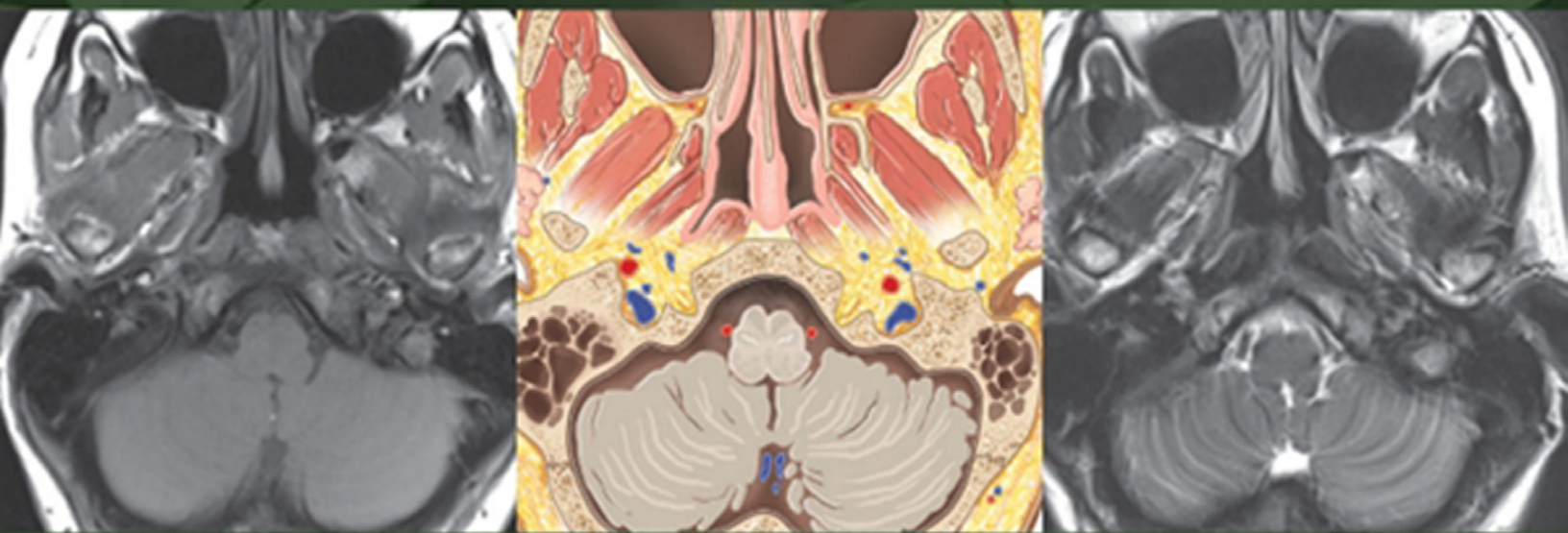


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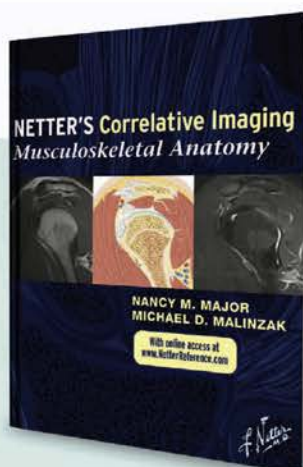
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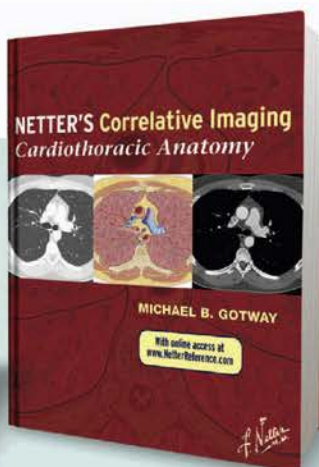
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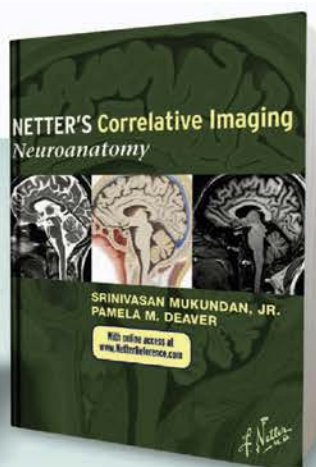
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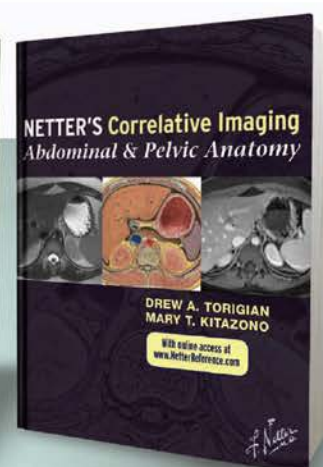
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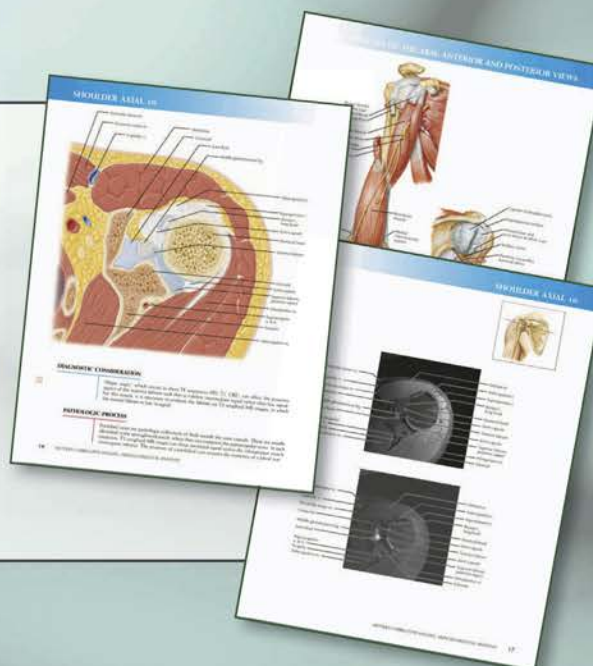


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Volume Editors

THOMAS C. LEE, MD

Assistant Section Head

Neuroradiology

Instructor

Harvard Medical School

Boston, Massachusetts

SRINIVASAN MUKUNDAN, JR., MD, PhD

Neuroradiology Network Chief

Brigham and Women's Hospital

Associate Professor of Radiology

Harvard University

Boston, Massachusetts

Series Editor

NANCY M. MAJOR, MD

Director of Diagnostic Imaging

Orthopaedic Associates of Allentown

Allentown, Pennsylvania

Illustrations by

Frank H. Netter, MD

Contributing Illustrators

Tiffany Slaybaugh DaVanzo, MA, CMI

Carlos Machado, MD

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*To my wonderful parents, Wendy and Doug,
for their unwavering support and encouragement
To my siblings, Ashley, Hillary, MacGregor, and Alex,
who have been permanent sources of love and inspiration
McKinley D. Nickerson, Project Coordinator*

*To my inspirational parents, Sun Hyee and Chang Whan Lee,
who provided my foundation
To my sister and brother-in-law, Jane and Richard, and their son,
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To my supportive wife, Ji In, who is my one and only soulmate
Thomas C. Lee*

*To my wife, Nancy, and our sons, TJ and Dev
To my parents, teachers, and mentors
To students past, present, and future, who,
through their study and dedication, validate this effort
Srinivasan Mukundan*

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About the Artists

FRANK H. NETTER, MD

Frank H. Netter was born in 1906 in New York City. He studied art at the Art Students League and the National Academy of Design before entering medical school at New York University, where he received his MD 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 on the side 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.

In 2005, Elsevier, Inc., purchased the Netter Collection and all publications from Icon Learning Systems. There are now more than 50 publications featuring the art of Dr. Netter available through Elsevier, Inc. (in the US: www.us.elsevierhealth.com/Netter; outside the US: www.elsevierhealth.com).

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 important, 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 make them so intellectually valuable.

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

Learn more about the physician-artist whose work has inspired the Netter Reference collection: <http://www.netterimages.com/artist/netter.htm>

CARLOS MACHADO, MD

Carlos Machado was chosen by Novartis to be Dr. Netter's successor. He continues to be the main artist who contributes to the *Netter Collection of Medical Illustrations*.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter's original plates and has created many paintings of his own in the style of Netter as an extension of the Netter Collection. Dr. Machado's photorealistic expertise and his keen insight into the physician/patient relationship inform his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at:

<http://www.netterimages.com/artist/machado.htm>

TIFFANY SLAYBAUGH DAVANZO, MA, CMI

Tiffany Slaybaugh DaVanzo is a Certified Medical Illustrator and graduate of the Johns Hopkins University School of Medicine's Art as Applied to Medicine master's degree program. She has been a self-employed medical illustrator since 2006, and her work has received numerous awards. She specializes in art for medical publications, education, and the medical legal field.

The first medical text Tiffany owned was Netter's *Atlas of Human Anatomy*. It currently sits on her desk tattered and littered with Post-It notes from years of hard use, but is a tribute to Dr. Netter's influence on her art. She considers it a career highlight to be creating new artwork for the Netter collection. Tiffany lives in Tennessee with her husband and two young daughters.

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About the Editors

Thomas C. Lee, MD, grew up in Toronto, Ontario. He attended Harvard College and earned an AB degree with honors in biochemical studies. He graduated from medical school at McGill University in Montreal before returning to his hometown, where he completed a residency in diagnostic radiology, followed by a fellowship in neuroradiology, at the University of Toronto.

While a student at Harvard, he attended Addenbrooke's Hospital at Cambridge University, United Kingdom, as a Weissman Awardee. As a medical student, he won the BiochemPharma Award for McGill medical student research of highest scientific merit, and as a resident, he won the Radiological Society of North America Award for research excellence. He has co-authored several peer-reviewed manuscripts and book chapters. He has lectured at many local, national, and international meetings with a focus on head, neck, and spine imaging and intervention, most recently on MRI-guided cryoablation of nerves and tumors of the head, neck, and spine.

Dr. Lee is currently an instructor of radiology at Harvard Medical School, as well as assistant section head of neuroradiology at Brigham and Women's Hospital, and is a premedical advisor for Quincy House of Harvard College.

Srinivasan Mukundan, Jr., MD, PhD, grew up in Atlanta, Georgia, where he attended Emory University to study chemistry, earning his BS, MS, and PhD degrees. He then entered Emory University School of Medicine, earning his MD and completing a postdoctoral fellowship in cardiac MRI, a residency in diagnostic radiology, and a clinical fellowship in neuroradiology.

Dr. Mukundan has won research awards as a graduate student, medical student, and resident. He also received the Berlex-Neuroradiology Education Research Foundation Scholar Award from the American Society of Neuroradiology and the Scholar Award from the American Roentgen Ray Society. He has co-authored more than 80 peer-reviewed manuscripts, as well as 10 book chapters and one textbook. In addition, he is a frequent speaker both nationally and internationally on a variety of topics related to neuroradiology, MRI, and preclinical imaging.

Dr. Mukundan is currently an associate professor of radiology at Harvard Medical School and the section head of neuroradiology at Brigham and Women's Hospital. In addition, he holds several other administrative positions at Brigham and Women's Hospital, including neuroradiology network director, co-director of the Clinical Functional MRI Program, and chair of the Contrast Agent Safety Committee. He is also the first director of the Brigham and Women's Hospital Small Animal Imaging Laboratory.

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Acknowledgments

From our perspective, this project began several years ago with a phone call from Dr. Nancy Major, a dear colleague and friend. Nancy has served as the driving force behind the Netter's Correlative Imaging series, finding the authors and helping define the unique format of this project. In our specific project, she provided support and guidance at several key stages of the project.

The Elsevier publishing team is led by Elyse O'Grady, Senior Content Strategist, and Marybeth Thiel, Senior Content Development Editor. They practice their craft according to the finest traditions of book editing and publishing that have evolved from the time of the first presses. This is particularly admirable given that many of these traditions are challenged in our modern world. Mostly, Marybeth and Elyse are recognized for their patience and their passion in seeing this project through to its conclusion.

Several colleagues and friends have played significant roles during the evolution of this project. We extend heartfelt gratitude to these individuals:

Dr. Pamela Deaver

Dr. Leahthan Domeshak

Dr. Gerald Grant

Dr. Jeffrey Marcus

Dr. Karli Spetzler

Special thanks go to Frank H. Netter, MD, often considered the "Michelangelo of Medicine," who created and perfected this genre. Our artist, Tiffany DaVanzo, immersed herself in creating illustrations that are of high artistic quality, and then spent countless hours in conferences reviewing the fine details of the artwork on a plate-by-plate basis to ensure anatomic accuracy. Tiffany is recognized for her stewardship of the Netter tradition to which we are all committed.

Finally, **McKinley Nickerson** served as our project coordinator. Her myriad contributions have ranged from scheduling and coordination to assistance with image segmentation and digital proofs. Simply stated, this project would never have been completed without McKinley's participation.

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Preface

The study of anatomy, by its very nature, exposes the student to both the forms and the functions responsible for the inner workings of the human body—one of the most elegant demonstrations of the synthesis of art and science. This statement is never truer than when reviewing the works of Frank H. Netter, MD (1906-1991). His monumental works of art have educated countless generations of physicians and will continue to do so for many years to come.

The evolution of cross-sectional imaging technologies, including computed tomography (CT) and magnetic resonance imaging (MRI), has allowed physicians and aspiring physicians the ability to peer into the human body in many ways previously impossible. This, in turn, has forced the review of anatomy in a manner that was not contemplated when Dr. Netter began rendering his artwork more than three-quarters of a century ago. Limited spatial and temporal resolution, tissue parameters, image contrast, and partial volume averaging are all issues that confound the interpretation of MRI and CT images and are not part of conventional anatomic teaching in the dissection laboratory.

Despite the changing nature of the anatomy education problem, Dr. Netter's approach still provides the template for how to teach modern medical imaging. By directly correlating cross-sectional medical images with "Netter art" that is voxel matched, the student is provided with the key to unlock the anatomy hidden within.

Many existing textbooks with radiology images and clarifying illustrations focus on showing 3D renderings for better understanding of the entire course of a particular structure, such as a cranial nerve. Our goal, however, is to provide a more rigorous "slice-by-slice" reference guide for both the cross-sectional medical image and the corresponding illustration. For instance, someone may understand the general course of the facial nerve, yet still have difficulty identifying the fractional component of this structure on a single axial image. Conversely, individuals may need help identifying an unknown structure on a given image, particularly in the coronal or sagittal planes. Finally, the imaging characteristics on CT versus different sequences of MRI, such as T1- or T2-weighted imaging, can often be confusing and will hopefully be partially clarified through this book.

This volume remains true to the goals of the *Netter's Correlative Imaging* series. There is high-quality imaging, allowing the demonstration of important anatomic structures, including structures not always included in other sources. The book also serves as a user-friendly anatomy reference for commonly employed imaging techniques of the brain, head, neck, and spine. As with the other volumes in the series, the text is not inclusive of pathology. In addition, normal variant anatomy and clinical pearls are presented.

Structures are labeled using the most common terms and should be acceptable to radiologists, neurosurgeons, and neurologists.

It is our hope that this volume will serve as a primary source of knowledge to the novice and as a reference text for the seasoned veteran. In either case, we hope that it will be useful on a daily basis.

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PART

1

BRAIN

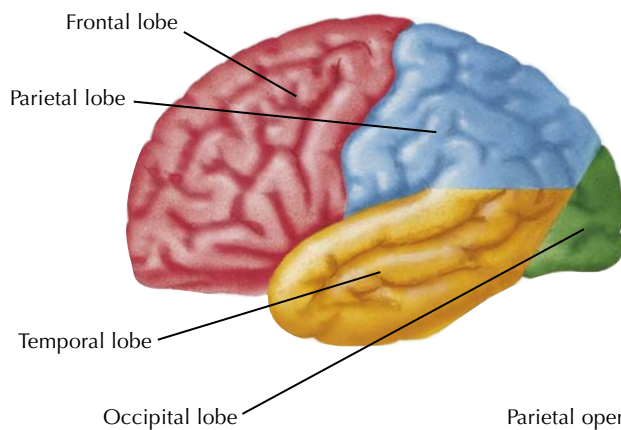
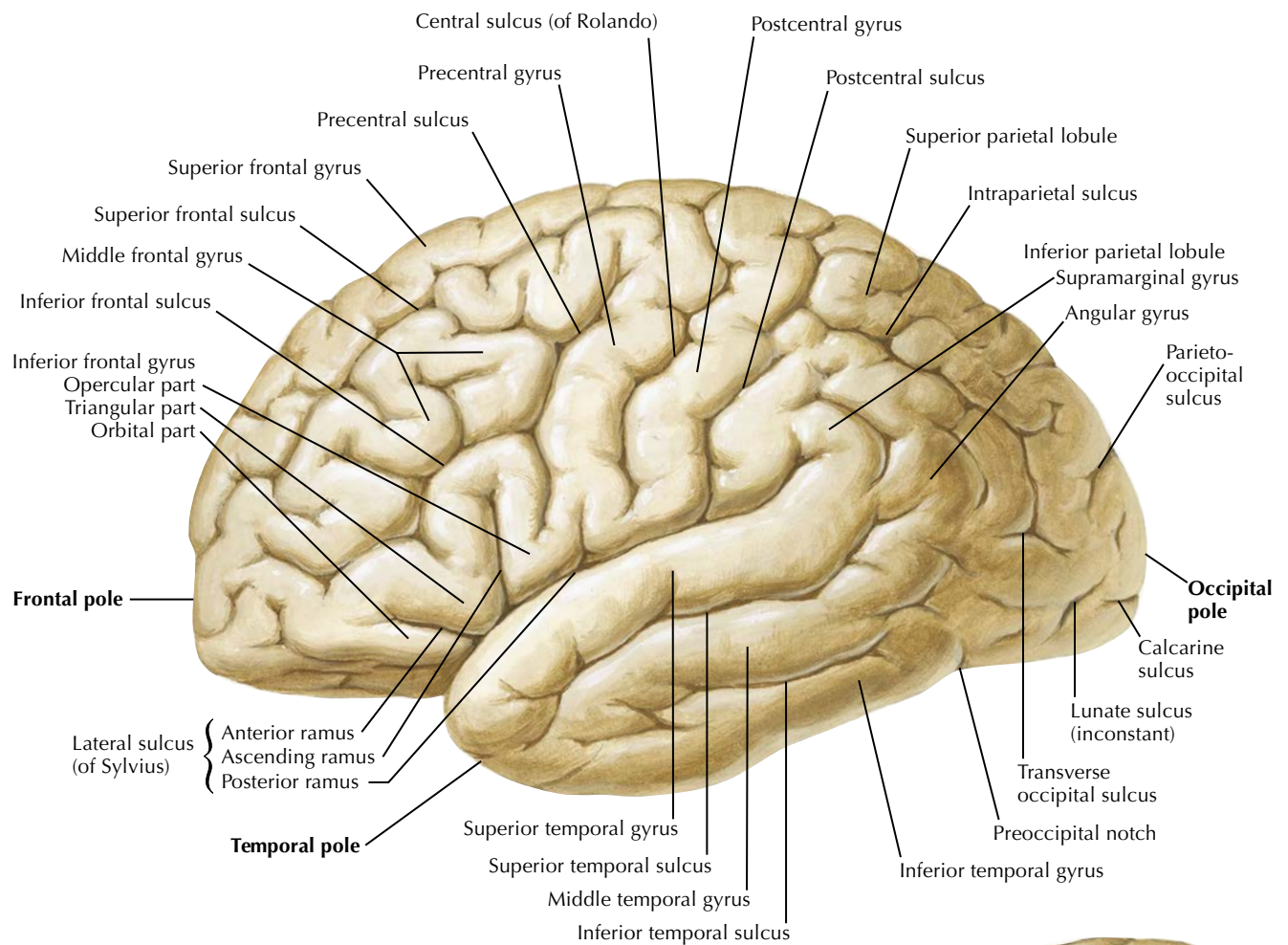
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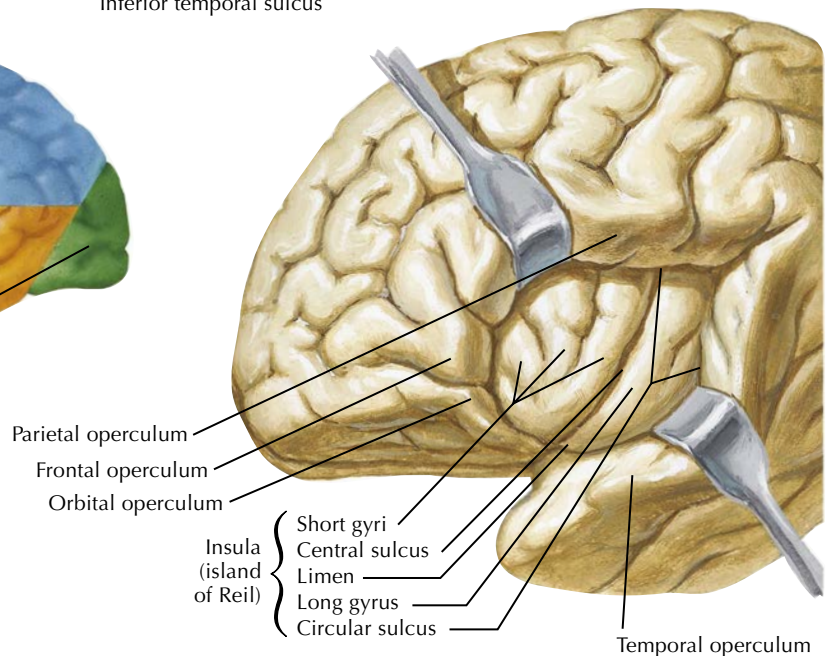
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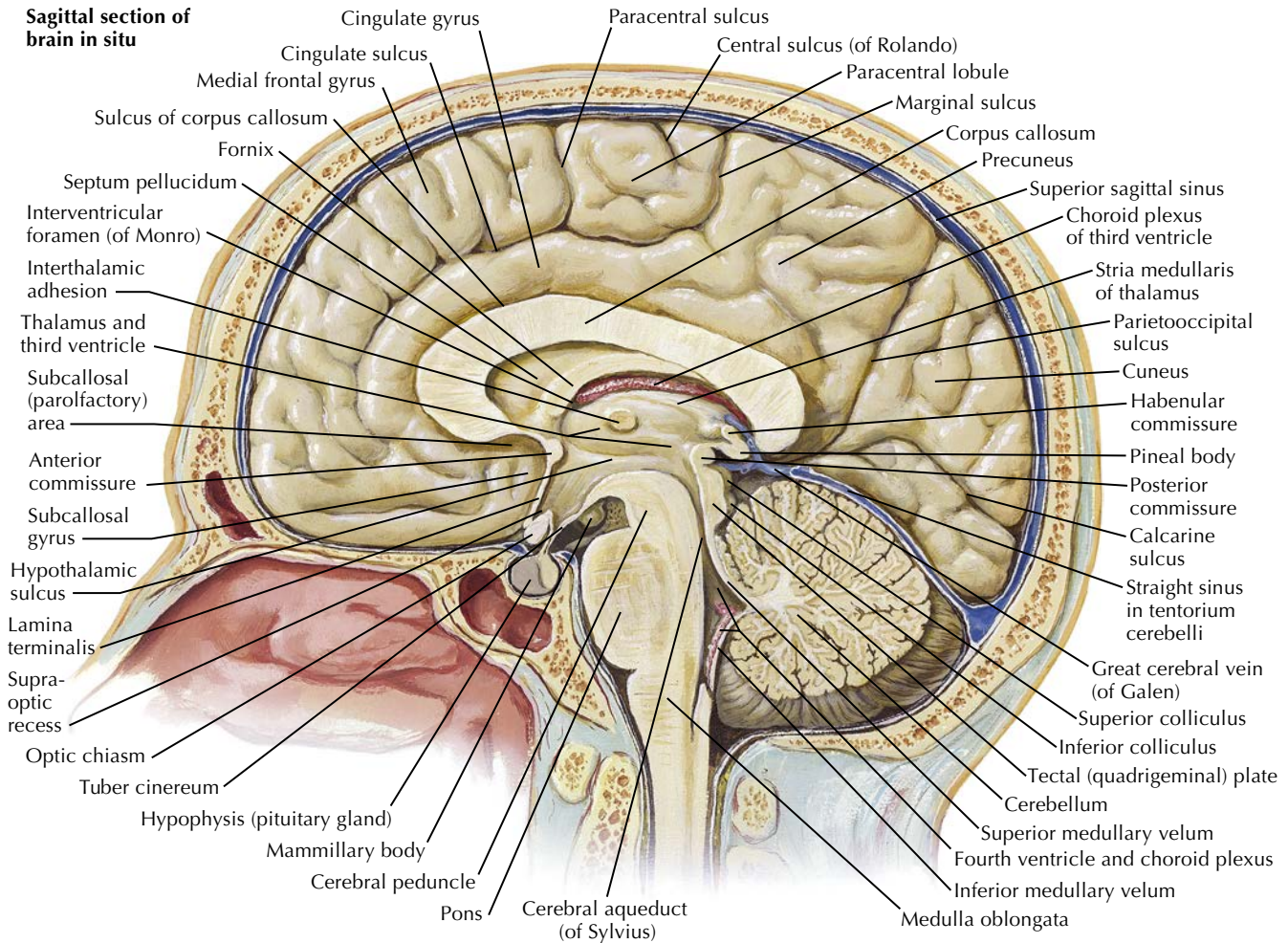


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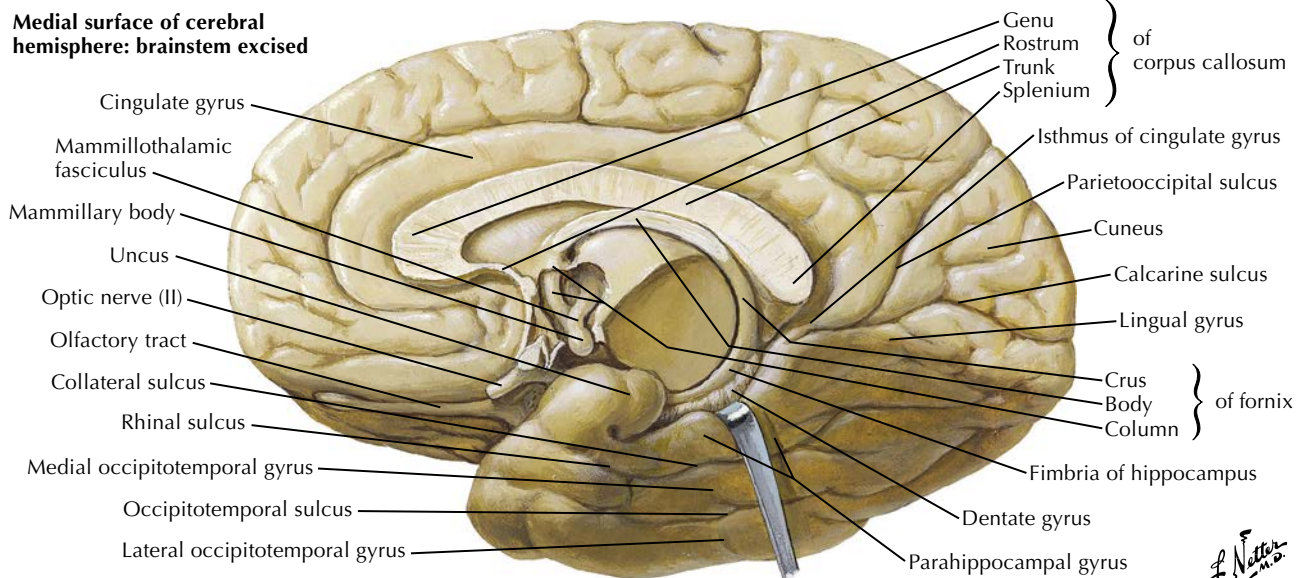


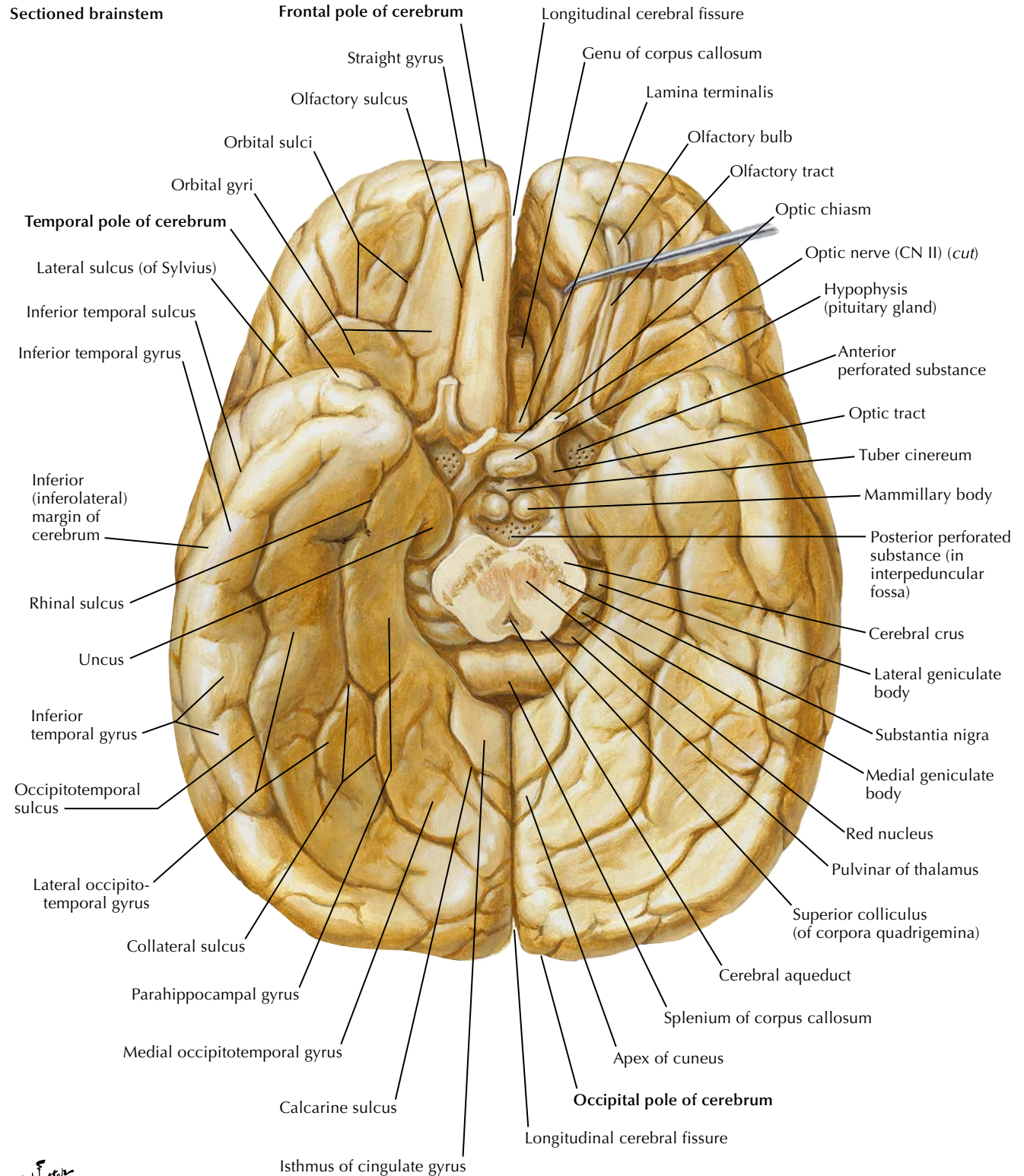
CEREBRUM: MEDIAL VIEWS

Sagittal section of brain in situ



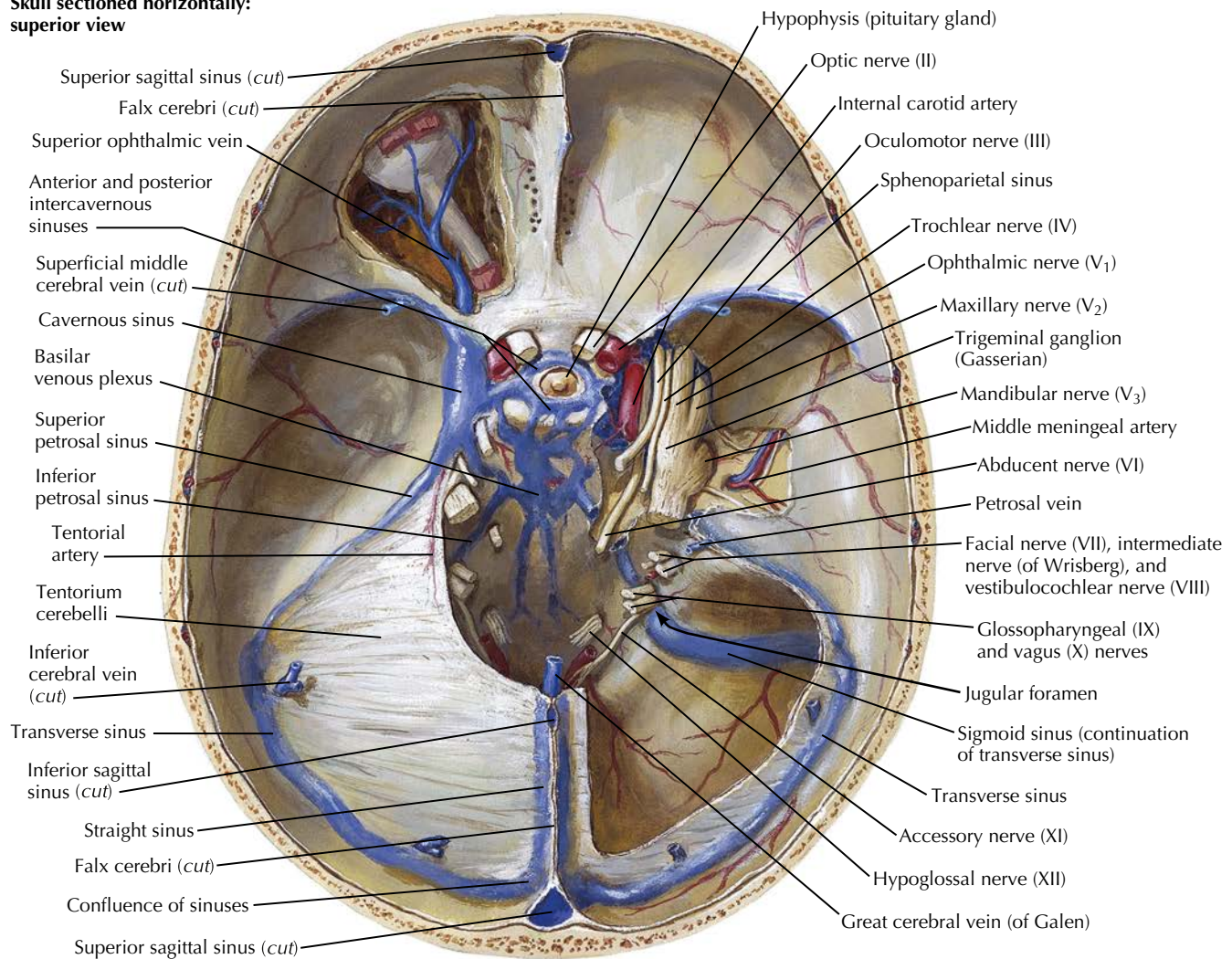
Medial surface of cerebral hemisphere: brainstem excised





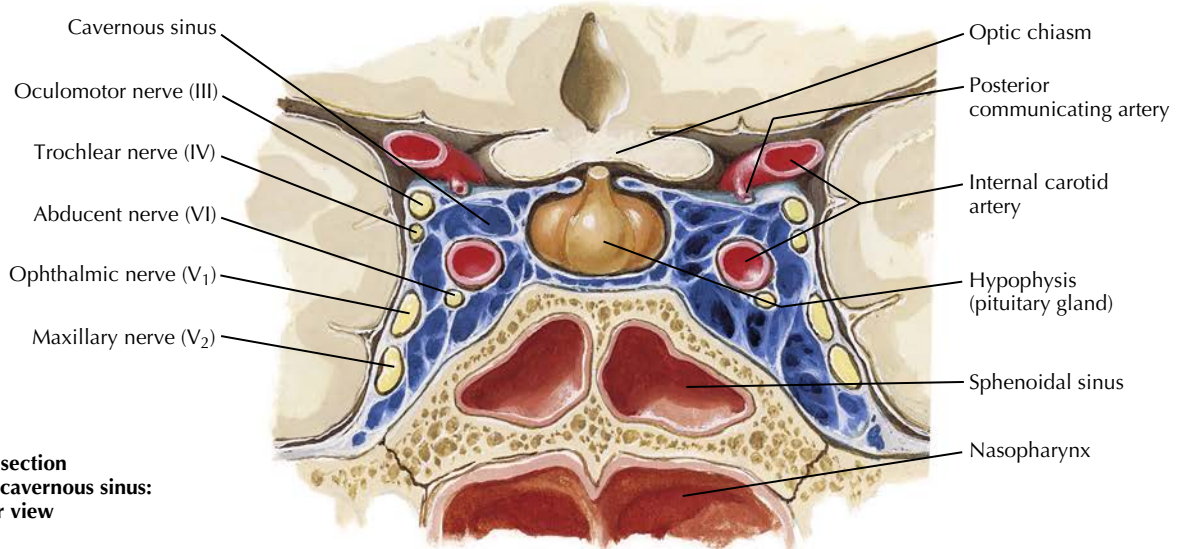
DURAL VENOUS SINUSES

Skull sectioned horizontally: superior view

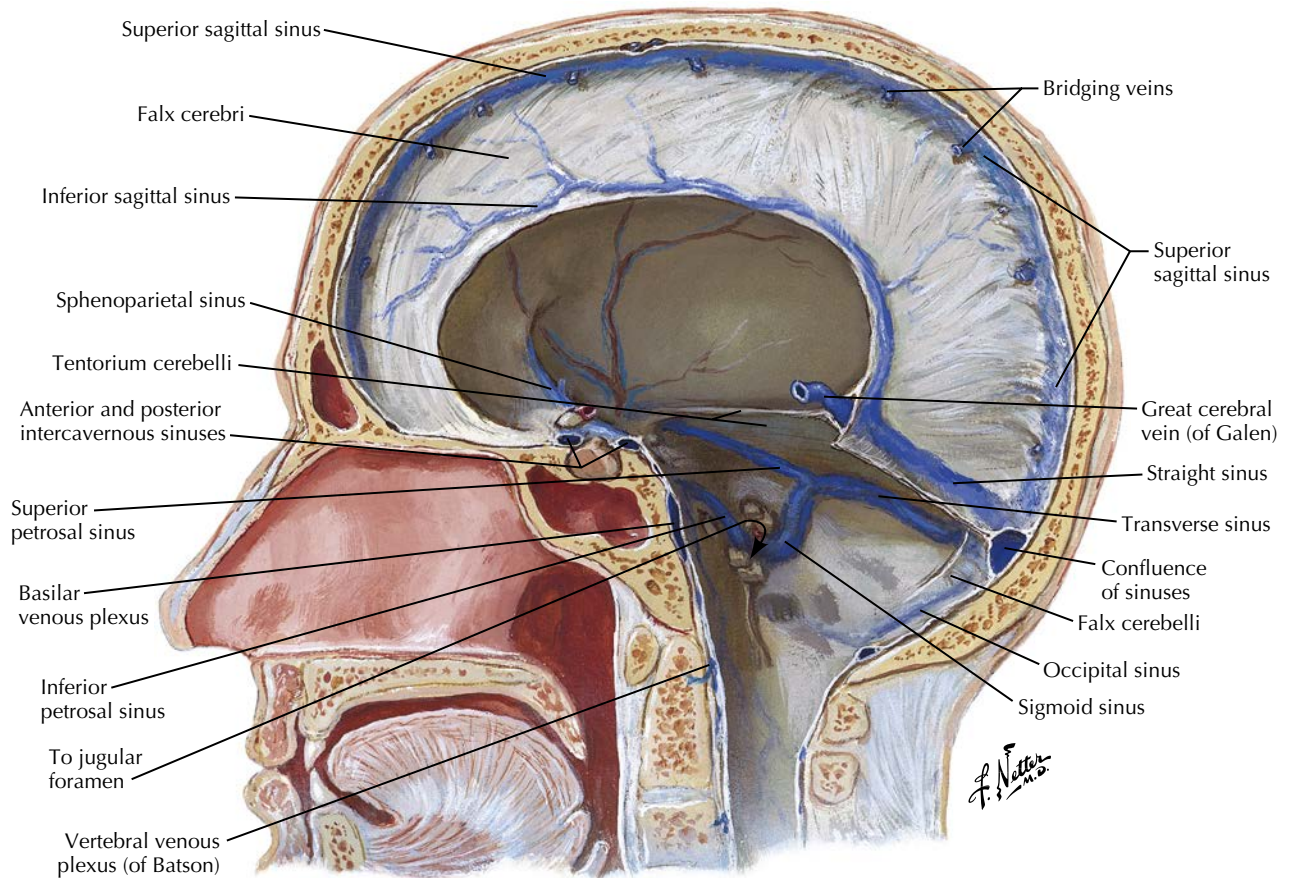


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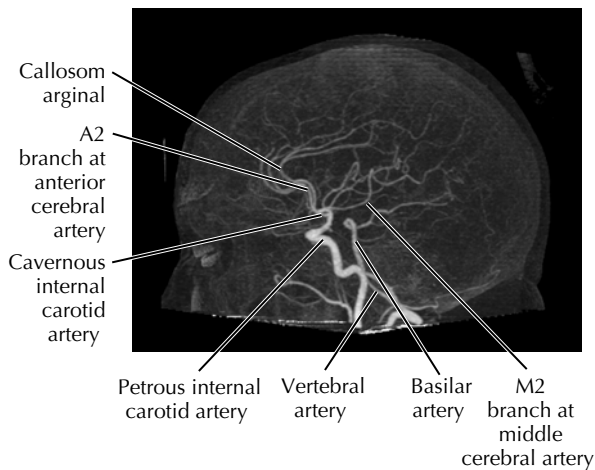
Coronal section through cavernous sinus: posterior view



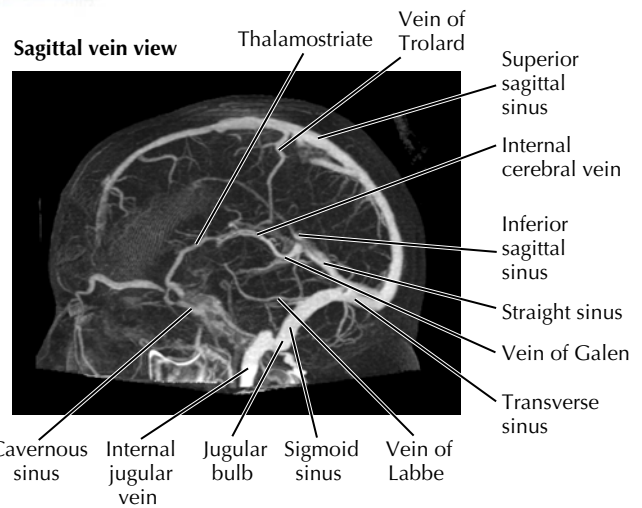
Sagittal section



Sagittal arterial view



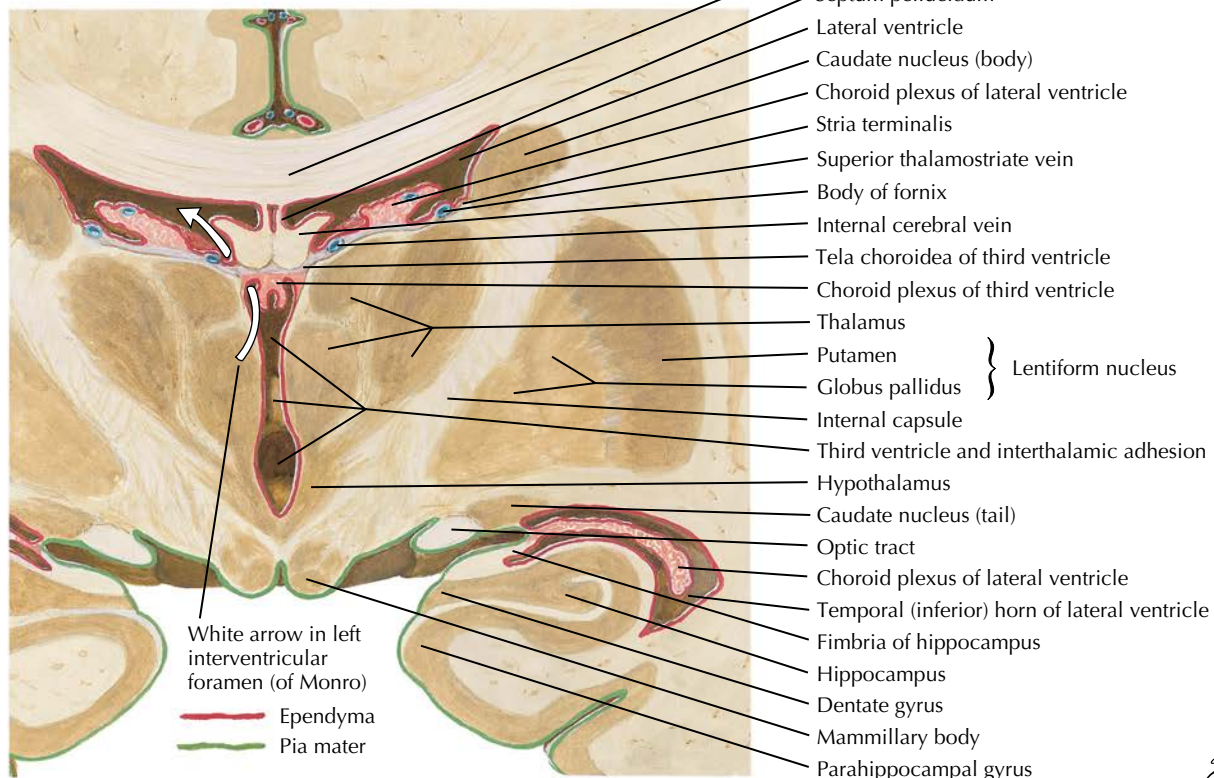
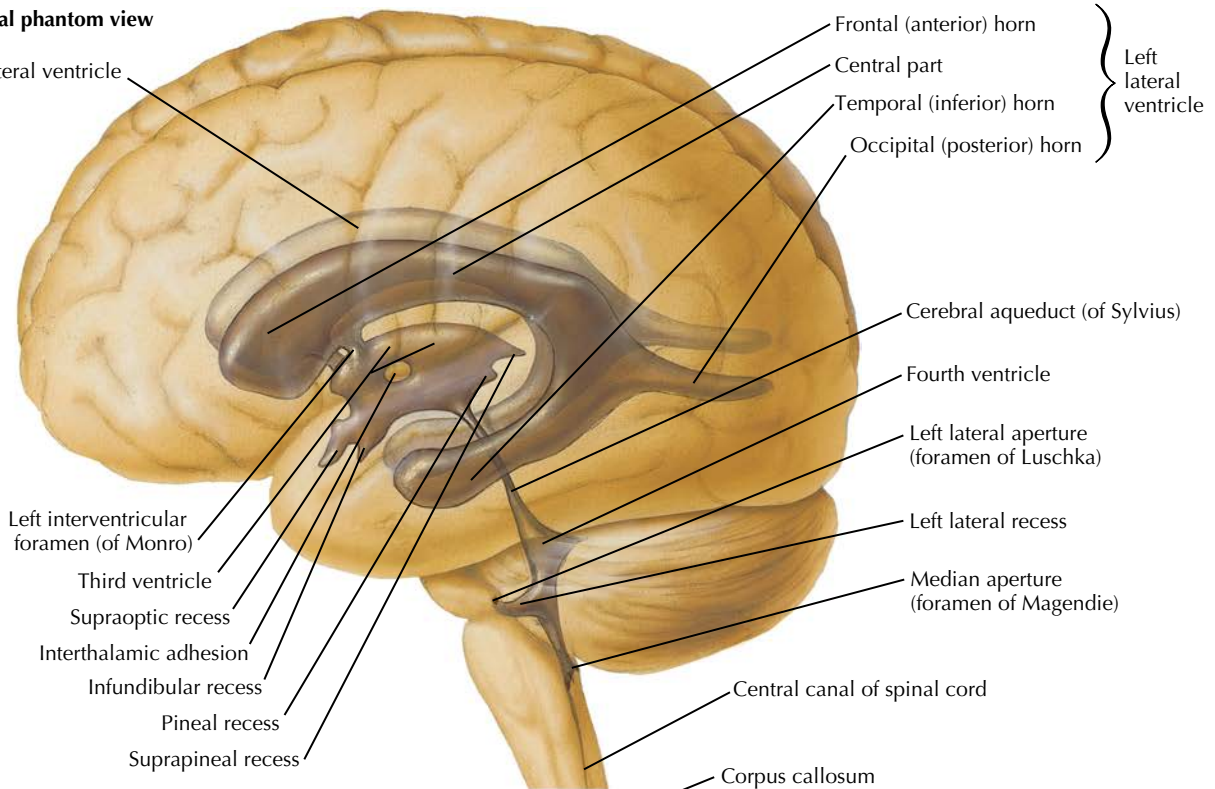
Sagittal vein view



VENTRICLES OF BRAIN

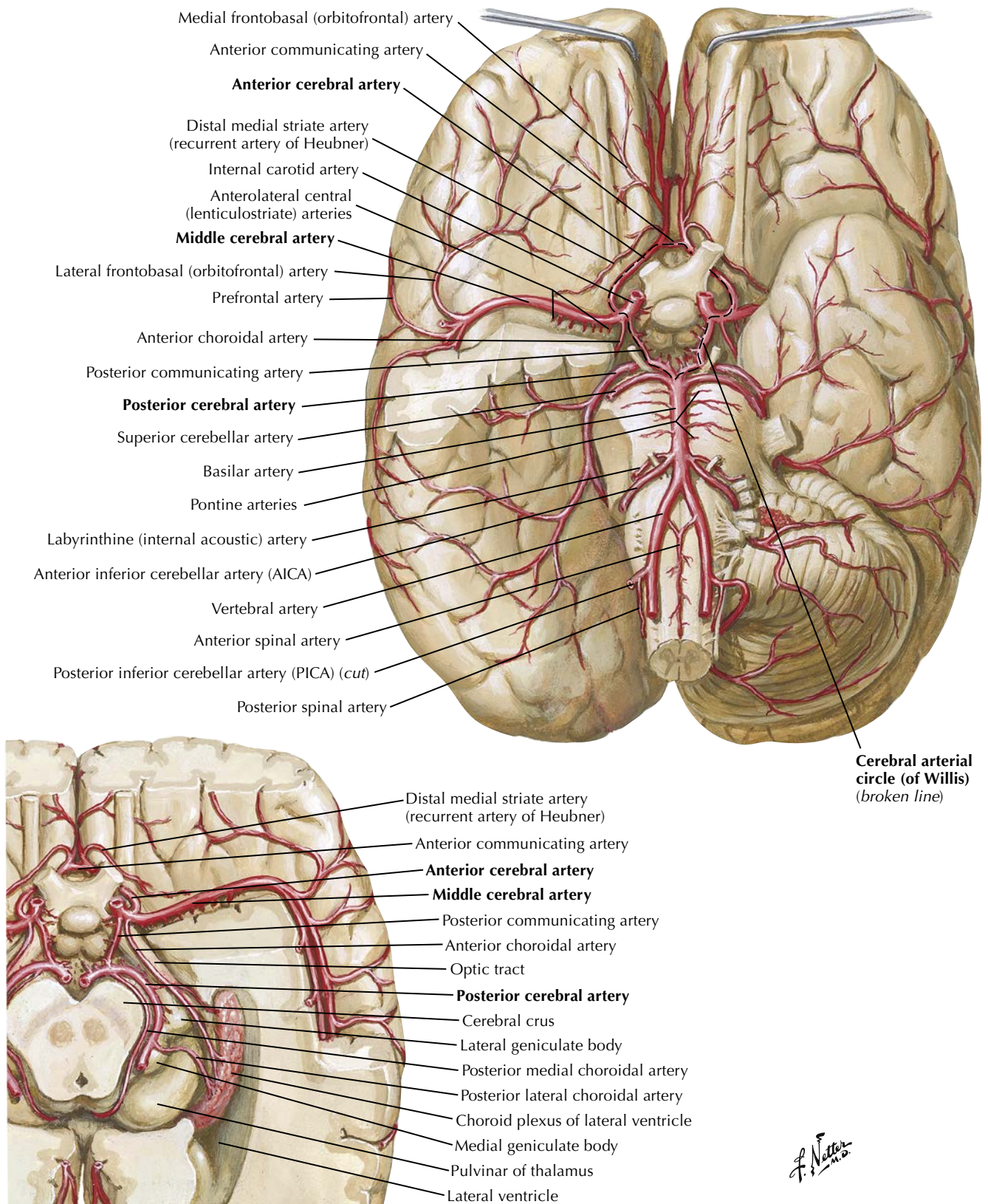
Left lateral phantom view

Right lateral ventricle



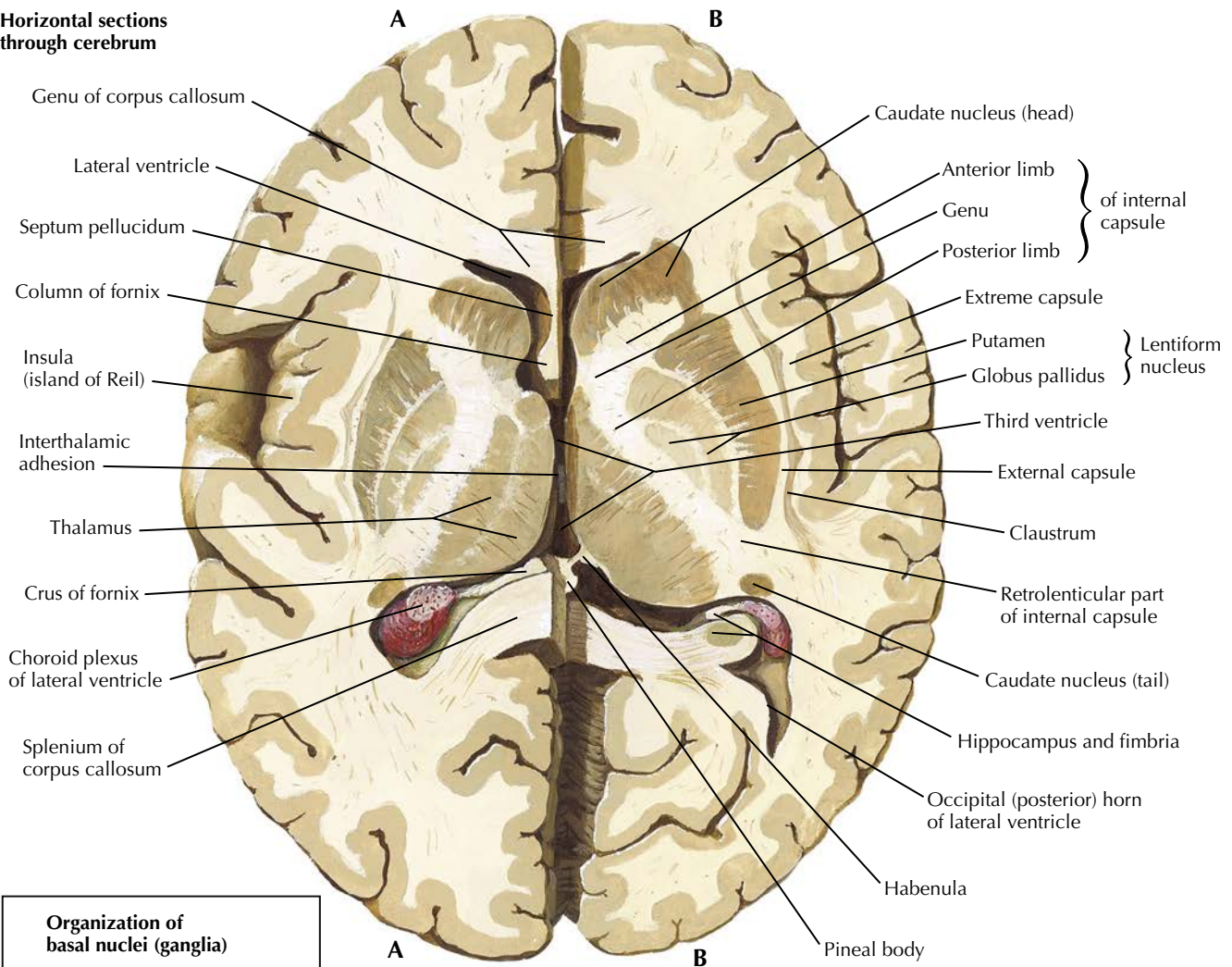
Coronal section of brain: posterior view

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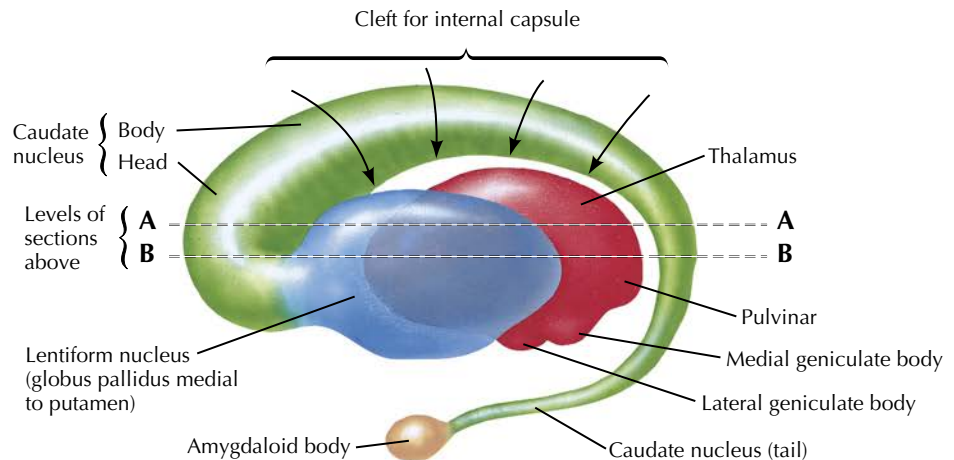
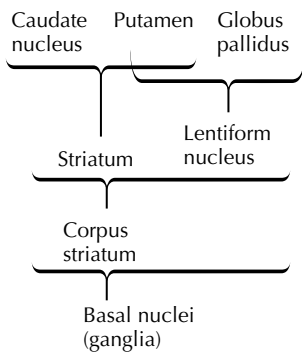


BASAL NUCLEI (GANGLIA)

Horizontal sections through cerebrum

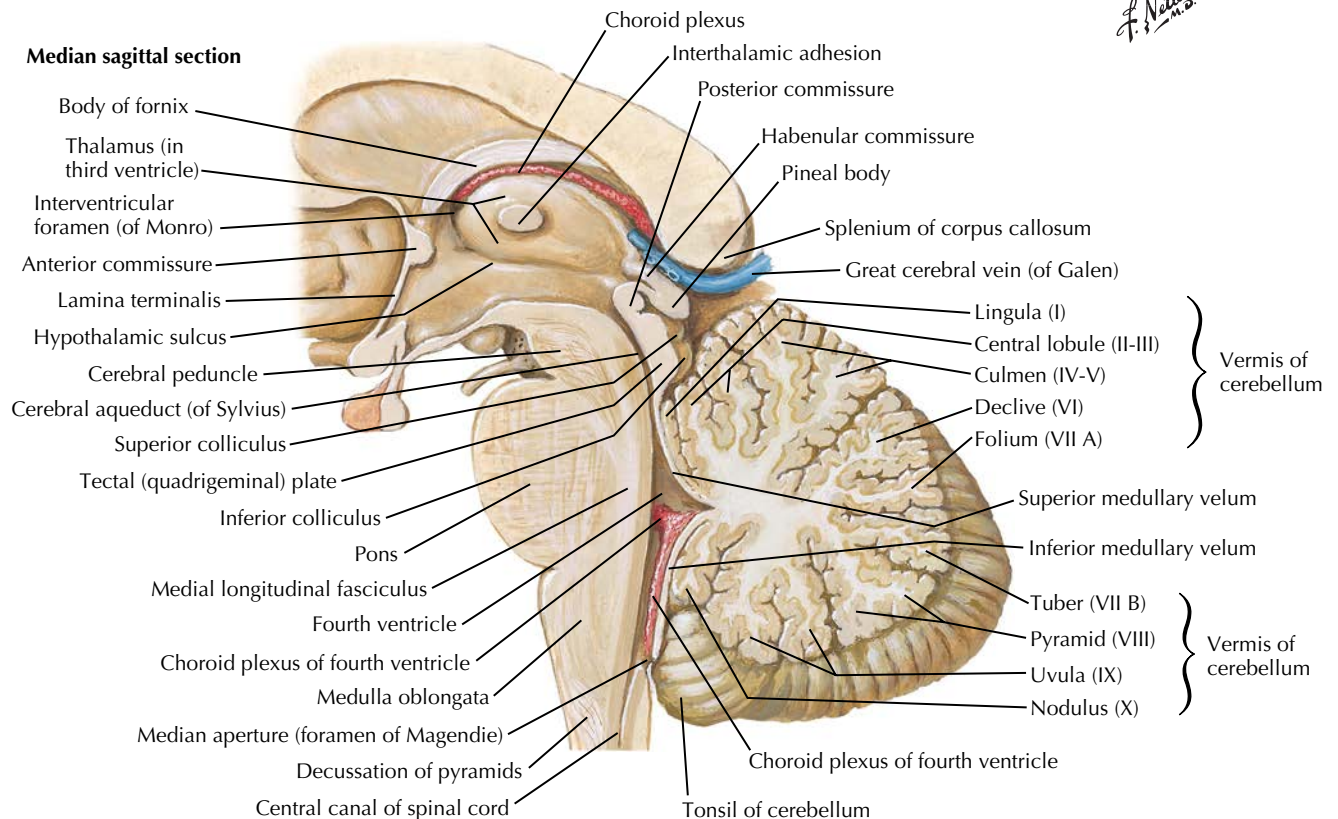
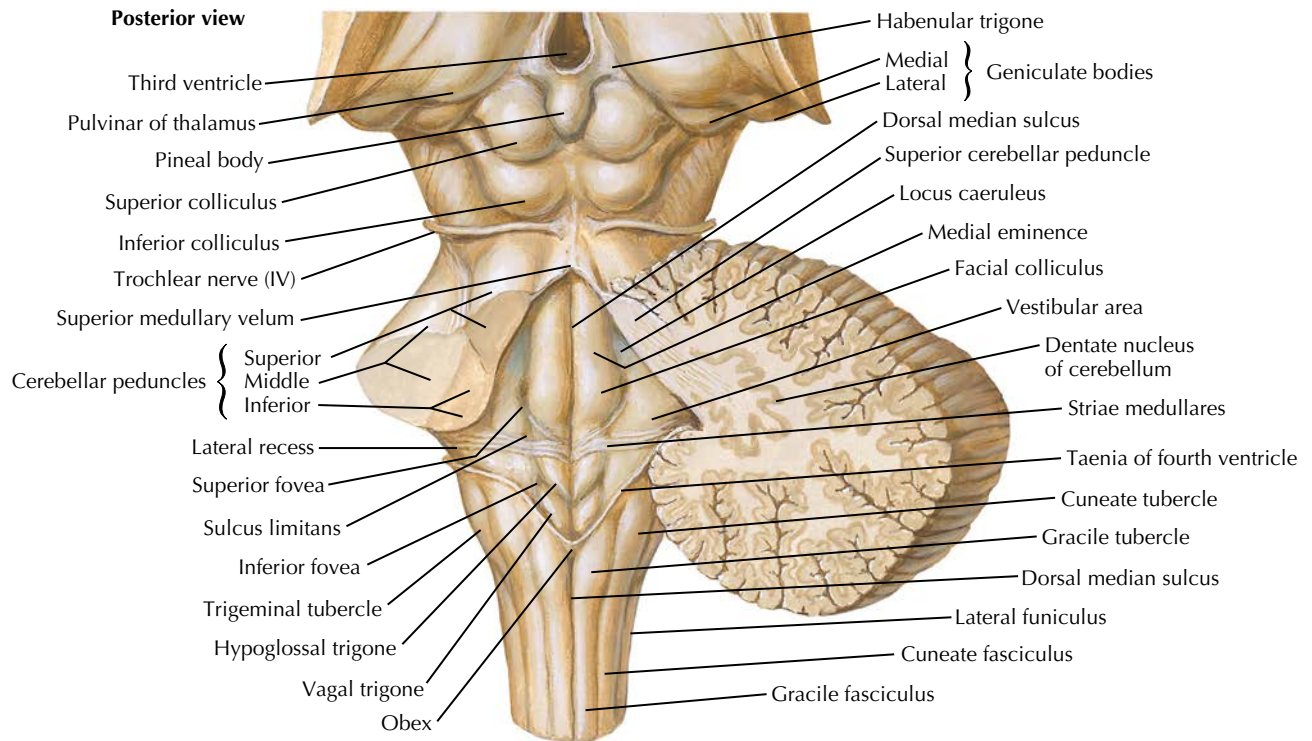


Organization of basal nuclei (ganglia)

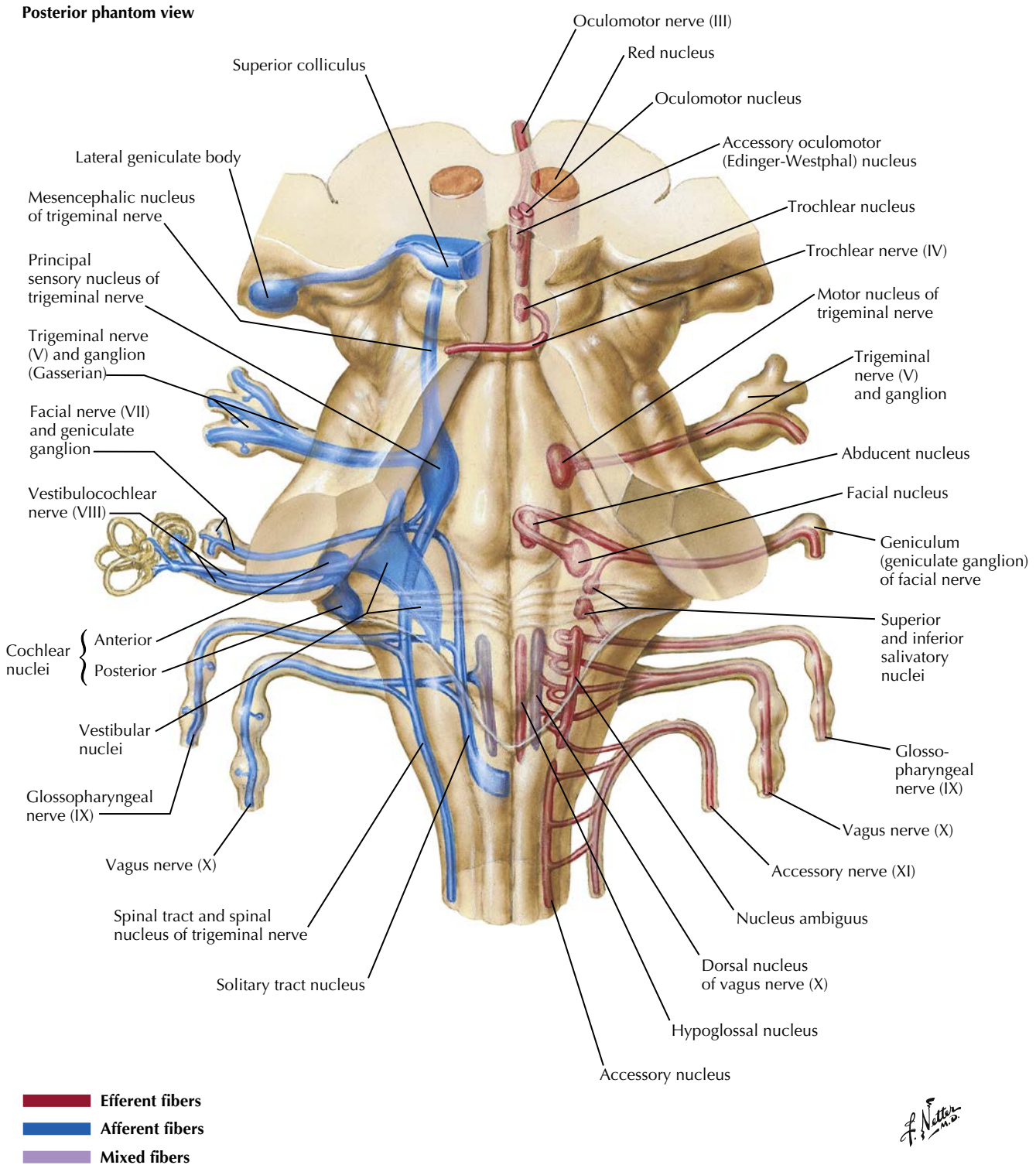


Interrelationship of thalamus, lentiform nucleus, caudate nucleus, and amygdaloid body (schema): left lateral view

F. Netter M.D.

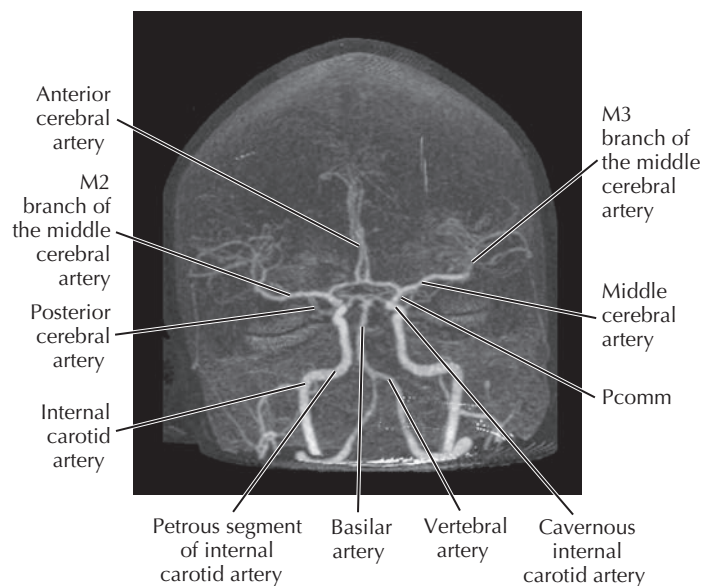


CRANIAL NERVE NUCLEI IN BRAINSTEM: SCHEMA

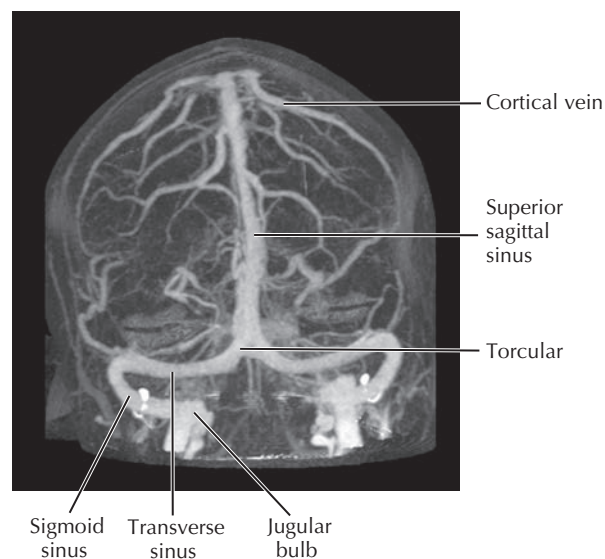


F. Netter M.D.

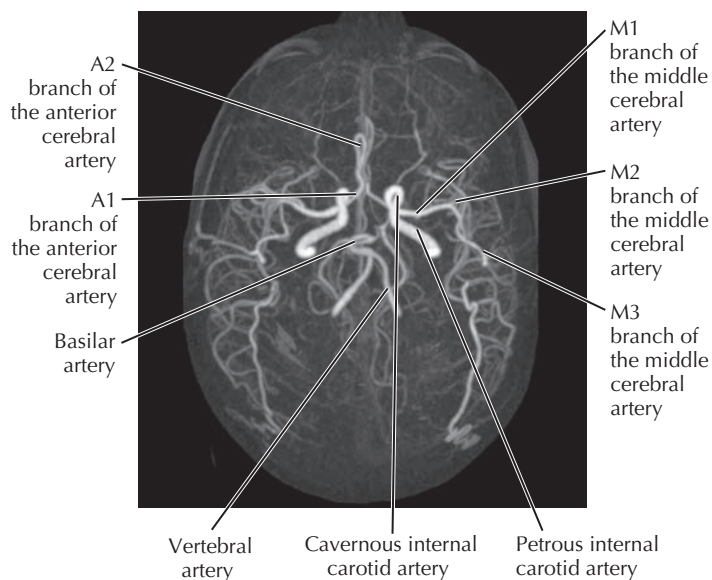
Coronal arterial view



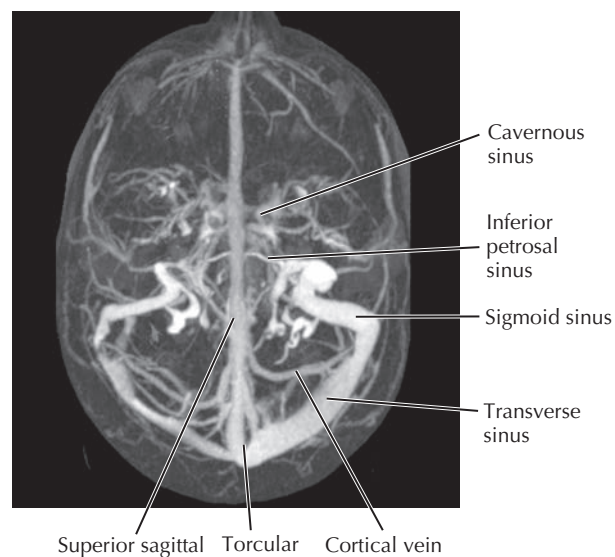
Coronal venous view



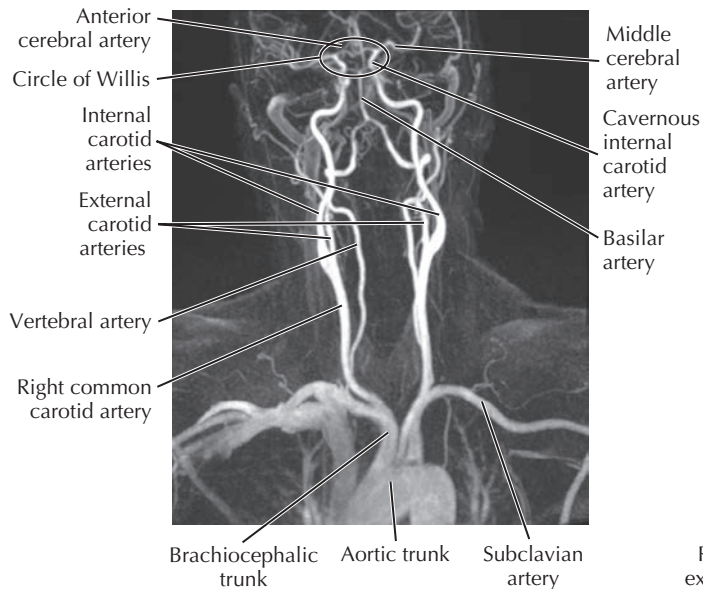
Axial arterial view



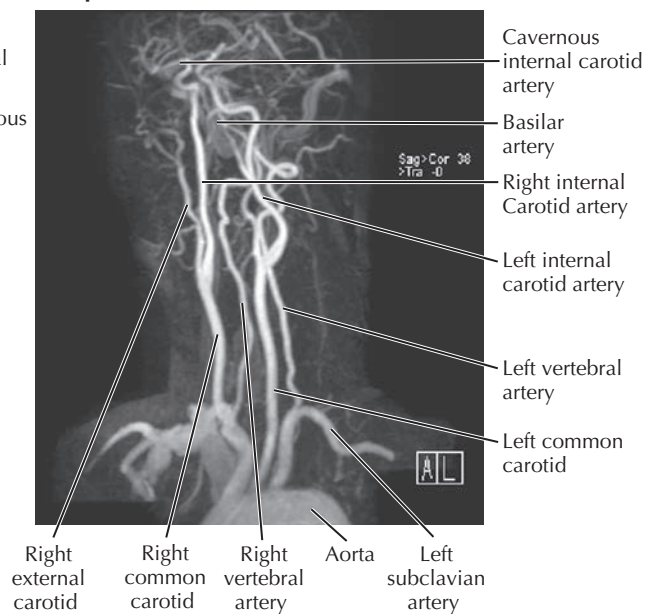
Axial venous view



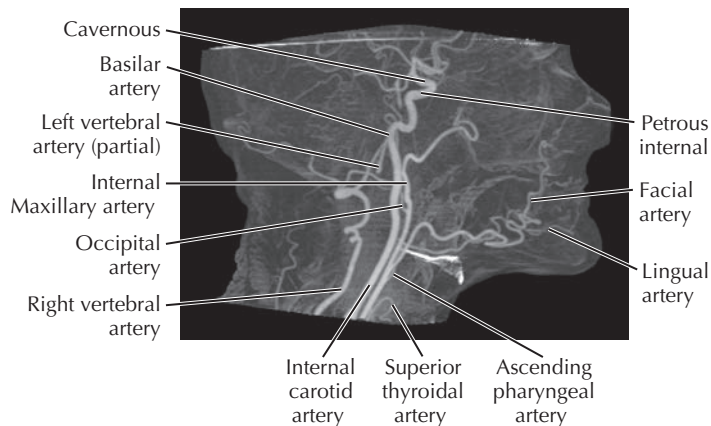
Frontal arterial neck view



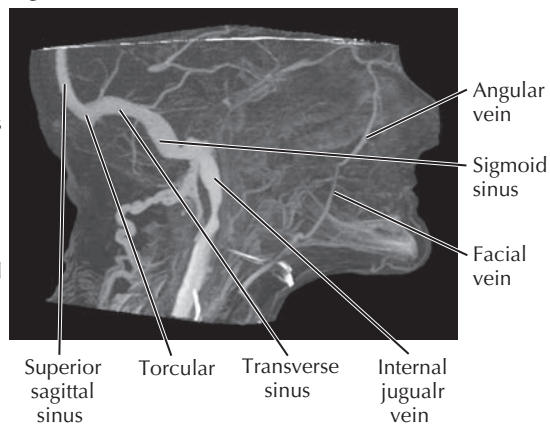
Oblique arterial neck view



Sagittal facial artery view



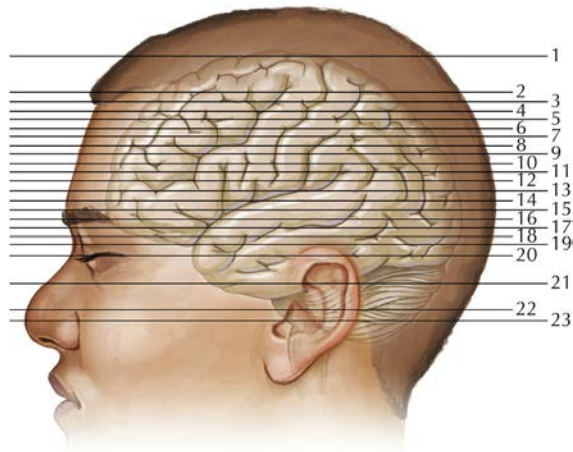
Sagittal facial veins view



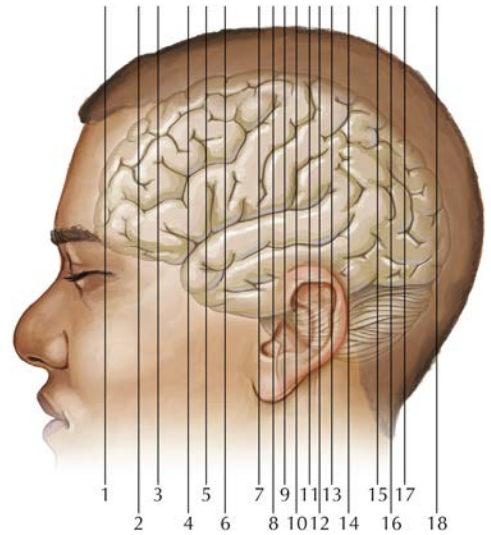
Chapter

2

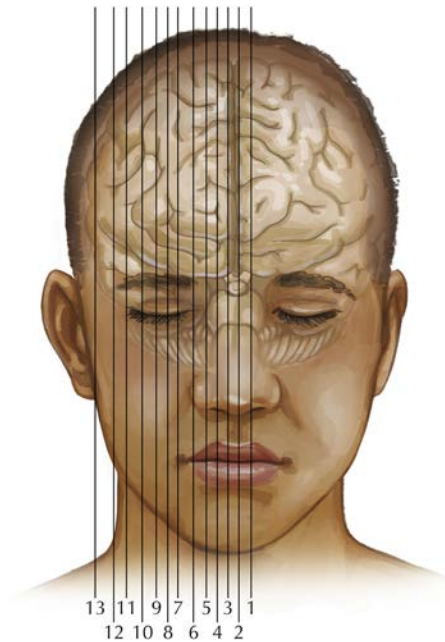
BRAIN



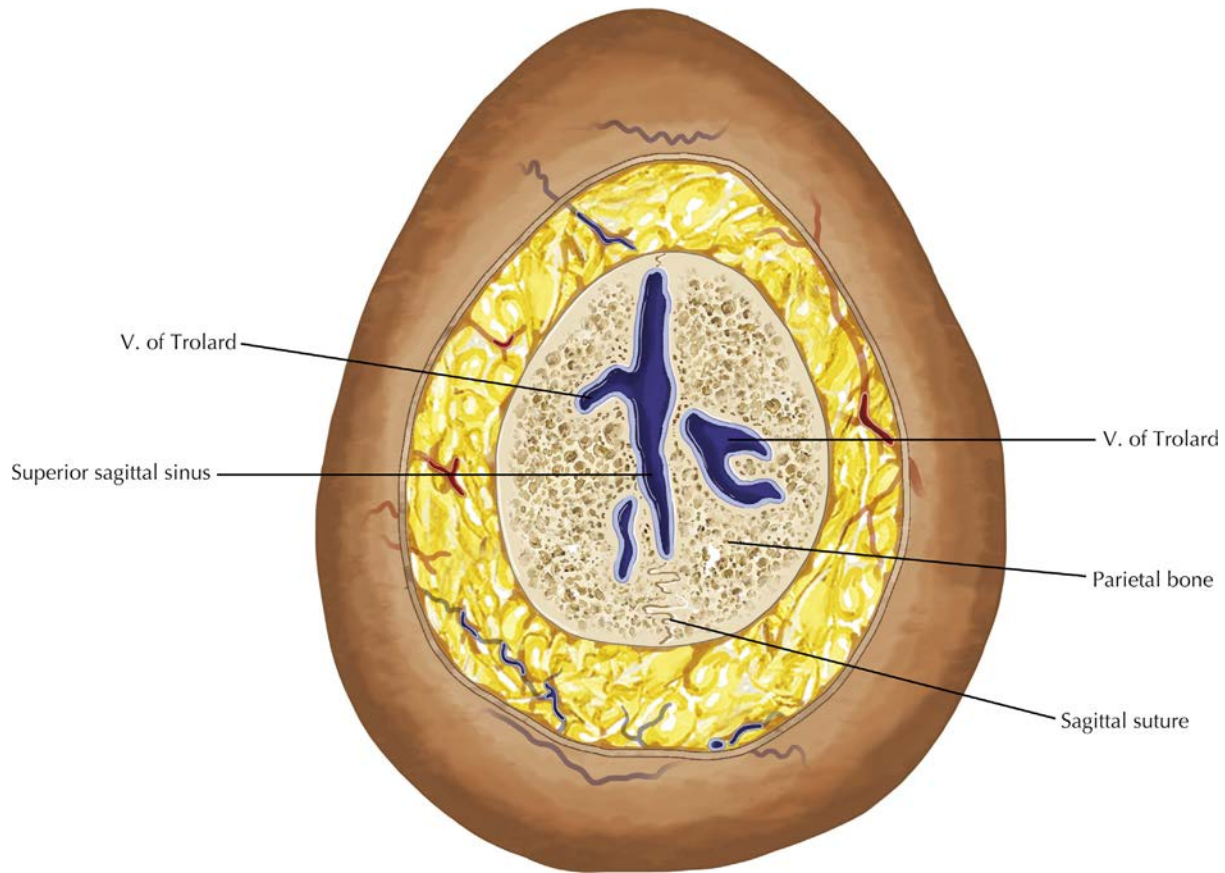
AXIAL 16



CORONAL 62



SAGITTAL 98



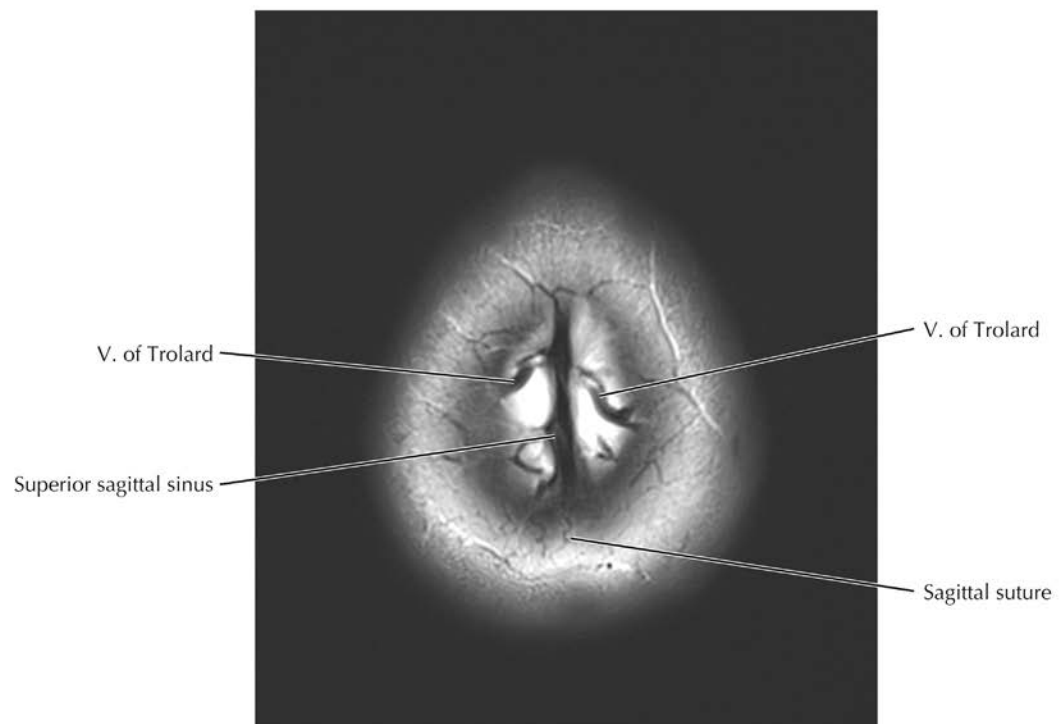
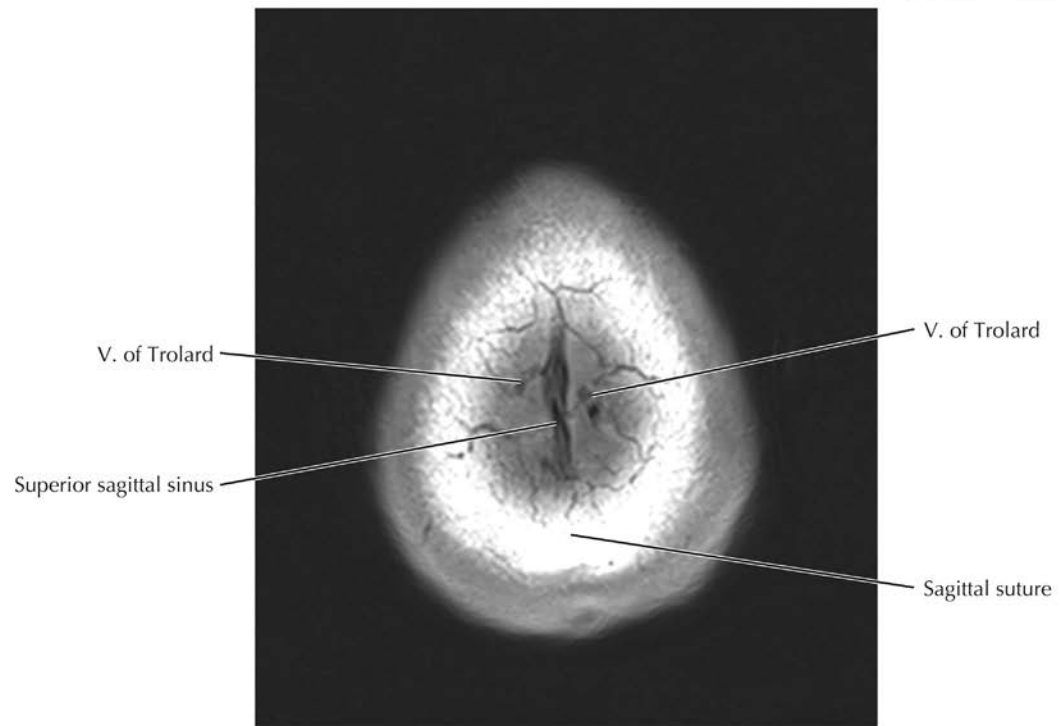
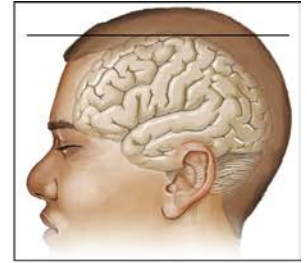
NORMAL ANATOMY

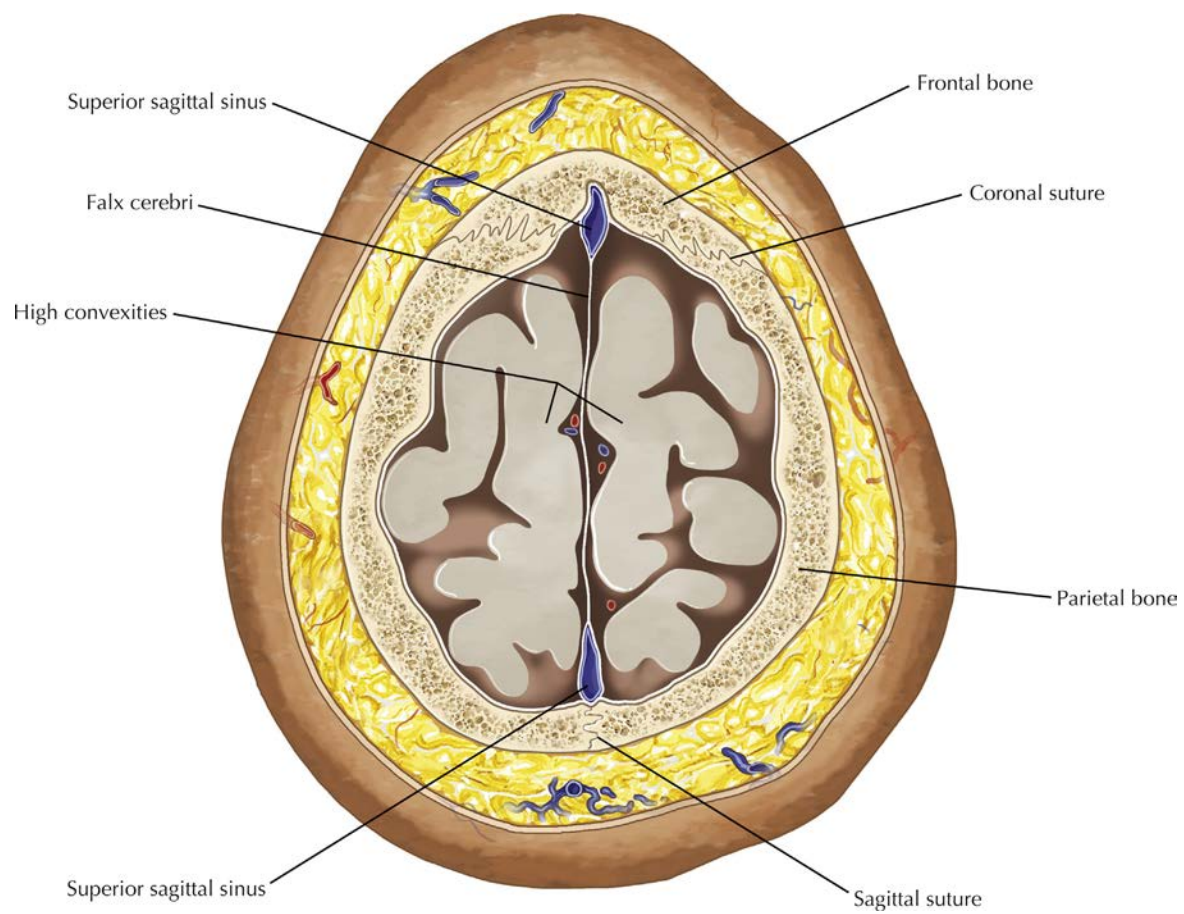
Named after the French anatomist Paulin Trolard (1842–1910) and also known as the superior anastomotic vein, the vein of Trolard is the largest cortical vein at the convexity (see also Brain Coronal 15). The vein of Trolard anastomoses with the middle cerebral vein and the superior sagittal sinus.

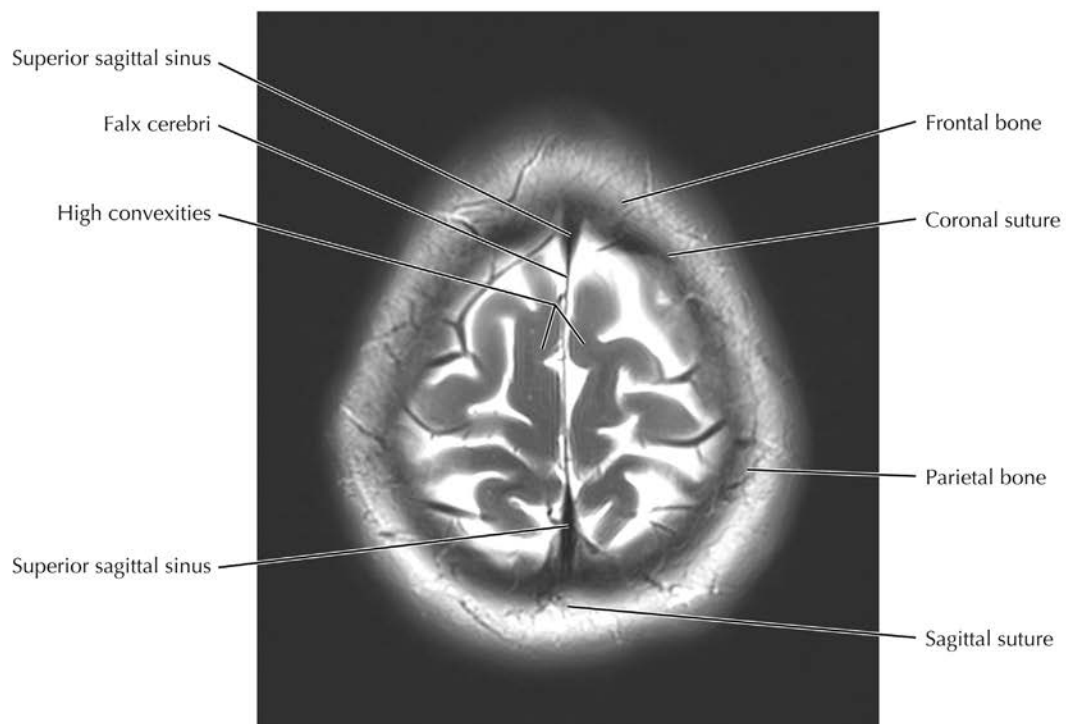
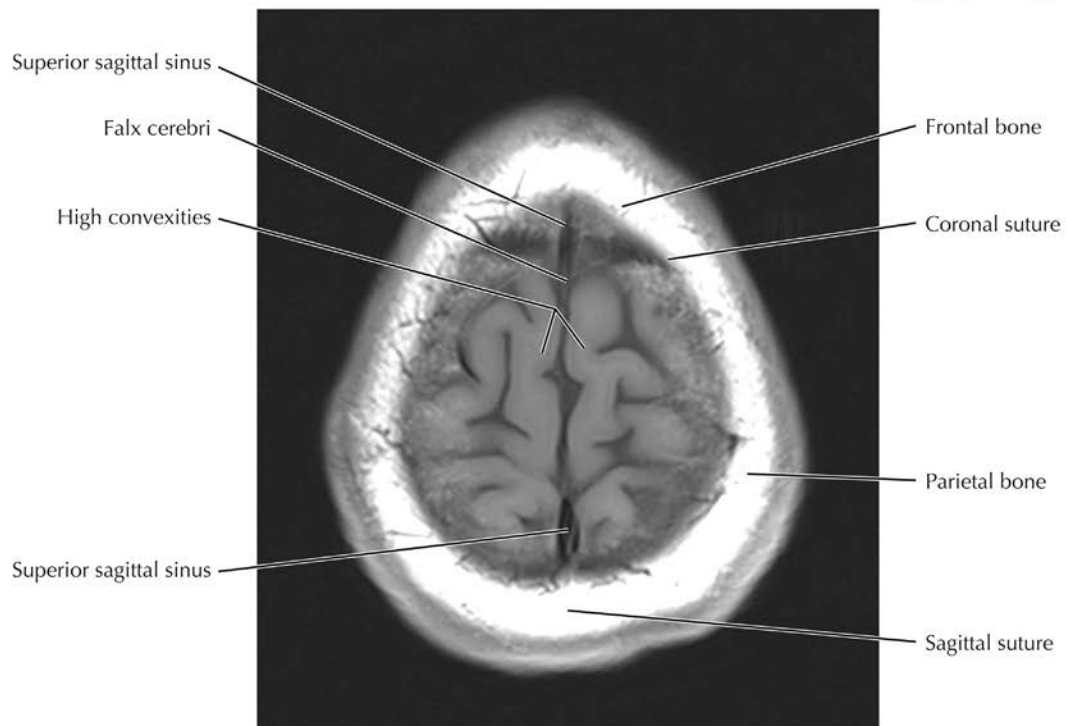
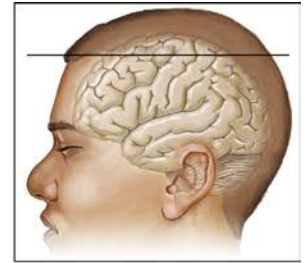
Note the first cranial nerves, the olfactory nerves, in the olfactory grooves along the medial inferior floor of the anterior cranial fossa. Please note there is volume averaging of cortical veins with the top of the calvaria such that the veins artifactually appear to be within the bone rather than within the cranial vault (see Brain Coronal 2).

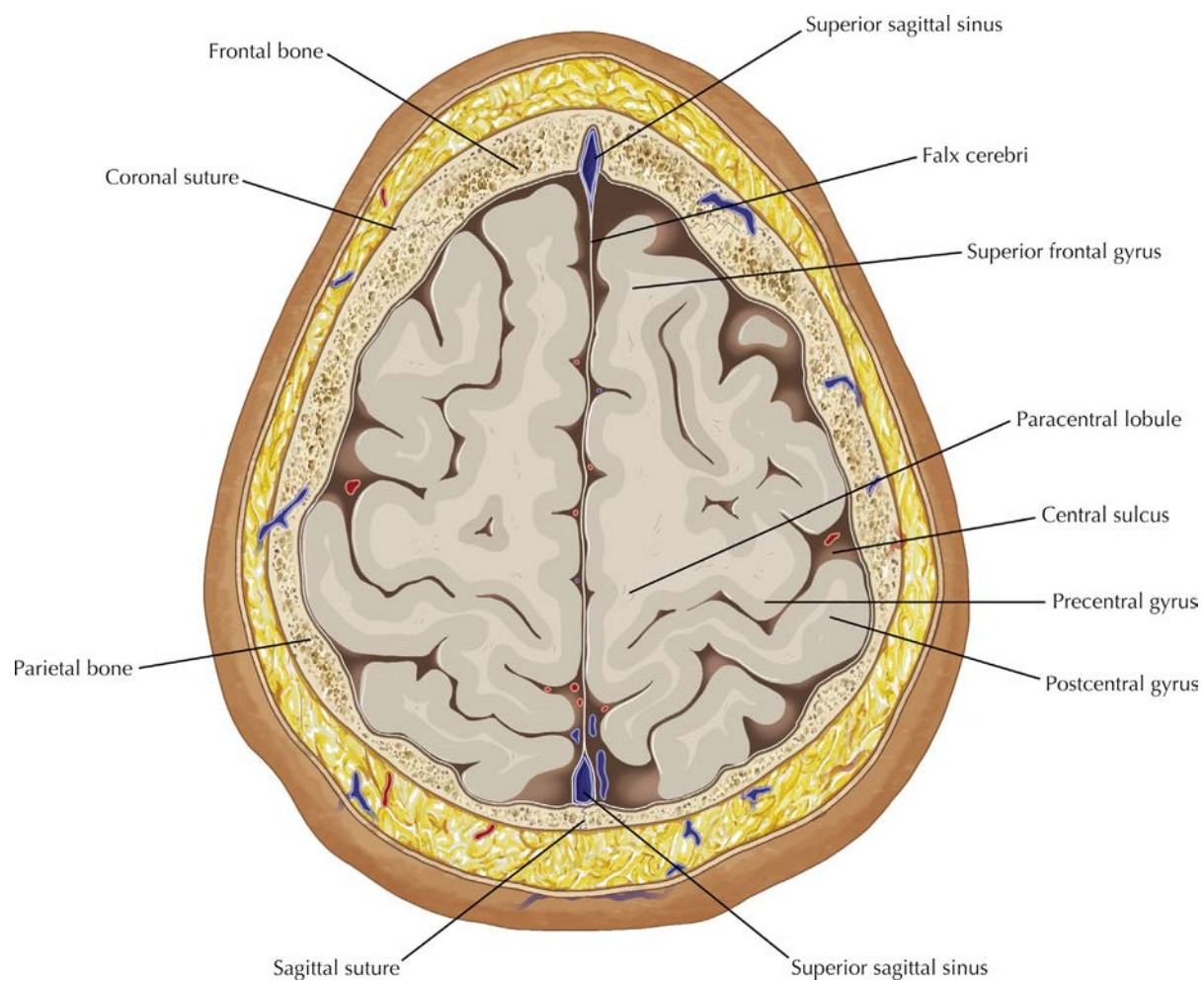
DIAGNOSTIC CONSIDERATION

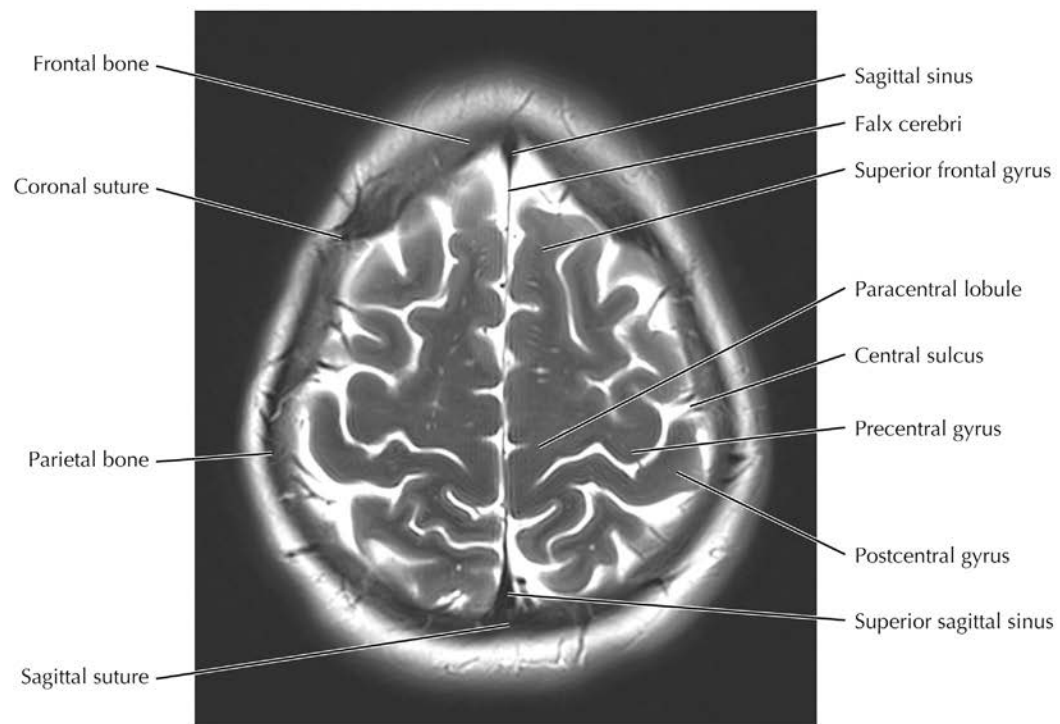
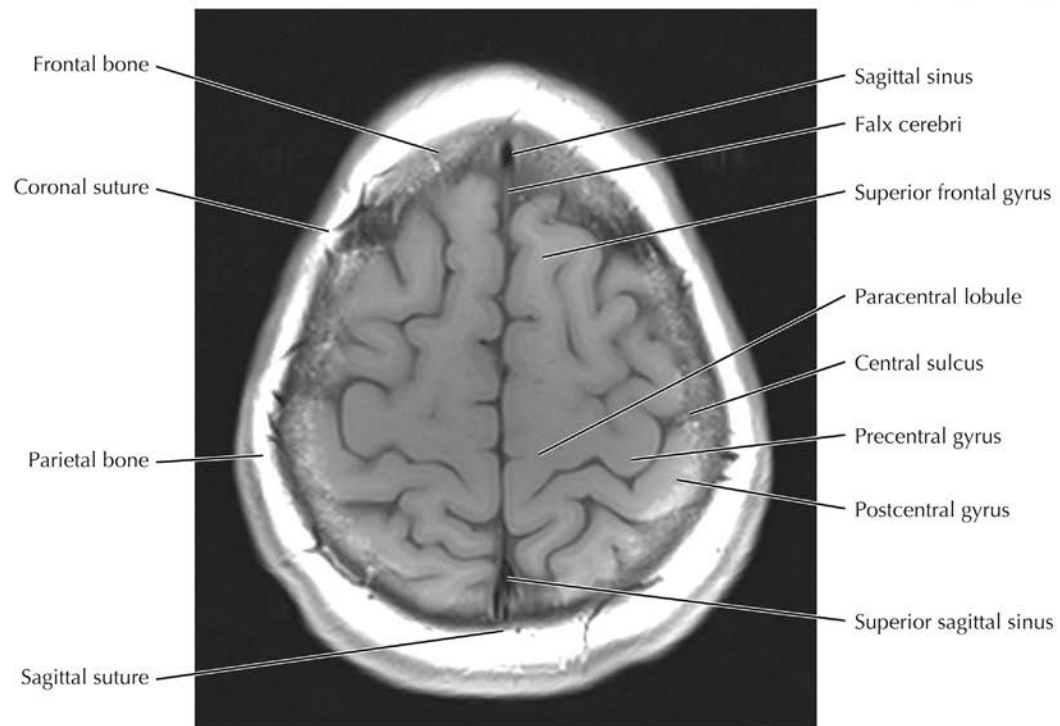
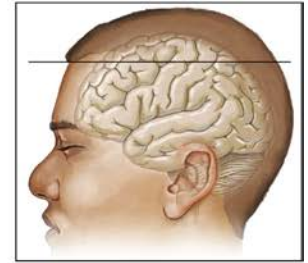
A lesion, such as a metastatic lesion in the marrow, can often be missed at the vertex (vertex crani). Diffusion-weighted magnetic resonance imaging (MRI) is often useful in identifying such lesions, not because the lesion is diffusion restricted, but because all the other structures are often low in signal, making the lesion conspicuously bright. The same principle holds for the base of the skull, where the presence of many structures can make pathologic lesions easy to overlook.

