CENTRAL NERVOUS SYSTEM

Spinal Cord and Brain Anatomy

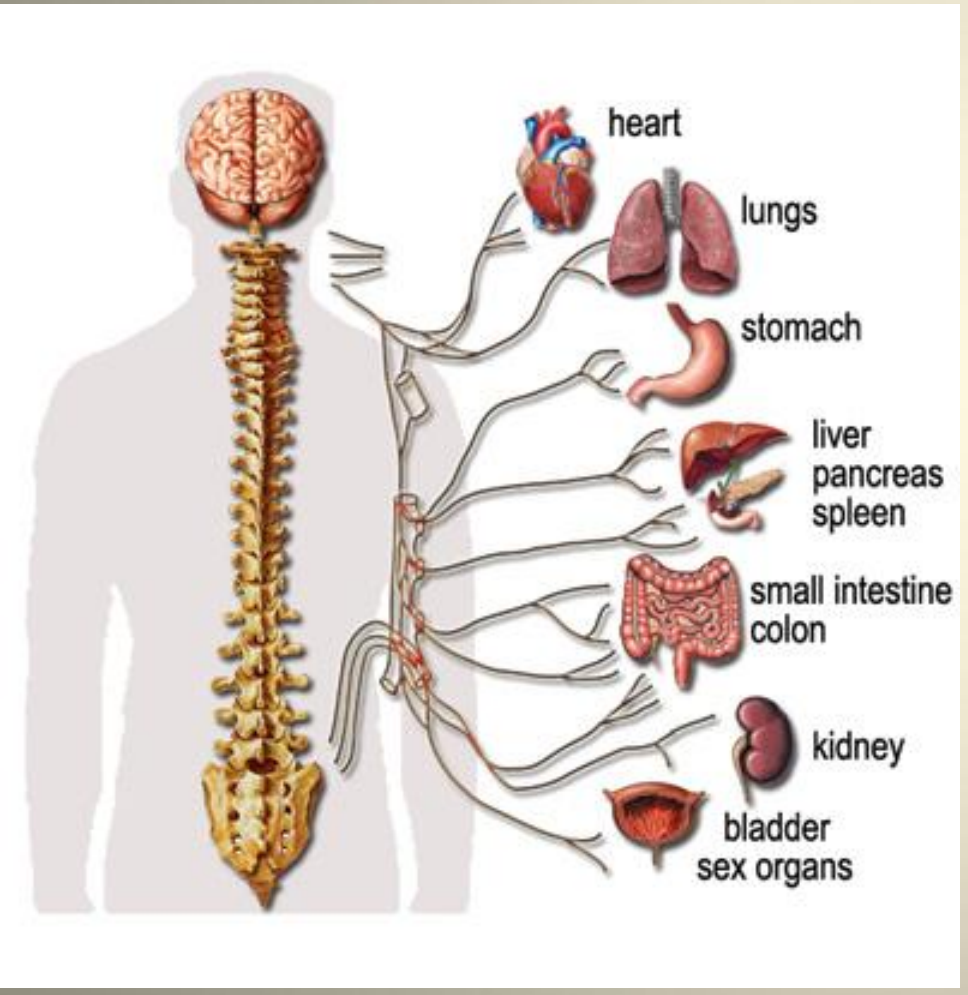
Integrative Function

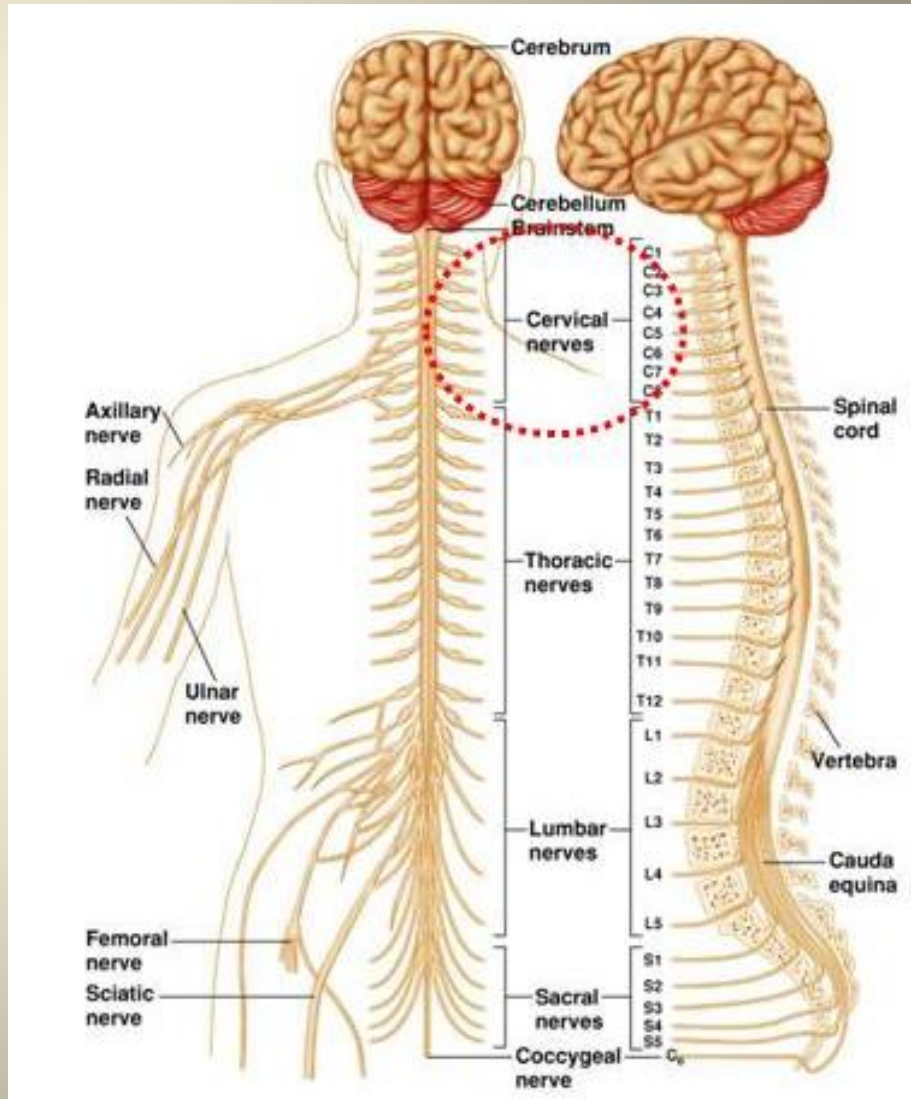
Chapter 48 page 1042-1051

Central Nervous System (CNS)

Organs	Bone	Fluid-filled cavity
Brain	Skull	Ventricles
Spinal Cord	Spinal column, spine, vertebrae	Central canal

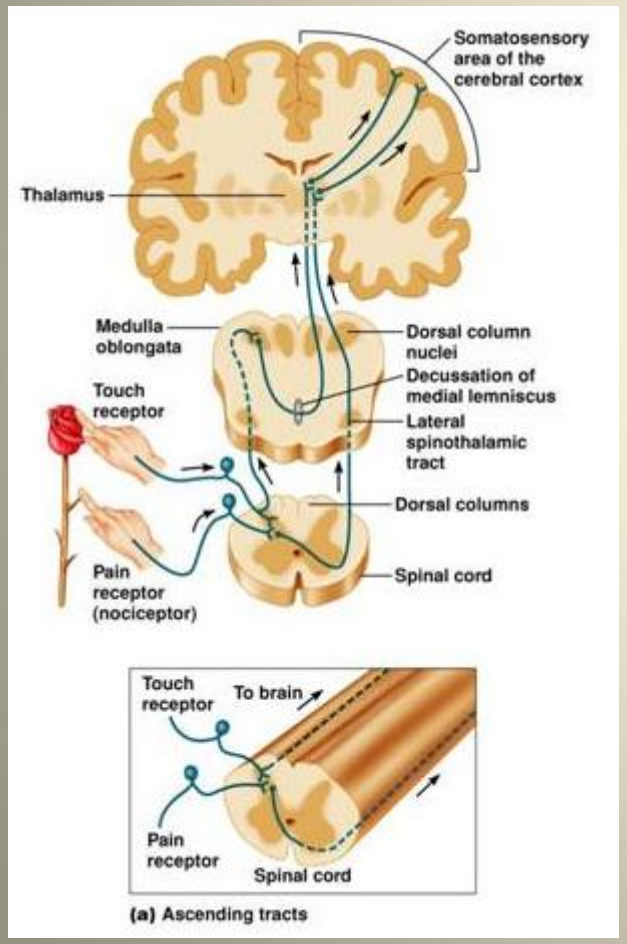
Spinal Cord


heart
lungs
stomach
liver
pancreas
spleen
small intestine
colon
kidney
bladder
sex organs

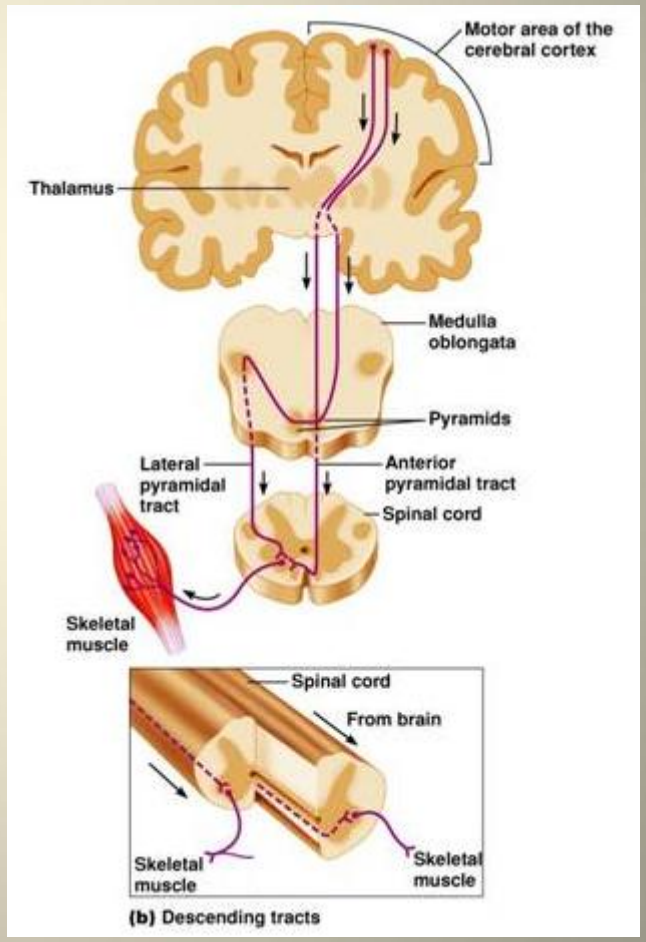

Cerebrum
Cerebellum
Brainstem
Cervical nerves
C1
C2
C3
C4
C5
C6
C7
C8
Axillary nerve
Radial nerve
Ulnar nerve
Thoracic nerves
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
Spinal cord
Vertebra
L1
L2
L3
L4
L5
Lumbar nerves
Cauda equina
Femoral nerve
Sciatic nerve
Sacral nerves
S1
S2
S3
S4
S5
Coccygeal nerve

Spinal cord

Ascending tract

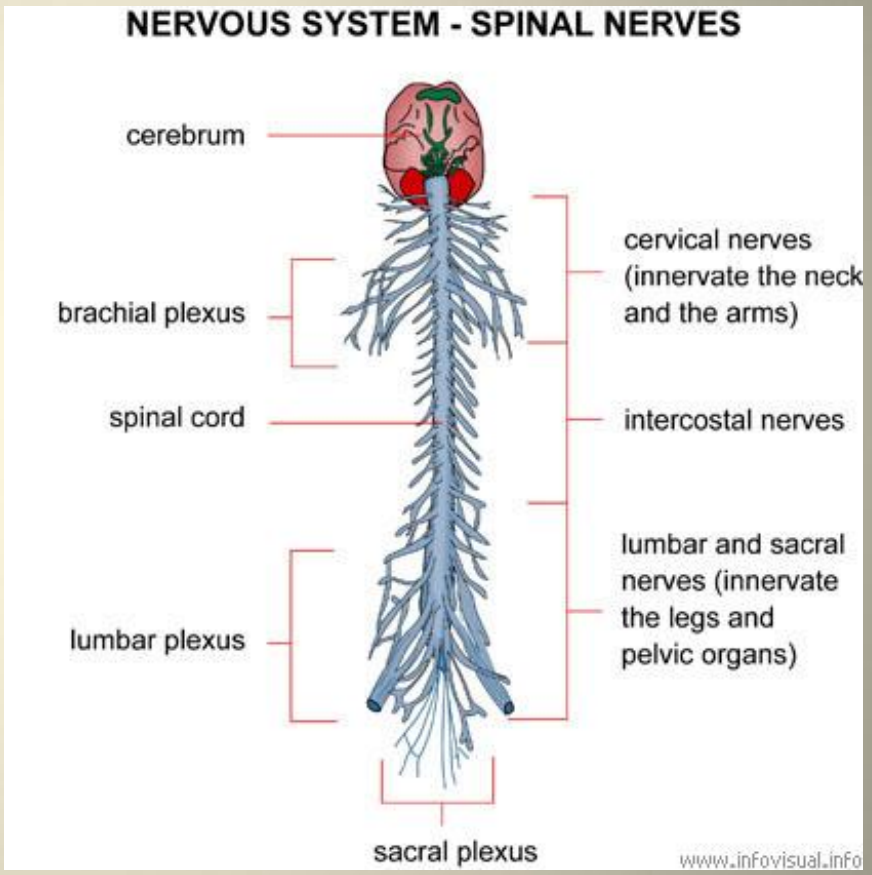


Descending tract



Paired Spinal Nerves

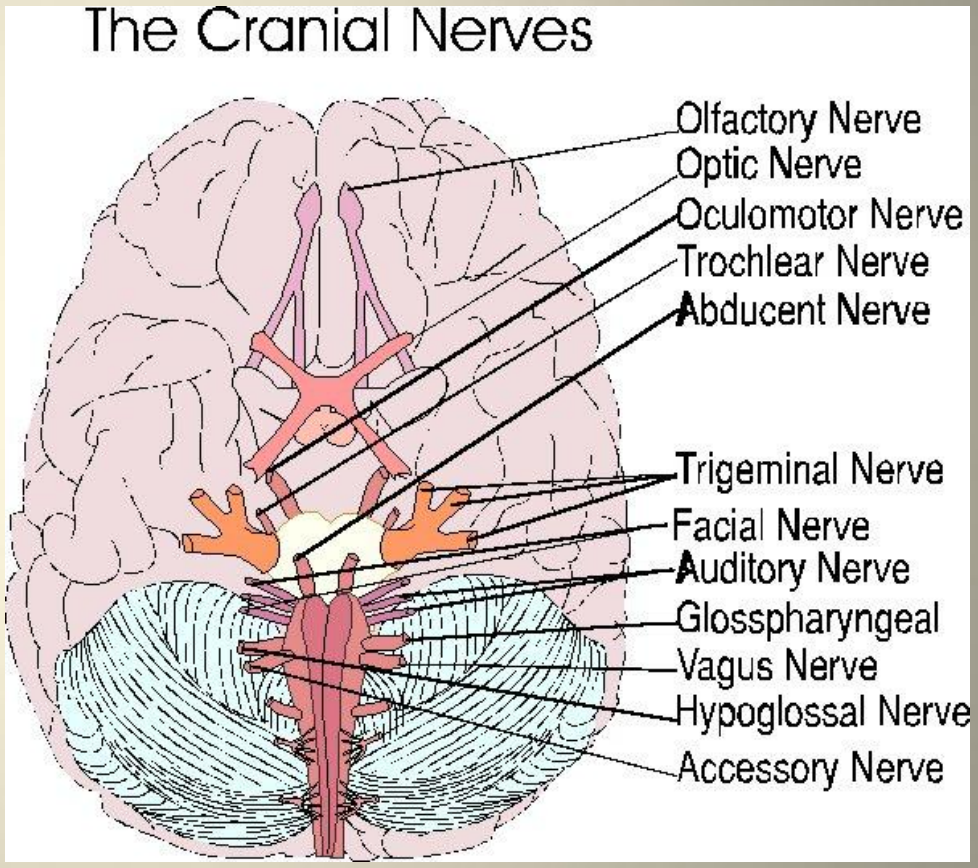
- Paired spinal nerves originate in the spinal cord and innervate the entire body.



From http://www.infovisual.info/03/039_en.html

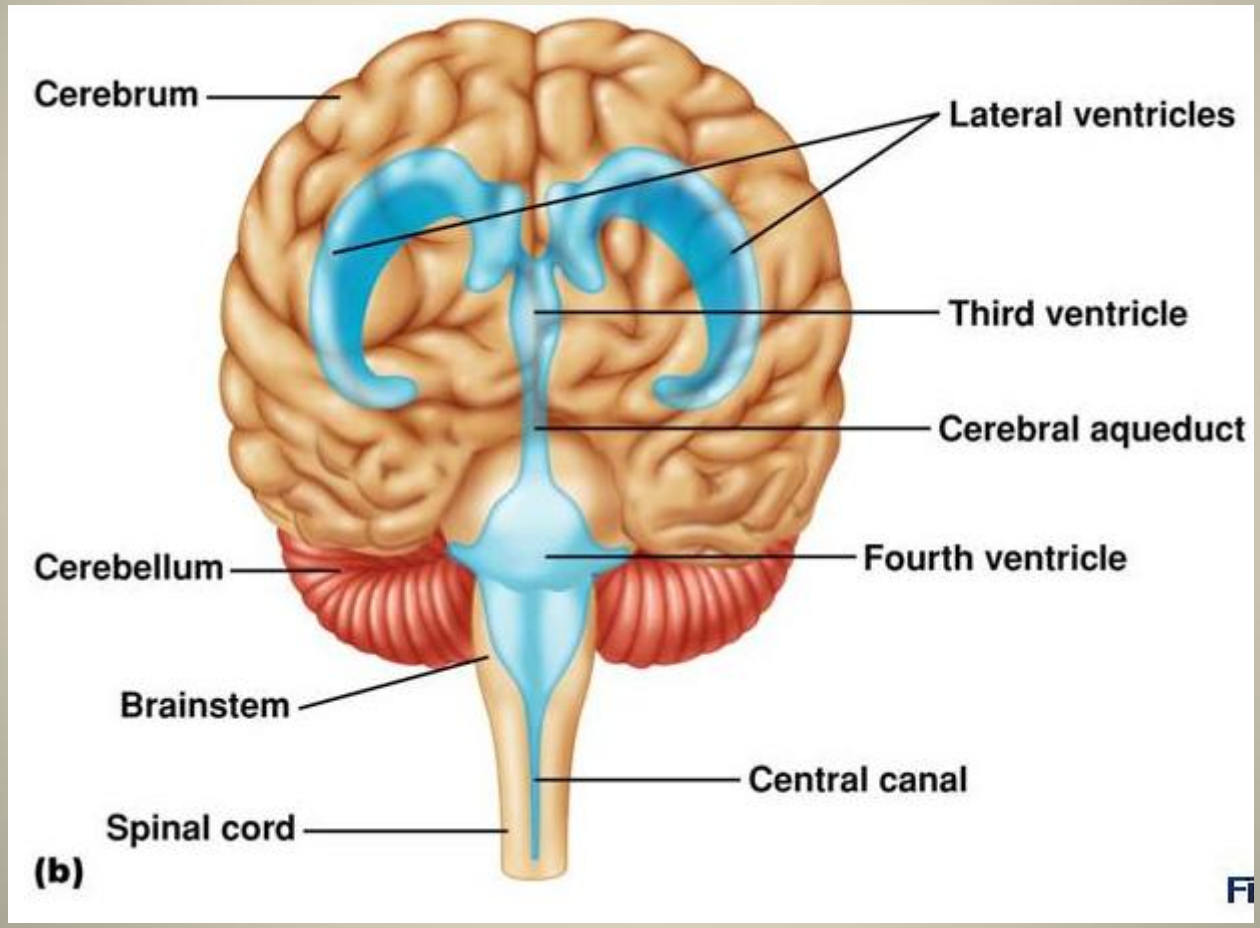
Paired Cranial Nerves

- Paired cranial nerves originate in the brain and innervate the head and face.

