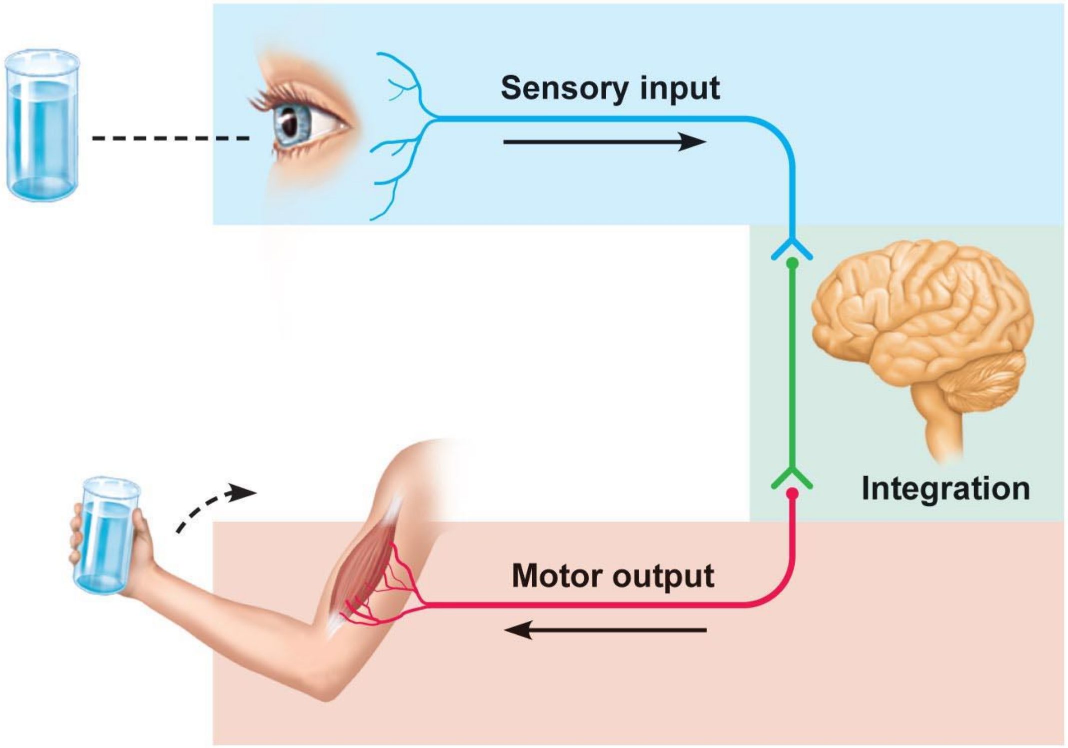
The Nervous System

Nervous System

- Master controlling and communicating system

Basic Functions

1. Sensory input – gather information
2. Integration – process and interpret sensory input
3. Motor output – response by muscles and glands



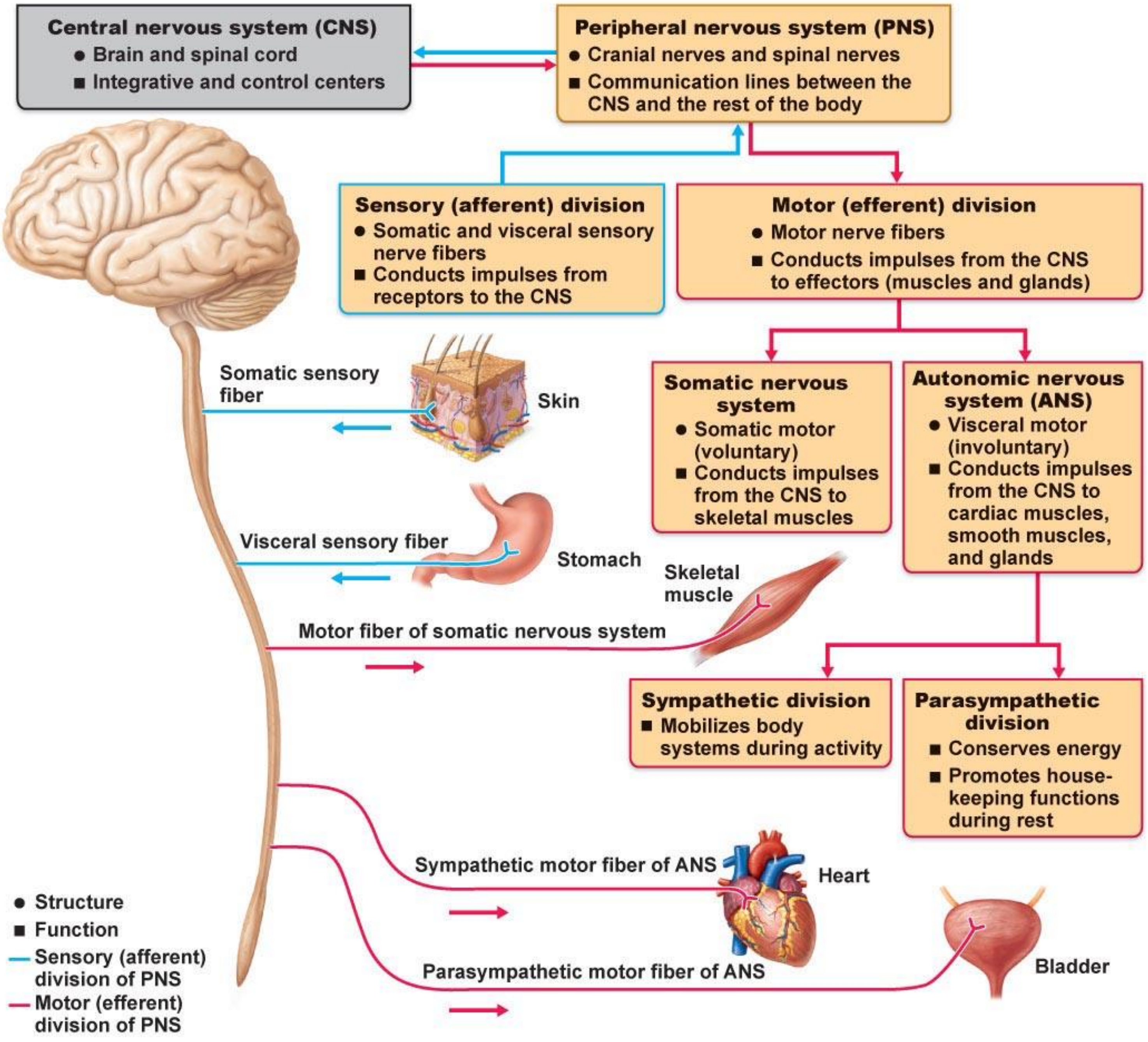
Organization

A. Central Nervous System (CNS)
   - Brain & spinal cord
   - Integrative and control centers

B. Peripheral Nervous System (PNS)
   - Nerves (spinal nerves, cranial nerves)
   - Communication lines between CNS and rest of body
   - Two Divisions:
     1. Sensory (afferent) Division: Sensory receptors → CNS
     2. Motor (efferent) Division: CNS → effectors (muscles & glands)

Motor Division

- <u>Somatic nervous system</u> (*voluntary*) – control skeletal muscles
- <u>Autonomic nervous system</u> (ANS) (*involuntary*) – regulate smooth muscles, cardiac, glands
  - <u>Subdivisions</u>: sympathetic & parasympathetic

