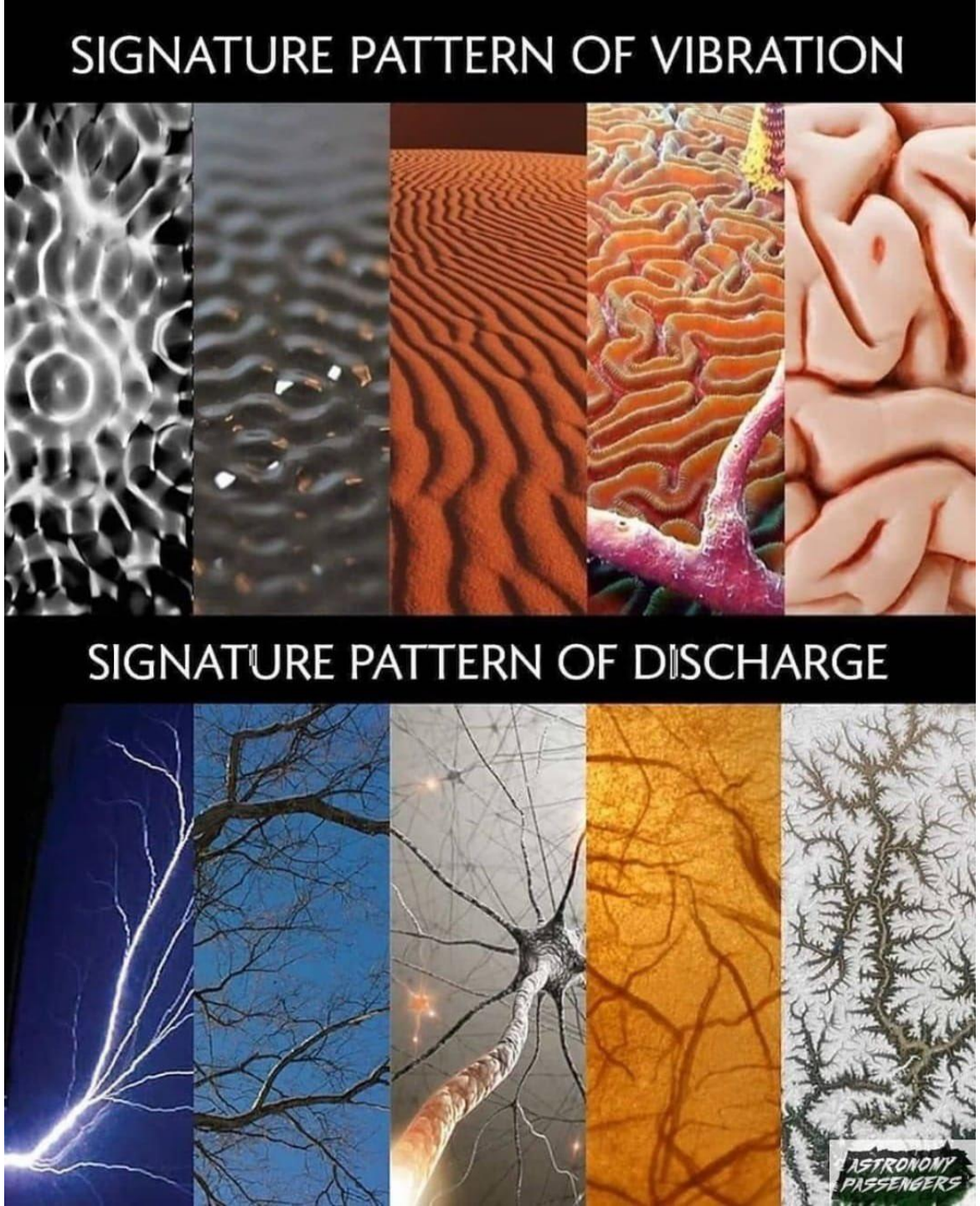
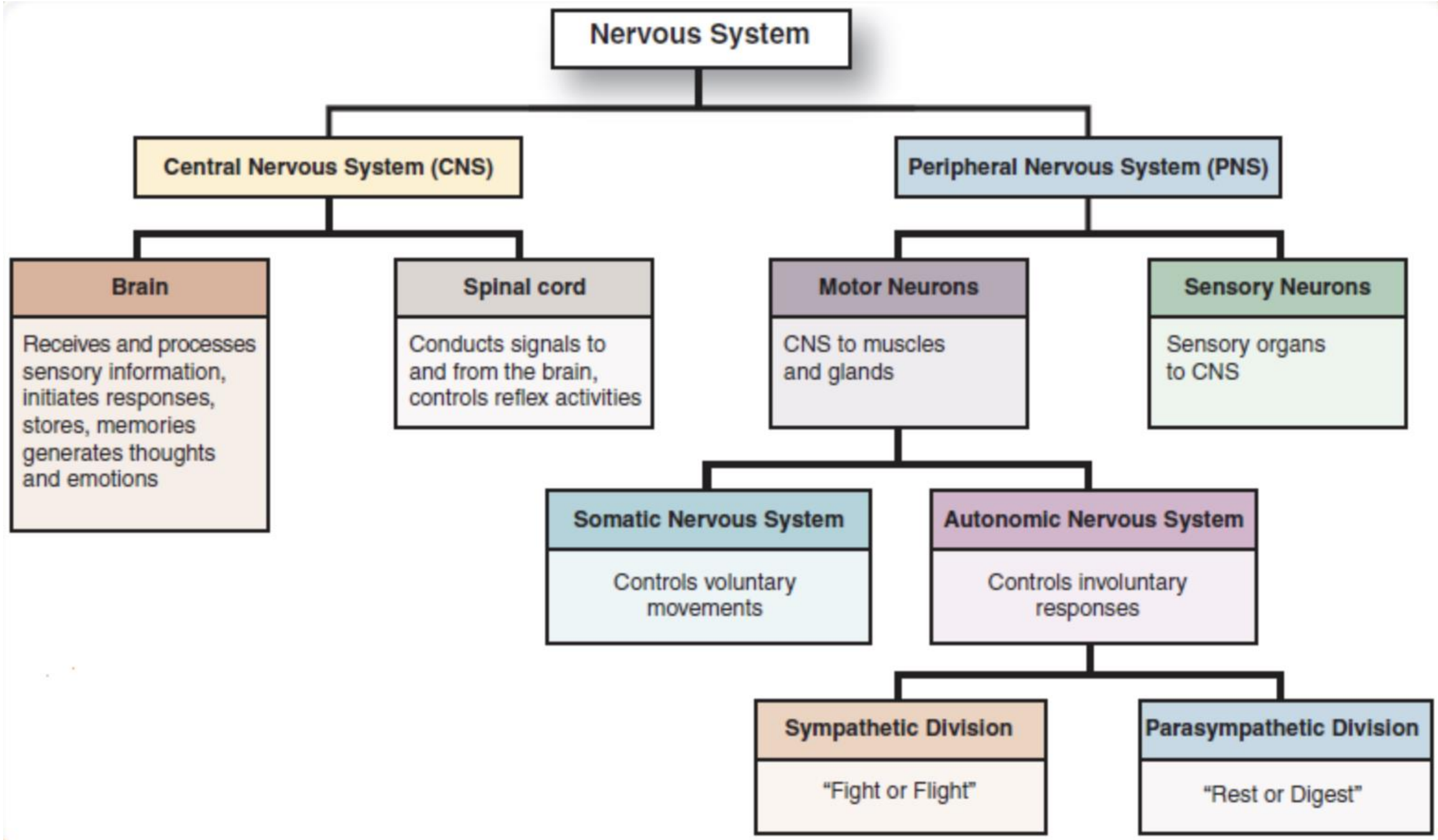
Neural Anatomy – The Brain

9/5/2024

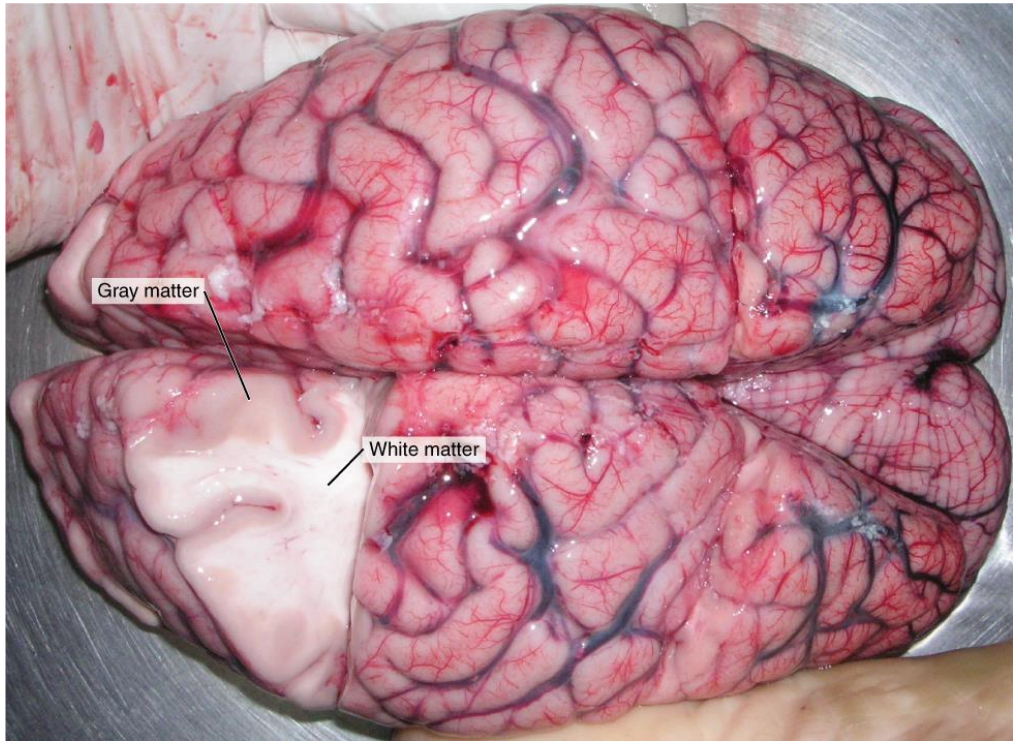


Neurotransmitter	Effect	CNS Functions	PNS Functions
Acetylcholine	**Excitatory**	**Attention, memory, learning, synaptic plasticity**	**Muscle activation, PNS regulation**
Norepinephrine	Excitatory	Arousal, alertness reset, focus, mood regulation	Fight-or-flight response, increases heart rate and blood pressure
Epinephrine/adrenaline	Excitatory	Limited CNS role, arousal and fight-or-flight, emotional memory formation	Fight-or-flight response, increases heart rate, blood flow to muscles
Serotonin	**Inhibitory**	**Mood regulation, appetite, sleep, anxiety, social rank**	**Regulation of gut motility and function**
Glutamate	**Excitatory**	**Learning, memory, synaptic plasticity, synaptic pruning**	**Limited PNS role, pain transmission, gut motility and function**
Gamma-aminobutyric acid (GABA)	**Inhibitory**	**Main inhibitory neurotransmitter in the CNS, reducing neuronal excitability**	**Limited PNS role, gut motility and secretion, immune modulation, muscle tone**
Dopamine	**Both**	**Reward, motivation, motor control, reinforcement learning, prediction error**	**Blood vessel function modulation, kidney function, and norepinephrine precursor**
Histamine	Excitatory	Regulation of sleep-wake cycles, arousal, and alertness, food intake	Immune response regulation, allergic reactions
Melatonin	**Modulatory**	**Regulation of sleep-wake cycle (circadian rhythm) and seasonal rhythms**	**Limited PNS role, antioxidant, anti-inflammatory agent, gut motility**
Endorphin	Inhibitory	Natural painkiller, involved in pleasure and well-being, “runner’s high” euphoria	Limited PNS role, pain modulation, immune response
Oxytocin	Modulatory	Social bonding, sexual reproduction, childbirth, in-group favoritism	Uterine contractions during childbirth, milk ejection during breastfeeding
Vasopressin	Modulatory	Social behavior, sexual motivation, pair bonding, territorial behavior	Water retention in kidneys, regulation of blood pressure, vasoconstriction

