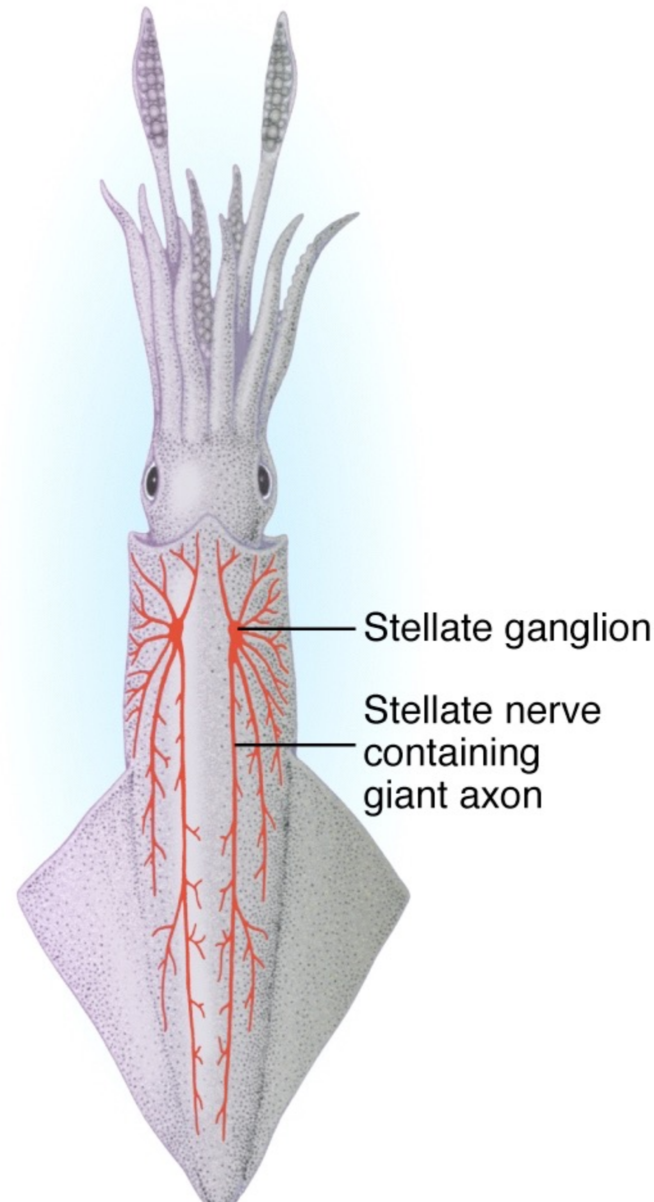
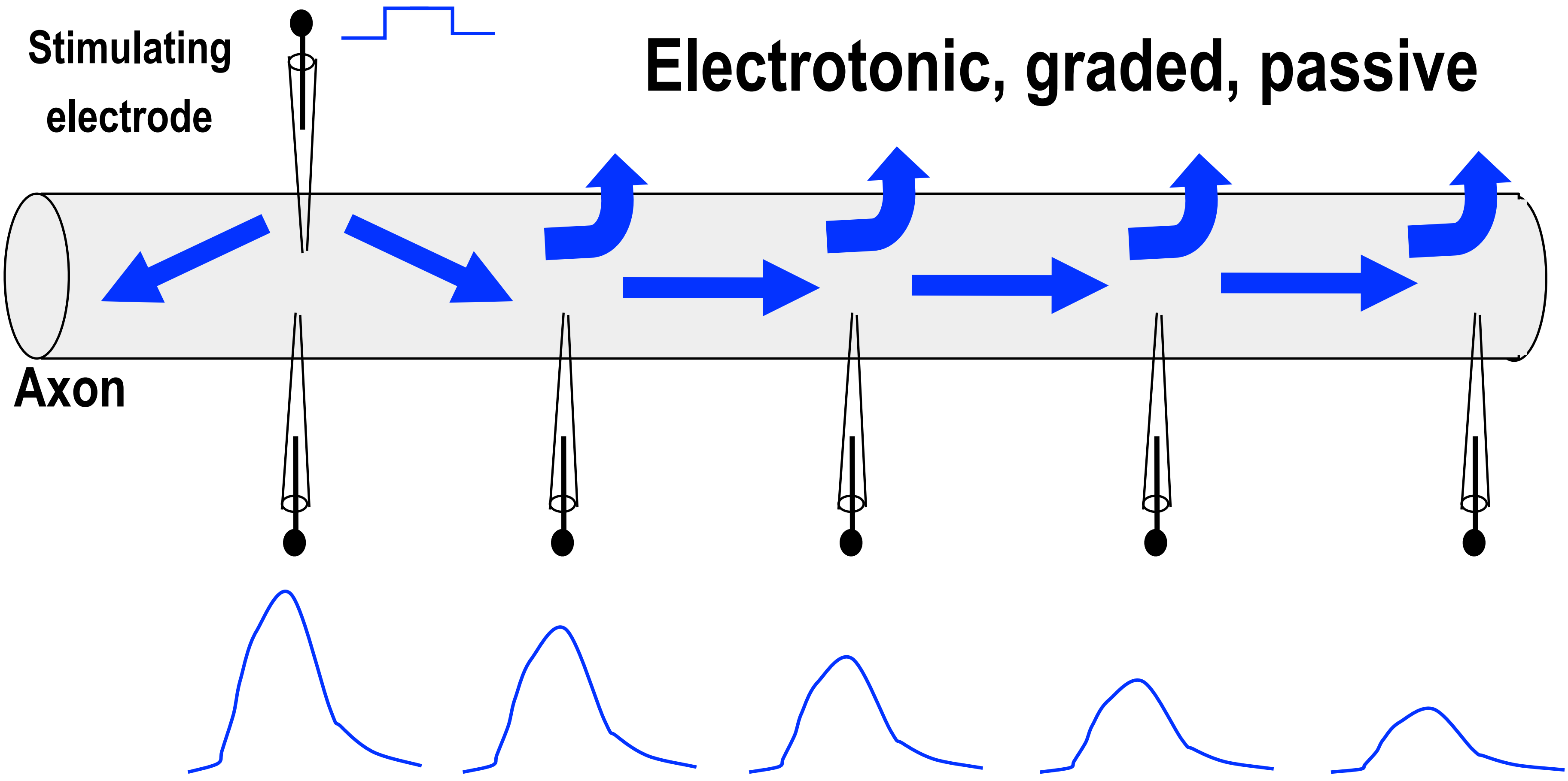
Neurobiology

Propagation & Integration of the Signal

Giant Axons in Squid



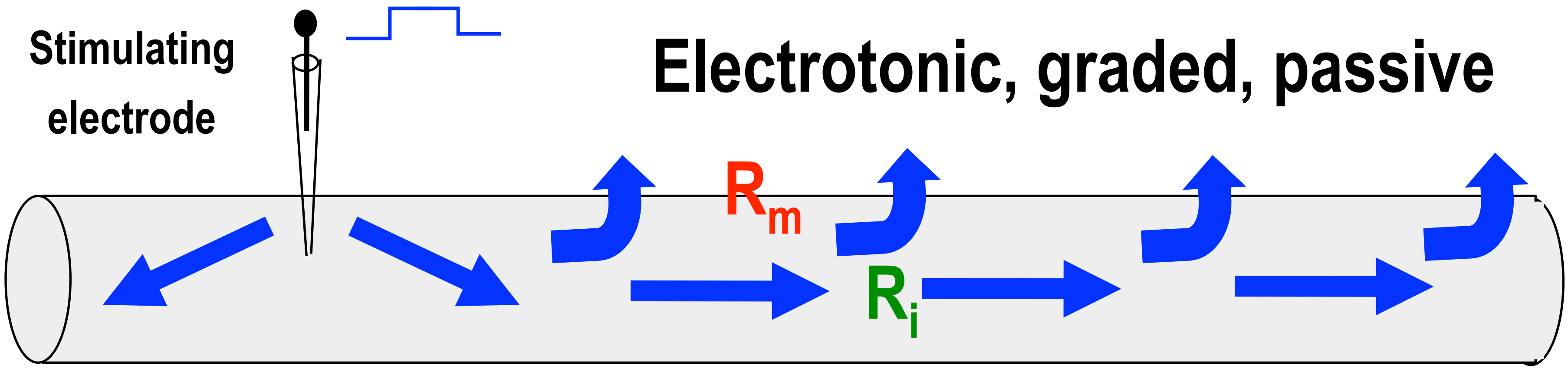
Propagation



Decays with distance!

Propagation

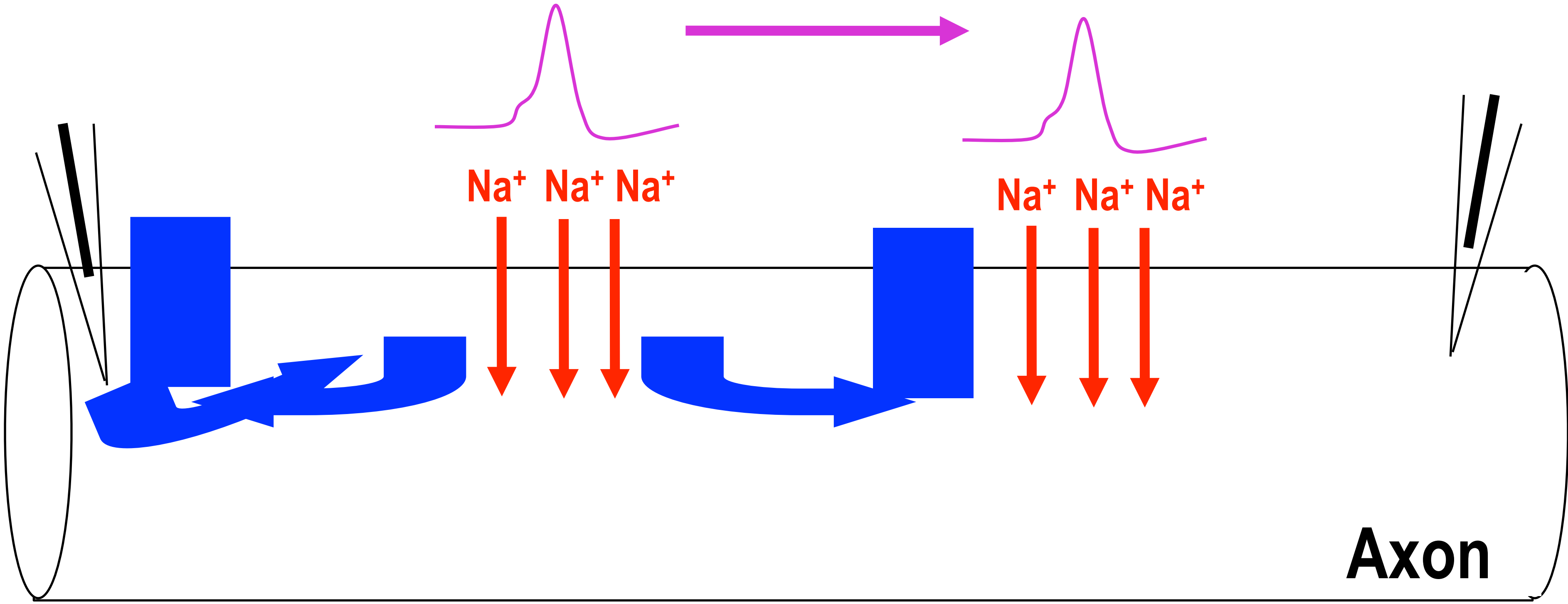
Electrotonic, graded, passive



What determines distance propagated?