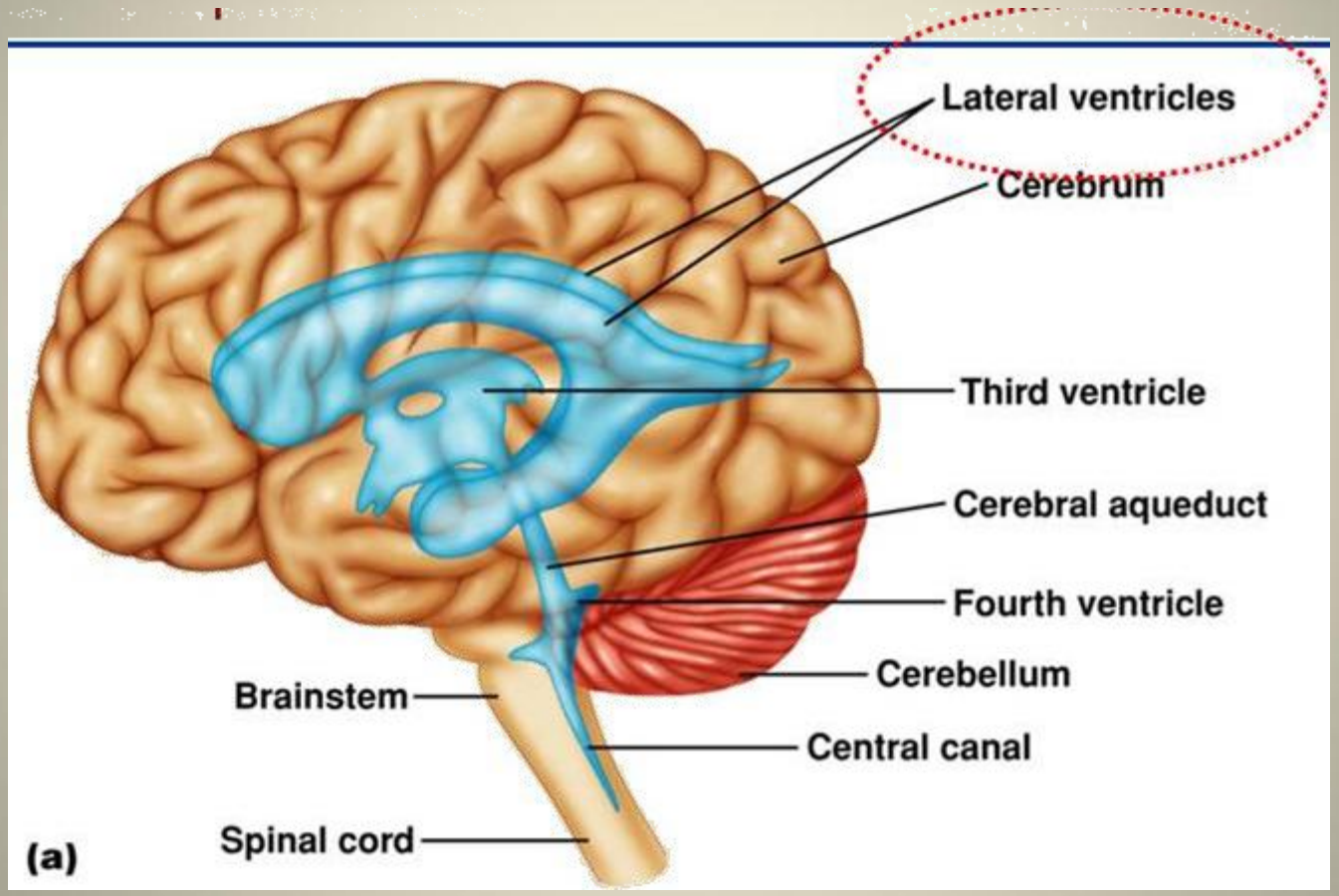


From http://www.chiro.org/chimages/diagrams/cranialn.jpg

Cavities – frontal view



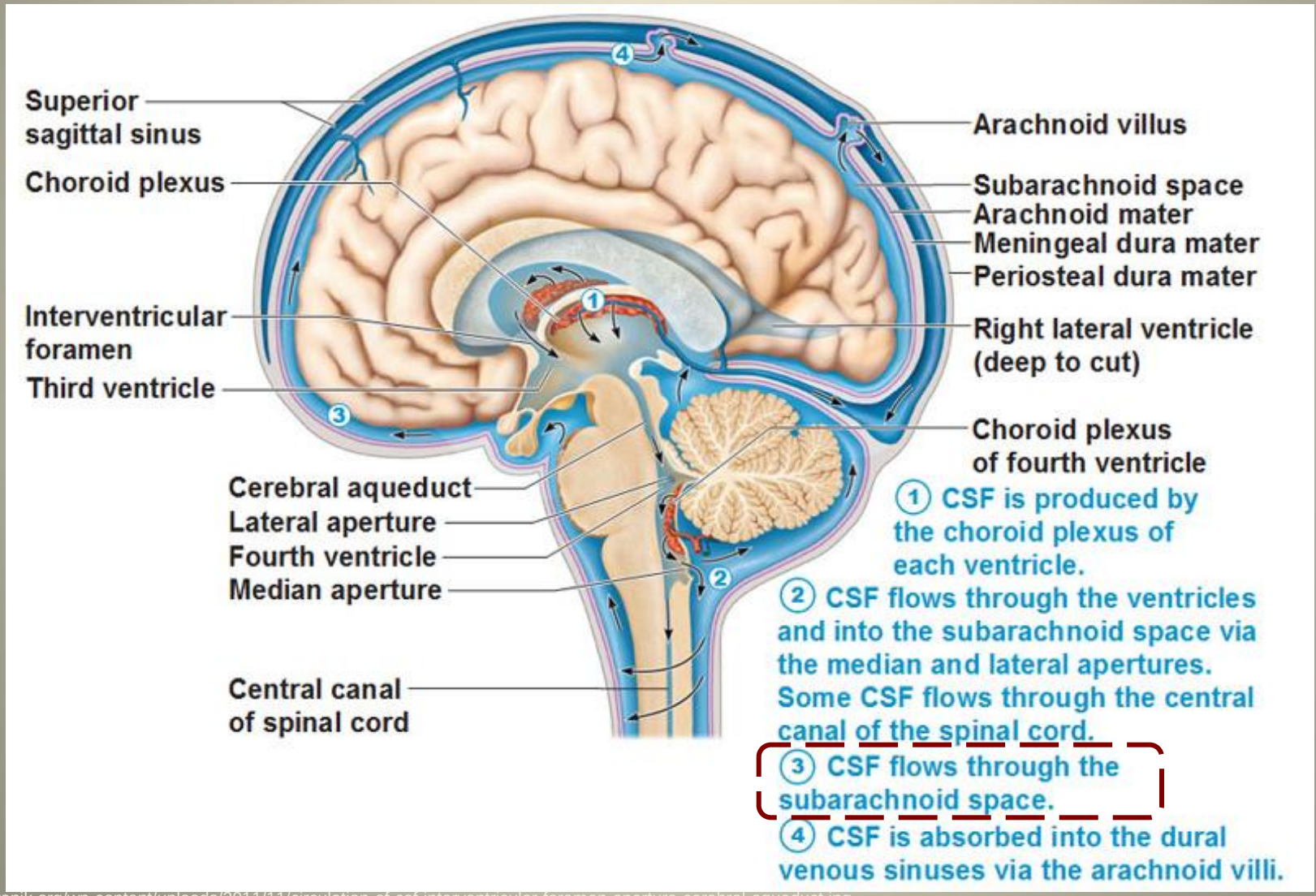
Cavities – lateral view



Cerebrospinal fluid (CSF)

- a fluid that fills the cavities in the CNS
- formed by filtration of blood
- contains nutrients, hormones, white blood cells
- act as shock absorber (cushion)

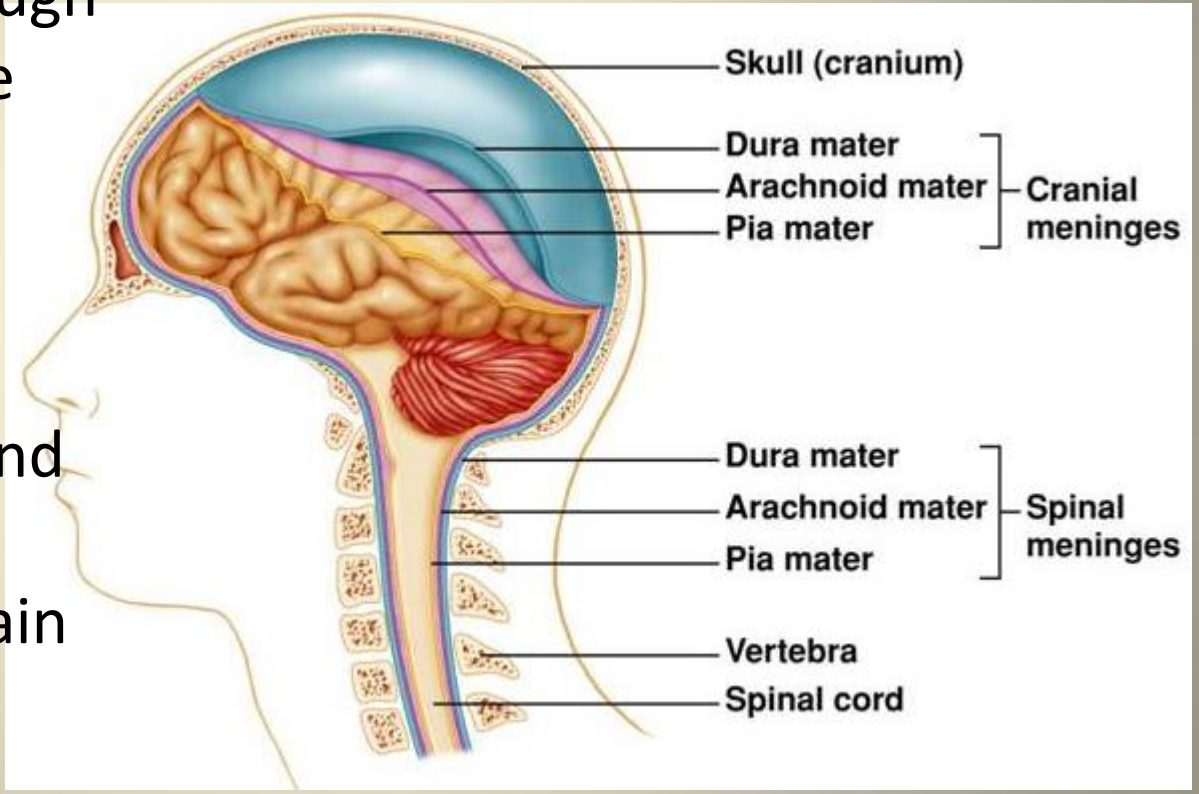
Cerebrospinal fluid (CSF)



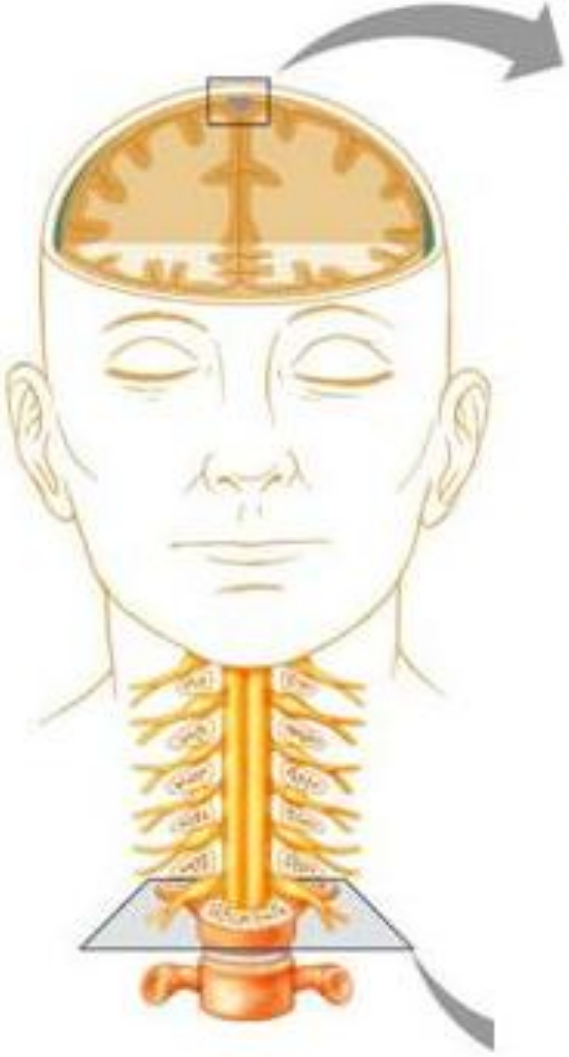
http://antranik.org/wp-content/uploads/2011/11/circulation-of-csf-interventricular-foramen-aperture-cerebral-aqueduct.jpg

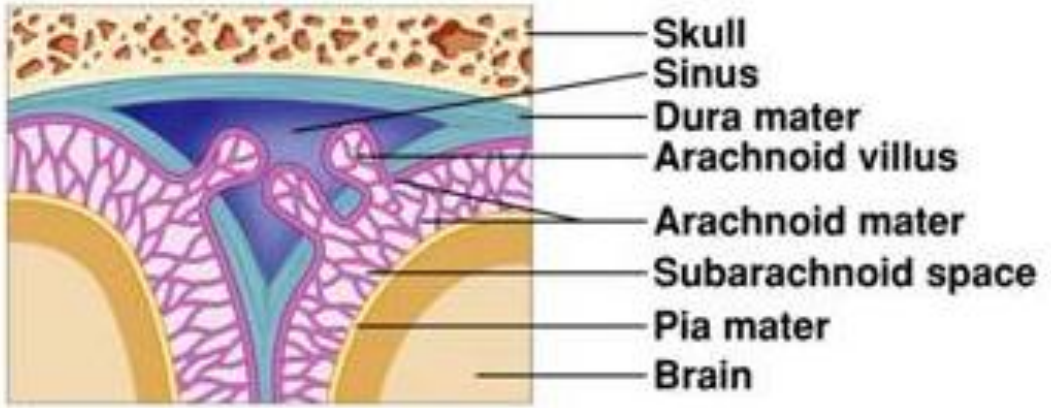
Meninges

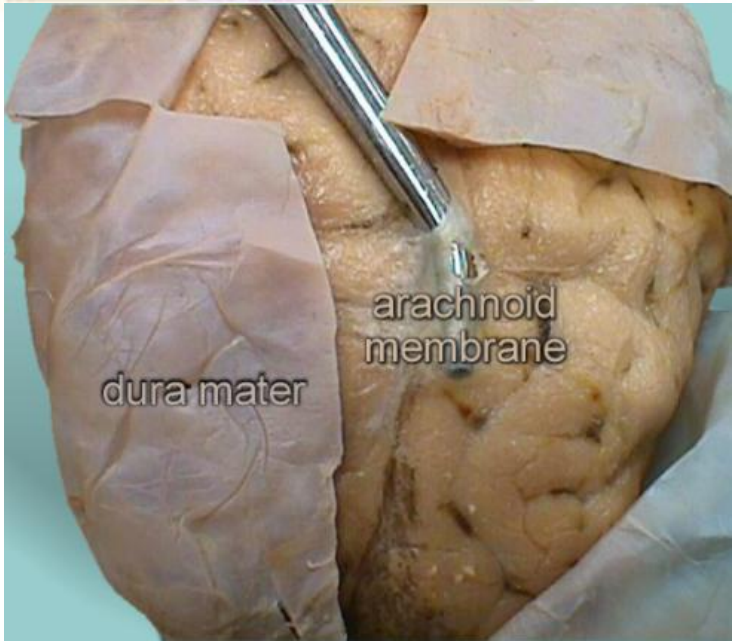
- three layers of tough elastic connective tissue
  - Dura Mater
  - Arachnoid Mater
  - Pia Mater
- within the skull and spinal column
- surrounds the brain spinal cord



