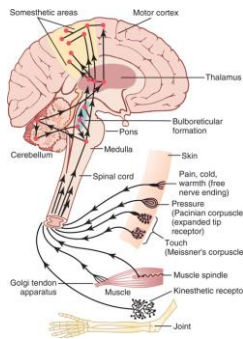


General Design of Nervous System:

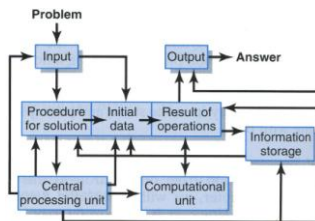


Input = **Sensory System**

Receptors:

- Tactile
- Visual
- Auditor
- Olfactory

Analogy = Computer

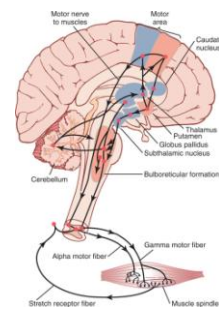


Processing = **Integrative System**

- 99% of sensory information discarded
- Synapses determine pathway of signals
- Information stored for future use

Memory:

Highly facilitated synaptic pathways (sensory input not required to excite pathway)



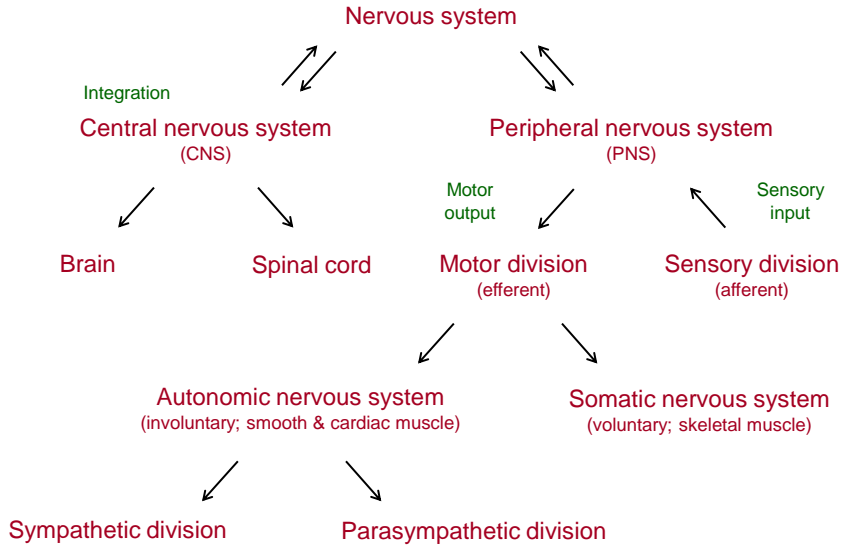
Output = **Motor System**

Effectors:

- Skeletal muscle
- Smooth muscle
- Glandular secretion

Fundamentals of Nervous System

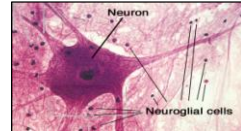
Organization of Nervous System:



Fundamentals of Nervous System

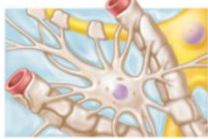
Histology of Nervous System:

A. **Neuroglia** (supporting cells – “nerve glue”)



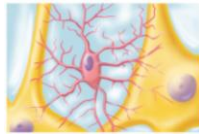
Central Nervous System (CNS)

(most common)



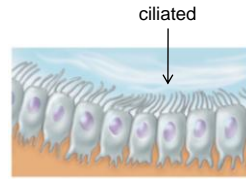
**Astrocytes:**

- anchor neurons to capillaries
- repair damaged neural tissue
- maintain “blood / brain barrier”



**Microglia:**

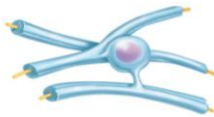
- macrophages; engulf invaders



ciliated

**Ependymal cells:**

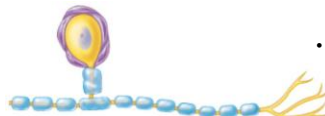
- line canals / ventricles of brain
- produce cerebrospinal fluid (CSF)



**Oligodendrocytes:**

- Insulate neurons (myelin sheath)

Peripheral Nervous System (PNS)



**Schwann cells:**

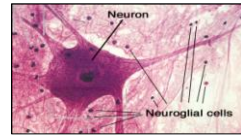
- Insulate neurons (myelin sheath)

**Satellite cells:**

- Function similar to astrocytes

Histology of Nervous System:

- Long-lived (~ 100 years)
- High metabolic rate

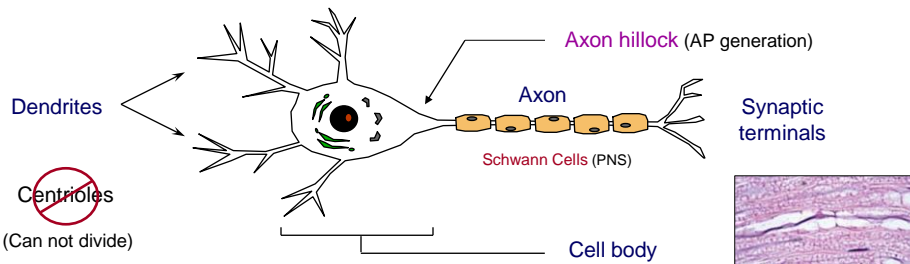


B. Neurons

- Specialized “excitable” cells
- Allow for communication throughout body (via electrical impulses)

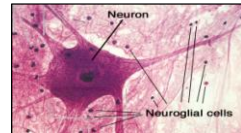
Neuron Anatomy:

- 1) **Dendrites**: Receive information (environment / other neurons)
- 2) **Cell body (soma)**: Integrates information / initiate response
- 3) **Axon**: Conducts **action potential** (AP – electrical impulse)
- 4) **Synaptic terminals**: Transmit signal (other neurons / effector organs)



Histology of Nervous System:

- Long-lived (~ 100 years)
- High metabolic rate

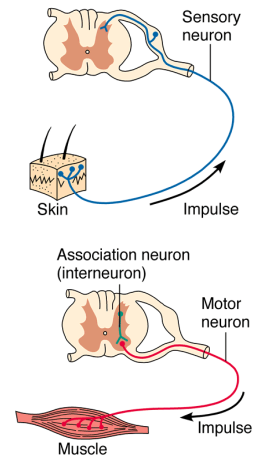


B. Neurons

- Specialized “excitable” cells
- Allow for communication throughout body (via electrical impulses)

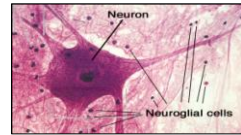
Functional Classification of Neurons:

- 1) **Sensory (Afferent) neurons**:
  - Carry information from sensory receptors to CNS
- 2) **Motor (Efferent) neurons**:
  - Carry information from CNS to effector organs
- 3) **Association neurons (Interneurons)**:
  - Interconnects neurons in brain / spinal cord



Histology of Nervous System:

- Long-lived (~ 100 years)
- High metabolic rate

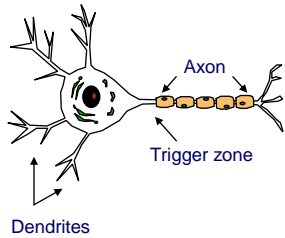


B. Neurons

- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

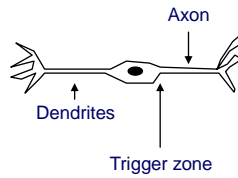
Structural Classification of Neurons (# of processes) :

**Multipolar**  
(≥ 3 processes)



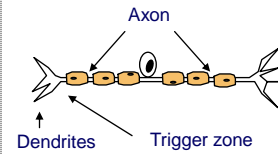
- Motor neurons
- Interneurons

**Bipolar**  
(2 processes)



- Sensory neurons  
(e.g., special sense organs)