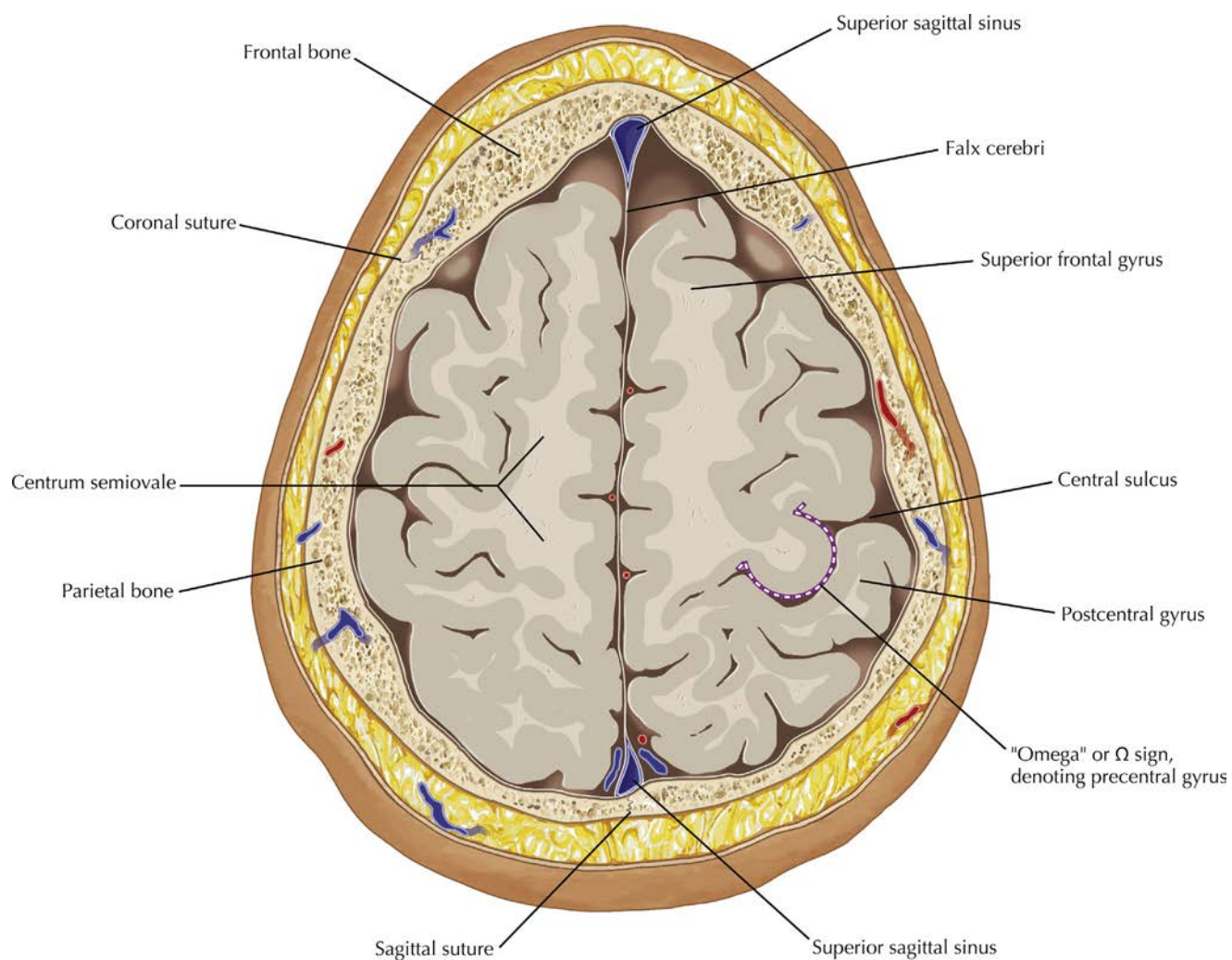


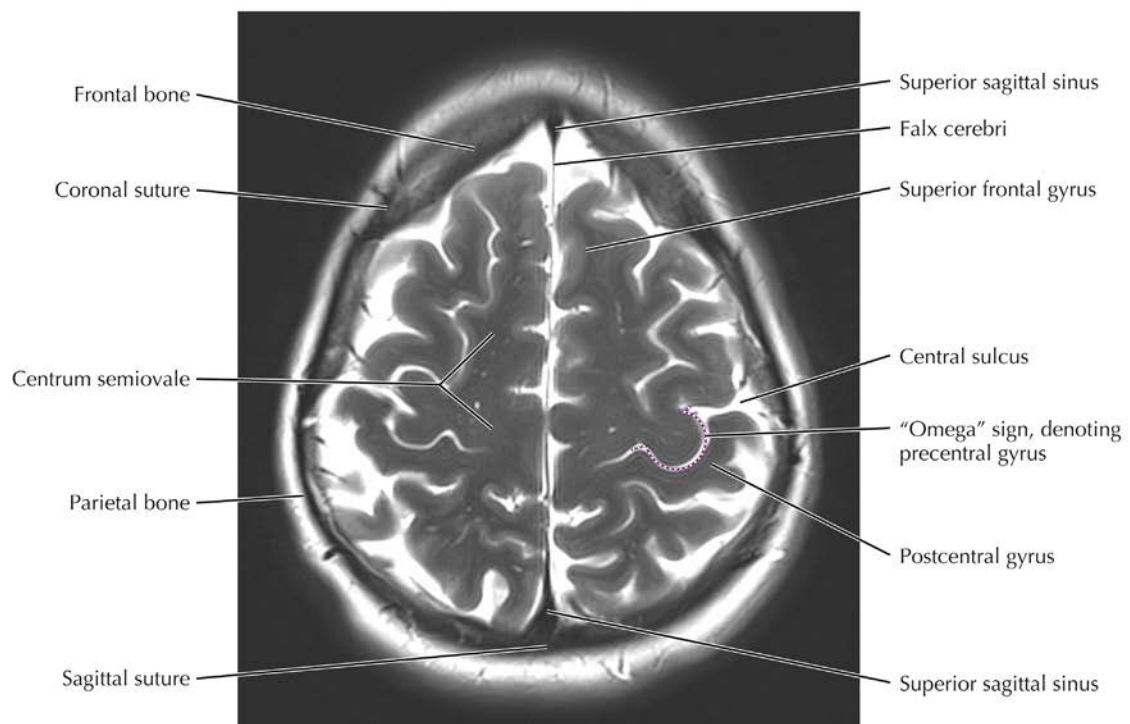
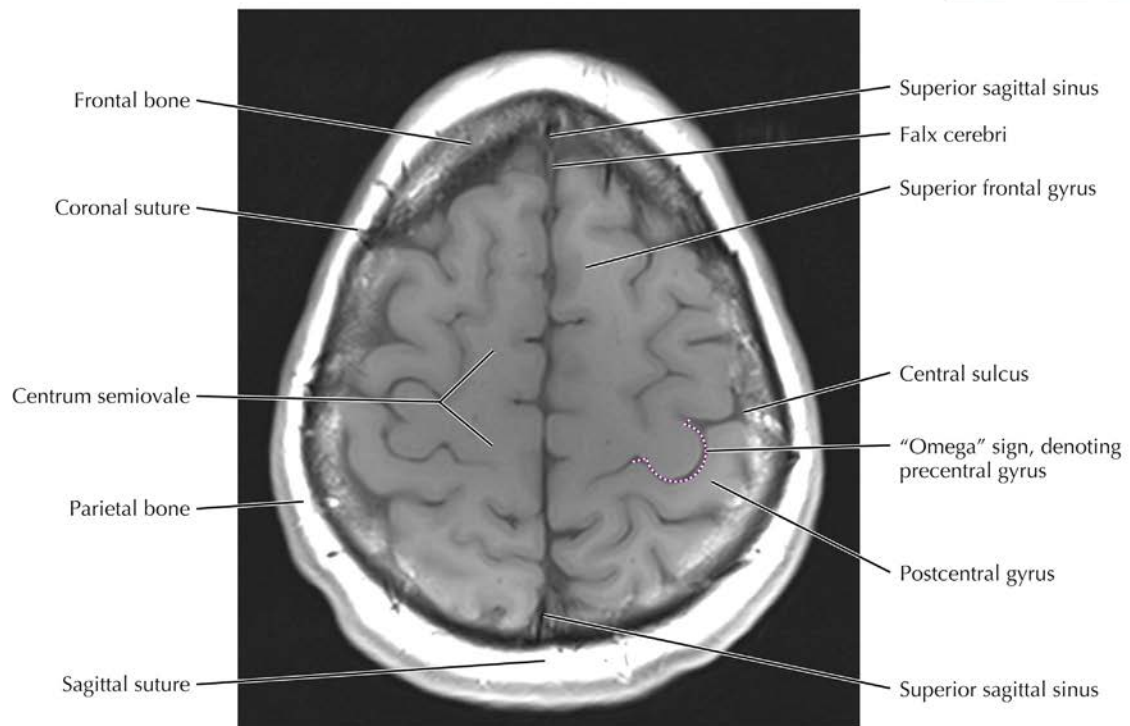
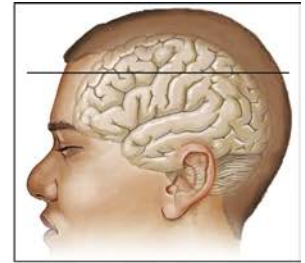


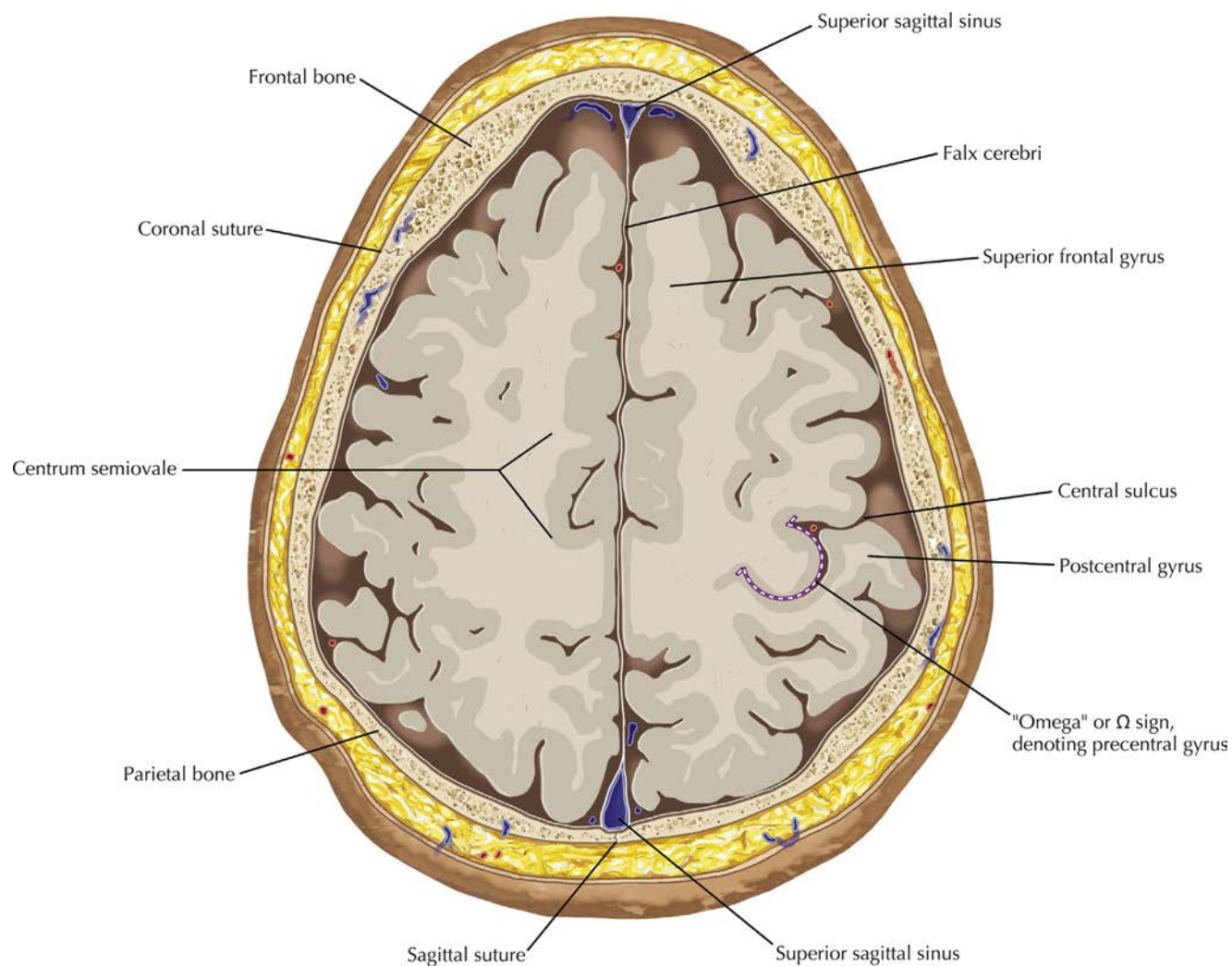






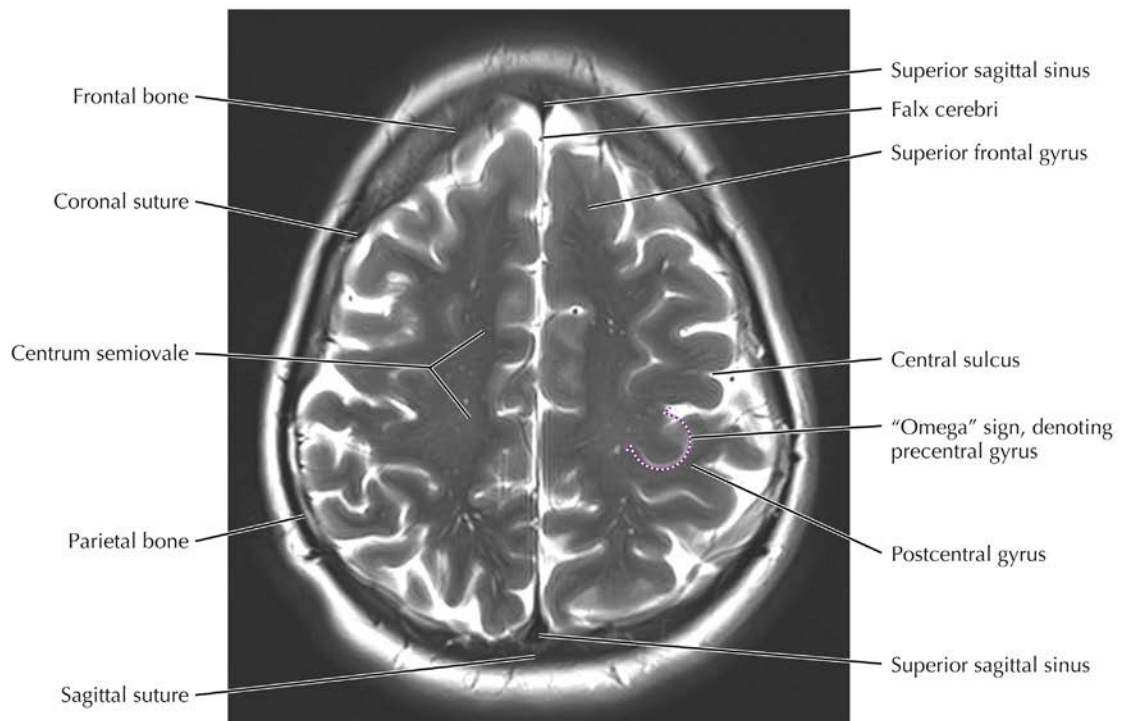
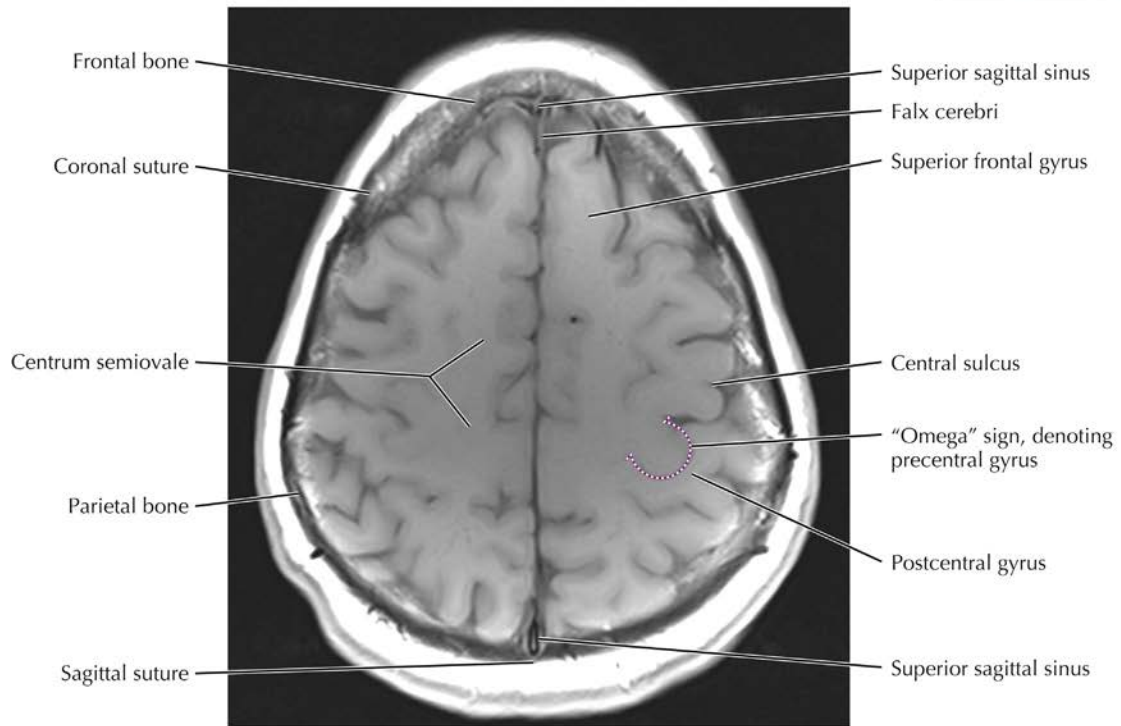
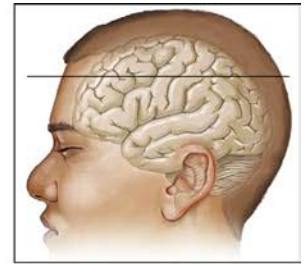


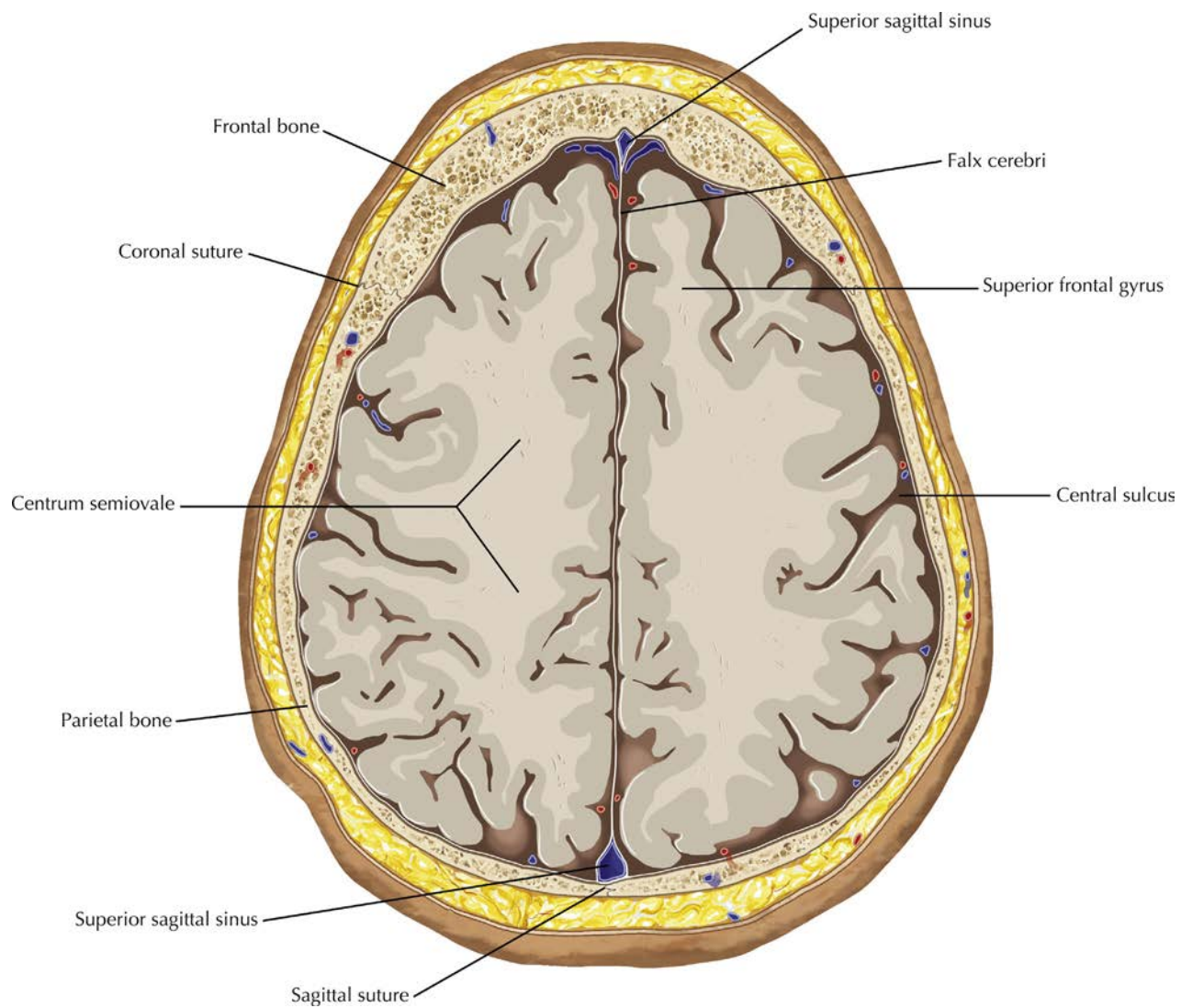


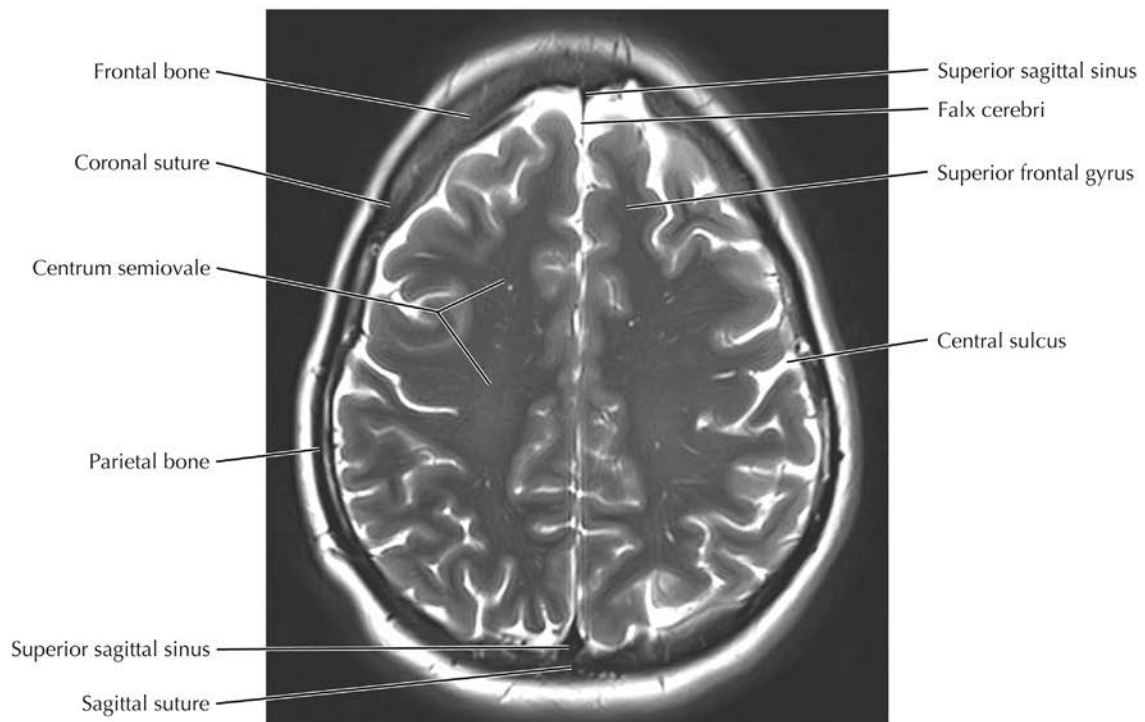
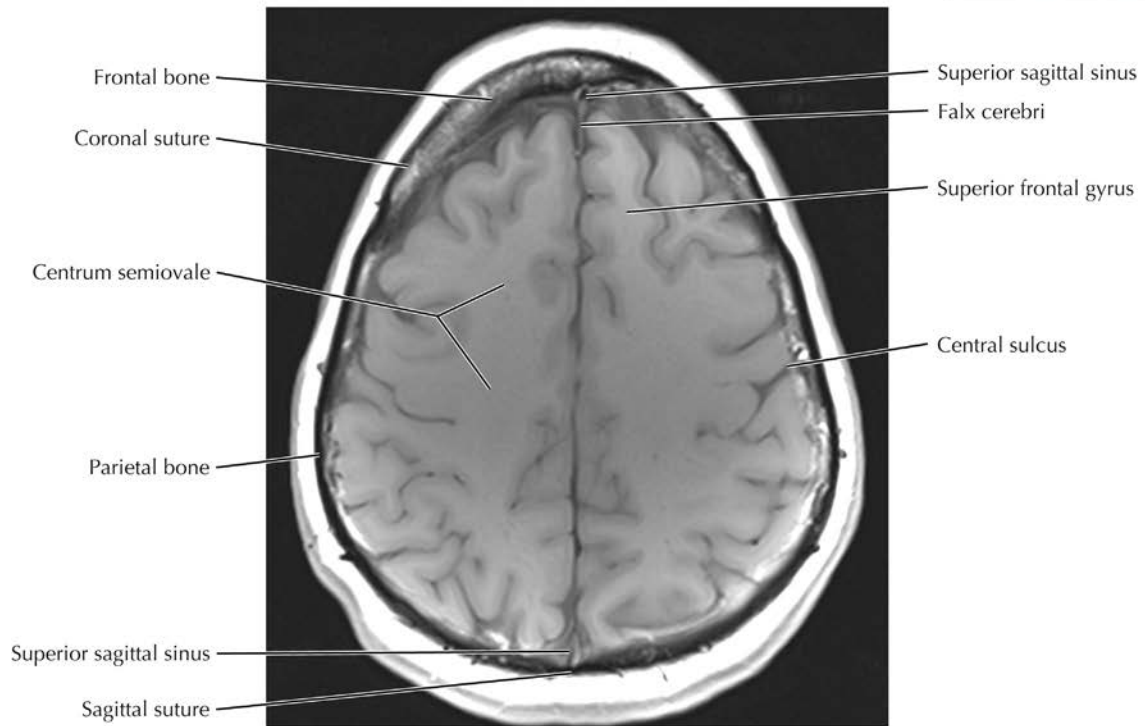
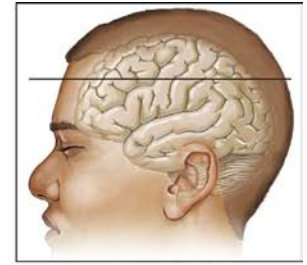


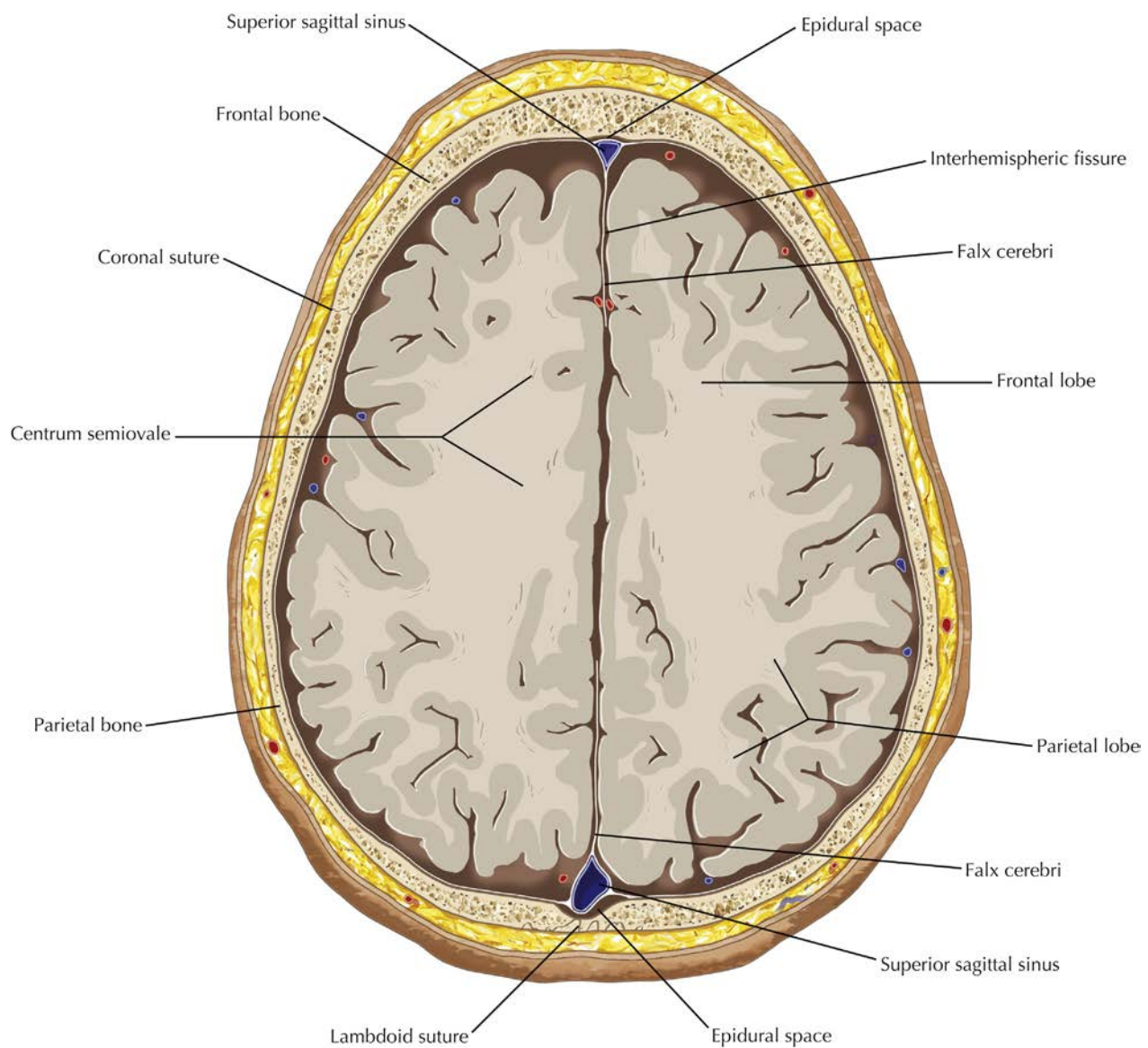
NORMAL ANATOMY

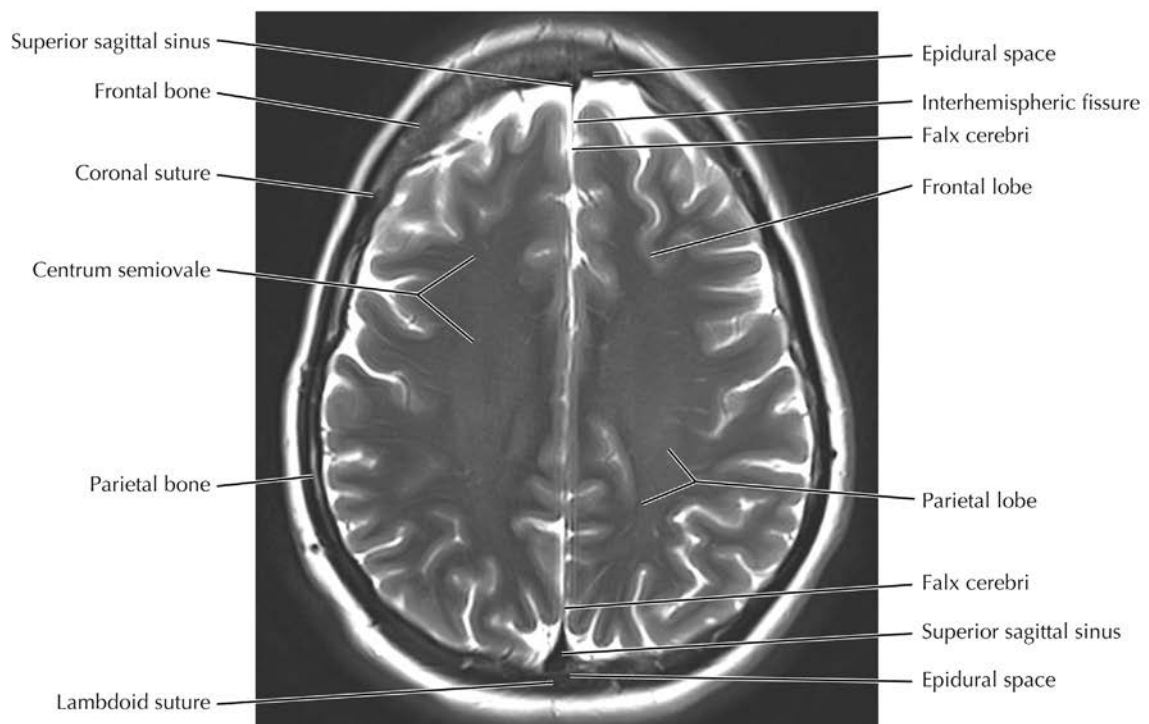
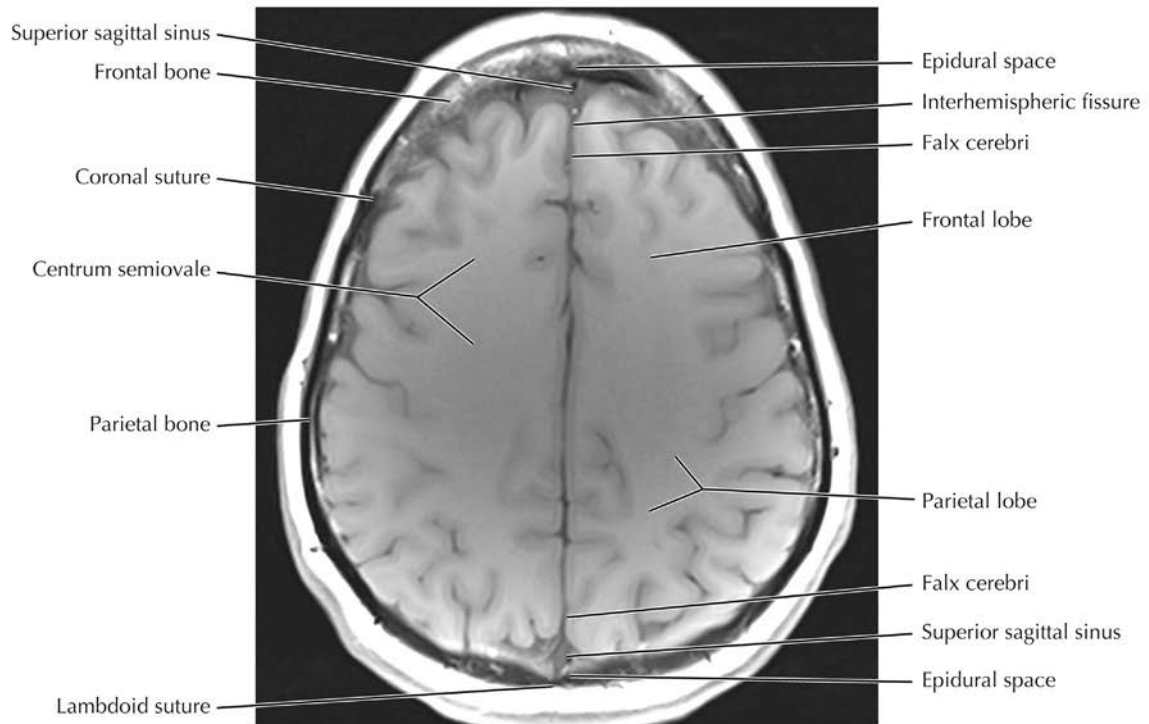
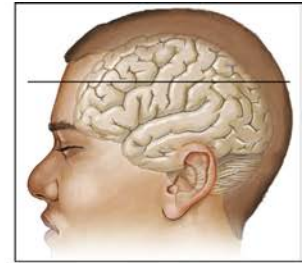
The "omega sign" denotes a sulcal configuration similar to the Greek letter Ω and is one sign of the central sulcus separating the motor strip anteriorly and the sensory cortex posteriorly. The omega sign also demarcates the frontal lobe from the parietal lobe. Note that the two sulci in the midline immediately posterior to the medial ends of the central sulci should resemble a smile.

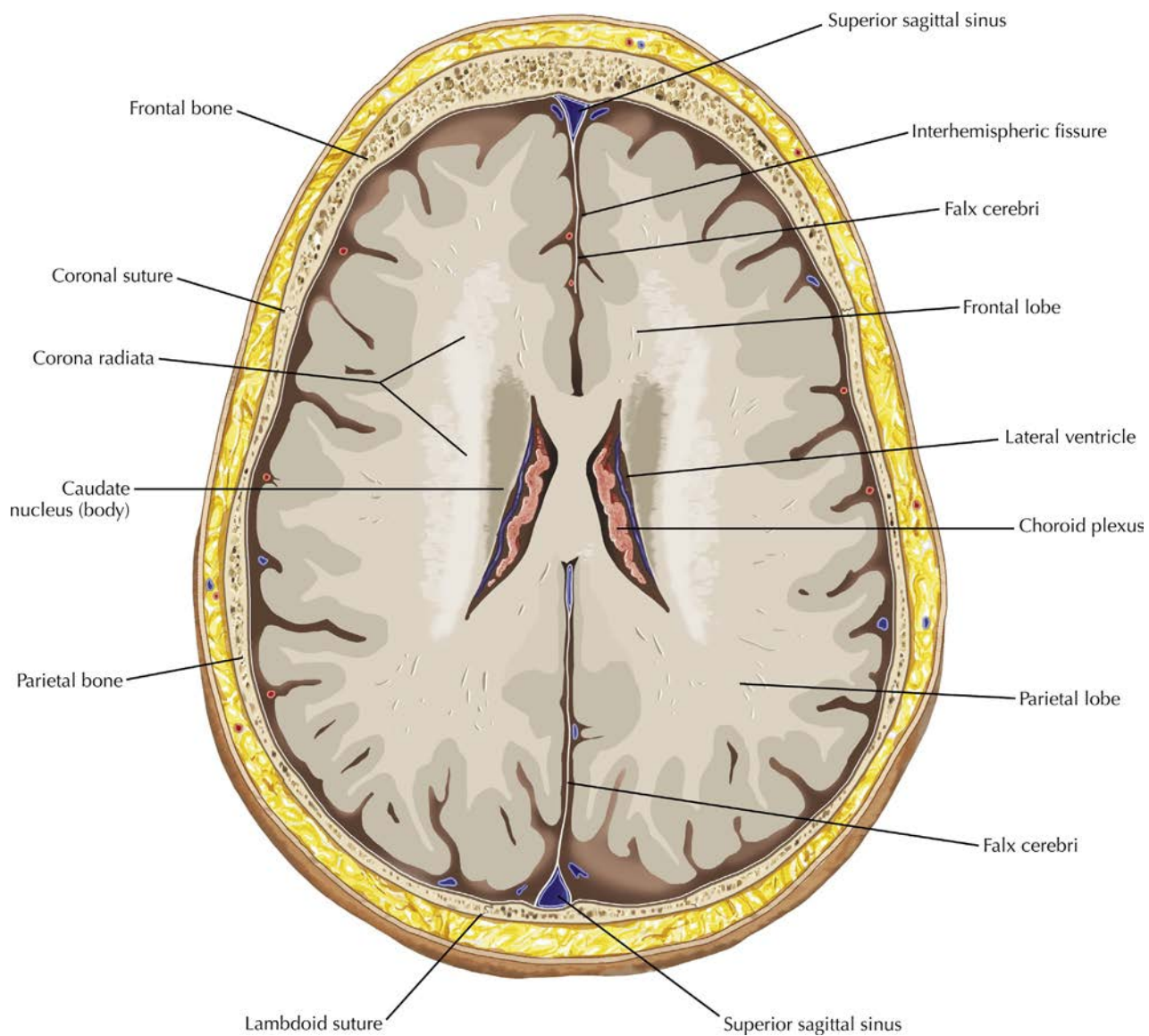


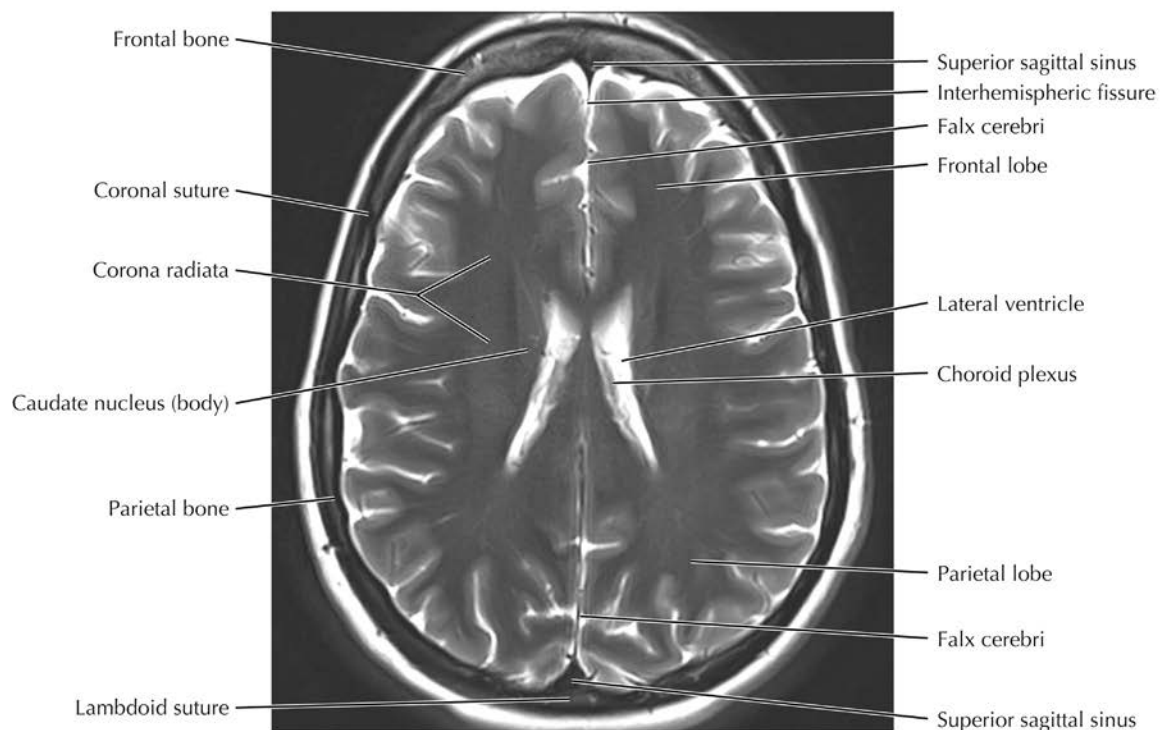
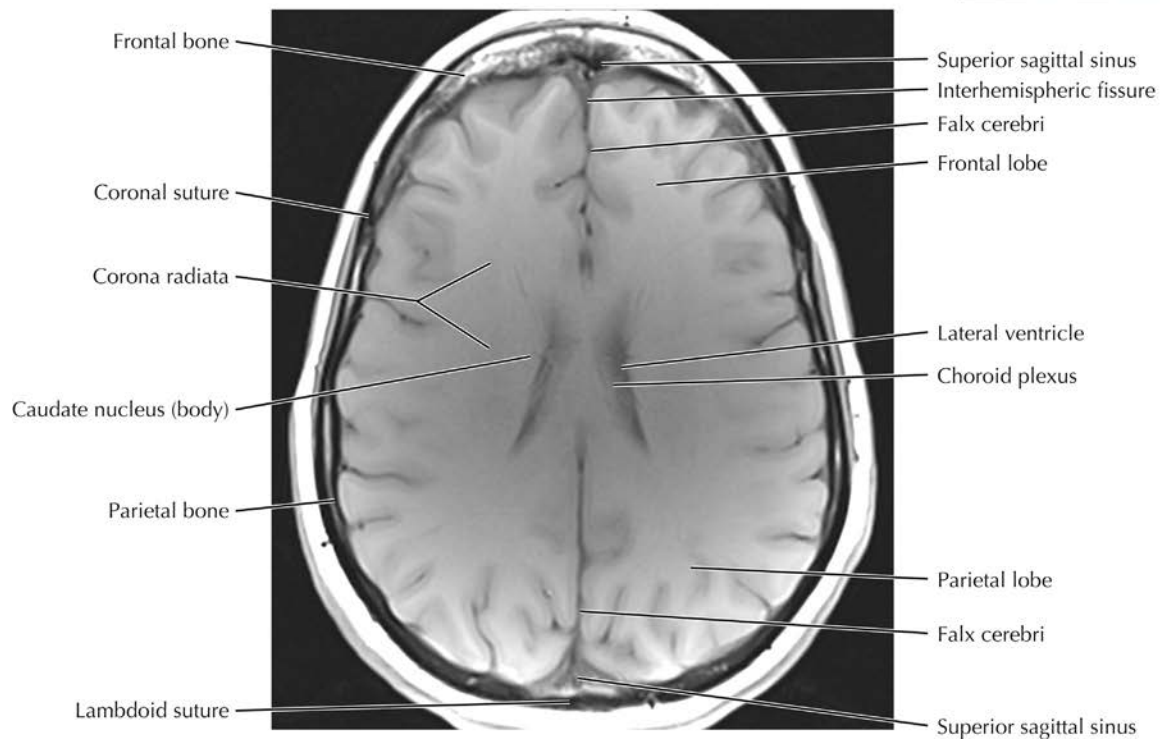
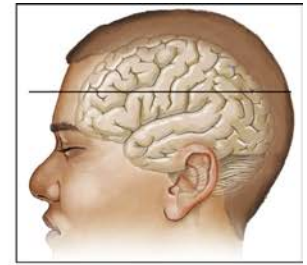


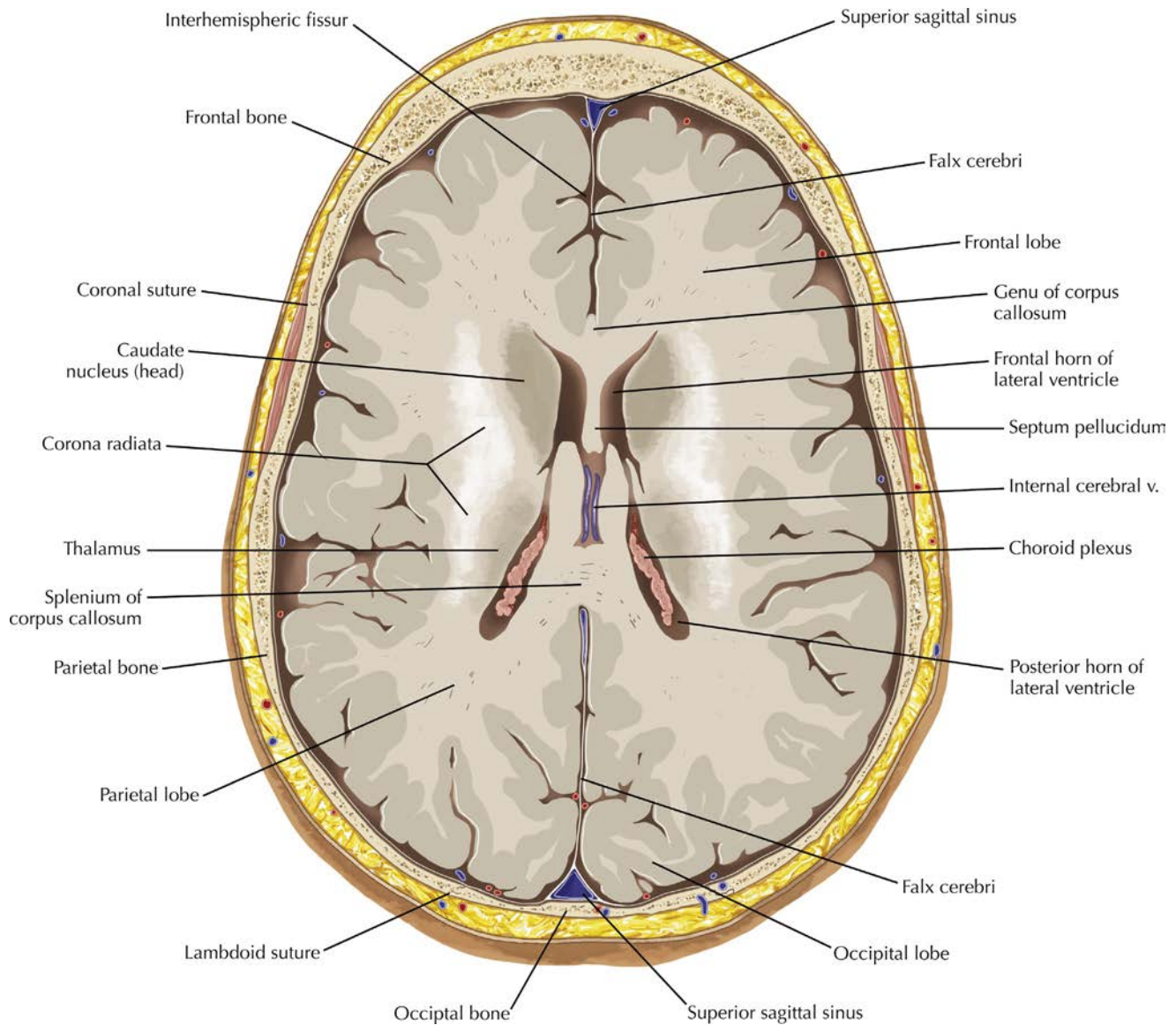






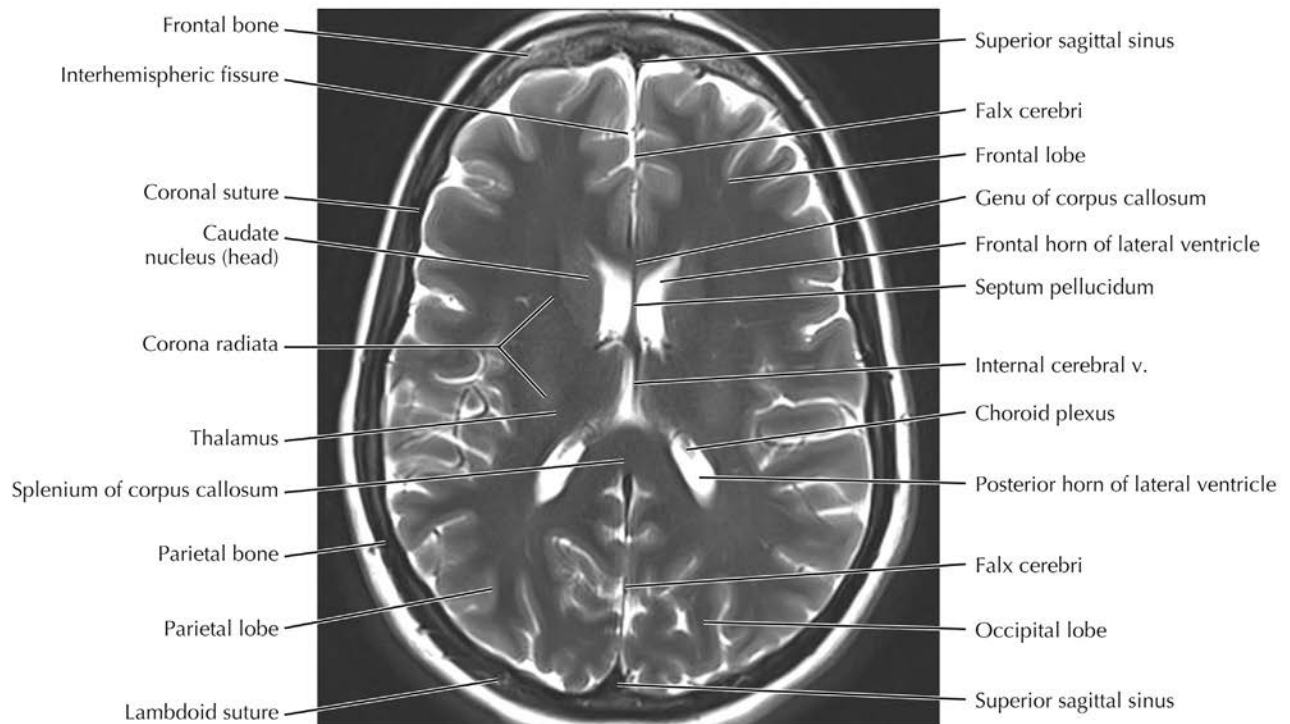
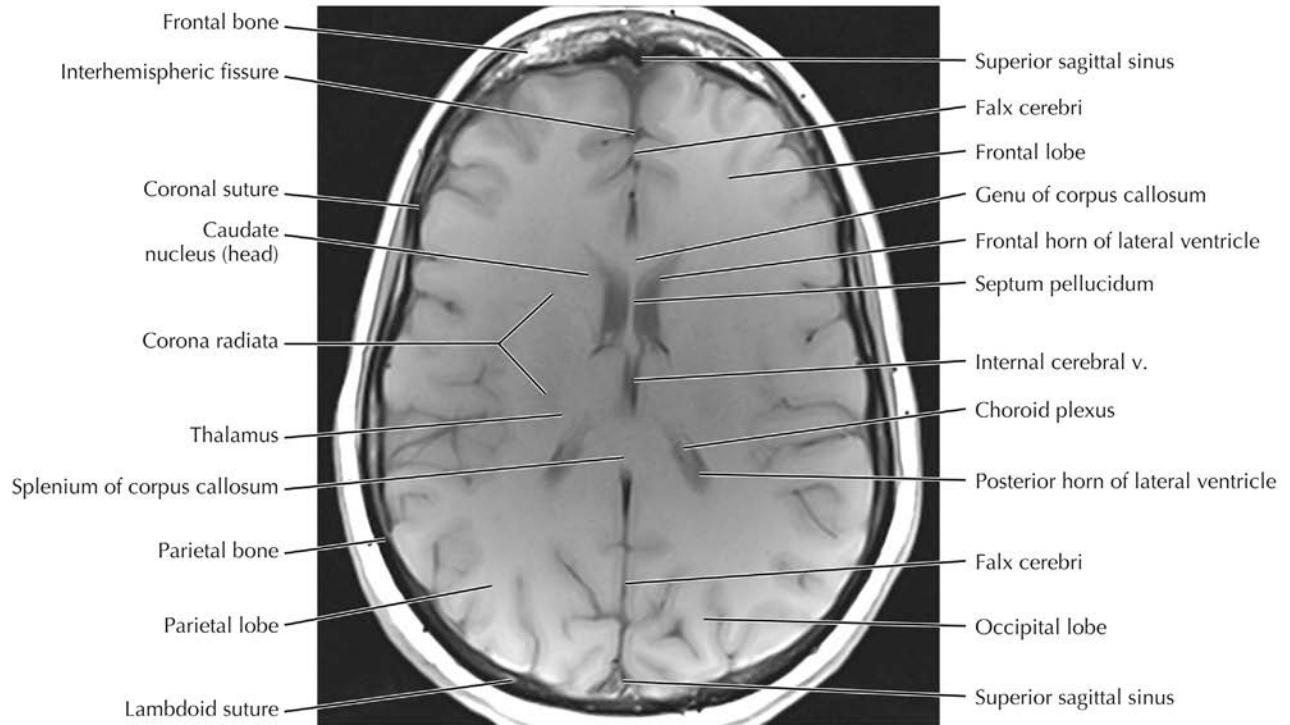
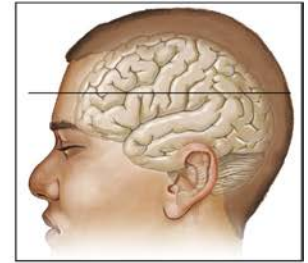


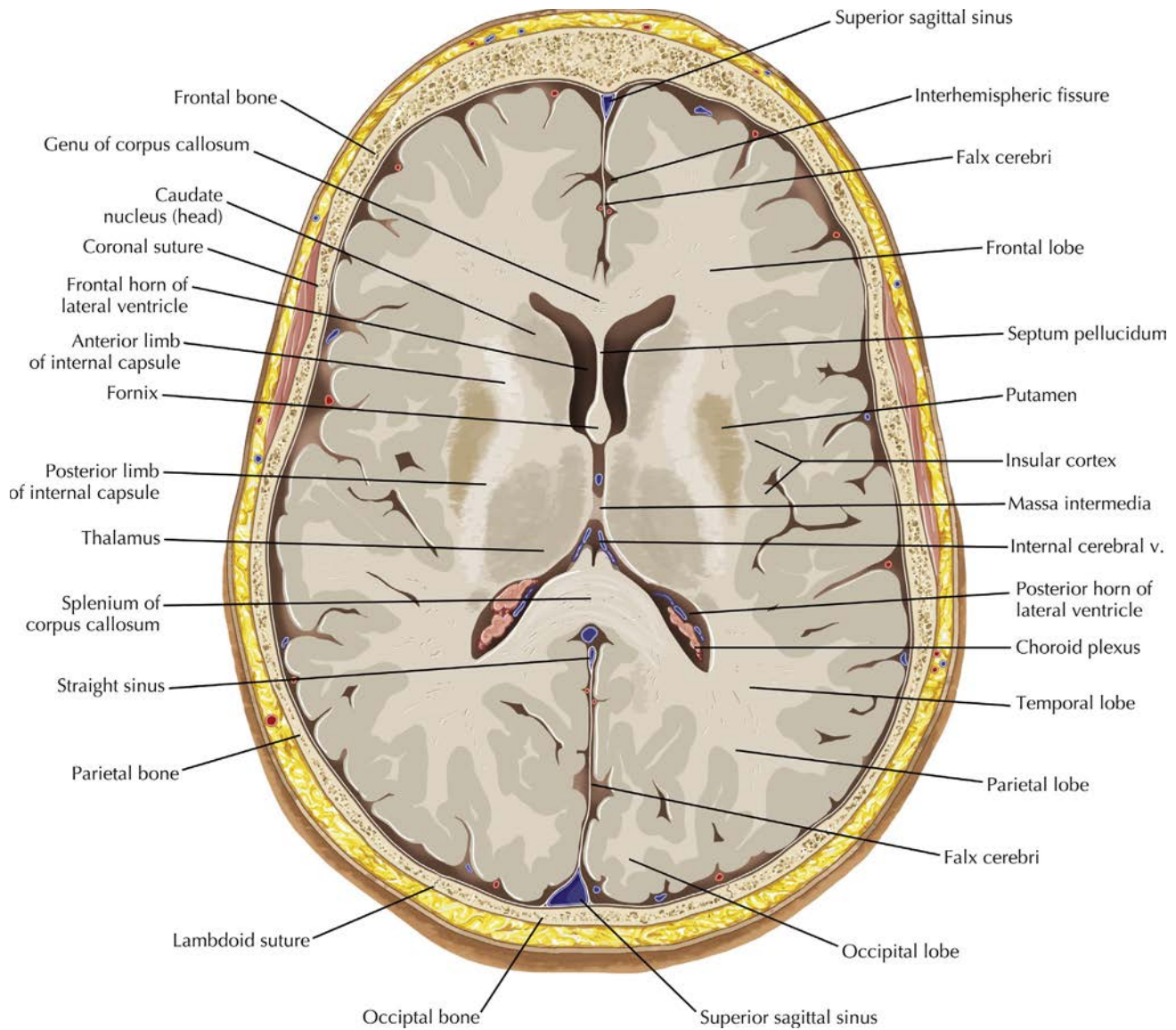




NORMAL ANATOMY

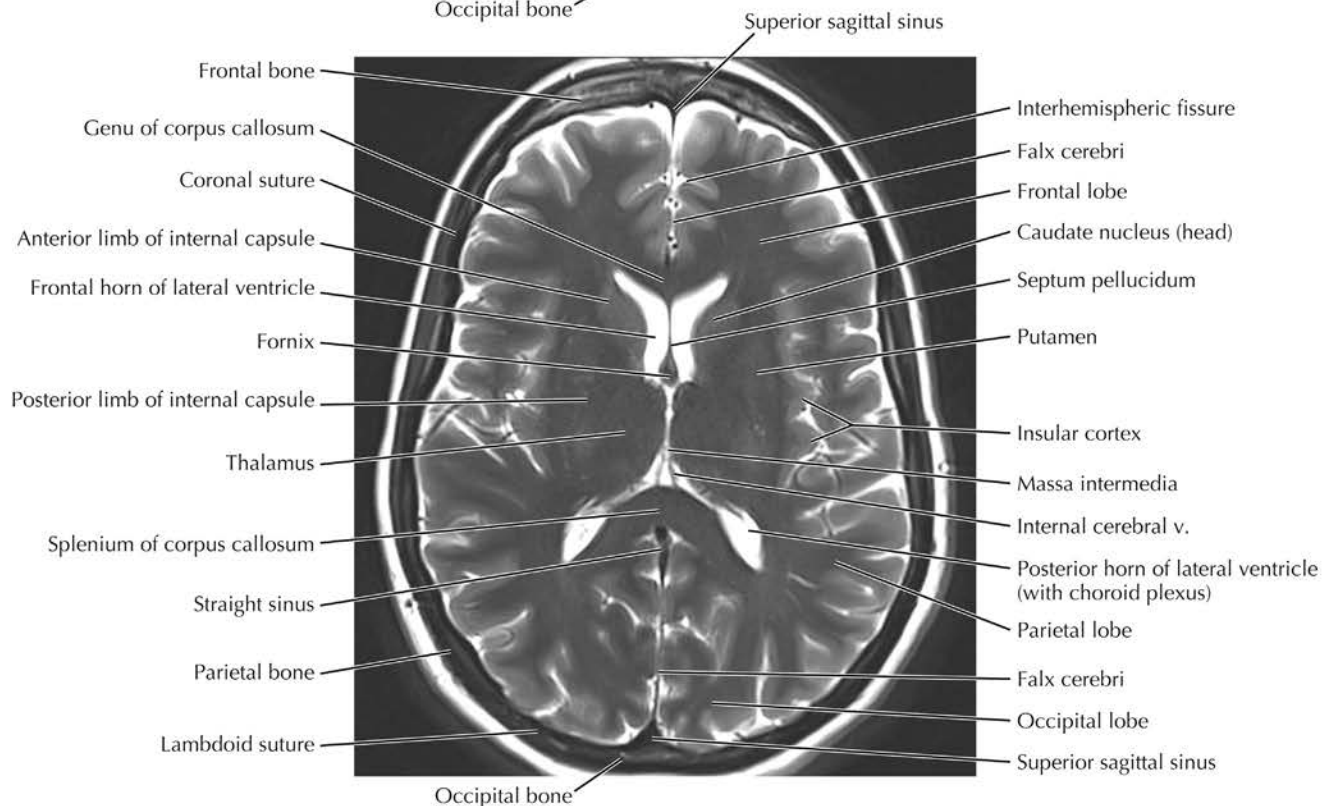
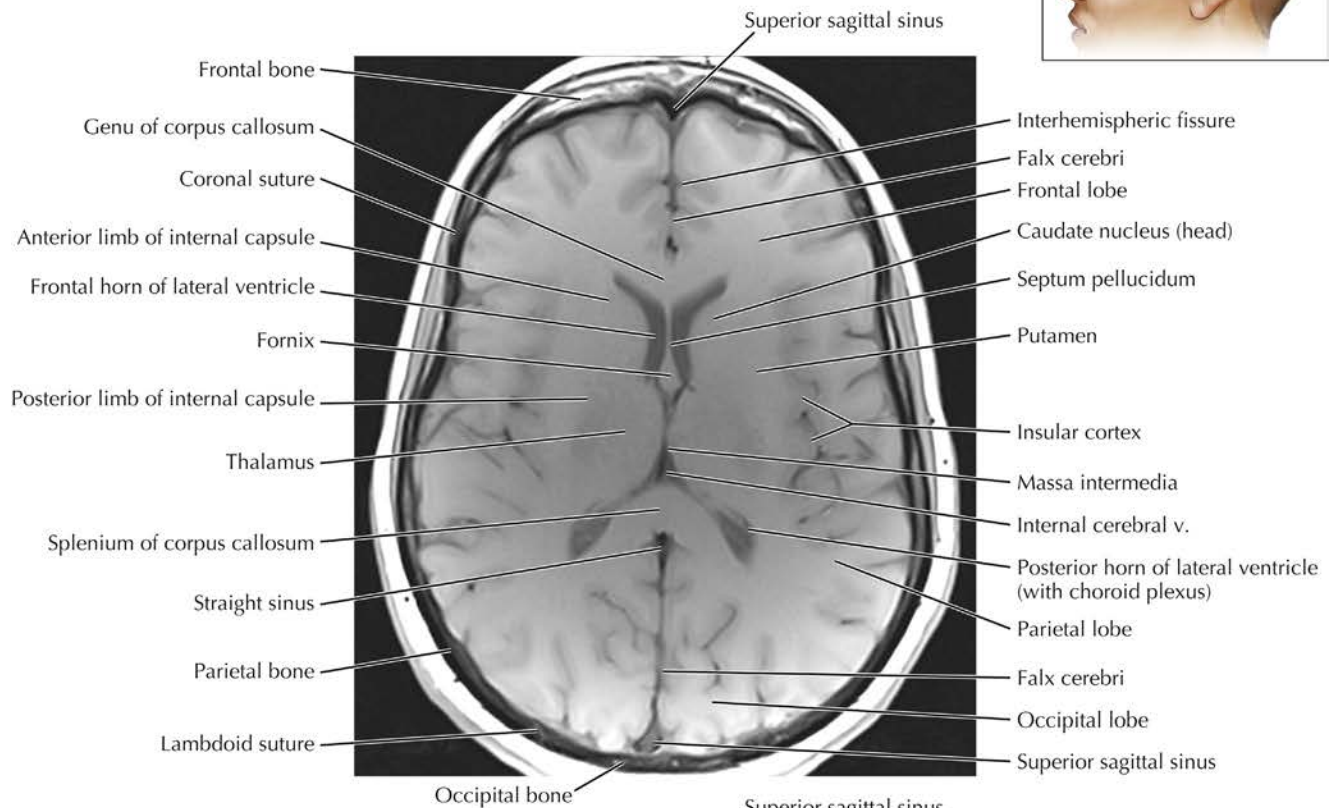
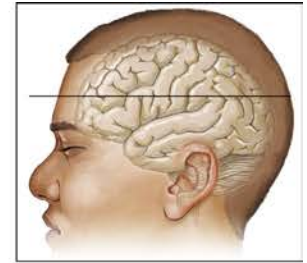
The white matter fibers at the level of the basal ganglia known as *internal capsule* (Axials 10 and 11) are known as *corona radiata* (Axials 8 and 9) more superiorly along the lateral margins of the ventricles, and as the *centrum semiovale* superior to the ventricles (Axial 7).

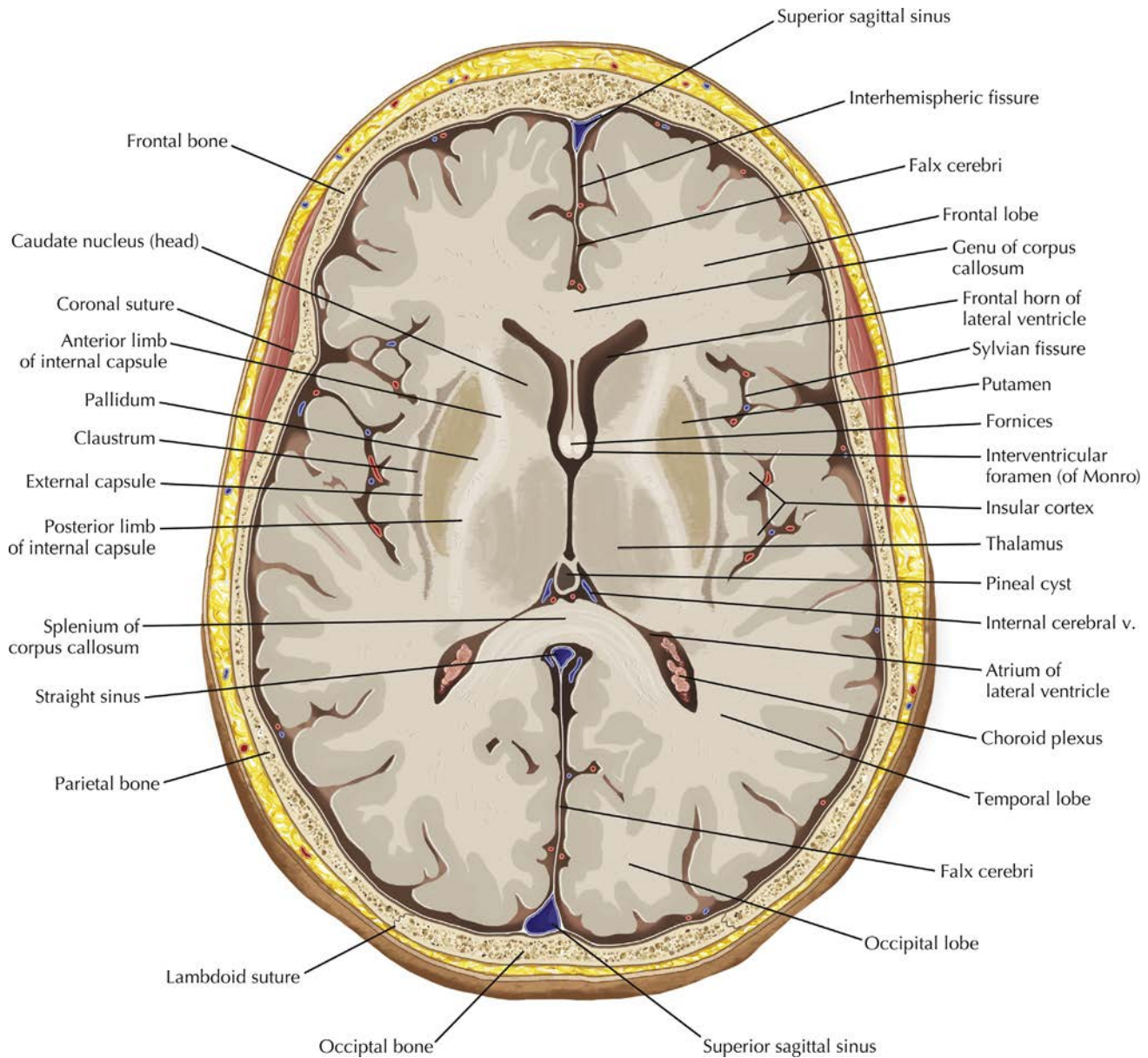




NORMAL ANATOMY

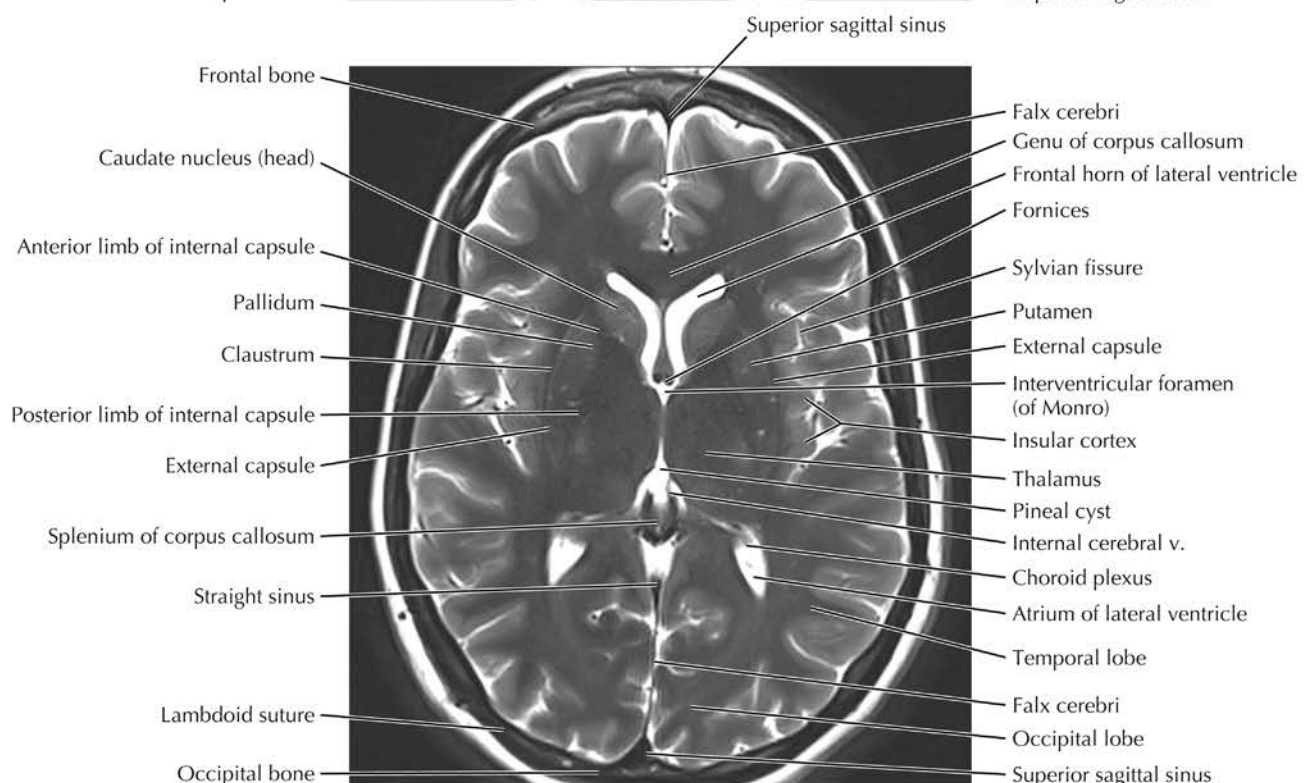
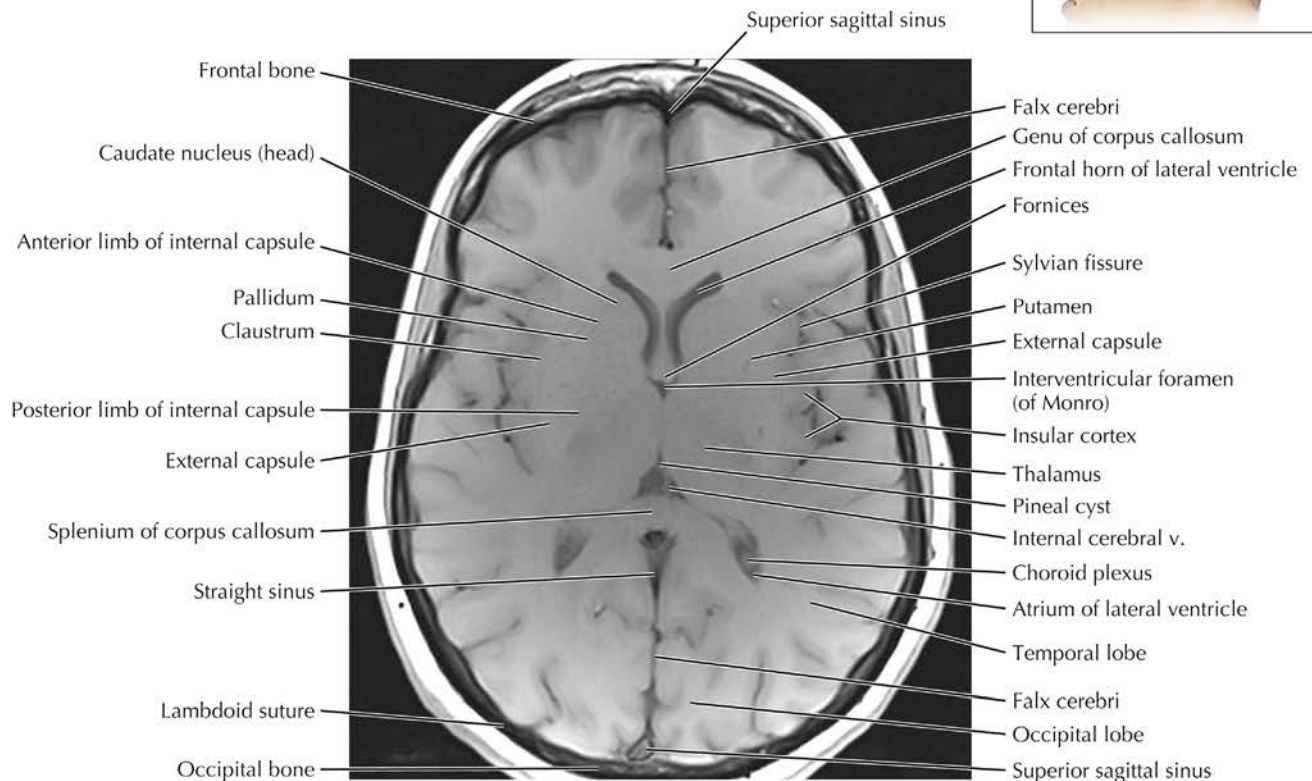
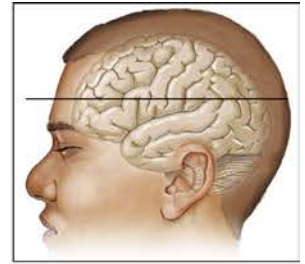
Note how the signal of the basal ganglia is not ideal on this MR sequence tailored to capture the entire brain. For better delineation, see Chapter 3.

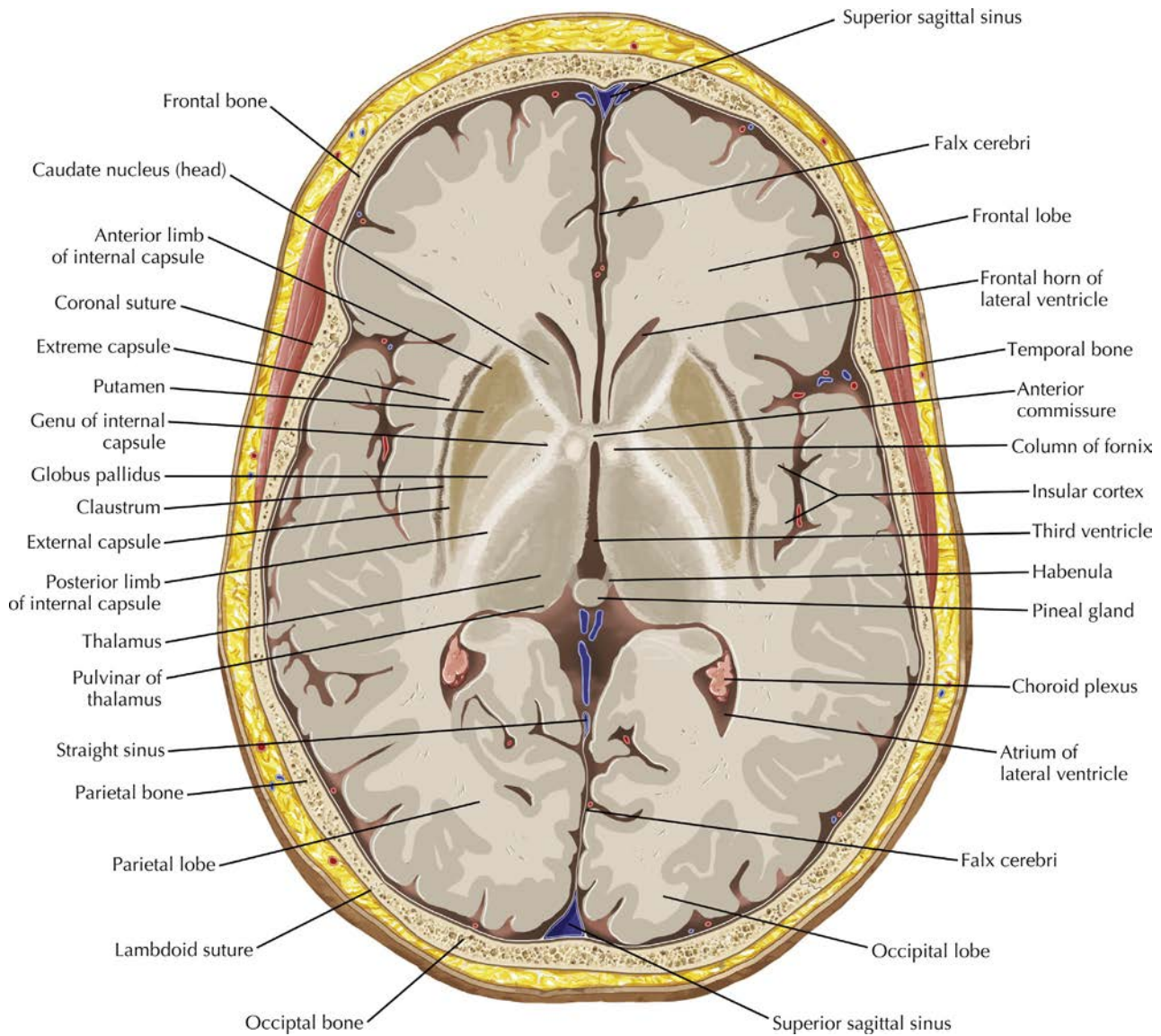




PATHOLOGIC PROCESS

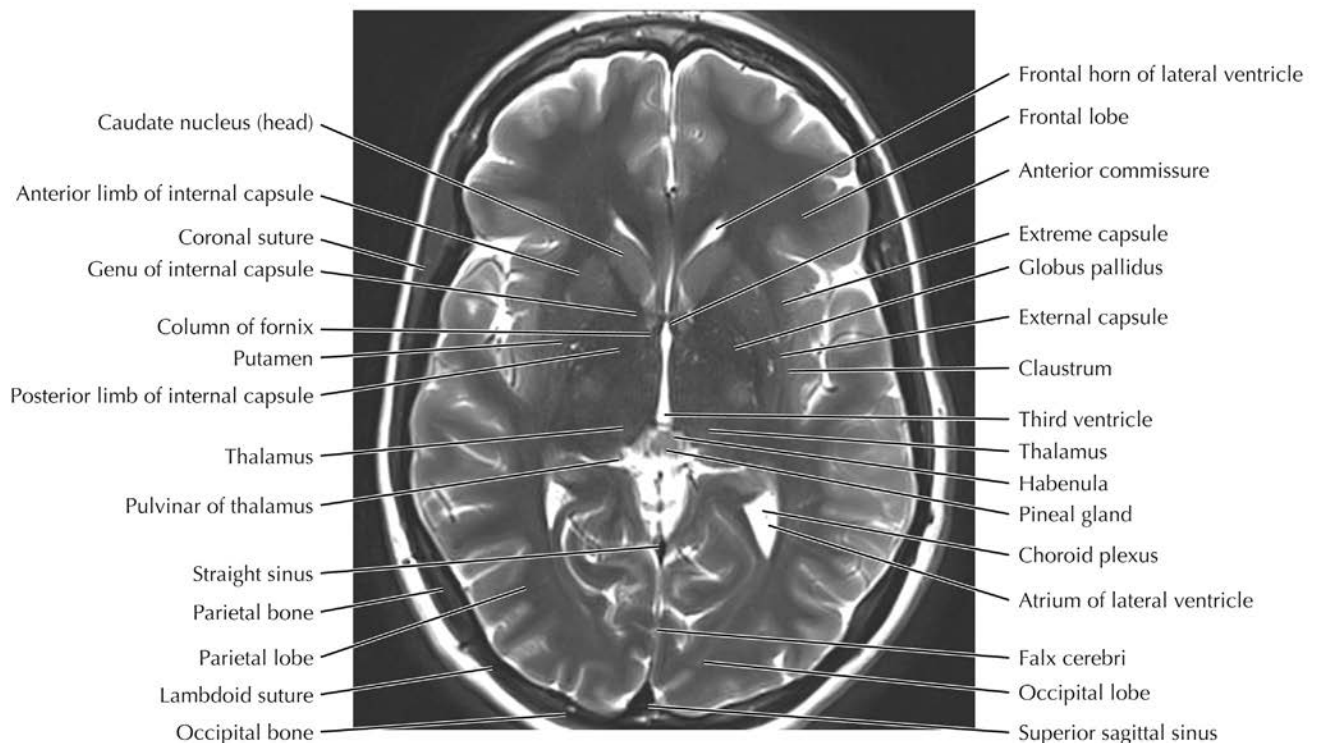
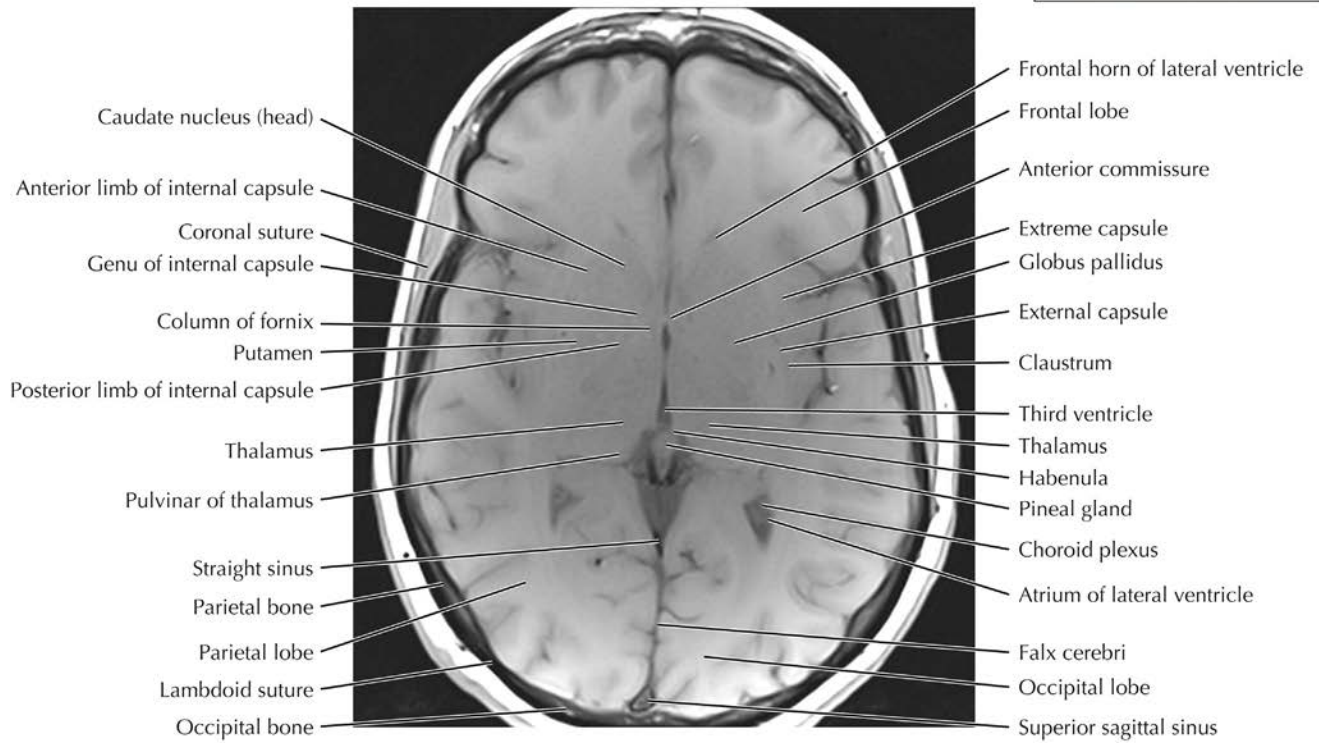
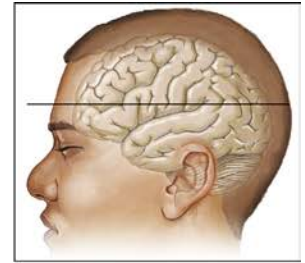
The foramen of Monroe (interventricular foramen) can be an important point of obstruction of cerebrospinal fluid (CSF) flow. A small colloid cyst can occasionally be found at this location and could cause obstruction in a relatively short time, rapidly becoming fatal if untreated. CSF is produced at a rate of about 500 mL/day and the subarachnoid space around the brain and spinal cord can contain only 150 mL. CSF intracranially and within the spinal canal turns over about four times a day.

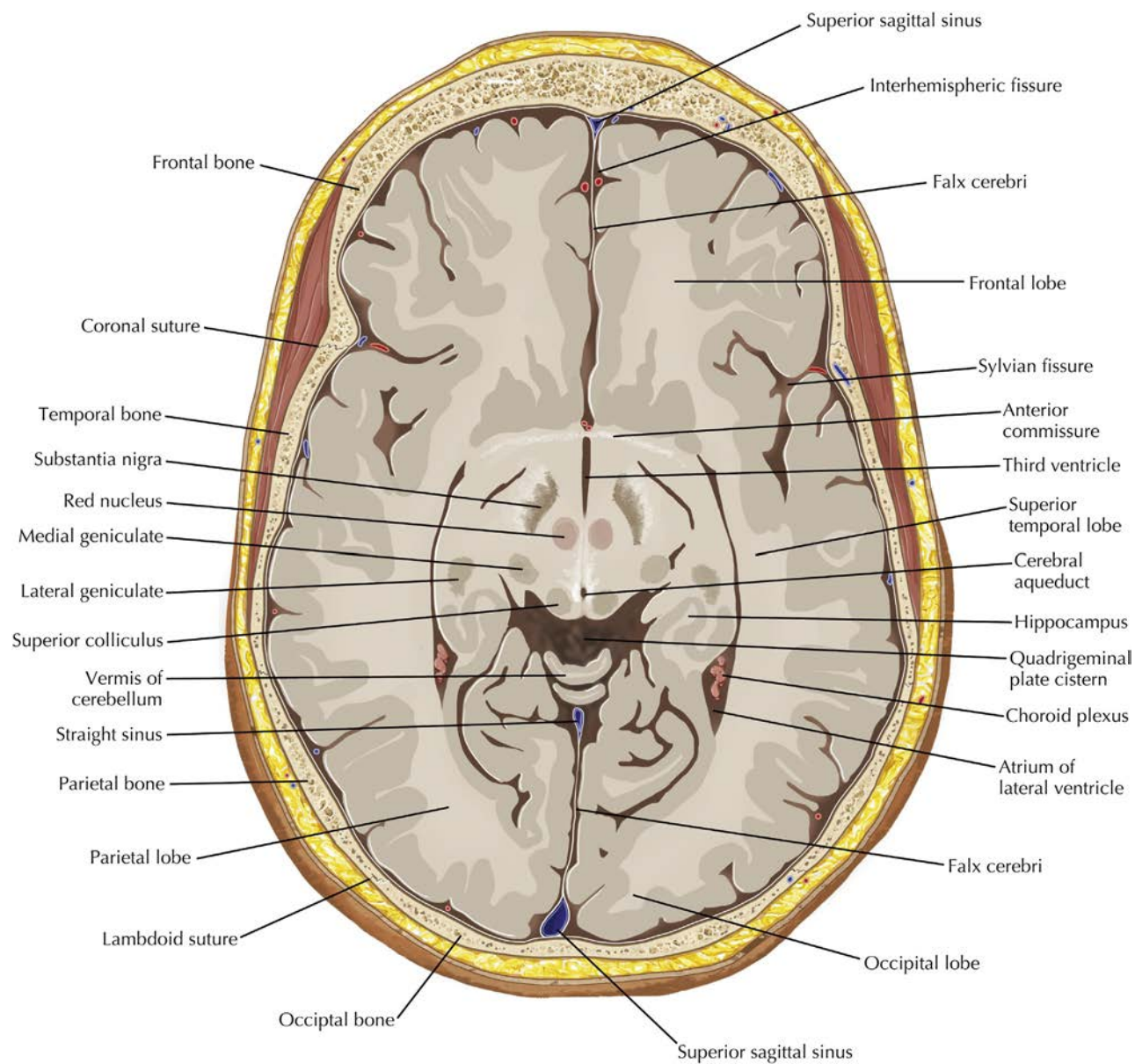


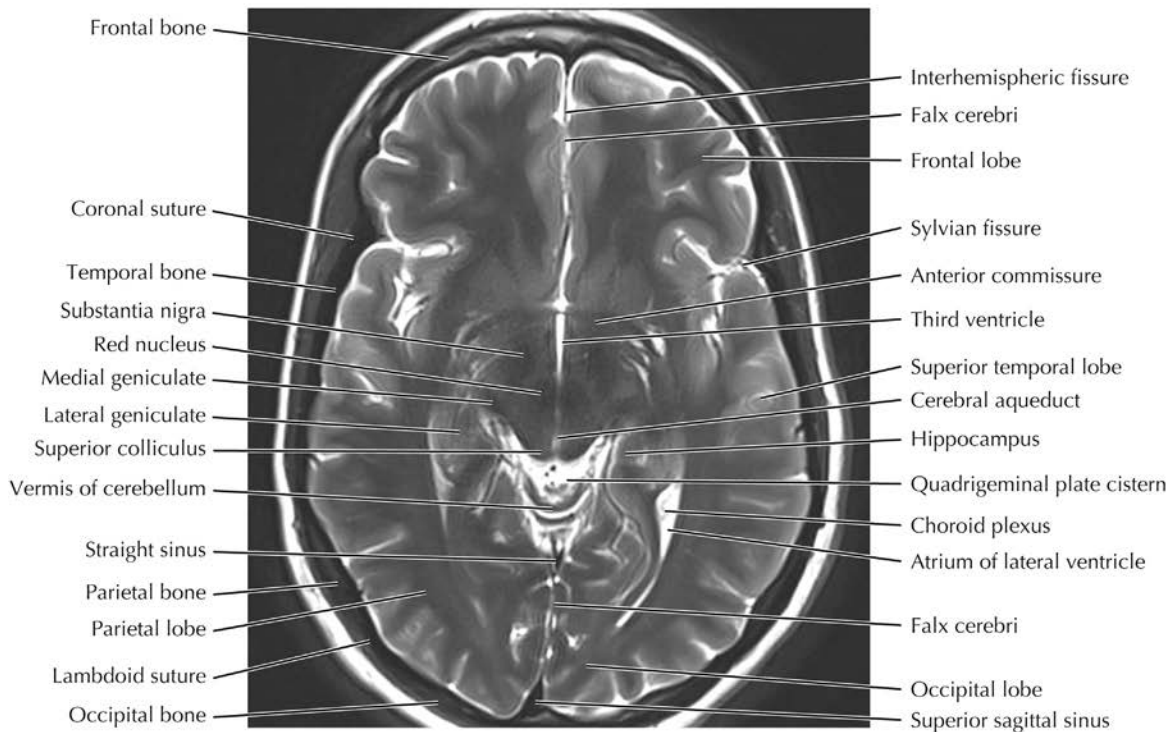
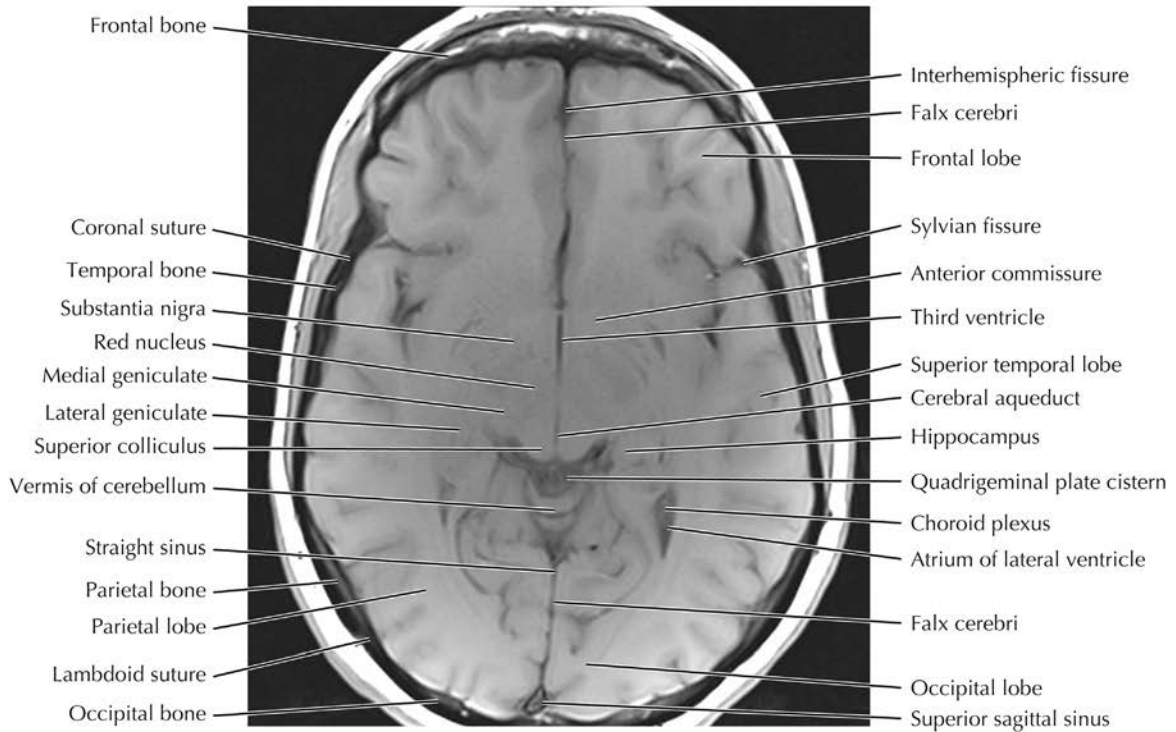
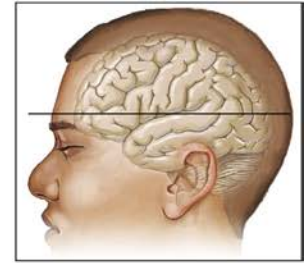


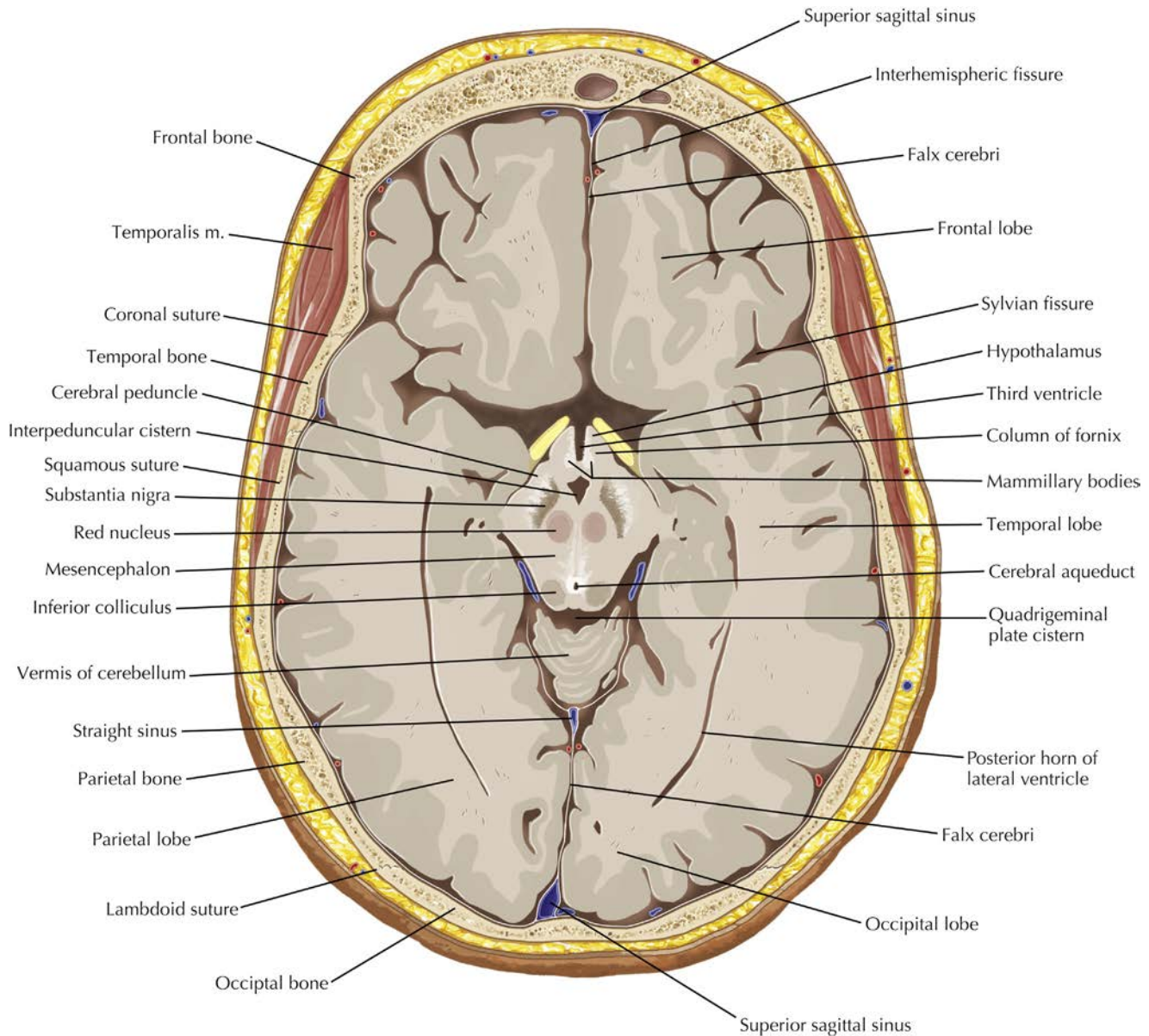
NORMAL ANATOMY

The habenula (Latin *habena*, "rein") originally referred to the pineal gland stalk but is now commonly used to indicate a nearby group of neurons in the dorsal and caudal thalamus. The insular cortex is often the first location where an infarct in the area of the middle cerebral artery will become evident on unenhanced computed tomography (CT) of the head. Loss of differentiation of the insular gray matter from the subinsular white matter should always be evaluated.



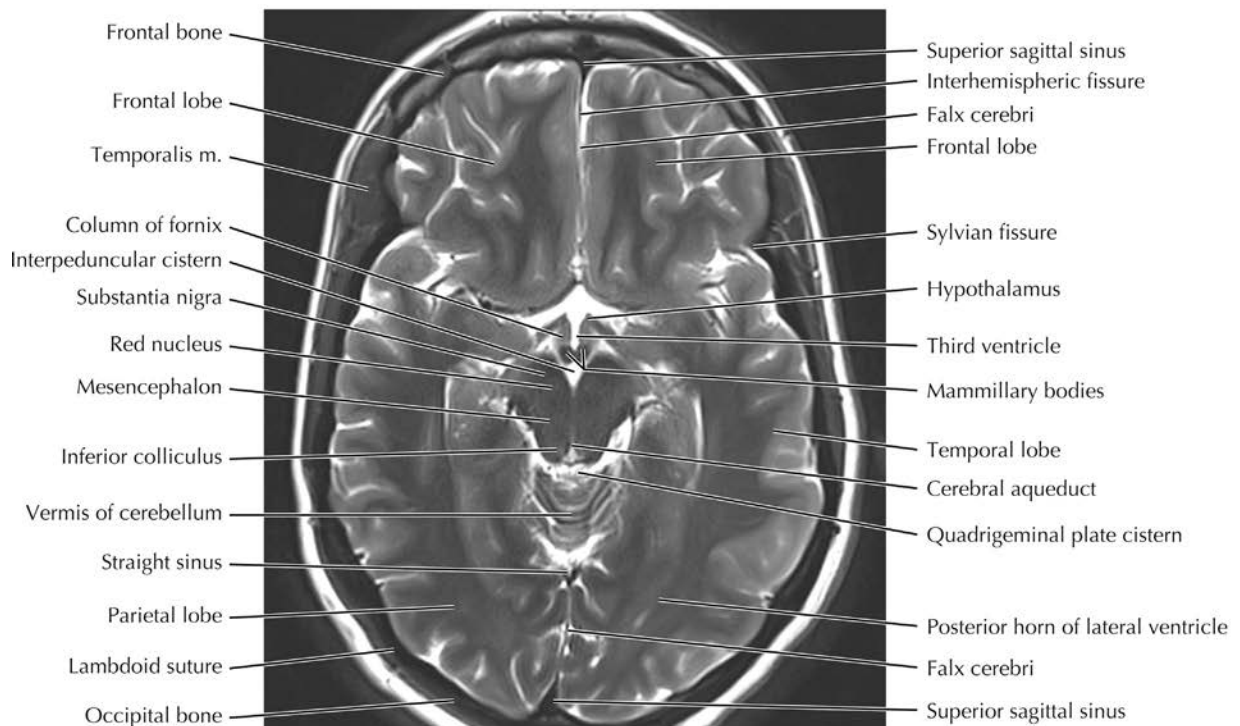
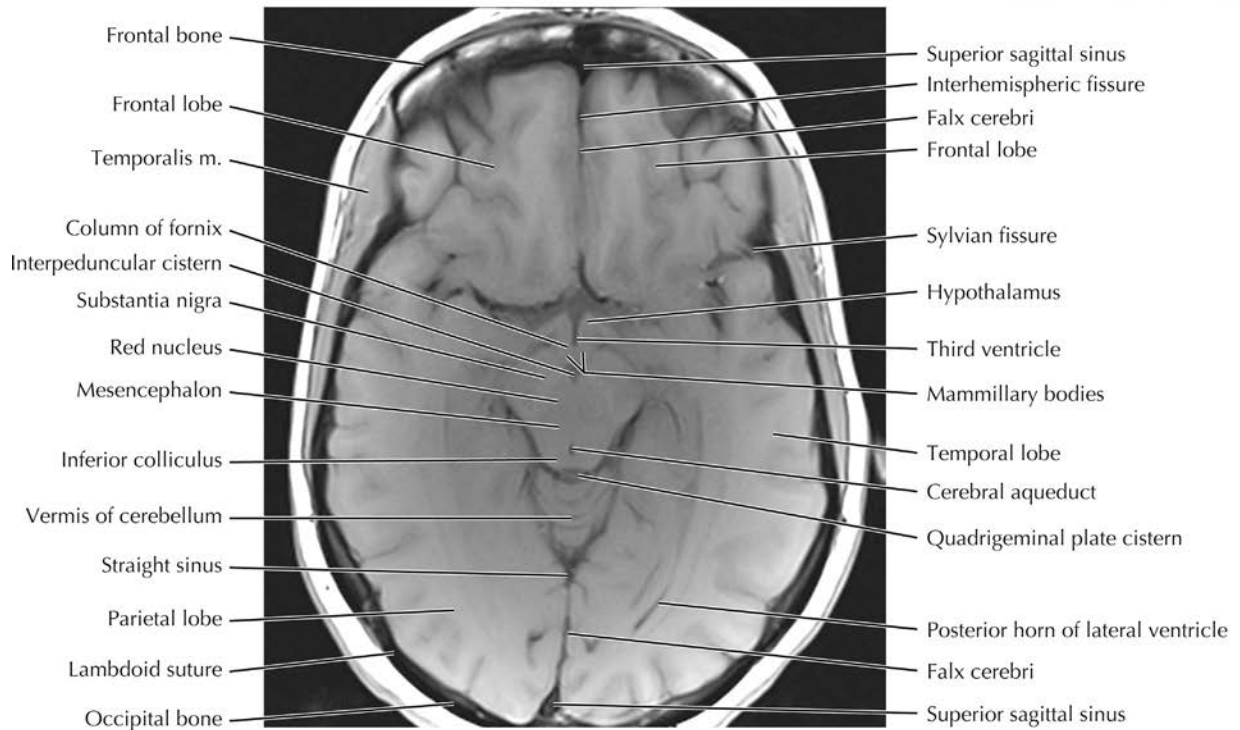
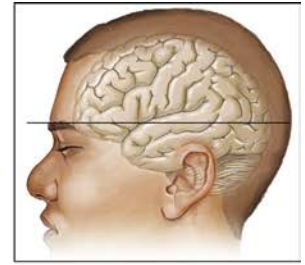


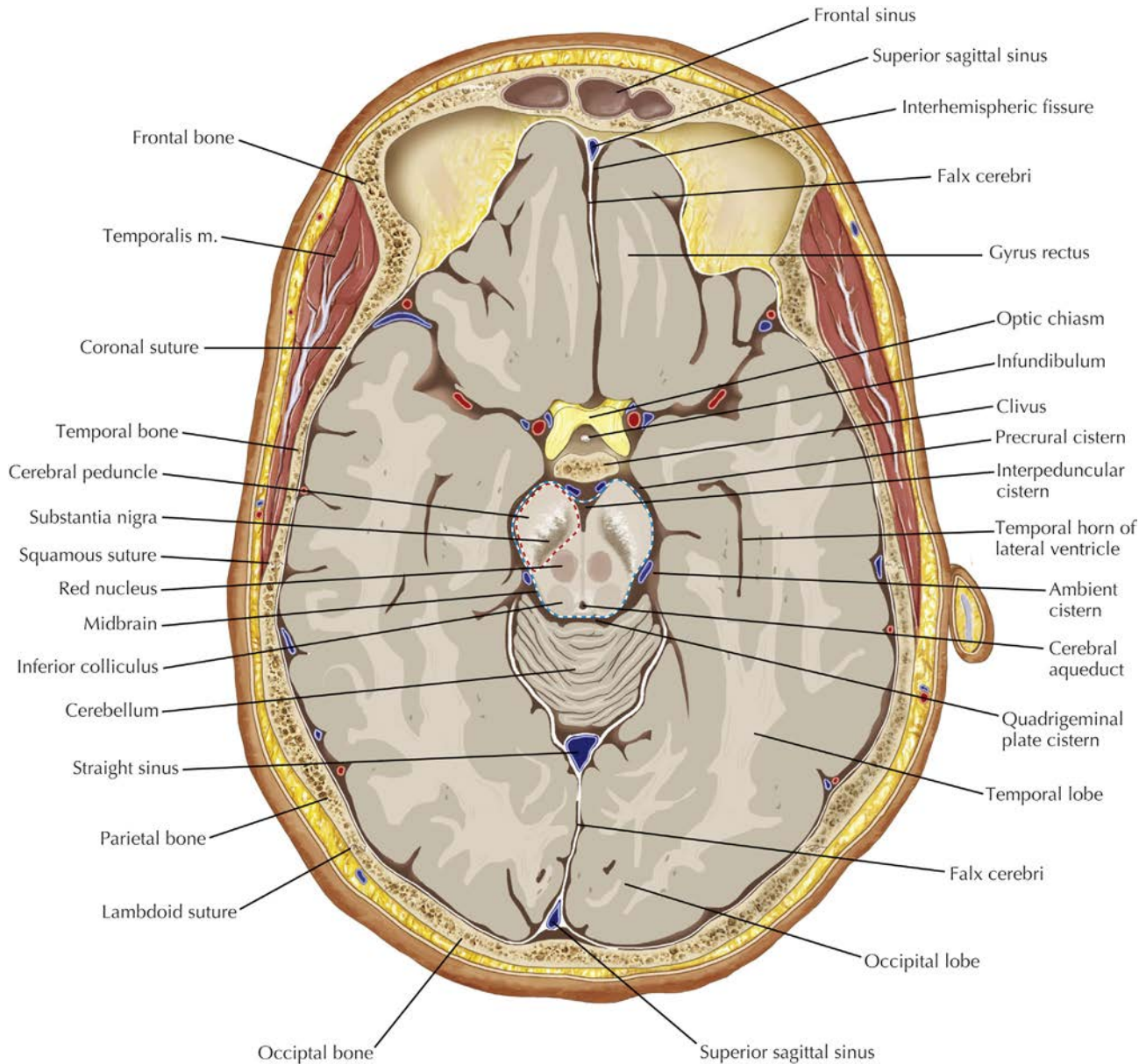




NORMAL ANATOMY

Note the small but conspicuous paired mammillary bodies anterior to the interpeduncular cistern, at the anterior end of the fornices. The mammillary bodies are part of the limbic system and are believed to add the element of smell to memories. The bodies can be enlarged and T2-weighted bright in Wernicke's encephalopathy. Do not confuse the mammillary bodies with the paired inferior and superior colliculi, which are located on the posterior surface of the brainstem.



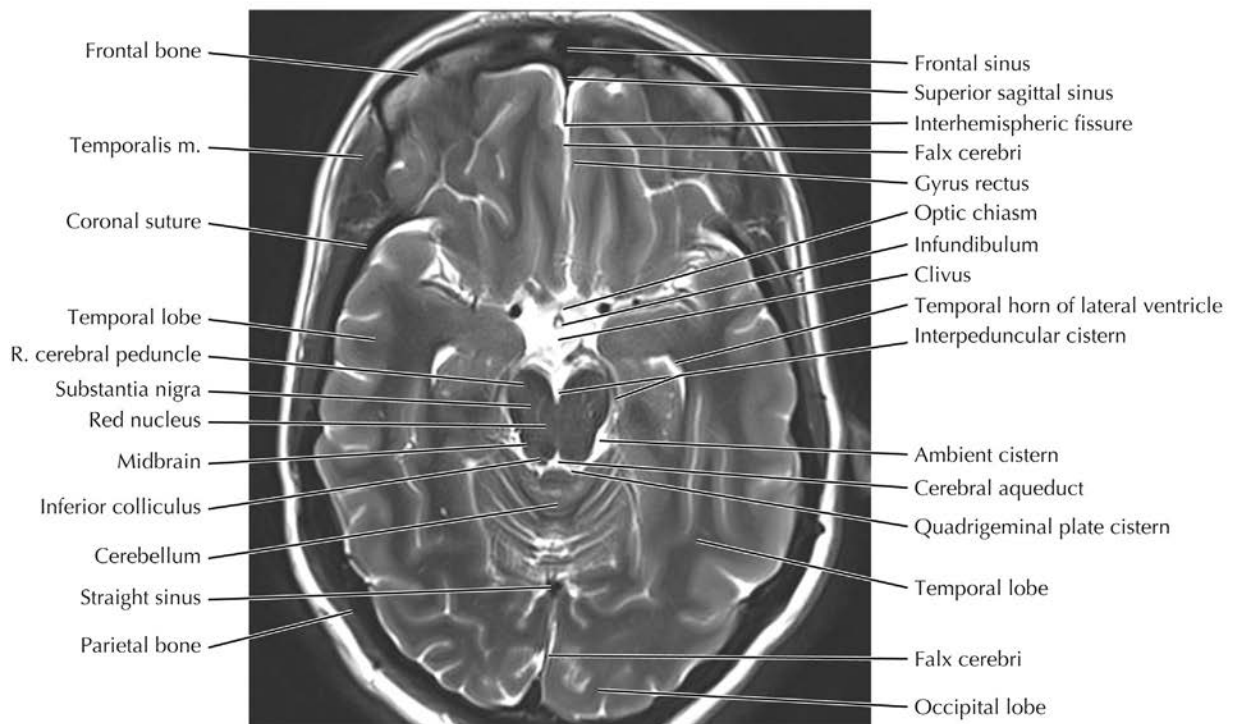
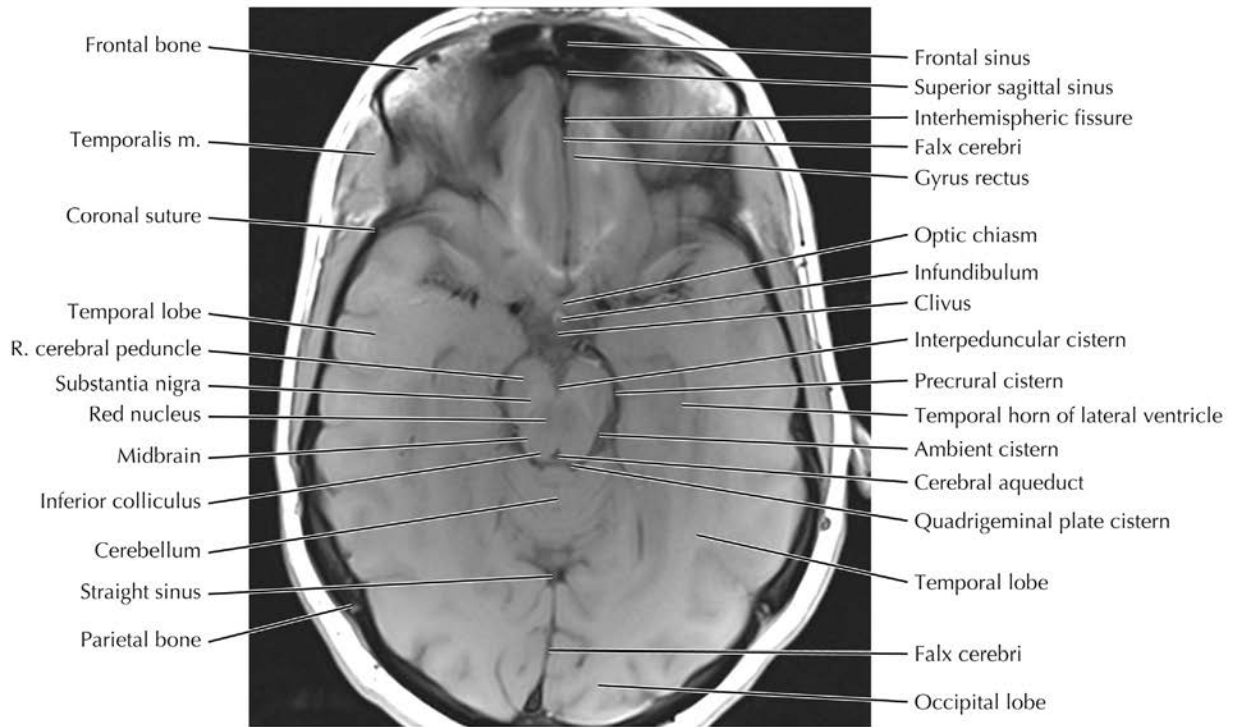
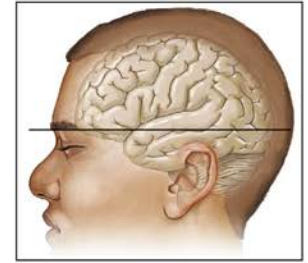


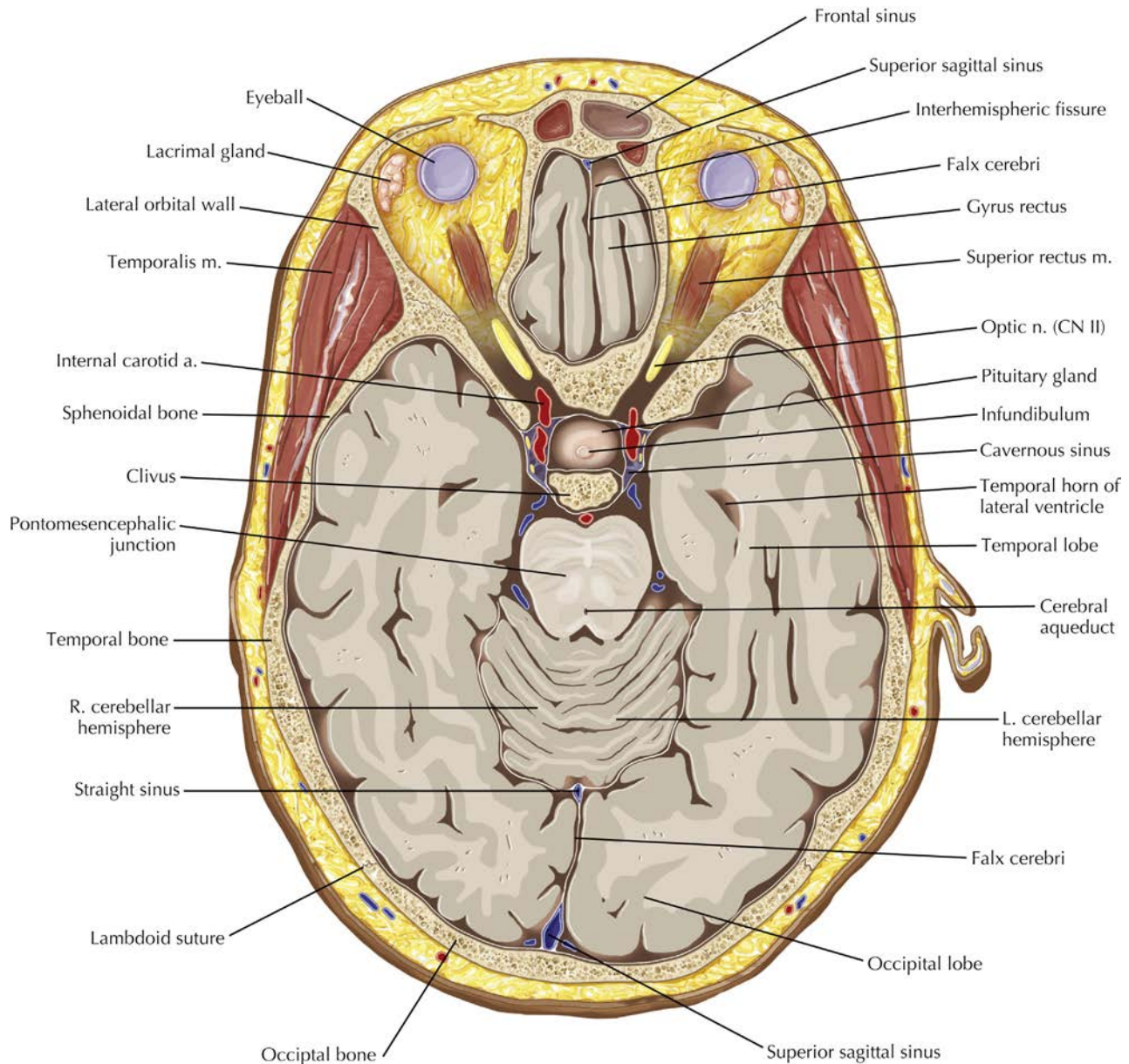
NORMAL ANATOMY

Note that the basal cisterns are composed of the suprasellar cistern, which resembles a six-pointed star, and the smile-shaped quadrigeminal plate cistern (see also Axial 14). The six points of the suprasellar cistern include the interhemispheric fissure, two Sylvian cisterns, two ambient cisterns, and the interpeduncular cistern.

PATHOLOGIC PROCESS

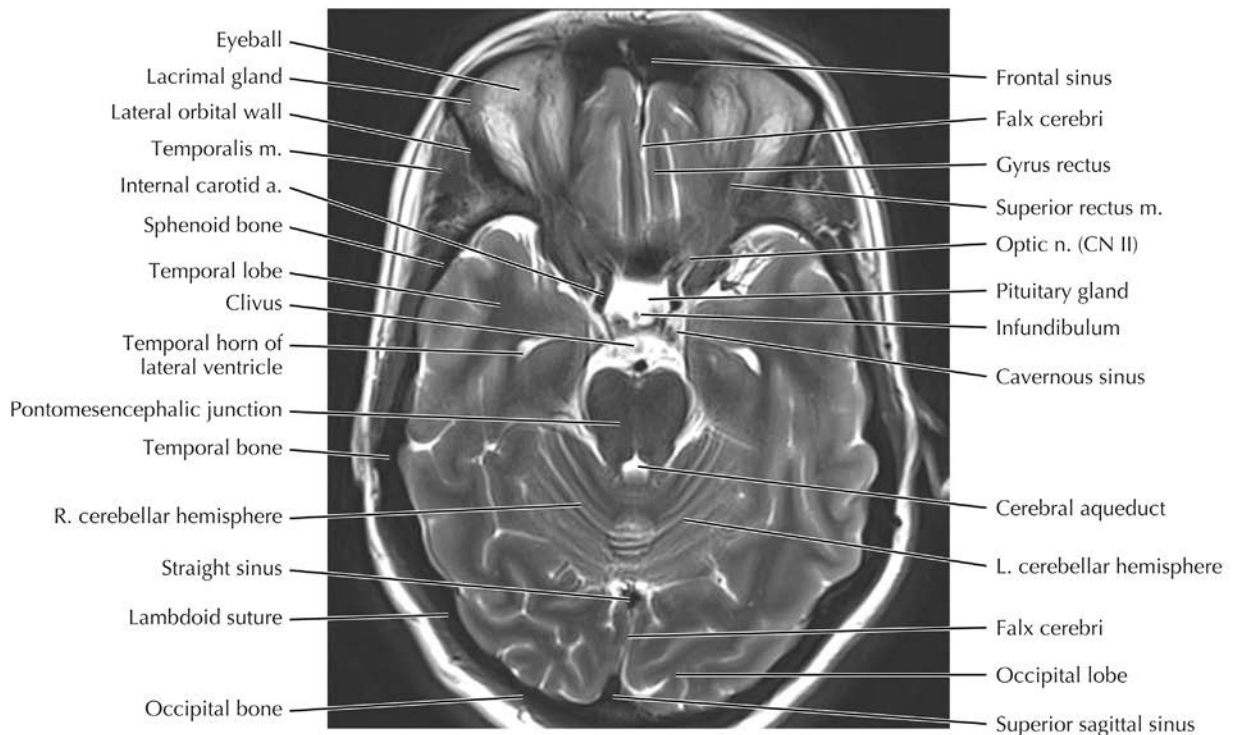
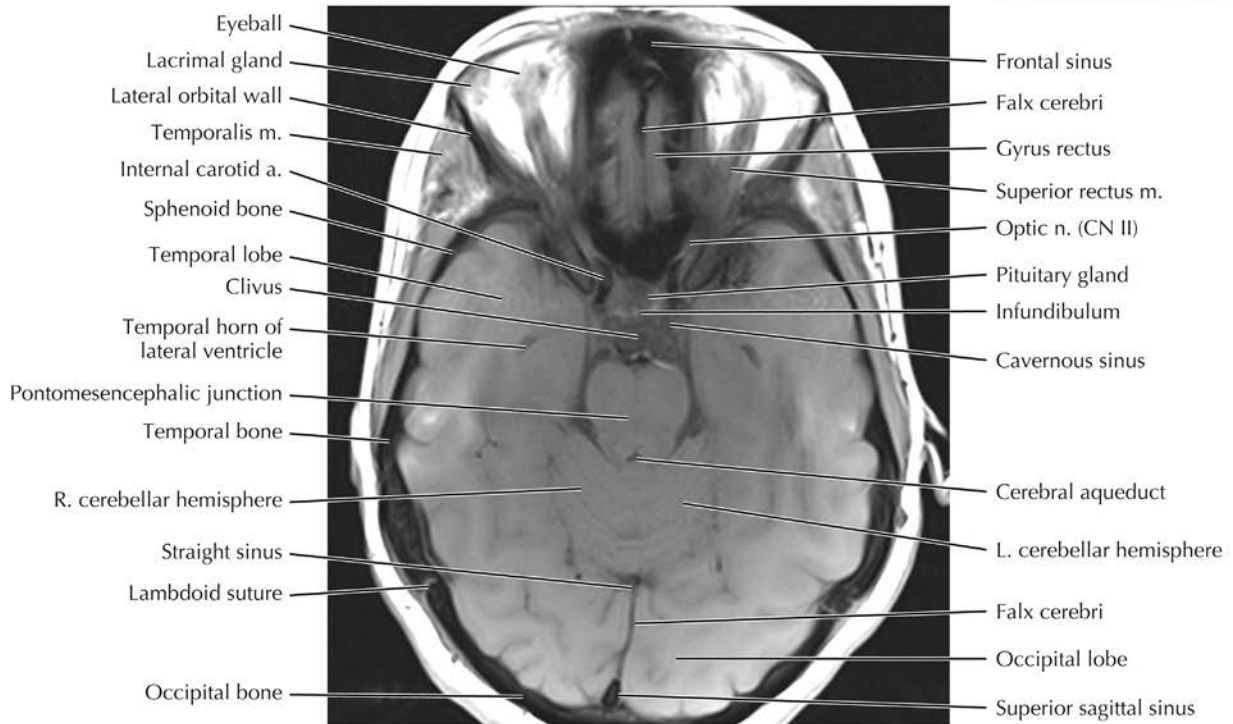
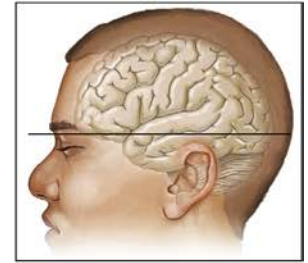
The interpeduncular cistern is a good anatomic feature to scrutinize; this location often first reveals subarachnoid hemorrhage when a brain aneurysm ruptures. This usually occurs from the area of the circle of Willis, which is prone to many anatomic vascular variations.

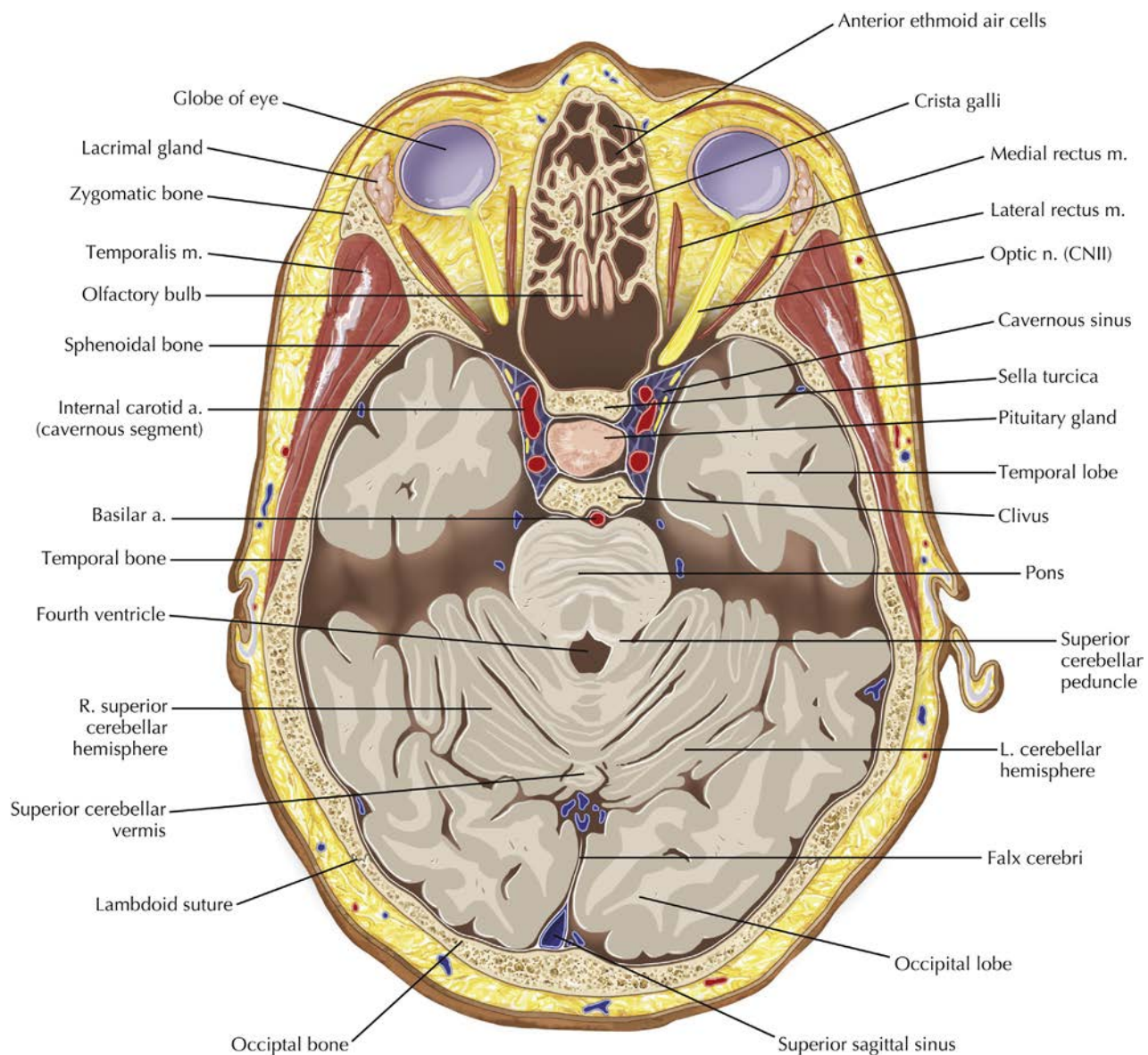


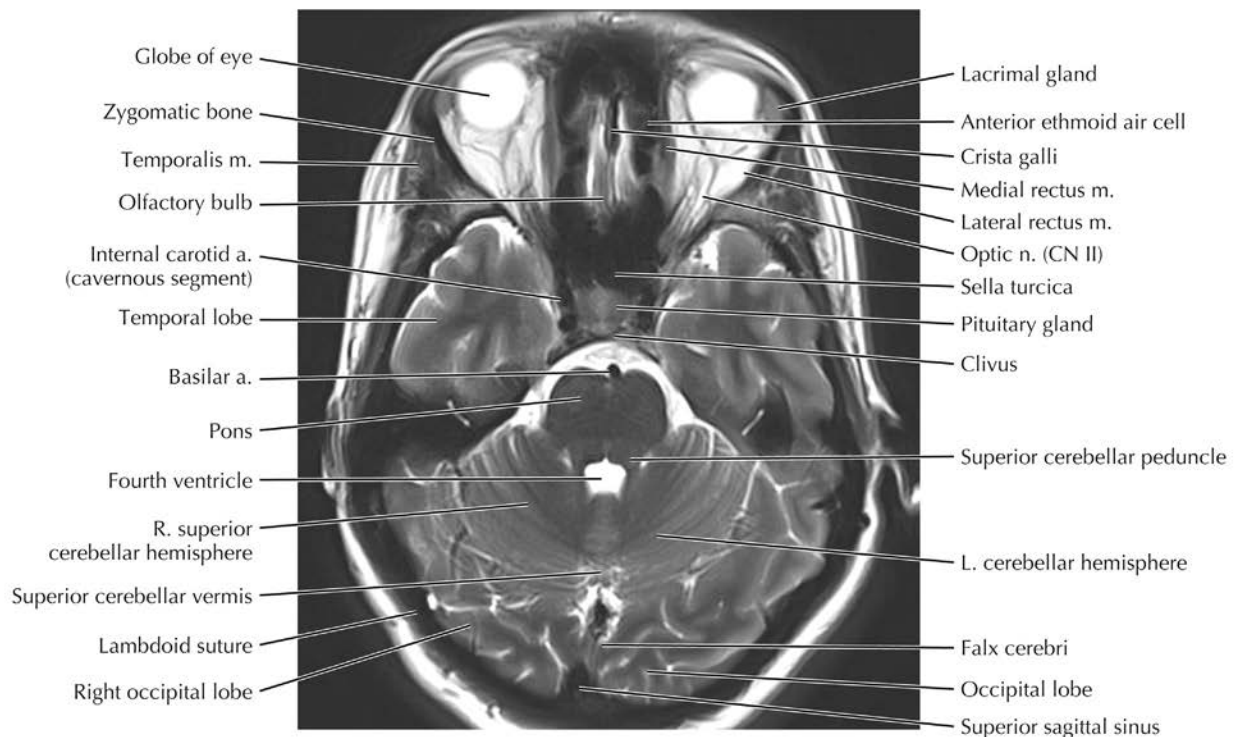
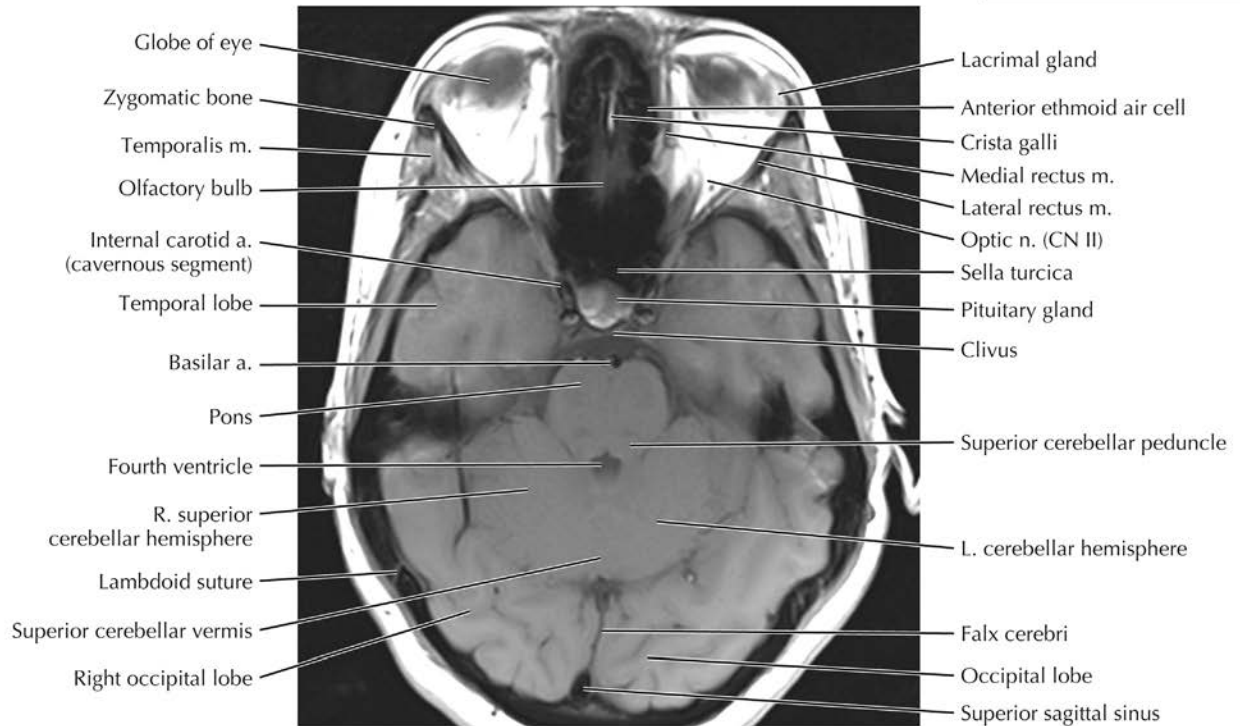
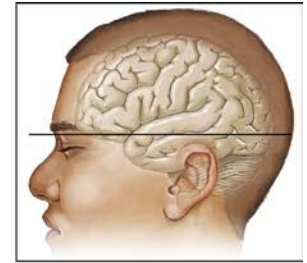


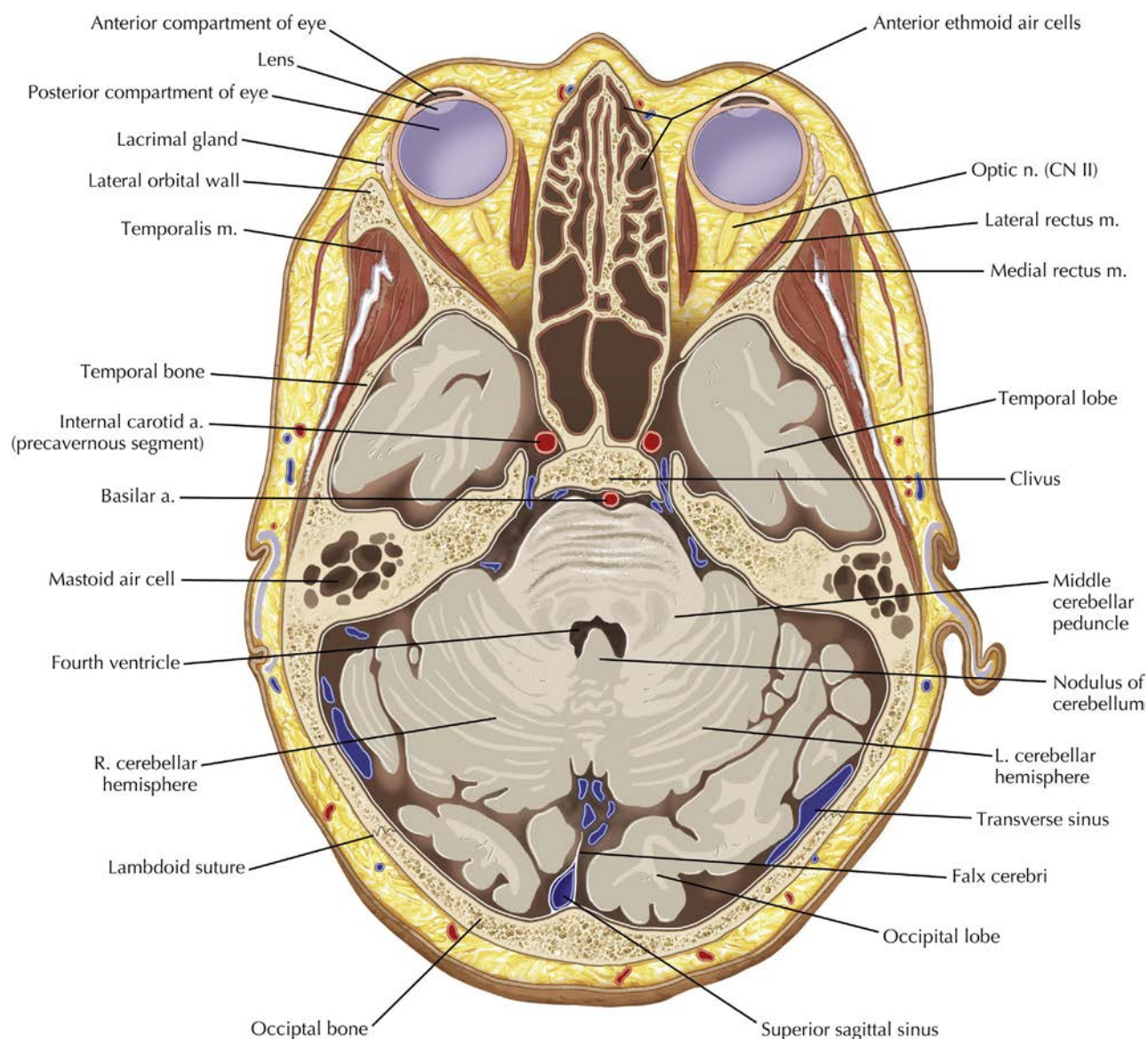
DIAGNOSTIC CONSIDERATION

The temporal horns can be useful to help differentiate true hydrocephalus from ex vacuo dilation of the ventricles from central white matter volume loss. In the former case, the temporal horns are dilated and in the latter case they are not. The body of the lateral ventricles can sometimes look prominent but with normal-sized temporal horns where there is central white matter volume loss from chronic microangiopathic disease. Since the body and temporal horns are continuous structures, both should be dilated in true hydrocephalus.