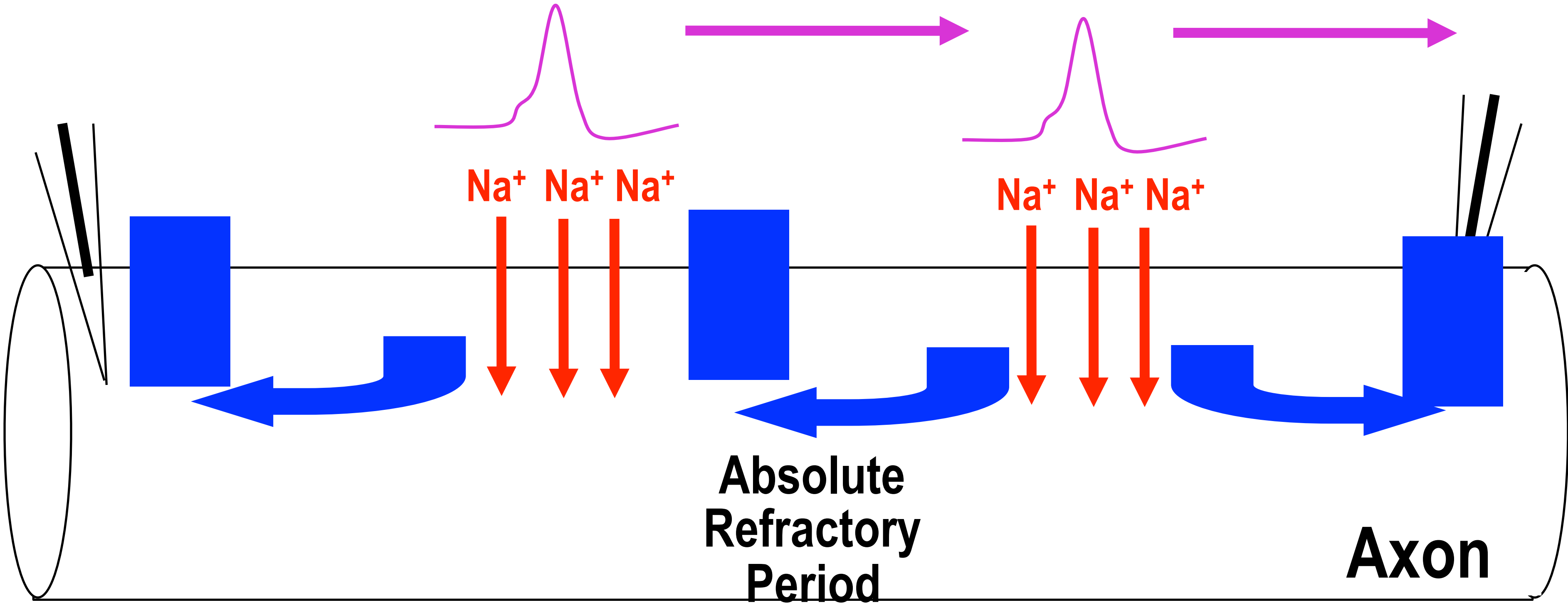
$$\text{Distance} \propto \frac{\text{Membrane Resistance } R_m}{\text{Internal Resistance } R_i}$$

Propagation



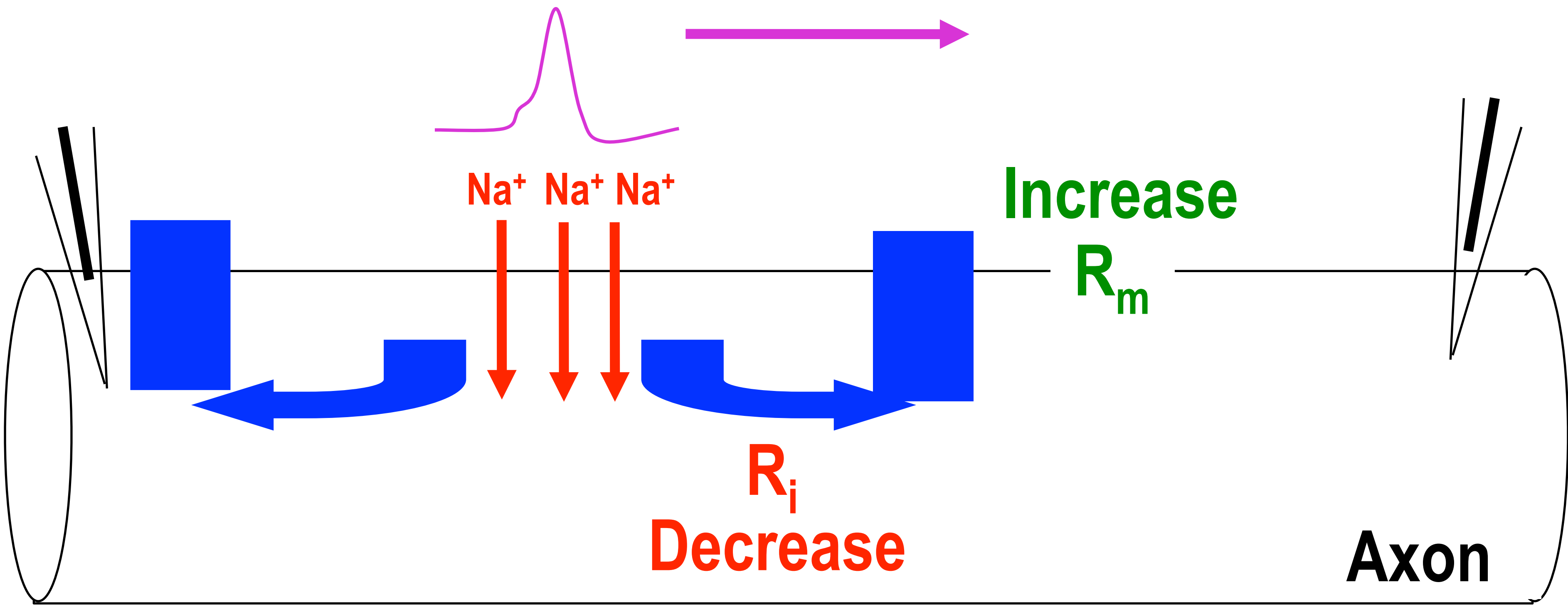
Action Potential - active, non-decremental

Propagation



Why directional?

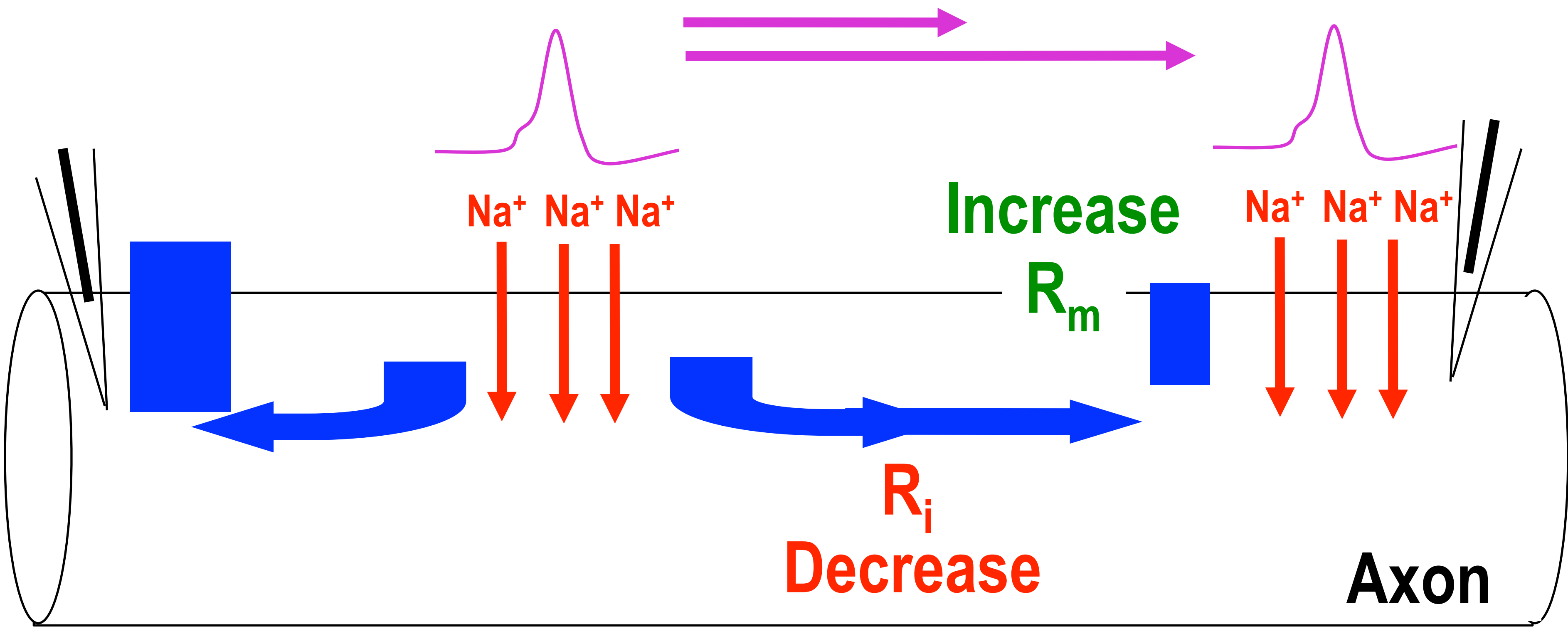
Propagation



How do you increase conduction velocity?

Must increase the distance traveled by electrotonic potential

Propagation



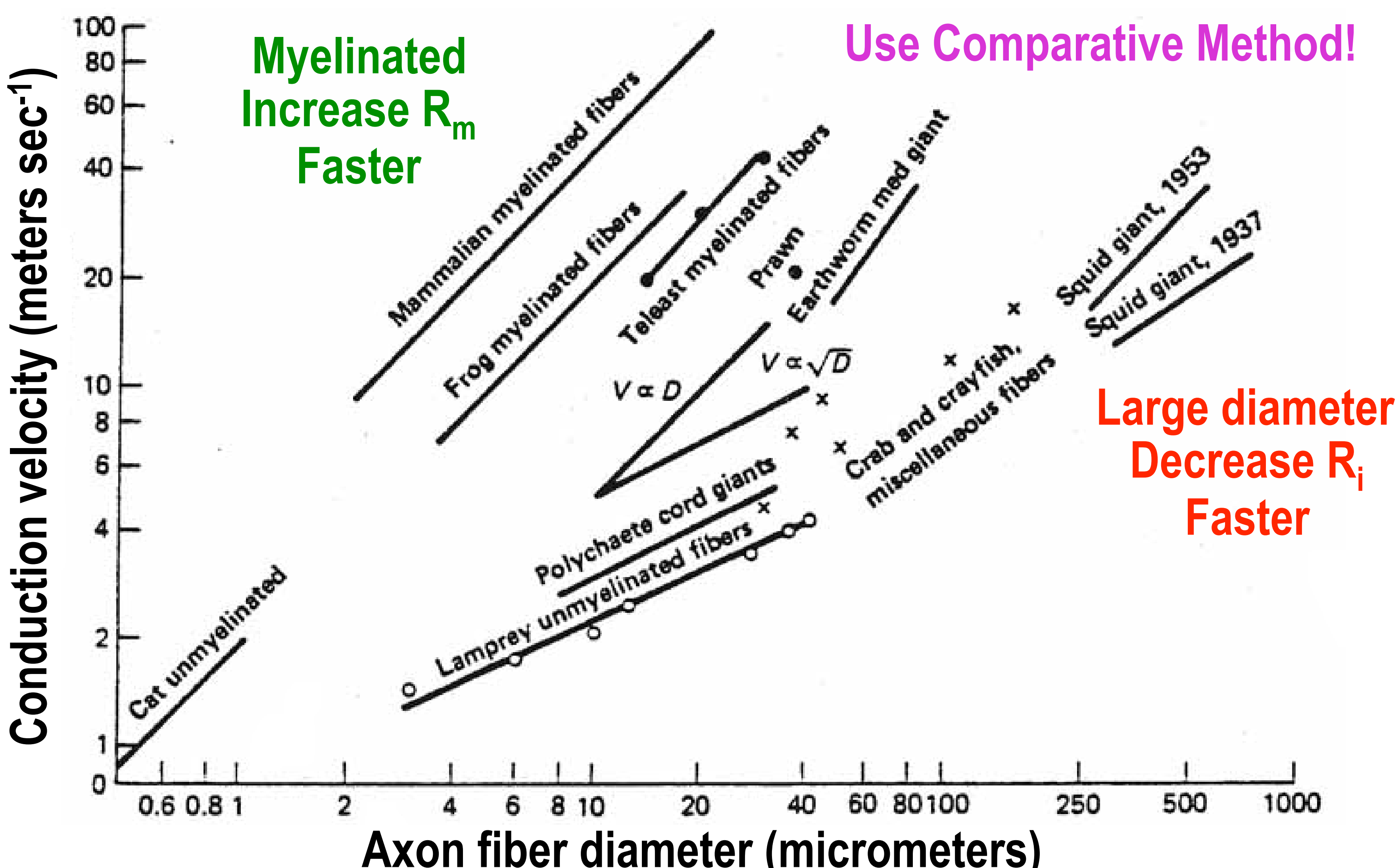
How do you increase conduction velocity?

