Announcements (1/28/02)

- 401B and 501B:
  - Laboratory Meeting Wed, 5-7 pm
- Electricity Test in 2 weeks (Feb 16)
- 3x5 Cards

Foundations:

Basic Electricity
Basic Neurophysiology
Basic Neuroanatomy

Part I: Basic Electricity

- Prelude
- Atomic Stuff
- Voltage, Resistance, Current, Power, Energy
- DC Series Circuits
- DC Parallel Circuits
- AC Circuits in brief

Prelude: Scale of Measurement

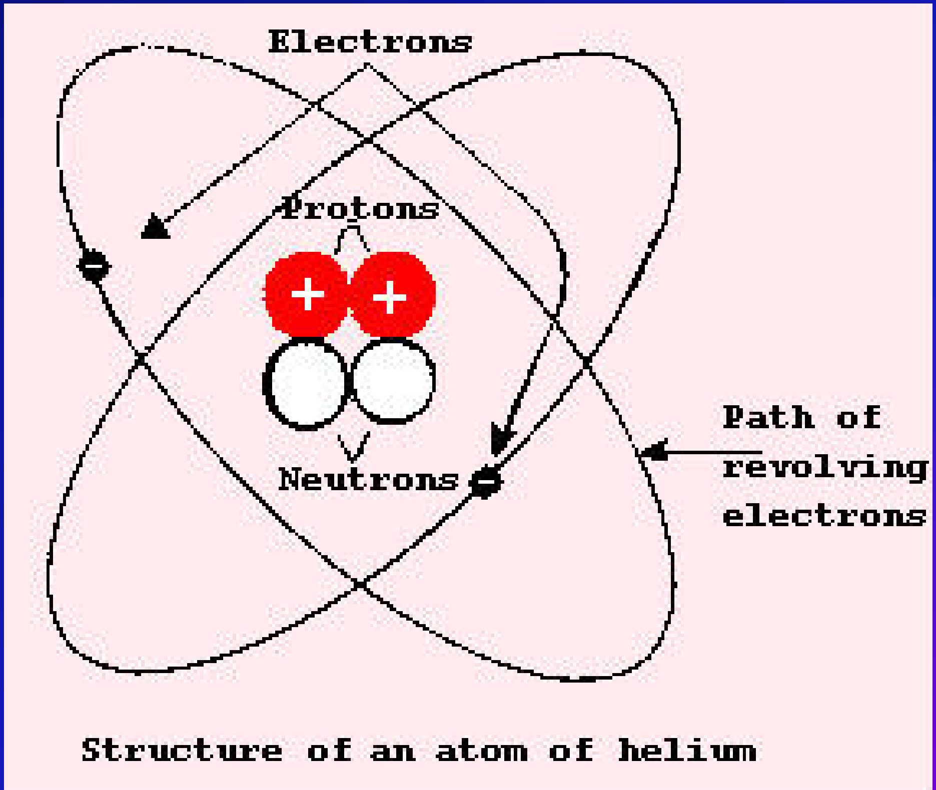
- Deci = 10^{-1}
- Centi = 10^{-2}
- Milli = 10^{-3}
- Micro = 10^{-6}
- Nano = 10^{-9}
- Fento = 10^{-15}
- Kilo = 10^{3}
- Mega = 10^{6}
- Giga = 10^{9}
- Tera = 10^{15}

Prelude: 3 Great Forces

- Nuclear
- Electrostatic
- Gravitational

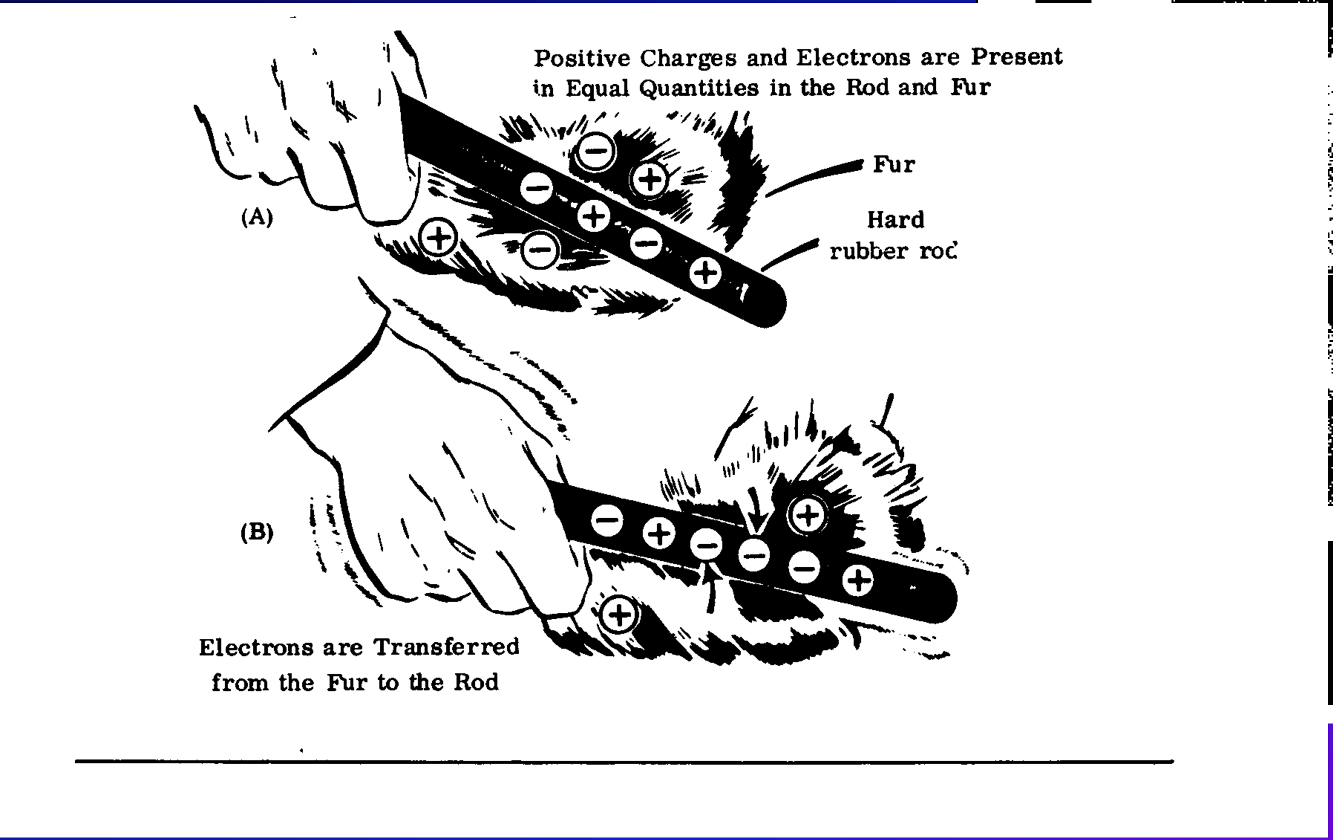
Electrostatic Forces

- Due to charged subatomic particles
  - Proton
  - Electron
  - but not Neutron
- The Law:
  - Unlike Charges Attract
  - Like Charges Repel



Free Electrons

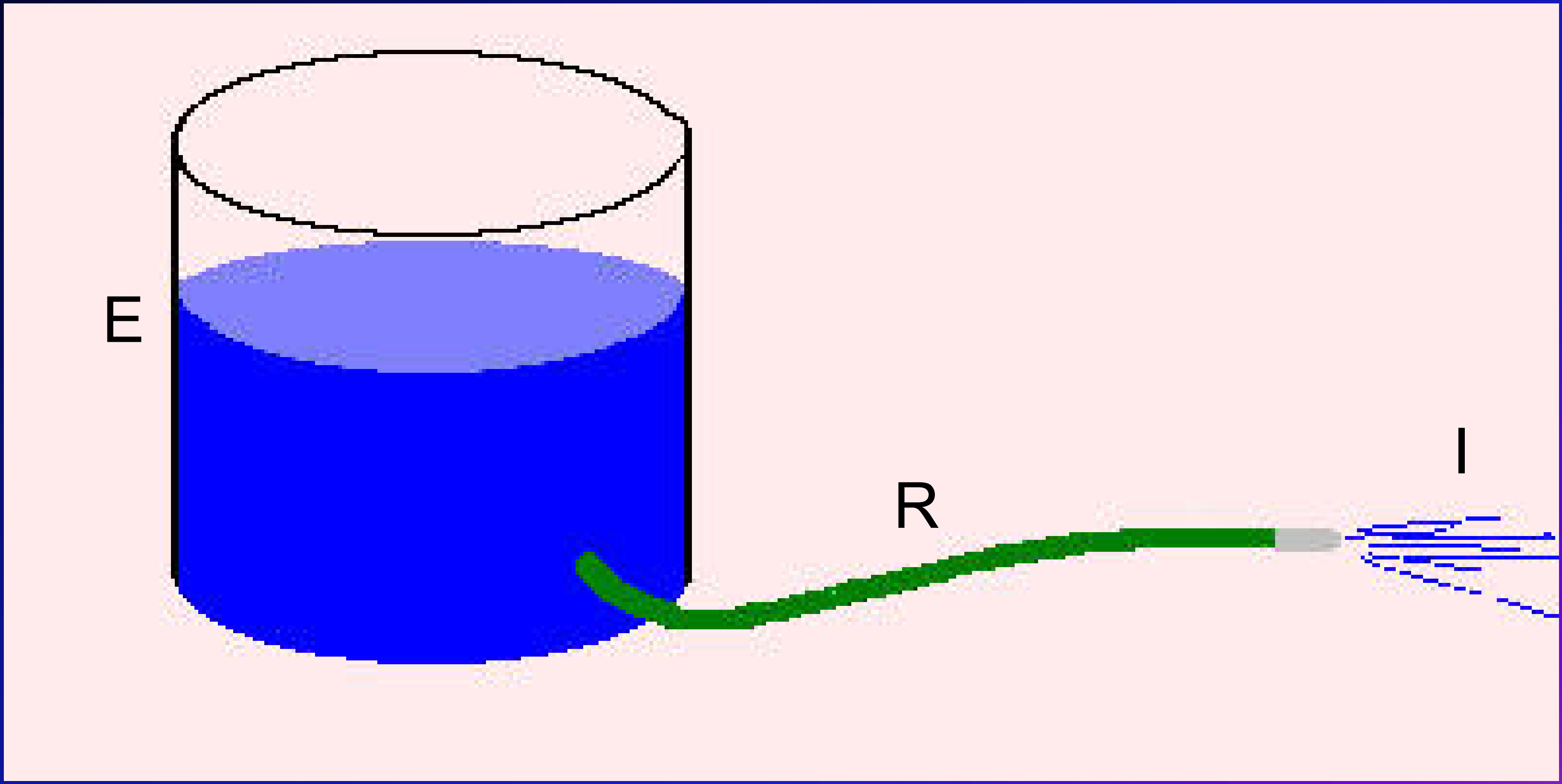
- Some electrons can be easily displaced

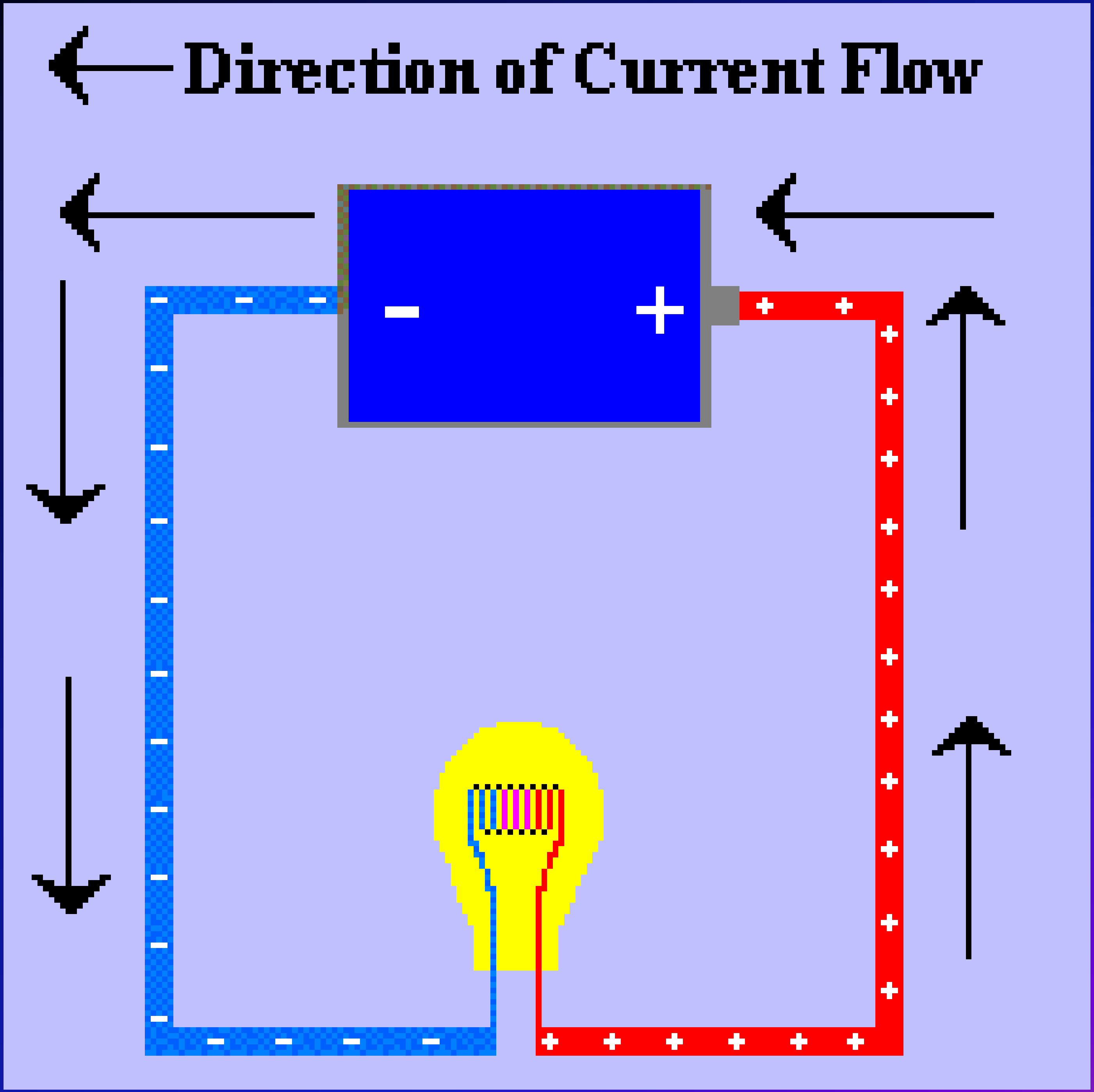


Static Electricity

- Friction with Poor Conductors
- Electrons displaced from one substance to the other (e.g Hair to comb, carpet to body)
- Leads to voltage potential (i.e., difference)

Basic Electricity by Analogy





DC
Anyway!

Details Details

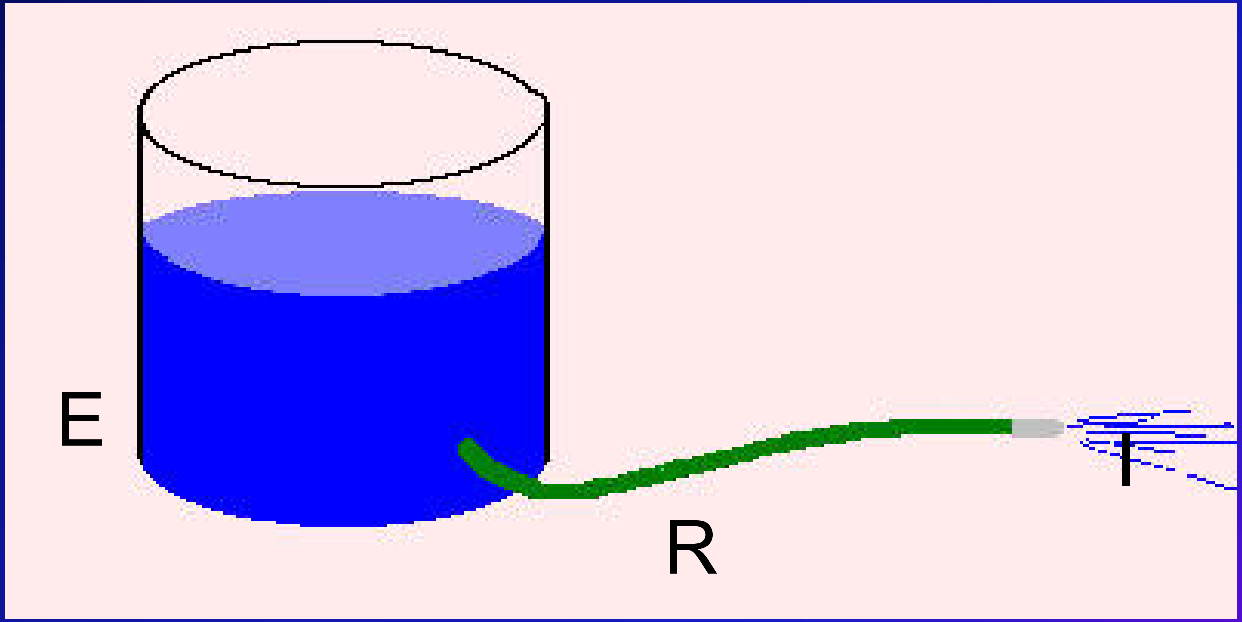
Symbol	Term	aka	Unit
E	Voltage	Electromotive Force	Volts (V)
I	Current	Rate of Flow	Amperes (A)
R	Resistance	--	Ohm (Ω)
P	Power	Rate of work	Watt (w)
W	Energy	Ability to do work	Watt-Second (Joule)

Ohm's Law

$$I = \frac{E}{R}$$

$$E = IR$$

$$R = \frac{E}{I}$$



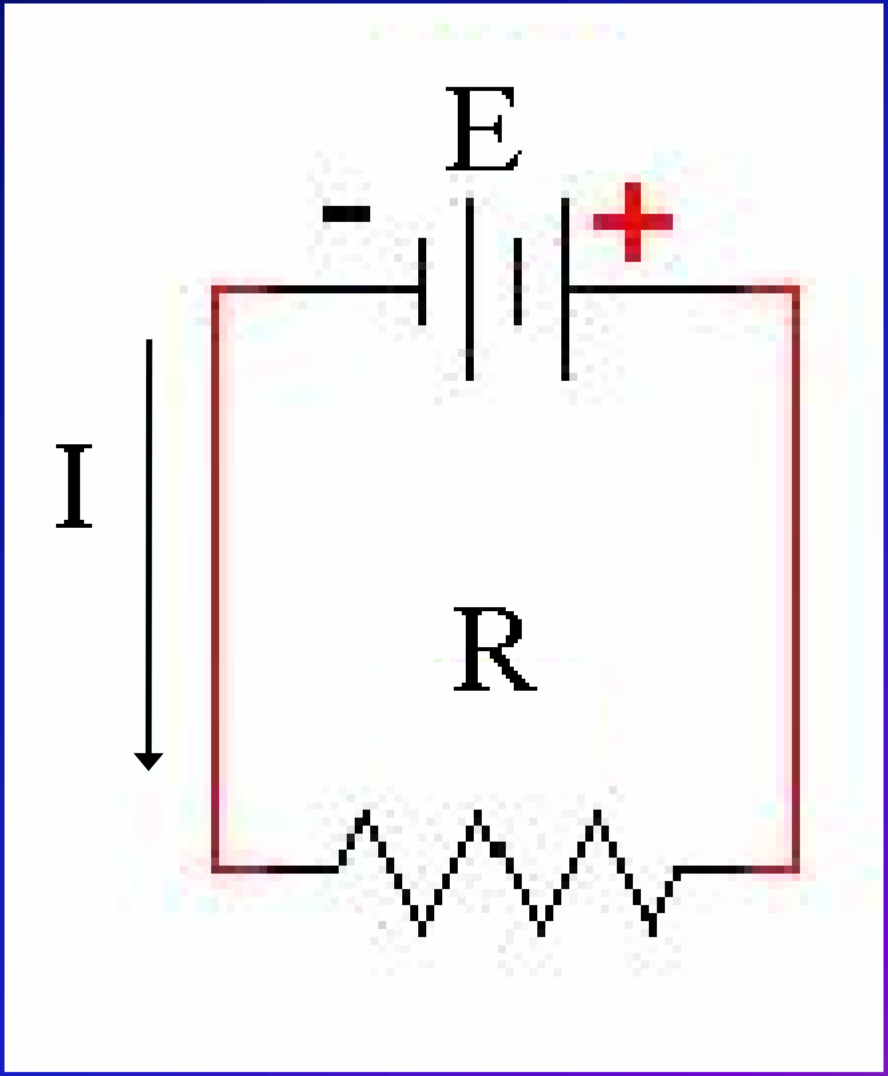
See also: http://ohmslaw.com/

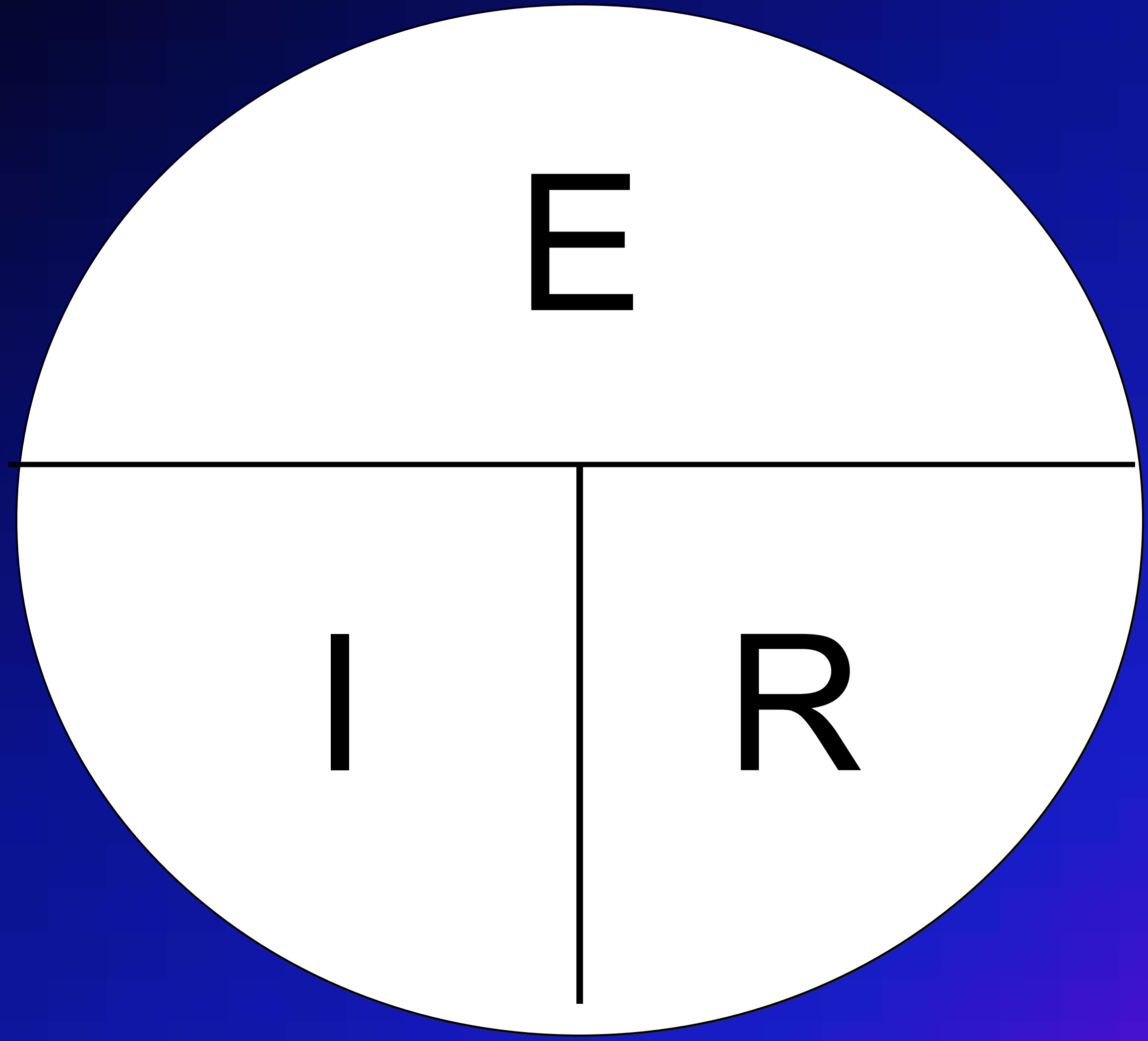
Ohm's Law

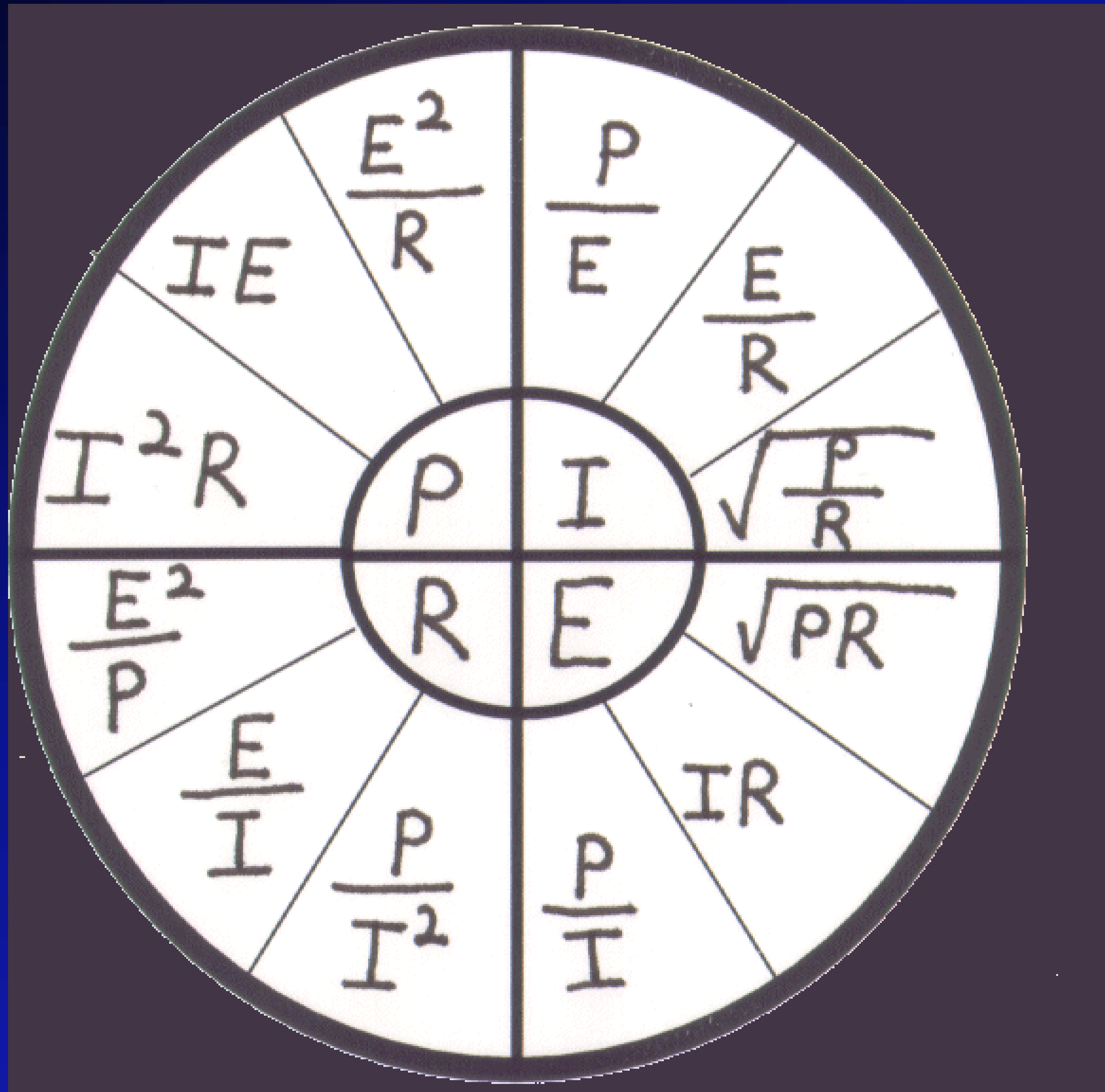
$$I = \frac{E}{R}$$

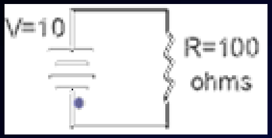
$$E = IR$$

$$R = \frac{E}{I}$$

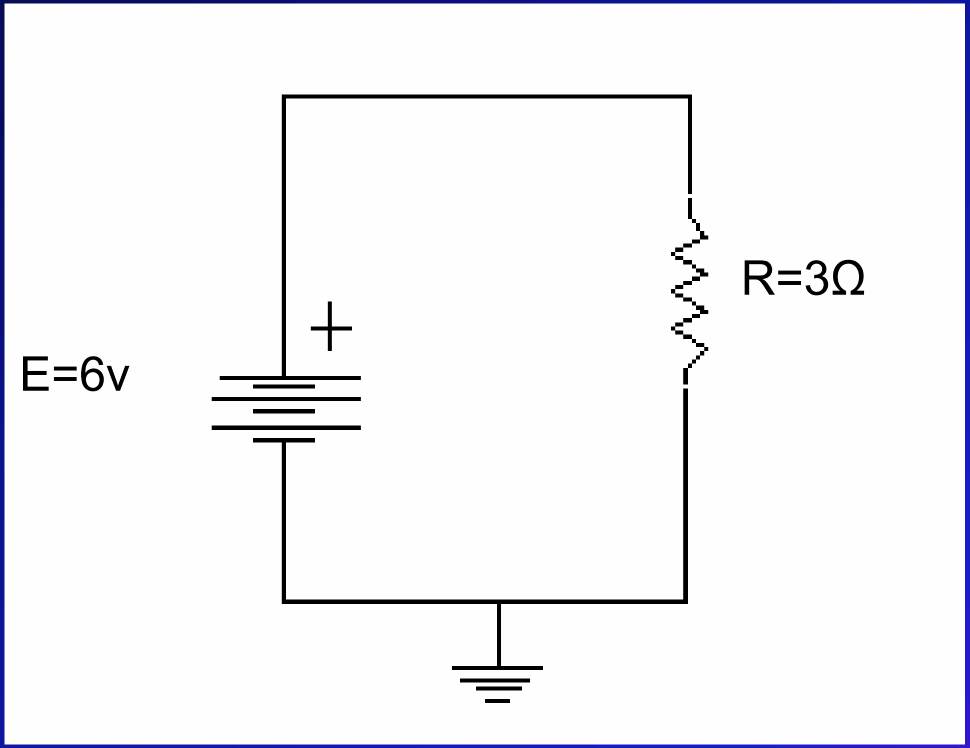



E
I
R

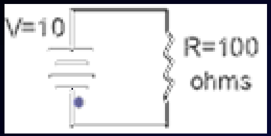

P
I
R
E
$\frac{P}{E}$
$\frac{E}{R}$
$\sqrt{\frac{P}{R}}$
$\sqrt{PR}$
IR
$\frac{P}{I}$
$\frac{P}{I^2}$
$\frac{E}{I}$
$\frac{E^2}{P}$
I^2R
IE
$\frac{E^2}{R}$



