Nervous System (NS)

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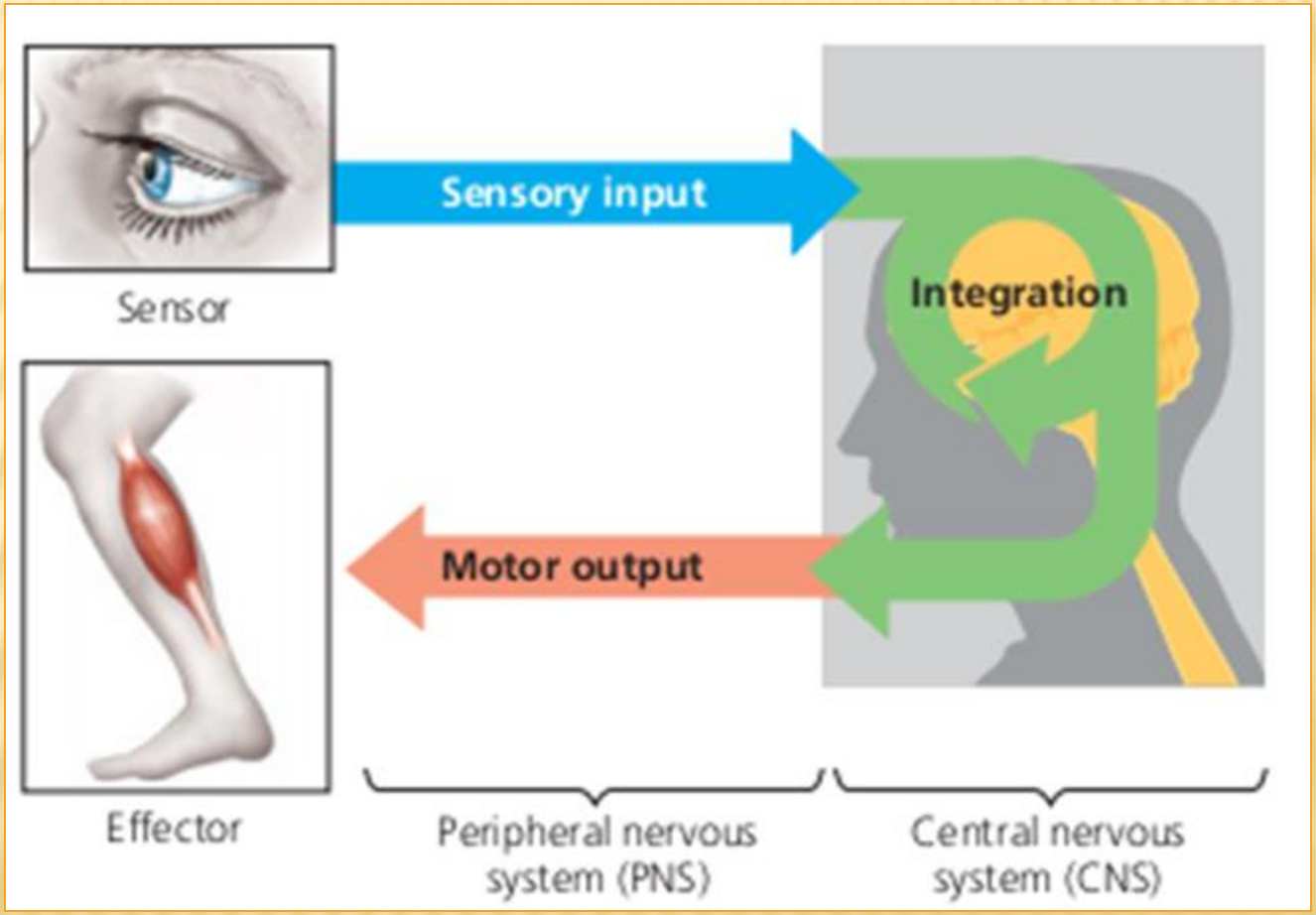
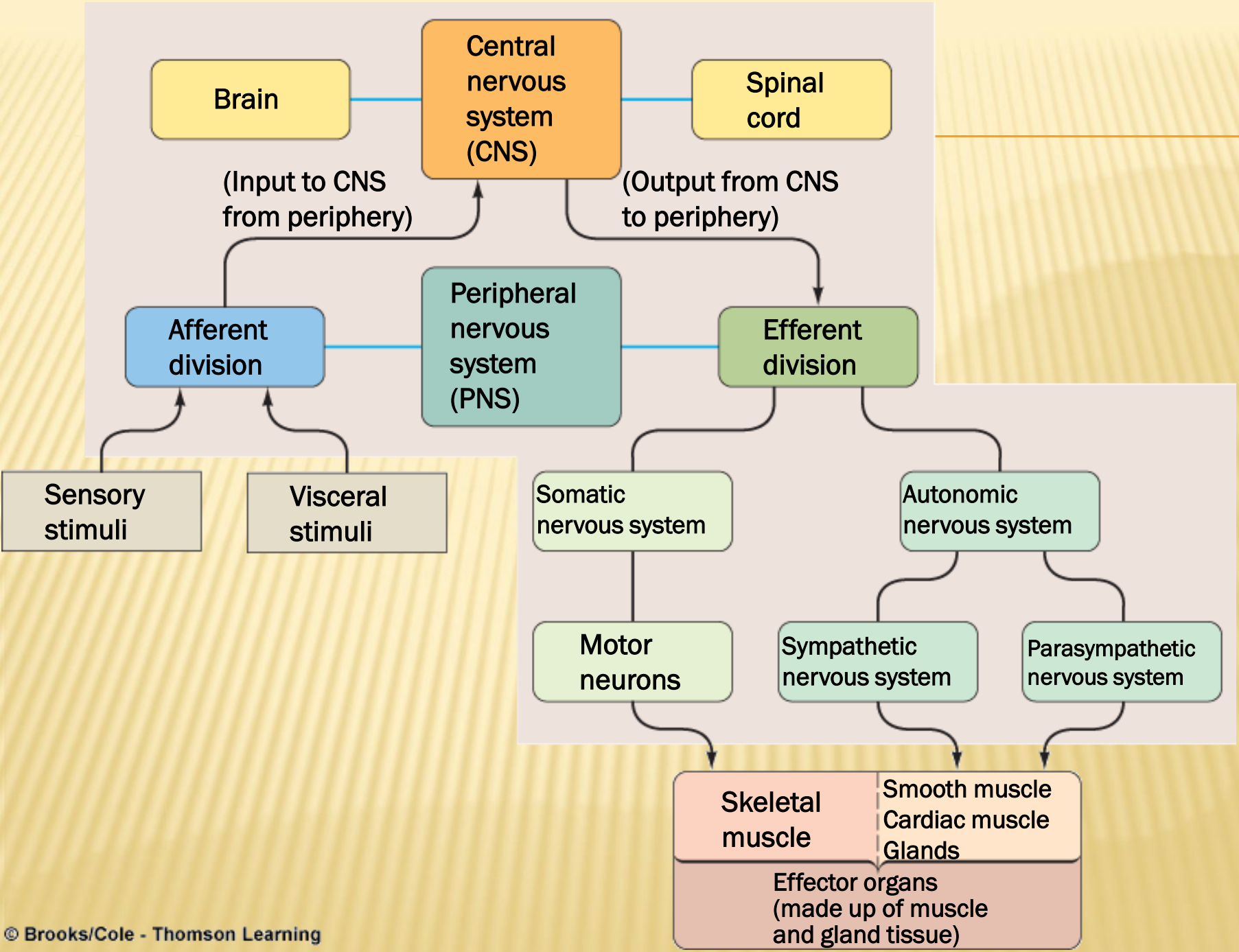
Organization of the Nervous System

- Based on differences in the structure, location, and functions, nervous system is subdivided into:

1. Central nervous system (CNS)
   - Brain and spinal cord
   - Contained within bone
2. Peripheral nervous system (PNS)
   - All nerve tissue outside CNS
   - Cranial and spinal nerves
   - Sensory & motor divisions

Generalized Model of Function of NS



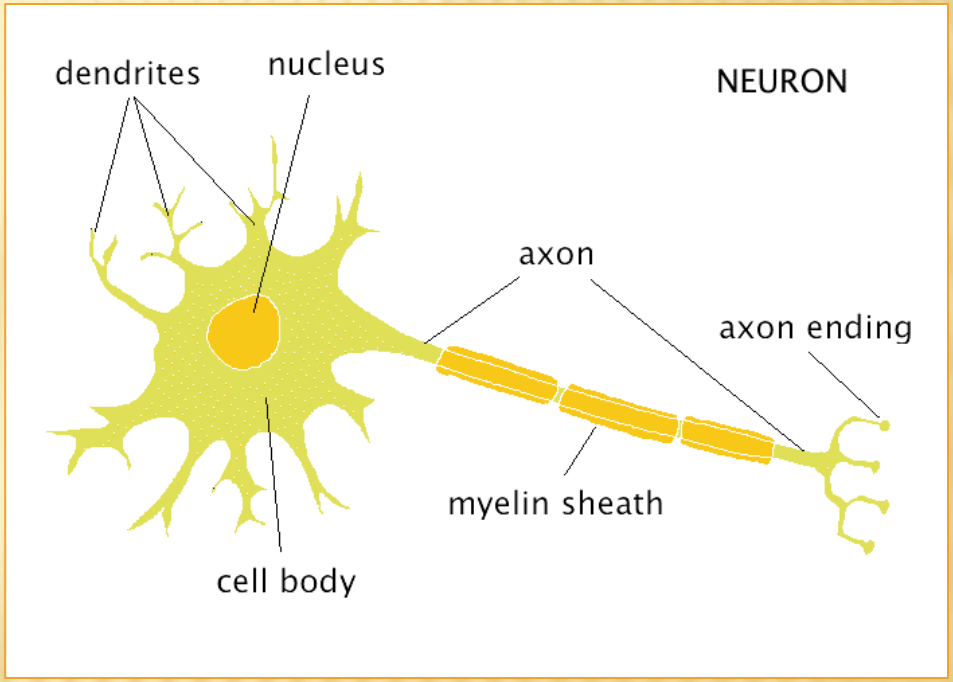


Cells of the Nervous System

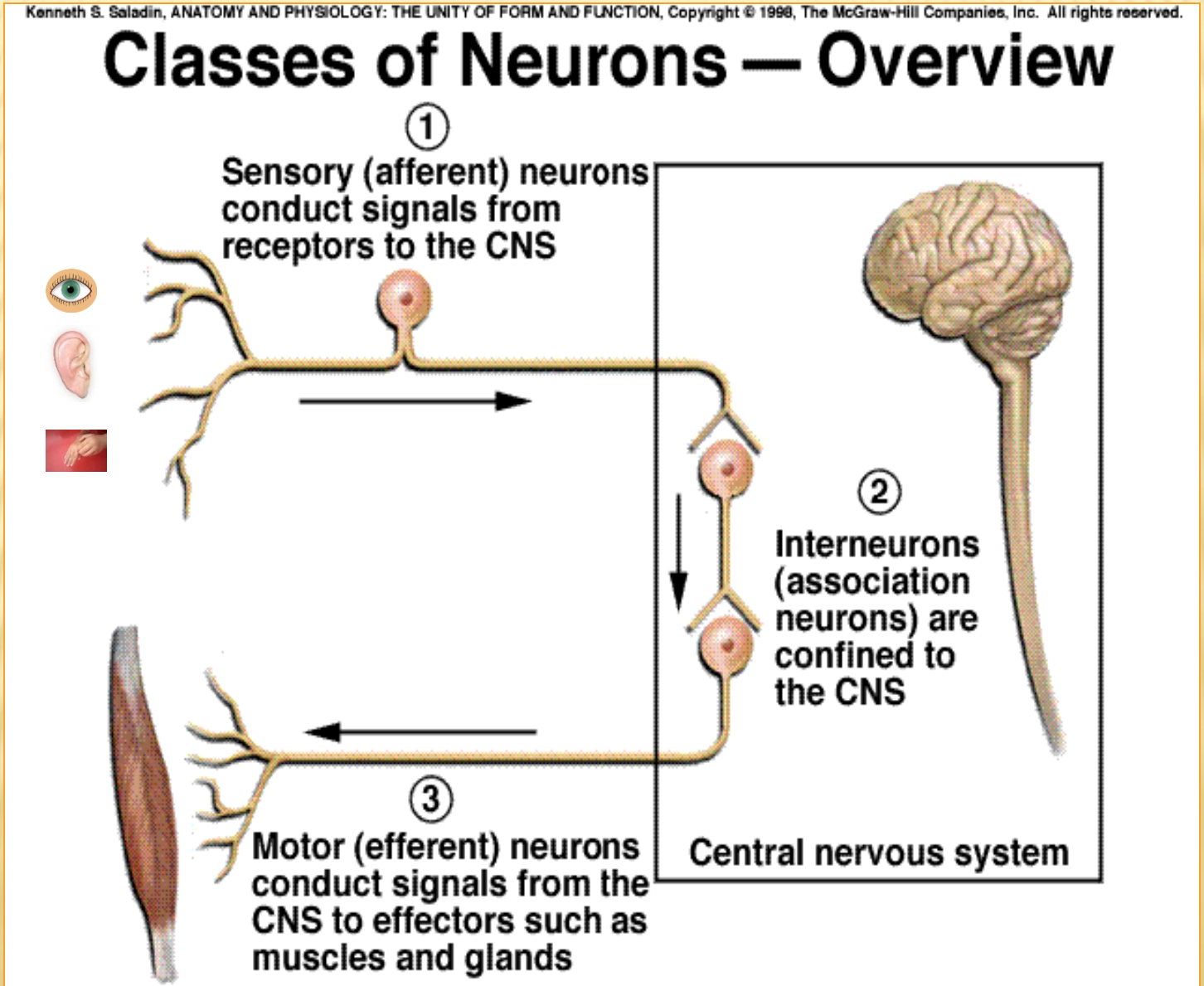
- Consists of 2 kinds of cells:
  - Neurons: functional units of NS
  - Supporting cells (= glial cells)
    - Maintain homeostasis
    - Are 5X more common than neurons
    - Schwann and satellite cells in the PNS
    - Oligodendrocytes, microglia, astrocytes and ependymal cells in the CNS