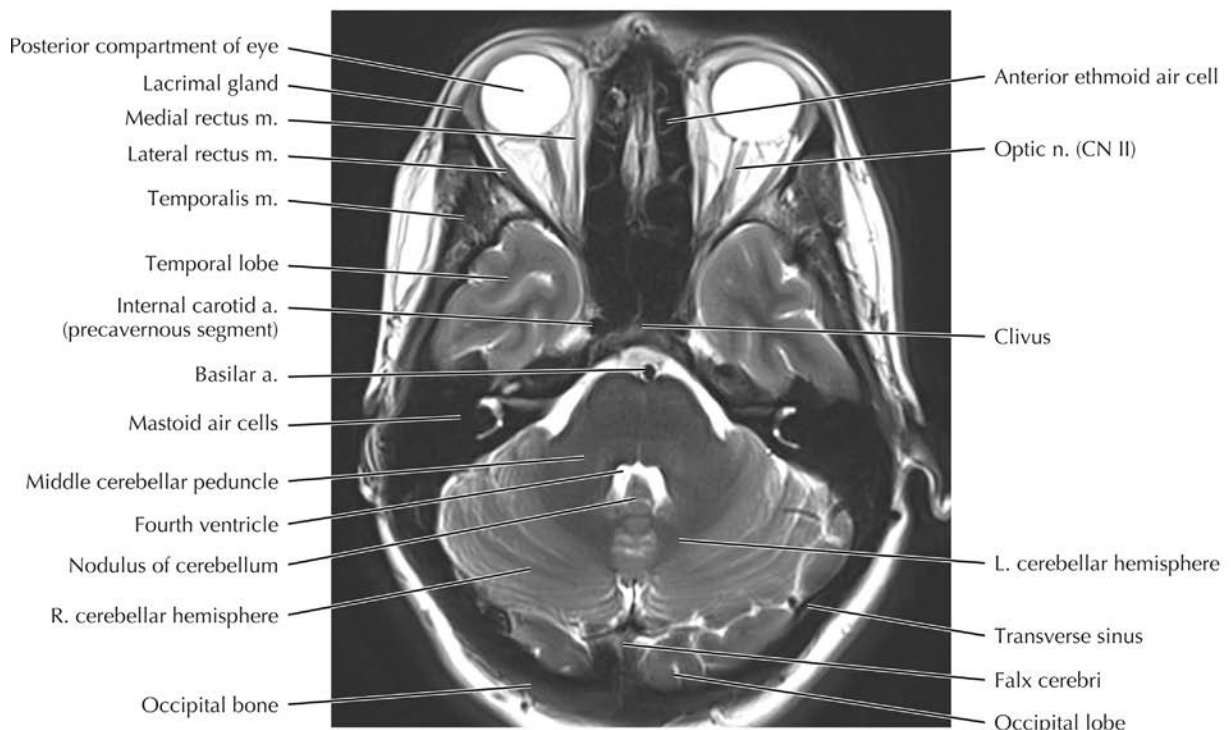
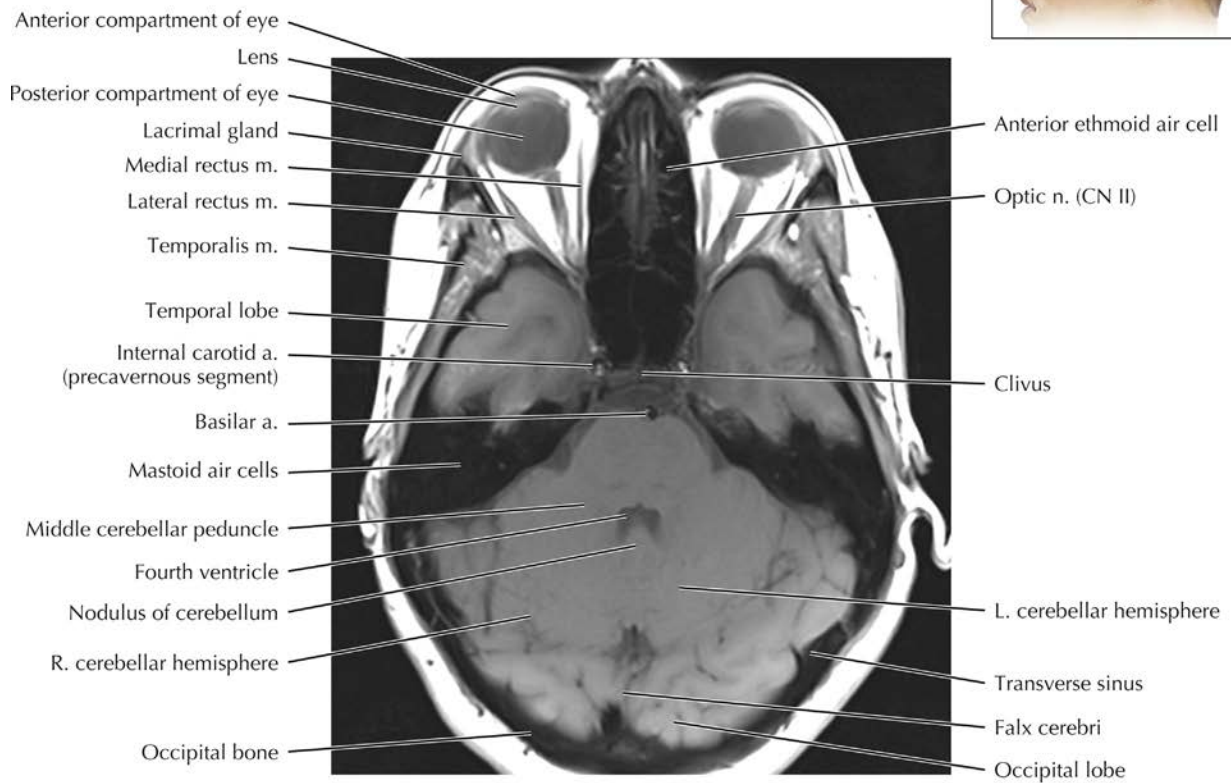
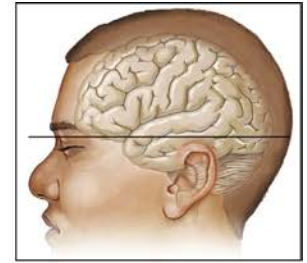


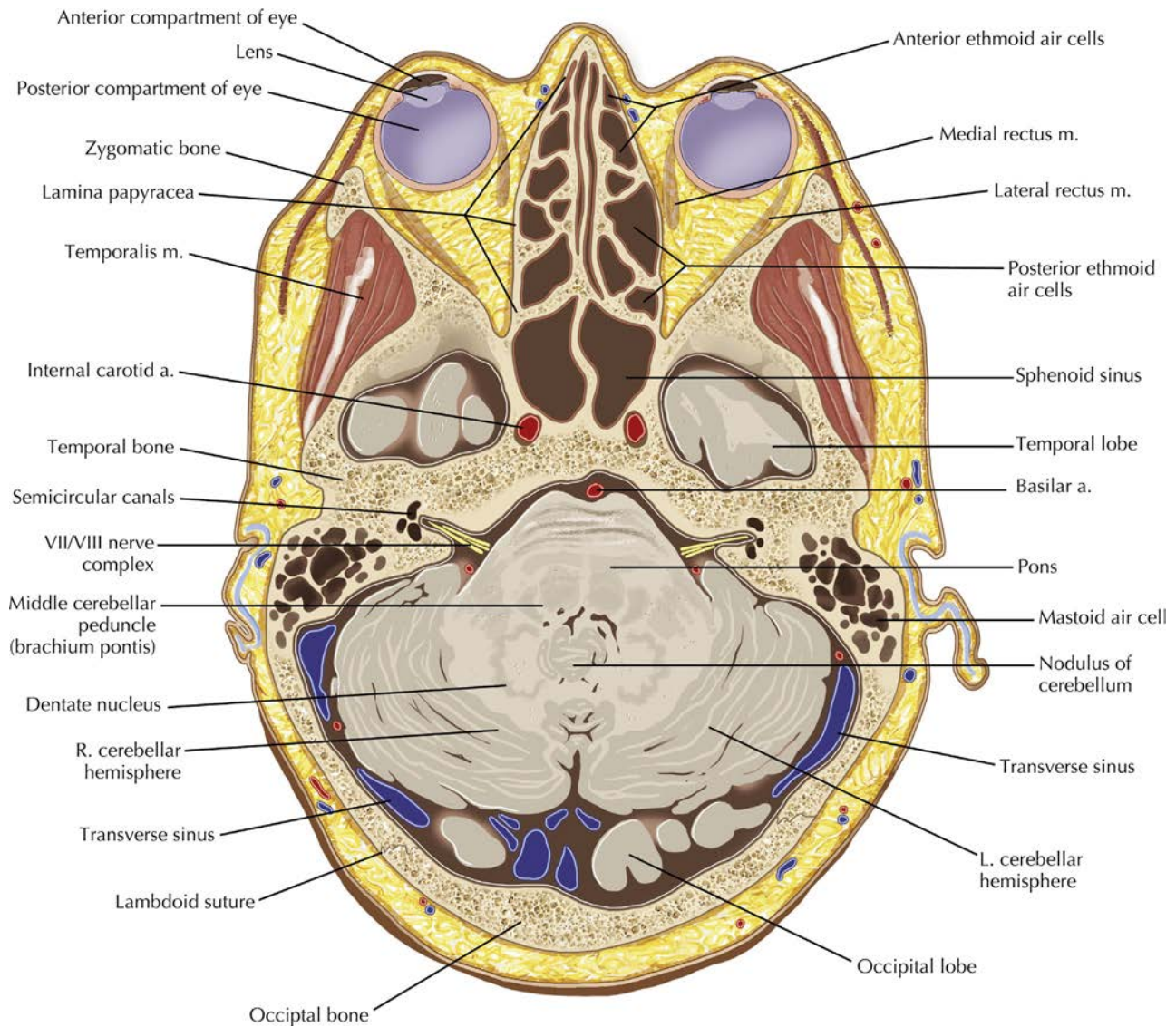




DIAGNOSTIC CONSIDERATION

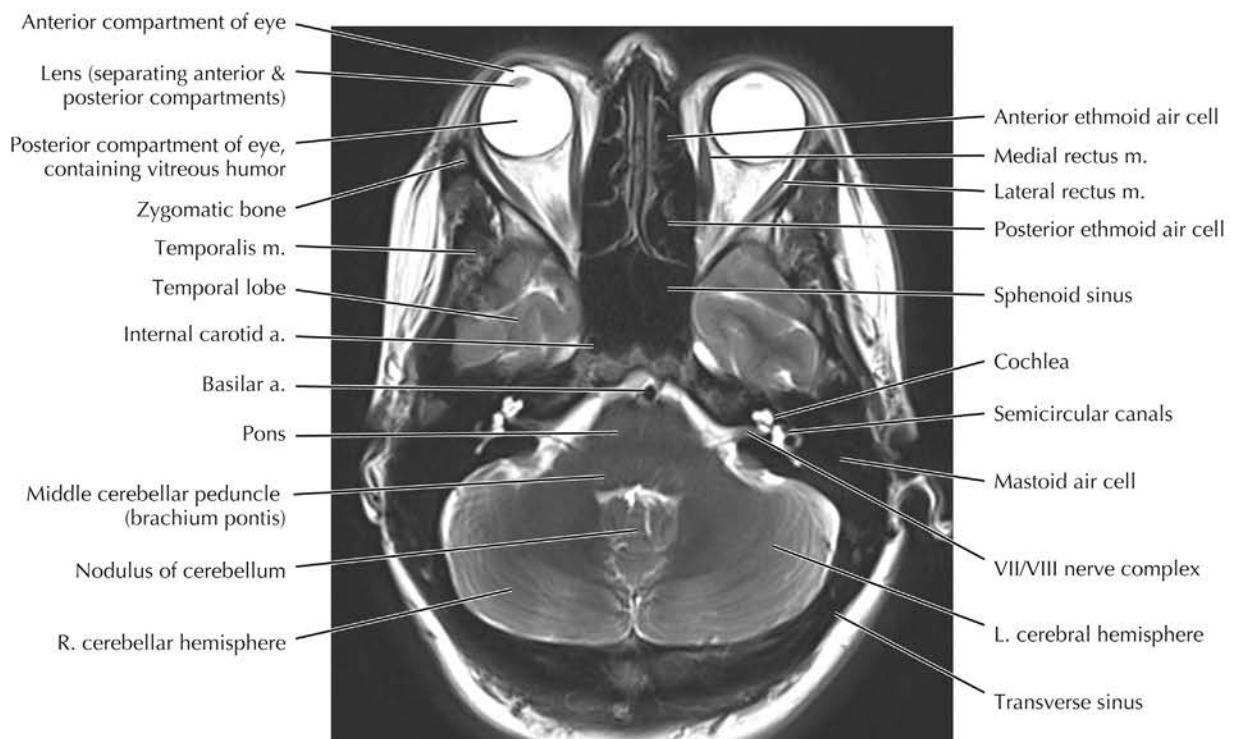
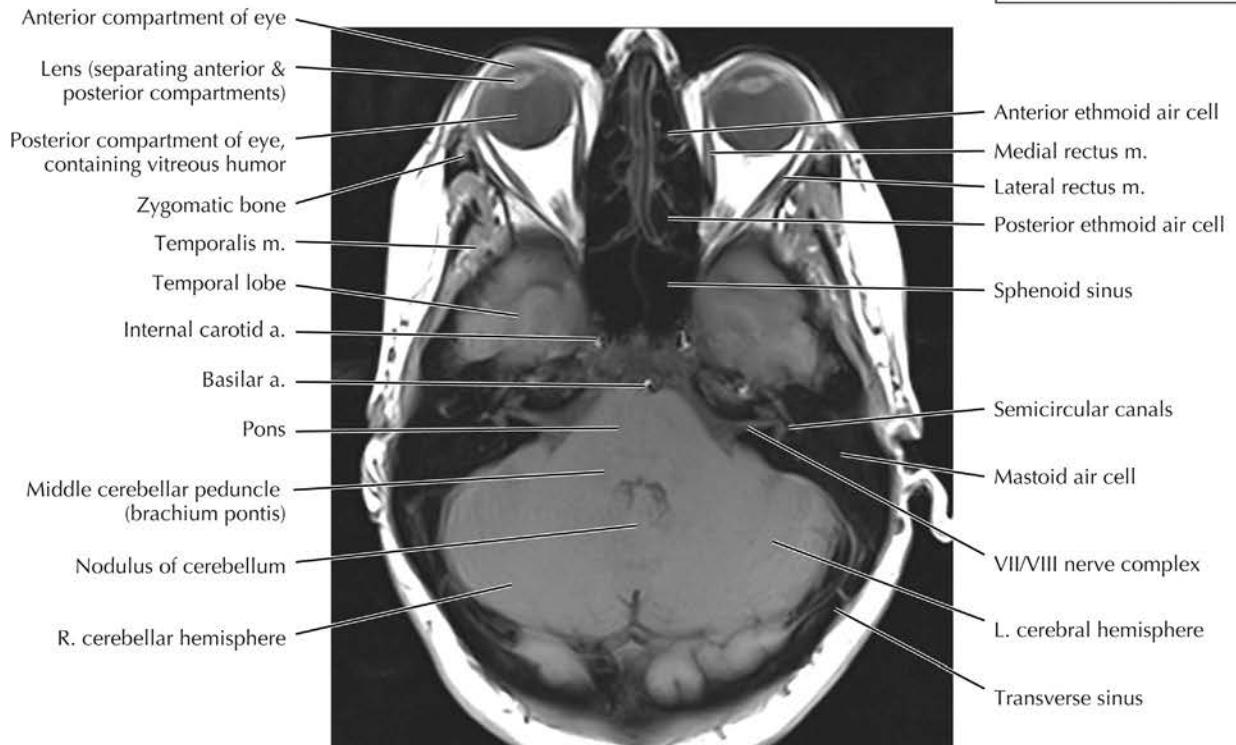
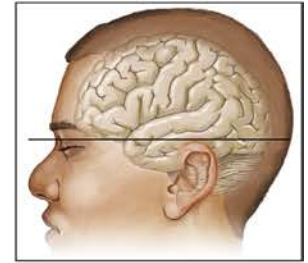
A subtle but important finding is loss of the normal dark flow void in the basilar artery, which may indicate a clot.

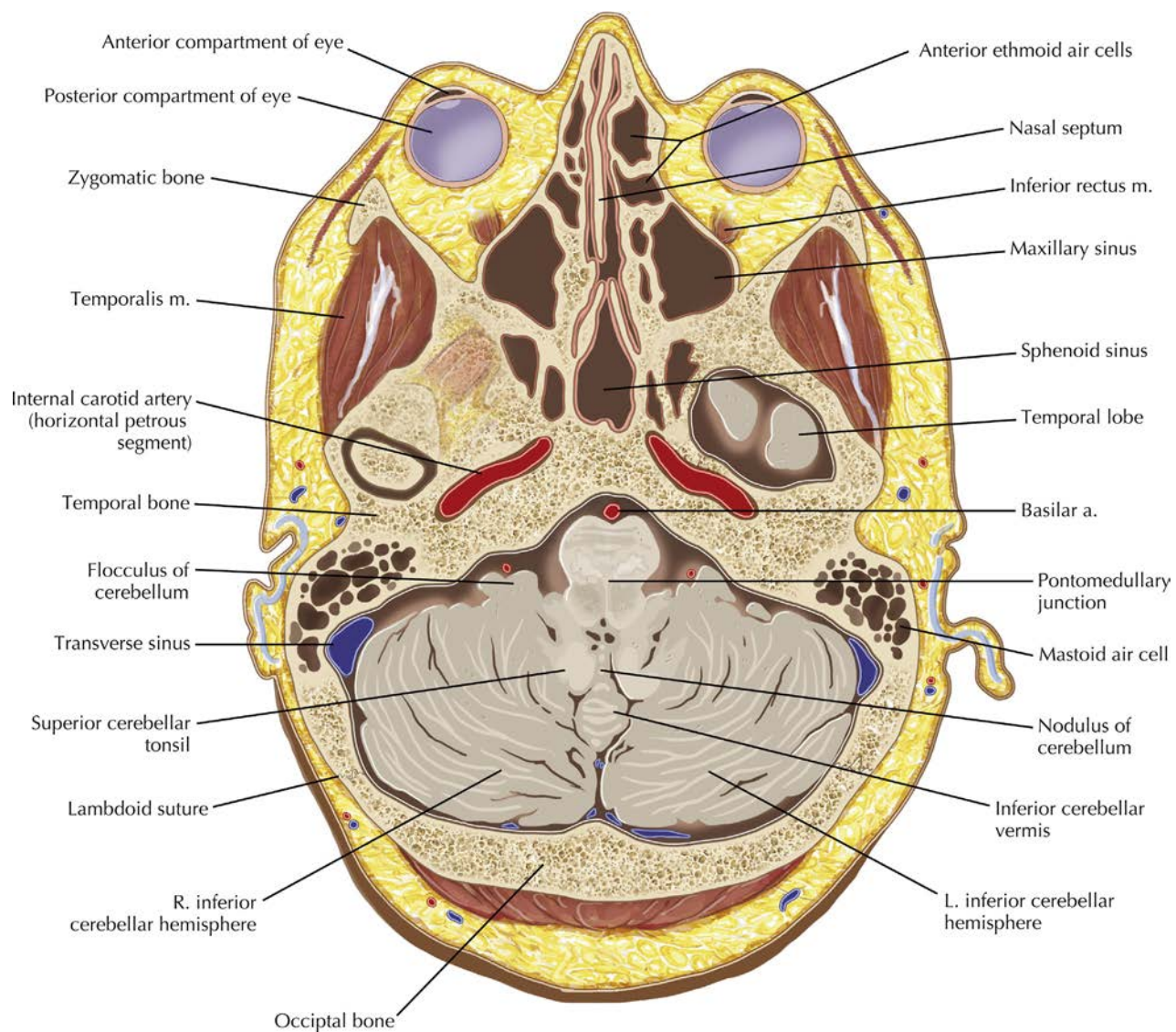


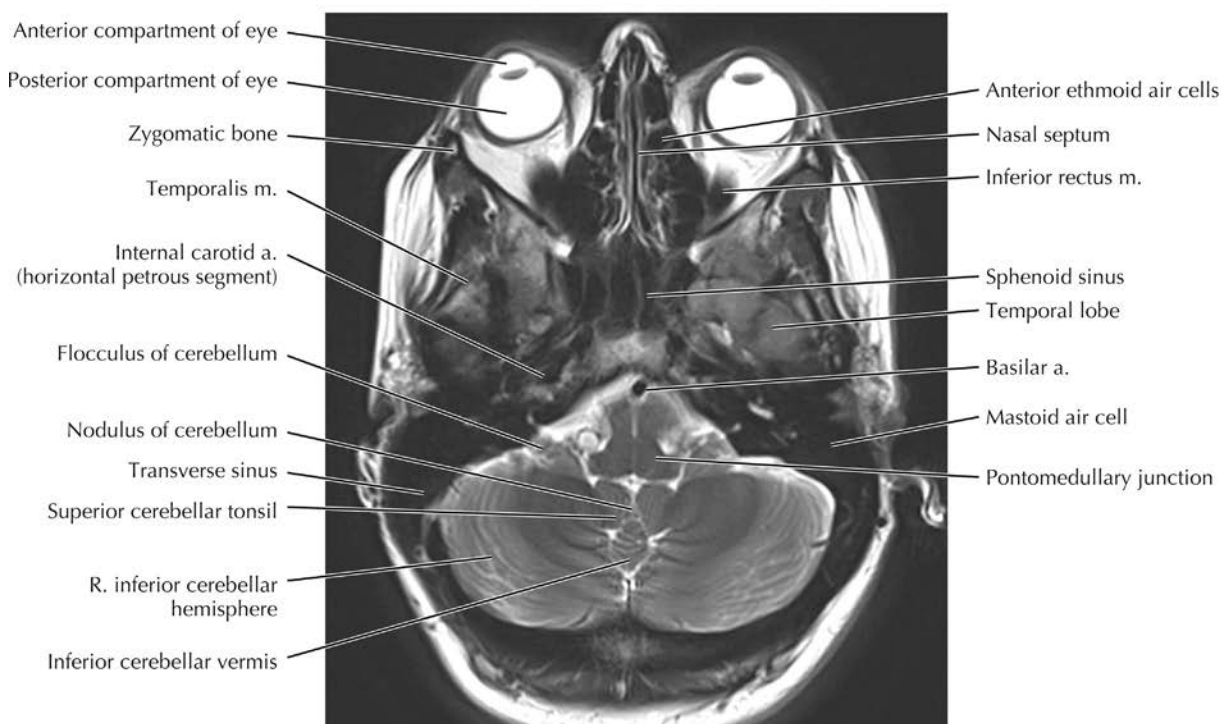
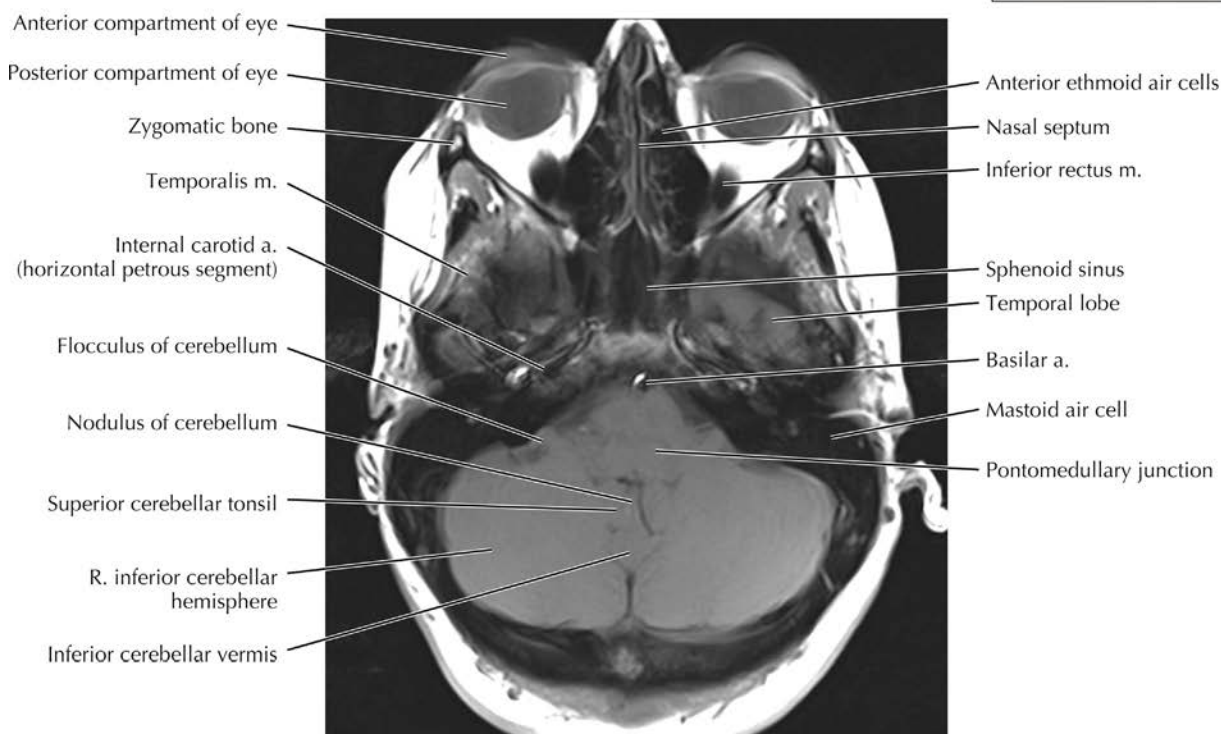
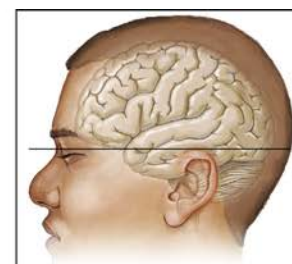


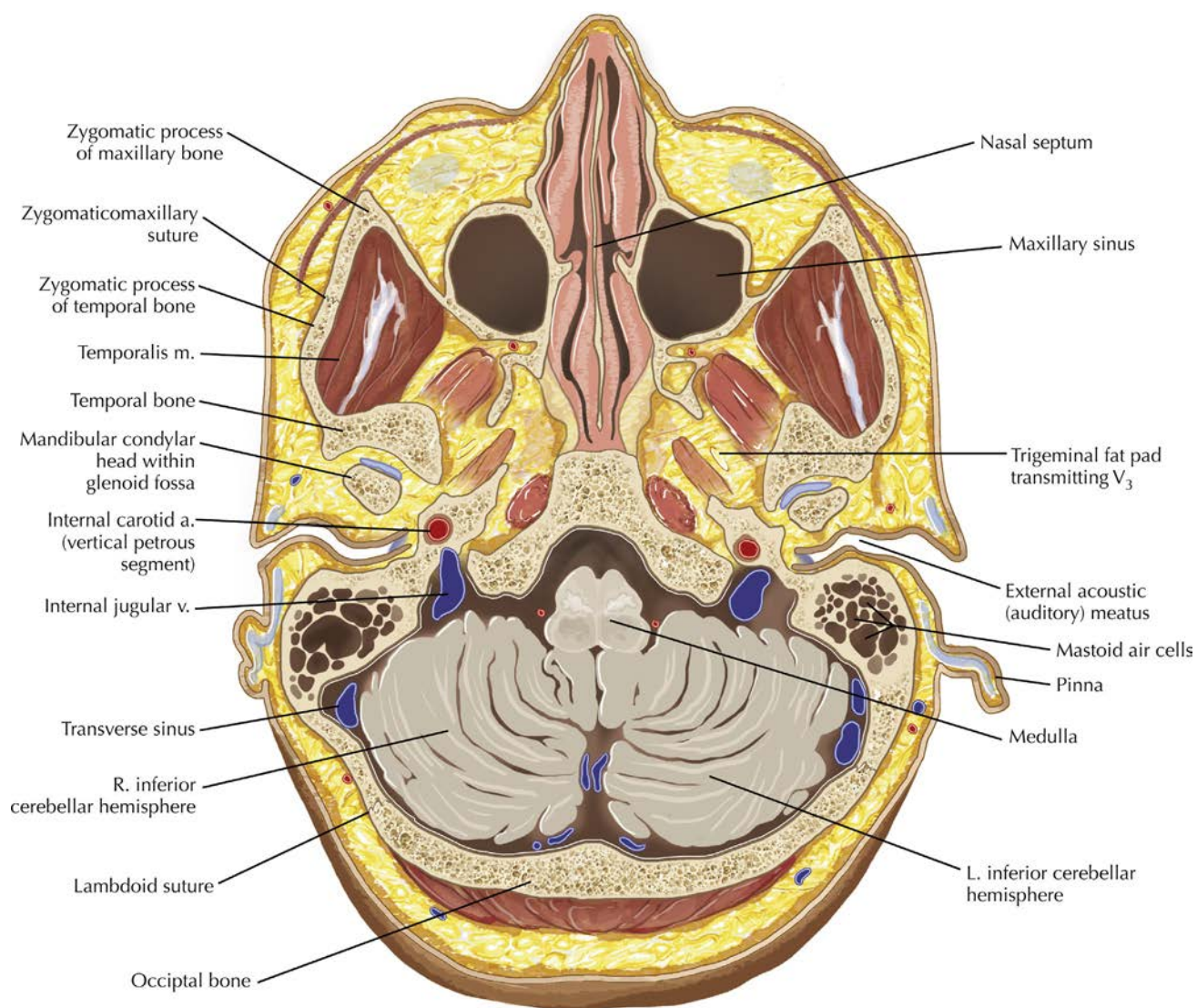
NORMAL ANATOMY

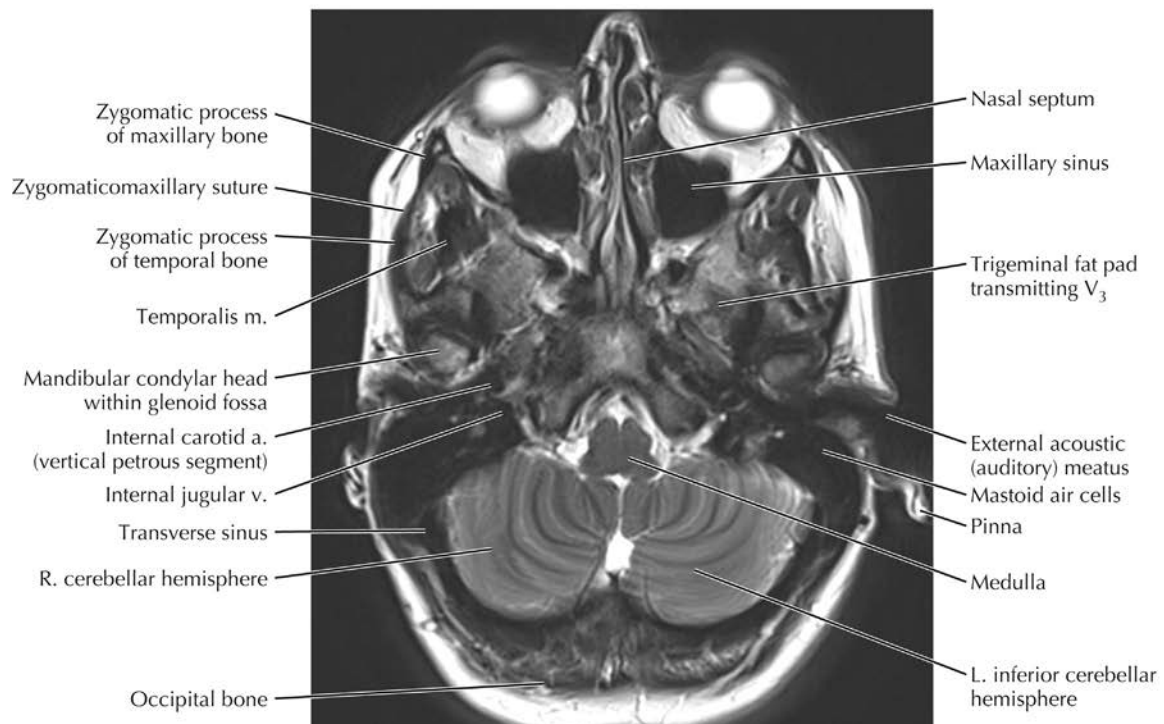
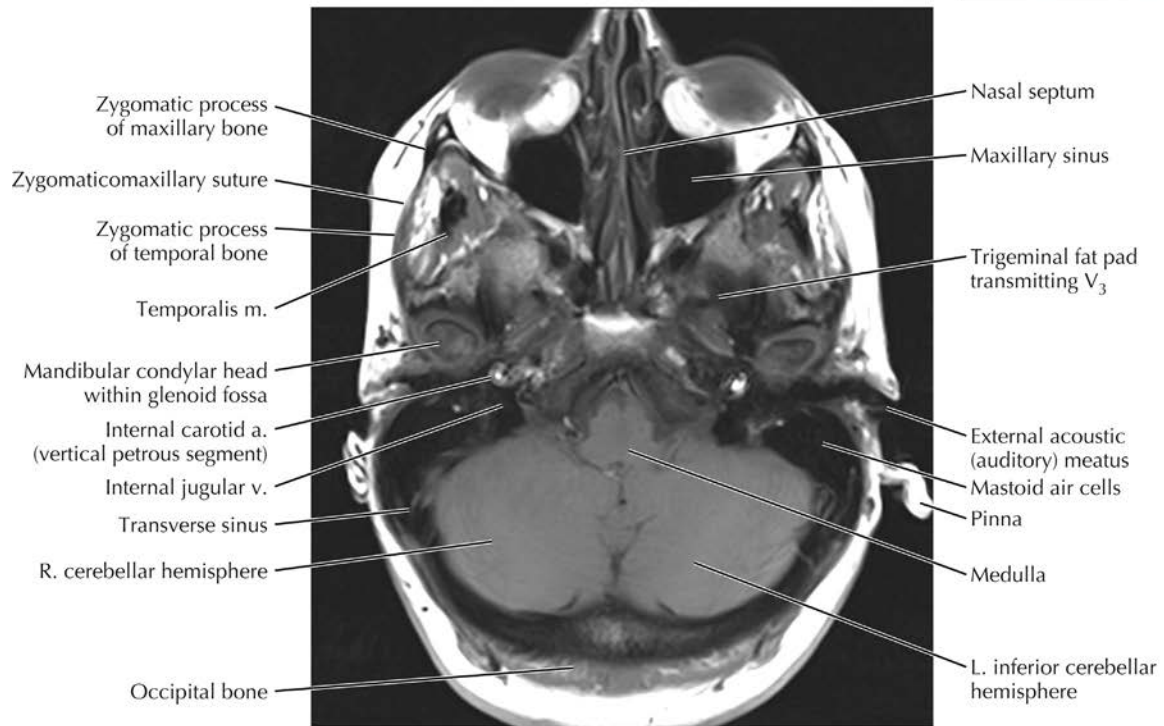
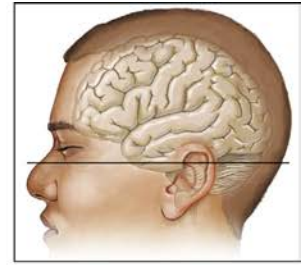
Note the regions with bright T2 fluid signal, including the vitreous humor, CSF in Meckel's cave, prepontine cistern, and endolymph fluid in the cochlea, semicircular canals, and internal auditory canals. Recall that fat is also bright on fast spin-echo T2-weighted MRI.

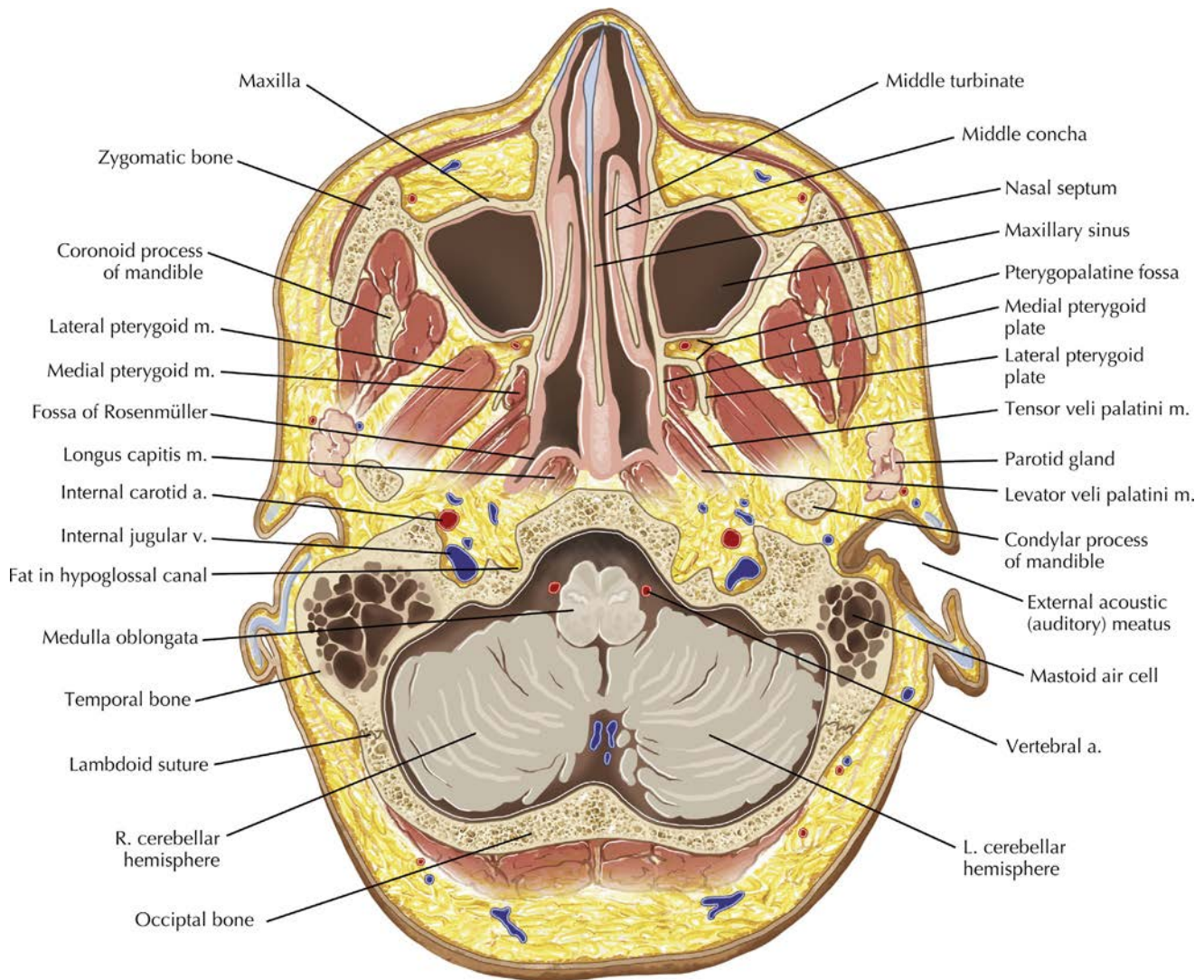






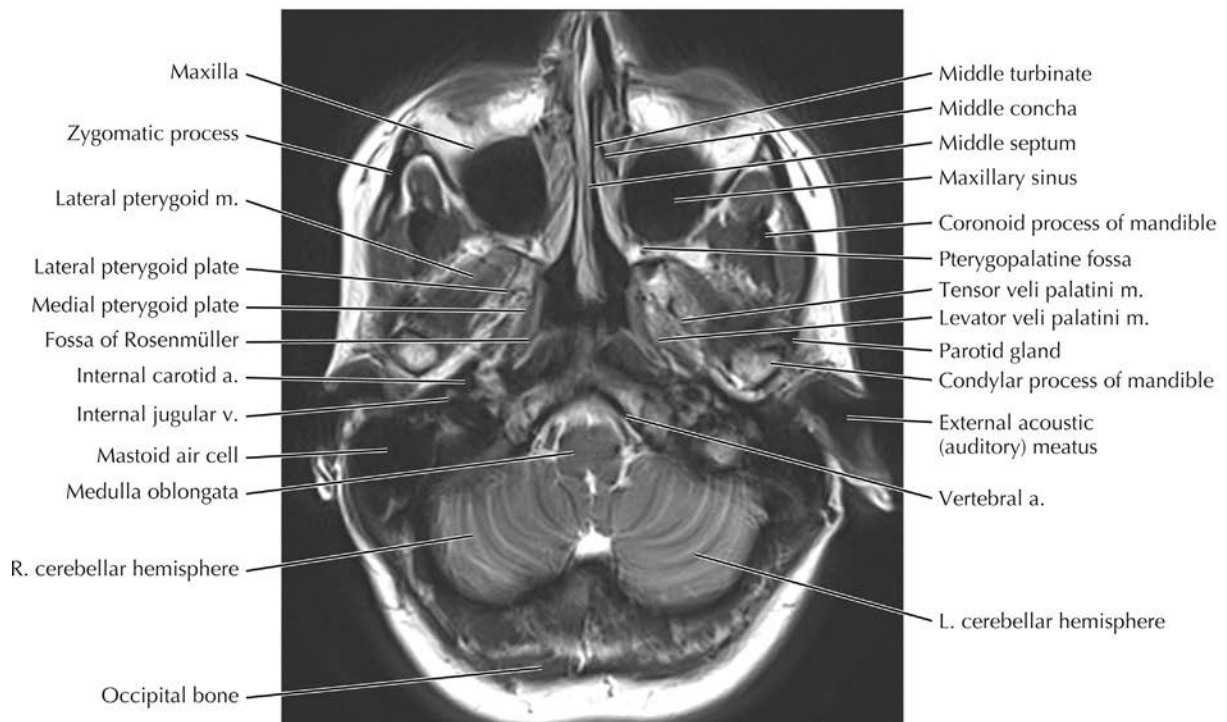
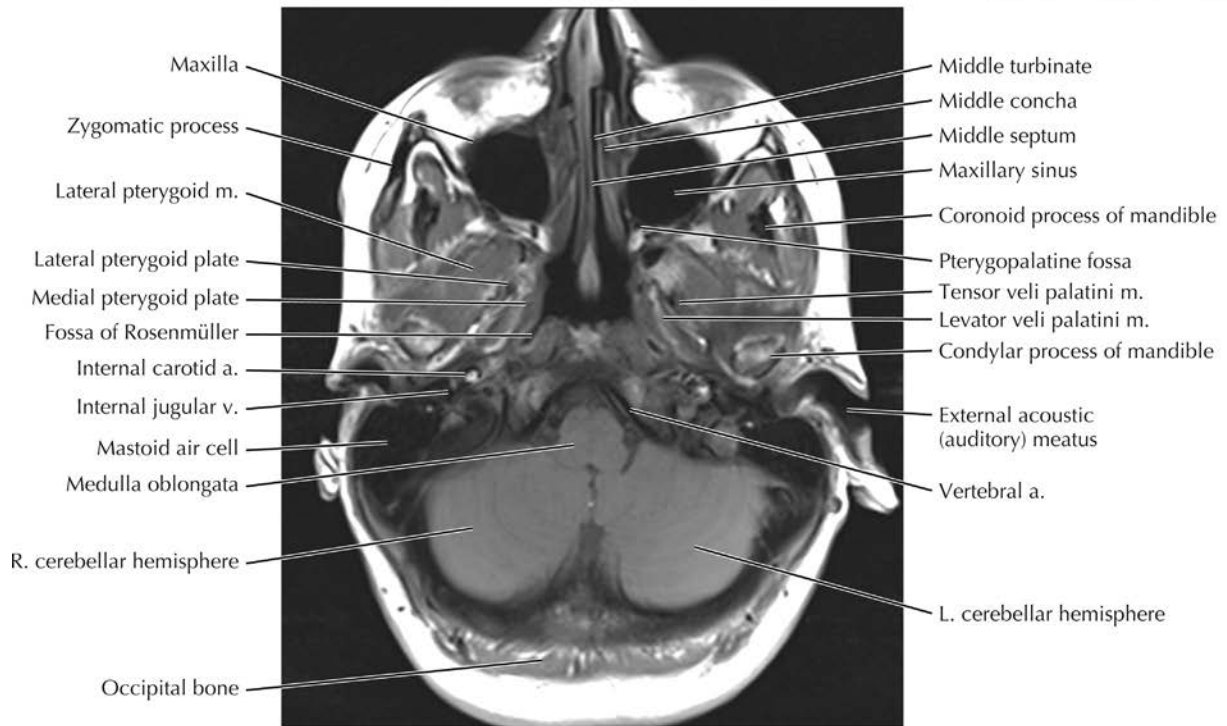
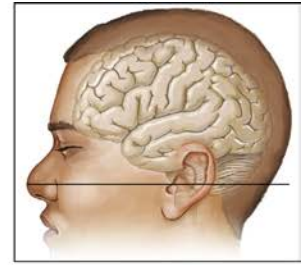


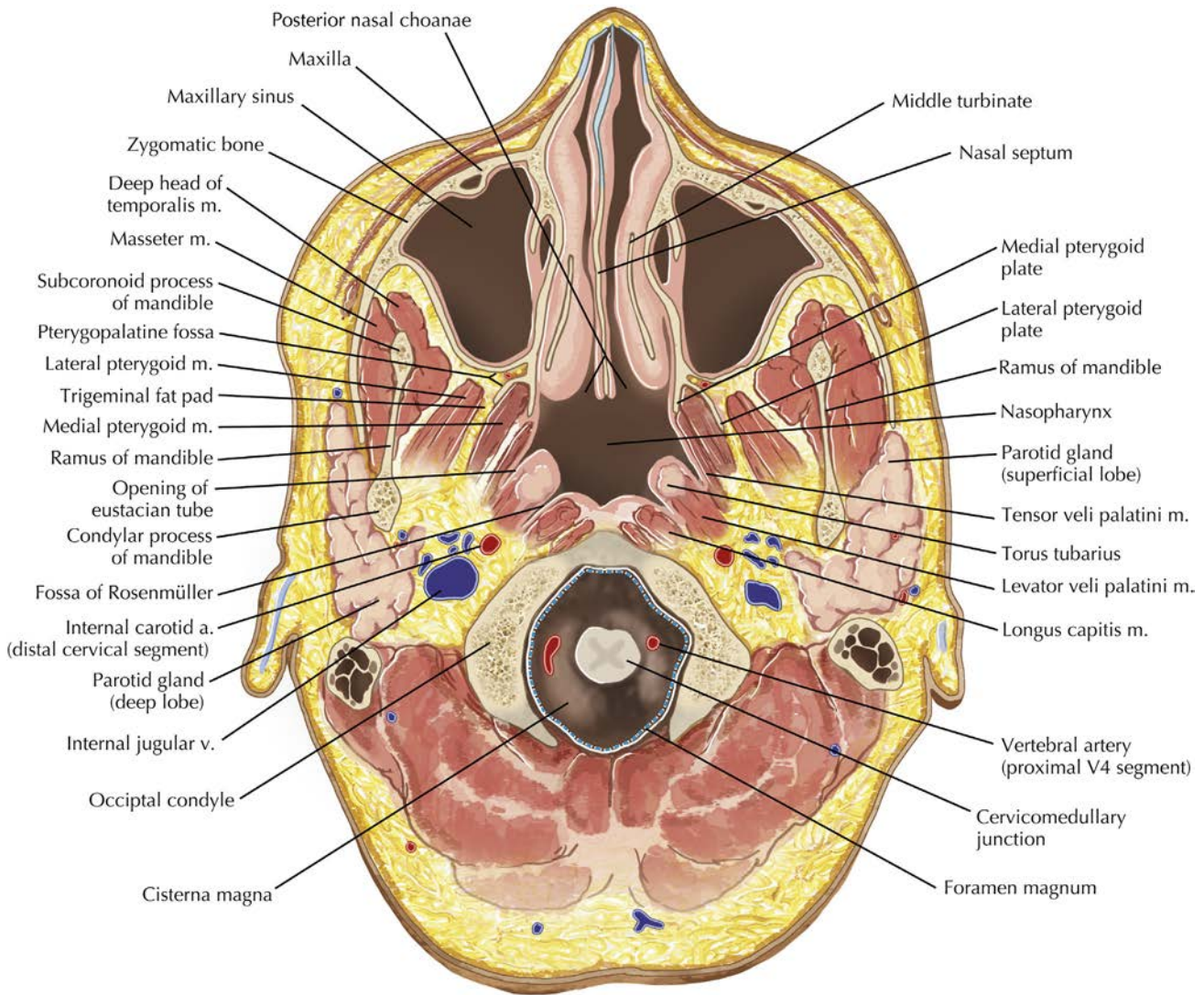




PATHOLOGIC PROCESS

Note the vessels and nerves in the pterygopalatine fossa surrounded by bright fat. Loss of this normal fat signal can be a sign of perineural spread of disease along the maxillary branch of the trigeminal nerve (V_2). Meckel's ganglion (pterygopalatine ganglion) sits in this fossa, as opposed to the Gasserian ganglion, which sits more posteriorly, in Meckel's cave.



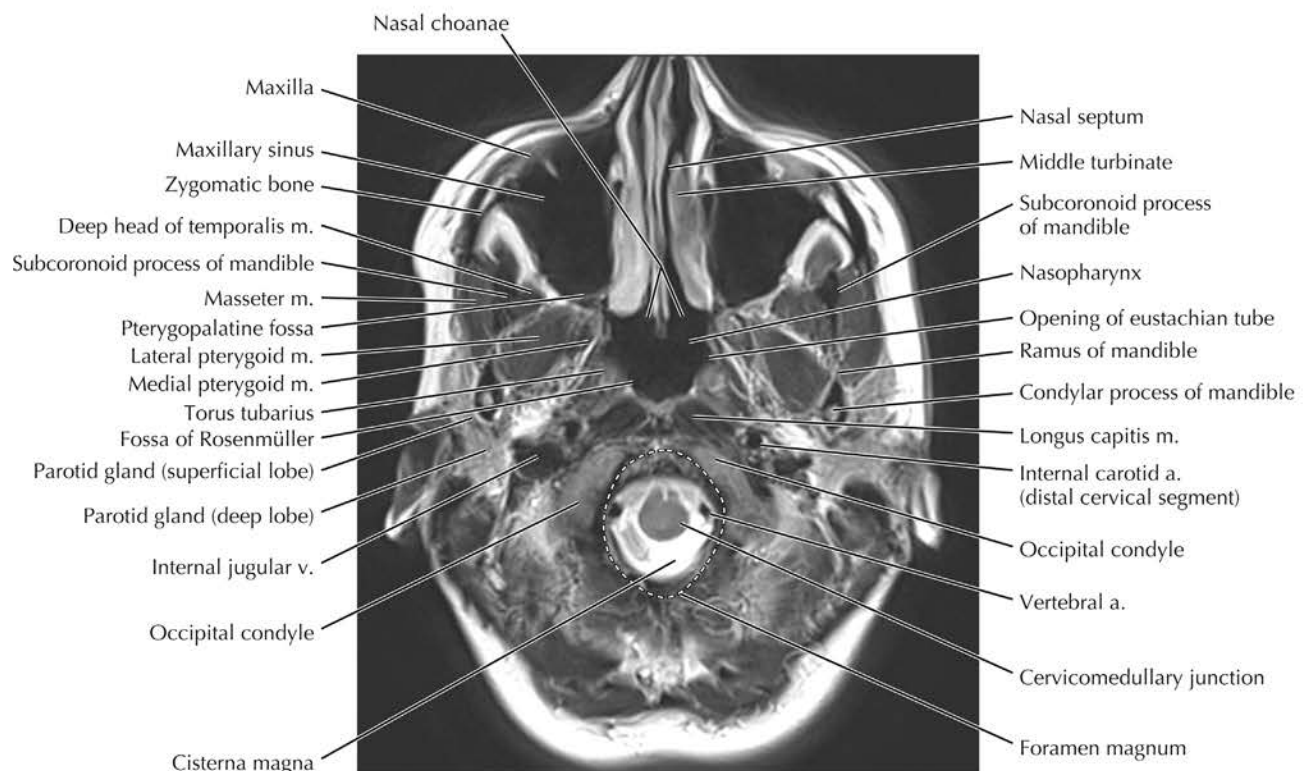
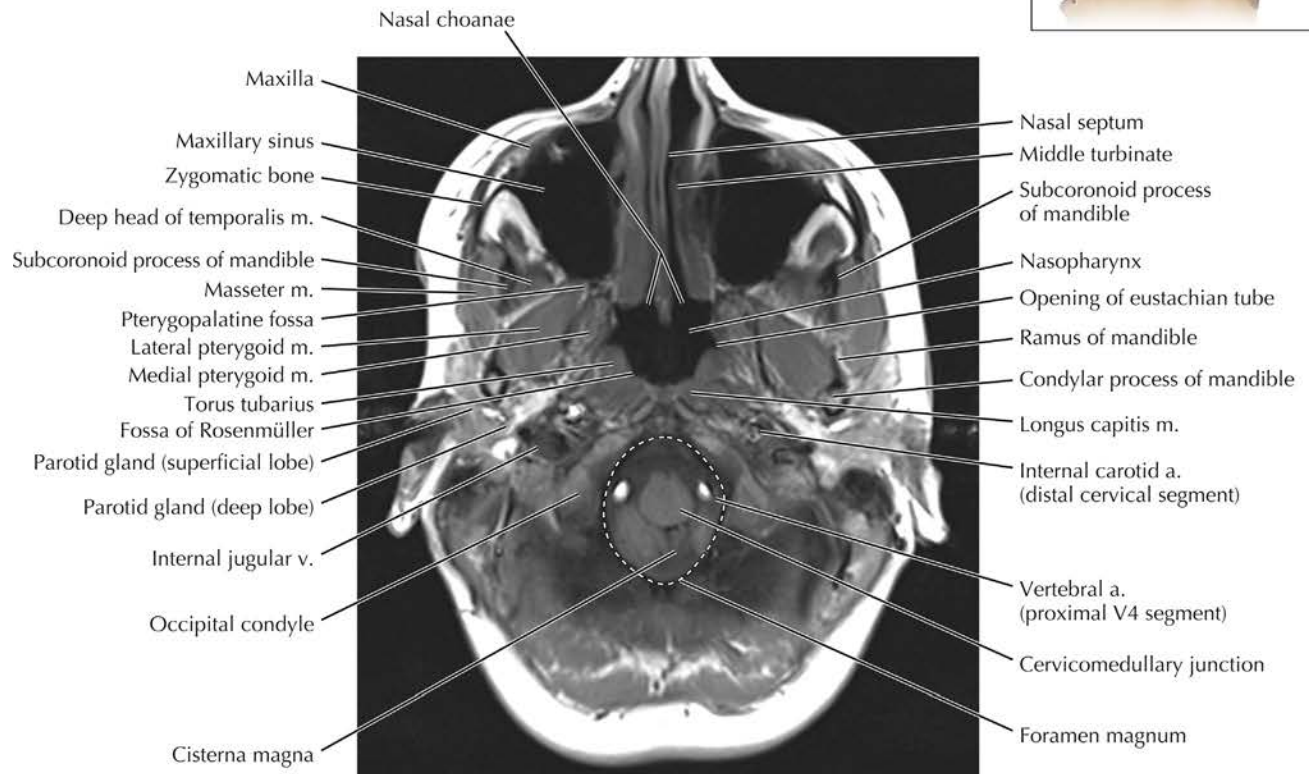
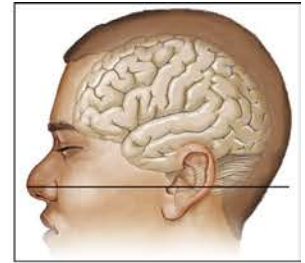


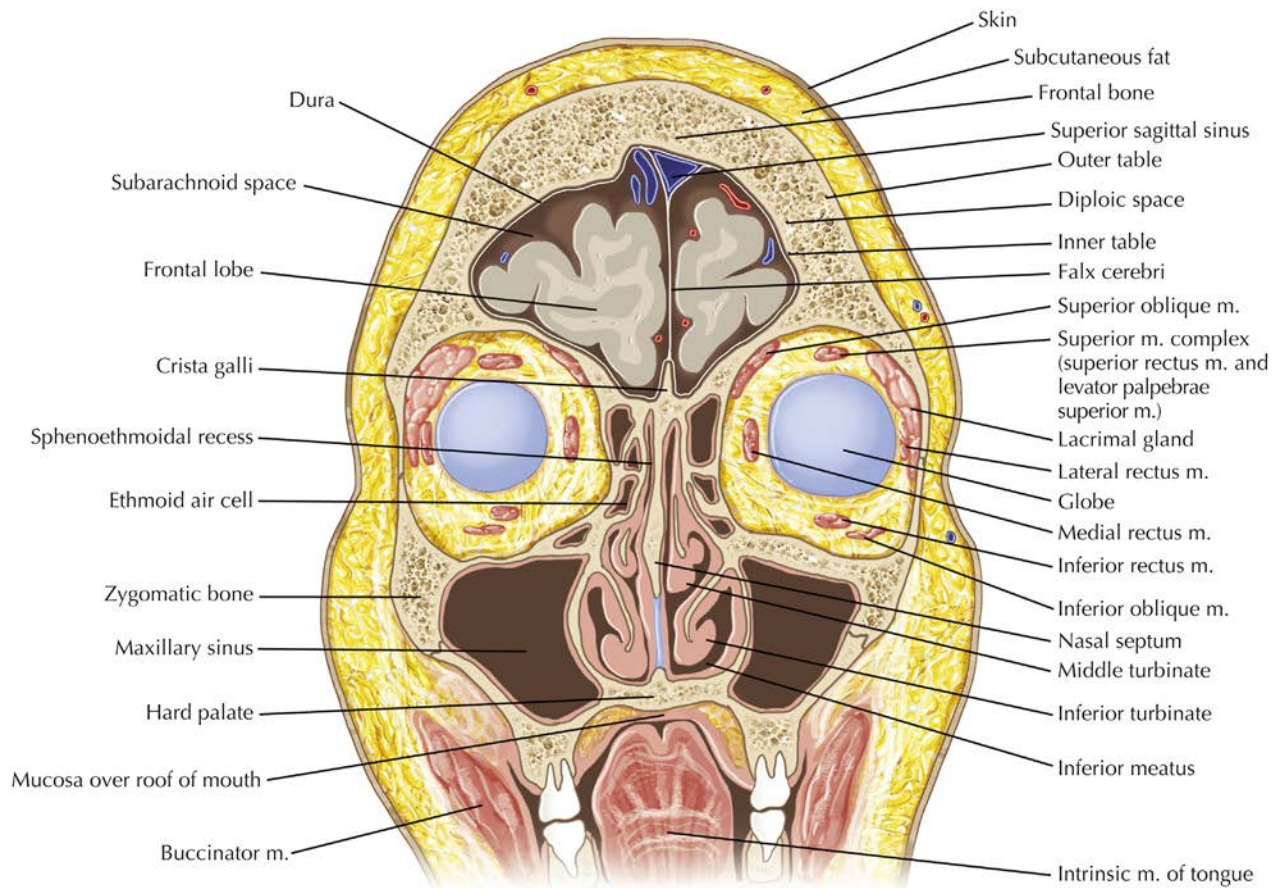
DIAGNOSTIC CONSIDERATIONS

On most head studies, the most inferior axial image will show the upper aspect of neck structures such as the parotid glands and nasopharynx. These are often "blind spots" for the unwary neuroradiologist. Loss of the normal "divot" caused by the blind-ending fossa of Rosenmüller between the longus capitis muscle and the torus tubarius in an adult patient may be a sign of nasopharyngeal carcinoma. This can also lead to obstruction of the Eustachian tube opening with fluid in the mastoid air cells. Parotid lesions, even benign tumors such as pleomorphic adenoma, are often resected, unlike thyroid lesions, most of which do not cause symptoms.

IMAGING TECHNIQUE CONSIDERATION

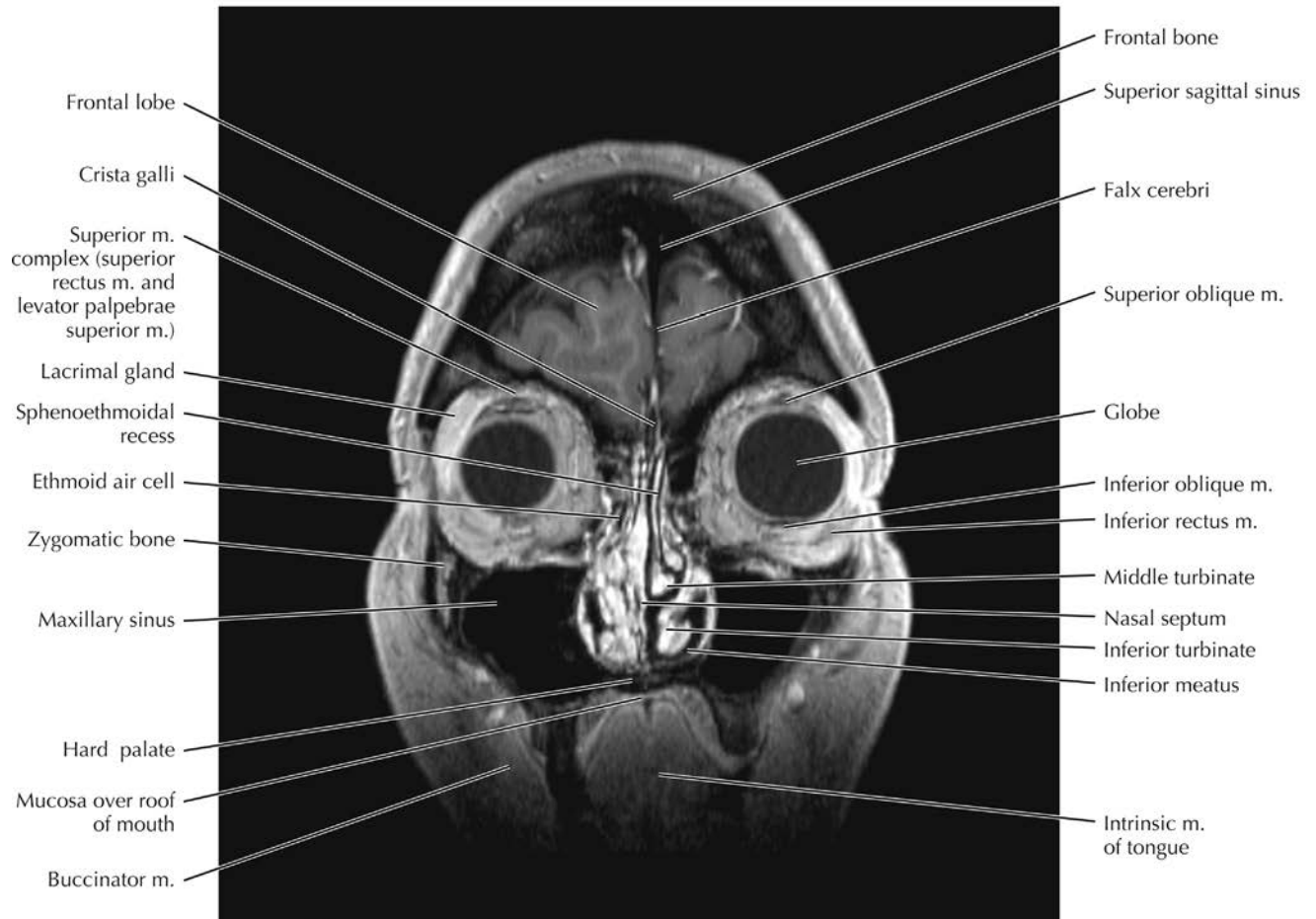
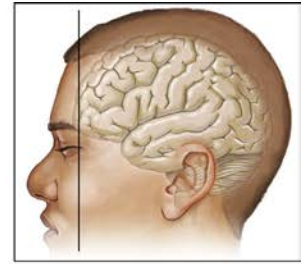
On fast spin-echo T2-weighted imaging, fat is bright, as on T1-weighted imaging. The best way to differentiate is to look at fluid, such as the CSF around the brainstem, which will be bright on T2-weighted imaging and gray on T1-weighted imaging. Please note that there is entry-slice phenomenon causing the lumina of the vertebral arteries to appear bright on T1-weighted imaging due to unsaturated blood entering the imaging slice; no contrast was given.

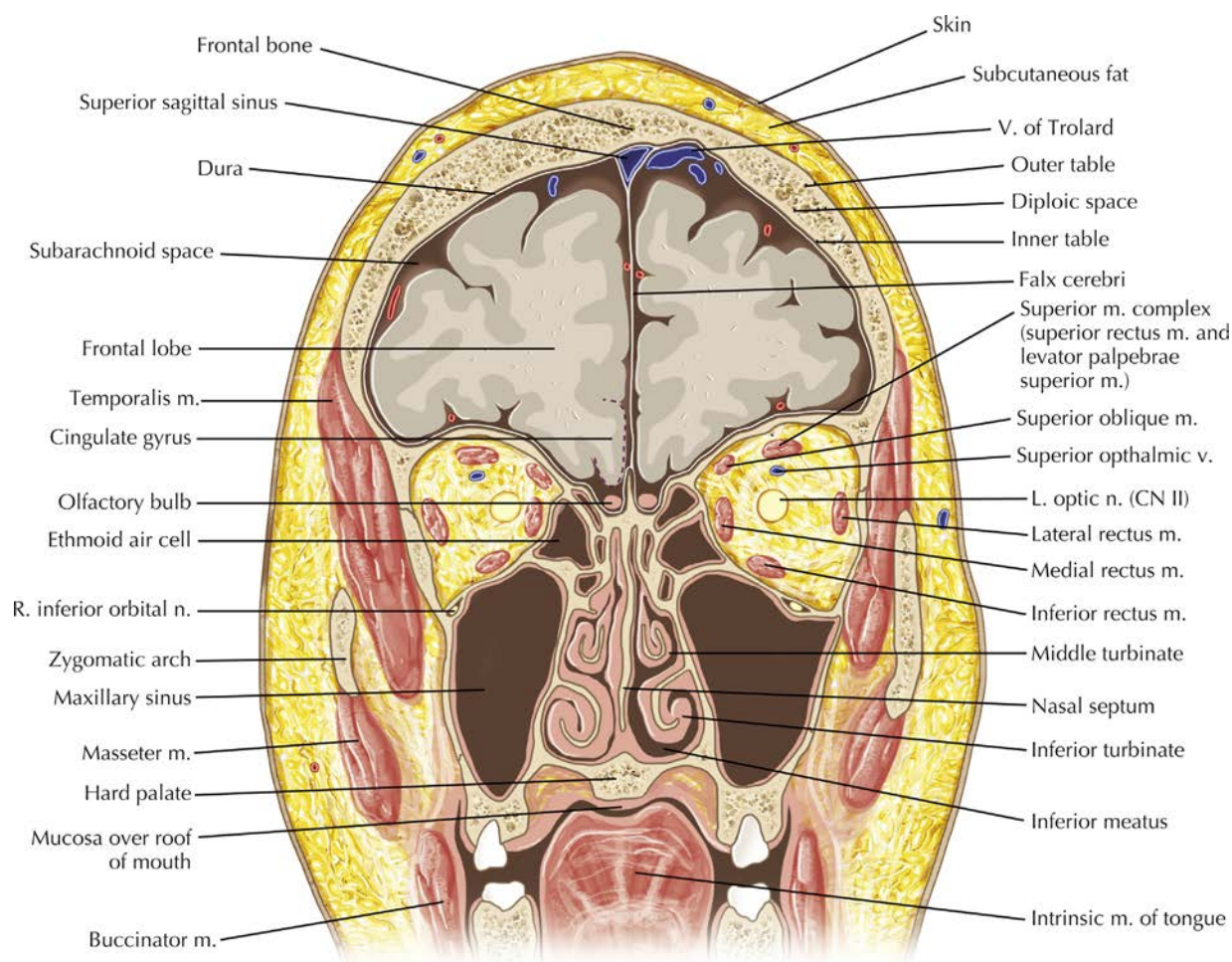


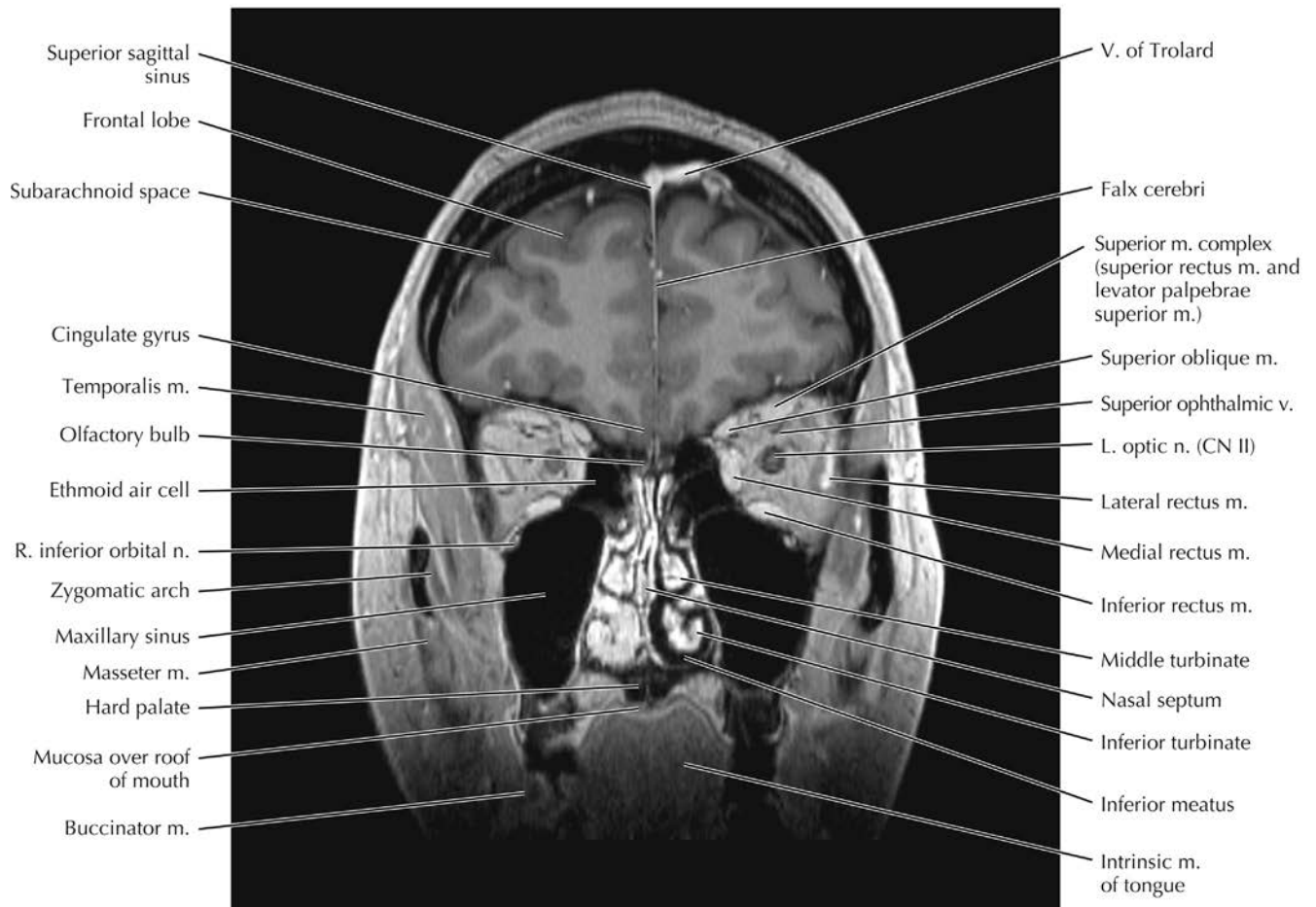
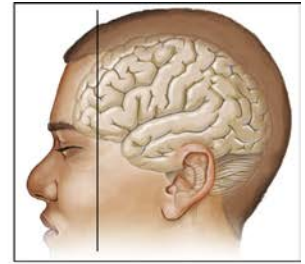


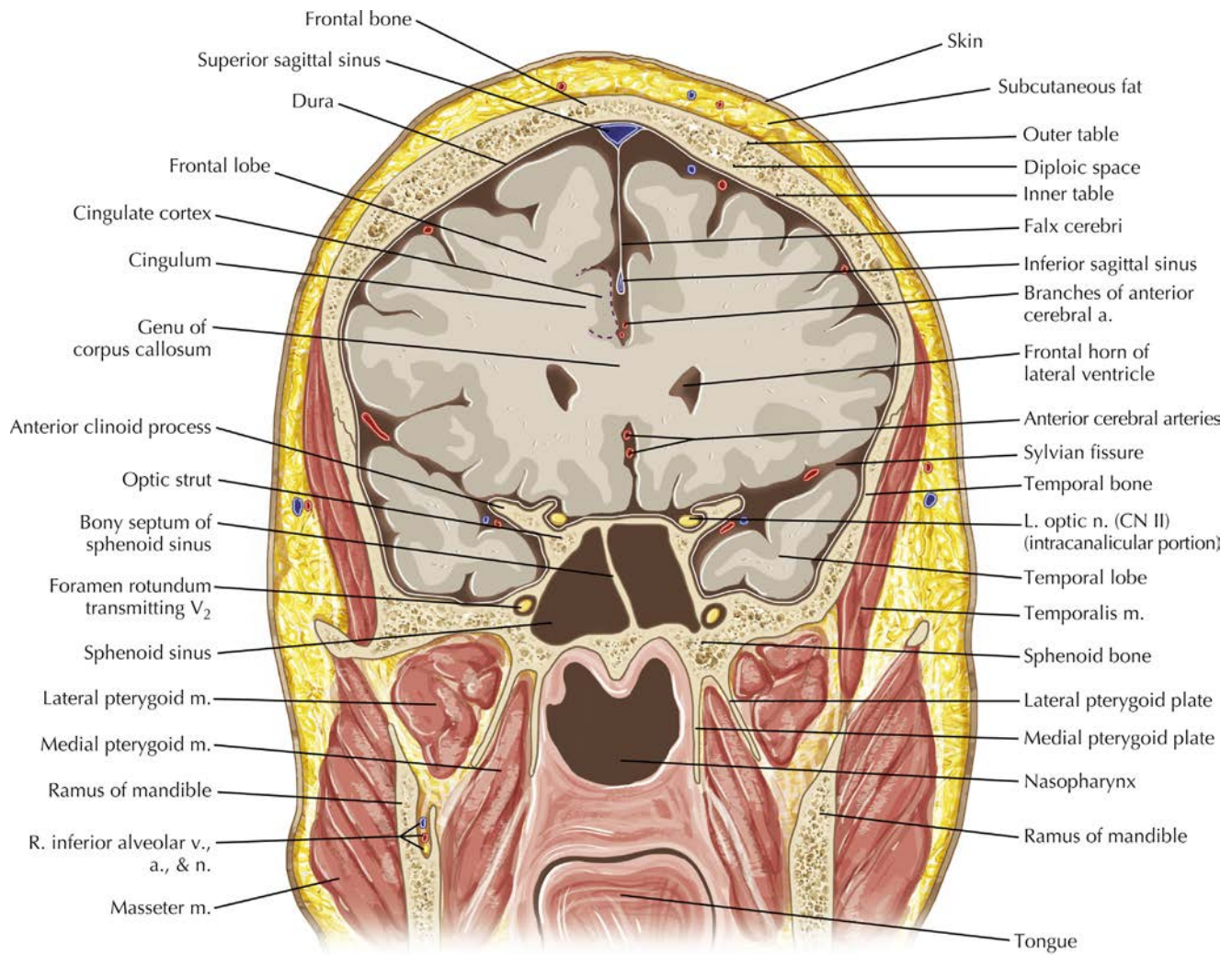
NORMAL ANATOMY

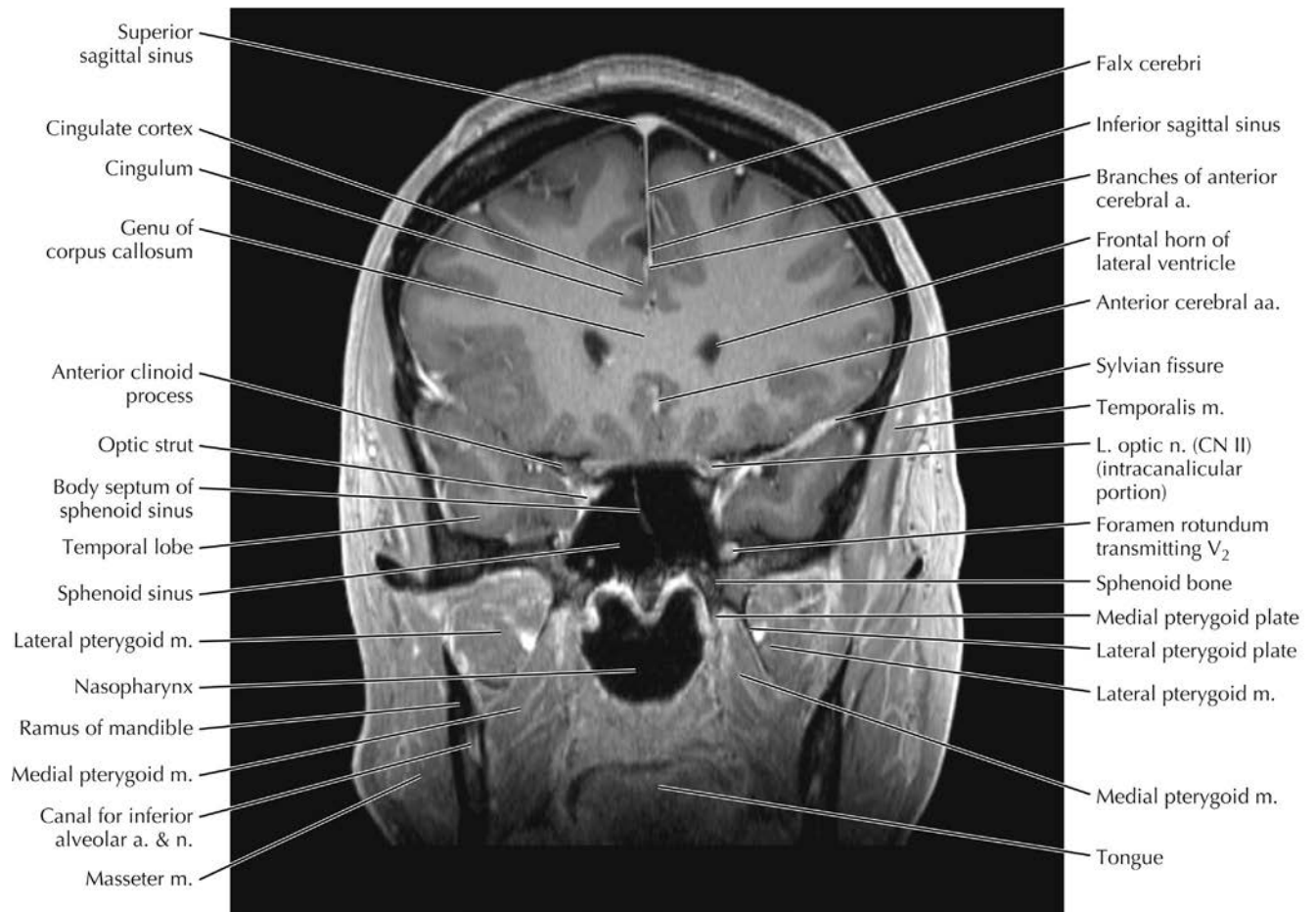
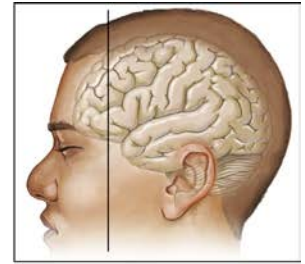
The *crista galli* (Latin, "crest of the cock") is a ridge of bone arising in the midline from the cribriform plate. The crista galli is the anterior attachment point of the falx to the skull. The olfactory nerves lie to either side of the crista galli within the olfactory grooves.

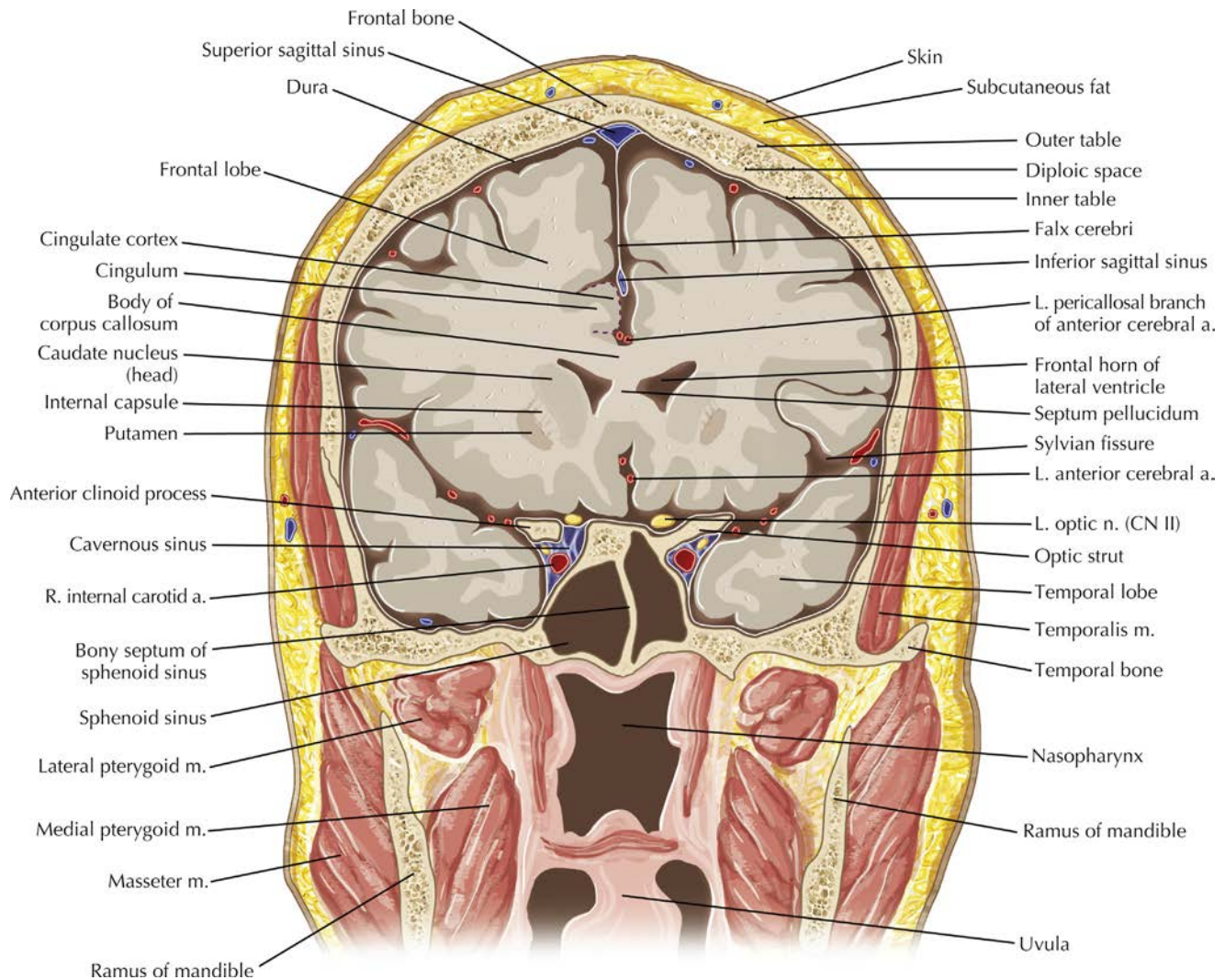


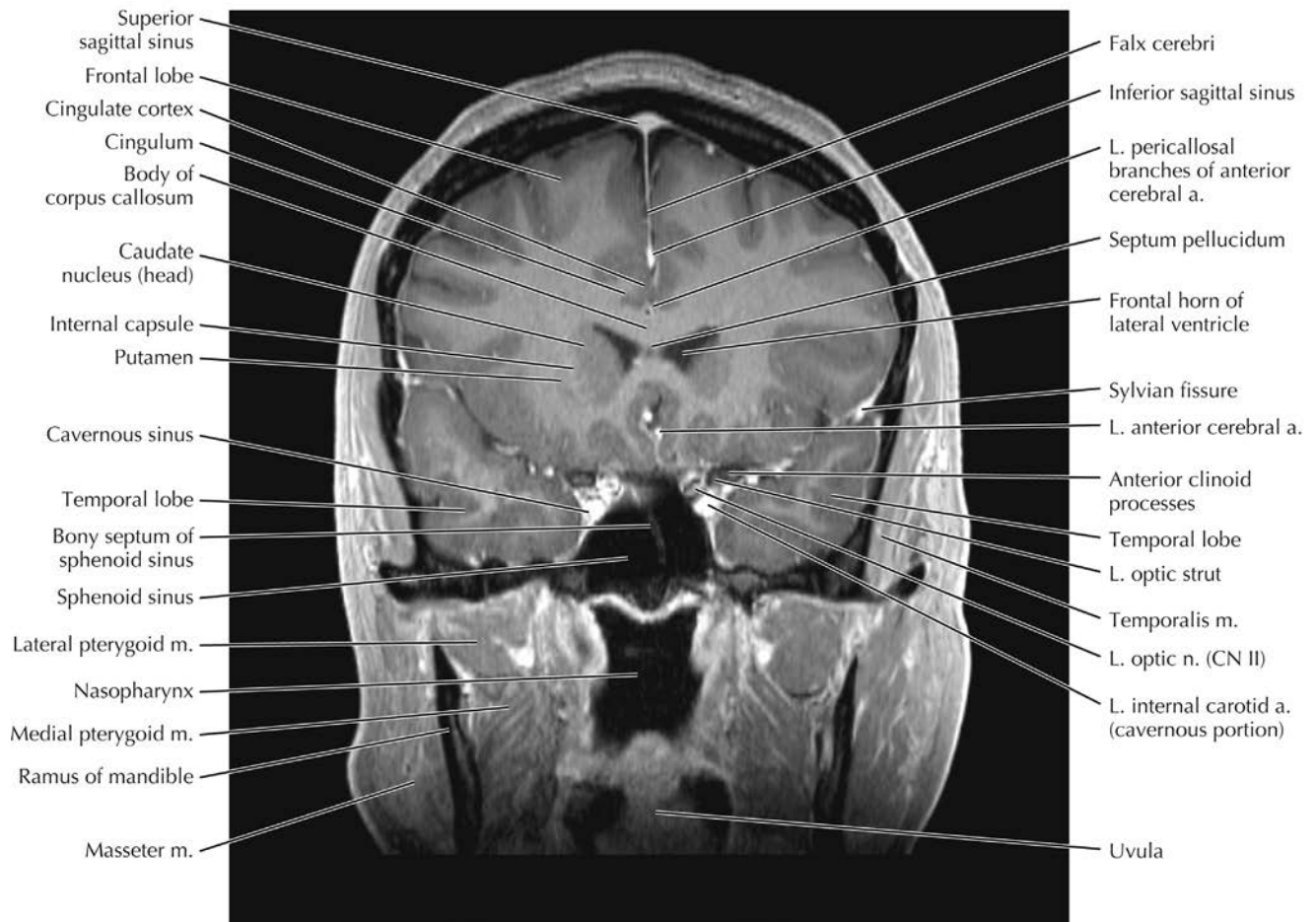
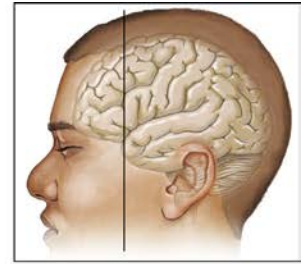


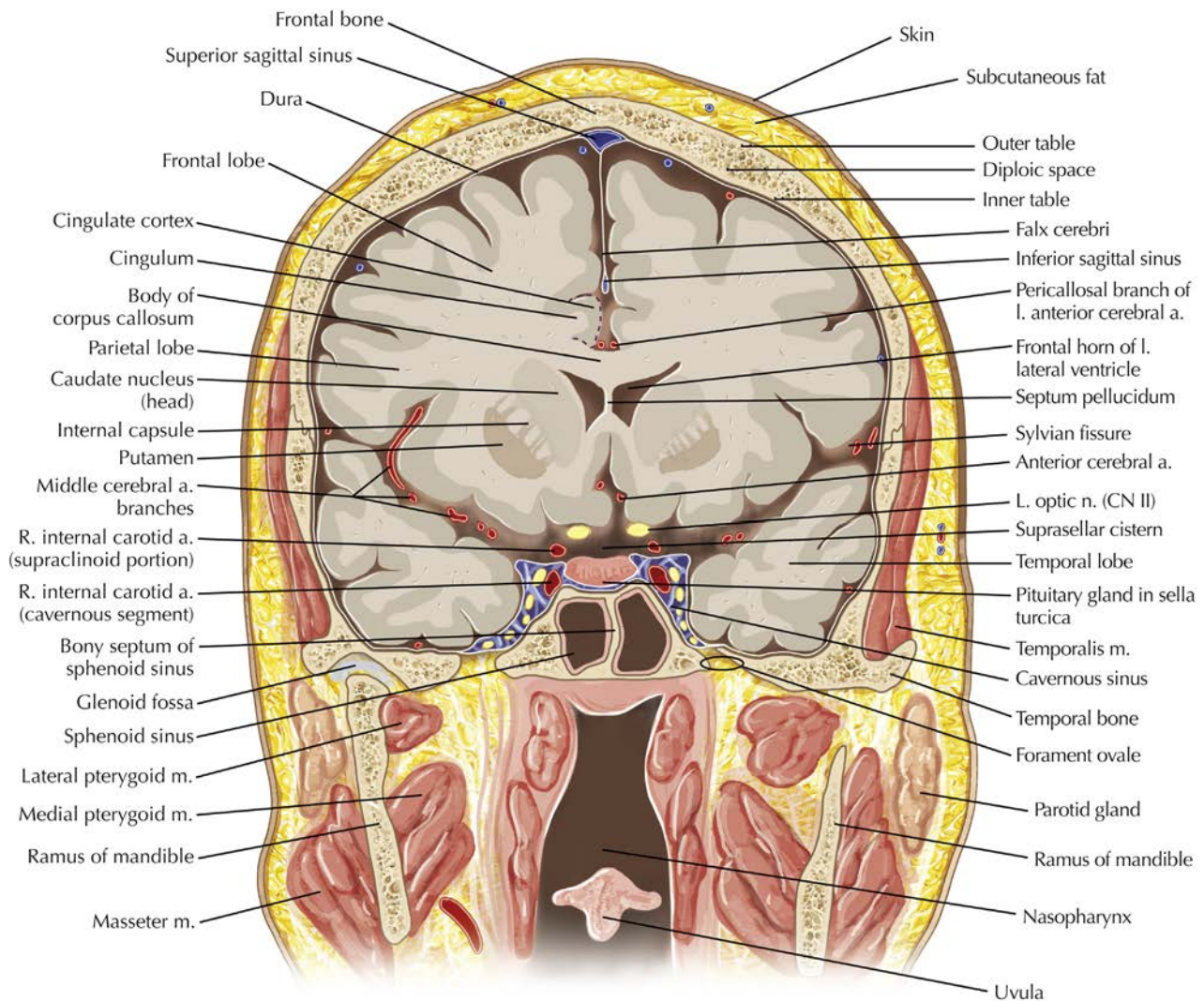


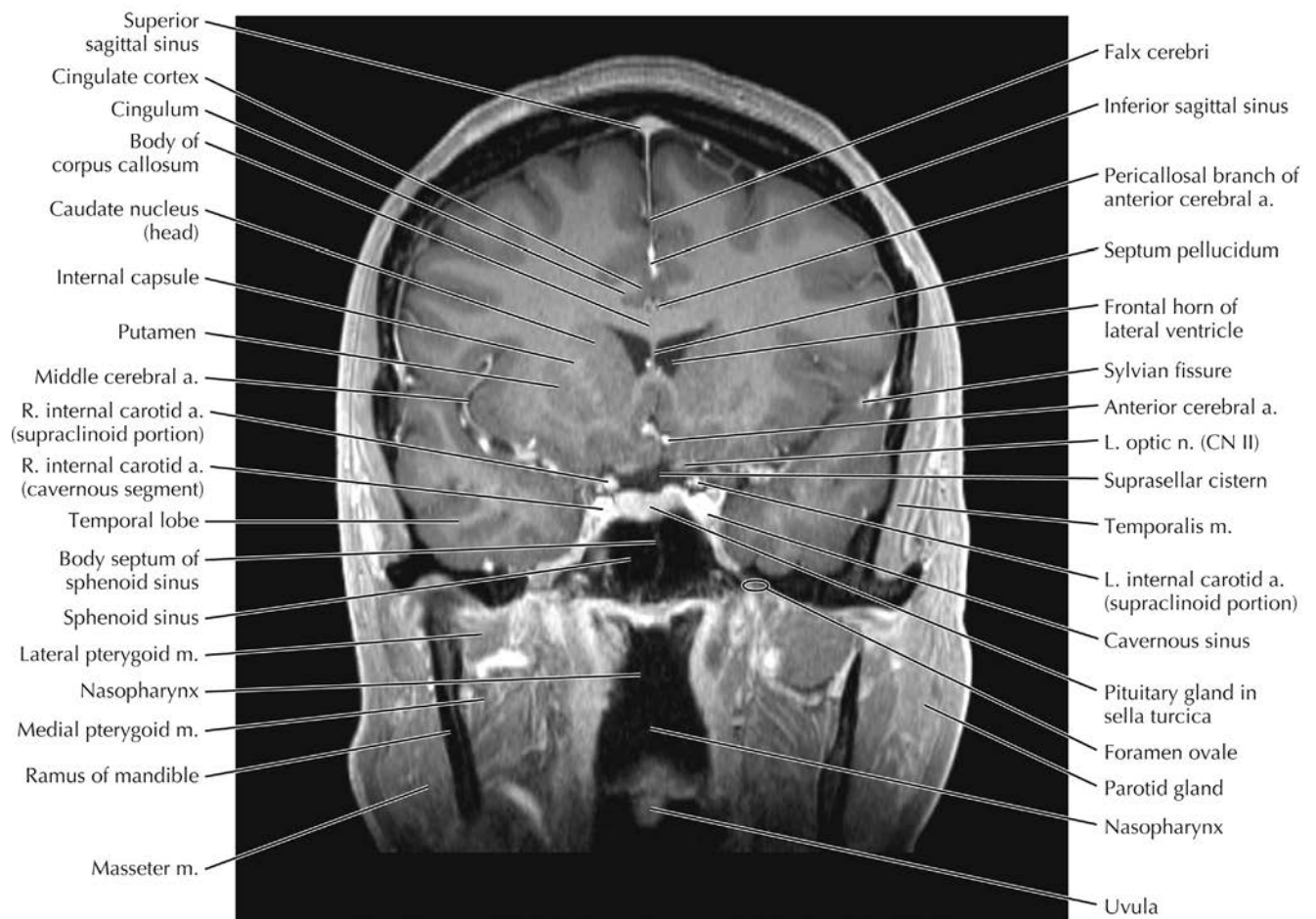
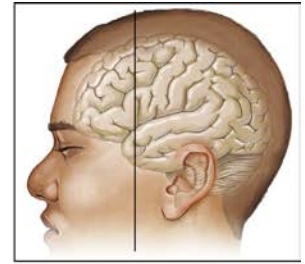


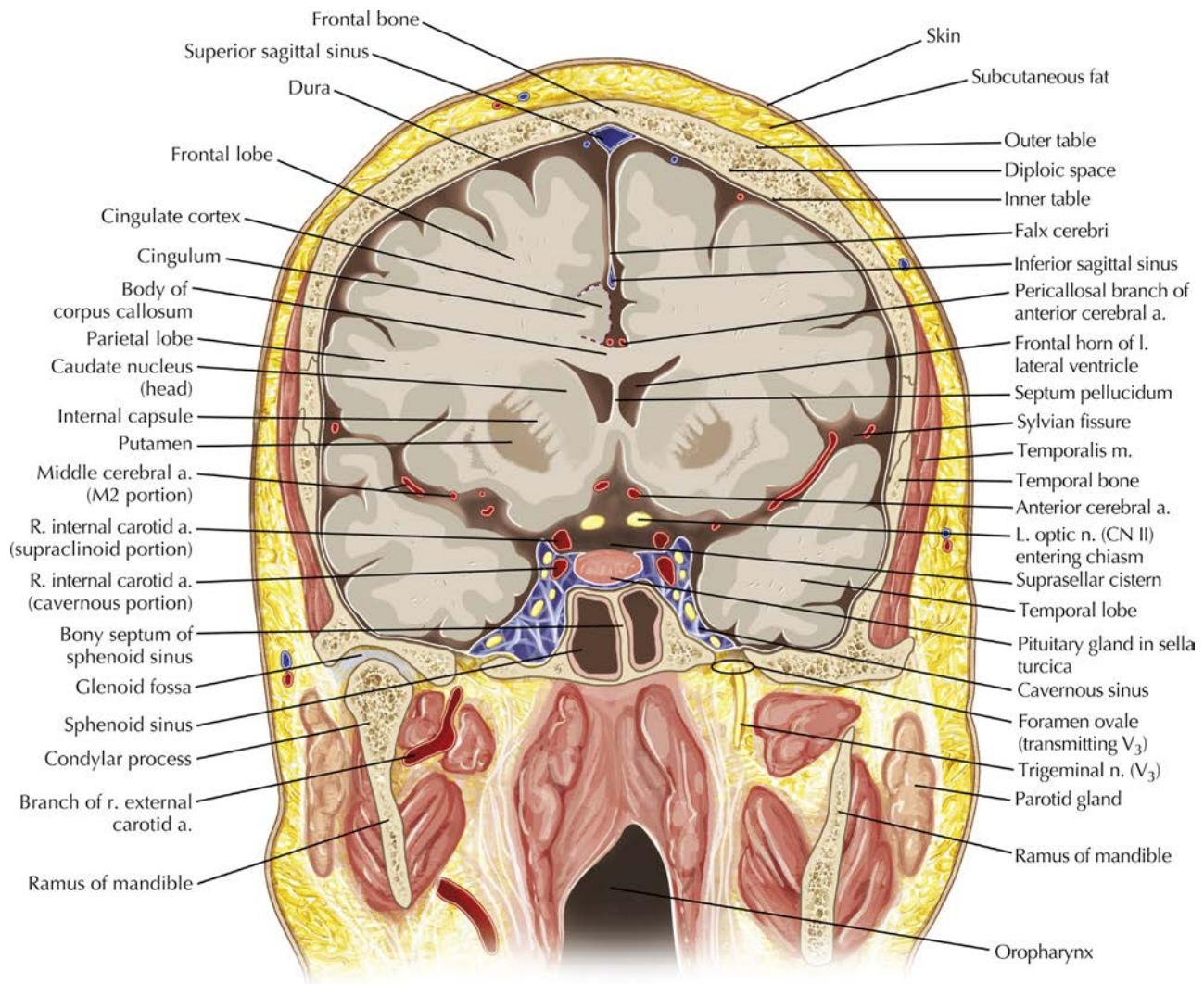






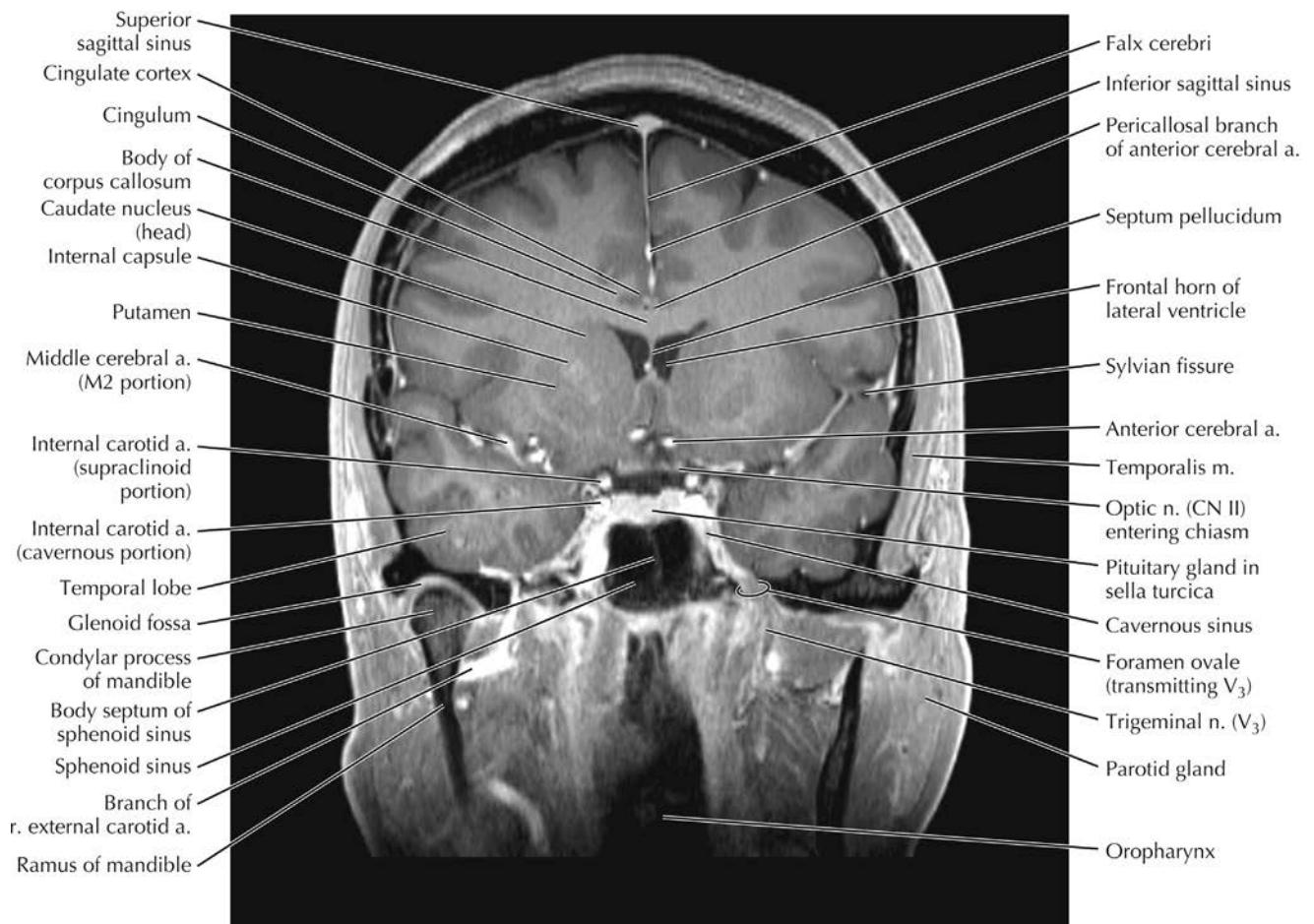
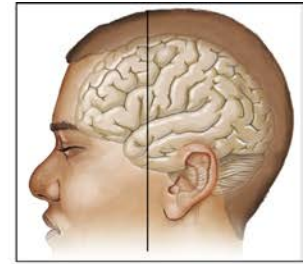


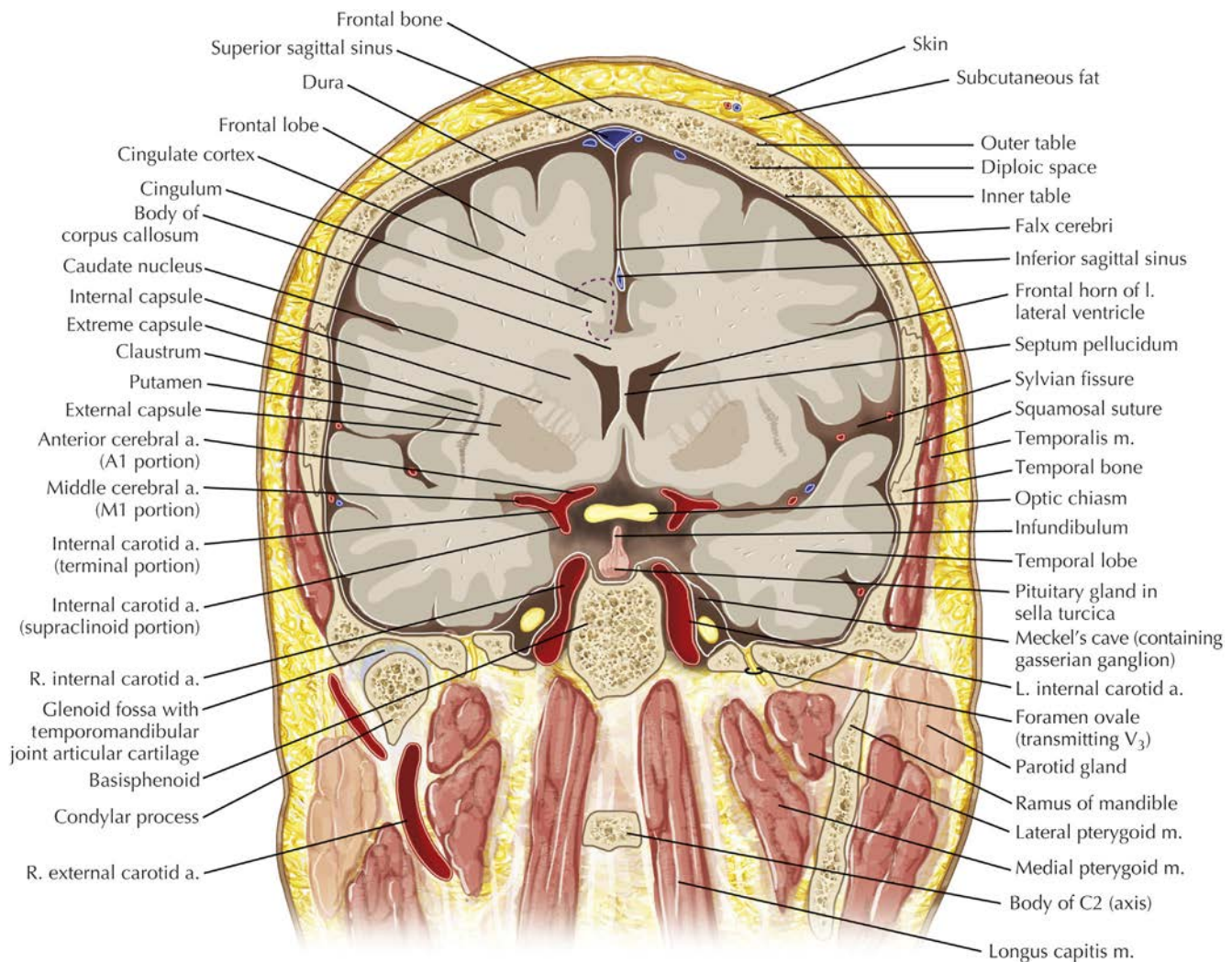




NORMAL ANATOMY

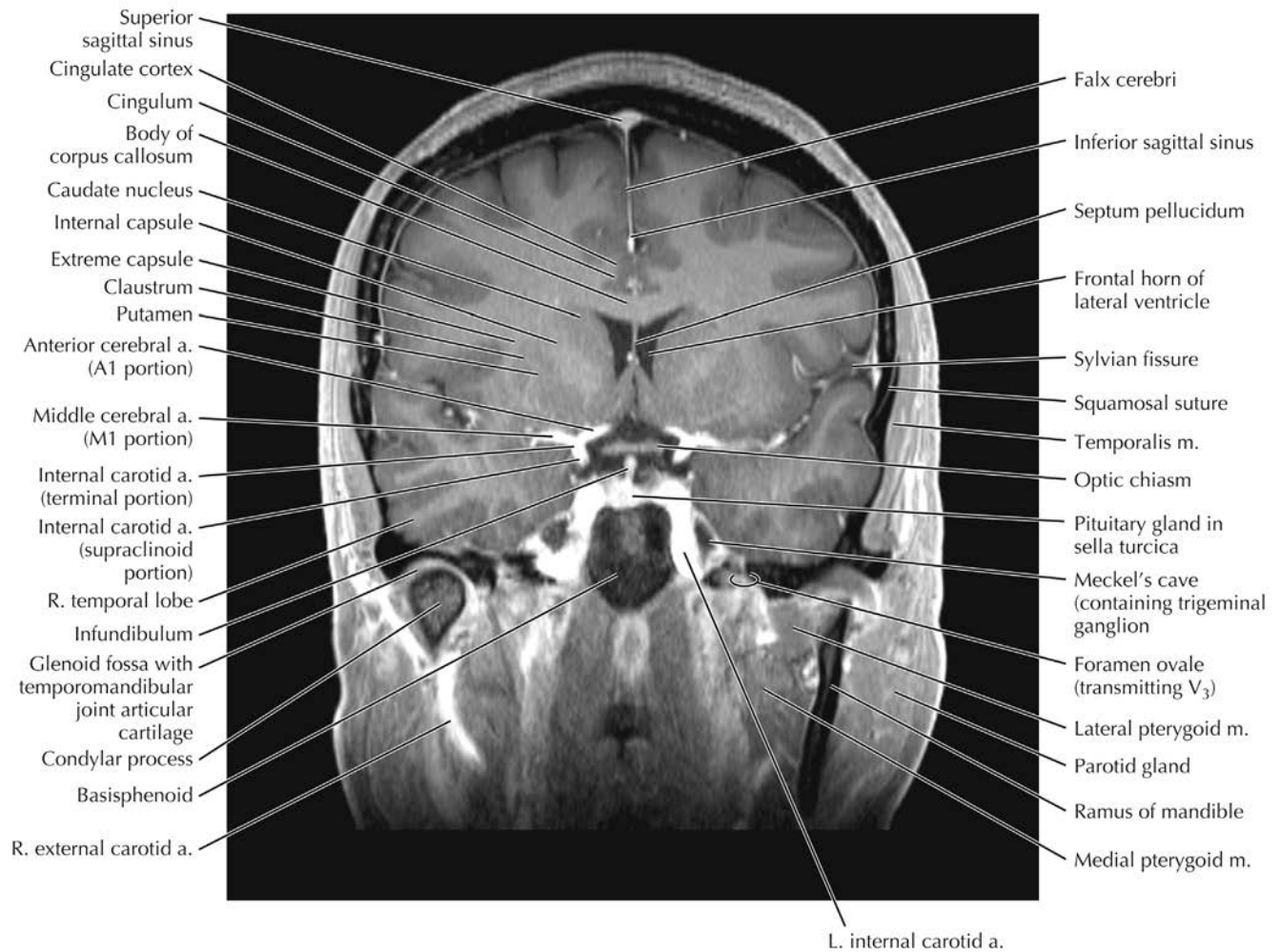
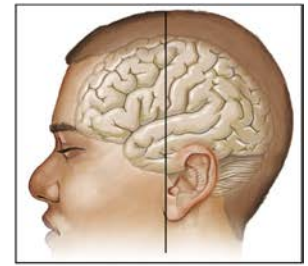
Note the mandibular branch of the trigeminal nerve (V₃) descending from Meckel's cave into the foramen ovale.

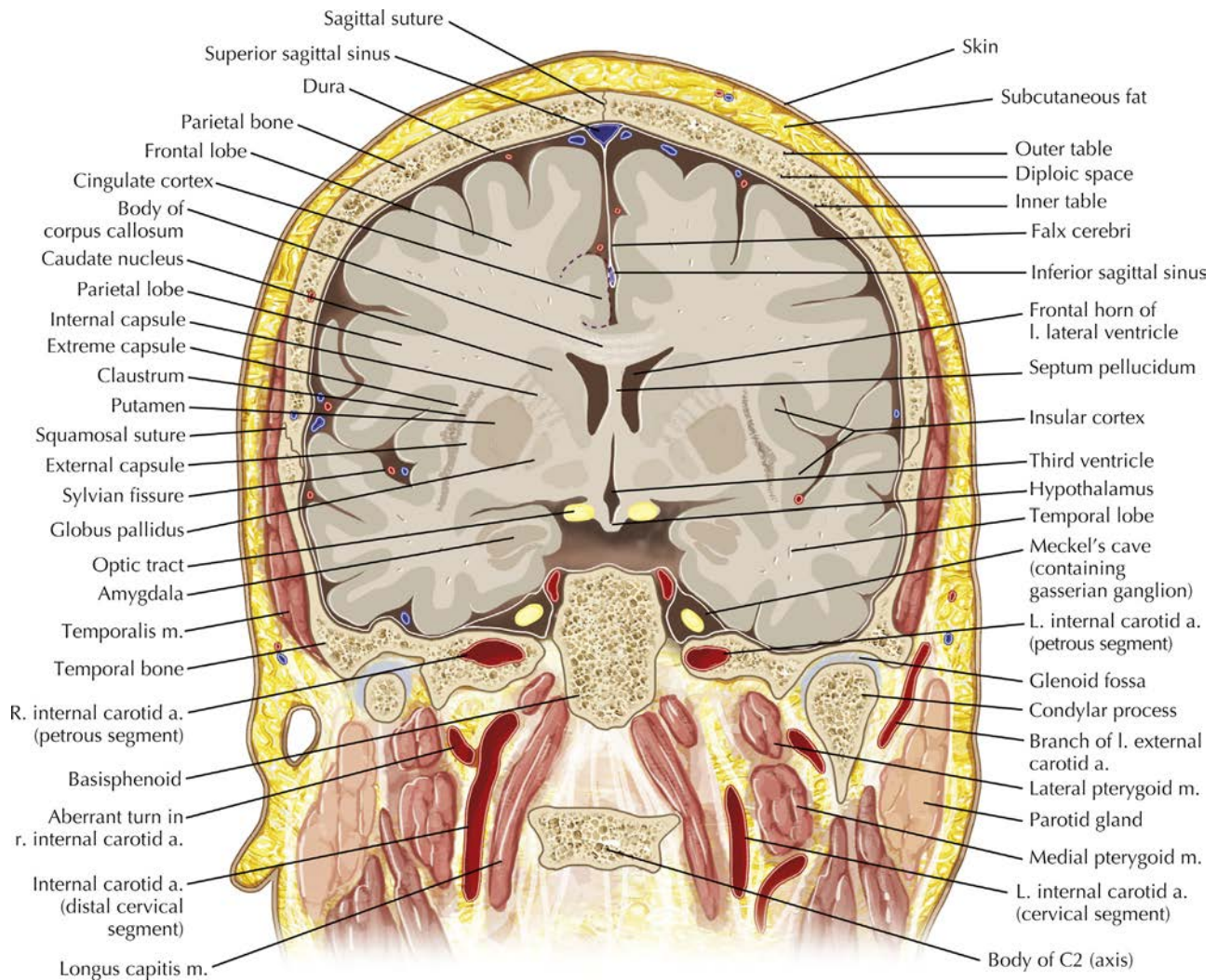




NORMAL ANATOMY

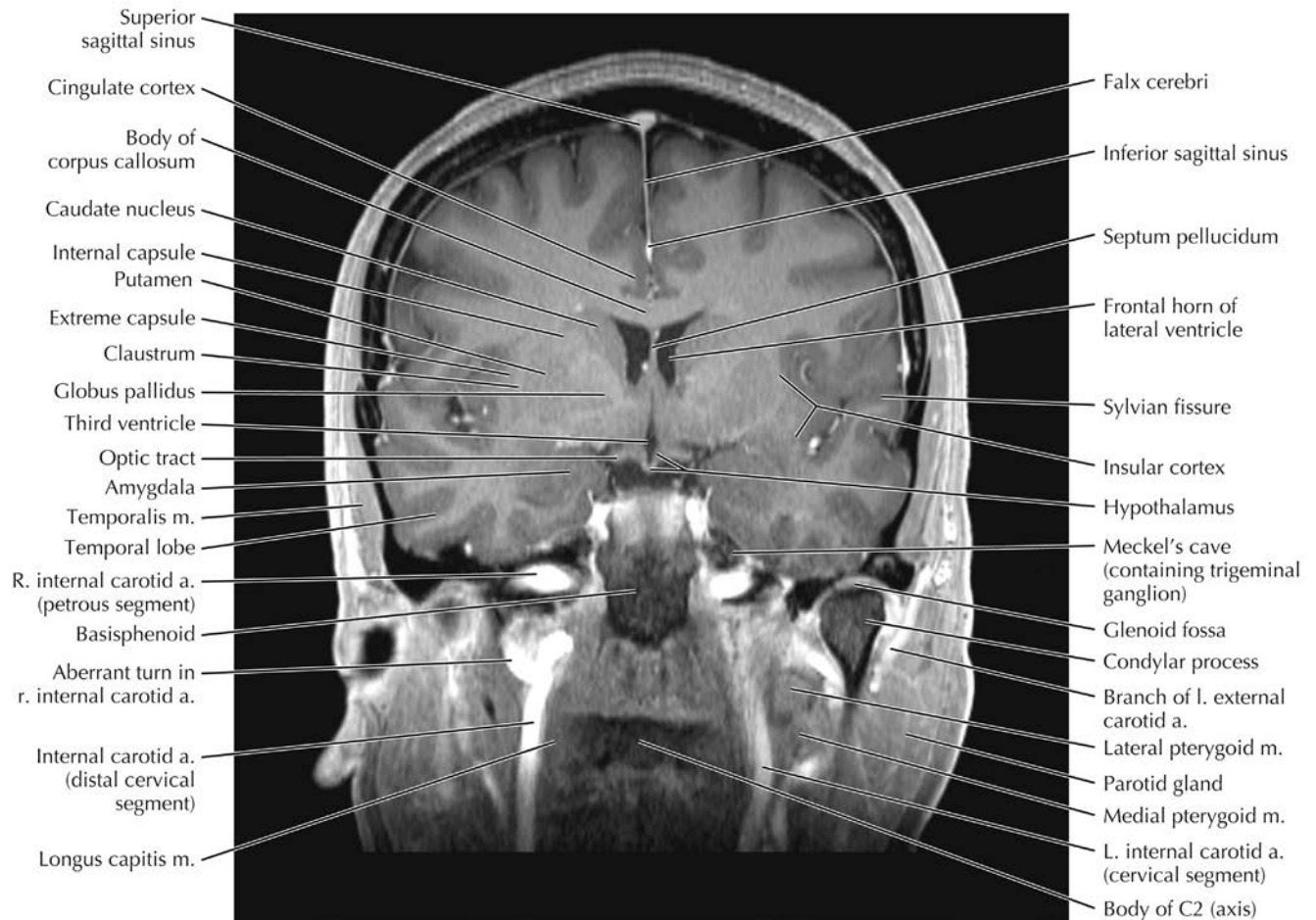
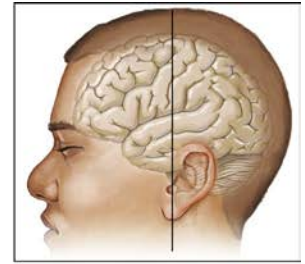
The coronal view is often the best view for assessing the pituitary gland, infundibulum, and optic chiasm. The infundibulum may be asymmetric in some cases, as in this image, where it is slightly deviated to the right as a normal variant, but in some cases it can be deviated from a pituitary mass. A large mass can extend into the suprasellar region and compress the optic chiasm, leading to bitemporal hemianopsia.

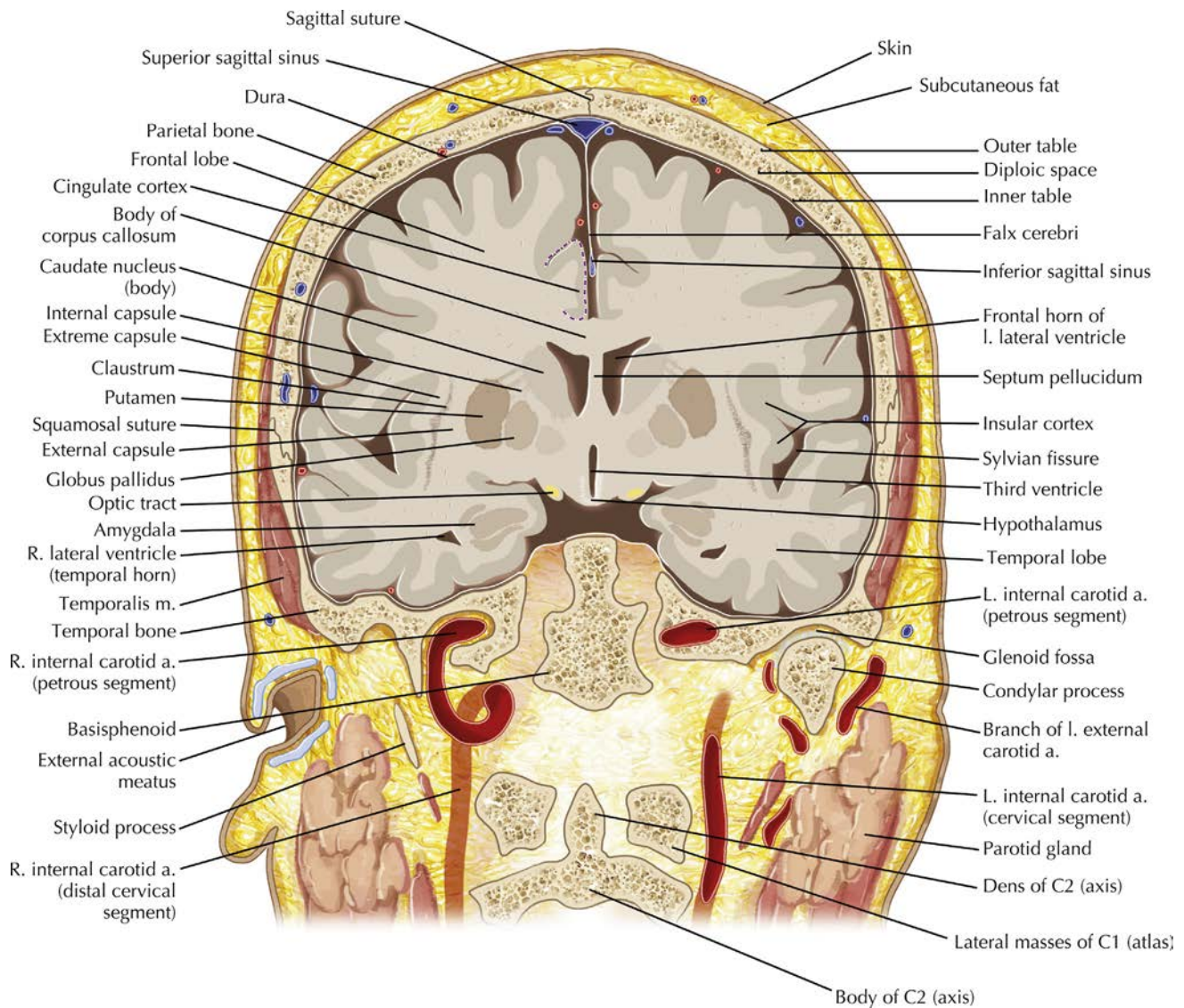




NORMAL ANATOMY

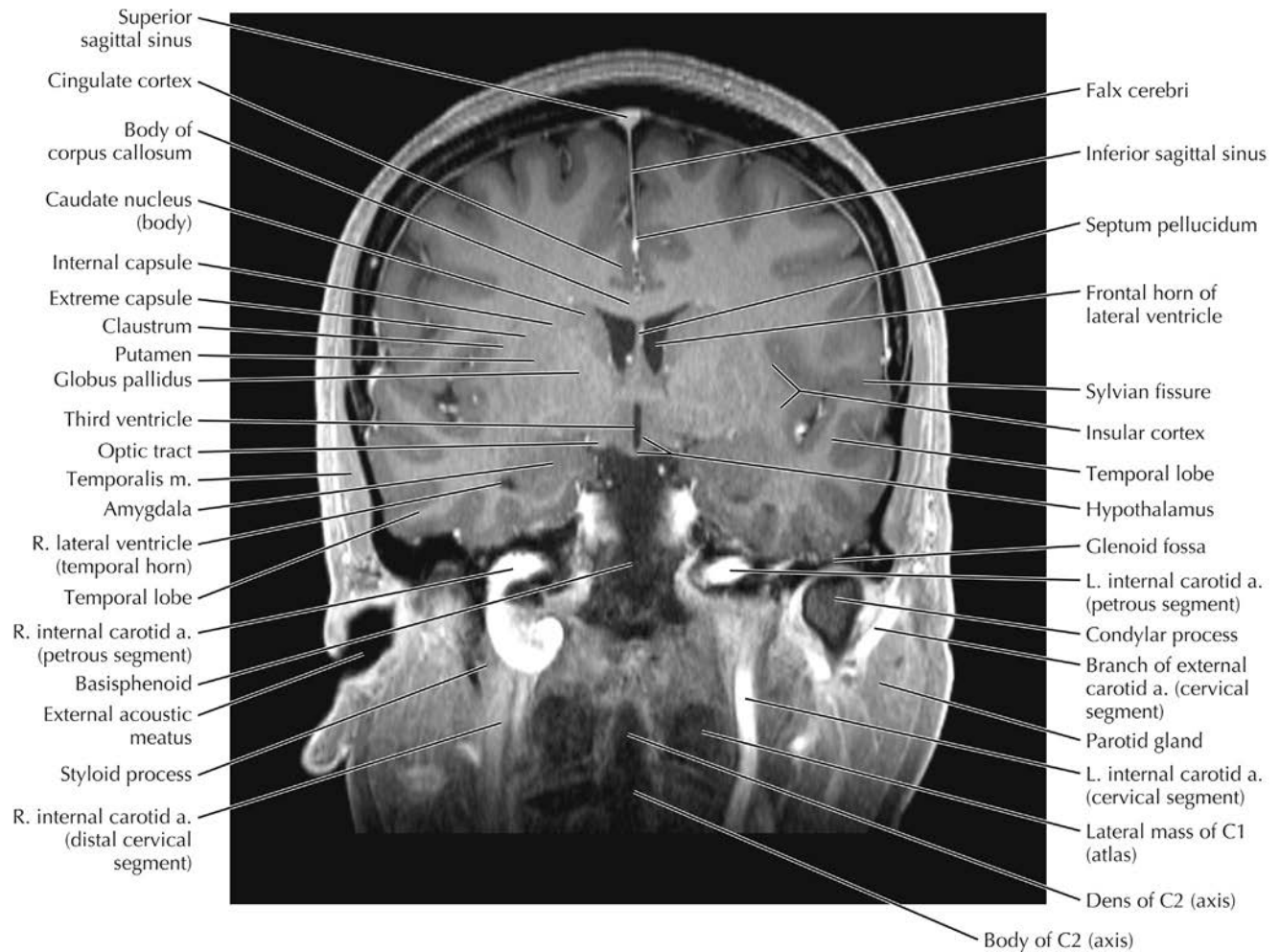
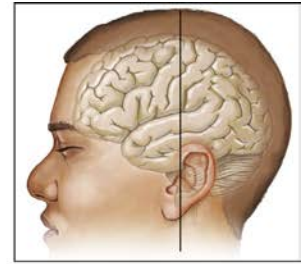
From the Greek meaning "under inner chamber," the hypothalamus forms the floor of the third ventricle and contains small nuclei with a variety of functions. One of the most important functions is to provide signals from the nervous system to the endocrine system through the pituitary gland.

