Netter's

CONCISE NEUROANATOMY

UPDATED EDITION

MICHAEL RUBIN AND JOSEPH E. SAFDIEH

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Netter's Concise Neuroanatomy – UPDATED EDITION

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To my wife, Annette.
Without you, little would be possible.
Even less would be worthwhile.
—M.R.

In honor of my wife, Esther, who is a source of unyielding support and devotion.
In memory of Mrs. Audrey Nasar, who served as a constant source of inspiration for me.
—J.S.

Preface

Neuroanatomy is the key to neurology; a solid grounding in neuroanatomy goes a long way in solving any neurodiagnostic challenge. Many fine neuroanatomy textbooks are available, some large, some small. What makes this text unique is the unparalleled Netter series of diagrams, coupled with the relevant points that the student needs to master, all presented in a clear, simplified, straightforward, tabulated format. Easy to grasp and review at a glance, they offer the student what (s)he needs to know without being overburdened with the details needed primarily by the board-certifying neurologist.

Arranged, for the most part, using the standard anatomic approach found in most texts, this atlas is designed to be broadly applicable to medical, dental, allied health and undergraduate neuroanatomy courses. Netter's illustrations provide an illustrative venue for understanding neuroanatomy, a science that is nothing if not visual. Netter's rich illustrations say more than words, while the text, primarily in tabular and point form, supplements and highlights the important aspects of the figures which you, the student, must master.

Acknowledgments

We would like to thank the reviewers who, anonymously, have helped us improve this text to the best of our ability. Any errors that remain are, of course, our own. Our developmental editor, Marybeth Thiel, has patiently worked with us in getting this atlas completed in a timely fashion, and has demonstrated that writing a book can be an enjoyable pastime. Michael Rubin would like to thank his father, a retired cardiologist and outstanding clinician in his own right, for being his guiding light, teacher, and exemplar of what it means to be a teacher and physician. Joseph Safdieh would like to thank his parents for their perpetual support. Finally, we both owe our thanks to Paul Kelly who, though unable to see this to completion, was the initiator of the project and to him we owe our gratitude.

Michael Rubin
Joseph Safdieh

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About the Authors

Michael Rubin, M.D., F.R.C.P.(C), is Professor of Clinical Neurology at the Joan and Sanford I. Weill Medical College of Cornell University and Director of the Neuromuscular Service and Electromyography Laboratory at New York Presbyterian Hospital-Cornell Medical Center. Dr. Rubin has been Director of the Neurology Clerkship at Weill-Cornell since 1996 and has received several teaching awards from medical students and neurology residents. In 2002, he was awarded the Teacher Recognition Certificate of the AB Baker Section on Education from the American Academy of Neurology, given to nationally recognized neurologic educators, and he has served as an Associate Examiner for the American Board of Psychiatry and Neurology. In addition to his clinical neurology practice and medical education focus at the student and resident level, Dr. Rubin directs the EMG Fellowship for post-residency trainees. His research interests encompass therapeutic clinical trials in the area of diabetic and HIV-associated peripheral neuropathy. Dr. Rubin is an assistant editor of Neurology Alert, a monthly survey of developments in neurologic medicine. A nonpracticing ordained orthodox rabbi, he enjoys giving a nightly Talmud class at his synagogue.

Joseph E. Safdieh, MD, is Associate Professor of Neurology and Vice Chairman for Education in the Department of Neurology at Joan and Sanford I. Weill Medical College of Cornell University and Associate Attending Neurologist at New York Presbyterian Hospital. He serves as Director of the Neurology Clerkship at Weill Medical College of Cornell University and Director of Outpatient Training for the Neurology Residency Program at New York Presbyterian Hospital. He has received numerous awards for his academic and teaching achievements. He is a member of Phi Beta Kappa and Alpha Omega Alpha. Dr. Safdieh received his bachelor's degree in neuroscience and his medical degree from New York University. He completed his neurology residency training at the Weill Cornell Campus of New York Presbyterian Hospital, where he also served as chief resident in neurology.

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Frank H. Netter, MD

Frank H. Netter was born in 1906, in New York City. He studied art at the Art Student's League and the National Academy of Design before entering medical school at New York University, where he received his MD degree in 1931. During his student years, Dr. Netter's notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the United States Army during World War II, Dr. Netter began his long collaboration with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

Icon Learning Systems acquired the Netter Collection in July 2000 and continued to update Dr. Netter's original paintings and to add newly commissioned paintings by artists trained in the style of Dr. Netter. In 2005, Elsevier, Inc. purchased the Netter Collection and all publications from Icon Learning Systems. There are now over 50 publications featuring the art of Dr. Netter available through Elsevier, Inc.

Dr. Netter's works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-book *Netter Collection of Medical Illustrations,* which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. *The Netter Atlas of Human Anatomy,* first published in 1989, presents the anatomical paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but, more importantly, for their intellectual content. As Dr. Netter wrote in 1949 ". . . clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a *medical illustration* if it does not serve to make clear some medical point." Dr. Netter's planning, conception, point of view, and approach are what inform his paintings and what makes them so intellectually valuable.

Frank H. Netter, MD, physician and artist, died in 1991.

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Acknowledgments

The Netter collection of medical illustrations contains a rich assortment of art depicting the complexities of the structure and function of the nervous system. The success of these illustrations is because of close collaboration of content expert and artist. Dr. Frank Netter's most comprehensive collection of neuroanatomy artwork is found in Volume 1, Part 1 of *The Netter Collection of Medical Illustrations*. Since Dr. Netter's passing, several artists have continued in the Netter tradition, working with leaders in various specialties to update some of the Netter plates and to develop new ones that reflect current scientific thought and clinical practice. In preparing *Netter's Atlas of Human Neuroscience*, David Felten, M.D., Ph.D. worked with artists John Craig, M.D. and Jim Perkins to create 117 new illustrations and modify 35 others for the Netter collection of medical illustrations. The creation of these fine images owes much to Dr. Felten who was the content expert for these illustrations, many of which appear in this book. Elsevier thanks them for their contributions to the collection without which many of the illustrations contained in this book would not have been available for reuse and modification.

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Netter's Concise Neuroanatomy

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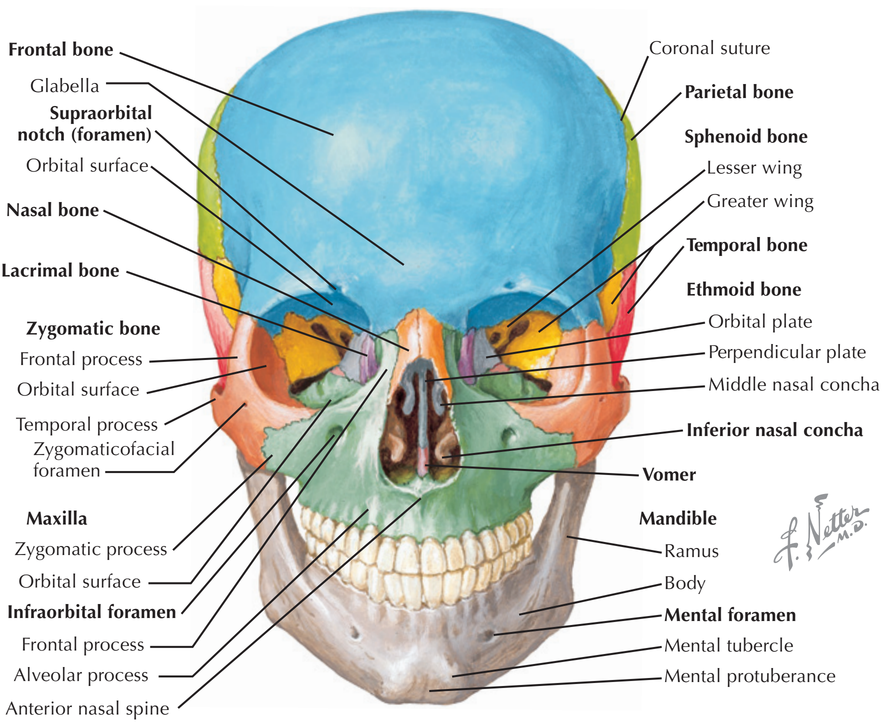
CHAPTER 1

Bony Coverings of the Brain and Spinal Cord

SKULL: ANTERIOR VIEW

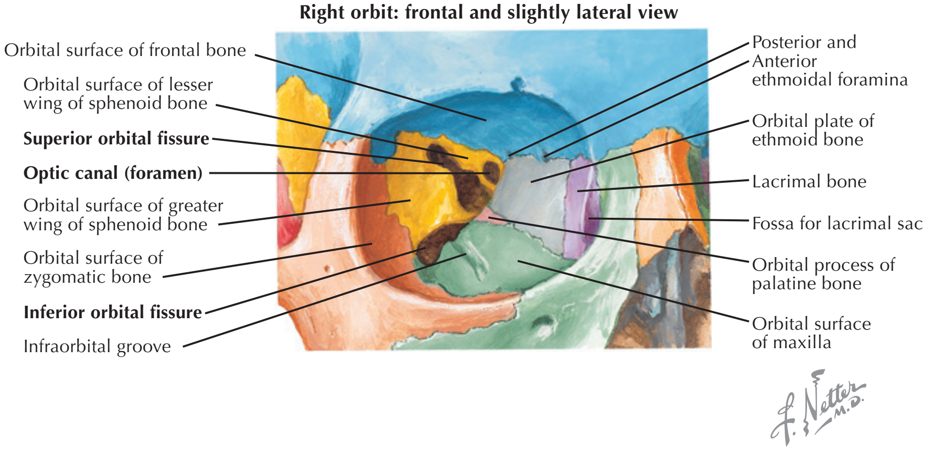
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Supraorbital notch	Transmits supraorbital nerve	A useful pressure point for evaluation of arousability in a comatose patient
Infraorbital foramen	Transmits infraorbital nerve	Supplies the skin of lower eyelid, cheek, side of nose, and upper lip
Mental foramen	Transmits mental nerve	Mental neuropathy causes a numb chin and may be a symptom of underlying malignancy; requires aggressive evaluation



ORBIT: ANTERIOR VIEW

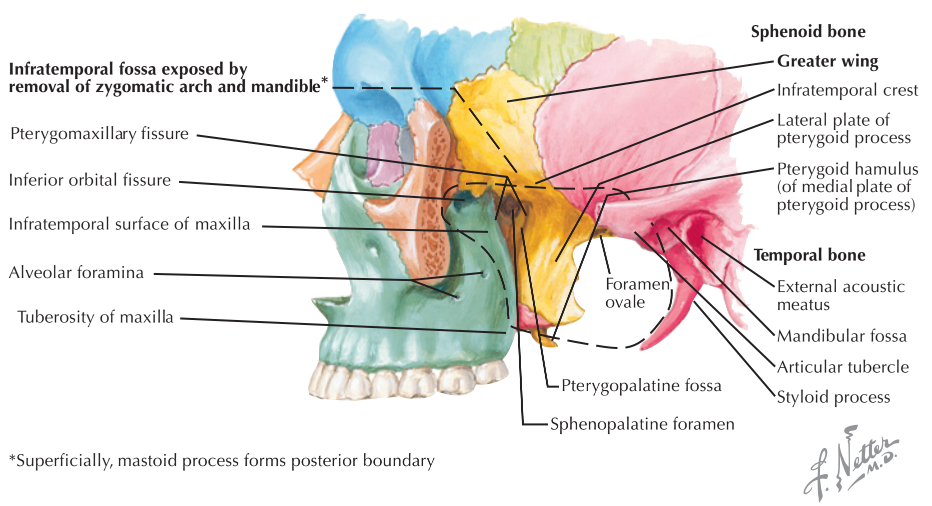
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Optic foramen	Transmits optic nerve (CN-II) and ophthalmic artery	Compression of CN-II causes blindness
Superior orbital fissure	Transmits oculomotor nerve (CN-III), trochlear nerve (CN-IV), and nasociliary branches of ophthalmic division of trigeminal nerve (V_1) and abducens nerve (CN-VI)	Tolosa-Hunt syndrome: idiopathic inflammatory process involving superior orbital fissure, causing eye pain and ophthalmoplegia from involvement of CN-III, -IV, and -VI
Inferior orbital fissure	Transmits maxillary nerve, venous plexus channels, fascicles from pterygopalatine ganglion	Trigeminal neuralgia (tic douloureux) usually involves maxillary and mandibular divisions of trigeminal nerve, rarely ophthalmic division

Right orbit: frontal and slightly lateral view



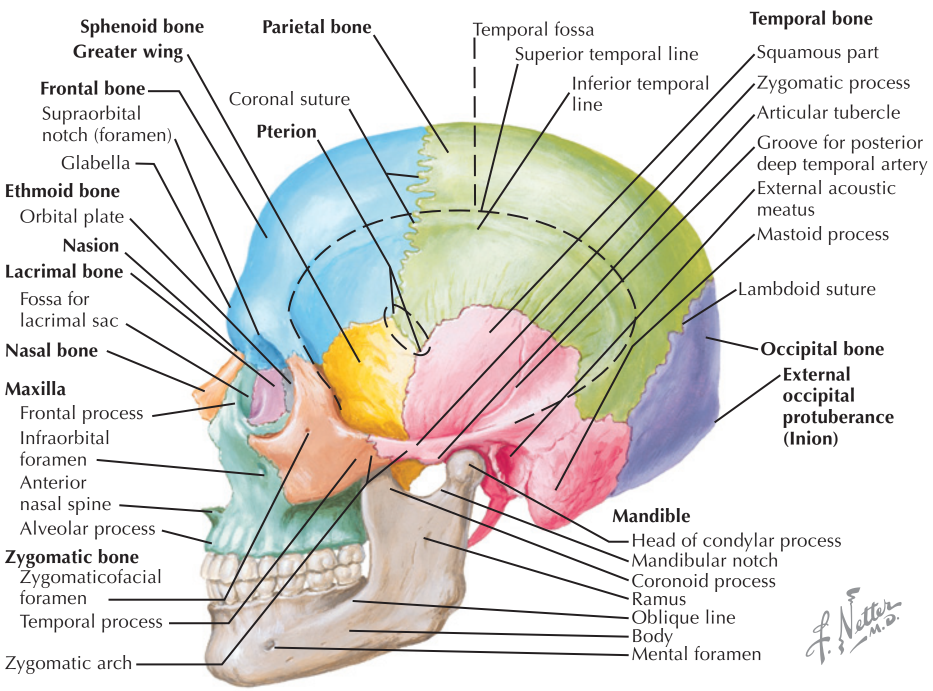
SKULL: LATERAL VIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Zygomatic bone	Yokes temporal (zygon), sphenoid (greater wing), frontal, and maxillary bones	Sphenoid wing is a common site of origin of meningioma
Pterion	Point where greater wing of sphenoid meets anteroinferior angle of parietal bone	Beneath the pterion lies the anterior branch of the middle meningeal artery, often injured from skull fracture
Nasion	Depression in midline at root of nose	Falx cerebri begins here and extends posteriorly to the inion
Inion	Identical to external occipital protuberance, junction of head and neck	Line joining nasion over skull to inion indicates the position of underlying falx cerebri, superior sagittal sinus, and longitudinal interhemispheric cerebral fissure



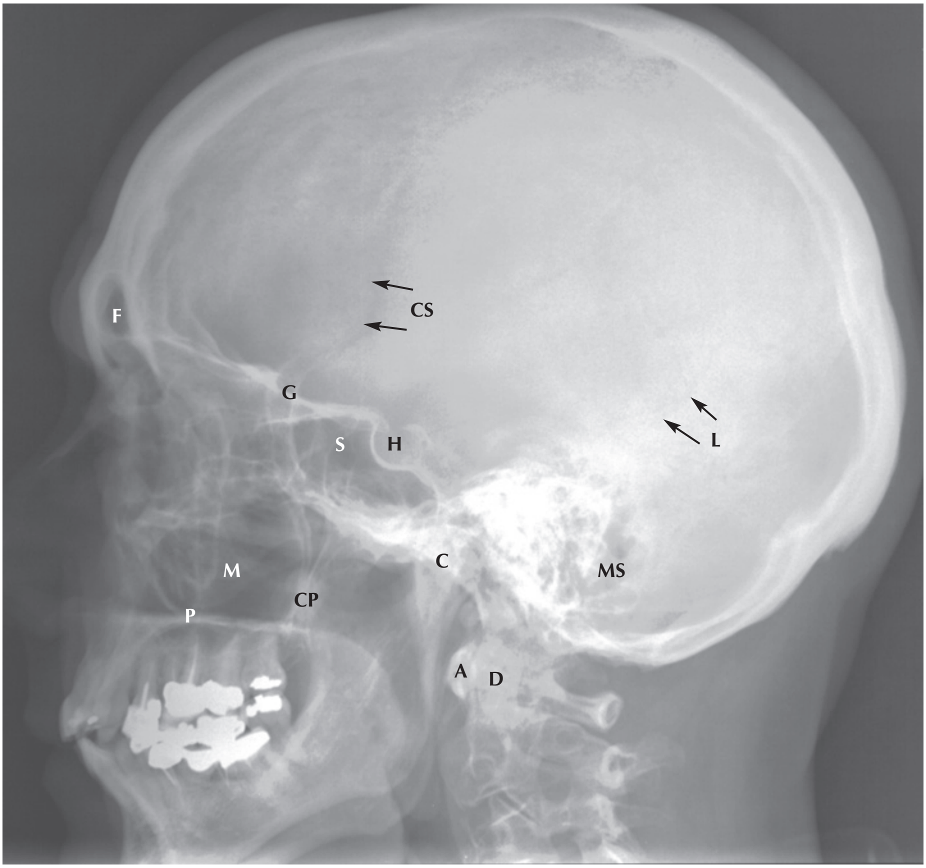
*Superficially, mastoid process forms posterior boundary

SKULL: LATERAL VIEW *continued*



SKULL: LATERAL RADIOGRAPH

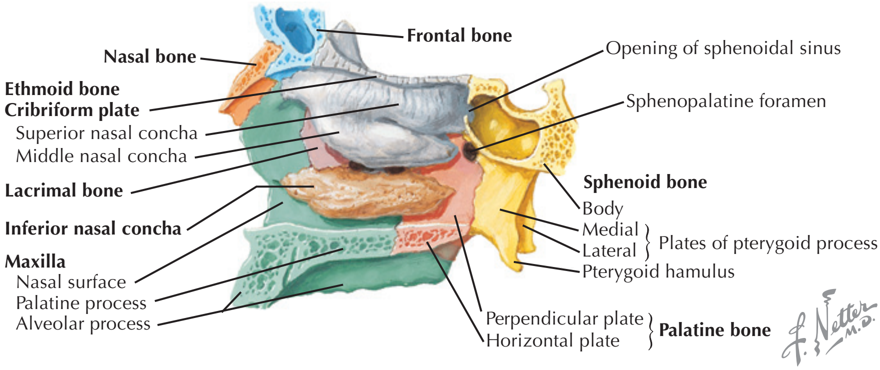
CLINICAL NOTE:
Enlargement of sella turcica on skull x-ray suggests pituitary tumor.



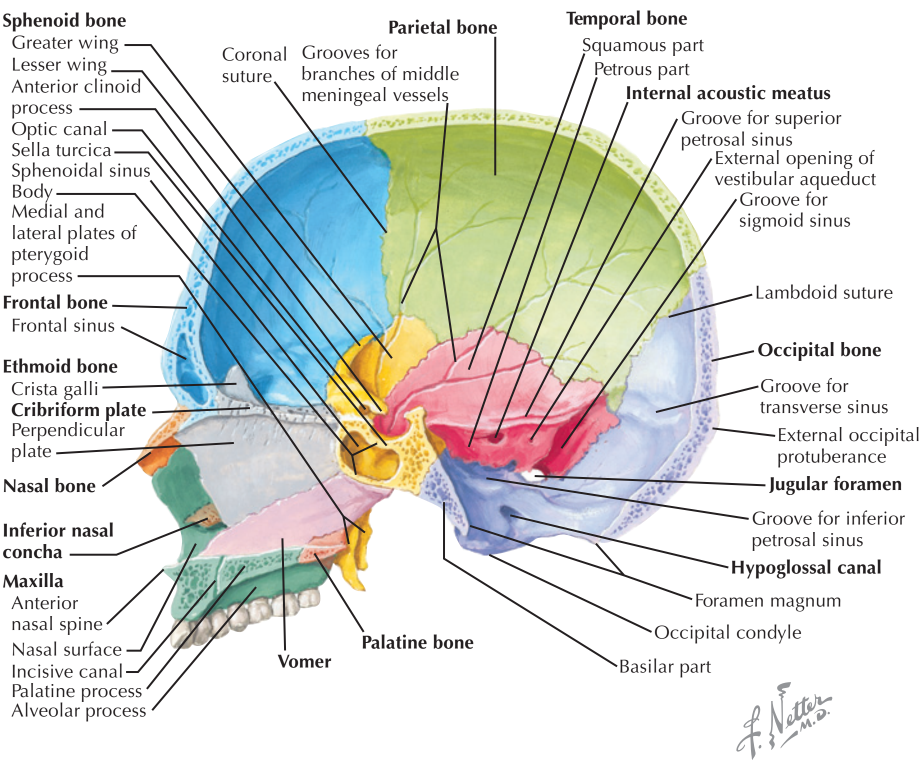
A	Anterior arch of atlas (CI vertebra)	**G**	**Greater wing of sphenoid**
C	Condyle of mandible	**H**	**Hypophyseal fossa (sella turcica)**
CP	Coronoid process of mandible	**L**	Lambdoid suture
CS	Coronal suture	**M**	Maxillary sinus
D	Dens of axis (C2 vertebra)	**MS**	Mastoid air cells
F	Frontal sinus	**P**	Palatine process of maxilla
		S	Sphenoid sinus

SKULL: MIDSAGITTAL VIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Internal acoustic (auditory) meatus	Transmits facial nerve (CN-VII), vestibulocochlear nerve (CN-VIII), and internal auditory artery	Internal acoustic meatus is near the cerebellopontine angle. Tumors in this region cause facial weakness (CN-VII nerve compression), deafness, tinnitus, and vertigo (CN-VIII nerve compression).
Jugular foramen	Lodges superior bulb of internal jugular vein and transmits glossopharyngeal nerve (CN-IX), vagus nerve (CN-X), and spinal accessory nerve (CN-XI)	Jugular foramen syndrome affects CN-IX, -X, -XI, causing hoarseness (vocal cord paralysis), dysphagia, deviation of soft palate to normal side, posterior pharyngeal wall anesthesia, trapezius and sternocleidomastoid weakness. May be due to posterior fossa tumor, vertebral artery aneurysm, or, on leaving the skull, internal carotid artery dissection.
Hypoglossal canal	Transmits hypoglossal nerve (CN-XII)	Hypoglossal nerve lesions (Lou Gehrig's disease, polio) cause tongue atrophy, weakness, and fasciculations.
Cribriform plate	Transmits olfactory nerves (CN-I) from nasal mucosa to olfactory bulb	Meningiomas of cribriform plate cause unilateral anosmia.



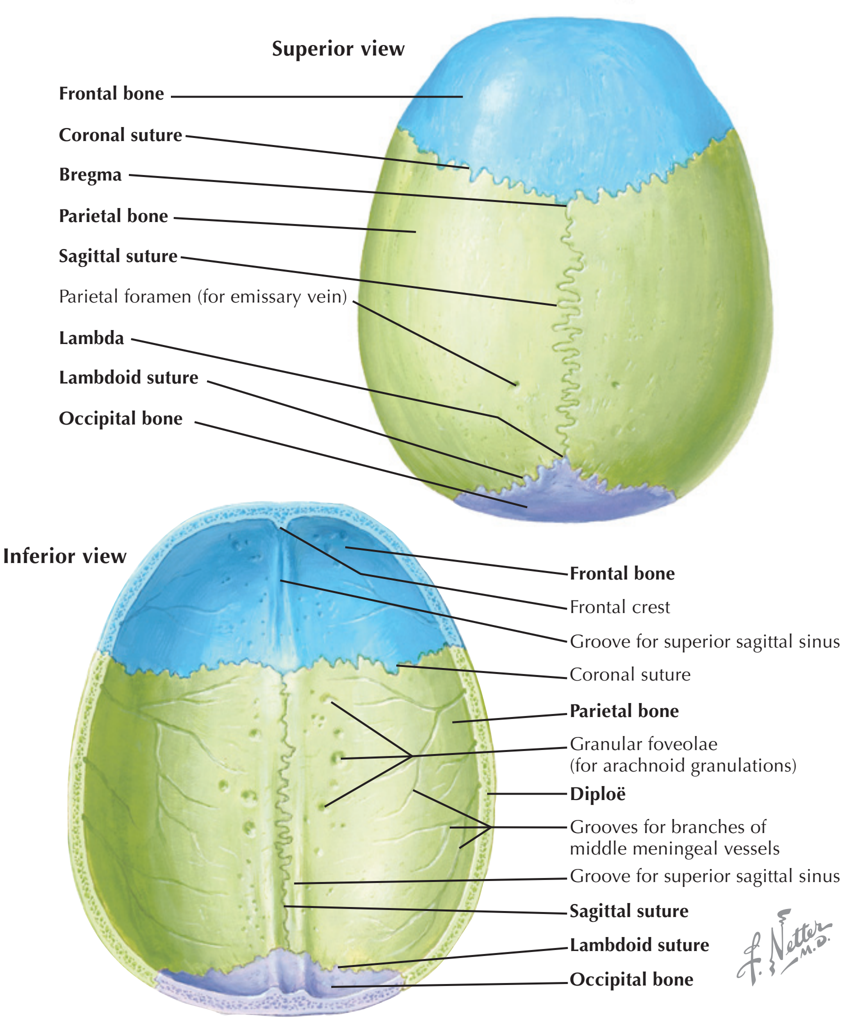
SKULL: MIDSAGITTAL VIEW *continued*



CALVARIUM

STRUCTURE	ANATOMIC NOTES
Calvarium	Skullcap Roof of the cranium is formed by frontal, parietal, and occipital bones
Frontal bone	Meets parietal bones at coronal suture
Parietal bones	Meet each other at midline sagittal suture, meet occipital bones at lambdoid suture
Bregma	Meeting point of sagittal suture and coronal suture
Lambda	Meeting point of sagittal suture and lambdoid suture
Vertex of skull	Highest point, lies in midline of sagittal suture
Skull bones	Possess outer and inner lamellae separated by diploe: layer of cancellous bone

CALVARIUM *continued*

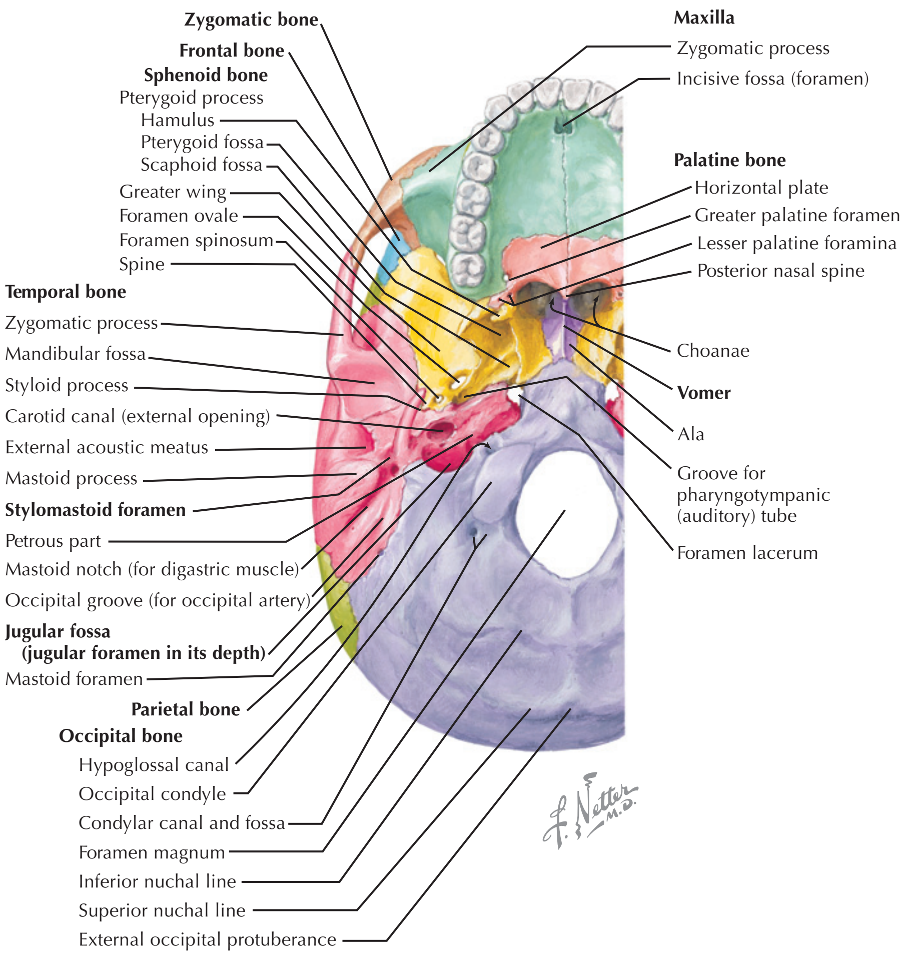


BASE OF SKULL: FROM BELOW

STRUCTURE	ANATOMIC NOTES
Incisive foramen	Transmits nasopalatine nerve terminal branches
Greater and lesser palatine foramina	Transmit corresponding nerves and arteries
Stylomastoid foramen	Transmits CN-VII
Jugular fossa	Lodges superior bulb of internal jugular vein

CLINICAL NOTES:

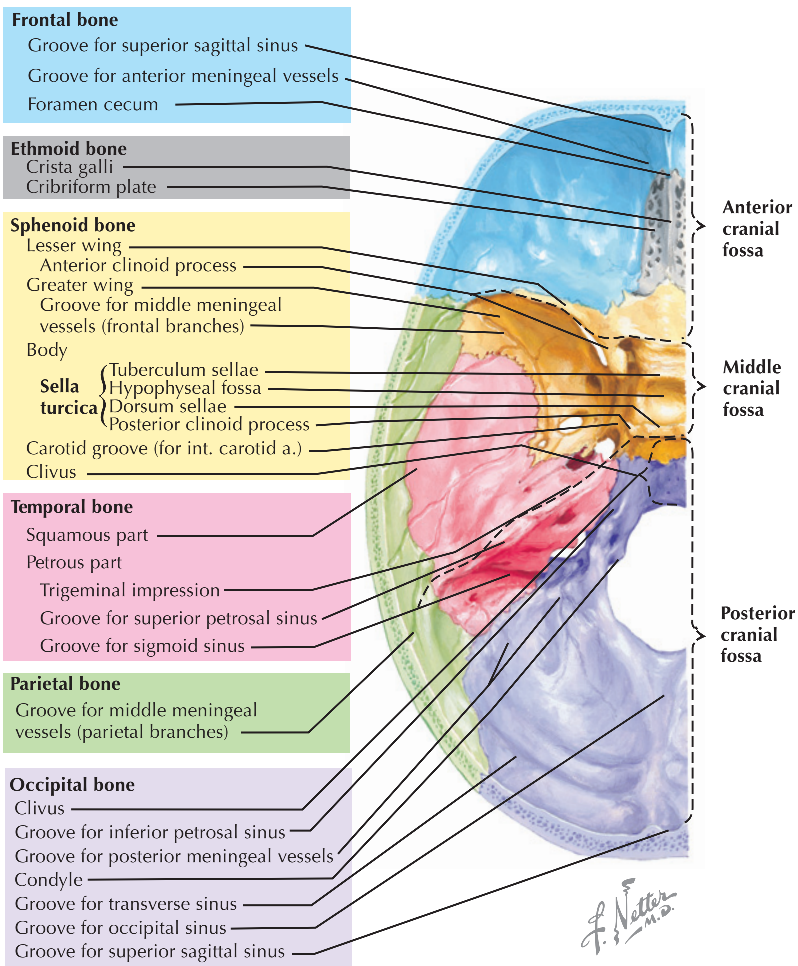
- Paget's disease may cause basilar invagination of skull base, resulting in lower cranial nerve (CN-IX, -X, -XI, -XII) abnormalities, high spinal myelopathy, and cerebellar findings.
- Nasopharyngeal carcinoma can spread from the nasopharynx along the skull base, picking off individual cranial nerves along its course and causing multiple cranial mononeuropathies, usually the trigeminal nerve (CN-V) and CN-VI, with resulting facial numbness (CN-V) and horizontal diplopia (CN-VI).



BASE OF SKULL: FROM ABOVE

STRUCTURE	ANATOMIC NOTES
Anterior cranial fossa	Houses the frontal lobes
Middle cranial fossa	Houses the temporal lobes
Posterior cranial fossa	Houses the cerebellum, pons, and medulla
Sella turcica	Houses the pituitary gland

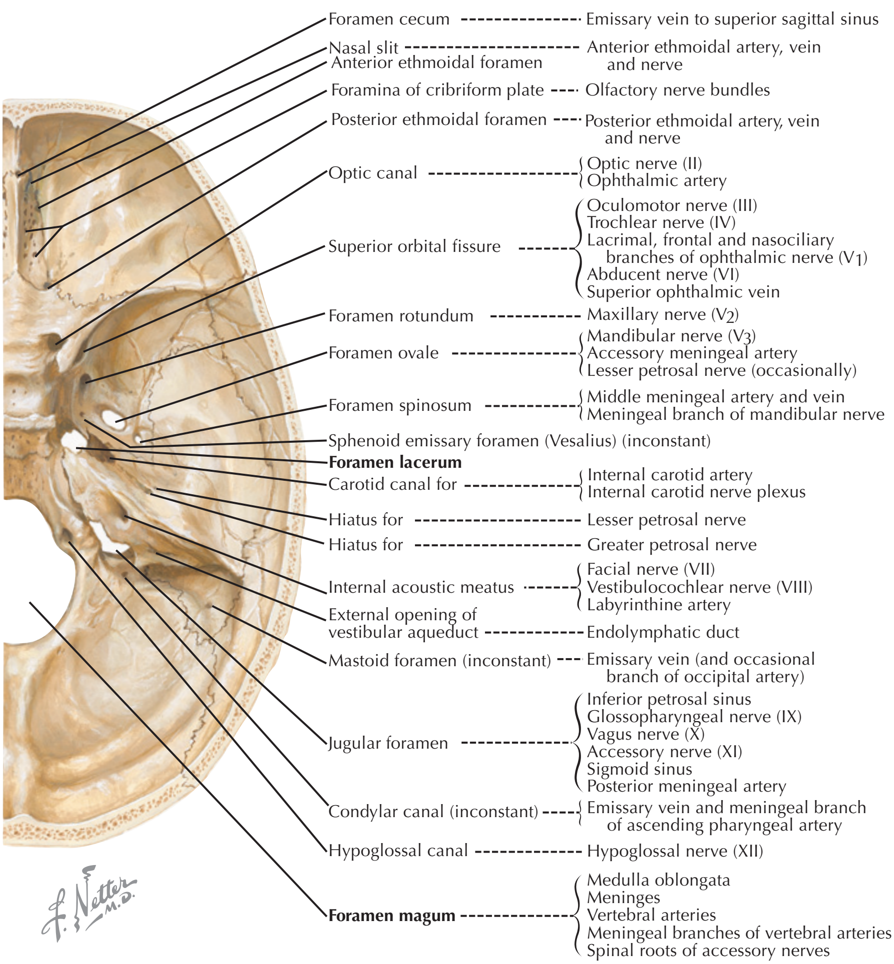
CLINICAL NOTES:
Lesser sphenoid wing meningiomas may expand medially to involve cavernous sinus (affecting CN-III, -IV, and -VI), anteriorly into orbit causing exophthalmos, or laterally into temporal bone, causing bulging of bone.



BASE OF SKULL: FROM ABOVE *continued*

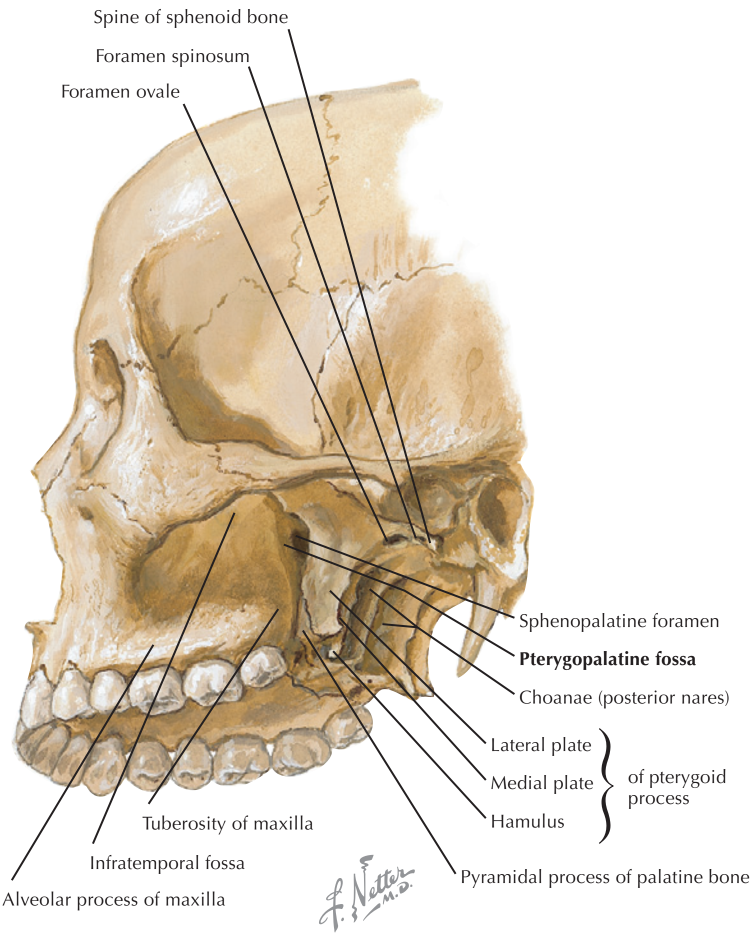
CLINICAL NOTES:

- Chronic meningeal diseases often involve the skull base (internally).
- Multiple cranial mononeuropathies occur as a result of contiguous spread of process with involvement of cranial nerves.
- Differential diagnoses include infection, autoimmune, and neoplasms.
- Foramen lacerum: Internal carotid artery enters foramen through carotid canal and then turns upward and forward into cavernous sinus.



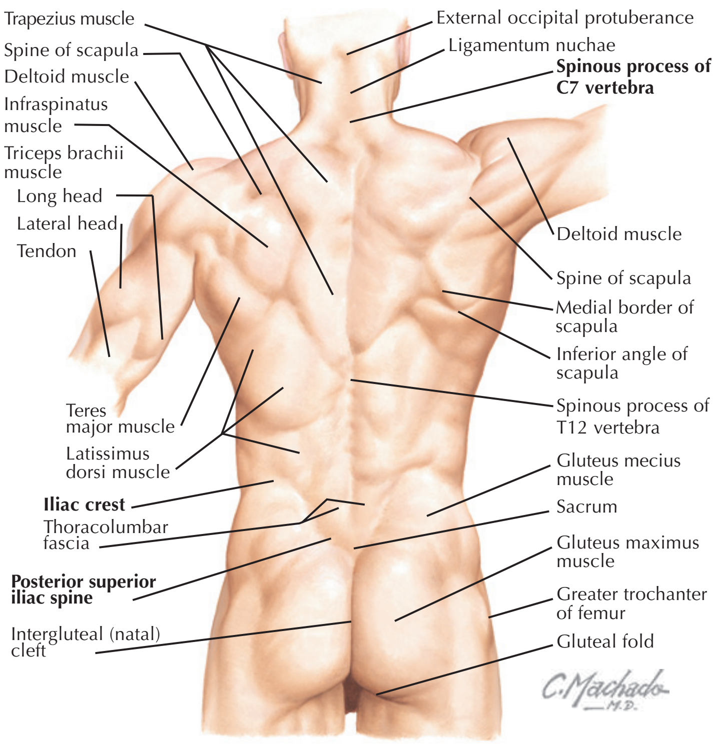
BONY FRAMEWORK OF HEAD AND NECK

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Pterygopalatine fossa	Small space behind and below the orbital cavity	Communicates: • Laterally with infratemporal fossa through pterygomaxillary fissure • Medially with nasal cavity through sphenopalatine foramen • Superiorly with skull through foramen rotundum • Anteriorly with orbit through inferior orbital fissure



SURFACE ANATOMY BACK

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Spinous process of C7 vertebra	Vertebra prominens	First spinous process to be felt; 1-6 are covered by ligamentum nuchae
Iliac crests	Horizontal line joining their highest point corresponds to L3-4 interspace	Landmark for lumbar puncture
Posterior superior iliac spines	Horizontal line joining them passes through S2 spinous process	Subarachnoid space with cerebrospinal fluid extends to this level



VERTEBRAL COLUMN

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
33 Vertebral bodies	7 Cervical, 12 thoracic, 5 lumbar, 5 fused sacral, 4 fused coccygeal	Increase in size caudally due to increasing weight they bear
Intervertebral discs	Between each vertebrae but lacking between occiput and atlas and between atlas and axis	Act as shock absorbers for spinal column
C7	Called vertebra prominens because it is the longest cervical spinous process	Highest spinous process palpable is C7

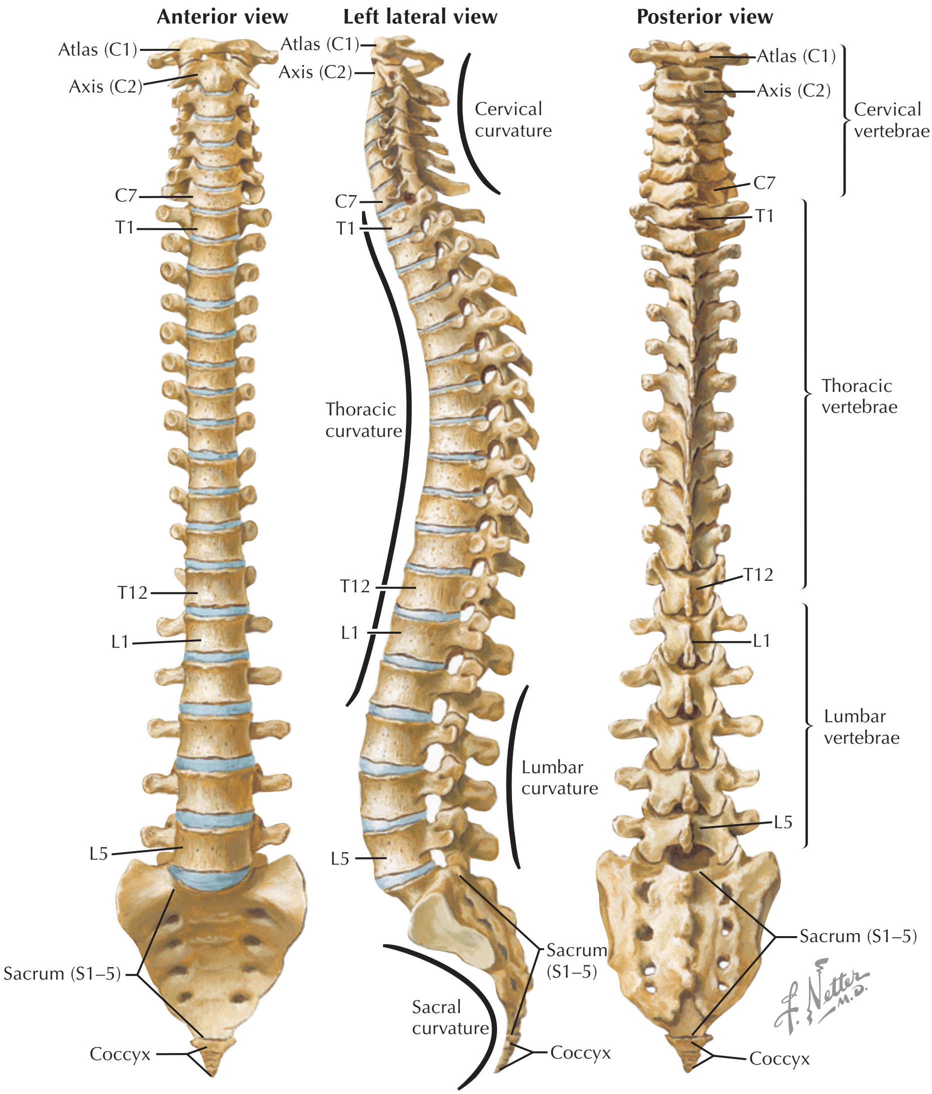
LEVEL	CORRESPONDING STRUCTURE
C2-3	Mandible
C3	Hyoid bone
C4-5	Thyroid cartilage
C6	Cricoid cartilage
C7	Vertebra prominens
T3	Spine of scapula
T8	Point of inferior vena cava piercing diaphragm
T10	Xiphisternal junction
T10	Point of esophagus entering stomach
T12	Point of aorta entering abdomen
L1	End of spinal cord
L3	Subcostal plane
L3-4	Umbilicus
L4	Bifurcation of aorta
L4	Iliac crests
S2	End of dural sac

From Hansen, J.T., & Lambert, D.R. (2006). Netter's Clinical Anatomy. Philadelphia, Elsevier.

CLINICAL NOTES:

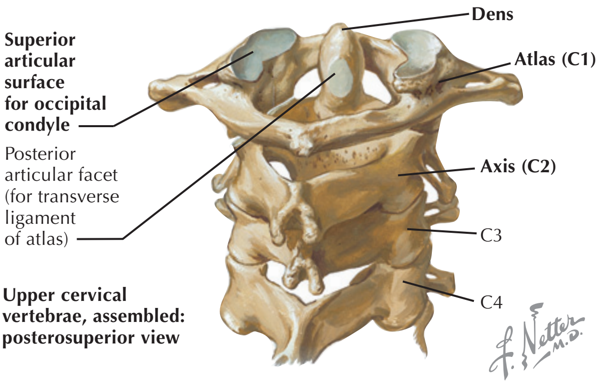
- Lumbar disc herniation is more frequent than cervical herniation.
- Disc between L5 and S1 vertebrae is the most common herniated disc.
- As one ascends, lumbar discs herniate with decreasing frequency in sequence (i.e., L4-5 more often than L3-4 > L2-3 > L1-2).
- Thoracic discs represent 0.5% of all surgically verified disc protrusions.
- Lower four thoracic interspaces are the most frequently involved.
- Lumbar puncture is done at L3-4 interspace, or the space above or below, to avoid puncturing the spinal cord that ends at L1-2 interspace.

VERTEBRAL COLUMN *continued*



CERVICAL VERTEBRAE: ATLAS AND AXIS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Atlas	First cervical vertebra Has no body Forms ring enclosing vertebral foramen Transverse processes pierced by transverse foramen for vertebral artery Occipital condyles of skull rest on superior articular facets of atlas	Paget's disease may cause basilar invagination (upward bulging of occipital condyles), causing neck shortening, cerebellar signs, and myelopathy
Axis	Second cervical vertebra	Hangman fracture, suffered in hanging death, involves fracture of C2, axis, with or without subluxation (slippage) of C2 on C3 and causes death by paralyzing breathing
Dens	Tooth-like process, projects upward from body A divorced portion of atlas that has united with axis	Forms a pivot around which atlas and skull can rotate

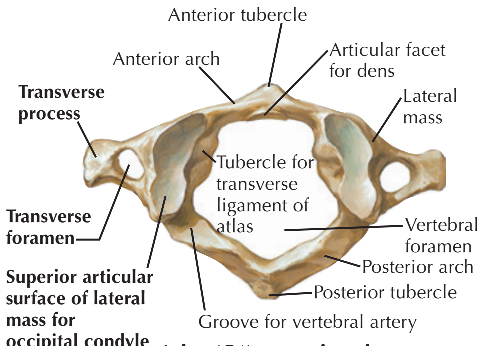


Upper cervical vertebrae, assembled: posterosuperior view

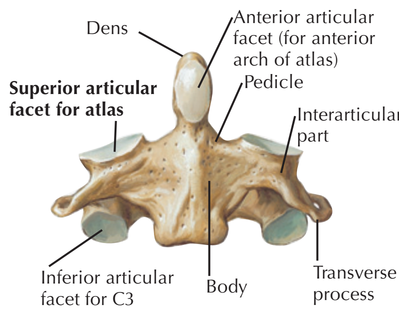
Radiograph of atlantoaxial joint

A Lateral masses of atlas (CI vertebra)
D Dens of axis (C2 vertebra)

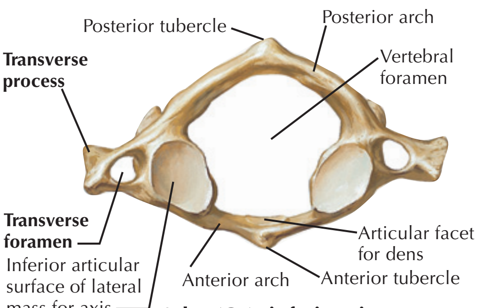
CERVICAL VERTEBRAE: ATLAS AND AXIS *continued*



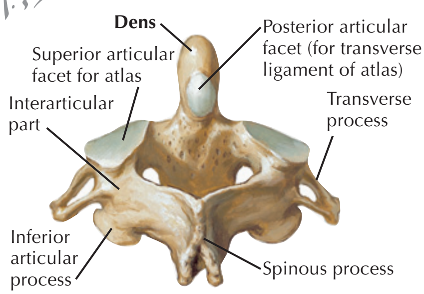
Atlas (C1): superior view



Axis (C2): anterior view



Atlas (C1): inferior view



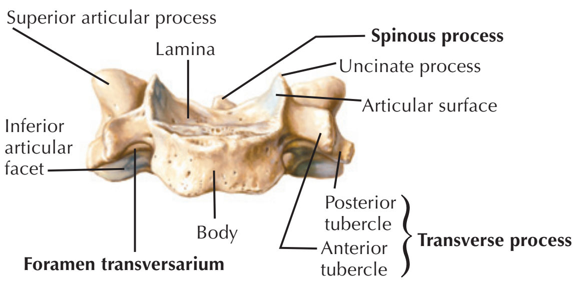
Axis (C2): posterosuperior view

CERVICAL VERTEBRAE

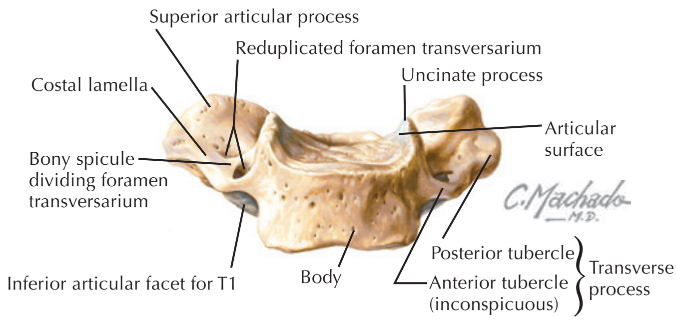
STRUCTURE	ANATOMIC NOTES
Cervical vertebra C1-7	Foramen in transverse processes for vertebral artery, which passes anterior to transverse process of C7 and runs upward from C6 to C1
Pedicles	Project posterolaterally from body of vertebra
Laminae	Directed medially and fuse posteriorly as spinous process
Superior and inferior articular facets	Lie at the junction of pedicle and lamina
Intervertebral foramina	Bordered by pedicles above and below, by intervertebral discs anteriorly, and by facets and facet joints posteriorly

CLINICAL NOTES:
- Dorsal and ventral spinal nerve roots fuse in the intervertebral foramen to form spinal nerve.
- Most common cervical herniated disc is C6-7 (70%).
- Next most common is C5-6 disc (20%), followed by C4-5 and C7-T1 (10%).

4th cervical vertebra: anterior view

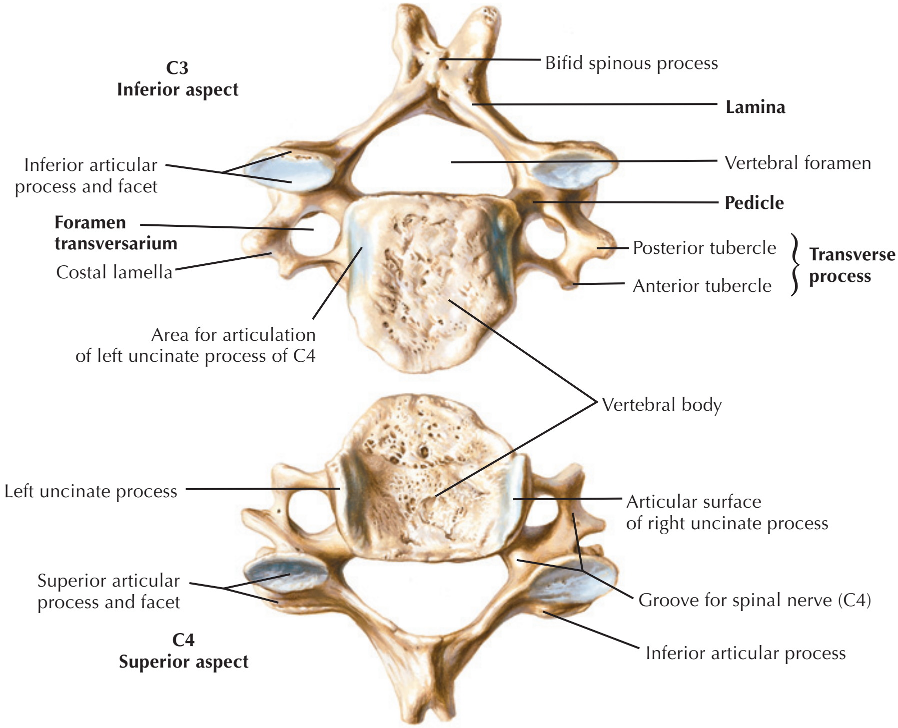


7th cervical vertebra: anterior view

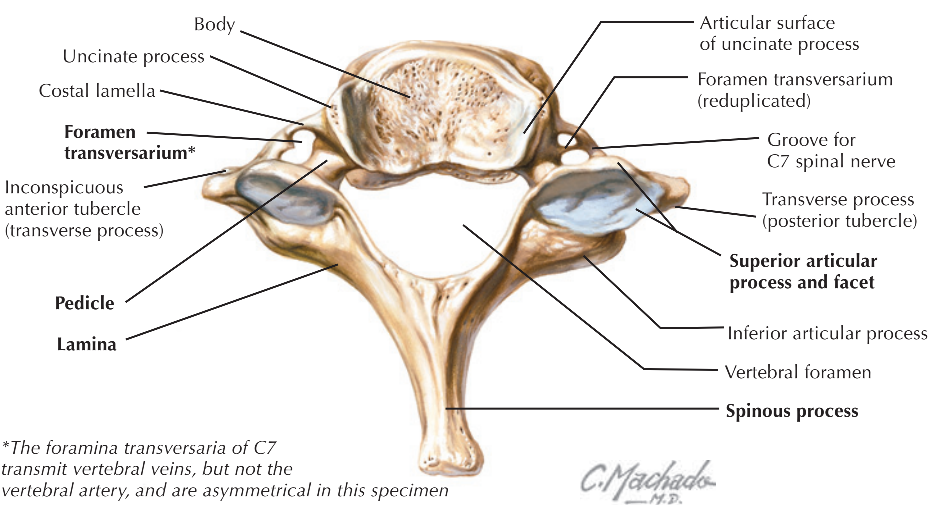


CERVICAL VERTEBRAE *continued*

Inferior aspect of C3 and superior aspect of C4 showing the sites of the facet and uncovertebral articulations



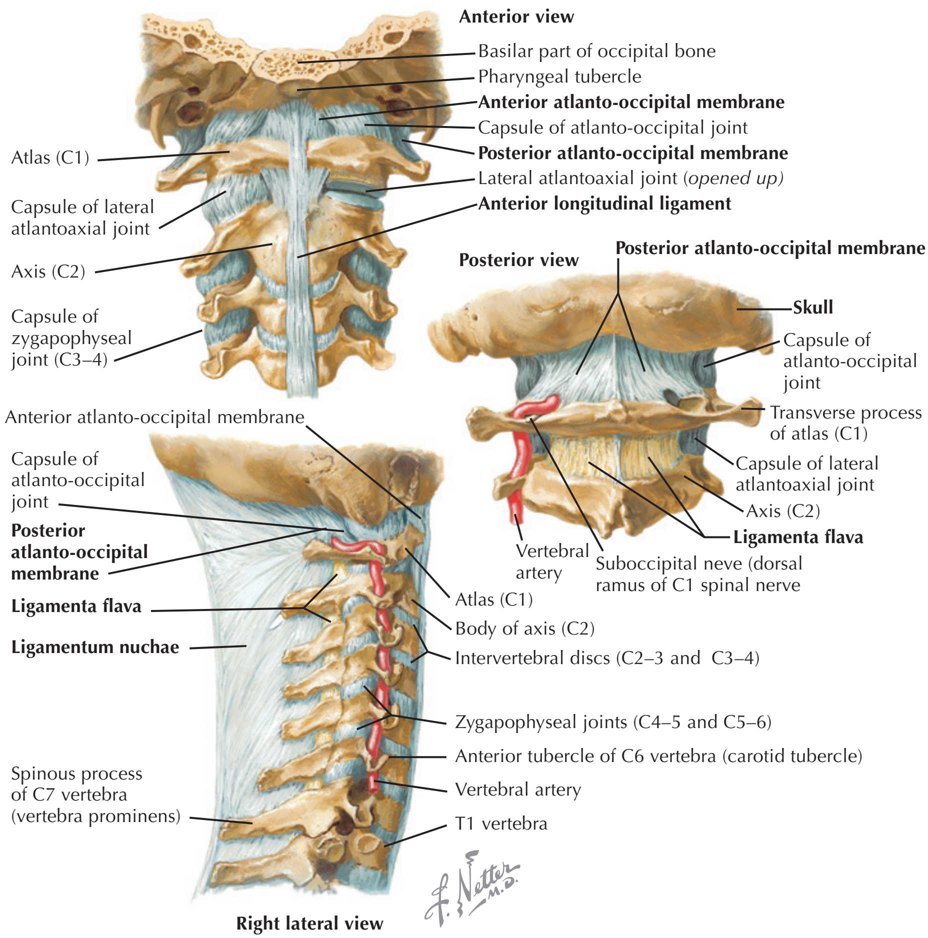
7th cervical vertebra (vertebra prominens): superior view



**The foramina transversaria of C7 transmit vertebral veins, but not the vertebral artery, and are asymmetrical in this specimen*

EXTERNAL CRANIOCERVICAL LIGAMENTS

STRUCTURE	ANATOMIC NOTES
Anterior longitudinal ligament	Runs anterior to vertebrae from base of skull to sacrum
Posterior longitudinal ligament	Runs within vertebral canal, posterior to vertebral body, from base of skull to sacrum (not shown)
Anterior atlanto-occipital membrane	Connects anterior margin of foramen magnum with anterior arch of atlas. It is the continuation of anterior longitudinal ligament
Posterior atlanto-occipital membrane	Connects posterior margin of foramen magnum with posterior arch of atlas
Ligamentum nuchae	Runs from external occipital protuberance to posterior tubercle of atlas and spinous processes of all cervical vertebrae
Ligamentum flavum	Connects laminae of adjacent vertebrae but is absent between skull and atlas



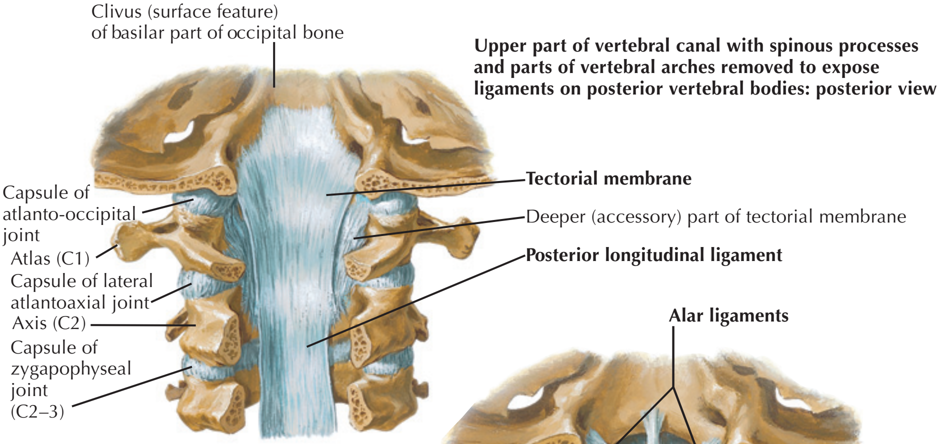
Right lateral view

INTERNAL CRANIOCERVICAL LIGAMENTS

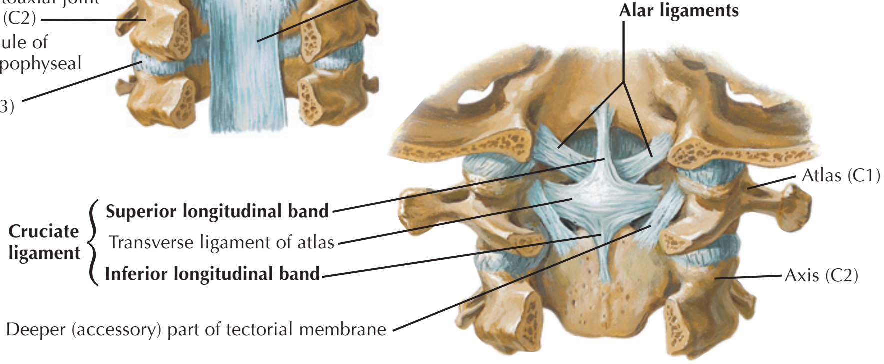
STRUCTURE	ANATOMIC NOTES
Posterior longitudinal ligament	Runs along posterior surface of vertebral bodies along anterior aspect of the vertebral canal
Tectorial membrane	Upward continuation of posterior longitudinal ligament; runs from posterior surface of dens to anterior/lateral margins of foramen magnum
Alar ligament	Connects dens (odontoid process) to the medial side of occipital condyles
Apical ligament	Connects apex of dens to the anterior margin of foramen magnum
Transverse ligament of atlas	Connects (right and left) lateral masses of atlas
Superior longitudinal fascicle	Runs from transverse ligament to basilar part of occipital bone
Inferior longitudinal fascicle	Runs from transverse ligament to posterior surface of body of axis
Cruciform (cruciate) ligament	Composed of transverse ligament of atlas and superior and inferior longitudinal fascicle

CLINICAL NOTE:
Alar ligament prevents excessive head rotation.

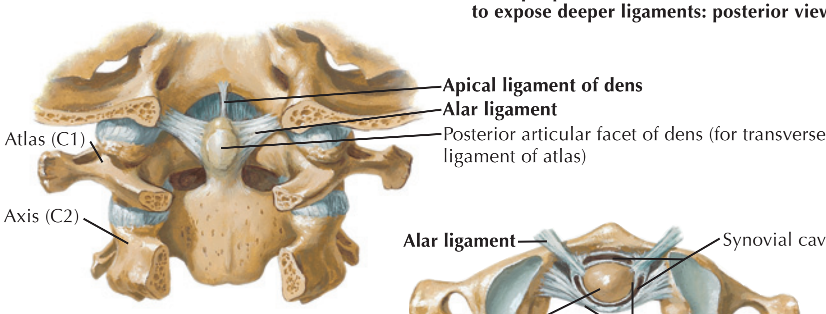
INTERNAL CRANIOCERVICAL LIGAMENTS *continued*



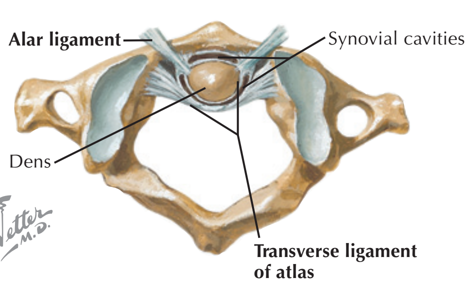
Upper part of vertebral canal with spinous processes and parts of vertebral arches removed to expose ligaments on posterior vertebral bodies: posterior view



Principal part of tectorial membrane removed to expose deeper ligaments: posterior view



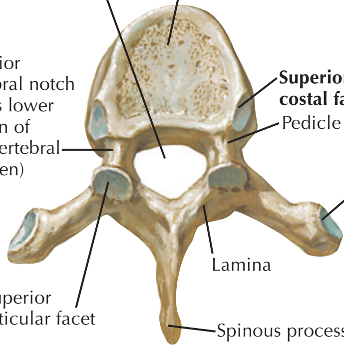
Cruciate ligament removed to show deepest ligaments: posterior view



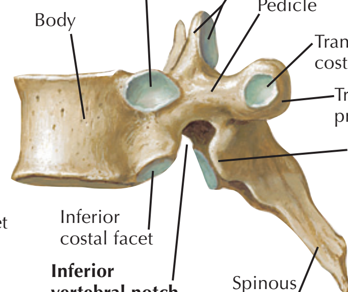
Median atlantoaxial joint: superior view

THORACIC VERTEBRAE

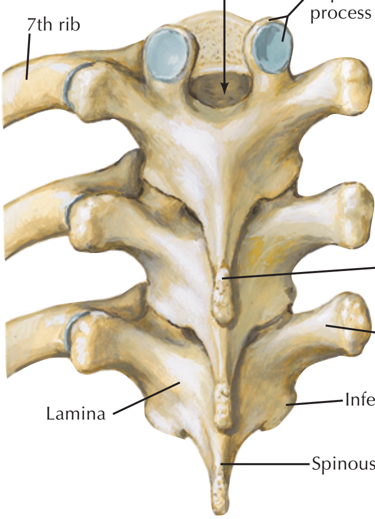
- Vertebral bodies of all thoracic vertebrae have superior and inferior costal facets for ribs.
- Transverse processes of thoracic vertebra T1-10 also have transverse costal facets for ribs.



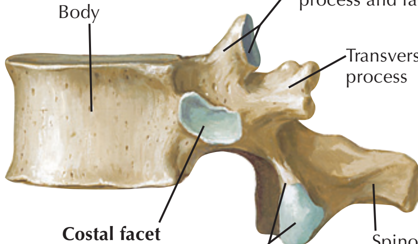
T6 vertebra: superior view



T6 vertebra: lateral view



T7, T8 and T9 vertebrae: posterior view



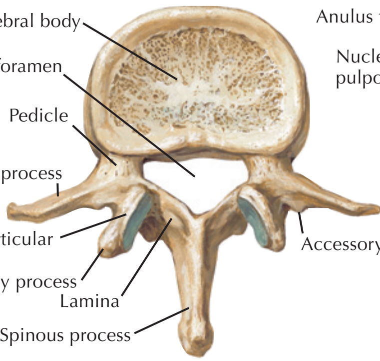
T12 vertebra: lateral view

LUMBAR VERTEBRAE

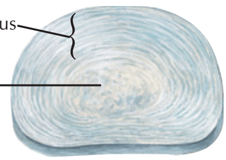
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Lumbar vertebrae	Largest individual vertebra L5 is largest lumbar vertebra	As one ascends, lumbar discs herniate with decreasing frequency in sequence (i.e., L4-5 more often than L3-4 > L2-3 > L1-2)
Intervertebral discs	Composed of annulus fibrosus and nucleus pulposus	Disc between L5-S1 vertebrae is most common herniated disc

CLINICAL NOTES:
- Intervertebral discs make up 25% of the length of the vertebral column.
- With aging, discs desiccate and lose height. Hence aging is associated with becoming shorter.
- Lumbar disc herniation is more frequent than cervical herniation.

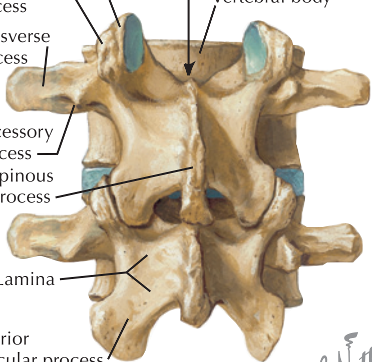
LUMBAR VERTEBRAE *continued*



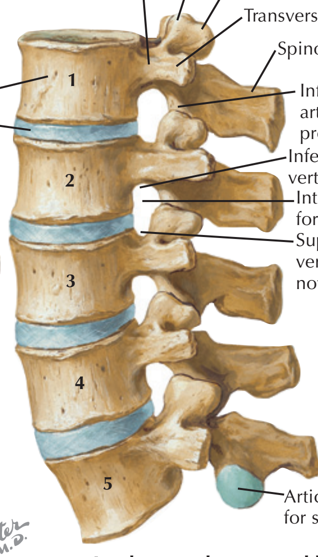
L2 vertebra: superior view



Intervertebral disc



L3 and L4 vertebrae: posterior view



Lumbar vertebrae, assembled: left lateral view

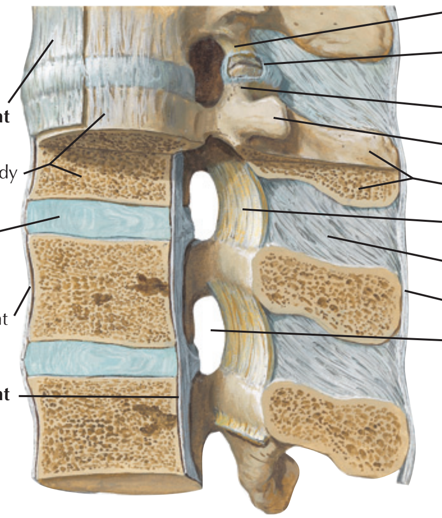
VERTEBRAL LIGAMENTS OF SPINAL COLUMN

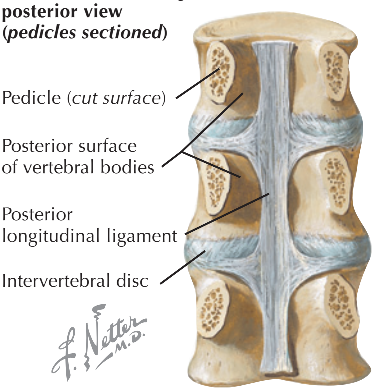
STRUCTURE	ANATOMIC NOTES
Anterior longitudinal ligament	Runs anterior to vertebrae from base of skull to sacrum
Posterior longitudinal ligament	Runs within vertebral canal, posterior to vertebral body, from the base of the skull to the sacrum
Ligamentum flavum	Connects adjacent laminae
Supraspinous ligament	Connects the tips of the vertebral spines throughout the spinal column
Interspinous ligament	Runs between adjacent spines throughout the spinal column, anterior to the supraspinal ligament

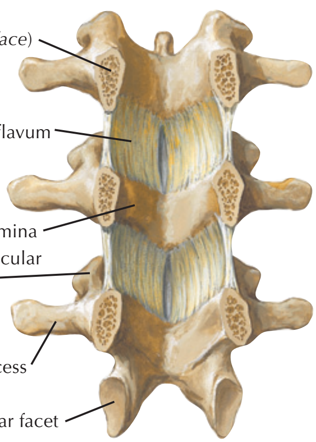
CLINICAL NOTE:

- Ligamentum nuchae, present in the neck only, are greatly thickened supraspinous and interspinous ligament.

VERTEBRAL LIGAMENTS OF SPINAL COLUMN *continued*





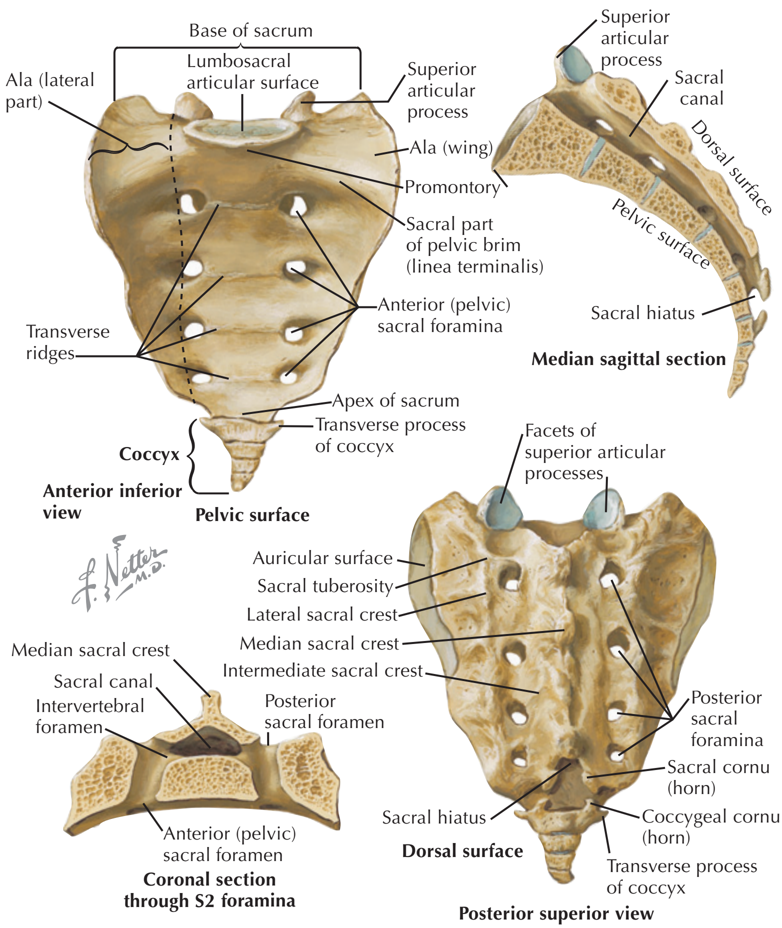


SACRUM AND COCCYX

STRUCTURE	ANATOMIC NOTES
Sacrum	Consists of 5 fused vertebrae, wedge-shaped, narrow inferior apex articulates with coccyx
Coccyx	Formed by fusion of 4 rudimentary tail vertebrae

CLINICAL NOTES:

- First four sacral nerve root ventral rami exit through four ventral pelvic sacral foramina to join the sacral plexus.
- First four sacral nerve root dorsal rami exit through four dorsal sacral pelvic foramina to supply the lower paraspinal muscles and skin.



CHAPTER 2

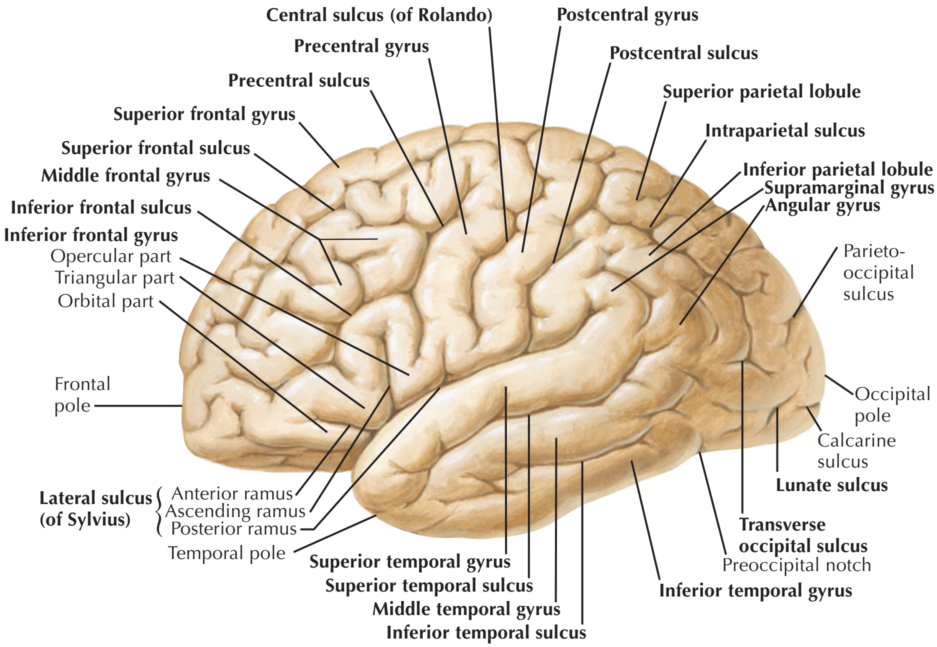
Gross Anatomy of the Brain and Spinal Cord

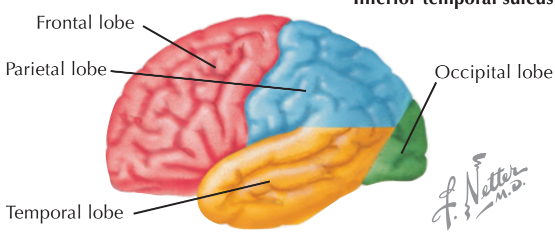
LATERAL SURFACE OF THE BRAIN

NOTABLE LATERAL SULCI	
Structure	**Anatomic Notes**
Lateral (Sylvian) fissure	Separates the temporal lobe from frontal and parietal lobes
Central (Rolandic) sulcus	Separates the frontal lobe from the parietal lobe

CORTICAL LOBES: LATERAL VIEW			
Lobe	**Notable Gyri**	**Notable Sulci**	**Notable Functions**
Frontal	Superior frontal gyrus Middle frontal gyrus Inferior frontal gyrus Precentral gyrus	Superior frontal sulcus Inferior frontal sulcus Precentral sulcus	Motor control, expressive speech, personality, drive
Parietal	Postcentral gyrus Superior parietal lobule Inferior parietal lobule: • Supramarginal gyrus • Angular gyrus	Postcentral sulcus Intraparietal sulcus	Sensory input and integration, receptive speech
Temporal	Superior temporal gyrus Middle temporal gyrus Inferior temporal gyrus	Superior temporal sulcus Inferior temporal sulcus	Auditory input and memory integration
Occipital		Transverse occipital sulcus Lunate sulcus	Visual input and processing

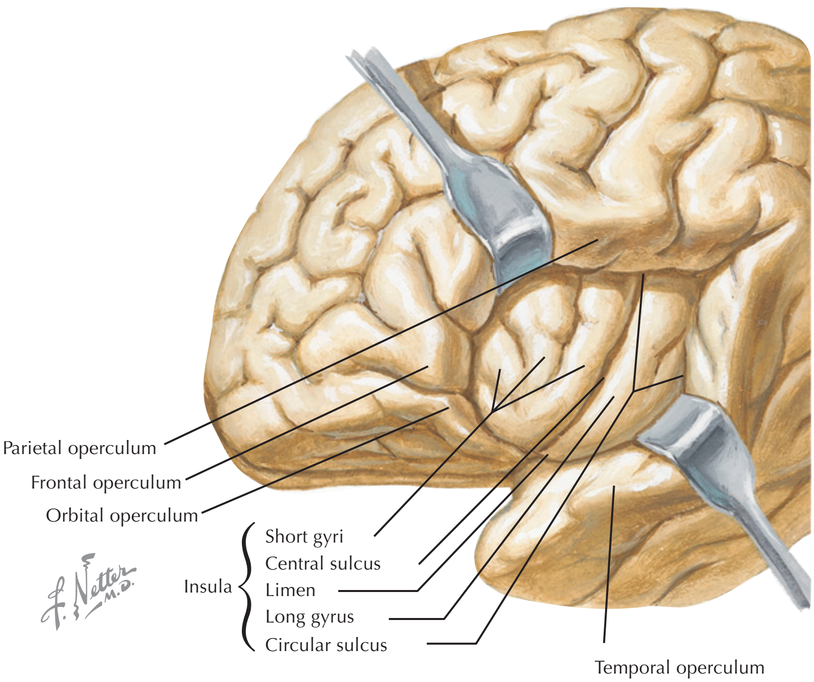
LATERAL SURFACE OF THE BRAIN *continued*





INSULA *(INSULAR CORTEX)*

STRUCTURE	ANATOMIC NOTES
Circular sulcus of the insula	Surrounds and demarcates the insula
Central sulcus of the insula	Divides the insula into anterior and posterior parts
Limen	The apex of the insula at its inferior margin
Short gyri and long gyrus	Gyri of the insula

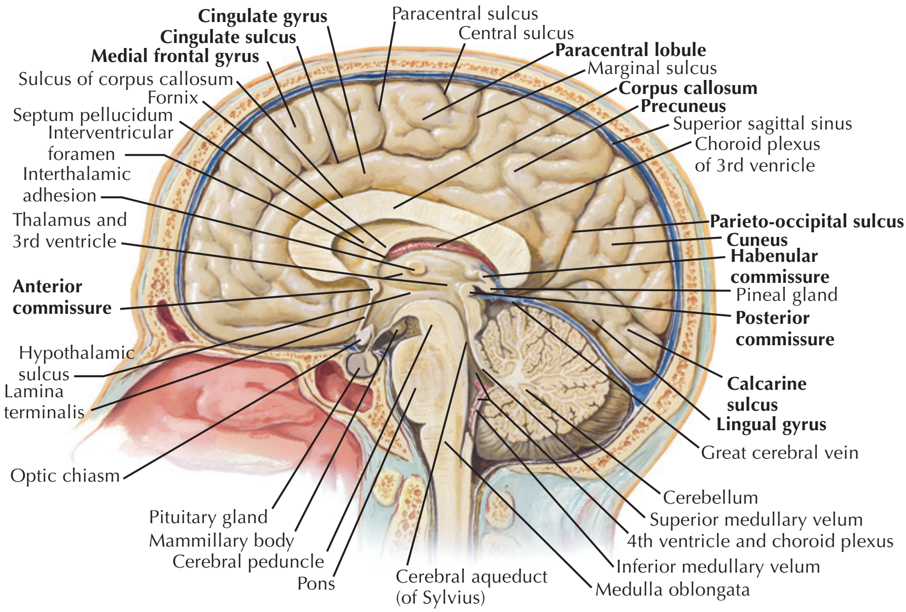


MEDIAL SURFACE OF THE BRAIN

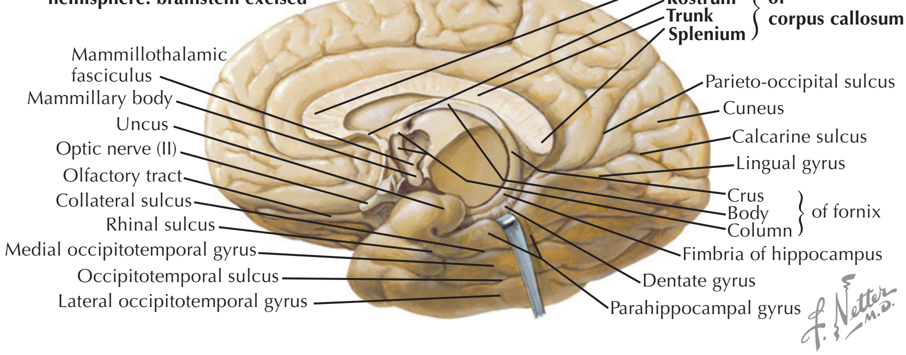
MEDIAL CORTICAL STRUCTURES		
Structure	**Anatomic Notes**	**Functional Significance**
Medial frontal gyrus	Medial portion of frontal lobe	Involved in motivation
Cingulate sulcus	Separates medial frontal gyrus from cingulate gyrus	
Cingulate gyrus	C-shaped gyrus, which loops around the corpus callosum	Involved in emotion as part of limbic system
Paracentral lobule	Medial extension of precentral and postcentral gyri	Controls motor and sensory function of legs
Precuneus	Part of the medial extension of parietal lobe	
Parieto-occipital sulcus	Prominent sulcus separating parietal and occipital lobes	
Cuneus	Superior portion of medial occipital lobe	Functions in visual processing
Calcarine sulcus	Separates occipital lobe into (upper) cuneus and (lower) lingua	Primary visual center lies on banks of this sulcus
Lingual gyrus	Inferior portion of medial occipital lobe	Functions in visual processing

INTERHEMISPHERIC CONNECTIONS (COMMISSURES)	
Commissure	**Anatomic Notes**
Anterior commissure	Contiguous and below the rostrum of corpus callosum
Corpus callosum	Large, C-shaped major conduit between 2 hemispheres Has following components: Rostrum—tapered extension from genu; forms part of the floor of the lateral ventricle Genu—curves anterior to the lateral ventricle Trunk (body)—largest portion; forms the roof of the lateral ventricle Splenium—the posterior-most portion
Posterior commissure	Crosses at the upper end of the cerebral aqueduct
Habenular commissure	Small commissure crossing superior to the pineal gland

MEDIAL SURFACE OF THE BRAIN *continued*



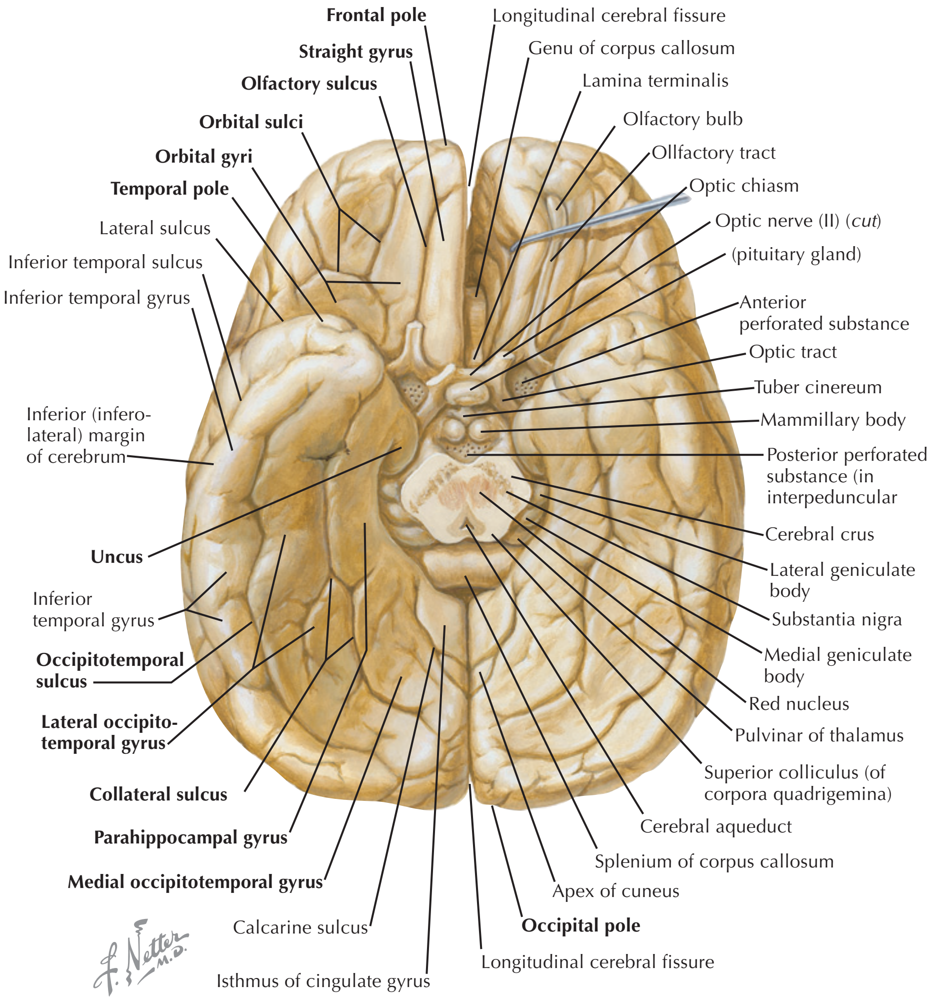
Medial surface of cerebral hemisphere: brainstem excised



INFERIOR SURFACE OF THE BRAIN

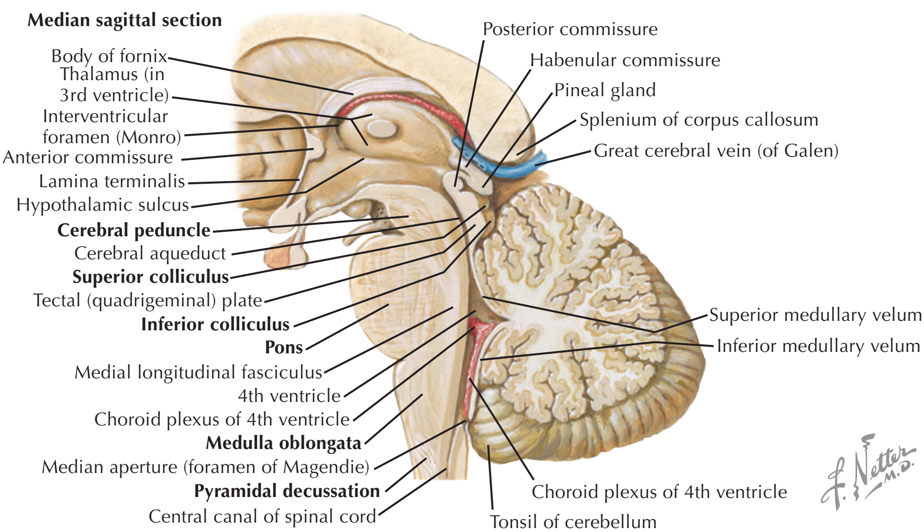
CORTICAL STRUCTURES		
Structure	**Anatomic Notes**	**Functional Significance**
Frontal pole	Anterior-most portion of frontal lobe	Vulnerable to injury during head trauma
Straight gyrus (gyrus rectus)	Most medial and inferior gyrus of frontal lobe	
Olfactory sulcus	Separates straight gyrus from more lateral orbital gyri	Olfactory tract travels with this sulcus
Orbital gyri and sulci	Form the floor of frontal lobes; rest on the roof of orbits	
Temporal pole	Anterior-most portion of temporal lobe	Vulnerable to injury during head trauma
Uncus	Medial-most bulb-shaped projection of temporal lobe	If swollen may compress the ipsilateral midbrain, causing contralateral hemiparesis
Parahippocampal gyrus	Large inferomedial temporal lobe gyrus	Involved in emotion as part of the limbic system
Collateral sulcus	Separates parahippocampal gyrus from medial occipitotemporal gyrus	
Medial occipitotemporal gyrus	Lies lateral to parahippocampal gyrus	
Occipitotemporal sulcus	Separates medial and lateral occipitotemporal gyri	
Lateral occipitotemporal gyrus	Forms inferolateral border of temporal lobe; contiguous with inferior temporal gyrus	
Occipital pole	Posterior-most portion of the occipital lobe	Vulnerable to injury during head trauma

INFERIOR SURFACE OF THE BRAIN *continued*



BRAINSTEM: MEDIAL VIEW

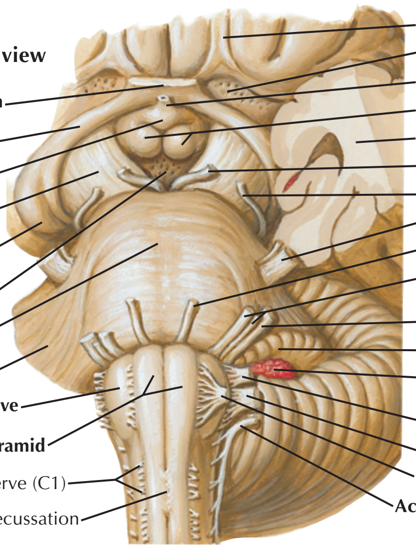
COMPONENT	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE AND CLINICAL NOTES
Midbrain	Encircles the cerebral aqueduct Dorsal tectum composed of superior and inferior colliculi Ventral tegmentum contains nuclei of cranial nerve III (CN-III) and CN-IV, red nucleus, substantia nigra, and cerebral peduncles (which contain fibers of corticospinal tract)	Serves as the center for vertical gaze and the pupillary light reflex In Parinaud's syndrome of the dorsal midbrain compression, upgaze is impaired Degeneration of the substantia nigra is responsible for Parkinson's disease
Pons	Pontine tectum lies anterior to fourth ventricle Contains nuclei of CN-V, -VI, -VII, and -VIII Pontine tegmentum forms large, conspicuous bulge and contains fibers of corticospinal tract	Serves as the center for horizontal gaze Tegmental pontine lesions can cause weakness of all four extremities and the face, with preserved consciousness, known as the *locked-in syndrome,* and sometimes mistaken for a coma
Medulla oblongata	Lowest portion of brainstem, between pons and spinal cord Contains nuclei of CN-IX, -X, -XI, and -XII Corticospinal tract and dorsal column decussation occurs here	Controls visceral and autonomic functions in the body Large, compressive lesions can lead to respiratory arrest and death



BRAINSTEM: ANTERIOR AND VENTRAL VIEWS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE AND CLINICAL NOTES
Optic chiasm	Two optic nerves join at the optic chiasm, partly decussate, and become optic tracts	Upward pressure on chiasm from pituitary masses can cause specific visual-field deficit involving both temporal fields
Tuber cinereum	Connects the hypothalamus to the pituitary stalk	Lesions cause hypopituitarism
Mammillary bodies	Ball-like inferior projections of the hypothalamus	Involved in memory and emotion as part of the limbic system
Cerebral peduncle	Contains the corticospinal tract	Cerebral peduncle and CN-III can be compressed by nearby uncus
Oculomotor nerve (CN-III)	Exits the midbrain ventrally	
Trochlear nerve (CN-IV)	Exits the midbrain dorsally, crosses midline, and loops around to the ventral surface	Only cranial nerve to exit dorsally; innervates superior oblique muscle
Basis pontis	Large "belly of the pons" is conspicuous on this view	Contains motor fibers from the corticospinal tract
Trigeminal nerve (CN-V)	Pierces and exits the basis pontis	Controls sensations of the face, mouth, tongue, and teeth as well as muscles of mastication
Abducens nerve (CN-VI)	Exits pons inferomedially	Innervates lateral rectus muscle
Facial and vestibulo-cochlear nerves (CN-VII and CN-VIII)	Exit together at the cerebellopontine angle	Facial nerve innervates most facial muscles Vestibulocochlear nerve mediates hearing and balance
Pyramid	Medial bulge of medulla *Note:* The two pyramids decussate in inferior medulla	Contains fibers of corticospinal tract
Olive (inferior)	Conspicuous lateral bulge of medulla	Involved in important cerebellar pathway, called *triangle of Guillain and Mollaret*
Glossopharyngeal, vagus and spinal accessory nerves (CN-IX, -X, and -XI)	Exit the medulla, posterior and lateral to olive and anterior to fasciculus cuneatus, as individual rootlets, which join to form nerves	CN-IX and CN-X control swallowing; CN-X provides parasympathetic input to the heart, lungs, and gut; CN-XI innervates the sternocleidomastoid and trapezius
Hypoglossal nerve (CN-XII)	Exits between olive and pyramid as individual rootlets, which join to form the nerve	Innervates most muscles in the tongue

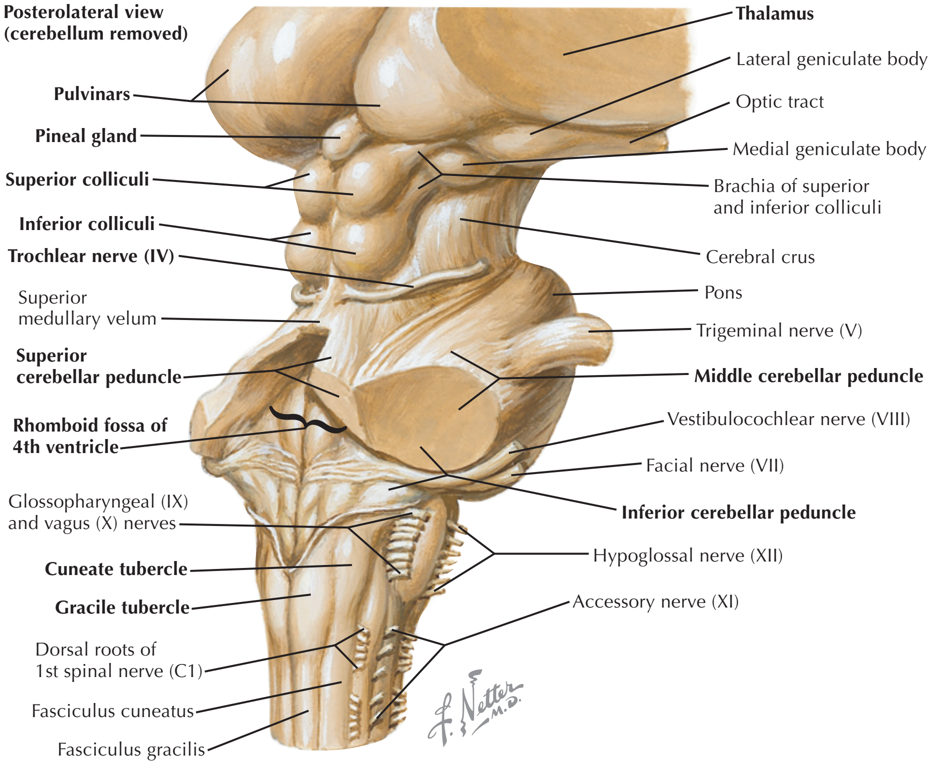
BRAINSTEM: ANTERIOR AND VENTRAL VIEWS *continued*



BRAINSTEM: POSTEROLATERAL VIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL AND CLINICAL NOTES
Thalamus	Large structure composed of many nuclei; sets deep in the brain, above the brainstem	Most nuclei function as relay centers between the cortex and subcortical structures
Pulvinar	Posterior-most nucleus of the thalamus	Involved in central visual processing
Pineal gland	Midline structure, dorsal to the upper midbrain	Can compress the dorsal midbrain, causing Parinaud's syndrome: poor upgaze, nystagmus, and eyelid retraction
Superior colliculus	Upper bulge from the midbrain tectum	Functions in generation of saccades
Inferior colliculus	Lower bulge from the midbrain tectum	Part of auditory relay input from the inner ear to the temporal lobe
Trochlear nerve	Exits the midbrain in this view	Innervates superior oblique
Superior cerebellar peduncle (*cut*)	Upper of 3 large conduits of information between the cerebellum and other structures	Contains mainly cerebellar output to the thalamus and red nucleus
Middle cerebellar peduncle (*cut*)	Middle of 3 large conduits of information between the cerebellum and other structures	Contains mainly input fibers to the cerebellum from the pons
Inferior cerebellar peduncle	Lower of 3 large conduits of information between the cerebellum and other structures	Contains mainly input fibers to the cerebellum from vestibular systems and spinal cord
Rhomboid fossa of fourth ventricle	Forms floor of 4th ventricle; the 2 median eminences bulge into it	
Fasciculus gracilis	Medial-most tract in the medulla	Contains fibers from medial portion of dorsal column of spinal cord; mediates discriminative touch, joint position, and vibration from legs
Fasciculus cuneatus	Lies lateral to the fasciculus gracilis in medulla	Contains fibers from the lateral portion of dorsal column of spinal cord; mediates discriminative touch, joint position, and vibration from arms
Cuneate and gracile tubercles	Visible bulge of respective nuclei	

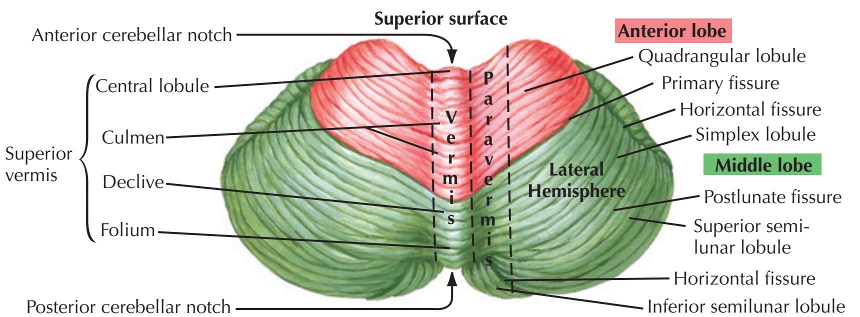
BRAINSTEM: POSTEROLATERAL VIEW *continued*

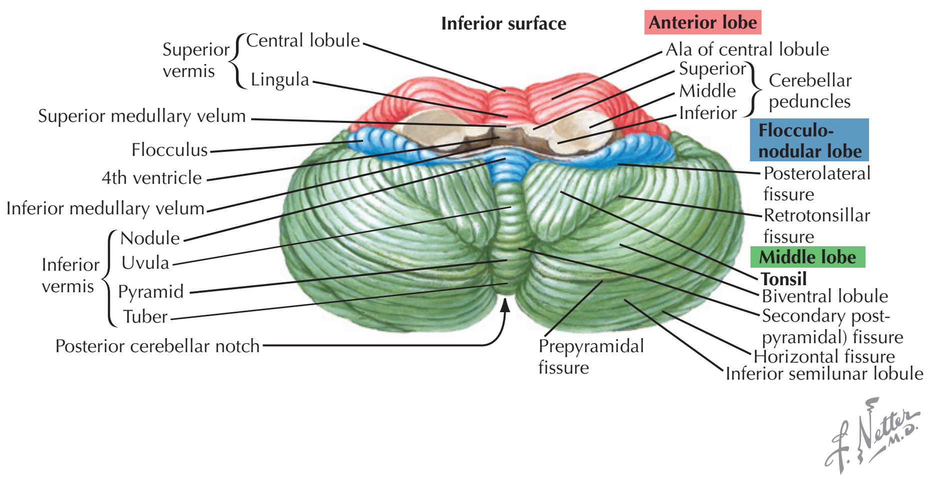


CEREBELLUM: SUPERIOR AND INFERIOR SURFACES

The cerebellum is formed by two hemispheres and a single median vermis.

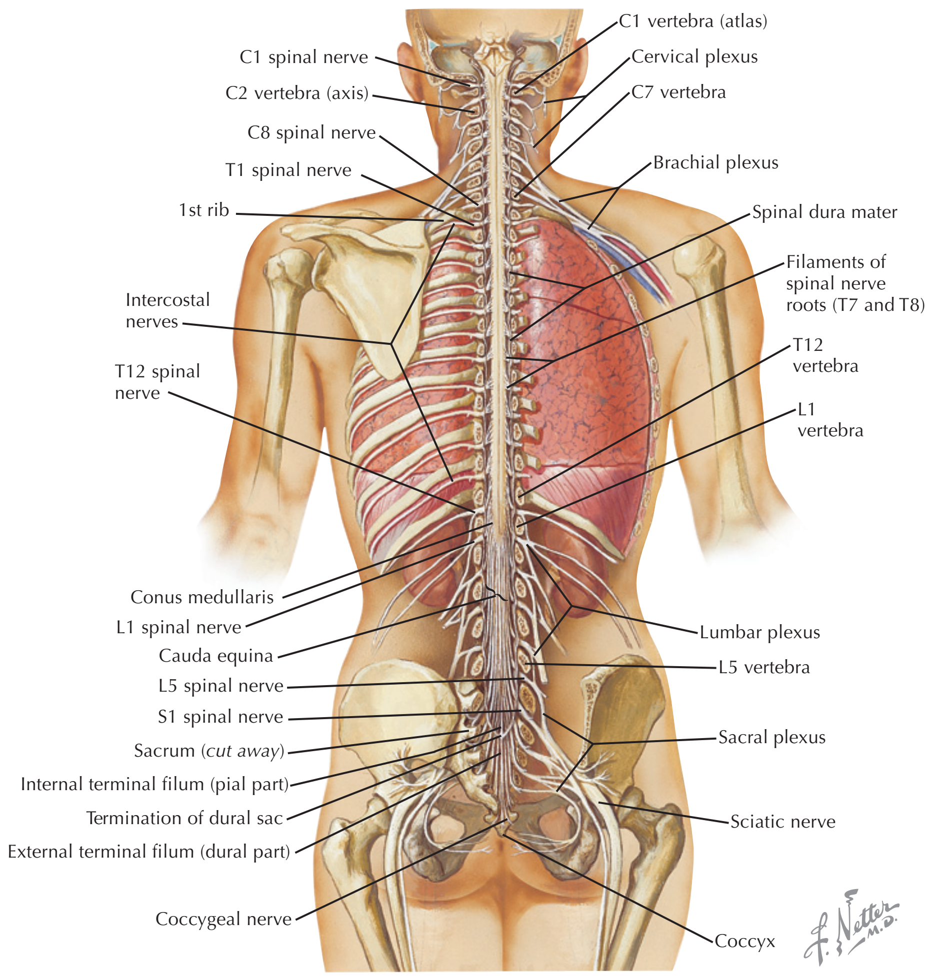
CEREBELLAR LOBE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Anterior	Separated from the middle lobe by primary fissure	Becomes atrophic in alcoholics
Middle	Lies posterior and inferior to anterior lobe; separated from it by primary fissure Tonsil is its inferior and medial-most projection	Cerebellar tonsil lies just lateral to the medulla; if displaced by pressure, can compress medulla, causing death; called *tonsillar herniation*
Flocculonodular	Flocculus is separated from the middle lobe by postero-lateral fissure Nodule is part of the vermis	Involved in balance by communicating with the vestibular system





SPINAL CORD IN SITU

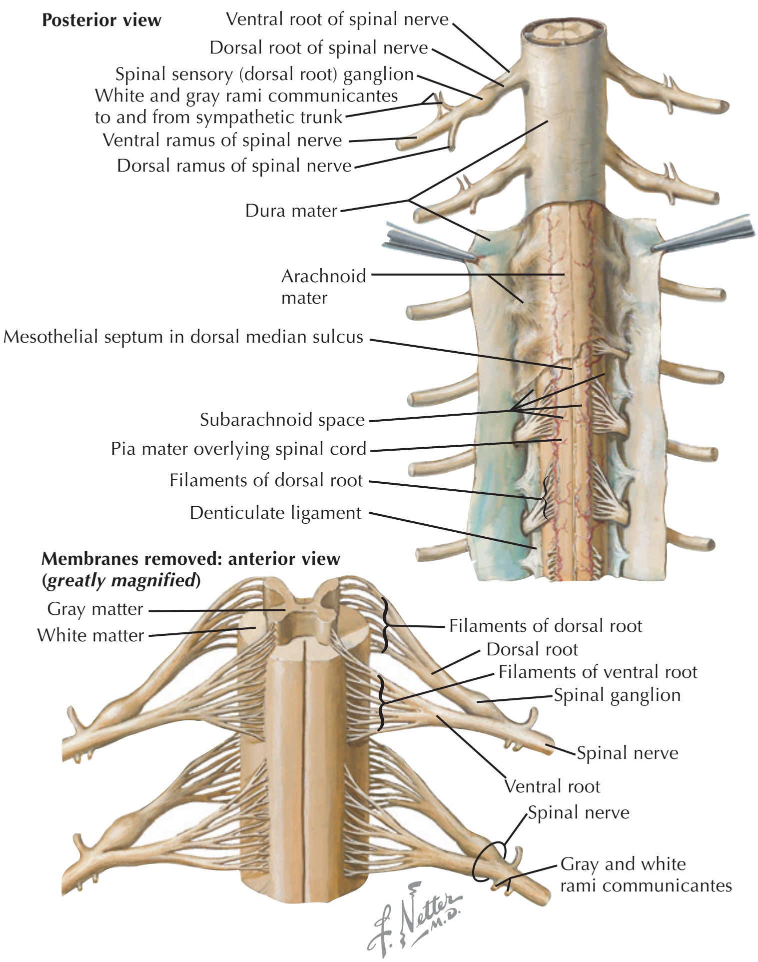
- Downward continuation of medulla oblongata, with transition located at the foramen magnum
- Descends through the spinal canal, protected by bony structures
- Tapers as conus medullaris at L1 level
- Terminates as filum terminale, a slender, fibrous thread that ends in the coccyx
- Has 31 segments, each associated with paired spinal nerves
- Has 31 paired spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal
- Lumbar and sacral nerves collectively termed *cauda equina,* because they resemble a horse's tail
- C1-7 nerves exit spinal canal above their respective vertebral level
- C8-L5 nerves exit spinal canal below their respective vertebral level



SPINAL CORD: ANTERIOR VIEW

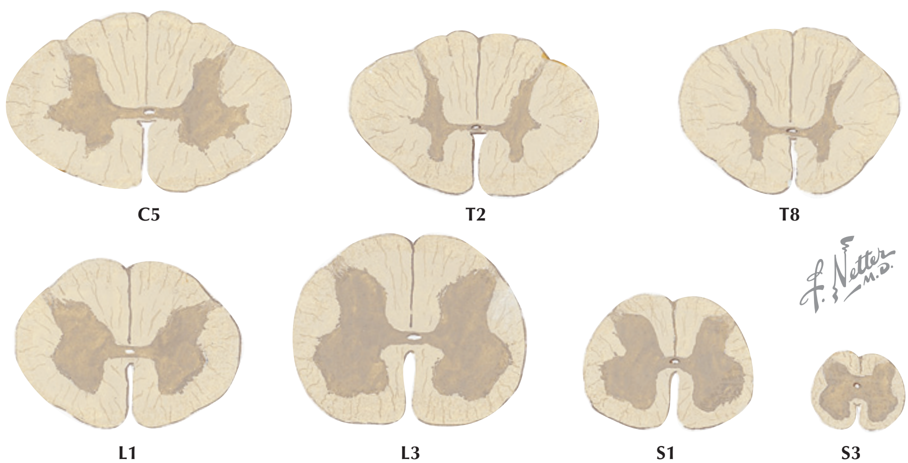
- Each spinal nerve is formed from the joining of dorsal ventral root filaments (rootlets).
- Dorsal roots carry sensory input.
- Ventral roots carry motor output to skeletal muscle.
- Spinal cord consists of gray and white matter.
- Gray matter is H-shaped and contains dorsal and ventral horns.
- Dorsal horns are involved in sensation.
- Ventral horns contain motor neurons, which innervate skeletal muscle.
- White matter contains compact axon columns ascending or descending the spinal cord.
- Spinal ganglia (dorsal root ganglia) contain the cell bodies of incoming sensory neurons.