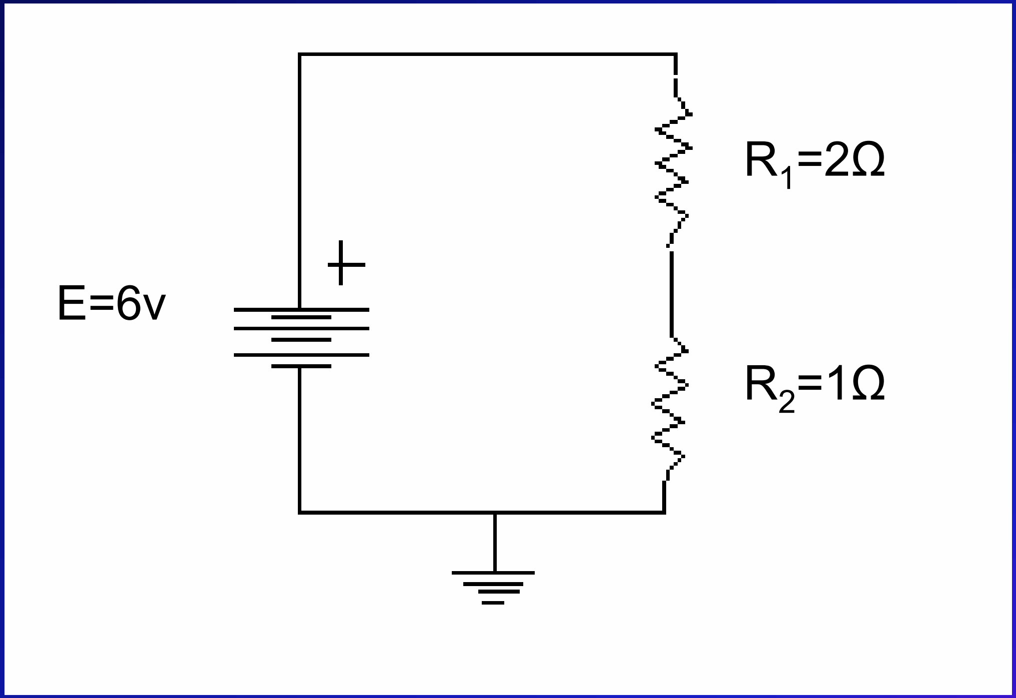
Basic Circuit



I = ?



Series Circuit

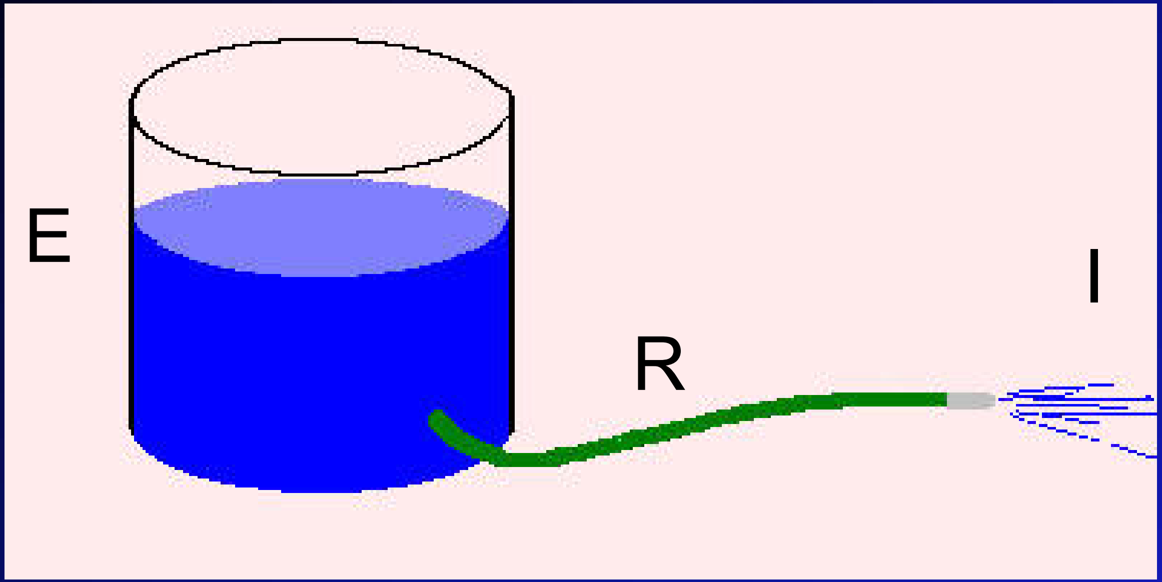


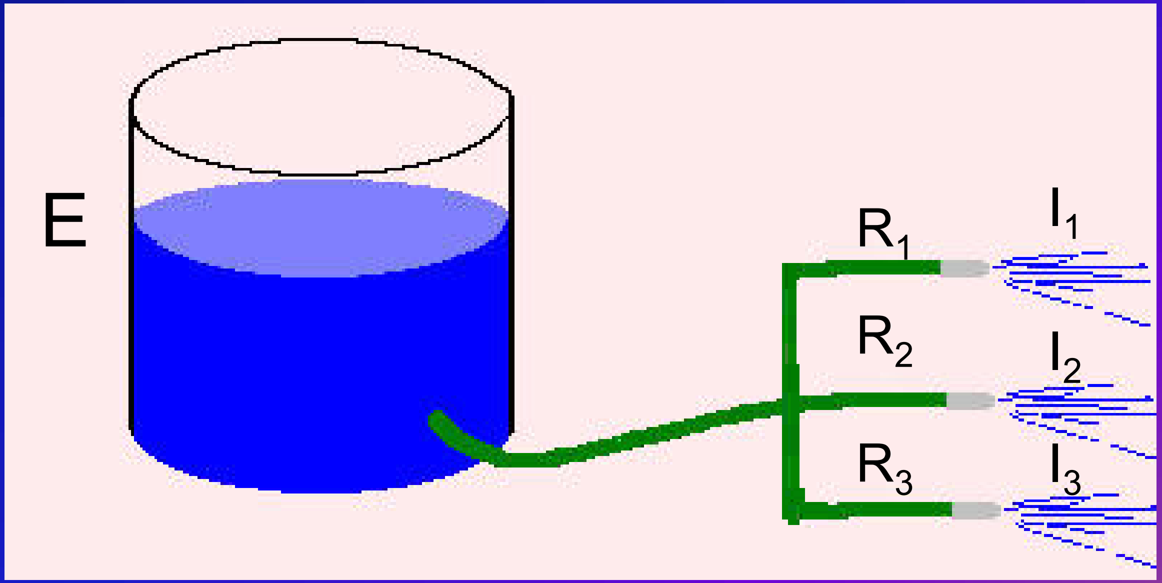
$I = ?$

$E_{R1}=?$

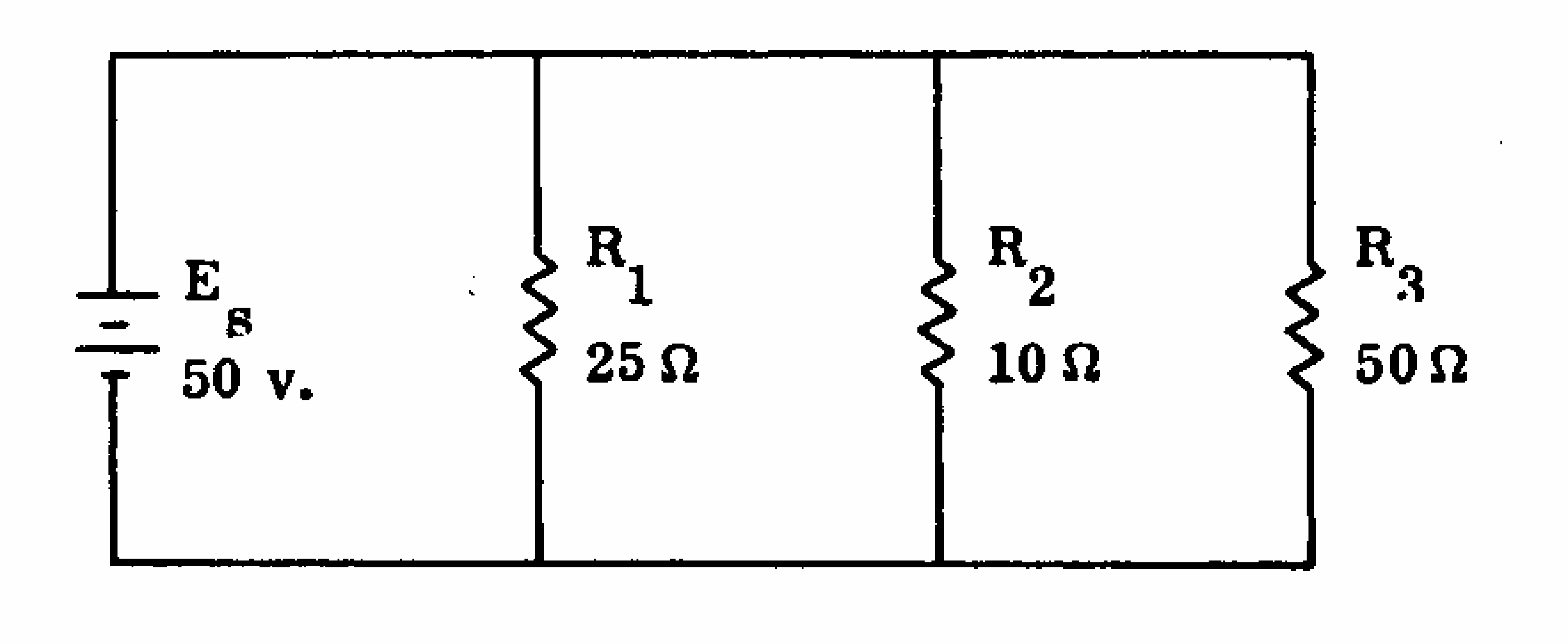
$E_{R2}=?$

By Analogy: Series Vs Parallel





Parallel Circuit



$R_T = ?$

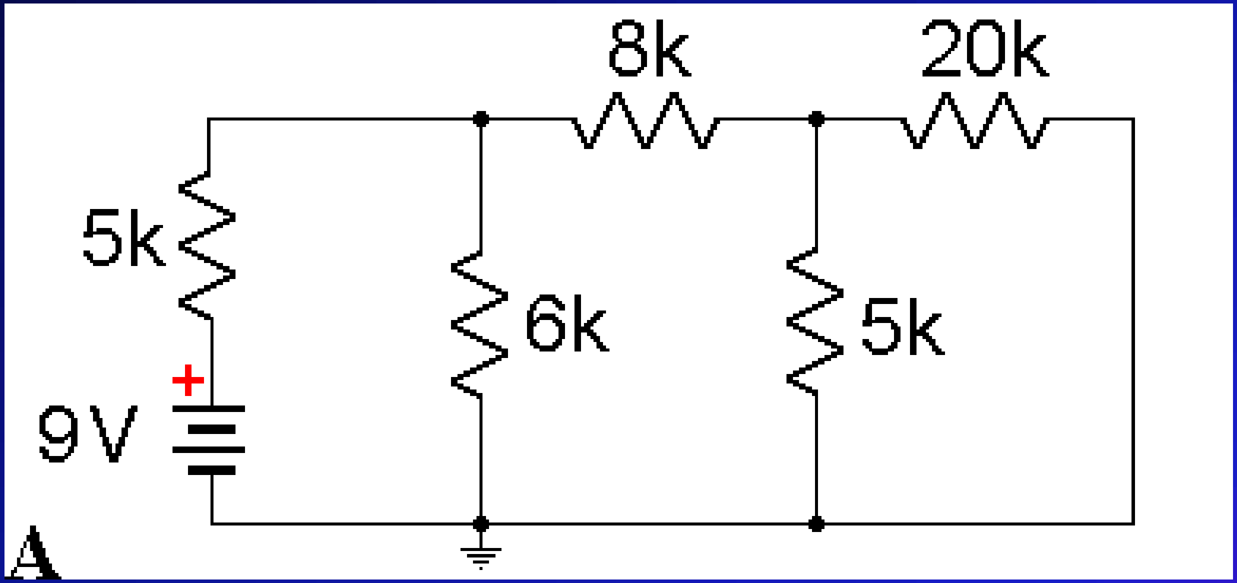
$I_1 = ?$

$I_3 = ?$

$I_T = ?$

$I_2 = ?$

Complex Circuits

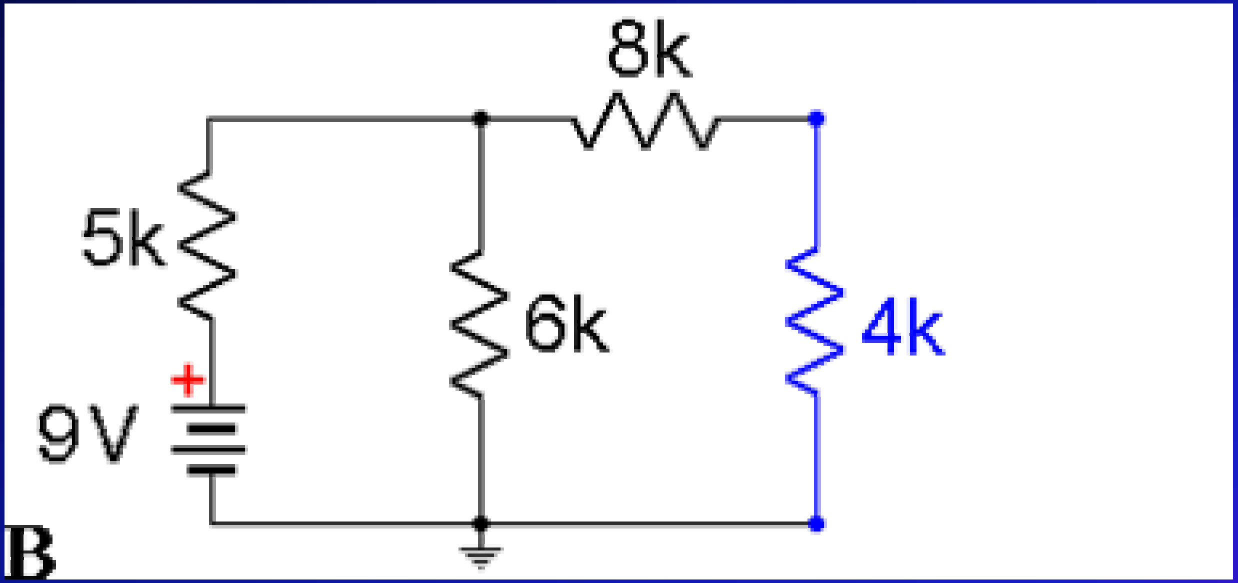


Find the current flowing in the circuit, and the voltage drops.

YIKES! Need to reduce. Start at the parallel combination of 20k and 5k resistors; it is replaced with its effective resistance of 4k [$1/R_{equiv}$ = 1/20 + 1/5 = 1/20 + 4/20 = 5/20 = 1/4].

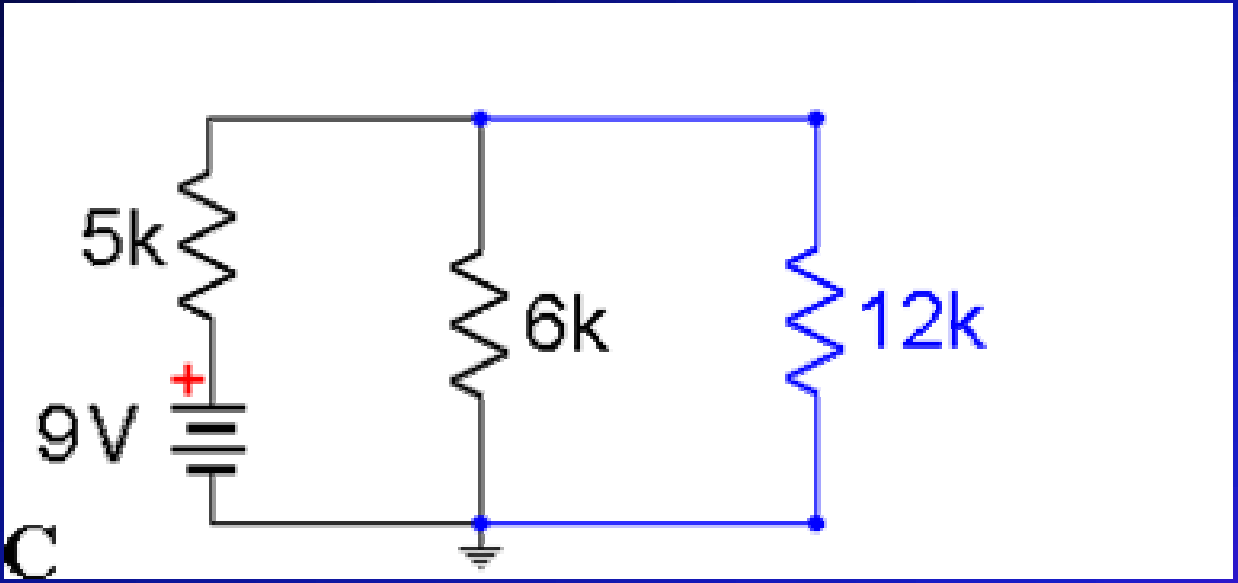
This and subsequent slides on this circuit adapted from: "http://www.physics.udel.edu/~watson/phys345/examples/effective-circuit.html"

Slightly less Complex Circuit



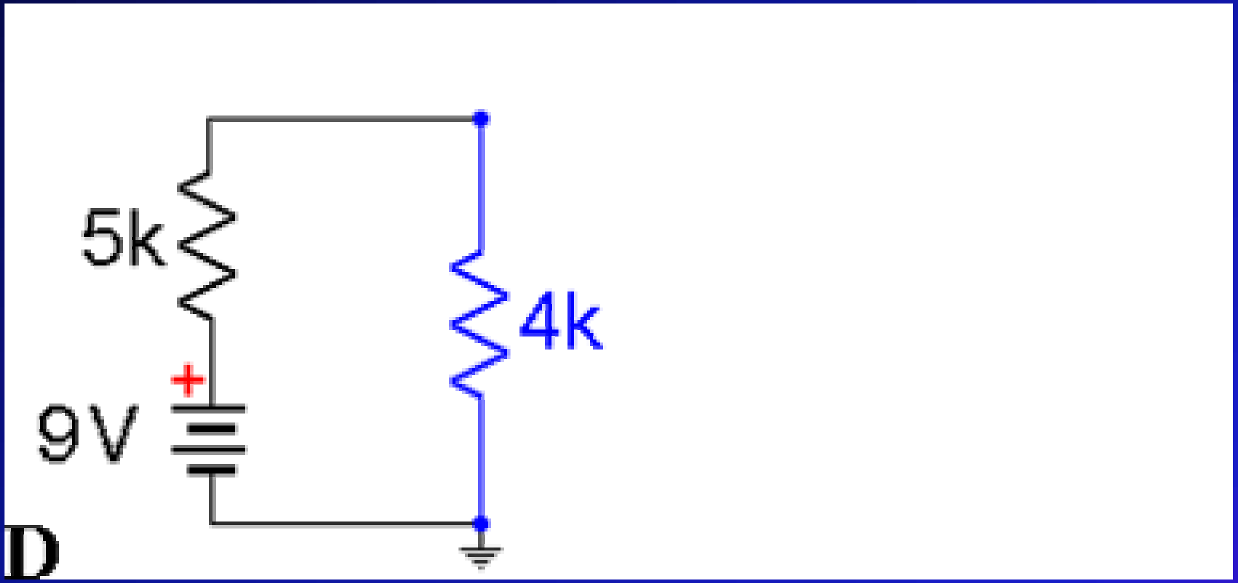
Looking Better. The effective resistance of 4k is in series with the actual resistance of 8k, leading to replacement by its effective resistance of 12k. [R_{equiv} = 4k + 8k]

Less Complex Still



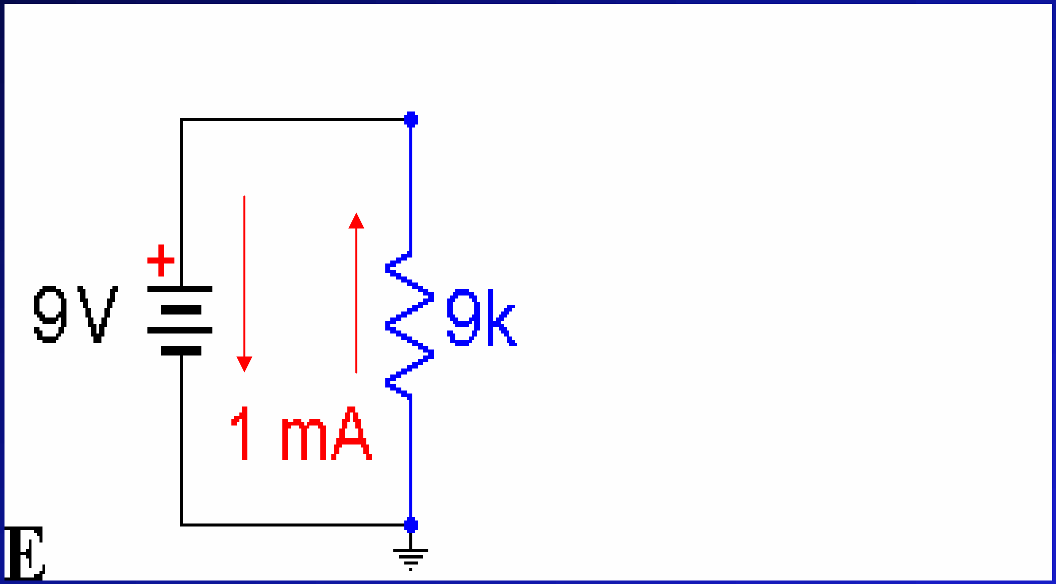
Better Still. Now there is a parallel combination of 12k and 6k resistors; it is replaced with its effective resistance of 4k
[$1/R_{equiv} = 1/12 + 1/6 = 1/12 + 2/12 = 3/12 = 1/4$].

Now Series: Almost Simple



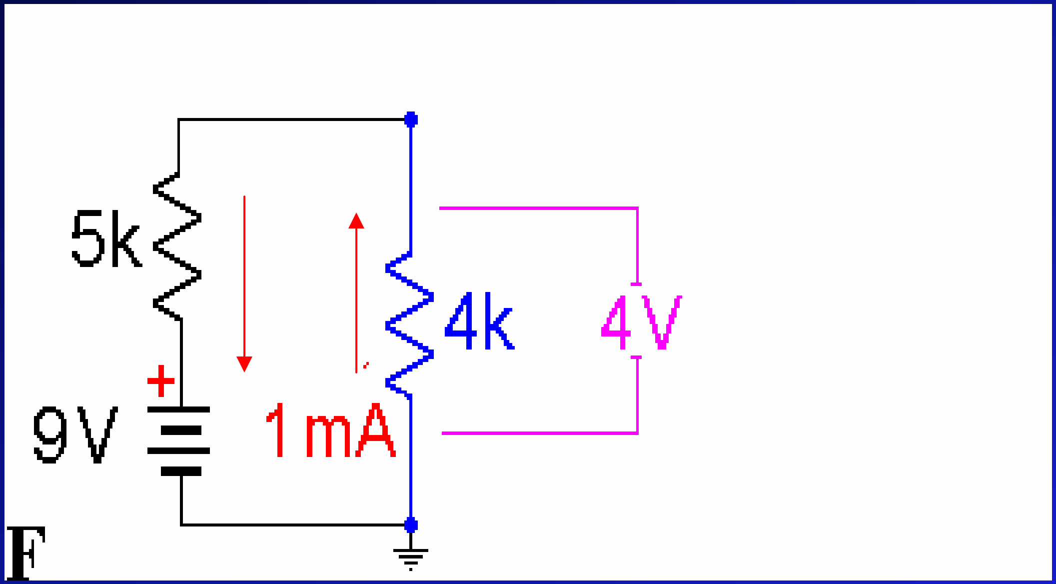
Now we have a simple series circuit!
Finally, the equivalent resistance for the entire circuit is 9k.
[R_{equiv} = 4k + 5k].