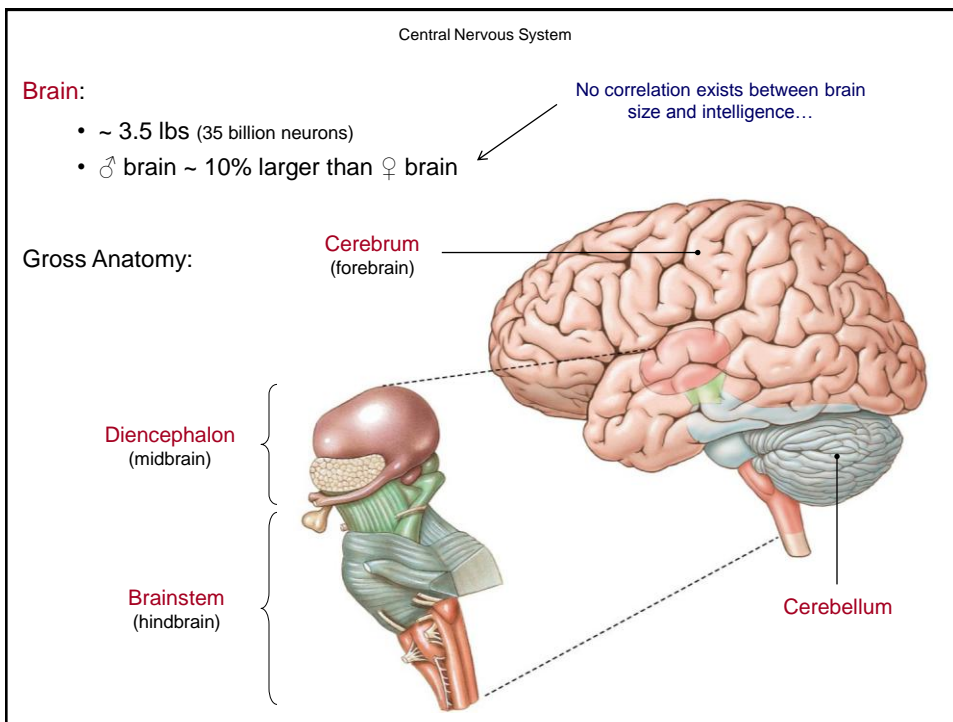
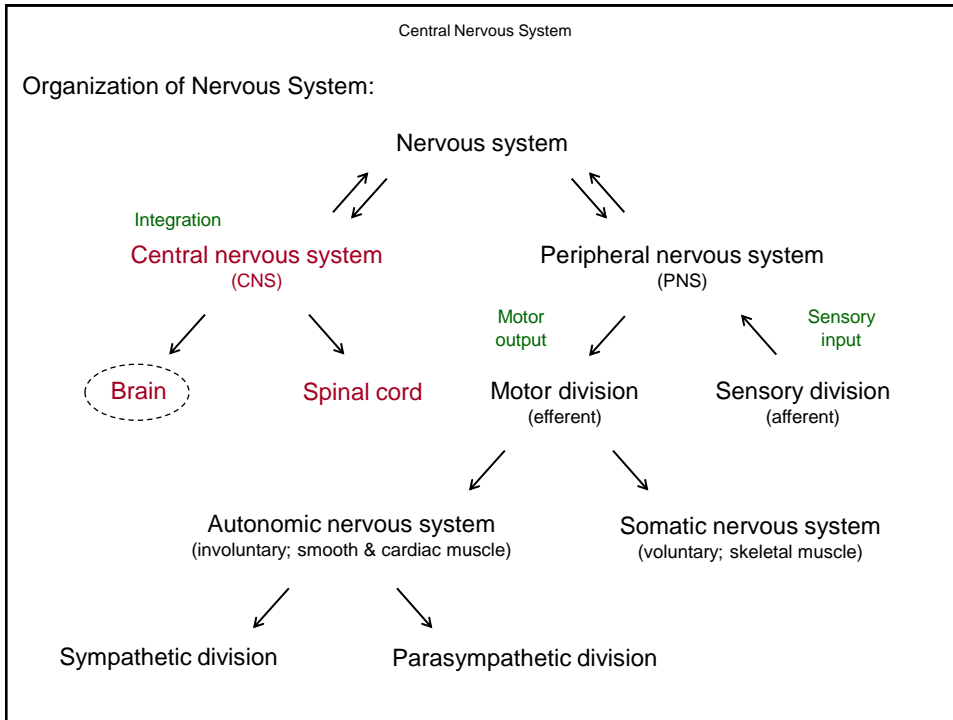
**Unipolar**  
(1 process)



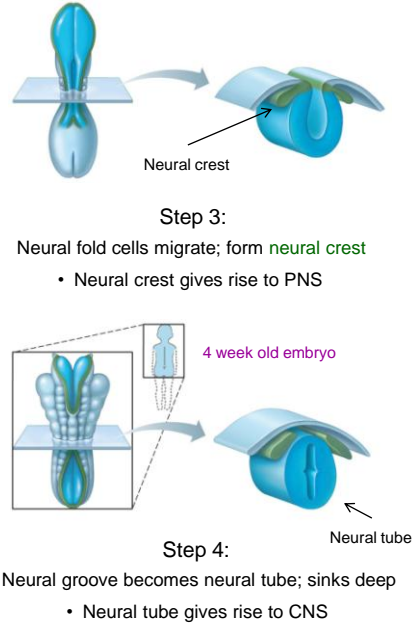
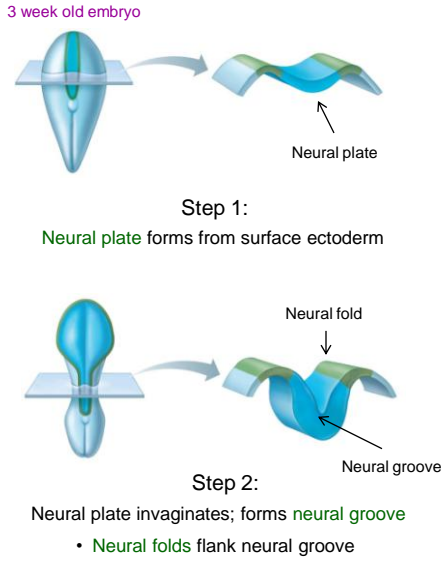
- Sensory neurons  
(PNS)

# Central Nervous System



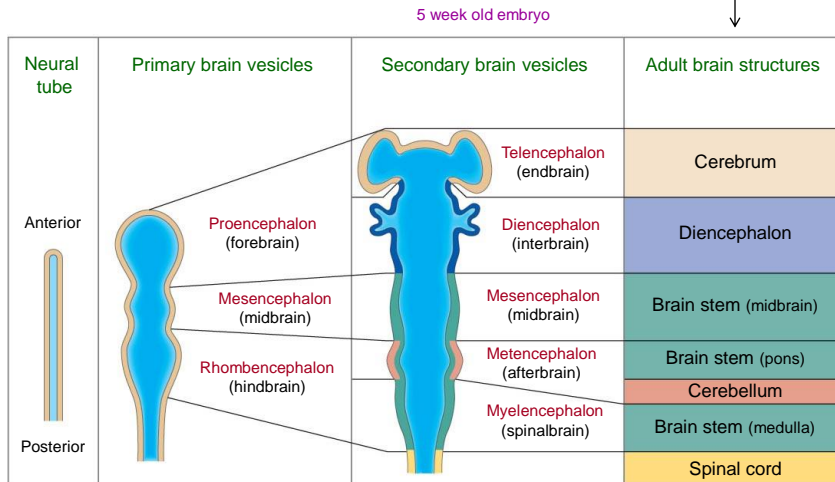


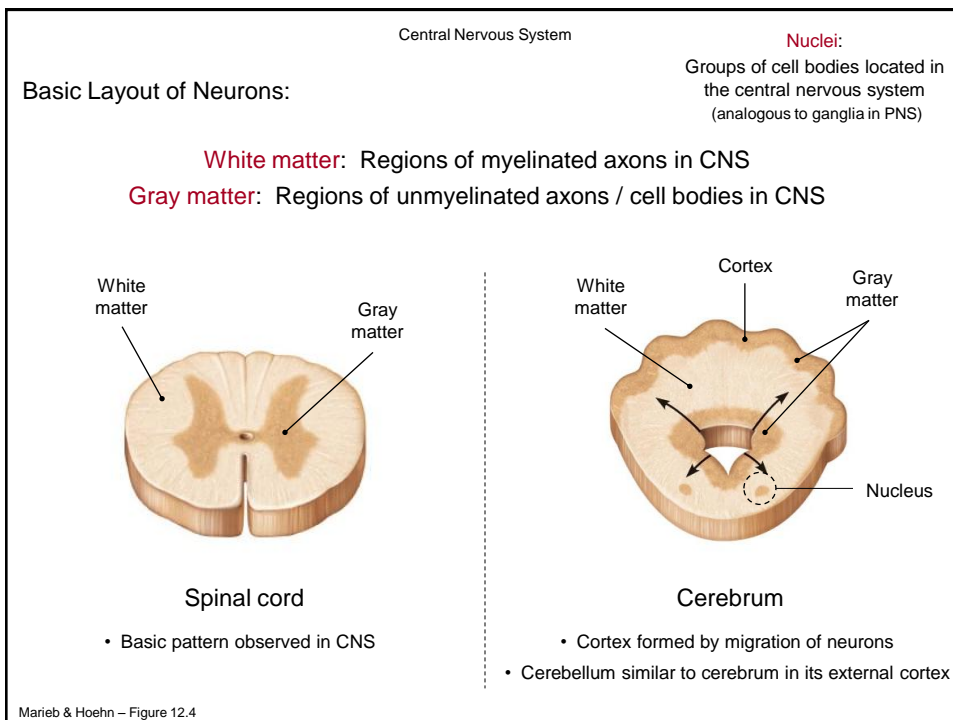
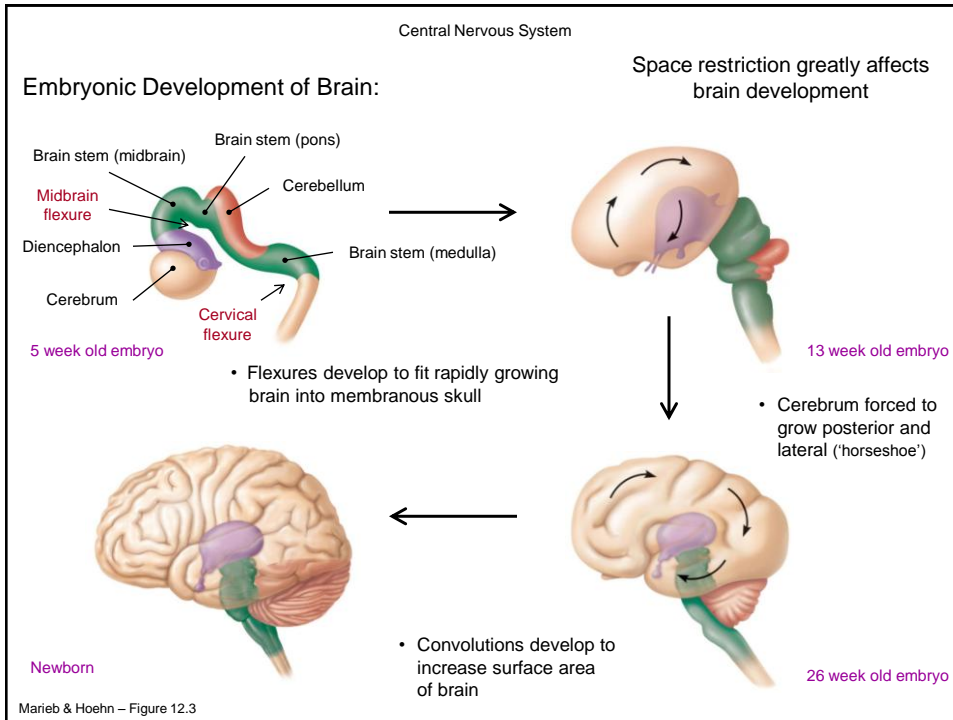
Embryonic Development of Brain:



Embryonic Development of Brain:

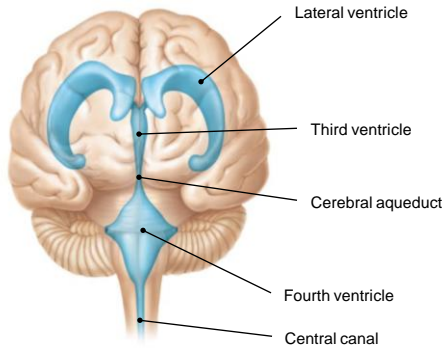
How we will consider brain anatomy





Brain Anatomy:

A. **Ventricles:** Hollow chambers enclosed within brain (continuous with each other...)



Ventricles lined with **ependymal cells**  
(circulate CSF)

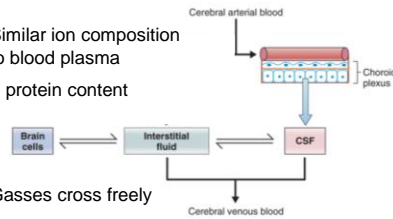
**Cerebrospinal fluid (CSF)**

- Provide constant, controlled environment for brain cells
- Protect brain from toxins
- Prevent escape of local neurotransmitters

**Choroid plexus:**

Vascular network; produces CSF

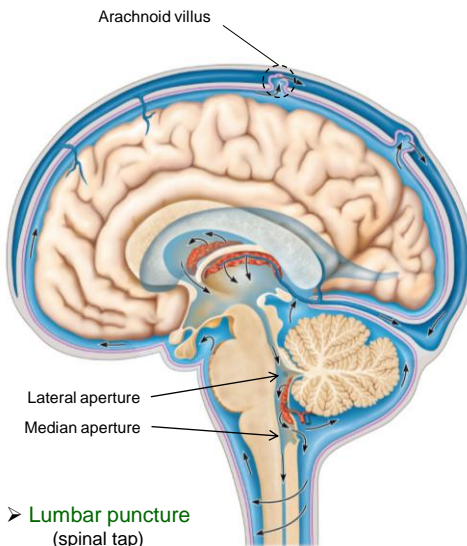
- Similar ion composition to blood plasma
- ↓ protein content



- Gasses cross freely
- 0.5 L / day produced

Costanzo – Figure 3.36

CSF Circulation:



➤ **Lumbar puncture**  
(spinal tap)

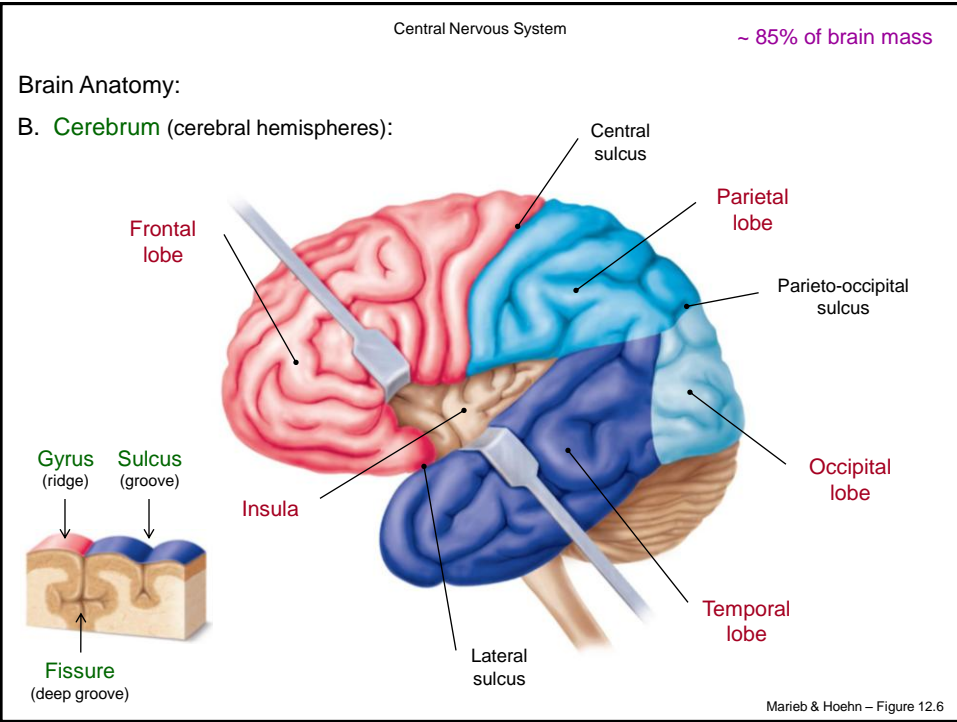
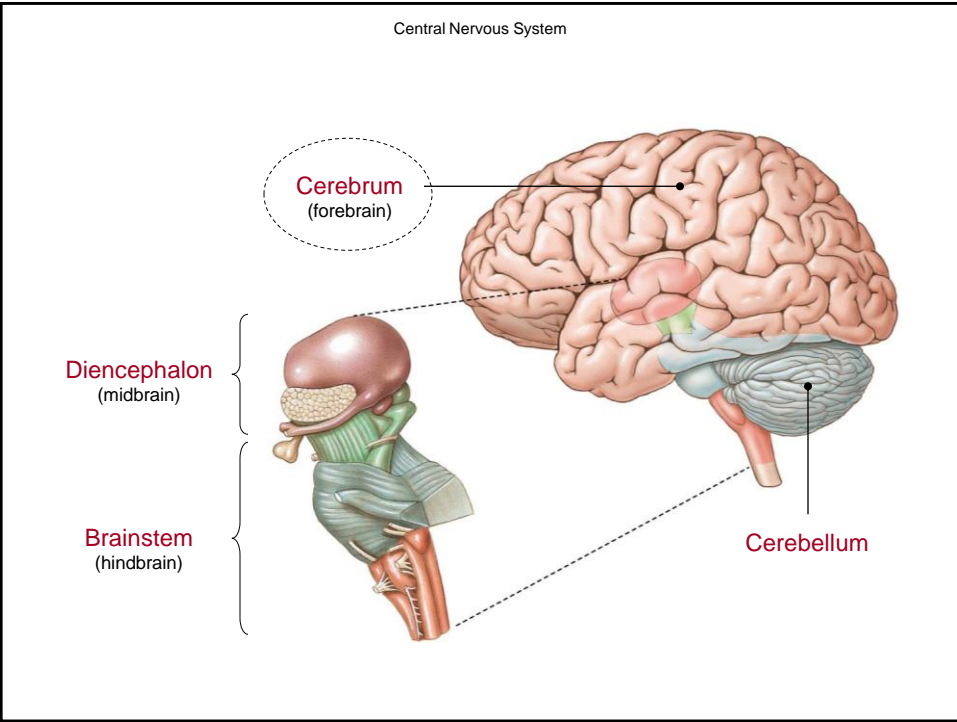
Presence of CSF in subarachnoid space gives buoyancy to brain (97% weight reduction)

- 1) CSF produced by choroid plexus in ventricles
- 2) CSF flows through ventricles and into subarachnoid space via **lateral and median apertures**
- 3) CSF exits subarachnoid space via **arachnoid villi**



**Hydrocephalus**  
("water on the brain")

Marieb & Hoehn – Figure 12.26



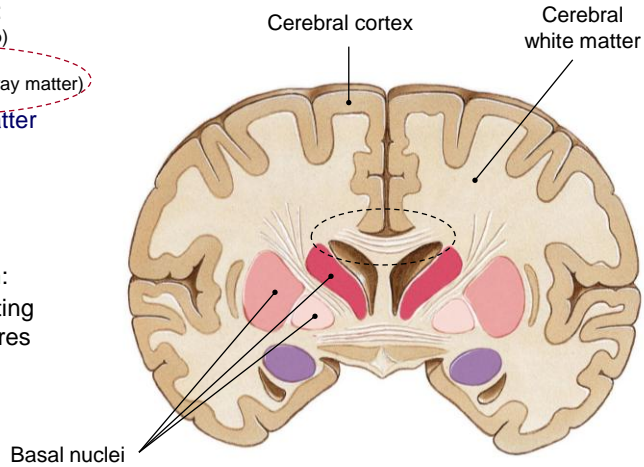
Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):

Basic regions:  
(superficial to deep)

- 1) **Cerebral cortex** (gray matter)
- 2) **Cerebral white matter**
- 3) **Basal nuclei**

**Corpus callosum:**  
White tract connecting cerebral hemispheres



Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):

