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Nervous System Anatomy

DND Primary Care Paramedicine

Module: 06

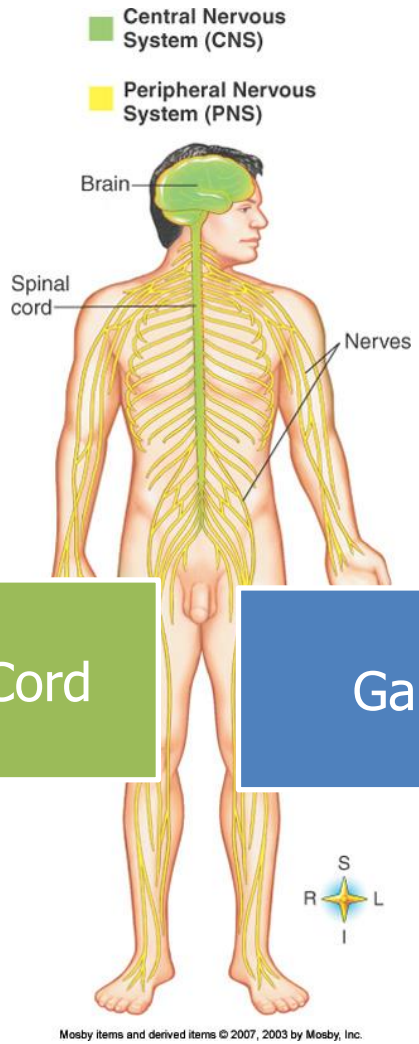
Section: 01

Nervous System

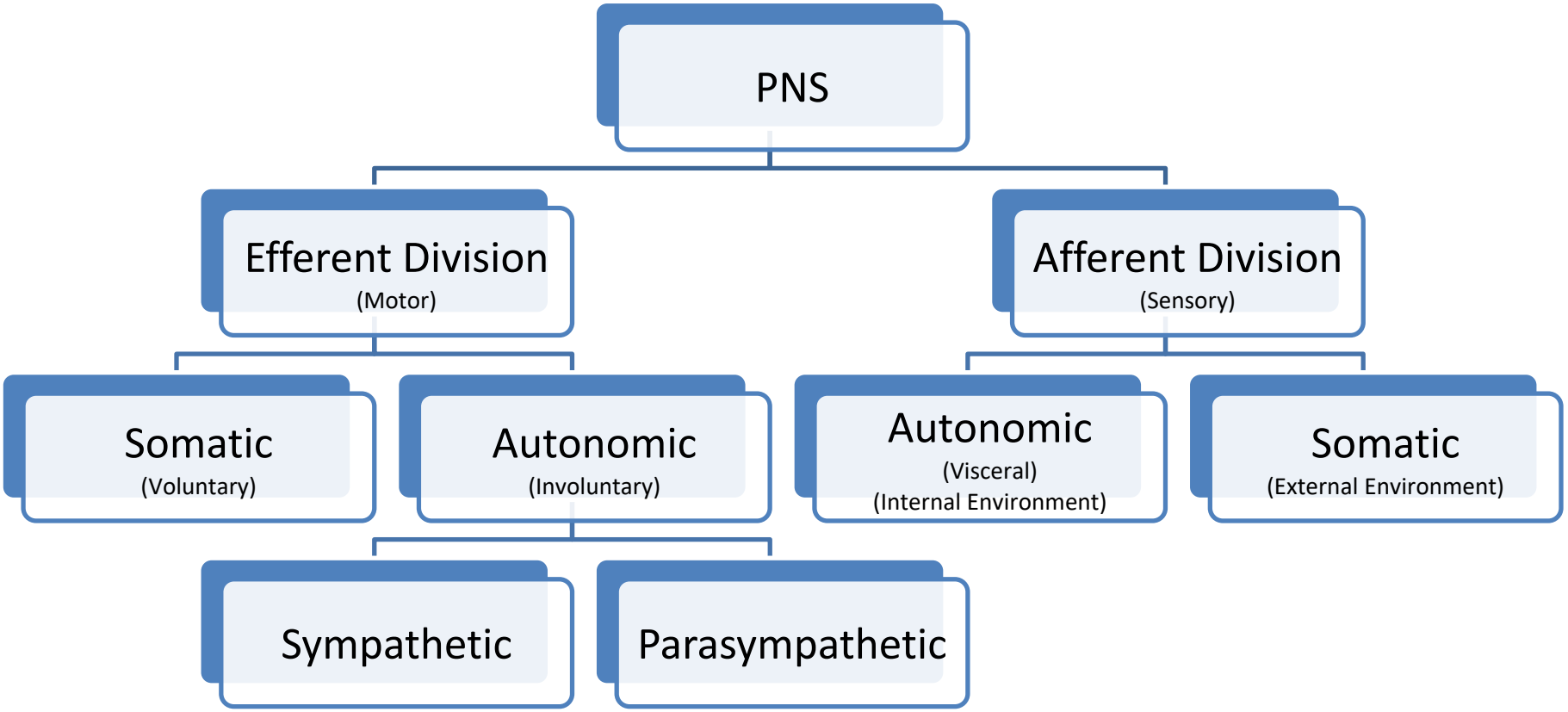
- Is the major controlling, regulatory and communicating system
- Works with the endocrine system to regulate and maintain homeostasis
- Maintains and internal and external check of the environment
- Consists of:
  - The brain
  - The spinal cord
  - The nerves
  - The ganglia

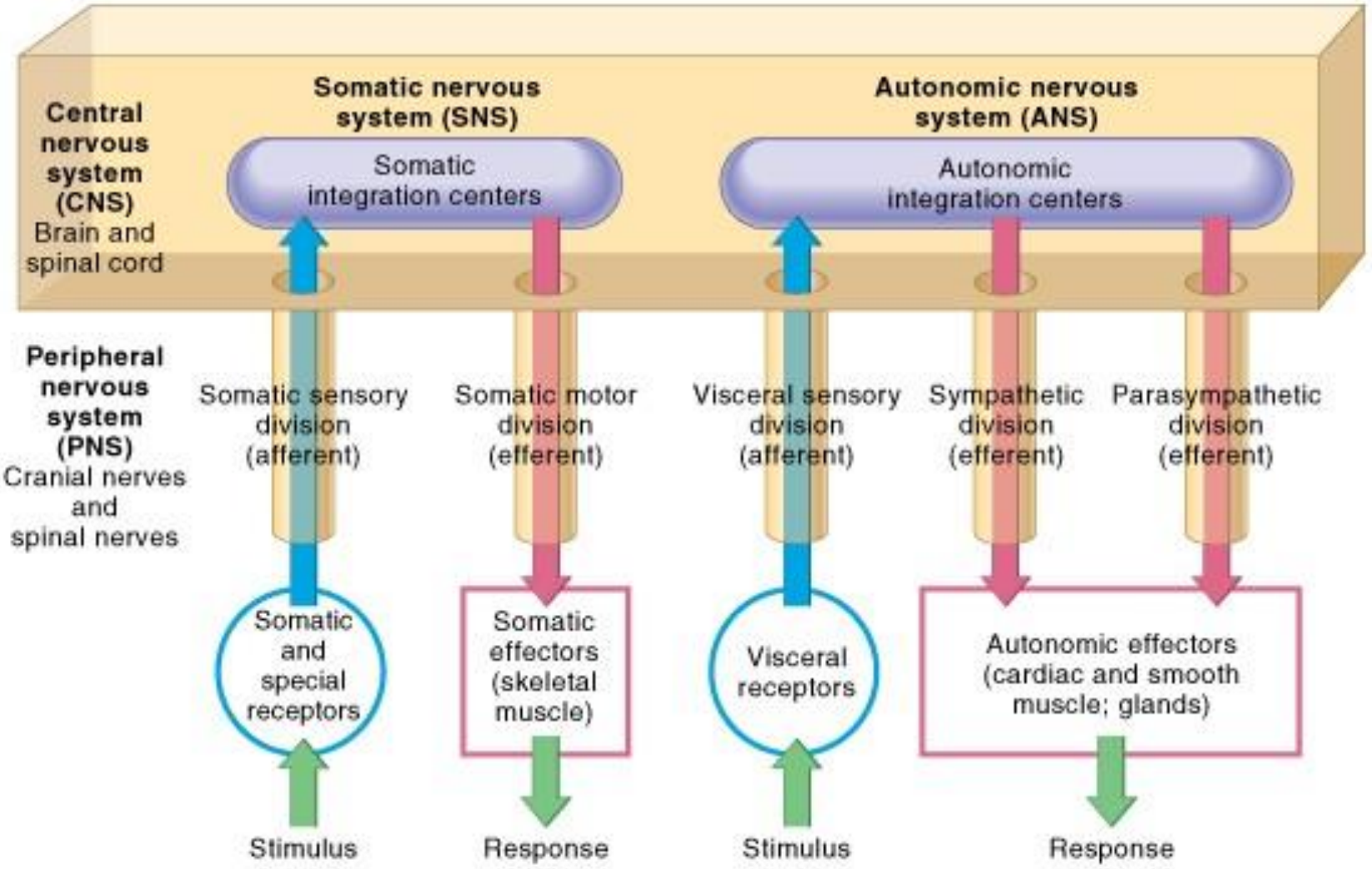
Functions

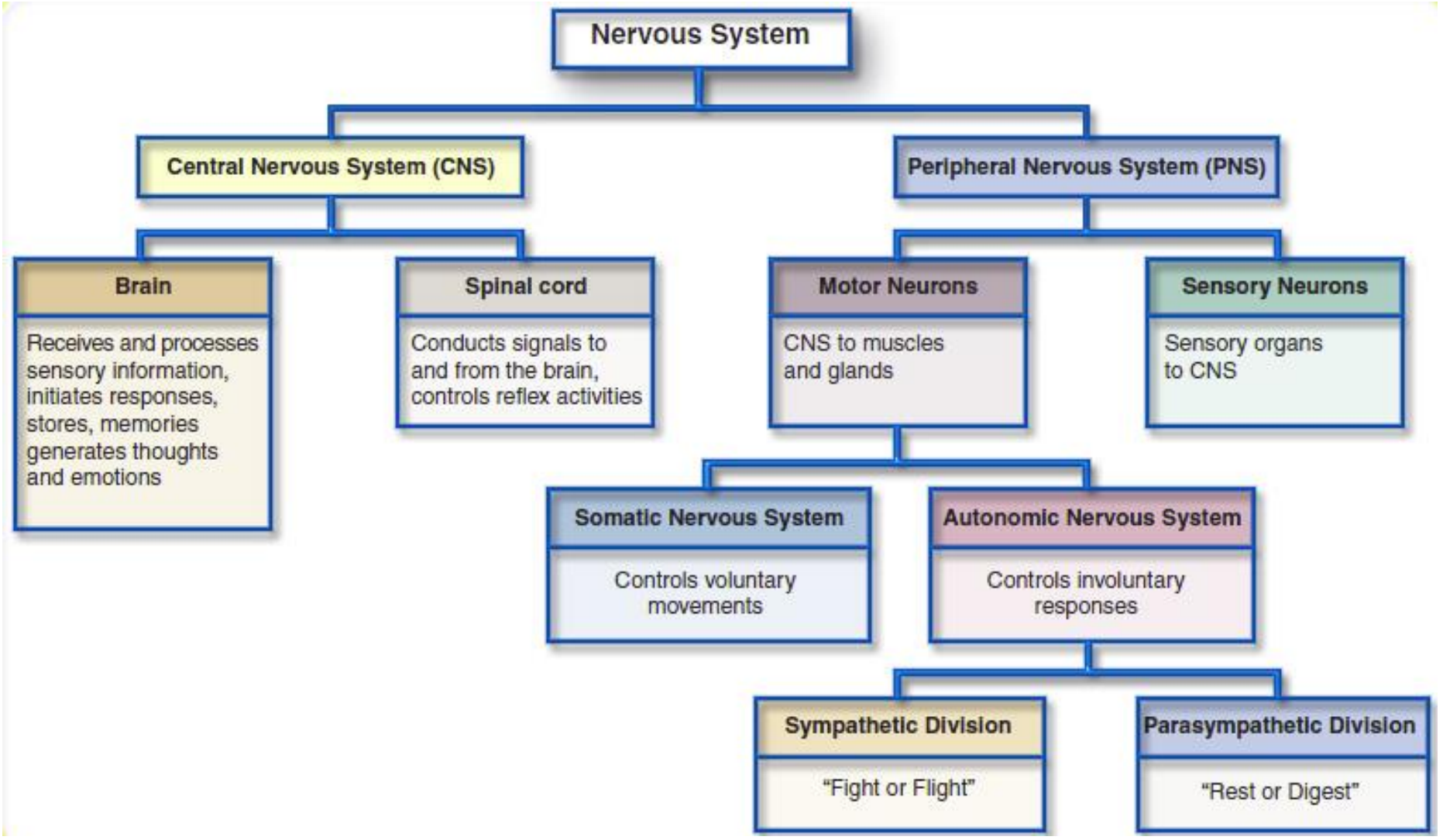
- Sensory
  - Detect changes (internal/external)
- Integration
  - Decisions made upon the signals received from the body
- Motor
  - A response to the sensory input and integration
  - Causes muscles and glands (effectors) to respond



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


PNS
Efferent Division
(Motor)
Afferent Division
(Sensory)
Somatic
(Voluntary)
Autonomic
(Involuntary)
Autonomic
(Visceral)
(Internal Environment)
Somatic
(External Environment)
Sympathetic
Parasympathetic




Nervous System
Central Nervous System (CNS)
Peripheral Nervous System (PNS)
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
Motor Neurons
CNS to muscles and glands
Sensory Neurons
Sensory organs to CNS
Somatic Nervous System
Controls voluntary movements
Autonomic Nervous System
Controls involuntary responses
Sympathetic Division
"Fight or Flight"
Parasympathetic Division
"Rest or Digest"

Central Nervous System

- Somatic nervous system (SNS)
- Autonomic nervous system (ANS)
- Two primary types of cells
  - Neurons
    - Conducting cells
    - Structural unit of the nervous system
  - Glia
    - Non-conductive
    - Give support to the neurons

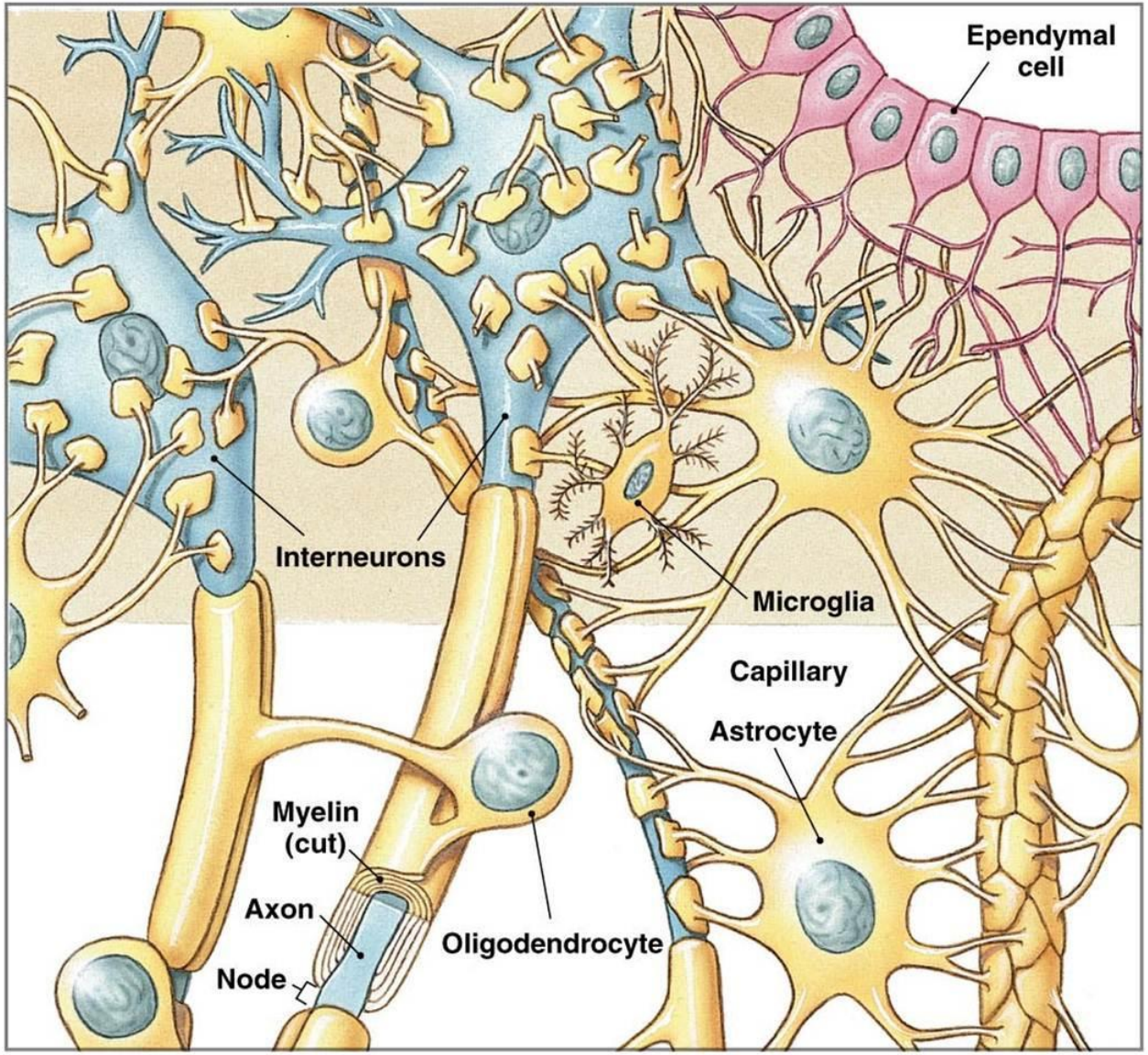
Glia (Neuroglia)

- 900 billion in number
  - approx. 90 % of brain cells
- The “ glue ” of the brain
- Mitotic
  - Replicate throughout life
- Susceptible to cancers
- 6 basic types

Glia

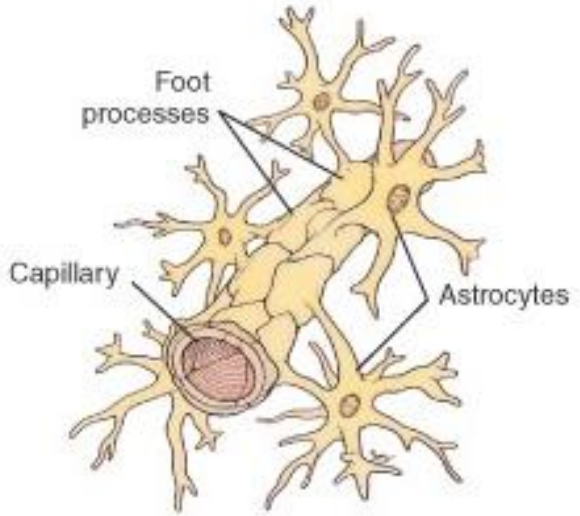
- 6 types
  - CNS
    - Astrocytes
    - Microglia
    - Ependymal
    - Oligodendrocytes (Oligodendroglia)
  - PNS
    - Schwann cells
    - Satellite cells

CNS Glia Cells

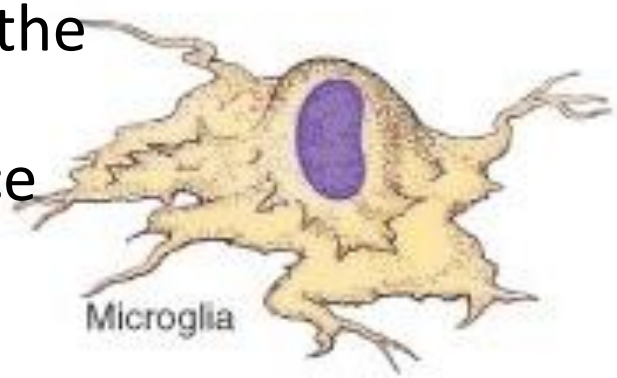


Glia Cells (CNS)

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

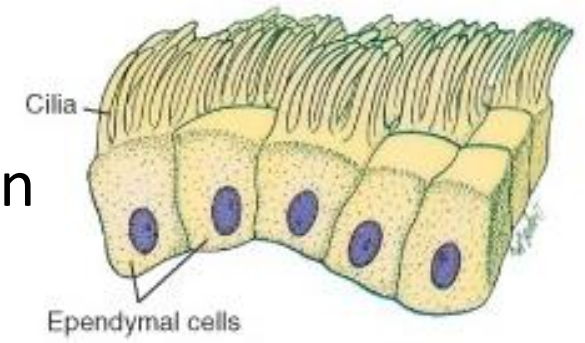


- Microglia
  - Responsible for phagocytosis in inflamed or degenerative tissue of the CNS
  - Main immune response in CNS since others cannot cross the BBB

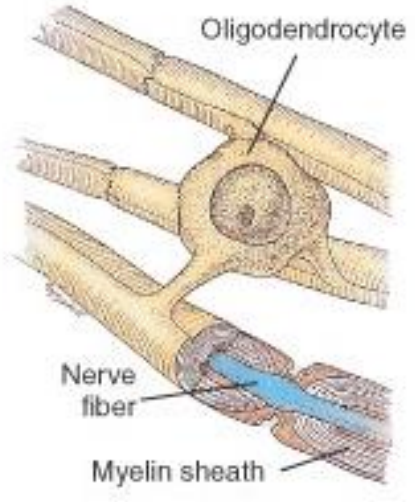


Glia cells (CNS)

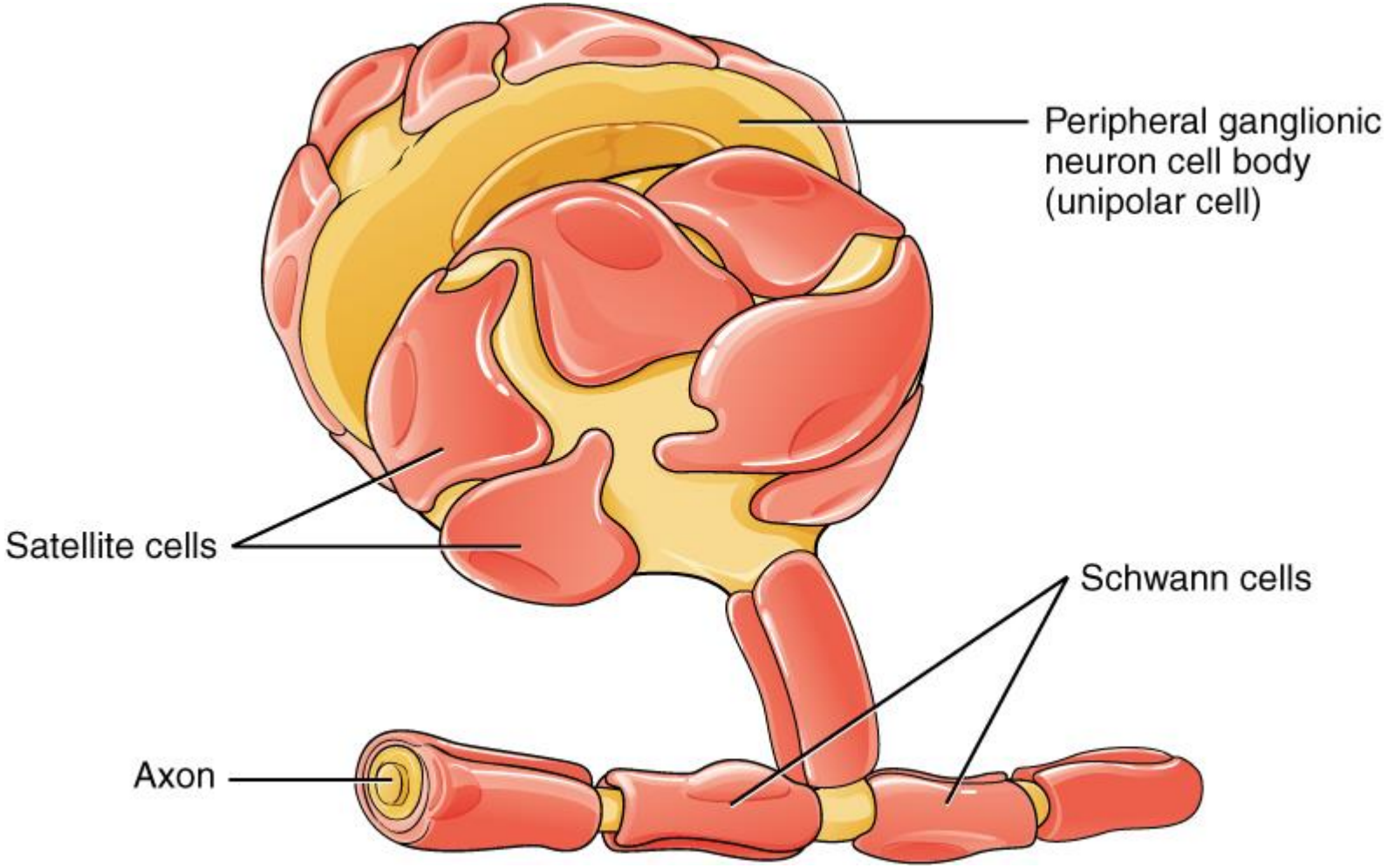
- Ependymal cells
  - Line the ventricles of the brain and central canal of spinal cord
  - Produce and circulate the fluids within these cavities
    - CSF



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

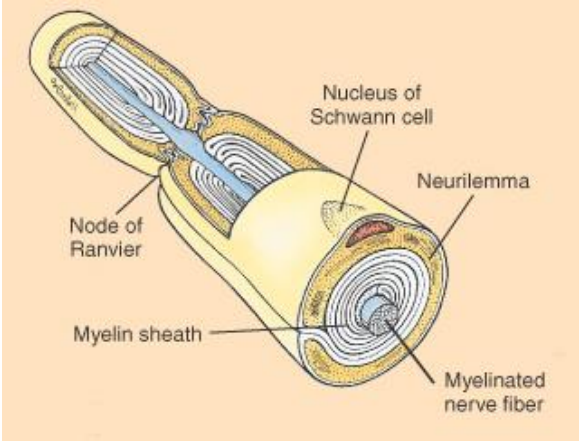


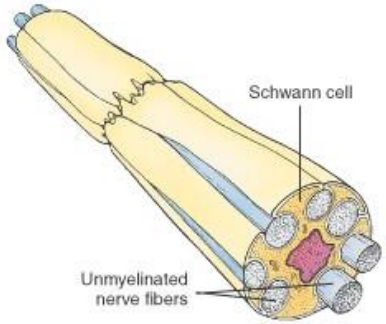
PNS Glia Cells

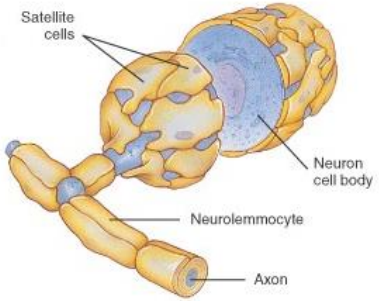


Glia cells (PNS)