Neurons

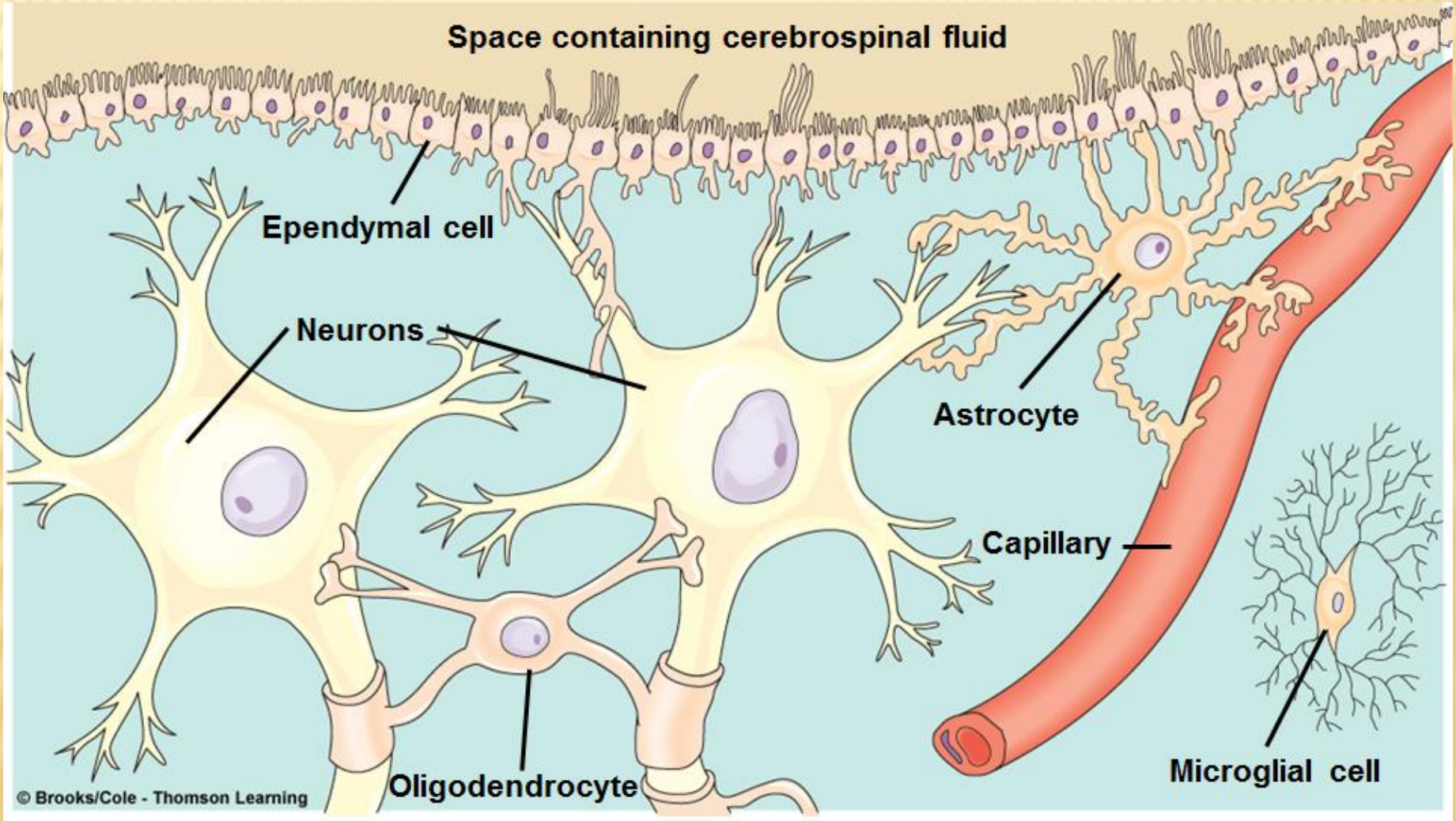
- **Gather and transmit information by:**
  - Responding to stimuli
  - Producing and sending electrochemical impulses
  - Releasing chemical messages
- **Have a cell body, dendrites and axon**
  - **Cell body**:
    - Contains the nucleus
    - Cell body is the nutritional center and makes macromolecules
    - Groups of cell bodies in CNS are called nuclei; in PNS are called ganglia
  - **Dendrites** receive information, convey it to cell body
  - **Axons** conduct impulses away from cell body



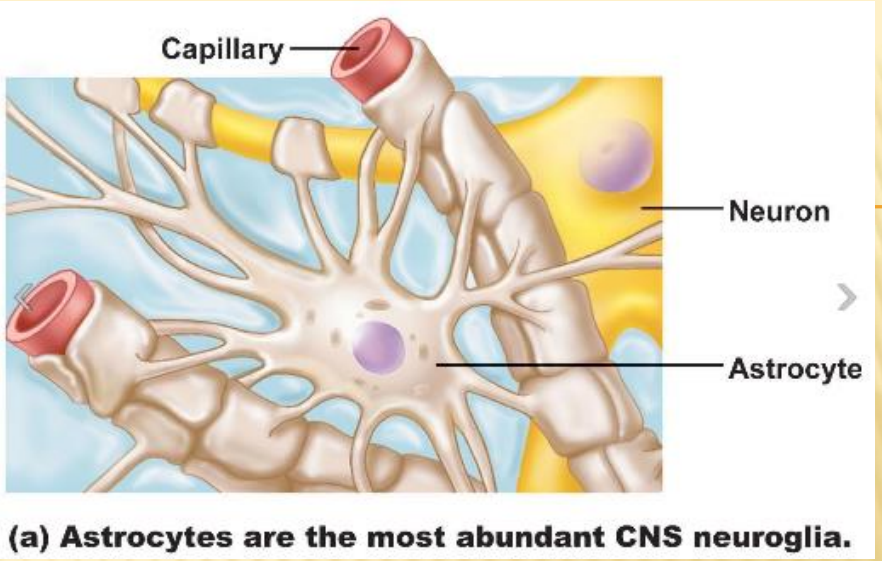
Functional Classes of Neurons



Functions of the Glial Cells



Astrocytes

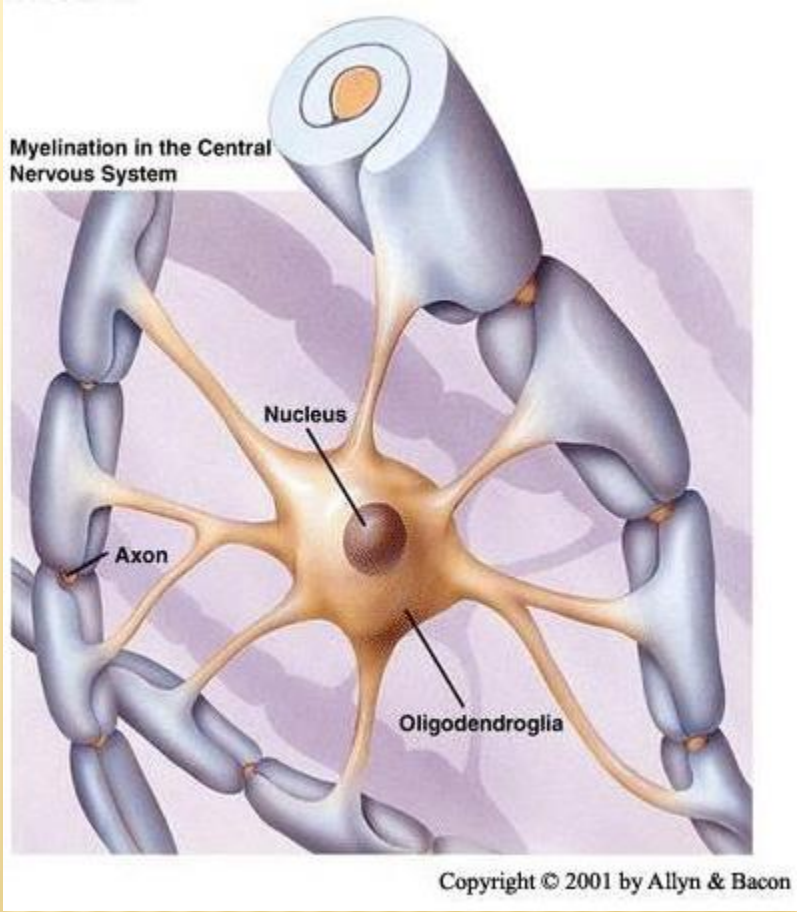


(a) Astrocytes are the most abundant CNS neuroglia.

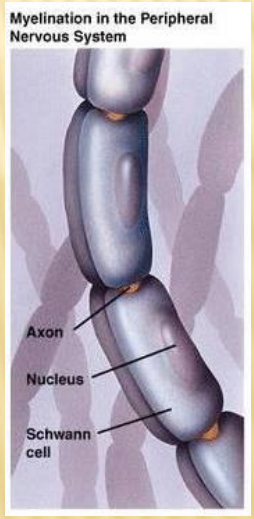
- Star-like shape
- The most abundant glial cells.
- Functions:
  1. The main “glue” of the CNS
  2. Scaffold to guide neurons to their proper final destination during fetal brain development
  3. Establishing the blood–brain barrier (BBB)
  4. Role in repairing brain injuries and neural scar formation
  5. Role in neurotransmitter activity; taking up and degrading glutamate (excitatory) and GABA (inhibitory)
  6. Taking up excess K from the brain ECF
  7. Communicating with neurons by means of local chemical signals (important in synaptic transmission and the brain’s processing of information).

Oligodendrocytes

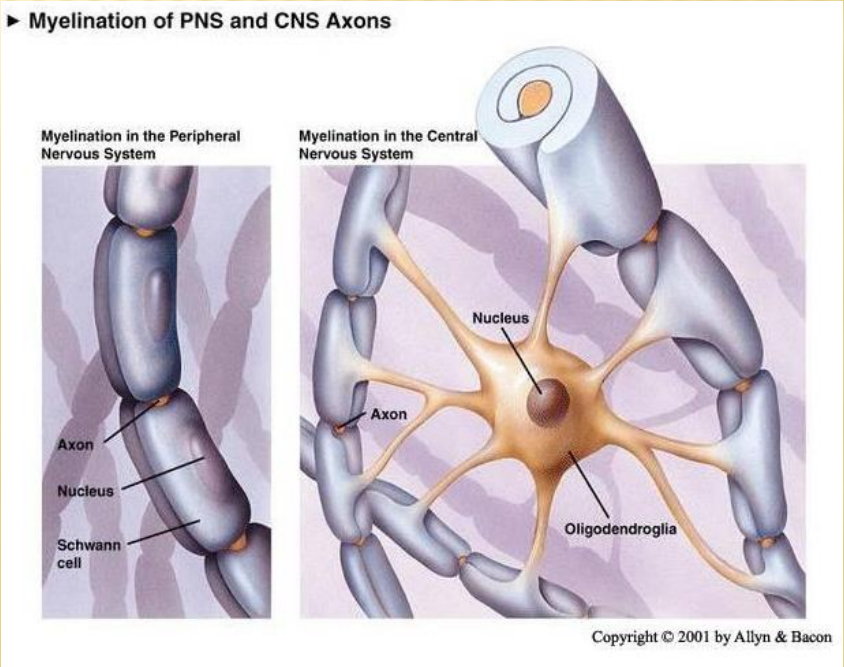
- Form myelin sheaths around axons in the CNS
- Secrete nerve-growth–inhibiting proteins e.g., *Nogo* late in fetal life; keeping new nerve endings from straying outside their proper paths



Schwann cells

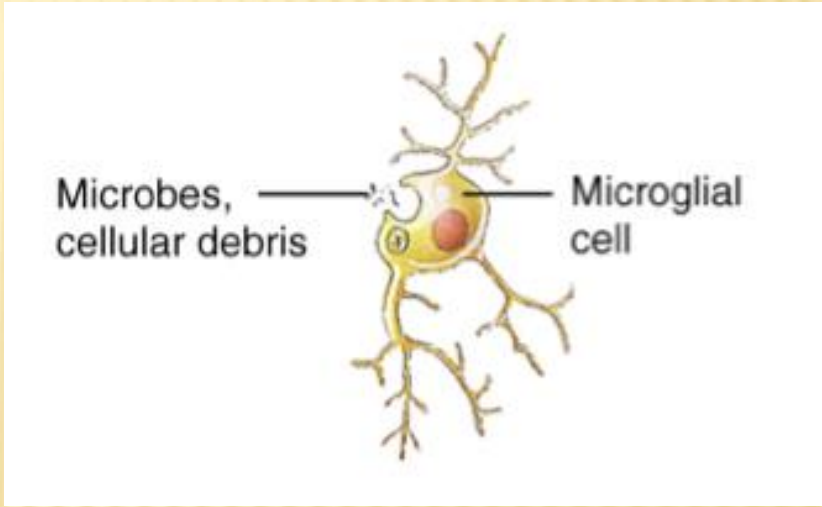


- Form myelin sheaths around axons in the PNS
- Form a regeneration tube and secrete nerve-growth–enhancing proteins that respectively guide and promote regrowth of damaged peripheral axons, as long as the cell body and dendrites remain intact (that is, as long as the neuron is still alive).
- **Schwann cells** can wrap around only one axon. While each **oligodendrocyte** forms one segment of myelin for several adjacent axons.



Microglia

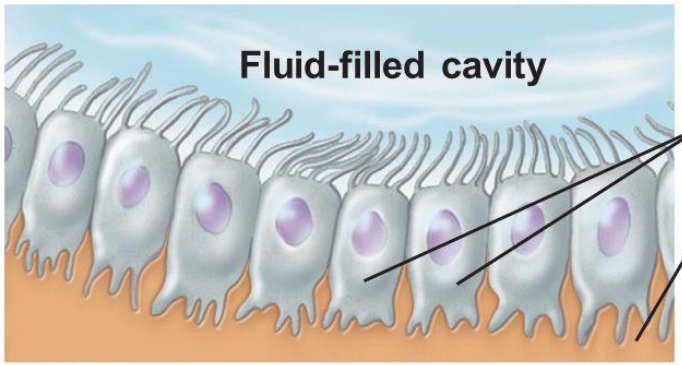
- The immune defense cells of the CNS.
- They are phagocytes; remain stationary until activated by an infection or injury.



- Activated microglia release destructive chemicals for assault against their target.