ADRENALINE for Fight or Flight	Also known as ‘epinephrine’, releases in response to stress. It increases heart rate, blood pressure, glucose metabolism to boost physical reflexes.
NORADRENALINE for Attention & Focus	Also known as ‘norepinephrine’, affects brain activity, contracts blood vessels, controls blood flow, regulates heartbeat and liver function.
ENDORPHIN for Pain Management	Releases during exercise, excitement, and sex. Produces the feeling of well-being, euphoria, and involved in pain management.
ACETYLCHOLINE for Memory & Learning	Linked with thought, learning, and memory. Stimulates muscle function, contractions of the digestive tract. Involved with focus and alertness.
HISTAMINE for Immune Protection	Controls vasodilation, inflammation, and immune response. Regulates metabolism, body temperature, hormone function, and sleep-wake cycle.
DOPAMINE for Repeat Behavior	Provides pleasure and motivation, motor control and movement. Responsible for any repeat behavior such as addiction.
GABA for Motor Control	High levels improve focus and low levels cause anxiety. Calms the firing nerves and contributes to motor control and vision.
SEROTONIN for Calming & Sleep	Helps in sleep, memory, mood, and relaxation. Affected by exercise and light exposure. Also released in the digestive tract and regulates appetite.


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"

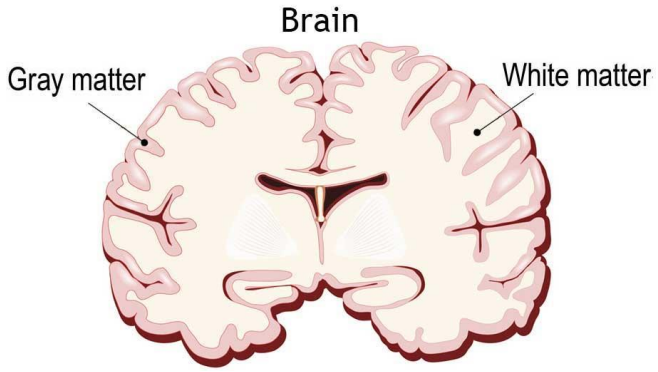
The Brain

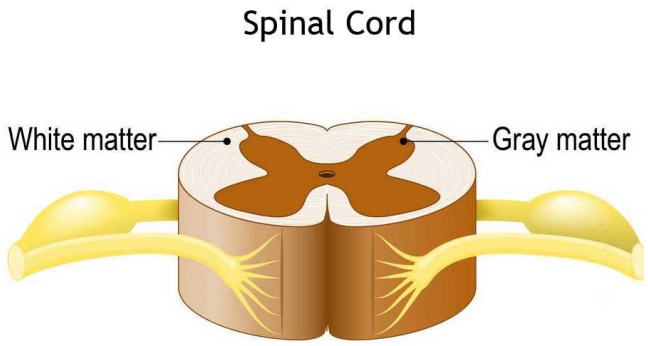


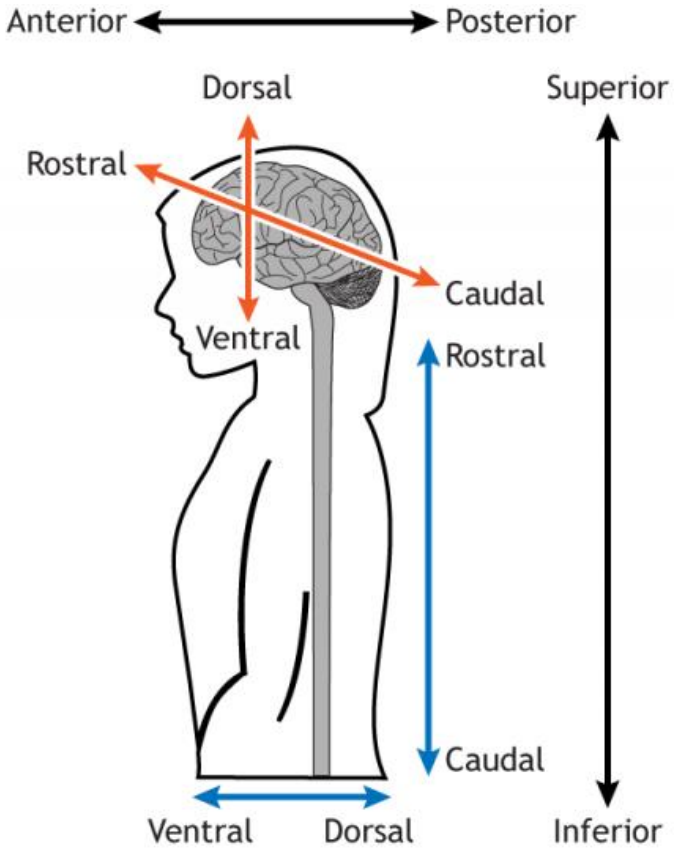
Introduction to the brain:
https://www.kaltura.com/index.php/extwidget/preview/partner_id/816122/uiconf_id/44640271/entry_id/0_a2151etx/embed/dynamic

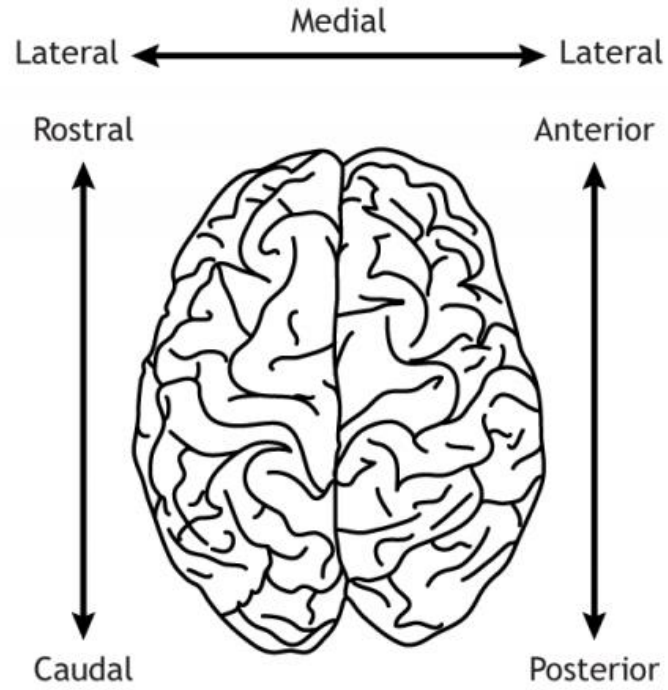
The Brain

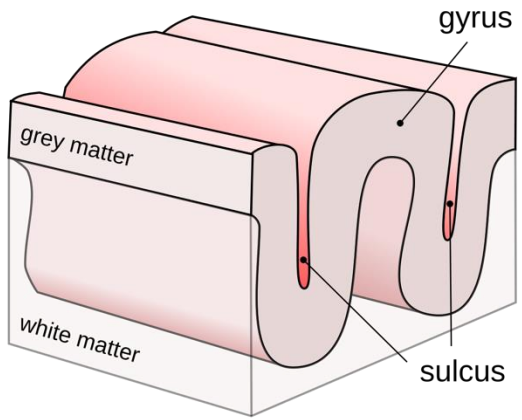
- Grey matter – cell bodies
- White matter – axonal fibers