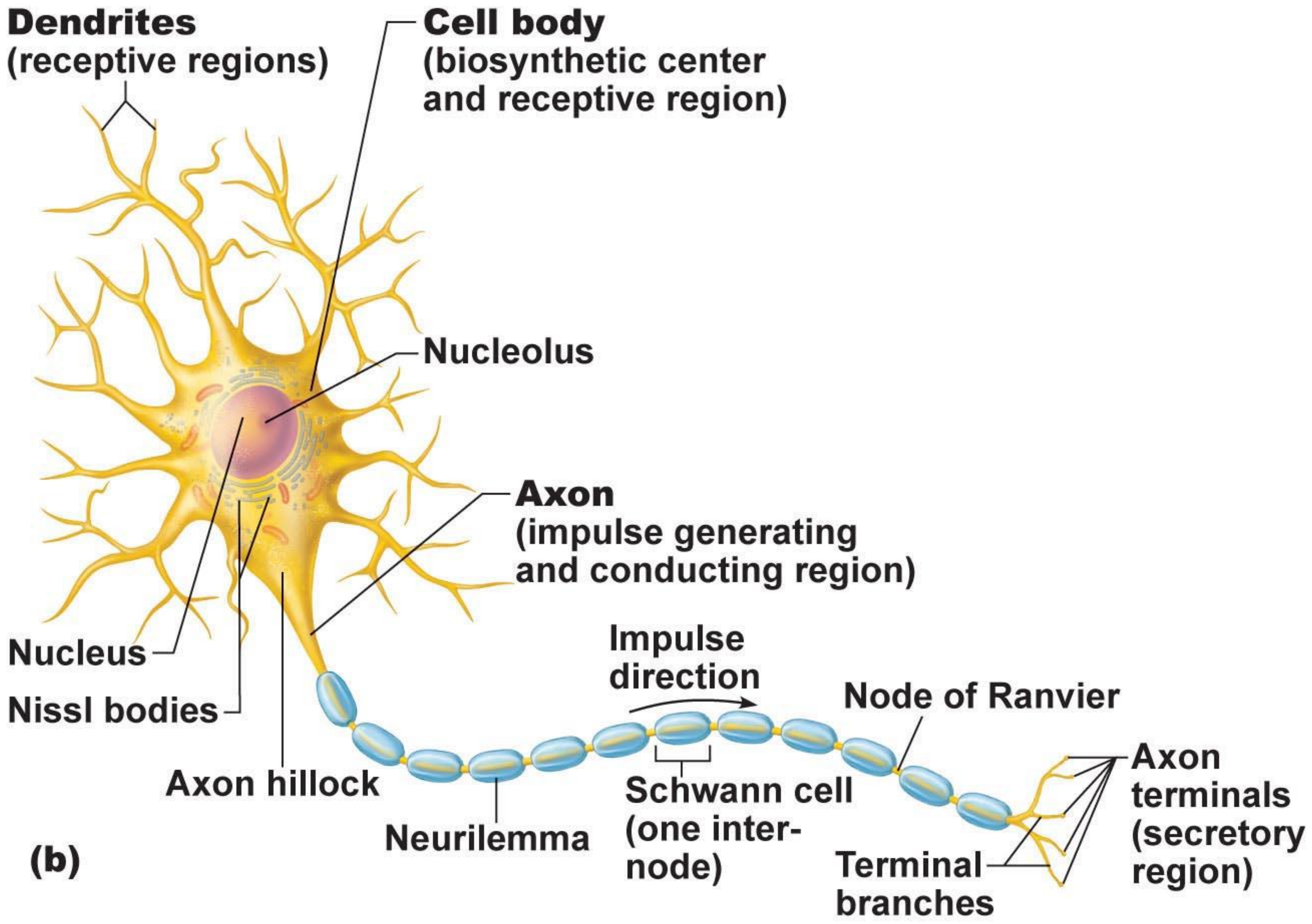

Central nervous system (CNS)
● Brain and spinal cord
■ Integrative and control centers
Peripheral nervous system (PNS)
● Cranial nerves and spinal nerves
■ Communication lines between the CNS and the rest of the body
Sensory (afferent) division
● Somatic and visceral sensory nerve fibers
■ Conducts impulses from receptors to the CNS
Motor (efferent) division
● Motor nerve fibers
■ Conducts impulses from the CNS to effectors (muscles and glands)
Somatic nervous system
● Somatic motor (voluntary)
■ Conducts impulses from the CNS to skeletal muscles
Autonomic nervous system (ANS)
● Visceral motor (involuntary)
■ Conducts impulses from the CNS to cardiac muscles, smooth muscles, and glands
Sympathetic division
■ Mobilizes body systems during activity
Parasympathetic division
■ Conserves energy
■ Promotes house-keeping functions during rest
Somatic sensory fiber
Skin
Visceral sensory fiber
Stomach
Skeletal muscle
Motor fiber of somatic nervous system
Sympathetic motor fiber of ANS
Heart
Parasympathetic motor fiber of ANS
Bladder
● Structure
■ Function
Sensory (afferent) division of PNS
Motor (efferent) division of PNS

Nervous Tissue

1. **Neurons** (nerve cells) - transmit message

Anatomy:

- Cell body – contains nucleus; metabolic center
- Dendrite – fiber that conveys messages ***toward*** cell body
- Axon – conduct nerve impulses ***away*** from the cell body
- Axon terminals – end of axon; contain neurotransmitters & release them
- Synaptic cleft/synapse – gap between neurons


Dendrites
(receptive regions)
Cell body
(biosynthetic center
and receptive region)
Nucleolus
Axon
(impulse generating
and conducting region)
Nucleus
Nissl bodies
Axon hillock
Impulse
direction
Node of Ranvier
Axon
terminals
(secretory
region)
Neurilemma
Schwann cell
(one inter-
node)
Terminal
branches
(b)

Nervous Tissue

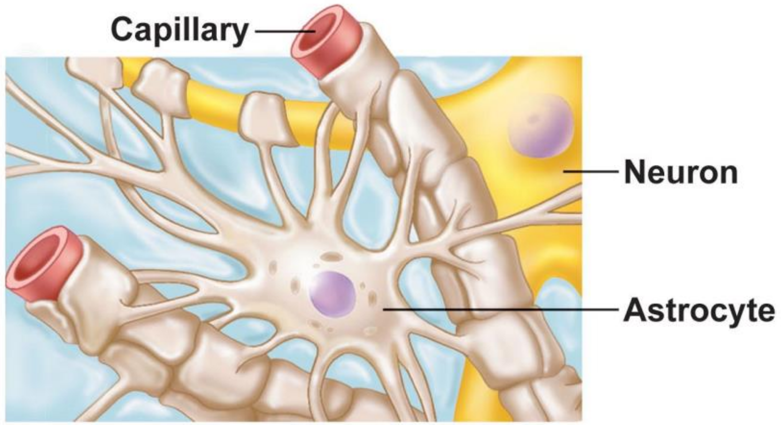
2. Supporting cells (**Neuroglia**)

CNS: astrocytes, microglia, ependymal cells, oligodendrocytes

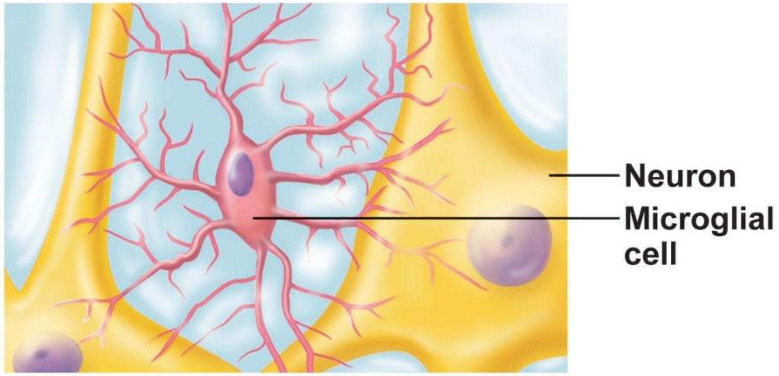
- barrier between capillaries and neurons
- protect neurons
- immune/defense
- line brain and spinal cord cavities
- wrap nerve fibers
- produces myelin sheaths (covering)

PNS: Schwann cells, satellite cells

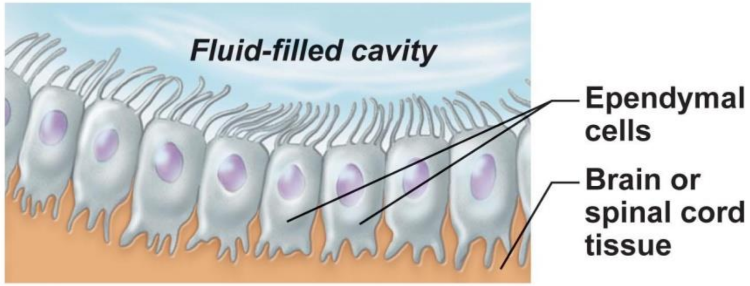
- surround large neurons
- protect & cushion



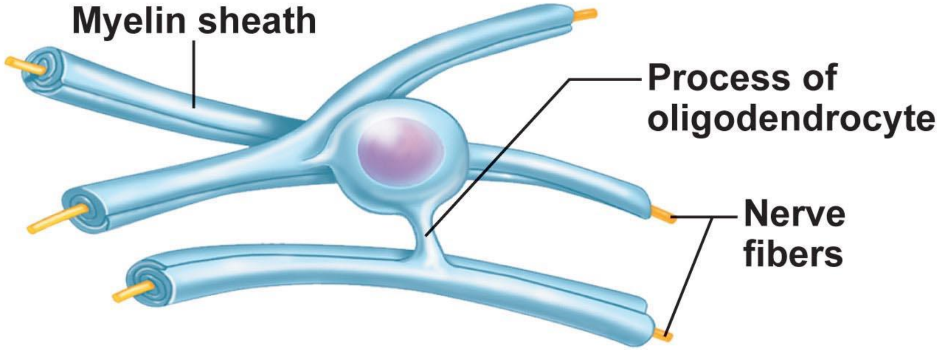
(a) Astrocytes are the most abundant CNS neuroglia.



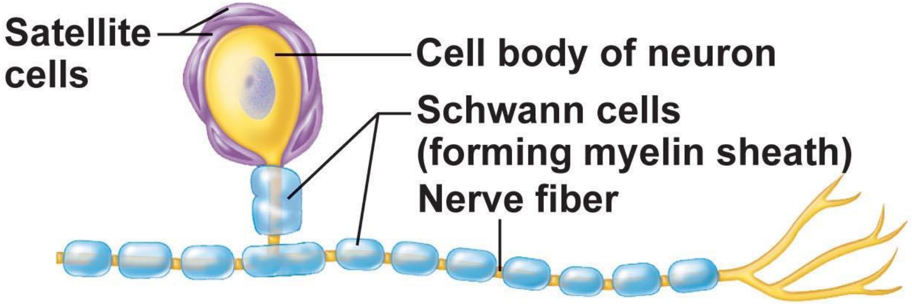
(b) Microglial cells are defensive cells in the CNS.



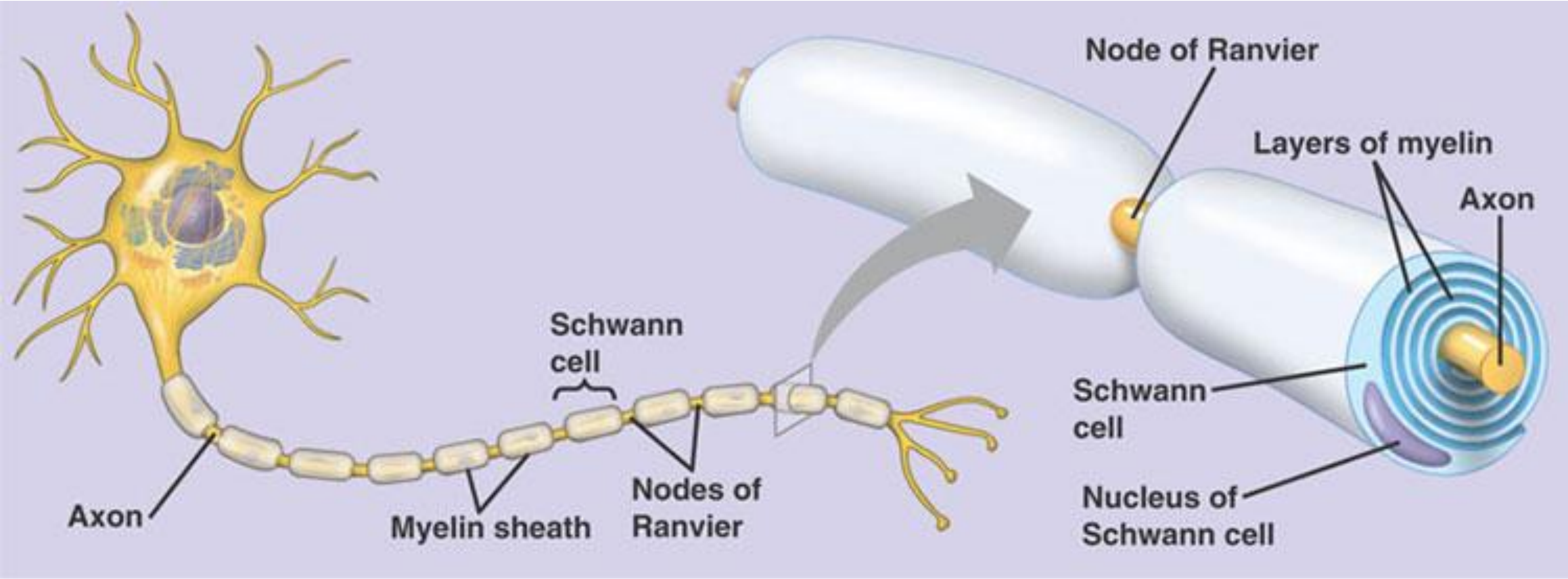
(c) Ependymal cells line cerebrospinal fluid–filled cavities.