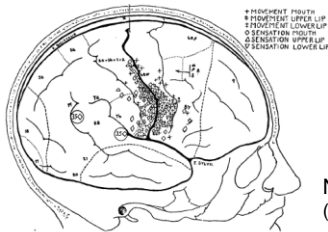
1) **Cerebral cortex:**

- Contains 3 types of functional areas:
  - 1) **Motor areas** (send output)
  - 2) **Sensory areas** (receive input)
  - 3) **Association areas** (interpret data)

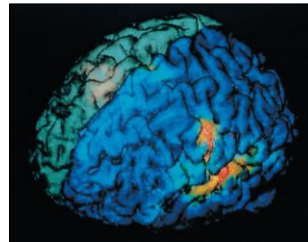
The cerebral cortex is the seat of conscious behavior

Only 2 - 4 mm thick but comprises 40% of the brain's mass

2.5 ft<sup>2</sup> of surface area



Functional MRI scan (measure blood flow)



Neural cartography (electrostimulation)

Brain Anatomy:

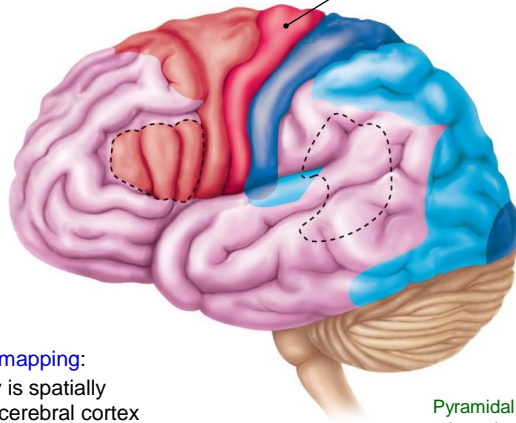
B. Cerebrum (cerebral hemispheres):

1) Cerebral cortex:

- Motor areas:

Primary motor cortex

Conscious control of skeletal muscle movements



Somatotopic mapping:

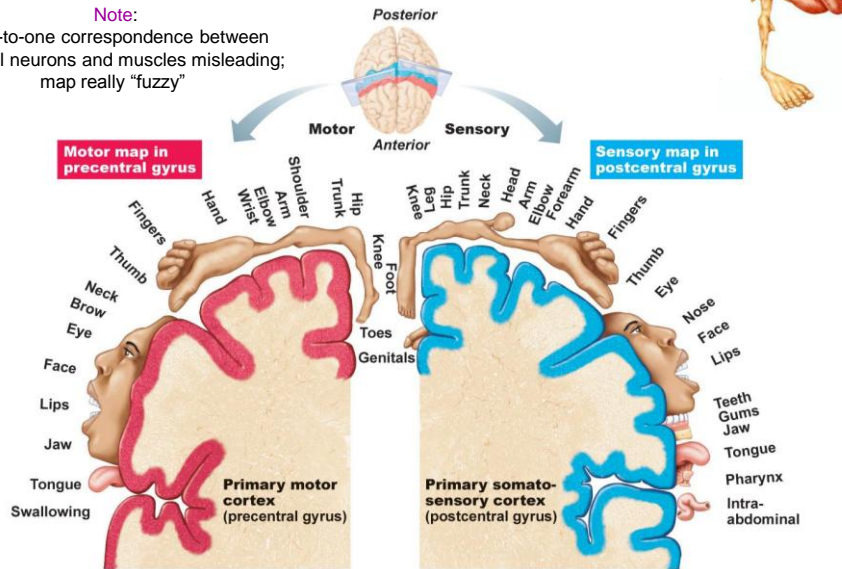
The entire body is spatially represented in the cerebral cortex

Pyramidal cells extend long axons to the spinal cord, forming pyramidal tracts, or corticospinal tracts

Homunculus ("little man"):

Note:

One-to-one correspondence between cortical neurons and muscles misleading; map really "fuzzy"



Brain Anatomy:

B. Cerebrum (cerebral hemispheres):

1) Cerebral cortex:

- Motor areas:

**Frontal eye field**

Controls voluntary movement of eyes

**Broca's area**

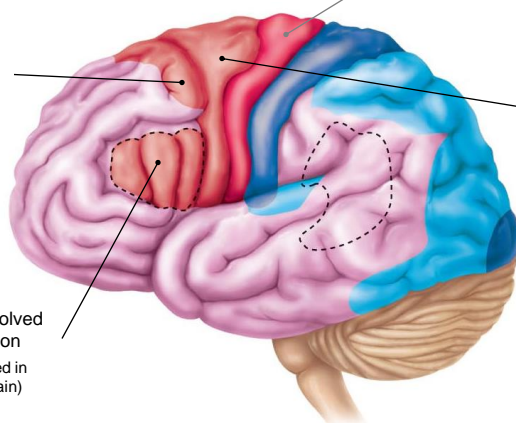
Controls muscles involved in speech production (often more pronounced in one hemisphere of brain)

**Primary motor cortex**  
Conscious control of skeletal muscle movements

communicates directly with primary motor cortex

**Premotor cortex**

Controls learned motor skills of repetitious or patterned nature (e.g., typing)



Brain Anatomy:

B. Cerebrum (cerebral hemispheres):

1) Cerebral cortex:

- Sensory areas:

**Gustatory cortex**

Receives / interprets sensations of taste

**Primary auditory cortex**

Receives auditory information (tonotopic mapping)

**Auditory Association area**

Integrates / interprets auditory inputs (e.g., music / thunder)

**Olfactory cortex**

Receives olfactory information

• Part of rhinencephalon ('nose brain')

**Primary somatosensory cortex**

Receives information from sensory receptors in skin & proprioceptors in joints

Spatial discrimination

**Somatosensory association cortex**

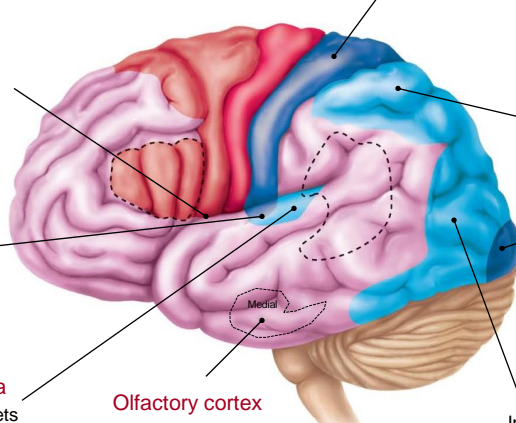
Integrates / interprets somatosensory inputs (e.g., temp. / pressure)

**Primary visual cortex**

Receives visual information (retinotopic mapping)

**Visual association area**

Integrates / interprets visual inputs (e.g., color / form)



Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):

Locations where sensations, thoughts, and emotions become conscious (makes us who we are...)

1) **Cerebral cortex:**

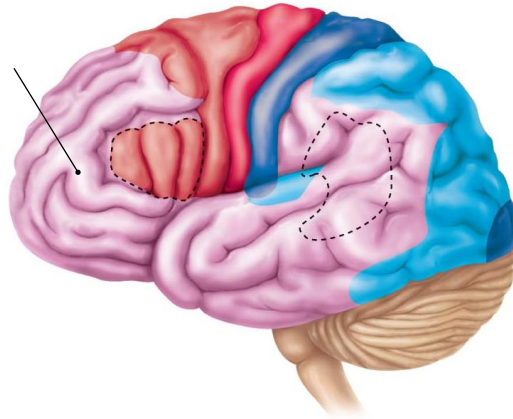
- Association areas (multimodal):

(matures slowly)

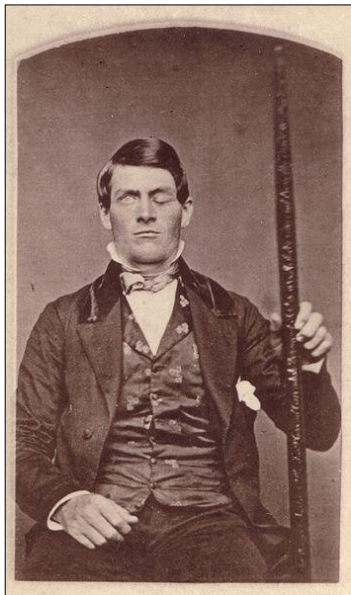
**Anterior association area**

(Prefrontal cortex)

- Intelligence
- Complex learning
- Recall
- Personality



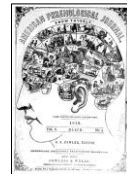
Phineus Gage (1823 – 1860)



**Phrenology:**

The brain is the organ of the mind; contains localized, specific modules

**Franz Gall**  
(1758 – 1828)



The American Crowbar Case

Introduction



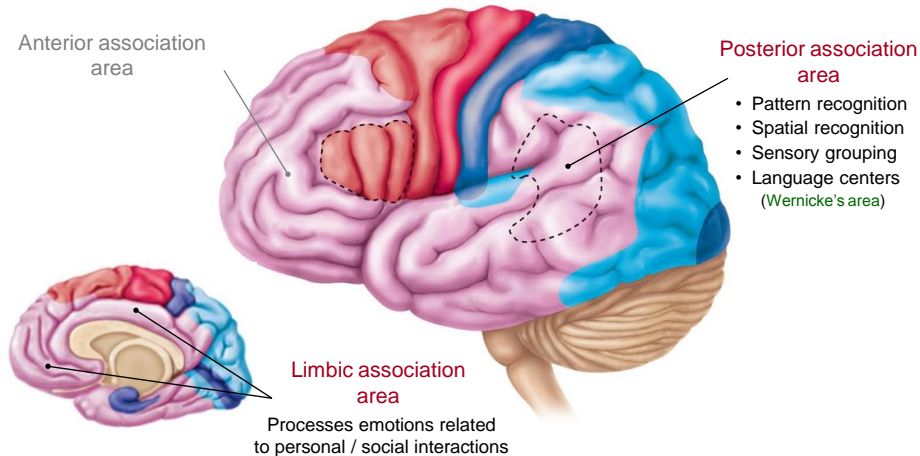
## Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):

Locations where sensations, thoughts,  
and emotions become conscious  
(makes us who we are...)

