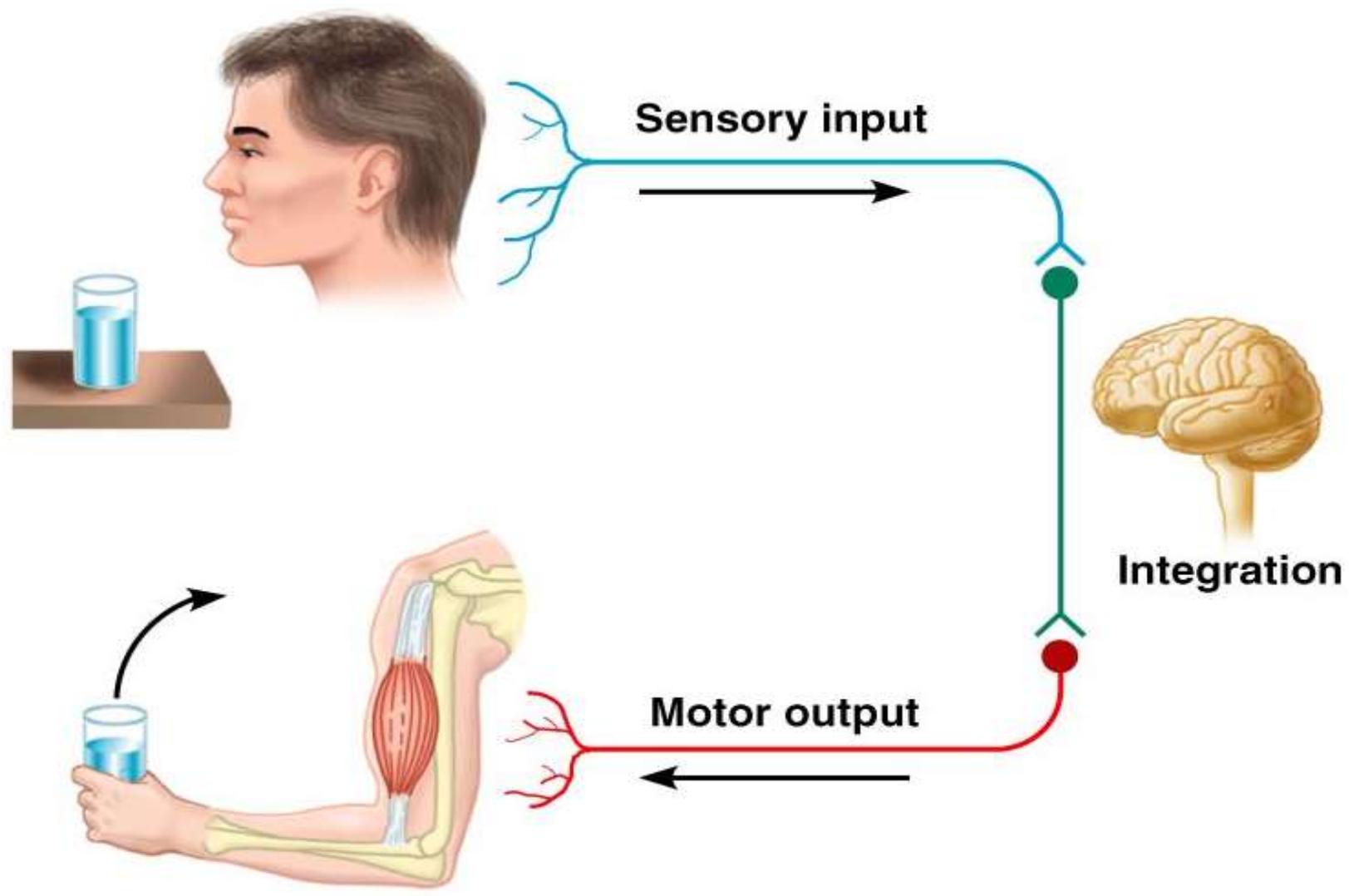
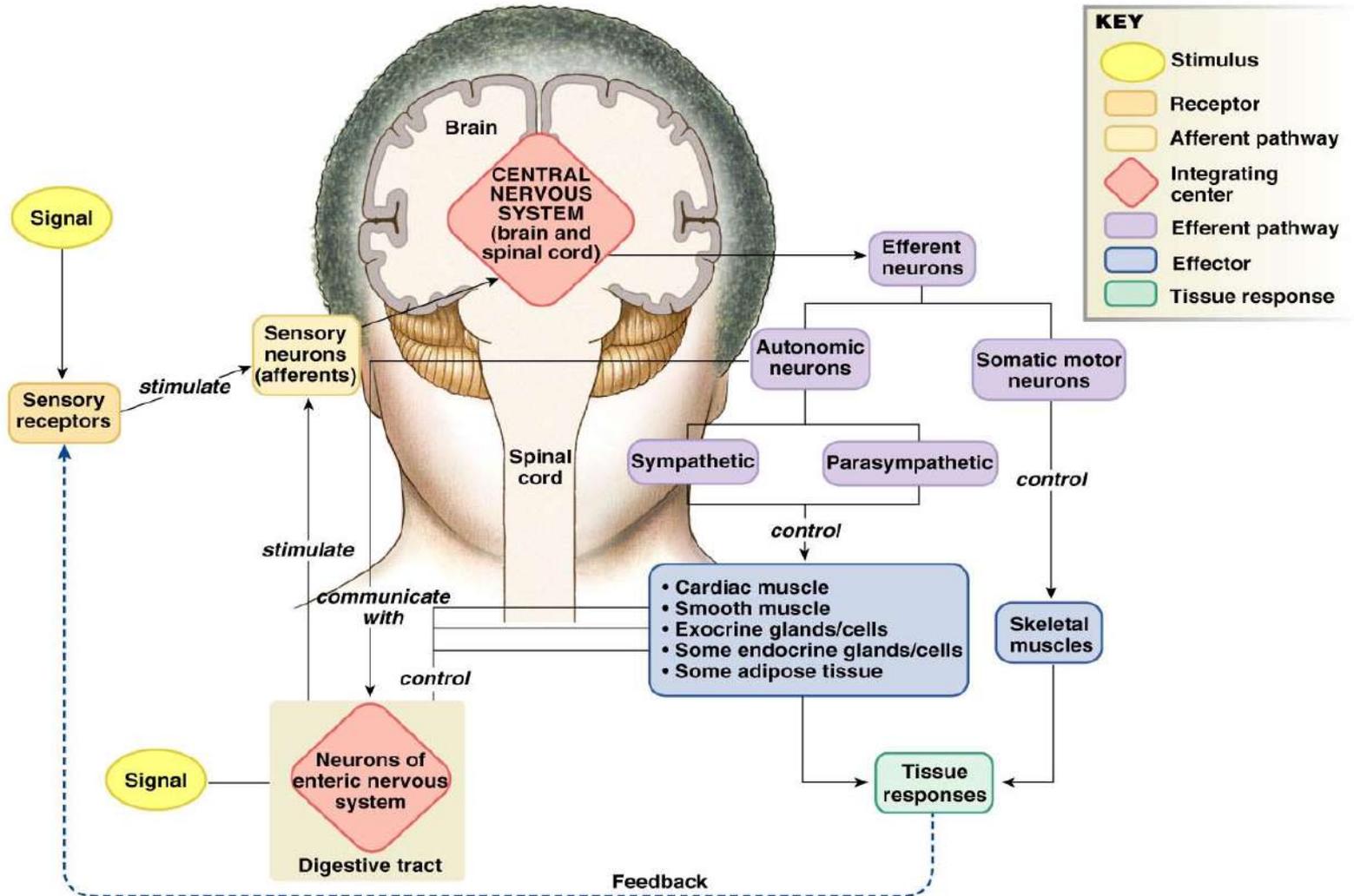


# Nervous System

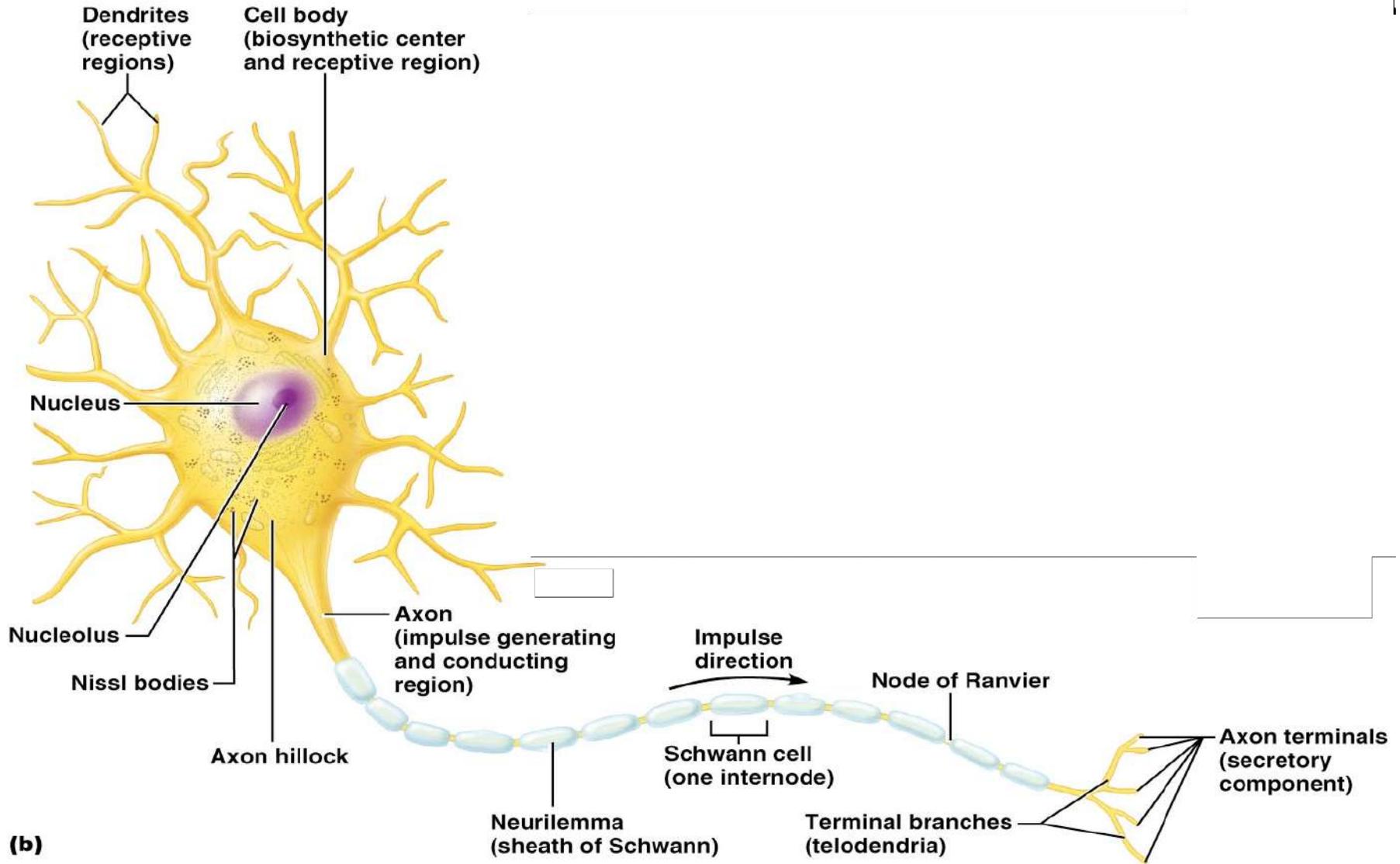


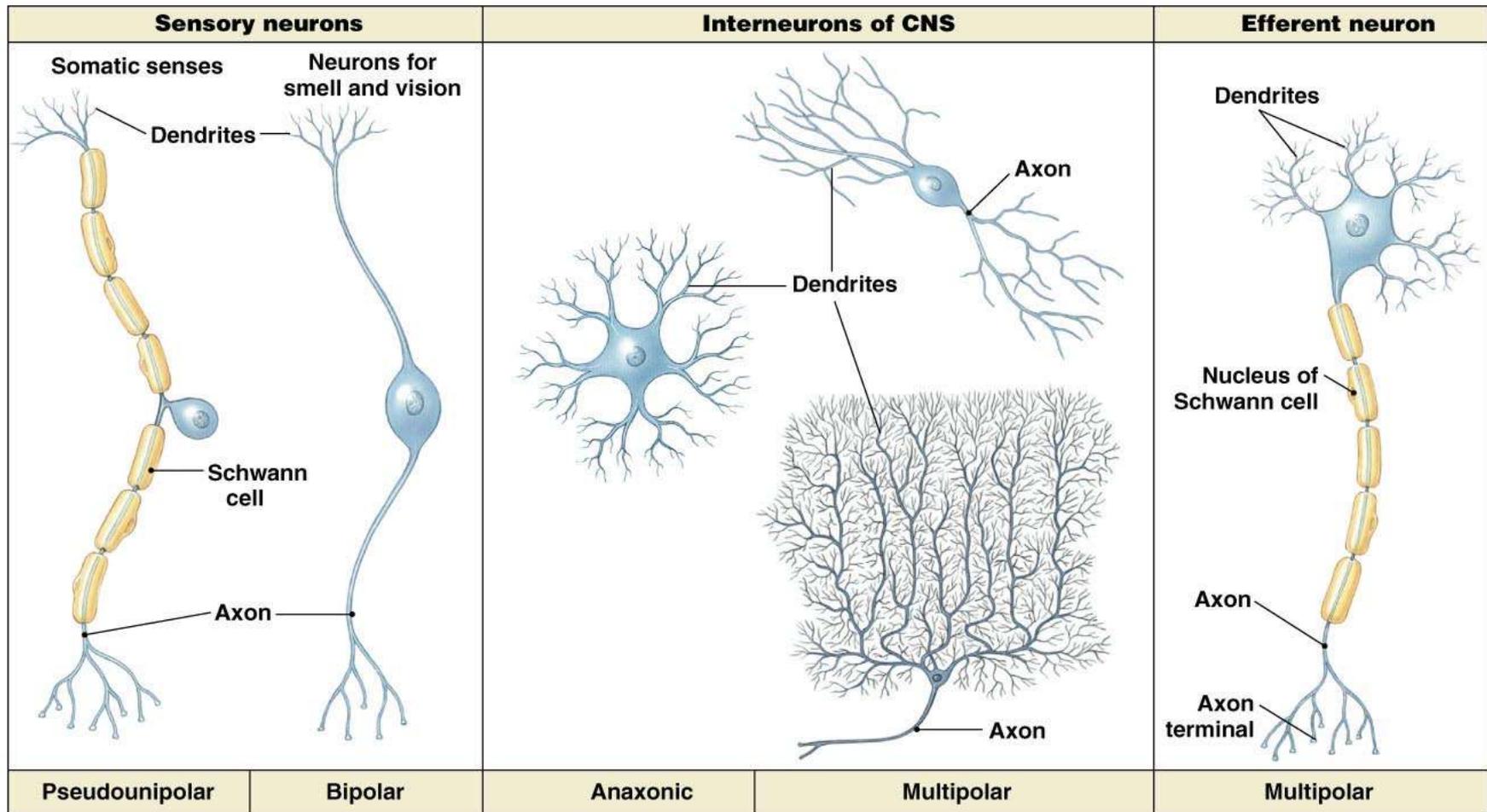
# Nervous System



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# Neurons (Nerve Cells)





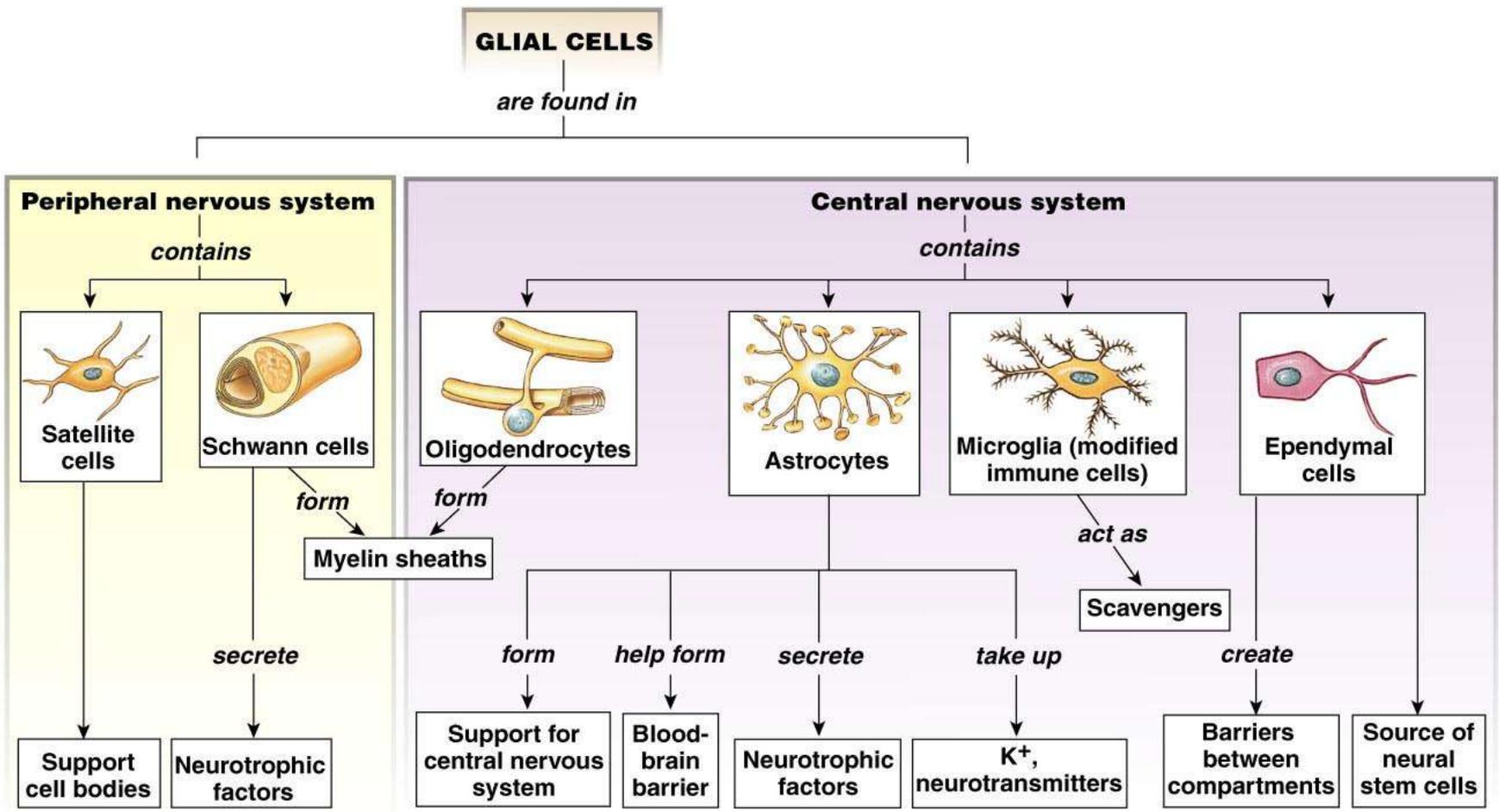
**(a)** Pseudounipolar neurons have a single process called the axon. During development, the dendrite fused with the axon.

**(b)** Bipolar neurons have two relatively equal fibers extending off the central cell body.

**(c)** Anaxonic CNS interneurons have no apparent axon.

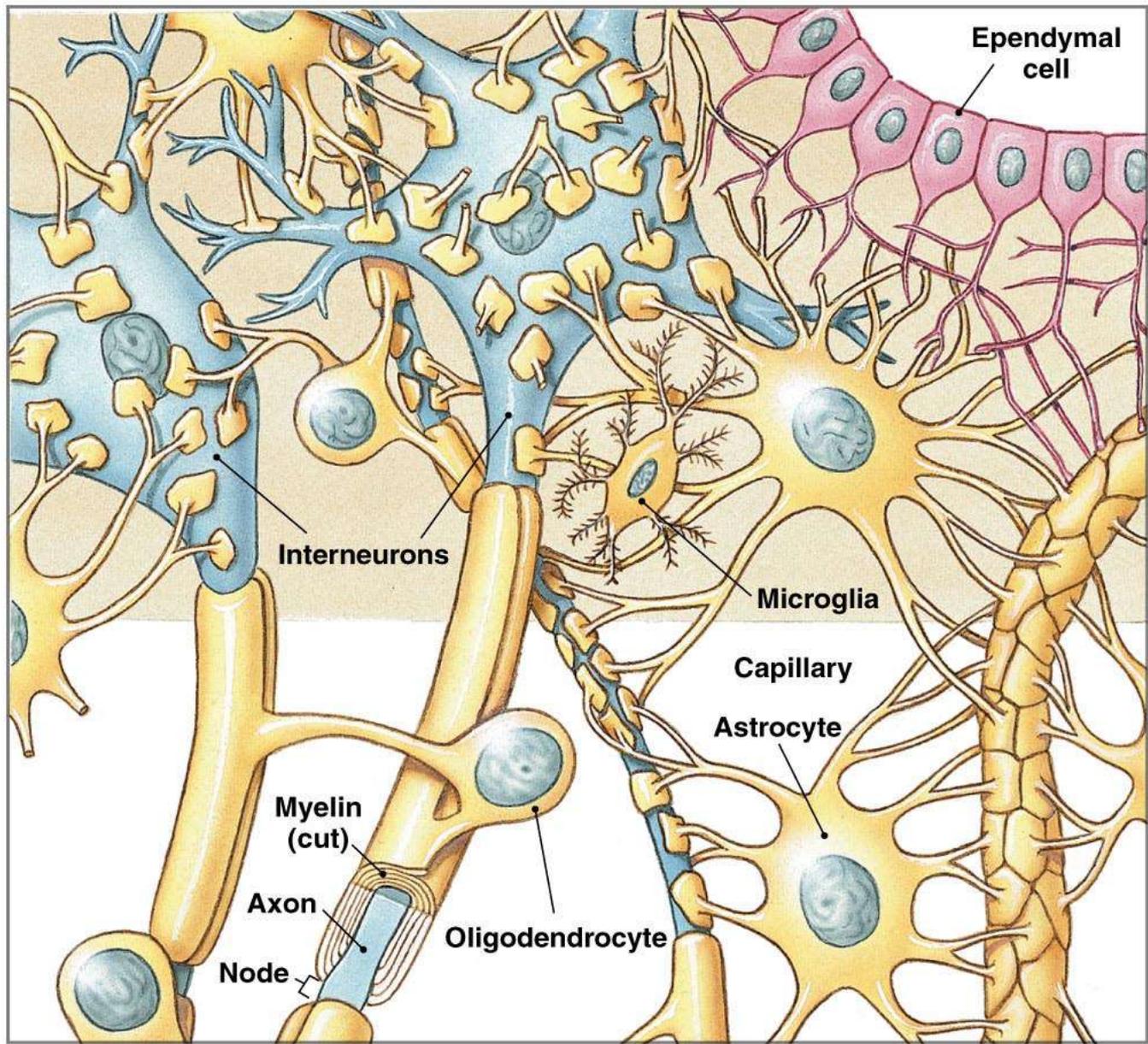
**(d)** Multipolar CNS interneurons are highly branched but lack long extensions.

**(e)** A typical multipolar efferent neuron has five to seven dendrites, each branching four to six times. A single long axon may branch several times and end at enlarged axon terminals.