Must increase the distance traveled by electrotonic potential

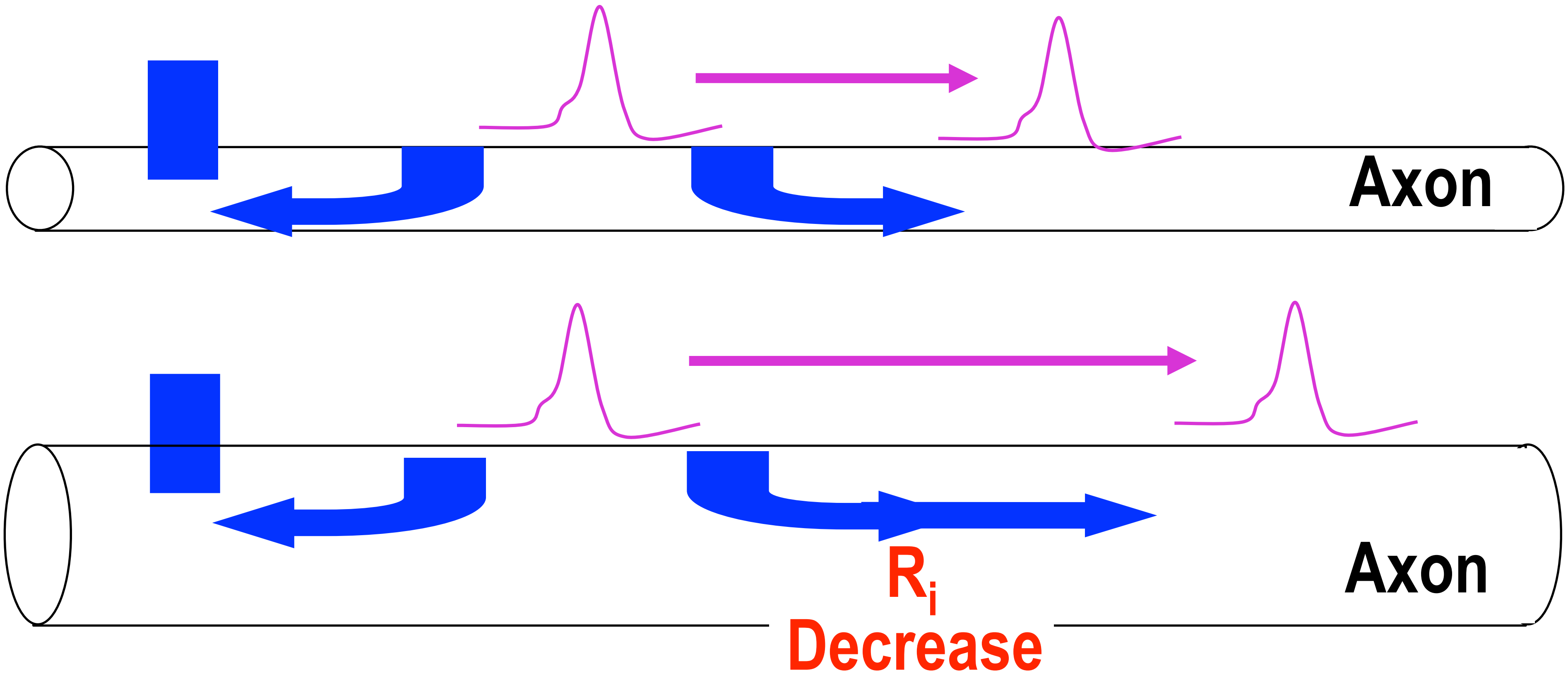
Hypothesis: Decrease internal resistance and/or

increase membrane resistance

Conduction Velocity



Propagation

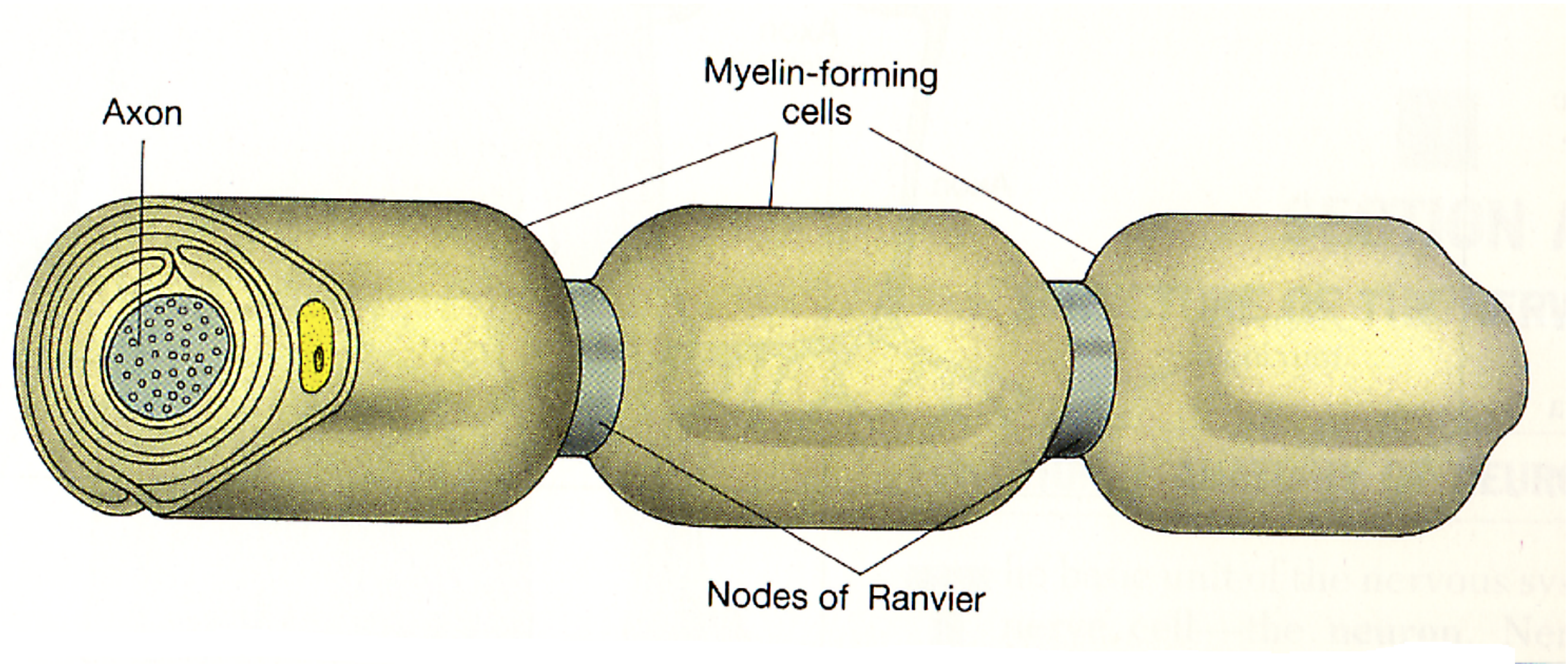


How do you increase conduction velocity?

Must increase the distance traveled by electrotonic potential

Decrease internal resistance by increasing axon diameter

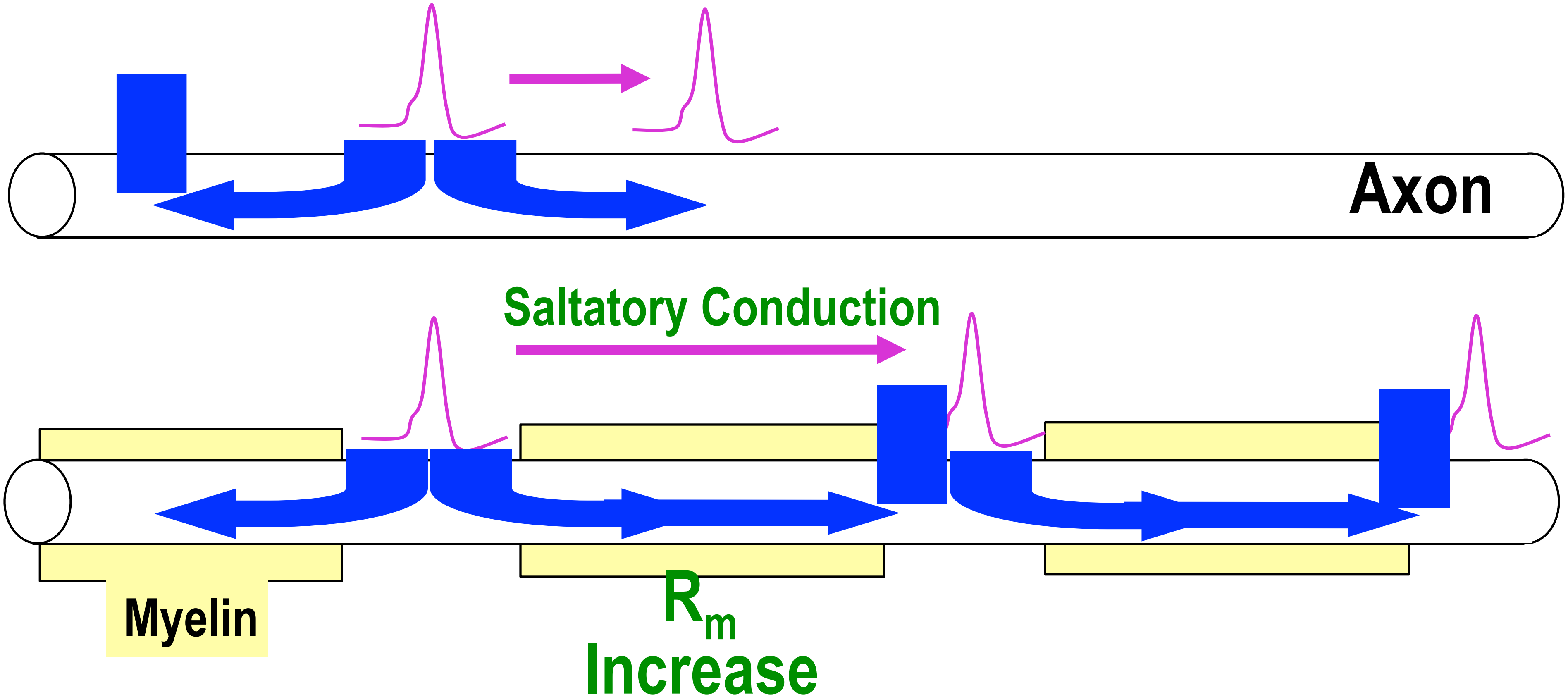
Myelin



Increase membrane resistance by adding insulation

Vander, Sherman and Luciano 1990

Propagation



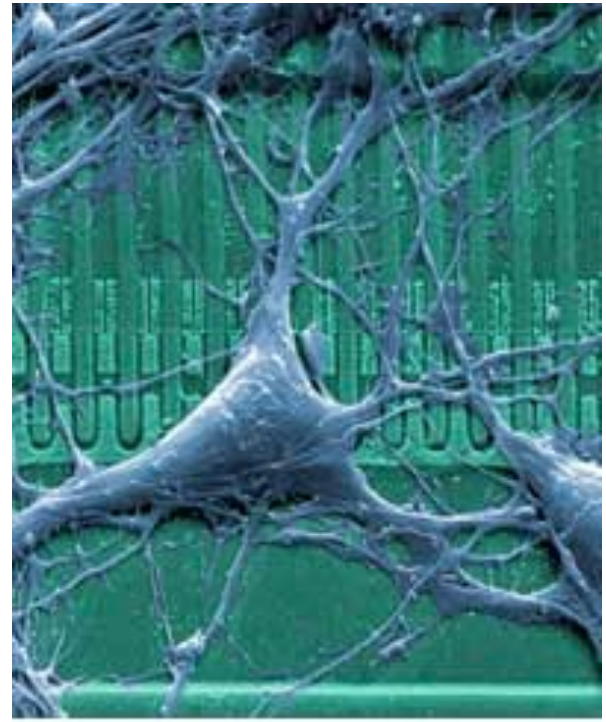
How do you increase conduction velocity?

