

BMD ENG 301

Quantitative Systems Physiology (Nervous System)

Lecture 2: Neuroanatomy

Professor Malcolm MacIver

Quick announcements

- Tuesday section 11-12
- Aim for each section to be 24
- We need 16 hands to go up to shift (at 1:40pm), of which 6 needs to be from the Friday section, and 11 needs to be from Tuesday section)

If you want to study the brain ...

- Classical Neuroanatomy
- Functional Neuroanatomy
- *In vivo* Modern Brain Imaging

Classical Neuroanatomy

TEST CASE MOUSE BRAIN SECTIONS

animal 1

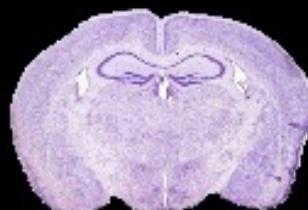


Bregma 1.42mm
3 serial sections

animal 2



Bregma -1.46mm
1 section

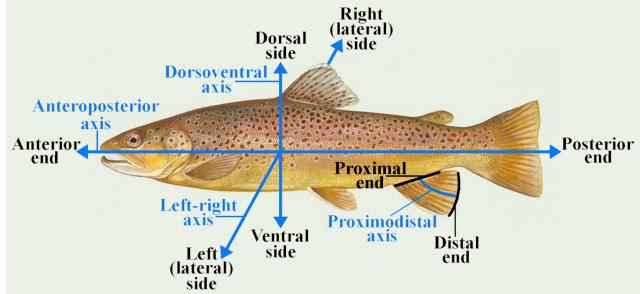


Bregma -3.88mm
1 section

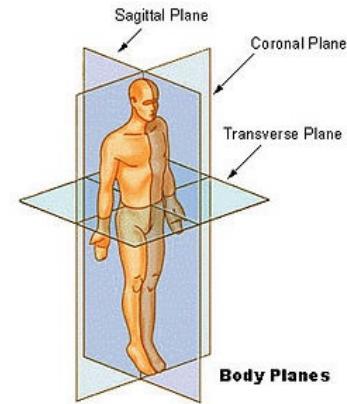
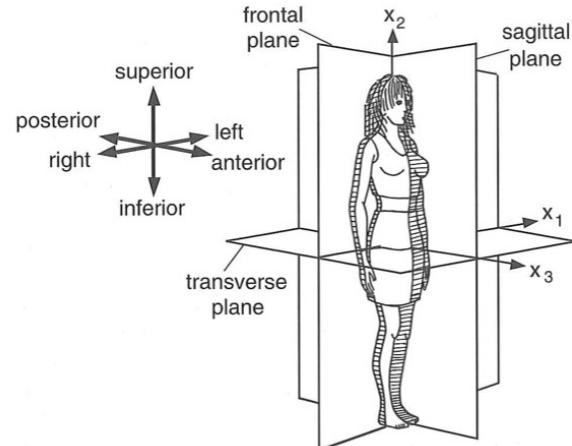
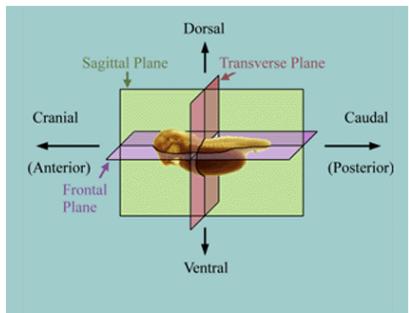


Reference H&E images from Allen Brain Atlas

Note: Not in textbook



terms of location
Vertebrates
(all non-human animals)



terms of location
humans

Neuroanatomical Nomenclature – Orientation terms

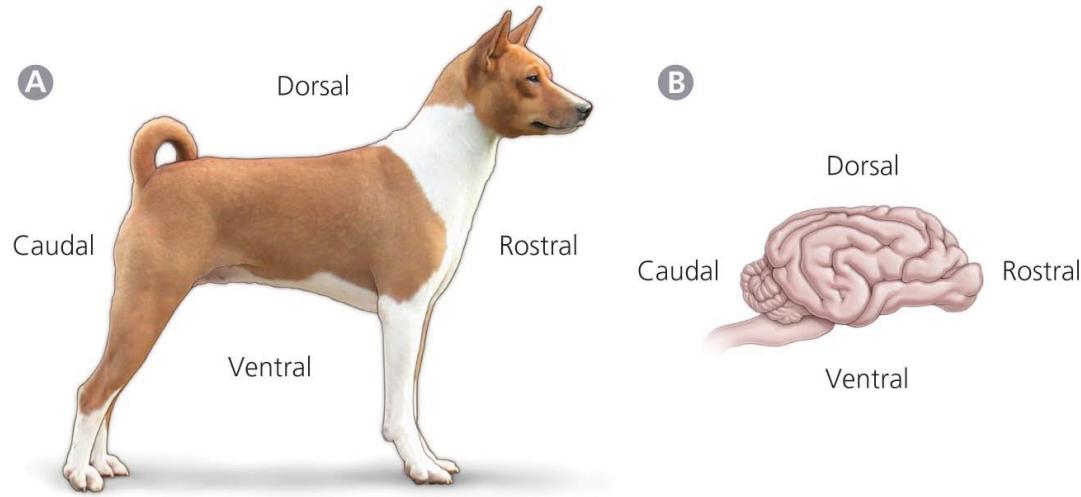


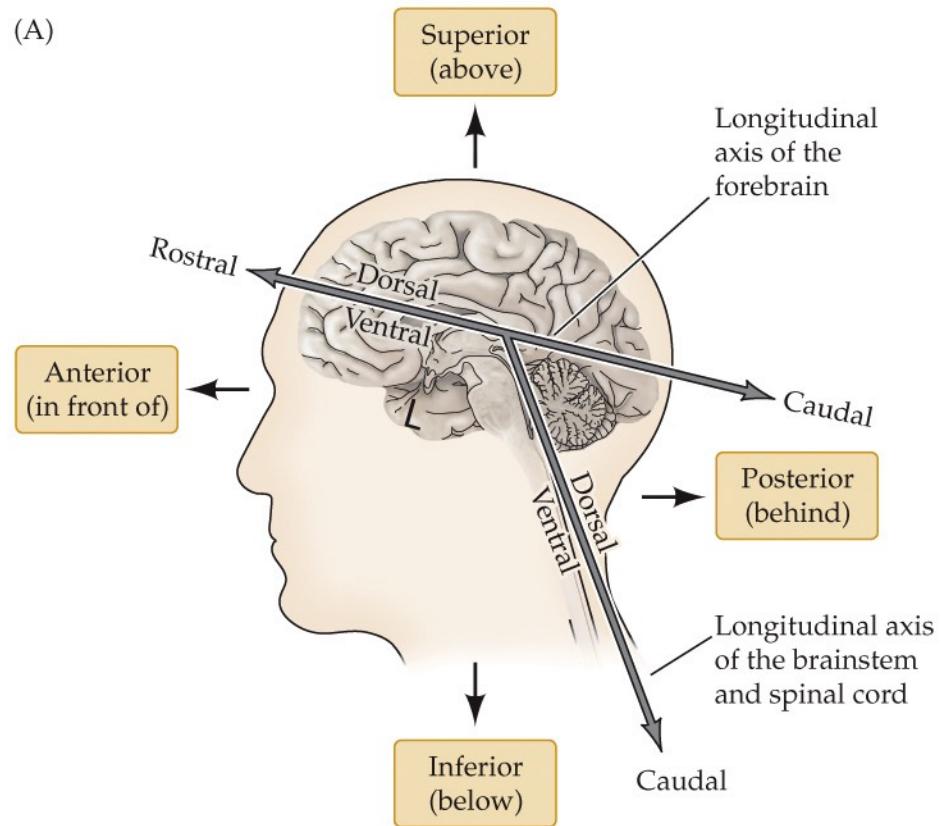
Fig. 1.2

Human bodies & brains require different orientation terms

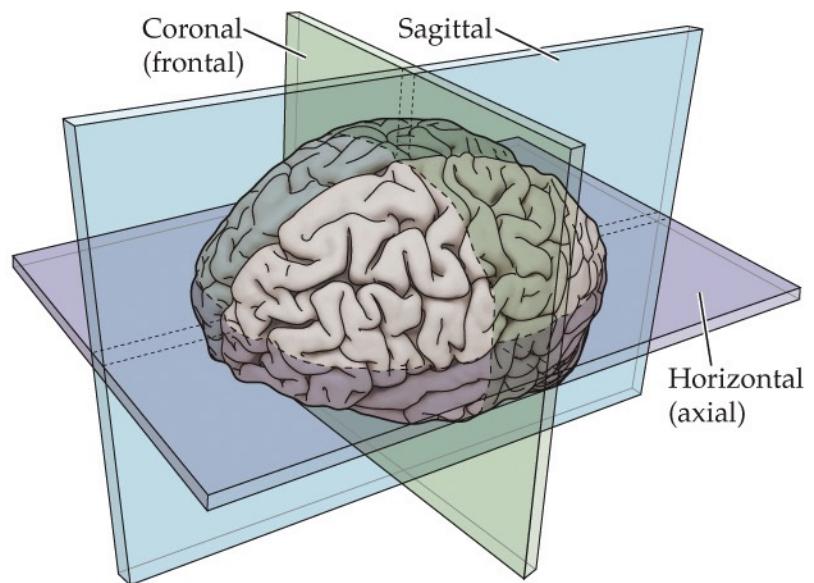


Fig. 1.2

(A)

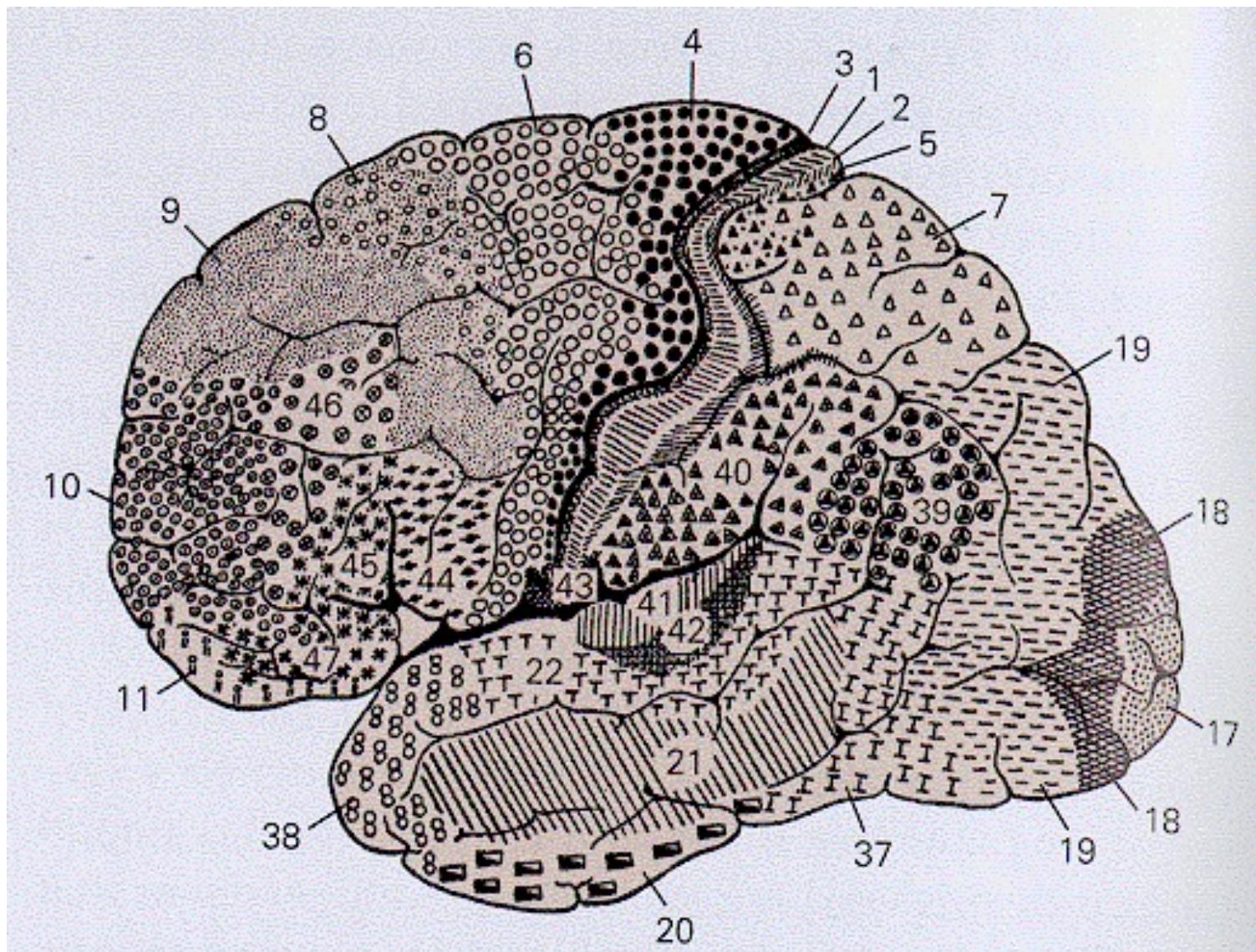


(B)