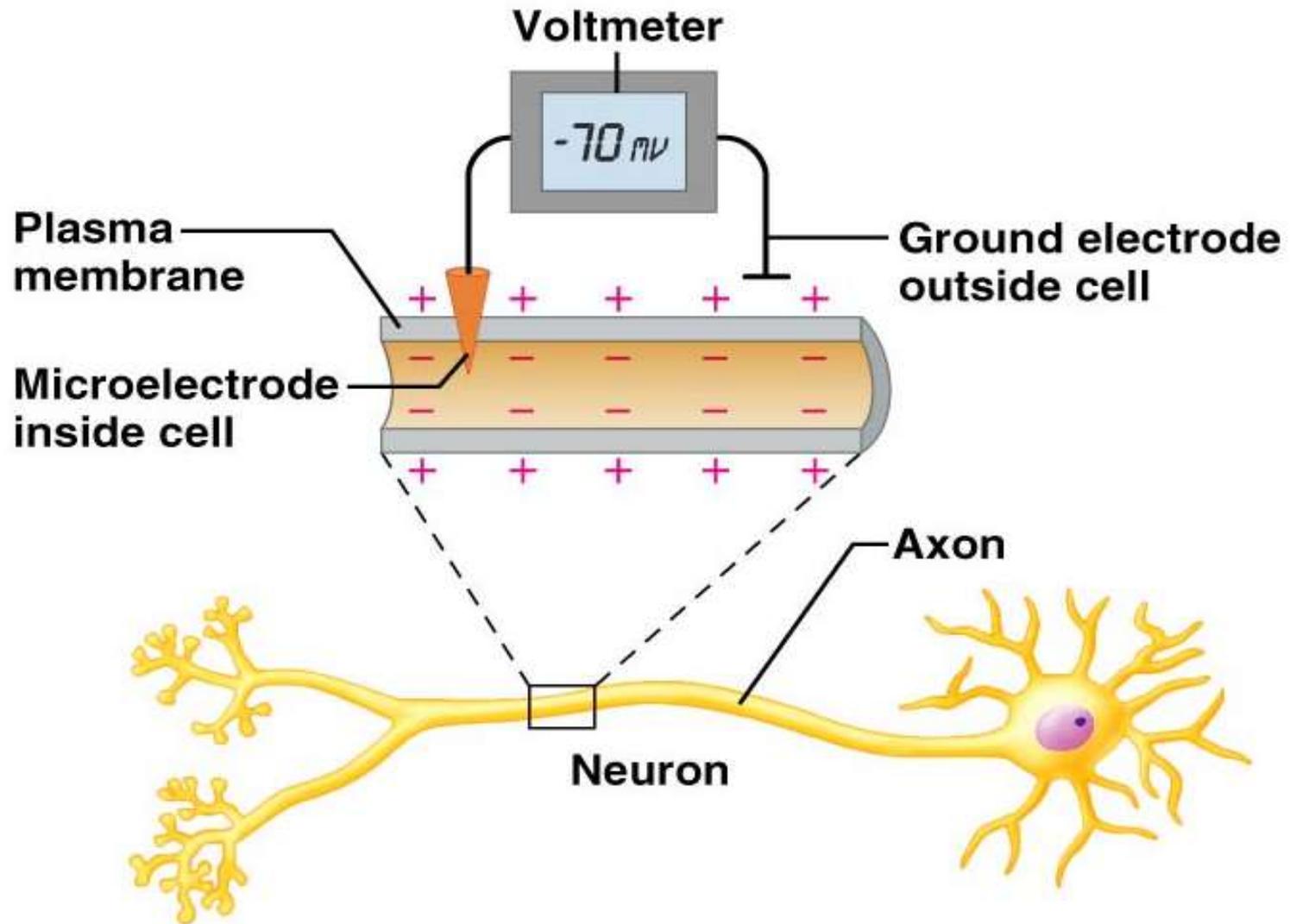
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**(a)** Glial cells of the central nervous system

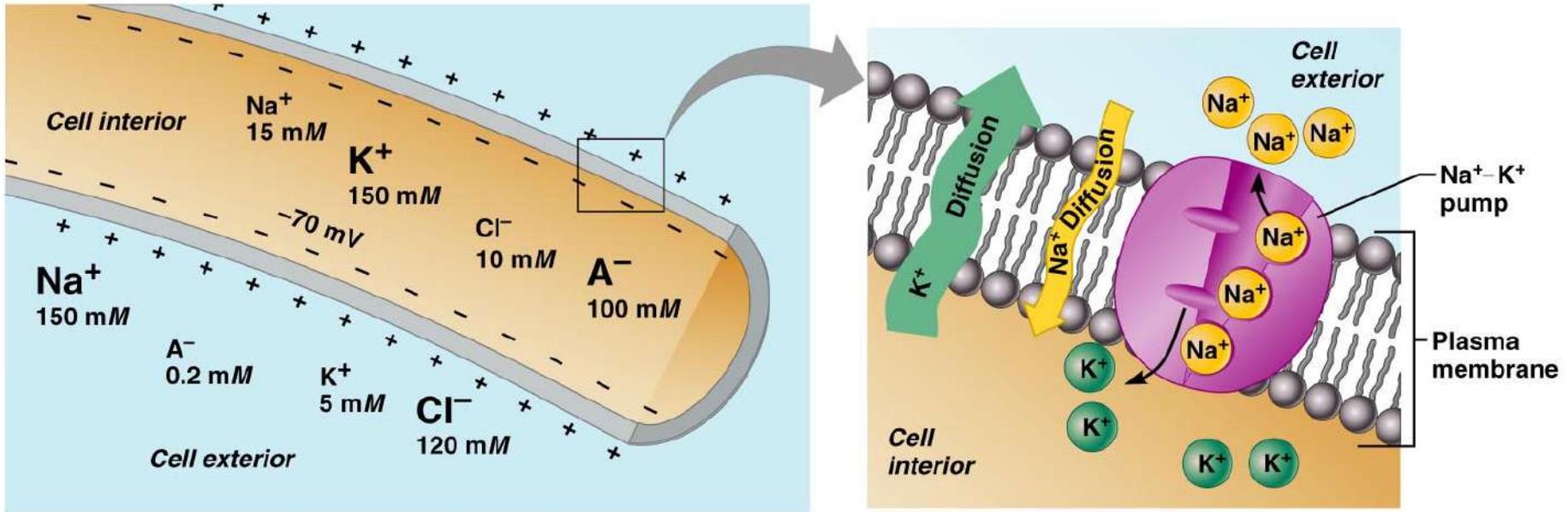


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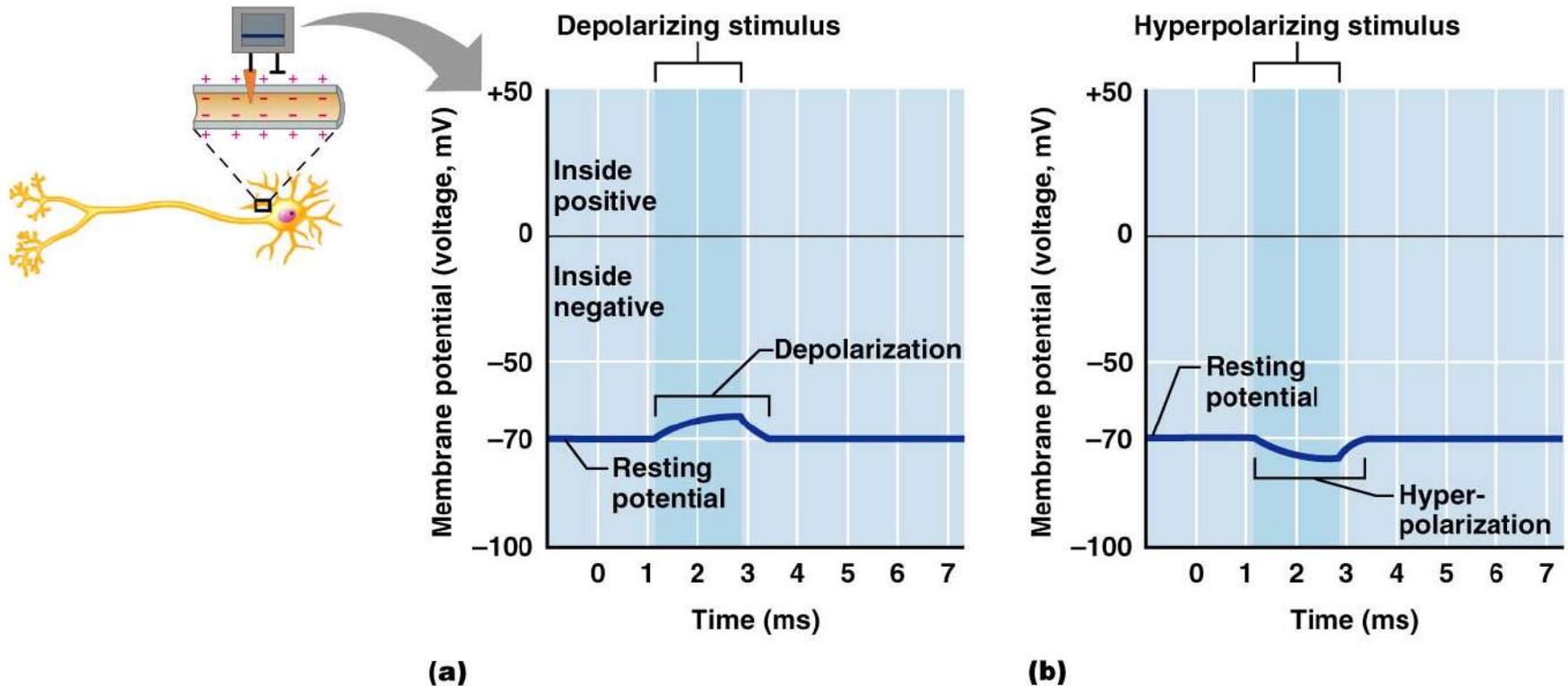
# Membrane Potential



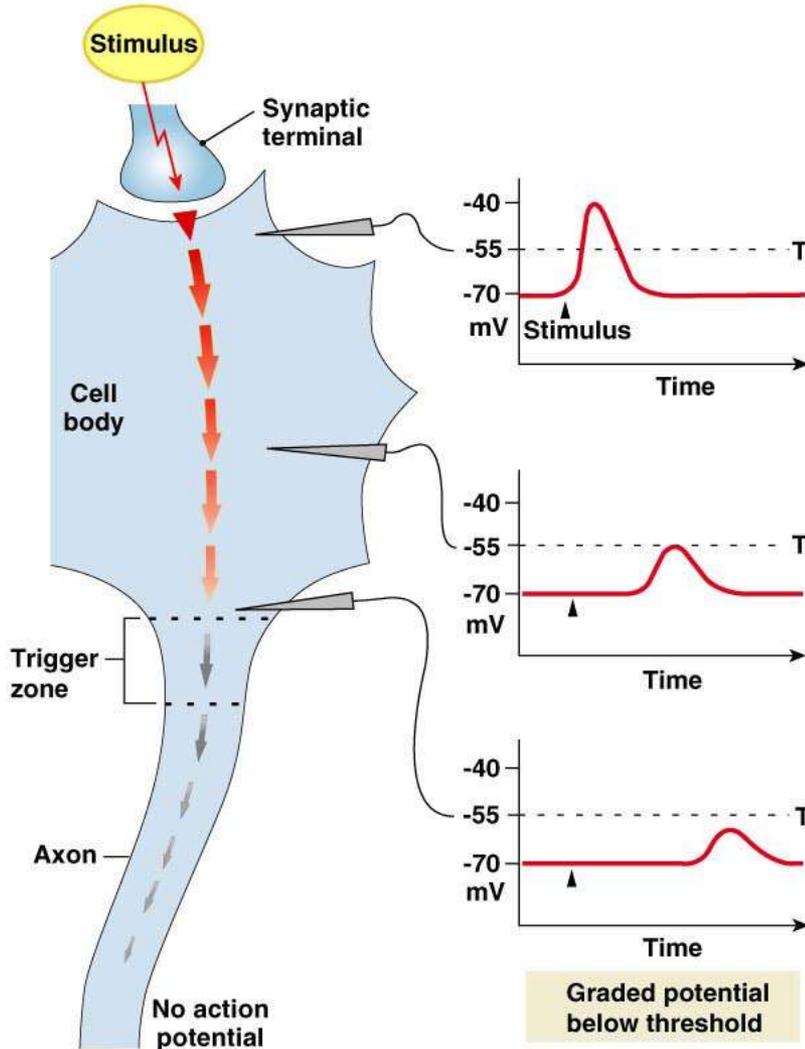
# Resting Membrane Potential ( $V_r$ )



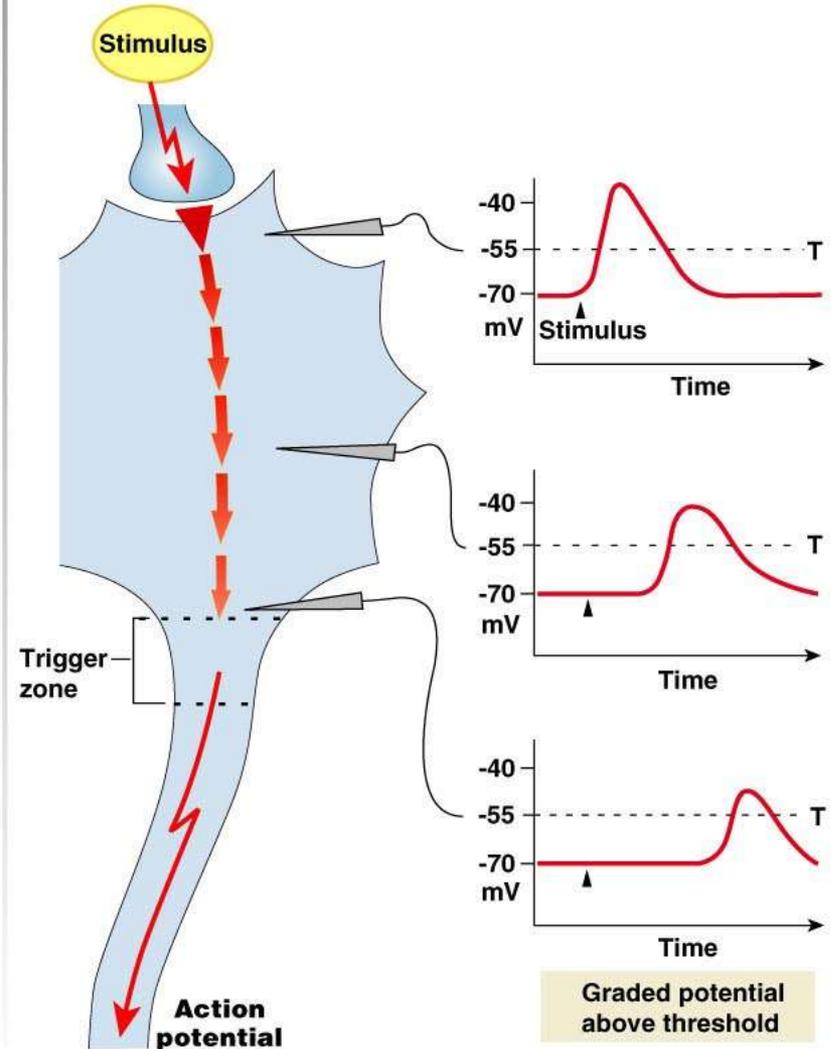
# Changes in Membrane Potential

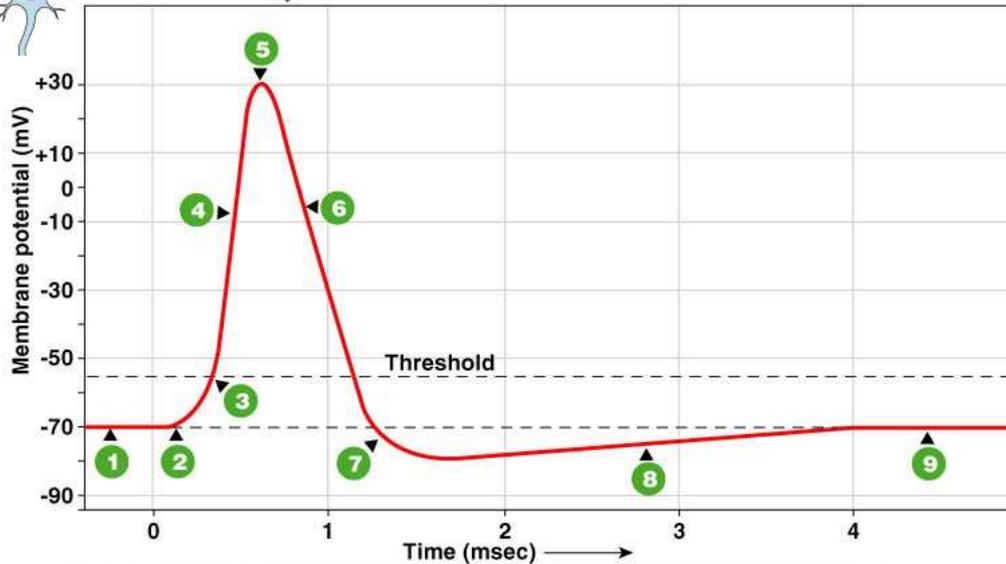
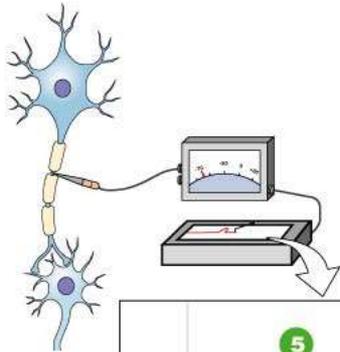


**(a)** A graded potential starts above threshold (T) at its initiation point, but decreases in strength as it travels through the cell body. At the trigger zone it is below threshold and therefore does not initiate an action potential.

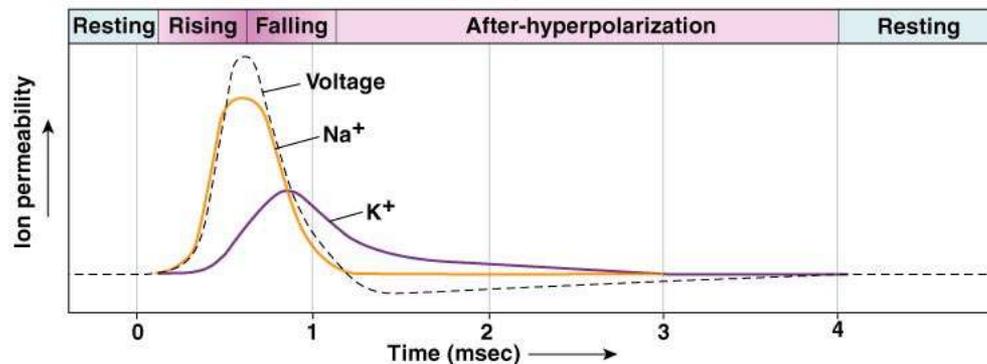


**(b)** A stronger stimulus at the same point on the cell body creates a graded potential that is still above threshold by the time it reaches the trigger zone, so an action potential results.





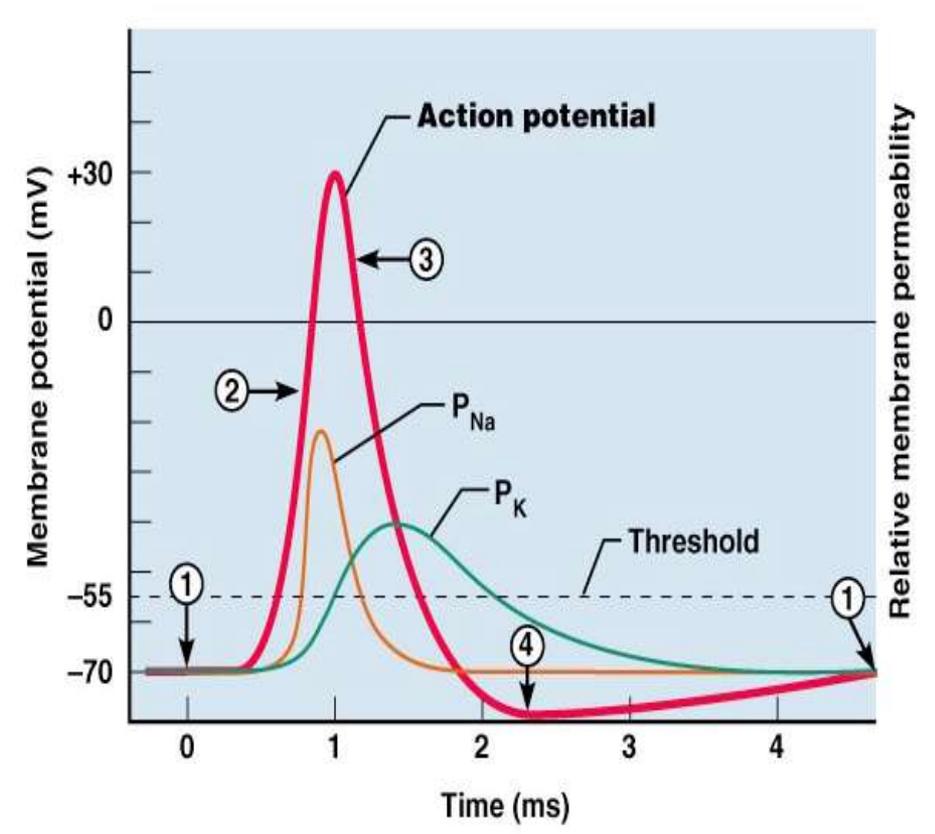
- 1 Resting membrane potential
- 2 Depolarizing stimulus
- 3 Membrane depolarizes to threshold. Voltage-gated Na<sup>+</sup> channels open and Na<sup>+</sup> enters cell. Voltage-gated K<sup>+</sup> channels begin to open slowly.
- 4 Rapid Na<sup>+</sup> entry depolarizes cell.
- 5 Na<sup>+</sup> channels close and slower K<sup>+</sup> channels open.
- 6 K<sup>+</sup> moves from cell to extracellular fluid.
- 7 K<sup>+</sup> channels remain open and additional K<sup>+</sup> leaves cell, hyperpolarizing it.
- 8 Voltage-gated K<sup>+</sup> channels close, less K<sup>+</sup> leaks out of the cell.
- 9 Cell returns to resting ion permeability and resting membrane potential.



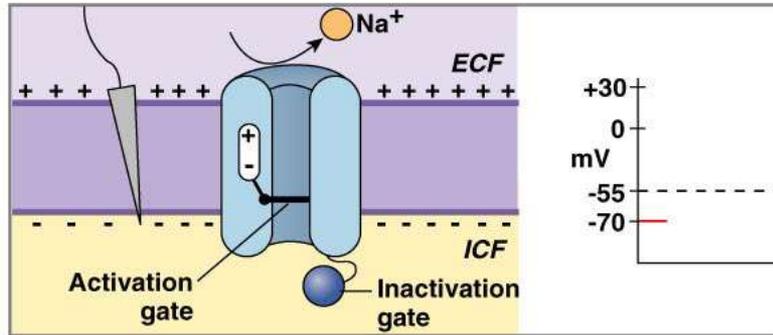
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# Phases of the Action Potential

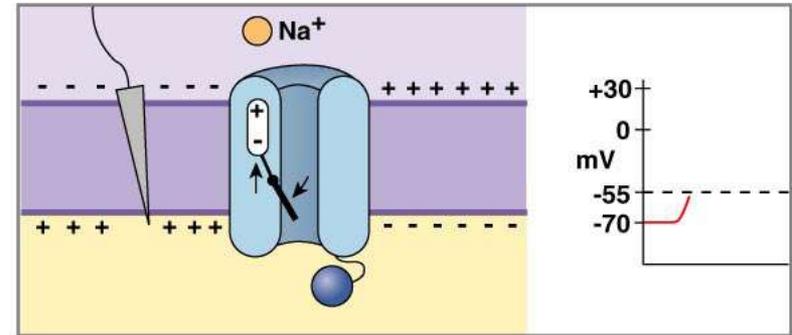
- 1 – resting state
- 2 – depolarization phase
- 3 – repolarization phase
- 4 – hyperpolarization



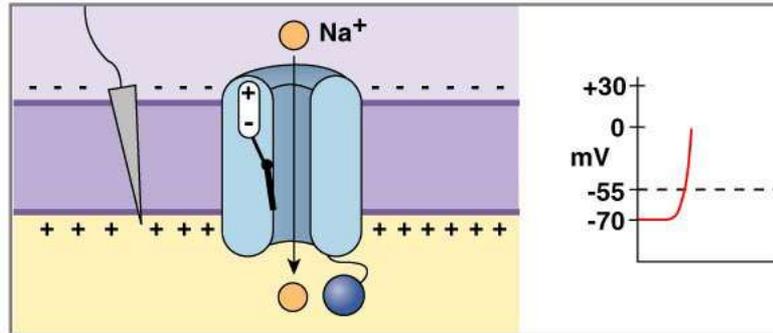
**(a)** At the resting membrane potential, the activation gate closes the channel.



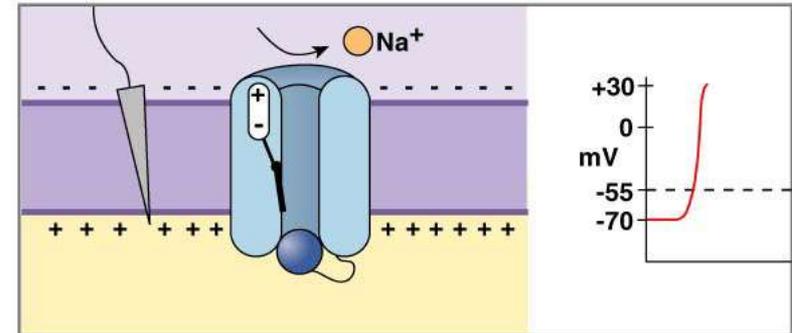
**(b)** Depolarizing stimulus arrives at the channel.



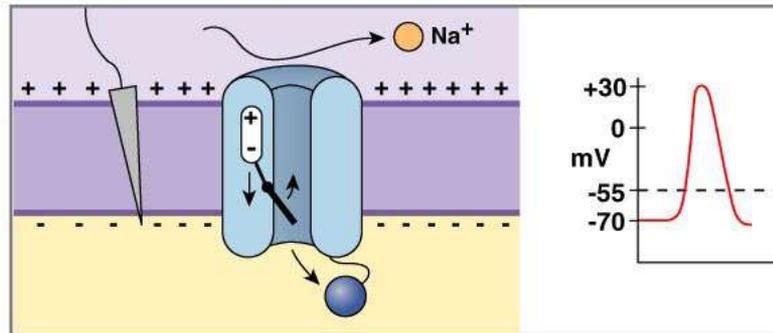
**(c)** With activation gate open, Na<sup>+</sup> enters the cell.

