ÉCOLE POLYTECHNIQUE
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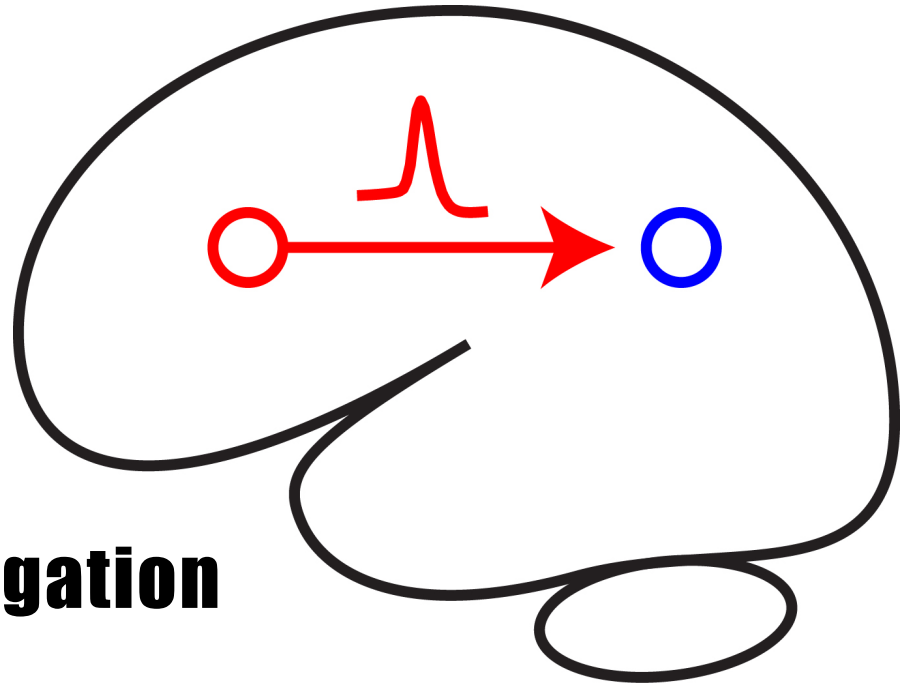