Ependymal Cells

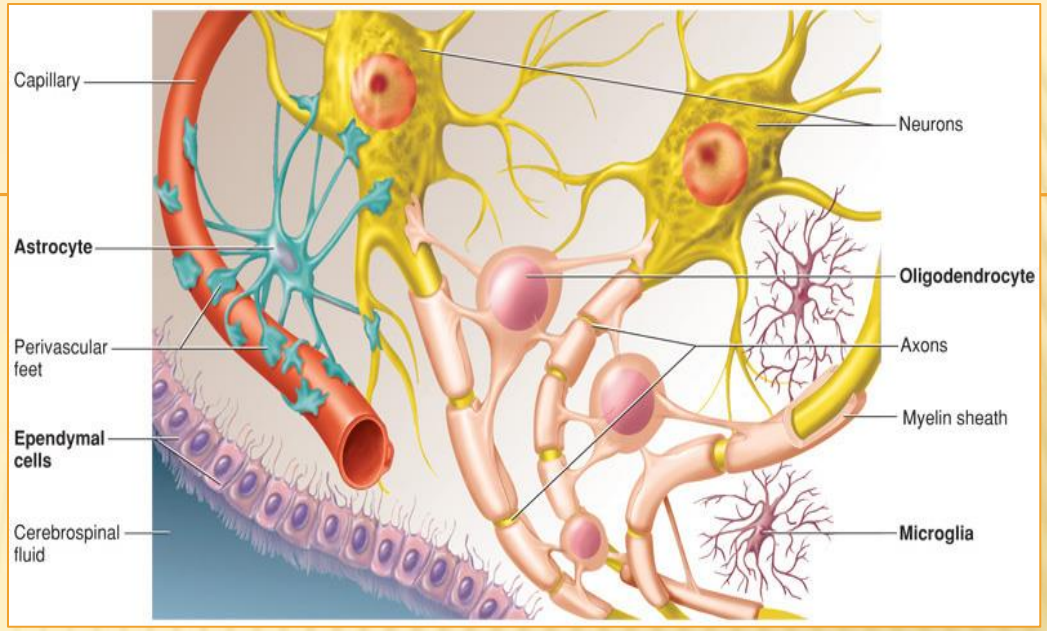
- Line the internal, fluid-filled cavities of the CNS—the ventricles of the brain and the central canal of the spinal cord.
- Serve as neural stem cells; potential of forming other glial cells & new neurons



(c) Ependymal cells line cerebrospinal fluid-filled cavities.

Figure 11.3c

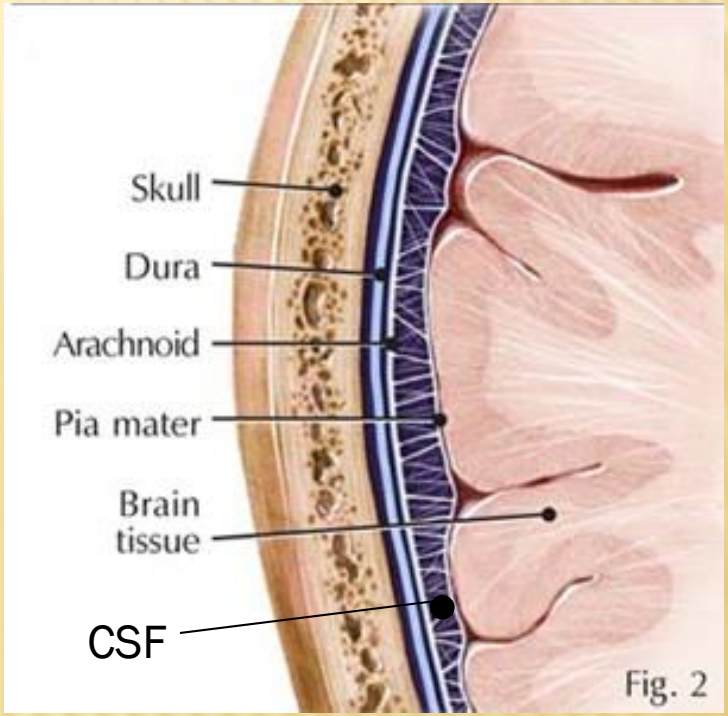
Functions of the Glial Cells



Neuroglia	Function
Schwann Cells	surround axons of all peripheral nerve fibres, form the myelin sheath.
Oligodendrocytes	form myelin sheath around central axons producing the white matter of central nervous system.
Astrocytes	cover capillaries of brain to form the blood brain barrier and help regulate passage of molecules from blood to brain.
Ependyma	line the ventricles or brain cavities and central canal of spinal cord.
Microglia	phagocytic amoeboid cells in central nervous system that remove foreign and degenerate material from the brain.

Protection of CNS

- Enclosed by hard, **bony structures**; the cranium (skull) encases the brain, and the vertebral column surrounds the spinal cord.
- Wrapped by three protective and nourishing membranes – **meninges**
- Floats in cushioning fluid – cerebrospinal fluid (**CSF**)

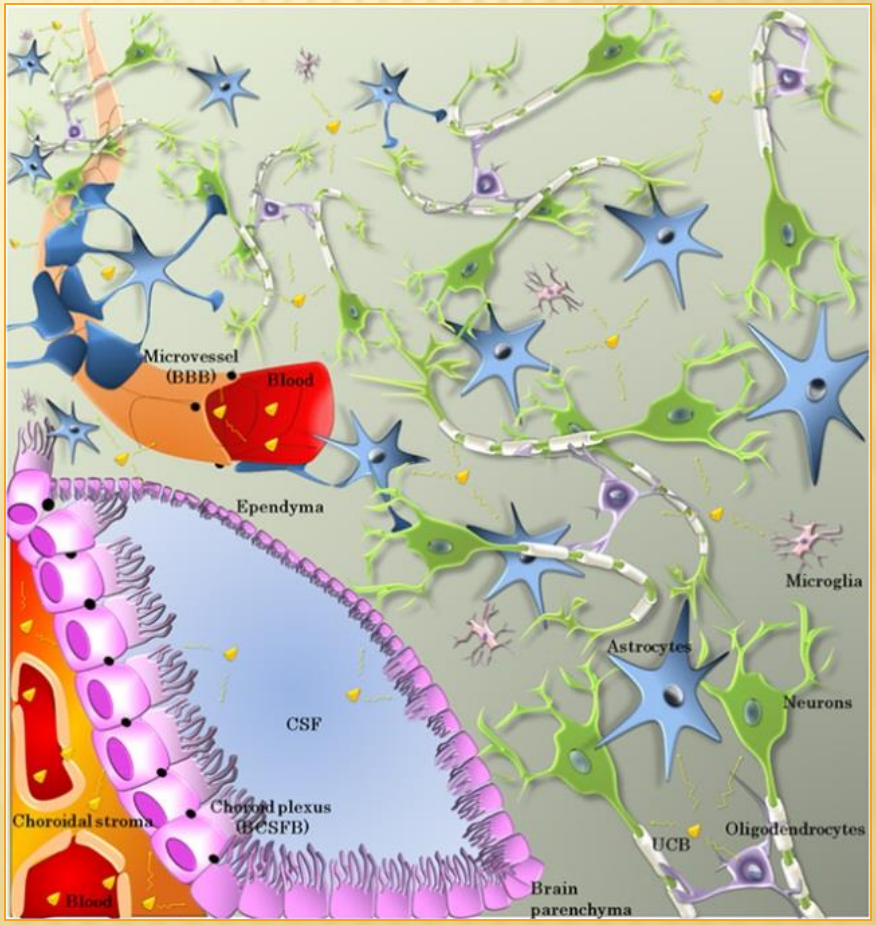


- Blood-brain barrier (**BBB**) limits access of blood-borne materials into brain tissue

Cerebrospinal Fluid (CSF)

- Four major fluid compartments in the brain:

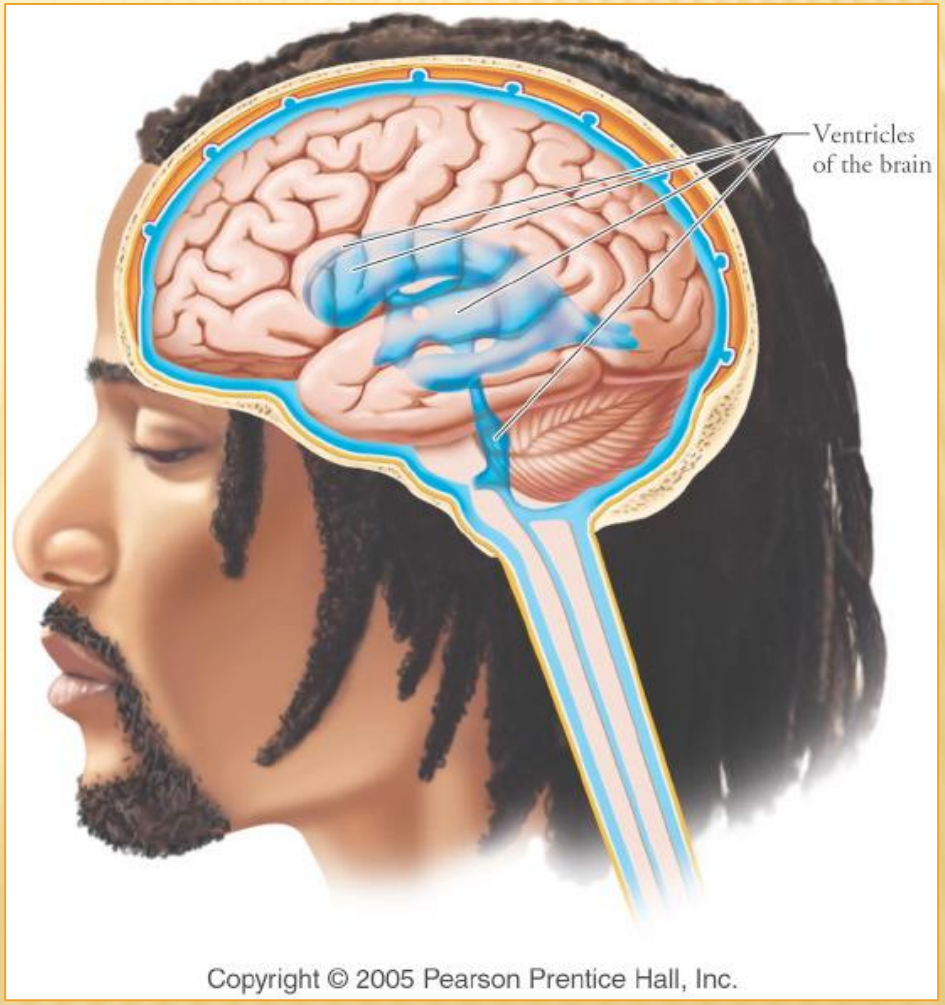
1. **blood** that flows through entire brain structures
2. **interstitial fluid** bathing neurons and neuroglia
3. **cerebrospinal fluid (CSF)**, circulates around brain ventricles, and spinal cord
4. **intracellular fluid** within brain cells



Gazzin et al., 2012

Cerebrospinal Fluid (CSF)

- Colorless protein-poor serous plasma filtrate surrounding brain & spinal cord
- ≈ 150 mL
- Occupying mainly:
  1. the ventricular system
  2. the subarachnoid space
  3. the central canal of the spinal cord

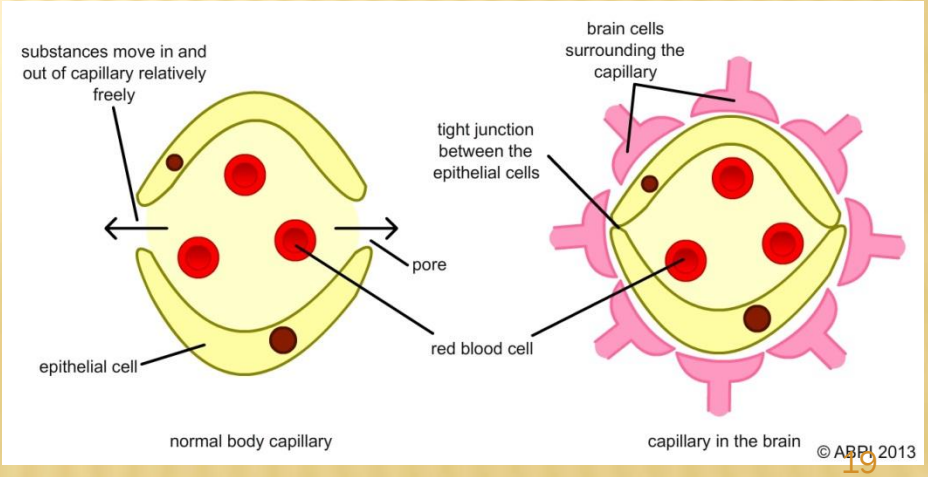


Cerebrospinal Fluid (CSF)

- **CSF functions:**
  - Shock absorption; fluid cushion for the brain and spinal cord
  - Second circulatory fluid; delivering oxygen and nutrients to the nervous tissue
  - Major route for removing potentially harmful brain metabolites; serving as a lymphatic system for the brain
  - Allows the brain to float, thereby reducing its effective weight in situ
  - Conduit for hormones that are secreted by hypothalamic neurons and act at remote sites in the brain

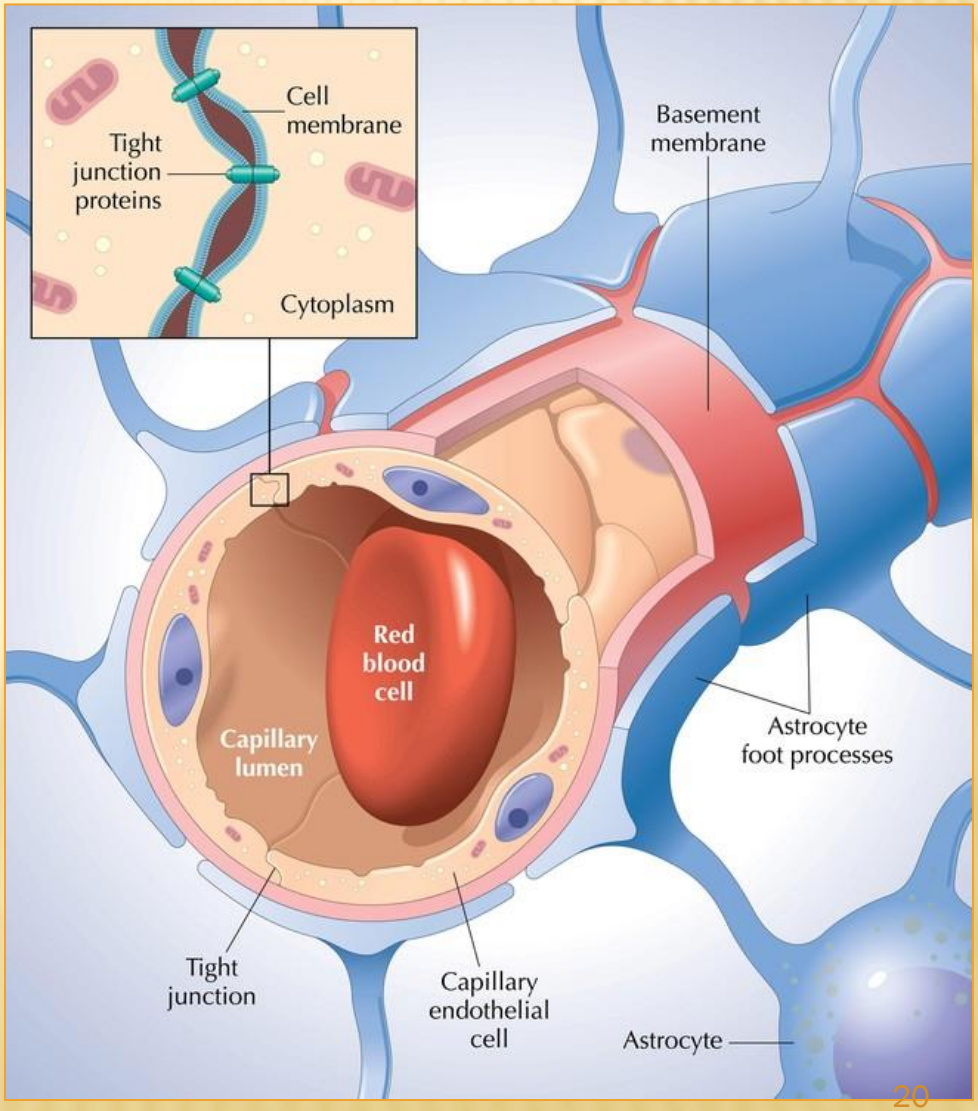
Blood Brain Barrier (BBB)