Must increase the distance traveled by electrotonic potential

Increase membrane resistance by adding insulation

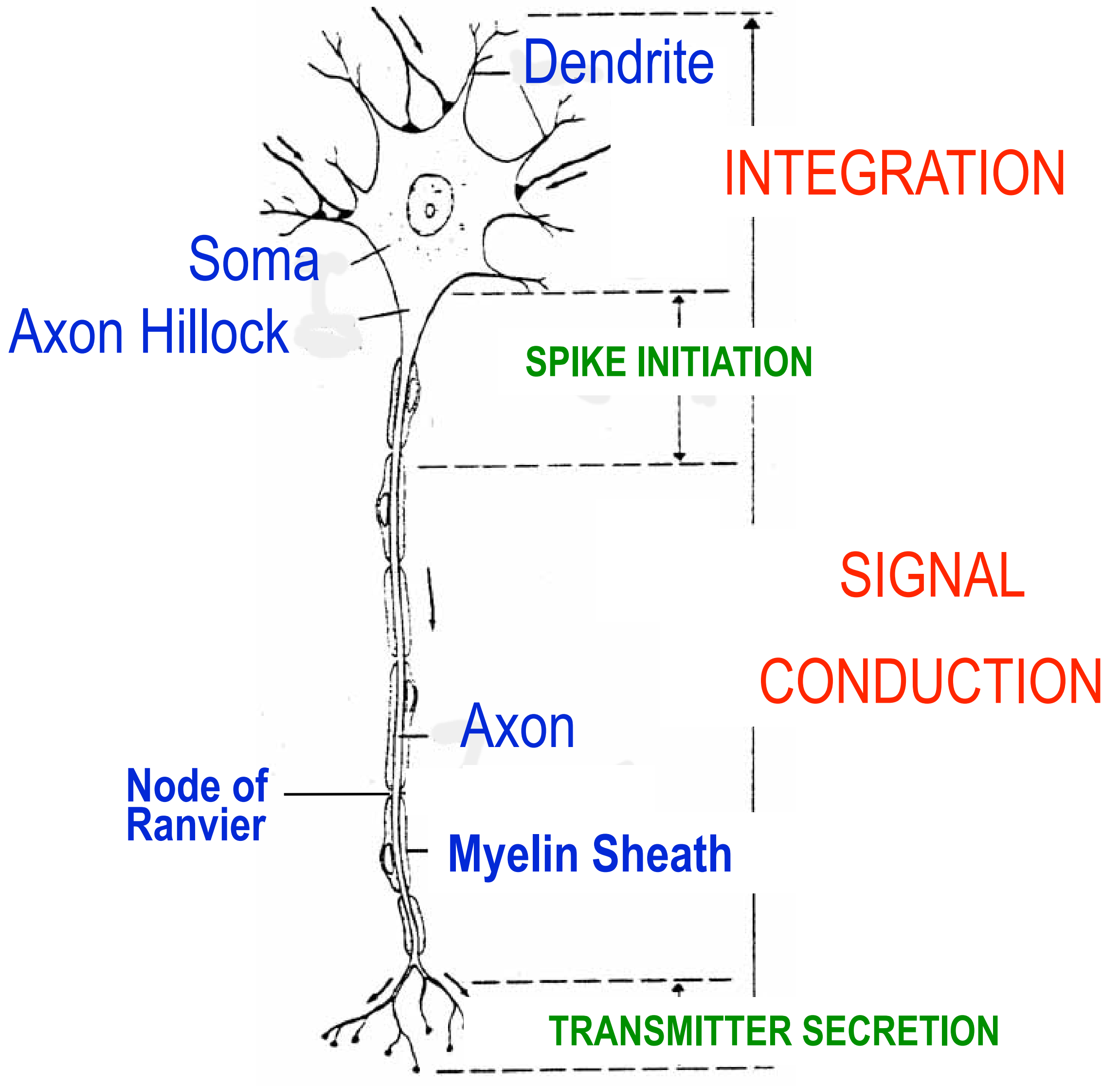
Direct Connections

A direct ion channel-electronic interface could eventually prove useful in biosensors, brain-computer interfaces, or even open up the possibility of neural prosthetics

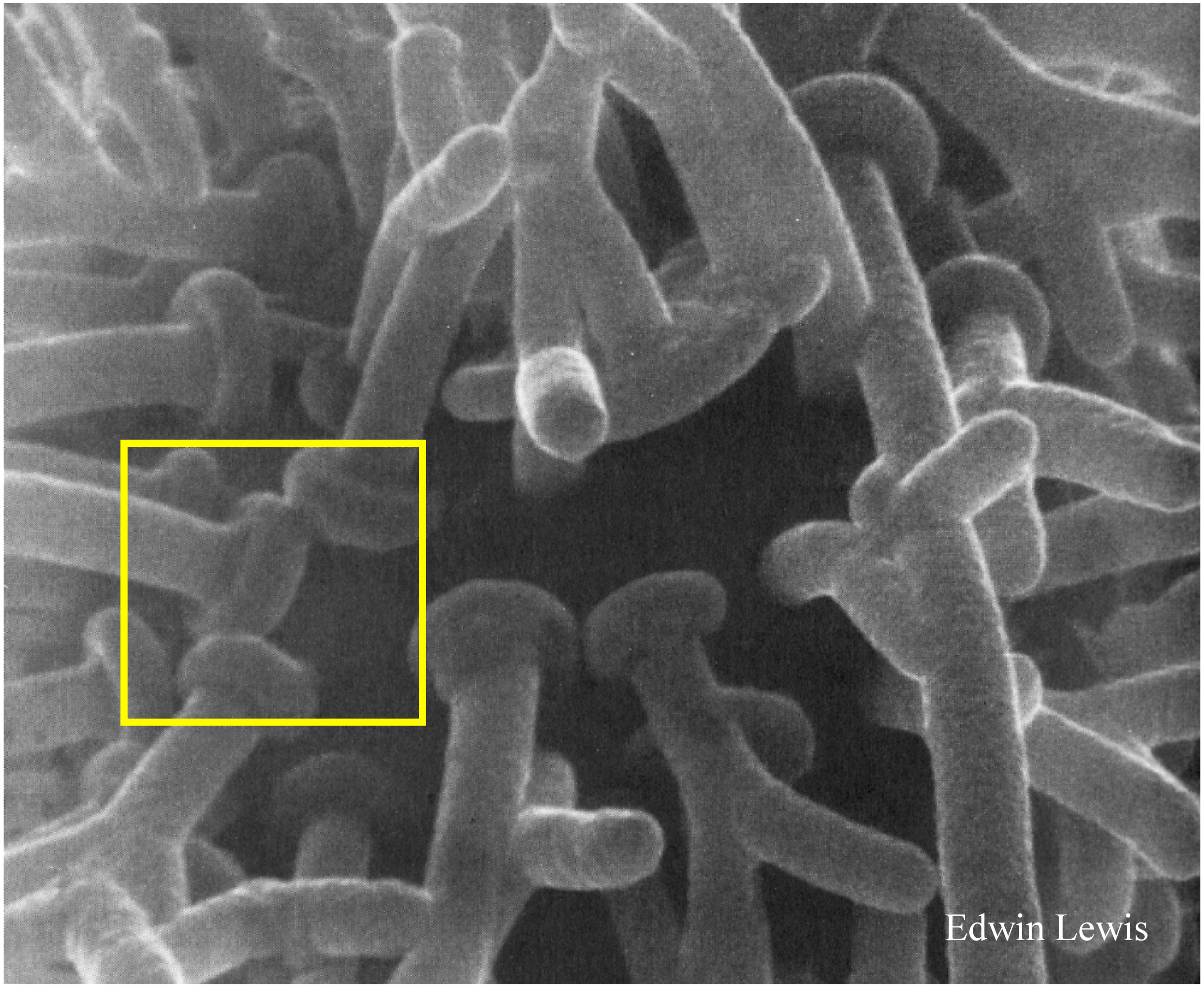


This electron micrograph shows a nerve cell connected to an oxidized silicon chip coated with collagen. The ion current the cell uses for communication flows along the narrow gap between the cell and chip and affects the silicon electrons' flow.