1) **Cerebral cortex:**

- Association areas (multimodal):



## Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):1) **Cerebral cortex:**

- Contains 3 types of functional areas
- Contralateral control (e.g., left hemisphere controls right body)

**Decussation:**

Location where neural pathways cross

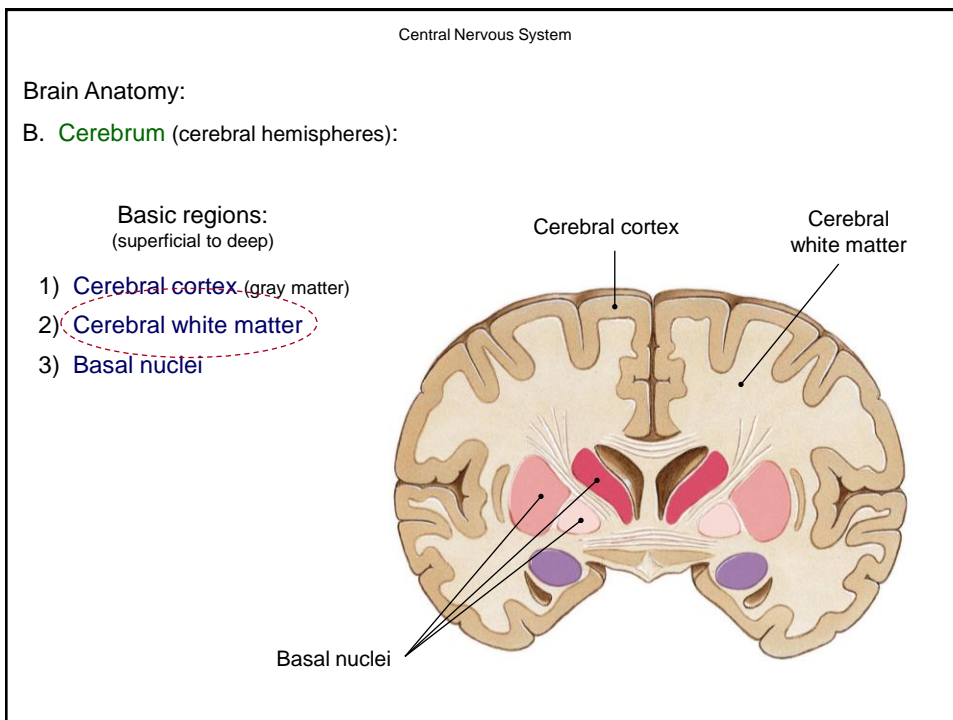
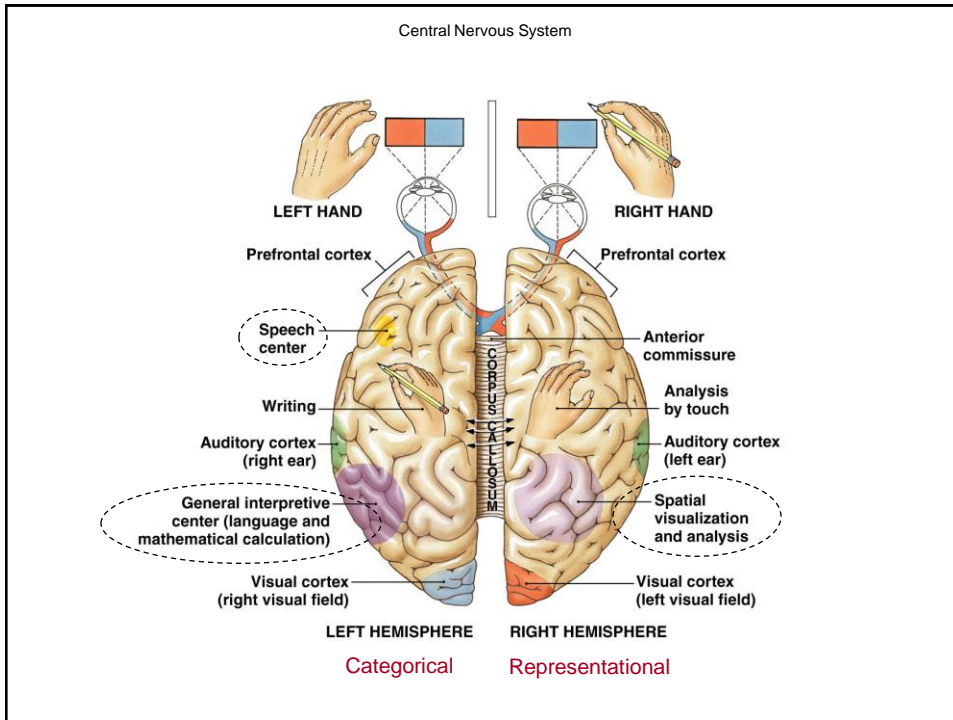
- Occur at different locations in CNS

- Lateralization (i.e., hemisphere specialization)

The cerebral cortex is the seat of conscious behavior

Only 2 - 4 mm thick but comprises 40% of the brain's mass

2.5 ft<sup>2</sup> of surface area



Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):

2) **Cerebral white matter**:

Fiber tracts responsible for communication between cerebral areas and lower CNS

A) **Commissural Fibers** (form **commissures**) :

- Interconnect cerebral hemispheres

B) **Association Fibers**:

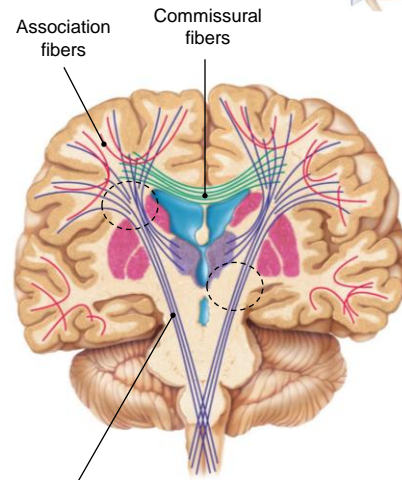
- Interconnect areas of neural cortex within a single hemisphere

C) **Projection Fibers**:

- Interconnect cerebral hemispheres with other regions of the brain

**Corona radiata**:

Point where projection fibers radiate fan-like through cerebral white matter



Projection fibers

**Internal capsule:**  
Compact band of projection fibers near diencephalon

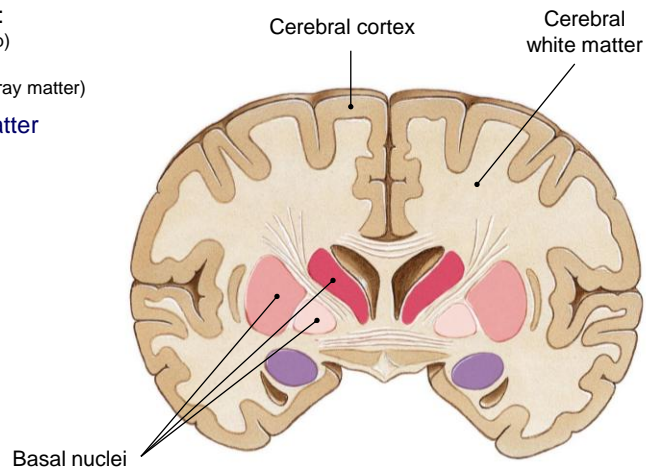
Marieb & Hoehn – Figure 12.10

Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):

Basic regions:  
(superficial to deep)

- 1) **Cerebral cortex** (gray matter)
- 2) **Cerebral white matter**
- 3) **Basal nuclei**

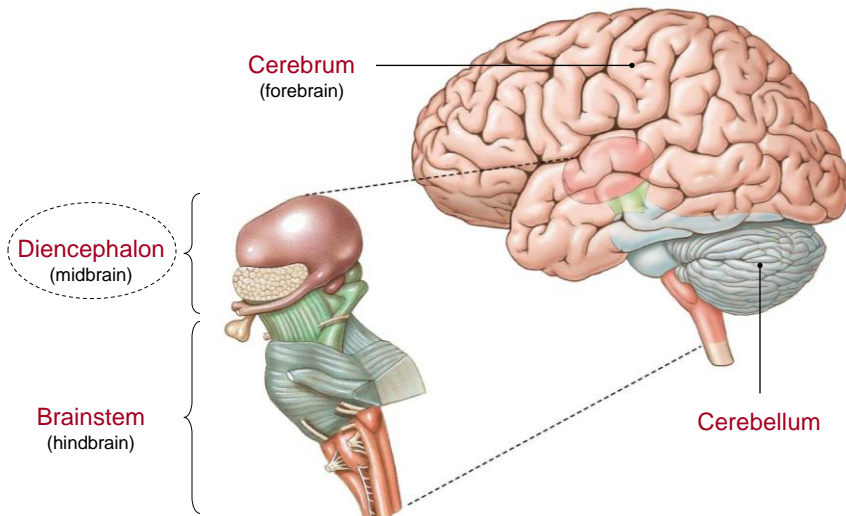
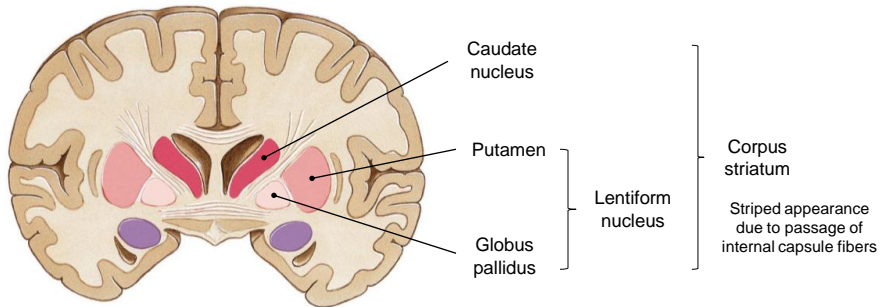