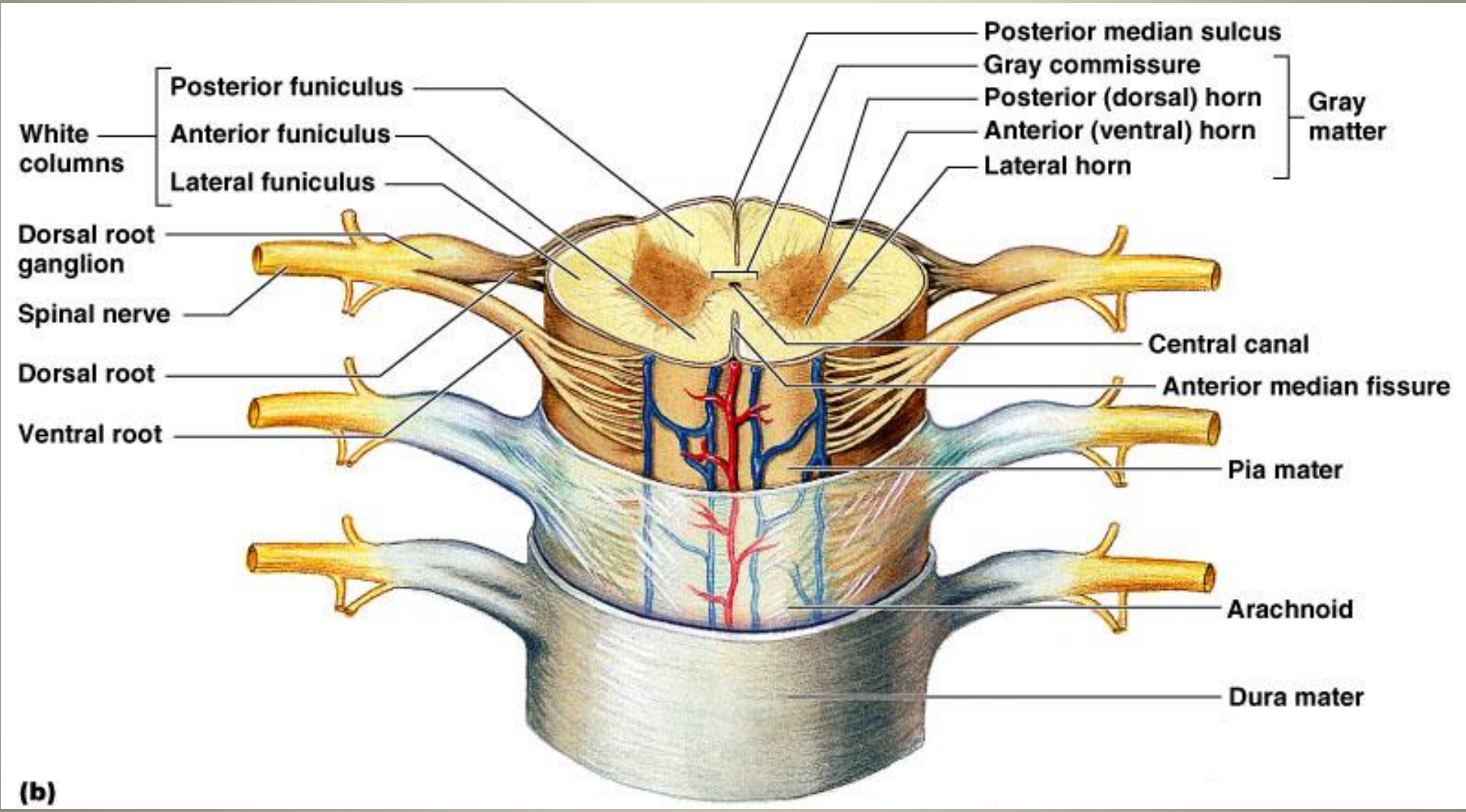
Meninges in Brain







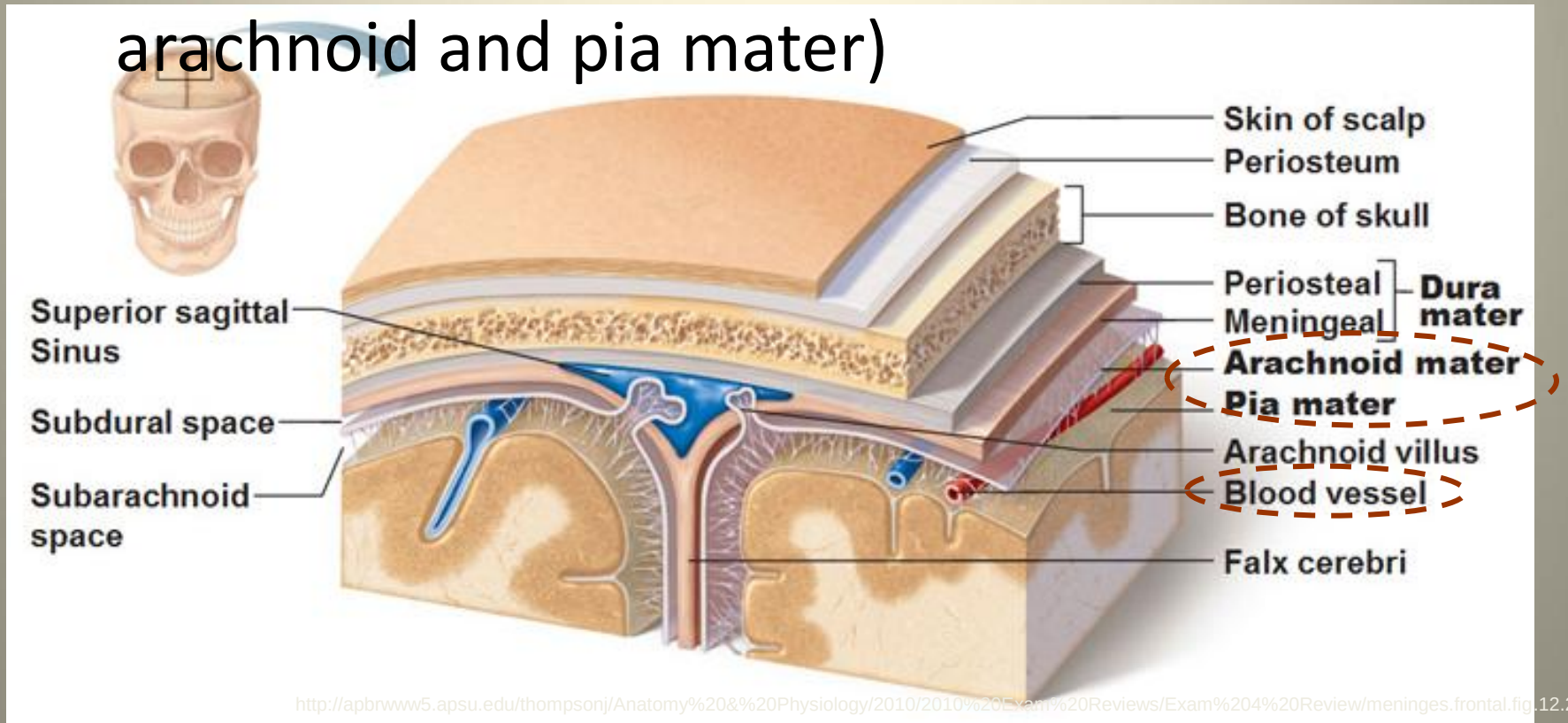
Meninges in Spinal Cord



http://biologydiaries.files.wordpress.com/2011/05/12-30b_spinalcord_1.jpg

Meninges Function

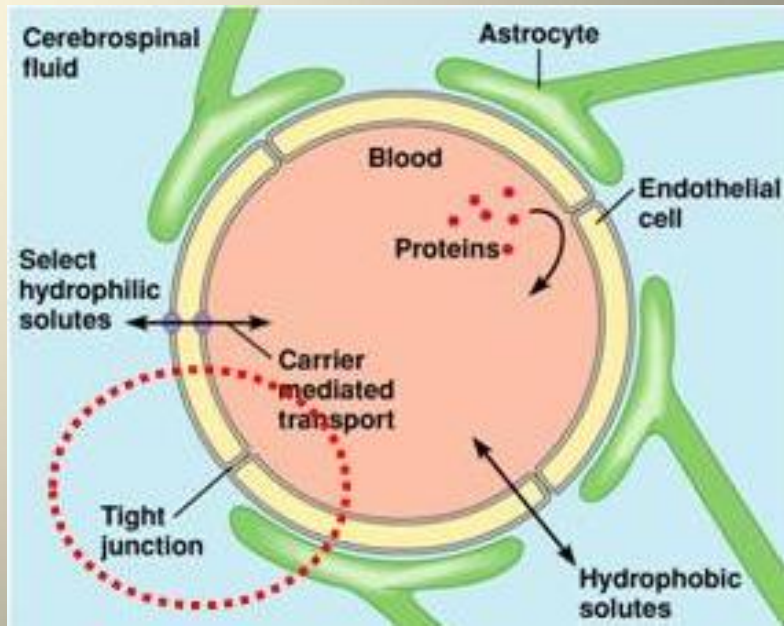
- Encase and protect your brain
- Blood-brain barrier: blood vessels located in the subarachnoid space (between the arachnoid and pia mater)



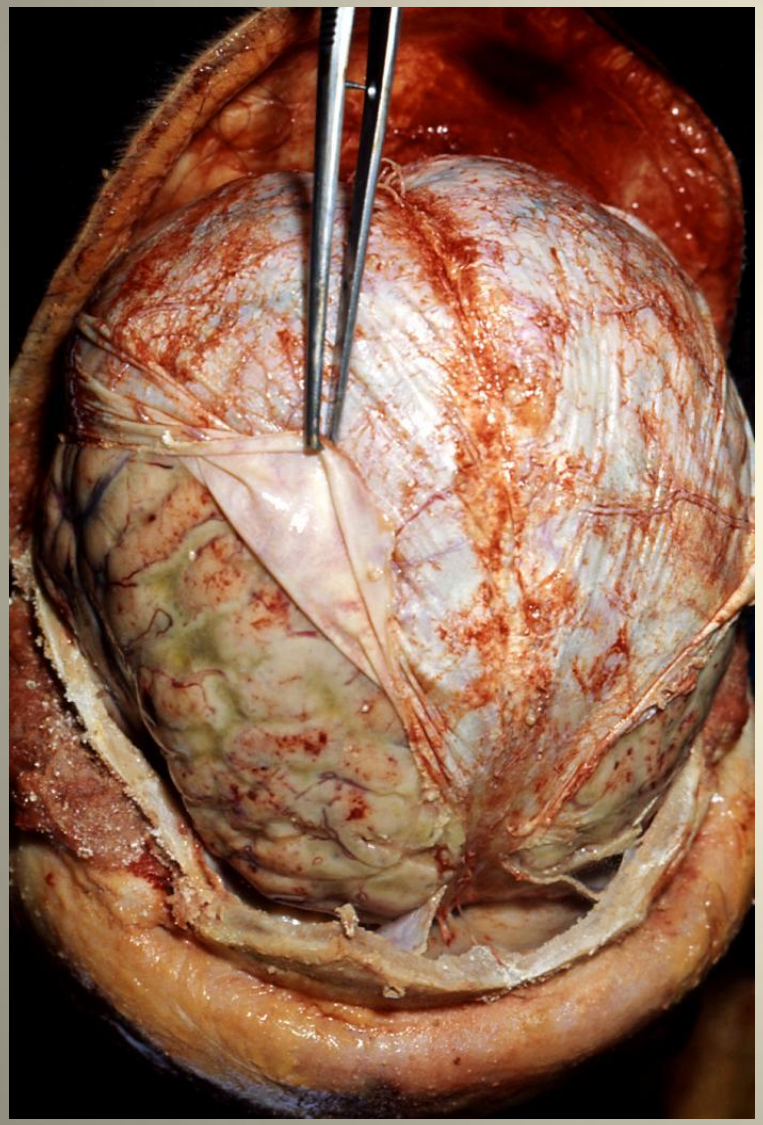
http://apbrwww5.apsu.edu/thompsonj/Anatomy%20&%20Physiology/2010/2010%20Exam%20Reviews/Exam%204%20Review/meninges.frontal.fig.12.20a.jpg

Meninges & the Blood-Brain Barrier

- Recall: blood-brain barrier prevents substances in the blood vessels from being absorbed into the brain.
- Selectively allows some substances to pass (e.g. oxygen, glucose)
- Nutrients to the brain is transported by the cerebrospinal fluid located in:
  - middle of the spinal cord
  - inner layers of meninges



Meningitis

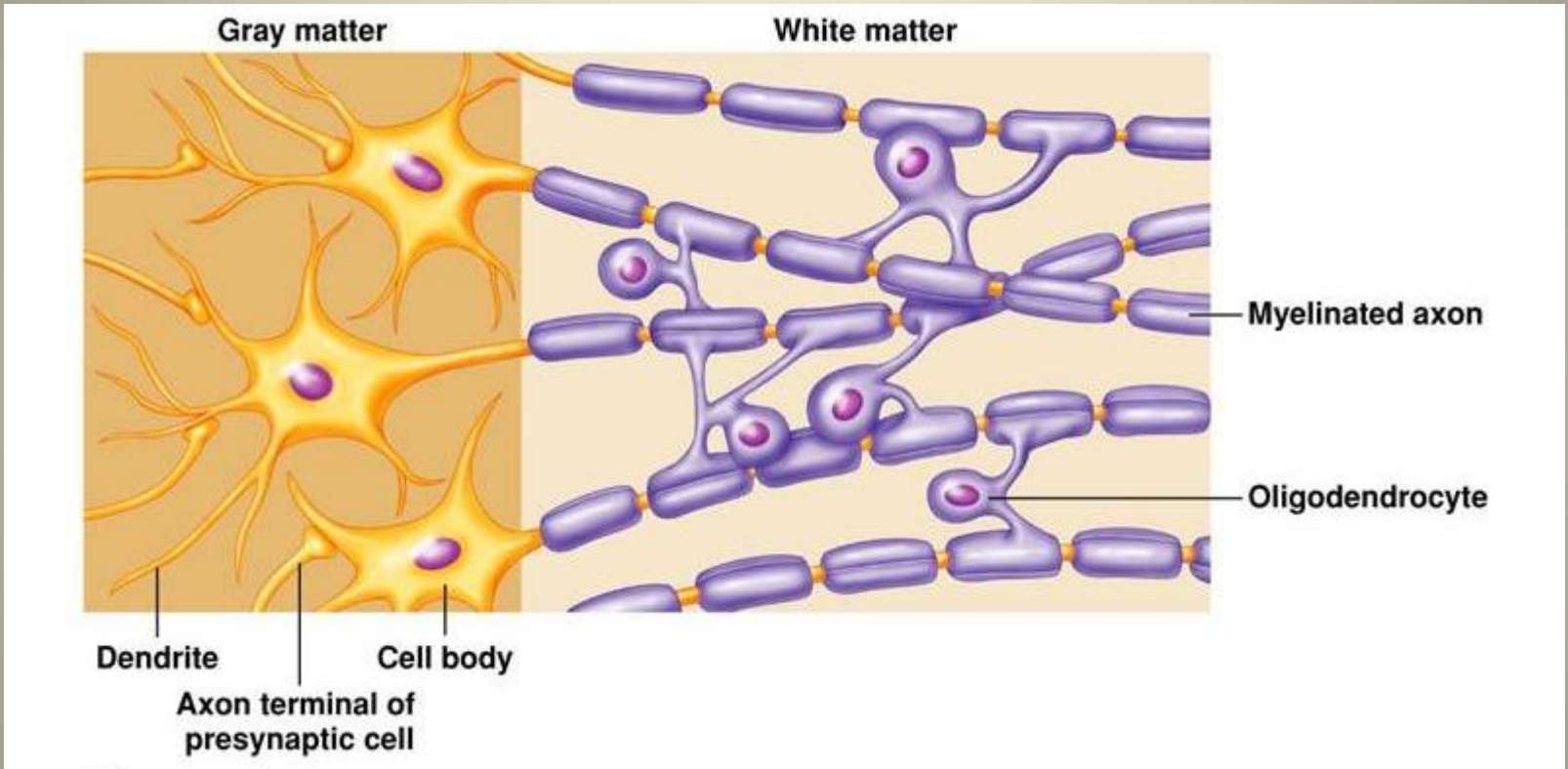


- inflammation of the meninges
  - viruses
  - bacteria
- antibodies do not reach the brain
- requires prompt medical treatment

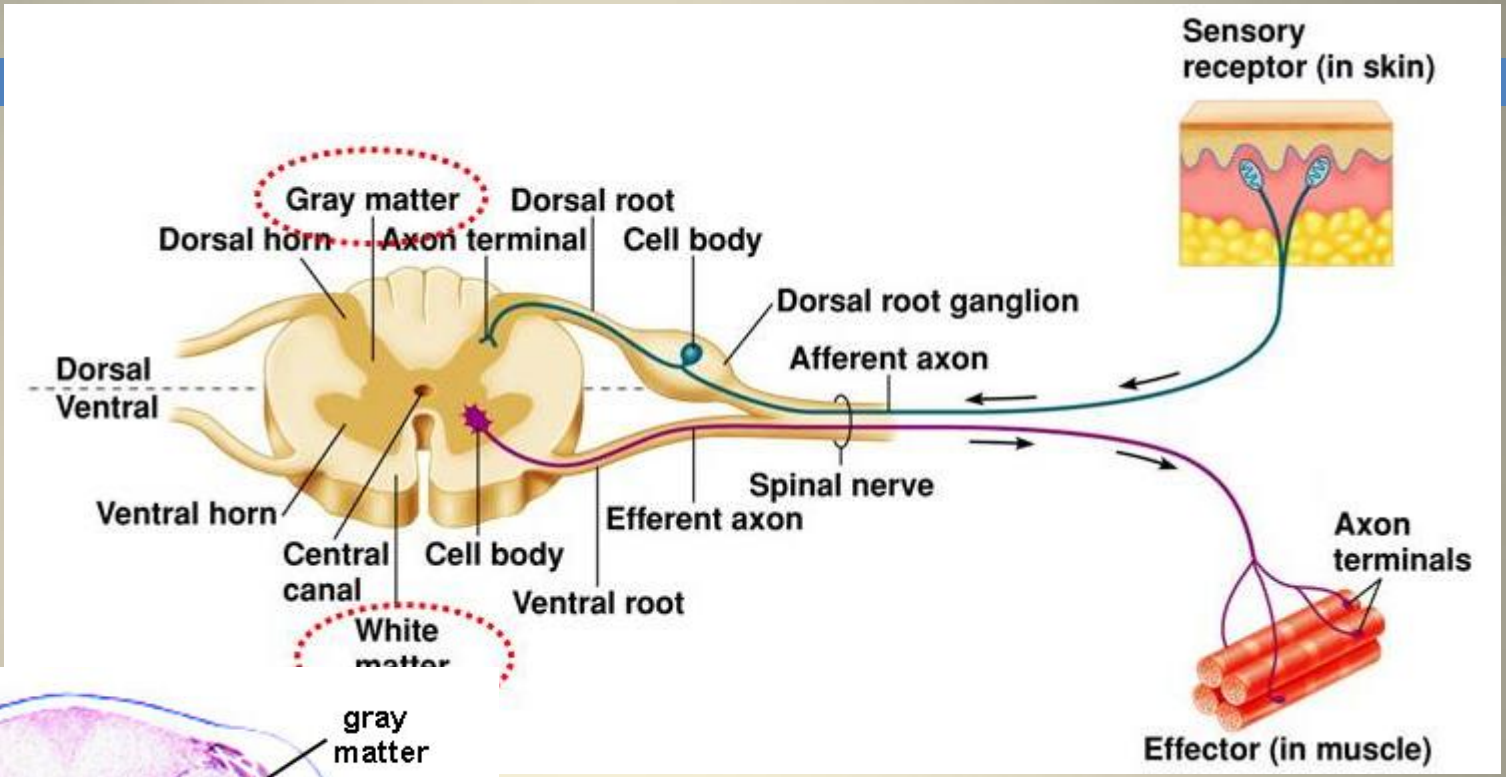
Bundling of axon

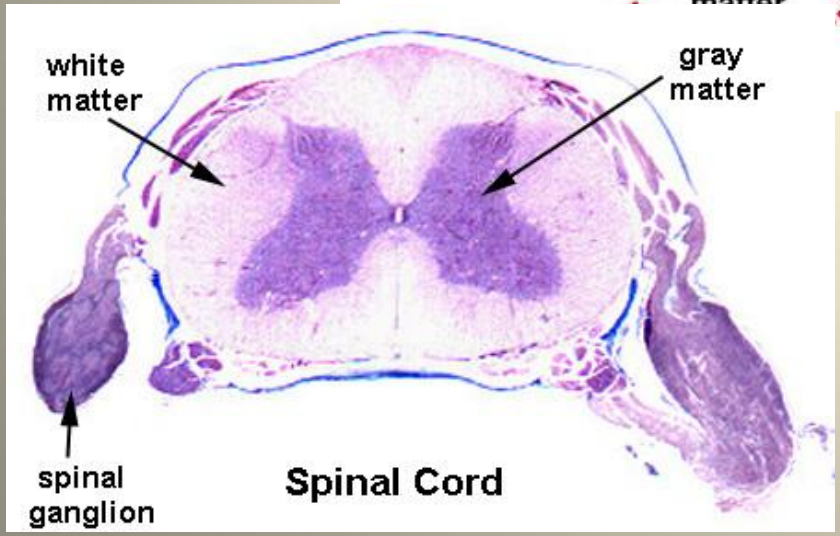
- White matter: bundles of myelinated axons
- Gray matter: unmyelinated axons, nuclei, and dendrites.

