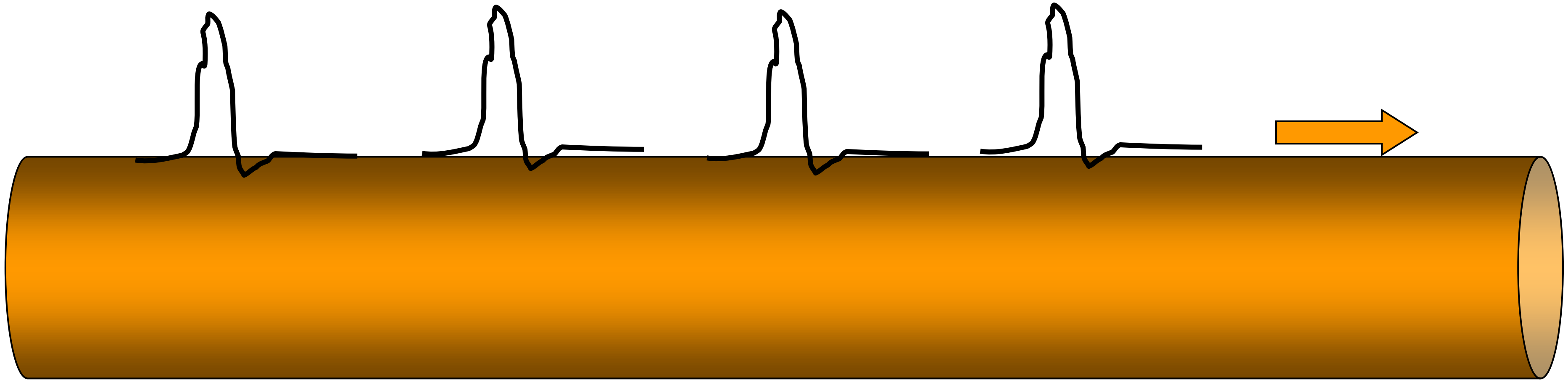
- 2nd phase called the relative refractory period

  Some but not all Na+ channels are responsive to further stimulus and are capable of being partially opened

Action potential refractory period



Refractory period helps propagate action potentials in one direction

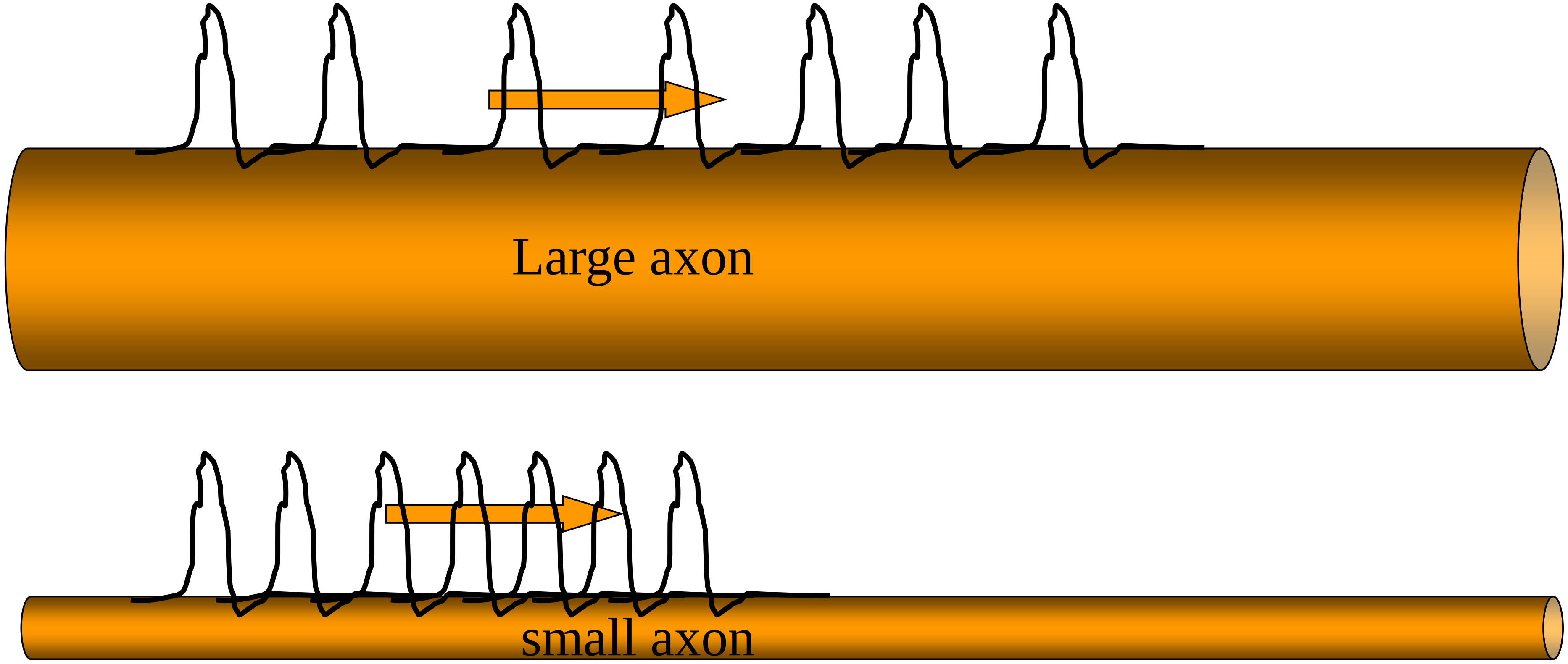


Action potential propagation

- Unidirectional electrical flow (one way)
- Constant stimulus strength (self perpetuating)
- Signals can be passed on to other neurons and effector organs (e.g.muscles, glands etc)

