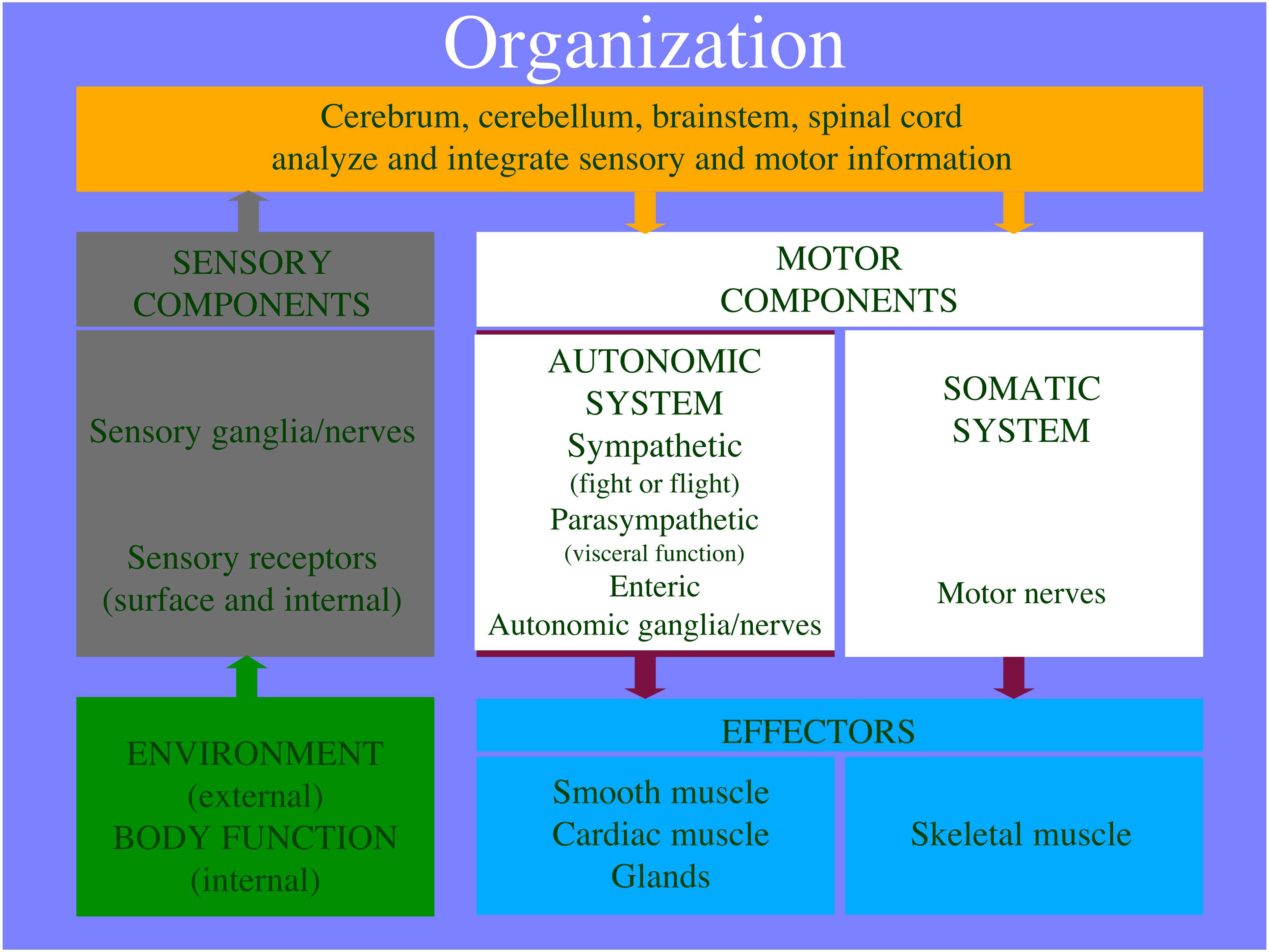
Lecture 15: The Neurosystem

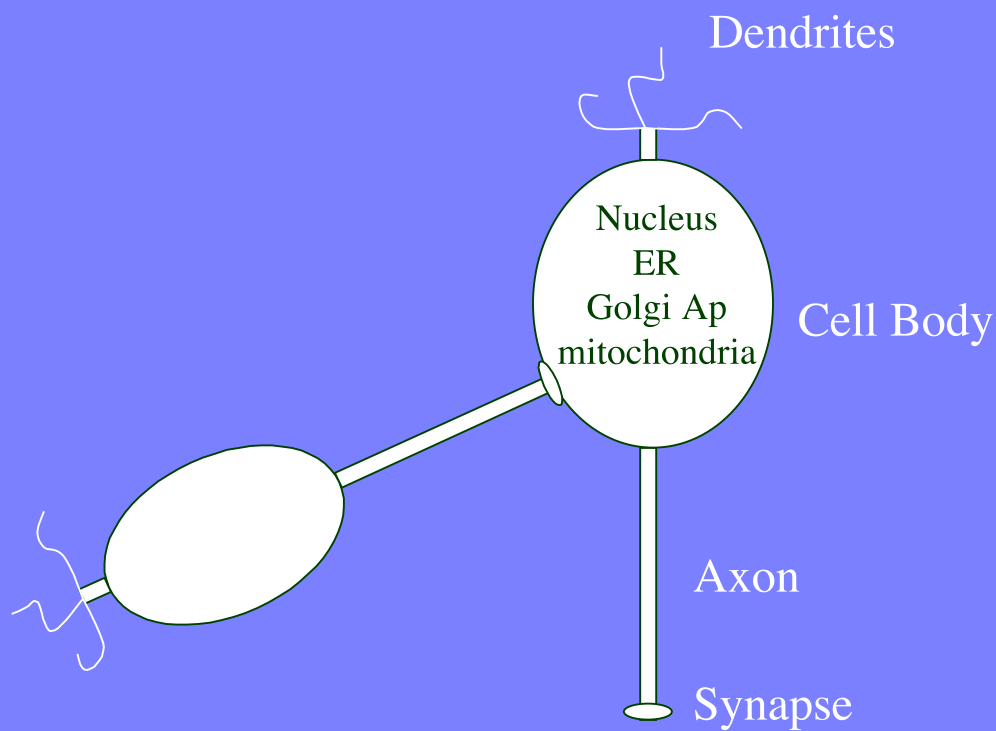
- The central nervous system
  - Brain
    - Sensory processing
    - Response
    - Motor control
    - Cognition and behavior
    - Memory
  - Spinal

- Peripheral somatic division
- Peripheral autonomic nervous system


Organization
Cerebrum, cerebellum, brainstem, spinal cord
analyze and integrate sensory and motor information
SENSORY COMPONENTS
Sensory ganglia/nerves
Sensory receptors (surface and internal)
MOTOR COMPONENTS
AUTONOMIC SYSTEM
Sympathetic
(fight or flight)
Parasympathetic
(visceral function)
Enteric
Autonomic ganglia/nerves
SOMATIC SYSTEM