Gray & White Matter



Spinal Cord: cross section



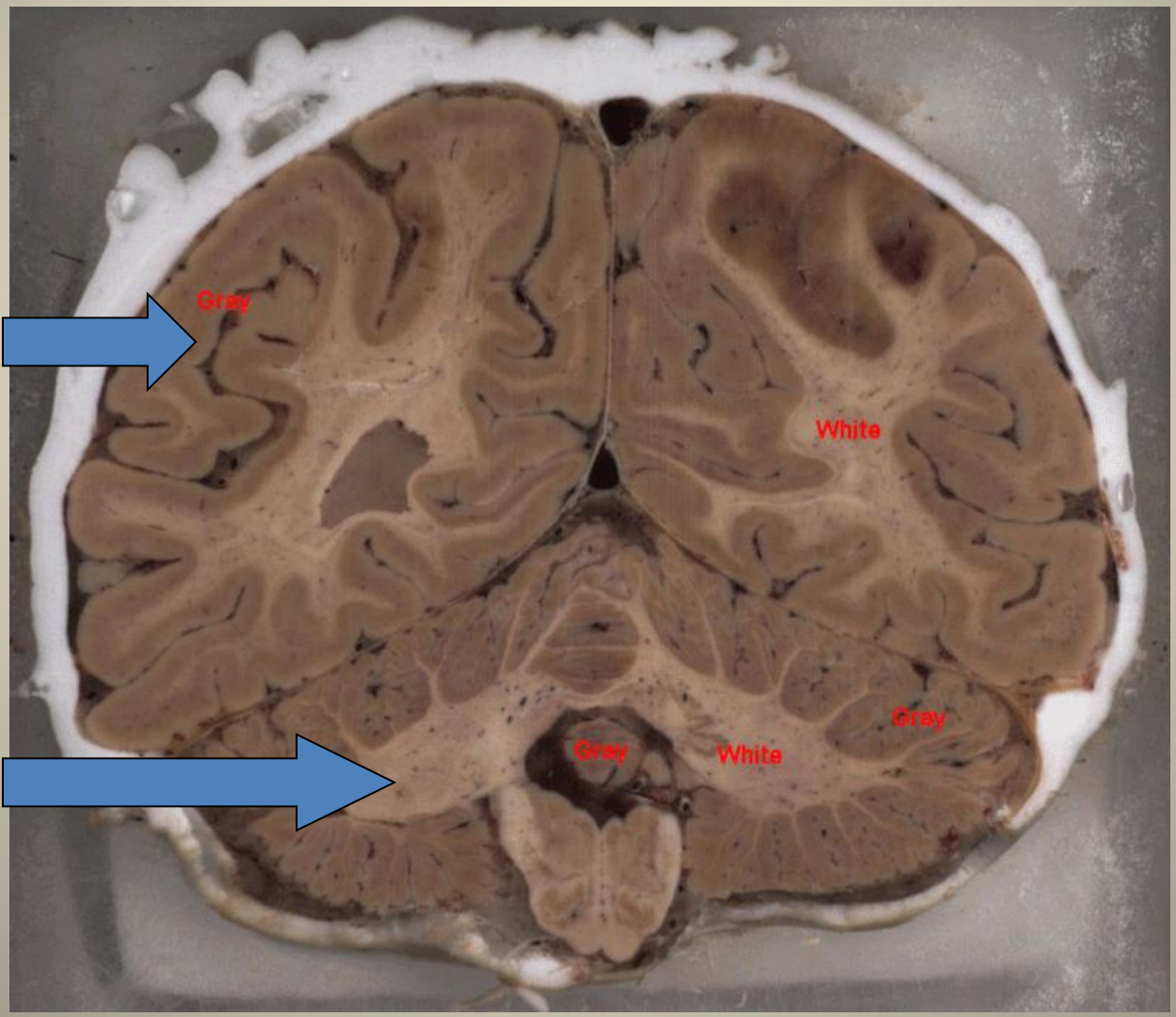


http://lifesci.rutgers.edu/~babiarz/histo/nerve/sc1L.jpg

White and gray matter in the brain

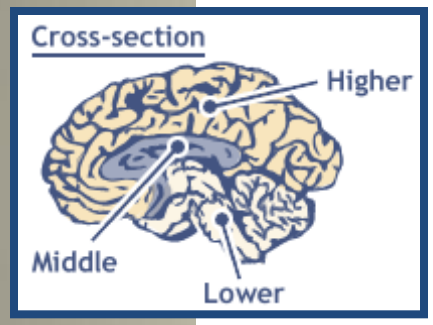
Gray matter

White matter



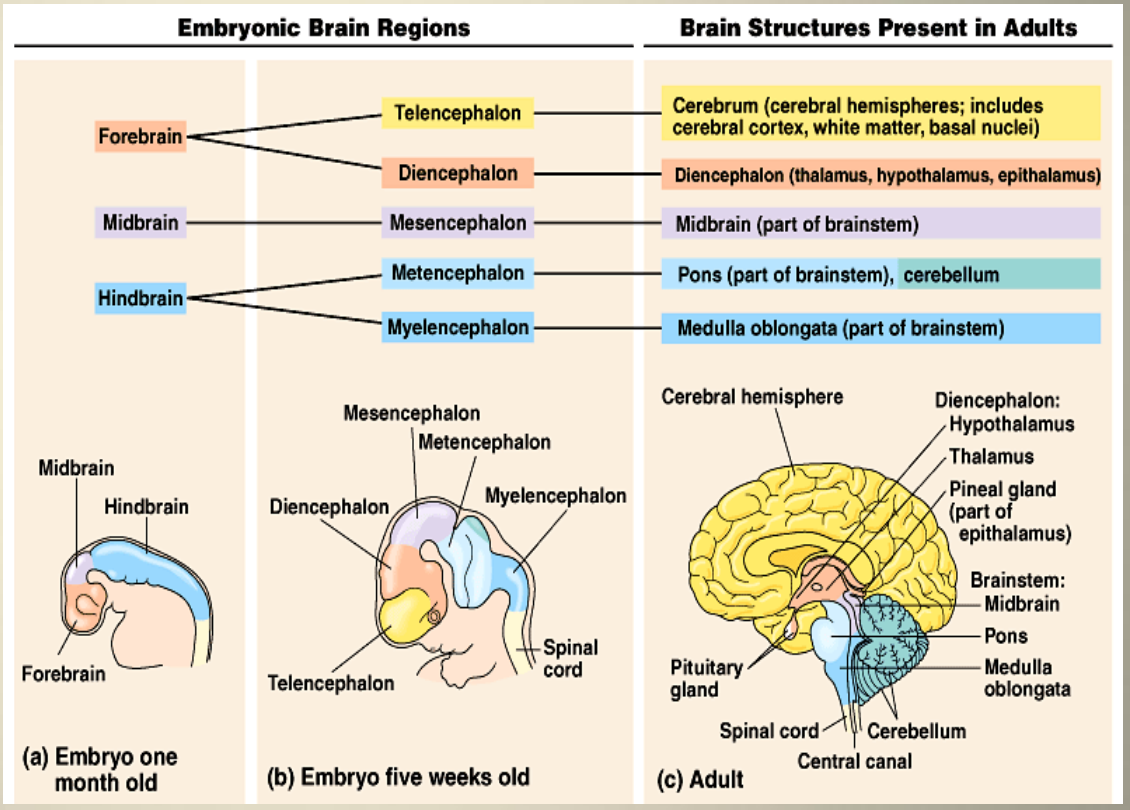
From http://cas.bellarmine.edu/tietjen/HumanBioogy/Brain01.gif

Anatomy of the Brain

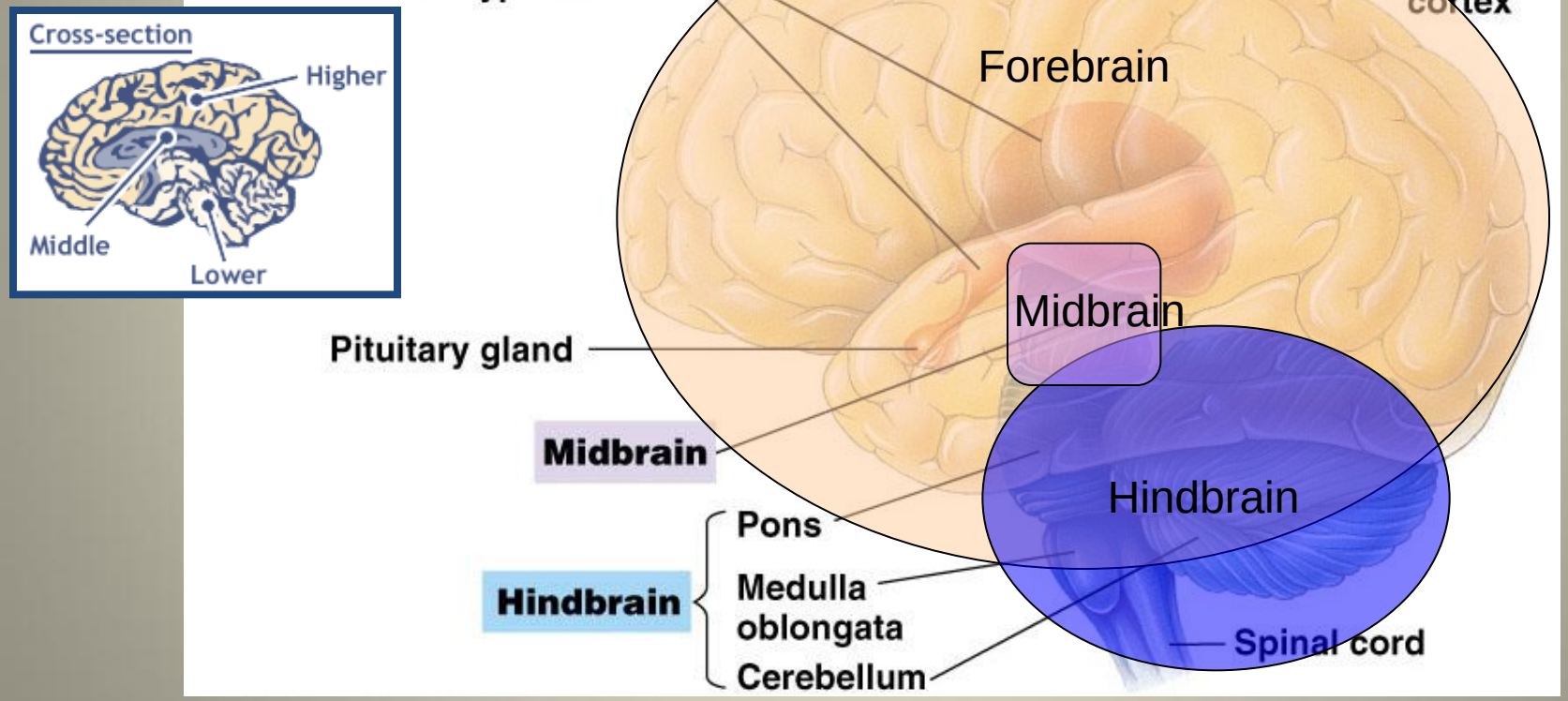


Three Sections of the Brain

1. Forebrain
2. Midbrain
3. Hind brain



Anatomy of the Brain



Brainstem

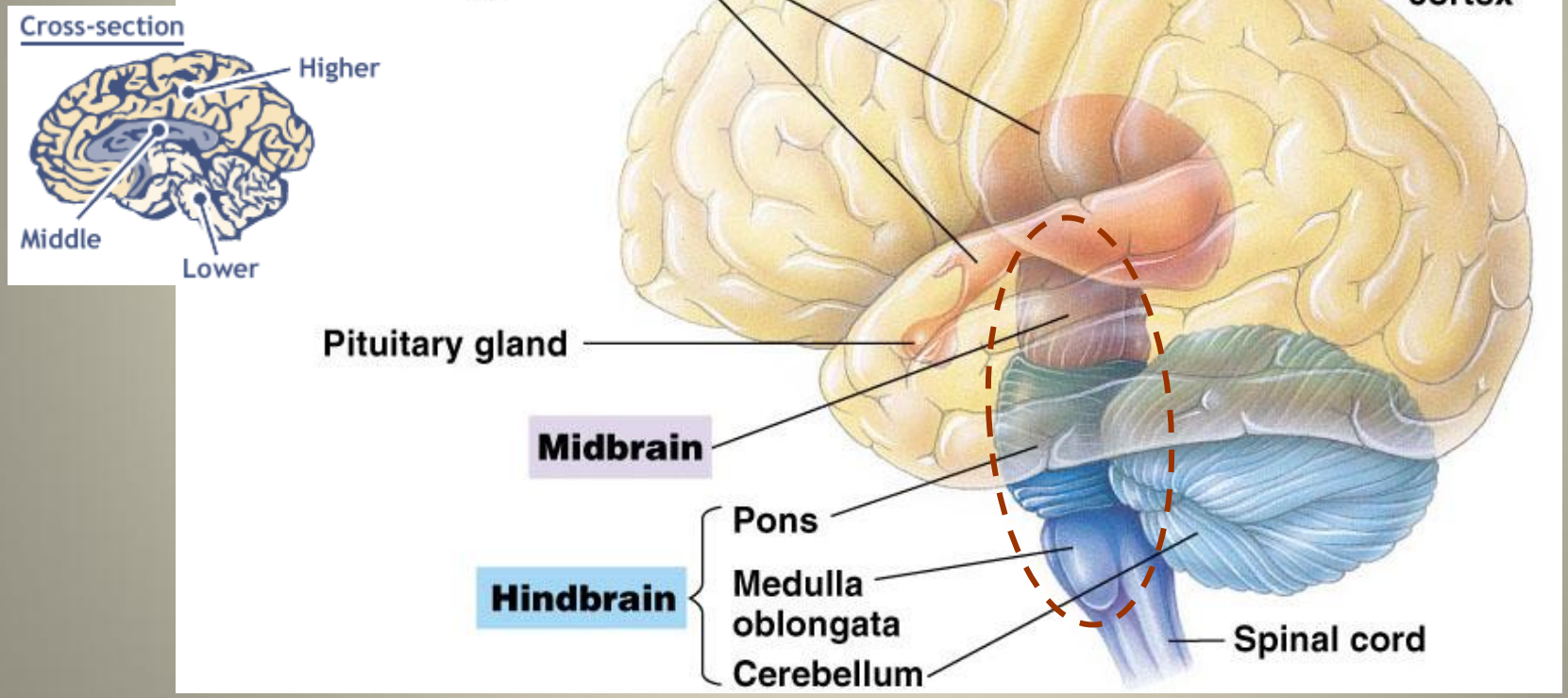
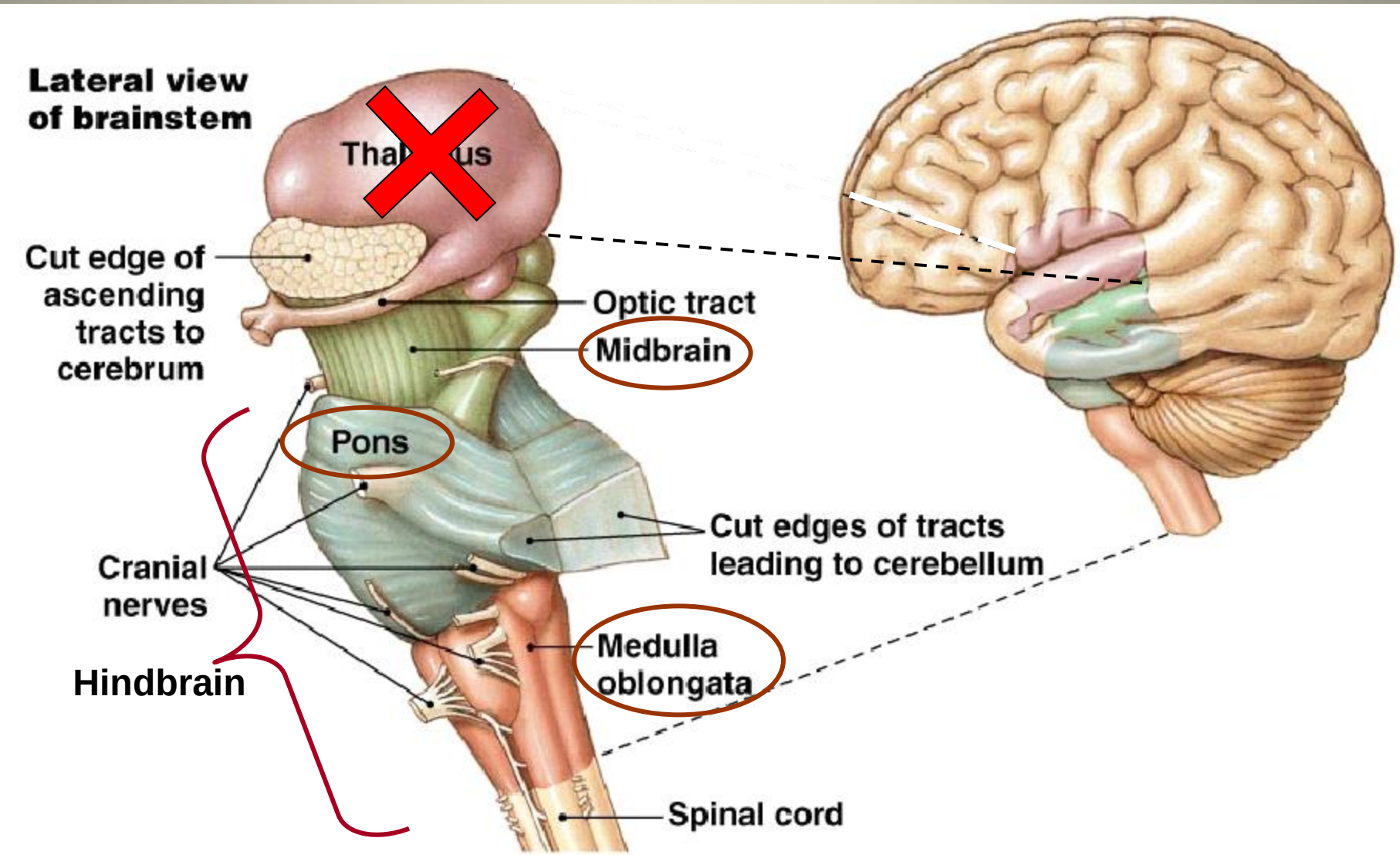
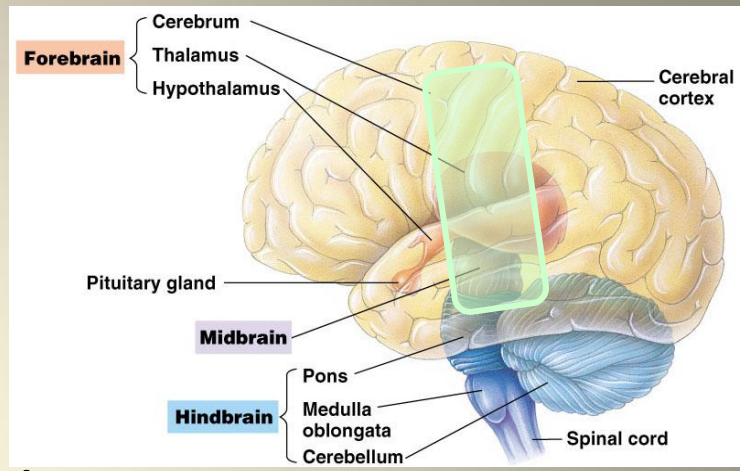


Fig. 48.20

Brainstem: “lower brain”