Spinal Membranes and Nerve Roots



SECTION THROUGH SPINAL CORD AT VARIOUS LEVELS

- More gray matter is in the cervical and lumbosacral cord than in the thoracic cord.
- Levels associated with arms and legs have more gray matter.
- Amount of white matter increases from sacral to cervical as sensory fibers are added at each level.
- The volume of motor fibers decreases at each descending level from cervical to sacral levels as they synapse on lower motor neurons.

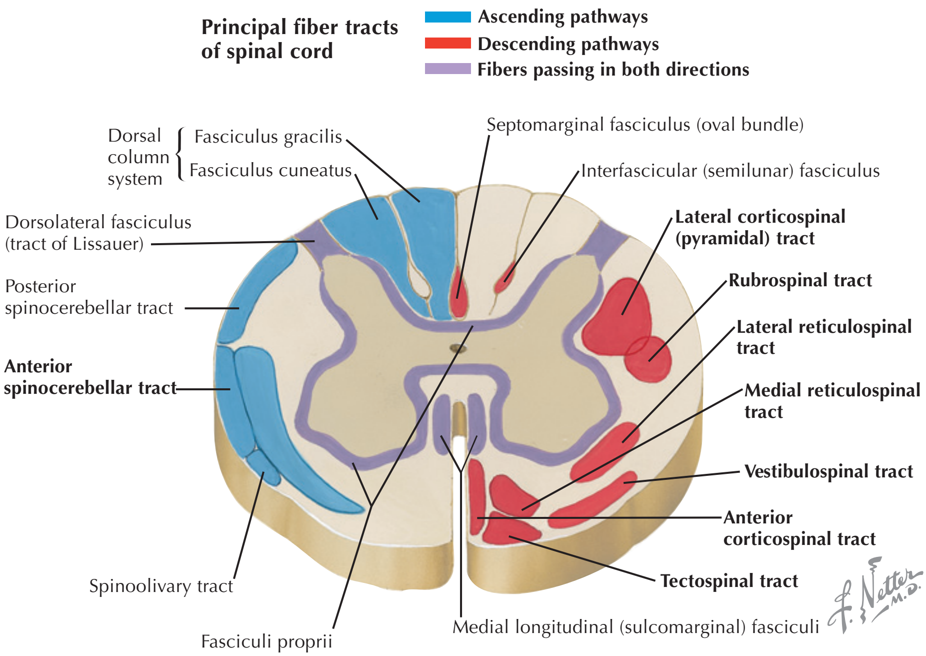


PRINCIPAL TRACTS OF THE SPINAL CORD

MAJOR ASCENDING PATHWAYS		
Tract	**Destination**	**Function**
Fasciculus gracilis	Nucleus gracilis in medulla	Discriminative touch, joint position, and vibration from legs
Fasciculus cuneatus	Nucleus cuneatus in medulla	Discriminative touch, joint position, and vibration from arms
Posterior (dorsal) and anterior (ventral) spinocerebellar	Cerebellum	Provide cerebellum with proprioceptive input from muscle and skin receptors
Spinothalamic	Ventral posterolateral nucleus of thalamus	Pain and temperature
Spinoreticular	Reticular formation in brainstem	Contributes to emotional connotation of pain

MAJOR DESCENDING PATHWAYS		
Tract	**Origin**	**Function**
Lateral corticospinal	Contralateral motor cortex	Controls muscle activity by innervating motor neurons
Anterior corticospinal	Ipsilateral motor cortex	Minor pathway compared with lateral corticospinal tract Controls muscle activity by innervating motor neurons
Rubrospinal	Contralateral red nucleus	Controls proximal muscles, especially flexors
Lateral vestibulospinal	Ipsilateral lateral vestibular nucleus	Involved in postural control (especially related to head movements) by inhibiting axial flexor muscles and stimulating axial extensor muscles
Lateral and medial reticulospinal	Ipsilateral and contralateral reticular formations	Modulate state of muscle spindles
Tectospinal	Superior colliculus	Moves head reflexively in response to significant auditory, visual or tactile stimuli

PRINCIPAL TRACTS OF THE SPINAL CORD *continued*



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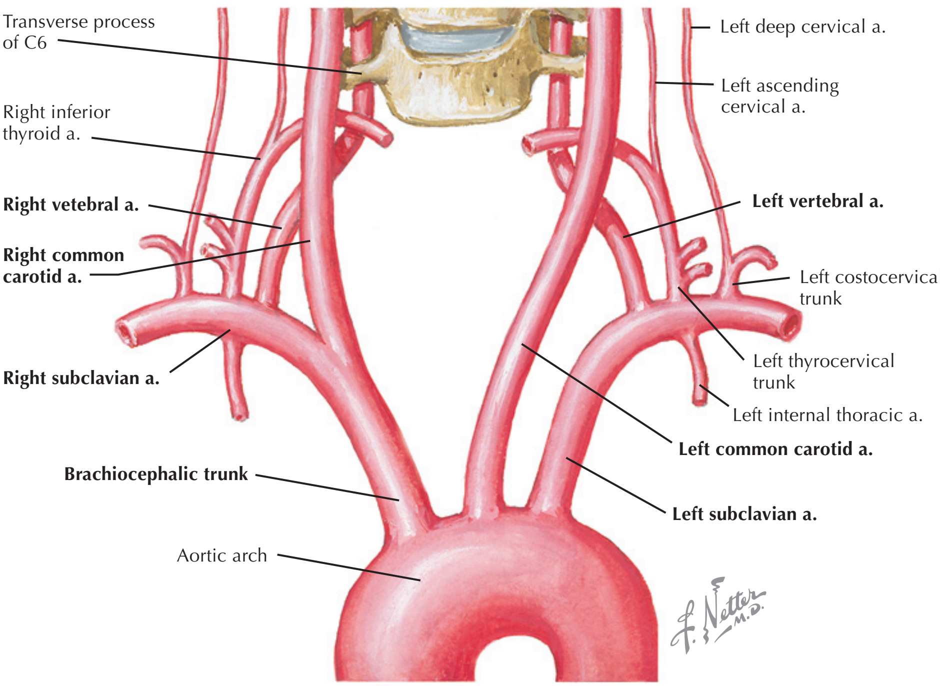
CHAPTER 3

Blood Vessels of the Brain and Spinal Cord

BRANCHES OF THE AORTA

ORDER	ARTERY	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
1st	Left subclavian	1st branch is left vertebral artery	Atherosclerosis can lead to shunting of blood away from the vertebral artery and to the arm, leading to symptoms of vertebral insufficiency and possible stroke. This is known as *subclavian steal.*
2nd	Left common carotid	Ascends the neck in carotid sheath before dividing into external and internal carotid arteries (bifurcation)	Atherosclerosis can occur at bifurcation, a common cause of stroke.
3rd	Brachiocephalic trunk	Divides to form right common carotid and right subclavian arteries Right vertebral artery is a branch of right subclavian artery	

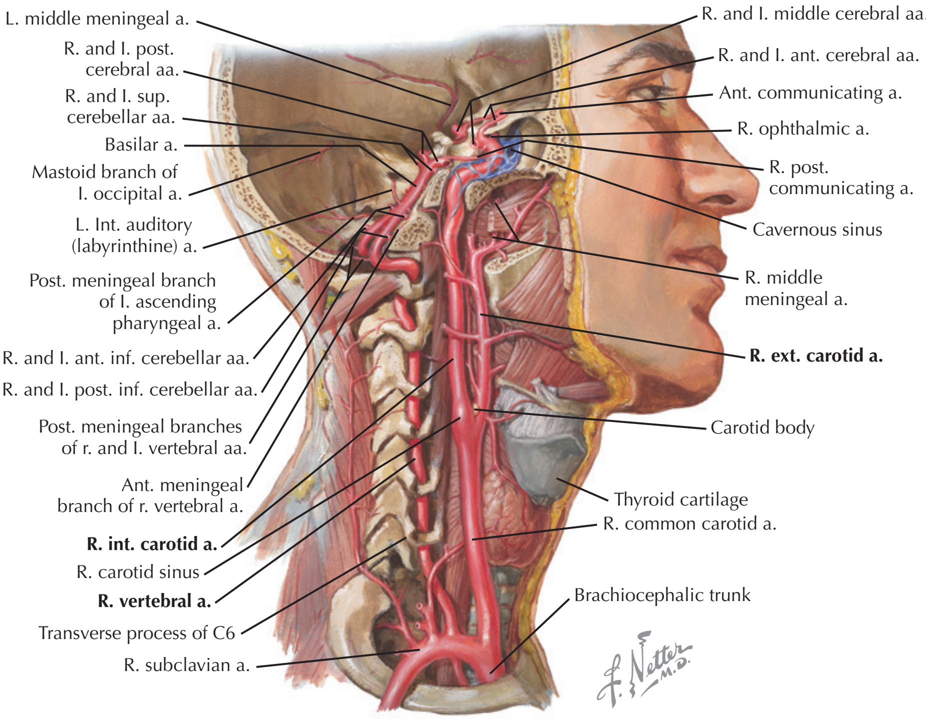


ARTERIAL SUPPLY TO BRAIN AND MENINGES

The brain and meninges derive all arterial supply via two arterial systems: carotid and vertebrobasilar.

ARTERY	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
External carotid (ECA)	Has multiple extracranial branches	Supplies the face, tongue, and anterior meninges
Internal carotid (ICA)	Has no extracranial branches Segments: • Cervical: ascends the neck posterior and medial to ECA • Petrous: bends to assume horizontal position, traversing the petrous portion of temporal bone • Cavernous: runs in cavernous sinus near CN-III, -IV, -V, and -VI • Supraclinoid: ascends posteriorly and laterally and terminates as middle and anterior cerebral arteries	Via its branches, supplies anterior circulation of the brain, including frontal, parietal, most of temporal lobes, and basal ganglia
Vertebral artery	Arises from subclavian artery Segments: • Prevertebral: ascends neck muscles to enter the bony canal within the spine at C6 through the foramen transversarium • Cervical: ascends the cervical spine through foramina in transverse processes • Atlantic: exits cervical spine at level of atlas (C1) and bends posteriorly to reach the dura • Intracranial: ascends anterior to the medulla and joins the contralateral vertebral artery to form basilar artery	Via its branches, supplies posterior circulation of the brain, including brainstem, cerebellum, thalamus, and occipital and inferior temporal lobes

ARTERIAL SUPPLY TO BRAIN AND MENINGES *continued*

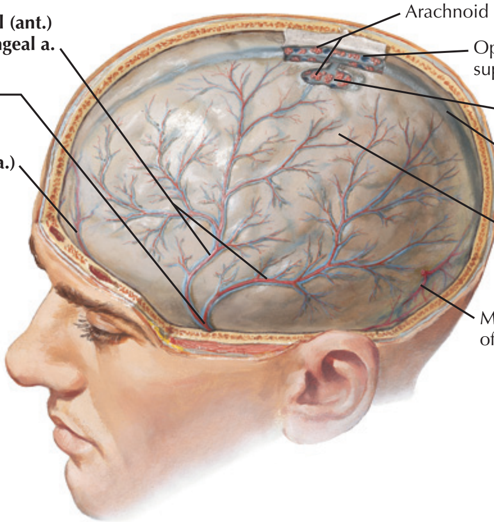


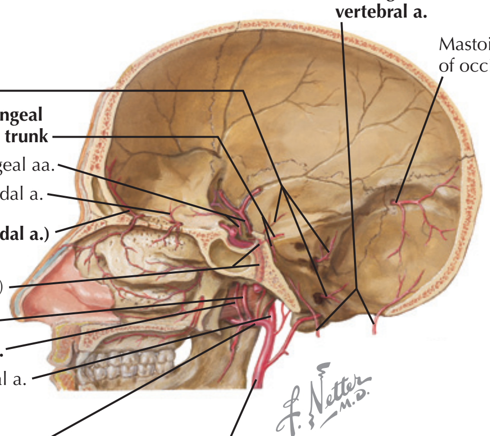
MENINGEAL ARTERIES

Meningeal arteries supply the dura mater and are located in the outer portion of the dura mater.

ARTERY	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Middle meningeal	Branch of the ECA system via maxillary artery Enters skull via foramen spinosum Has frontal and parietal branches	Injury to this vessel from head trauma can cause an epidural hematoma, which can lead to death by downward displacement of brain structures; known as **herniation**
Accessory meningeal and anterior meningeal	Arise from ECA system	Supply portions of dura
Tentorial and meningeal branches of the meningohypophyseal trunk	Arise from ICA system	Supply a small segment of dura
Anterior and posterior meningeal branches of vertebral artery		Supply dura in posterior fossa, below the tentorium cerebelli

MENINGEAL ARTERIES *continued*





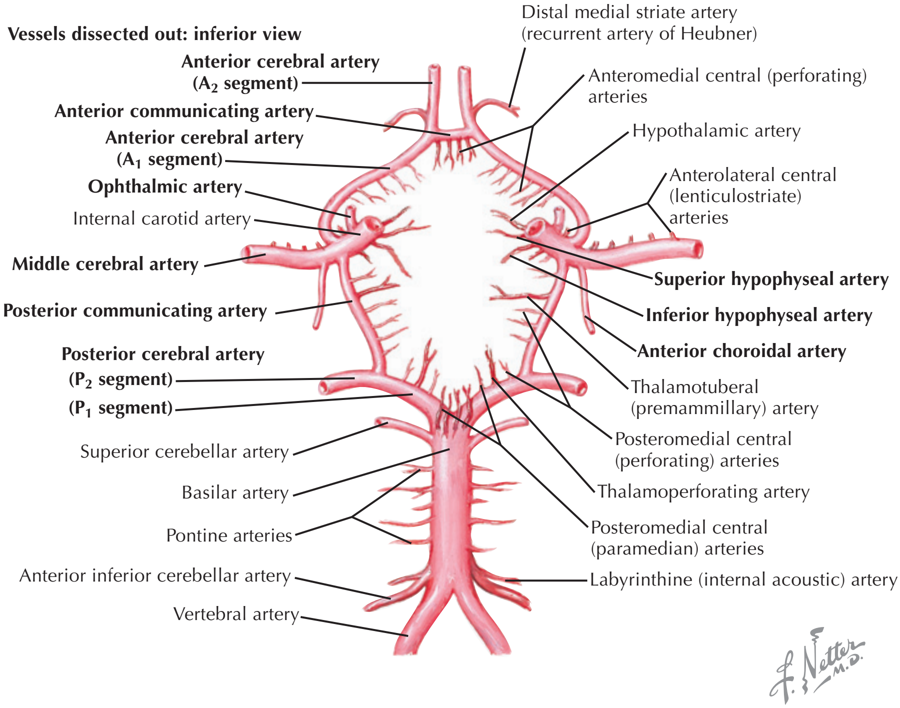
THE CIRCLE OF WILLIS

The circle of Willis is an anastomotic arterial network located at the base of the brain, surrounding the optic tracts, pituitary stalk, and basal hypothalamus. Major arterial feeders are the ICA and basilar artery.

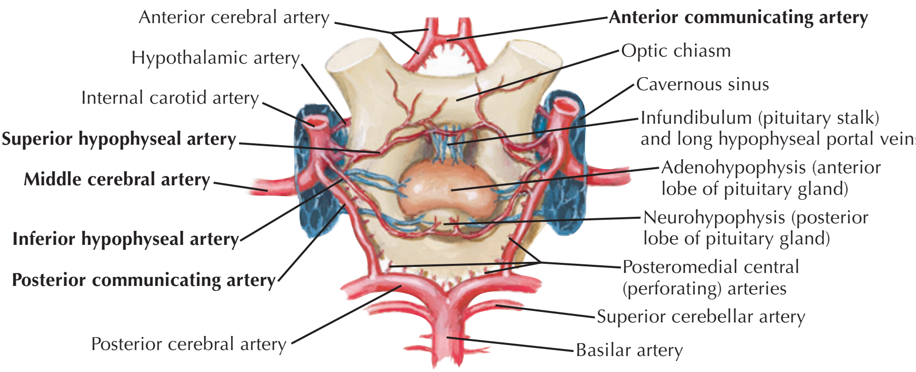
ARTERY	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Superior and inferior hypophyseal	Early branches of ICA	Supplies pituitary gland
Ophthalmic	Branch of ICA; runs with optic nerve into orbit	Supplies optic nerve and retina Embolus from ICA can lodge in this artery, causing monocular blindness
Posterior communicating	Connects ICA to posterior cerebral artery (PCA)	Connects anterior circulation to posterior circulation Runs parallel and near CN-III; so aneurysms can lead to pupillary and oculomotor problems
Anterior choroidal	Branch of ICA	Supplies optic tract, posterior limb of internal capsule, and lateral geniculate body
Anterior cerebral	Terminal branch of ICA	Supplies medial cortical structures and caudate
Middle cerebral	Terminal branch of ICA	Supplies lateral cortical structures and most of basal ganglia and posterior limb of internal capsule
Anterior communicating	Connects the two anterior cerebral arteries (ACAs)	Forms anterior-most portion of circle of Willis
Posterior cerebral	Terminal branch of the basilar system	Supplies occipital and inferior temporal lobe and the thalamus

THE CIRCLE OF WILLIS *continued*

Vessels dissected out: inferior view



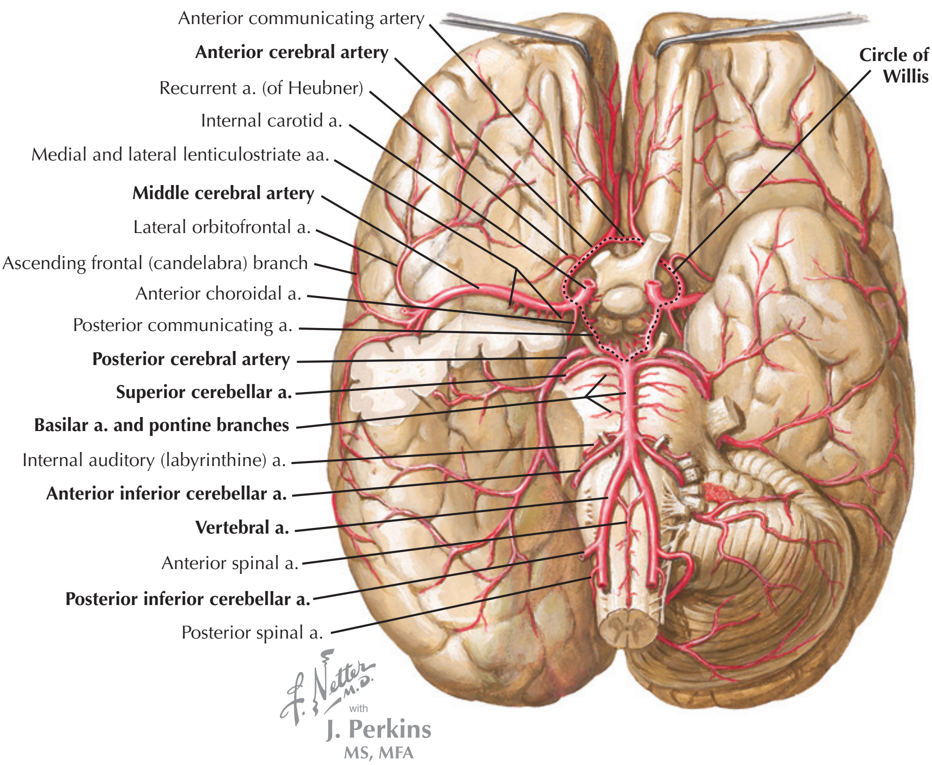
Vessels in situ: inferior view



ARTERIES OF THE BRAIN: BASAL VIEW

ARTERY	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Vertebral	The paired vertebral arteries ascend the medulla ventrally and join at the pontomedullary junction to form the basilar artery	Dissection and thrombosis of the vertebral artery in the neck can cause strokes by occlusion or dislodgement of embolic material
Posterior inferior cerebellar (PICA)	Long, circumferential artery, branch of the vertebral artery	Supplies a portion of the cerebellum and dorsolateral medulla Strokes in this distribution cause crossed sensory loss, vertigo, dysarthria, dysphagia, and Horner's syndrome
Basilar	Ascends basis pontis ventrally Gives off small penetrating branches to basis pontis Terminates by dividing into the 2 PCAs	Basilar occlusion can lead to infarction of basis pontis, causing a "locked-in" syndrome
Anterior inferior cerebellar (AICA)	Long circumferential artery, branch of the basilar artery	Supplies a portion of the cerebellum and dorsolateral pons
Superior cerebellar (SCA)	Long circumferential artery, branch of the basilar artery	Supplies superior surface of cerebellum and part of midbrain

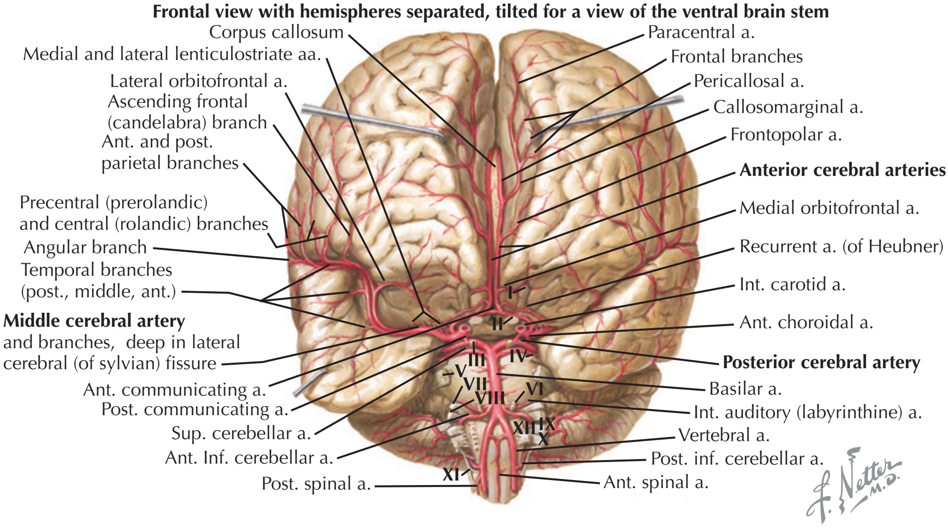
ARTERIES OF THE BRAIN: BASAL VIEW *continued*



ARTERIES OF THE BRAIN: FRONTAL VIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Oculomotor nerve (CN-III)	Exits upper midbrain ventrally, between the PCA and SCA; then runs parallel to the posterior communicating artery	Aneurysms of the posterior communicating artery can compress CN-III, causing a dilated pupil on that side.
Middle cerebral artery (MCA)	Courses through the sylvian fissure, exiting laterally over the frontal, parietal, and temporal cortex	MCA has a large area of distribution along lateral cortex. Deep branches supply the basal ganglia and internal capsule.
Anterior cerebral arteries	Paired ACAs run in parallel and loop around the midline just above the corpus callosum	ACA has a large area of distribution along the medial frontal and parietal cortex.

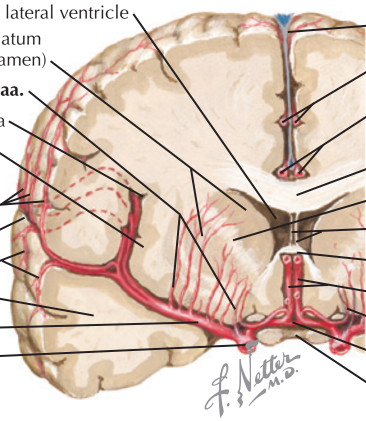
Frontal view with hemispheres separated, tilted for a view of the ventral brain stem



ARTERIES OF THE BRAIN: CORONAL SECTION

ARTERY	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Medial and lateral lenticulostriate	Thin, deep vessels that arise from the MCA in sylvian fissure	Supply basal ganglia and internal capsule Small vessels that can be occluded in diseases involving small vessels, such as diabetes and hypertension
Recurrent (of Heubner)	Small, deep branch of the ACA	Supplies a portion of the head of caudate and anterior limb of internal capsule May be damaged during surgery for ACA aneurysms

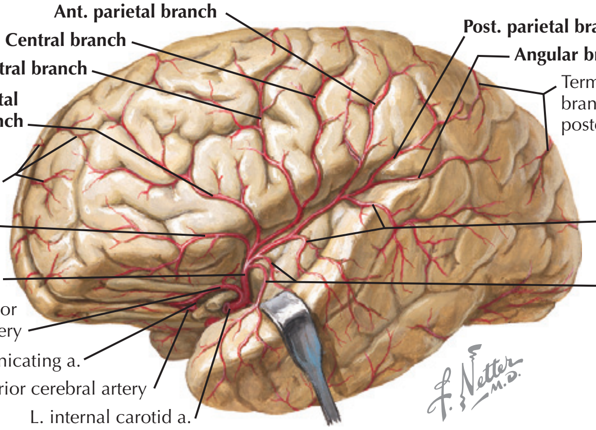
Coronal section through the head of the caudate nucleus



ARTERIAL DISTRIBUTION OF THE BRAIN: LATERAL VIEW

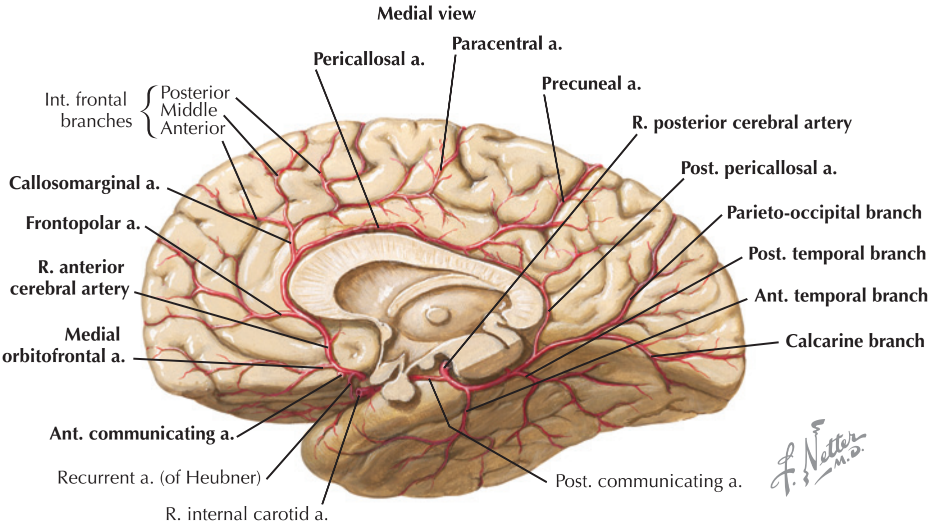
The MCA divides into two major divisions within the lateral (Sylvian) fissure.

MCA DIVISION	BRANCHES	FUNCTIONAL SIGNIFICANCE
Superior	Lateral orbitofrontal artery Ascending frontal branch Precentral branch Central branch	Supplies most of the lateral frontal lobes, including the primary motor cortex in the precentral gyrus and expressive language area
Inferior	Anterior temporal branches Posterior temporal branches Angular branch Posterior parietal branch Anterior parietal branch	Supplies the superior temporal and parietal lobes, including the primary sensory cortex in the postcentral gyrus and receptive speech area



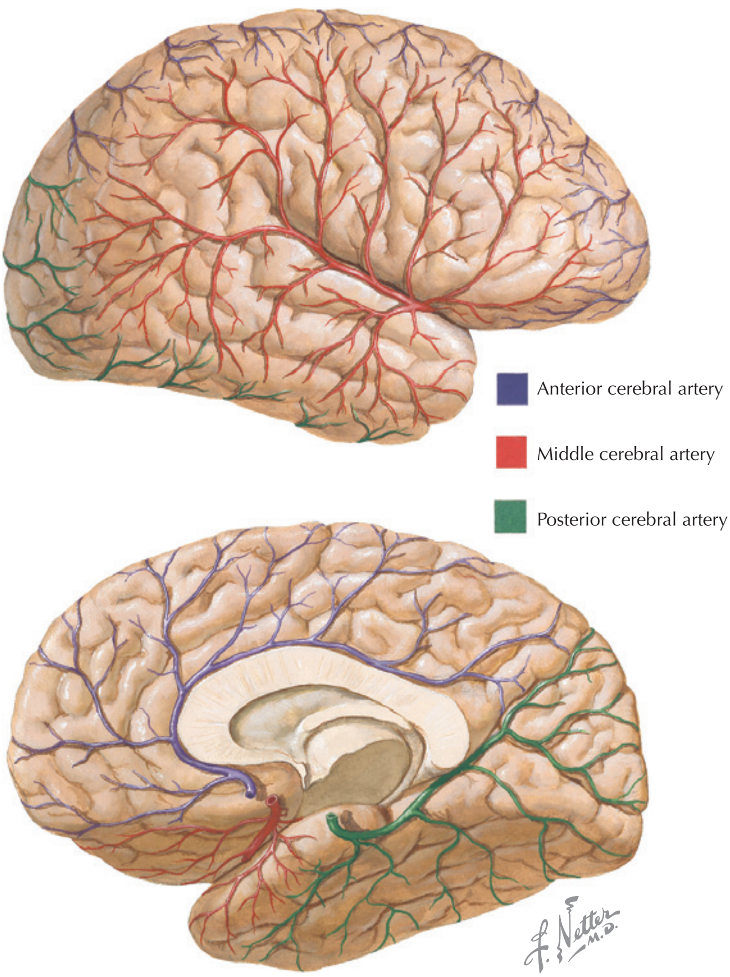
ARTERIAL DISTRIBUTION OF THE BRAIN: MEDIAL VIEW

ARTERY	BRANCHES	FUNCTIONAL SIGNIFICANCE
ACA	Anterior communicating artery Medial orbitofrontal artery Frontopolar artery Pericallosal artery, which terminates as the precuneal artery Callosomarginal artery, which has multiple inferior frontal branches and then terminates as the paracentral artery	Cortical ACA branches supply medial frontal and parietal lobes. Some of these areas are involved in leg strength and sensation, so ACA strokes can cause contralateral leg weakness and numbness.
PCA	Posterior communicating artery Anterior temporal branch Posterior temporal branch Posterior pericallosal artery Calcarine branch Parieto-occipital branch	Cortical PCA branches supply occipital lobes and inferior surface of temporal lobes. PCA strokes usually cause visual field deficits.



ARTERIAL DISTRIBUTION BY COLOR

CEREBRAL ARTERY	FUNCTIONAL SIGNIFICANCE
ACA	Distribution is mainly medial Supplies regions of the brain controlling motor and sensory function to the leg as well as motivation and judgment
MCA	Extensive lateral cortical distribution Supplies regions of the brain controlling motor and sensory function to the arm and face as well as speech, personality, and motivation
PCA	Occipitotemporal distribution Supplies regions of the brain controlling visual input and higher-level visual processing

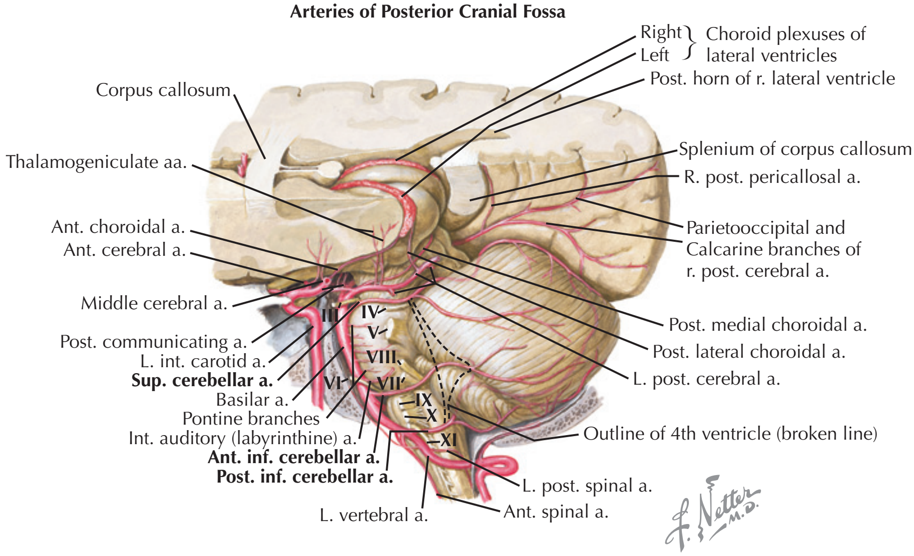


VERTEBROBASILAR SYSTEM

- Long, circumferential vessels supply cerebellum. They all loop around the brainstem, supplying dorsal and lateral portions.
- Ventral portions of the brainstem are supplied by short, penetrating branches off the vertebrobasilar system.

LONG CIRCUMFERENTIAL ARTERIES	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
PICA	Branch of vertebral artery Loops around medulla laterally to supply the cerebellum	Supplies inferior surface of cerebellum, choroid plexus of 4th ventricle, and much of the lateral medulla
AICA	Branch of basilar artery Loops around the caudal pons to supply the cerebellum	Supplies more anterior portions of inferior cerebellum and part of caudal pons
SCA	Branch of the basilar artery Loops around the upper pons to supply the cerebellum	Supplies the superior portion of the cerebellum and portions of the pons and midbrain

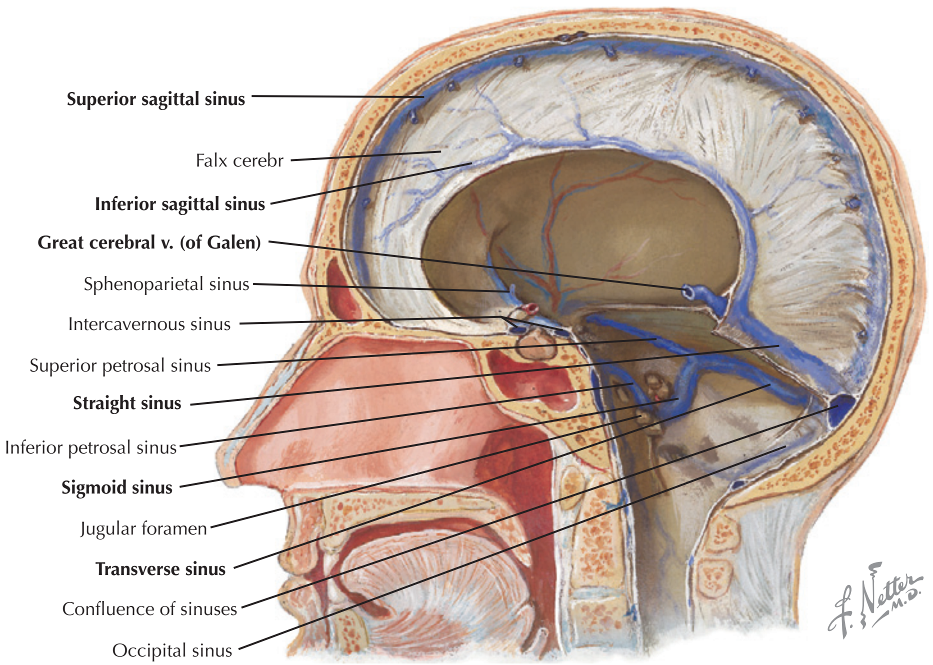
Arteries of Posterior Cranial Fossa



VENOUS SINUSES

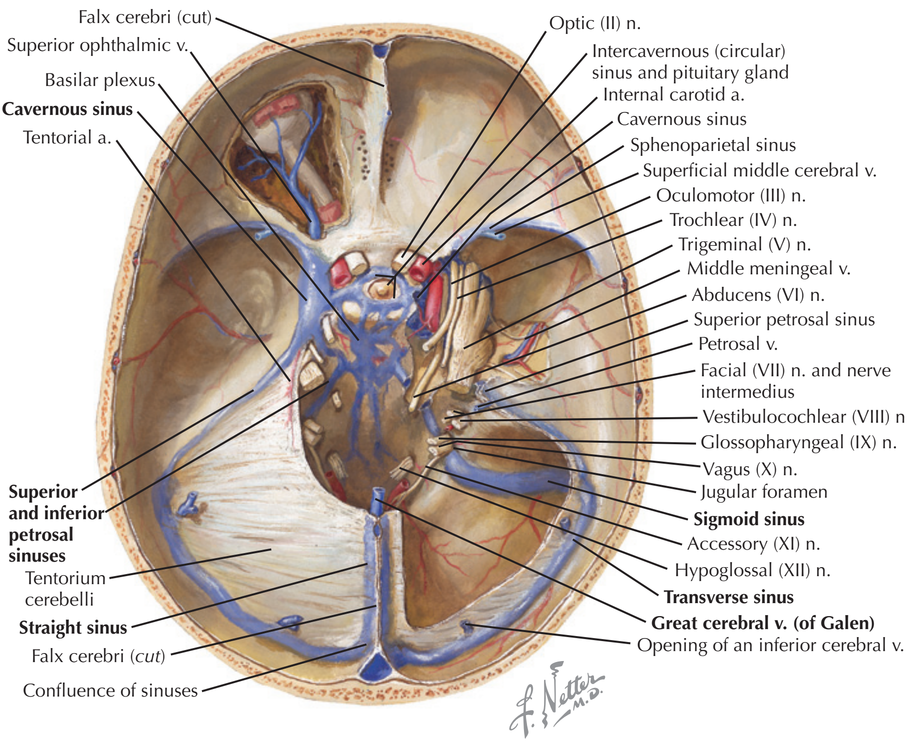
- Venous sinuses are located between the inner and outer layers of dura.
- Sinuses serve as conduits to drain venous blood from the brain to the jugular venous system.

VENOUS SINUS	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Superior sagittal	Follows the interhemispheric fissure and joins the straight sinus at the confluence of sinuses	Drains venous blood from the scalp, skull, and the meningeal and cerebral veins Collects reabsorbed cerebrospinal fluid (CSF) from arachnoid granulations Thrombosis can cause increased intracranial pressure resulting from backup of venous drainage
Inferior sagittal	Follows the base of falx cerebri and joins the great cerebral vein of Galen to form the straight sinus	Drains deeper veins



VENOUS SINUSES *continued*

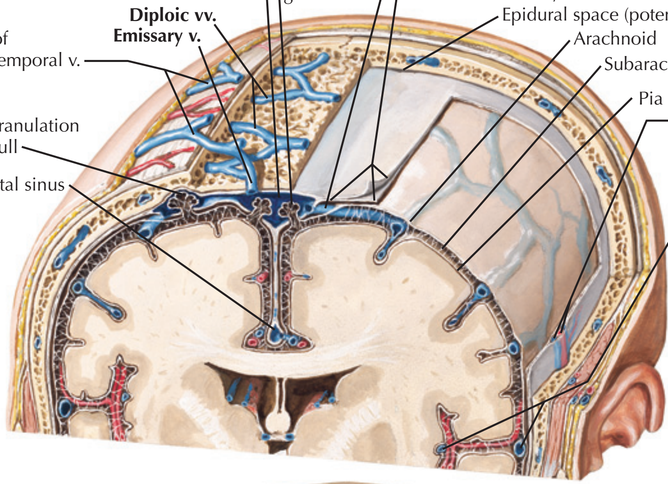
VENOUS SINUS	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Cavernous	Contains CN-III, -IV, -V and -VI Drains superior ophthalmic vein and drains into petrosal sinuses	Thrombosis can cause cranial nerve damage and venous backup in the retina.
Superior petrosal	Drains cavernous sinus and drains into transverse sinus	
Inferior petrosal	Drains venous blood from cavernous sinus and brainstem and drains into internal jugular vein	
Straight	Drains inferior sagittal sinus and great cerebral vein and then drains into the confluence of sinuses	
Transverse	Large structure that drains venous blood from the confluence of sinuses and drains into sigmoid sinus	Thrombosis can cause increased intracranial pressure due to backup of venous drainage.
Sigmoid	S-shaped sinus that drains blood from the transverse sinus. As it exits the jugular foramen, it becomes the internal jugular vein	



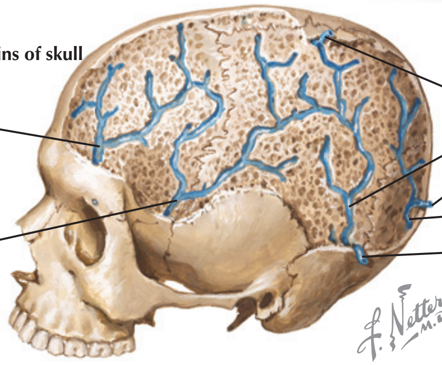
SUPERFICIAL VEINS

VEINS	ANATOMIC NOTES
Superficial cerebral	Located in the pia mater, they arise from the substance of brain and drain into venous sinuses
Meningeal	Follow meningeal arteries between the dura and skull and drain into venous sinuses
Diploic and emissary	Thin venous channels located between inner and outer layers of calvaria Include the frontal, anterior, and posterior temporal veins and the occipital diploic veins Drain into venous sinuses via small emissary veins

Scalp, skull, meningeal and cerebral blood vessels



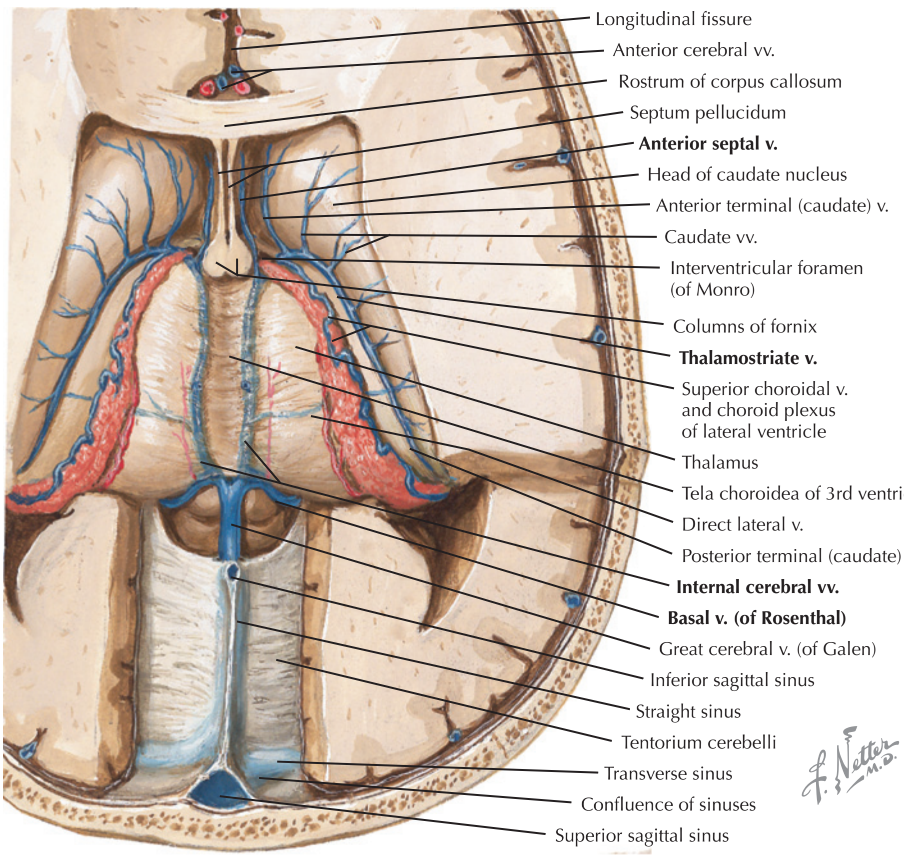
Diploic and emissary veins of skull



DEEP AND SUBEPENDYMAL VEINS

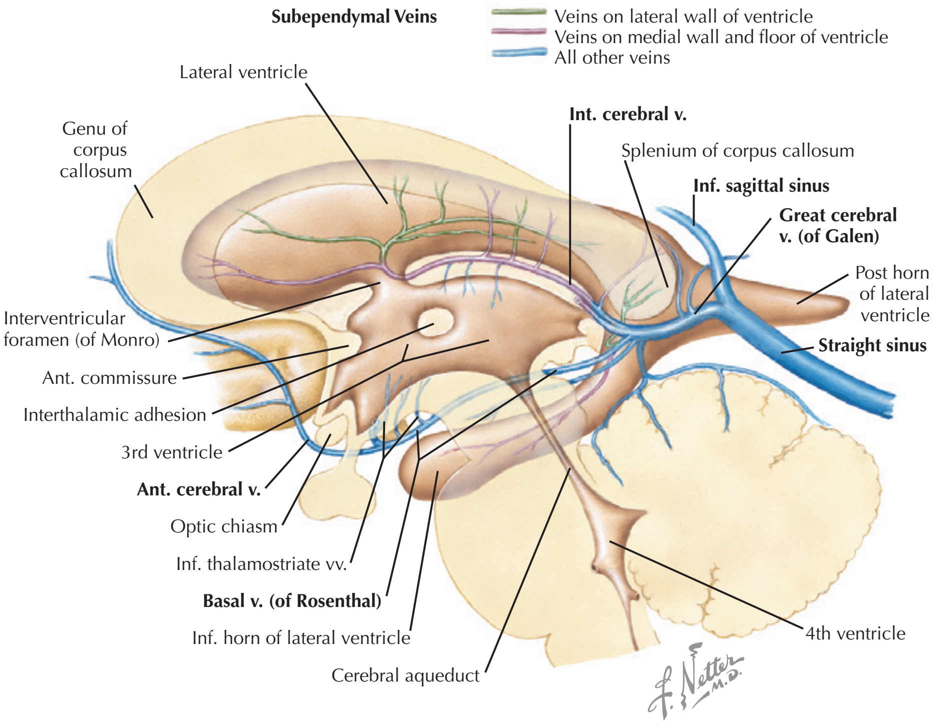
Deep veins collect venous blood from deep structures and eventually drain into venous sinuses.

VEINS	ANATOMIC NOTES
Anterior septal	Drains deep white matter of the frontal lobe
Thalamostriate	Drains caudate, internal capsule, and deep white matter of the parietal lobe
Internal cerebral	Formed by union of the anterior septal and thalamostriate veins
Basal vein of Rosenthal	Joins internal cerebral vein to form the great cerebral vein of Galen



DEEP VEINS

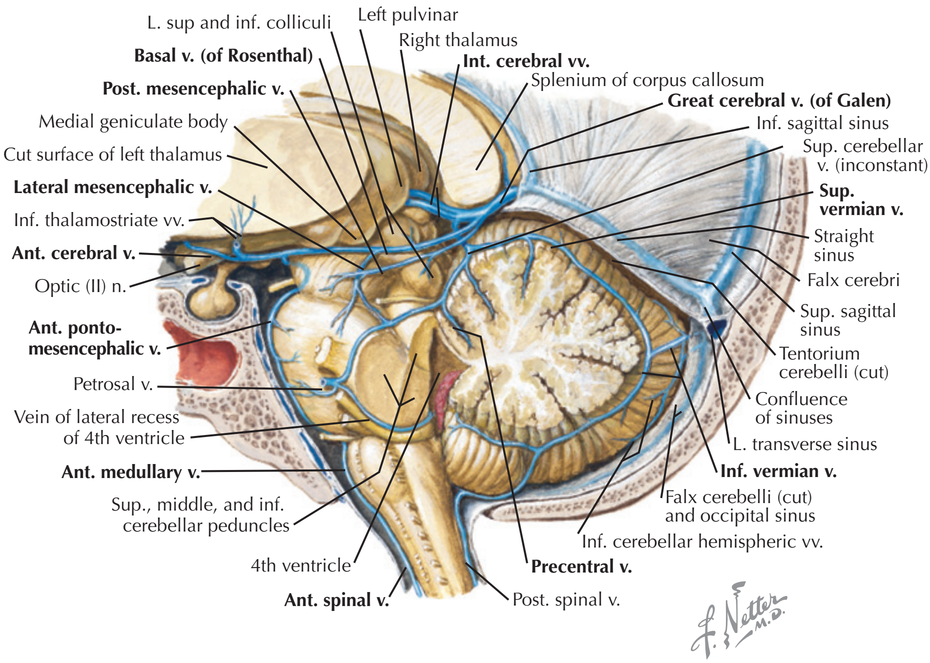
VEINS	ANATOMIC NOTES
Subependymal	Drain venous blood from subependymal regions, which are adjacent to the ventricular wall. They all eventually drain into the great cerebral vein of Galen or the inferior sagittal sinus.
Anterior cerebral	Medial vein that drains the medial frontal lobe and anterior portion of corpus callosum and drains into the basal vein of Rosenthal



VEINS OF THE POSTERIOR CRANIAL FOSSA

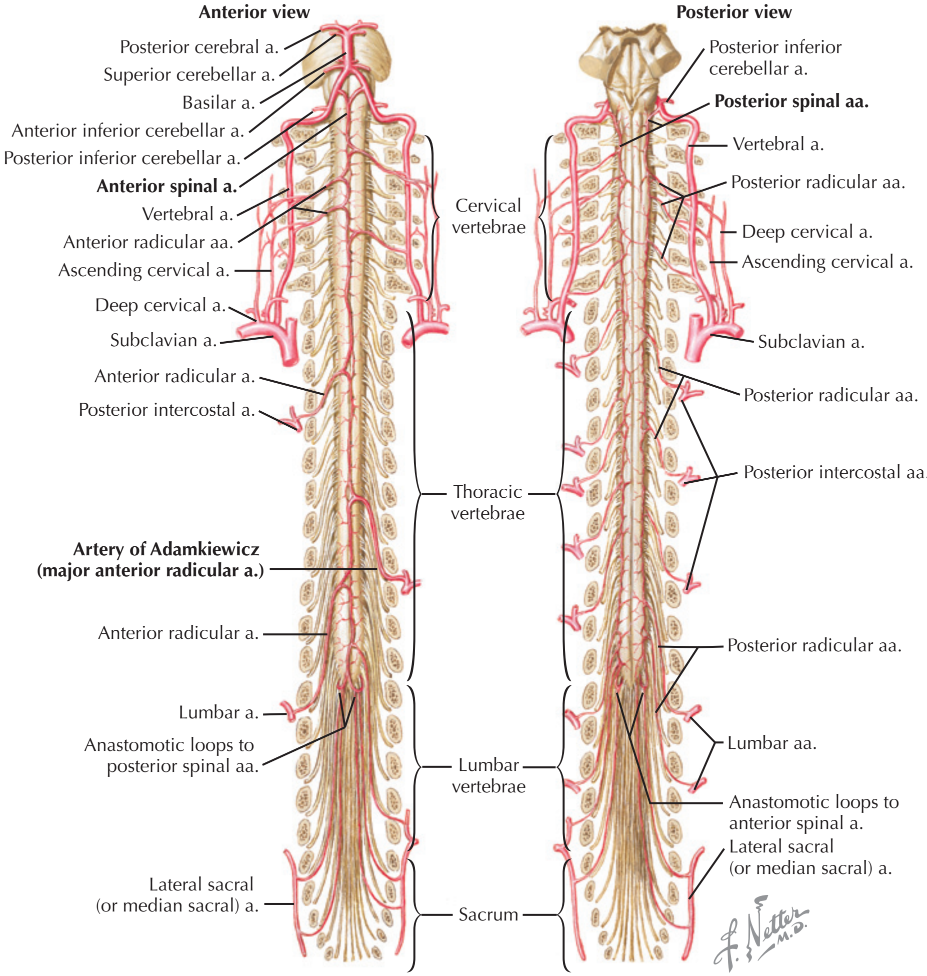
GROUP	VEINS	STRUCTURES DRAINED
Superior	Precentral vein, which drains into the great cerebral vein Superior vermian vein, which drains into the great cerebral vein Posterior mesencephalic vein, which runs parallel to the basal vein Lateral mesencephalic vein, which drains into the basal or posterior mesencephalic vein	Drain superior cerebellum and upper brainstem
Anterior	Anterior spinal vein becomes anterior medullary vein, which becomes anterior pontomesencephalic vein, which drains into the anterior cerebral vein There are many other small named and unnamed veins that are not shown	Drain the anterior brainstem and cerebellar hemispheres
Posterior	Inferior vermian vein drains into straight sinus and forms anastomosis with the superior vermian vein Superior and inferior cerebellar hemispheric veins drain superomedial and inferomedial cerebellar surfaces, respectively	Drain the inferior vermis and cerebellar hemispheres

Veins of Posterior Cranial Fossa



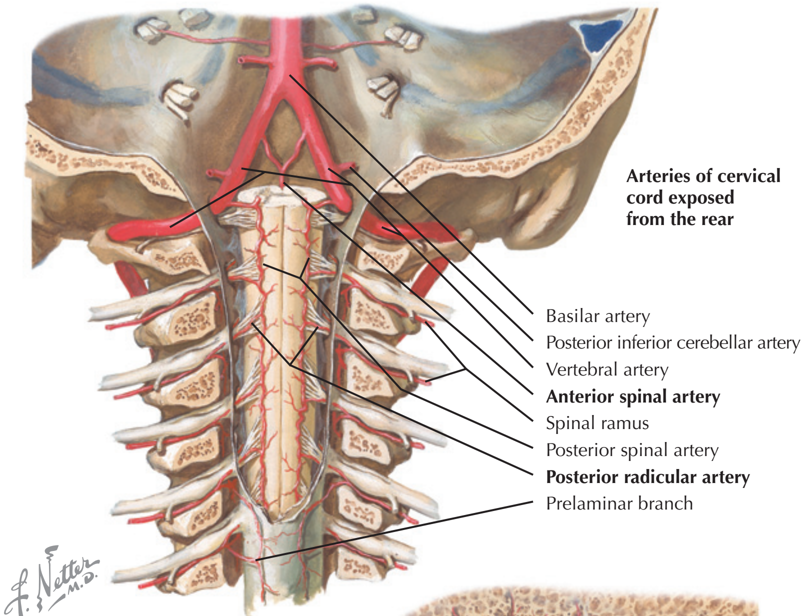
BLOOD SUPPLY TO THE SPINAL CORD

- Anterior and paired posterior spinal arteries branch off vertebral arteries.
- All spinal arteries receive additional supply from radicular arteries off the aorta.
- Major anterior radicular artery (of Adamkiewicz) supplies anterior spinal artery from T8 to the conus.
- Spinal cord segments from T3 to T7 are most vulnerable to ischemia because of the minimal arterial input from radicular vessels at these levels.

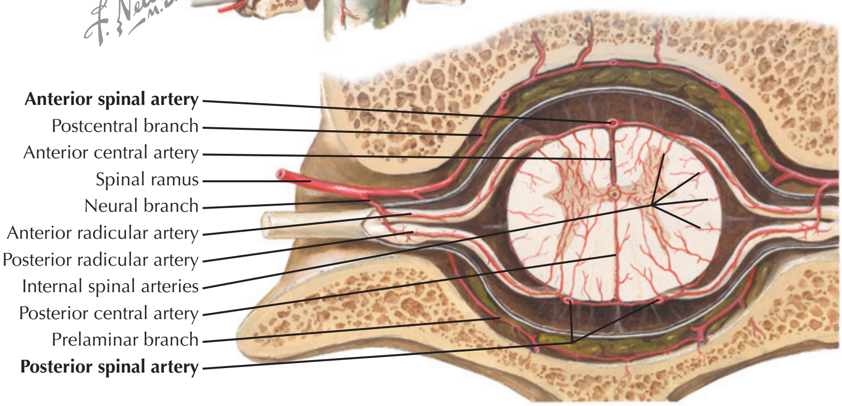


DISTRIBUTION OF ANTERIOR AND POSTERIOR SPINAL ARTERIES

ARTERY	FUNCTIONAL SIGNIFICANCE
Anterior spinal	Supplies anterior ⅔ of spinal cord Infarcts cause leg weakness and loss of pain sensation below the level of the lesion with spared vibration and proprioception (posterior column function)
Posterior spinal	Supplies posterior columns Occlusion would cause loss of vibration and proprioception below the level of the lesion



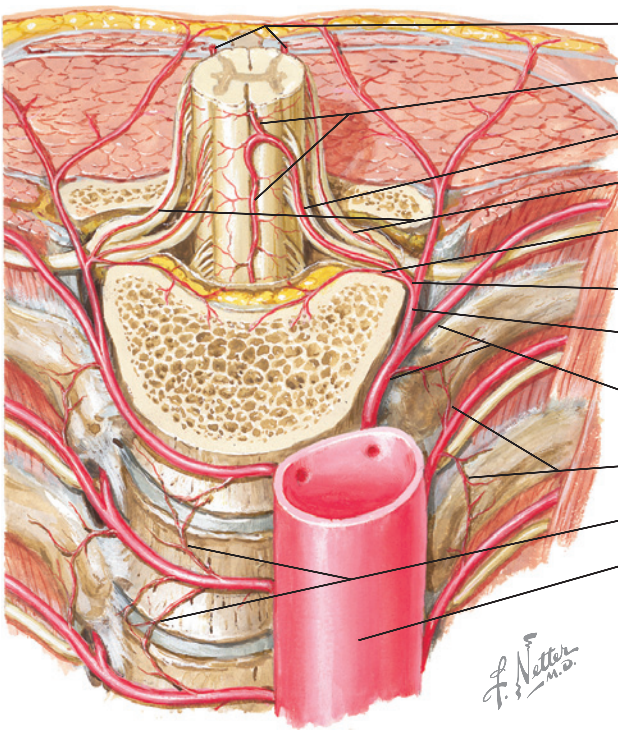
Arteries of cervical cord exposed from the rear



Arteries of spinal cord diagrammatically shown in horizontal section

RADICULAR ARTERIES

- Radicular arteries arise from the aorta in the thoracic region.
- They branch into anterior and posterior radicular arteries.
- Anterior radicular arteries supply the anterior spinal artery.
- Posterior radicular arteries supply the posterior spinal artery.

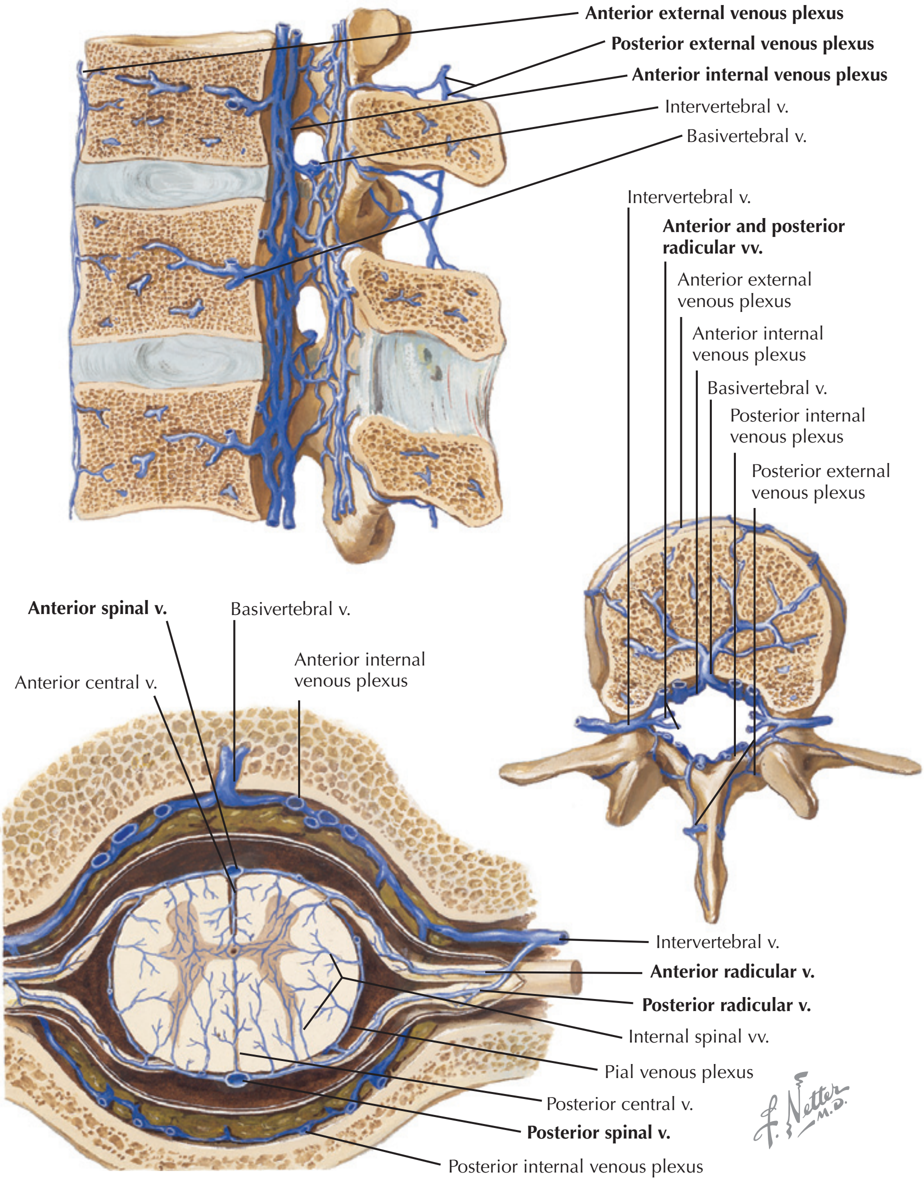


Section through thoracic spine

VEINS OF SPINAL CORD AND VERTEBRAE

VENOUS STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
External venous plexus	Anterior external venous plexus lies anterior to the vertebral bodies Posterior external venous plexus lies over the vertebral laminae	Venous plexuses are valveless, allowing infection and malignant tissue access to the spine.
Internal venous plexus	A network of veins in the epidural space of the spinal cord Basivertebral veins drain the vertebral bodies and join the various plexus	
Anterior and posterior spinal veins	Adjacent to anterior and posterior spinal arteries	All spinal veins eventually drain into intervertebral veins, which exit the spinal canal via intervertebral foramina.
Anterior and posterior radicular veins	Adjacent to anterior and posterior radicular arteries.	

VEINS OF SPINAL CORD AND VERTEBRAE *continued*



CHAPTER 4

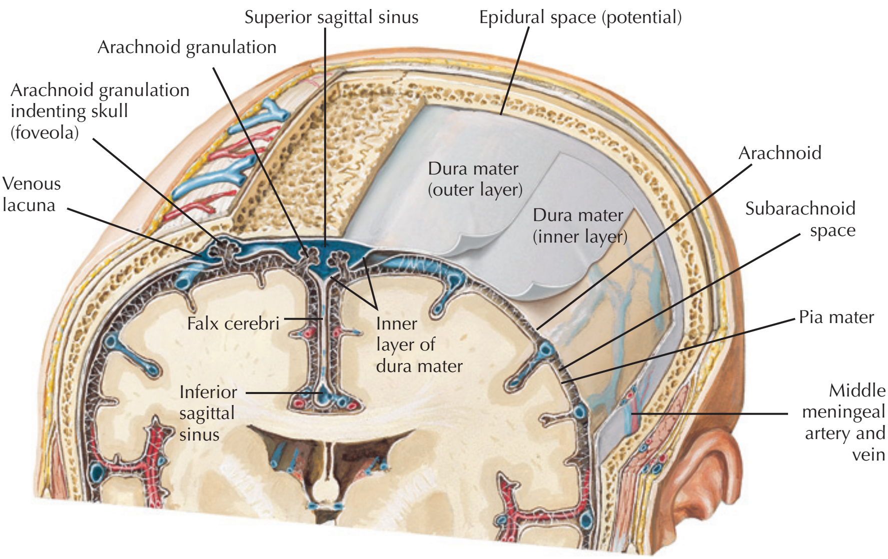
Cerebrospinal Fluid and Coverings of the Brain

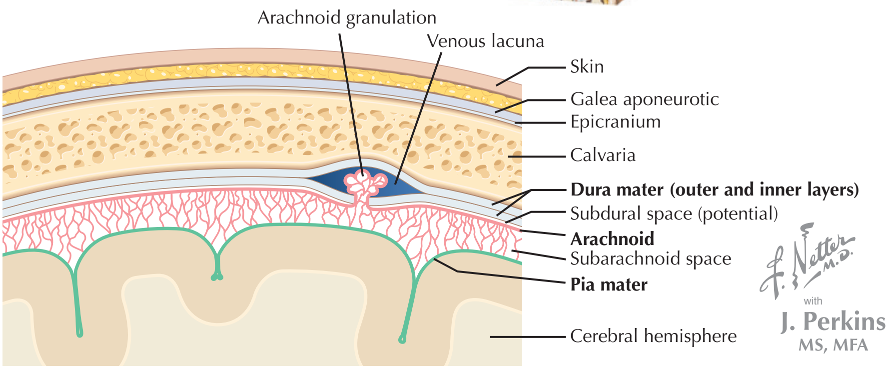
MENINGES

In addition to the protection of the skull, the brain is protected and surrounded by a set of coverings known as the *meninges.*

LAYER	LOCATION	ANATOMIC NOTES	CLINICAL NOTES
Dura mater	Outermost layer	Leathery consistency Lies just under the inner surface of the skull Has 2 layers separated by potential space	Epidural hematomas form between the dura and the skull. They are typically caused by injury to the middle meningeal artery. Subdural hematomas form between the dura and the arachnoid. They are typically caused by rupture of bridging veins.
Arachnoid mater	Middle layer	Fine, lacy membrane, deep to the dura mater Contains cerebrospinal fluid (CSF) and cerebral arteries	Subarachnoid hemorrhages form between the arachnoid and the pia. They are most commonly caused by rupture of an aneurysm of a cerebral artery.
Pia mater	Inner layer	Thin membrane Adheres to contours of the cerebral cortex	

MENINGES *continued*

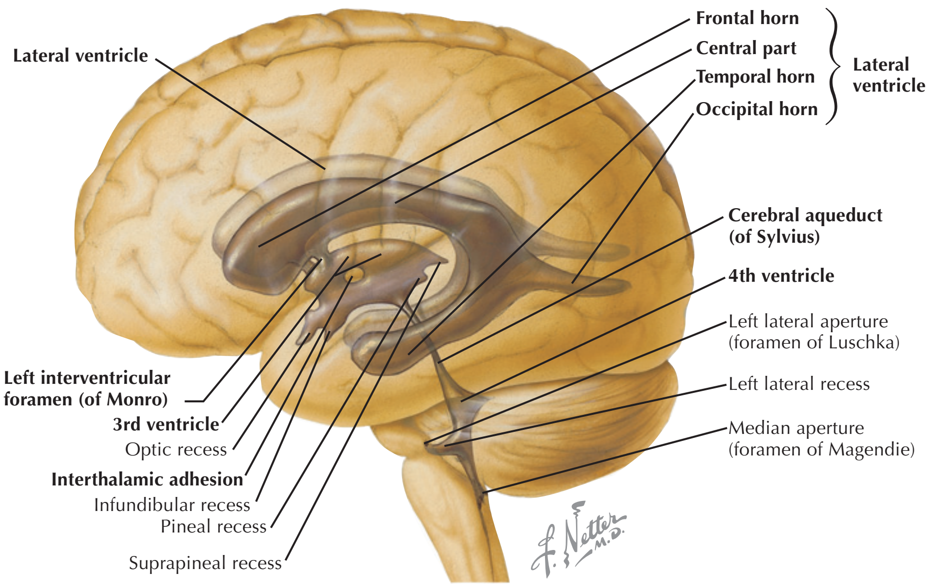




VENTRICULAR SYSTEM

VENTRICLE	ASSOCIATED STRUCTURE	ANATOMIC NOTES	CLINICAL NOTES
Lateral	Cortex	C-shaped structure Frontal horns are most anterior and are inferior to the corpus collosum Temporal horns are inferior and lie in close relationship to the hippocampus Occipital horns are small posterior extensions CSF exits into the third ventricle via paired foramina of Monro	Obstruction of flow at 1 or both foramina of Monro can cause enlargement of the ventricles called *noncommunicating hydrocephalus.*
Third	Thalamus and hypothalamus	Thin midline structure between the thalami Interrupted by the interthalamic adhesion, which connects the 2 thalami	
Cerebral aqueduct	Midbrain	Thin tubelike structure that connects 3rd to 4th ventricles	Because of its small size, it can be compressed, causing noncommunicating hydrocephalus.
Fourth	Pons and medulla	Rhombus-shaped structure Extends from the upper pons to lower medulla Roofed by the cerebellum	Hemorrhages or masses in the pons or cerebellum can compress the 4th ventricle, causing acute hydrocephalus, which causes headache and may progress to coma.

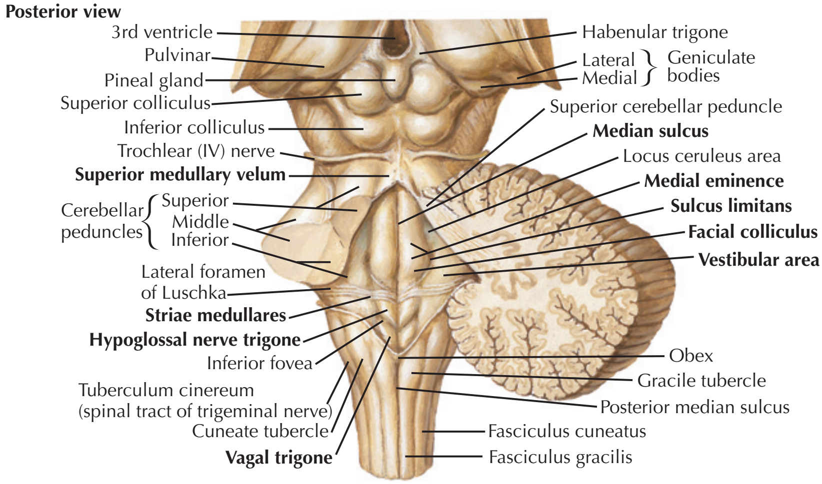
VENTRICULAR SYSTEM *continued*

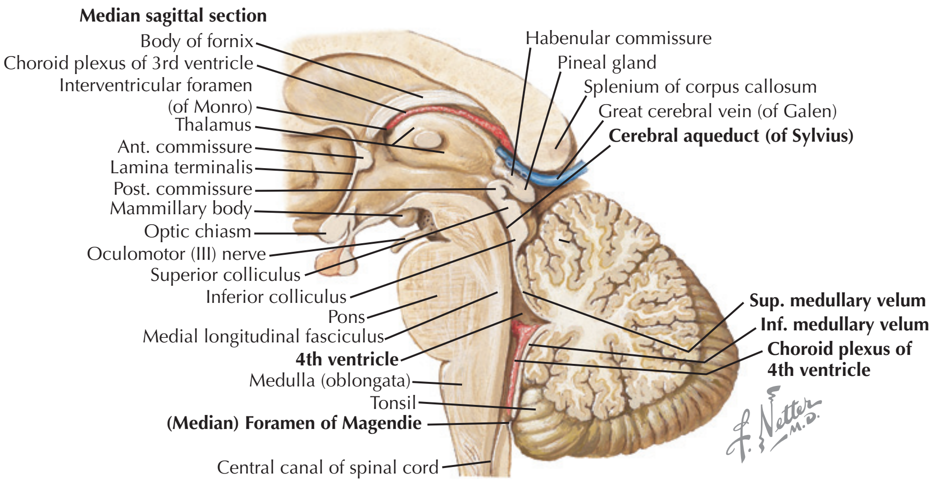


THE FOURTH VENTRICLE

FEATURE	DESCRIPTION
CSF entry	From the cerebral aqueduct CSF is also produced by the choroid plexus of the 4th ventricle
CSF exit	To the subarachnoid cisterns via laterally placed foramina of Luschka and medially placed foramen of Magendie Small amount of CSF continues into the central canal of the spinal cord
Roof	Formed by the superior and inferior medullar vela, which are thin white-matter structures that lie below the superior and inferior cerebellar peduncles
Floor	Shaped like a rhombus Most visible when the cerebellum and cerebellar peduncles are removed Important structures: • Striae medullares: separates the upper pontine portion from the lower medullary portion • Median sulcus: vertical sulcus that divides the floor symmetrically • Medial eminence: longitudinal elevation lateral to the medial sulcus. Its superior part is formed by the locus ceruleus, a bluish nucleus that produces norepinephrine • Facial colliculus: overlies the abducens nucleus and facial nerve in the pons • Sulcus limitans: a sulcus that lies lateral to the medial eminence • Vestibular area: overlies the vestibular nuclei in the pons and medulla • Hypoglossal trigone: overlies the hypoglossal nucleus in the medulla • Vagal trigone: overlies nuclei of the vagal and hypoglossal nerves

THE FOURTH VENTRICLE *continued*

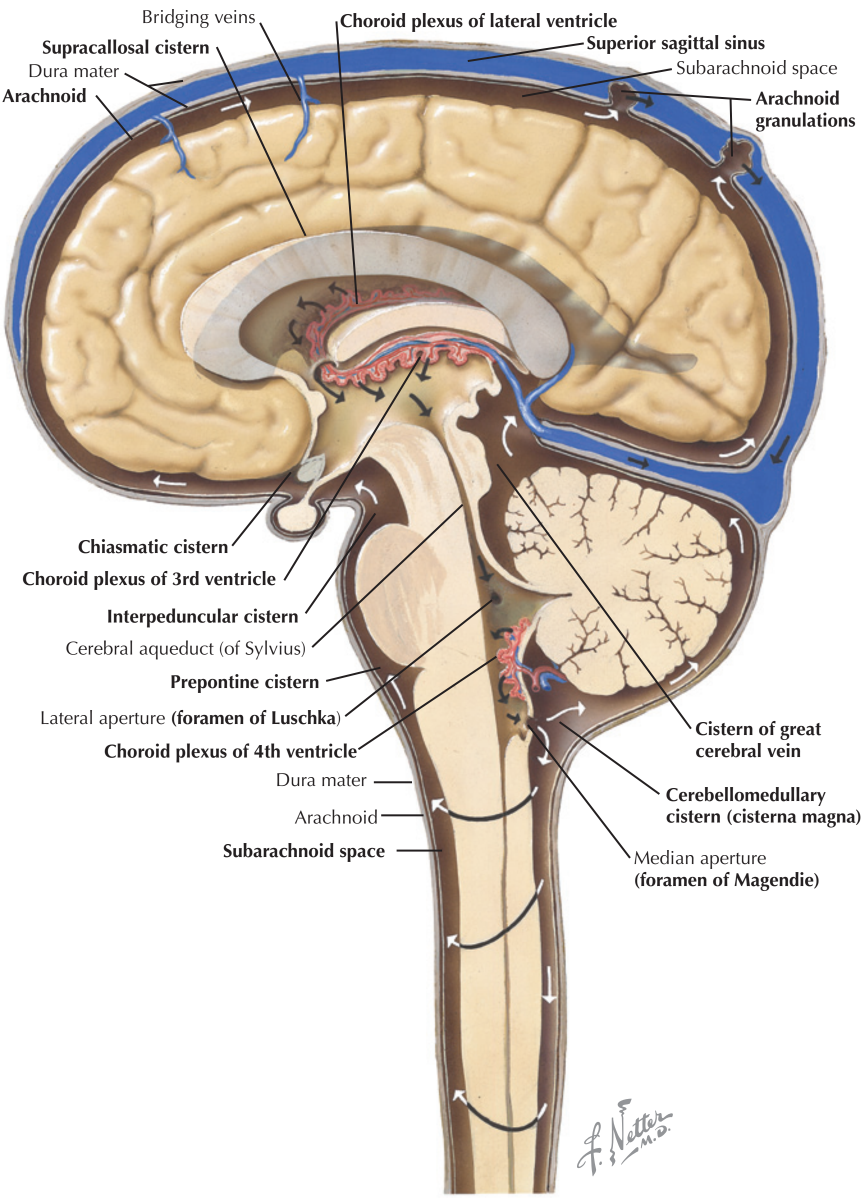




CEREBROSPINAL FLUID CIRCULATION

- Flows freely through the ventricular system
- Formed in the highly vascular choroid plexus located in the lateral ventricles, third ventricle, and fourth ventricle
- Exits the ventricular system in the medulla, through the foramina of Luschka and Magendie
- After exiting the ventricular system, CSF flows in the subarachnoid cisterns at the base of the brain, which include the following:
    - The cerebromedullary cistern (cisterna magna)—around the medulla
    - The prepontine cistern—anterior to the pons
    - The interpeduncular cistern—anterior to the midbrain
    - The chiasmatic cistern—surrounds the optic chiasm
    - The cistern of the lateral fossa (not shown)
    - The cistern of the great cerebral vein (cisterna ambiens)—between the corpus collosum and the cerebellum
- In addition, some of the CSF flows in the subarachnoid space around the spinal cord. Because the spinal cord ends in the upper lumbar spine, but the subarachnoid space ends in the sacrum, there is a lumbar cistern, where fluid is removed during lumbar puncture.
- CSF eventually reaches the supracollosal cistern, where it is absorbed into the superior sagittal sinus through arachnoid granulations.
- Diseases of the subarachnoid space, such as meningitis and subarachnoid hemorrhage, can clog the arachnoid granulations, leading to decreased CSF reabsorption and subsequent hydrocephalus.

CEREBROSPINAL FLUID CIRCULATION *continued*



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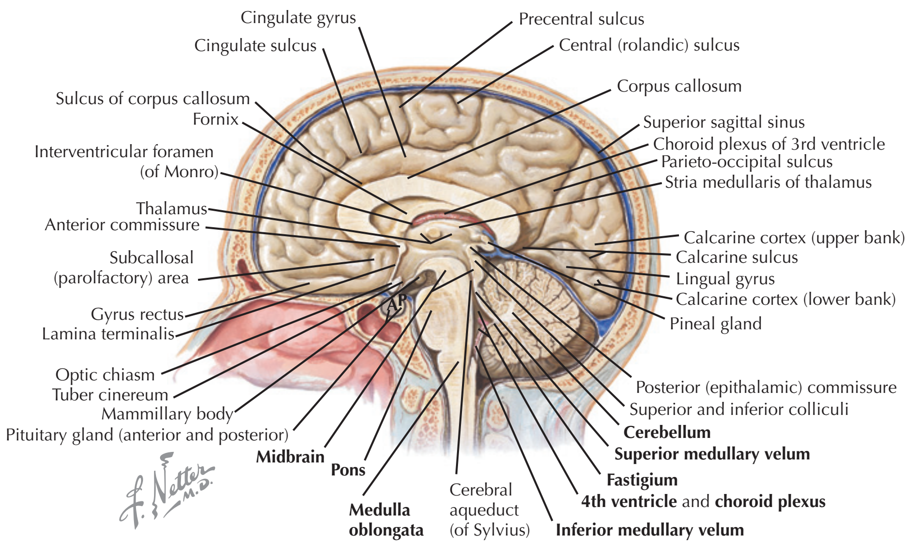
CHAPTER 5

Medulla Oblongata

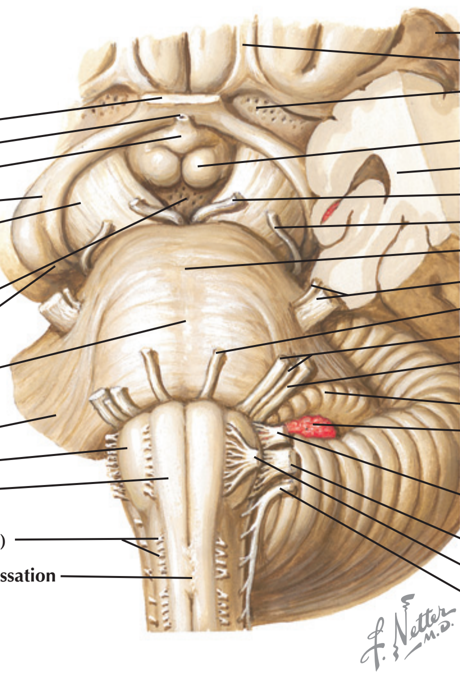
GROSS BRAINSTEM: MIDSAGITTAL VIEW

STRUCTURE	ANATOMIC NOTES
Superior medullary velum	Roofs pontine part of ventricle
Inferior medullary velum	Roofs medullary part of ventricle
Fastigium	Apex in the cerebellum toward which superior and inferior medullary velum extend
Roof of 4th ventricle	Formed by the cerebellum and superior and inferior medullary velum



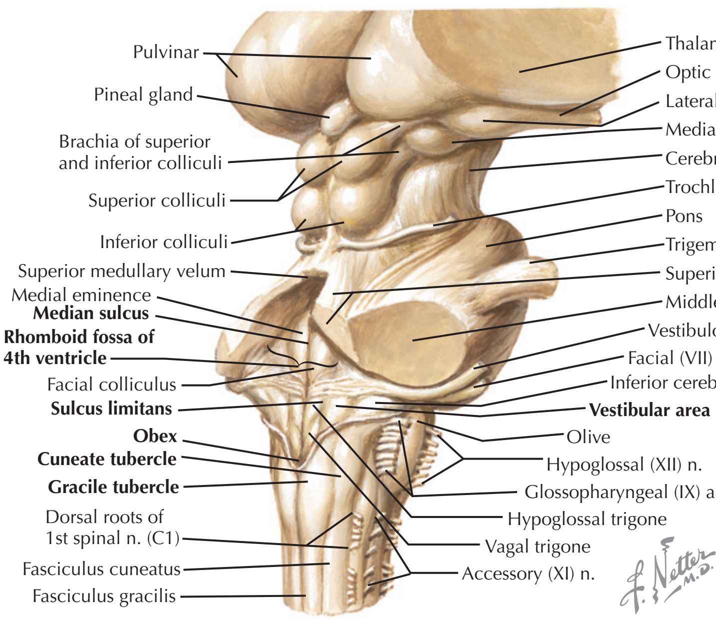
GROSS BRAINSTEM: ANTERIOR VIEW

STRUCTURE	ANATOMIC NOTES
Pyramidal decussation	Marks the transition from spinal cord to lower medulla
Caudal medulla	Rostral to highest cervical rootlets
Inferior olivary nuclei	Oval eminences posterolateral to pyramids that give medulla characteristic appearance above the transition zone



GROSS BRAINSTEM: POSTEROLATERAL VIEW

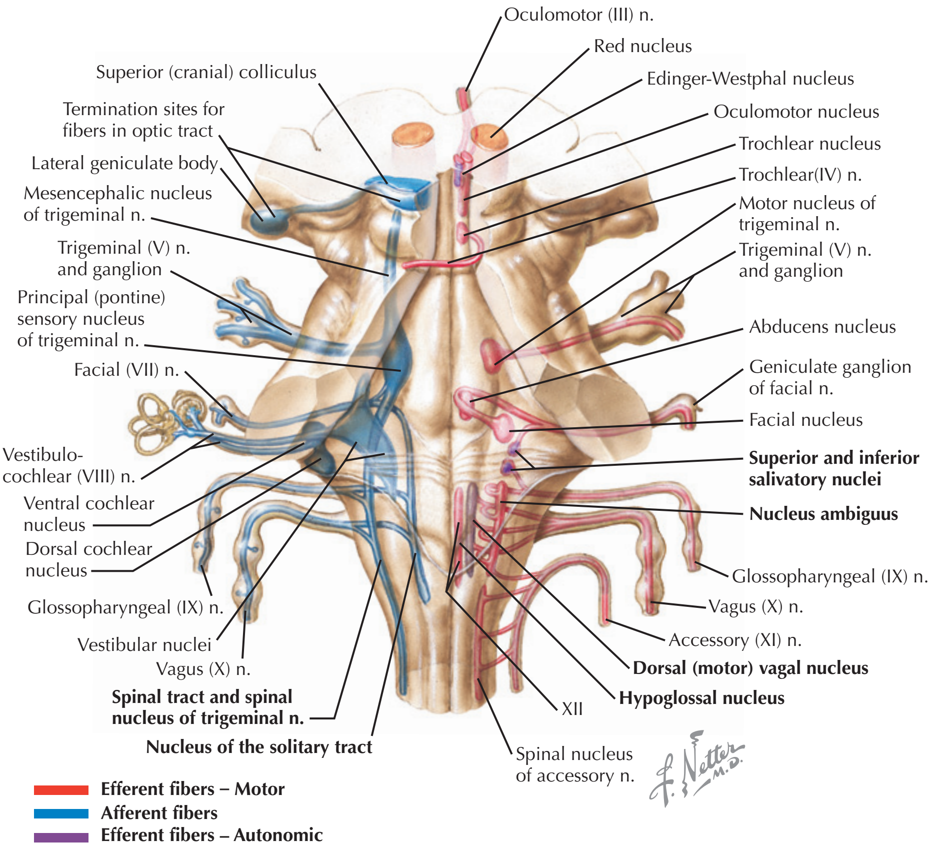
STRUCTURE	ANATOMIC NOTES
Rhomboid fossa	Forms floor of 4th ventricle, overlying the pons and medulla
Fourth ventricle	Extends from the central canal of the cervical cord to the cerebral aqueduct of the midbrain
Median sulcus	Divides the rhomboid fossa into symmetrical halves
Sulcus limitans	Divides each half of the rhomboid fossa into medial eminence and lateral vestibular area. Vestibular nuclei lie beneath the vestibular area
Obex	Caudal junction of walls of 4th ventricle
Cuneate and gracile tubercles	Lie caudal to 4th ventricle



CRANIAL NERVES AND NUCLEI OF MEDULLA

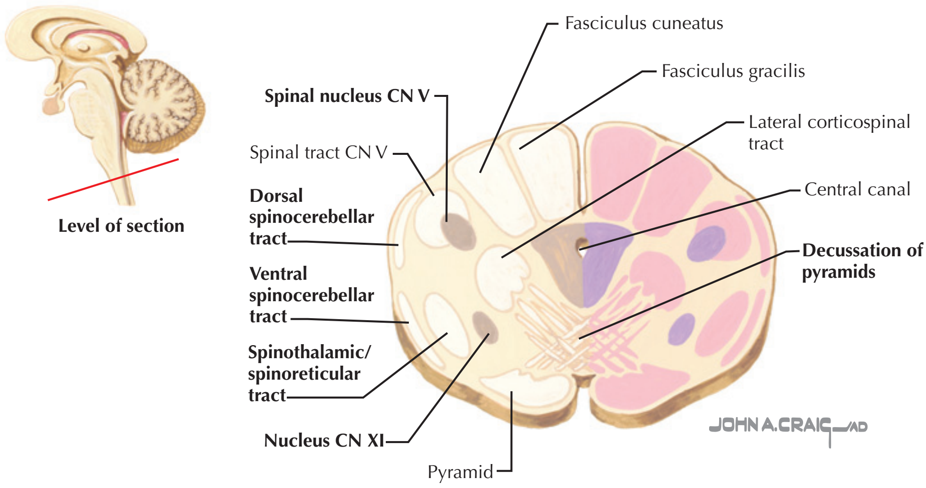
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Descending (spinal trigeminal) nucleus of CN-V	Continuation of substantia gelatinosa of cervical spinal cord	Conveys pain, thermal, and tactile sense from face, forehead, and mucous membranes of nose and mouth
Nucleus of the solitary tract	Solitary nuclei of both sides merge at obex to form commissural nucleus of vagus	Rostral part (*gustatory nucleus*) receives taste from CN-VII and CN-IX. Caudal part receives visceral afferents from CN-X (GI tract, pulmonary, and carotid sinus afferents)
Inferior (CN-IX) salivatory nucleus	Impossible to distinguish from reticular neurons	Innervates otic ganglion, via lesser petrosal nerve, to stimulate parotid gland
Dorsal vagal nucleus (CN-X)	Occupies medial portion of vagal trigone in floor of 4th ventricle	Gives rise to preganglionic parasympathetic fibers
Nucleus ambiguus	Column of cells in reticular formation, midway between spinal trigeminal nucleus and inferior olive	Caudal pole gives rise to cranial root of spinal accessory nerve (CN-XI)
Hypoglossal nerve (CN-XII)	18-mm column of motor cells in central grey of median eminence	Innervates somatic skeletal muscles of tongue

CRANIAL NERVES AND NUCLEI OF MEDULLA *continued*



MEDULLA: SPINAL CORD TRANSITION

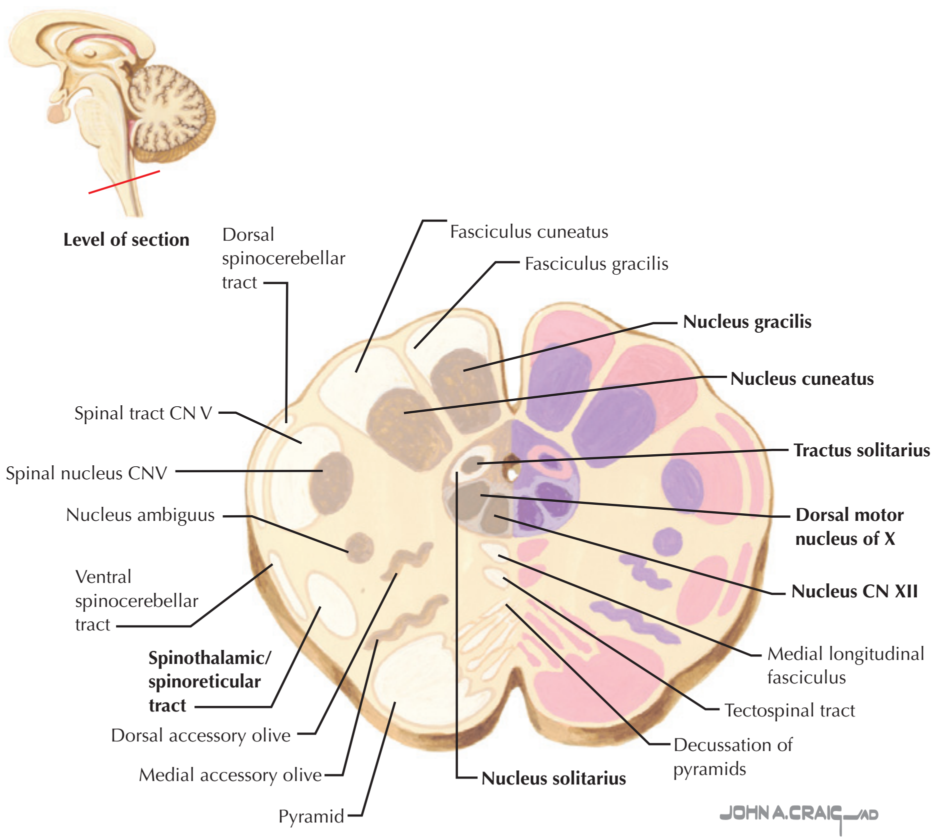
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Decussation of pyramids (corticospinal tracts)	Conspicuous external demarcation of medulla into the spinal cord	90% of each descending corticospinal tract crosses to the opposite side at this point
Spinal nucleus of CN-V	Rostral continuation of substantia gelatinosa of the cervical cord	Lesions here result in a loss of pain and thermal sense in the area innervated by the trigeminal nerve
Dorsal spinocerebellar tract	Uncrossed pathway from periphery to cerebellar vermis Enters inferior cerebellar peduncle	Used in fine coordination of posture and movement of individual limb muscles
Ventral spinocerebellar tract	Predominantly crossed pathway (in cat) from periphery to anterior lobe of cerebellum Ascends to pons and enters superior cerebellar peduncle	Conveys information regarding movement and posture of the whole limb
Spinothalamic tract	Crossed pathway of pain and temperature sense	Injury results in contralateral loss of pain and temperature sense
Nucleus CN-XI (spinal accessory nerve)	Spinal portion arises from the anterior horn cell column of C1-5, enters the skull through the foramen magnum, joins the cranial portion of nerve, and exits via the jugular foramen with CN-IX and CN-X	Innervates sternocleidomastoid and trapezius muscles



MEDULLA: DORSAL COLUMN NUCLEI LEVEL

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Nucleus gracilis	Fasciculus gracilis fibers synapse in this nucleus	Conveys position and vibration sensation from the leg
Nucleus cuneatus	Fasciculus cuneatus fibers synapse in this nucleus	Conveys position and vibration sensation from the arm
Tractus solitarius	Extends rostrally to lower pons	Vagal visceral afferents travel in the tractus solitarius and synapse in the nucleus solitarius
Nucleus solitarius (rostral)	Gustatory nucleus	Receives taste fibers from CN-VII and CN-IX
Nucleus solitarius (caudal)	Vagal visceral afferents synapse in the nucleus solitarius	Receives general visceral afferents from the vagus (carotid sinus, thoracic and abdominal viscera)
Dorsal motor nucleus of CN-X	Gives rise to efferent preganglionic parasympathetic fibers	Innervates thoracic and abdominal viscera
Spinothalamic tract	Posterolateral spinothalamic tract fibers are from the lower body; anteromedial fibers from the arm and neck	Injury results in contralateral loss of pain and temperature sense
Hypoglossal nucleus (CN-XII)	Forms column 18 mm long in central gray; fibers emerge from the medulla between pyramid and inferior olivary complex	Lesion results in weakness and atrophy of the ipsilateral half of the tongue

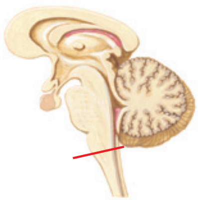
MEDULLA: DORSAL COLUMN NUCLEI LEVEL *continued*

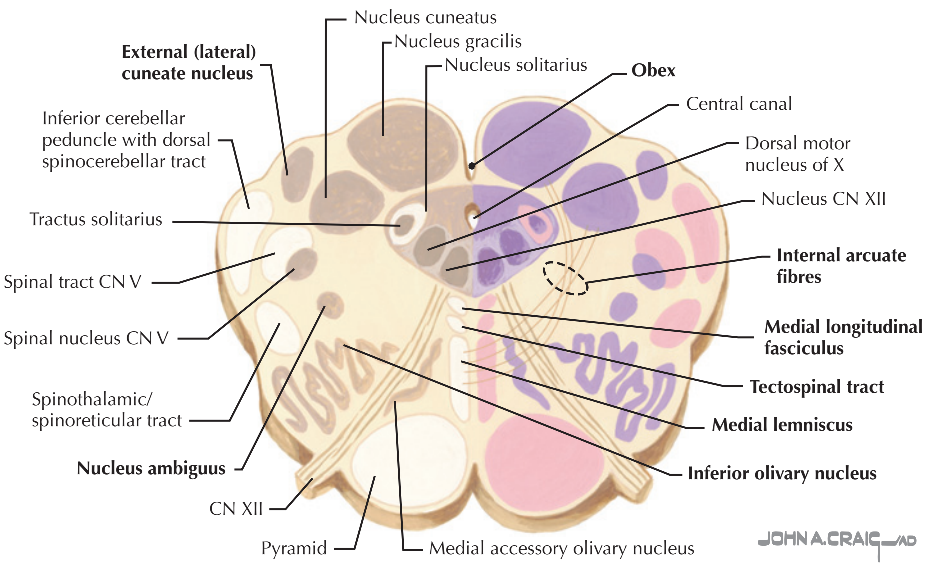


MEDULLA: OBEX LEVEL

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Obex	Lies between the area postrema on each side of 4th ventricle	Area postrema is an emetic chemoreceptor trigger zone
Internal arcuate fibers	Myelinated fibers that sweep ventromedially from the nucleus gracilis and cuneatus to form contralateral ascending medial lemniscus	Crossing provides anatomic basis for sensory representation of half the body in the contralateral cerebral cortex
Medial longitudinal fasciculus (MLF)	Extends from the upper midbrain to spinal levels	Mediates conjugate horizontal eye movements
Tectospinal tract	Arises from the superior colliculus and terminates mostly in the upper 4 cervical segments	Mediates reflex postural movements in response to visual and perhaps auditory stimuli
Medial lemniscus	Contains 2nd-order neurons of the posterior column pathway	Mediates position and vibration sensation
Inferior olivary nucleus	Fibers enter the contralateral inferior cerebellar peduncle and end as climbing fibers in the cerebellar cortex	Largest medullary cerebellar relay nucleus, receiving input from cortex, red nucleus, pons, and spinal dorsal column
Nucleus ambiguus	Caudal pole of the nucleus ambiguus is nucleus of CN XI	Caudal parts give rise to cranial part of CN-XI fibers Rostral parts give rise to CN-IX fibers to stylopharyngeus
External (lateral) cuneate nucleus	Medullary equivalent of the dorsal nucleus of Clarke of spinal cord (which gave rise to uncrossed fibers of the dorsal spinocerebellar tract)	Gives rise to cuneocerebellar tract, the upper-limb equivalent of the dorsal spinocerebellar tract

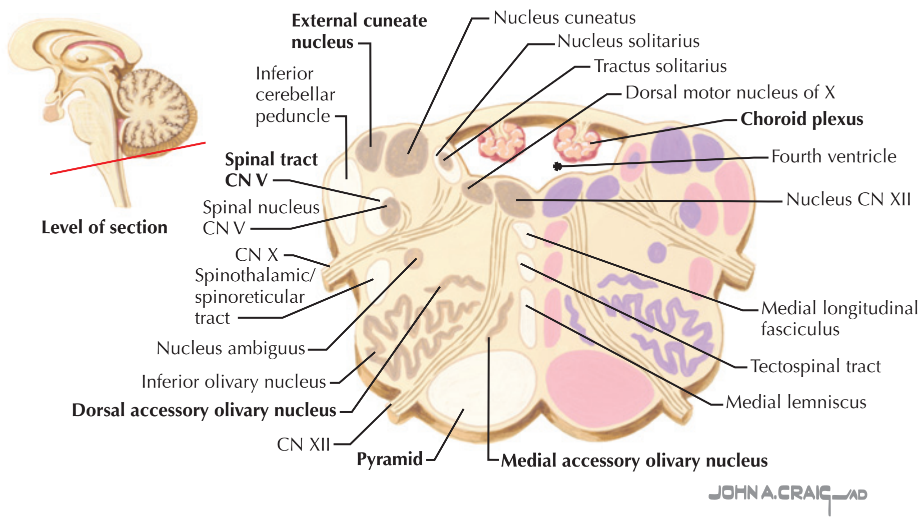
MEDULLA: OBEX LEVEL *continued*





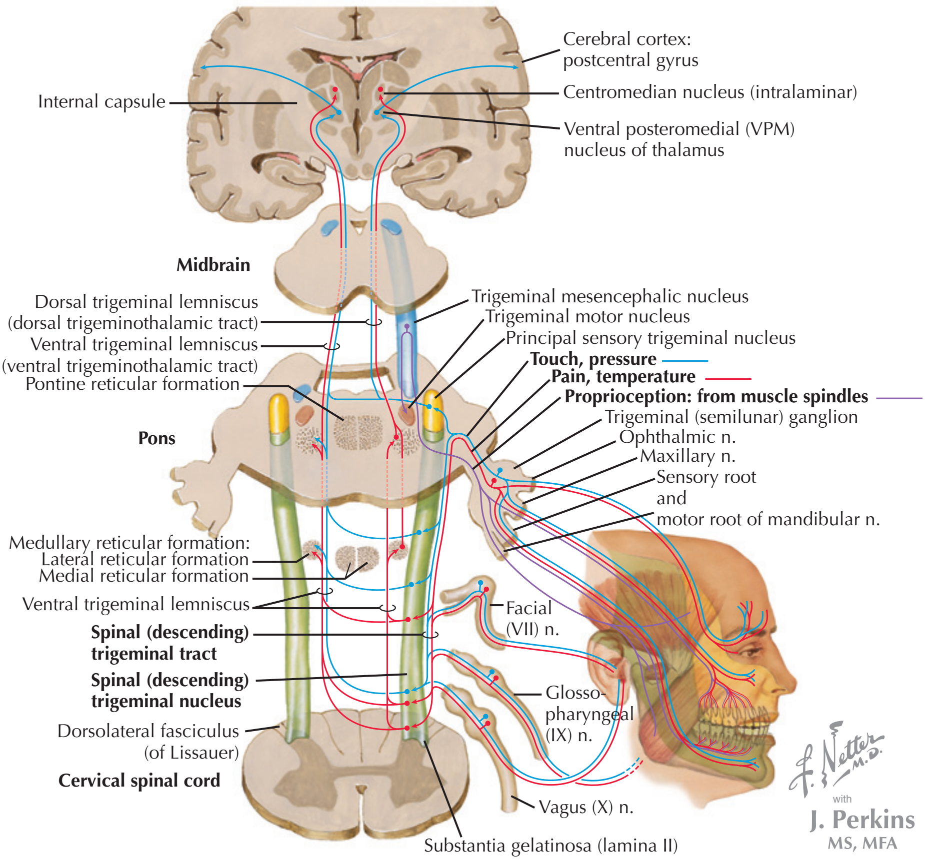
MEDULLA: INFERIOR OLIVE LEVEL

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
External cuneate nucleus	Medullary equivalent of the dorsal nucleus of Clarke; gives rise to uncrossed cuneocerebellar fibers	Upper-limb equivalent of the posterior spinocerebellar tract
Spinal tract of CN-V	Afferent trigeminal fibers enter the upper pons and descend the dorsolateral brainstem as spinal trigeminal tract	Tractotomy may relieve severe pain of trigeminal neuralgia
Dorsal accessory olivary nucleus	Project largely to the cerebellar vermis	Modulates cerebellar processing
Medial accessory olivary nucleus	Project largely to the cerebellar vermis	Modulates cerebellar processing
Pyramid	Conveys descending corticospinal fibers	Lesion results in contralateral hemiparesis
Choroid plexus	Projects into the caudal part of the 4th ventricle	Main site of cerebrospinal fluid (CSF) formation Renews entire CSF 4-5 times per day



TRIGEMINAL SYSTEM: LONGITUDINAL BRAINSTEM VIEW

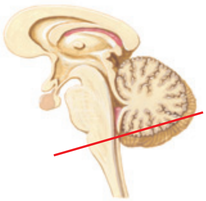
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Spinal (descending) trigeminal nucleus	Merges with the substantia gelatinosa in dorsal spinal gray matter	Mediates pain, temperature, and tactile sense from the face, forehead, muscosa of the nose and mouth
Spinal (descending) trigeminal tract	Close to the spinothalamic tract	Due to the proximity of these 2 tracts, injury to this area (stroke) results in crossed hemianalgesia of the face and body (one side of the face and the opposite side of the body have impaired pain sensation)



MEDULLA: VESTIBULAR NUCLEI LEVEL

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Reticular formation	Constitutes a matrix throughout the lower brainstem, within which nuclei and tracts are embedded	Involved in consciousness and alertness Brainstem stroke results in coma due to injury of this region
Tractus solitarius	Constitutes a descending bundle of visceral afferents comparable to the spinal trigeminal tract, which contains general somatic afferents	Surrounded by, and synapses in, the nucleus solitarius, which rostrally subserves taste (i.e., the gustatory nucleus), and caudally subserves cardiorespiratory function and general visceral sensation
Inferior and medial vestibular nuclei	Two of the 4 vestibular nuclei. Due to the rostrocaudal extent of nuclei, only 2 can be seen in any single section	Innervate semicircular canals, utricle, and saccule Involved in balance and orientation in space
Inferior cerebellar peduncle	Formed by tracts and fibers from the medulla and spinal cord: the spinocerebellar and olivocerebellar tracts, lateral reticular, arcuate, and cuneate nuclei fibers	Most cerebellar afferents enter via inferior and middle cerebellar peduncles, conveying stretch, vestibular, visual, and other impulses
Medial lemniscus	Carries dorsal column sensation to the ventroposterlateral nucleus of the thalamus	Lesion results in contralateral loss of position and vibration sensation
Tectospinal tract	Originates in the superior colliculus, crosses in the midbrain, descends through anterior funiculus of the cervical spinal cord	Believed to play a role in head turning in response to light stimulation
Medial longitudinal fasciculus (MLF)	Contains fibers from all vestibular nuclei: descending vestibular MLF fibers project mainly to cervical spinal levels, ascending vestibular MLF fibers project to nuclei of extraocular muscles	Ascending MLF fibers in the pons also contain CN-VI internuclear neurons that cross to the contralateral CN-III nucleus to mediate conjugate horizontal eye movements

MEDULLA: VESTIBULAR NUCLEI LEVEL *continued*



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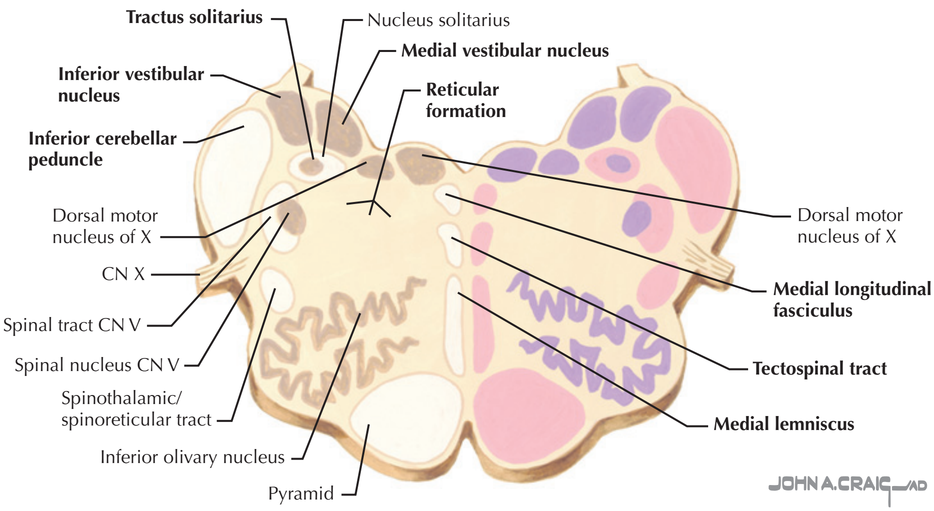
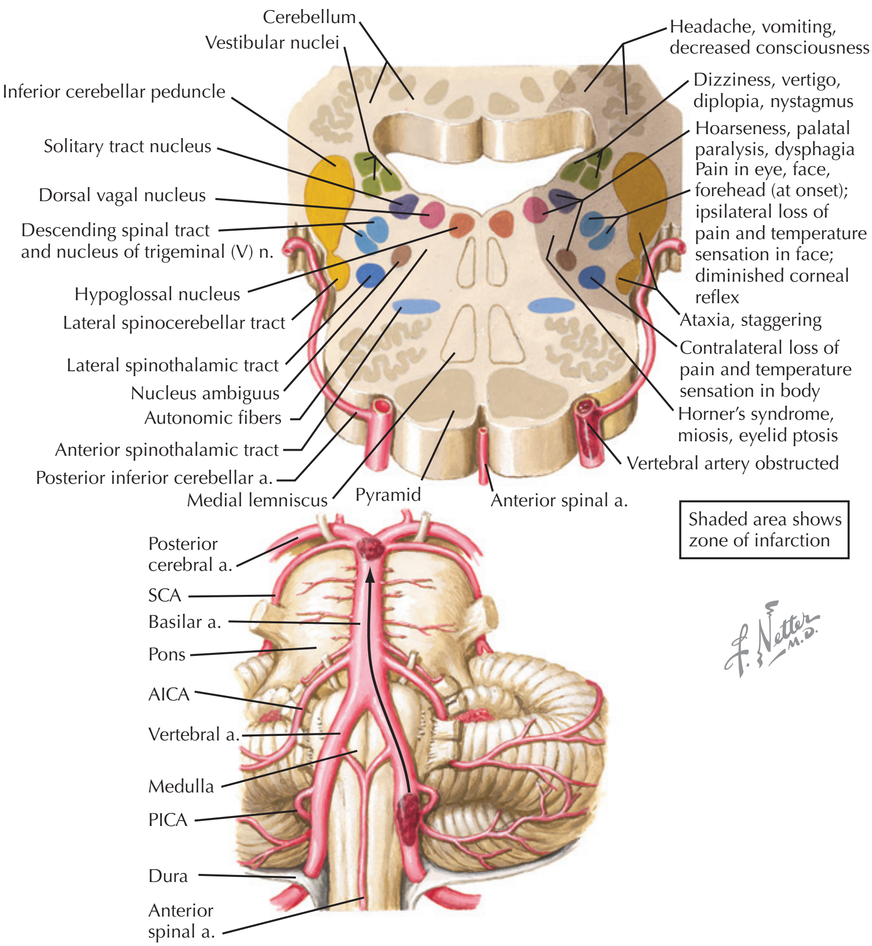


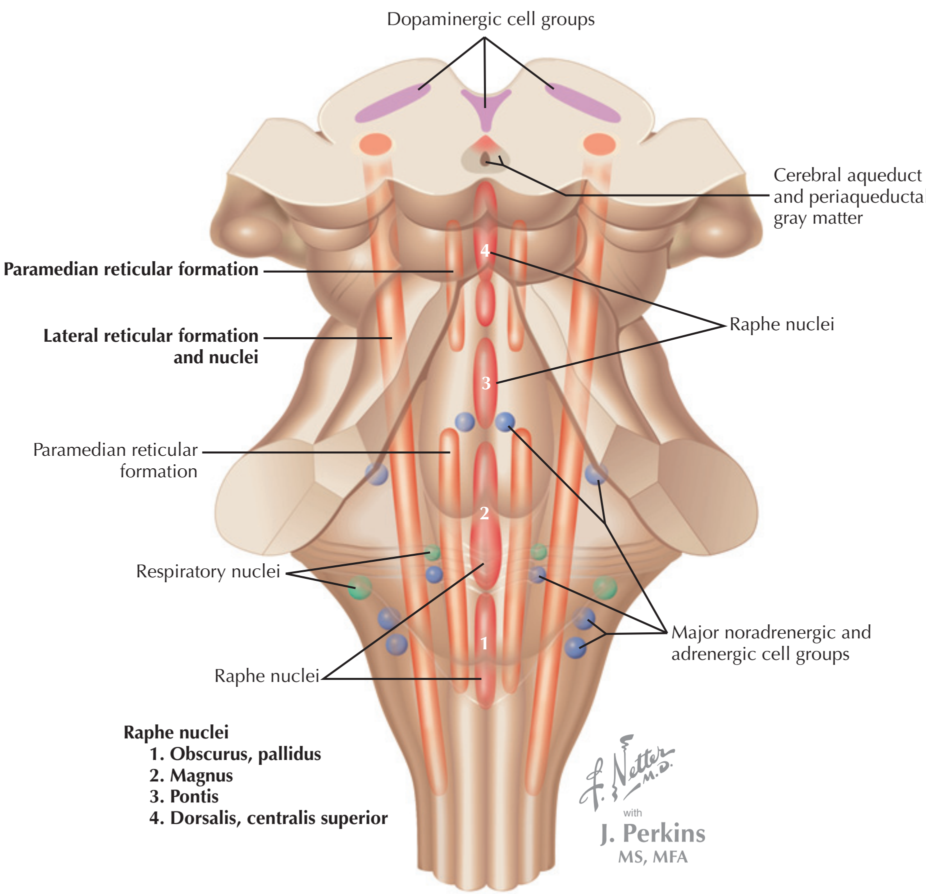
INTRACRANIAL OCCLUSION OF VERTEBRAL ARTERY

Lateral medullary infarction is due to vertebral artery (80%) or posterior inferior cerebellar artery (20%) occlusion and involves a wedge of medulla posterior to inferior olives. Characteristic of medullary lesions is crossed sensory disturbance: loss of pain and temperature on one side of the face and on the opposite side of the body. This is accounted for by involvement of descending trigeminal tract or nucleus and crossed lateral spinothalamic tract on one side of the brainstem. This crossed phenomenon would not occur with involvement in the upper medulla, pons, and midbrain because at these levels the crossed trigeminothalamic tract and lateral spinothalamic tract run together. A lesion at these levels will cause pain and temperature loss of both the face and body on the side opposite the lesion.