(d) Oligodendrocytes have processes that form myelin sheaths around CNS nerve fibers.

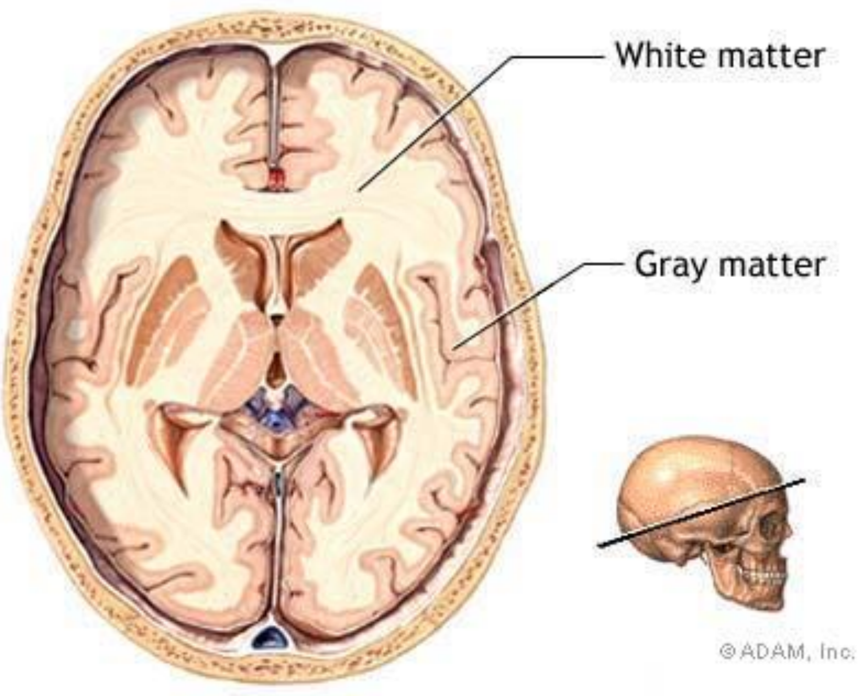


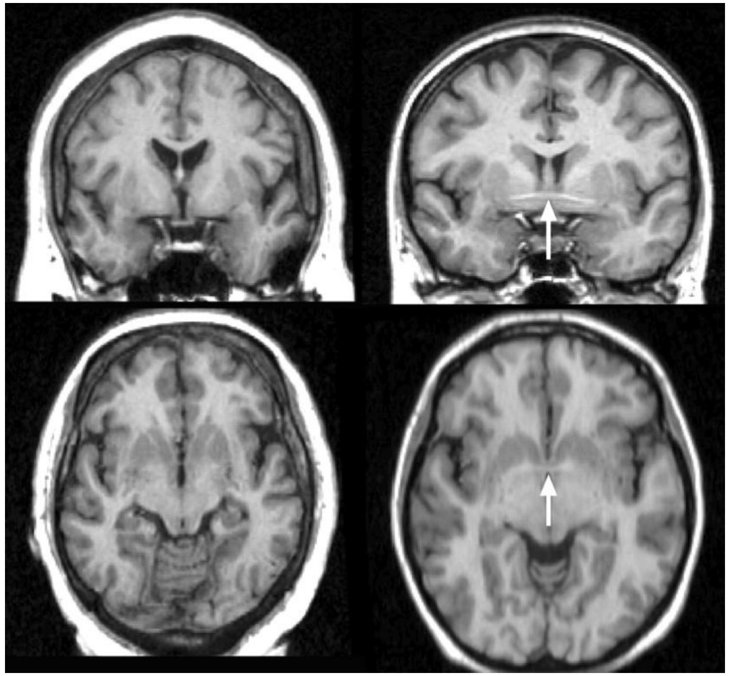
(e) Satellite cells and Schwann cells (which form myelin) surround neurons in the PNS.



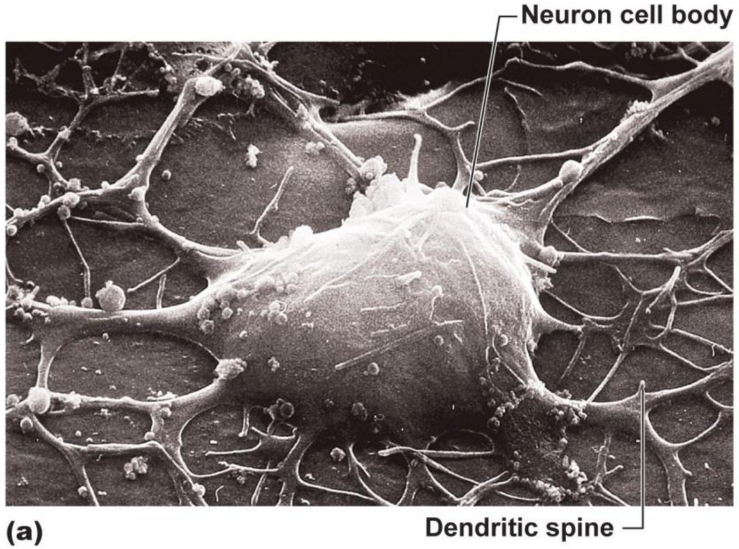
- Myelin: whitish, fatty material that covers nerve fibers to speed up nerve impulses
- Schwann cells: surround axons and form myelin sheath
- Myelin sheath: tight coil of wrapped membranes
- Nodes of Ranvier: gaps between Schwann cells

- Ganglia: collections of cell bodies
- Bundles of nerve fibers = tracts (CNS) or nerves (PNS)
- White matter: dense collections of myelinated fibers
- Gray matter: unmyelinated fibers & cell bodies





It’s a Mad, Mad, Mad Neuron



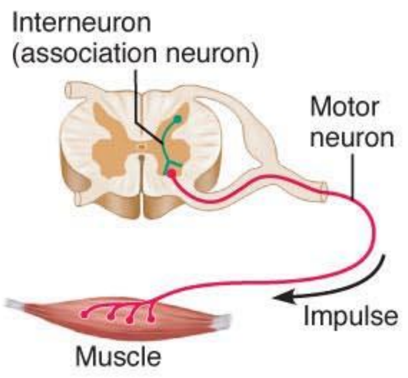
Classification of Neurons

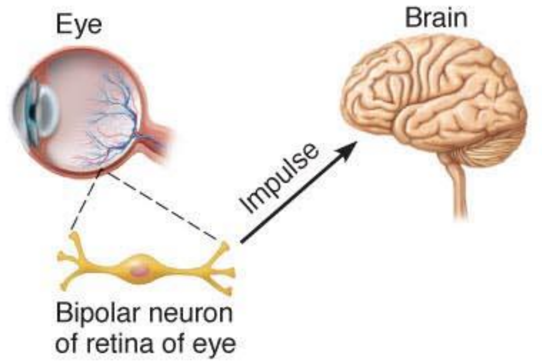
1. **Functional Classification**: direction nerve impulse is traveling

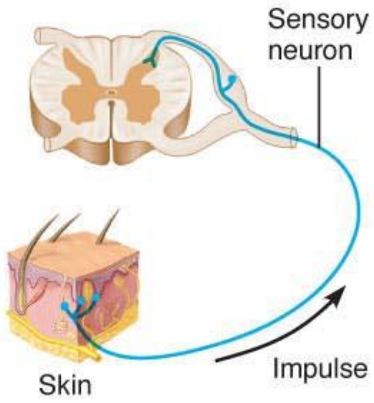
Sensory neurons	Motor neurons	Interneurons
carry impulses from sensory receptors to CNS	carry impulses from CNS to muscles & glands	connect sensory & motor neurons
Vision, hearing, equilibrium, taste, smell, pain, pressure, heat		

TABLE 11.1 Comparison of Structural Classes of Neurons *(continued)*

NEURON TYPE		
MULTIPOLAR	**BIPOLAR**	**UNIPOLAR (PSEUDOUNIPOLAR)**
Functional Class: Neuron Type According to Direction of Impulse Conduction		
1. Most multipolar neurons are **interneurons (association neurons)** that conduct impulses within the CNS, integrating sensory input or motor output; may be one of a chain of CNS neurons, or a single neuron connecting sensory and motor neurons. **2.** Some multipolar neurons are **motor neurons** that conduct impulses along the efferent pathways from the CNS to an effector (muscle/gland).	Essentially all bipolar neurons are **sensory neurons** that are located in some special sense organs. For example, bipolar cells of the retina are involved with the transmission of visual inputs from the eye to the brain (via an intermediate chain of neurons).	Most unipolar neurons are **sensory neurons** that conduct impulses along afferent pathways to the CNS for interpretation. (These sensory neurons are called primary or first-order sensory neurons.)