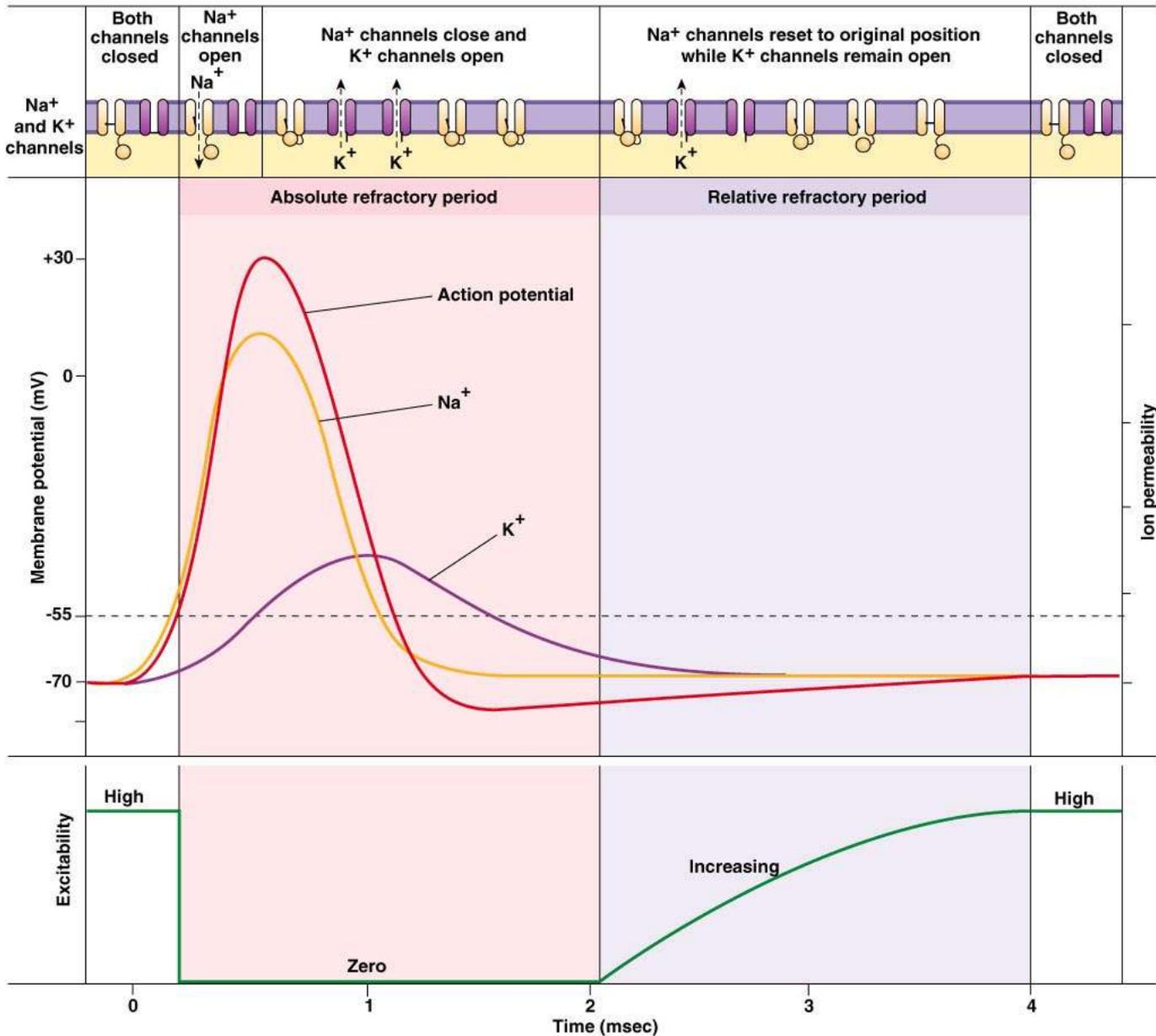


**(d)** Inactivation gate closes and Na<sup>+</sup> entry stops.



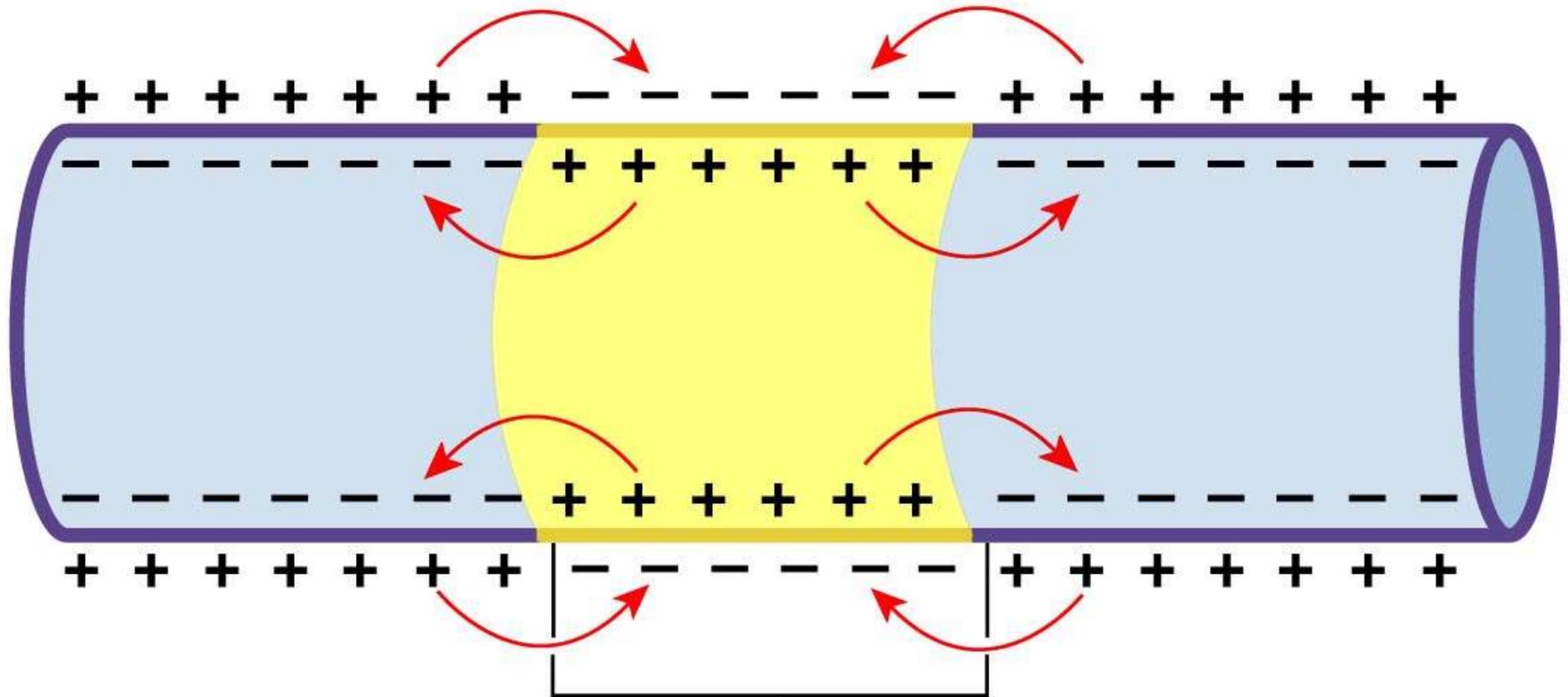
**(e)** During repolarization caused by K<sup>+</sup> leaving the cell, the two gates reset to their original positions.





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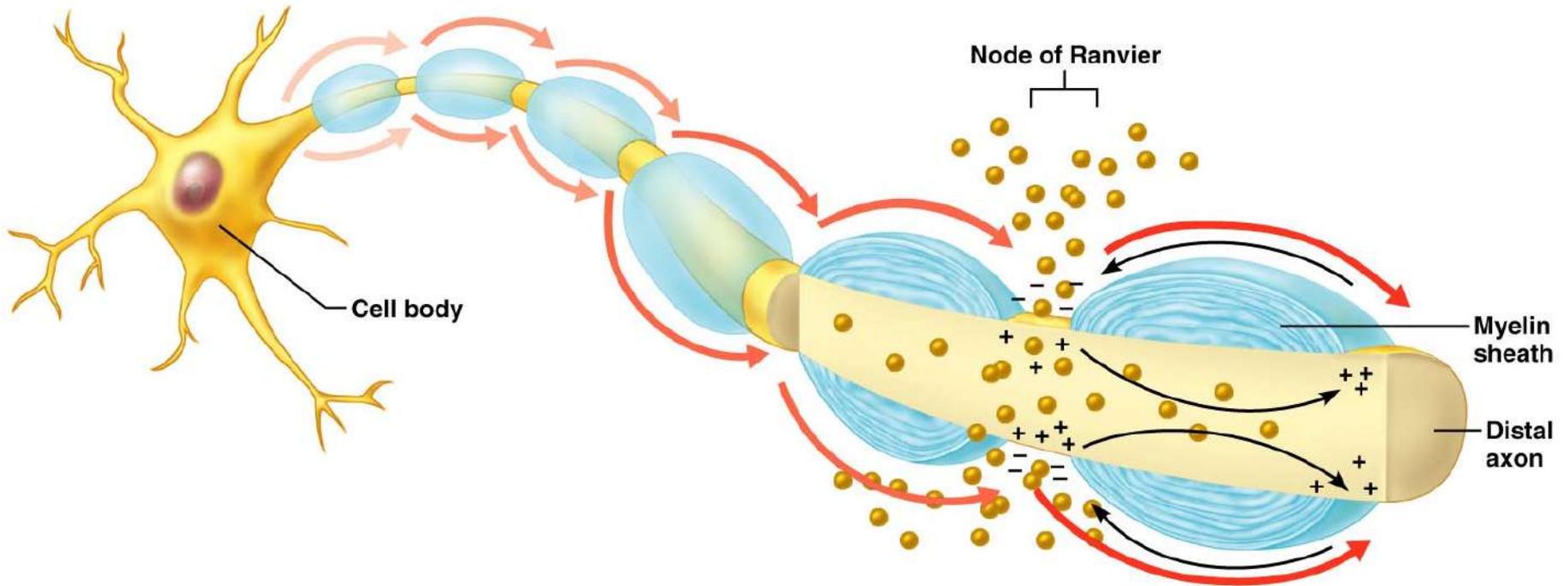
## Local current flow



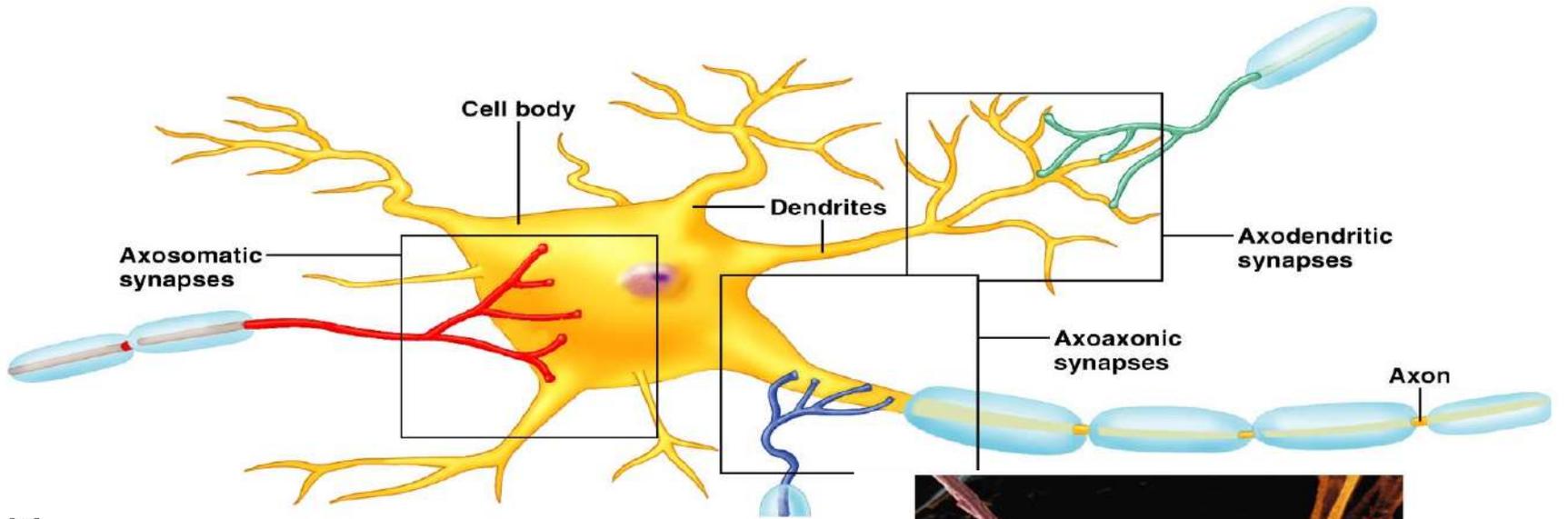
## Depolarized section of axon

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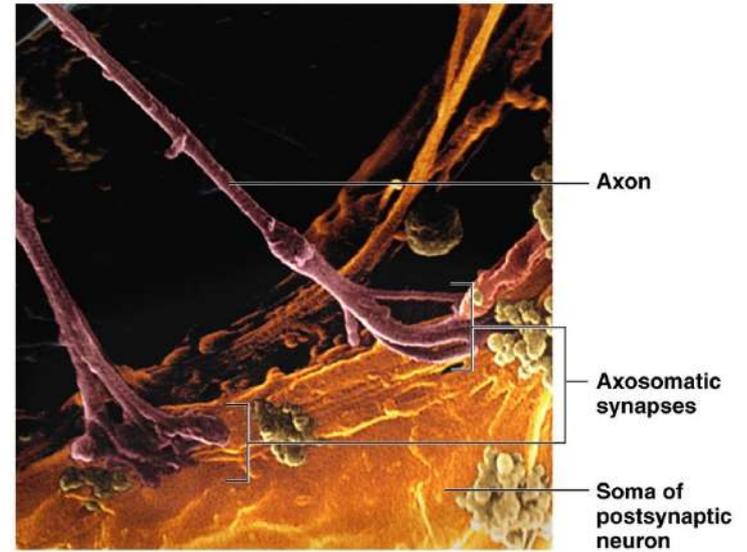
# Saltatory Conduction



# Synapses

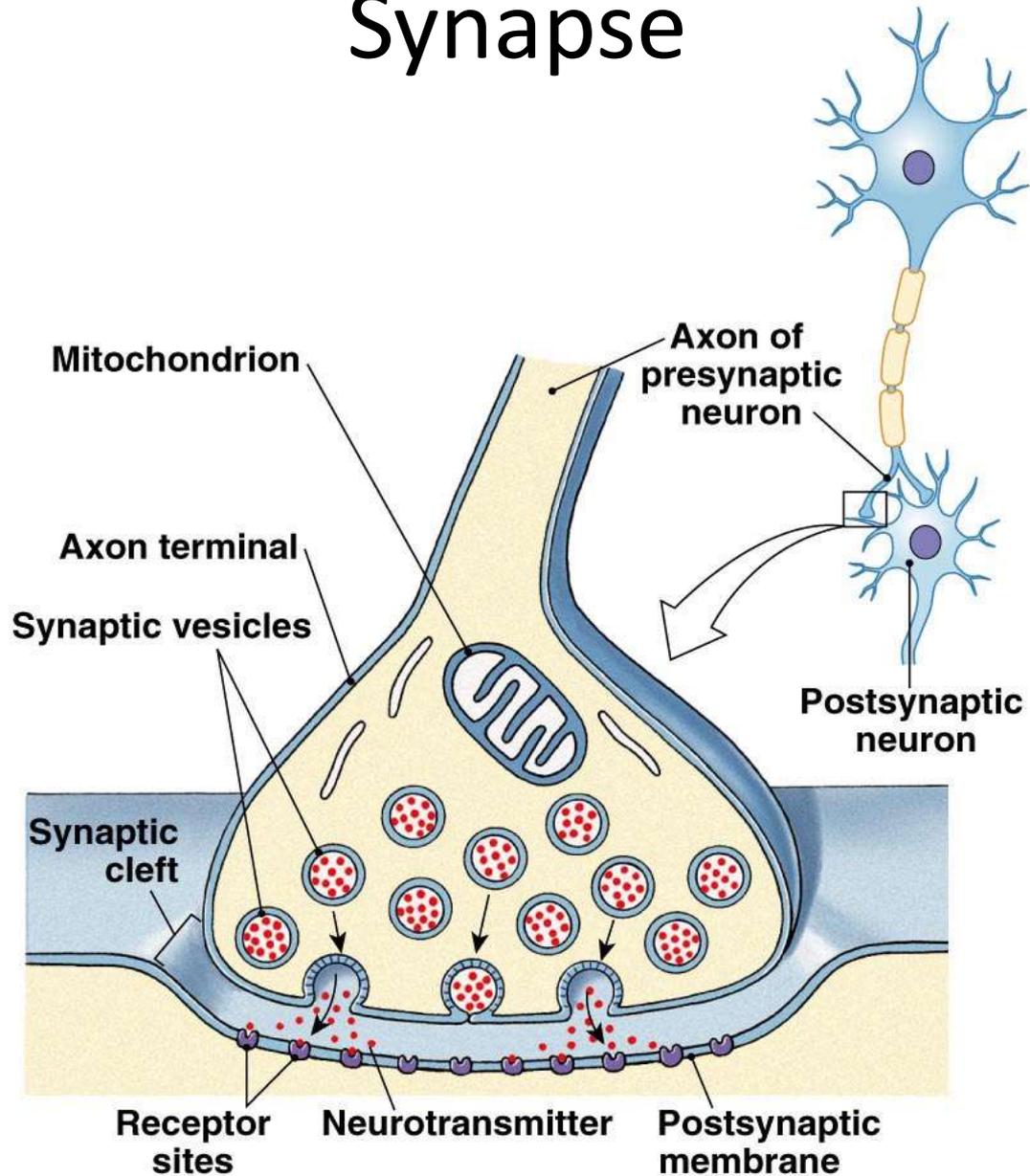


(a)



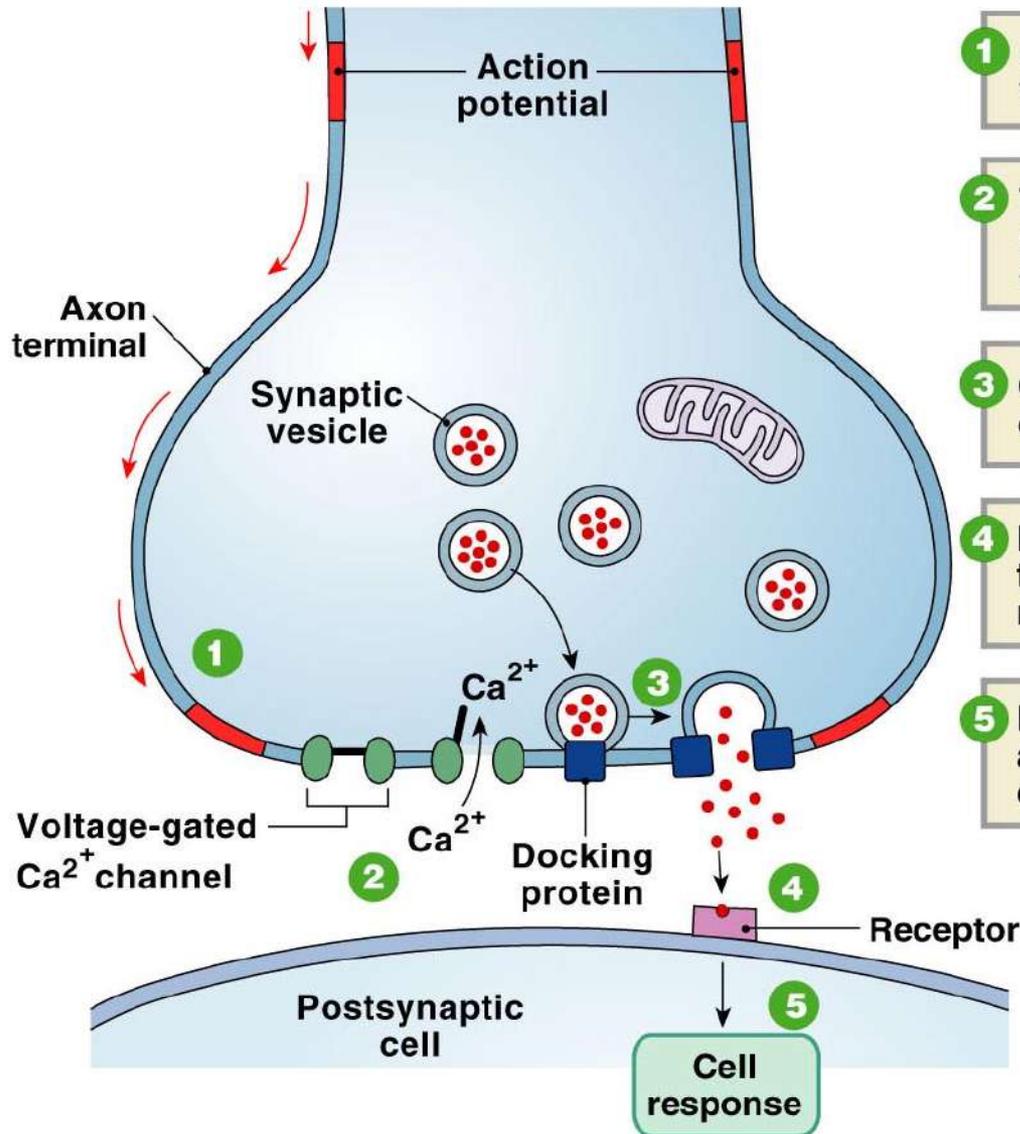
(b)