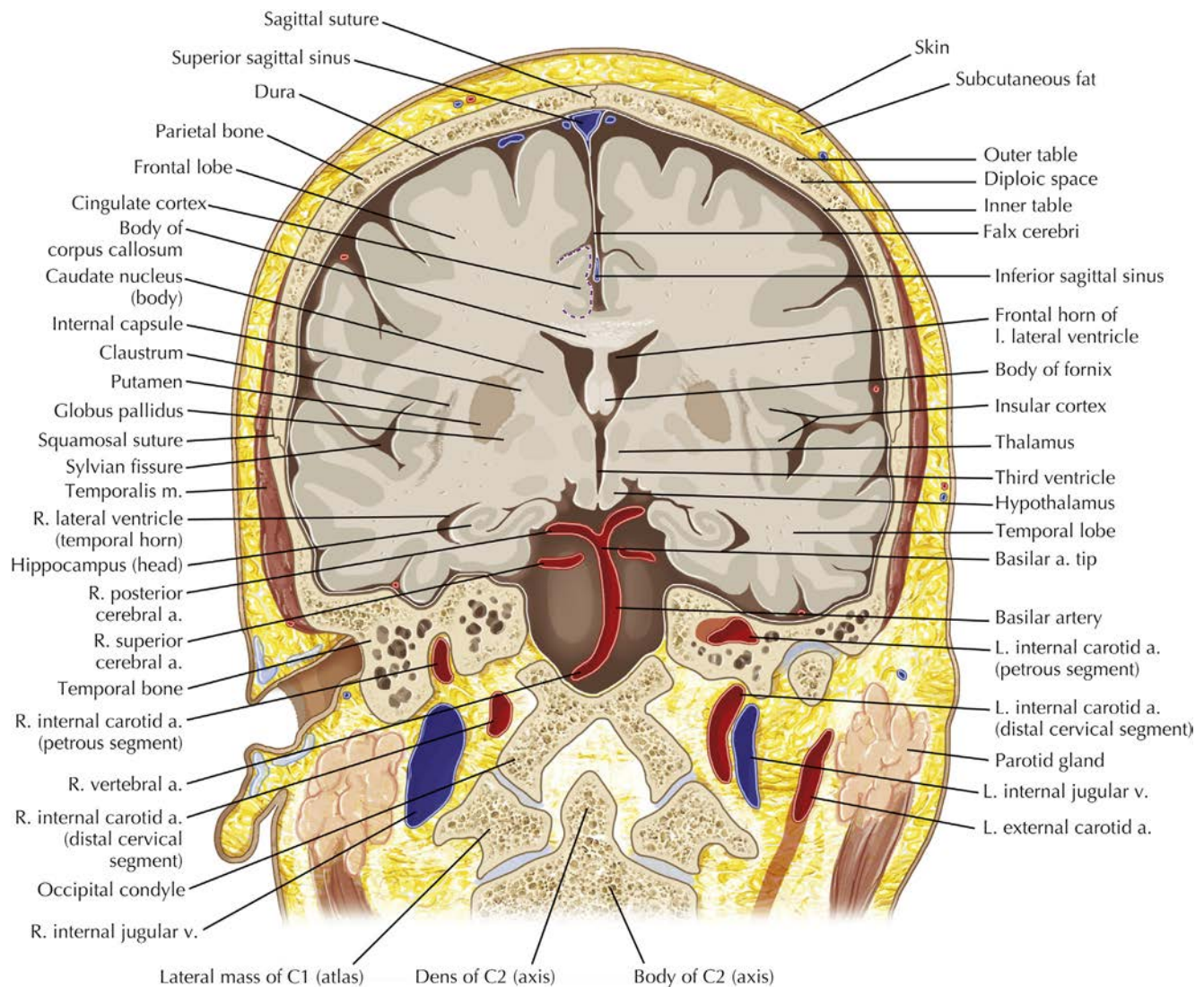


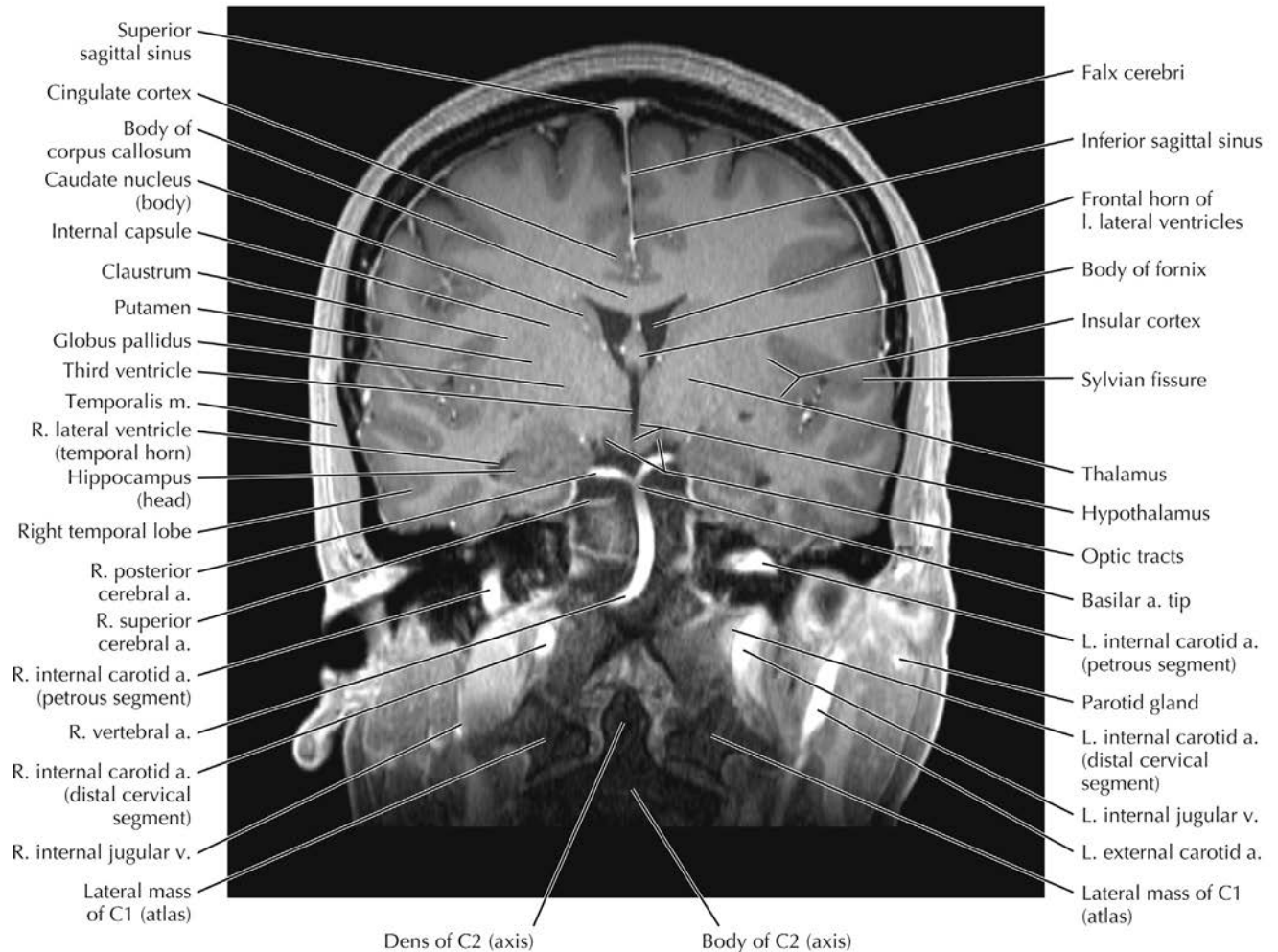
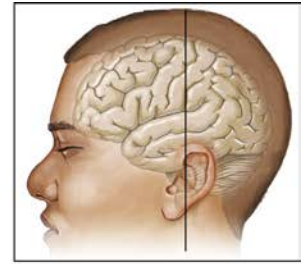


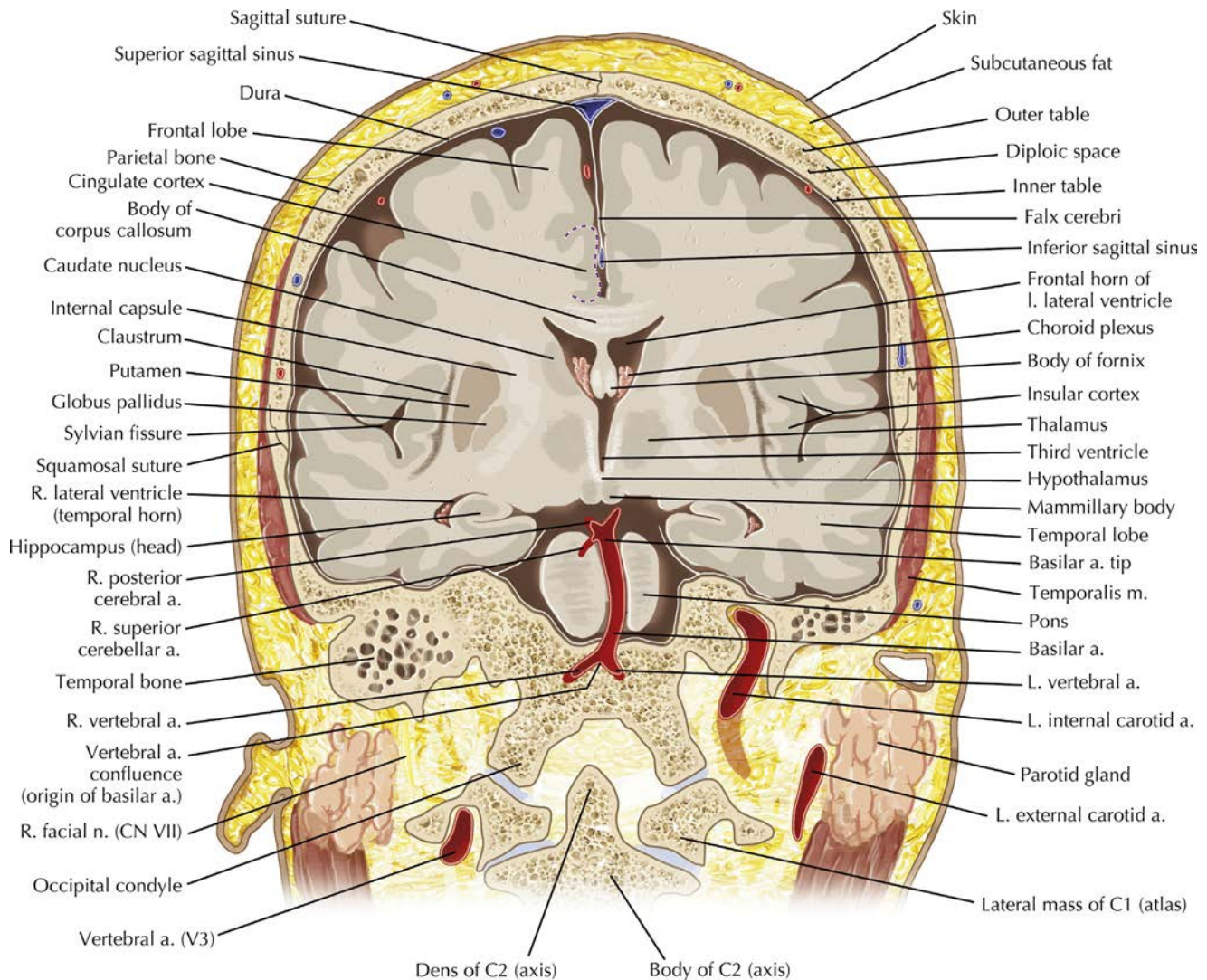
NORMAL ANATOMY

The cingulate cortex is located on the medial surface of the cerebral hemisphere adjacent to the corpus callosum. The cingulate cortex is usually considered part of the limbic system, which is involved with emotion, learning, and memory. The combination of these three functions makes the cingulate cortex extremely influential in associating behavioral outcomes to motivation.



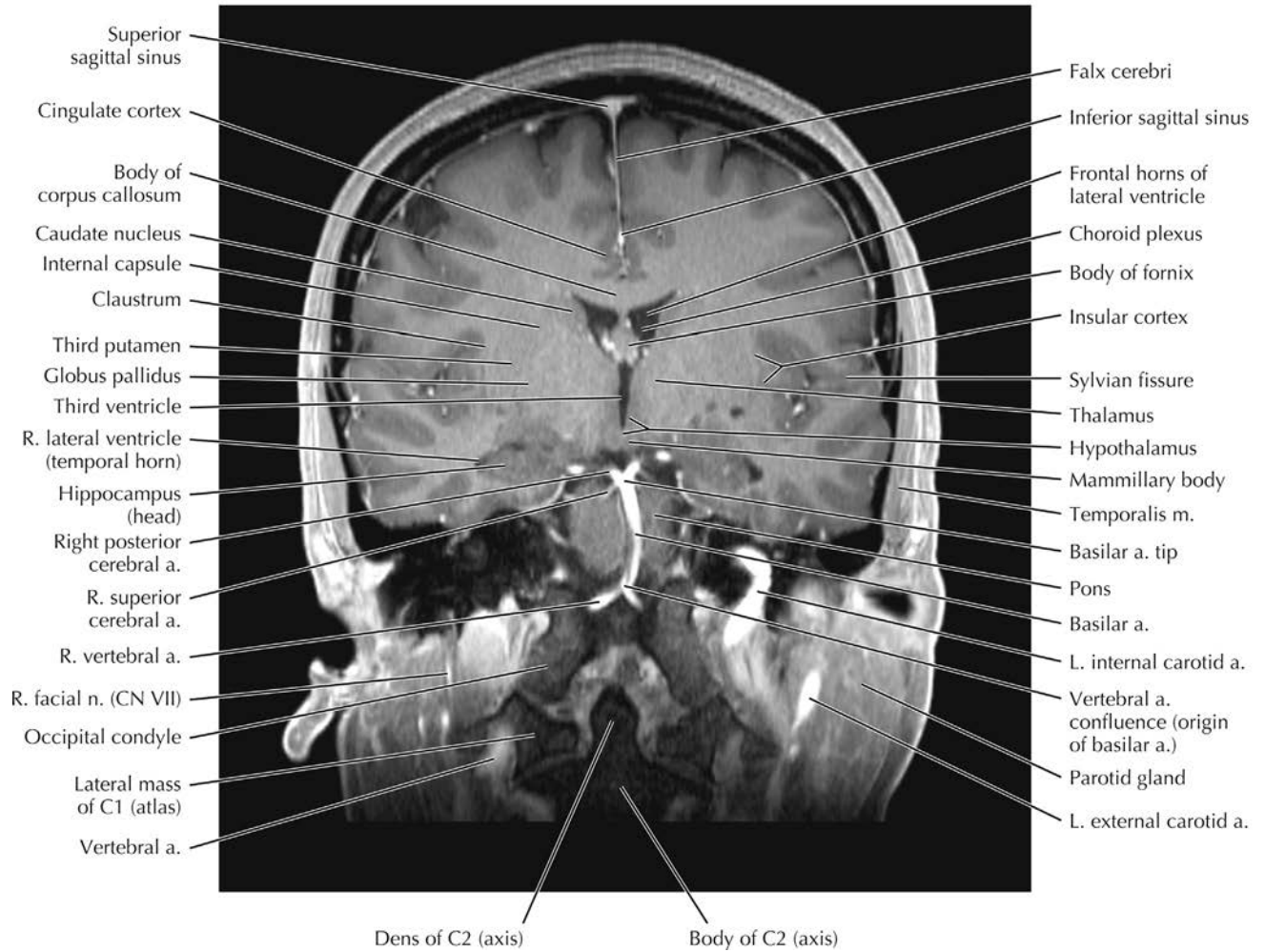
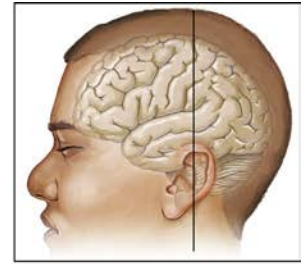


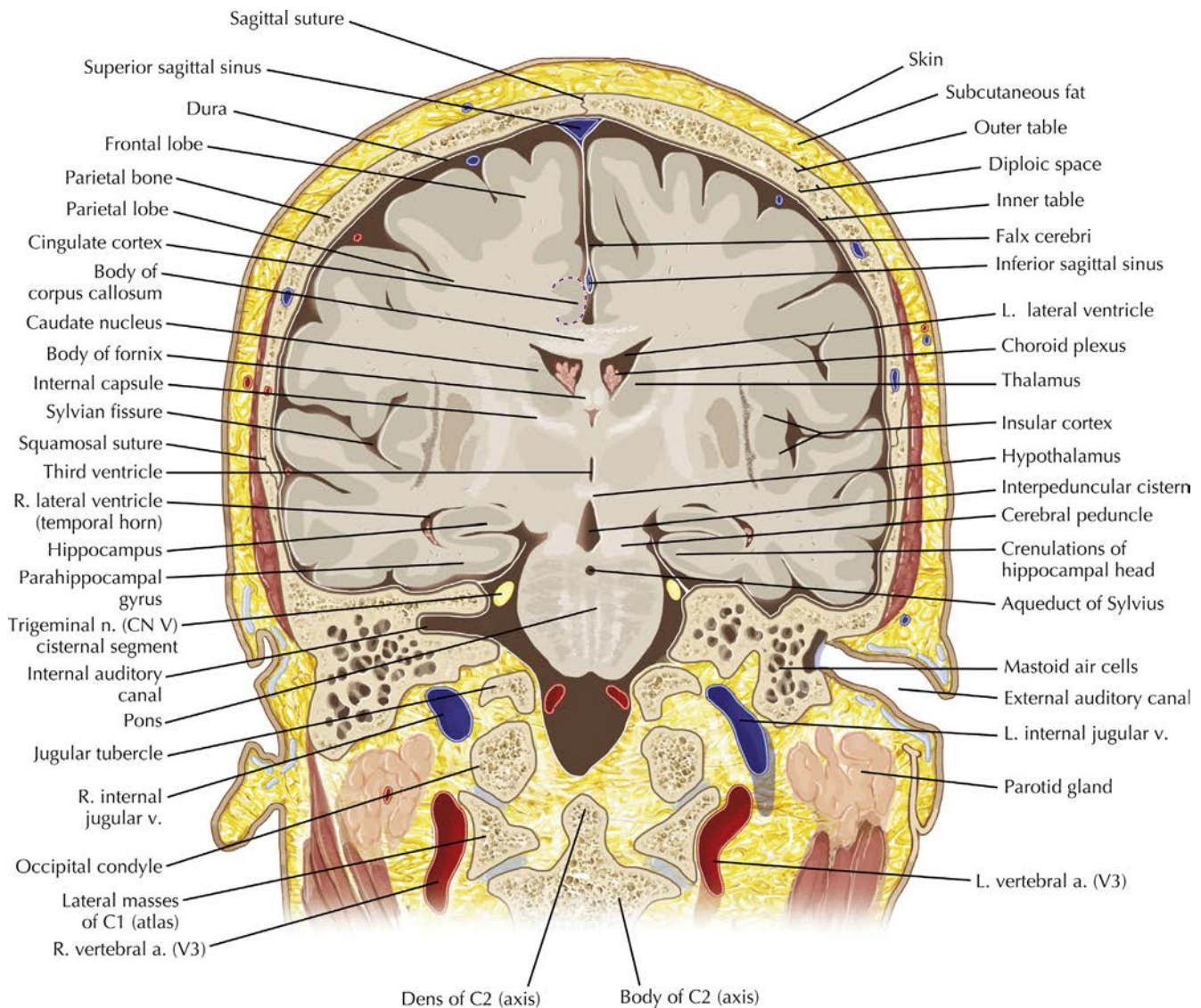




NORMAL ANATOMY

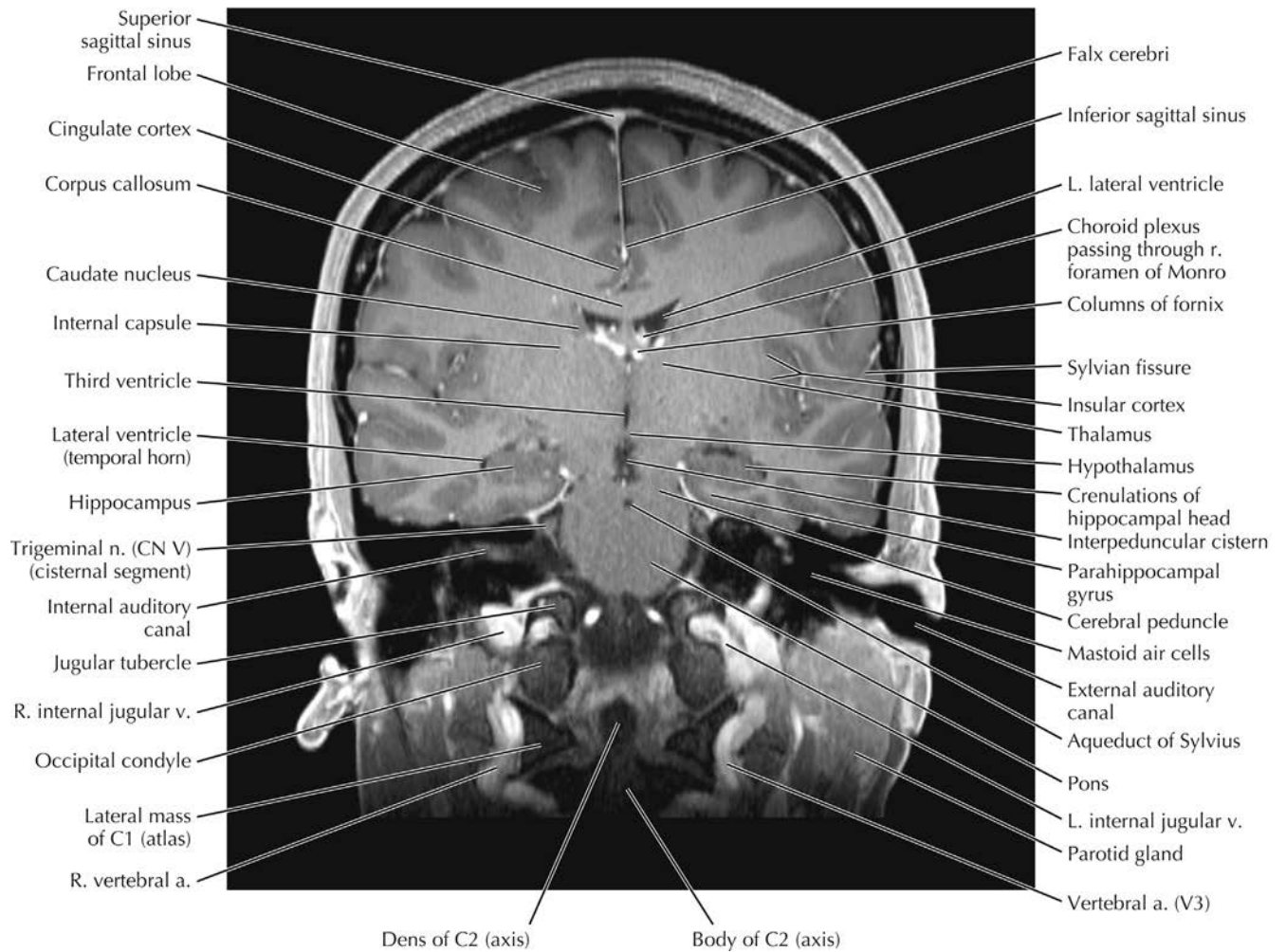
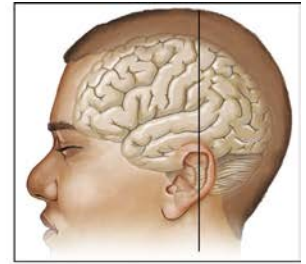
The coronal plane is an excellent view for obtaining an overview of the vertebrobasilar system in assessing for stenoses or aneurysms. In just a few coronal images, the neuroradiologist can often see both vertebral arteries with the posterior inferior cerebellar artery origins, the anterior inferior cerebellar artery and superior cerebellar artery origins from the basilar artery, and the proximal posterior cerebral arteries originating from the basilar artery tip.

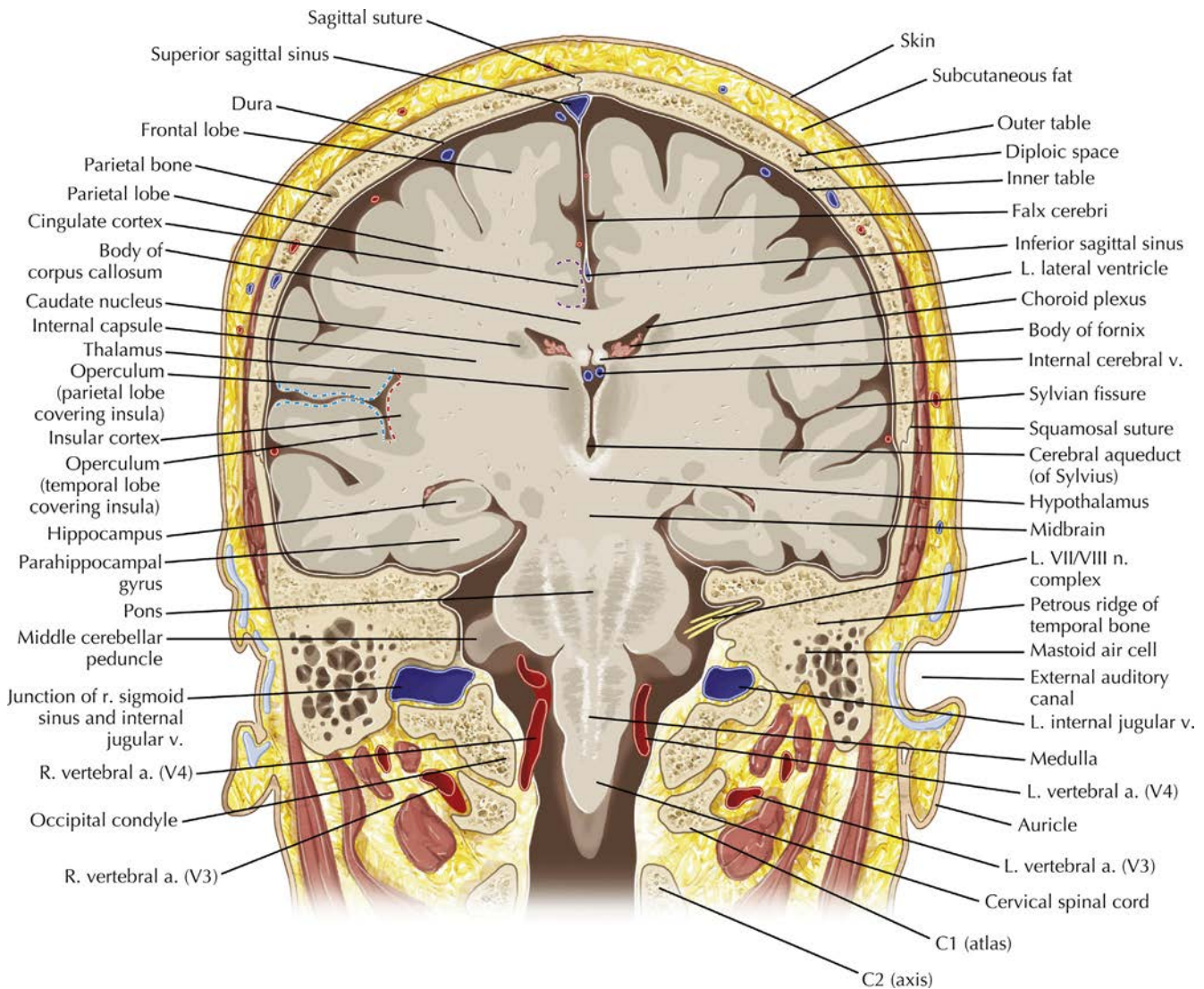




DIAGNOSTIC CONSIDERATION

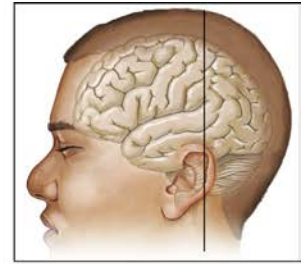
Injury to the cruciate ligaments with laxity of the odontoid ("toothlike") process of the second cervical vertebra (C2; dens axis) is more definitively assessed with voluntary flexion and extension radiographs. However, such injury may be suspected from asymmetric positioning of the odontoid process relative to the lateral masses on coronal MR view.

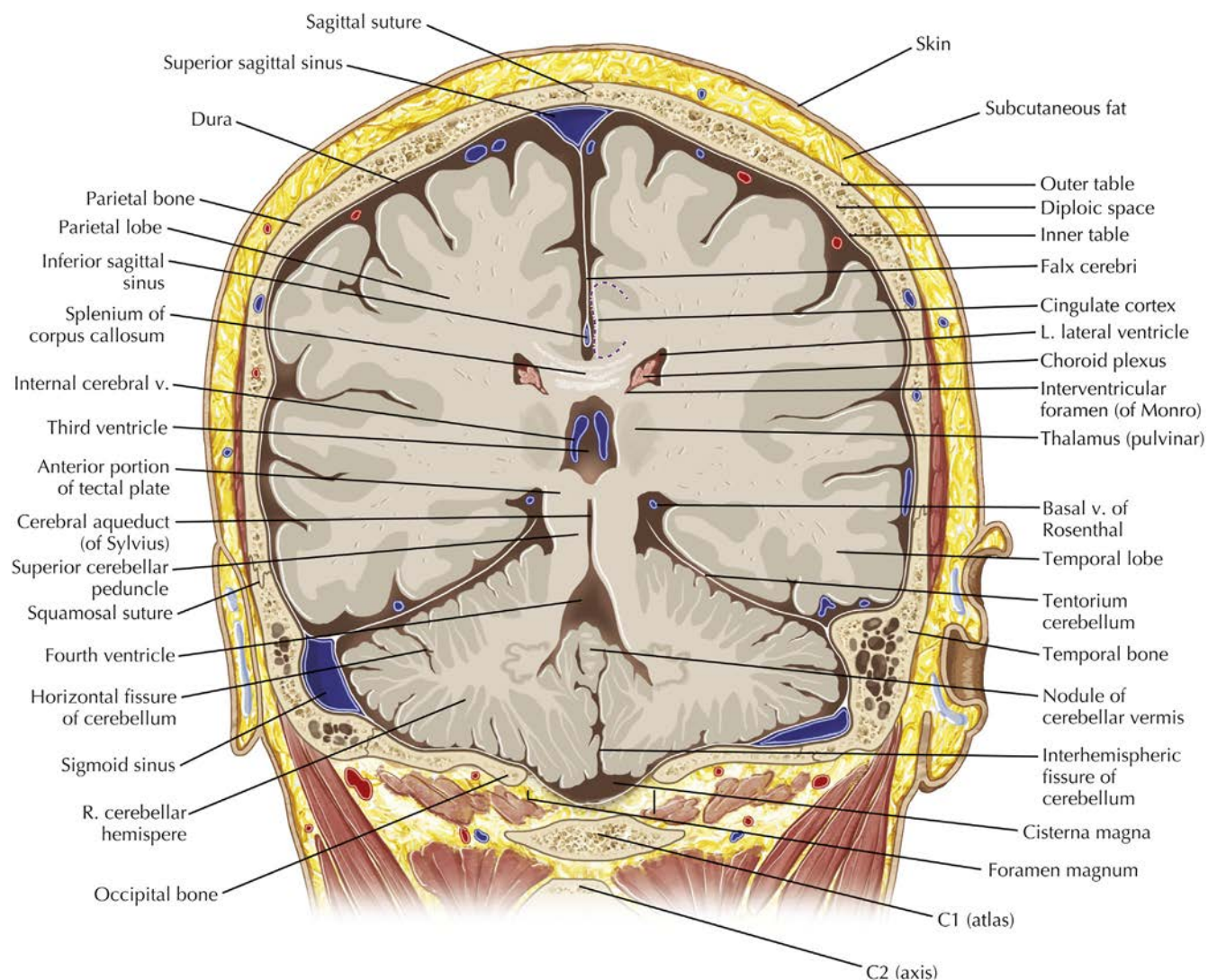


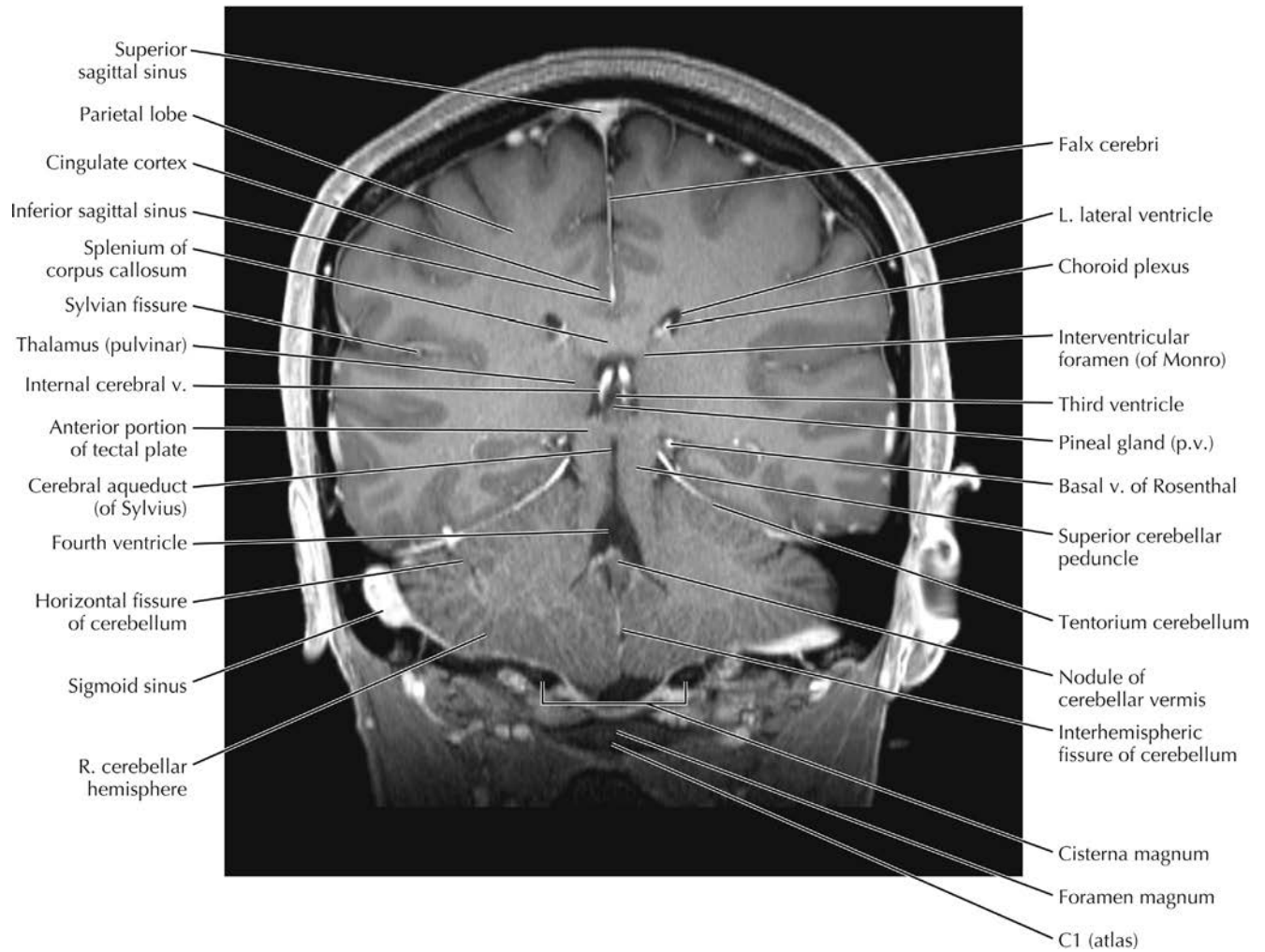
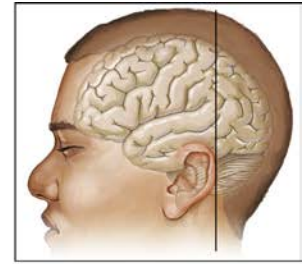


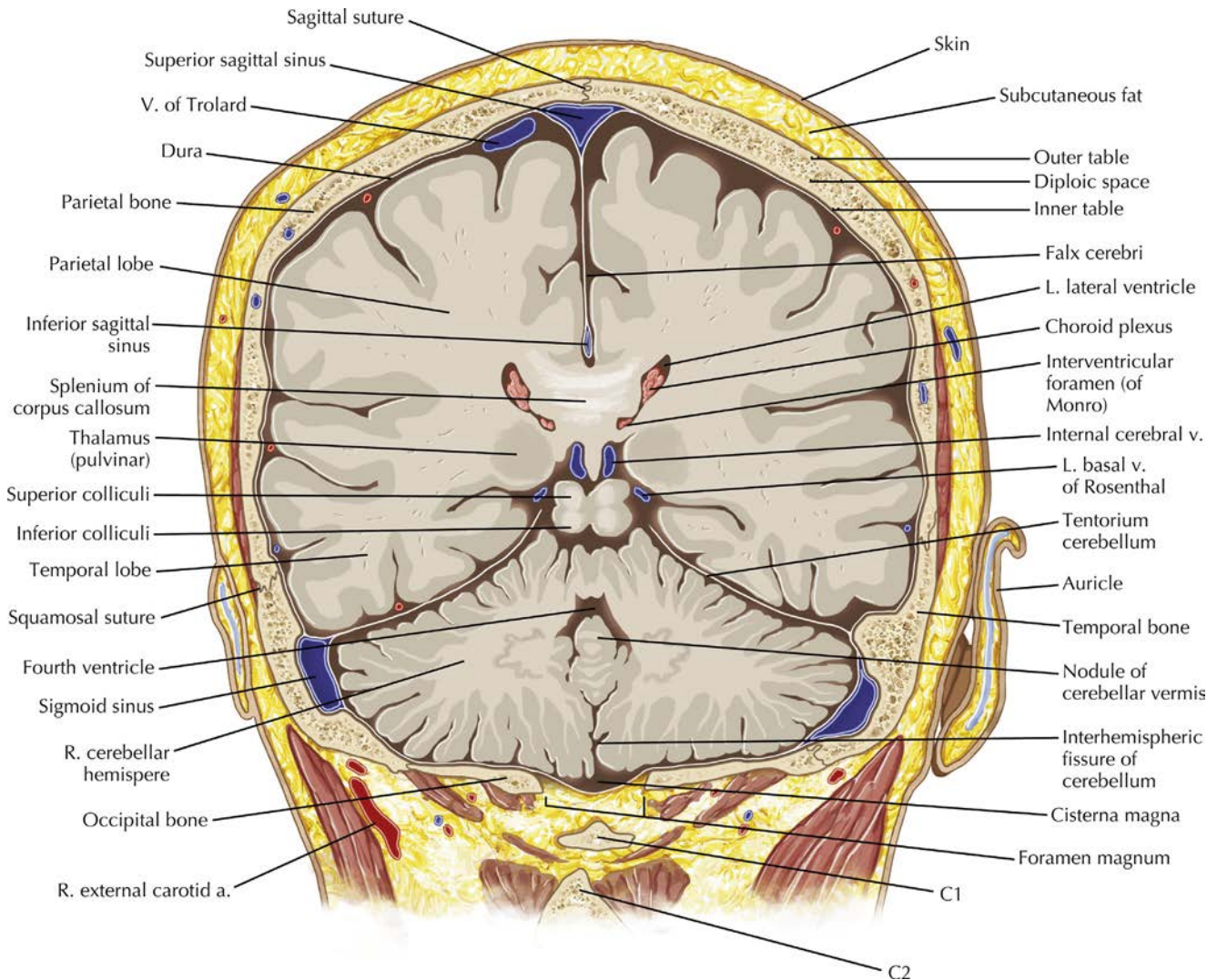
DIAGNOSTIC CONSIDERATION

Coronal imaging is the best way to assess the hippocampi, although size and abnormal signal are best assessed with T2-weighted fluid-attenuated inversion recovery (FLAIR) sequence (see Chapter 4).



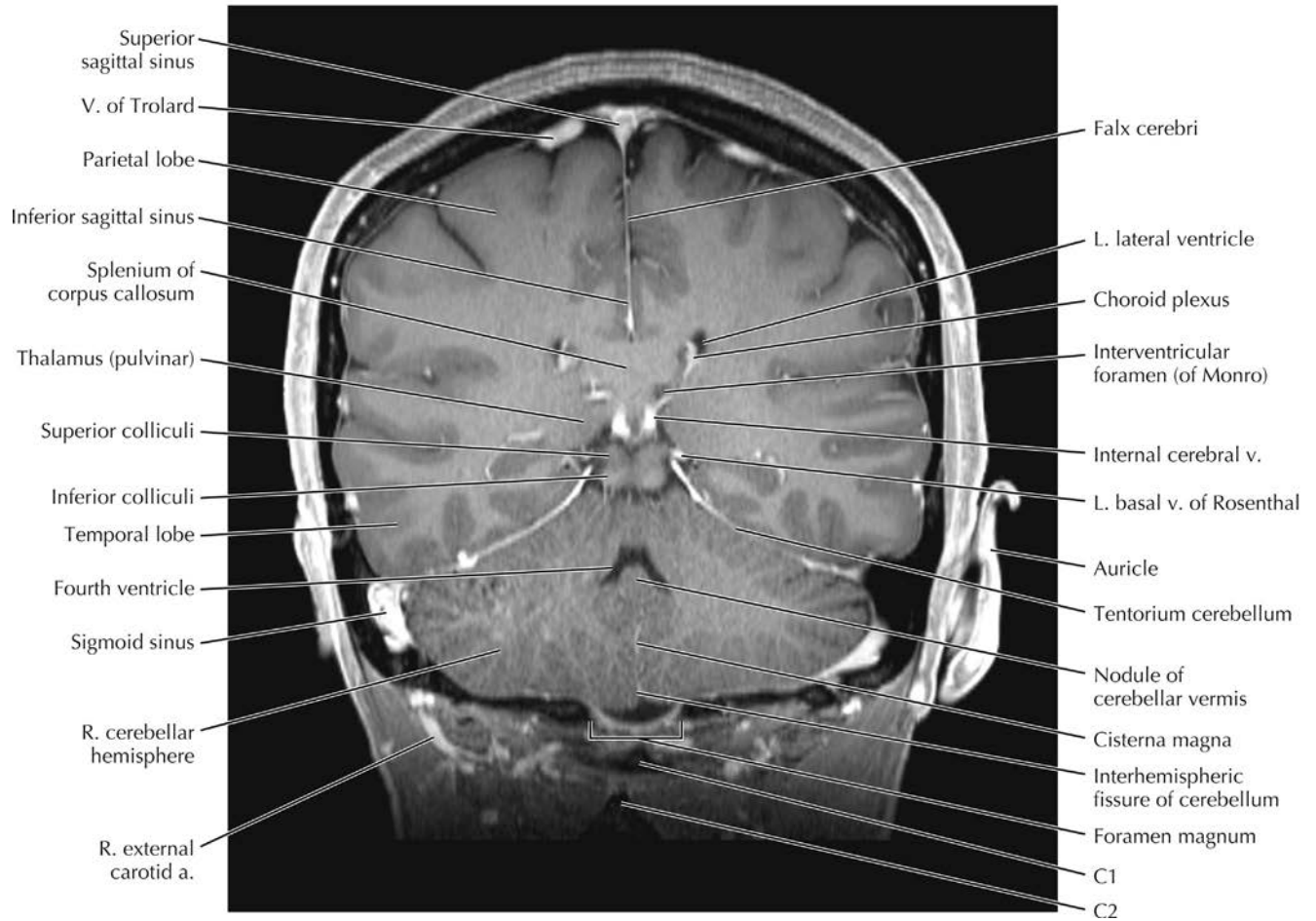
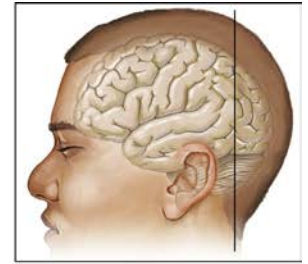


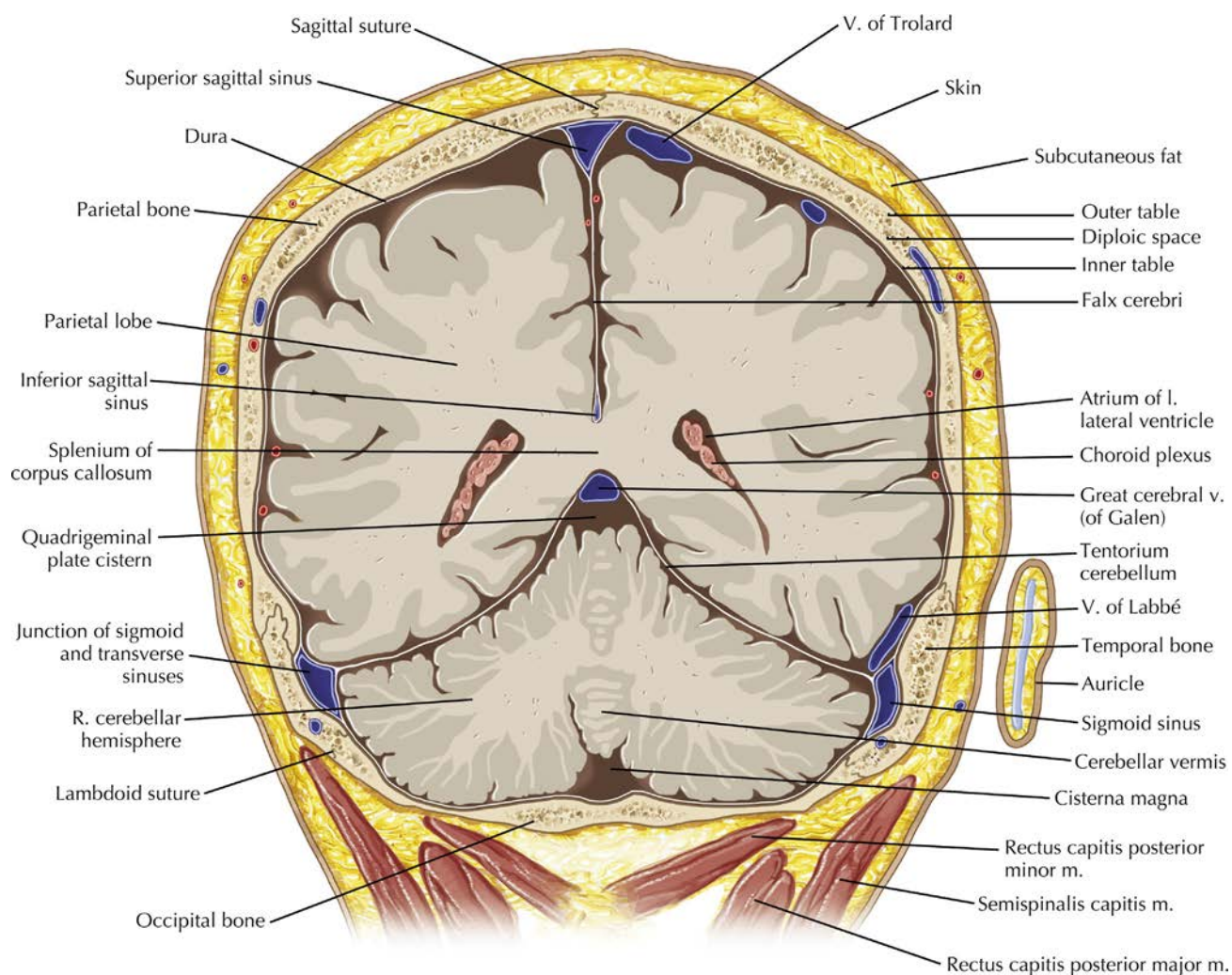


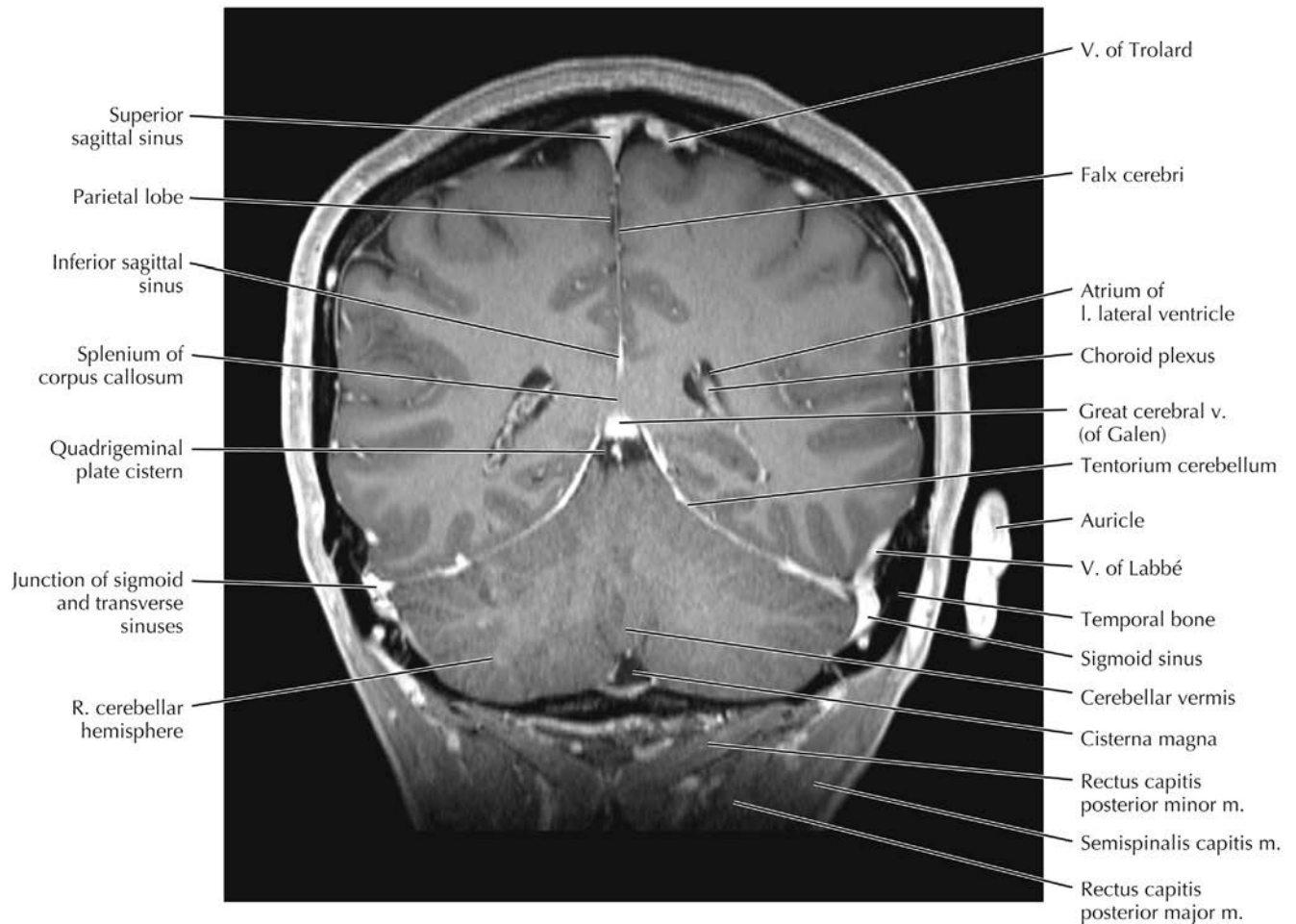
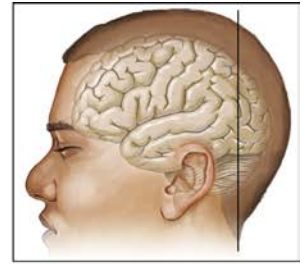


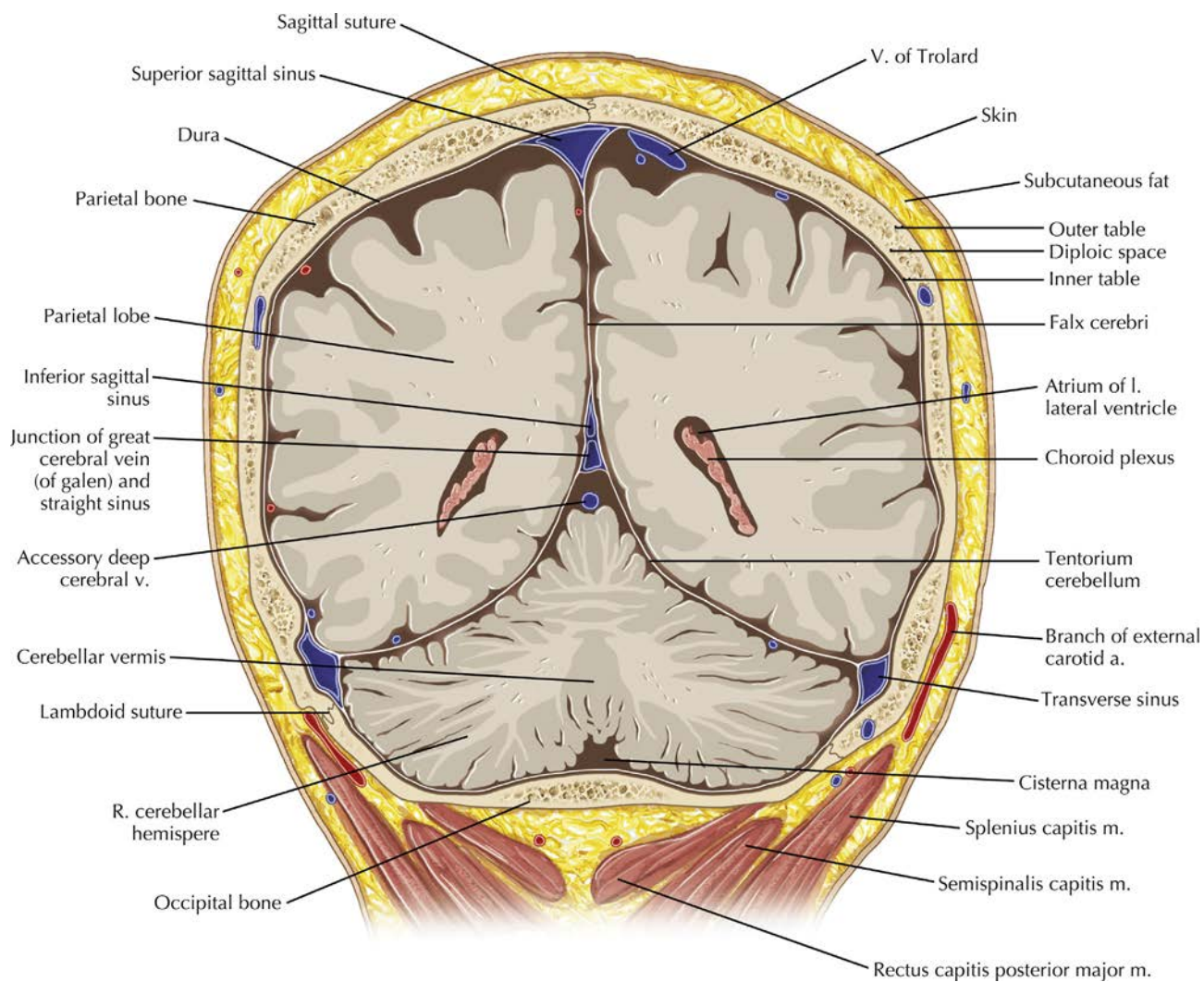
NORMAL ANATOMY

The internal cerebral veins, or deep cerebral veins, drain the deep portions of the hemisphere and are paired structures. Each internal cerebral vein is formed near the interventricular foramen, or foramen of Monro, by the union of the terminal and choroid veins. The veins course beneath the splenium of the corpus callosum and unite to form a short trunk, the great cerebral vein (of Galen). Just before this union, each cerebral vein receives the corresponding basal vein of Rosenthal. The basal vein is formed by the union of a small anterior cerebral vein, the deep middle cerebral vein (deep Sylvian vein), and the inferior striate veins.



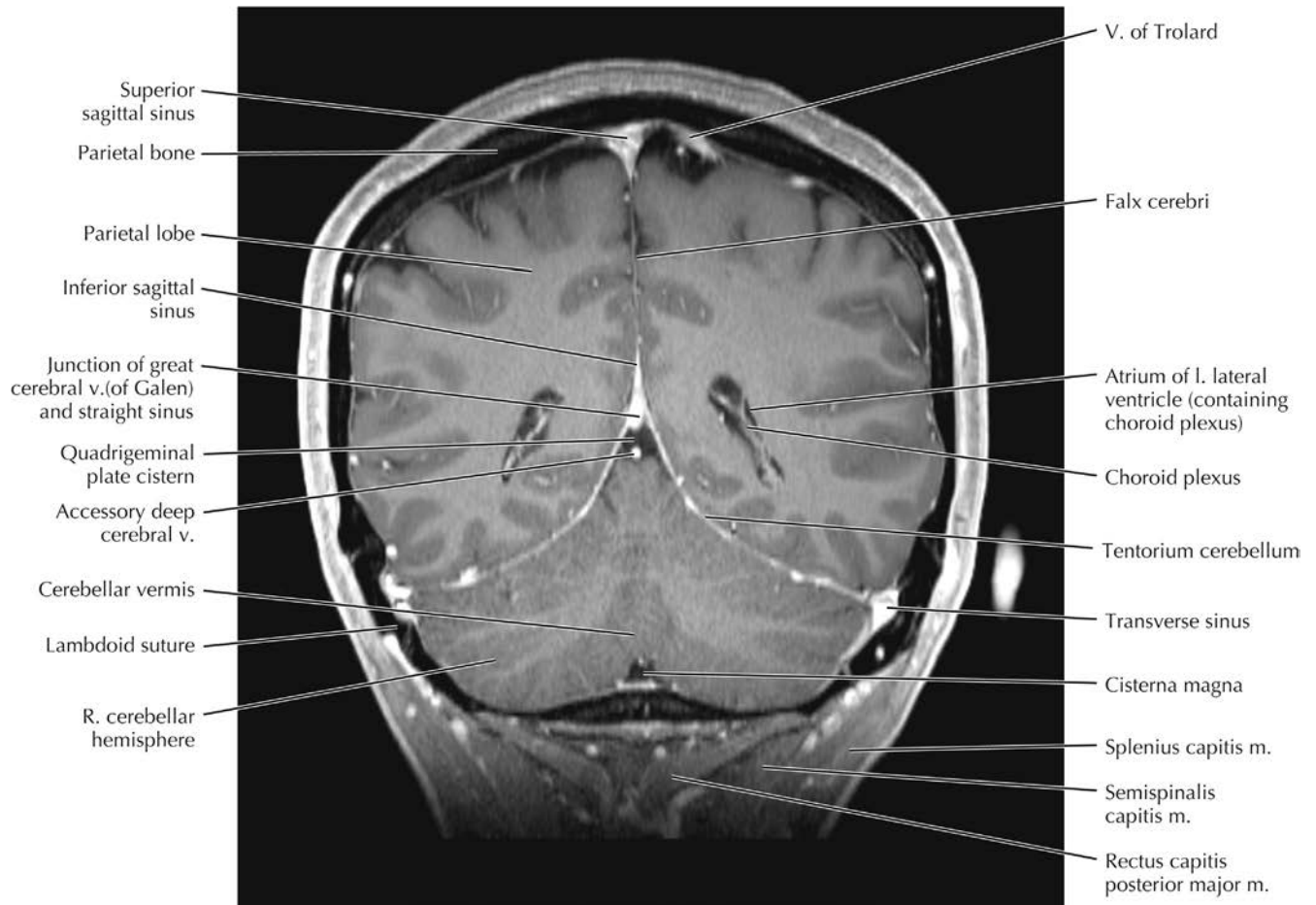
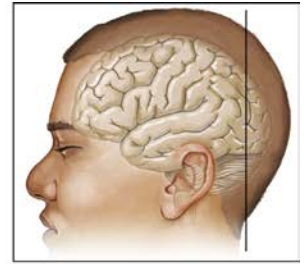


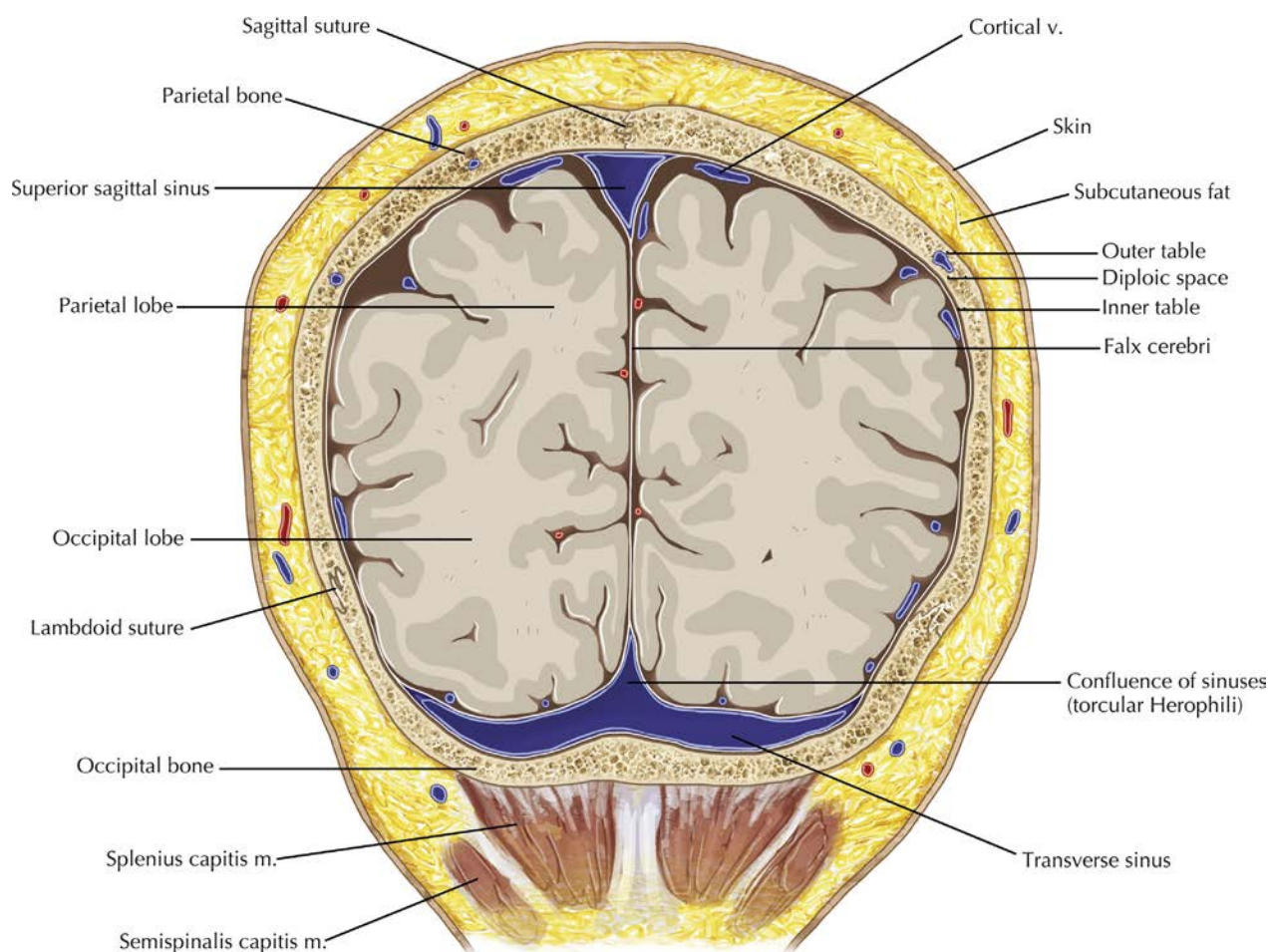




NORMAL ANATOMY

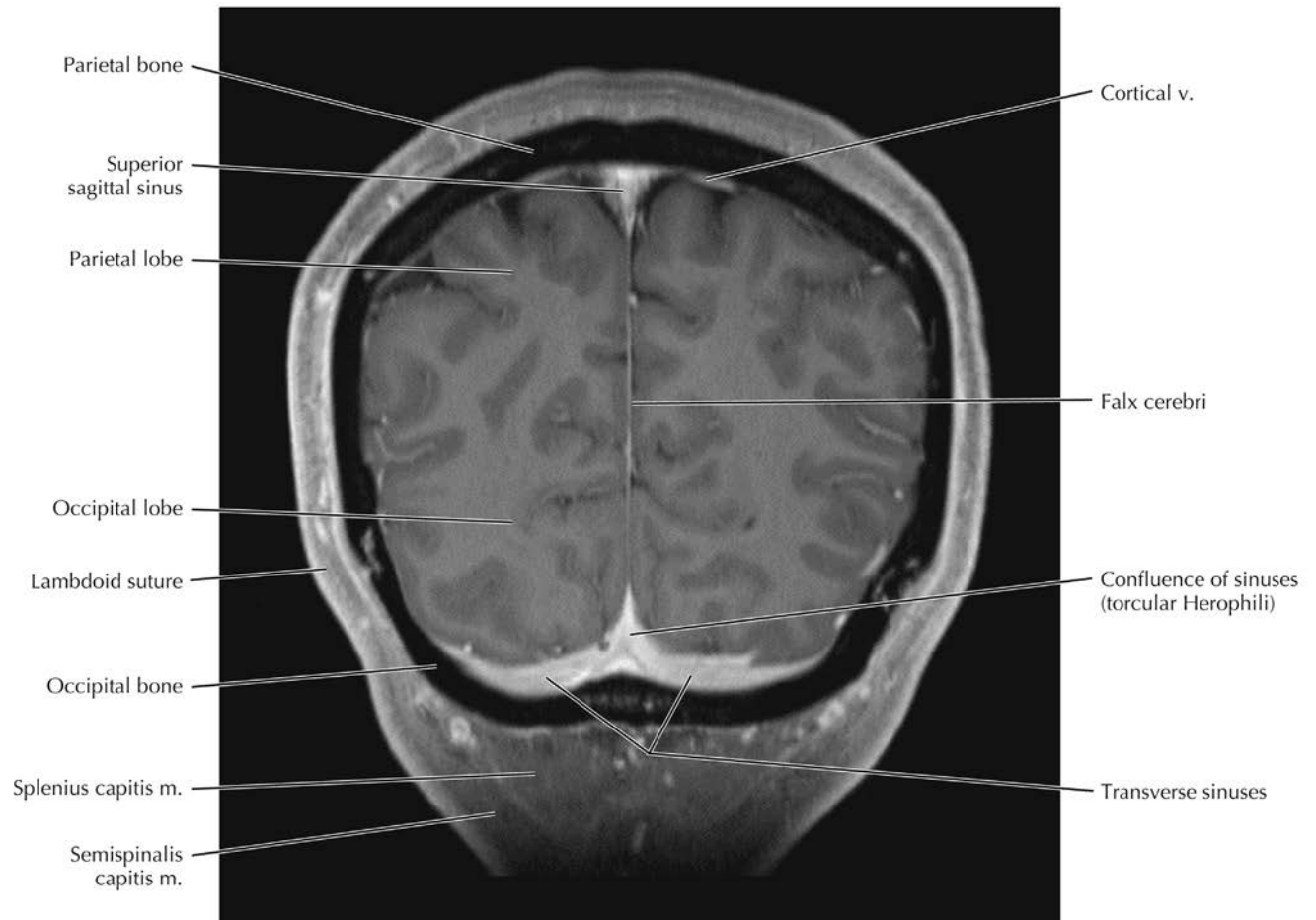
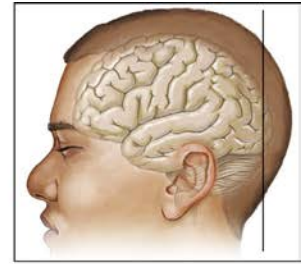
The cisterna magna in this view is within normal limits of size. An enlarged cisterna magna can be seen with arachnoid cysts and mega-cisterna magna.

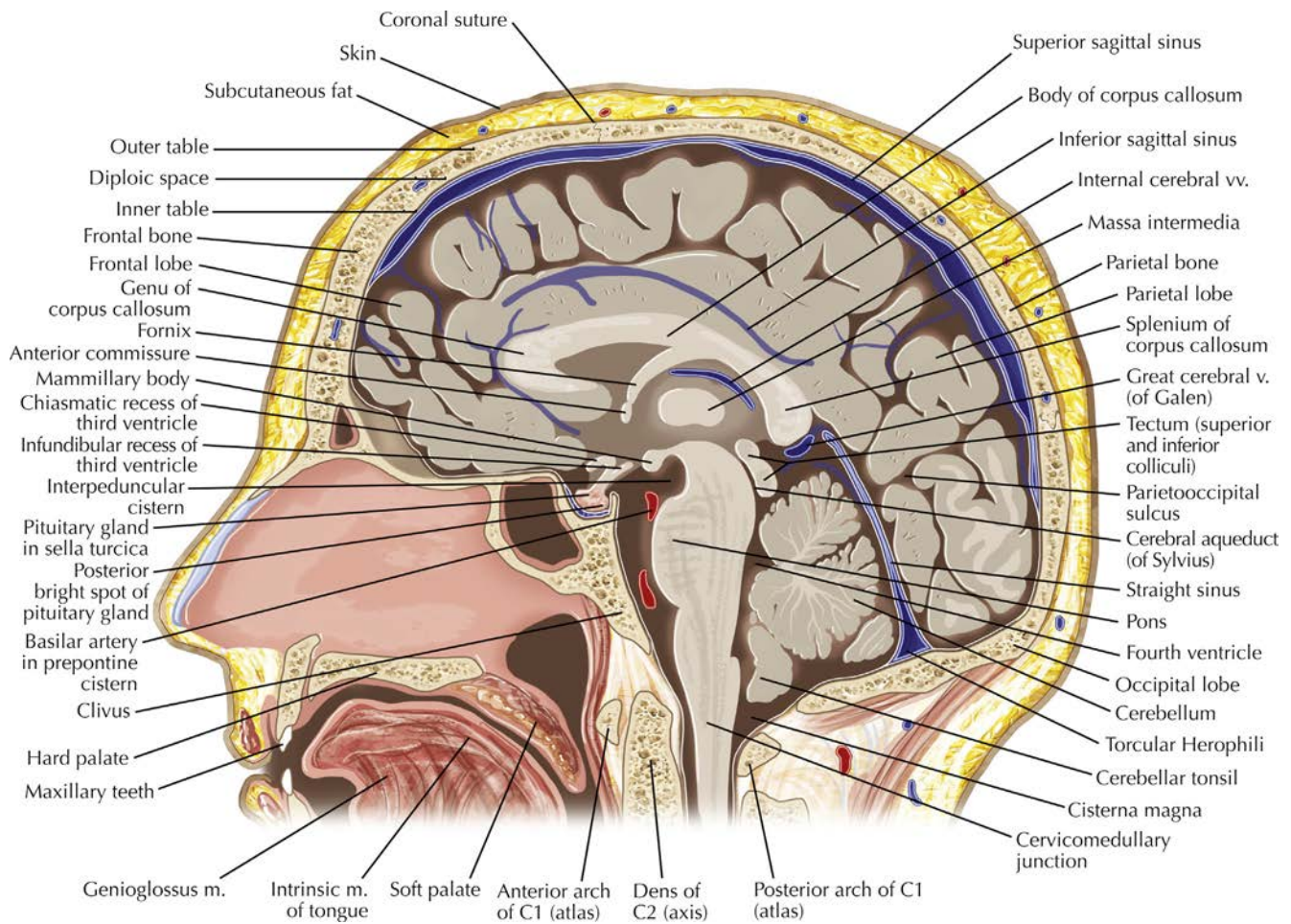


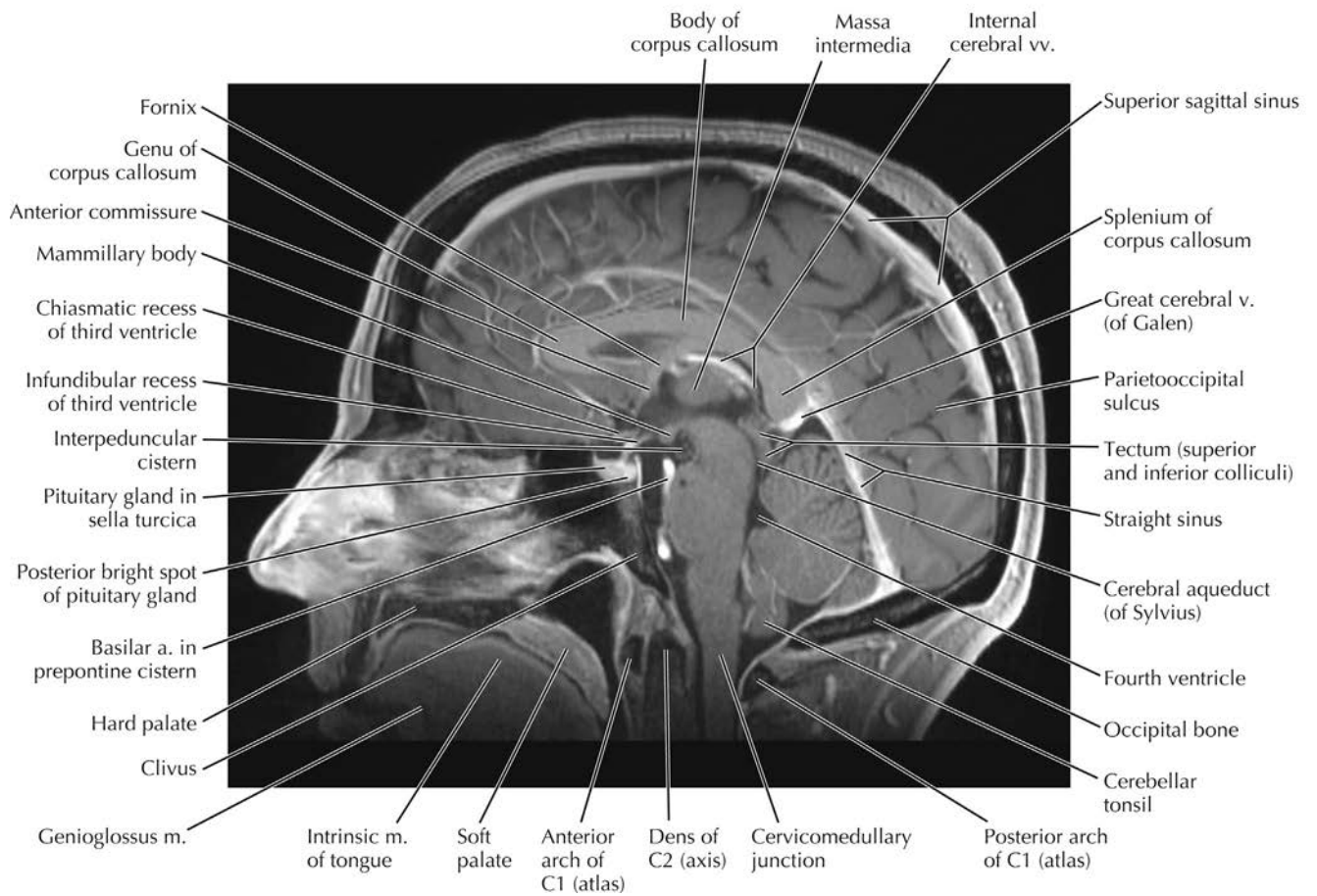
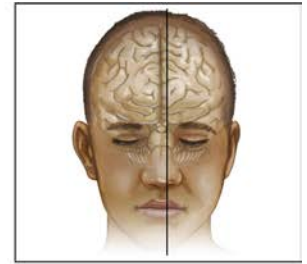


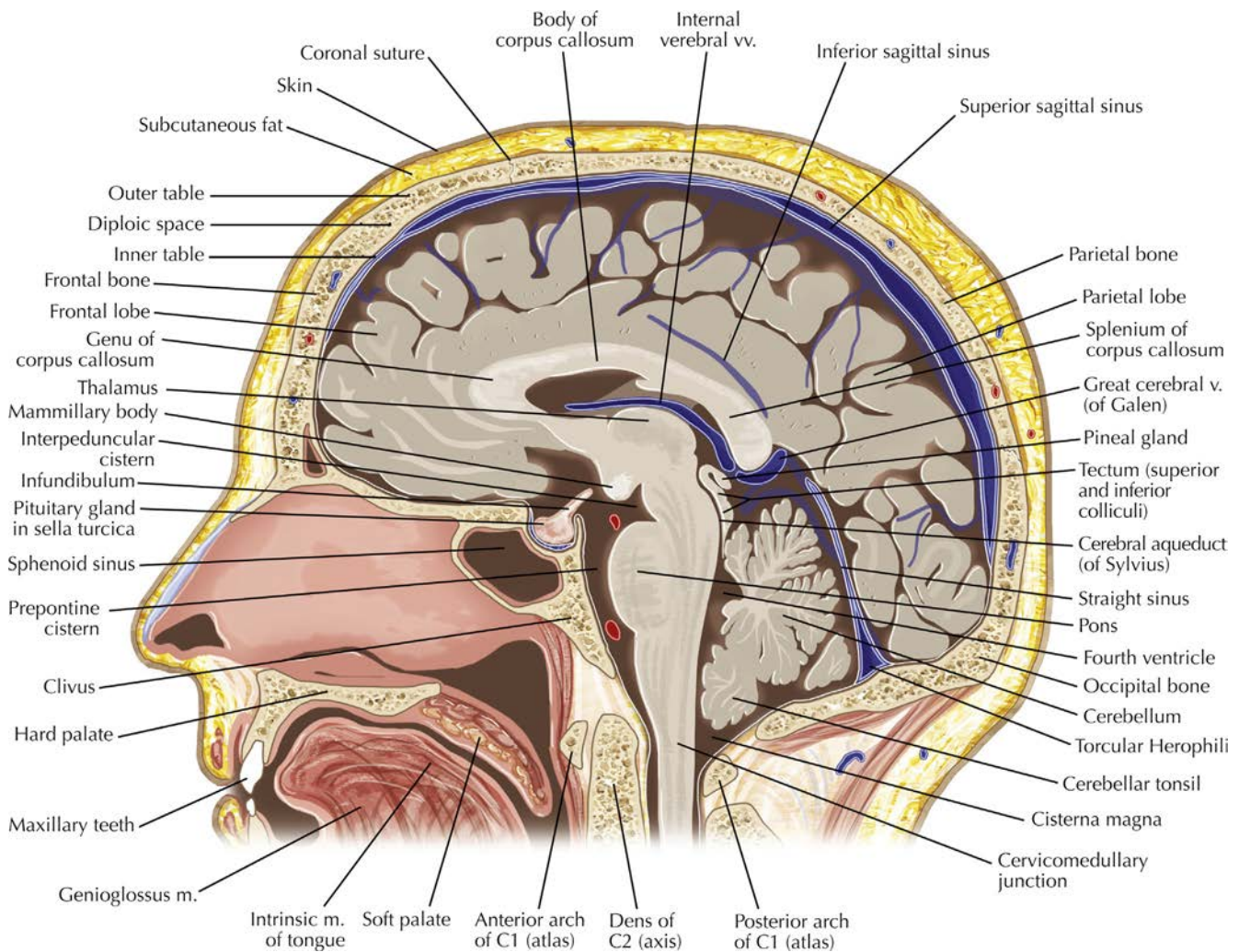
DIAGNOSTIC CONSIDERATION

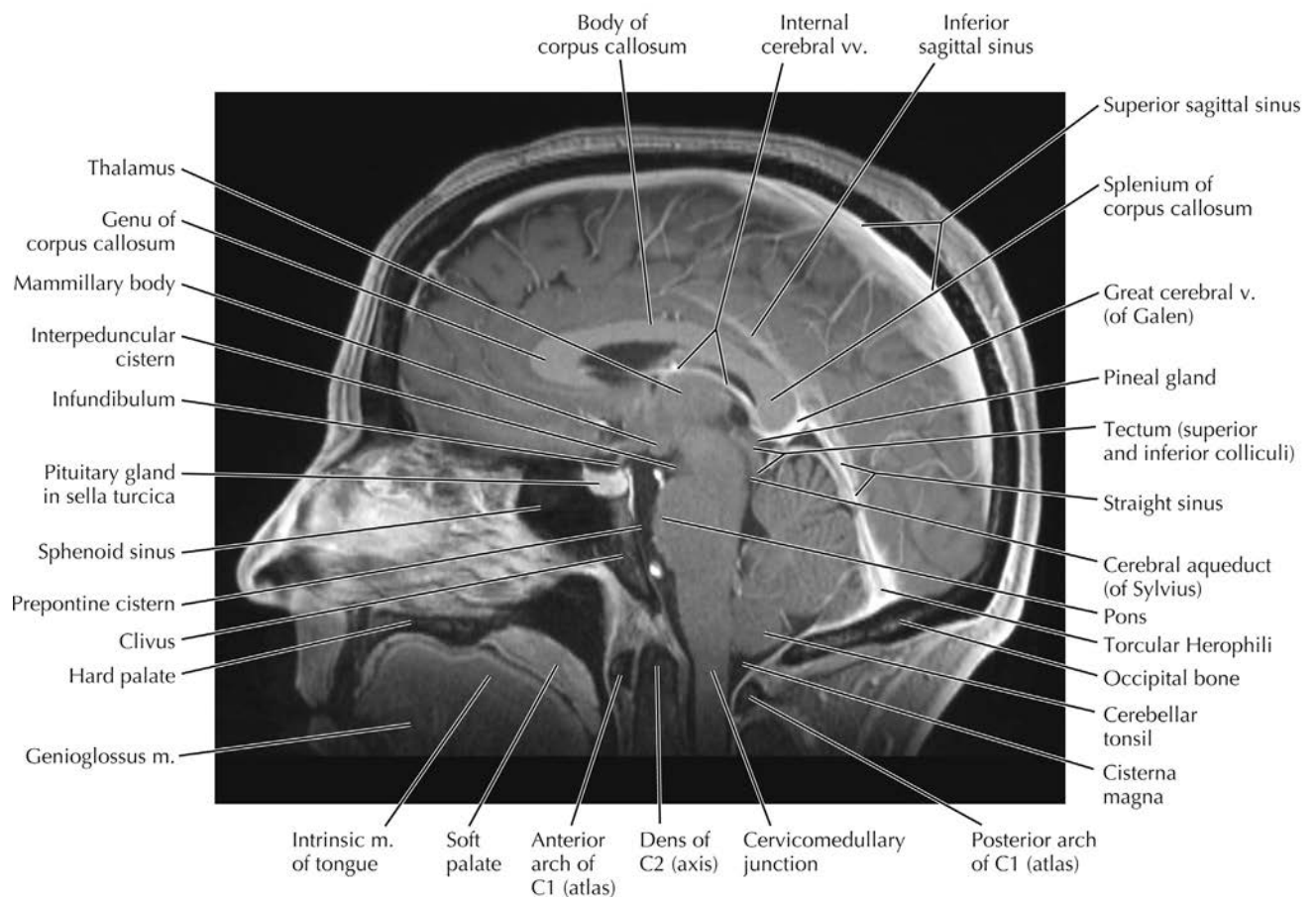
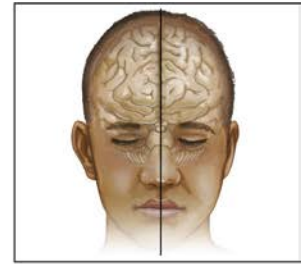
The coronal view is perpendicular to most of the superior sagittal sinus and is often the best view for assessment of venous thrombosis in the sinus. In this view there is a small, rounded filling defect in the right transverse sinus close to midline consistent with an arachnoid granulation.

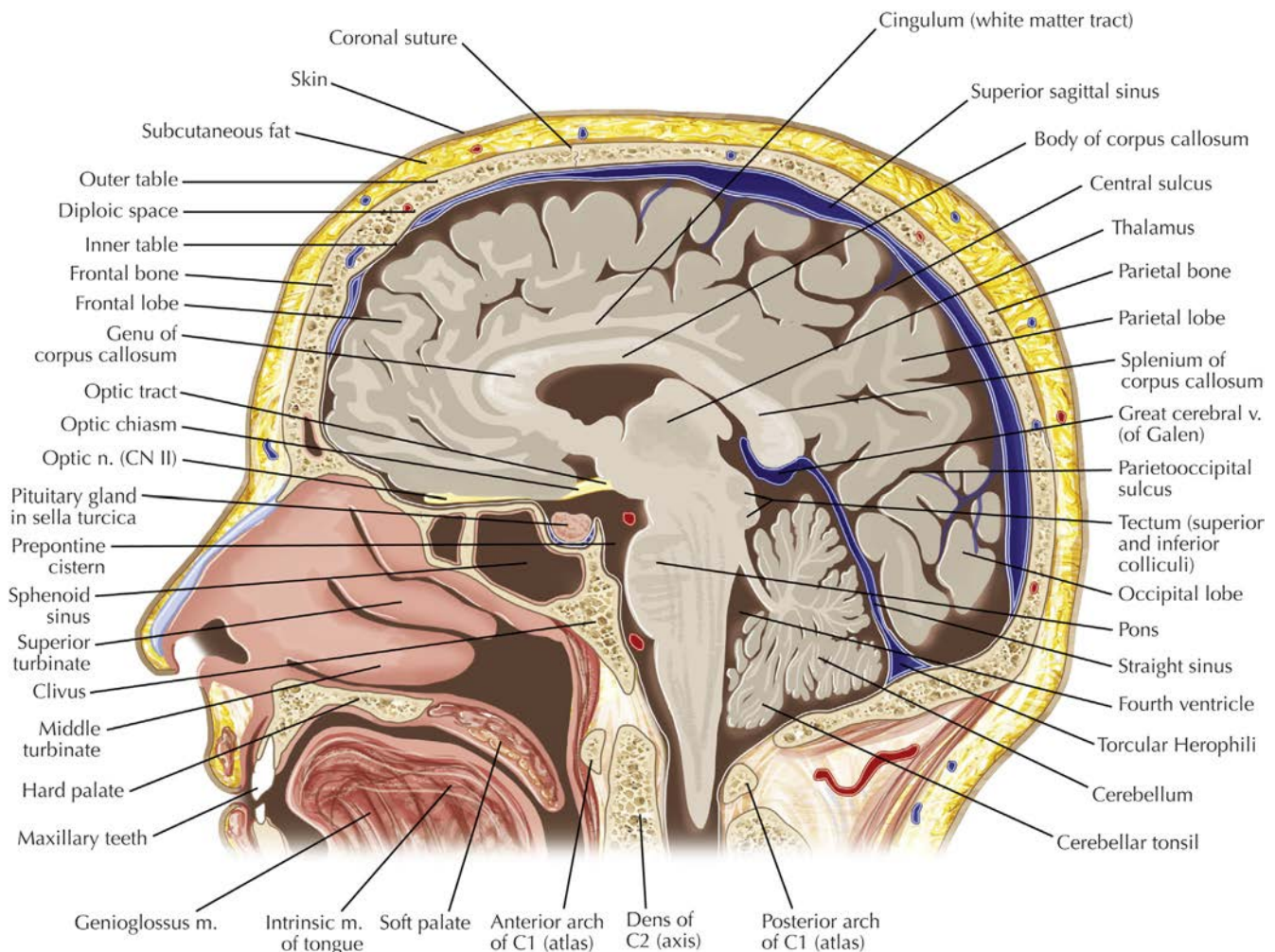












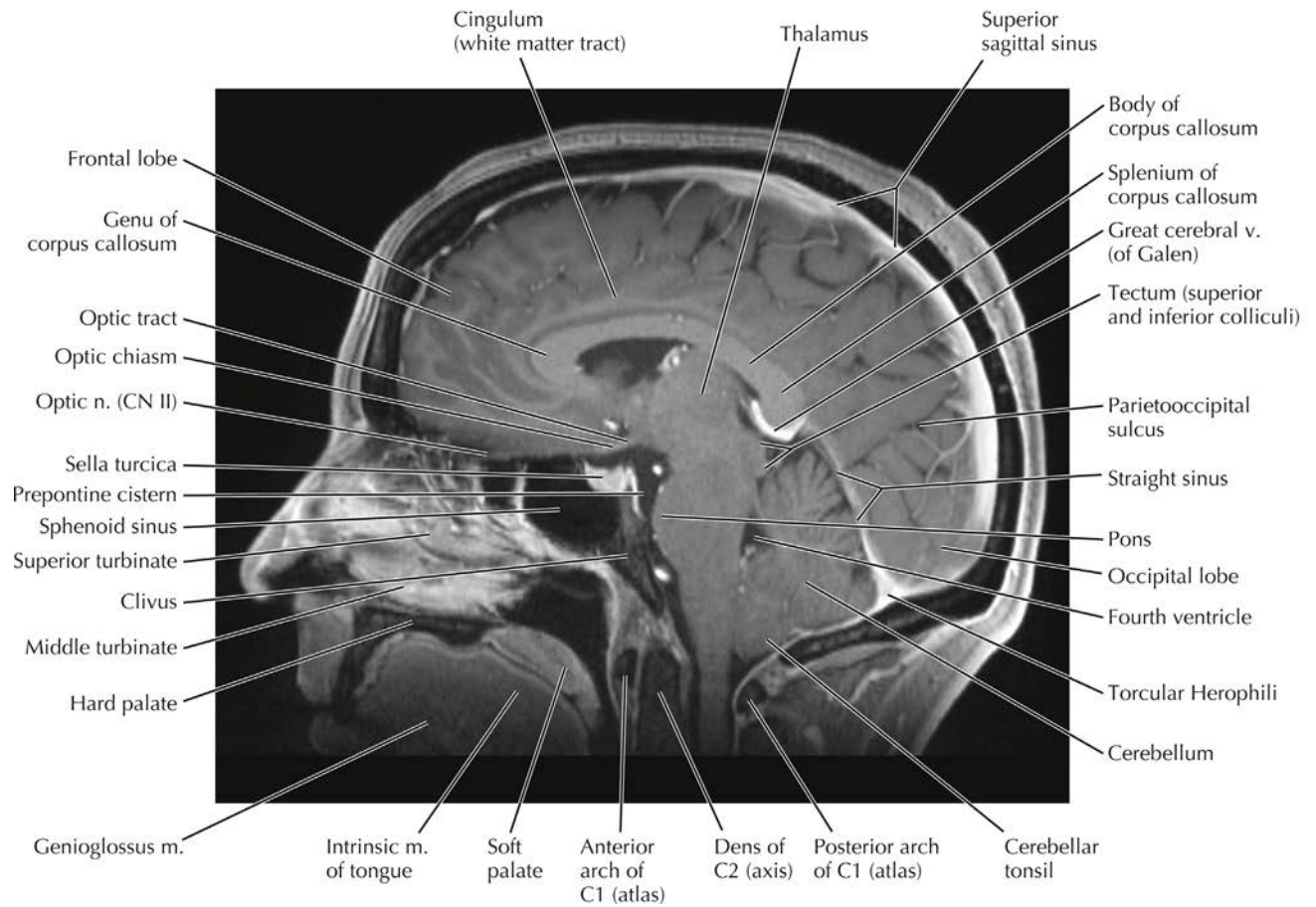
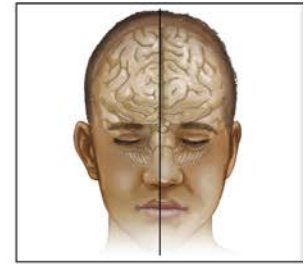
NORMAL ANATOMY

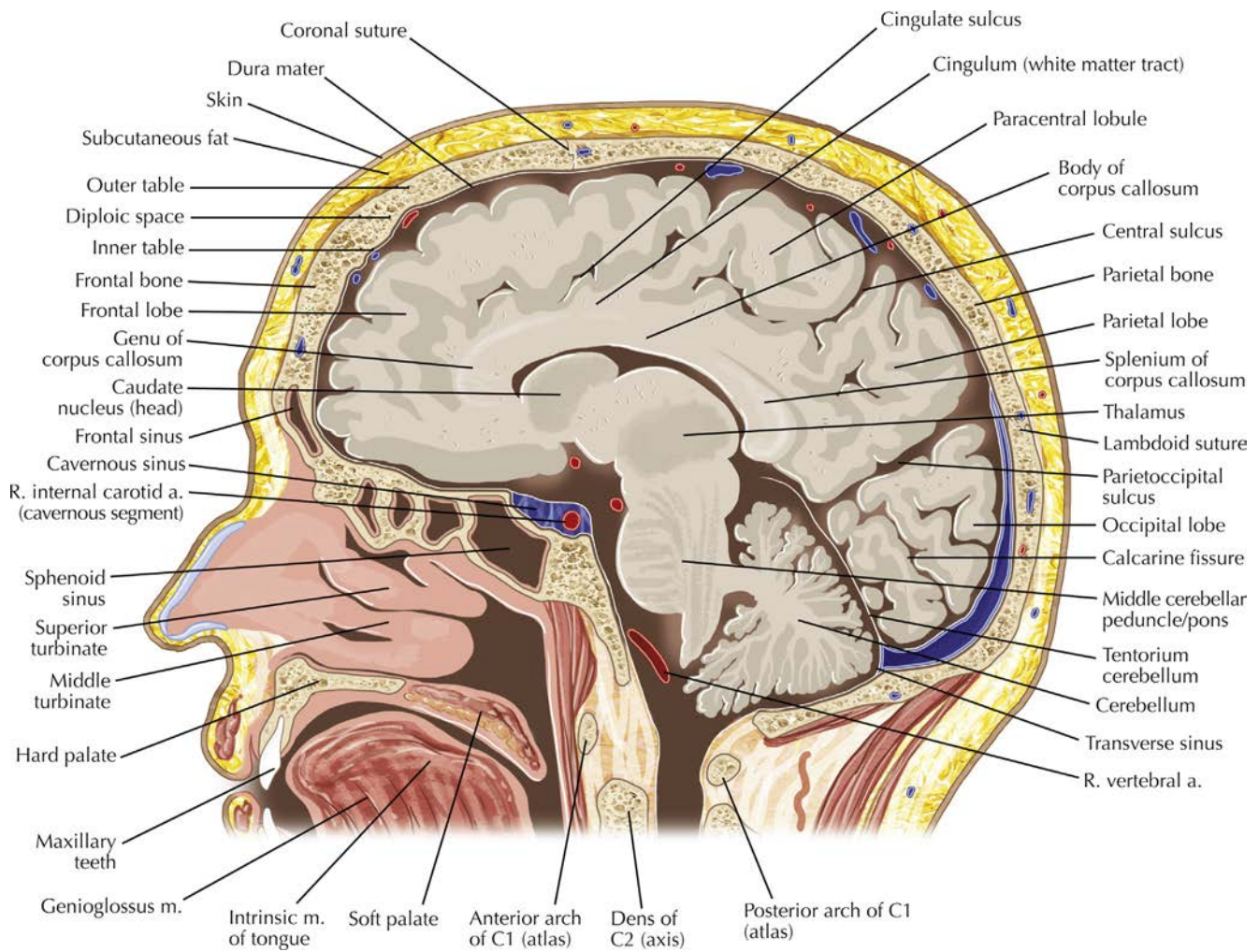
The lateral aspect of the cerebellar tonsils may lie lower than the midline vermis. In adults, up to 5 mm below the foramen magnum is within normal limits. The radiologist should also comment on whether the configuration is rounded or has an abnormal, pointed configuration.

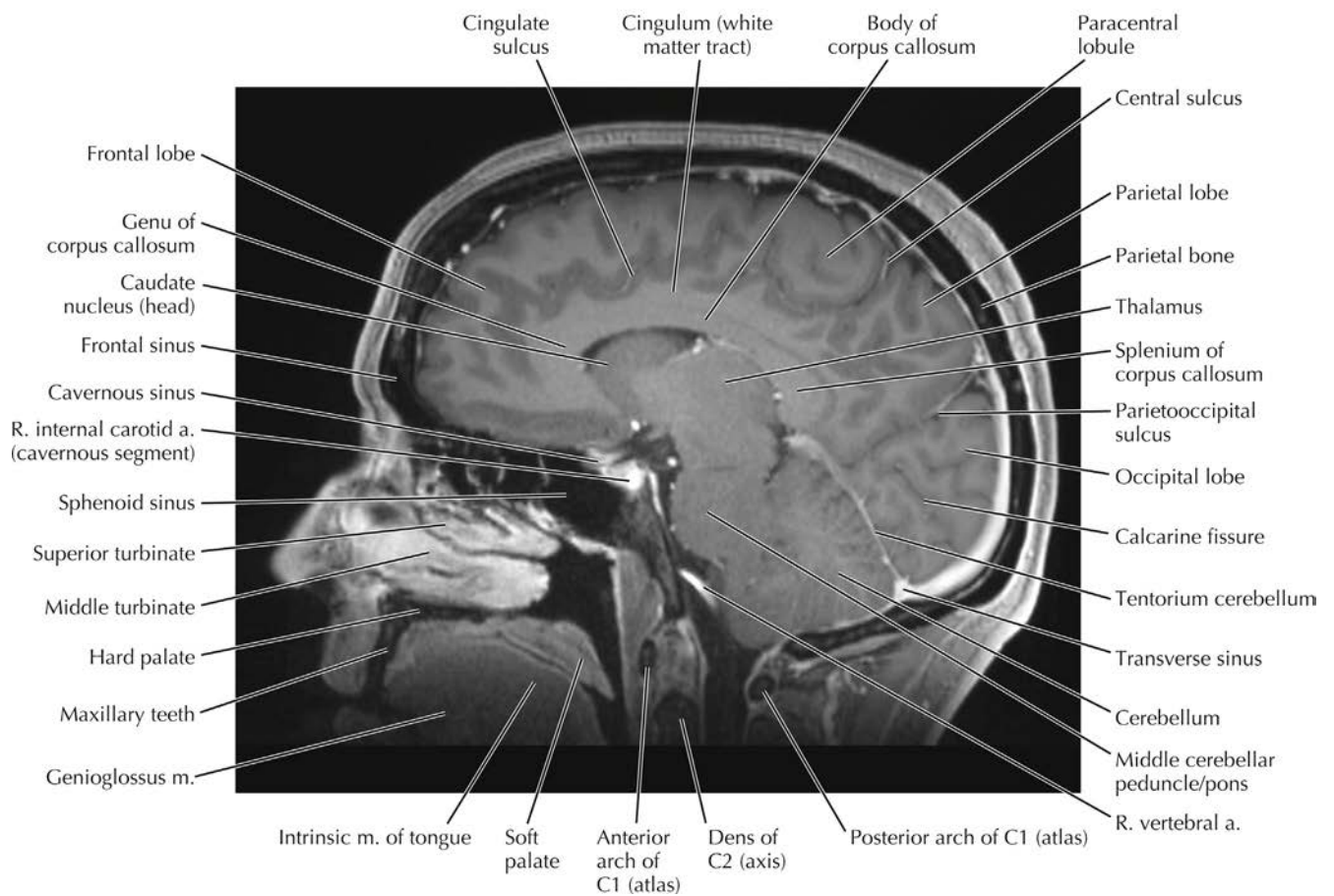
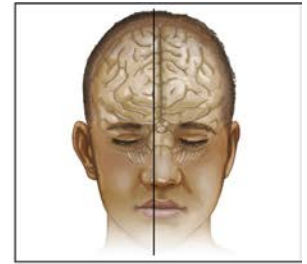
DIAGNOSTIC CONSIDERATION

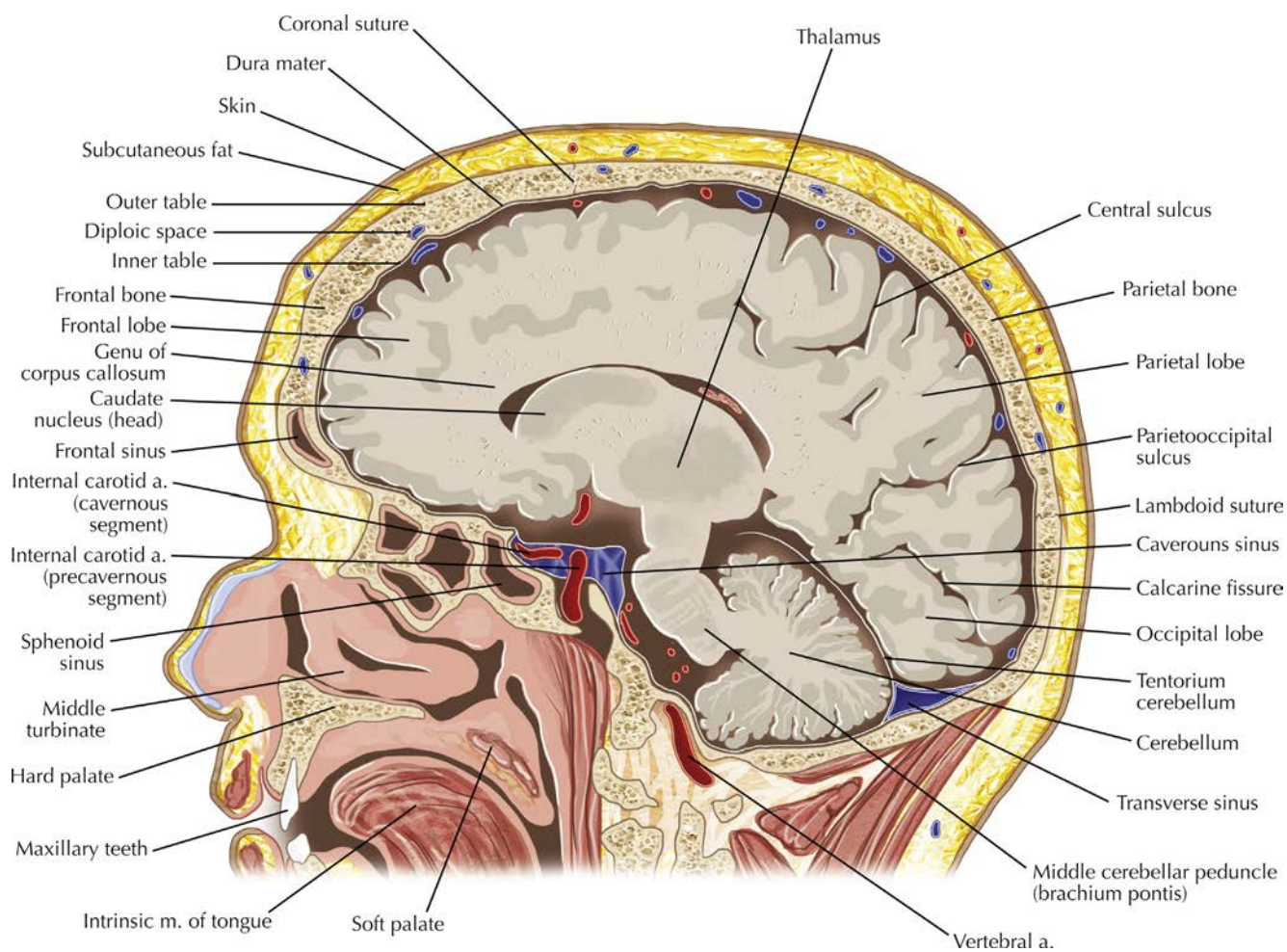
The superior sagittal sinus lies within the sagittal plane and thus may appear irregular because of volume-averaging effects. To assess for clots, a coronal or axial plane perpendicular to the superior sagittal sinus provides a more accurate view.

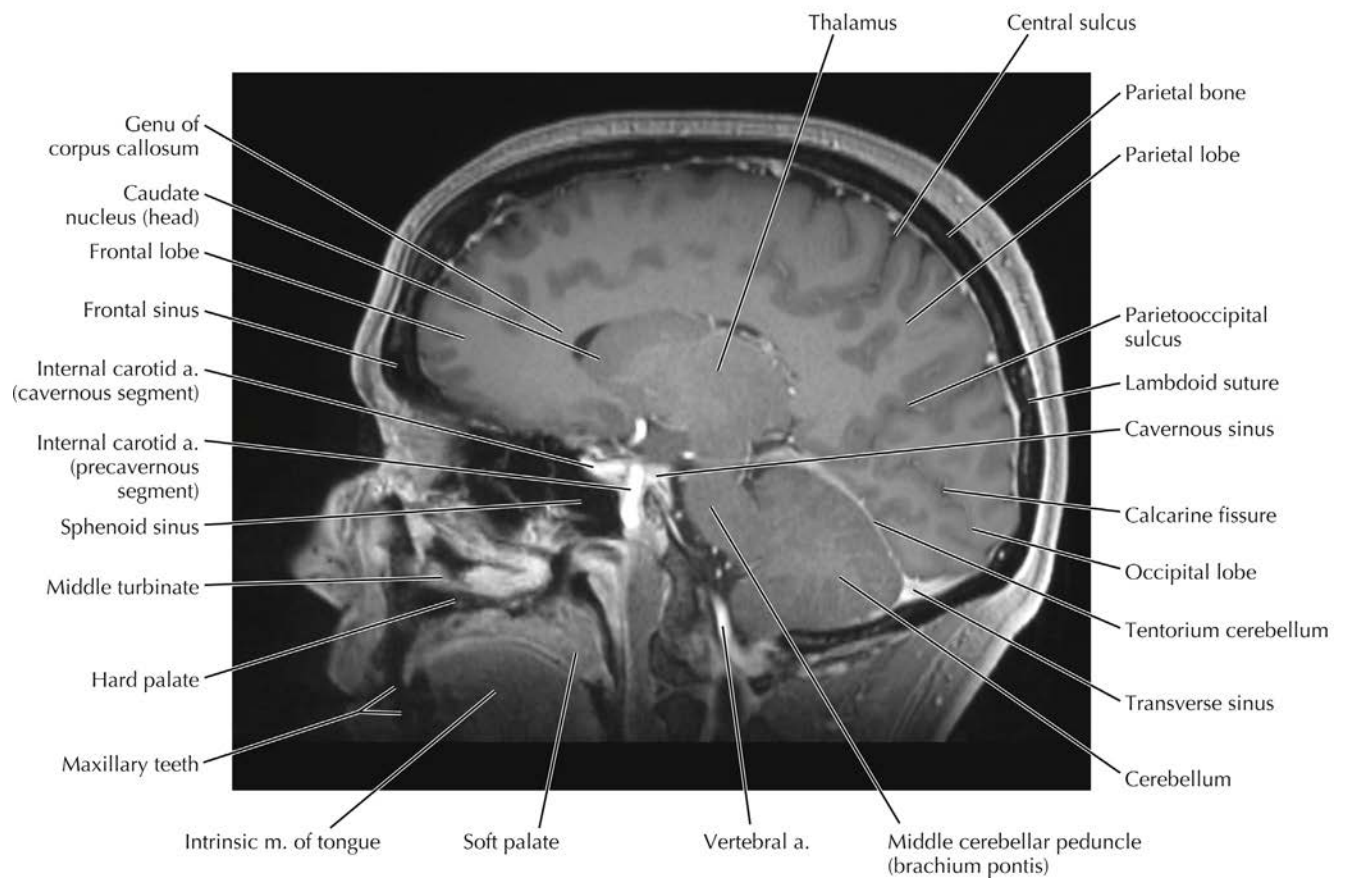
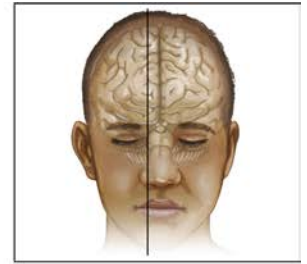
Note that the clivus lines up with the posterior aspect of the odontoid process, and the opisthion (posterior edge of foramen magnum) aligns with the anterior edge of the posterior arch of the first cervical vertebra (C1, atlas).

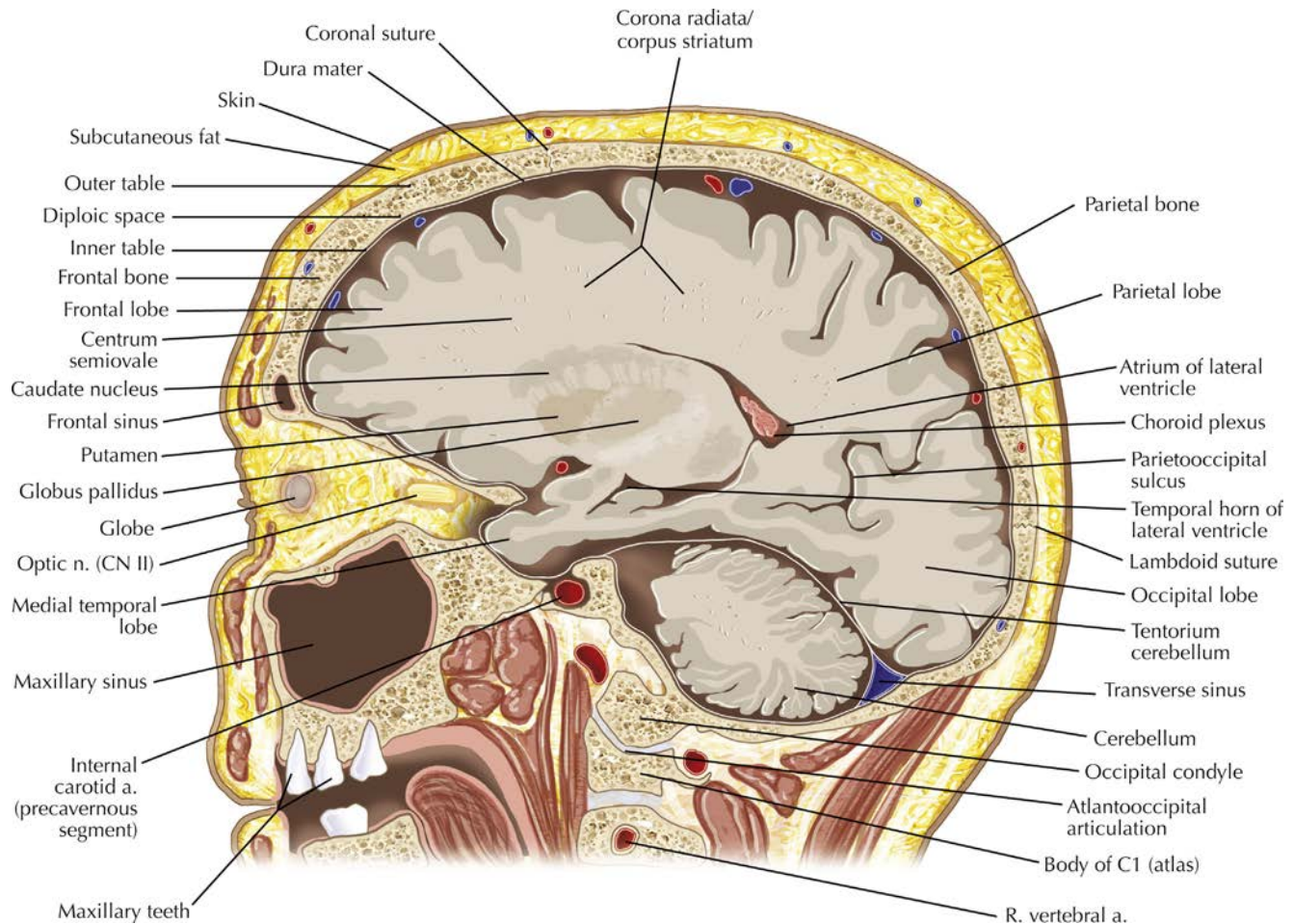








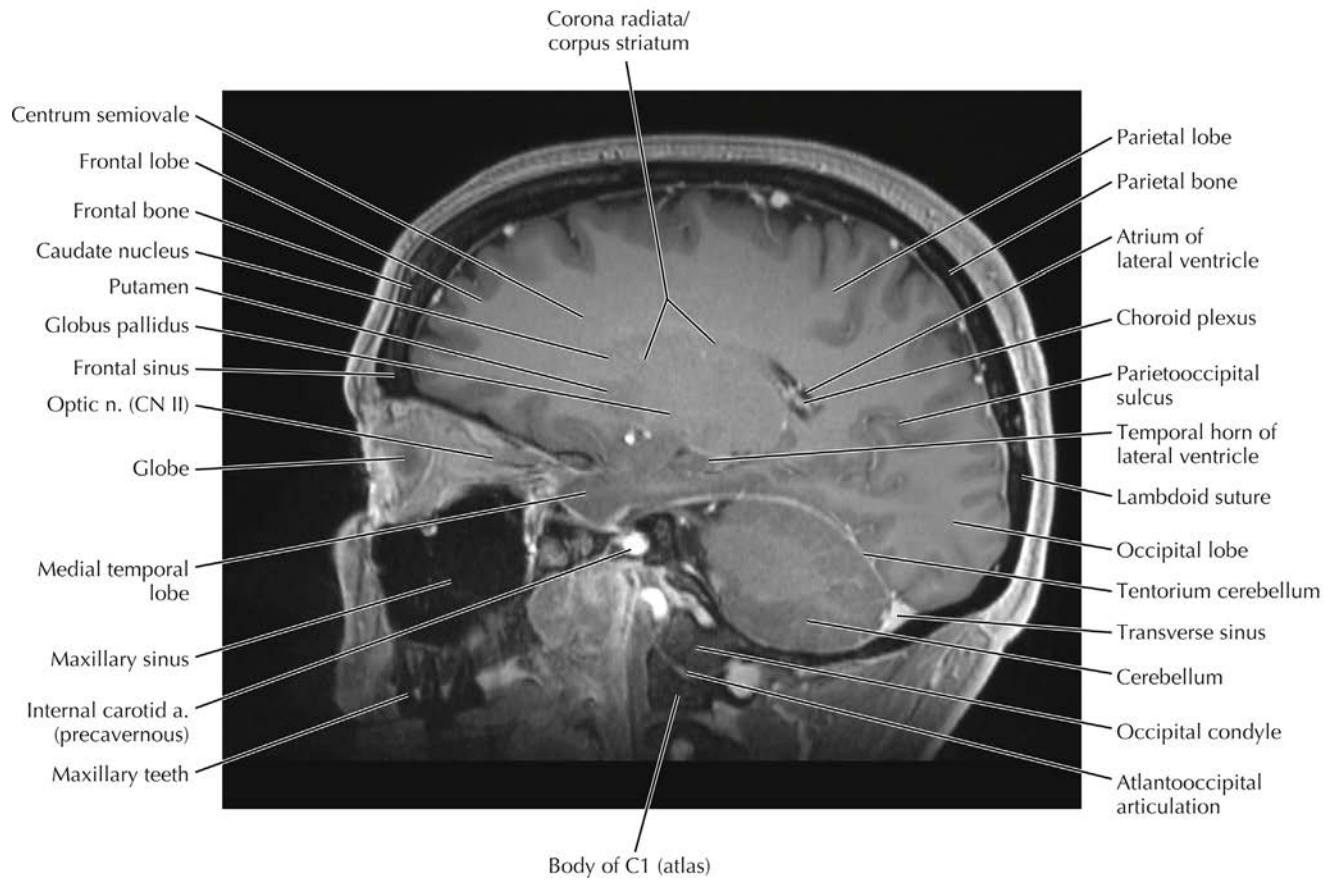
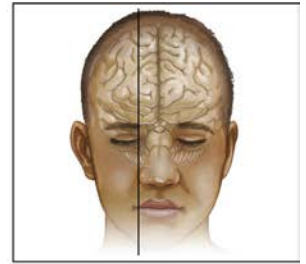


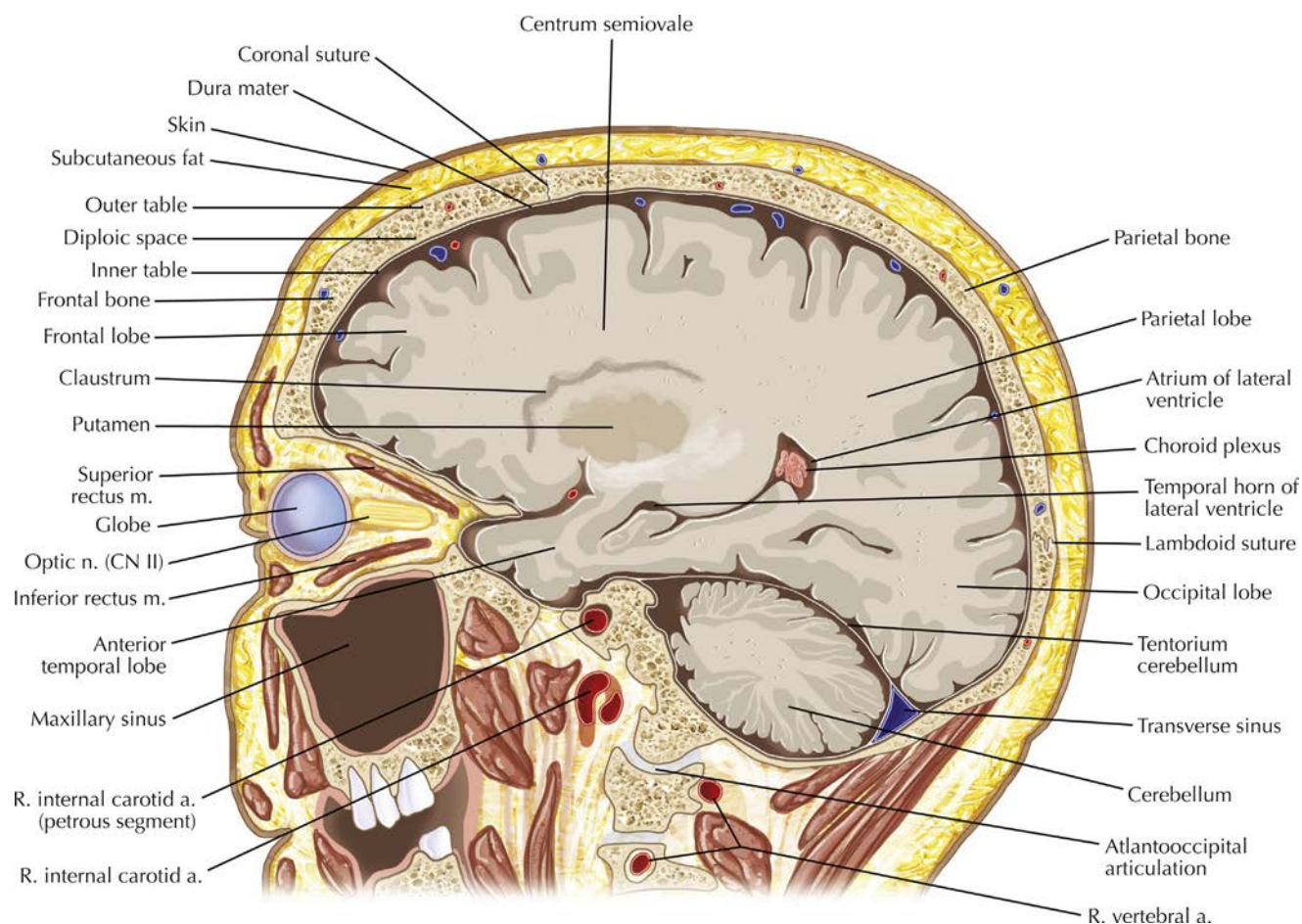


DIAGNOSTIC CONSIDERATIONS

As with the floor of the middle cranial fossa, which lies in the axial plane, the tentorium cerebellum can harbor a small meningioma or dural metastasis, which may be much more conspicuous on sagittal imaging.

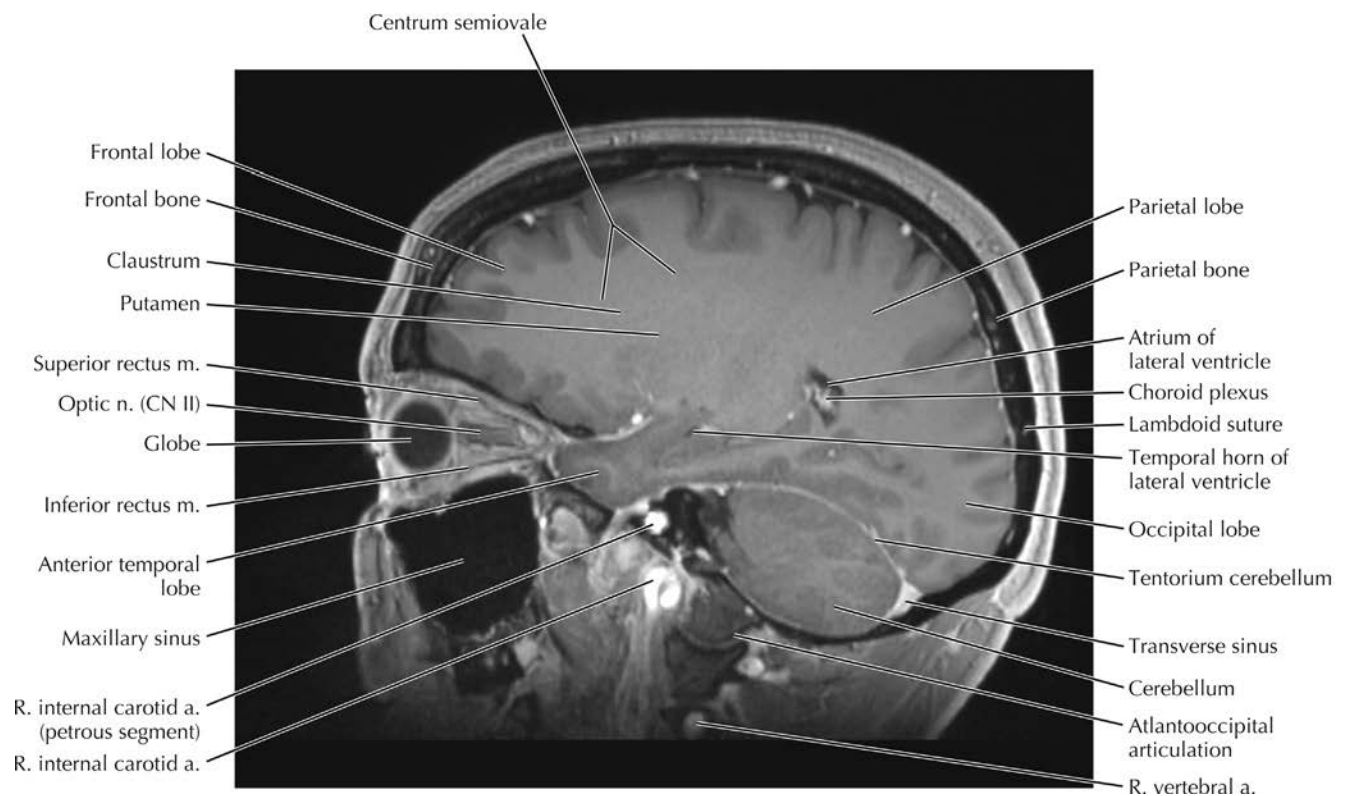
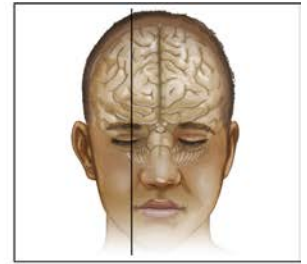
Note also the clear view of the alveolar roots of the maxillary teeth. Inflammatory changes in the maxillary sinuses may result from periodontal disease, an area that can be overlooked in imaging of the head.