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Brodmann Areas



Online resource

<https://scalablebrainatlas.incf.org>

Scalable Brain Atlas ▶

Scalable Brain Atlas - Neuroanatomy at your fingertips

Home SBA Original SBA Composer Terms of use Site map About

This site provides interactive access to more than twenty publicly accessible brain atlases. It displays brain regions and reference images in 2d and 3d multi-slice views, with easy search and navigation. A plugin mechanism enables client websites to show brain region related data in response to user actions, and an API is implemented as a set of web-services. All atlas pages are listed in the table below, a complete overview of available services is in the site map.

A recent development is SBA Composer, a WebGL-powered 3d viewer in which users can upload their own (experimental) data and display them together with brain region meshes and reference image sections. SBA Composer is in the beta stage (blog), available for atlases marked with a ★.

Macaque atlases

The Calabrese et al. (2015) MRI+DTI atlas ★ with Paxinos regions.
The Paxinos Rhesus Monkey atlas (2000).
The NeuroMaps Macaque atlas (2009).
The Markov et al. (2014) 91 cortical regions atlas.
Various templates available through Caret, registered to F99 space:

- Felleman and Van Essen (1991)
- Lewis and Van Essen (2000)
- Regional Map from Kotter and Wanke (2005)
- Poldrack Rhesus Monkey (2000)
- Markov, Misery et al. (2011)
- Markov, Ercey-Ravas et al. (2014)

Mouse atlases

The Allen Mouse Brain Common Coordinate Framework version 3 (ABA_v3) ★.
[archived: 2012 version, 2007 version]
The INCF Waxholm Space for the mouse (2012).
[archived: 2011 version, 2010 version, 2009 version]
The Hippocampus atlas of Badhwar et al. (2013).

Rat atlases

The Waxholm Space Sprague Dawley rat atlas of Papp et al. (2014).
The MR-histology atlas (age P80) of Calabrese et al. (2013) at age P80.
The *in vivo* MRI template of Valdés-Hernández et al. (2011).
The DTI Atlas (age P72) of Rumpé et al. (2013).
The Population-averaged DTI atlas of Veraart et al. (2011).

Human atlases

The Harvard Oxford cortical parcellation, as distributed with FSL.
The JuBrain cytoarchitectonic atlas by Amunts, Zilles et al., with maximum probability maps from Eickhoff et al. (2005).
The Neuroinformatics Inc. manually segmented brain, with cortical and subcortical parcellation.
The Brainnetome Atlas of Fan, Jiang et al. (2016), with maximum probability maps, anatomical and functional connectivity.
The LPBA40 parcellation, registered to SRI24 space.
The BigBrain Nissl stained slices resampled at 400 µm.
The Brodmann areas, projected on Conte69 space.

Ferret atlas

The Population based MRI/DTI atlas of the adult ferret ★ by Hutchinson et al. (2017).

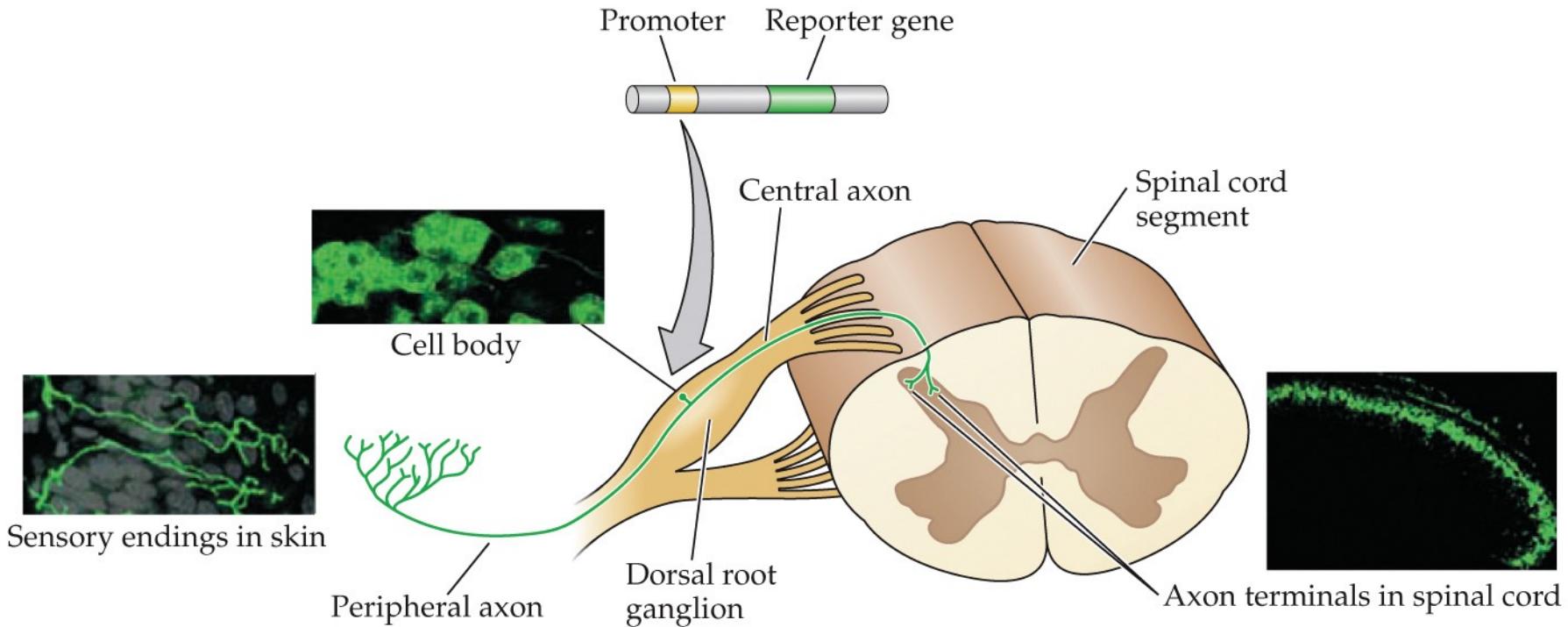
Marmoset atlas

The Marmoset atlas in Stereotaxic Coordinates

Opossum atlas

The Multimodal atlas of gray short-tailed opossum brain by Chłodzinska, Majka et. al.

Tracing Pathways



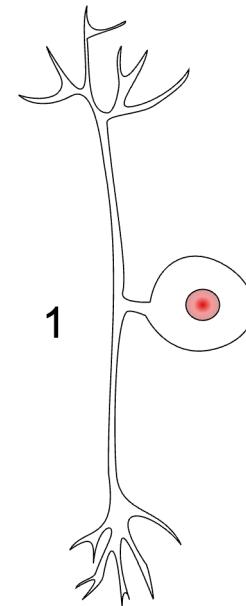
From Zylka et al. (2005) *Neuron* 46: 17–25.

NEUROSCIENCE 6e, Figure 1.15
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The pseudounipolar neuron

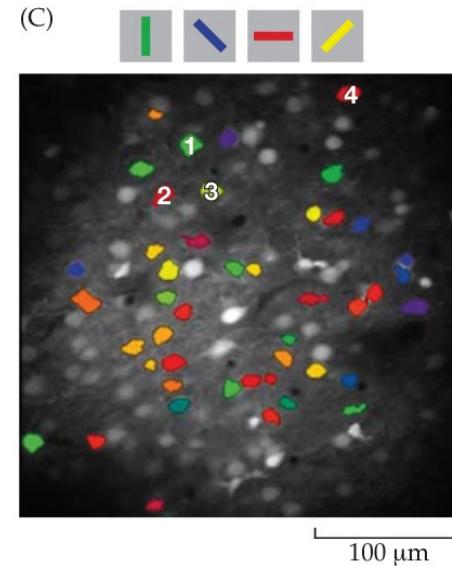
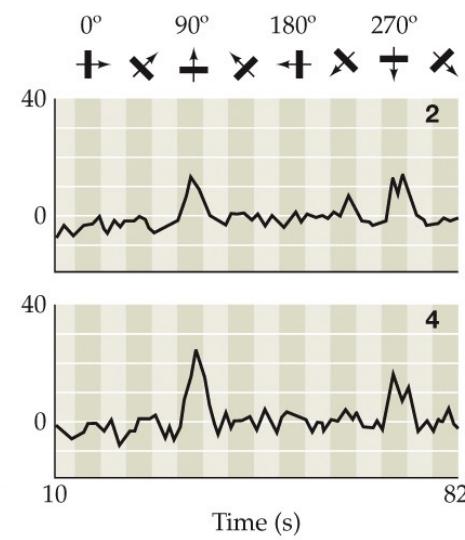
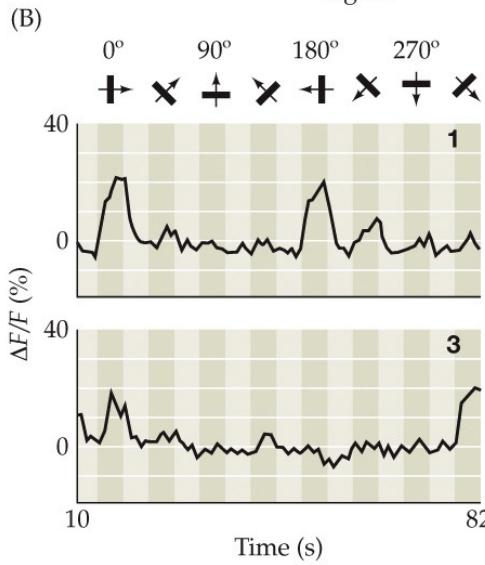
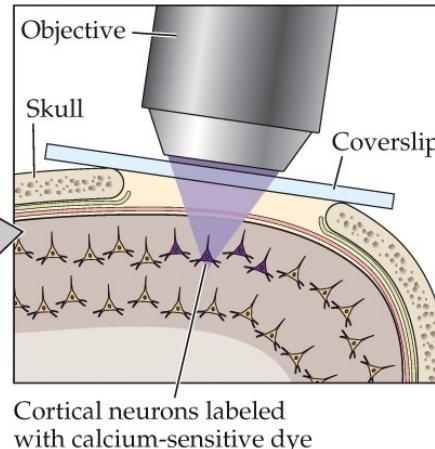
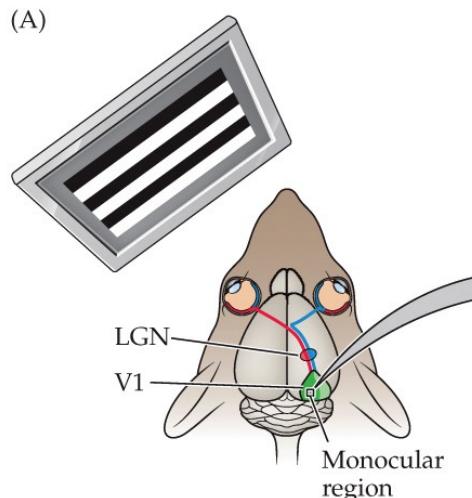
Most sensory afferent neurons are pseudounipolar.... Pseudounipolar neurons have one projection from the cell body, which splits into two axons: one that extends into the periphery and one that extends into the central nervous system.