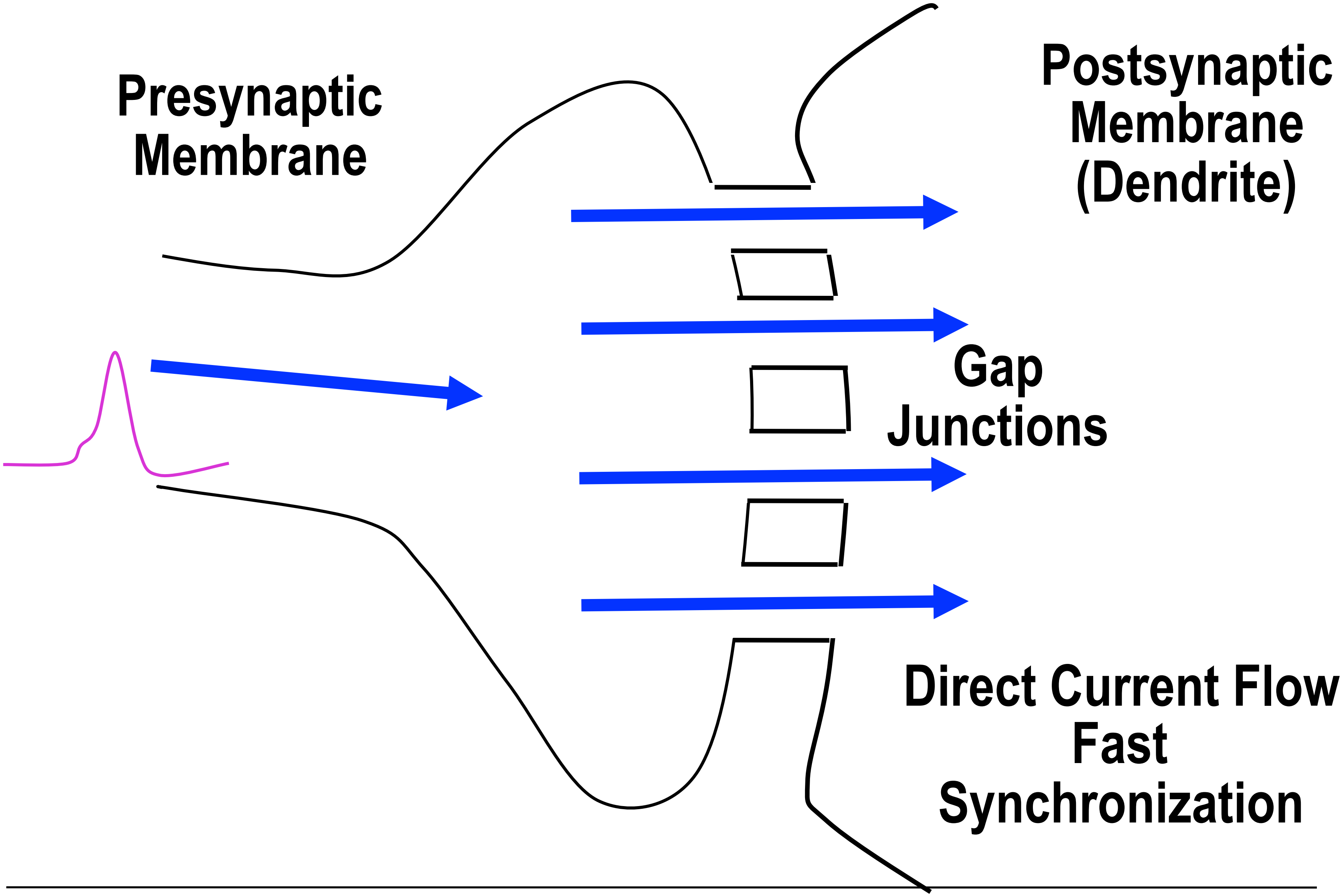
Structure of Neuron



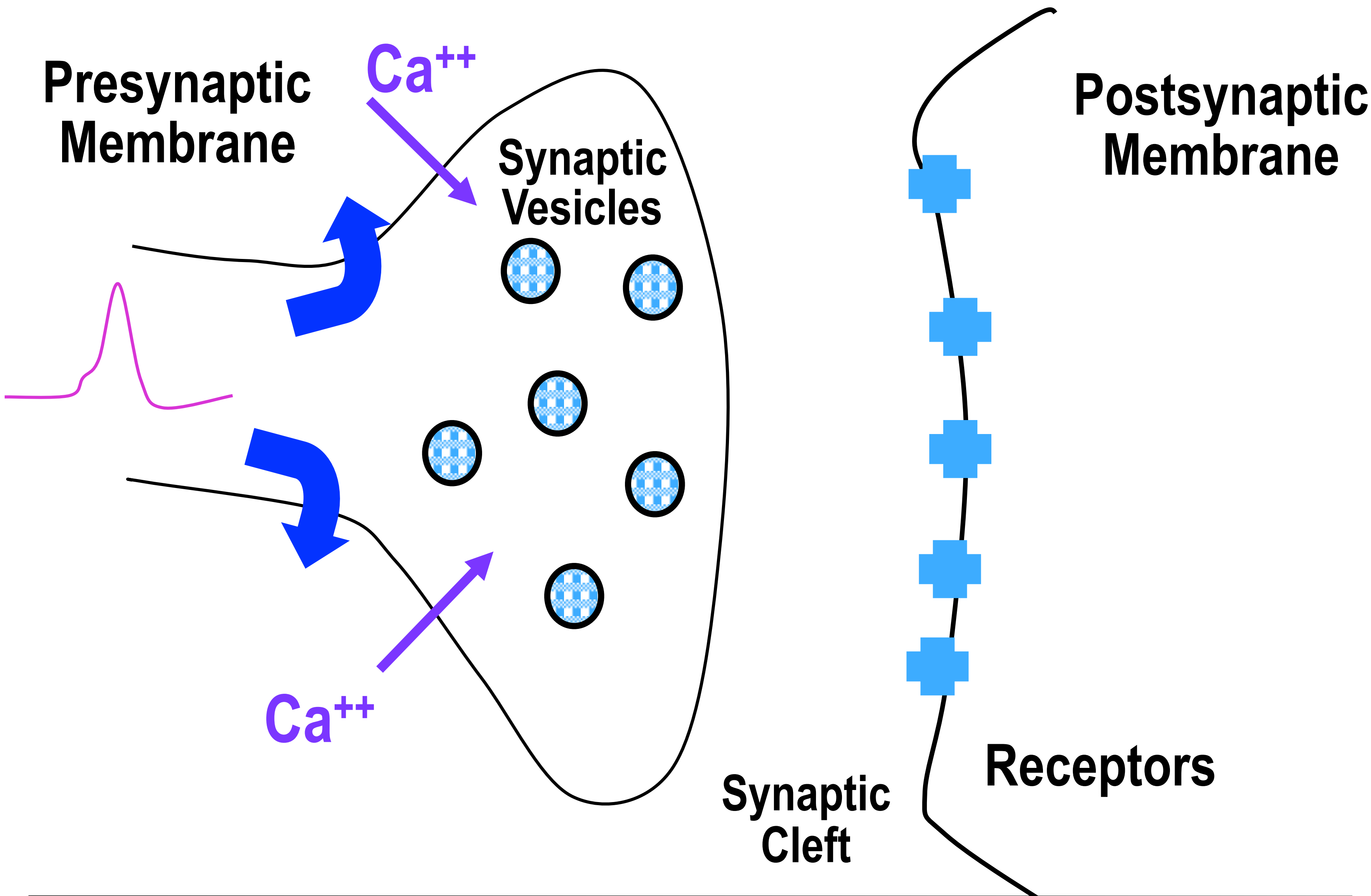
Synapatic Connections



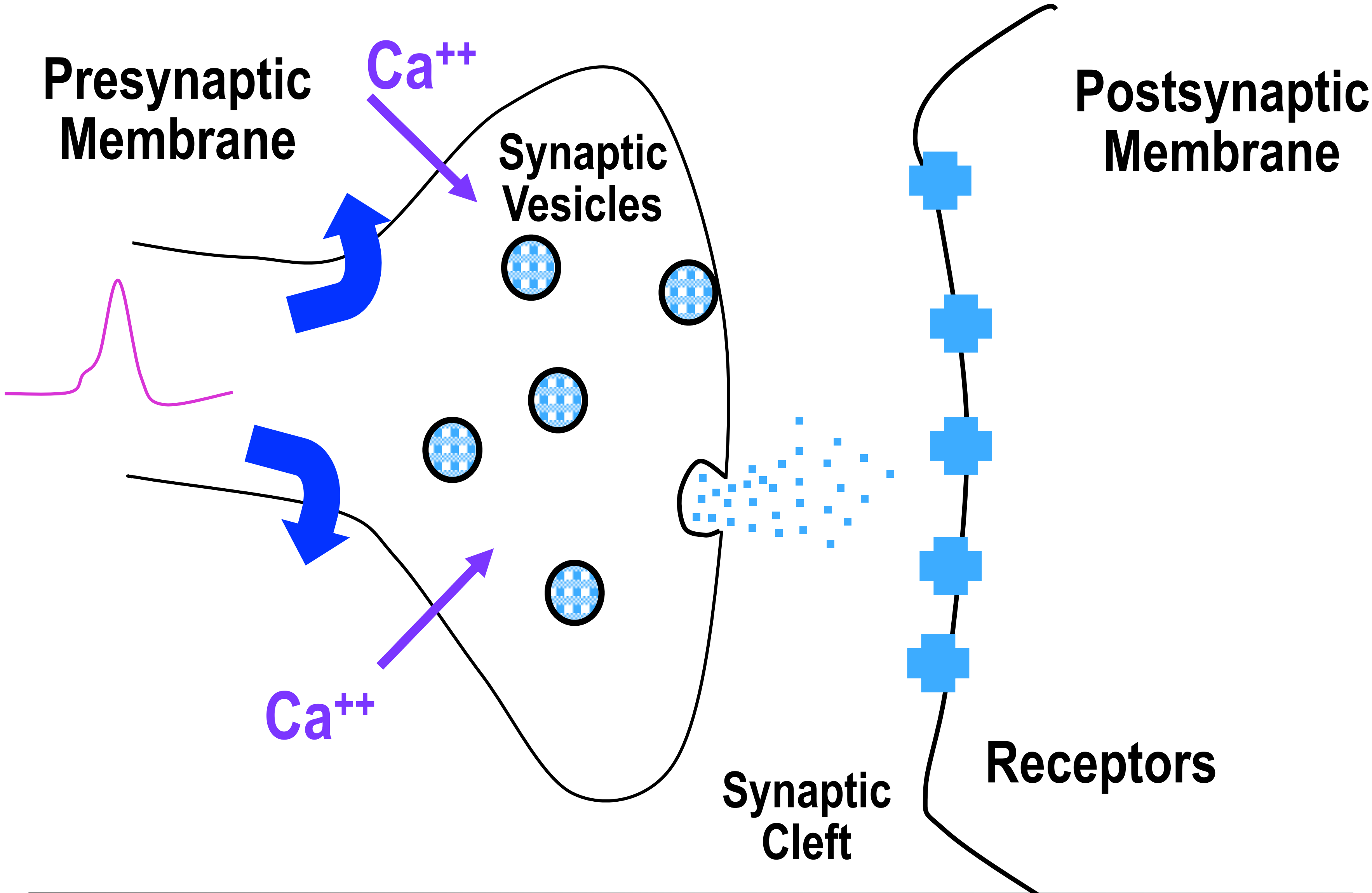
Electrical Synapse



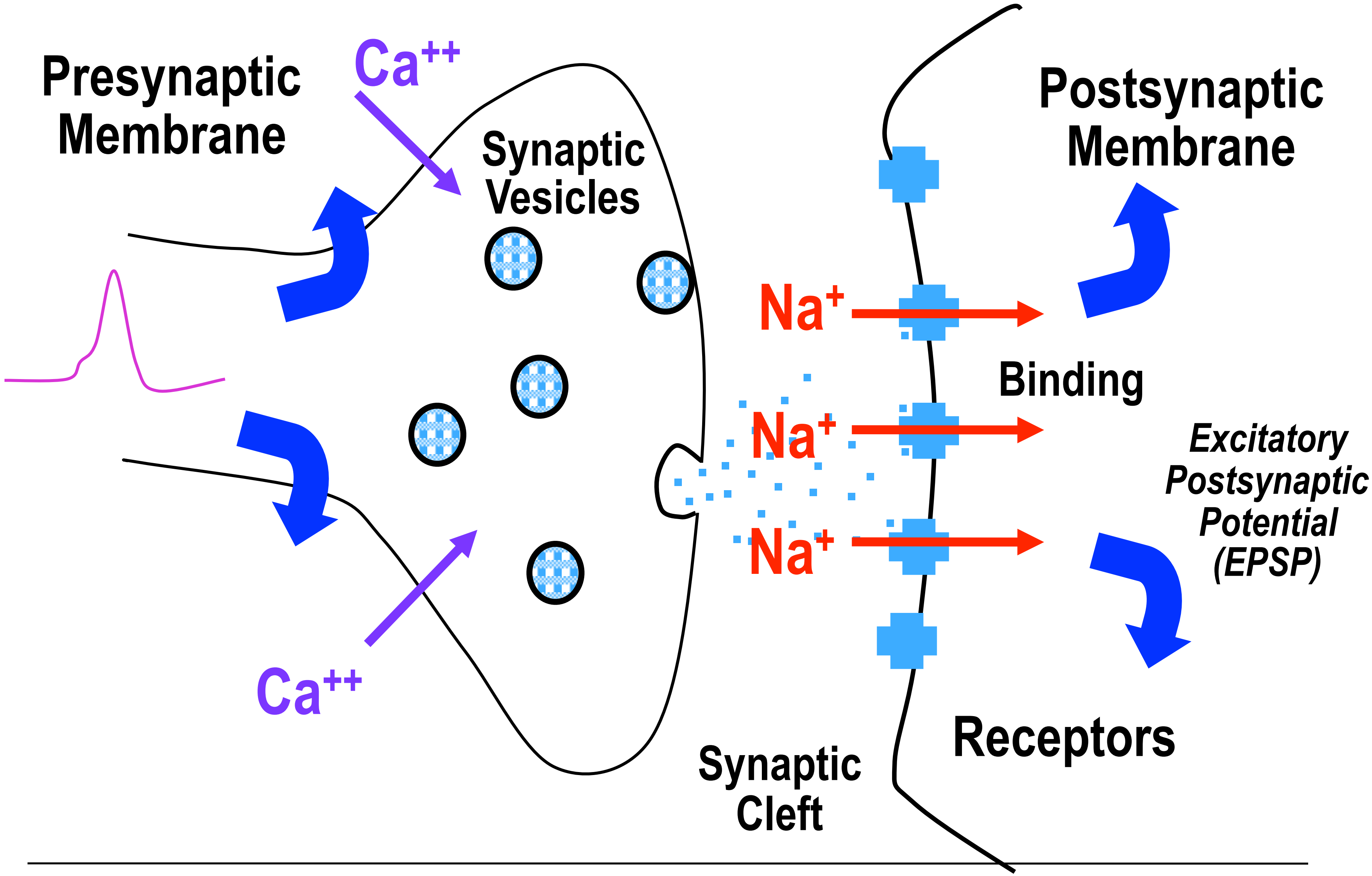
Chemical Synapse



Chemical Synapse



Chemical Synapse



Synaptic Potentials

Excitatory postsynaptic potential (EPSP)