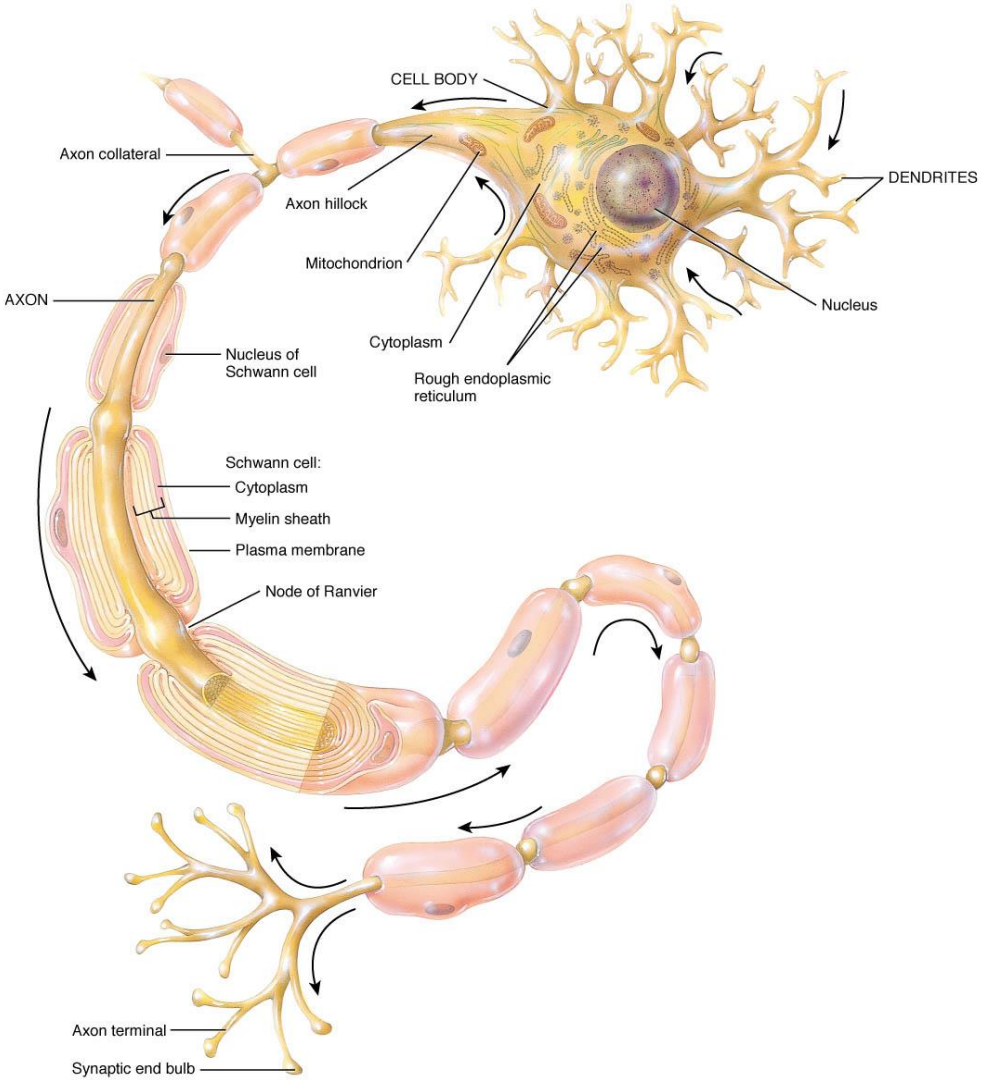
- Schwann cells (PNS Only)
  - Bundle nerve cells together
  - As it wraps around a nerve fiber
    - Nucleus and cytoplasm are squeezed to the perimeter to form outer portion of myelin sheath (Neurilemma)
  - Myelinated fibers (white fibers)
    - Encased by Schwann Cell
  - Unmyelinated fibers (gray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





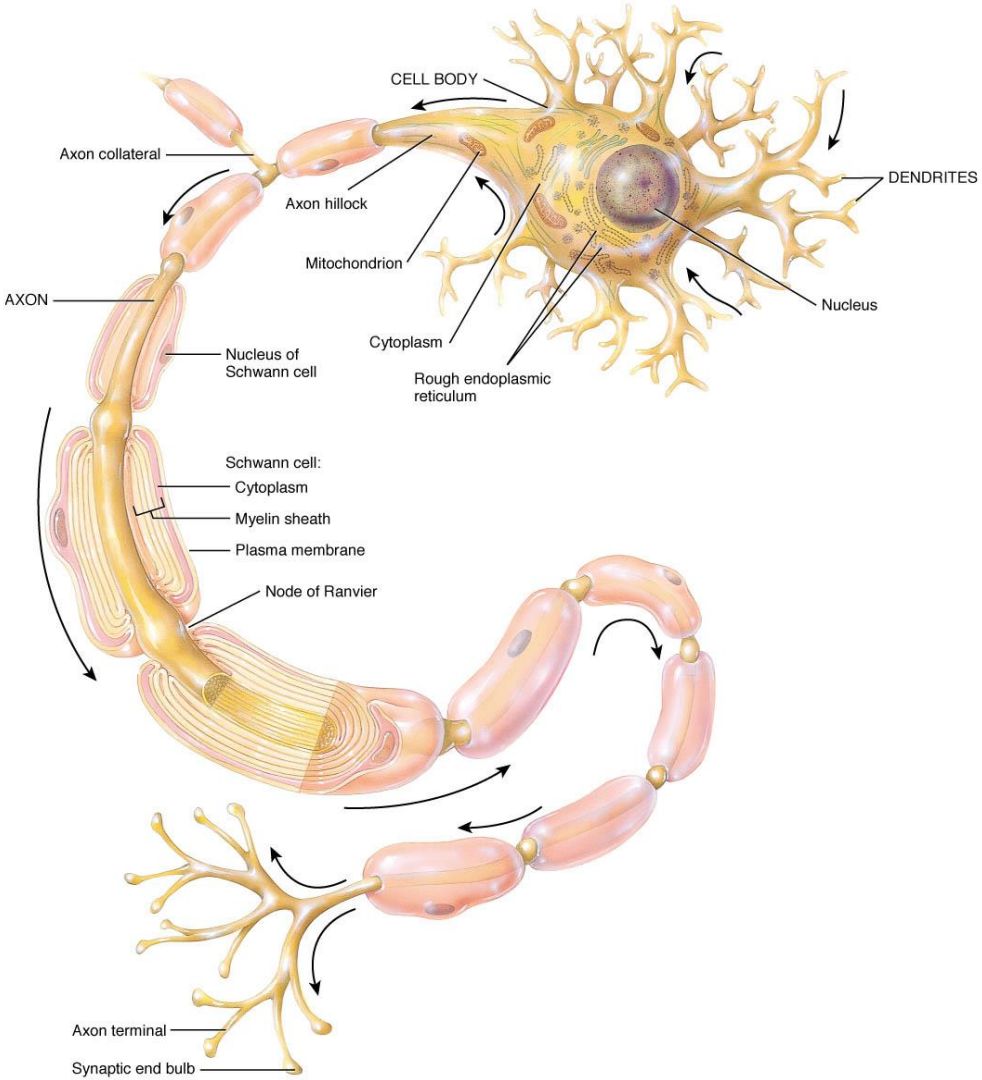


Neurons



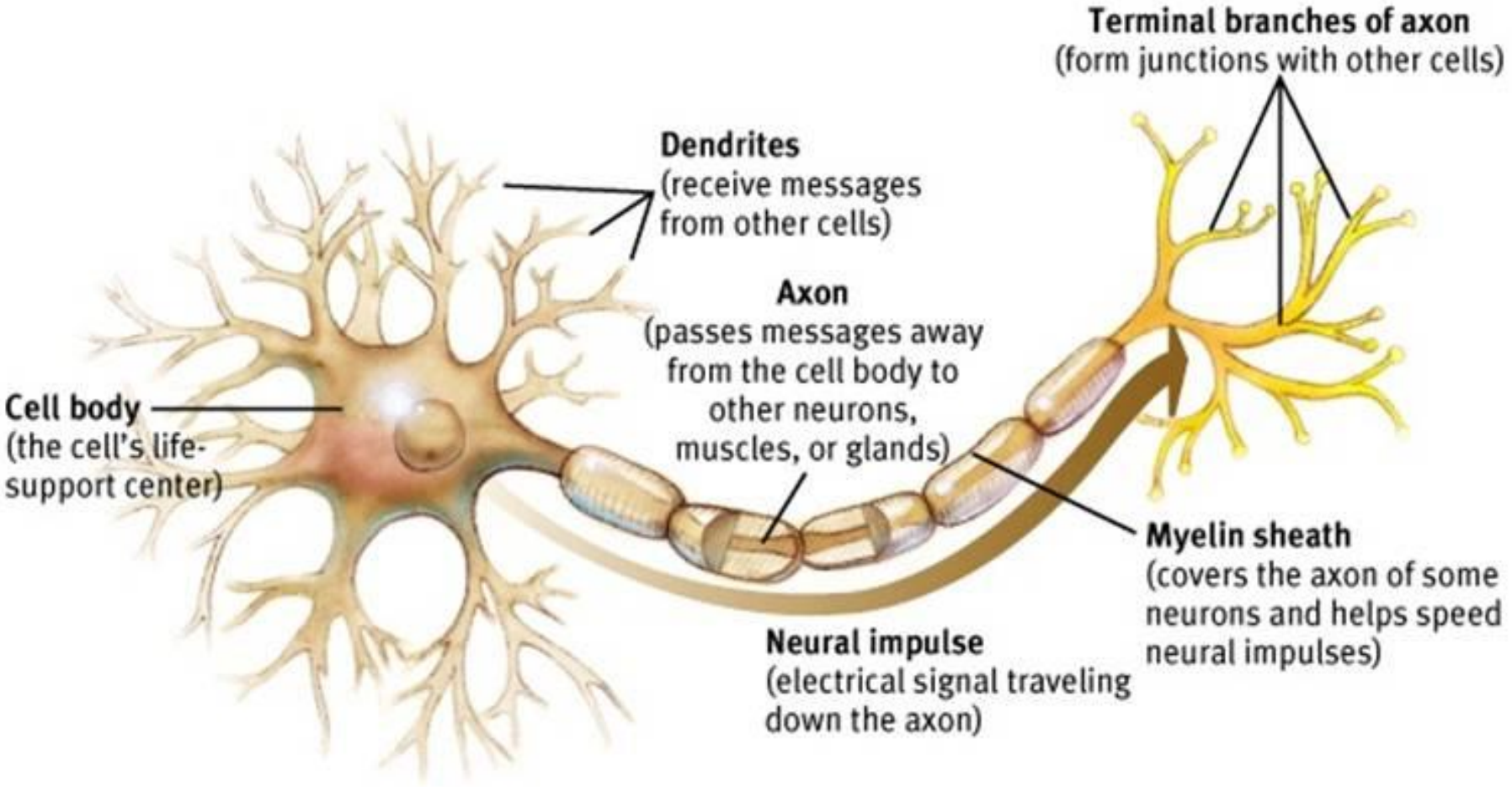
- Approximately 100 billion
  - 10% of brain cells
- Bundled fibers surrounded by connective tissues
- Conduct impulses to and from CNS
- The most complex tissues in the body due to their role in communication
  - Integrate various activities and coordinate bodily functions
- Specialized cell that is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

Neurons



- Each neuron has three main parts
  - Dendrites (Afferent)
  - Cell Body (Soma)
  - Axon (Efferent)
    - Axon may branch out to Axon collaterals
    - End with many short branches (telodendria)
    - The end of the telodendria are enlarged to form synaptic bulb

Neurons


Terminal branches of axon
(form junctions with other cells)
Dendrites
(receive messages from other cells)
Axon
(passes messages away from the cell body to other neurons, muscles, or glands)
Cell body
(the cell's life-support center)
Myelin sheath
(covers the axon of some neurons and helps speed neural impulses)
Neural impulse
(electrical signal traveling down the axon)

Dendrites

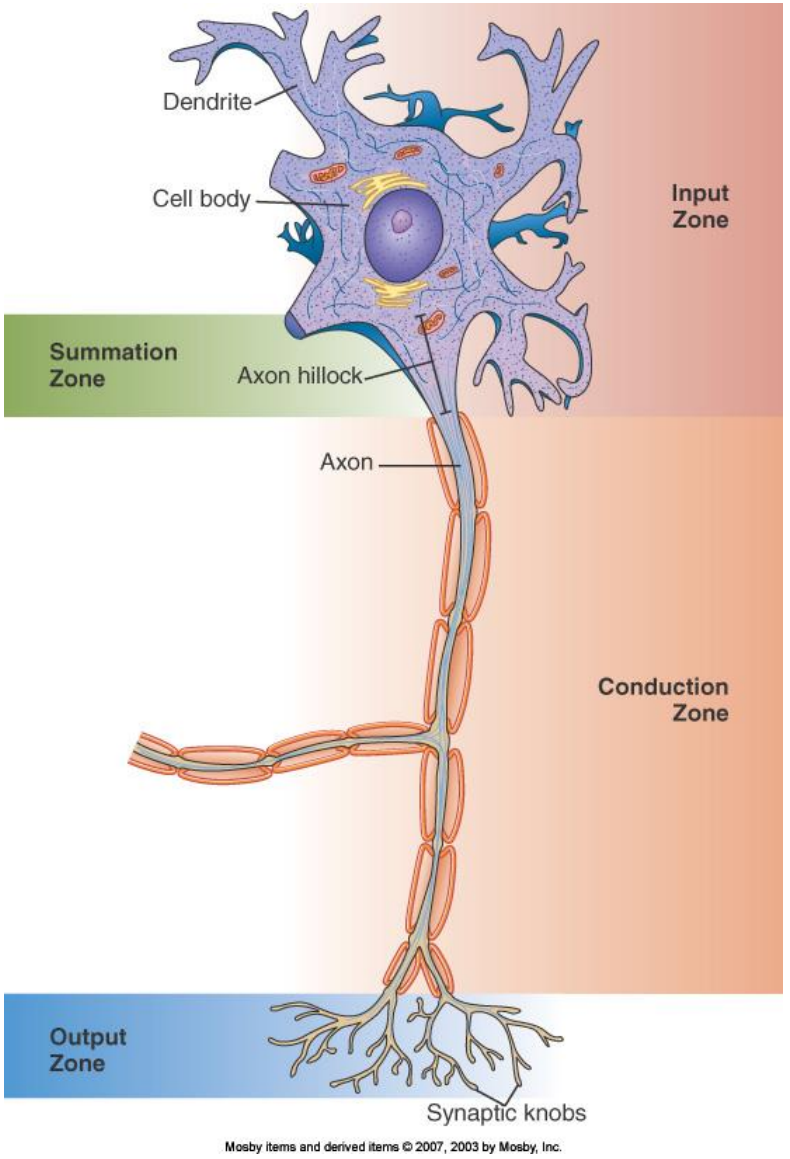
- Extensions of neuron
- Receives impulses from other neurons or other stimuli
- Transmits impulses to neuron body (soma)

Cell Body (Soma)

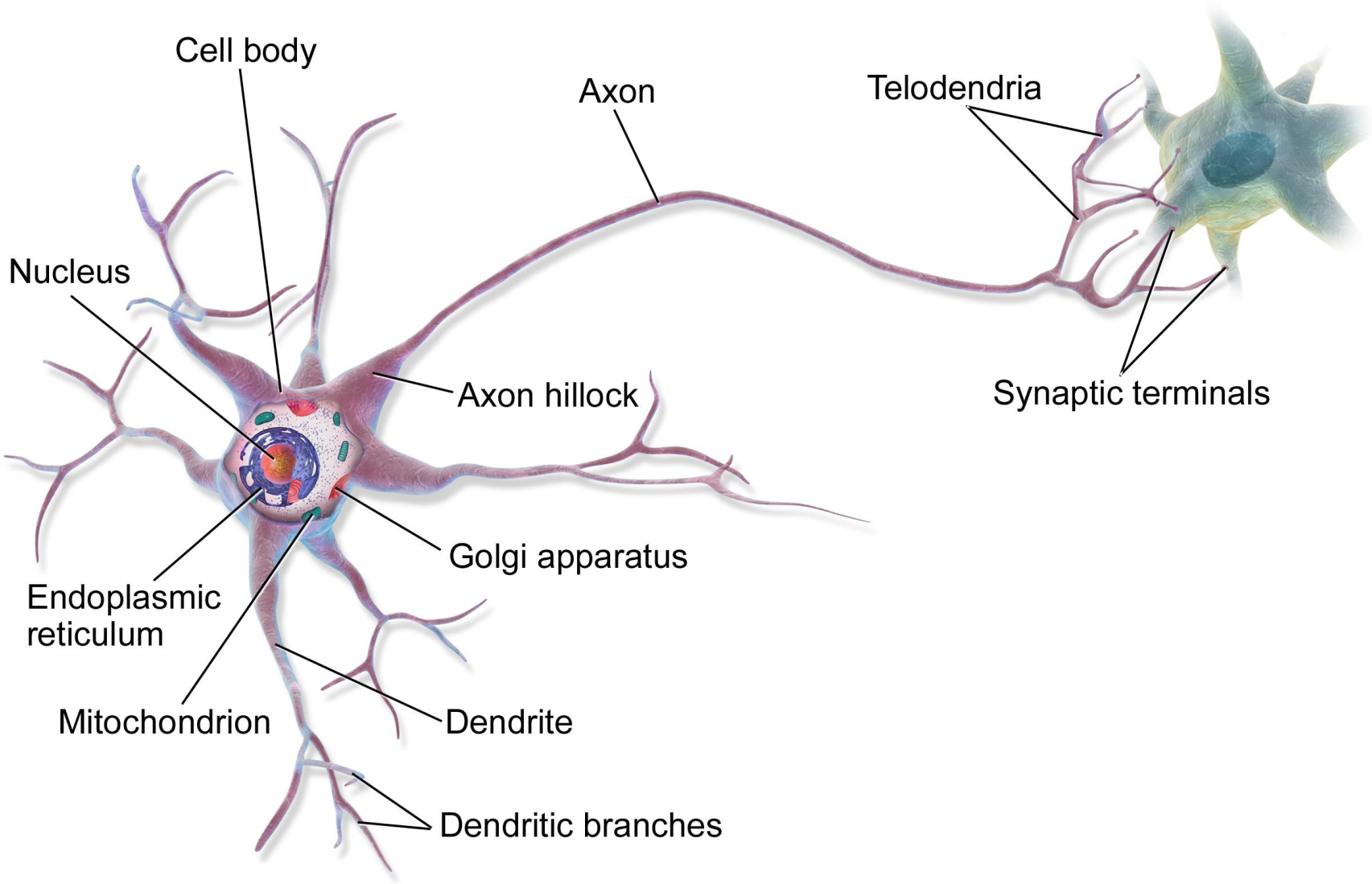
- Largest portion of the nerve cell
- Contains
  - Nucleus
  - Cytoplasm
  - Organelles (Mitochondria, GA)
- Neurofibrils (bundles of neurofilaments) extend through cytoplasm
- Nissal bodies
  - Portions of RER that provide proteins
    - For signal transmission
    - Maintaining and regenerating nerve fiber

Axons

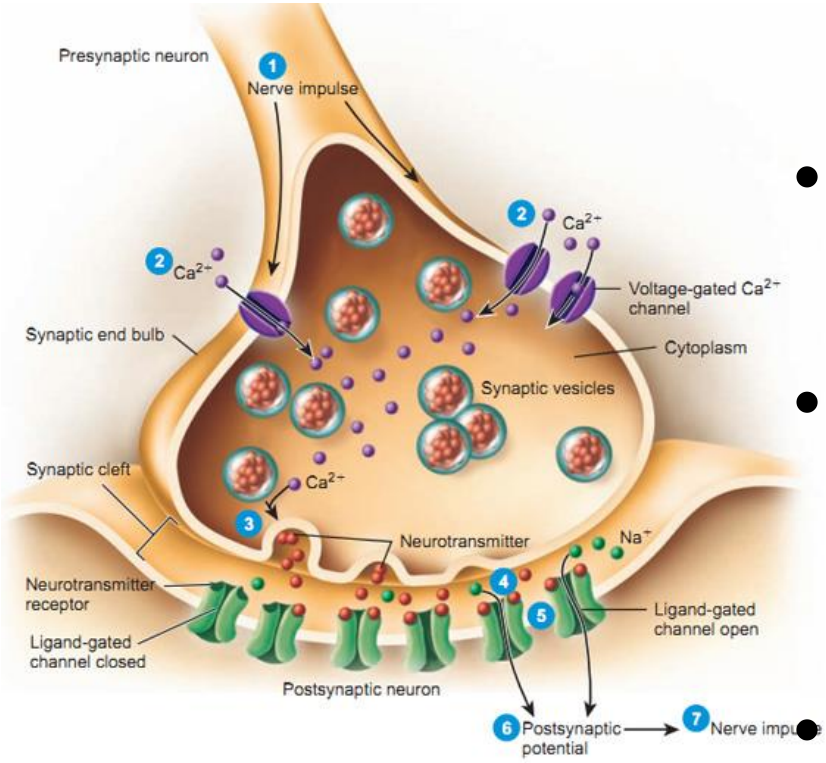
- Originate from axon hillock
- Conduct impulses away from the neuron (Size dependent)
- Axon collaterals branch off of axons



Axons


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

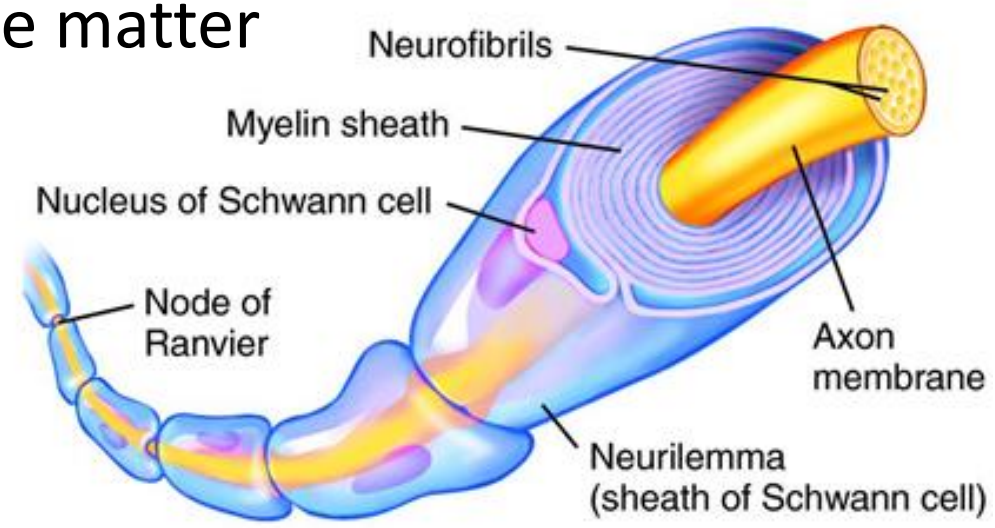
Synaptic knobs (bulbs)



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

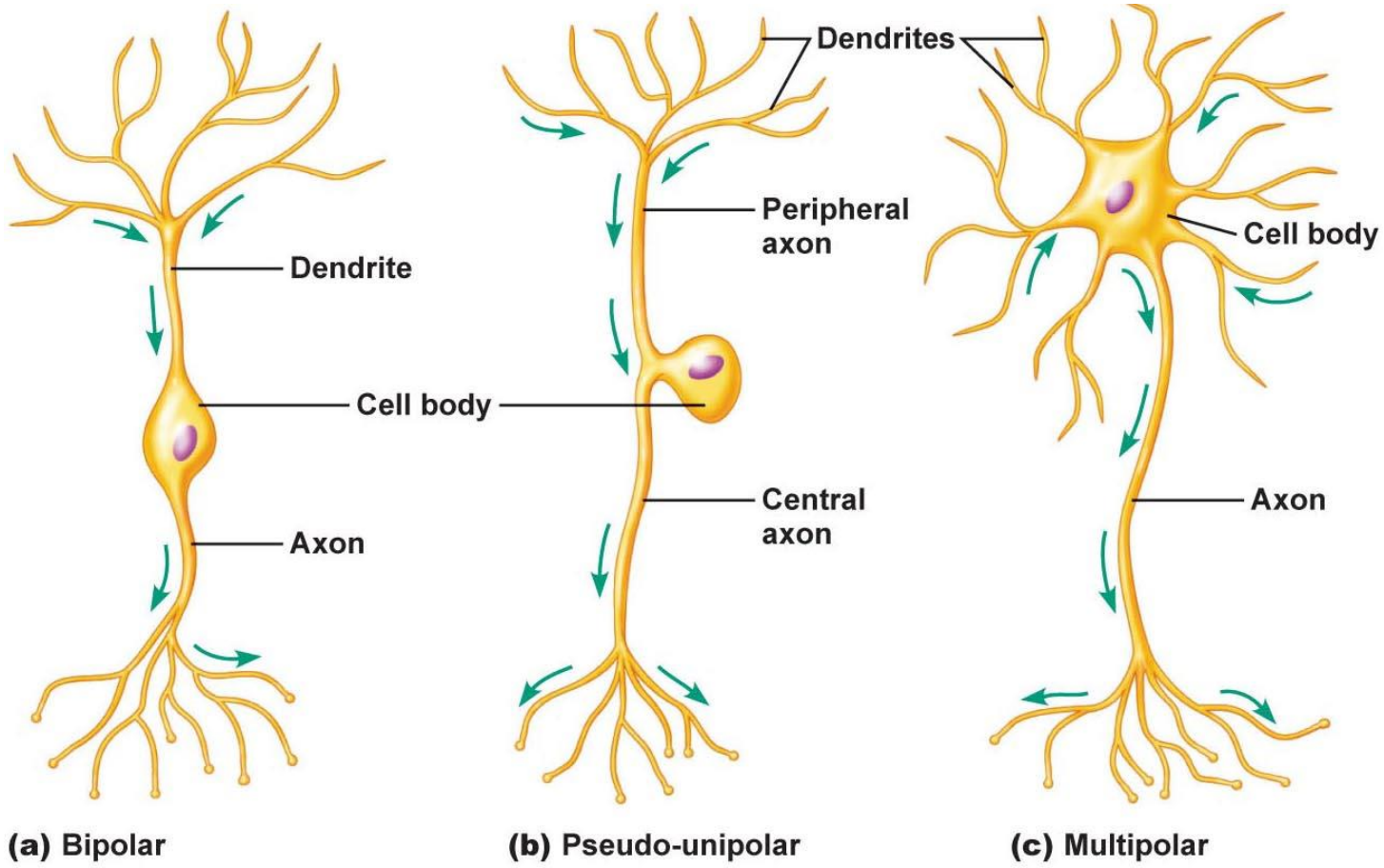
Myelin

- Lipoprotein produced by Schwann cells (PNS) or Oligodendrocytes (CNS)
- Found only on Axons
- Facilitates high speed impulse conduction to and from CNS
- Causes pigment in white matter