Velocity of propagation of action potentials

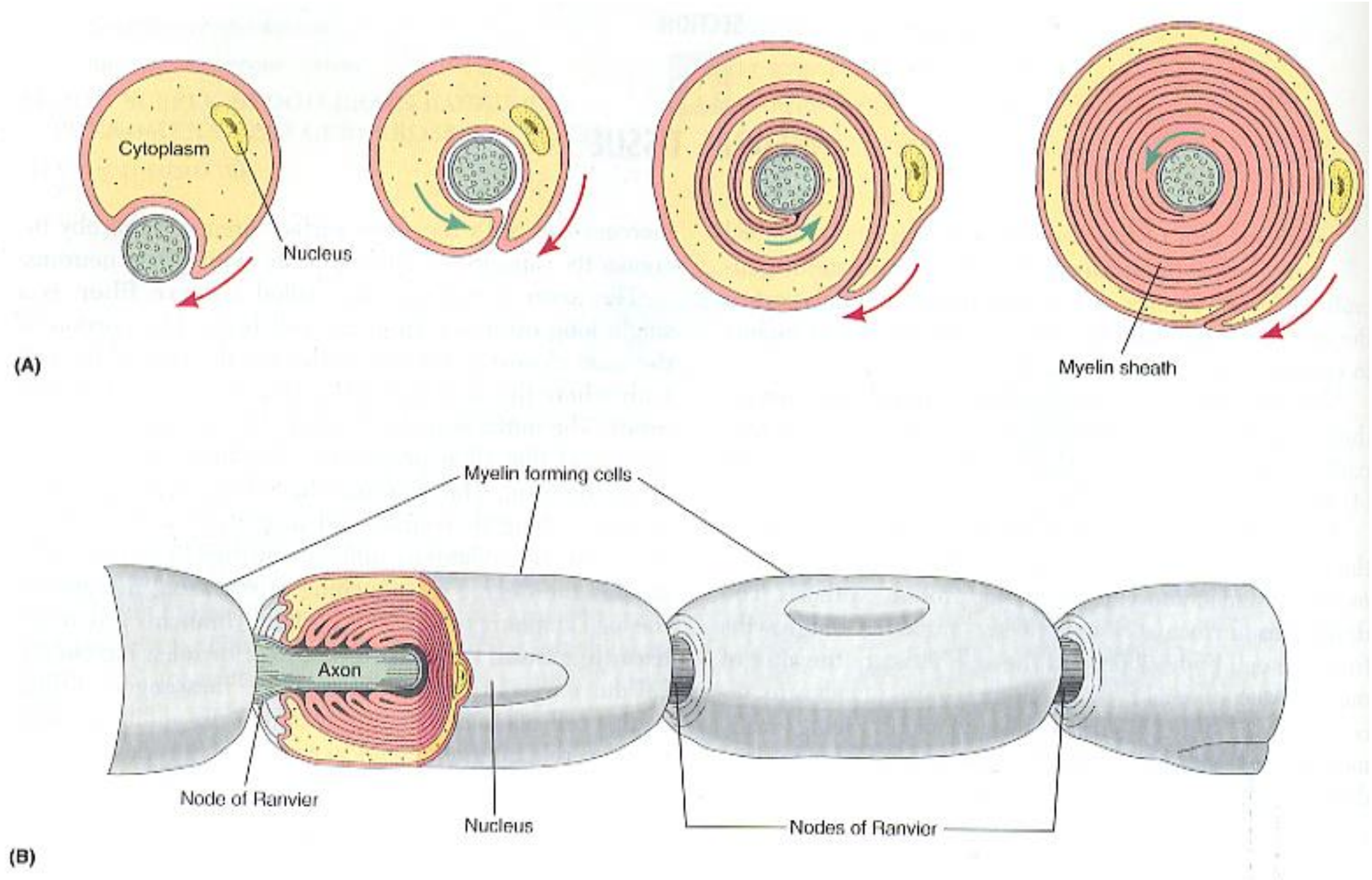
Larger axons propagate action potentials at faster velocities