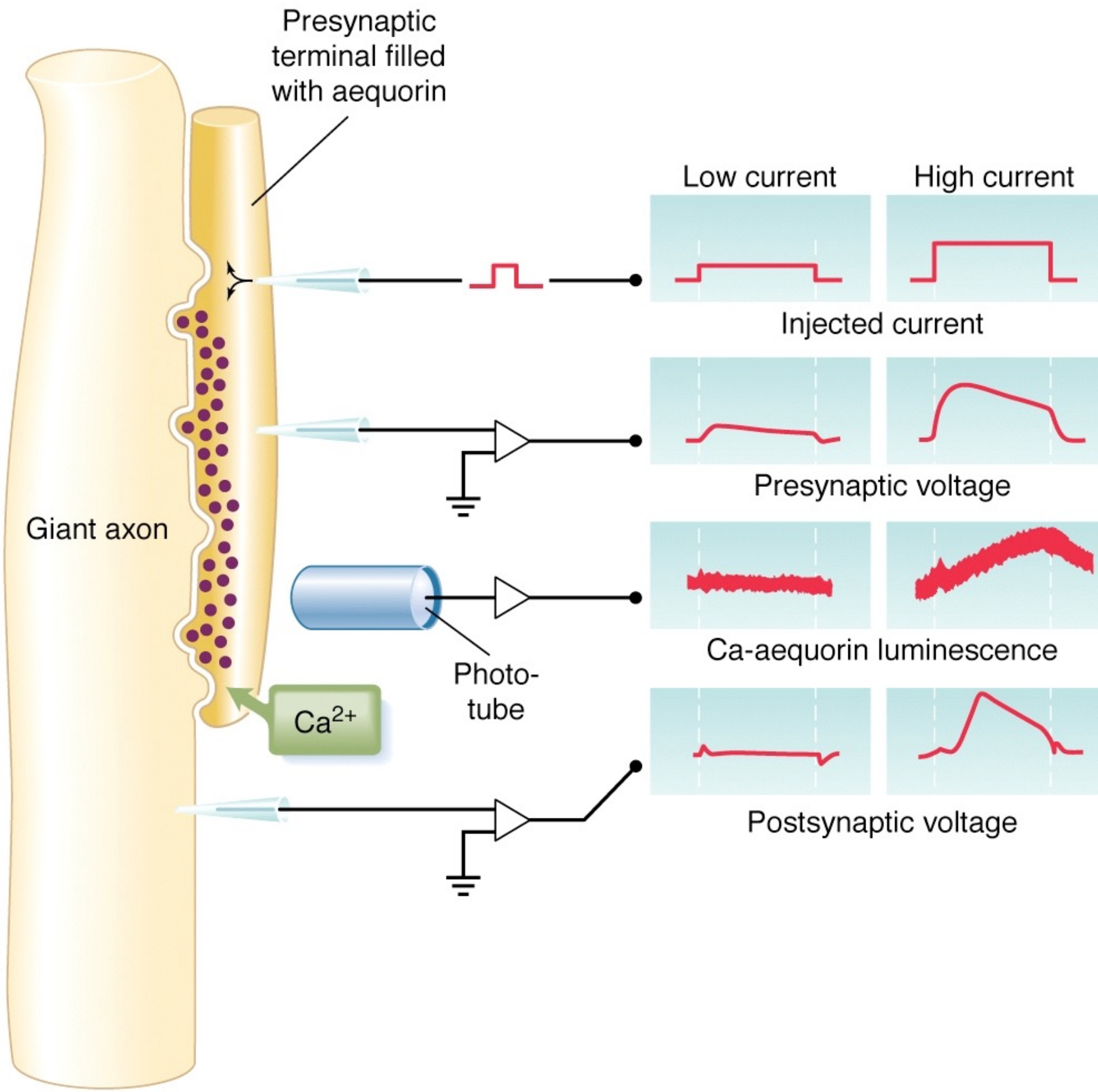
- increase the likelihood that neuron will transmit impulse
- leads to a depolarization of the post-synaptic neuron
- resulting from increase in P_{Na} or P_{Ca}
- if stimulus sufficient may lead to an action potential

Inhibitory postsynaptic potential (IPSP)

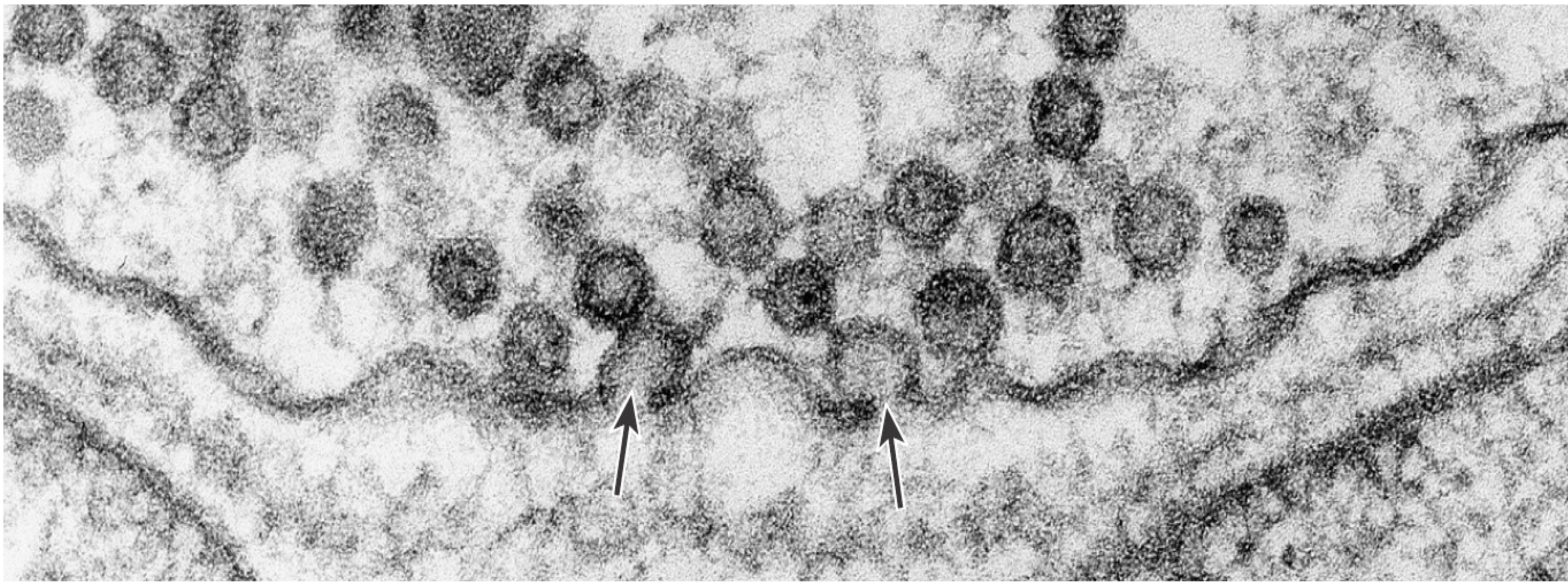
- will decrease the likelihood that neuron will transmit impulse
- hyperpolarization or stabilization of V_m
- resulting from increase P_K or P_{Cl}
- greater than normal excitatory stimulus required to trigger an action potential

Ca Required at Synapse

Aequorin isolated from jellyfish that glow.
Allows discovery of Ca participation in synaptic vesicle release.



Vesicle Fusion



Neurotransmitters

E Excitatory

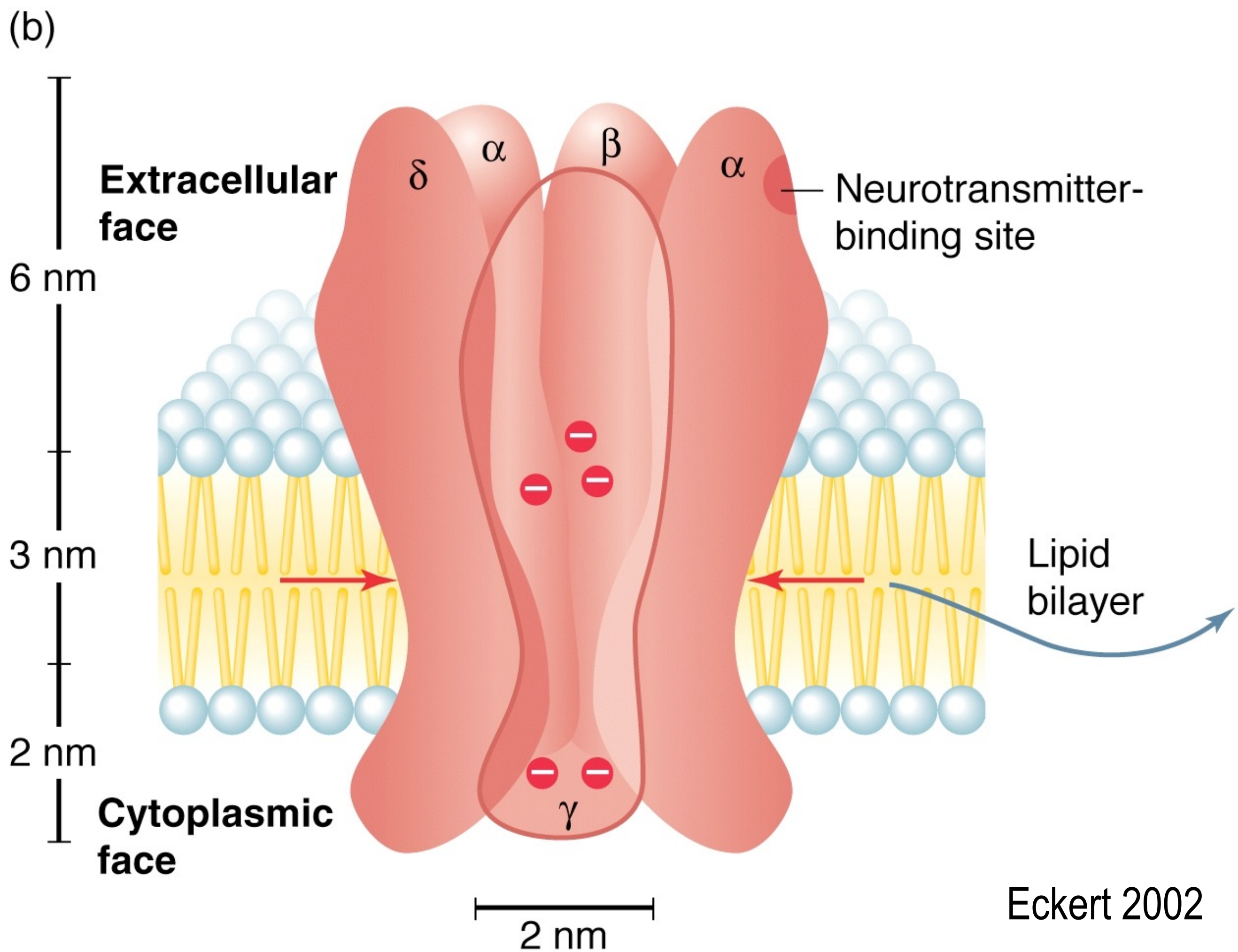
I Inhibitory

Widespread

Transmitter	Animal	Action	
Acetylcholine	Vertebrate muscle	E	
	Vertebrate CNS	E	
	Invertebrate CNS	E or I	
Norepinephrine	Vertebrate CNS	E or I	Mimic (Amphetamines) Block inactivation (Cocaine)
Glutamic acid	Vertebrate CNS	E	
	Crustacean CNS	E	
GABA	Vertebrate CNS	I	
	Crustacean CNS	I	
	Annelid CNS	I	
Serotonin	Vertebrate CNS	I	Block re-uptake (Prozac)
	Invertebrate CNS	I	
Dopamine	Vertebrate CNS	E or I	Pleasure producing pathways (Addiction)
	Arthropod CNS	E or I	
	Annelid CNS	E or I	

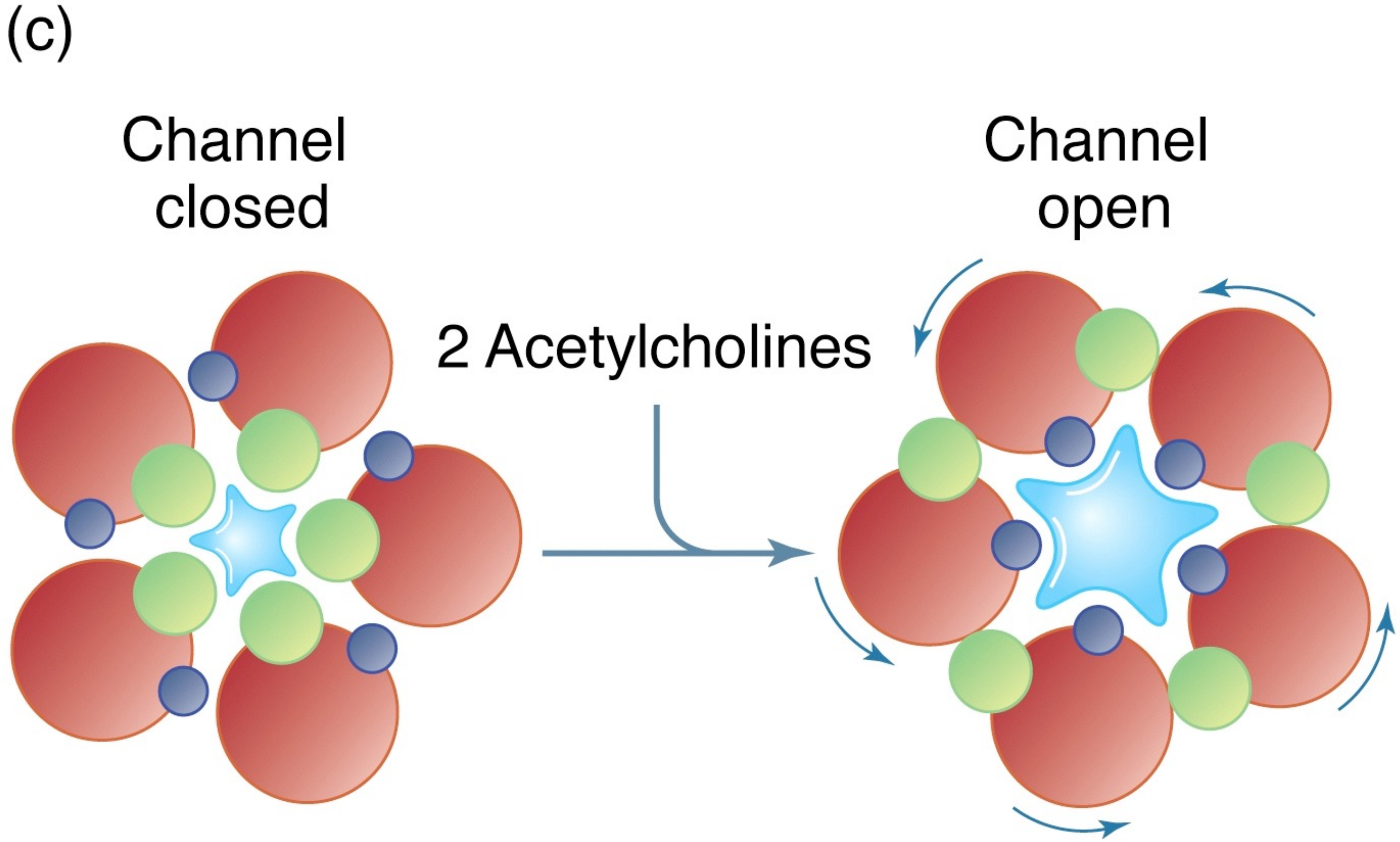
Acetylcholine Receptor

Isolated from Electric fish!