Neurons

- Structural Classifications



Neurons

- Functional Classifications
  - Afferent (Sensory) Neurons
    - Carry impulses from PNS to CNS
    - Have long dendrites and short axons
  - Efferent (Motor) Neurons
    - Carry impulses from CNS to effector organs
    - Have short dendrites and long axons
  - Interneurons (association neurons)
    - Are totally in CNS
    - Connect link between efferent and afferent neurons
    - Have short dendrites and may have long/short axons

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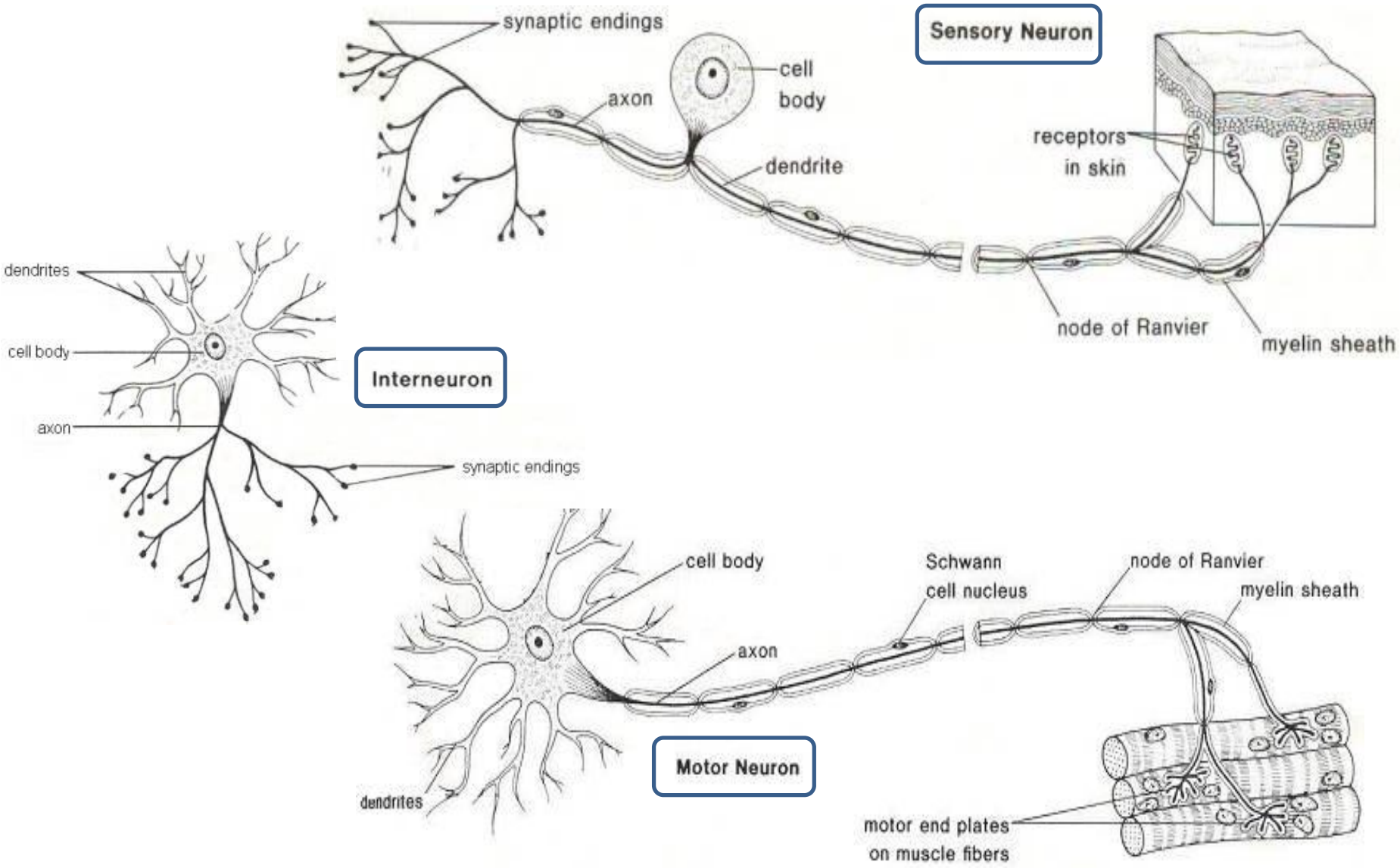
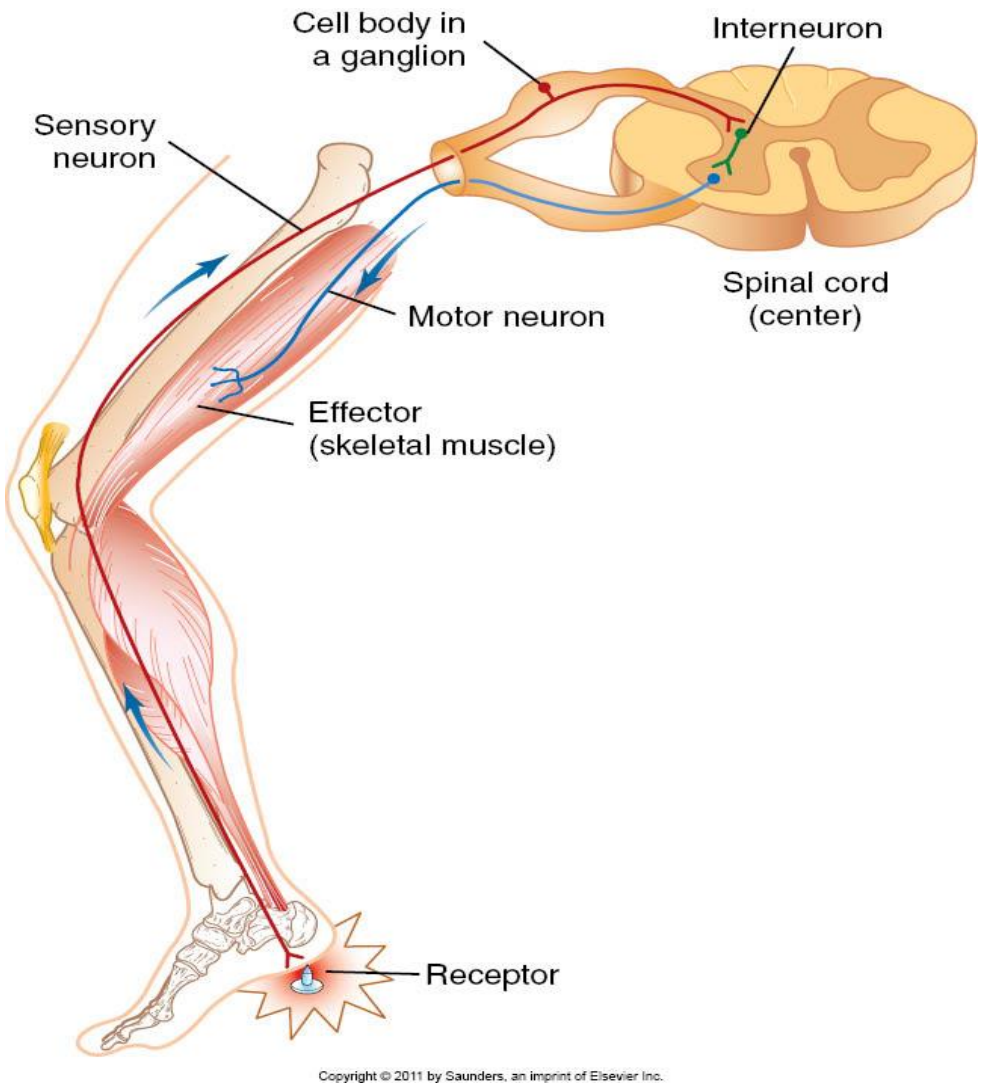
Neurons

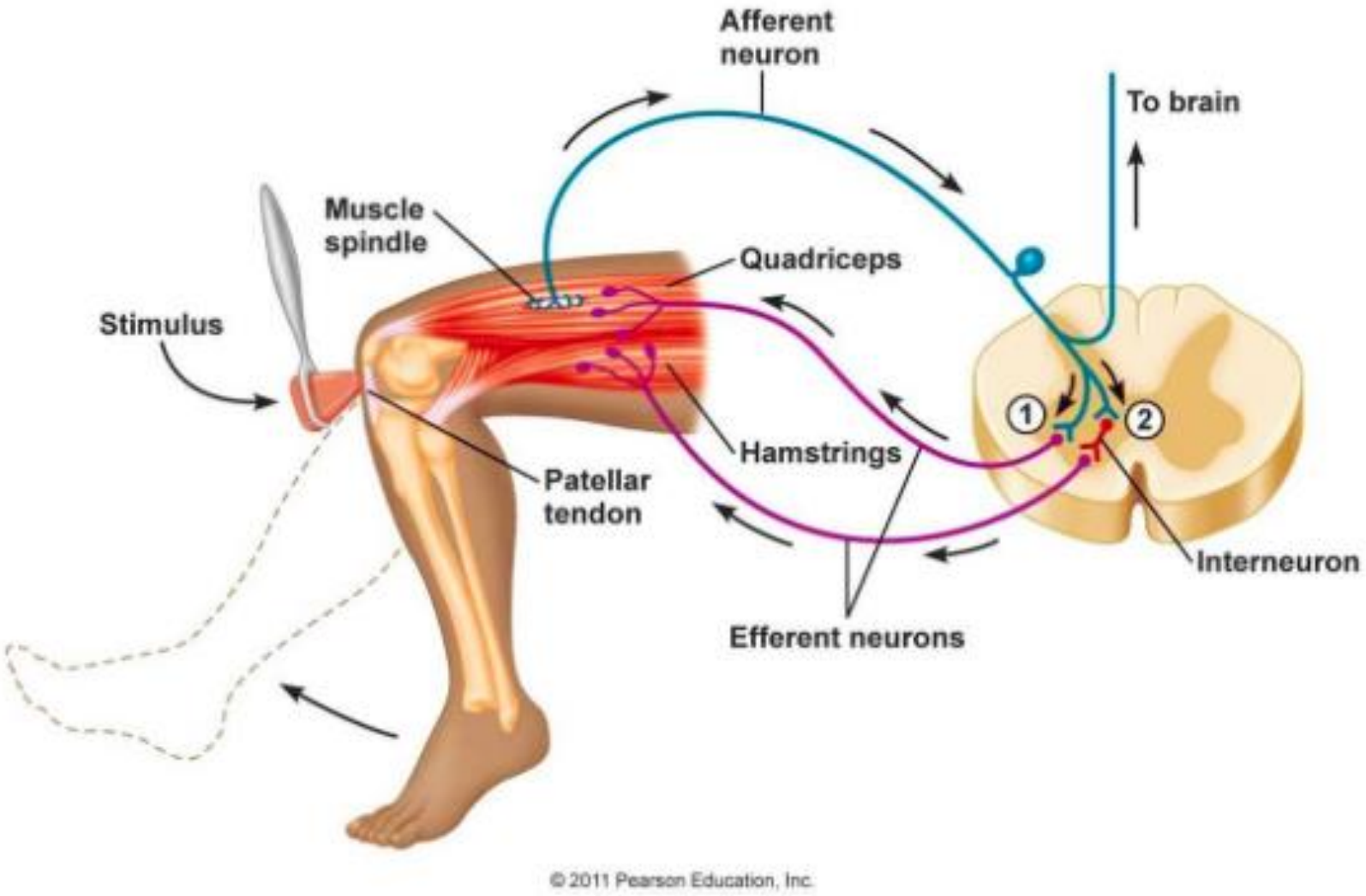


Reflex Arcs

- 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
1
2
Hamstrings
Patellar tendon
Interneuron
Efferent neurons
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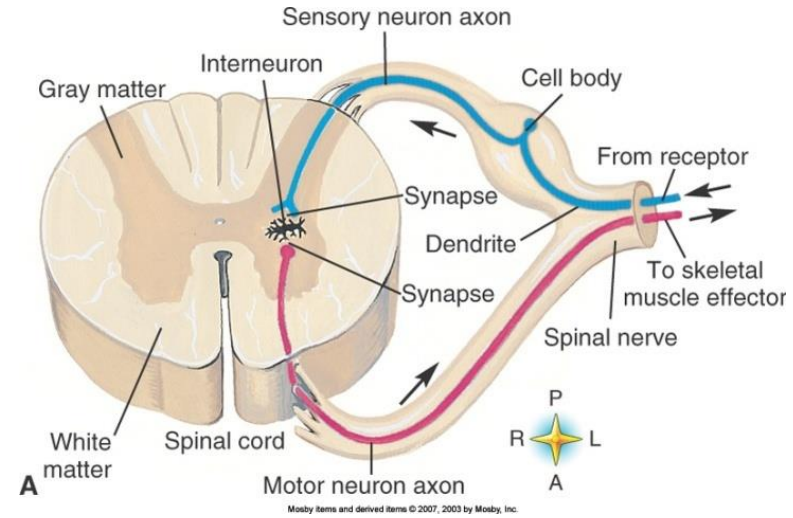
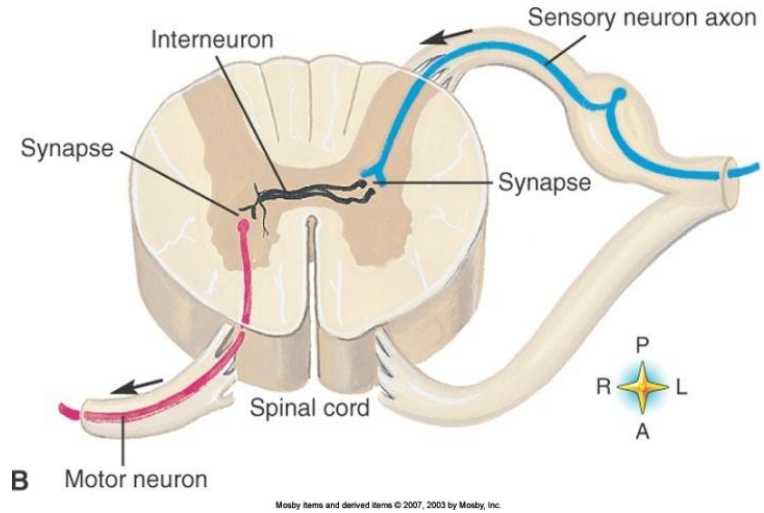
Reflex Arcs

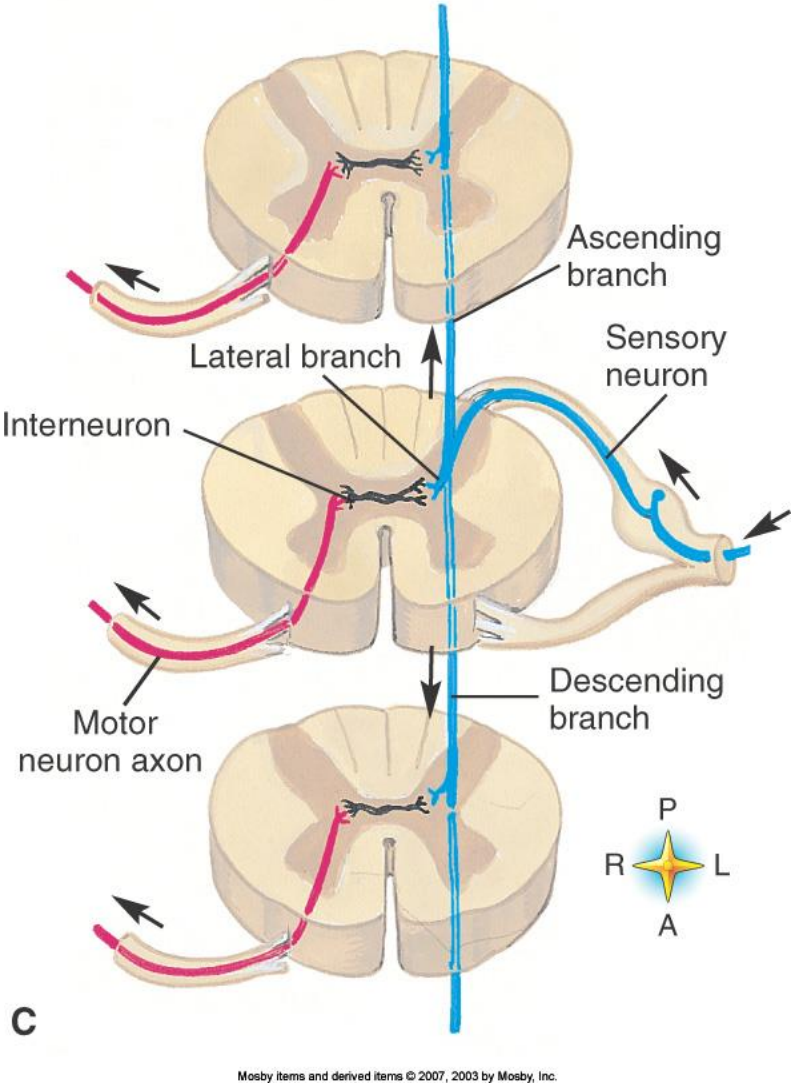
Ipsilateral



Contralateral

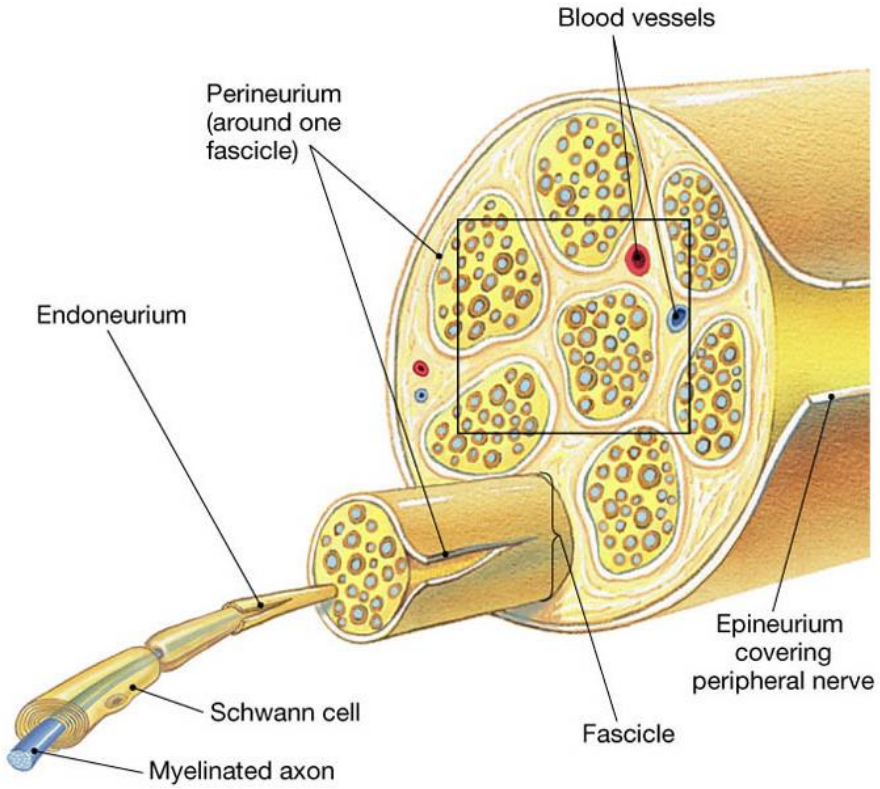


Intersegmental Contralateral



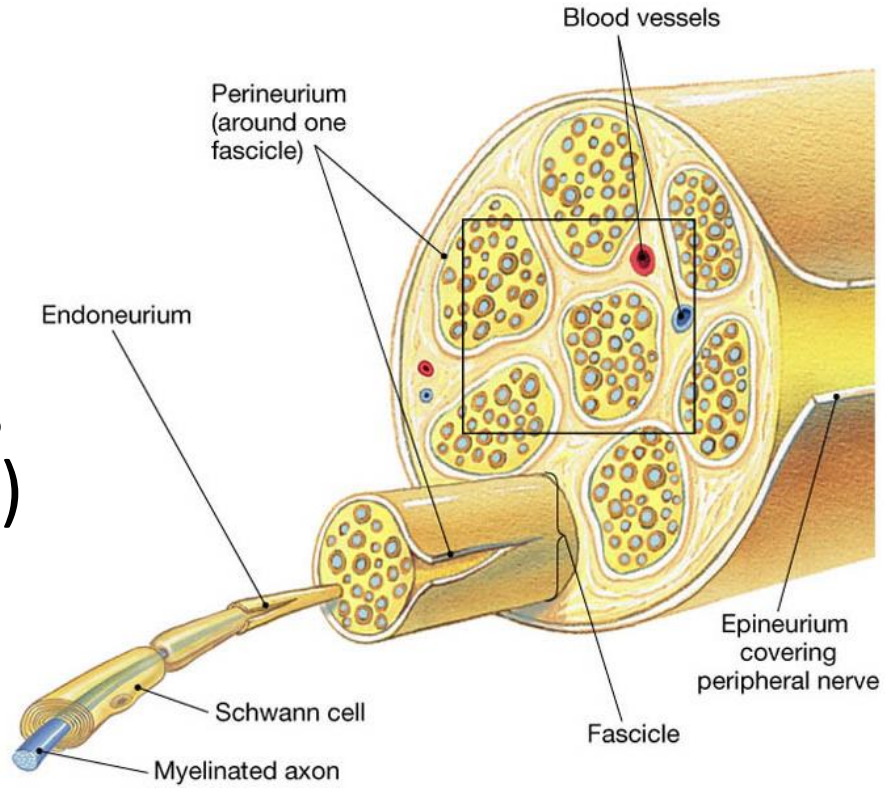
Nerves and Tracts

- 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

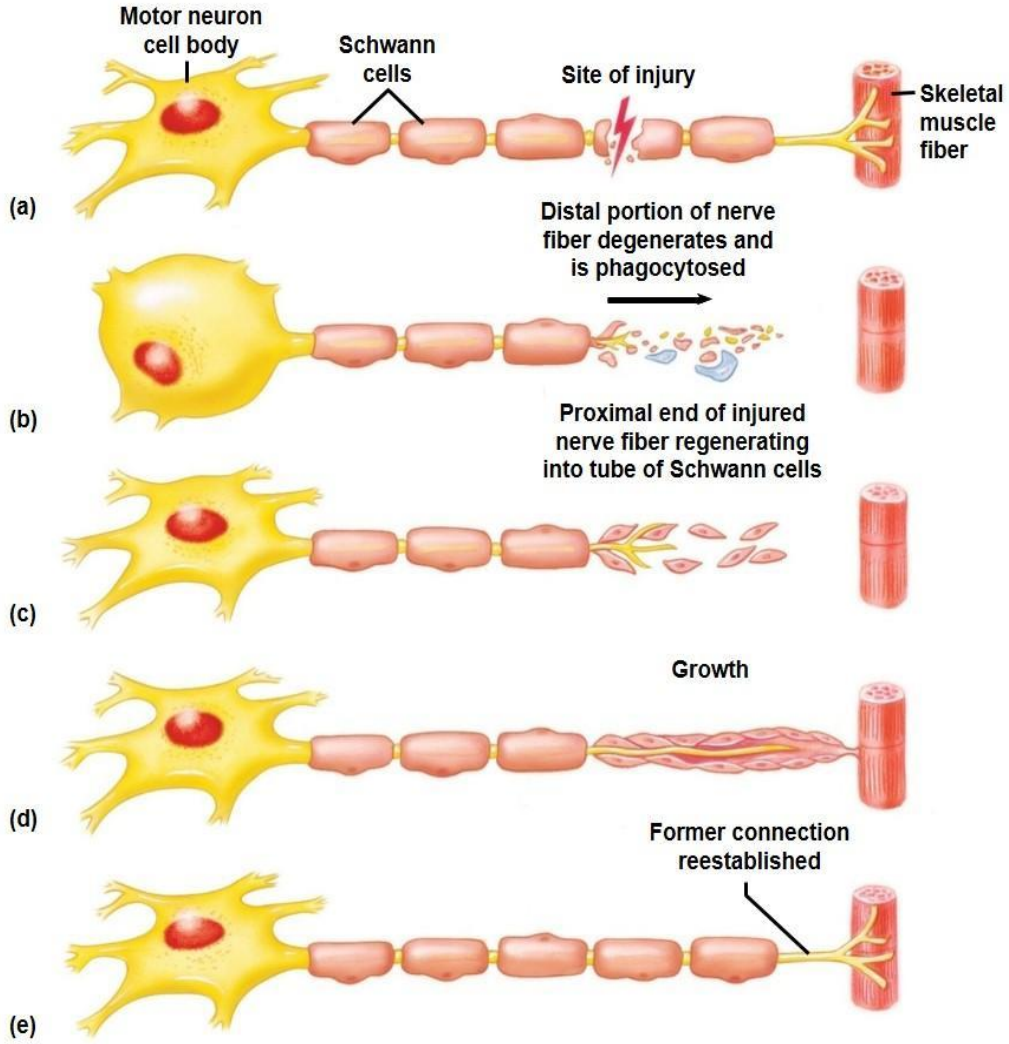


Repair

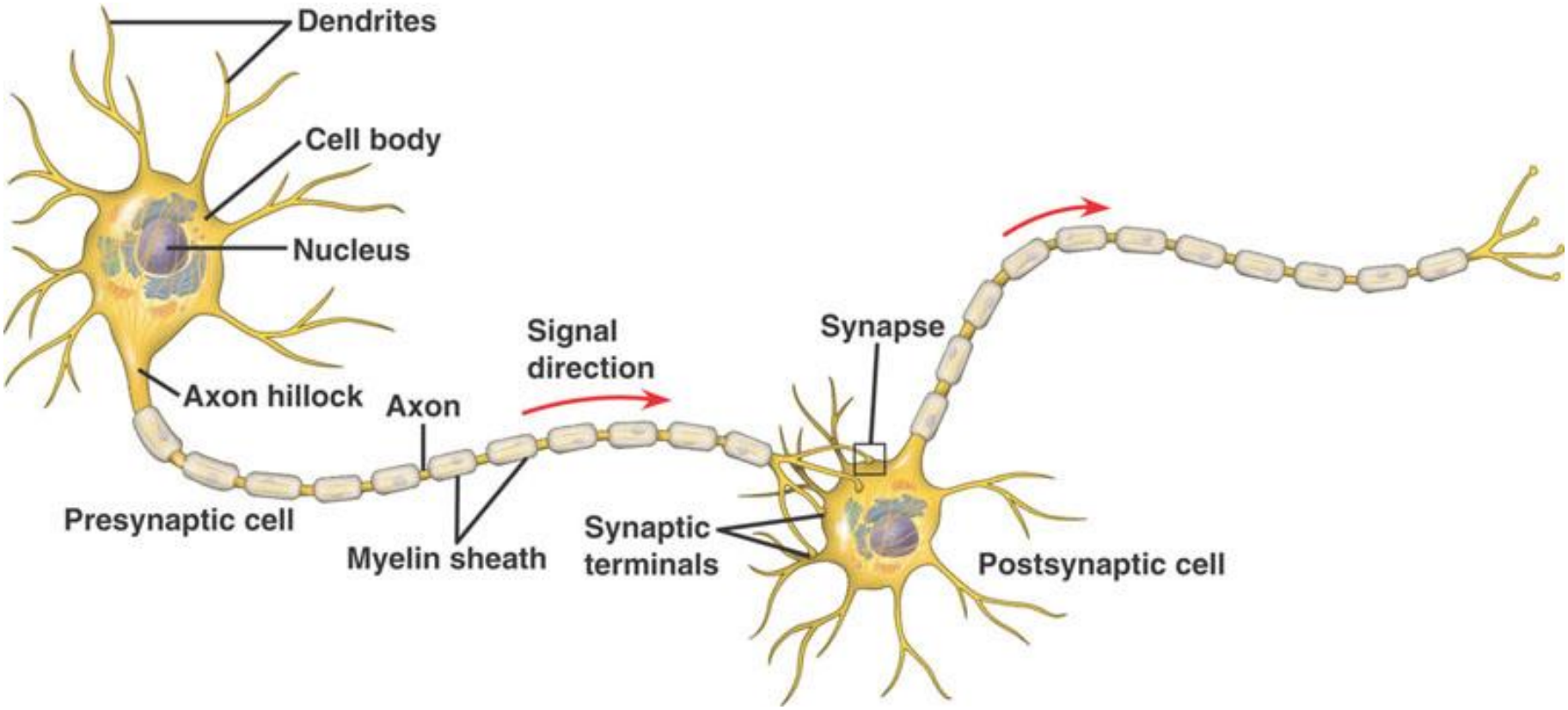
- Mature neurons are amitotic
- Healing is based on repairing existing neurons
- Neurons have limited capacity for repair
- Repair may be possible if injury is not extensive and the cell body and the neurilemma remain intact

Repair

- PNS repair
  - Possible due to the presence of the neurilemmal
- CNS repair
  - Very unlikely
  - Lack neurilemma to create tunnel
    - Oligodendrocytes vs. Schwann cells
  - Astrocytes quickly fill damaged area and block regrowth



Impulse Conduction



How does this occur ?