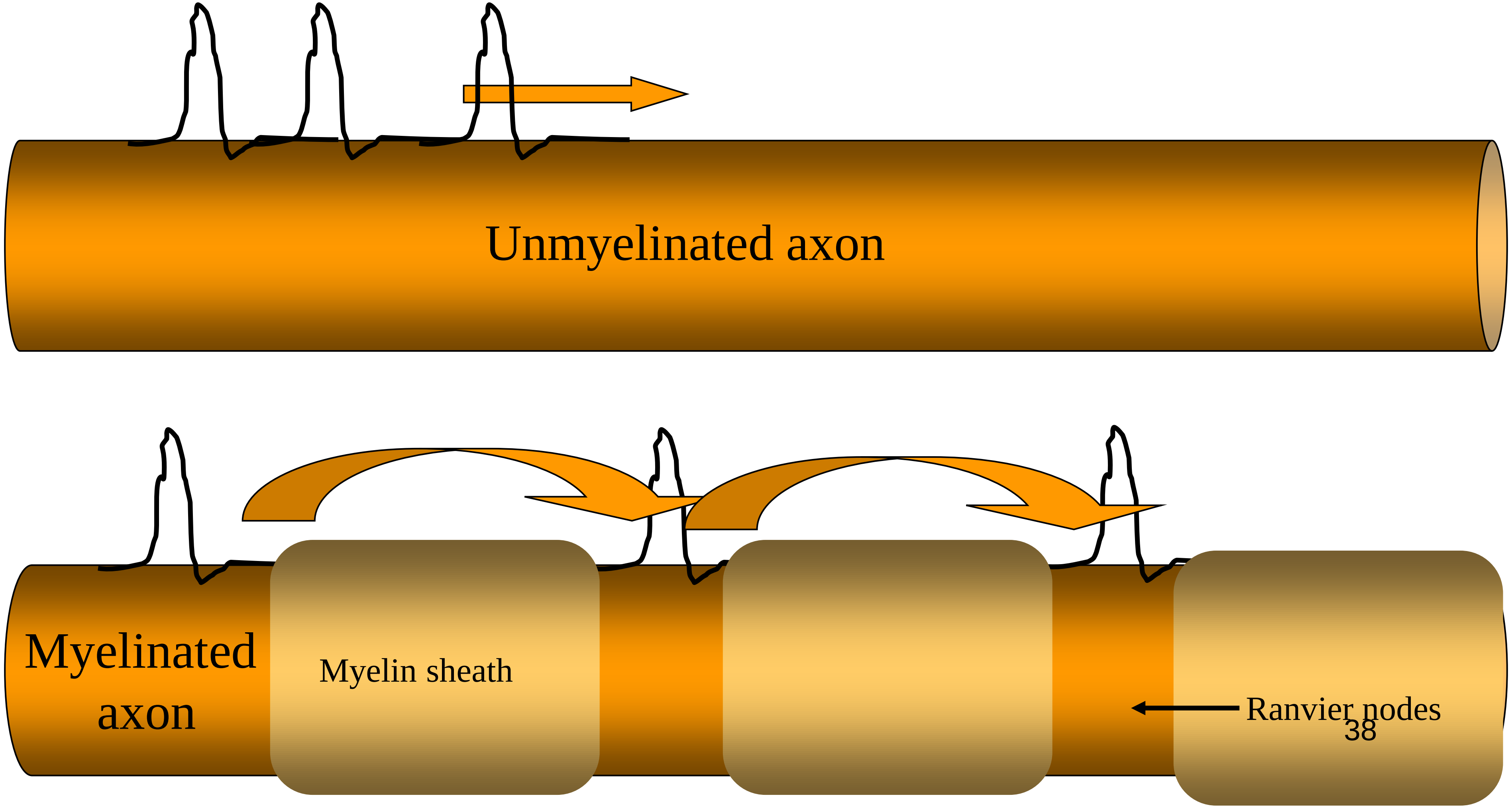
The effects of myelination on AP speed

Source Rhoades p230

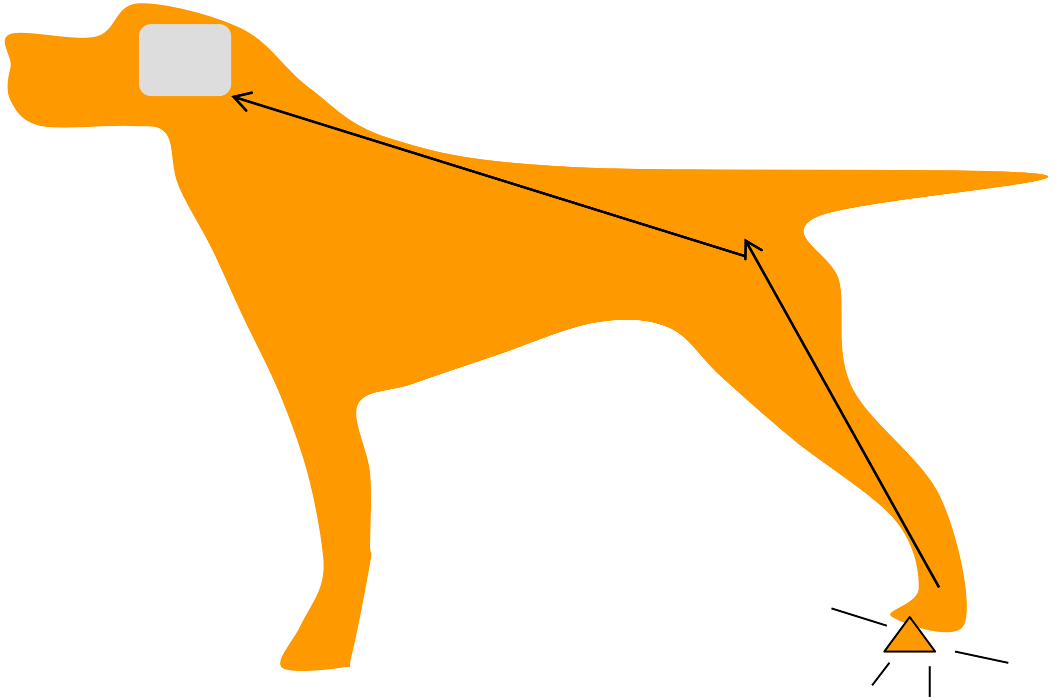
Myelinated nerves



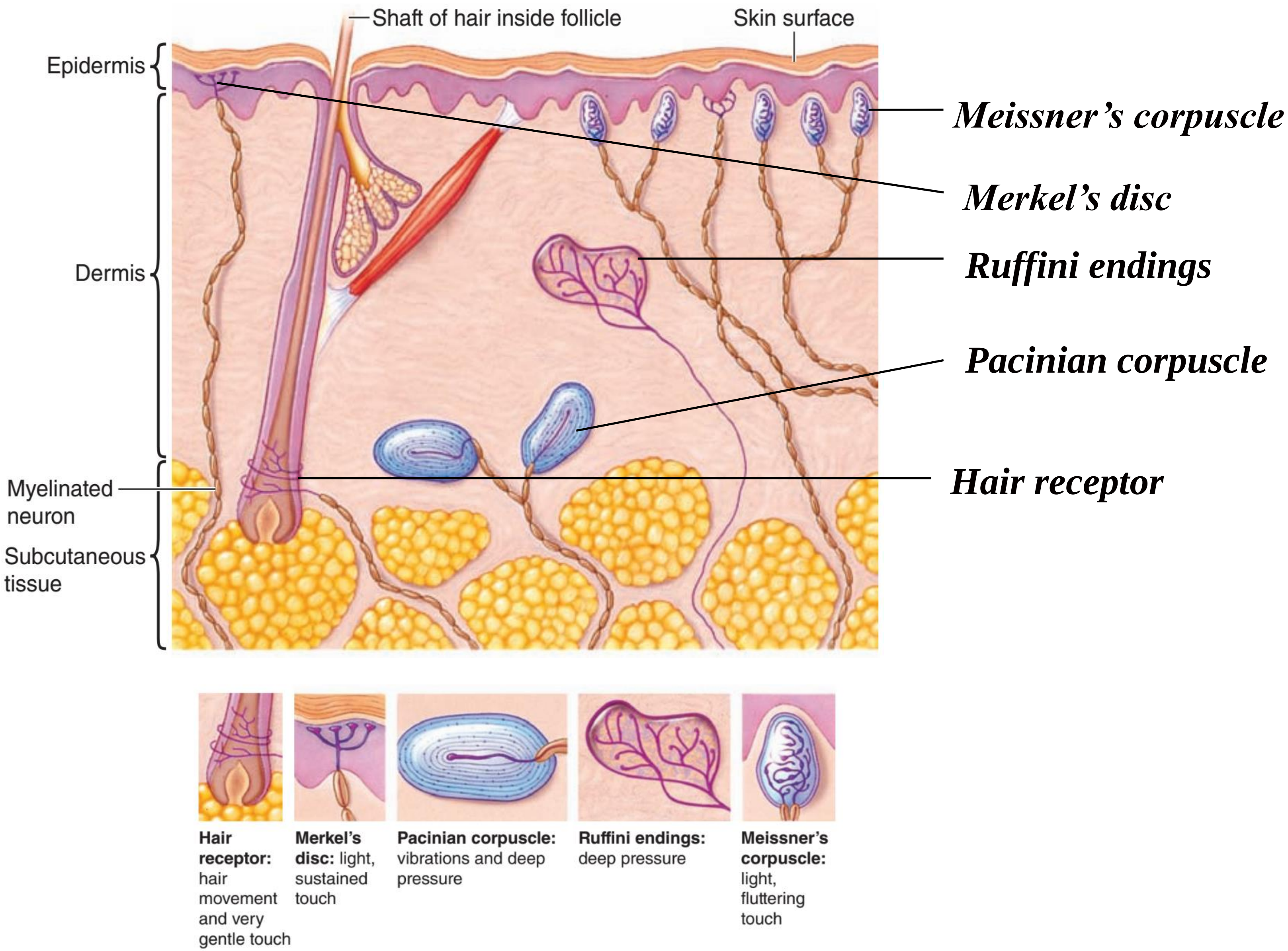