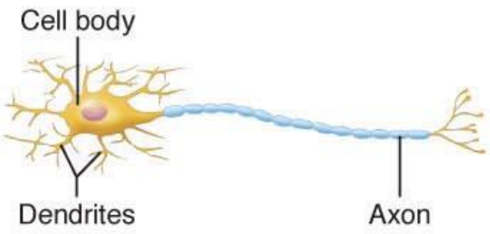
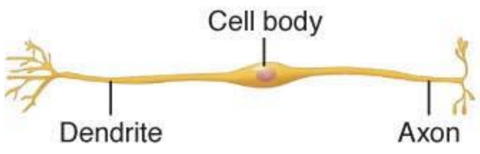
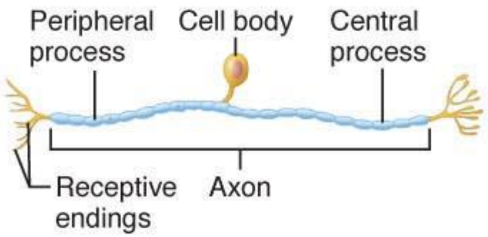
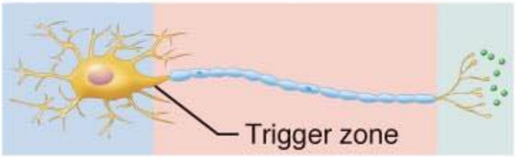
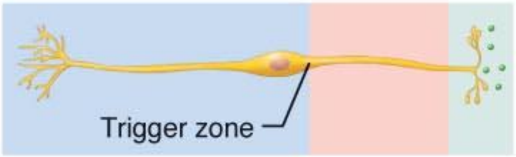
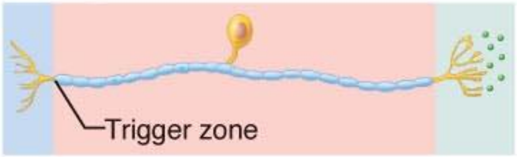




2. **Structural Classification**: # processes extending from cell body

Multipolar	Bipolar	Unipolar
1 axon, several dendrites	1 axon, 1 dendrite	1 process
Most common (99%)	Rare	Short with 2 branches (sensory, CNS)
Eg. Motor neurons, interneurons	Eg. retina, nose, ear	Eg. PNS ganglia

TABLE 11.1 Comparison of Structural Classes of Neurons

NEURON TYPE		
MULTIPOLAR	**BIPOLAR**	**UNIPOLAR (PSEUDOUNIPOLAR)**
Structural Class: Neuron Type According to the Number of Processes Extending from the Cell Body		
Many processes extend from the cell body; all are dendrites except for a single axon.	Two processes extend from the cell body: One is a fused dendrite, the other is an axon.	One process extends from the cell body and forms central and peripheral processes, which together comprise an axon.
		
Relationship of Anatomy to the Three Functional Regions		
Receptive region (receives stimulus). Plasma membrane exhibits chemically gated ion channels.	Conducting region (generates/transmits action potential). Plasma membrane exhibits voltage-gated Na^+ and K^+ channels.	Secretory region (axon terminals release neurotransmitters). Plasma membrane exhibits voltage-gated Ca^+ channels.
		
	(Many bipolar neurons do not generate action potentials and, in those that do, the location of the trigger zone is not universal.)	

Nerve Impulses

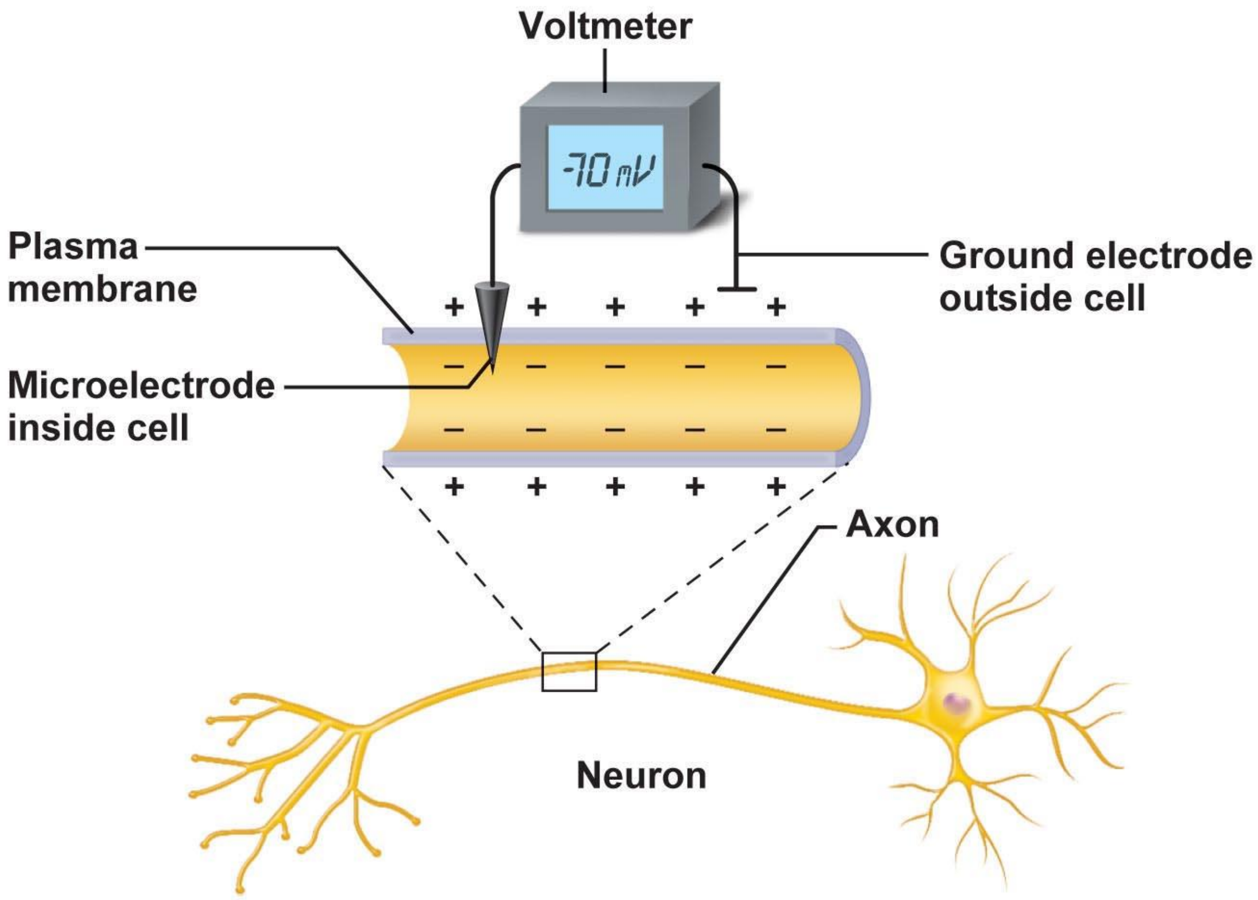
Neuron Function

1. Irritability: ability to respond to stimulus & convert to nerve impulse
2. Conductivity: transmit impulse to other neurons, muscles, or glands

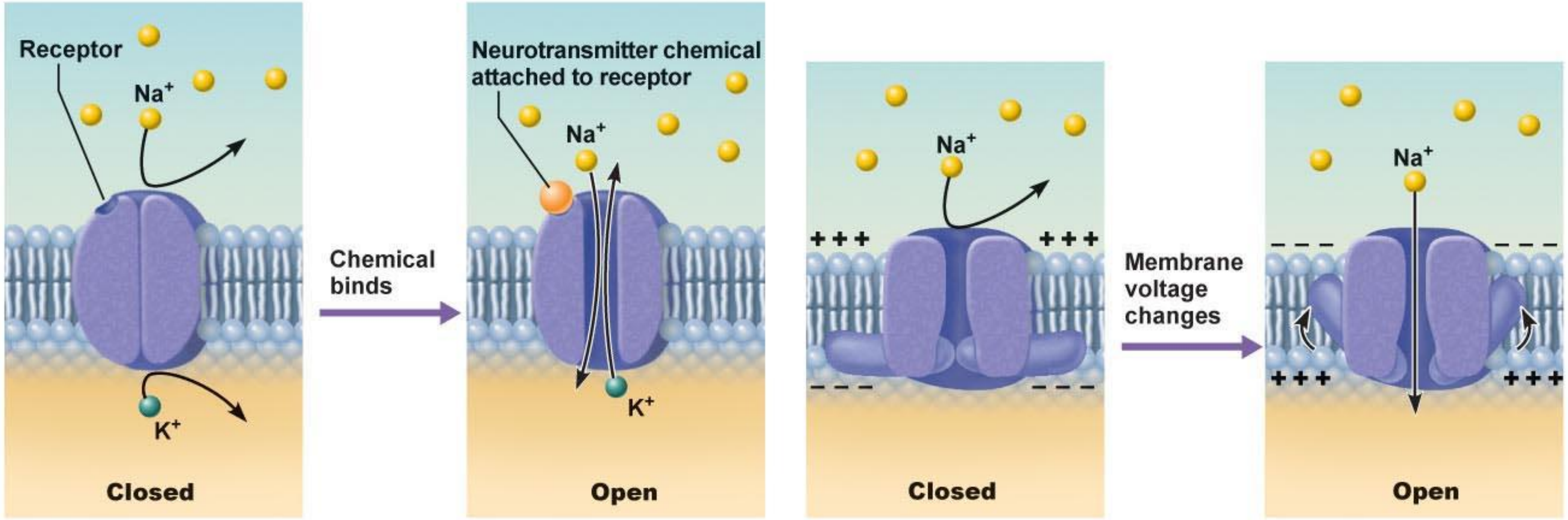
Exciting a Neuron:

- Cell membrane at rest = polarized
  - Na^+ outside cell, K^+ inside cell
  - Inside is (-) compared to outside
- Stimulus → excited neuron (Na^+ rushes in) → becomes depolarized
- Depolarization activates neuron to transmit an action potential (nerve impulse)
  - All-or-none response
  - Impulse conducts down <u>entire</u> axon
- K+ diffuses out → repolarization of membrane
- Na+/K+ ion concentrations restored by sodium-potassium pump (uses ATP)

Resting membrane potential (-70mV)



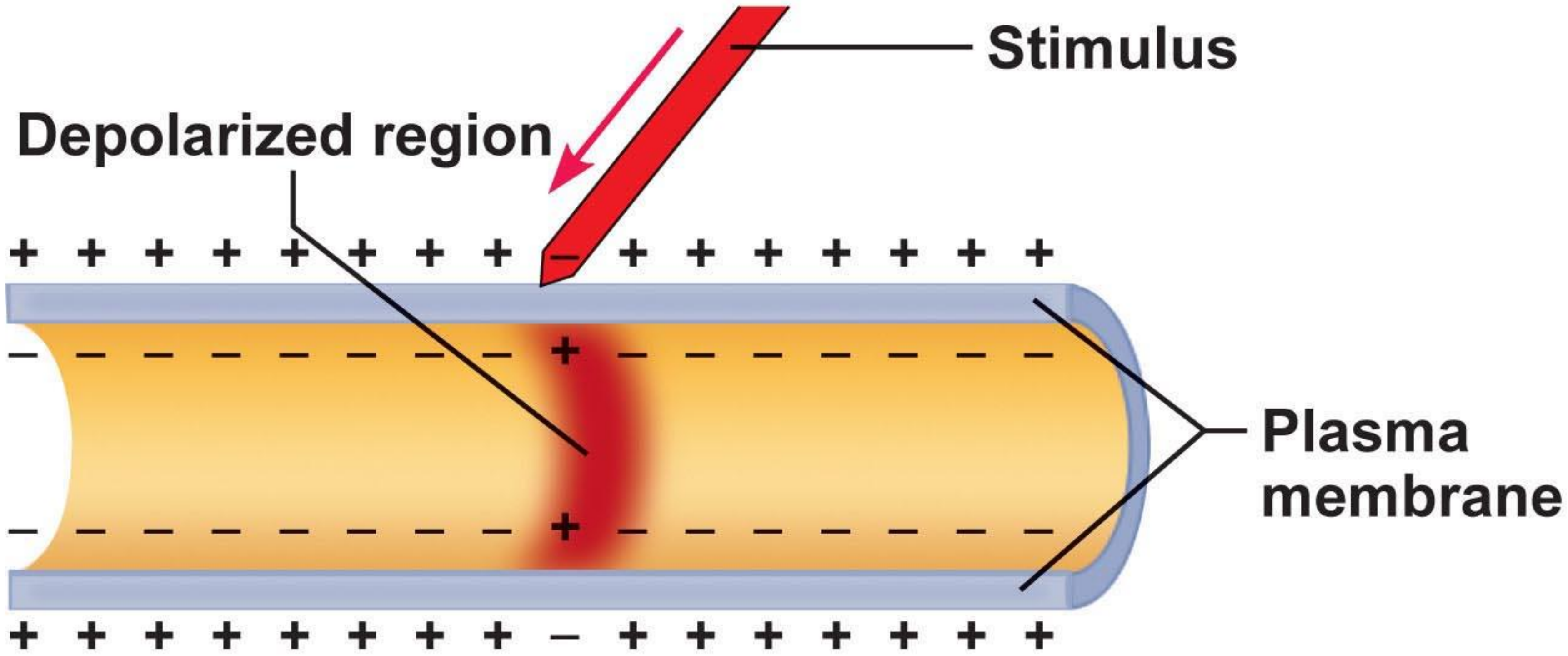
Gated Ion Channels (Na^+ and K^+)



(a) Chemically (ligand) gated ion channels open when the appropriate neurotransmitter binds to the receptor, allowing (in this case) simultaneous movement of Na^+ and K^+.

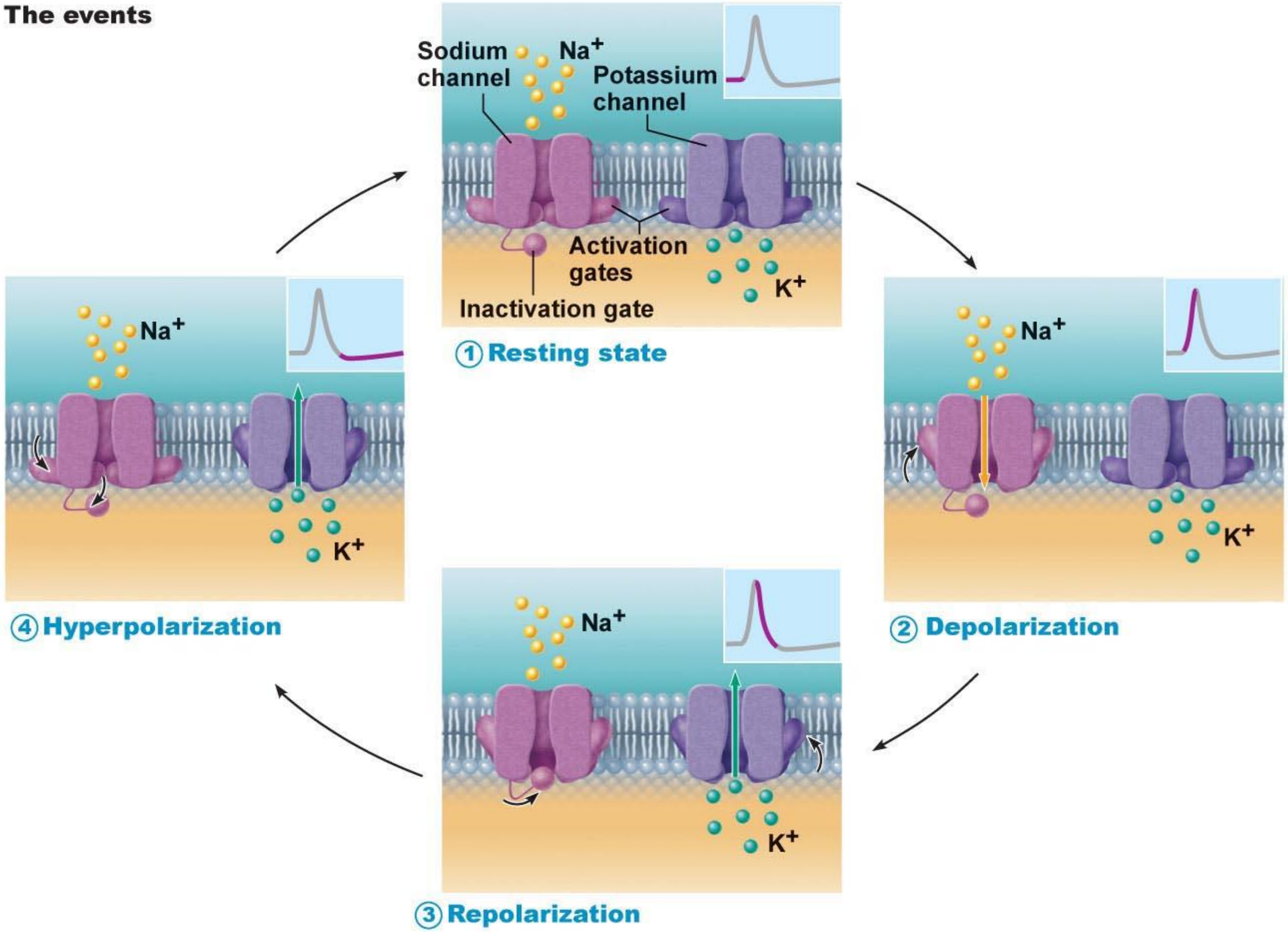
(b) Voltage-gated ion channels open and close in response to changes in membrane voltage.

