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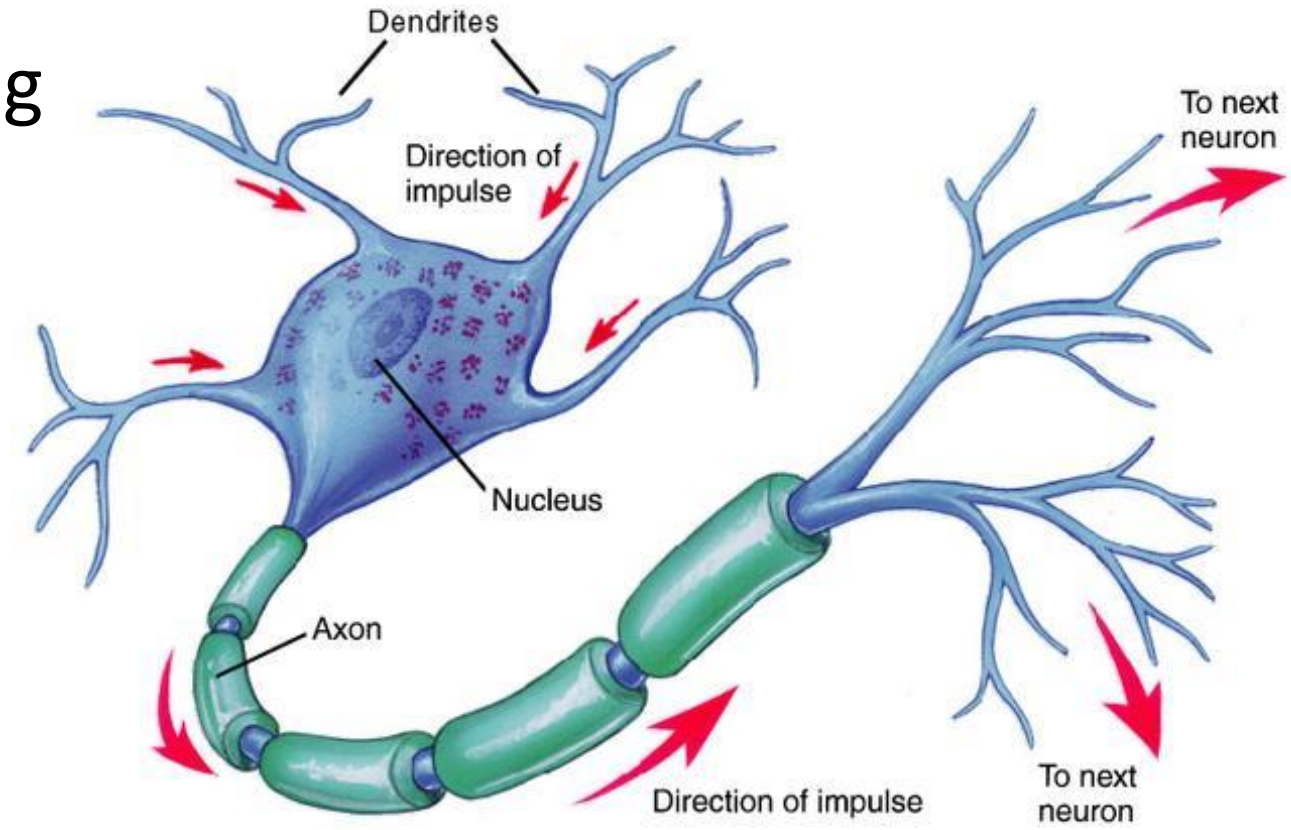
Nervous System Anatomy

Primary Care Paramedicine

Module:13
Section:01

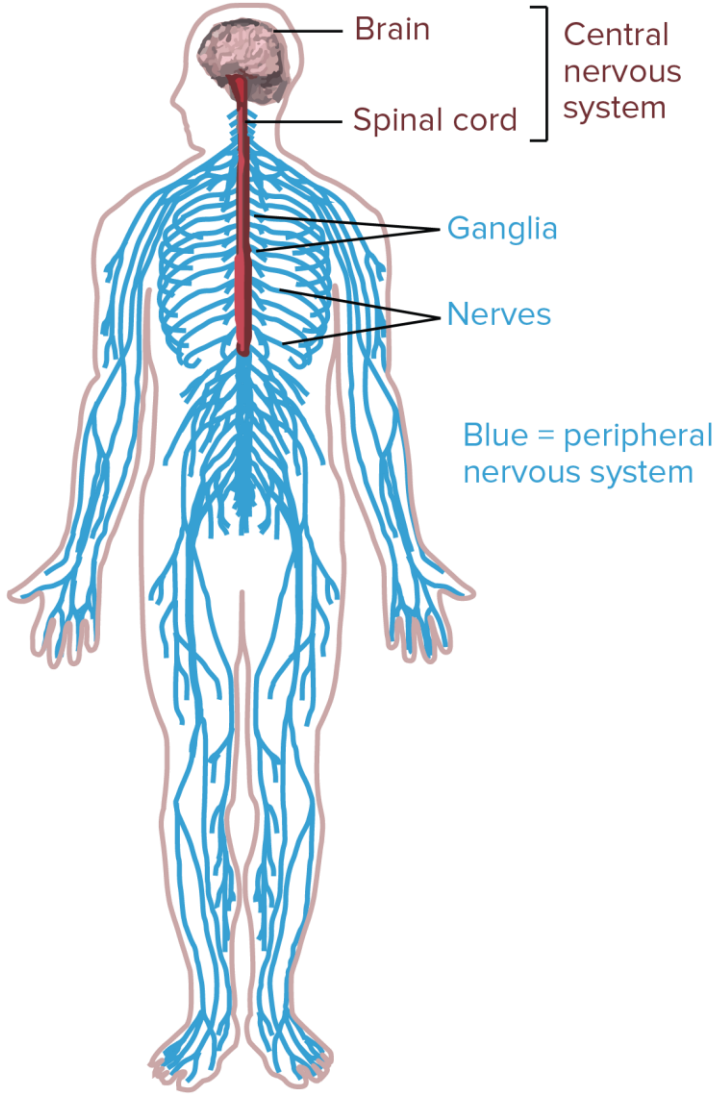
Nervous System

- Is the major controlling, regulatory and communicating system
- Works with the endocrine system to regulate and maintain homeostasis
- Maintains any internal and external check of the environment



Nervous System

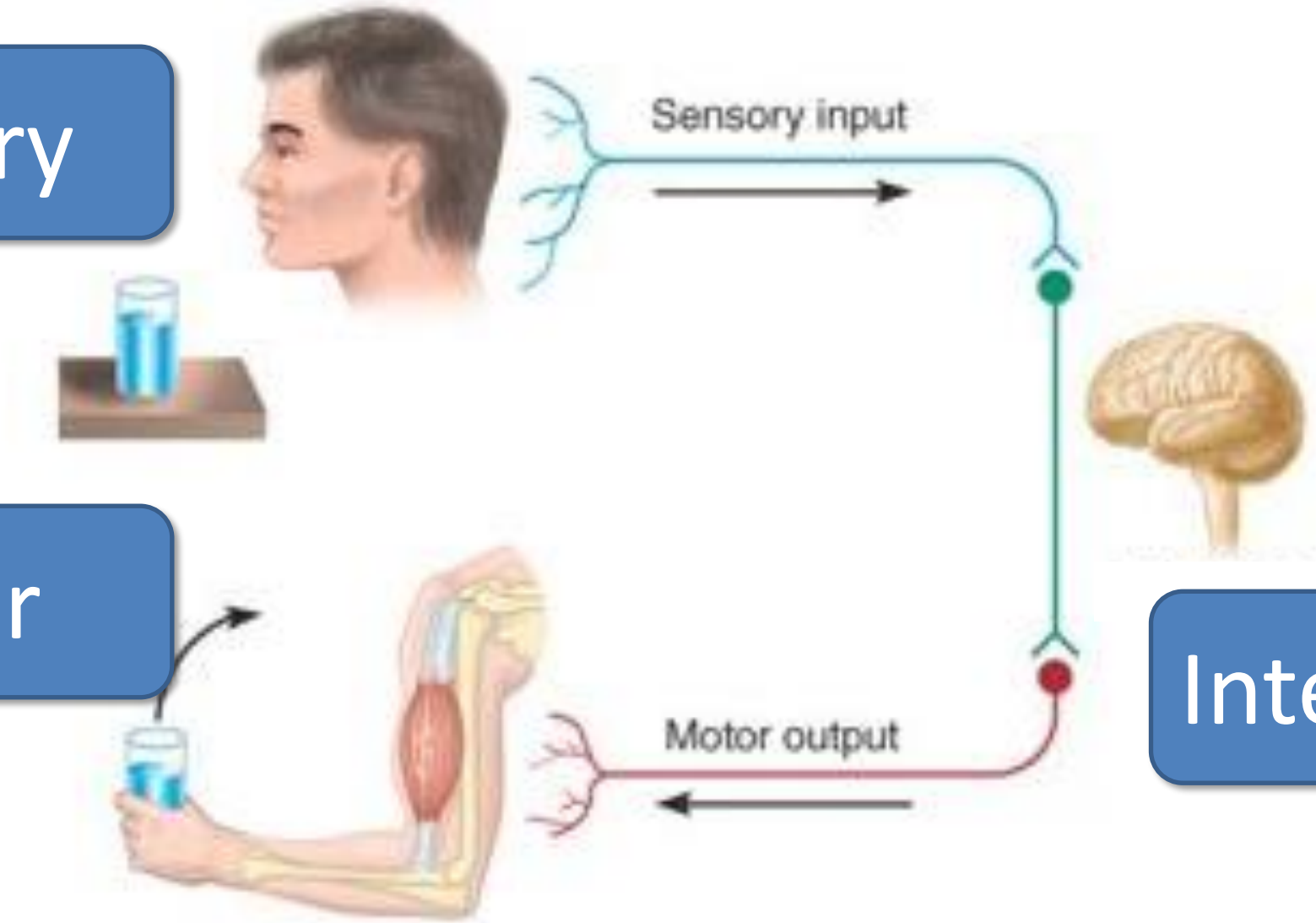
- Consists of:
  - The brain
  - The spinal cord
  - The nerves
  - The ganglia



Functions

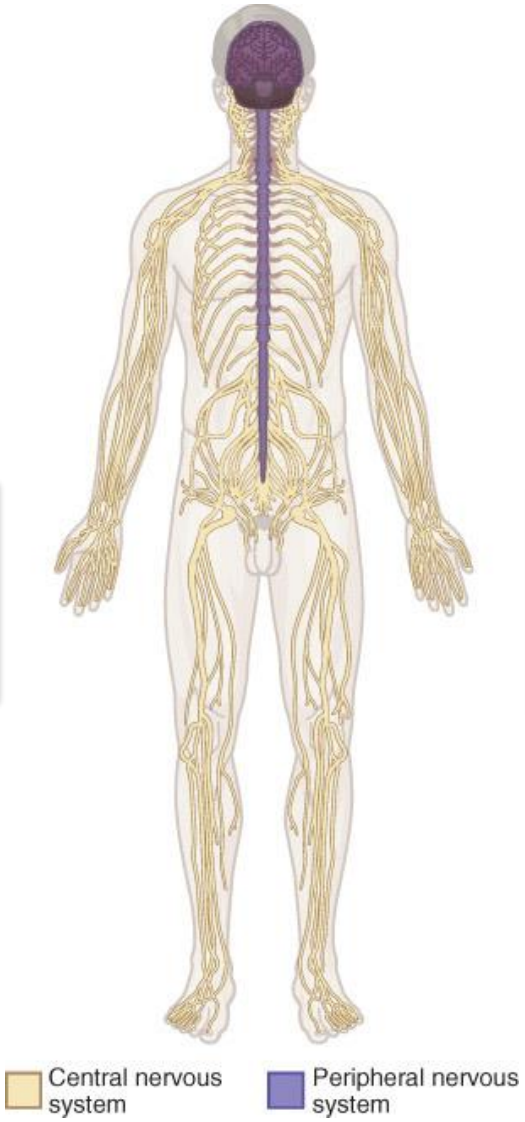
Sensory

Motor



Integration

- Central Nervous System (CNS)
  - Brain
  - Spinal Cord
- Peripheral Nervous System (PNS)
  - Ganglia
  - Nerves



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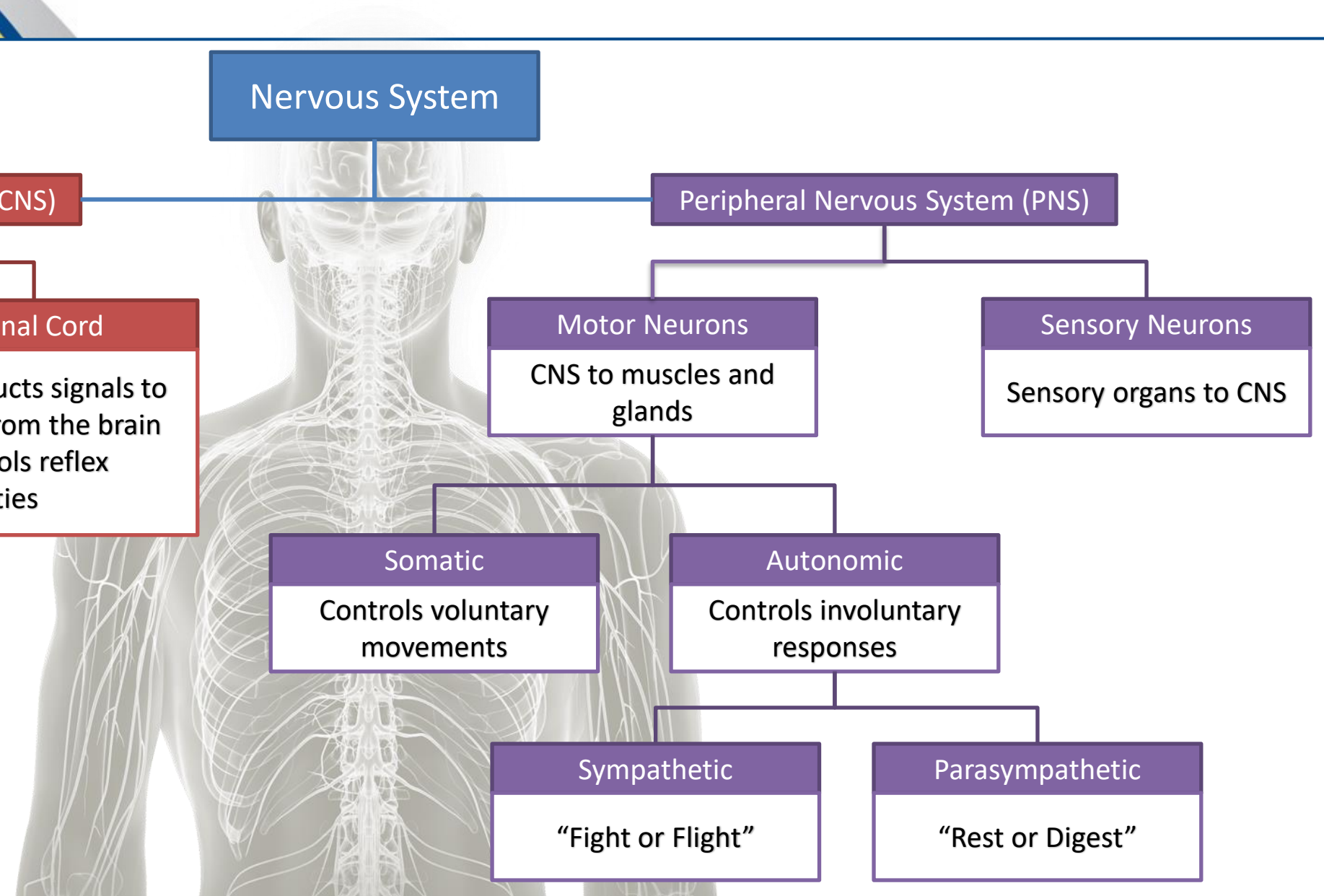
Nervous System



Nervous System

Central Nervous System (CNS)

Brain

- Receives and processes sensory information
- Initiates responses
- Stores memories
- Generates thoughts and emotions

Spinal Cord

- Conducts signals to and from the brain
- Controls reflex activities

Peripheral Nervous System (PNS)

Motor Neurons

CNS to muscles and glands

Sensory Neurons

Sensory organs to CNS

Somatic

Controls voluntary movements

Autonomic

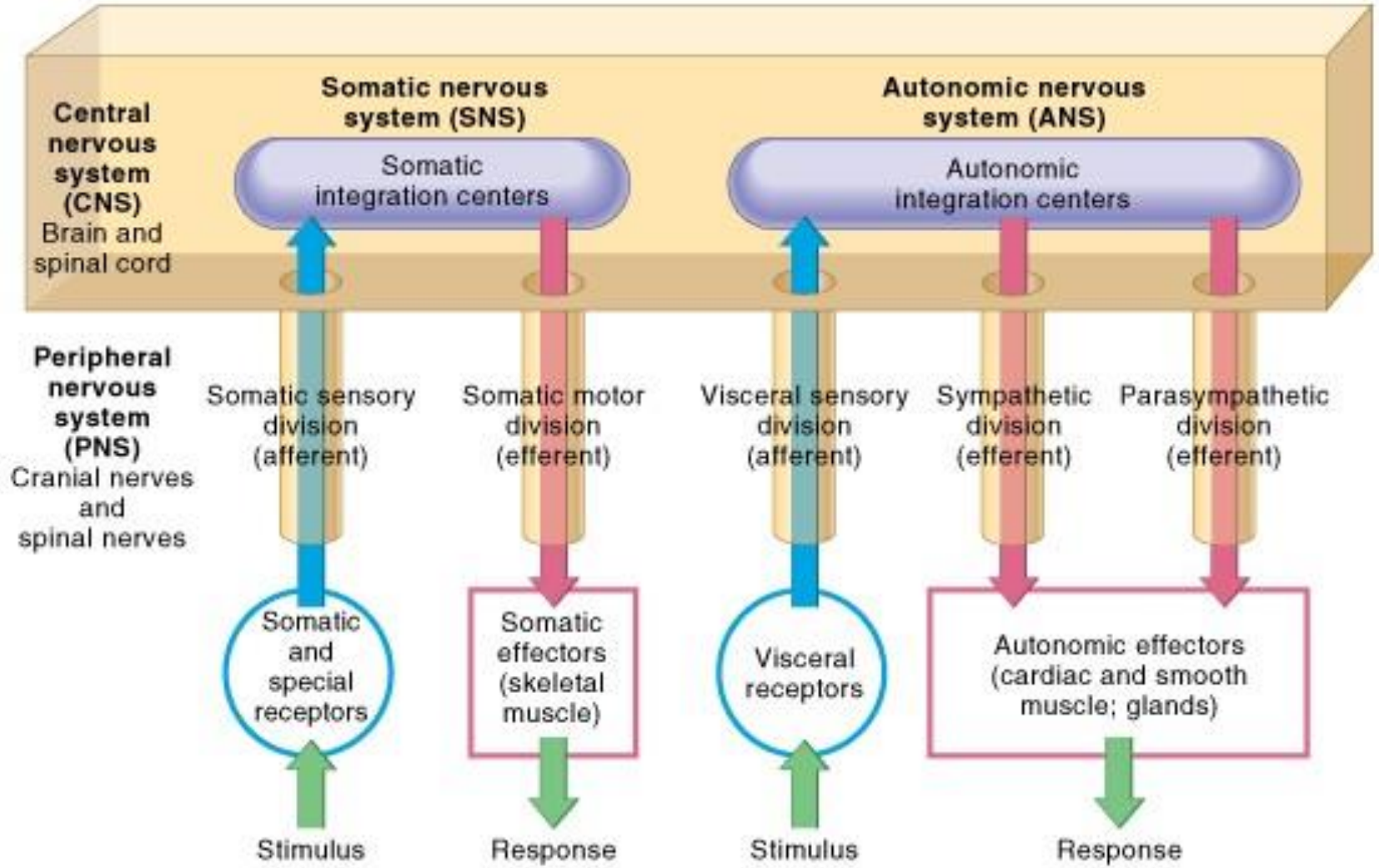
Controls involuntary responses

Sympathetic

"Fight or Flight"

Parasympathetic

"Rest or Digest"



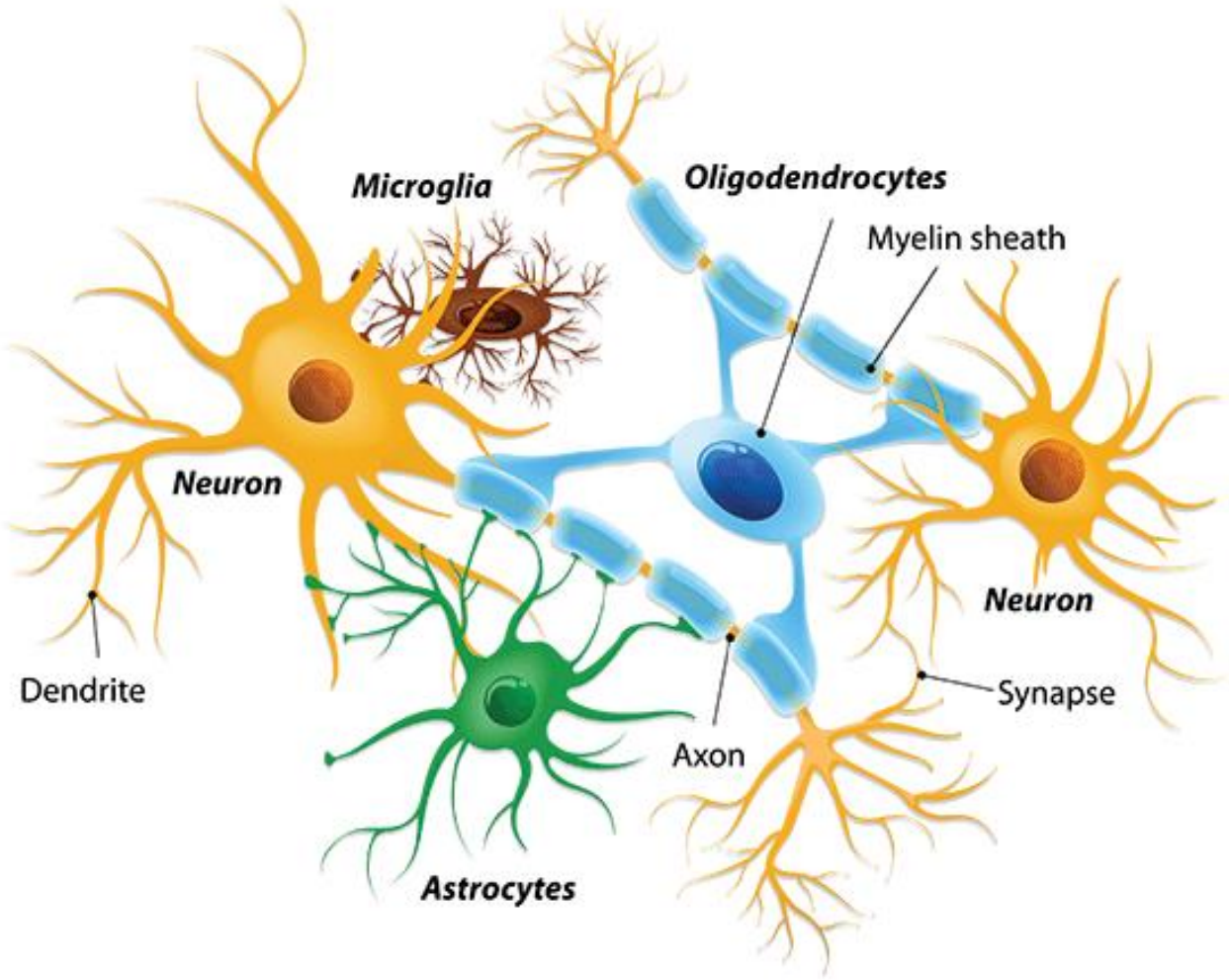
Central Nervous System

Neurons

- **Conducting cells**
- Structural unit of the nervous system

Glia

- **Non-conductive**
- Provide support
- Protect the cell membranes
- Regulate interstitial fluid composition
- Defend from pathogens/aid in repair



Glia

CNS

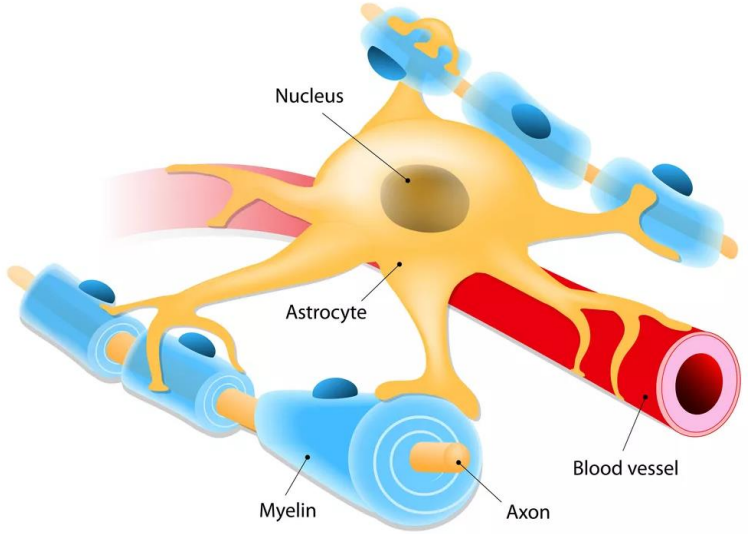
- Astrocytes
- Microglia
- Ependymal
- Oligodendrocytes (Oligodendroglia)

PNS

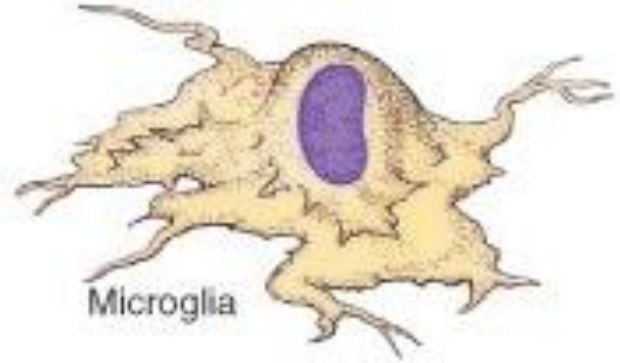
- Schwann cells
- Satellite cells

Glia Cells (CNS)

- Astrocytes
  - Star shaped
  - Found in CNS only
  - Transforms glucose into lactate
  - Help form blood brain barrier

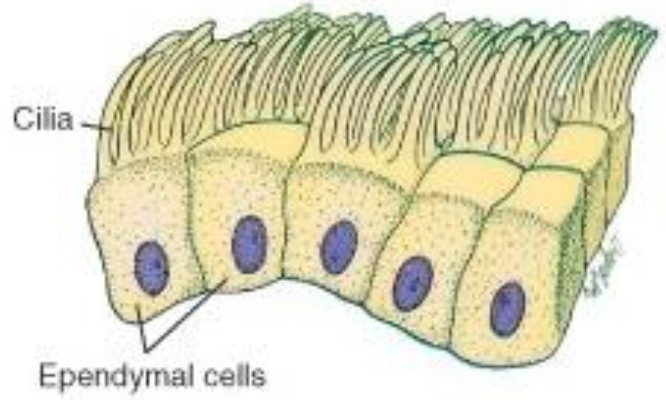


- Microglia
  - Responsible for phagocytosis in inflamed or degenerative tissue of the CNS
  - Main immune response in CNS since others cannot cross the BBB

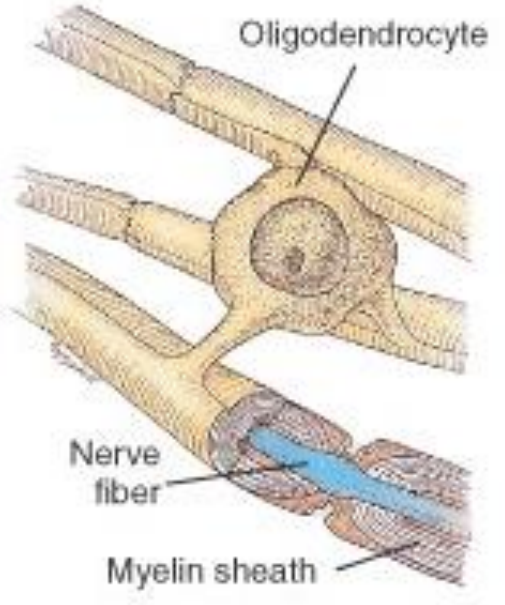


Glia cells (CNS)

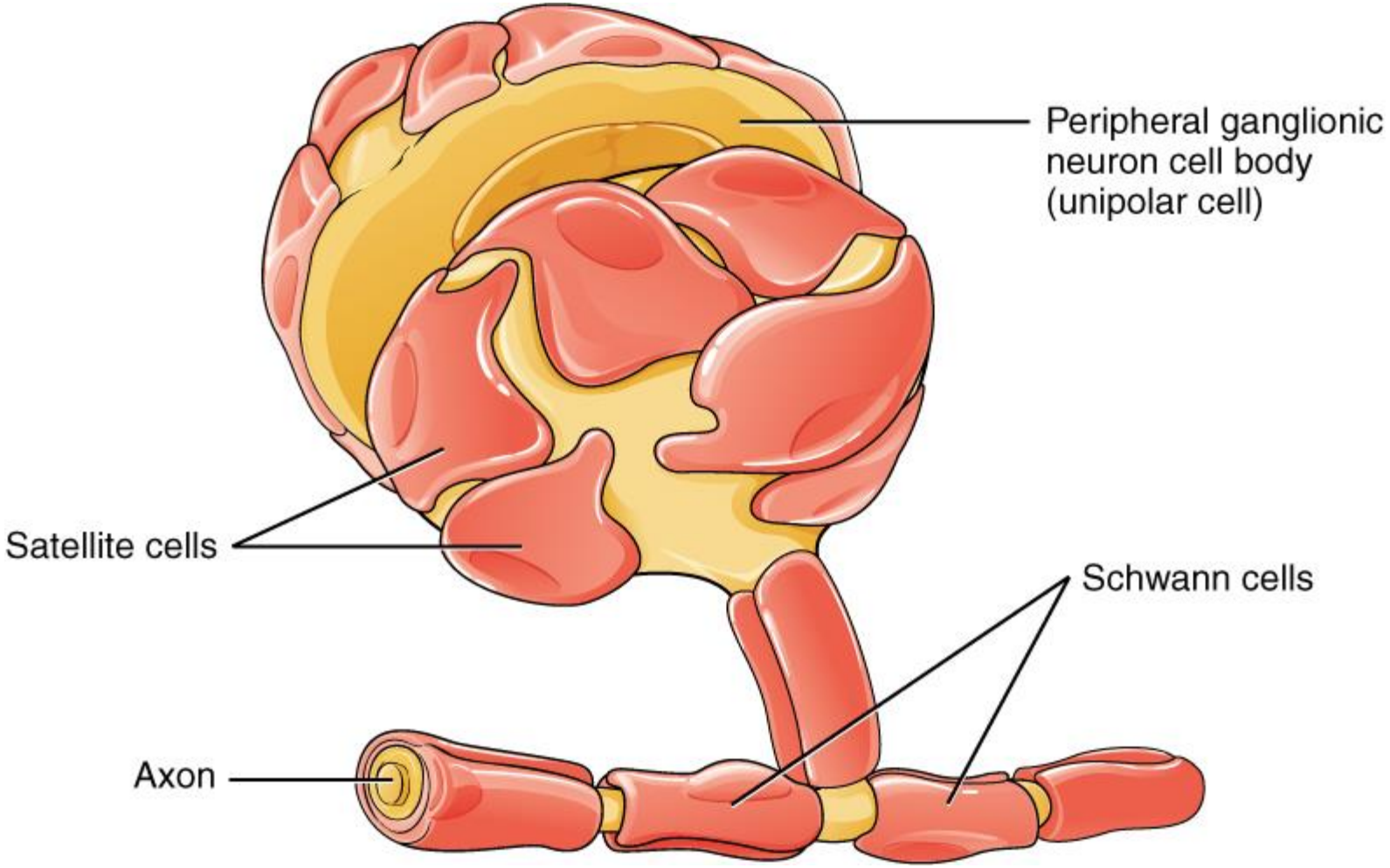
- Ependymal cells
  - Line the ventricles of the brain and central canal of spinal cord
  - Produce and circulate the fluids within these cavities
    - CSF