- Neurons initiate excitability and conductivity
  - Excitability: the ability to respond to a stimulus
  - Conductivity: the ability to transmit an impulse from one point to another
- A nerve impulse is a wave of energy traveling along the plasma membrane.
- This causes a change in the polarity (electrical charge) of the neuron
- Caused by an increase in the amount of Na^+ within the membrane of the cell
- Is dependent on the potential of the membrane to accept said change

Terms of Reference

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

Resting Membrane Potential

- The state of inactivity during which a neuron is not conducting and impulse - resting state
- Typical RMP is -70 mV (more negative inside the cell in comparison to the outside of the cell)
- This exists due to a slight imbalance in ions across the plasma membrane
- Membrane has established amounts of Na^+ and K^+ ions on either side, leaving the inside of the neuron negatively charged relative to the outside.
- During resting state, Na^+ channels are closed while K^+ remain open
- Some K^+ can readily diffuse while Na^+ remains outside

Threshold Potential

- Level of stimulation that a neuron must receive to reach action potential
- If not reached then no further response will happen
  - I.e. subthreshold stimulus
- If reached then action potential will begin
  - Follows the “All or None” Principle

"All or None" Principle

- The ability of a membrane to conduct an impulse, and the strength of said ability
- Occurs when the threshold of excitation (threshold potential) has been reached/surpassed
- Causes a brief reversal of polarity across the membrane of the stimulated axon

Depolarization

- Stimulus opens Na^+ gated channels allowing for influx of Na^+ to the cell
- Decreases the negative charge inside the membrane
- Known as the “upswing”

Repolarization

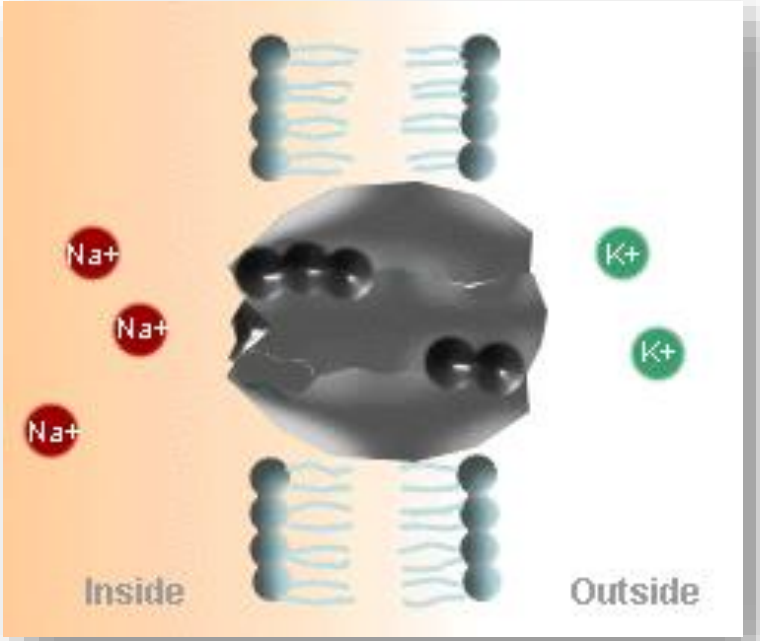
- Electric gradient reached due to Na^+ influx (+30 mV)
- Na^+ influx stopped due to reaching equilibrium
- Opens K^+ gated channels
- K^+ leaves the neuron and the cell returns to its resting state
- Known as the “down swing”

Hyperpolarization

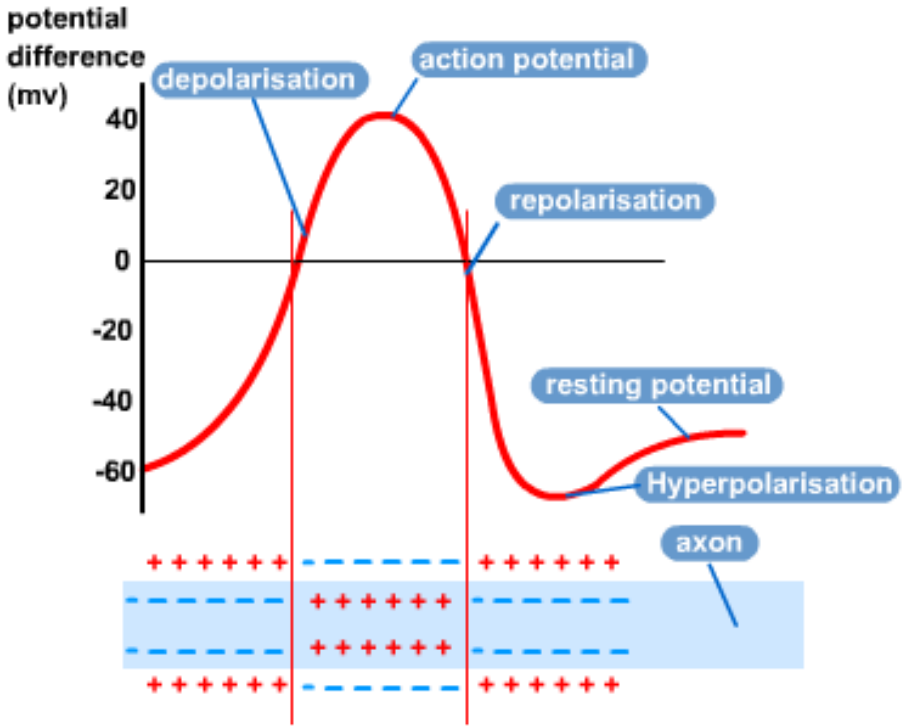
- At peak of repolarization, Na^+ channels are fully closed and K^+ channels stay open for approx. 1 millisecond
- This prevents another action potential from being triggered (refractory period)

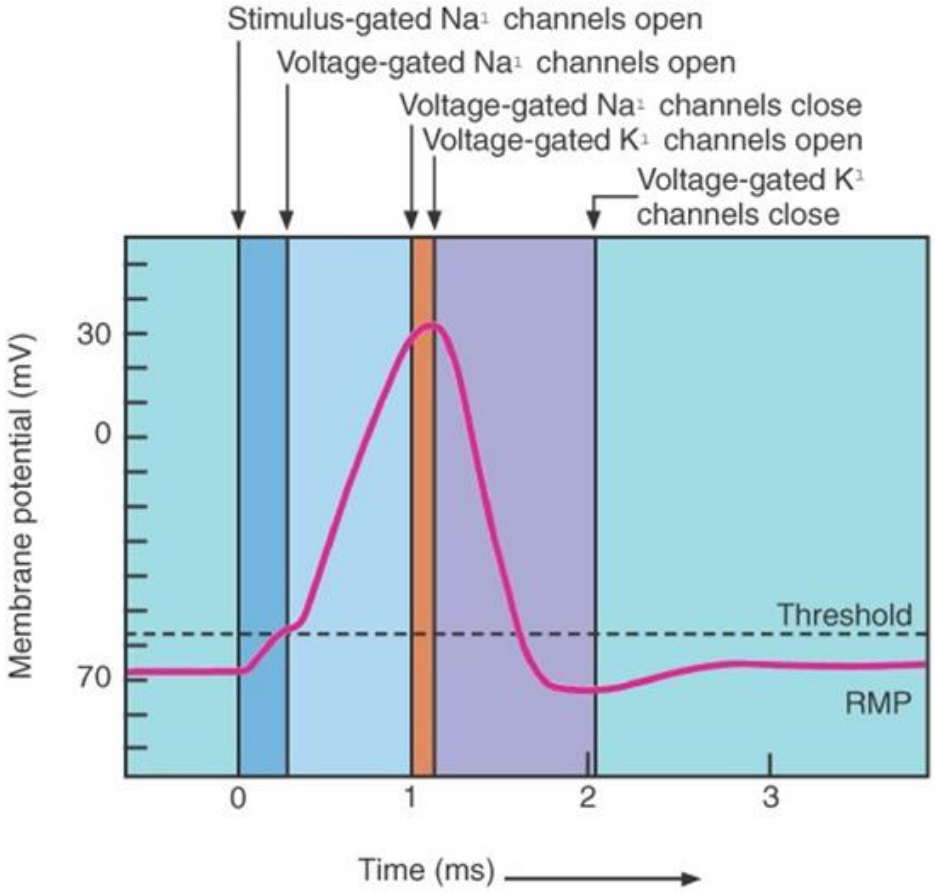
Na-K Pump

- Also referred to as Na^+/K^+-ATPase
- Returns the cell back to RMP by moving the Na^+ and K^+ back to their original concentrations on either side of the membrane
- The ratio of movement is 3 Na^+ for every 2 K^+
- This requires ATP



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

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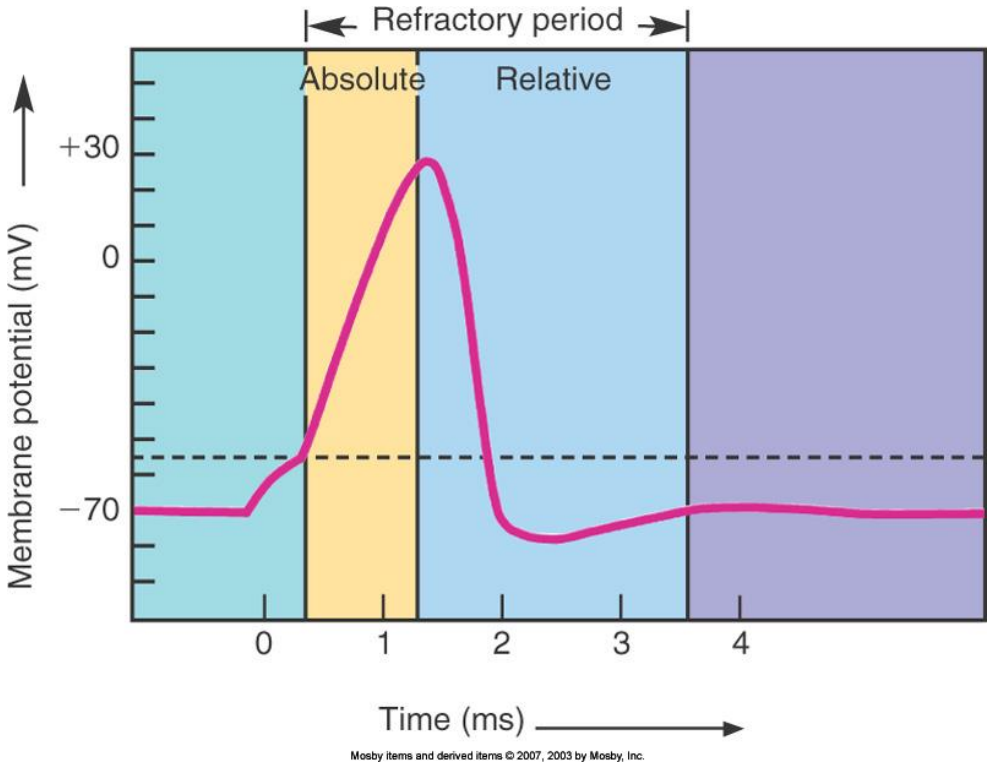
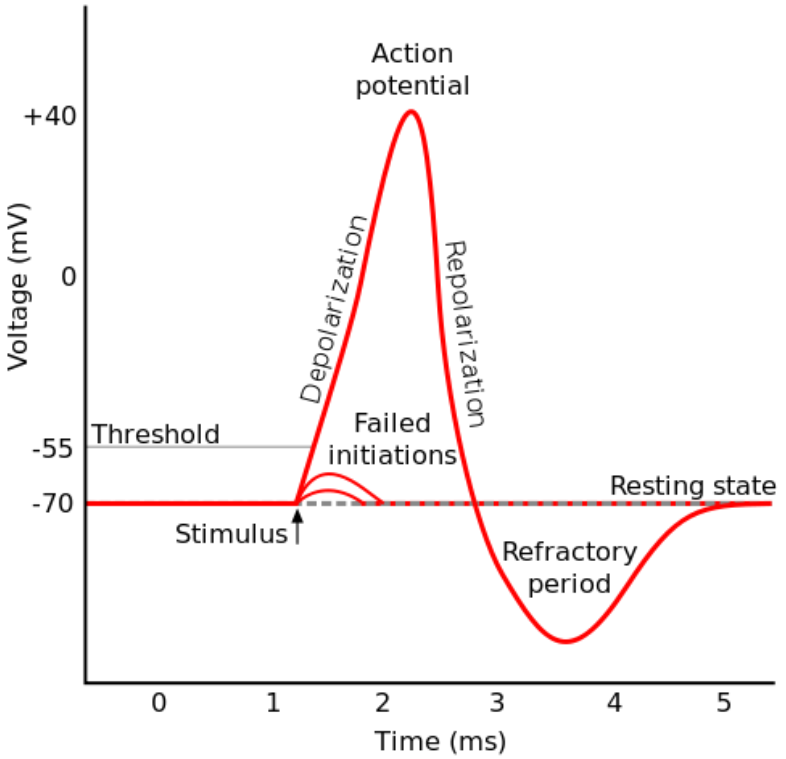
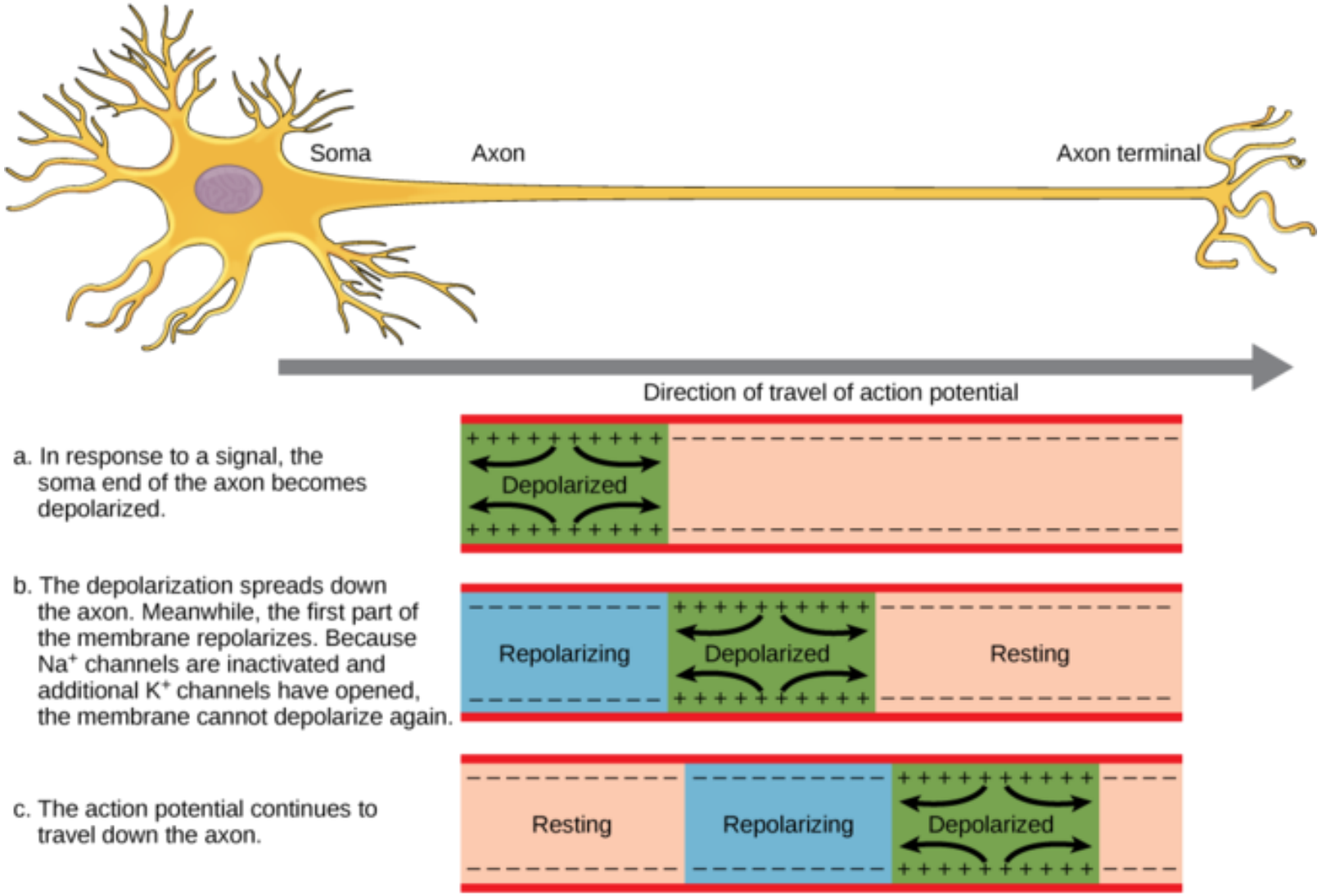
Refractory Period