- Between the blood and brain fluid (at capillaries)
- All over the brain except some areas e.g., hypothalamus
- Allows only certain compounds to enter brain
- Capillaries are not as leaky as those in body
  - Gaps between adjacent cells are closed by tight junctions



Blood Brain Barrier (BBB)

- Consists of:
  - Capillary endothelial cells
    - Gaps between adjacent cells are closed by tight junctions
  - Continuous basement membrane
  - The processes of astrocytes (astrocytic endfeet)



The Central Nervous System (CNS)

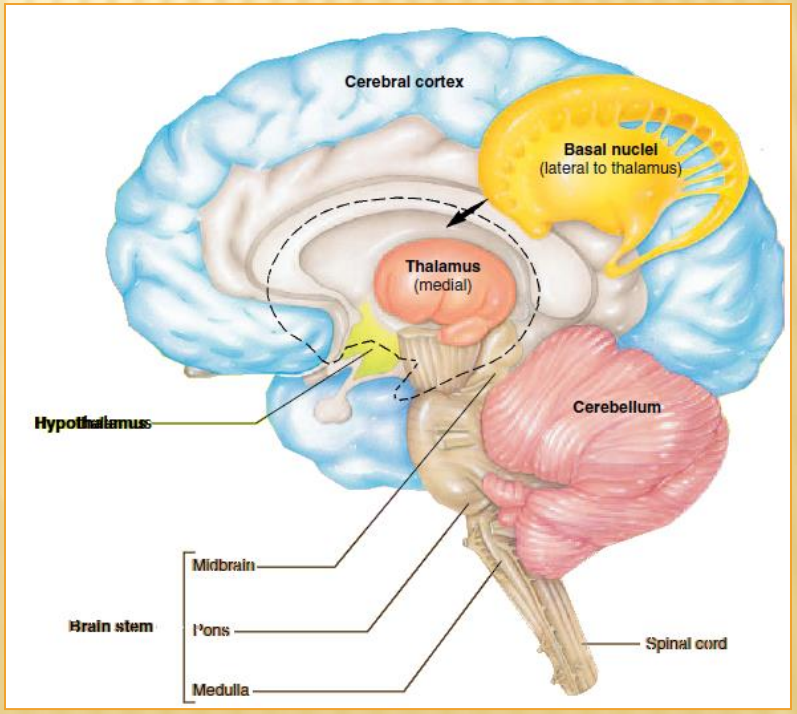
- Consists of:

1. The brain
2. Spinal cord

The Brain

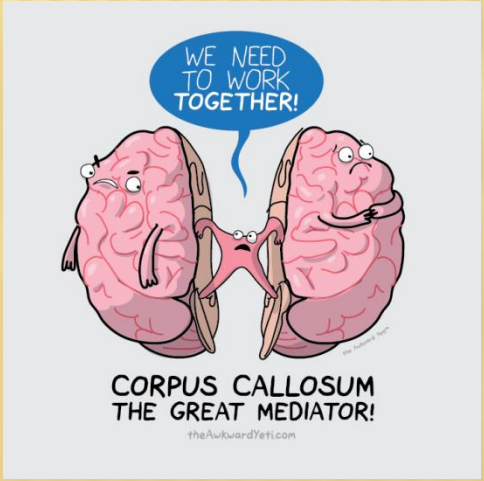
- **Major brain functions (Brain functions as a whole (neurons linked via synapsis):**
  - ✓ Regulating internal environment
  - ✓ Experiencing emotions
  - ✓ Voluntarily controlling movements
  - ✓ Perceiving own body and surroundings
  - ✓ Engagement in other higher cognitive processes (e.g. thought and memory)

- **Brain Regions**
  1. Brain stem (Medulla, pons, midbrain)
  2. Cerebellum
  3. Forebrain
     a. Diencephalon
        - Hypothalamus
        - Thalamus
     b. Cerebrum
        - Basal nuclei
        - Cerebral cortex



Cerebral Cortex

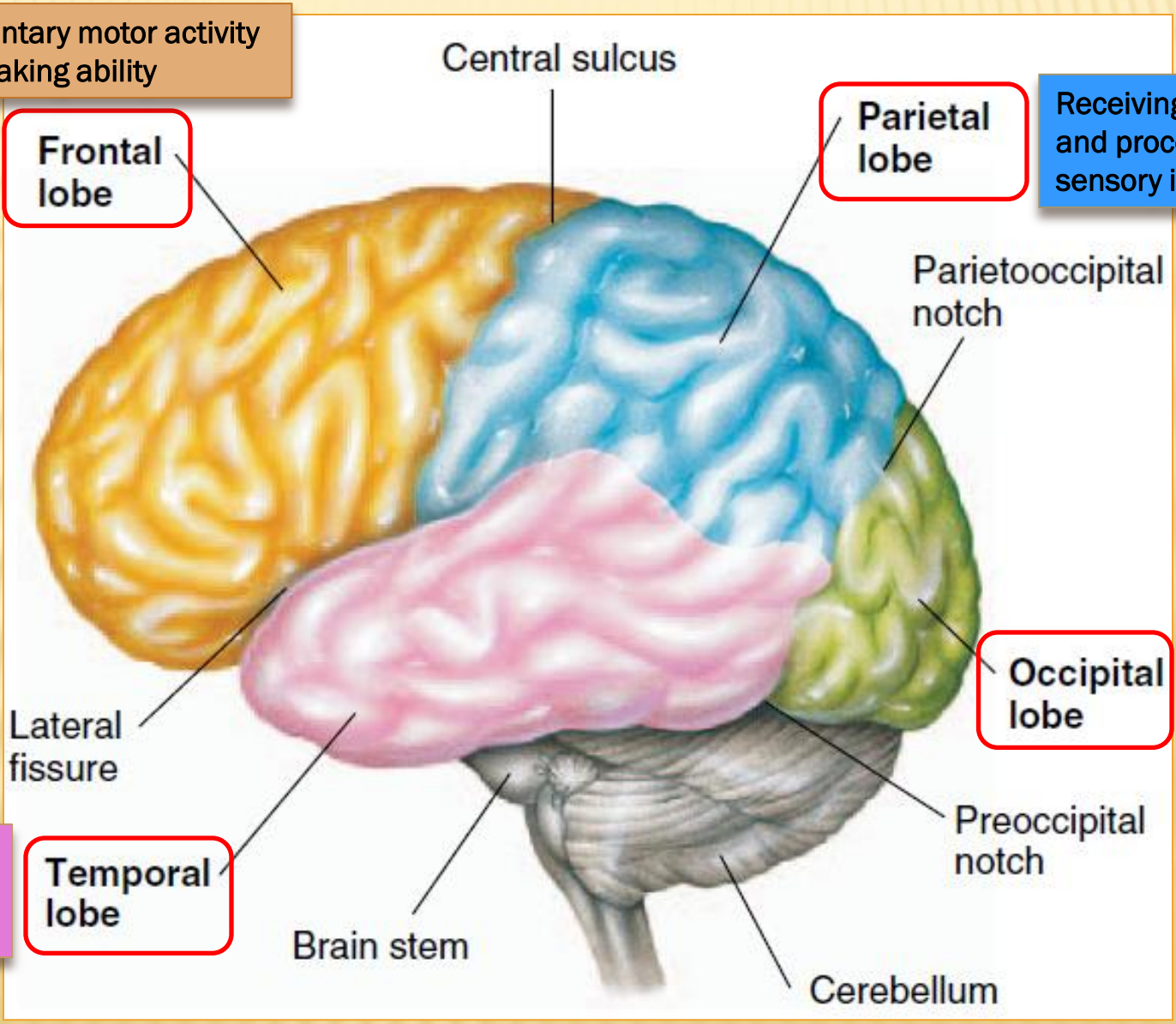
- The outermost sheet of neural tissue (gray matter) of the cerebrum of the brain
  - Convoluted
  - Total surface area: 2200 cm2 (2.5 ft2)
  - Thickness: 1.5 mm - 4.5 mm
  - Weight: 600 gm (40 % of total brain weight)
  - 180 gm --------- neurons (10-15 billion neurons)
  - 420 gm --------- glial cells
  - Two hemispheres connected to each other by the corpus callosum "information superhighway"



- Function: motor control of the body & information processing center

Functions of Cortical Lobes

- Voluntary motor activity
- Speaking ability



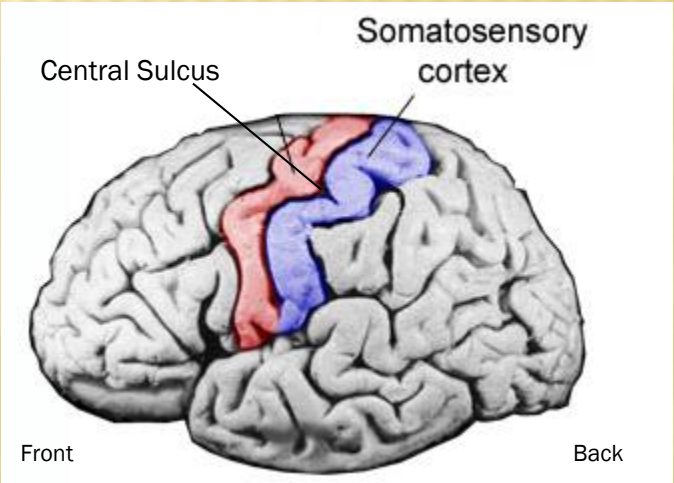
Receiving and processing sensory input

Initial processing of visual input

sound (auditory) sensation

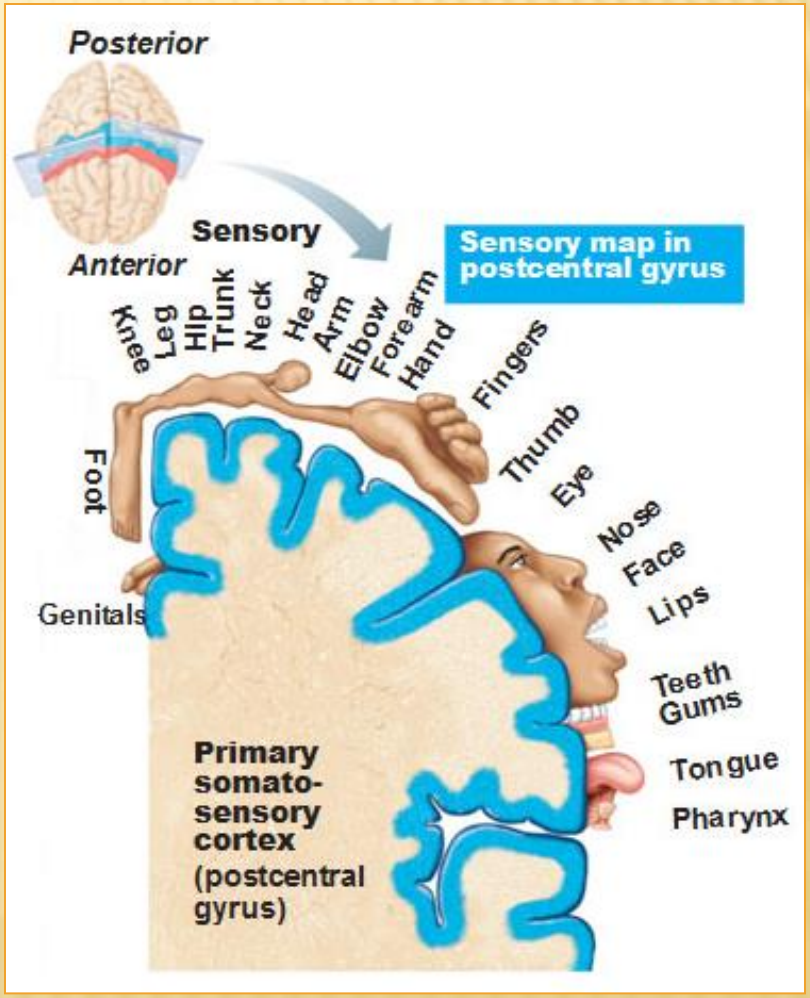
Somatosensory Cortex

- located in the front portion of each parietal lobe
- Immediately behind the central sulcus
- Post-central gyrus
- It is the site for initial cortical processing and perception of:
  - Somesthetic sensations from the surface of the body, such as touch, pressure, heat, cold, and pain
  - Proprioceptive sensation (awareness of body position)



Somatosensory Cortex

- Each region within the somatosensory cortex receives input from a specific area of the body.
- Different parts of the body are not equally represented
- The size of each body part in this homunculus indicates the relative proportion of the somatosensory cortex devoted to that area. (e.g., fingers >>> trunk)
- Reception of <u>opposite side</u> inputs

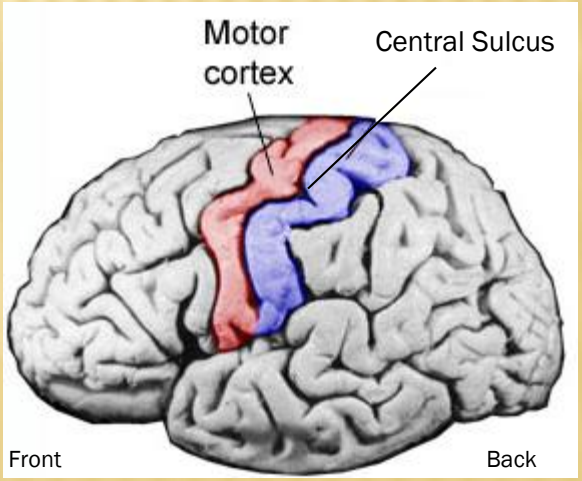


Sensory Homunculus

Proportional representation of the different body parts and areas in brain hemispheres