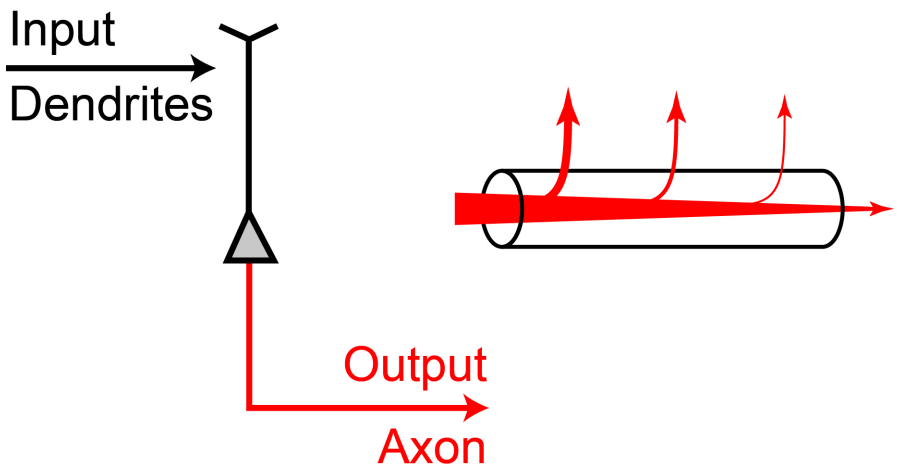
2.4 Action potential propagation

Cellular Mechanisms of Brain Function

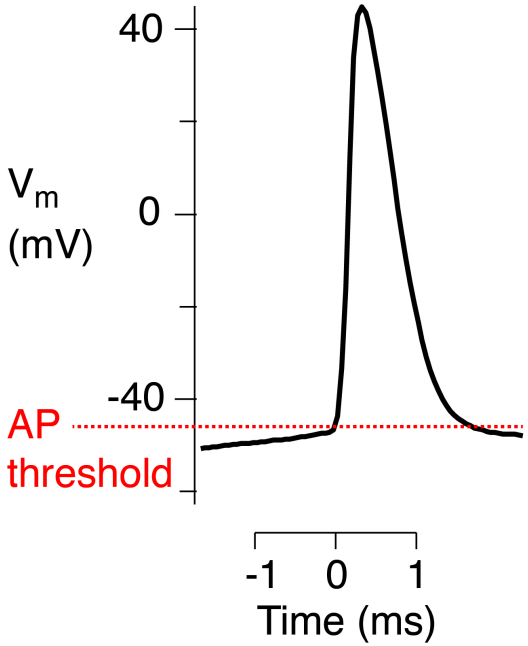
Prof. Carl Petersen

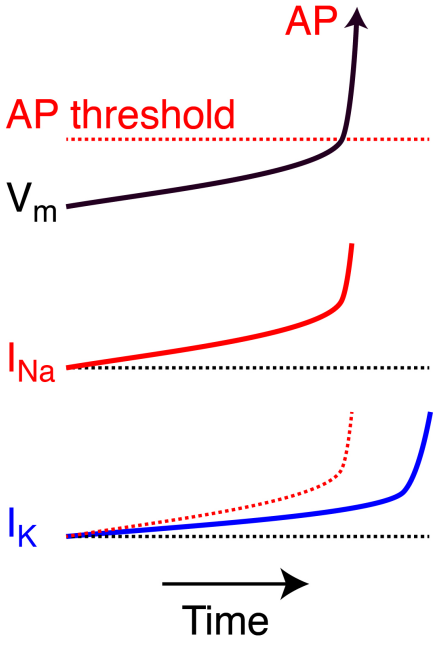
Digital communication

Spatiotemporal membrane potential dynamics



Action potential initiation



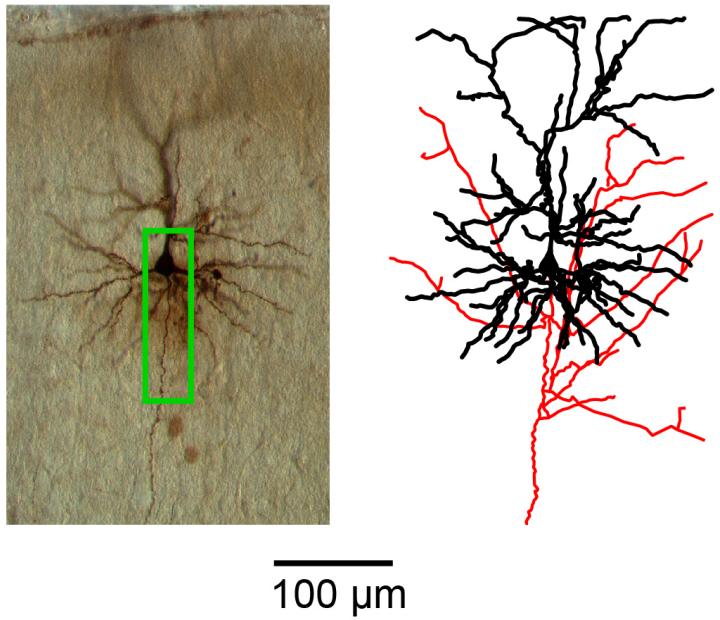


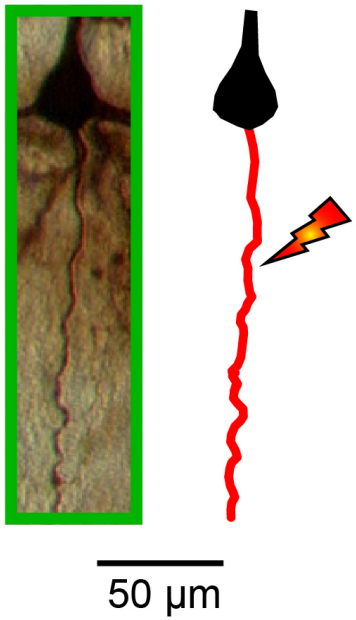
Action potential threshold depends upon voltage-gated Na^+ and K^+ channel:

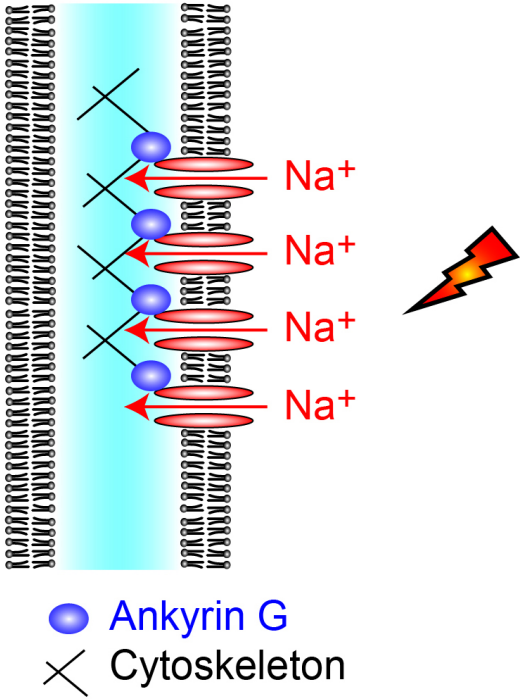
i) densities
ii) activation V_m & dynamics
iii) inactivation V_m & dynamics