MEDULLA: BRAINSTEM RETICULAR FORMATION

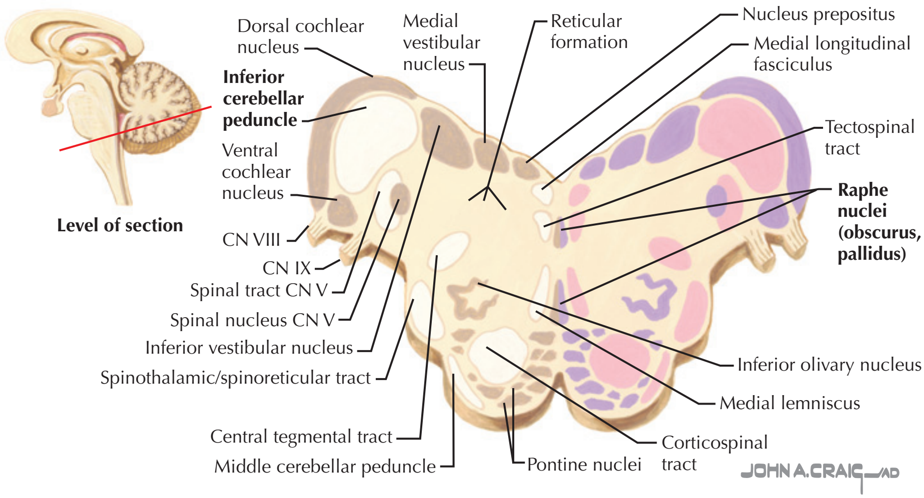
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Reticular formation	Morphologic region from the low medulla through the hypothalamus into the septal region	Constitutes a matrix embedded with nuclei and tracts
Medullary reticular formation	Consists of paramedian, central, and lateral nuclear groups Afferent fibers from spinothalamic, auditory, trigeminal, and vestibular pathways spinoreticular, cerebelloreticular, and corticoreticular projections Efferent fibers from medullary reticular formation project to the thalamus, cerebellum, and spinal cord	Reticular formation is involved in wakefulness Brainstem infarction involving reticular formation results in coma



MEDULLA-PONTINE JUNCTION: COCHLEAR NUCLEI LEVEL

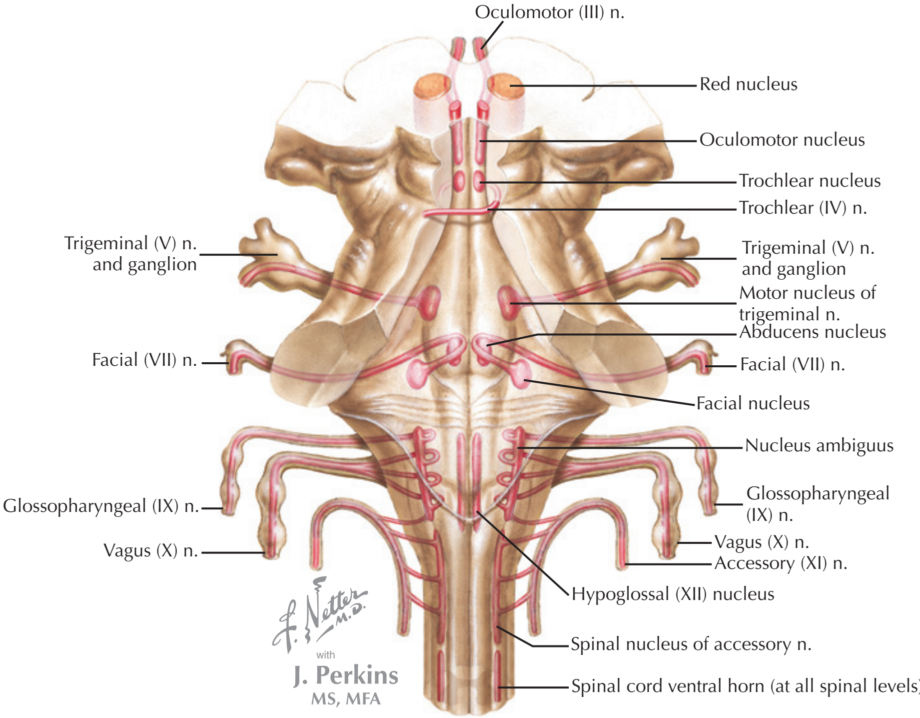
- Raphe nuclei are situated along midline of medulla, pons, and midbrain.
- Midbrain and pontine serotonergic cells project to the diencephalon and cerebral cortex.

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Medullary raphe nuclei	Include nucleus raphe magnus, obscurus, pallidus	Synthesize serotonin, project to the spinal cord
Inferior cerebellar peduncle	Contains mostly crossed olivocerebellar fibers, also posterior spinocerebellar tract	Olivocerebellar fibers may convey information regarding interneuron activity at spinal and brainstem levels Posterior spinocerebellar tract conveys impulses from muscle stretch receptors and touch and pressure receptors in the skin



LOWER MOTOR NEURON ORGANIZATION IN MEDULLA

- Lower motor neurons (LMNs) are found in the spinal cord, medulla, pons, and midbrain.
- LMNs send axons into the cranial nerves, terminating on skeletal muscle fibers, and allow for voluntary movement.



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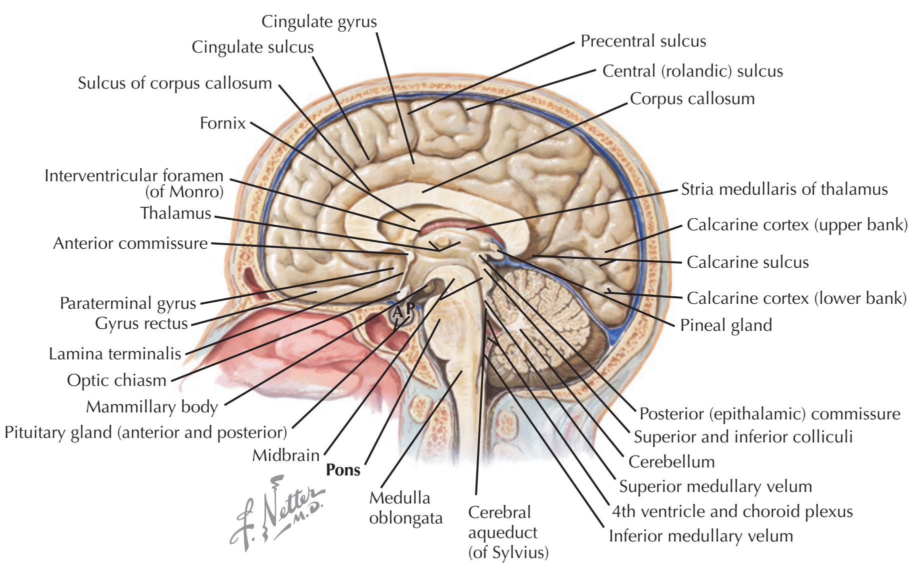
CHAPTER 6

Pons

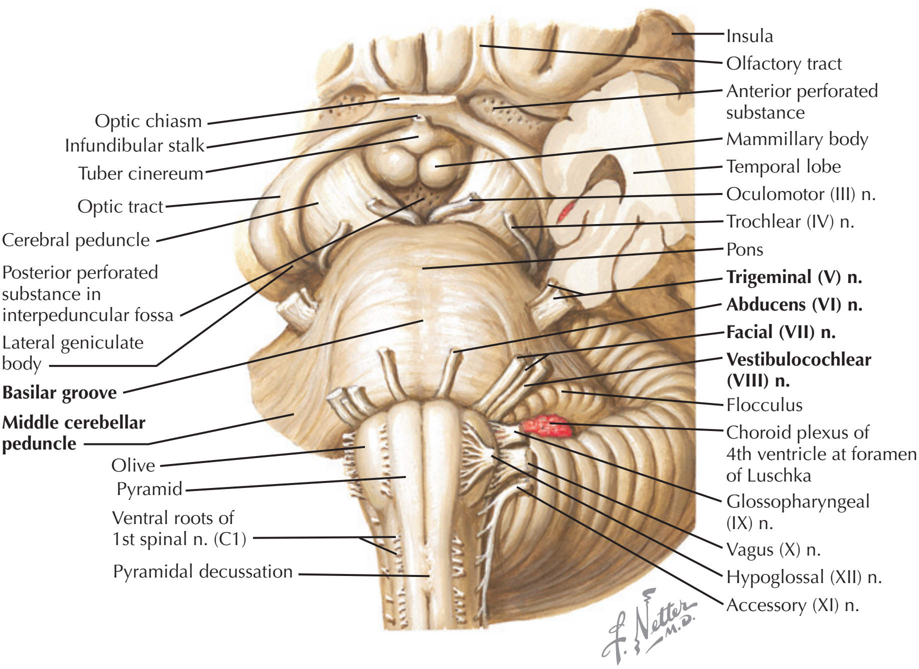
GROSS BRAINSTEM: MIDSAGITTAL VIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Pons (metencephalon)	Separated from the midbrain by superior pontine sulcus and from the medulla by inferior pontine sulcus	Largest portion of the brainstem
Basis pontis	Massive ventral portion; composed of descending tracts, pontine nuclei, and transversely oriented fibers projecting to the cerebellum	Among most common sites for hypertensive bleed; results in locked-in state
Tegmentum (anterior to ventricle)	Smaller dorsal part; contains reticular formation as central core, continuous with reticular formation of medulla and midbrain	Reticular formation is crucial for maintenance of awake state



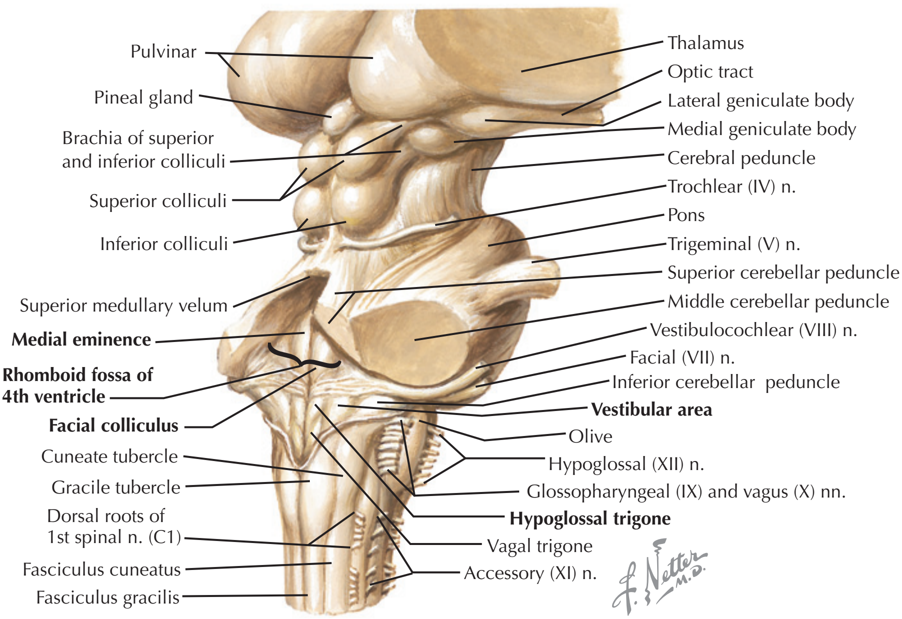
GROSS BRAINSTEM: ANTERIOR VIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Basilar groove (sulcus)	Anterior midline depression	Indicates position of basilar artery
Middle cerebellar peduncle	Formed by predominantly transverse fibers in the ventral pons	Most important pathway from cerebral cortex to contralateral cerebellum, via pontine relay nuclei
Trigeminal nerve (CN-V)	Largest cranial nerve Passes through rostral parts of the middle cerebellar peduncle to reach its nuclei	Supplies muscles of mastication, tensor tympani, tensor veli palatini, mylohyoid, anterior belly of digastric, and facial sensation
Abducens nerve (CN-VI)	Nucleus lies in floor of 4th ventricle	Nerve often is stretched with increased intracranial pressure, resulting in horizontal diplopia
Facial nerve (CN-VII) and vestibulocochlear nerve (CN-VIII)	Exit and enter at cerebellopontine angle (junction of pons, medulla, and cerebellum)	May be compressed with cerebellopontine angle tumors



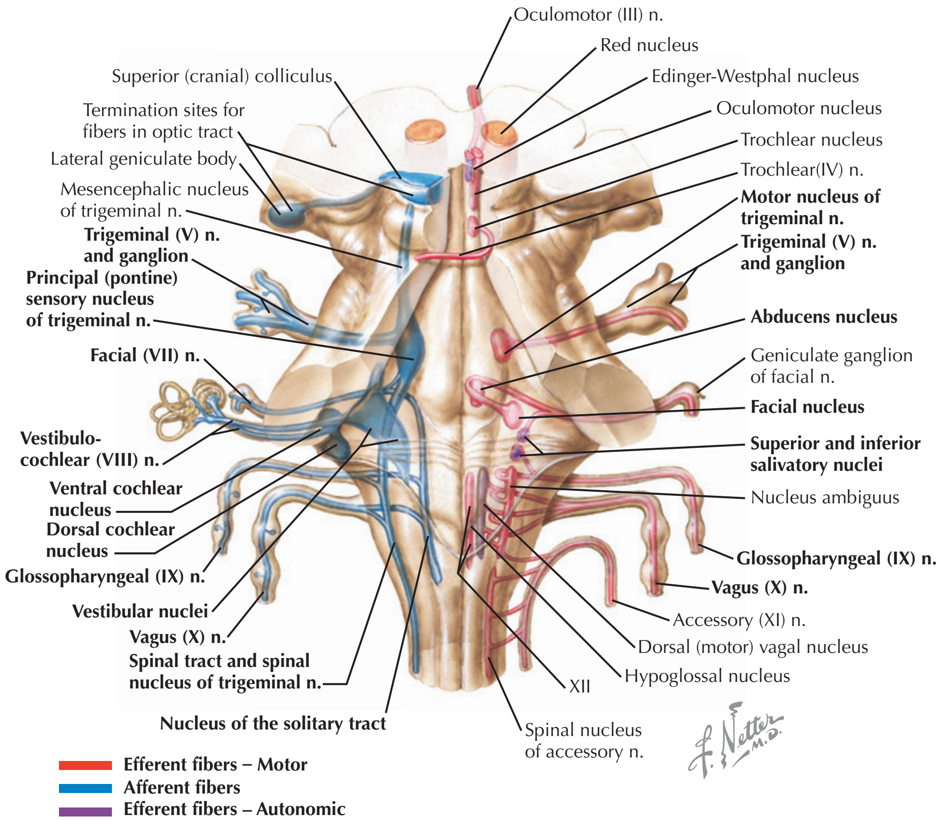
GROSS BRAINSTEM: POSTEROLATERAL VIEW

STRUCTURE	ANATOMIC NOTES
Rhomboid fossa	Forms floor of 4th ventricle, overlying pons and medulla
Fourth ventricle	Extends from the central canal of the cervical cord to the cerebral aqueduct of the midbrain
Vestibular nuclei	Lie beneath the vestibular area
Facial colliculus, hypoglossal trigone	Lie within the medial eminence
Lateral portion of medial eminence	Formed by the abducens nucleus



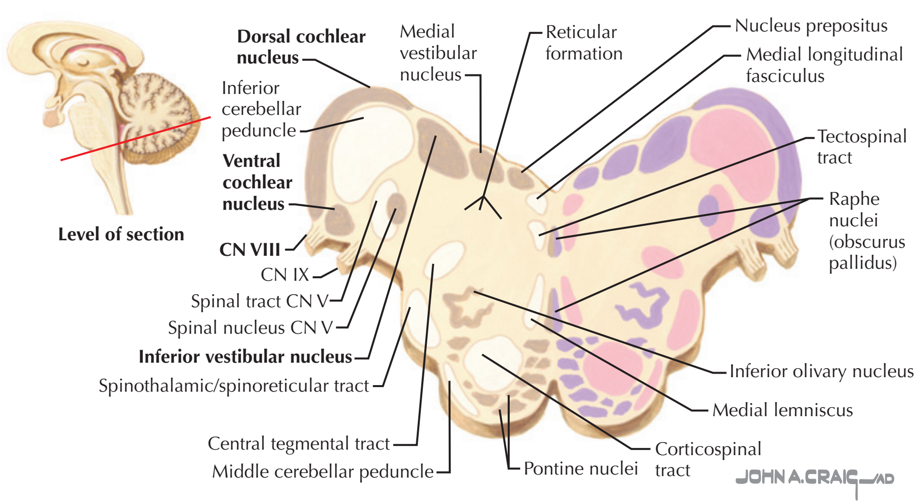
CRANIAL NERVES OF PONS

- Lower motor neurons of pons are localized in the following:
  - Medial column (CN-VI)
  - Lateral column (CN-V, -VII)
- Preganglionic parasympathetic nuclei are located laterally in the superior (CN-VII) salivatory nucleus.
- Secondary sensory nuclei include the following:
  - Main sensory nucleus of CN-V
  - Descending nucleus of CN-V
  - Vestibular and cochlear nuclei (CN-VIII)
  - Nucleus solitarius (CN-VII, -IX, -X)



LEVEL OF THE COCHLEAR NUCLEUS

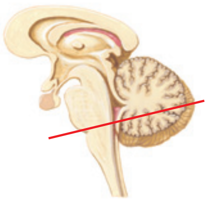
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-VIII	Runs from the internal auditory meatus to the cerebellopontine angle Cochlear division enters the brainstem lateral and caudal to vestibular division	Vestibular nerve mediates equilibrium and spatial orientation; cochlear nerve mediates audition.
Cochlear nerve (division)	Fibers terminate in the dorsal and ventral cochlear nuclei, on the lateral surface of the inferior cerebellar peduncle	Basal cochlear fibers (high tones) end in the dorsal part of the dorsal cochlear nucleus. Apical cochlear fibers (low tones) end in the ventral part of the dorsal cochlear nucleus and in the ventral nucleus.
Dorsal and ventral cochlear nuclei	Fibers project bilaterally to the superior olive, trapezoid body, and lateral lemniscus	Once fibers project bilaterally, unilateral lesion will not result in deafness.
Vestibular nerve (division)	Enters the cerebellopontine angle medial to the cochlear nerve Passes dorsally between the inferior cerebellar peduncle and spinal trigeminal tract Distributes to vestibular nuclei: inferior (largest number), superior, medial, lateral	Acoustic neuromas almost always originate on this division of the 8th nerve.



LEVEL OF THE FACIAL NUCLEUS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Dorsal pons (pontine tegmentum)	Rostral continuation of the medullary reticular formation	Contains cranial nuclei CN-V to CN-VIII, reticular nuclei, and ascending and descending tracts
Medial lemniscus	Lies anterior to the pontine tegmentum	Second-order neurons for position and vibration sensation
Vestibular nuclei	Present in floor of 4th ventricle throughout caudal pons	Posterior circulation ischemia affecting these nuclei result in vertigo, nausea, and vomiting
CN-VII motor nucleus	Pear-shaped mass in the lateral part of the reticular formation	Bell's palsy results from inflammation of CN-VII axons after they leave brainstem
CN-VII root fibers	Form the intramedullary loop around the abducens nucleus, medial to lateral	Both CN-VI and CN-VII would be affected by a lesion in the intramedullary loop area, such as multiple sclerosis, stroke, or tumor
Medial longitudinal fasciculus (MLF)	*Contains:* Ascending fibers from vestibular nuclei projecting to extraocular muscle nuclei, CN-VI internuclear neurons that cross and terminate in CN-III nuclear complex	Lesions of MLF most commonly seen in multiple sclerosis
Intermediate nerve	Enters pons between CN-VII and vestibular nerve (hence "intermediate")	Conveys taste from anterior ⅔ of the tongue via chorda tympani nerve, terminating on rostral part of solitary (gustatory) nucleus (nucleus solitarius)
Ventral pons	Consists of transverse and longitudinal fiber bundles between pontine nuclei	Longitudinal: corticospinal, corticobulbar, corticopontine Transverse: axons of pontine nuclei crossing to the other side to form middle cerebellar peduncle
Pontine nuclei	Grouped into lateral, medial, dorsal, and ventral nuclear masses	Functions vary from balance to wakefulness

LEVEL OF THE FACIAL NUCLEUS *continued*



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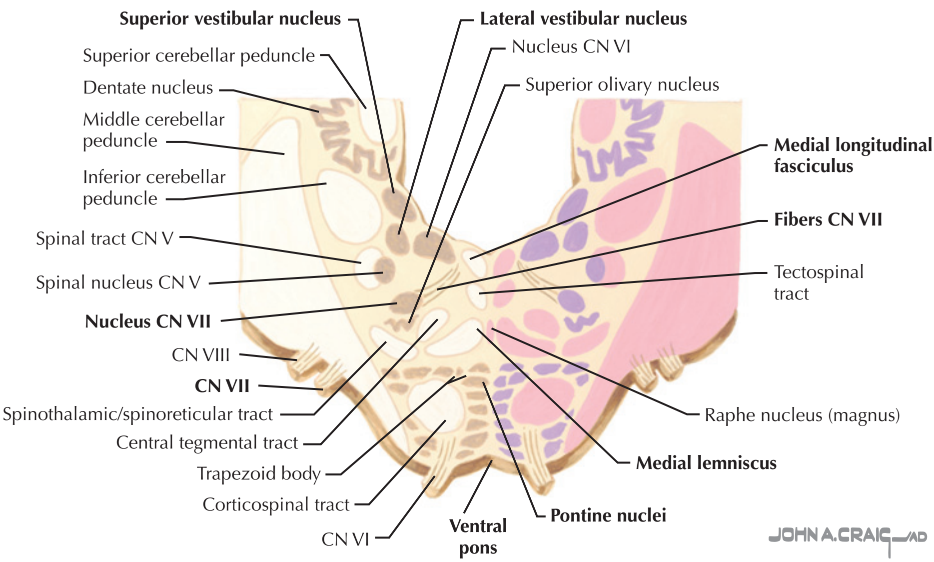
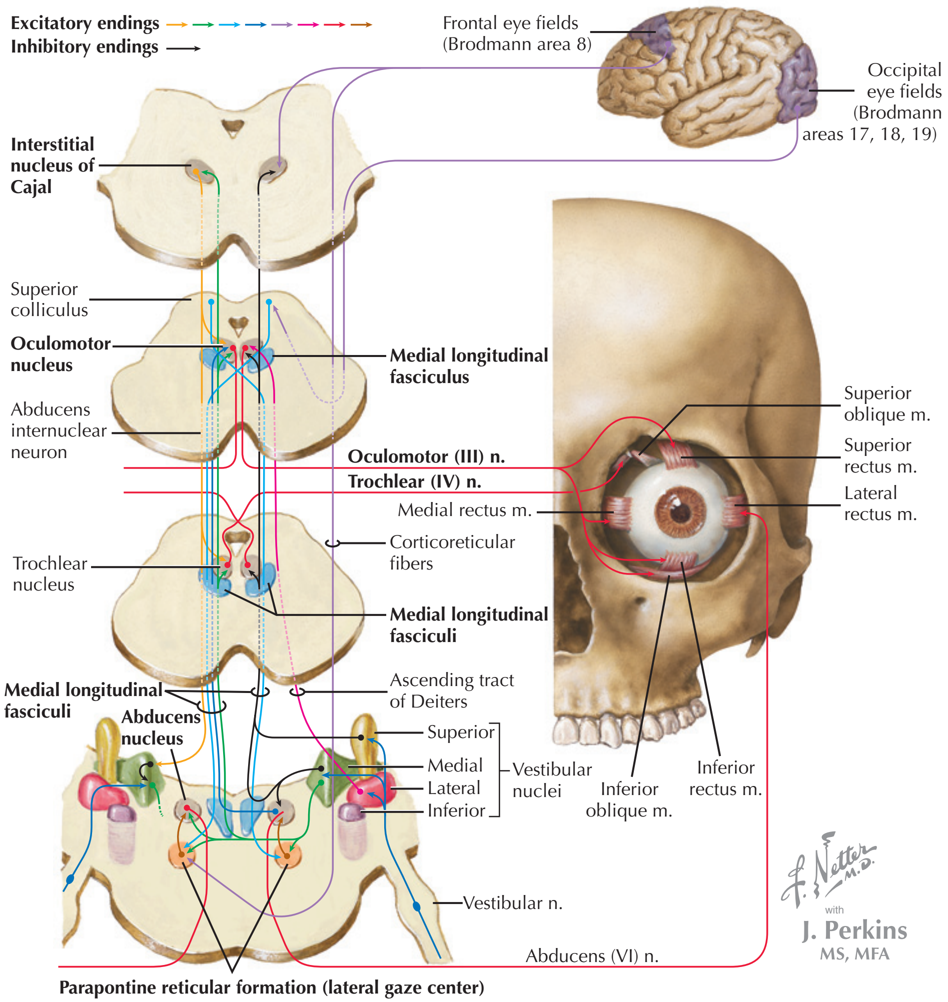


CENTRAL CONTROL OF EYE MOVEMENTS

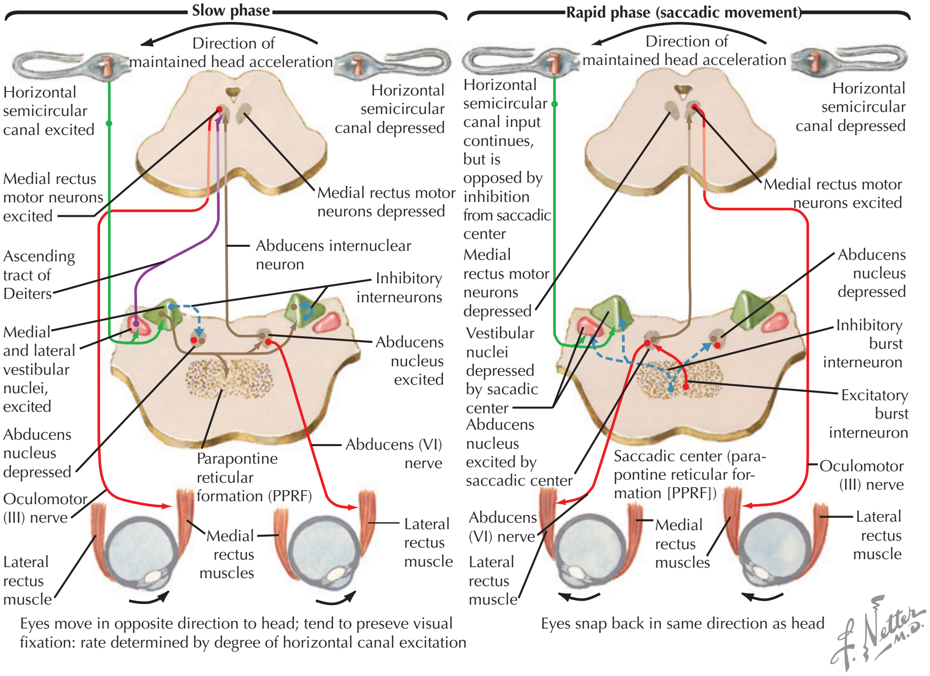
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Paramedian pontine reticular formation (PPRF)	Projects directly to the abducens nucleus Input: • Vestibular nuclei • Superior colliculus • Frontal eye fields • Interstitial nucleus of Cajal Supplies: • Ipsilateral CN VI • Contralateral CN III via MLF • VI nuclear interneurons for medial rectus	Horizontal gaze center Unilateral lesion causes paralysis of ipsilateral gaze Bilateral PPRF lesions may impair both horizontal and vertical gaze
Interstitial nucleus of Cajal	Lies lateral to the MLF in rostral midbrain	Coordinates vertical and oblique eye movements

CENTRAL CONTROL OF EYE MOVEMENTS *continued*



NYSTAGMUS

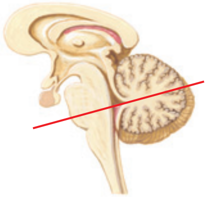
- Alternating back and forth eye movement
- Optokinetic nystagmus: activated by tracking mechanisms
- Vestibular nystagmus: involves vestibular projections via MLF
- Slow phase (drift): caused by asymmetrical input from the following:
    - Semicircular canals
    - Vestibular nuclei
    - Vestibular cerebellum
    - Fast phase (saccade): provoked return to forward position



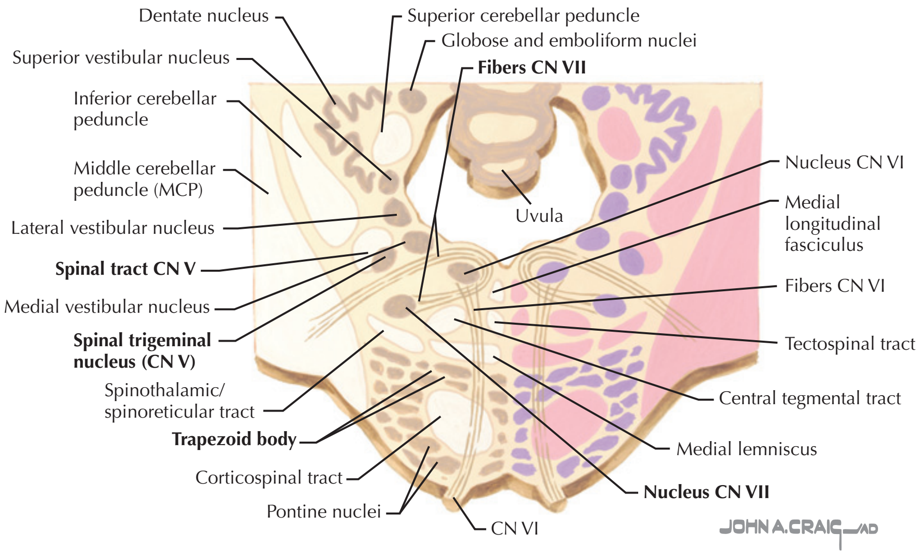
LEVEL OF FACIAL GENU

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Trapezoid body	Transverse fibers in ventral pontine tegmentum Fibers arise from ventral cochlear nucleus Most fibers cross to the other side, through the medial lemniscus Reach the ventrolateral tegmentum, turn sharply longitudinally Form lateral lemniscus Lateral lemniscus terminates in the inferior colliculus	Second-order neurons from the cochlear nuclei
Motor nucleus of CN-VII	Forms column in ventrolateral tegmentum, dorsal to superior olive, ventromedial to spinotrigeminal nucleus	Supplies axons to the muscles of facial expression
CN-VII root fibers	Make sharp lateral bend around rostral abducens nucleus Pass ventrolaterally, medial to the spinotrigeminal complex, lateral to the superior olive	Emerge from brainstem near caudal pons, at CP angle, where may be compressed by CP angle tumors
Spinal trigeminal nucleus (CN-V)	Forms long column medial to spinal trigeminal tract Rostrally merges with main sensory nucleus of CN-V Caudally blends into *substantia gelatinosa* Axons cross to contralateral medial lemniscus Terminate in the ventroposteromedial (VPM) nucleus of thalamus	Mediates pain sensation to face. Throughout, face is upside down: jaw dorsal, forehead ventral

LEVEL OF FACIAL GENU *continued*

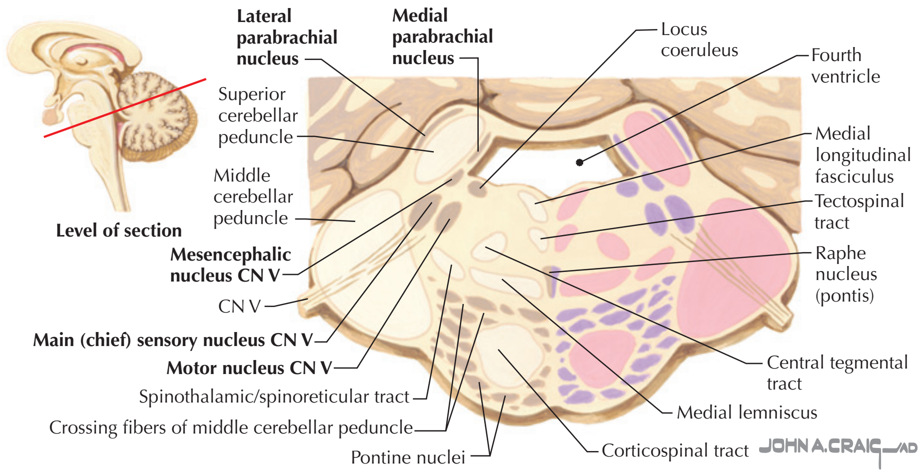


Level of section



LEVEL OF THE TRIGEMINAL NUCLEI

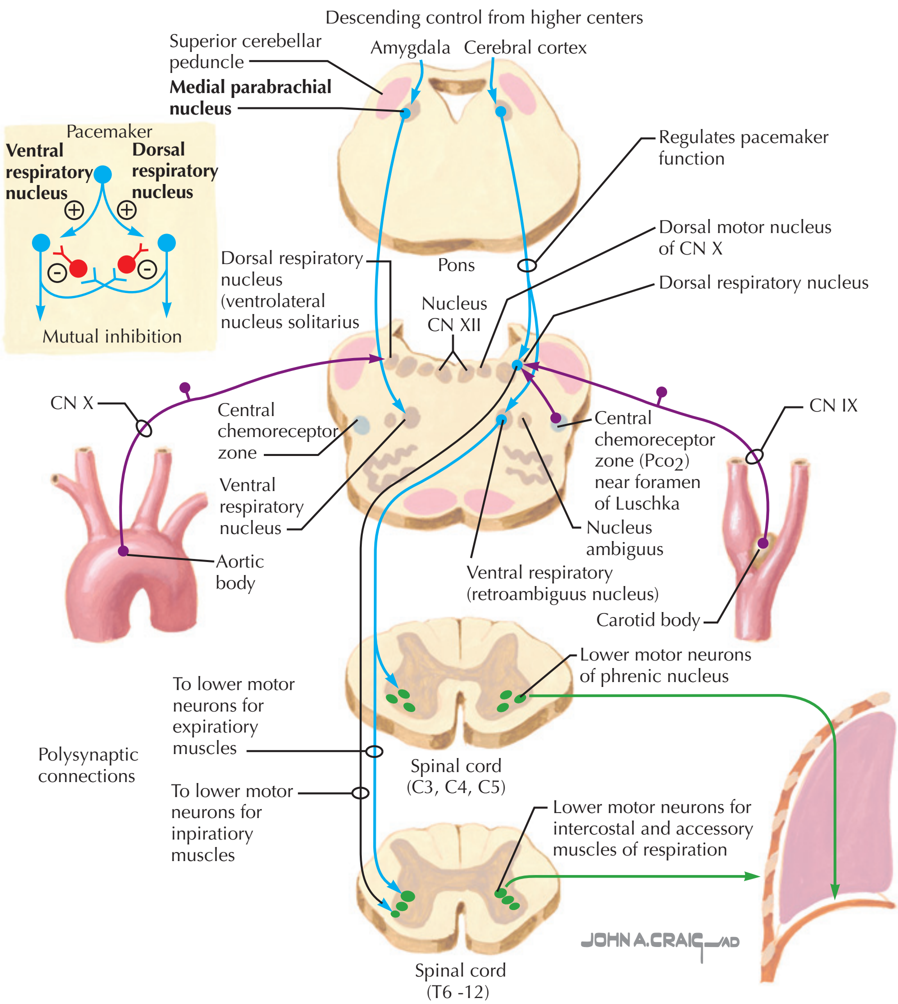
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Main sensory nucleus of CN-V	Axons travel crossed and uncrossed to VPM nucleus of thalamus	Mediates touch and pressure, distributed as in spinal trigeminal nucleus
Mesencephalic nucleus of CN-V	Slender cell column near lateral margin of the central gray of the upper 4th ventricle and cerebral aqueduct Unique because primary sensory neurons are in this brainstem nucleus, not in the trigeminal ganglion Central pathway remains obscure	Mediates proprioception from teeth, periodontium, muscles of mastication, and joint capsules; controls force of bite
Motor nucleus of CN-V	Ovoid column medial to main sensory nucleus and motor root	Supplies muscles of mastication (masseter, temporalis, medial and lateral pterygoids), tensor tympani and veli palatini, mylohyoid, and anterior belly of digastric
Parabrachial nuclei	Juxtaposed to brachium conjunctivum (superior cerebellar peduncle)	Synaptic station for gustatory pathways



PARABRACHIAL NUCLEI: CONTROL OF RESPIRATION

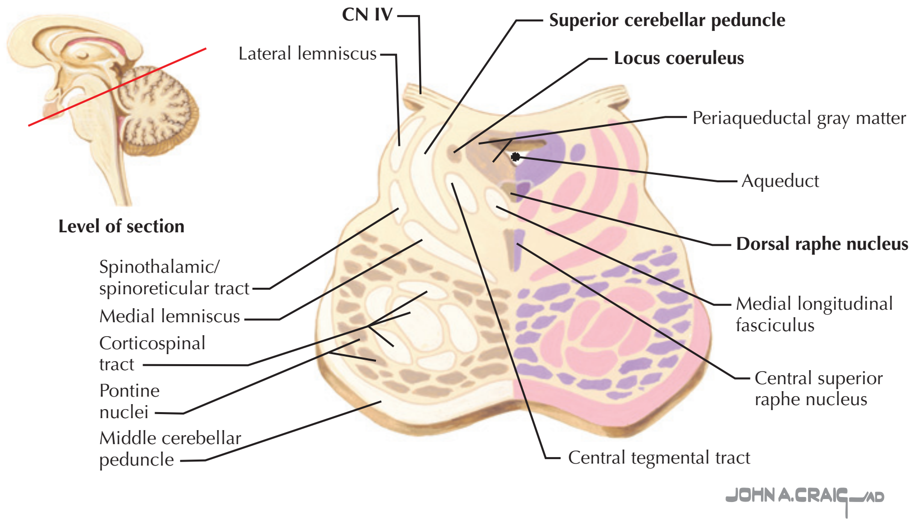
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Parabrachial nuclei (PBN)	Contains neuromelanin-containing catecholamine neurons Fibers connect with hypothalamus, amygdala, stria medullaris, brainstem nuclei	Believed to play a role in autonomic regulation
Medial PBN	Together with a lateral segment, makes up PBN	Acts as respiratory pacemaker to regulate dorsal respiratory nucleus (DRN) (lateral nucleus solitarius) and ventral respiratory nucleus (VRN) (nucleus retroambiguus)
Dorsal respiratory nucleus axons	Cross and terminate on phrenic nerve cervical cord motor neurons and thoracic cord motor neurons	Supplying inspiratory respiratory muscles
Ventral respiratory nucleus axons	Cross and terminate on thoracic cord motor neurons	Supplying expiratory respiratory muscles

PARABRACHIAL NUCLEI: CONTROL OF RESPIRATION *continued*



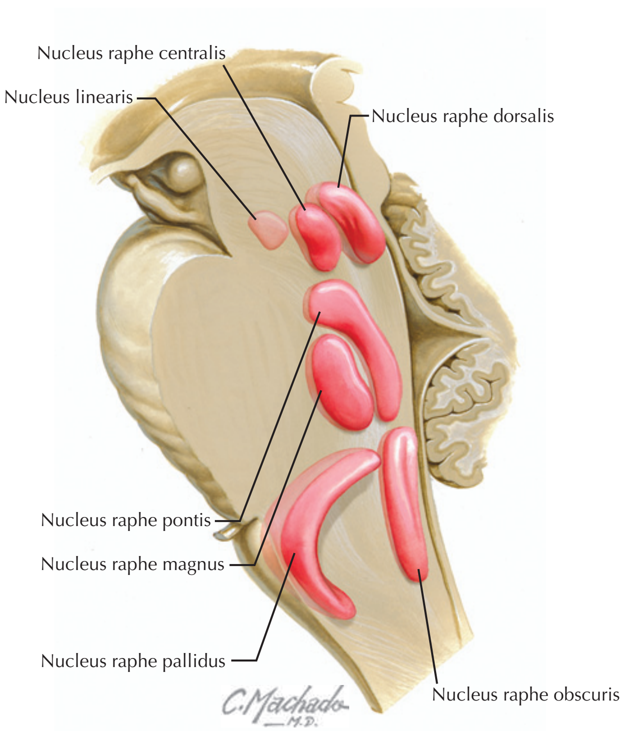
PONS-MIDBRAIN JUNCTION: CN-IV

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Pons-midbrain junction (isthmus rhombencephali)	Fourth ventricle narrows, resembles cerebral aqueduct Roof consists of superior medullary velum	Coma and central neurogenic hyperventilation result with pathology at this level
CN-IV	Decussates in the superior medullary velum	Supplies superior oblique muscle
Superior cerebellar peduncle	Lies medial to the lateral lemniscus Arises from dentate, emboliform, and globose nuclei of cerebellum Decussates in midbrain, ends in red nucleus and VL nucleus of thalamus	Forms the most important efferent system from the cerebellum
Locus ceruleus	Pigmented cells near periventricular gray of upper 4th ventricle	Lost in Parkinson's disease
Nuclei of raphe region	Part of brainstem nuclei of reticular formation, which also include parmedian, medial, and lateral reticular nuclear groups	Contain serotonin (5-hydroxytryptamine, 5-HT).



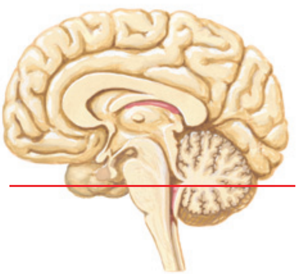
RAPHE NUCLEI

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Raphe nuclei	Situated along the midline of medulla, pons, midbrain	Caudal group involved in pain mechanisms; rostral group involved with wakefulness, alertness, and sleep
Inferior central nucleus	Appears at the pontomedullary junction and caudal pons; represents the rostral part of the nucleus raphe magnus	Electrical stimulation of this nucleus inhibits spontaneous activity of thalamic neurons in cats
Nucleus raphe pontis	Rostral to the inferior central nucleus	Receives vestibular input and is involved in the generation of saccadic eye movements
Superior central nucleus (i.e., median raphe nucleus)	Rostral extension of the pontine raphe nuclei	Together with dorsal nucleus, give rise to principal serotonin ascending fibers
Dorsal nucleus of raphe	On each side of midline, dorsal to MLF, merges with dorsal tegmental nucleus	Together with superior central nucleus, give rise to principal serotonin ascending fibers

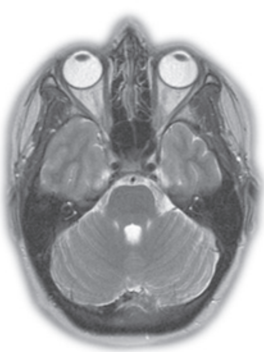


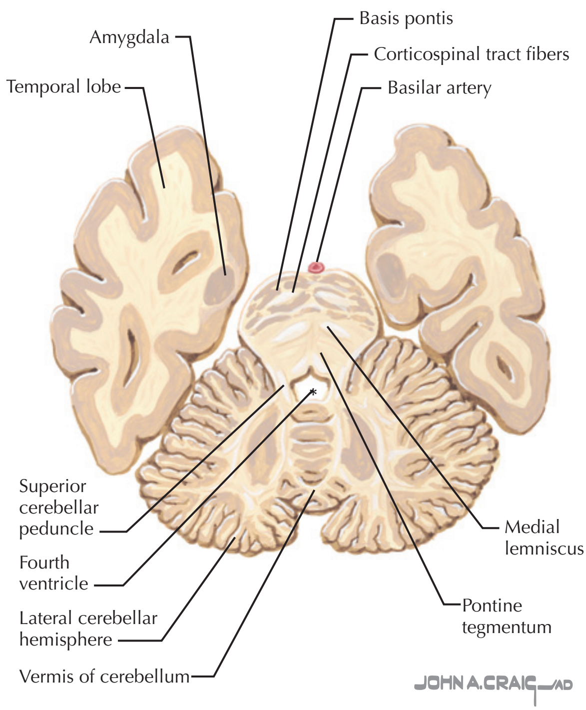
ROSTRAL PONS

MAGNETIC RESONANCE IMAGING: CROSS–SECTIONAL CORRELATION



Level of section (rostral pons)



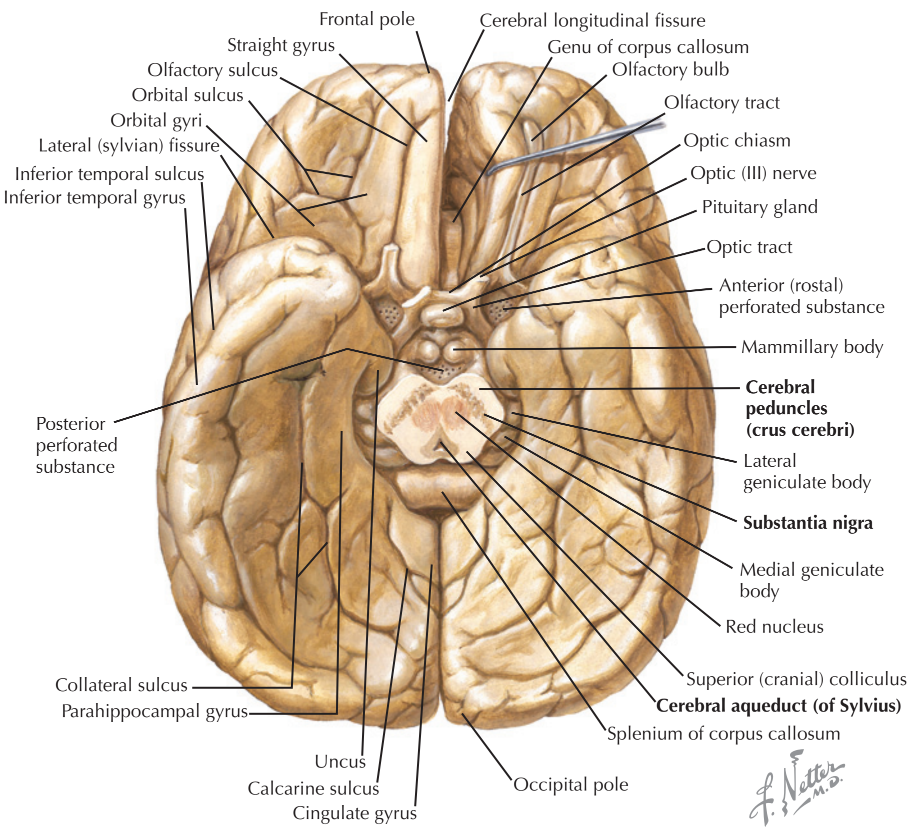


CHAPTER 7

Midbrain (Mesencephalon)

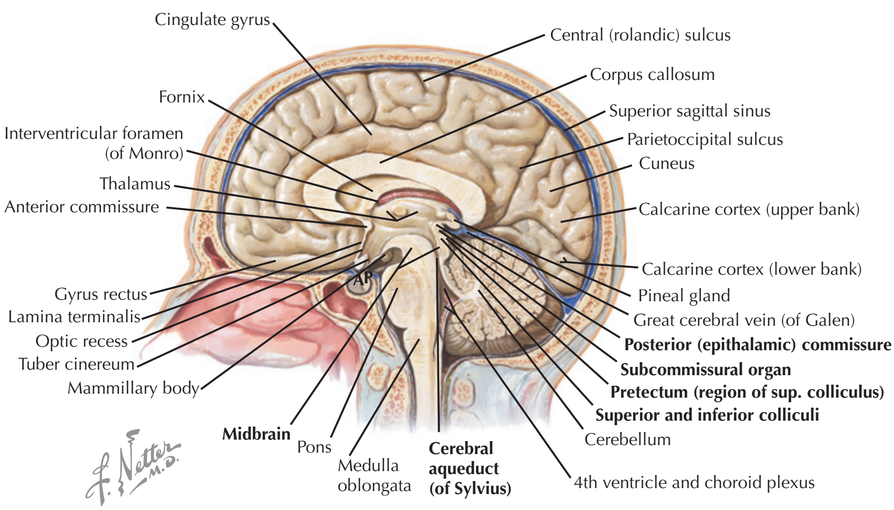
MIDBRAIN IN SITU

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Tectum	Dorsal to cerebral aqueduct	Lesions here cause pupils to be in midposition and light-fixed, but to spontaneously fluctuate in size.
Crura cerebri	Separated from tegmentum by pigmented nuclear mass, the substantia nigra	Loss of pigmented cells characteristic of Parkinson's disease
Tegmentum	Located centrally Cerebral aqueduct is surrounded by central gray matter that separates tectum from tegmentum	Rostral continuation of the pontine tegmentum
Cerebral peduncle	Dorsal part is tegmentum Ventral part is crus cerebri	Denotes ½ of the midbrain, excluding tectum



GROSS BRAINSTEM: MIDSAGITTAL VIEW

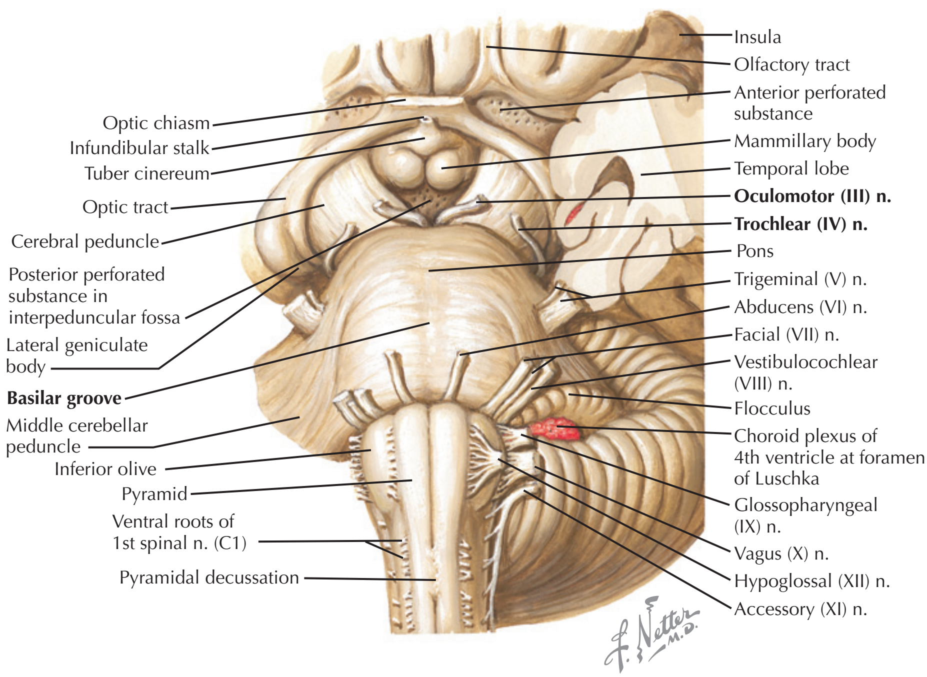
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Superior colliculus region	Known as *pretectum*	Superior colliculi influence the position of the head and eyes in response to visual, auditory, and somatic stimuli
Inferior colliculi	3 main nuclei: • Central • Pericentral • External	Relay nuclei transmitting auditory information to medial geniculate body, thence to primary auditory cortex
Pretectal region	Immediately rostral to superior colliculus at the posterior commisure level	Principal midbrain center involved in pupillary light reflex
Posterior commisure	Region of transition from midbrain to diencephalon	Lesions here produce bilateral eyelid retraction and impaired vertical eye movement
Subcommisural organ	Modified ependymal plate in the roof of the cerebral aqueduct, immediately beneath posterior commisure	Function in humans is unknown



Midbrain (Mesencephalon)

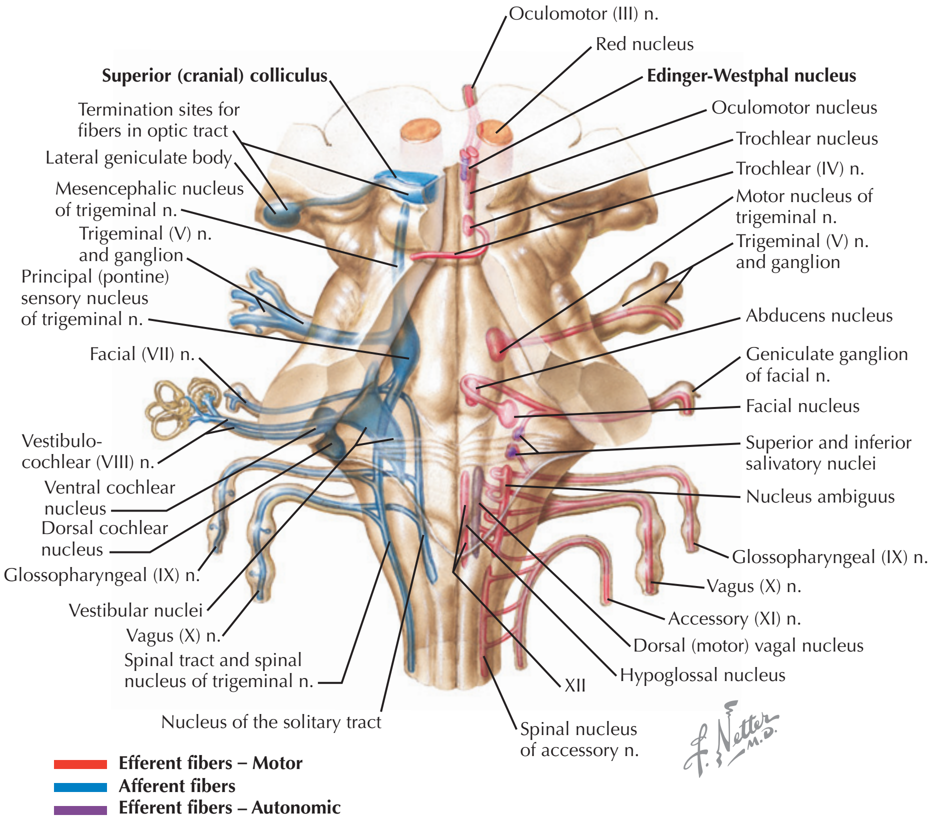
GROSS BRAINSTEM: ANTERIOR VIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Basilar groove (sulcus)	Anterior midline depression	Indicates position of basilar artery
Oculomotor nerve (cranial nerve [CN]-III)	Emerges from interpeduncular fossa between the crura cerebri	Weber syndrome: CN-III palsy with contralateral hemiparesis resulting from involvement of CN-III and crus cerebri (descending corticospinal tract)
Trochlear nerve (CN-IV)	Exits dorsal midbrain, crosses in superior medullary velum, and courses anteriorly around brainstem	Longest, most delicate cranial nerve Often injured in head trauma, causing diplopia and head tilt



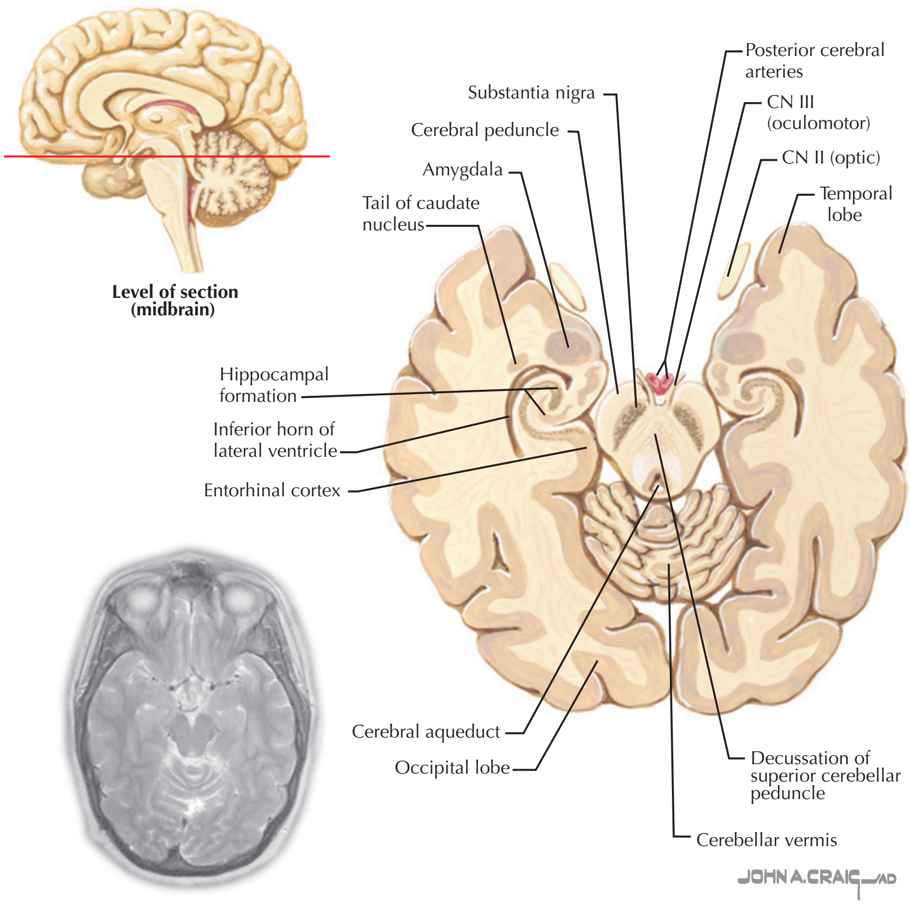
CRANIAL NERVES OF MIDBRAIN

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Nucleus of Edinger-Westphal (CN-III)	Preganglionic parasympathetic nucleus Gives rise to uncrossed parasympathetic fibers	Involved in accommodation and pupillary light reflex
Superior colliculus	Receive input from optic tract	Visual way station, together with lateral geniculate body
Inferior colliculus	Receives input from cochlear nuclei and other accessory auditory nuclei	Auditory way station, together with medial geniculate body



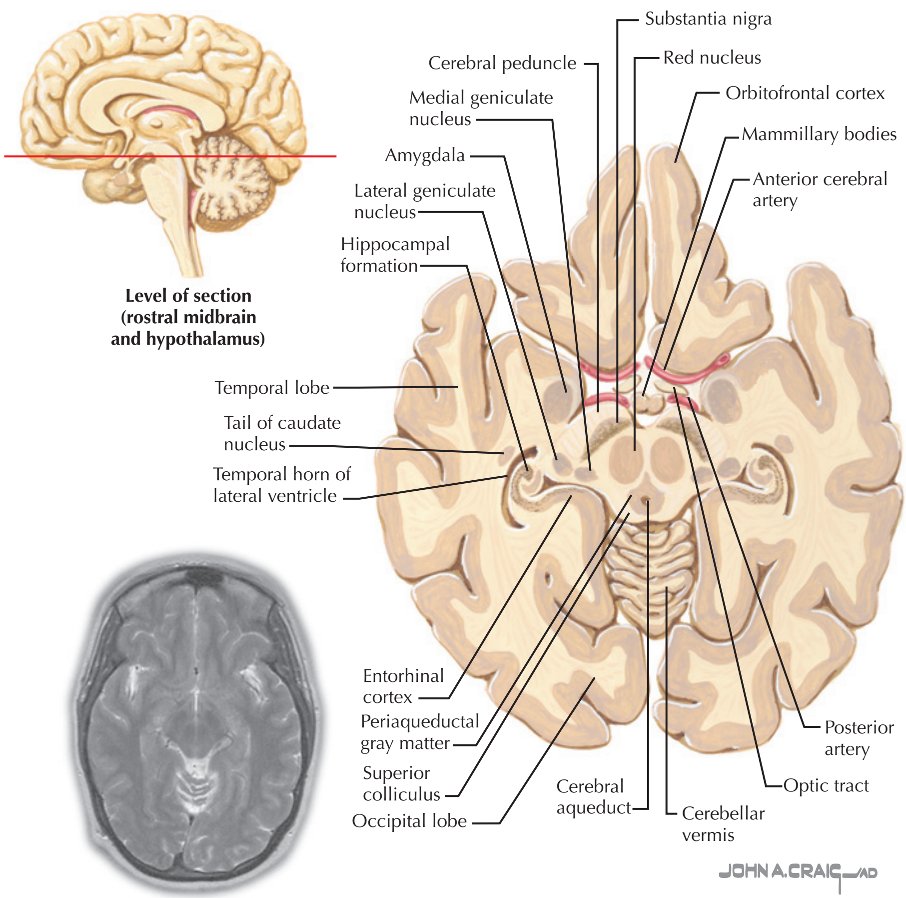
LOWER MIDBRAIN

MAGNETIC RESONANCE IMAGING (MRI): CROSS-SECTIONAL CORRELATION



UPPER MIDBRAIN

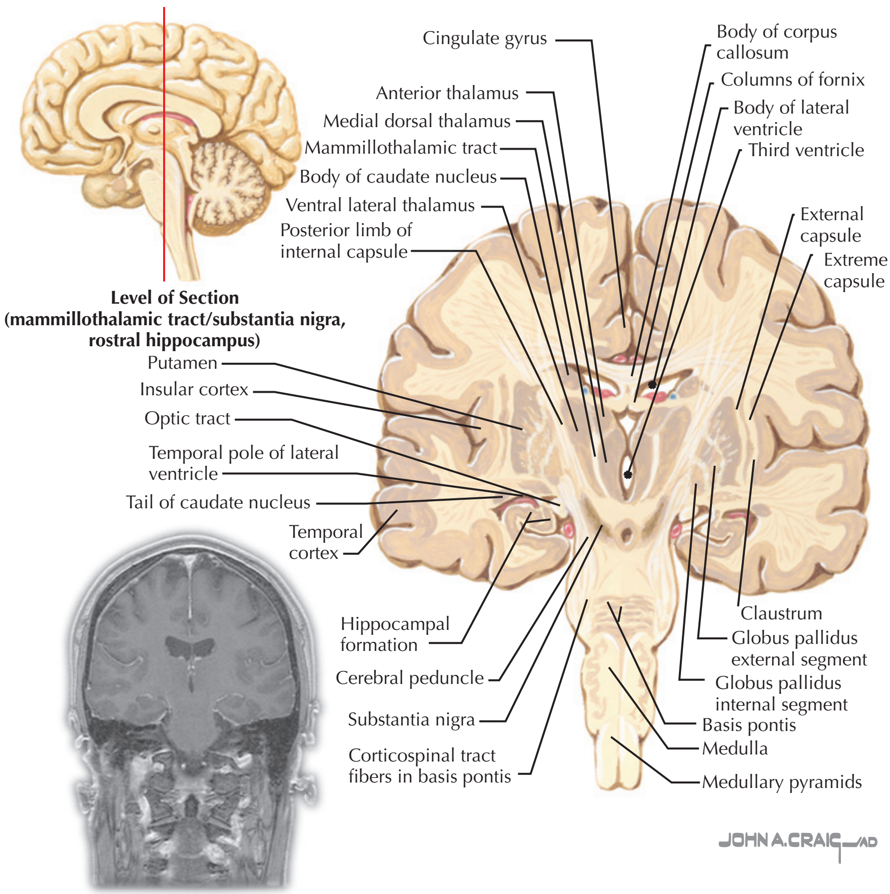
MRI: CROSS-SECTIONAL CORRELATION

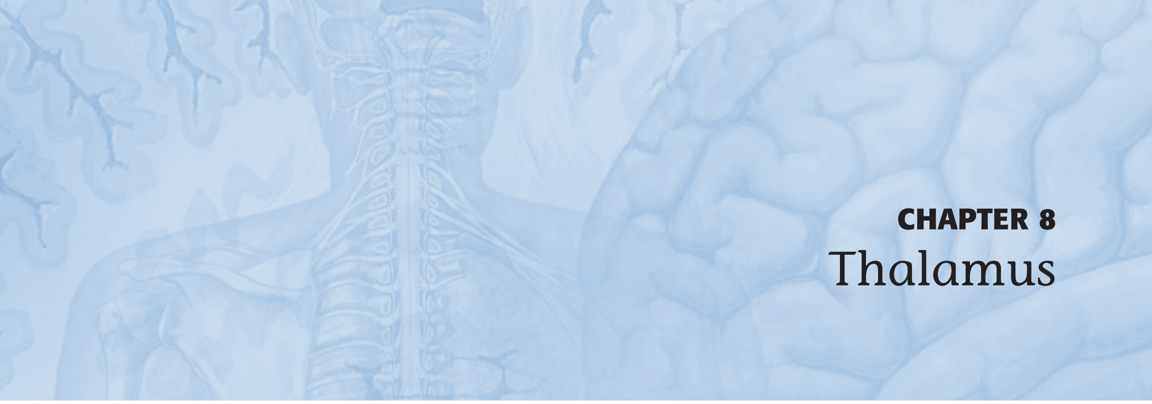


Level of section (rostral midbrain and hypothalamus)

CORONAL SECTION THROUGH SUBSTANTIA NIGRA

MRI: CROSS-SECTIONAL CORRELATION

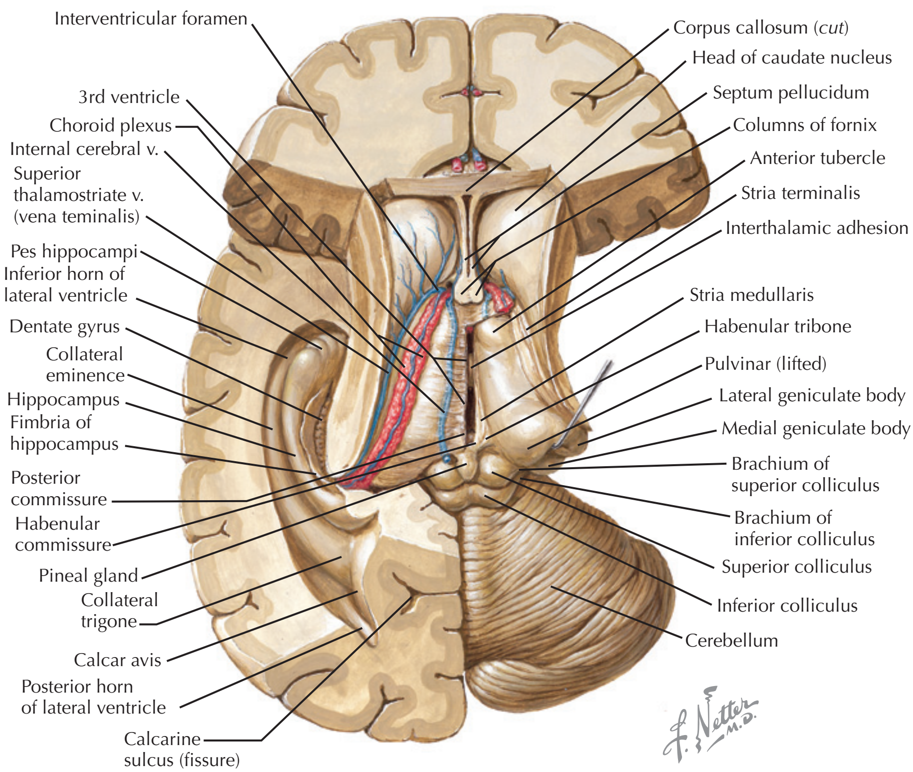




CHAPTER 8
Thalamus

THALAMUS IN SITU

Location	Paired, medially placed, deep egg-shaped nuclear structures that form part of the lateral wall of the 3rd ventricle
Architecture	Composed of multiple nuclei, which receive input from many cortical and subcortical structures
Function	Functions as the "gateway to the cortex." Sensory input, other than olfaction, relays through the thalamus before reaching the cortex. All output to the cortex from the cerebellum and basal ganglia relays through the thalamus. The thalamus also relays limbic input to the cortex
Clinical Significance	Due to its multiple functions, damage to the thalamus can cause many problems, including sensory abnormalities, visual-field deficits, and behavioral changes Lesions to the sensory area can cause numbness on the contralateral body and face

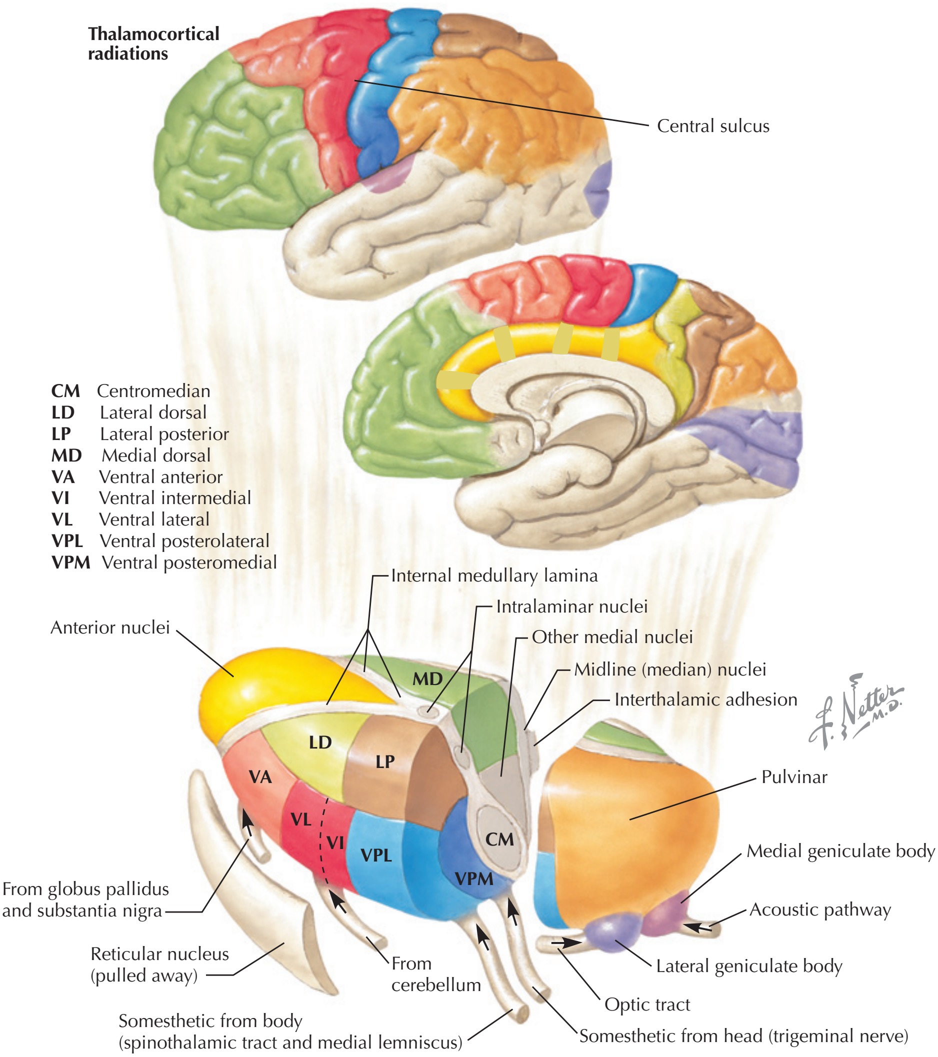


THALAMIC NUCLEI

- The thalamus is composed of many nuclei, which have motor, sensory, and limbic connections.
- Some nuclei are nonspecific in nature.

NUCLEUS	INPUT(S)	OUTPUT(S)	FUNCTION
Sensory Nuclei			
Ventroposterolateral (VPL)	Spinothalamic tract Medial lemniscus	Primary sensory cortex	Somatic sensation for contralateral body
Ventroposteromedial (VPM)	Trigeminothalamic tract, pontine taste area	Primary sensory cortex	Somatic sensation for contralateral face, taste
Medial geniculate (MGN)	Brachium of the inferior colliculus	Primary auditory cortex	Hearing
Lateral geniculate (LGN)	Optic tract	Primary visual cortex	Vision
Pulvinar	Lateral geniculate body (LGB), medial geniculate body (MGB), superior and inferior colliculi	Visual association cortex	Visual processing
Motor Nuclei			
Ventrolateral (VL)	Cerebellum and basal ganglia	Primary motor cortex	Modulation and coordination of movement
Ventroanterior (VA)	Basal ganglia	Premotor cortex	Initiation and planning of movement
Ventrointermedial (VI)	Cerebellum	Primary motor cortex	Coordination of movement
Limbic and Nonspecific Projection Nuclei			
Anterior (Ant)	Mammillothalamic tract	Cingulate cortex	Memory storage and emotion
Mediodorsal (MD)	Temporal lobe, amygdala, hypothalamus	Prefrontal cortex	Motivation, drive, emotion
Centromedian (CM)	Slow pain pathways	Nonspecific cortical projections	Emotional content of pain

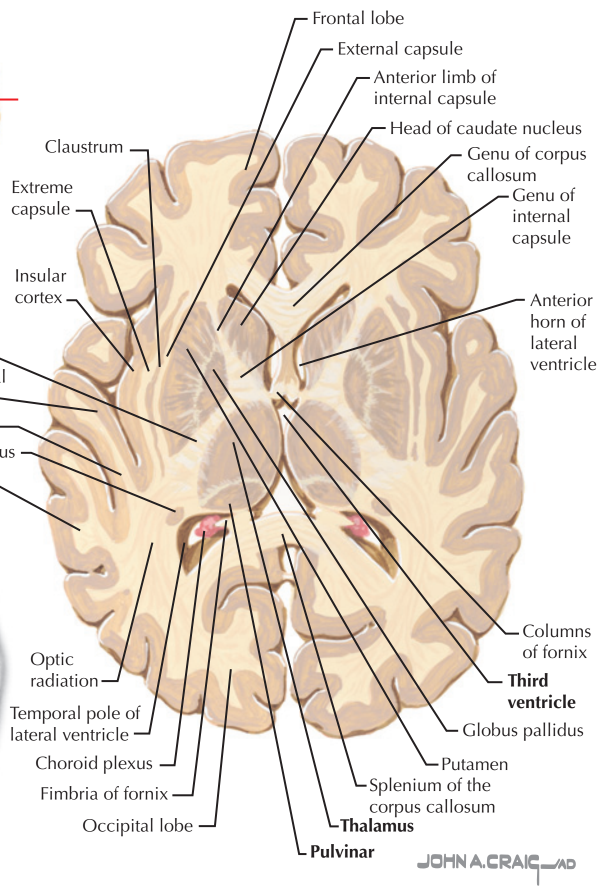
THALAMIC NUCLEI *continued*

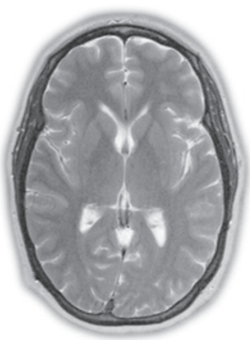


THALAMUS IN HORIZONTAL SECTION

- Thalami form the lateral walls of the third ventricle.
- Posterior limb of the internal capsule separates thalamus from the lentiform nucleus.
- Pulvinar is demonstrated in the artwork below.

Level of section (head of caudate and mid thalamus)

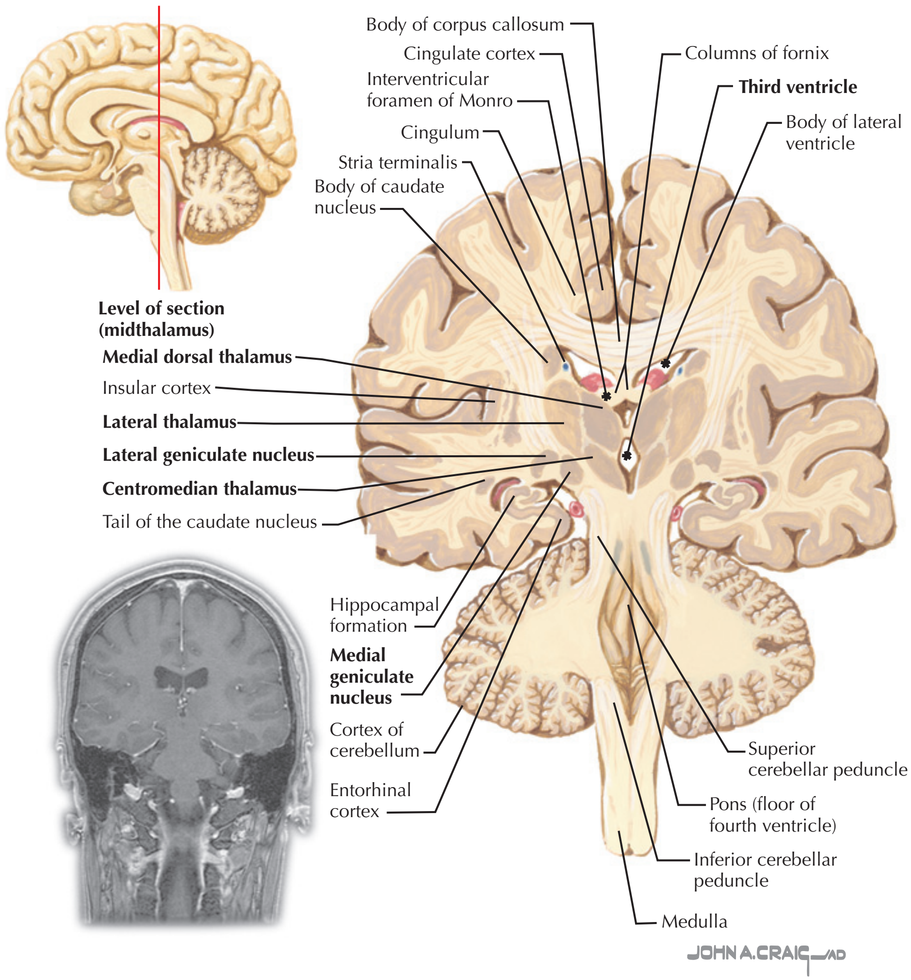




THALAMUS IN CORONAL SECTION

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Thalamus	Individual nuclei are anatomically separated. The thalamus defines the borders of the 3rd ventricle	
LGN of the thalamus	Comma-shaped, lateral nucleus of the thalamus	Serves as the visual relay center from the optic tract to occipital cortex. Lesions can cause visual field defects
MGN of the thalamus	Medial to the lateral geniculate nucleus	Serves as the auditory relay center from the inferior colliculus to auditory cortex
MDN of the thalamus	Most dorsal and medial nucleus; forms part of the wall of the 3rd ventricle	Part of the limbic system
CM thalamus	Located ventral to the MDN	Involved in the central modulation and perception of pain
Lateral thalamus	Contains multiple nuclear structures, including the VL and VPL	Involved in motor and sensory relays

THALAMUS IN CORONAL SECTION *continued*



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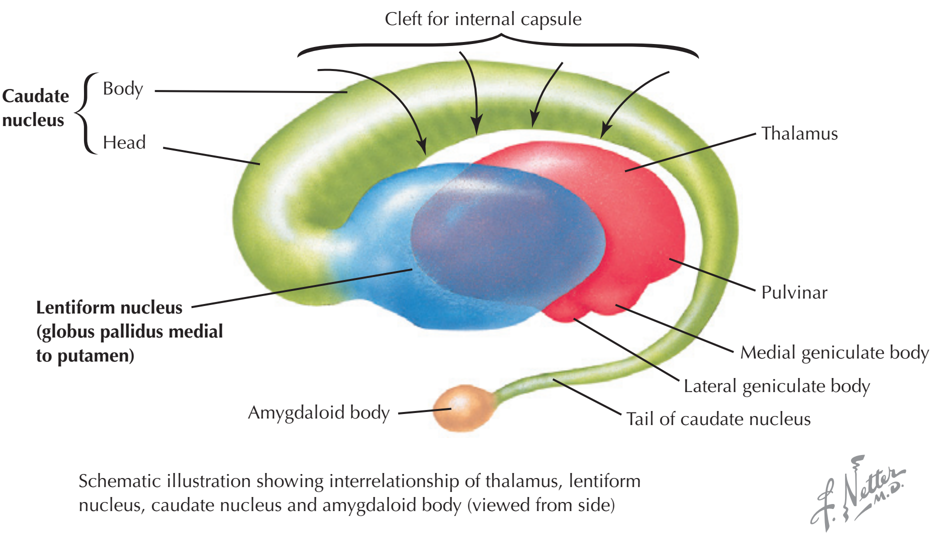
CHAPTER 9

Basal Ganglia

9 Basal Ganglia

BASAL GANGLIA: OVERVIEW

Function	Involved in the initiation and modulation of movement
Organization	Deep set of nuclear structures Receive input from the cerebral cortex, process it, and relay back to the cerebral cortex via the thalamus
Structures	Caudate nucleus, putamen, globus pallidus (internal and external segments), subthalamic nucleus, substantia nigra
Disease Status	Diseases can lead to a paucity of movement (hypokinetic states) or abnormal movements (hyperkinetic states)



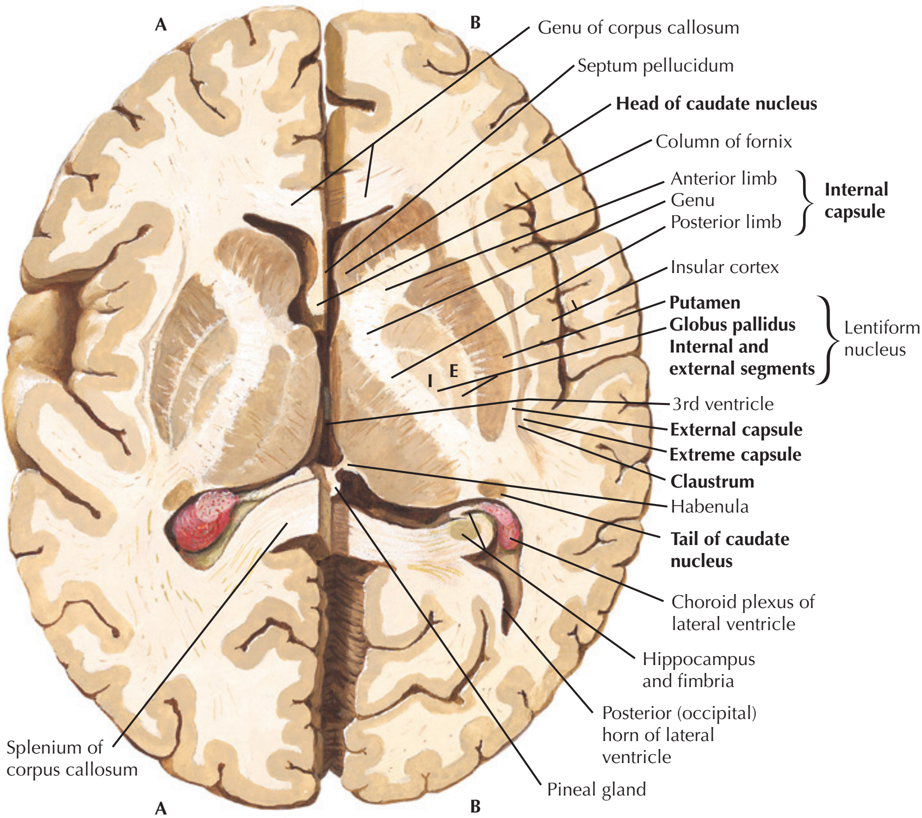
Schematic illustration showing interrelationship of thalamus, lentiform nucleus, caudate nucleus and amygdaloid body (viewed from side)

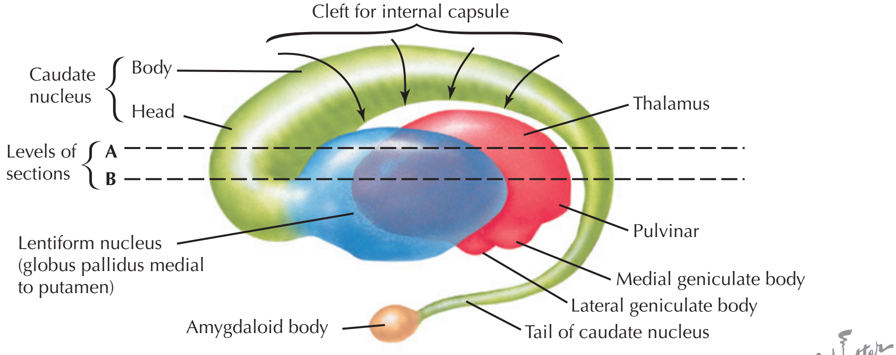
AXIAL VIEW OF THE BRAIN AT THE LEVEL OF THE BASAL GANGLIA

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Caudate nucleus*	C-shaped structure that is lateral to the lateral ventricle The *head of the caudate* bulges into the frontal horn of the lateral ventricle The *body of the caudate* sweeps into a C shape with the lateral ventricle The *tail of the caudate* is located in the temporal lobe superior and lateral to the temporal horn of the lateral ventricle	Serves as the major input nucleus of the basal ganglia Degeneration of the caudate is typical of Huntington's disease and can be easily appreciated on computed tomography scans, with loss of the normal indentation into the lateral ventricle
Internal capsule	U-shaped in axial sections The anterior limb separates the head of the caudate nucleus from the lentiform nucleus (putamen and globus pallidus) The posterior limb separates the thalamus from the globus pallidus The genu is the bend that connects the anterior and posterior limbs	Important white matter structure that conduits information from the basal ganglia, thalamus, and cerebellum to cortex The posterior limb contains the descending upper motor neurons from the cortex
Putamen*	Lens-shaped structure lateral to the globus pallidus Anteriorly and inferiorly, it is connected to the caudate Together the putamen and caudate are called the *corpus striatum*	Although separated by the internal capsule, the putamen is histologically and functionally equivalent to the caudate
Globus pallidus (GPe and GPi)*	Composed of an internal (GPi) and an external (GPe) segment Conspicuously pale, hence the name, which means "pale globe" Together, putamen and globus pallidus are called the *lentiform nucleus*	The GPi serves as the major output nucleus of the basal ganglia system The GPe is part of the internal circuitry of the basal ganglia
External capsule	Thin white matter band lateral to putamen	
Claustrum	Thin gray matter band lateral to the external capsule	Function not well elucidated
Extreme capsule	Thin white matter band lateral to claustrum	

*Structures of the basal ganglia

AXIAL VIEW OF BRAIN AT THE LEVEL OF THE BASAL GANGLIA *continued*





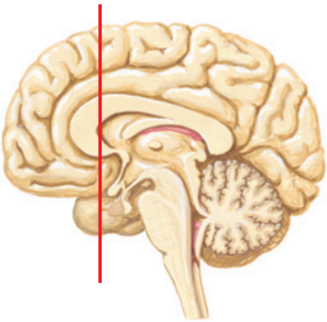
Schematic illustration showing interrelationship of thalamus, lentiform nucleus, caudate nucleus and amygdaloid body (viewed from side)

CORONAL VIEW OF THE BRAIN AT THE LEVEL OF THE HEAD OF THE CAUDATE

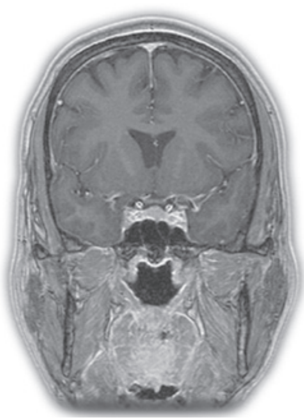
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Nucleus accumbens	Ventral nuclear structure located at the junction of the caudate and putamen	Involved in modulation of emotions by communicating with the limbic system Implicated in addiction behaviors
Head of the caudate nucleus	Note again that it bulges into the frontal horn of the lateral ventricle	
Anterior limb of the internal capsule	In this coronal view, it can be seen separating the caudate and putamen Note the bands of gray matter connecting the caudate and putamen	Contains fibers traveling from cerebellum and basal ganglia to the cortex
Putamen	At this anterior level, the globus pallidus is not yet visible	
External capsule, claustrum, extreme capsule	Again, note the relationship of these 3 structures to each other	

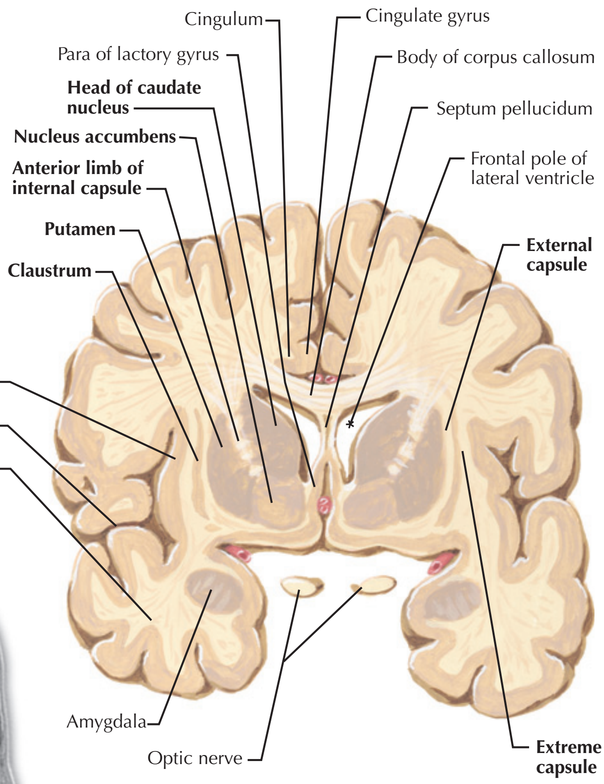
CORONAL VIEW OF THE BRAIN AT THE LEVEL OF THE HEAD OF THE CAUDATE

continued



Level of section (head of caudate nucleus/ nucleus accumbens)

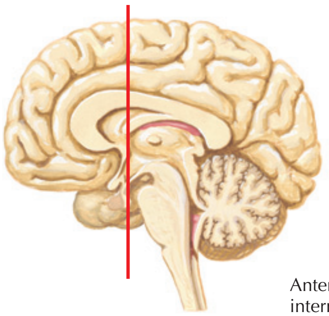




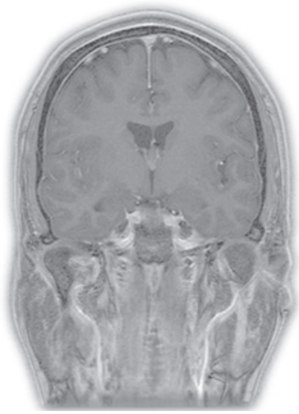
CORONAL VIEW OF THE BRAIN AT THE LEVEL OF THE ANTERIOR LIMB OF THE INTERNAL CAPSULE

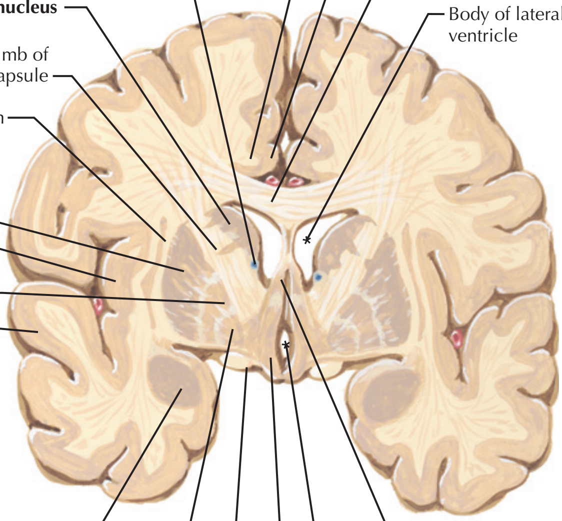
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Body of caudate	Note that the caudate tapers in size from the head to the body	The body and head have similar functions as the input zone of the basal ganglia
GPi segment	The innermost segment of the globus pallidus	Functions as an output nucleus of the basal ganglia to thalamus, en route to the cortex
GPe segment	The outermost segment of the globus pallidus	Functions as an intrinsic nucleus, relaying information from striatum to other structures in basal ganglia
Putamen	Lateral to the globus pallidus Note that the putamen and globus pallidus are closely positioned and lens-shaped, known together as the *lentiform nucleus*	Although close to globus pallidus, the putamen is histologically and functionally equivalent to the caudate

CORONAL VIEW OF THE BRAIN AT THE LEVEL OF THE ANTERIOR LIMB OF THE INTERNAL CAPSULE *continued*



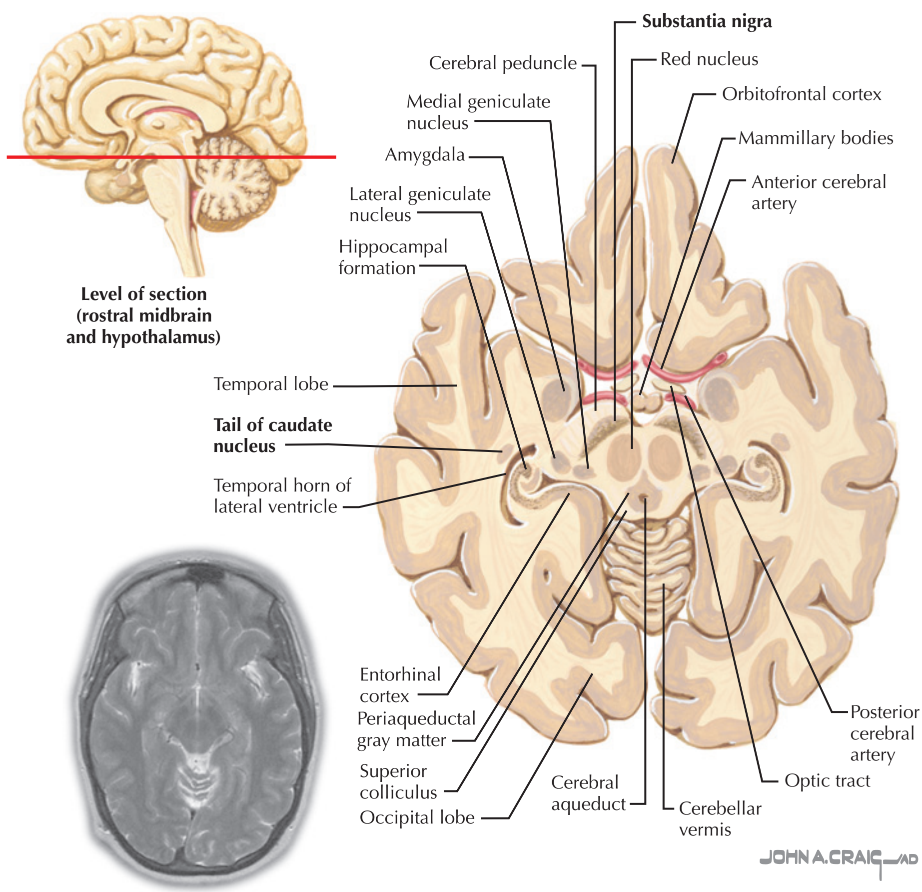
Level of section (amygdala, anterior limb of internal capsule)





AXIAL VIEW OF THE BRAIN THROUGH THE MIDBRAIN

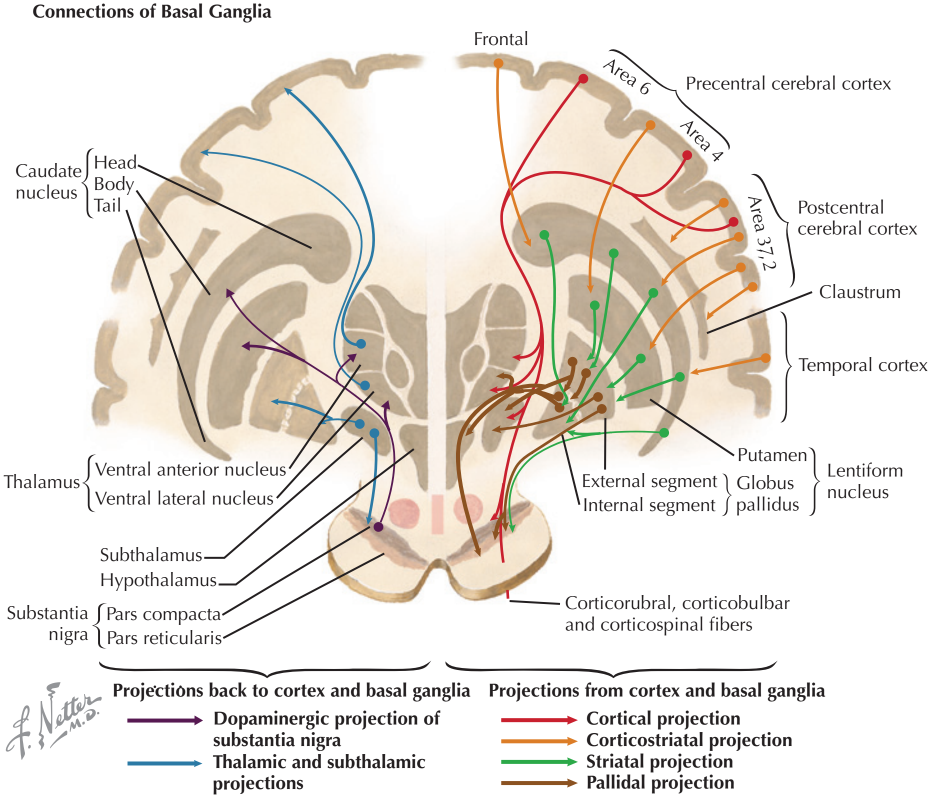
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Substantia nigra	Located in the ventral midbrain Appears brown owing to neuromelanin pigmentation Has two internal subdivisions called the *pars compacta* and *pars reticularis*	Pars compacta has dopamine-producing neurons, which project to the striatum and facilitate movement. Pars reticularis, like the GPi, is an output nucleus of the basal ganglia. Degeneration of the substantia nigra causes Parkinson's disease.
Tail of the caudate nucleus	Can be seen here in its expected location, superior and lateral to the temporal horn of the lateral ventricle	

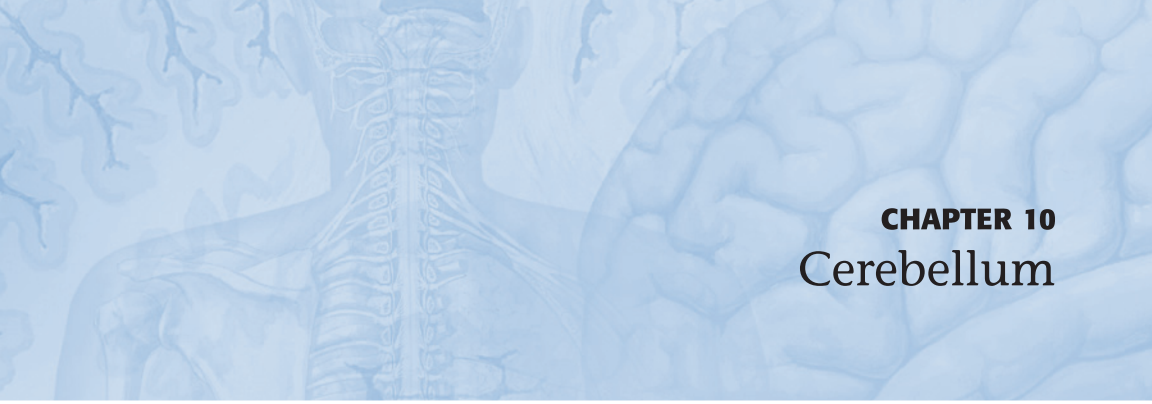


CONNECTIONS OF THE BASAL GANGLIA

ANATOMIC NOTES	PATHWAYS	FUNCTIONAL SIGNIFICANCE
Basal ganglia are involved in a complex set of loop pathways Basic principle is that all loops follow the following general path: cortex→basal ganglia→ thalamus→cortex *Input* All input to basal ganglia goes to striatum (caudate, putamen, nucleus accumbens) *Output* All output from basal ganglia comes from GPi and substantia nigra pars reticulata (SNr)	Two distinct pathways through basal ganglia: *Direct pathway* Facilitates movement cortex→striatum→GPi + SNr→thalamus→ cortex *Indirect pathway* Inhibits movement cortex→striatum→ GPe→subthalamic nucleus→GPi + SNr→ cortex	Dopamine from pars compacta of the substantia nigra facilitates movement by exciting direct pathway and suppressing indirect pathway. In Parkinson's disease, dopaminergic neurons in the pars compacta of substantia nigra degenerate, causing decreased speed of movements, known as *bradykinesia.*

Connections of Basal Ganglia





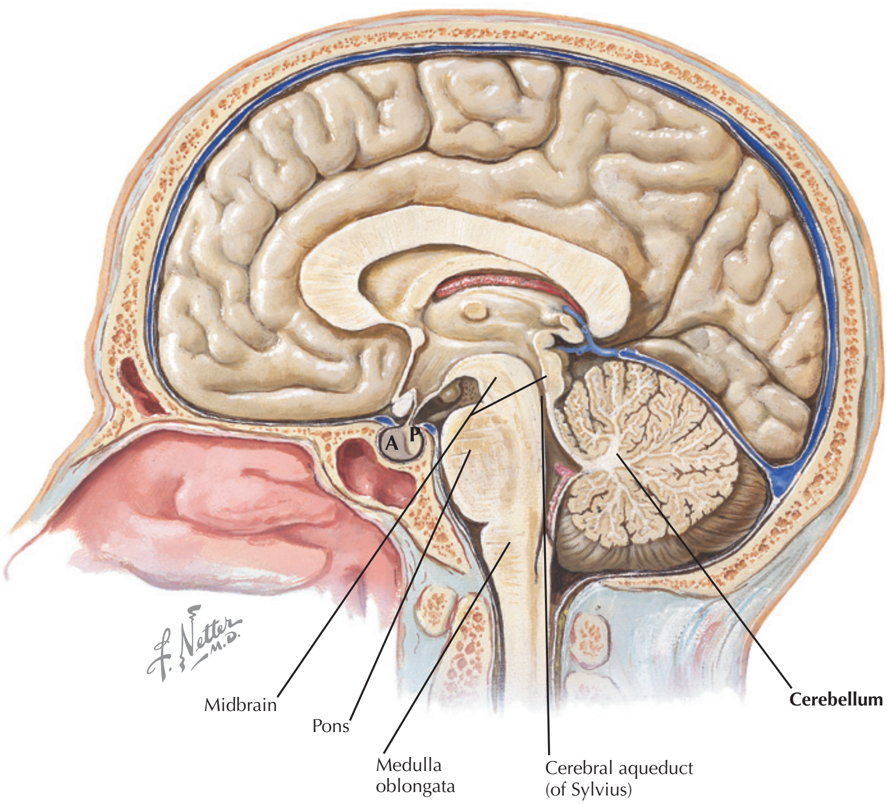
CHAPTER 10

Cerebellum

OVERVIEW OF THE CEREBELLUM

Location	Posterior fossa, below the tentorium cerebelli
Architecture	Similar to cerebrum, contains folded cortex, white matter, and deep nuclear structures
Function	Major function is to coordinate and stabilize movement Important in maintenance of balance
Clinical Significance	Cerebellar diseases can cause poor coordination, slurred speech, and gait imbalance Midline lesions tend to cause more gait problems

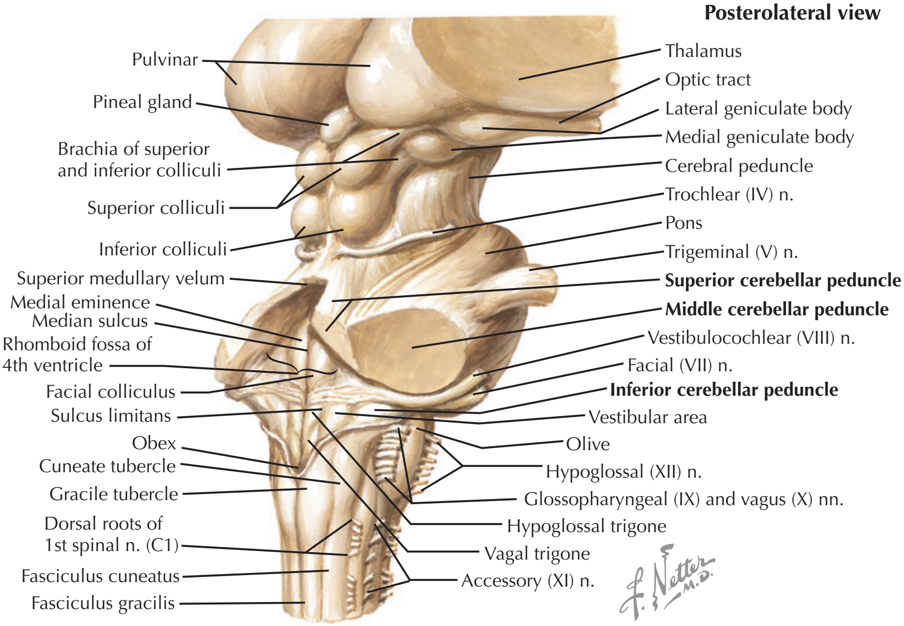
Midsagittal View of Brain



CEREBELLAR PEDUNCLES

- In this dorsal view of the brainstem, the cerebellum has been removed to expose its three peduncles.
- Cerebellum communicates with rest of the nervous system through its peduncles.