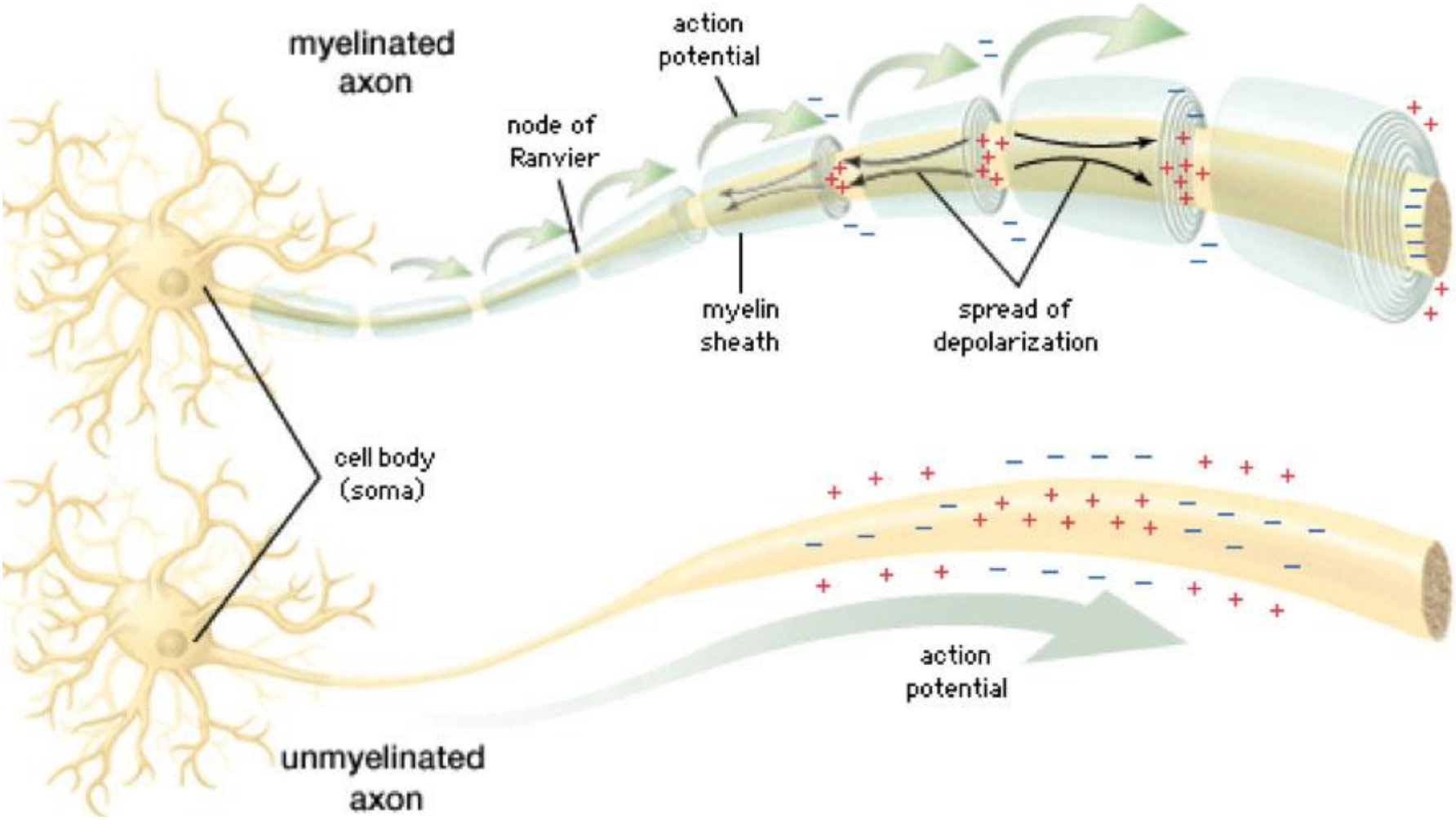


Refractory Period



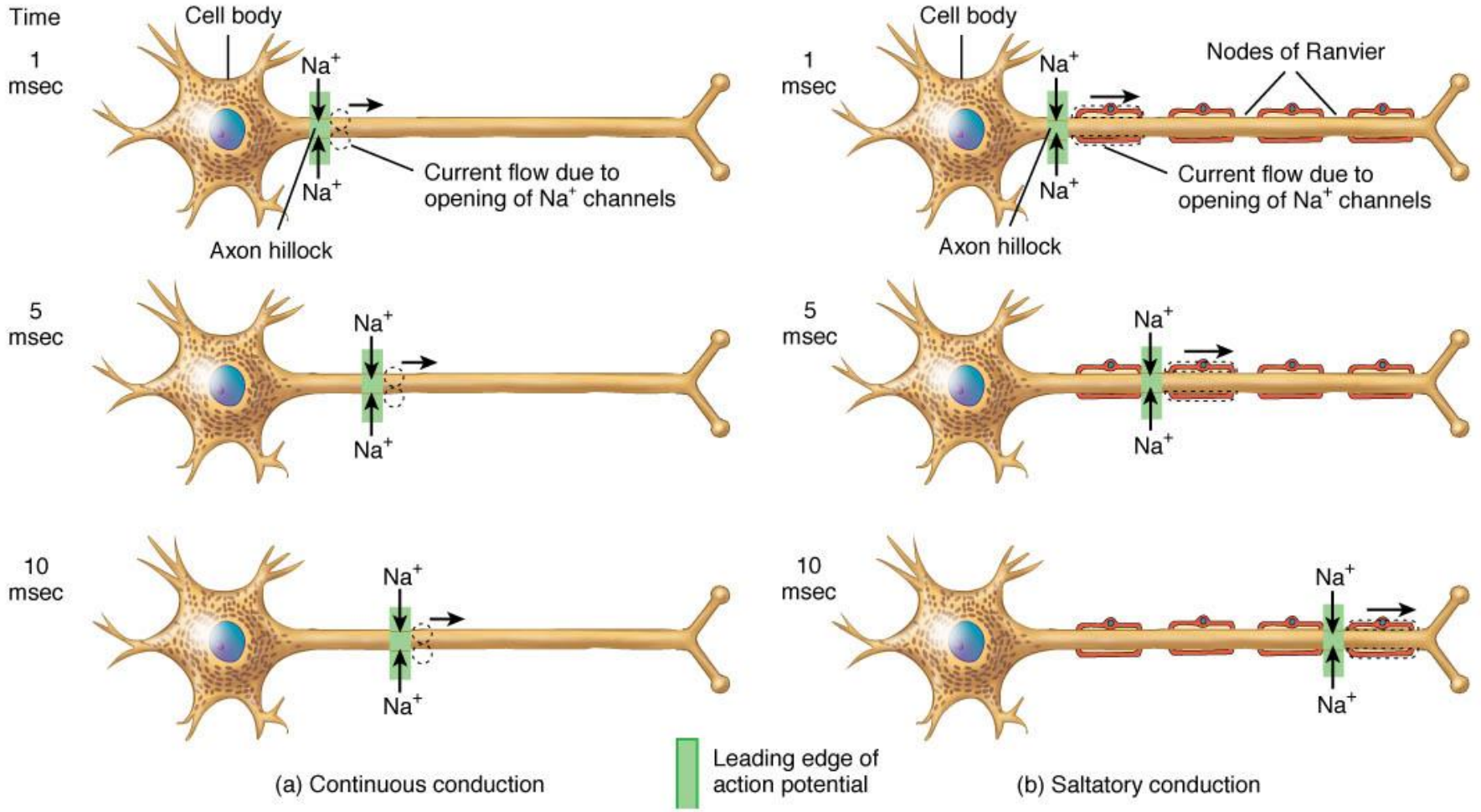
Nerve Impulses

Saltatory Conduction



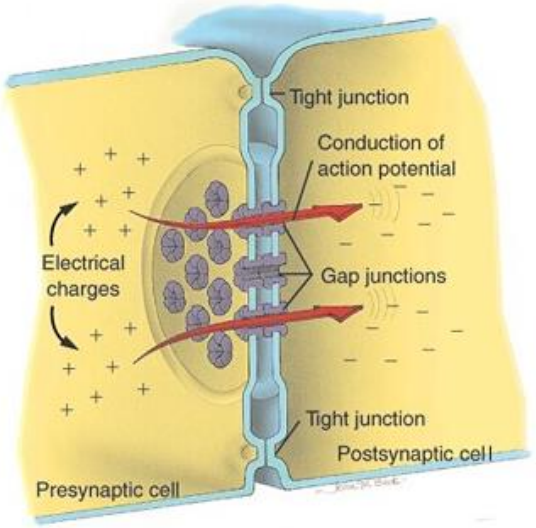
Propagated (Continuous) Conduction

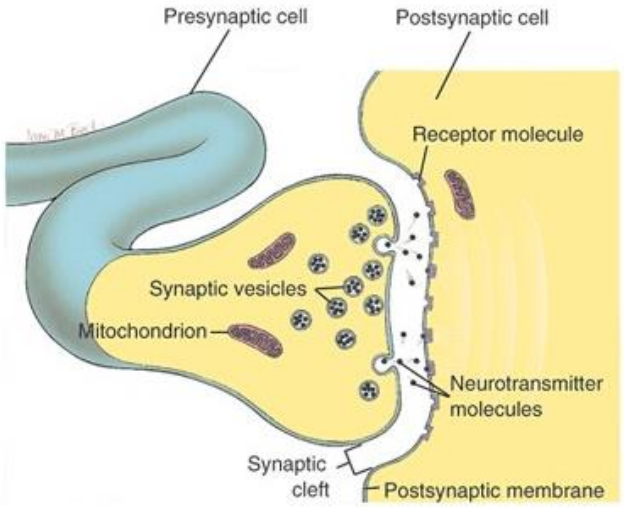
Nerve Impulses



Synaptic Transmission

- Two types
  - 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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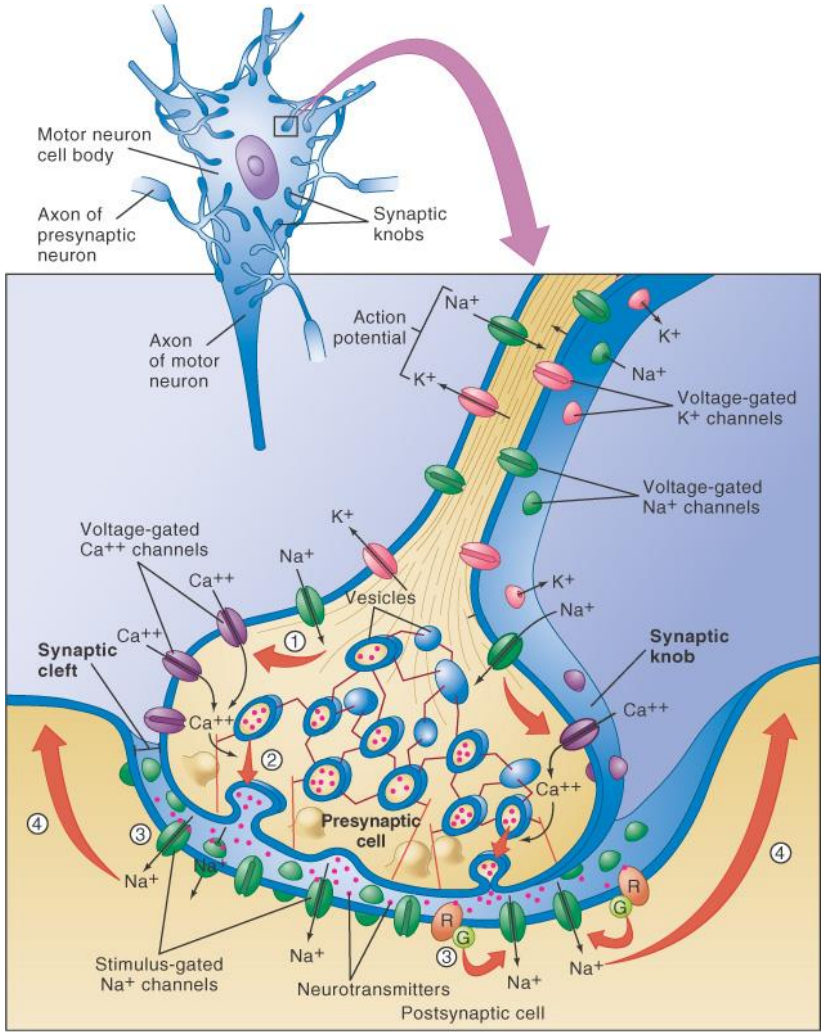
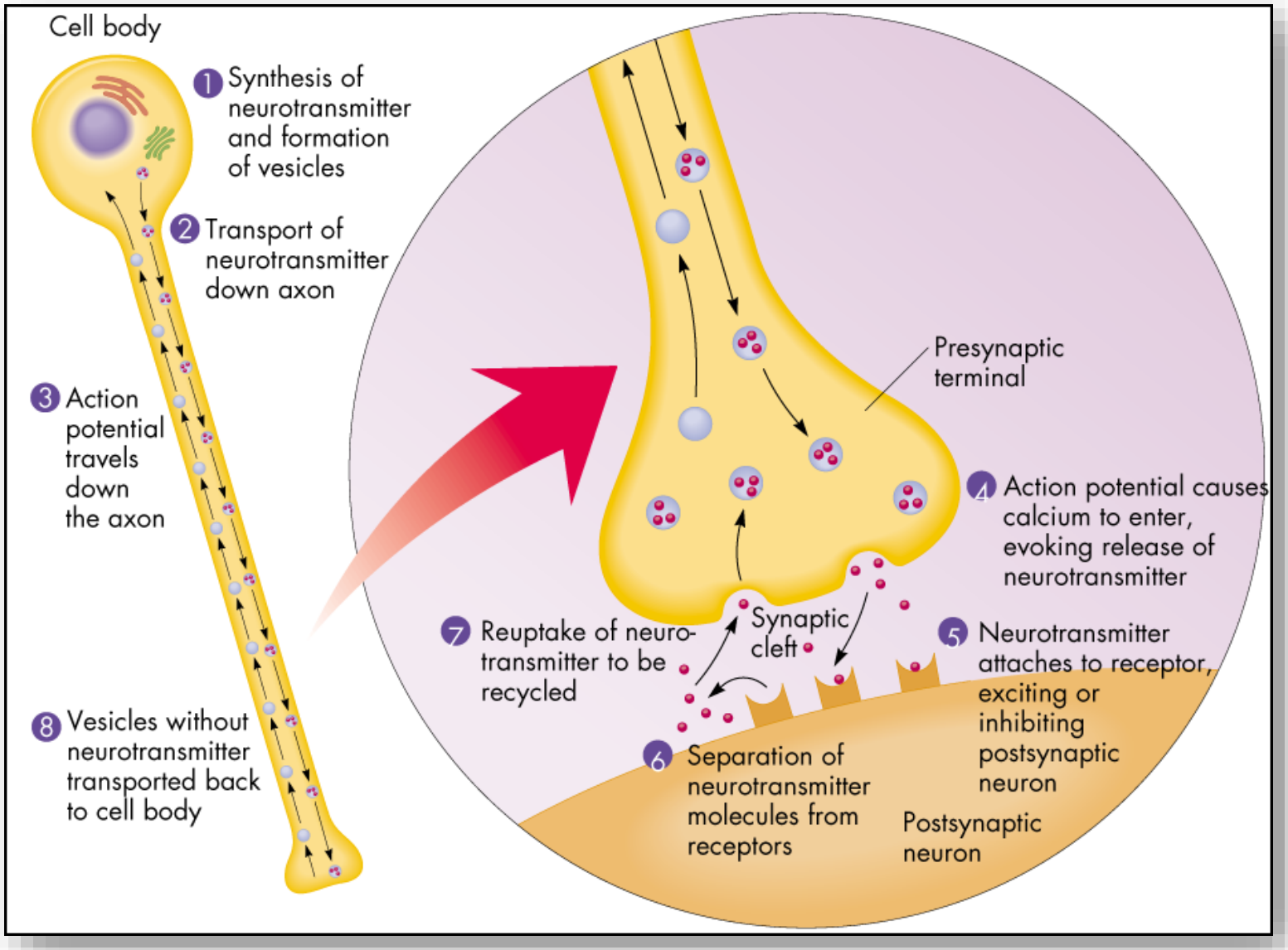
Conduction at the Synapse



- 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
5 Neurotransmitter attaches to receptor, exciting or inhibiting postsynaptic neuron
7 Reuptake of neuro-transmitter to be recycled
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

- More then 50 known compounds
  - Another 50 or so suspected
- Specific NTM are located in discrete areas thus released in specific pathways
- Are
  - Excitatory
  - Inhibitory
  - Both
    - Acetylcholine excites skeletal muscle but inhibits cardiac muscle

Neurotransmitters

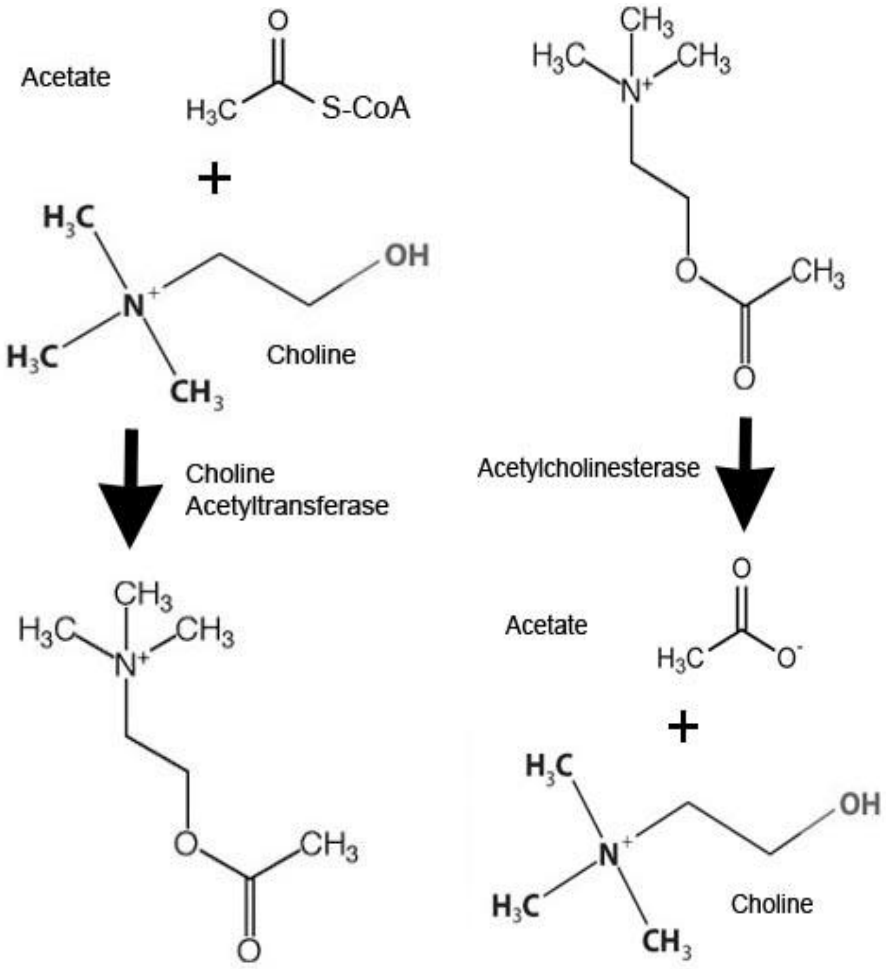
- NTM may
  - Bind with receptor sites causing the ion channel to open or close
  - Bind to receptor sites and stimulate the activation of a chemical messenger already in the cell (2nd messenger response)
    - Slower process (will see more with endocrine)

Neurotransmitters

- Can be classed by chemical structure
  - Small molecule transmitters
    - Acetylcholine
    - Amines
    - Amino acids
    - Other small molecules
  - Large molecule transmitters
    - Neuropeptides

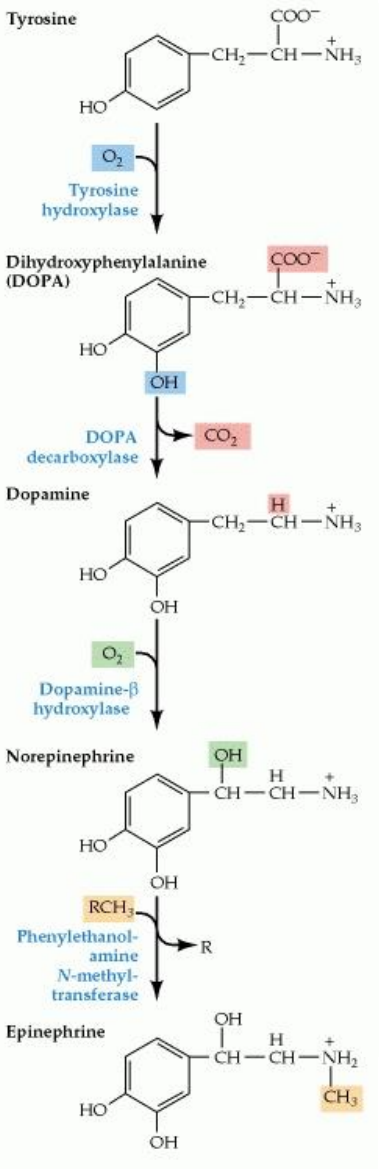
Acetylcholine

- Synthesized in neurons by combining acetyl-coenzyme-A (acetate) with choline
- Inactivated at the post synaptic membrane by acetylcholinesterase
- Choline molecules released in this reaction are reabsorbed by the presynaptic membrane to create more ACh



Amines

- Synthesized from amino acids
  - Tyrosine, tryptophan or histidine
- Includes:
  - Serotonin
  - Histamine
  - Catecholamine
    - Epinephrine
    - Norepinephrine
    - Dopamine
- Found in the brain
  - Some autonomic neurons in the adrenal gland release Epi and NE directly into the blood stream
  - Histamine and Dopamine also found in the PNS



Amino Acids

- Are found in all cells of the body to help produce proteins
- In the CNS also stored in synaptic vesicles to act as NTM
- Receptors in the post synaptic membrane are sensitive to high levels of amino acids and create the desired response
- Glutamate
  - Responsible for 75% of excitatory signals
- Gamma-aminobutyric acid (GABA)
  - A derivative of glutamate
  - Most common inhibitory NTM in the brain
- Glycine
  - Found in the spinal cord
  - An inhibitory NTM

Neuropeptides

- Strands of amino acids held together by peptide bonds
  - Originally discovered in the stomach
  - Some found to be acting as NTM in the brain
- May bind with opioid sites
  - Enkephalins and Endorphins
    - Bind to opioid receptors to produce pain relief
- Also thought to be released with other NTM to act as neuromodulator
  - Regulates the effects of the NTM released with it

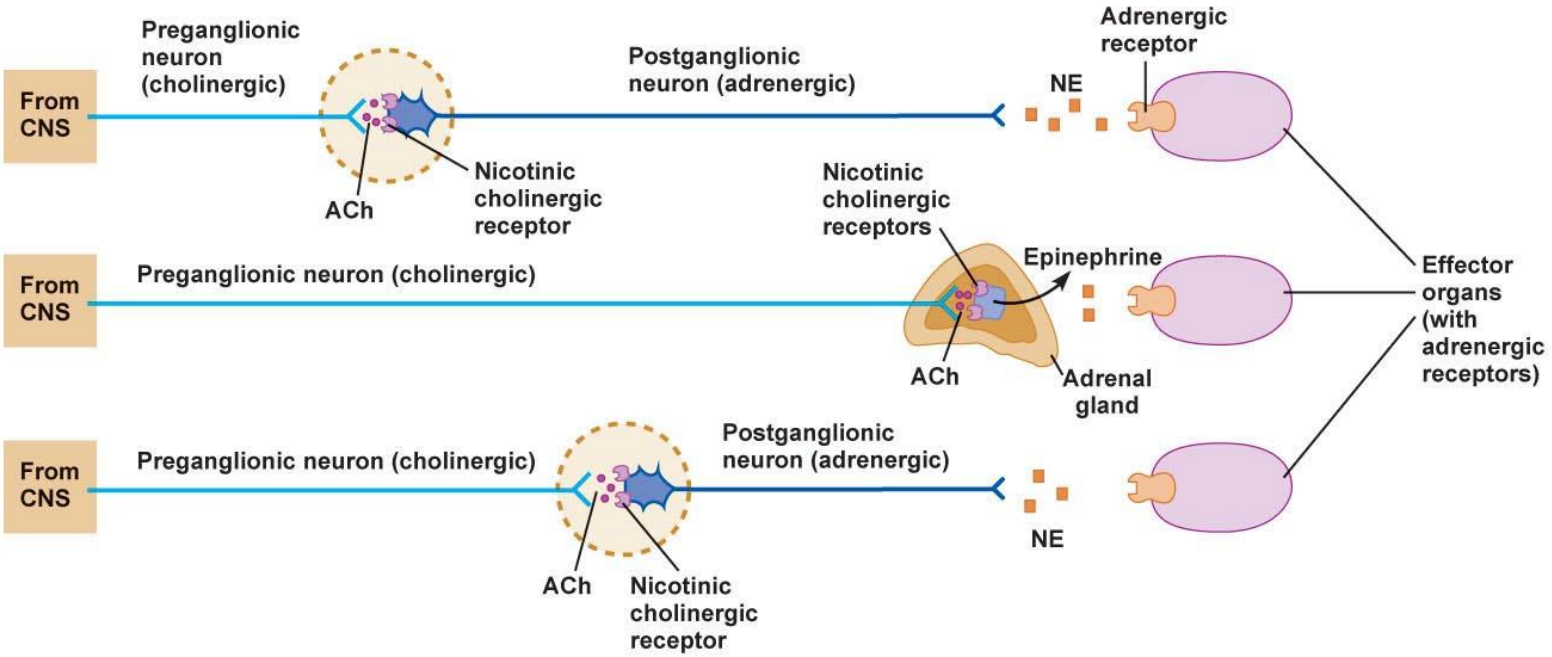
Neurotransmitters

- Acetylcholine
- Amines
  - Serotonin
  - Histamine
  - Nor-epinephrine
  - Epinephrine
  - Dopamine
- Amino Acids
  - Glutamate
  - GABA
  - Glycine
- Neuropeptides
  - Endorphins
  - Enkephalin

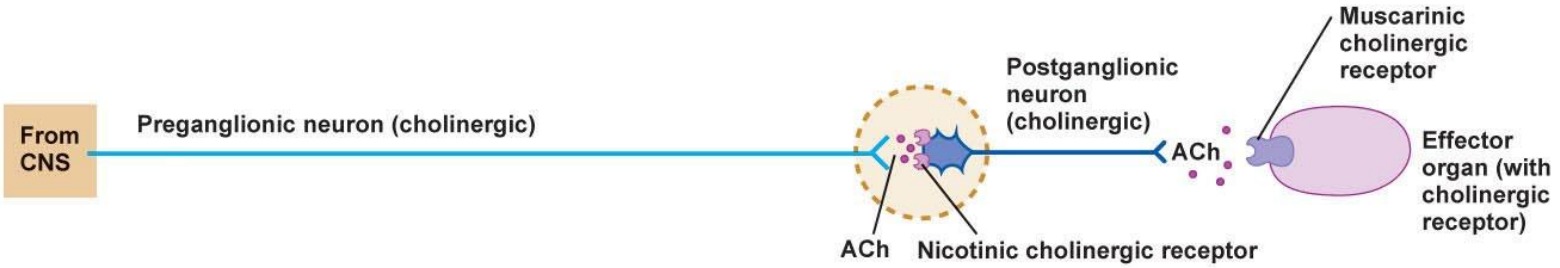
Neurotransmitters (NTM)

- Epi and/or NEpi
  - Actions terminated by
    - Initially Monoamine Oxidase (MAO)
    - Second Catechol-O-Methyl transferase (COMT)
  - Both are relatively slow
- ACh
  - Actions terminated by Acetylcholinesterase
  - Quick

Conduction at the Synapse



(a) Sympathetic nervous system



(b) Parasympathetic nervous system

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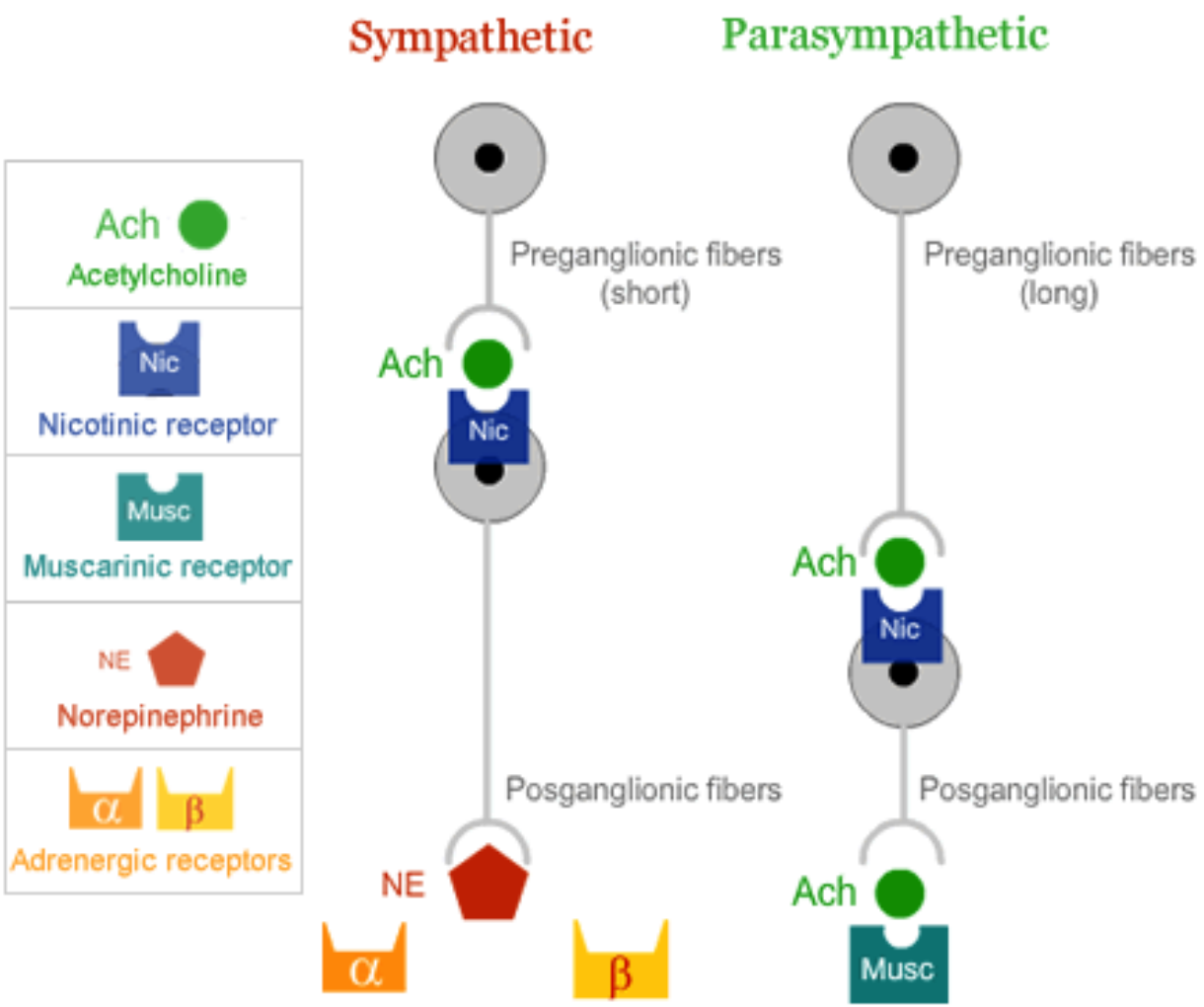
Conduction at the Synapse