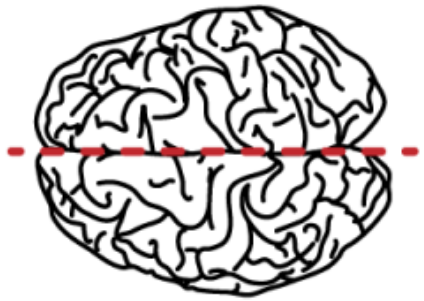


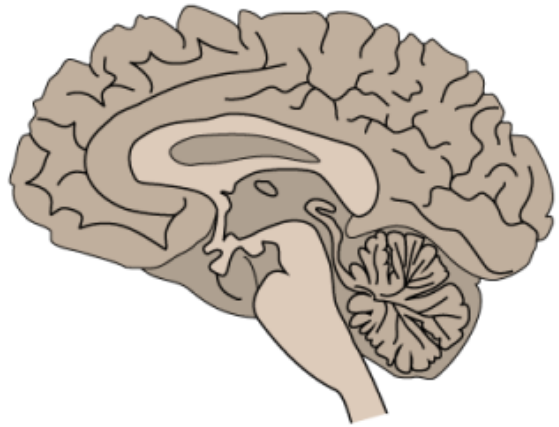




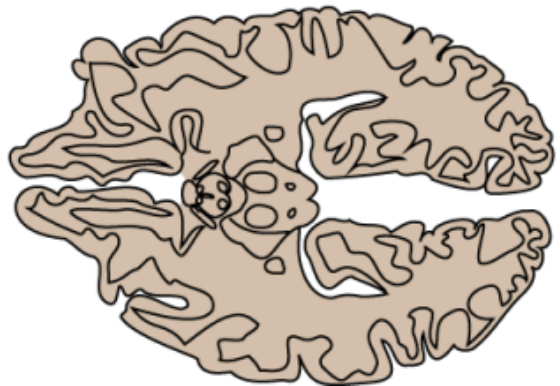
Frontal or coronal plane

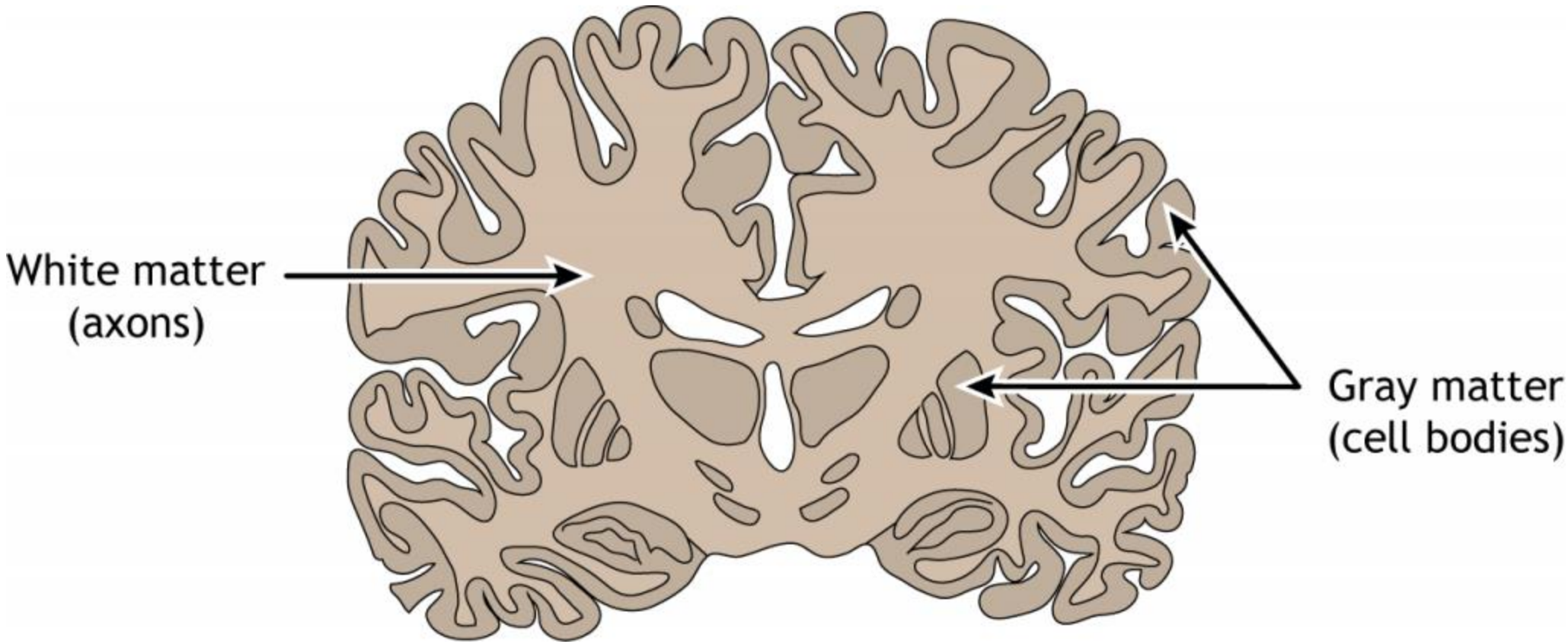
Sagittal plane





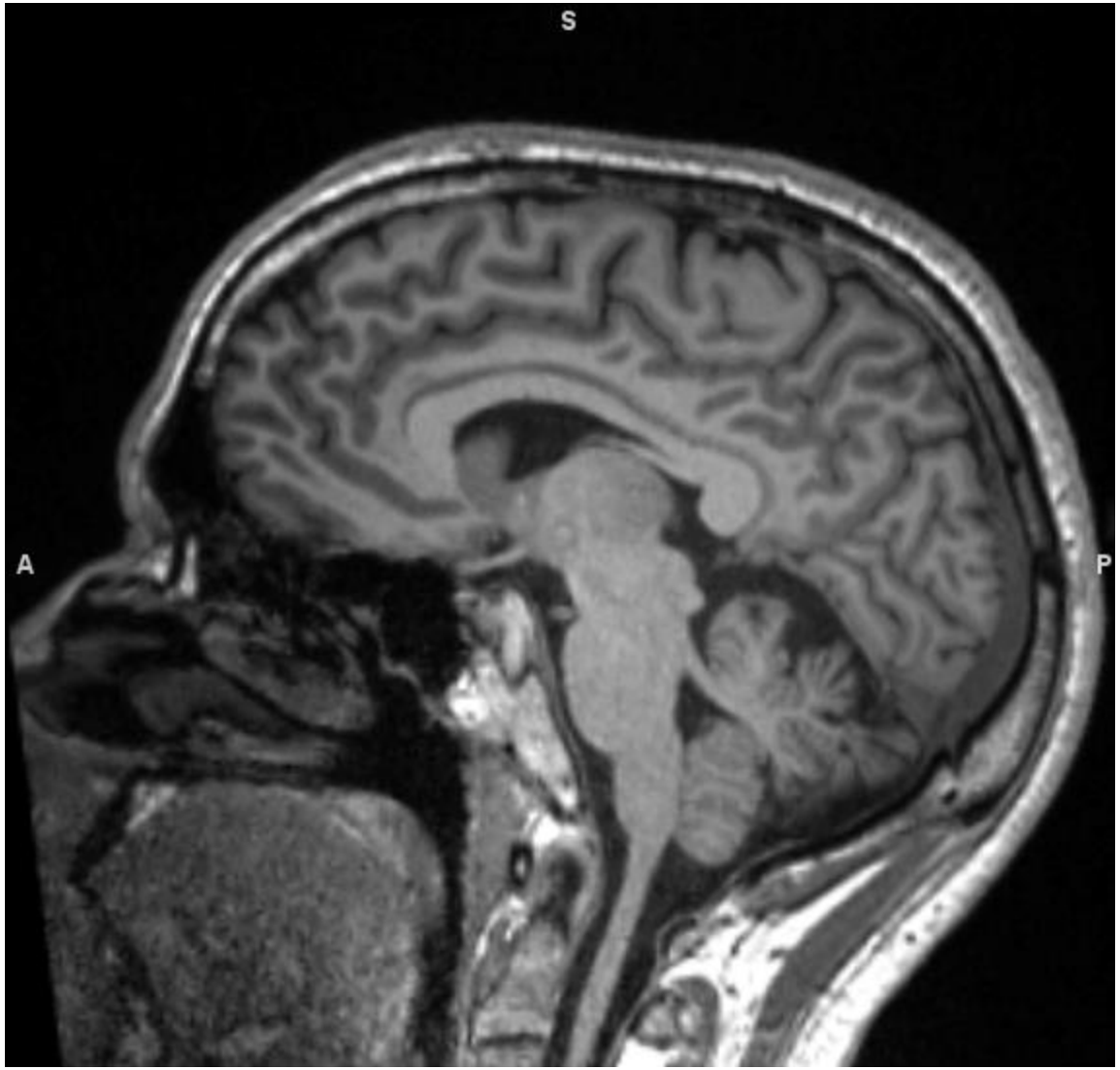
Horizontal plane




White matter
(axons)
Gray matter
(cell bodies)