$I_{Na} > I_K$

The axon initial segment

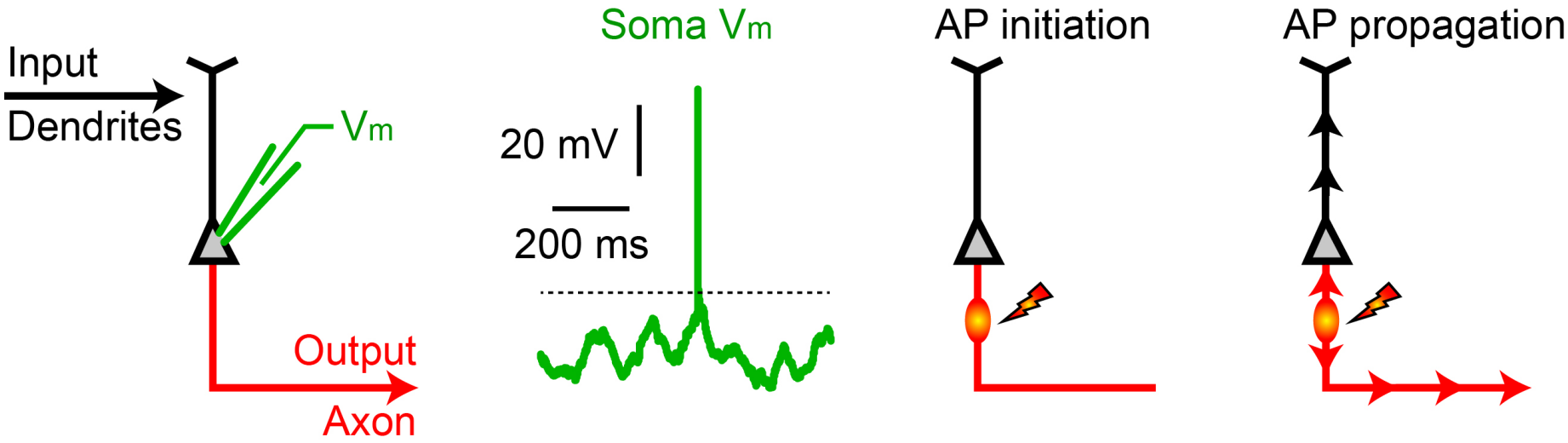




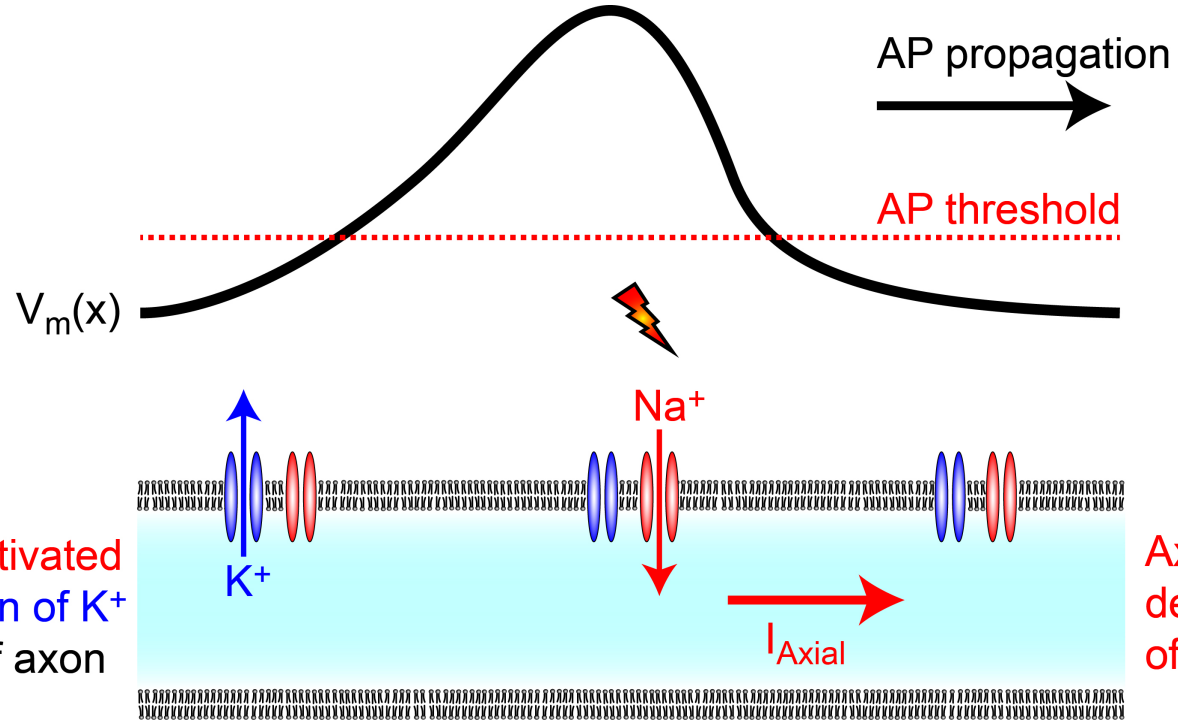


Petersen and Sakmann, 2001

Action potential propagation



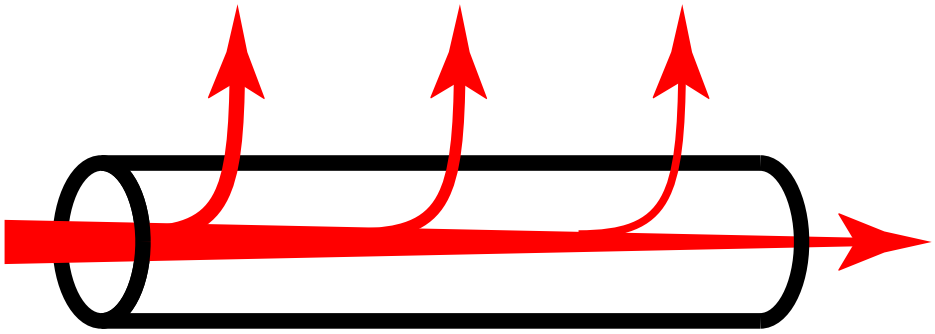
Active amplification of action potentials