Myelination increases the speed of action potential propagation



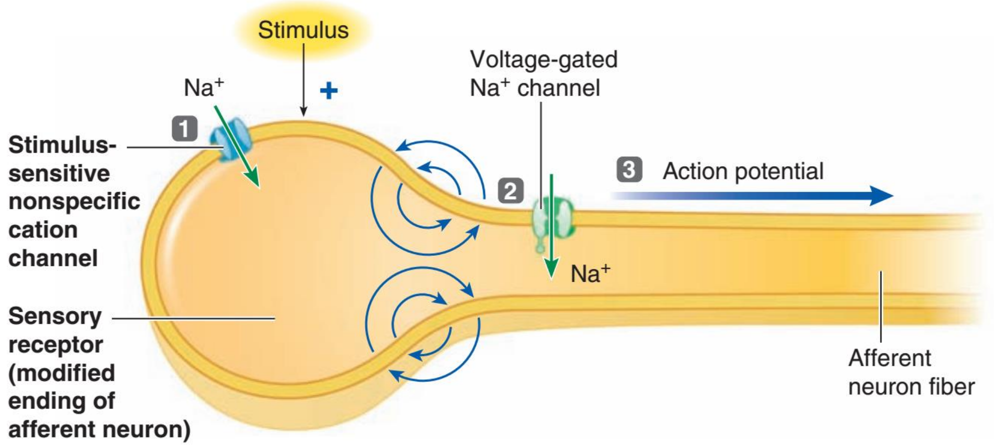
How is sensory information converted to a language that the CNS can understand?