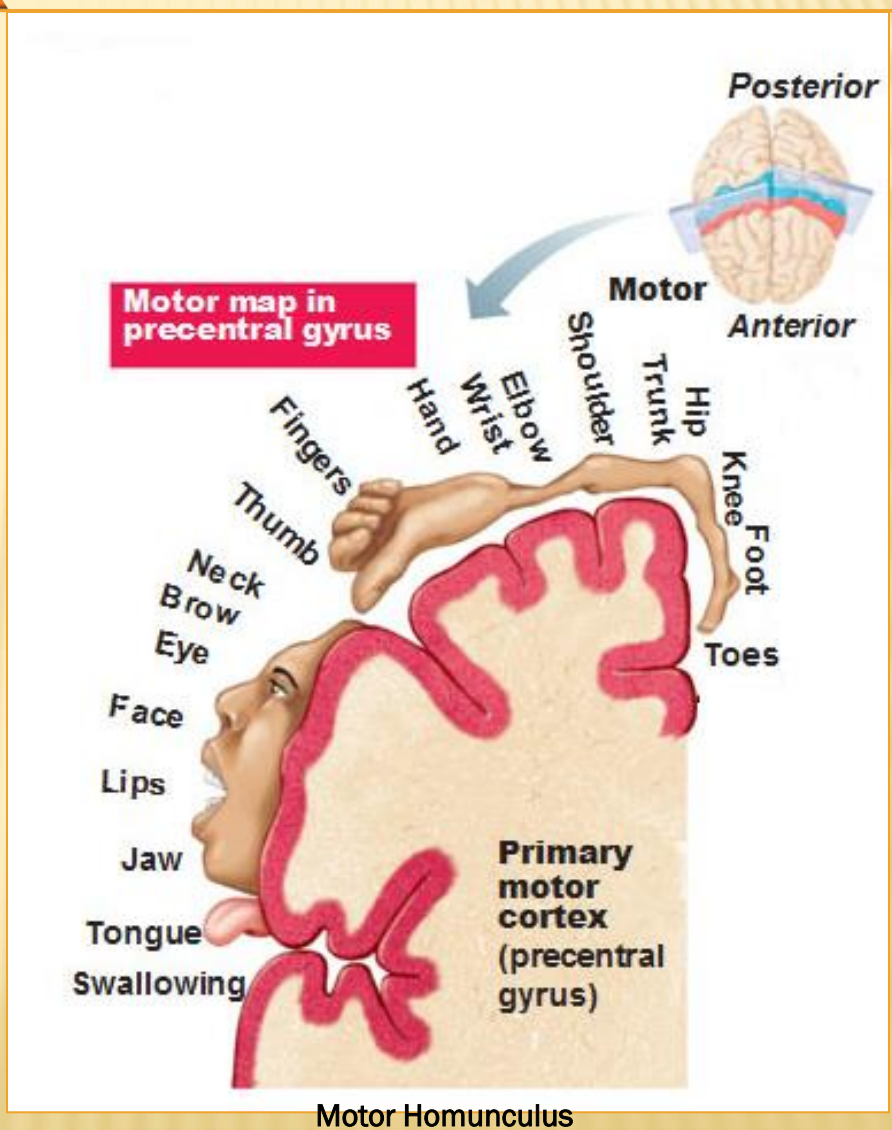
Primary Motor Cortex

- Immediately in front of the central sulcus
- Pre-central gyrus
- Next to the somatosensory cortex
- Confers voluntary control over movement produced by skeletal muscles.



Primary Motor Cortex

- Controls opposite side muscles of the body
- The extent of representation in the motor cortex is proportional to the precision and complexity of motor skills required of the respective part
- **E.g., lips are >>> trunk area**



Motor Homunculus

Proportional representation of the different body parts and areas in brain hemispheres

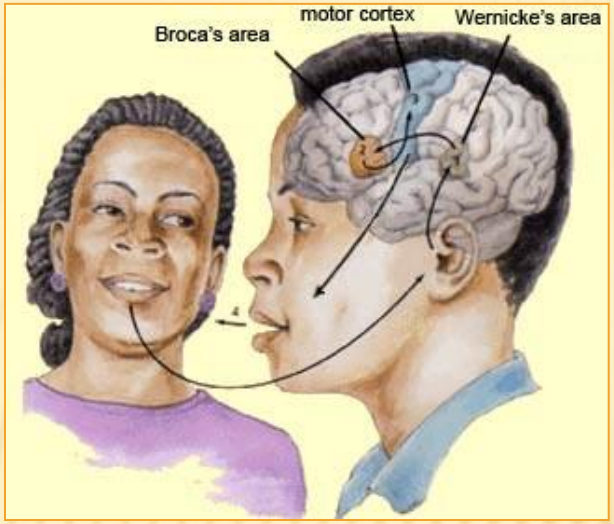
Brain Plasticity

- When an area of the brain associated with a particular activity is destroyed, other areas of the brain may gradually assume some or all of the functions of the damaged region

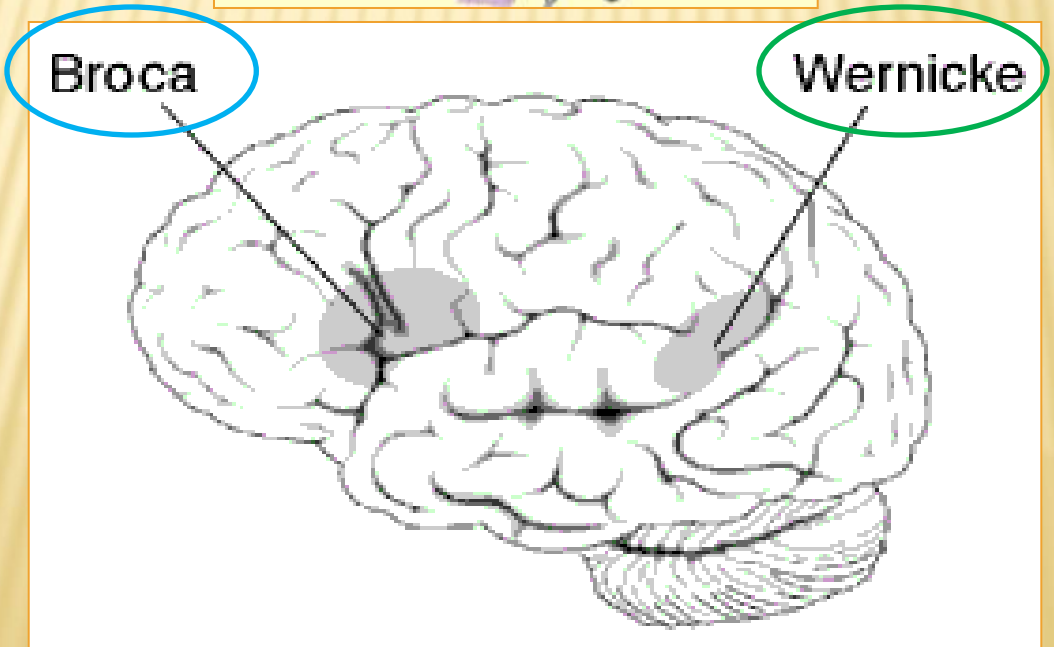
- Mechanism:

??? formation of new neural pathways (not new neurons, but new connections between existing neurons)

Control of Language



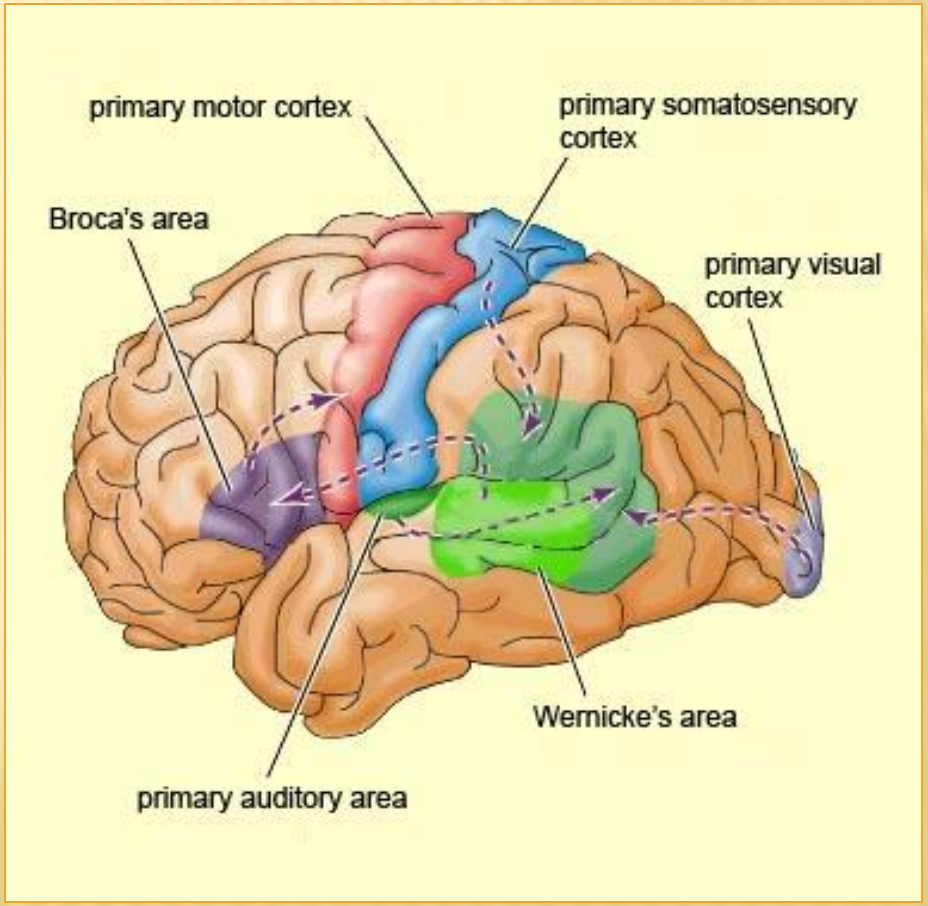
motor output
(language output)
- vocalization



sensory input
(language input)
- Vision
- Hearing

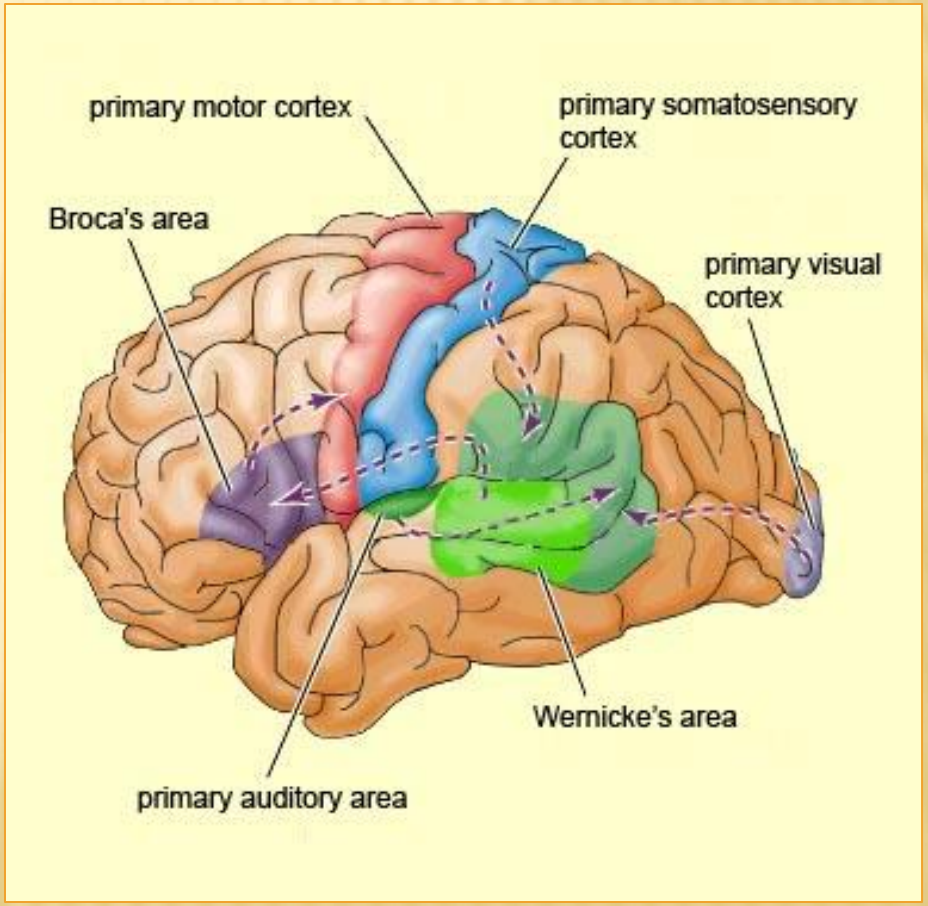
Wernicke's Area

- Role with the language comprehension;
  - ✓ Formulating coherent patterns of speech that are transferred via a bundle of fibers to broca's area
  - ✓ Understanding both spoken and written messages
  - ✓ Inputs from
    - i. Visual cortex
    - ii. Auditory cortex
- Damage: patient looses the ability to arrange read or heard words into coherent thought "Wernicke's Aphasia"



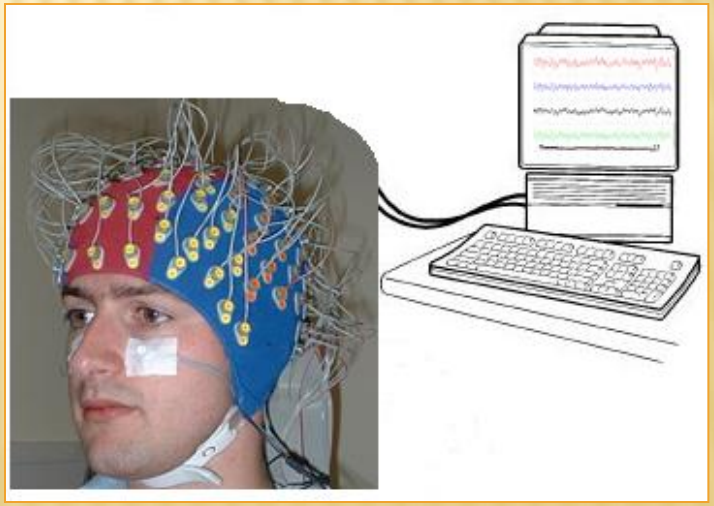
Broca's area

- Initiates and executes the expression of individual words or even short phrases (i.e., word formation)
  - ✓ Responsible for formation of words by exciting simultaneously the laryngeal muscles, respiratory muscles, and muscles of the mouth (via it's connection with motor cortex)
  - ✓ Near motor area for mouth, tongue & vocal cords
  - ✓ Damage; patient is capable of deciding what he or she wants to say but cannot make the vocal system emit words "Motor or Broca's Aphasia"