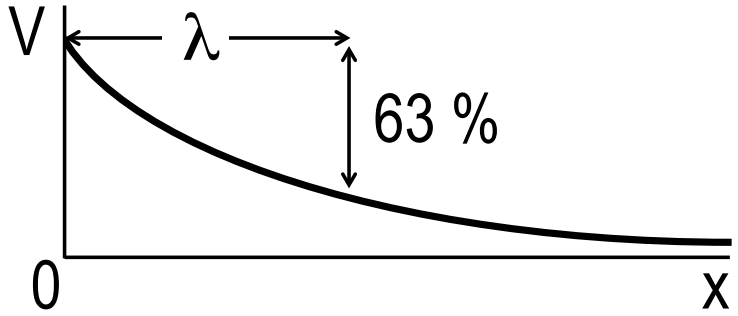


Na^+ channel inactivated
Delayed activation of K^+
Refractory part of axon

Axial current flow depolarises next part of axon to threshold

Passive spread of subthreshold V_m



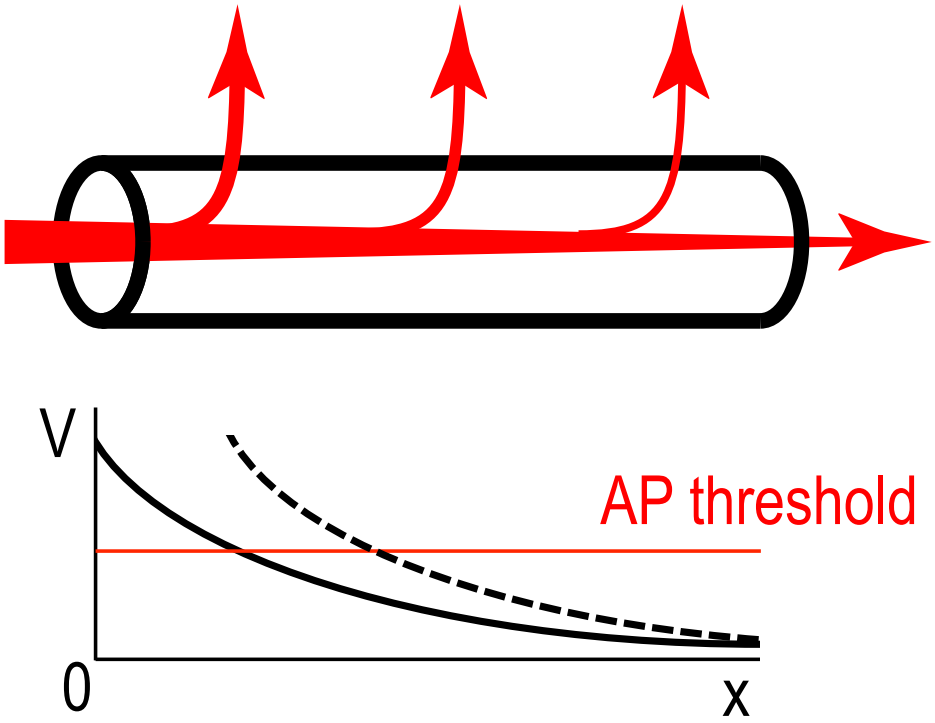


$$\lambda^2 \frac{\partial^2 V}{\partial x^2} - \tau \frac{\partial V}{\partial t} - V = 0$$