- Oligodendrocytes
  - Hold neurons together
  - Involved in myelin sheath formation (CNS only)

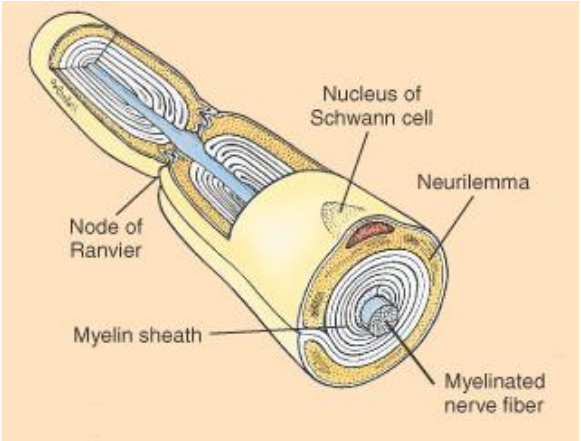


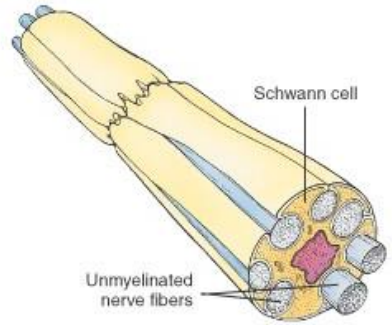
PNS Glia Cells

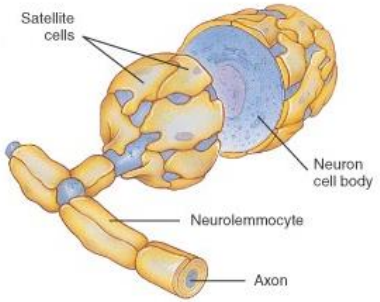


Glia cells (PNS)

- Schwann cells (PNS Only)
  - Bundle nerve cells together
  - As it wraps around a nerve fiber
    - Nucleus and cytoplasm are squeezed to the perimeter to form outer portion of myelin sheath (Neurilemma)
  - Myelinated fibers (white fibers)
    - Encased by Schwann Cell
  - Unmyelinated fibers (gray fibers)
    - Held together by Schwann Cell
- Satellite cells
  - Found in ganglia
  - Provide physical support for neurons

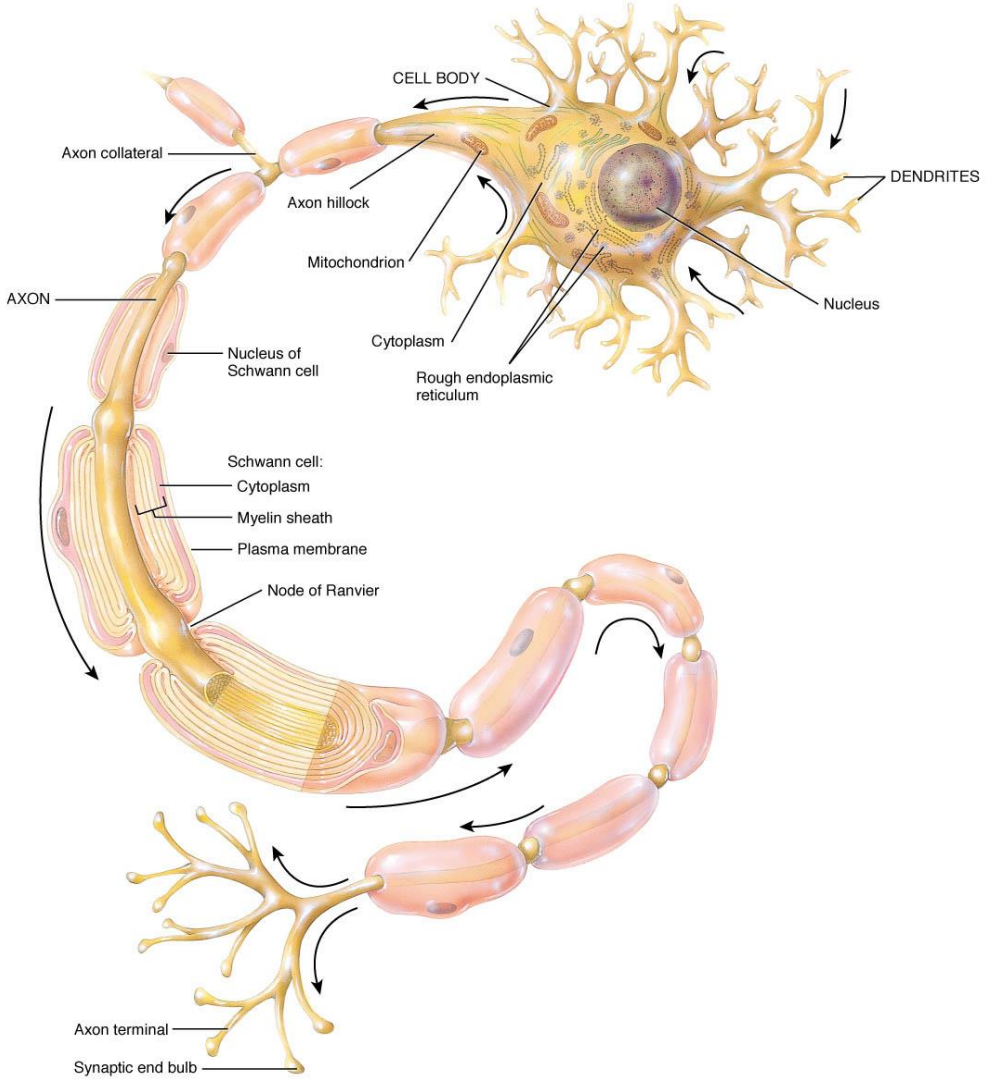






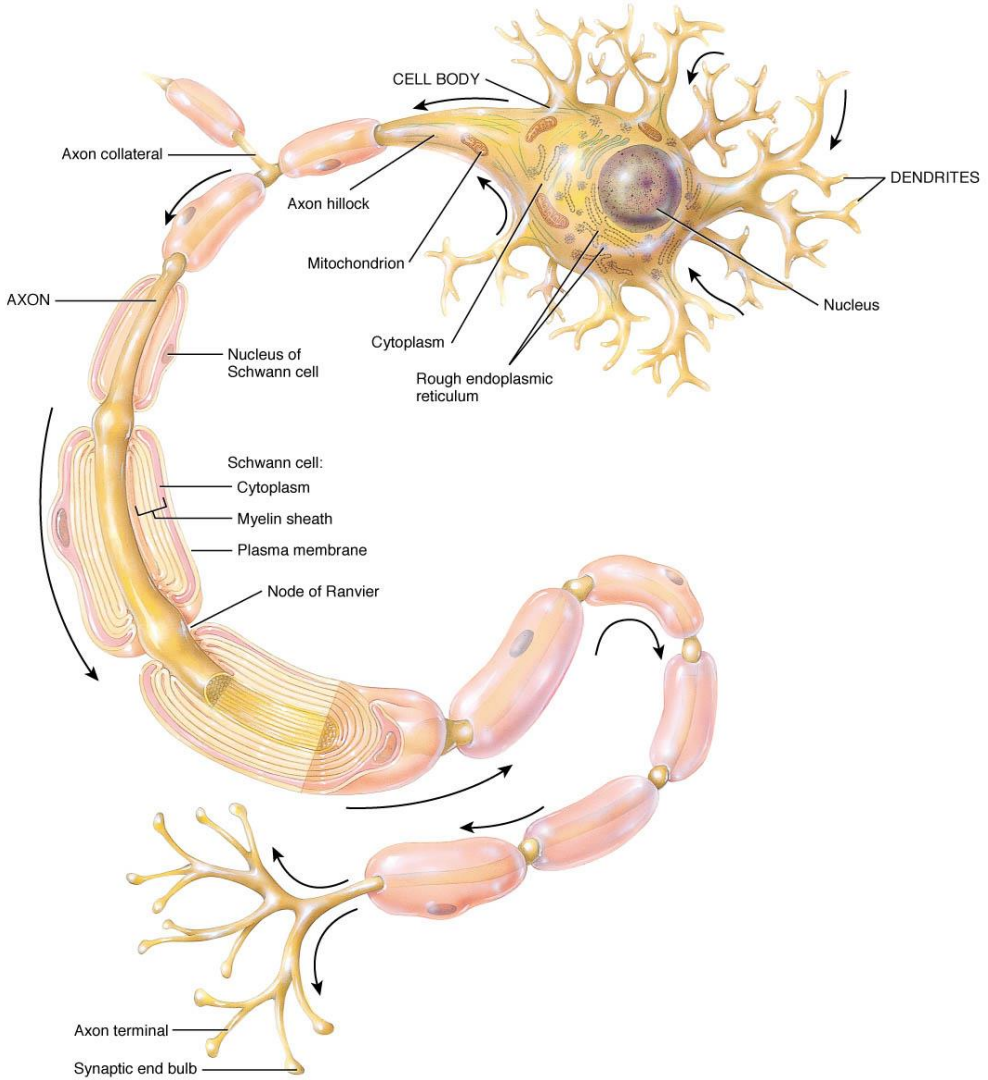
Neurons

- Approximately 100 billion
  - 10% of brain cells
- Bundled fibers surrounded by connective tissues
- Conduct impulses to and from CNS
- The most complex tissues in the body due to their role in communication
  - Integrate various activities and coordinate bodily functions
- Specialized cell that is amitotic



Neurons

- Each neuron has three main parts
  - Dendrites (Afferent)
  - Cell Body (Soma)
  - Axon (Efferent)



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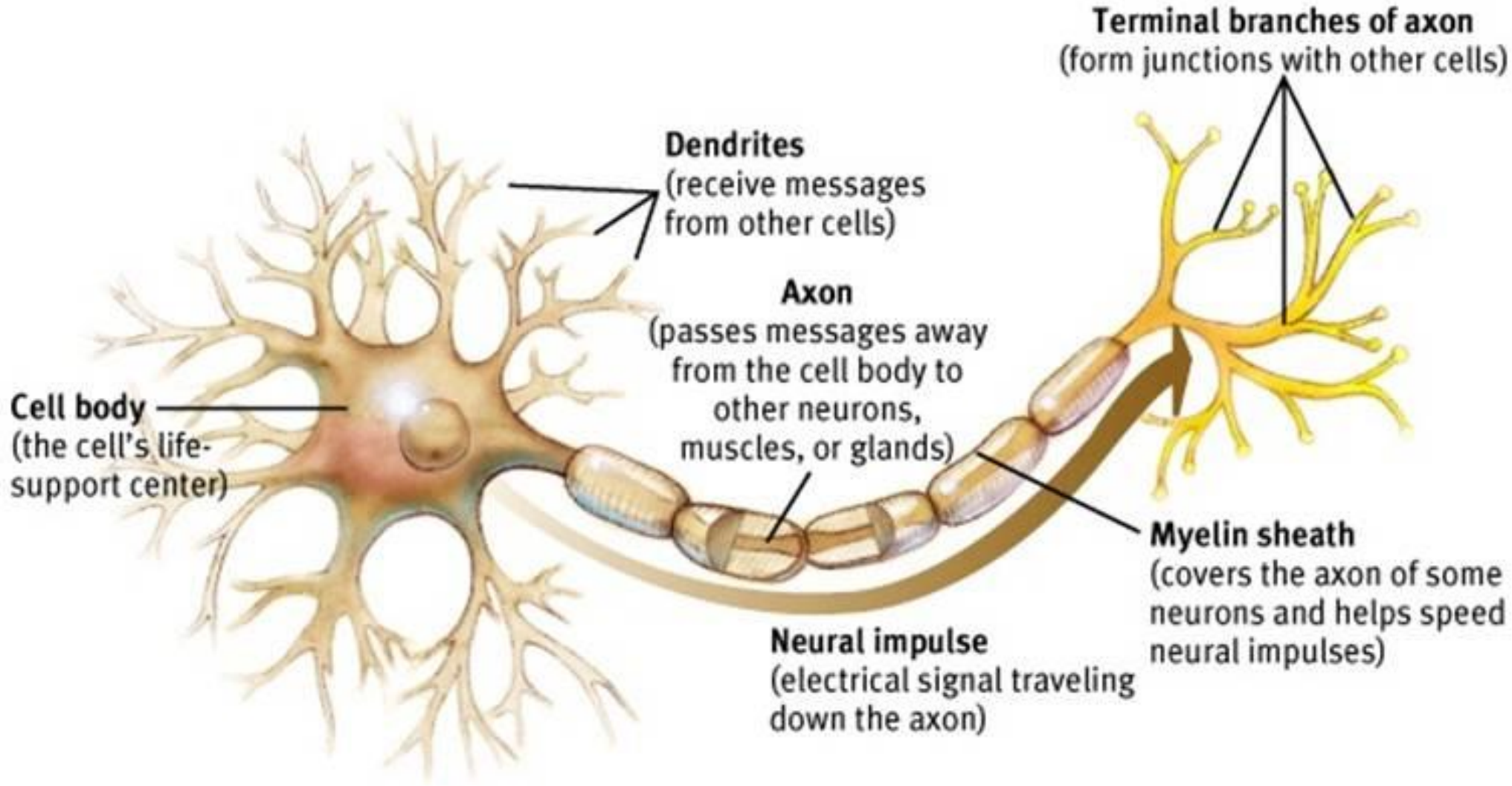
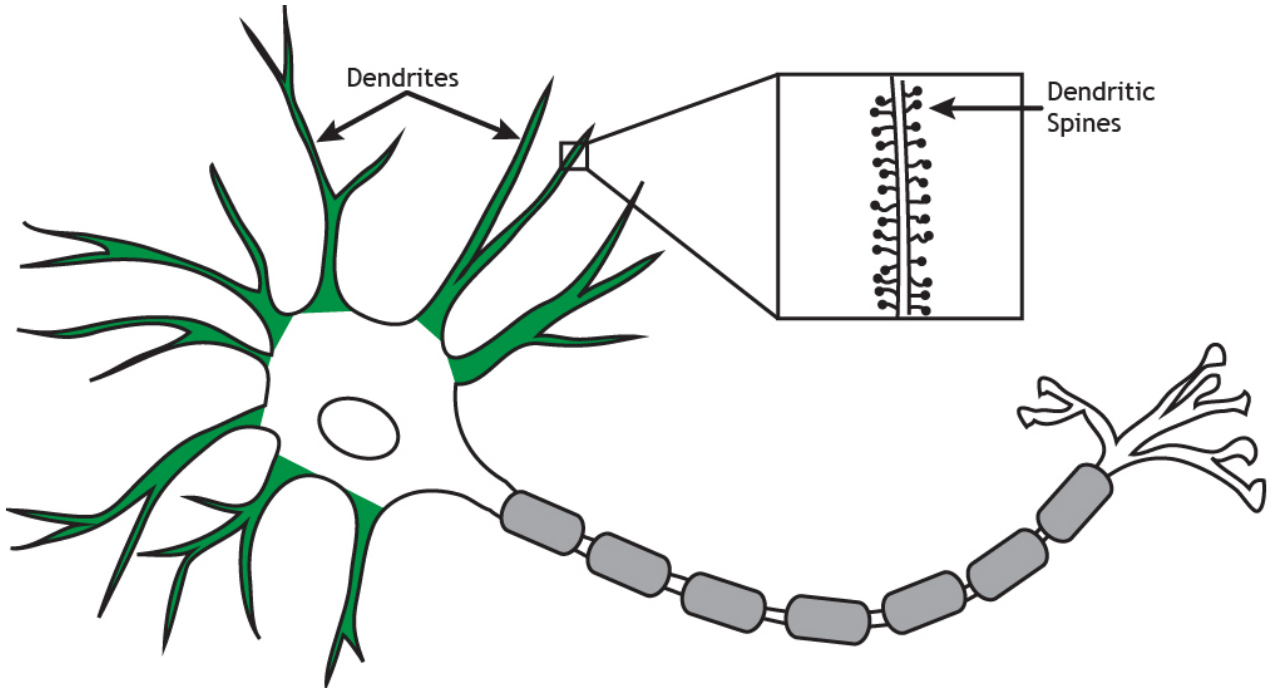
Neurons

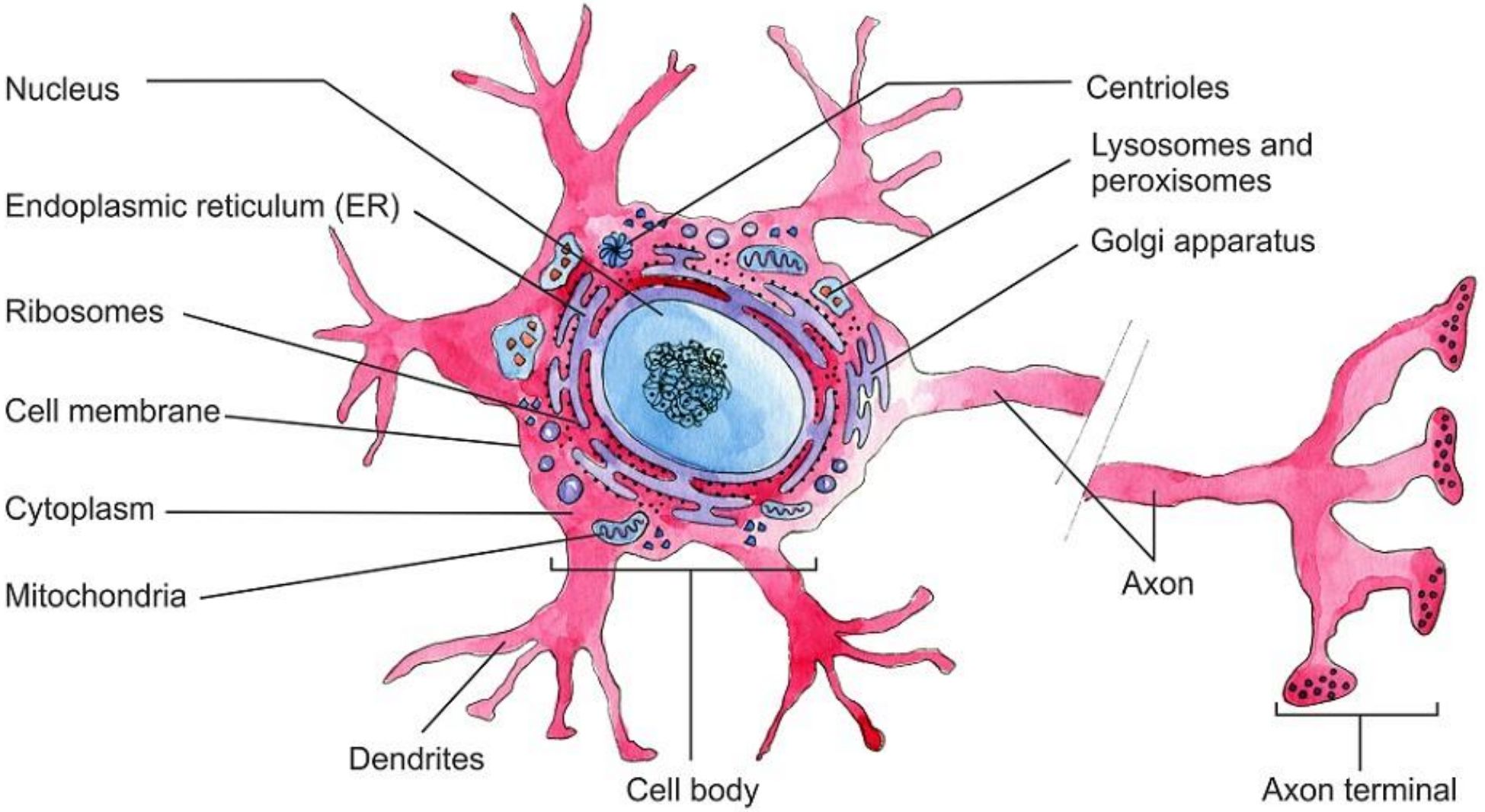


Dendrites

- Extensions of neuron
- Receives impulses from other neurons or other stimuli
- Transmits impulses to neuron body (soma)

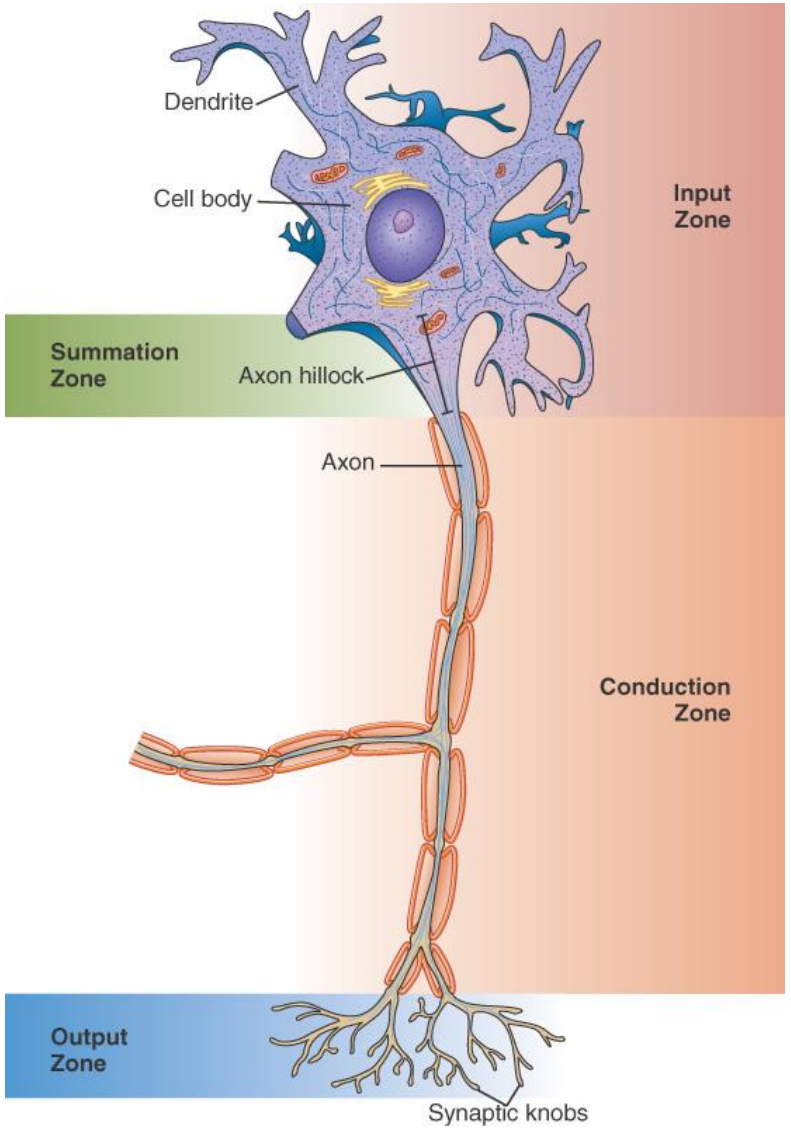


Cell Body (Soma)

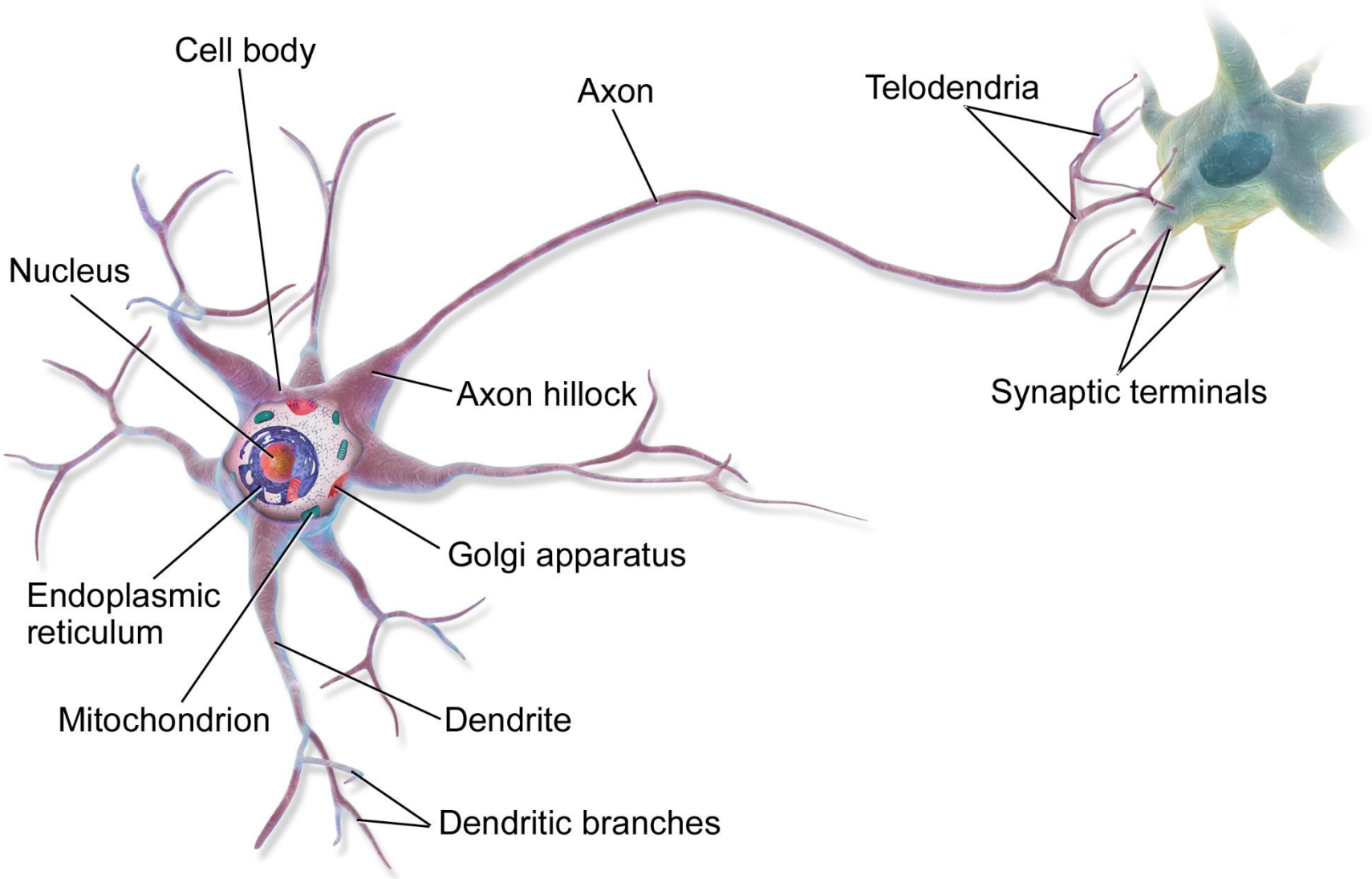


Axons

- Originate from axon hillock
- Conduct impulses away from the neuron (Size dependent)
- Axon collaterals branch off of axons

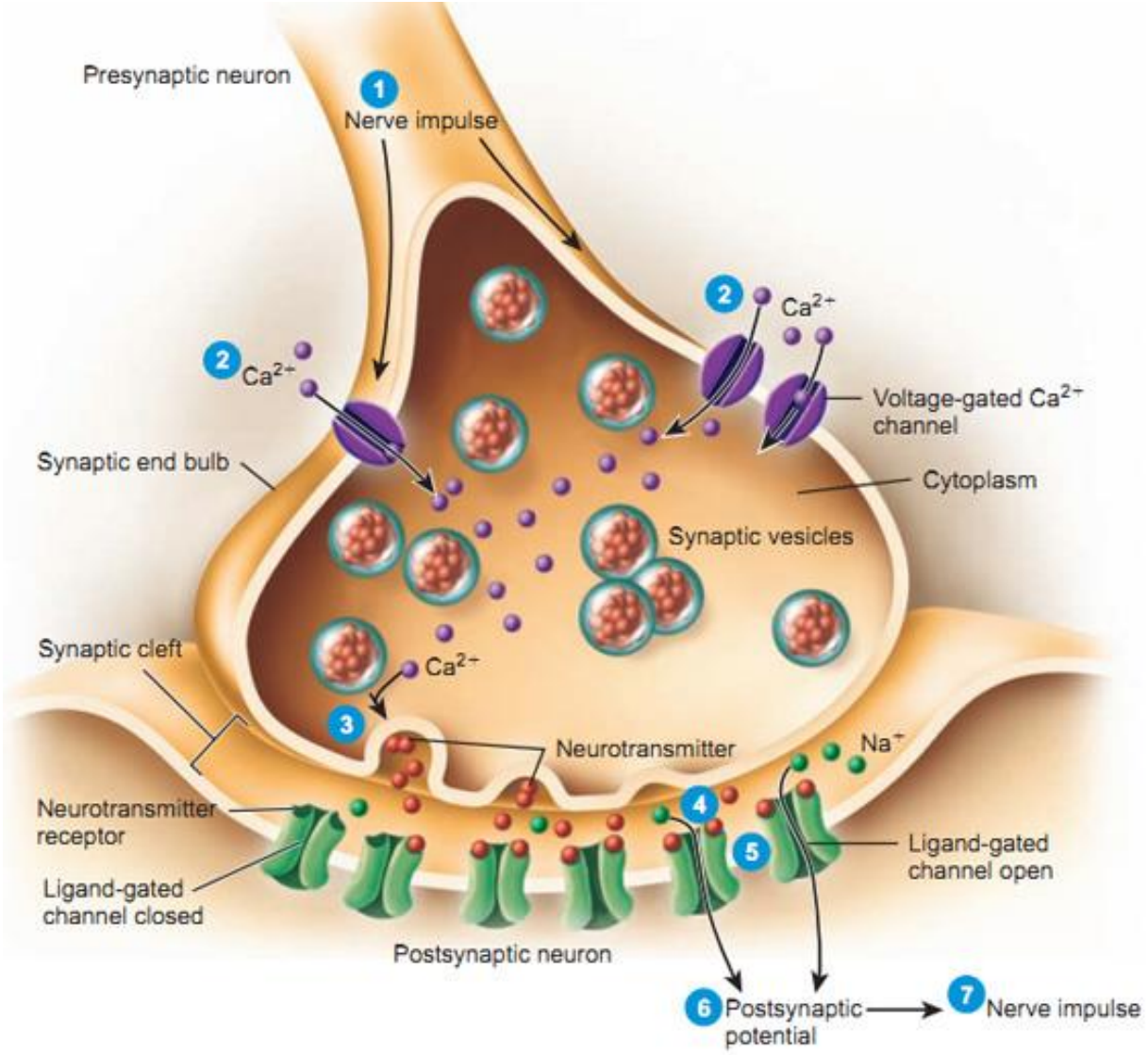


Axons


Cell body
Axon
Telodendria
Nucleus
Axon hillock
Synaptic terminals
Golgi apparatus
Endoplasmic reticulum
Mitochondrion
Dendrite
Dendritic branches

Synaptic knobs (bulbs)

- Distal terminal ends of neuron structure
- Joined to axon by telodendria
- Transmit impulses to dendrites of other neuron or target site
- Contain synaptic vesicles