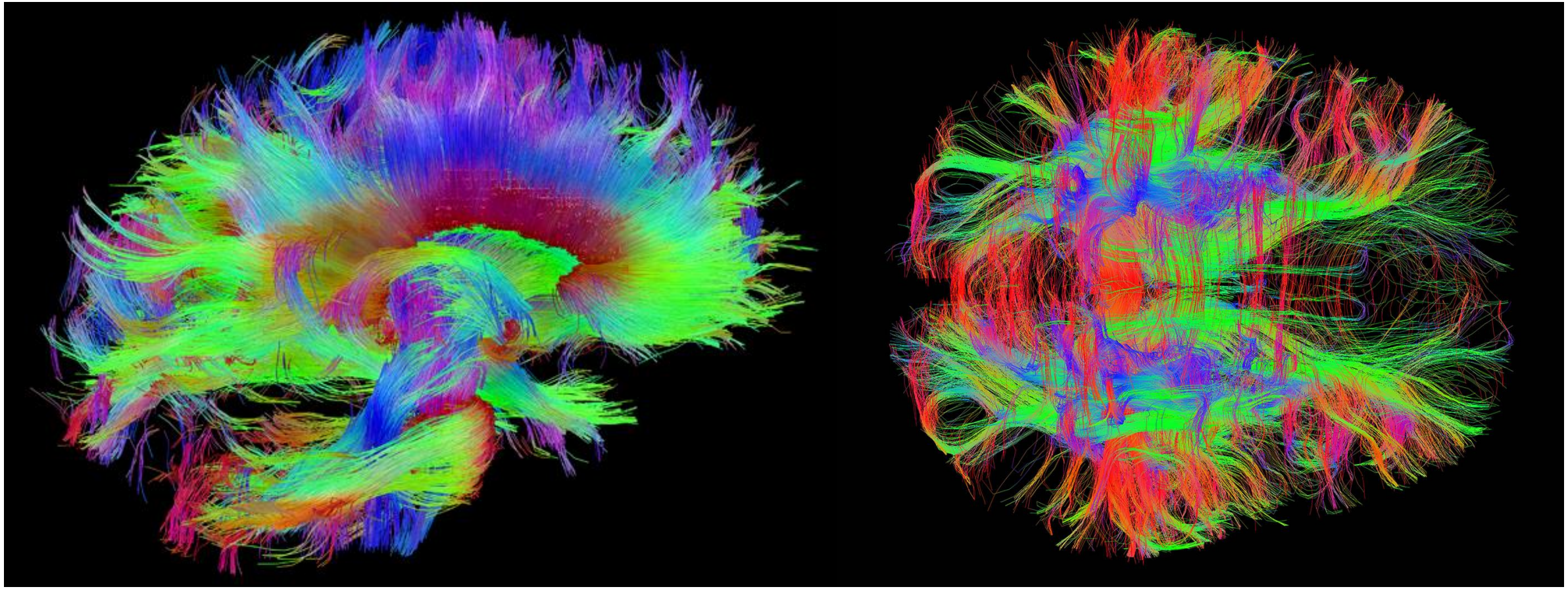
MRI images of the brain

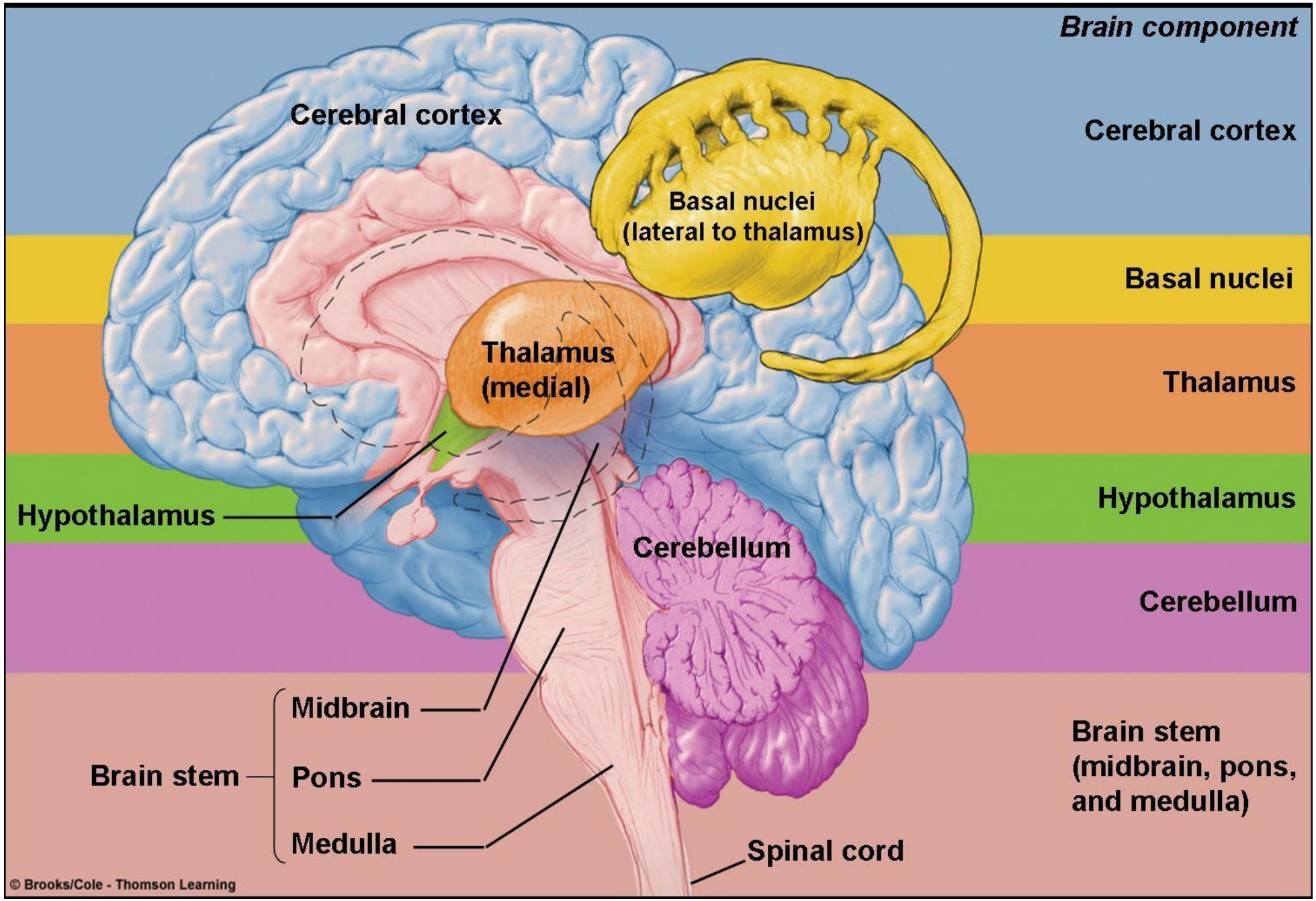
Different types of MRI images allow you to visualize and segment different types of tissue



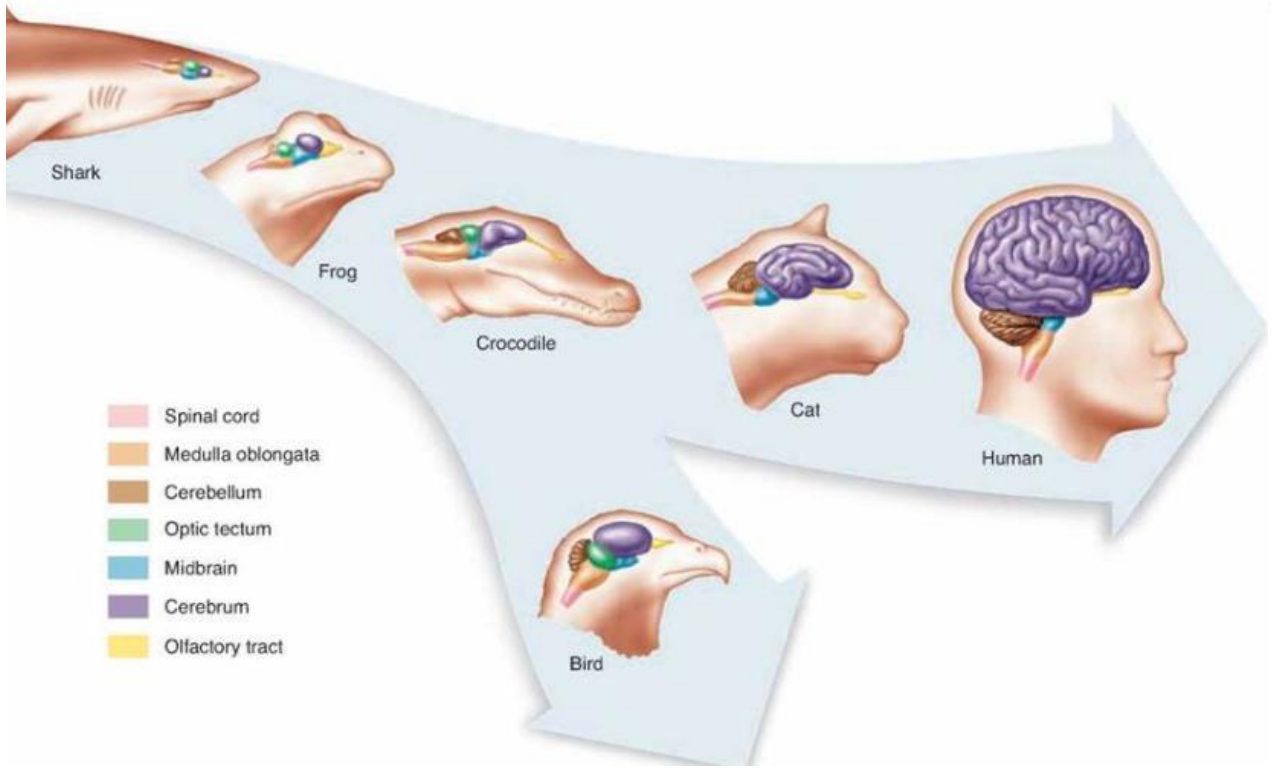
White matter tracts

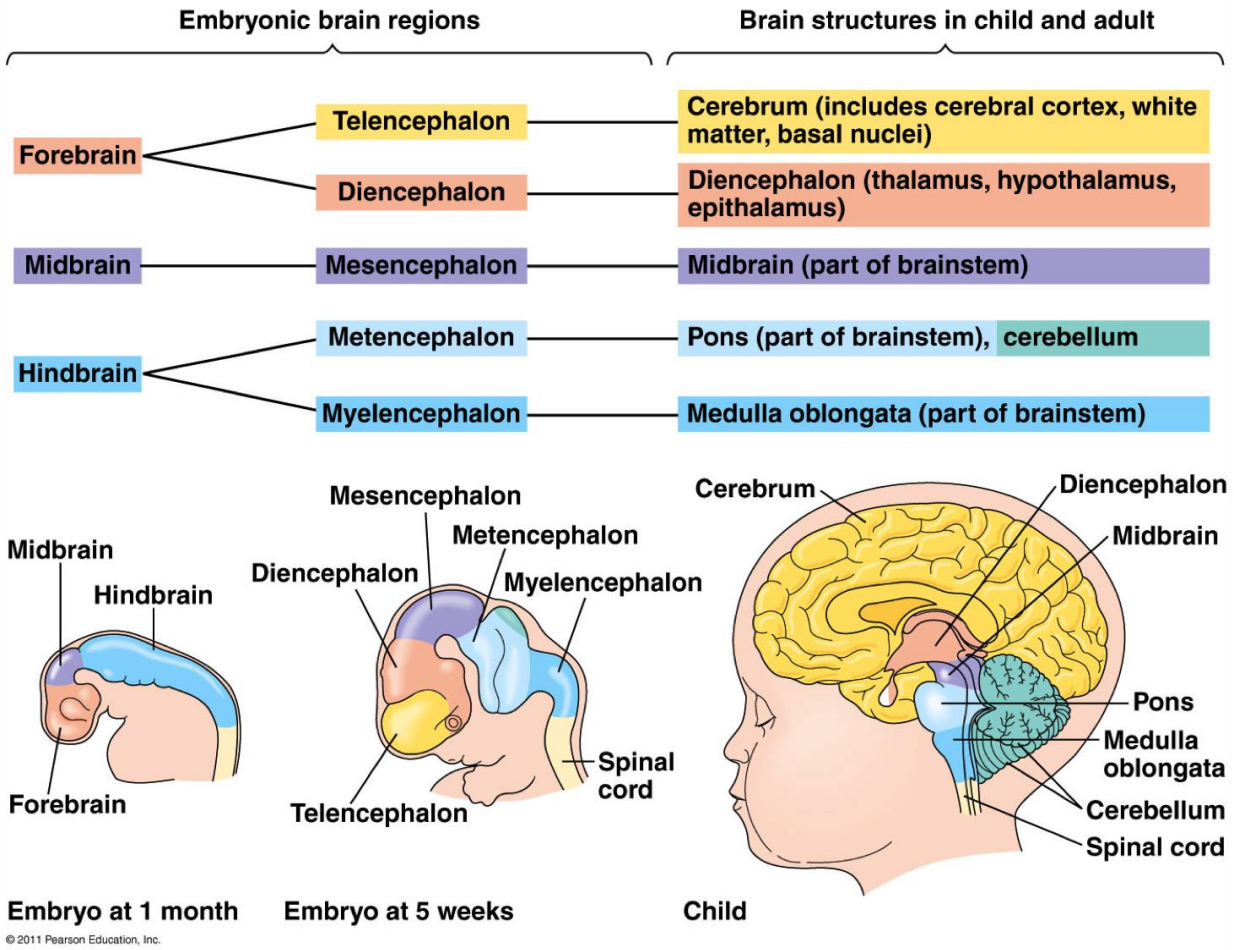
- Axonal fiber bundles, or white matter tracts, connect neurons to each other
- They are white due to the fatty myelin sheaths




Brain component
Cerebral cortex
Basal nuclei
Thalamus
Hypothalamus
Cerebellum
Brain stem (midbrain, pons, and medulla)
Cerebral cortex
Basal nuclei (lateral to thalamus)
Thalamus (medial)
Hypothalamus
Cerebellum
Brain stem
Midbrain
Pons
Medulla
Spinal cord
© Brooks/Cole - Thomson Learning