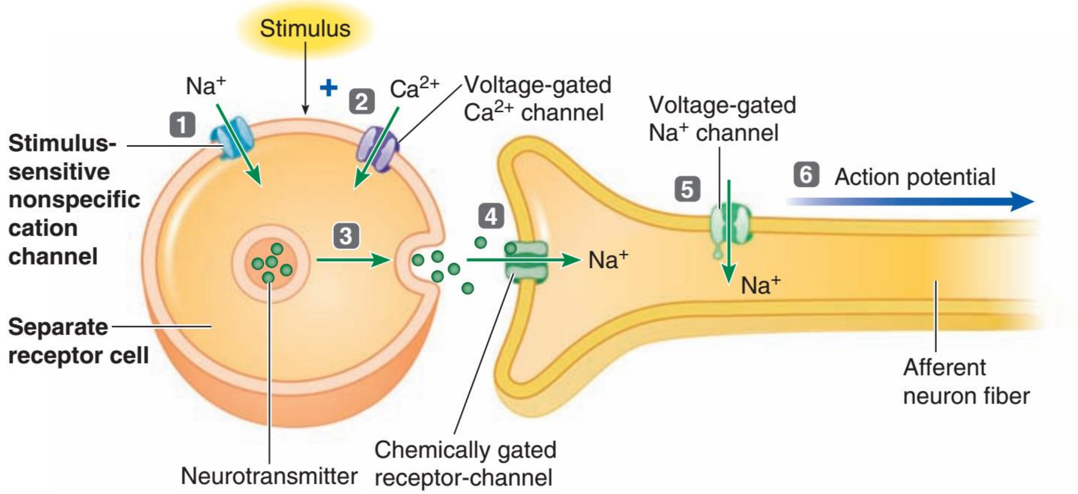
The sensory receptor and nerve endings



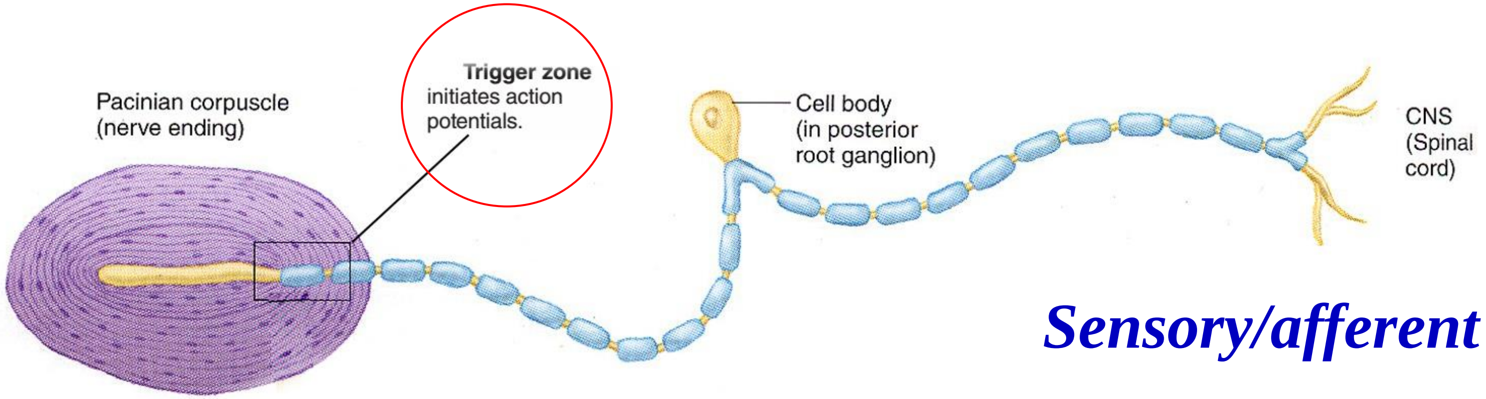
How sensory receptors work



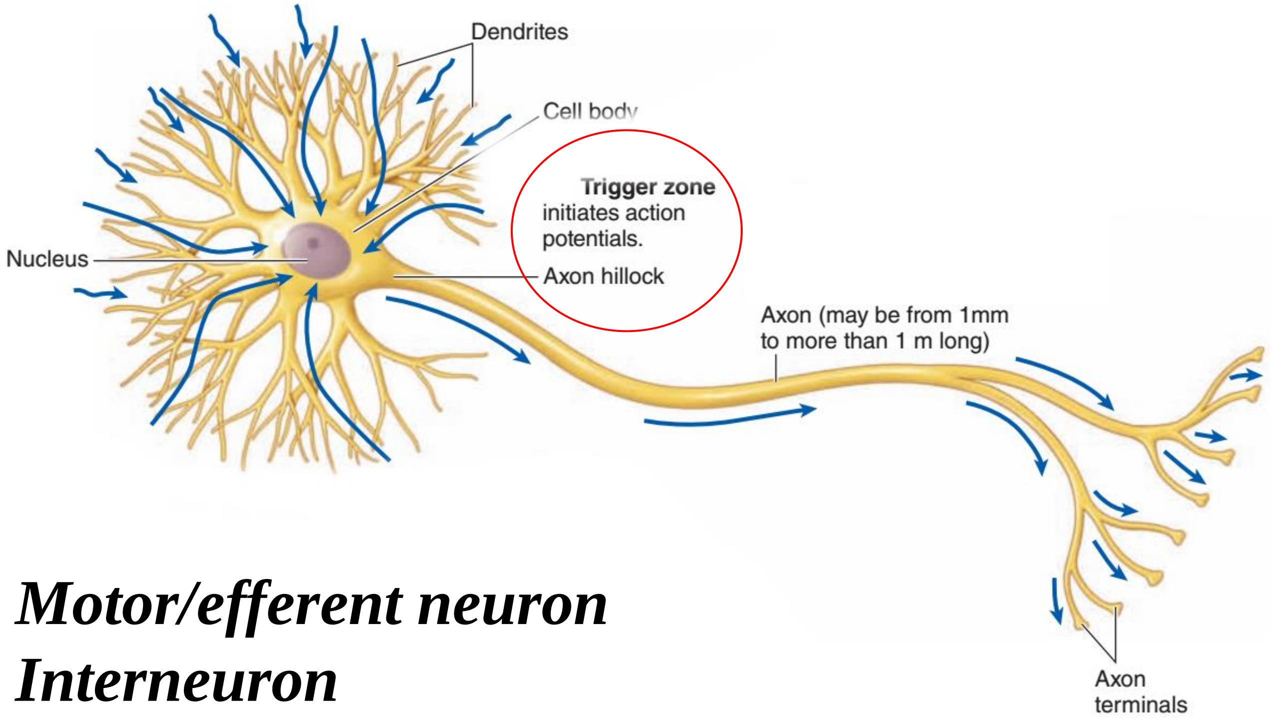
(a) Receptor potential in specialized afferent ending