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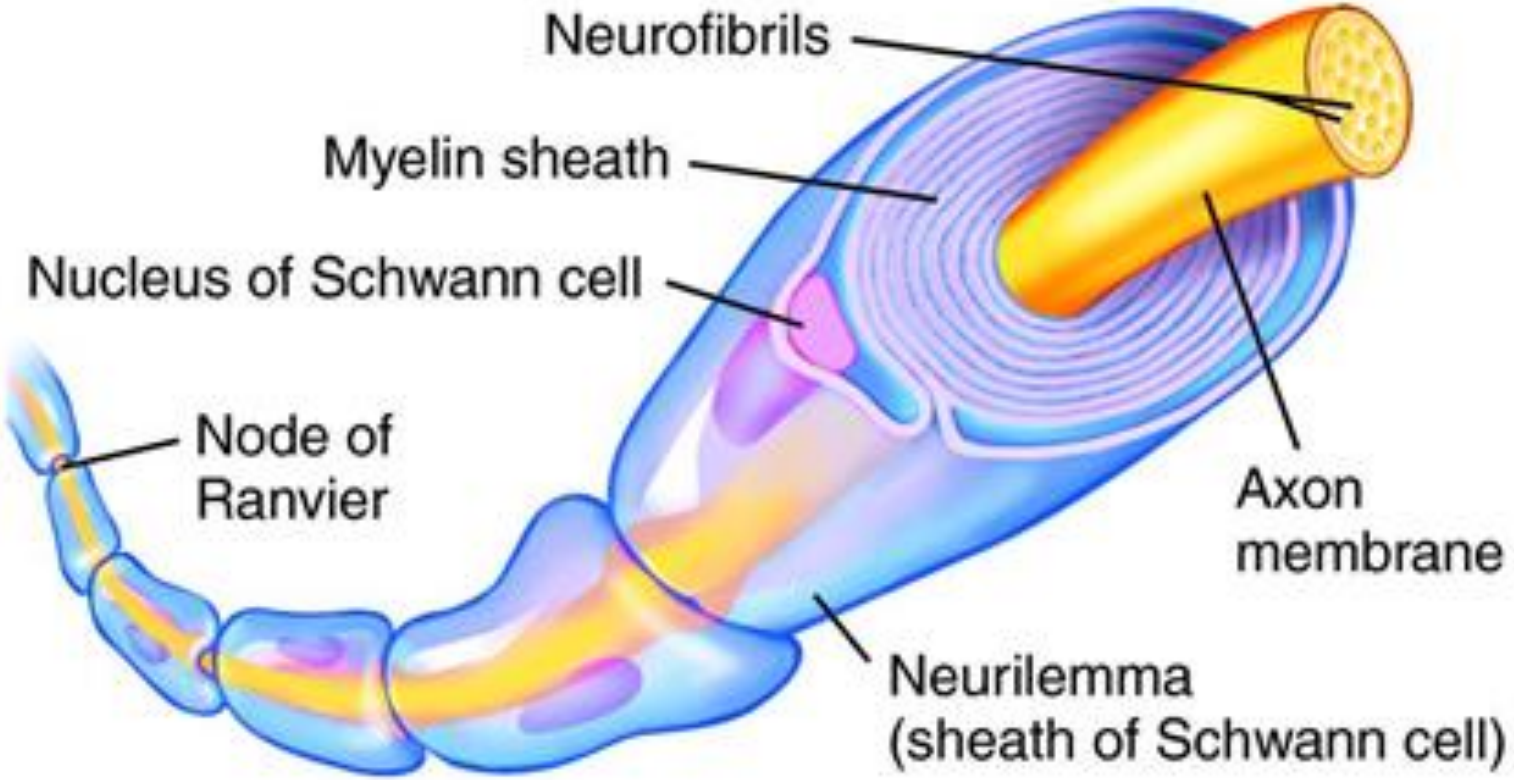
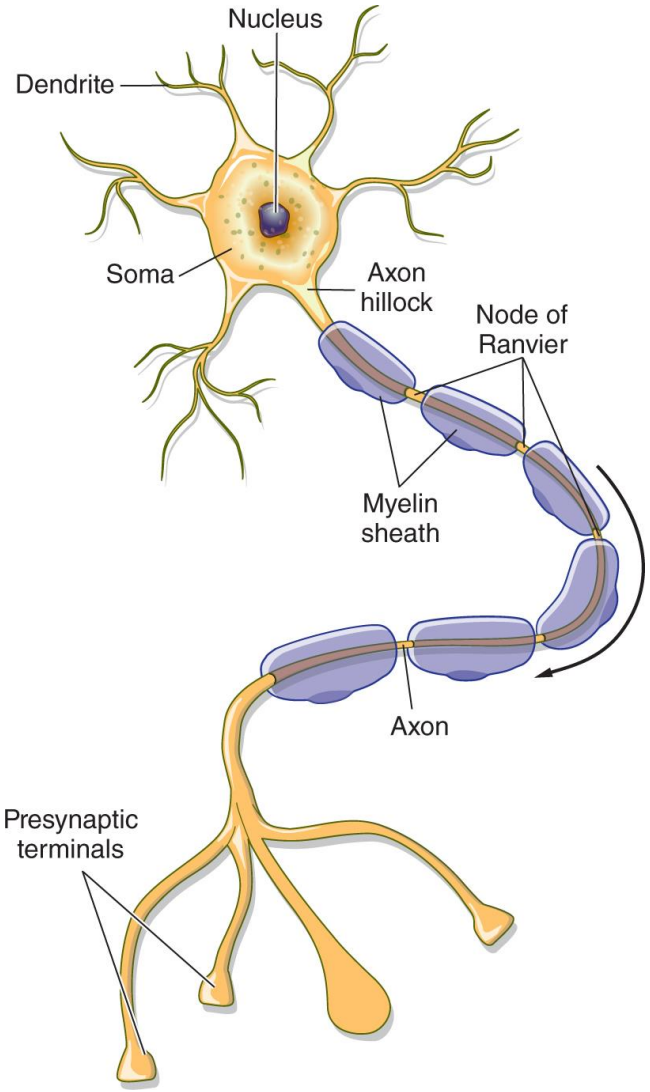
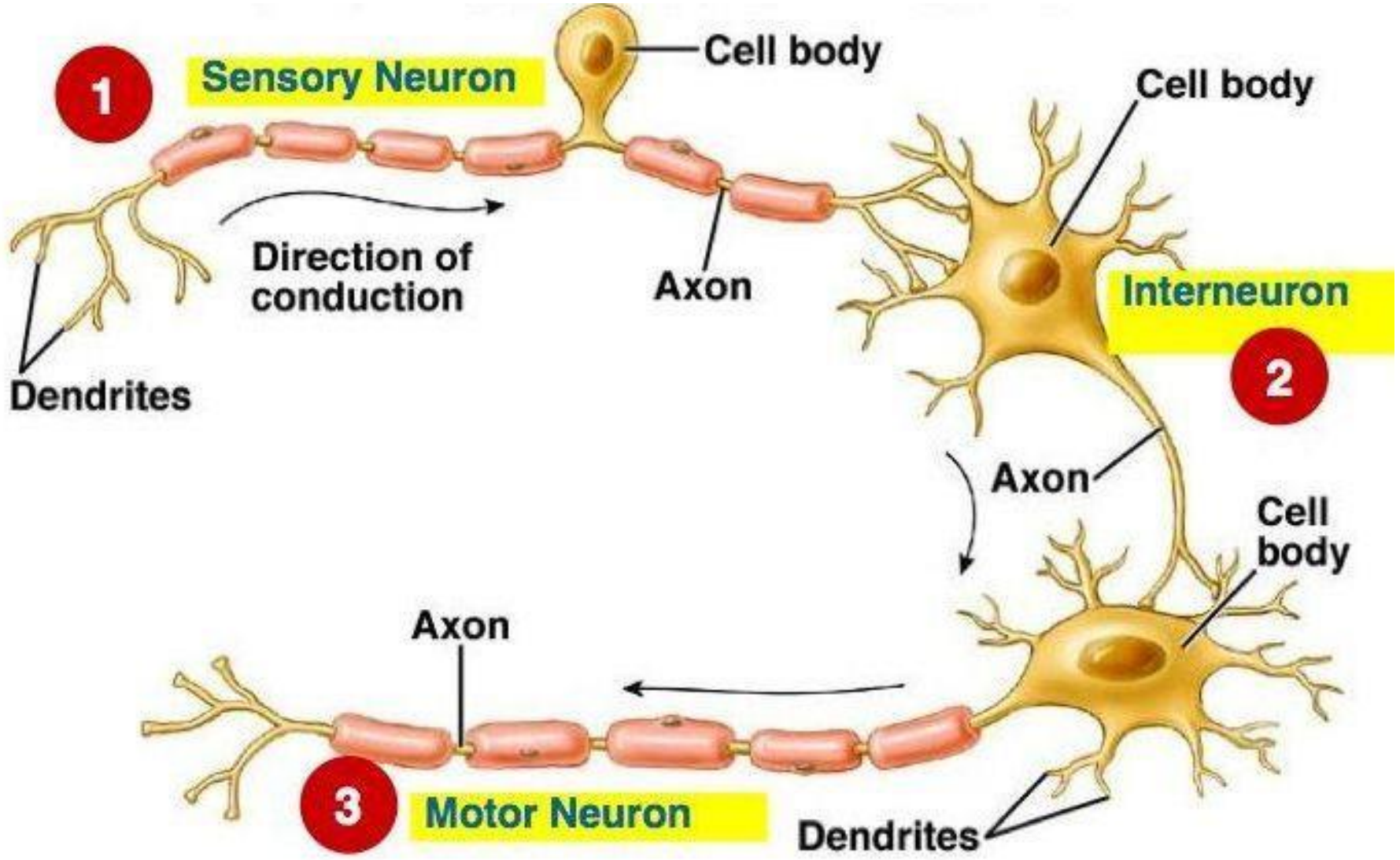
Myelin

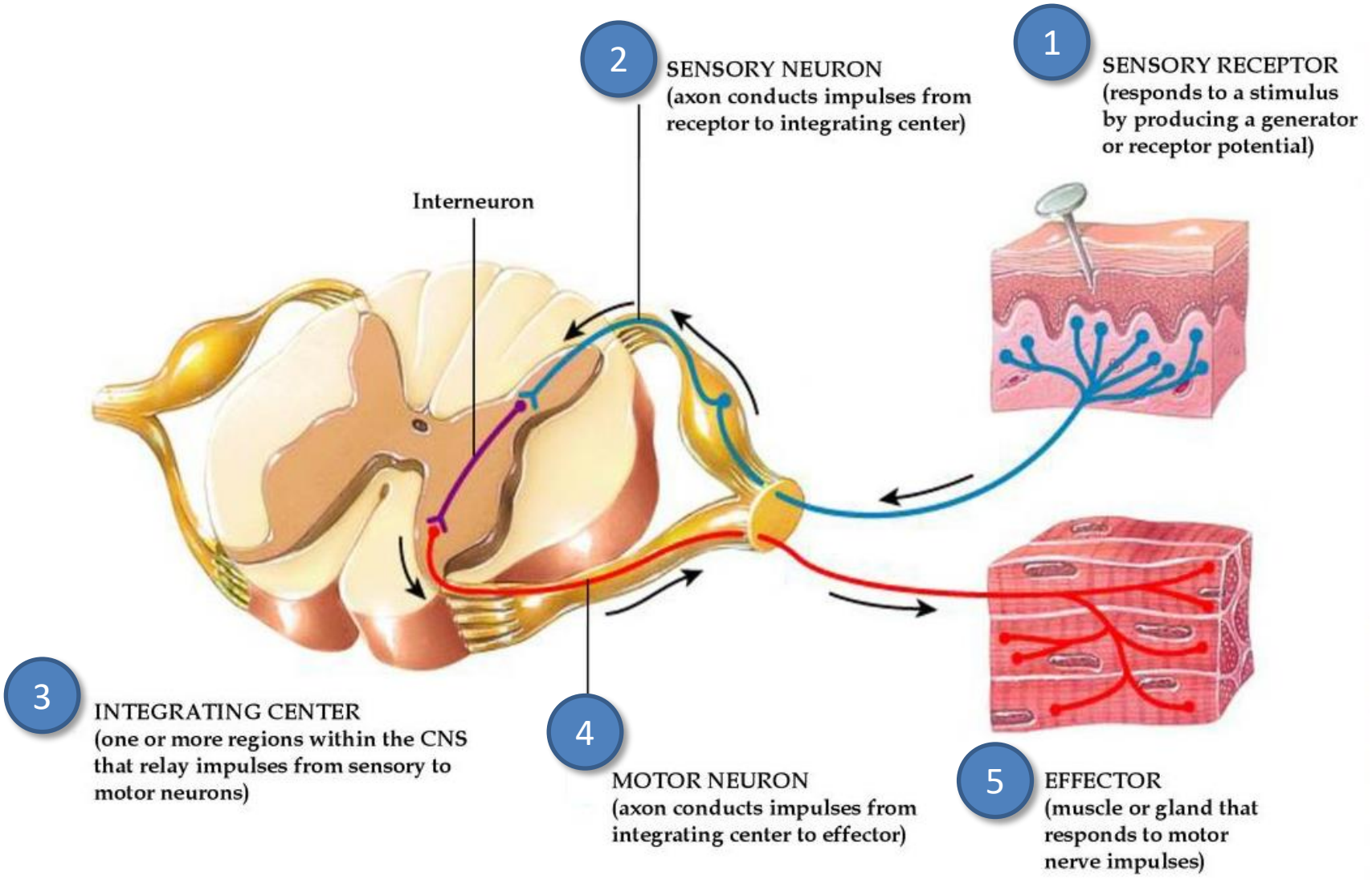




Functional Classifications of Neurons

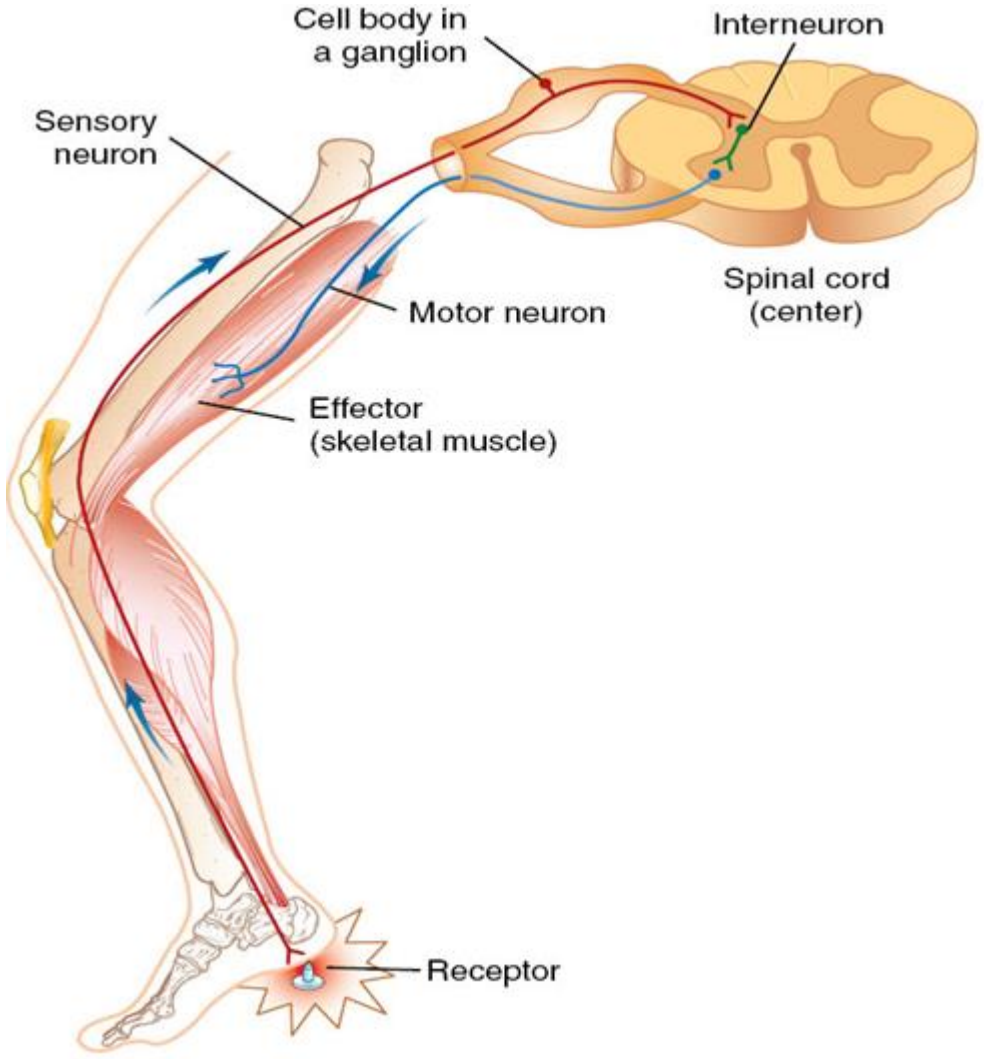


Neurons

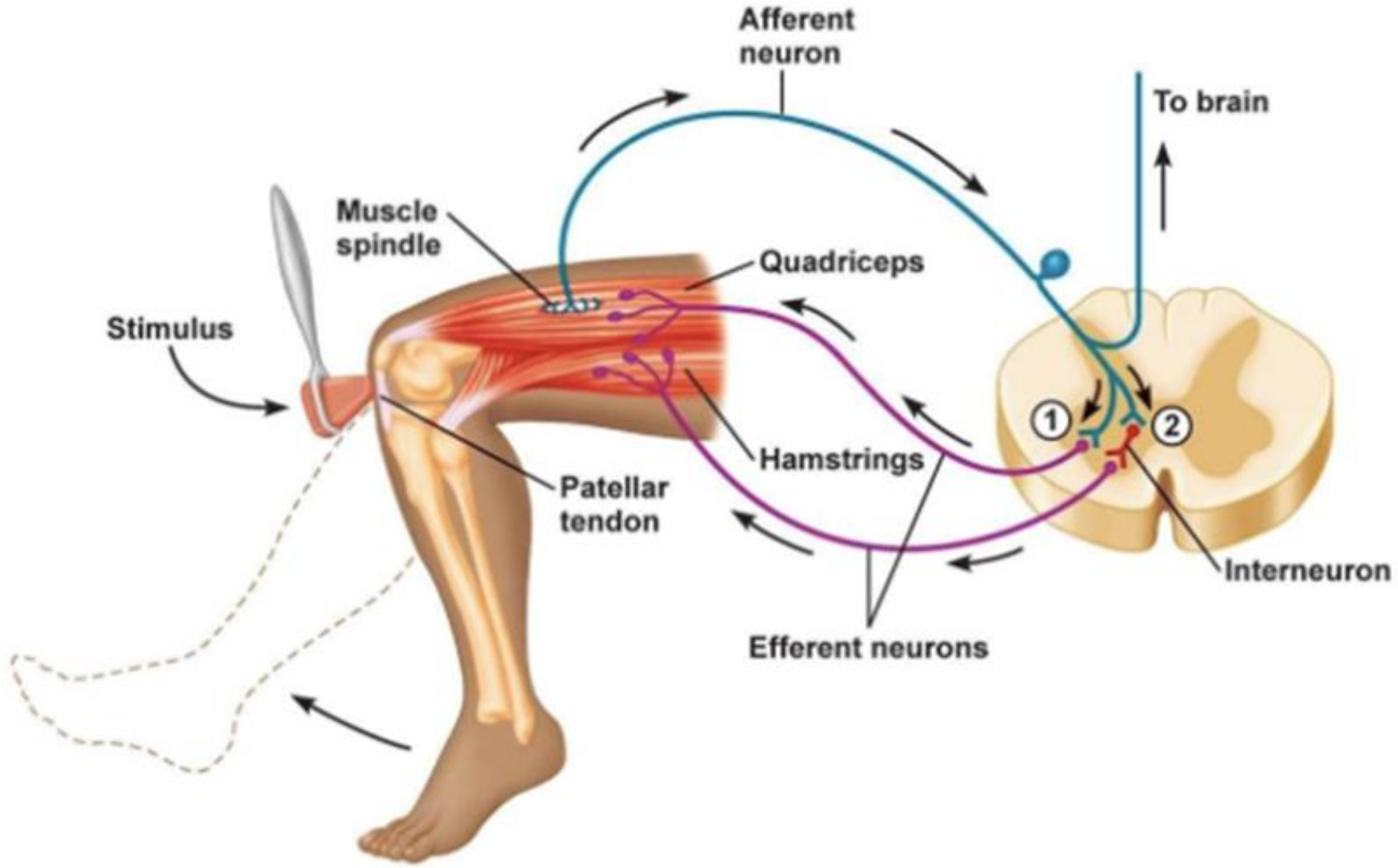

1
SENSORY RECEPTOR
(responds to a stimulus by producing a generator or receptor potential)
2
SENSORY NEURON
(axon conducts impulses from receptor to integrating center)
Interneuron
3
INTEGRATING CENTER
(one or more regions within the CNS that relay impulses from sensory to motor neurons)
4
MOTOR NEURON
(axon conducts impulses from integrating center to effector)
5
EFFECTOR
(muscle or gland that responds to motor nerve impulses)

Reflex Arcs

- A functional unit of the nervous system
- Involuntary response
- Contains
  - Receptor
  - Sensory Neuron
  - Center
  - Motor Neuron
  - Effector

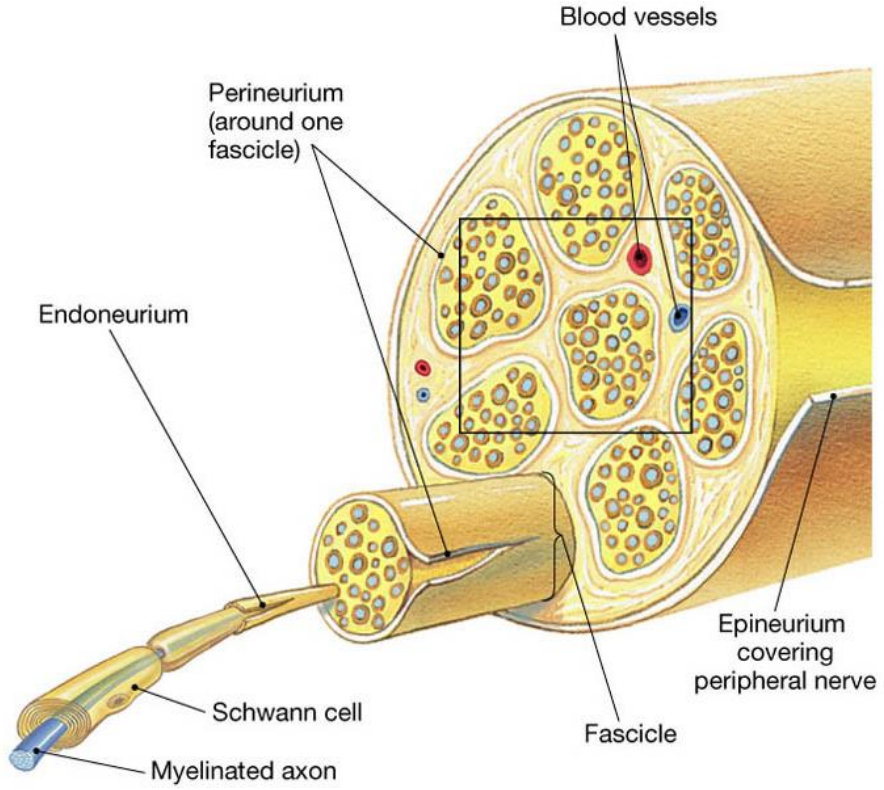


Reflex Arcs


Afferent neuron
To brain
Muscle spindle
Quadriceps
Stimulus
Hamstrings
Patellar tendon
1
2
Interneuron
Efferent neurons

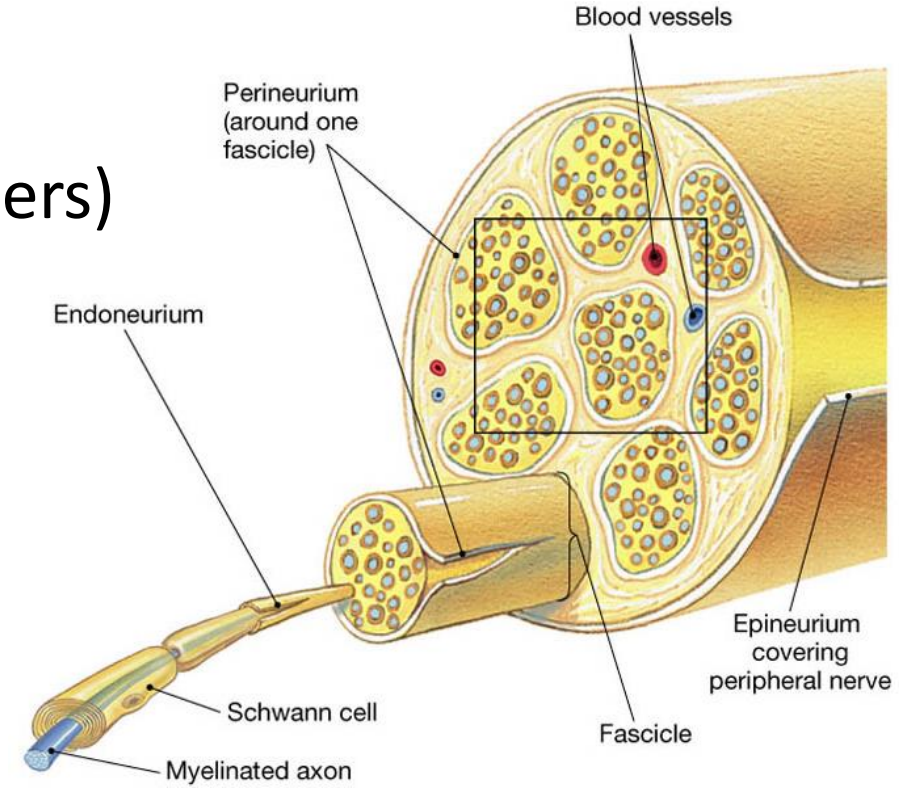
Nerves and Tracts

- Nerves
  - Bundles of peripheral nerve fibers
  - Each nerve fiber is surrounded by layer of connective tissue (endoneurium)
  - Fascicles
    - Bundles of fibers are held together by a layer of connective tissue (perineurium)
  - Numerous fascicles are collectively held together by the epineurium to form the Nerve
- Tracts
  - Name given to bundles of nerve fiber in the CNS



Nerves and Tracts

- White Matter
  - PNS
    - Myelinated nerve
  - CNS
    - Myelinated tract
- Grey Matter (Cell bodies and unmyelinated fibers)
  - PNS
    - Ganglia
  - CNS
    - Nuclei

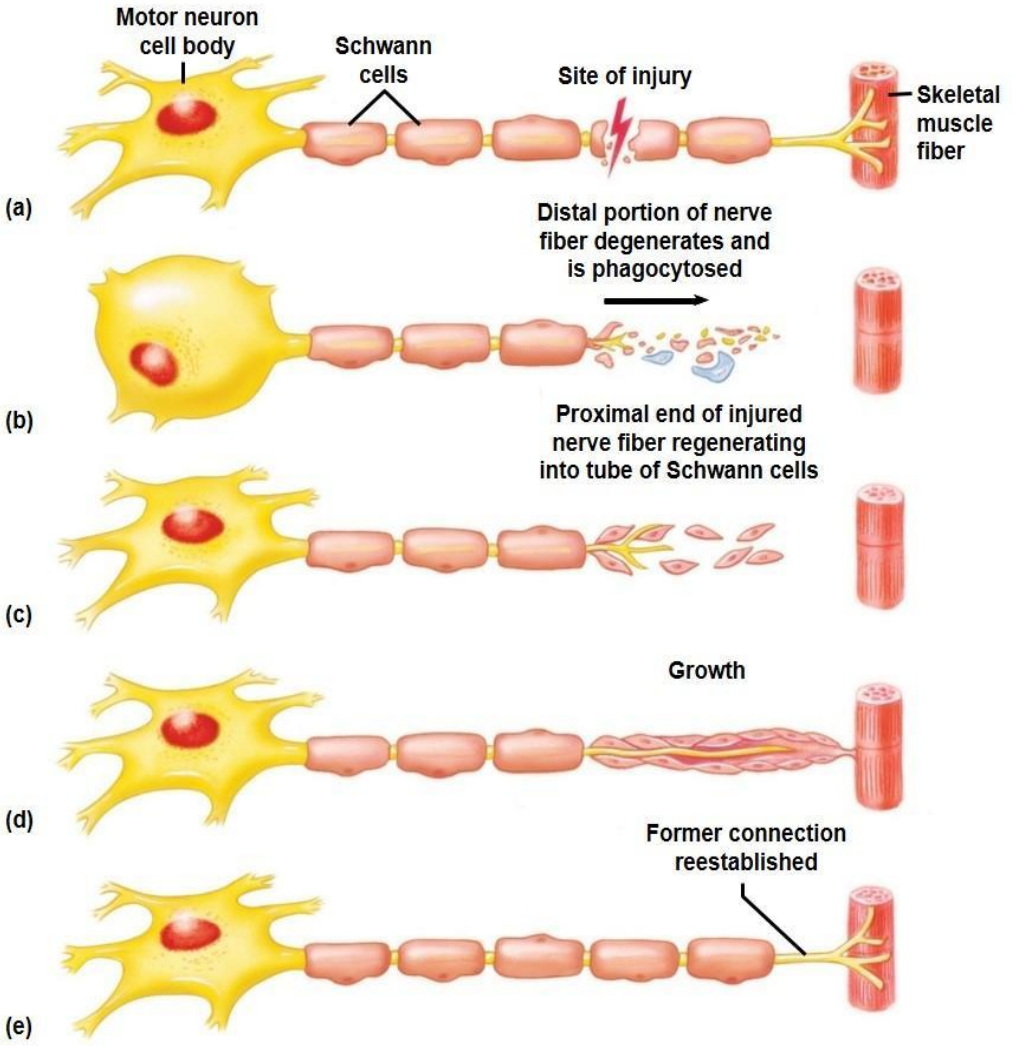


Repair

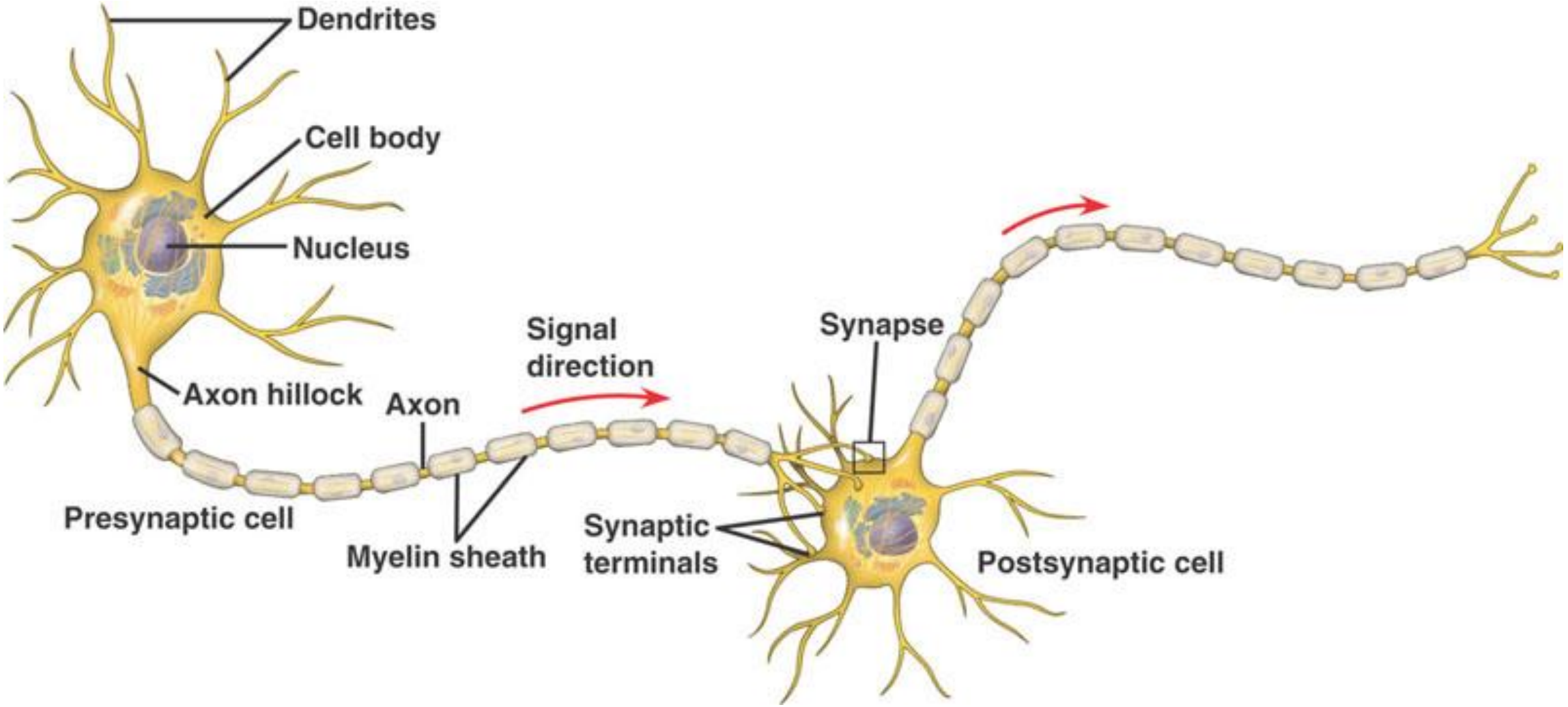
- Mature neurons are amitotic
- Healing is based on repairing existing neurons
- Neurons have limited capacity for repair
- Repair may be possible if injury is not extensive and the cell body and the neurilemma remain intact