Afferents that project into the spinal cord from skin and muscle are typically pseudounipolar. The cell bodies of these afferents are located in the dorsal root ganglia near the spinal cord.... The peripheral branch extends through a peripheral nerve, and is part of the sensory receptor in skin or muscle. The central branch projects through the dorsal (posterior) root into the spinal cord, and terminates on interneurons or motoneurons in the spinal cord, and may even project to the brainstem.



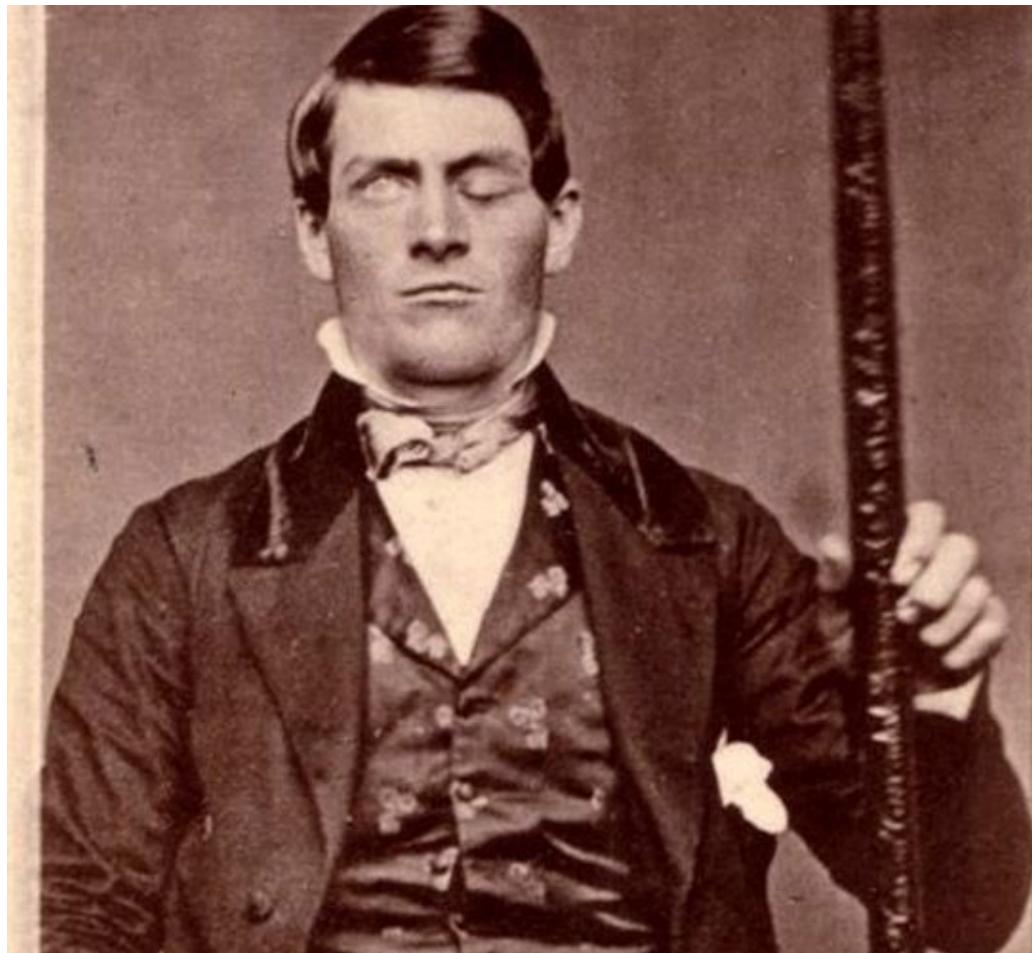
From: <http://pittmedneuro.com/neuron.html>

Functional Neuroanatomy



[from Mank et al. (2008) *Nat Meth* 5: 805–811; (from Ohkii et al. (2005) *Nature* 433: 597–603]

Functional Neuroanatomy



Phineas Gage

In vivo Structural Brain Imaging

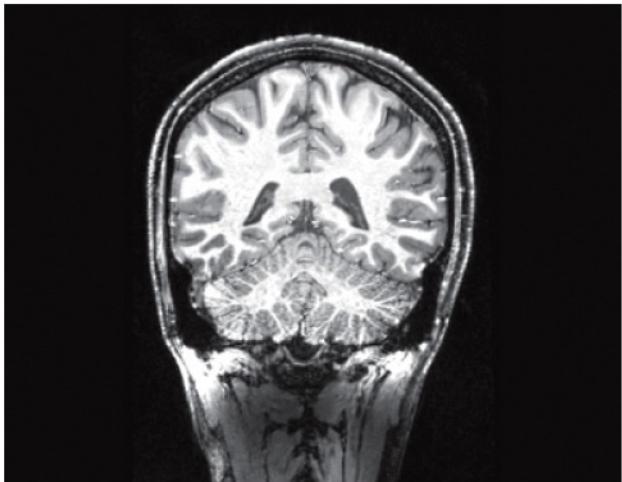
(A)



© iStock.com/kot63.

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(B)