Motor nerves
ENVIRONMENT (external)
BODY FUNCTION (internal)
EFFECTORS
Smooth muscle
Cardiac muscle
Glands
Skeletal muscle

Neurons are Nerve Cells

- Specialized for ELECTRICAL telecommunication



Up to 1 METER long!!!

- Variety of mophologies & functions
- Glial cells are NOT glue:
  - maintain ionic concentrations, modulate nerve signal processing, modulate synaptic action, control neurotransmitters

Neurons are organized into Circuits

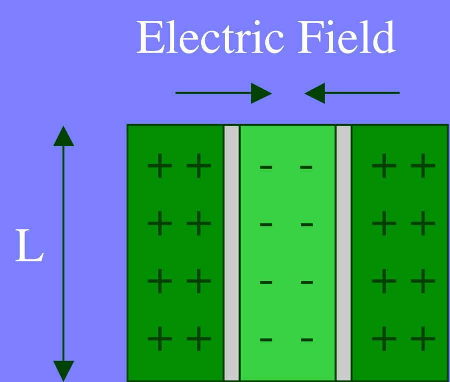
- Neurons conduct in one direction (diodes?)
  - Afferent (transmit toward central nervous system)
  - Efferent (transmit away from central nervous system)
  - Interneurons

e.g. Knee Jerk Reflex:

Nerve Conduction

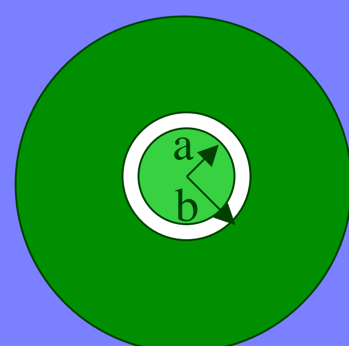
- Nerve signals PROPOGATE moving CHARGE

(ionic concentrations)



CAPACITOR
(cylindrical)

$C/L = 2\pi\epsilon_0\epsilon/\ln(b/a) \sim a/t$



$b=a+t$

$a=10\ \mu m,\ t = 0.1\ \mu m$

$C/L = 5.5$ pF/mm

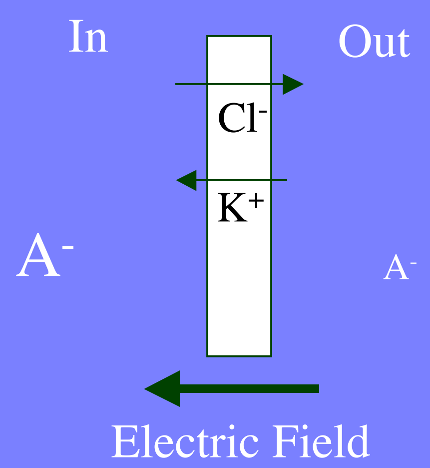
Ionic Concentration Gradients

Squid Neuron (mM)

	Intracellular	Extracellular
K^+	400	20
Na^+	50	440
Cl^-	40-150	560
Ca^{++}	0.0001	10
Mg^{++}	10	50
A^-	345	50

Mammalian Neuron (mM)

	Intracellular	Extracellular
K^+	140	5
Na^+	5-15	145
Cl^-	4-30	110
Ca^{++}	0.0001	1-2
Mg^{++}	15	1
A^-	75	15



Goldman Equation - Nernst Potential

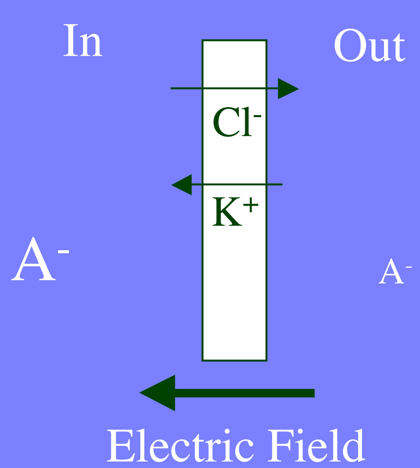
$C_{p\uparrow}/C_{p\downarrow} = e^{2\mu B/kT}$ (NMR)

$[X_{out}]/[X_{in}] = e^{qV/kT}$

$V=(kT/ze)\ln\{\Sigma_x P_x[X_{out}]/\Sigma_x P_x[X_{in}]\} \sim 58mV \log_{10}\{[K^+_{out}]/[K^+_{in}]\}$

↑
permeability

= -84 mV (resting potential)



Mammalian Neuron (mM)