Electroencephalogram (EEG)

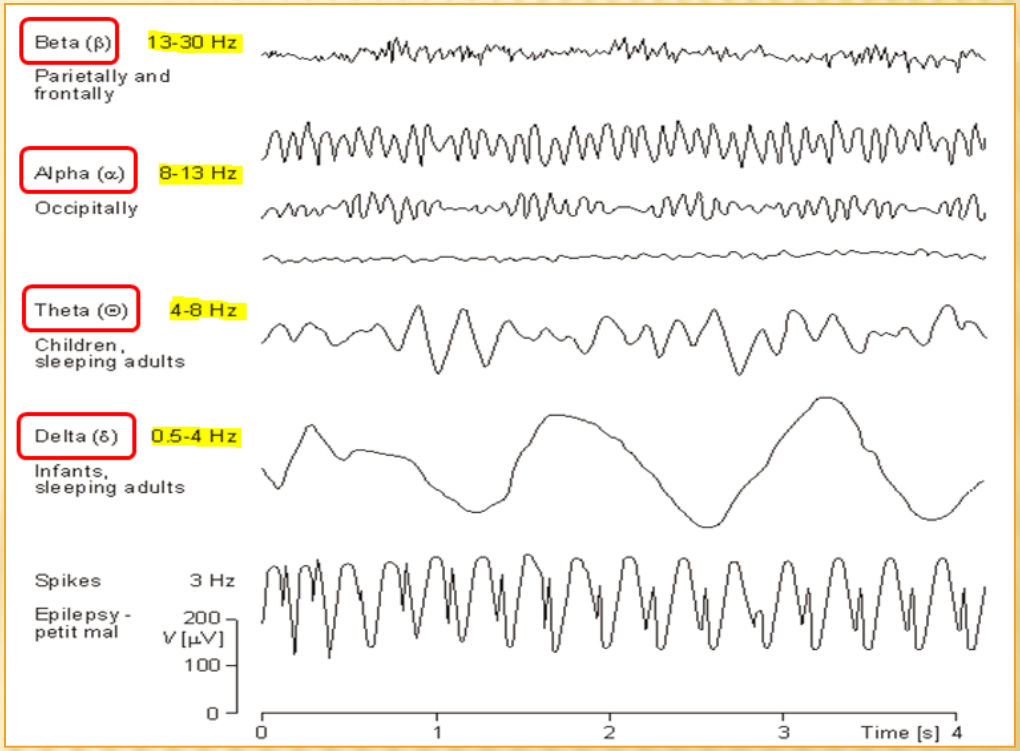
- The recording of electrical activity (potentials) along the scalp
- A tracing (measurement) of voltage fluctuations resulting from ionic current flows within the neurons of the brain versus time recorded from electrodes placed over scalp in a specific array
- Deep parts of the brain are not well sampled
- EEG Elements:
  - ✓ Active electrodes: Attached to the scalp
  - ✓ Reference electrode: Mastoid, nose, ear lobe…
  - ✓ Amplifier



- The EEG records differences in voltage – difference in electrical potential from one electrode to another

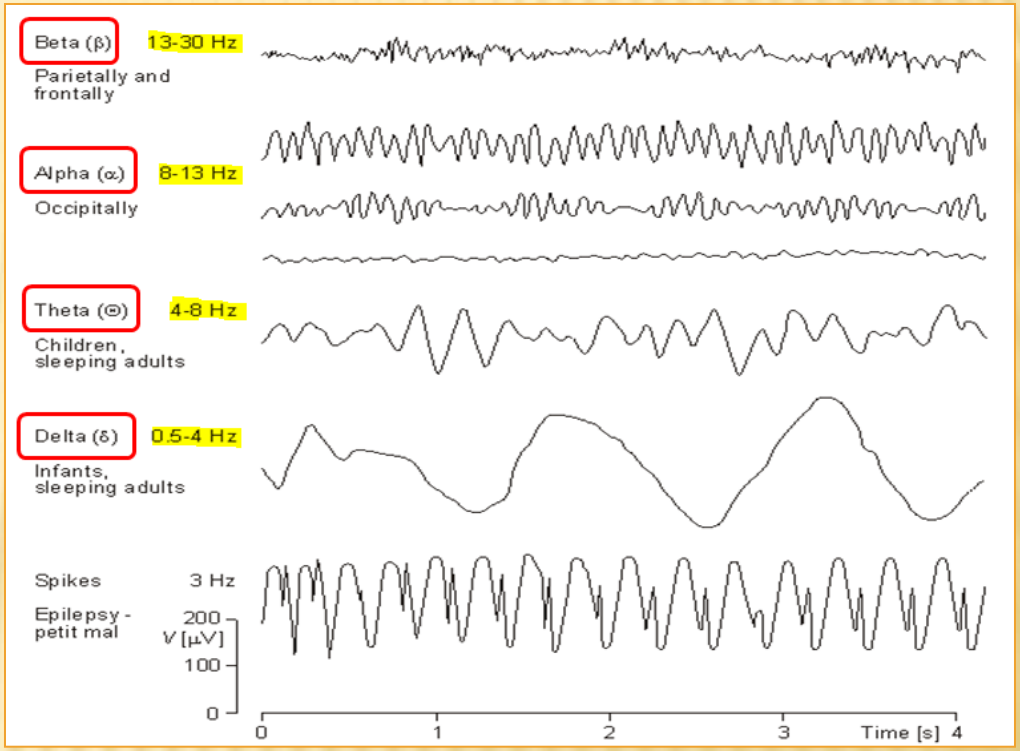
EEG Waves

- **Beta (β) waves**
  - ✓ Small in amplitude
  - ✓ More evident anteriorly
  - ✓ Drugs, such as barbiturates and benzodiazepines, augment beta waves



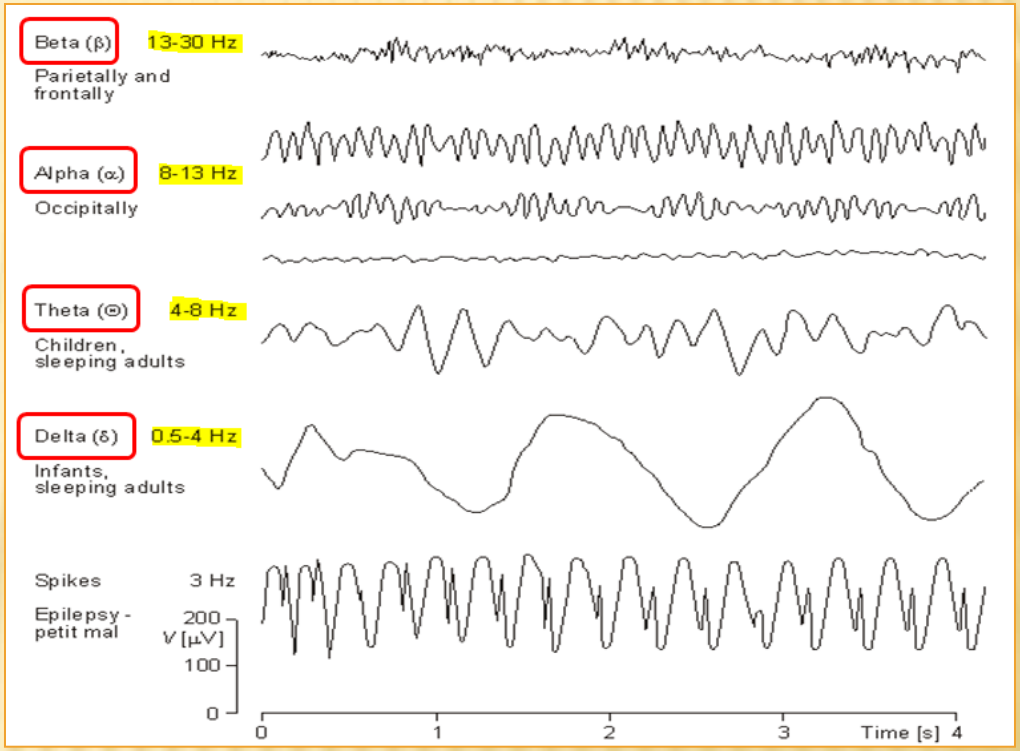
EEG Waves

- **Alpha (α) waves**
  - ✓ Most common in adults.
  - ✓ Posteriorly (occipital) more than anteriorly
  - ✓ Especially prominent with closed eyes and with relaxation.
  - ✓ Disappears normally with attention (e.g., mental arithmetic, stress, opening eyes).
  - ✓ In most instances, it is regarded as a normal waveform.



EEG Waves

- **Theta (θ) waves**
  - ✓ Normally seen in sleep
  - ✓ In awake adults, these waves are abnormal if they occur in excess.
- **Delta (δ) waves**
  - ✓ Normally seen in deep sleep.
  - ✓ Delta waves are abnormal in the awake adult.



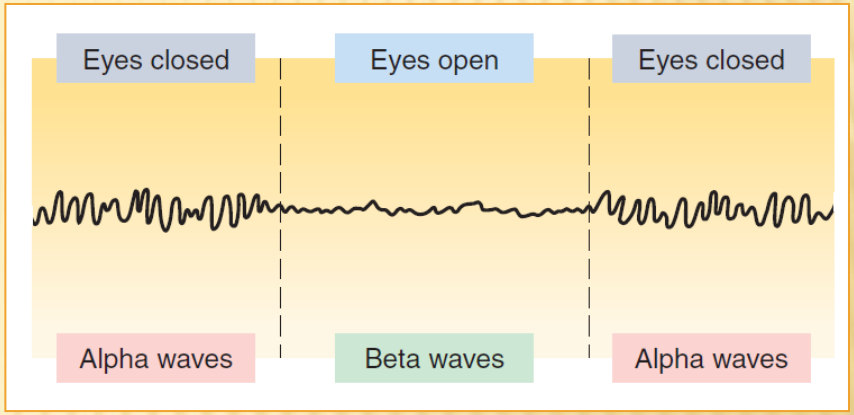
- ✓ Often, they have the largest amplitude of all waves. **Theta** and **delta** waves are known collectively as **slow waves**.

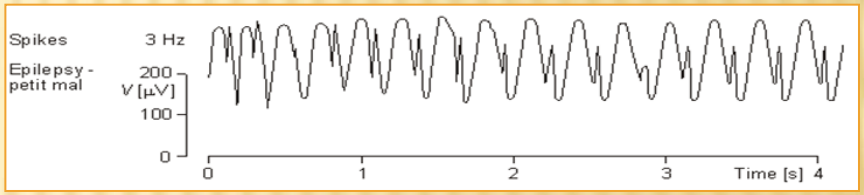
EEG Uses

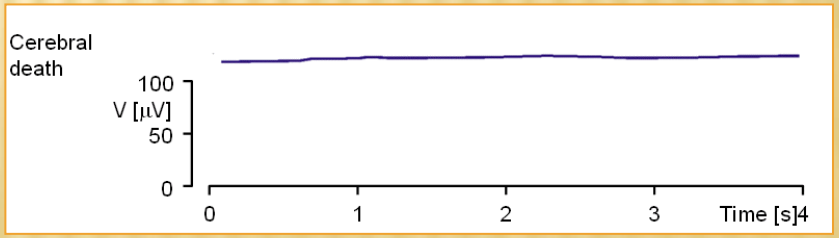
1. To distinguish various stages of sleep

2. A clinical tool in the diagnosis of cerebral dysfunction (e.g. **Epilepsy**)

3. Legal determination of brain death





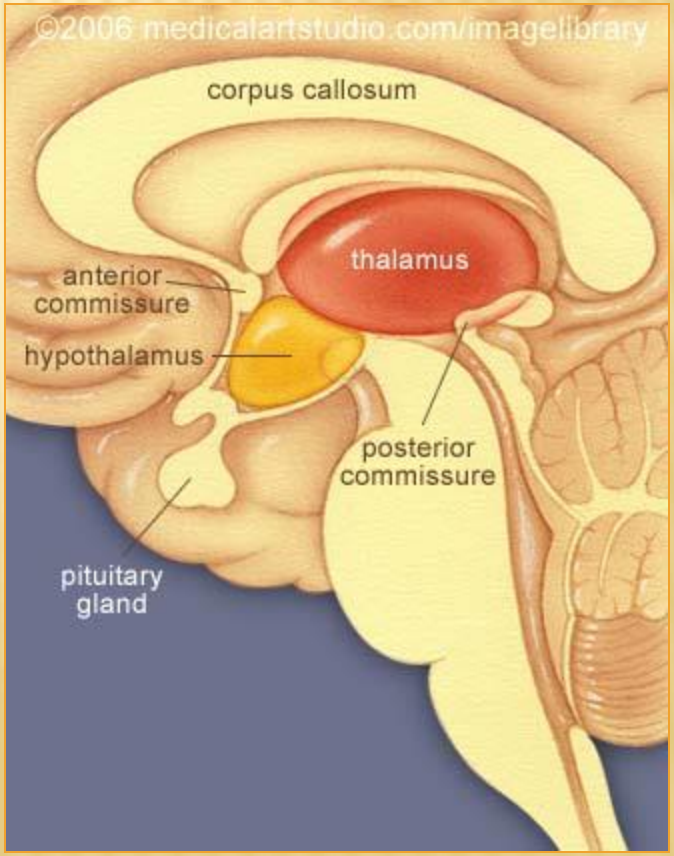


Nervous System – Brain & cranial nerves

The Thalamus

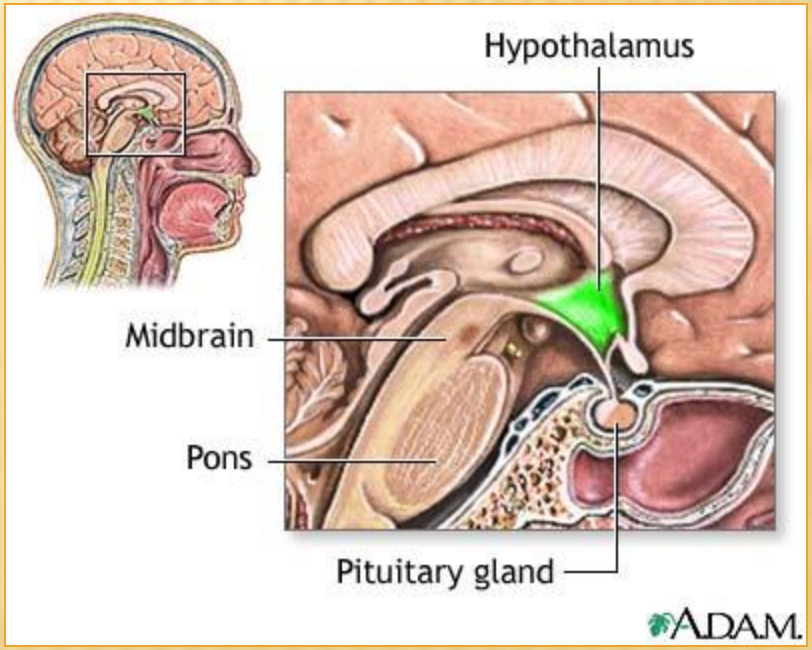
- "Relay station" and synaptic integrating center for preliminary processing of all sensory input on its way to the cortex