PEDUNCLE	ALTERNATE NAME	FUNCTIONAL SIGNIFICANCE
Superior cerebellar peduncle	Brachium conjuctivum	Primarily carries output from cerebellum
Middle cerebellar peduncle	Brachium pontis	Exclusively carries input to cerebellum
Inferior cerebellar peduncle	Restiform body	Primarily carries input to cerebellum

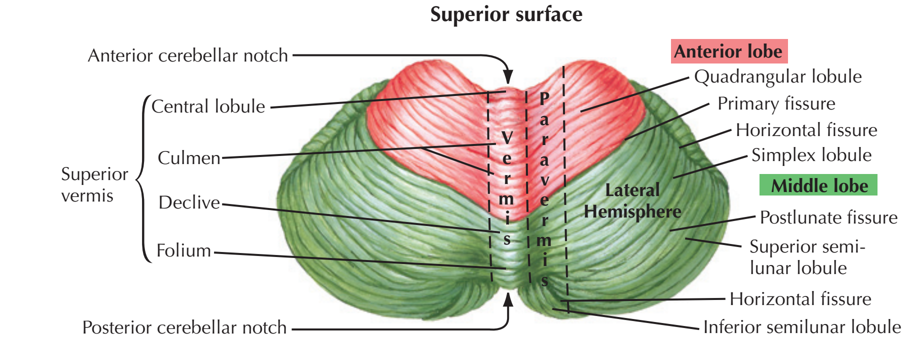


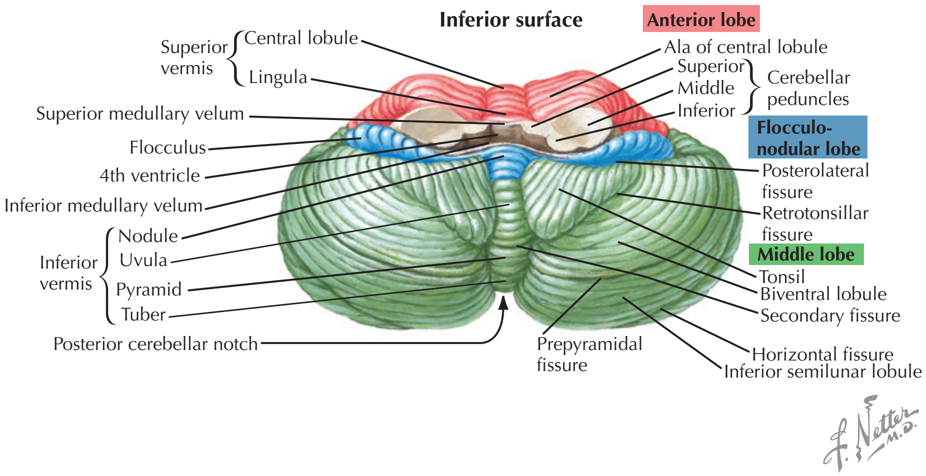
CEREBELLAR ANATOMY

CEREBELLAR SURFACE ANATOMY			
Cerebellar Lobe	**Associated Lobules**	**Anatomic Notes**	**Functional Significance**
Anterior lobe	Quadrangular Ala of central lobule	Separated from the middle lobe by primary fissure	Becomes atrophic in alcoholics
Middle lobe	Simplex Superior semilunar Inferior semilunar Biventral Tonsil	Lies posterior and inferior to anterior lobe, separated from it by primary fissure Tonsil is its inferior and medial-most projection	Cerebellar tonsils lie just lateral to the medulla and, if displaced by pressure, can compress the medulla, causing death, called tonsillar herniation
Flocculonodular lobe	Flocculus Nodule of the vermis	Flocculus is separated from the middle lobe by posterolateral fissure	Involved in balance by communicating with vestibular system

FISSURES OF THE MIDDLE LOBE	
Fissure	**Anatomic Notes**
Postlunate	Separates simplex from superior semilunar lobule
Horizontal	Separates superior and inferior semilunar lobules
Prepyramidal	Separates inferior semilunar from biventral lobule
Retrotonsillar	Separates biventral lobule from tonsil

CEREBELLAR ANATOMY *continued*



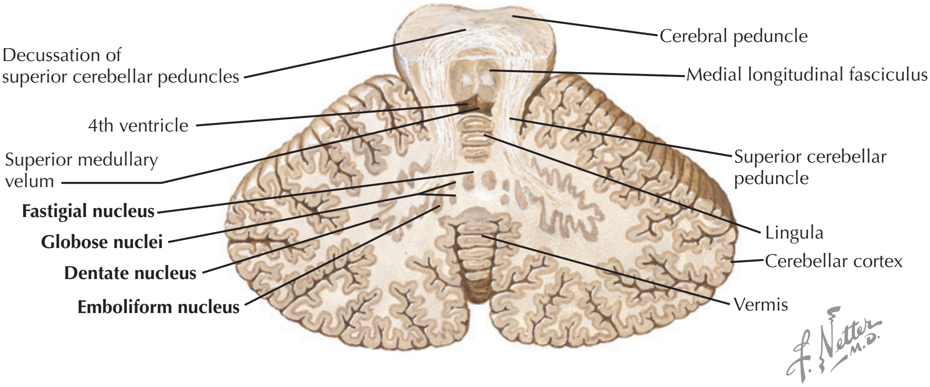


INTERIOR OF CEREBELLUM

- The cerebellum has cortex, white matter, and deep nuclei.
- The cerebellar cortex is folded into folia, collectively forming the arbor vitae cerebelli.
- Input to the cerebellum goes mainly to the cerebellar cortex.
- Output from the cerebellum comes from deep nuclei.

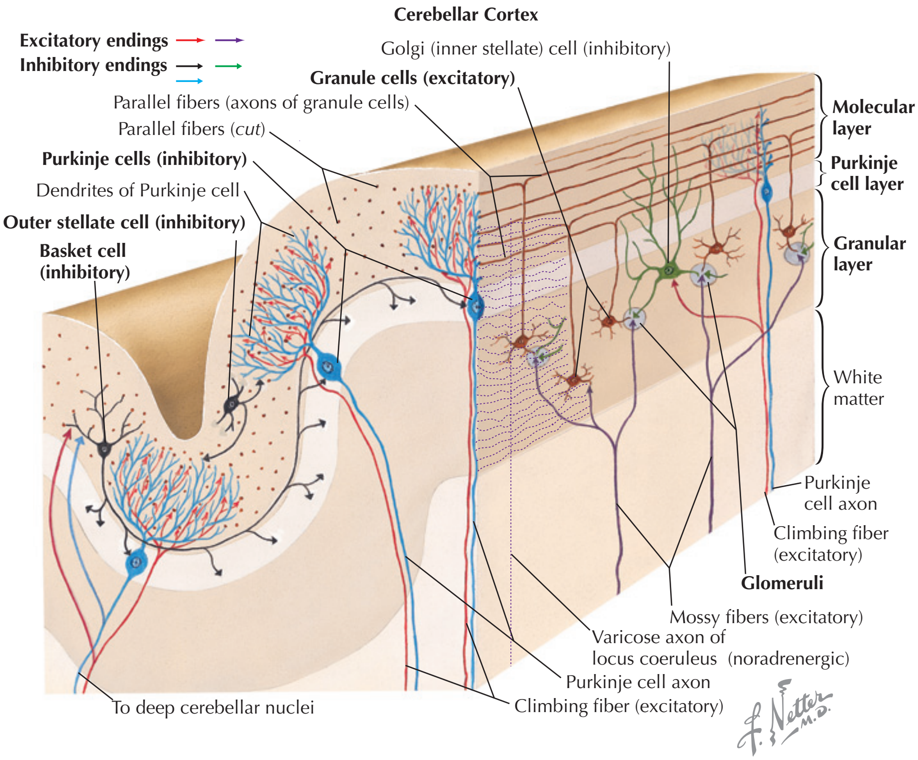
DEEP NUCLEUS	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Dentate nucleus	Largest, lateral-most, deep nucleus	Receives input from the lateral hemispheres and outputs via the superior cerebellar peduncle
Globose nuclei Emboliform nucleus	Collectively known as the *interposed nuclei*	Receive input from paravermian regions and send output via the superior cerebellar peduncle
Fastigial nucleus	Medial-most deep nucleus	Receives input from the vermis and flocculonodular lobe and outputs via the juxtarestiform body of the inferior cerebellar peduncle

Section in plane of superior cerebellar peduncle



CEREBELLAR CORTEX TYPES

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Purkinje cell	Large, flask-shaped cells uniformly arranged along the upper margin of granular layer Purkinje cell axons are the only ones to emerge from the cerebellar cortex and enter the white matter	All impulses entering the cerebellar cortex must converge on these cells to reach efferent cerebellar pathways γ-aminobutric acid (GABA) is neurotransmitter released at synapse
Basket cell	Situated in the molecular layer, in the vicinity of Purkinje cell bodies	Gives rise to branching dendrites, which ascend in the molecular layer to produce a fan-shaped field in sagittal plane, and to axons which arborize around somata of 10 Purkinje cells
Granule cell	Fills granular layer which has appearance of packed chromatic nuclei with irregular light spaces called cerebellar islands or glomeruli which are complex synaptic structures	Prodigious in number (3-7 million granule cells/mm^3 of granular layer)
Outer stellate cell	Situated in molecular layer	Establish synaptic contacts with Purkinje cell dendrites



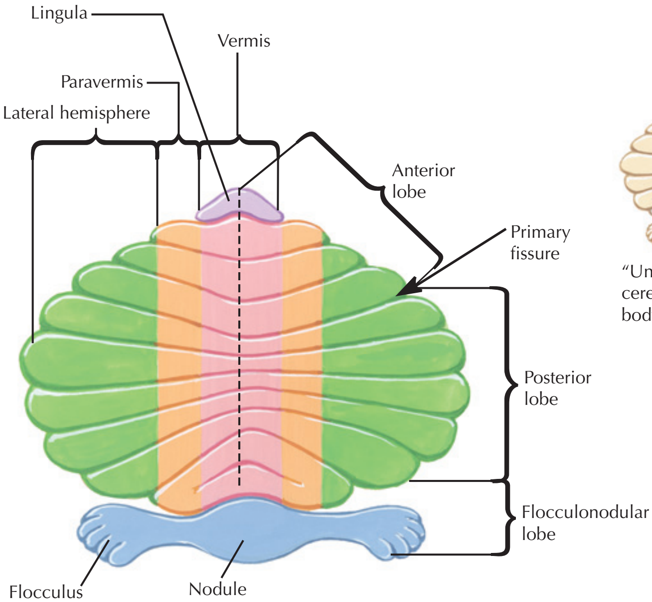
FUNCTIONAL SUBDIVISIONS OF THE CEREBELLUM

The cerebellum can be divided into functional lobes:

- Lateral hemispheres
- Paravermis
- Vermis and flocculonodular lobe

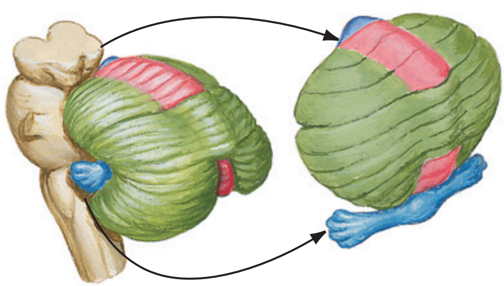
The cerebellum has somatotopic organization:

- Body is represented three times
- Each hemisphere and the vermis have a somatotopic map



"Unfolded" schematic of cerebellum demonstrating regions and lobes

"Unfolded" schematic of cerebellum demonstrating body map areas



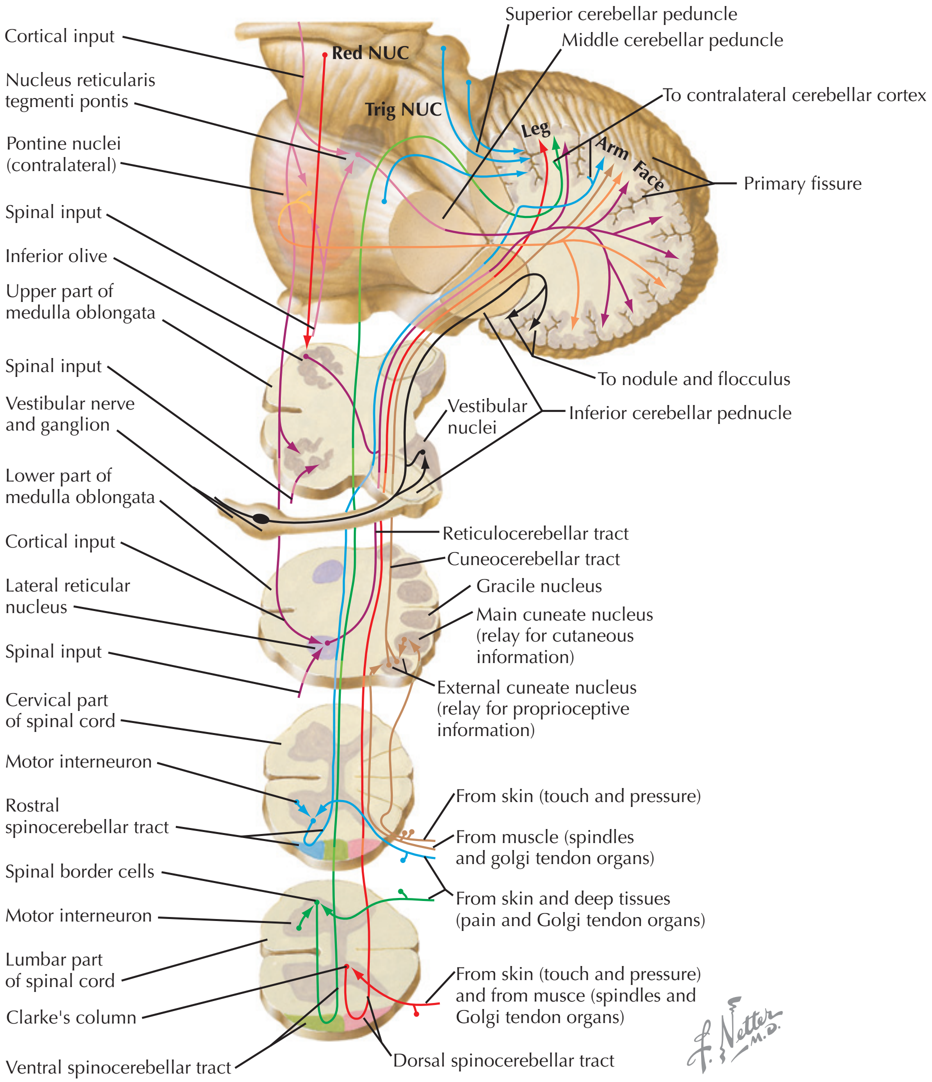
Schema of theoretical "unfolding" of cerebellar surface in derivation of above diagram

CEREBELLAR INPUT

- Input to the cerebellum arises from multiple locations in the nervous system.
- Input from the spinocerebellar tracts provides unconscious proprioception.
- Inputs from the vestibular system provides information about acceleration and head position.
- Inputs from the motor cortex provides information about motor function.
- Cerebellum uses all input to assist in coordinating smooth motor function and balance.
- All input to the cerebellum from spinal cord is from the ipsilateral body.
- The ventral spinocerebellar tract double crosses.

PEDUNCLE	INPUT(S) TO CEREBELLUM
Superior	Ventral spinocerebellar tract Midbrain tectum (colliculi) Trigeminal system
Middle	Cerebral cortex (motor and sensory) via pontine nuclei
Inferior	Dorsal spinocerebellar tract Rostral spinocerebellar tract Cuneocerebellar tract Reticulocerebellar tract Inferior olive Trigeminal system Vestibular system

CEREBELLAR INPUT *continued*



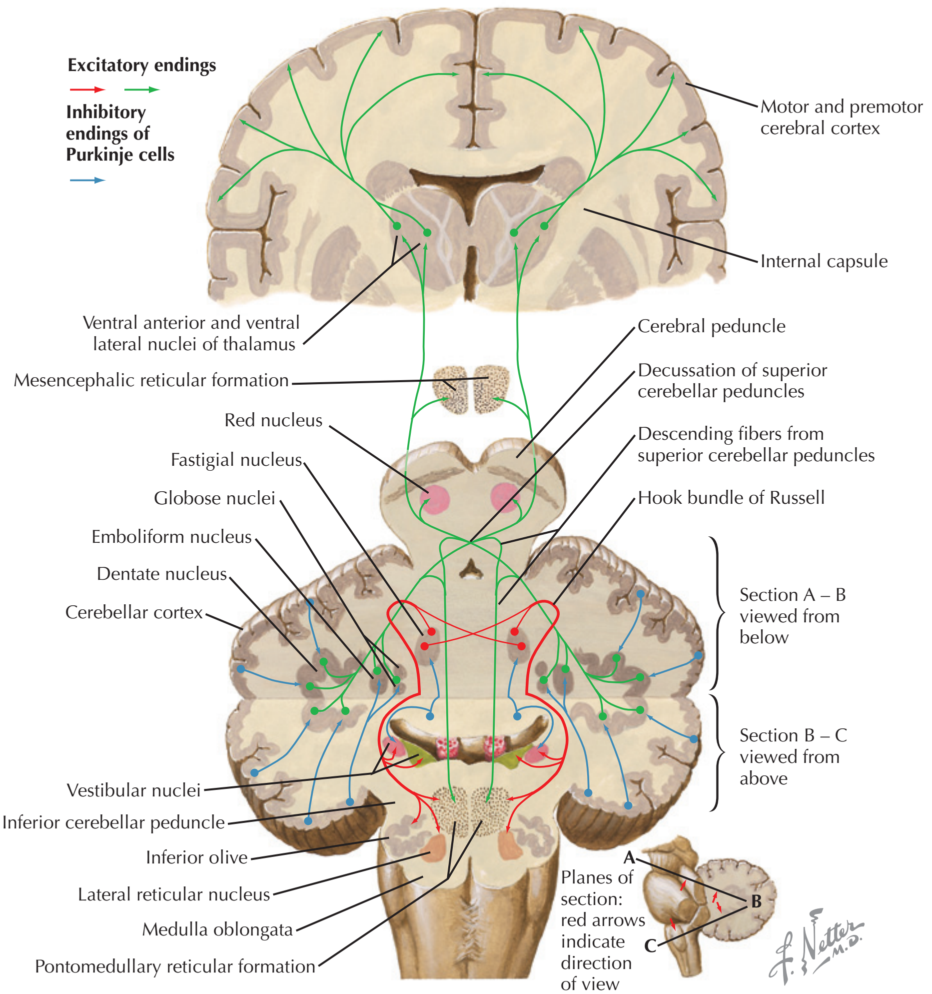
CEREBELLAR OUTPUT

- Output from the cerebellum comes from deep nuclei.
- The flocculonodular cortex also outputs directly to vestibular nuclei.

PEDUNCLE	CEREBELLAR OUTPUT(S)
Superior	Thalamus (ventrolateral [VL] nucleus) Red nucleus Reticular formation
Middle	None
Inferior	Vestibular nuclei (via hook bundle of Russel) Reticular formation

CEREBELLAR CIRCUITRY BY FUNCTIONAL LOBE				
Functional Lobe	**Input**	**Deep Nucleus**	**Output**	**Function**
Lateral hemispheres	Motor and sensory cortex	Dentate	Thalamus VL to the premotor cortex	Coordinates movement by influencing the corticospinal tract
Paravermis	Muscle spindles and Golgi tendon organs via spinocerebellar tracts	Interposed (globose and emboliform)	Red nucleus	Modulates movement by influencing rubrospinal tract
Vermis and flocculonodular lobe	Vestibular system	Fastigial and vestibular nuclei	Vestibular system	Modulates balance and truncal stability

CEREBELLAR OUTPUT *continued*

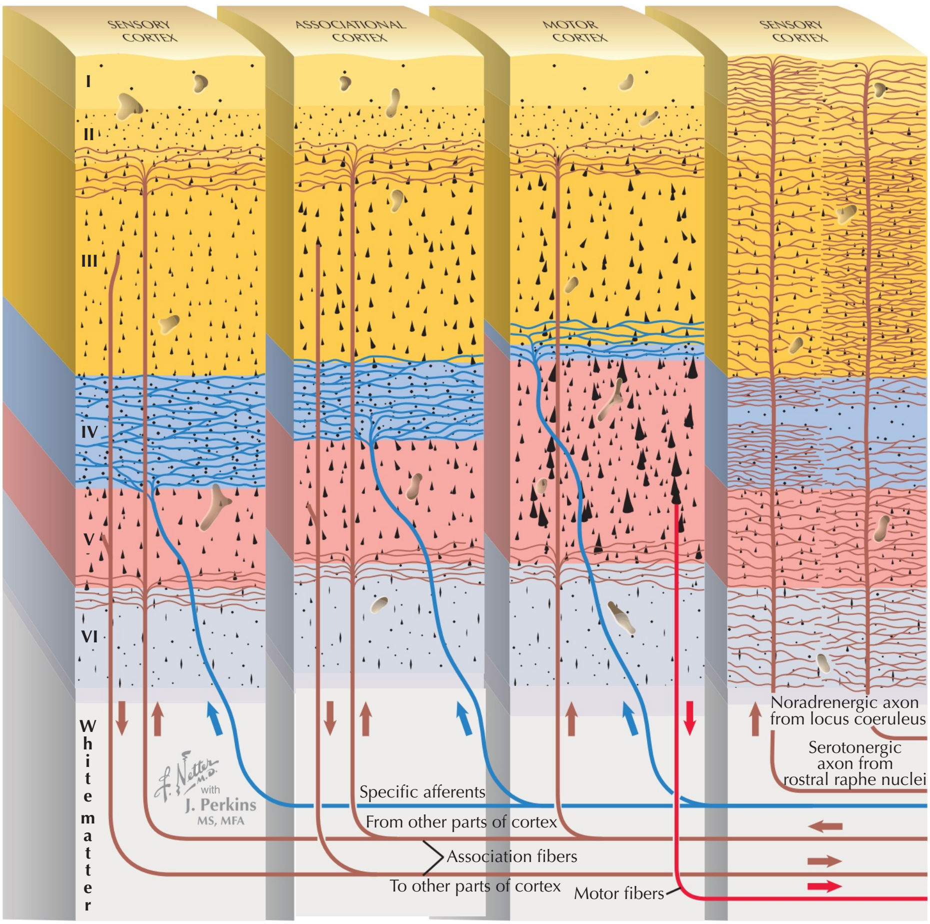


CHAPTER 11

Cerebral Cortex

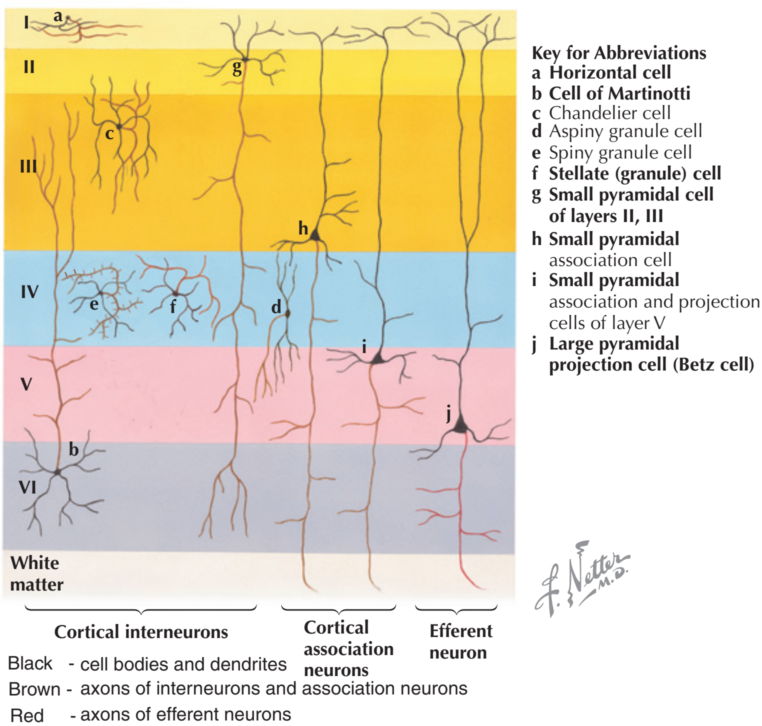
LAYERS OF THE CEREBRAL CORTEX

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Sensory cortex	Large granule cell layers (granular cortex) for receiving input	Receives afferent fibers and terminals from other parts of nervous system (e.g., thalamocortical)
Association cortex	Most association fibers arise from superficial layers of cortex	Axons interrelate cortical regions of same or opposite hemisphere
Motor cortex	Most projection neurons arise from deeper layers of cortex	Contains projection neurons to other parts of the neuraxis (e.g., corticospinal, corticobulbar)



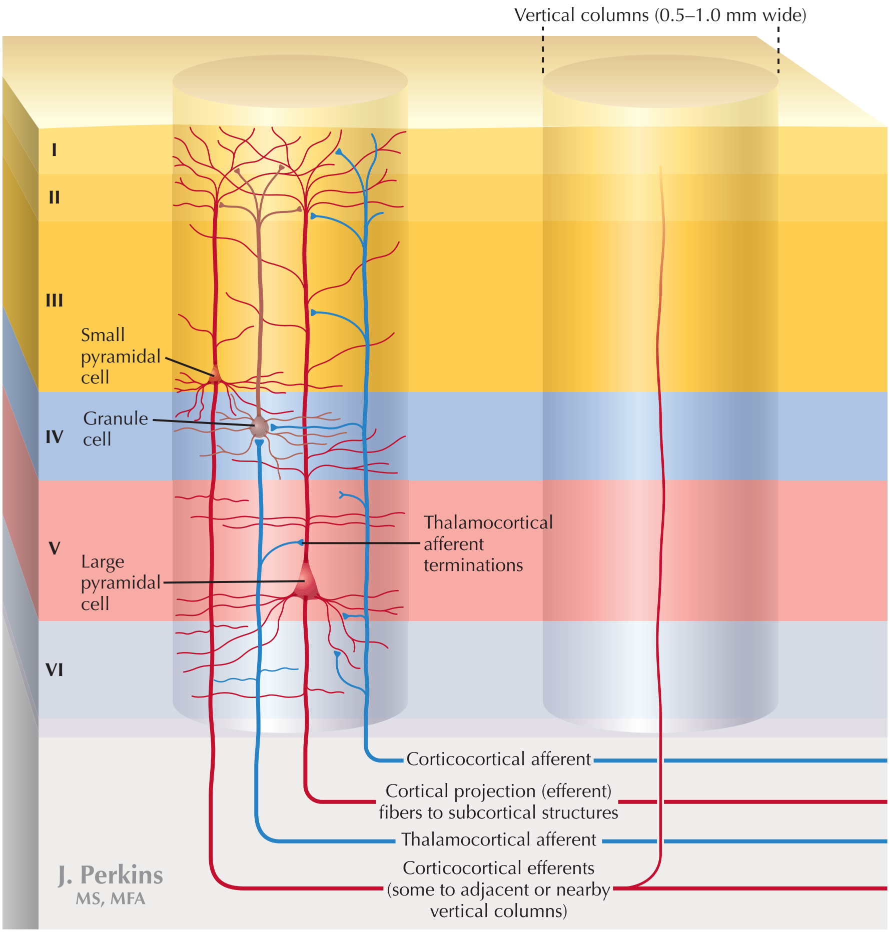
CORTICAL NEURONAL CELL TYPES

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Stellate (granule) cells	Small bodies, localized dendritic trees All layers of cortex, most in layer IV	Receiving neurons for thalamic input Modulate excitability of other cortical neurons
Pyramidal cells	Varied cell bodies Large basal and apical dendritic branching patterns run perpendicular to the cortical surface and arborize in upper layers.	Projection neurons (e.g., corticobulbar, corticoreticular, corticothalamic tracts)
Cells of Martinotti	Small triangular cells present in all cortical layers	Intracortical neuron
Horizontal cell (of Cajal)	Small fusiform cells present mostly in superficial cortical layer	Intracortical neuron
Betz cell	Giant pyramidal cells	Concentrated in Brodmann area 4, primary motor cortex Give rise to corticospinal tract



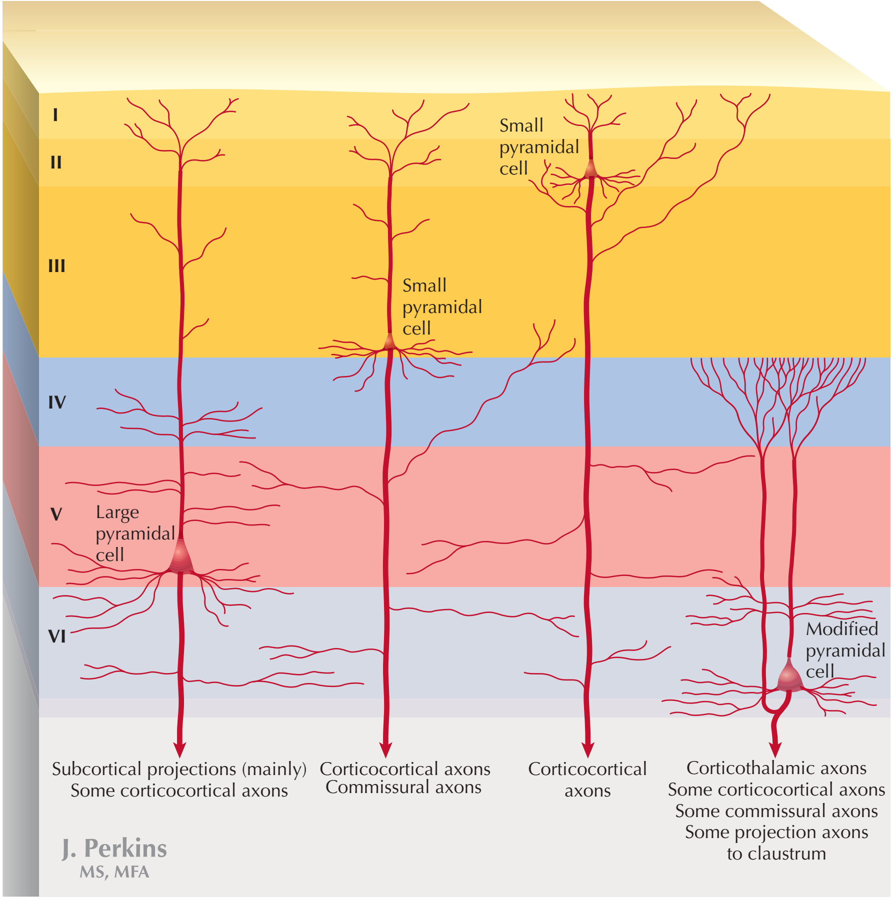
SENSORY CORTEX VERTICAL COLUMNS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Vertical cell columns in sensory and visual cortex	Neurons of particular column are all related to same peripheral receptive field	Constitute elementary functional cortical unit Neurons of same vertical column are activated by same peripheral stimulus



NEURONAL ORIGINS OF EFFERENT CORTICAL CONNECTIONS

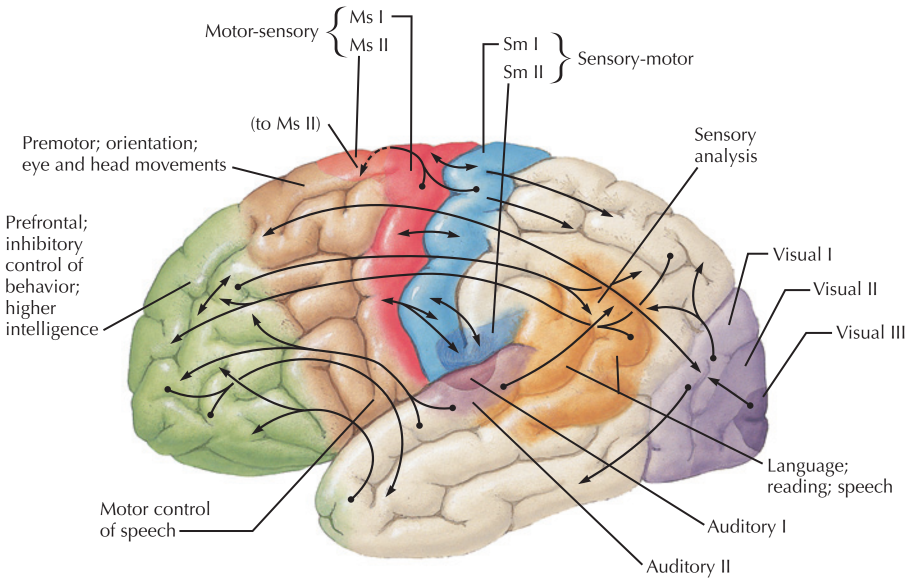
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Corticocortical columns	Same size as functional columns of sensory cortex	Delineated by pattern of termination of association and commissural fibers Afferent fibers converge from multiple vertical columns to create vast mosaic of cortical connections

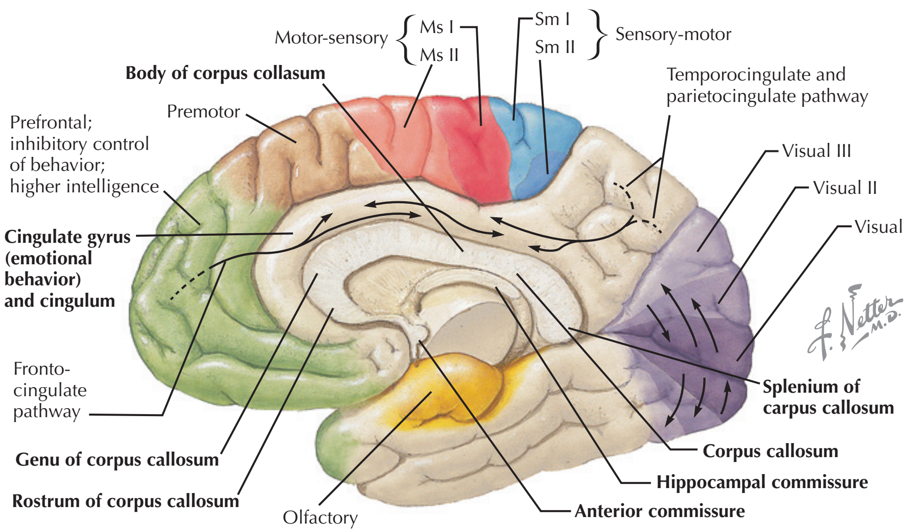


COMMISSURAL AND OTHER ASSOCIATION FIBER SYSTEMS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Corpus callosum: genu	Interconnects prefrontal cortex	Enables the reorganization of cerebral functions to compensate for disruption caused by lateralized brain insult
Corpus callosum: rostral part of body	Interconnects premotor and supplementary motor cortices	Callosotomy surgery for seizure control sections this region
Corpus callosum: middle part of body	Interconnects primary motor and primary and secondary somatic sensory areas	Sectioning during callosotomy results in left-sided neglect, aphasia, and disorders of visuospatial transfer
Corpus callosum: caudal part of body	Interconnects posterior parietal cortex	Interhemispheric transfer of tactile information
Corpus callosum: splenium	Interconnects temporal and occipital cortices	Lesion in splenium causes “pure” word blindness (alexia without agraphia): inability to read aloud, understand written script, and often to name colors Conversation, repetition, and writing remain intact
Anterior commissure	Interconnects 2 temporal lobes	Sectioned along with anterior $\frac{2}{3}$ of the corpus callosum during surgery for seizure control
Hippocampal commissure	Interconnects 2 hippocampi	Temporal lobe discharges may not propagate through corpus callosum or hippocampal commissure, resulting in little interhemispheric coherence, and supporting a multisynaptic route for seizure spread
Cingulum	White-matter core of cingulate gyrus Long-association fiber system connecting the anterior perforated substance and the parahippocampal gyrus	Important for emotional functions

COMMISSURAL AND OTHER ASSOCIATION FIBER SYSTEMS *continued*

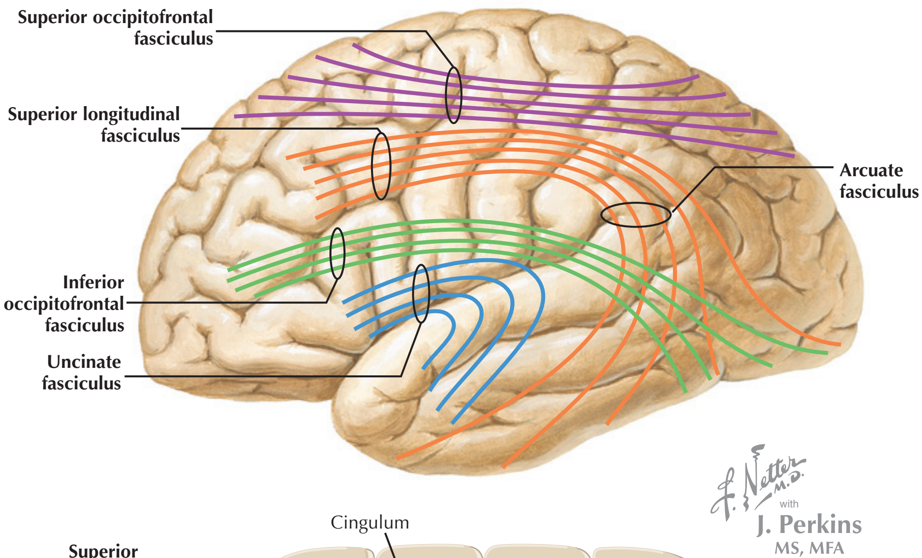


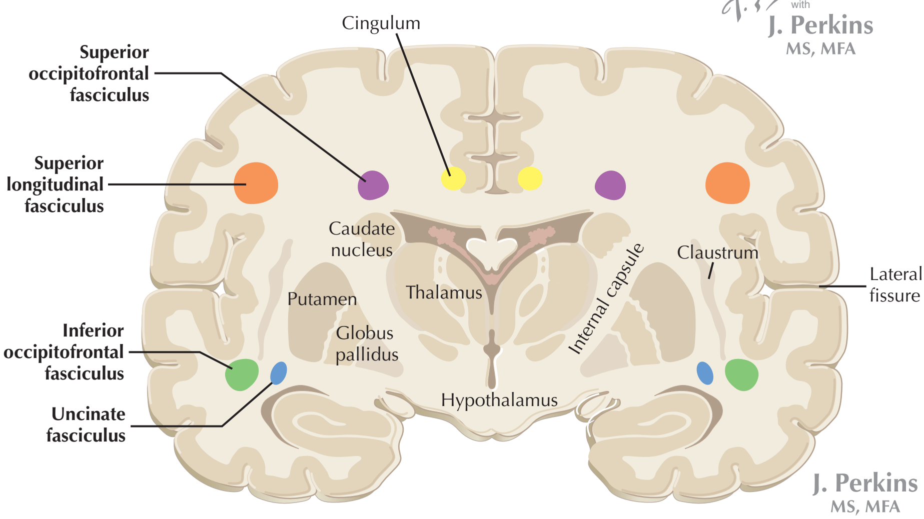


MAJOR CORTICAL ASSOCIATION BUNDLES

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Superior longitudinal fasciculus	In the lateral part of the hemisphere above the insula	Long-association fiber system connecting the frontal lobe with the parietal, occipital, and temporal lobes
Arcuate fasciculus	Part of the superior longitudinal fasciculus sweeping around insula, connecting Broca's speech area in inferior frontal gyrus and Wernicke's area in superior temporal gyrus	Lesions here result in conduction aphasia. Speech output is normal, comprehension is preserved, but repetition is severely affected
Occipitofrontal fasciculus	Two subdivisions: • Superior bundle • Inferior bundle	Connects frontal lobe with temporal and occipital lobes
Superior bundle	Dorsolateral to lateral ventricle, between corpus callosum, internal capsule, and caudate nucleus	Its existence is subject to controversy
Inferior bundle	Lateral to the temporal horn of the lateral ventricle, below the lateral ventricle and insular cortex	Links the orbital cortex and anterior temporal cortex
Uncinate fasciculus	Component of inferior occipitofrontal fasciculus, courses at the bottom of the sylvian fissure	Connects the inferior frontal gyrus with the anterior temporal lobe

MAJOR CORTICAL ASSOCIATION BUNDLES *continued*

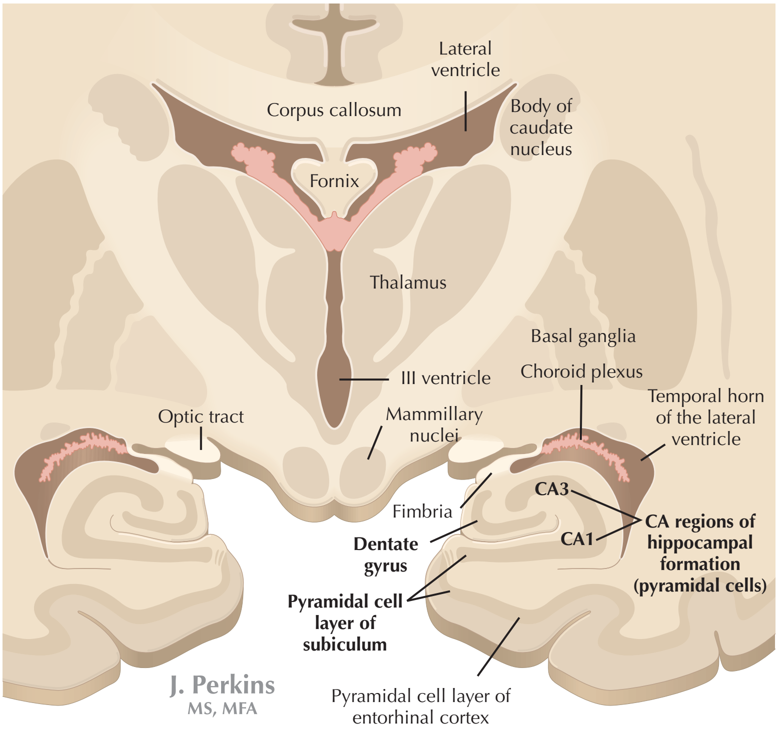




HIPPOCAMPAL FORMATION

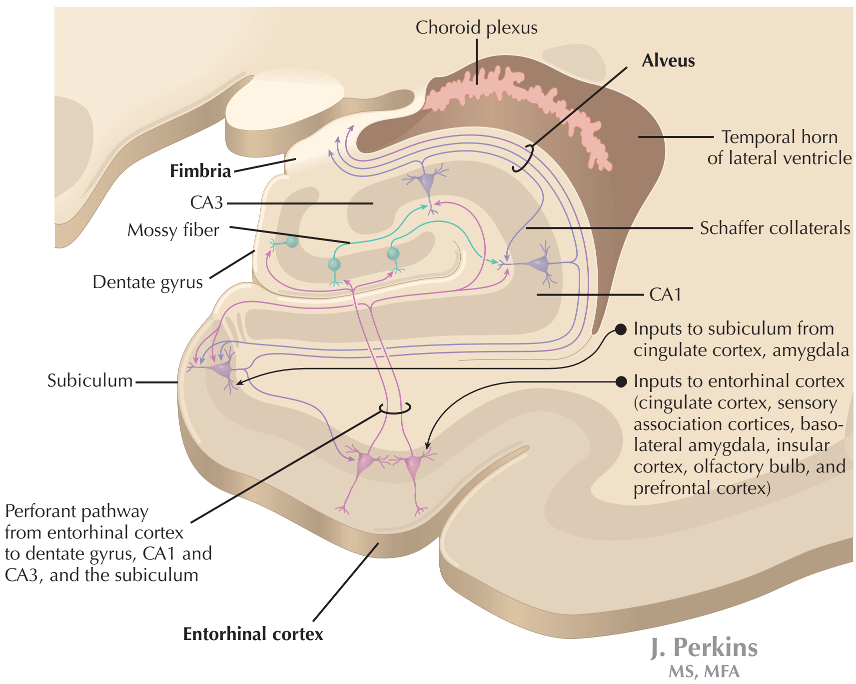
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Hippocampal formation	Consists of: • Dentate gyrus • Hippocampus • Subiculum	Involved in consolidation of short-term memory into long-term traces
Dentate gyrus	3-Layer structure, like the hippocampus: • Molecular • Pyramidal • Polymorphic (stratum oriens, most superficial)	Output of the dentate gyrus does not leave the hippocampal formation
Hippocampus	In the 1500s, called *hippocampus* because of its resemblance to a seahorse Later called *Ammon's horn* (cornu ammonis, or CA) because of its resemblance to a ram's horn (the Egyptian deity Ammon)	Divided into fields: CA 1-4 Pyramidal cells of CA1 (Sommer's sector) highly sensitive to anoxia and ischemia, and are a trigger zone for some forms of temporal lobe epilepsy
Subiculum	3 layers, like rest of hippocampal formation	Axons of pyramidal neurons, like those of the hippocampus, contribute to the output of hippocampal formation

HIPPOCAMPAL FORMATION *continued*



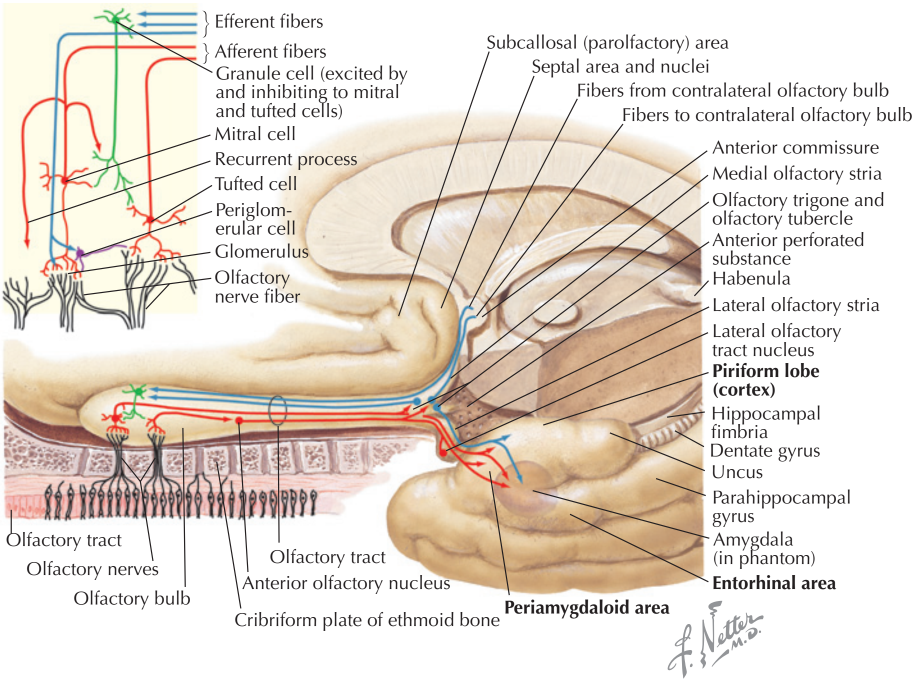
ENTORHINAL CORTEX

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Alveus	Axons of pyramidal neurons gather at the ventricular surface of the hippocampus as alveus	Myelinated envelope surrounding the hippocampal formation
Fimbria	Alveus fibers converge to form flattened ribbon of white matter, the fimbria	Traced posteriorly, the fimbria, at posterior limit of hippocampus, arches under splenium of corpus callosum to form the crus of the fornix
Entorhinal cortex	Bulk of extrinsic input to hippocampal formation comes from the entorhinal cortex	Information from many cortical areas (visual, auditory, sensory) converge here and is conveyed to the hippocampus



OLFACTORY CORTEX

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Olfactory cortex	Located in temporal lobe Composed of: • Pyriform cortex • Periamygdaloid area • Part of entorhinal area	Exceptionally small area in humans; concerned with conscious perception of olfactory stimuli
Pyriform cortex	Projects fibers to entorhinal cortex	Major link between the olfactory regions of the temporal and frontal lobes
Periamygdaloid area	Dorsal and rostral to the amygdala	Intimately related to the prepyriform area
Entorhinal area	Rostral part of parahippocampal gyrus, corresponding to Brodmann area 28	Constitutes a secondary olfactory cortex projecting to hippocampal formation, insula, and frontal cortex



CHAPTER 12

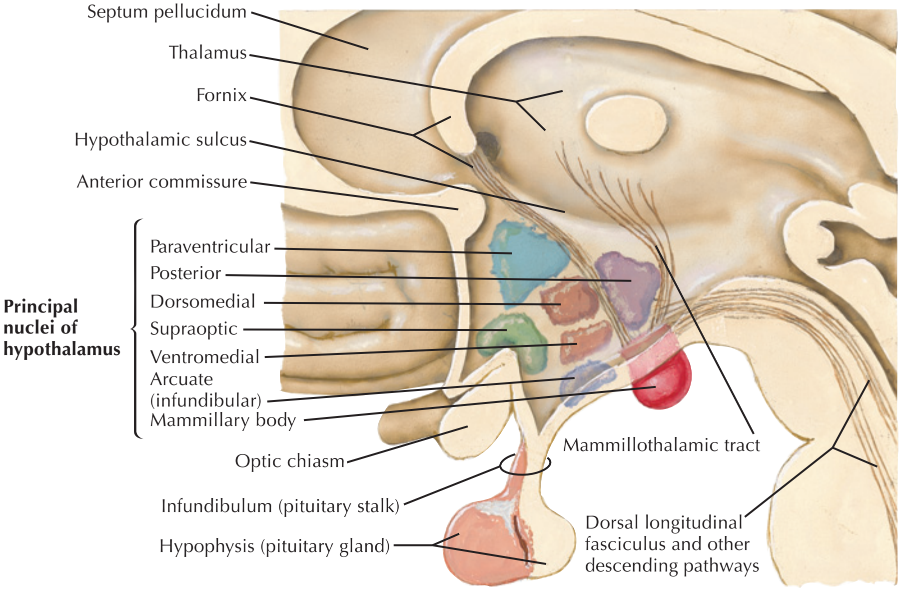
Hypothalamus

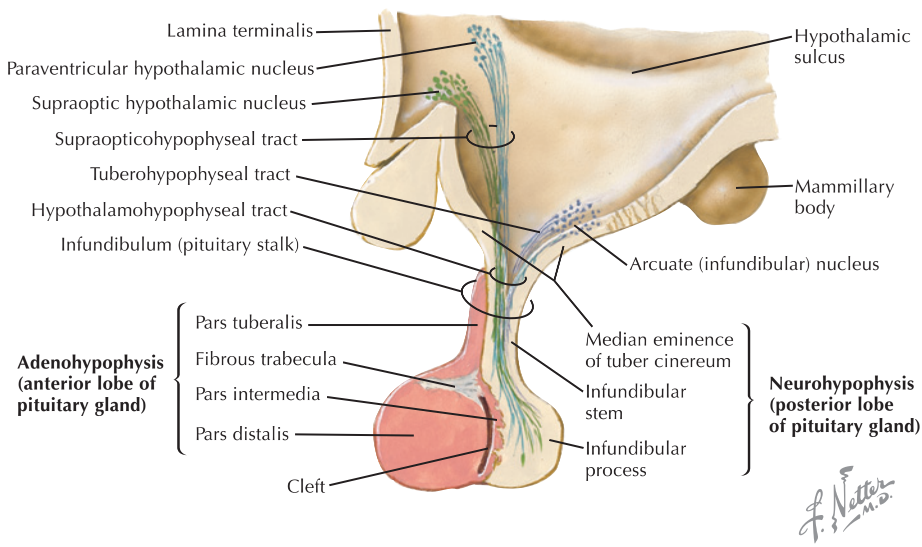
12 Hypothalamus

ANATOMY OF THE HYPOTHALAMUS

Location	Located in ventral diencephalon along the walls of 3rd ventricle, below the hypothalamic sulcus and above the pituitary gland Anterior border is the lamina terminalis Lateral border is indistinct
Architecture	Composed of a collection of nuclei and fiber tracts In the sagittal plane can be divided into periventricular, medial, and lateral zones Connected to multiple parts of the nervous system
Function	Serves as a central regulator of homeostasis Controls the autonomic nervous system, visceral functions; participates in the limbic system Regulates appetite, temperature, thirst, stress response, lactation, and cardiorespiratory function
Clinical Significance	Lesions can lead to autonomic, emotional, or endocrine dysfunction, including precocious puberty

ANATOMY OF THE HYPOTHALAMUS *continued*

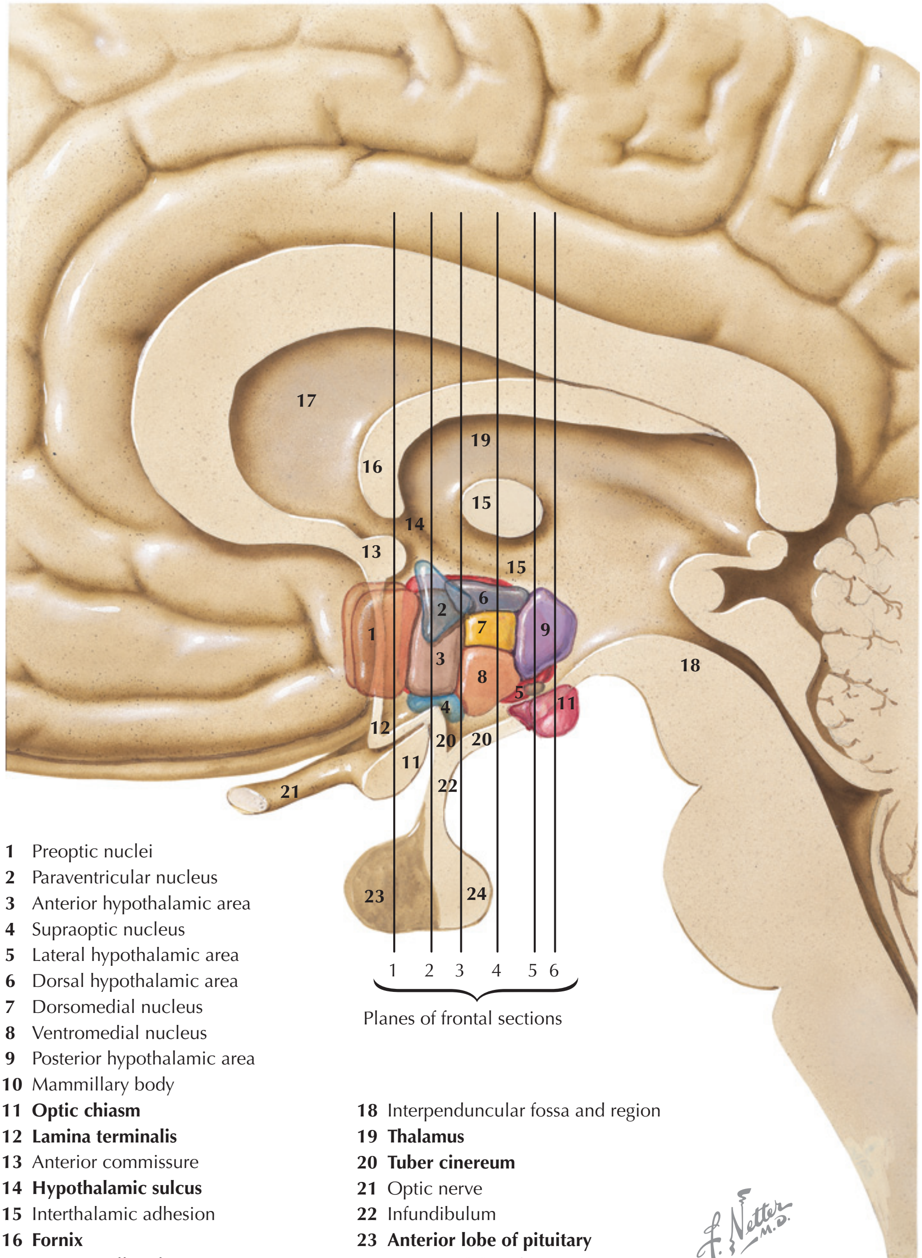




THE HYPOTHALAMUS IN RELATION TO OTHER MEDIAL STRUCTURES

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE AND CLINICAL NOTES
Thalamus	Like the hypothalamus, the thalamus is a diencephalic structure Located above the hypothalamic sulcus lateral to the 3rd ventricle	As structures lining the 3rd ventricle, both the medial thalamus and hypothalamus can be damaged in thiamine deficiency
Hypothalamic sulcus	A groove in the wall of the 3rd ventricle, which separates the thalamus superiorly from the hypothalamus inferiorly	
Fornix	In sagittal section, it swings above and around the thalamus Separates medial from lateral hypothalamus. Carries hippocampal output to the hypothalamic mammillary body	Damage to this structure can cause problems with emotions and memory The pathway from the hippocampus to the mammillary bodies is part of the Papez circuit of the limbic system
Lamina terminalis	Represents the anterior end of the neural tube and the anterior border of the hypothalamus	Location of the rostral neural tube closure
Optic chiasm	Lies below the hypothalamus and above the pituitary	Pituitary lesions can compress the optic chiasm, causing visual-field deficits, specifically a bitemporal field cut
Tuber cinereum	Layer of hypothalamic gray matter that forms the floor of the 3rd ventricle and descends to form the infundibulum	
Anterior lobe of pituitary gland	The anterior portion of the pituitary gland Also known as adenohypophysis	Produces and secretes various hormones into the systemic circulation; regulates the endocrine system. Its function is regulated by releasing factors from the hypothalamus
Posterior lobe of pituitary gland	The posterior portion of the pituitary Also known as *neurohypophysis* Direct extension of the hypothalamus, connected via the infundibulum	Secretes 2 hormones, vasopressin and oxytocin, which are produced in the hypothalamus

THE HYPOTHALAMUS IN RELATION TO OTHER MEDIAL STRUCTURES *continued*



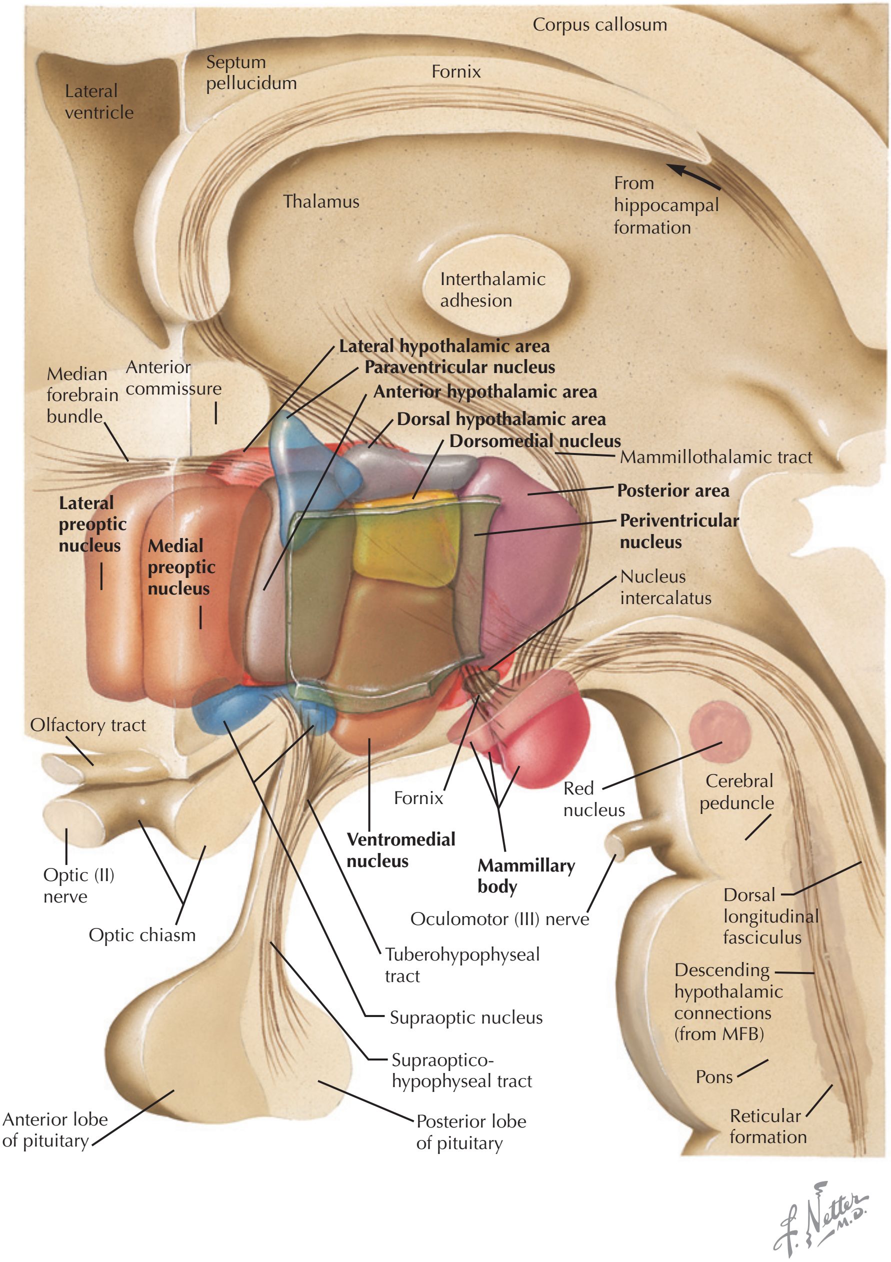
1 Preoptic nuclei
2 Paraventricular nucleus
3 Anterior hypothalamic area
4 Supraoptic nucleus
5 Lateral hypothalamic area
6 Dorsal hypothalamic area
7 Dorsomedial nucleus
8 Ventromedial nucleus
9 Posterior hypothalamic area
10 Mammillary body
11 Optic chiasm
12 Lamina terminalis
13 Anterior commissure
14 Hypothalamic sulcus
15 Interthalamic adhesion
16 Fornix
17 Septum pellucidum
18 Interpenduncular fossa and region
19 Thalamus
20 Tuber cinereum
21 Optic nerve
22 Infundibulum
23 Anterior lobe of pituitary
24 Posterior lobe of pituitary

HYPOTHALAMIC NUCLEI

- Composed of medial and lateral zones separated by the fornix as it traverses hypothalamus
- Can also be divided into anterior to posterior zones

NUCLEUS	ZONE
Medial preoptic	Preoptic
Lateral preoptic	Preoptic
Supraoptic	Anterior (supraoptic)
Suprachiasmatic	Anterior (supraoptic)
Anterior hypothalamic area	Anterior (supraoptic)
Paraventricular	Anterior (supraoptic)
Dorsomedial	Tuberal
Ventromedial	Tuberal
Arcuate	Tuberal
Dorsal hypothalamic area	Tuberal
Posterior hypothalamic area	Posterior (mammillary)
Mammillary bodies	Posterior (mammillary)
Lateral hypothalamic area	Spans anterior, tuberal, and posterior
Periventricular	Spans anterior and tuberal

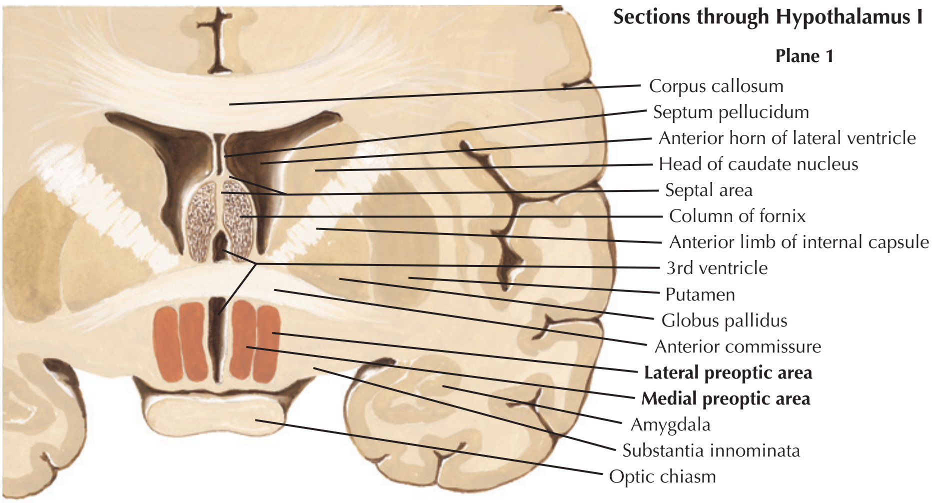
HYPOTHALAMIC NUCLEI *continued*

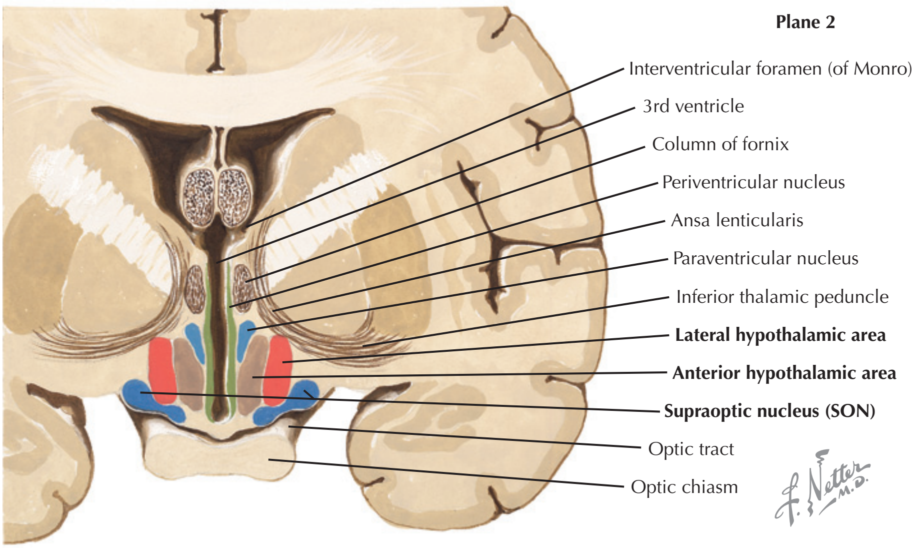


PREOPTIC AND ANTERIOR (SUPRAOPTIC) ZONE NUCLEI

NUCLEUS	FUNCTION
Medial preoptic	Regulates the parasympathetic nervous system
Lateral preoptic	Not clearly established; involved in sleep, sexual function, and reward behaviors
Supraoptic	Produces vasopressin (antidiuretic hormone), which is transported via axons to the posterior pituitary. Vasopressin causes vasoconstriction and water retention
Anterior hypothalamic area	Involved in temperature, appetite, and sexual regulation. Regulates the parasympathetic nervous system
Paraventricular	Produces oxytocin, which is transported via axons to the posterior pituitary; oxytocin causes uterine contractions and milk ejection
Suprachiasmatic (not shown)	Receives input from the retina; controls the circadian rhythm, partly by influencing the pineal gland
Lateral hypothalamic area	Involved in appetite, thirst, and temperature regulation

PREOPTIC AND ANTERIOR (SUPRAOPTIC) ZONE NUCLEI *continued*



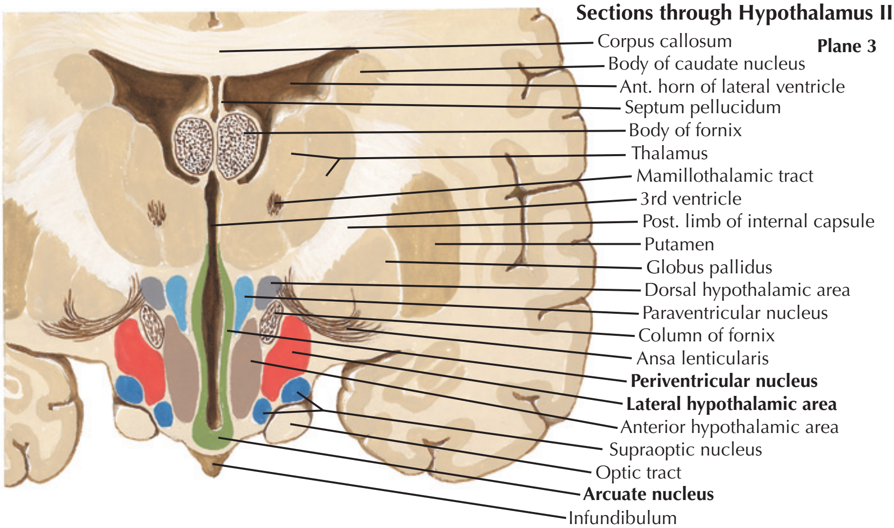


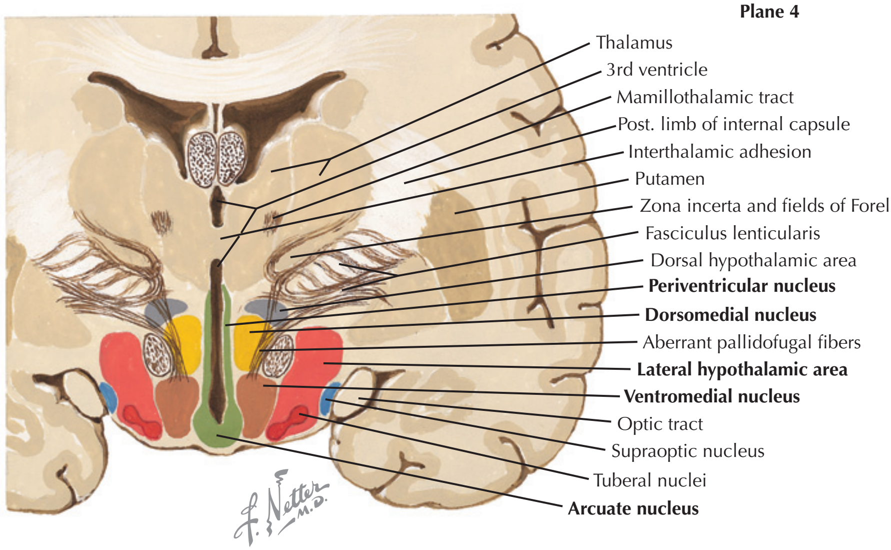
TUBERAL ZONE NUCLEI

NUCLEUS	FUNCTION
Dorsomedial	Represents the satiety center of the brain Lesions can lead to obesity
Ventromedial	Involved in emotions and rage responses
Arcuate	Produces dopamine which inhibits prolactin release from the anterior pituitary Involved in appetite regulation
Periarcuate area	Produces β-endorphins
Periventricular	Produces releasing and inhibiting factors, which are sent to the median eminence for release into hypothalamic-pituitary portal system and control hormone release from the anterior pituitary
Lateral hypothalamic area	Involved in appetite, thirst, and temperature regulation

TUBERAL ZONE NUCLEI *continued*

Sections through Hypothalamus II

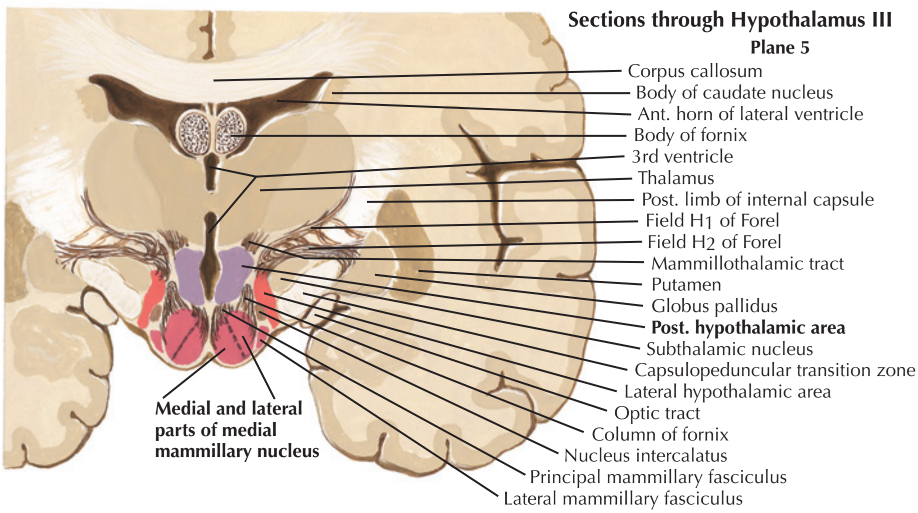


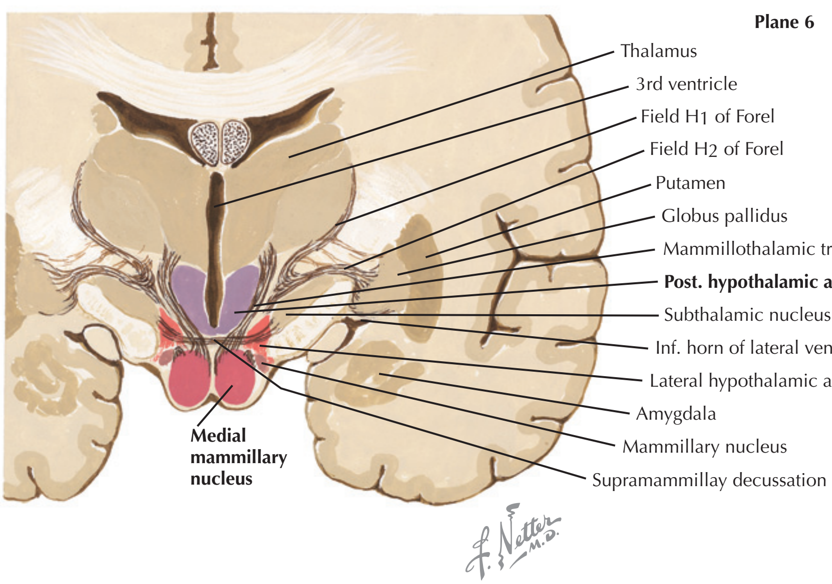


POSTERIOR (MAMILLARY) ZONE NUCLEI

NUCLEUS	FUNCTION
Posterior hypothalamic area	Regulates the sympathetic nervous system; involved in the response to cold
Medial and lateral mammillary nuclei	Integral part of the limbic system Receive hippocampal input via the fornix and project to the anterior nucleus of the thalamus Damage causes inability to form new memories; can be damaged by thiamine deficiency, common in alcoholics, known as *Wernicke-Korsakoff syndrome*

POSTERIOR (MAMILLARY) ZONE NUCLEI *continued*





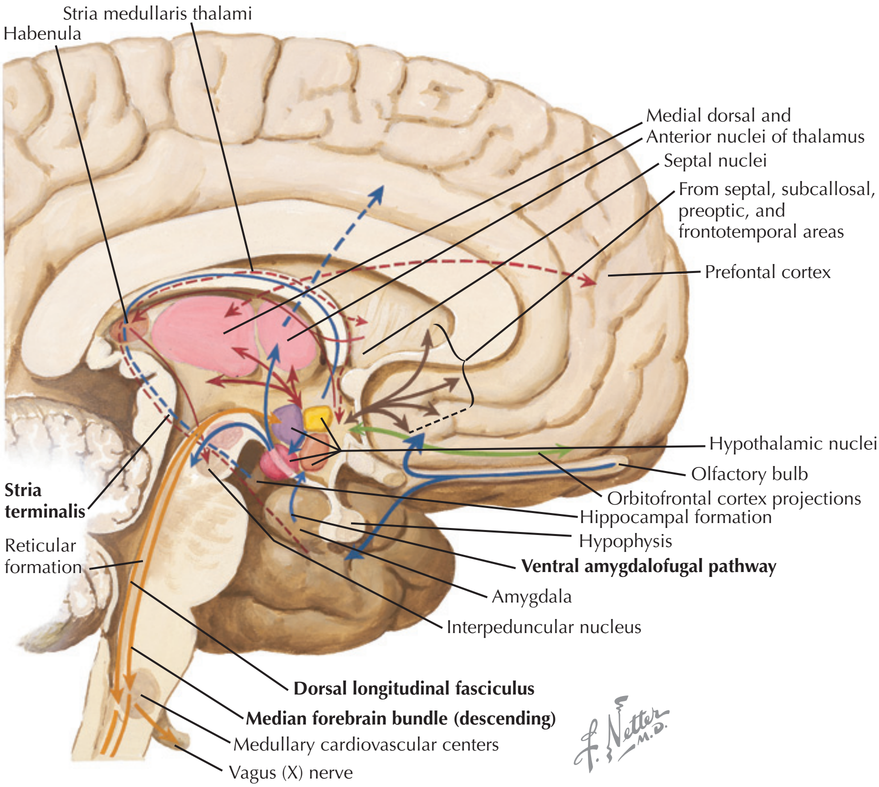
HYPOTHALAMIC PATHWAYS

The hypothalamus is integrally connected with multiple parts of the nervous system.

SELECTED AFFERENT PATHWAYS			
Input	**Pathway**	**Destination**	**Function**
Retina	Retinohypothalamic	Suprachiasmatic nucleus	Sets the circadian rhythm
Median dorsal thalamus		Multiple nuclei	Limbic-emotional modulation
Cerebral cortex	Median forebrain bundle	Lateral hypothalamus	Limbic-emotional modulation
Amygdala	Stria terminalis Ventral amygdalofugal	Multiple nuclei	Limbic-emotional modulation Olfactory input modulation
Hippocampus	Fornix	Medial mamillary	Memory formation Part of Papez circuit
Brainstem autonomic structures	Medial forebrain bundle Dorsal longitudinal fasciculus	Multiple nuclei	Autonomic modulation

SELECTED EFFERENT PATHWAYS			
Output Nucleus	**Pathway**	**Destination**	**Function**
Paraventricular and supraoptic	Supraopticohypophyseal tract	Posterior pituitary	Delivery of vasopressin and oxytocin
Multiple regions		Median eminence	Release of releasing and inhibiting factors for anterior pituitary
Lateral hypothalamus	Median forebrain bundle	Septal nuclei	Limbic-emotional modulation
Medial mammillary	Mammillothalamic tract	Thalamus (anterior nucleus)	Part of Papez circuit
Periarcuate area	β-endorphin pathway	Multiple subcortical and brainstem	Modulates stress responses
Multiple regions	Medial tegmental tract	Reticular formation, tegmental nuclei	Modulation of arousal and autonomic systems

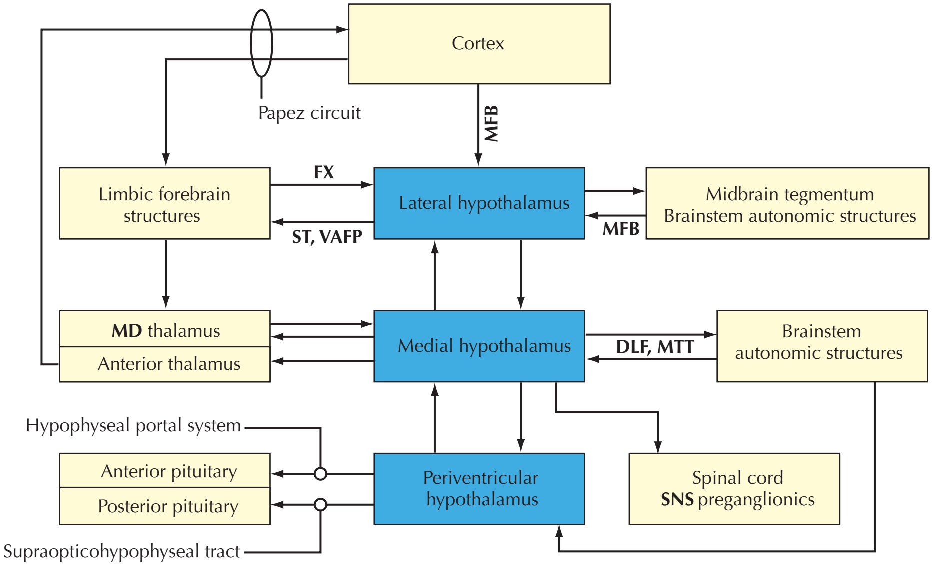
HYPOTHALAMIC PATHWAYS *continued*



12 Hypothalamus

SUMMARY OF HYPOTHALAMIC INPUT AND OUTPUT

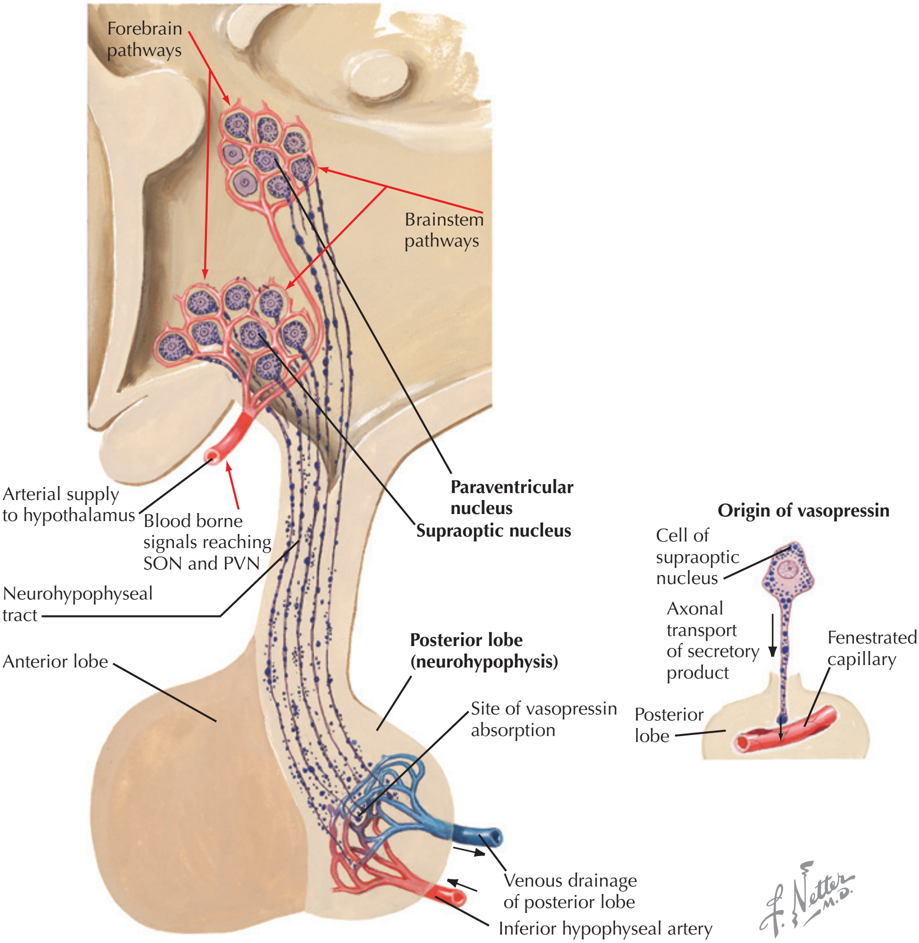
KEY HYPOTHALAMIC PATHWAYS



DLF = Dorsal longitudinal fasciculus
MFB = Median forebrain bundle
ST = Stria terminalis
VAFP = Ventral amygdalofugal pathway
MD = Medial dorsal nucleus of thalamus
FX = Fornix
MTT = Mammillothalamic tract
SNS = Sympathetic nervous system

POSTERIOR PITUITARY

Location	Is a direct extension of the hypothalamus, connected via the infundibulum
Architecture	Composed of descending axons from the supraoptic and paraventricular nuclei of hypothalamus
Function	Secretes oxytocin and vasopressin (antidiuretic hormone, or ADH) into the systemic circulation through fenestrated capillaries
Clinical Significance	Oxytocin causes uterine contractions during childbirth. Vasopressin causes water retention by the kidney and vasoconstriction. In severe brain injuries, damage can cause failure of ADH release, known as diabetes insipidus. Brain lesions can also cause the syndrome of inappropriate antidiuretic hormone (SIADH), leading to dilution of blood and low sodium

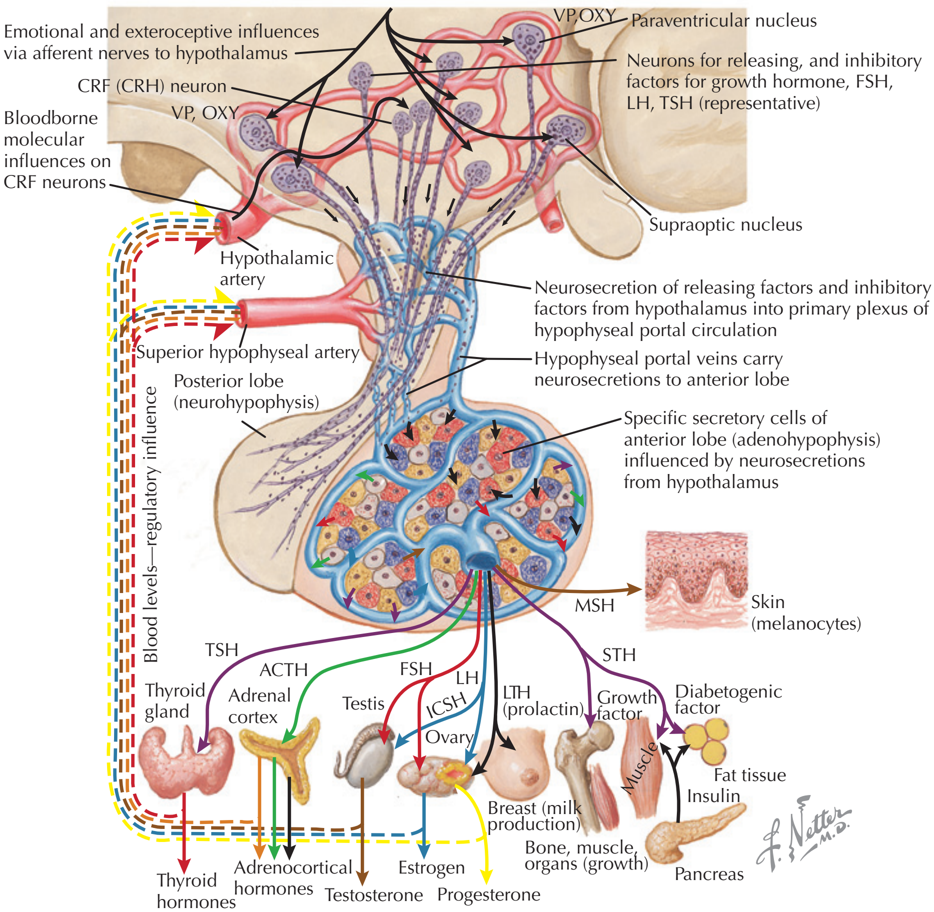


ANTERIOR PITUITARY

- Diffuse hypothalamic neurons release factors that are transported to the median eminence.
- These factors are released into the hypophyseal portal veins and influence the anterior pituitary.
- Unlike the posterior pituitary, the anterior pituitary is not a direct extension of the hypothalamus.

HYPOTHALAMIC RELEASING FACTORS (SELECTED)		
Factor	**Effect on Pituitary**	**Function**
Thyrotropin-releasing hormone (TRH)	Stimulates release of thyroid-stimulating hormone (TSH)	Stimulates thyroid gland to secrete thyroxine and tri-iodothyronine
Growth hormone–releasing hormone (GHRH)	Stimulates release of growth hormone (GH)	Stimulates the liver to produce insulin-like growth factor I
Gonadotropin-releasing hormone (GnRH)	Stimulates release of luteinizing hormone (LH) and follicle-stimulating hormone (FSH)	Modulates puberty, menstrual cycle, menopause and sexual drive
Corticotropin-releasing hormone (CRH)	Stimulates release of adrenocorticotropic hormone (ACTH)	Stimulates the adrenal grand to secrete cortisol
Dopamine	Inhibits release of prolactin	Modulates lactation
Somatostatin	Inhibits release of GH and TSH	Regulates thyroid and growth hormones

ANTERIOR PITUITARY *continued*



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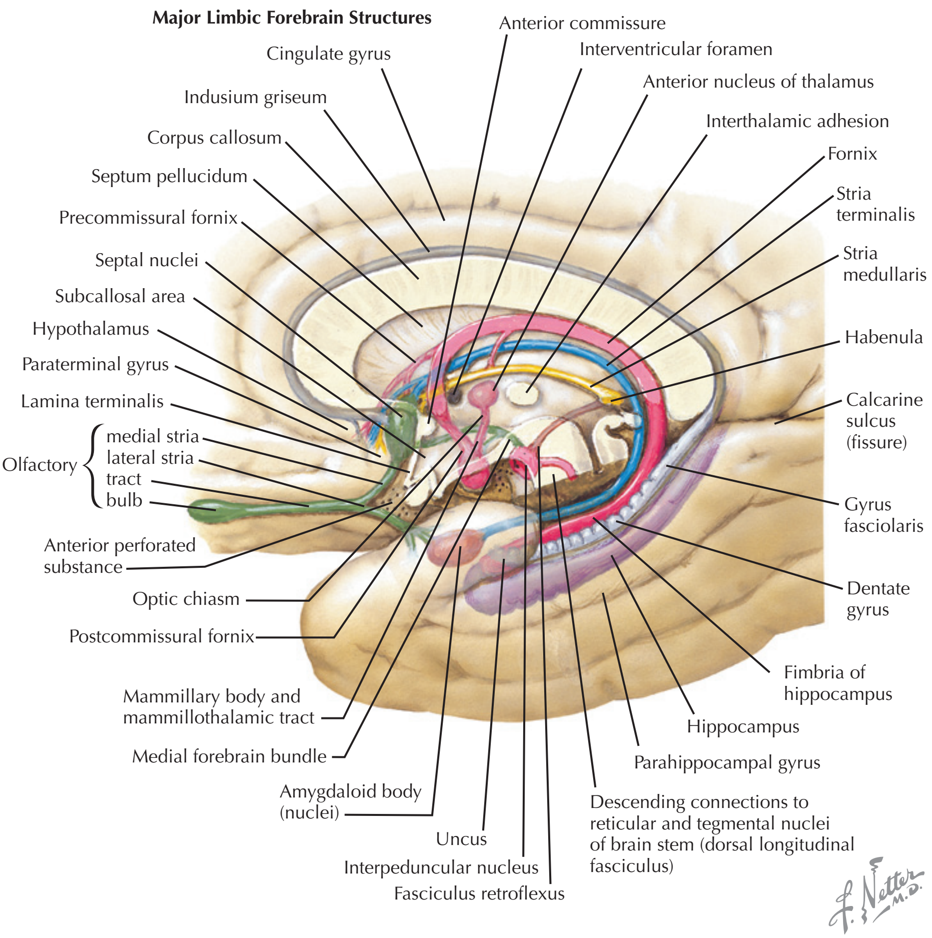
CHAPTER 13

Limbic System

GENERAL FEATURES OF THE LIMBIC SYSTEM

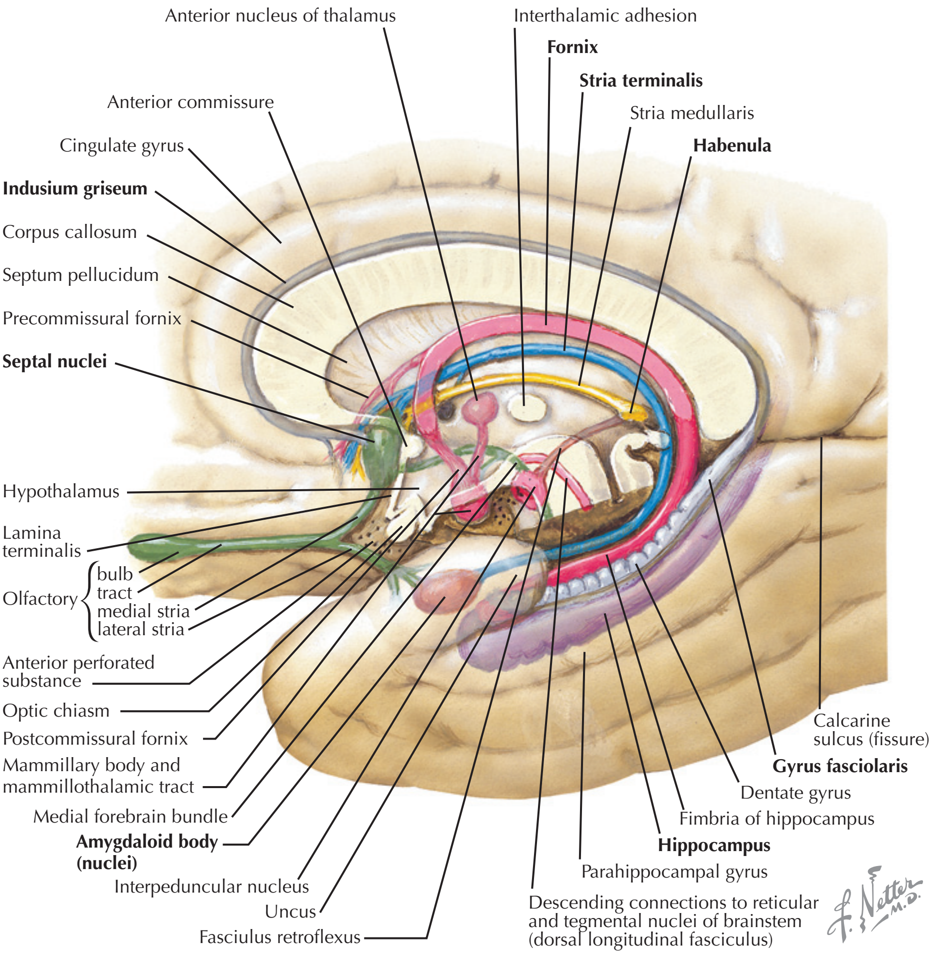
Location	A system of nuclear structures and tracts found in a ring that encircles the thalamus
Architecture	Composed of multiple structures that interact with each other and have significant connections with other cortical and subcortical structures
Function	Serves a major central regulator of emotional control and memory encoding
Clinical Significance	Damage can lead to aggression, apathy, or anterograde amnesia (inability to form new memories).