Now Series: Almost Simple



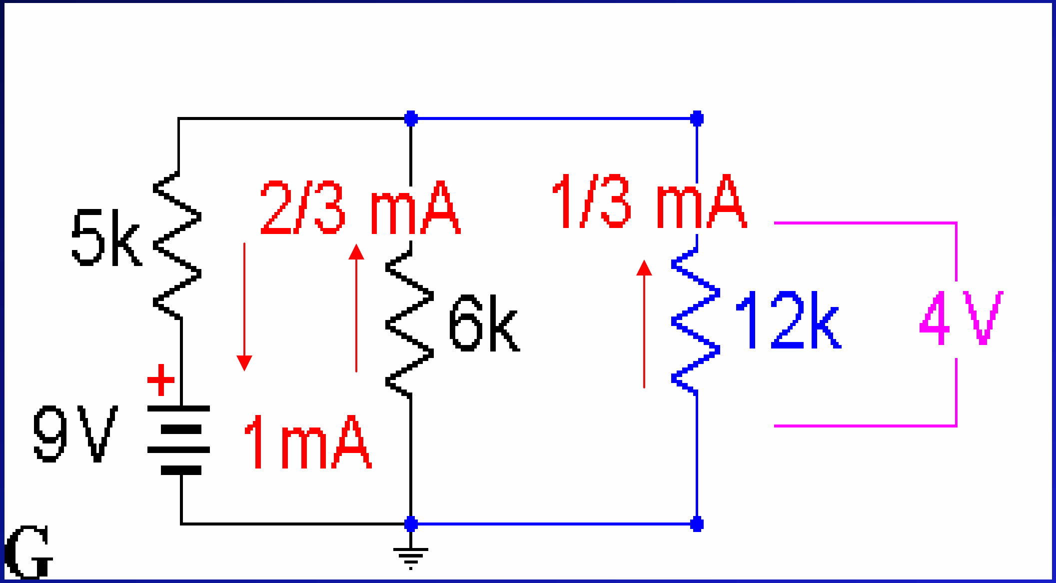
I = ?
[I = E/R = 9 V/9 k = 1 mA]

Working Back: Voltage Drops and Current



The real 5k resistor and the effective 4k resistance each have 1 mA of current since they are in series. Thus the 4k resistance has 4V of voltage difference across it (by Ohm's law).

Working Back: Voltage Drops and Current

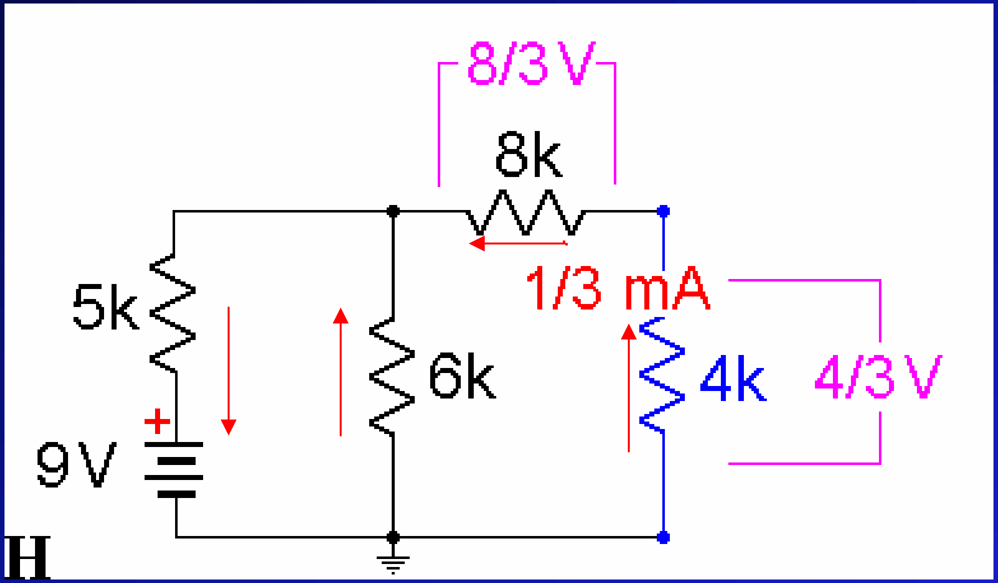


Breaking the 4k resistance into its component parts (in parallel), we find that 2/3 mA of current flows in the 6k resistor and 1/3 mA flows in the effective resistance of 12k.

I = E/R = 4/6K = 2/3 mA

I = E/R = 4/12K = 1/3 mA

Working Back: Voltage Drops and Current

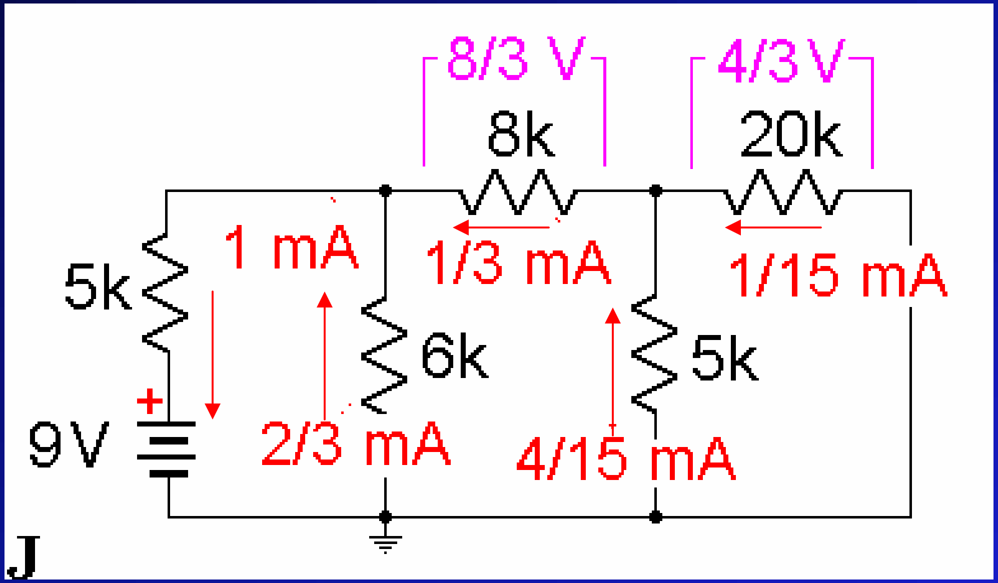


Breaking the 12k resistance into its component parts (in series), we find that there is 8/3 V across the 8k resistor and 4/3 V across the effective resistance of 4k.

$E = IR = 4K\Omega * 1/3\ mA = 4/3\ V$

$E = IR = 8K\Omega * 1/3\ mA = 8/3\ V$

Working Back: Voltage Drops and Current

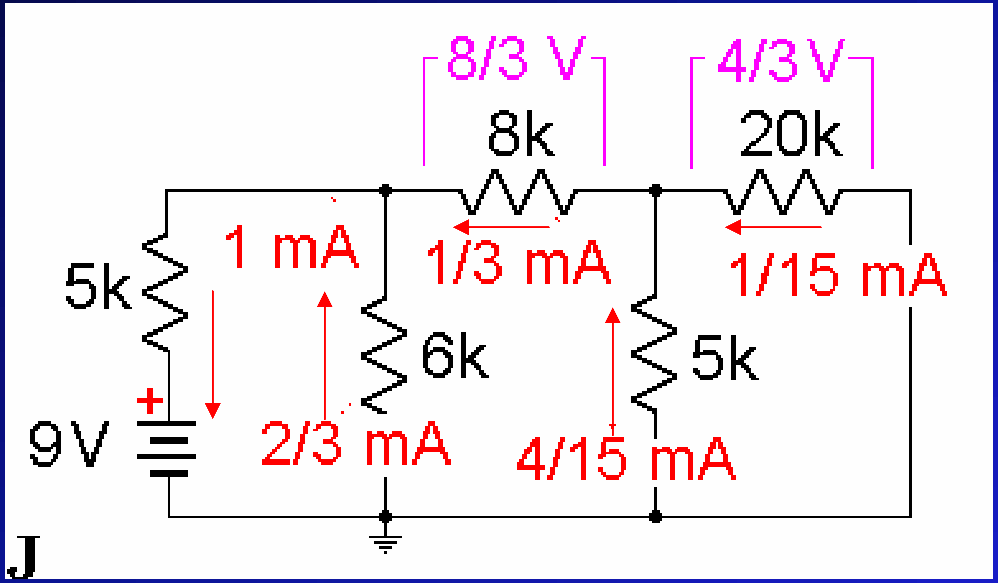


Finally, breaking the 4k resistance into its component parts (in parallel), we find that 1/15 mA of current flows in the 20k resistor and 4/15 mA flows in the 5k resistor.

I = E/R = (4/3V)/20KΩ = 4/60 mA = 1/15 mA

I = E/R = (4/3V)/5KΩ = 4/15 mA

Working Back: Voltage Drops and Current

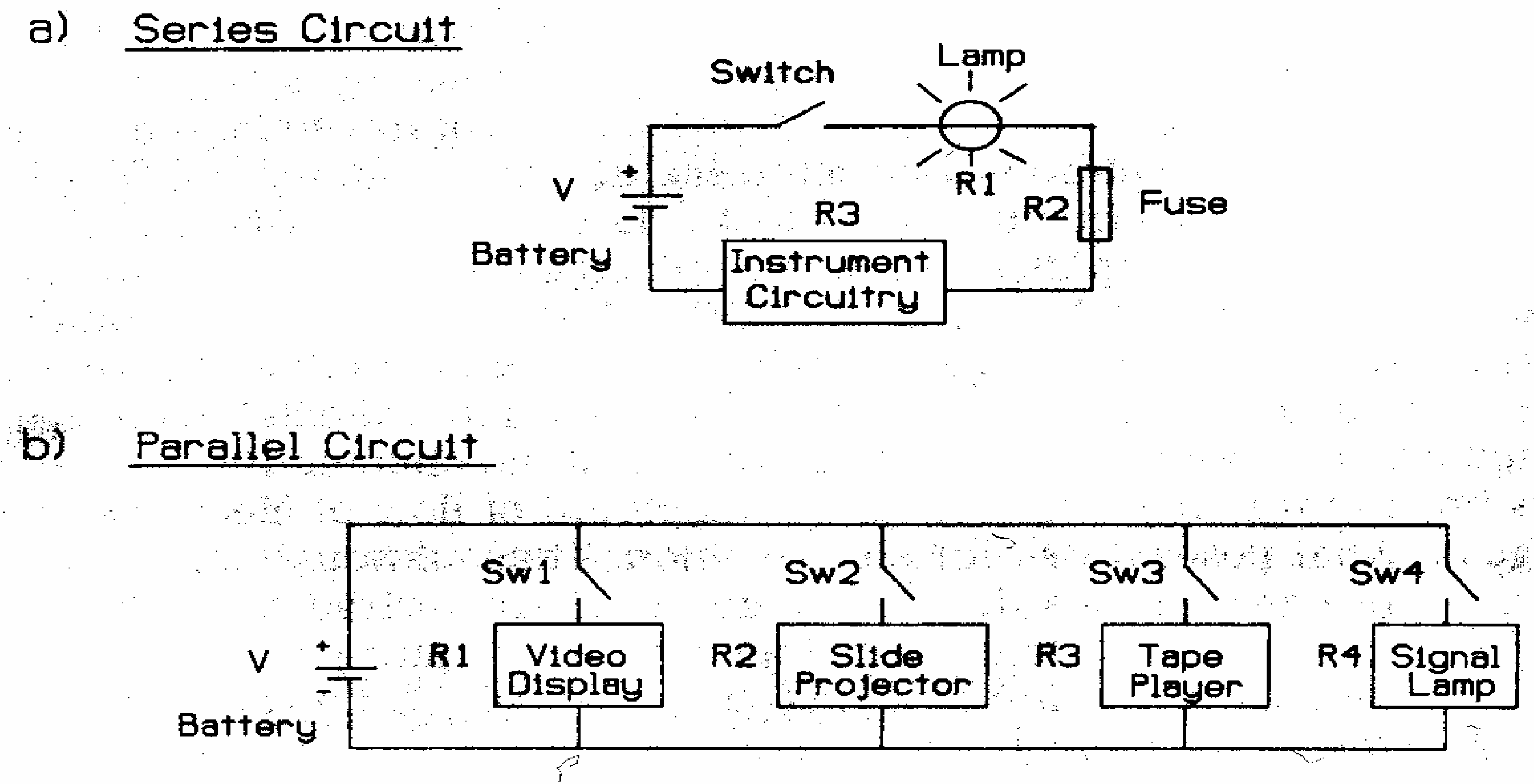


Summarizing:

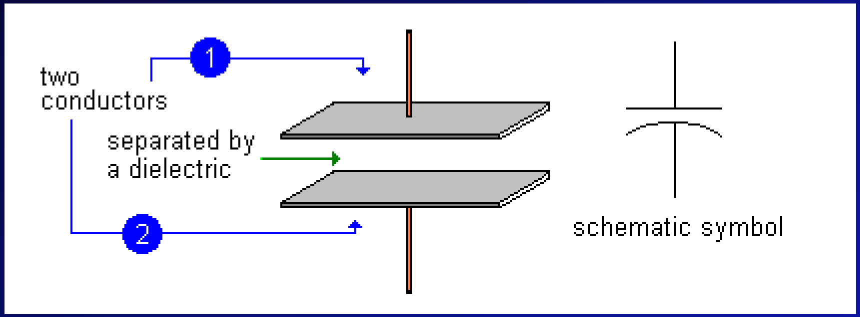
1. Current through the battery? 1 mA
2. Current through the 8k resistor? 1/3 mA
3. Voltage difference across the 20k resistor? 4/3 V
4. Rate of energy dissipated by the 6k resistor? P = (2/3 mA) x (4 V) = 8/3 mW

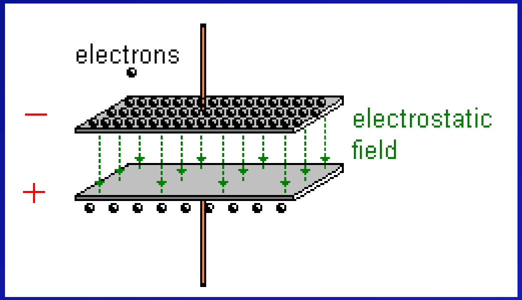
In Real Life…

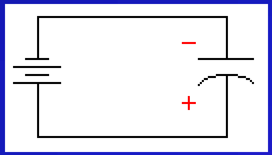
B. MARSHALL-GOODELL, L. TASSINARY, AND J. CACIOPPO



Capacitance







Capacitor = two conductors separated by a dielectric.

Dielectric = material that is a good insulator (incapable of passing electrical current), but is capable of passing electrical fields of force.

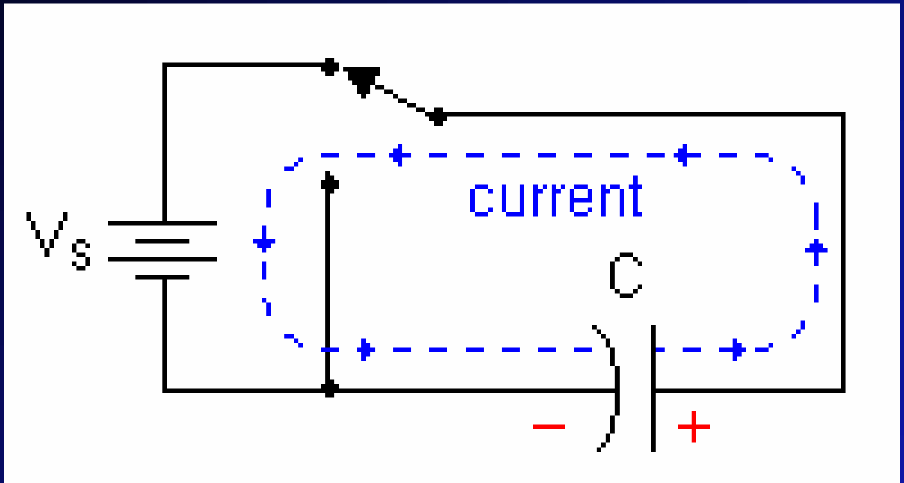
Charged Capacitor = more electrons on one conductor plate than on the other.

Capacitance

- Two closely spaced plates – offer essentially no resistance

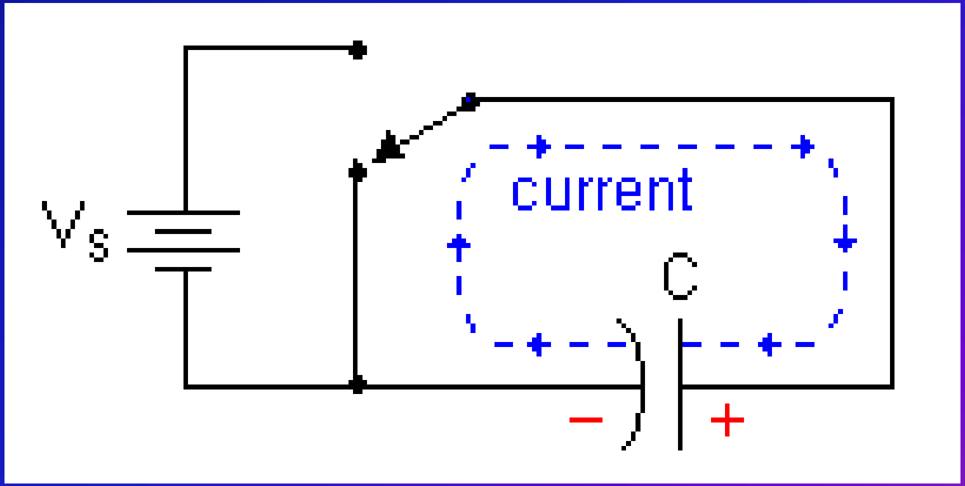
- As negative charge built up on first plate due to flow of electrons, a positive charge would build up on second plate
  - The current **charges** the plates of the capacitor, **but does not flow through the capacitor**, itself.

Capacitance



Charging – current flows until capacitor is fully charged, then stops

Discharging – current flows in reverse direction until capacitor fully discharged

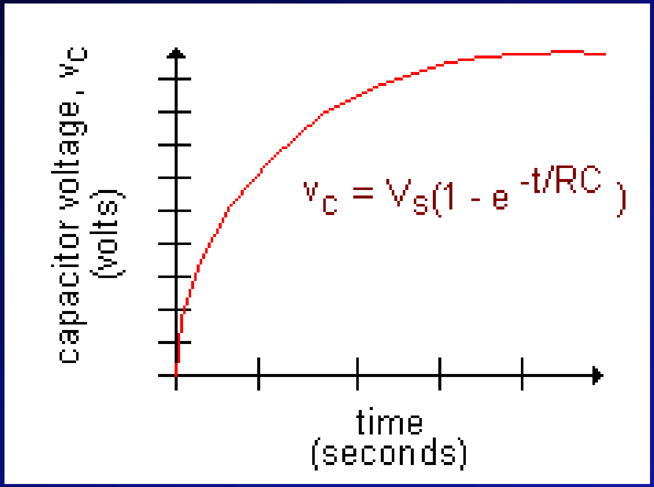


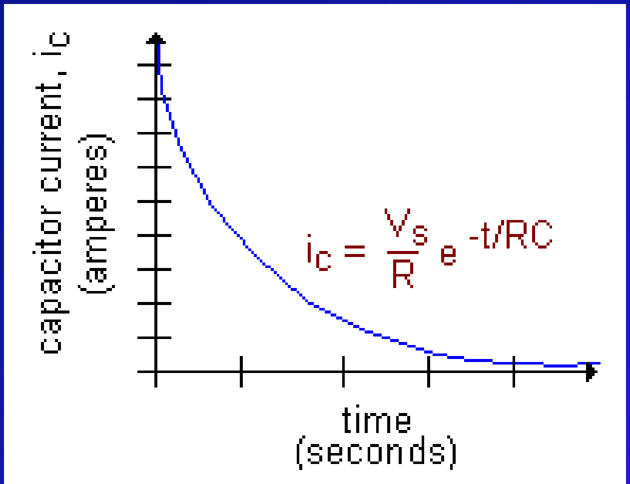
Capacitance – Size Matters

- Which has more capacity?

- More capacity, more current flows before capacitor is fully charged

Capacitor Time Constants





Over time…

Capacitor's voltage increases

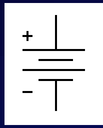
Current flow grinds to a halt

The capacitor's time constant TC=

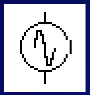
- The time in seconds for it to become 63.2% charged
- The time in seconds for current flow have slowed by 63.2% from its starting value

More info: http://www.sweethaven.com/acee/forms/frm0402.htm

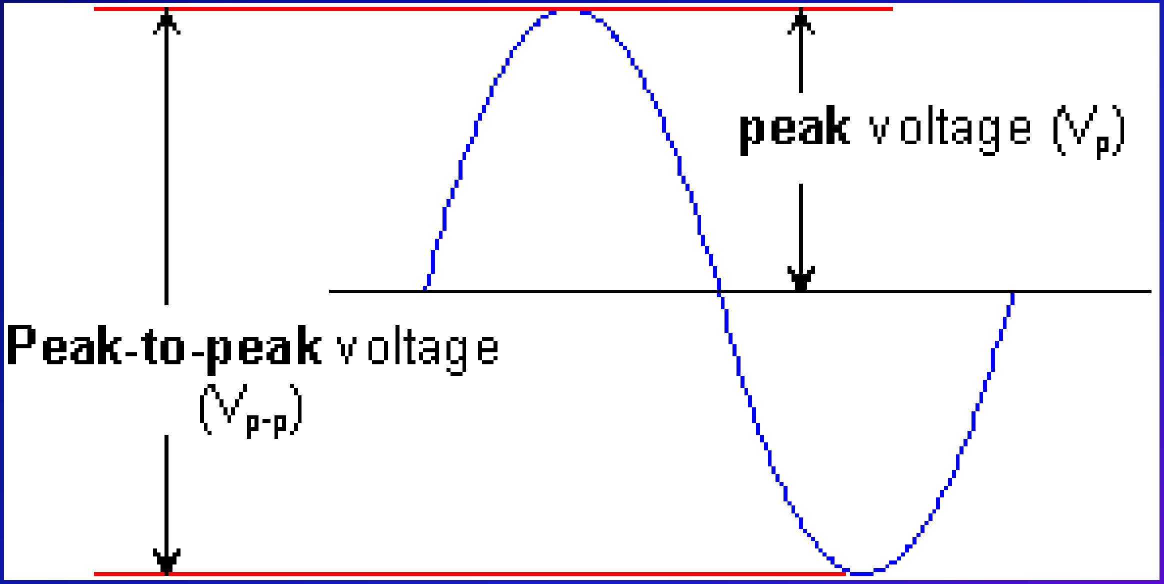
AC Circuits



- DC Circuit: Current Flow is unidirectional, from – to +



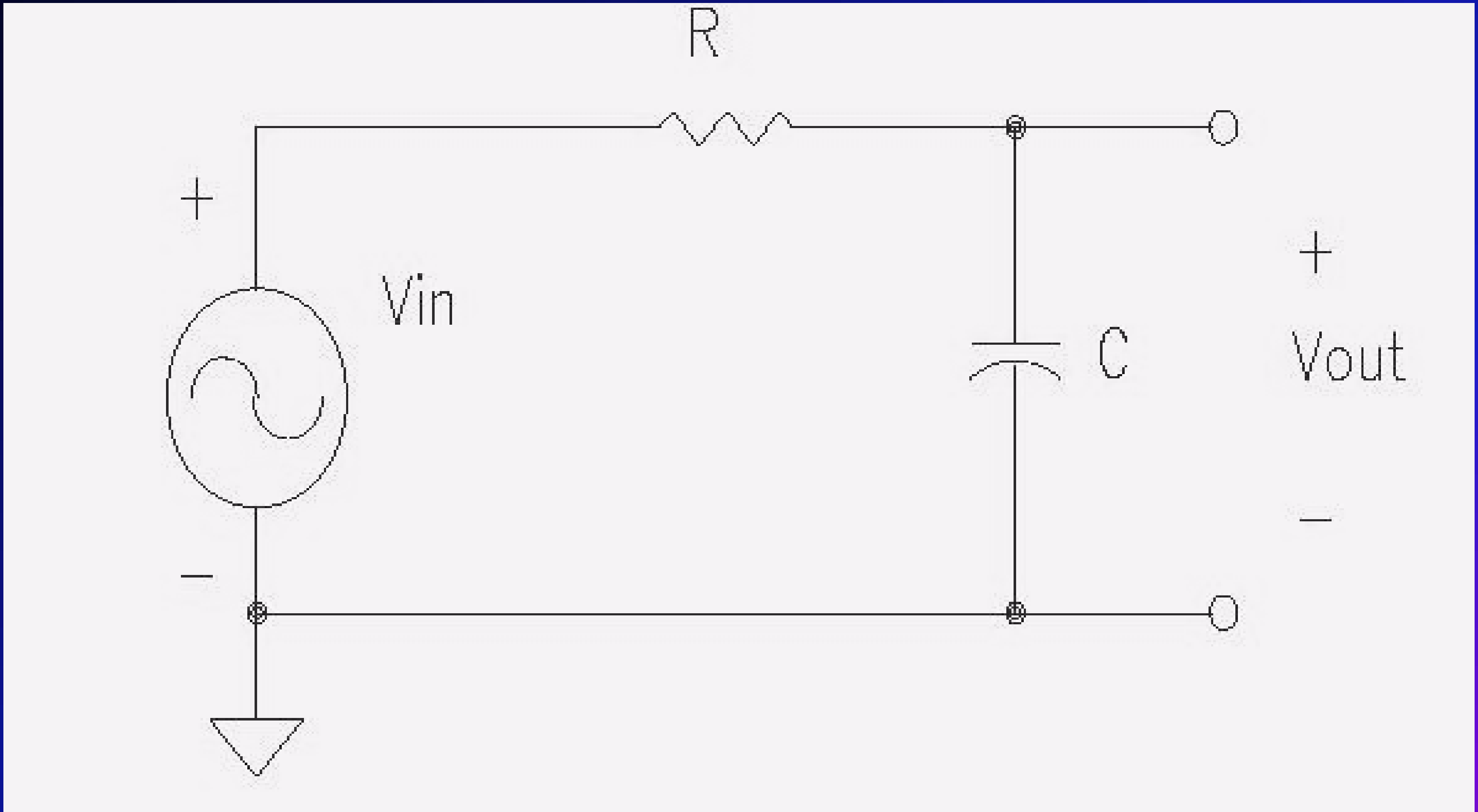
- AC Circuit: Current Flow switches direction periodically (at a given frequency in Hz)