$$\lambda = \sqrt{(R_m / R_{Axial})} \qquad \tau = R_m C_m$$

At steady state $V = V_0 e^{-(x / \lambda)}$

Action potential propagation speed

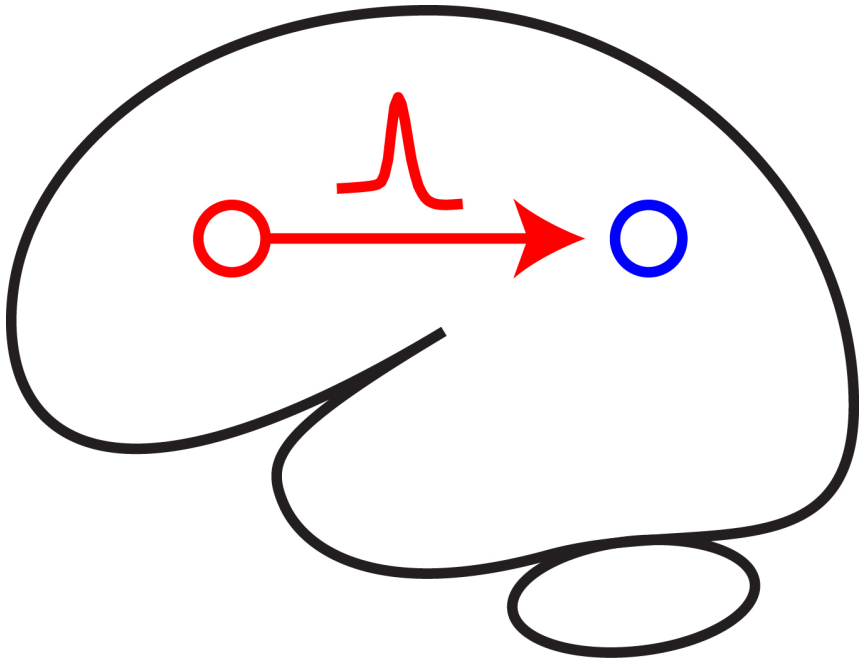


Action potential propagation speed depends upon axial current flow.

AP speed increases with:
i) Higher membrane resistance
ii) Lower axial resistance
iii) Lower membrane capacitance

Typical AP speed = ~1 m/s

Action potential initiation and propagation

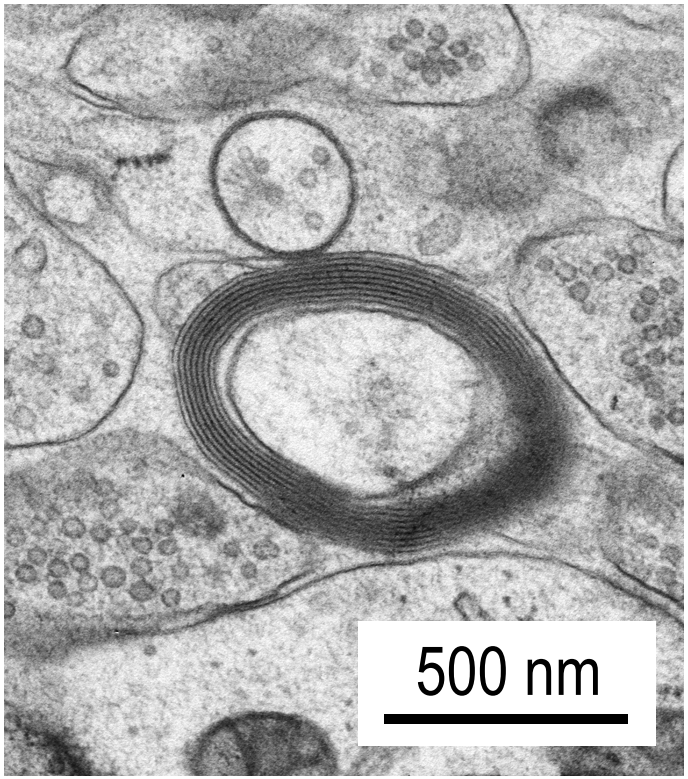


Myelination

Specialised glial cells (oligodendrocytes and Schwann cells) wrap very thin processes around selected axons. The myelin processes contain 80% lipid, which is a good electrical insulator.