Repair

- PNS repair
  - Possible due to the presence of the neurilemmal
- CNS repair
  - Very unlikely

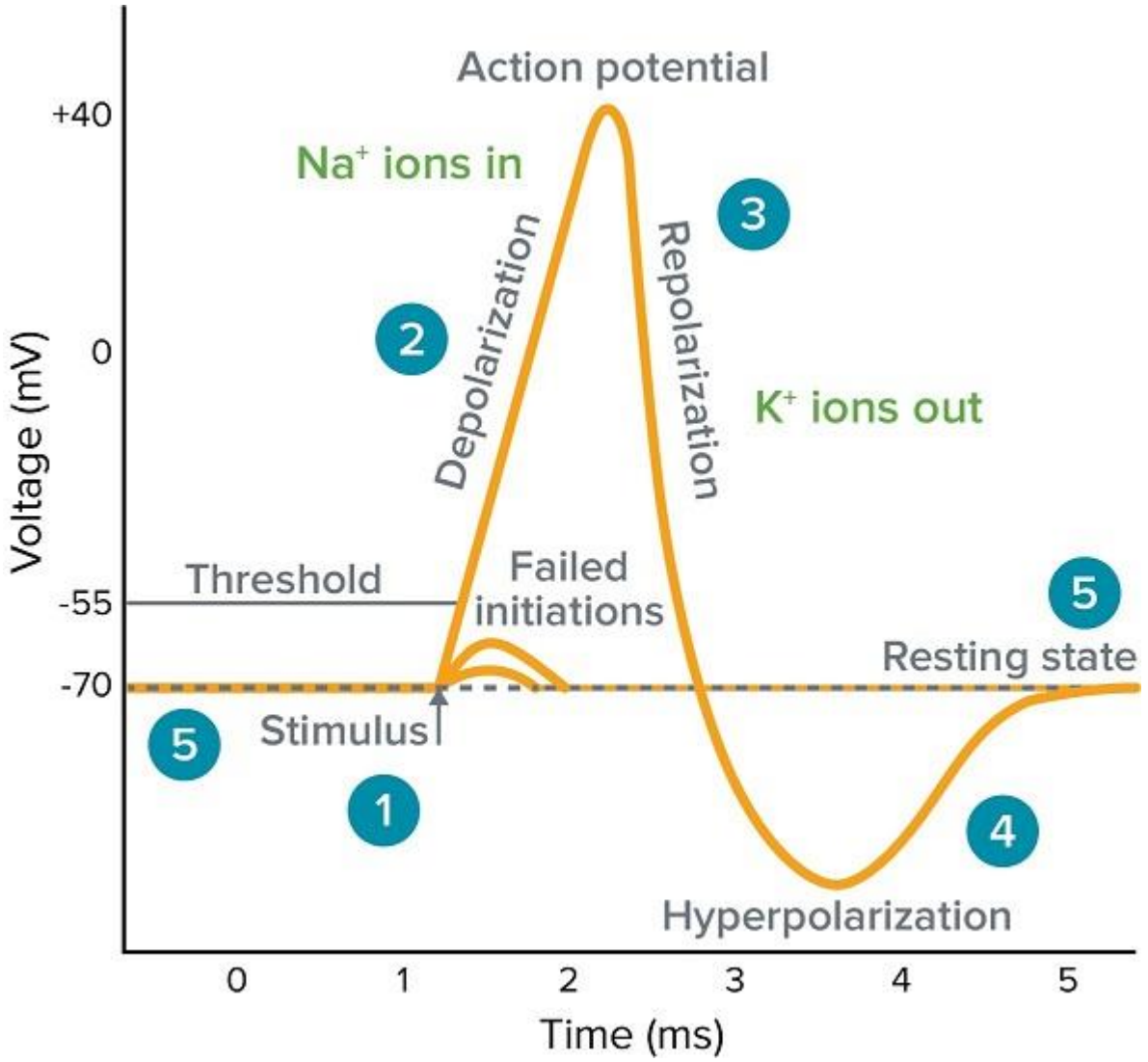


Impulse Conduction

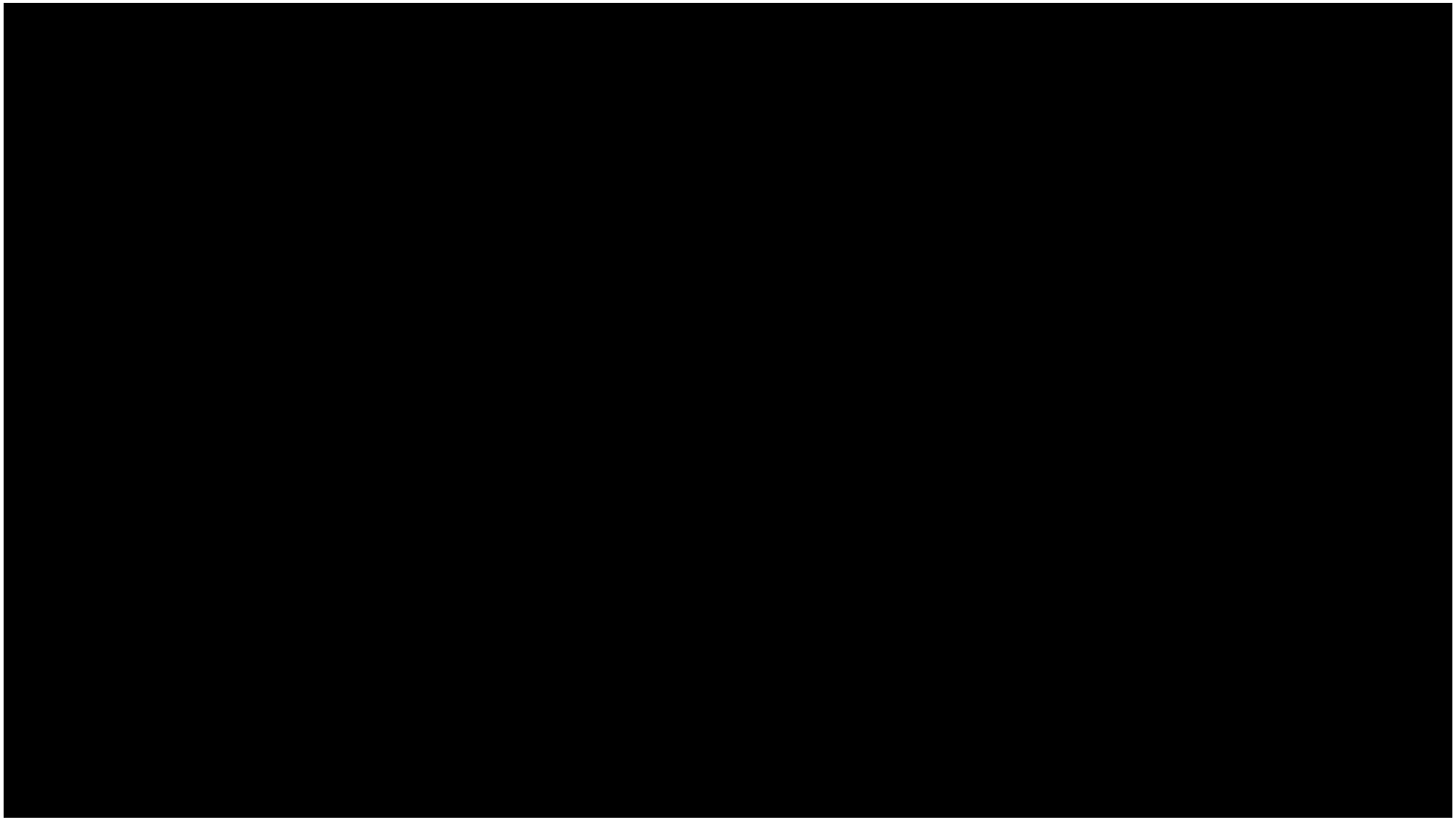


Terms of Reference

- Resting membrane potential
- Threshold of excitation
- Action potential
  - Depolarization
  - Repolarization
  - Hyperpolarization



How does this occur ?



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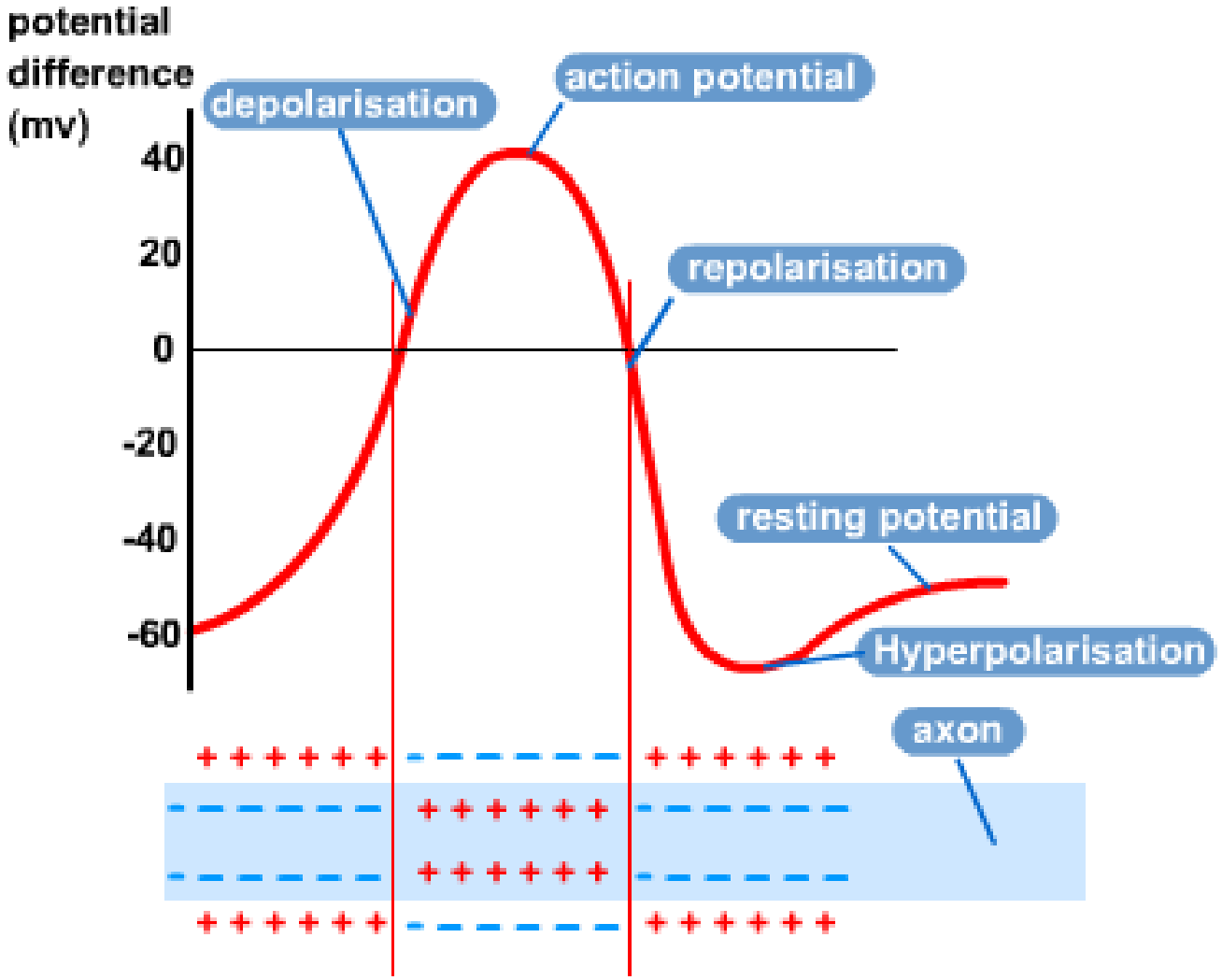
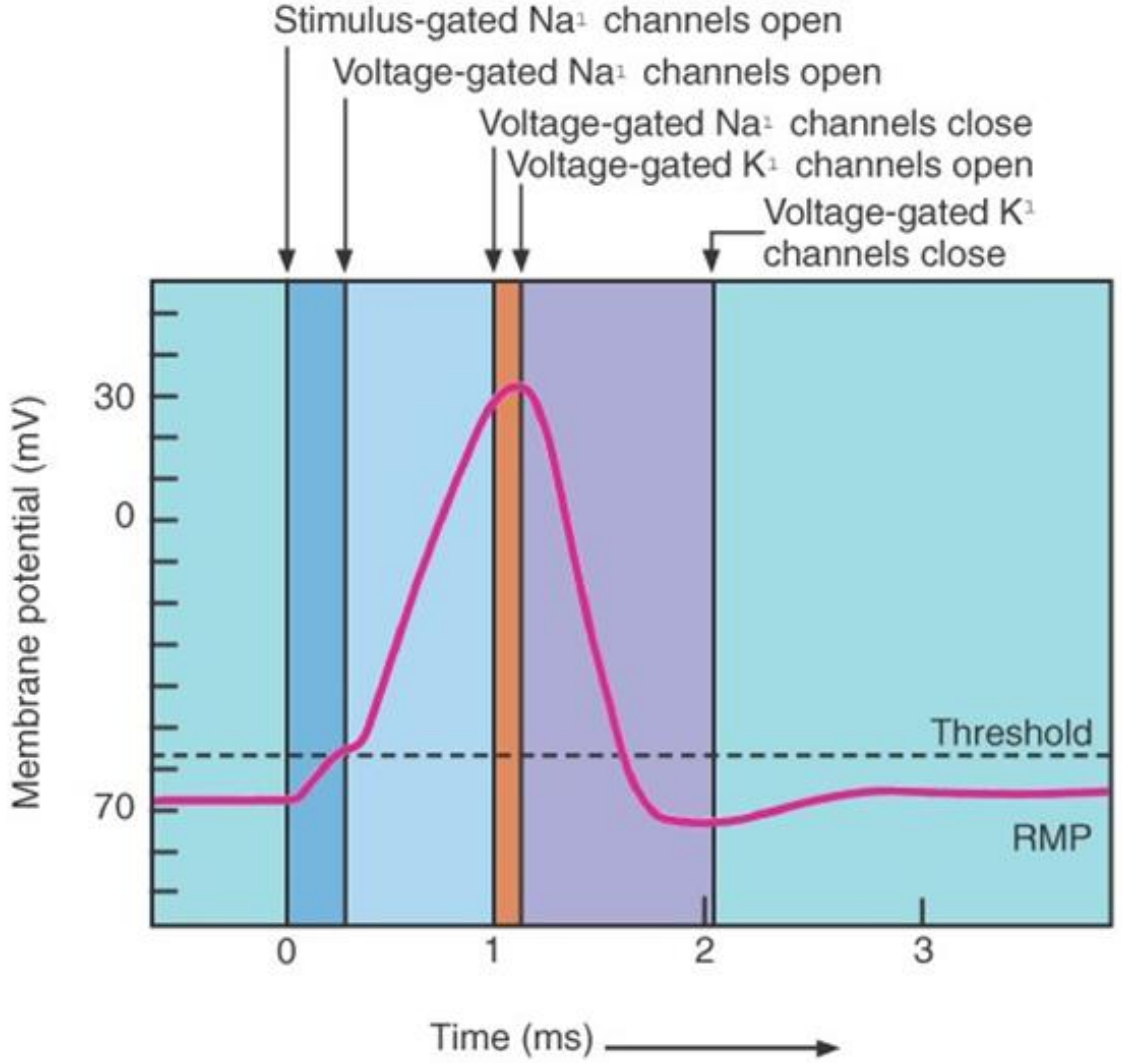
Action Potential

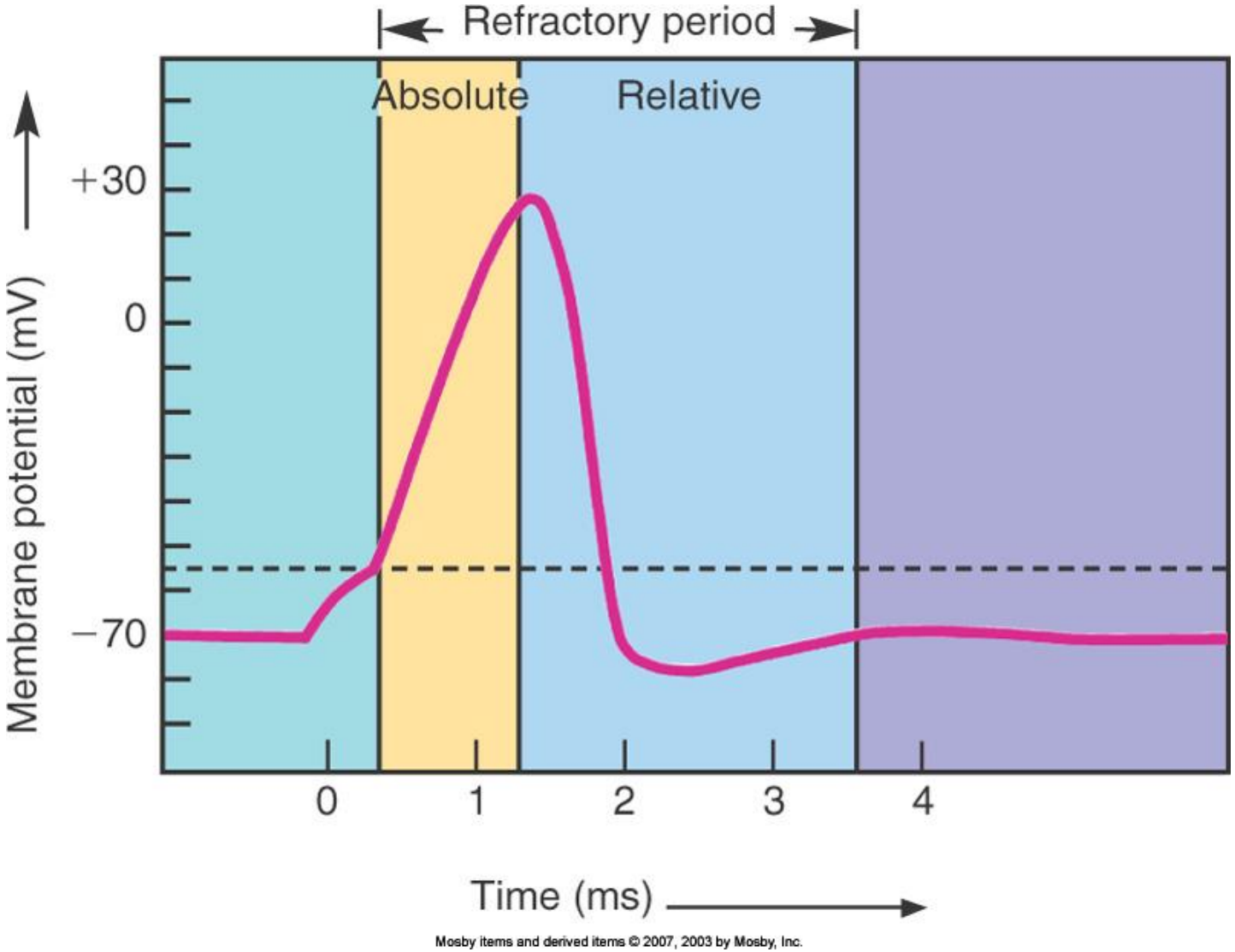


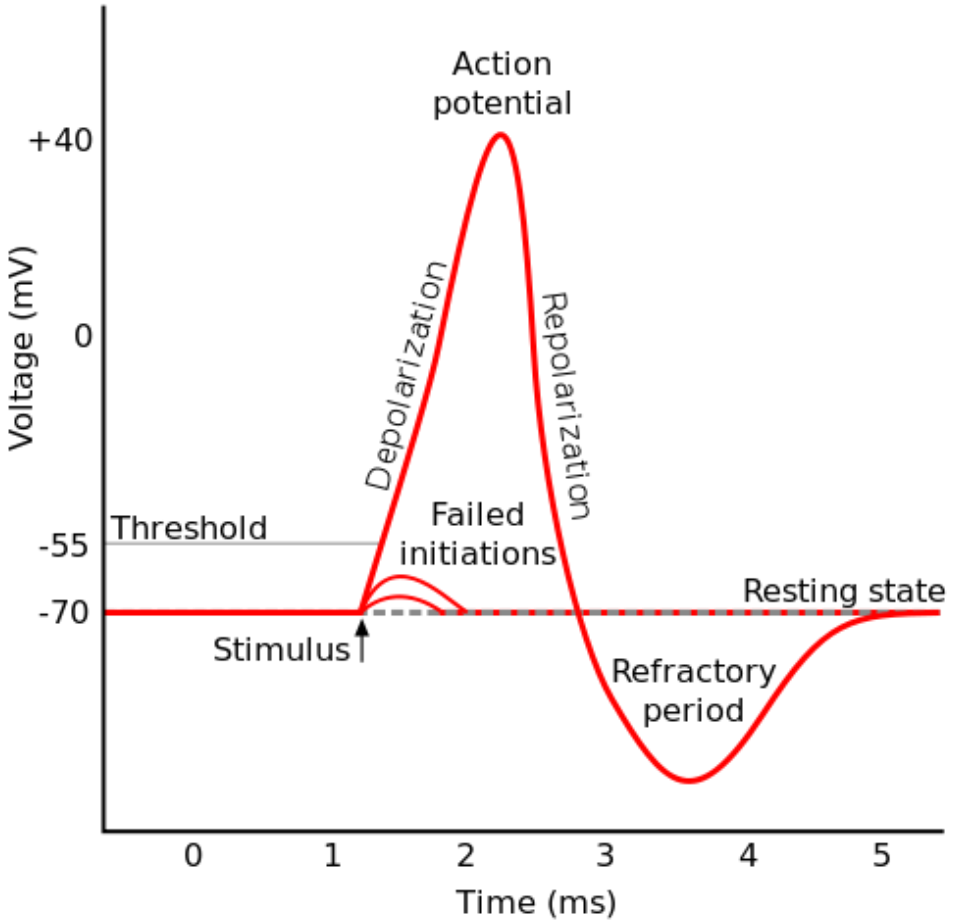


Refractory Period

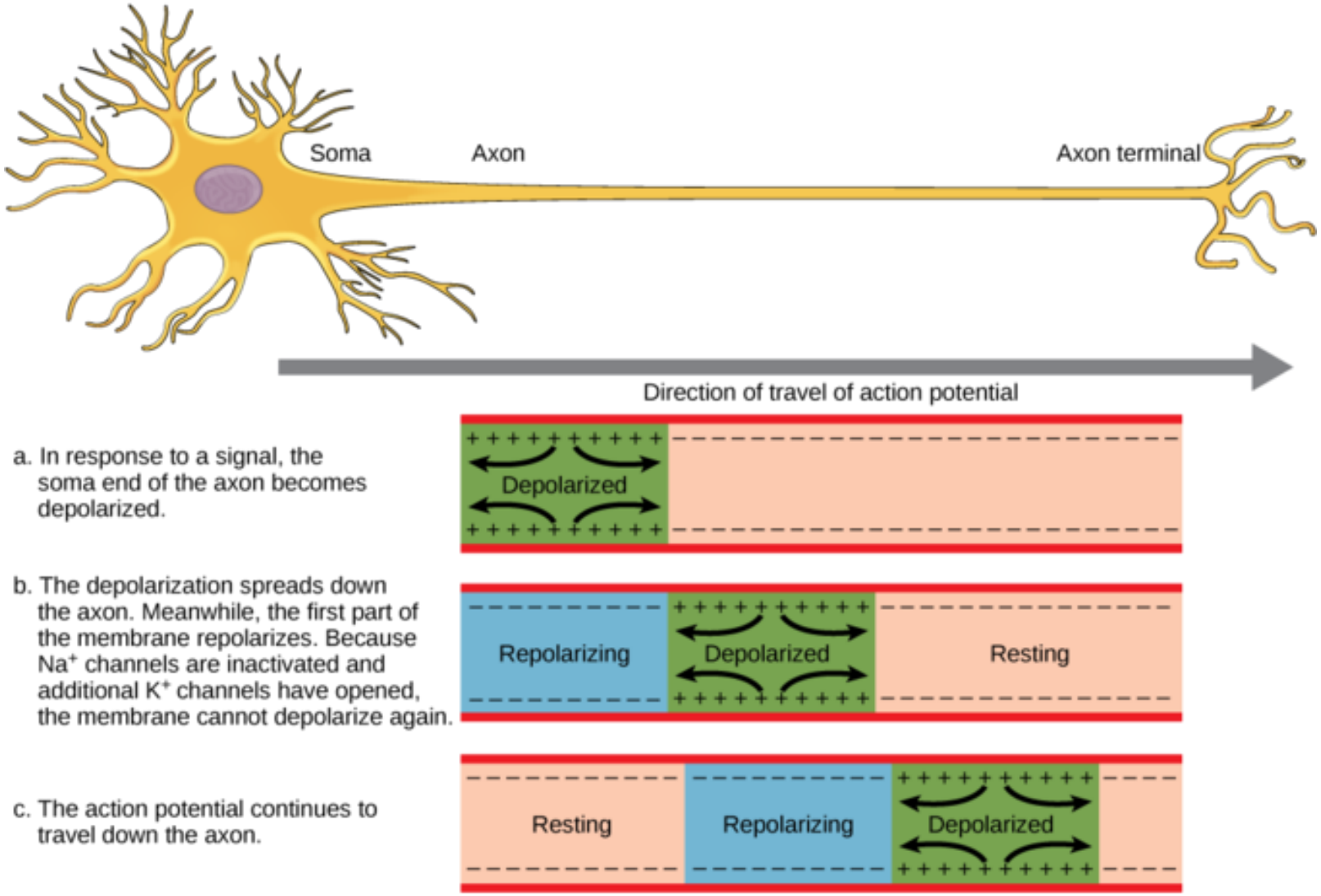
- Time in which the cell membrane is recovering
- Absolute Refractory Period
  - When the membrane cannot respond to a second stimulus no matter how strong
- Relative Refractory Period
  - Brief period of time after the stimulus in which a stronger than normal stimulus will reach the threshold