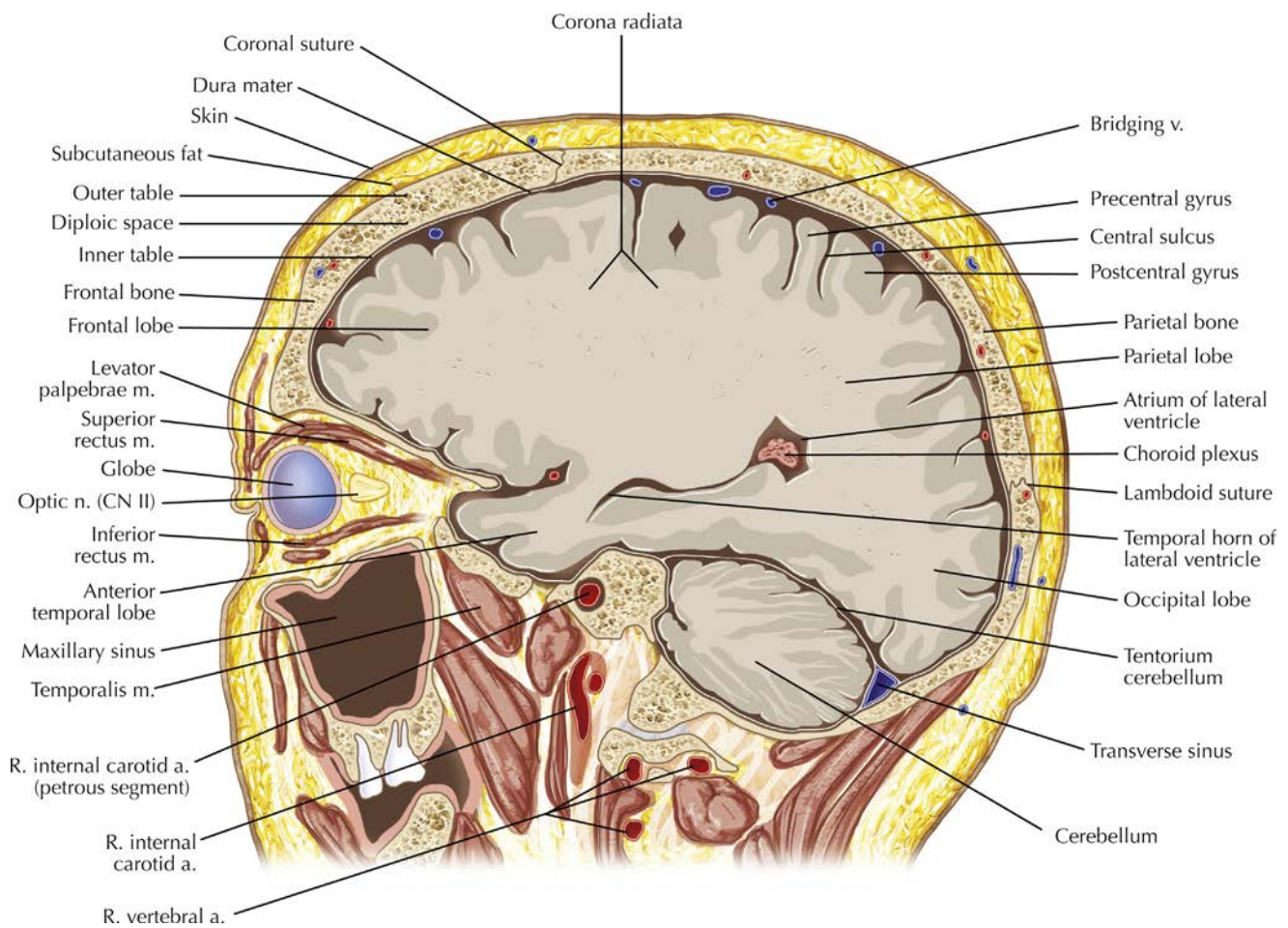


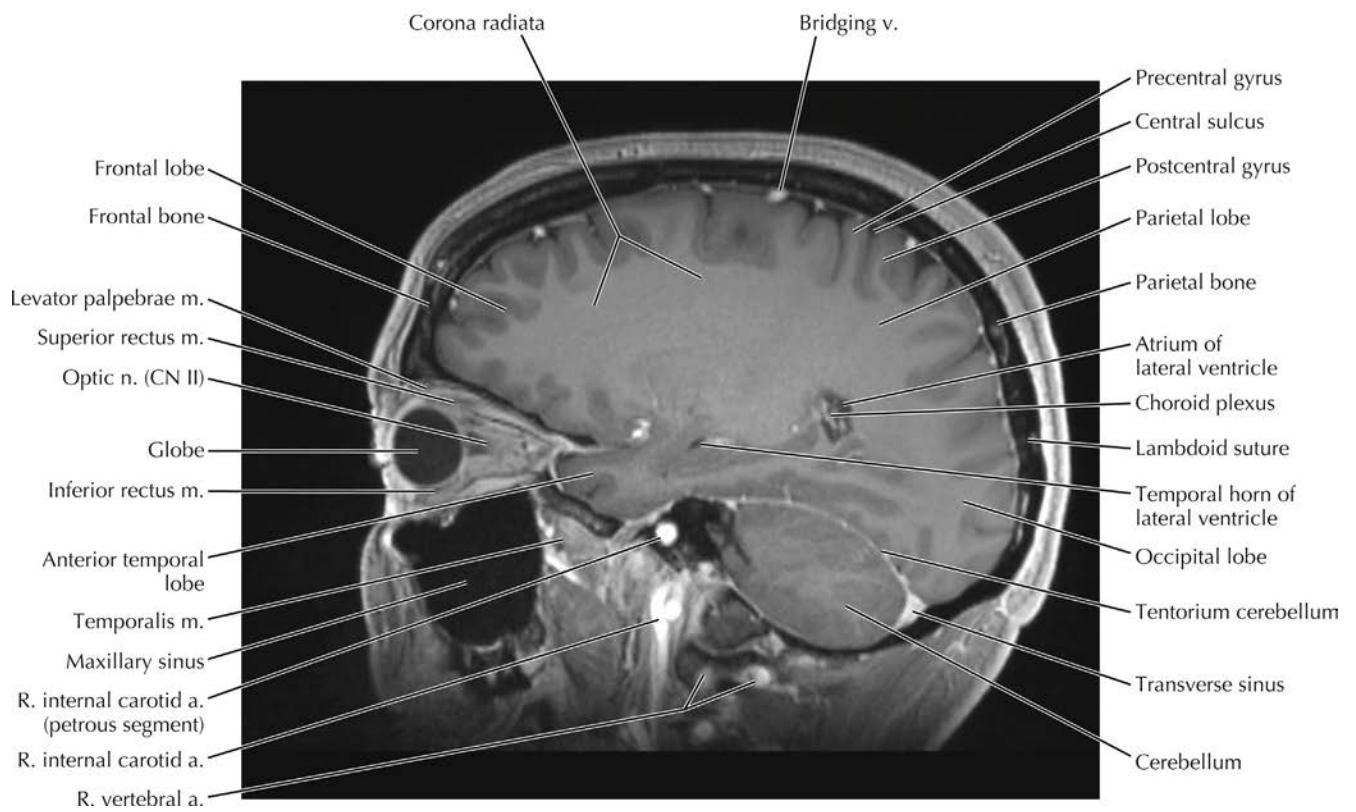
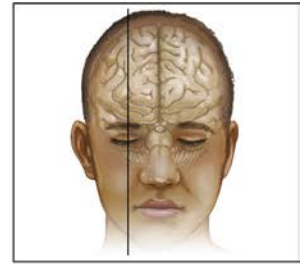


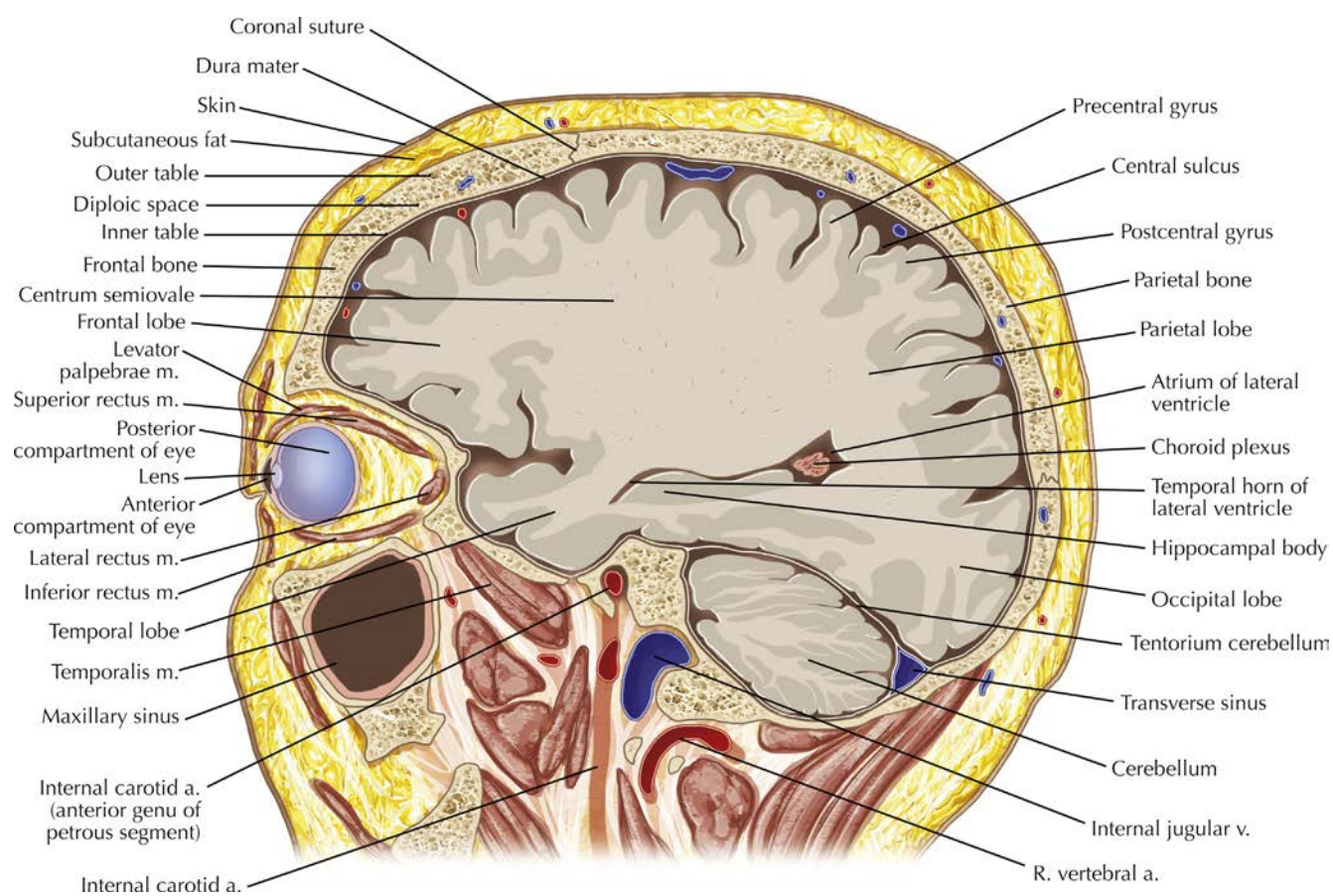
DIAGNOSTIC CONSIDERATION

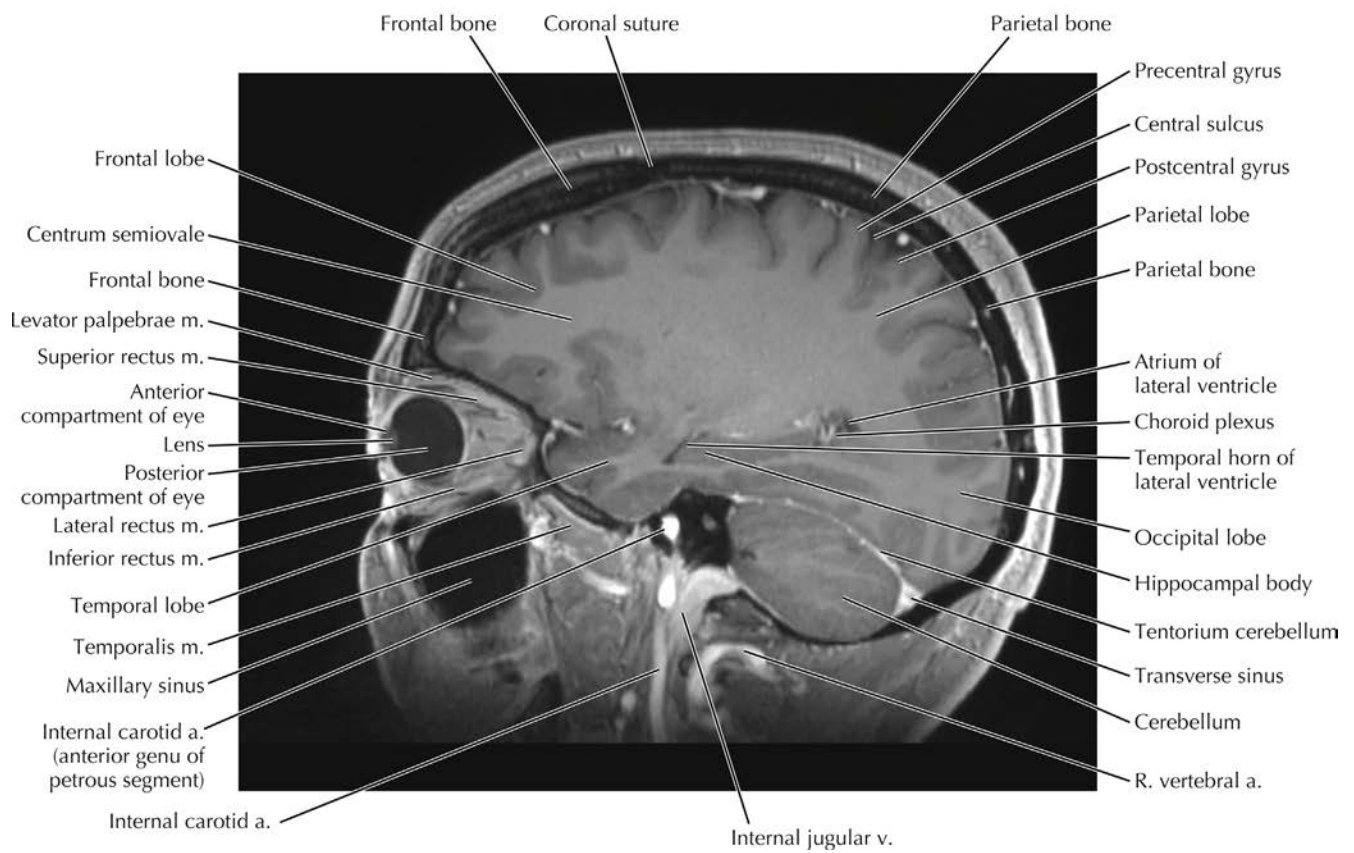
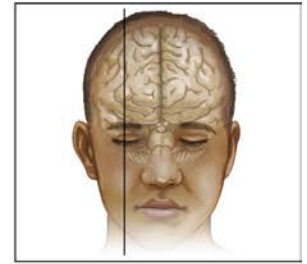
It is important to assess the visualized portions of the upper cervical spine on any head study. In this view, the radiologist can see the atlantooccipital articulation. Dislocation or subluxation is often much more conspicuous on a sagittal than an axial view.

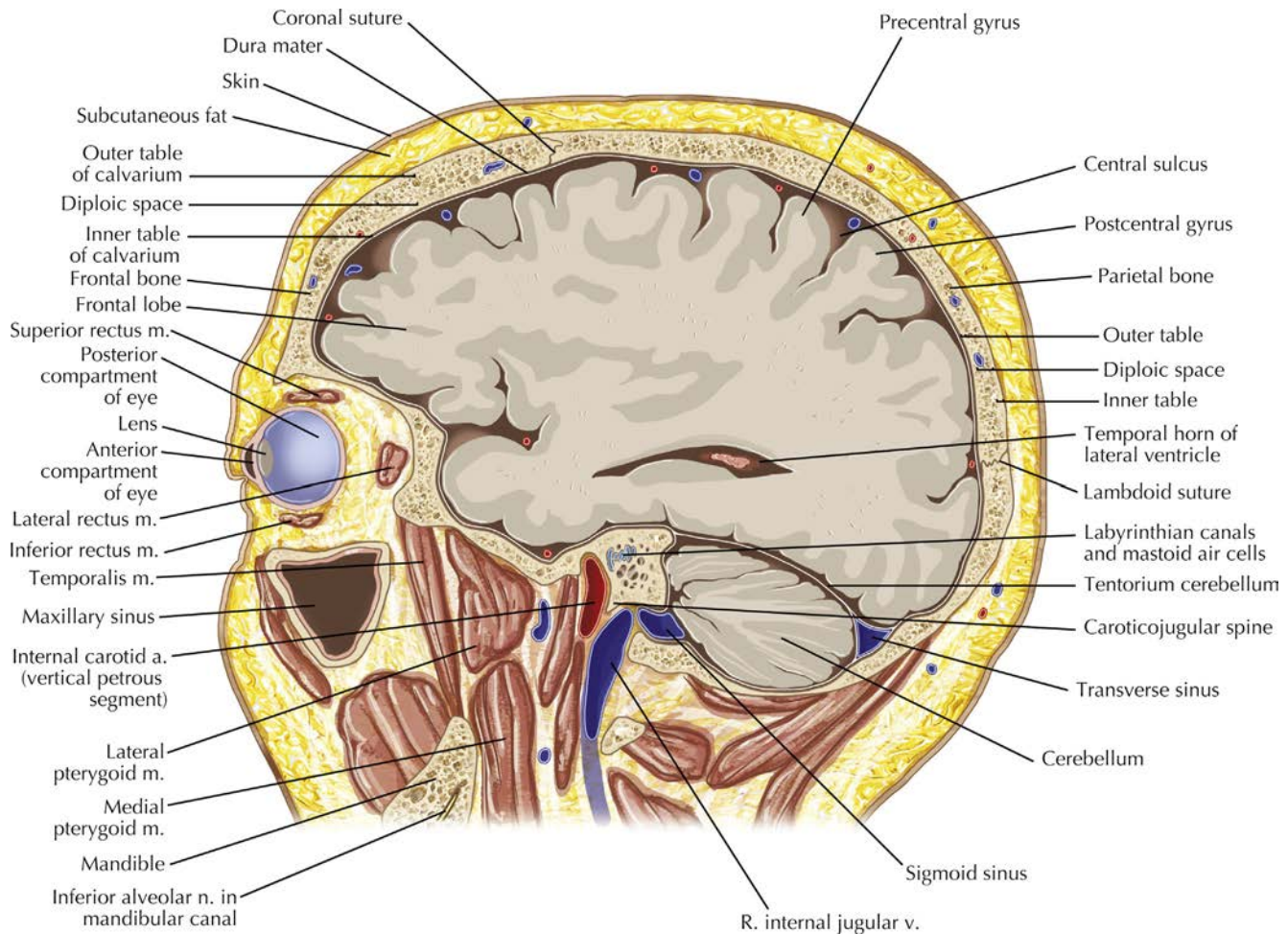






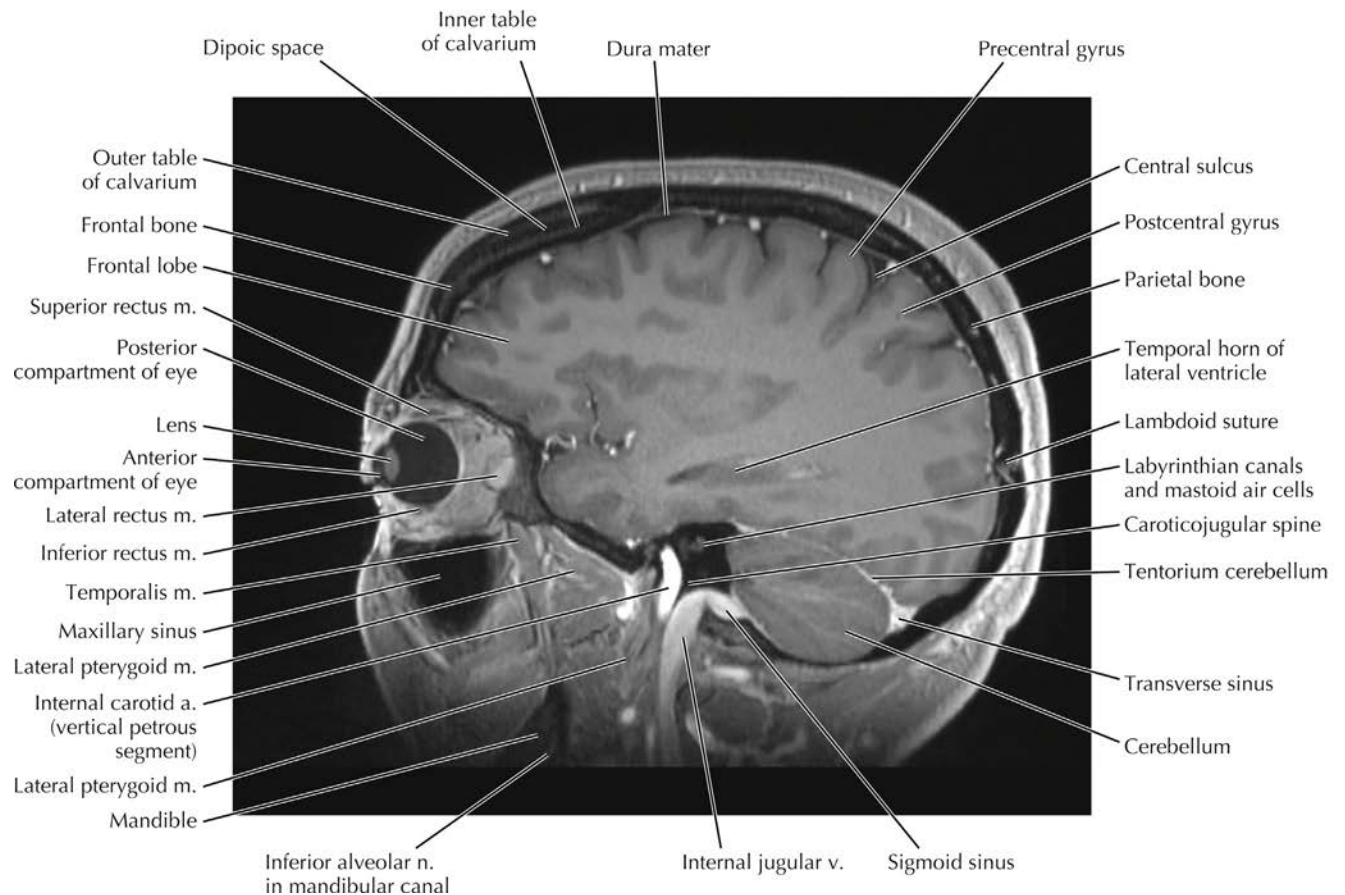
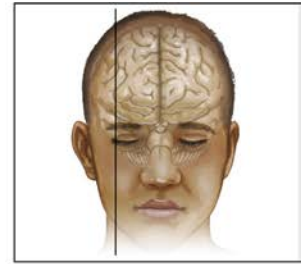


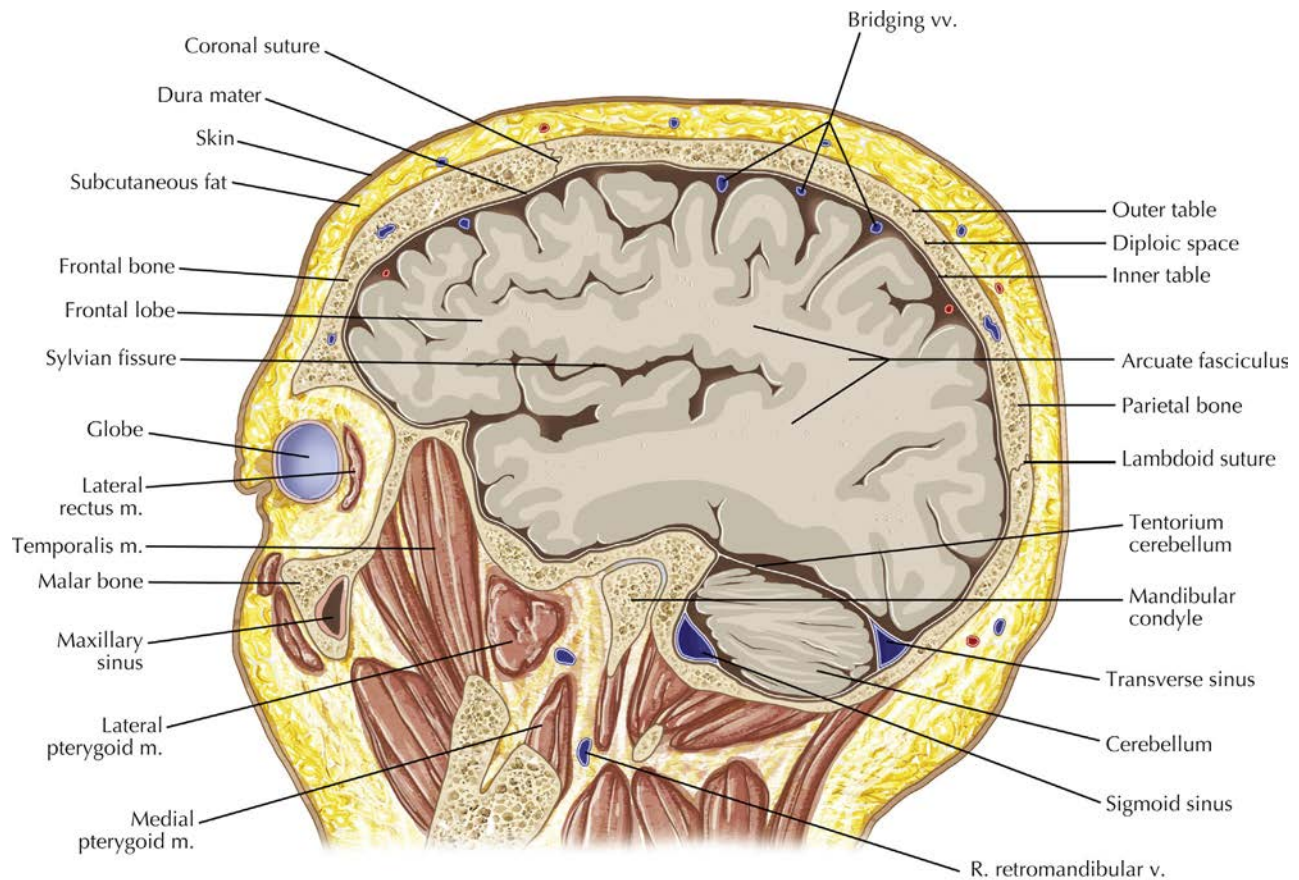




DIAGNOSTIC CONSIDERATION

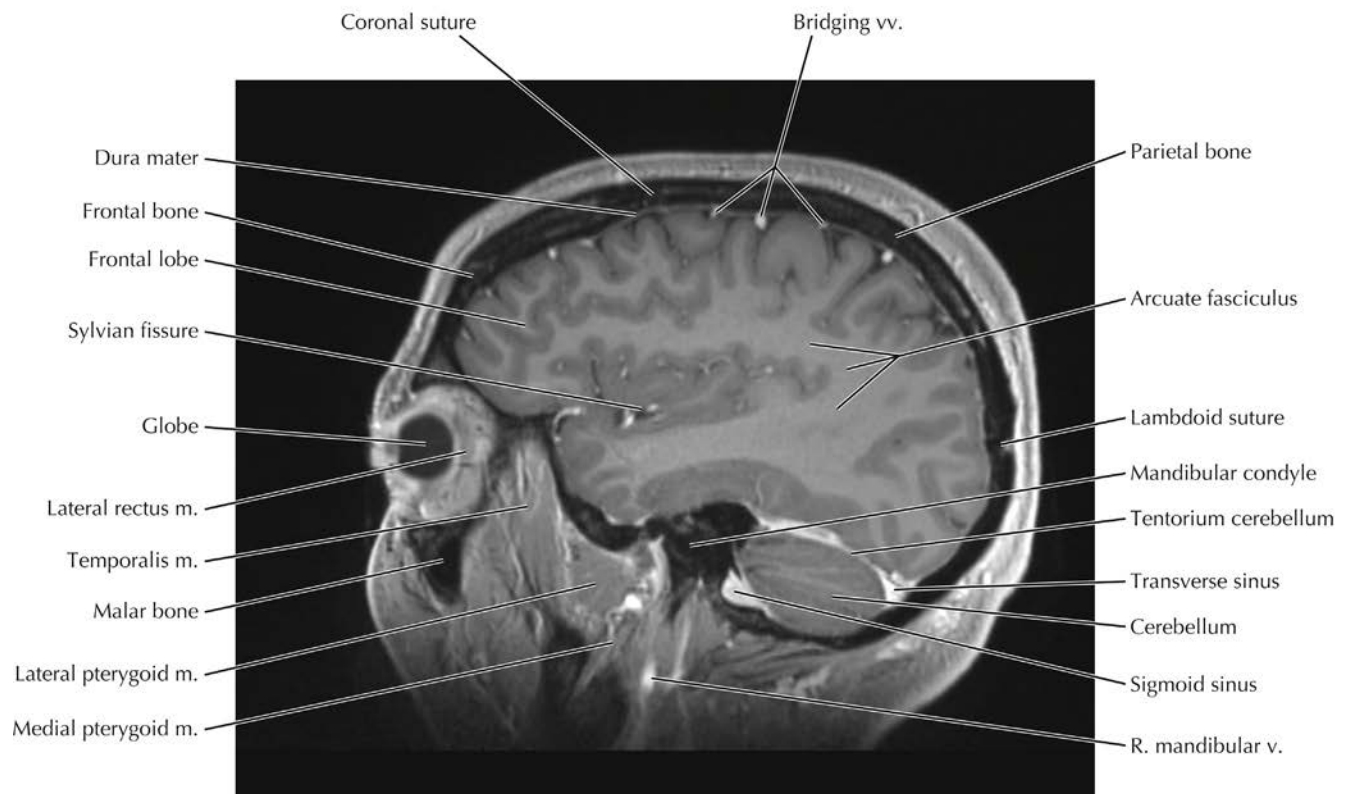
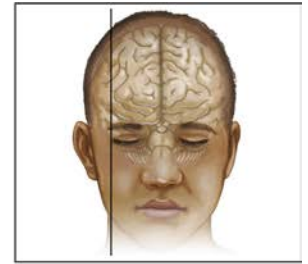
For any patient presenting with headache, the neuroradiologist should carefully assess the dural venous sinuses (e.g., transverse and sigmoid sinuses) for evidence of a filling defect to indicate venous thrombosis. Often, a rounded filling defect with a focus of central enhancement is seen; this appearance is typical of arachnoid granulation, unlike the linear wormlike filling defect of venous clots.

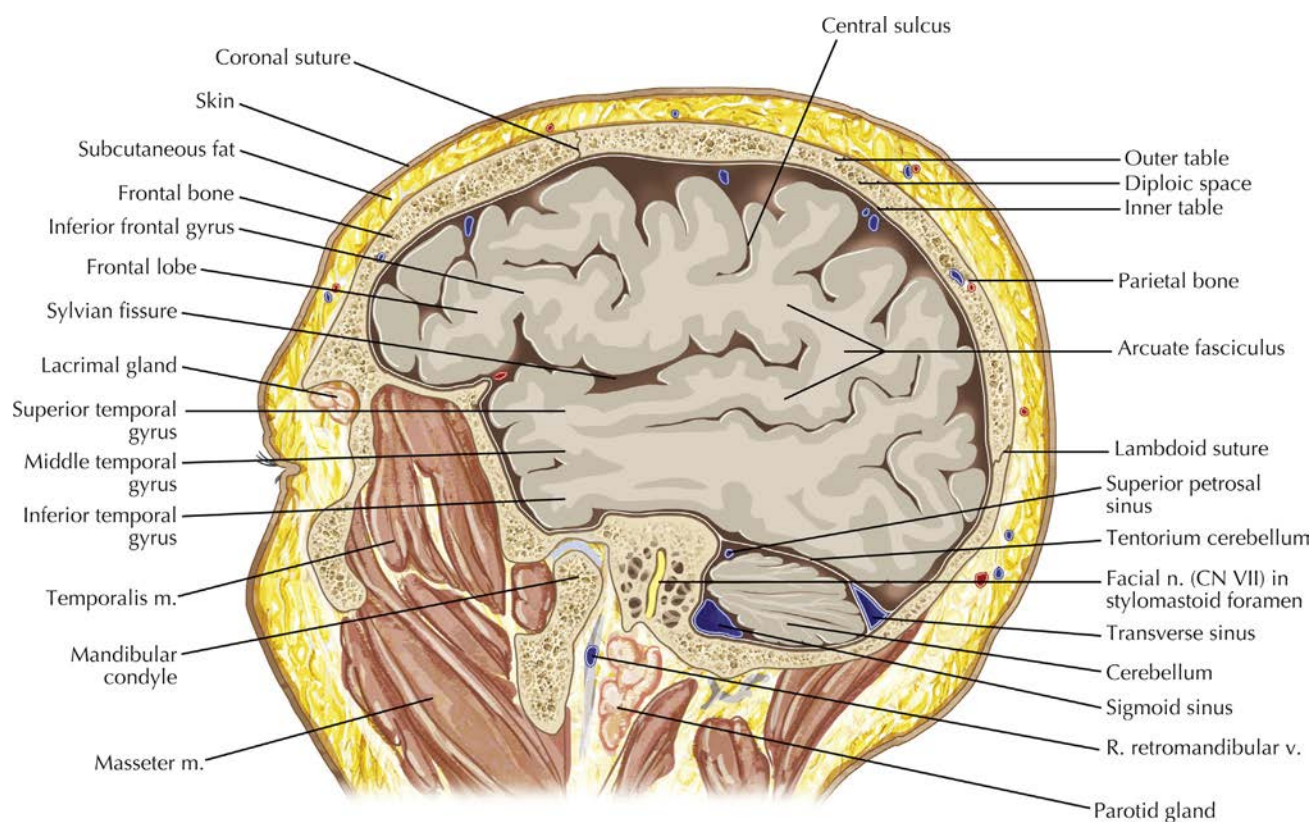




DIAGNOSTIC CONSIDERATION

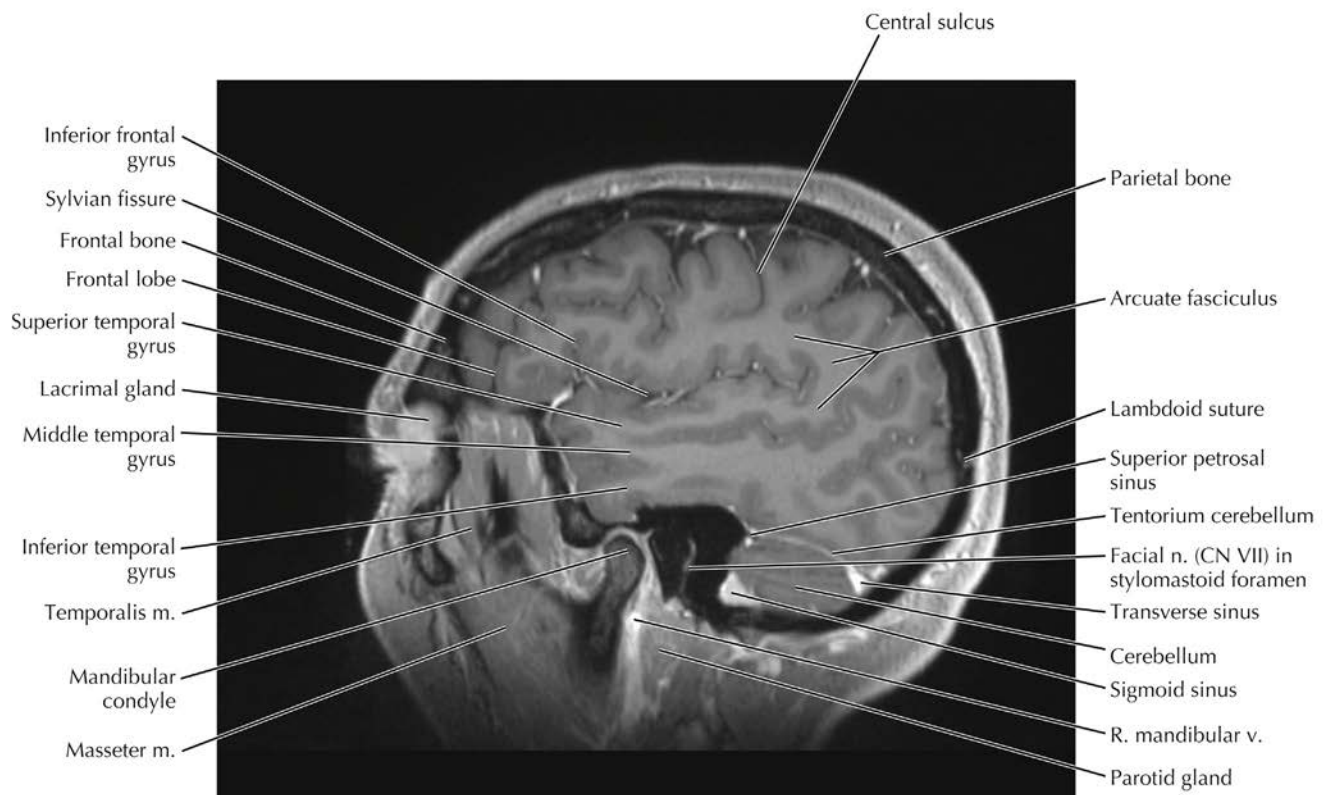
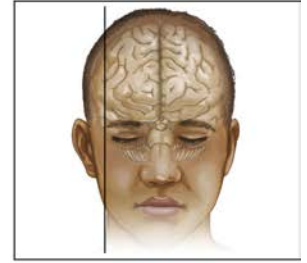
One of the most difficult diagnoses to make in neuroradiology is *cortical vein thrombosis*. Clinical presentation may be simply that of a headache, with MRI showing a single cortical vein occluded. An unenhanced sagittal image may most conspicuously show a T1-weighted bright clot within a single cortical vein. If untreated, this may progress to a hemorrhagic venous infarct.

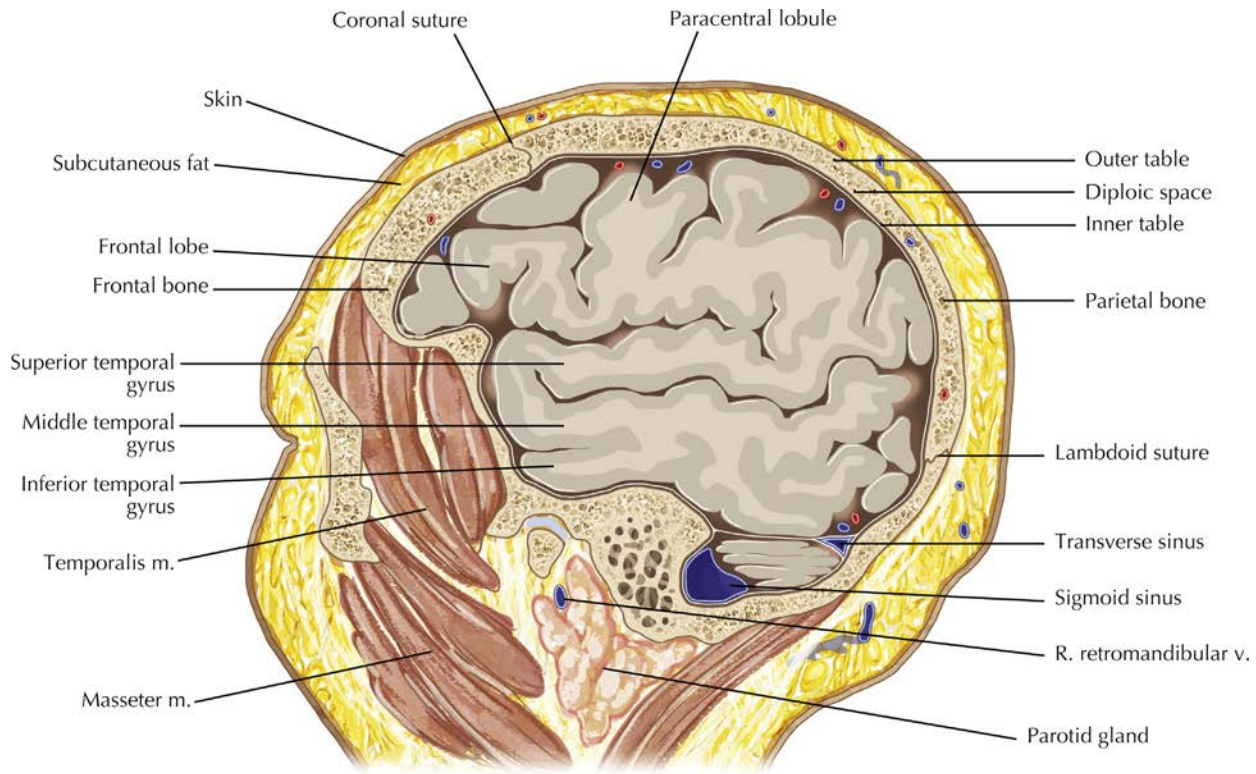




NORMAL ANATOMY

Note that this sagittal view shows the mastoid segment of the facial nerve (seventh cranial nerve, CN VII) as it descends through the mastoid bone and exits the stylomastoid foramen. Injury to the facial nerve (e.g., temporal bone fracture) can lead to hemifacial paralysis mimicking stroke, with life-altering effects on social interaction.



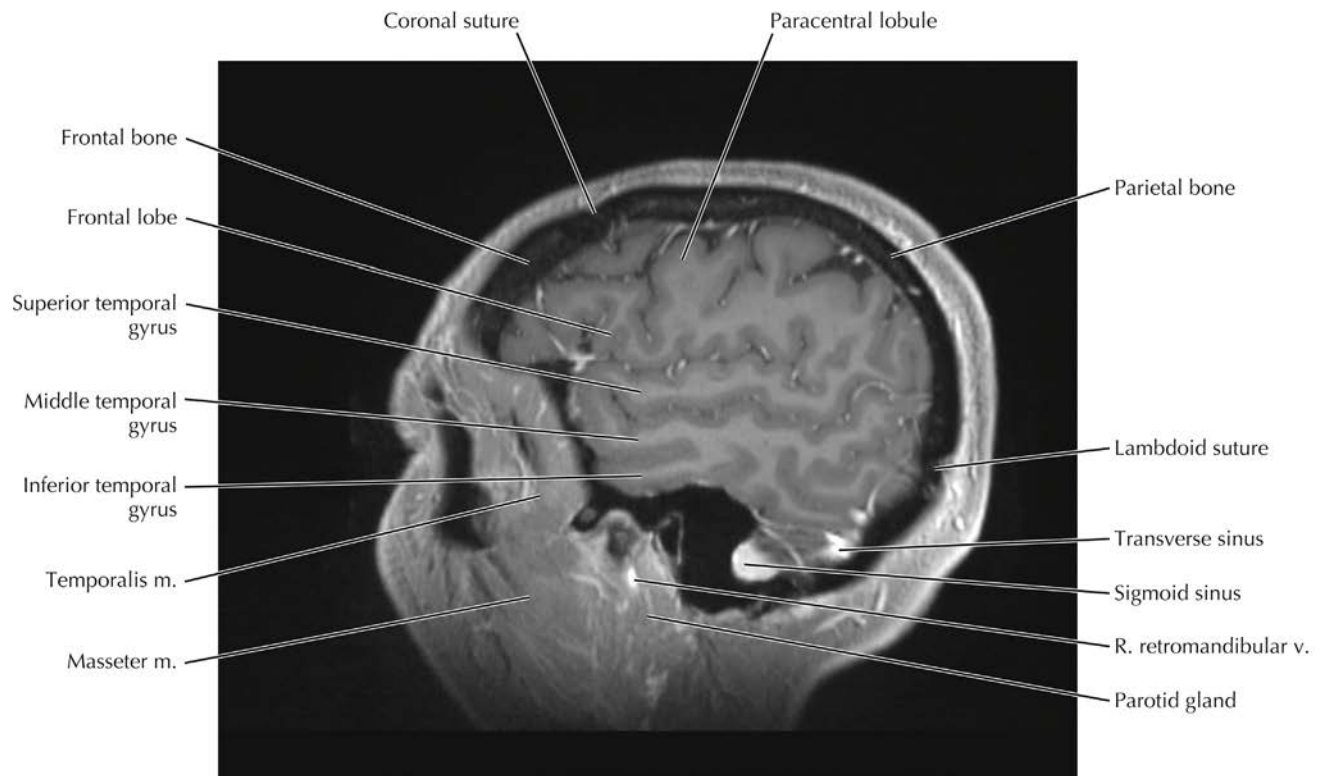
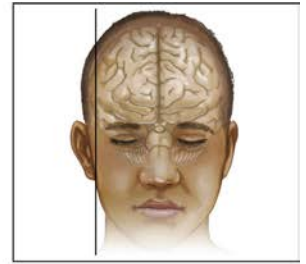


IMAGING TECHNIQUE CONSIDERATION

Note that the vessels such as the transverse sinus and cortical vessels are bright because contrast has been given for this sagittal reformation of an axially acquired three-dimensional spoiled GRASS (3D SPGR) sequence. The advantage of 3D-acquired sequences is that the data can then be reformatted to thinner slices or any plane with minimal degradation of quality, unlike 2D-acquired spin-echo sequences. The disadvantage is that any motion will degrade the entire sequence rather than just one slice.

DIAGNOSTIC CONSIDERATION

The midline sagittal view is often recognized as important in assessing the pituitary gland, pineal gland, and cerebellar tonsils. Although the more laterally positioned sagittal views are often unappreciated in diagnostic evaluation because of the lack of symmetry, sagittal MR images are often valuable in assessing for lesions along the floor of the middle cranial fossa or at the vertex.



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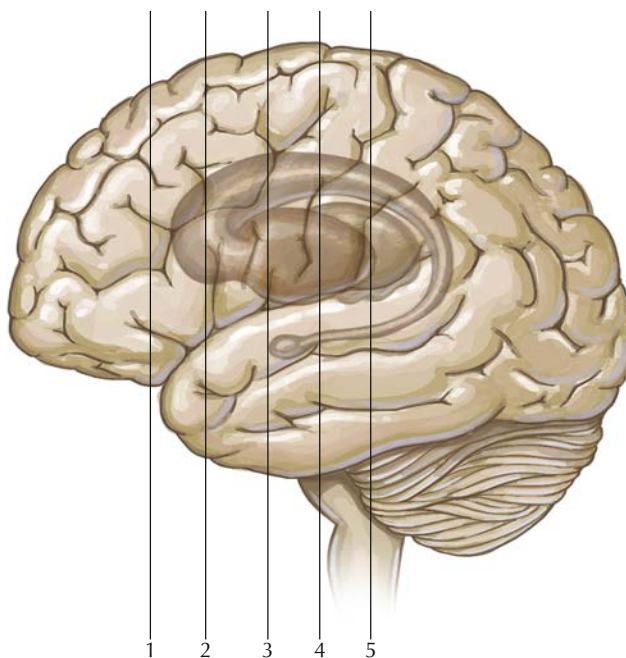
Chapter

3

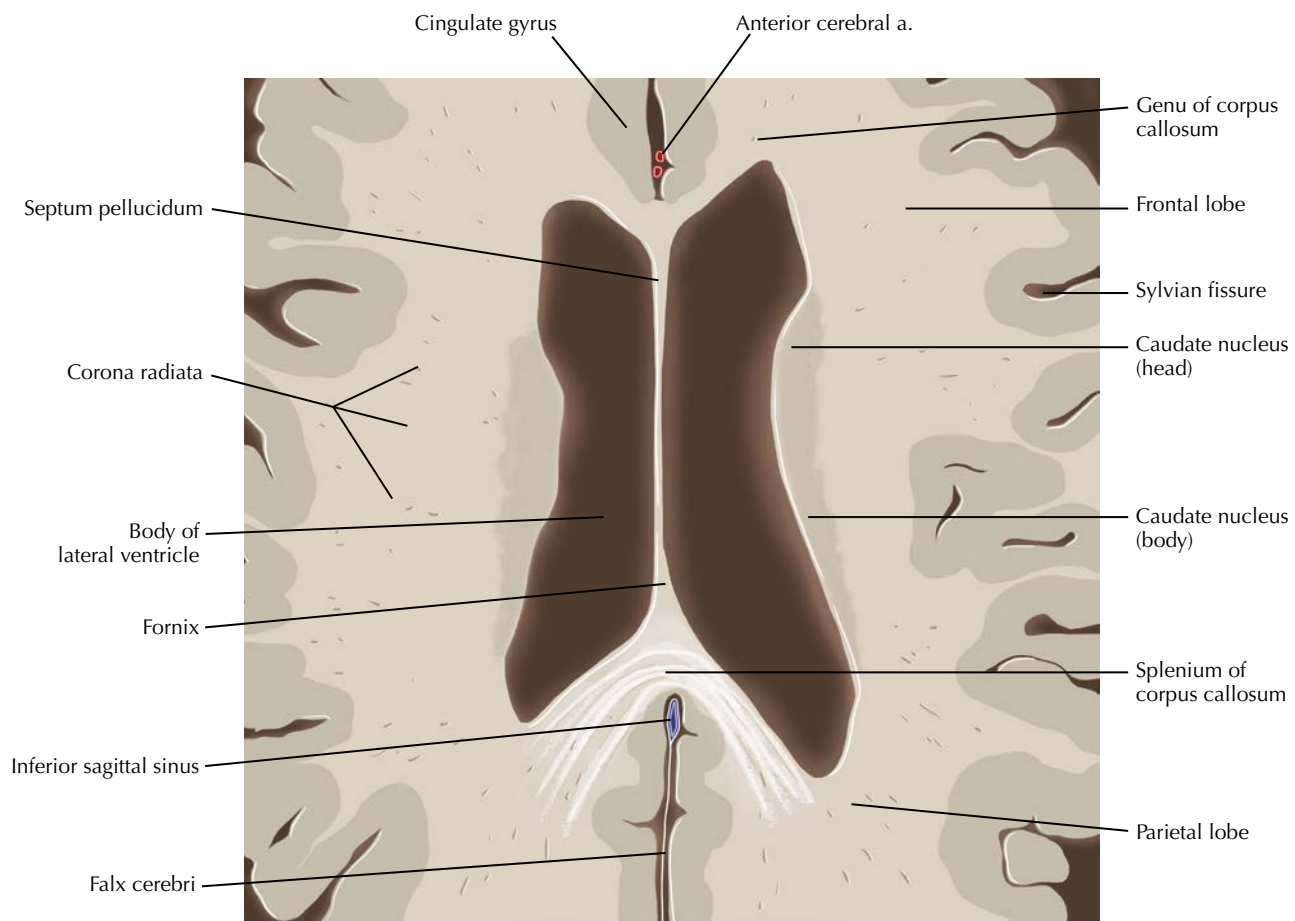
THALAMUS AND BASAL GANGLIA



AXIAL 126

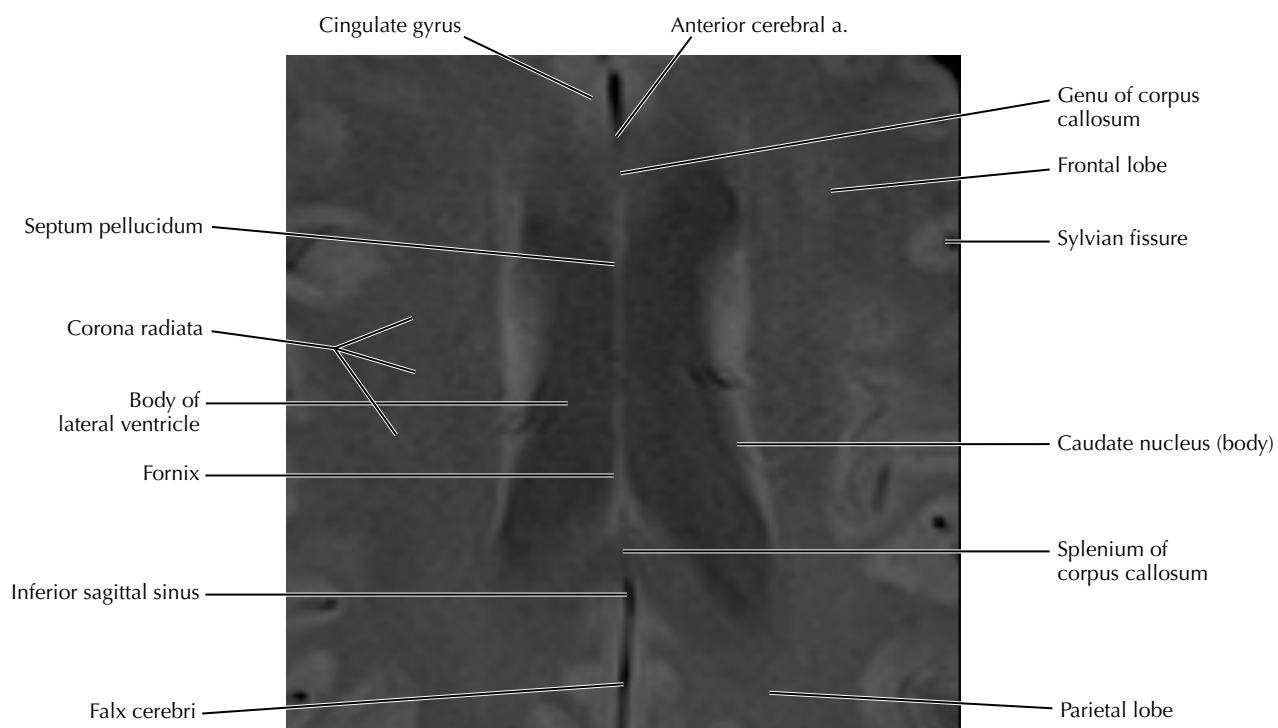
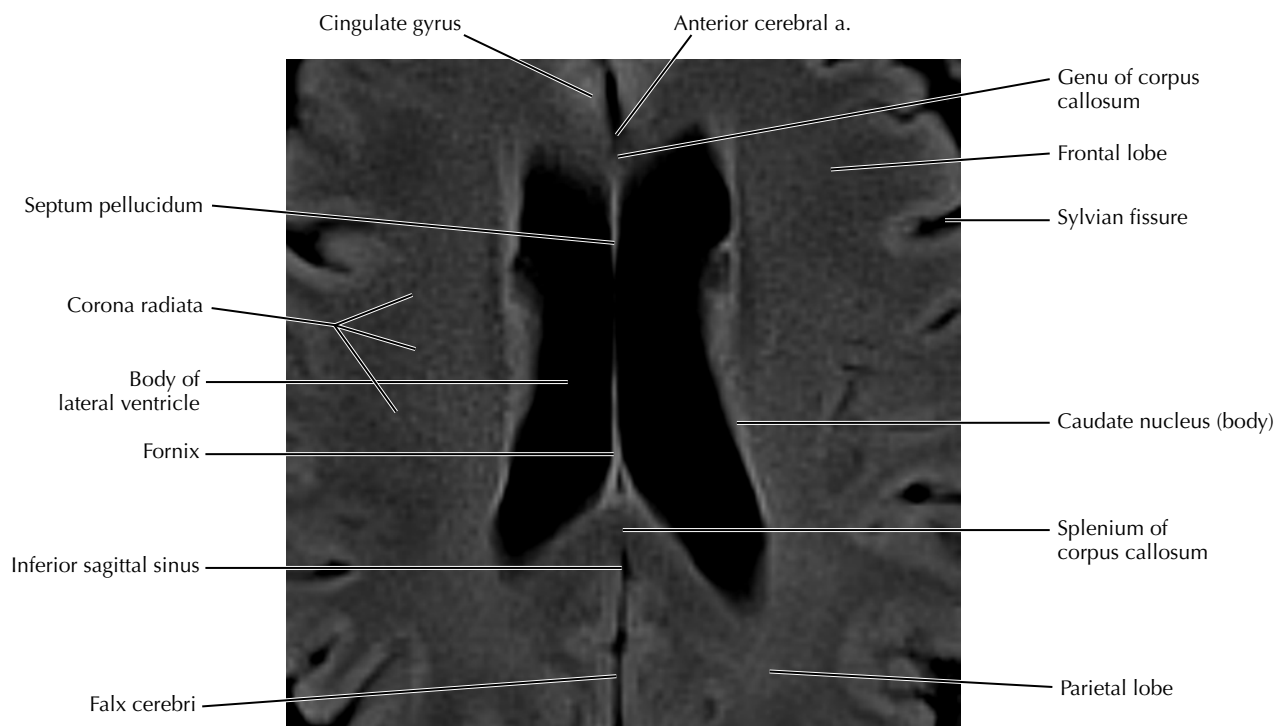
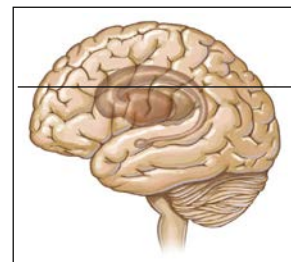


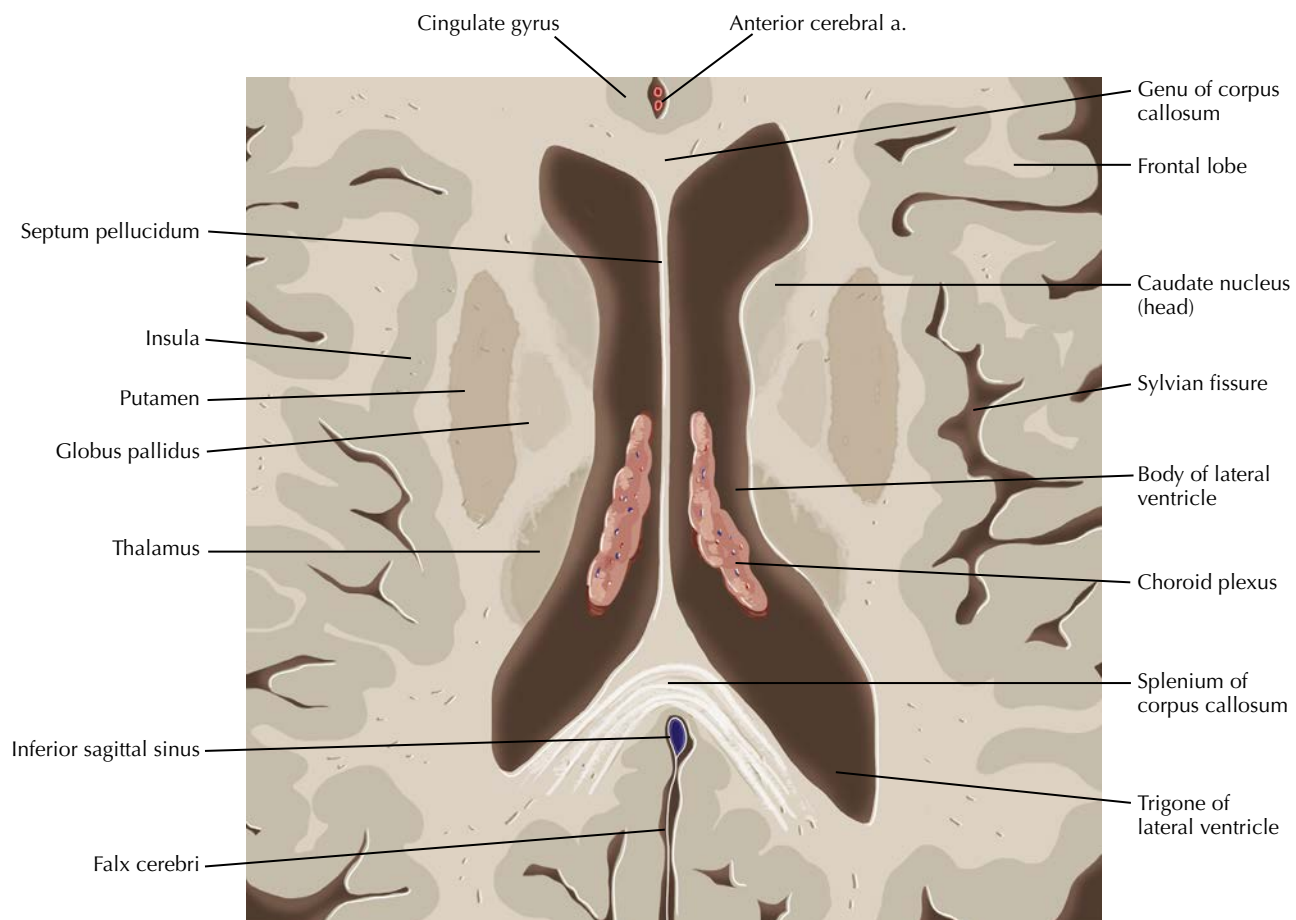
CORONAL 136



NORMAL ANATOMY

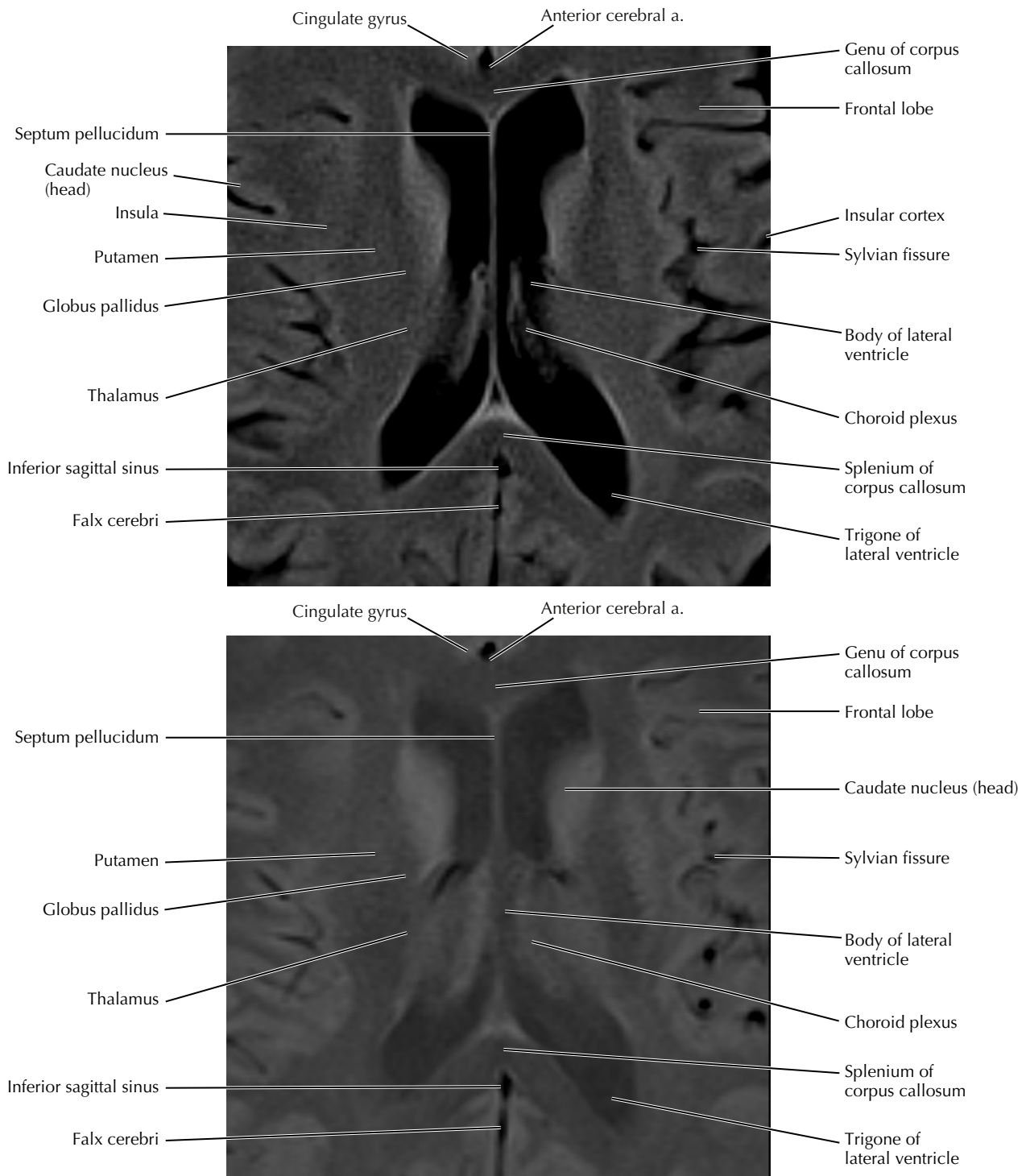
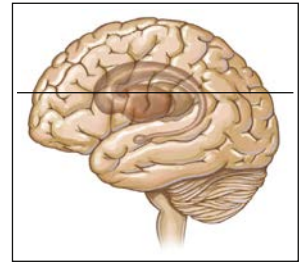
The centrum semiovale, corona radiata, and internal capsules are all continuous white matter tracts. The *centrum semiovale* is the white matter deep to the gray matter on the surface of the brain and has an ovular shape. On axial imaging, it is generally a term used for white matter superior to the ventricles. The *corona radiata* (Latin: "sunburst") is the white matter connecting the centrum semiovale superiorly and the internal capsules inferiorly. On axial imaging the corona radiata can be seen with ventricles. The *internal capsule* connects the corona radiata superiorly with the pyramids of the medulla inferiorly. On axial imaging, the internal capsule is between the caudate and lentiform nucleus anteriorly and the thalamus and lentiform nucleus posteriorly.

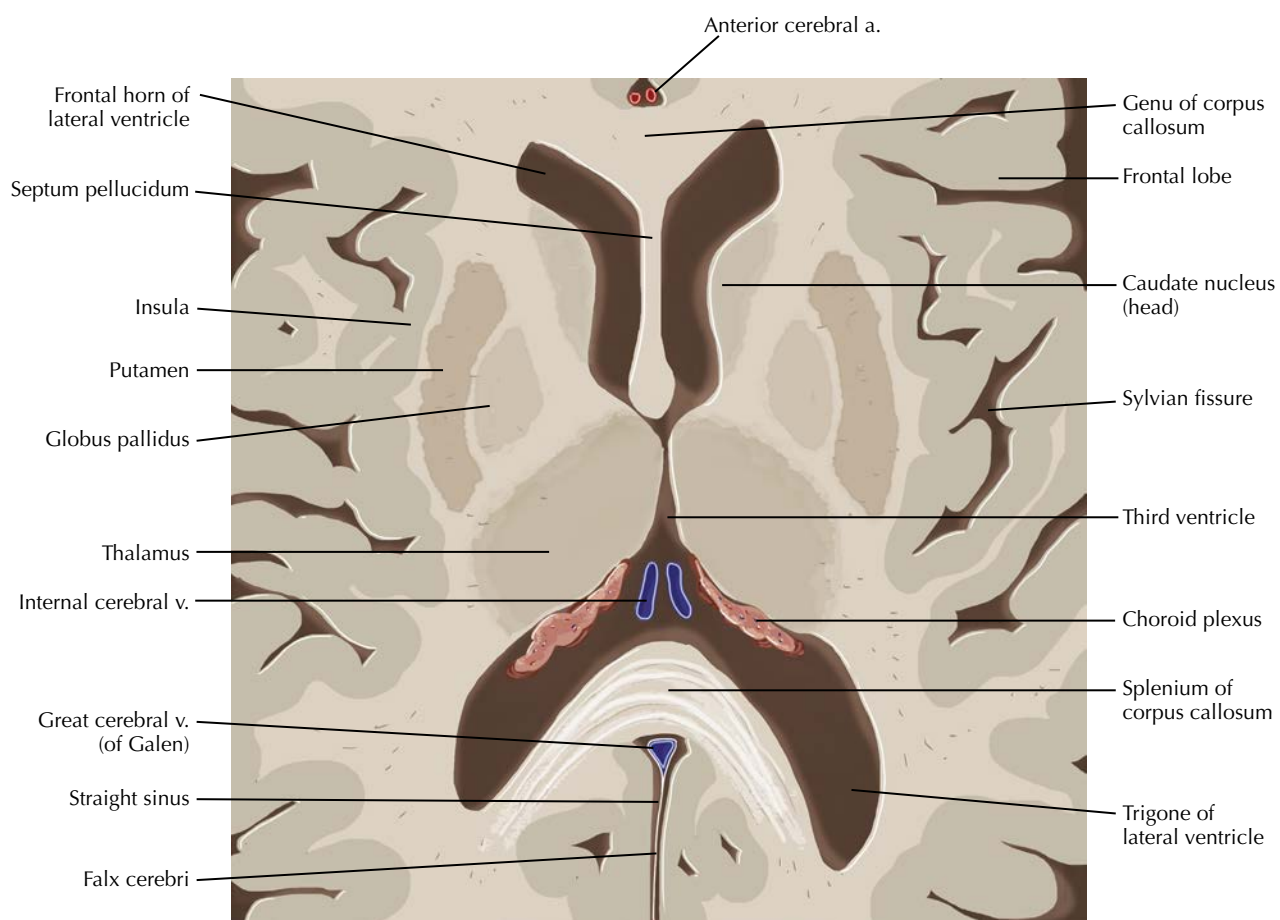


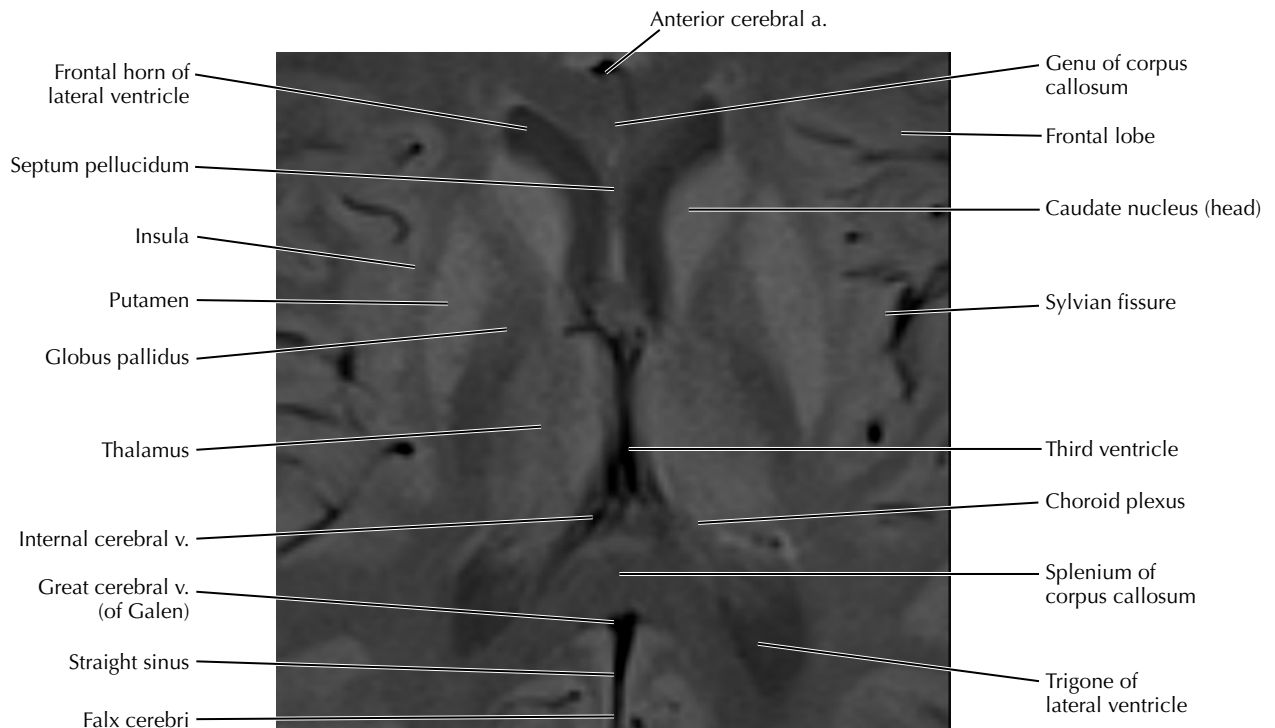
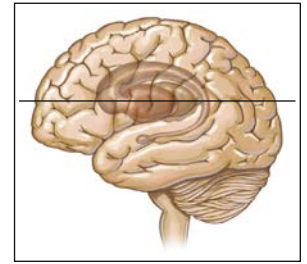


NORMAL ANATOMY

The *lentiform nucleus*, a triangular-shaped structure on axial imaging, consists of the globus pallidus medially and the putamen laterally. The lentiform nucleus with the caudate nucleus constitutes the basal ganglia. The *basal ganglia* represent a large collection of nuclei that constantly modifies movement along with the cerebellum. The motor cortex sends information to both the cerebellum and basal ganglia, and both structures send information back to cortex via the thalamus (i.e., to gain access to the cortex, signals must pass through the thalamus).



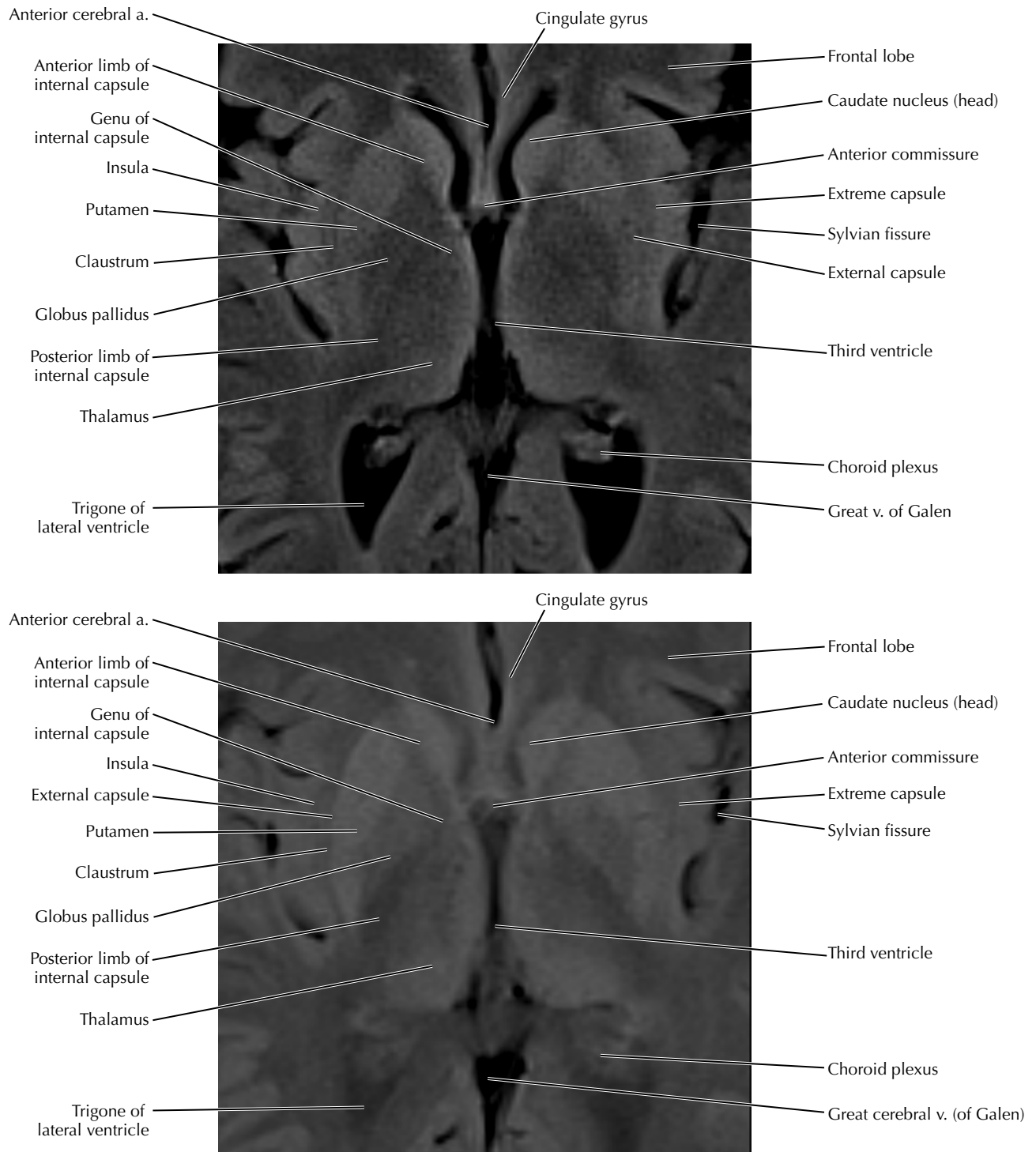
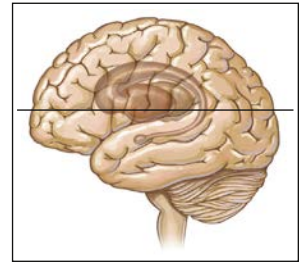


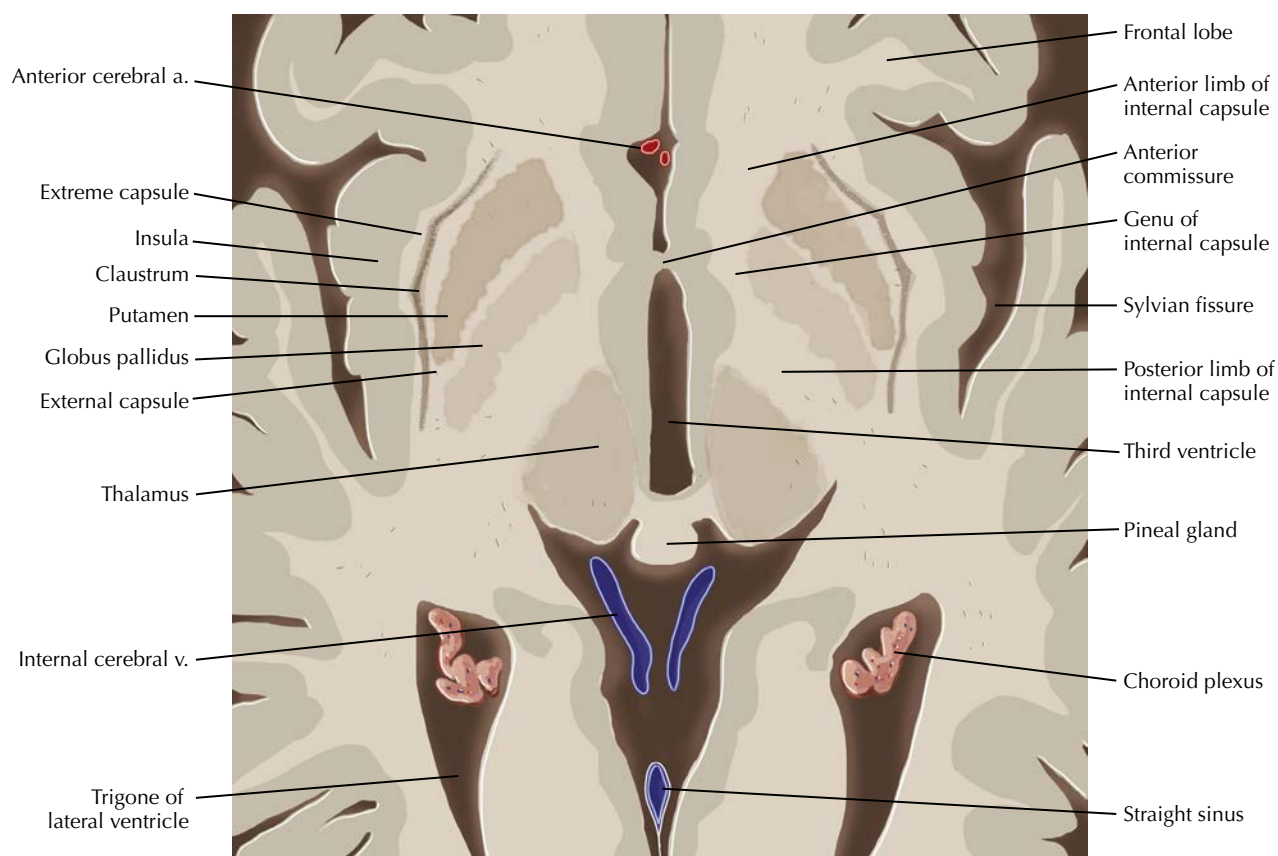




DIAGNOSTIC CONSIDERATION

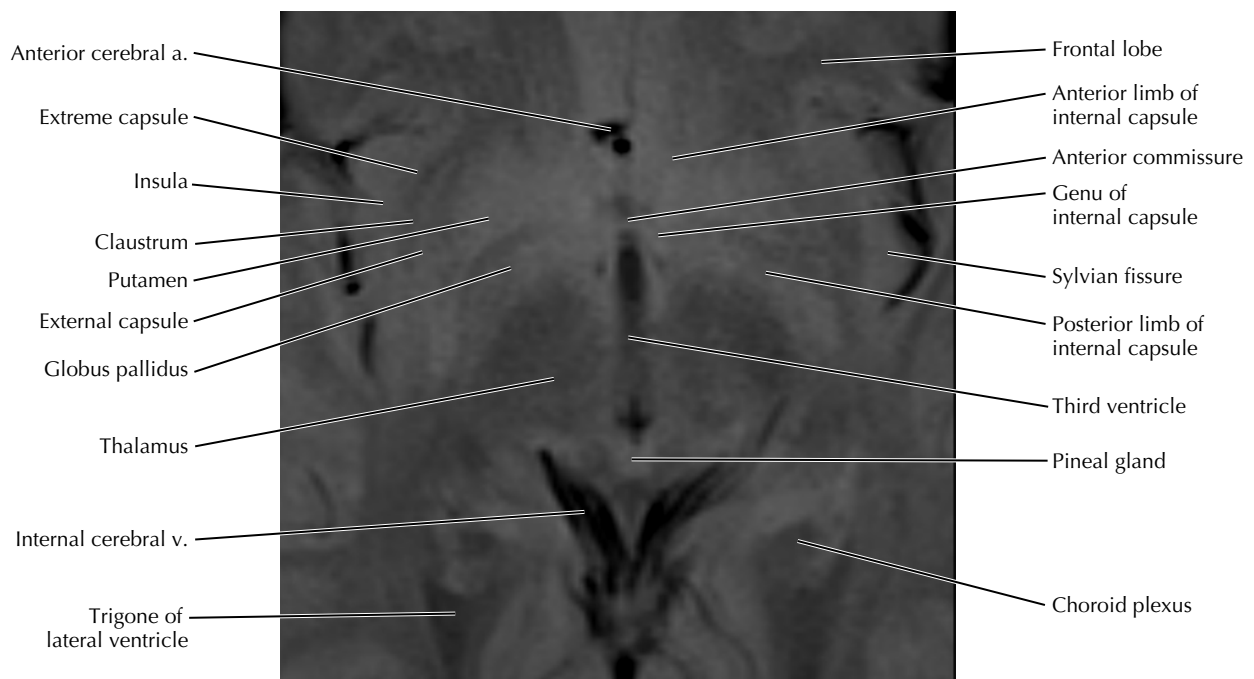
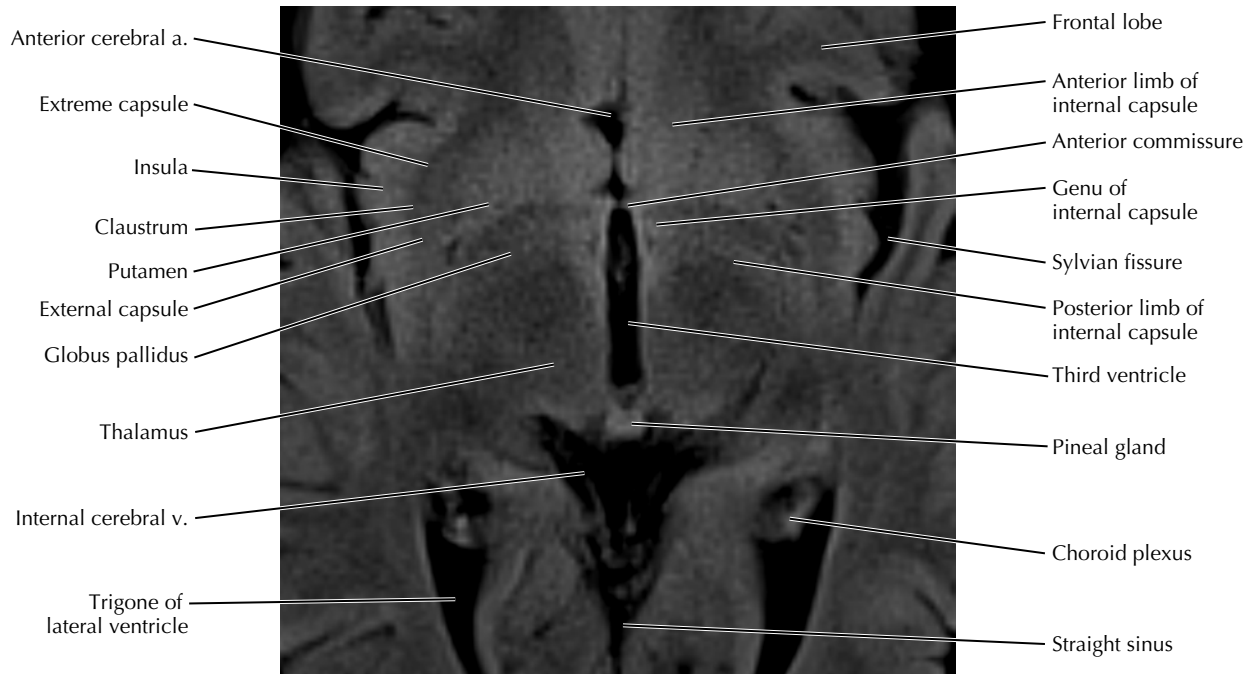
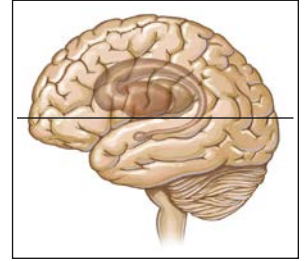
Proton-density (PD) sequence is used instead of the more routine T1-weighted sequence to accentuate the signal in the basal ganglia and thalami (compare with T1-weighted images in chapter 4).

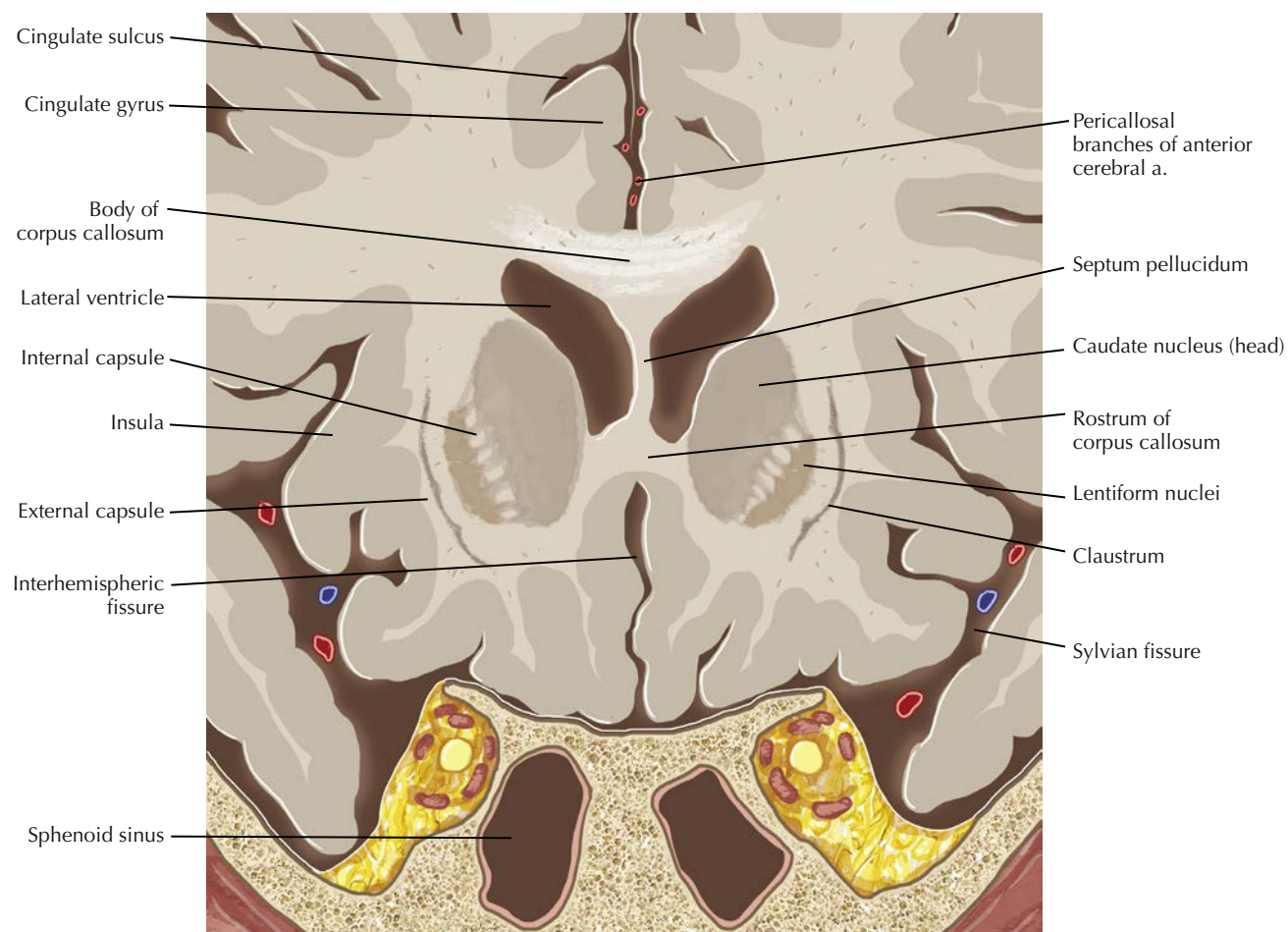




NORMAL ANATOMY

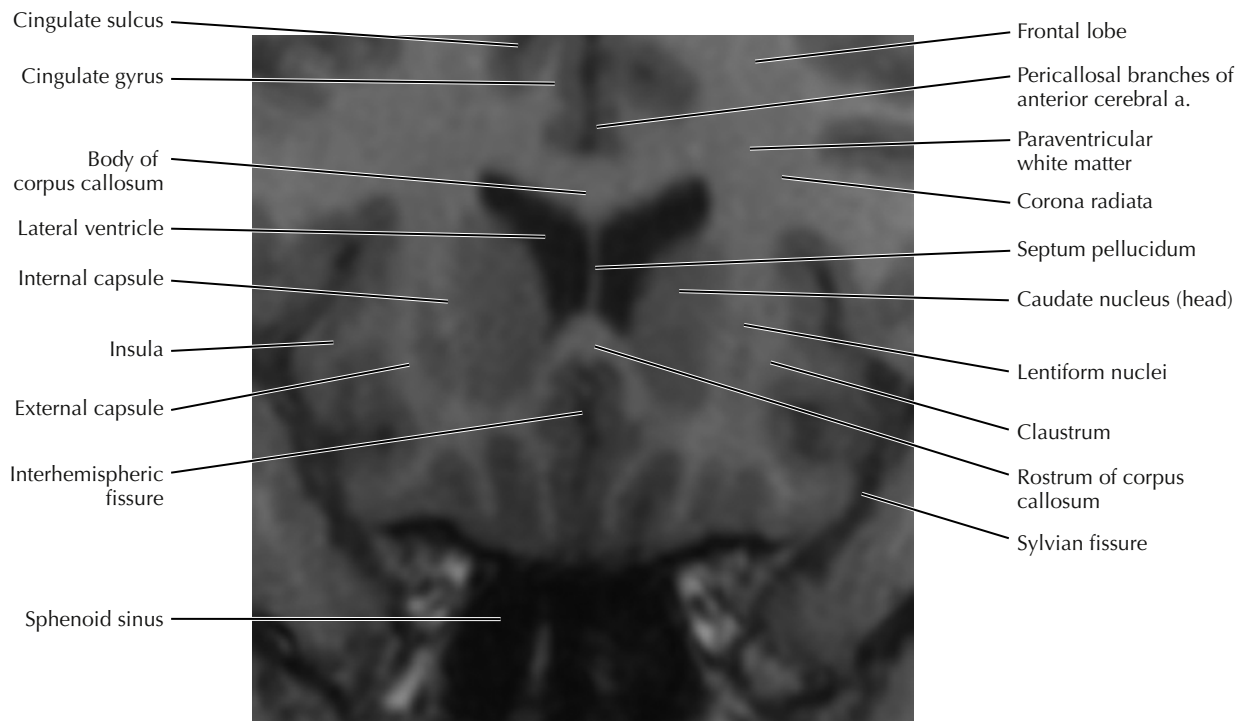
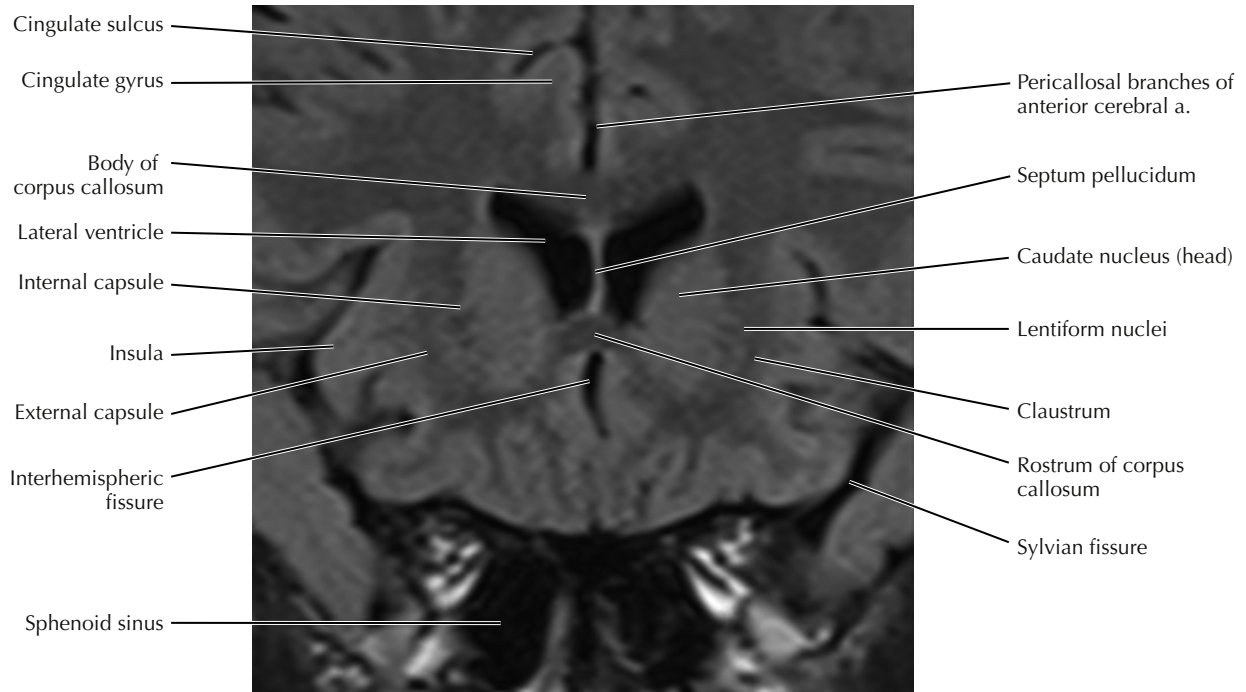
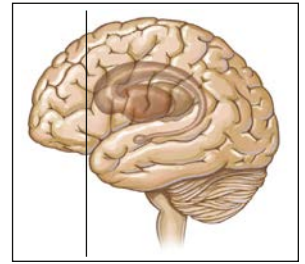
The vein of Galen (great cerebral vein) is a triangular-shaped structure on axial imaging, larger than the paired internal cerebral veins that feed into it, and larger than the inferior sagittal sinus that joins the vein of Galen to feed into the straight sinus. Loss of the normal dark flow void on T2-weighted or PD-weighted images is seen with venous sinus thrombosis.

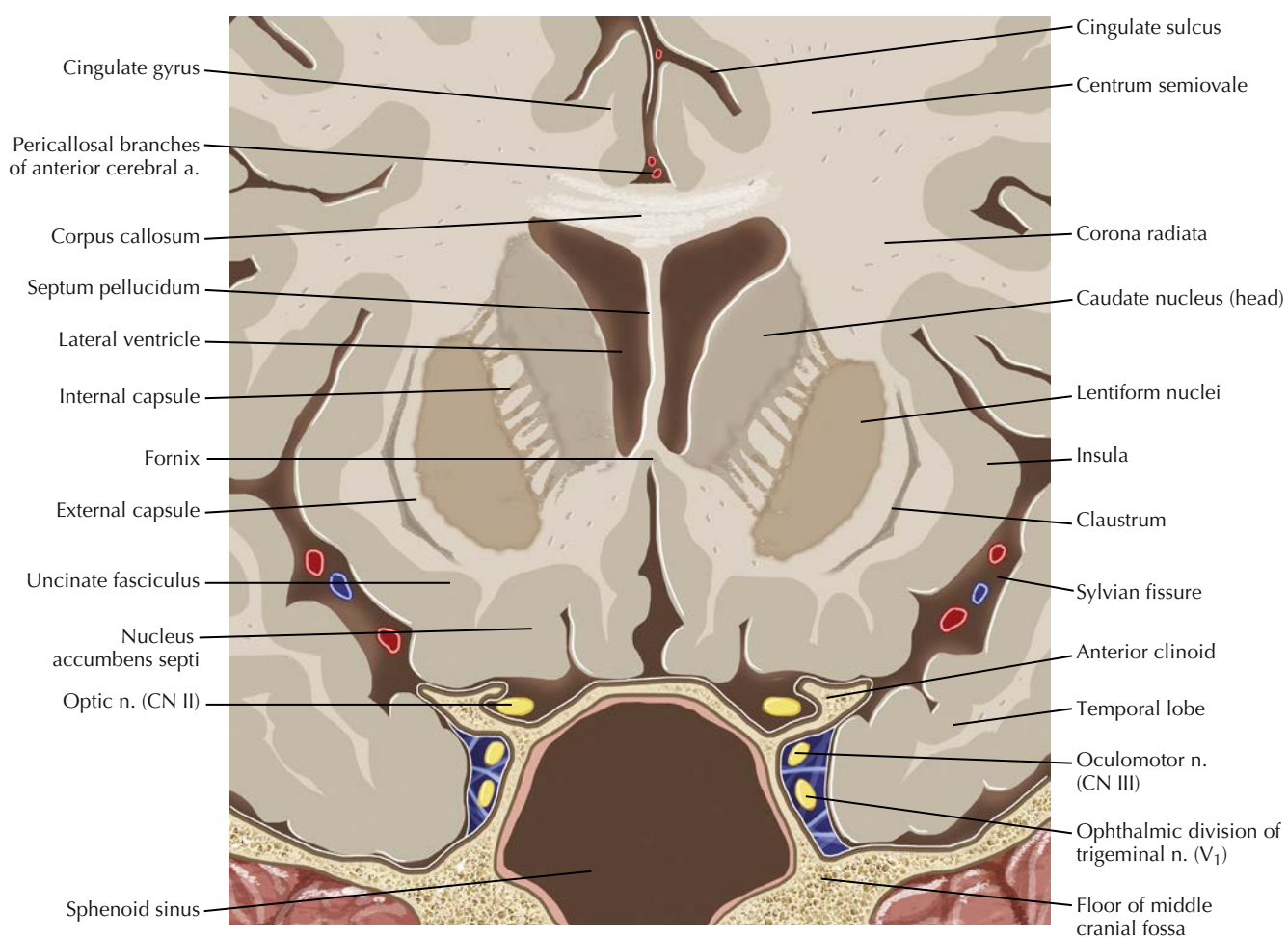


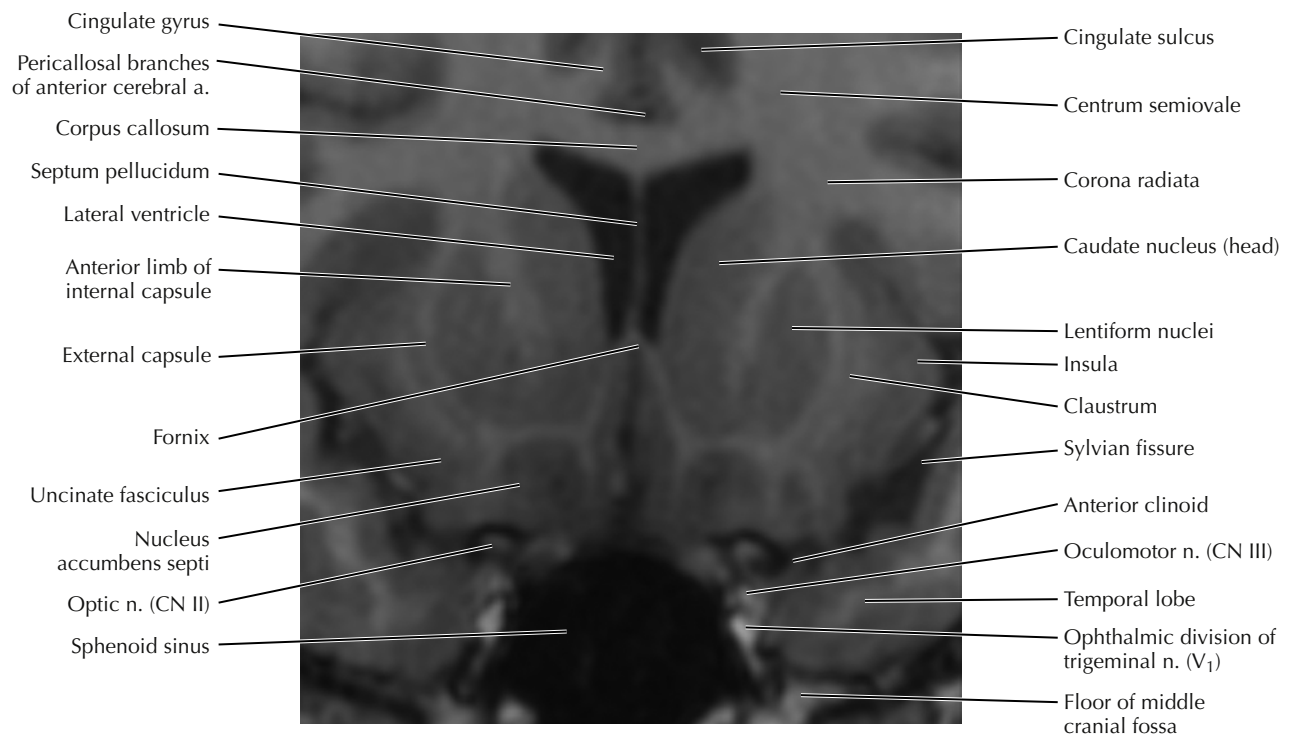
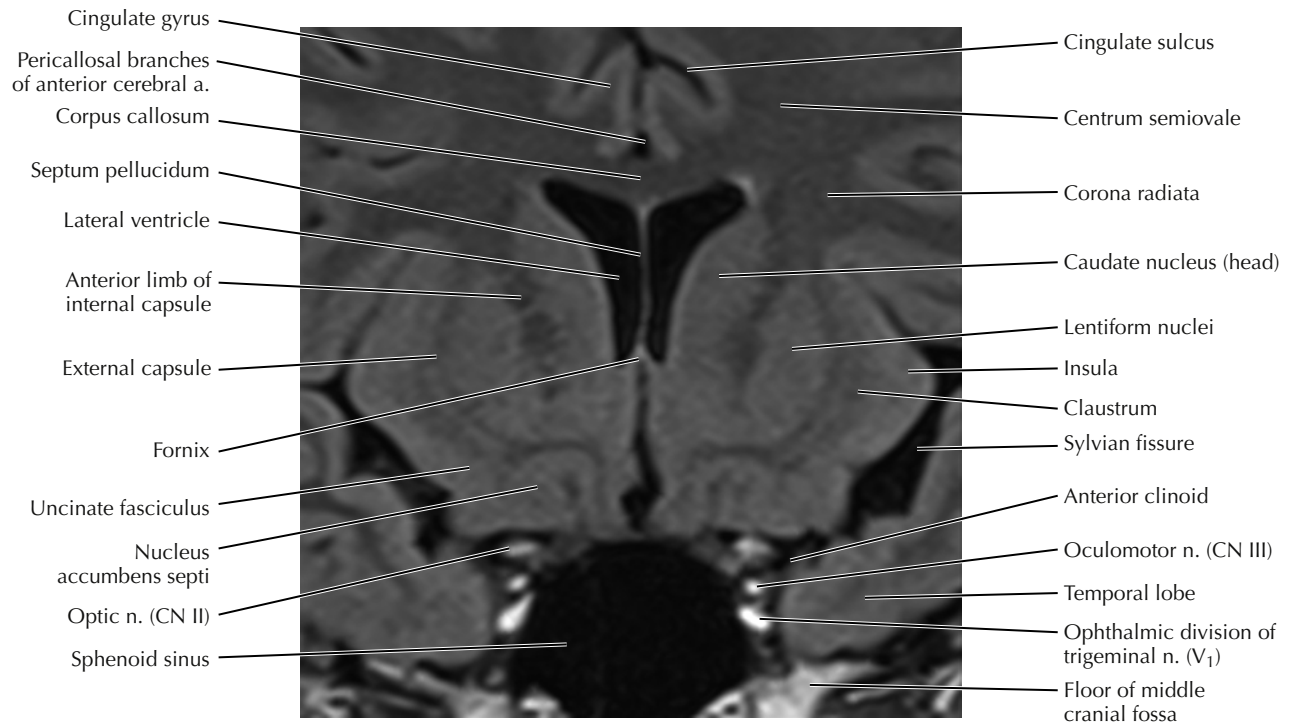
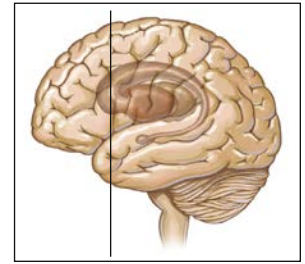


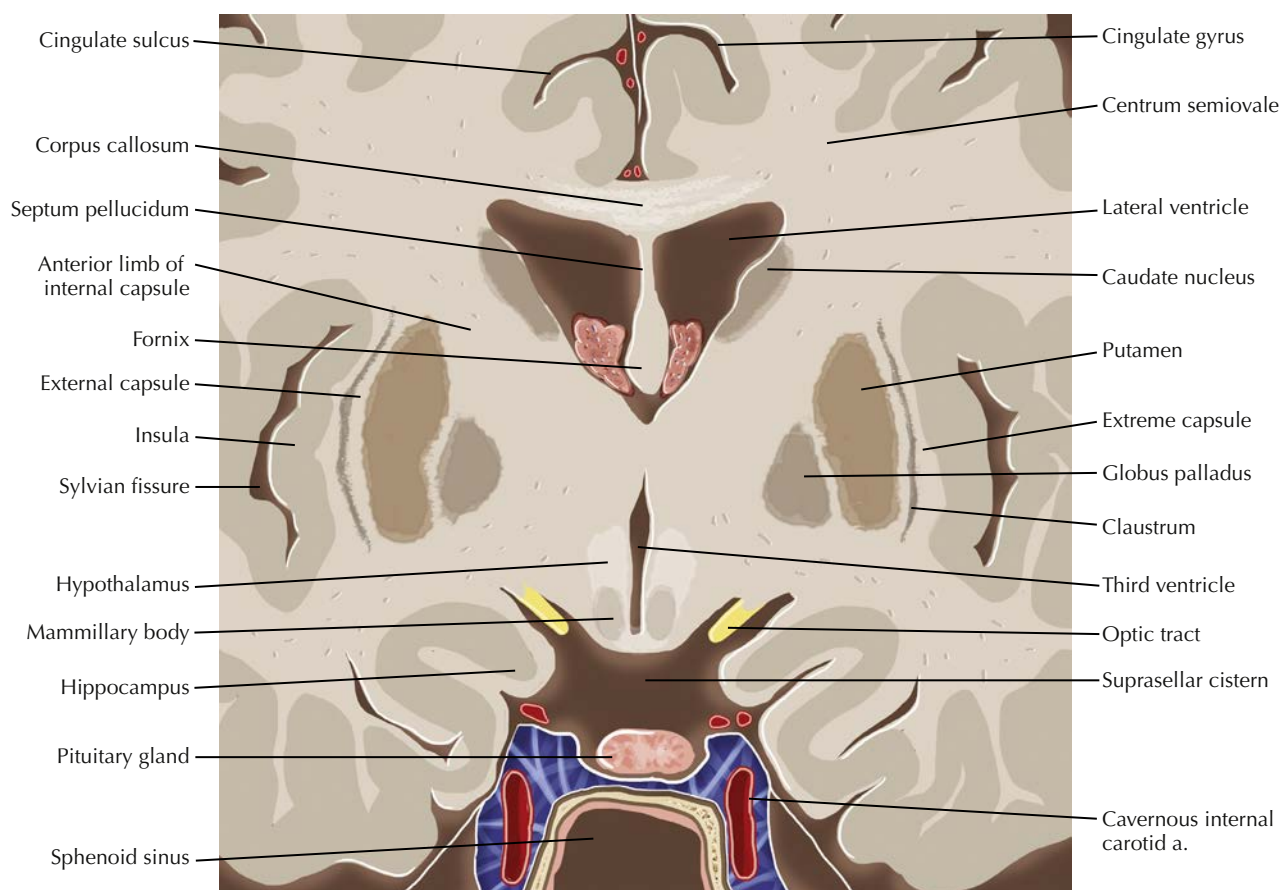
NORMAL ANATOMY

Note that from medial to lateral on this coronal MR image, the structures are septum pellucidum, lateral ventricle, caudate nucleus, internal capsule, lentiform nucleus, external capsule, claustrum, extreme capsule (difficult to see on most images), and insular cortex.



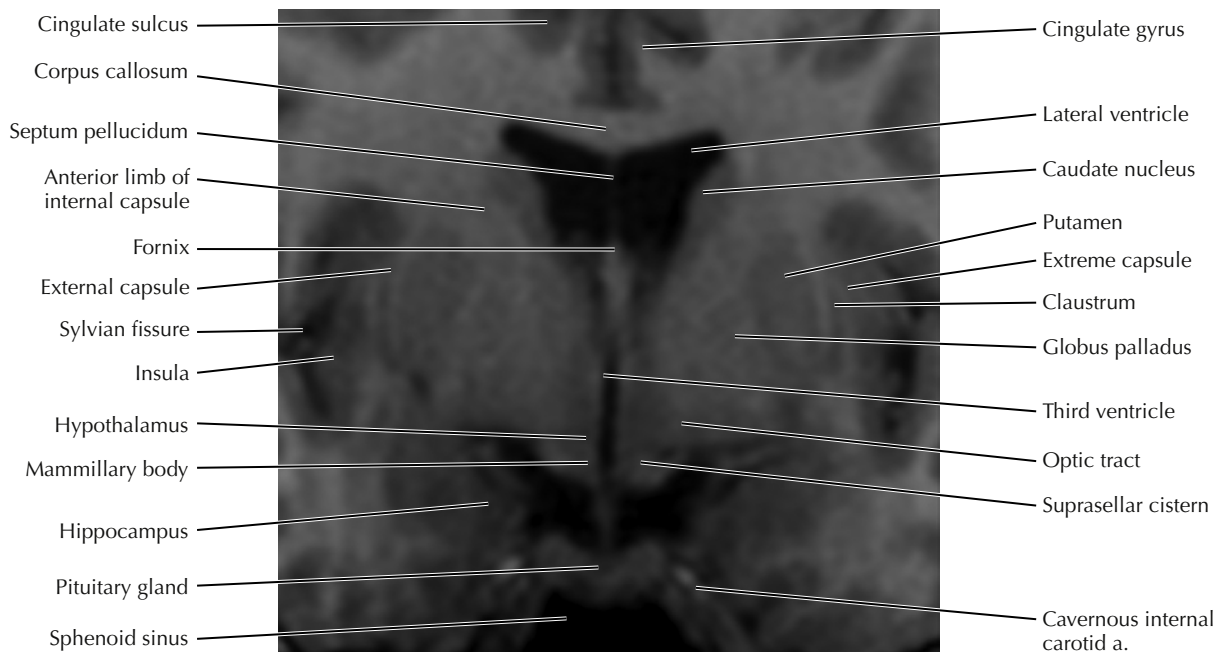
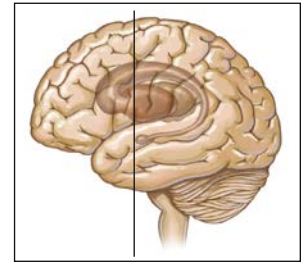




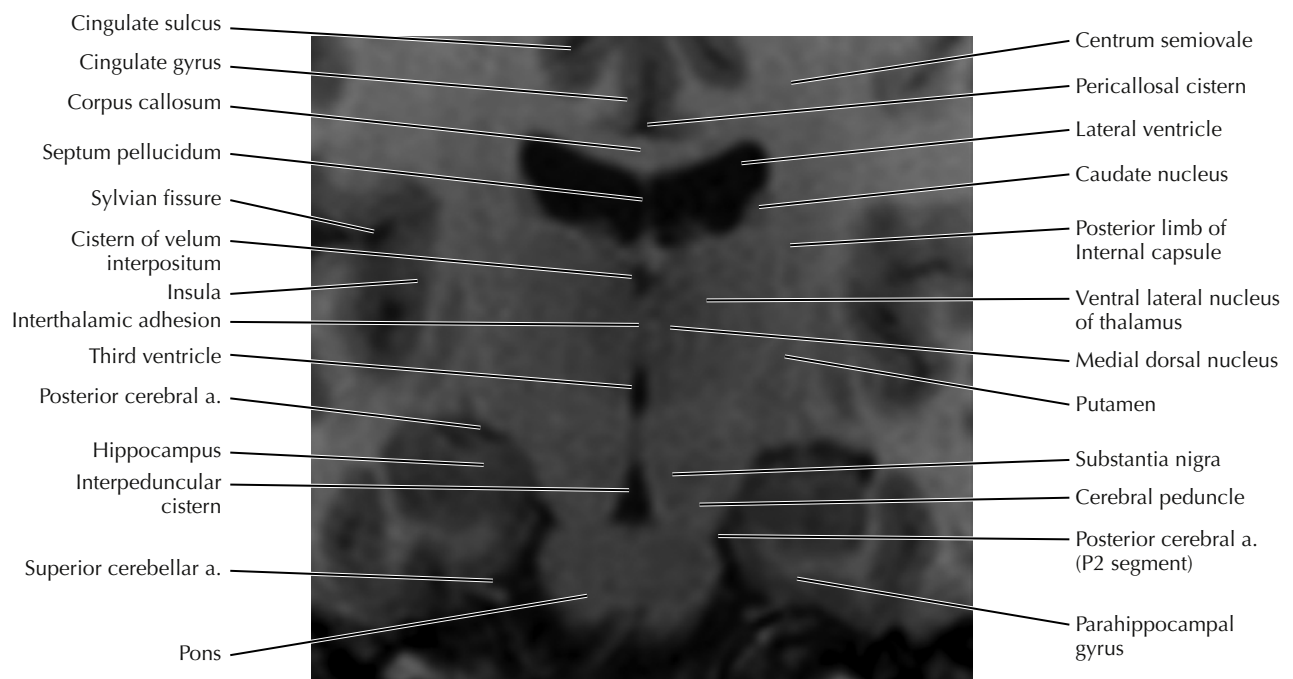
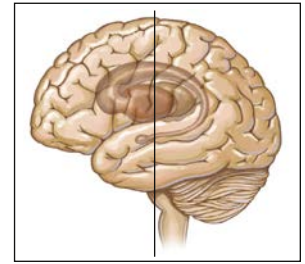


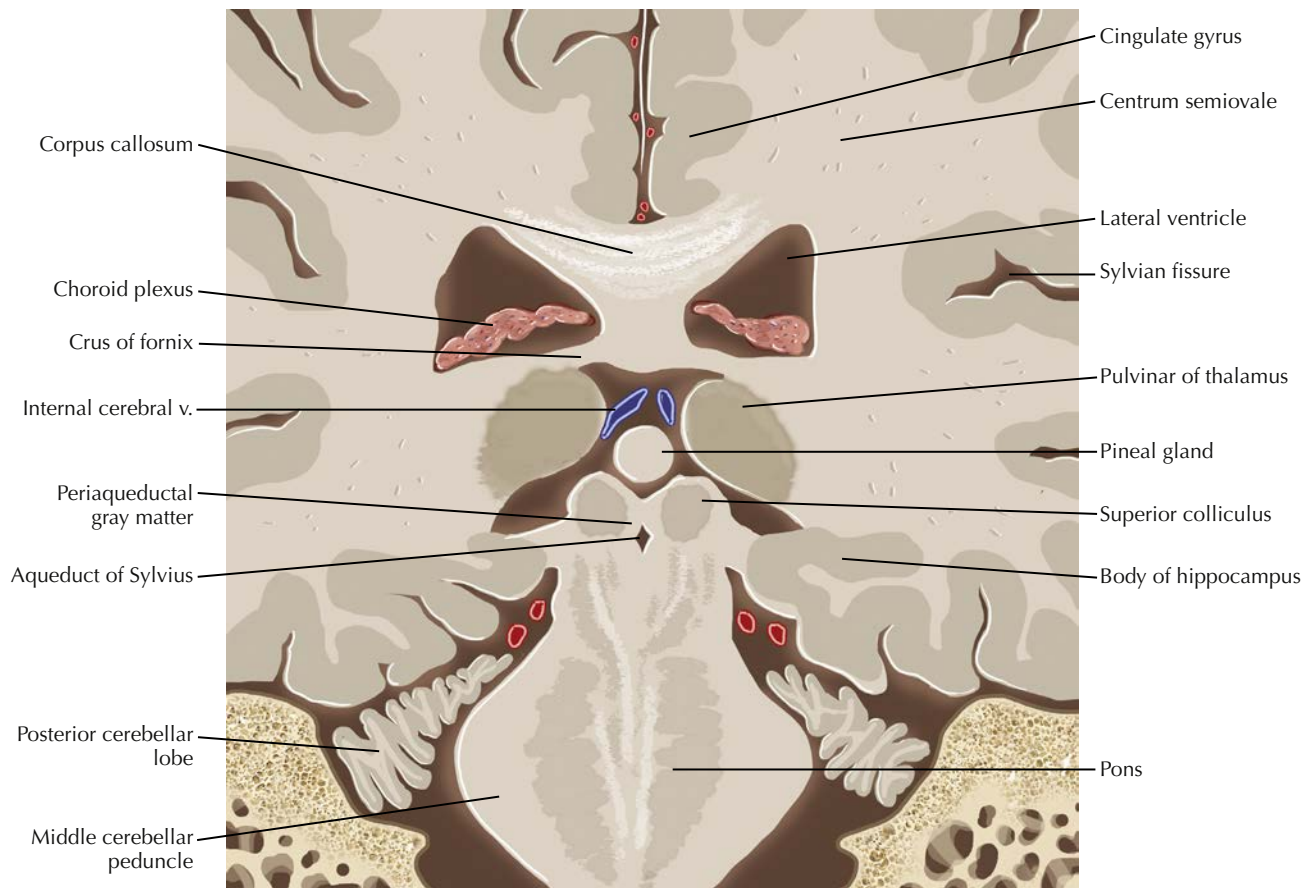
DIAGNOSTIC CONSIDERATION

Loss of differentiation between the insular cortex and the subjacent white matter (extreme and external capsules) is an early sign of infarct in middle cerebral artery territory.





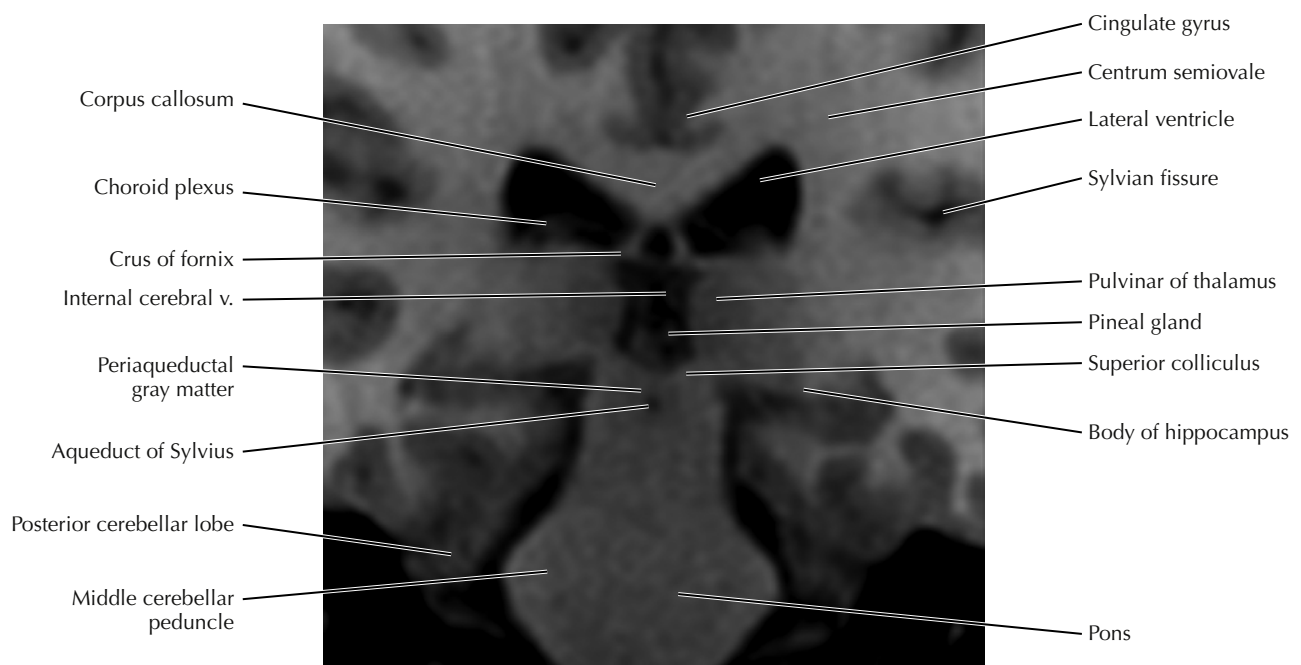
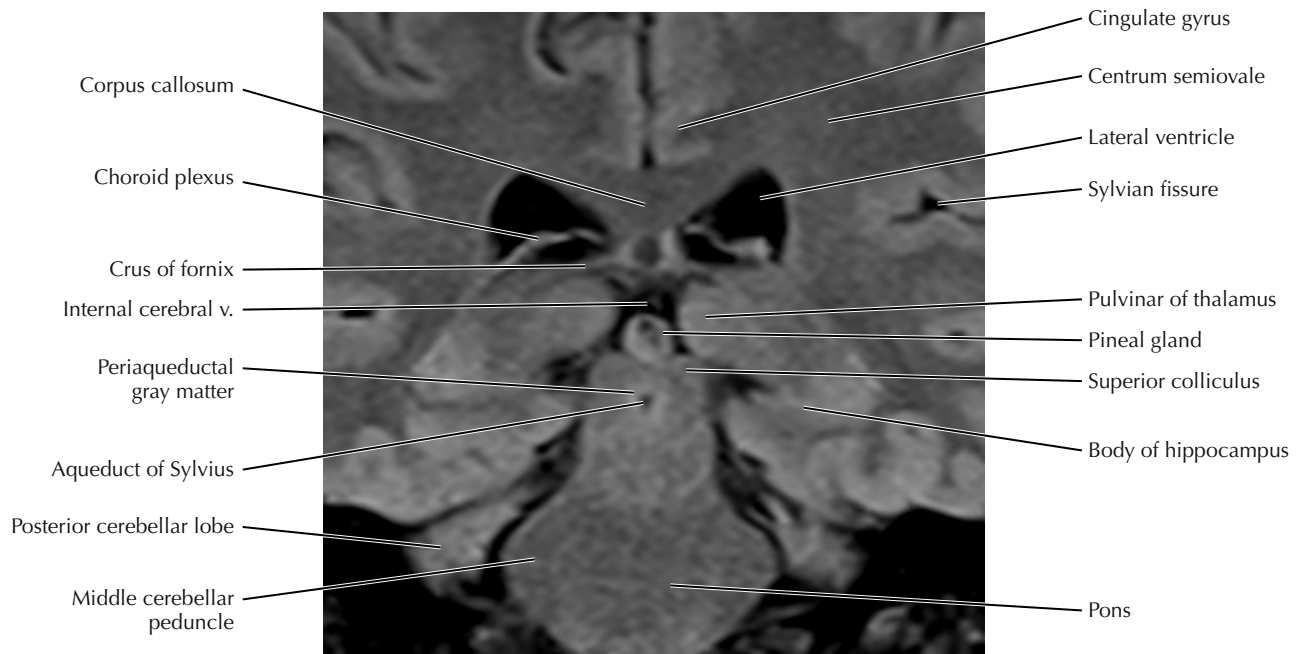
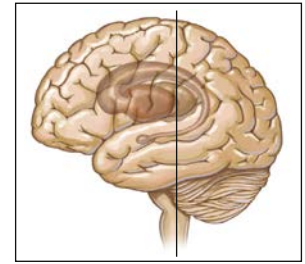




IMAGING TECHNIQUE CONSIDERATION

The white matter is "white" on T1-weighted MRI. One simple mnemonic to remember this fact is to think of myelin sheaths as "fatty," with fat typically bright on T1-weighted images. Fat is not bright on standard T2-weighted images; however, most T2-weighted images are now done with multiple spin-echo pulses (e.g., Turbo-SE), which breaks the strong homonuclear forces (molecules with identical nuclei), called *J-coupling*, between the hydrogen (H) atoms on the long hydrocarbon chains of fat. This allows the H atoms to precess more freely, similar to the two hydrogen atoms on an H₂O molecule, making the appearance of fat bright, like water.

Note that on the superior radiology image, T2-weighted fluid-attenuated inversion recovery (FLAIR) images, the white matter is darker than the cortex.