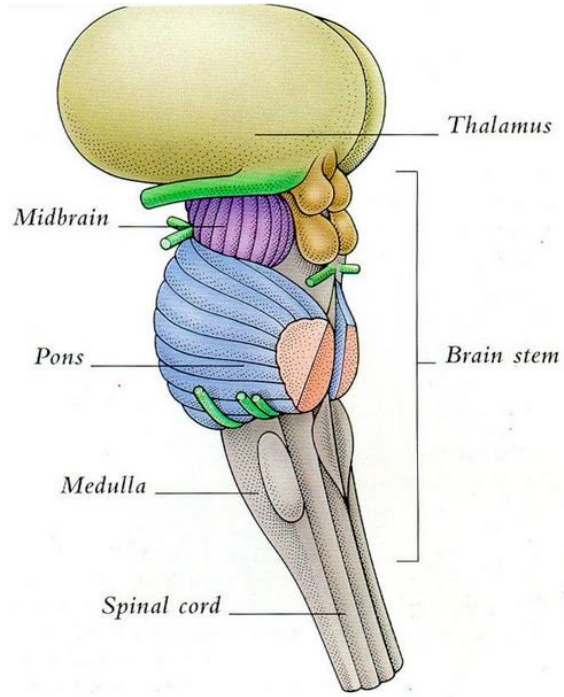
Brain Evolution & Development

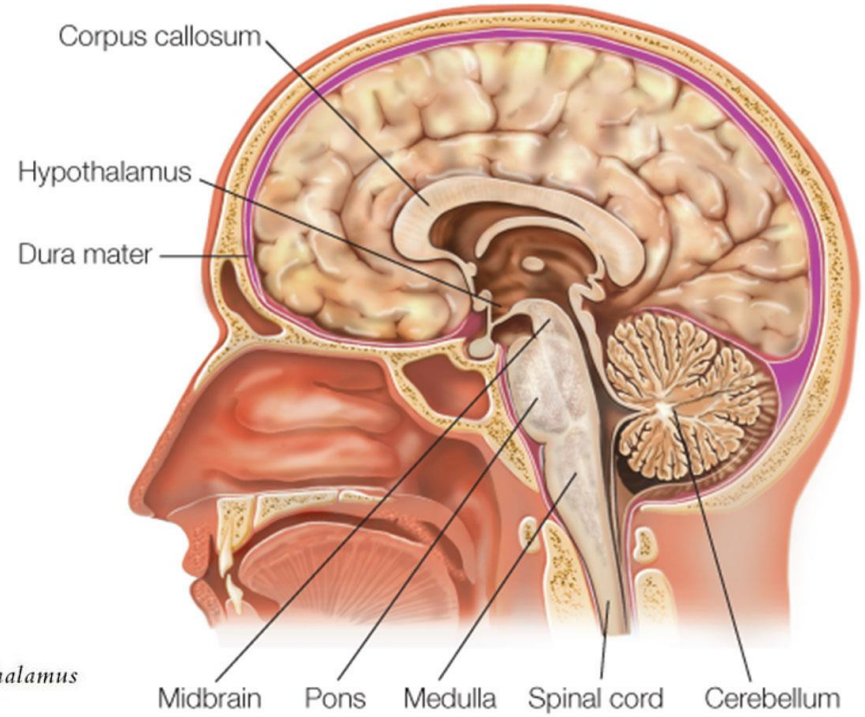




The Brainstem

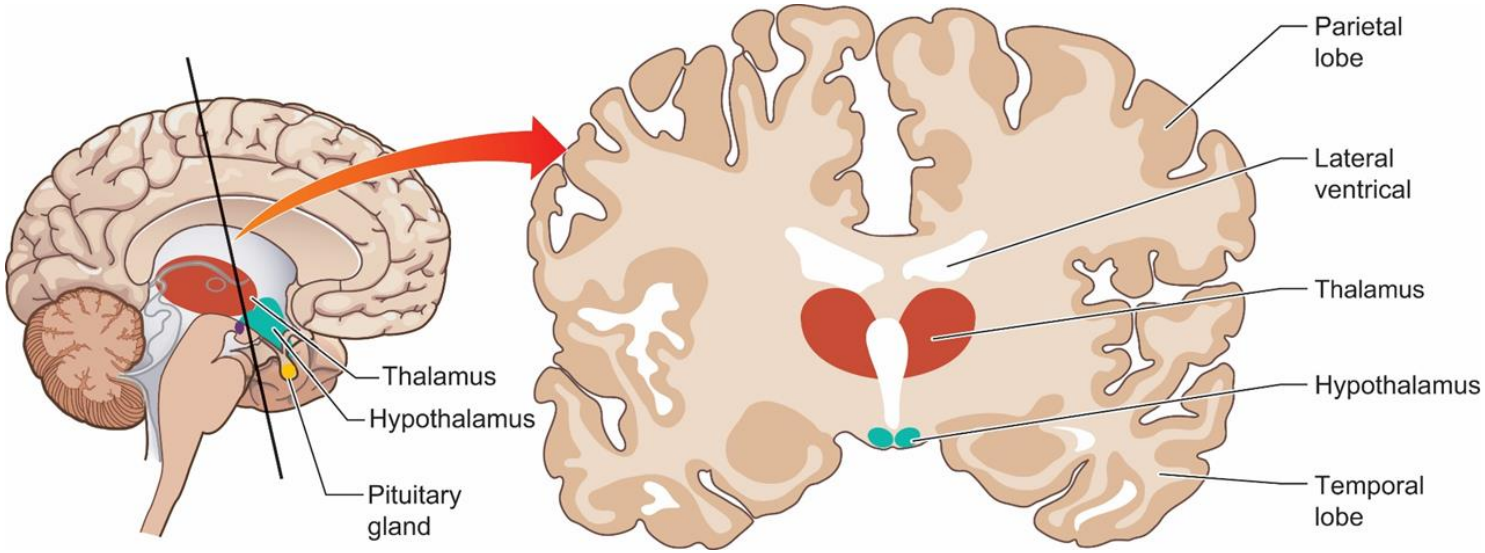
- Connects the brain with the spinal cord
- Controls autonomic functions like breathing, heart rate, blood pressure, and digestion
- Regulates arousal and consciousness
- Involved in motor control, especially reflexes, posture, and balance
- Central relay station for sensory and motor signals





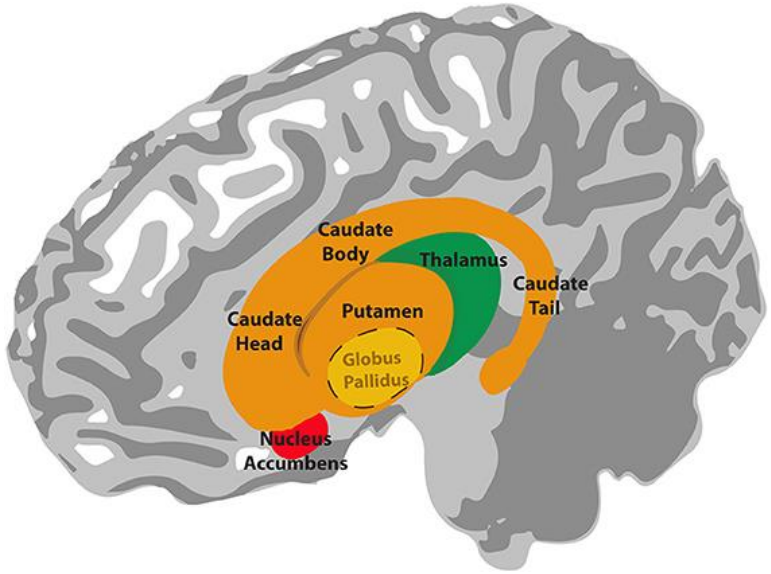
Thalamus and Hypothalamus

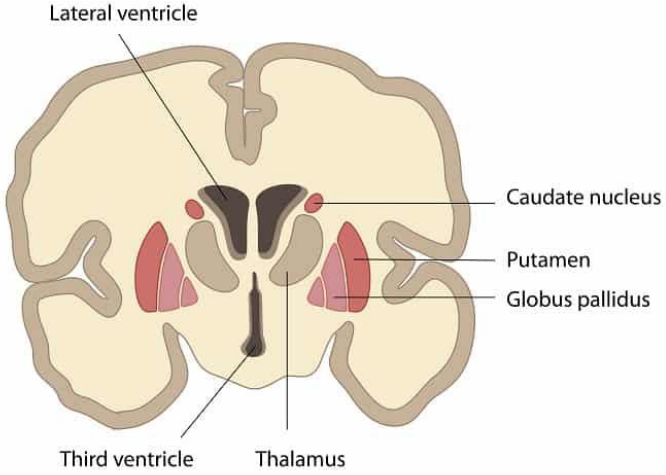
- **Thalamus** – major relay station
  - All sensory information (except smell) pass through thalamus before going to the cortex
  - Information from cerebellum and basal ganglia pass through on their way to the motor cortex
  - Helps regulate arousal, emotional response
- **Hypothalamus** – hormonal control
  - Helps body regulate homeostasis – body temperature, hunger, thirst, circadian rhythms
  - Controls autonomic nervous system (ANS) – heart rate, blood pressure, digestion, respiration
  - Regulates hormones controlling growth, metabolism, stress, and reproduction through secretion of hormones in the **pituitary gland**
  - Helps regulate emotional behaviors like aggression, pleasure, and sex
  - Keeps the body's central circadian rhythm in the **suprachiasmatic nucleus (SCN)**



Basal Ganglia

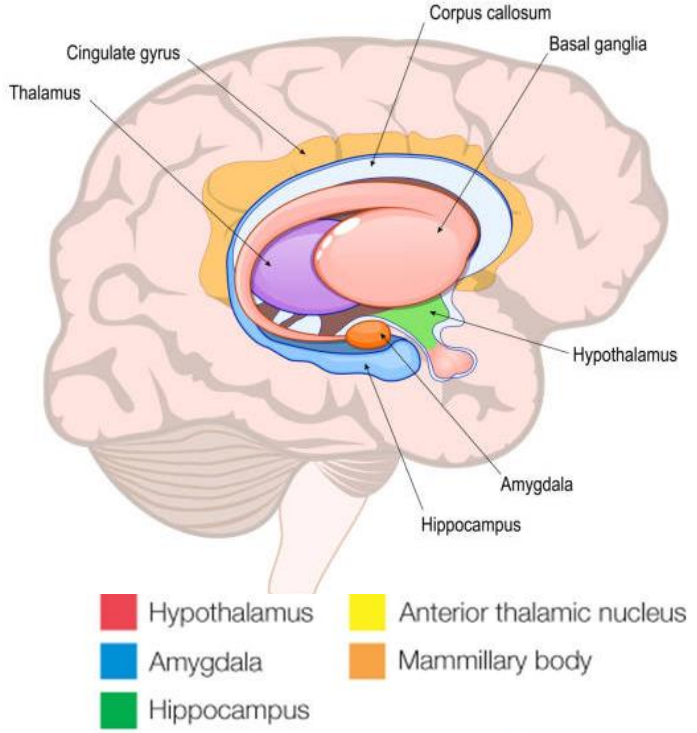
- Structures that surround and overhang the thalamus
- Motor control – initiation and regulation of **voluntary movements**; inhibition of involuntary movements that get in the way
- Learning routines and habit formation, including both motor skills and cognitive responses
- Interacts with **limbic system** to regulate emotional responses and motivation