Intracellular

Extracellular

K^+	140	5
Na^+	5-15	145
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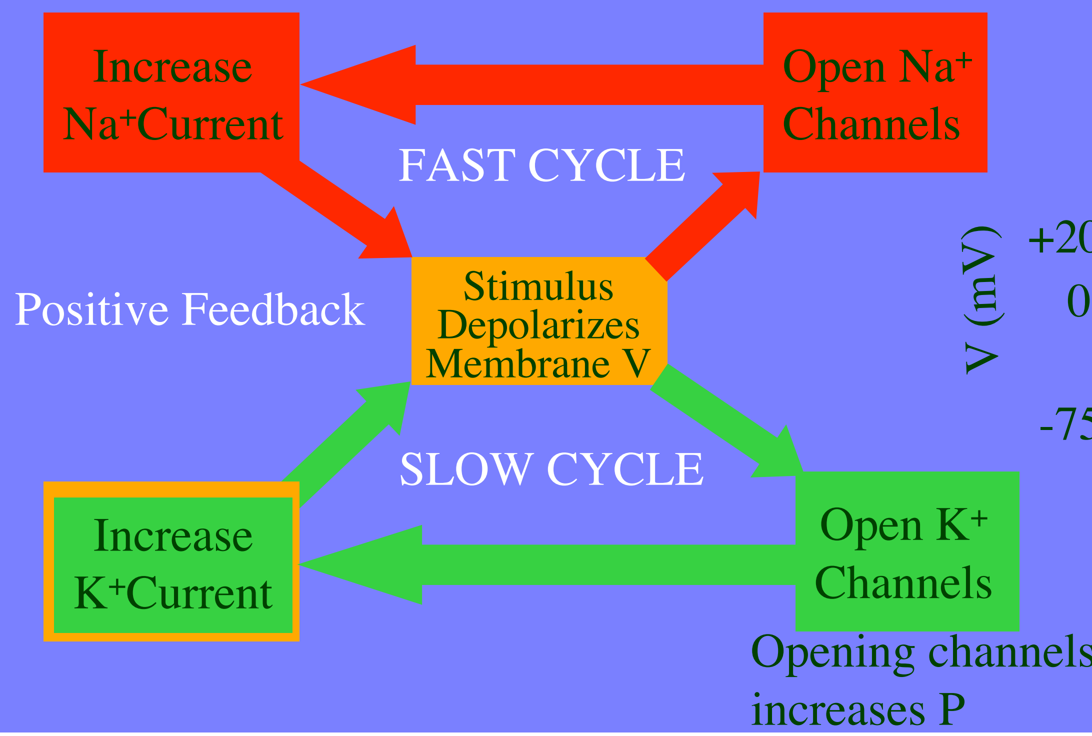
Action Potential

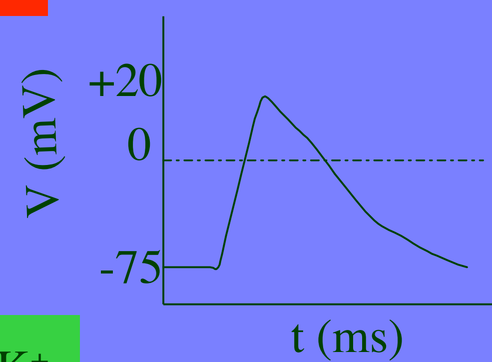
ION CHANNELS move ions WITH concentration gradients

ION PUMPS move ions AGAINST concentration gradients

ION PERMEABILITY CHANGES (in response to $[Na^+]$

$$V=(kT/ze)\ln\left\{\sum_x P_x[X_{out}]/\sum_x P_x[X_{in}]\right\}$$

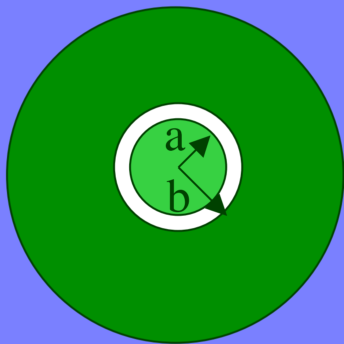




Conduction Velocity and Time

$$Q(t) \sim e^{-t/RC}$$

CAPACITOR
(cylindrical)