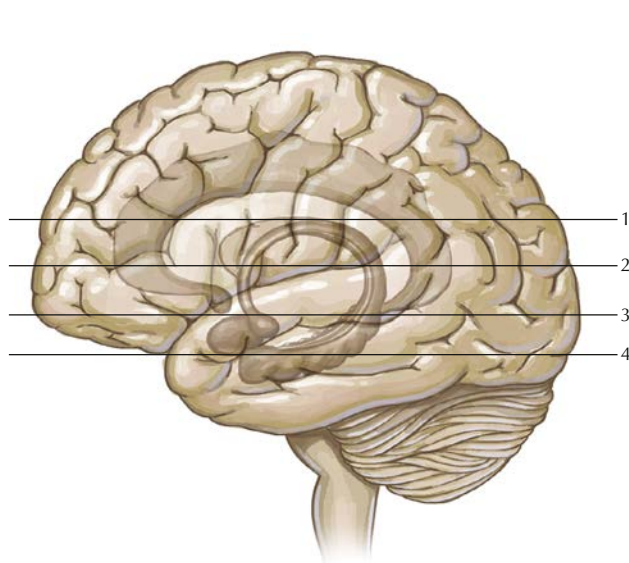


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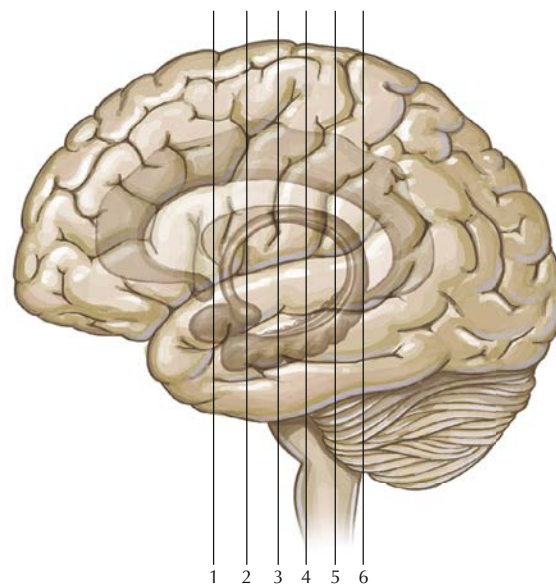
Chapter

4

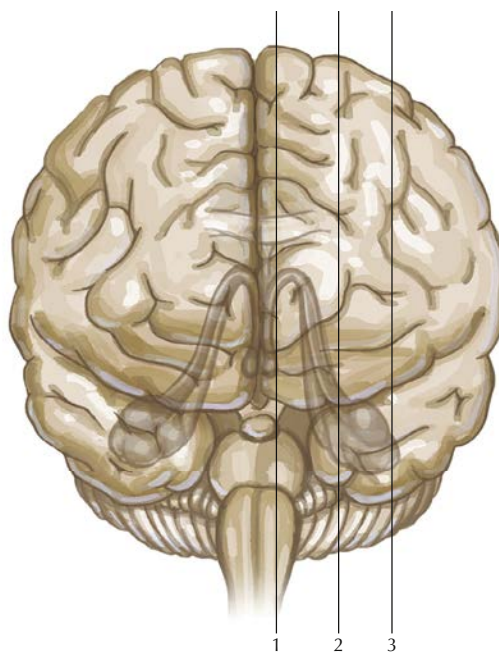
LIMBIC SYSTEM



AXIAL 148

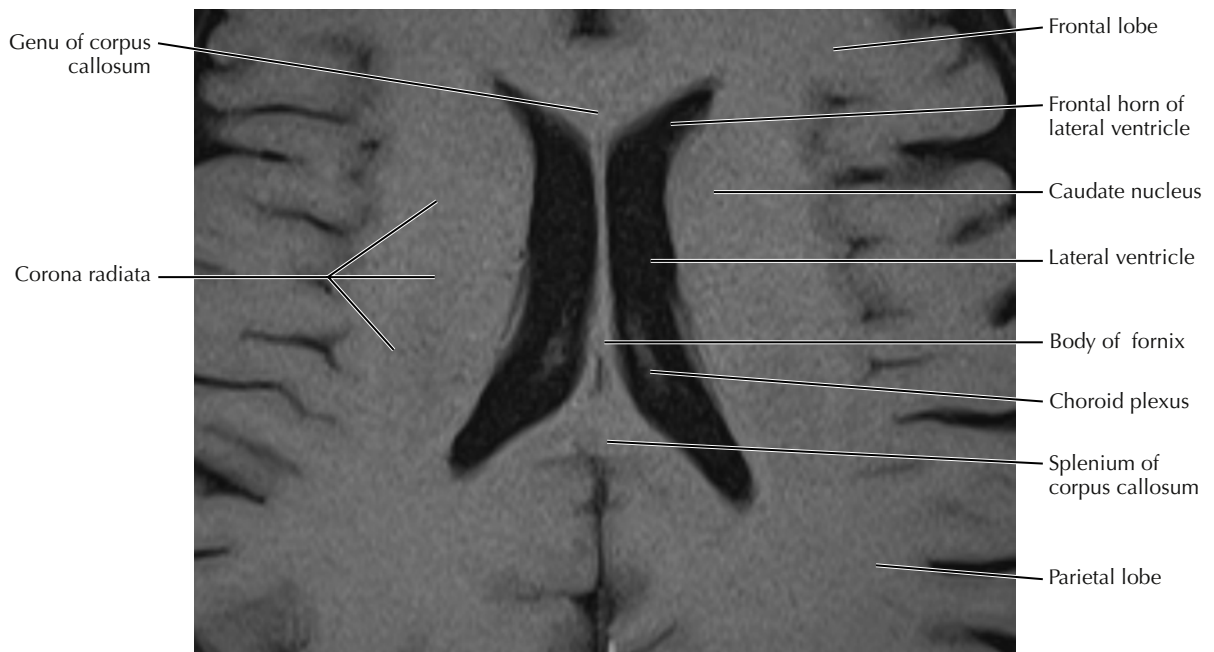
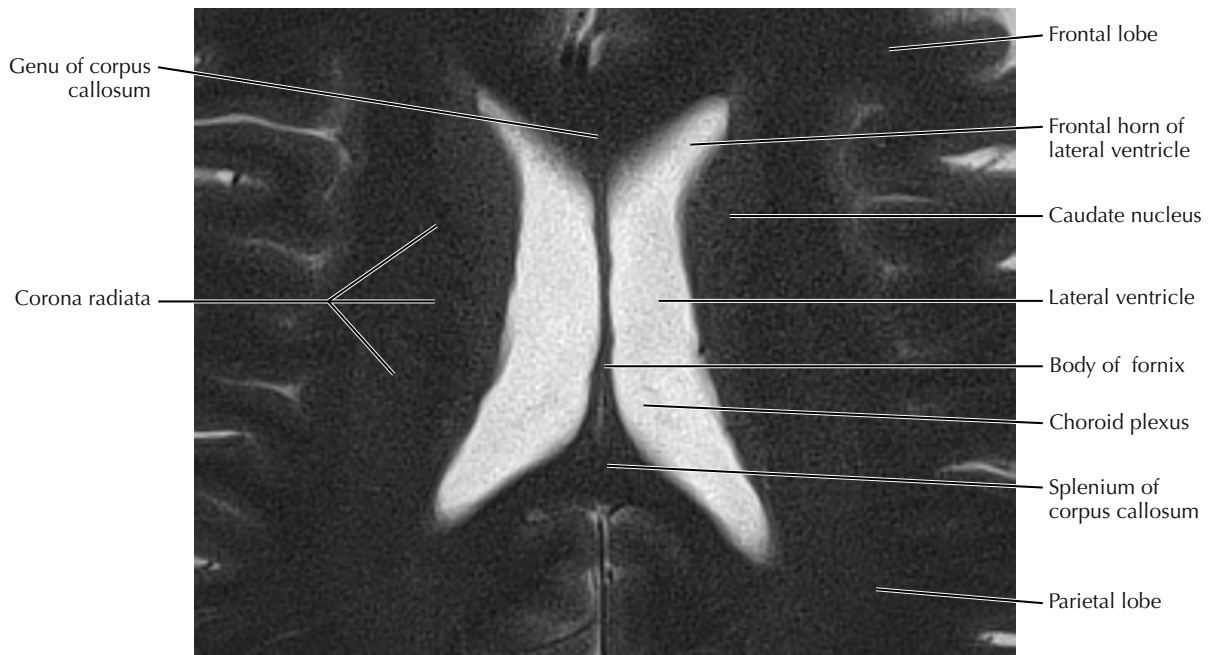
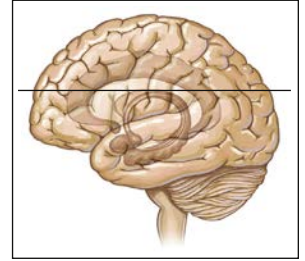


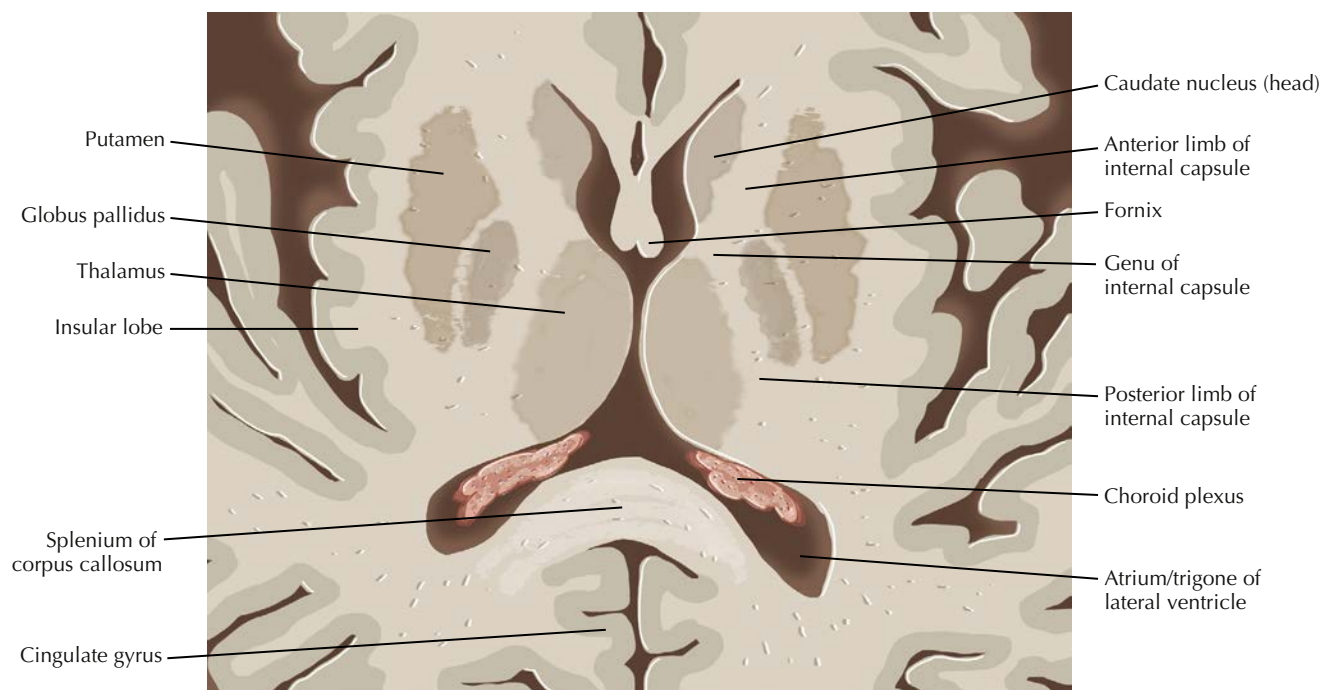
CORONAL 156



SAGITTAL 168

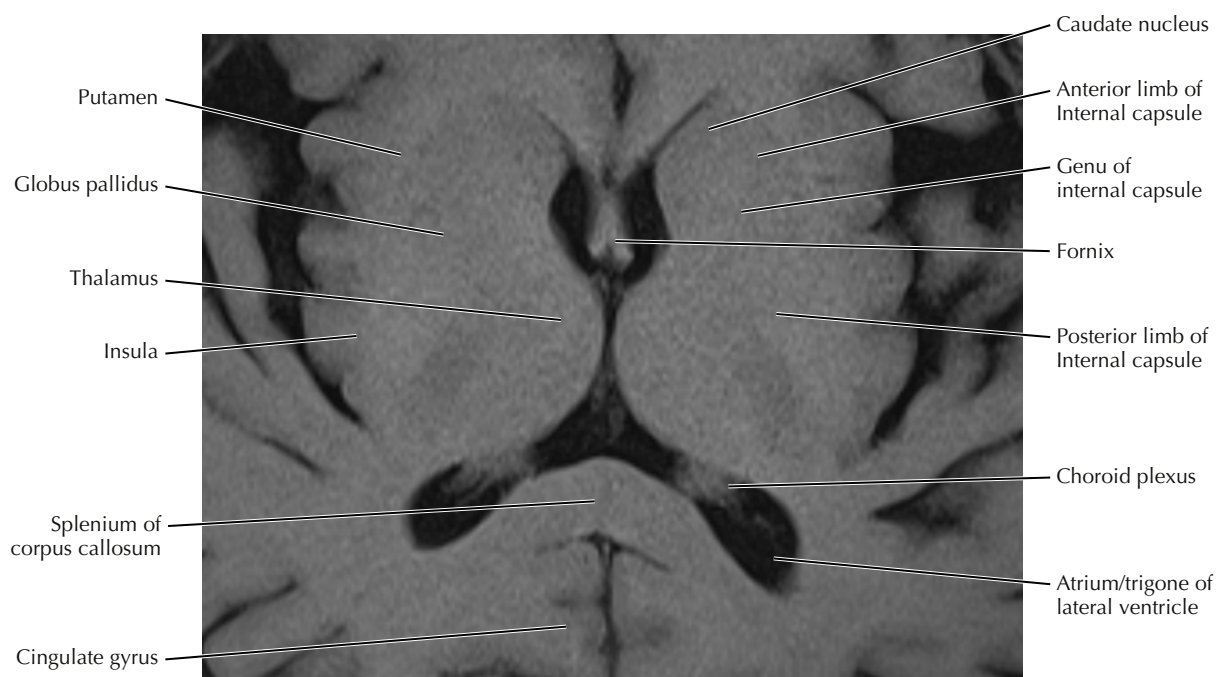
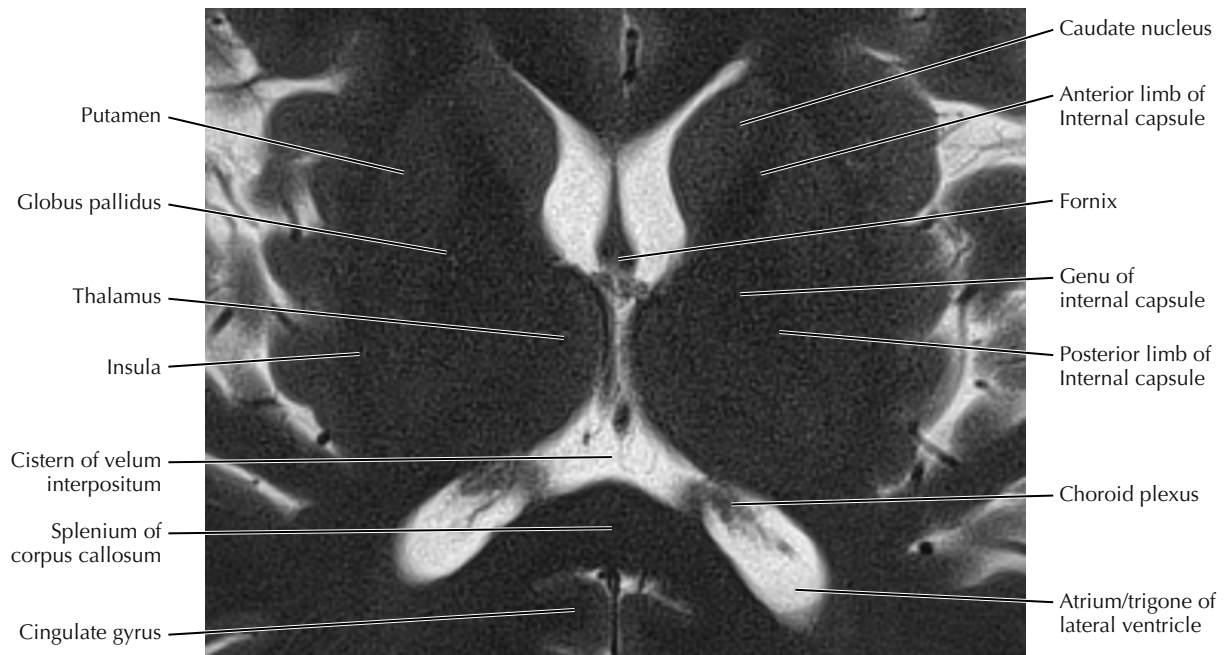
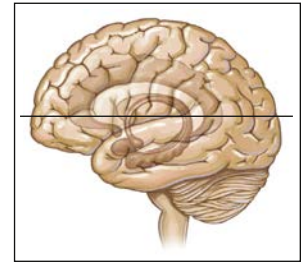




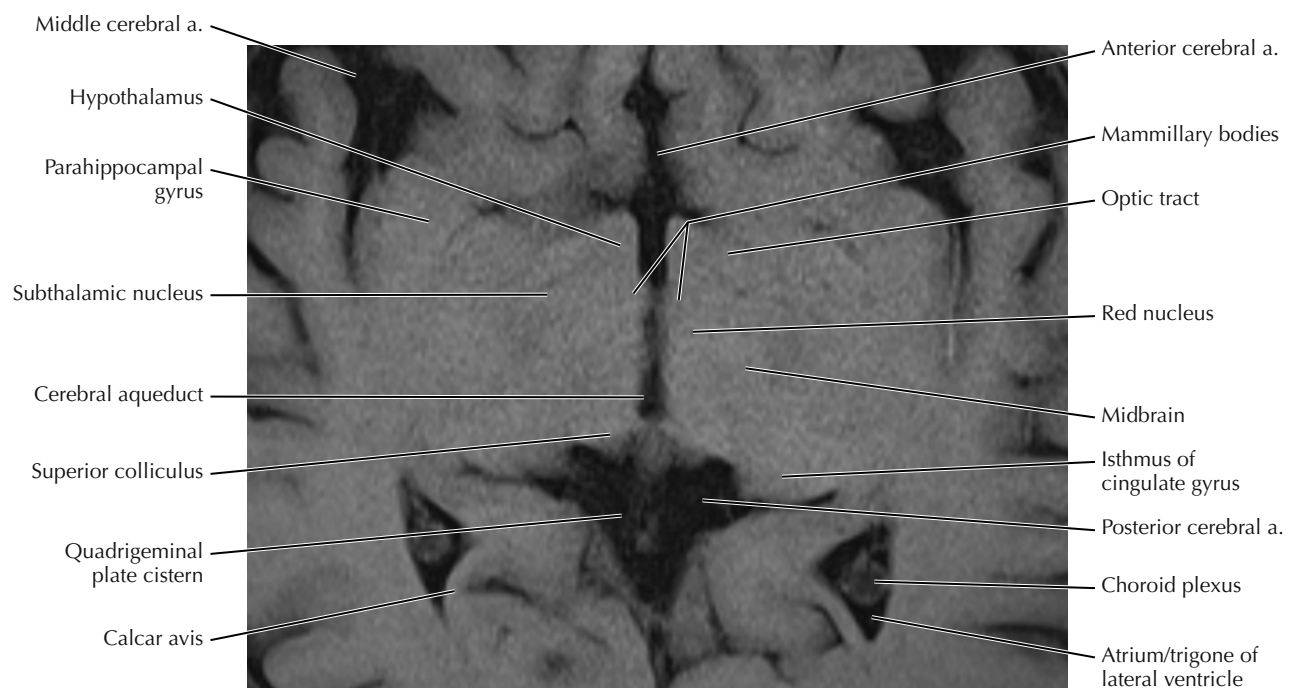
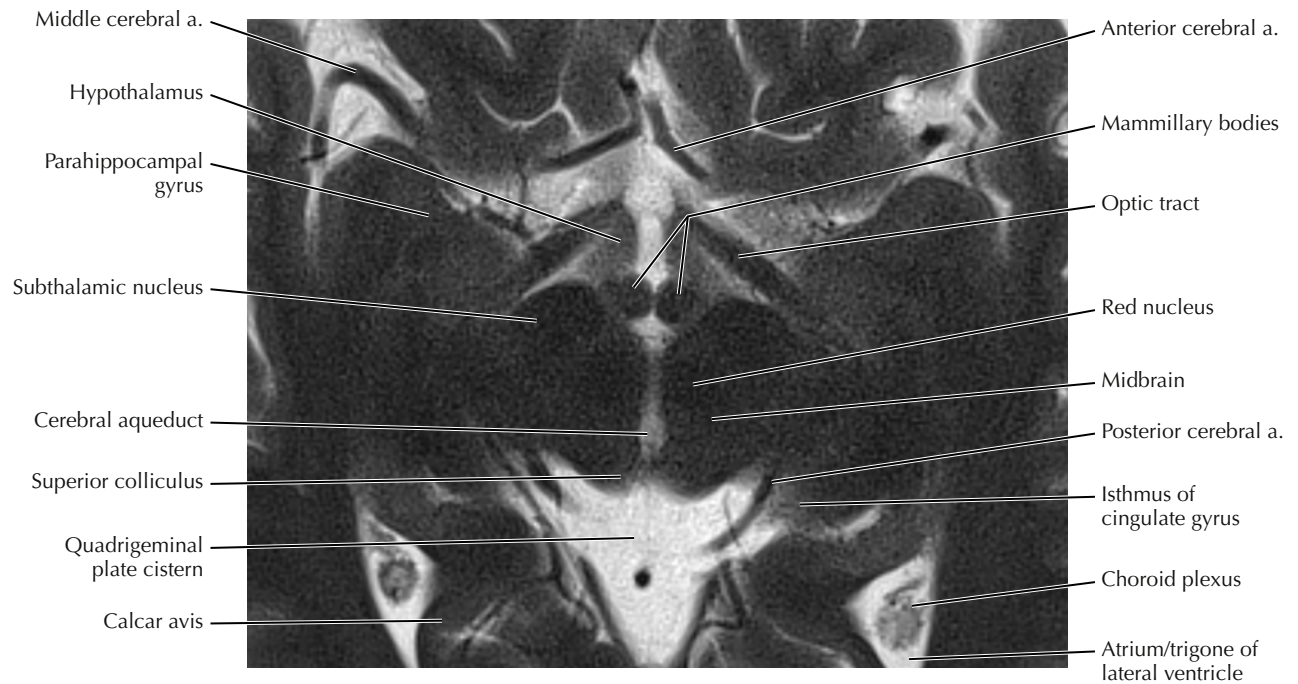
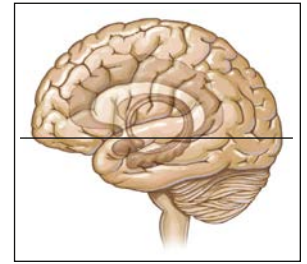


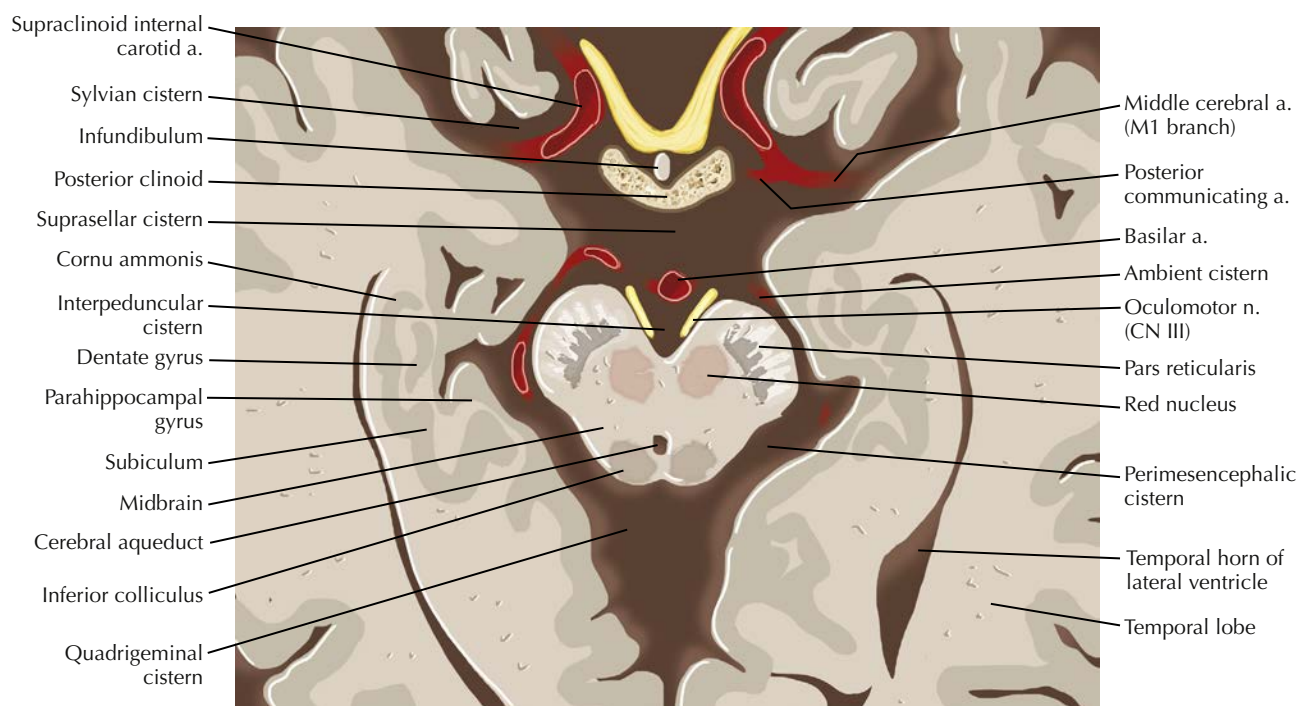
NORMAL ANATOMY

Note how the *fornix* (Latin, "arch" or "vault") is more easily seen as a paired structure on the T2-weighted axial magnetic resonance image (upper radiology image), compared with the fornix as seen in the Chapter 3 images focusing on the basal ganglia and thalami. The fornix is a C-shaped bundle of axons in the brain and carries signals from the hippocampus to the hypothalamus.



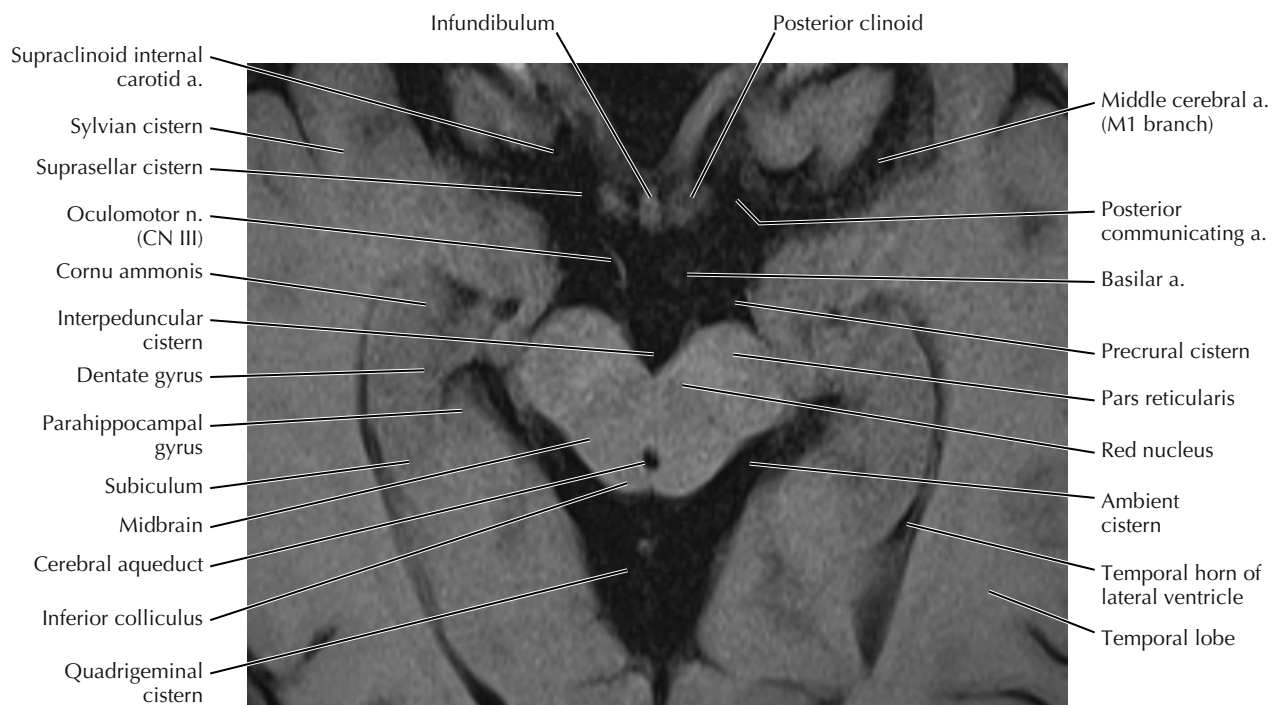
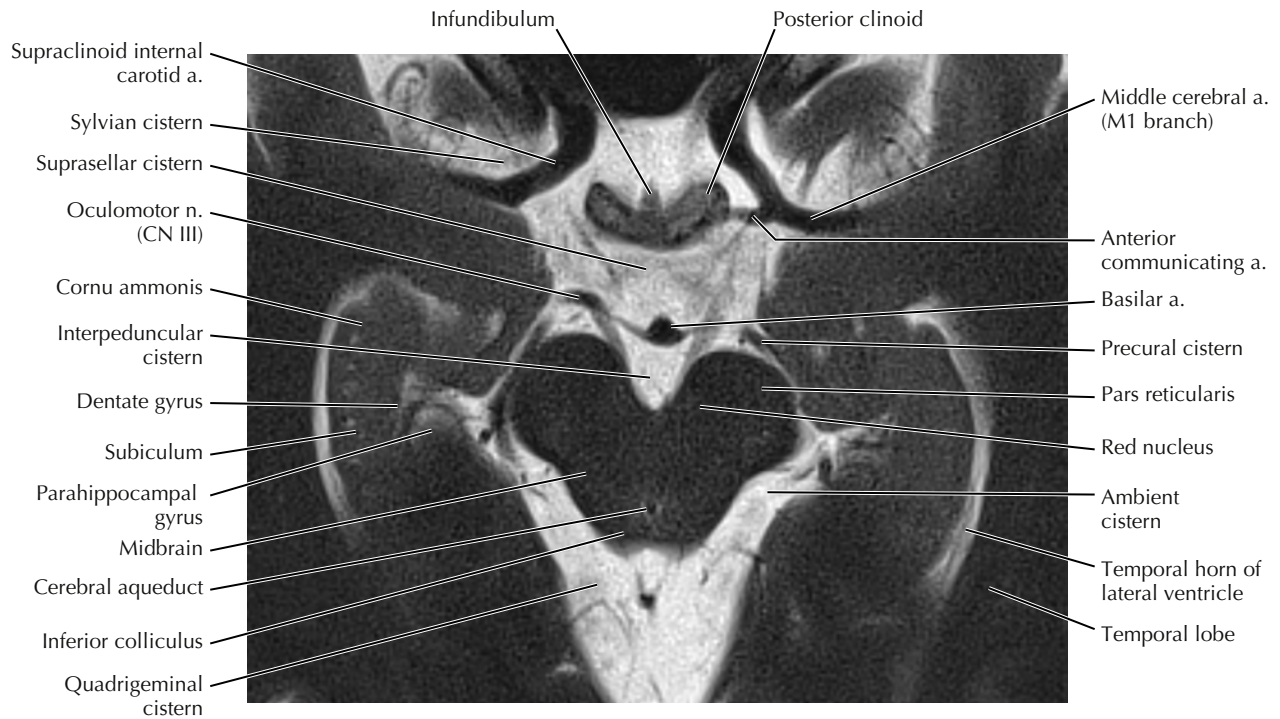
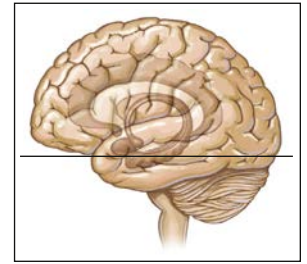


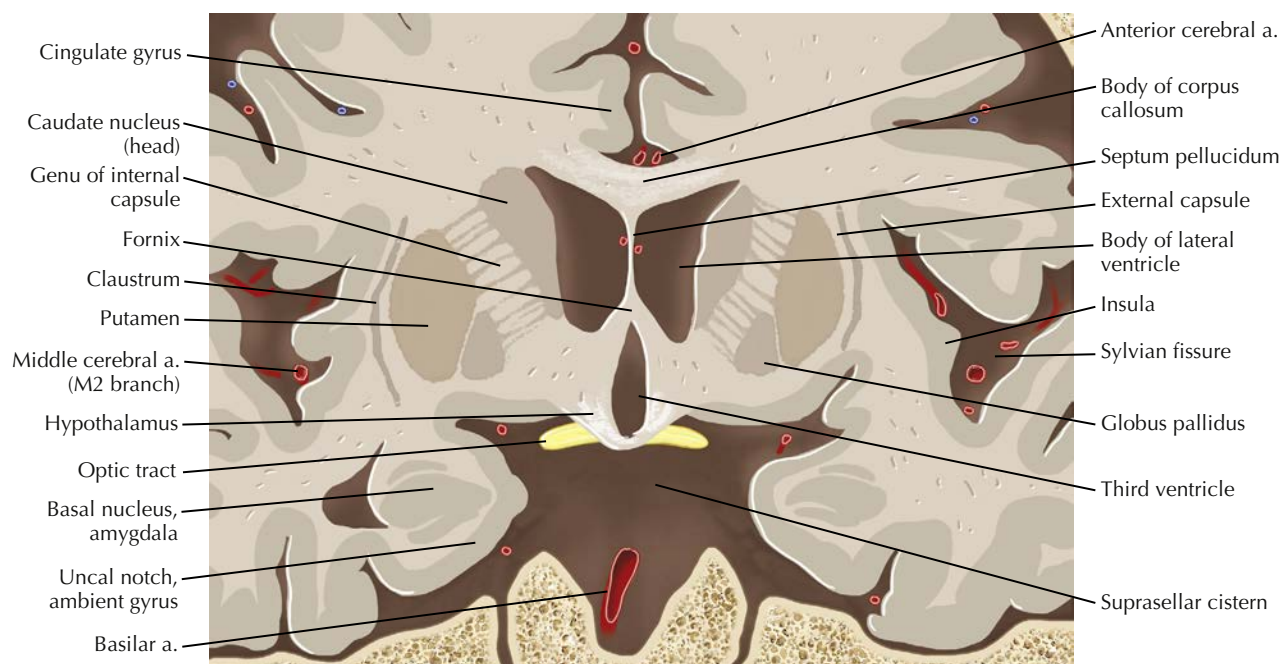


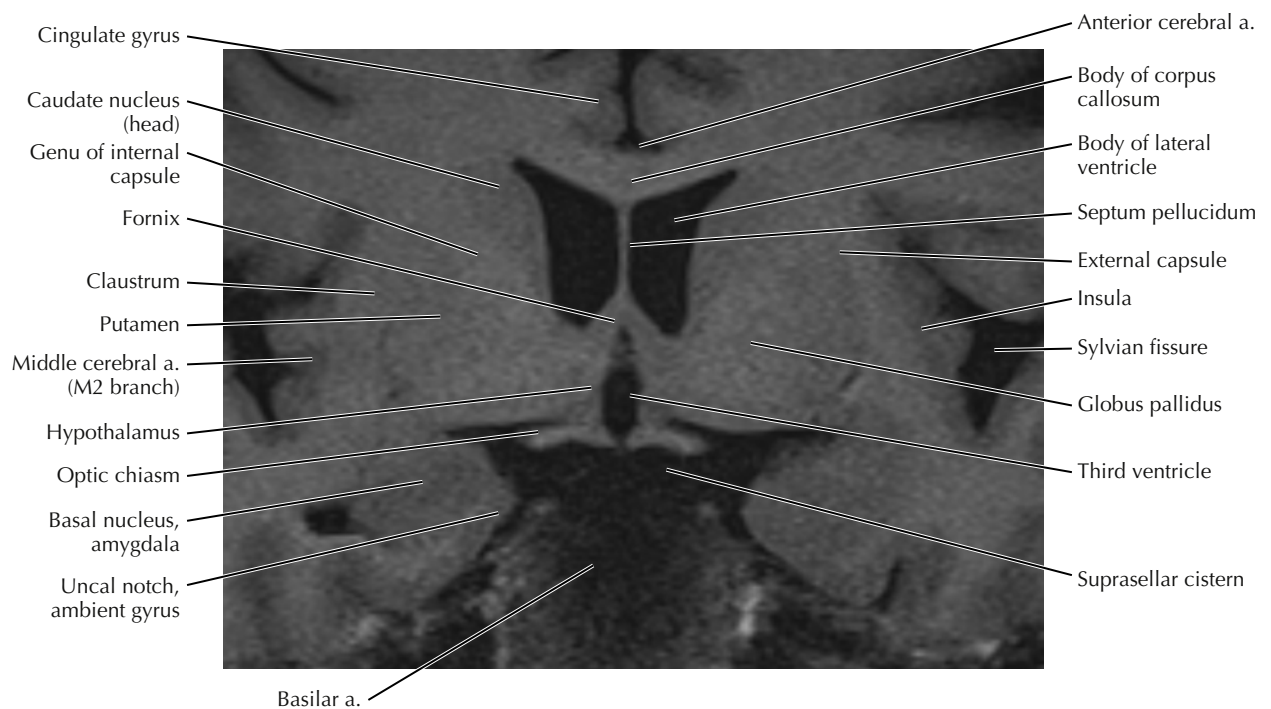
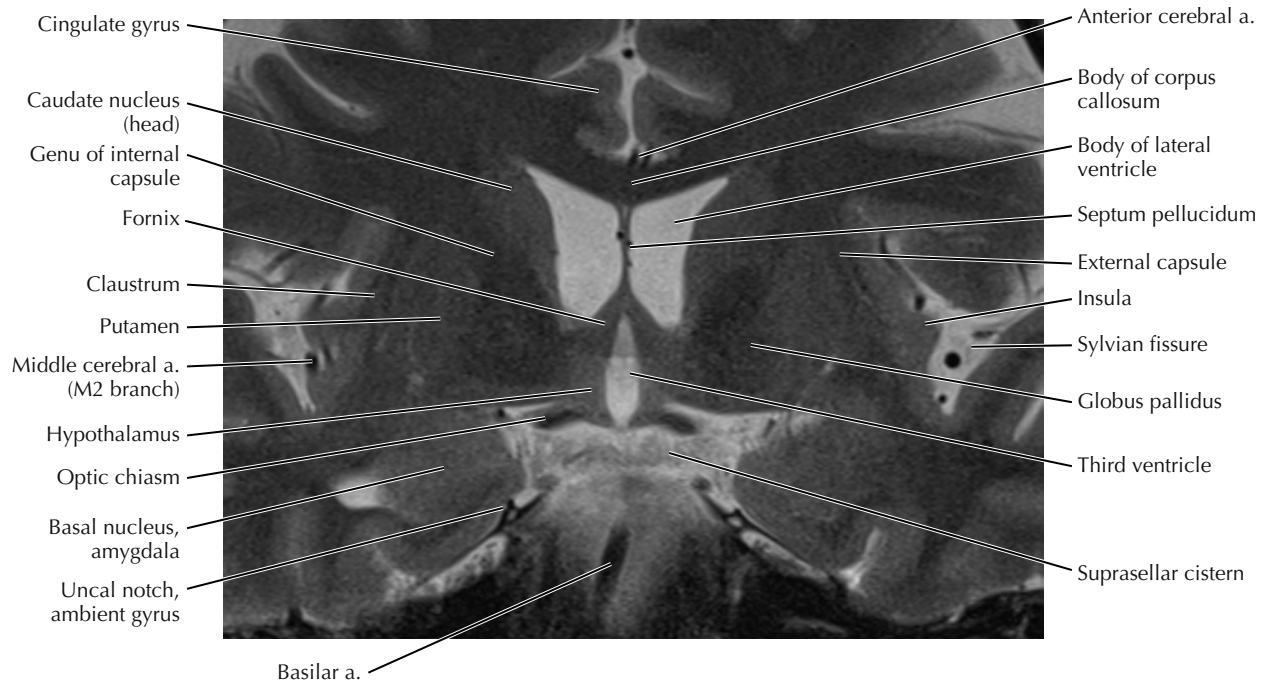
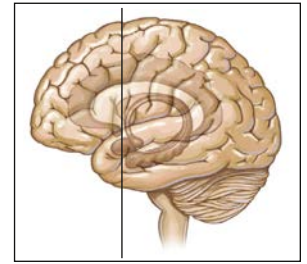


NORMAL ANATOMY

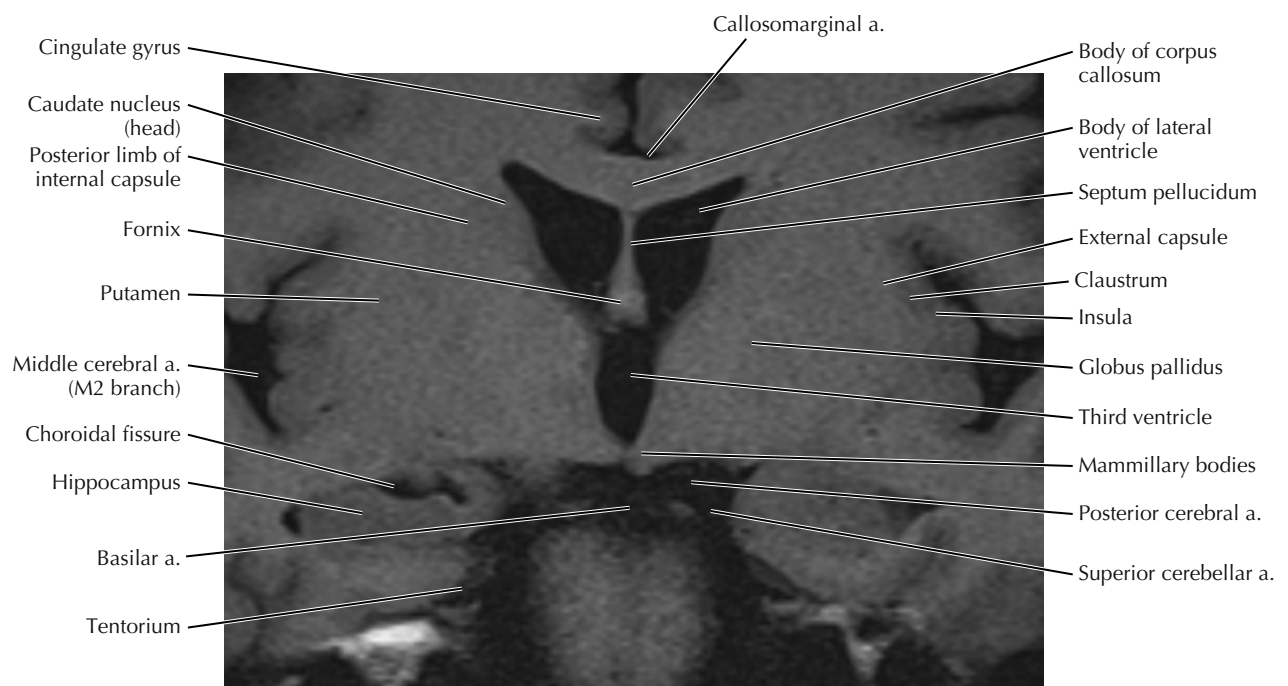
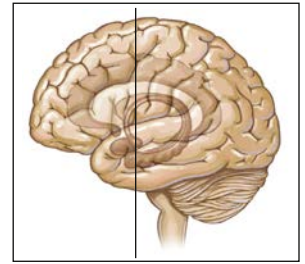
The architecture of the dentate nucleus and cornu ammonis (hippocampus) is not well defined on axial magnetic resonance imaging. Asymmetry and abnormal signal are much better appreciated on coronal MR images.

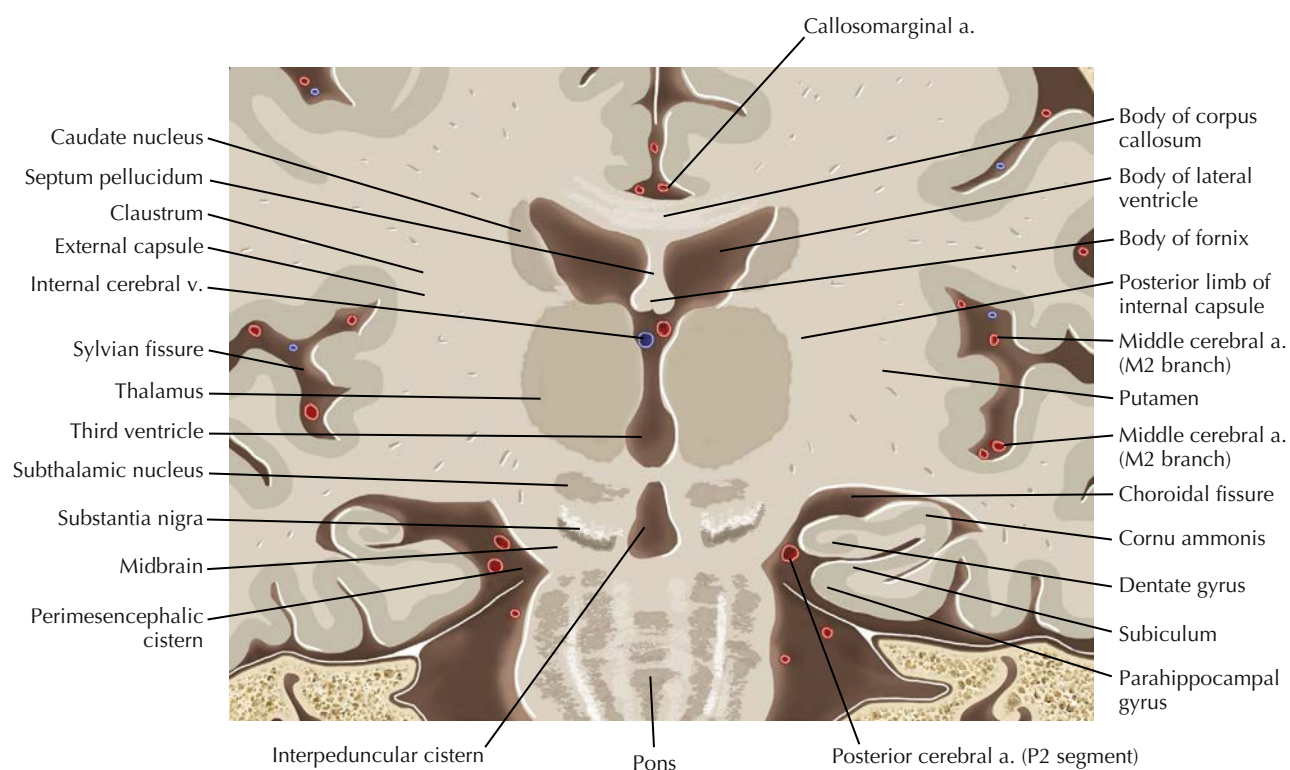






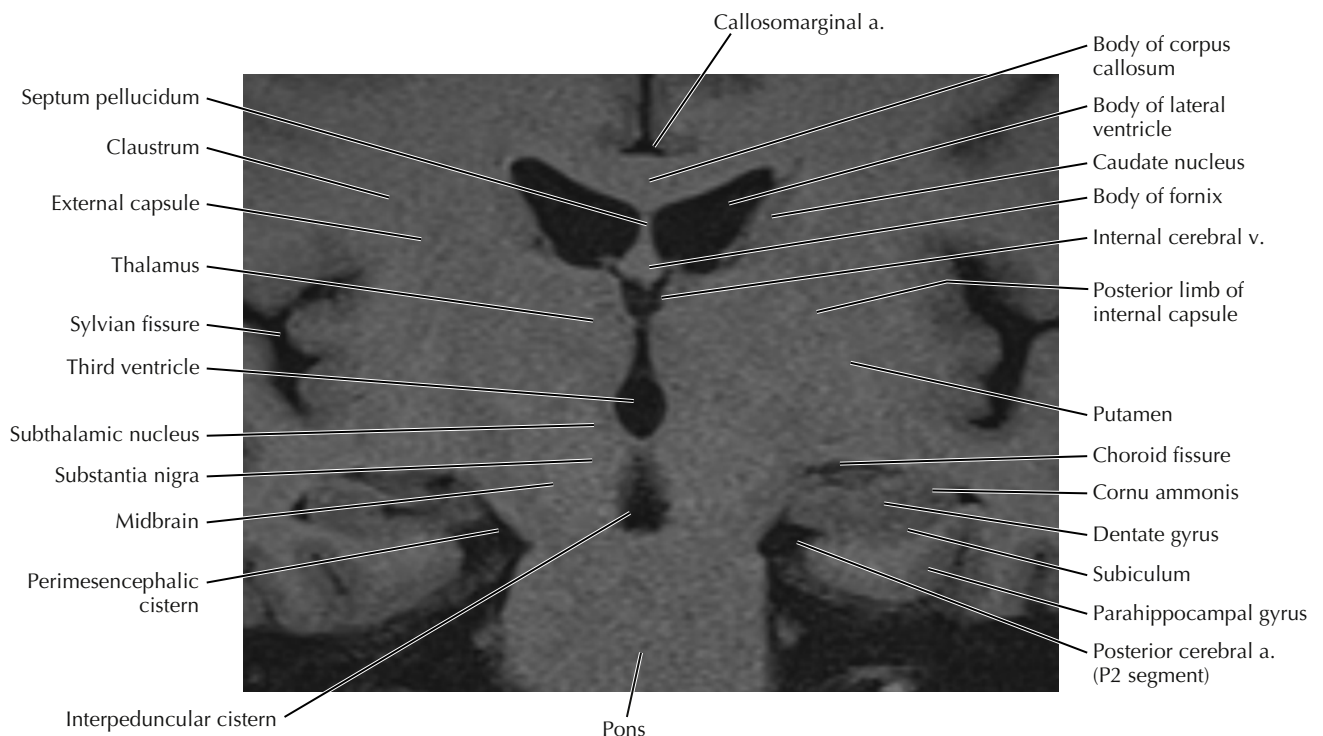
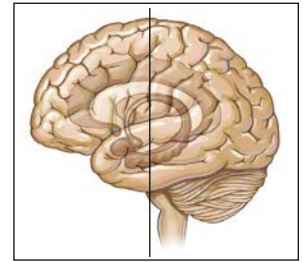


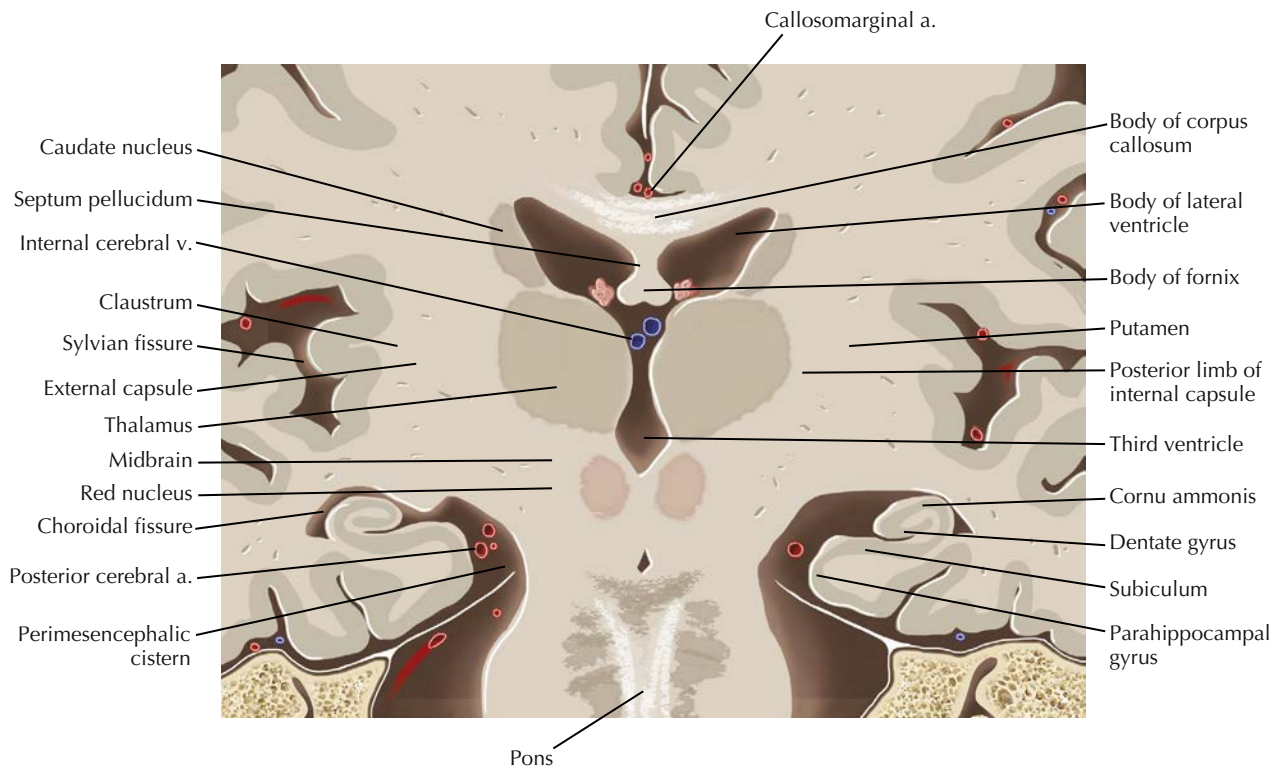




NORMAL ANATOMY

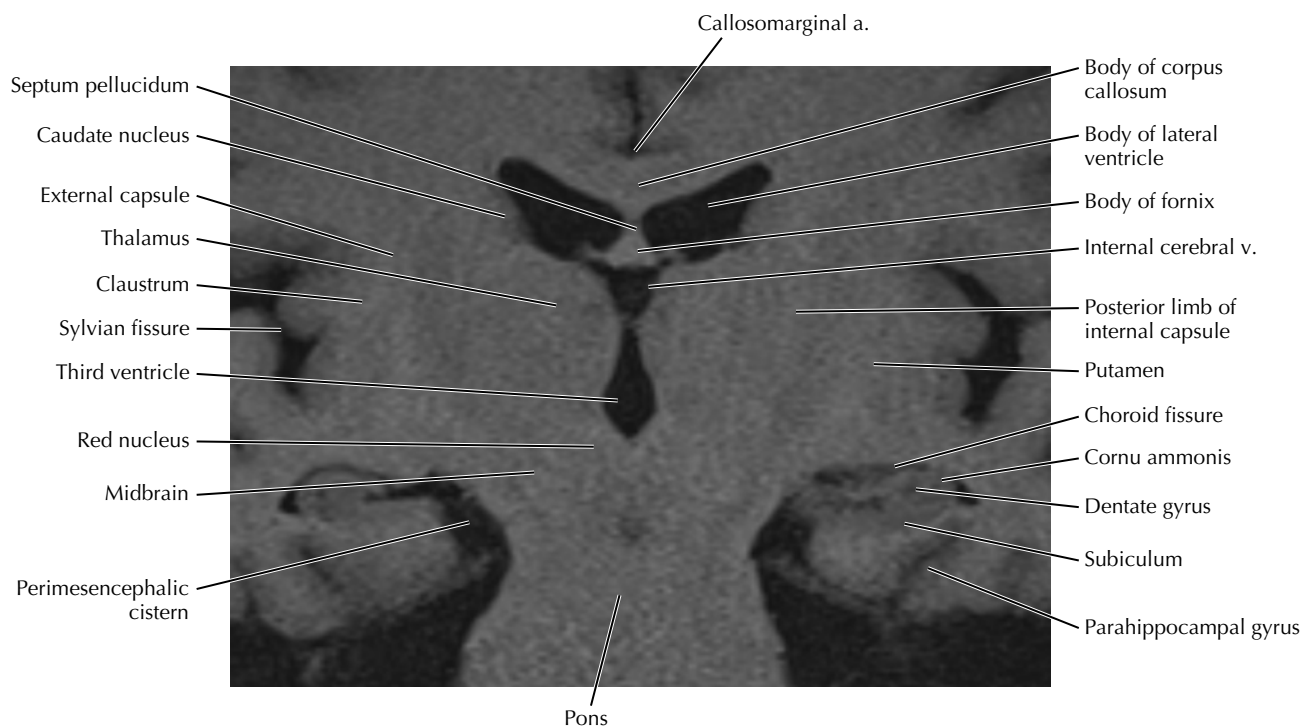
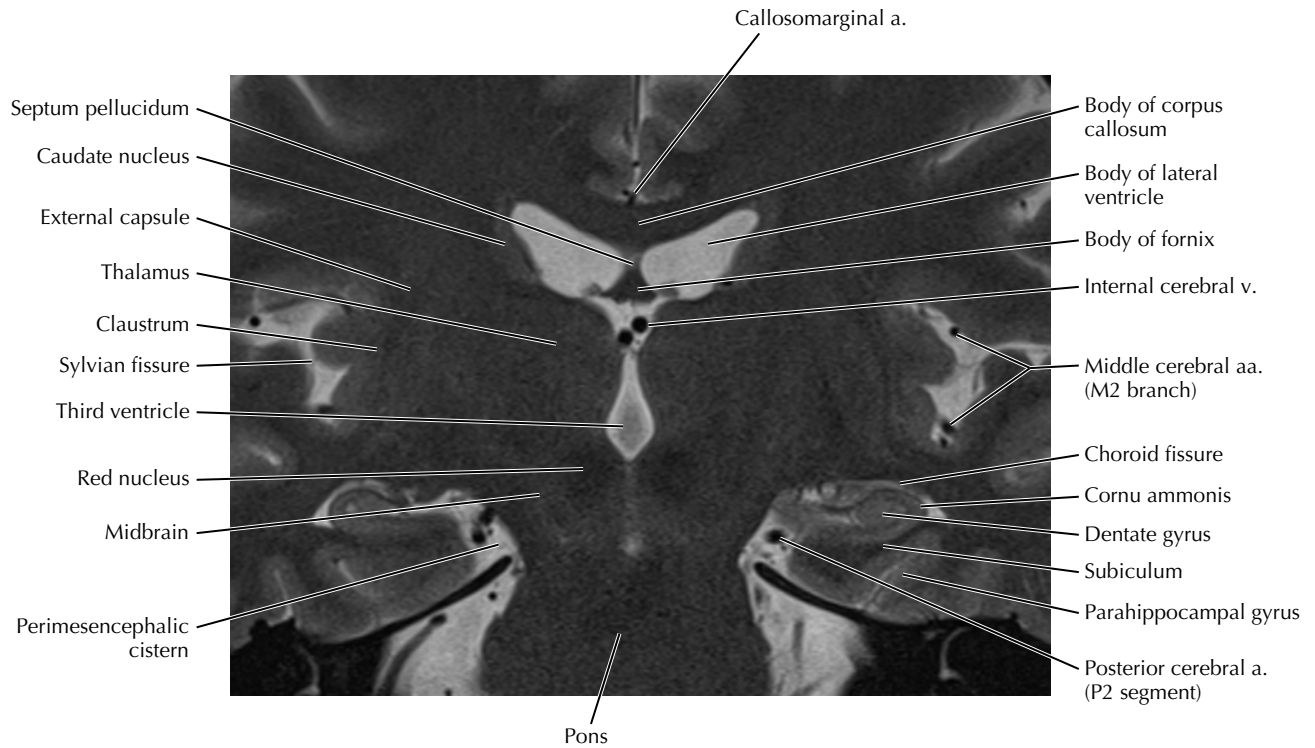
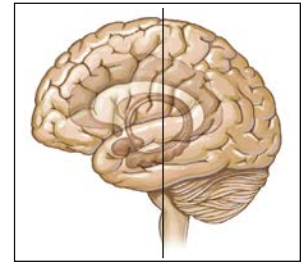
The normal appearance of the hippocampus on coronal MRI is that of a jelly roll, with the dentate gyrus in the center and the four segments of the cornu ammonis wrapped around it (see Axial 4).

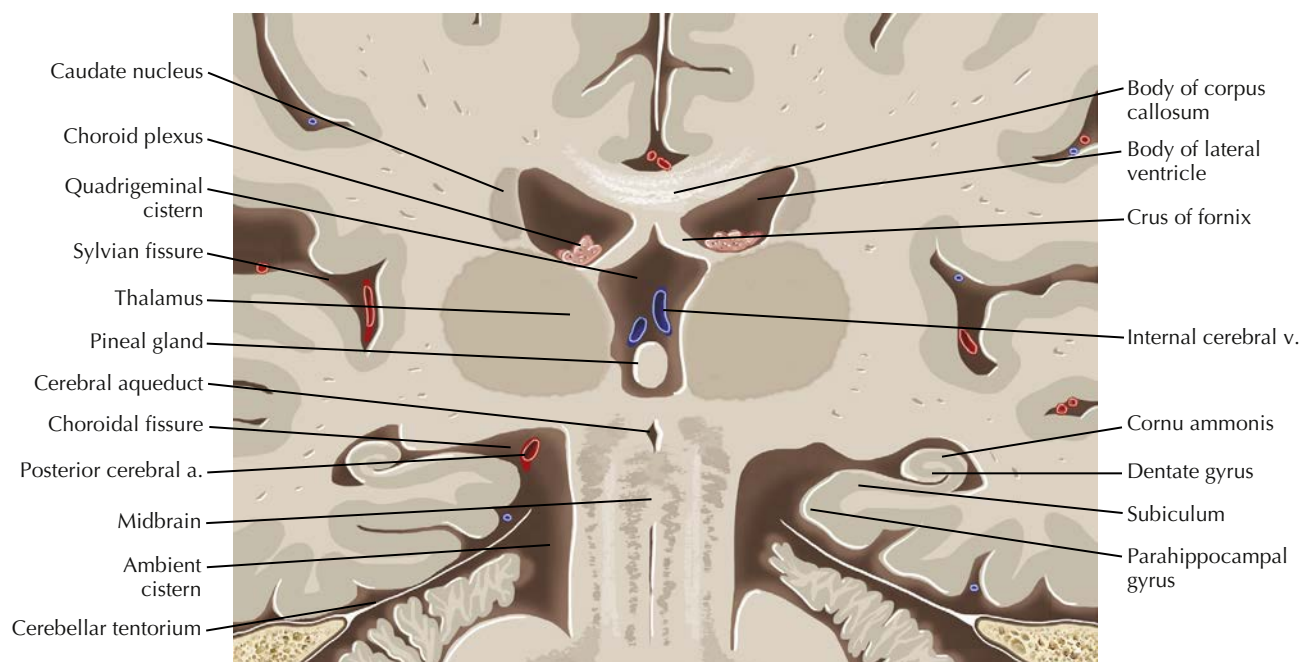


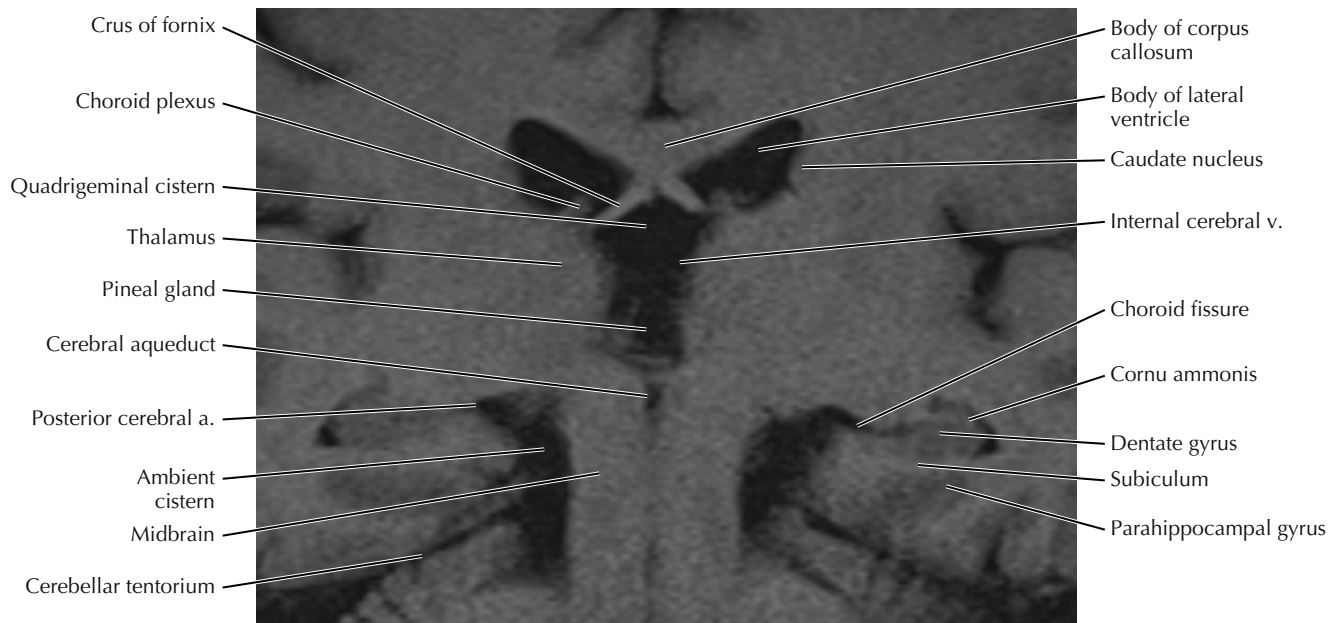
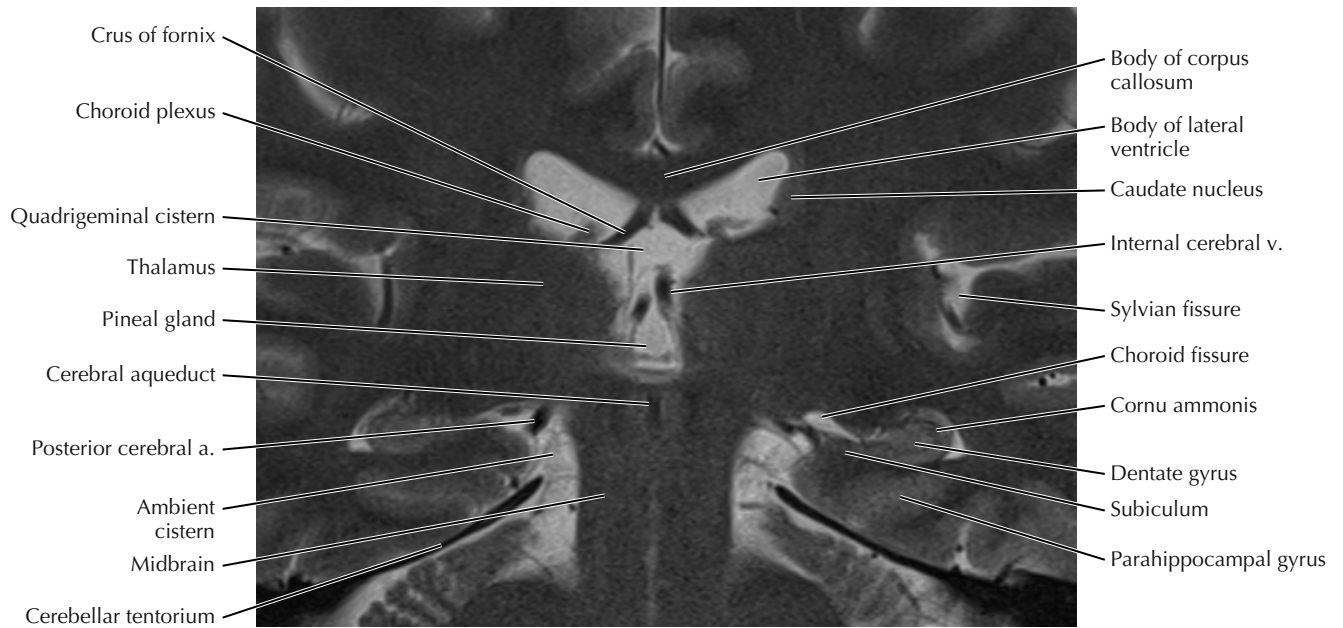
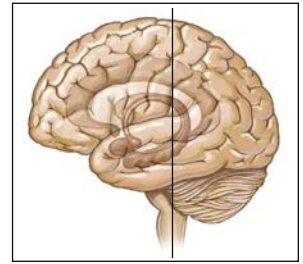


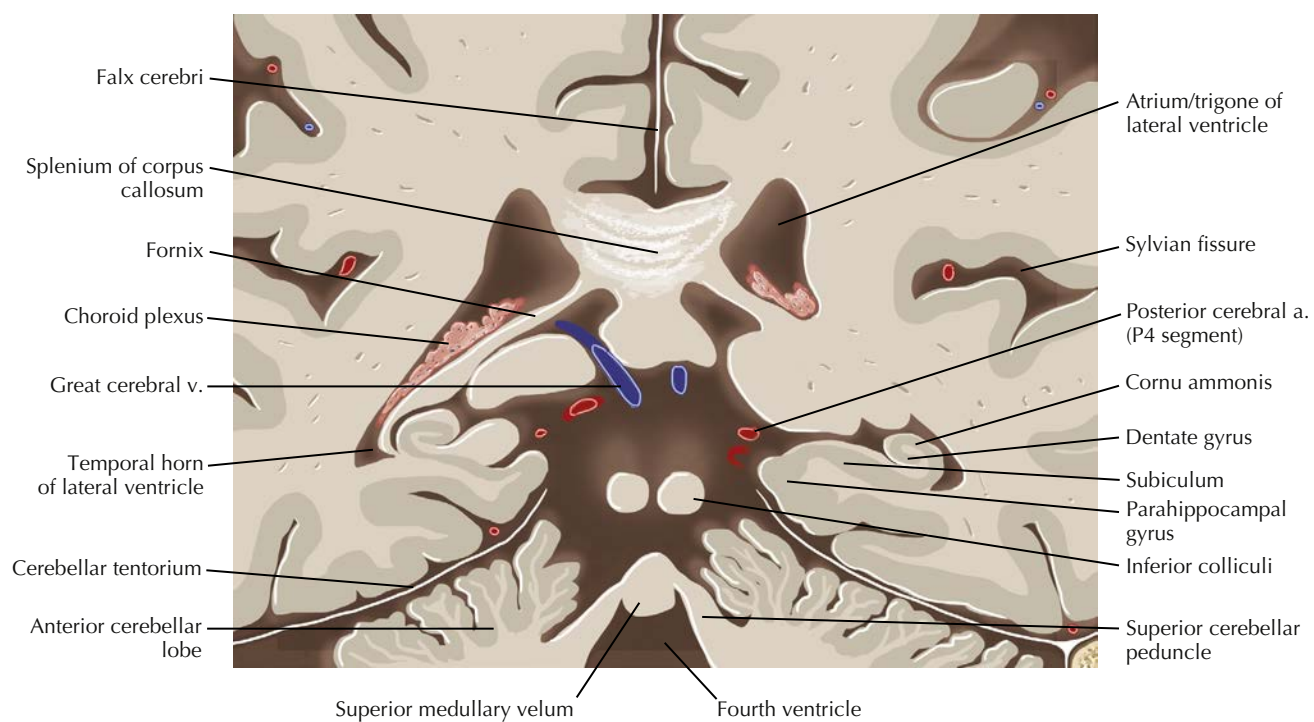
PATHOLOGIC PROCESS

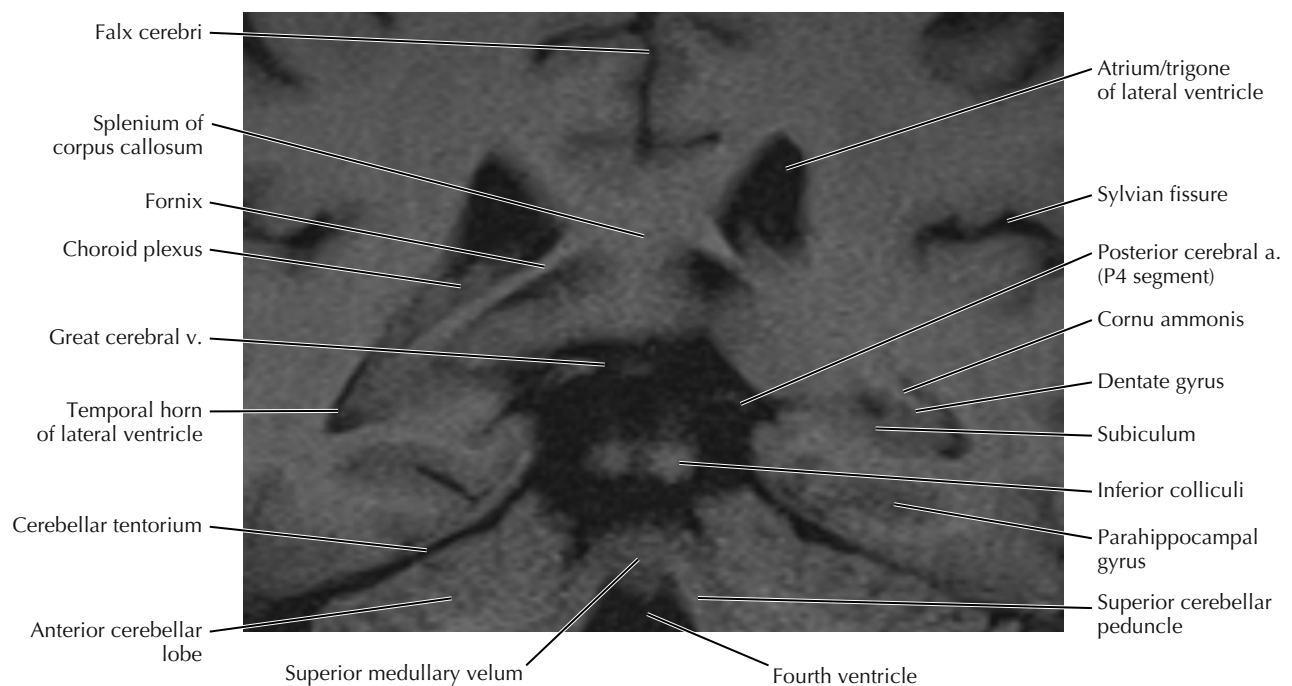
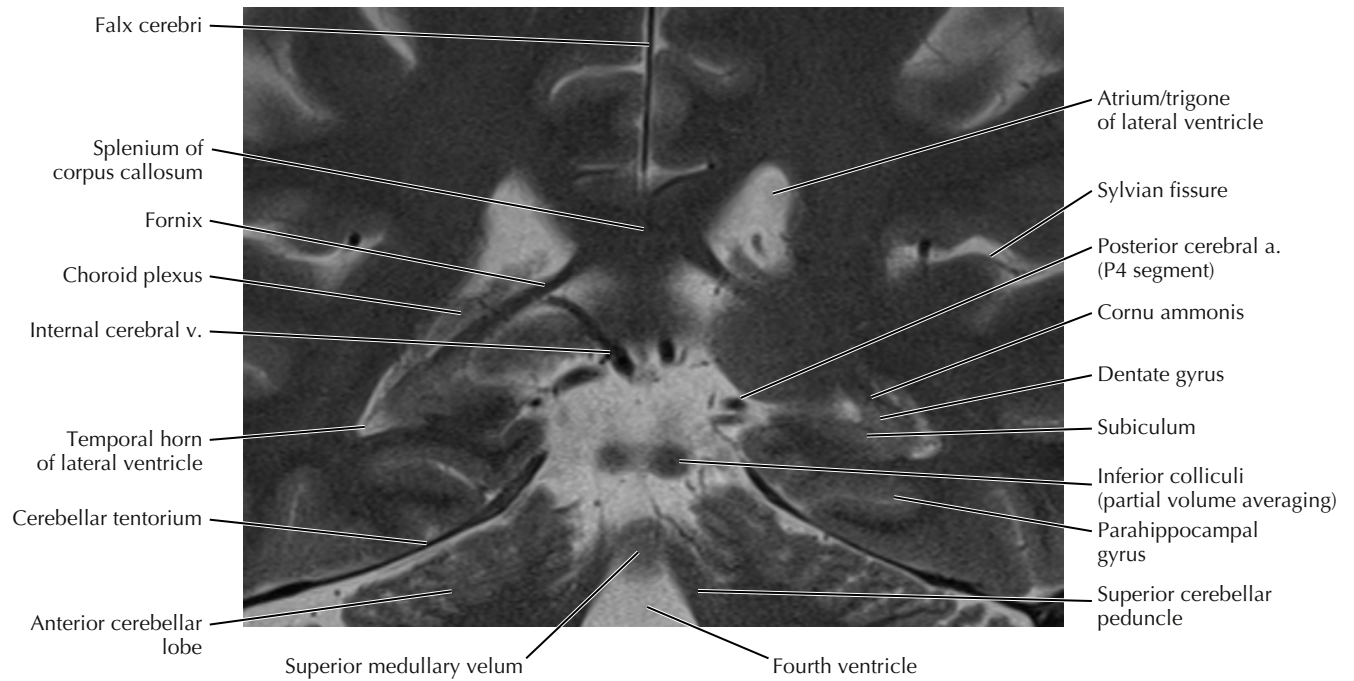
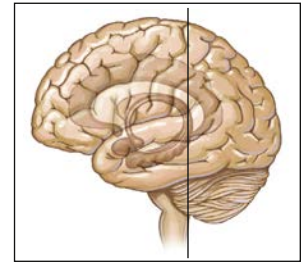
Coronal imaging through the hippocampus and amygdala is not part of routine brain MRI. However, coronal images are helpful for evaluation of temporal lobe epilepsy, which may show findings of *mesial temporal sclerosis*, typically seen as an asymmetrically small hippocampus and amygdala with increased T2-weighted signal. Electroencephalography (EEG) will typically show temporal lobe seizure activity localized to the abnormal side. If refractory to medication, the seizure patient can be treated with temporal lobectomy.

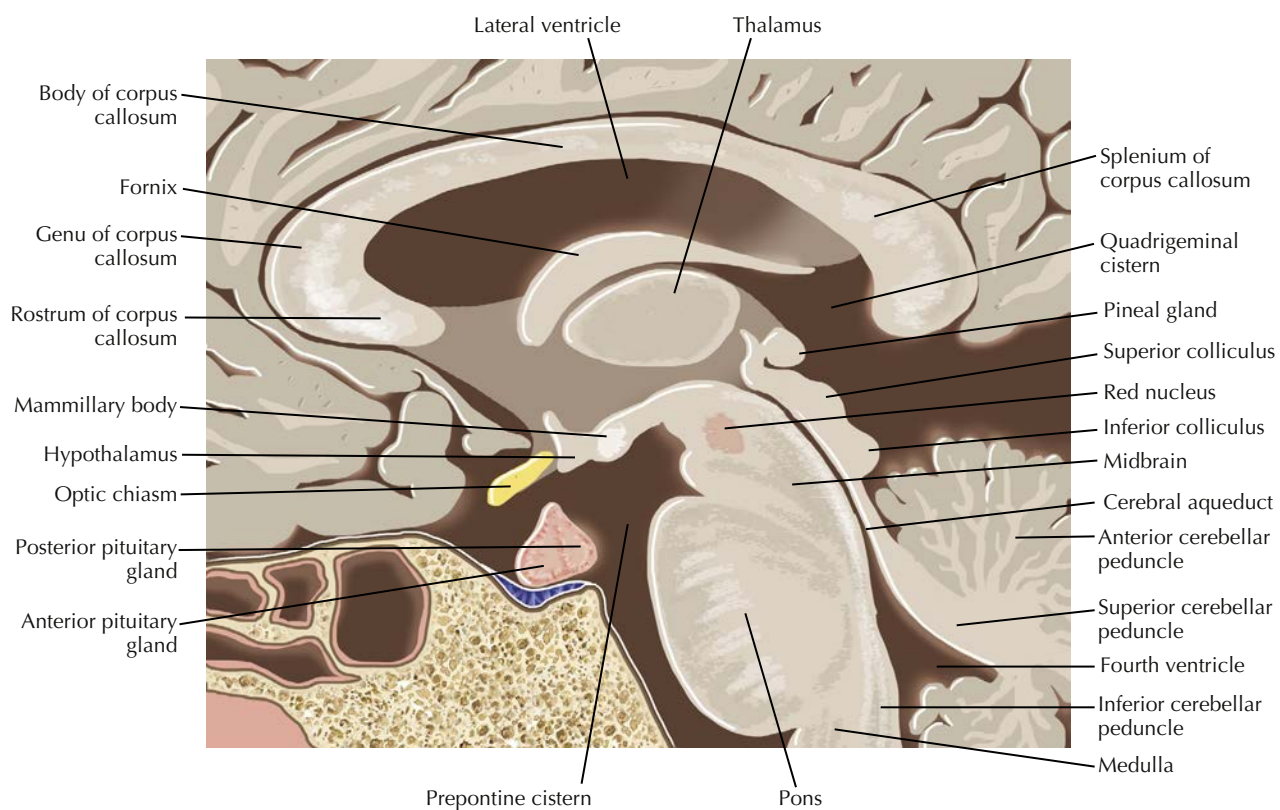


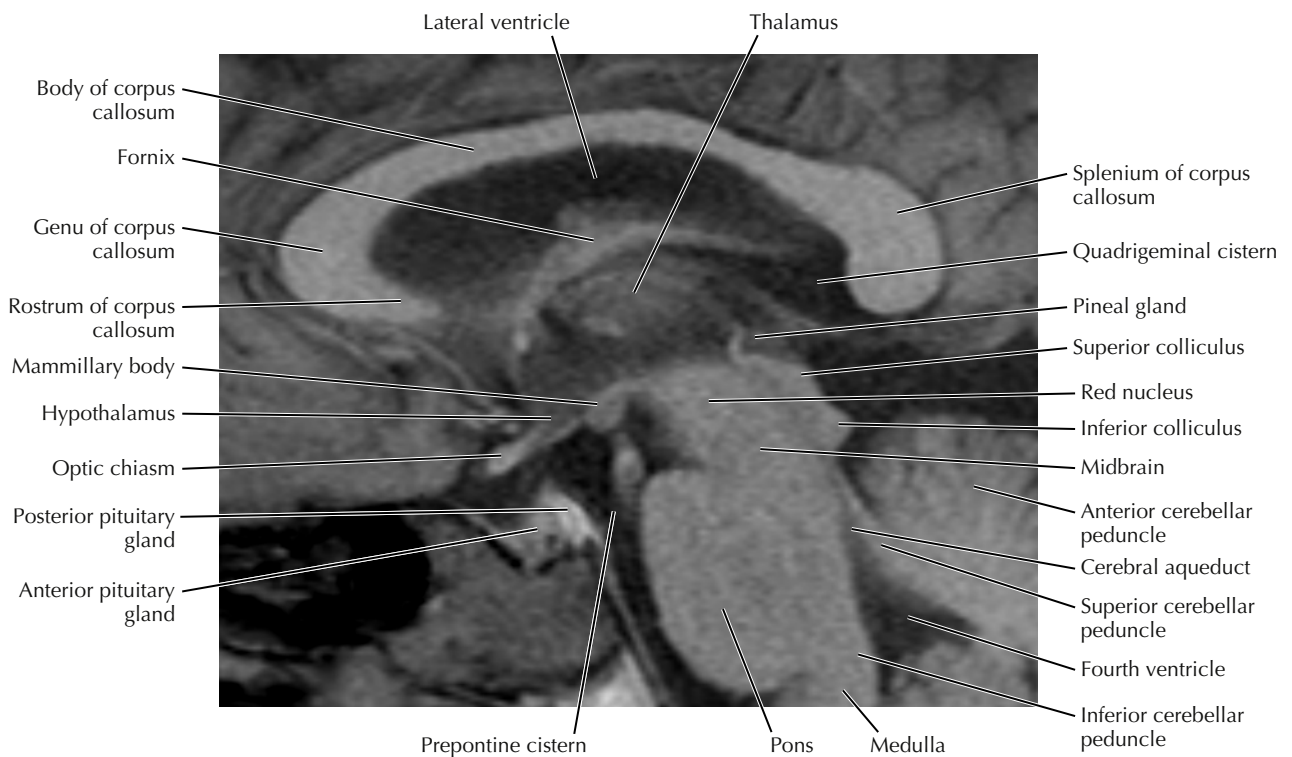
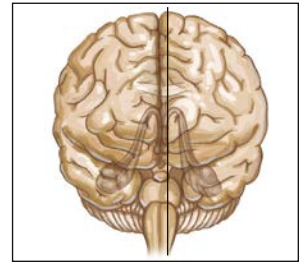


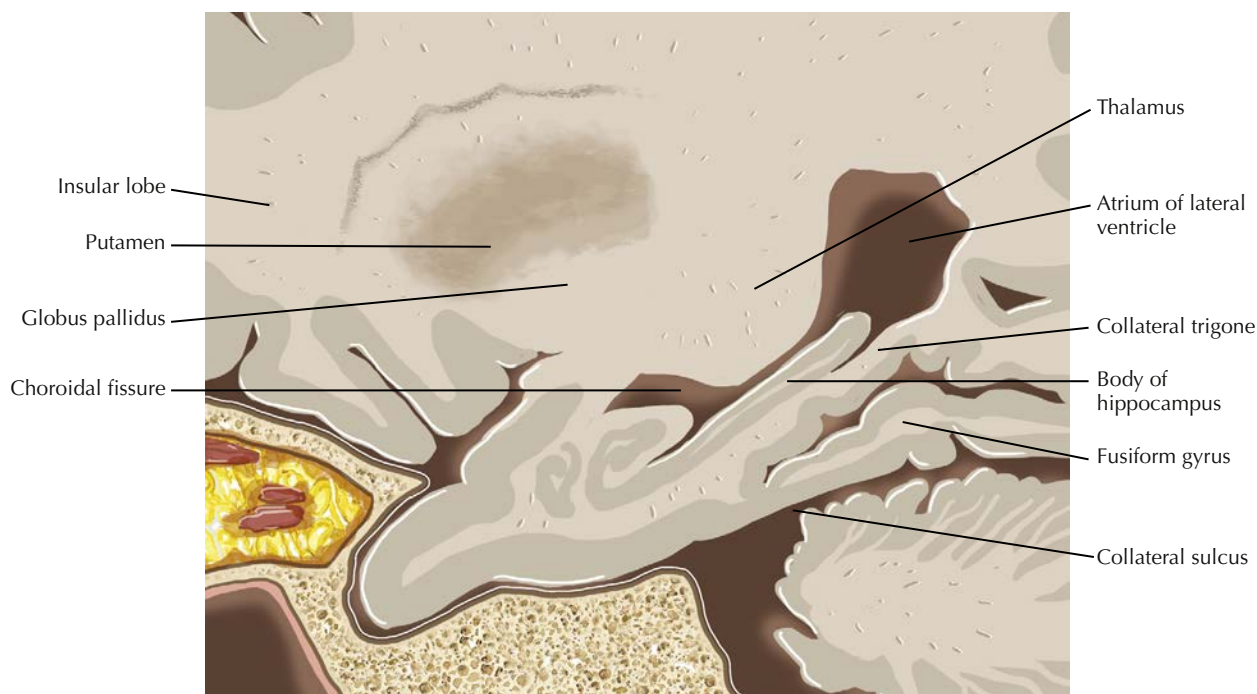






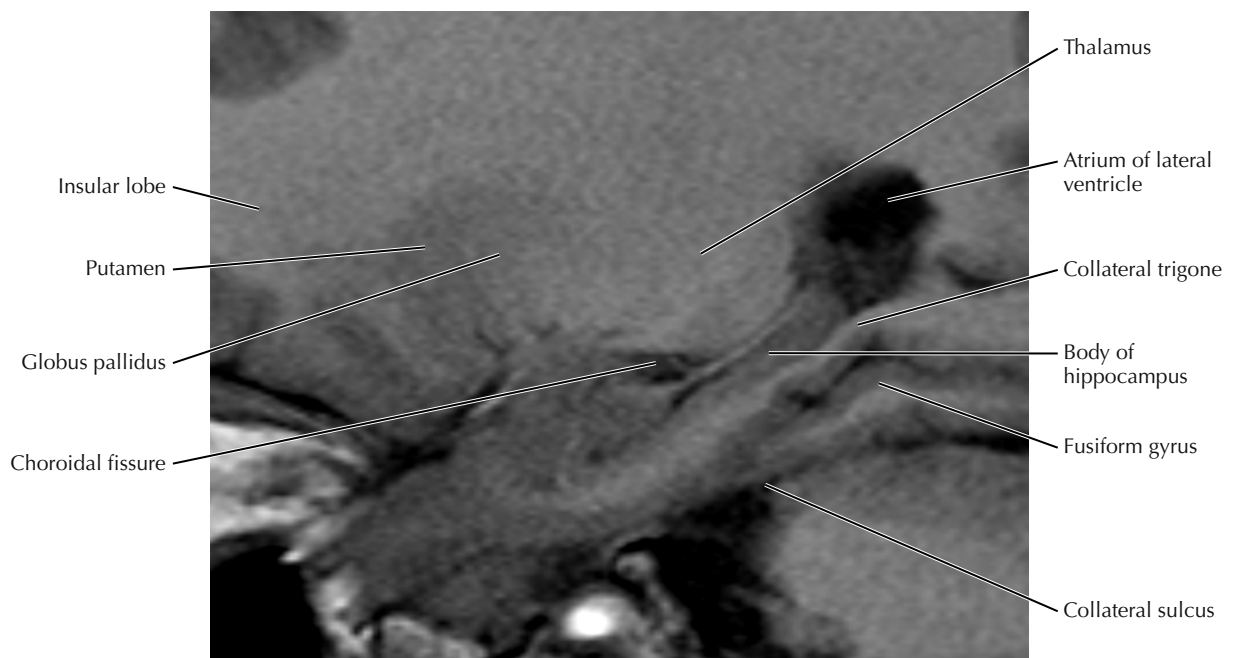
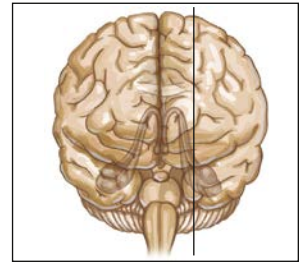


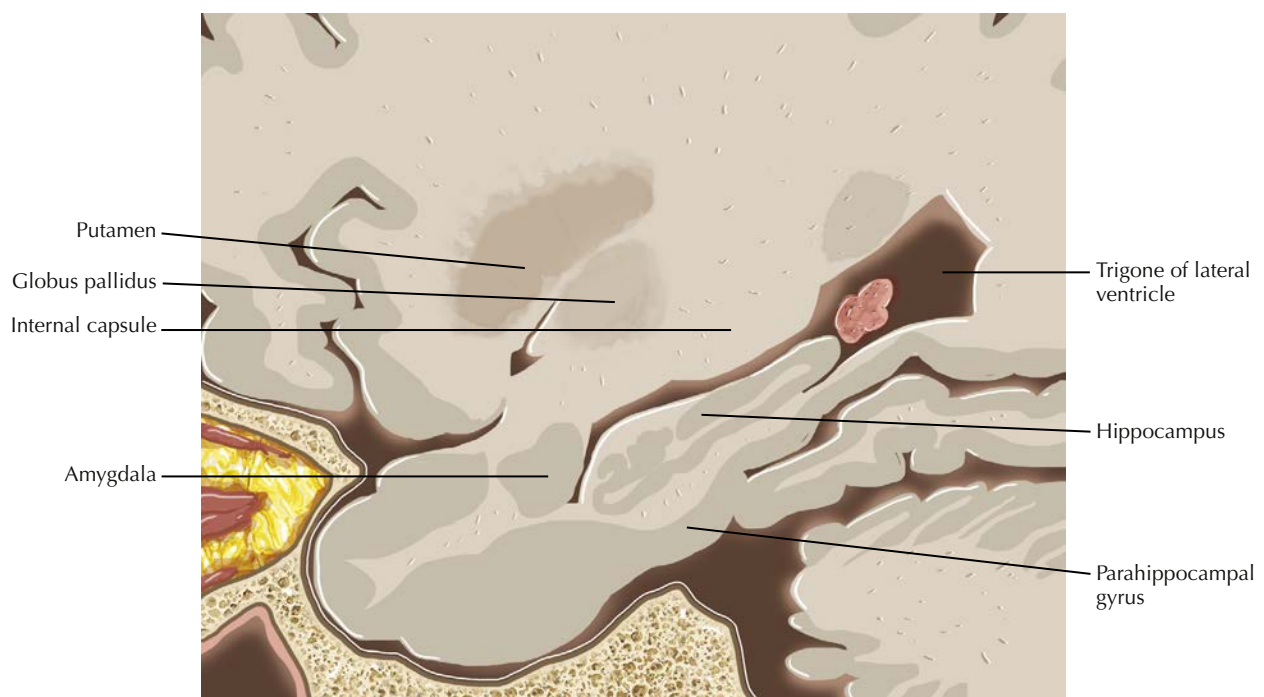


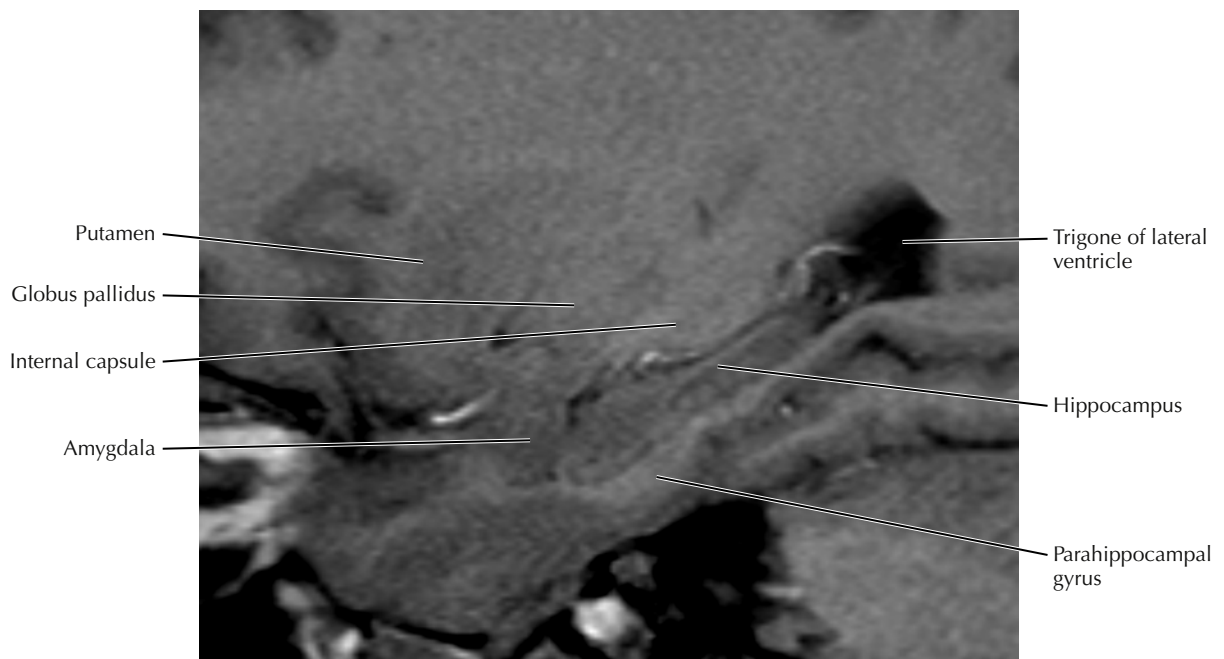
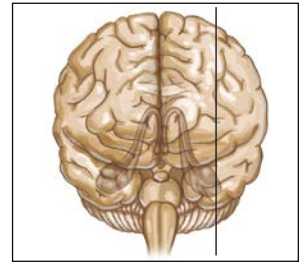


NORMAL ANATOMY

The hippocampus is a ridge running along the floor of the temporal horn of the lateral ventricle. Venetian anatomist Aranzi (1578) first described its seahorse appearance using the Latin term *hippocampus* (Greek *hippokampos*). In 1832, Parisian surgeon de Garengeot used the term *cornu ammonis* ("horn of Ammon").







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Chapter

5

BRAINSTEM AND CRANIAL NERVES

OLFACTORY NERVE (CN I)

Axial 176

Coronal 178

OPTIC NERVE (CN II)

Axial 180

Coronal 186

Sagittal 198

OCULOMOTOR NERVE (CN III)

Axial 200

Coronal 208

TROCHLEAR NERVE (CN IV)

Axial 218

Coronal 222

TRIGEMINAL NERVE (CN V)

Axial 224

Sagittal 242

Coronal 244

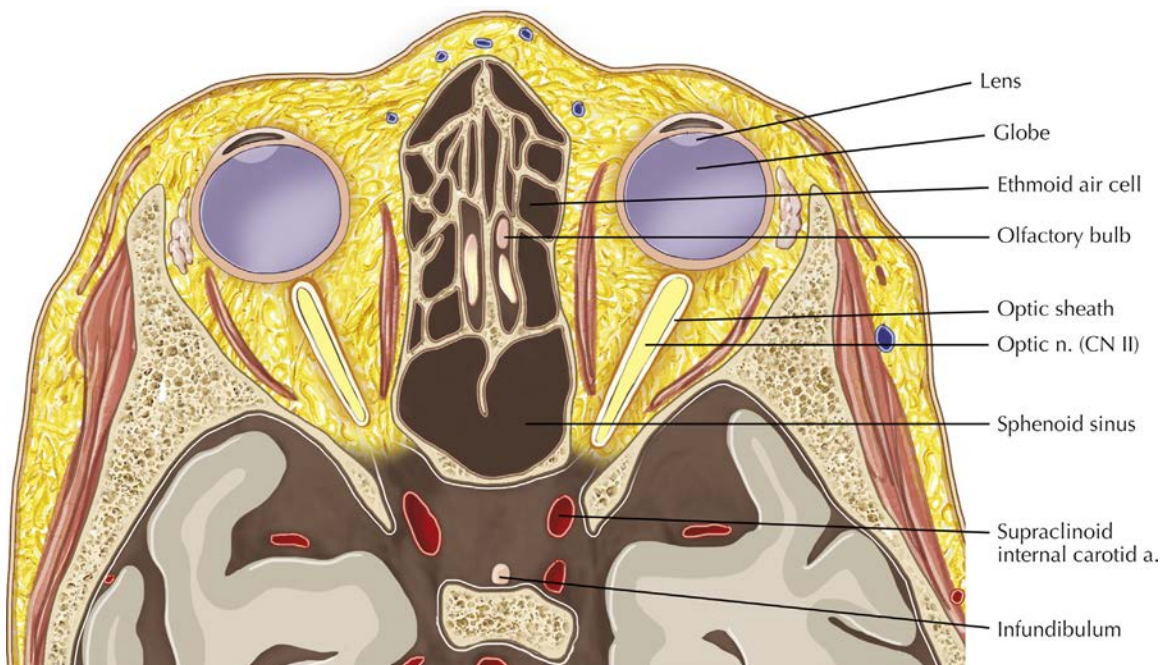
ABDUCENS (CN VI), FACIAL (CN VII), AND VESTIBULOCOCHLEAR (CN VIII) NERVES

Axial 246

Sagittal 260

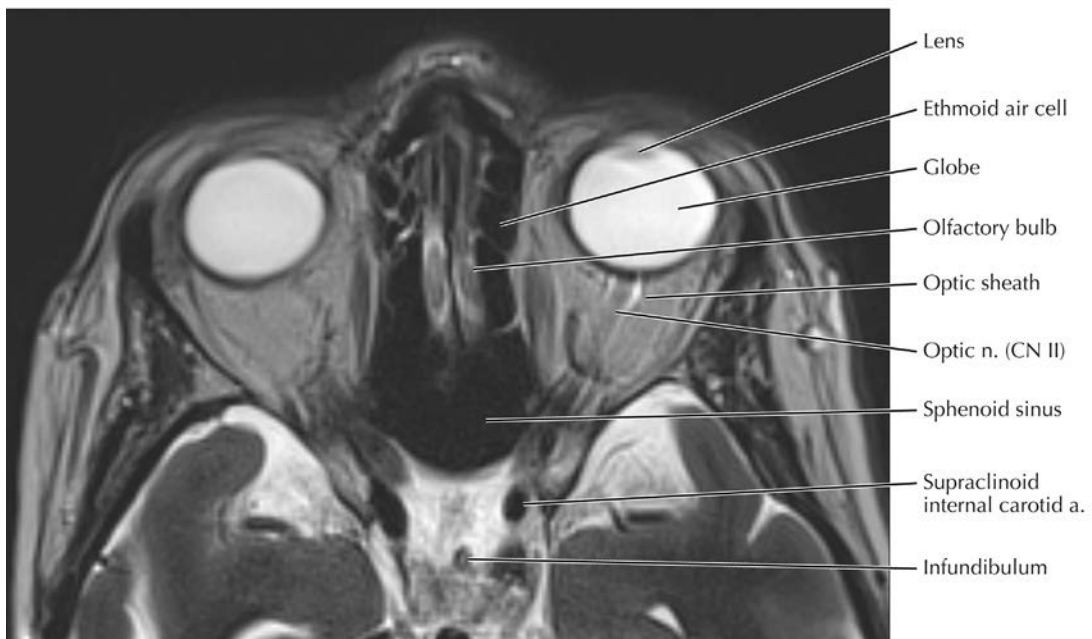
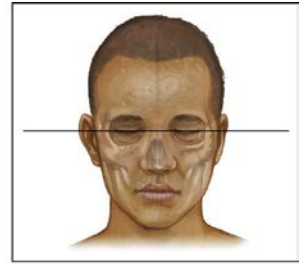
GLOSSOPHARYNGEAL (CN IX), VAGUS (CN X), ACCESSORY (CN XI), AND HYPOGLOSSAL (CN XII) NERVES

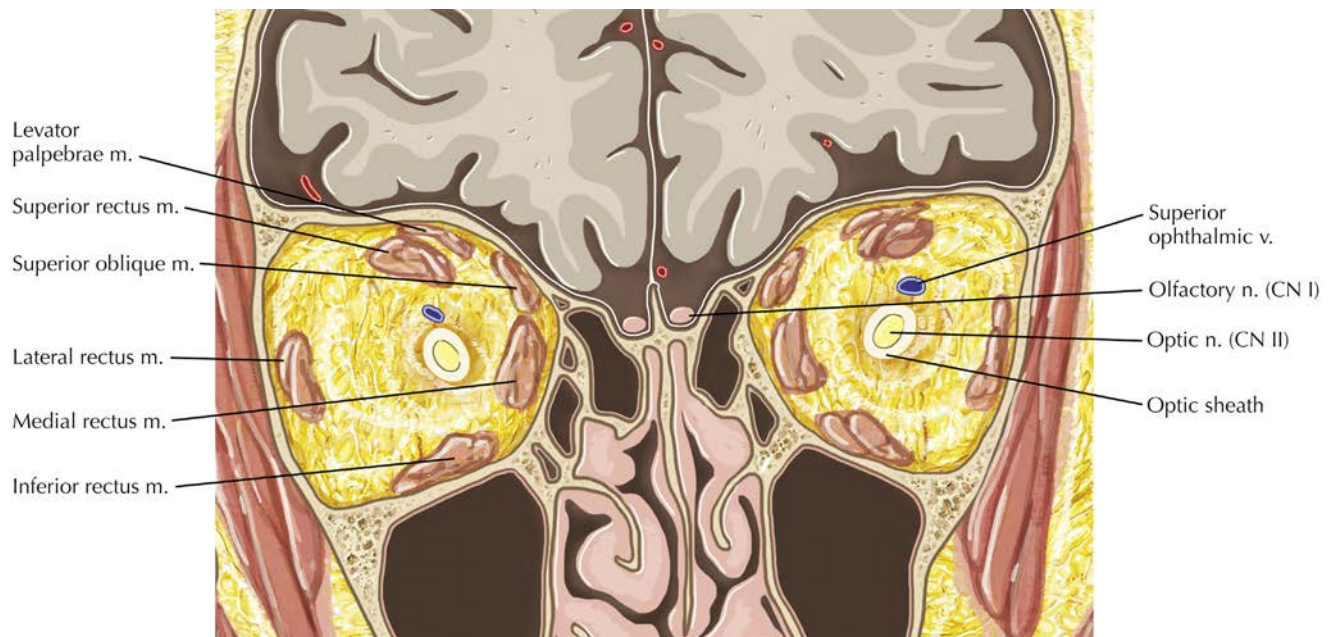
Axial 264



NORMAL ANATOMY

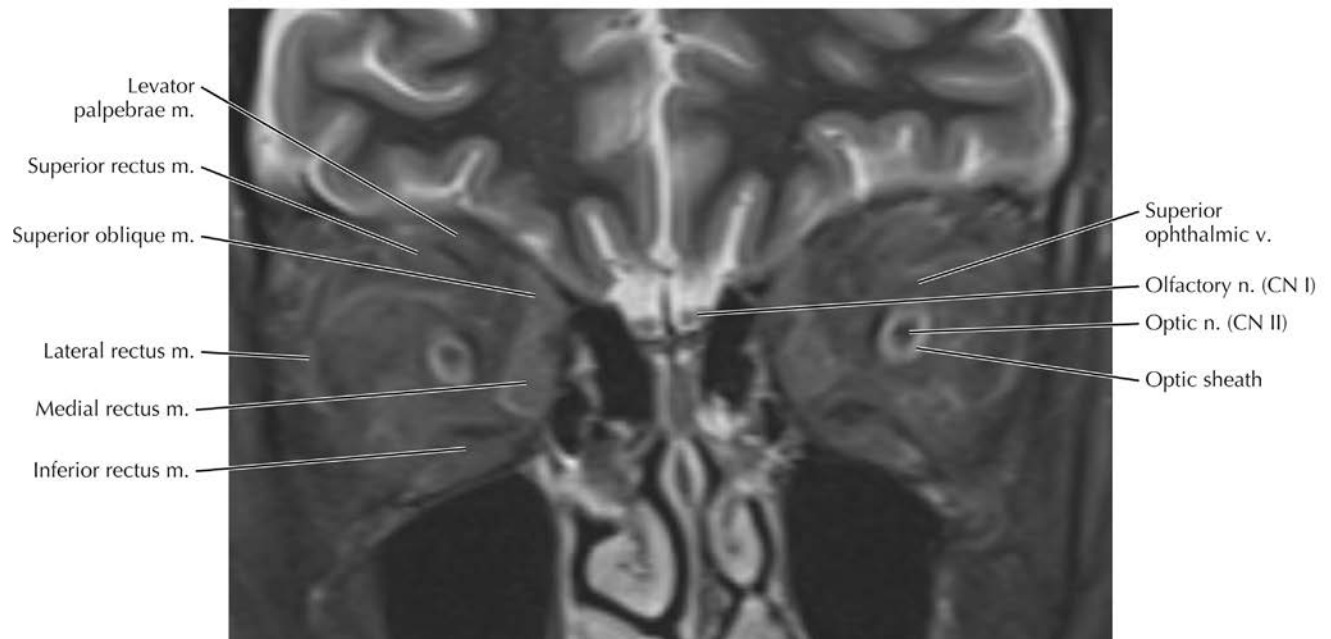
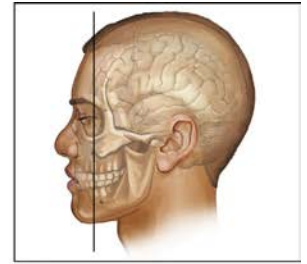
The olfactory nerve, or cranial nerve (CN) I, is the first of 12 cranial nerves and provides innervation for the sense of smell. CN I can often be seen on axial magnetic resonance imaging of the brain at the level of the temporal lobes. Nerve fibers from the olfactory mucosa in the anterosuperior nasal cavity join with the olfactory bulb, from which signals pass through nerves running within olfactory foramina in the cribriform plate in the superior nasal cavity.

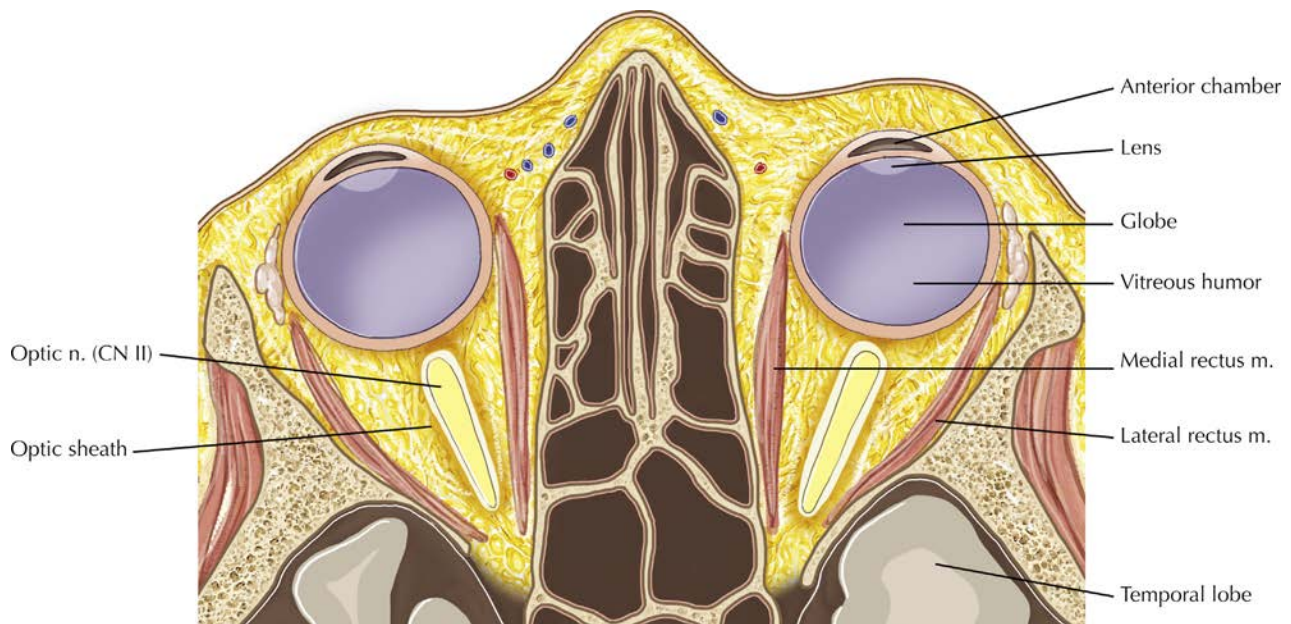




IMAGING TECHNIQUE CONSIDERATION

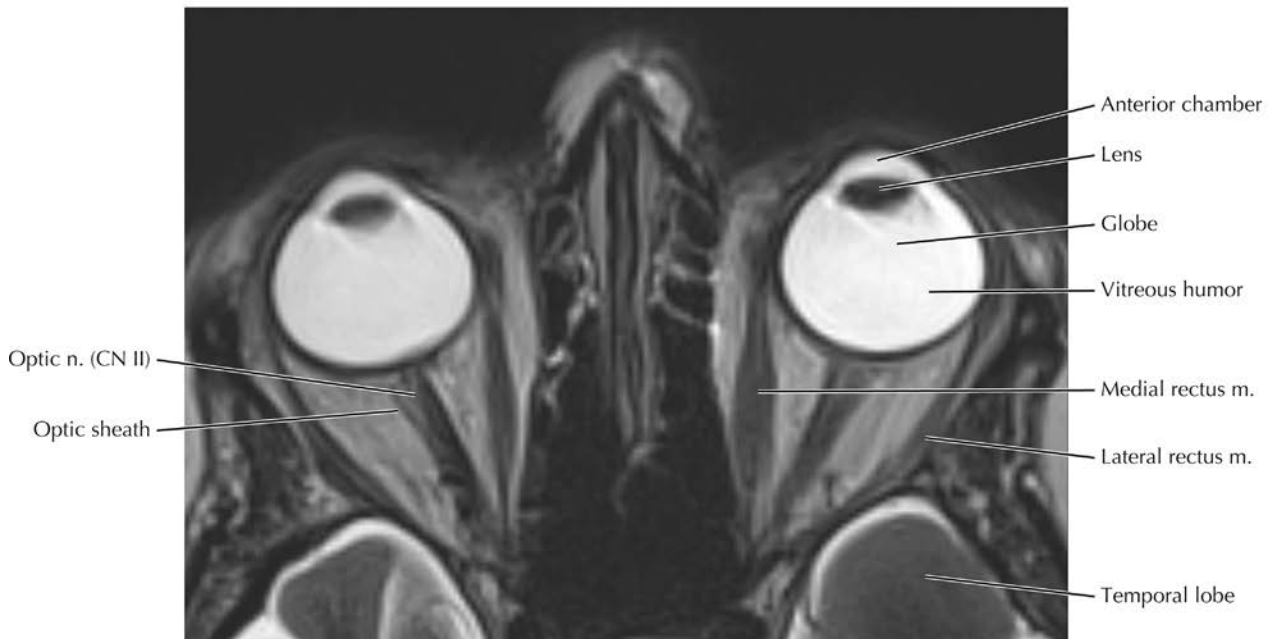
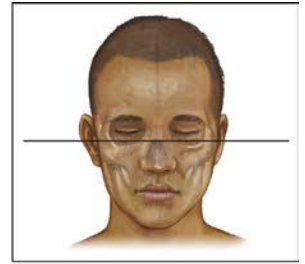
Clinicians should always approach loss of smell as a serious symptom and explore anatomic causes. The best imaging plane to assess the olfactory nerves is coronal, perpendicular to the long axis of the nerves. T2-weighted MR coronal images help to delineate the olfactory nerves, with surrounding cerebrospinal fluid (CSF) between the nerves and the bony walls of the olfactory grooves. In some patients, one olfactory groove may be asymmetrically lower than the other, an important consideration if the patient may be undergoing functional endoscopic sinus surgery (FES). One notable tumor centered on the olfactory nerves is *esthesioneuroblastoma* (olfactory neuroblastoma).

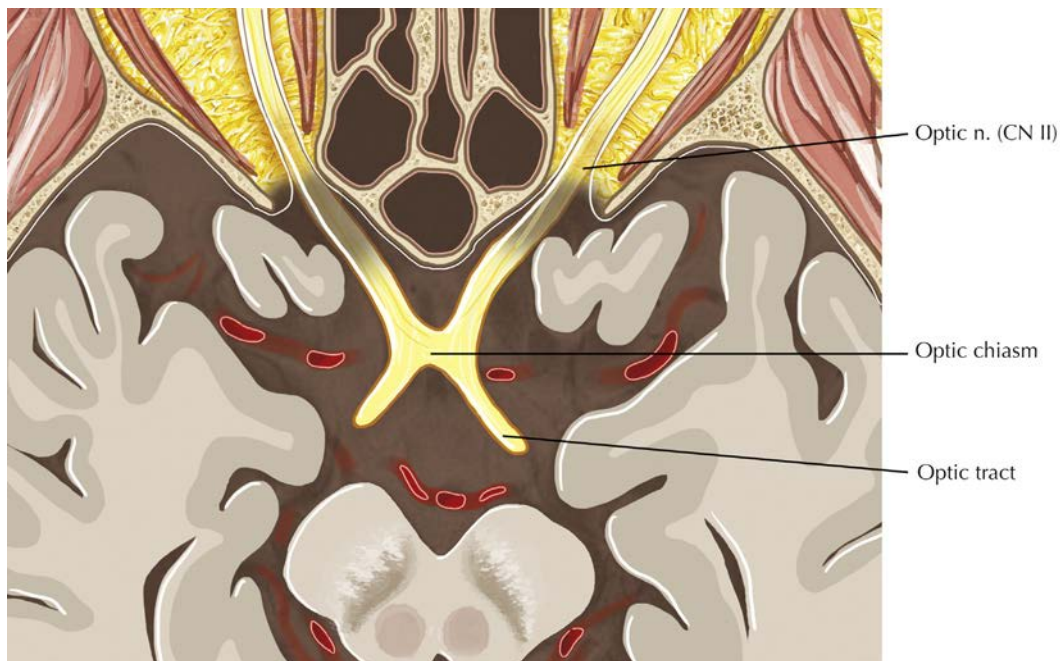




DIAGNOSTIC CONSIDERATION

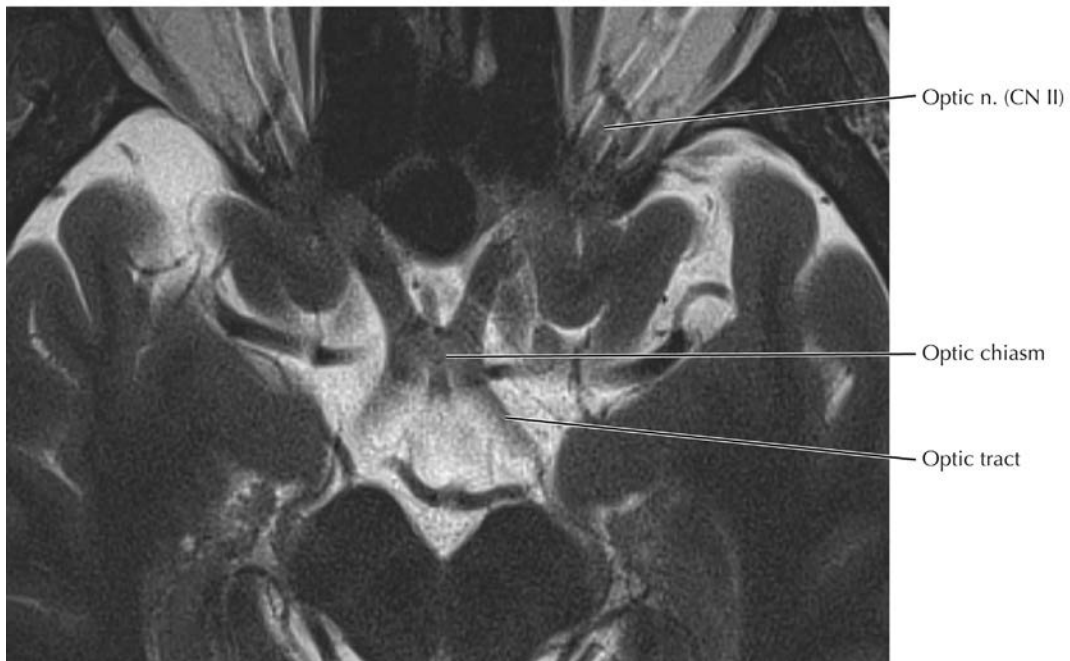
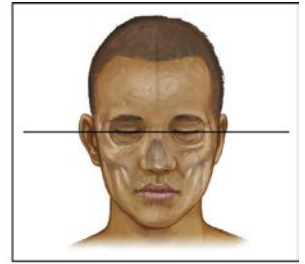
The optic nerve (second cranial, CN II) is the only cranial nerve that is part of the central nervous system. CN II is a direct extension of the brain and thus is surrounded by CSF and a dural sheath. Ophthalmoscopic (fundusoscopic) examination of the eyes can reveal papilledema when intracranial pressure is increased. On axial imaging, flattening of the posterior aspect of the globes has been described as the most specific sign of *idiopathic intracranial hypertension*, also called benign intracranial hypertension or pseudotumor cerebri.

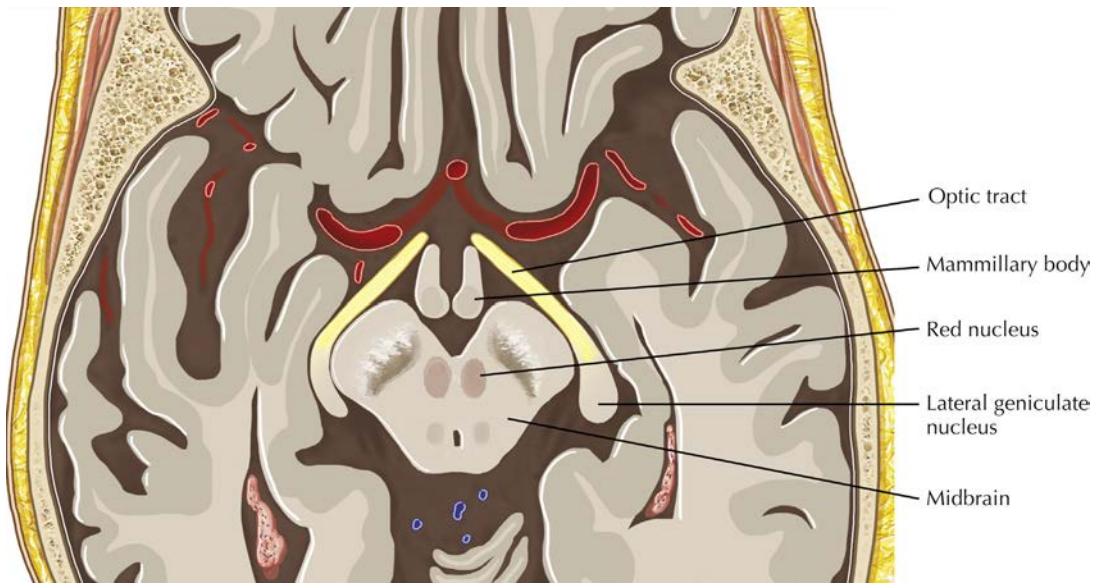




NORMAL ANATOMY AND PATHOLOGIC CONSIDERATION

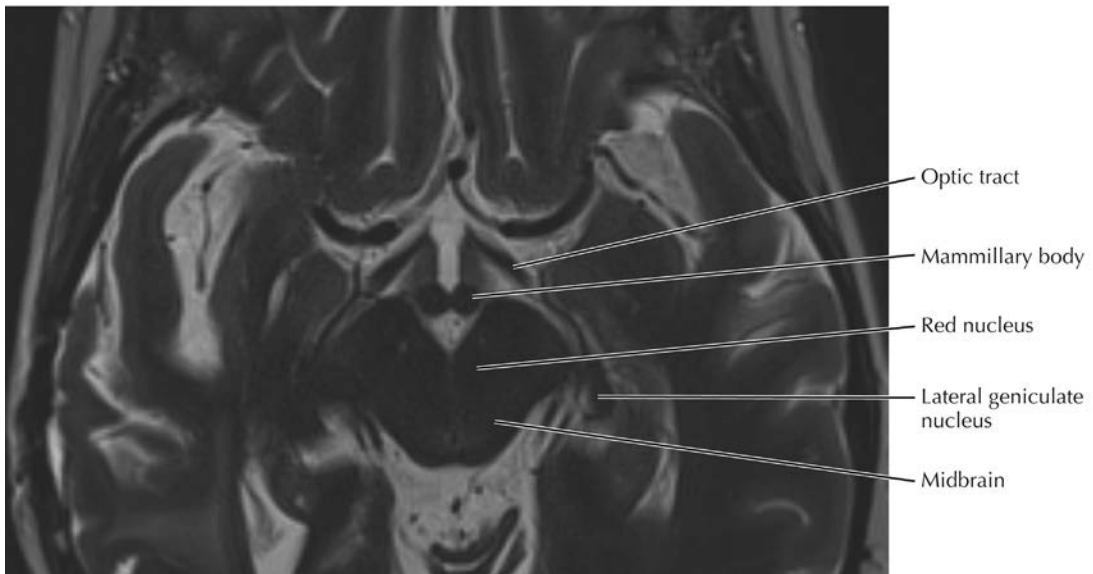
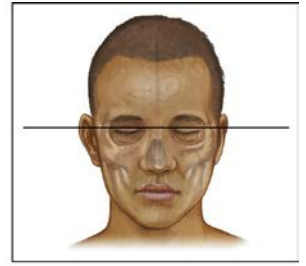
Sensory signals from the retina transmit posteriorly along the optic nerves until the signals join at the optic chiasm, where the medial fibers of each nerve cross to the other side. The optic chiasm is immediately superior to the pituitary gland (hypophysis) and suprasellar cistern. A large pituitary adenoma therefore can compress the crossing fibers, leading to *bitemporal hemianopia* (or hemianopsia), with defects in the temporal, or lateral, half of the visual field in each eye. A light object in the temporal (lateral) field of view sends light through the lens to the nasal (medial) retina, which then sends signals through the medial fibers of the optic nerves, which in turn cross midline at the optic chiasm.

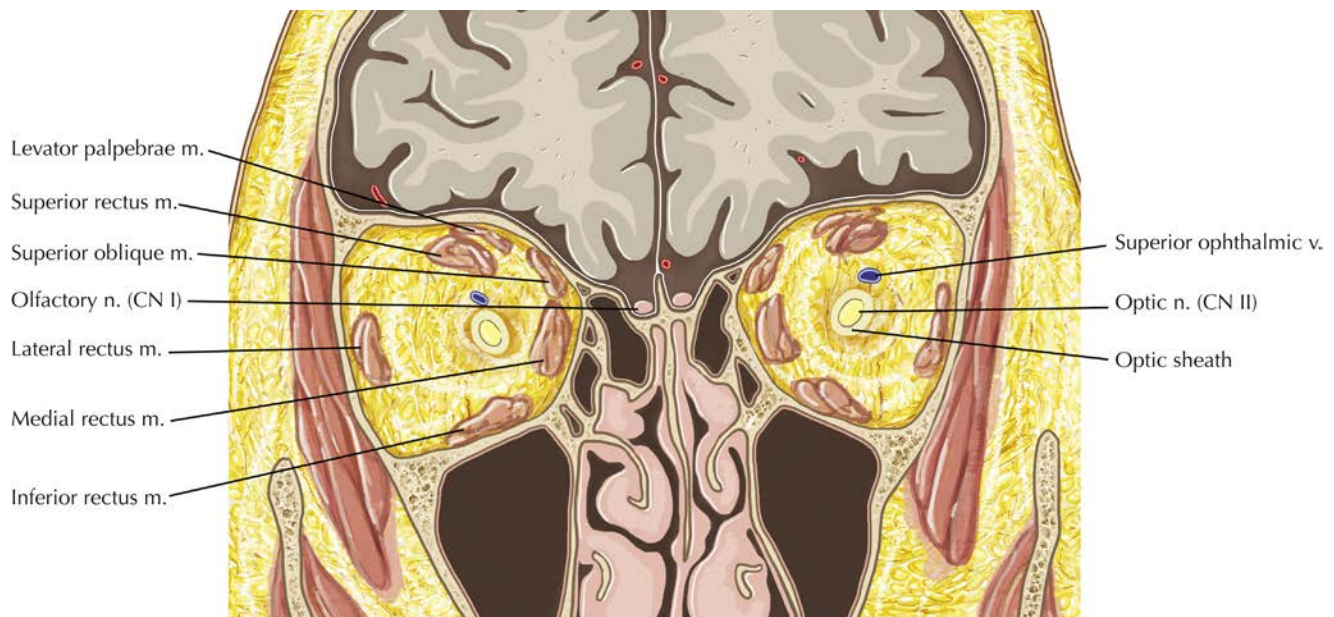




NORMAL ANATOMY

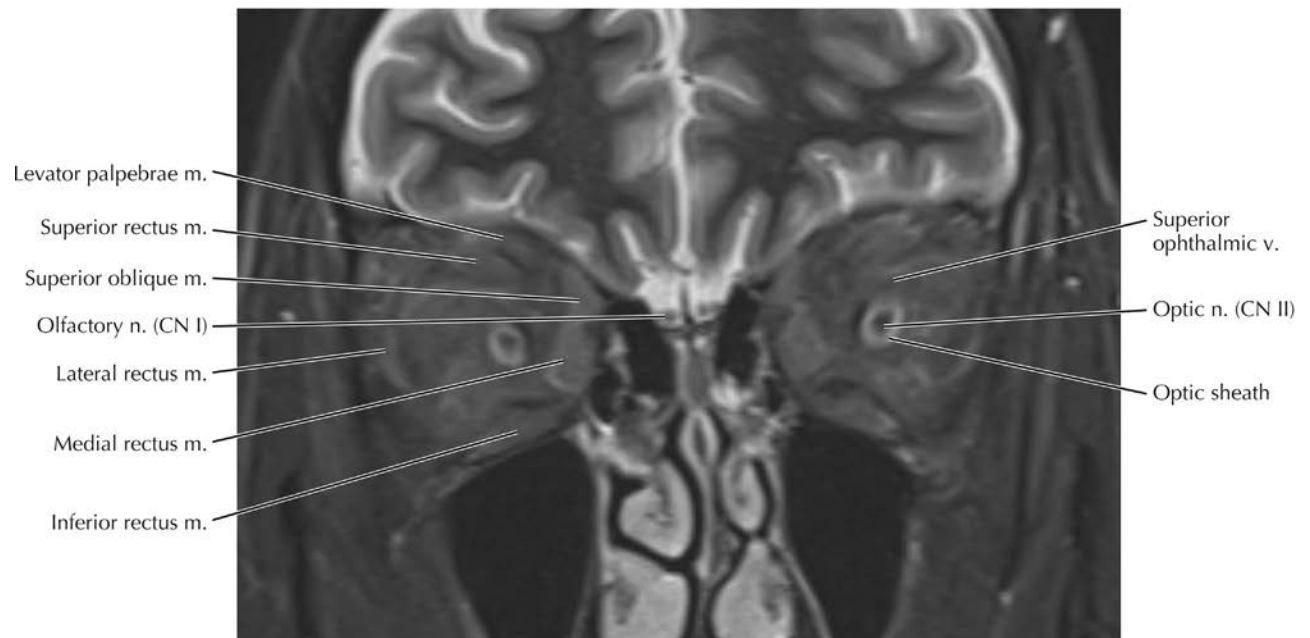
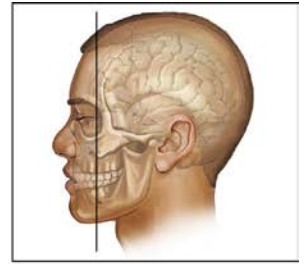
The optic tract contains the lateral, or temporal, nerves of the ipsilateral optic nerve and the medial, or nasal, nerves of the contralateral optic nerve. The optic tract joins the optic chiasm to the lateral geniculate nucleus (LGN). The LGN is located within the thalamus and is the primary relay center for visual information received from the retina. A mass along the optic tract can cause contralateral hemianopia, with blocked signals at the right optic tract causing a left-sided hemianopia.