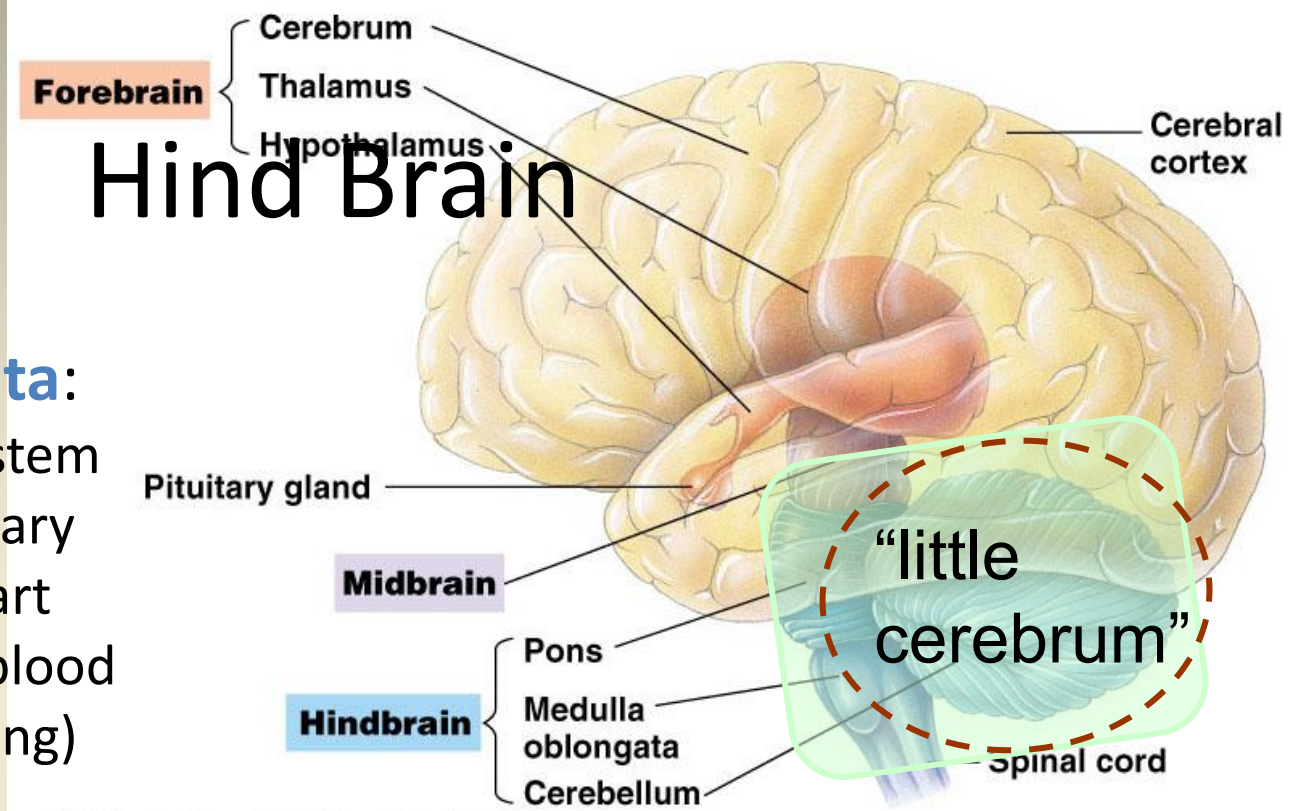


Brainstem Function



- Data conduction
  - Relay information from higher brain regions
- Large-scale coordination
  - body movement (e.g. walking)

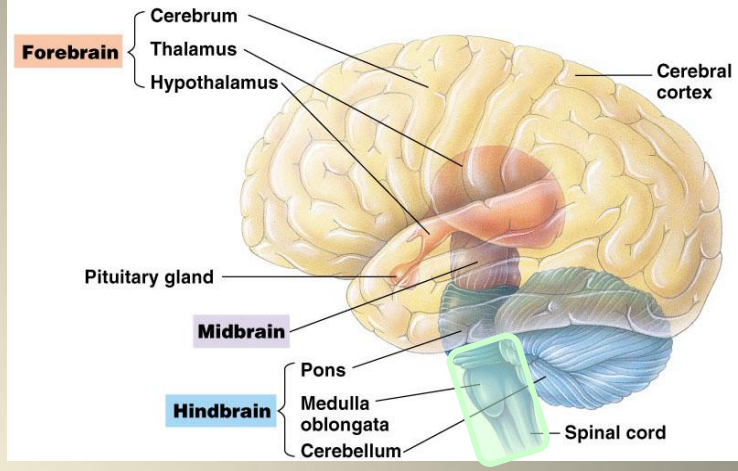
Hind Brain



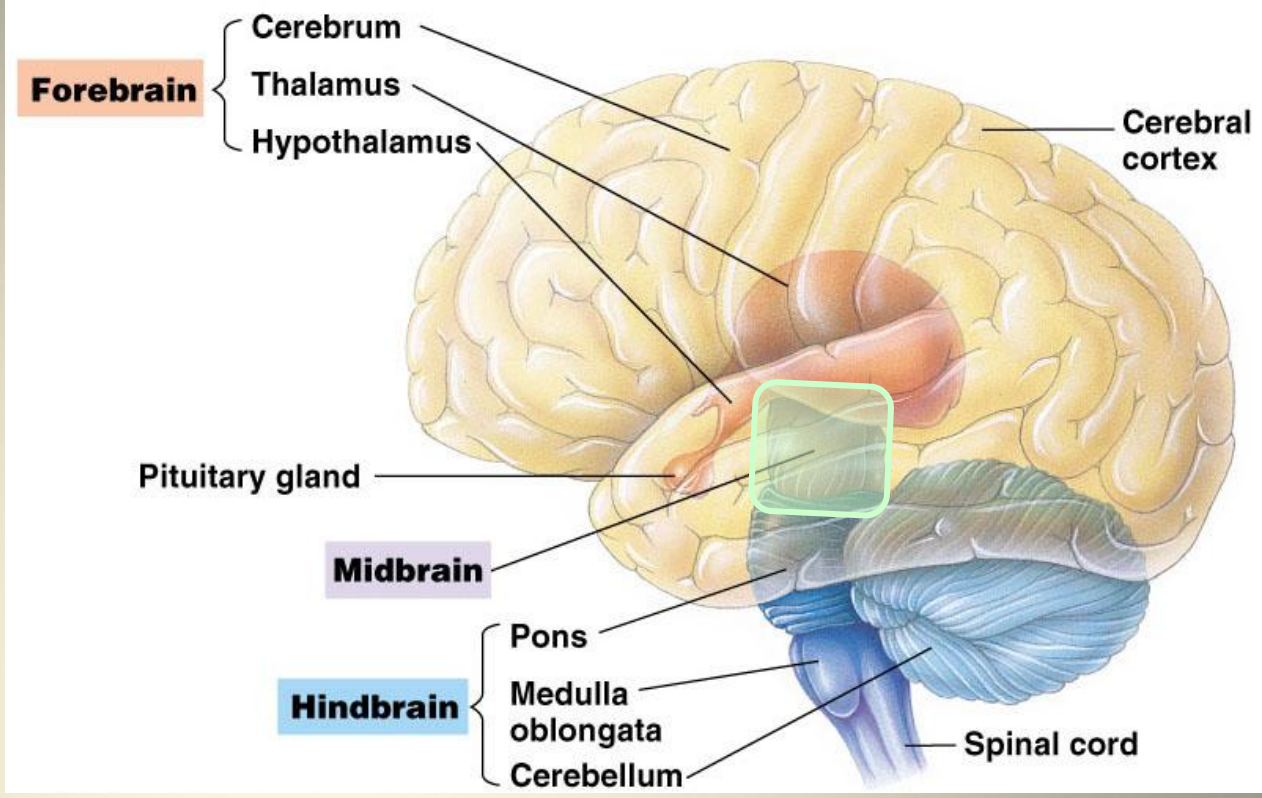
- **Medulla oblongata**:
  - at base of brain stem
  - controls involuntary muscles (e.g. heart rate, dilation of blood vessels, swallowing)
- **Pons**: bridges information between cerebellum and medulla oblongata

- **Cerebellum**:
  - Unconcious coordination: posture, body/limb movement, balance
  - Voluntary motor skills (e.g. writing, riding a bike)

Medulla Oblongata

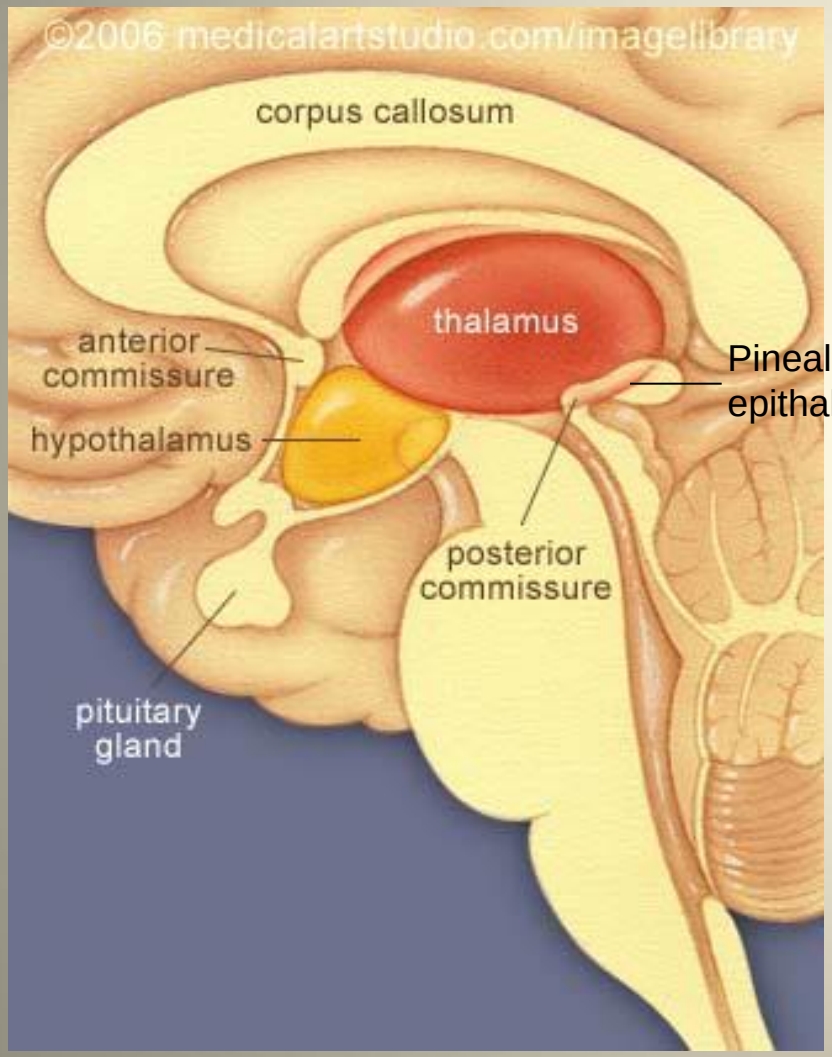


- Descending axons (brain to spinal cord) carrying instructions about movement will crisscross from right to left (and vice versa)
  - Thus right side of brain controls movement of left side of body etc.
- Crossing of axons occur at the medulla

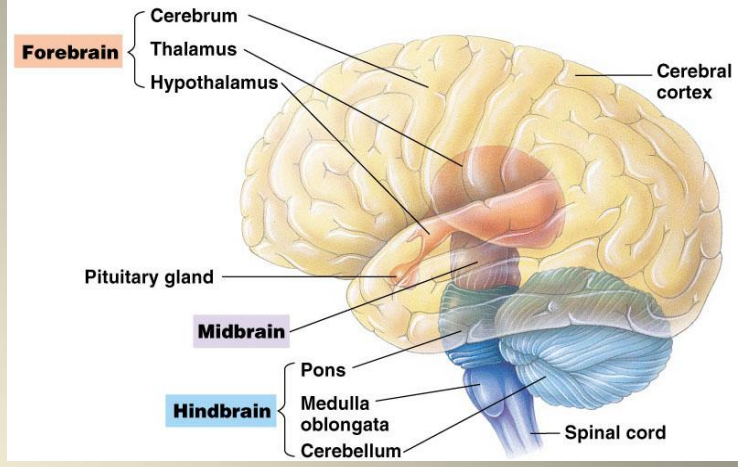


- Processes information from eyes, ears, nose
- Integration of sensory information
  - Superior colliculi: visual
  - Inferior colliculi: auditory system

Forebrain Regions



Pineal gland in epithalamus



- Regions:
  - Thalamus
  - Epithalamus
  - Hypothalamus
  - Pituitary gland
  - Cerebrum

"Lower"

Forebrain in the “lower brain”

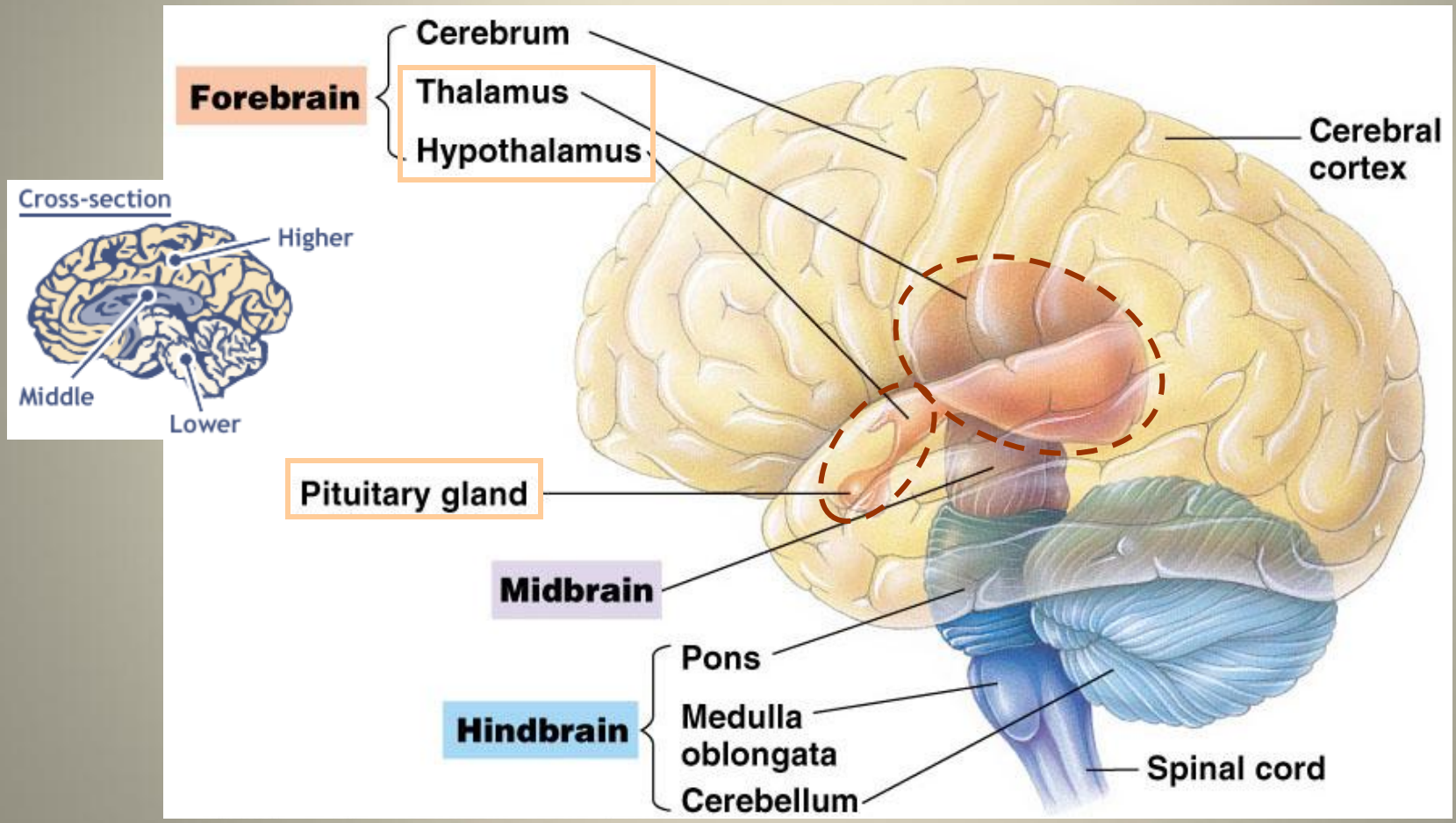
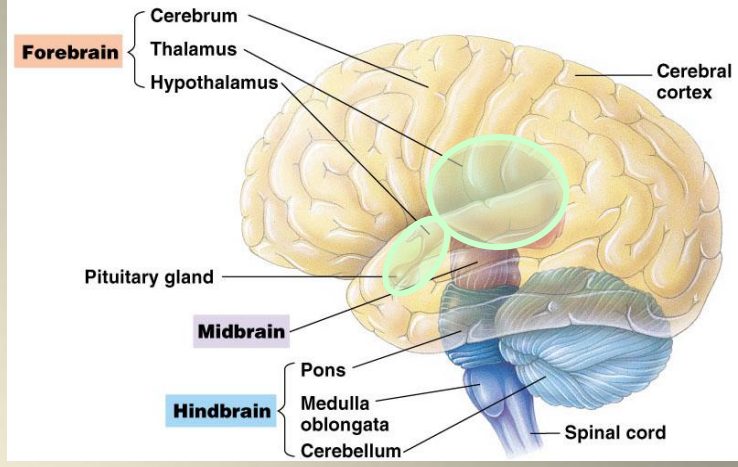


Fig. 48.20

Forebrain
"Lower" Functions



- **Thalamus**: "great relay station"
  - Receives sensory input and sorts and sends to cerebrum
  - Receives motor output information from cerebrum
- **Epithalamus**:
  - Has a tiny projection called the **pineal gland** that secretes a hormone to regulate functions related to light and seasonal changes
- **Hypothalamus & Pituitary gland**: homeostatic regulation (hormone production)

Forebrain “higher” brain

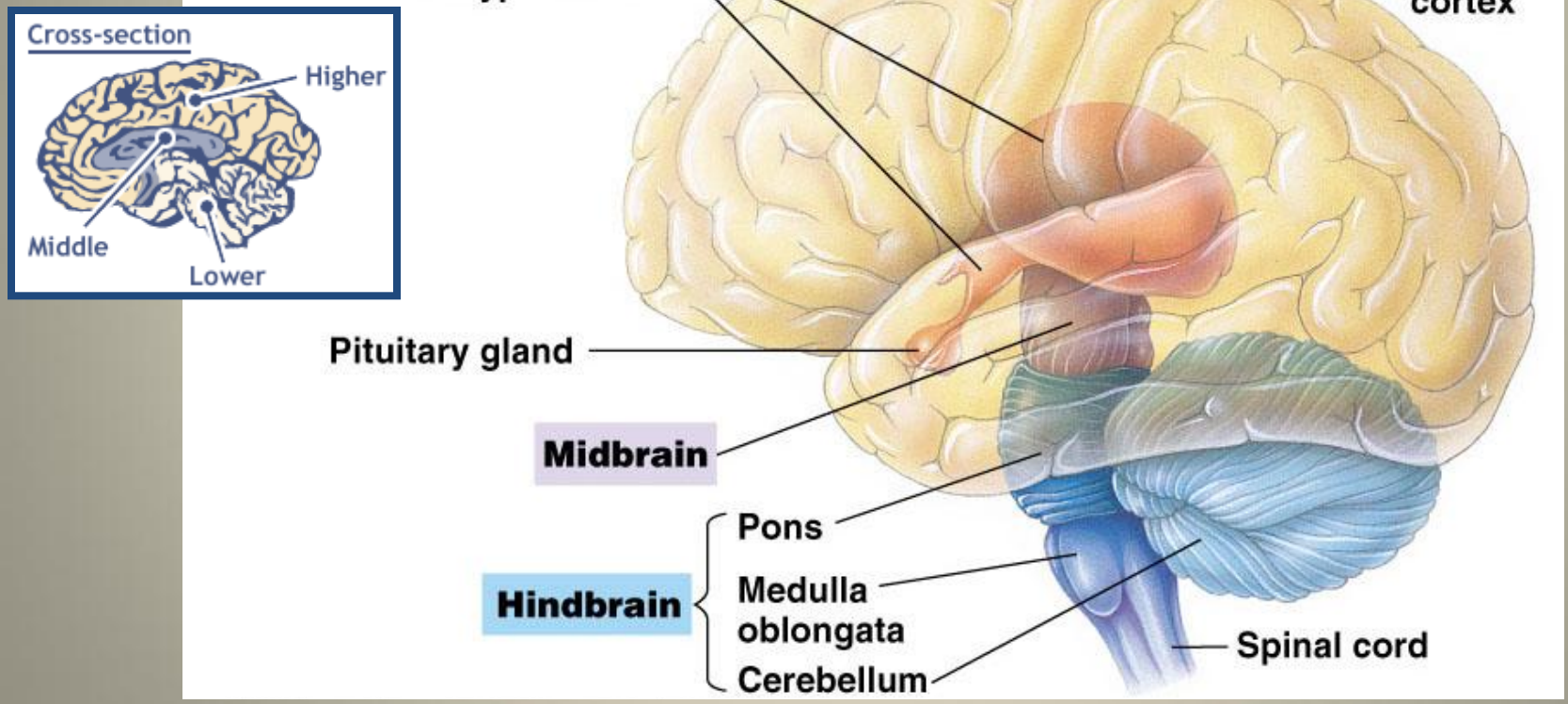


Fig. 48.20

Cerebrum

- Largest and most highly evolved structure of mammalian brain
- Divided into **2 hemispheres** and **4 lobes**
- **Corpus callosum**:
  - Connects left and right side
  - Communication between hemispheres
  - White matter