# Synapse



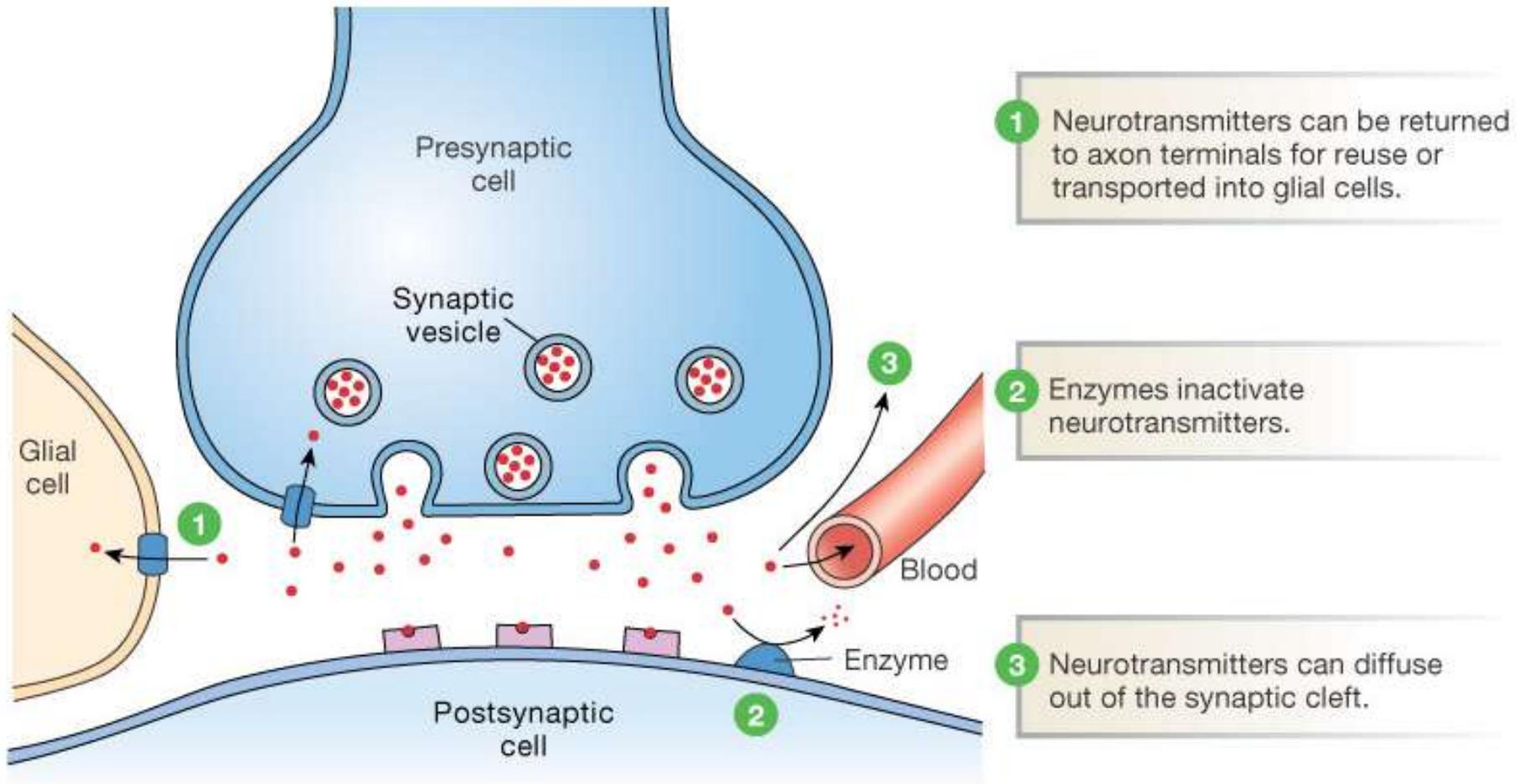
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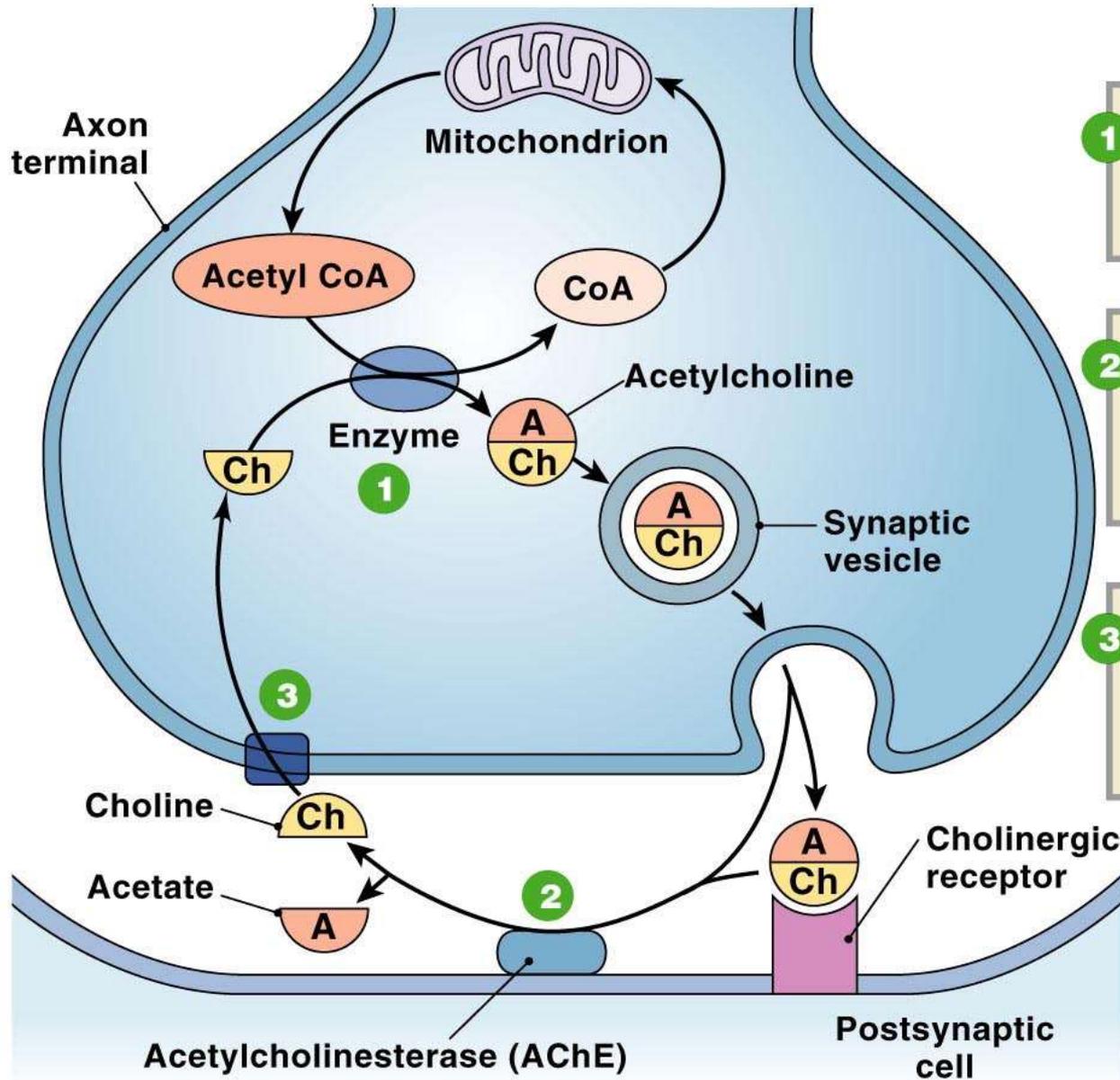
# Synaptic Transmission



- 1 An action potential depolarizes the axon terminal.
- 2 The depolarization opens voltage-gated  $\text{Ca}^{2+}$  channels and  $\text{Ca}^{2+}$  enters the cell.
- 3 Calcium entry triggers exocytosis of synaptic vesicle contents.
- 4 Neurotransmitter diffuses across the synaptic cleft and binds with receptors on the postsynaptic cell.
- 5 Neurotransmitter binding initiates a response in the postsynaptic cell.

# Inactivation of Neurotransmitters





**1 Acetylcholine (ACh) is made from choline and acetyl CoA.**

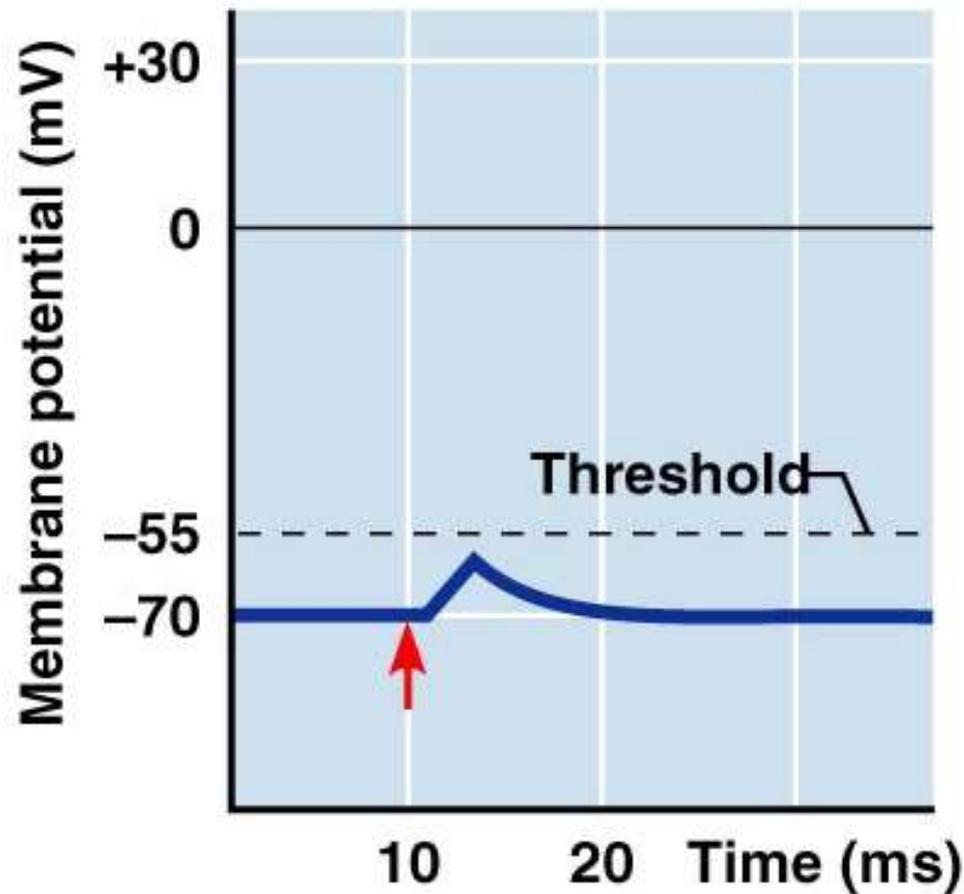
**2 In the synaptic cleft ACh is rapidly broken down by the enzyme acetylcholinesterase.**

**3 Choline is transported back into the axon terminal and is used to make more ACh.**

# Excitatory Postsynaptic Potentials

- EPSPs are graded potentials that can initiate an action potential in an axon
  - Use only chemically gated channels
  - $\text{Na}^+$  and  $\text{K}^+$  flow in opposite directions at the same time
- Postsynaptic membranes do not generate action potentials

# Excitatory Postsynaptic Potential

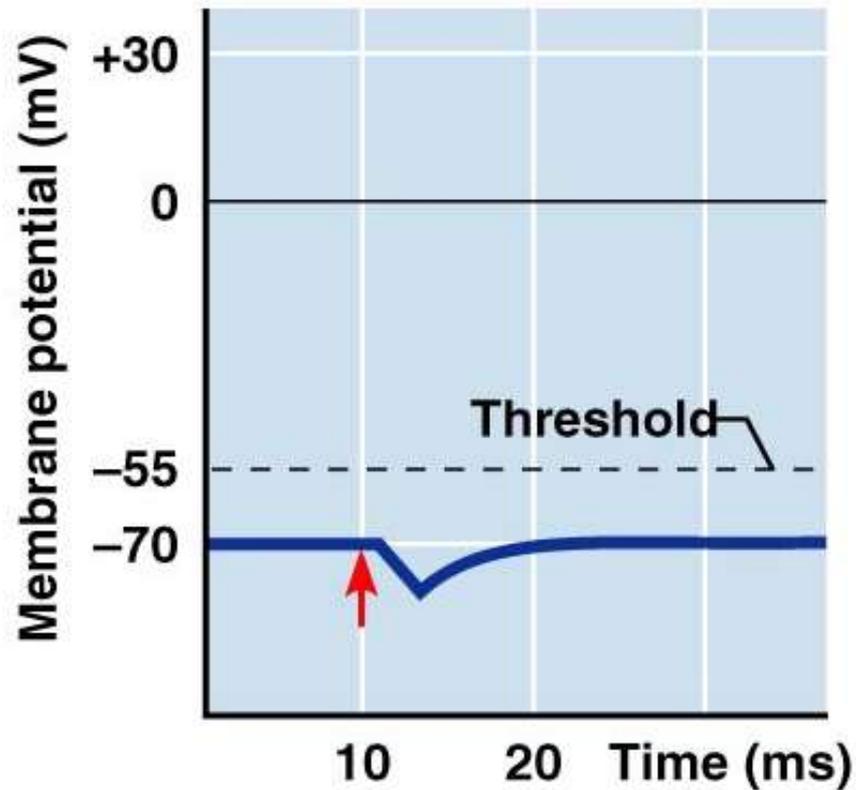


**(a) Excitatory postsynaptic potential (EPSP)**

# Inhibitory Synapses and IPSPs

- Neurotransmitter binding to a receptor at inhibitory synapses:
  - Causes the membrane to become more permeable to potassium and chloride ions
  - Leaves the charge on the inner surface negative
  - Reduces the postsynaptic neuron's ability to produce an action potential

# Inhibitory Postsynaptic (IPSP)

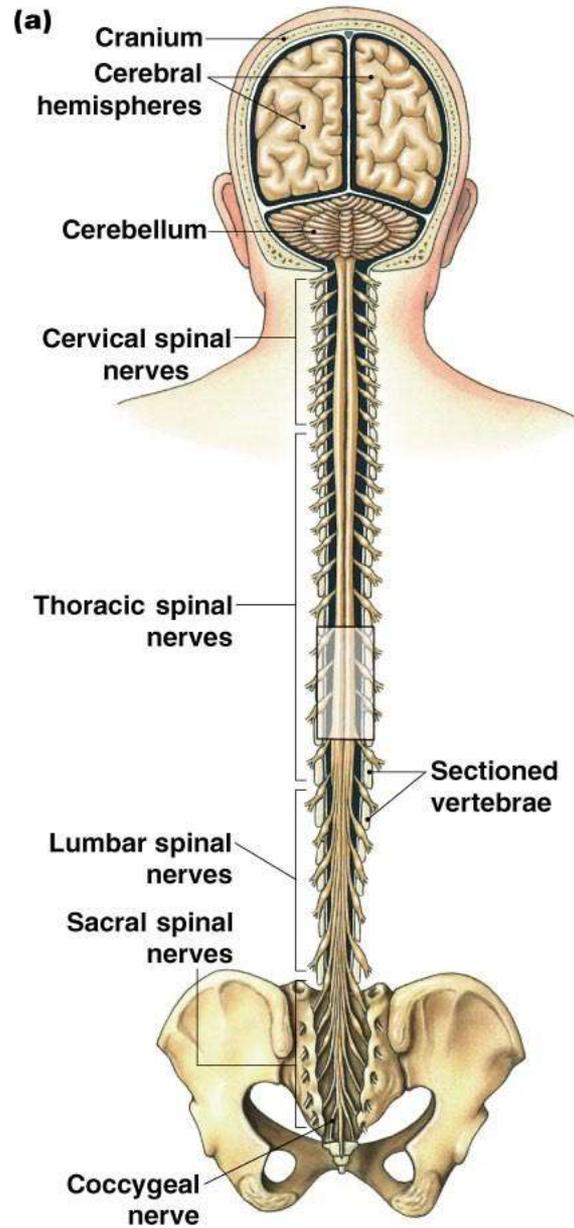


**(b) Inhibitory postsynaptic potential (IPSP)**

# Chemical Neurotransmitters

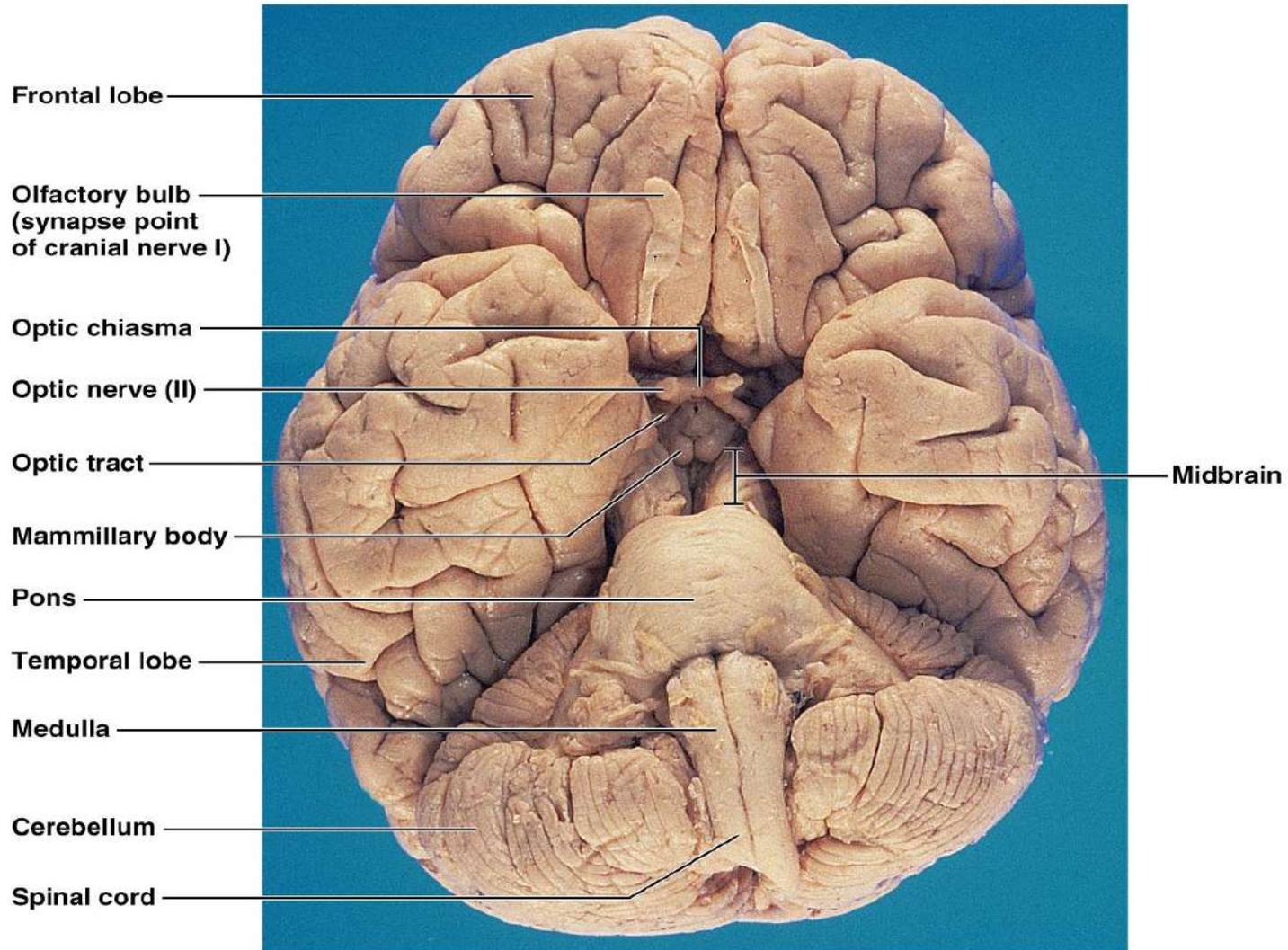
- Acetylcholine (ACh)
- Biogenic amines
- Amino acids
- Peptides
- Novel messengers: ATP and dissolved gases  
NO and CO

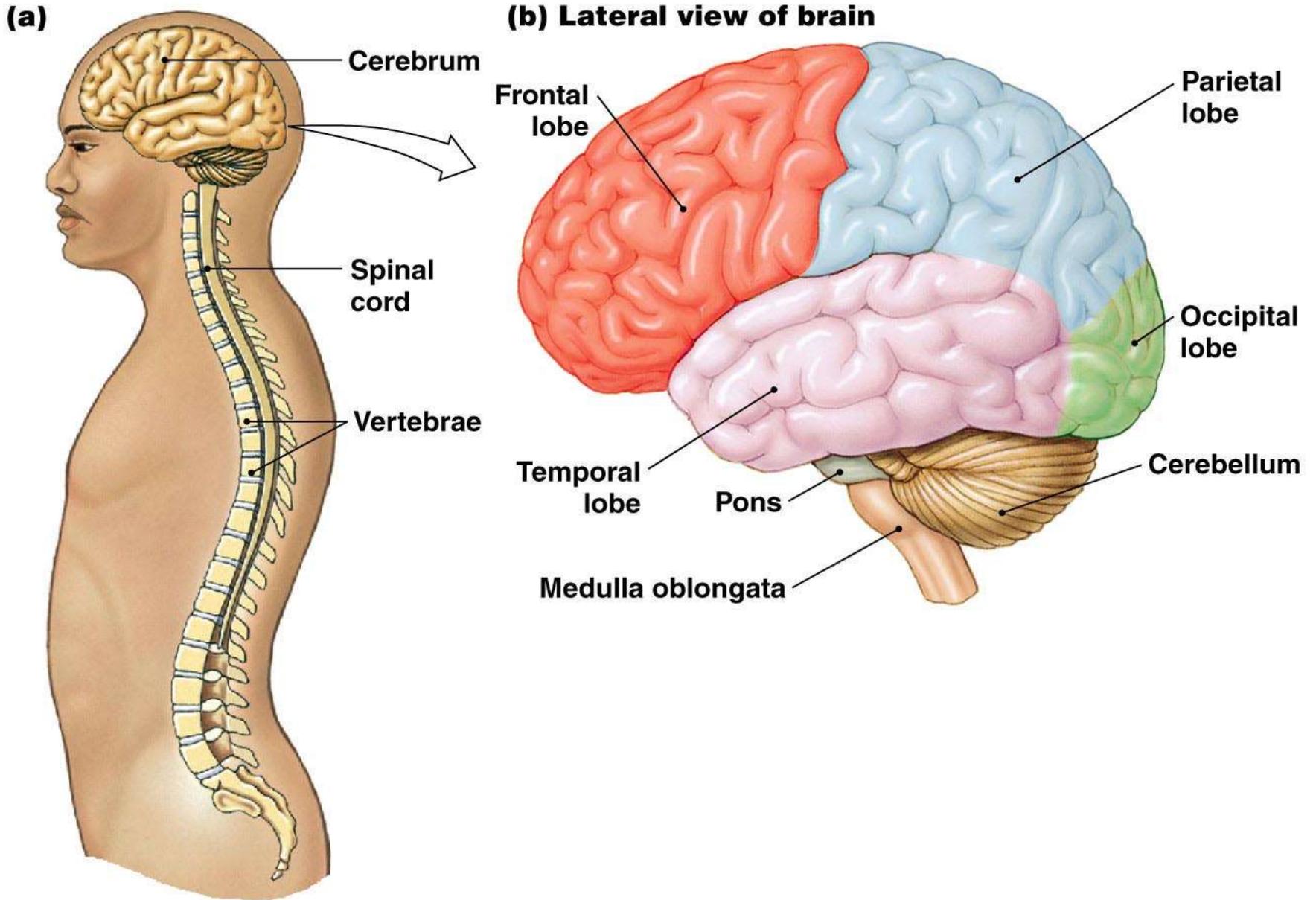
# Central Nervous System (CNS)



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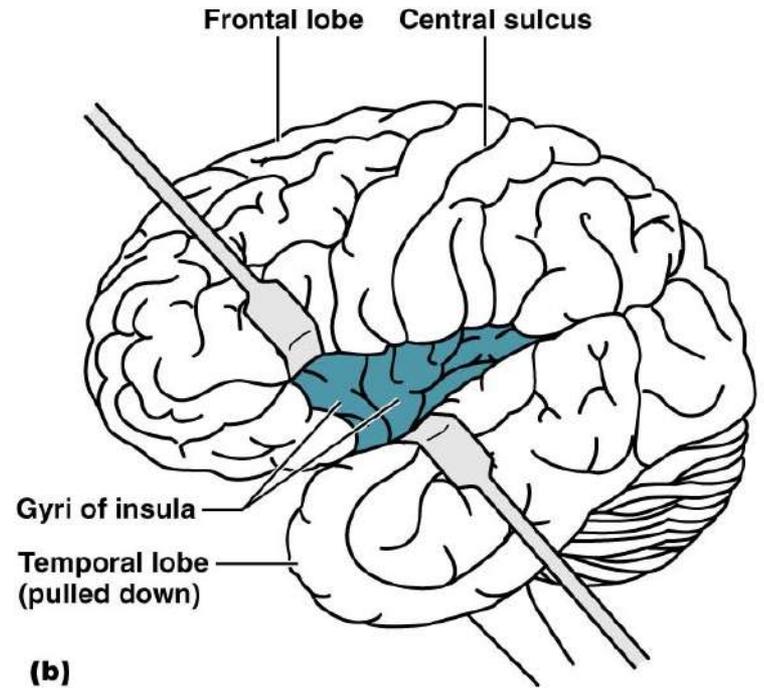
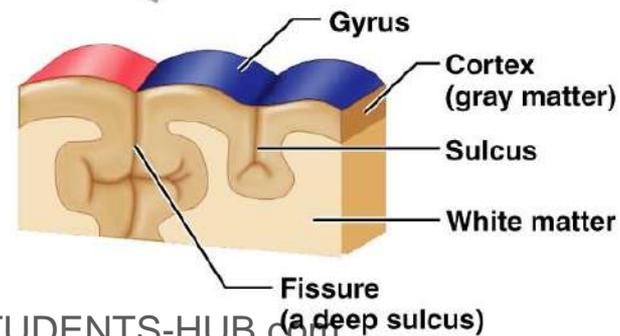
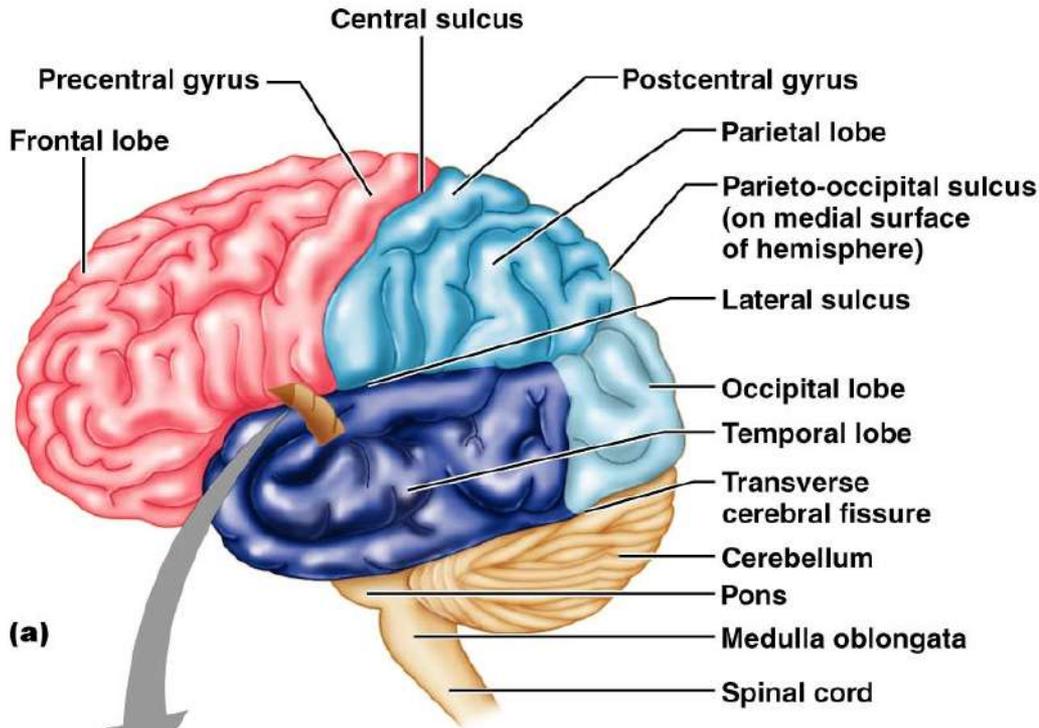
# Human Brain: Ventral Aspect