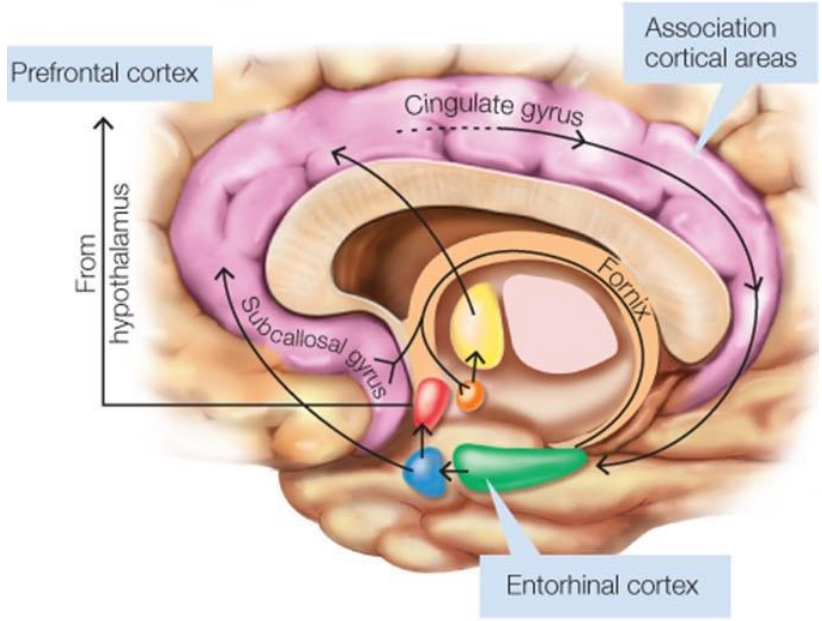




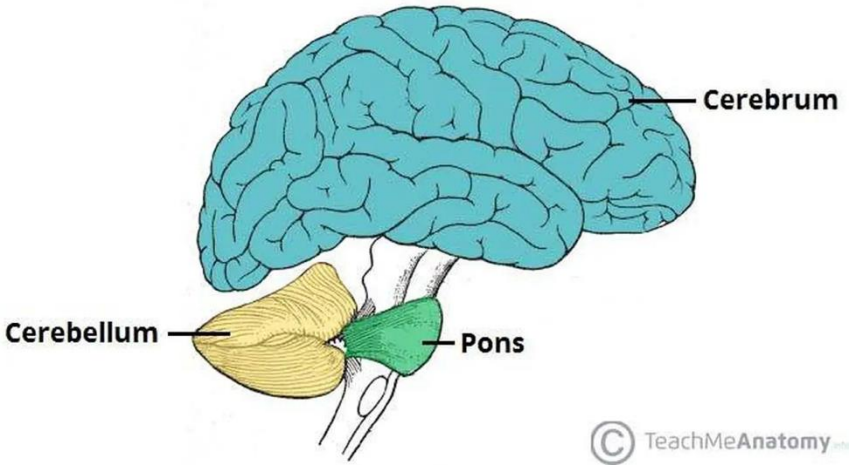
Limbic System

- Set of structures responsible for regulating emotions, motivation, long-term memory, and olfaction
- **Amygdala** – processes emotions like fear, anger, pleasure; important for emotional conditioning and memory
- **Hippocampus** – essential for formation and retrieval of long-term memories; spatial navigation
- **Cingulate** – emotion processing, behavioral regulation, sensory integration and sense of self, motivation and willpower, pain processing
- **Olfactory bulbs** – sense of smell; direction connection to limbic system gives smell strong link to emotion and memory

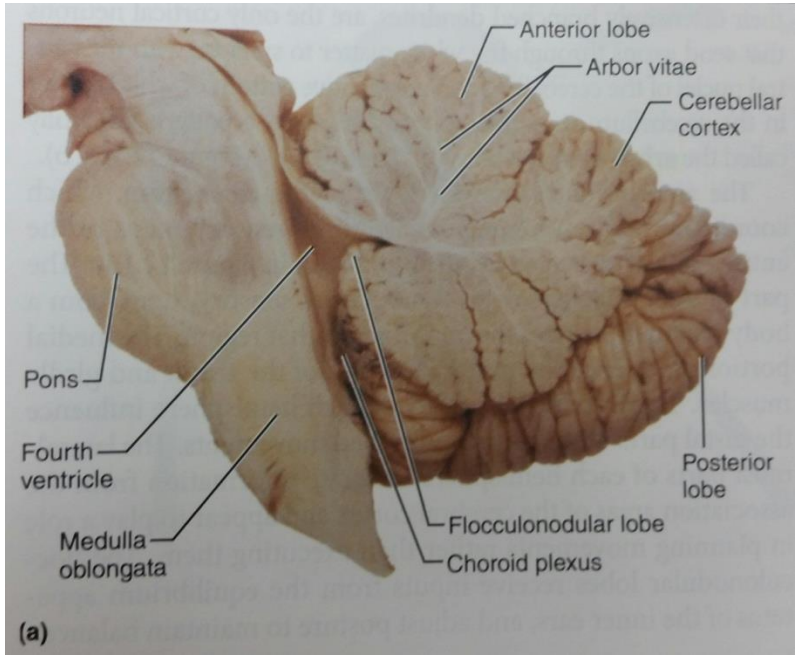




The Cerebellum

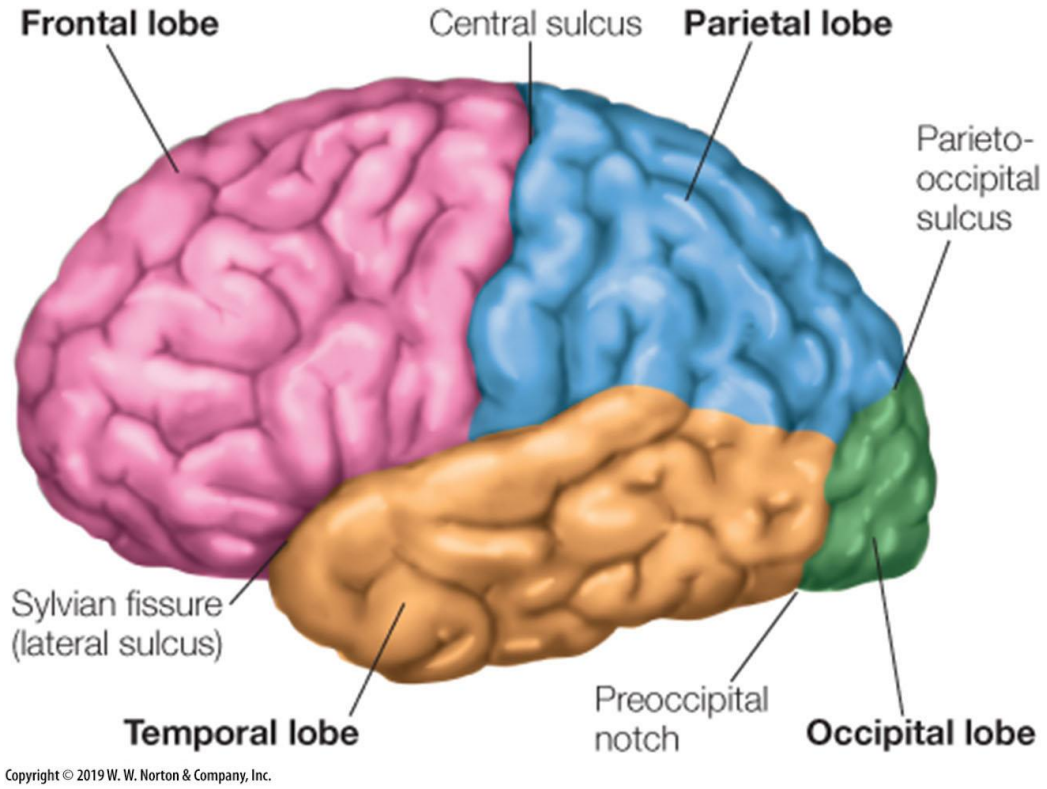


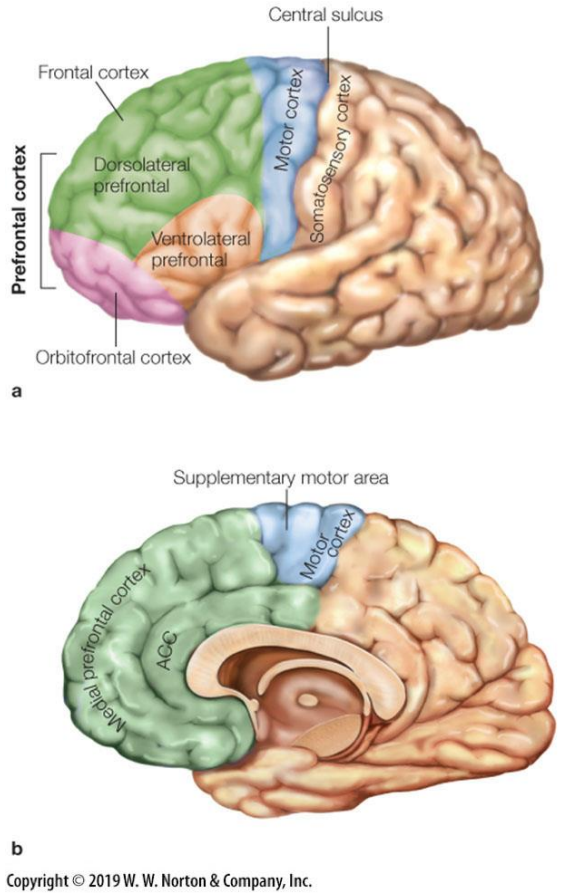
- Contains more neurons than the rest of the brain combined
- Connects through the brainstem to the rest of the brain
- Involved in fine-tuning of motor control, balance, posture, learning of motor skills, and movement adaptation
- Also involved in higher cognitive functions like attention, language, executive functioning, and social behavior



The Cerebral Cortex

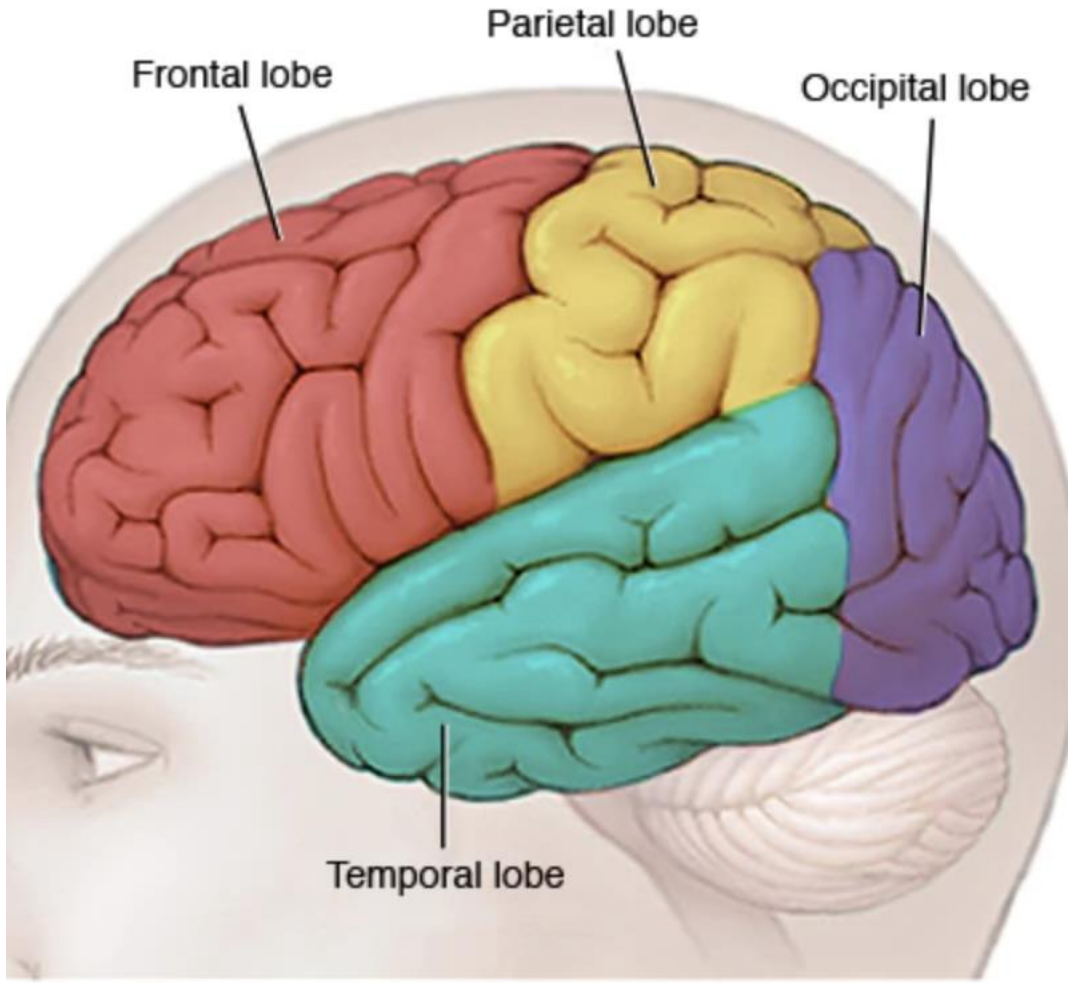
- Do we need it? https://youtu.be/CmuYrnOVmfk?si=7_m4G5ywNOFgzvZb&t=2085