Brain Anatomy:

B. **Cerebrum** (cerebral hemispheres):

3) **Basal nuclei:**

- Composed of gray matter (neuron cell bodies)
- Function: 1) Subconscious control of skeletal muscle tone  
2) Control stereotypical motor movements (e.g., arm swing)
  - Regulate intensity / inhibit unnecessary movements



Brain Anatomy:

C. Diencephalon:

Thalamus:

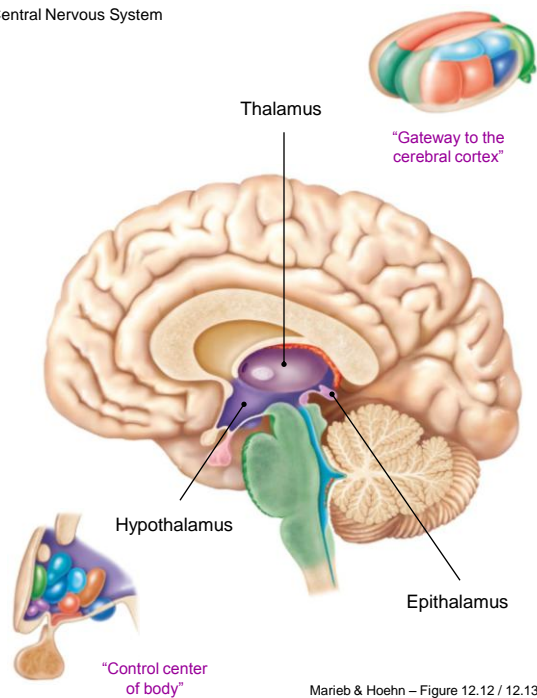
- Composes 80% of diencephalon
- Relay station for all information entering / exiting the cerebral cortex

Hypothalamus:

- Autonomic control center
- Center for emotional response
- Body temperature regulation
- Regulation of food / water intake
- Regulation of sleep-wake cycles
- Control of endocrine system

Epithalamus:

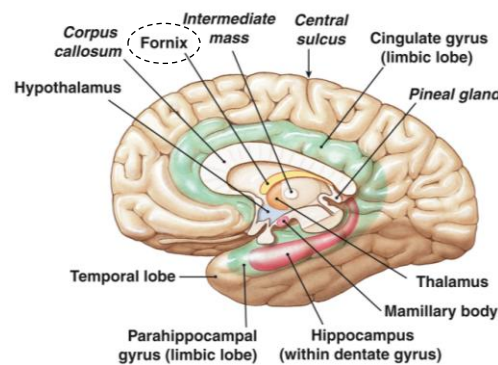
- Houses pineal gland (melatonin) and choroid plexus (forms CSF)



Marieb & Hoehn – Figure 12.12 / 12.13

Brain Anatomy:

Limbic system (functional brain system):



Fornix:  
Fiber tract linking regions together

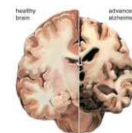
“Emotional brain”

Diencephalon structures:

- Thalamus (anterior thalamic nuclei)
- Hypothalamus

Cerebral cortex structures:

- Cingulate gyrus
- Parahippocampal gyrus
- Hippocampus
- Amygdala

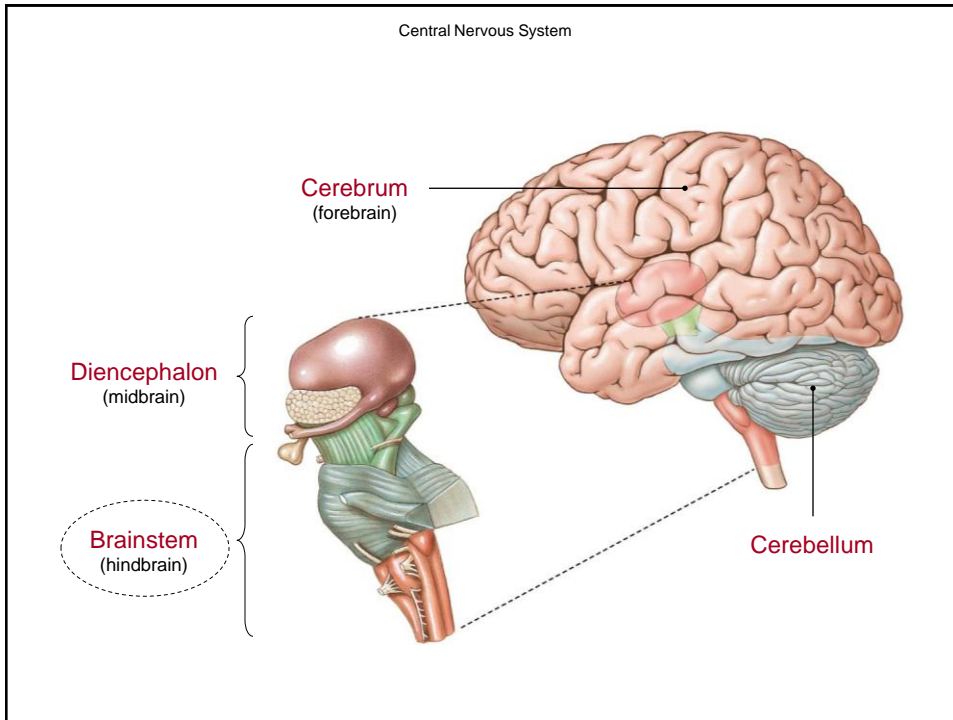


➤ Alzheimer's Disease:

Progressive degenerative disease of the brain

- Memory loss
- Disorientation
- Moodiness / confusion

- Control emotional states (e.g., fear) / behavioral drives (e.g., sex drive)
- Link conscious (cerebral cortex) with unconscious function (brain stem)
  - Psychosomatic illnesses = emotion-induced illness
- Long-term memory storage / retrieval



Central Nervous System

Brain Anatomy:

D. **Brain stem:**

- Deep gray matter; superficial white matter
- Produce rigidly programmed, autonomic behaviors necessary for survival
- Conduction pathways between higher and lower brain centers

**Midbrain:**

- Visual / auditory reflex centers

**Pons:**

- Regulate respiration rate / depth

**Medulla oblongata:**

- Location where fiber tracts from spinal cord cross over (**decussation**)
- Autonomic reflex center
  - Heart rate / blood pressure
  - Respiratory rhythm
  - Vomiting / hiccupping / etc.

**Thalamus**

**Midbrain**

**Pons**

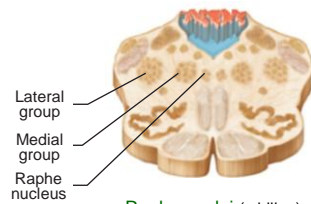
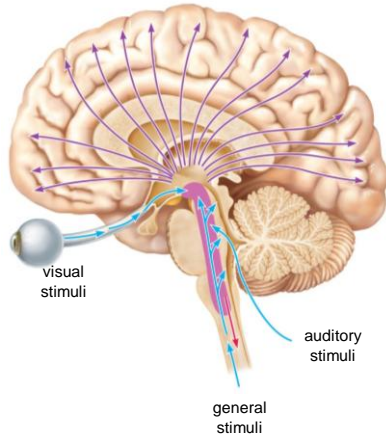
**Medulla oblongata**

Marieb & Hoehn – Figure 12.15

Brain Anatomy:

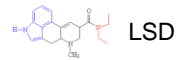
Reticular Activating System (RAS - functional brain system):

Aggregation of loosely clustered neurons:

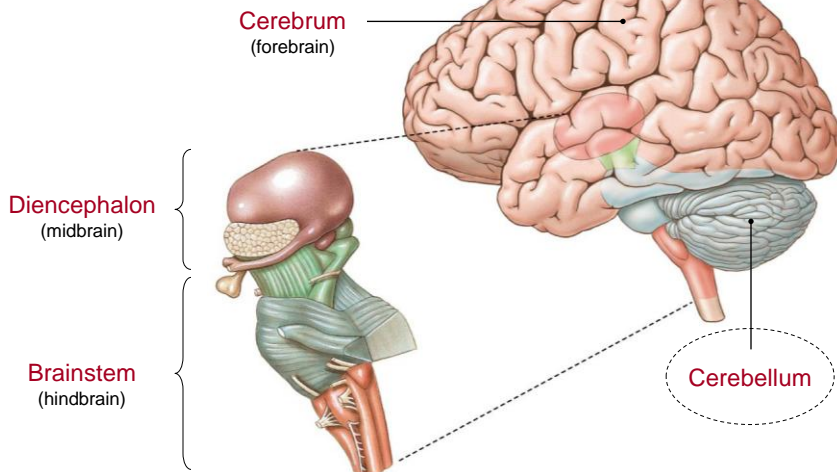


- Raphe nuclei (midline)
- Medial (large cell) group
- Lateral (small cell) group

Twisting of brain stem can lead to irreversible coma



- Maintains cerebral cortical alertness (e.g., on / off switch)
- Filters out repetitive stimuli (~ 99% of stimuli filtered...)