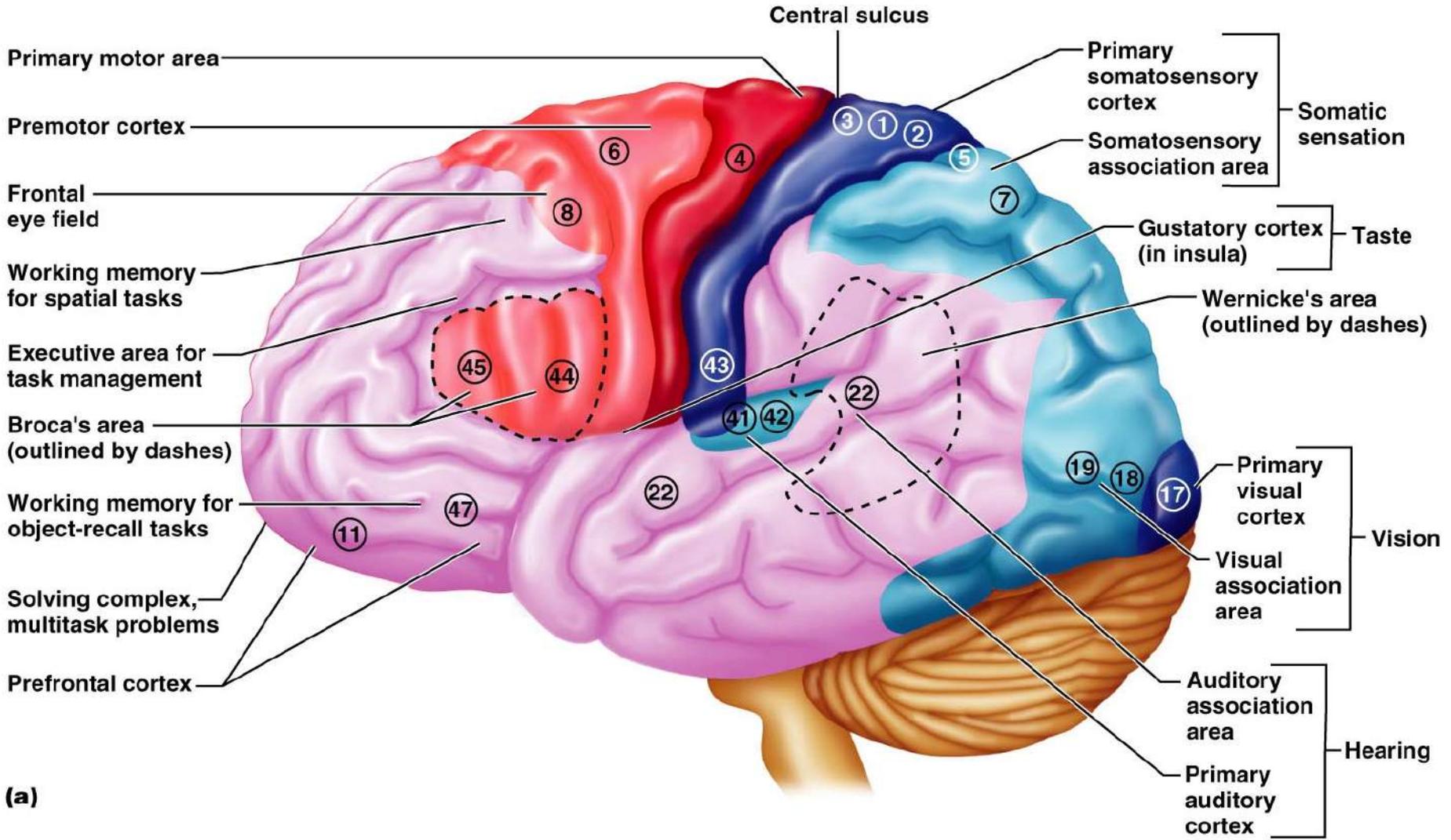


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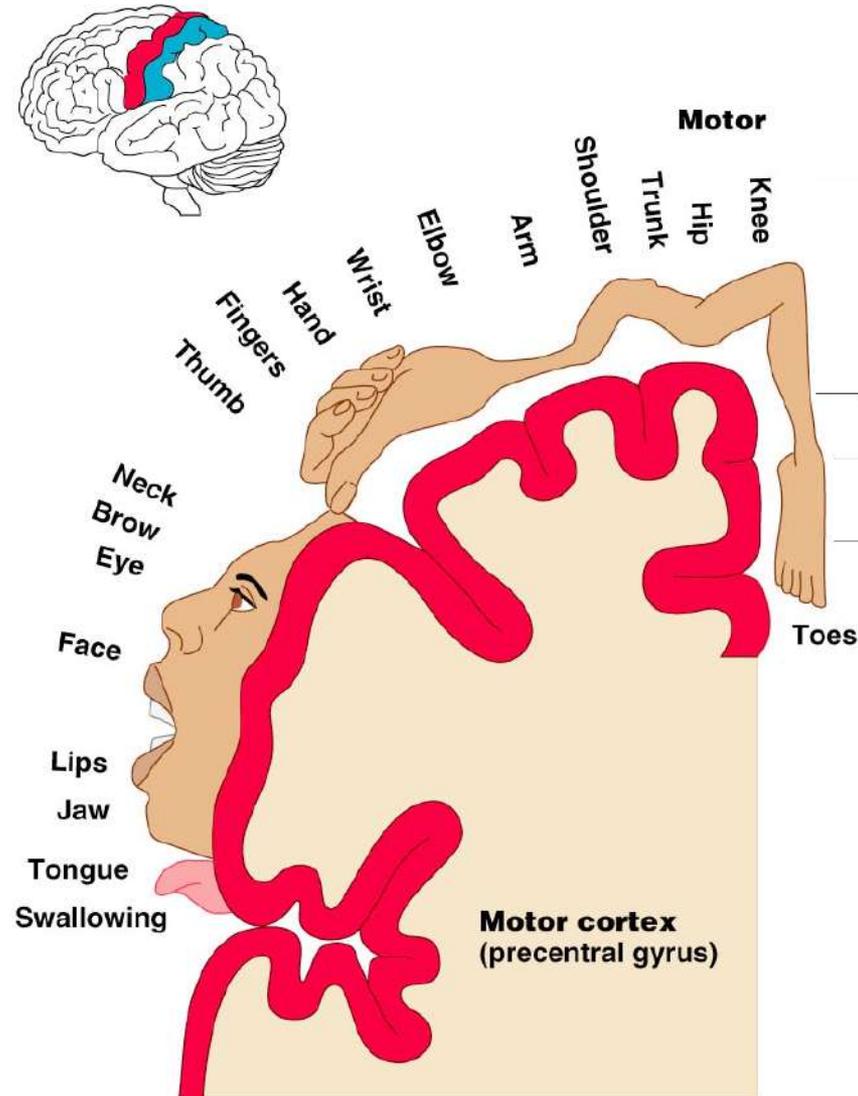
# Brain Lobes



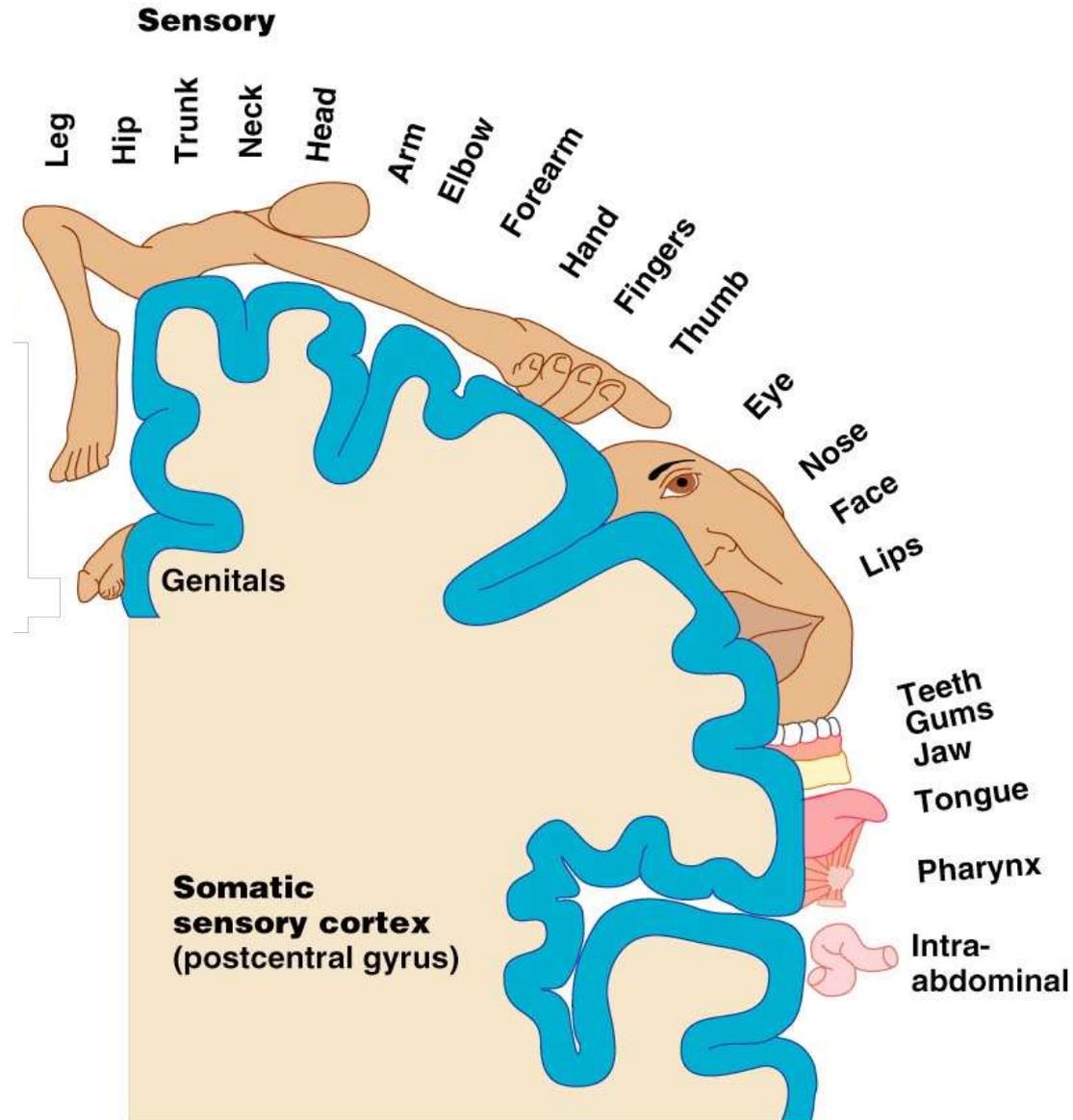
# Functional Areas of the Cerebral



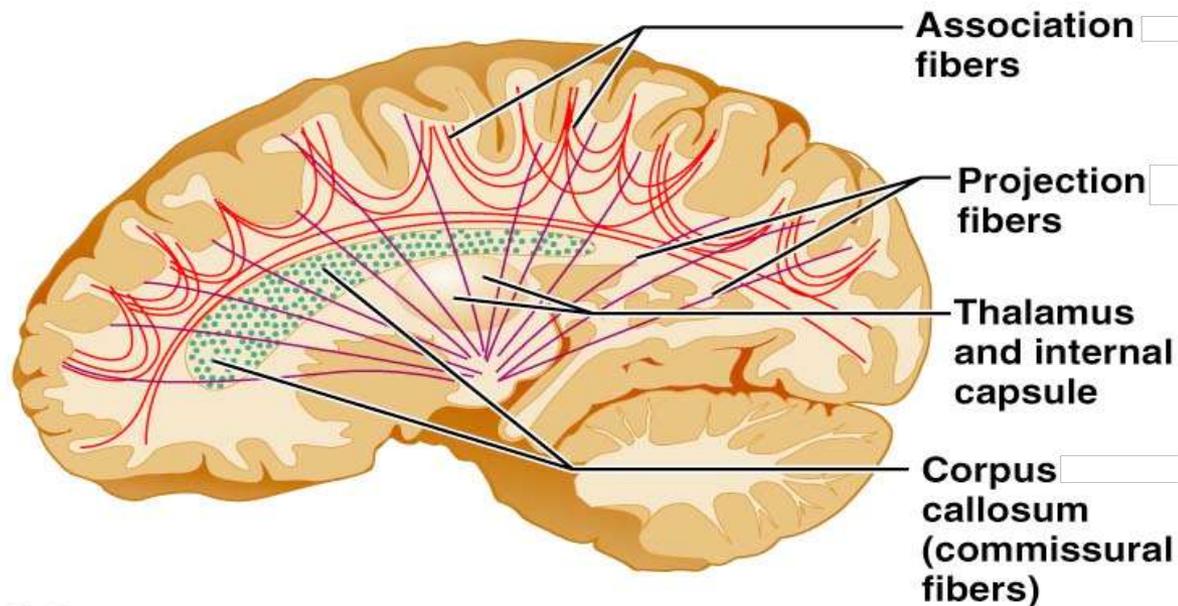
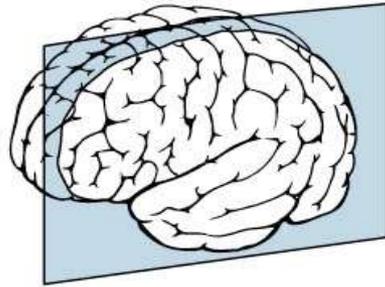
# Primary Motor Cortex Homunculus



# Primary Somatosensory Cortex

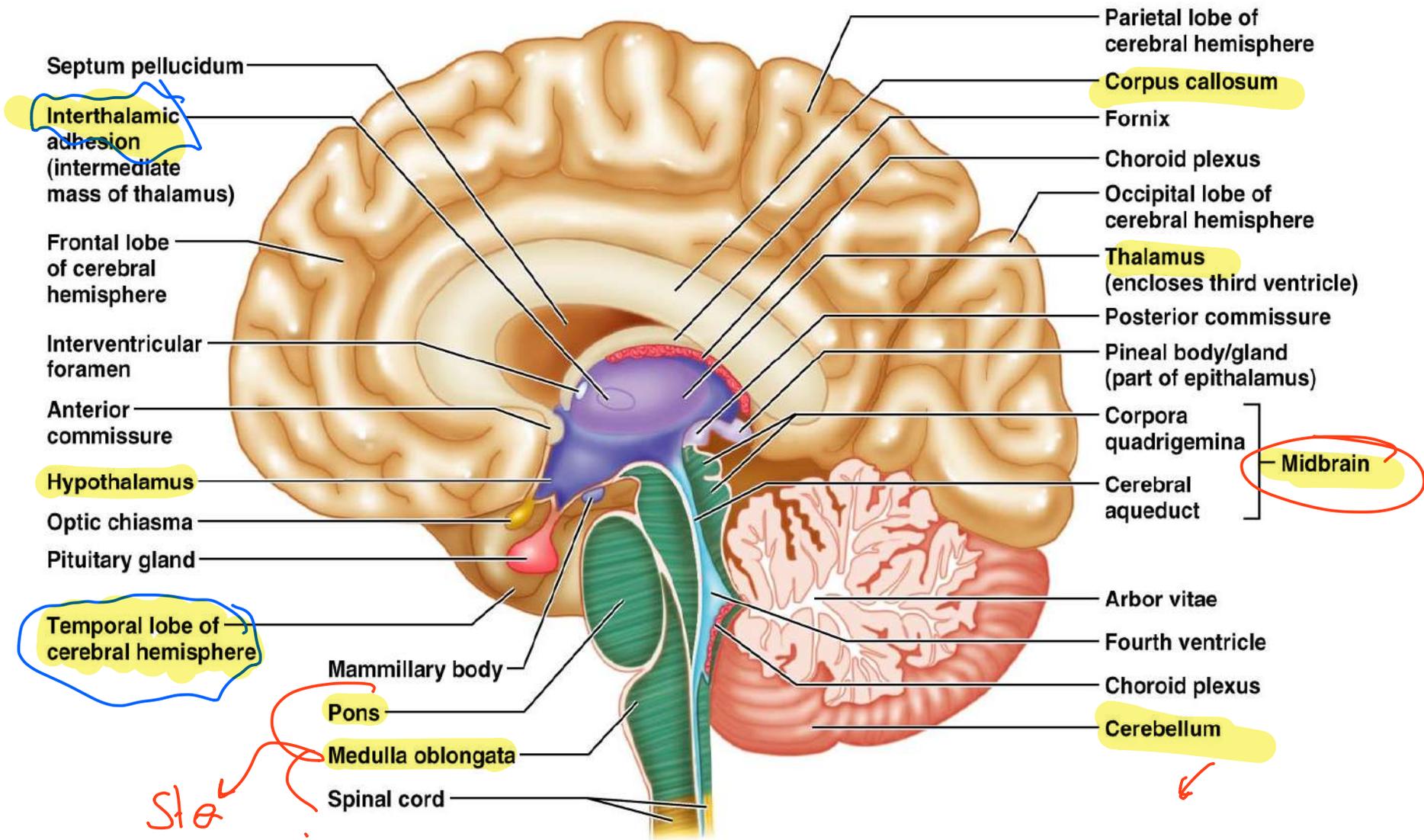


# Fiber Tracts in White Matter

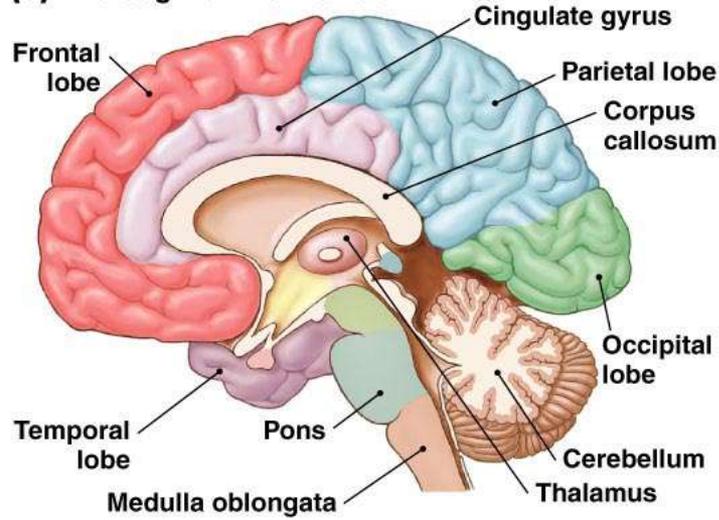


(a)