- It screens out insignificant signals and routes the important sensory impulses to appropriate areas of the somatosensory cortex (e.g., attention to stimuli of interest)



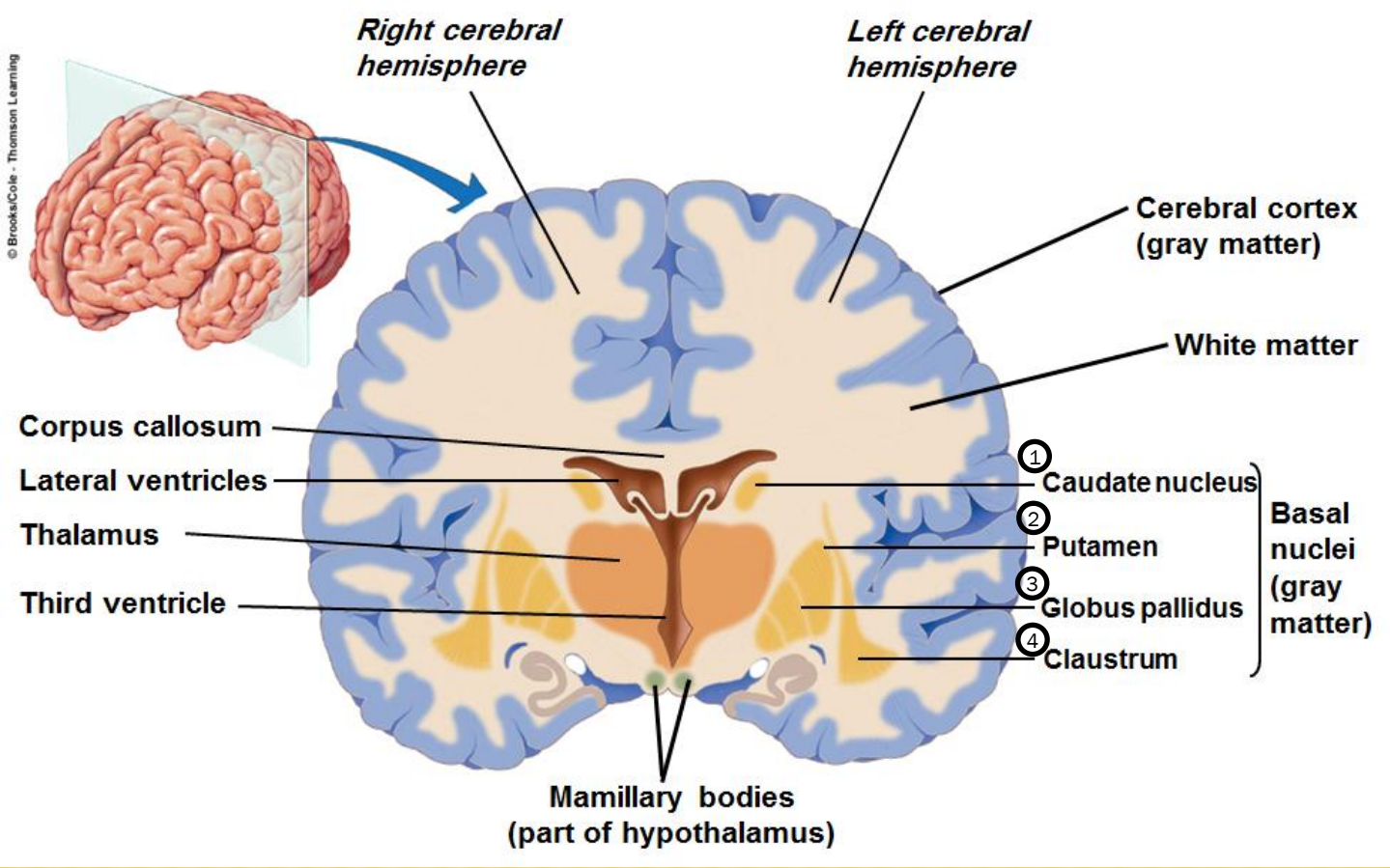
The Hypothalamus

- Important **link** between the autonomic nervous system and the endocrine system via the pituitary gland
- Brain area most involved in directly regulating internal environment
  - Controls body temperature
  - Controls thirst and urine output
  - Controls food intake
  - Controls anterior pituitary hormone secretion
  - Produces posterior pituitary hormones
  - Controls uterine contractions and milk ejection
  - Serves as a major ANS coordinating center
  - Plays role in emotional and behavioral patterns
  - Participates in sleep-wake cycle



The Basal Nuclei

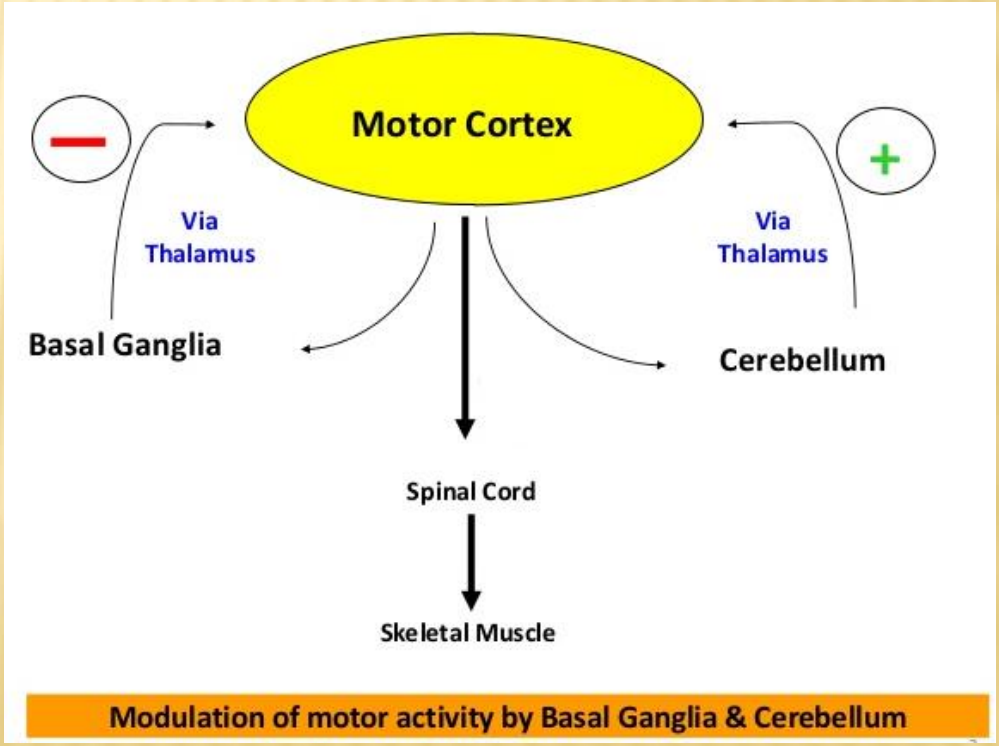
- Masses of gray matter (neuron cell bodies) located deep within the cerebral white matter



The Basal Nuclei

- Functions (by modifying ongoing activity in motor pathways):
  - Fine tuning muscle tone; inhibiting muscle tone throughout the body
  - Selecting and maintaining purposeful motor activity while suppressing useless or unwanted patterns of movement

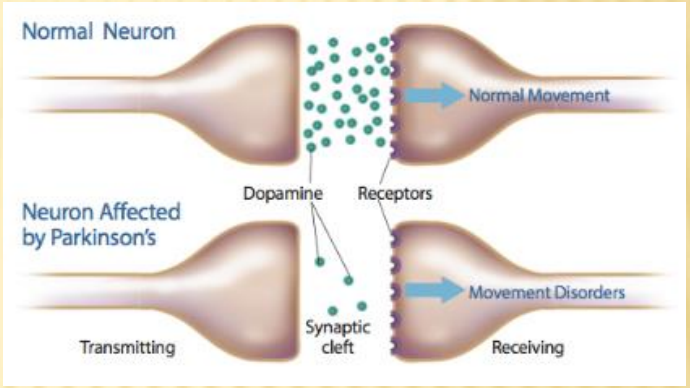
❖ Proper muscle tone is normally maintained by a balance of excitatory and inhibitory inputs to the neurons that innervate skeletal muscles

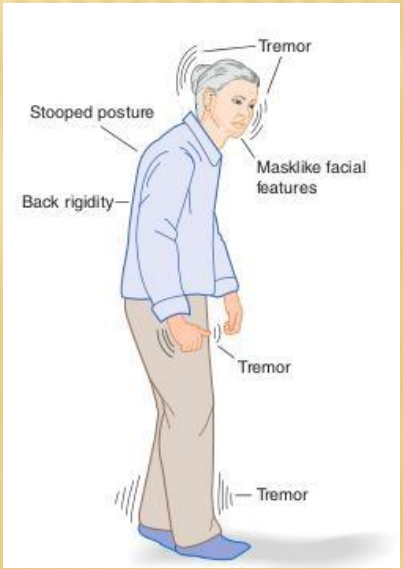


The Basal Nuclei

- Improper function: **Parkinson's disease**

- Deficiency of dopamine, an important neurotransmitter in the basal nuclei

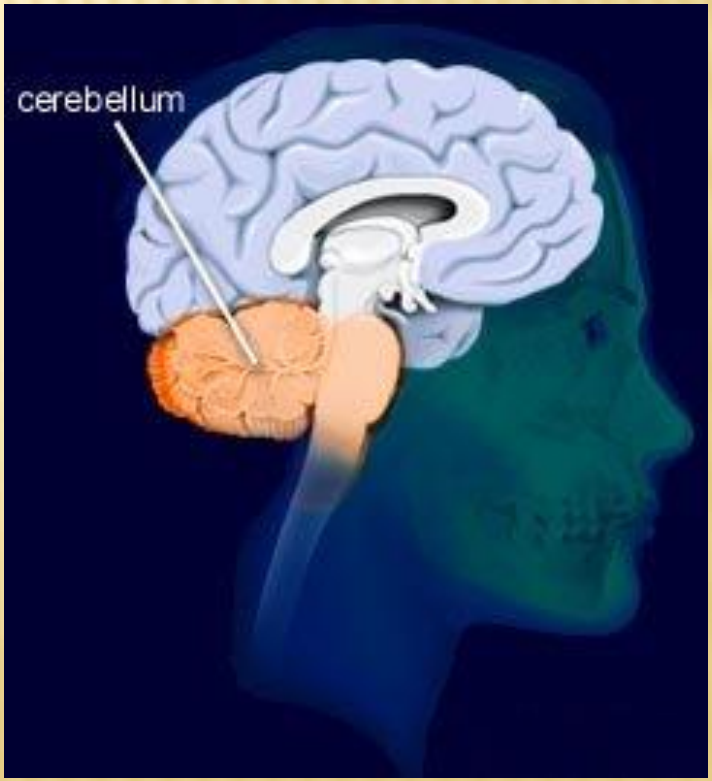




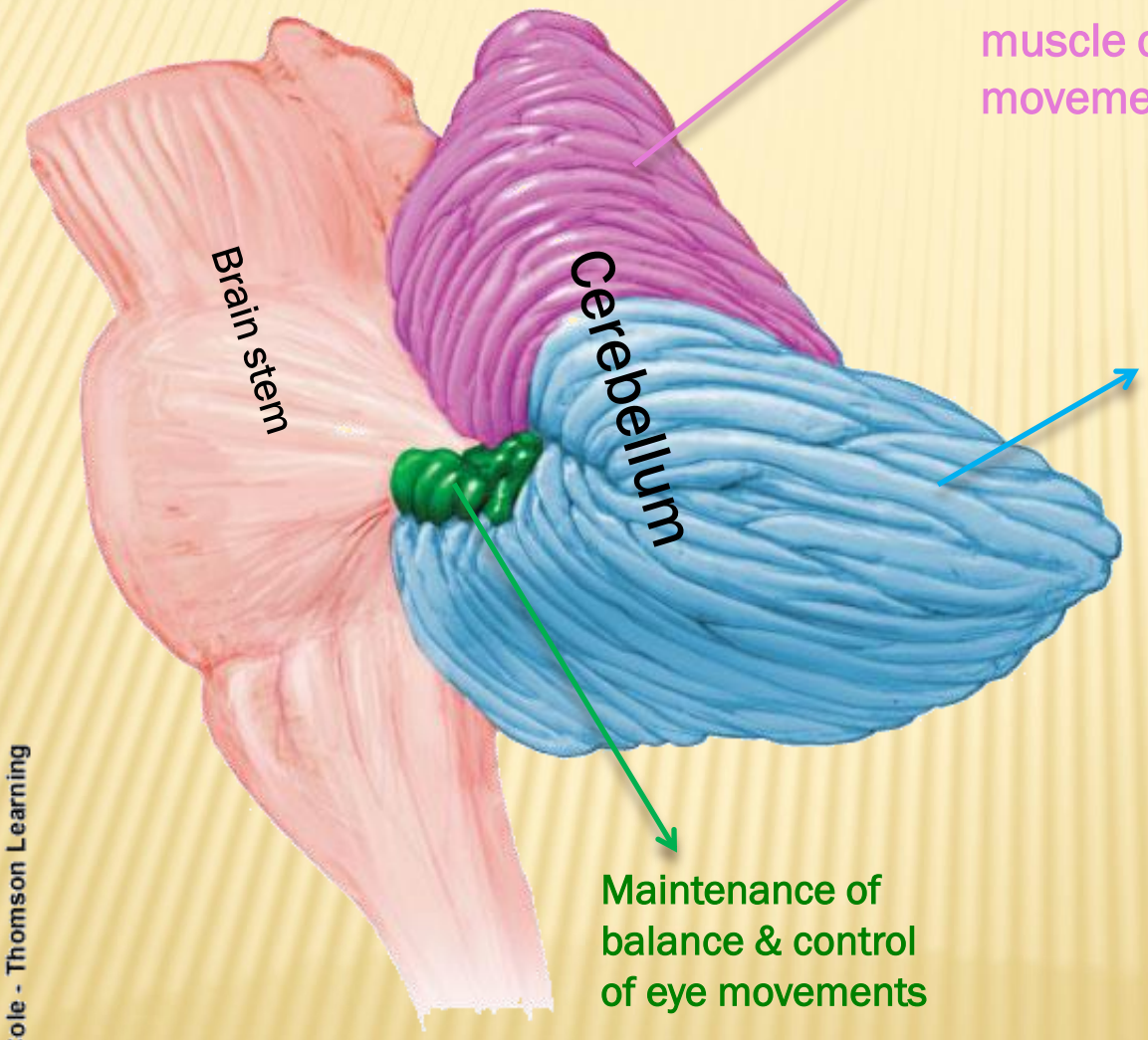
- Signs and symptoms:
  - ✓ Increased muscle tone, or rigidity
  - ✓ Involuntary, useless, & unwanted movements, such as **resting tremors** (e.g., hands rhythmically shaking)
  - ✓ Slowness in initiating and carrying out different motor behaviors

Cerebellum

- Attached to the back of the upper portion of the brain stem, Lies underneath the occipital lobe of the cortex
- Does not initiate movement, but contributes to coordination, precision, and accurate timing.
- Three different parts:
  1. Vestibulocerebellum
  2. Spinocerebellum
  3. Cerebrocerebellum



- Enhancing muscle tone
- Coordination of skilled voluntary movement; accurate timing of various muscle contractions to coordinate movements involving multiple joints.