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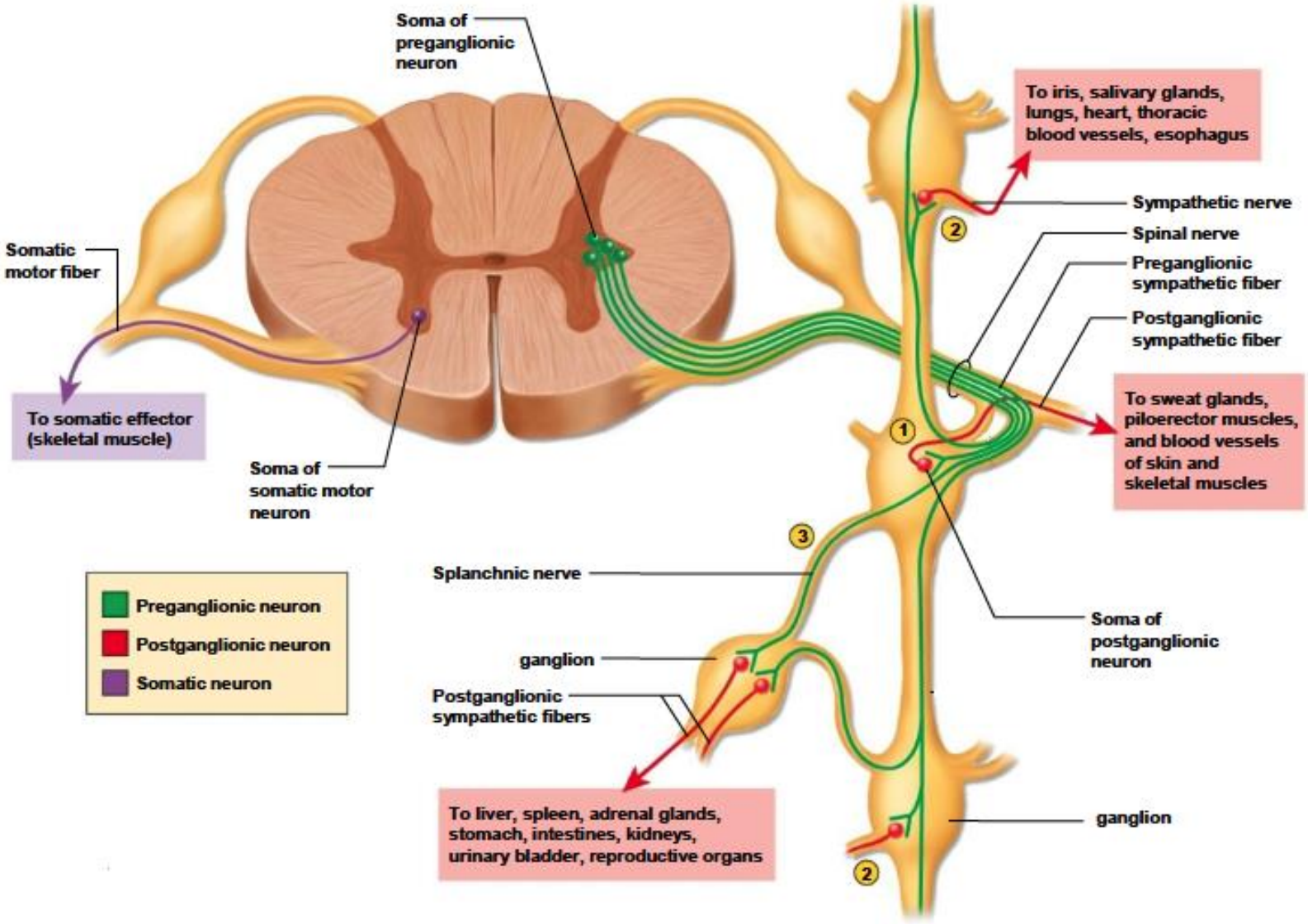
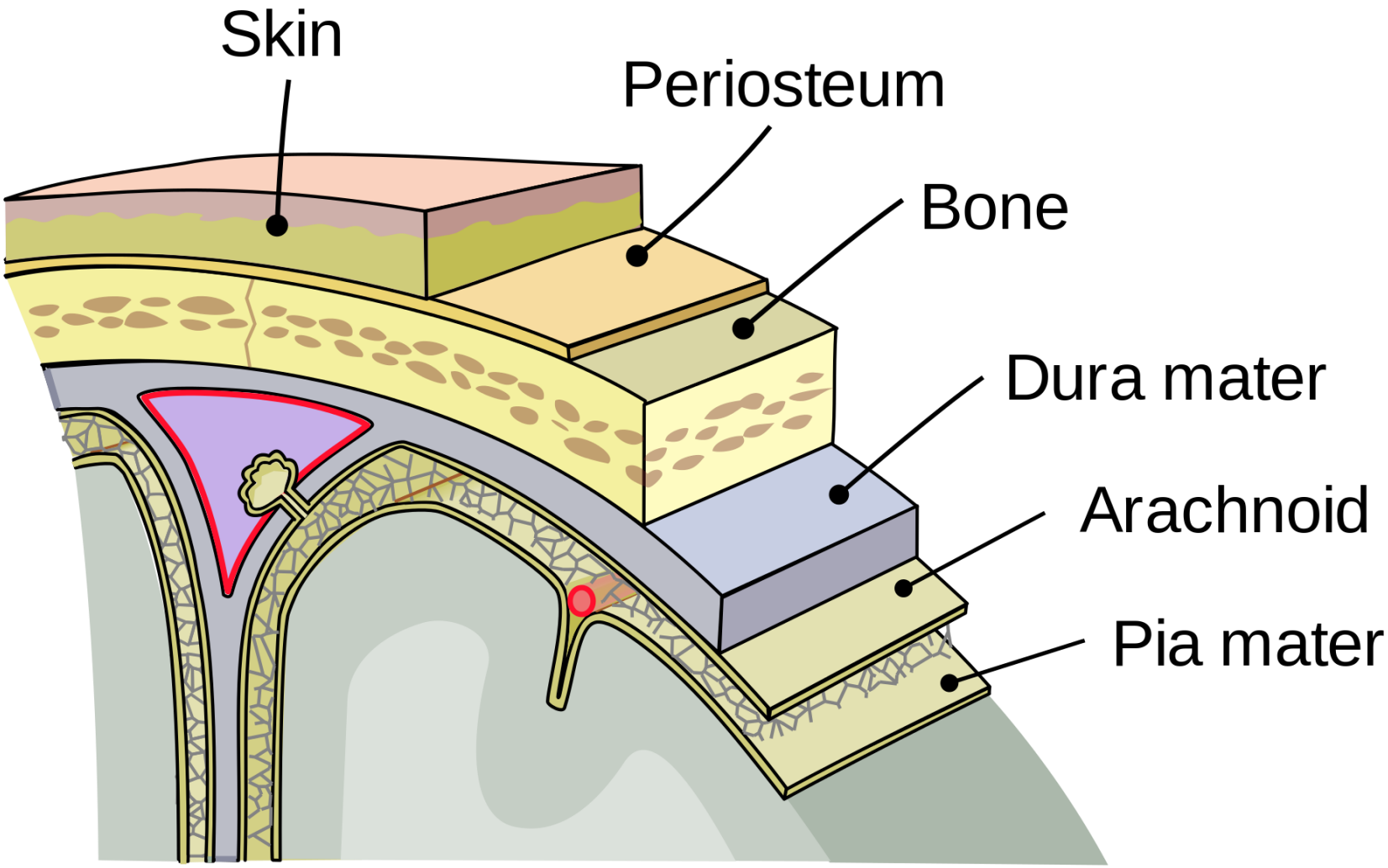
Conduction at the Synapse



Nervous System Anatomy

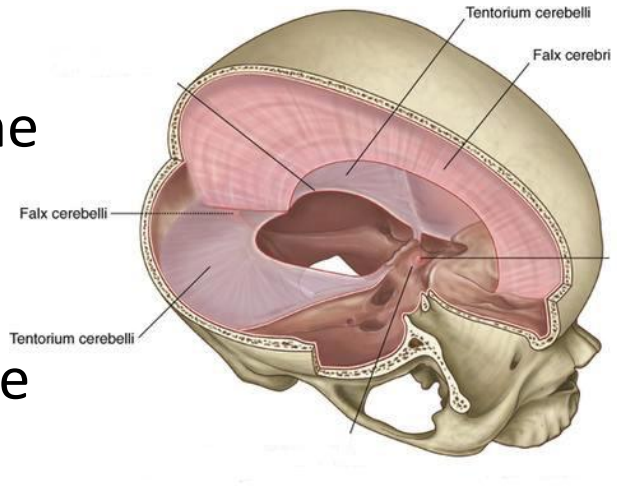
CENTRAL NERVOUS SYSTEM

Coverings of the CNS



Dura Mater

- Strong fibrous tissue
- Has 3 important inward extensions
  - Falx cerebri
    - Projects into the longitudinal fissure to form a partition between cerebral hemispheres
  - Falx cerebelli
    - Separates the hemispheres of the cerebellum
  - Tentorium cerebelli
    - Separates the cerebrum from the cerebellum



Meninges

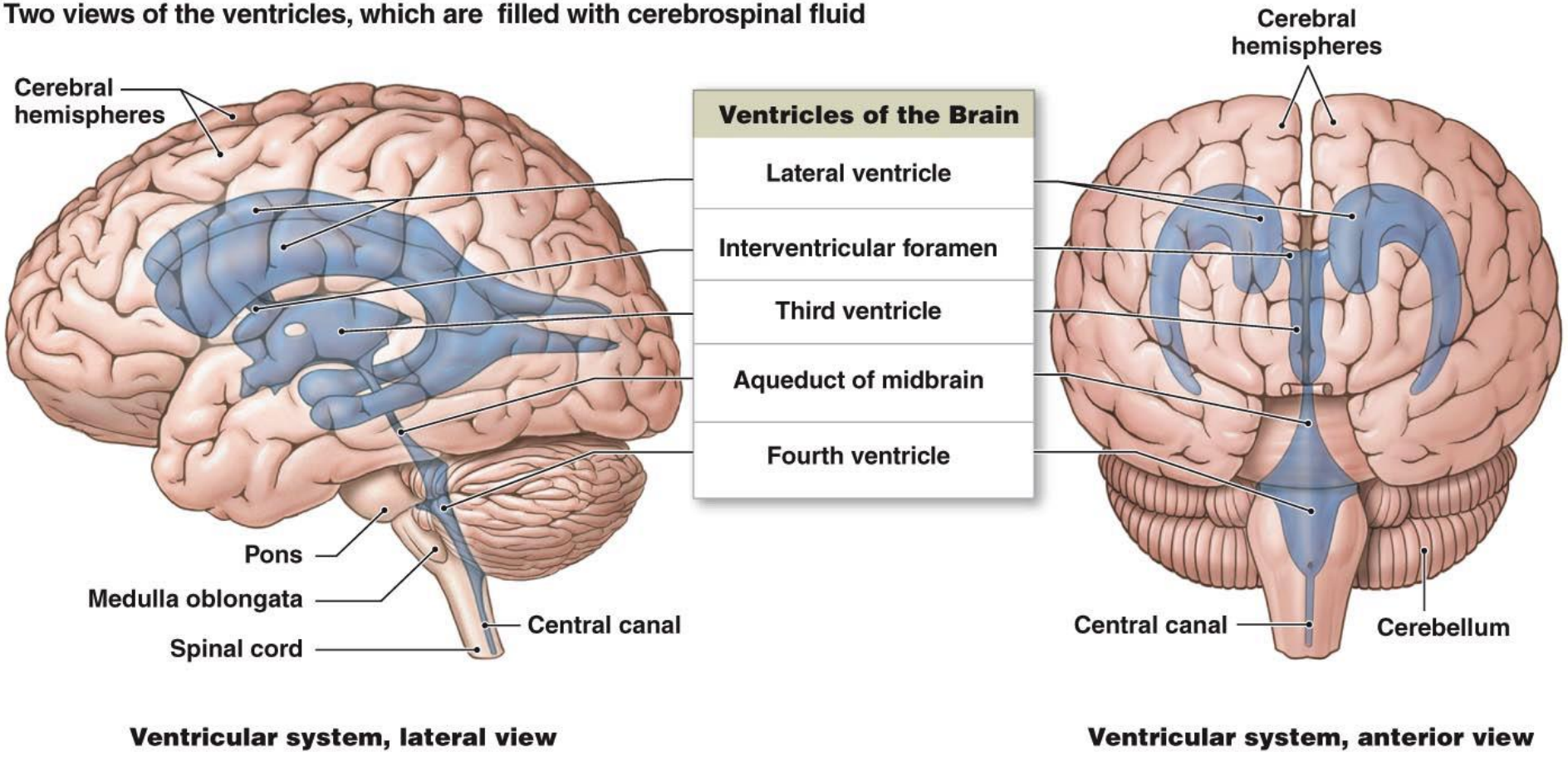
- Arachnoid membrane
  - Cob-web like
  - Numerous threadlike strands attach it to Pia Mater
  - Space underneath contains the CSF and blood vessels
    - Aka Subarachnoid space
  - Avascular
- Pia Mater
  - Thin, transparent layer
  - Adheres to the outer layer of the brain and spinal cord
  - Highly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

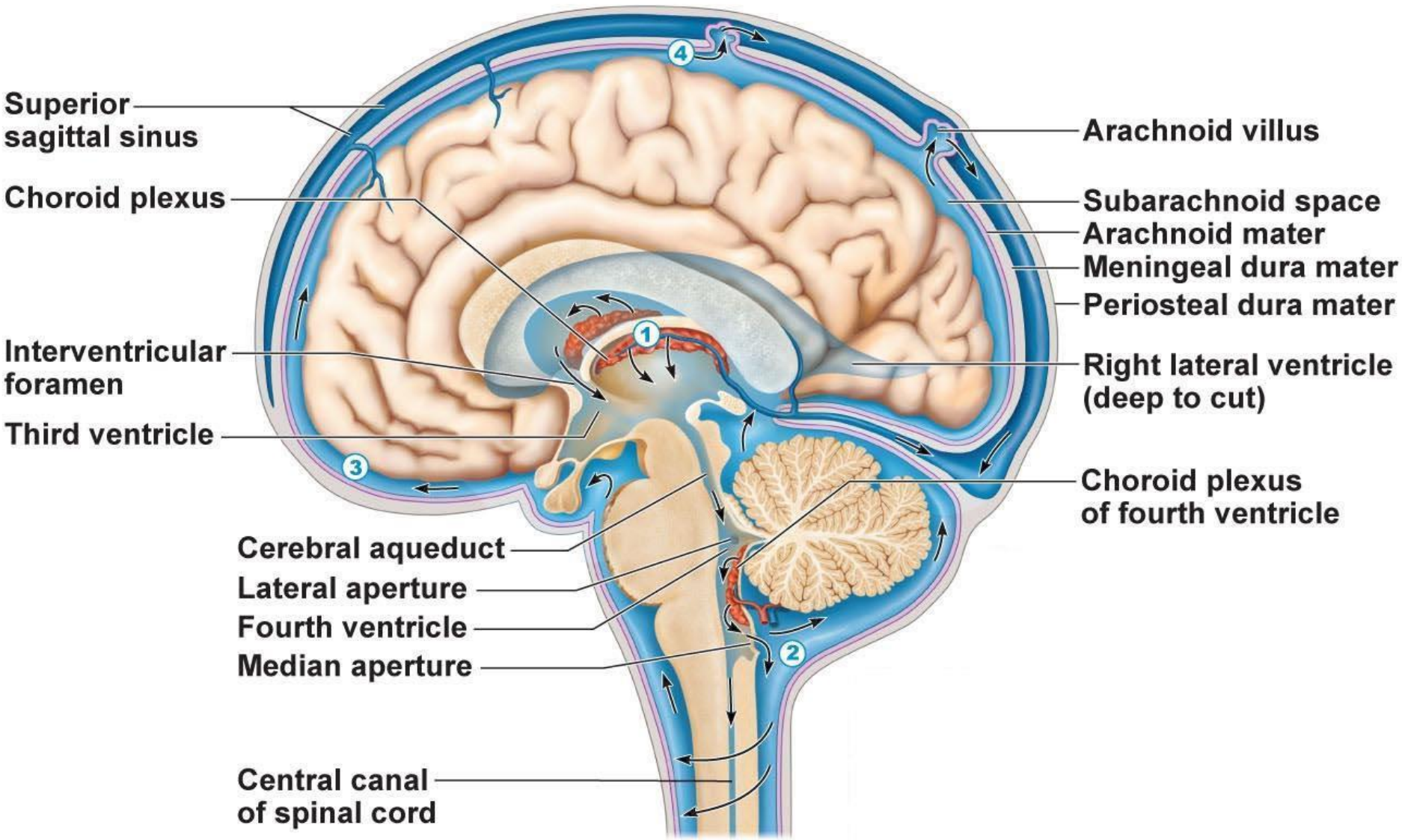


Ventricular system, lateral view

Ventricular system, anterior view

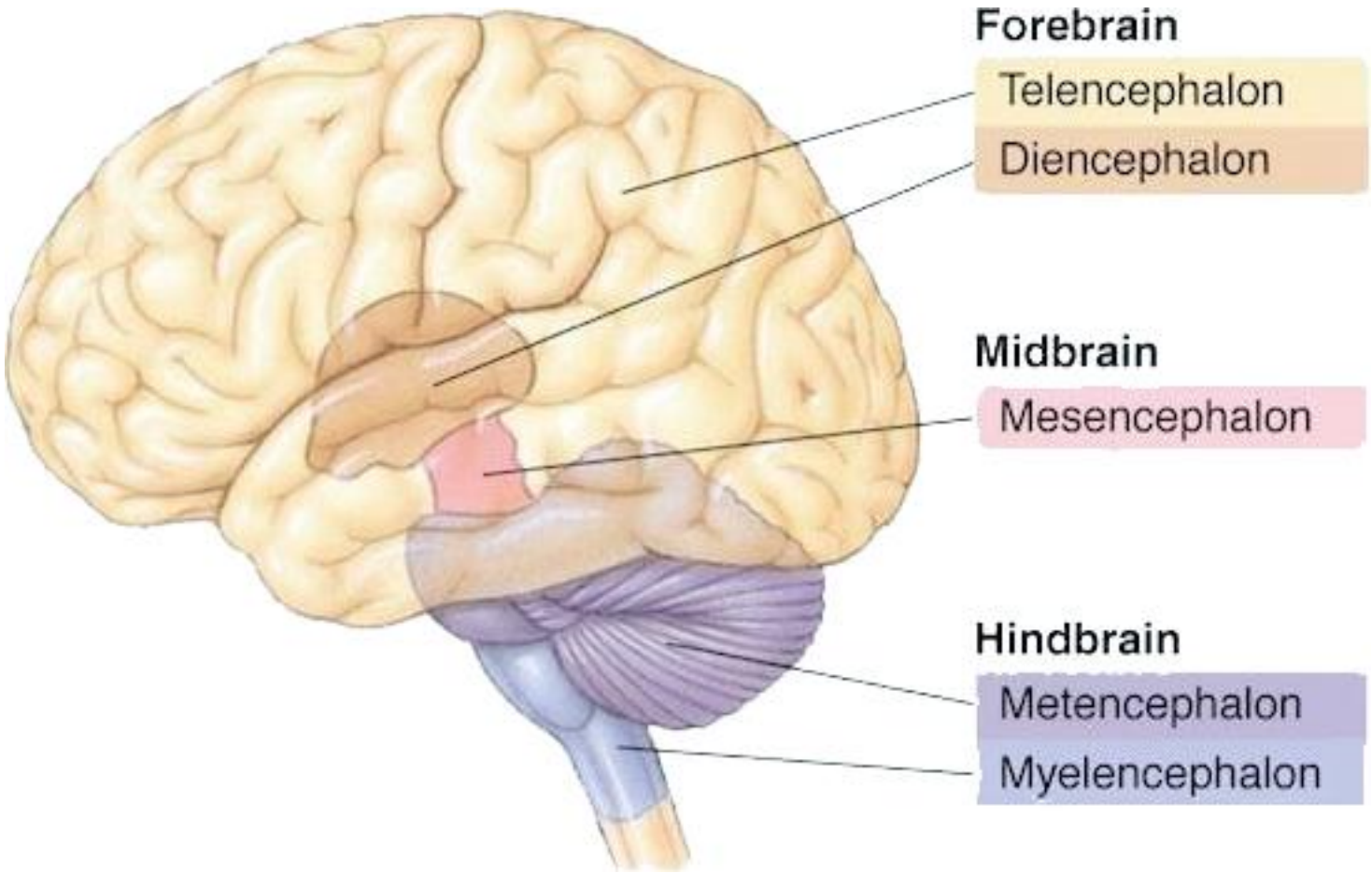
CSF

- 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

Brain

- 5 Divisions



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 (Mesencephalon)
- Hindbrain
  - Metencephalon
    - Pons
    - Cerebellum
  - Myelencephalon
    - Medulla
- Spinal Cord

Telencephalon

- Cerebral Cortex
  - Frontal lobe
  - Temporal lobe
  - Parietal lobe
  - Occipital lobe
- Subcortical Structures
  - Basal Ganglia
  - Hippocampus and Amygdala (parts of the Limbic System)
- Corpus Collosum

Cerebral Cortex

- 6 layer shell of grey matter
  - 2 - 4 mm thick (1/12 - 1/6 inches)
  - Millions of axon terminals/layer
  - Millions of dendrites
  - Millions of cell bodies

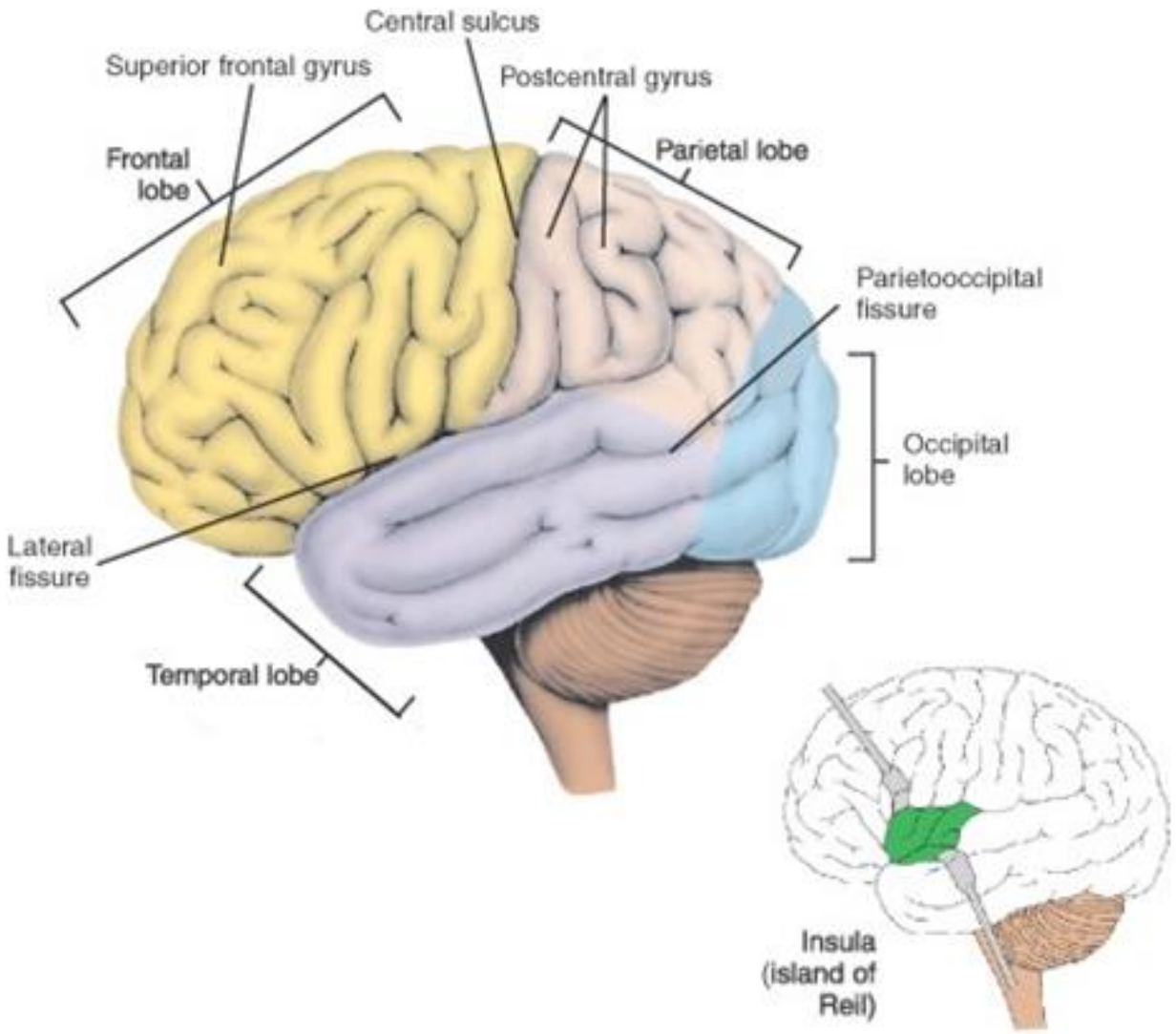
Cerebrum

- Largest component of CNS
  - Gray matter Cerebral cortex
  - White matter Myelinated nerve fibers

- Right and left hemispheres
- Five lobes
  - Each hemisphere is divided into lobes named for the bones that lie over them

Lobes of the Brain

- Frontal
- Parietal
- Insula
- Temporal
- Occipital



Frontal lobe

- Divided into
  - Prefrontal
  - Premotor
  - Frontal eye field
  - Broca area (speech)
  - Primary somatic motor

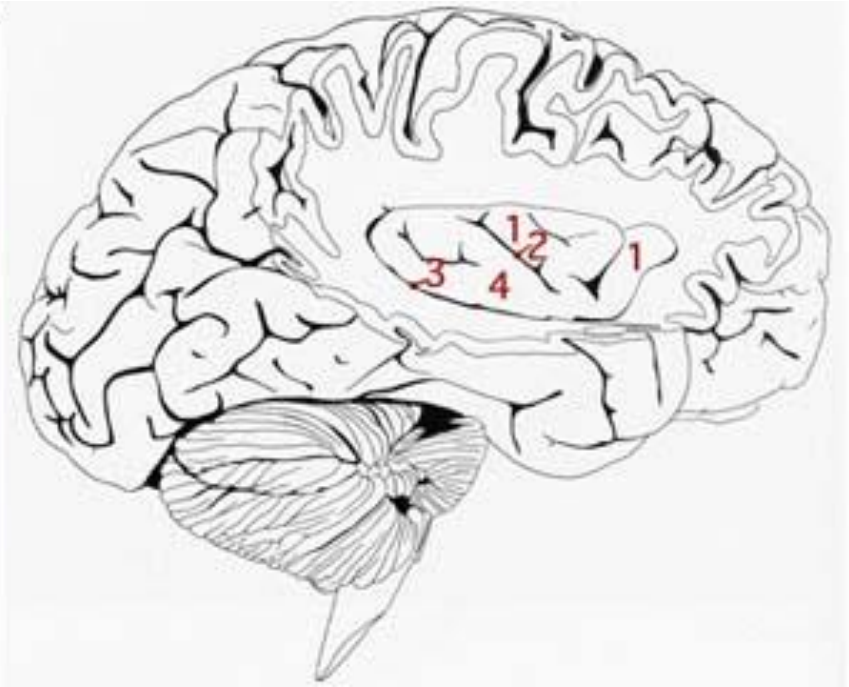
Prefrontal area

- Goal oriented behaviour
- Short term memory / recall
- Elaboration of thought
- Limbic inhibitions