Refractory Period



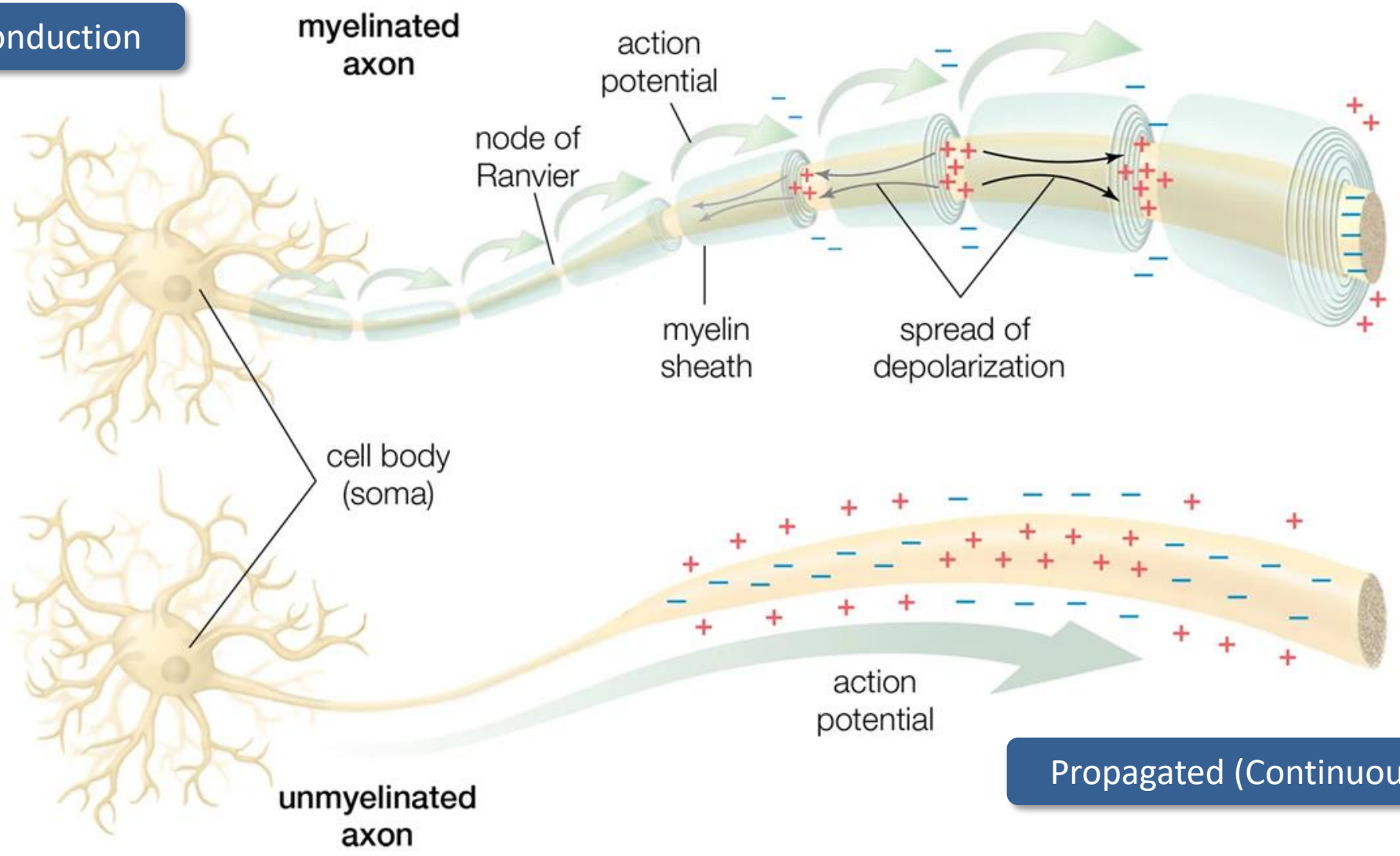


Refractory Period



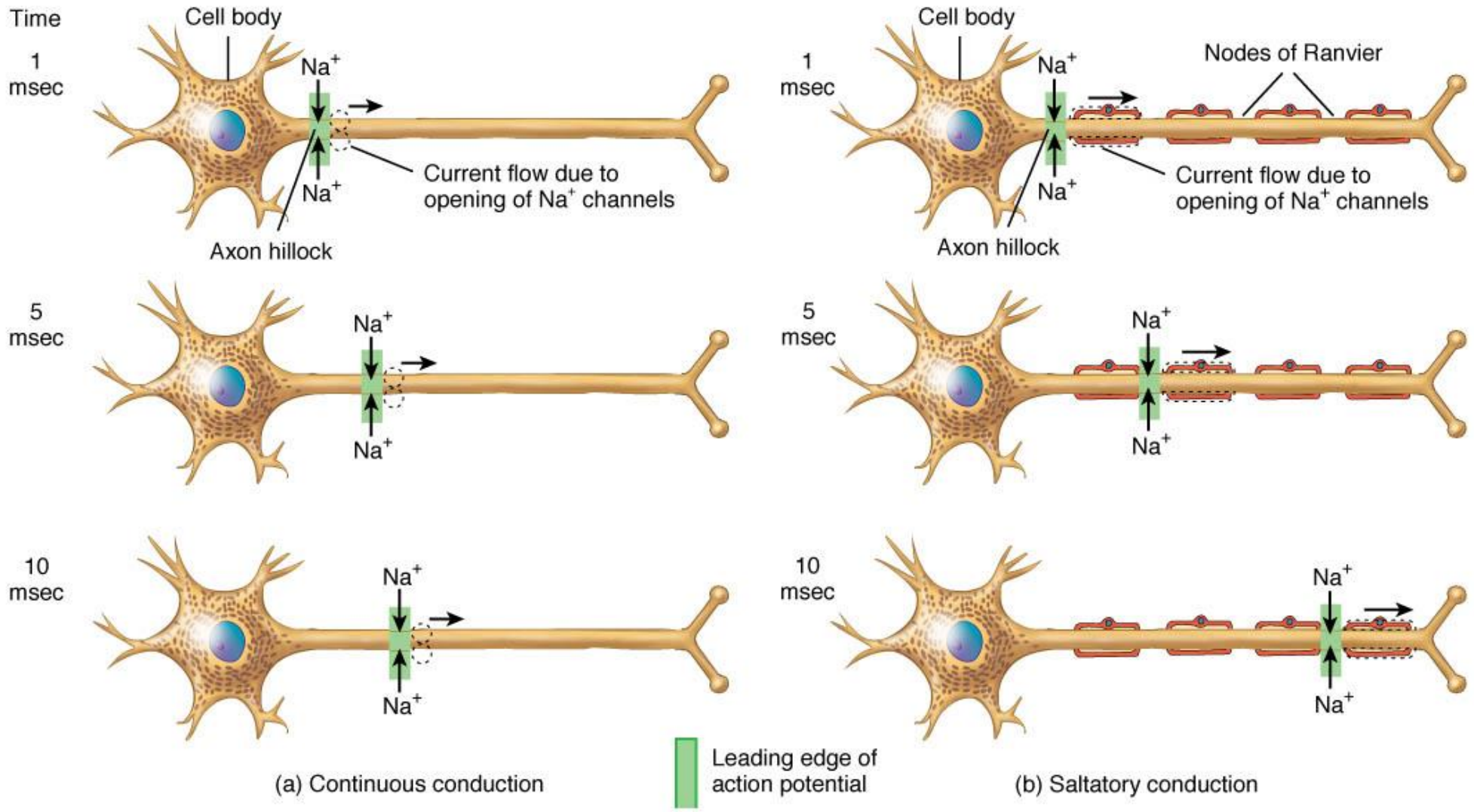
Nerve Impulses

Saltatory Conduction



Propagated (Continuous) Conduction

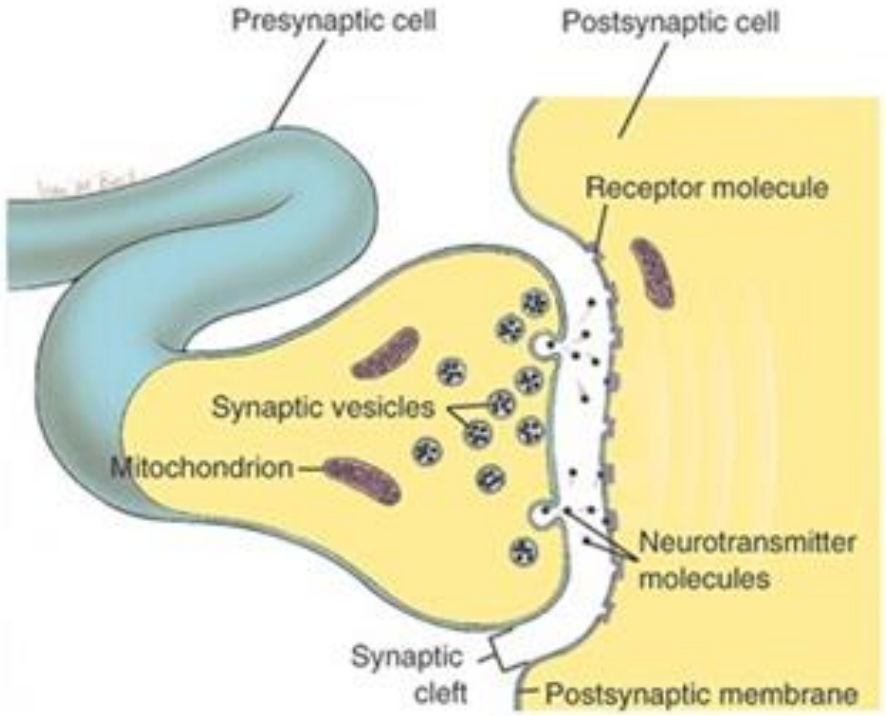
Nerve Impulses



Synaptic Transmission

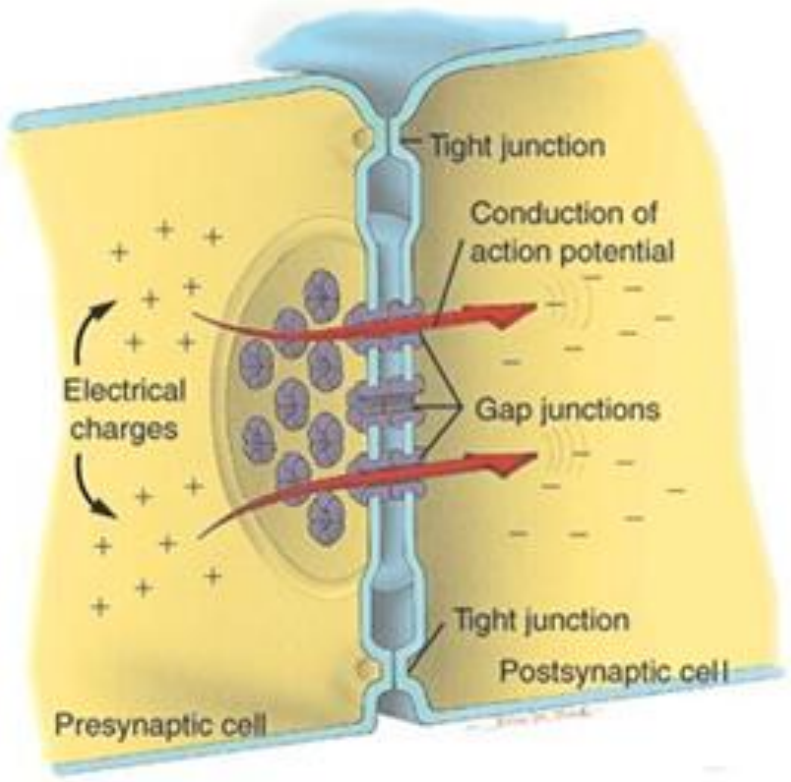
Chemical

- Use neurotransmitters



Electrical

- Found in cardiac and some muscle



Conduction at the Synapse

- Synapse has three parts
  - Synaptic bulb
    - Contains synaptic vesicles which release neurotransmitters
  - Synaptic cleft
  - Postsynaptic membrane
- First neuron is presynaptic neuron
- Second neuron is postsynaptic neuron

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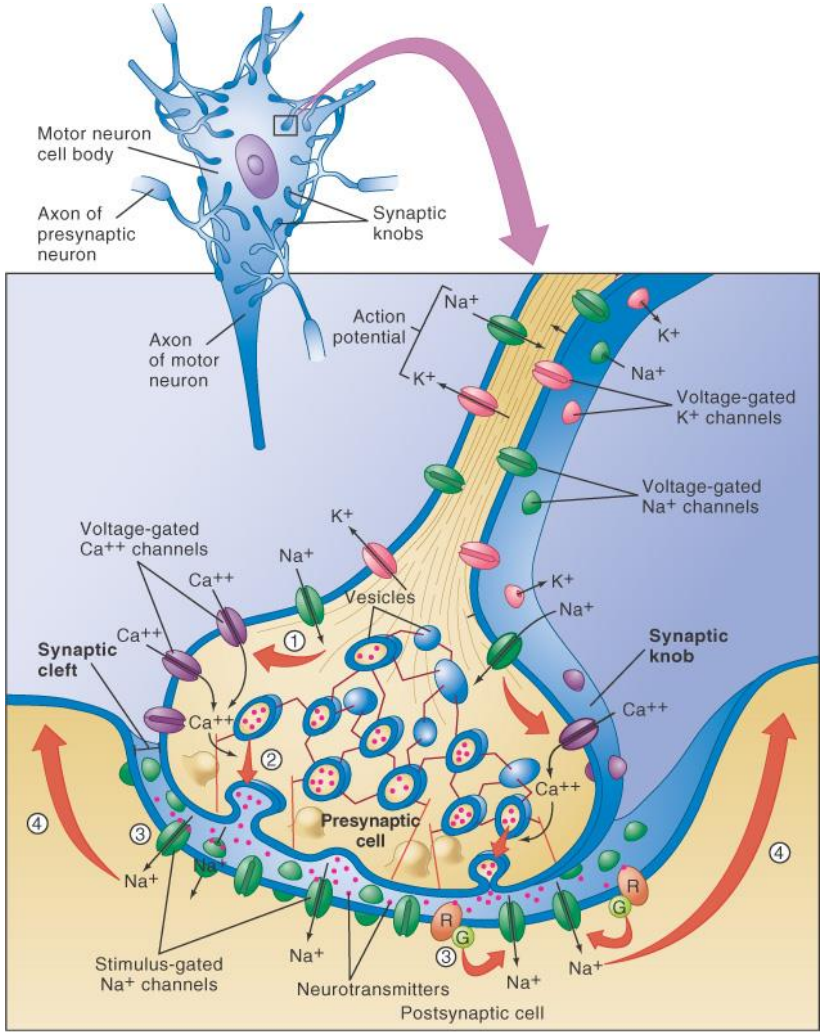
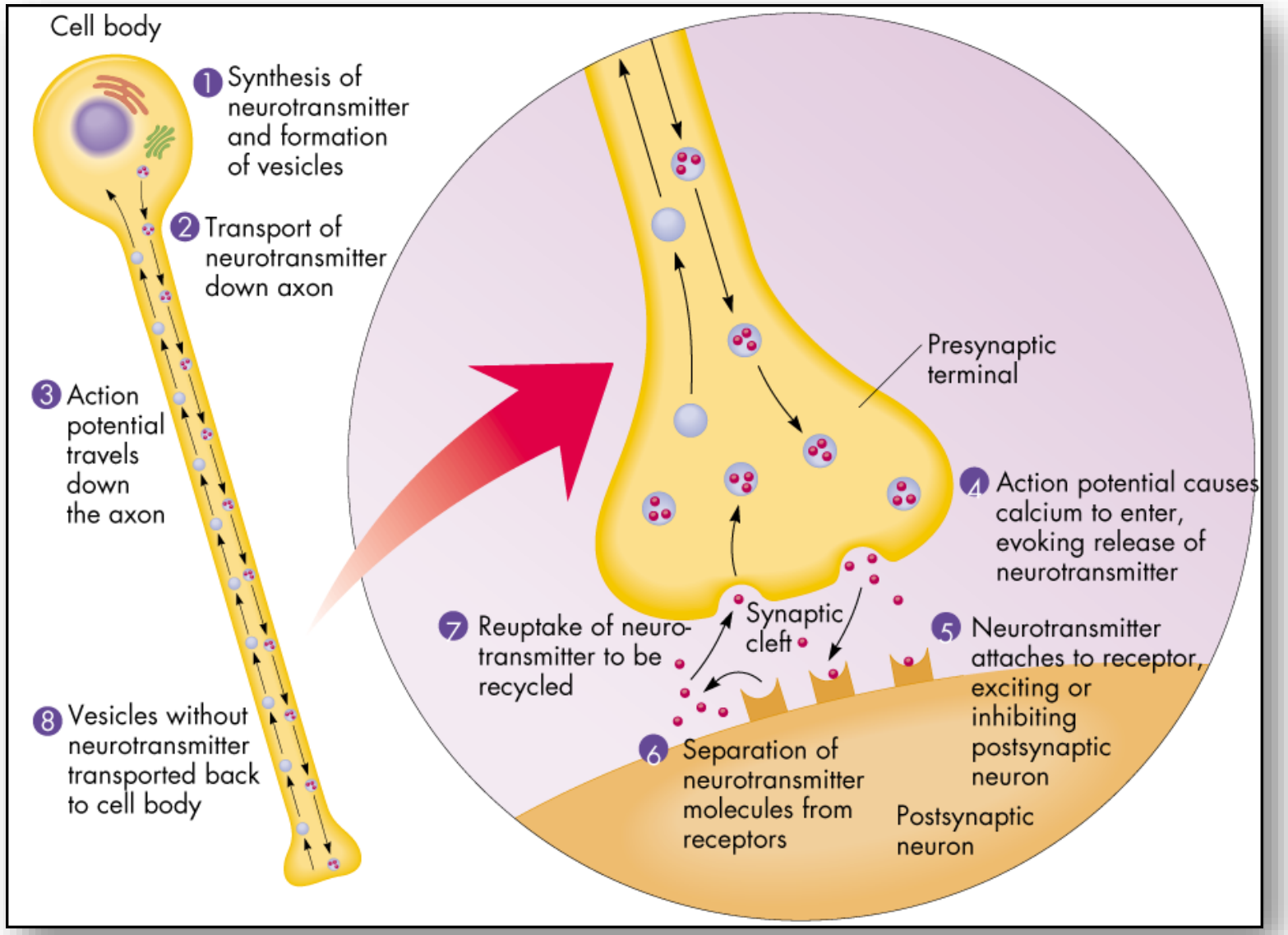
Conduction at the Synapse



- Impulse reaches synaptic bulb and is stopped and opens Ca^{2+} Channels to open
- Influx of Ca^{2+} triggers vesicles to move to the membrane
- Causes release of NTM into synaptic cleft
- They react with receptor sites on postsynaptic membrane and cause ion channels to open causing a postsynaptic potential
- Impulse continues on
- NTM quickly inactivated by enzymes

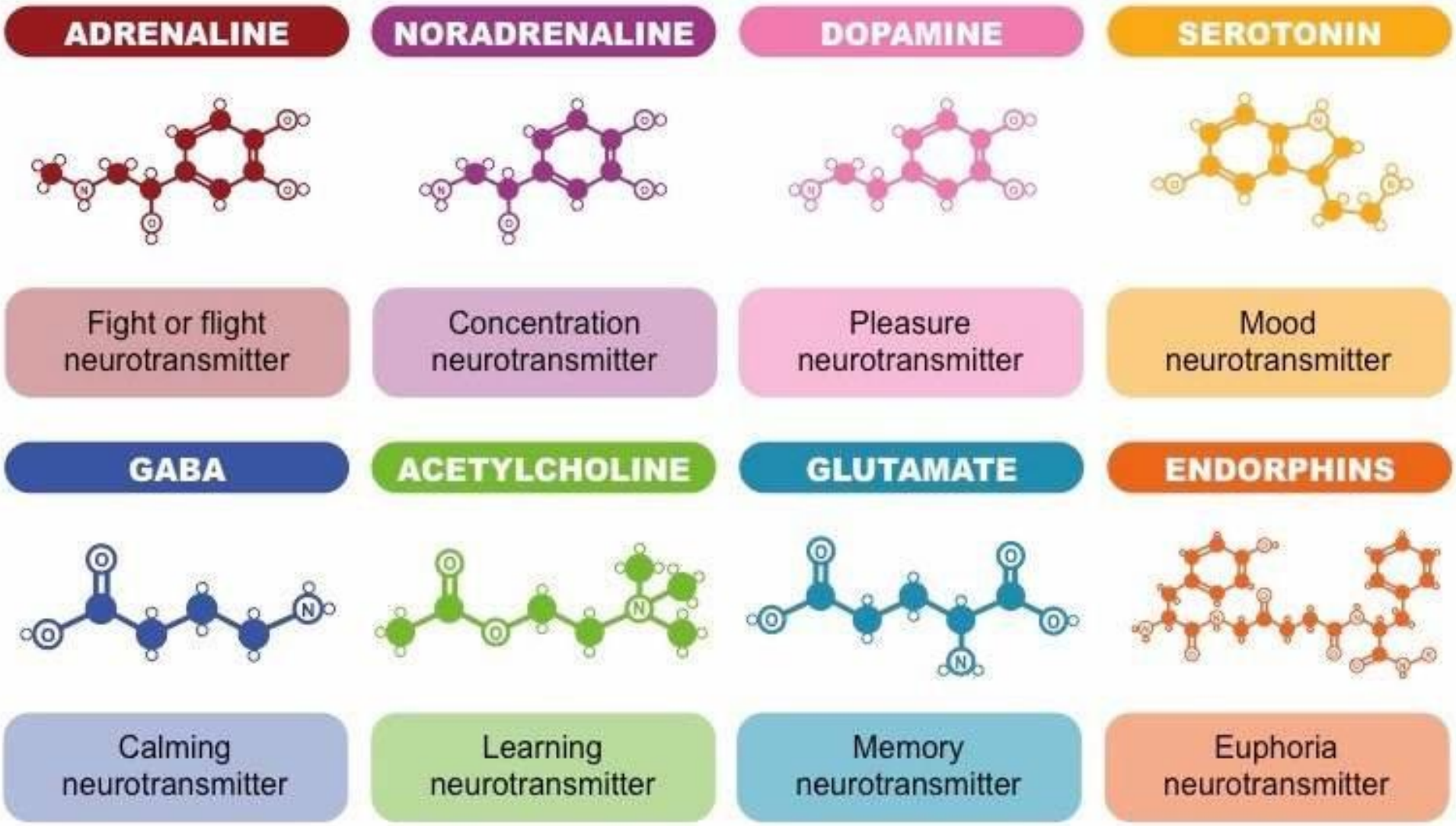

Cell body
1 Synthesis of neurotransmitter and formation of vesicles
2 Transport of neurotransmitter down axon
3 Action potential travels down the axon
8 Vesicles without neurotransmitter transported back to cell body
Presynaptic terminal
4 Action potential causes calcium to enter, evoking release of neurotransmitter
Synaptic cleft
7 Reuptake of neuro-transmitter to be recycled
5 Neurotransmitter attaches to receptor, exciting or inhibiting postsynaptic neuron
6 Separation of neurotransmitter molecules from receptors
Postsynaptic neuron

Conduction at the Synapse

- Excitatory transmission
  - Na^+ and K^+ channels are opened
    - Excitatory postsynaptic Potential (EPSP)
  - NTM excites next neuron to continue impulse
    - Examples: ACh

- Inhibitory transmission
  - Causes the fiber to allow K^+ and/or Cl^- to move but not Na^+ causing the membrane potential to become even more negative (hyperpolarized)
    - Inhibitory postsynaptic potential (IPSP)
    - Examples: GABA in CNS

Neurotransmitters



Neurotransmitters

Function	Examples
Excitatory (leads to depolarization)	Glutamate
	Aspartate
	Serotonin
	Histamine
	ATP, CO
Inhibitory (leads to hyperpolarization)	Glycine
	Gamma amino butyric acid (GABA)
	Taurine
Excitatory & Inhibitory (leads to depolarization and hyperpolarization depending on type of receptor)	Acetylcholine
	Epinephrine (Adrenaline)
	Dopamine
	Norepinephrine (Noradrenaline)
	NO
	Endorphins, enkephalins, substance P, cholecystokinin

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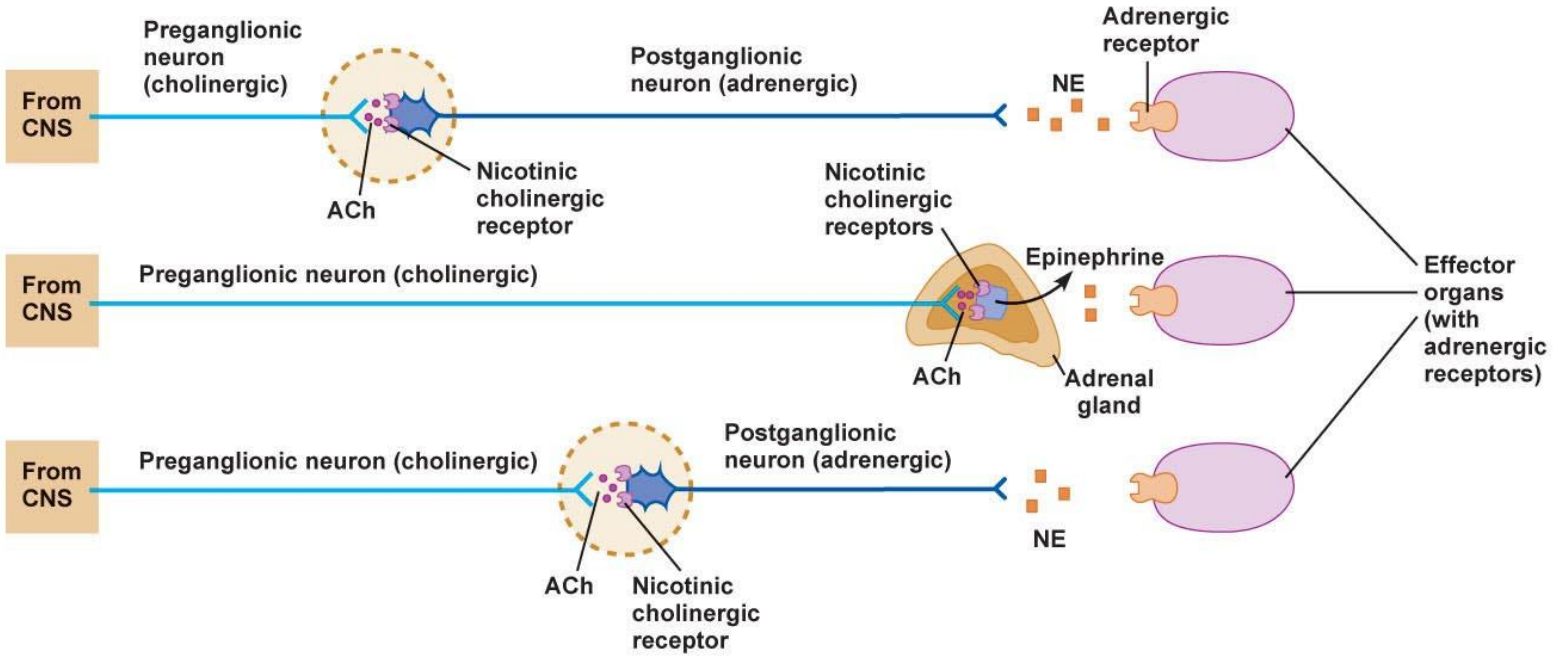
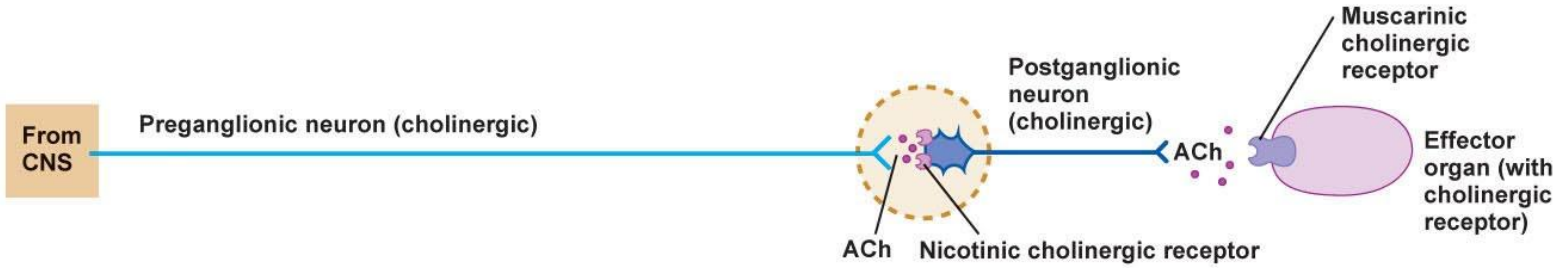
Conduction at the Synapse



(a) Sympathetic nervous system



(b) Parasympathetic nervous system

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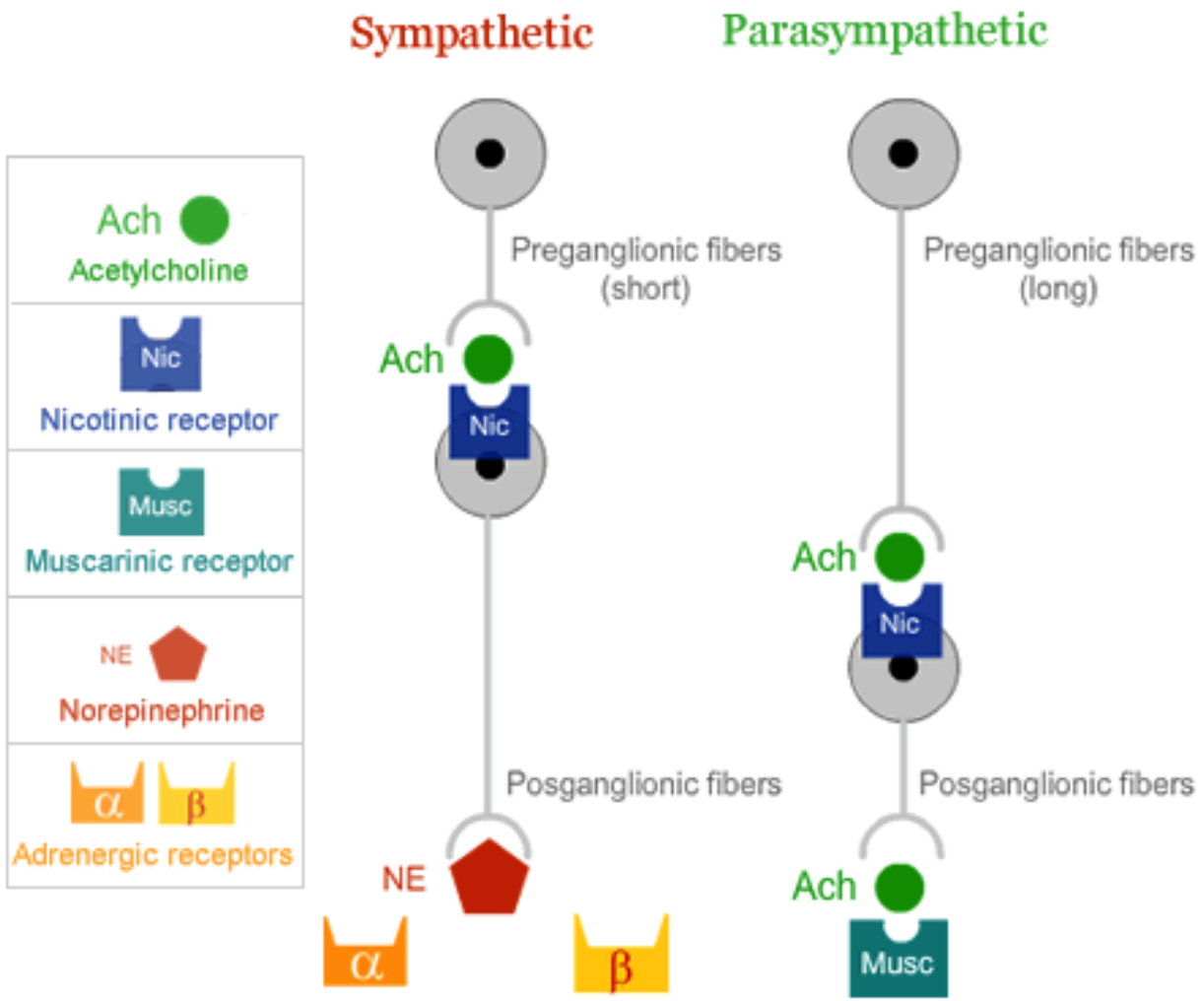
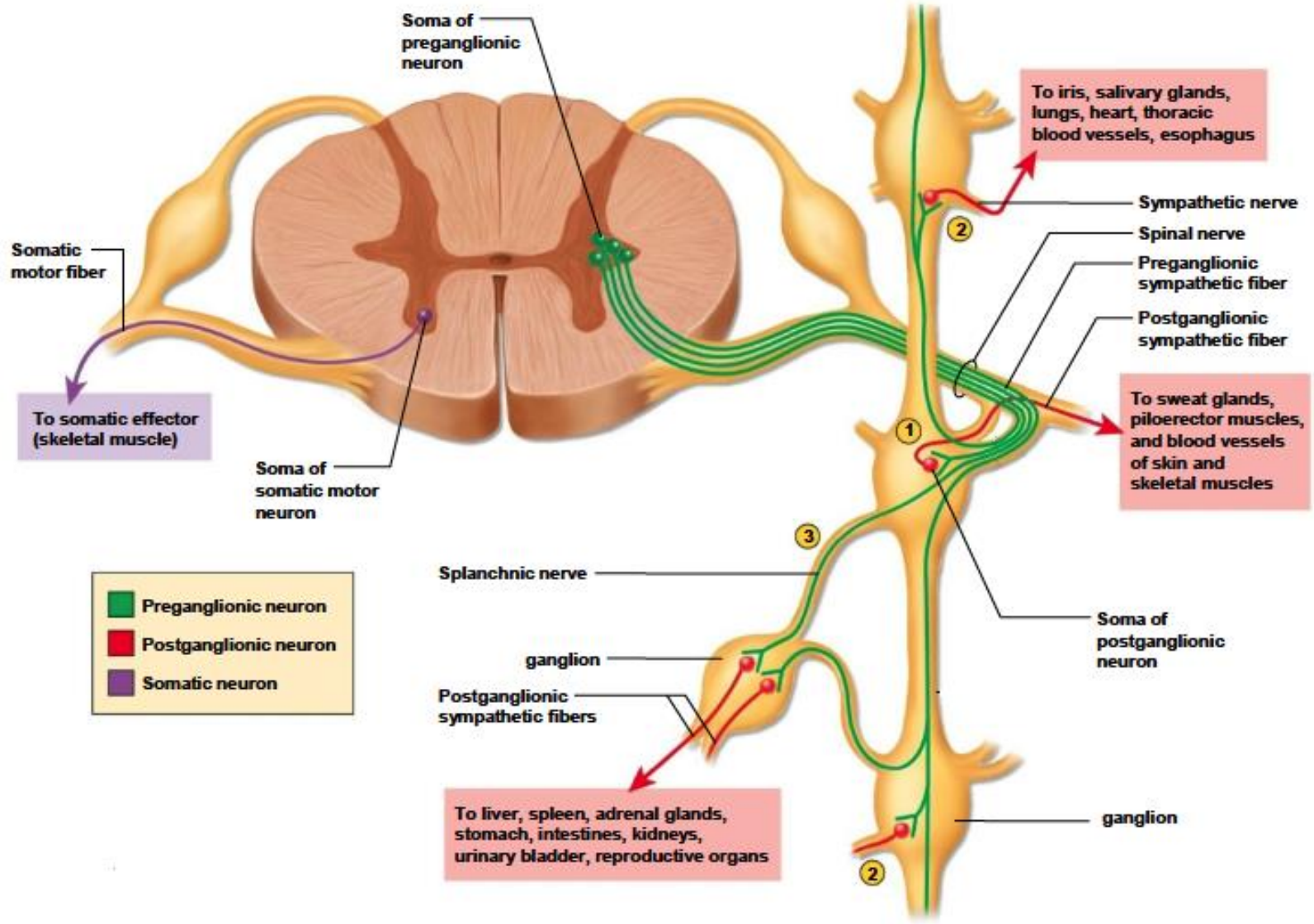
Conduction at the Synapse