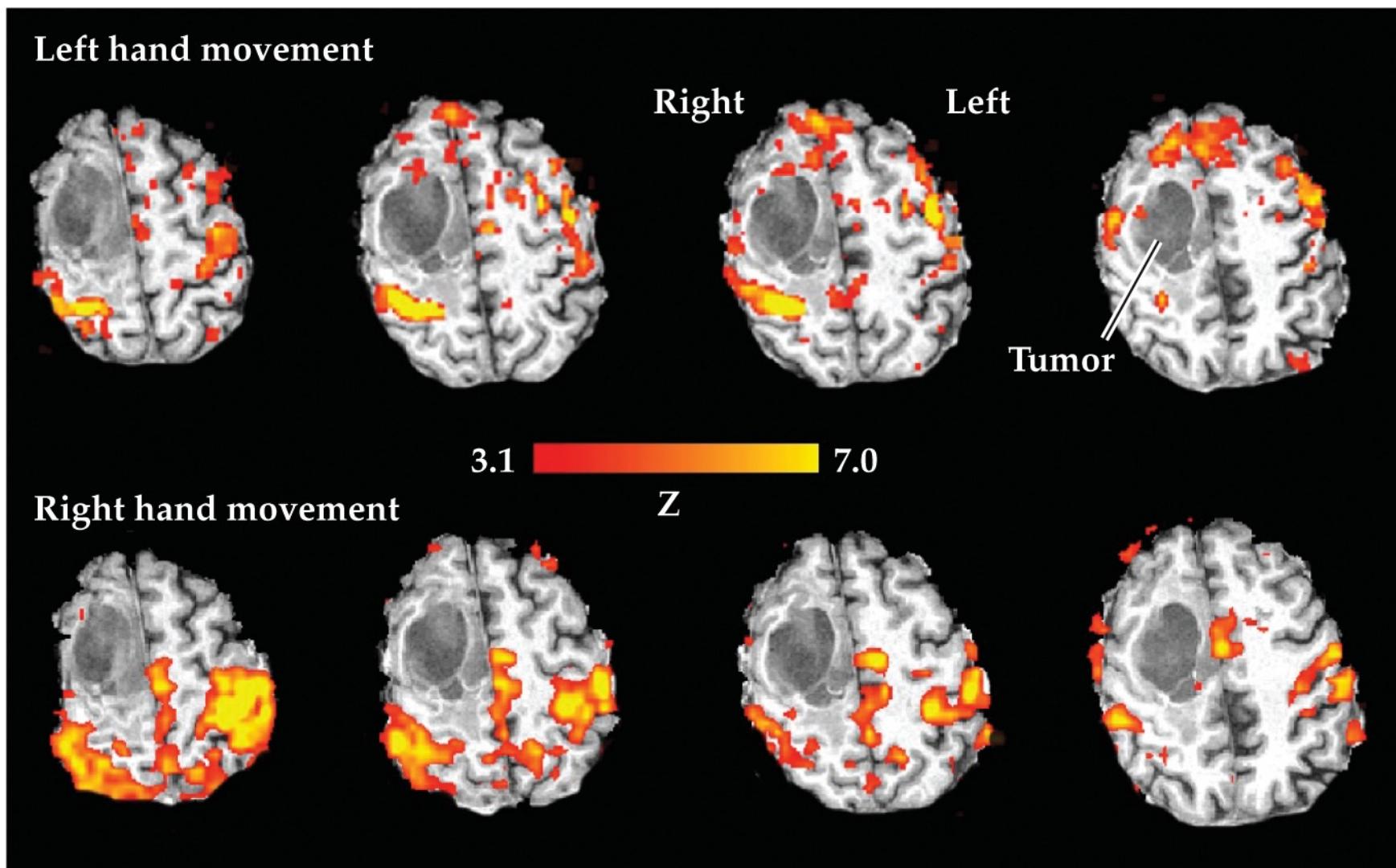


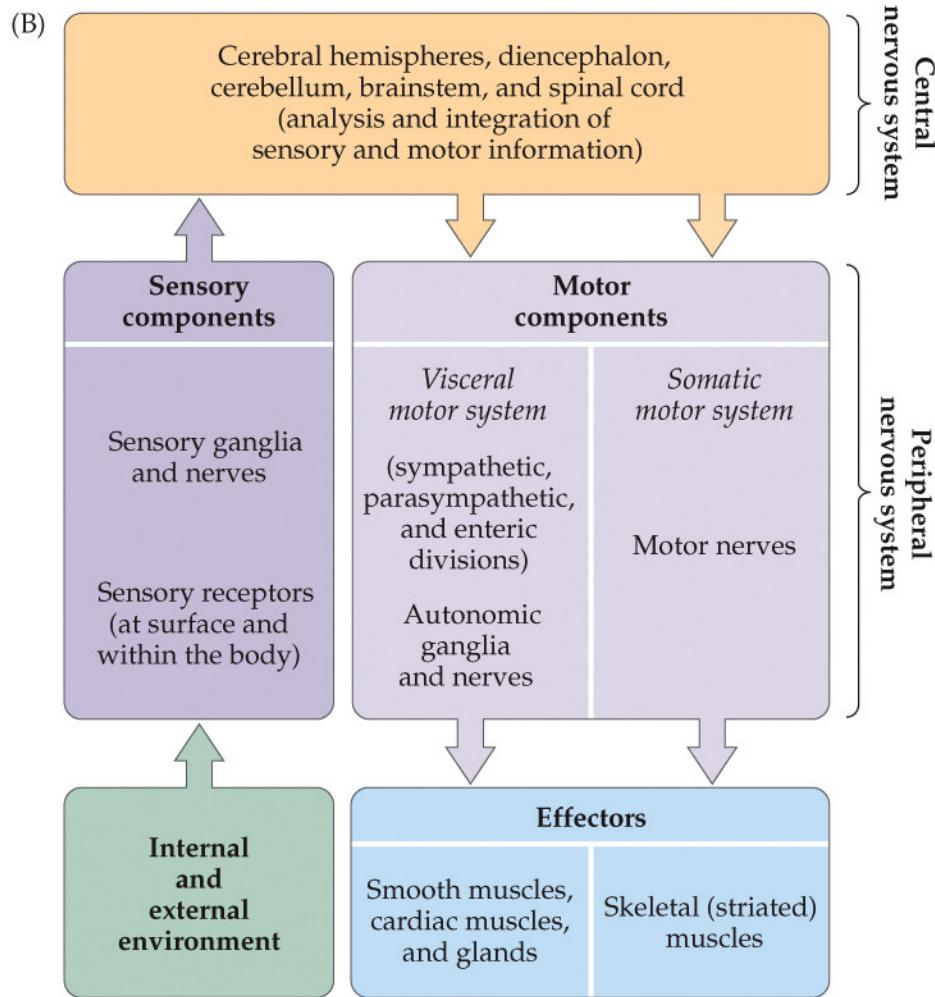
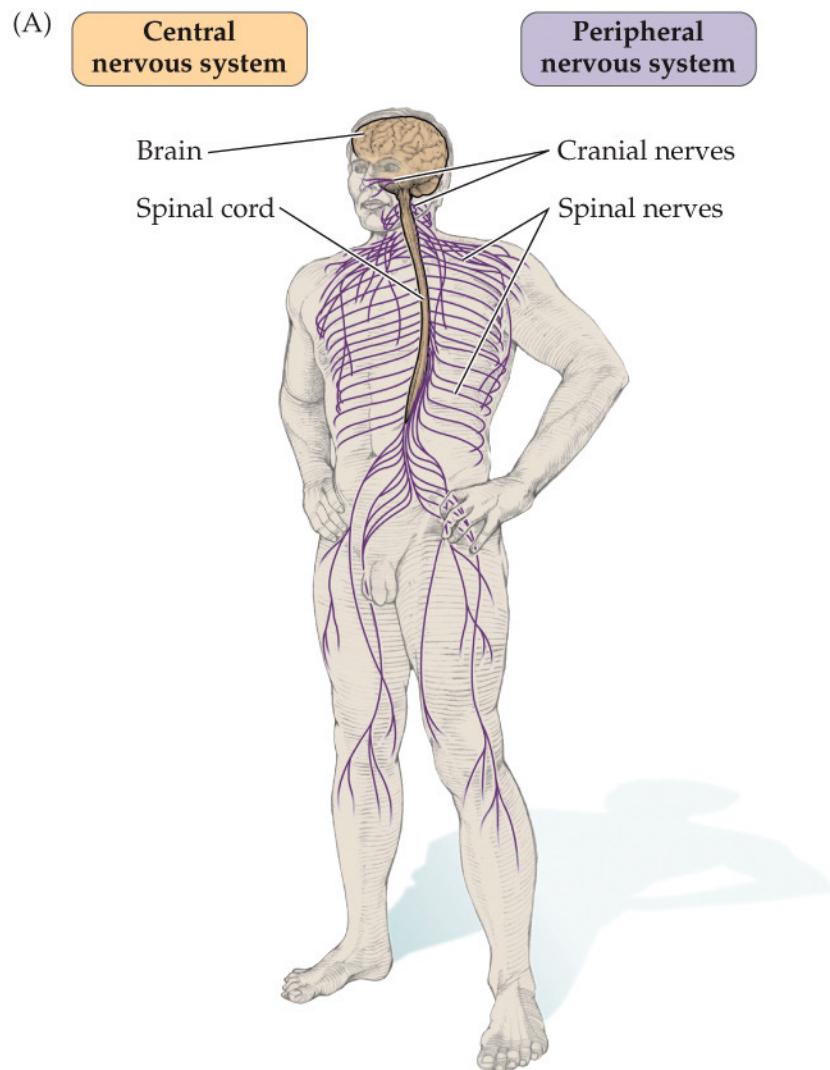
B, C from Seiger et al. (2015) *Neuroimage* 113: 207–216.

(C)

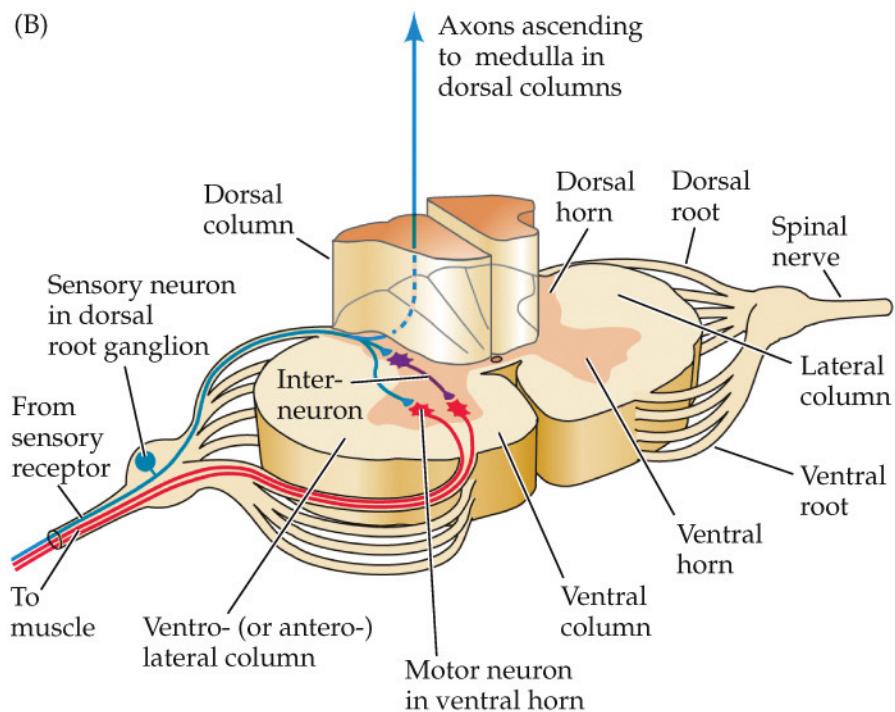
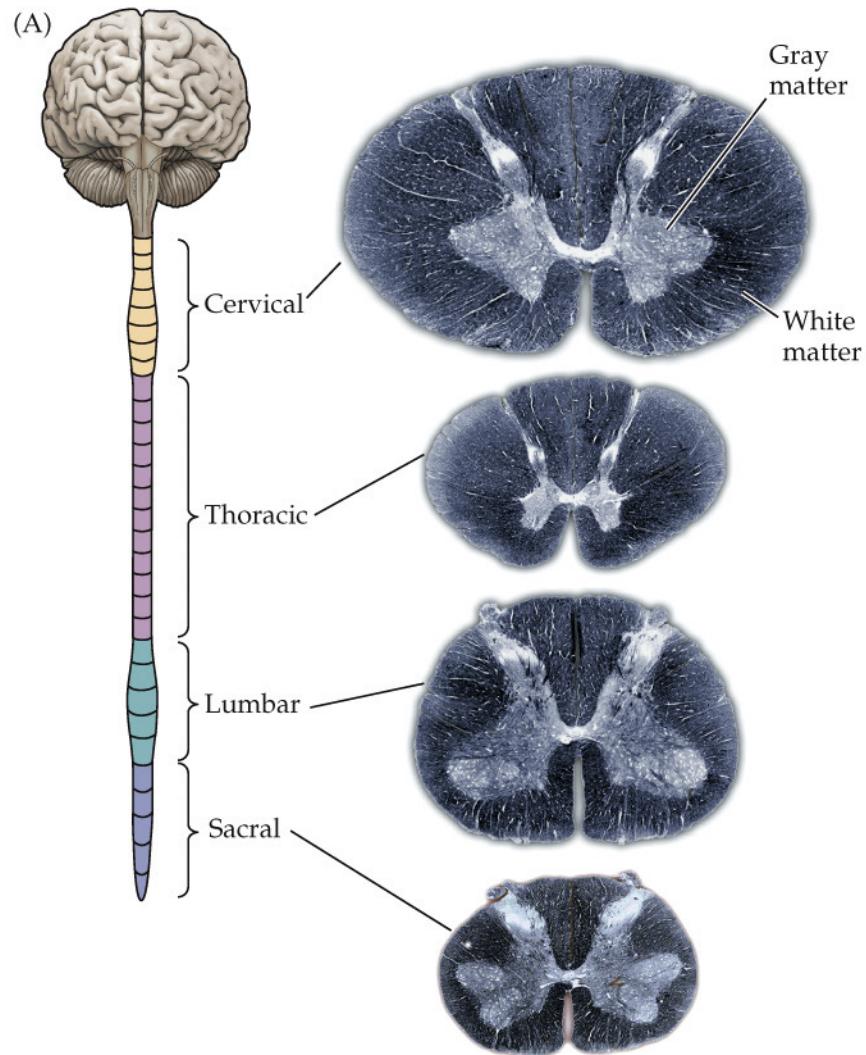