Temporal lobe

- Visual Memory
- Processing sensory input
  - Auditory (Hearing)
  - Visual
- Language recognition
- New memories (helping with long term)

Insula



Insula

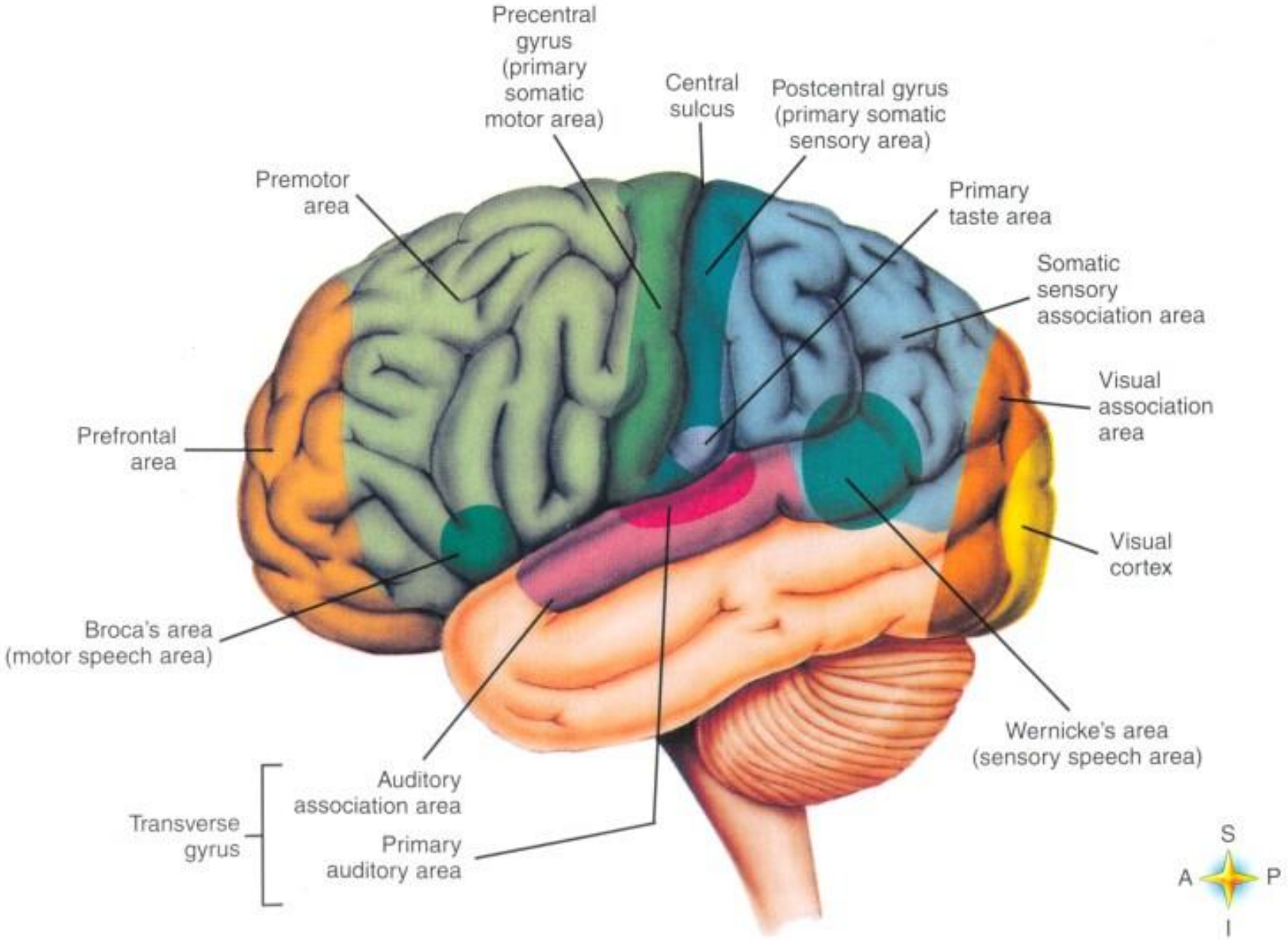
- “Island of Reil”
- Found within cerebral cortex
- The insula plays a role in or will influence
  - Homeostasis
  - Perception and self-awareness
  - Cognitive function
  - Motor control
  - Interoceptive awareness (self awareness)
    - Perception of pain is controlled to a limited degree
    - Feelings of empathy
  - Social emotions

Parietal lobe

- Somatic sensory output
  - Integrating sensory information from various parts of the body
- Communication between motor and sensory areas
  - Processing information relating to the sense of touch
  - Visuospatial processing

Occipital lobe

- Primary visual cortex
- Visual association


Precentral gyrus (primary somatic motor area)
Central sulcus
Postcentral gyrus (primary somatic sensory area)
Premotor area
Primary taste area
Somatic sensory association area
Visual association area
Prefrontal area
Visual cortex
Broca's area (motor speech area)
Wernicke's area (sensory speech area)
Auditory association area
Transverse gyrus
Primary auditory area
S
A
P
I

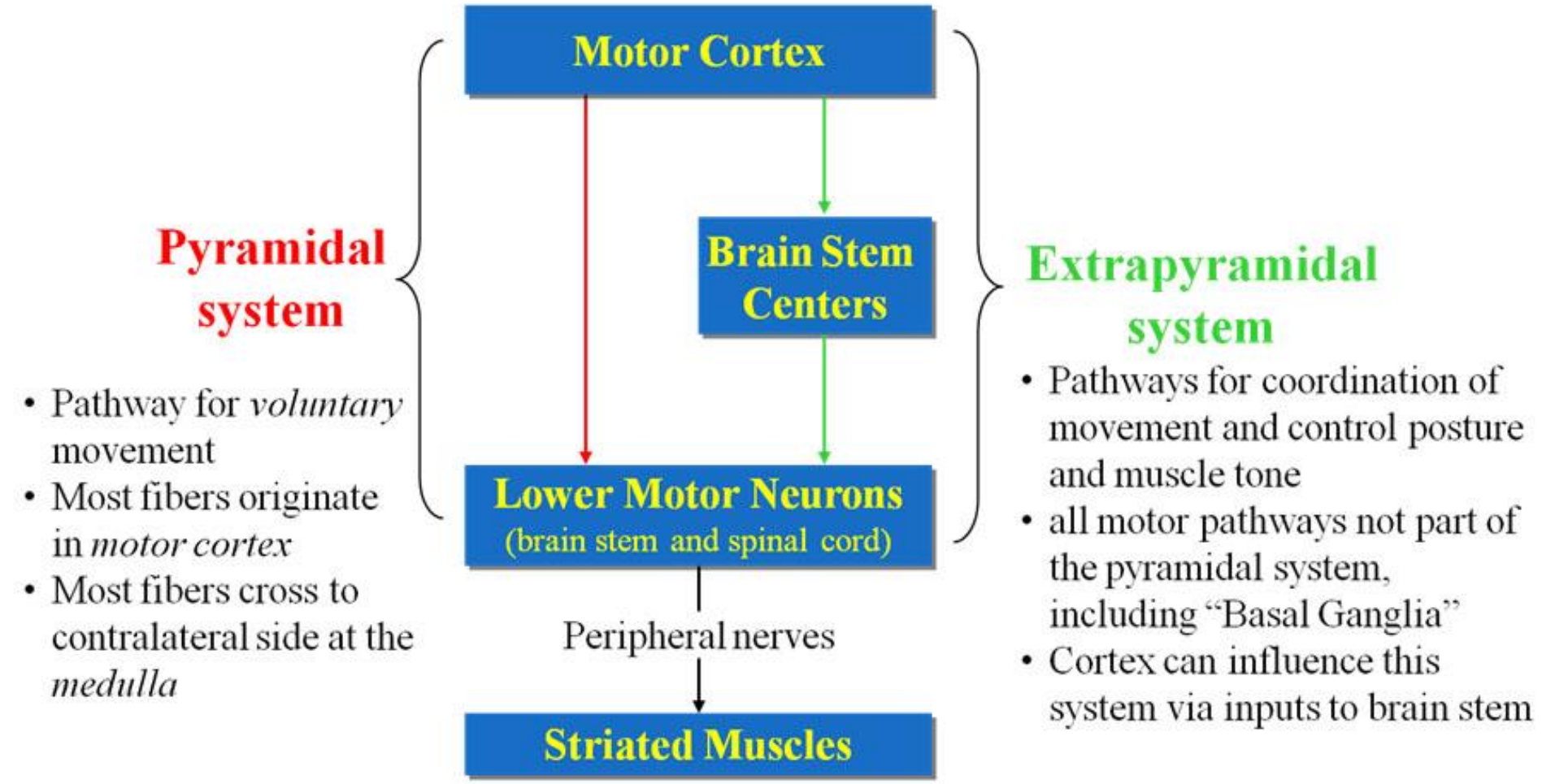
Basal Nuclei (Ganglia)

- Collective group of cerebral tracts
- 3 types
  - Projection
    - Extensions of the sensory/motor tracts
  - Association
    - Bridge tracts within the hemisphere
  - Commissural
    - Bridge tracts between R & L hemispheres
    - Corpus collossum

Basal Nuclei

- Component structure responsible for:
  - Regulation of voluntary motor functions
    - Maintaining posture
    - Walking
    - Other gross or repetitive movements

Basal Ganglia
Extrapyramidal System



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- Hindbrain
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    - Pons
    - Cerebellum
  - Myelencephalon
    - Medulla
- Spinal Cord

Diencephalon

- Located between the brain stem and the cerebrum
- Components
  - Thalamus
  - Hypothalamus
  - Optic chiasma
    - R and L optic nerves cross through
  - Pineal body (gland)
    - Produces melatonin (hormone for synchronizing body functions with the external environment)

Thalamus

- Largest portion of diencephalon
- 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
    - Synthesizes hormones of pituitary gland
      - (Indirectly involved in water regulation)
    - Releases hormones to regulate pituitary hormones
  - Sexual activity
  - Temperature regulation
  - Important in maintaining awake state
  - Appetite center

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- Spinal Cord

Midbrain (Mesencephalon)

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

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    - Pons
    - Cerebellum
  - Myelencephalon
    - Medulla
- Spinal Cord

Metencephalon

- Part of the hindbrain
- Components
  - Pons
  - Cerebellum

Pons

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

Cerebellum

- Aka “little brain”
  - Cauliflower like in appearance
- 2nd largest portion of the brain
- Has more neurons than all others combined

Cerebellum

- Exterior cortex is Grey matter
- Interior is Arbor vitae (white matter)
  - "Tree of life"
- Works with cerebral cortex to produce fine motor function
- Assists in posture control
- Subconscious functioning
- Controls skeletal muscles to maintain balance

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- Spinal Cord

Medulla (Myelencephalon)

- Most inferior portion of brainstem
- 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
    - Heart rate
    - Contractile strength
  - Vasomotor Center
    - Blood vessel diameter
    - Blood pressure
  - Respiratory Center
    - Rate, rhythm and depth of breathing
- Other centers of control:
  - Swallowing
  - Vomiting
  - Coughing
  - Sneezing

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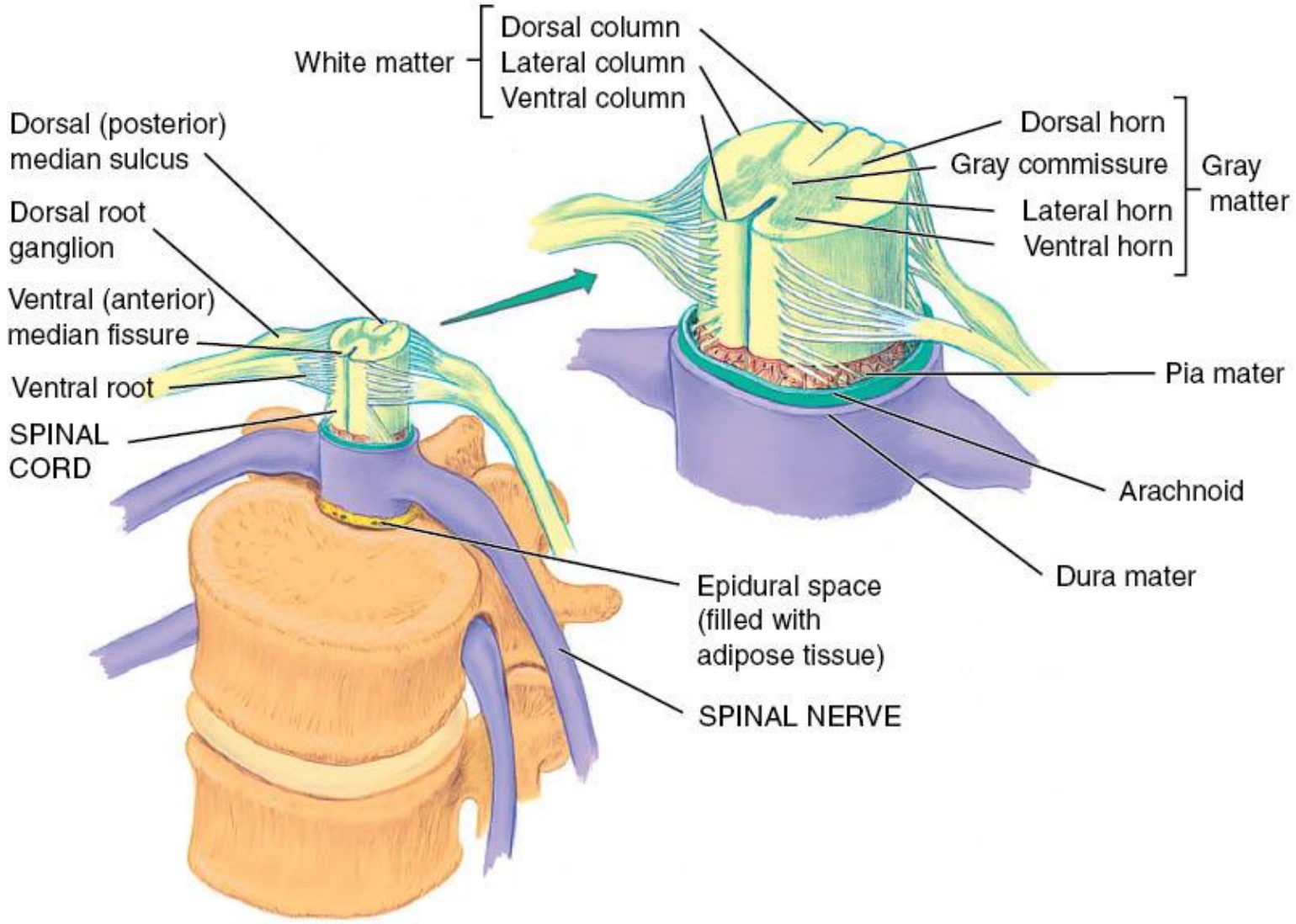
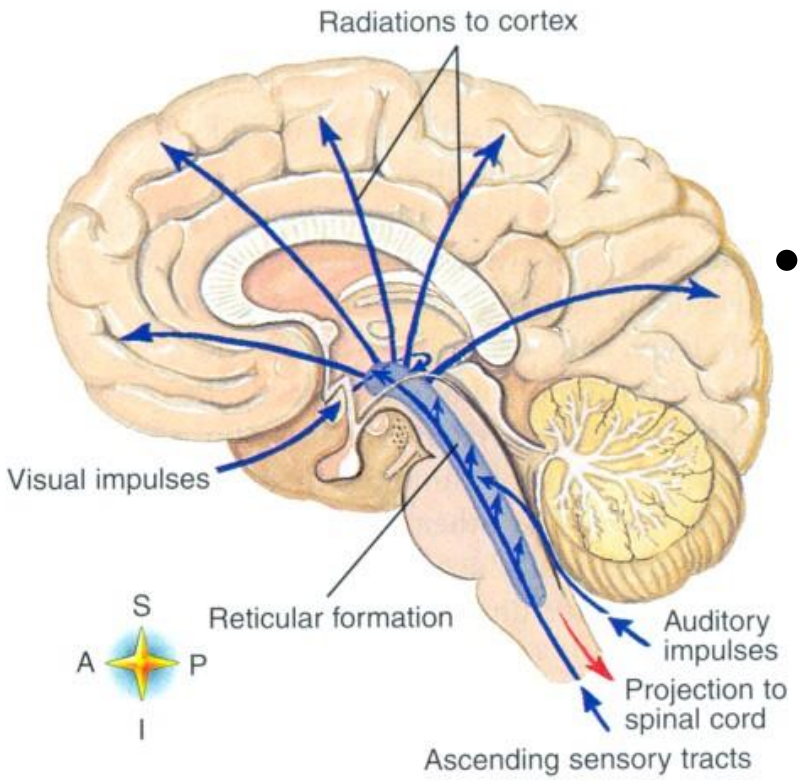
Spinal Cord



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

Nervous System Anatomy

PERIPHERAL NERVOUS SYSTEM

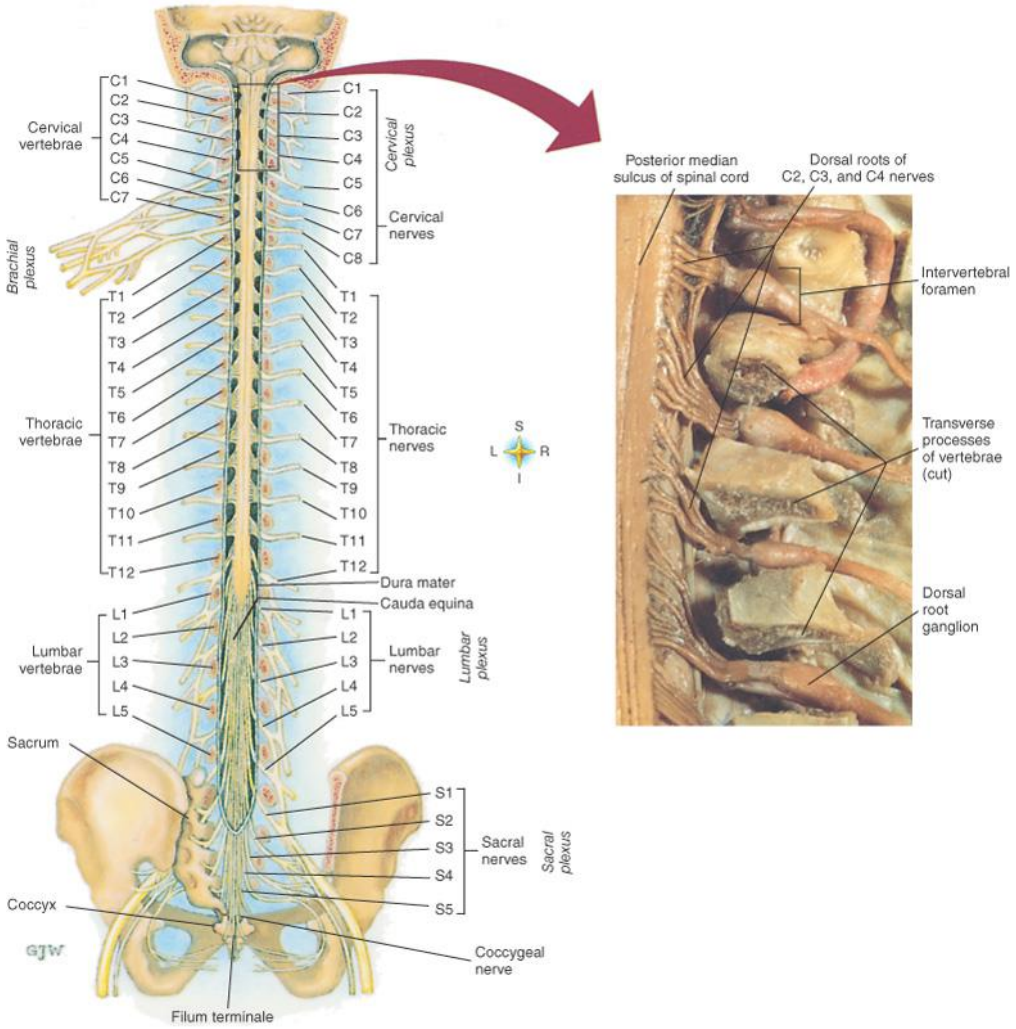
Peripheral (Somatic) Nervous System

- 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
  - Thirty-one pairs of spinal nerves are connected to the spinal cord (Figure 14-1)
  - No special names; are numbered by level of vertebral column at which they emerge from the spinal cavity
    - Eight cervical nerve pairs (C1 through C8)
    - Twelve thoracic nerve pairs (T1 through T12)
    - Five lumbar nerve pairs (L1 through L5)
    - Five sacral nerve pairs (S1 through S5)
    - One coccygeal nerve pair
  - Lumbar, sacral, and coccygeal nerve roots descend from point of origin to lower end of spinal cord (level of first lumbar vertebra) before reaching the intervertebral foramina of the respective vertebrae, through which the nerves emerge
  - Cauda equina—describes the appearance of the lower end of the spinal cord and its spinal nerves as a horse's tail

Spinal Nerves



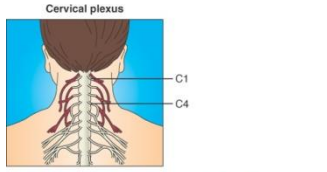
Spinal Nerves

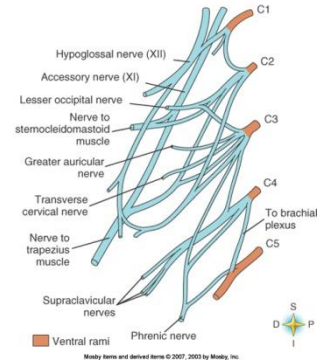
- Structure of spinal nerves
  - Each spinal nerve attaches to spinal cord by a ventral (anterior) root and a dorsal (posterior) root
  - Dorsal root ganglion
    - swelling in the dorsal root of each spinal nerve
  - All spinal nerves are mixed nerves

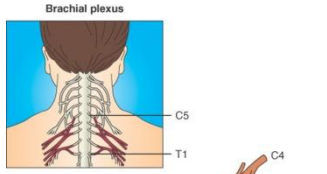
Spinal Nerves

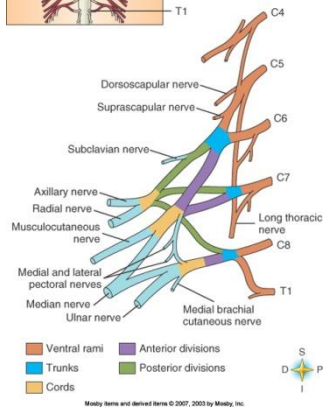
- Nerve plexuses
  - Complex networks formed by the ventral rami of most spinal nerves (not T2 through T12) subdividing and then joining together to form individual nerves
  - Each individual nerve that emerges contains all the fibers that innervate a particular region of the body
  - In plexuses, spinal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

Spinal Nerves



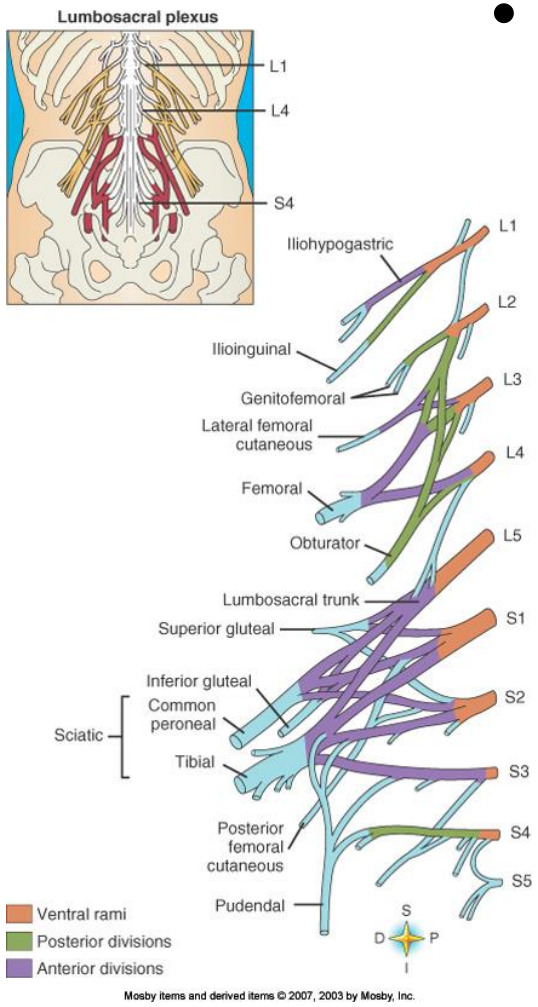






- There are four major pairs of plexuses:
  - Cervical plexus
    - Located deep within the neck
    - Made up of ventral rami of C1 through C4 and a branch of the ventral ramus of C5
    - Individual nerves emerging from cervical plexus innervate the muscles and skin of the neck, upper shoulders, and 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