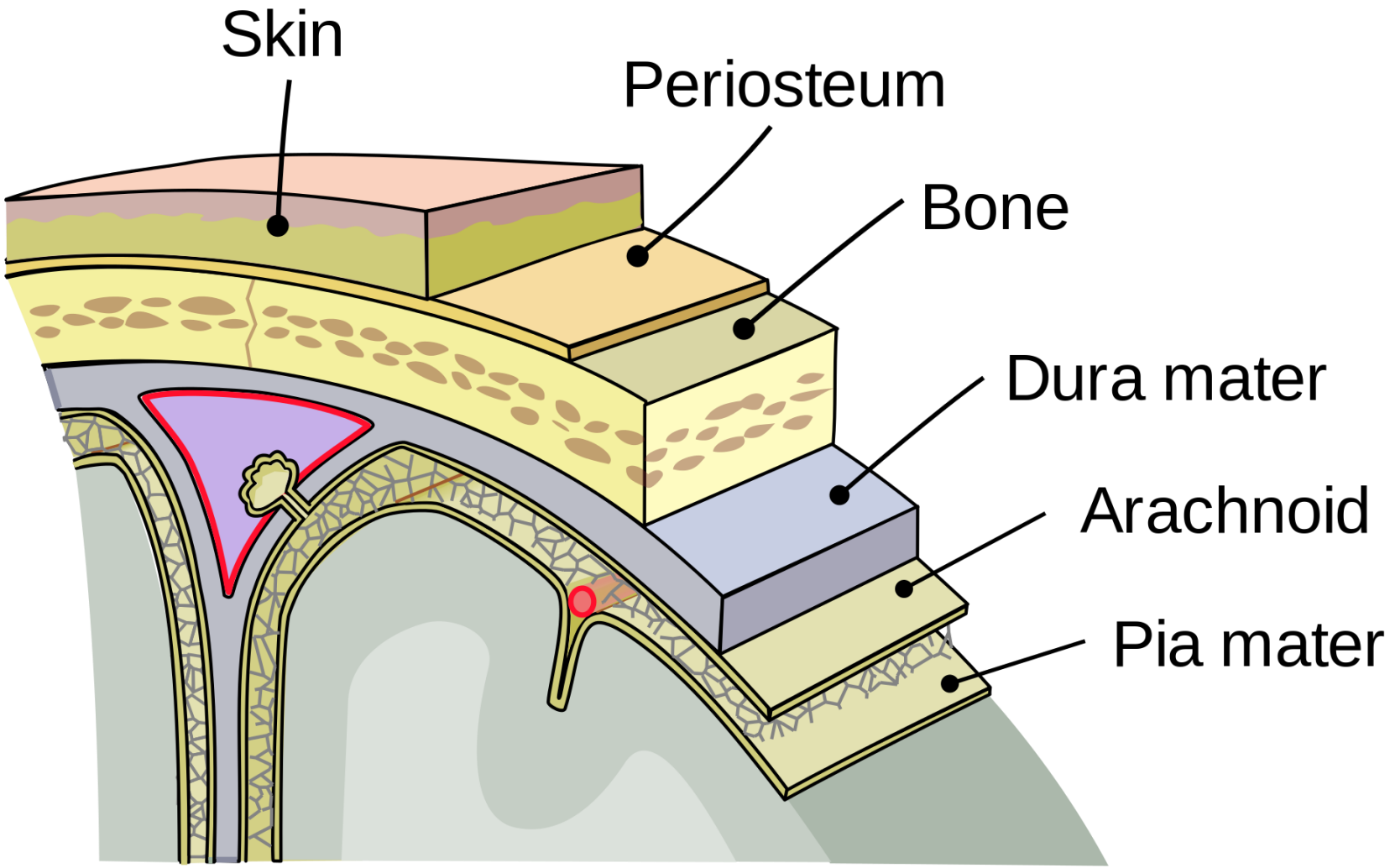
Conduction at the Synapse



Nervous System Anatomy

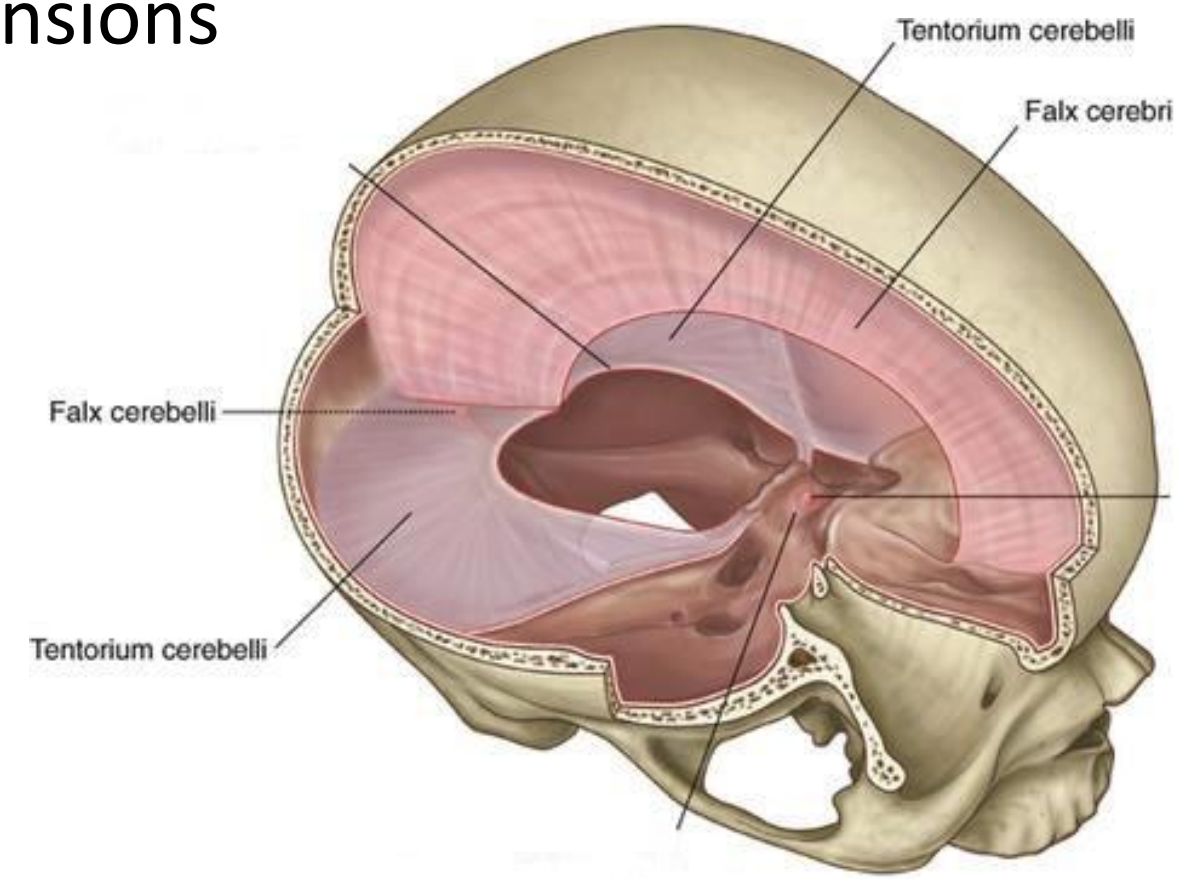
CENTRAL NERVOUS SYSTEM

Coverings of the CNS



Dura Mater

- Strong fibrous tissue
- Has 3 important inward extensions
  - Falx cerebri
  - Falx cerebelli
  - Tentorium cerebelli



Meninges

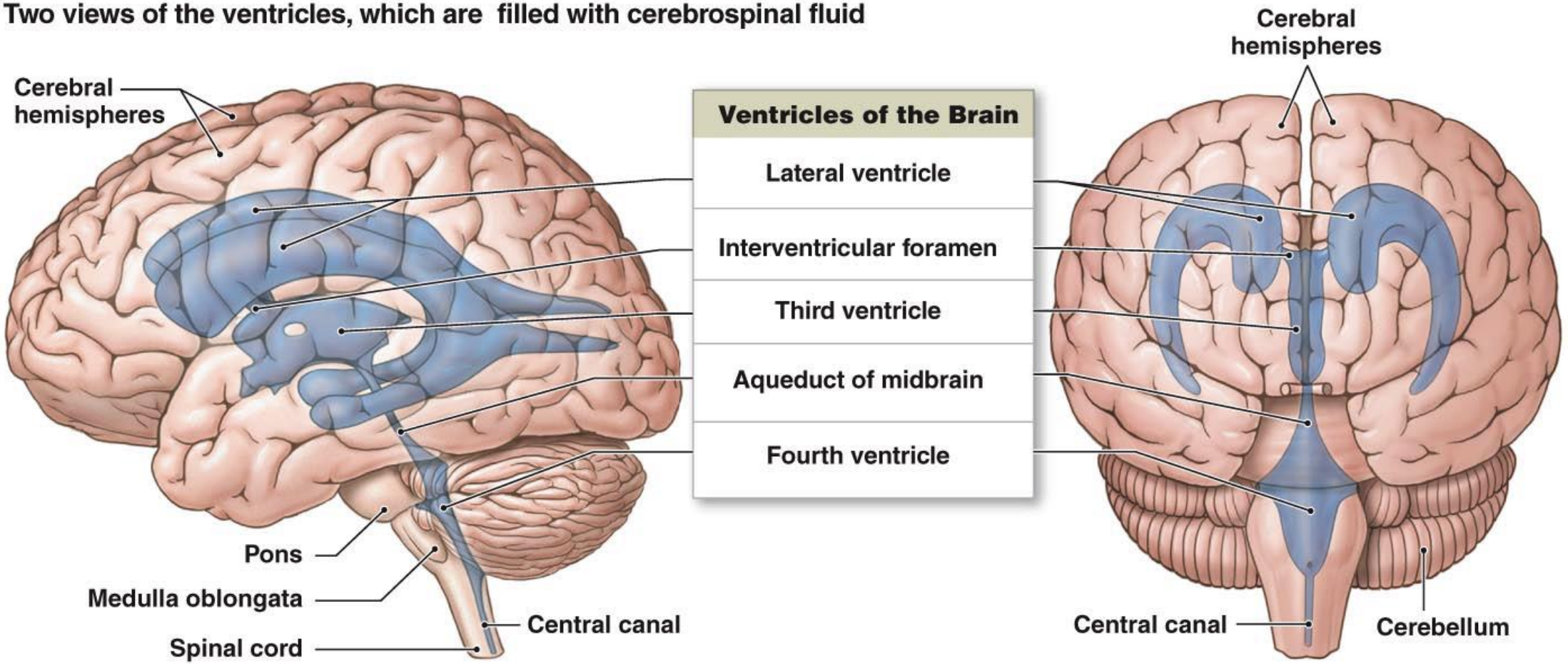
- Arachnoid membrane
  - Cob-web like
  - Numerous threadlike strands attach it to Pia Mater
  - Space underneath contains the CSF and blood vessels
    - Aka Subarachnoid space
  - Avascular
- Pia Mater
  - Thin, transparent layer
  - Adheres to the outer layer of the brain and spinal cord
  - Highly vascular

Cerebrospinal Fluid

- Provides protective cushion
- Also a reservoir for fluid that the brain monitors for changes
- Is found in the subarachnoid space and in the cavities and canals of the brain and spinal cord
- Ventricles
  - Four different locations
    - 1st and 2nd
      - Lateral ventricles found in each hemisphere of the cerebrum
    - 3rd
      - Vertical pocket, connects the 1st and 2nd
    - 4th
      - Diamond shaped pocket where the cerebellum attaches to the brain stem

Ventricles

Two views of the ventricles, which are filled with cerebrospinal fluid

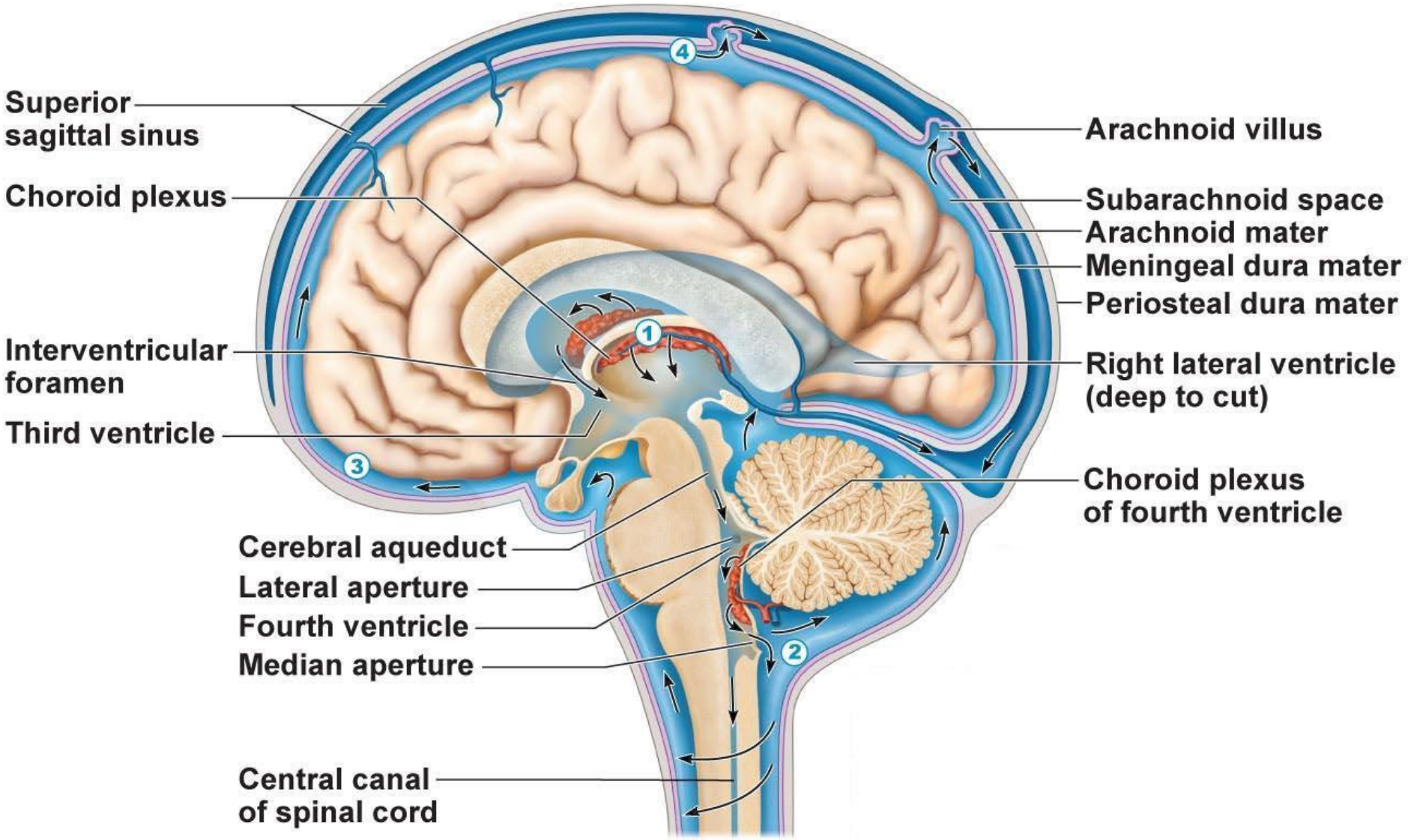


Ventricular system, lateral view

Ventricular system, anterior view

CSF

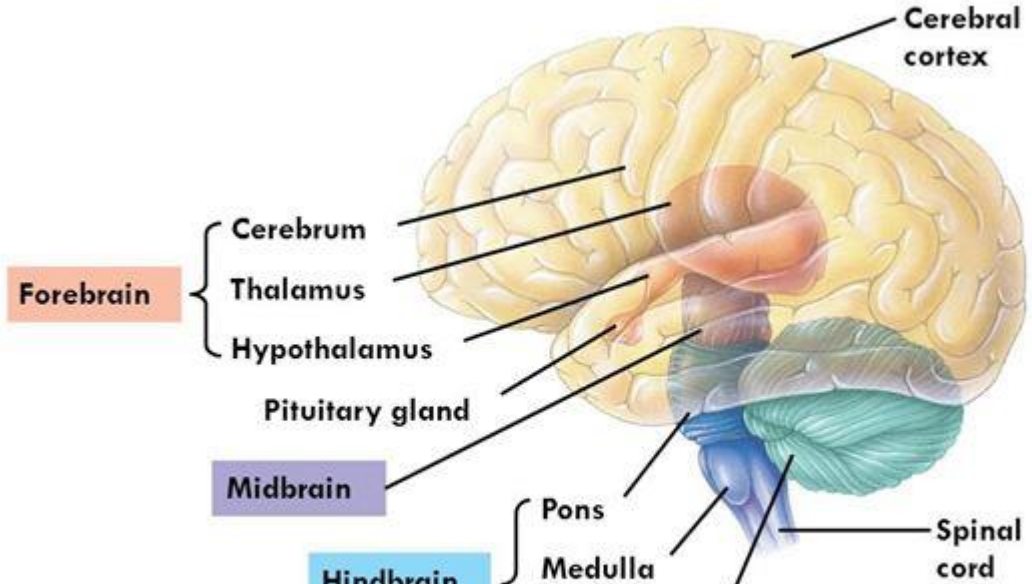
- Created by separation of fluid from blood at the choroid plexus
  - Networks of capillaries from the Pia mater into the lateral ventricles
- Moves down to 4th where some enters the spinal canal or the subarachnoid space (in openings in the roof of the 4th)
- Once in the Subarachnoid space it can be reabsorb into venous blood through the arachnoid villi


Superior sagittal sinus
Choroid plexus
Interventricular foramen
Third ventricle
Cerebral aqueduct
Lateral aperture
Fourth ventricle
Median aperture
Central canal of spinal cord
Arachnoid villus
Subarachnoid space
Arachnoid mater
Meningeal dura mater
Periosteal dura mater
Right lateral ventricle (deep to cut)
Choroid plexus of fourth ventricle
1
2
3
4

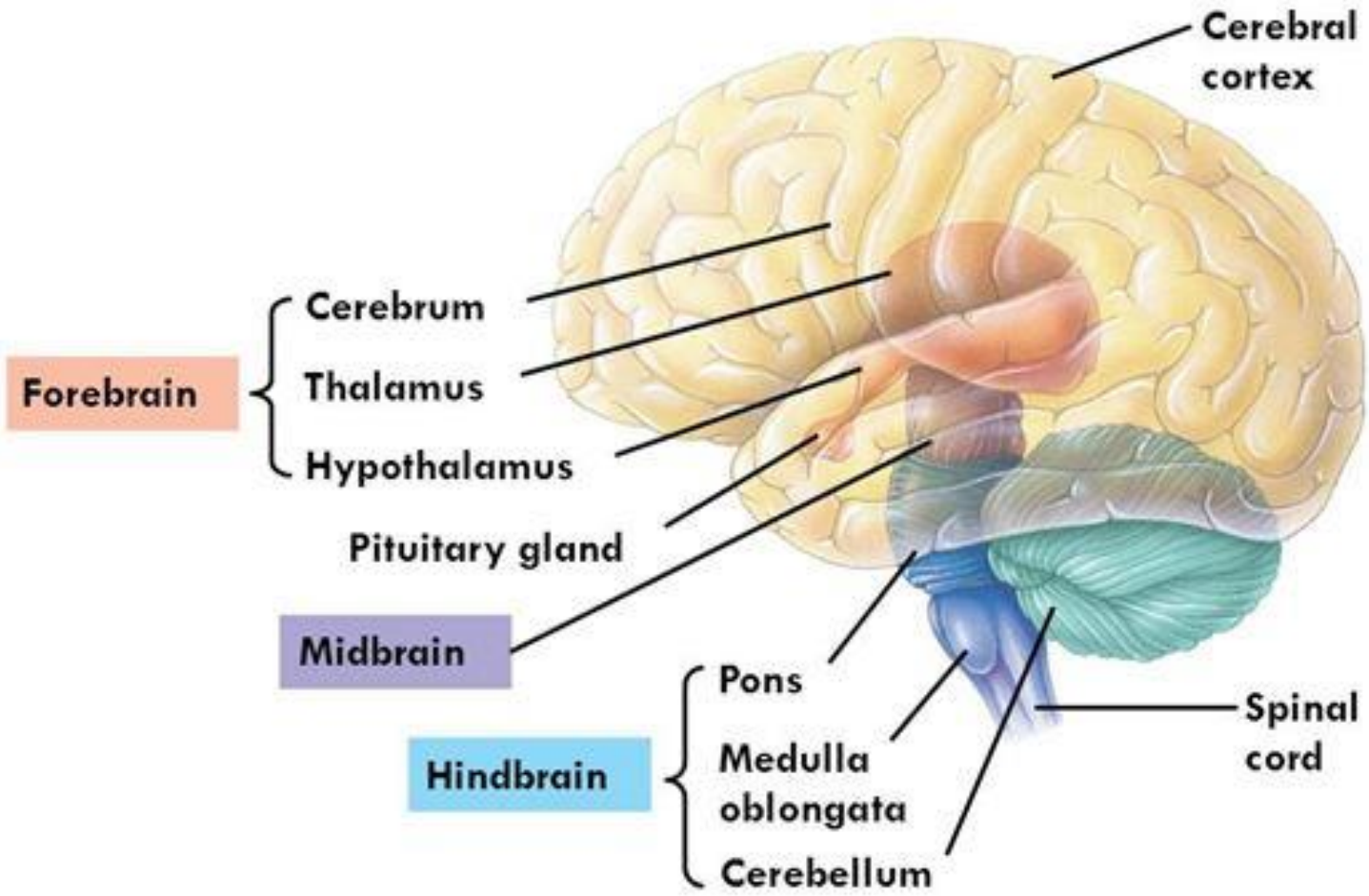
CNS components

- The central nervous system can be broken down structurally as follows:

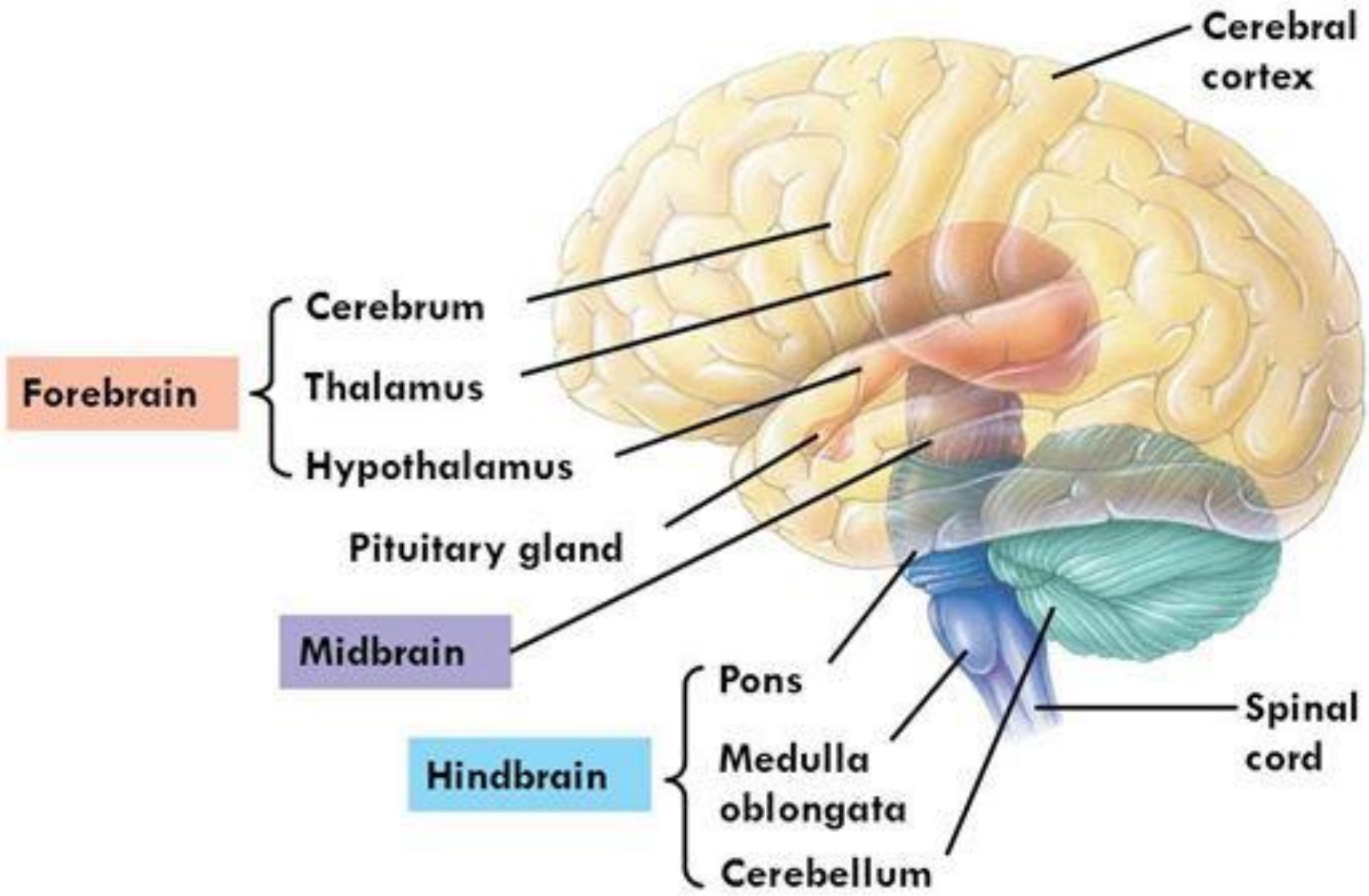
- Forebrain
  - Telencephalon
    - Cerebral Cortex
    - Subcortical Structures
    - Corpus Collosum
  - Diencephalon
    - Thalamus
    - Hypothalamus
    - Pineal Gland
- Midbrain (Mesencepha
- Hindbrain
  - Metencephalon
    - Pons
    - Cerebellum



CNS components



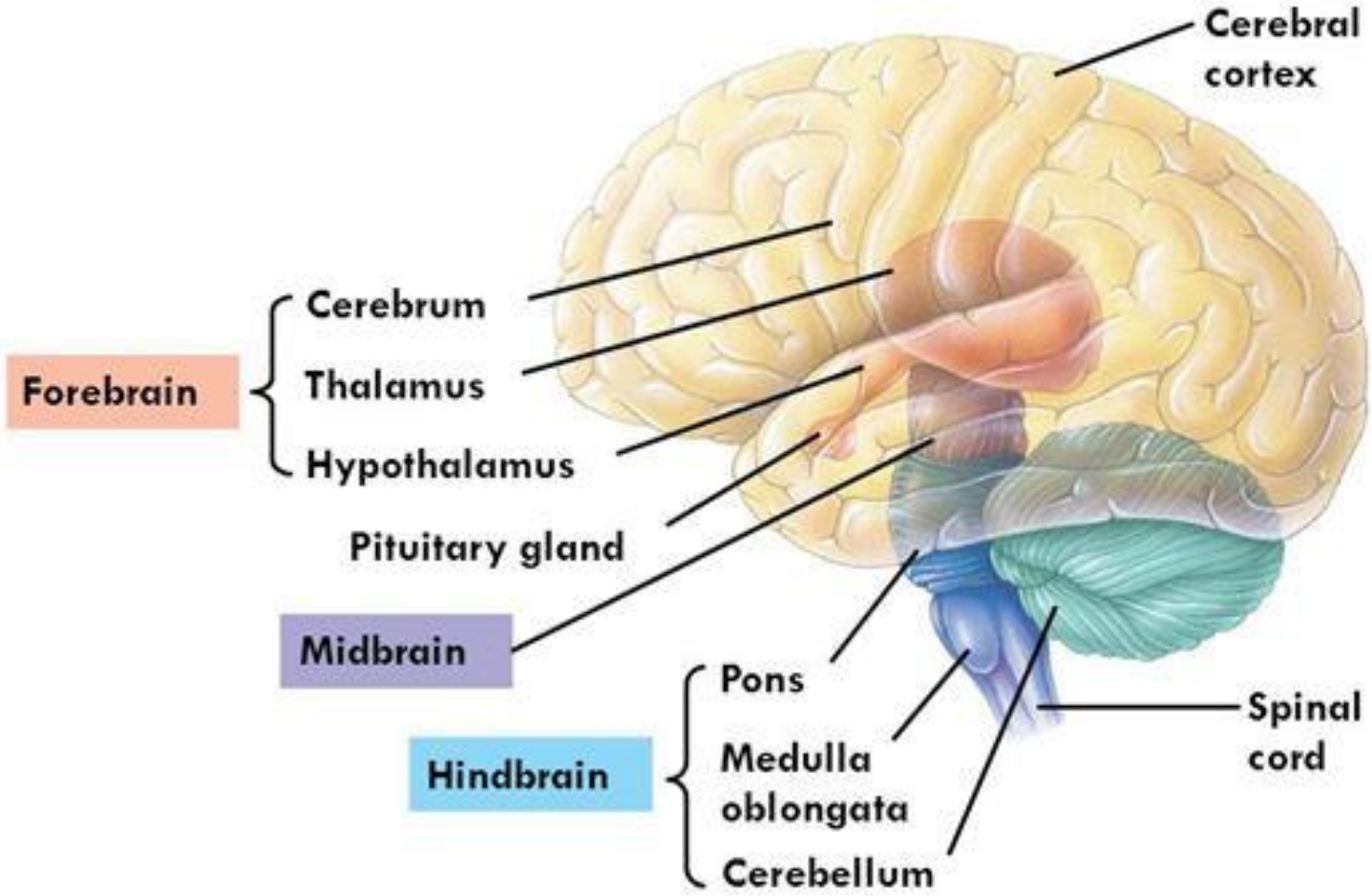
CNS components



Cerebral Cortex

- 6 layer shell of grey matter
  - Millions of neurons

CNS components

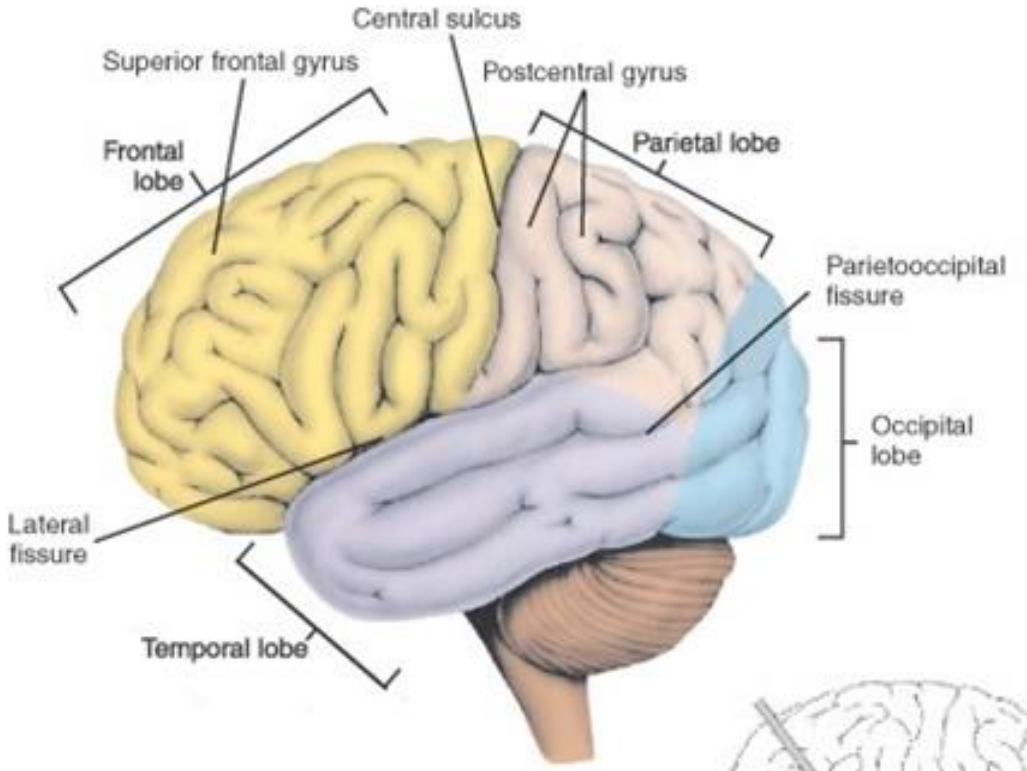


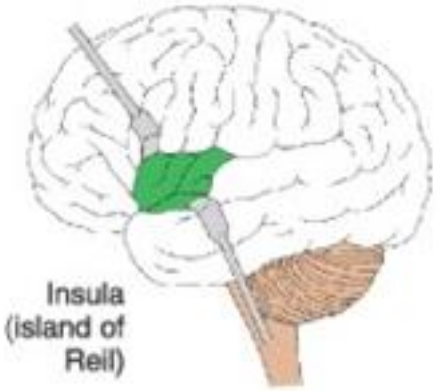
Forebrain

- Cerebrum
- Thalamus
- Hypothalamus

Cerebrum

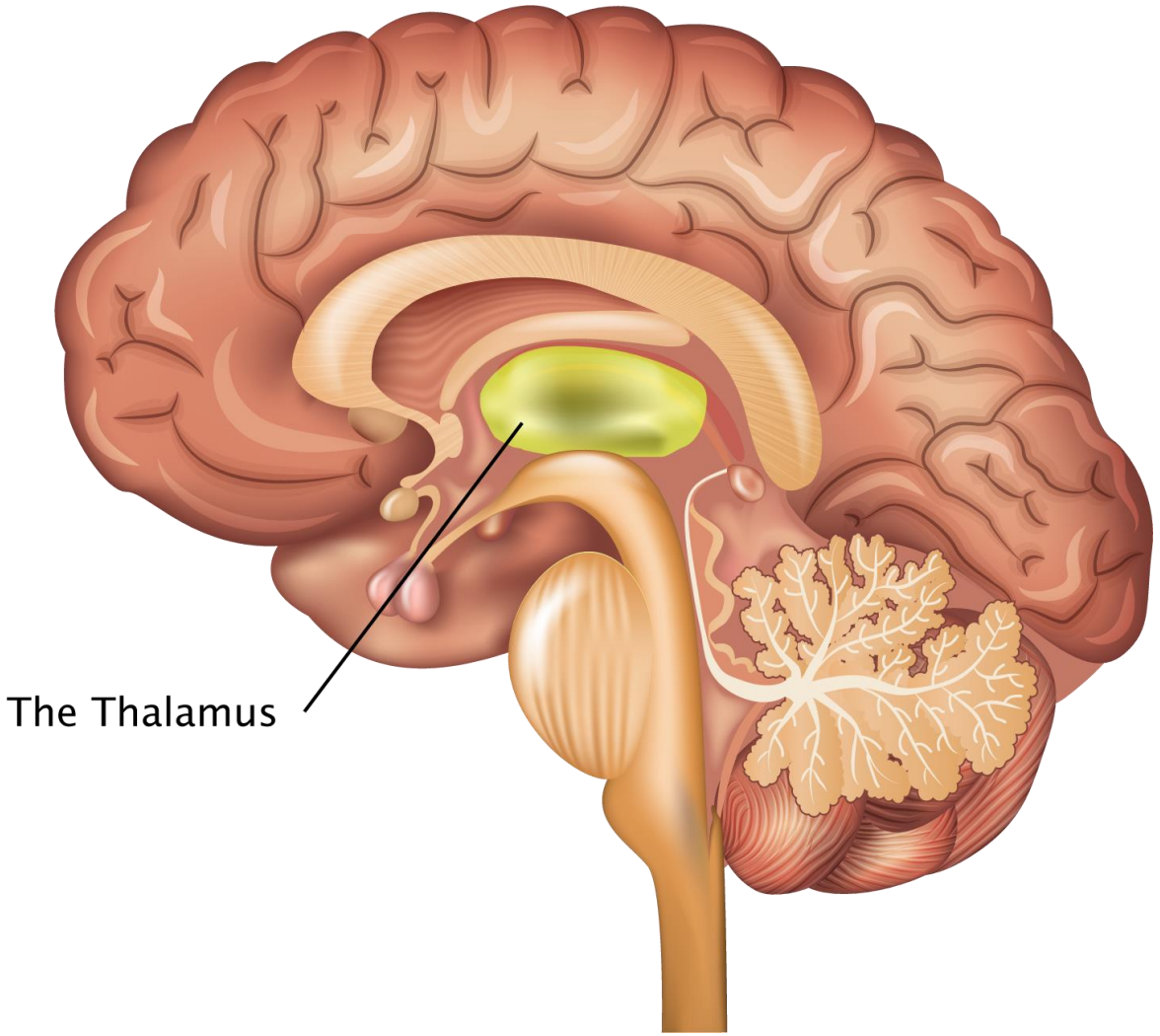
Lobe	Functions
Frontal	functioning of reasoning, planning, emotions, parts of speech & problem solving capabilities
Parietal	sense of touch, pain & temperature. It helps in distinguishing between shape, size & color. It controls spatial & visual perception
Occipital	visual processing
Temporal	speech, memory, hearing, sequencing & organization
Insula	plays a role in homeostasis, perception and self-awareness, cognitive function, motor control, self awareness, social emotions