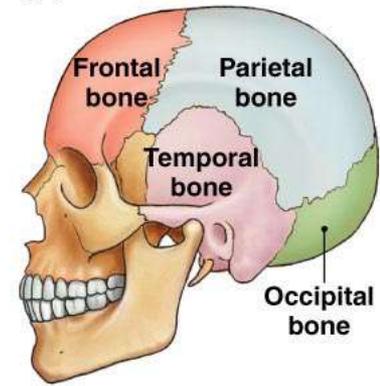
Projection (internal capsule) fibers



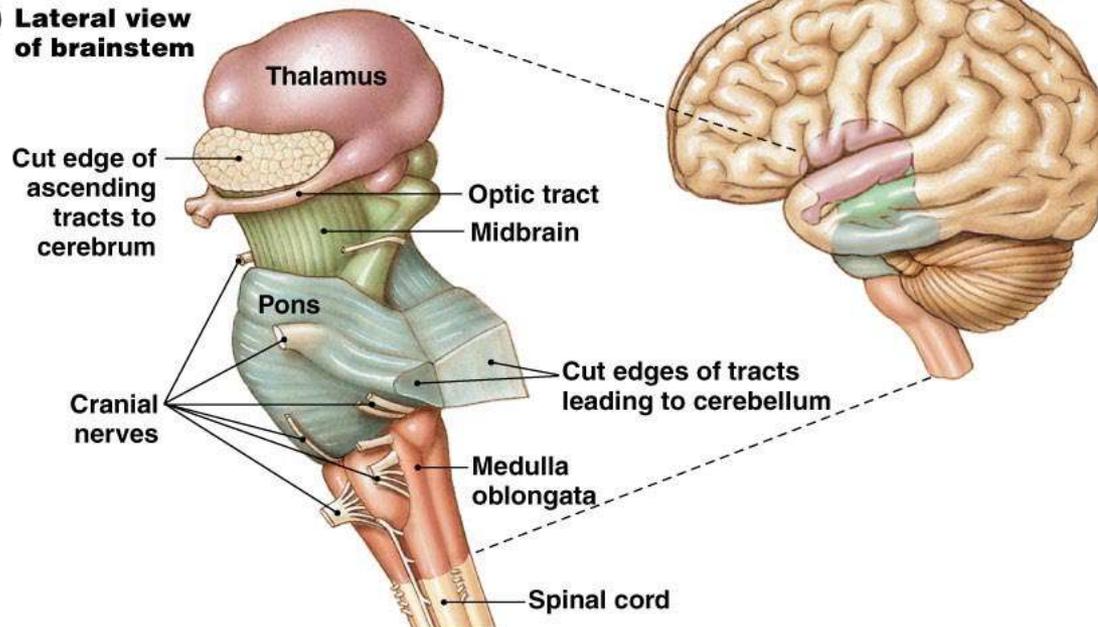
**(c) Mid-sagittal view of brain**

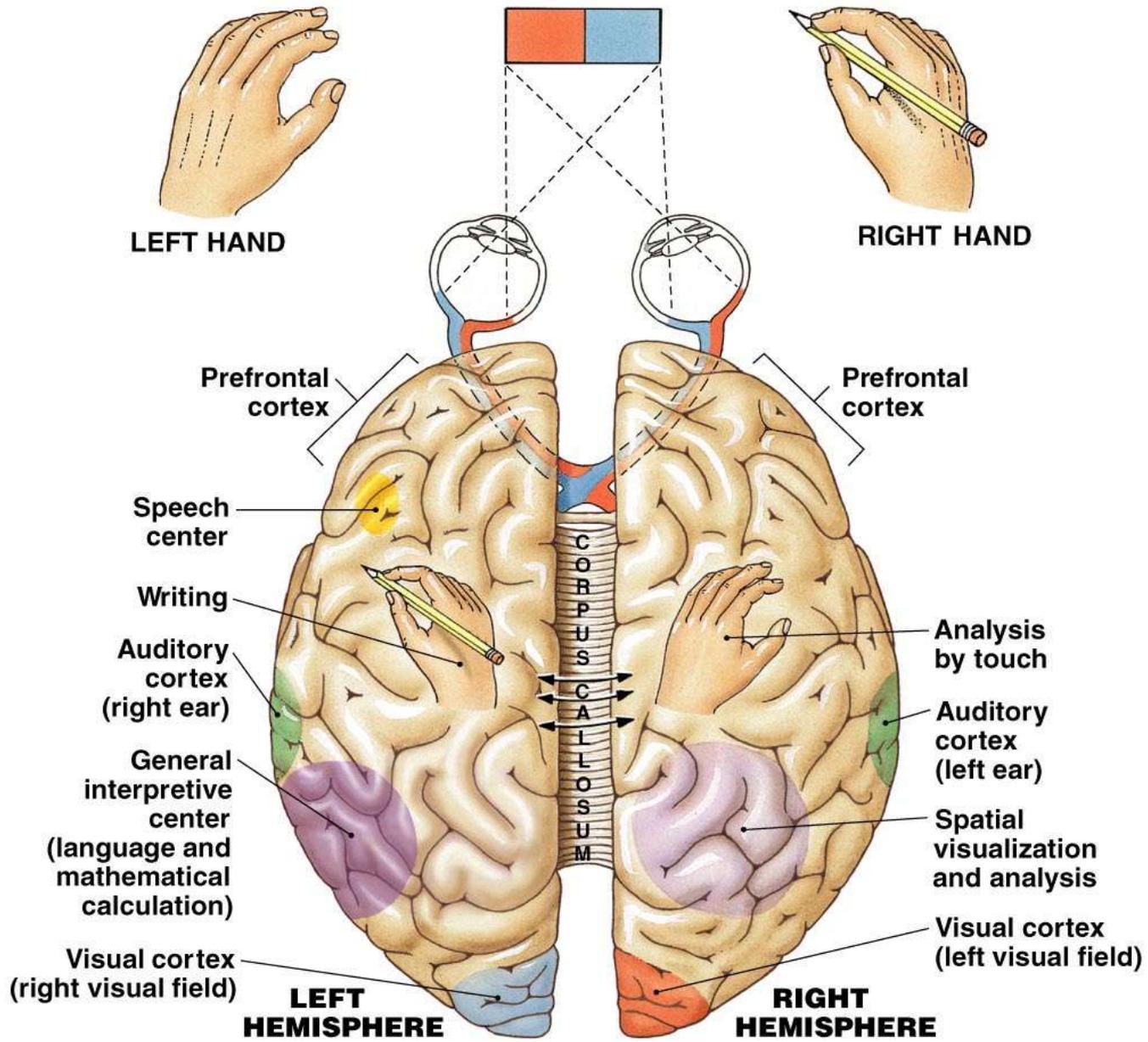


**(e) The skull**



**(d) Lateral view of brainstem**

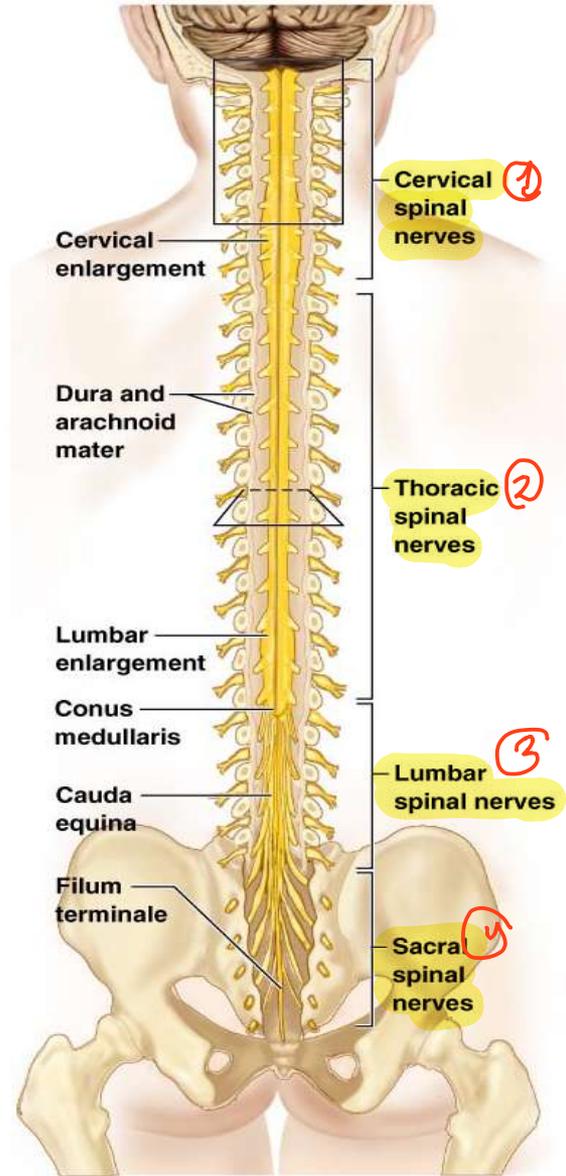




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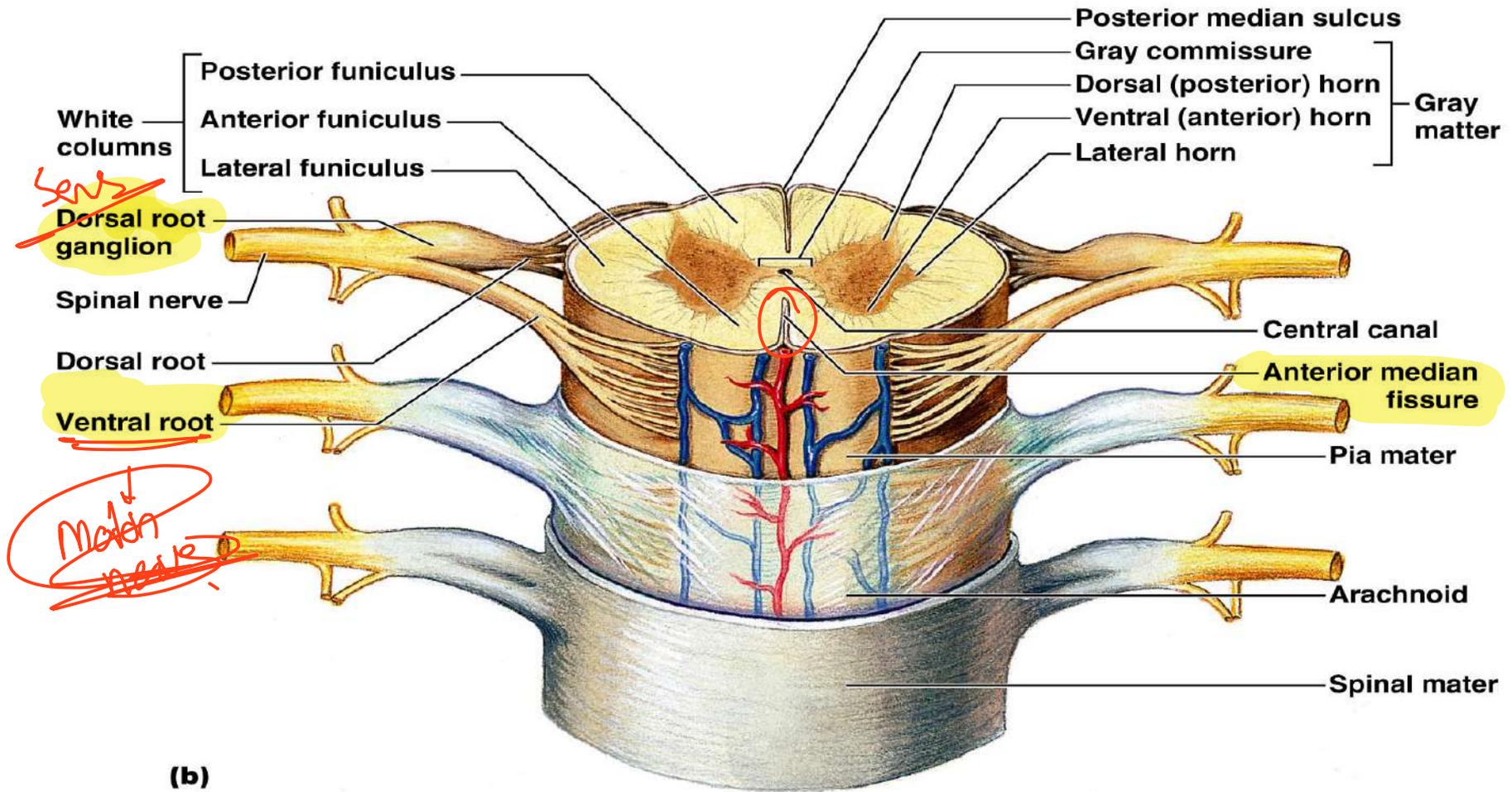
# Spinal Cord

↳ Part of the CNS



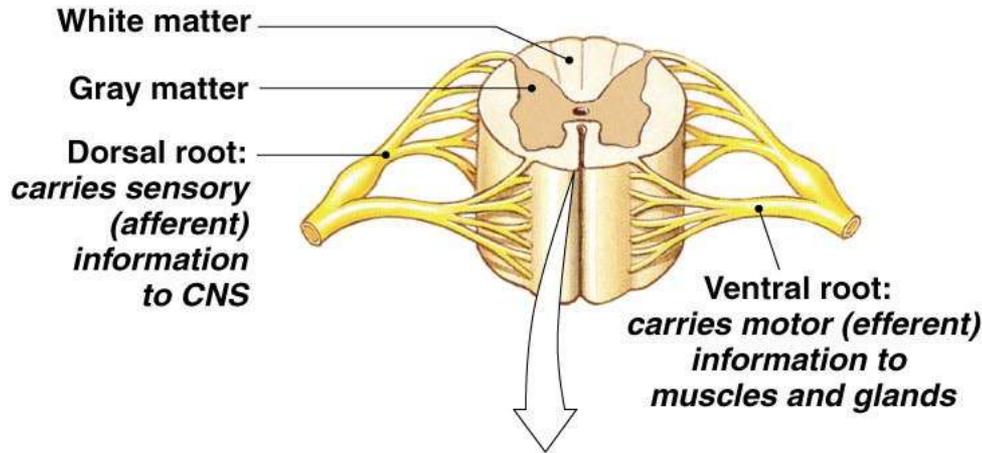
(a)

# Gray Matter and Spinal Roots

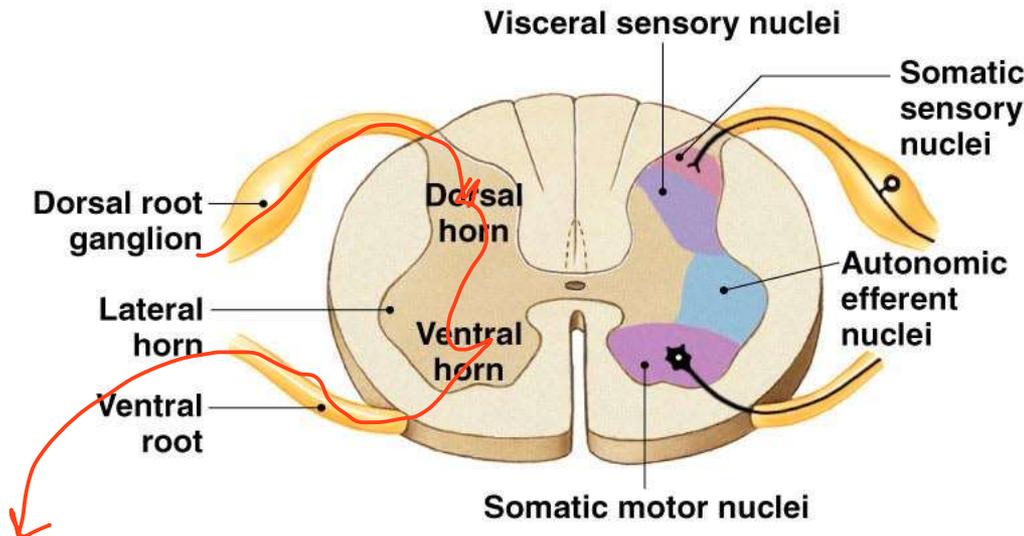


(b)

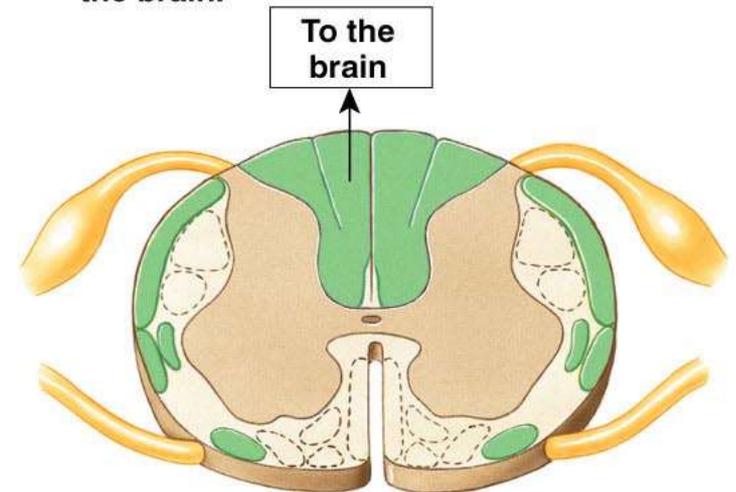
**(a)** One segment of spinal cord, ventral view, showing its pair of nerves



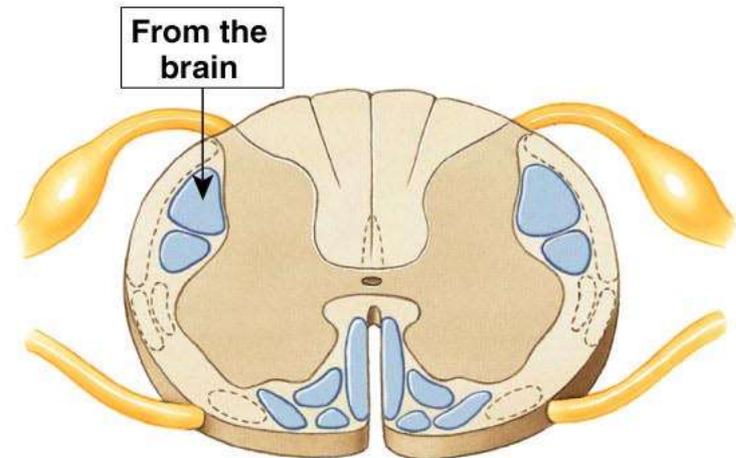
**(b)** Gray matter consists of sensory and motor nuclei



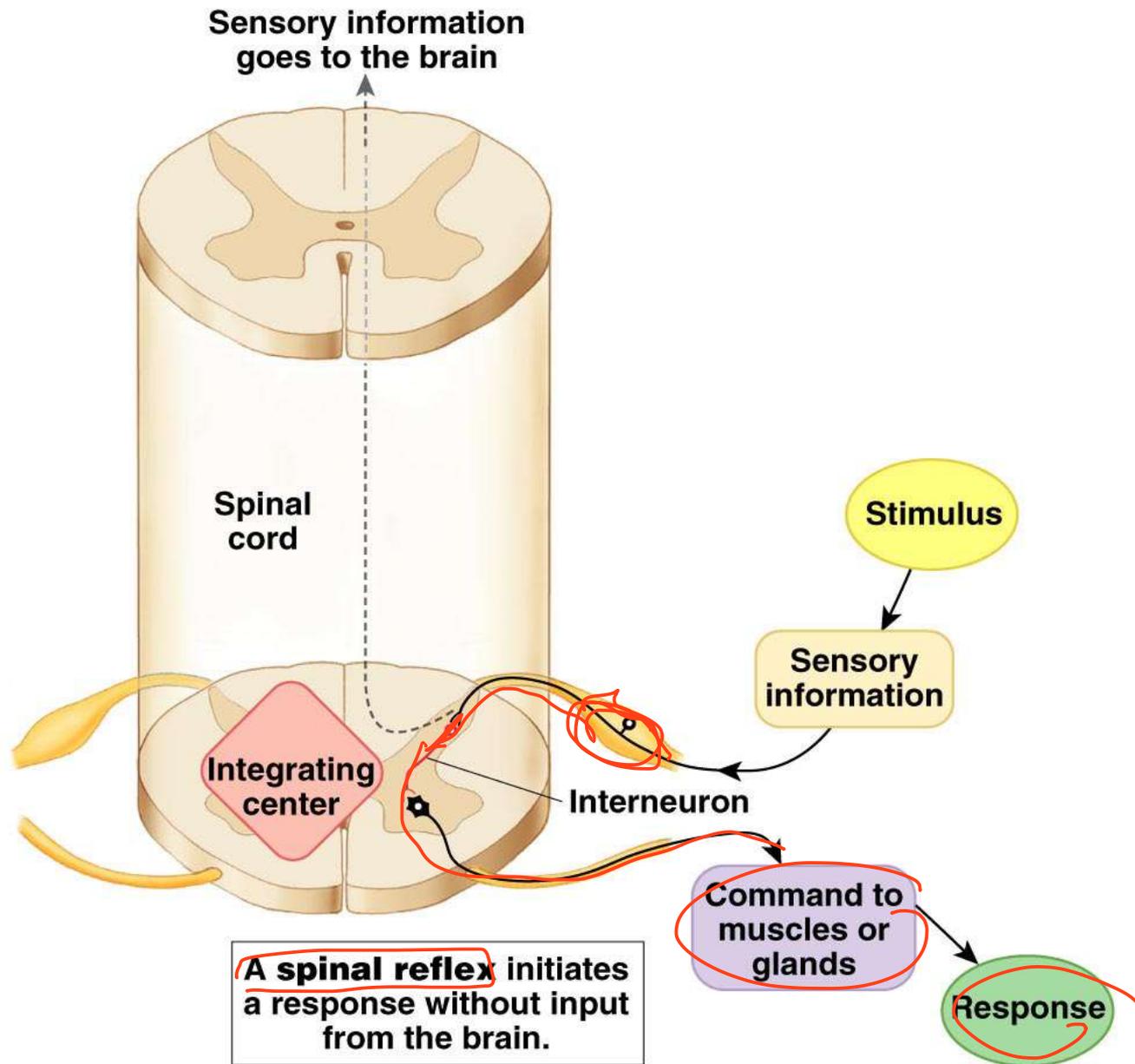
**(c)** White matter in the spinal cord consists of axons carrying information to and from the brain.



Ascending tracts carry sensory information to the brain.



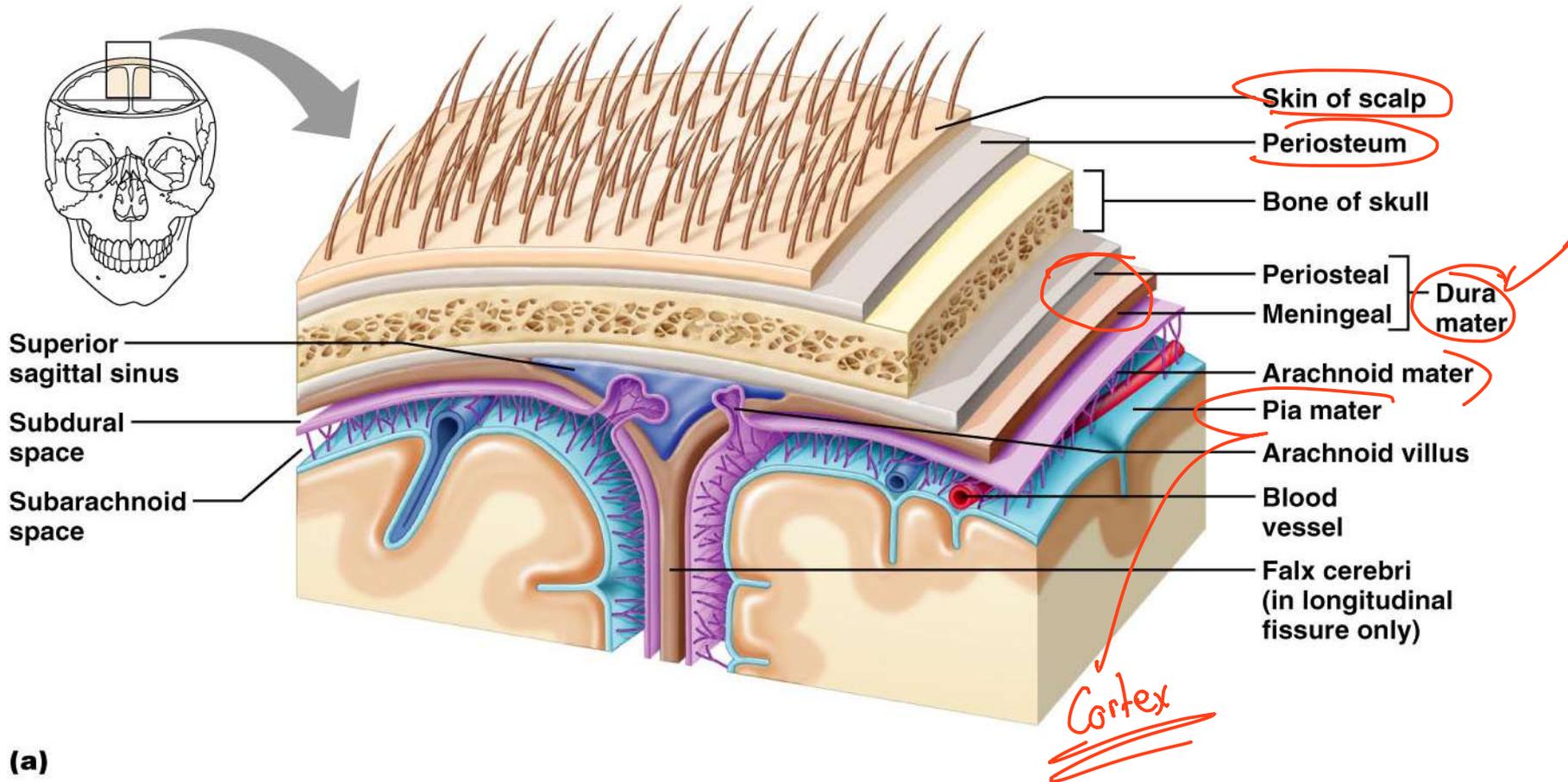
Descending tracts carry commands to motor neurons.



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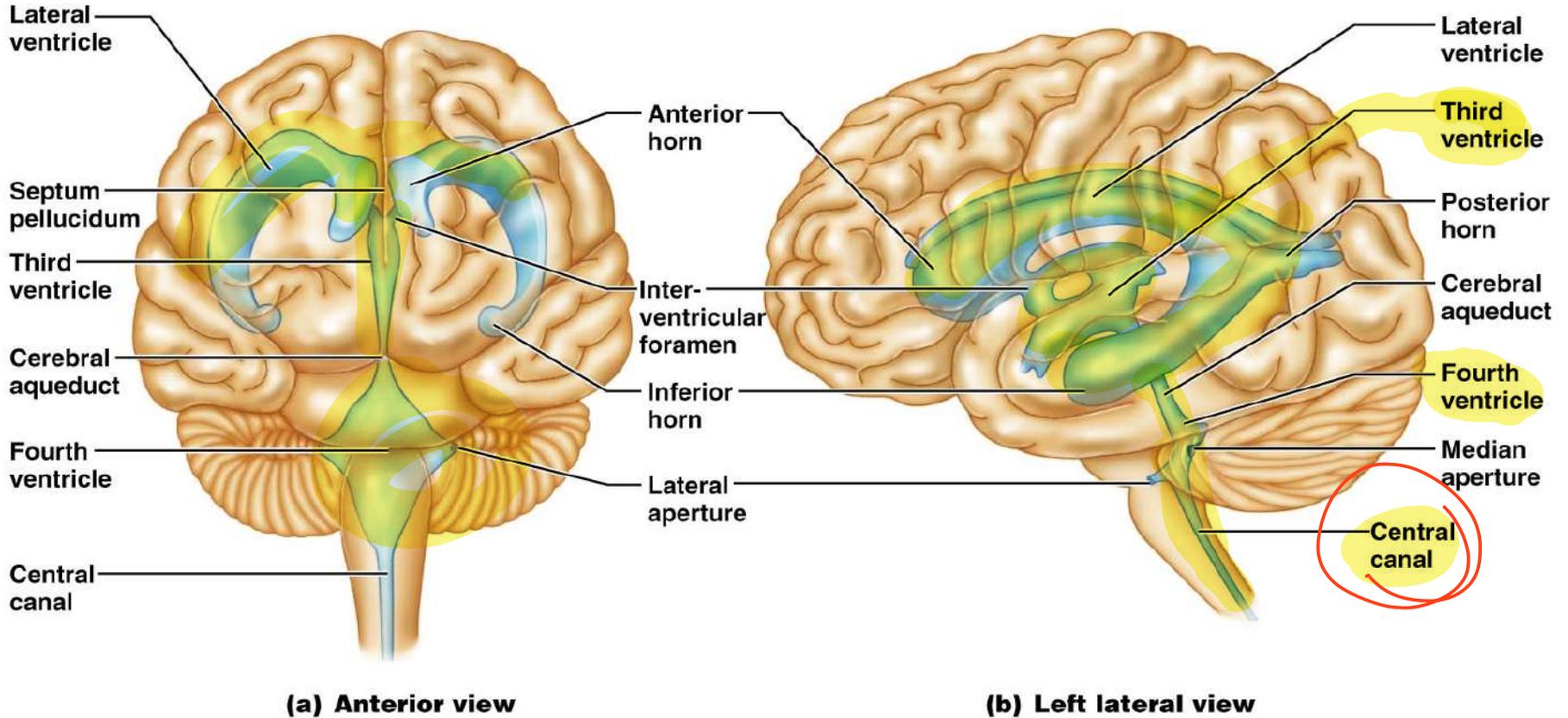
Dura mater  $\Rightarrow$  2 layer

# Meninges



(a)

# Ventricles of the Brain



# Cerebrospinal Fluid (CSF)

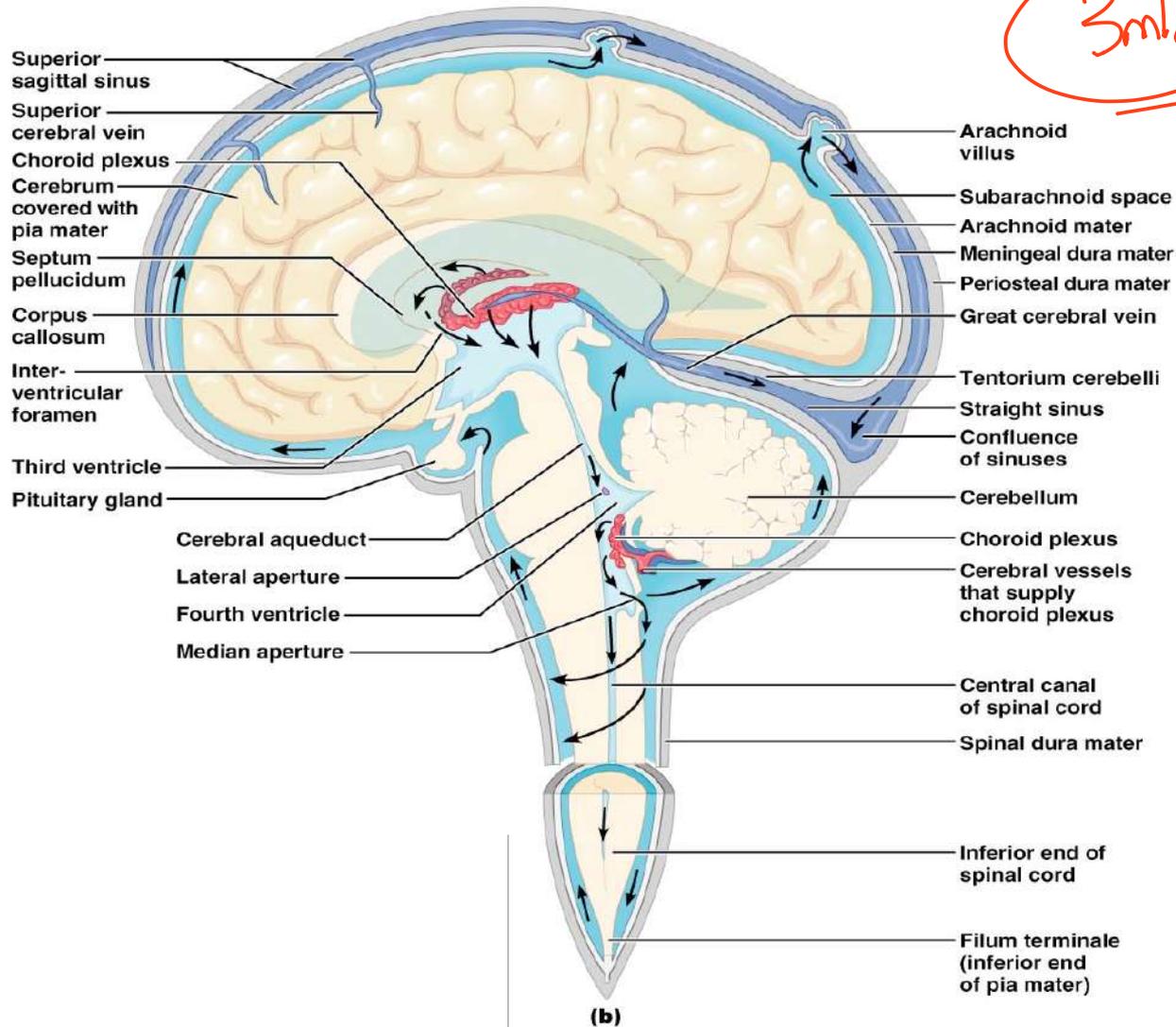
- Watery solution similar in composition to blood plasma
- Contains less protein and different ion concentrations than plasma
- Forms a liquid cushion that gives buoyancy to the CNS organs