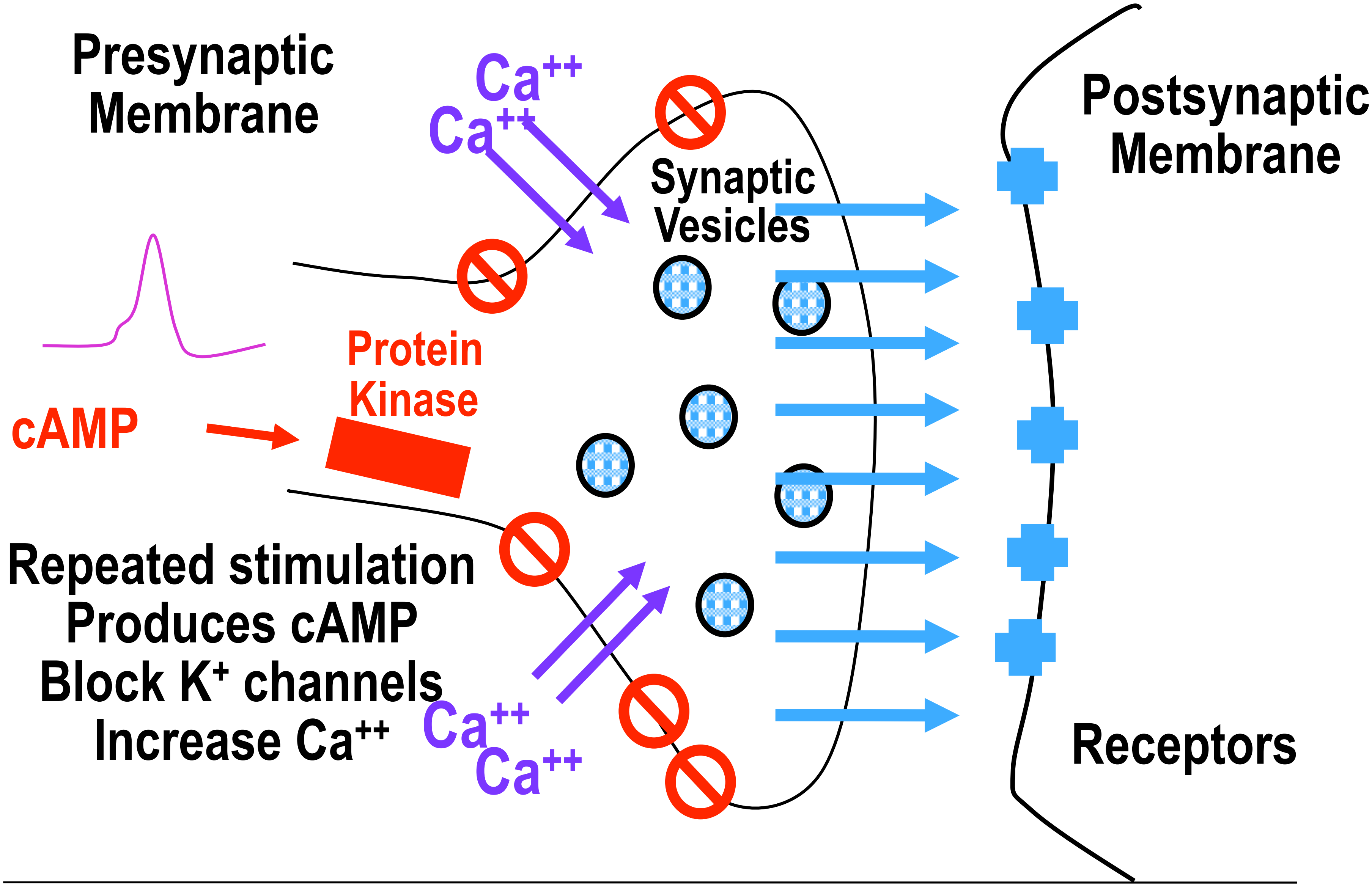


Eckert 2002

Acetylcholine Receptor



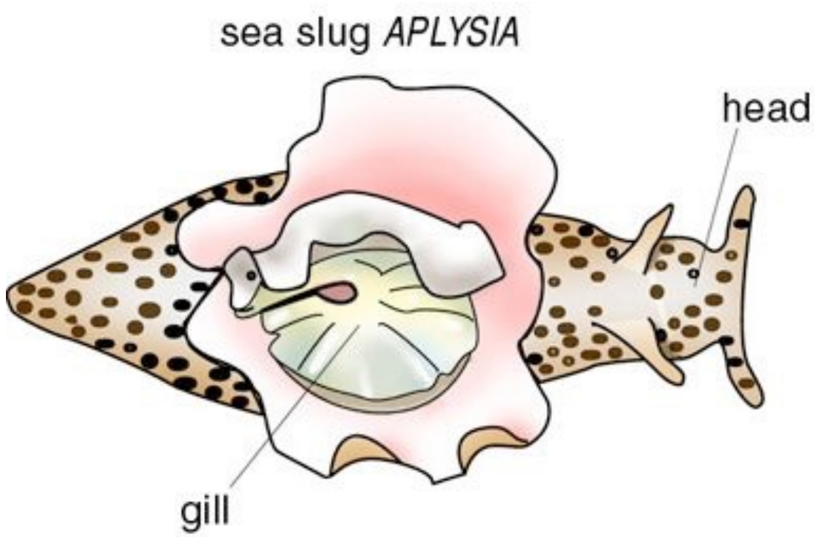
Secrets of Memory

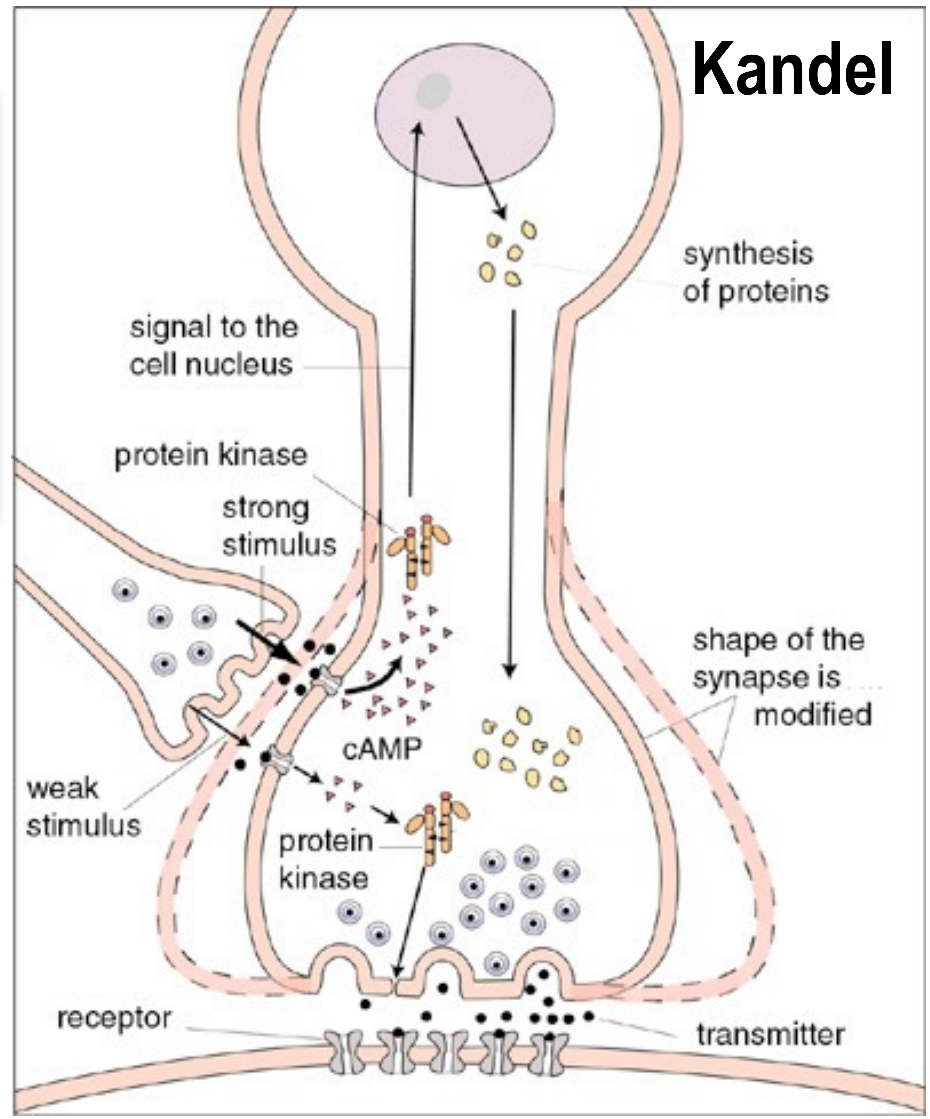


Secrets of Memory

Short term memory - weak stimulus causes a protein phosphorylation of ion channels, which leads to a release of an increased amount of transmitter.

Long term memory requires a stronger and more long-lasting stimulus and issues orders to synthesize new proteins. Leads to changes in the form and function of the synapse. The efficacy of the synapse can then be increased and more transmitter released.