DIAGNOSTIC CONSIDERATION

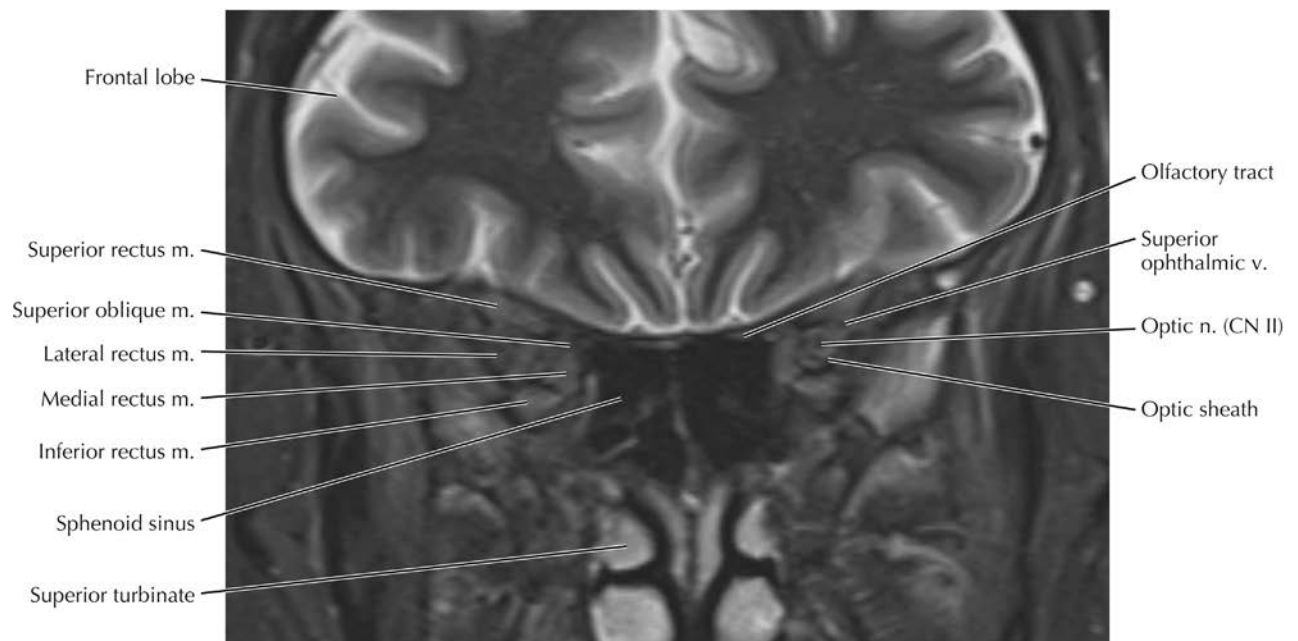
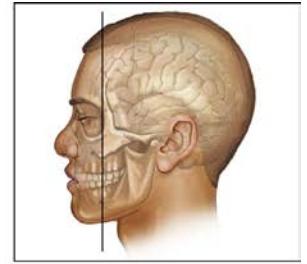
The coronal plane is often the best imaging plane to assess the optic nerve (CN II). Note the ring of cerebrospinal fluid around the optic nerves. As an extension of the brain and dura, the optic nerve sheath complex is subject to the same pathology, such as a glioma of the optic nerves or meningioma of the surrounding dural sheath. This coronal plane is often the best plane to identify a mass arising from the sheath and compressing the optic nerve, versus an expansion of the optic nerve.

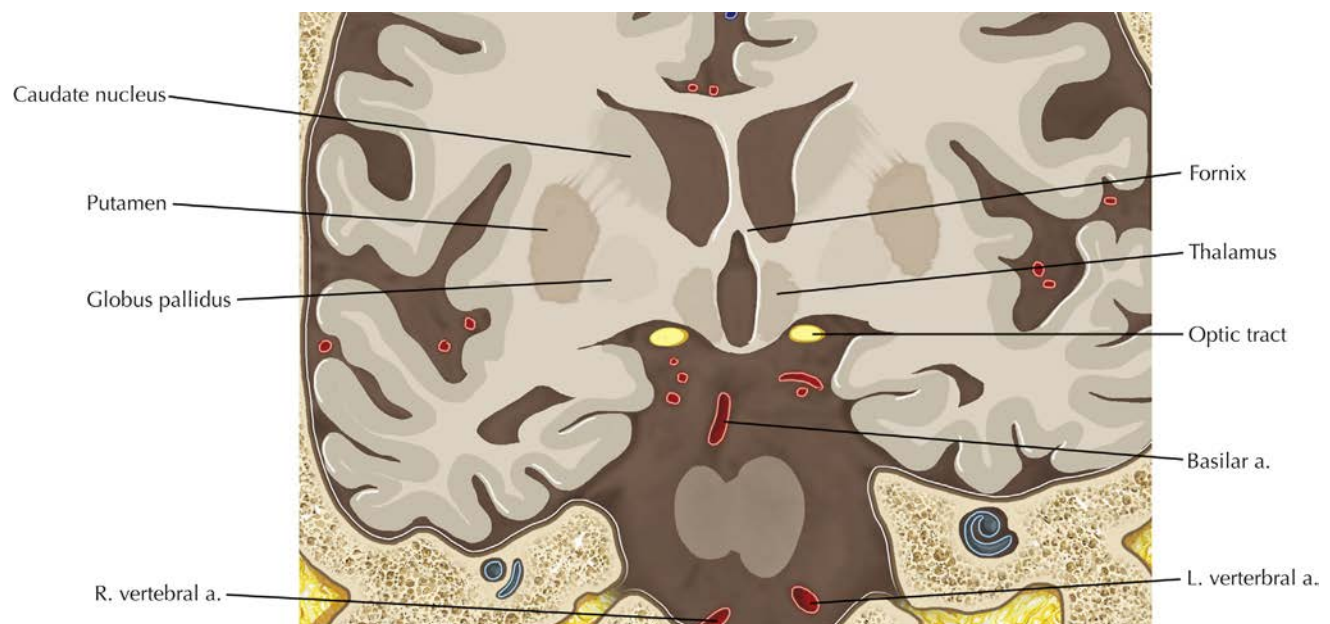


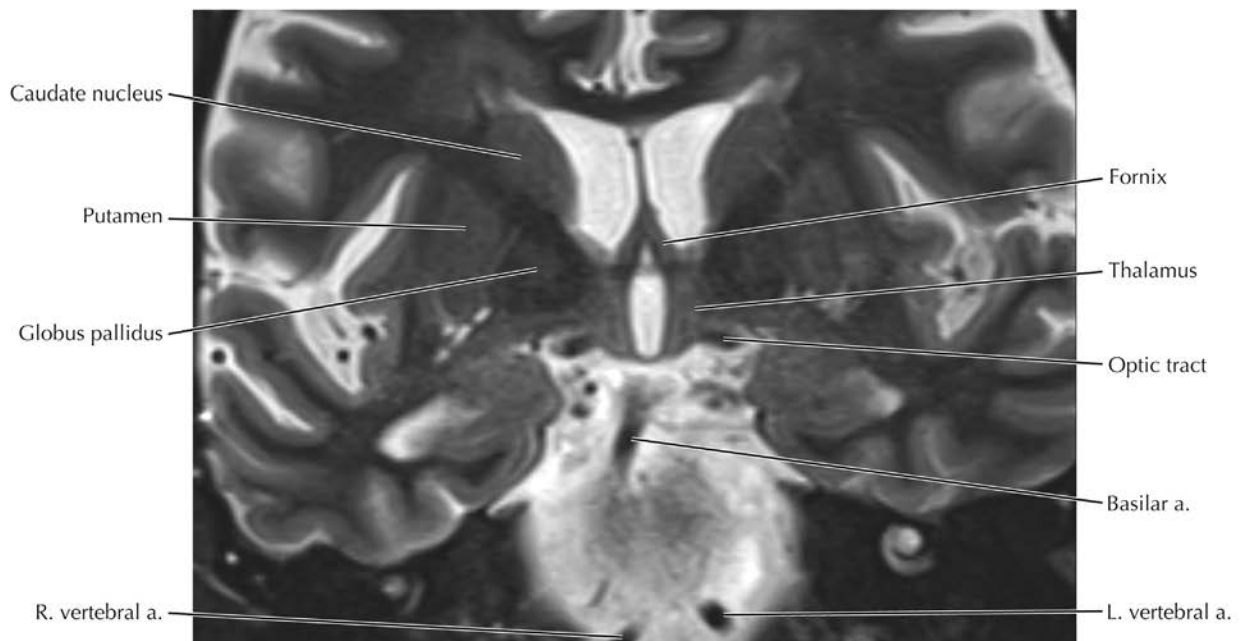
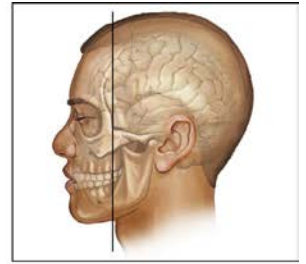


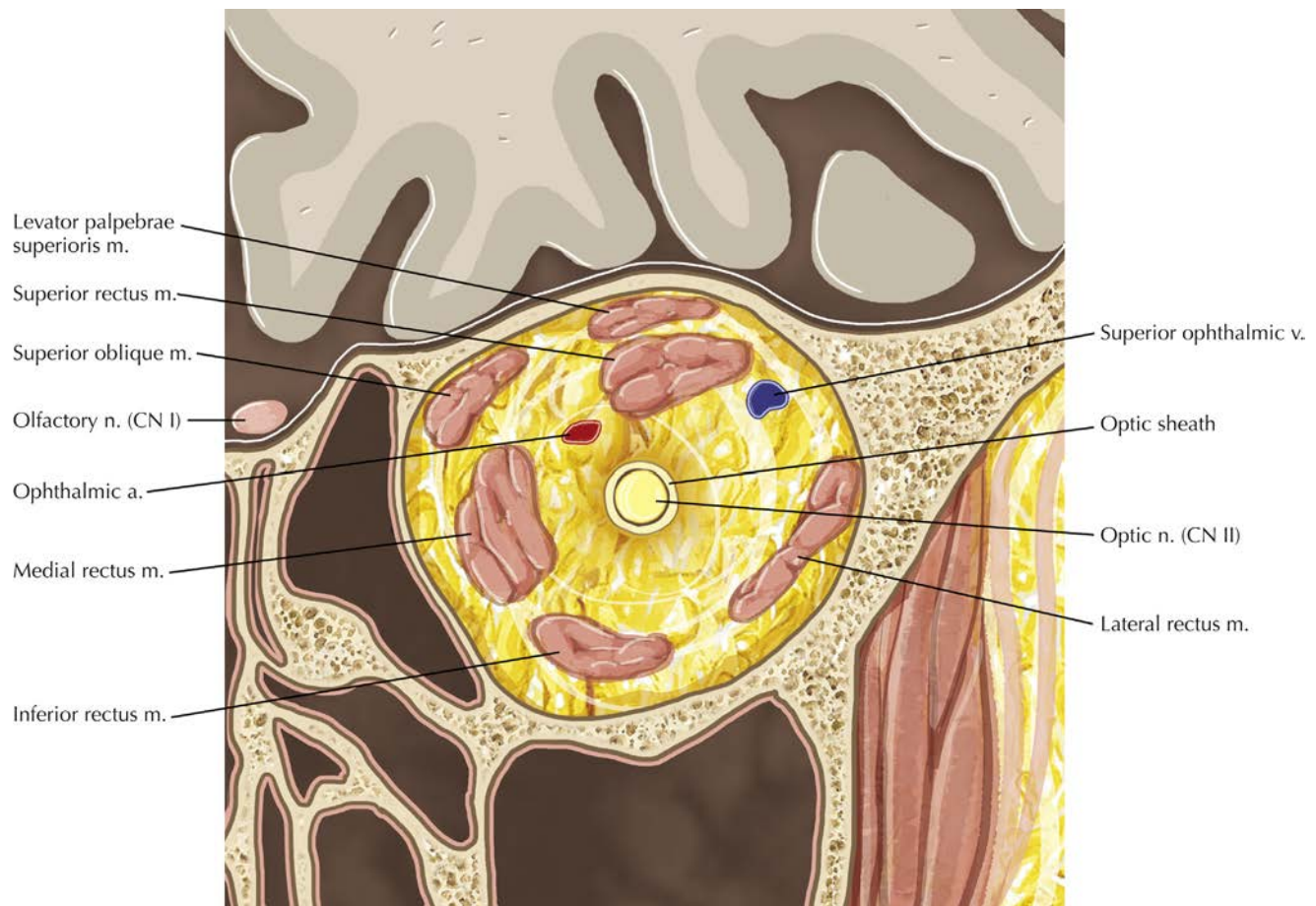
NORMAL ANATOMY

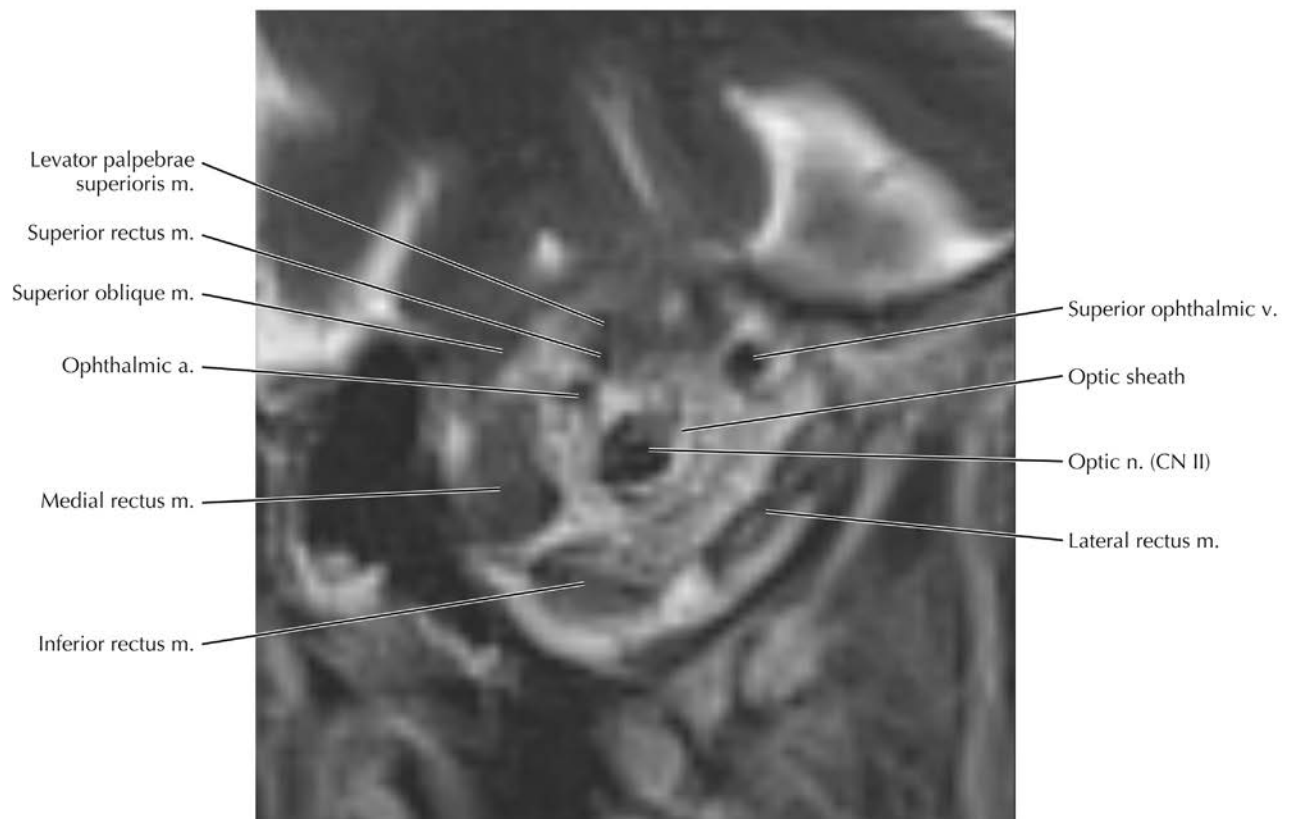
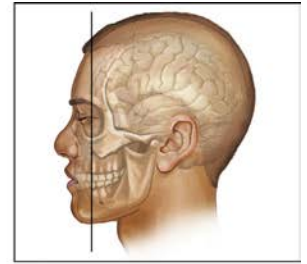
Note the superior ophthalmic vein above the optic nerve. Abnormal shunting of arterial blood into the cavernous sinus, as in a post-traumatic carotid cavernous fistula (CCF), will cause enlargement of the superior ophthalmic vein.

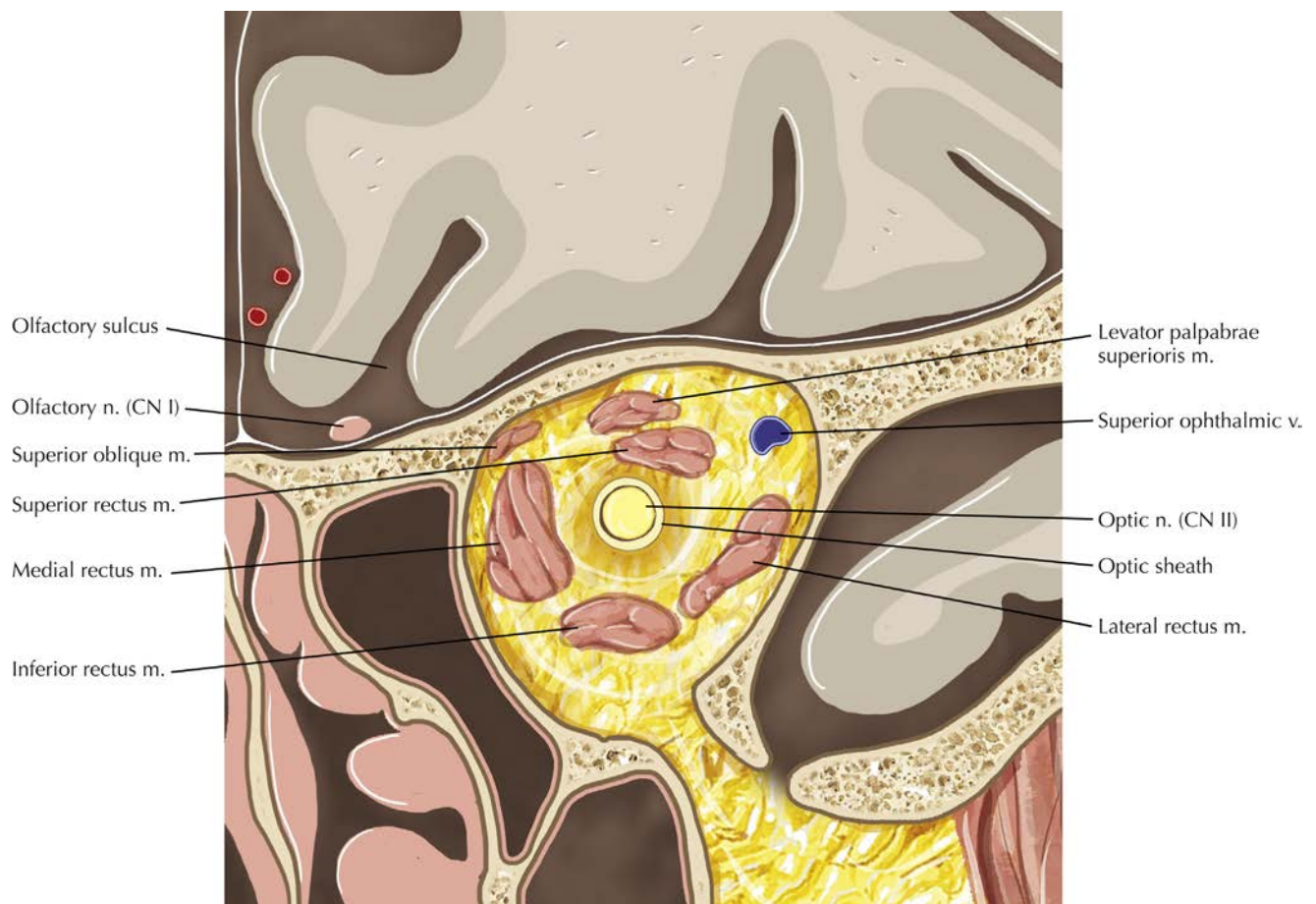


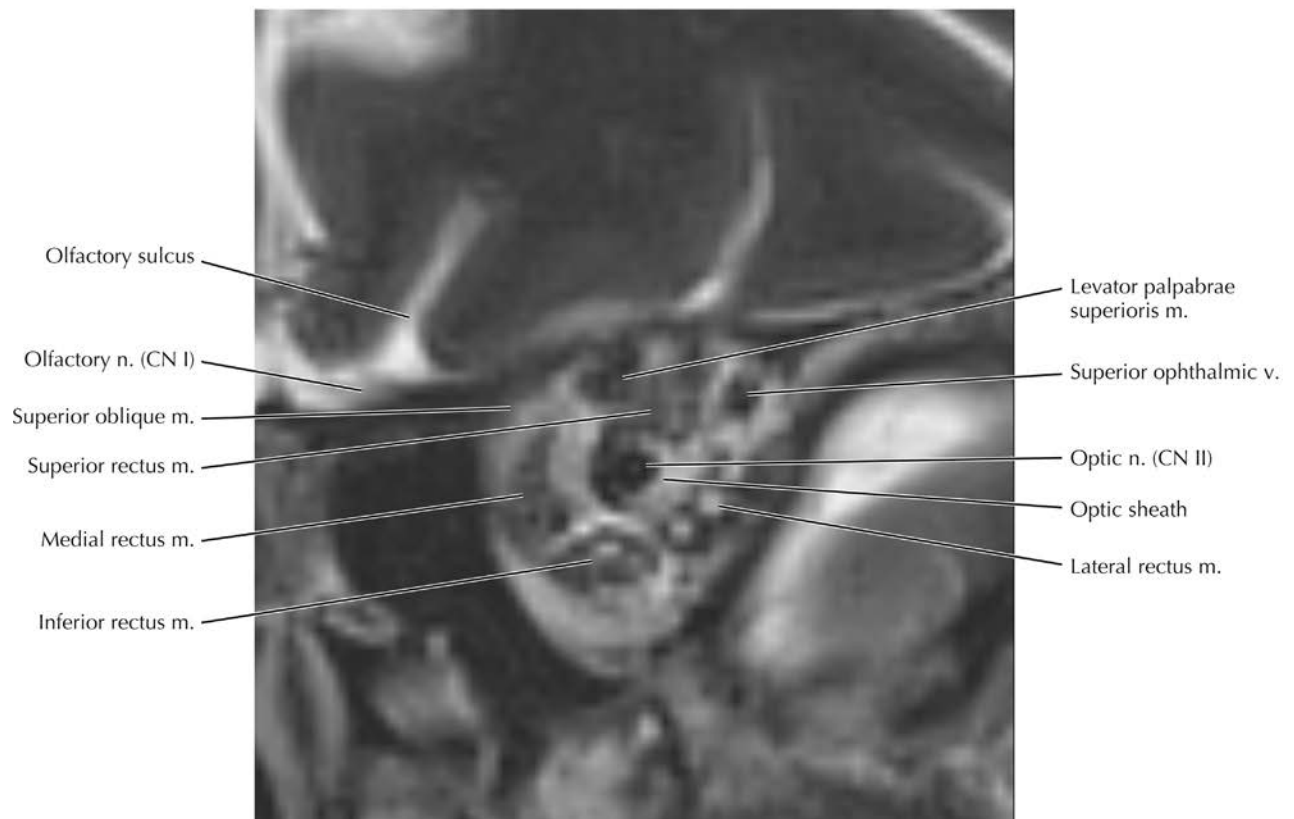
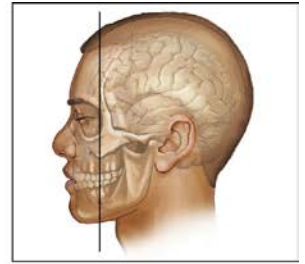








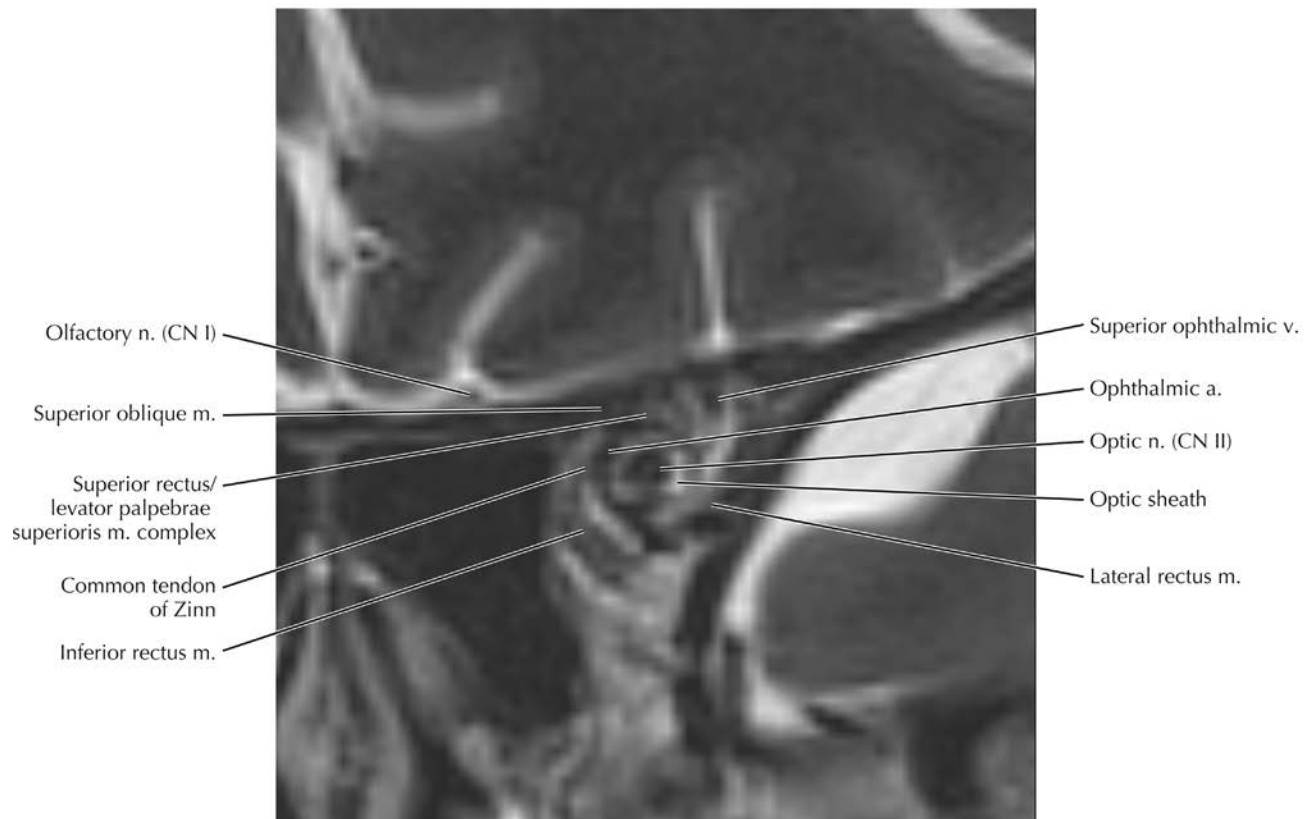
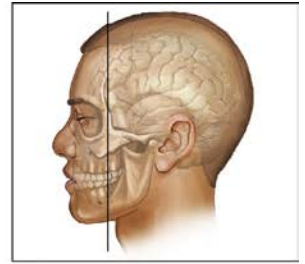


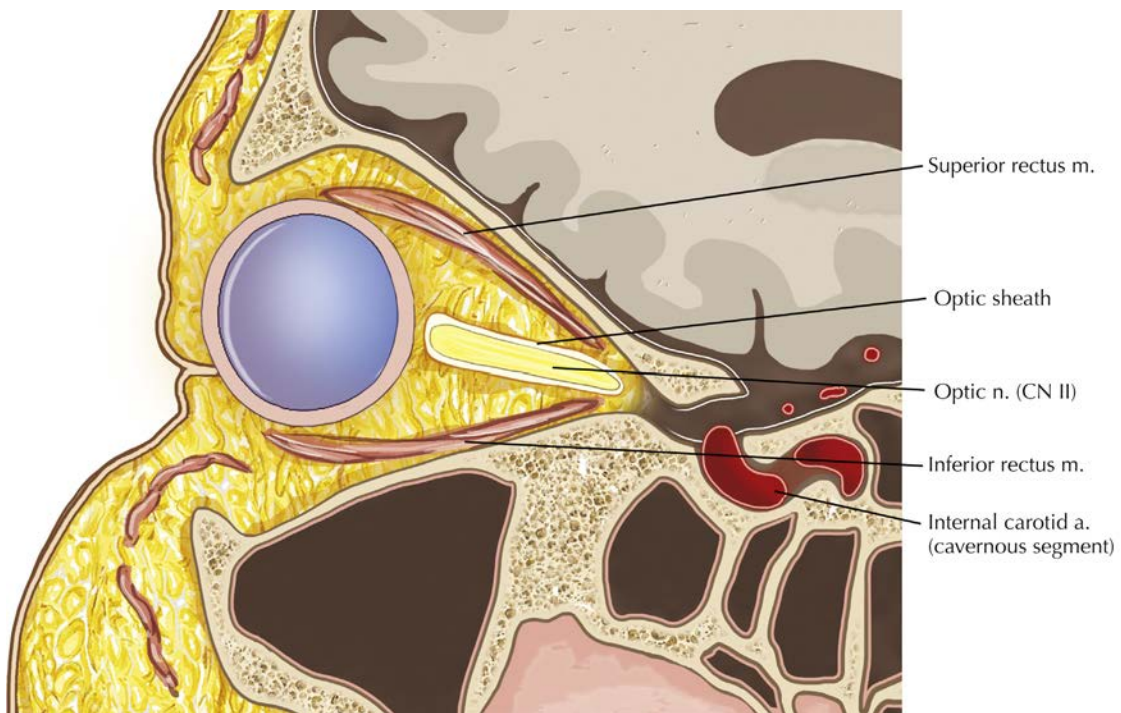




DIAGNOSTIC CONSIDERATION

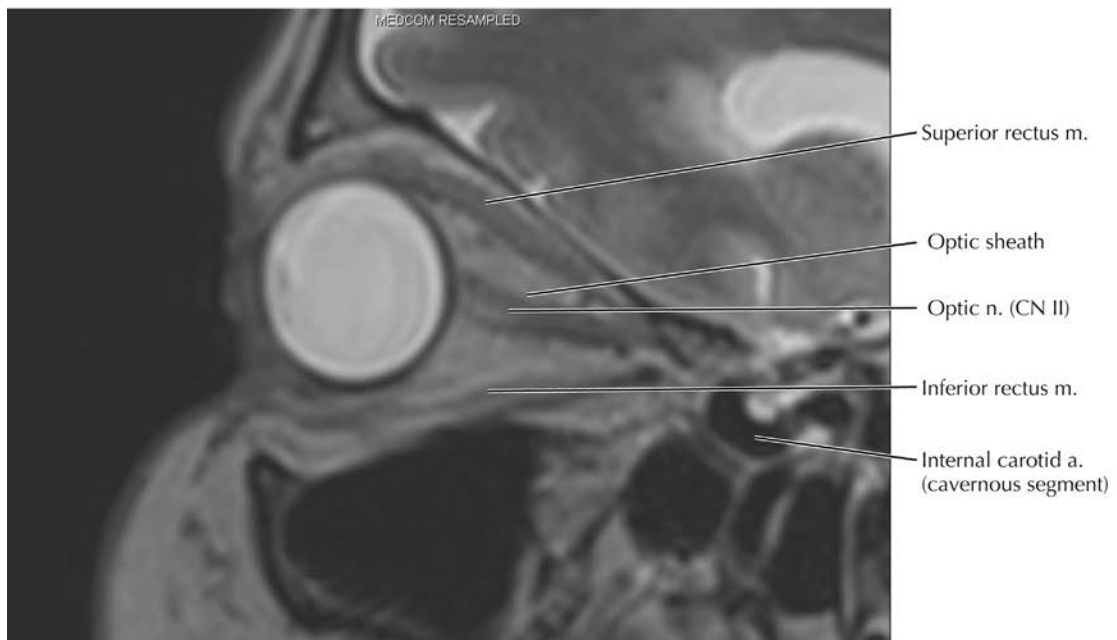
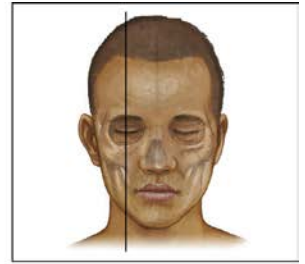
As the optic nerve passes posteriorly in the orbit toward the apex, it is often difficult to separate the nerve from the surrounding orbital muscles and bony walls of the apex. Subtle lesions may be detected best on a coronal oblique image aligned perpendicular to the optic nerve, as seen in this image.

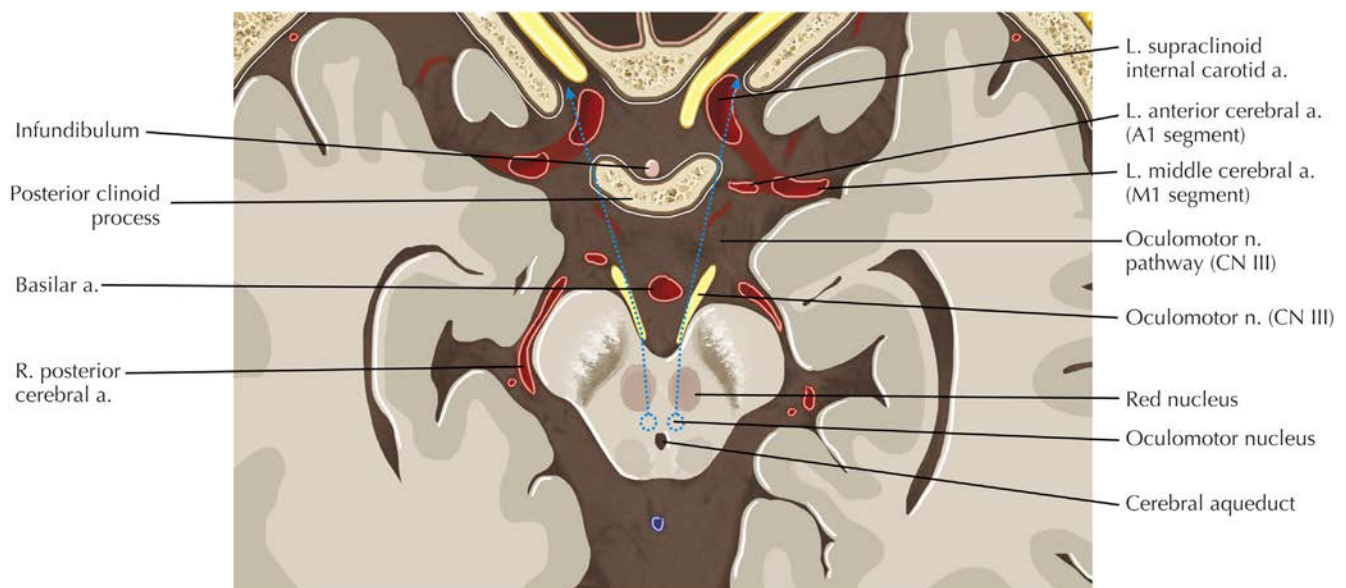




NORMAL ANATOMY

Pathology, such as a posterior cerebral infarct involving the left occipital lobe, may result in a right-sided visual field deficit in each eye.

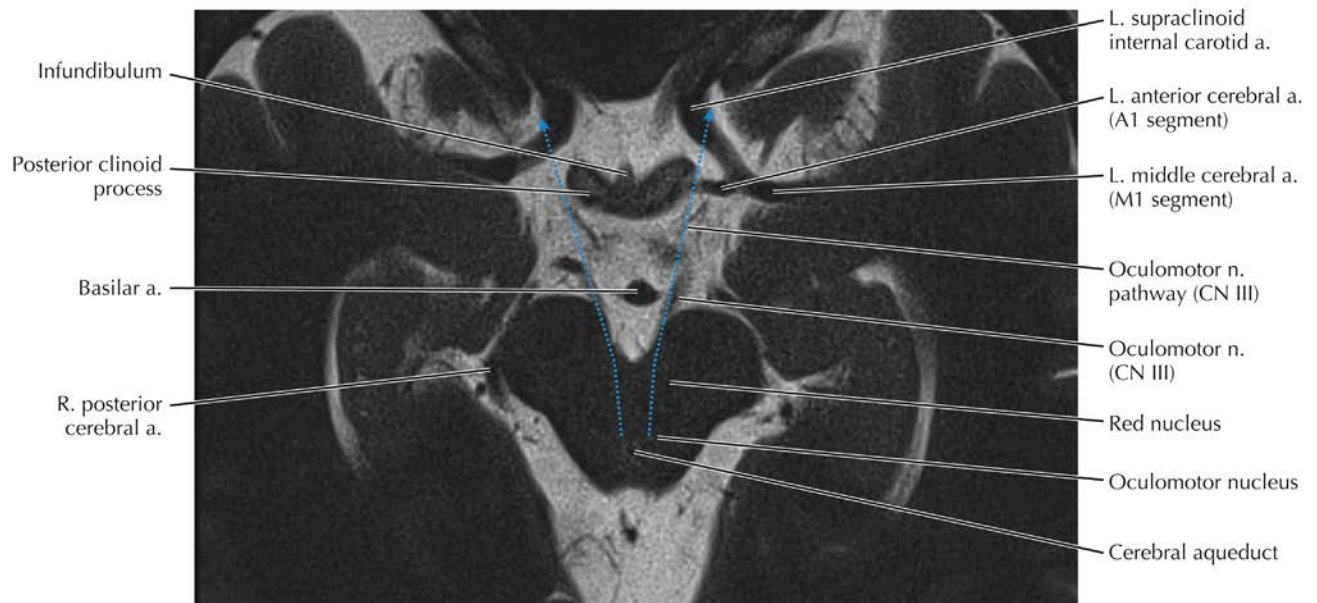
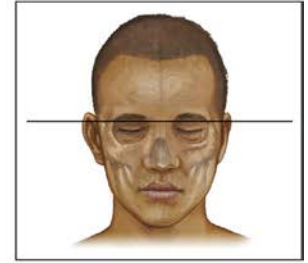




NORMAL ANATOMY

The oculomotor nerve (CN III) is the third of the 12 pairs of cranial nerves. CN III arises from two nuclei. The *oculomotor nucleus* originates at the level of the superior colliculus and controls the striated muscle in the levator palpebrae superioris and all extraocular muscles, except the superior oblique and lateral rectus muscles (see also Optic Coronal 6). *Edinger-Westphal* (accessory oculomotor) *nuclei* supply parasympathetic fibers to the eye through the ciliary ganglia and control the sphincter pupillae muscle for pupil constriction and the ciliary muscle for accommodation.

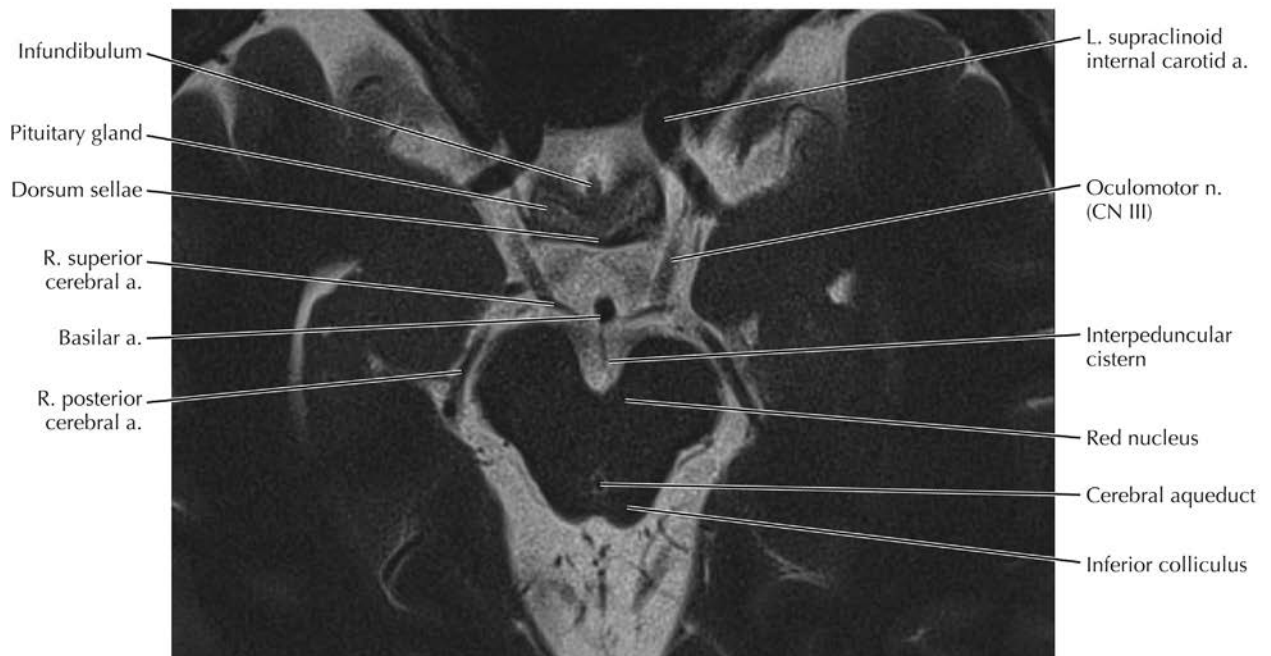
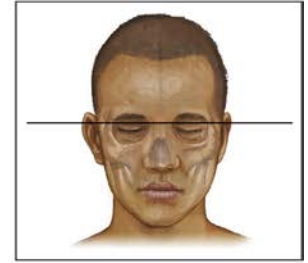
Fibers for the oculomotor nerve pass anteriorly from the oculomotor nucleus through the red nucleus and substantia nigra and exit the brainstem at the interpeduncular fossa.



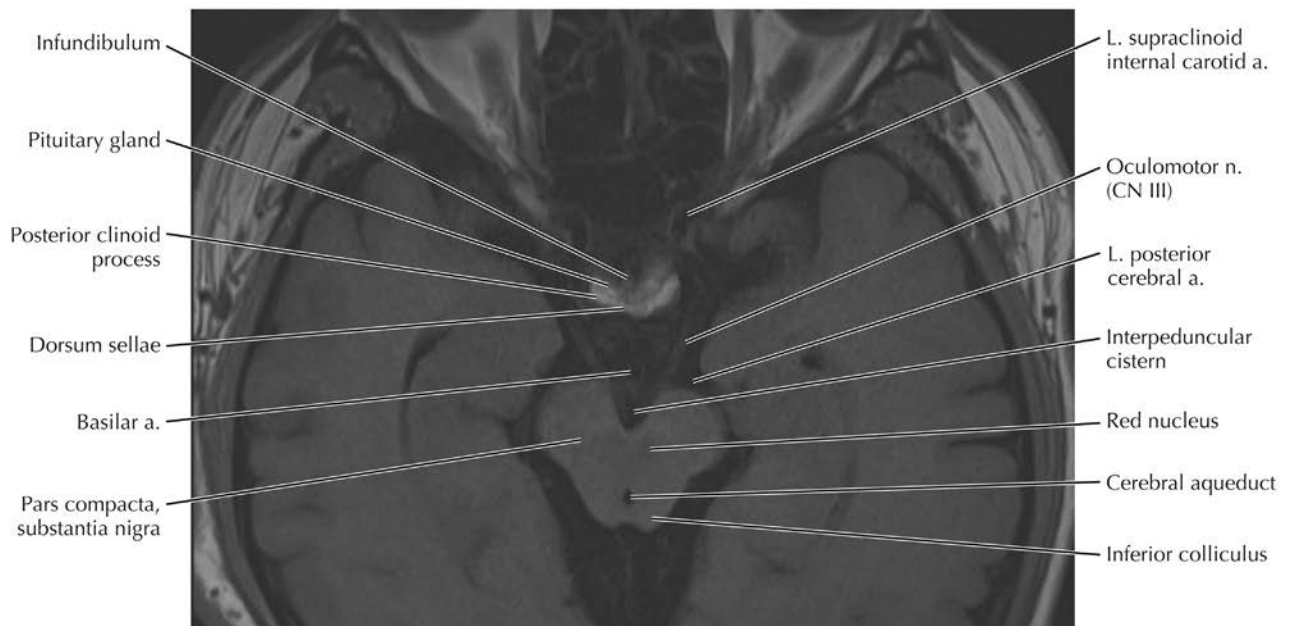
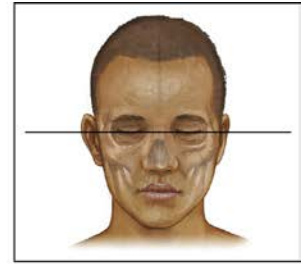


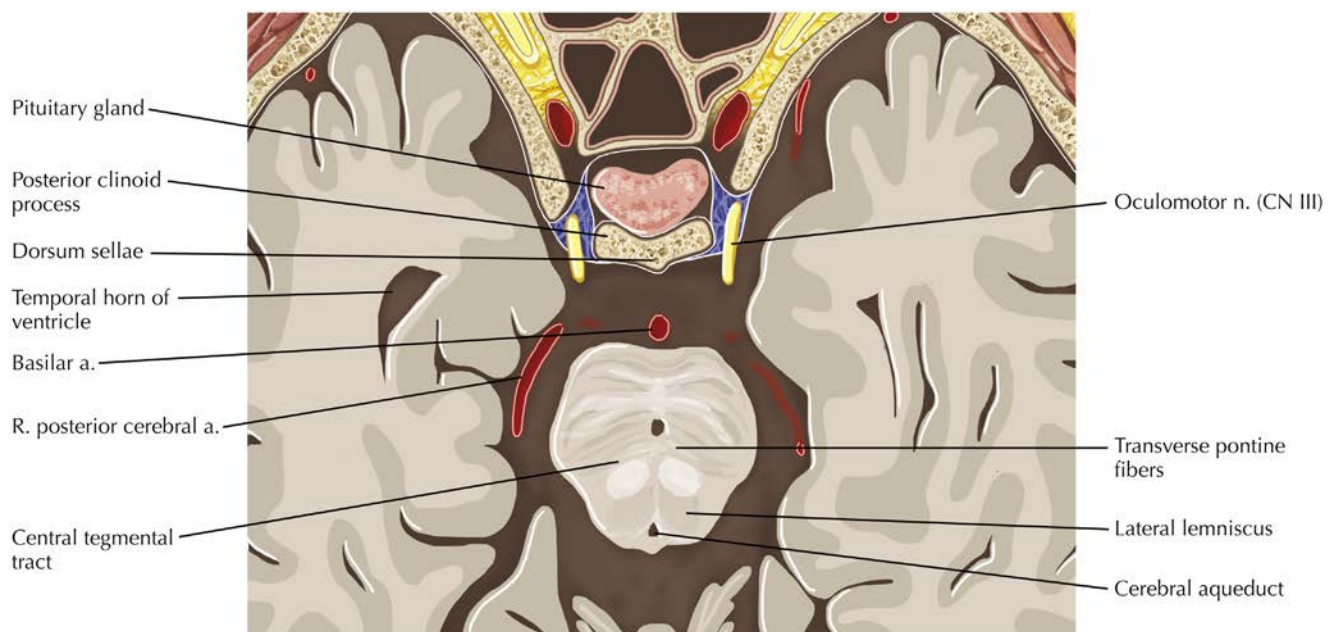
PATHOLOGIC PROCESS

The cisternal segment of the oculomotor nerve is intimately associated with blood vessels of the circle of Willis. After exiting the brainstem, CN III passes anteriorly between the posterior cerebral and superior cerebellar arteries and parallels the posterior communicating artery before entering the cavernous sinus. An aneurysm arising from the origin of the posterior communicating artery off the internal carotid artery classically causes compression of CN III, leading to oculomotor nerve palsy.



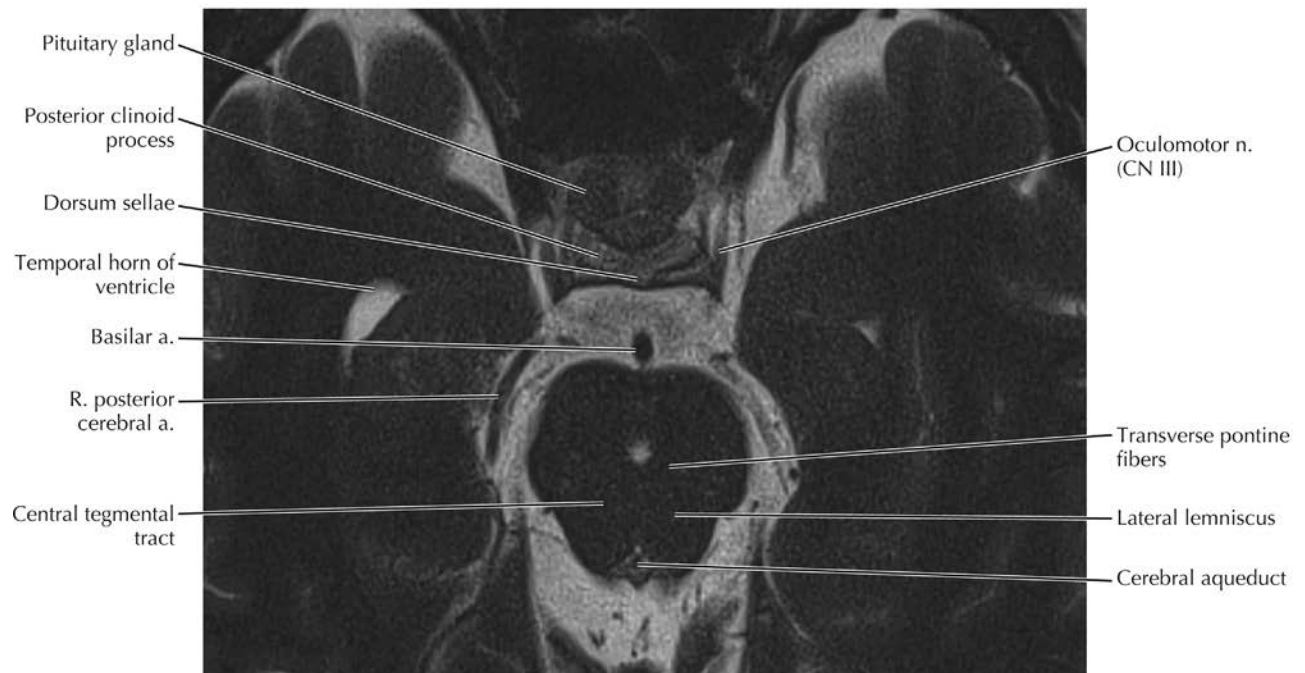
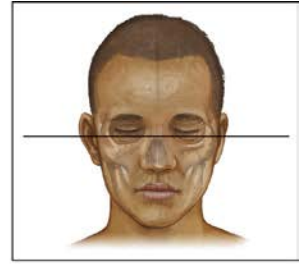






NORMAL ANATOMY

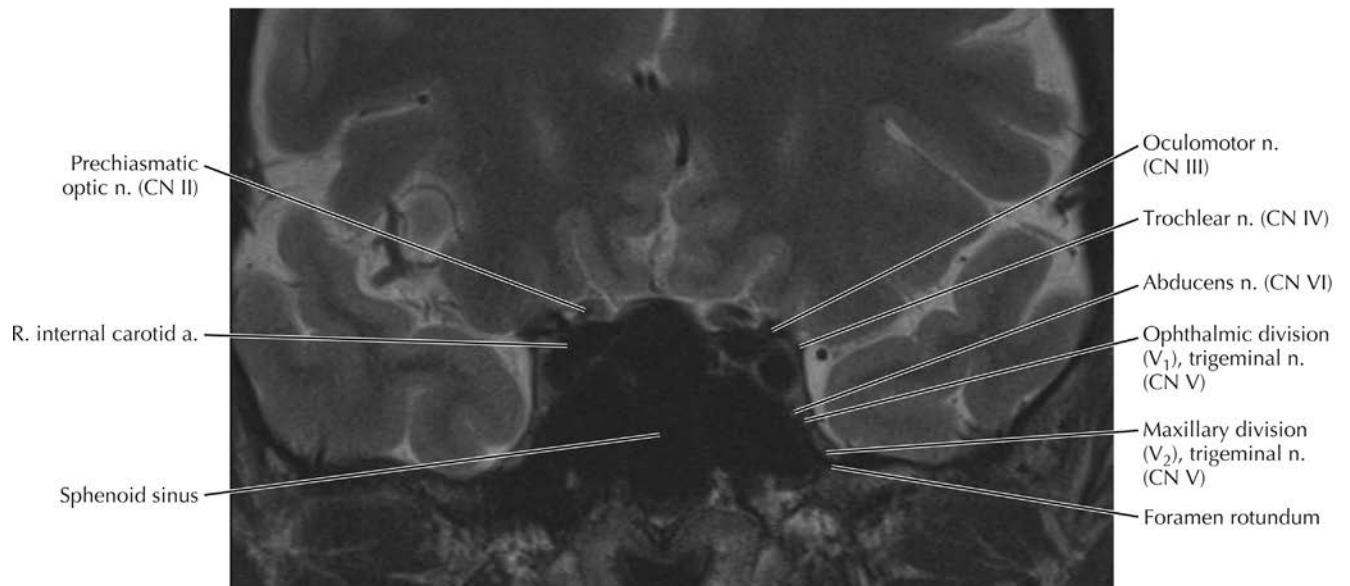
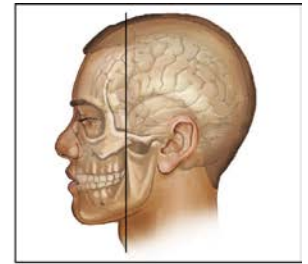
Note there is an incidental tiny cyst in the middle of the pons on this image. The aqueduct is located more posteriorly.

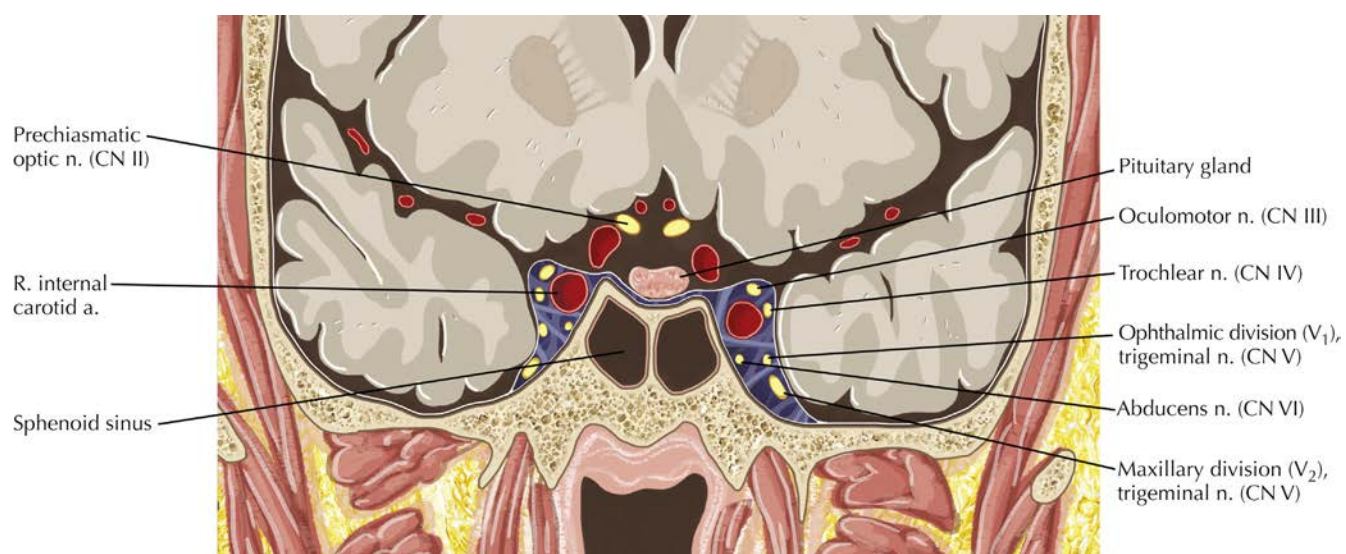


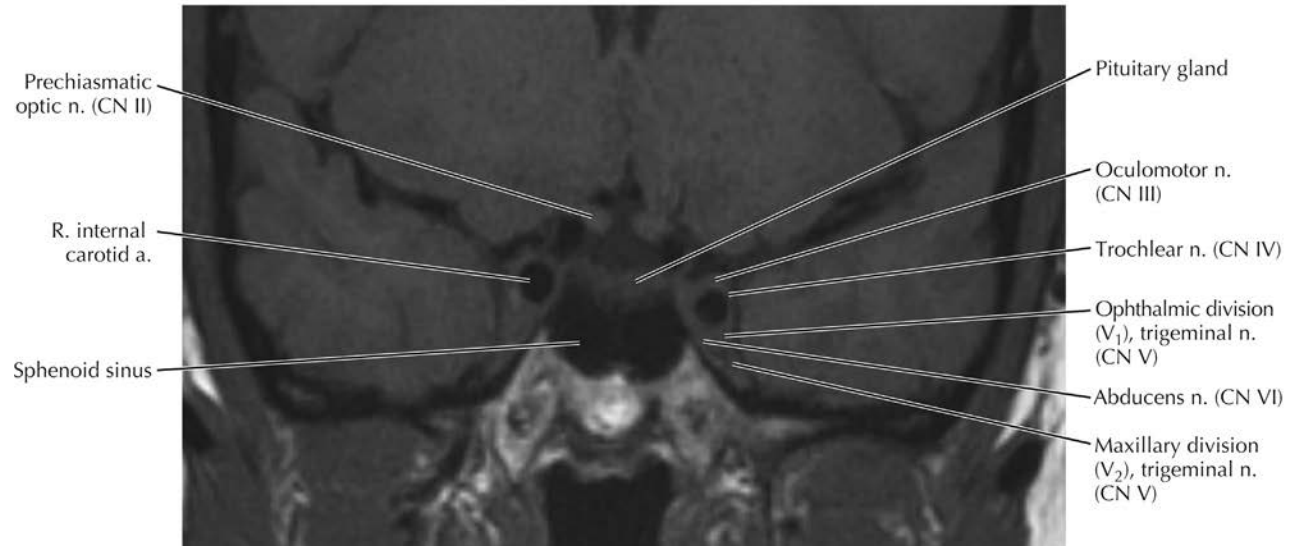
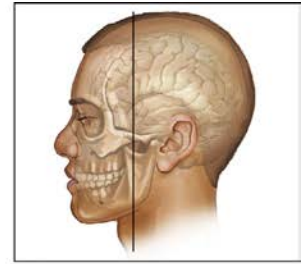


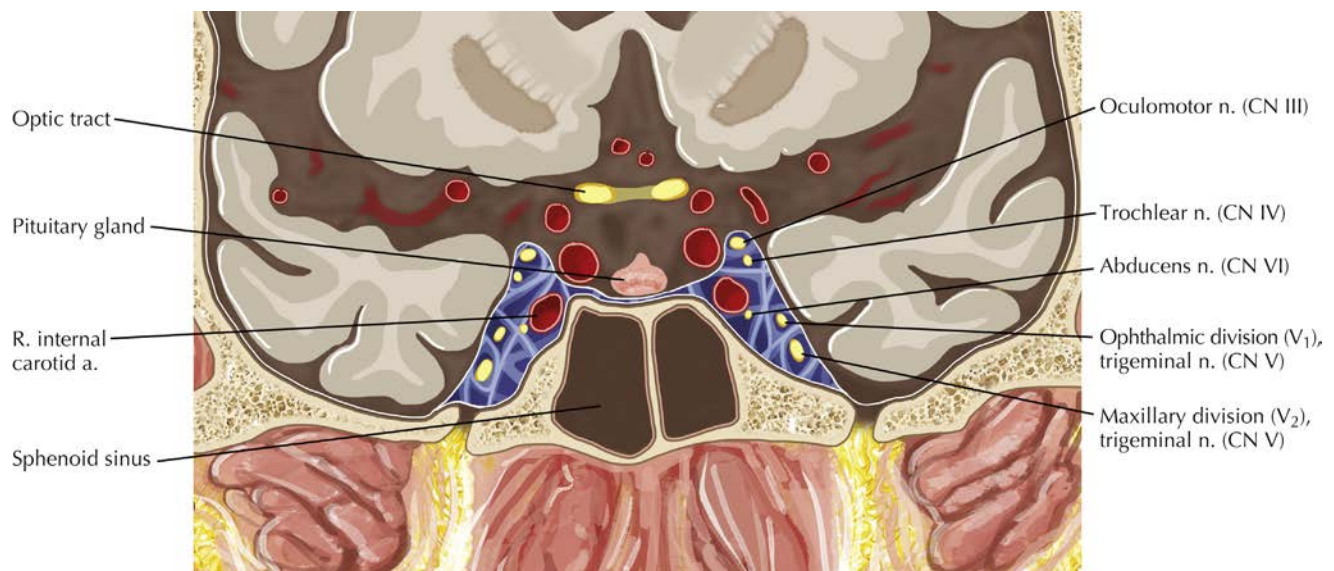
NORMAL ANATOMY

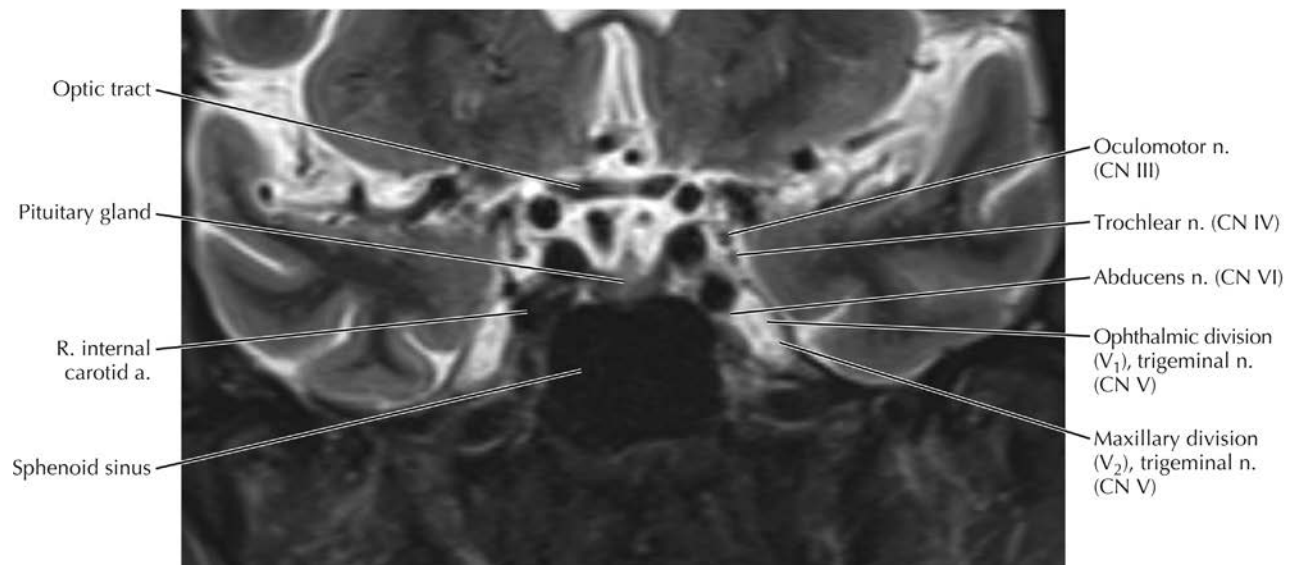
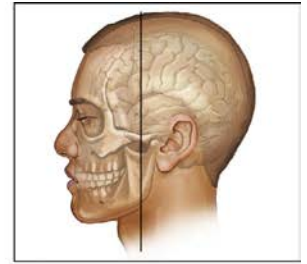
The oculomotor nerve (CN III) is the most superior of the cranial nerves in the cavernous sinus.



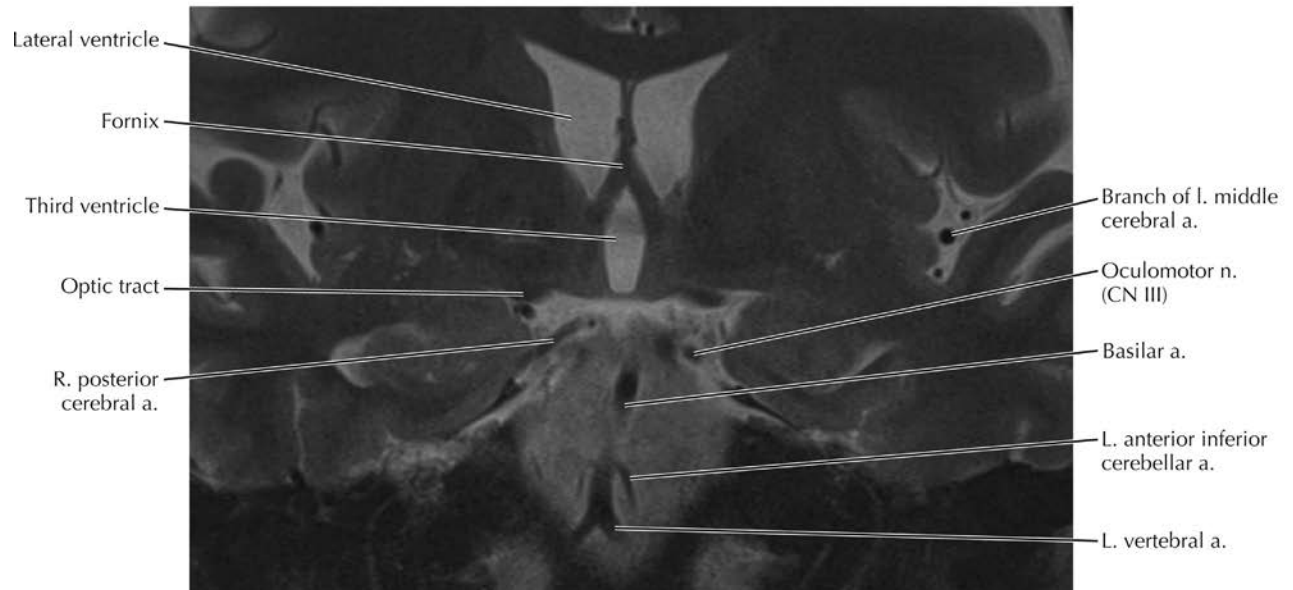
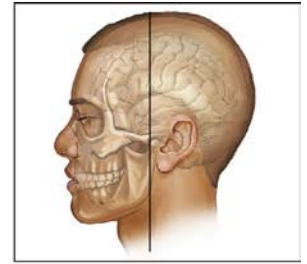








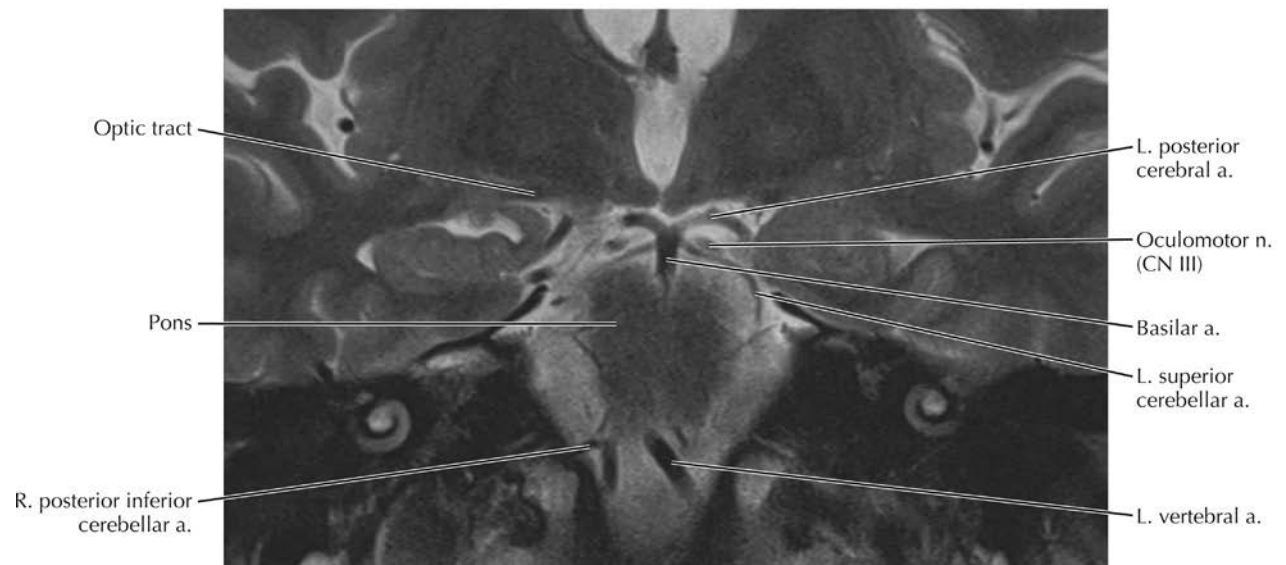
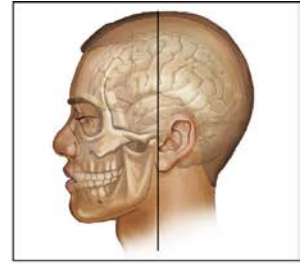


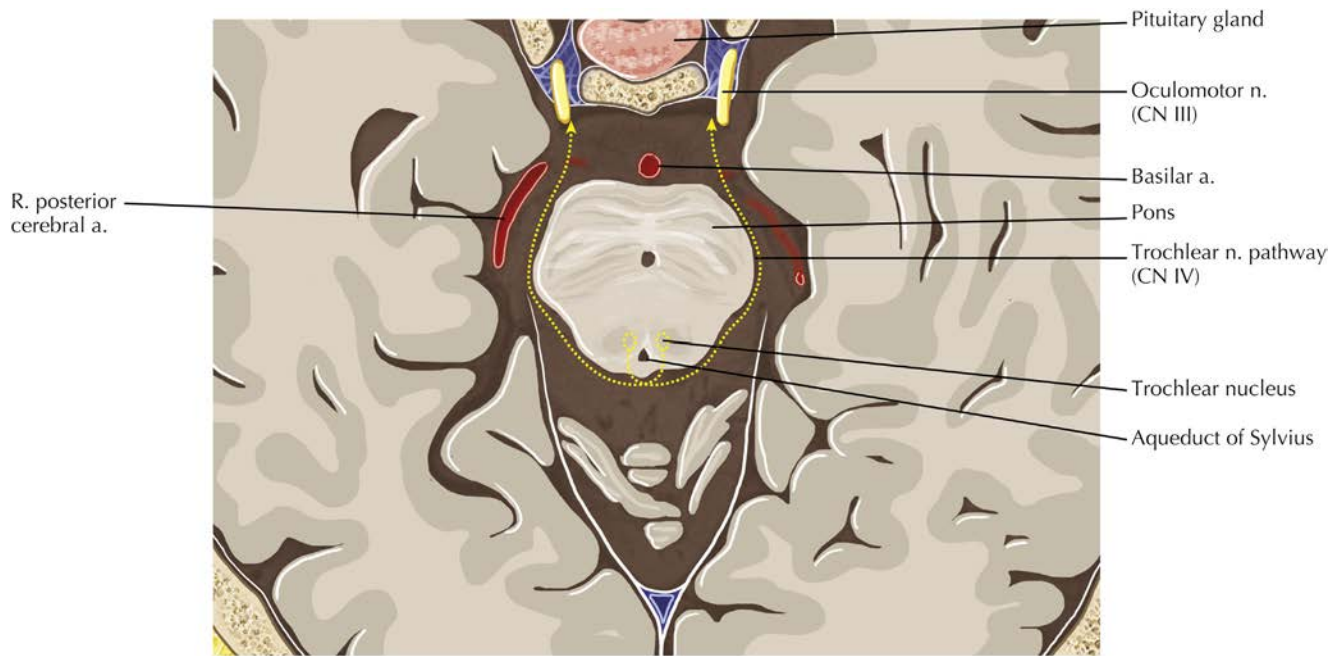




NORMAL ANATOMY

Note the oculomotor nerve passing between the posterior cerebral artery and superior cerebellar artery.

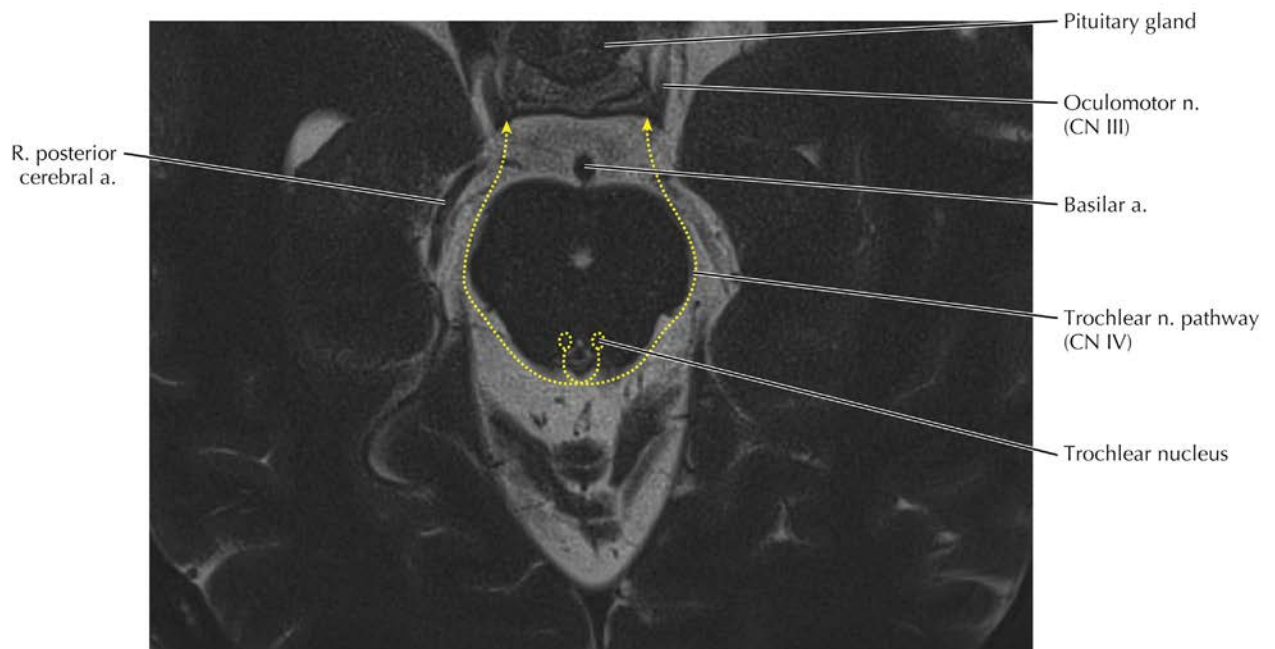
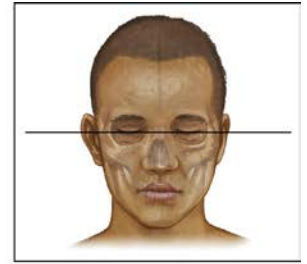


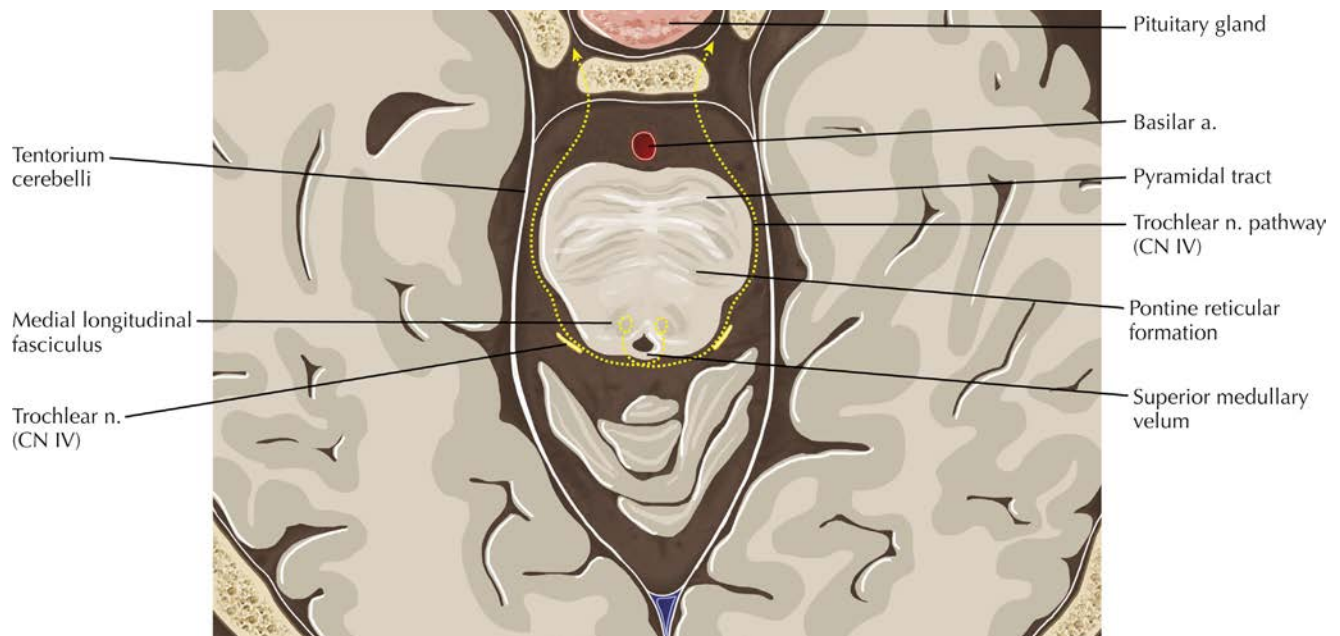


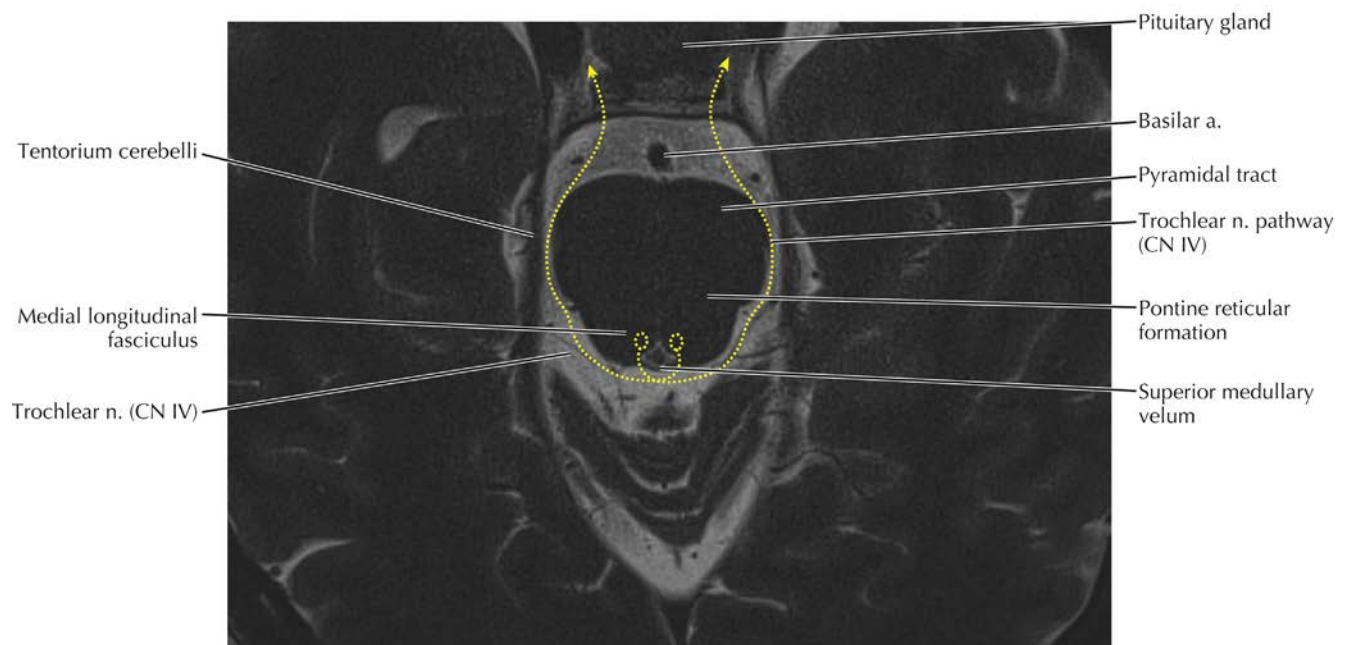
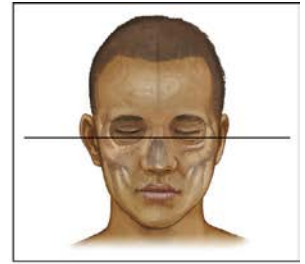
NORMAL ANATOMY

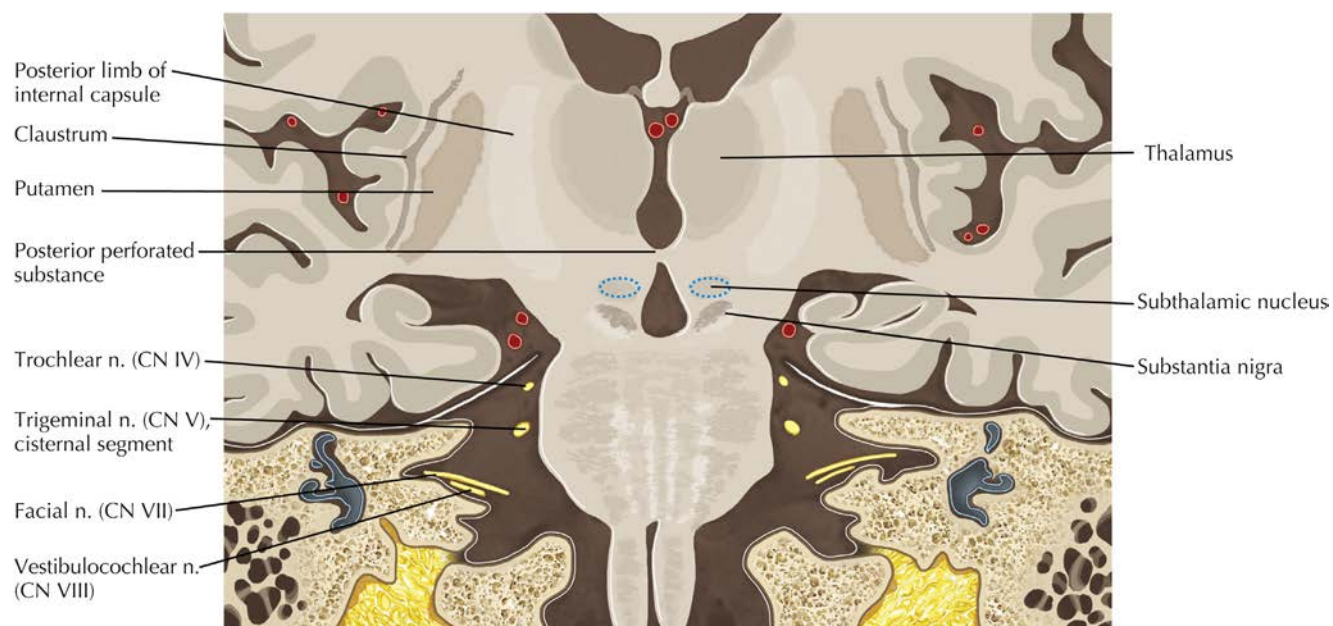
The trochlear nerve (fourth cranial, CN IV) is a motor nerve innervating the superior oblique muscle of the orbit. Contraction of this muscle will point the eye medially and inferiorly toward the tip of the nose. CN IV is the thinnest cranial nerve but the longest intracranially, the only cranial nerve to exit the brainstem dorsally. The trochlear nerve is also the only cranial nerve to cross the midline posterior to the brainstem, with the medial fibers of the optic nerve the only other cranial nerve to cross the midline.

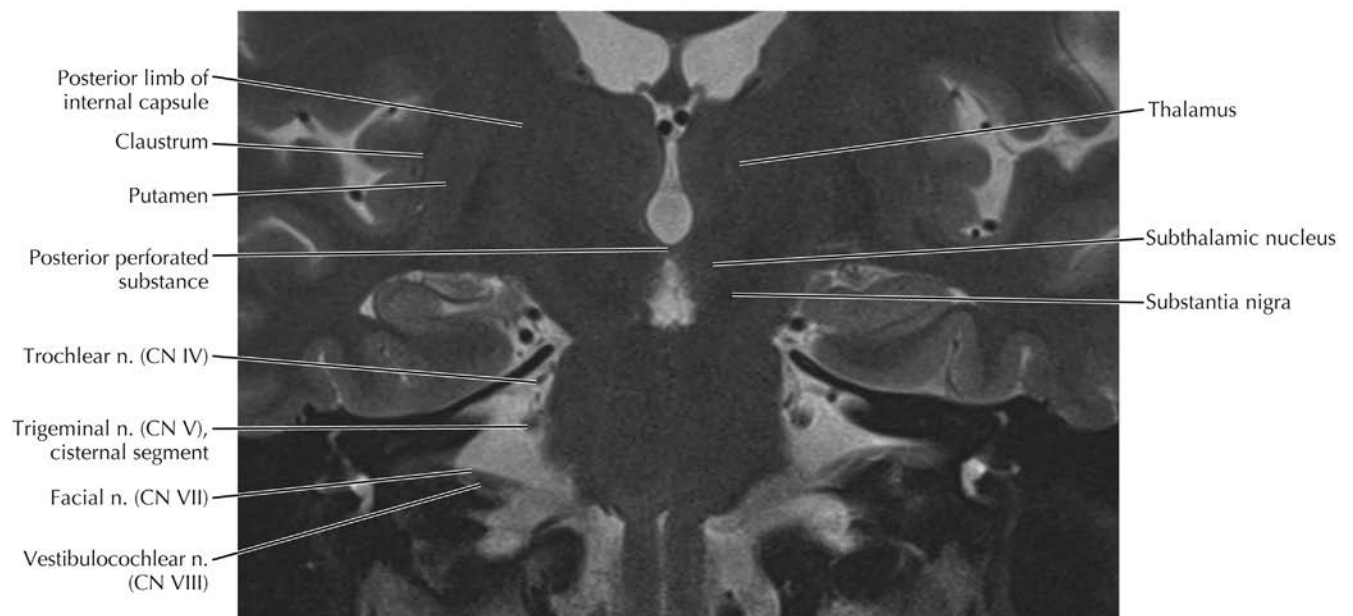
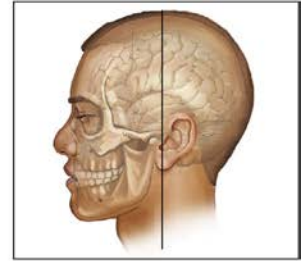
The tiny incidental cyst in the middle of the pons in this axial MR image is not the aqueduct of Sylvius (cerebral aqueduct), which can be seen between the trochlear nuclei. The dark signal in the middle of the aqueduct is caused by CSF flow.

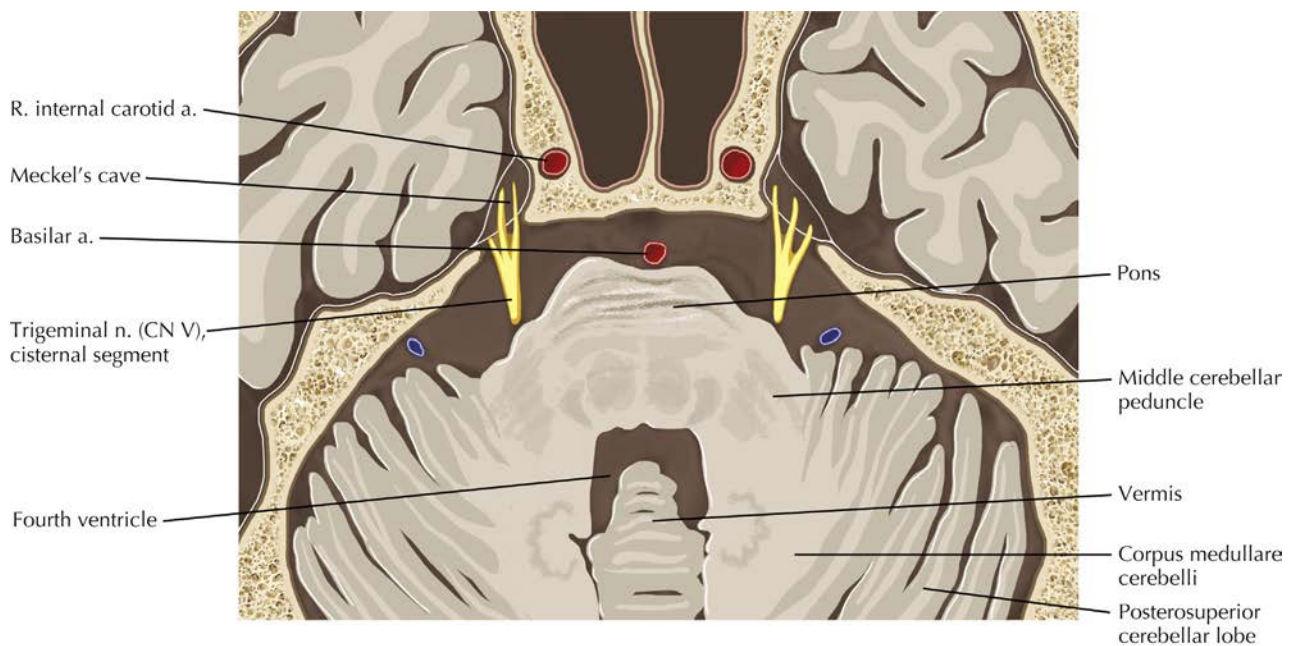








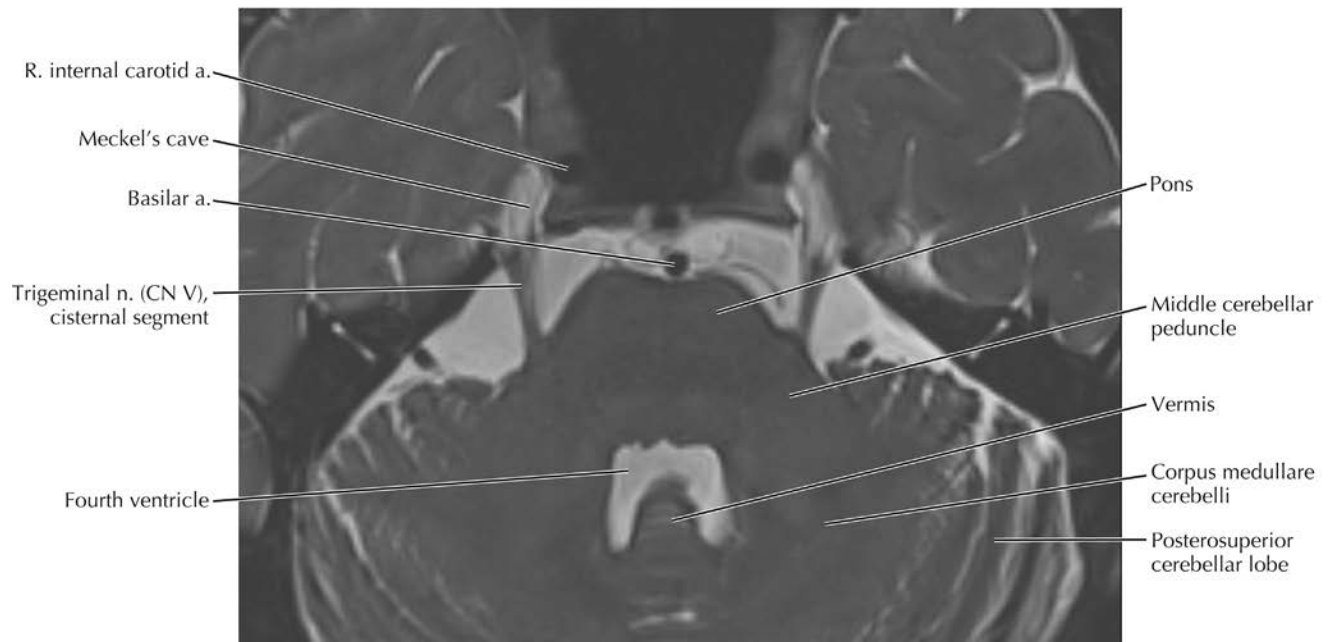
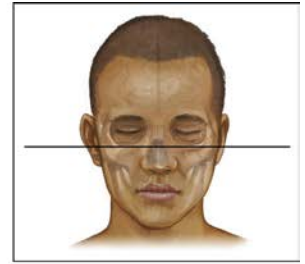




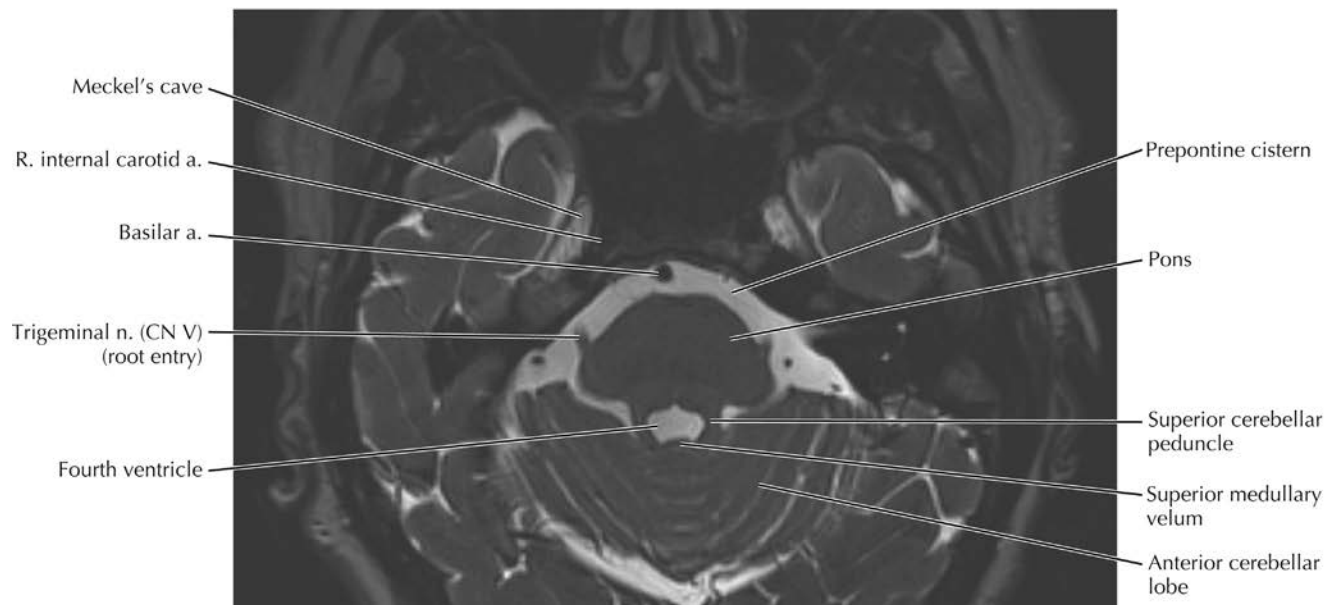
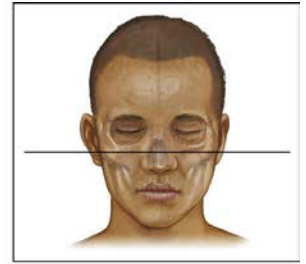
NORMAL ANATOMY

The trigeminal nerve (fifth cranial, CN V) is named for its three major branches: ophthalmic (V_1), maxillary (V_2), and mandibular (V_3). CN V innervates sensation of the face and the muscles of mastication; V_1 and V_2 branches are cutaneous sensory nerves only, whereas V_3 has cutaneous sensory and motor functions.

The trigeminal nerve is the largest of the cranial nerves, and its cisternal segment has a fan-shaped appearance on axial imaging as it courses from the brainstem to Meckel's cave. The ganglion within Meckel's cave is called the *trigeminal*, or Gasserian, *ganglion*. Meckel's ganglion along V_2 is located within the pterygopalatine fossa more anteriorly (see also Trigeminal Axial 9).



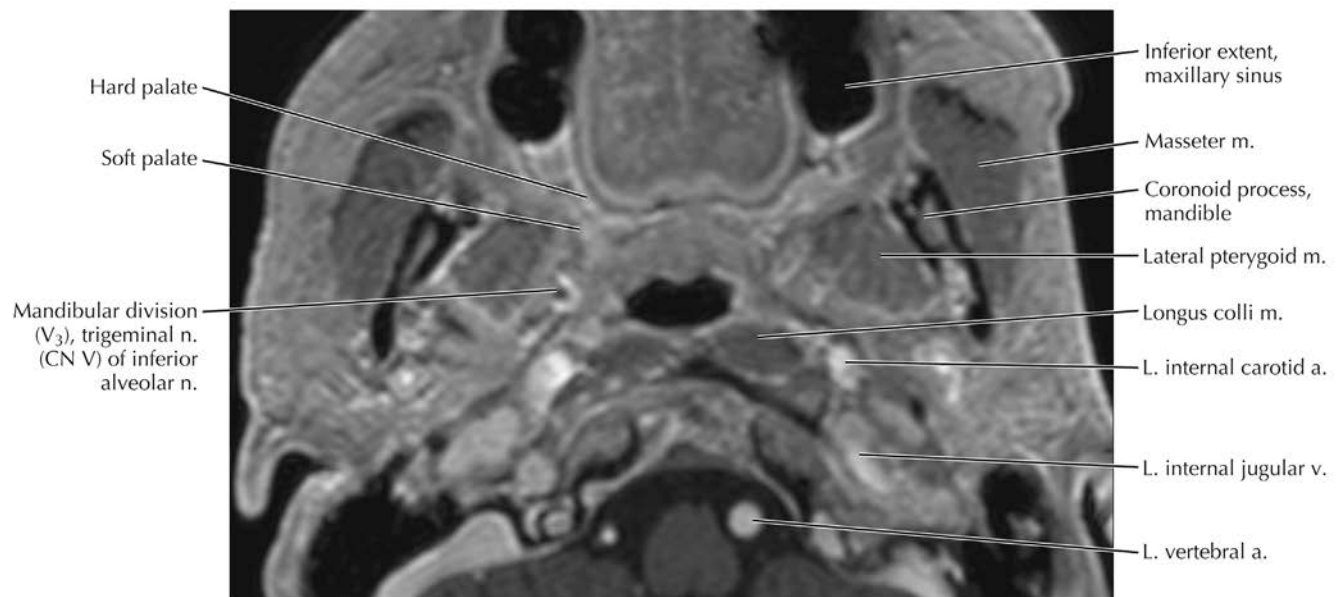
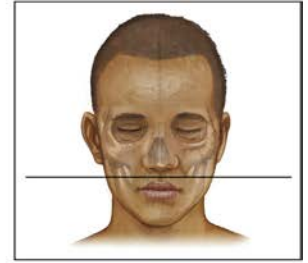




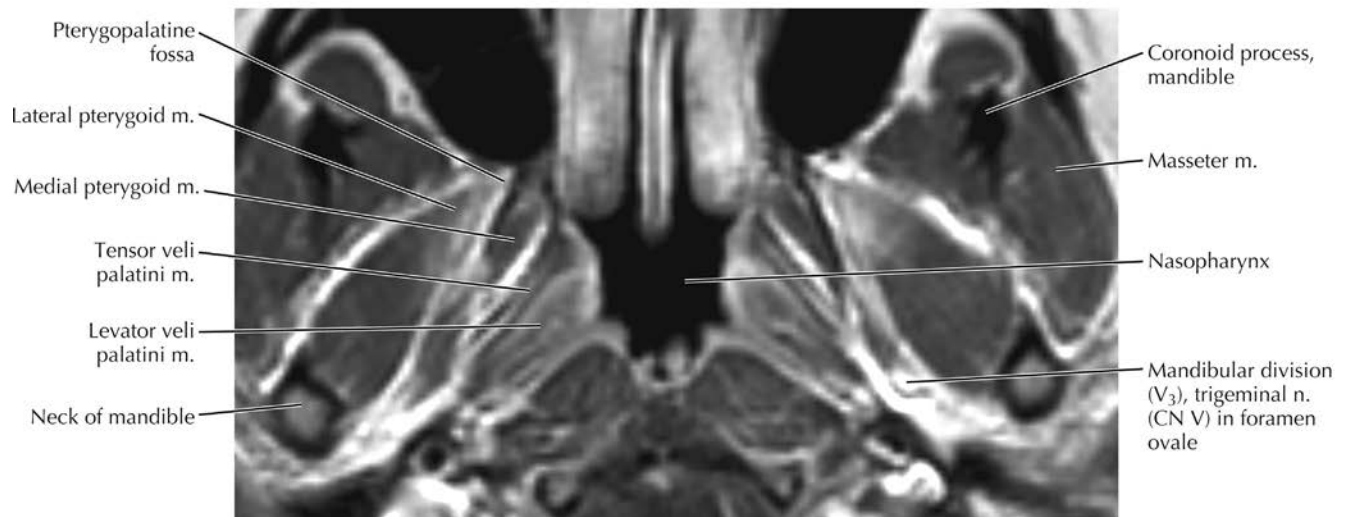
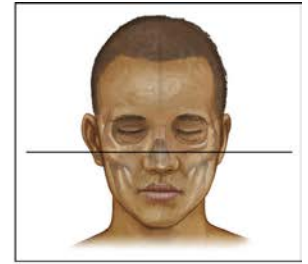


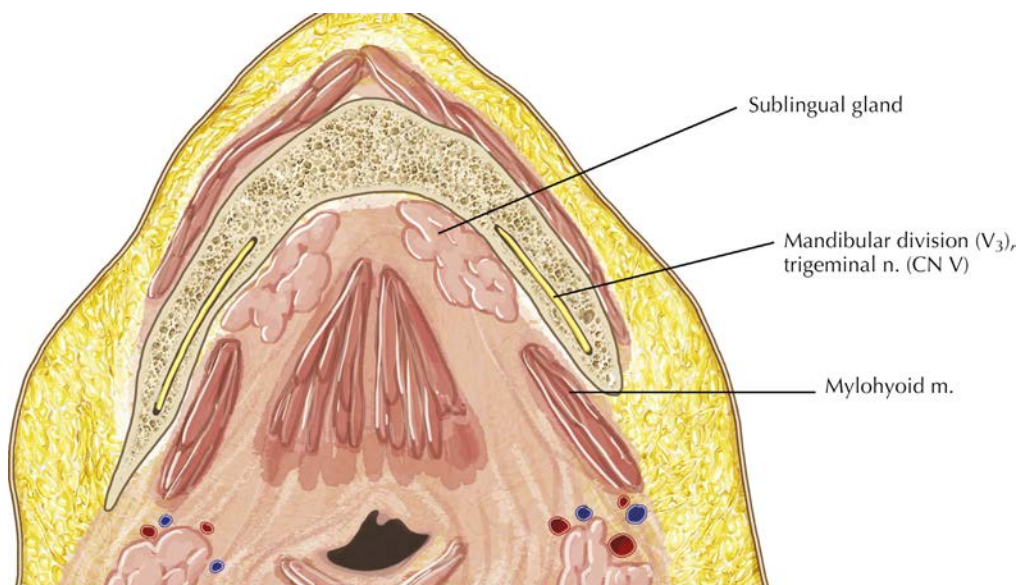
NORMAL ANATOMY

The mandibular branch (V₃) of the trigeminal nerve arises from the trigeminal ganglion and descends vertically out of the skull through the foramen ovale.



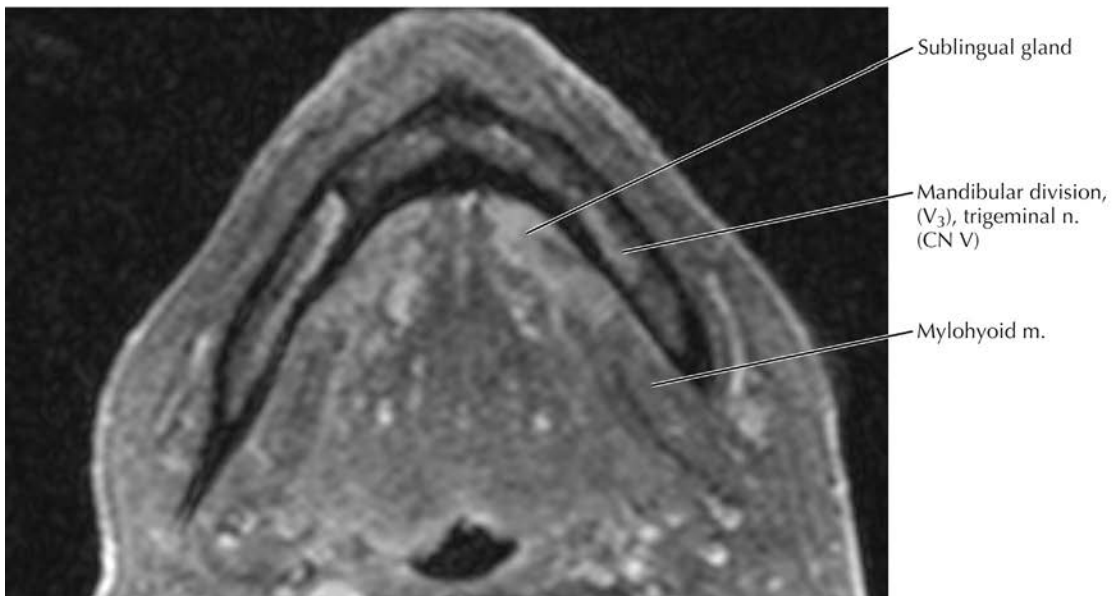
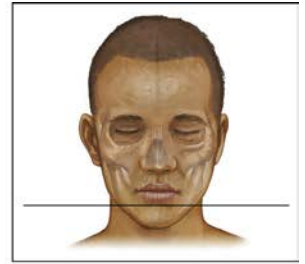


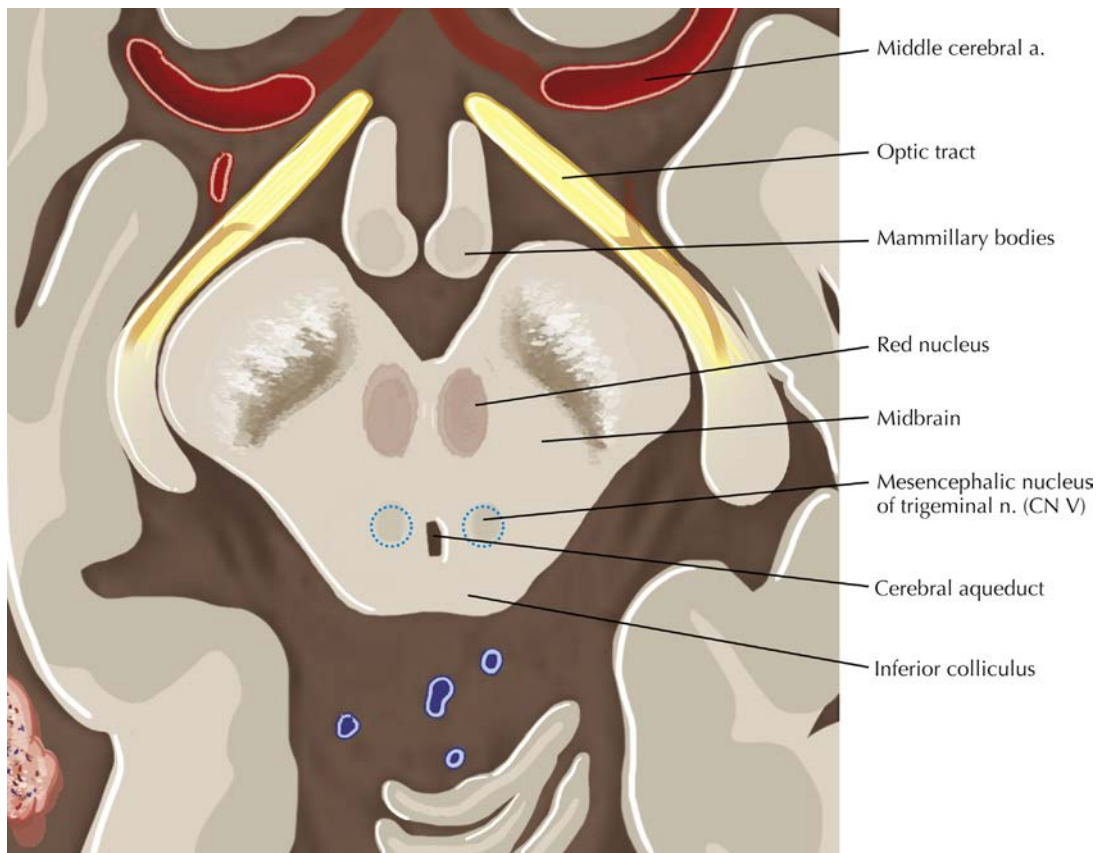




NORMAL ANATOMY

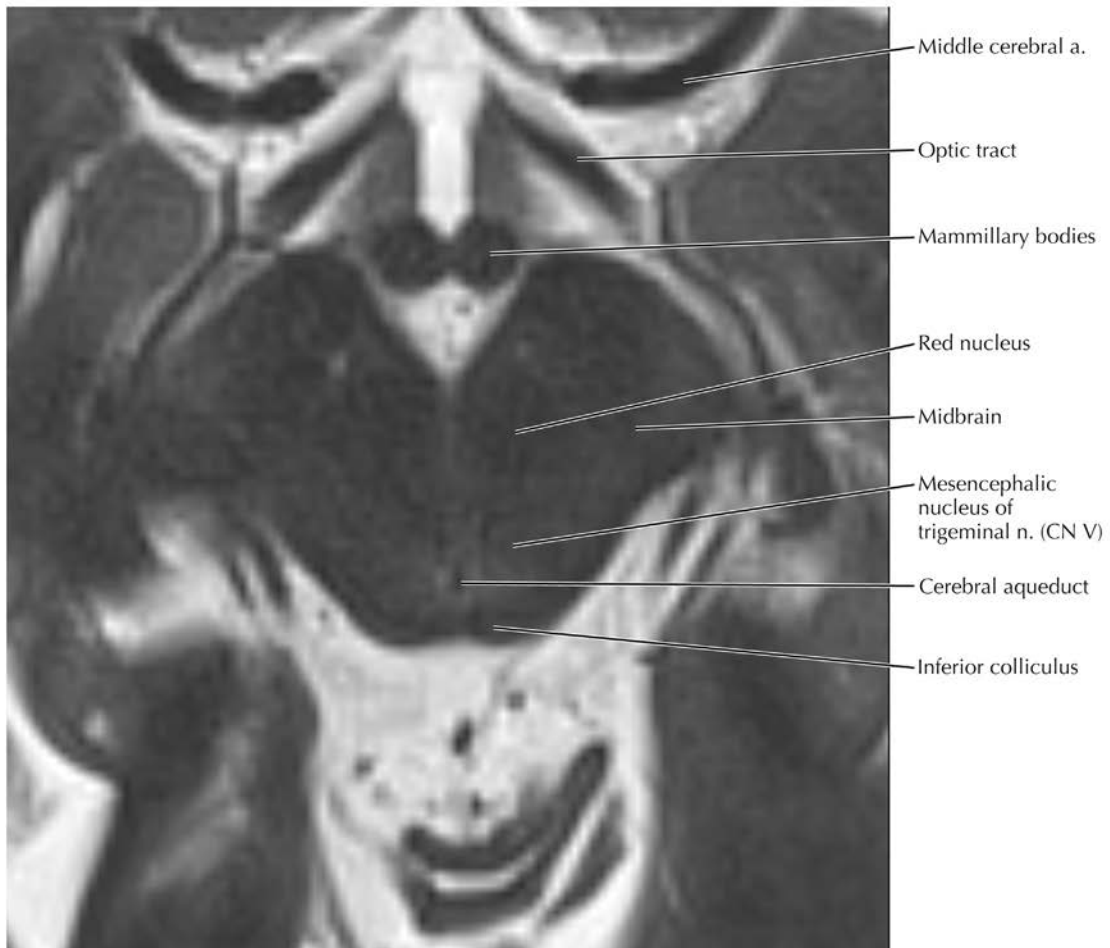
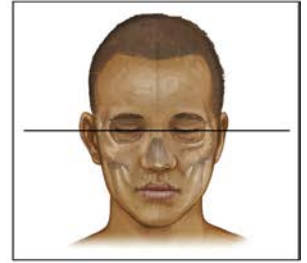
The mandibular branch (V₃) of the trigeminal nerve gives rise to the alveolar nerve, a sensory branch that courses through the alveolar canal in the mandible and exits the mental foramen into the subcutaneous tissues. A squamous cell carcinoma along the alveolar ridge of the teeth can invade the mandible and infiltrate the mandibular nerve.

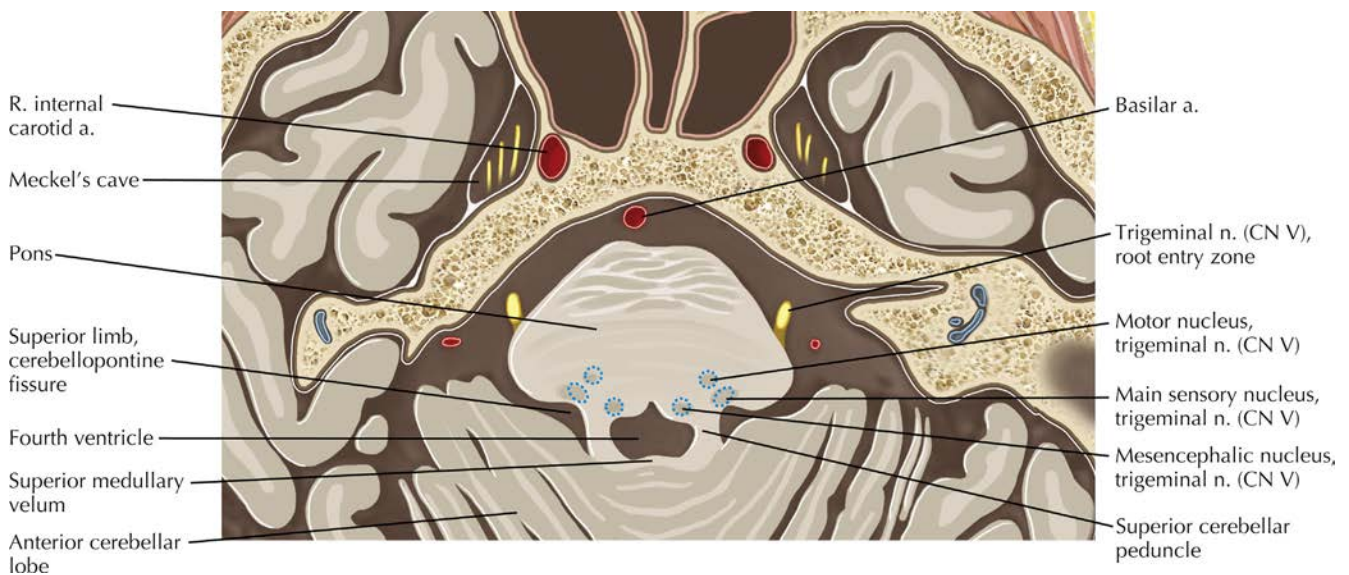


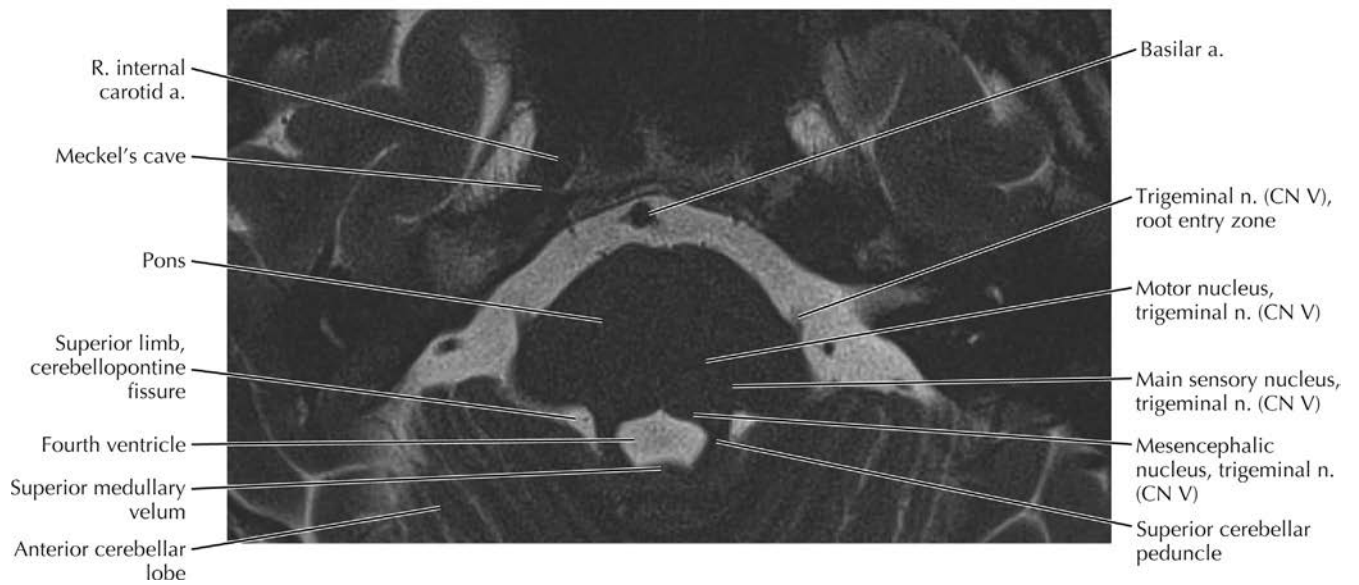
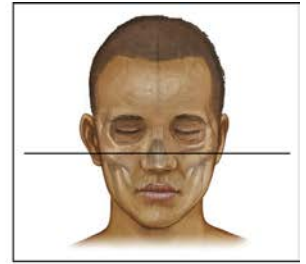


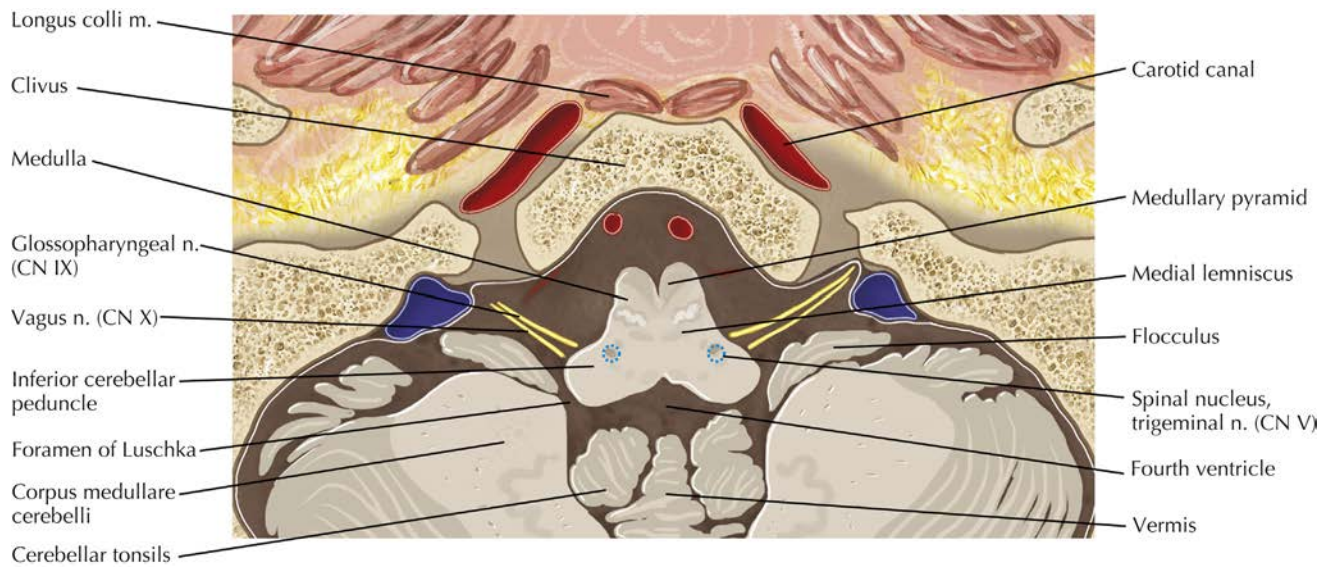
NORMAL ANATOMY

The mesencephalic nucleus of the trigeminal nerve senses the location of the jaw. This nucleus usually is not discernible on MRI.



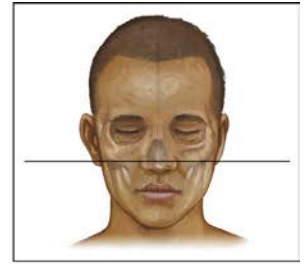


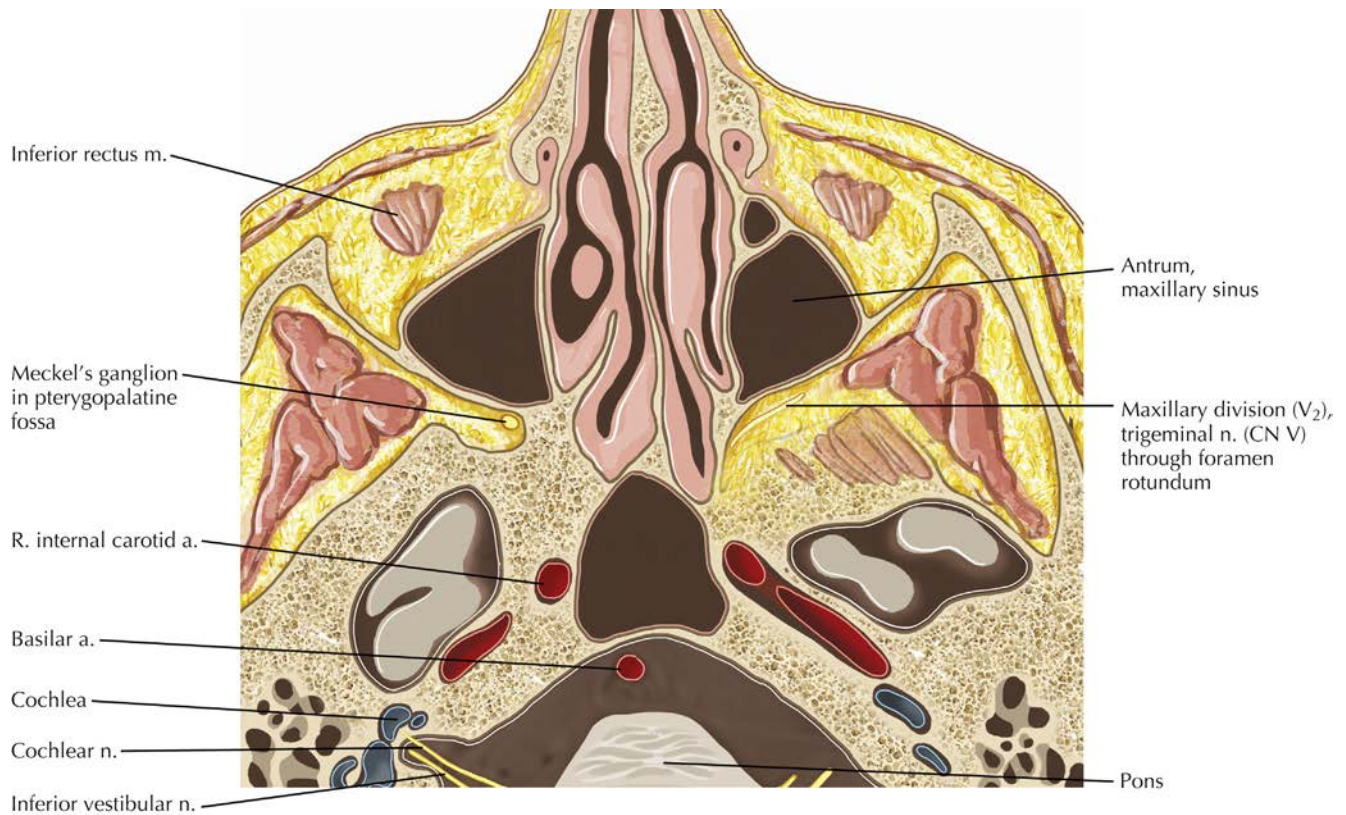




NORMAL ANATOMY

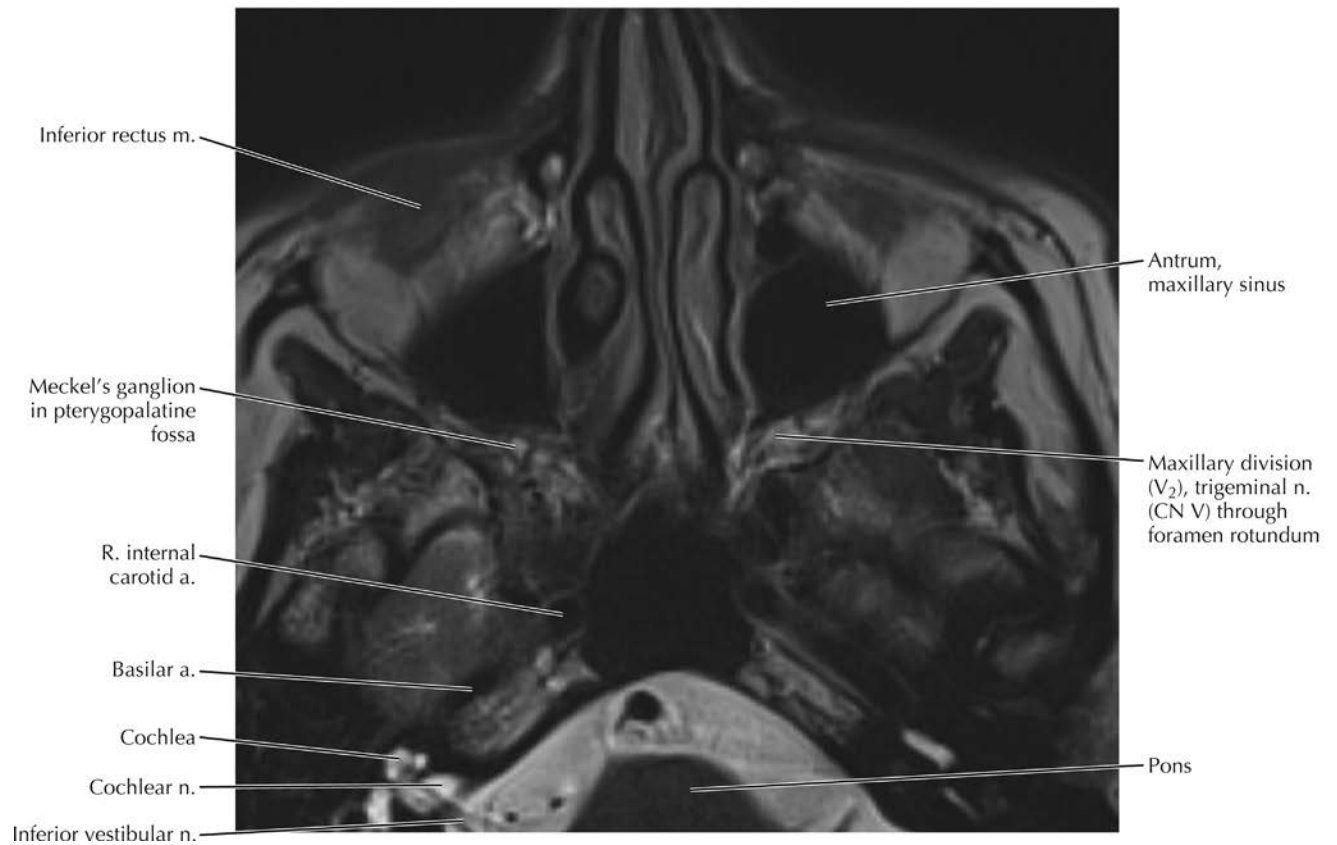
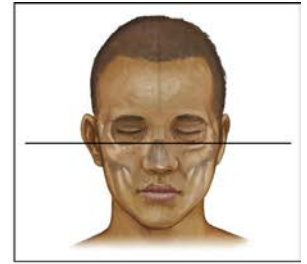
The spinal nucleus of the trigeminal nerve receives pain and temperature sensation from the face.