# Cerebrospinal Fluid (CSF)

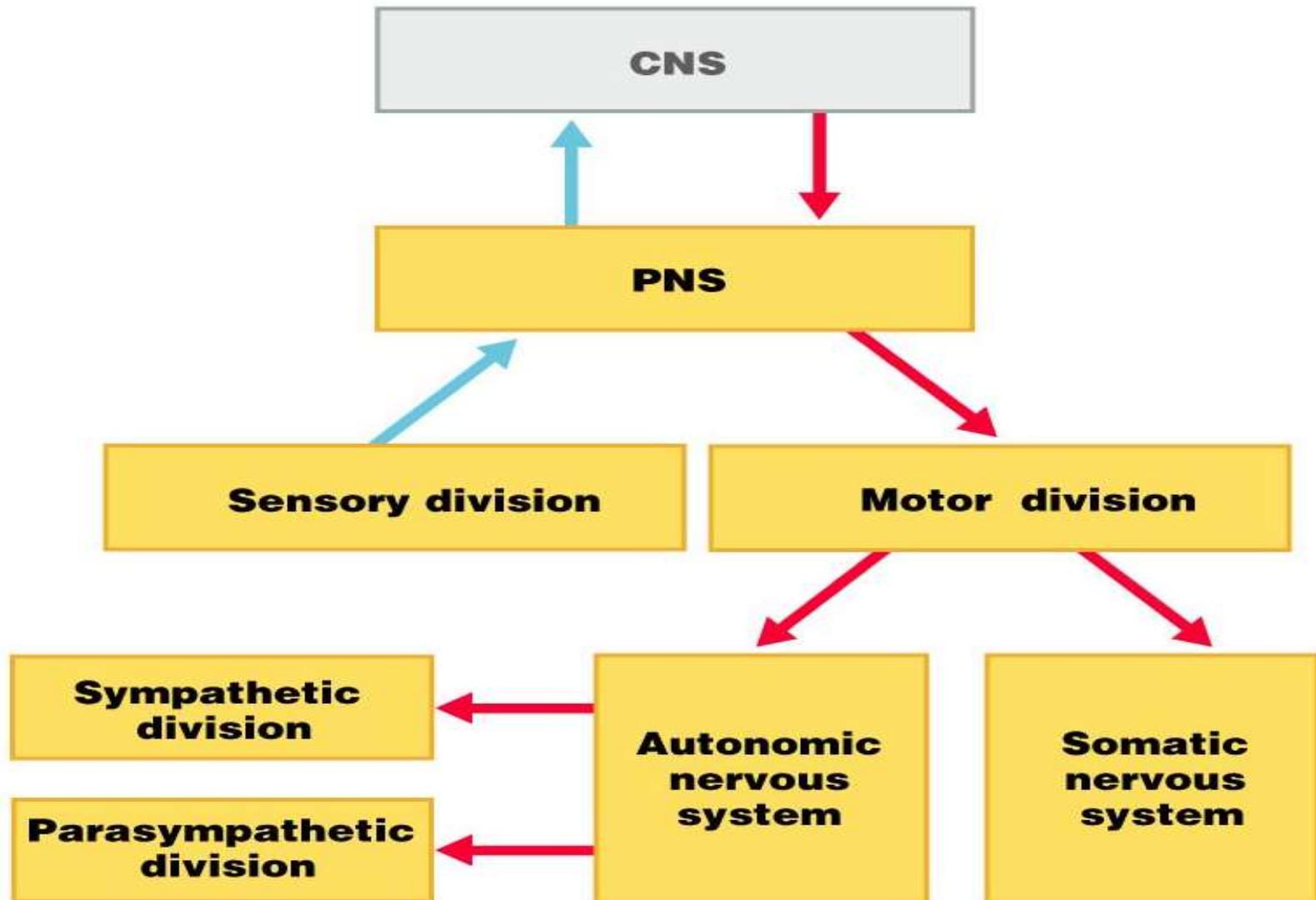
- Prevents the brain from crushing under its own weight
- Protects the CNS from blows and other trauma
- Nourishes the brain and carries chemical signals throughout it

# Circulation of CSF

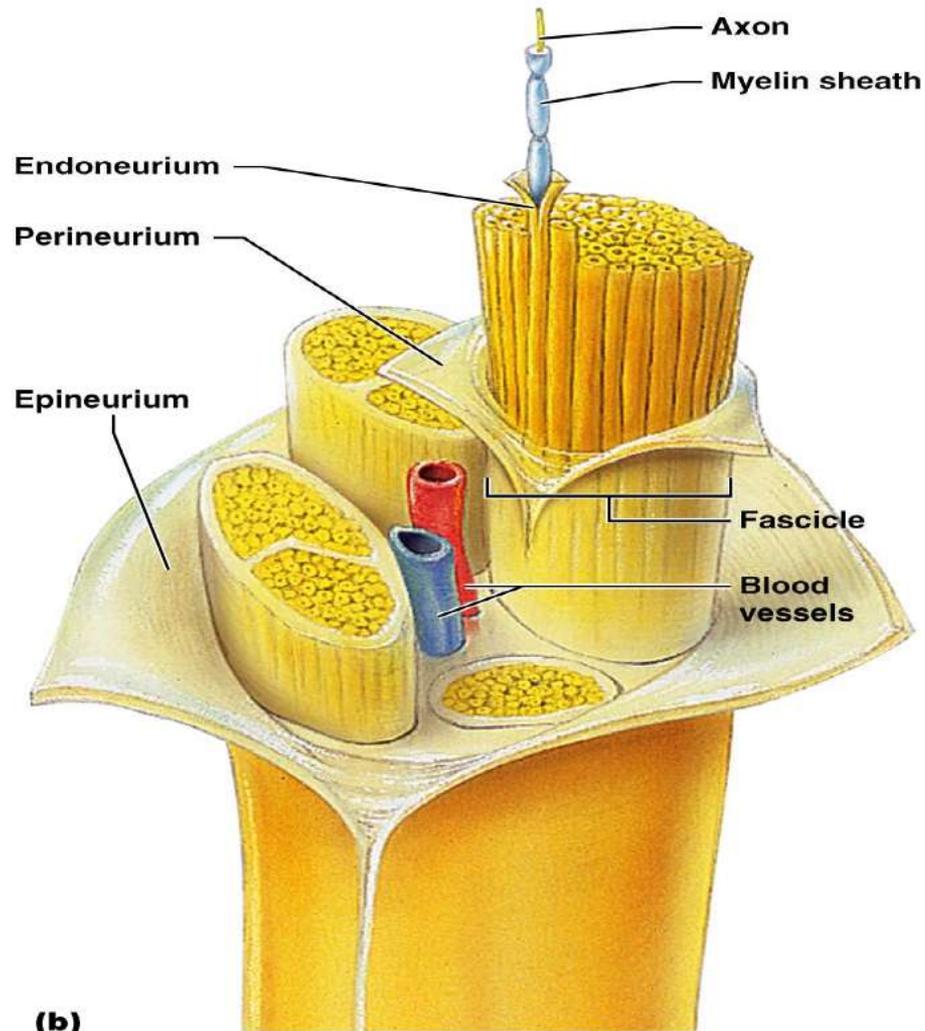
3ml/day

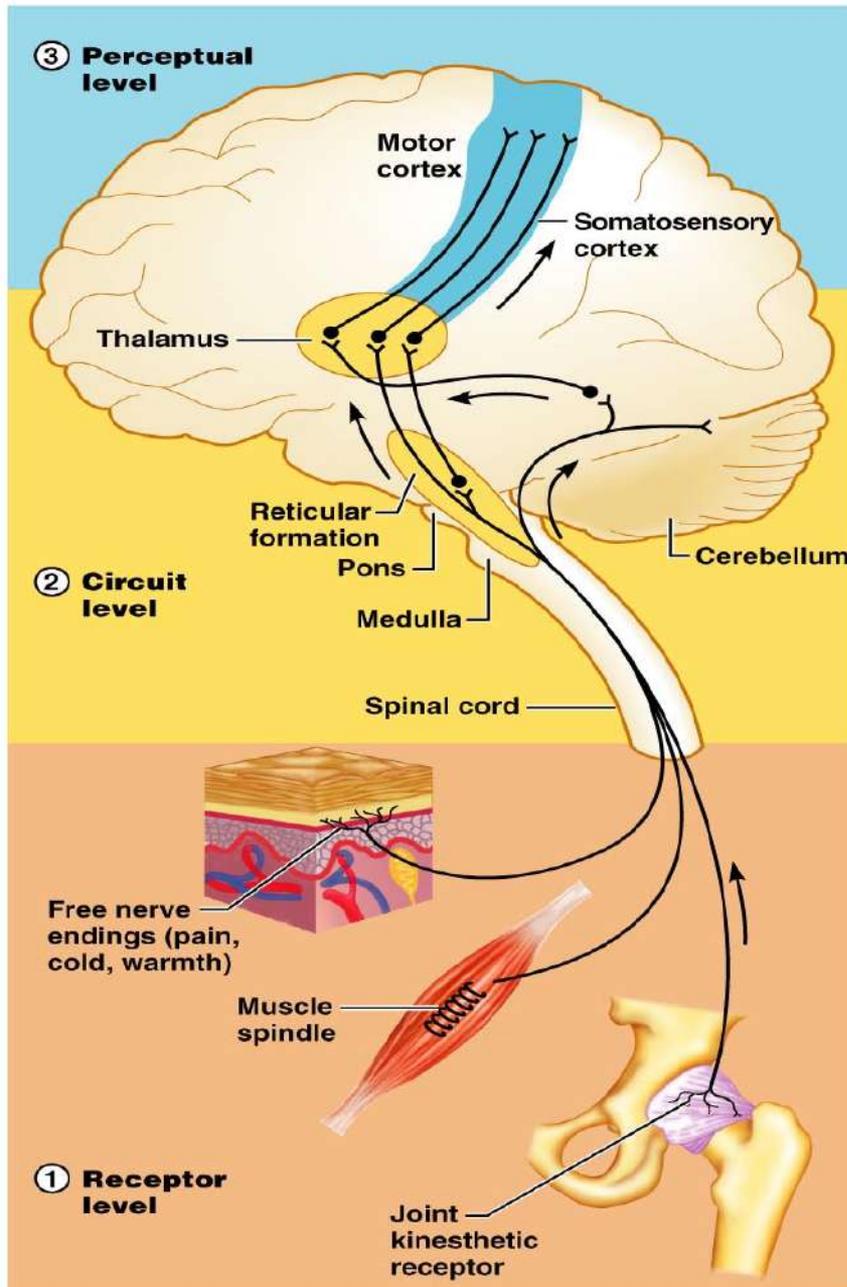


# PNS in the Nervous System

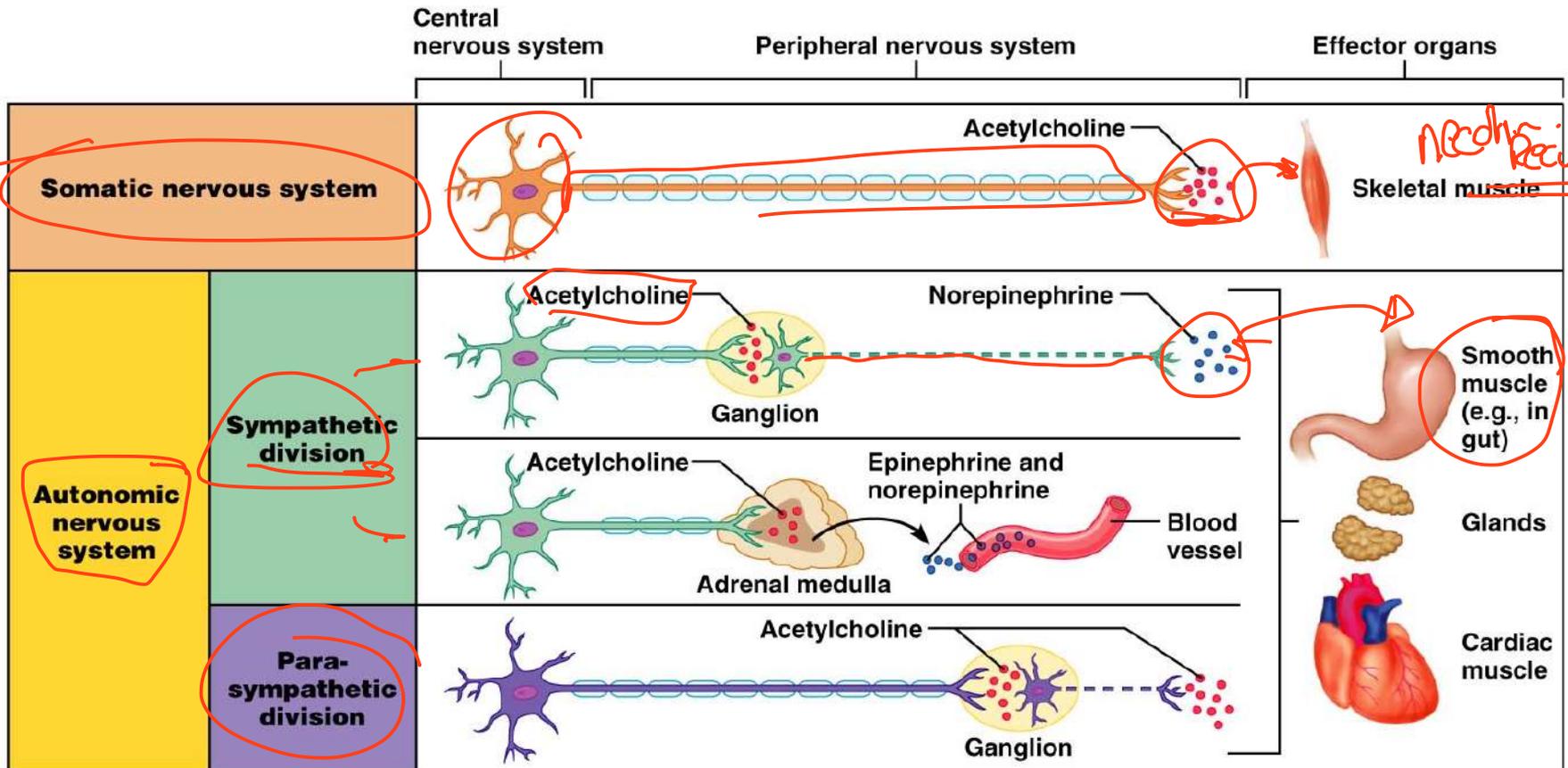


# Structure of a Nerve



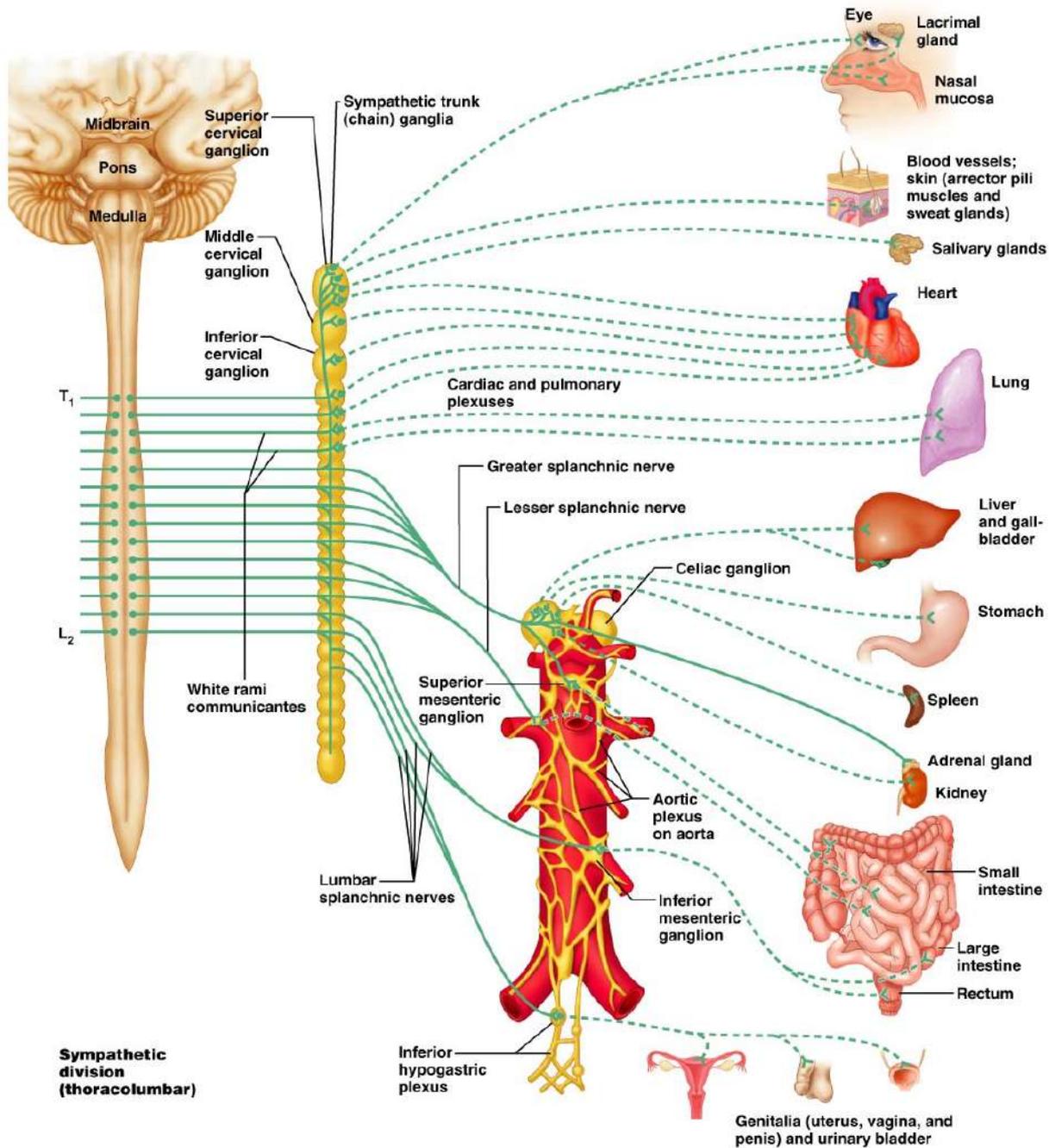


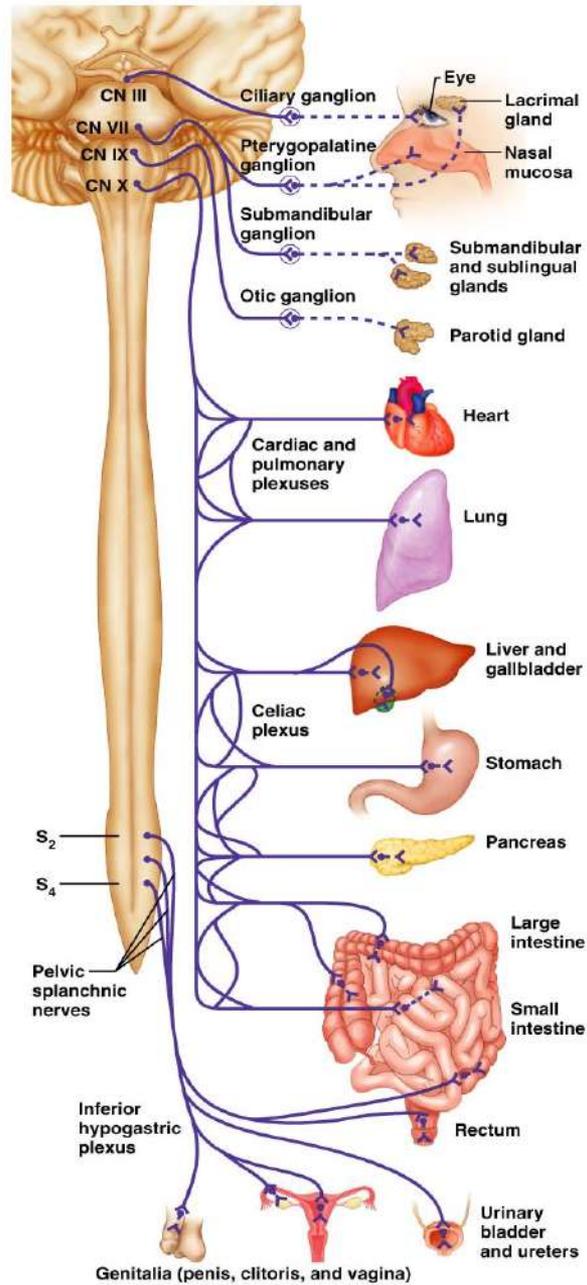
# Comparison of Somatic and Autonomic Systems



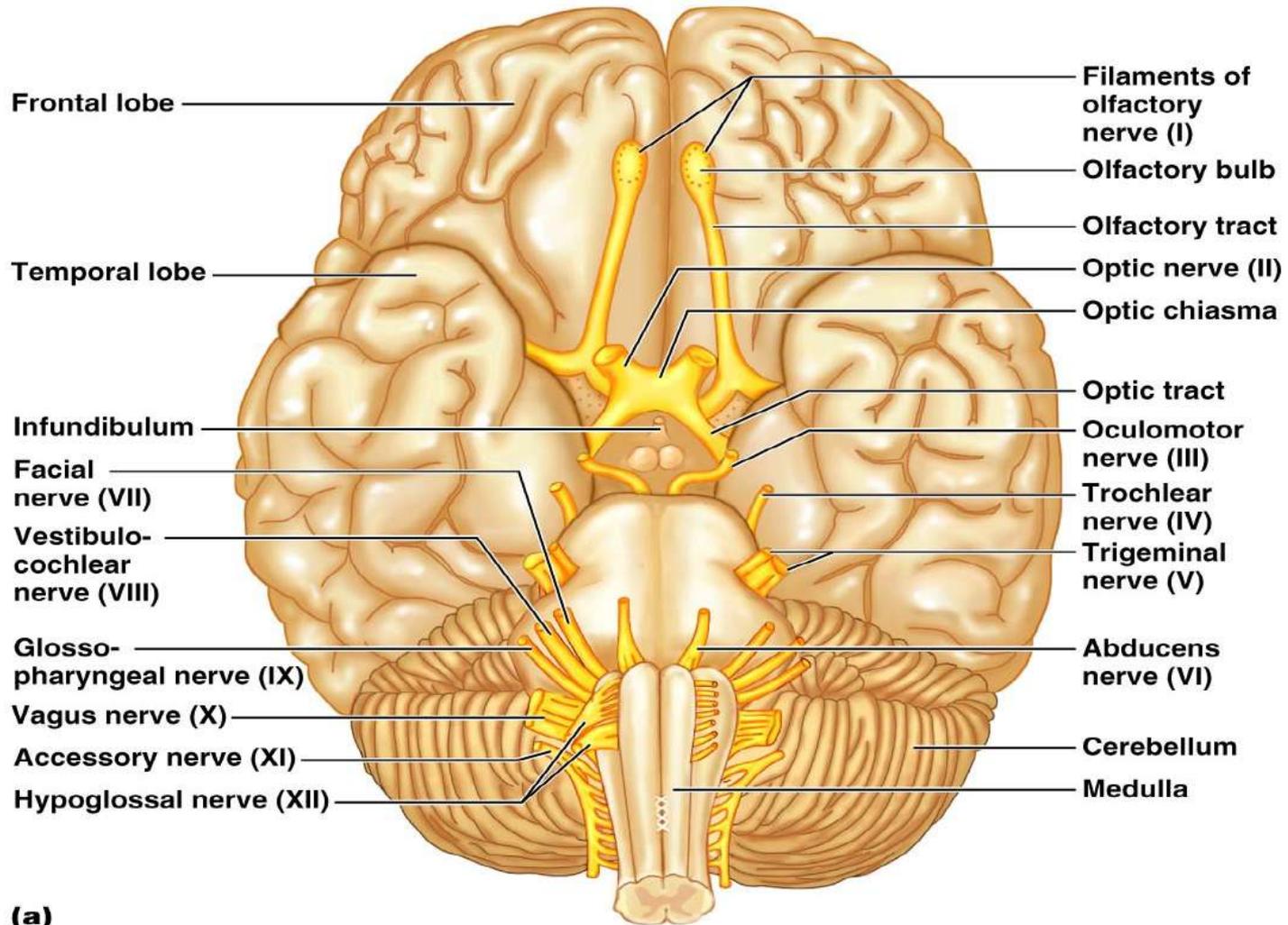
**Key:**

— = Preganglionic axons (sympathetic)   
 - - - = Postganglionic axons (sympathetic)   
 = Myelination   
 — = Preganglionic axons (parasympathetic)   
 - - - = Postganglionic axons (parasympathetic)