MAJOR LIMBIC FOREBRAIN STRUCTURES

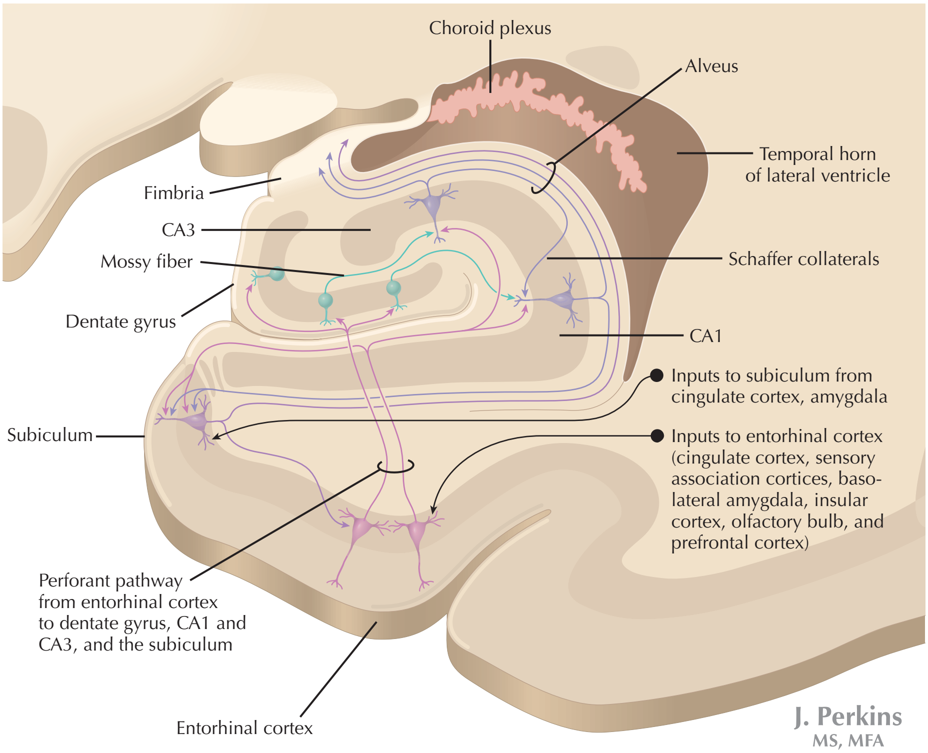
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE AND CLINICAL NOTES
Hippocampus	Lies deep in the medial temporal lobe, medial to the temporal horn of the lateral ventricle	Major regulator of the limbic system, especially memory encoding
Fornix	C-shaped structure that extends from the hippocampus, travels inferior to the corpus callosum, and dives down to mammillary bodies	Carries output from the hippocampus to mammillary bodies of the hypothalamus and to septal nuclei
Amygdala	Almond-shaped structure located anterior to the hippocampus deep in the temporal lobe	Involved in emotional responses, including rage Lesions can cause behavioral outbursts or docility
Stria terminalis	Thin C-shaped tract connecting amygdala to the hypothalamus and basal forebrain	Major output from amygdala Involved in autonomic response to fear, rage, and other emotions
Habenula	Small nuclear structure, rostral to the pineal gland	Part of the epithalamus; major input from the septal nucleus and thalamus via the stria medullaris Major output to the interpeduncular nucleus via the fasciculus retroflexus
Septal nuclei	Set of nuclear structures rostral to the anterior commissure	Functions as the pleasure center of the brain Communicates with the hippocampus, amygdala, and hypothalamus

MAJOR LIMBIC FOREBRAIN STRUCTURES *continued*

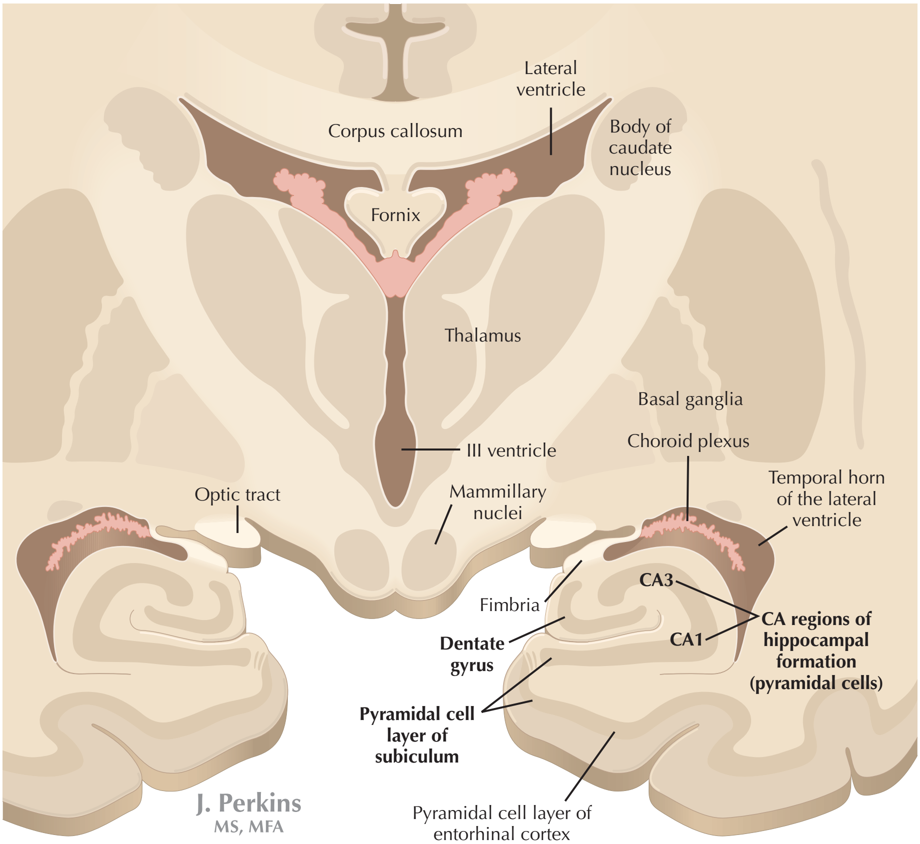


HIPPOCAMPUS

Location	Medial to the temporal horn of the lateral ventricle in the deep anterior temporal lobe
Architecture	Seahorse-shaped structure composed of the dentate gyrus, CA regions, and subiculum. Unlike most of the cortex, the hippocampus has 3 neuronal layers
Circuitry	Internal circuitry: entorhinal cortex→ dentate gyrus→ CA3→ CA1→subiculum→ entorhinal cortex Major external circuit (Papez circuit): hippocampus→ fornix→ mammillary bodies→ anterior nucleus of thalamus→ cingulate cortex→ temporal cortex→ hippocampus Other input and output involving the amygdala, olfactory system, septal nuclei, and sensory association areas
Function	Subserves memory encoding using Papez circuit Involved in emotional modulation, but this is not its major function
Clinical Significance	Bilateral hippocampal damage can occur with anoxia or paraneoplastic syndromes. Clinically, patients develop amnestic syndromes

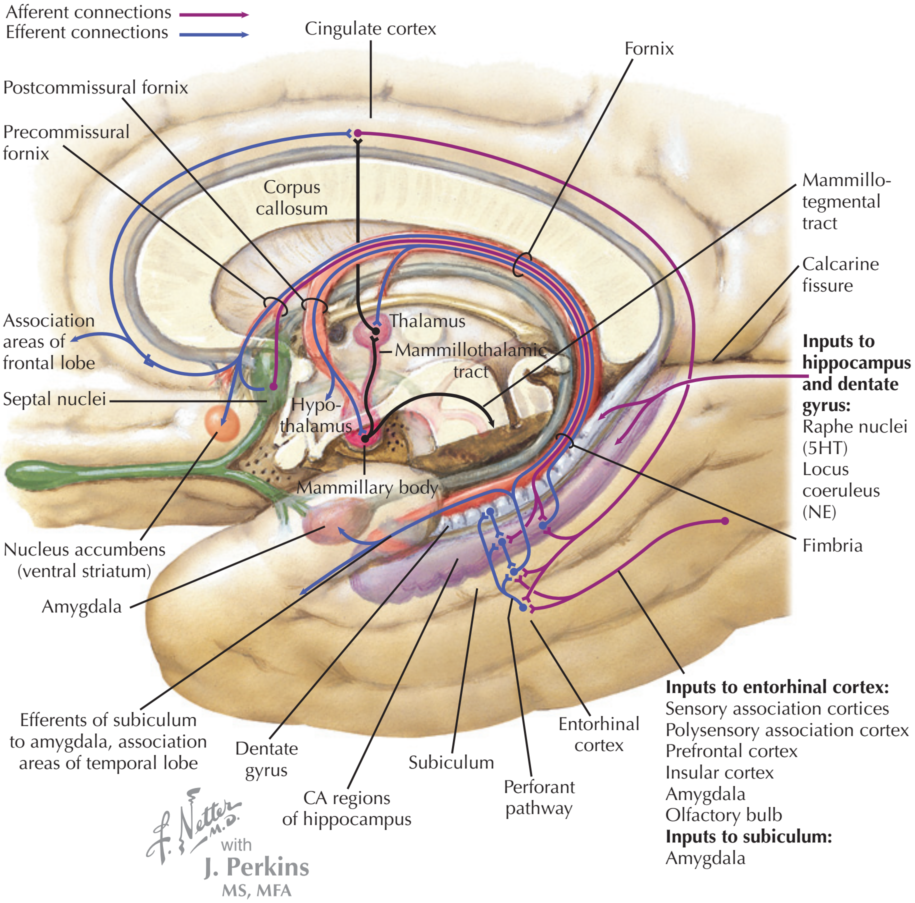


HIPPOCAMPUS *continued*



MAJOR HIPPOCAMPAL INPUTS AND OUTPUTS

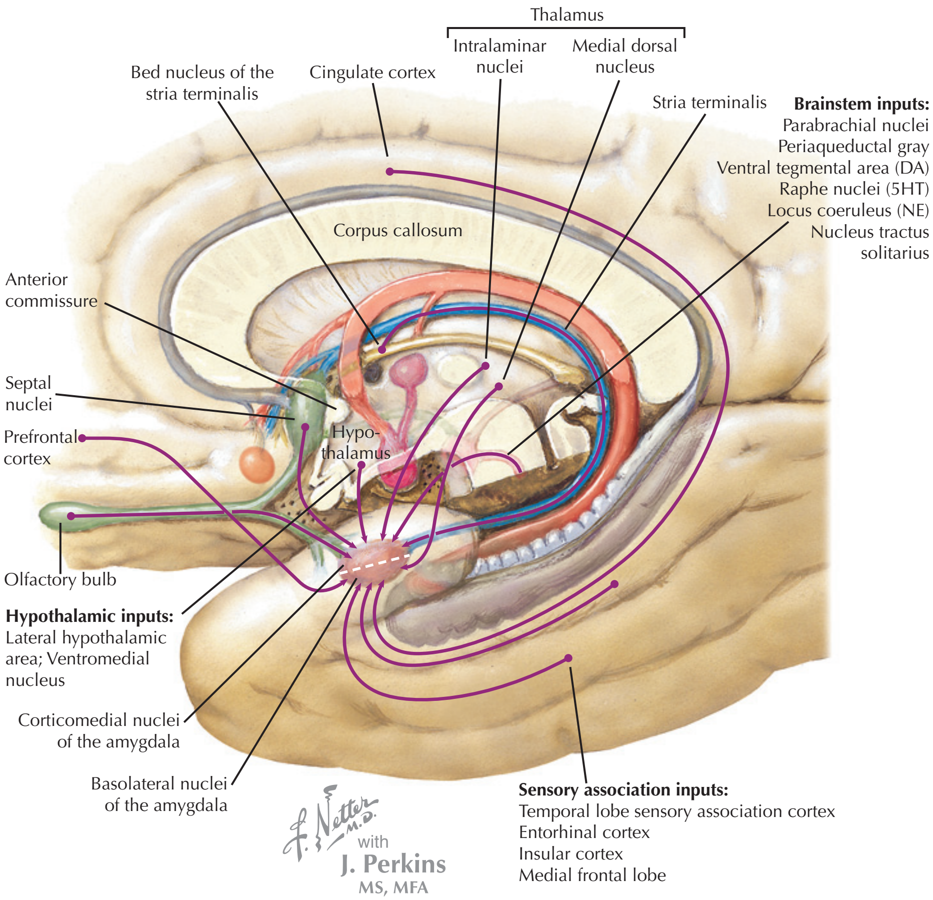
HIPPOCAMPAL INPUTS	HIPPOCAMPAL OUTPUTS
Septal nuclei→fornix→dentate and CA regions (cholinergic input vital for memory and degenerates in Alzheimer's disease)	Subiculum→fornix→mammillary bodies
Multiple cortical areas→entorhinal cortex→dentate gyrus	CA1/CA3→fornix→septal nuclei, nucleus accumbens, hypothalamus, cingulate cortex, frontal lobes



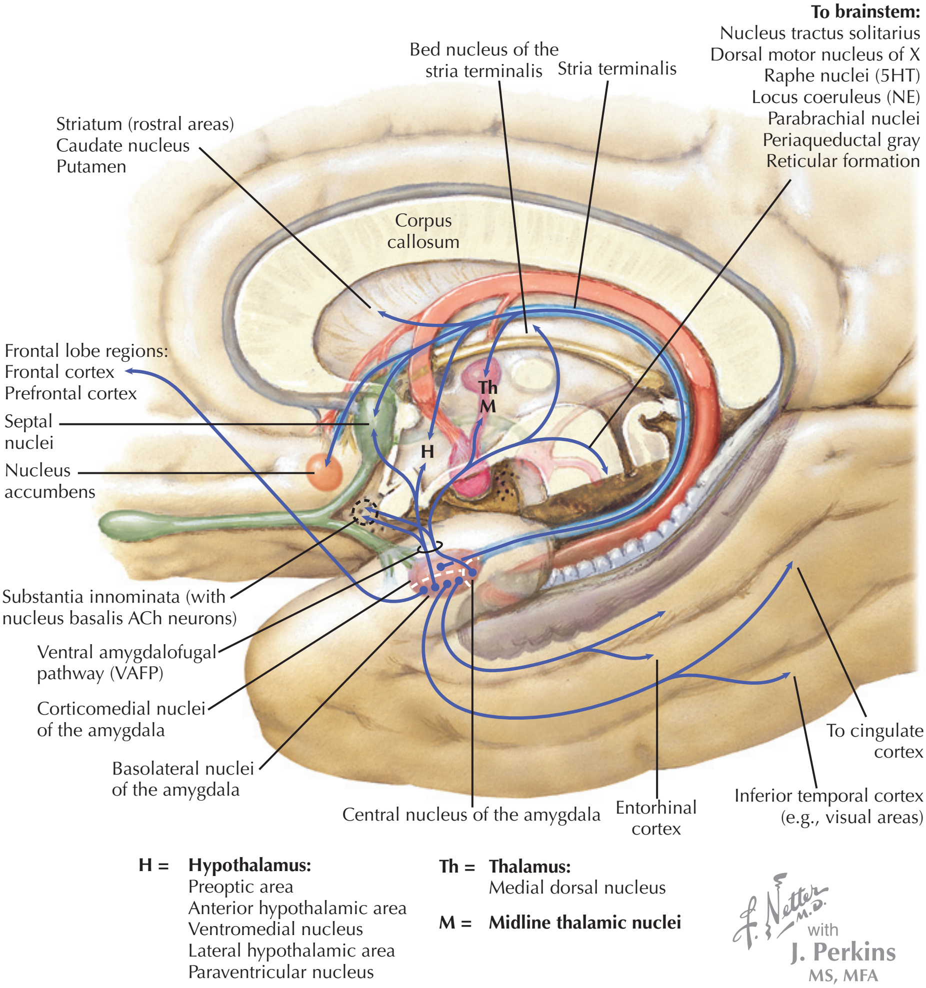
AMYGDALA

Location	Almond-shaped structure located anterior to the hippocampus in the anterior portion of the medial temporal lobe
Architecture	Composed of 3 sets of nuclei: • Basolateral nuclei • Corticomedial nuclei • Central nucleus
Inputs	Major inputs include highly processed sensory stimuli from the temporal lobe, direct olfactory information, and limbic and autonomic information from the orbitofrontal lobe, cingulate gyrus, hypothalamus, and midbrain tegmentum
Outputs	Major outputs include the hypothalamus (via the ventral amygdalofugal pathway), thalamus, striatum, septal nuclei (via stria terminalis), hippocampus, and multiple cortical areas
Function	Regulates the emotional interpretation of environmental and internal stimuli, especially relating to fear and anger
Clinical Significance	Lesions of the amygdala can cause behavioral abnormalities. Bilateral amygdala damage causes emotional blunting, hyperphagia, and hypersexuality, known as Klüver-Bucy syndrome

AMYGDALA *continued*

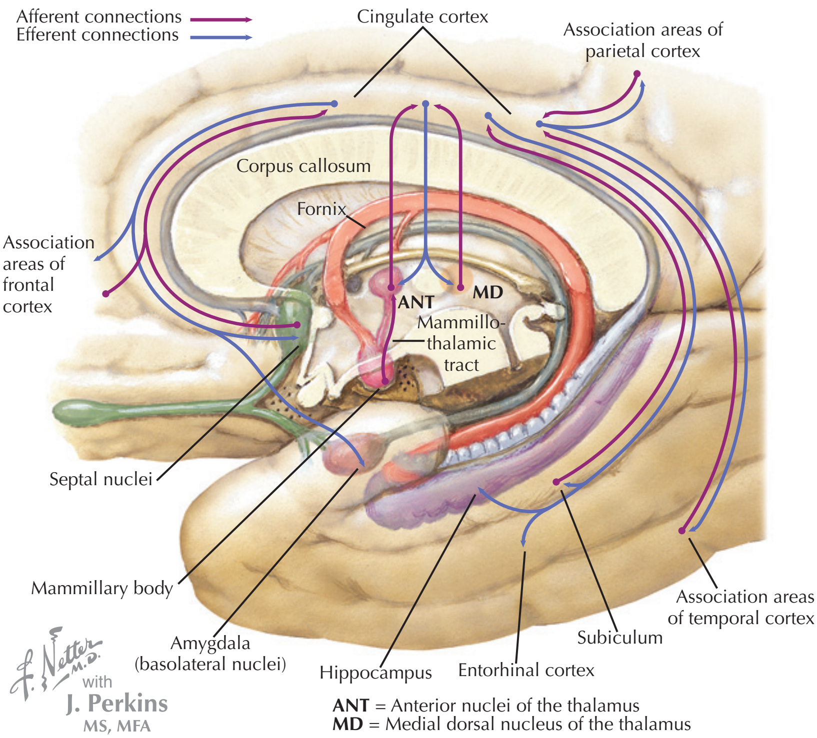


AMYGDALA *continued*



CINGULATE CORTEX

Location	Located above the body of the corpus callosum
Architecture	C-shaped deep cortical structure
Inputs	Major input received from the anterior nucleus of the thalamus as a part of Papez circuit Receives input from association cortices, septal nuclei, and subiculum
Outputs	Output to the entorhinal cortex is part of the Papez circuit. Outputs to association cortices, septal nuclei, and thalamus
Function	Cortical regulation of basic autonomic functions, including respiration, circulation, and digestion. Also involved in behavior and emotional modulation of pain
Clinical Significance	Lesions can cause indifference to pain and social indifference. May be involved in depression



ANT = Anterior nuclei of the thalamus
MD = Medial dorsal nucleus of the thalamus

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CHAPTER 14

Cranial Nerves I-XII

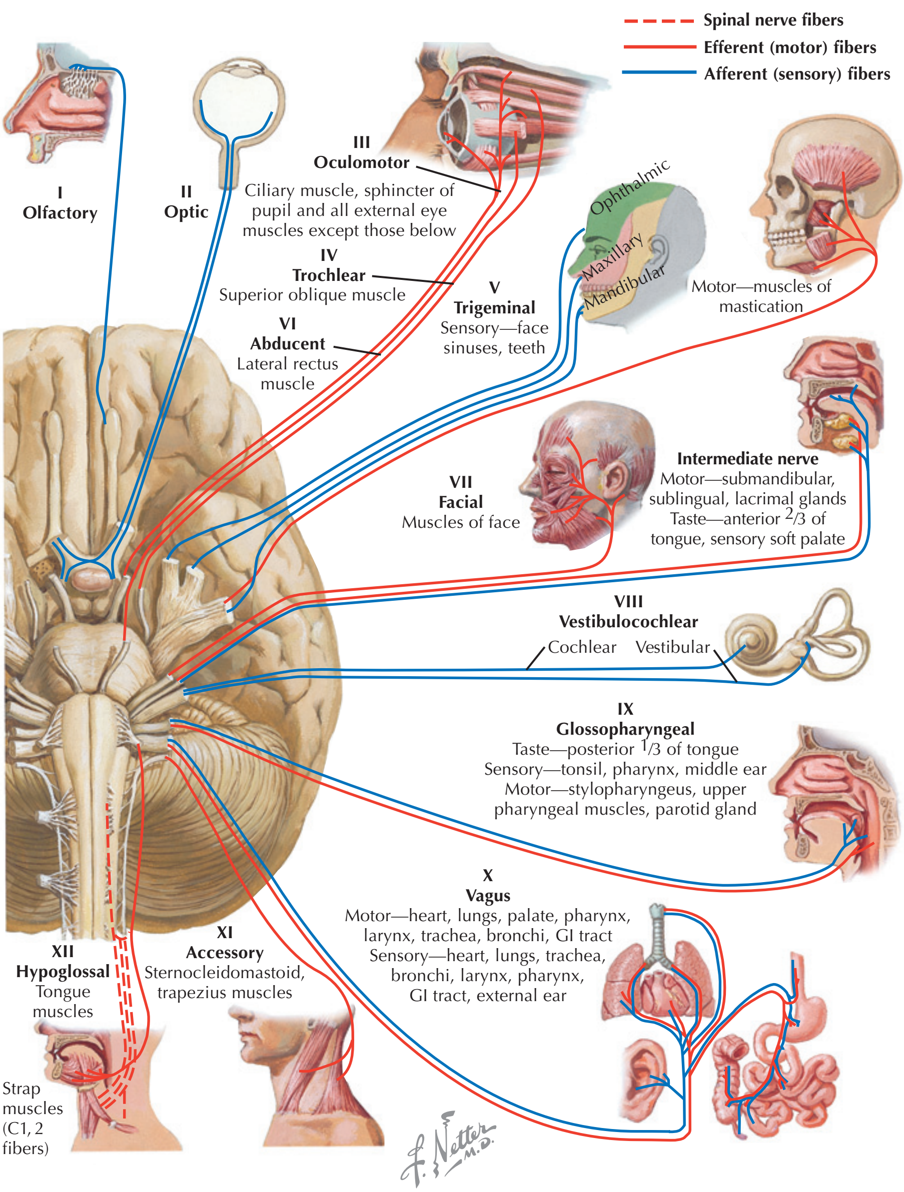
CRANIAL NERVES: OVERVIEW

- So-called because they emerge from the cranium
- Carry 6 modalities, 3 motor and 3 sensory

ANATOMIC MODALITY	FUNCTIONAL SIGNIFICANCE
Somatic motor nerves	Innervate muscles that develop from somites
Branchial motor nerves	Innervate muscles that develop from branchial arches
Visceral motor nerves	Innervate viscera, including glands and smooth muscles
General sensory nerves	Mediate touch, pain, temperature, pressure, vibration, proprioception
Visceral sensory nerves	Sensory input from viscera
Special sensory nerves	Smell, vision, taste, hearing, balance

CRANIAL NERVES: OVERVIEW *continued*

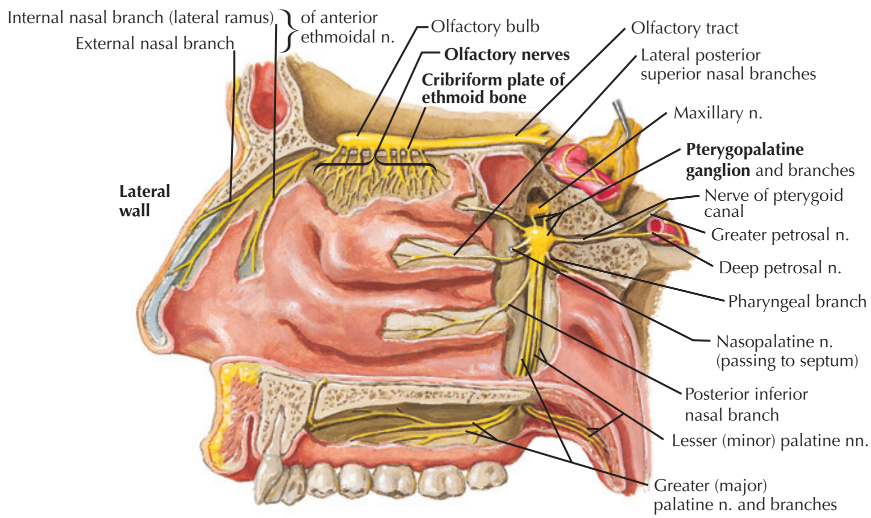
Cranial Nerves (Motor and Sensory Distribution): Schema

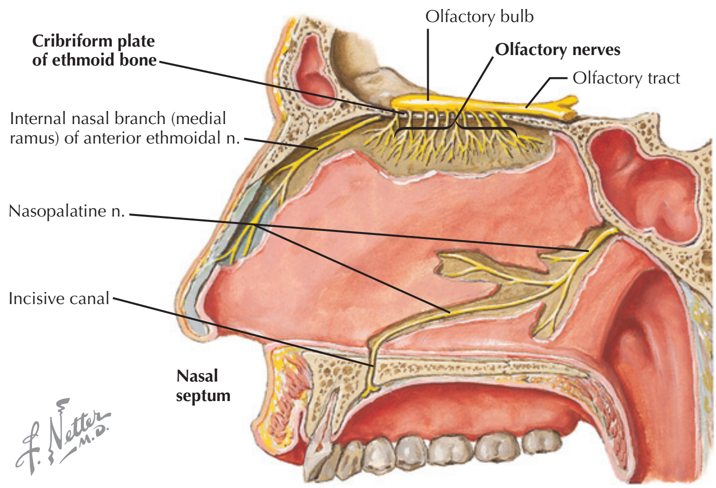


OLFACTORY NERVE (CN-I)

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Olfactory nerves	Axons traverse the cribriform plate of ethmoid to synapse in the olfactory bulb	Special sensory—smell

Head trauma can shear the olfactory nerves as they traverse cribriform plate, resulting in a loss of sense of smell. More severe head trauma may fracture cribriform plate, again resulting in transection of the olfactory nerves with loss of sense of smell.

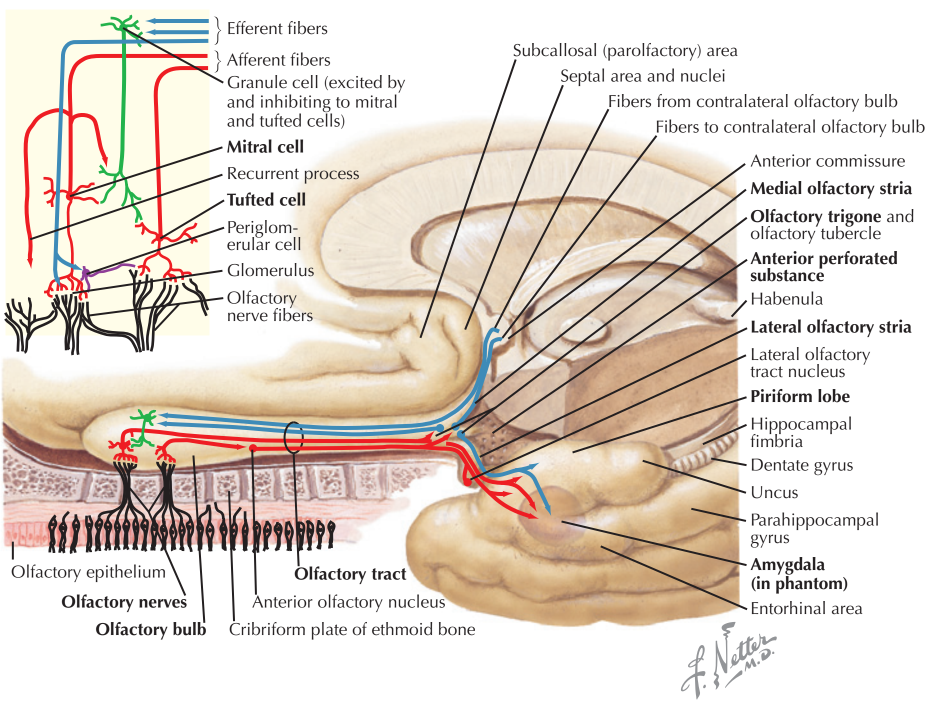




OLFACTORY NERVE (CN-I) *continued*

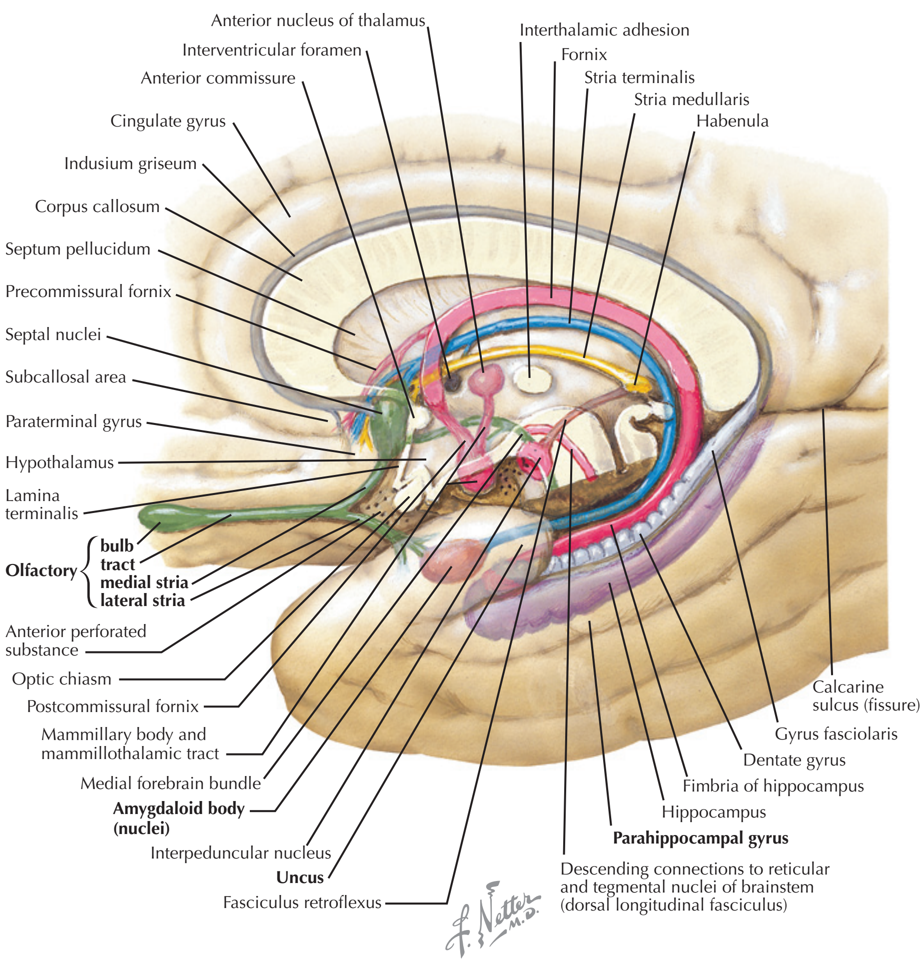
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Rhinencephalon	"Nose brain"	Central nervous system (CNS) structures involved in olfaction
Olfactory cells	Sensory receptors	Transmit sensation via olfactory nerves to bulb
Olfactory bulb	Lies on the cribriform plate of ethmoid bone, near the rostral extent of the floor of anterior cranial fossa	Contains cell bodies of secondary sensory neurons for relay of olfaction
Mitral cells Tufted cells	Secondary sensory neurons whose axons form olfactory tract	Compression of olfactory tract can cause unilateral loss of smell (anosmia)
Olfactory trigone	Divergence of olfactory tract into medial and lateral stria just rostral to the anterior perforated substance	Prepyriform cortex and periamygdaloid area receive fibers from the lateral olfactory stria and constitute primary olfactory cortex

Meningioma in the floor of the anterior cranial fossa can compress the olfactory bulb or tract and cause unilateral loss of smell *(anosmia).*



OLFACTORY NERVE (CN-I) *continued*

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Olfactory tract	Most axons of the tract pass via the lateral olfactory stria to the lateral olfactory area: uncus, parahippocampal gyrus, amygdala	Uncus, parahippocampal gyrus, and amygdala are common sites for seizure focus, causing an aura of a sense of smell at onset
Lateral olfactory stria, uncus, and medial parahippocampal gyrus	Comprises the pyriform (pear-shaped) lobe	Olfactory "hallucinations" caused by irritation of the uncus, parahippocampal gyrus, or amygdala; called *uncinate fits* and may precede a generalized convulsion

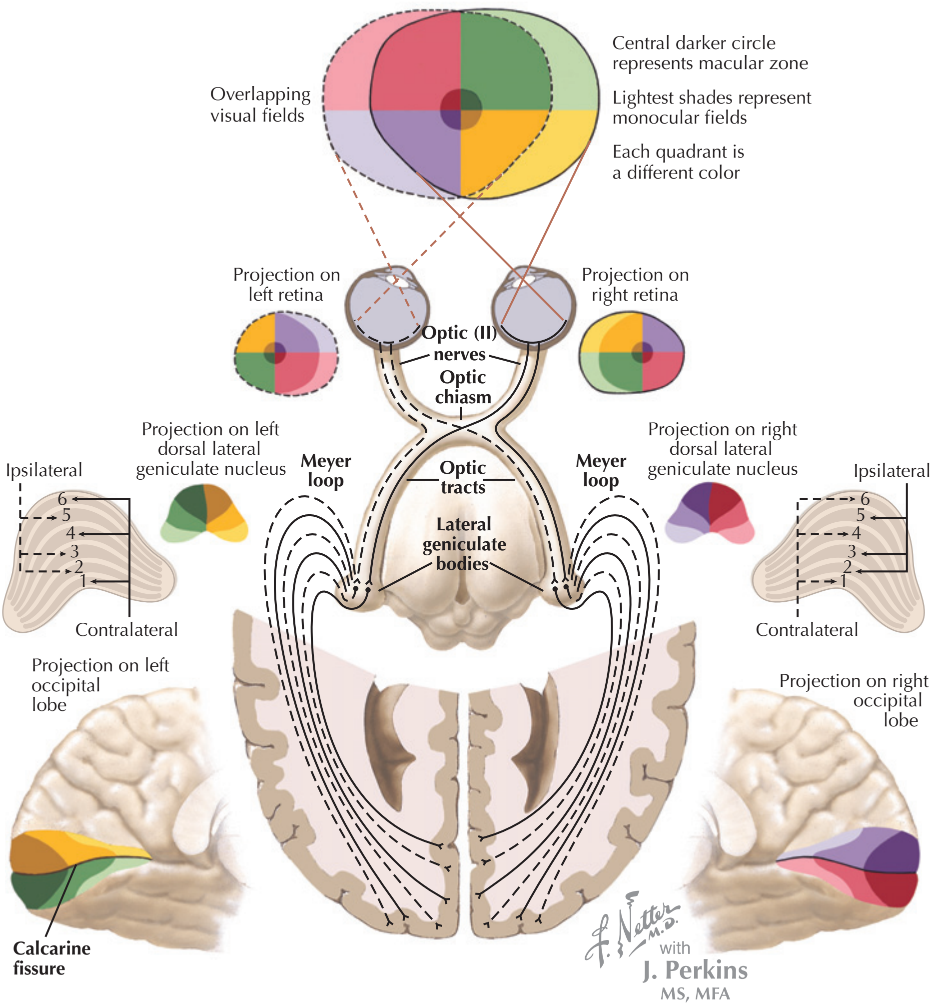


OPTIC NERVE (CN-II)

OPTIC NERVE (CN-II)		
Structure	**Anatomic notes**	**Functional Significance**
Optic nerve	Enters the cranial fossa through the optic foramen Four quadrants of nerve correspond to 4 quadrants of the retina; upper-quadrant retinal fibers remain superior; lower quadrant retinal fibers remain lower; macular fibers are in the center of CN II	Special sensory: vision from the contralateral visual field Visual-field defects affecting only 1 eye indicate retinal or optic nerve pathology Optic nerve lesion causes central scotoma in the ipsilateral eye (central macular fibers) and contralateral temporal-field defect
Optic chiasm	Nasal retinal fibers cross in the chiasm, upper retinal fibers cross dorsally, lower retinal fibers cross ventrally	Chiasmal lesions, usually compressive, produce bitemporal visual-field defects (nasal retinal fiber involvement)
Optic tract	Superior retinal quadrant fibers occupy medial optic tract, inferior retinal quadrant fibers occupy lateral optic tract	Optic tract lesion produces homonymous hemianopia that is incongruous (not identical in both eyes)
Lateral geniculate body	Origin of geniculocalcarine tract, optic radiations; passes through the retrolenticular portion of the internal capsule to end in the striate cortex (area 17)	Lesions of the lateral geniculate body cause strikingly incongruous visual-field defects
Optic radiations: dorsal fibers	Pass almost directly back to the striate cortex (area 17) on the medial surface of occipital lobes on both banks of the calcarine fissure	Lesion in the retrolenticular portion of the internal capsule can produce motor and sensory impairment, with homonymous hemianopia
Optic radiations: ventral fibers	First turn forward and downward into temporal lobe, spread out over the rostral part of the inferior (temporal) horn of lateral ventricle, then loop backward, running close to the outer wall of the temporal horn of the lateral ventricle to occipital cortex (the Meyer loop)	Stroke or tumor involving the temporal lobe can affect the Meyer loop, resulting in contralateral upper quadrantanopia ("pie in the sky") visual-field deficit
Occipital pole	Macula projects here	Macular sparing, retention of central 5 degrees of visual field, occurs with occipital lobe infarction due to the middle cerebral artery's contribution to this cortical area

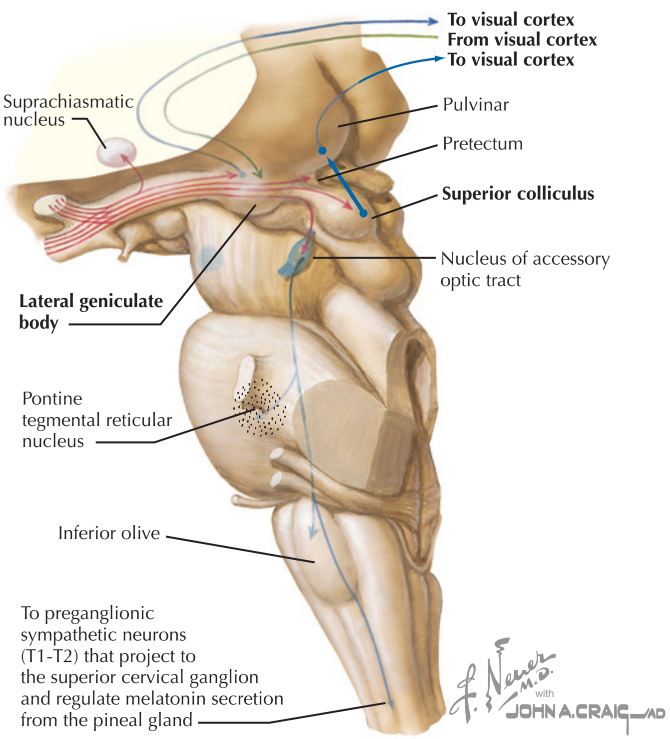
- Light from the upper half of the visual field falls on the lower half of the retina and vice versa.
- Light from the temporal half of the visual field falls on the nasal half of the retina and vice versa.

OPTIC NERVE (CN-II) *continued*



OPTIC TRACT (CN-II)

ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Sweeps out and back, around the hypothalamus and rostral crus cerebri	Pituitary tumor may compress the chiasm, resulting in bitemporal hemianopia
Most fibers terminate in the lateral geniculate body Small portion continue as brachium of the superior colliculus to the superior colliculi	Fibers from the upper retinal quadrants (lower visual field) terminate in the medial lateral geniculate, and those from the lower retinal quadrants (upper visual field) terminate in the lateral part of the lateral geniculate
Medial half of the lateral geniculate project to the superior lip of the calcarine fissure via the superior portion of the optic radiation	Transmits vision from the upper retinal quadrant (lower visual field)
Lateral half of the lateral geniculate project to the inferior lip of the calcarine fissure via the inferior portion of optic radiation (the Meyer loop)	Transmits vision from the lower retinal quadrant (upper visual field)



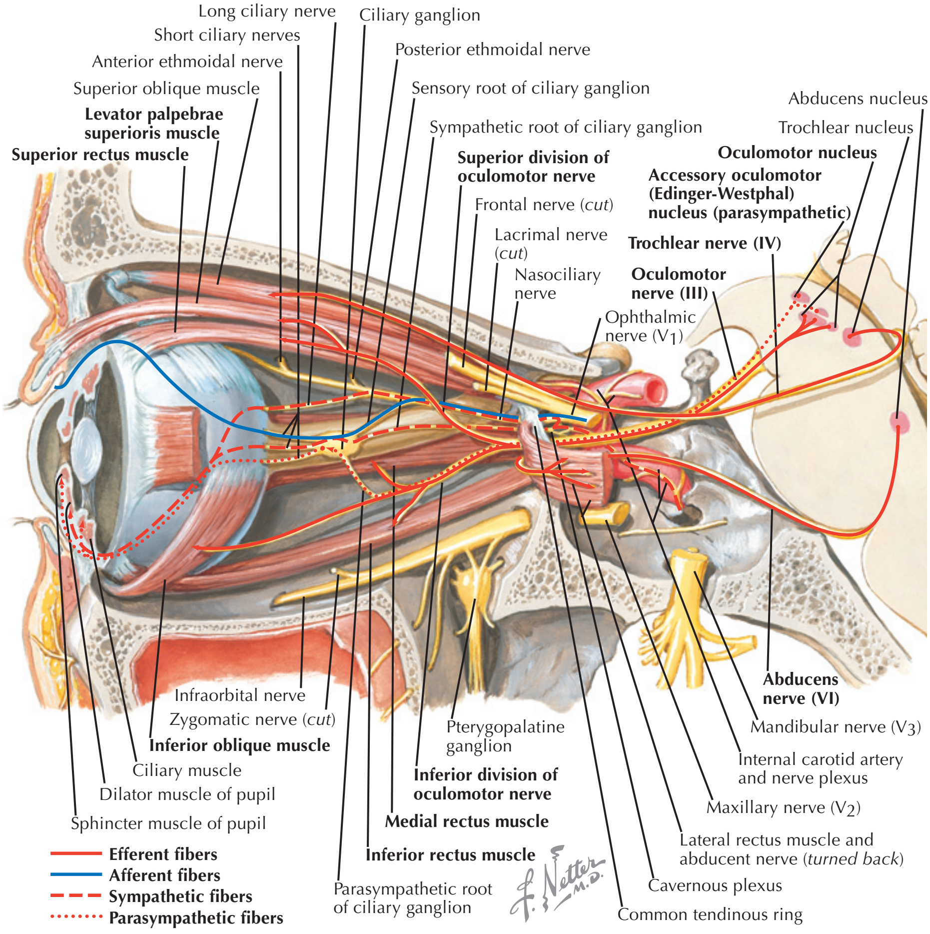
OCULOMOTOR NERVE (CN-III)

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Oculomotor nucleus	Located at the level of superior colliculus	Somatic motor fibers from the oculomotor nucleus combine with parasympathetic fibers from the Edinger-Westphal nucleus to form CN-III.
Oculomotor nerve (CN-III)	Passes anteriorly between the posterior cerebral and superior cerebellar arteries, pierces the dura, and enters cavernous sinus In sinus, CN-III runs along the lateral wall, superior to the trochlear nerve (CN-IV), enters the orbit through the superior orbital fissure, and splits into superior and inferior divisions	Superior division supplies the superior rectus and levator palpebrae superioris. Inferior division supplies the inferior and medial recti and inferior oblique.

Diabetic third-nerve palsy causes unilateral painful diplopia with weakness of the superior, inferior, and medial recti and the inferior oblique, but it spares the pupil because pupillary fibers run along the outer layer of the nerve and diabetes causes ischemia, which is most profound in the inner layers of the nerve. Compression of CN-III by a posterior cerebral artery aneurysm results in dilated pupil and ophthalmoplegia involving the superior, medial, and inferior recti and the inferior oblique. The pupil is affected because the nerve is compressed from the outside, which is where the pupillary fibers run.

OCULOMOTOR NERVE (CN-III) *continued*

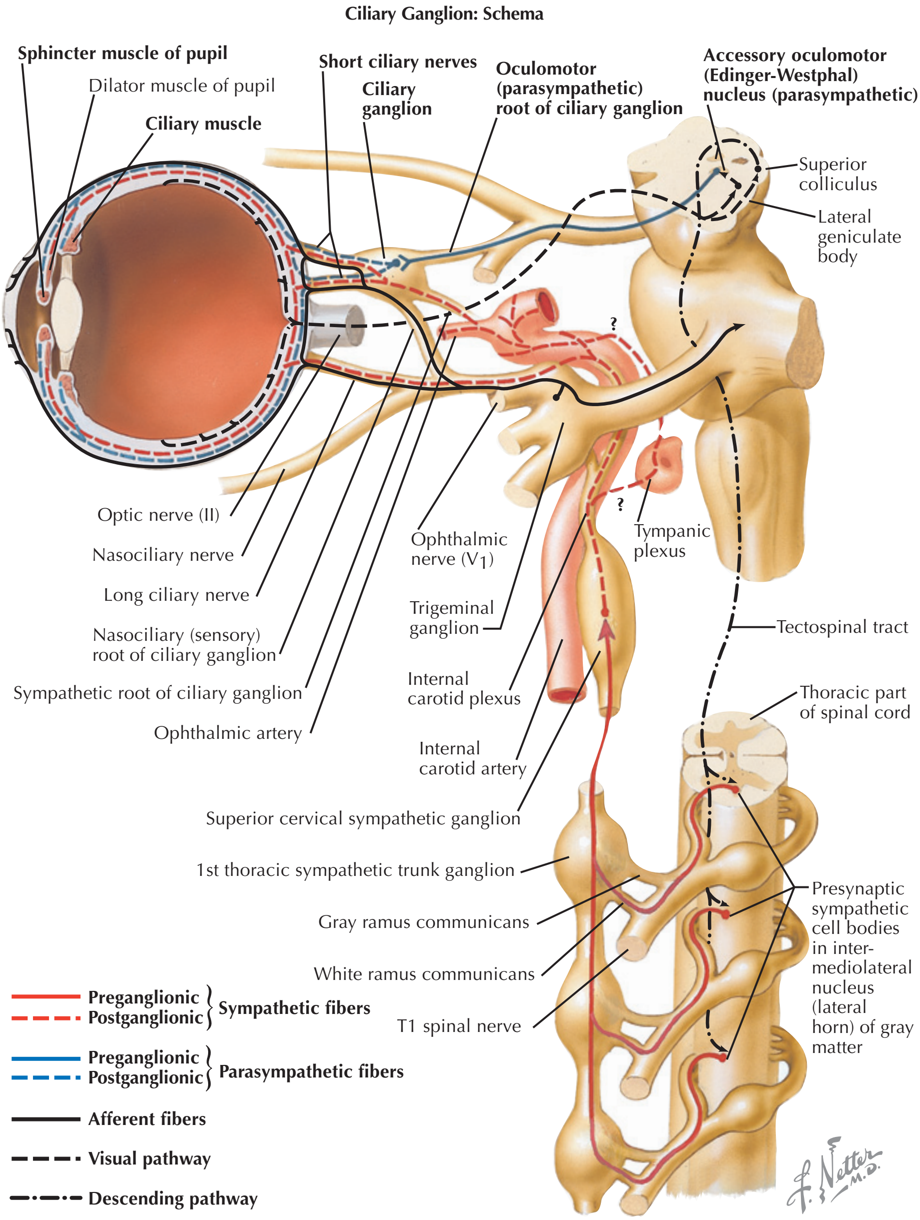
Oculomotor (III), Trochlear (IV) and Abducens (VI) Nerves: Schema



OCULOMOTOR NERVE (CN-III): PARASYMPATHETIC COMPONENT

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Edinger-Westphal nucleus	Dorsal to oculomotor complex Innervates sphincter of pupil and ciliary muscles via ciliary ganglion Fibers run with CN-III to enter the orbit. There they leave the nerve and terminate in the ciliary ganglion near the apex of the cone of extraocular muscles	Visceral motor
Postganglionic axons	Leave ciliary ganglion as 6-10 short ciliary nerves and enter the eye along with sympathetic fibers In eyeball, fibers run forward between the choroid and sclera to terminate in sphincter muscle of the pupil (iris)	Iris sphincter muscle encircles the pupil and pulls toward the center, causing the pupil to constrict Ciliary muscles cause a change in the shape of the lens for additional refraction on near gaze

OCULOMOTOR NERVE (CN-III): PARASYMPATHETIC COMPONENT *continued*



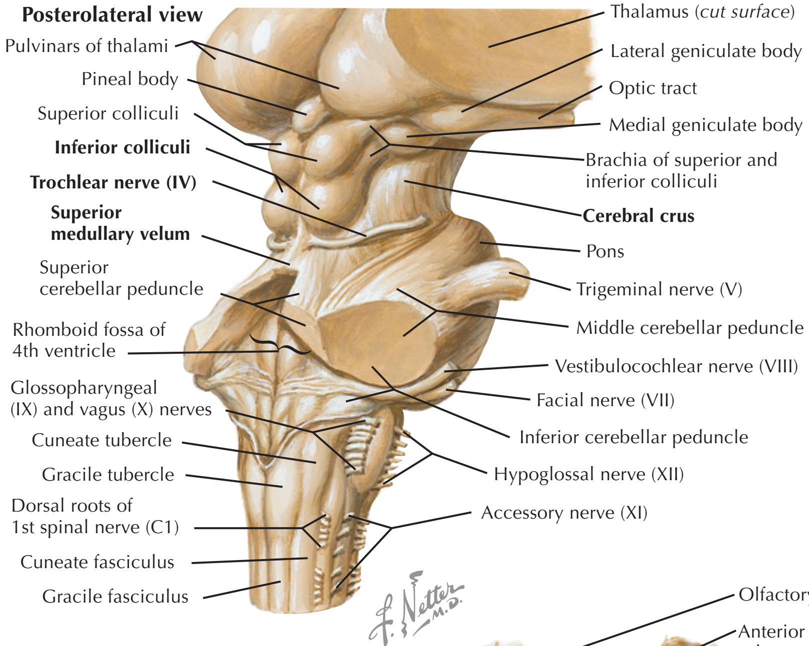
TROCHLEAR NERVE (CN-IV)

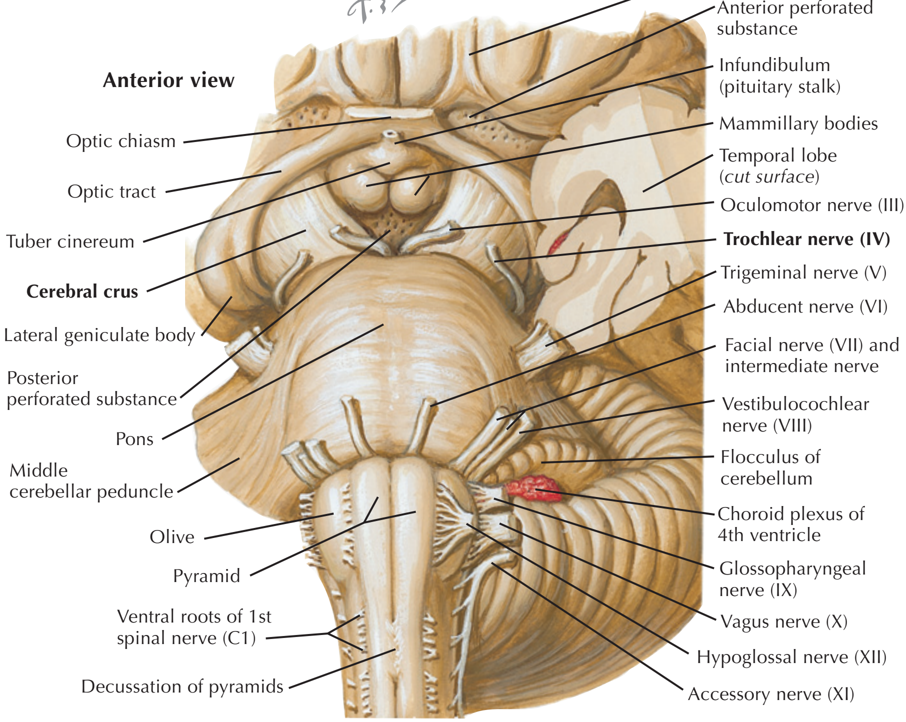
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Trochlear nucleus	In midbrain tegmentum, at the level of the inferior colliculus, ventral to the aqueduct	Somatic motor
Trochlear nerve	Axons leave the trochlear nucleus in the caudal midbrain Course dorsally and caudally around the aqueduct Decussate in the superior medullary velum Exit brainstem dorsally, caudal to the inferior colliculus Cross to the opposite side (the left trochlear nucleus gives rise to the right trochlear nerve and vice versa) Curve around the cerebral peduncle (crus) Pass between posterior cerebral and superior cerebellar arteries with CN-III Pierce the dura and enter the cavernous sinus with CN-III, -V_1, and -VI Run along the lateral wall, inferior to CN-III Continues through the superior orbital fissure, close to the roof of the orbit, to the superior oblique	Supplies the superior oblique Susceptible to injury following head trauma, resulting in vertical diplopia with head tilt to the opposite side to correct superior oblique weakness

See pages 223–4 for Oculomotor and Abducens Nerves: Schema.

TROCHLEAR NERVE (CN-IV) *continued*

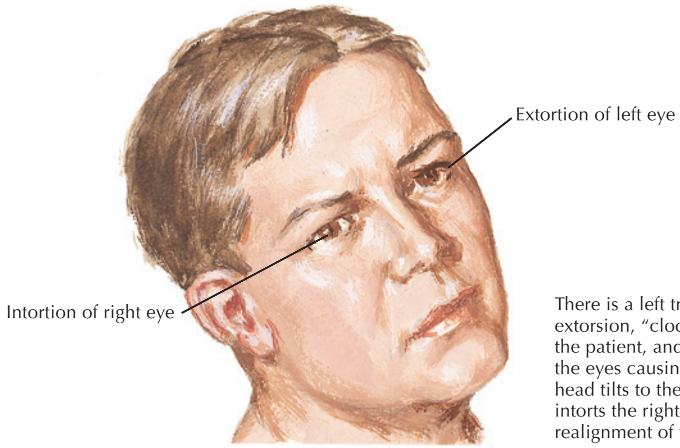
Brainstem





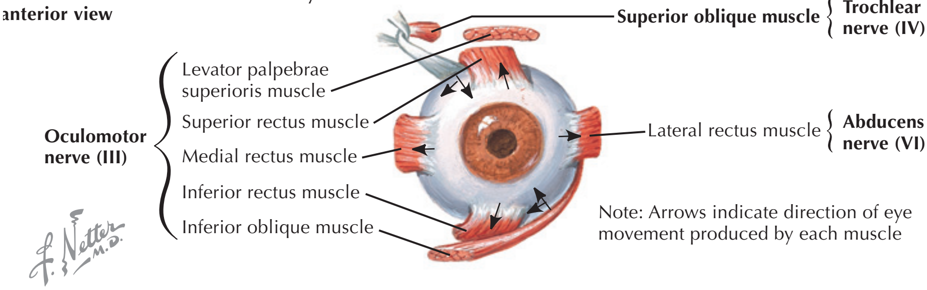
TROCHLEAR NERVE (CN-IV) *continued*

ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
So-called because of the “trochlea” (pulley) through which the superior oblique muscle passes to reach the eyeball insertion site	Causes inward rotation (intortion) and downward and lateral movement of eye
Smallest nerve, 2400 axons, versus 1 million in the optic nerve Only cranial nerve to exit the dorsal brainstem Only nerve in which all lower motor axons decussate Nerve with longest intracranial course is 7.5 cm	In addition to vertical diplopia, when patient looks down, injury to the trochlear nerve results in a head tilt to the unaffected side as patients correct their (extorted) affected eye by intorting their good eye toward the affected side



There is a left trochlear palsy, causing left eye extorsion, “clockwise” rotation as you look at the patient, and a rotational misalignment of the eyes causing diplopia. To compensate, the head tilts to the unaffected right side. This intorts the right eye resulting in rotational realignment of the (both) eyes.

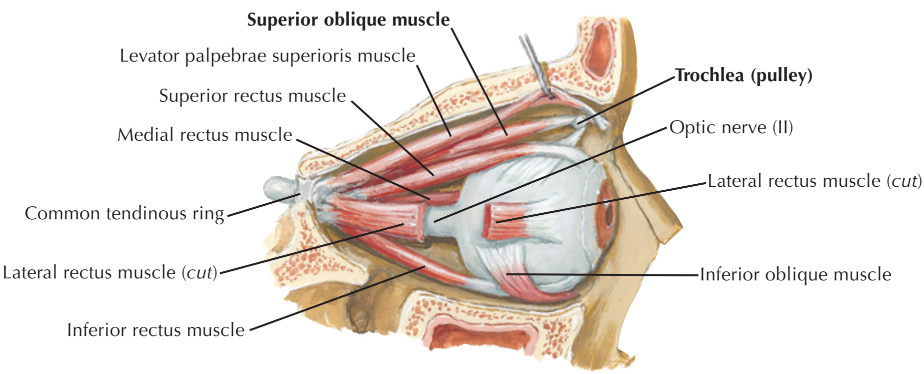
Innervation and action of extrinsic eye muscles: anterior view



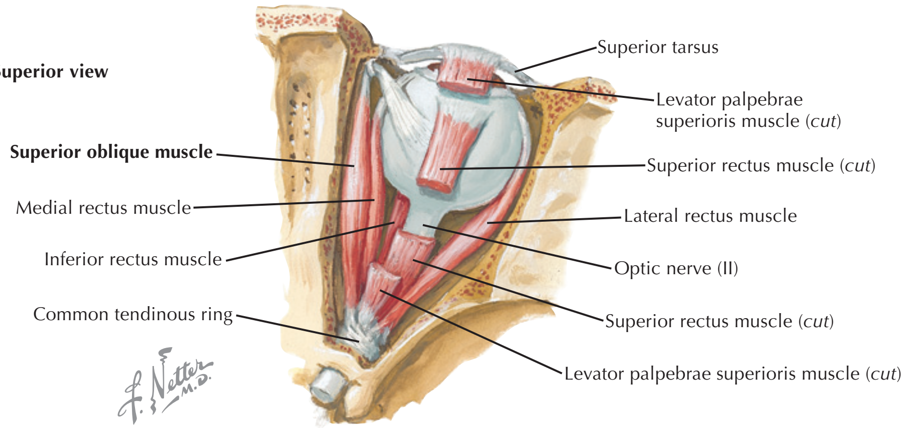
Note: Arrows indicate direction of eye movement produced by each muscle

TROCHLEAR NERVE (CN-IV) *continued*

Right lateral view

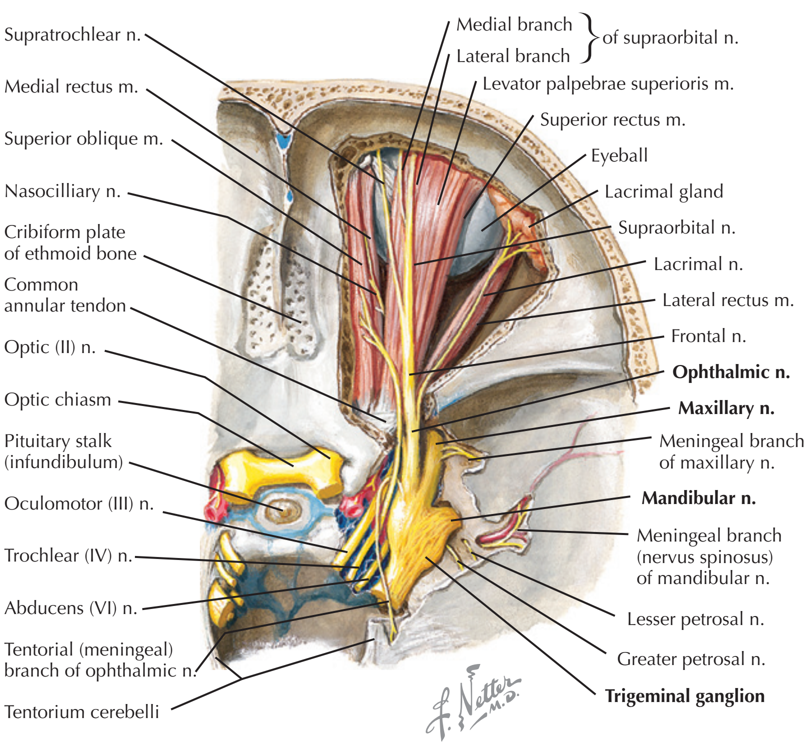


Superior view



TRIGEMINAL NERVE (CN-V)

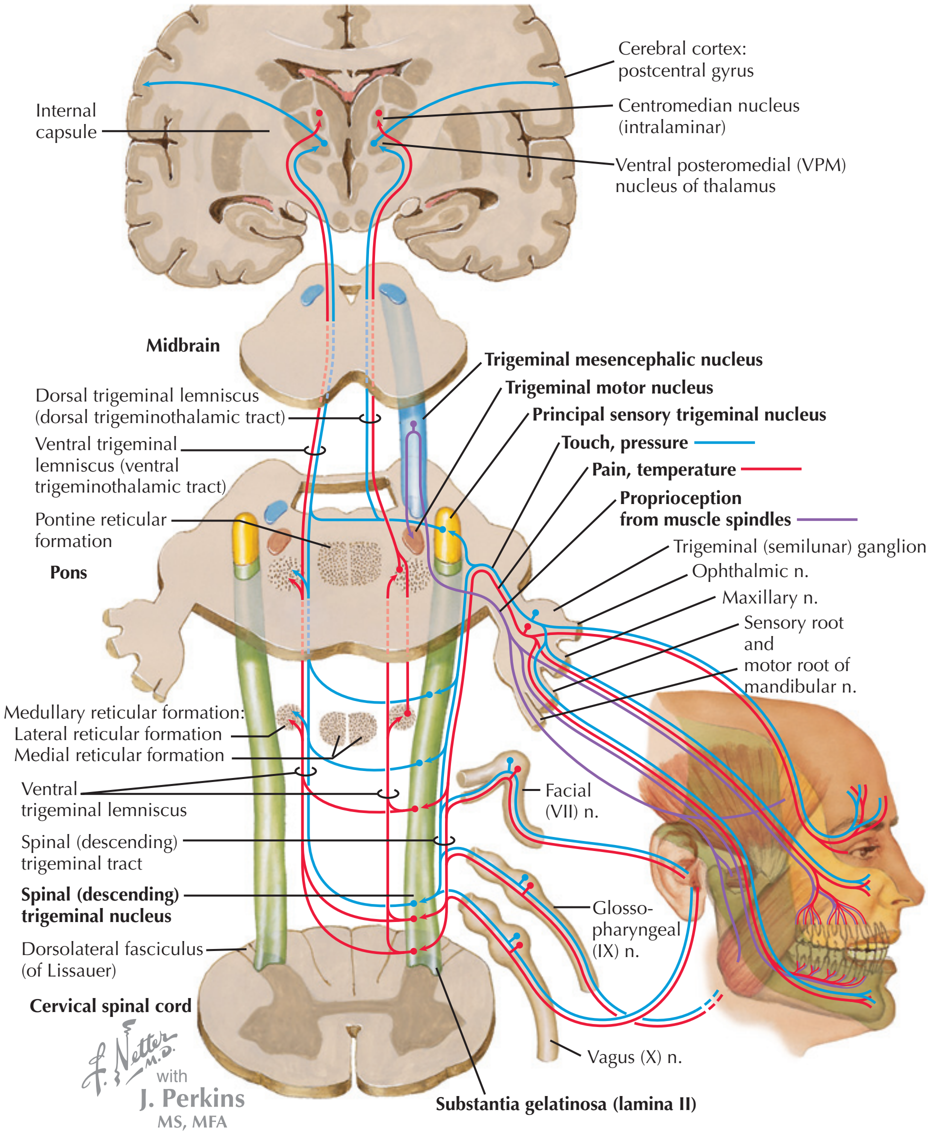
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Trigeminal nerve	Emerges from the midlateral pons as a large sensory root and a smaller motor root	Branchial motor to muscles of mastication, tensor tympani and palatini, mylohyoid, and anterior belly of digastric
Trigeminal sensory ganglion	Sits in a depression (Meckel's cave) in the floor of the middle cranial fossa	General sensory to the face, anterior scalp to the vertex of the skull, conjunctiva, globe of eye, mucous membranes of the paranasal, nasal, and oral cavities, anterior $^2/_3$ of the tongue, part of the external tympanic membrane, meninges of the anterior and middle cranial fossa
Trigeminal nerve	3 divisions exit the cranial fossa: • V_1 (ophthalmic division) through superior orbital fissure • V_2 (maxillary division) through foramen rotundum • V_3 (mandibular division) through foramen ovale	V_1 and V_2 run through the cavernous sinus before exiting the cranial fossa Motor root travels with V_3



TRIGEMINAL NERVE NUCLEI

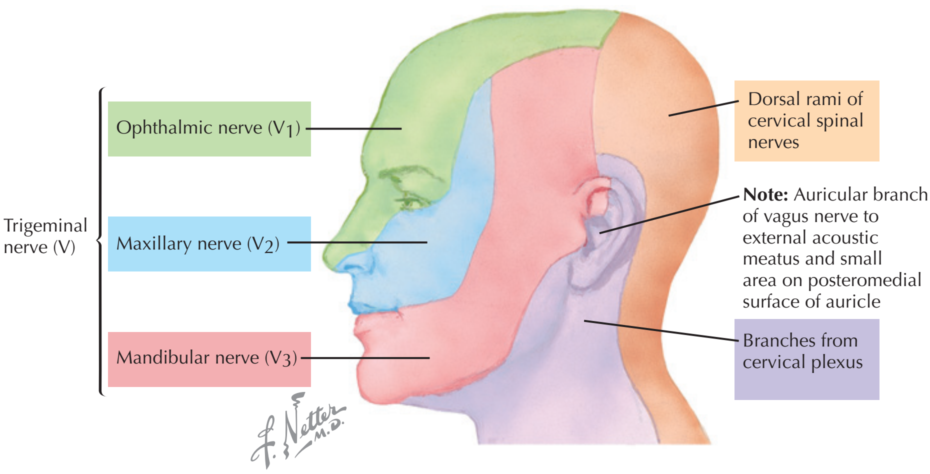
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Motor (masticator) nucleus	Midpons, medial to the main sensory nucleus Input from corticobulbar fibers, reticular neurons, and collaterals from the mesencephalic root and other trigeminal afferents	Controls muscles of chewing, swallowing, and hearing
Sensory nucleus	Extends from midbrain to the spinal cord C2, largest grouping of cranial nerve nuclei, consisting of mesencephalic, principal sensory, and spinotrigeminal nuclei	Lesion involving this nucleus anywhere along its course (multiple sclerosis, stroke, tumor) impairs facial sensation
Mesencephalic nucleus	Column of primary sensory neurons Only primary sensory neurons in humans that reside within the central nervous system (CNS)	Carries proprioception from muscles of mastication and facial expression, for control of bite and facial movements
Principal sensory trigeminal nucleus	In pons near the entry point of the nerve	Carries fine touch, pressure, and vibration sensations from the face
Spinotrigeminal nucleus	Long cell column extending from the caudal pons to the upper cervical spinal cord, where it merges with the substantia gelatinosa of the dorsal gray matter	Carries pain and temperature mainly, also crude touch

TRIGEMINAL NERVE NUCLEI *continued*

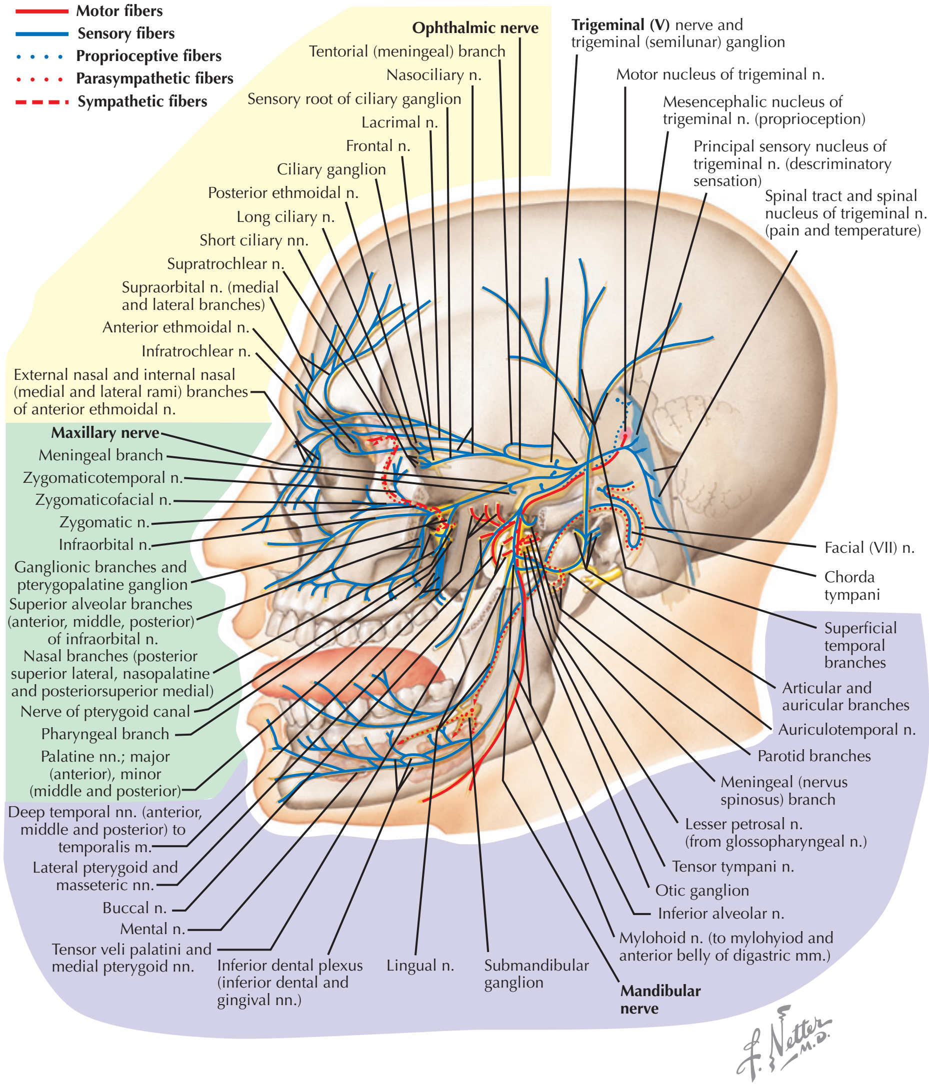


TRIGEMINAL NERVE MOTOR AND SENSORY BRANCHES

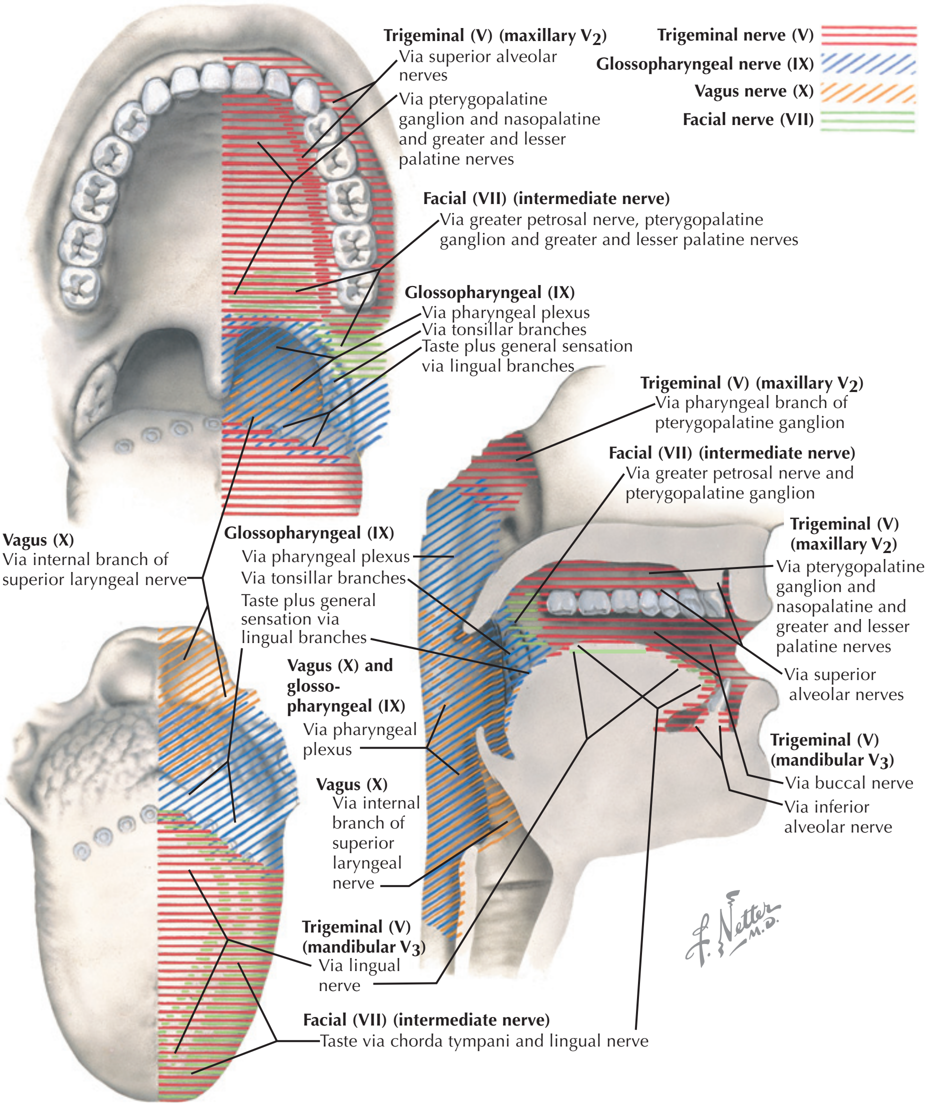
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Efferent motor fibers	Exit the pons medial to sensory root to join sensory V_3 branches outside the cranium to form mandibular nerve	Mediates chewing, swallowing, and reflexive control of hearing
V_1 (ophthalmic division)	Exits through the superior orbital fissure	Mediates sensation from conjunctiva, cornea, orbit, dorsal aspect of the nose, upper eyelid, forehead to the vertex of skull, ethmoid, and frontal sinuses; proprioception from the extraocular and facial muscles of the eyelid and forehead
V_2 (maxillary division)	Exits through the foramen rotundum	Mediates sensation from maxilla and overlying skin, including the upper lip, side of nose, medial cheek, nasal cavity, palate, nasopharynx, and meninges of the anterior and middle cranial fossa
V_3 (mandibular division)	Exits through the foramen ovale	Mediates sensation from the buccal region, including the mucous membrane of the mouth, gums, the side of the head, scalp, entire lower jaw including teeth, gums, anterior $^2/_3$ of the tongue, chin, lower lip, and meninges of the anterior and middle cranial fossa



TRIGEMINAL NERVE MOTOR AND SENSORY BRANCHES *continued*



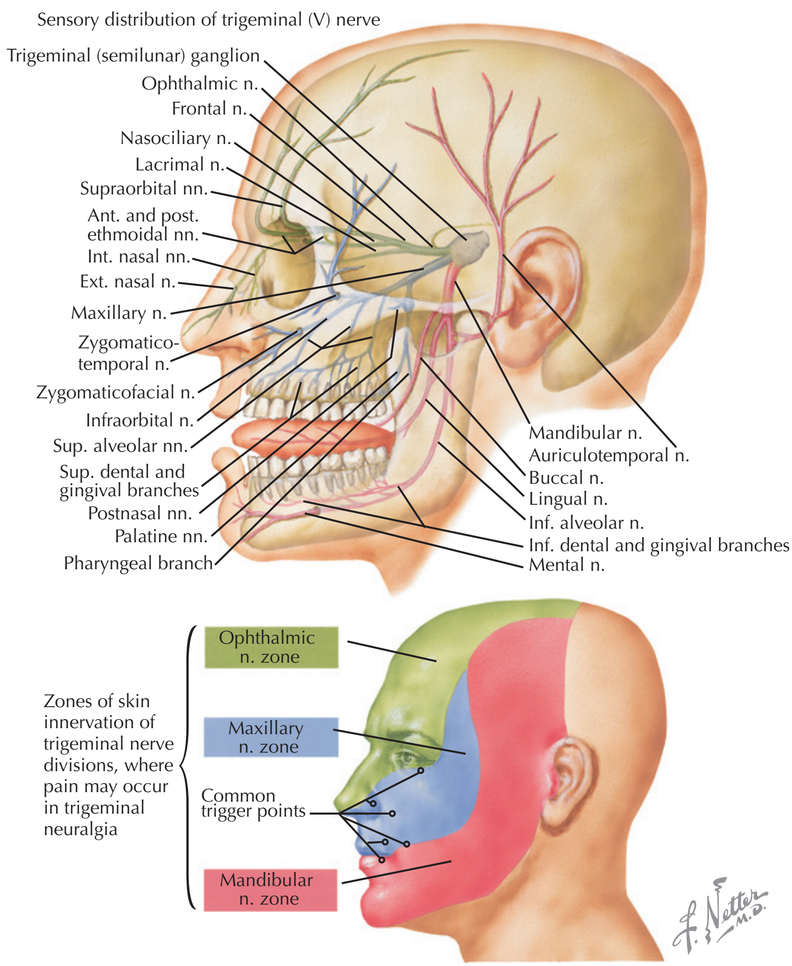
TRIGEMINAL NERVE MOTOR AND SENSORY BRANCHES *continued*



TRIGEMINAL NEURALGIA (TIC DOULOUREUX)

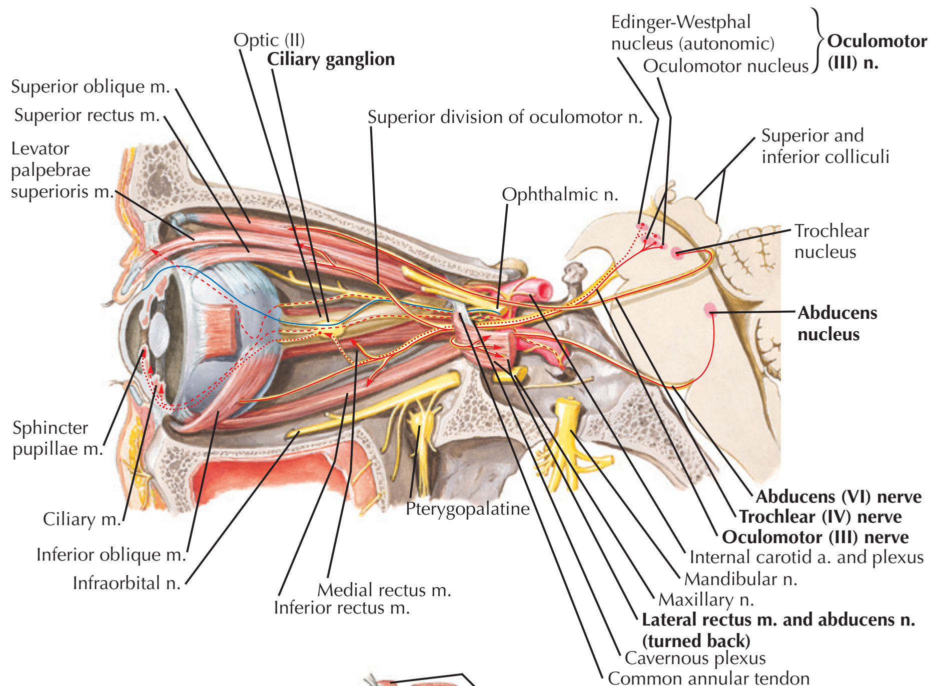
- Stabbing pain in distribution of V_1 or V_2, rarely V_3
- Lasts seconds or a minute or two but so intense that the patient winces, hence called *tic*
- Paroxysms recur frequently, day or night, for weeks at a time
- No sensory or motor loss present on examination
- Aberrant vascular course of superior cerebellar artery, crossing the trigeminal branch, often cited as cause
- Most often, no lesion is identified, and etiology is labeled idiopathic

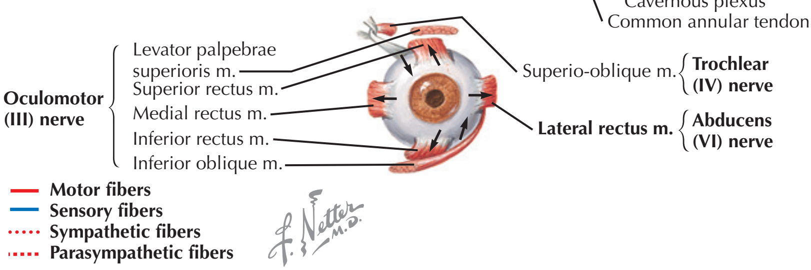
Trigeminal Neuralgia



ABDUCENS NERVE (CN-VI)

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Abducens nucleus	Located in the pontine tegmentum close to midline, just ventral to 4th ventricle	Somatic motor to lateral rectus Mediates eye abduction
Abducens nerve	Axons leave the nucleus, course ventrally through the tegmentum to exit at the junction of pons and medulla, near the midline In subarachnoid space of posterior fossa, runs anterolaterally, pierces the dura lateral to the dorsum sella, enters the cavernous sinus, lateral to carotid artery, medial to CN-III, -IV, -V_1, and -VI, continues through the medial portion of the superior orbital fissure, to the lateral rectus	With cavernous sinus thrombosis, headache, ptosis, ocular palsy, eye pain, and sensory loss over the forehead occur due to involvement of these nerves

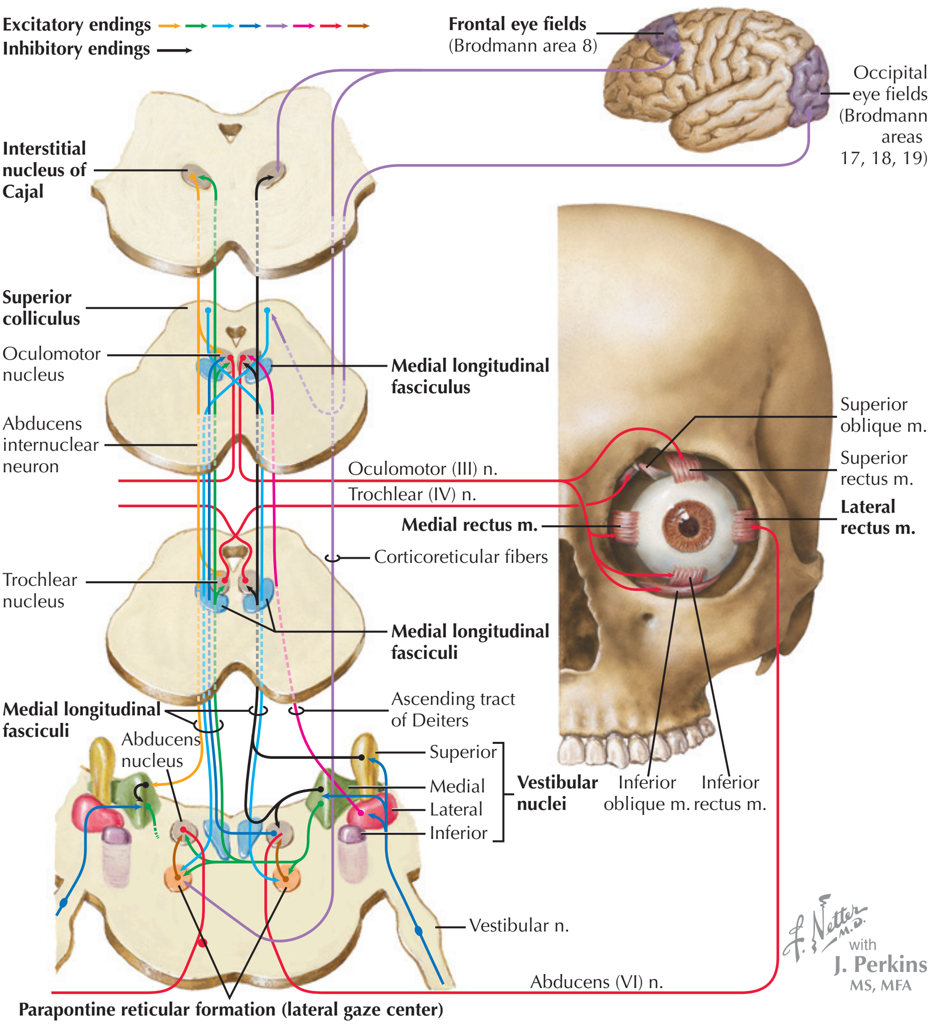




CONTROL OF EYE MOVEMENTS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Paramedian pontine reticular formation (PPRF)	Input: • Vestibular nuclei • Superior colliculus • Frontal eye fields • Interstitial nucleus of Cajal	Horizontal gaze center Because stimulation of the frontal eye field causes eye deviation to the opposite side by stimulating the contralateral PPRF, stroke involving frontal eye field results in conjugate eye deviation to same side of the lesion due to inability to look to opposite side
PPRF	Supplies: • Ipsilateral CN-VI to the lateral rectus • Contralateral CN-III via CN-VI nuclear interneurons and/or PPRF to the medial rectus, through the medial longitudinal fasciculus	Unilateral pontine stroke involving PPRF results in inability to move eyes ipsilaterally, to side of lesion Transiently, the eyes may be contralaterally deviated due to uninhibited action of the contralateral PPRF moving eyes to that side. Nystagmus occurs when the patient looks to intact field of movement, with quick phase directed toward that side
Interstitial nucleus of Cajal	Projects axons to spinal cord and contralateral interstitial nucleus of Cajal	Axial muscle control and coordinates vertical and oblique eye movements

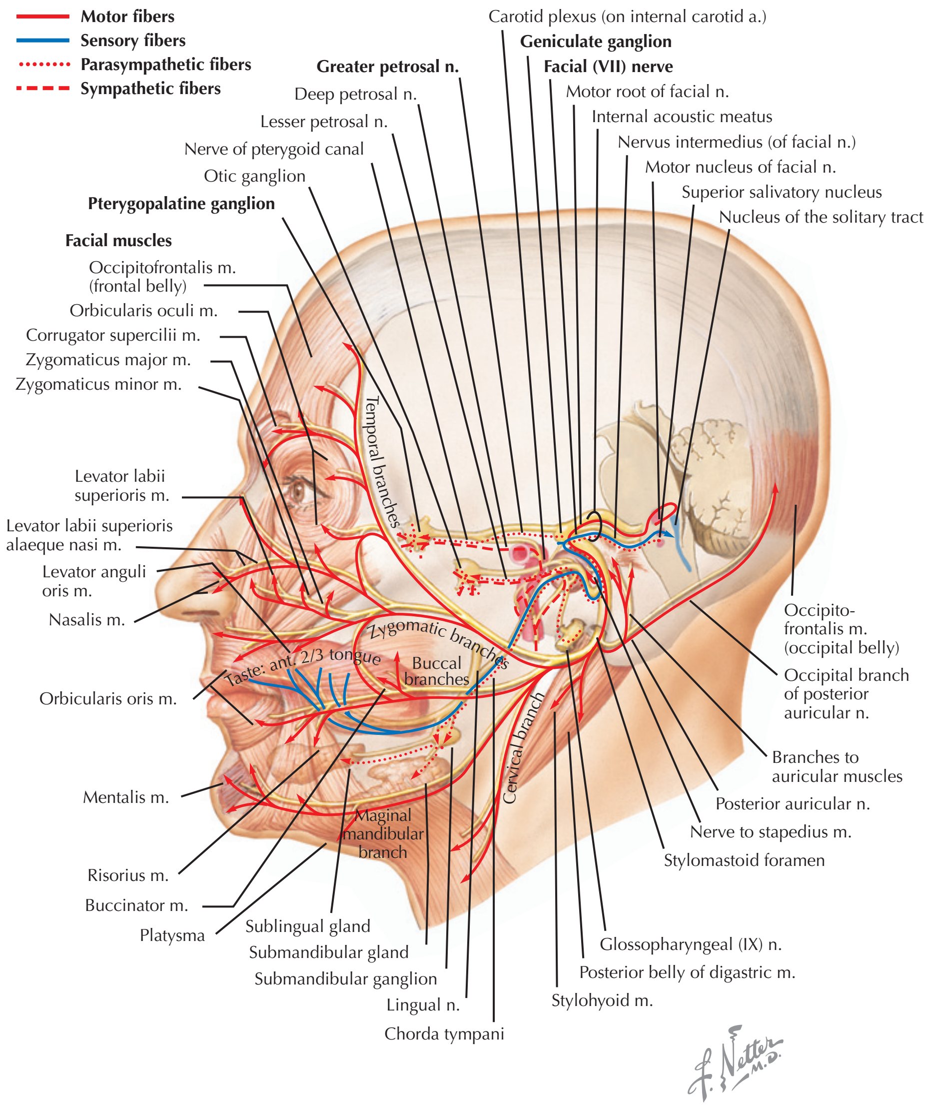
CONTROL OF EYE MOVEMENTS *continued*



FACIAL NERVE (CN-VII)

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Facial nerve	Emerges at the pontomedullary junction and enters the internal auditory meatus	Bell's palsy: acute facial muscle paralysis due to herpes simplex virus I infection of CN-VII
Branchial motor fibers	Emerge at the stylomastoid foramen, pass through the parotid gland	Innervates stapedius, stylohyoid, posterior digastric, and facial muscles
Visceral motor fibers	In petrous bone: preganglionic parasympathetic axons in the greater petrosal nerve, which branch off to pterygopalatine ganglion	Innervates lacrimal, submandibular, and sublingual glands and mucous membranes of the nose and palate
General sensory fibers	Accompany those of the auricular branch of vagus CN-X	Supply skin of the concha of the auricle and a small area behind the ear
Special sensory	As CN-VII courses through the petrous portion of the temporal bone, it displays a swelling, the geniculate ganglion (nerve cell bodies of taste fibers of tongue)	Taste from anterior $^2/_3$ of the tongue and the hard and soft palate (enter through chorda tympani), carrying taste from (and parasympathetic motor to) the tongue
Corticobulbar fibers	Project bilaterally to the portion of the facial nucleus that innervates forehead muscles but, to remaining (lower) facial muscles, projects only contralaterally	Lesion of cortical fibers thus causes contralateral weakness of facial muscles but spares the forehead; so-called upper motor neuron CN-VII or central CN-VII weakness

FACIAL NERVE (CN-VII) *continued*

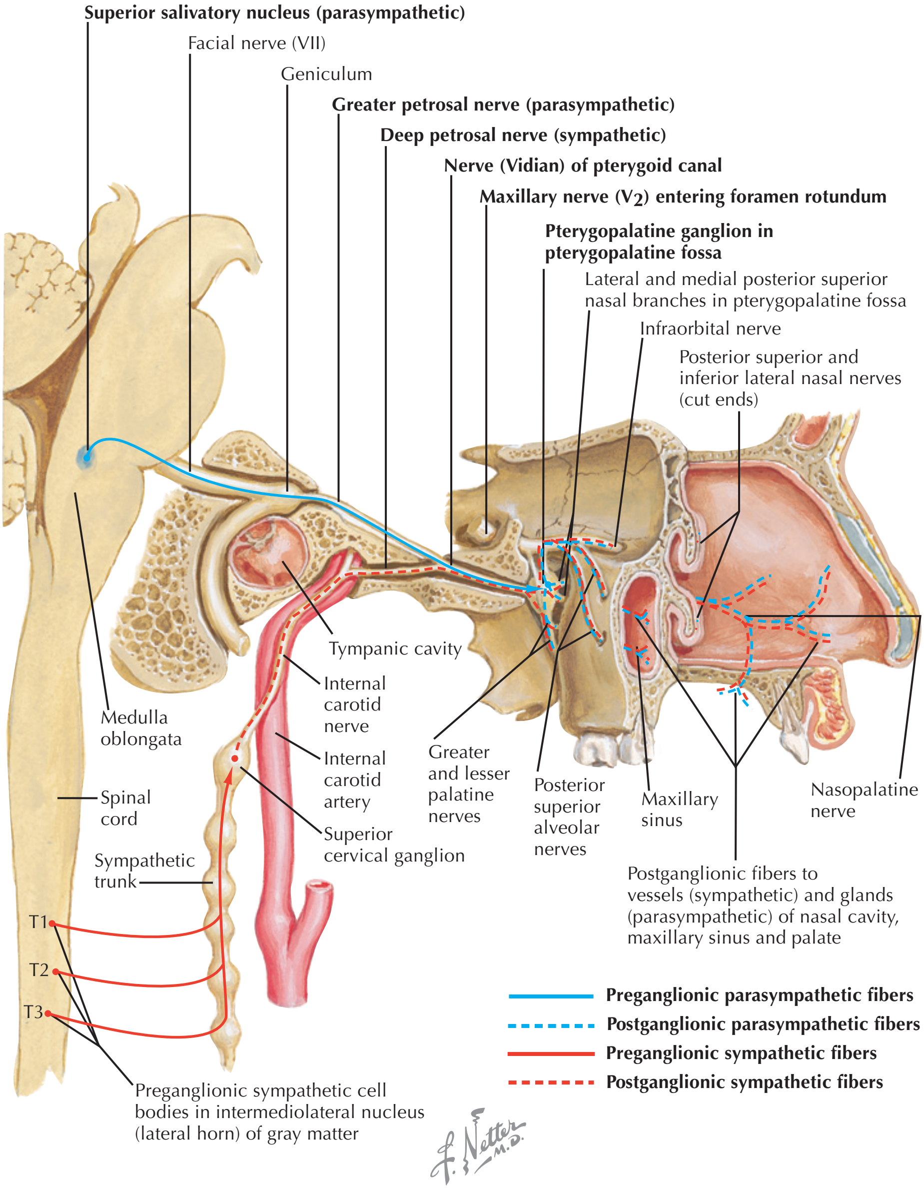


FACIAL NERVE CRANIAL NERVE VII

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Visceral motor	Cell bodies (preganglionic autonomic motor neurons) are scattered in the pontine tegmentum, called the superior salivatory nucleus, influenced by the hypothalamus	Parasympathetic to lacrimal, submandibular, and sublingual glands and the mucous membranes of the nose and palate
Superior salivatory nucleus (SSN)	Impulses from the limbic system enter the hypothalamus and are relayed via the dorsal longitudinal fasciculus to the SSN	Efferents from the SSN travel in the nervus intermedius and divide in the facial canal into the greater petrosal (to lacrimal and nasal glands) and chorda tympani (submandibular and sublingual glands)
Greater petrosal nerve	Exits the petrous bone via greater petrosal foramen to reach the foramen lacerum to reach the pterygoid canal to join deep petrosal nerve to become the nerve of the pterygoid canal, which opens into the pterygopalatine fossa from which the pterygopalatine ganglion is suspended from V_2	Preganglionic parasympathetic axons in the nerve of pterygoid canal synapse in pterygopalatine ganglion; postganglionic fibers go via V_2 branches to lacrimal and mucous glands
Chorda tympani	Joins the lingual branch of V_3 after V_3 passes through the foramen ovale Travels to the lateral floor of the mouth	Contains efferent preganglionic parasympathetic (secretomotor) fibers to the submandibular ganglion; relayed as postganglionic fibers to the submandibular and sublingual glands. Most fibers carry taste (see below)

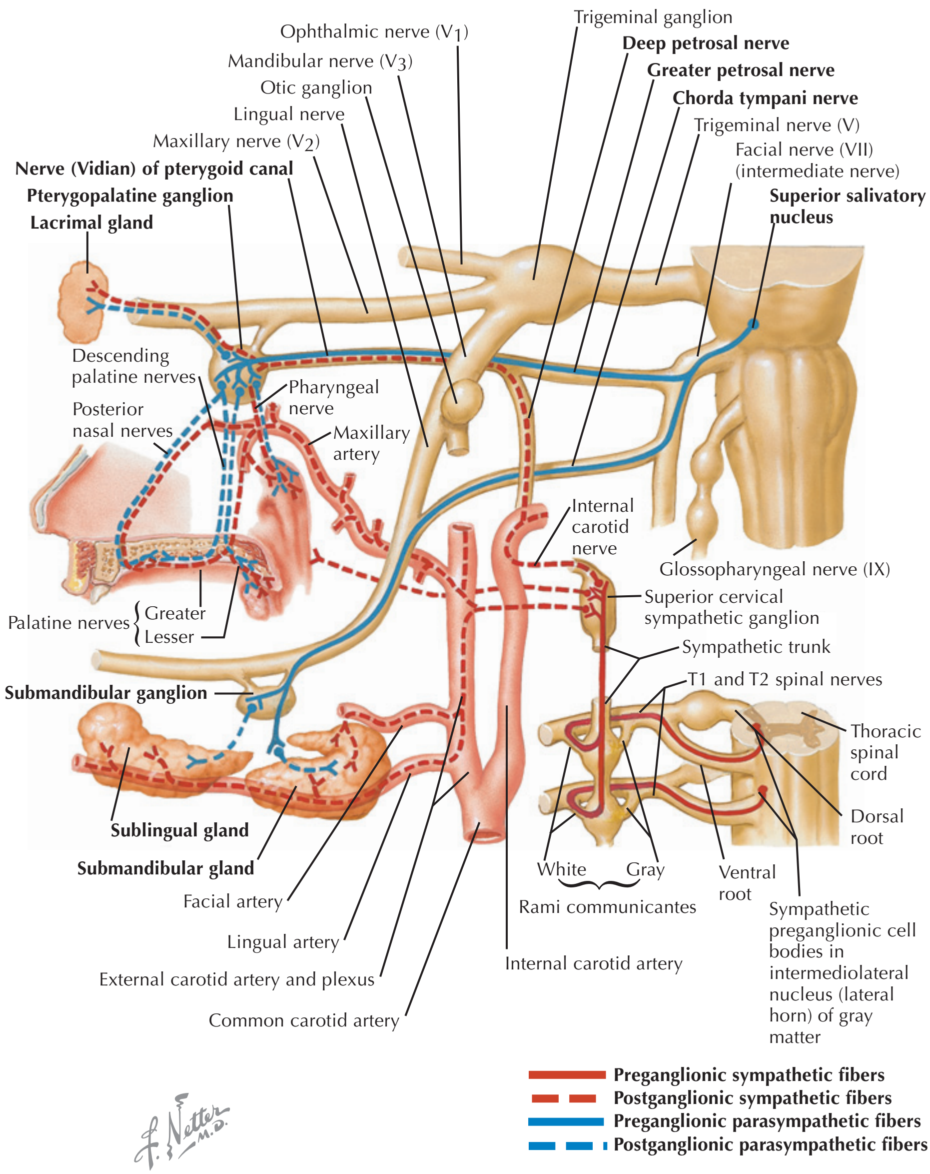
FACIAL NERVE CRANIAL NERVE VII *continued*

Autonomic Innervation of Nasal Cavity



FACIAL NERVE CRANIAL NERVE VII *continued*

Pterygopalatine and Submandibular Ganglia: Schema

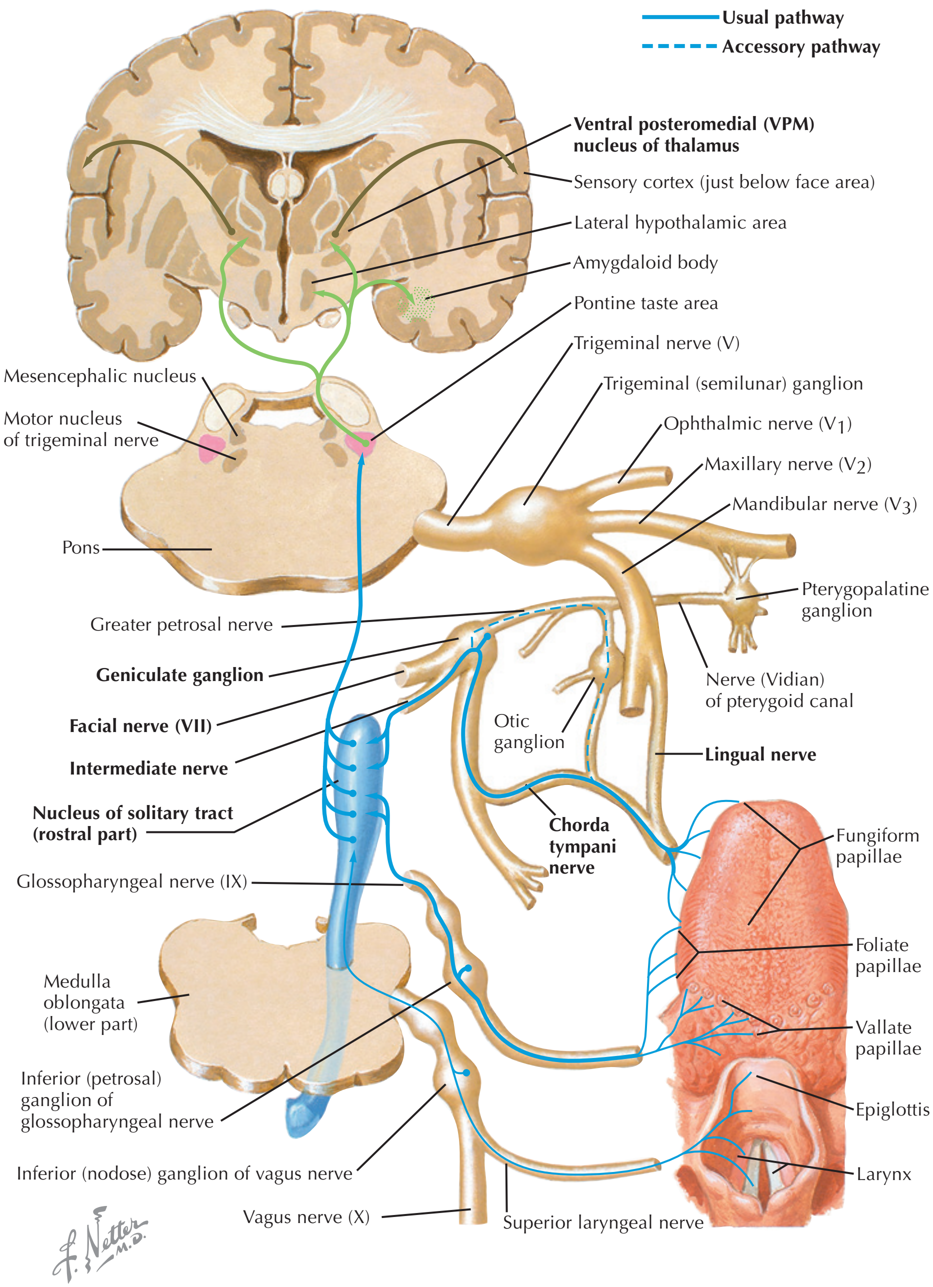


FACIAL NERVE SENSORY

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
General sensory fibers	Cell bodies of these fibers are in geniculate ganglion in temporal bone. Impulses enter the brainstem via the intermediate nerve (sensory root of CN-VII), synapse in the spinotrigeminal tract, project to contralateral ventroposterolateral (VPL) thalamus, then to sensory cortex.	For skin of the concha of the auricle and small area behind ear, supplements V_3
Special sensory fibers	Cell bodies of these fibers are in the geniculate ganglion in temporal bone Peripheral processes run with the lingual nerve, then separate to become chorda tympani, which joins the facial nerve in petrous temporal bone. Fibers enter the brainstem at the caudal pons with intermediate nerve (sensory root of CN-VII); enter the tractus solitarius, synapse in the rostral nucleus solitarius (gustatory nucleus), and ascend to the bilateral ventroposterior (VP) thalamus and then to the posterior internal capsule to the cortex.	Taste from anterior $\frac{2}{3}$ of the tongue and hard and soft palate

FACIAL NERVE SENSORY *continued*

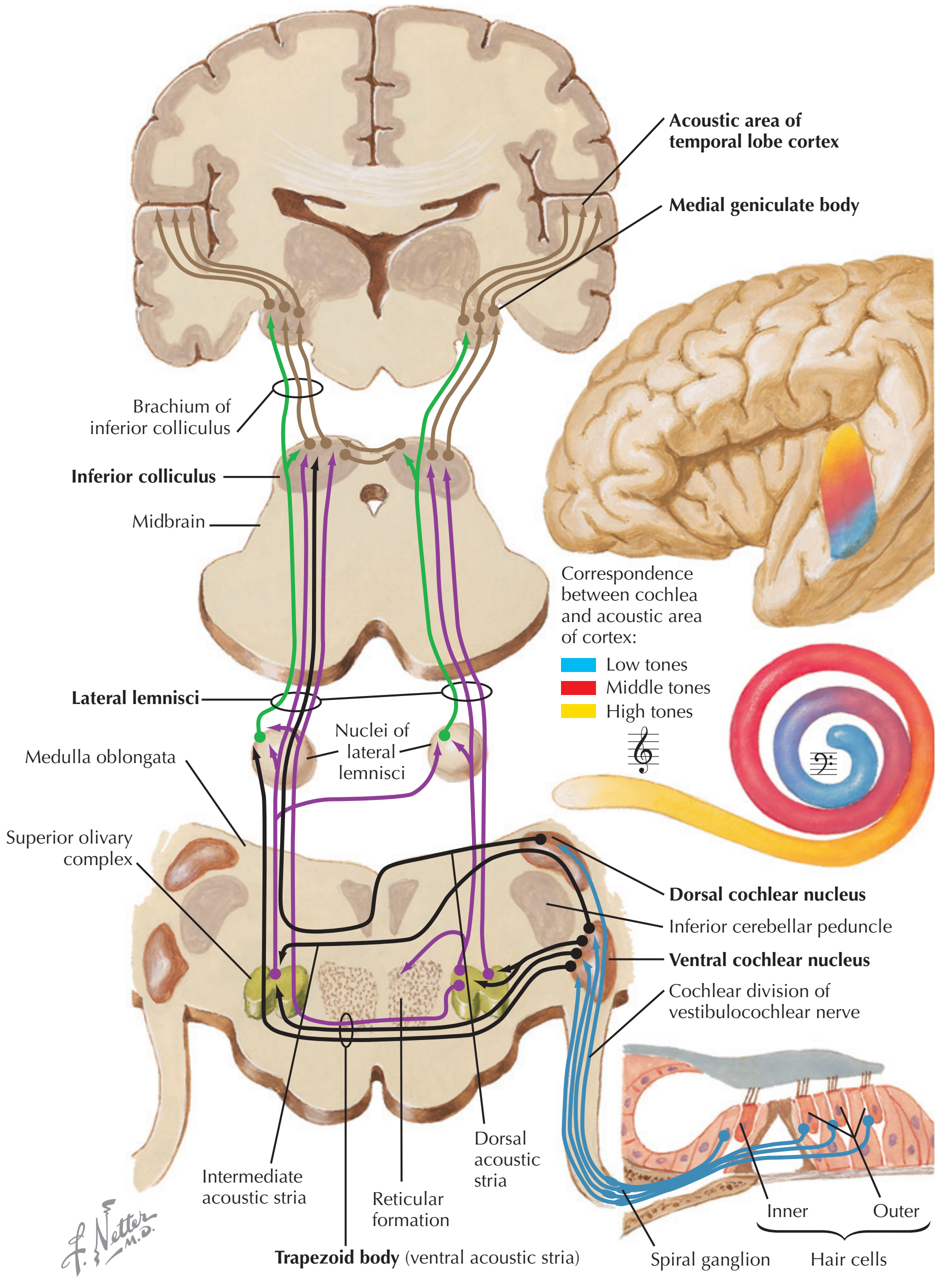
Taste Pathways: Schema



VESTIBULOCOCHLEAR NERVE (CN-VIII): AUDITORY COMPONENT

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-VIII (vestibular and auditory components)	Enters the brainstem at the cerebellopontine angle	Special sensory nerve Auditory from the cochlea, balance from semicircular canals
CN-VIII (cochlear primary sensory neuron cell bodies)	Lie around modiolus (center) of the cochlea, where they constitute cochlear (spiral) ganglion	Their central processes form auditory component of CN-VIII
CN-VIII axons	Travel through the internal auditory meatus with CN-VII to enter pontomedullary junction, just lateral to CN-VII, and synapse in the cochlear nuclei	Peripheral lesion (e.g., compression by cerebellopontine angle tumor) produces ipsilateral deafness
Second-order cochlear neurons	Mostly cross via trapezoid body and ascend the contralateral lateral lemniscus to synapse in the inferior colliculus, then to medial geniculate (thalamus), and then through the internal capsule to the acoustic cortex (transverse temporal gyri of Heschl)	Because of the bilaterality of ascending pathways, central lesions (stroke, tumor) do not produce deafness but produce bilateral hearing reduction, which is worse on the contralateral side

VESTIBULOCOCHLEAR NERVE (CN-VIII): AUDITORY COMPONENT *continued*

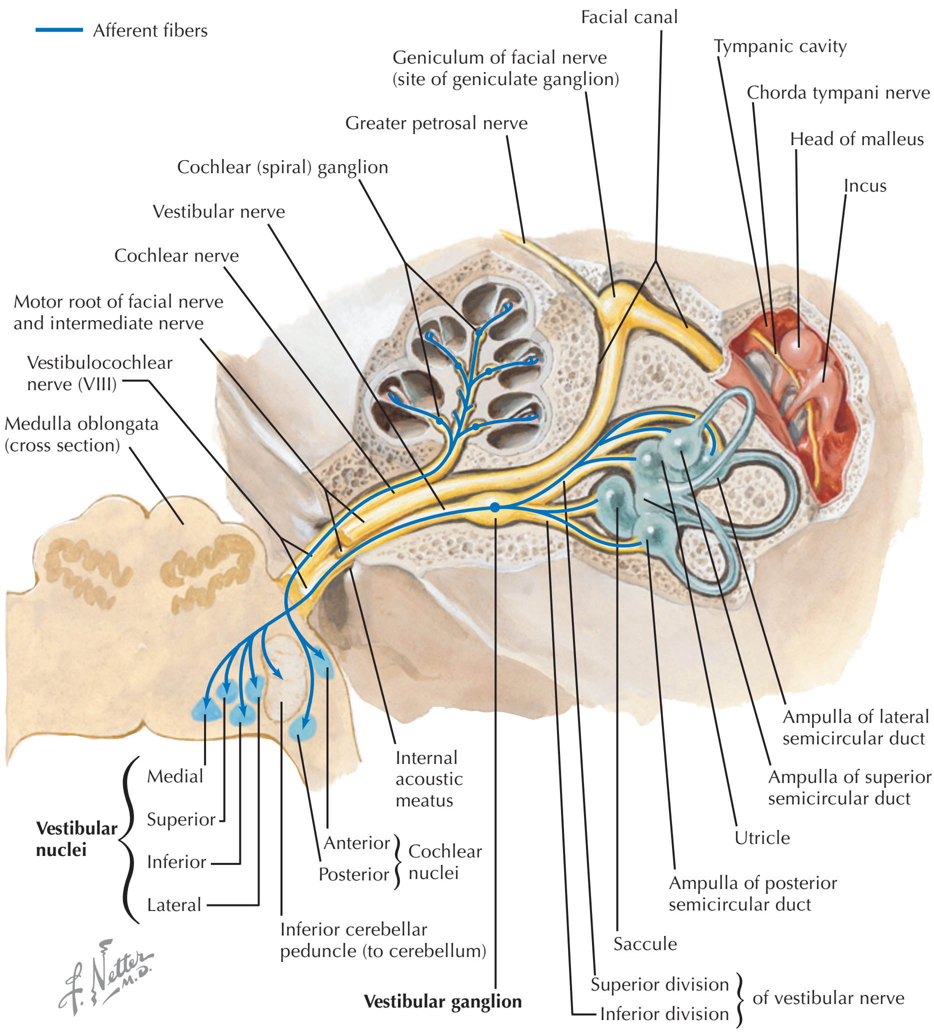


VESTIBULOCOCHLEAR NERVE (CN-VIII): VESTIBULAR

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-VIII vestibular primary sensory neuron cell bodies	Lay in the vestibular ganglion	Central processes form the vestibular component of CN-VIII mediating balance
CN-VIII axons	Travel through the internal auditory meatus with cochlear division and CN-VII to enter the pontomedullary junction, just lateral to CN-VII, and synapse in the vestibular nuclear complex in the floor of the 4th ventricle	Second-order vestibular neurons send axons to: • The cerebellum (vestibulocerebellar tract) to coordinate balance • Lower motor neurons in the brainstem and spinal cord (vestibulospinal tract) to antigravity muscles • Medial longitudinal fasciculus (MLF) to maintain orientation in space
Second-order vestibular neurons	Send axons to: • Cerebellum via vestibulocerebellar tract • Lower motor neurons in the brainstem and spinal cord via vestibulospinal tract • Descending medial longitudinal fasciculus (MLF)	Vestibulocerebellar tract coordinates balance Vestibulospinal tract innervates antigravity muscles for balance MLF maintains orientation in space

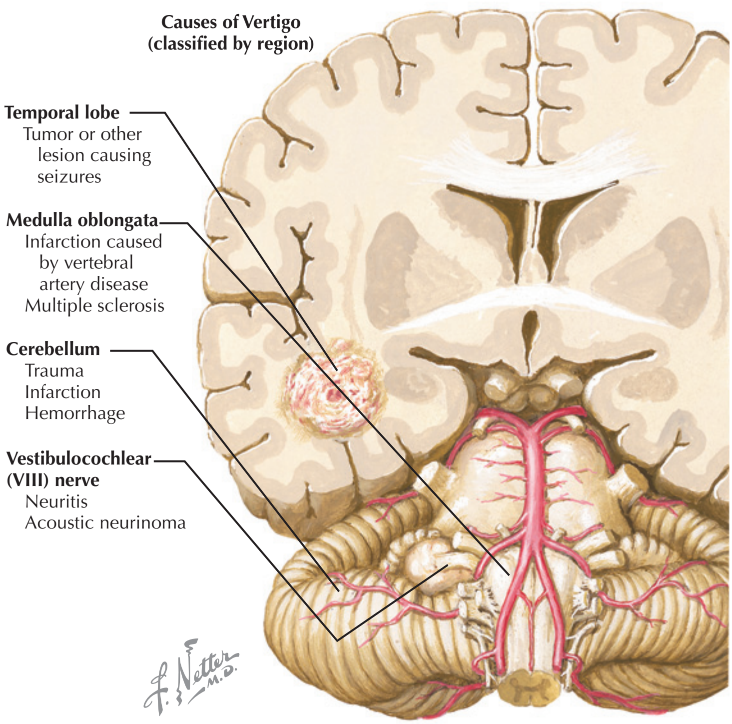
VESTIBULOCOCHLEAR NERVE (CN-VIII): VESTIBULAR *continued*

Vestibulocochlear Nerve (VIII): Schema



CAUSES OF VERTIGO

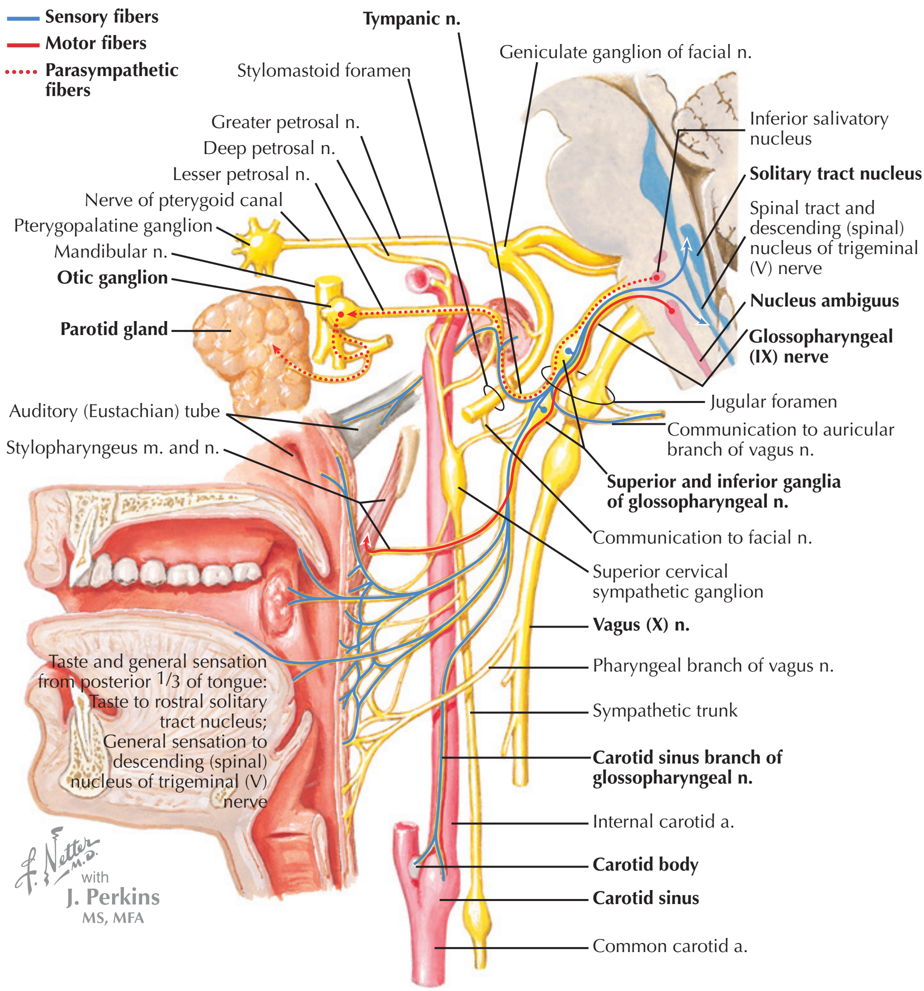
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Cerebellopontine angle	CN-VII and CN-VIII found here	Tumors (acoustic neuroma) can compress CN-VIII and CN-VII, causing vertigo, tinnitus, deafness, and facial asymmetry
Medulla	Lateral medulla co-localizes: • Vestibular nuclei • Spinothalamic tract • Sympathetic tract • CN-IX and-X fibers • Spinocerebellar fibers • Descending nucleus V • Nucleus solitarius	Lateral medullary infarction (Wallenberg's syndrome) include: • Nystagmus, vertigo, nausea, vomiting • Contralateral hemisensory loss of pain and temperature • Ipsilateral Horner's syndrome • Hoarseness, dysphagia • Ipsilateral ataxia • Ipsilateral pain, burning, and impaired sensation of the face • Loss of taste