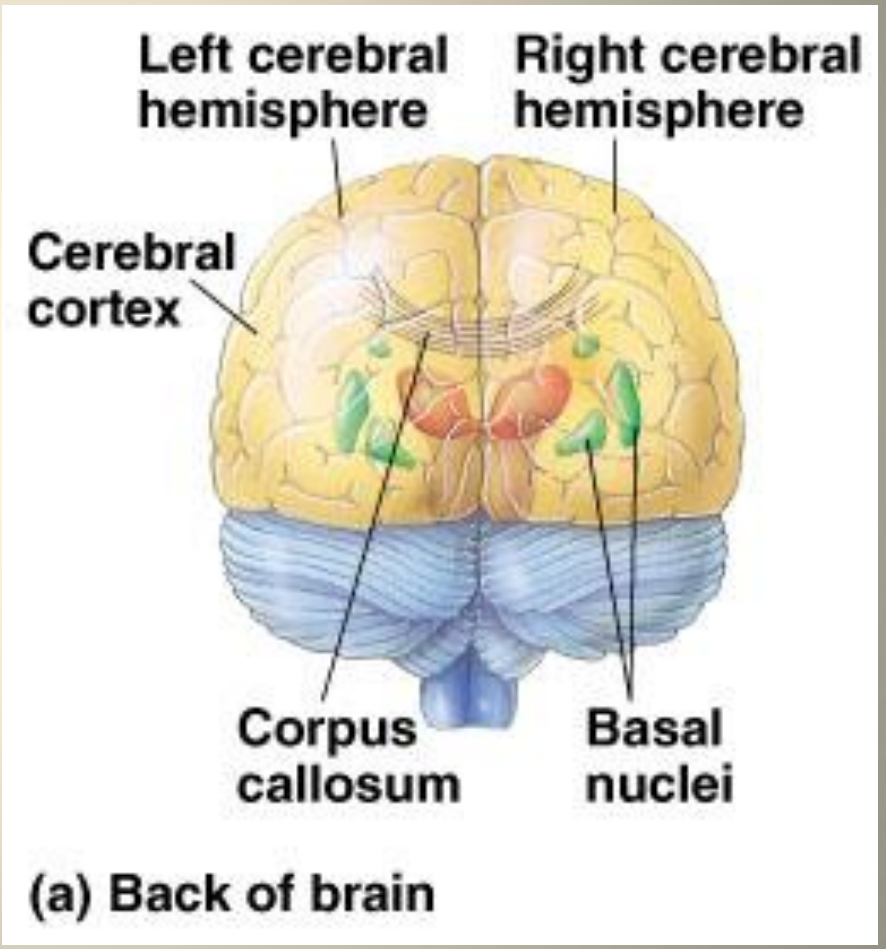
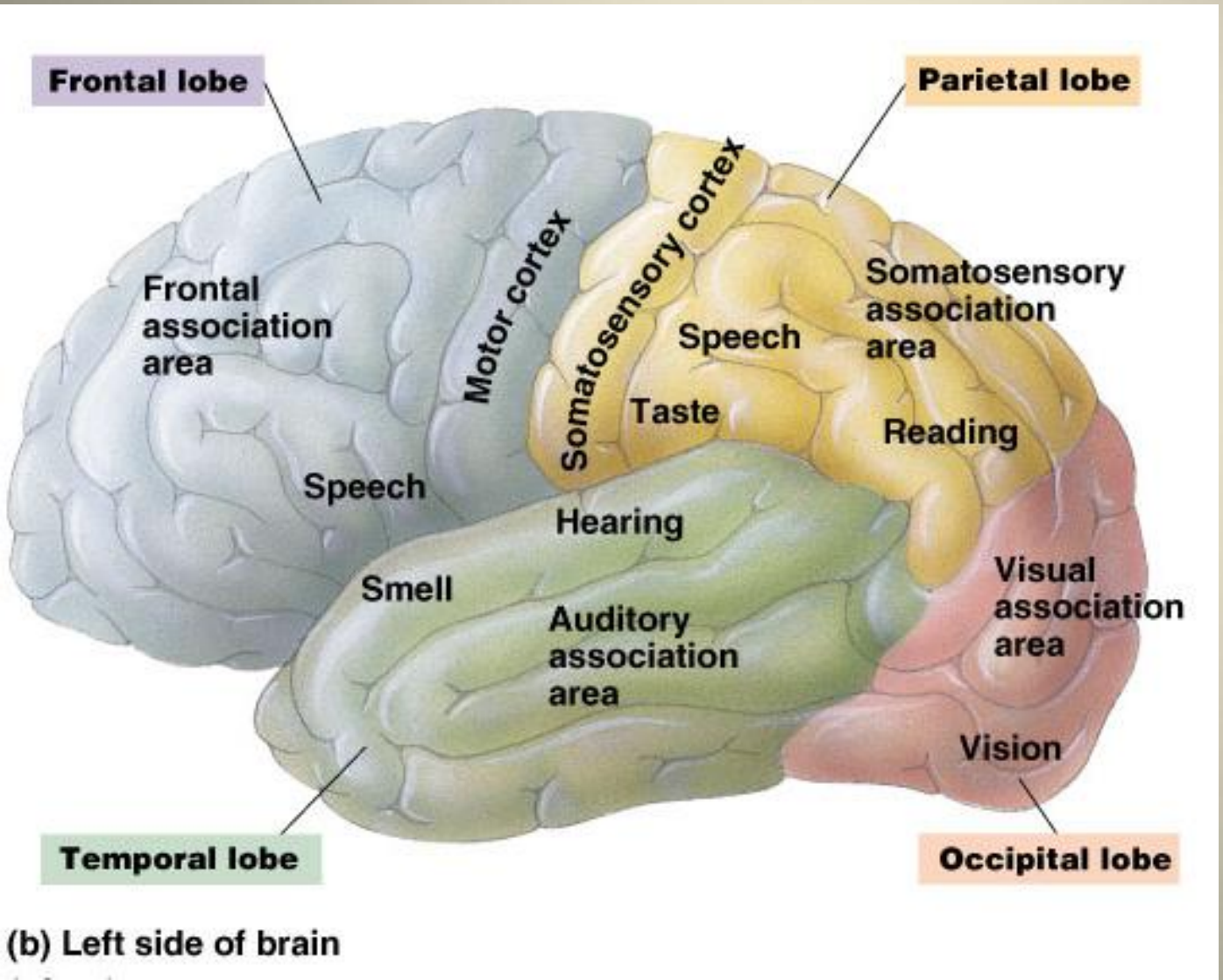


Fig. 48.24a

Cerebral Cortex

- Outer covering for mammals
- Gray matter
- 6 sheets of neurons on brain surface
- 5 mm thick, but 80%of total brain mass
- Convolutions increase surface area
- Greater cognitive abilities, more sophisticated behaviour

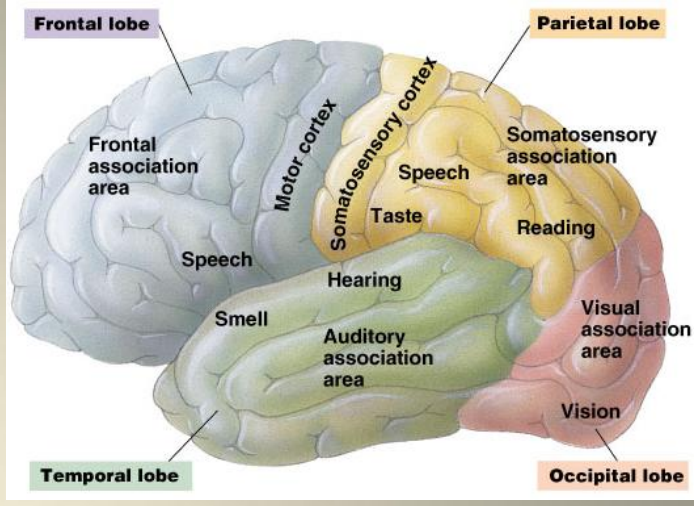
4 Lobes of the Cerebrum



(b) Left side of brain

Fig. 48.24b

Frontal Lobe

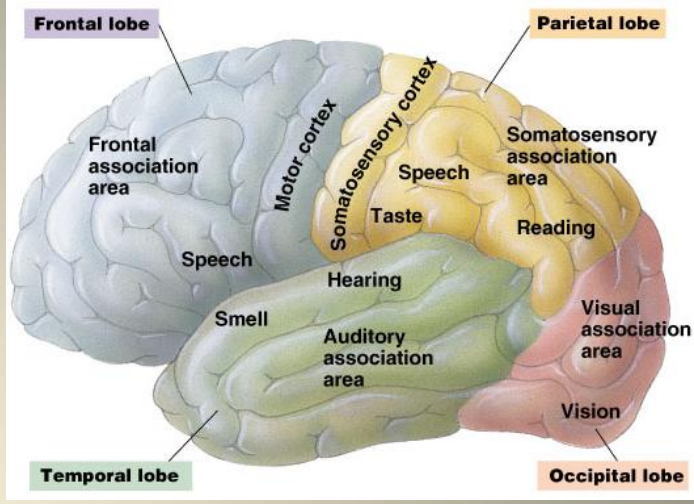


- controls **voluntary muscle movement**
- responsible for reasoning
- modulates emotions based on socially acceptable norms
- **Integrates** sensory information from the other lobes
- **Short-term memory**

Phineas Gage Story

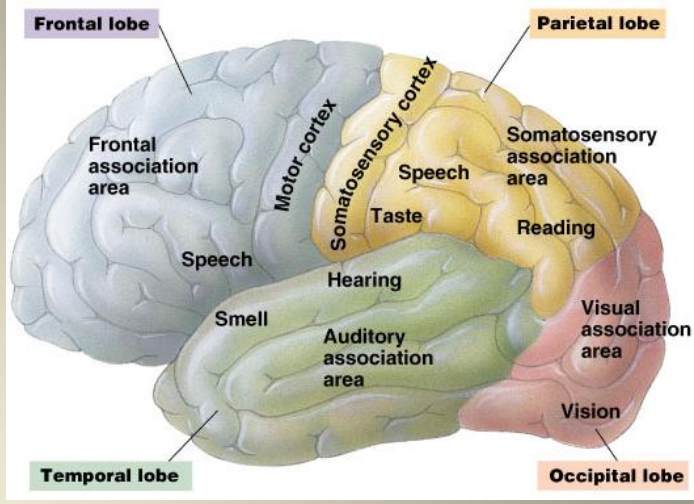
- On September 13, 1848 twenty-five-year-old Gage was foreman of a work gang blasting rock while preparing the roadbed for the Rutland & Burlington Railroad outside the town of Cavendish, Vermont.
- Setting a blast involved boring a hole deep into a body of rock; adding blasting powder, a fuse, and sand; then compacting this charge into the hole using a *tamping iron*—a large iron rod.
- Gage was doing this around 4:30 PM when the iron struck a spark against the rock (possibly because the sand was omitted) and the powder exploded, carrying an instrument through his head an inch and a fourth in diameter, and three feet and seven inches in length, which he was using at the time. The iron entered on the side of his face passing back of the left eye, and out at the top of the head
- The equilibrium or balance, so to speak, between his intellectual faculties and animal propensities, seems to have been destroyed. He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operations, which are no sooner arranged than they are abandoned in turn for others appearing more feasible. **A child in his intellectual capacity and manifestations, he has the animal passions of a strong man**.
- Previous to his injury, although untrained in the schools, he possessed a well-balanced mind, and was looked upon by those who knew him as a shrewd, smart businessman, very energetic and persistent in executing all his plans of operation. In this regard his mind was radically changed, so decidedly that his friends and acquaintances said he was "no longer Gage"

Temporal Lobe



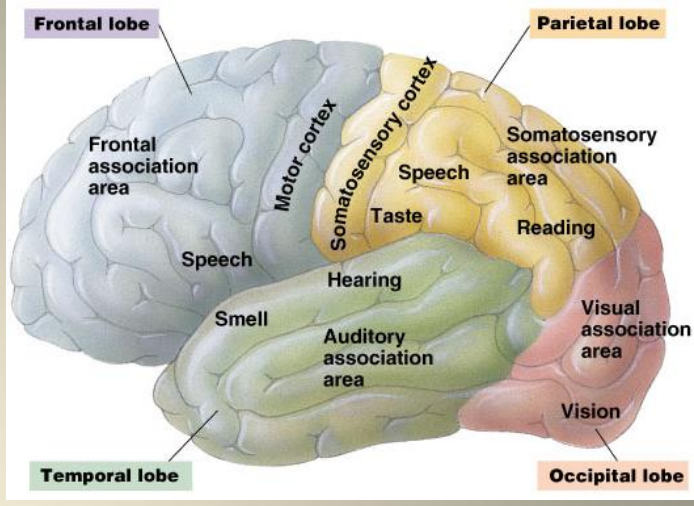
- Processes **hearing**
- **Hippocampus**: long-term memory
- **Amygdala**: processes memory and emotions

Occipital Lobe



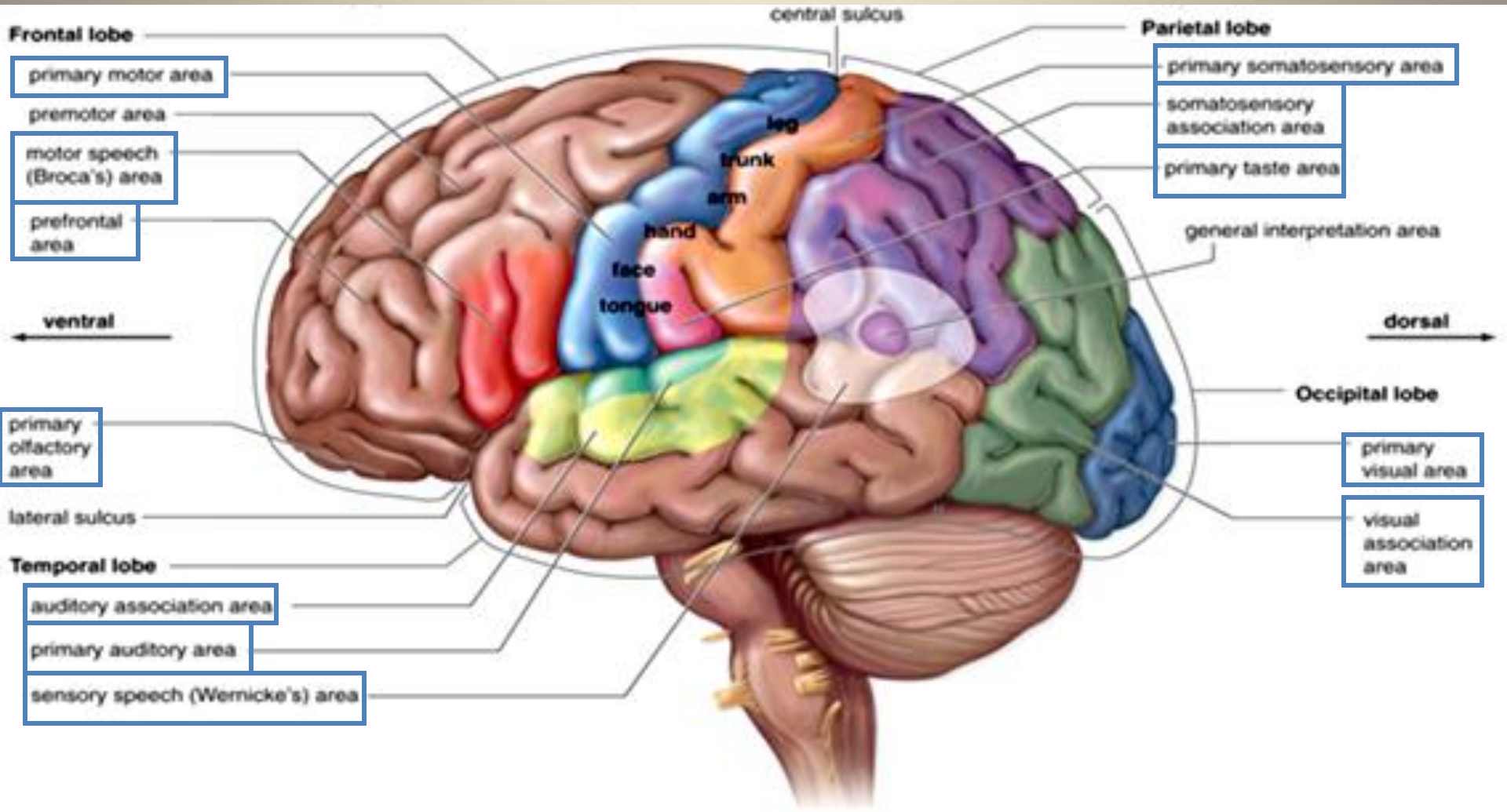
- responsible for primary **visual** information processing
- coordinates information gathered from the retina

Parietal Lobe



- Processes **touch & temperature** (somatosensory cortex), and **taste**
- **Visuospatial** analysis
  - examines numbers and processes ratios
  - Visuospatial Tests: http://www.alliqtests.com/tests/6/11/

Regions of the Cerebrum



http://lh4.ggpht.com/_lRGislJejZ0/SRp7sb6QjHI/AAAAAAAAB8c/xeGXGZP0LUY/image20_thumb4.png?imgmax=800