AC Circuits and Capacitance

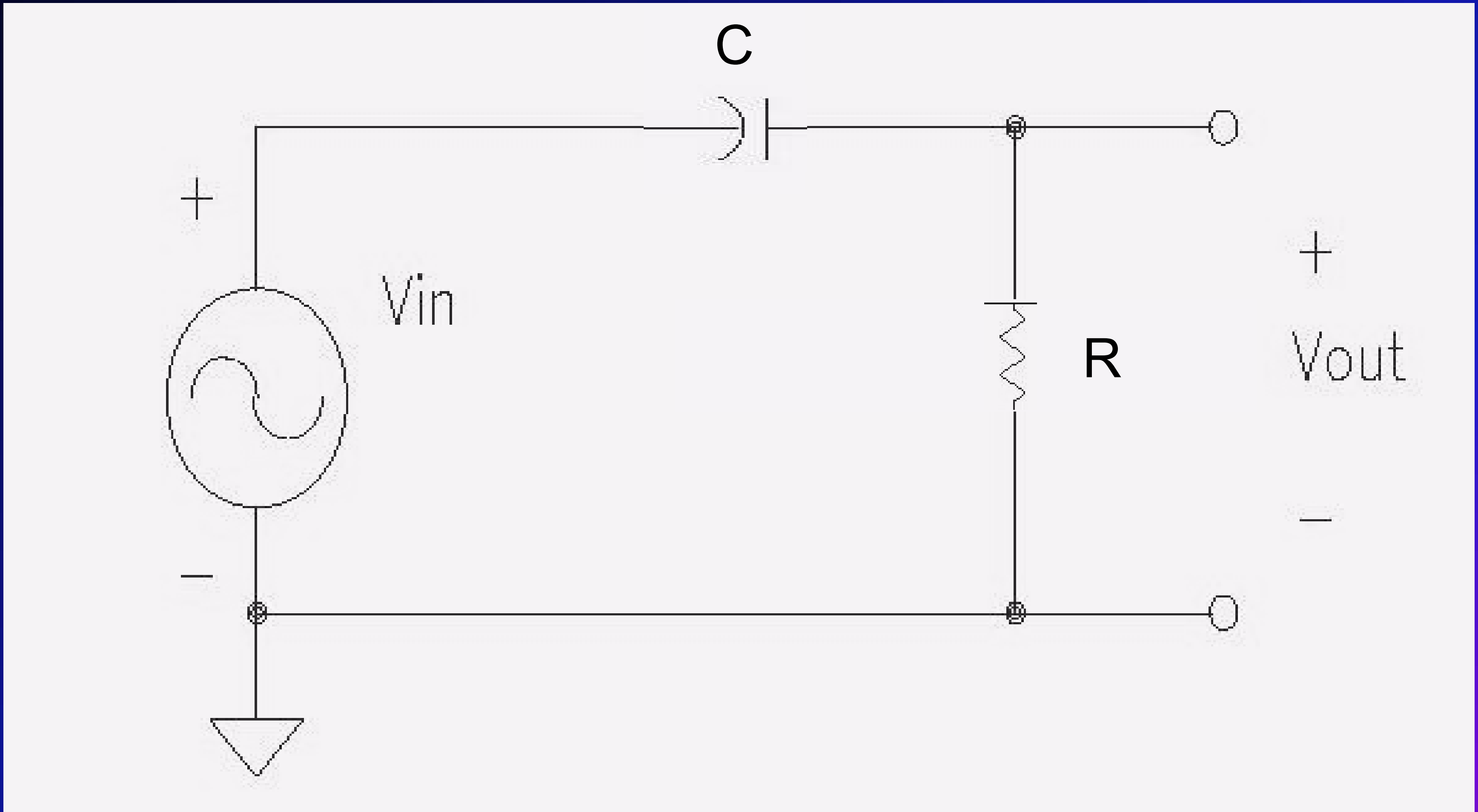
- Slowly alternating signals
  - will fully charge capacitor, and signal will be impeded
- Rapidly alternating signals
  - will not fully charge the capacitor before the direction of flow reverses, allowing signals to pass unimpeded

Using Capacitors to make Low Pass Filters

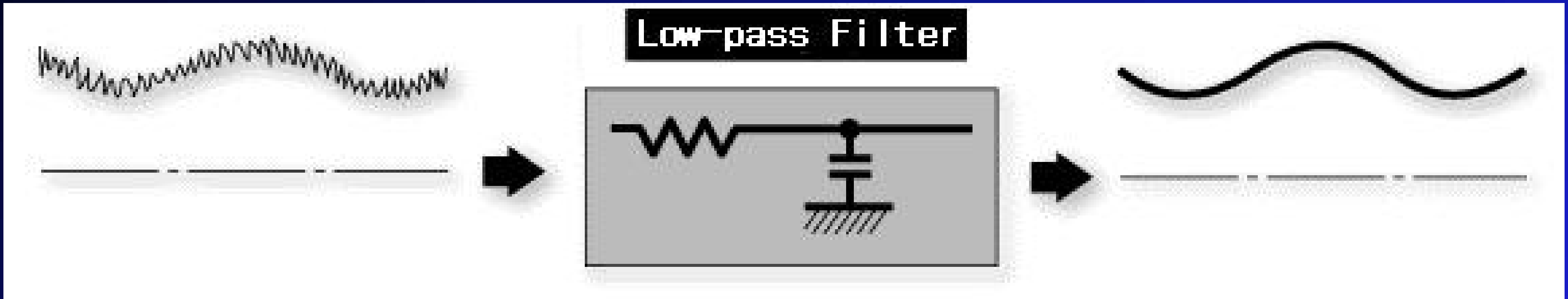


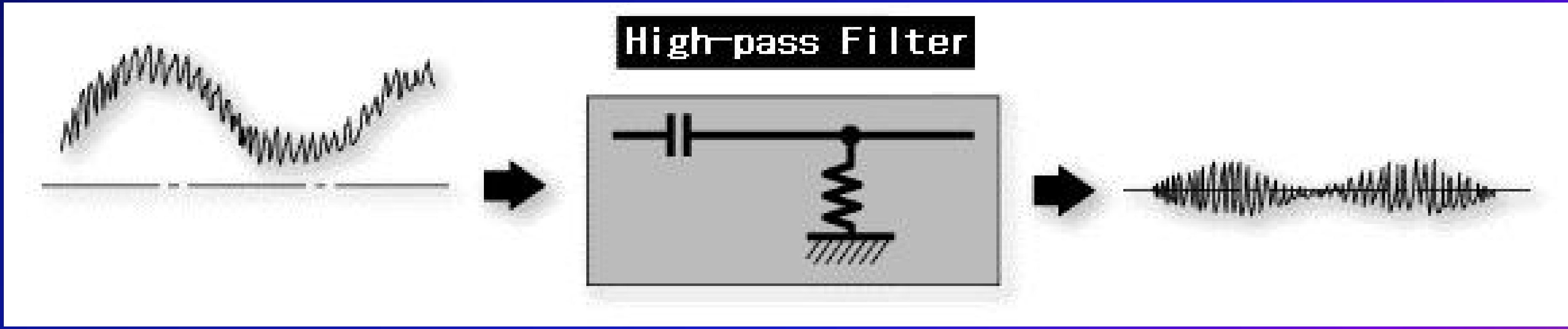
What will happen to fast signals; slow signals?

Using Capacitors to make High Pass Filters



What will happen to fast signals; slow signals?

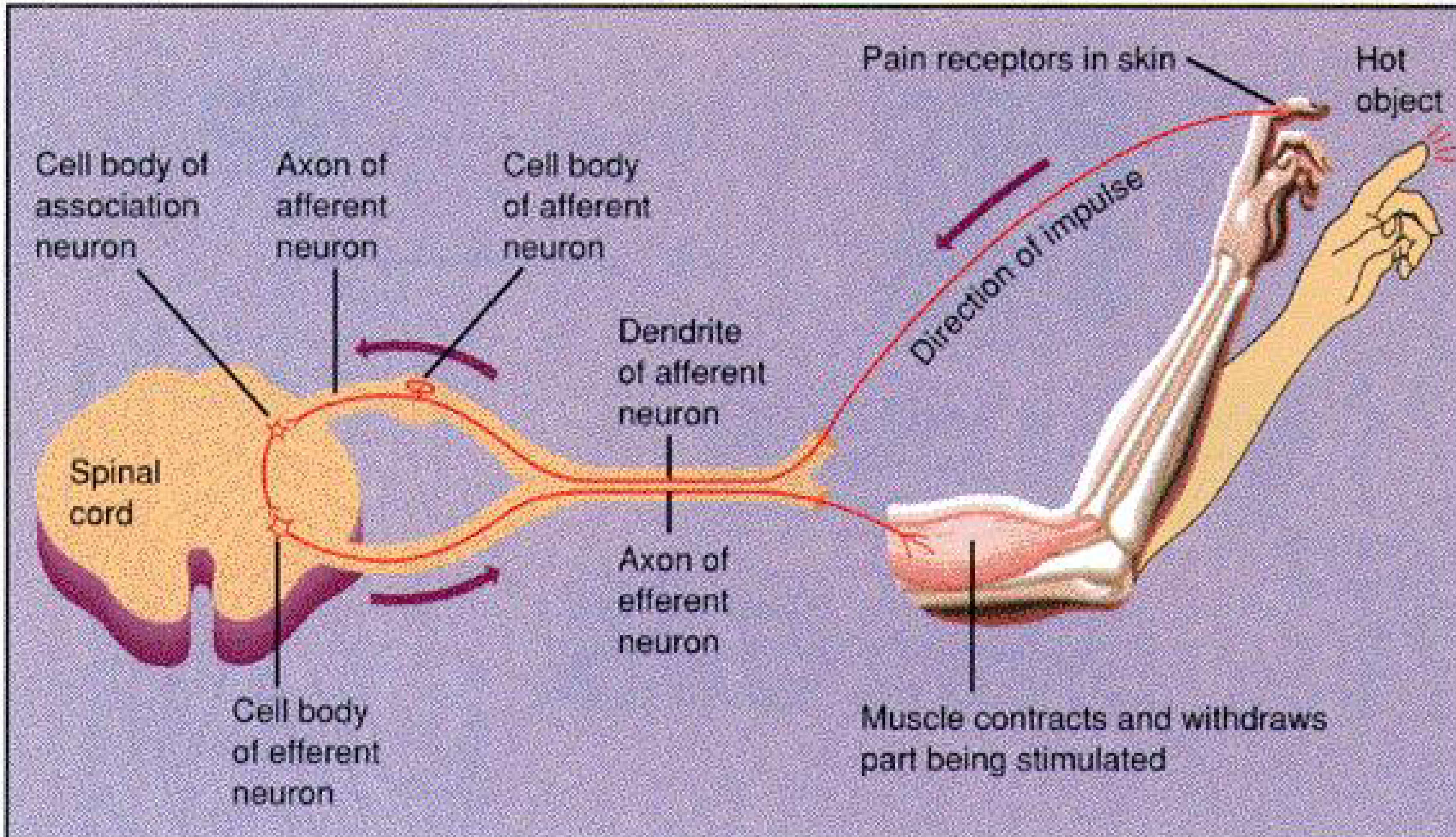

Low-pass Filter


High-pass Filter

Part II: Basic Neurophysiology

- Three basic units inside the brain
  - Glial cells
  - Extracellular space: not really space
  - The neuron
    - Three types:
      - Sensory
      - Motor
      - Interneuron

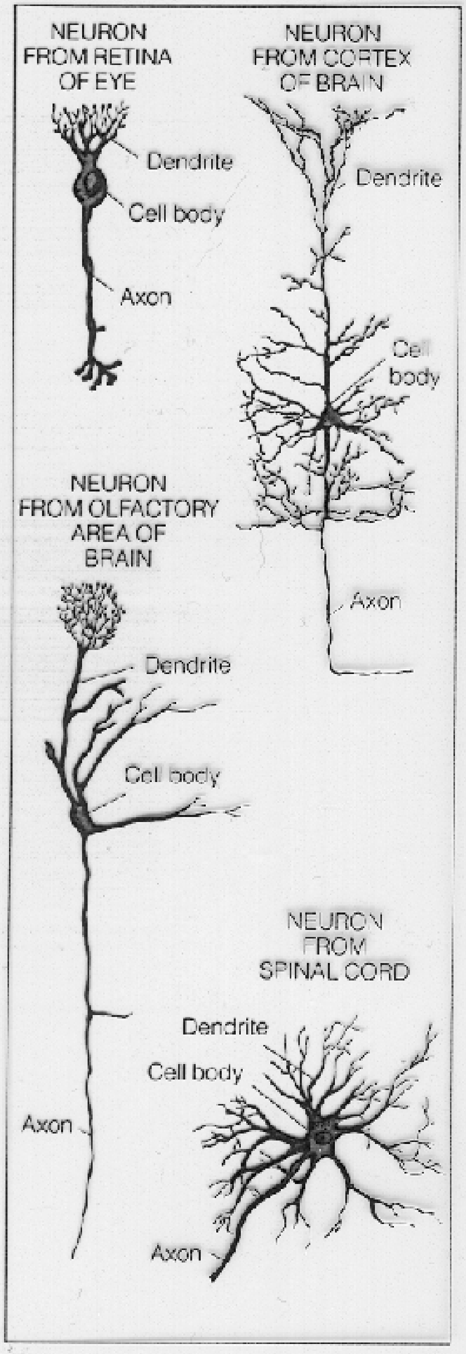
Withdrawal Reflex



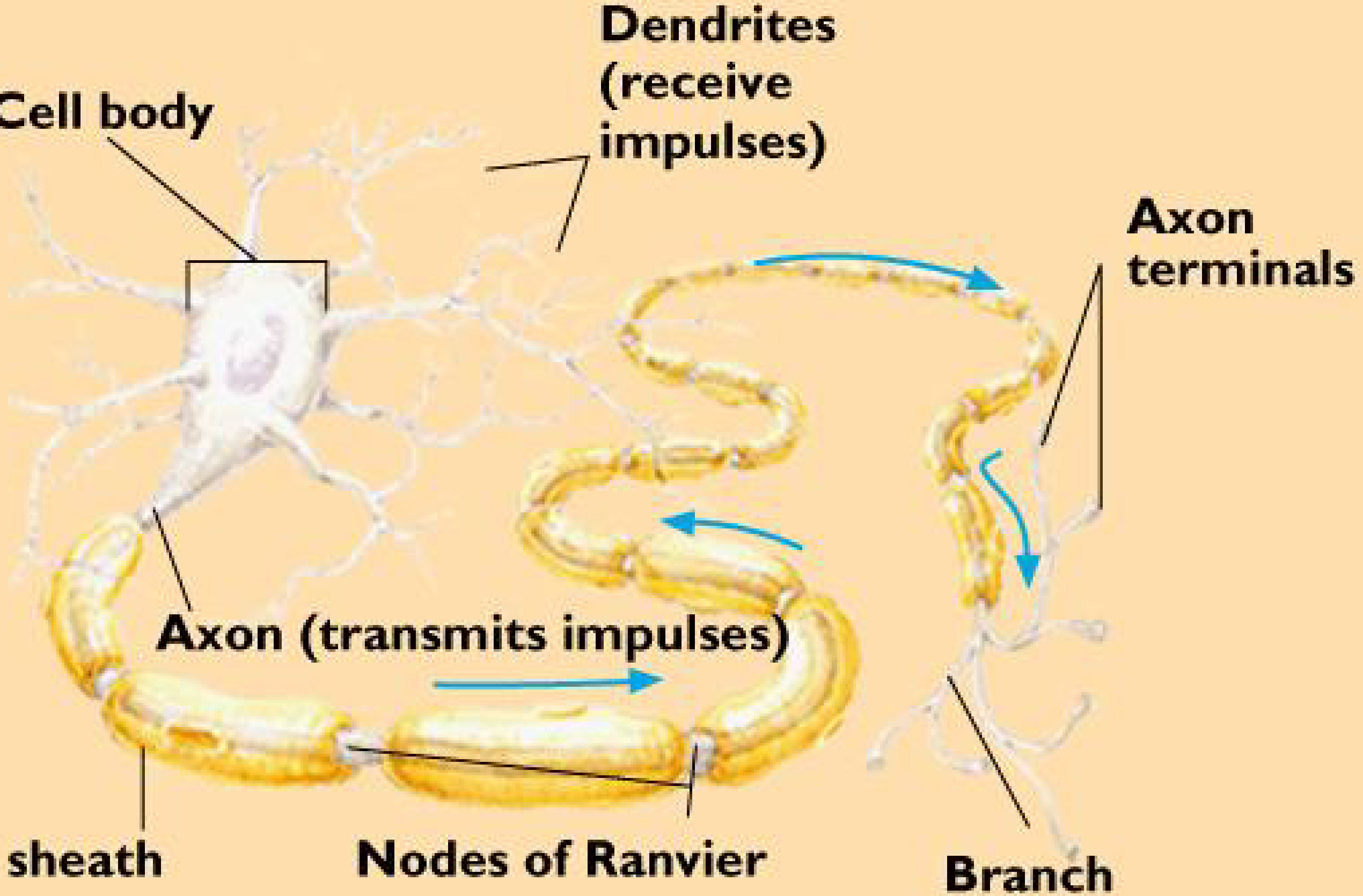
The Common Household Neuron

- Vary widely, but all have:
  - Cell body (soma)
  - Dendrites
  - Axon
    - Myelin sheath
    - Nodes of Ranvier
    - Microtubules
    - Terminal buttons (AKA synaptic knob)
- Nerve = a bundle of axons

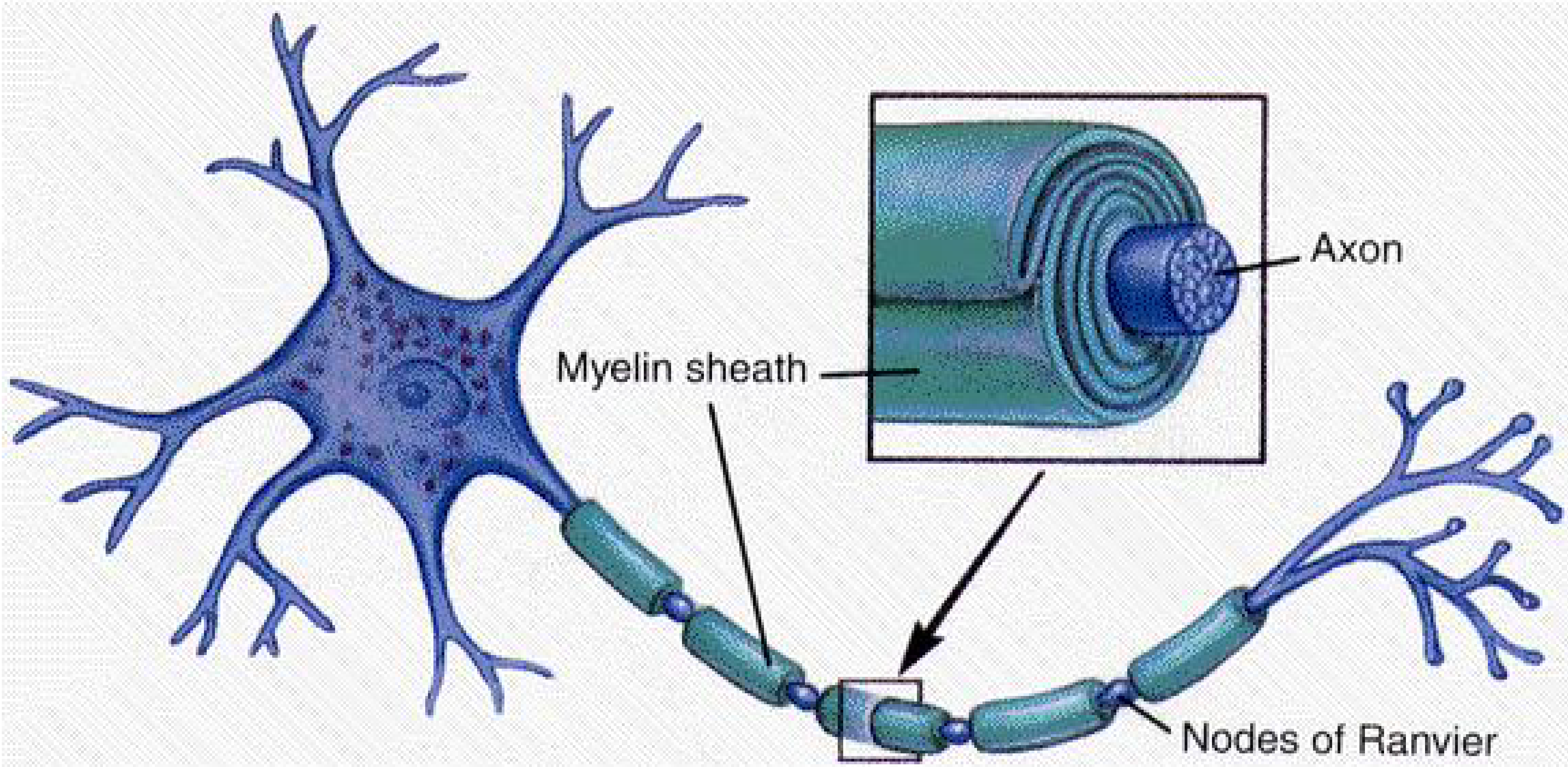
Jump to Next


NEURON
FROM RETINA
OF EYE
Dendrite
Cell body
Axon
NEURON
FROM CORTEX
OF BRAIN
Dendrite
Cell
body
Axon
NEURON
FROM OLFACTORY
AREA OF
BRAIN
Dendrite
Cell body
Axon
NEURON
FROM
SPINAL CORD
Dendrite
Cell body
Axon

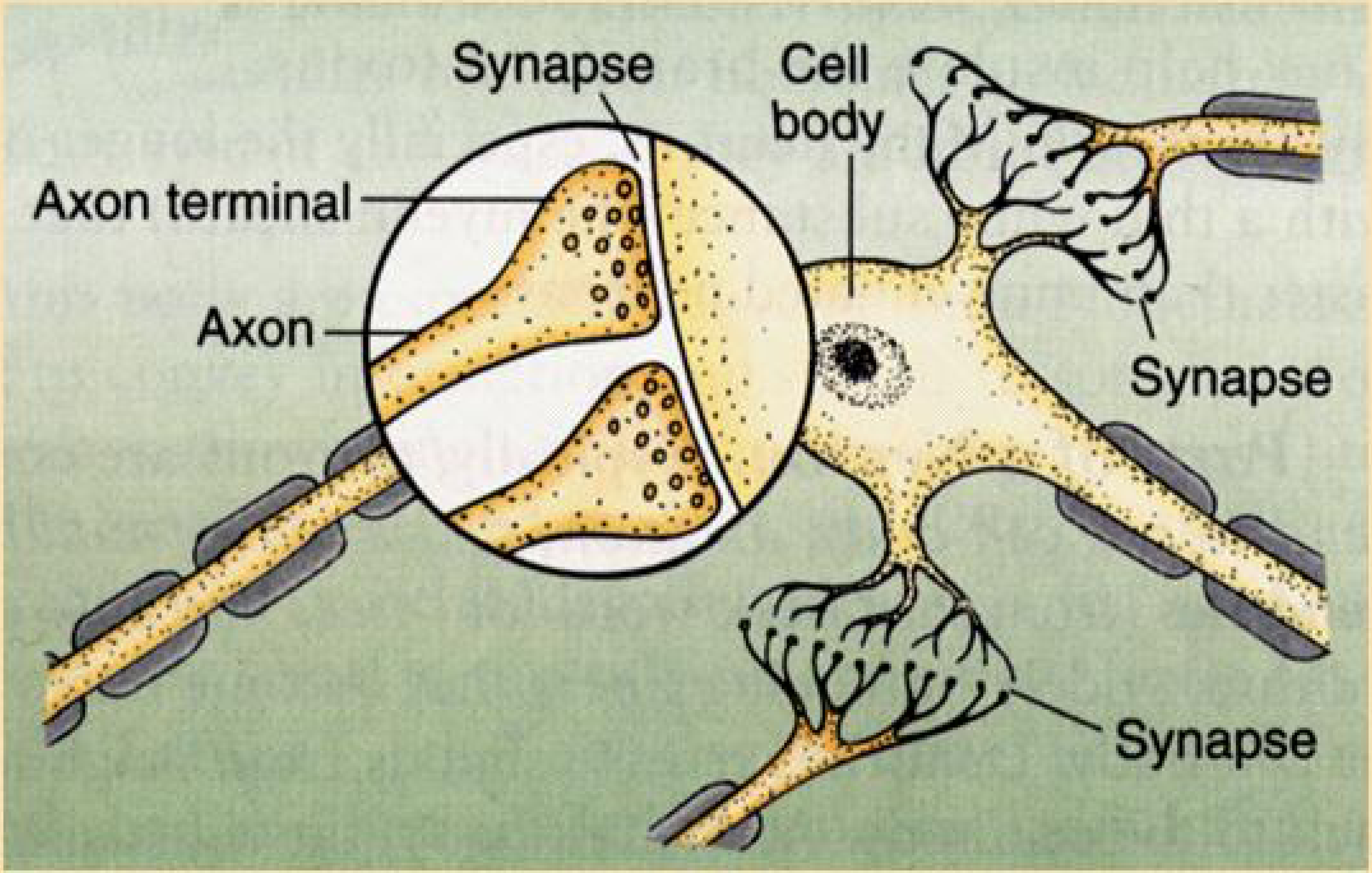
Neuron Structure



Myelin Sheath



The Synapse



Neural Communication

- Axonal Conduction (electro-chemical)
- Synaptic Transmission (chemico-eletrical)

Axonal Conduction

- Resting potential
  - Inside of cell slightly negative
  - Two forces act upon these ions
    - Concentration gradient--osmotic force
    - Electromotive force
  - Equilibrium potential:
    - $E_{ion} = (R*T/z*F) * \ln(Conc_{Ex}/Conc_{In})$
    - where R is gas constant, T is temperature, z is ionic valence, and F is Faraday's constant.
  - The Hodgkin & Huxley Model

Axonal Conduction

- Depolarization
  - Threshold
  - Axon Hillock
  - Na ions rush in resulting in:
  - Action potential;
    - All or none phenomenon, high frequency
    - Afterpotentials; hyperpolarizing, depolarizing; slow frequency
    - Changes in membrane permeabilities
    - Propagation
- Refractory period