GLOSSOPHARYNGEAL NERVE (CN-IX)

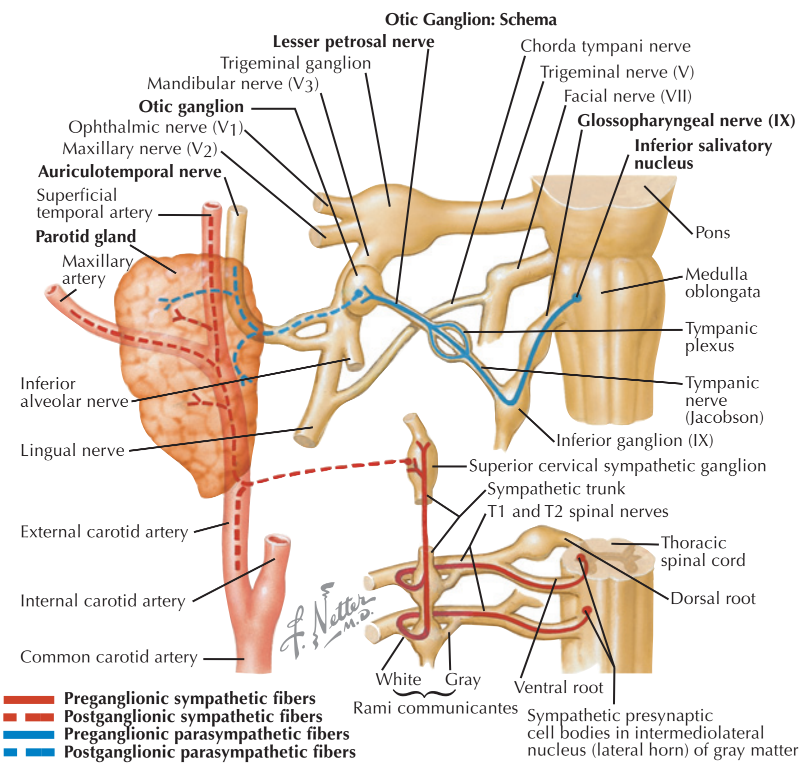
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-IX	Emerges from the medulla between the inferior olive and inferior cerebellar peduncle In jugular fossa, the tympanic nerve is given off Main trunk then exits the jugular foramen containing the superior and inferior glossopharyngeal ganglia (i.e., nerve cell bodies for general visceral and special visceral sensation)	Branchial motor—innervates the stylopharyngeus Visceral motor supplies preganglionic parasympathetic fibers to the otic ganglion, which sends fibers to the parotid gland General sensory—sensation posterior ⅓ tongue, skin of external ear, internal surface of tympanic membrane Visceral sensory—mucous membranes of the pharynx, middle ear, unconscious sensory input from the carotid body and sinus Special sensory—taste posterior ⅓ tongue
Inferior glosso-pharyngeal ganglion	Located in the jugular foramen, central fibers enter the brainstem and travel through the solitary tract to the rostral solitary tract nucleus (gustatory nucleus) in medulla	Mediates taste posterior ⅓ tongue
Rostral solitary tract nucleus (gustatory nucleus)	Axons of these cells ascend central tegmental tract to the bilateral ventroposteromedial (VPM) nucleus of the thalamus. From thalamus they ascend through the posterior limb of the internal capsule to the postcentral gyrus	Central lesions do not affect taste
Corticobulbar fibers	Synapse *bilaterally* on lower motor neurons in the rostral nucleus ambiguus	Because of bilaterality, central lesions affecting the descending fibers do not affect the stylopharyngeus
CN-IX	Emerges from medulla between the inferior olive and inferior cerebellar peduncle, passes laterally in the posterior fossa to exit the jugular foramen anterior to CN-X and CN-XI and descends in the neck to the stylopharyngeus	Elevates the pharynx during swallow and speech

GLOSSOPHARYNGEAL NERVE (CN-IX) *continued*



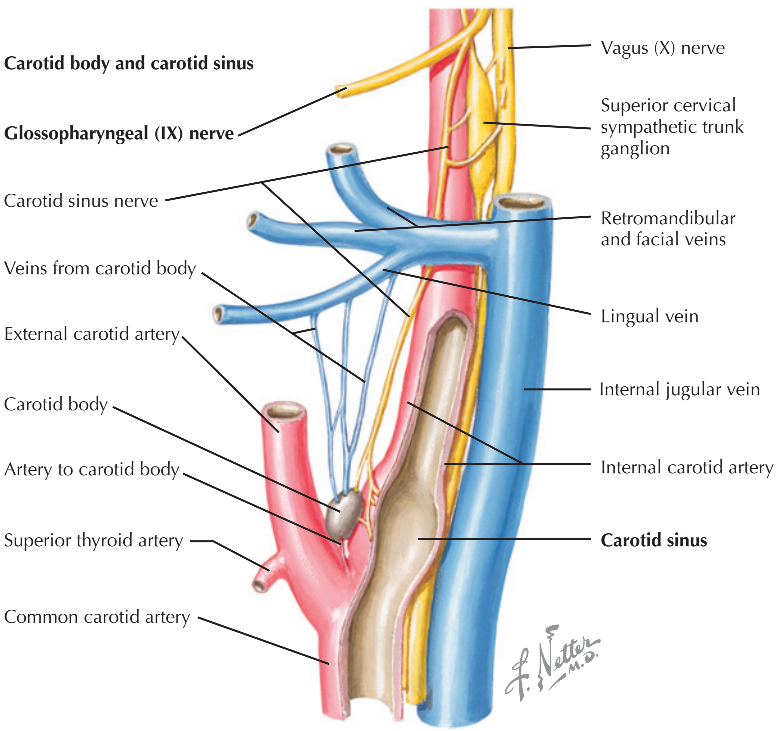
GLOSSOPHARYNGEAL NERVE (CN-IX): VISCERAL MOTOR

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Intracranial CN-IX preganglionic parasympathetic neurons	Located in the inferior salivatory nucleus in medulla Axons join CN-IX and exit jugular foramen	Visceral motor: supplies otic ganglion, which sends postganglionic parasympathetic fibers to the parotid gland
Extracranial CN-IX preganglionic parasympathetic neurons	Branches to form the lesser petrosal nerve that travels back into the cranium through a small canal to reach the middle cranial fossa and descend through the foramen ovale to synapse in otic ganglion (immediately below foramen ovale) From otic ganglion, postganglionic fibers join auriculotemporal nerve	Supply the secretomotor fibers to the parotid gland



GLOSSOPHARYNGEAL NERVE (CN-IX): VISCERAL SENSORY

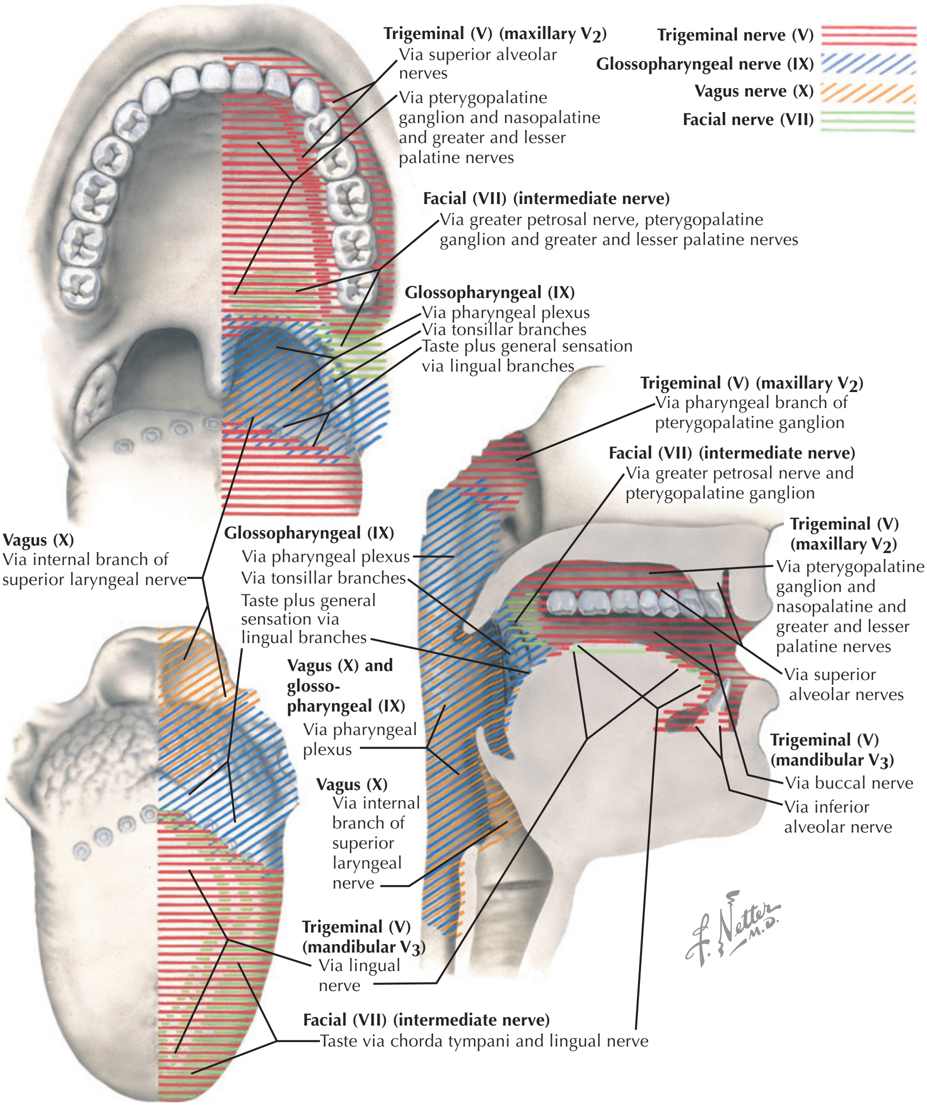
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-IX	Information is relayed from the carotid sinus nerve to the inferior ganglion of CN-IX, to the solitary tract, to the caudal solitary nucleus, to the reticular formation and hypothalamus for appropriate reflex responses	Chemoreceptors in the carotid body monitor blood oxygen Baroreceptors in the carotid sinus monitor arterial blood pressure



GLOSSOPHARYNGEAL NERVE (CN-IX): GENERAL SENSORY

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-IX	Cell bodies located in superior or inferior glossopharyngeal ganglion	Superior glossopharyngeal ganglion: contains primary sensory neurons mediating cutaneous sensation from area back of ear. central processes of these cells enter the spinal trigeminal tract and nucleus Inferior glossopharyngeal ganglion: contains cell bodies of visceral afferent fibers. Conveys touch, pain, and temperature from eustachian tube, posterior $\frac{1}{3}$ tongue, tonsil, and upper pharynx
CN-IX Secondary neurons	Cross the midline of the medulla and ascend to the VP nucleus of the thalamus Tertiary neurons thence project to the postcentral sensory gyrus	Same pathway is probably used for touch and pressure and is important for gag reflex

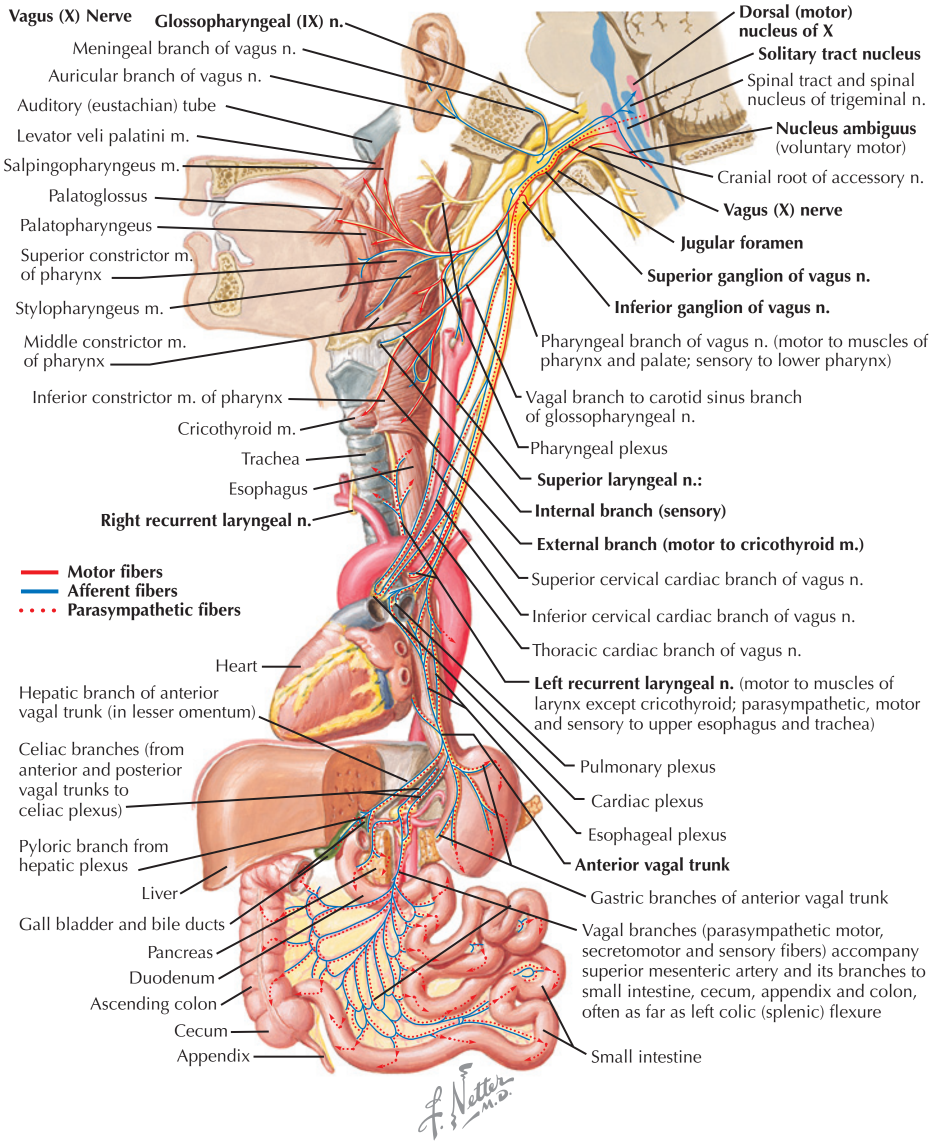
GLOSSOPHARYNGEAL NERVE (CN-IX): GENERAL SENSORY *continued*



VAGUS NERVE (CN-X)

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-X	Emerges from the medulla as several rootlets, converge into 2 roots, exit cranial fossa through jugular foramen In the neck, the vagus nerve lies between the internal jugular vein and internal carotid artery	Branchial motor—striated muscle of pharynx (palatoglossus), larynx, and soft palate (except tensor veli palatini and stylopharyngeus) Visceral motor—smooth muscles and glands of pharynx, larynx, thoracic and abdominal viscera General sensory—skin of back of ear, external auditory meatus, external tympanic membrane General visceral sensory—input from viscera Special visceral sensory—input from periepiglottal taste buds
Superior (jugular) and inferior (nodosal) vagal ganglia	Two sensory ganglia of vagus, located on the nerve in the jugular foramen Inferior ganglion is joined by fibers from the nucleus ambiguus, which traveled with CN-XI	Superior (jugular) ganglion contains cells that give rise to general sensory afferents Inferior (nodosal) ganglion contains cells that give rise to both general and special visceral sensory afferents
Dorsal motor nucleus of X	Preganglionic parasympathetic nerve cell bodies of CN-X; gets input from hypothalamus, olfactory system, reticular formation, solitary tract nucleus	Secretomotor center (visceral motor) of CN-X sends preganglionic parasympathetic fibers to postganglionic cells that innervate all thoracic and abdominal viscera down to the left colic (splenic) flexure
Solitary tract nucleus	Visceral sensory input enters the nucleus and projects to the reticular formation, hypothalamus, and thalamus	Rostral part (gustatory nucleus) receives taste from CN-VII and CN-IX (special visceral sensory) Caudal part receives mainly general visceral afferents from CN-X
Recurrent and internal laryngeal nerves	Internal laryngeal unites with the external laryngeal to form the superior laryngeal nerve, which travels up CN-X to the inferior vagal ganglion	Internal laryngeal nerve—visceral sensory afferent from the larynx as far as the vocal cords External laryngeal—branchial motor to cricothyroid muscle Recurrent laryngeal nerve—branchial motor to all laryngeal muscles except cricothyroid, and visceral sensory afferent from larynx below vocal cords, and mucous membranes of the upper trachea
Auricular branch	Enters the superior vagal ganglion	Carries sensation from the ear

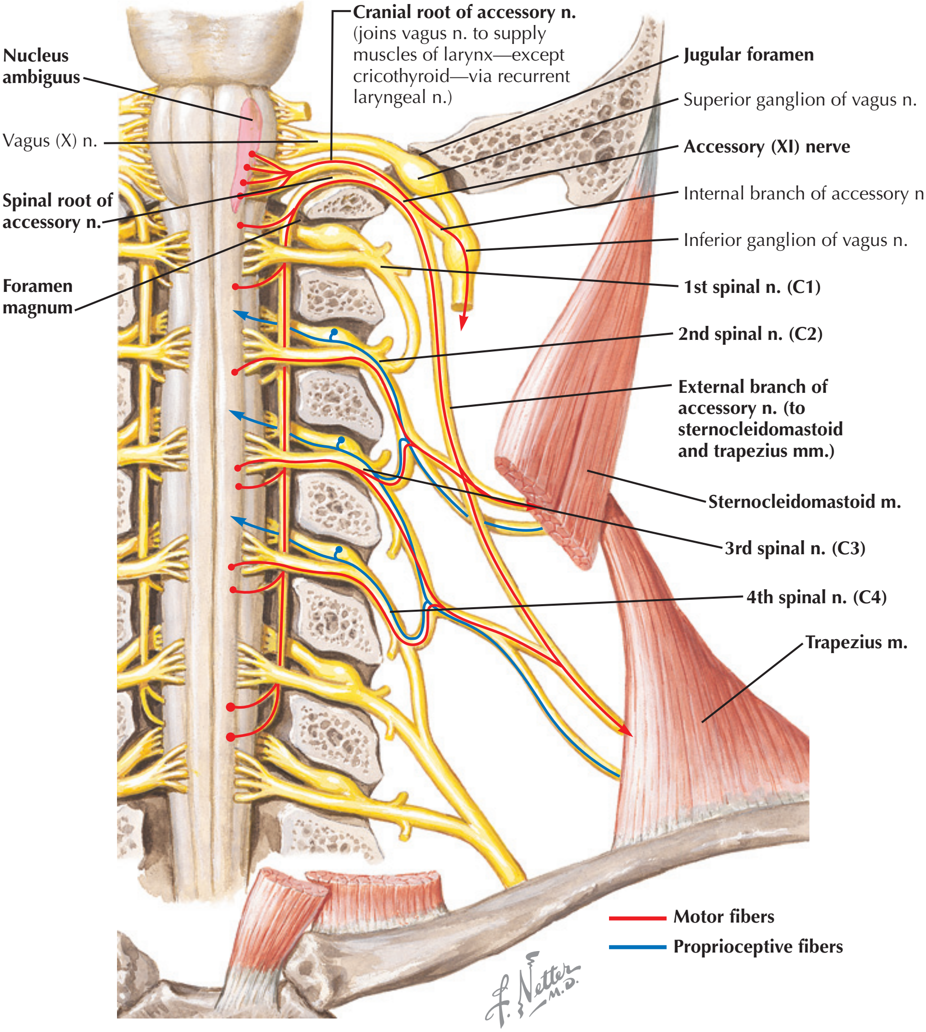
VAGUS NERVE (CN-X) *continued*



ACCESSORY NERVE (CN-XI)

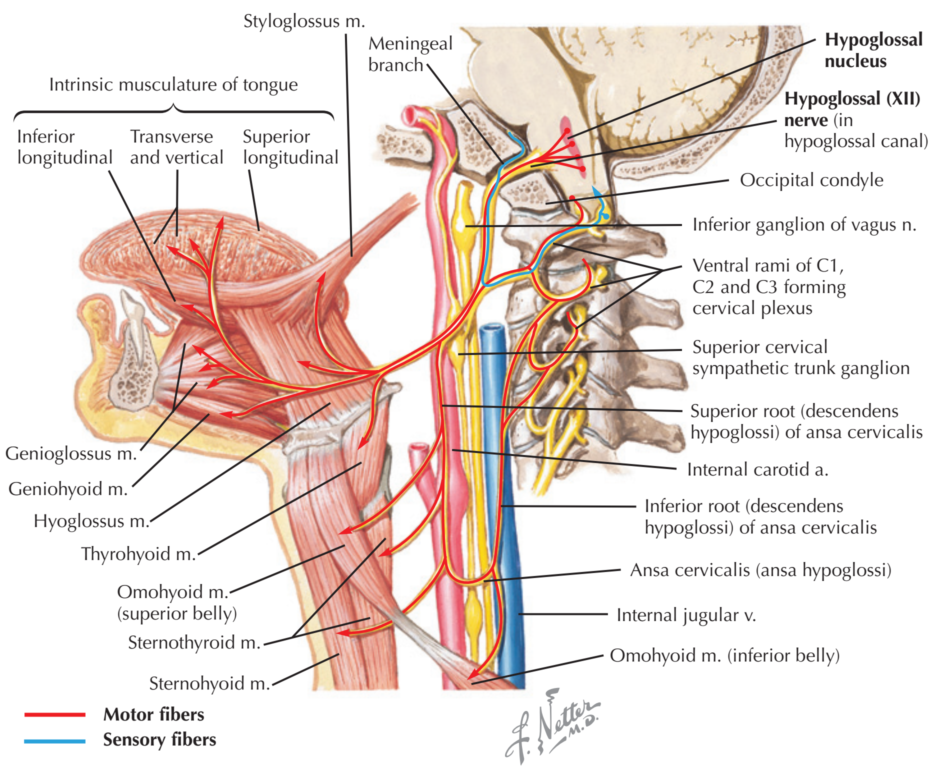
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-XI	Accessory nerve has cranial root and spinal root (both motor) that briefly run together as they enter jugular foramen	Branchial motor to trapezius and sternocleidomastoid (SCM)
Spinal root	Lower motor neurons located in spinal cord segments C1-5 Axons ascend through the foramen magnum, exit the jugular foramen, and enter their muscles	Radical neck surgery for cancer often involves dissection of cervical lymph nodes. As they are closely associated with accessory nerve, injury to this nerve is common and results in shoulder droop (trapezius), and weakness of head turning to the contralateral side (SCM)
Cranial root	Cell bodies reside in the caudal part of nucleus ambiguus Axons from this nucleus briefly join the spinal root of CN-XI, pass through the jugular foramen, and join CN-X to form the motor component of recurrent laryngeal nerve	May be involved in motor-neuron disease, poliomyelitis, syringobulbia

ACCESSORY NERVE (CN-XI) *continued*



HYPOGLOSSAL NERVE (CN-XII)

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
CN-XII	Corticobulbar fibers descend to the contralateral hypoglossal nucleus	Somatic motor to all tongue muscles except palatoglossus (CN-X)
CN-XII	Axons emerge between the olive and pyramid (preolivary sulcus) as a number of rootlets which converge and exit cranial fossa through the hypoglossal (anterior condylar) foramen	Complete interruption of the nerve results in paralysis of the ipsilateral side of the tongue with concomitant atrophy and muscle fasciculations (lower motor neuron lesion)
CN-XII	Passes laterally and downward to between the internal carotid artery and internal jugular vein, loops anteriorly above the hyoid, to innervate tongue	Occasionally damaged in neck surgery Rarely, carotid artery aneurysm may compress nerve

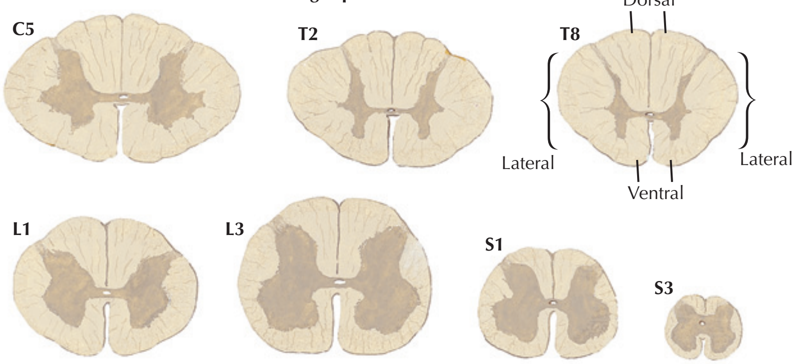


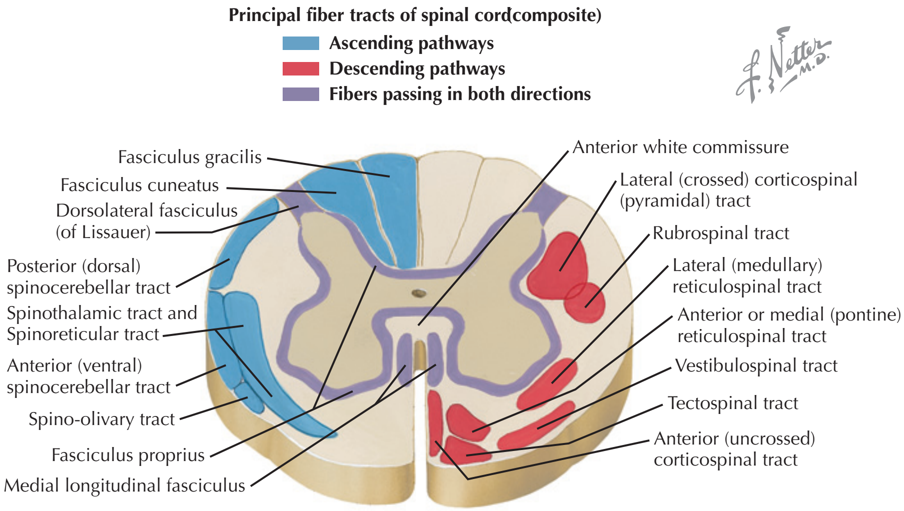
CHAPTER 15

Major Sensory and Motor Pathways

SPINAL CORD PATHWAYS

White matter is divided into *dorsal* (top of each spinal cord cross-sectional drawing), *ventral* (bottom of each spinal cord cross-sectional drawing), and *lateral* (sides of each spinal cord cross-sectional drawing) columns (funiculi), each containing multiple fiber tracts.

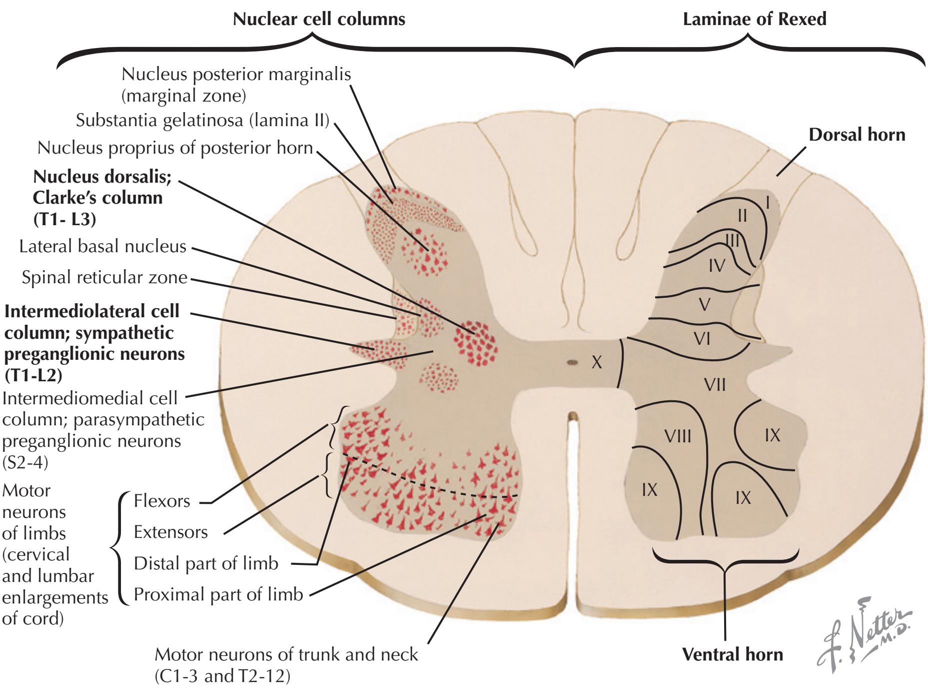




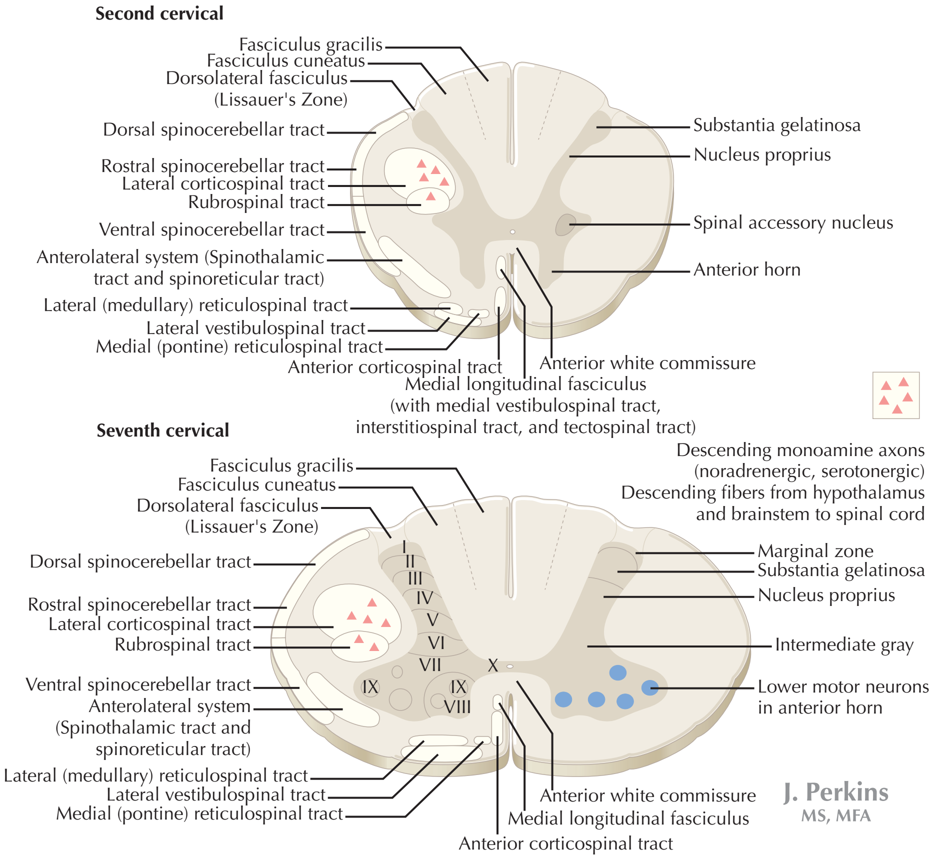
SPINAL CORD CYTOARCHITECTURE

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Gray matter	Butterfly-shaped pattern Divided into dorsal, intermediate, and ventral horns	Contains cell bodies of neurons (e.g., anterior horn cells of lower motor neurons) In amyotrophic lateral sclerosis, these cells degenerate
Dorsal horn	Larger at cervical and lumbosacral enlargements owing to innervation of arm and leg	Site of major sensory processing
Intermediolateral gray	Lateral horn seen from T1-L2 and S2-4	Preganglionic sympathetic (T1-L2) and parasympathetic (S2-4) neurons reside here
Ventral horn	Larger at cervical and lumbosacral enlargements owing to innervation of arm and leg	Anterior horn cells reside here
Laminae of Rexed	System of architectural classification	Most precise and widely used method for describing cell groups in the spinal cord
Nucleus dorsalis (of Clarke)	Cell column in the medial portion of lamina VII Begins to be well defined at the C8 level Gives rise to the uncrossed posterior spinocerebellar tract	Receives collaterals of dorsal roots from the entire body except the head and neck Functionally related primarily to the legs and lower trunk

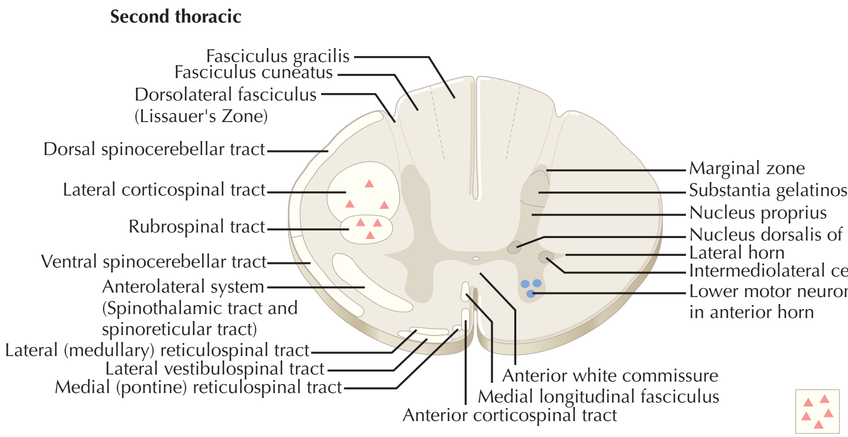
SPINAL CORD CYTOARCHITECTURE *continued*

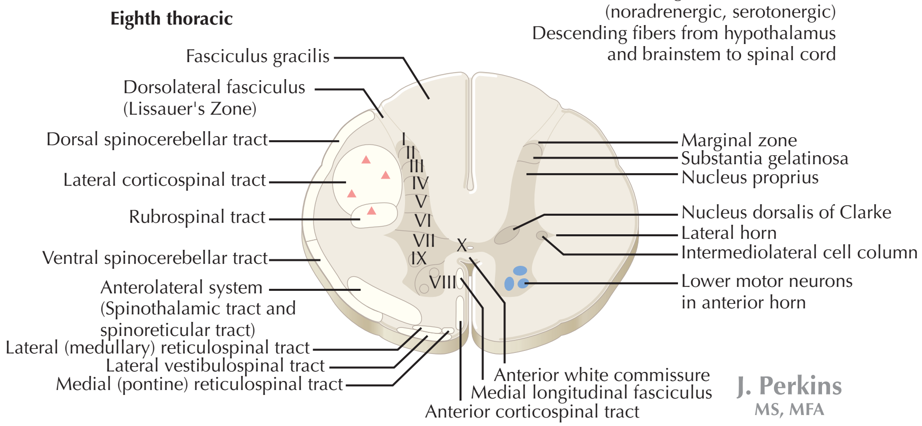


SPINAL CORD LEVELS: CERVICAL

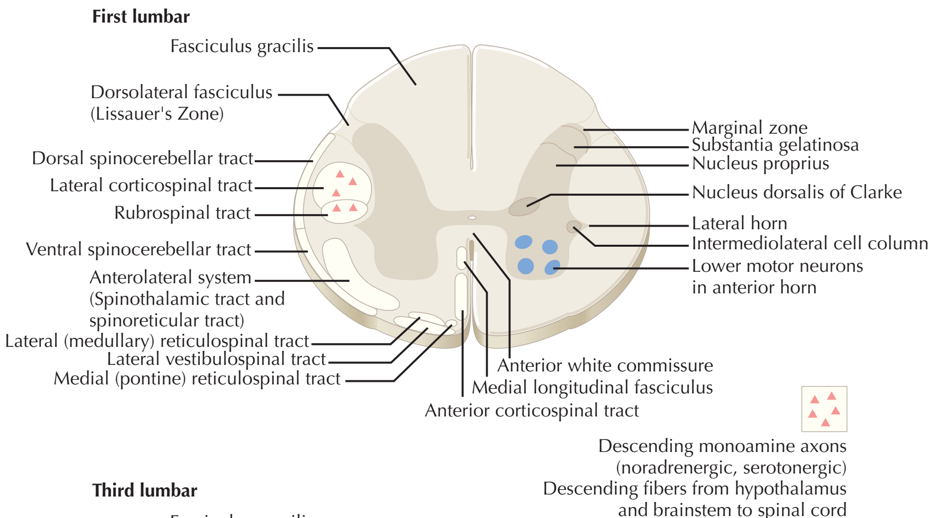


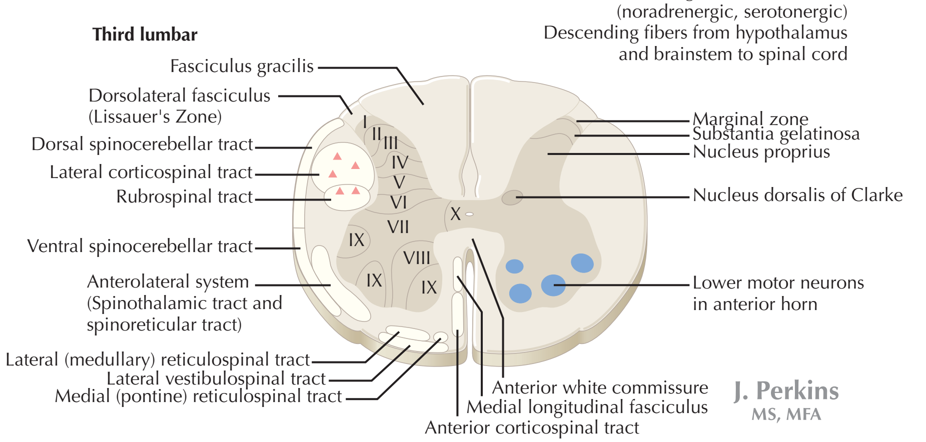
SPINAL CORD LEVELS: THORACIC



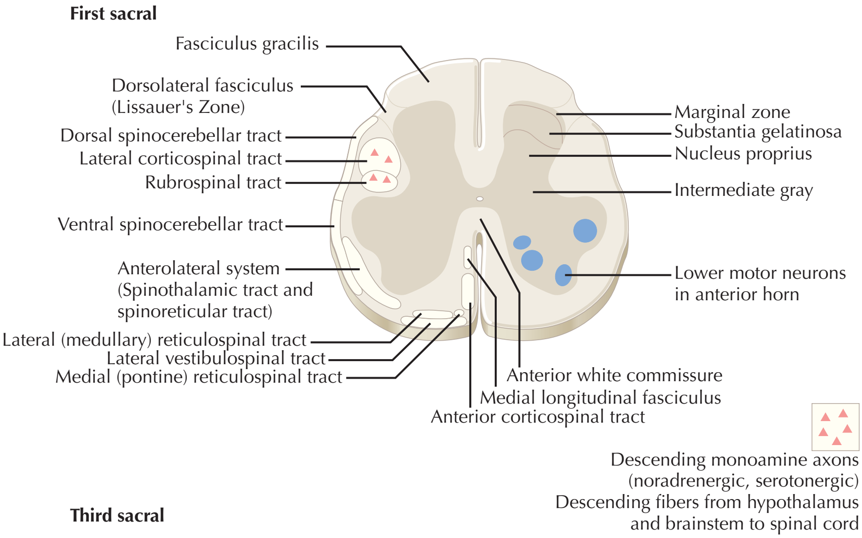


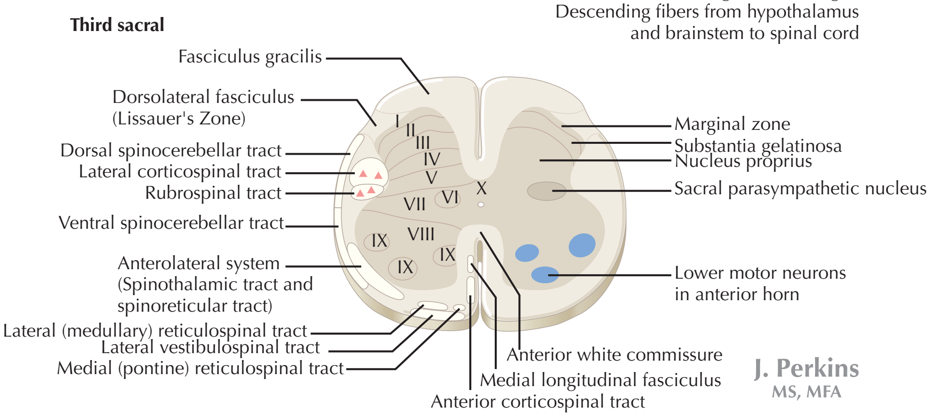
SPINAL CORD LEVELS: LUMBAR





SPINAL CORD LEVELS: SACRAL



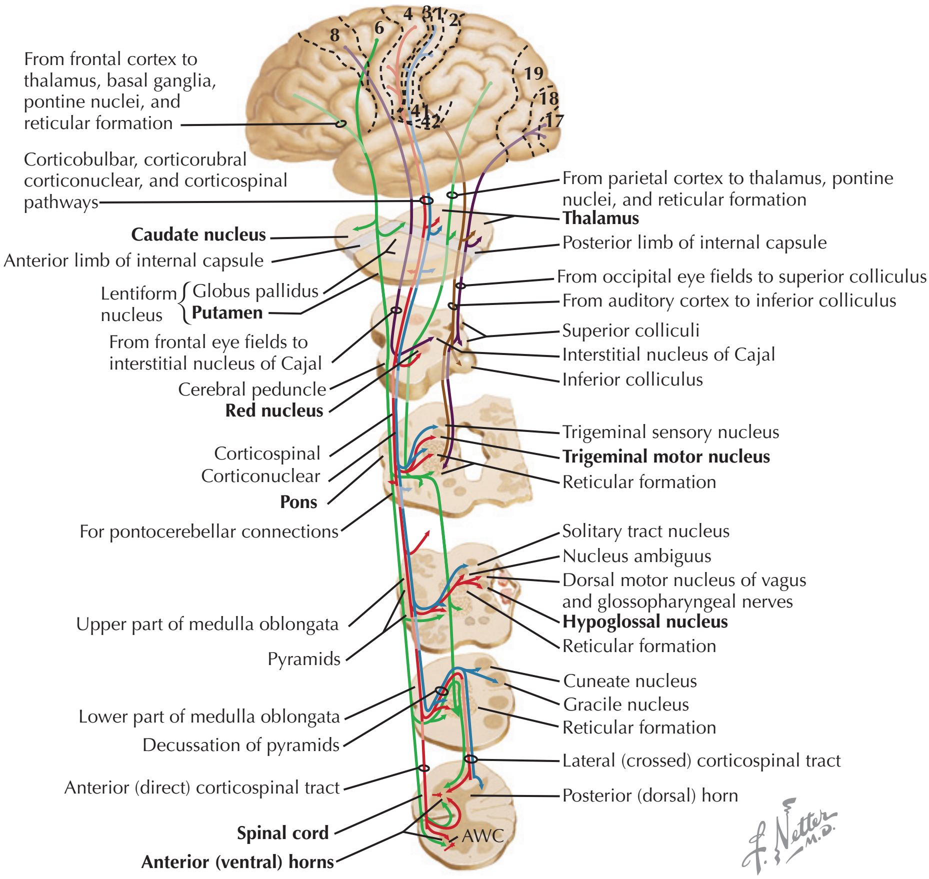


CORTICAL EFFERENT PATHWAYS

BRODMANN AREA	PROJECTS TO	ANATOMIC NOTES
4 and 6 (motor and premotor cortex)	Basal ganglia (caudate, putamen) Thalamus: ventroanterior (VA), ventrolateral (VL) Red nucleus Pontine nuclei Motor cranial nuclei Spinal cord ventral horn	Corticostriate projections Corticothalamic projections Corticorubral projections Corticopontine projections Corticobulbar tract bilaterally Corticospinal tract, mainly contralaterally
3, 1, and 2 (sensory cortex)	Secondary sensory nuclei Thalamus	Regulate incoming lemniscal projections
8 (frontal eye fields)	Superior colliculus Horizontal (paramedian pontine reticular formation [PPRF]) and vertical-gaze centers in the brainstem Interstitial nucleus of Cajal	Coordinate voluntary eye and head movement

CORTICAL EFFERENT PATHWAYS *continued*

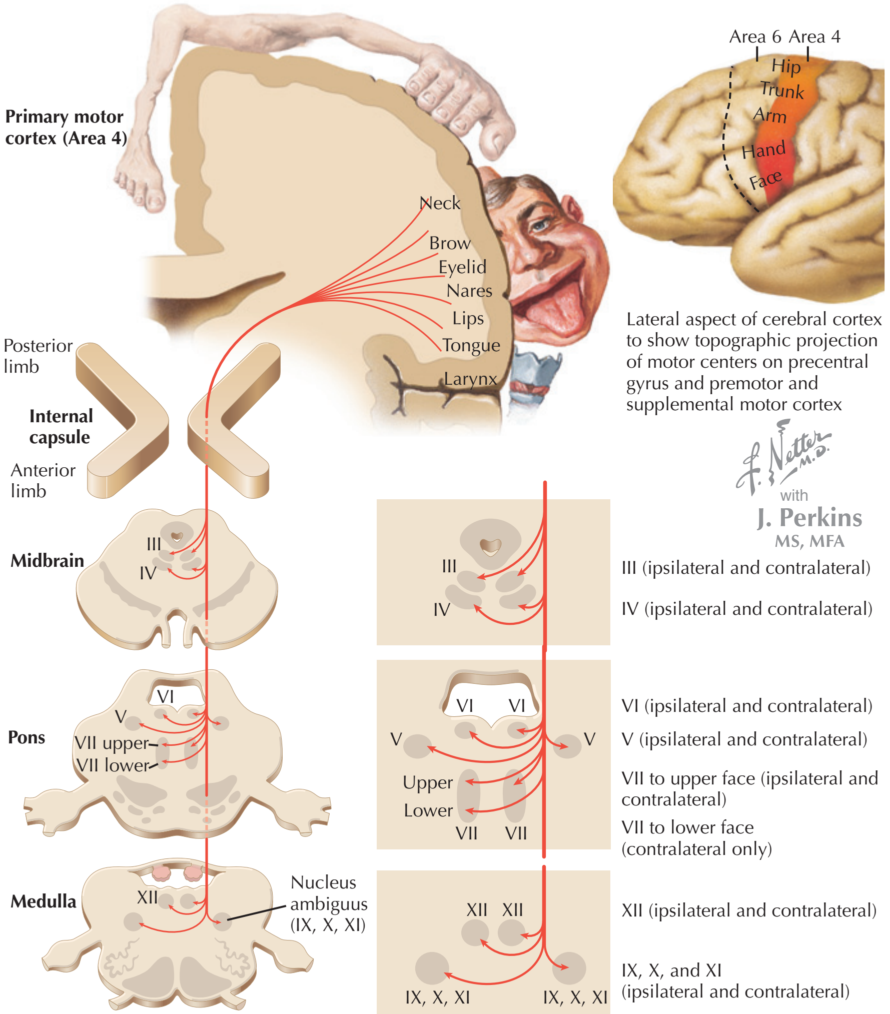
Cerebral Cortex: Efferent Pathway



CORTICOBULBAR PATHWAYS

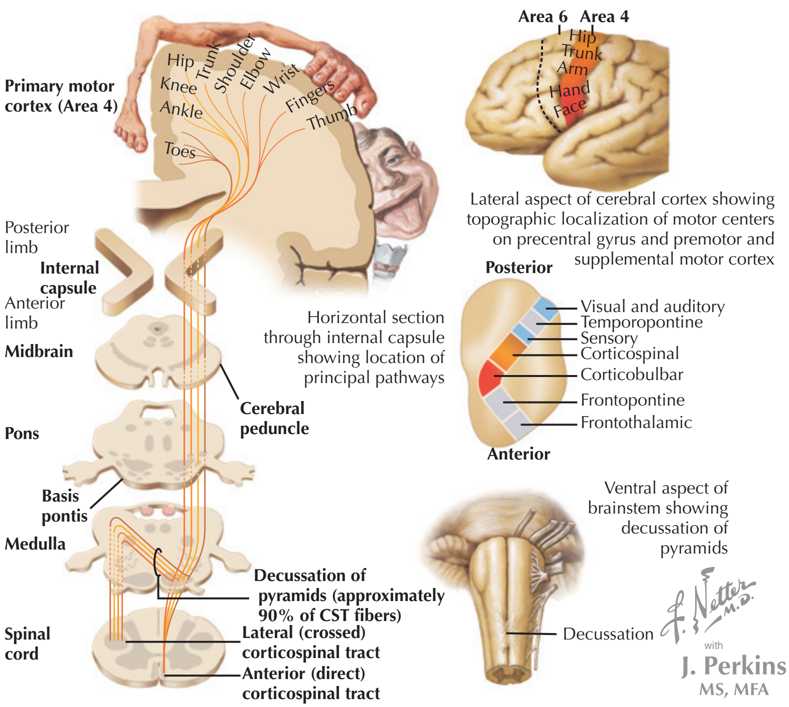
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Corticobulbar pathways	Arise mainly from precentral and postcentral gyri	Project to sensory relay nuclei, reticular formation, and certain cranial motor nuclei
Sensory relay nuclei	Include: • Nucleus gracilis • Nucleus cuneatus • Sensory trigeminal nuclei • Solitary nucleus	Transmit sensory information from periphery to higher cortical centers
Corticoreticular fibers	Project bilaterally to: • Nucleus reticularis gigantocellularis in the medulla • Nucleus reticularis pontis oralis in the pons	Important in arousal and maintenance of the awake state
Corticobulbar pathways to the motor cranial nerve	Largely bilateral Include: • Laryngeal muscles • Pharyngeal muscles • Palatal muscles • Muscles of mastication • Extraocular muscles • Upper facial muscles (muscles that, as a rule, cannot be contracted voluntarily on one side)	Pseudobulbar palsy results from bilateral lesions of the corticobulbar system Characterized by weakness of chewing, swallowing, breathing, and speaking, without muscle atrophy

CORTICOBULBAR PATHWAYS *continued*



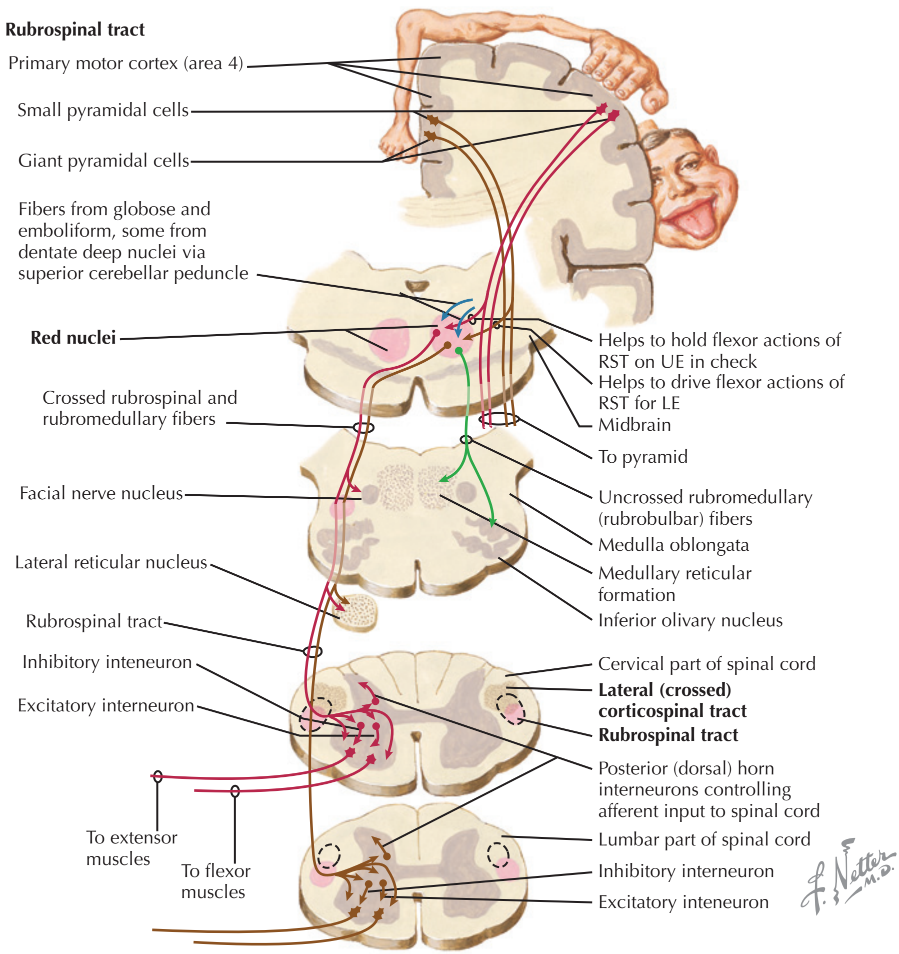
CORTICOSPINAL TRACT

ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Originates in the primary motor cortex (area 4), premotor cortex (area 6), postcentral gyrus (areas 3a, 3b,1, and 2), and parietal cortex (area 5)	Largest descending system in humans >1,000,000 fibers 70% myelinated
Descends through the corona radiata, internal capsule, cerebral peduncle, basis pontis, and medullary pyramid	Occlusion of small penetrating vessels in these areas results in lacunar infarction and causes contralateral hemiparesis
90% decussate in pyramid to descend in the lateral corticospinal tract of cord Synapse on anterior horn cells	Infarct or tumor in pyramid will cause ipsilateral tongue paralysis and contralateral hemiparesis
10% do not decussate in the pyramid Most of these descend in the anterior corticospinal tract, cross in the cervical spine, and synapse on the contralateral anterior horn cells to the arms and neck	It is not possible clinically to recognize lesions specifically involving anterior corticospinal tract



RUBROSPINAL TRACT

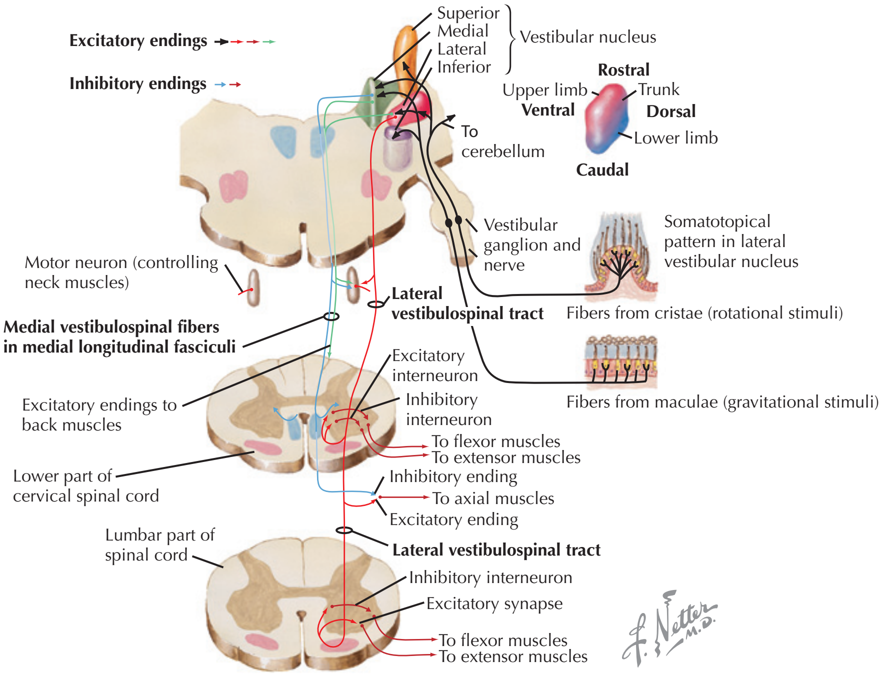
ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Arises from cells in the red nucleus, and crosses the median raphe in the ventral tegmental decussation	Red nucleus lesion results in rubral (wing-beating) tremor
Descends to spinal levels anterior to the lateral corticospinal tract Terminates on the anterior horn cells	Controls muscle tone in the flexor muscle groups



VESTIBULOSPINAL TRACT

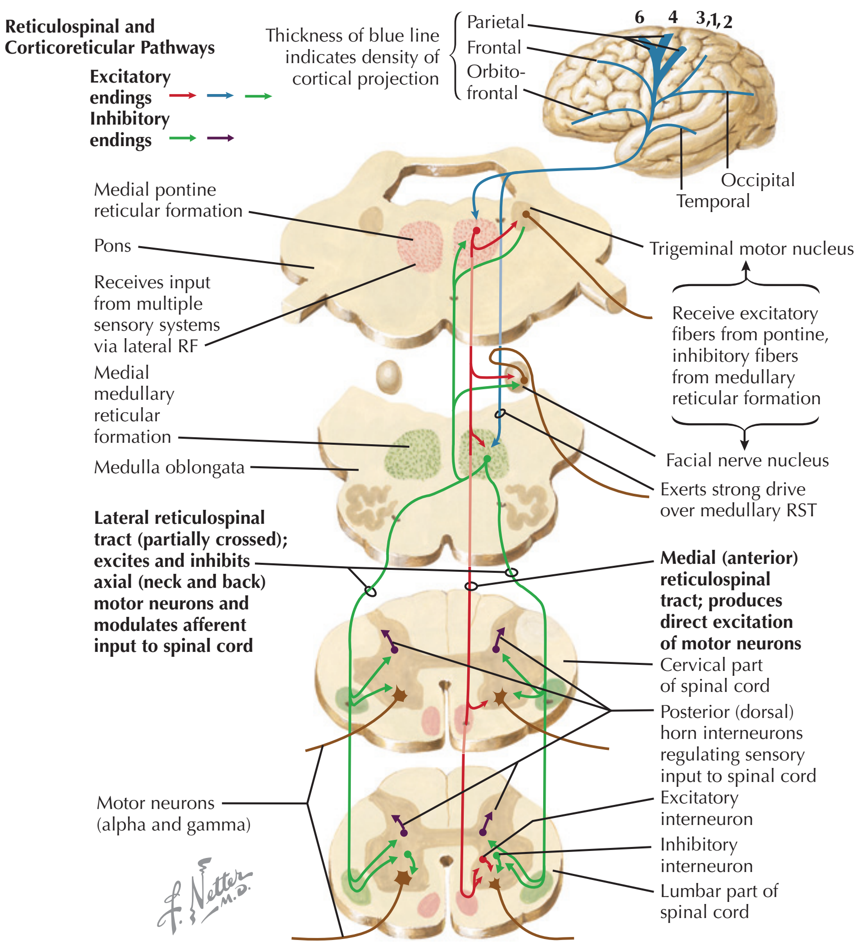
The vestibulospinal tracts work with the reticulospinal tracts to control tone and posture.

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Lateral vestibulospinal tract	Arises from the lateral vestibular nucleus Descends the anterior part of the lateral funiculus of the spinal cord Terminates on the ipsilateral anterior horn cells	Associated with the extensor musculature to control tone and posture
Medial vestibulospinal tract	Arises from the medial vestibular nucleus	Inhibits the cervical spinal motor neurons controlling the neck and trunk



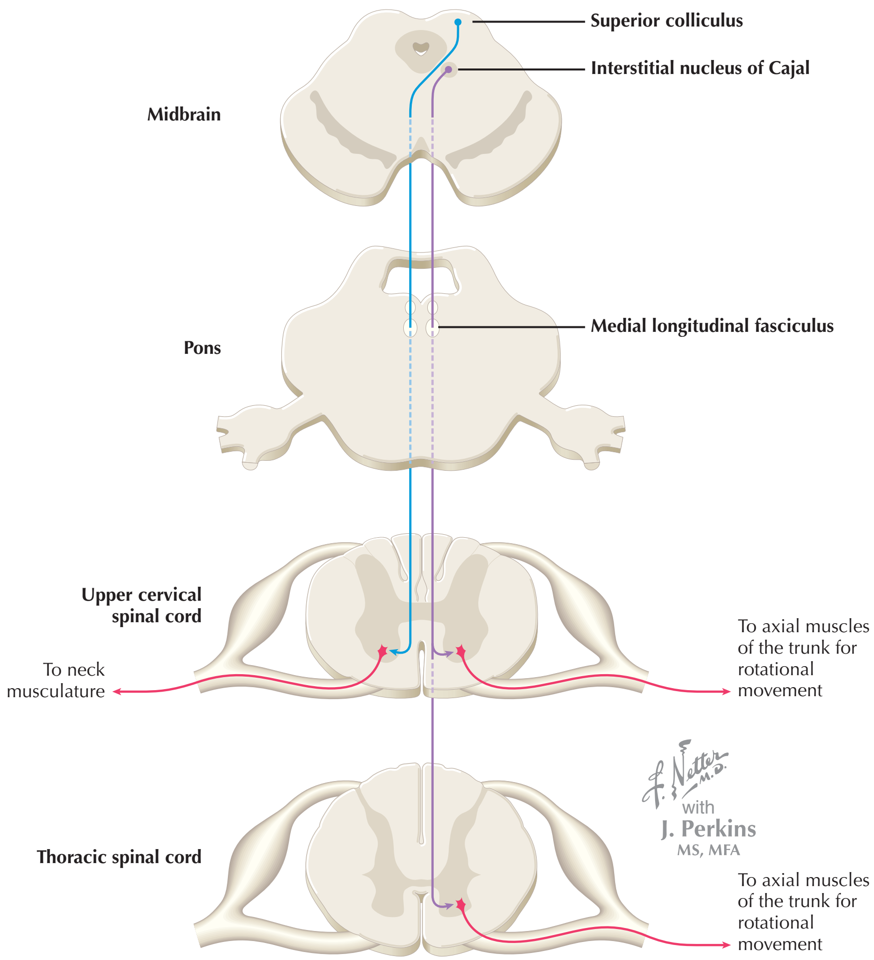
RETICULOSPINAL AND CORTICORETICULAR PATHS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Pontine reticulospinal tract	Descends ipsilaterally Arises from nuclei in the medial pontine reticular formation (pontis caudalis and oralis)	Distinct extensor bias, reinforcing lateral vestibulospinal tract to regulate tone and posture
Medullary reticulospinal tract	Descends bilaterally Arises from nucleus gigantocellularis	Distinct flexor bias, reinforcing the corticospinal and reticulospinal tracts to regulate tone and posture



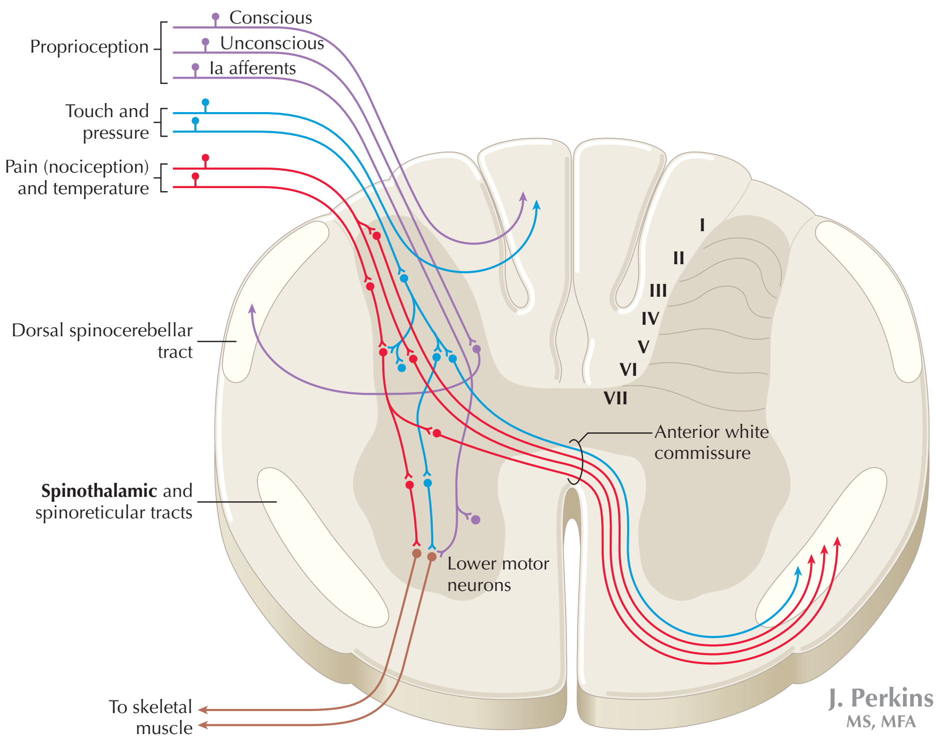
TECTOSPINAL TRACT AND MEDIAL LONGITUDINAL FASCICULUS (MLF)

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Tectospinal tract	Arises from the superior colliculus Descends contralaterally ventral to the MLF Terminates mainly in upper 4 cervical spinal segments	Mediates reflex and visual tracking for head and neck movement
Interstitiospinal tract	Arises from the interstitial nucleus of Cajal Descends in the ipsilateral MLF	Terminates on spinal motor neurons associated with rotational trunk movement



ASCENDING SPINAL CORD PATHWAYS

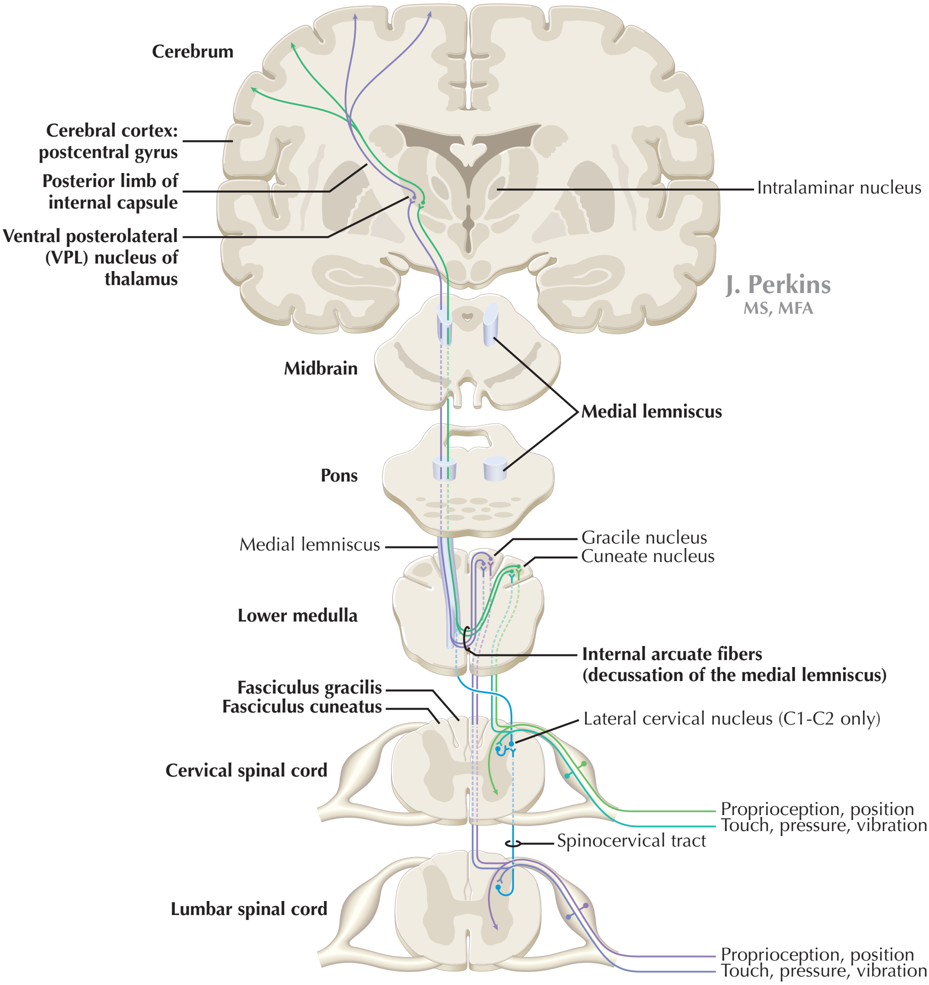
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Unmyelinated and small myelinated axons	Terminate in laminae I and V	Origin of the spinothalamic tract
Myelinated axons	Ascend the posterior columns	Mediate vibration and position



POSTERIOR WHITE COLUMNS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Myelinated axons	Enter the dorsal horn, ascend the fasciculus gracilis (medial, from leg) and cuneatus (lateral, from arm) to medullary nuclei	Mediate touch, vibration, position Posterior column lesion (B_{12} deficiency, demyelinating multiple sclerosis plaque) results in ataxia
Second-order neurons	Cross ventromedially as internal arcuate fibers Turn upward as medial lemniscus Medial lemniscus ascends to ventroposterolateral nucleus (VPL) of thalamus	Mediate touch, vibration, position Thalamic infarct results in contralateral numbness May cause contralateral pain syndrome
Third-order neurons	From the thalamus ascend the posterior limb internal capsule to terminate in the sensory cortex	Cortical infarction results in loss of cortical sensation, including graphesthesia, stereognosis

POSTERIOR WHITE COLUMNS *continued*

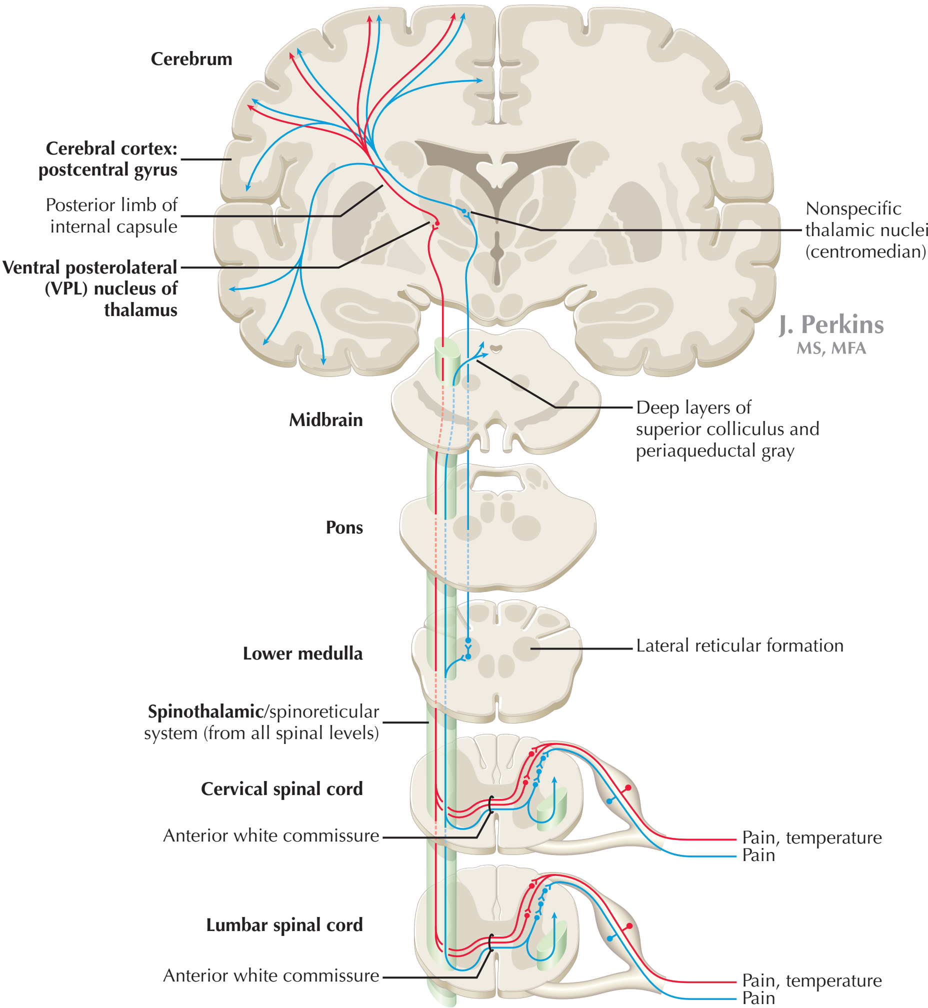


SPINOTHALAMIC AND SPINORETICULAR TRACT

- Unilateral section of the spinothalamic tract produces contralateral sensory loss to a level 1 segment below the lesion owing to oblique crossing of fibers.
- Unilateral lesions do not markedly affect anogenital region.

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Peripheral receptors for pain and temperature	Send central processes to the zone of Lissauer	Small-fiber neuropathy results in painful feet
Cells in laminae I, IV, and V	Give rise to axons that cross in anterior white commissure	Syrinx in the central canal interrupts these fibers with loss of pain and temperature in affected segments
Spinothalamic tract	Ascends in the contralateral lateral funiculus as the lateral spinothalamic tract Lateroposterior fibers represent the lower body; medial anterior fibers represent arms and neck	Compression of this tract affects pain and thermal sense below level of pathology
Spinoreticular tract	Ascends in the spinal cord with the spinothalamic tract Projects to the brainstem reticular formation, thalamus, and cortex	Processes information related to slow, excruciating pain

SPINOTHALAMIC AND SPINORETICULAR TRACT *continued*

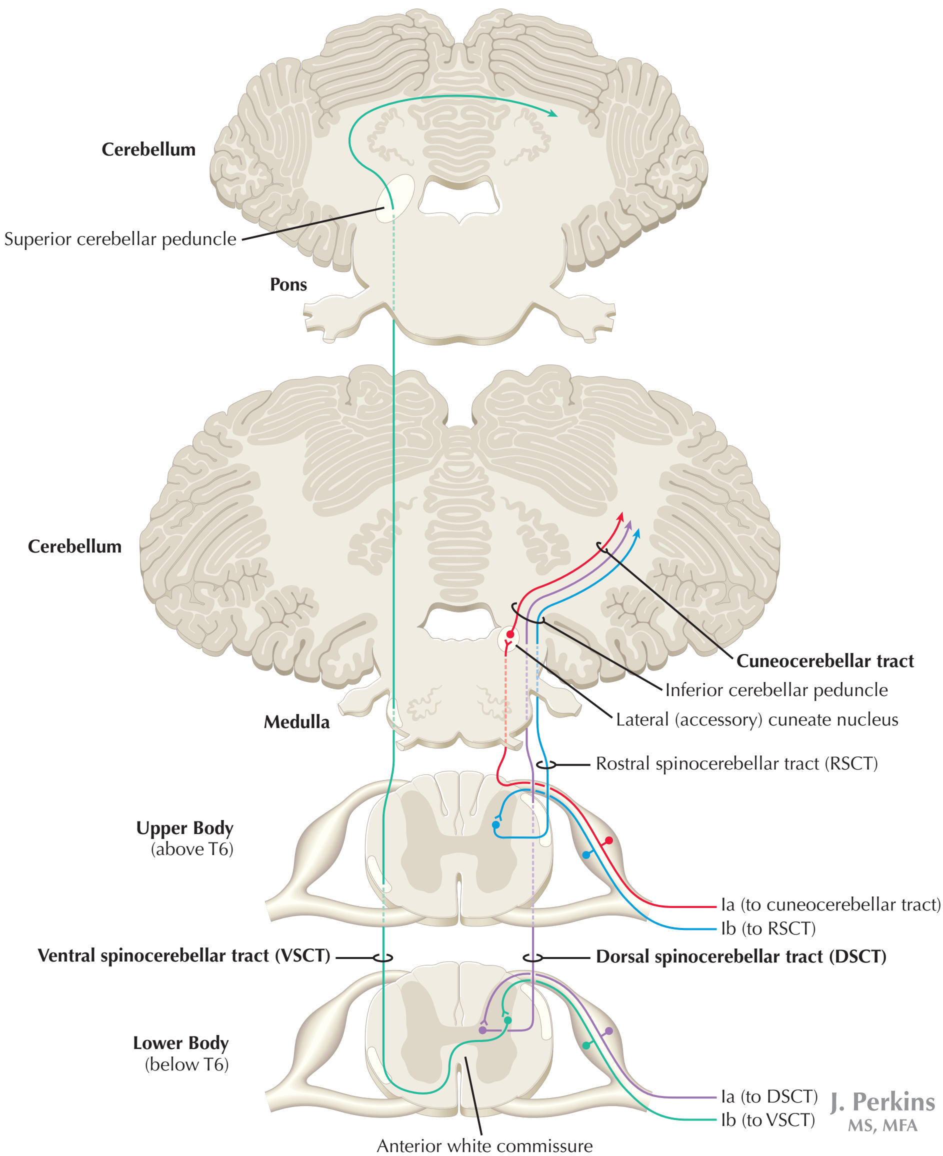


SPINOCEREBELLAR PATHWAYS

- Dorsal and cuneocerebellar tracts remain ipsilateral.
- Ventral spinocerebellar tract crosses twice, once in anterior commissure, again in cerebellum, thus remaining ultimately ipsilateral.

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Ventral (anterior) spinocerebellar tract	Crosses in the anterior commissure, ascends to the superior cerebellar peduncle (brachium conjunctivum) Crosses again in cerebellum to contralateral cortex	Conveys impulses from the lower body Golgi tendon organ via Ib afferents Equivalent in the upper body is the rostral spinocerebellar tract
Dorsal (posterior) spinocerebellar tract	Projects to the ipsilateral nucleus dorsalis (Clarke column) and remains ipsilateral Nucleus dorsalis axons form the dorsal (posterior) spinocerebellar tract Ascends to the inferior cerebellar peduncle to the cerebellar cortex	Conveys impulses below T6 from muscle spindles and Golgi tendon organ via Ia, Ib, and II fibers Equivalent in the upper body is the cuneocerebellar tract
Cuneocerebellar tract	Cervical dorsal root fibers synapse in the accessory cuneate nucleus Second-order neurons form the cuneocerebellar tract Remains ipsilateral and travels with the dorsal spinocerebellar tract to the cerebellum	Clarke's column is not present above C8 but is replaced by accessory cuneate nucleus Equivalent in lower body is dorsal (posterior) spinocerebellar tract

SPINOCEREBELLAR PATHWAYS *continued*

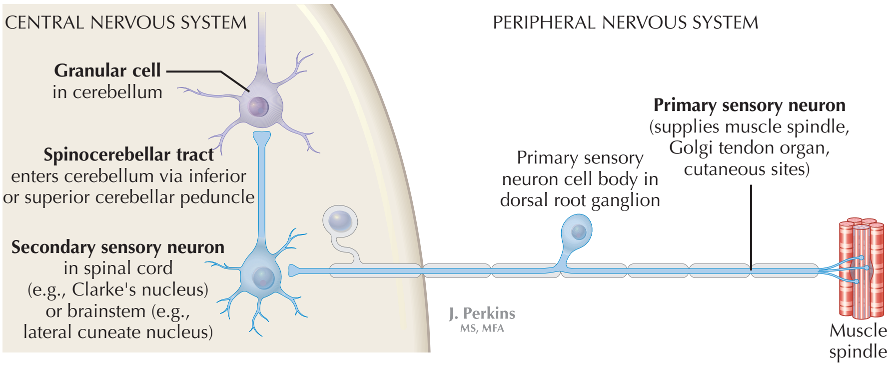


SPINOCEREBELLAR SYNAPTIC PATHWAY

Primary somatosensory axons transmit information from the following:
- Muscle spindles
- Golgi tendon organs
- Touch and pressure receptors

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Dorsal and ventral spinocerebellar tract	Enter via the dorsal root Convey information to the ipsilateral cerebellum	Carry information from T6 and below
Rostral spinocerebellar tract and cuneocerebellar tract	Enter via the dorsal root Convey information to the ipsilateral cerebellum	Carry information from above T6

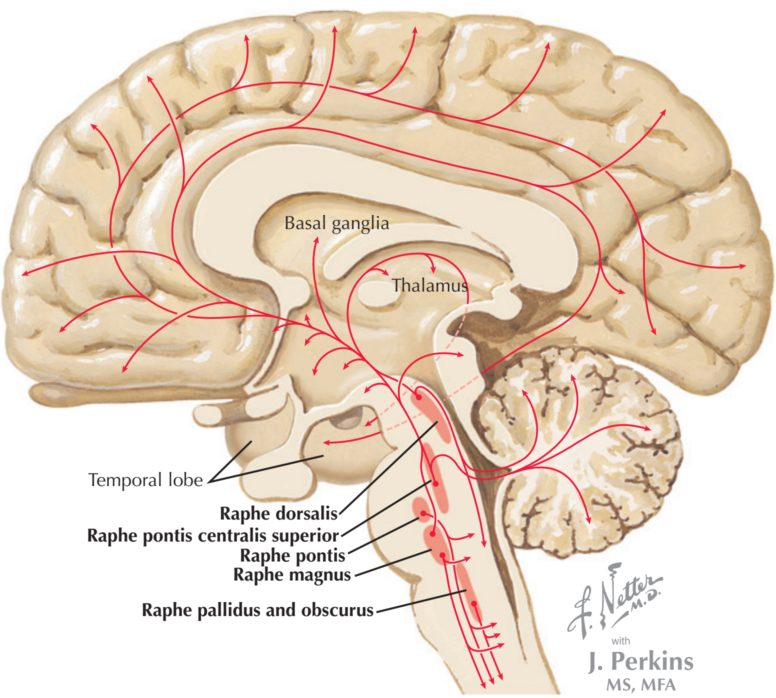
Sensory Channels - Cerebellar



RAPHE NUCLEI AND SEROTONERGIC PATHWAYS

- Main source of serotonin to central nervous system
- Important for wakefulness and sleep

STRUCTURE	ANATOMIC NOTES
Raphe dorsalis nucleus	Projects upward to the substantia nigra, lateral geniculate body, pyriform lobe (anteromedial temporal lobe), olfactory bulb, amygdaloid nuclear complex Projects downward to the locus ceruleus and parabrachial nucleus surrounding the superior cerebellar peduncle
Raphe pontis centralis superior (median raphe) nucleus	Projects upward to the interpeduncular nucleus, mammillary bodies, hippocampal formation Projects downward to the cerebellum (via middle cerebellar peduncle), locus ceruleus, pontine reticular formation
Nucleus raphe pontis	Projects to the brainstem and spinal cord
Nucleus raphe magnus	Projects, via the dorsal longitudinal fasciculus, to the dorsal motor nucleus of X, nucleus solitarius, spinal trigeminal nucleus, spinal cord (substantia gelatinosa)
Nucleus raphe pallidus and obscurus	Project to the spinal cord

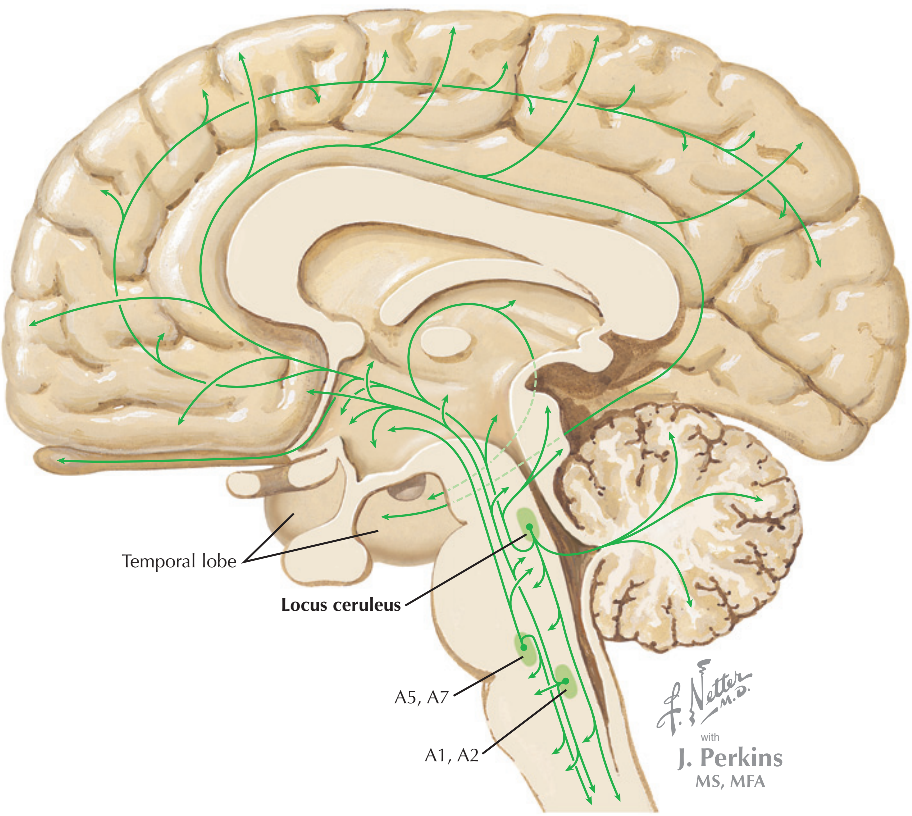


LOCUS CERULEUS (NORADRENERGIC PATHWAYS)

- Provides noradrenergic innervation to most of central nervous system
- Believed to play role in regulation of respiration and in rapid eye movement (REM) sleep

STRUCTURE	ANATOMIC NOTES
Locus ceruleus (nucleus pigmentosus)	Small nucleus in the upper pons, near the periventricular gray of the upper 4th ventricle
Descending pathway	Fibers descend in the anterior and lateral funiculi, largely uncrossed, ending in the anterior horn, intermediate gray, and ventral half of the posterior horn
Ascending pathway	Fibers ascend through the midbrain, lateral to the MLF, and ventrolateral to central gray In caudal diencephalon, fibers enter the medial forebrain bundle, via the mammillary peduncle, to and through the lateral hypothalamus Fibers continue rostrally to the anterior commissure, divide, and innervate the diencephalon and telencephalon Stria medullaris component turns caudally to innervate the midline thalamus Stria terminalis component supplies the amygdaloid nuclear complex Most rostral fibers pass from the medial forebrain bundle to the external capsule to frontal cortex

LOCUS CERULEUS (NORADRENERGIC PATHWAYS) *continued*



CHAPTER 16

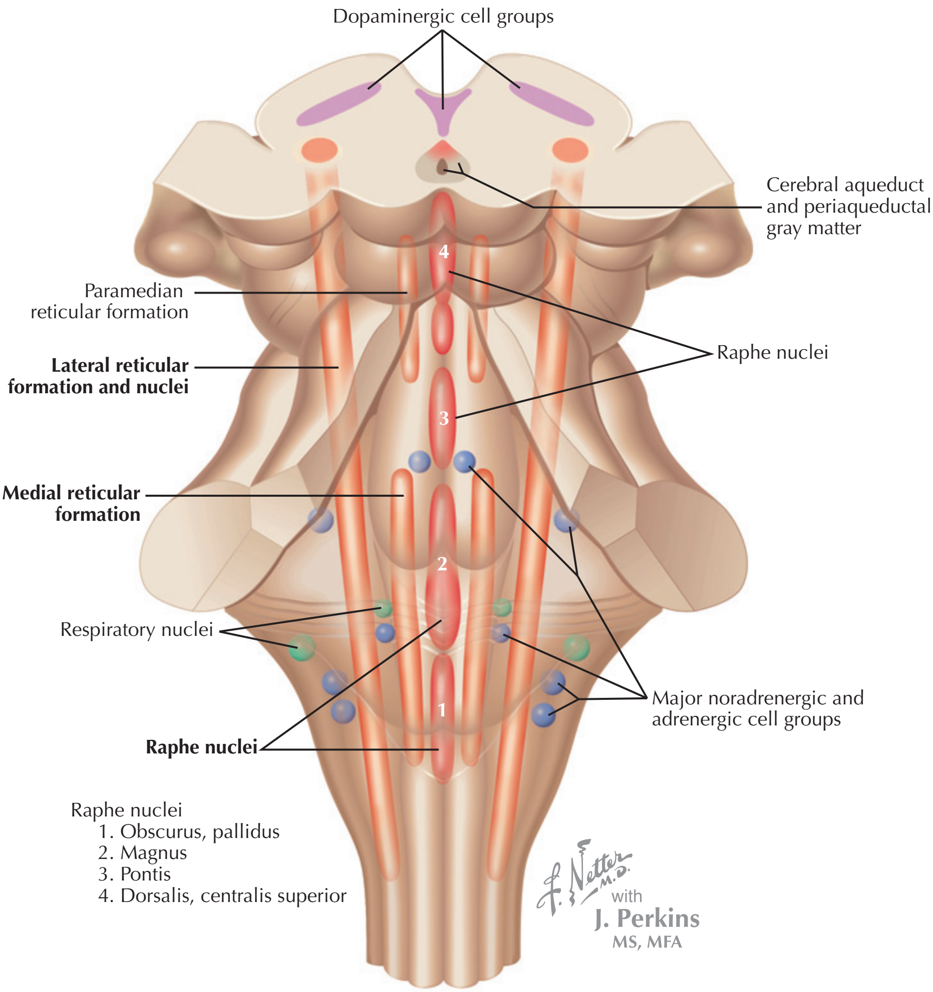
Reticular Formation

RETICULAR FORMATION: OVERVIEW

- A somewhat diffuse collection of neurons and nerve fibers extending from the caudal medulla, beginning just above the pyramidal decussation, to the rostral midbrain, and continuous with the subthalamic zona incerta and thalamic nuclei
- Essentially a matrix within which nuclei and tracts are embedded
- Neurons within the reticular formation discharge in relation to multiple stimuli, including sensory input, pain and escape behavior, conditioning and habituation, arousal, complex motivational states, rapid eye movement (REM) sleep, eye movements, respiration, and locomotion

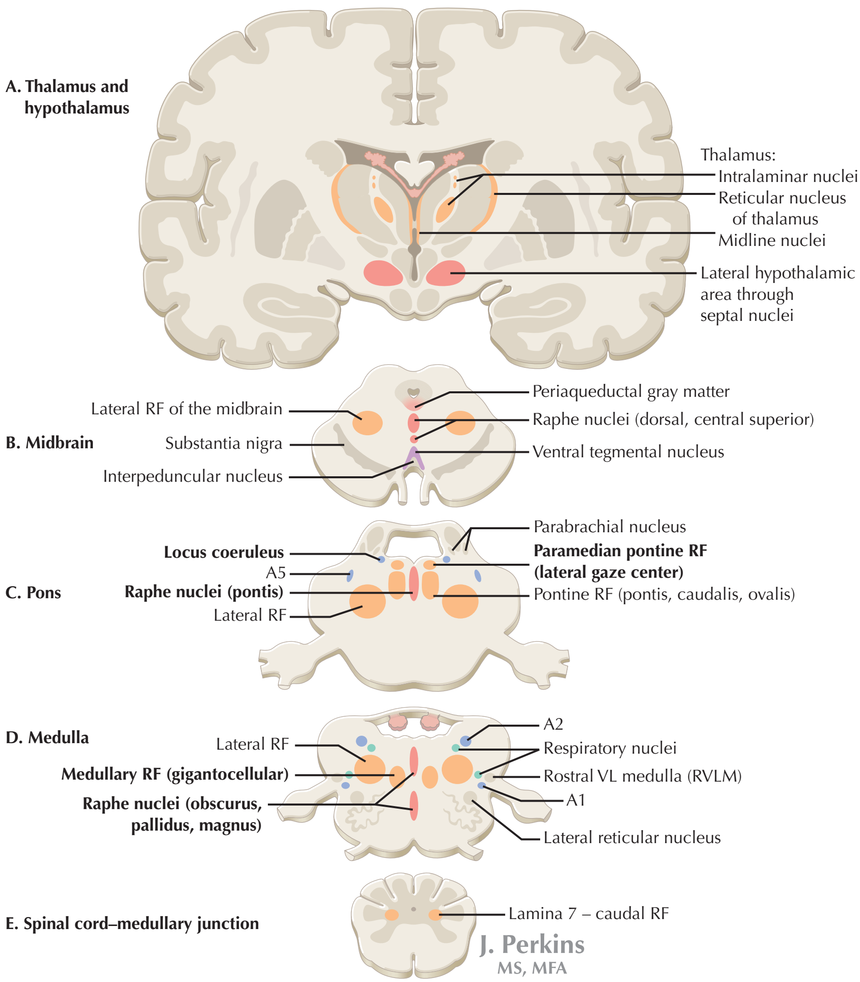
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Lateral group nuclei	Includes: • Nucleus reticularis lateralis in the medulla • Nucleus reticularis parvocellularis in the pons and medulla • Parabrachial and pedunculopontine in the pons and midbrain • Cuneiform and subcuneiform in the midbrain	Relate to locomotion and autonomic regulation
Medial group nuclei	Includes: • Nucleus reticularis gigantocellularis in the medulla • Nucleus reticularis pontis caudalis and oralis in the pons	Descending connections play a role in motor control, ascending connections play a role in consciousness and alertness
Column of raphe nuclei	Includes: • Raphe obscurus and pallidus in medulla • Raphe magnus in pons and medulla • Dorsal raphe and superior central nuclei in midbrain	Caudal nuclei concerned with pain mechanisms; rostral nuclei relate to sleep, wakefulness, and alertness

OVERVIEW *continued*

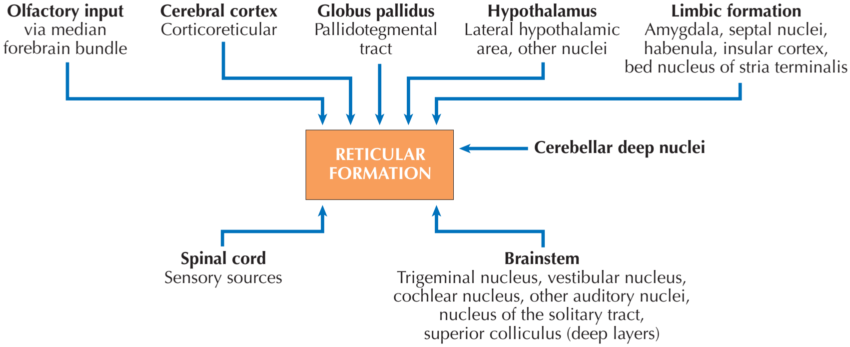


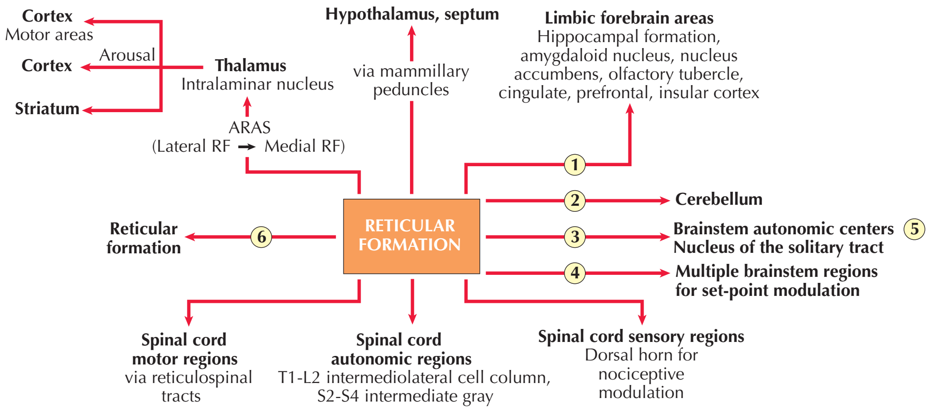
RETICULAR NUCLEI

STRUCTURE	FUNCTIONAL SIGNIFICANCE
Nucleus reticularis gigantocellularis	Reticulospinal regulation of spinal cord lower motor neurons
Paramedian pontine reticular formation (PPRF)	Lateral gaze center
Raphe nuclei	Rostral nuclei are part of ascending reticular activating system concerned with sleep, wakefulness, and alertness
Locus ceruleus	Ascending noradrenergic system involved in attention, mood, and sleep-wake state



MAJOR AFFERENT AND EFFERENT CONNECTIONS OF THE RETICULAR FORMATION





1. From lateral reticular nucleus
   Nucleus reticularis tegmenti pontis, paramedian reticular nucleus, locus ceruleus, raphe nuclei
2. From locus ceruleus, raphe nuclei, ventral tegmental area
3. Via median forebrain bundle, dorsal longitudinal fasciculus, habenulopeduncular tract, mammillotegmental tract
4. From adrenergic, noradrenergic (tegmental and locus ceruleus), serotonergic (raphe) nuclei
5. Including ventrolateral and ventromedial tegmentum of caudal brain stem
6. Intrareticular connections

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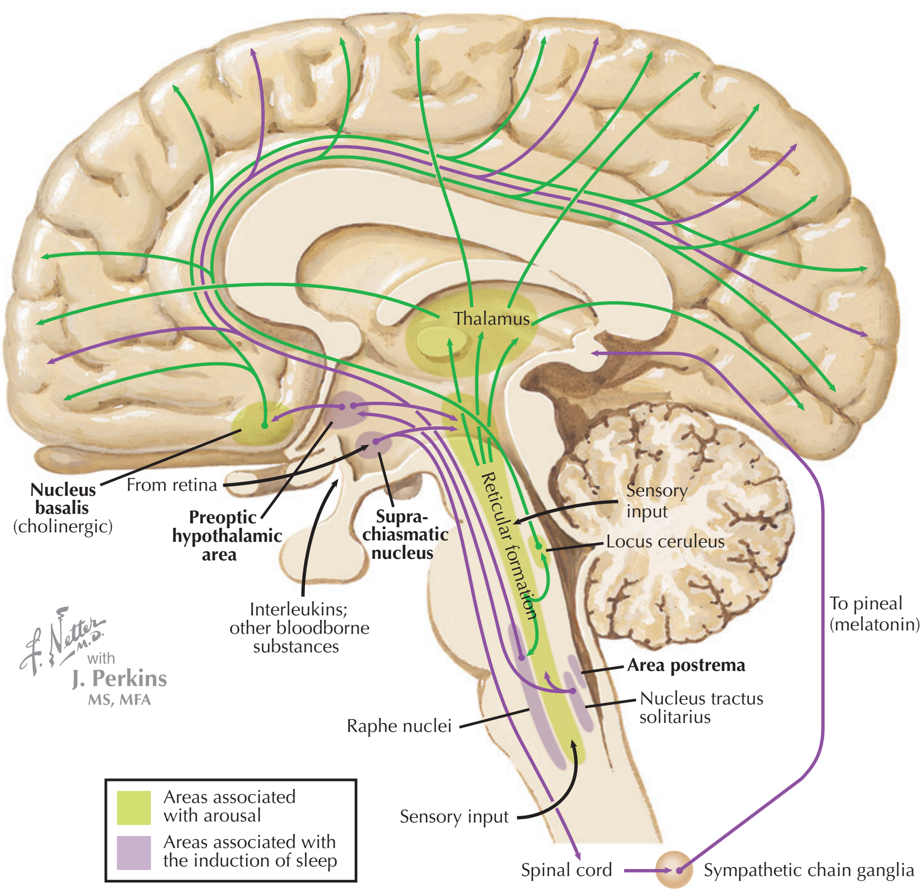
MS, MFA

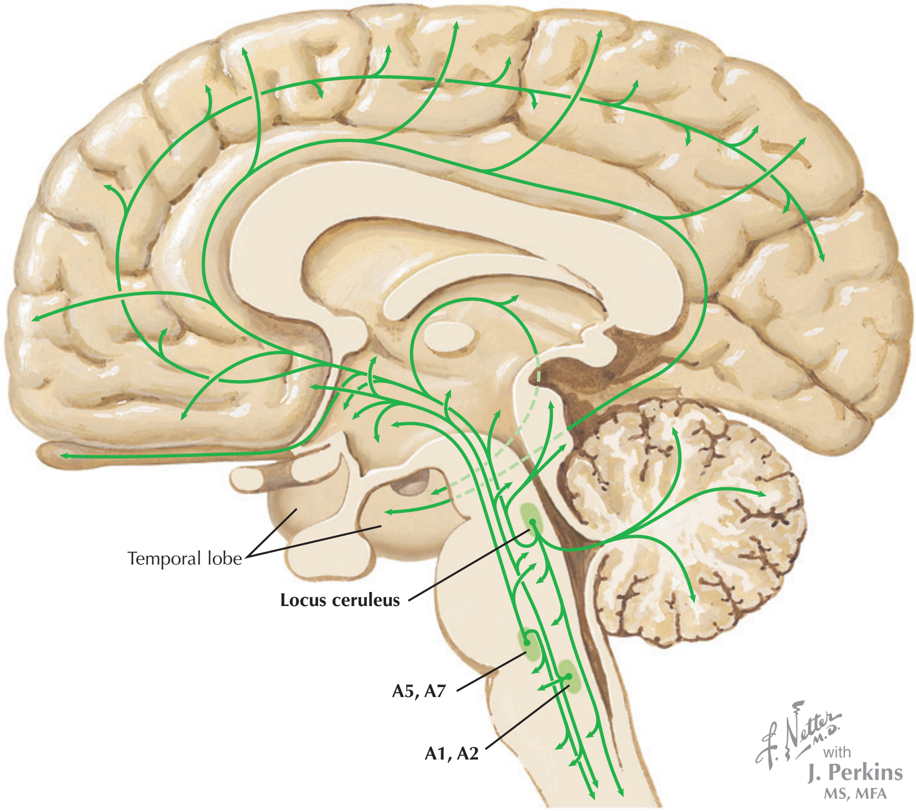
SLEEP WAKE CONTROL

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Area postrema	Rostral to obex on each side of 4th ventricle	Associated with sleep induction. Also emetic chemoreceptor trigger zone
Suprachiasmatic nucleus of hypothalamus	Dorsal to the optic chiasm, close to the ventral part of the 3rd ventricle	Lesioning eliminates circadian rhythm of sleep-wake cycle
Preoptic hypothalamic area	Periventricular grey of most rostral part of 3rd ventricle	Receives fibers that carry sleep-inducing peptides enkephalin and endorphin
Nucleus basalis	Rostrally lies under cortex of anterior perforated substance	These cholinergic projection neurons are lost in Alzheimer's disease



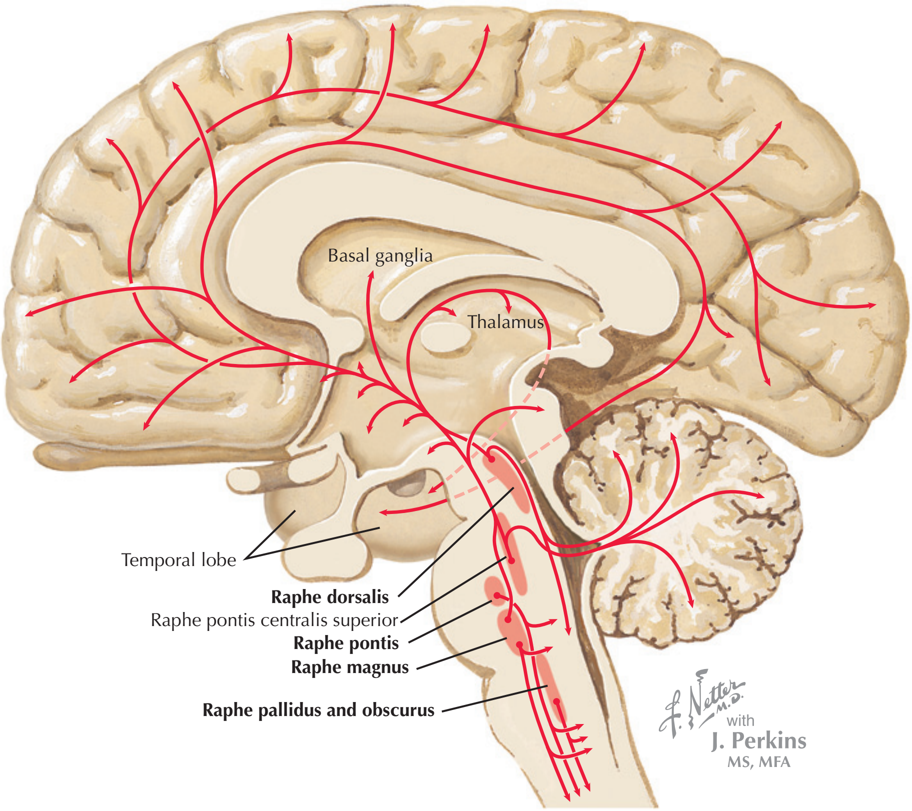
NORADRENERGIC PATHWAYS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Locus ceruleus	Gives rise to 3 major ascending tracts: • Central tegmental tract • Dorsal longitudinal fasciculus • Medial forebrain bundle	Ascending system involved in modulation of attention, sleep-wake state, and mood
Groups A1-A7 (lateral tegmental noradrenergic system)	Noradrenergic cell groups scattered in pons and medulla	Axons directed to the spinal cord/ brainstem (modulate sympathetic function) and diencephalon/ telencephalon (sleep-wake state)



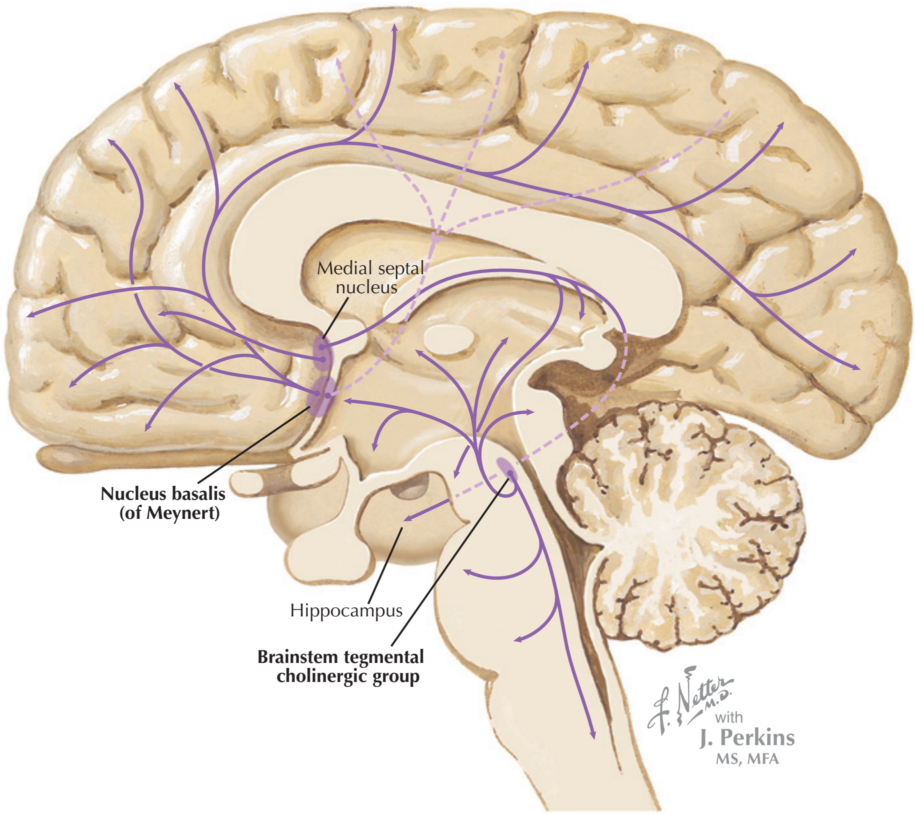
SEROTONERGIC PATHWAYS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Groups B1-B7	Serotonergic neurons within the raphe nuclei of the medulla, pons, and midbrain	Regulate diverse physiologic processes including sleep, aggressive behavior, neuroendocrine function
Raphe dorsalis	Projects to the entire forebrain	Plays a role in psychiatric disorders: depression, anxiety, obsession-compulsion
Raphe pontis, magnus, pallidus, and obscurus	Project to the cerebellum, medulla, spinal cord	Inhibit dorsal horn neurons that give rise to the spinothalamic tract, modulating pain input



CENTRAL CHOLINERGIC PATHWAYS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Brainstem tegmental group	Includes pedunculopontine reticular nucleus and adjacent lateral dorsal tegmental nucleus	Role in arousal and movement Pedunculopontine nucleus is affected in progressive supranuclear palsy
Nucleus basalis	Located in basal forebrain	Sends axons to almost the entire cerebral cortex
Medial septal nucleus	In subcallosal area, rostral to the anterior commissure	Provides interaction between the limbic and diencephalic structures Lesions in mice produce rage, hyperemotionality, heightened activity



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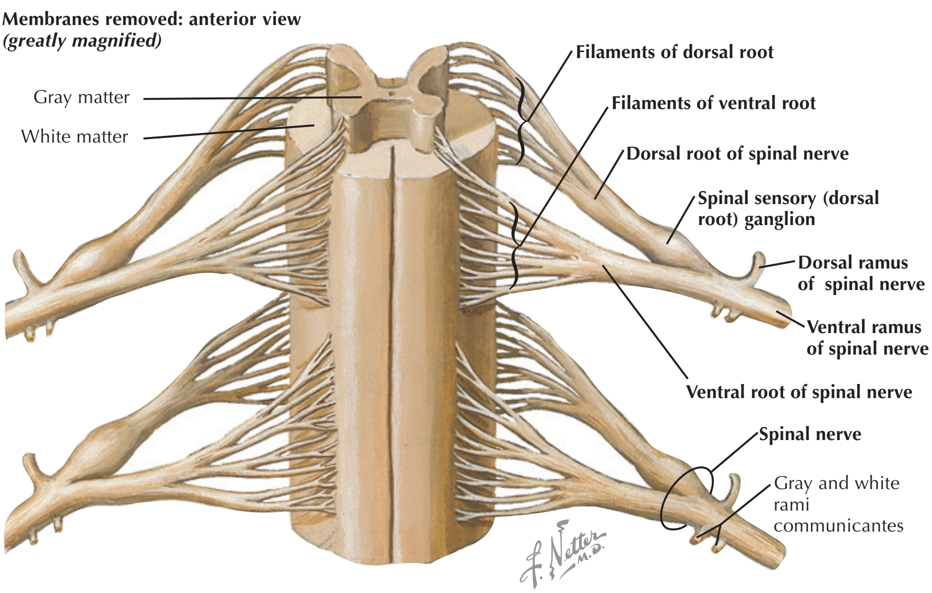
CHAPTER 17

Anatomy of the Peripheral Nervous System: Upper Extremity

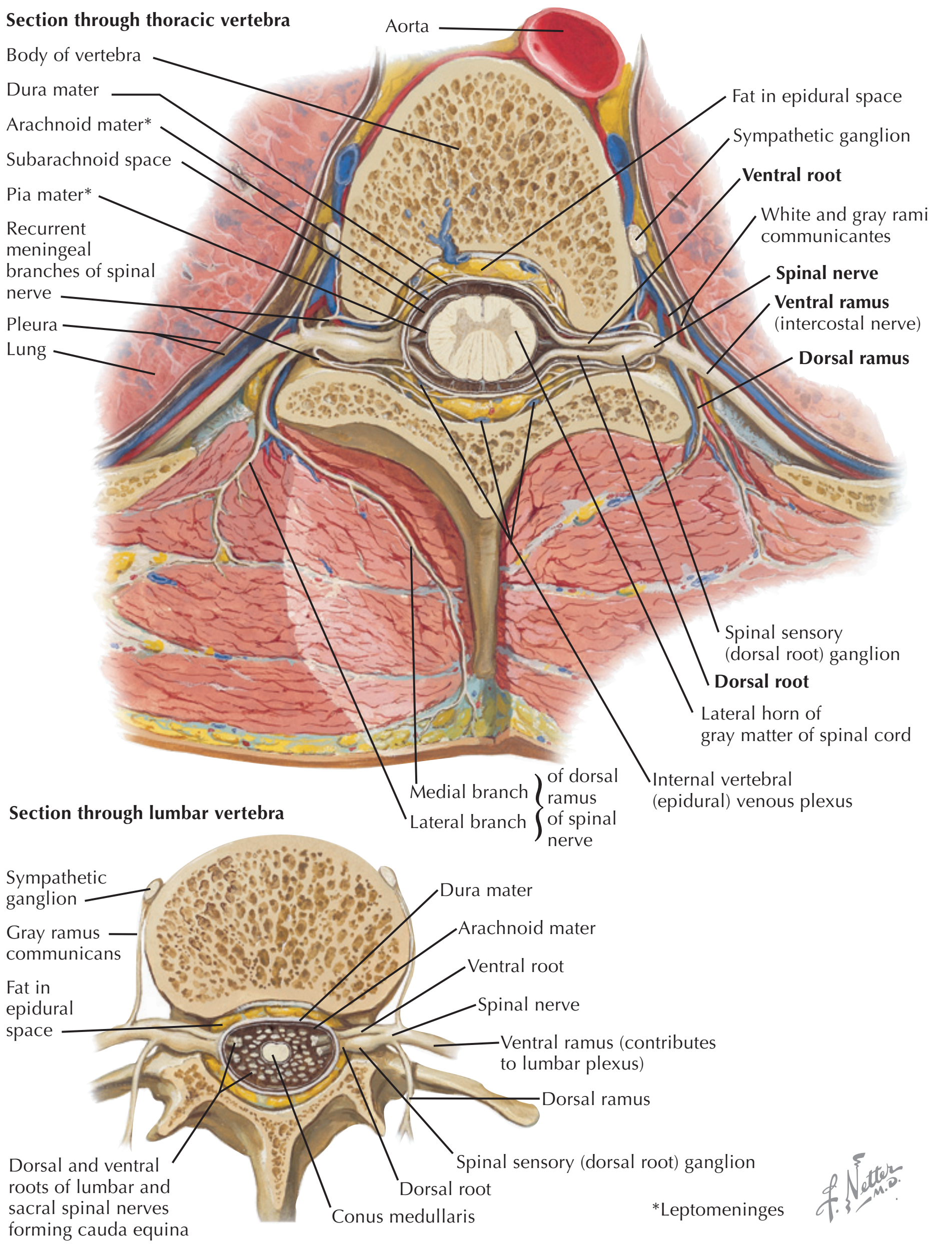
CERVICAL ROOT ANATOMY

- Filaments (rootlets) emerge from the spinal cord and combine to form the dorsal and ventral spinal nerve roots.
- Nerve roots fuse in the intervertebral foramen, distal to the dorsal root ganglion, to form short spinal nerves.
- C1 to C7 spinal nerves pass above the same-numbered cervical vertebrae to exit the spinal canal.
- C8 passes under C7 and above the T1 vertebra; T1 exits between T1 and T2 vertebrae.
- Spinal nerves divide into the dorsal and ventral ramus (plural, *rami*) on exiting foramen (except for C1, which has no dorsal ramus).
- Dorsal rami supply the skin and paraspinal muscles (except for C1, which has no cutaneous supply).
- The C2 dorsal ramus becomes the greater occipital nerve.
- Ventral rami of C1-4 form the cervical plexus.
- Ventral rami of C5-8 and T1 form the brachial plexus.