- Planning and initiation of voluntary activity by providing input to cortical motor areas
- Storing procedural memories

Maintenance of balance & control of eye movements

Spinocerebellum
Cerebrocerebelum
Vestibulocerebellum

Brain Stem

- Vital link between the spinal cord and higher brain regions

- Main functions:

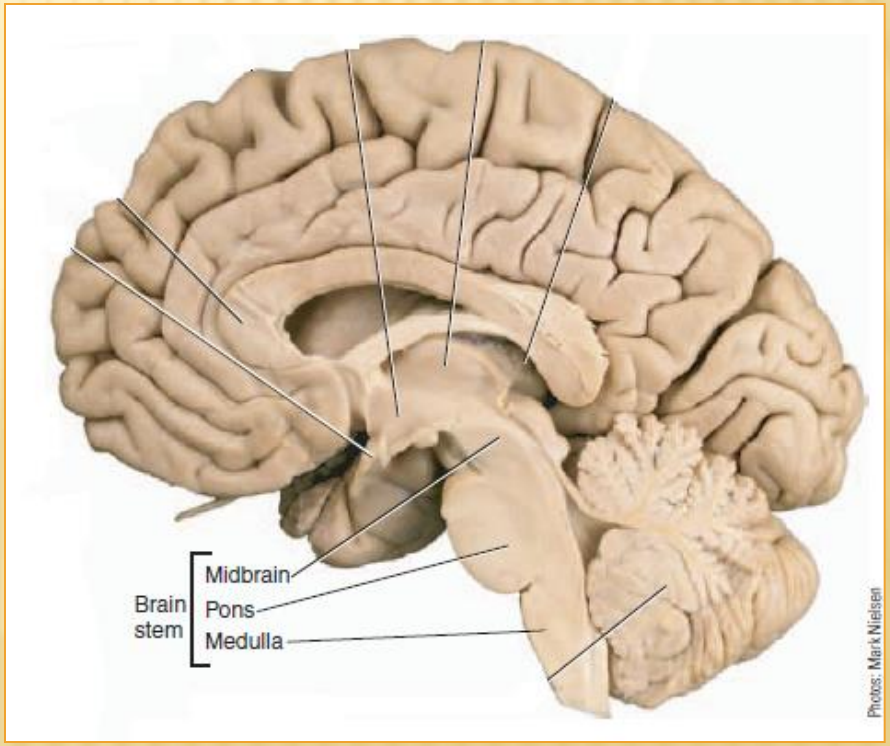
✓ The majority of the 12 pairs of **cranial nerves** arise from the brain stem

✓ Centers that control heart and blood vessel function, respiration, and many digestive activities

✓ Plays role in regulating muscle reflexes involved in equilibrium and posture

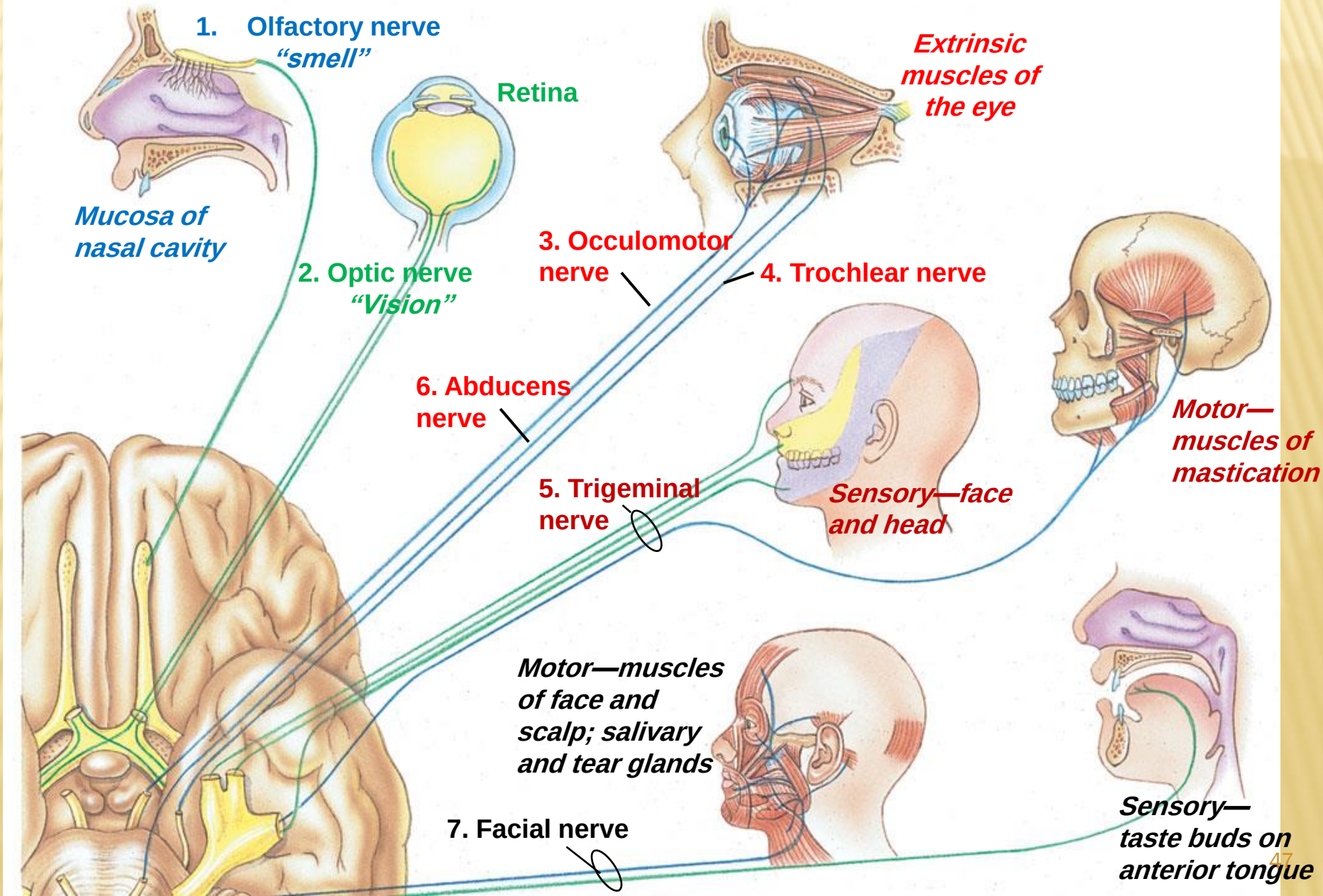
✓ Reticular formation within brain stem receives and integrates all incoming sensory synaptic input; important for brain arousal (being awake & alert)

✓ Centers that govern sleep



= Sensory fibers

= Motor fibers

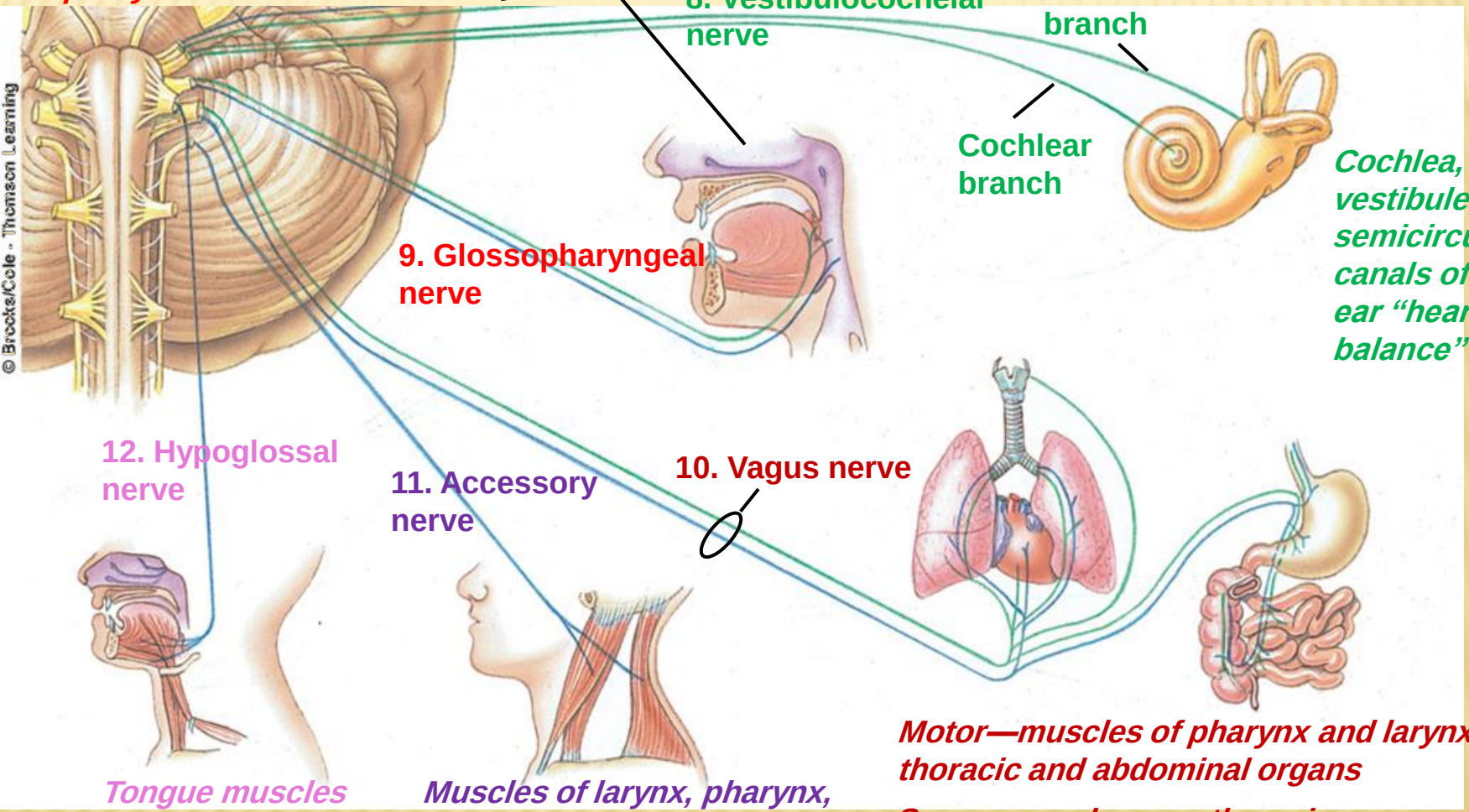


= Sensory fibers

= Motor fibers

Motor—muscles of pharynx; parotid gland

Sensory—taste buds on posterior tongue; receptors in pharynx and carotid sinus



Cochlea, vestibule, and semicircular canals of inner ear "hearing & balance"

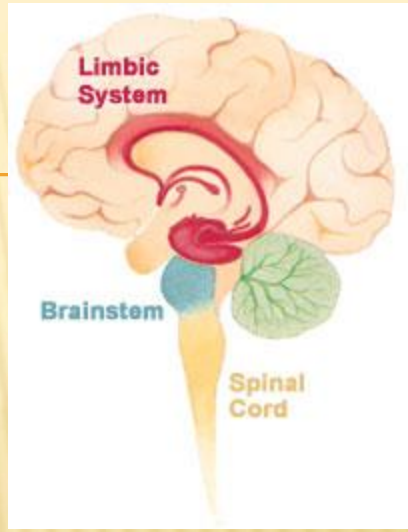
Tongue muscles

Muscles of larynx, pharynx, soft palate, shoulder, and neck

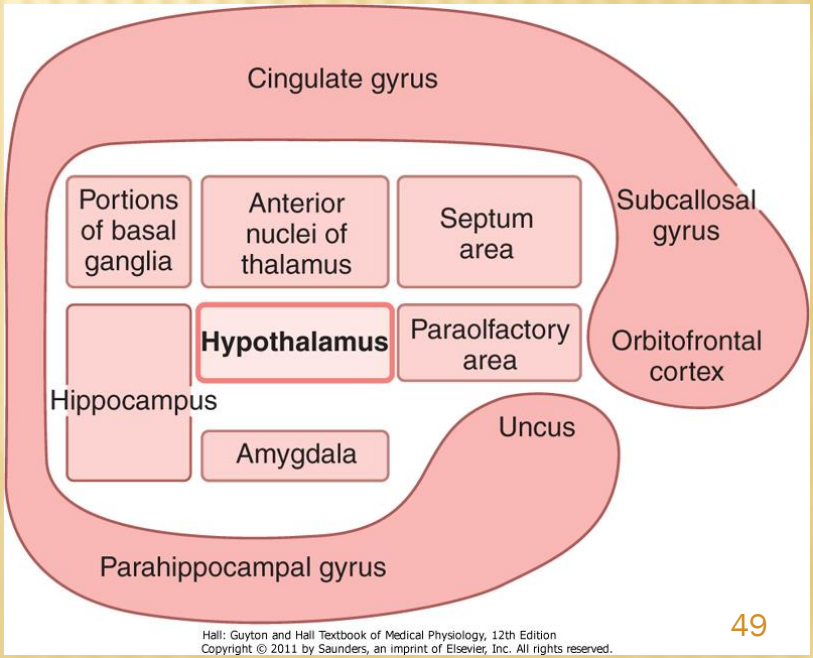
Motor—muscles of pharynx and larynx; thoracic and abdominal organs

Sensory — pharynx; thoracic and abdominal organs

Limbic System



- Includes portions of the hypothalamus and other forebrain structures that encircle brain stem
- Plays a key role in emotion.
- Works with the higher cerebral cortex to control behavioral patterns related to survival and perpetuation of the species.
- The limbic system has reward and punishment centers.
- Plays important role in motivation and learning



The END