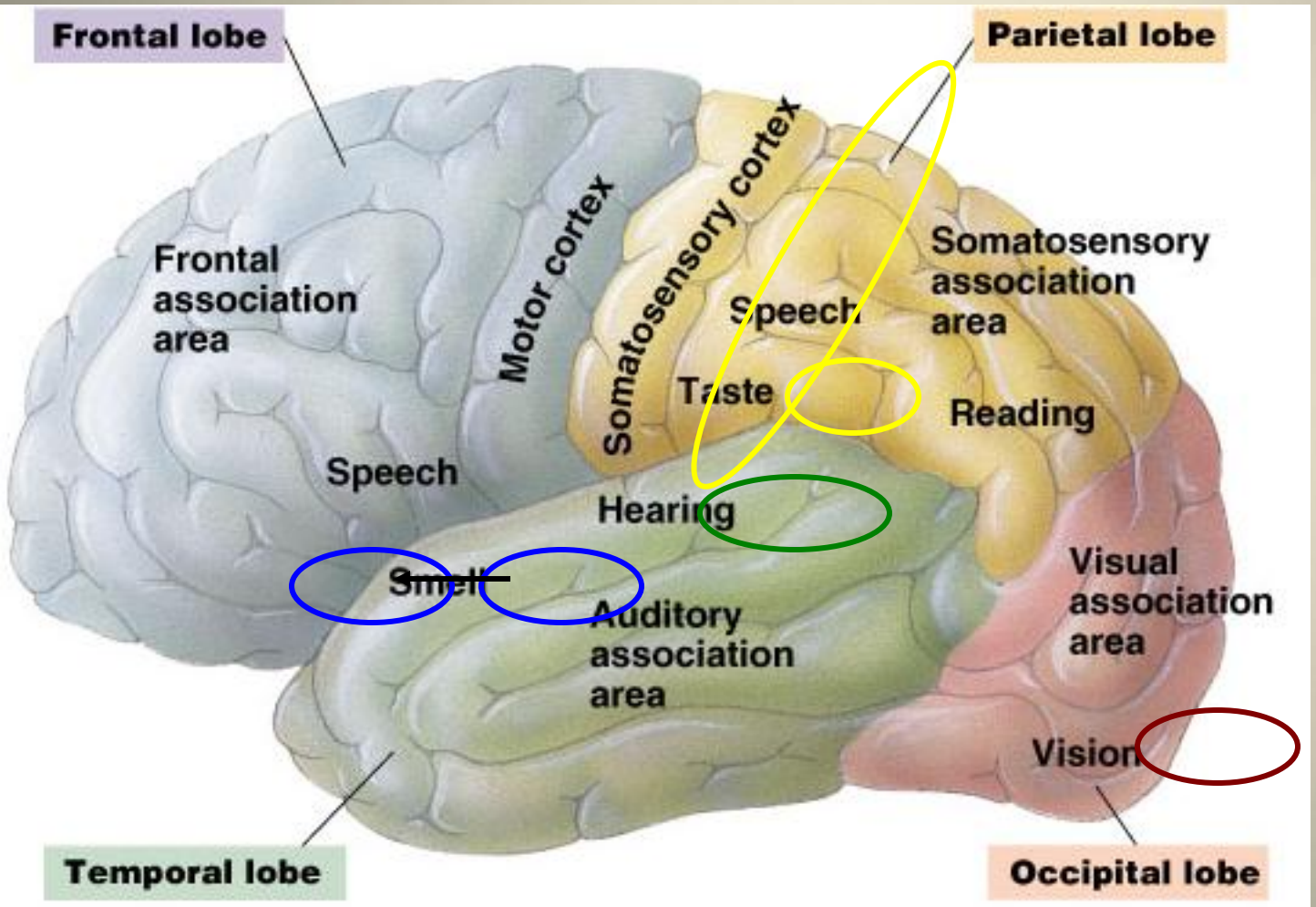
Integrative Function

- Specialized function in the brain that integrate various areas of the cerebrum
- Forms of integration
  A. Processing of sensory input
  B. Lateralization
  C. Language and Speech
  D. Emotions
  E. Memory and Learning

A. Processing of Sensory Input

1. Sensory input (sensory receptors & afferent neurons)
2. Primary sensory areas in lobes
   - Parietal, Occipital, temporal, frontal
3. Adjacent association areas in lobes
   - Information is integrated and assessed for significance
4. Frontal association area in frontal lobe
   - Compose a motor response
5. Primary Motor cortex
   - Direct movement of skeletal muscles
6. Motor Output (efferent neurons & effector cells)

A. Processing of Sensory Input: Primary sensory areas



(b) Left side of brain

Fig. 48.24b

Sensory Input Processing in Lobes of Cerebrum

Sensory input	Primary sensory areas in lobes	Adjacent association area
Visual		
Hearing		
Smell		
Taste		
Touch: pain, pressure Temperature Limb position		

Sensory Input Processing in Lobes of Cerebrum

Sensory input	Primary sensory areas in lobes	Adjacent association area
Visual	Occipital	
Hearing	Temporal	
Smell	Frontal	
Taste	Parietal: taste	
Touch: pain, pressure Temperature Limb position	Parietal: primary somatosensory cortex	

A. Processing of Sensory Input

1. Sensory input (sensory receptors & afferent neurons)
2. Primary sensory areas in lobes
3. Adjacent association areas in lobes
   - Information is integrated and assessed for significance
4. Frontal association area in frontal lobe
   - Composed a motor response
5. Primary motor cortex
   - Direct movement of skeletal muscles
6. Motor output (efferent neurons & effector cells)

A. Processing of Sensory Input: Adjacent association areas

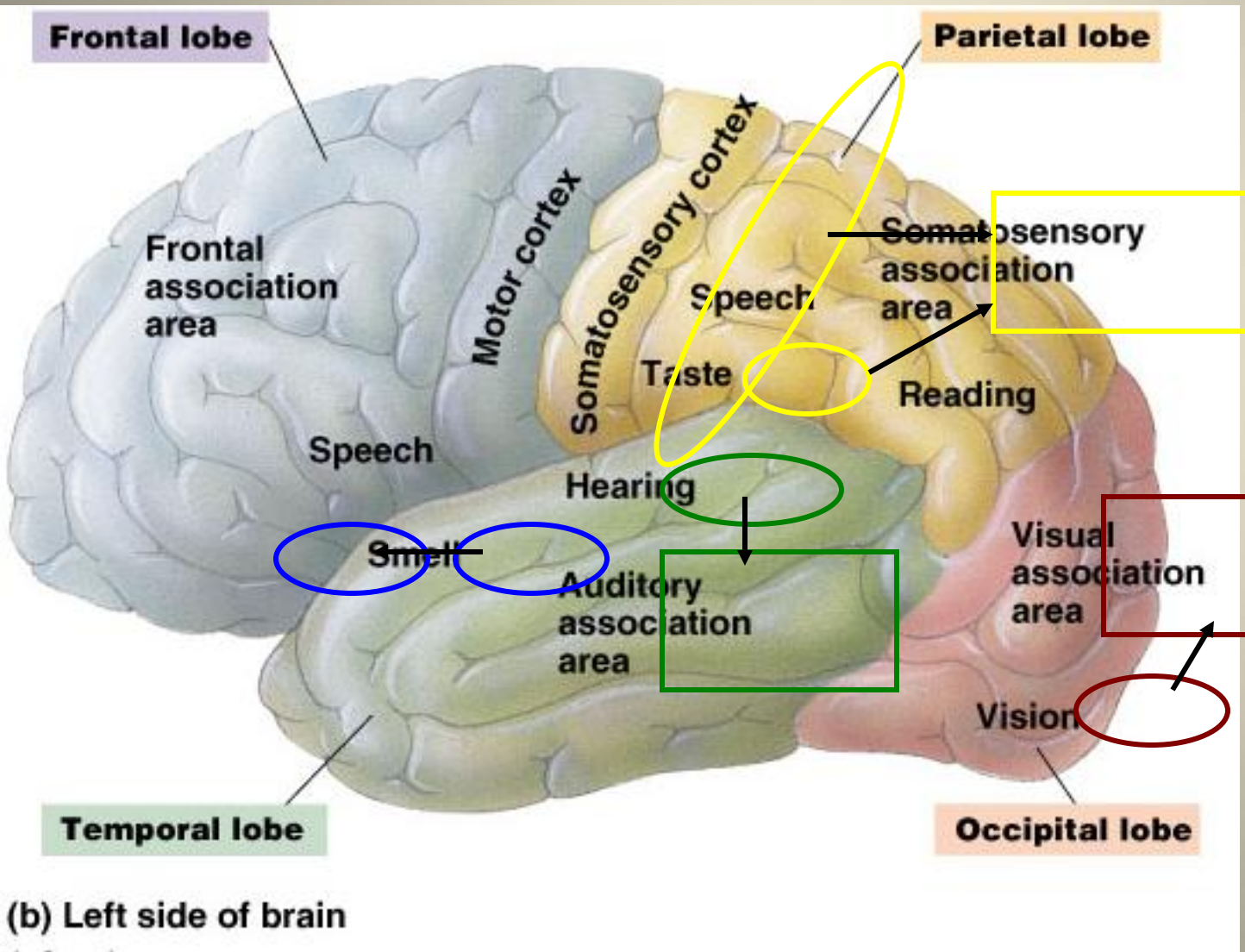


Fig. 48.24b

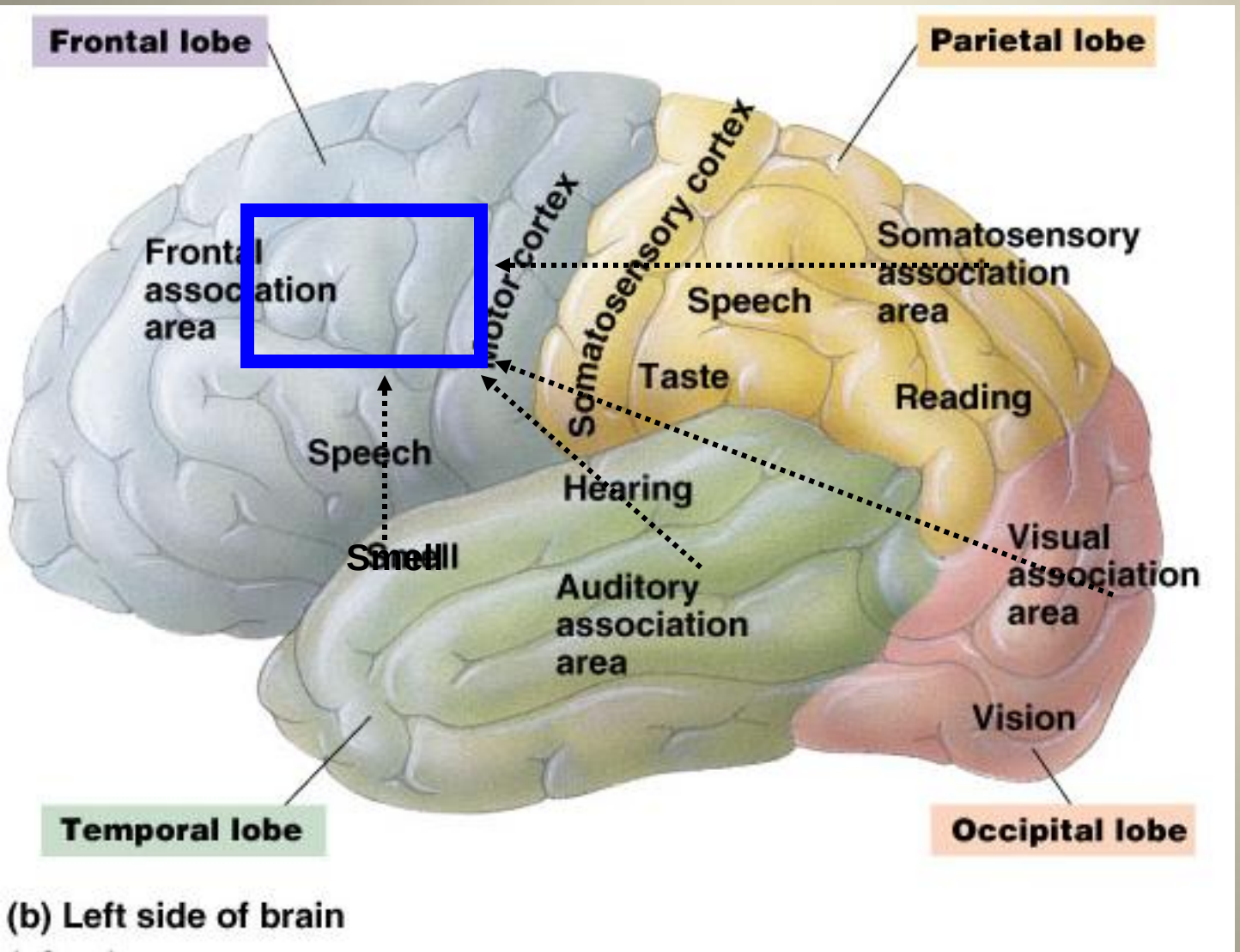
Sensory Input Processing in Lobes of Cerebrum

Sensory input	Primary sensory areas in lobes	Adjacent association area
Visual	Occipital	Visual
Hearing	Temporal	Auditory
Smell	Frontal	Frontal
Taste	Parietal: taste	Somatosensory
Touch: pain, pressure Temperature Limb position	Parietal: primary somatosensory cortex	Somatosensory

A. Processing of Sensory Input

1. Sensory input (sensory receptors & afferent neurons)
2. Primary sensory areas in lobes
3. Adjacent association areas in lobes
   - Information is integrated and assessed for significance
4. Frontal association area in frontal lobe
   - Composed a motor response
5. Primary motor cortex
   - Direct movement of skeletal muscles
6. Motor output (efferent neurons & effector cells)

A. Processing of Sensory Input: Frontal association area



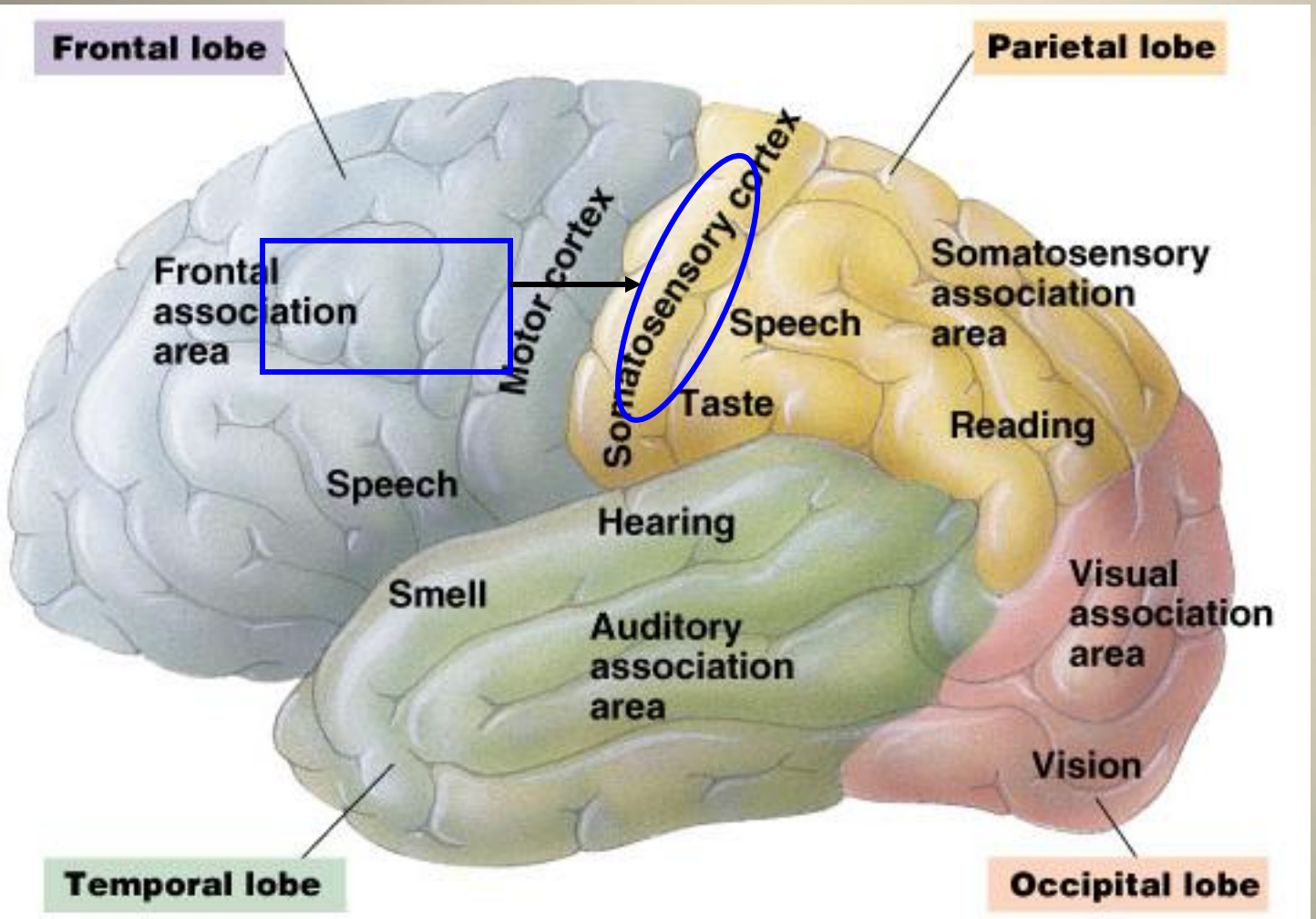
(b) Left side of brain

Fig. 48.24b

A. Processing of Sensory Input

1. Sensory input (sensory receptors & afferent neurons)
2. Primary sensory areas in lobes
3. Adjacent association areas in lobes
   - Information is integrated and assessed for significance
4. Frontal association area in frontal lobe
   - Composed a motor response
5. Primary motor cortex
   - Direct movement of skeletal muscles
6. Motor output (efferent neurons & effector cells)

A. Processing of Sensory Input



(b) Left side of brain

Fig. 48.24b

Primary Cortex

Motor Output
(Voluntary control of skeletal muscles)

Sensory Input:
Somatic sense of touch
(Not specialized senses: sight, sound, smell, taste)

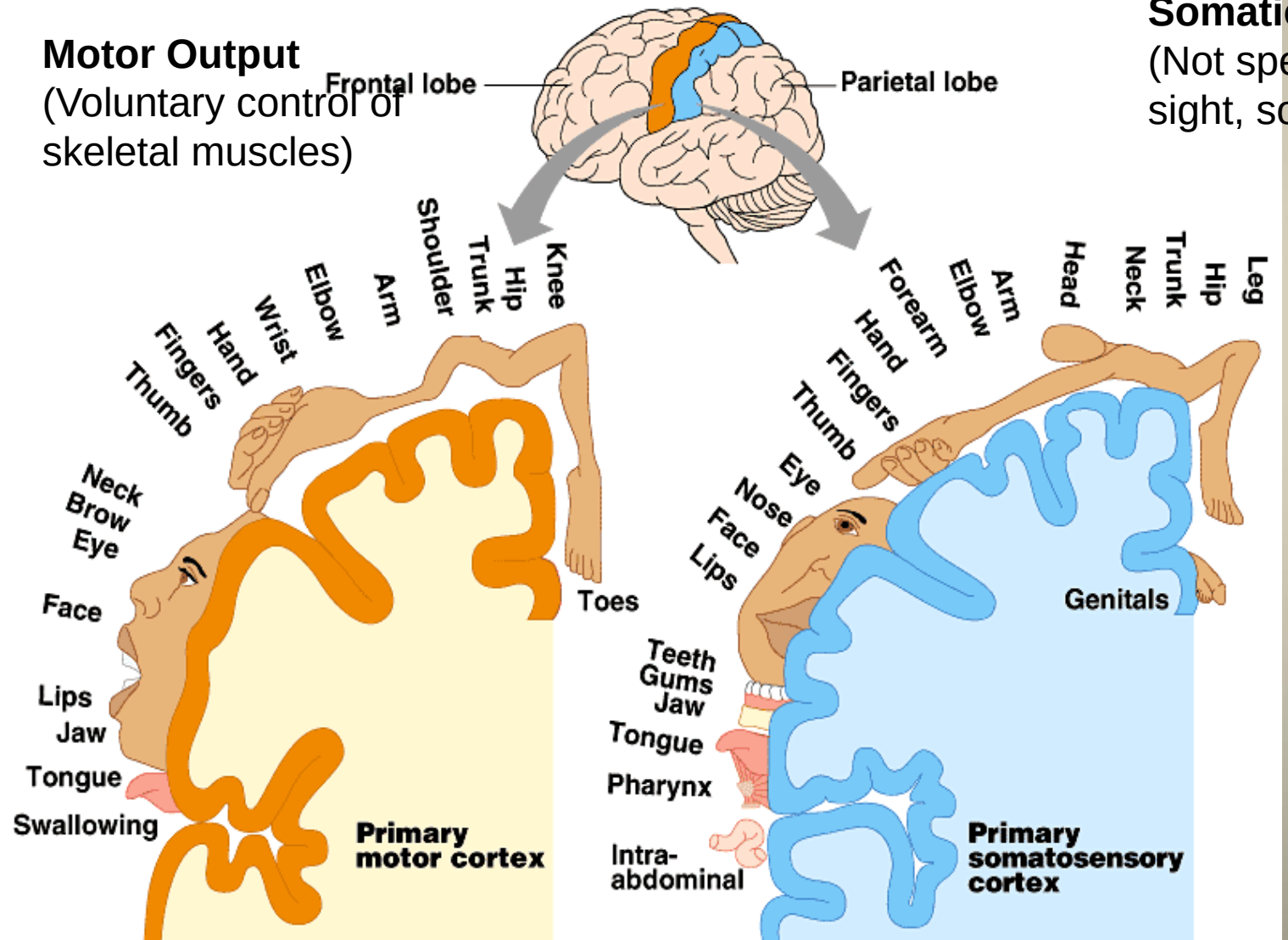


Fig. 48.25

Primary Cortex

- Primary somatosensory cortex
  - receives and integrates sensory information
  - Input from: skin, muscle, joints
  - Senses: touch, temperature, limb position
- Primary motor cortex
  - sends signals to skeletal muscles