Jump to Next

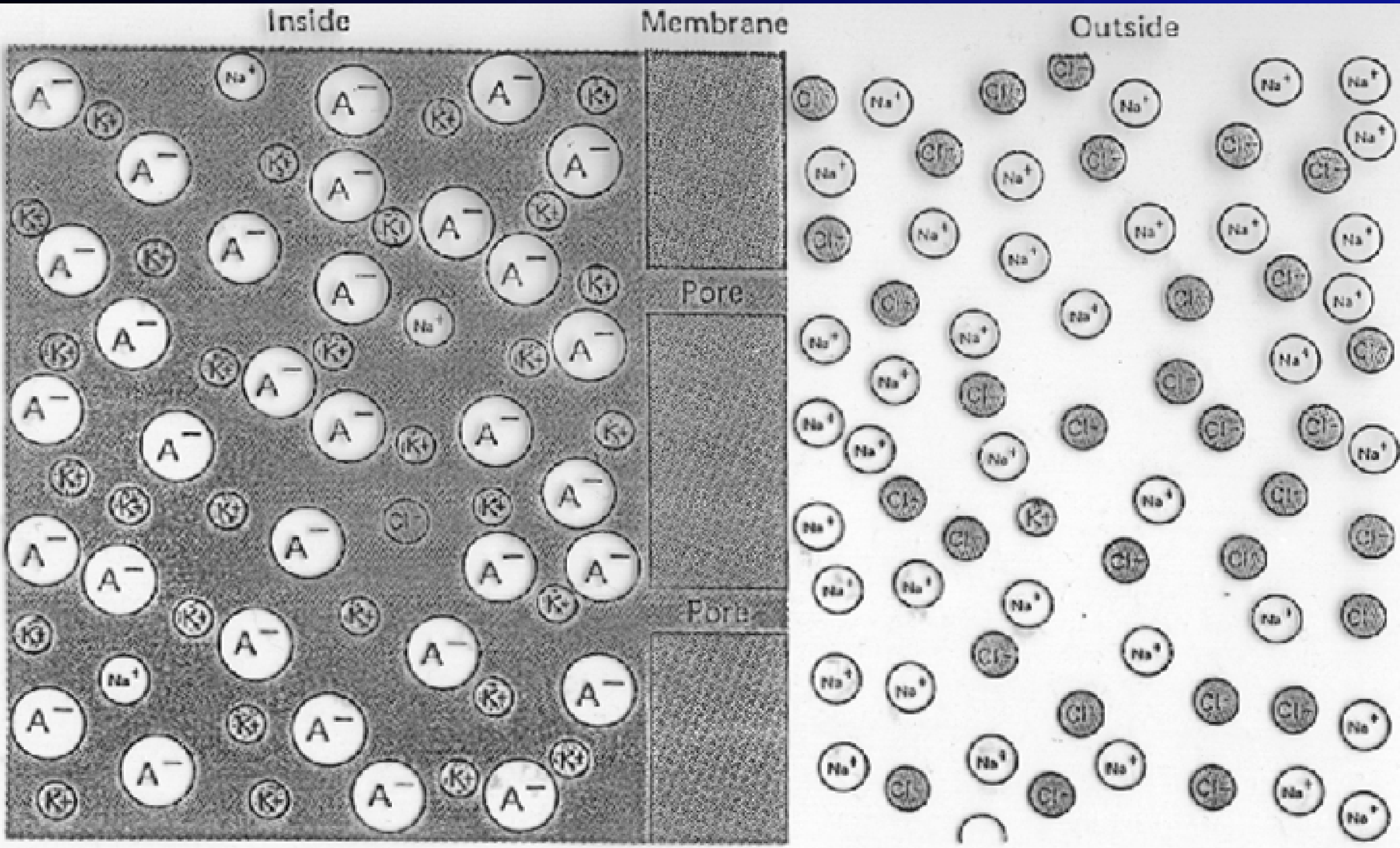
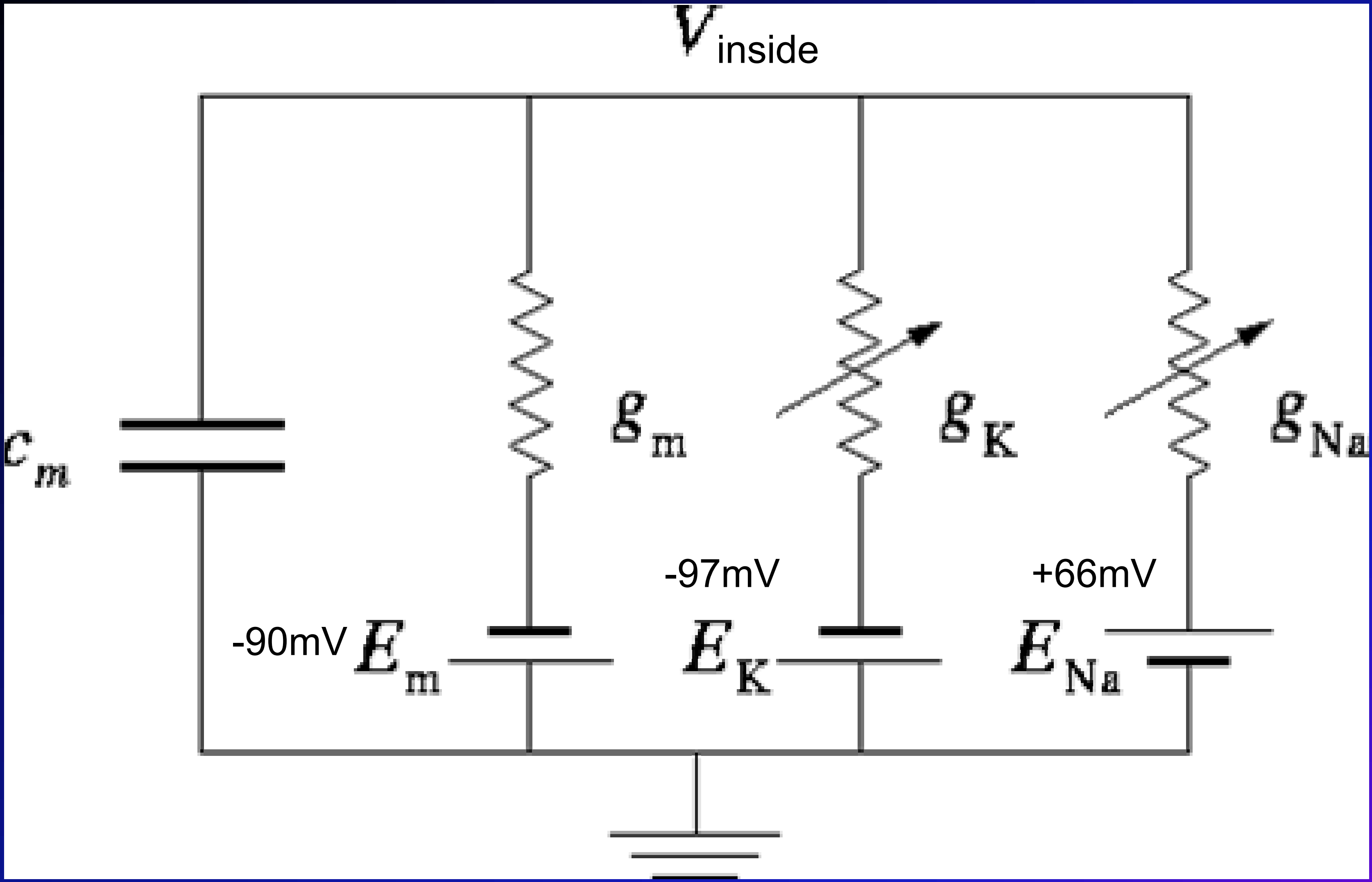
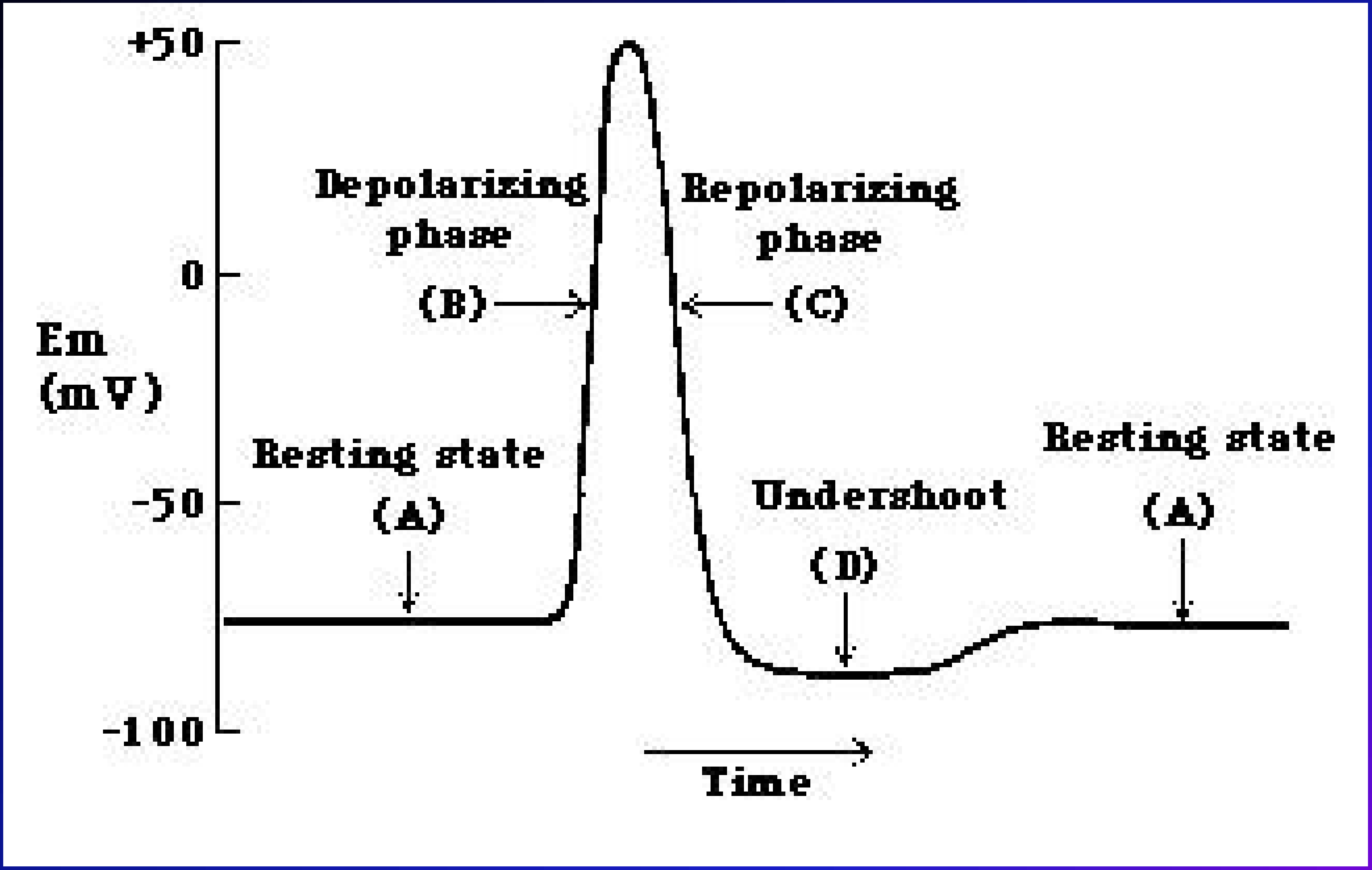
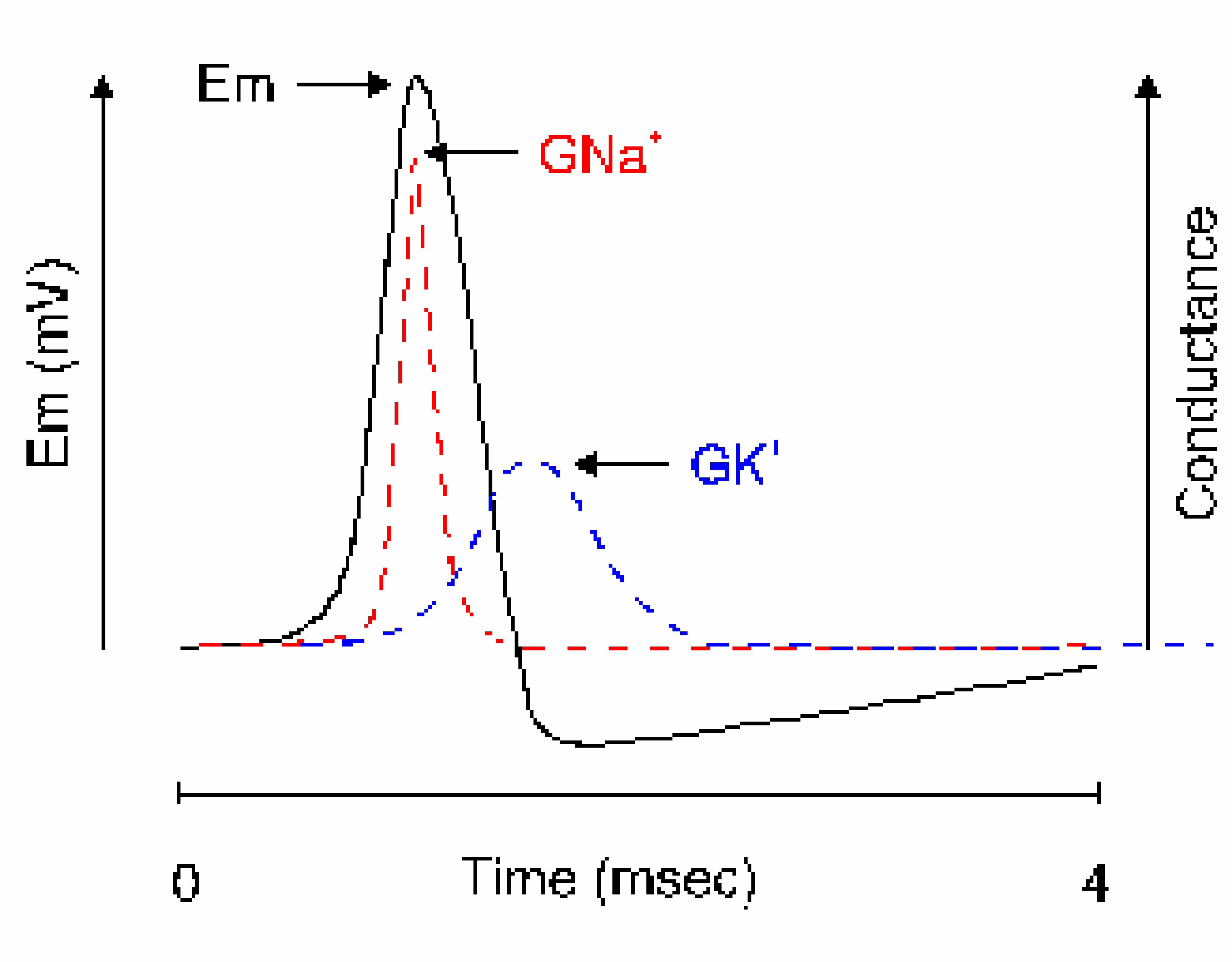


Fig. 2-3. Intra- and extracellular distribution of the ions. On both sides of the membrane, the different ions are indicated by *circles of different diameter*, proportional in each case to the diameter of the (hydrated) ion. A^- designates the large intracellular protein anions. The passages through the membrane, the "pores," are just large enough to permit the K^+ ions to diffuse through.

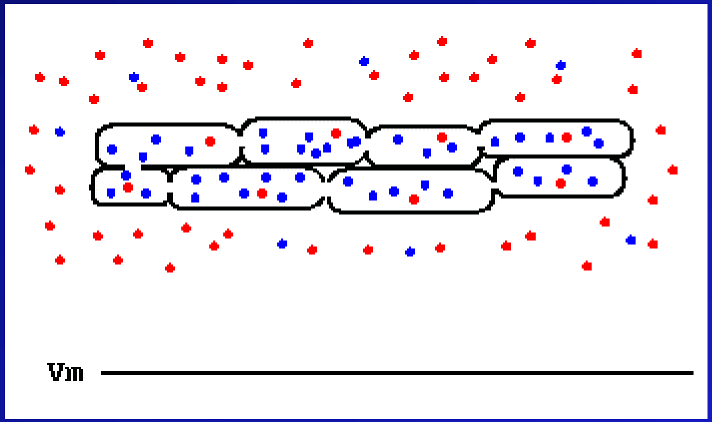


For interactive link: http://ssd1.bme.memphis.edu/icell/squid.htm


+50
0
-50
-100
Em
(mV)
Depolarizing
phase
(B)
Repolarizing
phase
(C)
Resting state
(A)
Undershoot
(D)
Resting state
(A)
Time



Em
GNa+
GK+
Em (mV)
Conductance
0
Time (msec)
4


Vm

Synaptic Transmission

- Not an all-or-none phenomenon
- Synaptic gap or cleft at the synaptic junction
- Single axon splits near end--**terminal arborization**
- As action potential arrives (demo)
  - synaptic vesicles migrate to cell membrane fuse and release
  - Neurotransmitters diffuse across the synaptic cleft
  - combine with **post-synaptic receptors**
  - When neurotransmitter binds to a receptor on the post-synaptic cell, a slow electrical potential (**post-synaptic potential**) is generated:
  - 5 to 20 mV at peak amplitude
  - 20-150 msec in duration (50 to 6 Hz)

Synaptic Transmission

- Post-synaptic potentials (PSP's);
  - Excitatory
  - Inhibitory
  - Interaction
- **Summation/Integration**
  - **temporal**
  - **spatial**
  - **decremental conduction** on dendrites and soma
  - axon hillock is critical area at which threshold must be reached
- After release of neurotransmitter,
  - reuptake
  - degradation
- **Functional Synaptic Units**

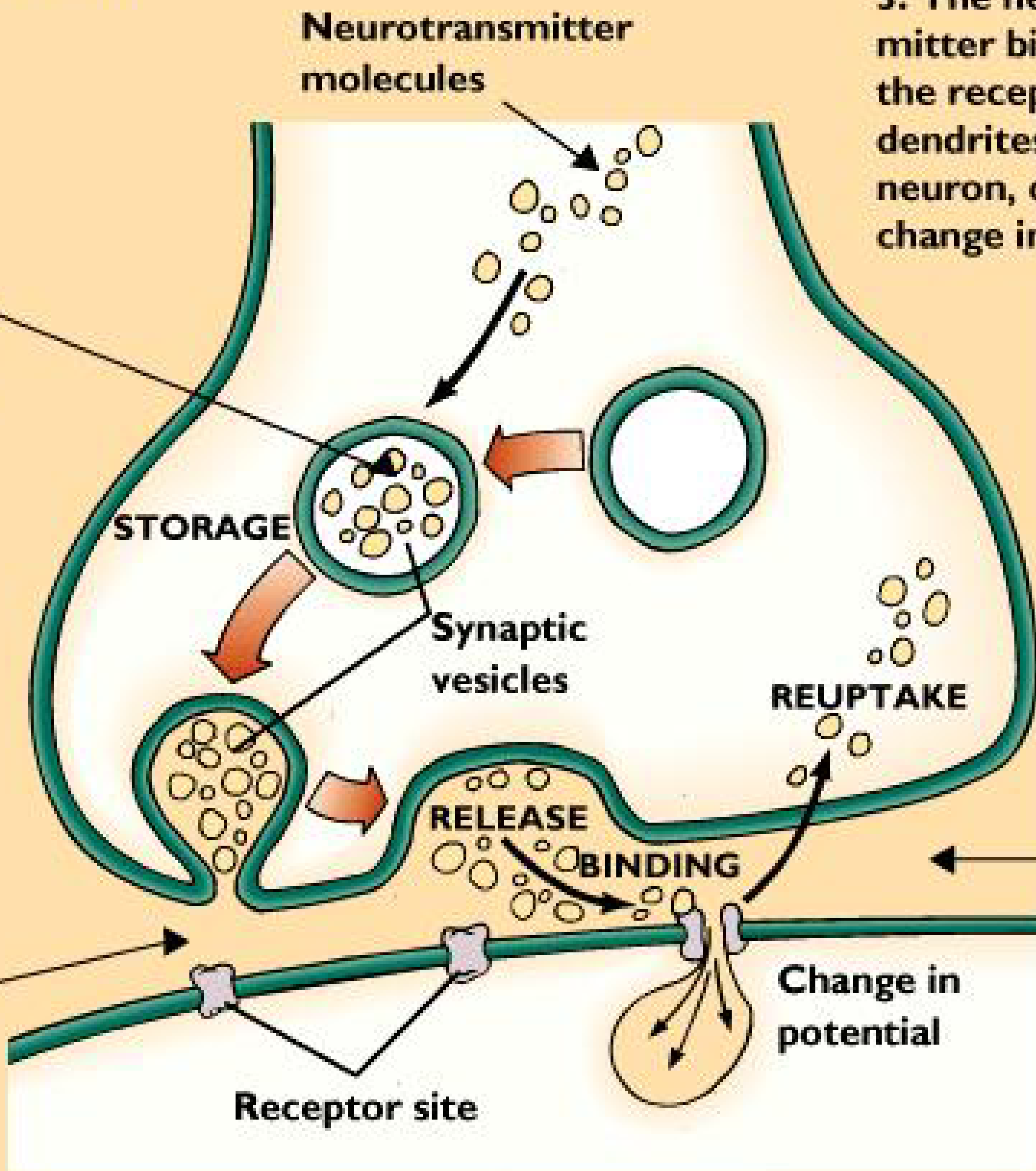
Jump to Next

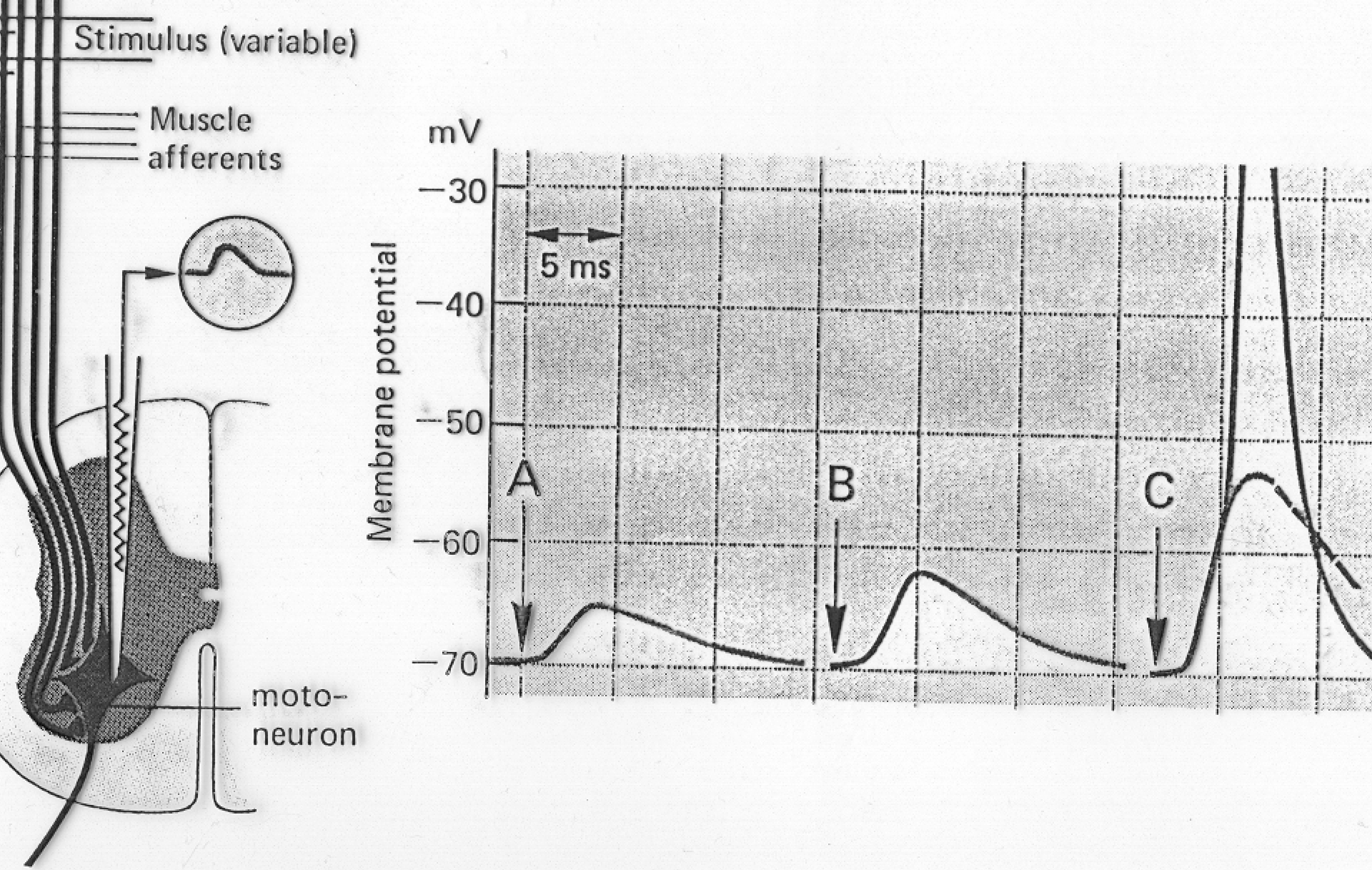
Synaptic Transmission

1. Within the axons of the neuron are neurotransmitters, which are held in storage-like vesicles until they are released when the neuron is stimulated.

2. The small space between the axon terminal and the dendrite of the next axon is called the synapse. An action potential stimulates the release of neurotransmitters across the synapse.

3. The neurotransmitter binds itself to the receptor sites on dendrites of the next neuron, causing a change in potential.





3-10. Excitatory postsynaptic potentials, recorded intracellularly from a moto
Afferents in the peripheral nerve from the associated muscle are stimulated el

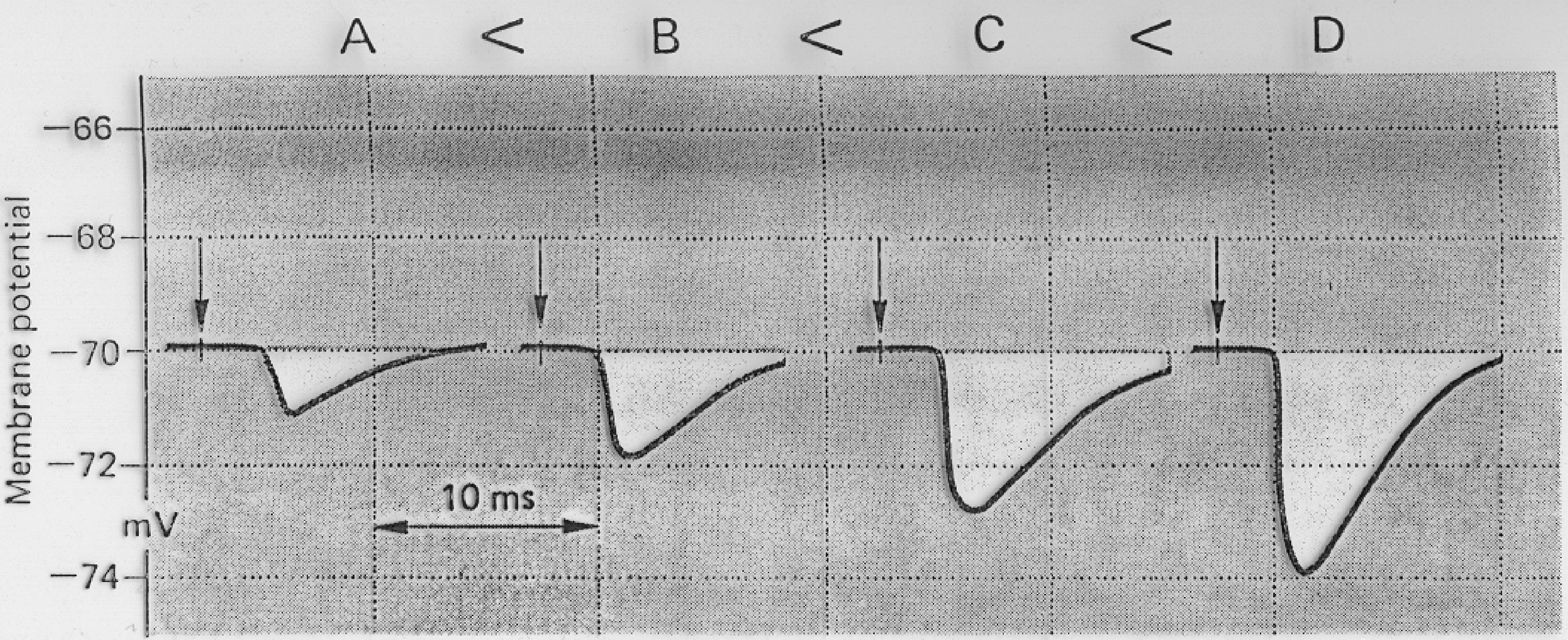


Fig. 3-11. Inhibitory postsynaptic potentials. Experimental arrangement as in Fig. 3-10, except that here an antagonist nerve is stimulated.