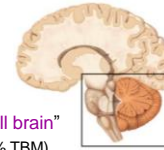


Brain Anatomy:

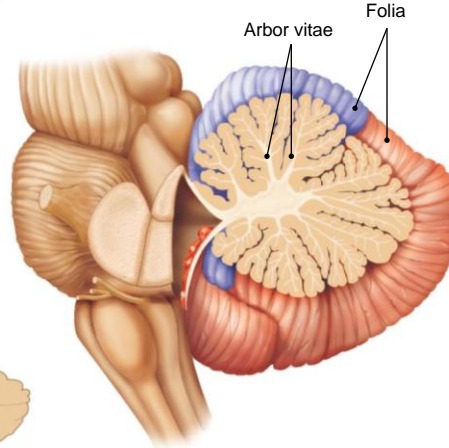
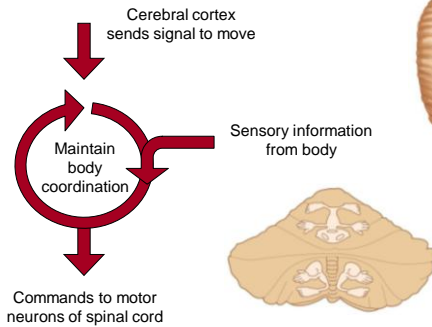
E. Cerebellum:

- Gray matter superficial; white matter deep
- Precise timing of muscle coordination  
(balance, posture, repeated movements)
- All activity subconscious

"Small brain"  
(11% TBM)



Cerebellar Processing:



Marieb & Hoehn – Figure 12.17

Protection of the Brain:

- 1) **Bone** (Skull – cranium portion)
- 2) **Meninges** (specialized connective tissue membranes)

Meningitis:

Inflammation of the meninges

A) **Dura mater** ("tough mother")

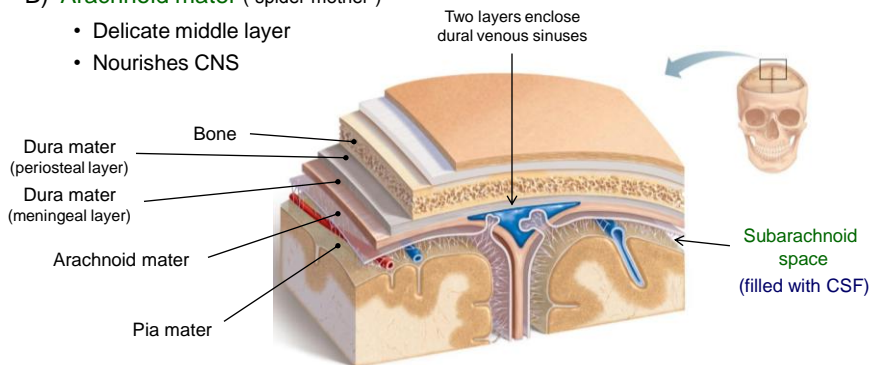
- Fibrous outer coating (2 layers)
- Protects CNS

C) **Pia mater** ("gentle mother")

- Thin inner membrane
- Contains blood vessels

B) **Arachnoid mater** ("spider mother")

- Delicate middle layer
- Nourishes CNS



Marieb & Hoehn – Figure 12.24

Central Nervous System

Protection of the Brain:

Constant internal environment necessary for proper neuronal functioning in brain

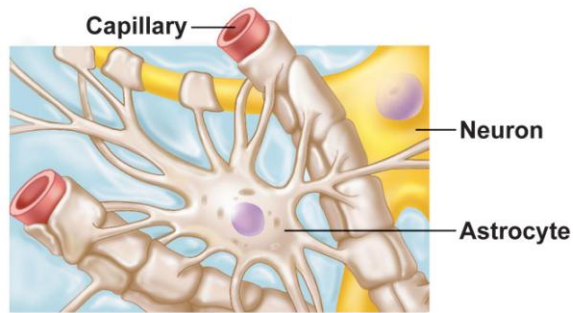
- 1) **Bone** (Skull – cranium portion)
- 2) **Meninges** (specialized connective tissue membranes)
- 3) **Blood-brain barrier**: Astrocyte-maintained barrier lining blood capillaries

Three layers of protection:

- A. Capillary endothelium
- B. Thick basal lamina
- C. Bulbous 'feet' of astrocytes
  - Signal tight junction formation

Tightly regulate substances bathing brain:

- In:** glucose, amino acids, selected electrolytes
- Out:** metabolic waste (urea), proteins, toxins, drugs



- Displays differentially permeable (e.g., vomit center → brain stem)

Marieb & Hoehn – Figure 11.3

Central Nervous System

Homeostatic Imbalances of the Brain:

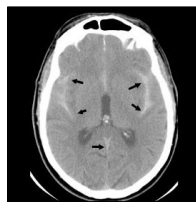
- 1) **Traumatic brain injury**

Leading cause of accidental death in North America



**Concussion**

Alteration in brain function following blow to head



**Subdural hemorrhage**

Bleeding into subarachnoid space via ruptured vessels

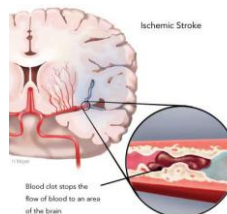


**Cerebral edema**

Swelling of the brain

- 2) **Cerebrovascular accident**
- 3) **Degenerative brain disorders**

- **Alzheimer's disease**
- **Parkinson's disease**
- **Huntington's disease**

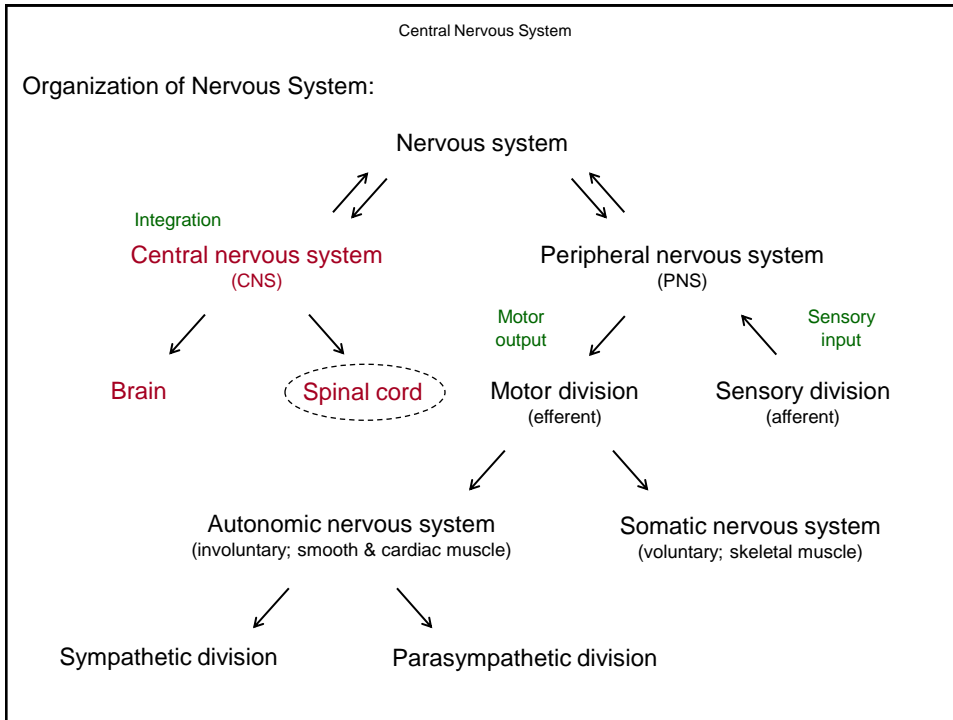


Third leading cause of death in North America

**Ischemic stroke**

Blockage of blood supply to brain due to blood clot

- May be transient



Central Nervous System

Protected by vertebral column / meninges

Spinal Cord:

- Provides conduction pathway to / from brain
- Contains major reflex centers
- Independently initiates patterns of motor activity (e.g., walking)

Gross Anatomy:

- ~ 18 inches long (via vertebral foramen)
- Two enlargements (cervical / lumbar)
  - Innervation of limbs
- Cord proper ends at L<sub>1</sub>
  - **Cauda equina** ("horse's tail")
- Spinal nerves (31 pairs)

Cervical enlargement

Lumbar enlargement

Conus medullaris

Cauda equina

Cervical region (8)