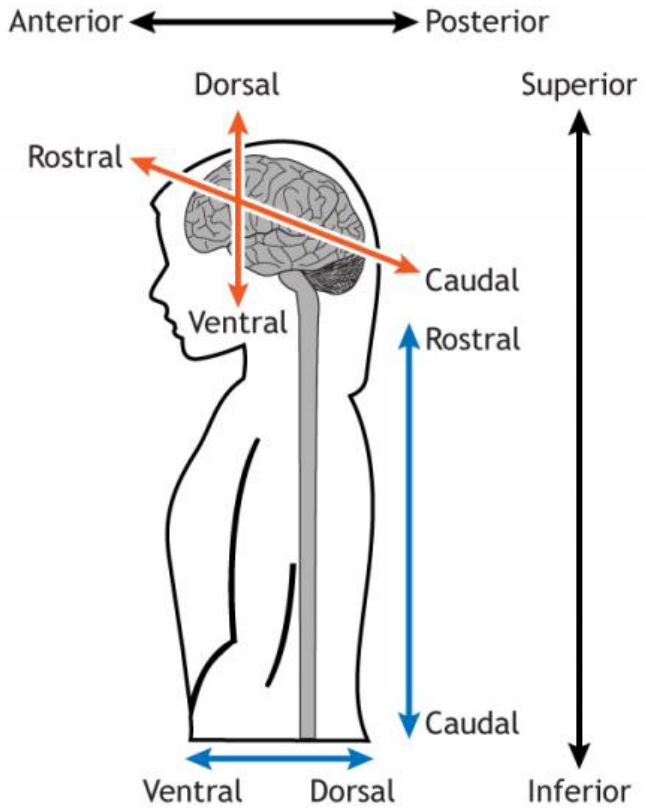
The Lobes

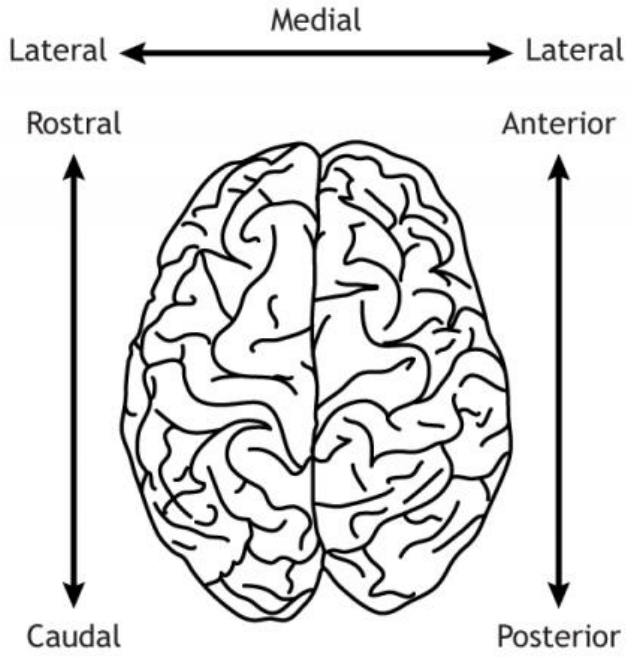
- **Frontal**: executive functions, decision-making, and primary motor cortex
- **Parietal**: sensory integration, spatial awareness, and attention
- **Temporal**: auditory processing, memory formation, and language
- **Occipital**: visual processing and interpretation

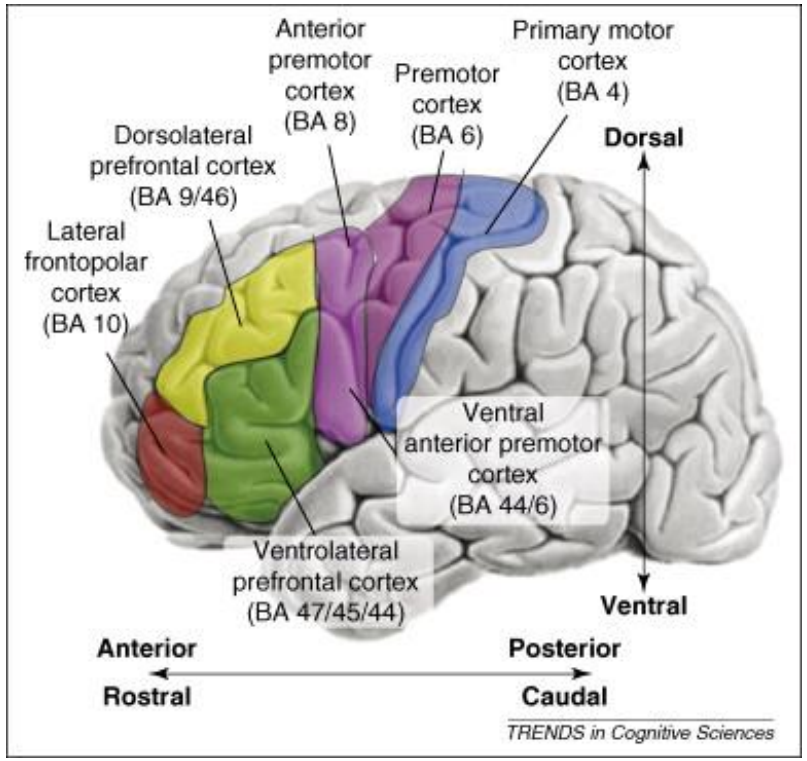


Brain Locations

- You can use those directional terms to specify areas in the brain

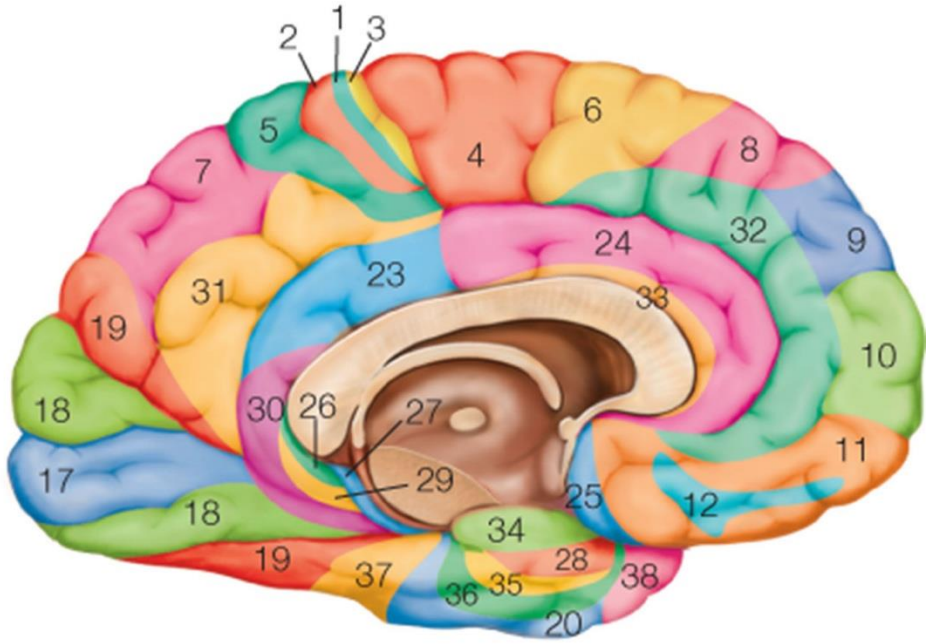




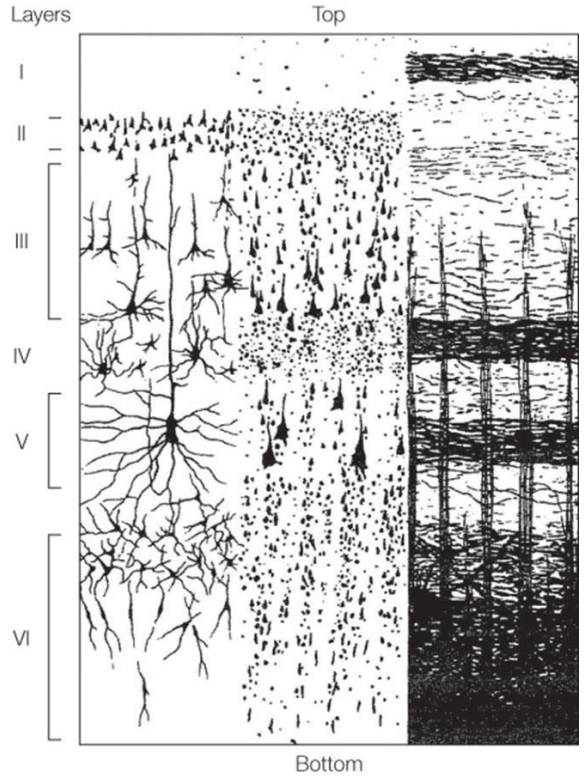


How to segment the cerebral cortex?