(b) Receptor potential in separate receptor cell



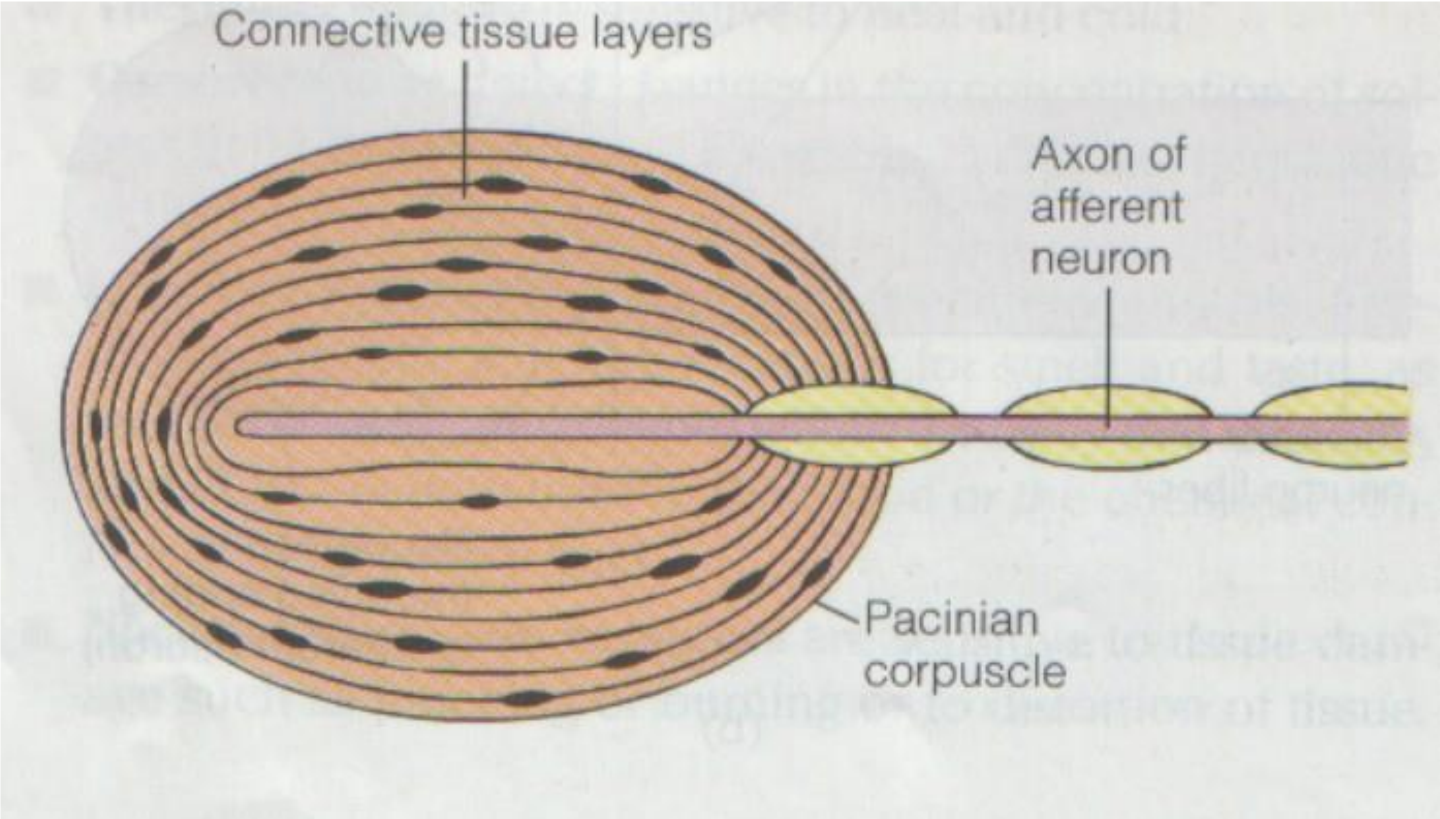
Sensory/afferent neuron



Motor/efferent neuron

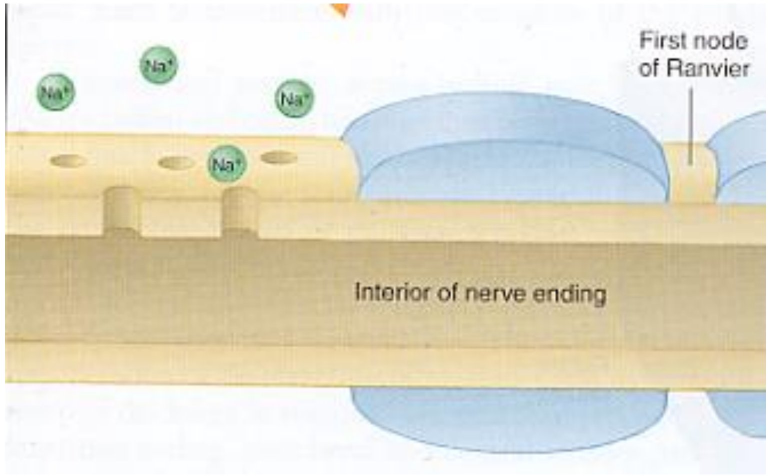
Interneuron

The Pacinian receptor

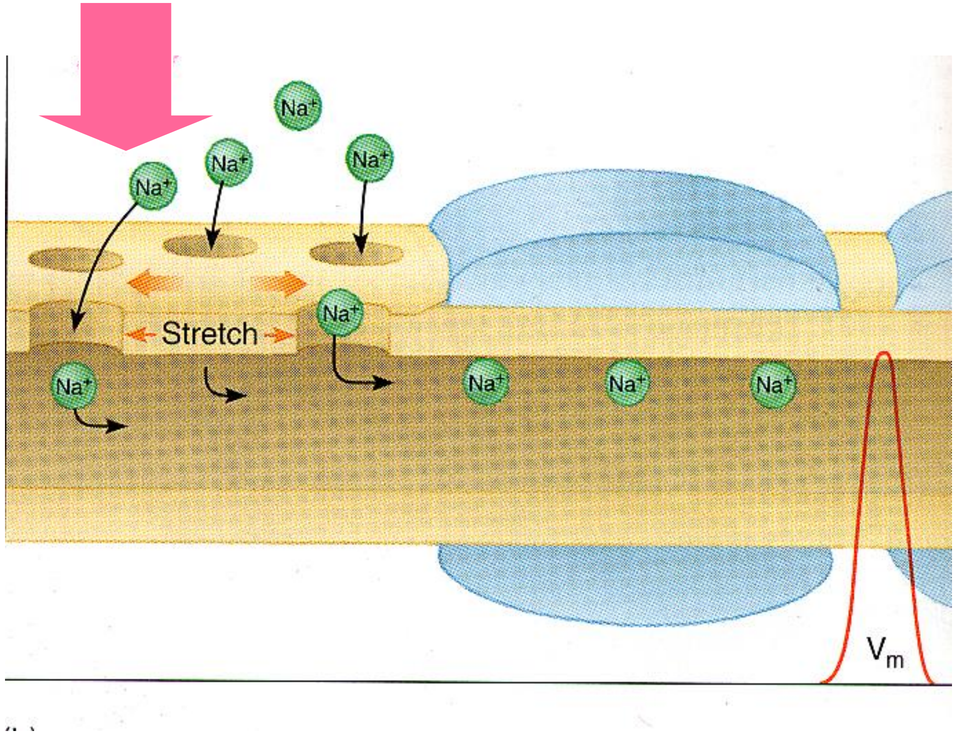


Signals change in pressure and vibration

The stimulation of the Pacinian receptor

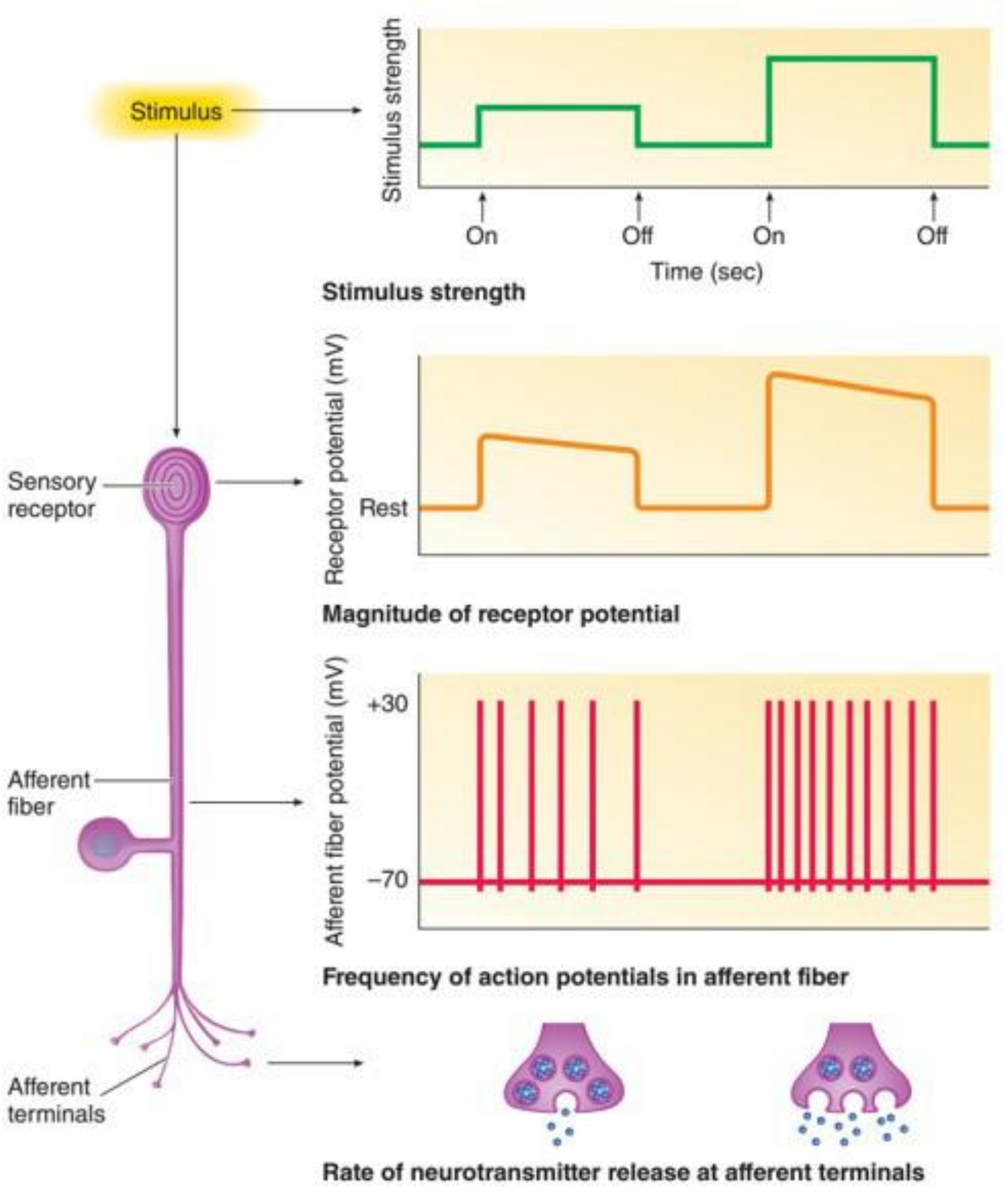


Compression

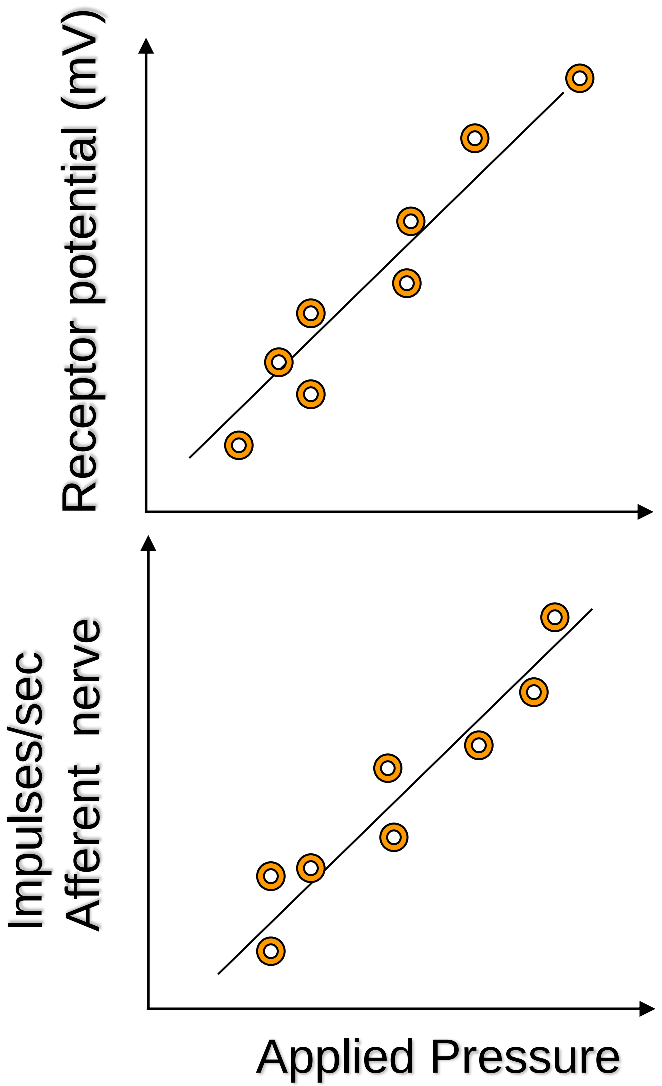


Rhoades 256

Sensory signal intensity & AP frequency



Receptor signals



The intensity of stimulus is directly proportional to the frequency of AP. A stronger stimulus generates a greater receptor potential which is then transduced into more impulses of AP's per second

In conclusion…

- All cells have membrane potentials, due to differences in the ion concentration between the ECF and ICF.
- When messages are sent along neurons, a rapid transient change in resting membrane potentials called action potentials can be generated.
- Action potentials result from temporary changes in permeability to Na+, then K+ ions,
- Action potentials
    a) are unidirectional
    b) do not lose amplitude along an axon,
    c) messages are capable of being sent long distances,
    d) message intensity is sent via the frequency of action potentials
- The refractory period refers to a short time interval when the axonal membrane is no longer receptive to stimulus
- Myelinated and larger diameter axons have greater velocity of action potential propagation than unmyelinated and small diameter axons.