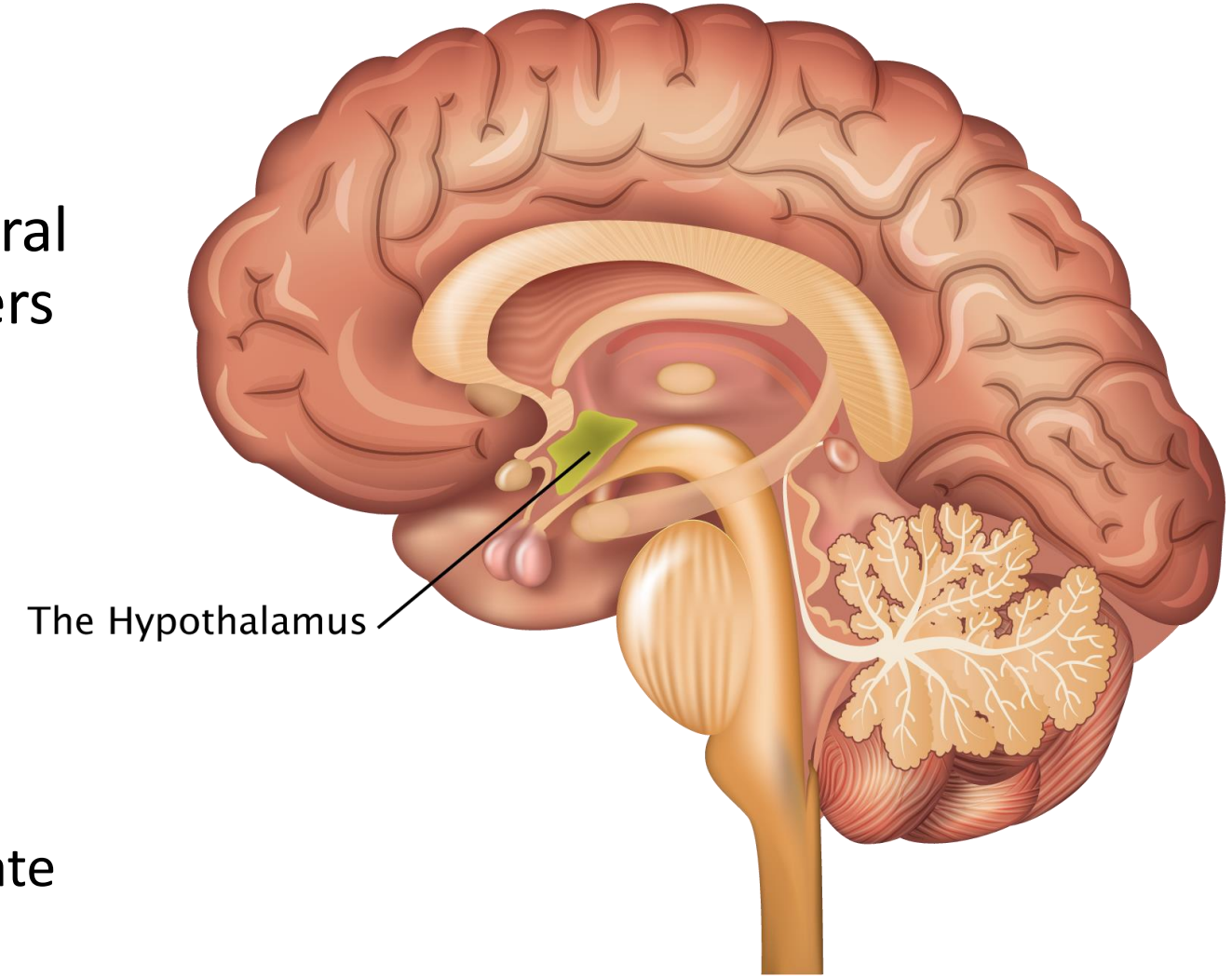
Thalamus

- Receives sensory input and relays impulses to cerebral cortex
- Responsible for:
  - Conscious recognition of pain, temperature and touch
  - Plays a part in Reflex movements
  - Influences mood and general body movements associated with strong emotions
  - Plays a part in arousal or alerting mechanisms

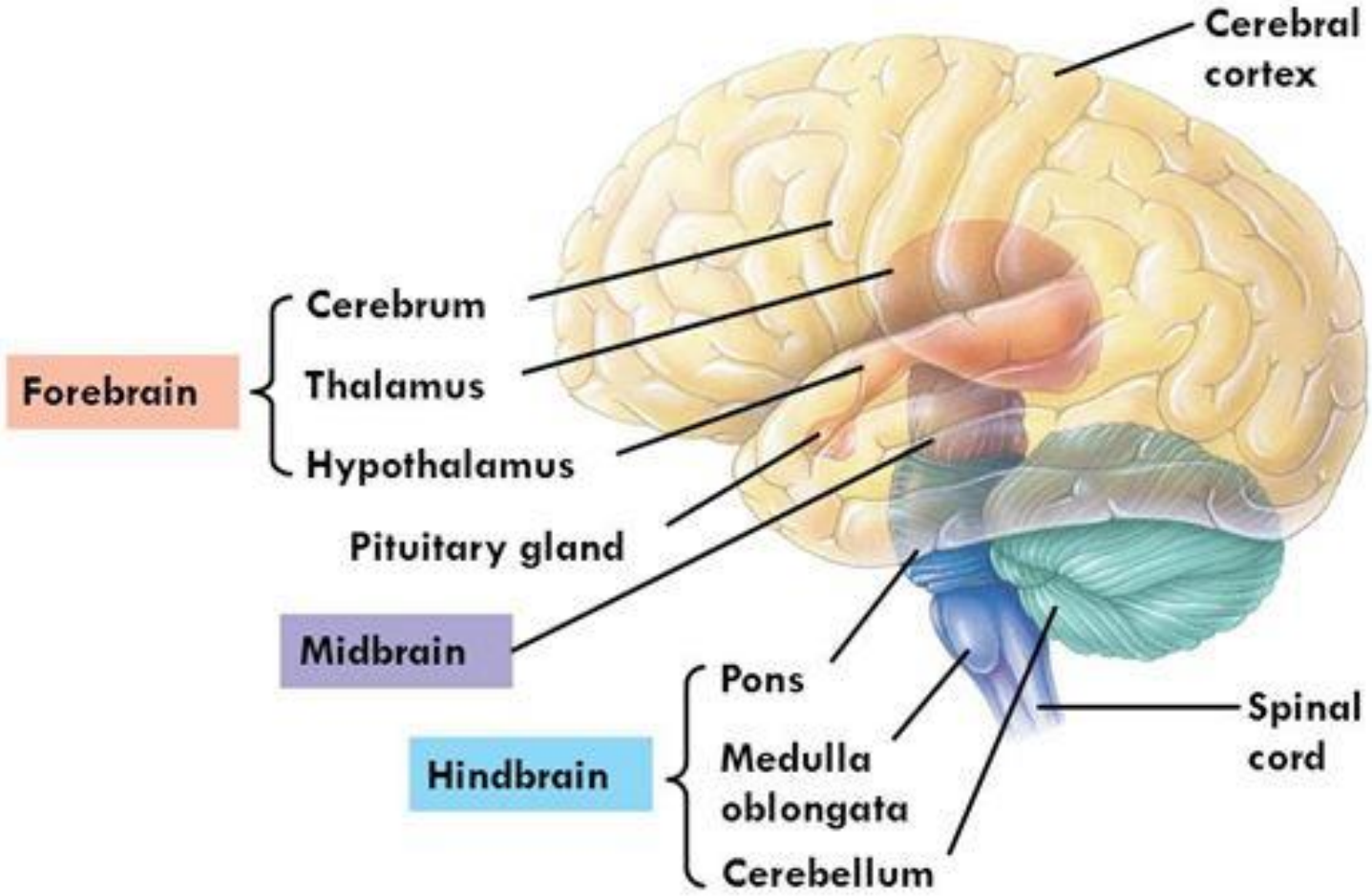


Hypothalamus

- Regulates and controls autonomic activity
- Major relay center between cerebral cortex and lower autonomic centers
  - “Gatekeeper" to cerebrum
- Active in:
  - Emotions
  - Hormonal cycles
  - Sexual activity
  - Temperature regulation
  - Important in maintaining awake state
  - Appetite center



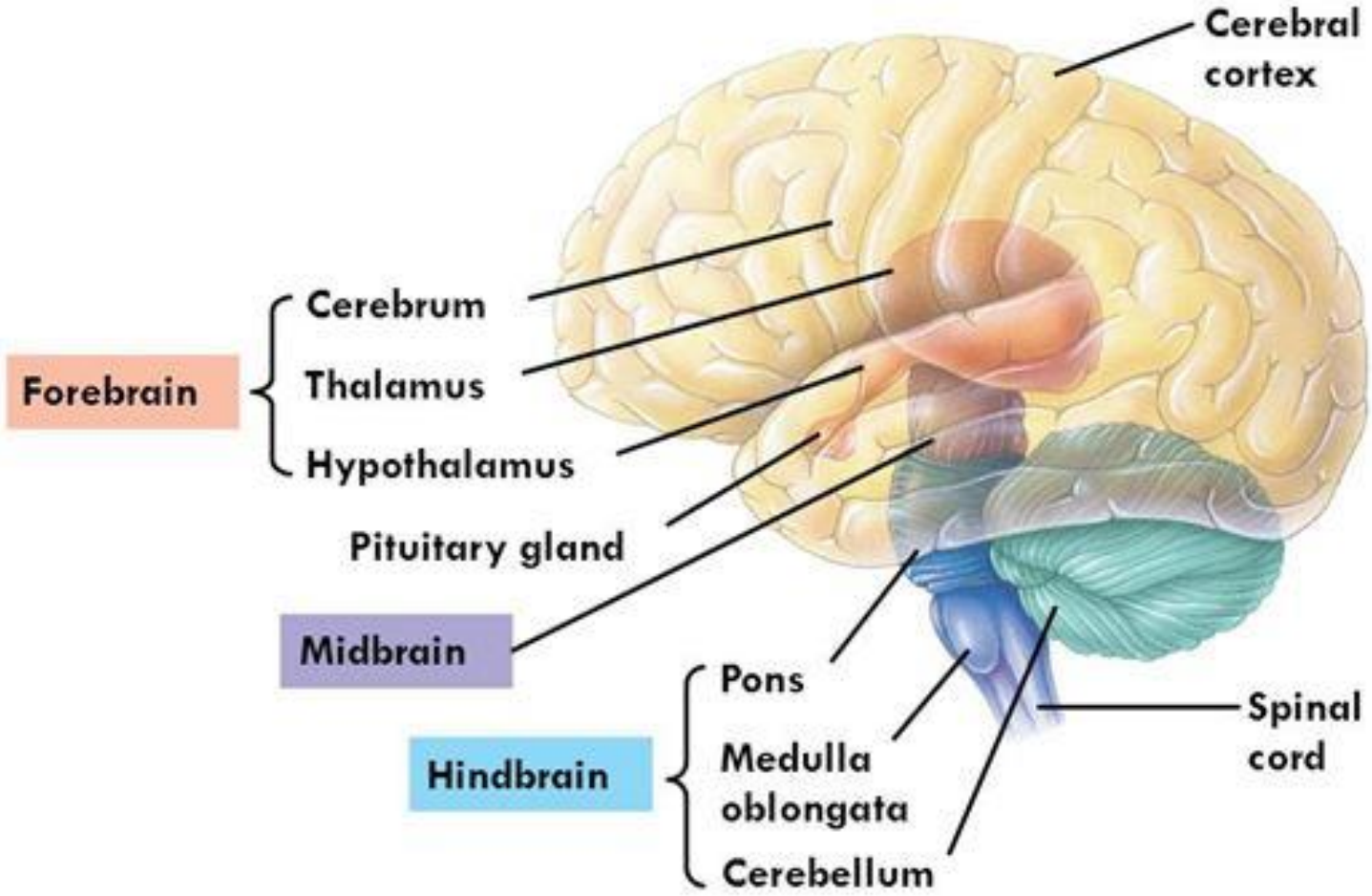
CNS components



Midbrain

- Smallest region of brain stem
- Involved in:
  - Audio pathways
  - Visual reflexes
  - Helps regulate coordination of motor activities and muscle tone

CNS components

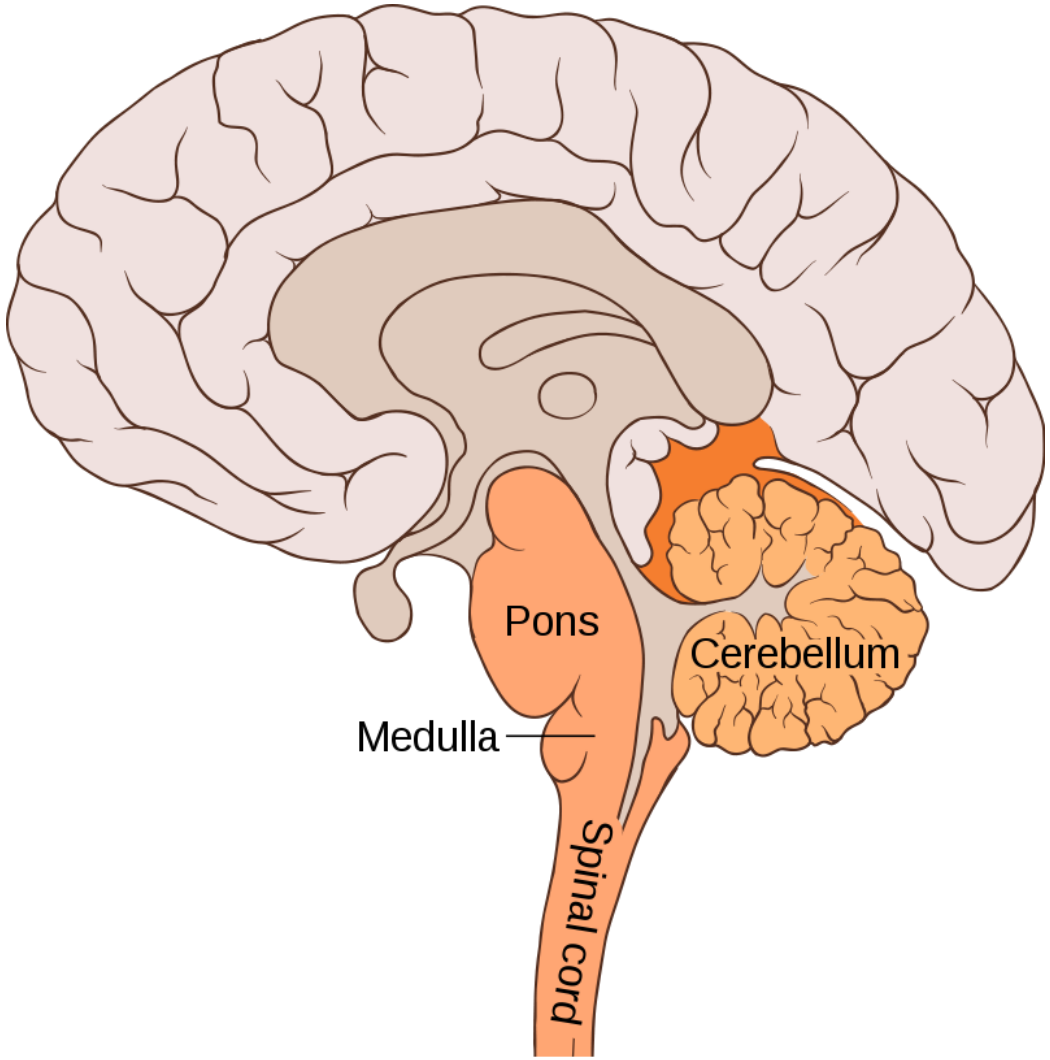


Hindbrain

- Pons
- Medulla
- Cerebellum

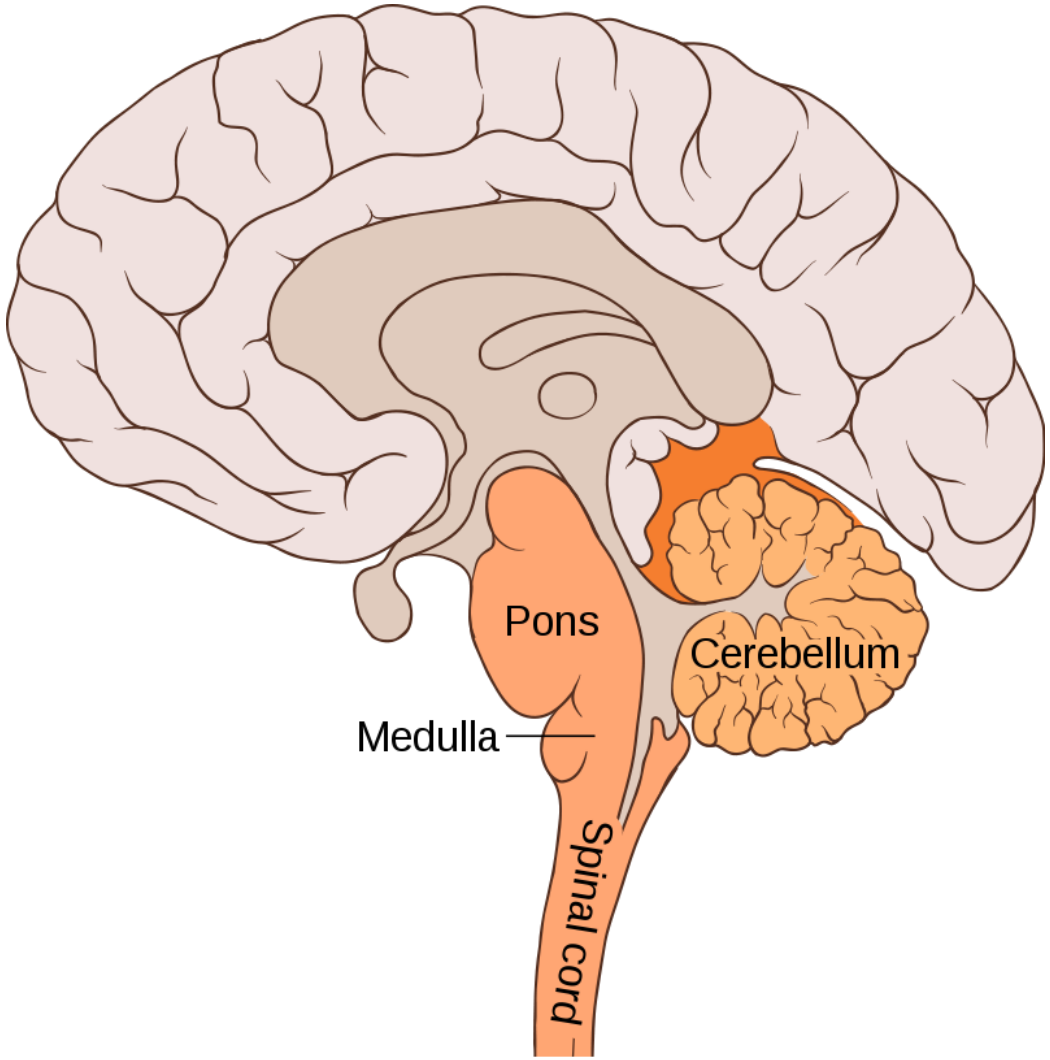
Pons

- Relays information from cerebrum to cerebellum
- Houses sleep center and respiratory center (pneumotaxic and apneustic centers)
- Helps control breathing



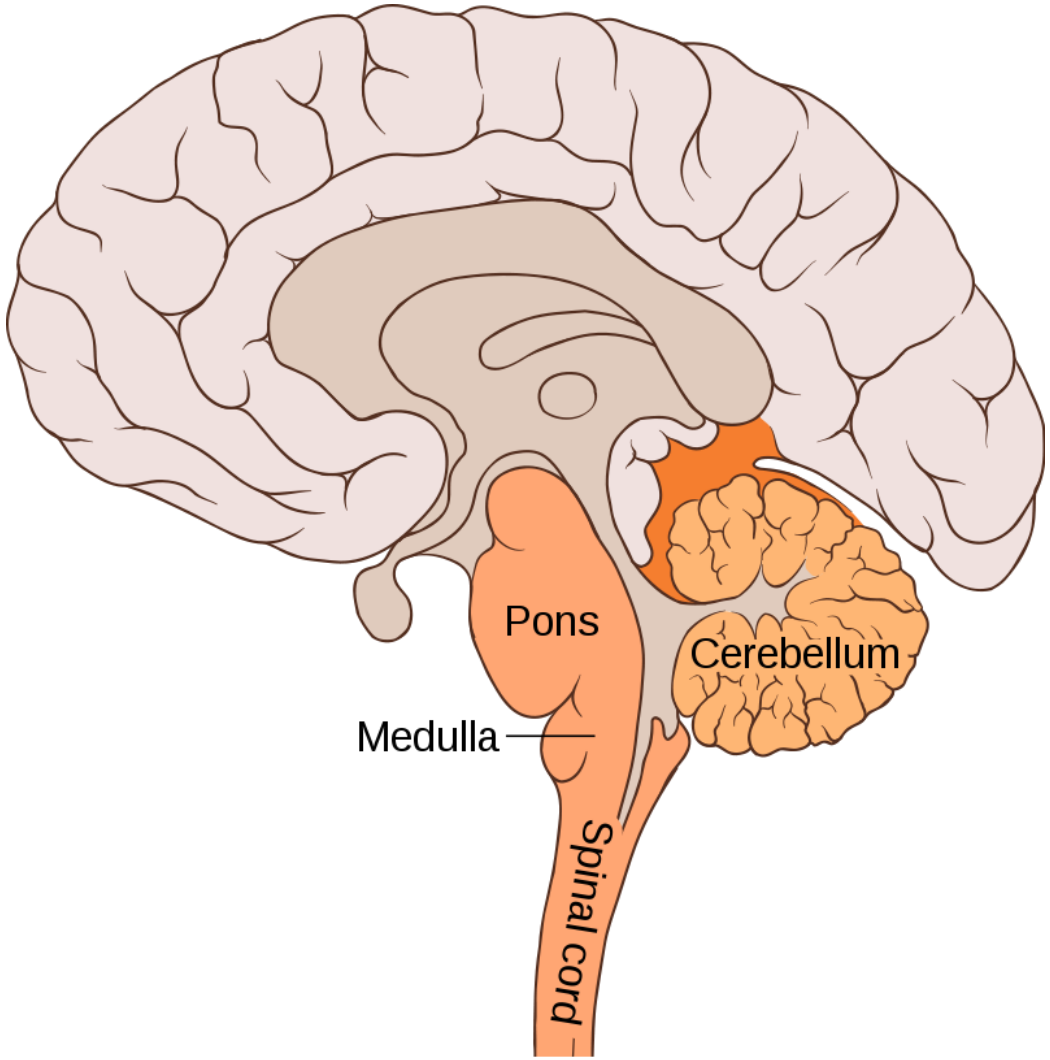
Medulla

- Provides pathway for both ascending and descending nerve tracts
- Pathways crossover from R to L (Decussation)
  - Brain controls motor function on opposite side
- 3 major centers:
  - Cardiac Center (HR, Contractile strength)
  - Vasomotor Center (PVR, BP)
  - Respiratory Center (Rate, rhythm and depth)
- Other centers of control:
  - Swallowing
  - Vomiting
  - Coughing
  - Sneezing



Cerebellum

- Aka “little brain”
  - Cauliflower like in appearance
- 2nd largest portion of the brain
- Has more neurons than all others combined
- Works with cerebral cortex to produce fine motor function
- Assists in posture control
- Subconscious functioning
- Controls skeletal muscles to maintain balance



Cranial Nerves

- Connect to undersurface of the brain (mostly on brainstem)
- Identified by name and number
  - Name gives function and/or distribution
  - Number gives order in which they connect from anterior to posterior
- May be sensory, motor or mixed

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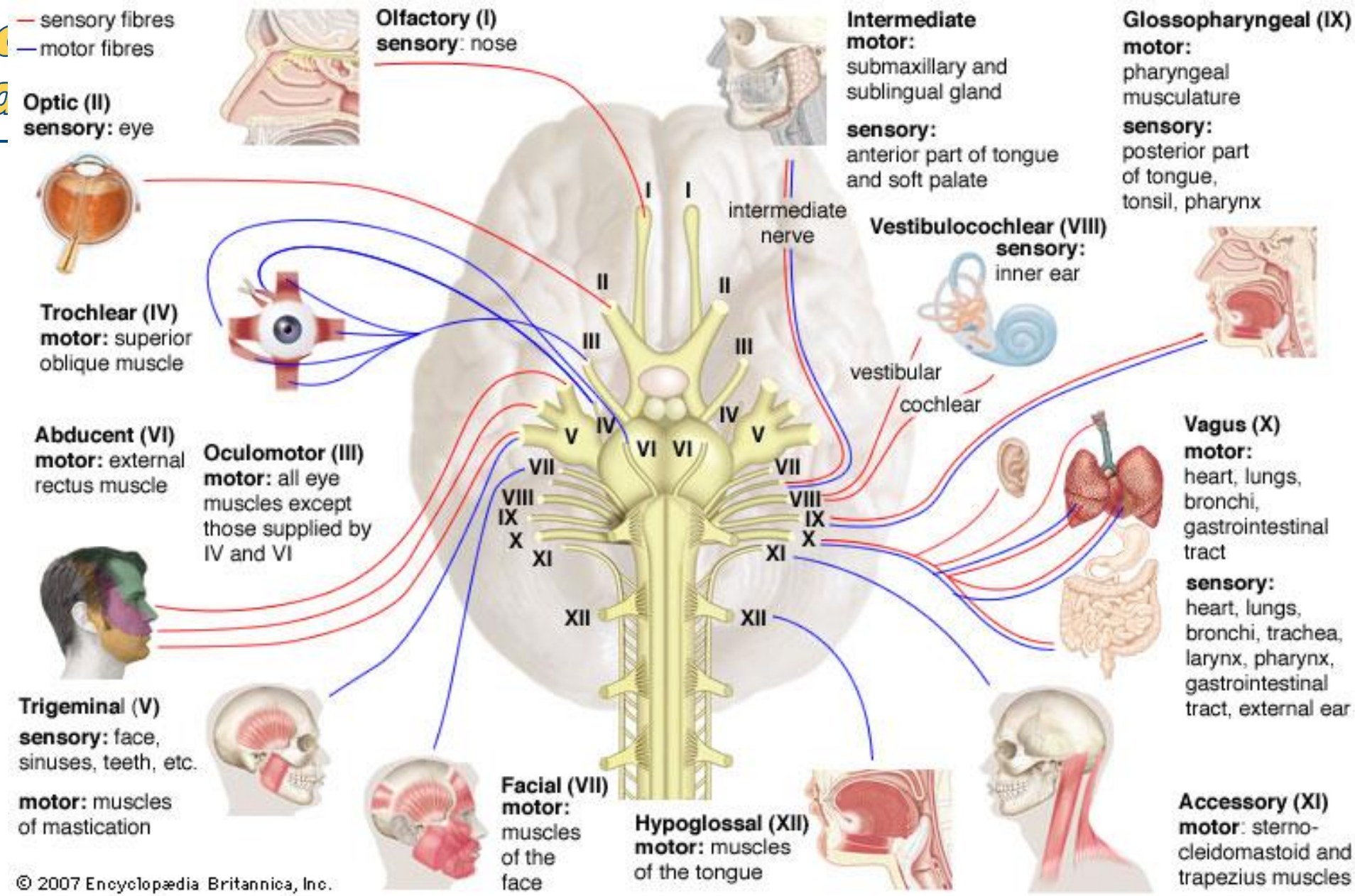
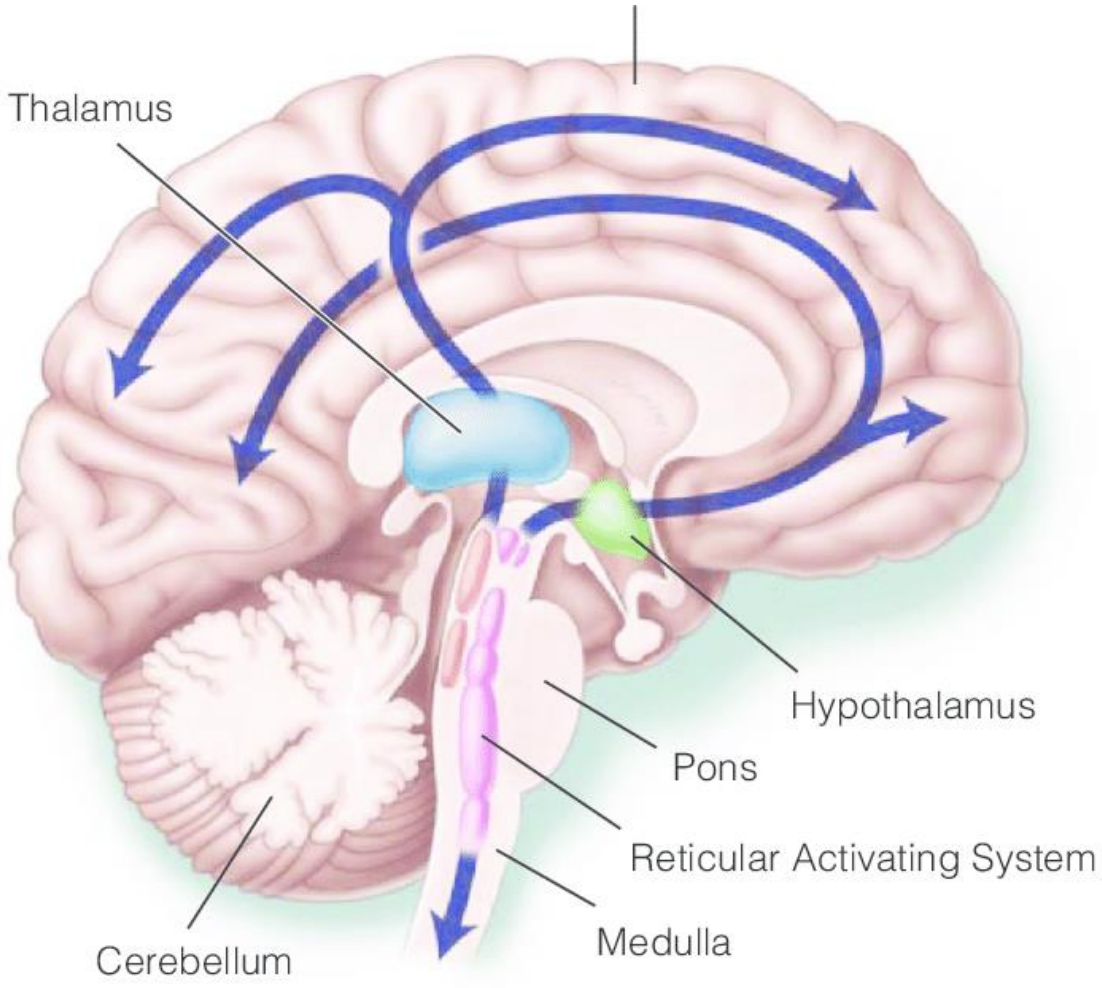
Cranial Nerves