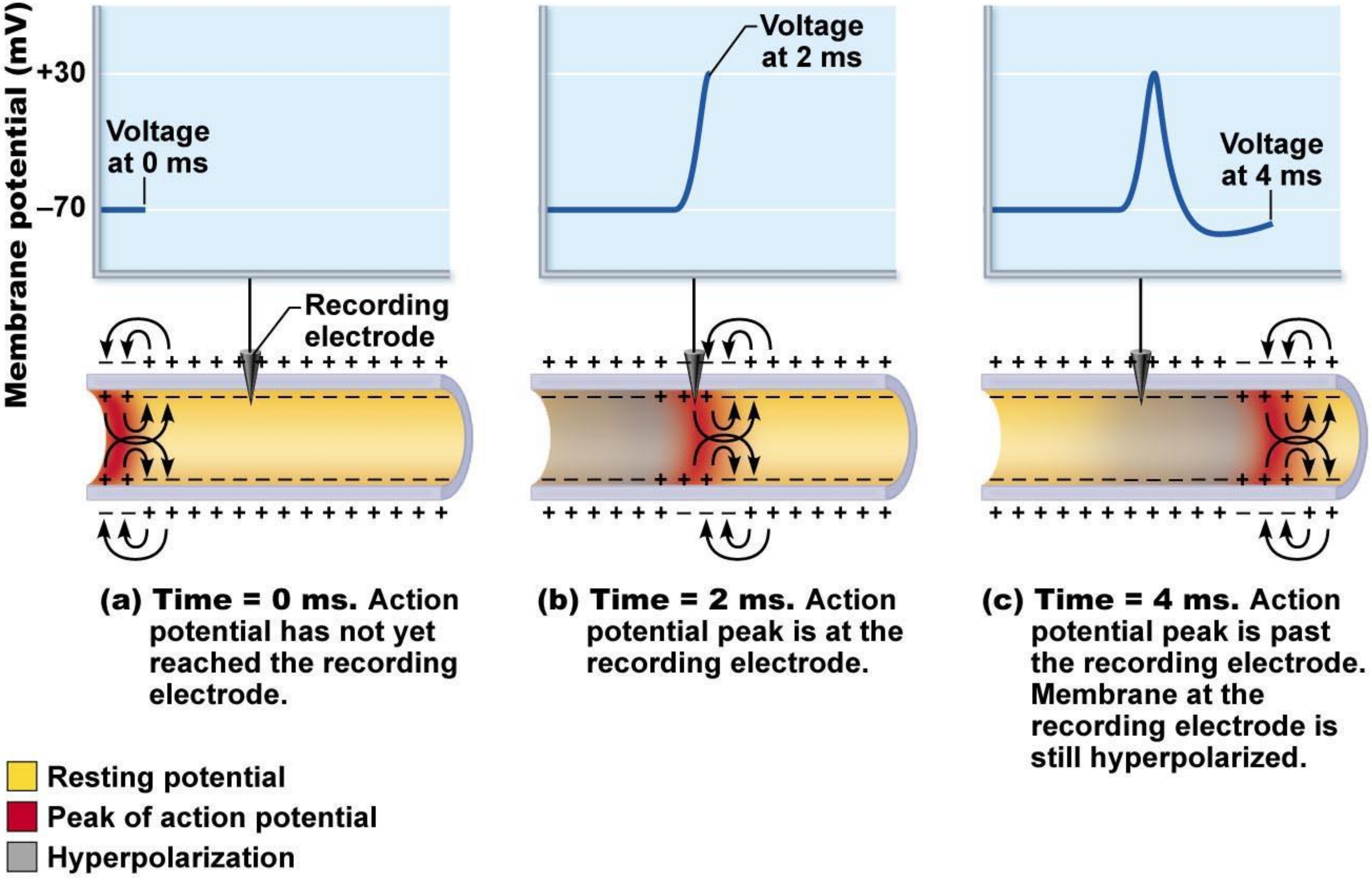
Depolarization



(a) Depolarization: A small patch of the membrane (red area) has become depolarized.

The events

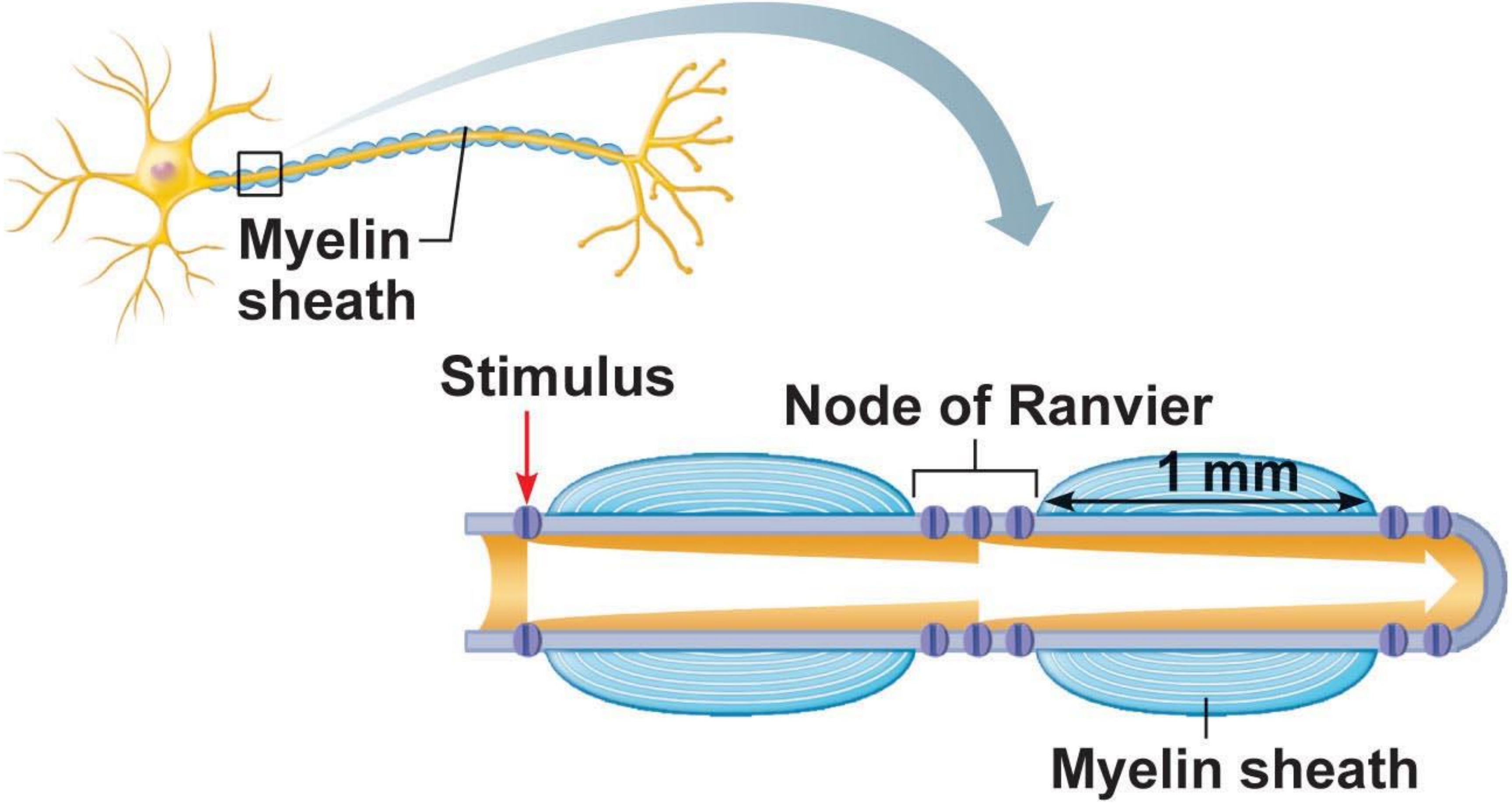

Sodium channel
Na+
Potassium channel
Activation gates
Inactivation gate
K+
① Resting state
Na+
K+
② Depolarization
Na+
K+
③ Repolarization
Na+
K+
④ Hyperpolarization



(a) Time = 0 ms. Action potential has not yet reached the recording electrode.

(b) Time = 2 ms. Action potential peak is at the recording electrode.

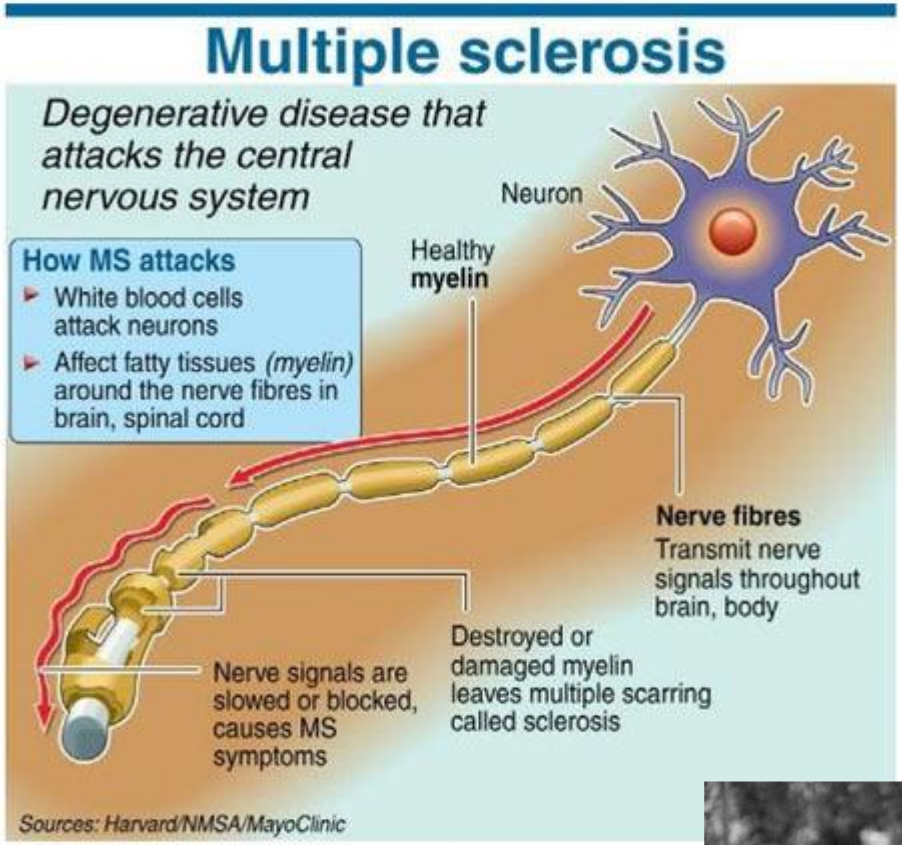
(c) Time = 4 ms. Action potential peak is past the recording electrode. Membrane at the recording electrode is still hyperpolarized.

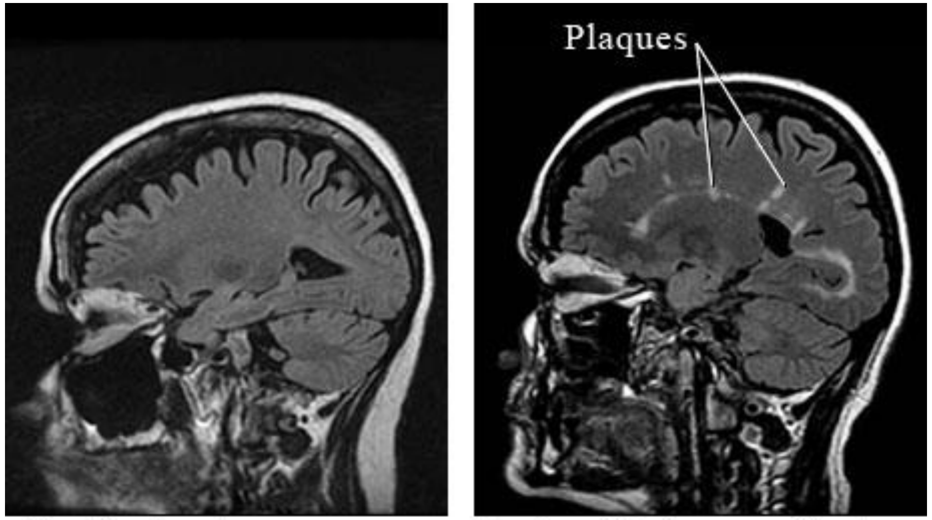


- <u>Saltatory conduction</u>: electrical signal jumps from node to node along myelinated axon (30x faster!)