# Cranial Nerves



(a)

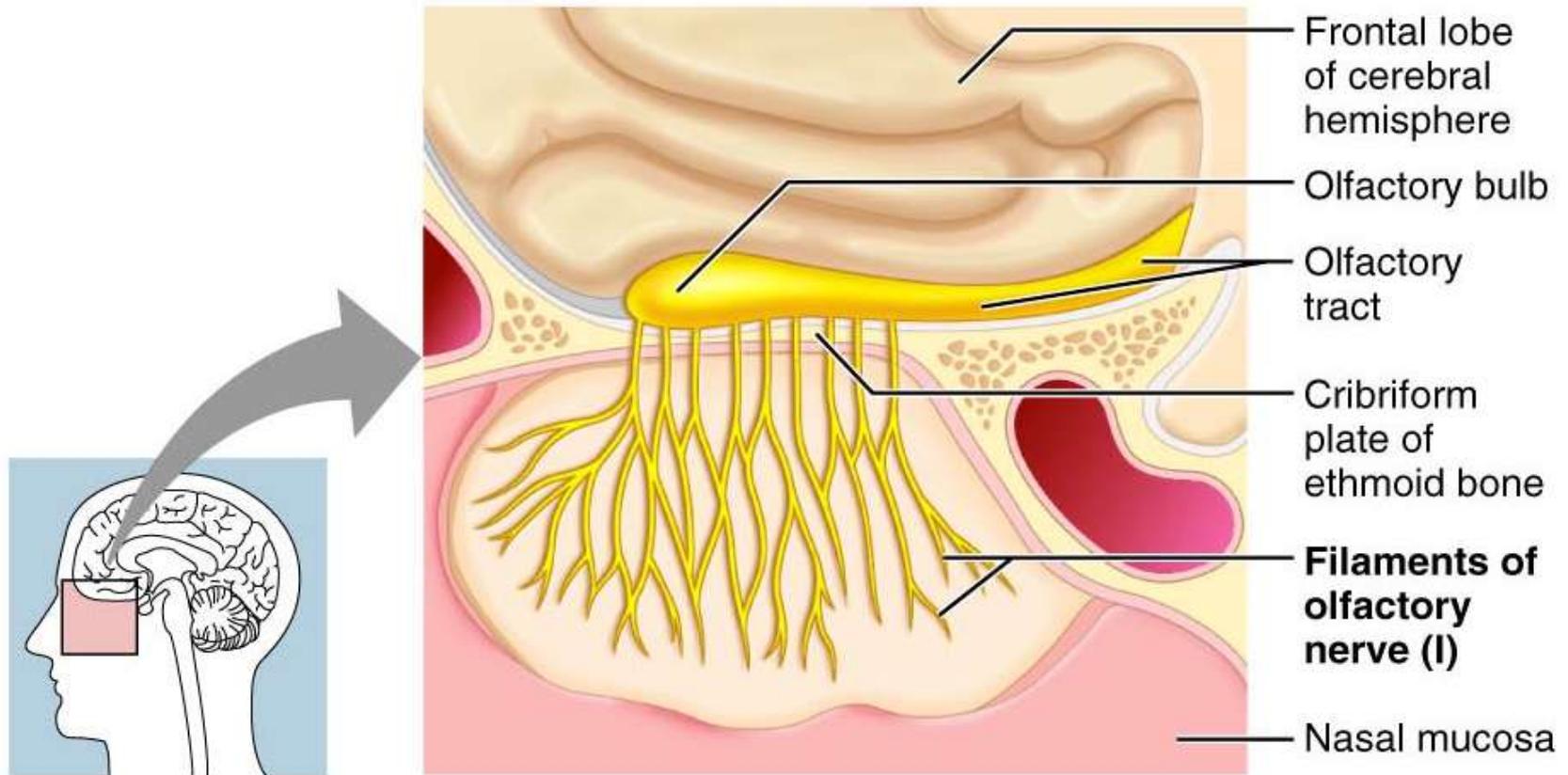
# Summary of Function of Cranial

<b>Cranial nerves I – VI</b>	<b>Sensory function</b>	<b>Motor function</b>	<b>PS* fibers</b>
I Olfactory	Yes (smell)	No	No
II Optic	Yes (vision)	No	No
III Oculomotor	No	Yes	Yes
IV Trochlear	No	Yes	No
V Trigeminal	Yes (general sensation)	Yes	No
VI Abducens	No	Yes	No

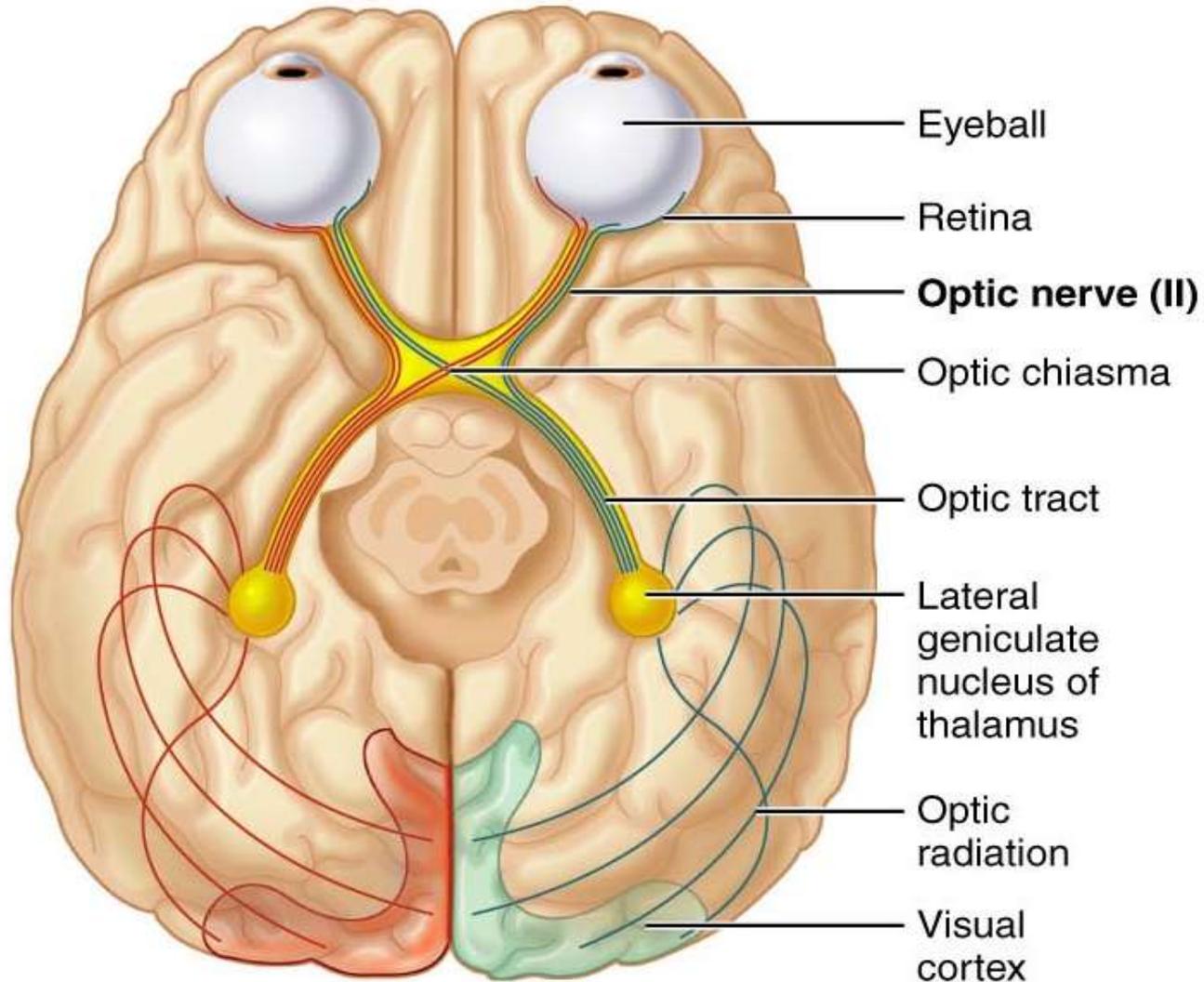
<b>Cranial nerves VII – XII</b>	<b>Sensory function</b>	<b>Motor function</b>	<b>PS* fibers</b>
VII Facial	Yes (taste)	Yes	Yes
VIII Vestibulocochlear	Yes (hearing and balance)	Some	No
IX Glossopharyngeal	Yes (taste)	Yes	Yes
X Vagus	Yes (taste)	Yes	Yes
XI Accessory	No	Yes	No
XII Hypoglossal	No	Yes	No

**(b)** \*PS = parasympathetic

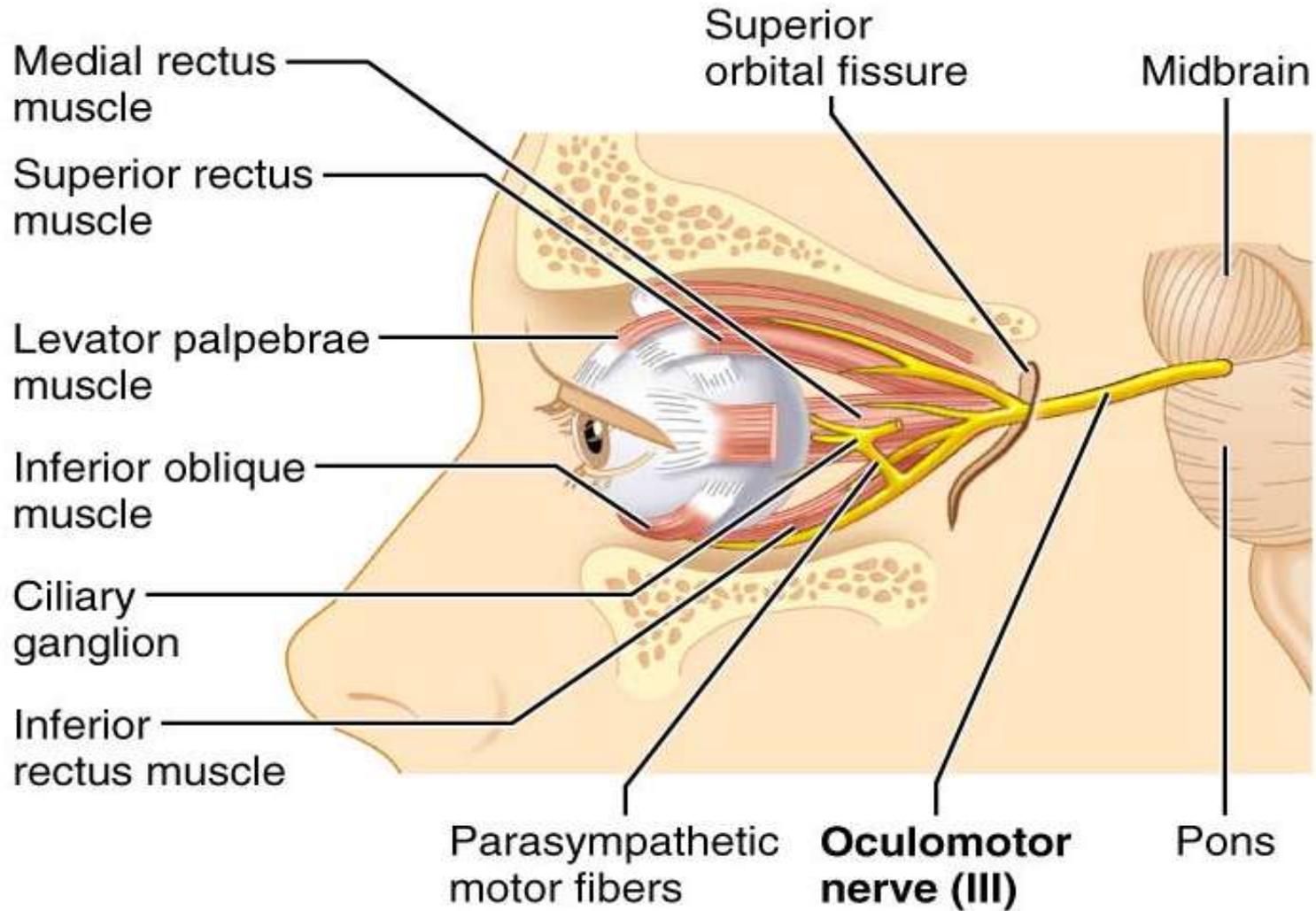
# Cranial Nerve I: Olfactory

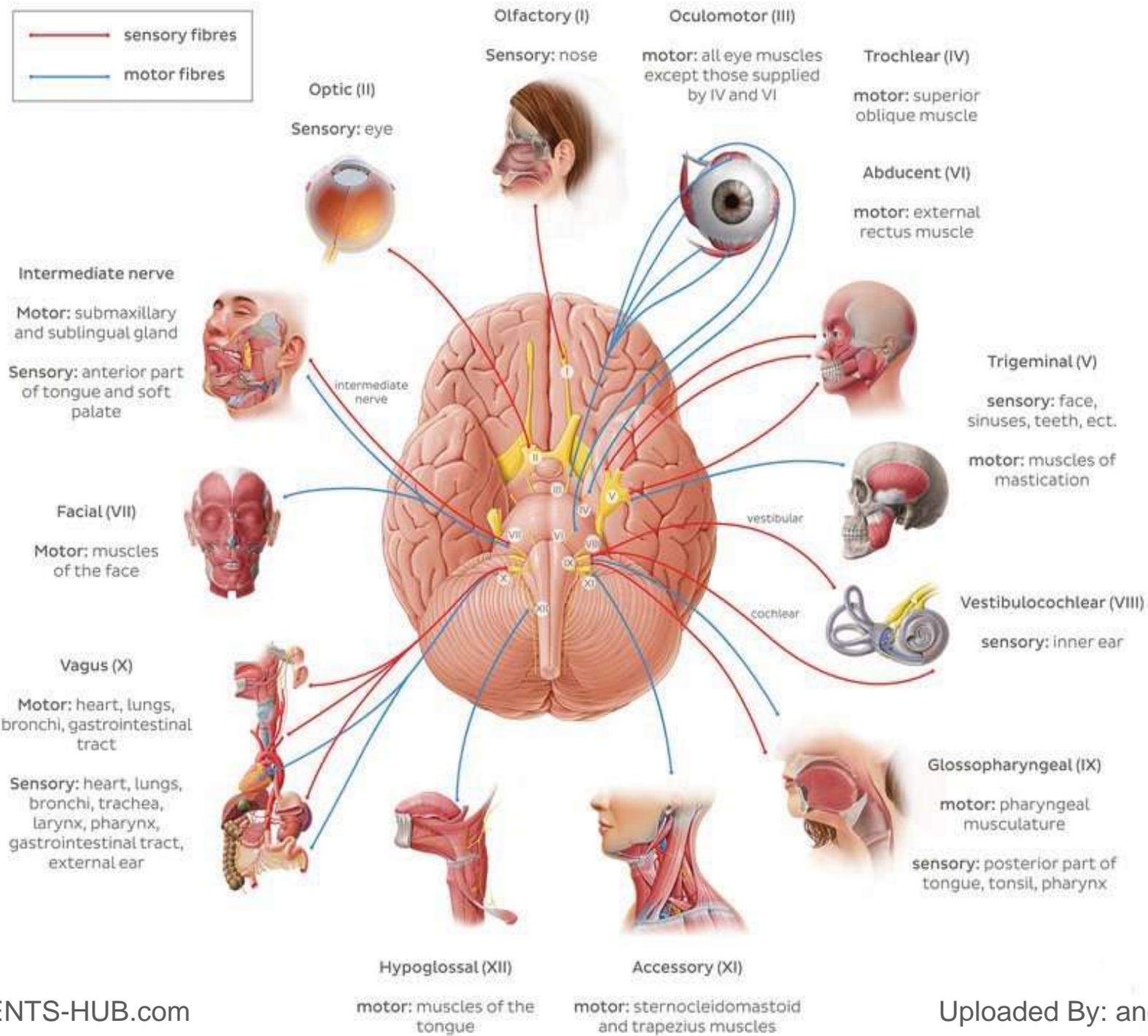


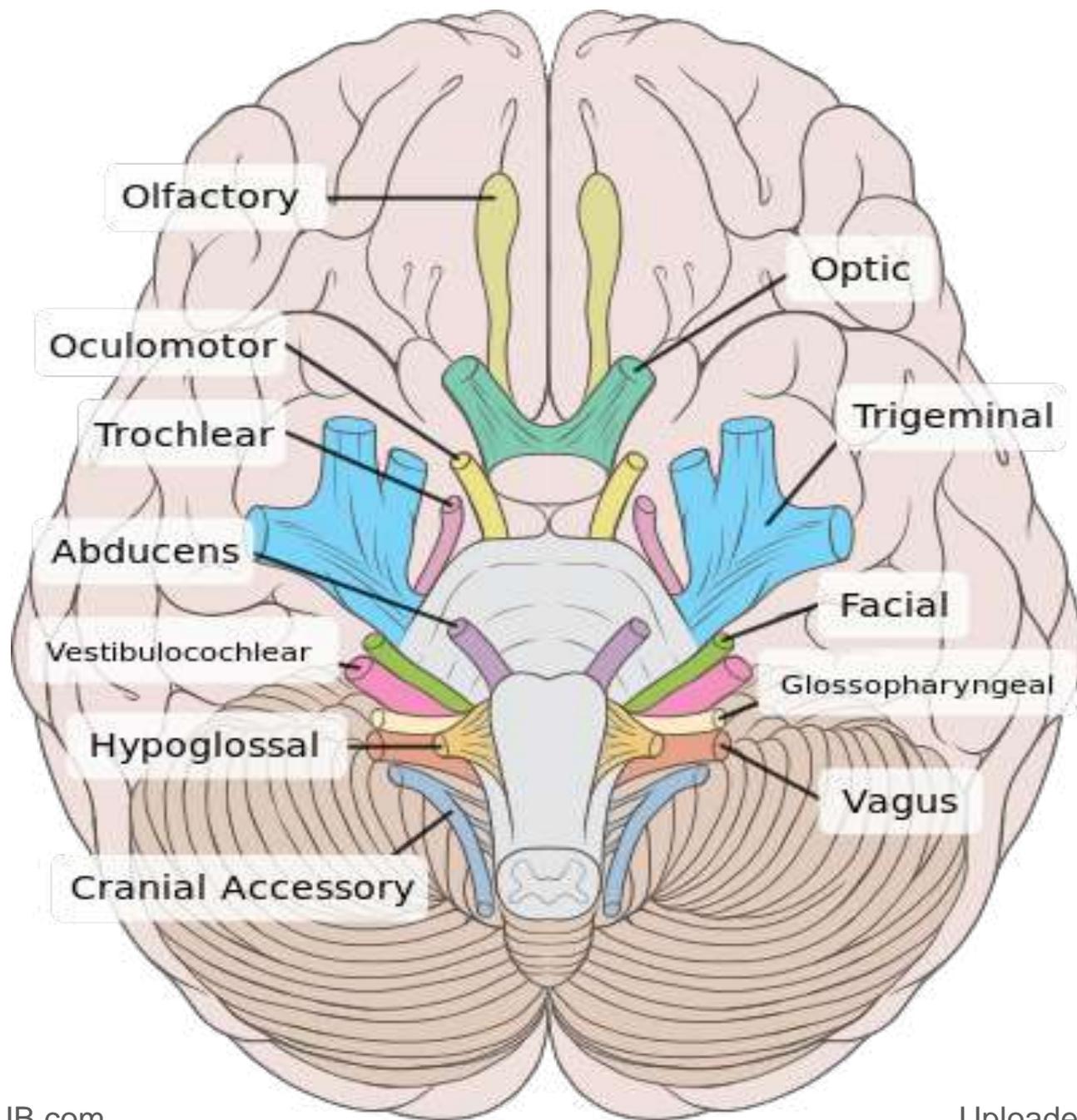
# Cranial Nerve II: Optic

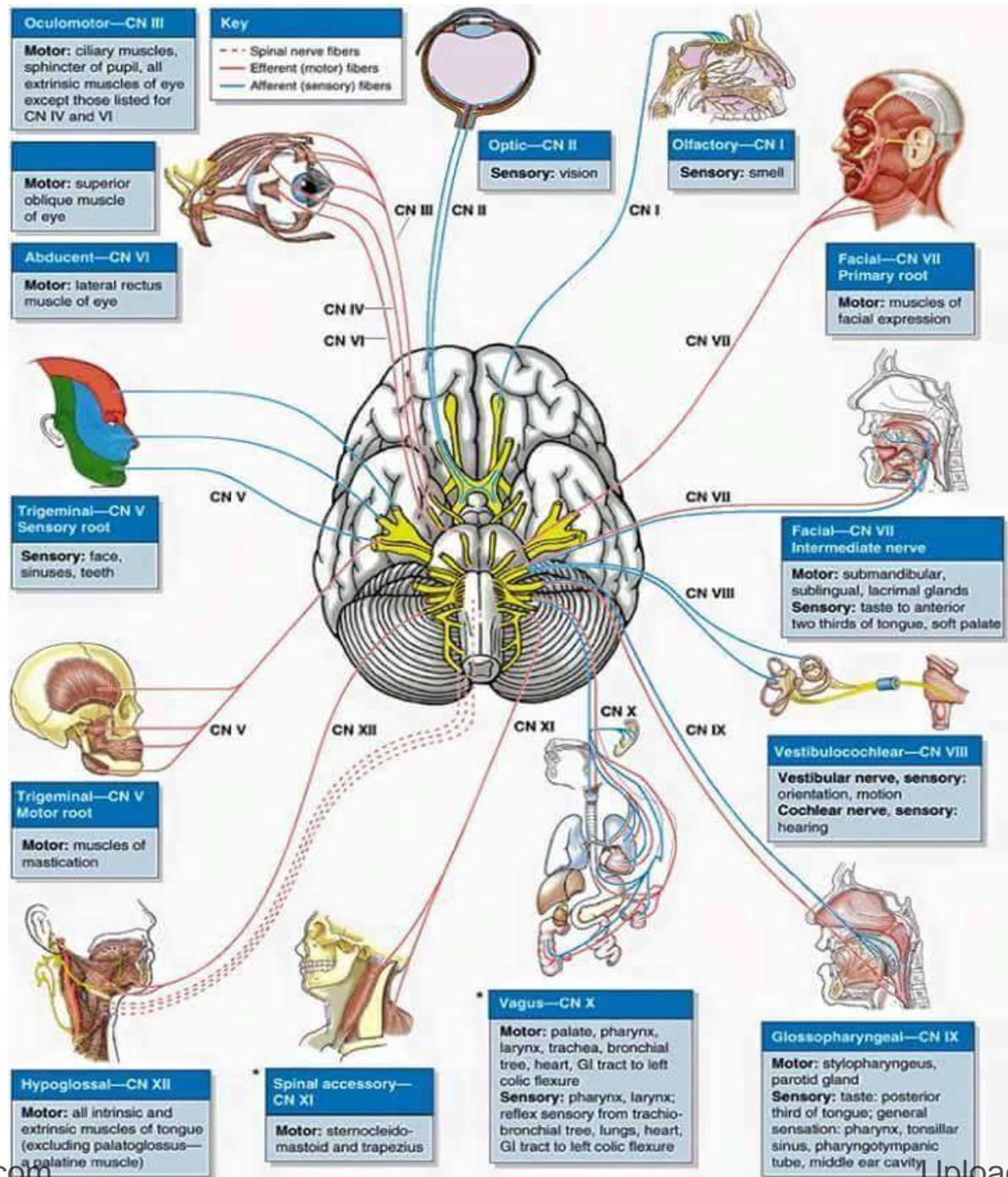


# Cranial Nerve III: Oculomotor









# Referred Pain

- Pain stimuli arising from the viscera are perceived as somatic in origin
- This may be due to the fact that visceral pain afferents travel along the same pathways as somatic pain fibers