CERVICAL ROOT ANATOMY *continued*

Spinal Nerve Origin: Cross Section



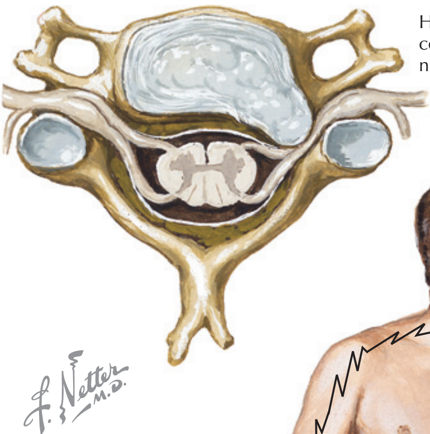
CERVICAL DISC HERNIATION SYNDROME

DISC LEVEL	ROOT AFFECTED	WEAKNESS	NUMBNESS	REFLEX AFFECTED
C3-4	C4	None	Epaulet	None
C4-5	C5	Rhomboid, supraspinatus, infraspinatus, deltoid, biceps, brachioradialis	Skin over deltoid muscle	Biceps, brachioradialis
C5-6	C6	C5 muscles above and extensor carpi radialis longus (ECRL), supinator, pronator teres	Thumb	Biceps, brachioradialis
C6-7	C7	Triceps, wrist and finger extensors, flexor carpi radialis (FCR), pronator teres	Middle (3rd) finger	Triceps
C7-T1	C8	C7 muscles above and finger flexors, flexor carpi ulnaris (FCU), intrinsic hand muscles	Fingers 4 and 5 and hypothenar eminence	Triceps, finger flexor reflex
T1-2	T1	Intrinsic hand muscles	Medial elbow region	Finger flexor reflex

Patients with radiculopathy infrequently lose sensation over the entire dermatome; rather, the sensory abnormality is confined to “signature areas.”

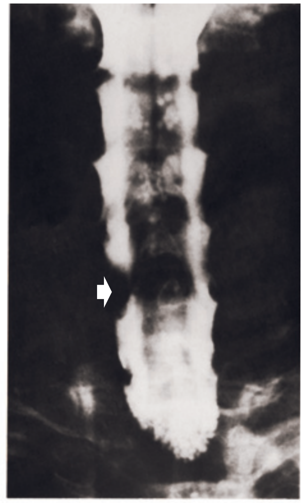
CERVICAL DISC HERNIATION SYNDROME *continued*

Cervical disc herniation: clinical manifestations

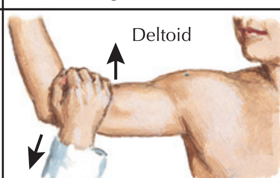
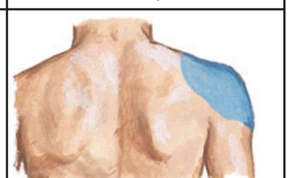
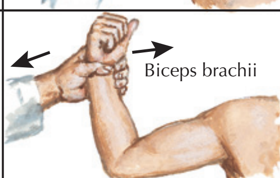
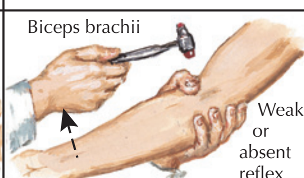
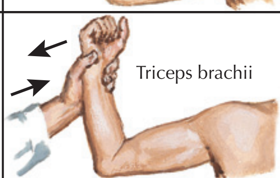
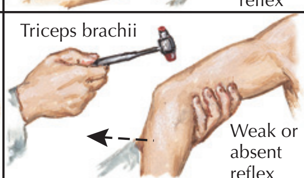
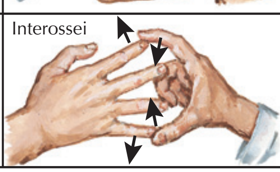
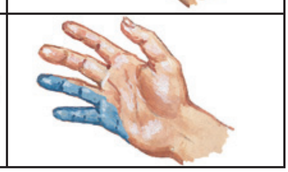


Herniated disc compressing n. root

Spurling's maneuver
Hyperextension of neck and rotation away from side of lesion cause radicular pain in neck and down arm



Myelogram (AP view) showing prominent (open arrow) at C6-7 extradural defect

Level	Motor signs (weakness)	Reflex signs	Sensory loss
C5	 Deltoid	0	
C6	 Biceps brachii	 Biceps brachii; Weak or absent reflex	
C7	 Triceps brachii	 Triceps brachii; Weak or absent reflex	
C8	 Interossei	Horner's syndrome 	

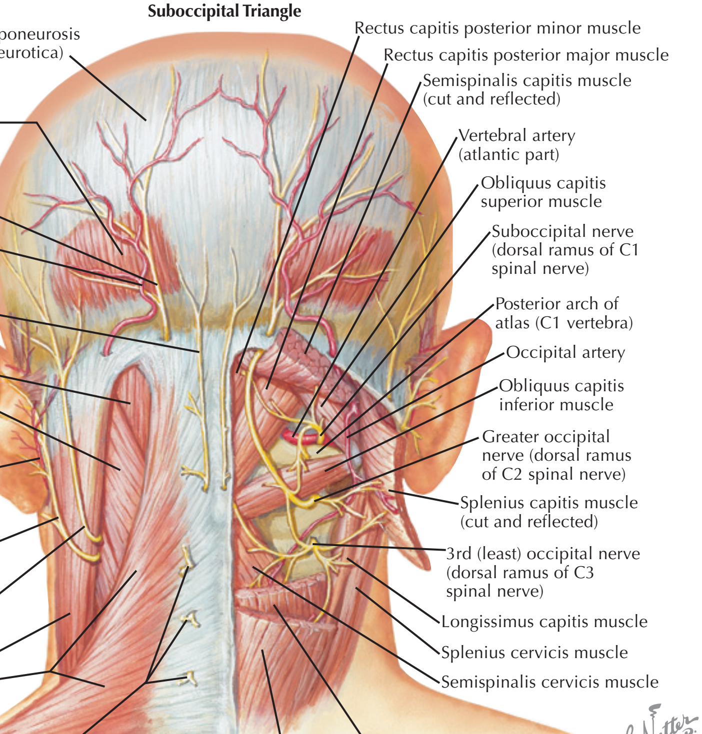
CERVICAL PLEXUS

The cervical plexus has four cutaneous branches that emerge from the posterior border of the sternocleidomastoid.

- The great(er) auricular (C2-3) supplies skin over the angle of the mandible, parotid, mastoid, and auricle
- Lesser occipital (C2-3) supplies the lateral part of the occiput and medial surface of the auricle
- Supraclavicular (C3-4)
- The transverse cervical nerve (transverse cutaneous of neck) (C2-3) supplies skin over the anterior and lateral neck from the mandible to the sternum

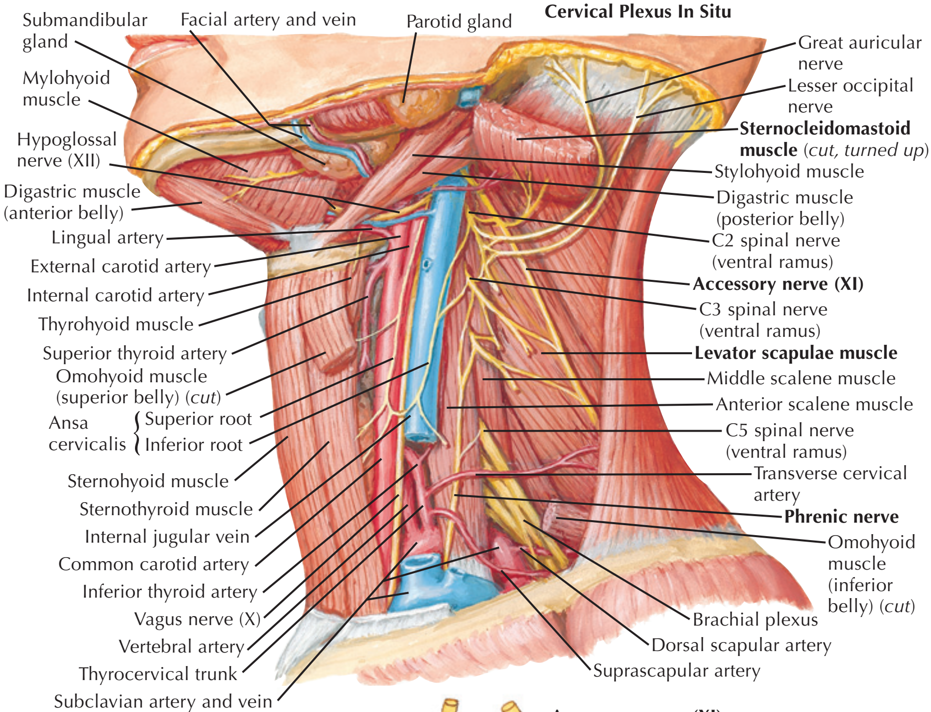
The cervical plexus has several muscular branches:

- Phrenic nerve (C3-4-5 to diaphragm)
- Accessory nerve: receives branches from the cervical plexus; these branches ascend to enter the foramen magnum, join cranial nerve (CN)-XI, and exit through the jugular foramen with CN-IX and -X. This nerve supplies the trapezius and sternocleidomastoid
- The levator scapulae (C3-4) raises the medial border of the scapula and braces the shoulder backward
- Short, muscular branches to adjacent muscles

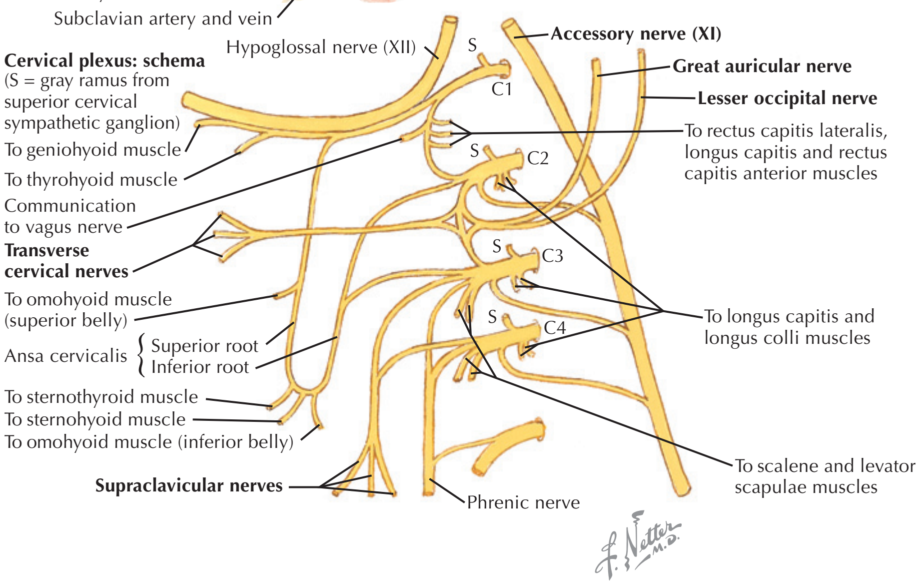


CERVICAL PLEXUS *continued*

Cervical Plexus In Situ



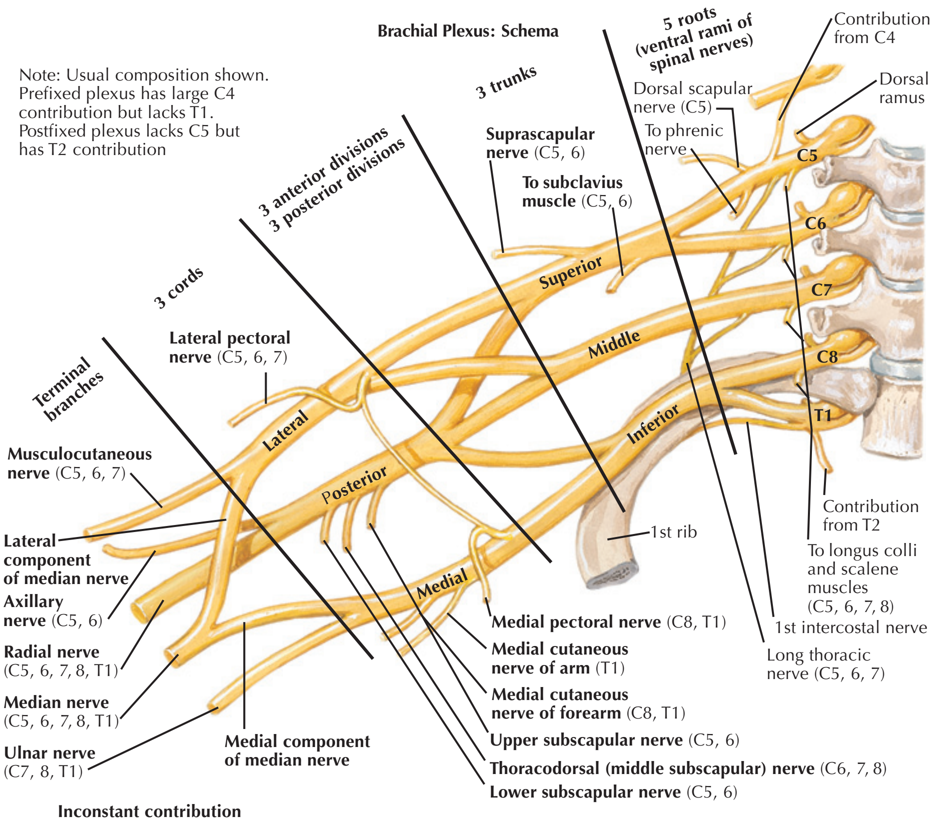
Cervical plexus: schema
(S = gray ramus from superior cervical sympathetic ganglion)

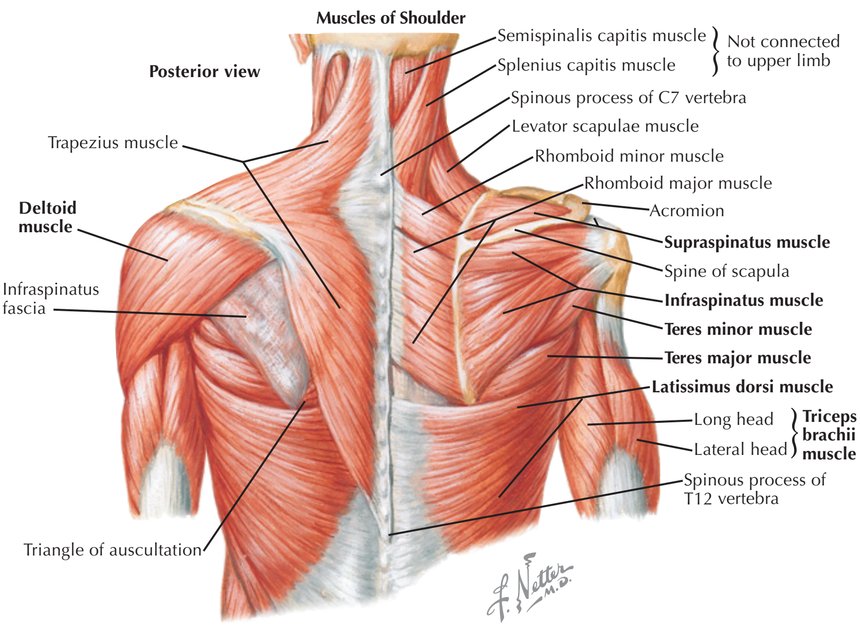


BRACHIAL PLEXUS COMPONENTS

NERVE	ROOT(S)	MUSCLE INNERVATED (ACTION)	SENSORY DERMATOME
Upper Trunk			
Suprascapular	C5-6	Supraspinatus (first 15 degrees of shoulder abduction), infraspinatus (external rotation)	None
To the subclavius	C5-6	Subclavius (depresses the clavicle and steadies it during shoulder movement)	None
Lateral Cord			
Lateral pectoral	C5-7	Upper part of the pectoralis major	None
Musculocutaneous	C5-6	Elbow flexors: biceps brachii, coracobrachialis, brachialis	Lateral aspect of forearm
Lateral component of median	C5-6 (C7 from middle trunk)	Pronator teres, flexor carpi radialis (FCR)	Median hand
Posterior Cord			
Thoracodorsal	C6-8	Latissimus dorsi	None
Upper subscapular	C5-6	Subscapularis	None
Lower subscapular	C5-6	Subscapularis, teres major	None
Axillary	C5-6	Deltoid, teres minor	Patch of skin over deltoid
Radial	C5-8	All radial muscles	Lateral 3 and ½ dorsal hand
Medial Cord			
Medial pectoral	C8-T1	Lower part pectoralis major, pectoralis minor	None
Medial cutaneous nerve of the arm	C8-T1	None	Medial aspect of the arm
Medial cutaneous nerve of the forearm	C8-T1	None	Medial aspect of the forearm
Ulnar	C8-T1	All ulnar muscles	Medial 1 and ½ hand
Medial component of median	C8-T1	Flexor digitorum superficialis (FDS), flexor pollicis longus (FPL), flexor digitorum profundus (FDP) I and II, lumbricals, opponens pollicis, abductor pollicis brevis, flexor pollicis brevis (superficial head) (LOAF)	None

BRACHIAL PLEXUS COMPONENTS *continued*





17 Anatomy of the Peripheral Nervous System: Upper Extremity

BRACHIAL PLEXUS

The brachial plexus forms from the ventral rami of C5-8 and T1:

- C5 and C6 ventral rami join to form the superior (upper) trunk.
- C7 ventral ramus continues alone to form the middle trunk.
- C8 and T1 ventral rami join to form the inferior (lower) trunk.

Each trunk divides into an anterior and posterior division:

- All three posterior divisions join to form the posterior cord.
- Anterior divisions of the superior and middle trunks join to form the lateral cord.
- The anterior division of the inferior trunk continues as the medial cord.

In the neck, the brachial plexus lies between the anterior and medial scalene muscles and above the first rib:

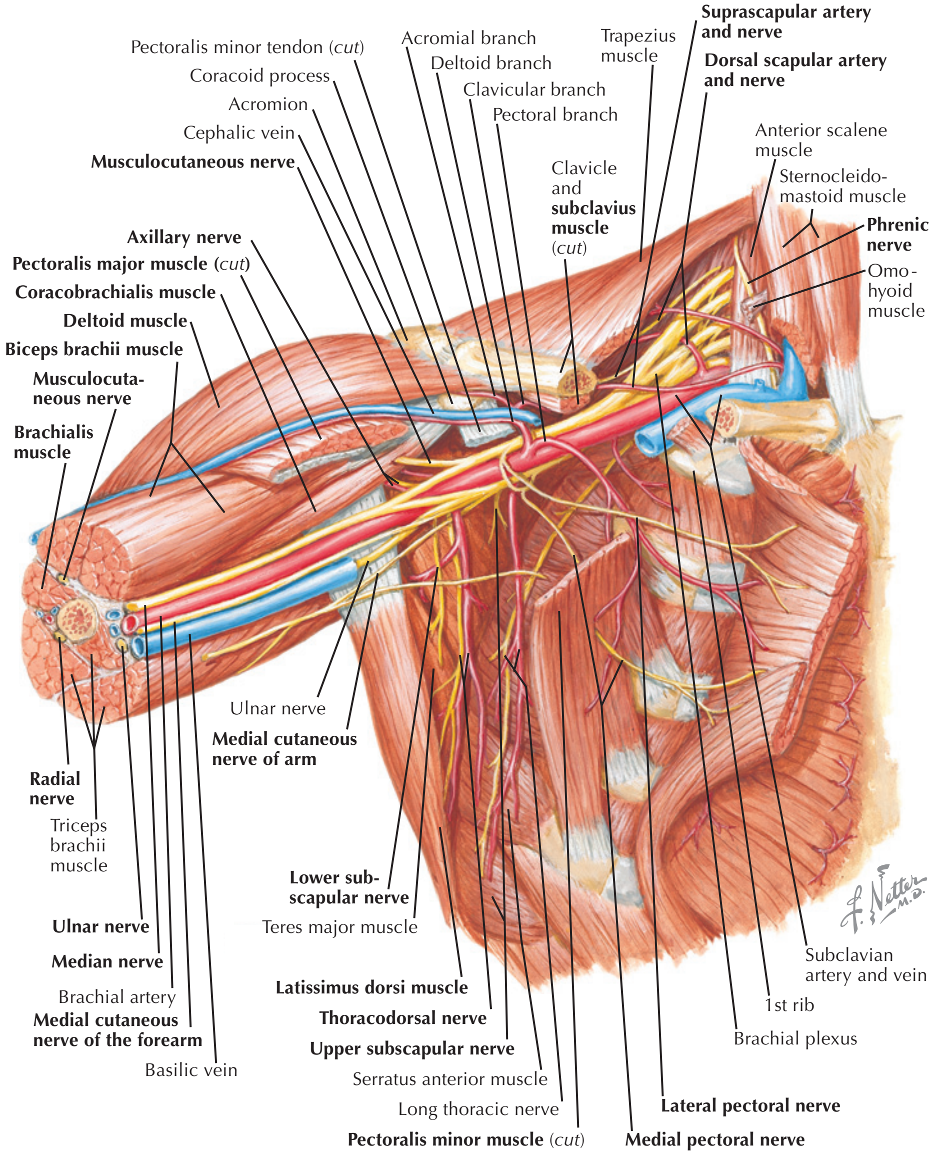
- It emerges behind the lower part of the sternocleidomastoid.
- It passes under the clavicle, over the first rib, to reach the axilla.
- The T1 ramus and lower trunk lie on pleura over the lung apex, and the trunk curves over the first rib to reach the axilla.

The dorsal scapular nerve supplies the rhomboid (elevates the medial border of the scapula and pulls it medially); it arises from the C5 ventral ramus.

- The phrenic nerve supplies the diaphragm; it arises from the ventral rami of C3-5.
- The long thoracic nerve supplies the serratus anterior; it arises from the ventral rami of C5-7.

BRACHIAL PLEXUS *continued*

Axilla (Dissection): Anterior View

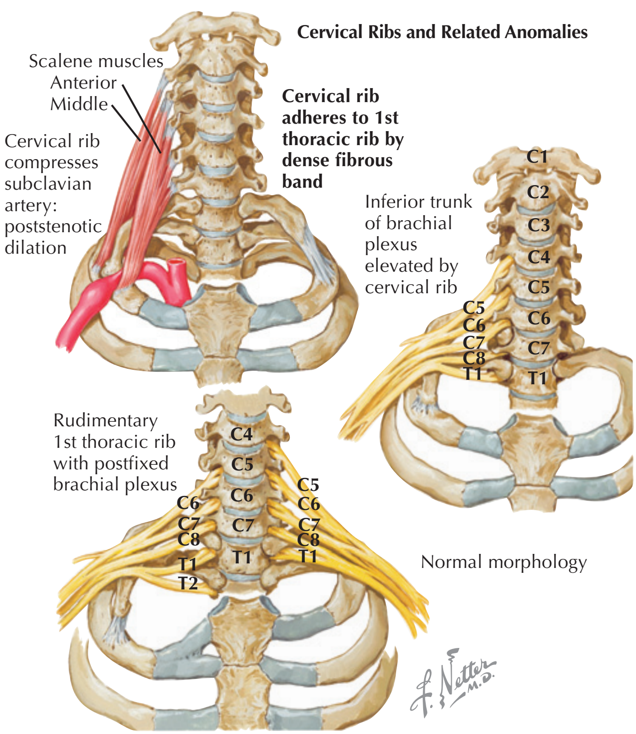


BRACHIAL PLEXOPATHY

Causes of brachial plexopathy include the following:

- Trauma
- Tumor invasion
- Radiation-induced
- Acute brachial plexus neuropathy (brachial neuritis, neuralgic amyotrophy, Parsonage-Turner syndrome)
- Cervical rib (see Thoracic Outlet Syndrome to follow)
- Hereditary neuropathy with liability to pressure palsies

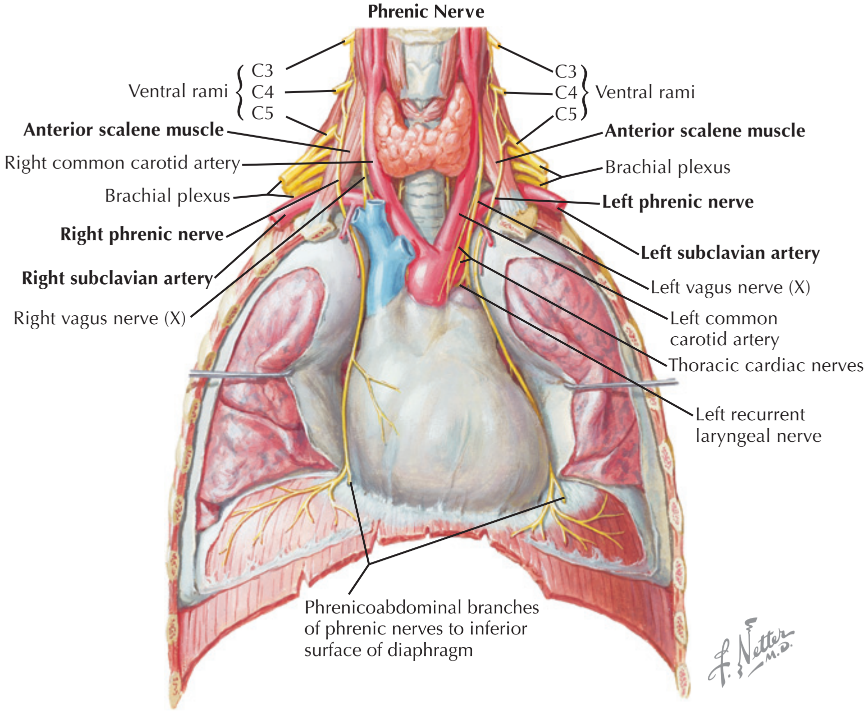
WEAKNESS PATTERN IN FOCAL BRACHIAL PLEXOPATHY	
Upper Trunk	Supraspinatus and infraspinatus, deltoid, biceps, brachioradialis (BR)
Middle Trunk	Latissimus dorsi, radial muscles (except BR), pronator teres, FCR
Lower Trunk	Intrinsic hand muscles, FCU, FDS, FPL, FDP
Lateral Cord	Biceps, FCR, pronator teres
Posterior Cord	Radial muscles, deltoid, latissimus dorsi
Medial Cord	Intrinsic hand muscles, FCU, FDP, FPL



THORACIC OUTLET

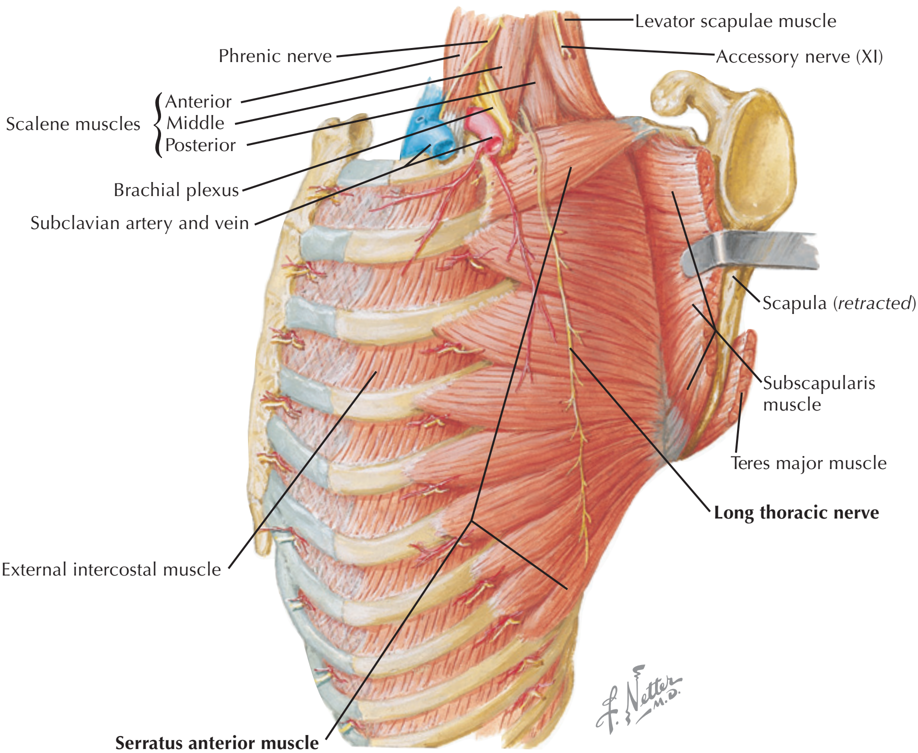
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Thoracic outlet	This area contains the lower portions of the anterior and middle scalene muscles, the 1st rib, and the clavicle. The brachial plexus and subclavian artery and subclavian vein pass through it. The apex of the lung projects into it from below.	Thoracic outlet syndrome (TOS) denotes: • Arterial compromise of the subclavian artery (arterial TOS) • Venous compromise of the subclavian vein (venous TOS) • Neurologic compromise of the brachial plexus (neurologic TOS) with the lower trunk of the brachial plexus being stretched over a rudimentary cervical rib or fibrous band (lower trunk brachial plexopathy) • Combinations of the above Patients experience: • Wasting and weakness of the hand • Paresthesias over the medial forearm and hand • Aching of arm (pain is unusual)

Phrenic Nerve



NERVES OF THE BRACHIAL PLEXUS

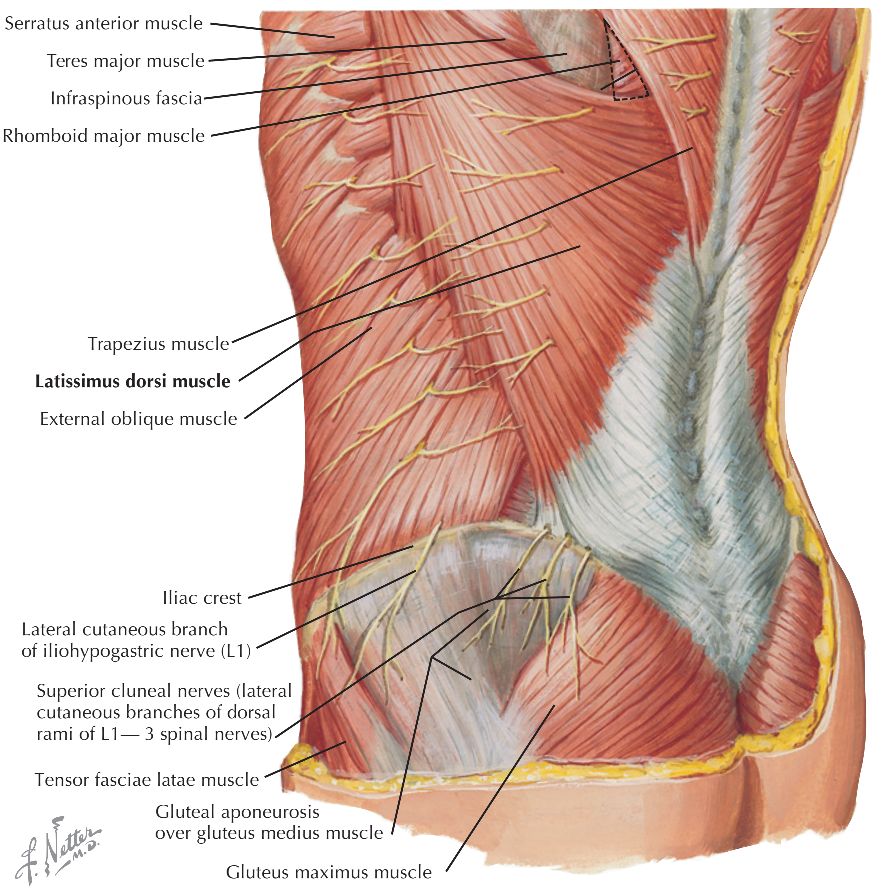
NERVE	ROOTS	SUPPLIES	COURSE	INJURY
Long thoracic	C5-7 ventral rami directly	Serratus anterior	Down the anterolateral chest wall to digitations of serratus anterior	Results in winged scapula



NERVES OF THE BRACHIAL PLEXUS *continued*

NERVE	ROOTS	SUPPLIES	COURSE	INJURY
Thoracodorsal	C6-8 ventral rami, posterior cord	Latissimus dorsi	Runs down on the subscapularis to reach latissimus dorsi muscle	Weakness of arm extension and adduction

Posterolateral Abdominal Wall

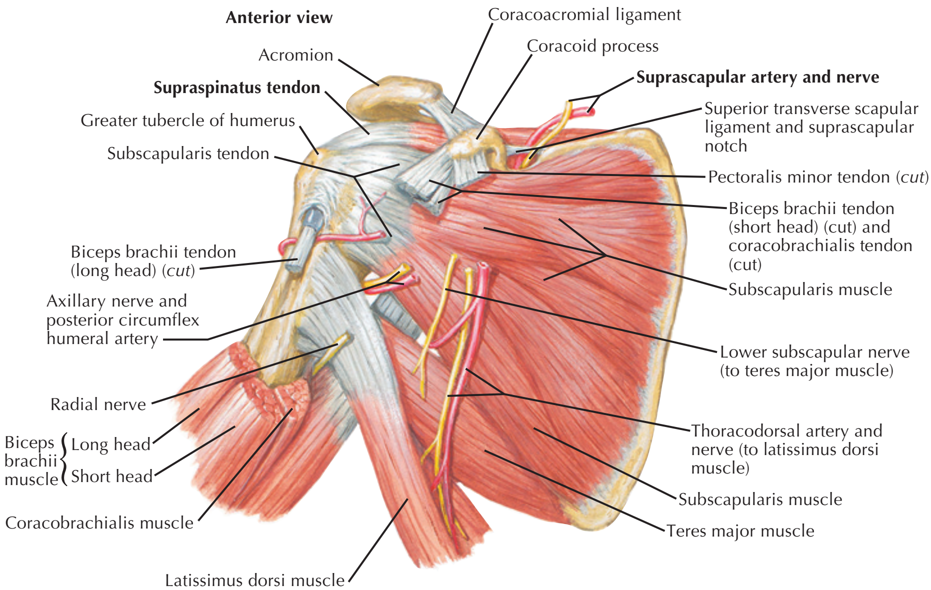


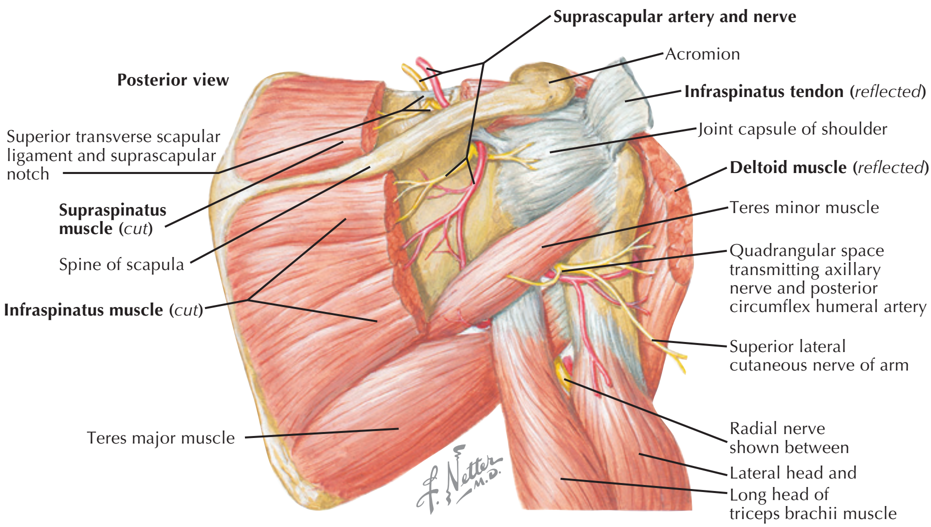
NERVES OF THE BRACHIAL PLEXUS *continued*

NERVE	ROOTS	SUPPLIES	COURSE	INJURY
Suprascapular	C5-6 ventral rami, upper trunk	Supraspinatus and infraspinatus	Under the trapezius, through the suprascapular notch to the supraspinous fossa, and then around the spinoglenoid notch	Results in wasting and weakness of the supraspinatus (first 15 degrees of shoulder abduction) and infraspinatus (external [lateral] rotation of the shoulder)
Axillary nerve	C5-6 ventral rami, posterior cord	Deltoid muscle and skin over the deltoid muscle	Below the shoulder joint, around the posterior and lateral surface of the humerus, deep to the deltoid	Results in wasting and weakness of deltoid with weak shoulder abduction

NERVES OF THE BRACHIAL PLEXUS *continued*

Scapulohumeral Dissection





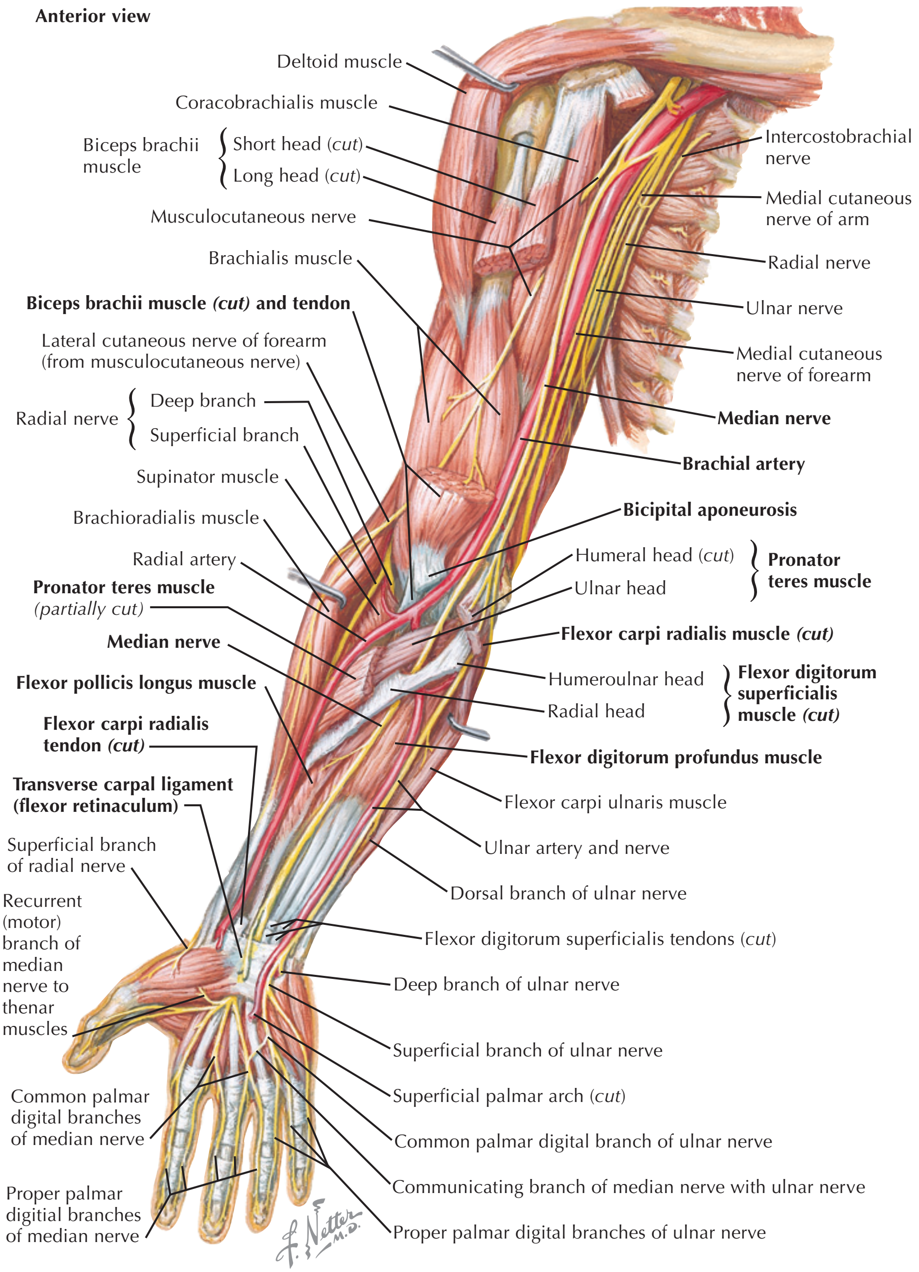
MEDIAN NERVE (TO WRIST)

Roots	C5-T1
Trunk of Brachial Plexus	Upper, middle, lower
Division of Brachial Plexus	Anterior division of the upper, middle, and lower trunk
Cord of Brachial Plexus	Lateral and medial
Course from Axilla to Hand	Union of the lateral and medial cord of the brachial plexus (See page 311) Lateral wall of axilla to the medial upper arm Crosses the antecubital fossa medial to the biceps tendon and brachial artery Passes beneath the bicipital aponeurosis (site of entrapment) Between the heads of the pronator teres (site of entrapment) Under the FDS sublimis bridge Descends the forearm between the FDS and FDP Enters the hand under the carpal ligament (the most common site of entrapment)
Muscles Innervated and Function	None above the elbow Pronator teres: pronates/flexes forearm FCR—flexes/abducts hand at wrist FDS—flexes the middle phalanx of fingers 2-5 Anterior interosseous nerve FPL—flexes distal phalanx of thumb* FDP—2 and 3: flexes distal phalanx fingers 2-3* Pronator quadratus—pronates forearm*
Sensory Branches and Dermatome	No sensation above the wrist Palmar cutaneous branch (arises above the wrist): supplies the thenar eminence
Injury	May be injured at: • Axilla—compression by crutches, anterior shoulder dislocation • Upper arm—sleep palsy, knife wounds, tourniquet, humerus fracture • Elbow—supracondylar ligament, elbow dislocation, injection injury • Pronator teres—produces pronator teres syndrome with weakness of median innervated muscles distal to pronator teres • Anterior interosseous neuropathy—fibrous band, radius fracture • Carpal tunnel syndrome (below the wrist)
Clinical Notes	Anterior interosseous neuropathy results in "O" sign due to inability to flex DIP joint of index finger (FDP 2) and IP joint of thumb (FPL). Median neuropathy at elbow causes clumsy or weak fingers 1-4 Tinel sign may be seen at site of lesion Median hand sensory symptoms occur with lesion at or above wrist

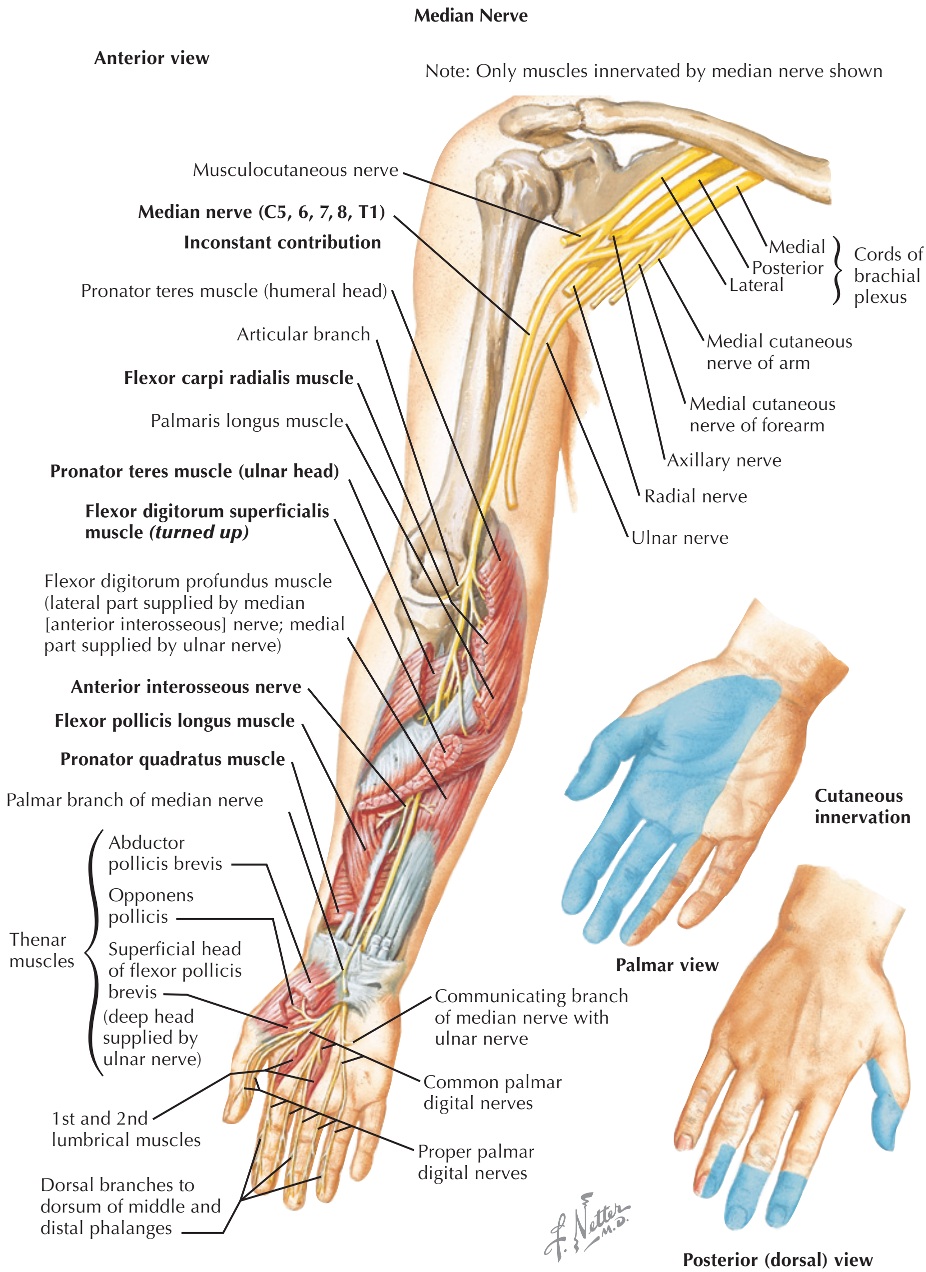
*The anterior interosseous nerve arises from the median nerve as it emerges between the two heads of the pronator teres. It supplies the FPL, FDP 2 and 3, and the pronator quadratus.

MEDIAN NERVE (TO WRIST) *continued*

Arteries and Nerves of Upper Limb



MEDIAN NERVE (TO WRIST) *continued*



MEDIAN NERVE (HAND)

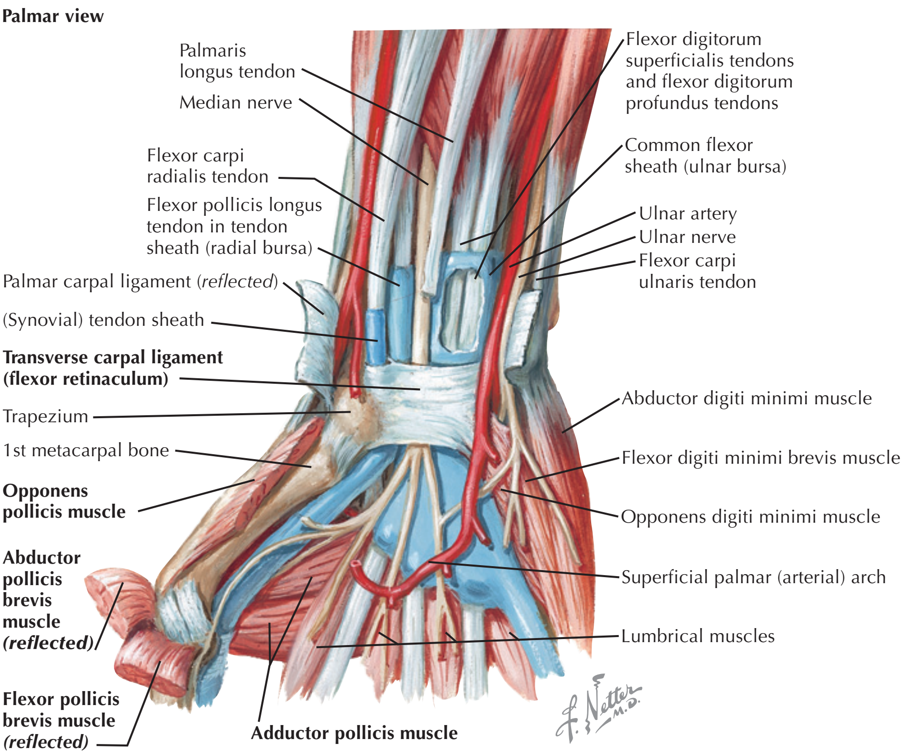
Course in the Hand	Enters the hand through the carpal tunnel Distal to the tunnel, it divides into 2 major branches: lateral and medial terminal branches Lateral terminal branch divides into common digital nerves to supply thumb and lateral side of index finger through proper palmar digital nerves Medial terminal branch divides into common digital nerves to supply the medial index, finger 3, and lateral finger 4 through proper palmar digital nerves
Muscles Innervated and Function	Branch to thenar eminence Abductor pollicis brevis—abducts thumb at carpometacarpal and metacarpophalangeal (MCP) joints Opponens—pulls the thumb metacarpal (MC) medially and forward Flexor pollicis brevis—flexes MCP joint of thumb Lumbricals 1,2—flex MCP, extend IP joints
Sensory Branches and Dermatome	Digital branches: Palmar surface of thumb, fingers 2, 3, lateral half of finger 4 and associated palm and dorsal tips of lateral 3 and ½ fingers
Disorders	Carpal tunnel syndrome
Clinical Notes	Paresthesiae and pain, particularly at night Relief by shaking hand Symptoms often worsen with hand activities Three times more common in women Dominant hand often first affected Often bilateral
Differential Diagnosis	C6 or C7 radiculopathy TOS

Mnemonic for median innervated intrinsic hand muscles is LOAF:

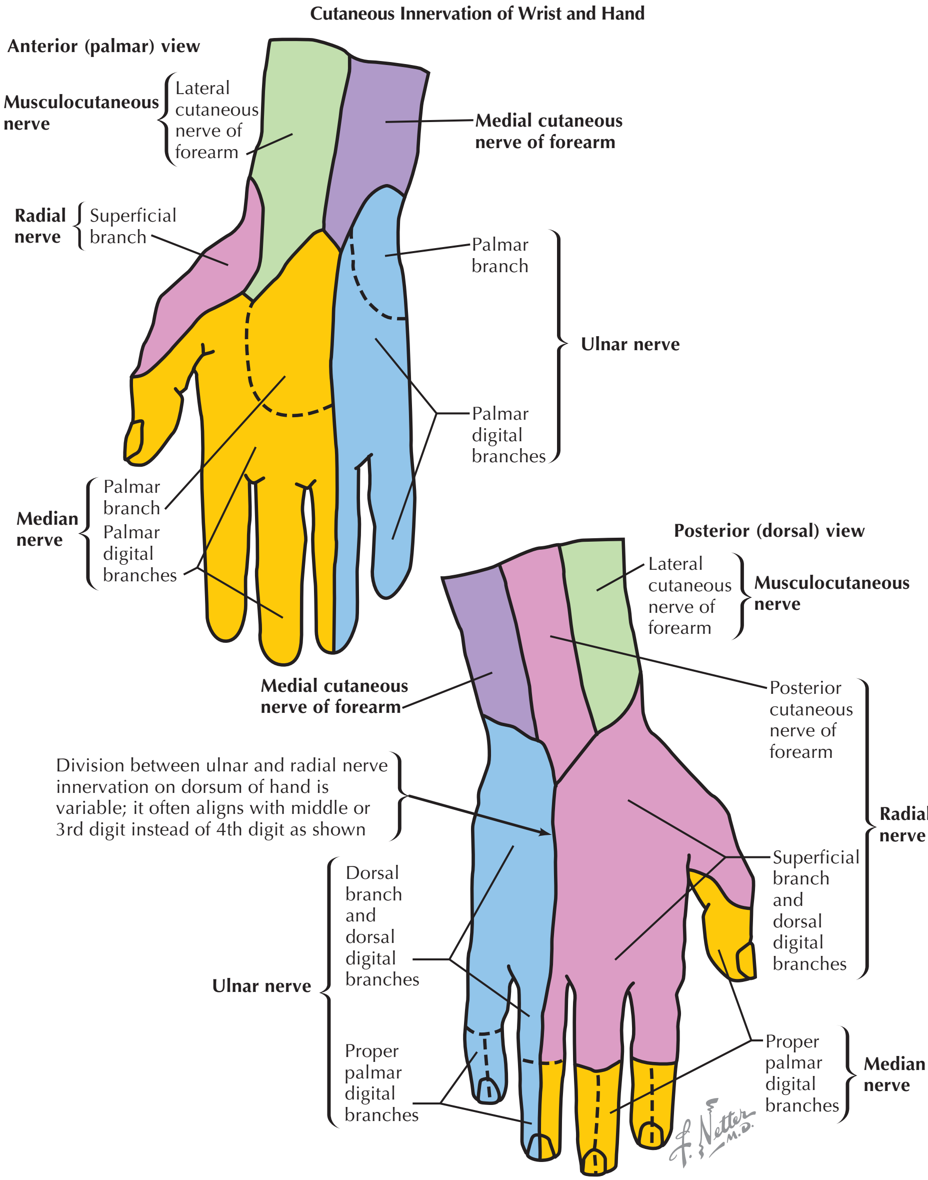
- **L**umbricals
- **O**pponens pollicis
- **A**bductor pollicis brevis
- **F**lexor pollicis brevis

MEDIAN NERVE (HAND) *continued*

Flexor Tendons, Arteries and Nerves at Wrist



MEDIAN NERVE (HAND) *continued*

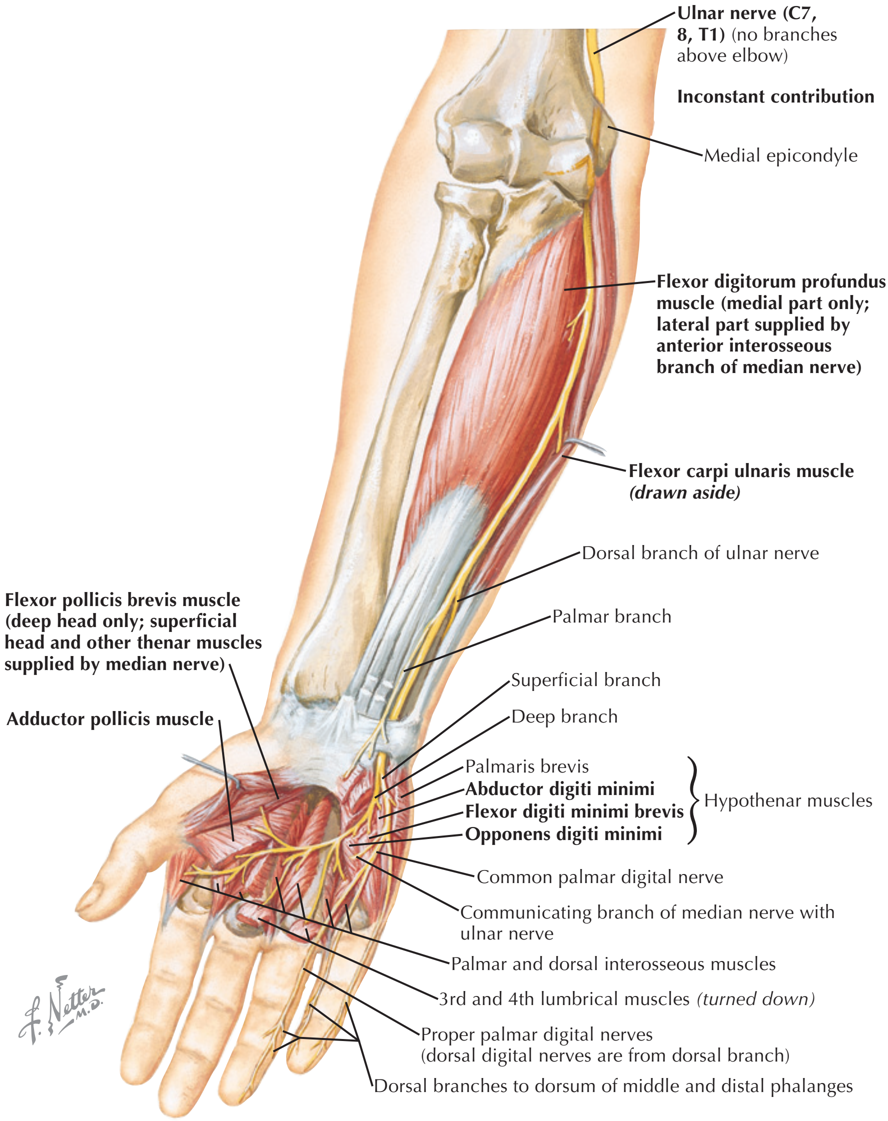


ULNAR NERVE (TO WRIST)

Roots	C8-T1
Trunk of Brachial Plexus	Lower
Division of Brachial Plexus	Anterior division of the lower trunk
Cord of Brachial Plexus	Medial
Course from Axilla to Hand	Medial cord brachial plexus Lateral wall of axilla Medial upper arm Behind the medial epicondyle of humerus Under the FCU aponeurosis Runs down the forearm between the FDP (posterior) and FCU (anterior) Enters the hand through the Guyon canal (between pisiform and hook of hamate)
Muscles Innervated	Above the elbow, no branches Below the elbow, in forearm; only 2 branches: • FCU—flex/adduct hand at wrist • FDP—flex distal interphalangeal (DIP) joint of fingers 4 and 5
Sensory Branches and Dermatome	Palmar cutaneous (arises midforearm, crosses the wrist, not through the Guyon canal)—supplies proximal medial palm below wrist Dorsal cutaneous (arises 5 cm above the wrist, winds dorsally around wrist)—supplies the ulnar dorsum of the hand and dorsal fingers 5 and medial half of 4
Disorders	Old elbow fracture—tardy ulnar palsy Acute trauma—fracture, dislocation of elbow External pressure at elbow Soft tissue elbow masses—ganglia, lipoma, epidermoid cyst
Clinical Notes	Sensory symptoms in the ulnar innervated hand and fingers Pain at the elbow or ulnar innervated parts of hand or diffuse in the arm Clumsy or weak fingers Tinel sign over nerve at the region of injury Ulnar hand sensory loss Ulnar claw deformity
Anatomic Notes	Only 2 ulnar innervated muscles above the wrist: FCU and FDP 4 and 5 All ulnar-innervated muscles have a C8-T1 root supply

ULNAR NERVE (TO WRIST) *continued*

Ulnar Nerve

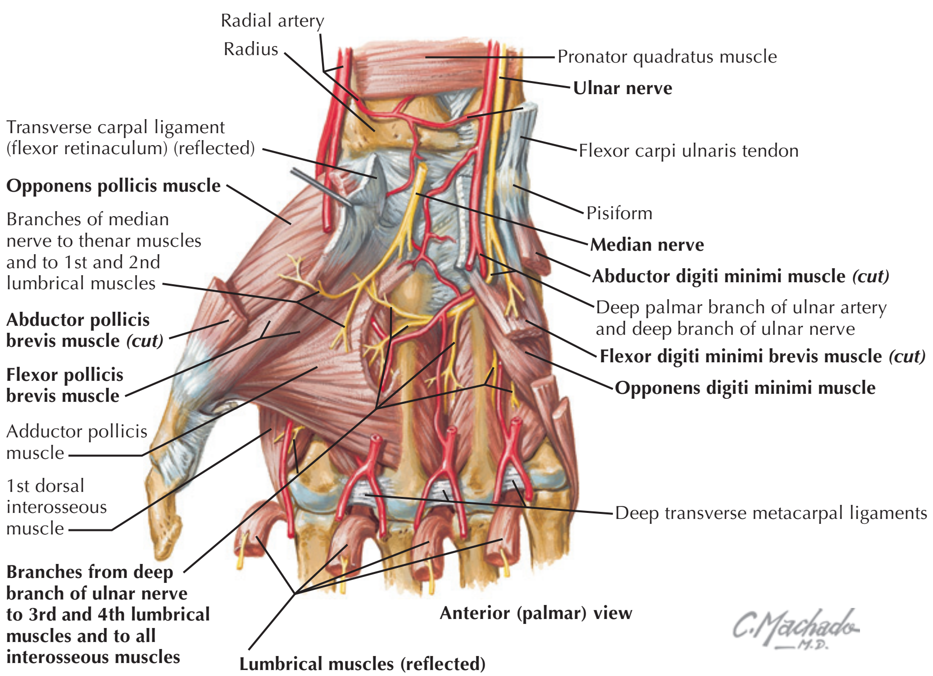


ULNAR NERVE: HAND

Course in the Hand	Enters the hand through the Guyon canal (between the pisiform and the hook of hamate) Distal to the tunnel, gives branch to palmaris brevis Then divides into the superficial and deep terminal branches Superficial terminal branch (mainly sensory) supplies the distal ulnar border of the palm and then divides into 2 palmar digital nerves that innervate medial 1 and ½ fingers Deep terminal branch (purely motor) supplies the opponens digiti minimi, then curves laterally deep to the flexor tendons, supplying the hypothenar muscles, interossei, lumbricals 3 and 4, and terminates in the thenar eminence, supplying the adductor pollicis and the ulnar head of the flexor pollicis brevis
Muscles Innervated and Function	Opponens digiti minimi rotates the 5th MC slightly Abductor digiti minimi abducts the 5th finger at MCP joint Flexor digiti minimi flexes 5th finger at MCP joint Dorsal interossei abduct fingers away from finger 3 Palmar interossei adduct fingers toward finger 3 Lumbricals 3 and 4 flex the MCP and extend IP joints Adductor pollicis adducts thumb at the carpometacarpal (CMC) and MCP joint Deep (ulnar head) of the flexor pollicis brevis (FPB) flexes the MCP of the thumb
Sensory Branches and Dermatome	Superficial terminal branch supplies distal ulnar border of the palm and then divides into 3 palmar digital branches to supply finger 5 and ulnar half of 4
Disorders	Compression in the Guyon canal Compression of the deep terminal branch distal to the hypothenar muscle innervation
Clinical Notes	Atrophy of intrinsic ulnar innervated muscles (varies with the precise site of lesion) Weakness of intrinsic ulnar innervated muscles (varies with the precise site of lesion) Ulnar distribution sensory loss (varies with the precise site of lesion)
Differential Diagnosis	Ulnar neuropathy at the elbow Amyotrophic lateral sclerosis C8-T1 radiculopathy

ULNAR NERVE: HAND *continued*

Intrinsic Muscles of Hand



Anterior (palmar) view

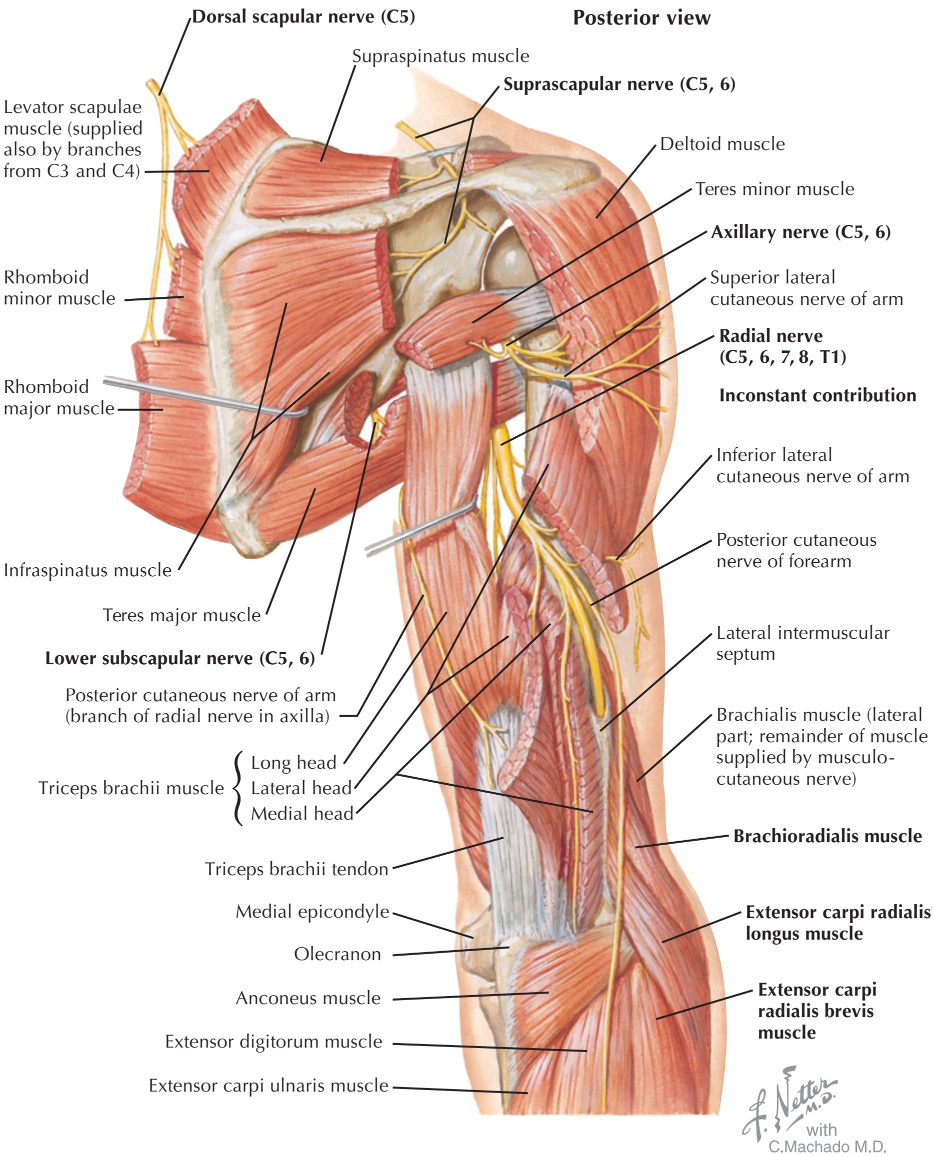
RADIAL NERVE

Roots	C5-T1
Trunk of Brachial Plexus	Upper, middle, lower
Division of Brachial Plexus	Posterior divisions of the upper, middle, and lower trunk
Cord of Brachial Plexus	Posterior
Course from Axilla to Elbow	Medial humerus Laterally around the spiral groove Lateral humerus below the deltoid insertion Enters the forearm between the biceps and the brachioradialis Divides into deep motor (posterior interosseous) and superficial radial sensory nerves
Muscles Innervated and Function	Above elbow branches: • Triceps extends the elbow • Brachioradialis flexes the elbow in neutral position • Extensor carpi radialis longus and brevis extend and abduct hand at the wrist At the level of the elbow joint, it divides into superficial sensory branch that supplies sensation to the dorsum of the hand and lateral 3 and ½ fingers and a motor branch (posterior interosseous) to: • Supinator supinates forearm • Extensor digitorum extends fingers 2-5 • Extensor digiti minimi extends little finger • Extensor carpi ulnaris extends and adducts hand at wrist • Abductor pollicis longus abducts thumb at the CMC joint • Extensor pollicis longus extends distal phalanx of thumb • Extensor pollicis brevis extends MCP joint of thumb • Extensor indicis extends index finger
Sensory Branches and Dermatome	Posterior cutaneous nerve of the arm arises in the upper spiral groove and supplies the posterior aspect of arm Lower lateral cutaneous nerve of the arm arises in the lower spiral groove and supplies lateral aspect of arm below deltoid mass Posterior cutaneous nerve of the forearm arises in the lower spiral groove and supplies posterior of forearm
Disorders	Axilla—crutch palsy Upper arm—humerus fracture, tourniquets, injections, muscular exertion "Saturday night palsy" Supinator syndrome—affects posterior interosseous nerve and causes fingerdrop

RADIAL NERVE *continued*

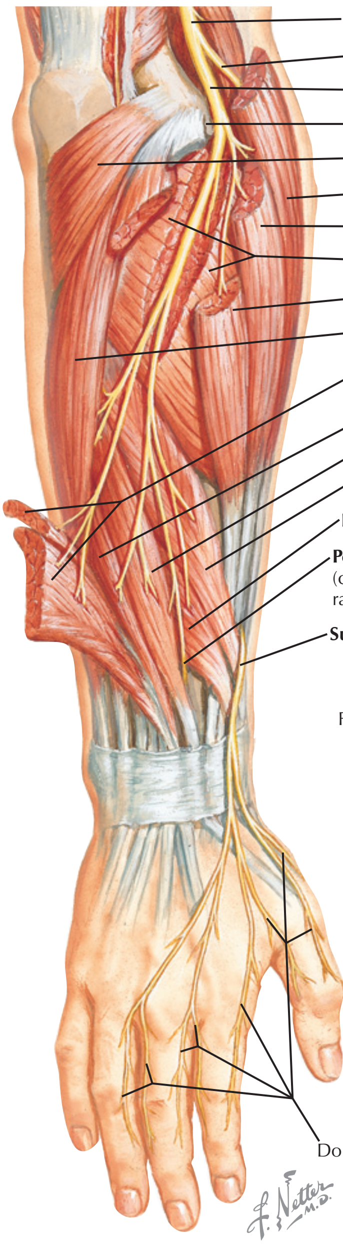
Clinical Notes	Wristdrop if the lesion is in the spiral groove Fingerdrop if the lesion affects the posterior interosseous nerve
Differential Diagnosis	C7 radiculopathy Posterior cord brachial plexopathy

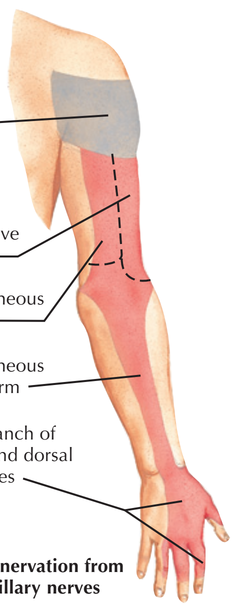
Radial Nerve in Arm and Nerves of Posterior Shoulder



RADIAL NERVE *continued*

Radial Nerve in Forearm





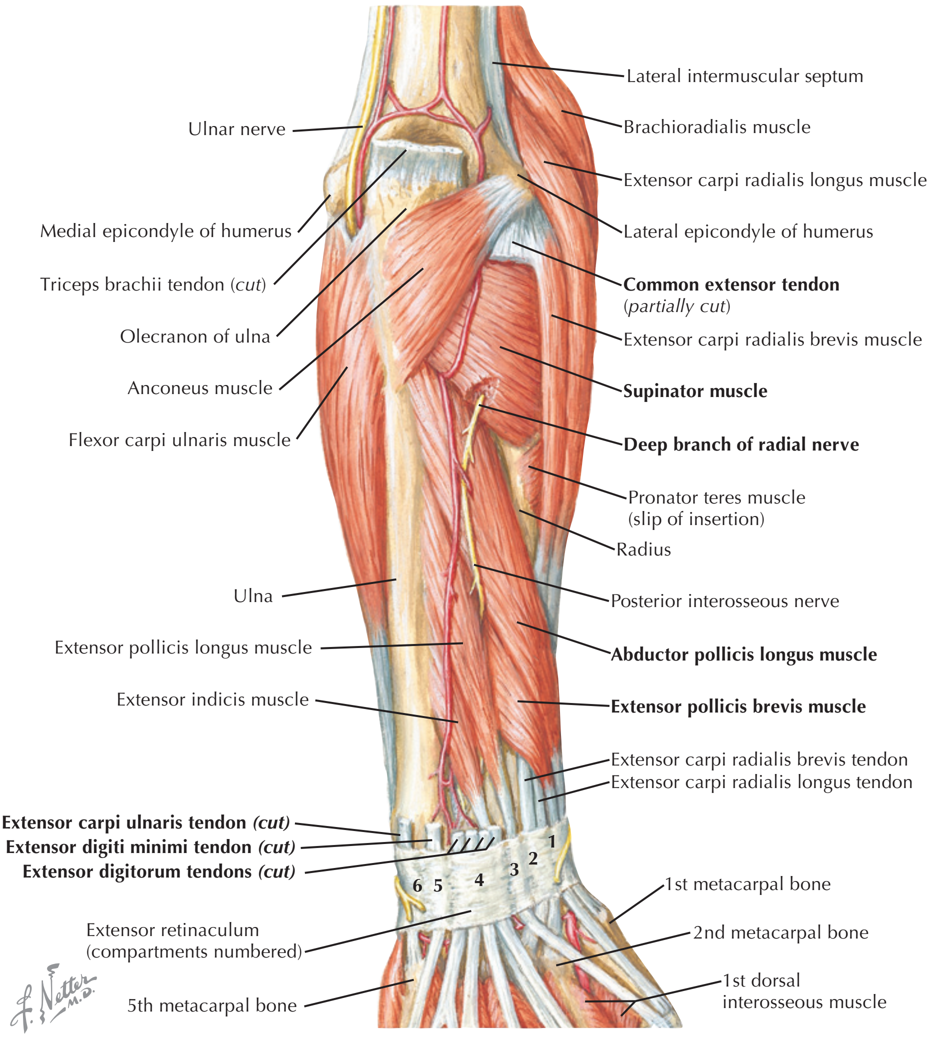
Cutaneous innervation from radial and axillary nerves

POSTERIOR INTEROSSEOUS NERVE

Roots	C6-8
Trunk of Brachial Plexus	Upper, middle, lower
Division of Brachial Plexus	Posterior divisions of upper, middle, lower trunk
Cord of Brachial plexus	Posterior
Course in Arm	Dorsolaterally around the neck of radius through supinator Enters supinator through "arcade of Frohse" Runs between superficial and deep parts of supinator Runs between the deep and superficial extensor muscles Terminates at the dorsum of the wrist
Muscles Innervated and Function	Supinator supinates forearm Extensor digitorum extends fingers 2-5 Extensor digiti minimi extends the little finger Extensor carpi ulnaris extends and adducts the hand at the wrist Abductor pollicis longus abducts thumb at the CMC joint Extensor pollicis longus extends the distal phalanx of the thumb Extensor pollicis brevis extends the MCP joint of the thumb Extensor indicis extends the index finger
Sensory Branches and Dermatome	None
Disorders	Radius fracture or dislocation Soft tissue masses Forearm laceration Idiopathic
Clinical Notes	Fingerdrop, no wristdrop Sensation normal
Differential Diagnosis	Extensor tendon rupture to the thumb and fingers (as in rheumatoid arthritis) Tennis elbow

POSTERIOR INTEROSSEOUS NERVE *continued*

Muscles of Forearm (Deep Layer): Posterior View

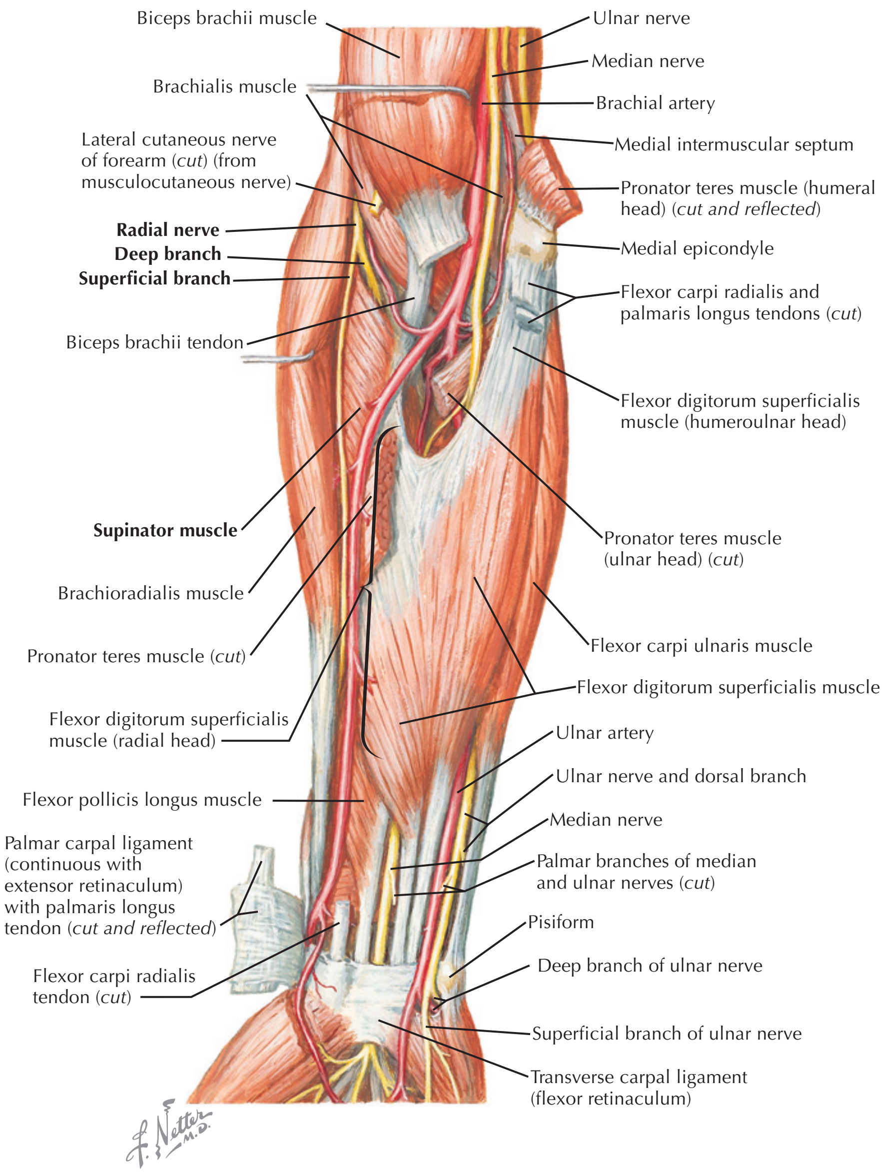


SUPERFICIAL RADIAL NERVE

Root	C6
Trunk of Brachial Plexus	Fibers pass through the upper trunk to reach the posterior division
Division of Brachial Plexus	Posterior
Cord of Brachial Plexus	Derives from the radial nerve, which comes off the posterior cord
Course from Elbow to Hand	Passes over the supinator Along the lateral radius in lower 3rd of the forearm Over the dorsolateral wrist
Muscles Innervated and Function	None
Sensory Branches and Dermatome	Terminal digital branches Dorsolateral hand and fingers 1-3
Disorders	Wrist—compression by handcuffs, tight cast
Clinical Notes	Sensory disturbance in distribution of nerve May be associated with causalgia

SUPERFICIAL RADIAL NERVE *continued*

Muscles of Forearm (Intermediate Layer): Anterior View

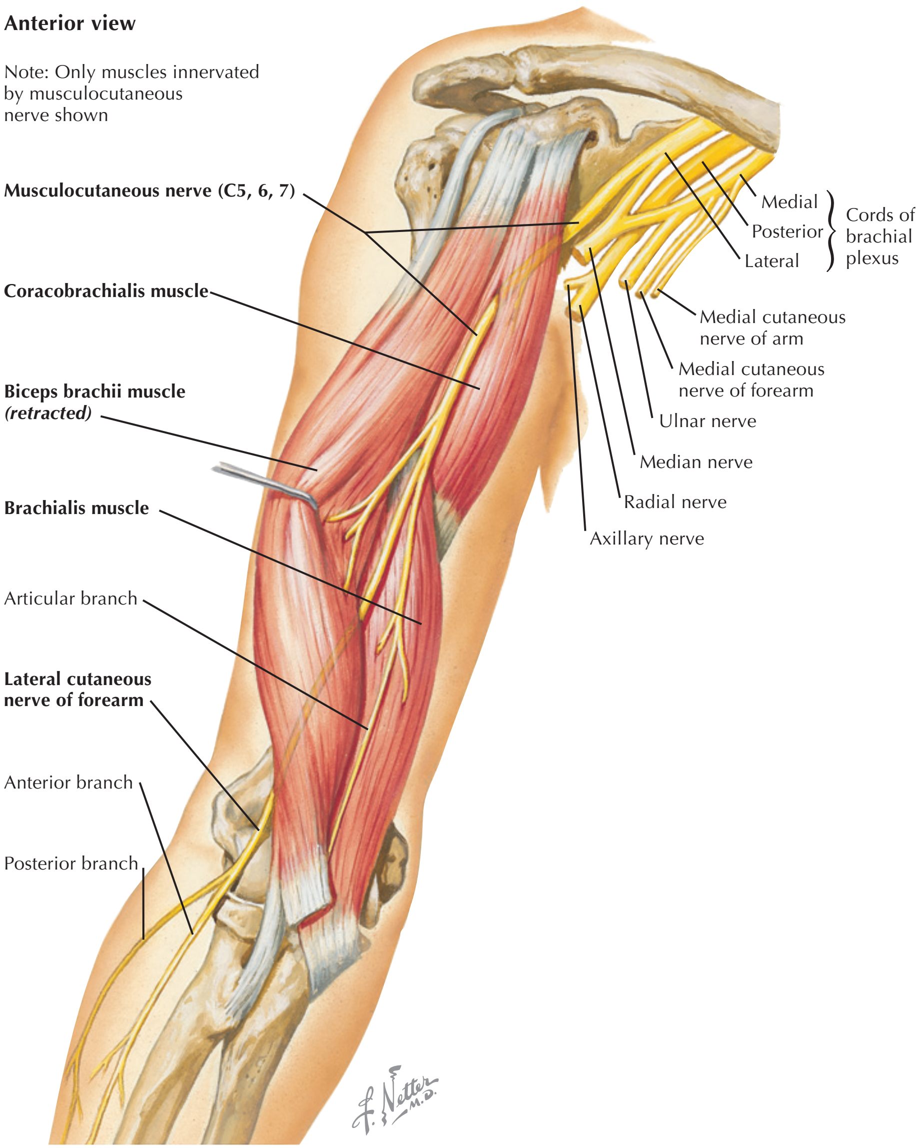


MUSCULOCUTANEOUS NERVE

Roots	C5-6
Trunk of Brachial Plexus	Upper
Division of Brachial Plexus	Anterior division of the upper trunk
Cord of Brachial Plexus	Lateral
Course from Axilla to Hand	Arises from lateral cord brachial plexus Pierces coracobrachialis Courses down anterior arm between biceps and brachialis Crosses anterior elbow lateral to biceps tendon Continues as lateral cutaneous nerve of forearm
Muscles Innervated and Function	Biceps brachii supinates forearm and flexes the elbow Coracobrachialis flexes the arm Brachialis flexes the elbow
Sensory Branches and Dermatome	Lateral cutaneous nerve of forearm Lateral forearm from elbow to wrist
Disorders	Shoulder dislocation Strenuous exercise Following general anesthesia Brachial neuritis (Parsonage-Turner syndrome)
Clinical Notes	Weak, wasted biceps with weak elbow flexion Numbness over the radial aspect of forearm
Differential Diagnosis	Biceps tendon rupture C6 radiculopathy

MUSCULOCUTANEOUS NERVE *continued*

Musculocutaneous Nerve



LATERAL CUTANEOUS NERVE OF FOREARM

Roots	C5 ventral ramus through the upper trunk, lateral cord
Supplies	Skin over the lateral forearm from elbow to wrist
Course	At the elbow lateral to the biceps tendon, crosses the cephalic vein, continues as the lateral cutaneous nerve of forearm (also called the *lateral antebrachial cutaneous nerve of forearm*)
Injury	May be injured during venipuncture Results in numbness over the radial aspect of the forearm

Anterior (palmar) view

Posterior (dorsal) view

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CHAPTER 18

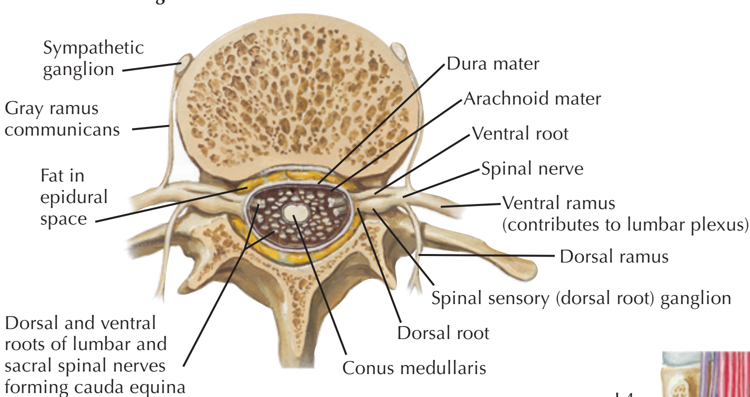
Anatomy of the Peripheral Nervous System: Lower Extremity

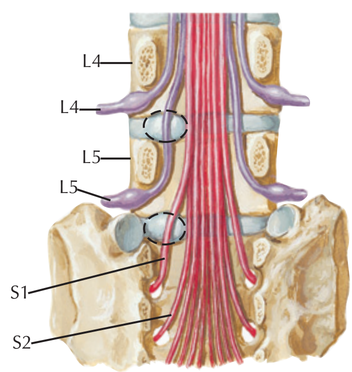
18 Anatomy of the Peripheral Nervous System: Lower Extremity

LUMBAR AND SACRAL ROOT ANATOMY

- Lumbar and sacral nerve roots arise from the conus medullaris, then travel downward and laterally to intervertebral foramen from which they exit the spinal canal.
- Lumbar nerve roots fuse in the intervertebral foramen, distal to the dorsal root ganglion, and form spinal nerves.
- Lumbar nerve roots pass below the pedicle of same-numbered vertebra but above the level of the disc to exit the spinal canal (i.e., L4 root exits below L4 pedicle, above the level of the disc). Therefore, a herniated lumbar disc compresses the root which exits at the next lower level (i.e., L4 disc herniation compresses the L5 root).
- Lumbar spinal nerves divide into dorsal and ventral rami on exiting foramen.
- Ventral rami pass into the lumbar plexus, and dorsal rami supply the skin and paraspinal muscles.
- Sacral ventral and dorsal roots fuse within the spinal canal to form sacral spinal nerves.
- Sacral spinal nerves divide within the spinal canal into ventral and dorsal rami.
- Ventral rami exit through the ventral pelvic sacral foramina to join the sacral plexi.
- Dorsal rami exit through the dorsal sacral pelvic foramina to supply the lower paraspinal muscles and skin.