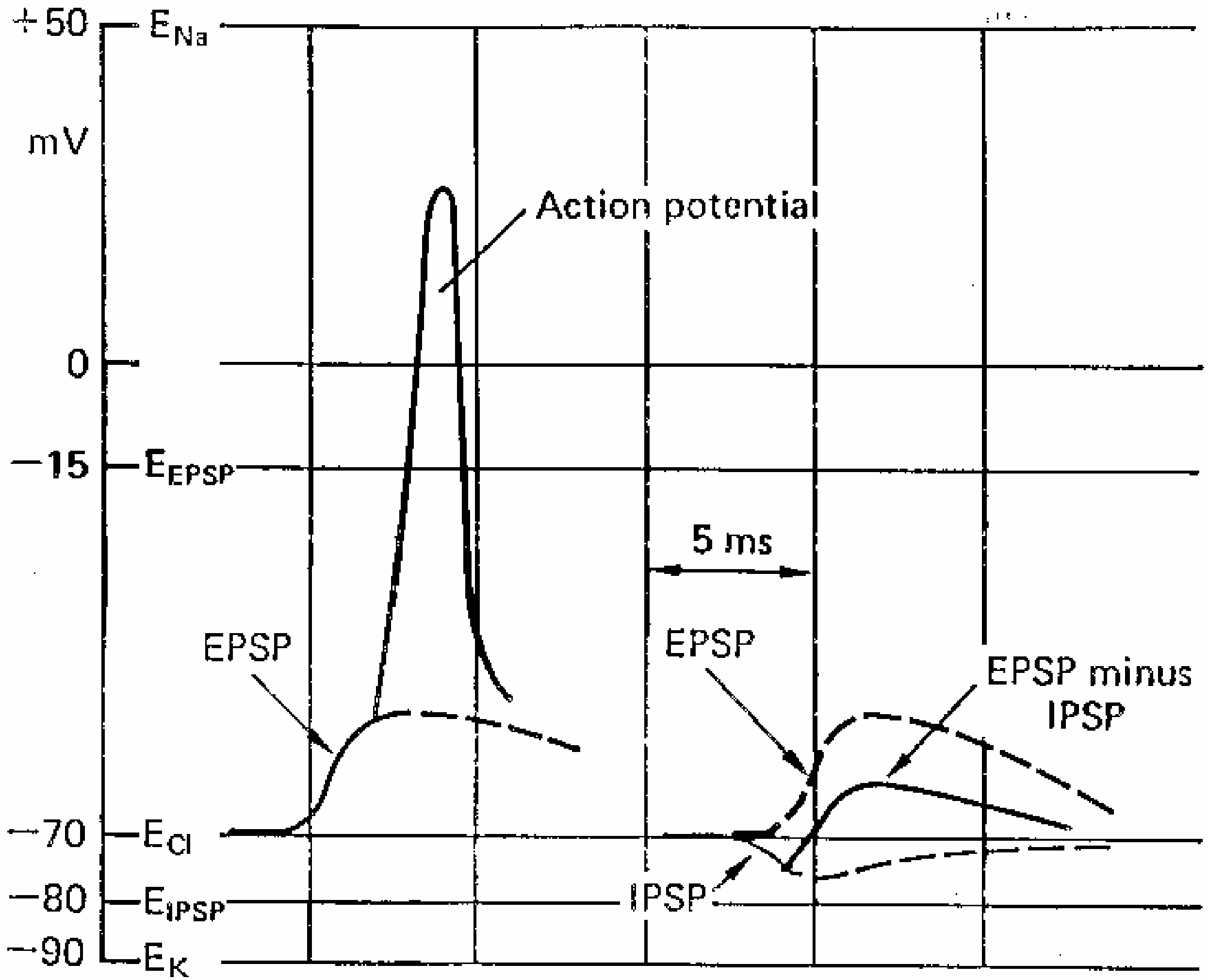
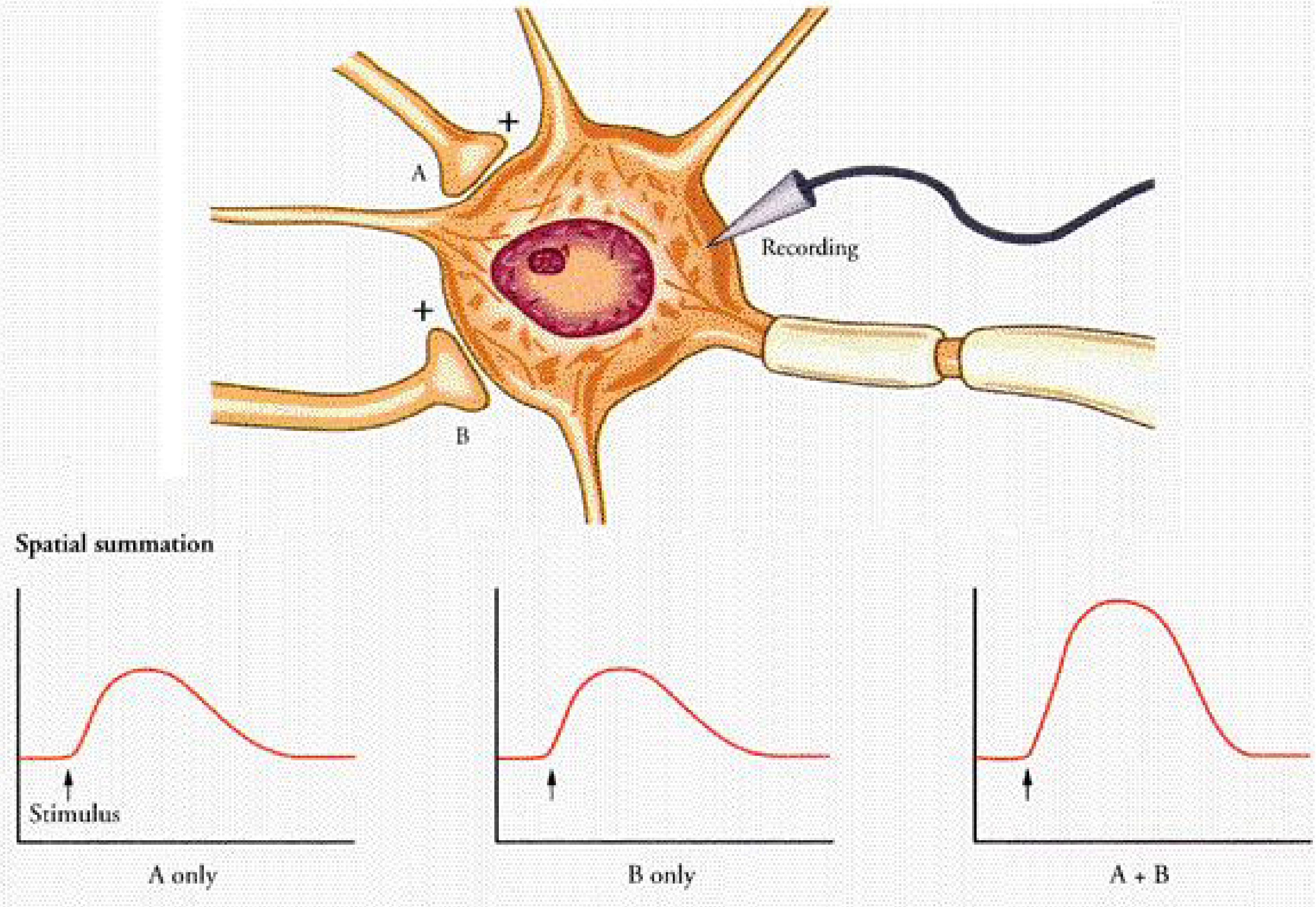
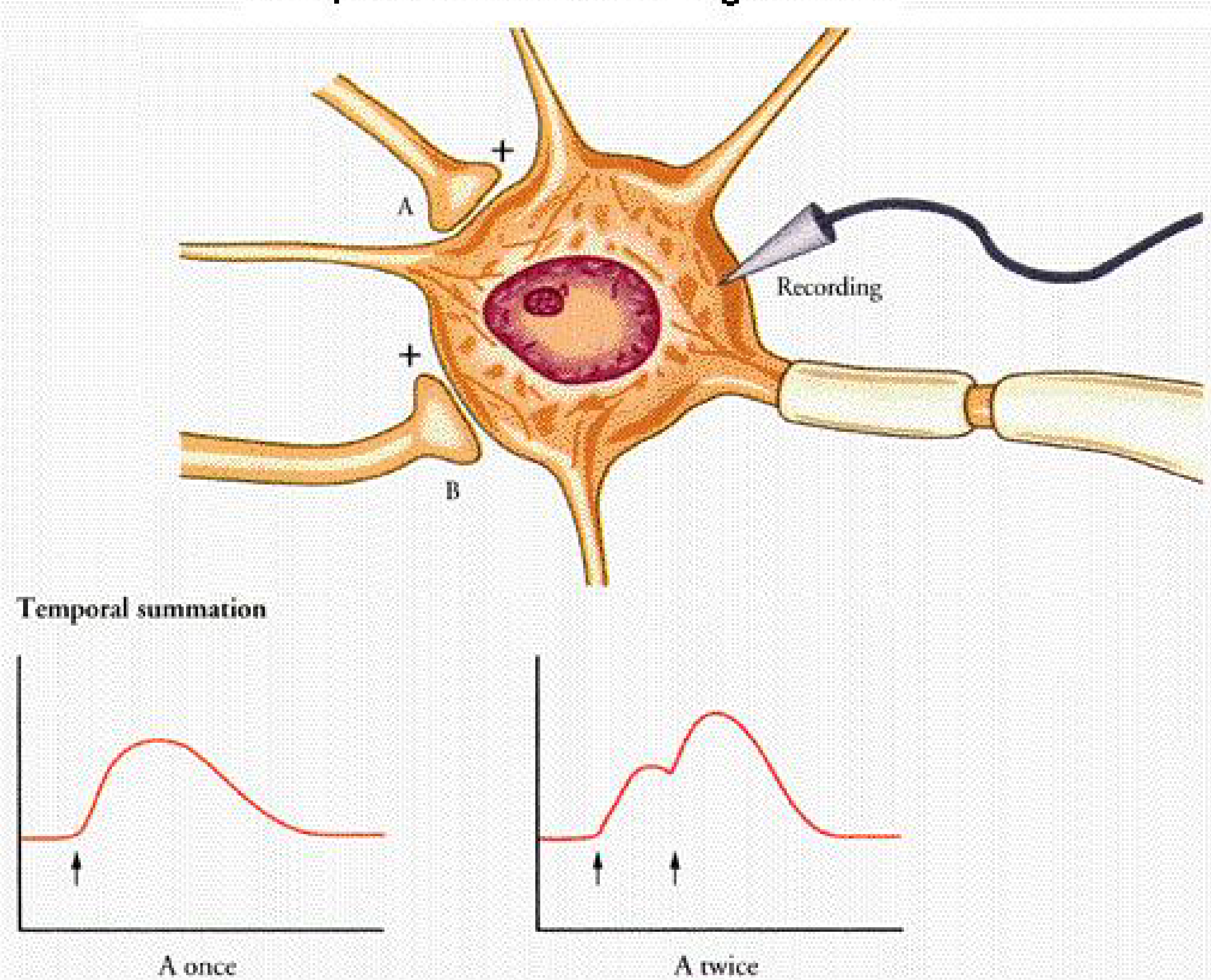


Fig. 3-14. The effect of an IPSP on the action potential; experimental arrangement as in Fig. 3-13. The homonymous nerve is stimulated strongly enough to produce a suprathreshold EPSP (*left*). On the *right*, the antagonist nerve is stimulated about 3 ms before the homonymous nerve. The equilibrium potentials of Na^+, K^+, Cl^-, EPSP, and IPSP are shown.

Spatial Summation. Figure 5.11



Temporal Summation. Figure 5.11



Part III: Basic Neuroanatomy

I. Organization of the nervous system

A. Central nervous system

1. Brain

2. Spinal cord

B. Peripheral nervous system

1. Somatic system

2. Autonomic system; two branches work in generally antagonistic fashion

a. Sympathetic nervous system

1. tends to have system-wide effects

2. flight or flight; activity

b. Parasympathetic nervous system

1. tends to affect one organ at a time

2. quiescent processes--digestion, protects and conserves energy

- c. Sympathetic vs. Parasympathetic

1. Is not an the case that one is "on" while the other is "off": complex interaction

2. Some systems have both parasympathetic and sympathetic inputs

Somatic	***Autonomic***

- Descending motor tracts within spinal synapse at approximate level of exit -- post-synaptic neuron directly innervates target tissue -- 2-neuron system - Descending motor tracts respond well to intentional control (e.g., striate muscle in fingers) - Awareness of processes generally present or possible	- Descending motor tracts within spinal cord synapse not necessarily at level of exit -- after exit synapse again before innervation -- 3-neuron system - Descending motor tracts much more difficult to control voluntarily (e.g., contract the smooth muscle of the stomach to make that food churn) - Awareness of process much less available to awareness (e.g., referred pain)

Sympathetic	***Parasympathetic***
- Prepares body for action - Catabolic processes that require energy expenditure - After synapse within grey-matter of spinal cord, the post-synaptic (pre-ganglionic) neurons exit in thoracic or lumbar regions -- *Thoracolumbar* system -- pre-ganglionic neurons travel to sympathetic chain (series of connected sympathetic ganglia▾*"swelling or knot"*, chain of neurons) -- post-ganglionic neurons generally travel a long distance to target organ - Pharmacologically, -- All synapses within the sympathetic ganglia are acetylcholinergic -- Terminal buttons on target organs are noradrenergic (except sweat glands: acetylcholinergic)	- Restores and maintains body resources - Anabolic processes that increase the body's supply of stored energy - After synapse within grey-matter of spinal cord, the post-synaptic (pre-ganglionic) neurons exit in cranial (especially cranial nerve #10, Vagus) or sacral regions -- *Craniosacral system* -- pre-ganglionic neurons travel some distance before synapsing in the parasympathetic ganglia located in the immediate vicinity of the target organ -- post-ganglionic neurons are therefore typically quite short - Pharmacologically, -- All synapses acetylcholinergic: both pre- and post-ganglionic neurons - Slower and more specific action of this system works to restore and maintain bodily resources; only

- Quick diffuse action of system due to the sympathetic ganglionic chain prepares organism for *fight-or-flight*; in synchrony, many systems activate -- dialation of bronchioles -- dialation of pupils (the better to see you with my dear) -- constriction of blood vessels to skin and gastrointestinal system -- inhibition of gastrointestinal system -- increased BP, stroke volume, cardiac output -- increased sweating	changes that are necessary generally occur (not all systems in synchrony) -- decreased heart rate, blood pressure -- constriction of pupils and bronchioles -- increases in digestive functions

II. The common household brain

A. Overview of brain

1. The primitive central core

2. Limbic system

3. Cerebrum (AKA cerebral hemispheres)

a. Ontogeny

b. Phylogeny

4. These three layers are interconnected extensively; do not function independently

5. Orientation

lateral--side; medial--middle

anterior--front; posterior/dorsal--back

rostral--towards the nose; caudal--towards the tail

ipsilateral--same; contralateral--opposite

proximal--toward the soma; distal--away from the soma efferent--output/motor; afferent--receiving/sensory

B. Specifically

1. Primitive central core

a. Cerebellum

1. "little brain" located to rear of brain stem

2. involved in smooth coordination of movements

3. learning of complex motor activities (e.g., piano, skiing)

b. Thalamus & Hypothalamus: located just above the brain stem & tucked inside the cerebral hemispheres

1. Thalamus is a relay station for sensory information

a. "Gateway to the cortex"

b. coming from spinal cord to cortex

c. taste touch hearing vision -- olfaction is exception

2. Hypothalamus

a. literally = "under thalamus" ; much smaller, but very important

b. 4 F's:

c. Reticular system

a. diffuse from brainstem to thalamus

b. 3 A's, arousal, awareness, attention

2. Limbic system

a. a group of structures lying along the innermost edge of the cerebral hemispheres

b. involved in instinctual behaviors in lower animals (caring for young, mating, fleeing from attackers, fleeing from prey)

c. involved in memory and emotion in humans

d. Especially important structures within the Limbic system:

i.. Hippocampus

ii. Amygdala

3. The cerebral hemispheres

a. Grey matter vs white matter

b. Four lobes: frontal, parietal, occipital, temporal

c. Motor area

1. topographic organization--Homunculus

2. contralateral control of body

d. Somatosensory area

1. heat, cold, touch, pain, sense of body movement

2. contralateral

3. space appropriated in accord to amount of use or need

e. Visual area

1. Contralateral visual field

2. Primary vs Secondary

f. Auditory area

1. bilateral representation

2. contralateral stronger

g. Association areas

1. functions which are not directly sensory or motor

2. Examples:

a. motor planning

b. thought

c. speech

d. problem solving

e. complex object recognition (e.g. disorder termed prosopagnosia)

f. Phylogeny of Association Cortex

C. The Cortex: **Luria's functional systems**

1. **Primary**

a. Motor (precentral gyrus);

(1) topographic organization

b. Sensory

(1) Somatosensory (post central gyrus)

(2) Visual (Occipital cortex)

(3) Auditory (Banks of Lateral Sulcus)

2. **Secondary**

a. Motor (rostral to precentral gyrus): motor programming, sequences of movements

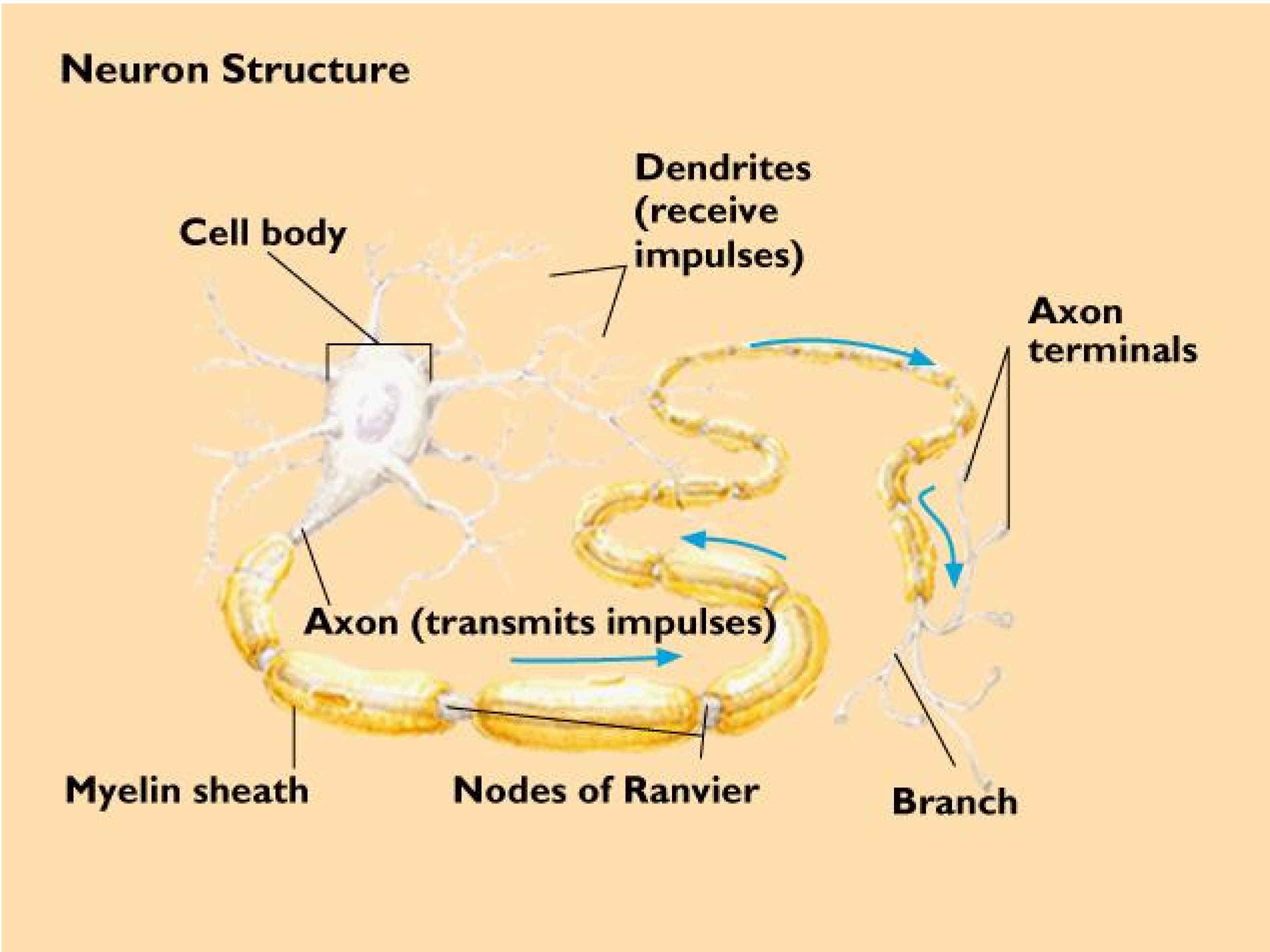
b. Sensory (caudal to postcentral gyrus): **unimodal** sensory integration

3. **Tertiary**

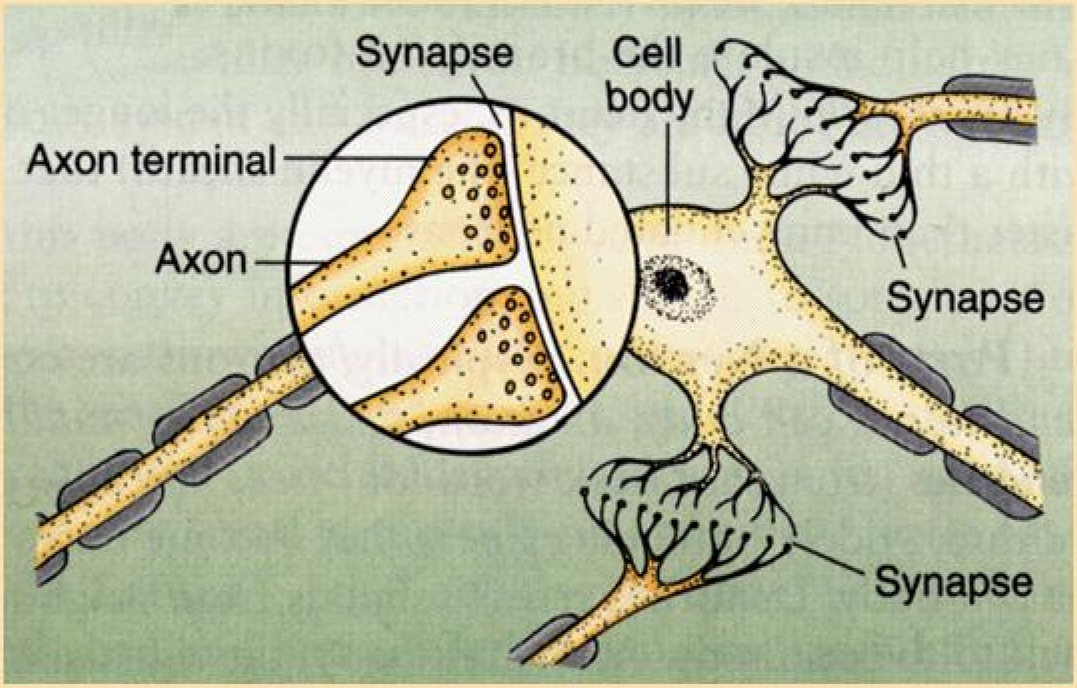
a. Motor (frontal lobes): goal directed acts, long-term & short-term planning, internal manipulation of "ideas" and representational systems that are basic to abstract thought

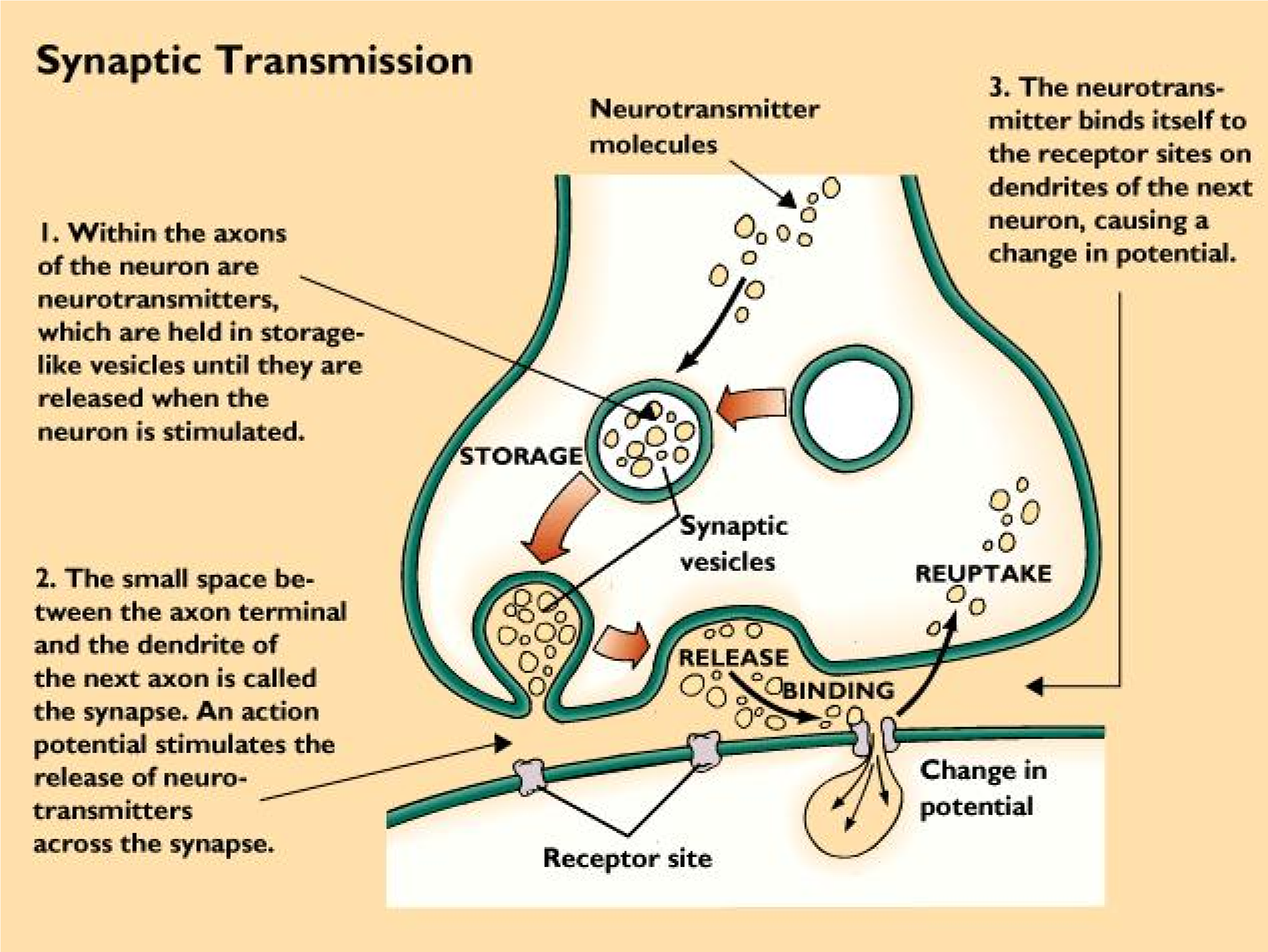
b. Sensory (parietal-temporal-occipital junction): cross-modal integration of sensory information

Images Start Here

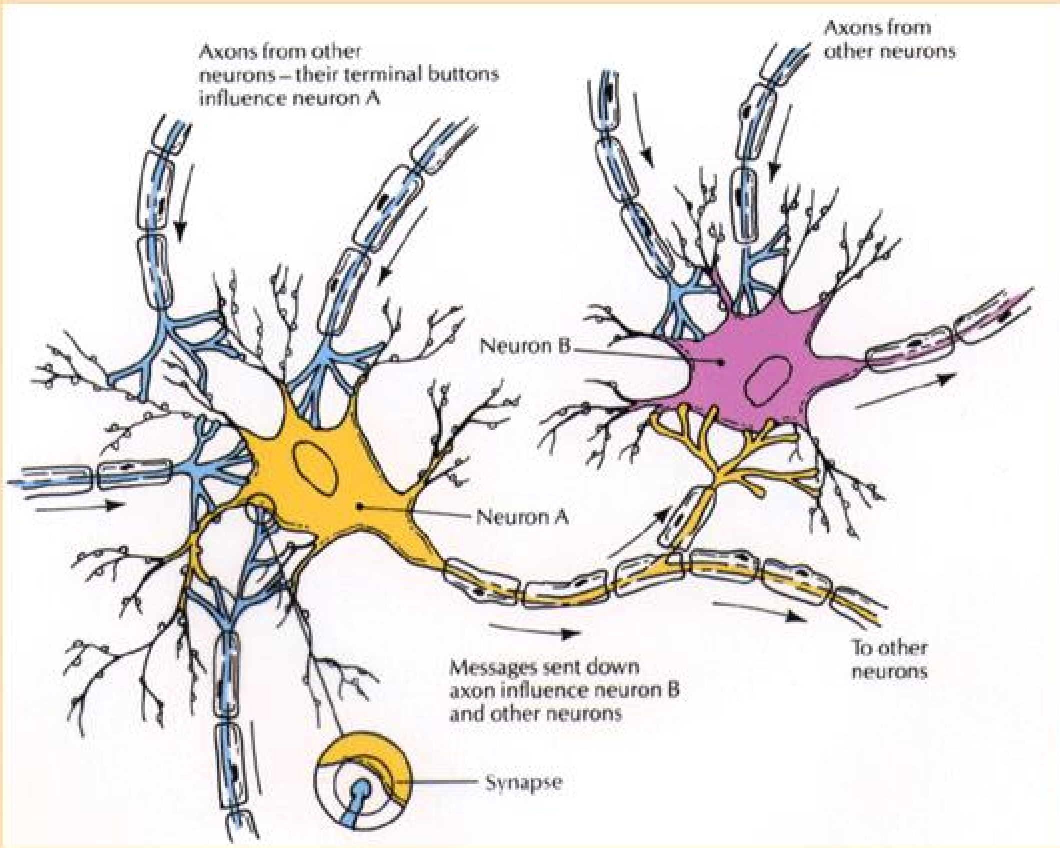


The Synapse

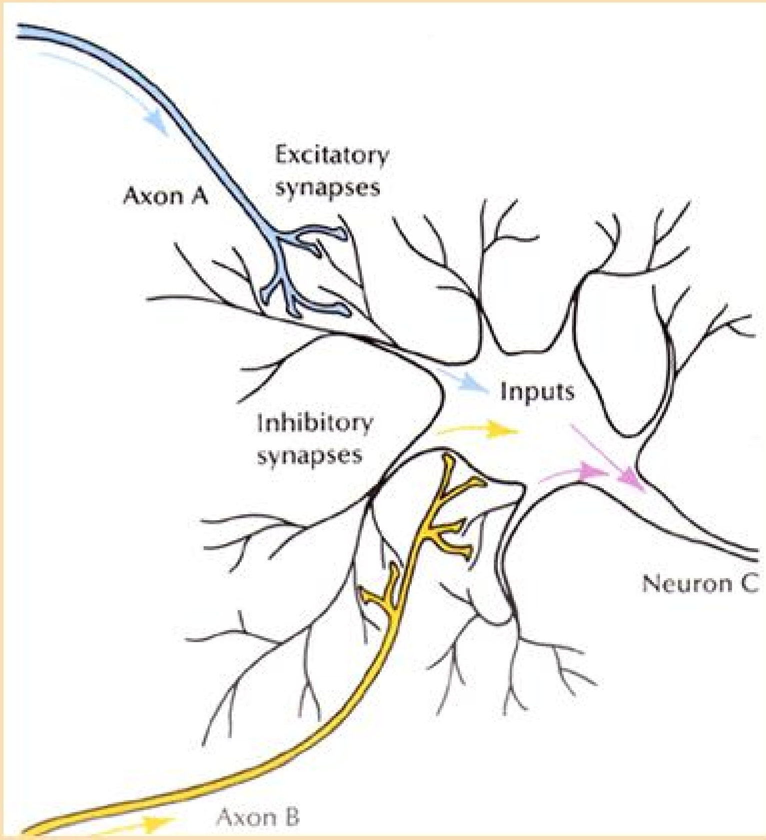



Synaptic Transmission
Neurotransmitter molecules
1. Within the axons of the neuron are neurotransmitters, which are held in storage-like vesicles until they are released when the neuron is stimulated.
3. The neurotransmitter binds itself to the receptor sites on dendrites of the next neuron, causing a change in potential.
STORAGE
Synaptic vesicles
2. The small space between the axon terminal and the dendrite of the next axon is called the synapse. An action potential stimulates the release of neurotransmitters across the synapse.
REUPTAKE
RELEASE
BINDING
Change in potential
Receptor site