In vivo Functional Brain Imaging

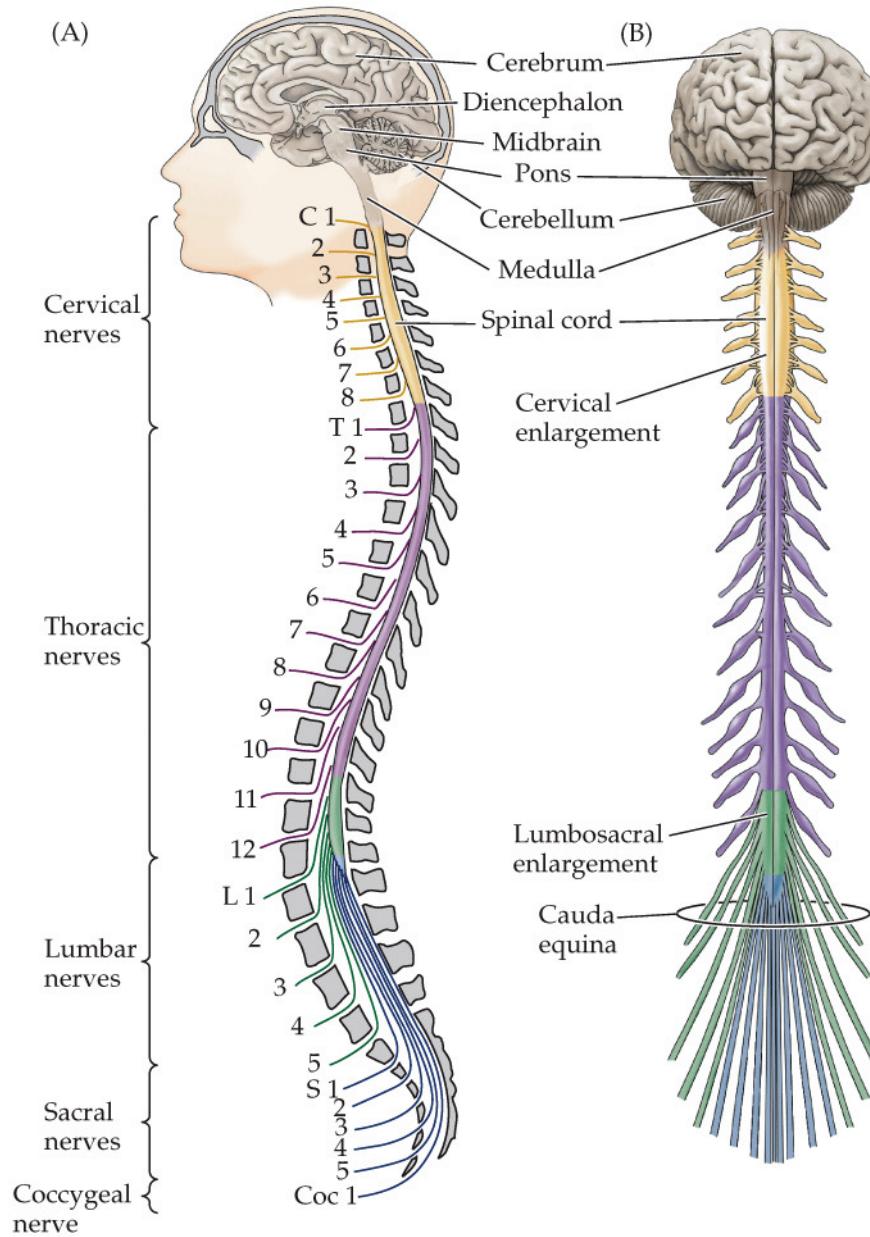




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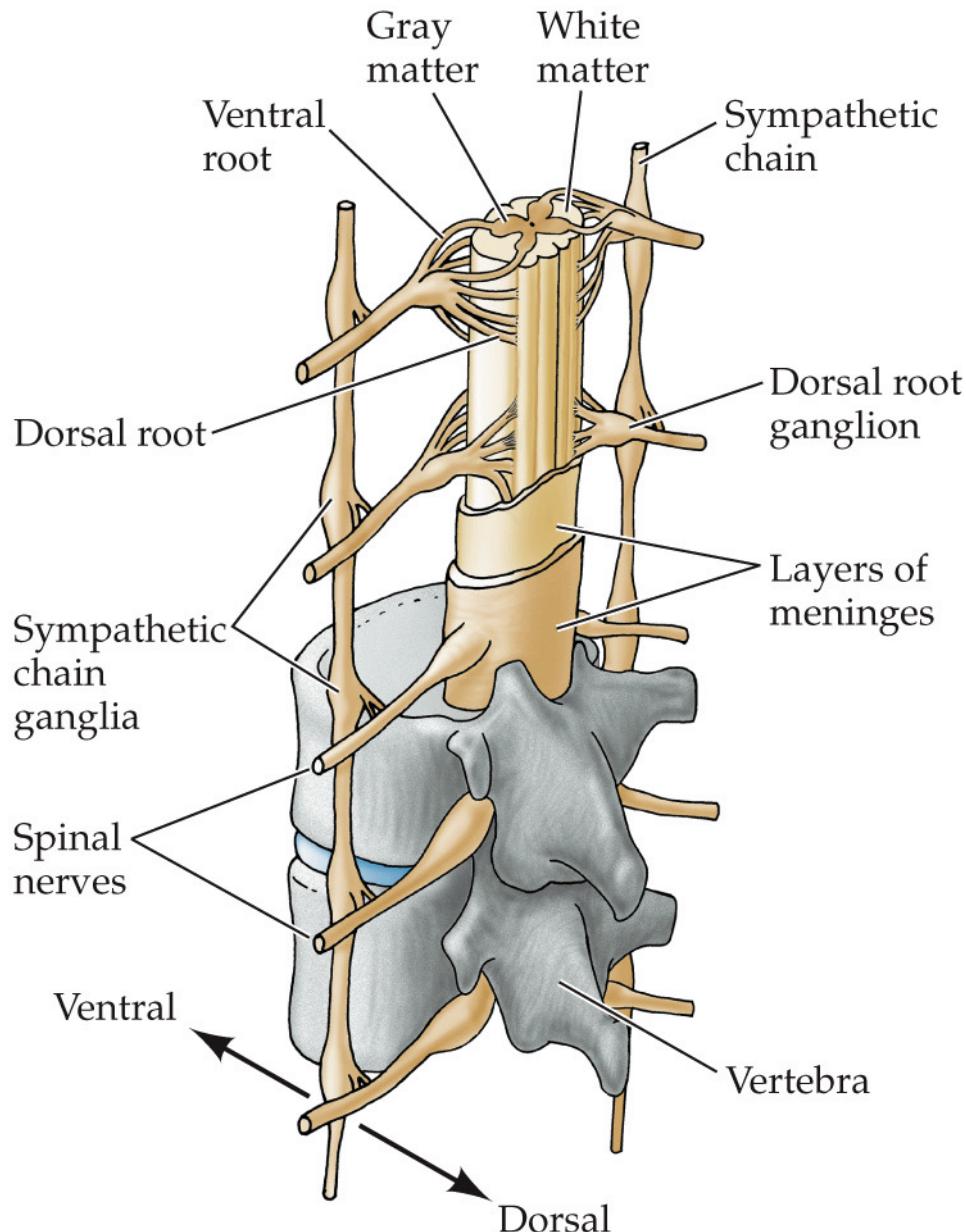


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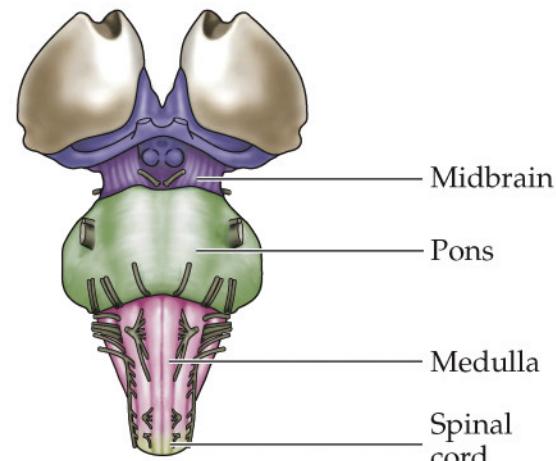
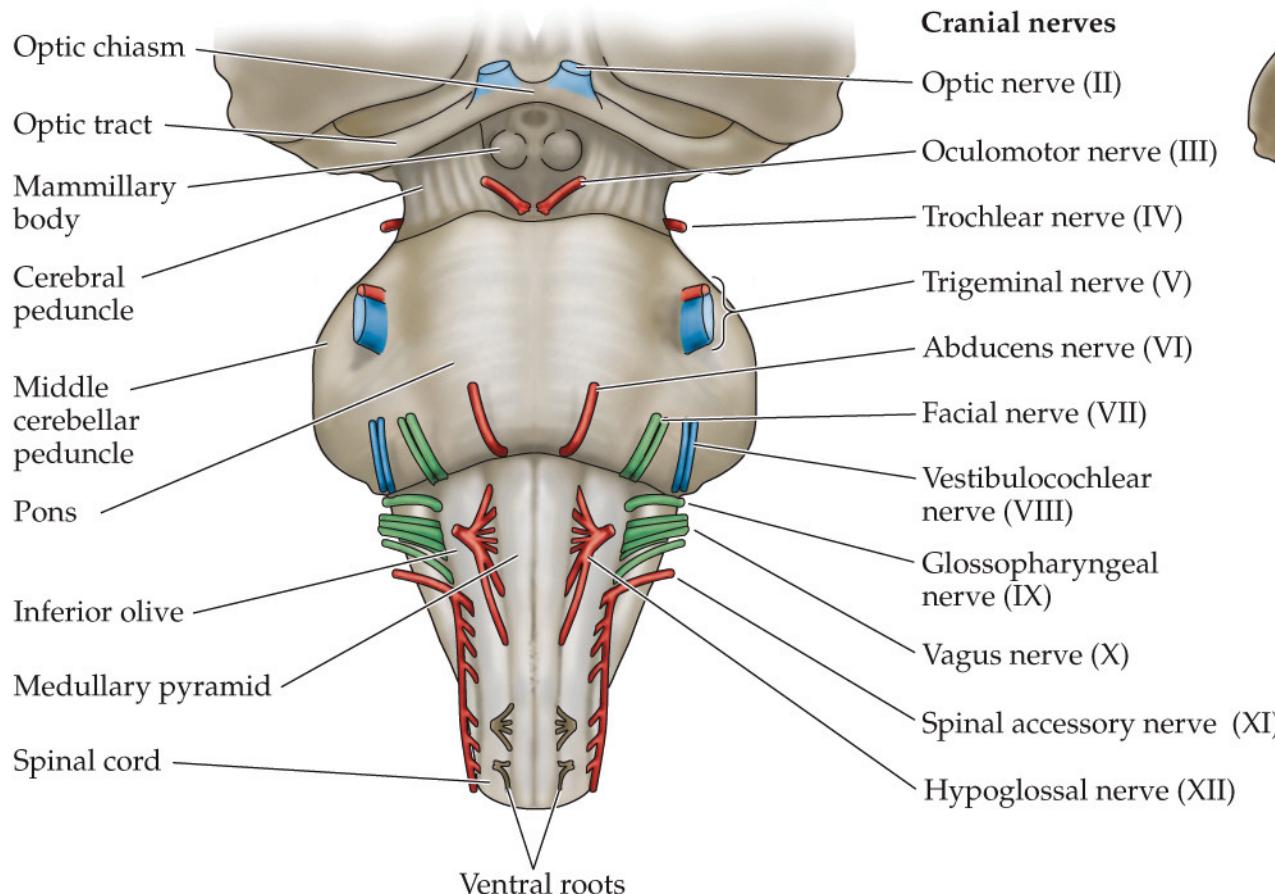
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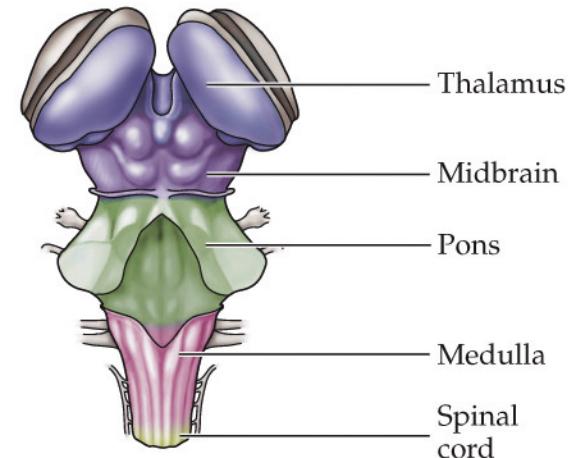
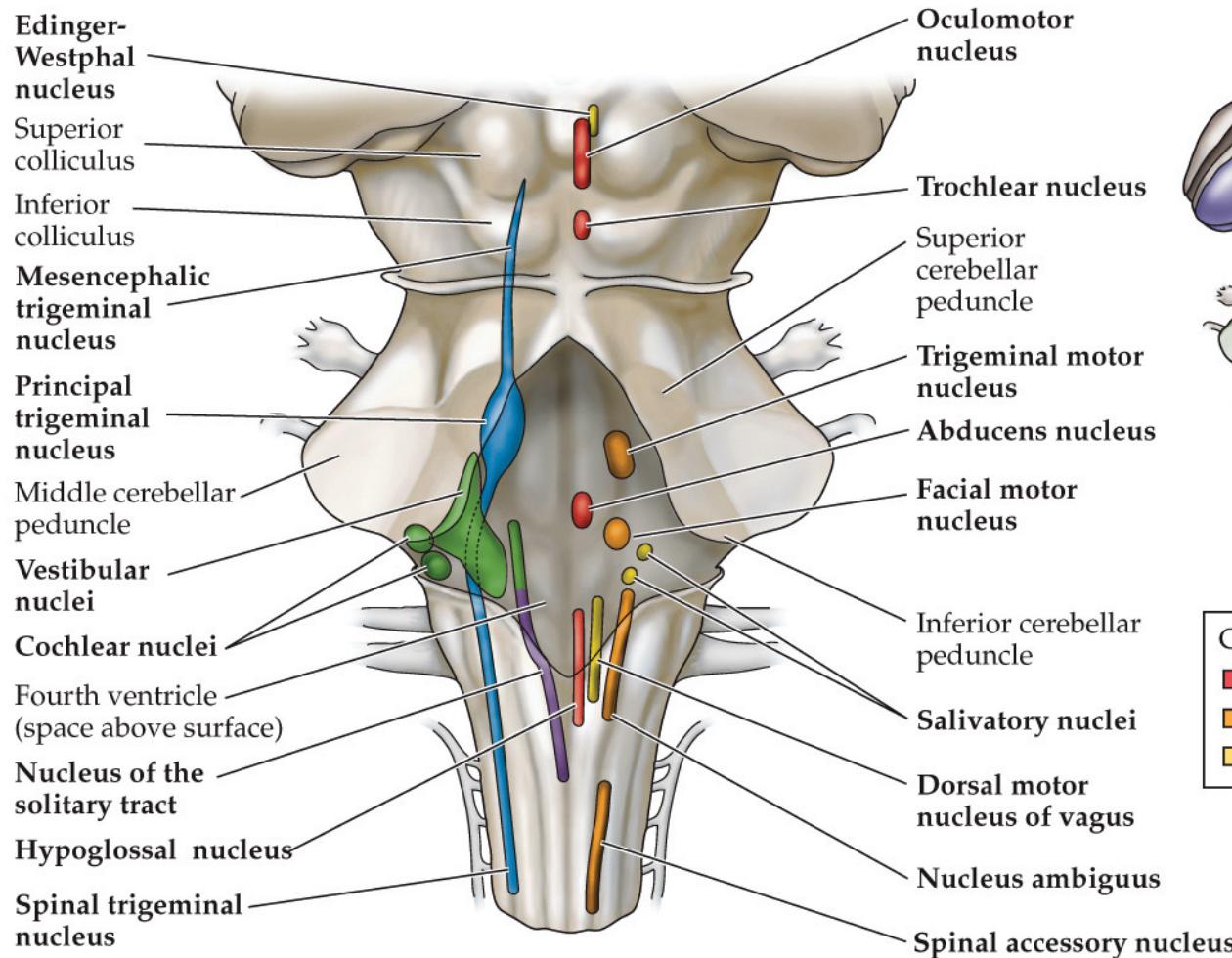
Cranial nerves of the brainstem