B. Lateralization

- allocation of brain function to right or left hemisphere
- occurs during brain development (child)

Lateralization of Brain Function

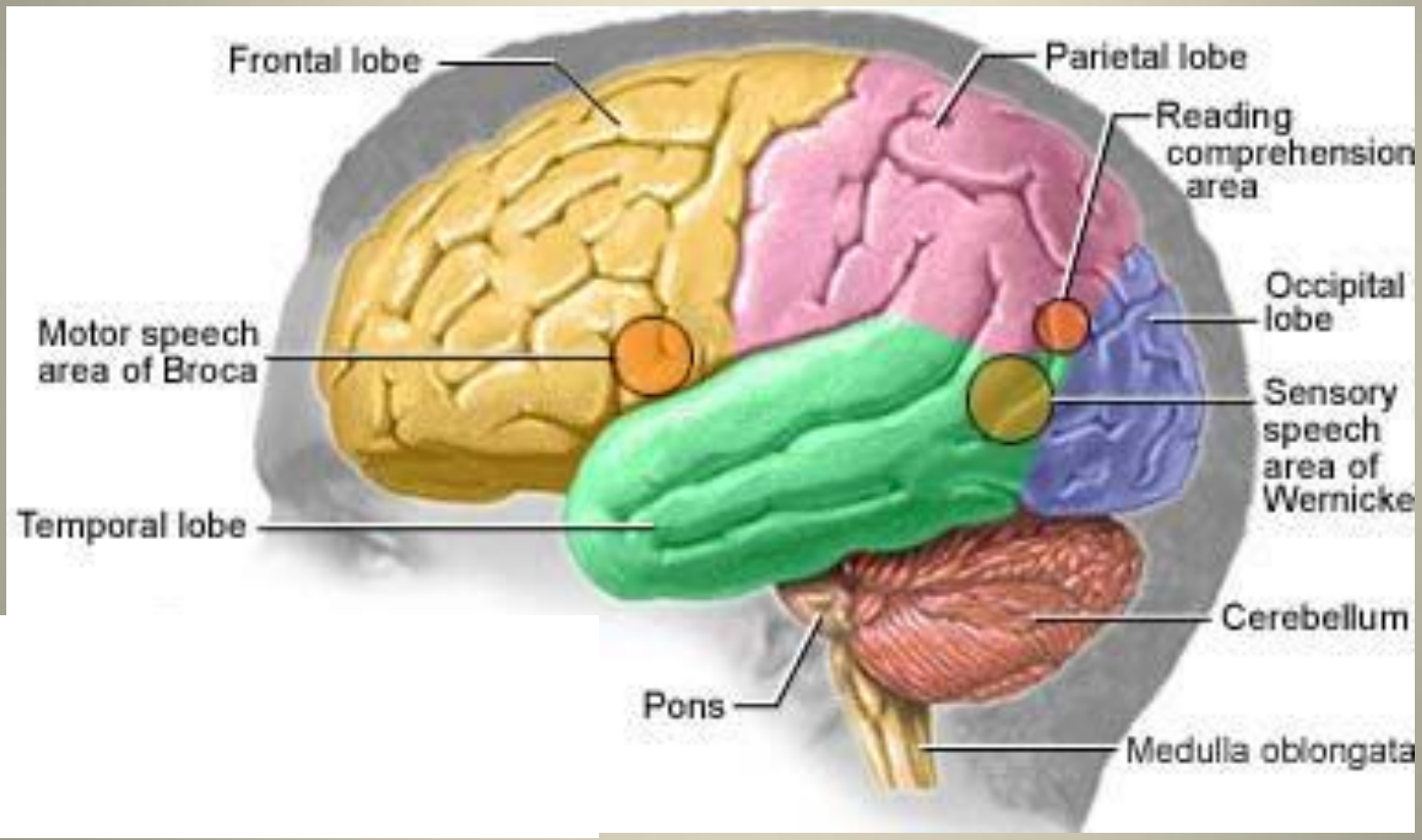
Left hemisphere

- Language
- math, logic operations
- processing of serial sequences of information
- Processing of fine visual & auditory details
- Specialized in detailed activities required for motor control

Right hemisphere

- pattern recognition, spatial relationships
- face recognition & emotional processing
- music
- Multi-tasking
- Specialized in interpreting whole context

C. Language and Speech areas

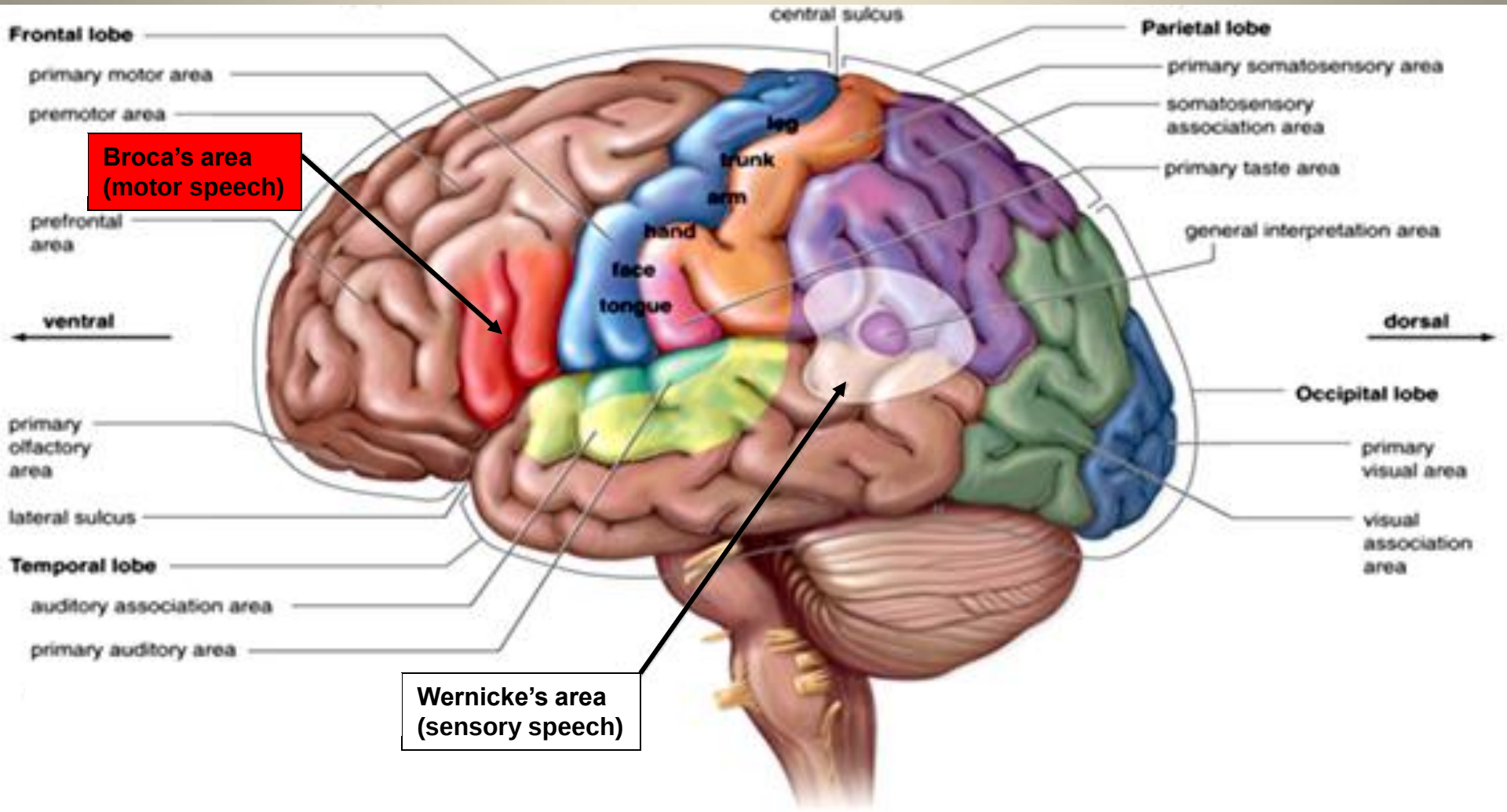


http://www.pennmedicine.org/health_info/body_guide/reftext/images/anatomy_brain.jpg

C. Language and Speech areas

Areas	Broca	Wernicke
Location	Frontal lobe	Temporal lobe
Function	Speech production (motor)	Speech comprehension (sensory)
Function when the area is damaged	Can understand speech, can't speak	Can say words, but doesn't make any sense

C. Language and Speech areas



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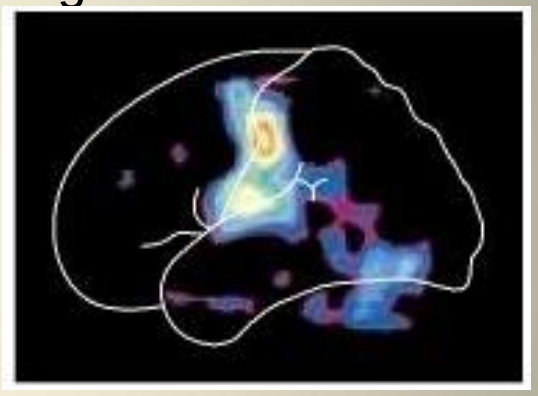
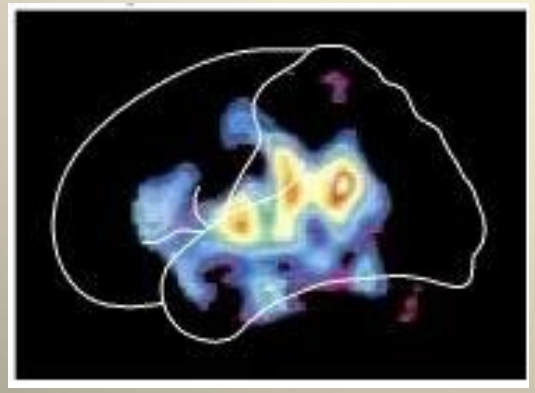
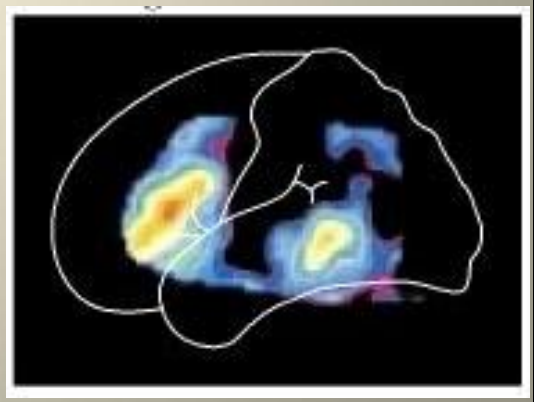
C. Language and Speech

- Other speech areas also involved
- Examples:
  - Reading printed words out loud: visual cortex and Broca (seeing, speaking, without understanding)
  - Determining meaning to generate words: frontal lobe & Wernicke

Mapping Language

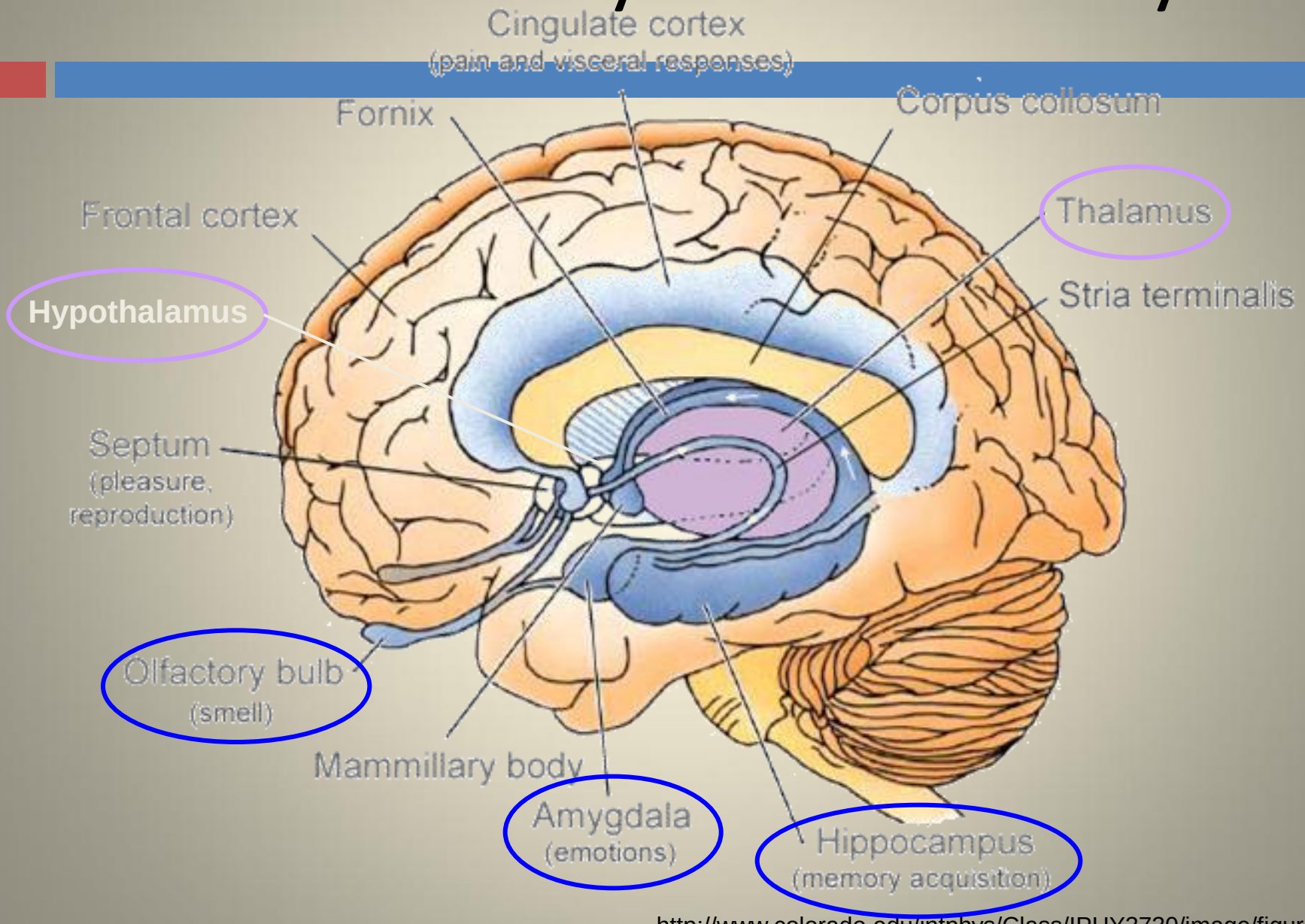
	No talking	Talking
No comprehension	Passively viewing words: Visual 	Speaking words: Broca 
Comprehension	Listening to words: Wernicke, auditory 	Generating words: Wernicke, Broca 

http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=neurosci&part=A1914

D. Limbic System: Function

- Generates emotions
- Mediates primary emotions: laugh, cry, fear anger
  - e.g. Instinct to nuture infants, emotional bonding
- Attaching emotions to basic survival programs
  - e.g. feeding, aggression, sexuality

D. Limbic System: Anatomy



http://www.colorado.edu/intphys/Class/IPHY3730/image/figure5-8.jpg

D. Limbic System: Anatomy

- Hippocampus
- Olfactory cortex
- Amygdala
- thalamus and hypothalamus

Amygdala

- In temporal lobe
- Receives input from the hippocampus
- Recognizes emotional content of facial expressions
- Identifies how other people are feeling
- Keeps a history of emotional memories
  - e.g. Infants learn to distinguish between “right” and “wrong” when the caregiver “smiles” or “frowns” respectively

E. Memory and Learning

- Nerve cells can make new connections as you learn/refine skills
- Skill memories, once learned, are difficult to unlearn (bad habits are hard to break)

Short-term memory

- Stored in frontal lobe
- has a limited capacity, about 7 items
- has a limited duration, about 30 seconds
- is the bottleneck in the memory system because it limits how much information we can transfer to long-term memory.

Long-term memory

- Activated by hippocampus
- enhanced by repetition
- influenced by emotional states mediated by the amygdala
- influenced by association with previously stored information

Types of Long Term Memory

- Declarative (explicit): can verbalize
  - Semantic: general knowledge about the world (can look up on an encyclopedia)
  - Episodic: personal
- Non-declarative (implicit): difficult to verbalize
  - Conditioning: making an association (e.g. understanding social norms, consequences)
  - Procedural: automatic, instinctive (e.g. riding bike, playing piano)

Models of Memory Formation

- Memory consolidation model

  Sensory experience → unstable STM → stable LTM

- Problem with this model is that it doesn't show that memory can be updated

Models of Memory Formation

- Memory reconsolidation model

Reactivation hippocampus

→

Inactive memory (stable state)

Active memory (unstable state)

←

Cortex reconsolidation

Functional Changes in synapses

- Long-term potentiation (LTP)
- Long-term depression (LTD)

Long-term potentiation (LTP)

- occurs when a postsynaptic neuron displays increased responsiveness to stimuli
- Induced by brief, repeated action potentials that strongly depolarize the postsynaptic membrane.
- May be associated with memory storage and learning.

Long-term depression (LTD)

- occurs when a postsynaptic neuron displays decreased responsiveness to action potentials
- Induced by repeated, weak stimulation
- E.g. inability to smell a stench after a period of continuous exposure

Neuronal plasticity

- **Plasticity**: the ability of mature nerves and neurons to adapt to environmental influences such as learning or compensation after disease or injury.

Neuronal plasticity

- Short-term plasticity: may involve the enhancement of existing synaptic connections.
- Long-term plasticity: may involve physical changes such as the formation of new synapses.

Examples of neuronal plasticity

- Rehabilitation after:
  - strokes
  - epilepsy
  - car crashes
  - loss of limbs
  - being in outer space