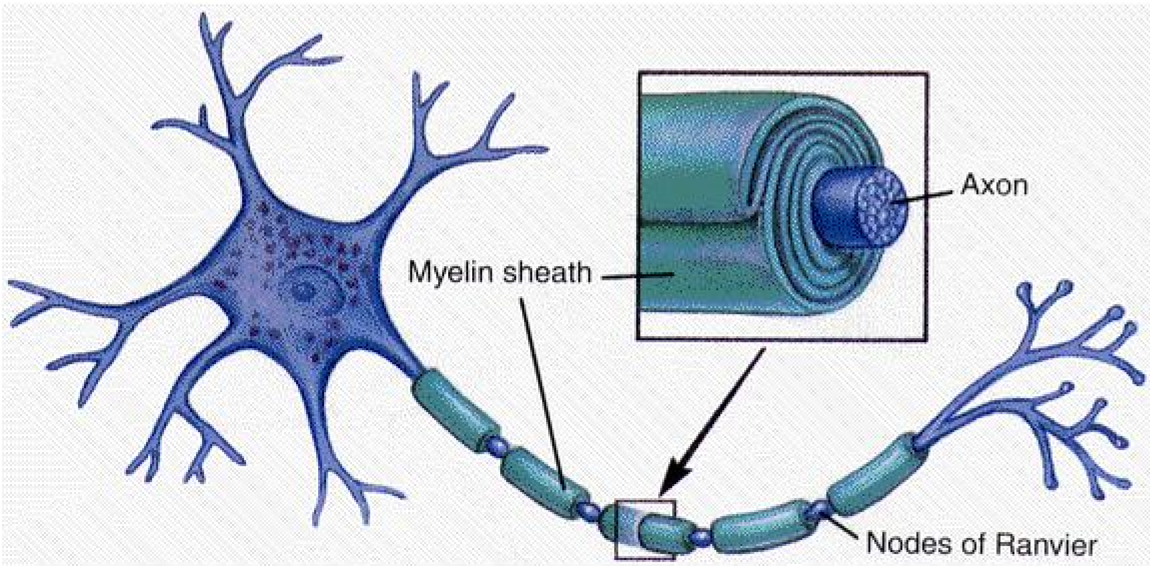
Synapses Between Several Neurons



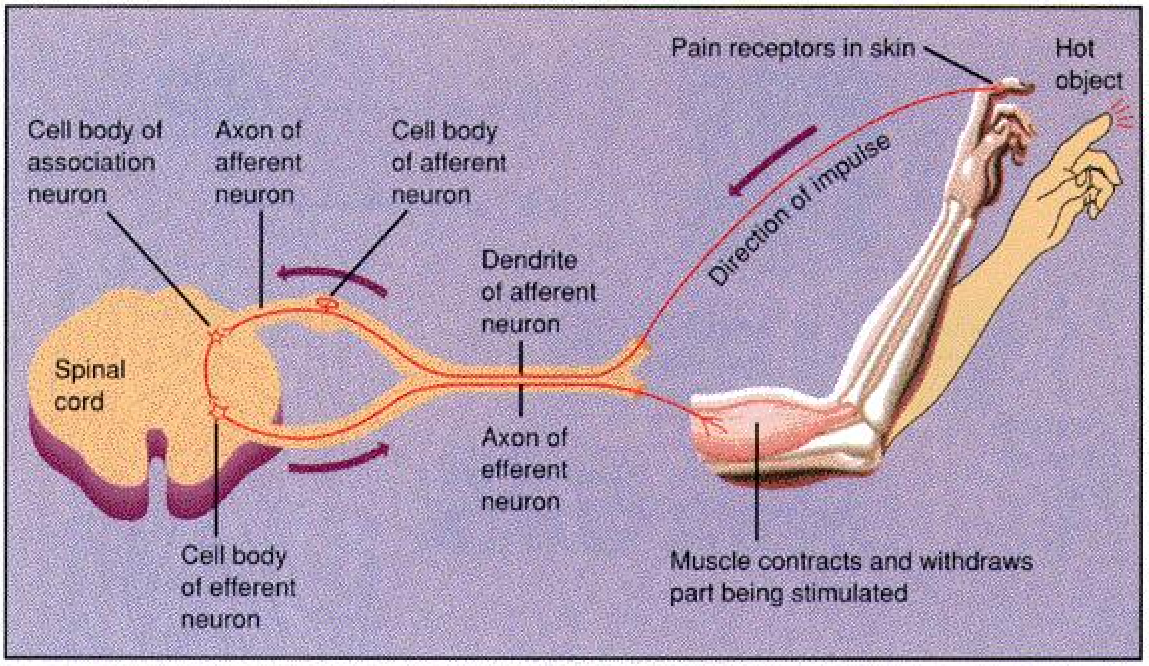
Neurotransmitters That Excite or Inhibit . . . Neurons



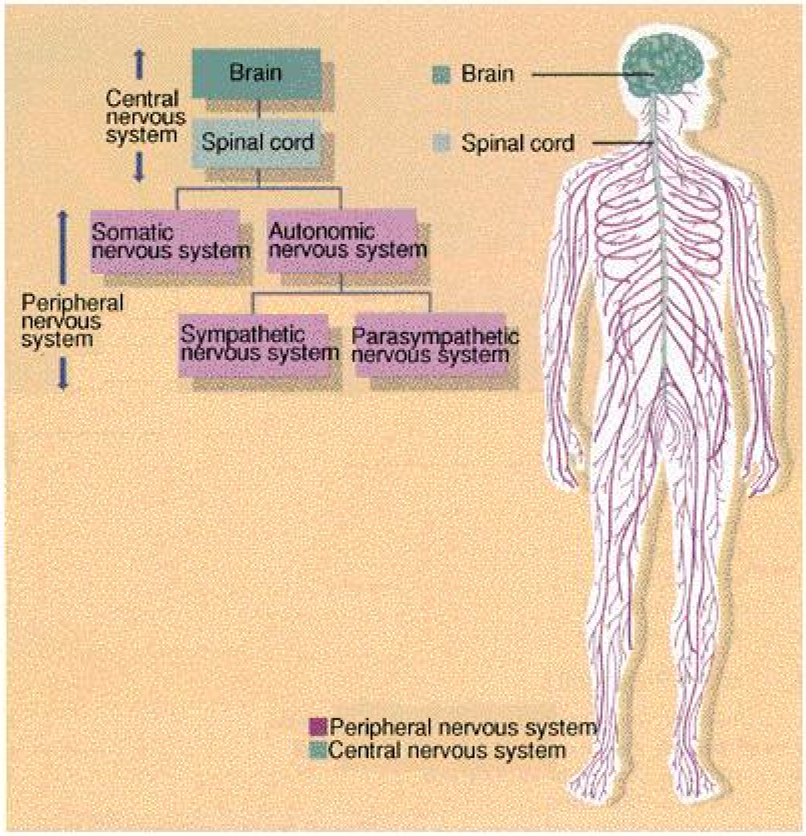
Myelin Sheath



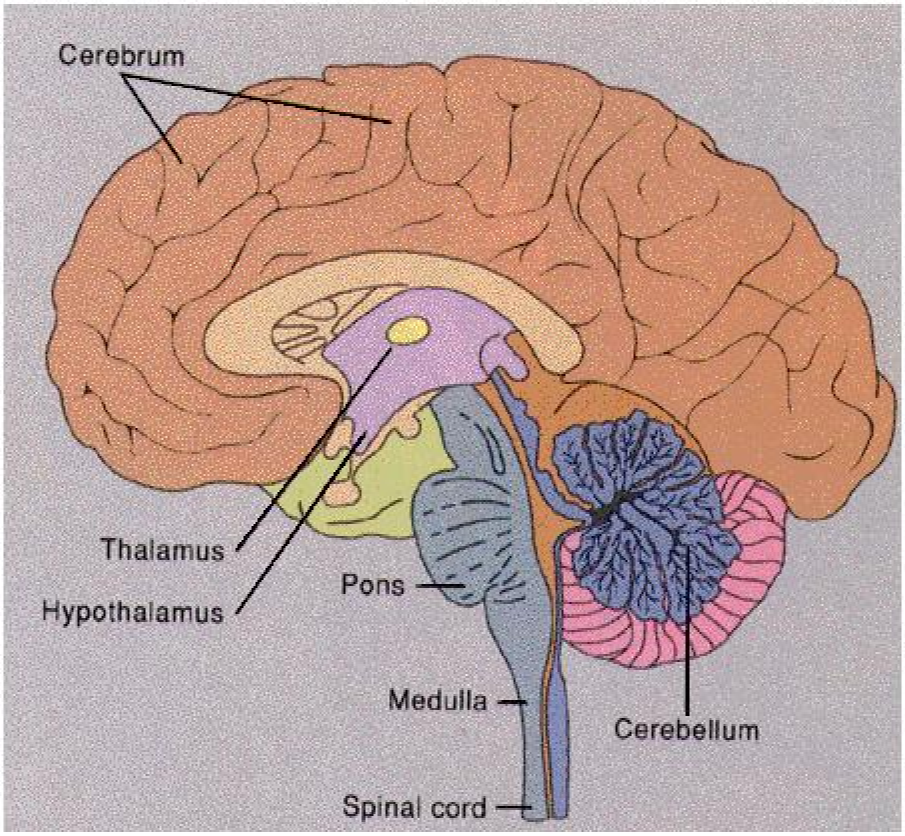
Withdrawal Reflex



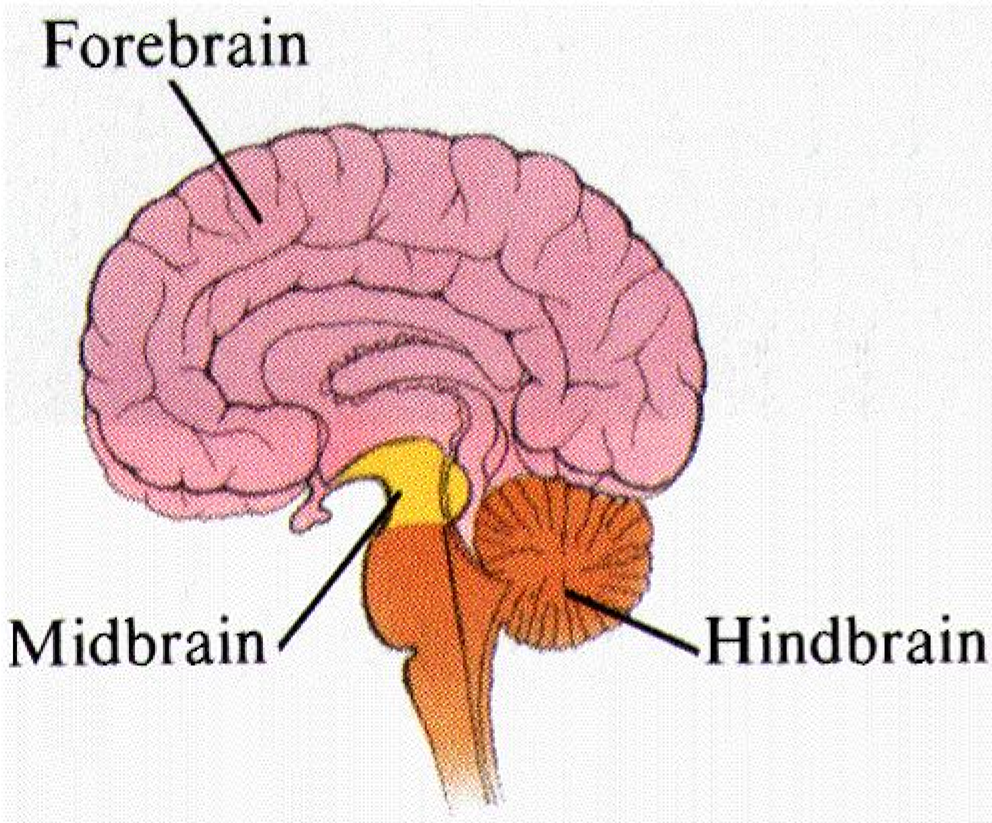
Human Nervous System

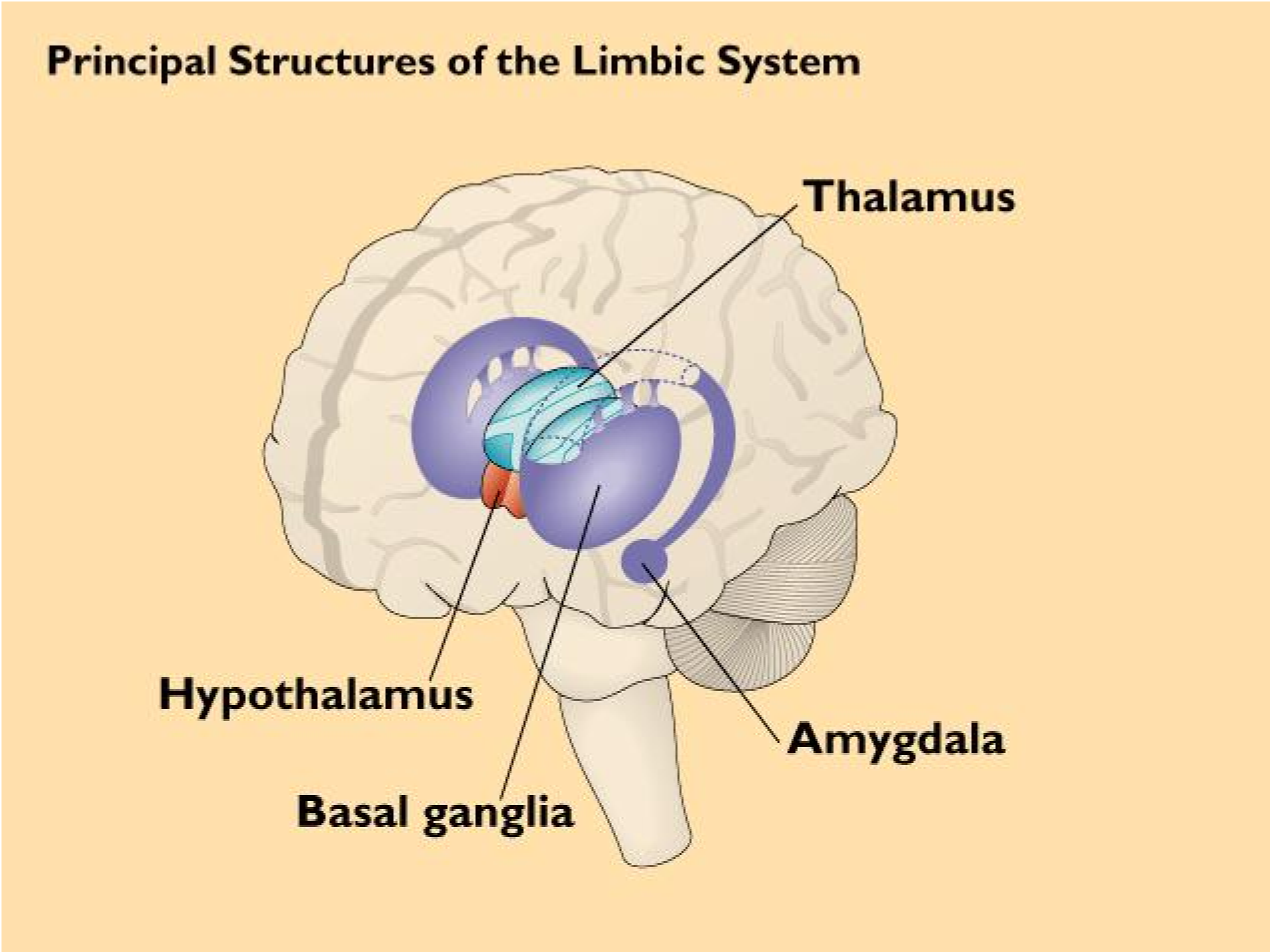


Brain's Main Structures

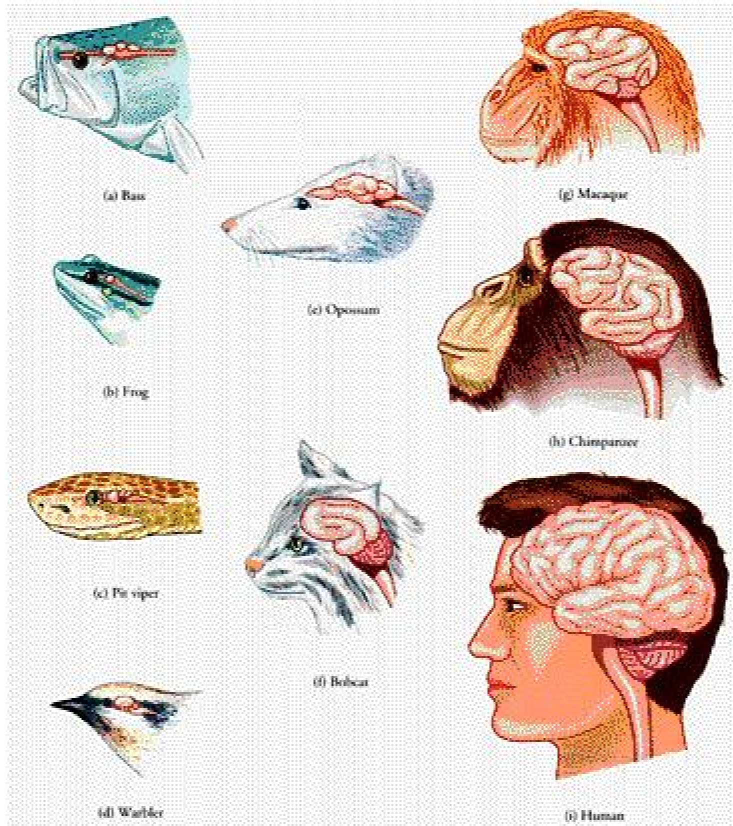


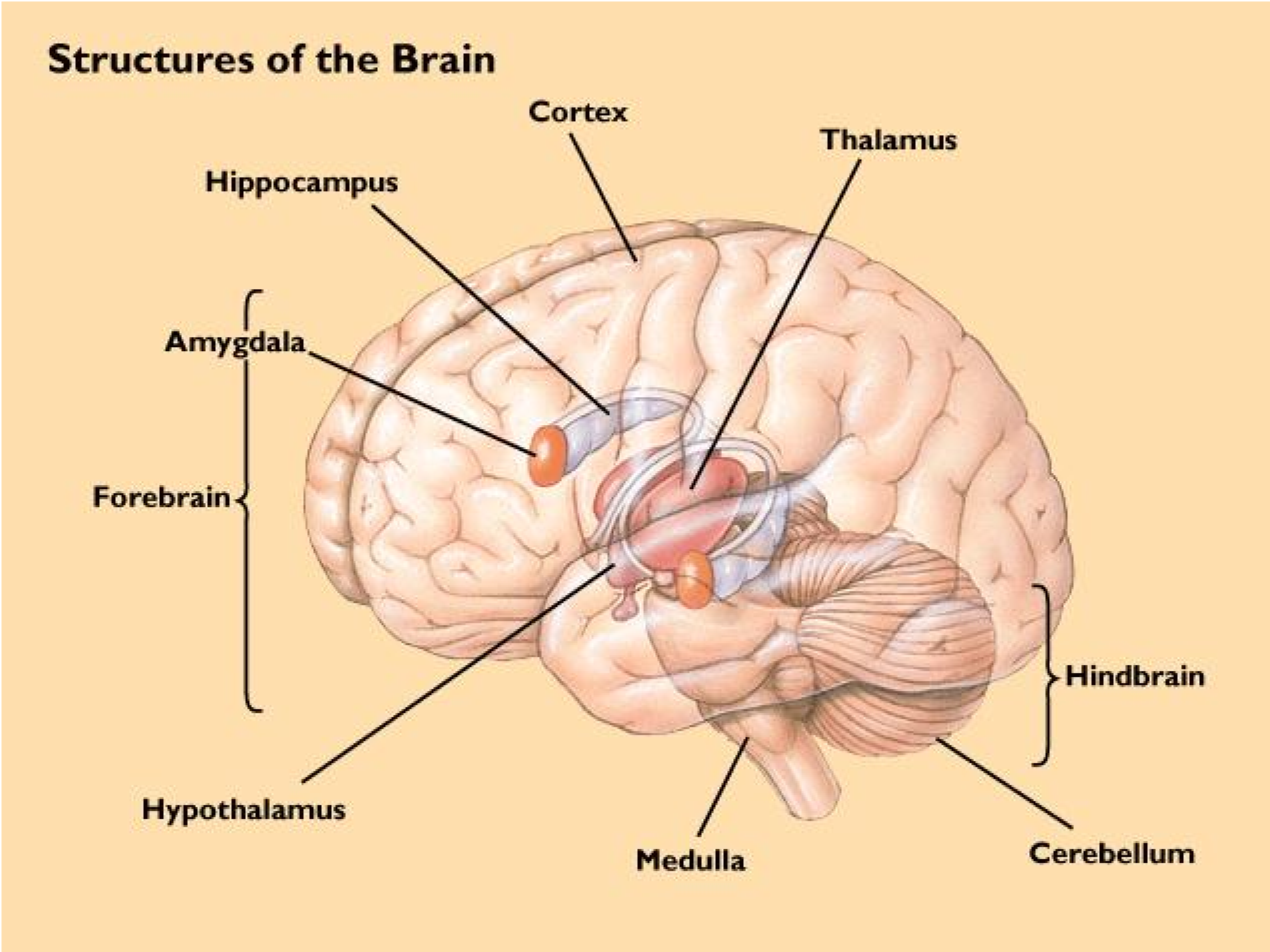
The Human Brain: Major Areas

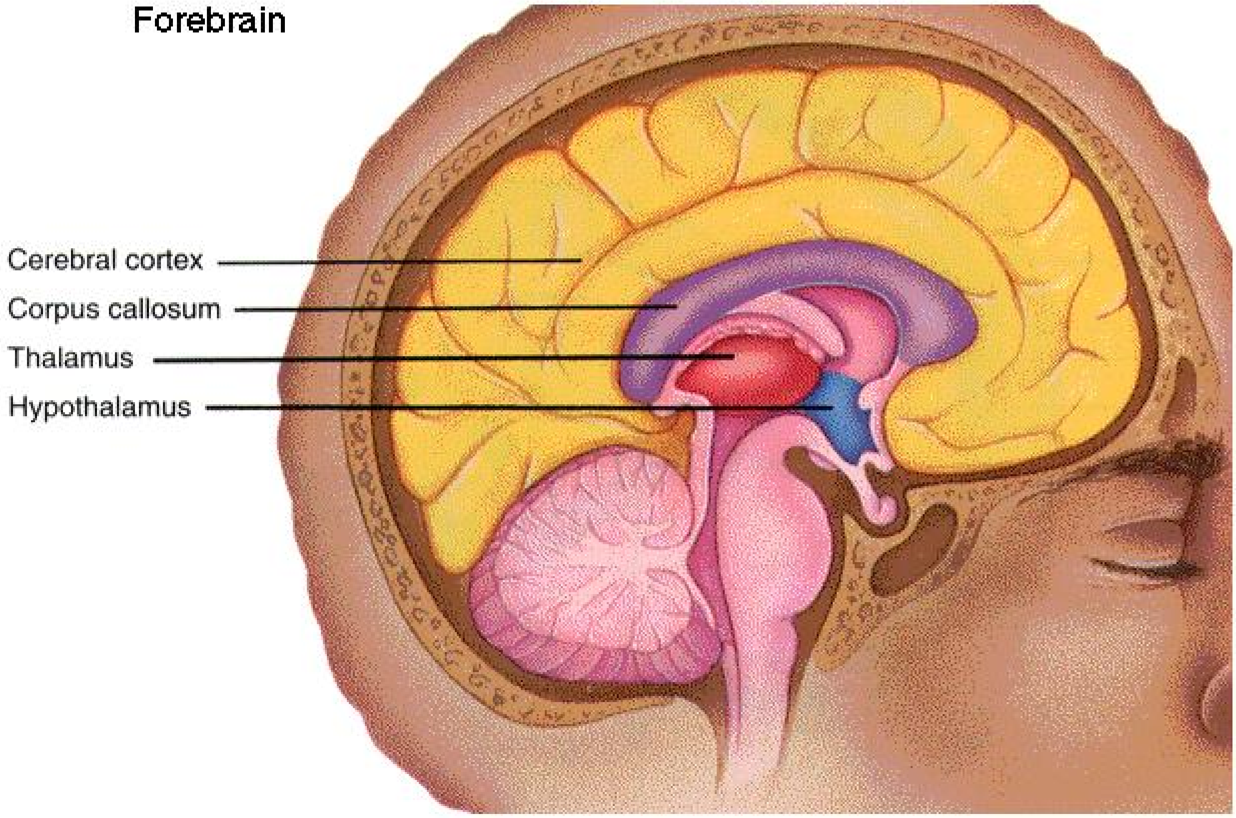



Principal Structures of the Limbic System
Thalamus
Hypothalamus
Amygdala
Basal ganglia