Color key for drawing at left:

- Sensory cranial nerves
- Motor cranial nerves
- Mixed (sensory and motor) cranial nerves

Cranial nerve nuclei of the brainstem

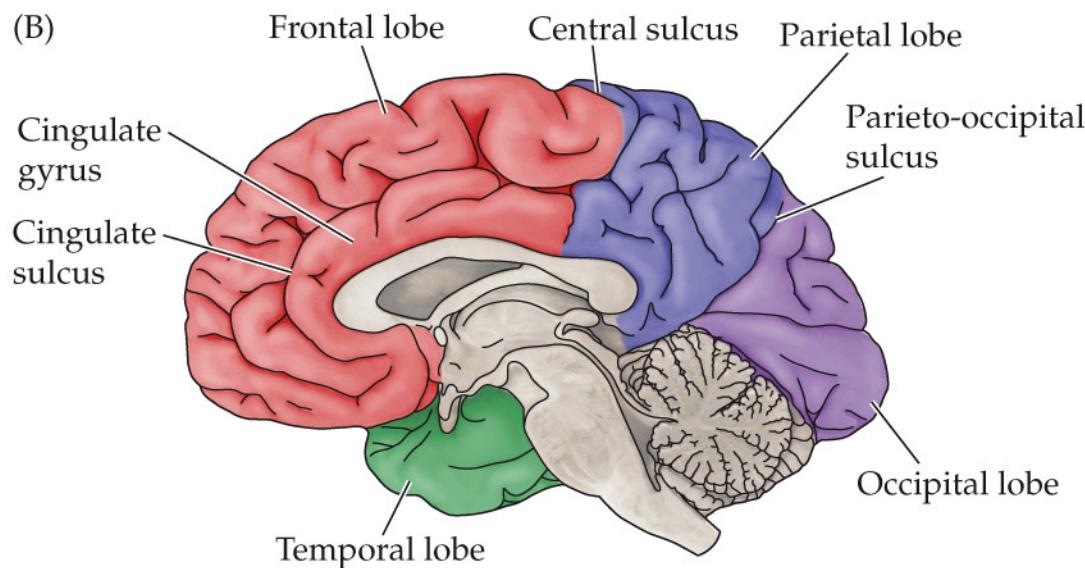
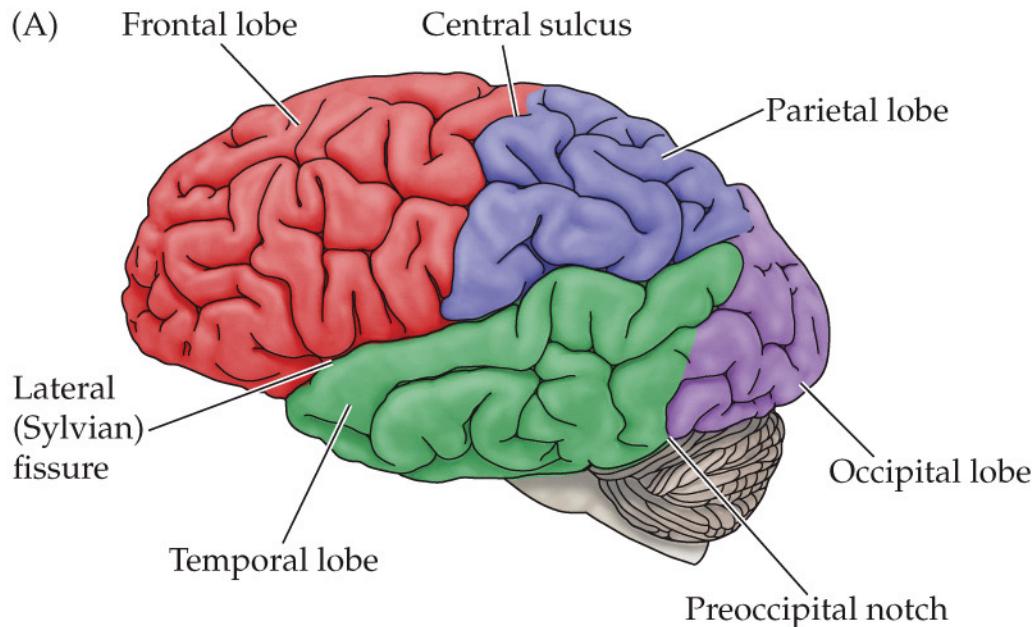


Color key for drawing at left:

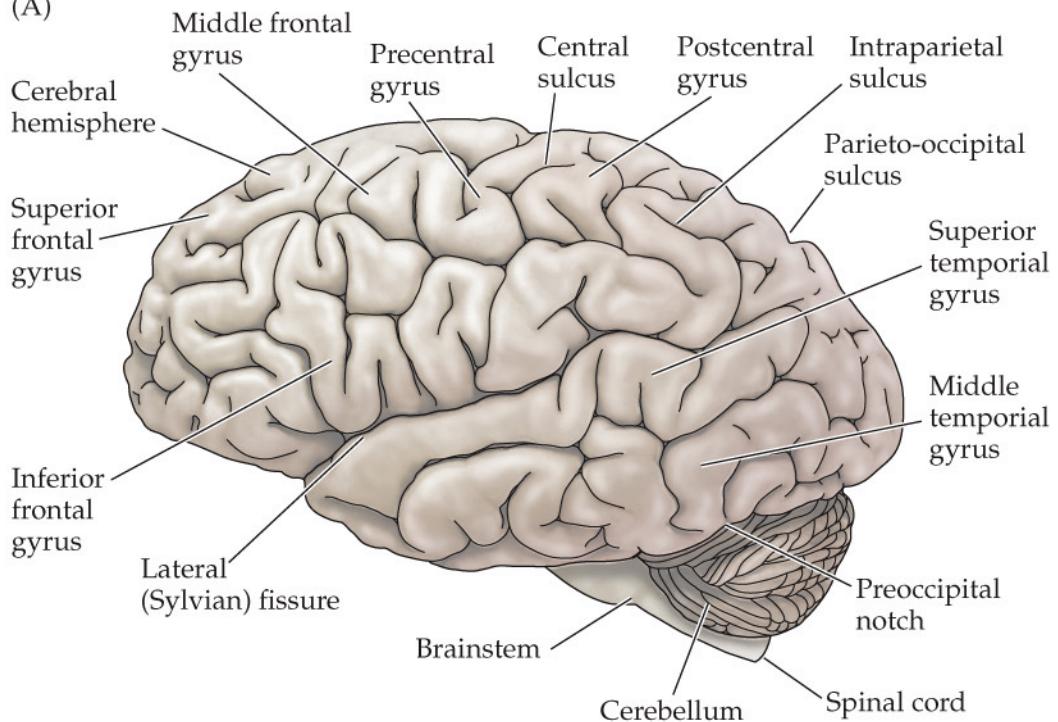
- | | |
|-------------------|--------------------|
| ■ Somatic motor | ■ General sensory |
| ■ Branchial motor | ■ Special sensory |
| ■ Visceral motor | ■ Visceral sensory |

Terminology

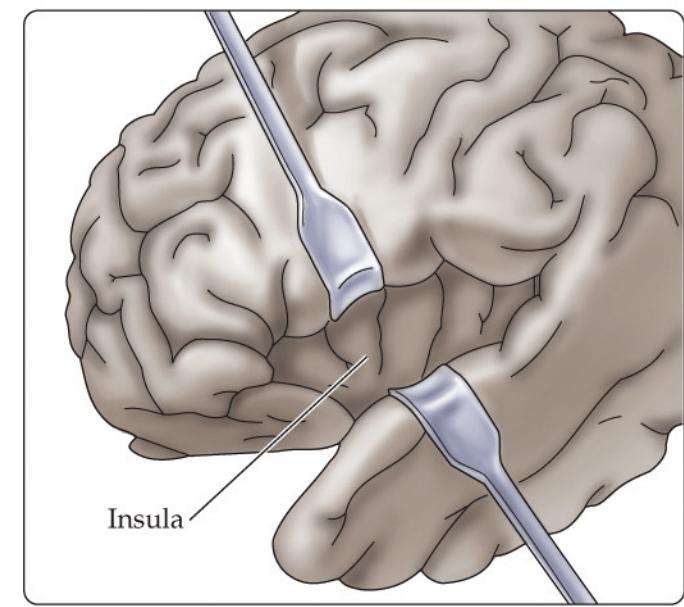
- Ganglion: Collections of hundreds to thousands of neuronal cell bodies found **outside the CNS** along the course of peripheral nerves
- Nucleus: Collections of hundreds to thousands of neuronal cell bodies found **inside the CNS**



(A)