Multiple Sclerosis (MS)

- Autoimmune disease
- Myelin sheaths destroyed → reduced to hardened lesions (scleroses)
- Blindness, muscle weakness, speech disturbance, urinary incontinence
- **Treatment**: interferons, glatiramer (hold off attacks)



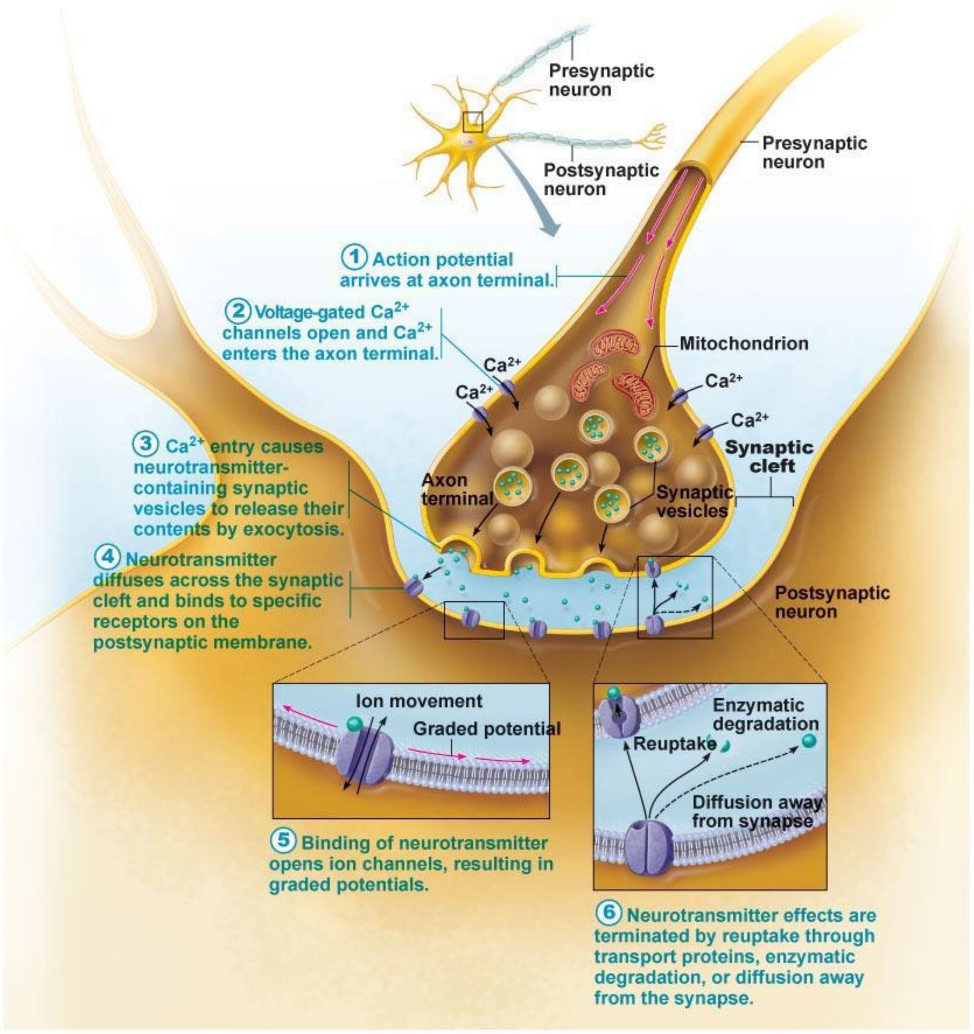


Healthy brain

Brain with damage (lesions or plaques) caused by MS

Nerve Conduction

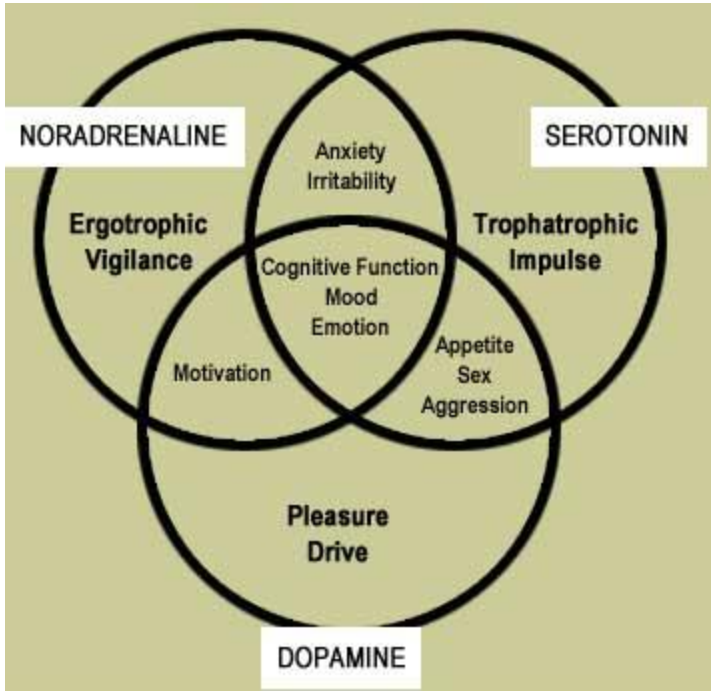
- Action potential reaches axon terminal → vesicles release neurotransmitters (NT) into synaptic cleft
- NT diffuse across synapse → bind to receptors of next neuron
- Transmission of a nerve impulse = electrochemical event

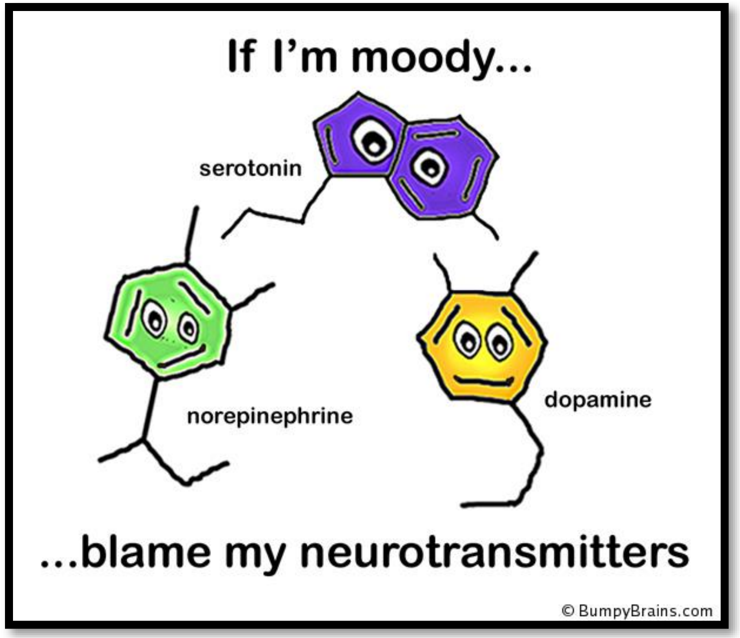


Neuron Talk

Neurotransmitters

- 50+ identified
- <u>Excitatory</u>: cause depolarization
- <u>Inhibitory</u>: reduce ability to cause action potential
- Eg. acetylcholine, serotonin, endorphins





Mouse Party

Neurotransmitters

Neurotransmitter	Action	Affected by:
Acetylcholine	muscle contraction	botulism, curare (paralytic), nicotine
Dopamine	“feeling good”	cocaine, amphetamines
Serotonin	sleep, appetite, nausea, mood, migraines	Prozac, LSD, ecstasy
Endorphins	inhibit pain	morphine, heroin, methadone
GABA	main inhibitory NT	alcohol, Valium, barbiturates