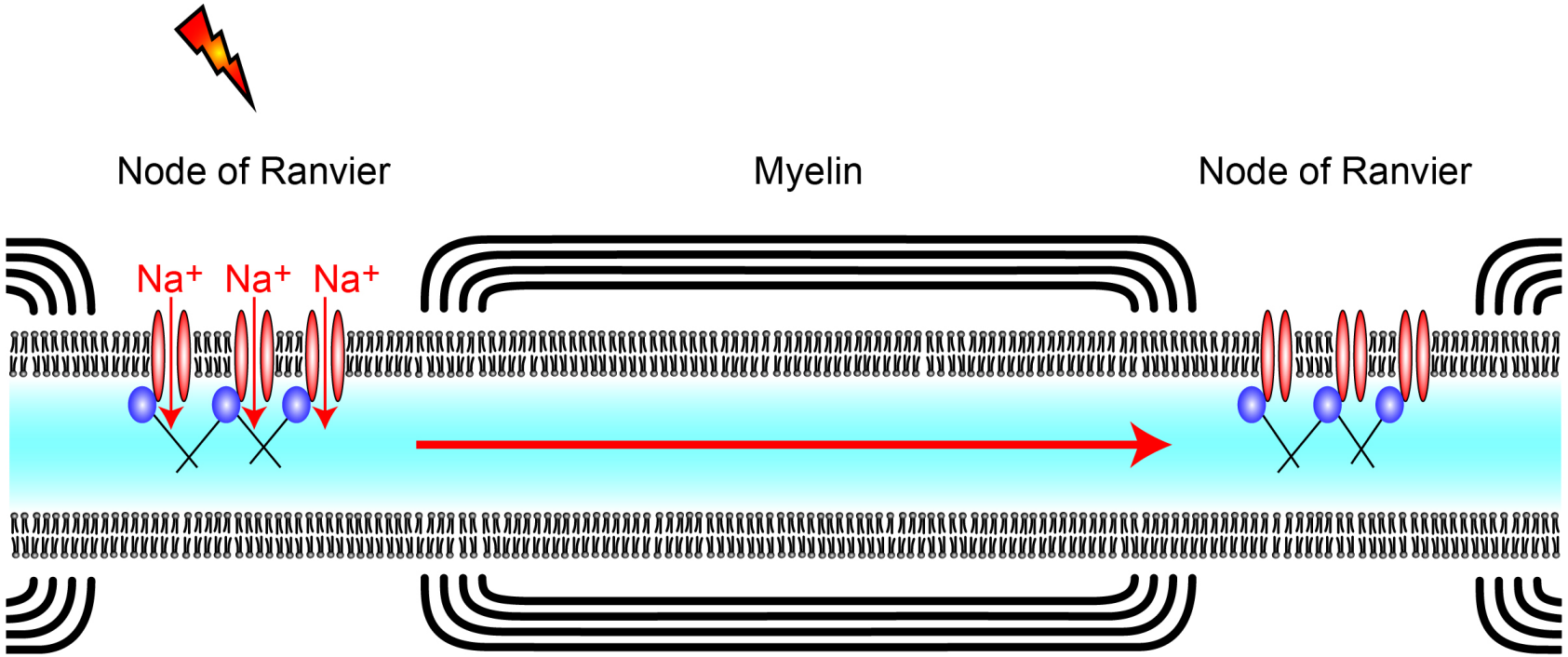
Myelination increases axonal membrane resistance by a factor of ~5,000 and decreases axonal capacitance by ~50.

$$\lambda = \sqrt{(R_m / R_{Axial})}$$



Korogod, Petersen and Knott

Nodes of Ranvier – saltatory AP propagation



Ankyrin G
Cytoskeleton

R_m high
C_m low

Action potential initiation and propagation

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- Action potentials are initiated at the axon initial segment, which contains a high density of voltage-gated Na^+ channels.

- Action potentials can propagate in axons and dendrites through all-or-none amplification of spreading waves of depolarisation by voltage-gated Na^+ channels.