$C/L = 2\pi\square_0\square/\ln(b/a) \sim a/t$

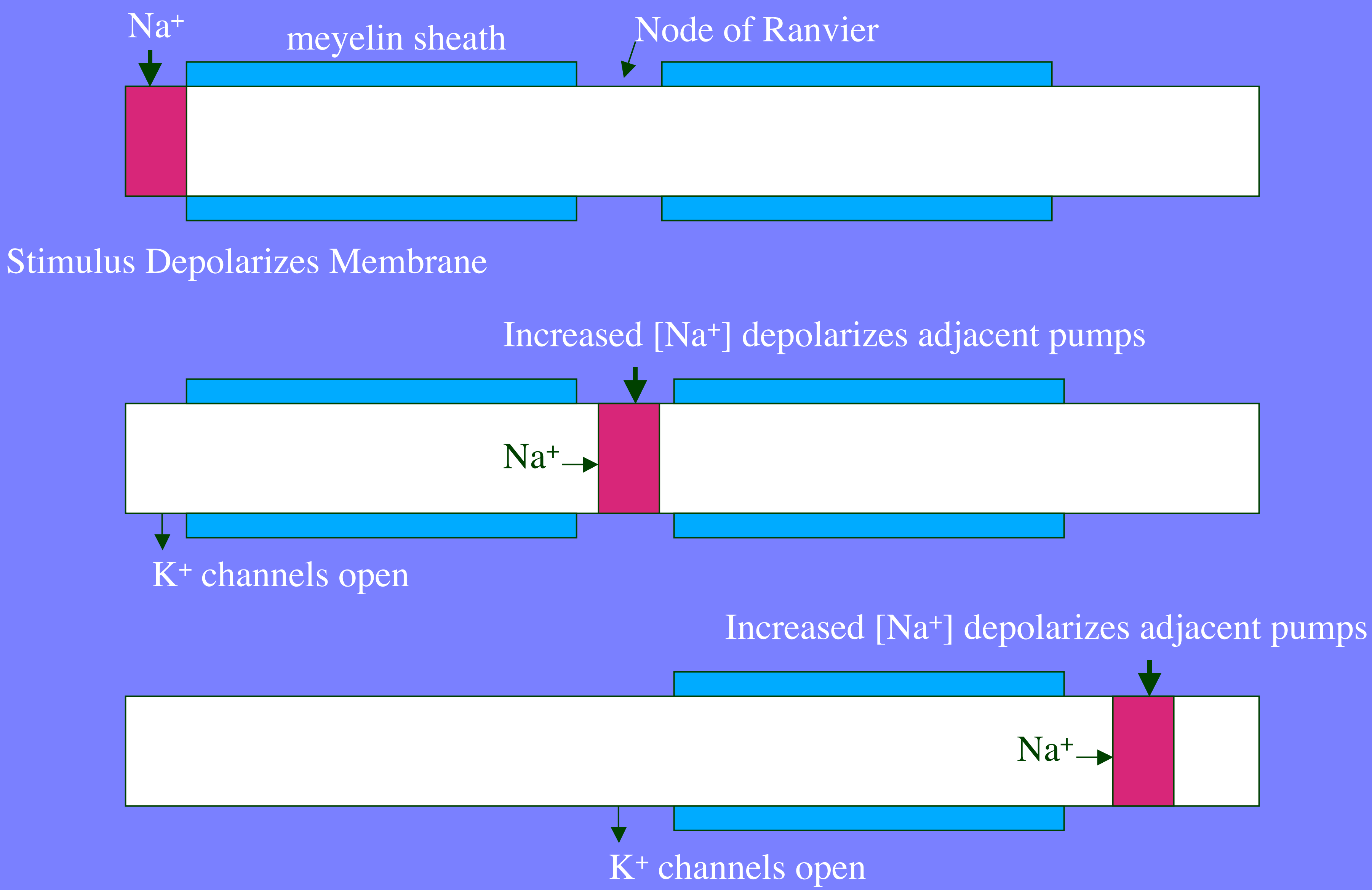
$b = a + t$
$a = 10\ \mu m,\ t = 0.1\ \mu m$
$C/L = 5.5$ pF/mm

RESISTANCE=1/CONDUCTANCE (active and passive)