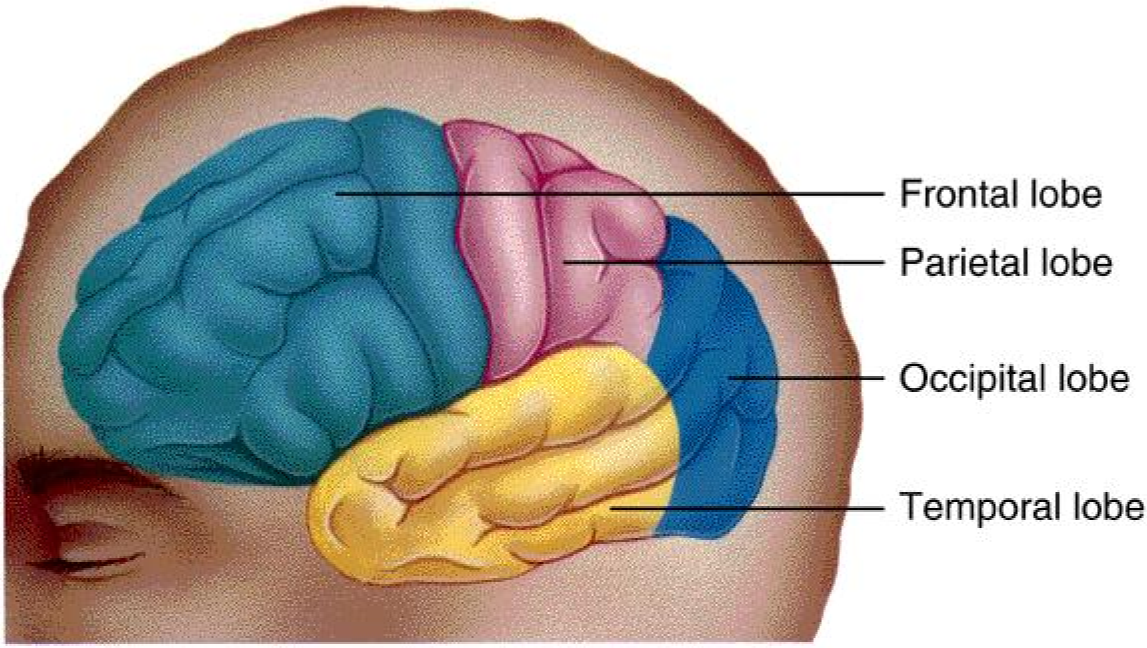
The Evolution of the Cerebrum*



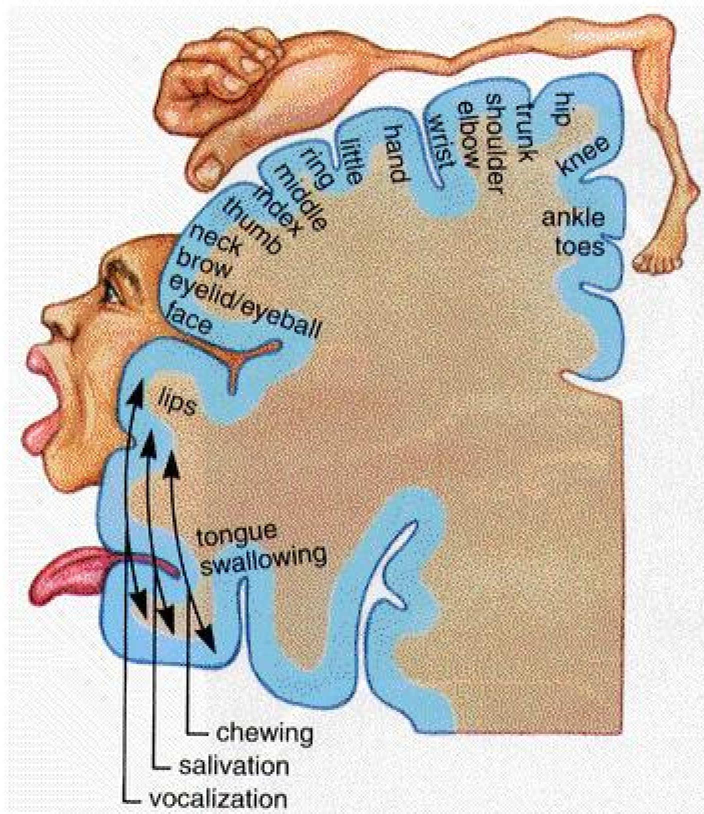

Structures of the Brain
Cortex
Thalamus
Hippocampus
Amygdala
Forebrain
Hindbrain
Hypothalamus
Medulla
Cerebellum


Forebrain
Cerebral cortex
Corpus callosum
Thalamus
Hypothalamus

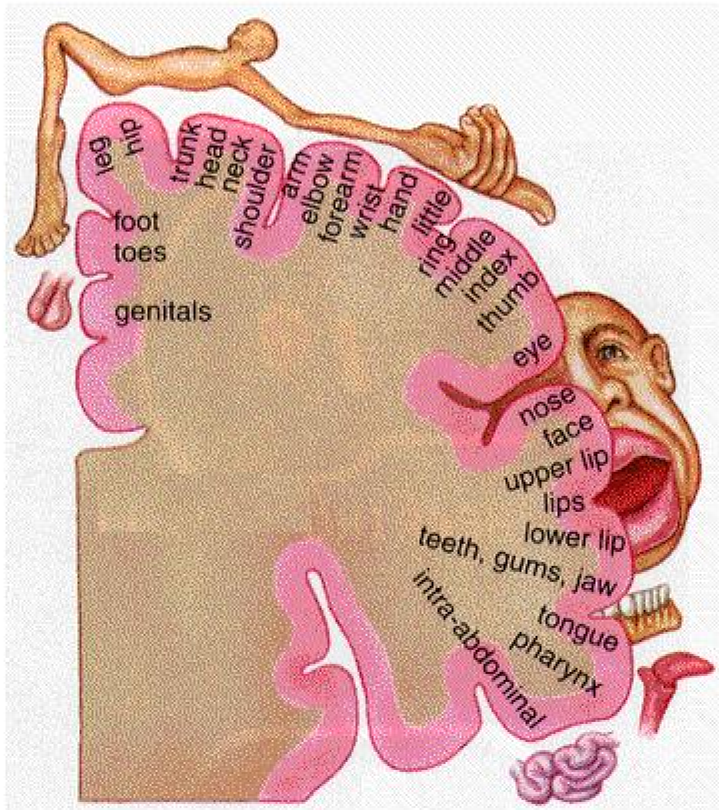
Four Lobes of the Cerebral Cortex



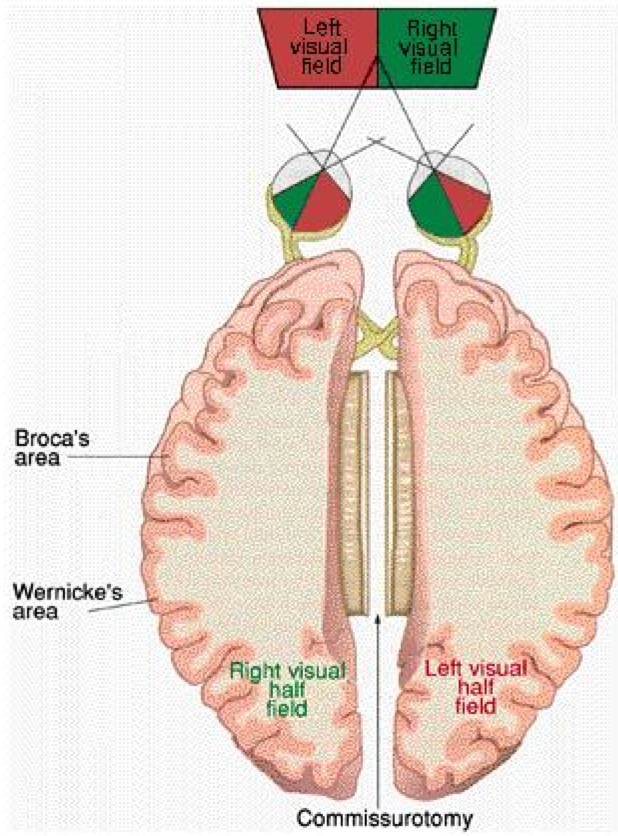
Motor Area


hip
trunk
shoulder
elbow
wrist
hand
little
ring
middle
index
thumb
neck
brow
eyelid/eyeball
face
knee
ankle
toes
lips
tongue
swallowing
chewing
salivation
vocalization

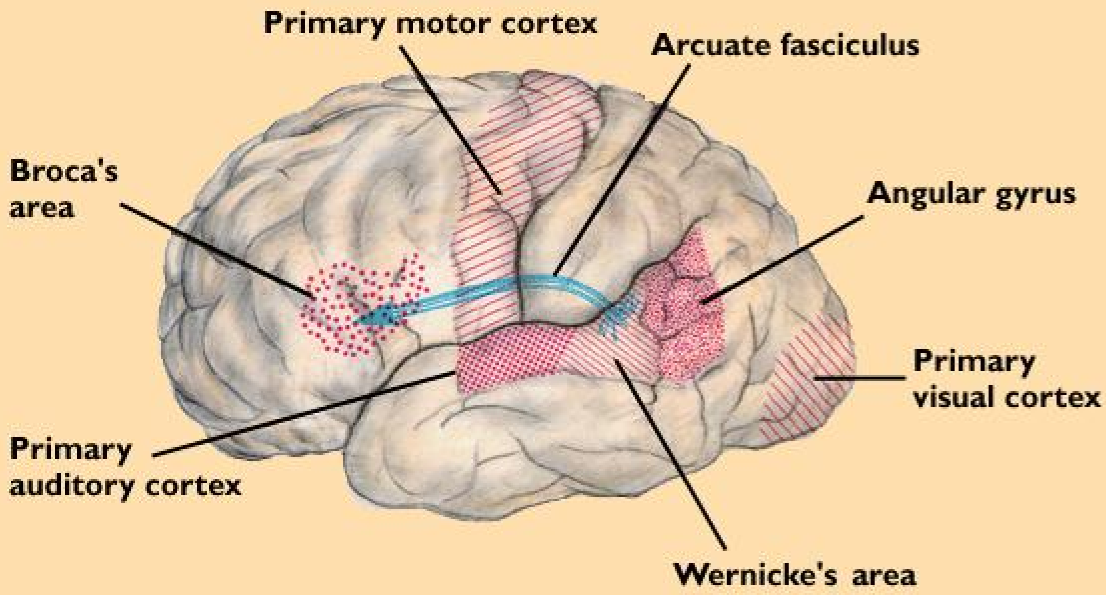
Sensory Area

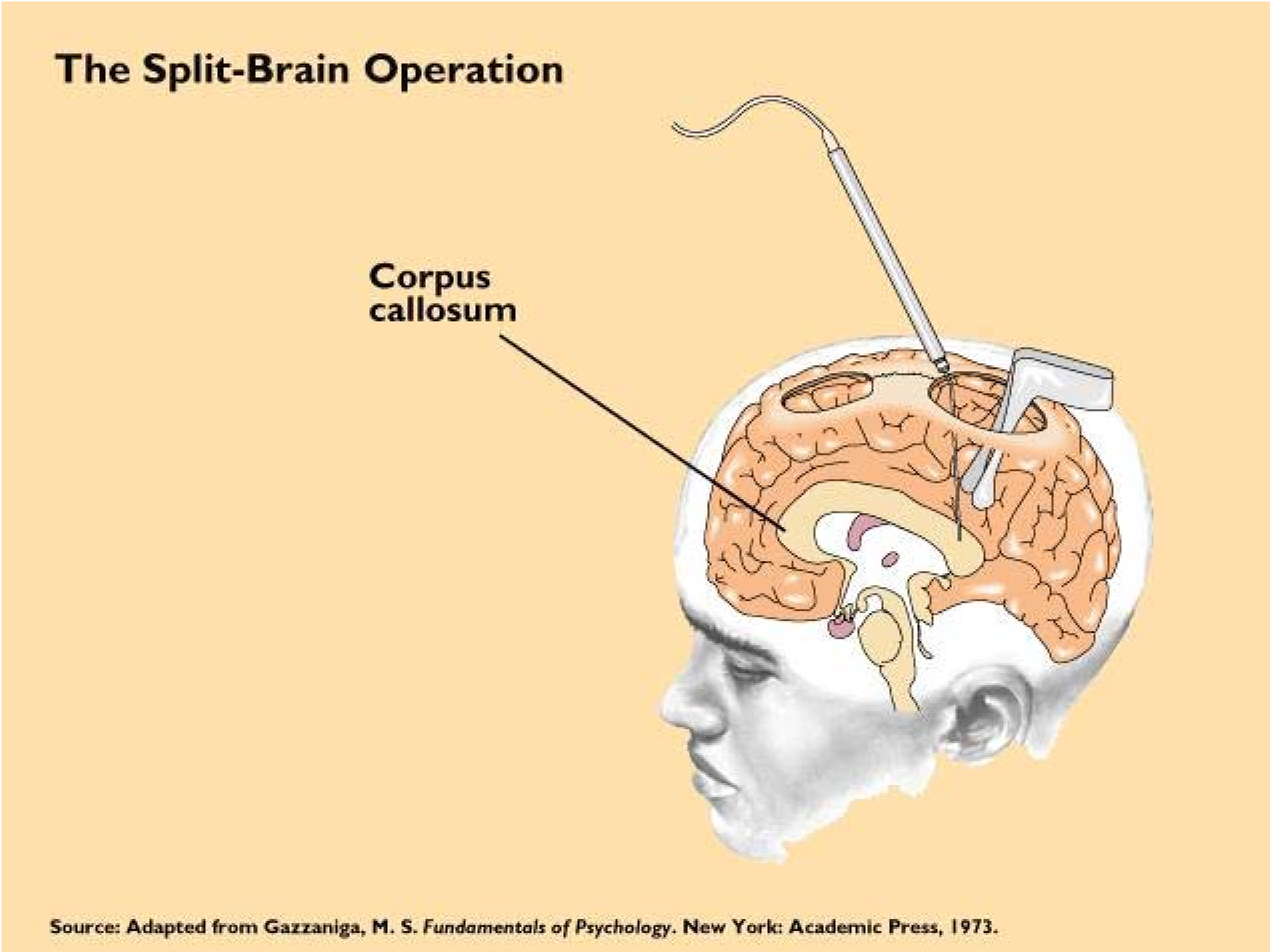


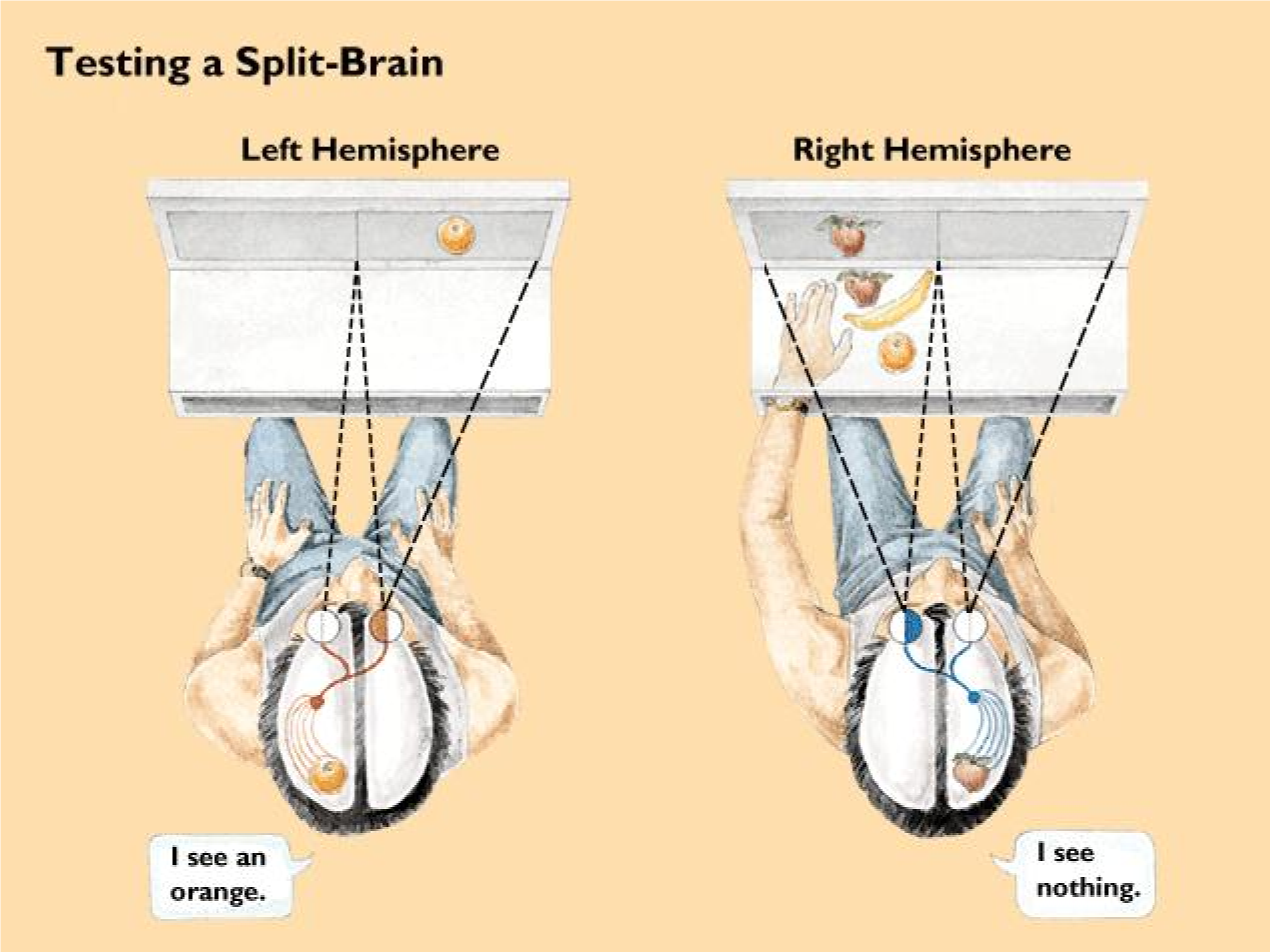
The Two Cerebral Hemispheres



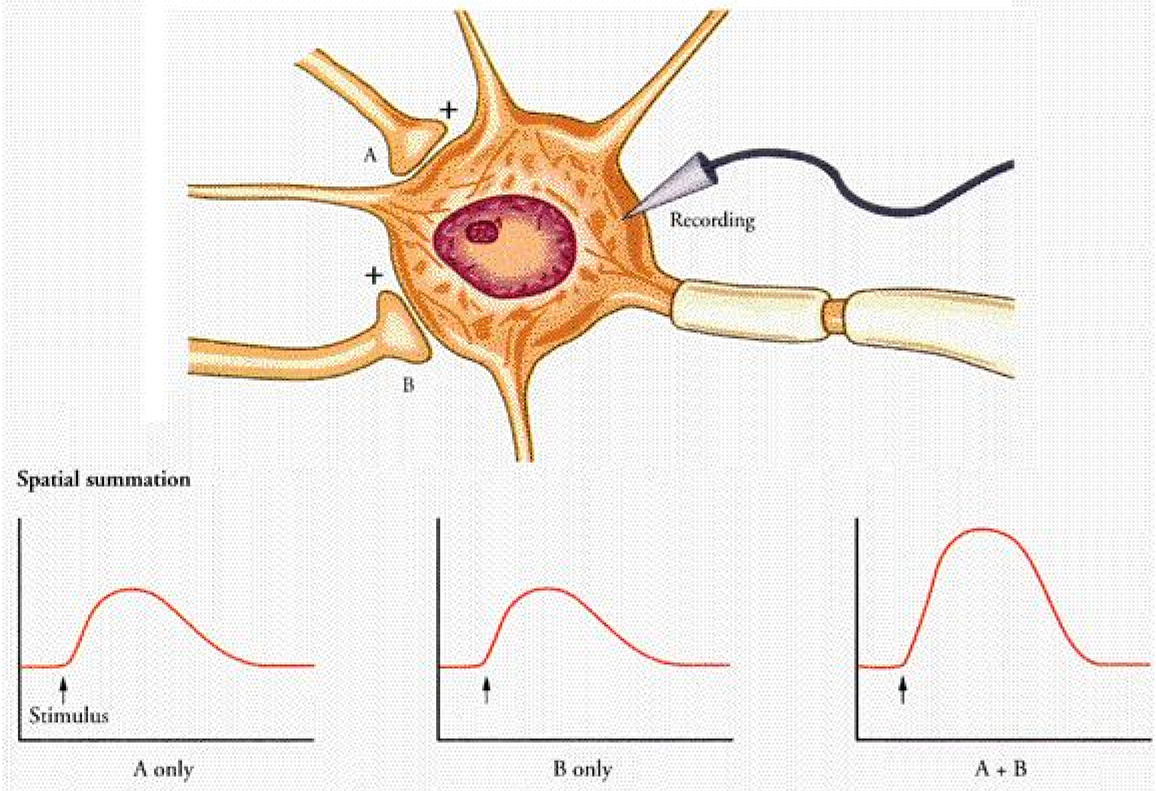
Seven Components of the Wernicke-Geschwind Model



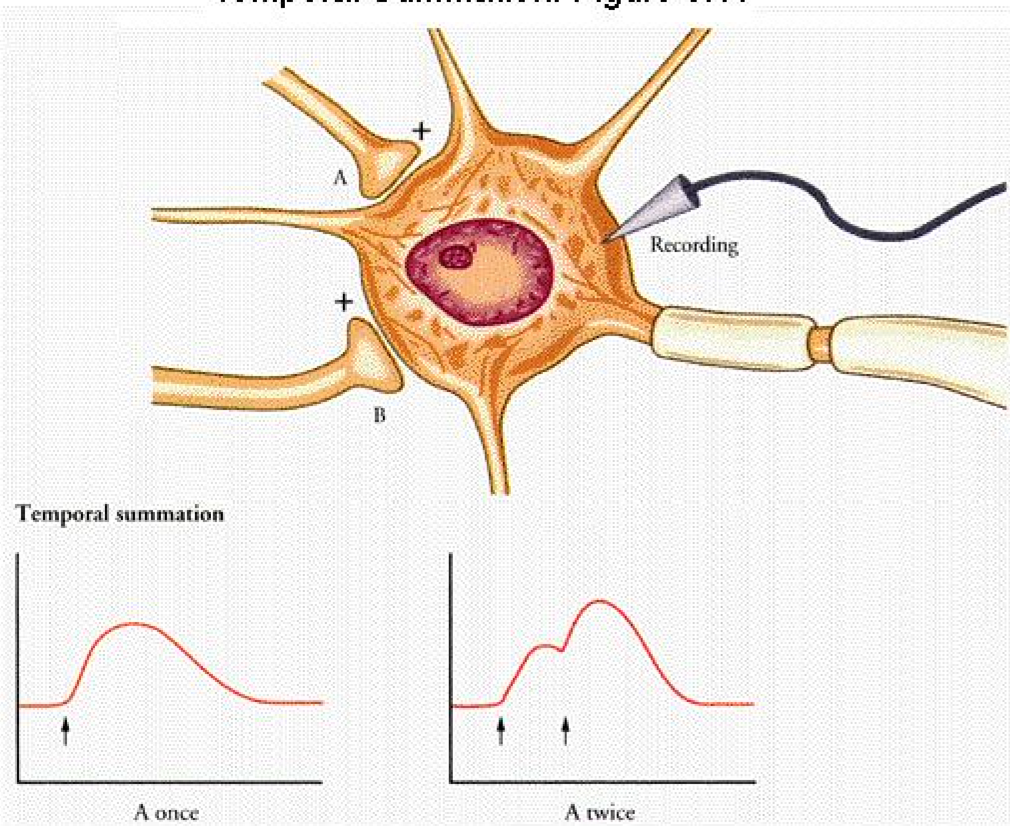

The Split-Brain Operation
Corpus
callosum
Source: Adapted from Gazzaniga, M. S. *Fundamentals of Psychology*. New York: Academic Press, 1973.

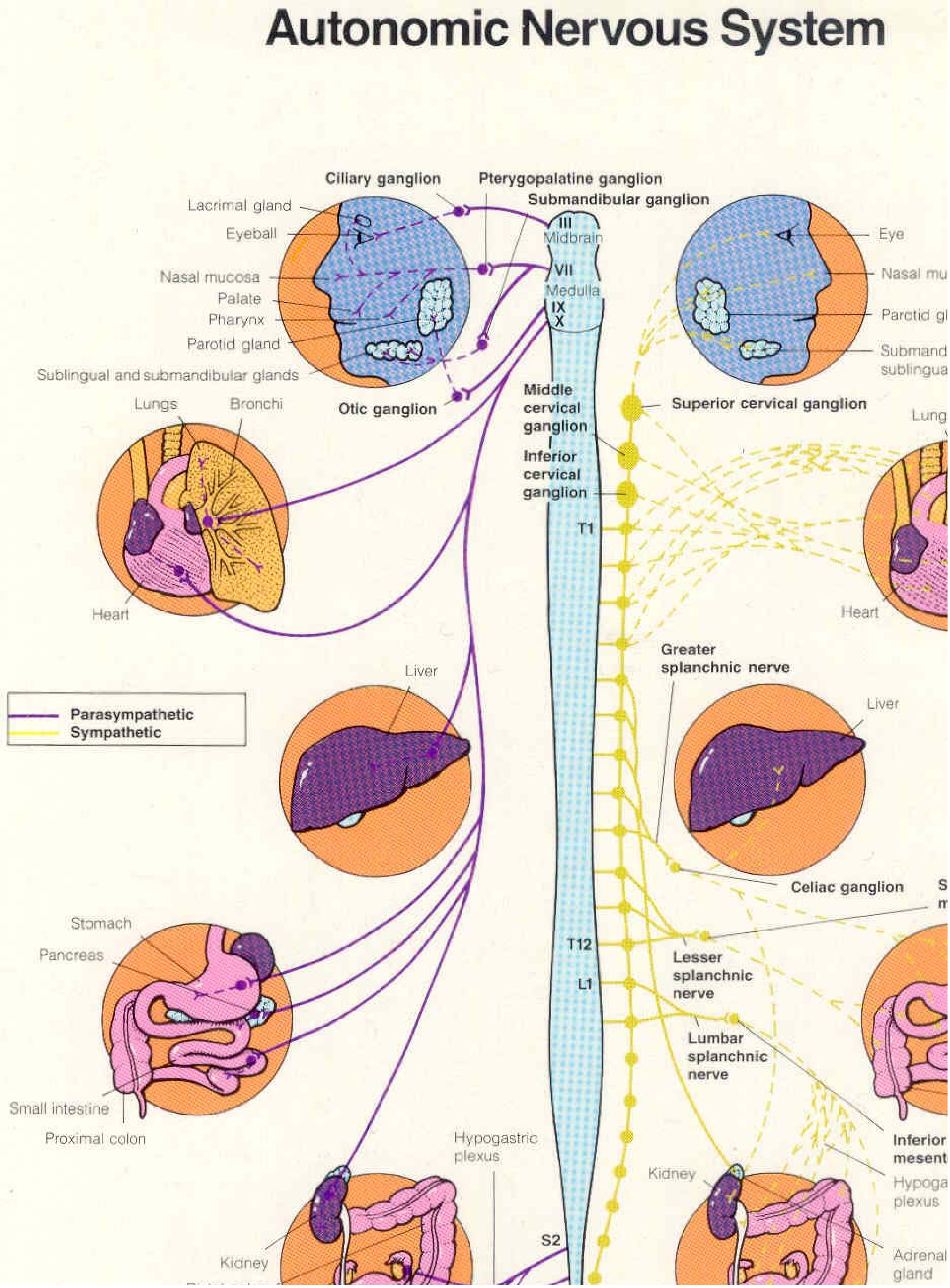

Testing a Split-Brain
Left Hemisphere
Right Hemisphere
I see an orange.
I see nothing.

Spatial Summation. Figure 5.11



Temporal Summation. Figure 5.11




Autonomic Nervous System
Ciliary ganglion
Pterygopalatine ganglion
Submandibular ganglion
Lacrimal gland
Eyeball
Nasal mucosa
Palate
Pharynx
Parotid gland
Sublingual and submandibular glands
III
Midbrain
VII
Medulla
IX
X
Otic ganglion
Lungs
Bronchi
Heart
Middle cervical ganglion
Inferior cervical ganglion
Superior cervical ganglion
T1
Eye
Liver
Parasympathetic
Sympathetic
Greater splanchnic nerve
Celiac ganglion
Stomach
Pancreas
Small intestine
Proximal colon
T12
L1
Lesser splanchnic nerve
Lumbar splanchnic nerve
Hypogastric plexus
Kidney
S2
Adrenal gland