- **Cytoarchitectonics** – different cell architectures, produces Brodmann's areas
- **Layers** – different cells at each layer of grey matter



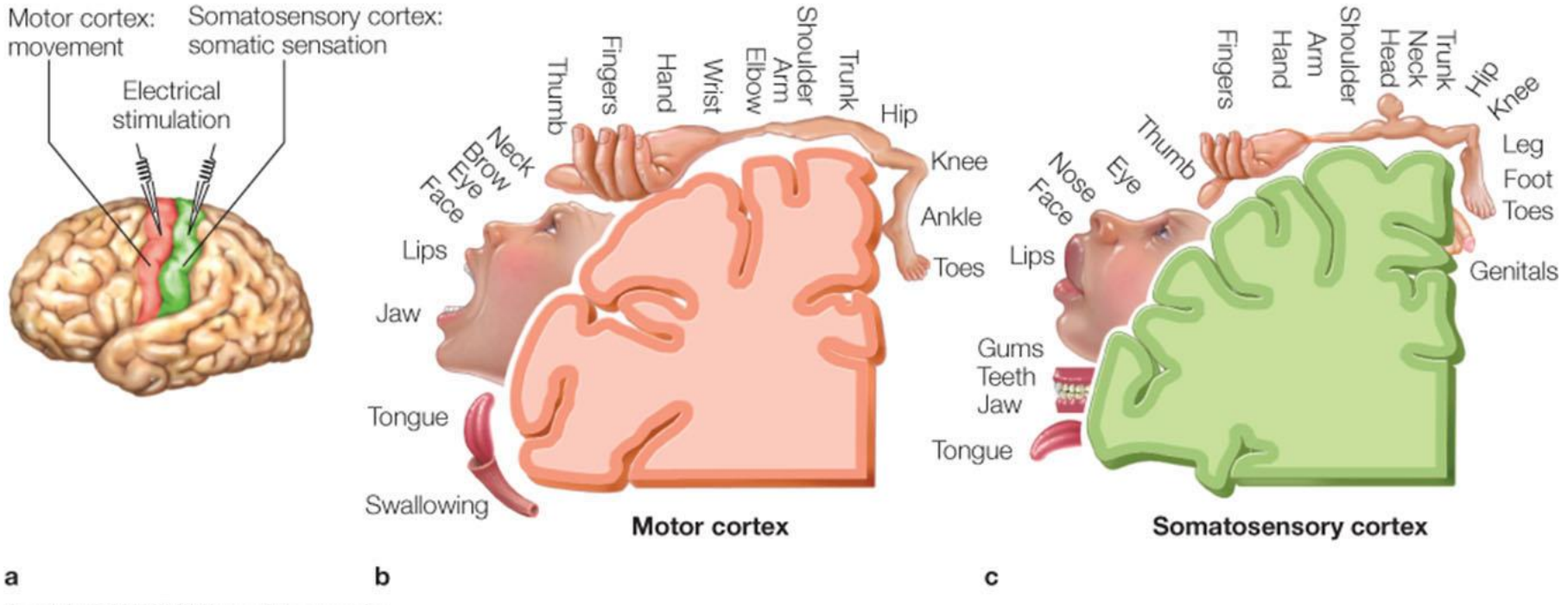
c

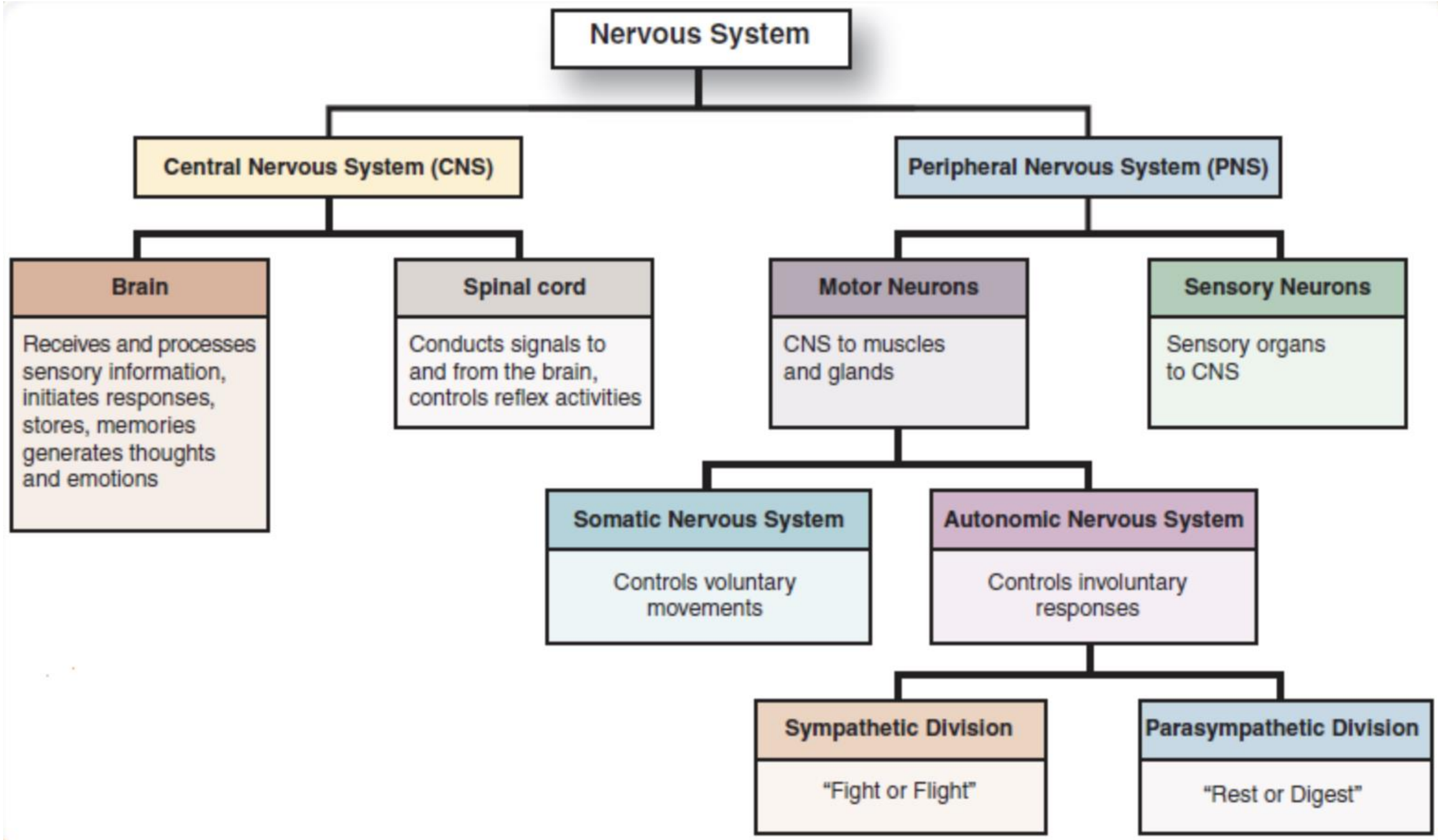


c

Somatosensory and motor cortex

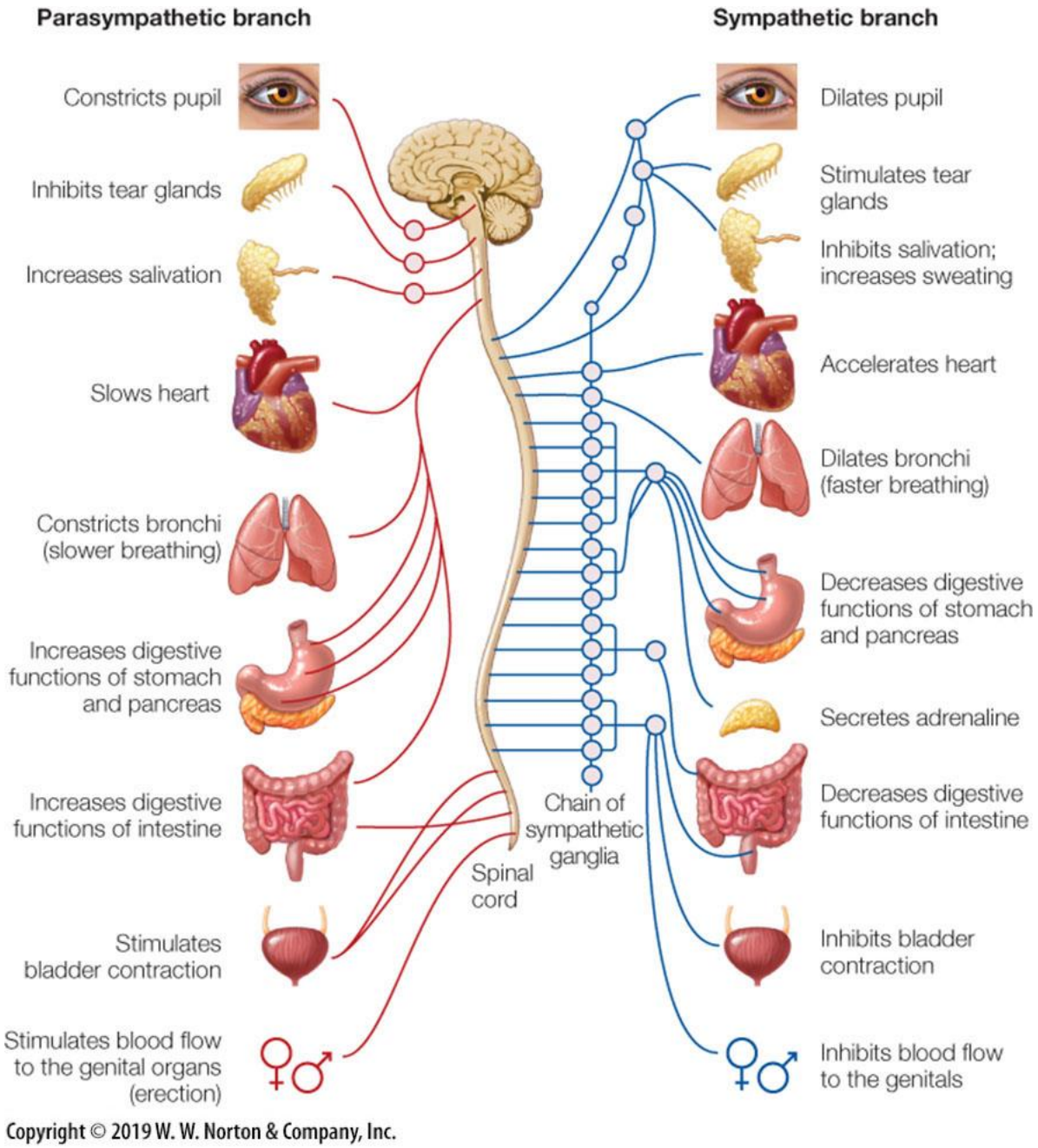
- There is a map of the body on the cortex




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"

Peripheral Nervous System

- **Autonomic regulation**: Manages involuntary bodily functions; controls heart rate, digestion, respiration
- **Reflexes**: Mediates rapid, automatic responses to stimuli, bypasses conscious control for quick protective reactions
- **Homeostasis**: Helps maintain internal body balance, regulates temperature, blood pressure, and other vital functions
- **Endocrine interaction**: works with the endocrine system to regulate hormones, influences metabolism, growth, and stress responses



Peripheral Nervous System

- Cranial nerves (I-XII) have diverse sensory, motor, and mixed functions
- Direct communication pathways between the brain and various structures in the head, neck, and upper body, controlling critical functions such as vision, hearing, taste, smell, facial movements, swallowing, and regulation of heart rate and digestion.
- **Afferent** – sensory input channels
- **Efferent** – output channels to muscles, glands, organs