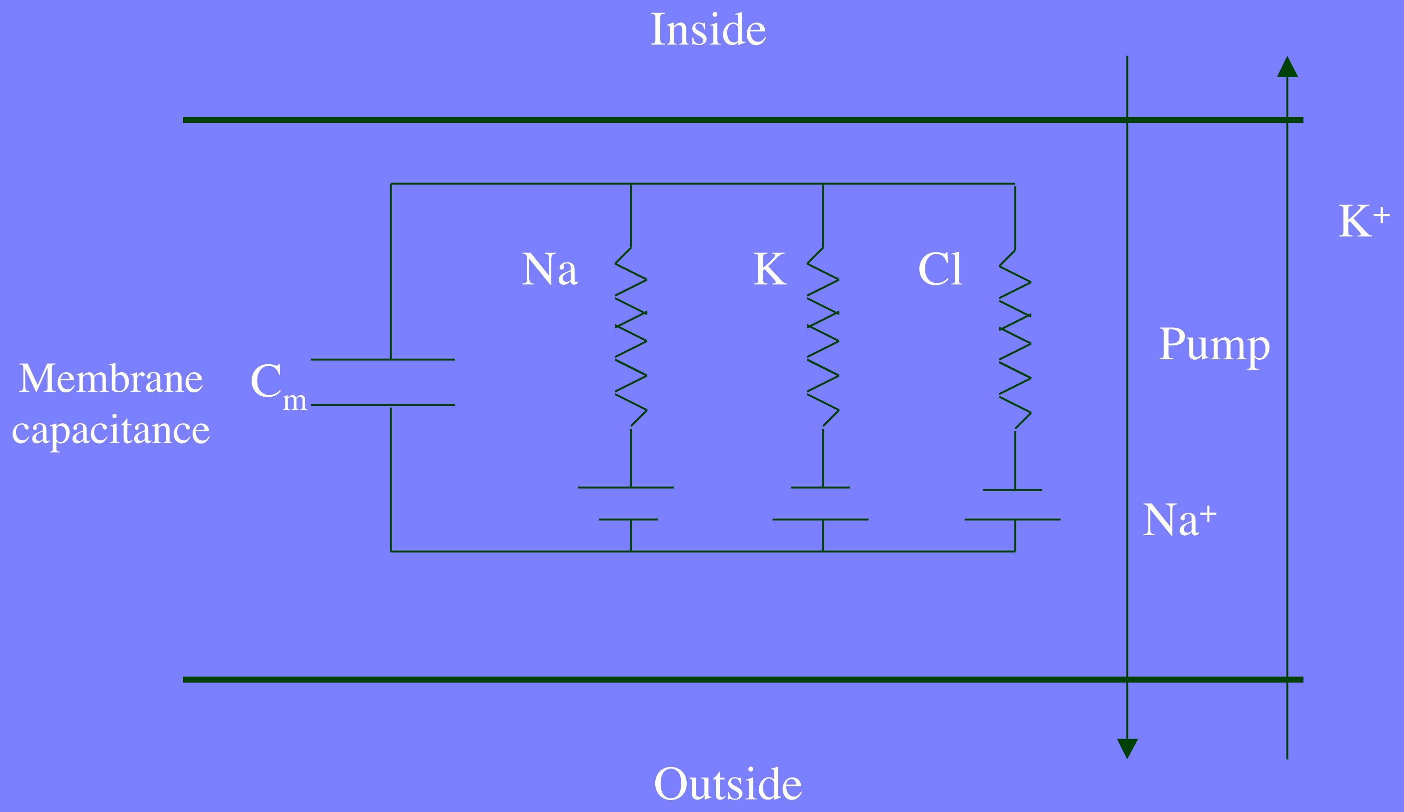
SQUID: Large Axon Reduces Resistance
MAMMAL: myelin wrapping of axon decreases diameter and C

Velocity: 100-150 m/s for myelinated axons

Nerve Conduction



Equivalent Circuit



Resistance $R \sim (1/P_K)[K^+_{in}]/[K^+_{out}]$

The BRAIN