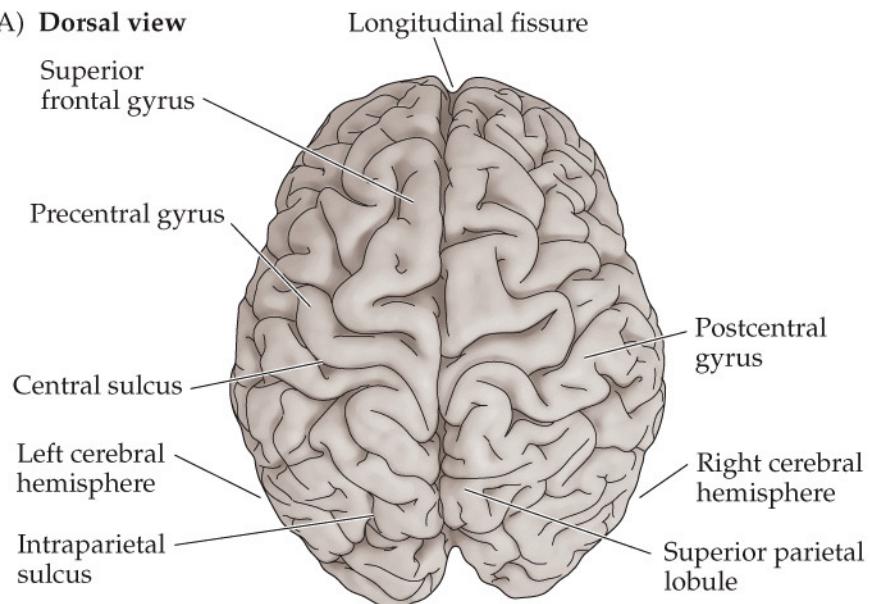
(B)



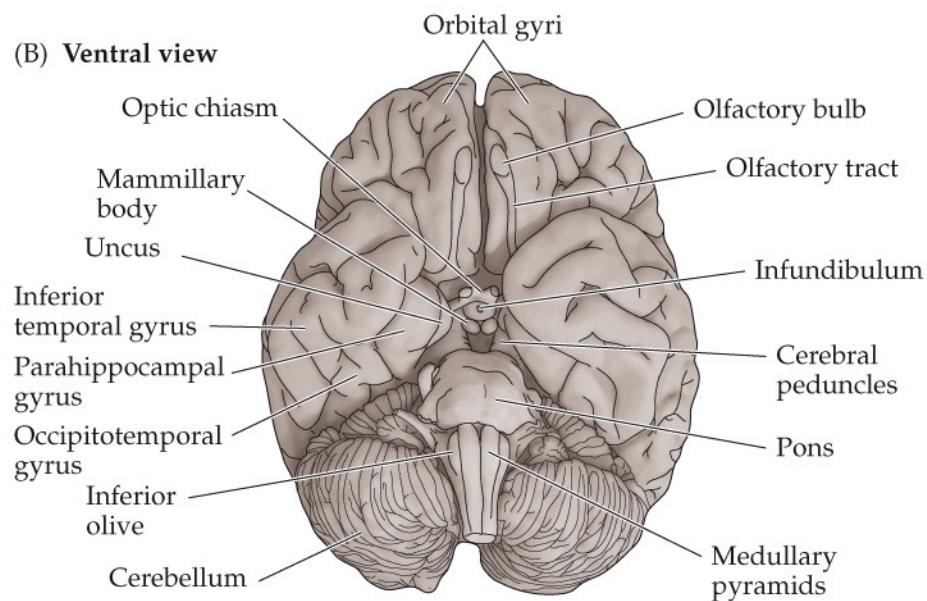
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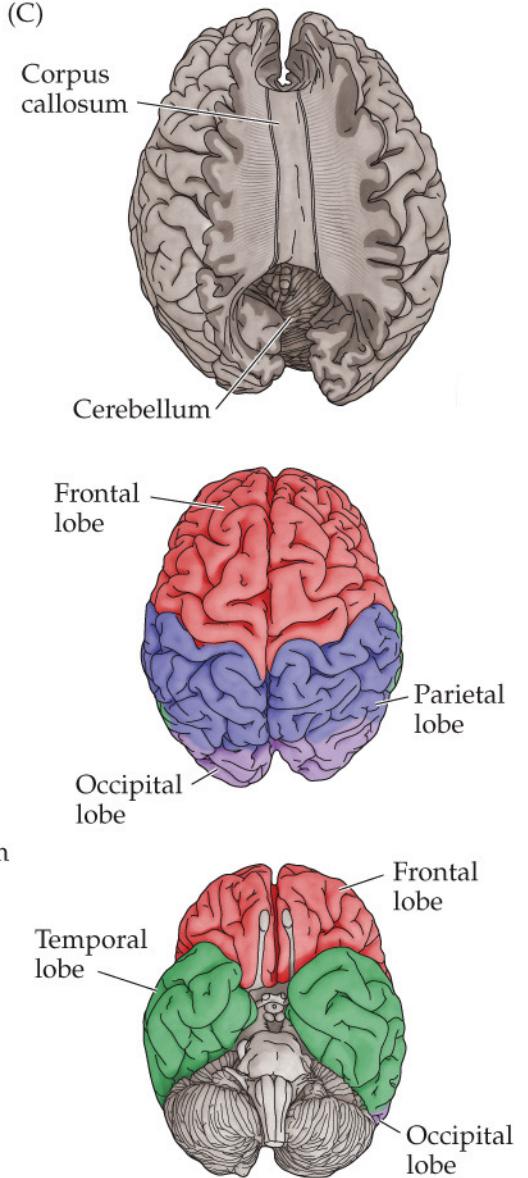
(A) Dorsal view

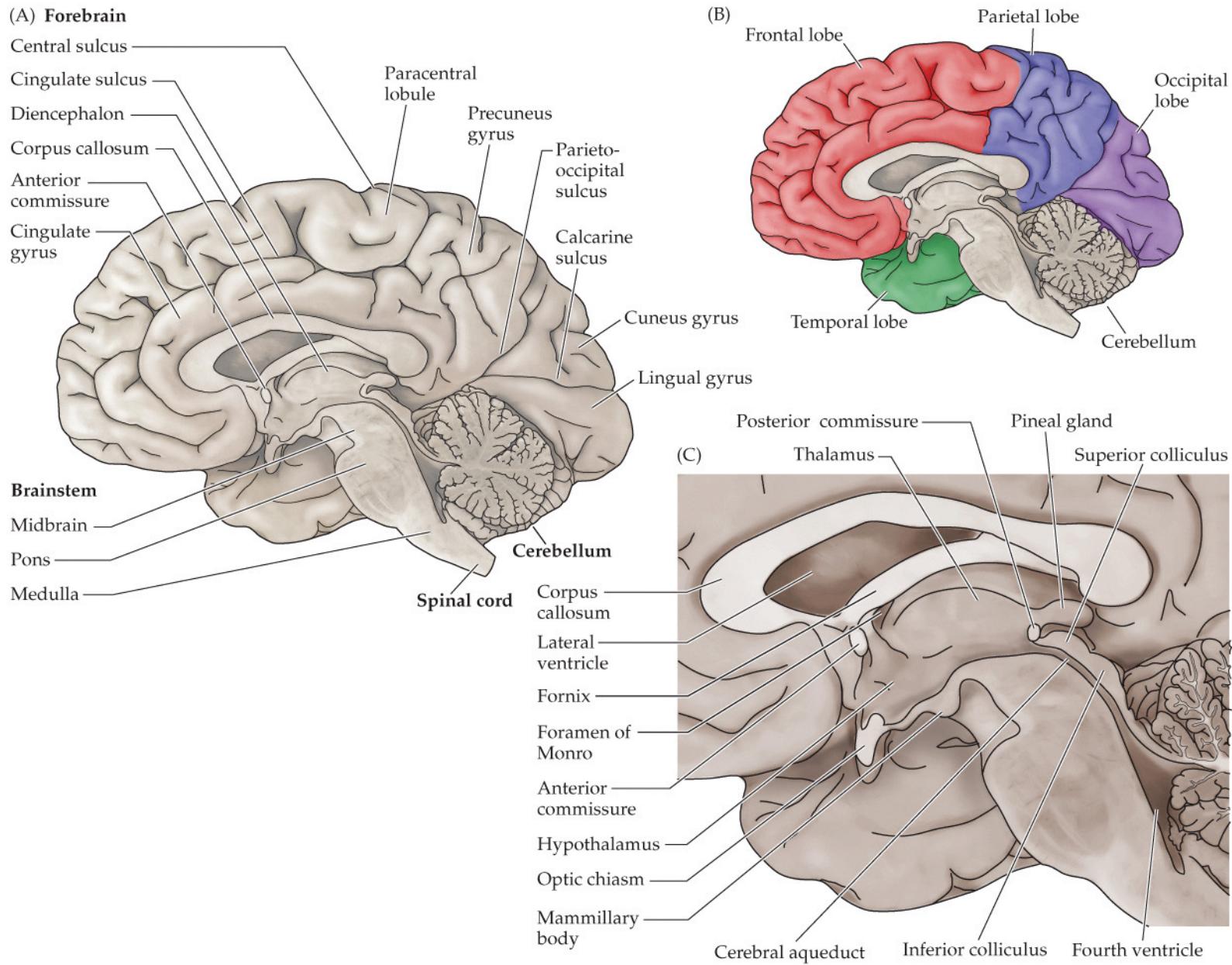


(B) Ventral view

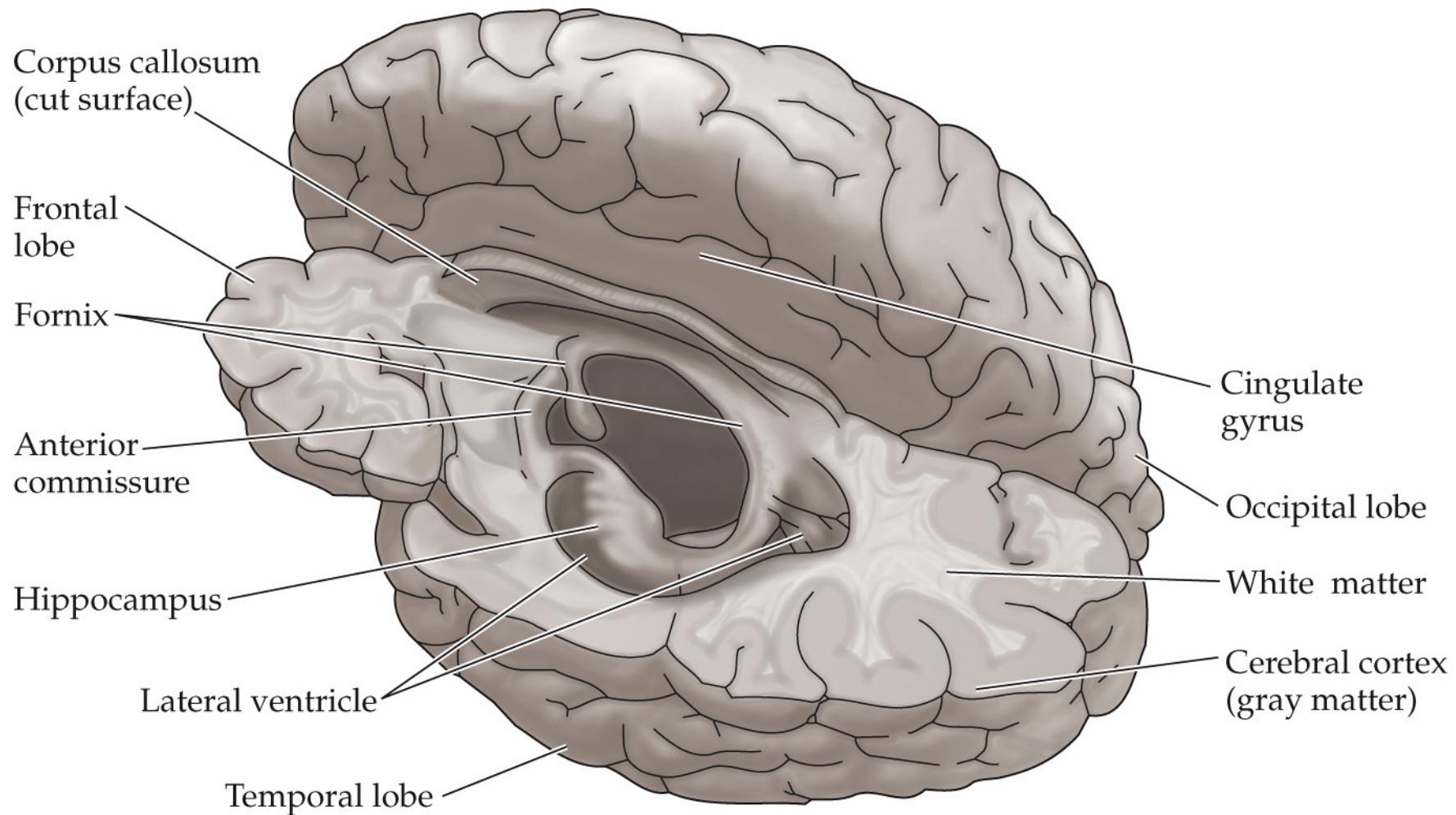


(C)