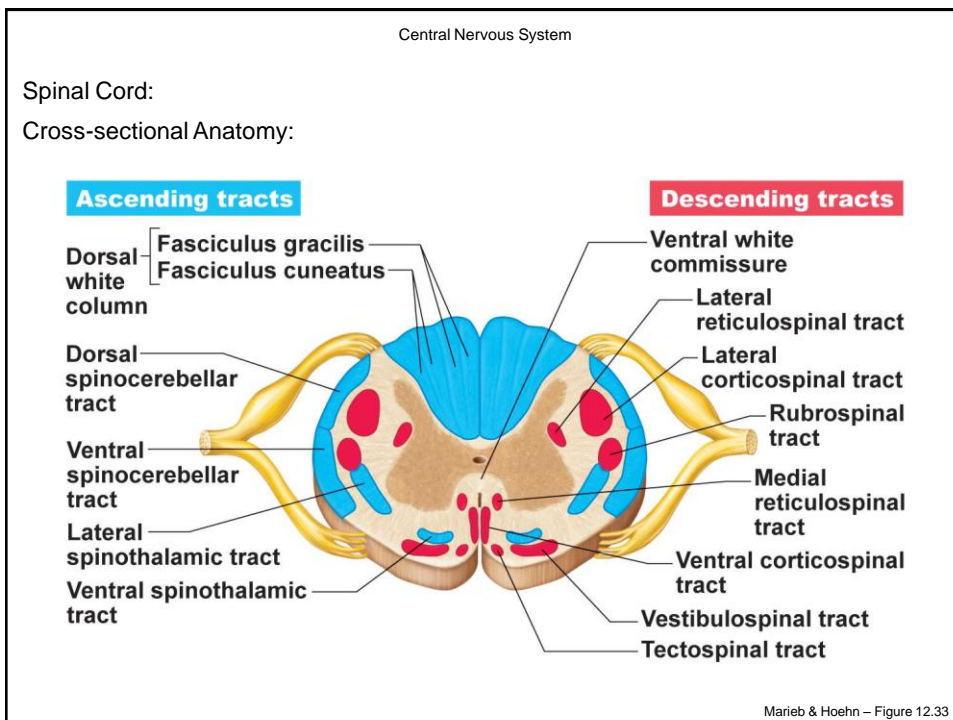
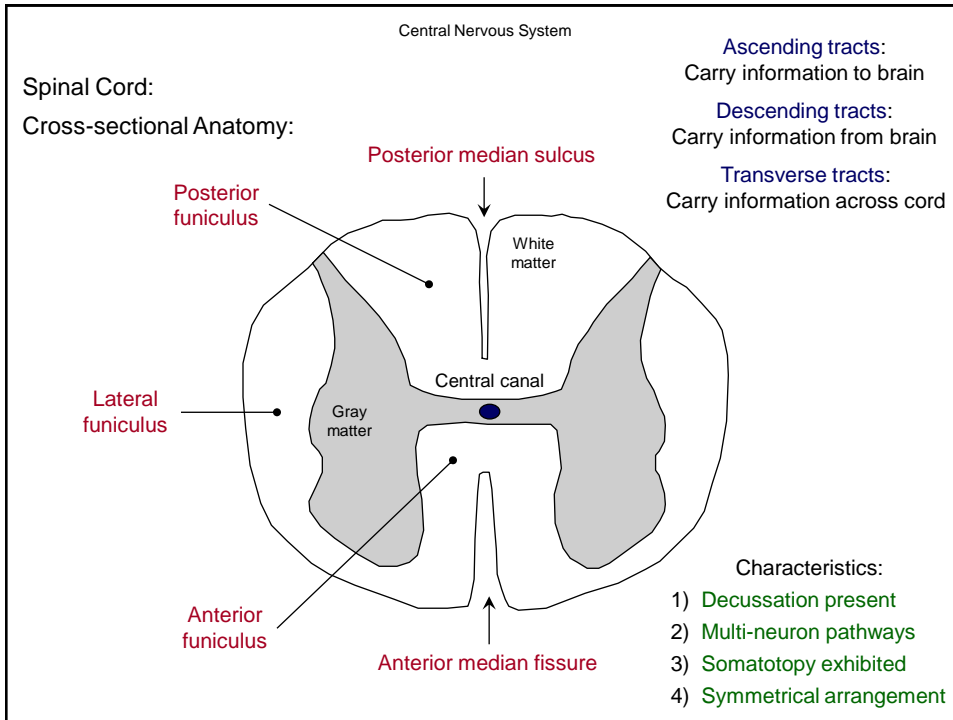
Thoracic region (12)

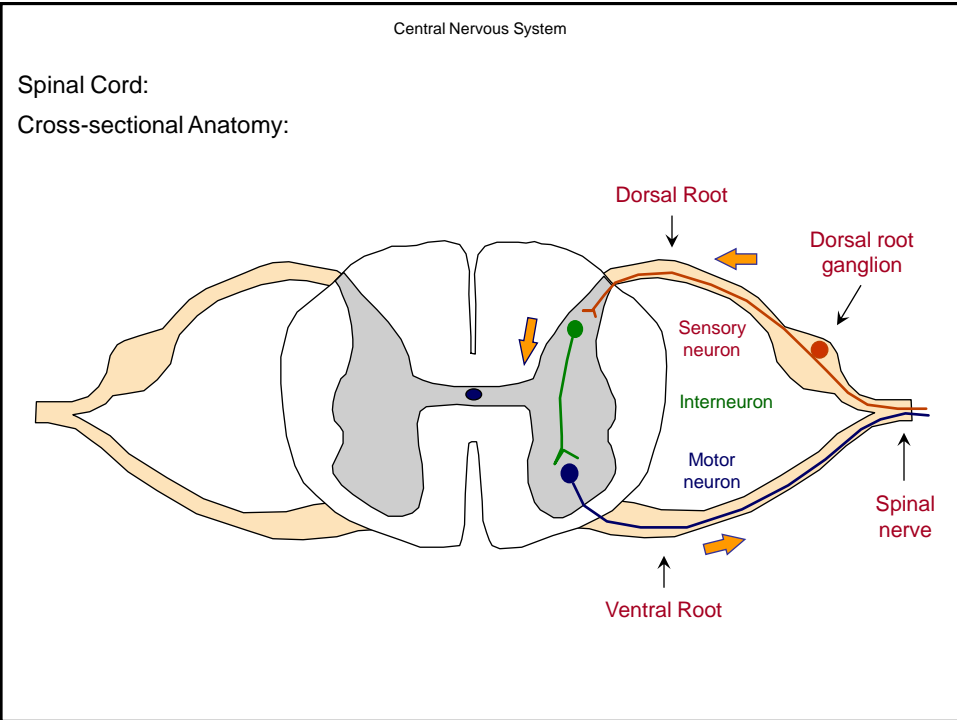
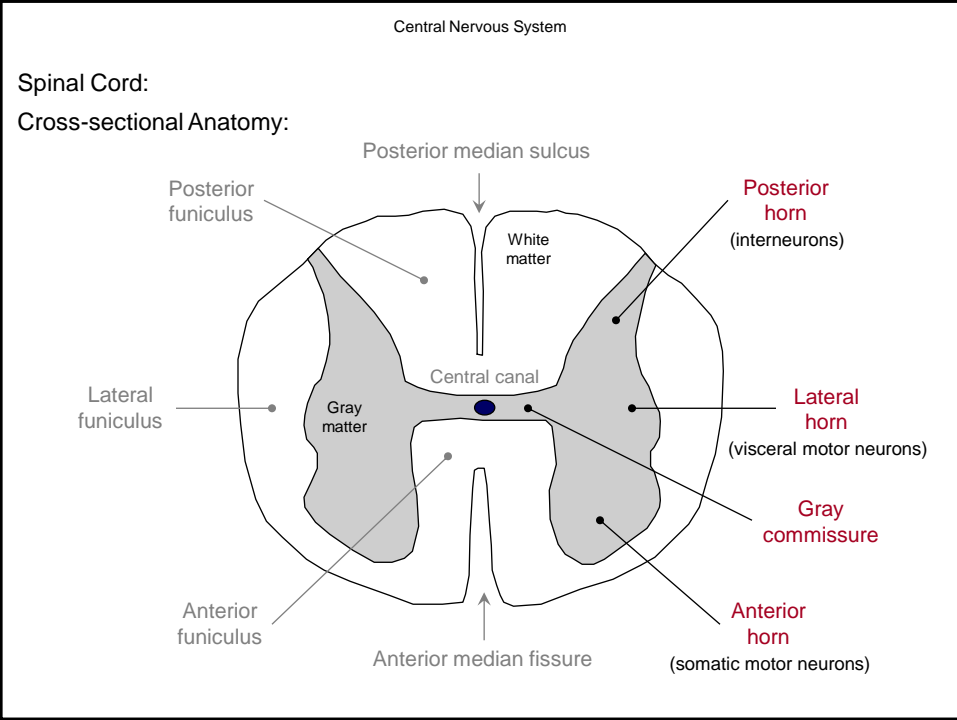
Lumbar region (5)

Sacral region (5)

(1)

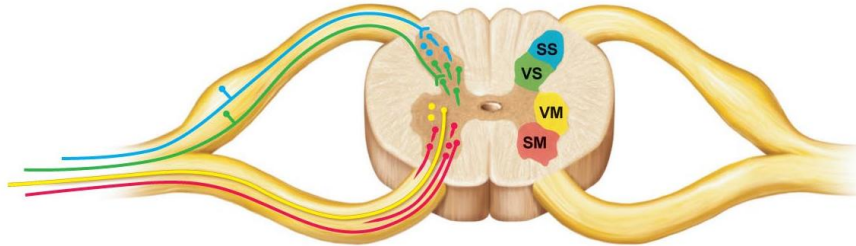
Marieb & Hoehn – Figure 12.29





Central Nervous System

Spinal Cord:  
Organization of Gray Matter:



- SS** Interneurons receiving input from somatic sensory neurons
- VS** Interneurons receiving input from visceral sensory neurons
- VM** Visceral motor (autonomic) neurons
- SM** Somatic motor neurons

Central Nervous System

Homeostatic Imbalances of the Spinal Cord:

1) Spinal cord trauma



**Paralysis / Paresthesias**

Damage to spinal cord leading to functional / sensory loss



**Paraplegia**

Transection of spinal cord between T<sub>1</sub> and L<sub>1</sub>



**Quadriplegia**

Transection of spinal cord between C<sub>4</sub> and C<sub>7</sub>

2) Poliomyelitis



Destruction of ventral horn motor neurons by poliovirus

3) Amyotrophic lateral sclerosis (ALS)



Lou Gehrig's disease

Progressive destruction of ventral horn motor neurons (autoimmune?)