reflexes

hours of fun
with blunt objects

Reflexes

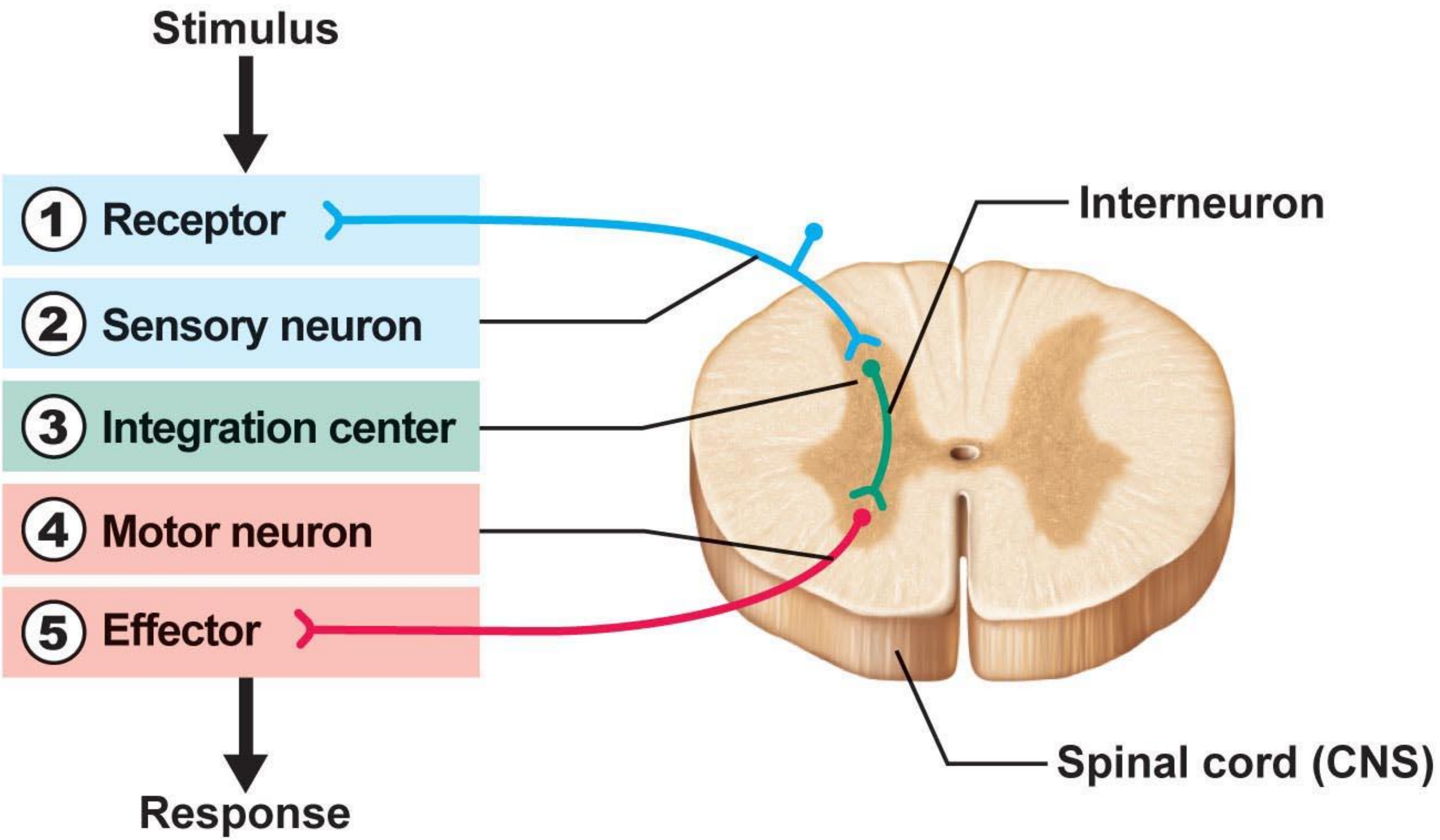
- Rapid, predictable, involuntary responses to stimuli

1. Somatic Reflexes: stimulate skeletal muscles
   - Eg. jerking away hand from hot object
2. Autonomic Reflexes: regulate smooth muscles, heart, glands
   - Eg. salivation, digestion, blood pressure, sweating

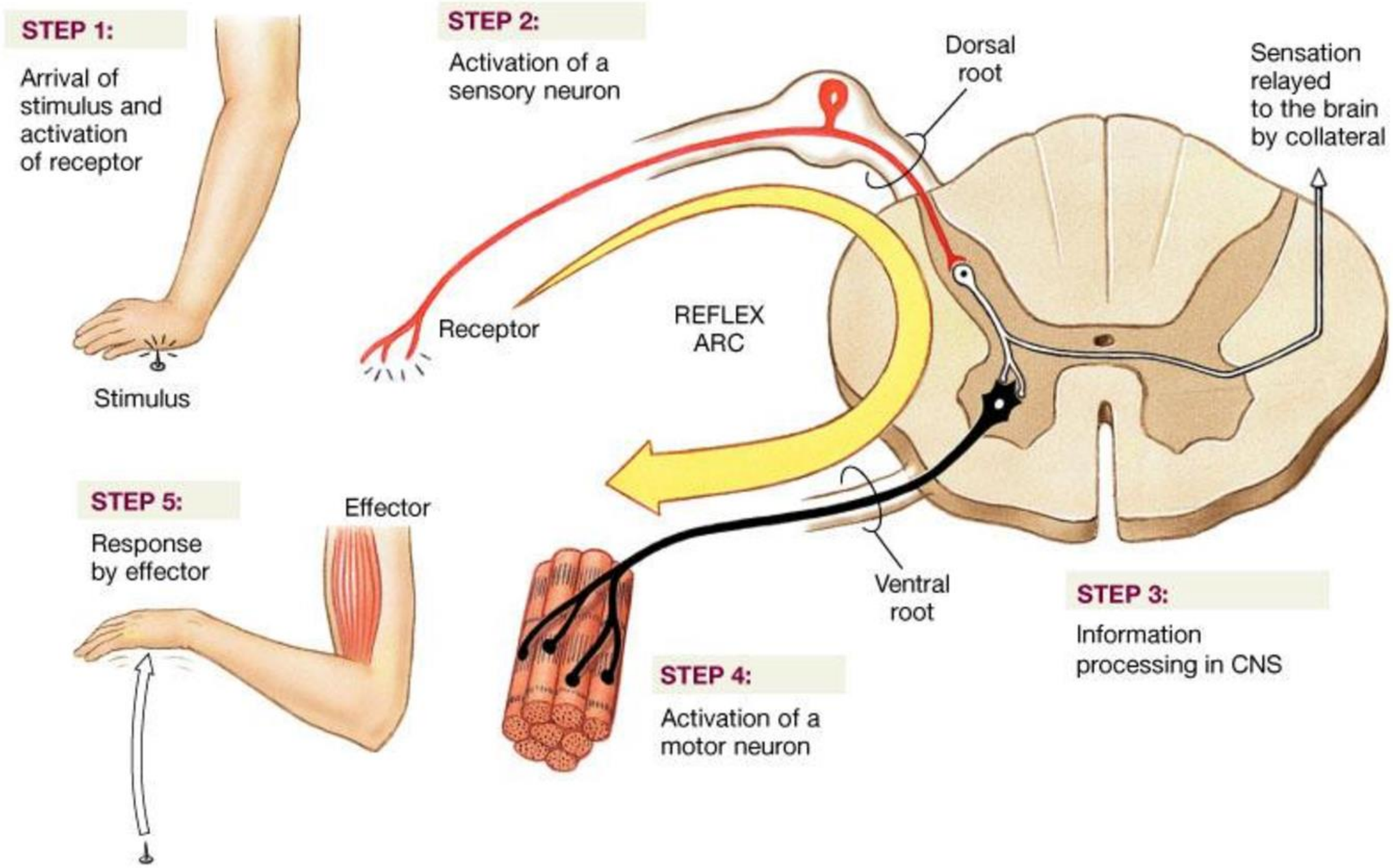
Reflex Arc (neural pathway)

Five elements:

1. Receptor – reacts to stimulus
2. Sensory neuron
3. CNS integration center
4. Motor neuron
5. Effector organ – muscle or gland


Stimulus
1 Receptor
2 Sensory neuron
3 Integration center
4 Motor neuron
5 Effector
Response
Interneuron
Spinal cord (CNS)

Review of reflex arc.



Reflex Activities

Patellar (Knee-jerk) Reflex

Pupillary Reflex

Patellar (Knee-jerk) Reflex

- Stretch reflex
- Tapping patellar ligament causes quadriceps to contract → knee extends
- Help maintain muscle tone, posture, & balance

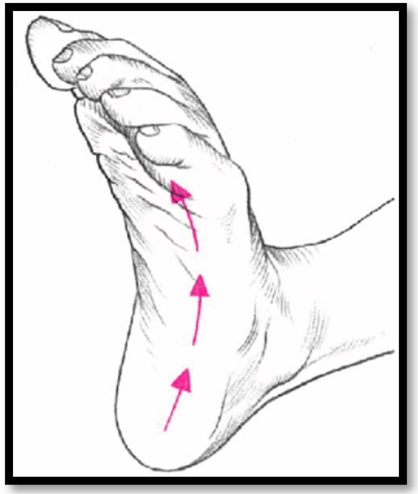
Pupillary Reflex

- Optic nerve → brain stem → muscles constrict pupil
- Useful for checking brain stem function and drug use

Flexor (withdrawal) reflex:

painful stimulus → withdrawal of threatened body part

- Pin prick



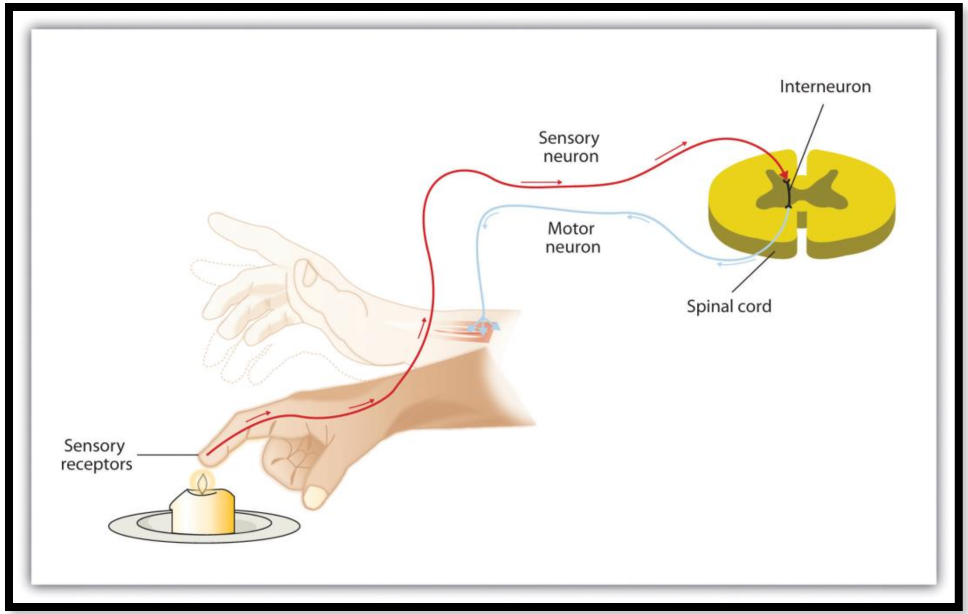
Plantar reflex:

draw object down sole of foot → curling of toes

- **Babinski's sign**: check to see if motor cortex or corticospinal tract is damaged

Voluntary Reactions

- More neurons and synapses are involved → longer response times



Reflex = Involuntary Reaction

Voluntary Reaction