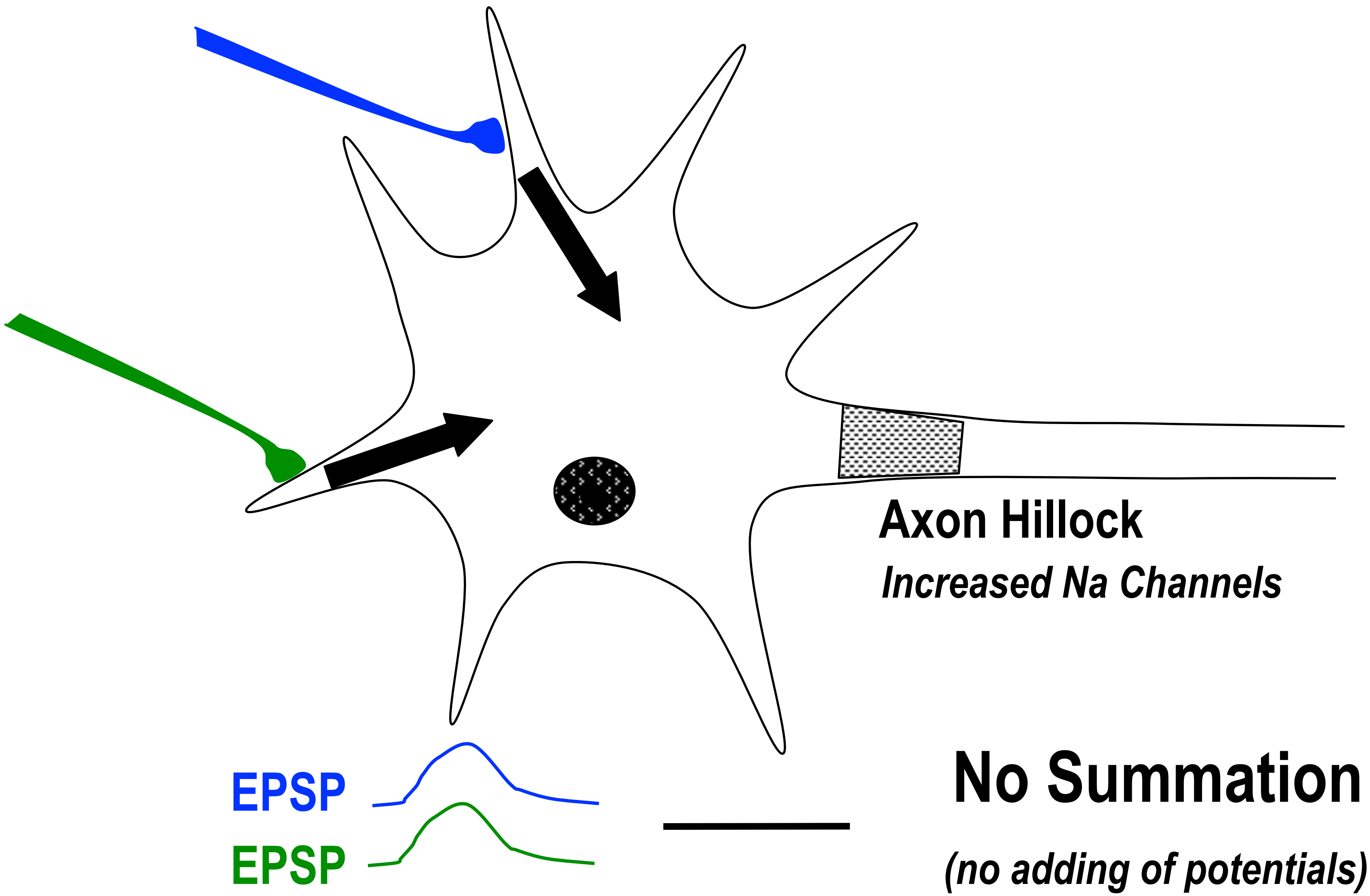


Secrets of Memory & Movement

2000 Nobel Prize in Medicine

Arvid Carlsson, Paul Greengard and Eric Kandel

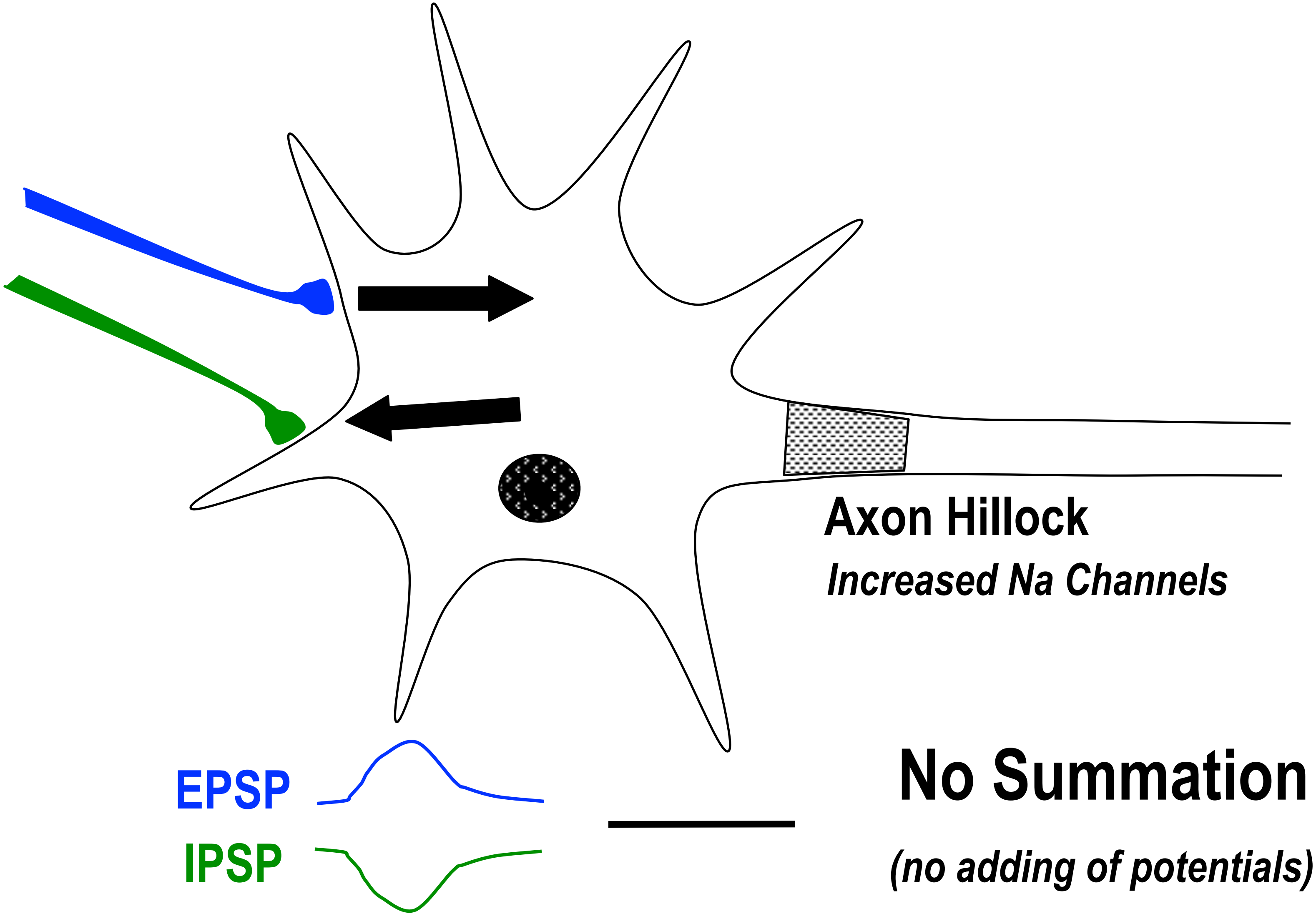
Synaptic Integration



No Summation

(no adding of potentials)

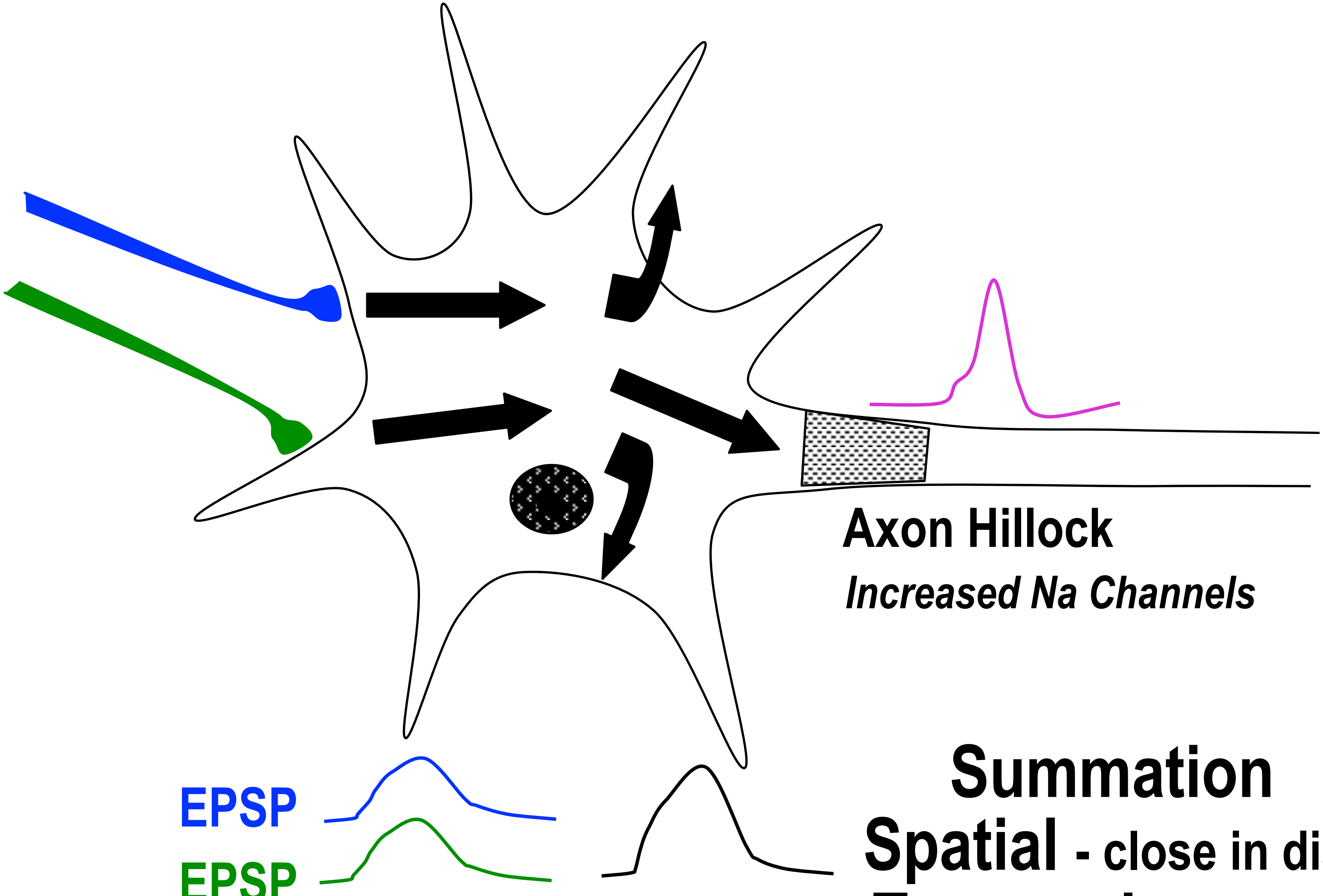
Synaptic Integration



No Summation

(no adding of potentials)

Synaptic Integration

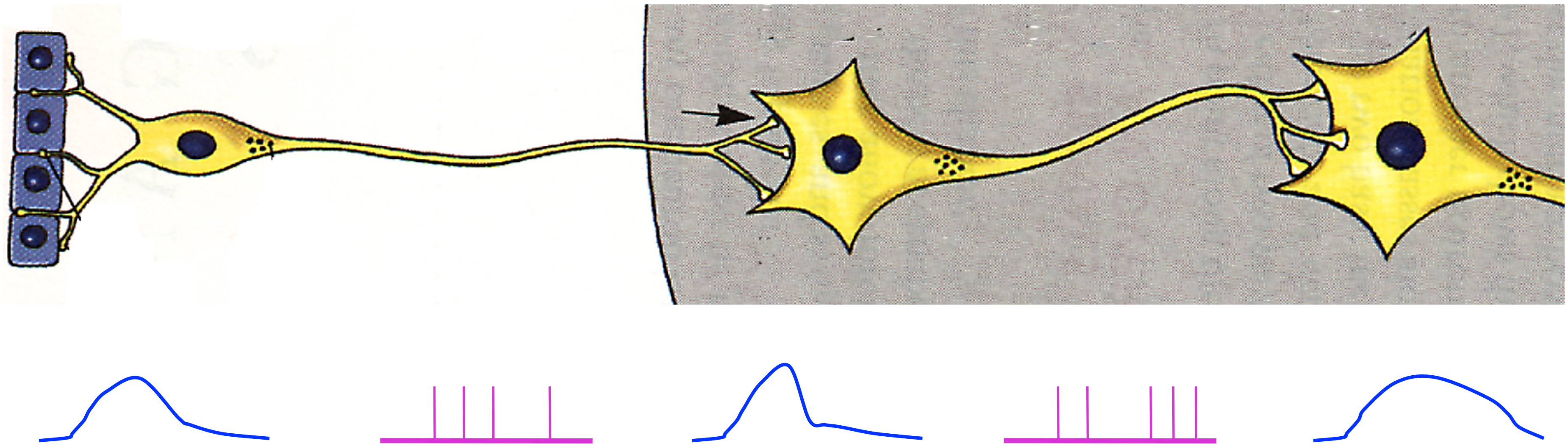


Summation

Spatial - close in distance

Temporal - close in time

Signal transmission



Graded Electrotonic Potential | All or none Action Potenital | Graded Electrotonic Potential | All or none Action Potenital | Graded Electrotonic Potential

Analog | **Digital** | **Analog** | **Digital** | **Analog**

Neuromorphic Chip

Computer Chips are typically digital in operation. 0 or 1

Dendrites of neurons are analog (continuous)

New neuromorphic chips are part analog (continuous)

Greater information transfer with less power!