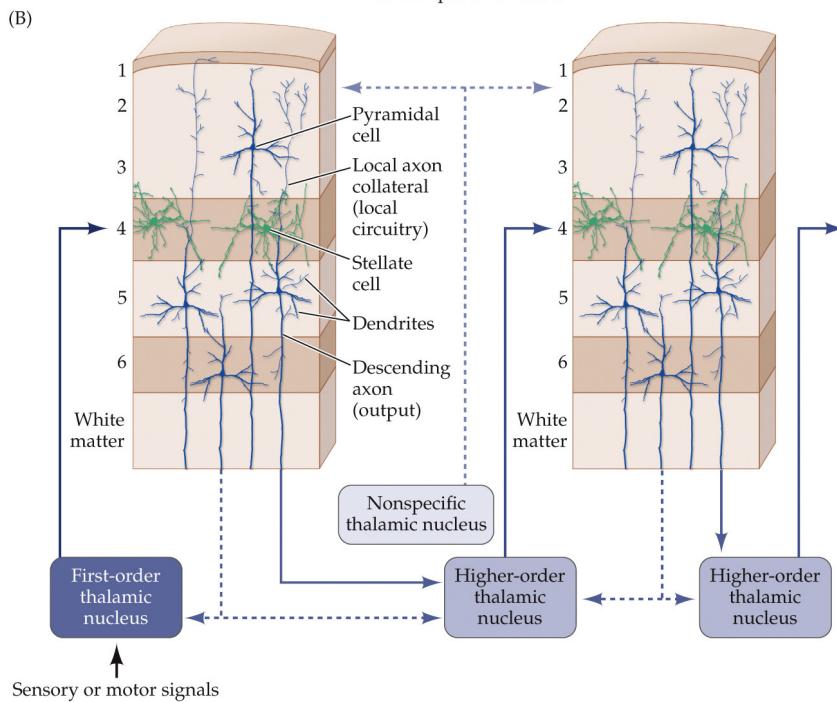
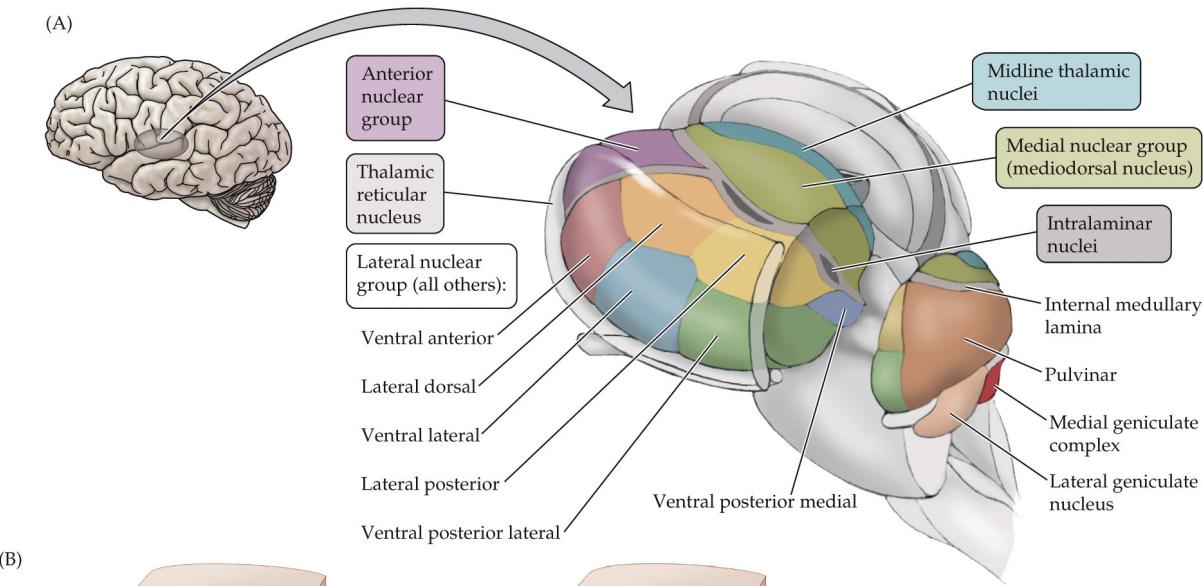


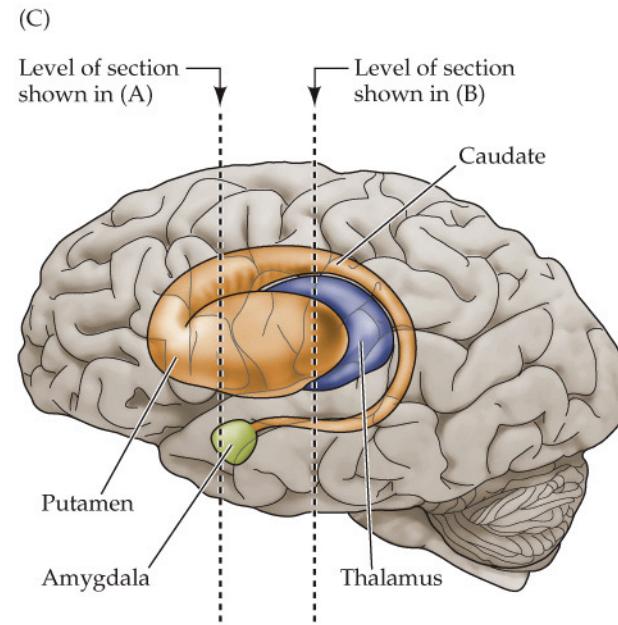
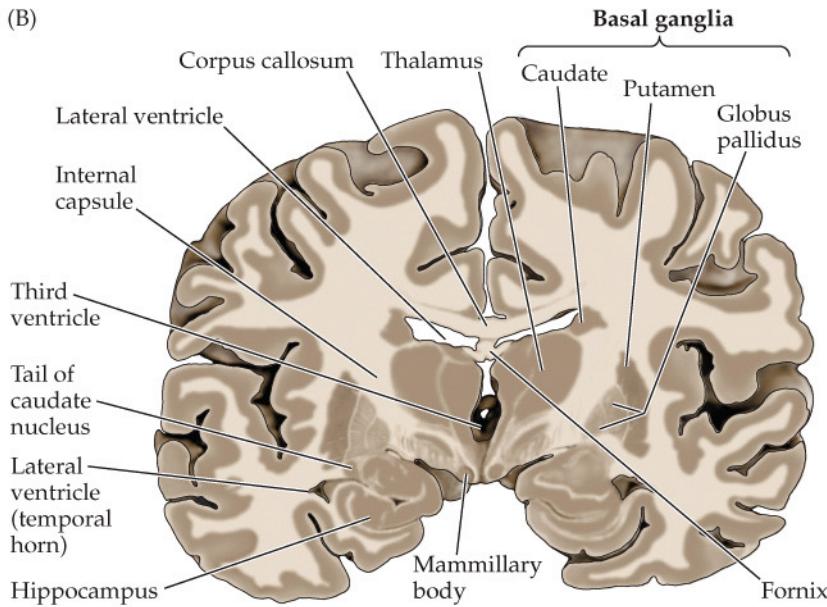
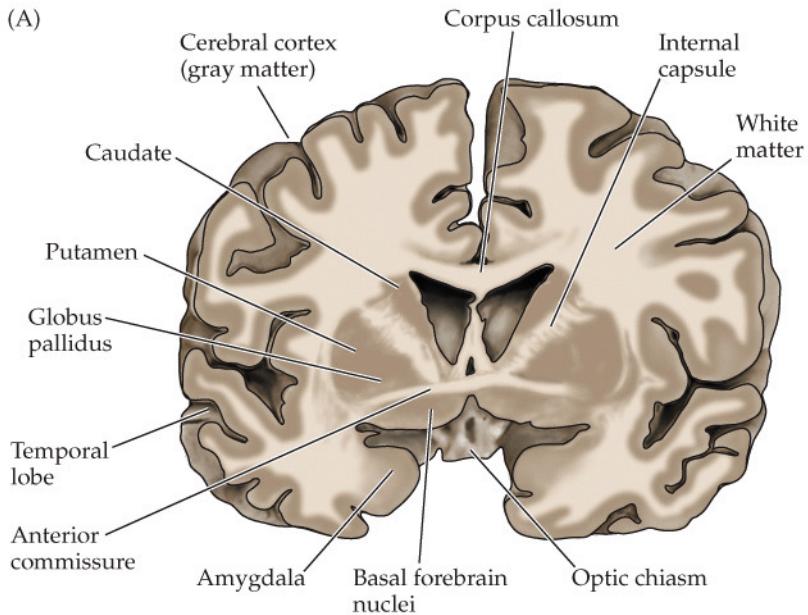
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Divisions of the CNS

- Cerebrum
 - cerebral hemispheres, basal ganglia, etc.
- Diencephalon
 - Thalamus, hypothalamus, retina, etc.
- Midbrain
 - Inferior and superior colliculi, etc.
- Pons
- Cerebellum
- Medulla
- Spinal cord

Embryonic brain	Adult brain derivatives	Associated ventricular space
Prosencephalon (forebrain)	Telencephalon Cerebral cortex Cerebral nuclei (basal ganglia, amygdala, basal forebrain) Diencephalon Thalamus Hypothalamus Retina	Lateral ventricles Third ventricle
Mesencephalon (midbrain)	Superior and inferior colliculi Red nucleus Substantia nigra	Cerebral aqueduct
Rhombencephalon (hindbrain)	Metencephalon Cerebellum Pons Myelencephalon Medulla oblongata	Fourth ventricle Fourth ventricle
Spinal cord	Spinal cord	Central canal

Recap

- CNS, PNS, Cranial nerves, Spinal nerves
- Cerebrum (Cerebral hemispheres), Diencephalon, Cerebellum, Brainstem (Midbrain, Pons, Medulla), Spinal Cord
- Cervical nerves, Thoracic Nerves, Lumbar Nerves, Sacral Nerves, Coccygeal Nerves
- Gray Matter, White Matter
- Dorsal, Ventral, Anterior, Posterior, Caudal, Rostral, Inferior, Superior, Coronal, Horizontal, Sagittal, Transverse