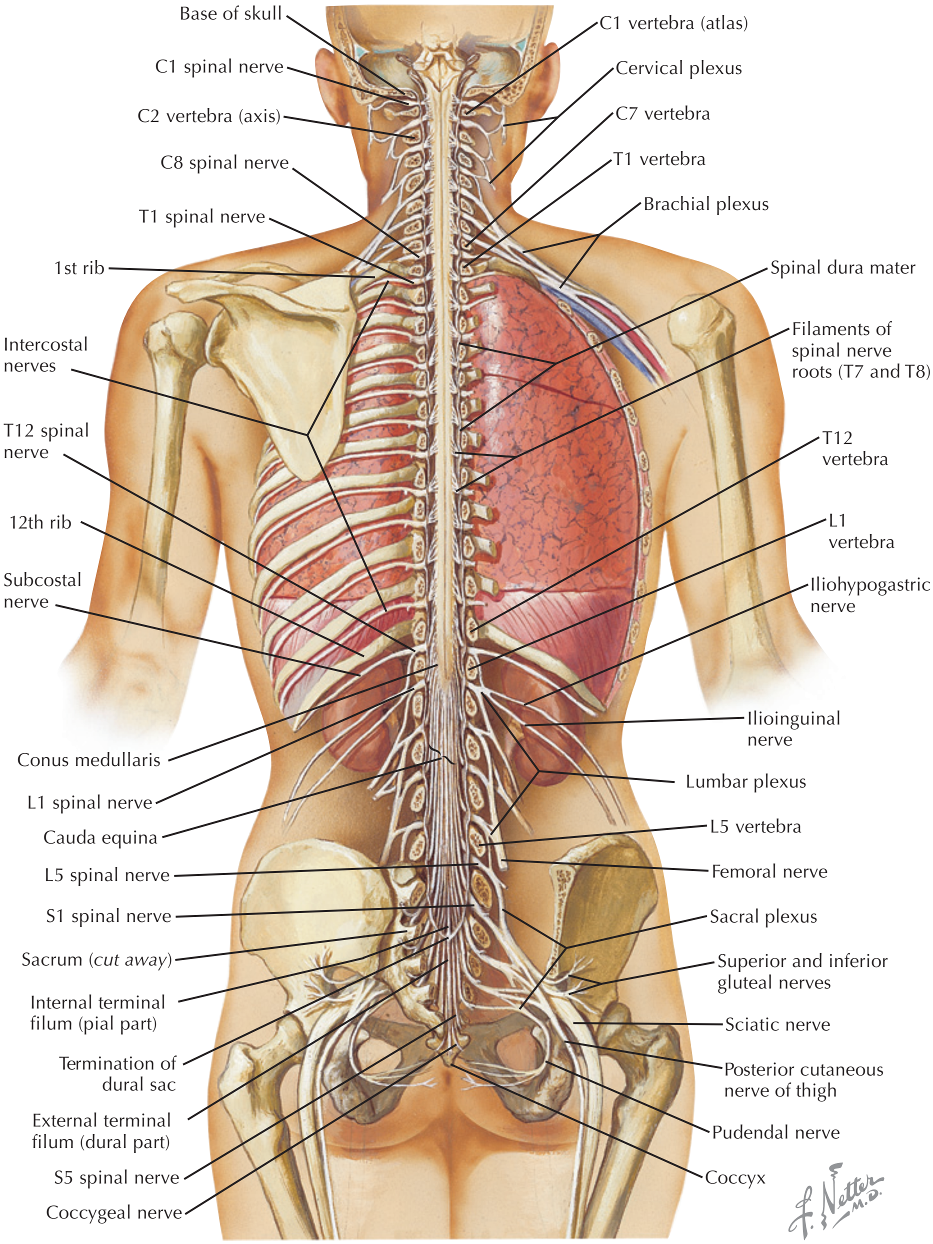
Section through lumbar vertebra



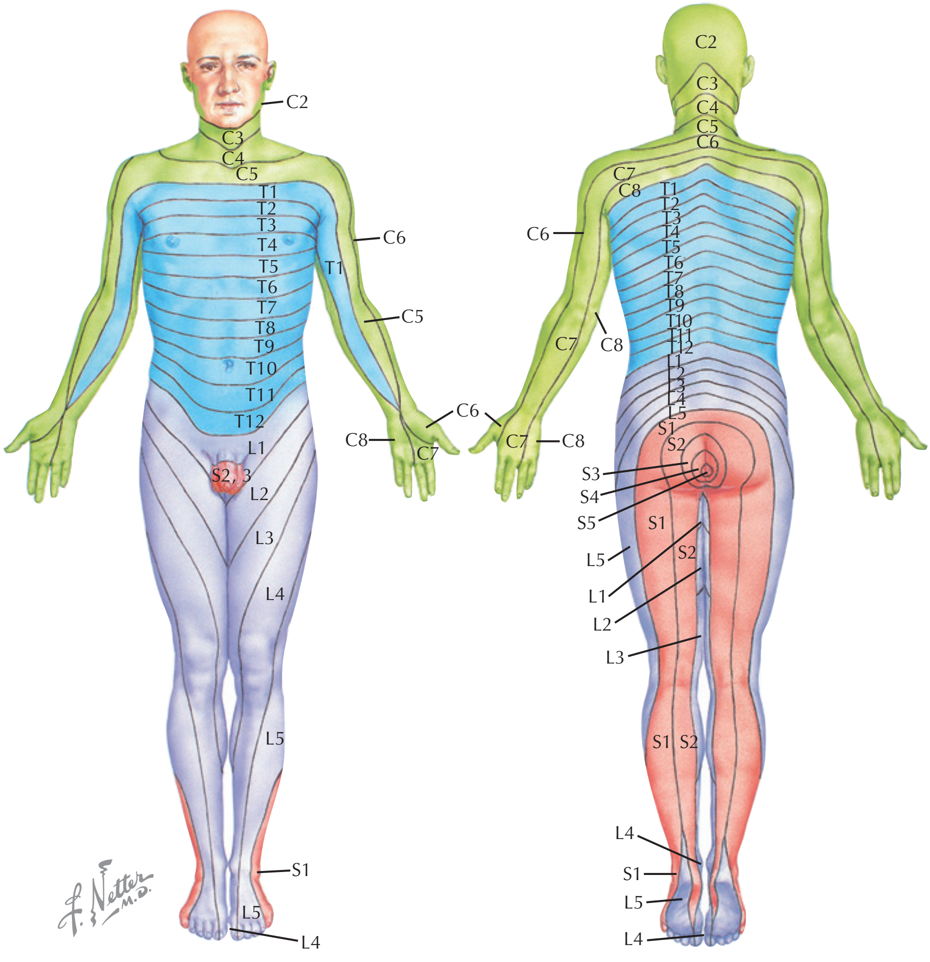


Lumbar disc protrusion does not usually affect nerve exiting above disc. Lateral protrusion at disc level L4–5 affects L5 spinal nerve, not L4 spinal nerve. Protrusion at disc level L5–S1 affects S1 spinal nerve, not L5 spinal nerve

LUMBAR AND SACRAL ROOT ANATOMY *continued*



LUMBAR AND SACRAL ROOT ANATOMY *continued*



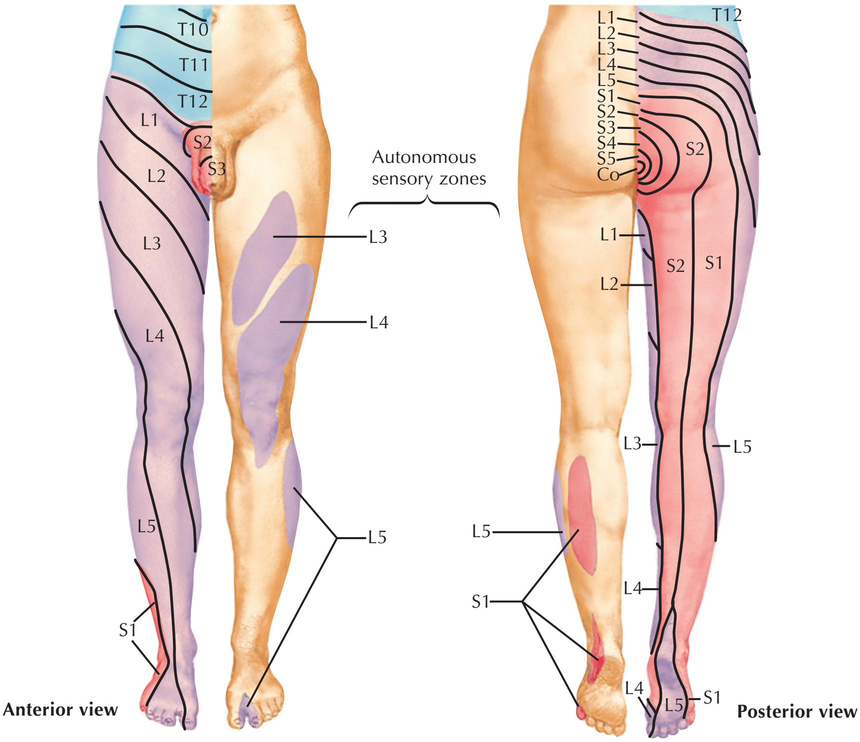
Levels of principal dermatomes

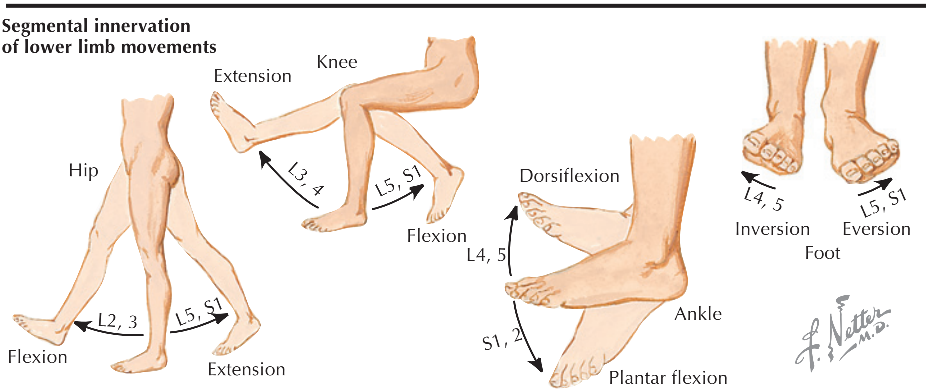
C5	Clavicles
C5, 6, 7	Lateral parts of upper limbs
C8, T1	Medial sides of upper limbs
C6	Thumb
C6, 7, 8	Hand
C8	Ring and little fingers
T4	Level of nipples
T10	Level of umbilicus
T12	Inguinal or groin regions
L1, 2, 3, 4	Anterior and inner surfaces of lower limbs
L4, 5, S1	Foot
L4	Medial side of great toe
S1, 2, L5	Posterior and outer surfaces of lower limbs
S1	Lateral margin of foot and little toe
S2, 3, 4	Perineum

LUMBOSACRAL RADICULOPATHY (DERMATOMES AND SEGMENTAL INNERVATION)

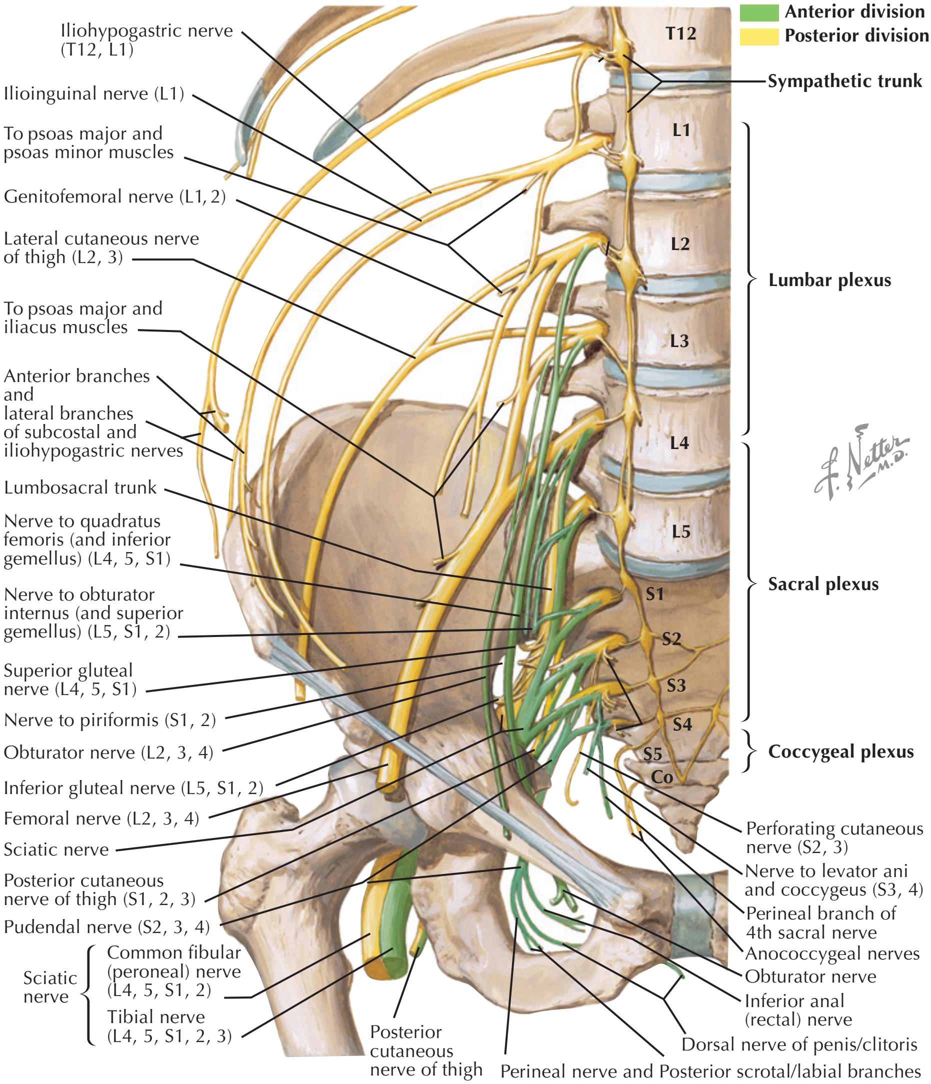
ROOT	REFLEX LOSS	SENSORY LOSS	MAJOR WEAKNESS	PAIN	MAIN DIFFERENTIAL DIAGNOSES
L2	None	Upper anterior thigh	Hip flexion	Anterior thigh	Femoral neuropathy
L3	Patella	Anterior knee	Hip flexion Knee extension Hip adductors	Anterior knee	Femoral neuropathy Obturator neuropathy
L4	Patella	Medial calf	Knee extension Ankle dorsiflexion	Medial calf	Femoral neuropathy Obturator neuropathy Common peroneal neuropathy
L5	None	Dorsal and medial foot Lateral calf	Ankle inversion, dorsiflexion Large-toe dorsiflexion	Lateral calf, dorsomedial foot, buttocks/posterior thigh	Common peroneal neuropathy
S1	Achilles	Plantar and lateral foot	Ankle plantarflexion Hip extension Knee flexion	Plantar and lateral foot, buttocks/ posterior thigh	Tibial neuropathy

LUMBOSACRAL RADICULOPATHY (DERMATOMES AND SEGMENTAL INNERVATION) *continued*





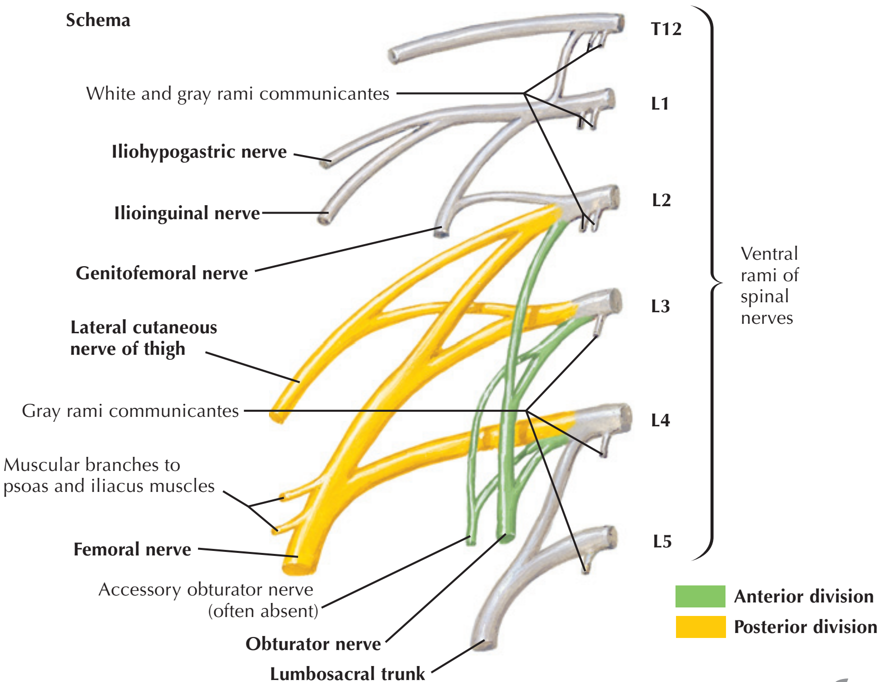
LUMBOSACRAL PLEXUS IN SITU

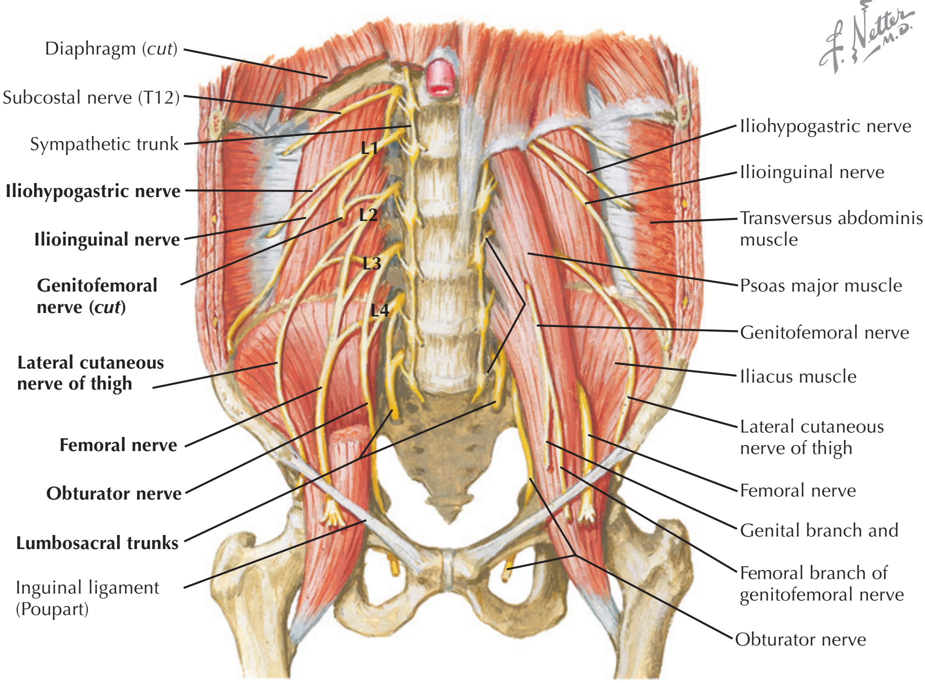


LUMBAR PLEXUS

NERVE	ROOT(S)	MUSCLE(S) INNERVATED (ACTION)	SENSORY DISTRIBUTION
Iliohypogastric	L1	Transversus abdominus (supports the abdominal wall) Internal oblique (supports the abdominal wall)	Lateral gluteal Above the pubis
Ilioinguinal	L1	None	Superomedial thigh and genitalia
Genitofemoral	L1-L2	Cremaster	Genitalia and skin over the femoral triangle
Lateral cutaneous nerve of the thigh	L2-L3	None	Lateral thigh
Femoral	L2-L4	Psoas, pectineus (hip flexors) Iliacus (hip flexor and internal rotator) Quadriceps femoris (knee extensors) Sartorius (hip flexor, abductor and external rotator) Articularis genus (retracts bursa as knee extends)	Anteromedial thigh Terminal branch (saphenous) supplies the medial leg
Obturator	L2-L4	Adductors longus, brevis and magnus (hip adductors) Gracilis (hip adductor) Obturator externus (hip external rotator) External oblique (supports abdominal wall)	Inferomedial thigh
Accessory obturator (variable)	L2-L4	Psoas (hip flexor)	None
Lumbosacral trunk	L4-L5	Contributes to sacral plexus	

LUMBAR PLEXUS *continued*

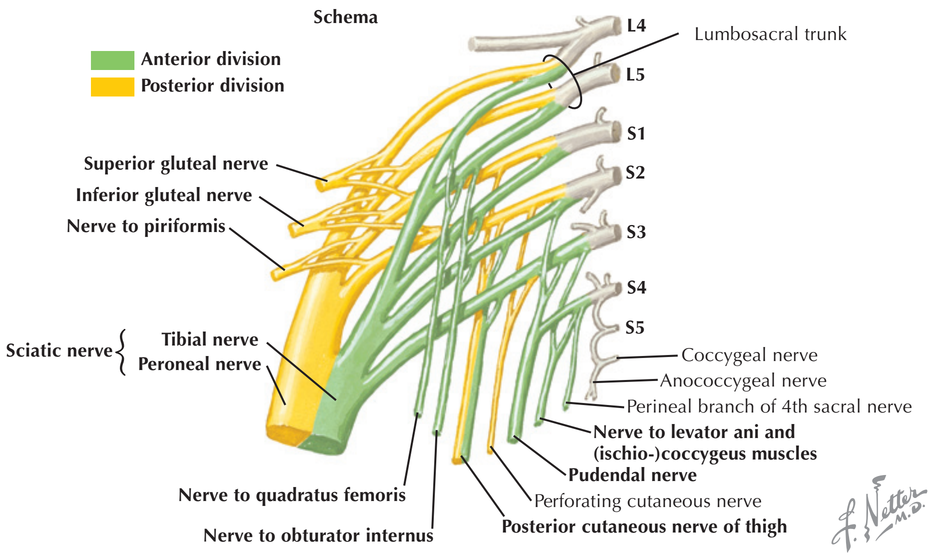


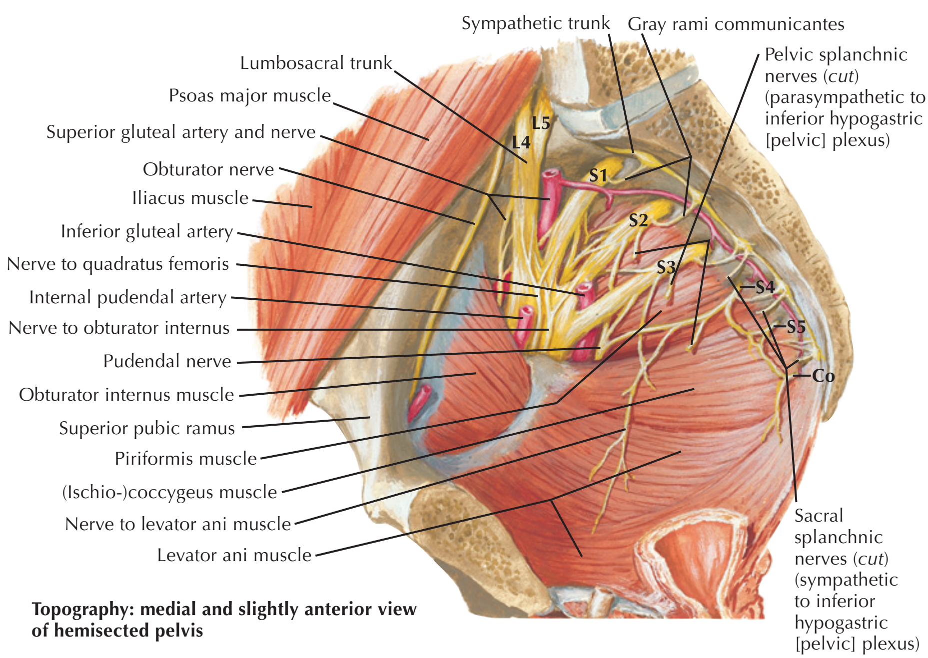


SACRAL PLEXUS

NERVE	ROOT(S)	MUSCLE(S) INNERVATED (ACTION)	SENSORY DISTRIBUTION
Sciatic	L4-S3	Main trunk: hamstrings group (knee flexors) Tibial division (*see page 362*) Peroneal division (*see page 360*)	None from the main trunk Tibial and peroneal divisions supply the entire lower leg except the medial portion
Nerve to quadratus femoris	L4-S1	Quadratus femoris (hip external rotator) Inferior gemellus (hip external rotator)	None
Nerve to obturator internus	L5-S2	Obturator internus (hip external rotator) Superior gemellus (hip external rotator)	None
Pudendal	S2-4	Perineal branch: • Bulbospongiosis (controls urination, ejaculation) • Ischiocavernosus (controls urination, ejaculation) • Urethral sphincter (controls urination, ejaculation) • Urogenital diaphragm (supports pelvic floor)	Perineum
		Inferior rectal branch—external anal sphincter (controls defecation)	Perianal skin
		Dorsal nerve to the penis/clitoris—no muscles	Penis/Clitoris
Nerve to coccygeus	S3-S4	Coccygeus (supports pelvic floor) Levator ani (supports pelvic floor)	None
Superior gluteal	L4-S1	Gluteus medius (hip abductor) Gluteus minimus (hip abductor) Tensor fascia lata (hip abductor, external rotator)	None
Inferior gluteal	L5-S2	Gluteus maximus (hip extensor)	None
Nerve to piriformis	S2	Piriformis (hip external rotator)	None
Posterior femoral cutaneous	S1-S3	None	Posterior thigh

SACRAL PLEXUS *continued*



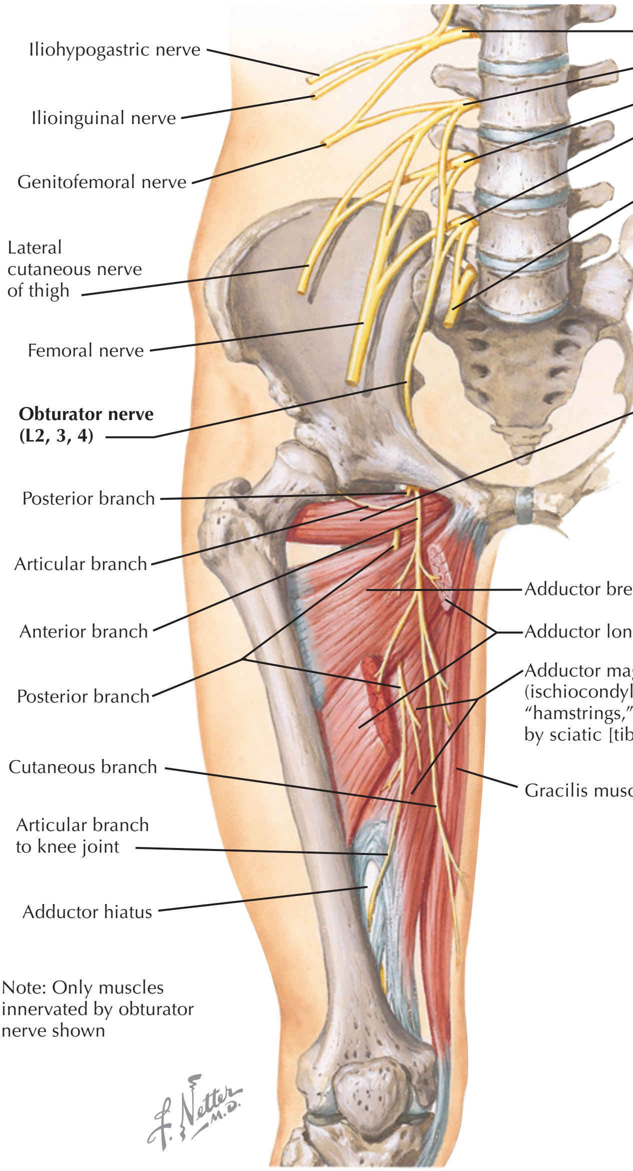


Topography: medial and slightly anterior view of hemisected pelvis

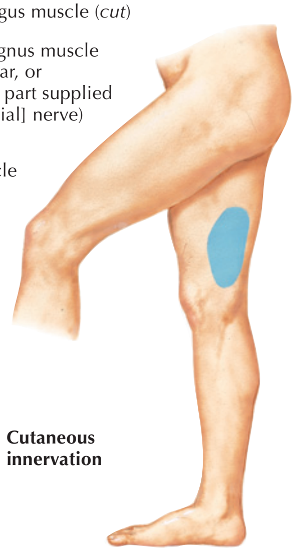
OBTURATOR NERVE

Roots	L2, L3, L4
Course	Forms in psoas muscle Descends through psoas Enters thigh by passing through obturator foramen
Muscles Innervated	Adductor longus (*hip adductor*) Adductor brevis (*hip adductor*) Adductor magnus (*hip adductor component*) Gracilis (*hip adductor*) Obturator externus (*hip external rotator*) External oblique (*supports abdominal wall*)
Sensory Innervation	Small patch of skin on the inferomedial thigh
Selected Disorders	Rarely damaged, but damage can be caused by: • Pelvic fractures • Hip replacement surgery • Obturator hernias • Pelvic masses • Parturition
Clinical Notes	Hip adduction is weak Patch of parasthesias and/or numbness in medial thigh
Differential Diagnosis	Lumbar plexus or L3/L4 lesion also involves quadriceps group (*knee extension*) and patellar reflex

OBTURATOR NERVE *continued*



Note: Only muscles innervated by obturator nerve shown

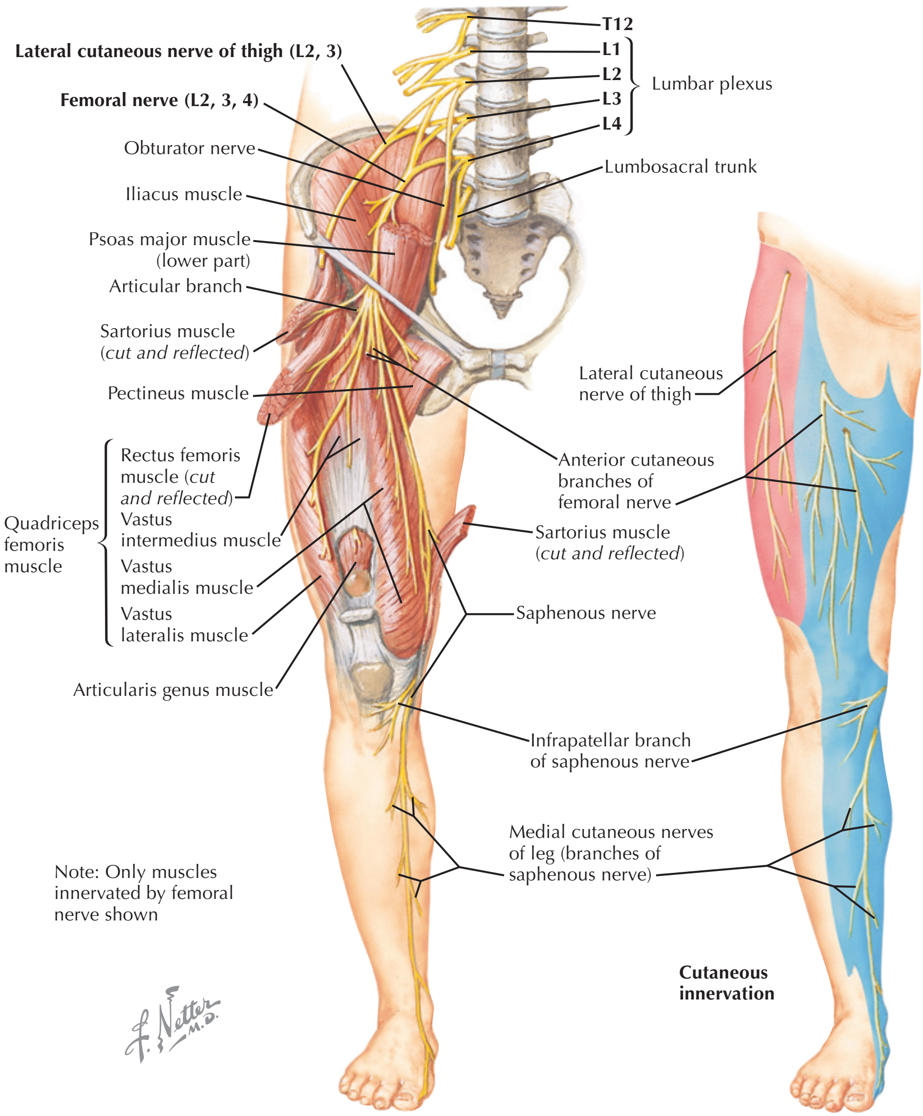


Cutaneous innervation

FEMORAL NERVE

Roots	L2, L3, L4
Course	Forms in psoas muscle Descends between psoas and iliacus mucles Passes under the inguinal ligament, lateral to the femoral artery and vein Branches off to supply individual muscles Terminal branch (saphenous nerve) descends within quadriceps in the subsartorial canal emerging above the knee, then descends down the medial leg, crossing the medial malleolus and ending in inner foot
Muscles	Psoas, pectineus (hip flexors)
Innervated	Iliacus (hip flexor and internal rotator) Quadriceps group (knee extensors): • Rectus femoris • Vastus lateralis • Vastus intermedius • Vastus medialis • Sartorius (hip flexor, abductor and external rotator) • Articularis genus (retracts bursa as knee extends)
Sensory Innervation	Anteromedial thigh via anterior cutaneous branches Medial knee via infrapatellar branch of saphenous Medial leg and medial malleolus via saphenous
Selected Disorders	Can be damaged with: • Pelvic, inguinal hernia, and hip surgery • Femoral artery catheterization • Childbirth (from the lithotomy position) • Hematomas in iliacus muscle • Diabetes usually causes lumbar plexopathy, may involve only femoral nerve • Saphenous nerve can be damaged at the knee (arthroscopy) and in the leg (varicose vein procedures)
Clinical Notes	Weakness mainly noted in knee extension Patellar reflex hypoactive or absent Sensory involvement variably present but should involve anteromedial thigh and medial leg
Differential Diagnosis	L3-4 radiculopathy or lumbar plexopathy would involve hip adduction and hip flexion (iliopsoas mainly innervated by upper lumbar plexus branches).

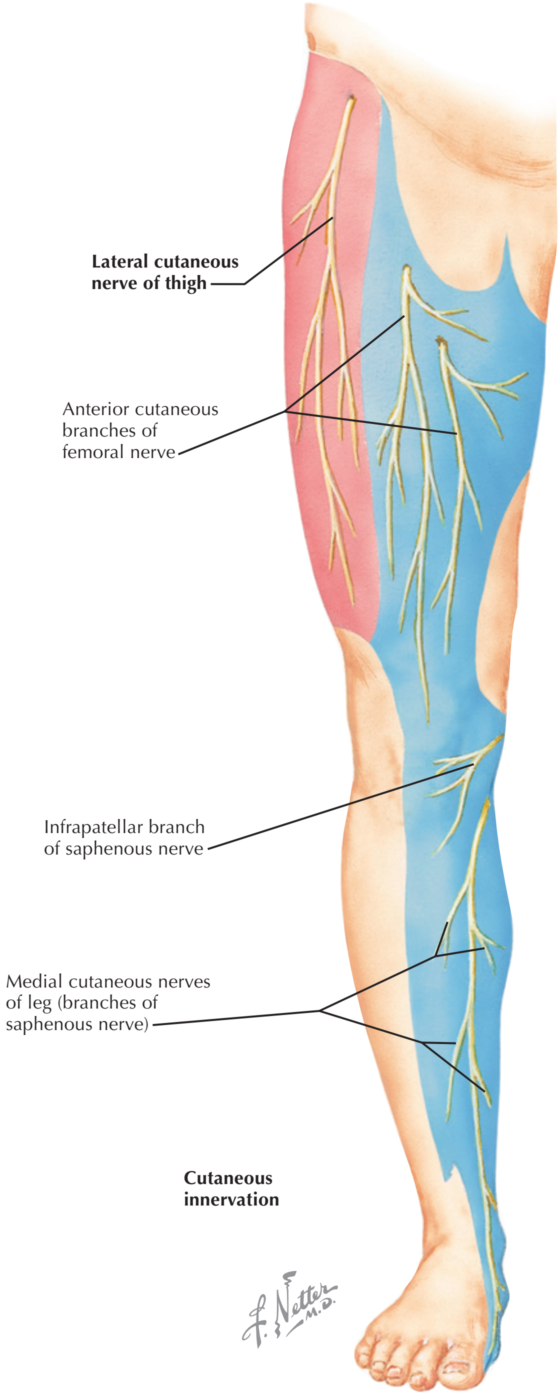
FEMORAL NERVE *continued*



LATERAL CUTANEOUS NERVE OF THE THIGH

Roots	L2, L3
Course	Variable course: • Emerges lateral to the psoas, crossing the iliacus • Passes under the lateral part of the inguinal ligament • May cross the anterior superior iliac spine or run in close proximity • Crosses over the upper part of the sartorius muscle • Terminates in the cutaneous branches
Muscles Innervated	None (purely sensory nerve)
Sensory Innervation	Lateral thigh
Selected Disorders	Can be damaged during surgery of retroperitoneum, iliac fossa, or inguinal region Compression by tight clothing or belts Usually no clear cause found
Clinical Notes	Syndrome known as *meralgia paresthetica* Pain and numbness in lateral thigh Usually numbness in smaller area than pain No weakness
Differential Diagnosis	L2 radiculopathy causes numbness in the lateral and anterior upper thigh L2 radiculopathy may cause weakness of hip flexion Lumbar plexopathy causes more extensive numbness with weakness Femoral neuropathy causes numbness in the anterior thigh and medial leg, knee extension weakness, and depressed patellar reflex

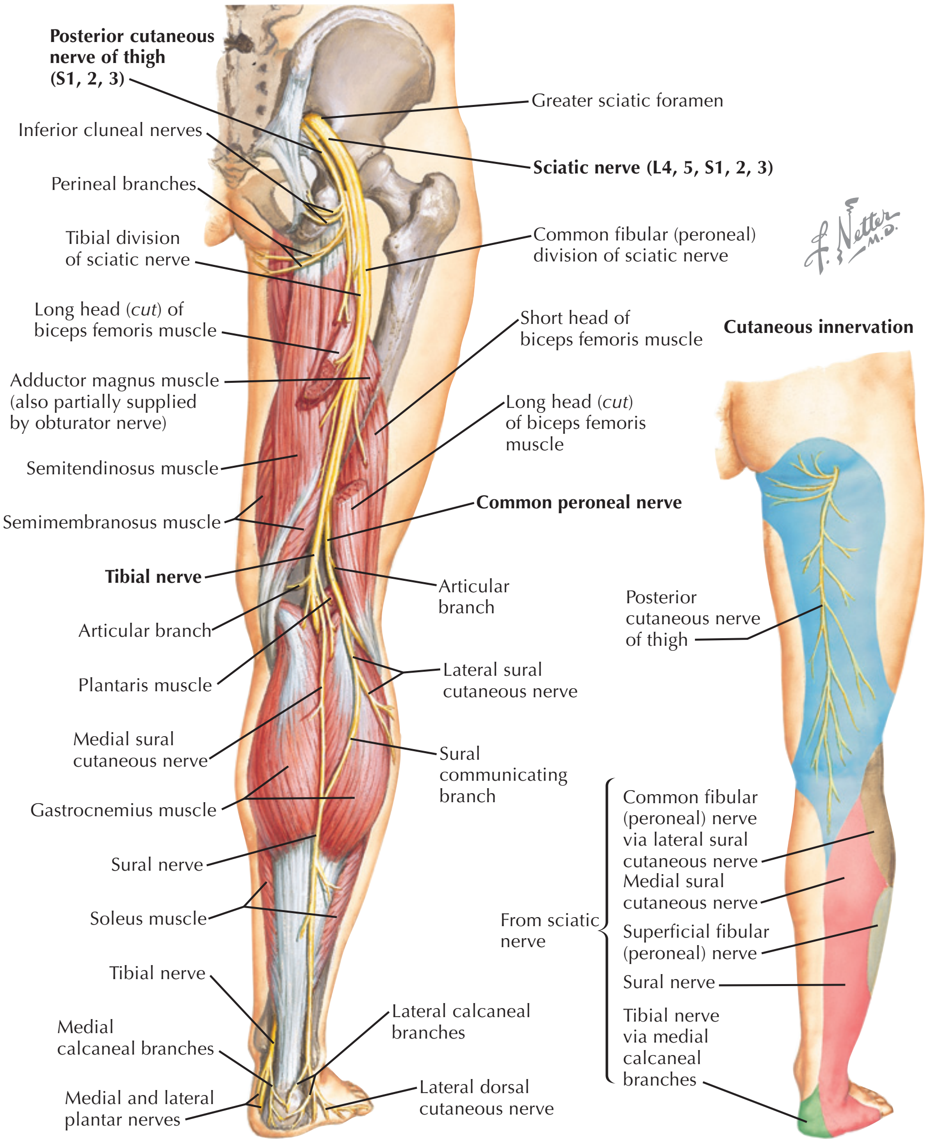
LATERAL CUTANEOUS NERVE OF THE THIGH *continued*



SCIATIC NERVE

Roots	L4-5 (lumbosacral trunk), S1, S2, S3
Course	Forms from the lumbosacral trunk and upper sacral plexus Travels down the inner wall of the pelvis Exits the pelvis through greater sciatic foramen Passes under the piriformis muscle Passes between the ischial tuberosity and greater trochanter of the femur Divides just above the popliteal fossa into the common peroneal (lateral trunk) and tibial nerve (medial trunk)
Muscles Innervated	Semitendinosus (medial trunk) Semimembranosus (medial trunk) Long head of the biceps femoris (medial trunk) Short head of the biceps femoris (lateral trunk) Adductor magnus (hip extensor component) Terminal branches of sciatic (tibial and common peroneal nerves) supply all muscles below the knee
Sensory Innervation	None from the sciatic trunk, although terminal branches (tibial and common peroneal nerves) supply much of the lower leg and foot
Selected Disorders	Hip trauma/fractures and hip surgeries Prolonged pressure against the nerve Gluteal hematomas Needle injury from injections into the buttock Thigh hematomas Femur fractures
Clinical Notes	Weakness of knee flexion if the lesion is proximal (gluteal region) Weakness of any muscles below the knee Usually weakness is variable below the knee and involves the common peroneal more than the tibial innervated muscles. Sciatic neuropathy may mimic common peroneal neuropathy
Differential Diagnosis	Difficult to differentiate from lumbosacral plexopathies Sacral plexopathies usually involve the pudendal nerve and posterior cutaneous nerve of the thigh Lumbosacral radiculopathies usually present with back pain Imaging pelvis/thigh with computed tomography (CT)/magnetic resonance imaging (MRI) helps to rule out hematomas Electromyography (EMG) is helpful in localization

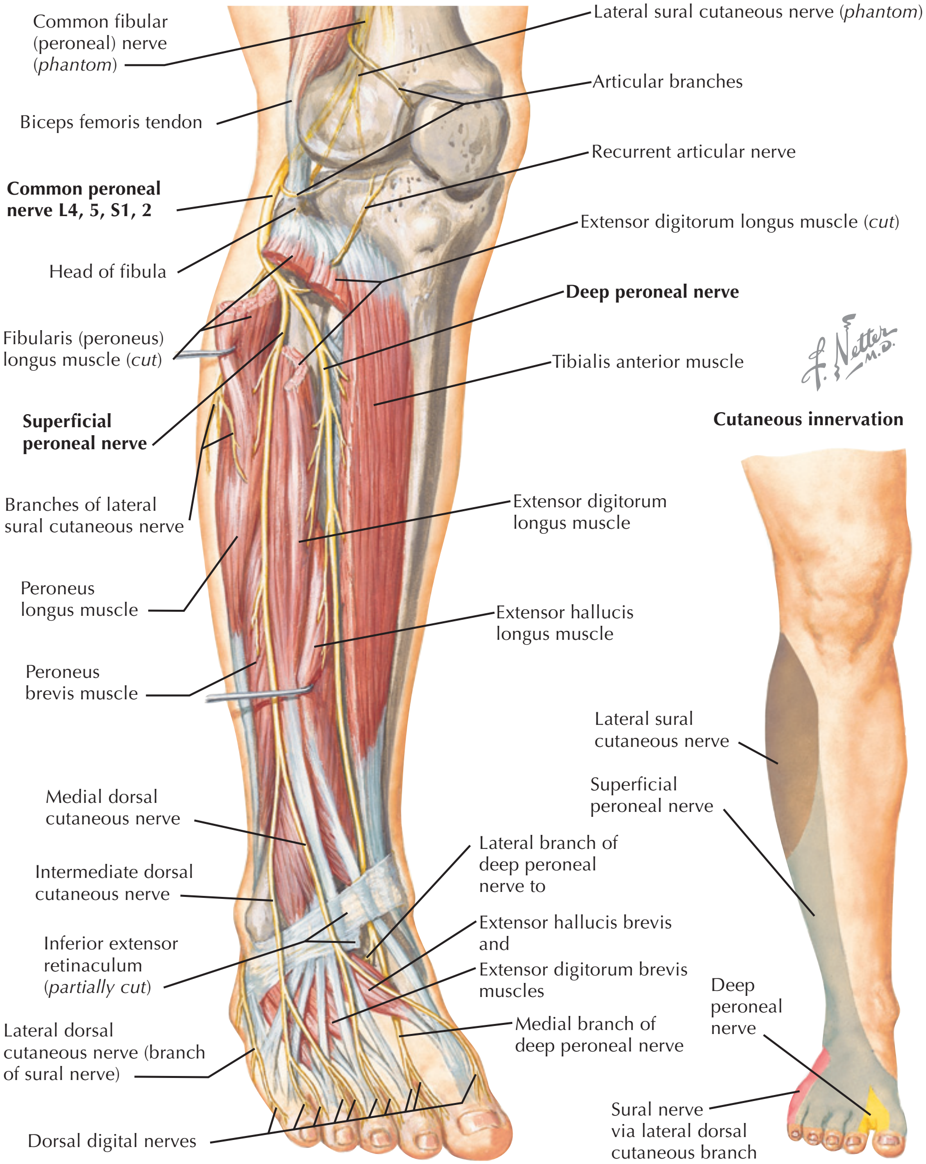
SCIATIC NERVE *continued*



COMMON PERONEAL NERVE

Roots	L4, L5, S1, S2
Course	Formed from the lateral trunk of the sciatic nerve after its bifurcation in the distal thigh Passes anterolaterally around the neck of the fibula, close to the skin Pierces the peroneus longus and runs through the fibular tunnel formed by this muscle Divides in the upper leg into the superficial and deep peroneal nerves Superficial branch runs down the leg with the fibula Deep branch runs deeper in the leg between the tibialis anterior and toe extensors
Muscles Innervated	Deep peroneal nerve: • Tibialis anterior (foot dorsiflexion) • Extensor hallicus longus (first toe dorsiflexion) • Extensor digitorum longus (dorsiflexion of last four toes) • Peroneus tertius (foot dorsiflexion and eversion) • Extensor hallicus brevis (first toe dorsiflexion) • Extensor digitorum brevis (dorsiflexion of last 4 toes) • Superficial peroneal nerve: • Peroneus longus (foot eversion) • Peroneus brevis (foot eversion) • Peroneus tertius (foot eversion)
Sensory Innervation	Proximal lateral leg via the lateral sural nerve Distal lateral leg and dorsal foot via the superficial peroneal nerve Dorsal interdigital space between toes 1 and 2 via the deep peroneal nerve
Selected Disorders	Most commonly injured by external compression against the fibular head Frequent causes include: • Habitual leg crossing • Anesthesia, coma, positioning during sleep • Below knee casts • Prolonged squatting
Clinical Notes	"Footdrop" caused by weak foot dorsiflexion with high-stepping gait Weak foot eversion Sensory loss in the lateral leg and dorsal foot if complete Isolated lesion of the deep peroneal nerve causes footdrop with numbness only in the webspace between first 2 toes
Differential Diagnosis	L5 radiculopathy Lumbosacral trunk compression (difficult labor) Sciatic neuropathy

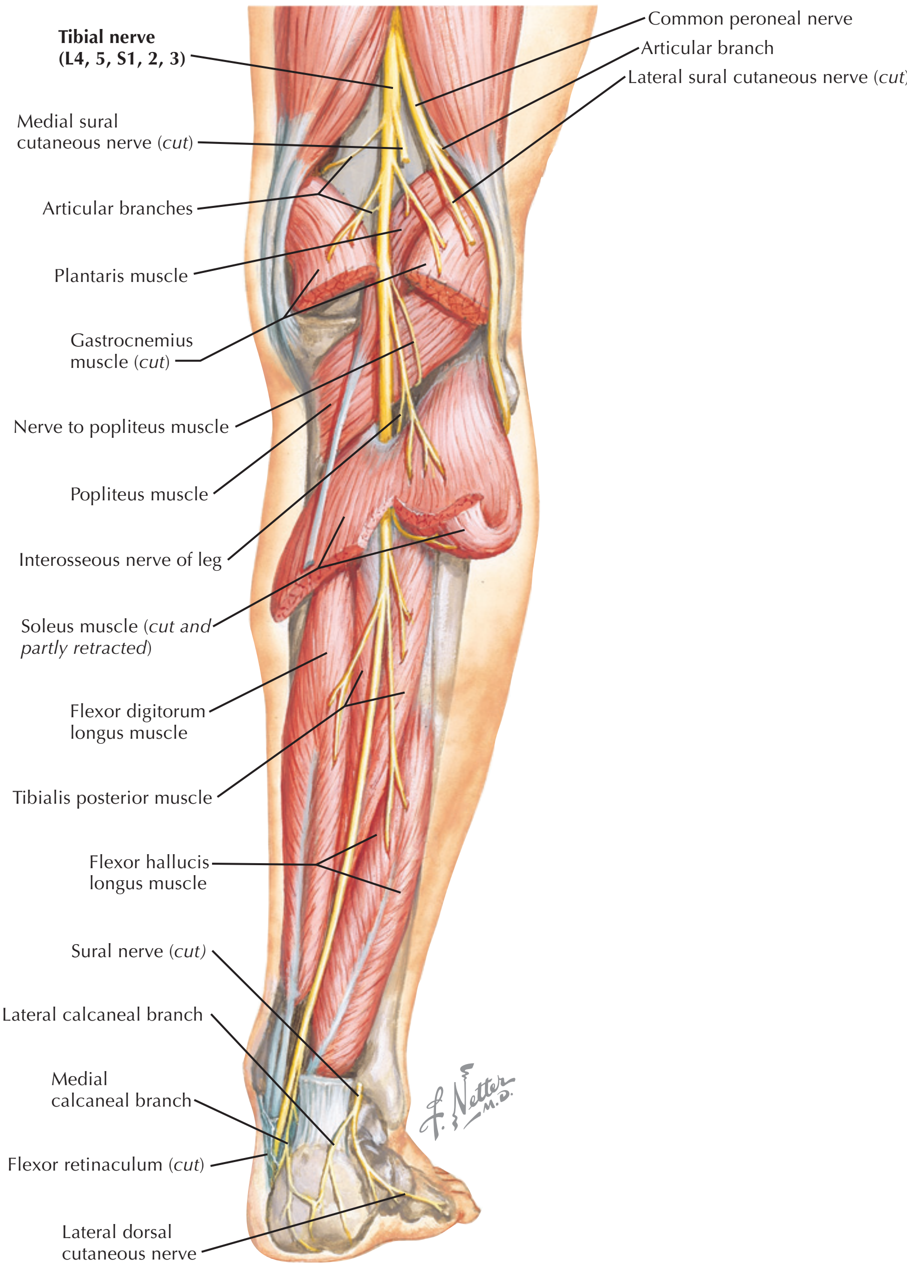
COMMON PERONEAL NERVE *continued*



TIBIAL NERVE

Roots	L5, S1, S2
Course	Formed from the medial trunk of the sciatic nerve after its bifurcation in the distal thigh Passes through the popliteal fossa between two heads of gastrocnemius Runs down the leg deep to the soleus Terminates in the tarsal tunnel as medial and lateral plantar nerves
Muscles Innervated	Soleus (ankle plantarflexor) Gastrocnemius (ankle plantarflexor) Plantaris (ankle plantarflexor) Popliteus (knee flexion) Tibialis posterior (foot inversion) Flexor hallicus longus (plantarflexor of the 1st toe) Flexor digitorum longus (plantarflexion of the lateral 4 toes) Via plantar divisions, supplies all foot muscles in the sole Medial plantar: • Abductor hallicus (*first toe abductor*) • Flexor digitorum brevis (*flexor of lateral 4 toes*) • First lumbrical (*flexes metatarsophalangeal joint, extends interphalangeal joint*) • Flexor hallicus brevis (*first toe plantarflexor*) Lateral plantar: • Abductor digiti minimi (*abducts 5th toe*) • Quadratus plantae (*flexes toes*) • Lumbricals 2-4 (*flexes metatarsophalangeal joint, extends interphalangeal joint*) • Abductor hallicus (*abuducts 1st toe*) • Flexor digiti minimi brevis (*flexes 5th toe*) • Dorsal interossei (*abduct toes*) • Plantar interossei (*adduct toes*)
Sensory Innervation	Posterolateral calf via medial sural and sural nerves Most of sole via calcaneal and plantar branches
Selected Disorders	Compression by Baker's cysts of knee Distal tibial nerve can be damaged by foot and ankle trauma Tarsal tunnel syndrome
Clinical Notes	Weakness of plantarflexion, foot inversion, toe flexion Hypoactive or absent Achilles tendon reflex Numbness/tingling in distribution of sural, calcaneal, or plantar nerves
Differential Diagnosis	S1 or S2 radiculopathy May be difficult to differentiate from partial sciatic neuropathy

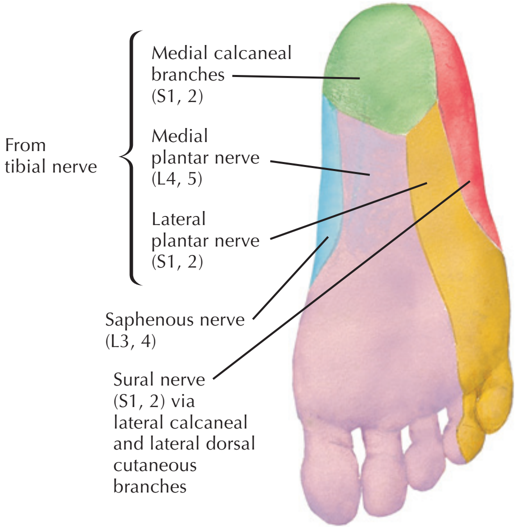
TIBIAL NERVE *continued*



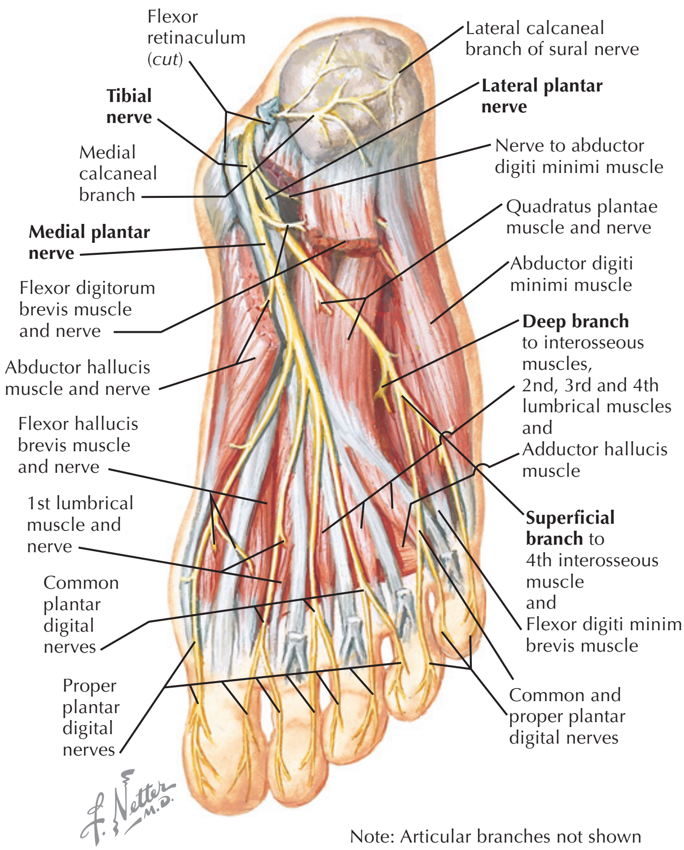
PLANTAR NERVES AND FOOT SENSORY

Roots	L4, L5, S1, S2
Course	Two plantar nerves (medial and lateral) form from bifurcation of tibial nerve in tarsal tunnel medial to Achilles tendon Traverse sole of foot and end as interdigital branches
Muscles Innervated	Medial plantar nerve: • Abductor hallicus (1st-toe abductor) • Flexor digitorum brevis (flexor of lateral 4 toes) • First lumbrical (flexes metatarsophalangeal joint, extends interphalangeal joint) • Flexor hallicus brevis (1st-toe plantarflexor) Lateral plantar nerve: • Abductor digiti minimi (abducts 5th toe) • Quadratus plantae (flexes toes) • Lumbricals 2-4 (flexes metatarsophalangeal joint, extends interphalangeal joint) • Abductor hallicus (abuducts first toe) • Flexor digiti minimi brevis (flexes 5th toe) • Dorsal interossei (abduct toes) • Plantar interossei (adduct toes)
Sensory Innervation	Most of the anterior ⅔ of the sole of the foot Calcaneal nerve supplies posterior ⅓
Selected Disorders	Nerves can be damaged within tarsal tunnel by: • External compression by hard casts or tight shoes • Ankle trauma • Endocrinopathies (hypothyroidism, acromegaly)
Clinical Features	Tarsal tunnel syndrome: foot pain, paresthesias, sensory loss in distribution of one or both plantar nerves Weakness difficult to detect as short-toe flexors less clinically important than long-toe flexors

PLANTAR NERVES AND FOOT SENSORY *continued*



Cutaneous innervation of sole



Note: Articular branches not shown

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CHAPTER 19

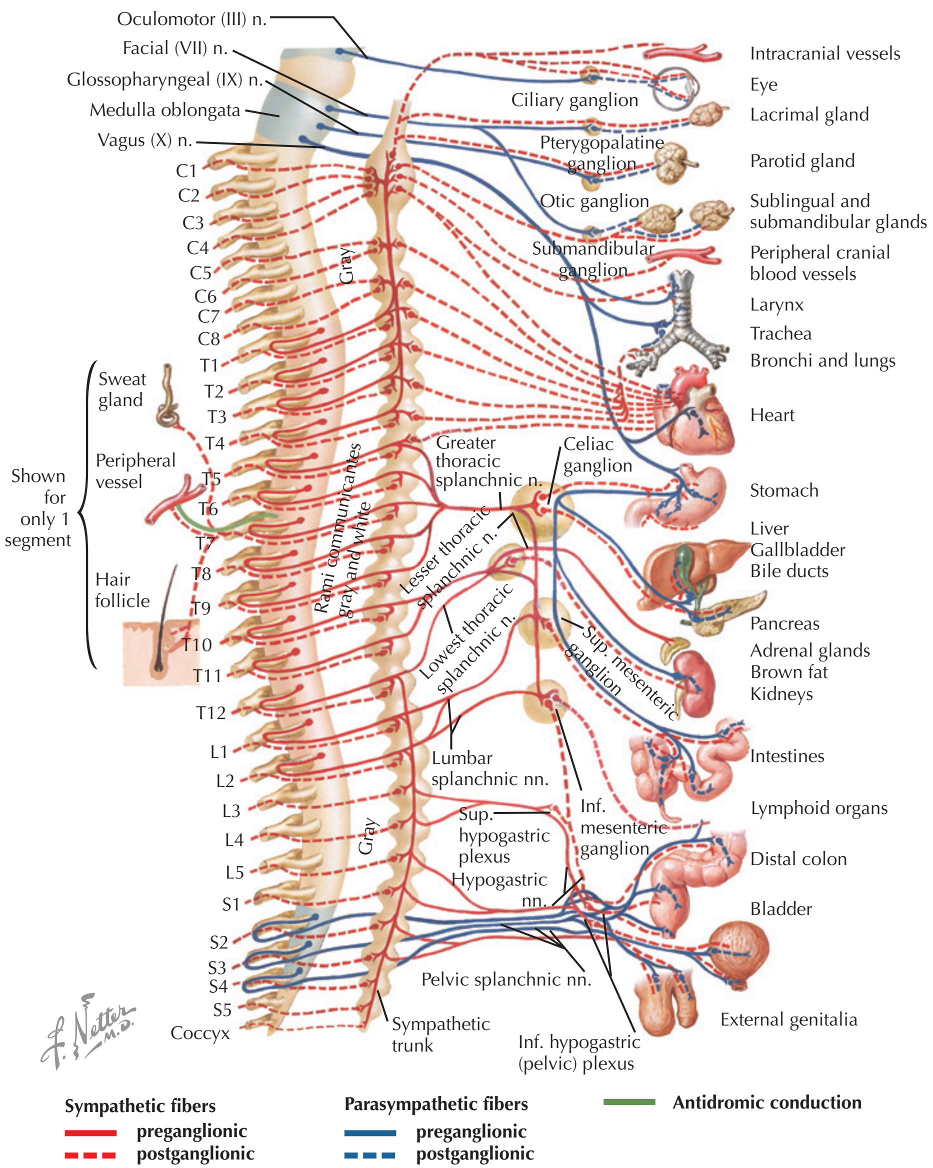
Autonomic Nervous System

AUTONOMIC NERVOUS SYSTEM SCHEMA

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Peripheral autonomic nervous system	2-Neuron chain: • Preganglionic • Postganglionic	Responsible for visceral or vegetative functions
Preganglionic parasympathetic neurons	Arise in the brainstem (cranial nerve (CN)-III, -VII, -IX, -X) and spinal cord S2-4 (craniosacral)	Largest source of preganglionic parasympathetic fibers is the vagus nerve (CN-X)
Preganglionic sympathetic neurons	Arise in spinal cord T1-L2 Exiting fibers enter the sympathetic chain and terminate on the paravertebral and prevertebral ganglia	Cell bodies located in intermediolateral cell column give cord characteristic appearance in cross section
Postganglionic parasympathetic neurons	Cell body lies in intramural ganglion near the organ innervated	Neurotransmitter: acetylcholine
Postganglionic sympathetic neurons	Cell body lies in the sympathetic (paravertebral) chain and collateral (prevertebral) ganglia	Neurotransmitter: norepinephrine, except acetylcholine at the sweat glands

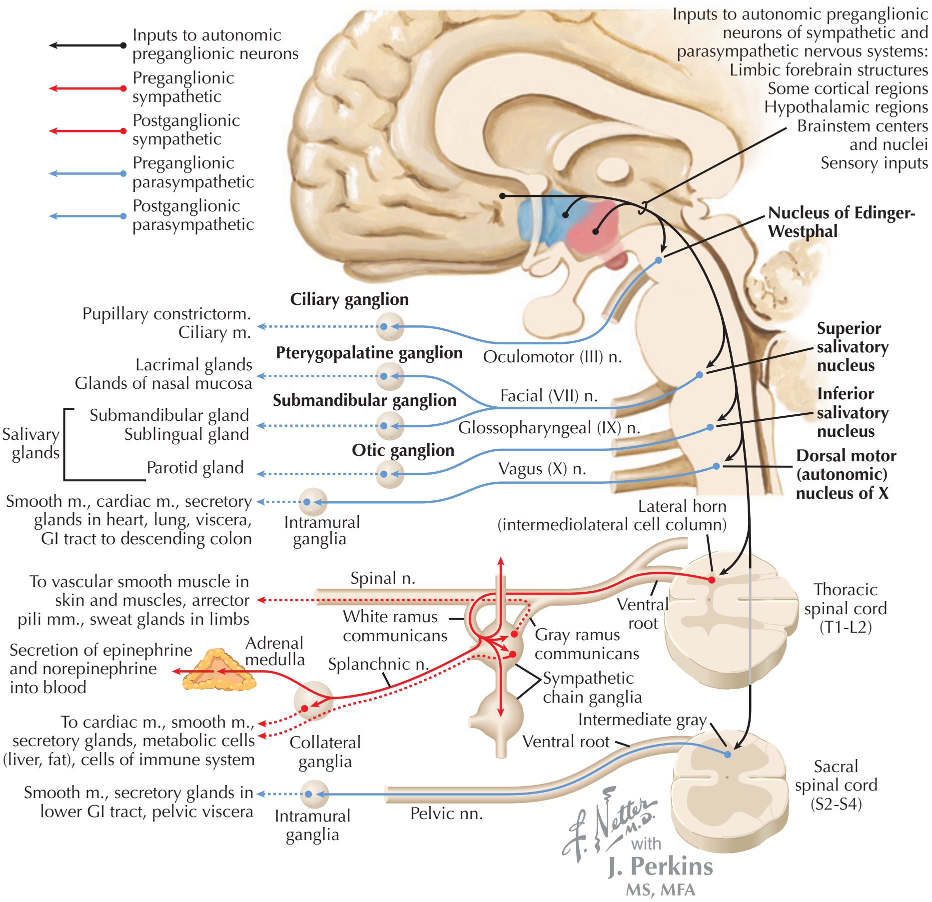
The neurotransmitter for all preganglionic autonomic fibers is acetylcholine.

AUTONOMIC NERVOUS SYSTEM SCHEMA *continued*



PARASYMPATHETIC AUTONOMIC CRANIAL NUCLEI: OVERVIEW

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Nucleus of Edinger-Westphal	Preganglionic parasympathetic nucleus; fibers synapse in ciliary ganglion	Innervate ciliary muscle (accommodation) and iris sphincter (pupillary constriction)
Superior salivatory nucleus	Fibers exit with CN-VII, synapse on pterygopalatine and submandibular ganglia	Secretomotor innervation to lacrimal and nasal mucosal glands
Inferior salivatory nucleus	Exits with CN-IX, synapses on otic ganglion	Secretomotor innervation to parotid gland
Dorsal motor nucleus of CN-X	Fibers synapse on the terminal ganglia in thoracic and abdominal viscera	Innervates thoracic and abdominal viscera

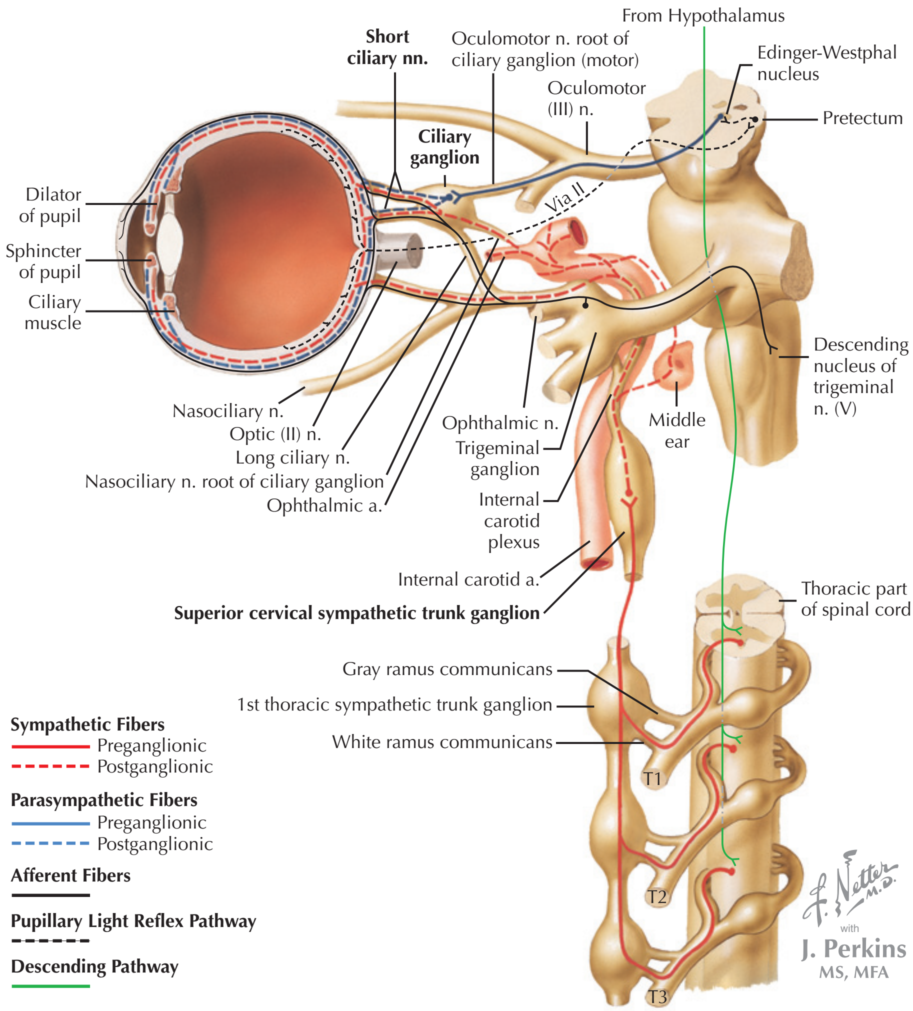


AUTONOMIC DISTRIBUTION TO THE EYE

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Ciliary ganglion (parasympathetic)	Sends short ciliary nerves to the ciliary body and the iris of the eye	Accommodation for near vision Constriction of pupil
Superior cervical ganglion (sympathetic)	Innervated by preganglionic sympathetic fibers from T1-2 intermediolateral cell column (ciliospinal center of Budge) Postganglionic fibers follow the internal carotid artery to the eye, and external carotid artery to sweat glands of face	Dilates pupil Innervates Muller's muscle in upper and lower eyelid Sweating on ipsilateral face

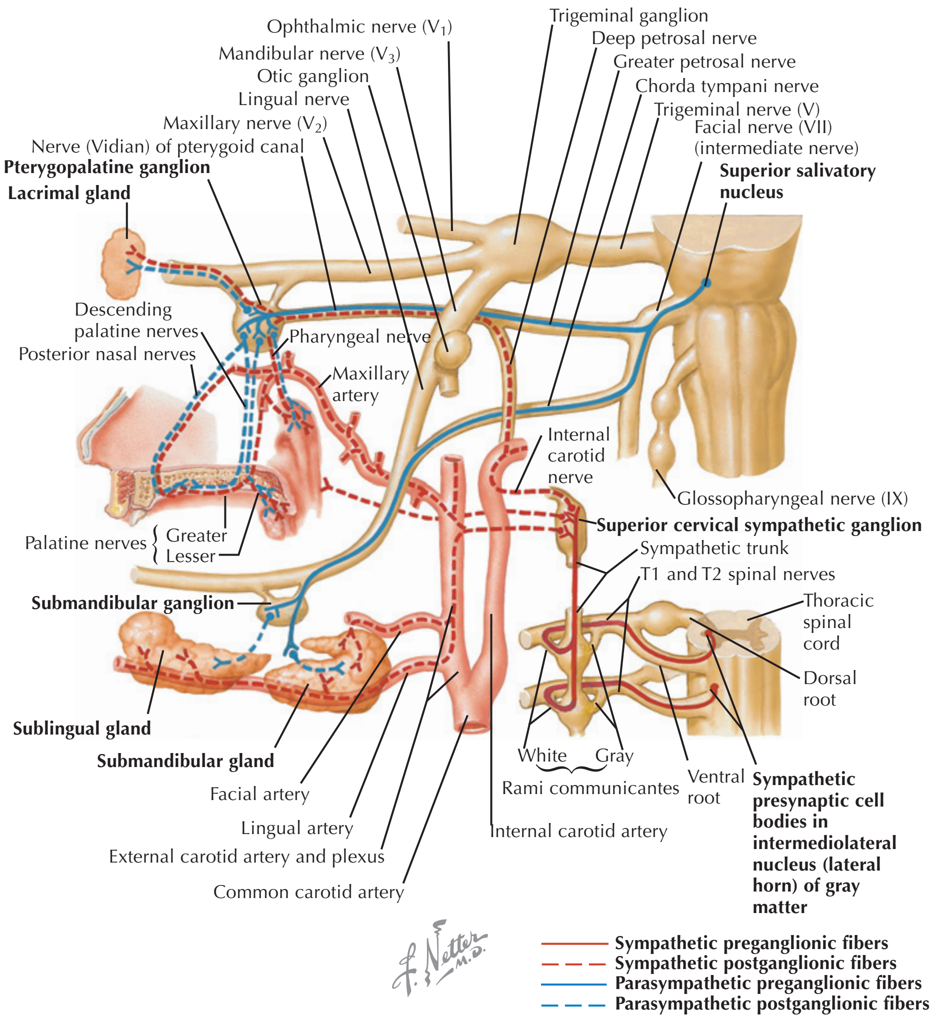
- Pupillary light reflex: light shined into one eye activates CN-II. CN-II fibers synapse in the superior colliculus, thence to the nucleus of Edinger-Westphal bilaterally via the posterior commissure. Efferent limb travels through CN-III bilaterally to constrict pupils.
- Horner's syndrome: ptosis, miosis, and anhydrosis resulting from interruption of sympathetic pupillomotor pathway. Anhydrosis occurs only with lesions proximal to the carotid artery bifurcation because the external carotid carries the sudomotor axons.

AUTONOMIC DISTRIBUTION TO THE EYE *continued*



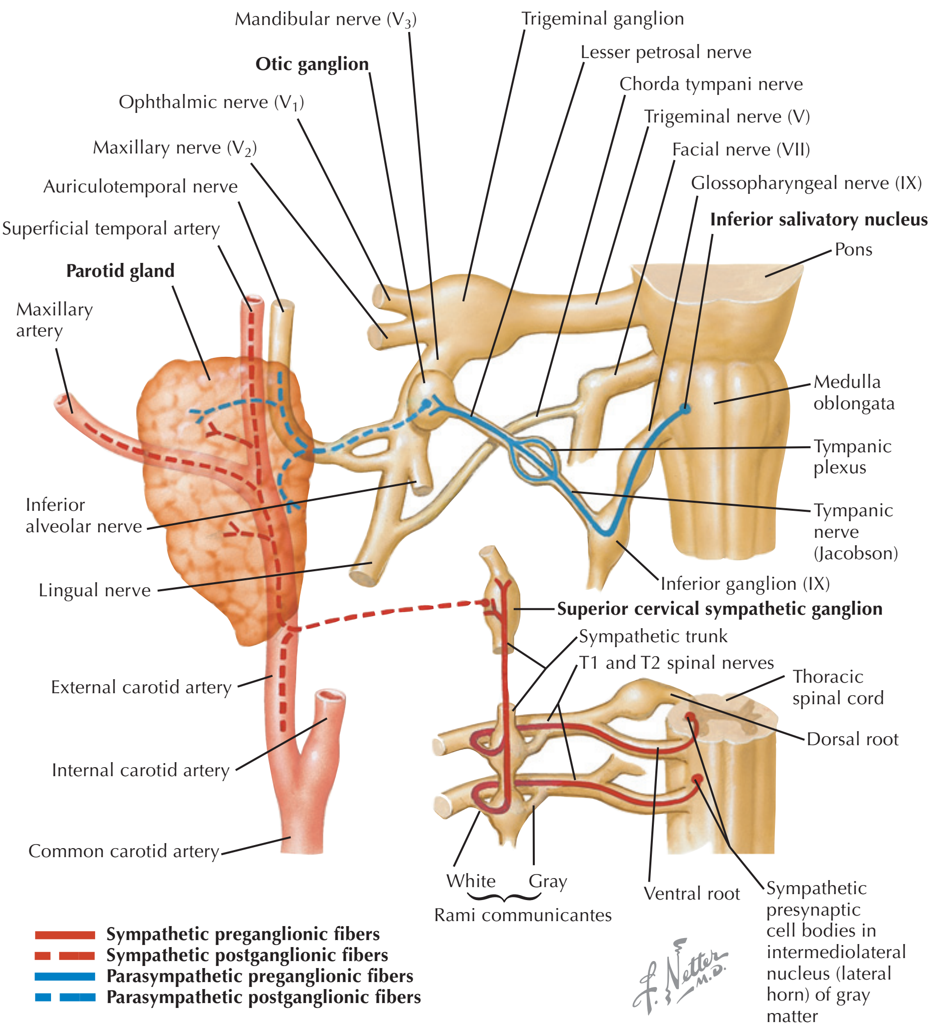
PTERYGOPALATINE AND SUBMANDIBULAR GANGLIA

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Pterygopalatine ganglion (parasympathetic)	Supplied by the superior salivatory nucleus	Lacrimal and nasal mucosal gland secretion
Submandibular ganglion (parasympathetic)	Supplied by the superior salivatory nucleus	Sublingual and submandibular gland secretion
Superior cervical ganglion (sympathetic)	Innervated by preganglionic sympathetic fibers from T1-2 intermediolateral cell column	Innervates blood vessels in, and causes low level secretion of, lacrimal and nasal mucosal glands, sublingual and submandibular glands



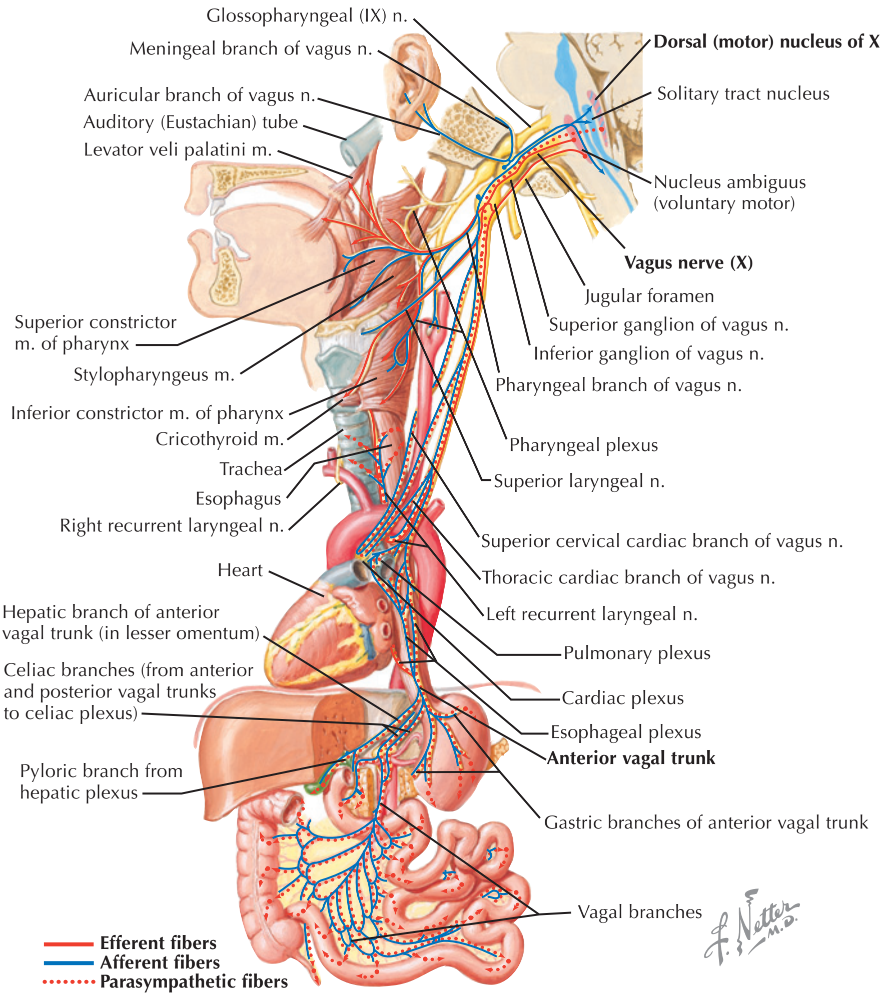
PAROTID GLAND INNERVATION

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Otic ganglion (parasympathetic)	Supplied by inferior salivatory nucleus	Parasympathetic secretomotor innervation to parotid gland
Superior cervical ganglion (sympathetic)	Innervated by preganglionic sympathetic fibers from T1-2 intermediolateral cell column Third-order neuron ascends external carotid artery to parotid	Sympathetic innervation to blood vessels in, and low level secretion of, the parotid gland



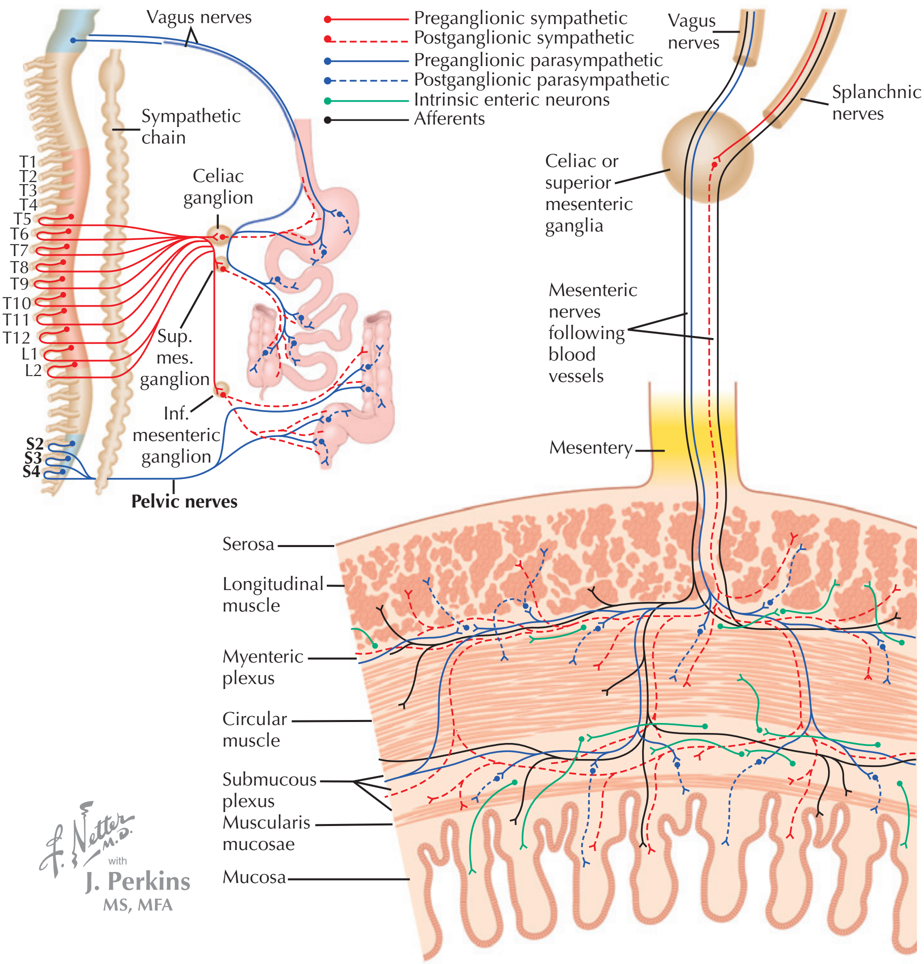
DORSAL MOTOR NUCLEUS OF CN-X

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Dorsal motor nucleus of CN-X (parasympathetic)	Fibers synapse on the terminal ganglia in thoracic and abdominal viscera	Parasympathetic innervation to the thoracic and abdominal viscera
Lungs and bronchi	Postganglionic cell bodies in the pulmonary plexus ganglia	Constriction of air passages
Heart	Postganglionic cell bodies in the intracardiac atrial ganglia	Decreased pulse and myocardial activity
Esophagus	Postganglionic cell bodies in the myenteric plexus	Increased peristalsis and motility
Stomach to transverse colon	Postganglionic cell bodies in the myenteric plexus	Increased peristalsis and motility



PARASYMPATHETIC AUTONOMIC SACRAL NUCLEI

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Autonomic nuclei of intermediate gray in S2-4 spinal cord segments (parasympathetic)	Fibers synapse in: • Hemorrhoidal and myenteric ganglia • Ganglia along aorta and internal iliac arteries • Ganglia along vesical branches of internal iliac artery	Innervates: • Descending colon and rectum (peristalsis) • Sex organs (erection) • Urinary bladder (sphincter relaxation and bladder wall contraction)

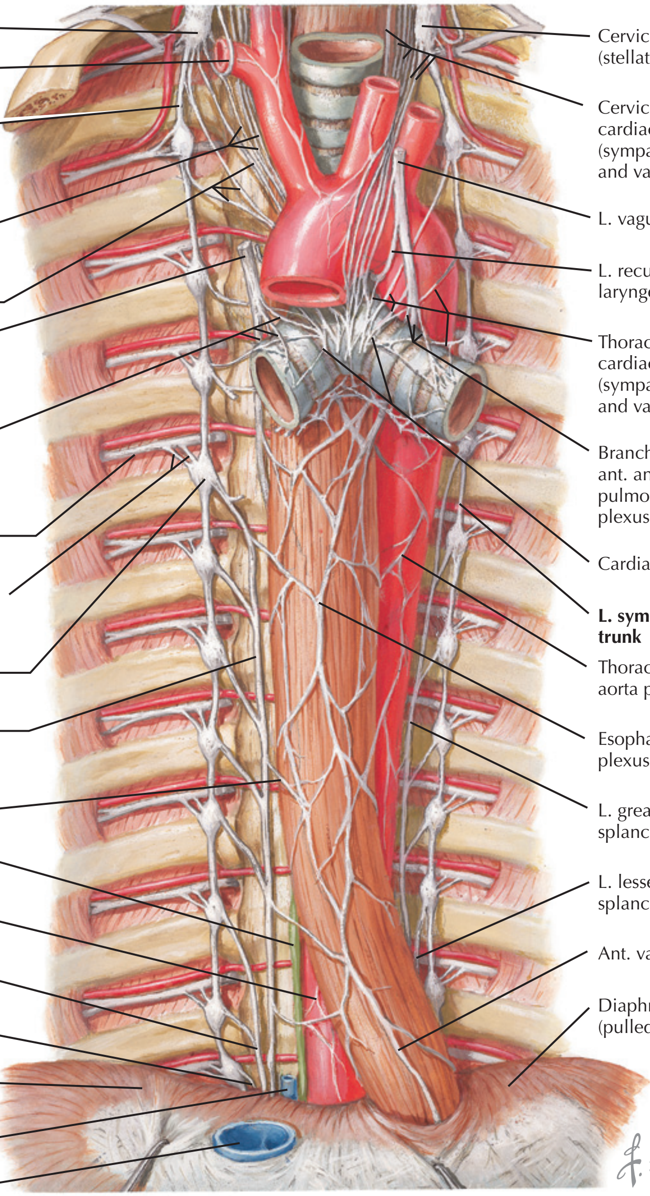


SYMPATHETIC SYSTEM

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Sympathetic trunks (paravertebral ganglia)	2 symmetrical, ganglionated cords along the anterolateral vertebral column, running from the base of the skull to the coccyx	Second-order neuron runs from the intermediolateral cell column (ILCC) to sympathetic prevertebral or paravertebral ganglia
Prevertebral ganglia	Irregular ganglionic masses surrounding visceral branches of aorta	Third-order neuron runs from paravertebral and prevertebral ganglia to end organ
White ramus communicans	Myelinated, 2nd-order, preganglionic fibers from the ILCC enter sympathetic trunk to terminate on the paravertebral or prevertebral ganglia	Limited to T1-L2
Gray ramus communicans	Every spinal nerve receives 1 from the sympathetic trunk	Unmyelinated, 3rd-order, postganglionic fibers. Innervate blood vessels, arrector pili muscles, and glands of body wall

First-order neuron begins in the posterolateral hypothalamus, descends the reticular formation dorsolateral to the red nuclei, through the lateral pons and medulla and synapses on intermediolateral cell column (ILCC) from T1-L2.

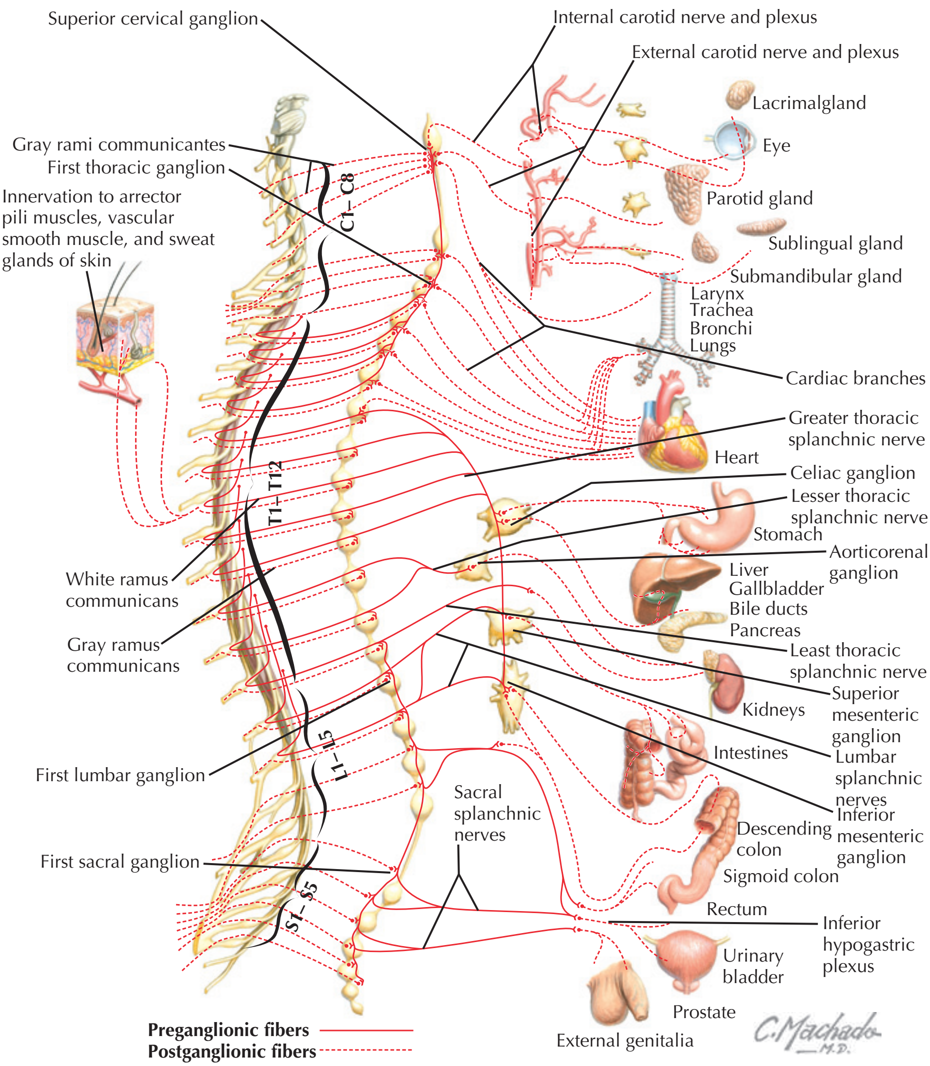
SYMPATHETIC SYSTEM *continued*



SYMPATHETIC INNERVATION OF THORACO-ABDOMINAL-PELVIC VISCERA

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
C8-T2 (3) intermediolateral cell column	Superior cervical sympathetic ganglia	Iris: pupillary dilation
T1-2 intermediolateral cell column	Superior and middle cervical sympathetic ganglia	Lacrimal gland: vasomotor to blood vessels and low level glandular secretion
T1-3 (4) intermediolateral cell column	Superior and middle cervical sympathetic ganglia	Submandibular and sublingual gland: vasomotor to blood vessels, and low level glandular secretion
T1-3 (4) intermediolateral cell column	Superior and middle cervical sympathetic ganglia	Parotid gland: vasomotor to blood vessels, and low level glandular secretion
T1-3 intermediolateral cell column	3 cervical sympathetic ganglia	Sweat glands in head and neck: secretion
T1-5 intermediolateral cell column	Inferior cervical and thoracic T1-5 sympathetic ganglia	Lungs and bronchi: dilation
T1-5 (6,7) intermediolateral cell column	3 cervical and thoracic T1-6 sympathetic ganglia	Cardiac: increased pulse rate and myocardial activity
T1-6 intermediolateral cell column	Thoracic T(1-3) 4-6 sympathetic ganglia	Esophagus: decreased motility
T5-T11 intermediolateral cell column	Celiac and superior mesenteric plexus	Stomach to transverse colon: decreased motility
T12-L3 intermediolateral cell column	Lumbar and inferior mesenteric plexus	Descending colon and rectum: decreased motility
T10-L2 intermediolateral cell column	Lumbar, sacral, and inferior mesenteric plexus	Sex organs: ejaculation
T12-L2 intermediolateral cell column	Lumbar and inferior mesenteric plexus	Urinary bladder: sphincter contraction and bladder wall relaxation
L1-2 intermediolateral cell column	Lumbar and sacral sympathetic ganglia	Sweat glands: secretion Leg blood vessels: arteriolar constriction (generally)

SYMPATHETIC INNERVATION OF THORACO-ABDOMINAL-PELVIC VISCERA *continued*

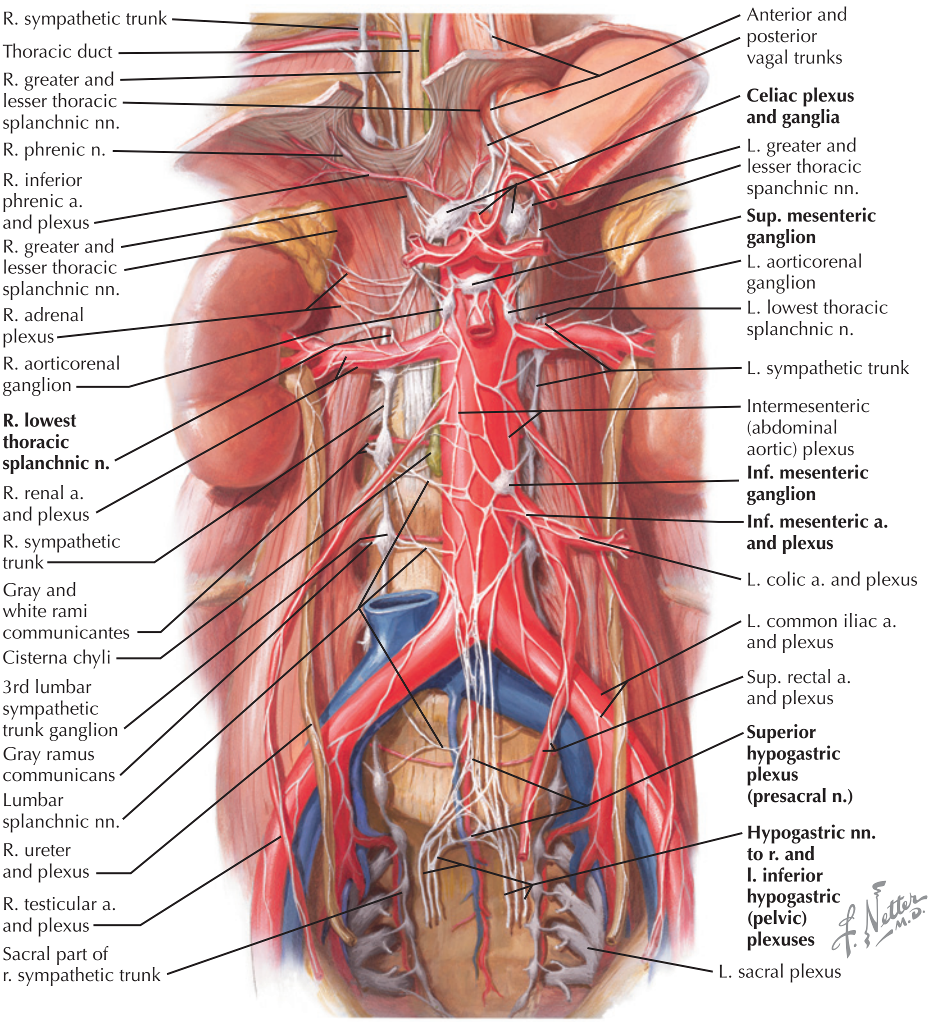


ABDOMINAL SYMPATHETIC AUTONOMIC NERVES AND GANGLIA

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Greater splanchnic nerve	Arises from T5-9 Correspond to the white ramus communicans	Preganglionic fibers that innervate the celiac plexus
Lesser splanchnic nerve	Arises from T10-11 Correspond to white ramus communicans	Preganglionic fibers that innervate the celiac plexus
Celiac plexus	Surrounds celiac and superior mesenteric arteries	Largest autonomic plexus Contains celiac and superior mesenteric ganglia
Hypogastric plexus	Unpaired	Innervates pelvic viscera

White ramus communicans: Preganglionic sympathetic fibers that arise from the intermediolateral cell column T1-L2, leave the spinal cord via ventral roots of T1-L2, then leave the spinal nerve as the white ramus communicans, enter the sympathetic trunk, and terminate on cells in the prevertebral and paravertebral ganglia.

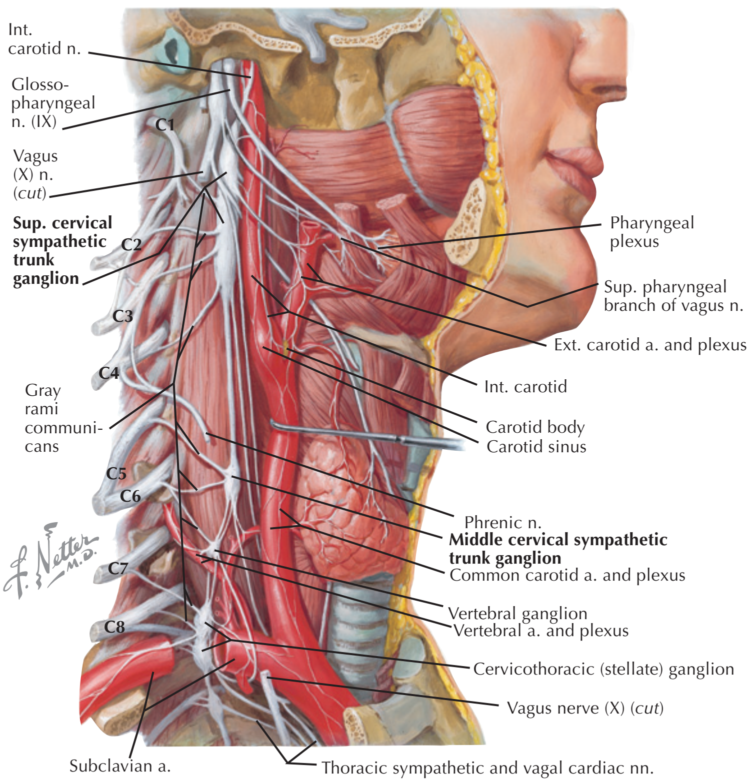
ABDOMINAL SYMPATHETIC AUTONOMIC NERVES AND GANGLIA *continued*



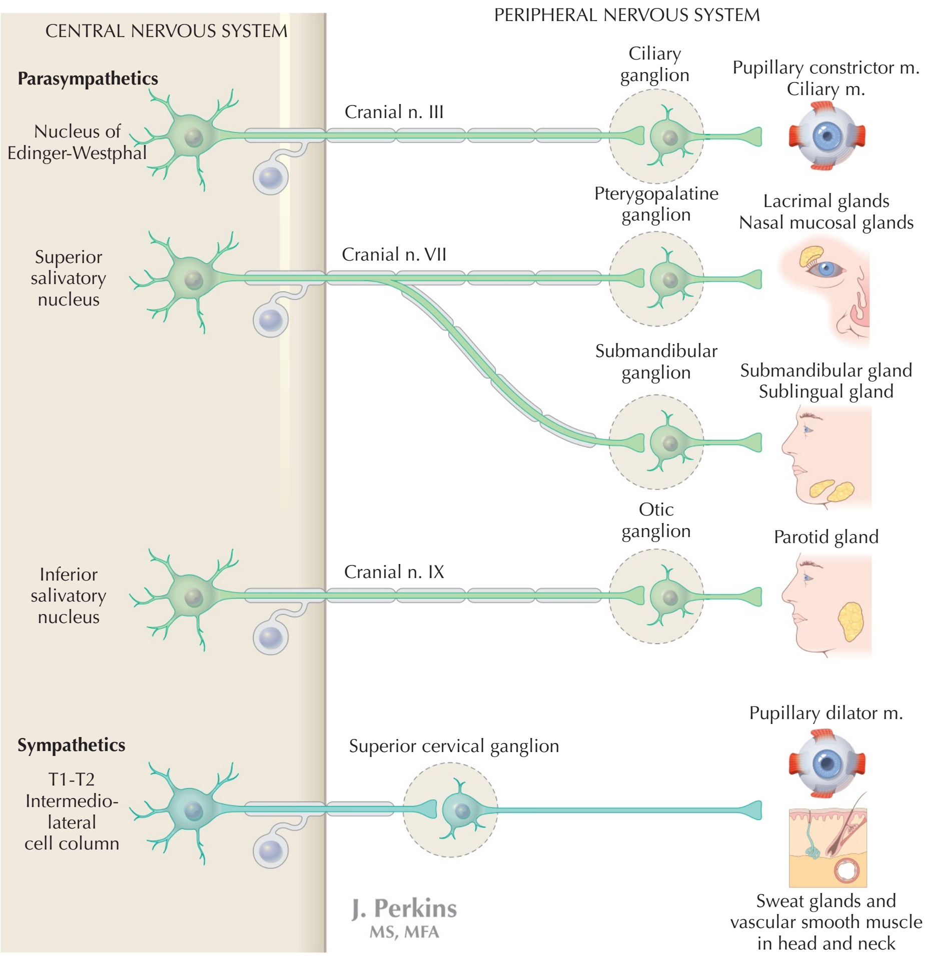
AUTONOMIC NERVES IN HEAD AND NECK

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Superior cervical ganglion	Largest of paravertebral ganglia	Gives rise to 3rd-order fibers to lower 4 cranial and upper 4 cervical nerves, pharynx, external and internal carotid arteries
Middle cervical ganglion	Lies near C6 vertebra	Often absent
Inferior cervical ganglion	Lies near the lower border of C7 vertebra. Often fuses with 1st thoracic ganglion to form the stellate ganglion	Furnishes gray rami communicantes to C7-T1

Gray ramus communicans: Each spinal nerve receives a gray ramus communicans from the sympathetic trunk that consists of unmyelinated postganglionic fibers that innervate blood vessels, glands, and arrector pili muscles.



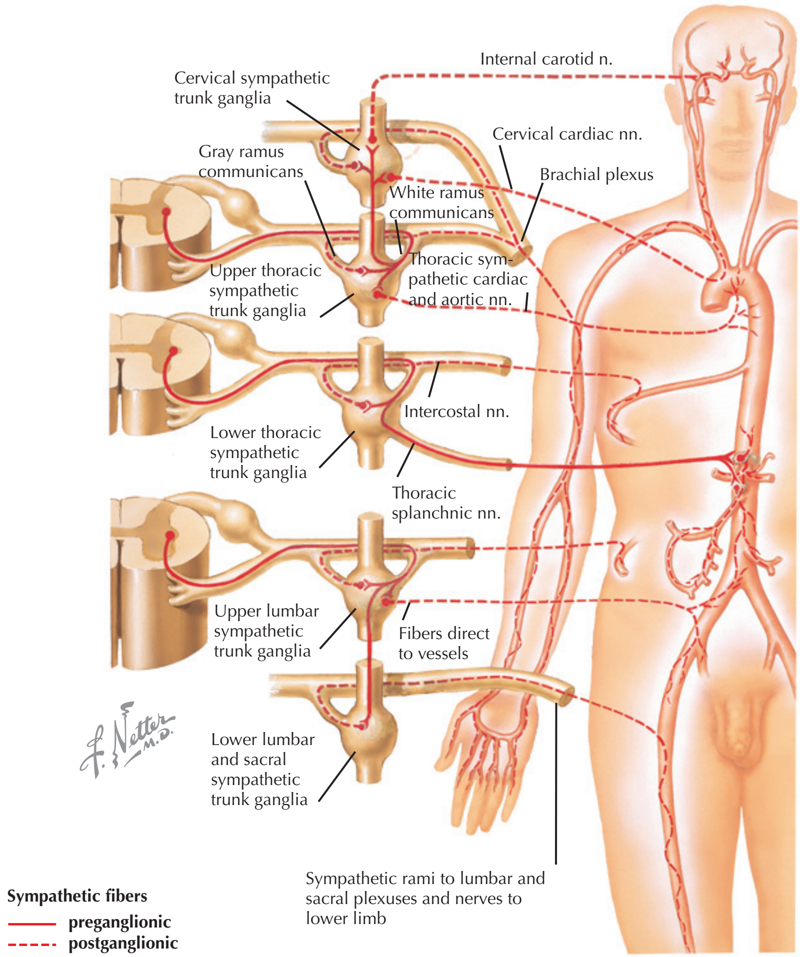
SCHEMATIC OF AUTONOMIC NERVES IN HEAD AND NECK



AUTONOMIC INNERVATION OF LIMBS

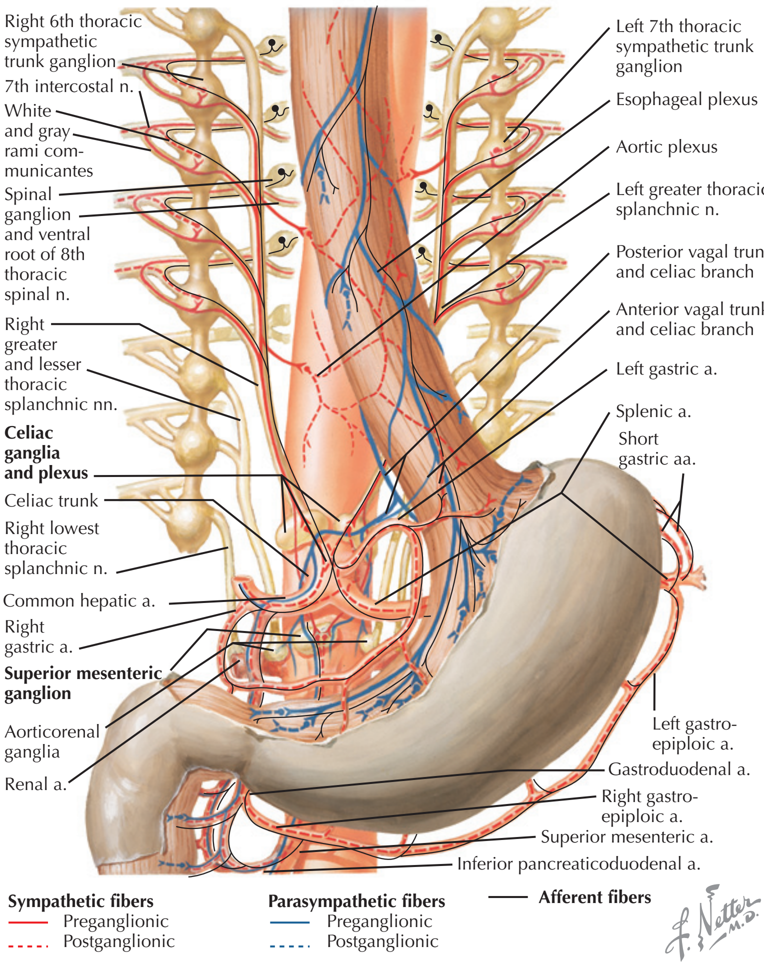
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
T1-L2 intermediolateral cell column	Sends preganglionic fibers to sympathetic chain ganglia, which send postganglionic fibers into the peripheral nerves	Vascular smooth muscle: constriction Sweat glands: secretion Arrector pili: pilomotor contraction, goosebumps, or raise hair

Autonomic innervation of the limbs derives only from the sympathetic nervous system.



AUTONOMIC INNERVATION OF STOMACH

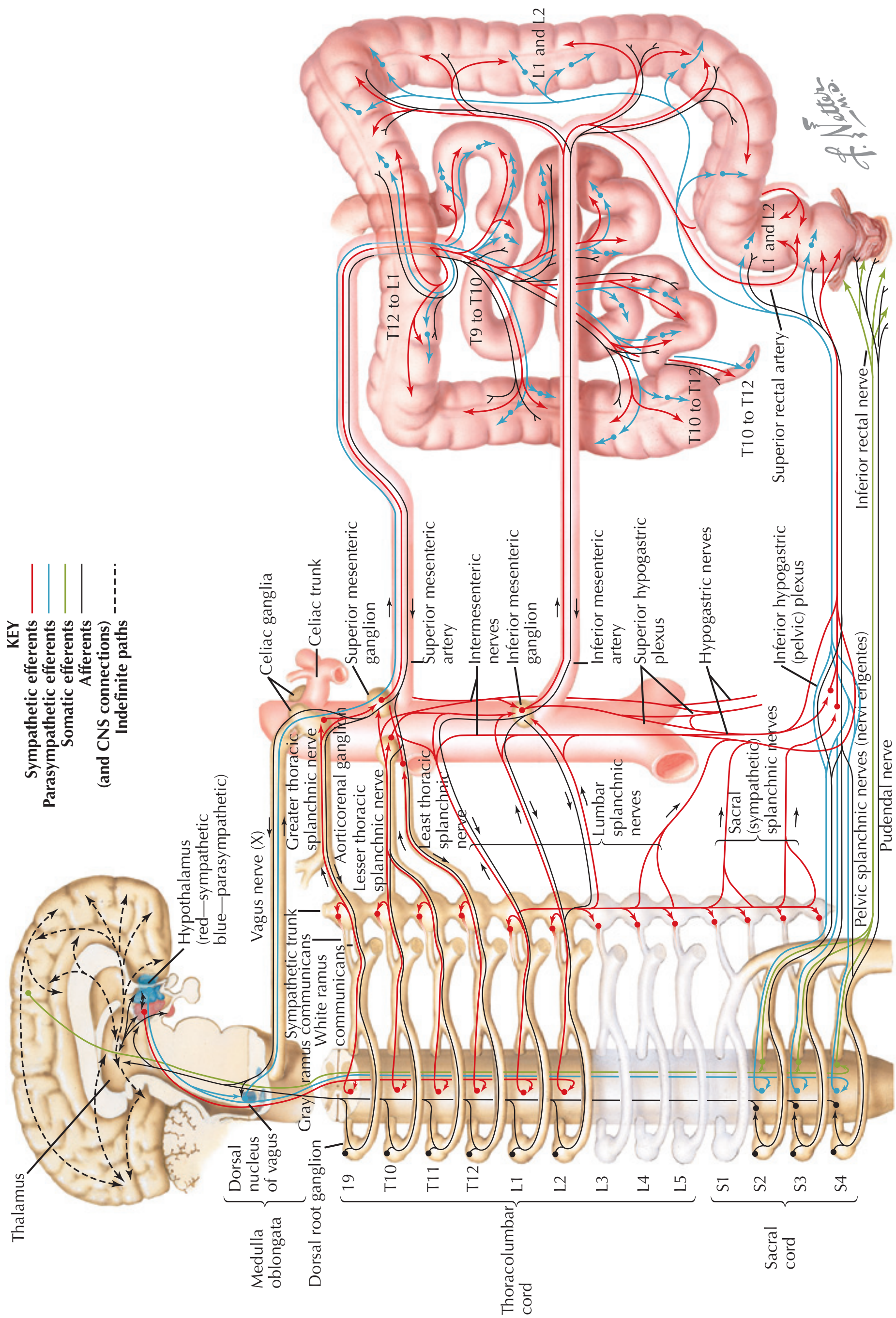
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
Celiac and superior mesenteric ganglia (sympathetic)	Greater and lesser thoracic splanchnic nerves provide preganglionic input to ganglia	Decreases peristalsis and secretomotor (e.g., gastrin, HCl) activity
Celiac branches of vagus (parasympathetic)	Supply stomach and proximal duodenum	Increases peristalsis and secretomotor activity and relaxes associated sphincters



AUTONOMIC INNERVATION OF INTESTINES

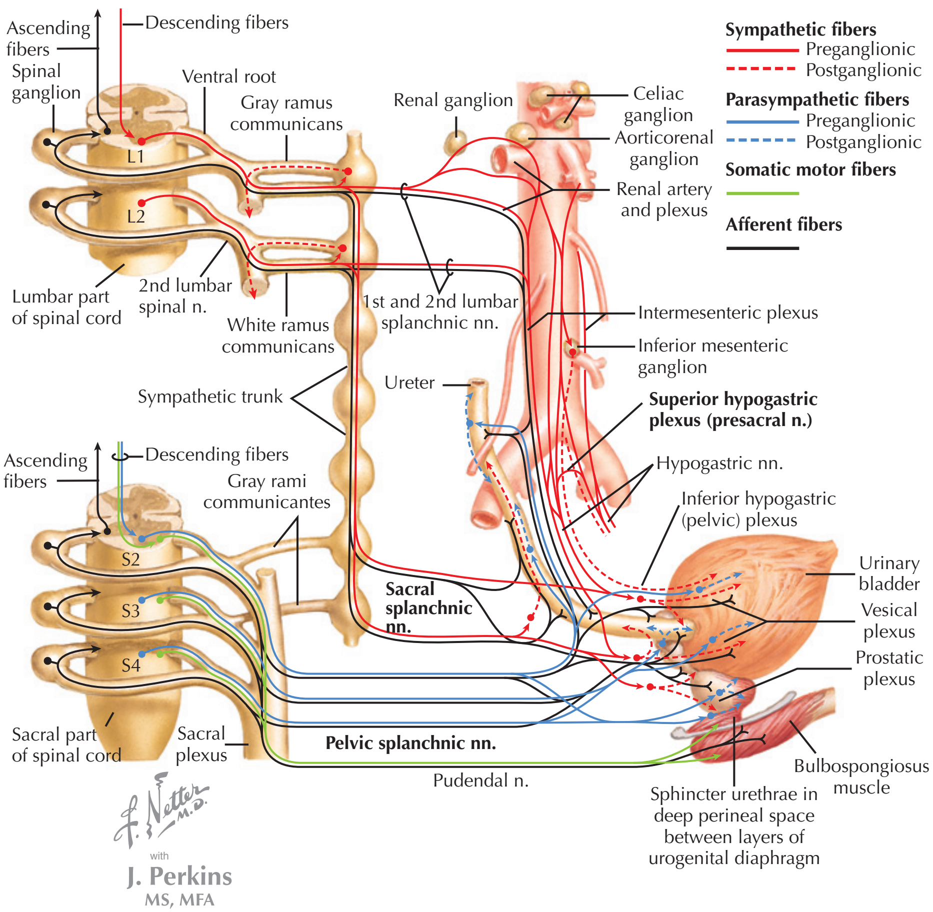
STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
T5-11 intermediolateral cell column (sympathetic)	Distributes to the superior and inferior mesenteric and celiac ganglia	Decreases peristalsis and secretomotor (fluid secretion) activity
Vagus nerve, S2-4 intermediate gray (parasympathetic)	Distributes to the intramural ganglia	Increases peristalsis and secretomotor activity and relaxes involuntary sphincters

AUTONOMIC INNERVATION OF INTESTINES *continued*



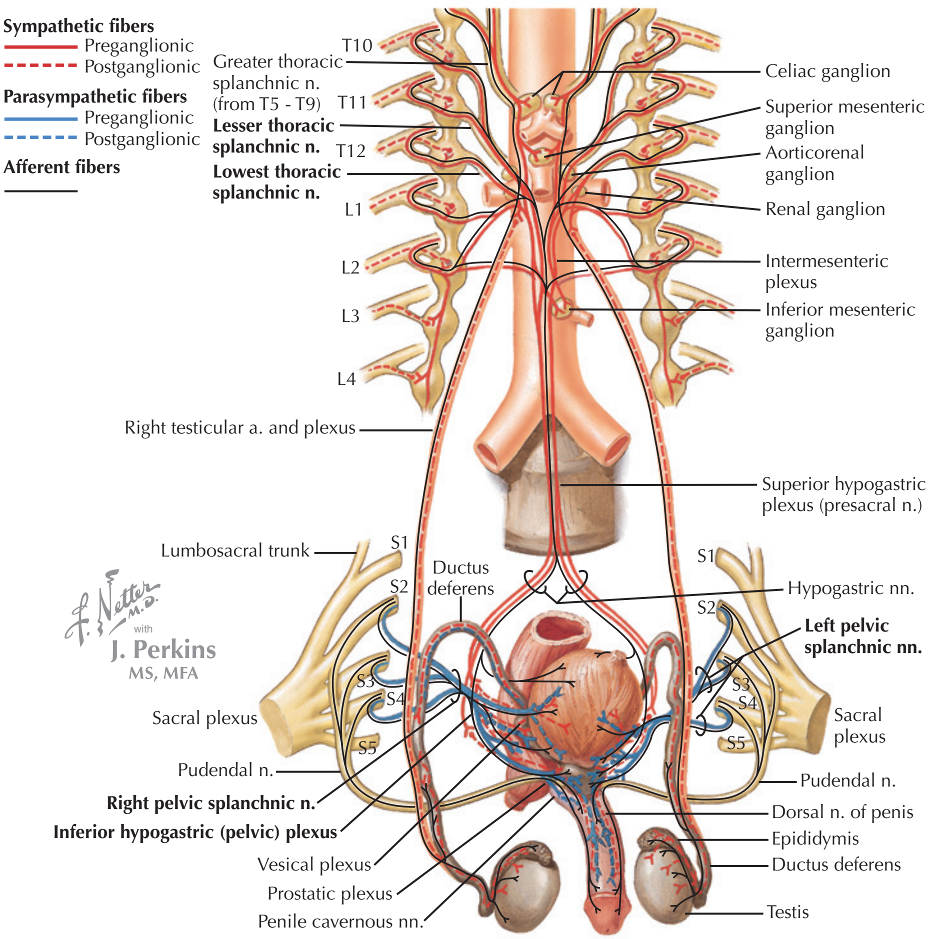
AUTONOMIC INNERVATION OF URINARY BLADDER

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
L1-2 intermediolateral cell column (sympathetic)	Through sacral splanchnic nerves to hypogastric plexus	Relax detrusor and contract trigone and internal sphincter
S2-4 intermediate gray (parasympathetic)	Through pelvic splanchnic nerves to intramural ganglia of bladder wall	Contract detrusor and relax trigone and internal sphincter to empty bladder



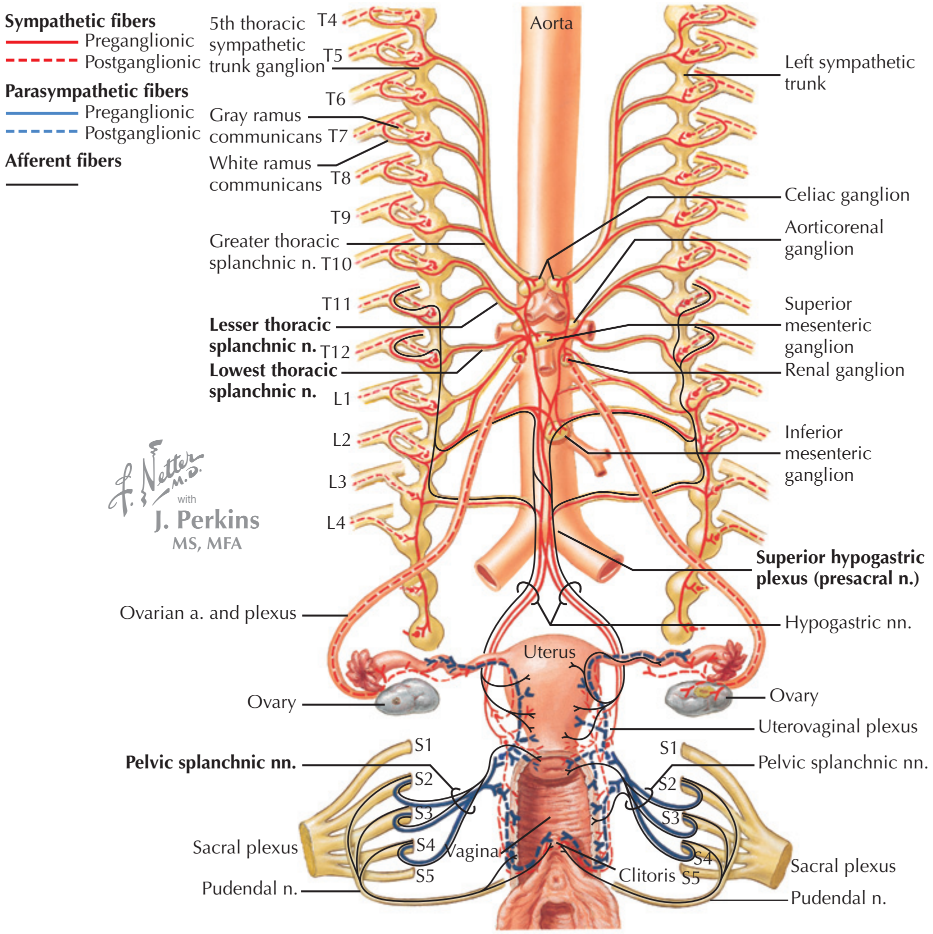
AUTONOMIC INNERVATION OF MALE REPRODUCTIVE ORGANS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
T10-L2 intermediolateral cell column (sympathetic)	Via thoracic and upper lumbar splanchnic nerves to superior hypogastric plexus	Contraction of vas deferens and prostate capsule and contraction of the bladder sphincter to prevent retrograde ejaculation
S2-4 intermediate gray (parasympathetic)	Via pelvic splanchnic nerves to inferior hypogastric plexus	Vascular dilation to initiate and maintain erection



AUTONOMIC INNERVATION OF FEMALE REPRODUCTIVE ORGANS

STRUCTURE	ANATOMIC NOTES	FUNCTIONAL SIGNIFICANCE
T10-L2 intermediolateral cell column (sympathetic)	Via the thoracic and upper lumbar splanchnic nerves to the superior hypogastric plexus	Contraction of the uterus. Also supplies vaginal arteries, vestibular glands, and erectile tissue
S2-4 intermediate gray (parasympathetic)	Via pelvic splanchnic nerves to the inferior hypogastric plexus	Muscular and mucous coat of the vagina and urethra; stimulates erectile tissue of the vestibular bulb and clitoris and supplies vestibular glands



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