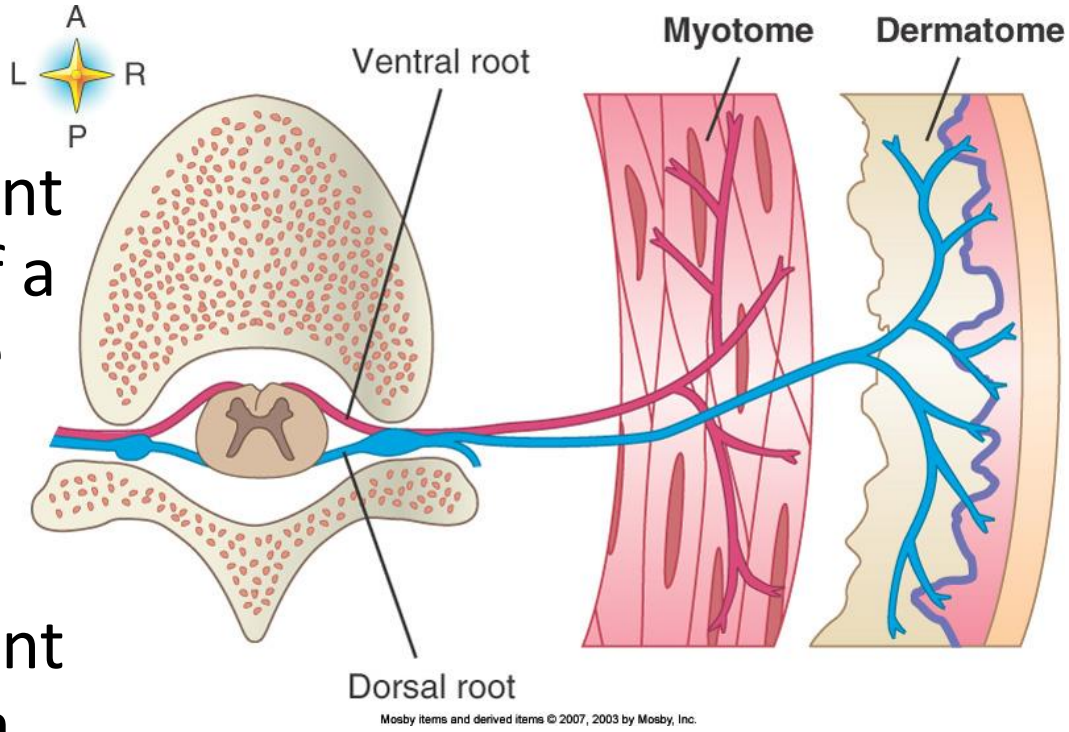
Spinal Nerves



- Four major pairs of plexuses (cont):
  - 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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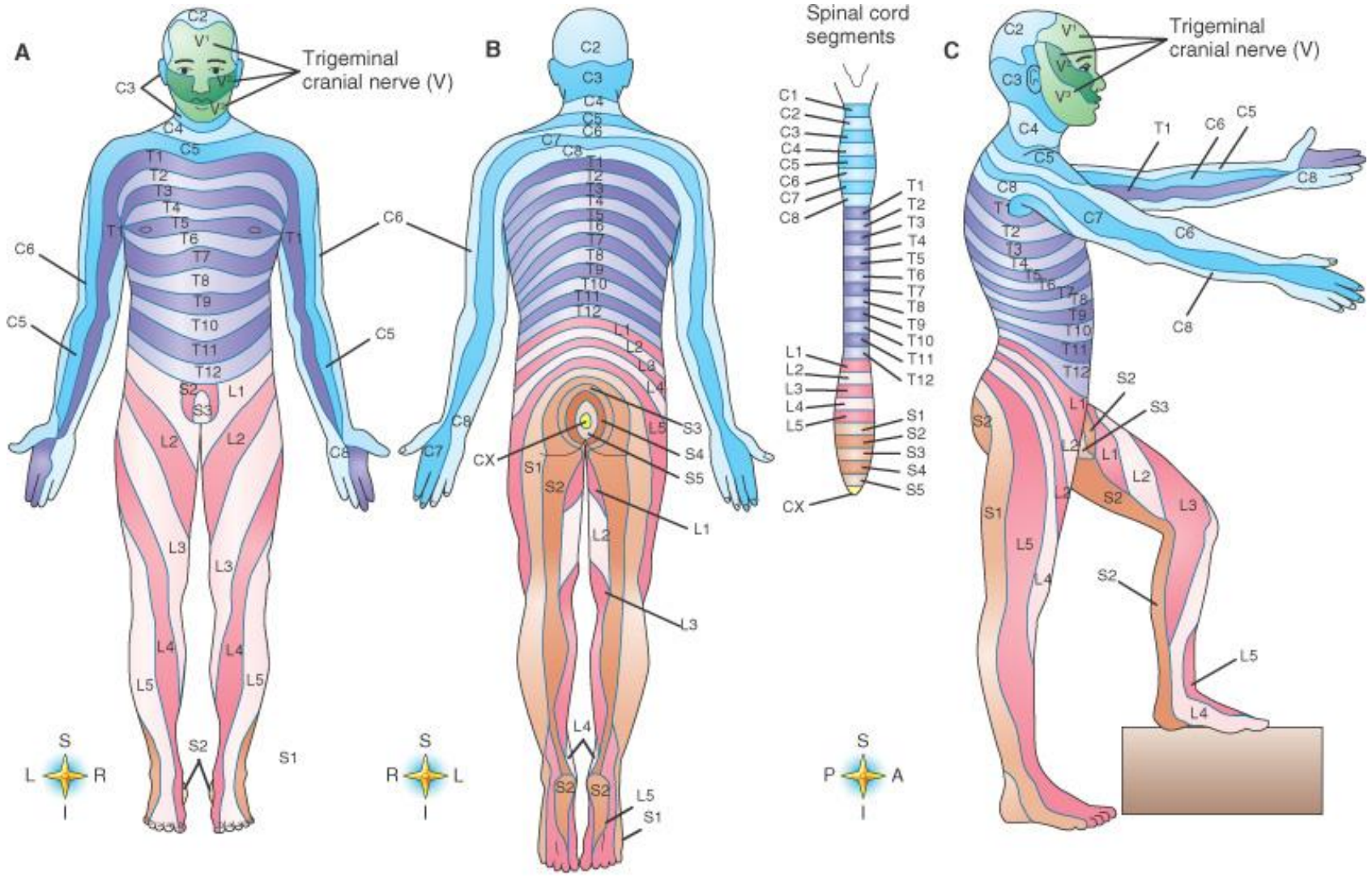
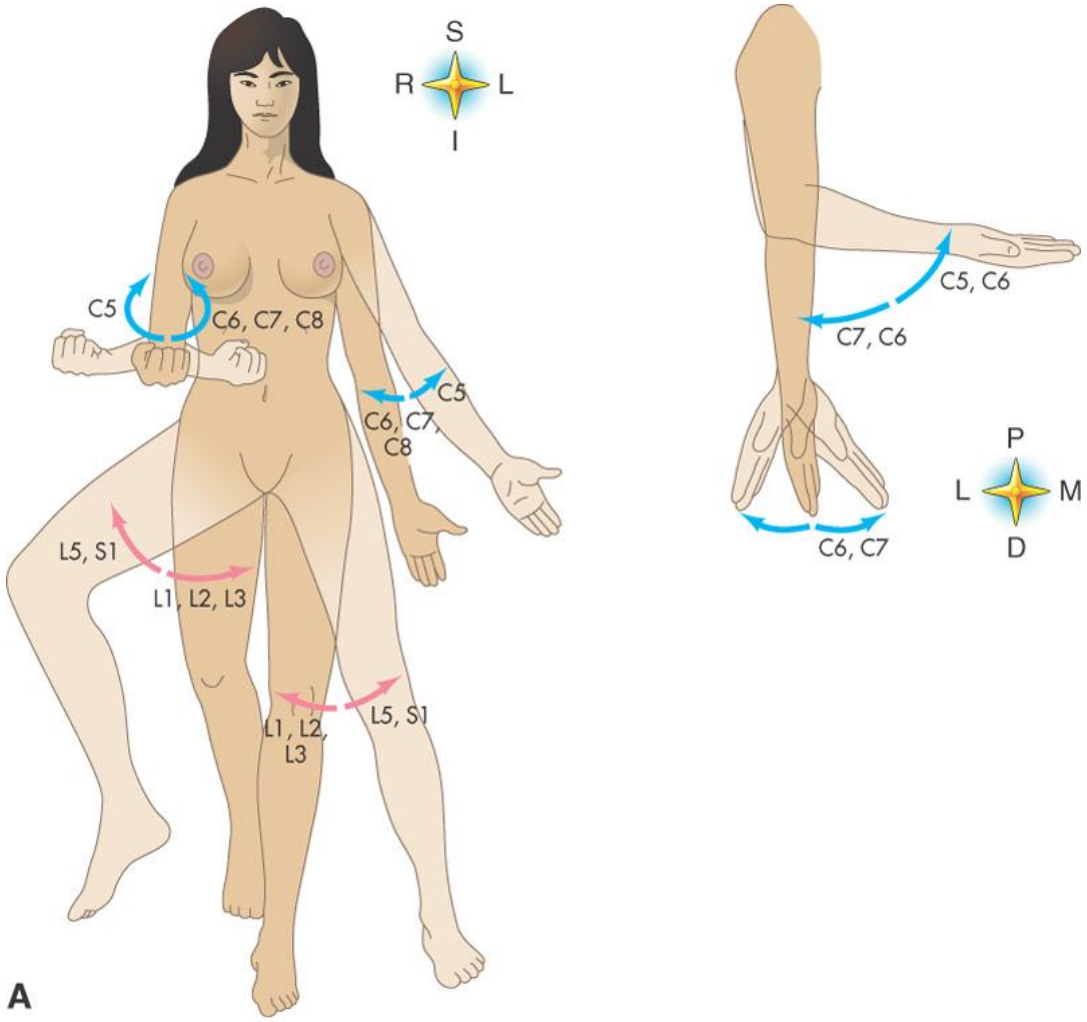
Dermatomes



Myotomes

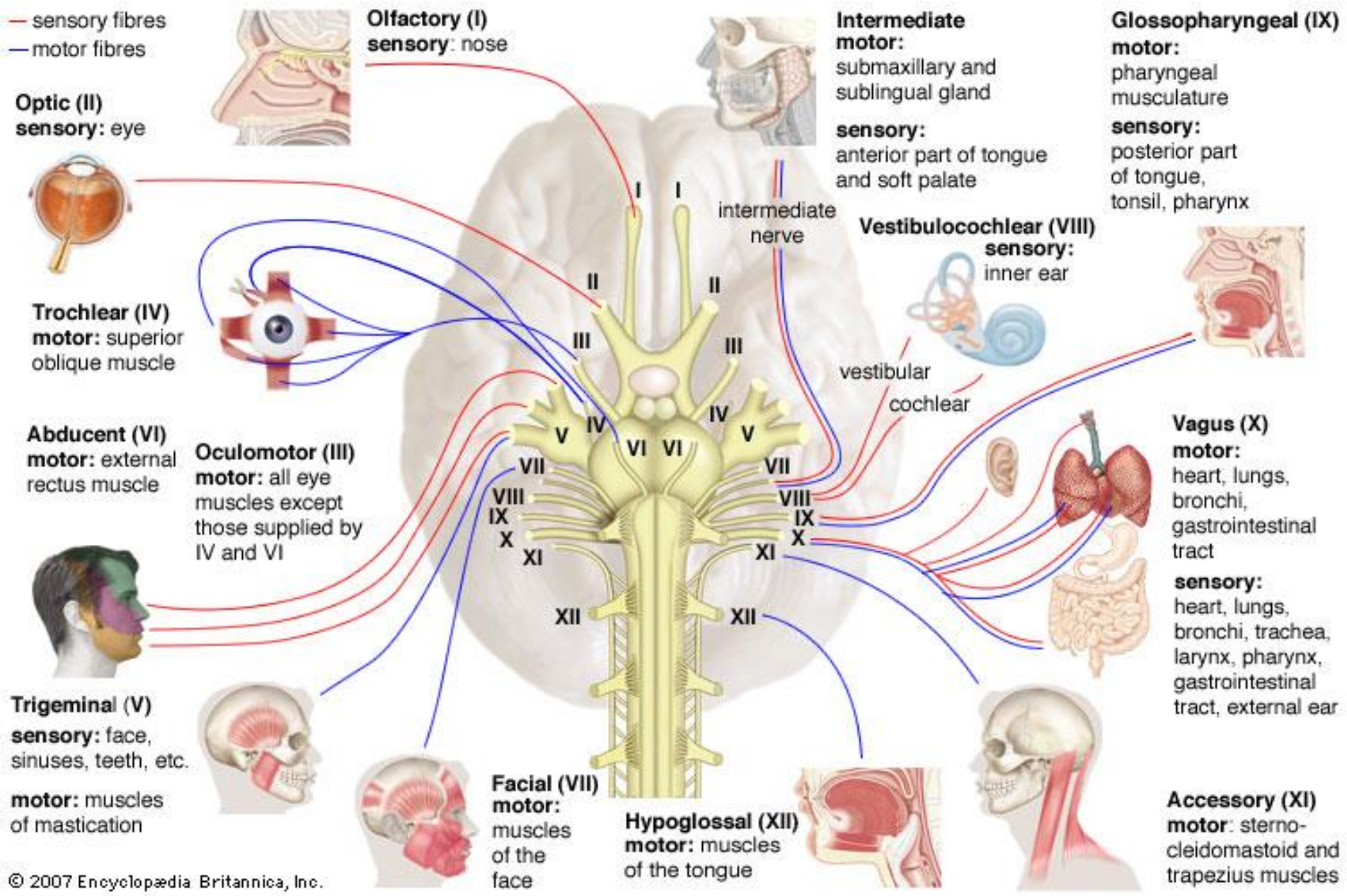


Cranial Nerves

- 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

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



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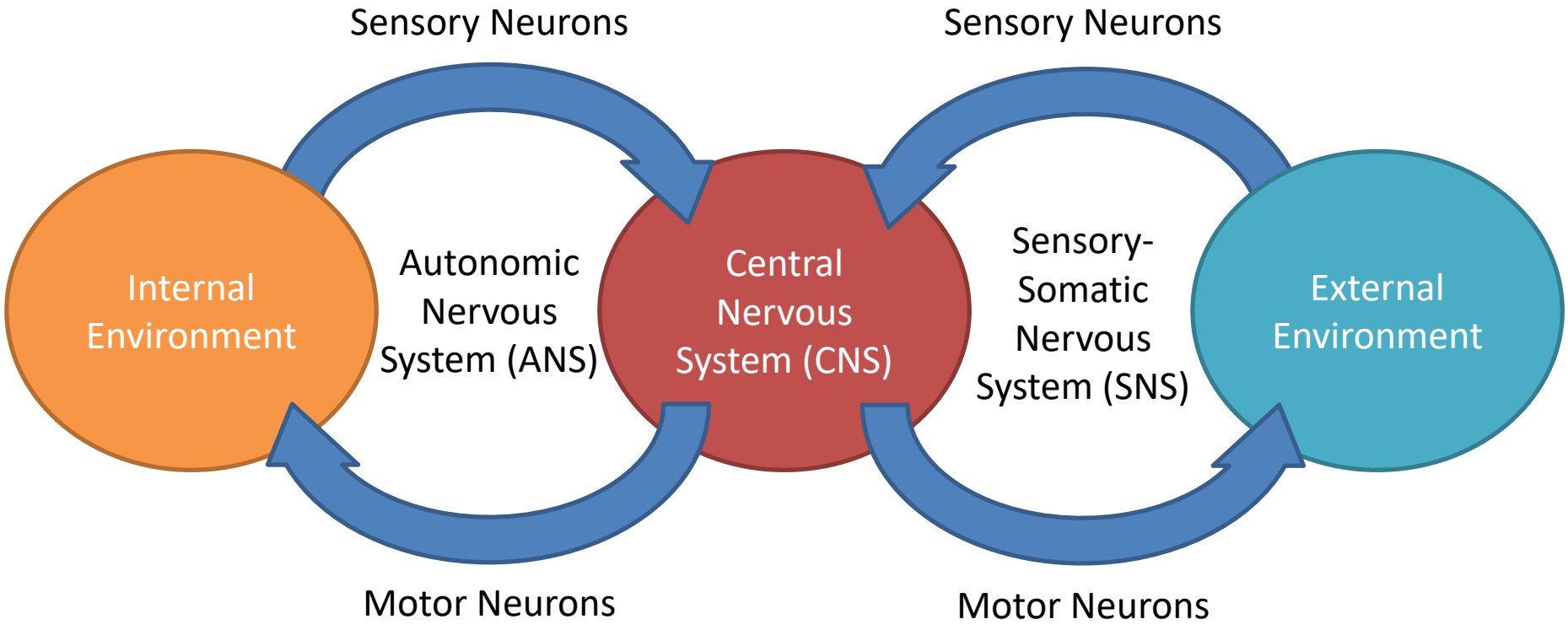
Somatic Nervous System



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

- Primarily regulates
  - Heart rate
  - Smooth muscle contraction
  - Glandular secretions
- Maintains homeostasis
- Primary afferent division - visceral sensory

ANS

- In short, the ANS allows us two modes of operation
  - Fight or flight
  - Rest and digest

- Both components work together to maintain normal function

Components of ANS Pathways

- Autonomic neurons
- Ganglia
- Plexuses

ANS Pathways

- Efferent pathways conduct impulses away from brainstem or spinal cord to autonomic effectors using two autonomic neurons

- Preganglionic neurons conduct impulses to autonomic ganglia

Pathways

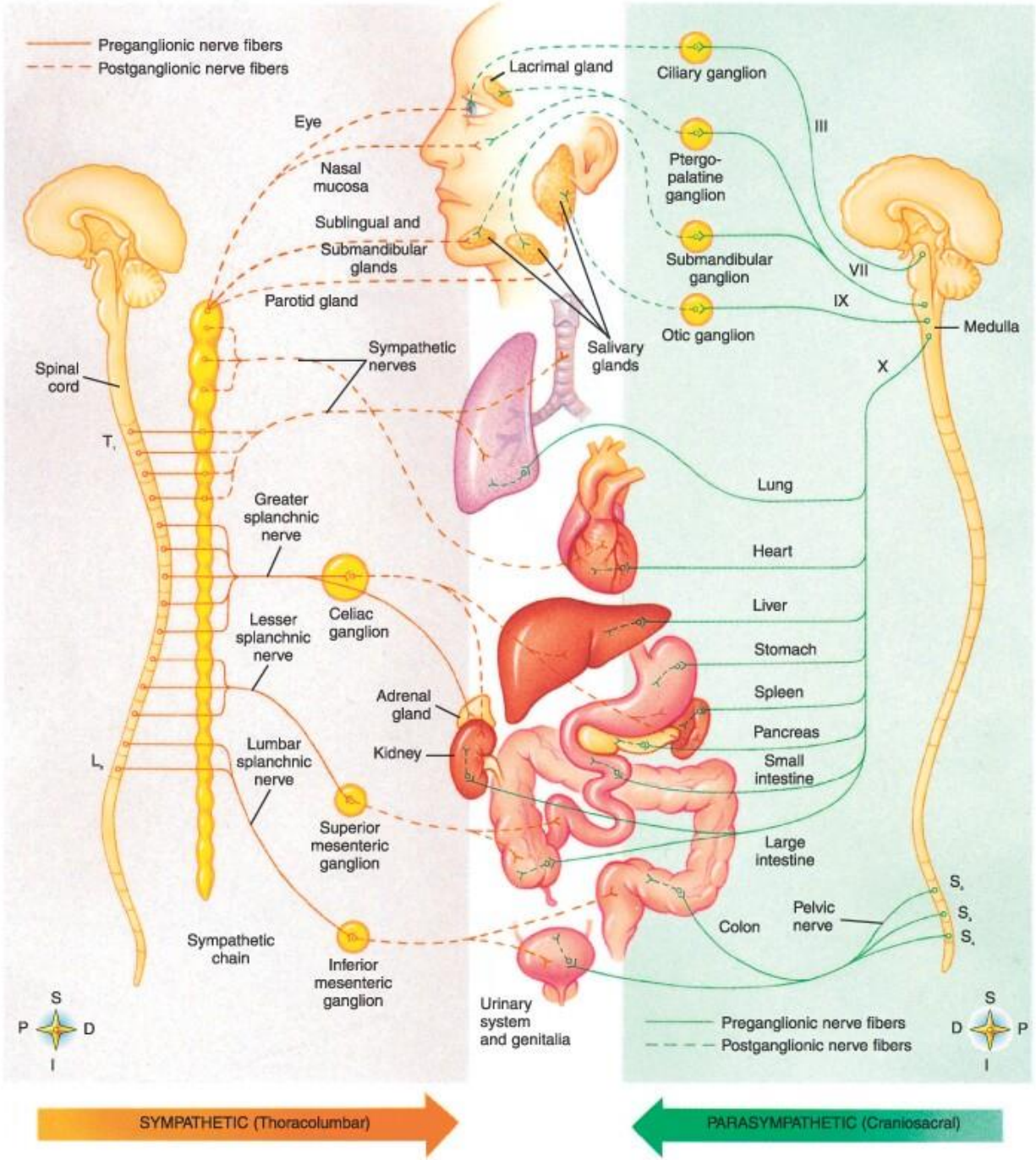
- Autonomic ganglia synapses with second efferent neuron (post ganglionic neuron)
- Post ganglionic neuron conducts impulses away from ganglia

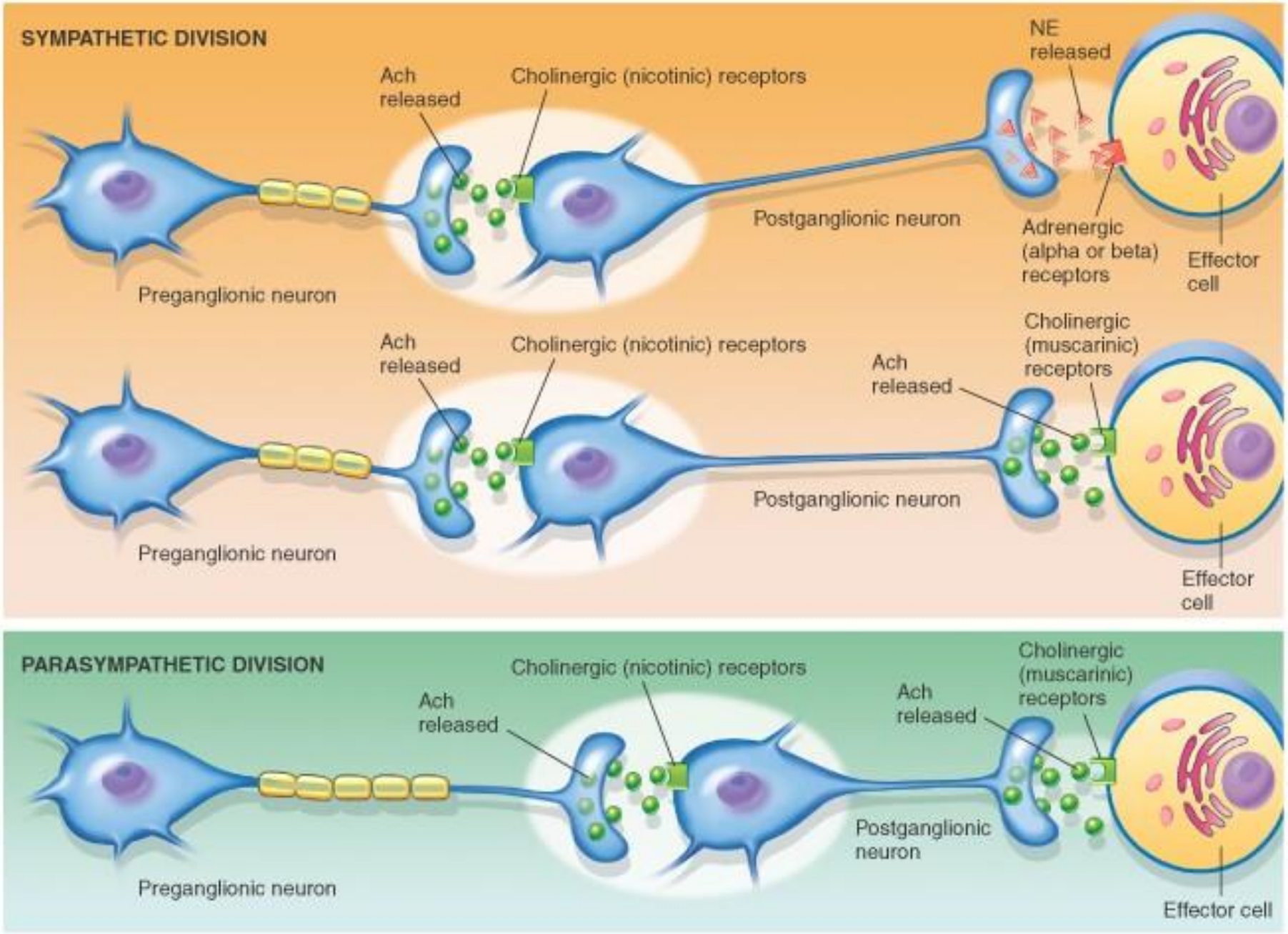
Sympathetic Nervous System

- “Fight or flight” system
- Originates in spinal cord @ thoracic and lumbar levels
- Causes effects through release of neurotransmitters
- Primary neurotransmitters are acetylcholine and norepinephrine

Parasympathetic Nervous System

- “Rest and digest” system
- Originate in medulla and sacral region
- Acetylcholine the primary neurotransmitter





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
- Estimated by
  - CPP = MAP – ICP
  - CPP = [(2 x DBP) + SBP)/3] - ICP
- CBF
  - Remains constant with CPP of 50 – 160 mmHg
  - Declines with CPP below 40 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

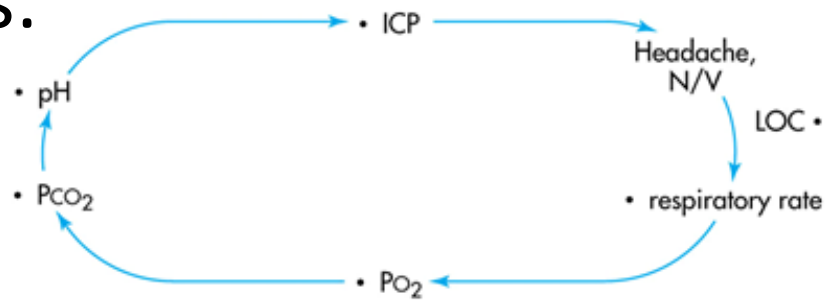
- As CO_2 levels rise in CSF:
  - Cerebral arteries dilate
  - Encourage blood flow
  - Reduce hypercarbia
- In the presence of already high ICP
  - Devastating results
  - Causes classic hyperventilation and hypertension
- Reduced levels of CO_2 in CSF
  - Cerebral vasoconstriction
  - Results in cerebral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

Intracranial Pressure (ICP)

- Normal range is 0-15 torr (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