#	Name	Function
I	Olfactory	Sensory
II	Optic	Sensory
III	Oculomotor	Motor
IV	Trochlear	Motor
V	Trigeminal	Mixed
VI	Abducens	Motor
VII	Facial	Mixed
VIII	Vestibulocochlear	Sensory
IX	Glossopharyngeal	Mixed
X	Vagus	Mixed
XI	Accessory	Motor
XII	Hypoglossal	Motor

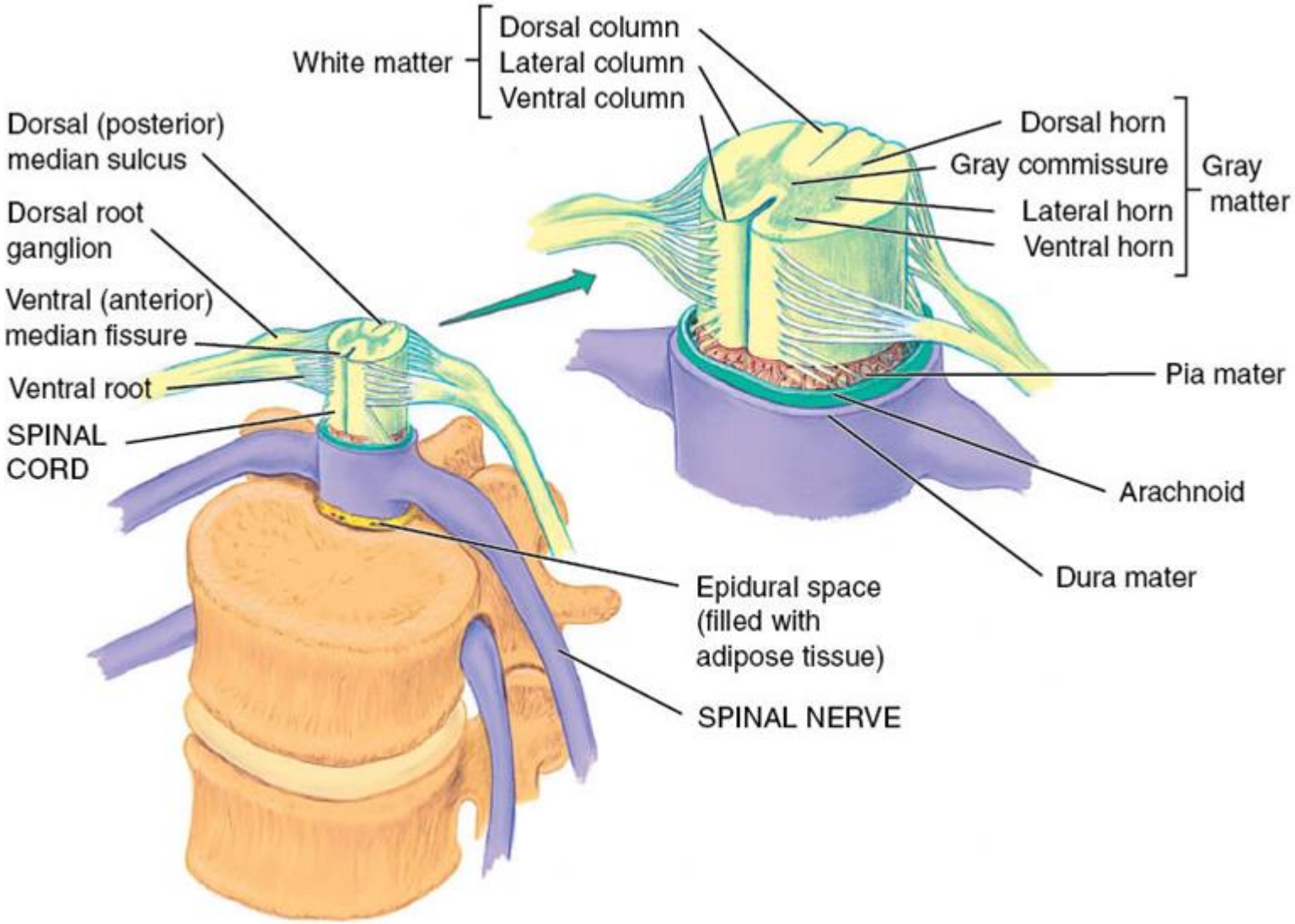


Reticular Formation

- A group of nuclei scattered throughout the brain stem
- Part of the reticular activating system
  - Involved in sleep-awake cycle and in maintaining consciousness



Spinal Cord


White matter
Dorsal column
Lateral column
Ventral column
Dorsal (posterior) median sulcus
Dorsal root ganglion
Ventral (anterior) median fissure
Ventral root
SPINAL CORD
Dorsal horn
Gray commissure
Lateral horn
Ventral horn
Gray matter
Pia mater
Arachnoid
Dura mater
Epidural space (filled with adipose tissue)
SPINAL NERVE

Intracranial Perfusion

- Brain is very perfusion sensitive
  - Rapid and devastating effects when compromised
- Cranial volume is fixed
  - Brain = 80%
  - Blood vessels and blood = 12%
  - CSF = 8%
- Increase in size of one component must be matched by a reduction in another

Cerebral Blood Flow

- Oxygen and glucose delivery are controlled by cerebral blood flow
  - A function of cerebral perfusion pressure (CPP) and resistance of the cerebral vascular bed

Cerebral Perfusion Pressure (CPP)

$$CPP = MAP - ICP$$

$$CPP = \left[\frac{SBP + (2\ X\ DBP)}{3}\right] - ICP$$

Normal
60 – 80 mmHg

Ischemia Occurs
30 – 40 mmHg

Irreversible Brain Damage
< 25 mmHg

Cerebral Blood Flow

- As ICP approaches MAP:
  - Gradient for flow decreases
  - Cerebral blood flow is restricted
- When ICP increases, CPP decreases
  - As CPP decreases, cerebral vasodilation occurs
  - Results in increased cerebral blood volume (increasing ICP) and further cerebral vasodilation

Cerebral Blood Flow

- Vascular tone in the normal brain is regulated by:
  - Carbon dioxide pressure (PCO_2)
  - Oxygen pressure (PO_2)
  - Autonomic and neurohumoral control
- PCO_2 has the greatest effect on intracerebral vascular diameter and subsequent resistance

Factors Affecting ICP

- Vasculature constriction
- Cerebral edema
- Systolic blood pressure
  - Low BP = Poor cerebral perfusion
  - High BP = Increased ICP
- Carbon dioxide
- Reduced respiratory efficiency

Role of Carbon Dioxide

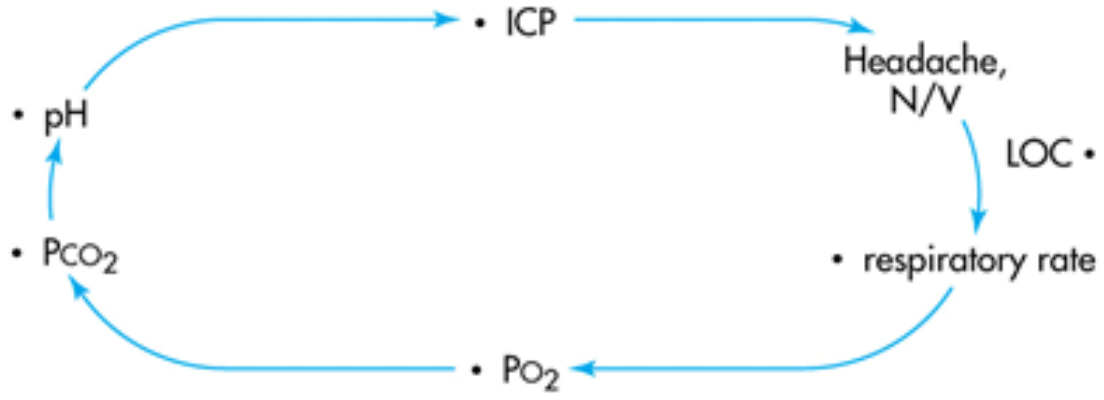
- As CO_2 levels rise in CSF:
  - Cerebral arteries dilate
  - Encourage blood flow
  - Reduce hypercarbia
- In the presence of already high ICP
  - Devastating results
  - Causes classic hyperventilation and hypertension
- Reduced levels of CO_2 in CSF
  - Cerebral vasoconstriction
  - Results in cerebral anoxia

Intracranial Pressure (ICP)

- Normal range is < 20 mmHg
- When ICP rises above this level, the ability to maintain CPP is compromised
  - Cerebral blood flow is diminished
- The body attempts to compensate for the decline in CPP by a rise in MAP
  - Further elevates ICP, and CSF is displaced to compensate for the expansion
- If unresolved, the brain substance herniates

Increased Intracranial Pressure

- Early signs and symptoms:
  - Headache
  - Nausea and vomiting
  - Altered level of consciousness
- Eventually followed by Cushing's triad:
  - Increased systolic pressure (widened pulse pressure)
  - Decreased pulse rate
  - Irregular respiratory pattern



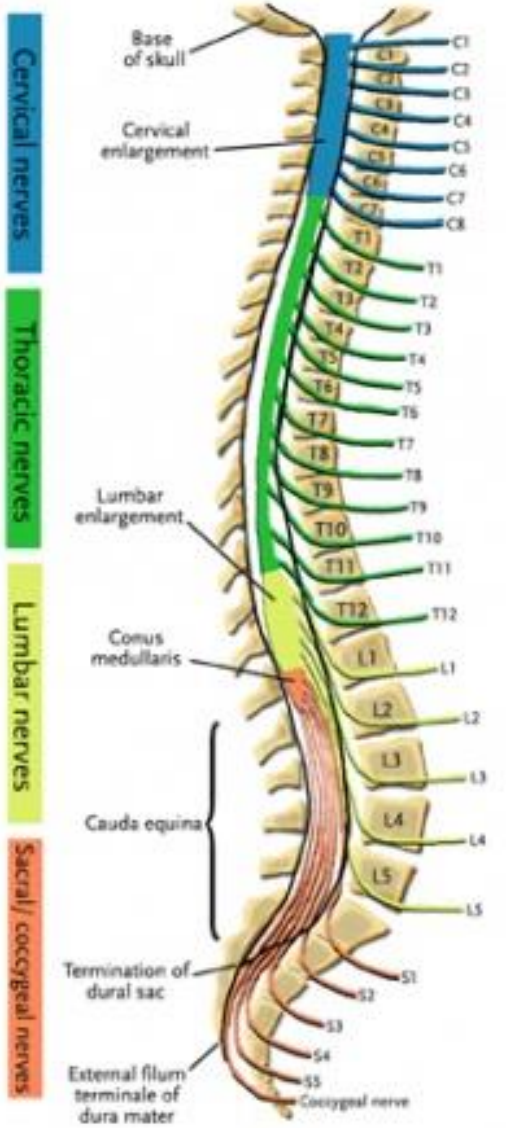
Nervous System Anatomy

PERIPHERAL NERVOUS SYSTEM

Peripheral (Somatic) Nervous System

- Consists of
  - 12 pairs of cranial nerves
  - 31 pairs of spinal nerves
  - Innervate the skeletal muscles, skin, glands, and connective tissue
- Involves both afferent and efferent nerves
- Provides automatic and involuntary response to stimulus
- Primary role is the interaction of the body with the environment

Spinal Nerves

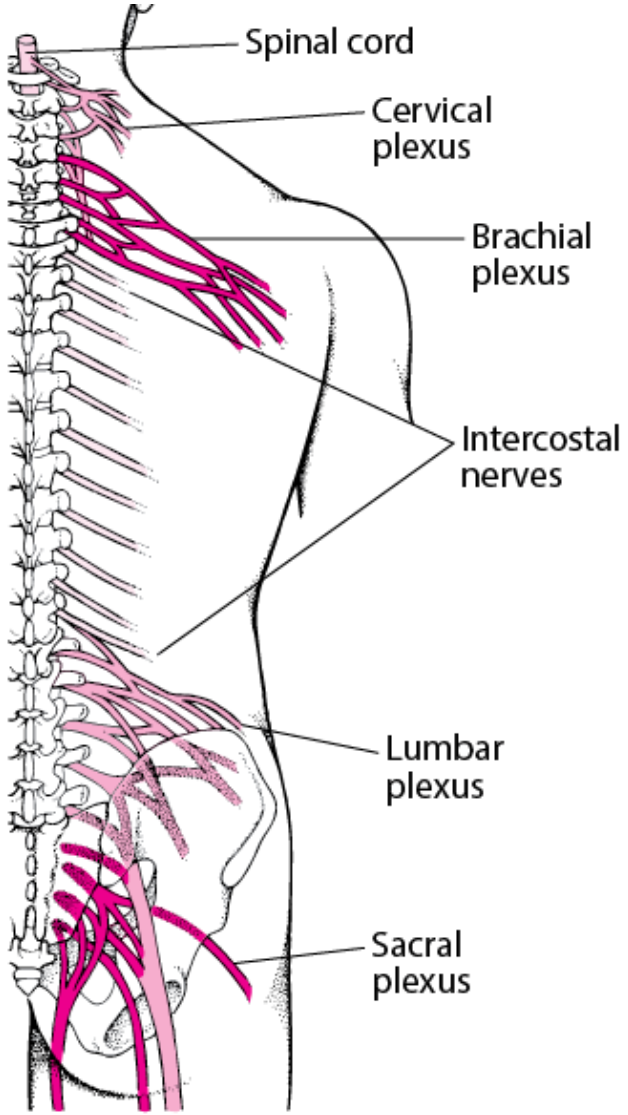


- Overview
  - 31 pairs
    - 8 Cervical nerve pairs (C1 through C8)
    - 12 Thoracic nerve pairs (T1 through T12)
    - 5 Lumbar nerve pairs (L1 through L5)
    - 5 Sacral nerve pairs (S1 through S5)
    - 1 Coccygeal nerve pair
  - Cauda equina

Spinal Nerves

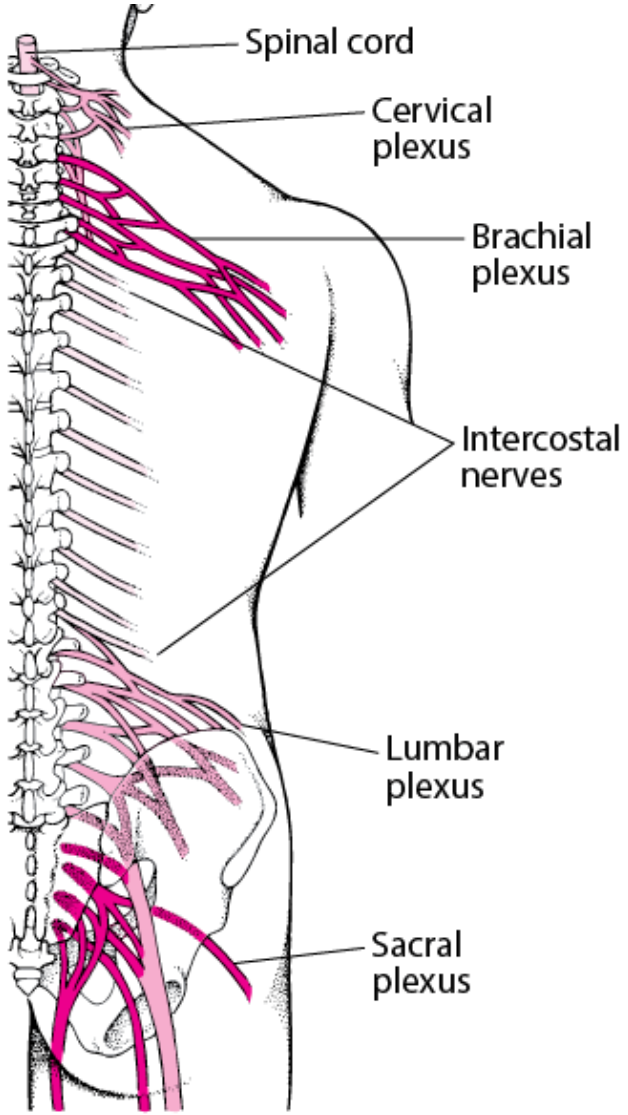
- Nerve plexuses
  - Complex networks formed by the ventral rami of most spinal nerves (not T2 through T12) subdividing and then joining together to form individual nerves
  - Each individual nerve that emerges contains all the fibers that innervate a particular region of the body
  - In plexuses, spinal nerve fibers are rearranged according to their ultimate destination, reducing the number of nerves needed to supply each body part

Spinal Nerves



- Cervical plexus
  - Located deep within the neck
  - Made up of ventral rami of C1 through C4 and a branch of the ventral ramus of C5
  - Individual nerves emerging from cervical plexus innervate the muscles and skin of the neck, upper shoulders, and part of the head
  - Phrenic nerve exits the cervical plexus and innervates the diaphragm
- Brachial plexus
  - Located deep within the shoulder
  - Made up of ventral rami of C5 through T1
  - Individual nerves emerging from brachial plexus innervate the lower part of the shoulder and the entire arm

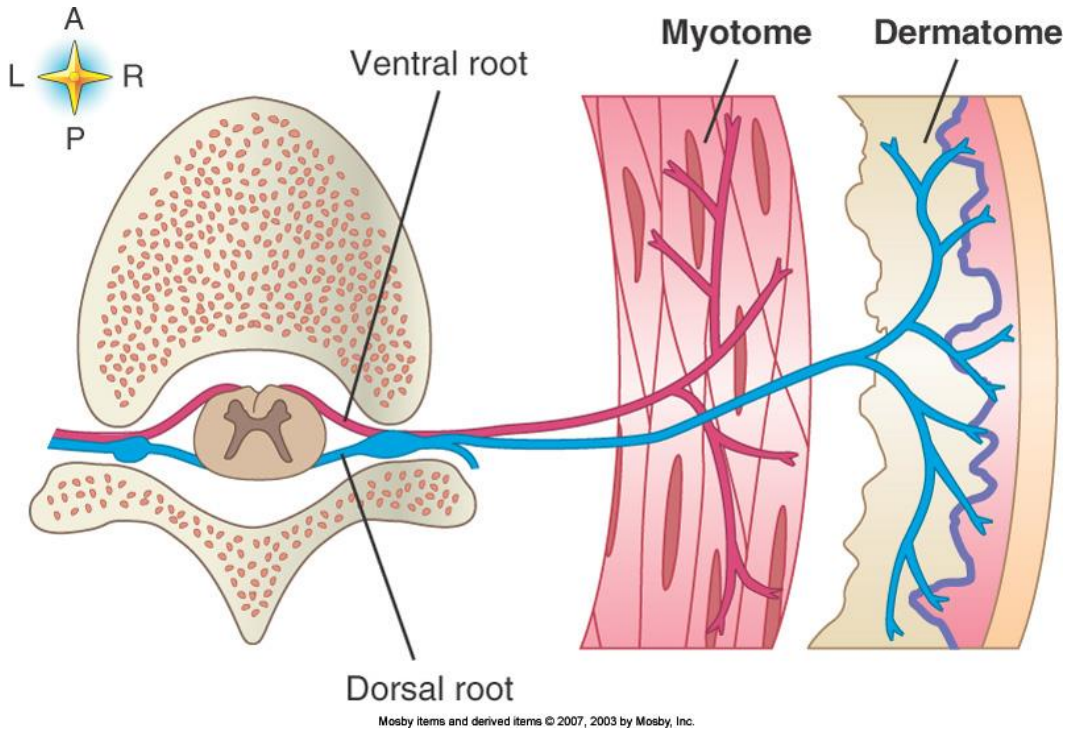
Spinal Nerves



- Lumbar plexus
  - Located in the lumbar region of the back in the psoas muscle
  - Formed by intermingling fibers of L1 through L4
  - Femoral nerve exits the lumbar plexus, divides into many branches, and supplies the thigh and leg
- Sacral plexus and coccygeal plexus
  - Located in the pelvic cavity in the anterior surface of the piriformis muscle
  - Formed by intermingling of fibers from L4 through S4
  - Tibial, common peroneal, and sciatic nerves exit the sacral plexus and supply nearly all the skin of leg, posterior thigh muscles, and leg and foot muscles

Dermatomes and Myotomes

- Dermatome
  - Region of skin surface area supplied by afferent (sensory) fibers of a given spinal nerve
- Myotome
  - Skeletal muscle(s) supplied by efferent (motor) fibers of a given spinal nerve



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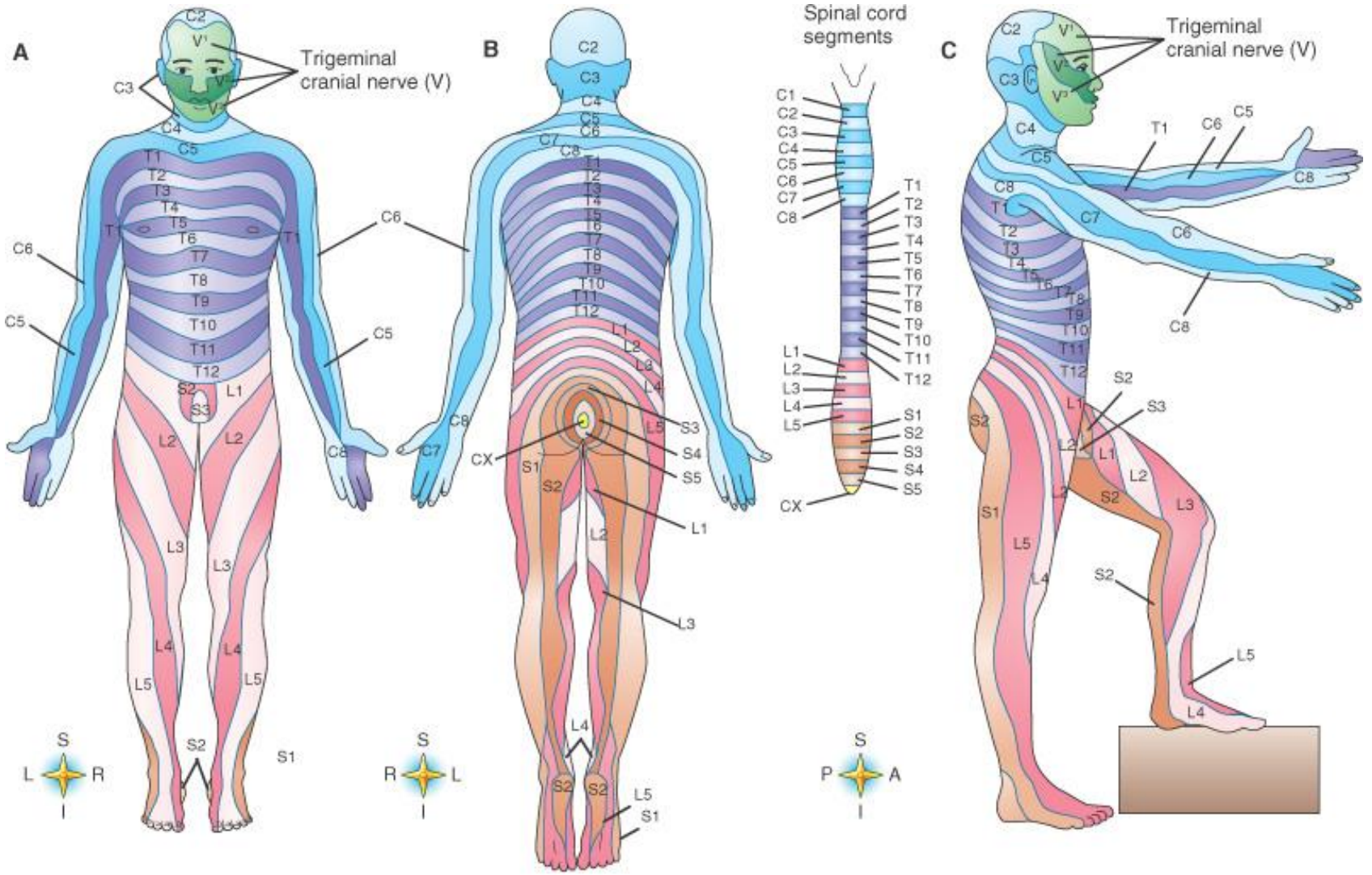
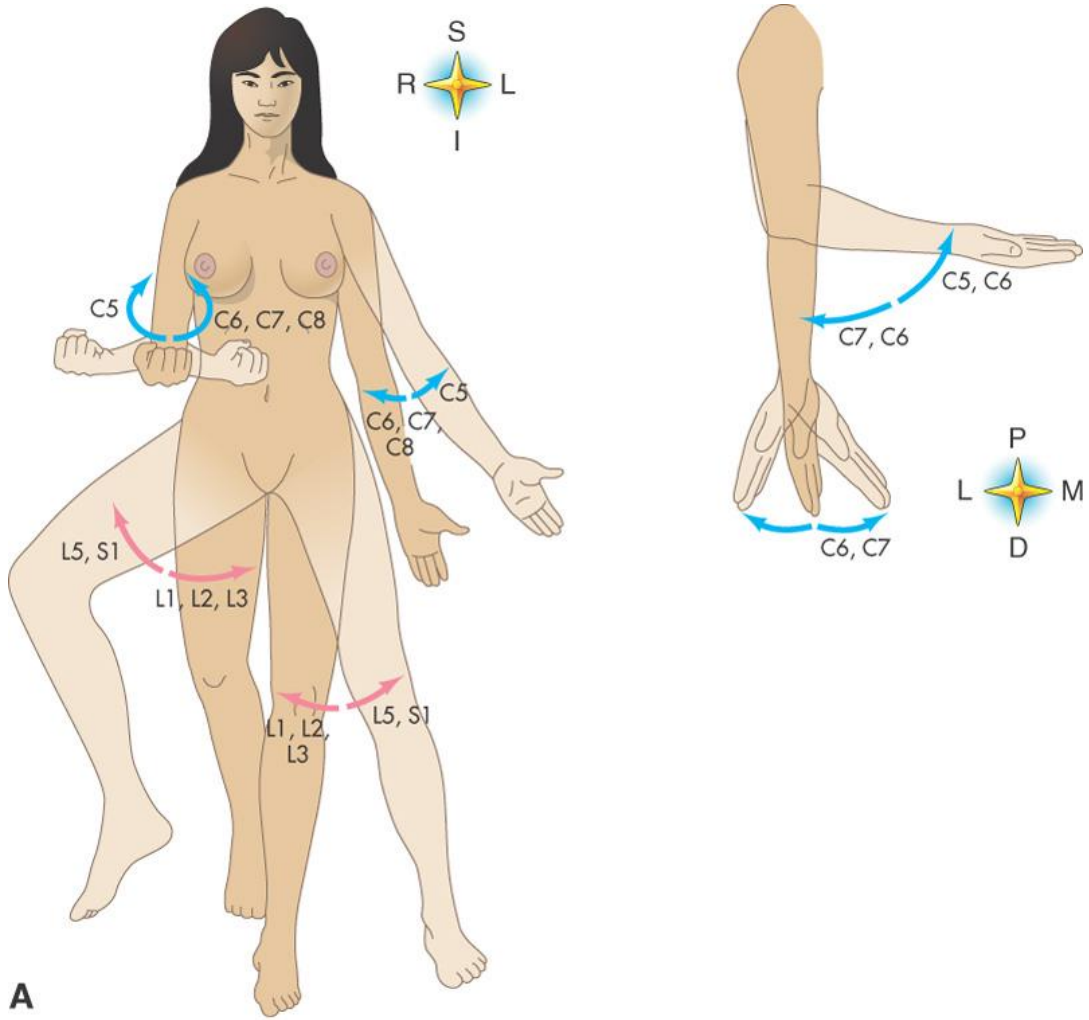
Dermatomes



Myotomes

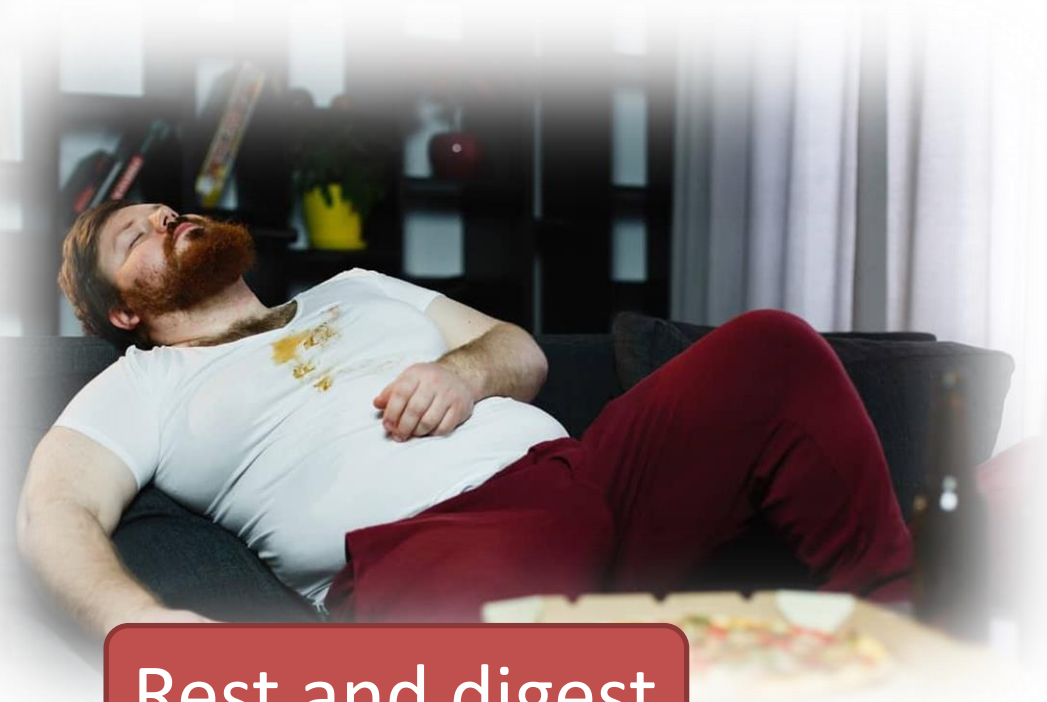


Autonomic Nervous System

- Aka “involuntary nervous system”
  - Regulates involuntary function i.e. digestion
  - Carries efferent signals to autonomic/visceral receptors
  - Two efferent divisions
    - Sympathetic
    - Parasympathetic

ANS

Fight or Flight



Rest and digest