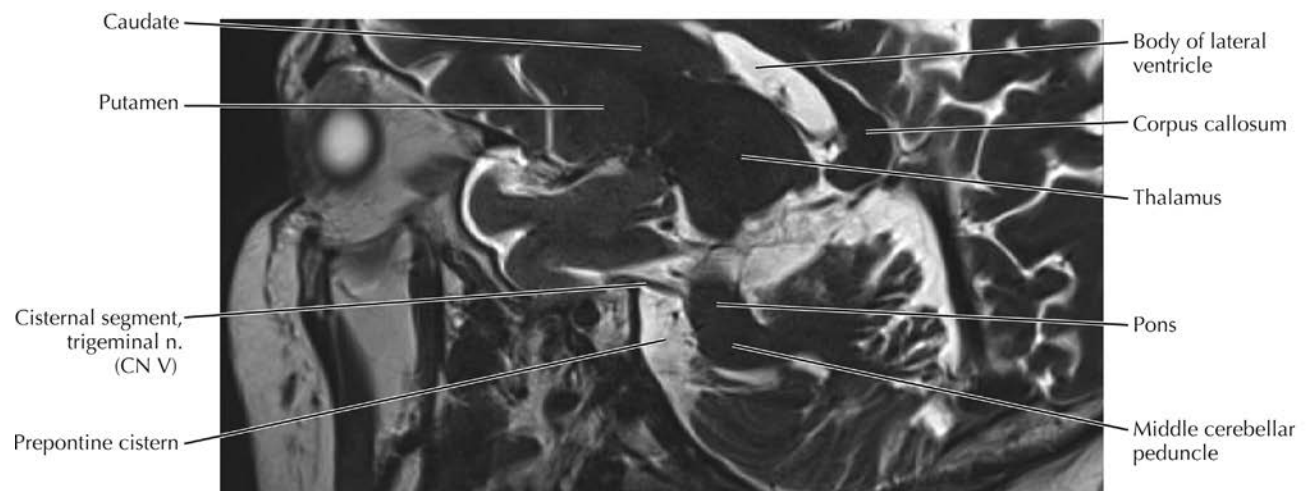
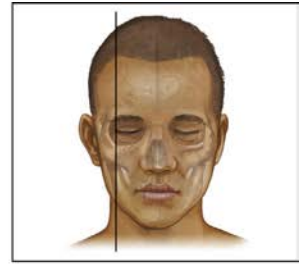


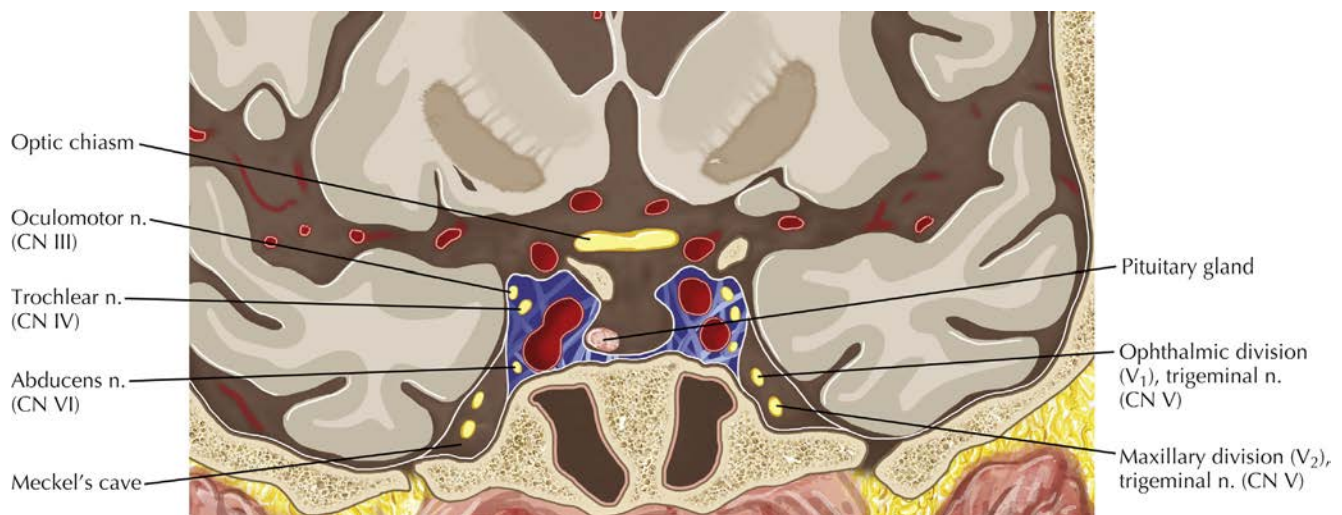
DIAGNOSTIC CONSIDERATION

Loss of normally bright T1-weighted fat signal in the pterygopalatine fossa can be a sign of perineural invasion from the face.



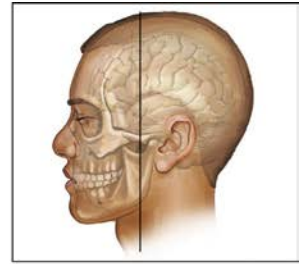






DIAGNOSTIC CONSIDERATION

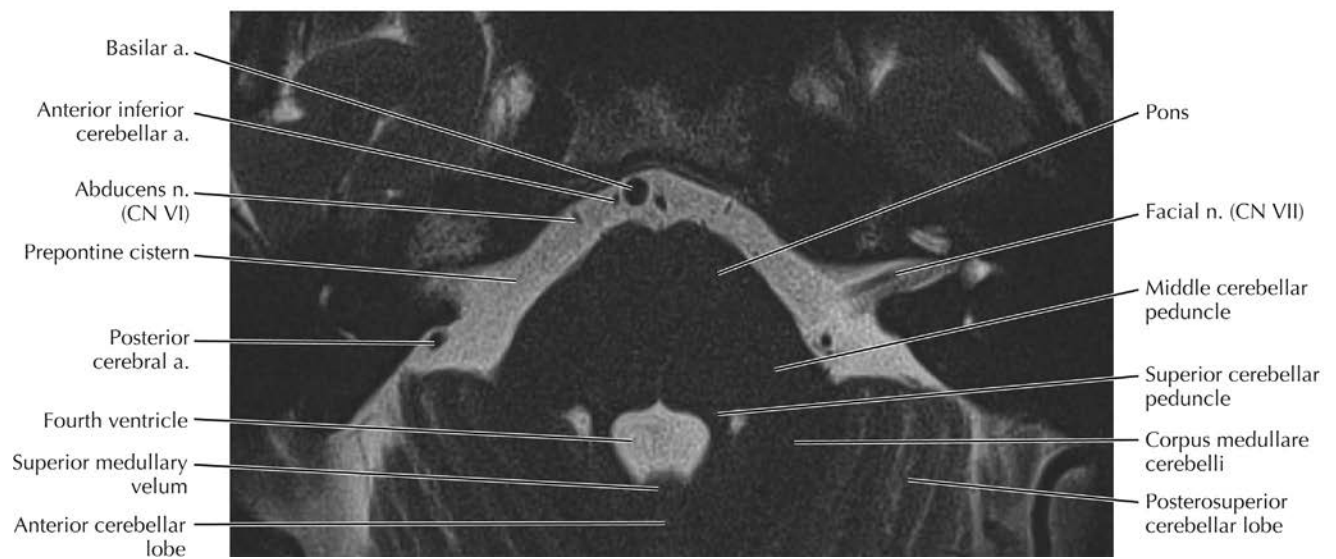
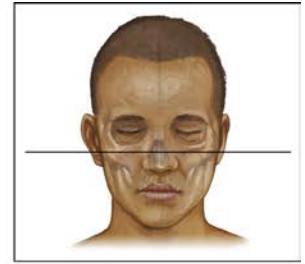
Although the trigeminal ganglion is located within Meckel's cave, on T2-weighted MR images the appearance is that of multiple branches passing through Meckel's cave, bathed in cerebrospinal fluid.

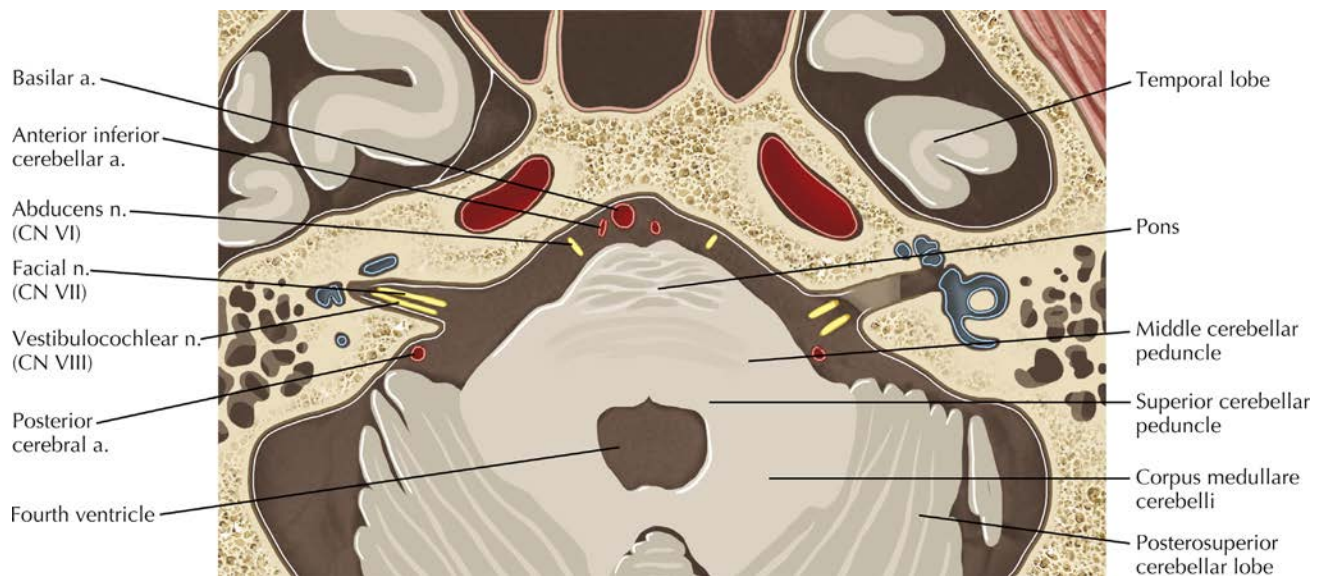




NORMAL ANATOMY

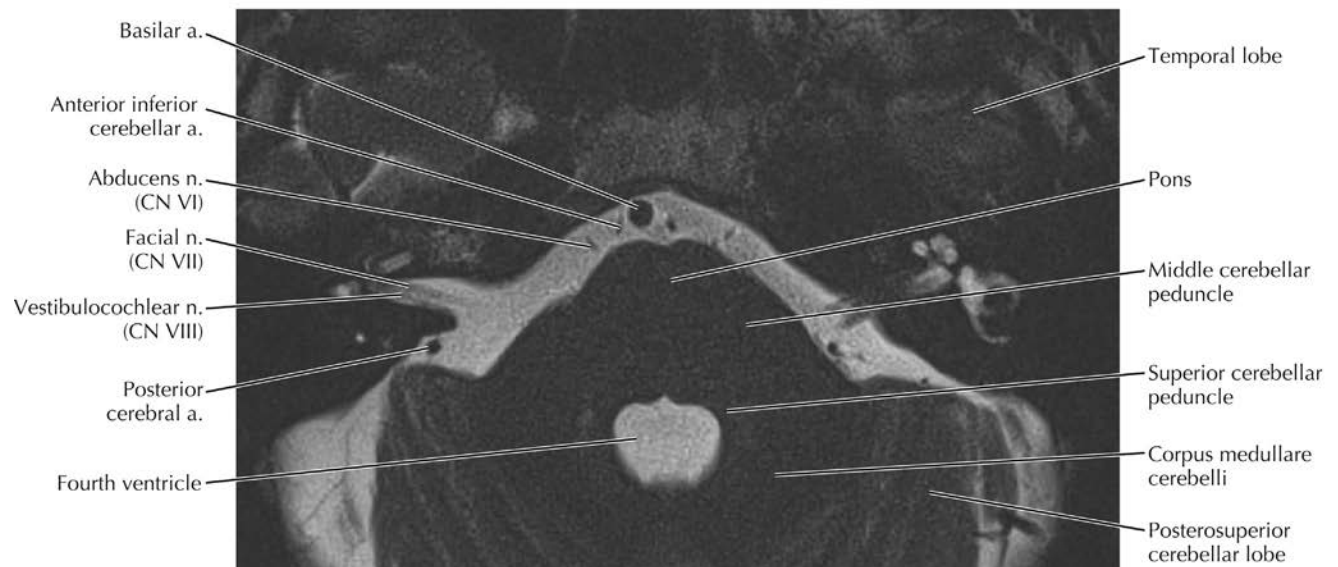
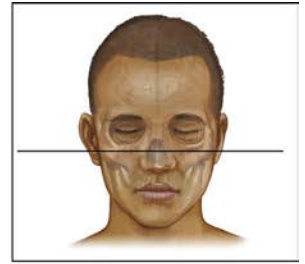
The abducens (or abducent) nerve (sixth cranial, CN VI) is a somatic efferent nerve that controls movement of the lateral rectus muscle of the orbit. Palsy of CN VI leads to a defect in directing the lateral gaze. The cisternal segment of the abducens nerve enters the base of the skull at Dorello's canal.

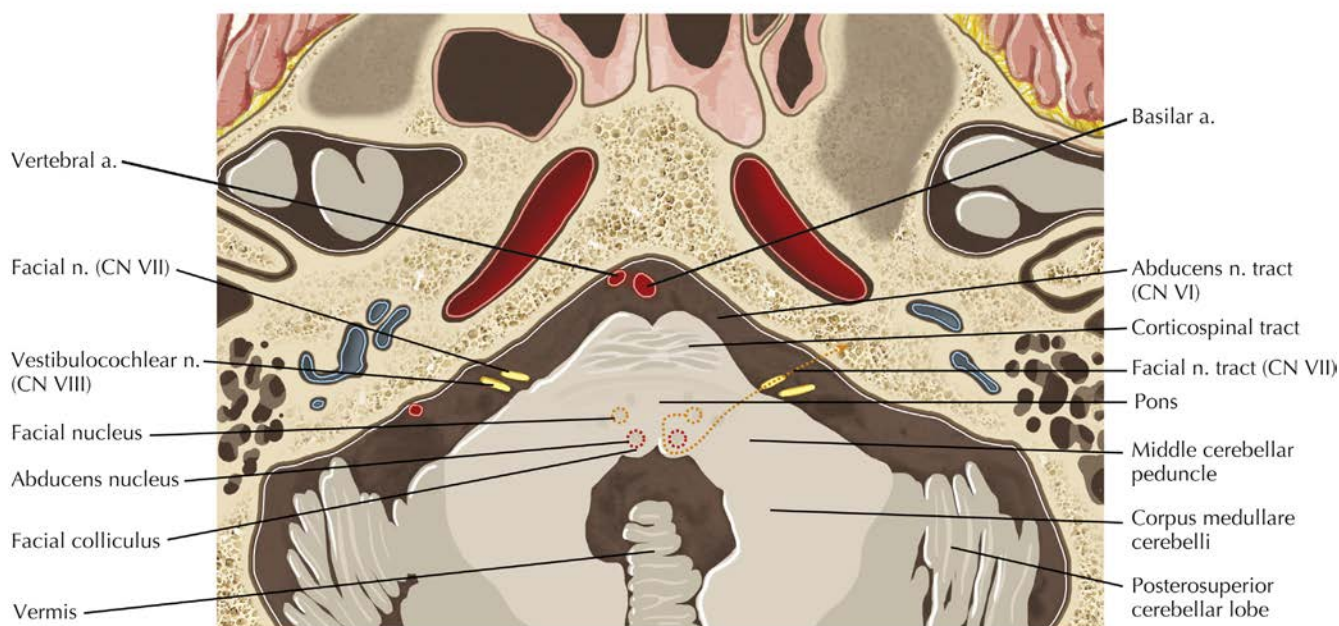
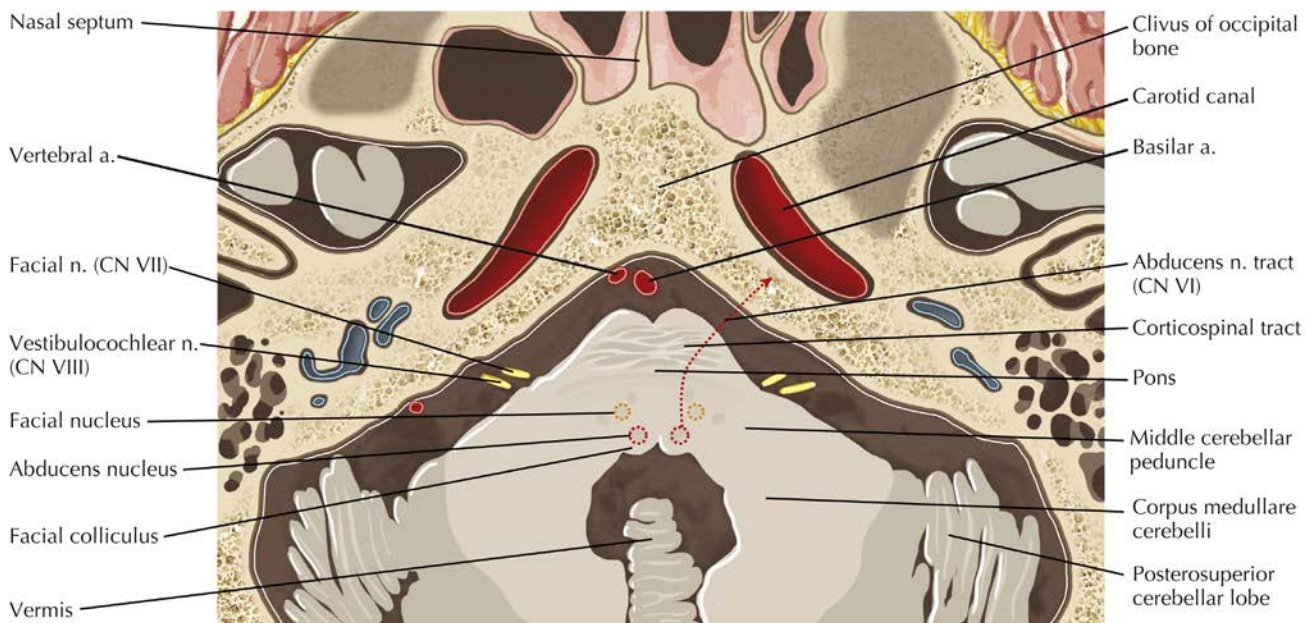




PATHOLOGIC PROCESS

The abducens nerve innervates a single muscle, as does the trochlear nerve, and is only slightly larger than the trochlear. CN VI exits the brainstem between the pons and medulla medial to the facial nerve (CN VII) and passes anteriorly and superiorly to enter the skull base at a slightly acute angle into Dorello's canal. At the tip of the petrous segment of the temporal bone, the abducens nerve makes another acute angle forward to enter the cavernous sinus, coursing alongside the cavernous segment of the internal carotid artery, and enters the orbit through the superior orbital fissure. Because of its long course from brainstem to eye and acute turns at bony structures, the abducens nerve is particularly vulnerable to injury.

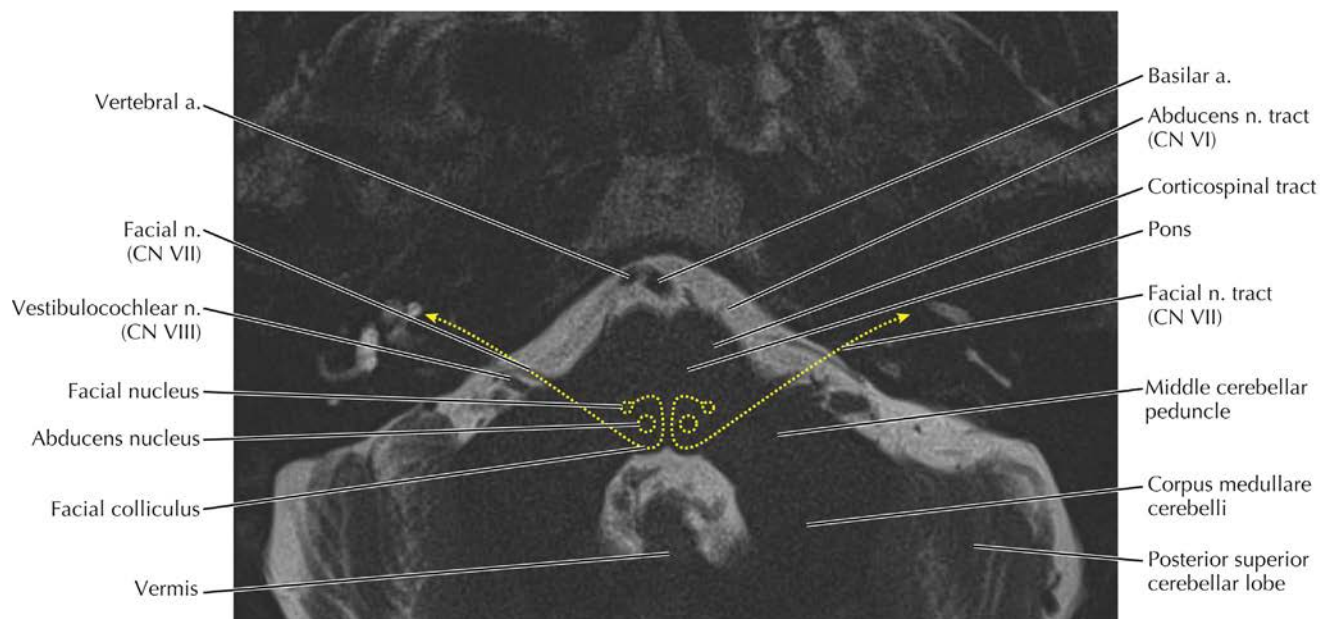
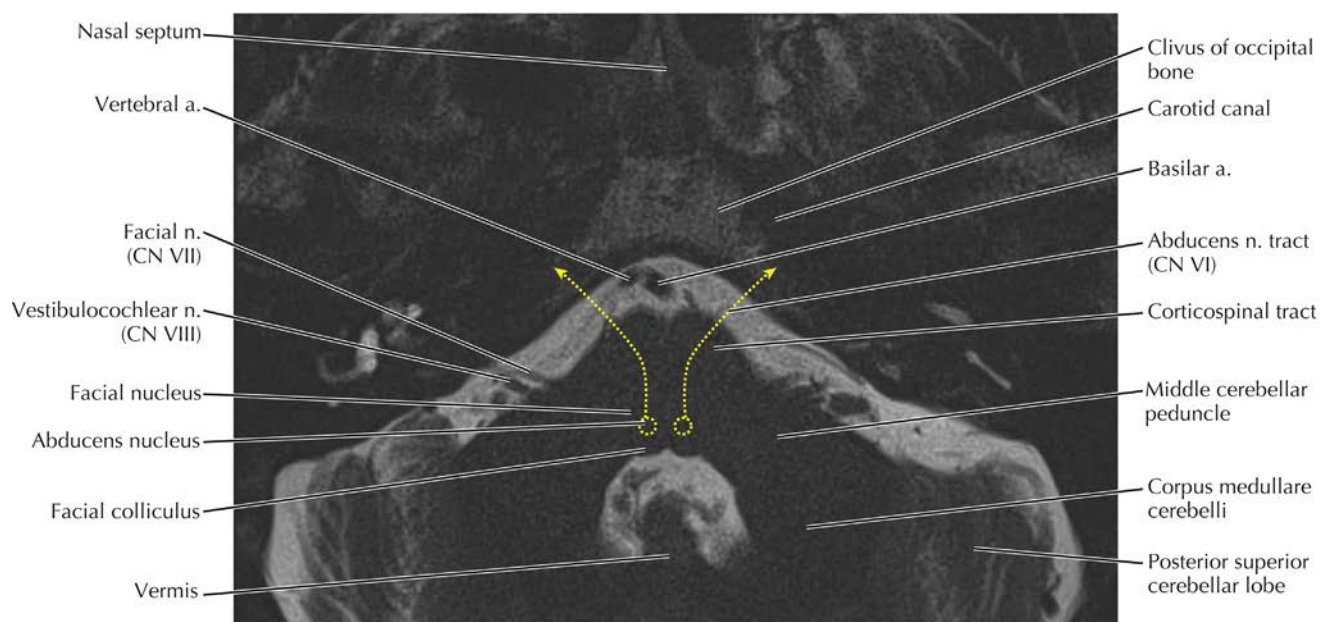
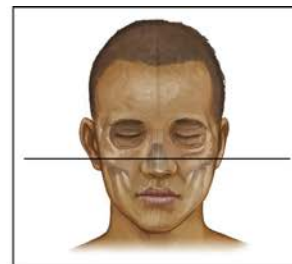


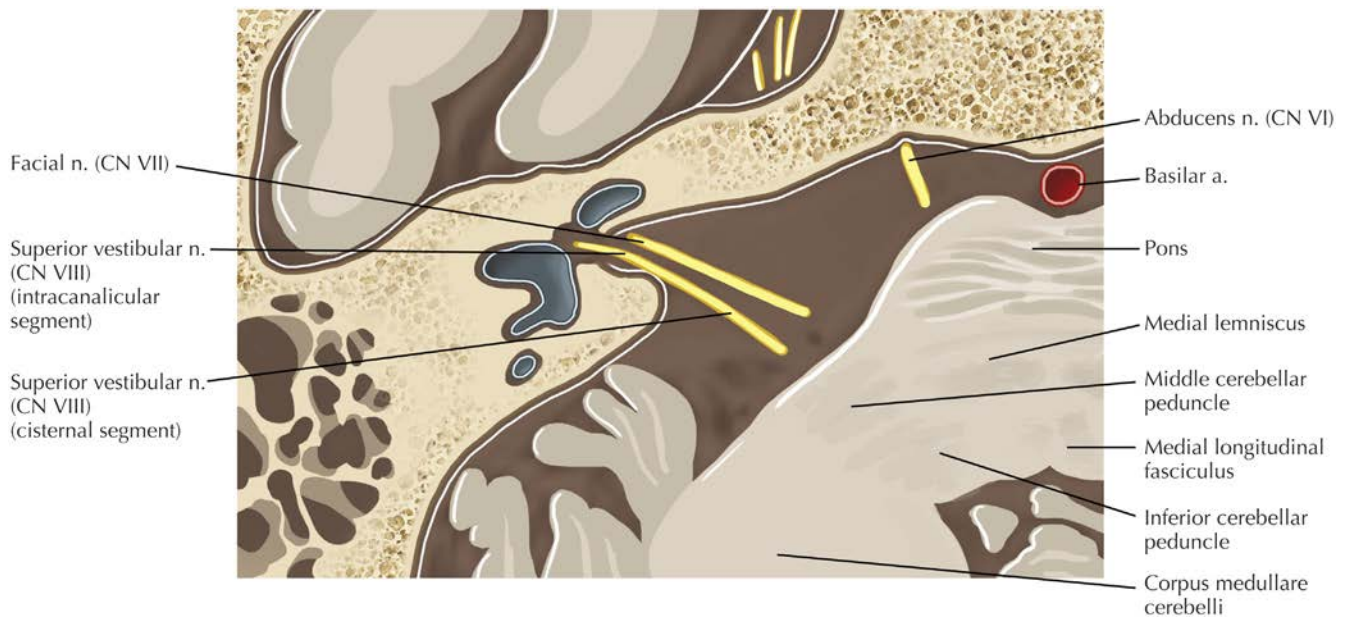


DIAGNOSTIC CONSIDERATION

The abducens nucleus is located in the pons along the anterior aspect of the fourth ventricle. Nerve fibers from the facial nucleus wrap medially and then posteriorly and laterally to the abducens nucleus, forming a bump on the anterior wall of the fourth ventricle called the *facial colliculus*. The abducens nuclei are close to the midline, as with the other nuclei that control ocular movement. The abducens axons pass from the nucleus anteriorly through the pons lateral to the corticospinal tract before exiting the brainstem and the pontomedullary junction.

Infarcts of the dorsal pons can injure both the abducens nucleus, causing lateral rectus palsy, and the facial nerve fibers, resulting in an ipsilateral facial palsy. Infarcts of the ventral pons can affect the abducens nerve and the corticospinal tract, producing lateral rectus muscle palsy and contralateral hemiparesis.

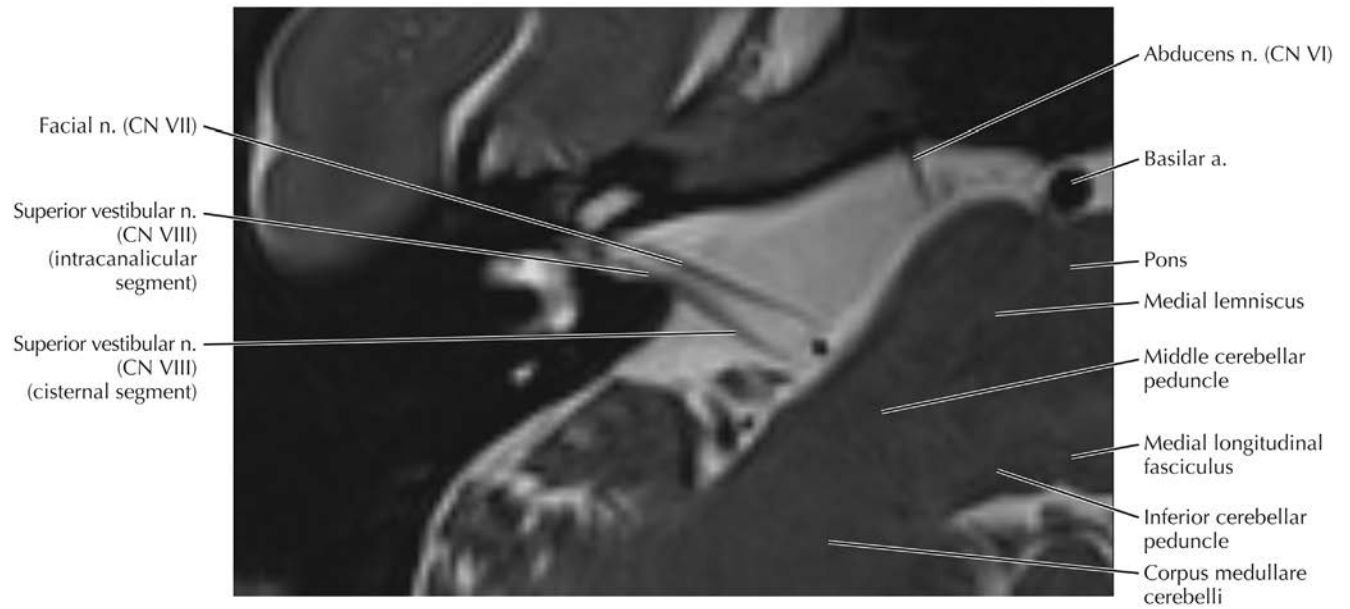
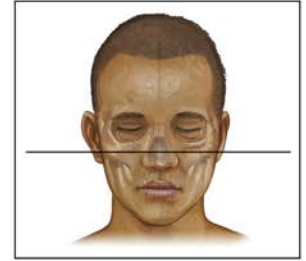


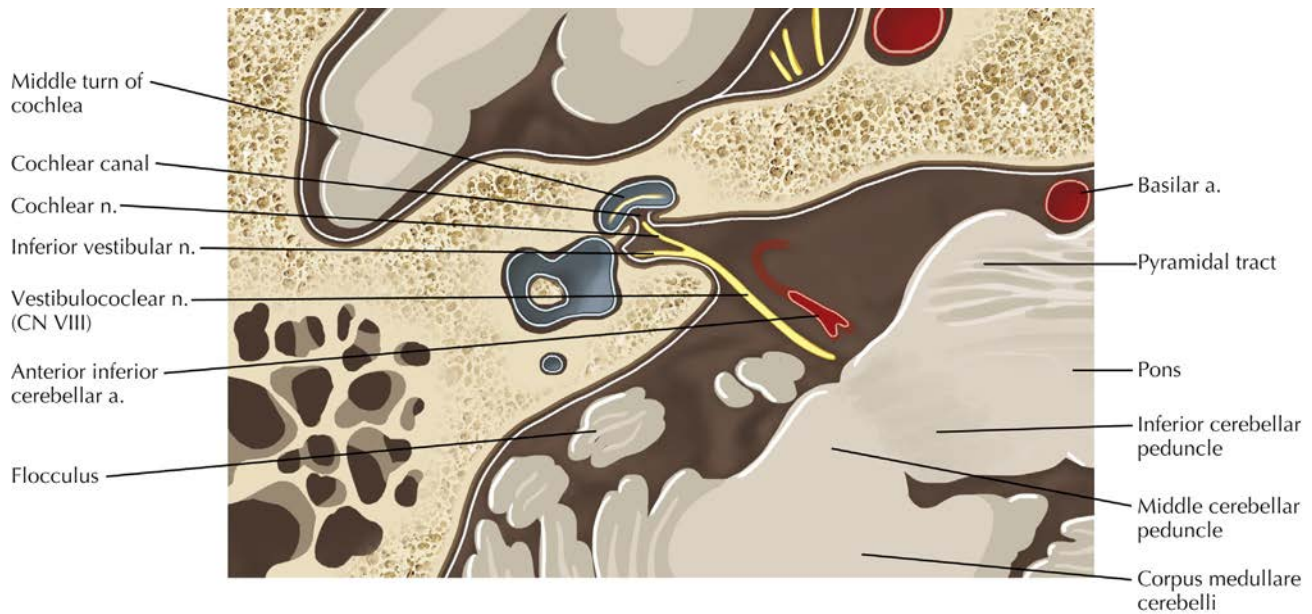


NORMAL ANATOMY

The facial nerve (seventh cranial, CN VII) exits the facial nucleus and wraps medial and posterior to the abducens nucleus to form a bump in the anterior wall of the fourth ventricle, called the *facial colliculus*. CN VII exits the brainstem at the lateral pontomedullary junction and courses through the CSF in the cerebellopontine angle anterior and parallel to the vestibulocochlear nerve (CN VIII) into the internal auditory canal. (For the segments of the facial nerve passing through bony canals as well as the semicircular canals, see Chapter 12.) The facial nerve is a motor nerve that supplies the muscles of the face. Injury to CN VII is of great clinical significance because of the stigma of ipsilateral facial palsy mimicking stroke and the impact on social interaction.

The vestibulocochlear nerve (eighth cranial, CN VIII) provides both balance and hearing functions. The vestibulocochlear nerve was formerly called the "acoustic" or "auditory" nerve, but these terms did not recognize the nerve's role in the vestibular system.





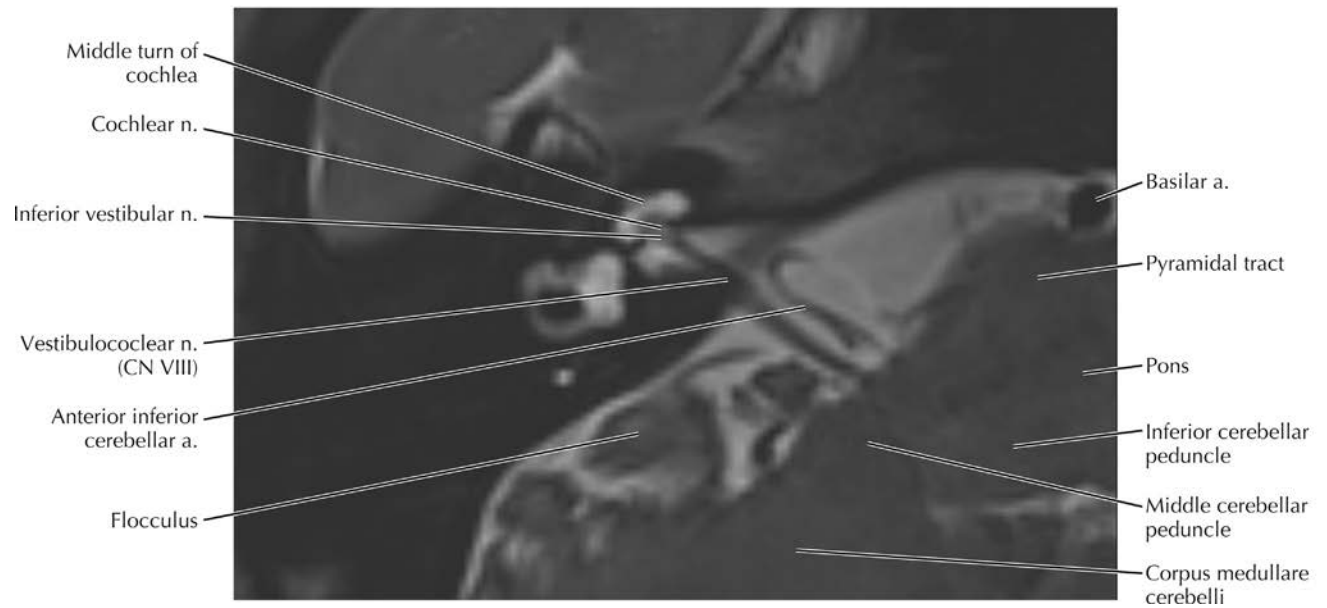
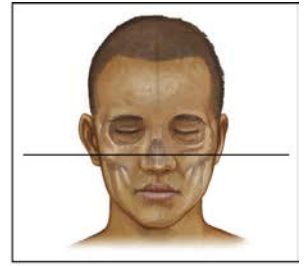
NORMAL ANATOMY

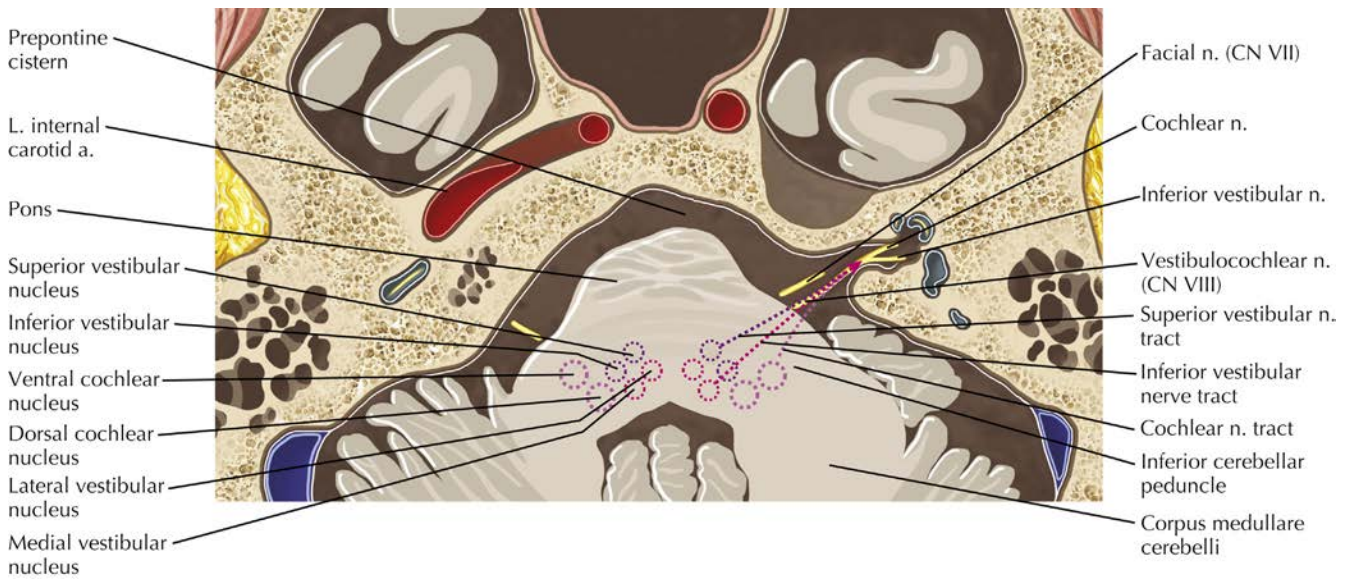
The cochlear branch of the vestibulocochlear nerve (CN VIII) courses in the anteroinferior quadrant of the internal auditory canal. The cochlear nerve passes laterally into the small cochlear canal and winds within the cochlea.

The inferior and posterior divisions of the vestibular branch of the vestibulocochlear nerve pass in the posterior quadrants of the internal auditory canal and provide innervation for equilibrium to the three semicircular canals.

DIAGNOSTIC CONSIDERATION

The anterior inferior cerebellary artery passes close to the porous acoustic meatus (auditory canal). In some people the anterior inferior cerebellary artery can pass into the internal auditory canal. Looping of this artery into the canal, particularly deeper than halfway, may be associated with pressure symptoms on the facial or vestibulocochlear nerves, including potentially debilitating pulsatile tinnitus.



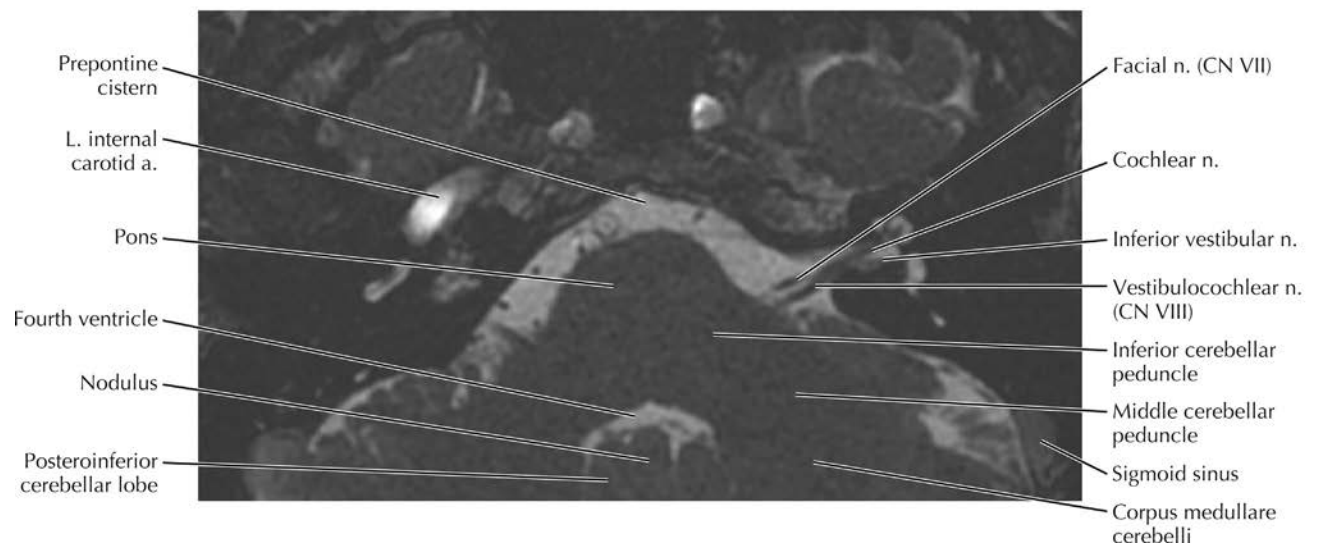
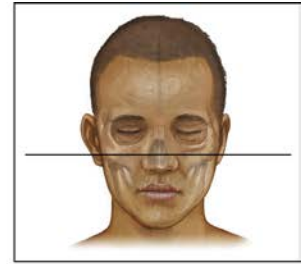


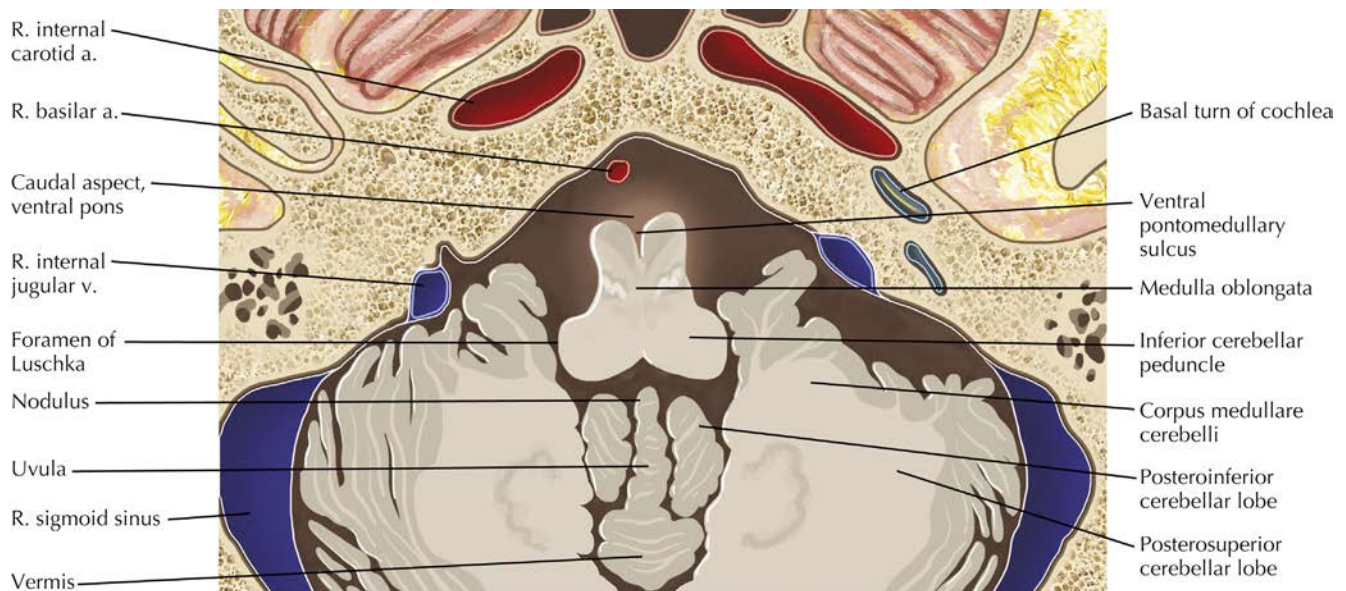
NORMAL ANATOMY

The four vestibular nuclei include the medial, lateral, and inferior nuclei, located within the medulla, and the superior nucleus within the pons. The vestibular nuclei are medial to the ventral and dorsal cochlear nuclei.

PATHOLOGIC PROCESS

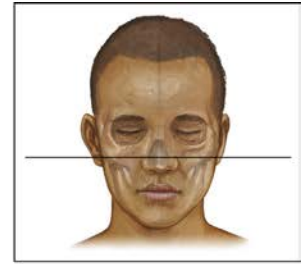
Note that this axial image is slightly tilted, showing a slightly lower aspect of the right side of the patient's head. The basal turn of the right cochlea is seen, as well as the middle and apical turns of the left cochlea. Note also the proximity of the petrous segment of the internal auditory canal to the basal turn. When the bony wall between this petrous segment and the basal turn is dehiscence, the patient may experience pulsatile tinnitus.

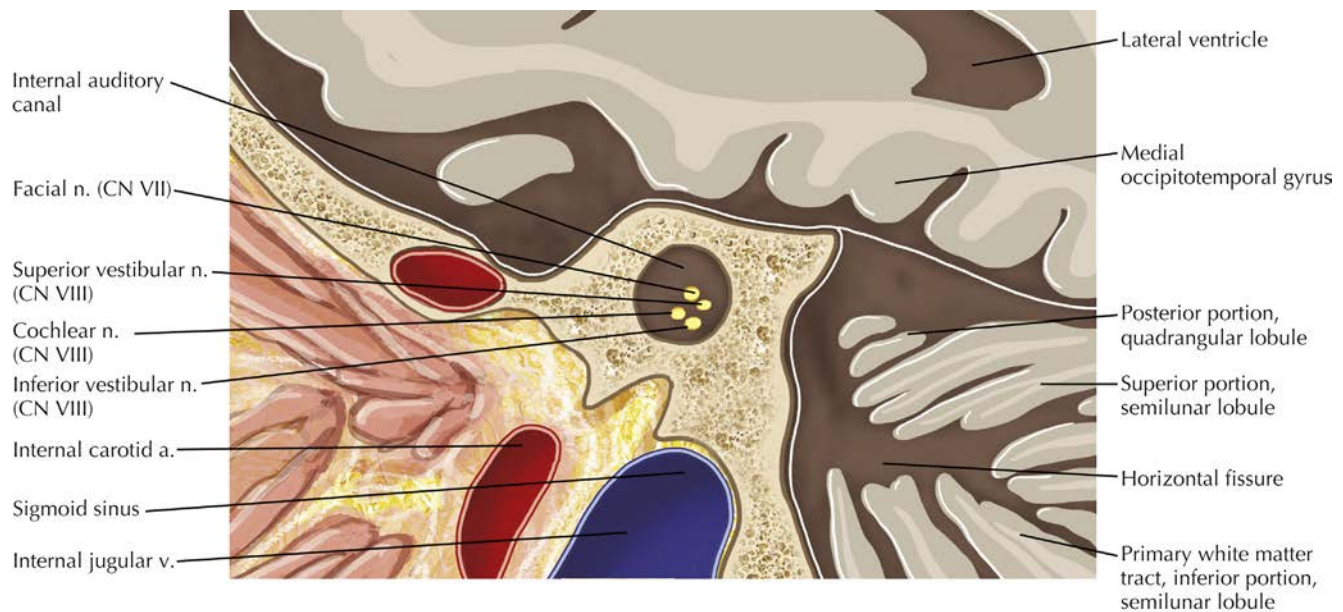




NORMAL ANATOMY

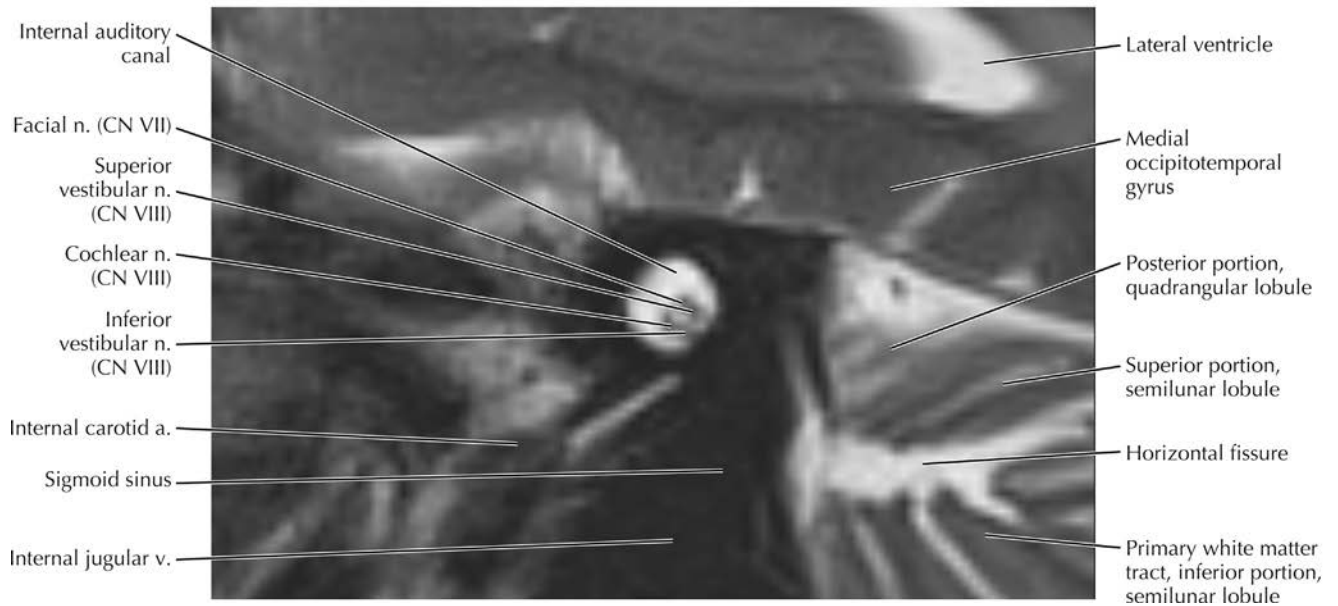
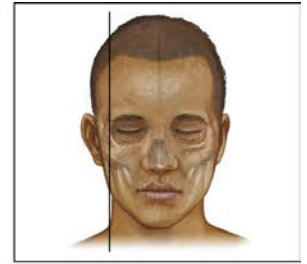
This image is slightly more caudal than the Axial 6 image, and the basal turn of the left cochlear has now come into view. The part of the cochlear nerve in this basal turn registers higher frequencies, up to 20,000 Hz. As the cochlear nerve winds deeper into the middle and apical turns, it registers lower frequencies, down to 20 Hz.

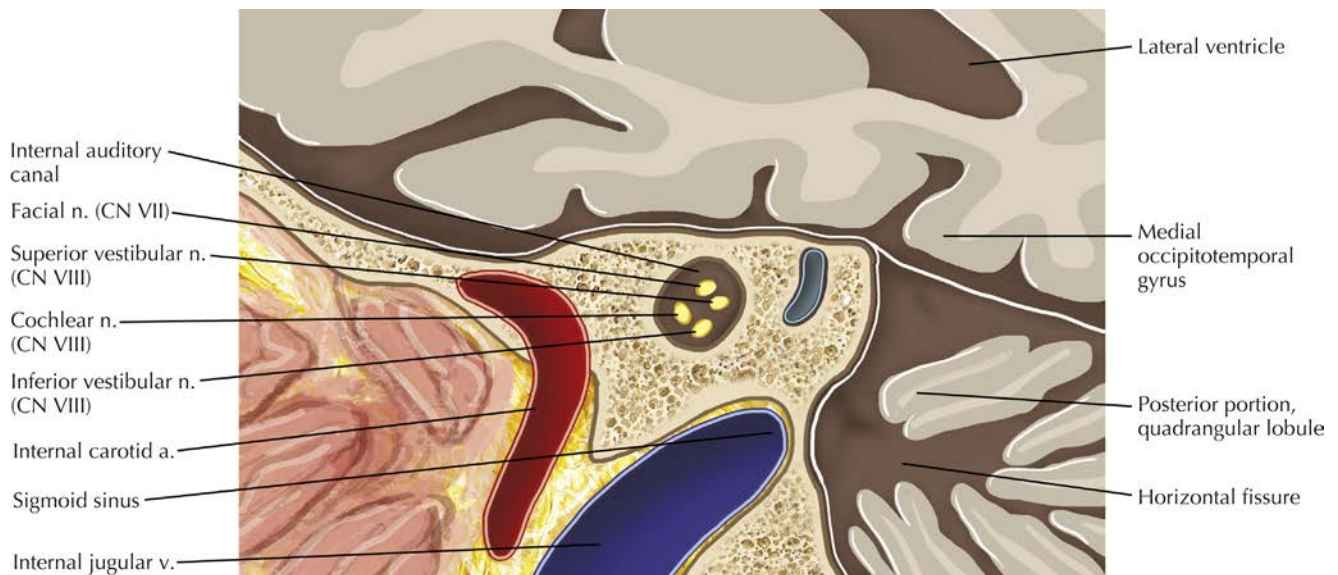




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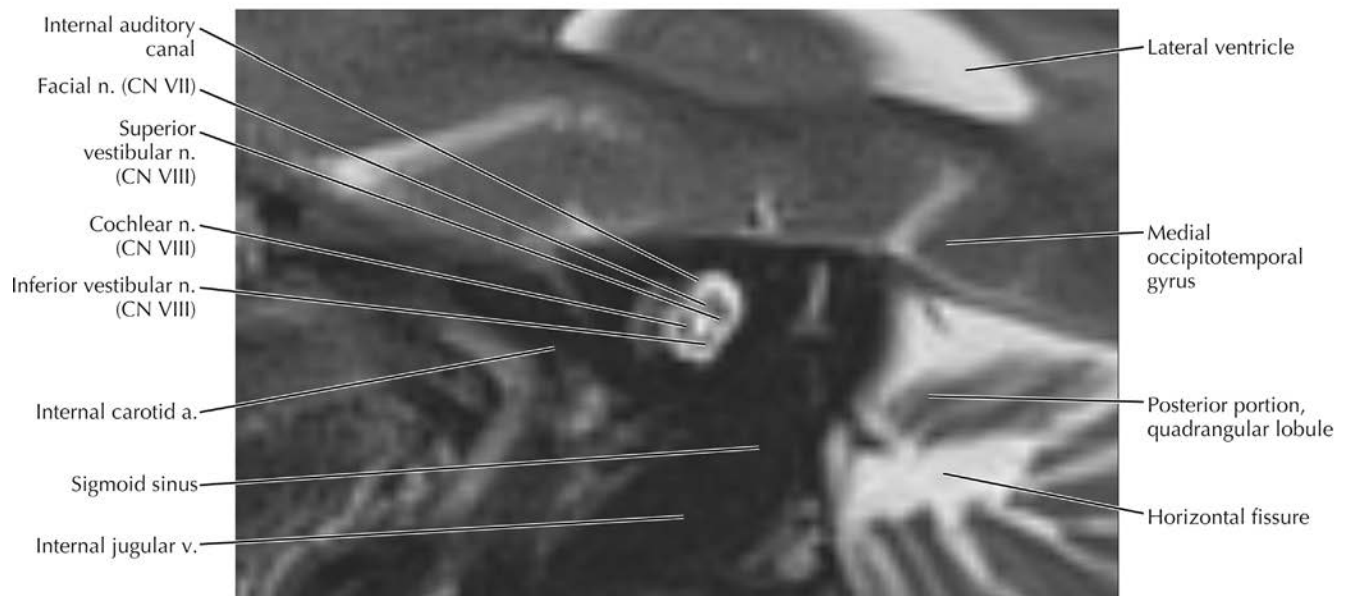
The sagittal MR projection is the best imaging plane for distinguishing the facial nerve and the cochlear and vestibular branches of the vestibulocochlear nerve. In this sagittal image the nerves are seen in cross section to their long axis, with the facial nerve in the anterosuperior quadrant, the cochlear nerve in the anteroinferior quadrant, the superior vestibular branch in the posterosuperior quadrant, and the inferior vestibular branch in the posteroinferior quadrant. The patient's neck is slightly extended, tilting the facial nerve into the most superior position.

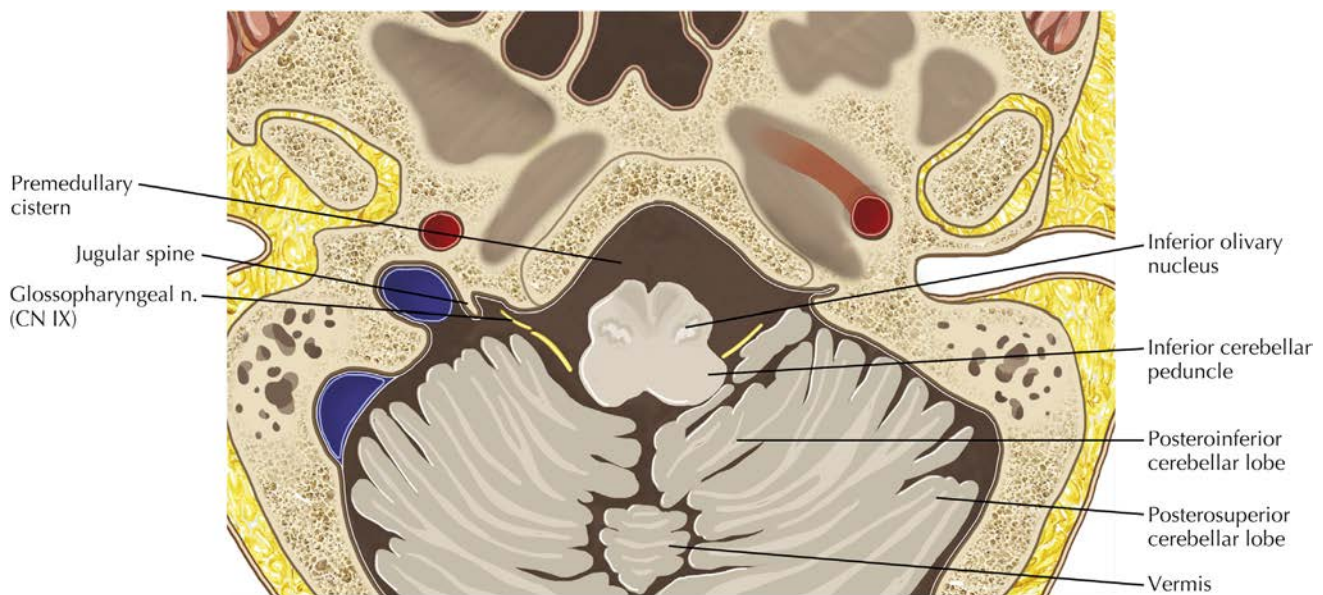




PATHOLOGIC PROCESS

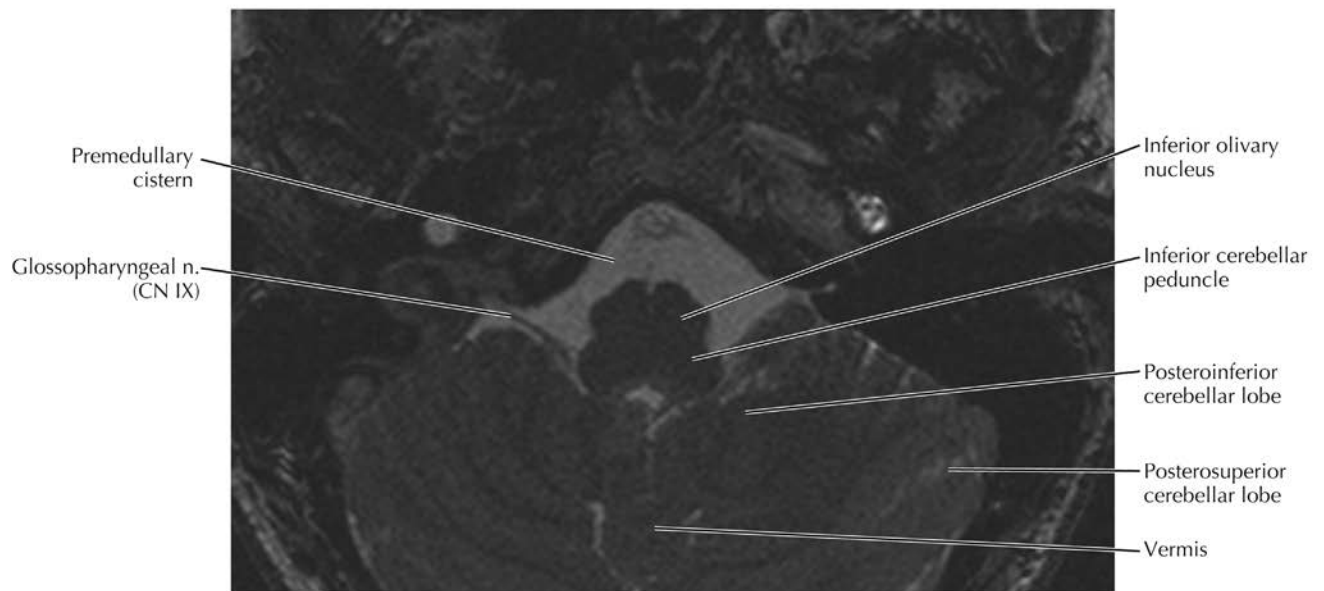
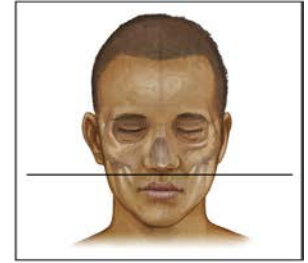
Acoustic neuroma (schwannoma) may be seen in the patient with neurofibromatosis 2 and typically arises from the vestibular branches of CN VIII.

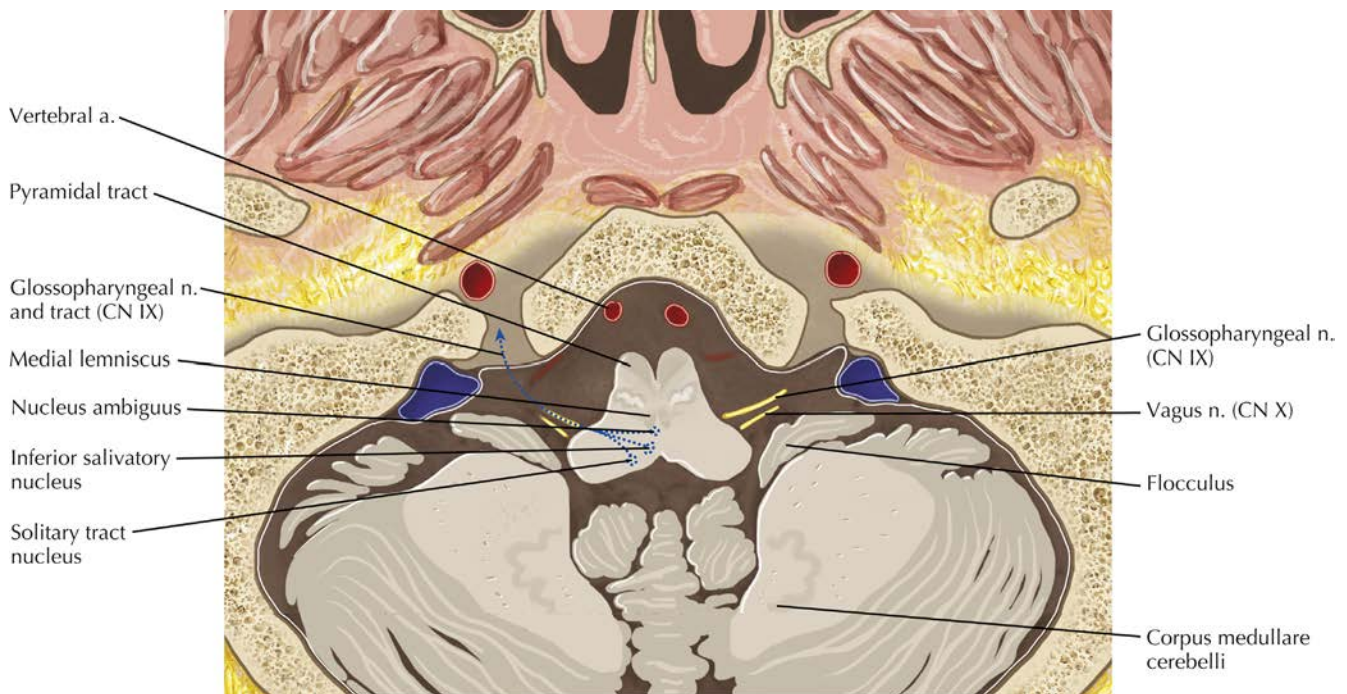




NORMAL ANATOMY

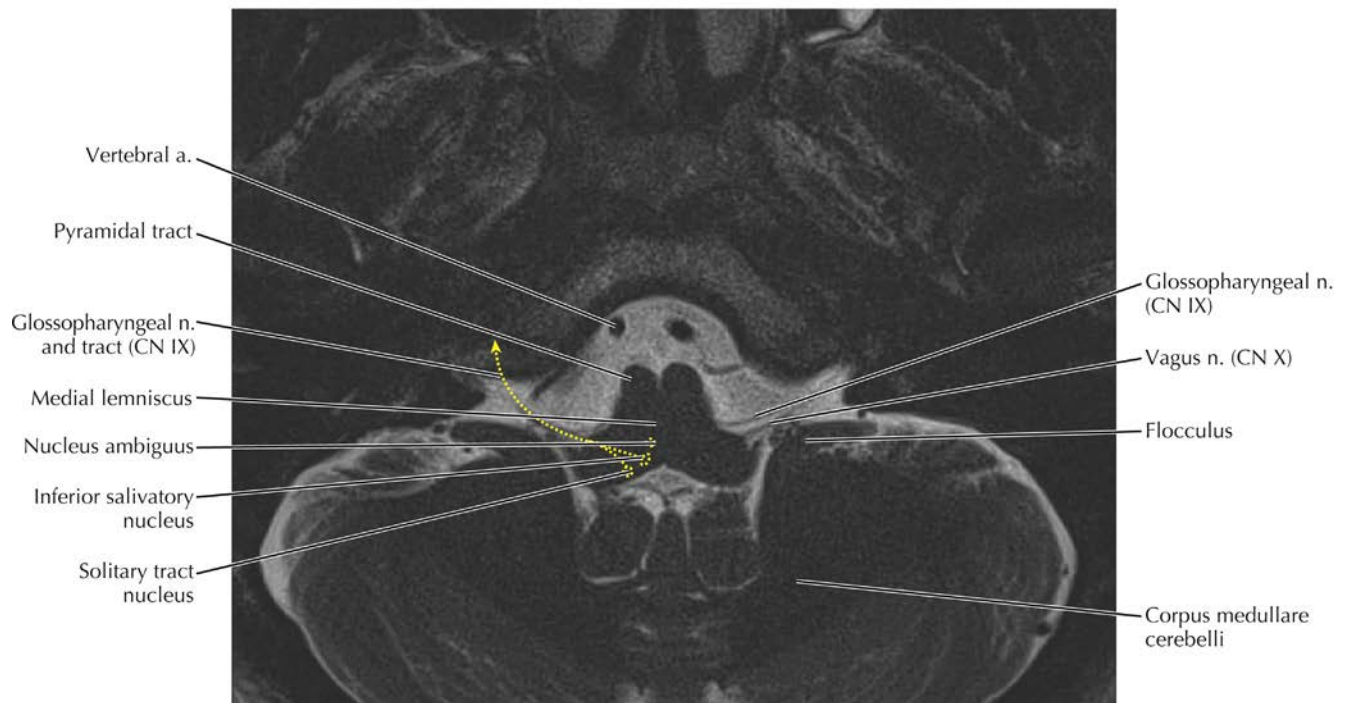
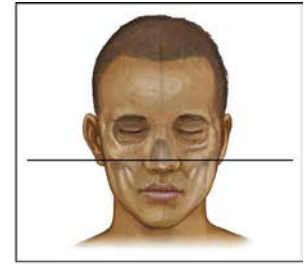
The glossopharyngeal nerve (ninth cranial, CN IX) exits the brainstem from the lateral aspect of the upper medulla just anterior to the vagus nerve. The glossopharyngeal nerve exits the skull base through the *pars nervosa*, a small anteromedial compartment of the jugular foramen separated from the larger posterolateral compartment by a small bony ridge called the "jugular spine."

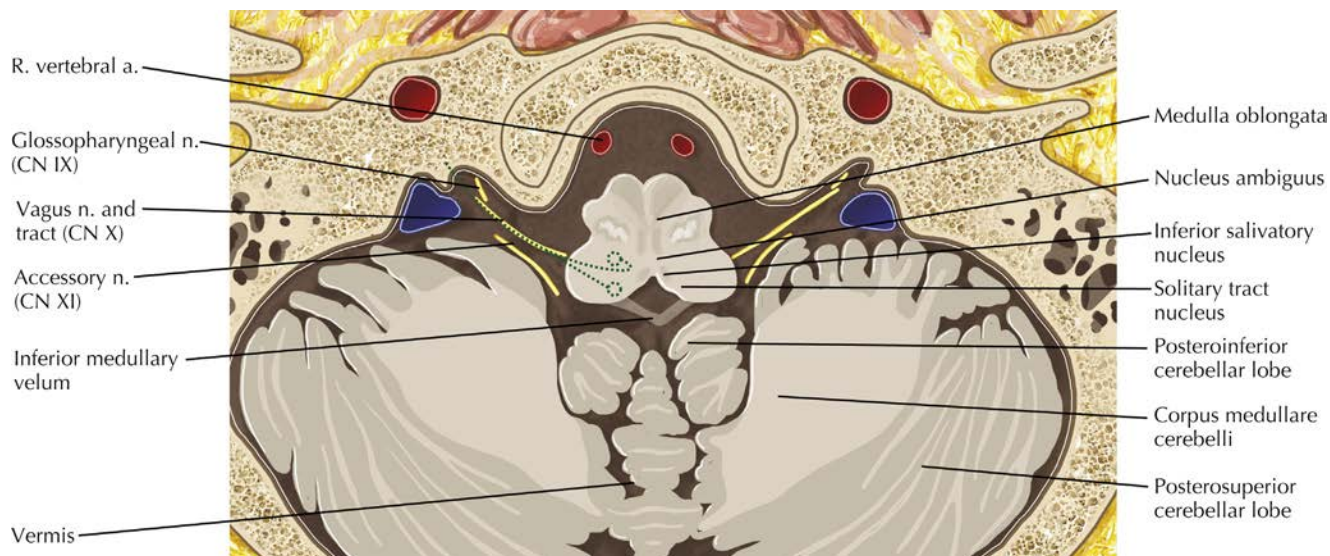




NORMAL ANATOMY

The nucleus ambiguus gives rise to motor fibers of the glossopharyngeal nerve and motor fibers of the vagus nerve. The inferior salivatory nucleus controls the parasympathetic input to the parotid gland and gives rise to axons traveling in the glossopharyngeal nerve. The solitary tract nucleus gives rise to fibers supplying the facial, glossopharyngeal, and vagus nerves and forms a circuit that contributes to autonomic regulation.



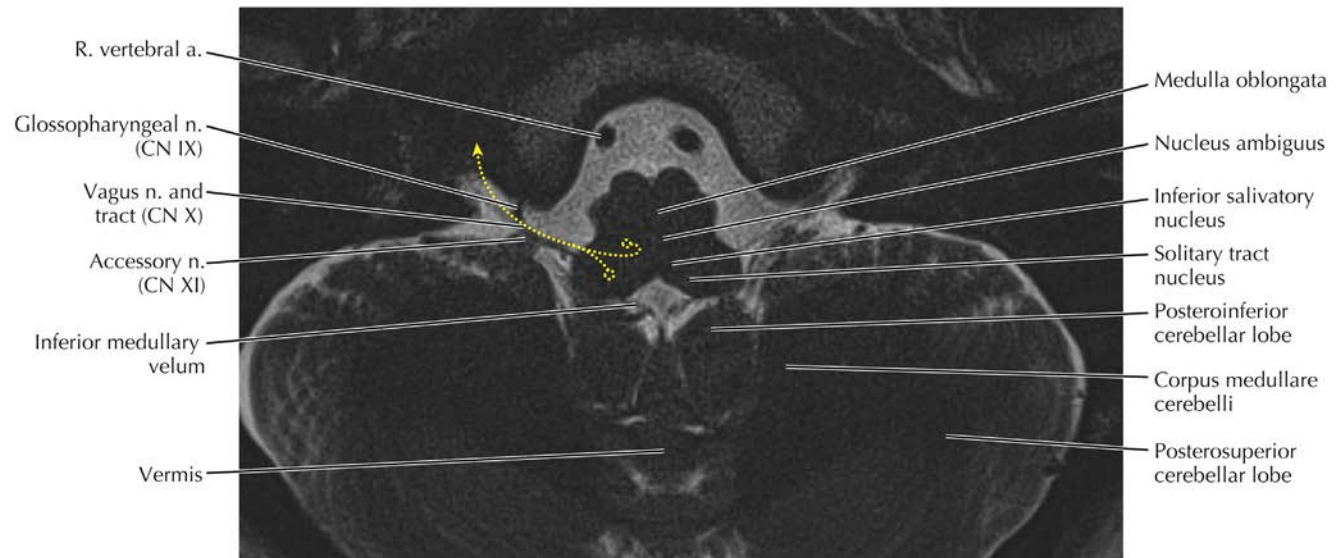
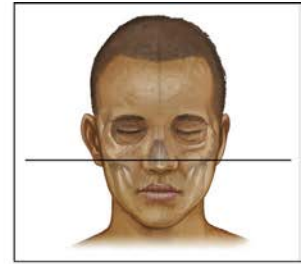


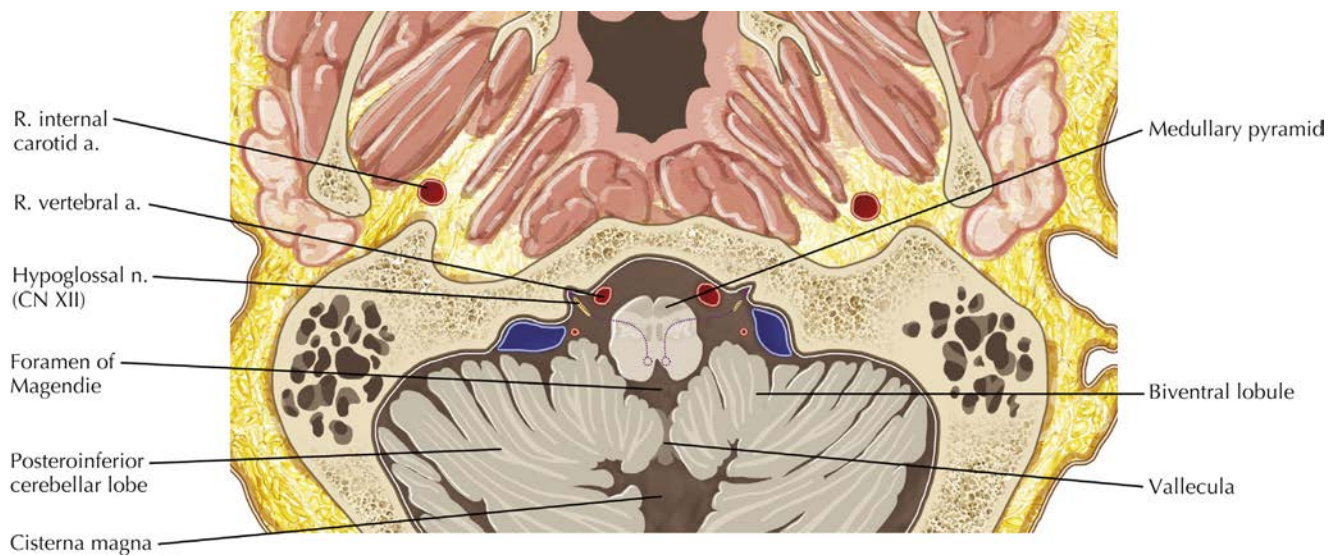
NORMAL ANATOMY

The vagus nerve (tenth cranial, CN X) is the longest cranial nerve. CN X exits the medulla between the medullary pyramid and inferior cerebellar peduncle, passes through the pars vascularis of the jugular foramen, courses inferior into the carotid sheath between the internal carotid artery the internal jugular vein, and then passes down into the neck, chest, and abdomen to innervate the viscera (Latin *vagus*, "wandering"). Most vagus nerve fibers provide sensory information about the state of organs to the brain, although some output also occurs.

The accessory nerve (CN XI) innervates the sternocleidomastoid and trapezius muscles of the neck and shoulder. Originally thought to be part of the brain, this nerve was designated the "eleventh cranial nerve" based on its location relative to other cranial nerves. However, the cranial component soon joins the vagus nerve, so more recently the accessory nerve is deemed to be synonymous with its spinal component and simply labeled *spinal accessory nerve*.

The spinal accessory nerve is the only cranial nerve that forms outside the skull. Nerve outlets originate from the upper spinal cord and coalesce to form the spinal accessory nerve, which then enters the skull through the foramen magnum, joining the vagus nerve to exit the skull through the pars vascularis compartment of the jugular foramen.

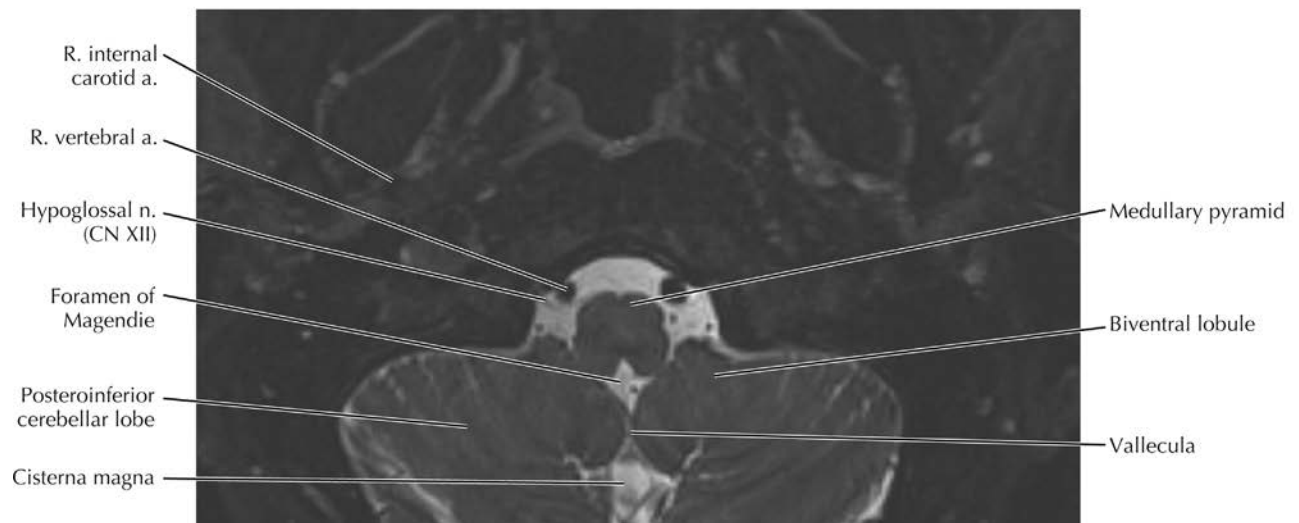
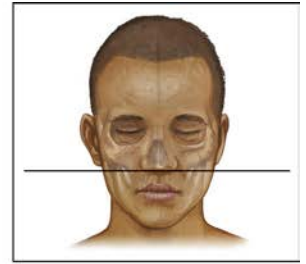




DIAGNOSTIC CONSIDERATION

The hypoglossal nerve (twelfth cranial, CN XII) innervates the muscles of the tongue. After exiting the medulla, CN XII exits the skull through its own canal, the hypoglossal canal, and courses anteriorly to innervate the tongue from inferiorly. This axial image shows its cisternal course immediately posterior to the intracranial segment of the vertebral artery.

Damage to the hypoglossal nerve can lead to atrophy of the ipsilateral muscles of the tongue and on protrusion of the tongue, deviation toward the affected side.



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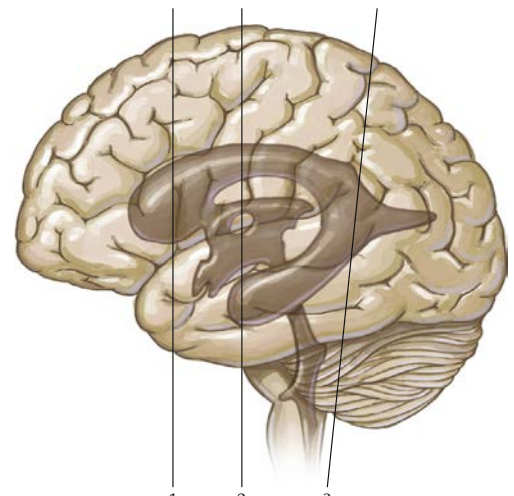
Chapter

6

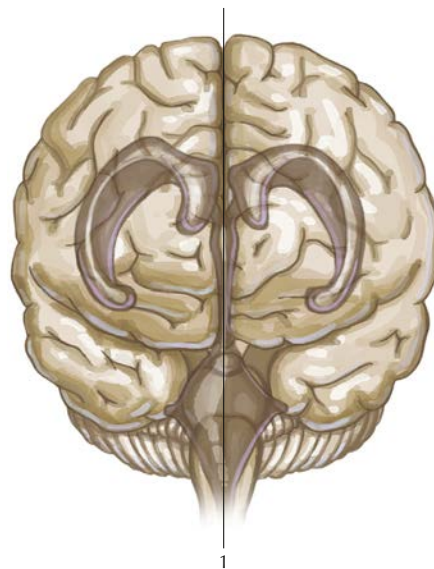
VENTRICLES AND CEREBROSPI- NAL FLUID CISTERNS



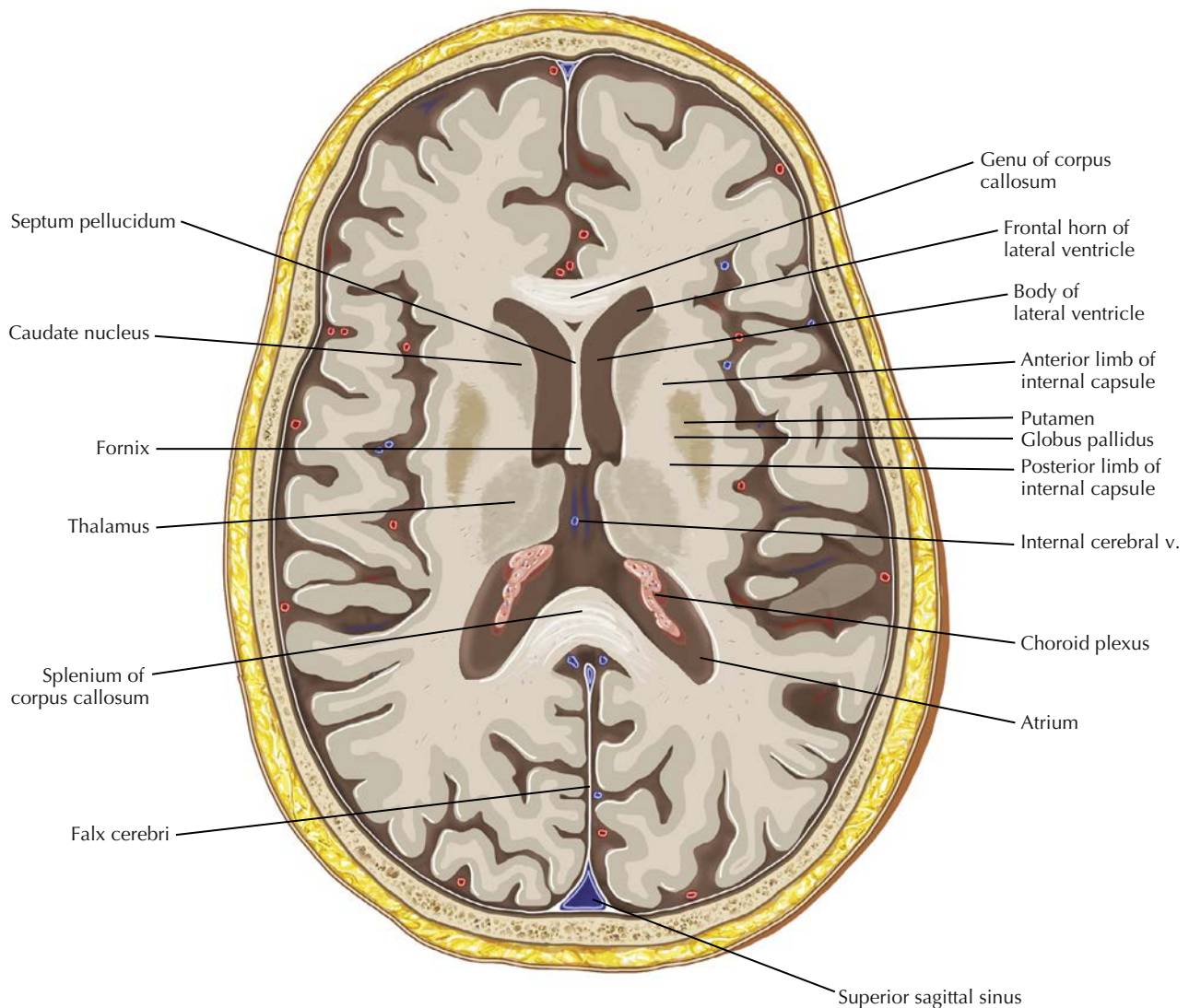
AXIAL 274



CORONAL 286



SAGITTAL 292

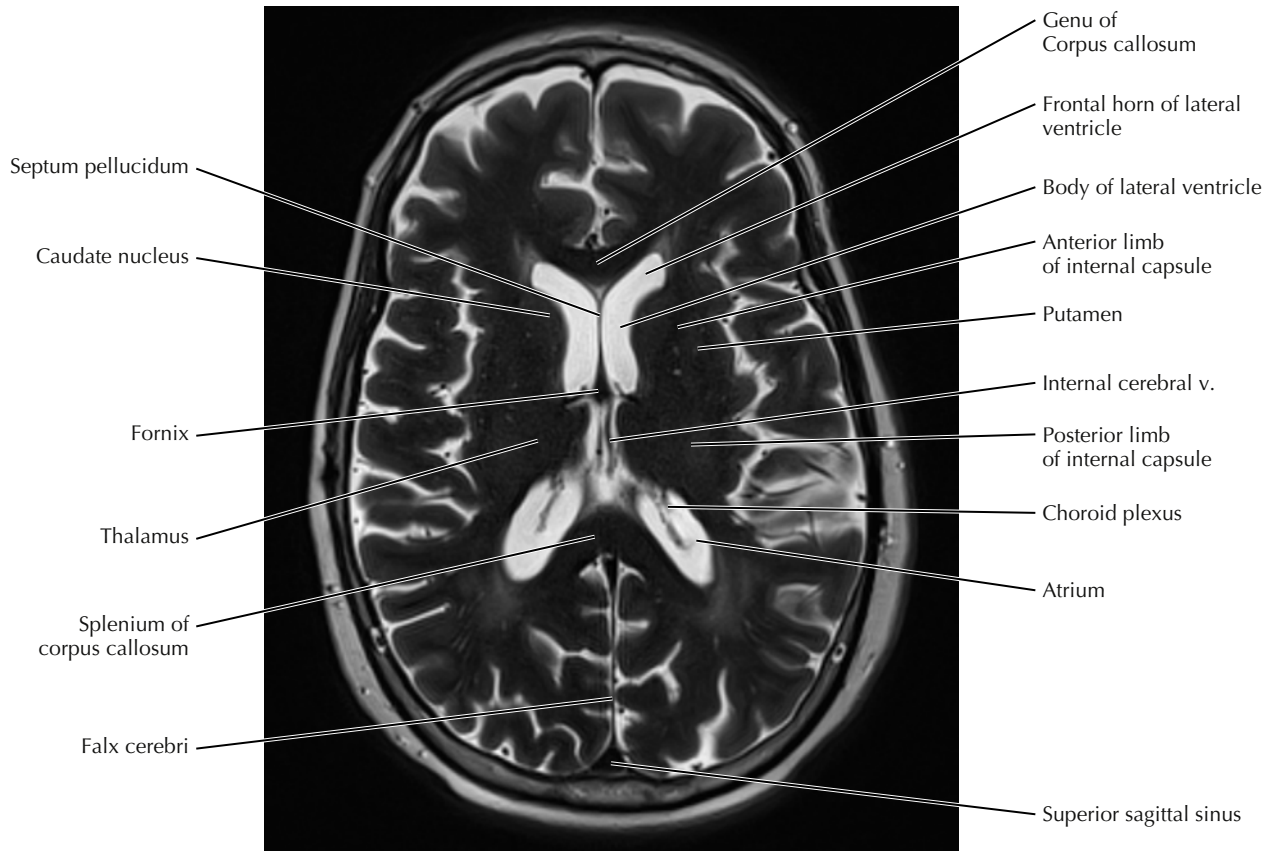
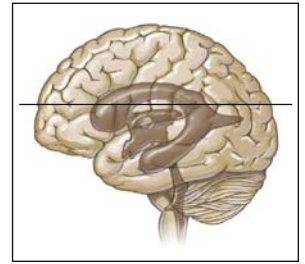


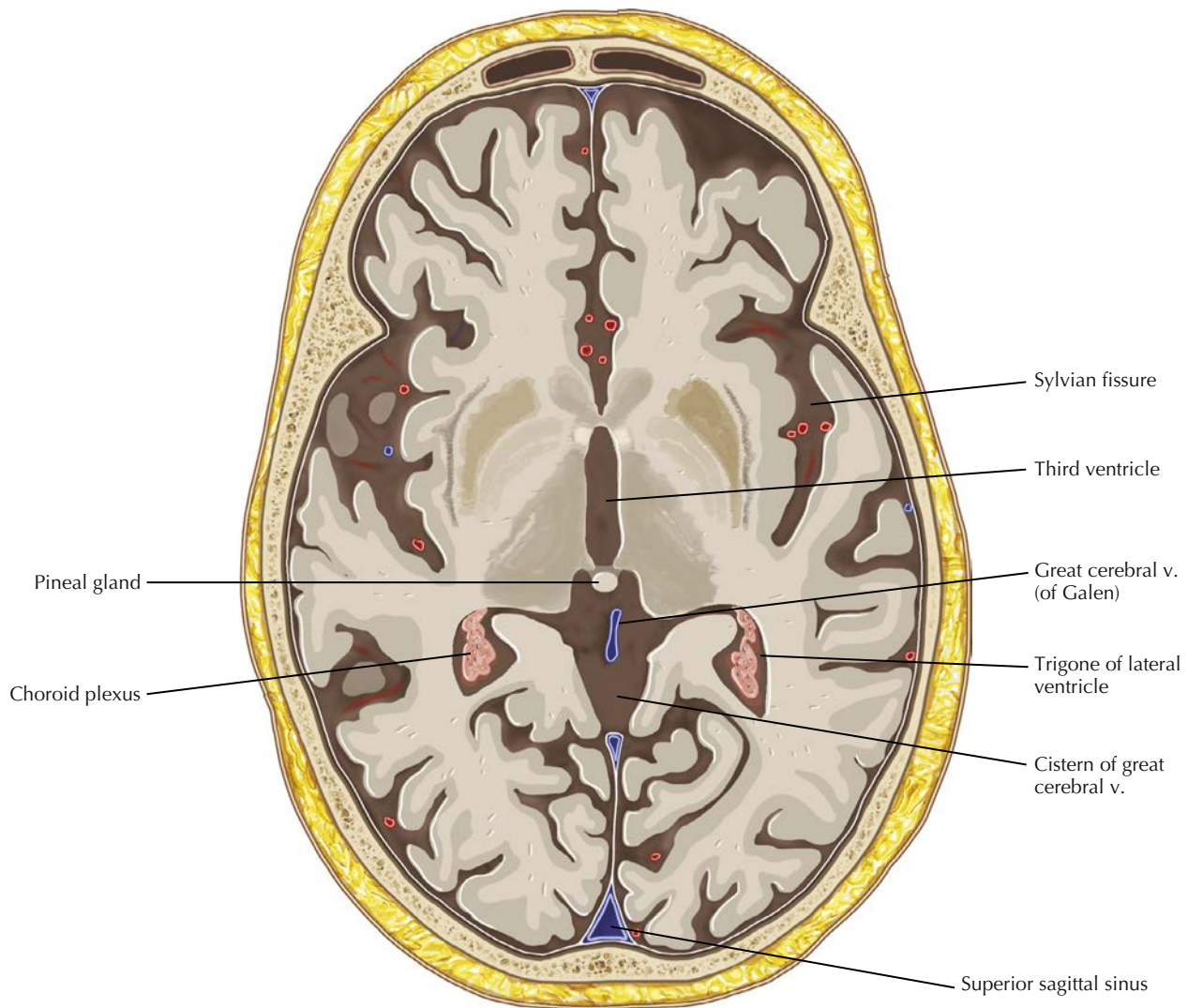
NORMAL ANATOMY

The ventricular system is located deep within the brain and is filled with cerebrospinal fluid (CSF). The normal appearance of CSF on magnetic resonance images is that of water. This axial MR image shows the *choroid plexus* within the ventricles, where CSF is produced. CSF is also seen outside the brain and within the sulci (subarachnoid space).

PATHOLOGIC PROCESS

A *colloid cyst* is a benign lesion located near the foramen of Munro that may lead to sudden CSF obstruction, brain edema, and death if not treated with drainage and resection. CSF is produced at a rate of 500 mL daily; the intracranial vault and spinal canal contain only 150 mL, so the CSF turns over about three times each day.



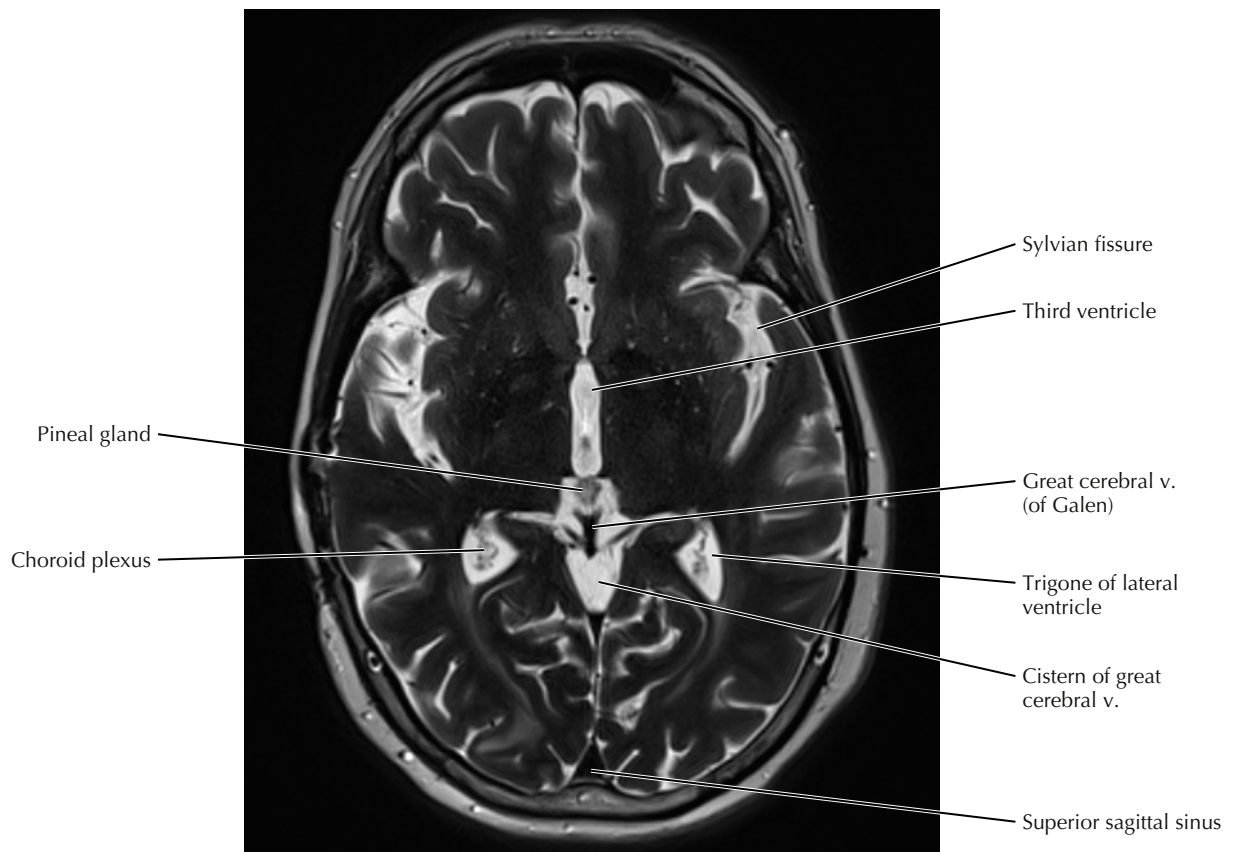
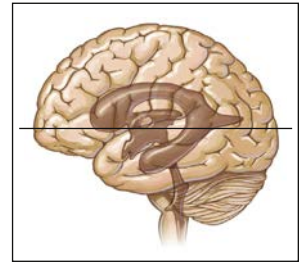


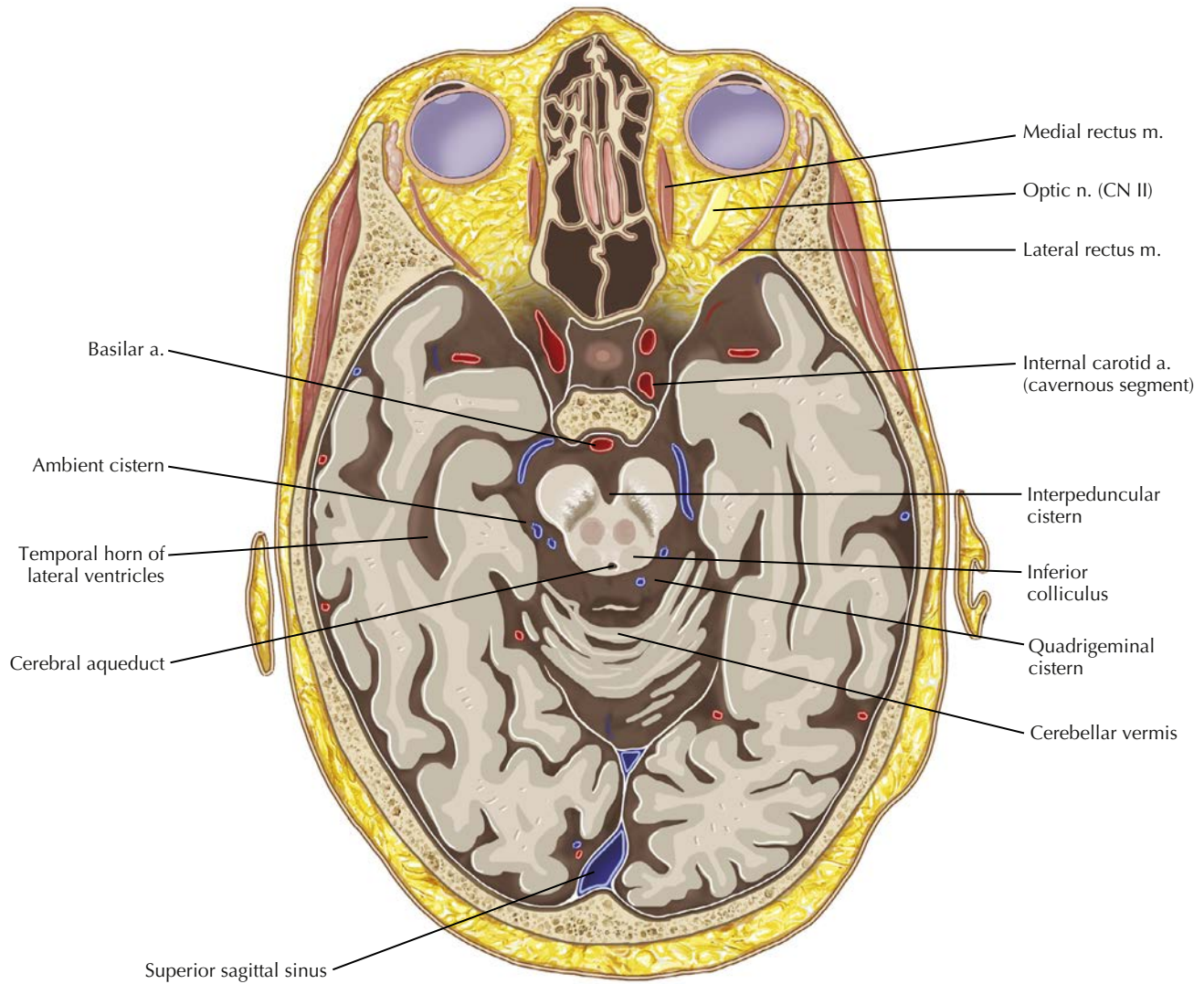
NORMAL ANATOMY

At this axial level, the atrium has a triangular appearance and thus is often referred to as the *trigone*.

IMAGING TECHNIQUE CONSIDERATION

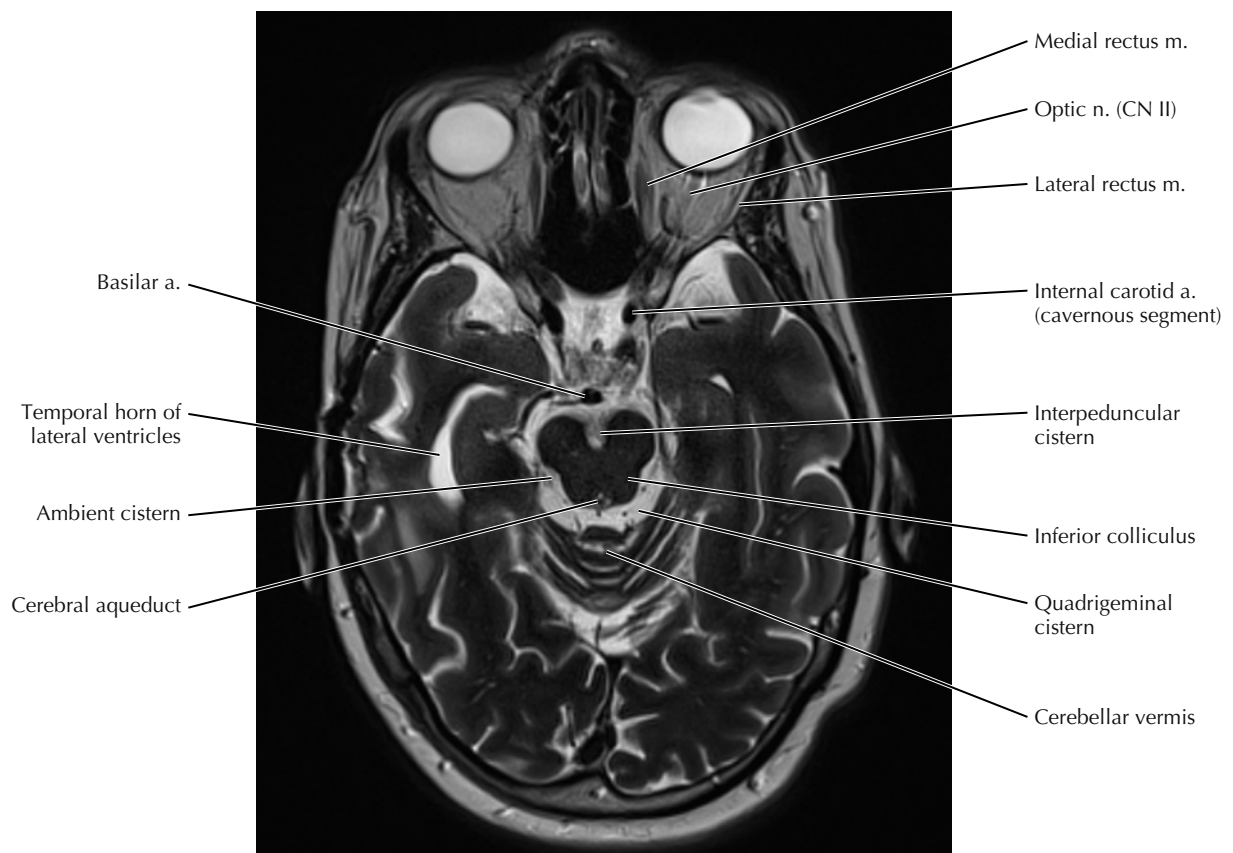
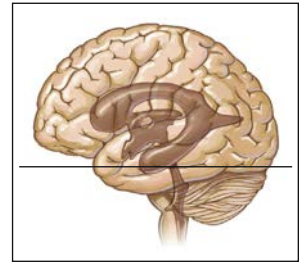
Note that fluid is bright on T2-weighted MRI. The subcutaneous fat shows some brightness on T2-weighted images when multiple spin-echo pulses are applied (fast, or "turbo," spin echo), as opposed to conventional spin echo T2-weighted imaging, where fat appears dark.

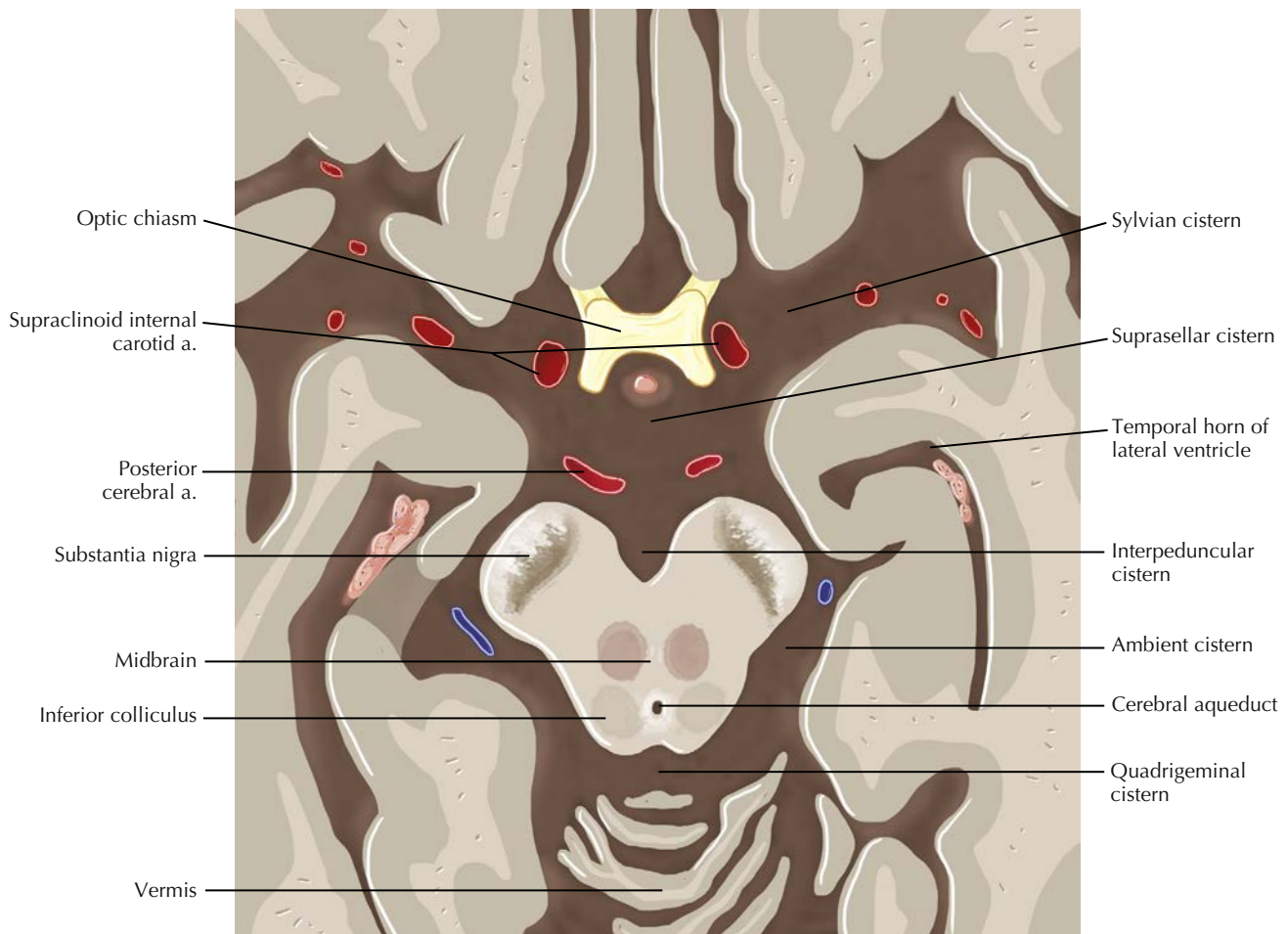




PATHOLOGIC PROCESS

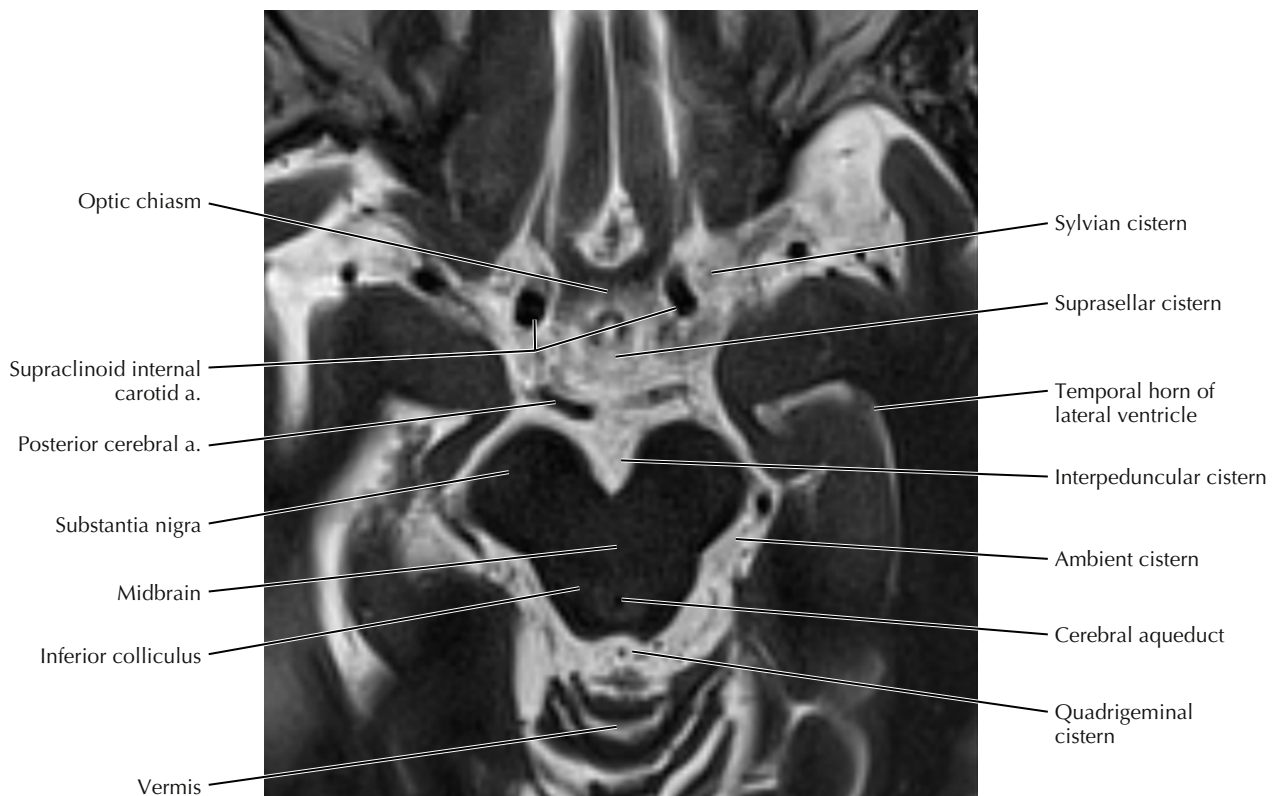
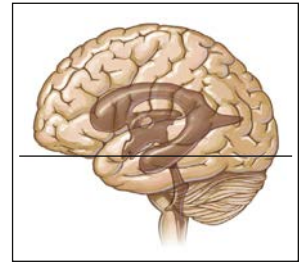
Note that the temporal horn is a contiguous part of the lateral ventricles. Dilatation of the temporal horns is frequently a sign of hydrocephalus.

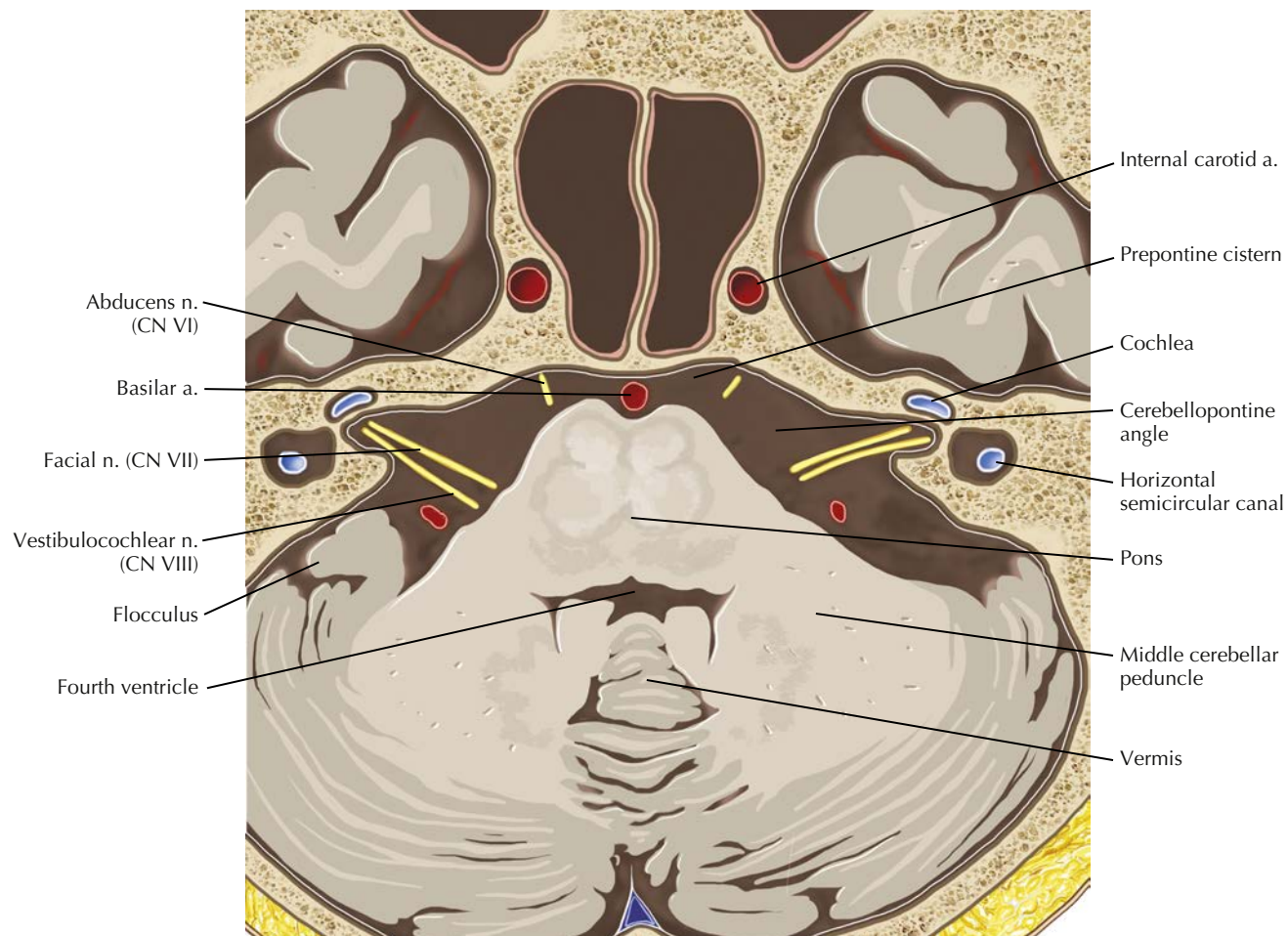




PATHOLOGIC PROCESS

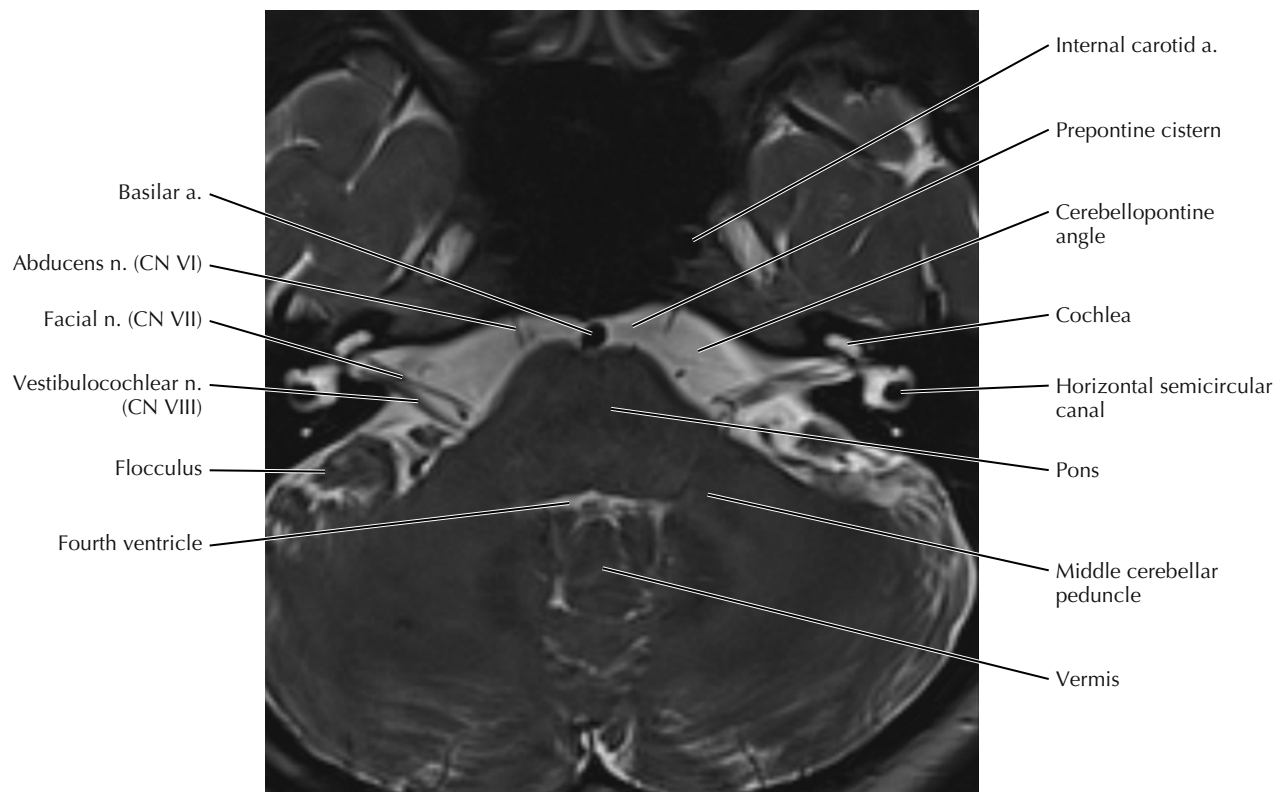
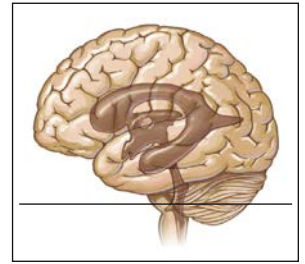
The suprasellar cistern has the shape of a six-pointed star. The interpeduncular cistern forms the posterior point of the star and is often the first location where a small amount of subarachnoid hemorrhage will layer when an aneurysm of the circle of Willis ruptures.

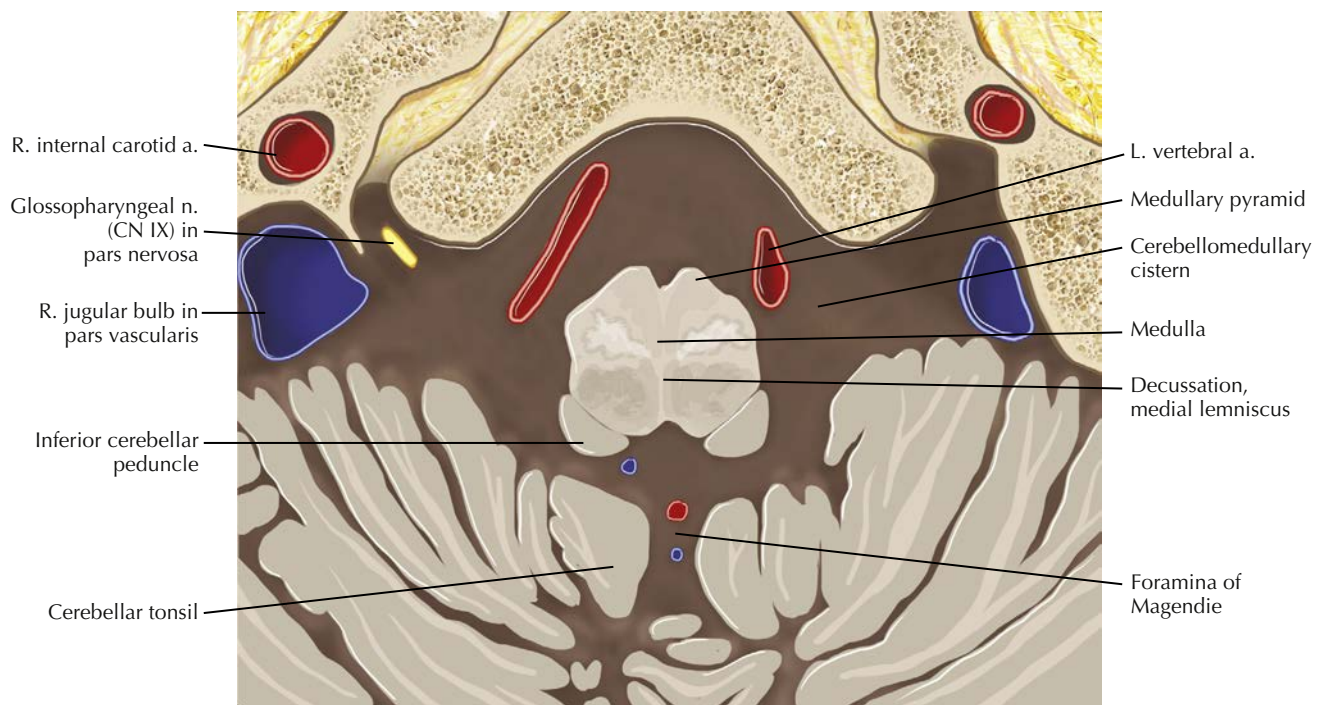




NORMAL ANATOMY

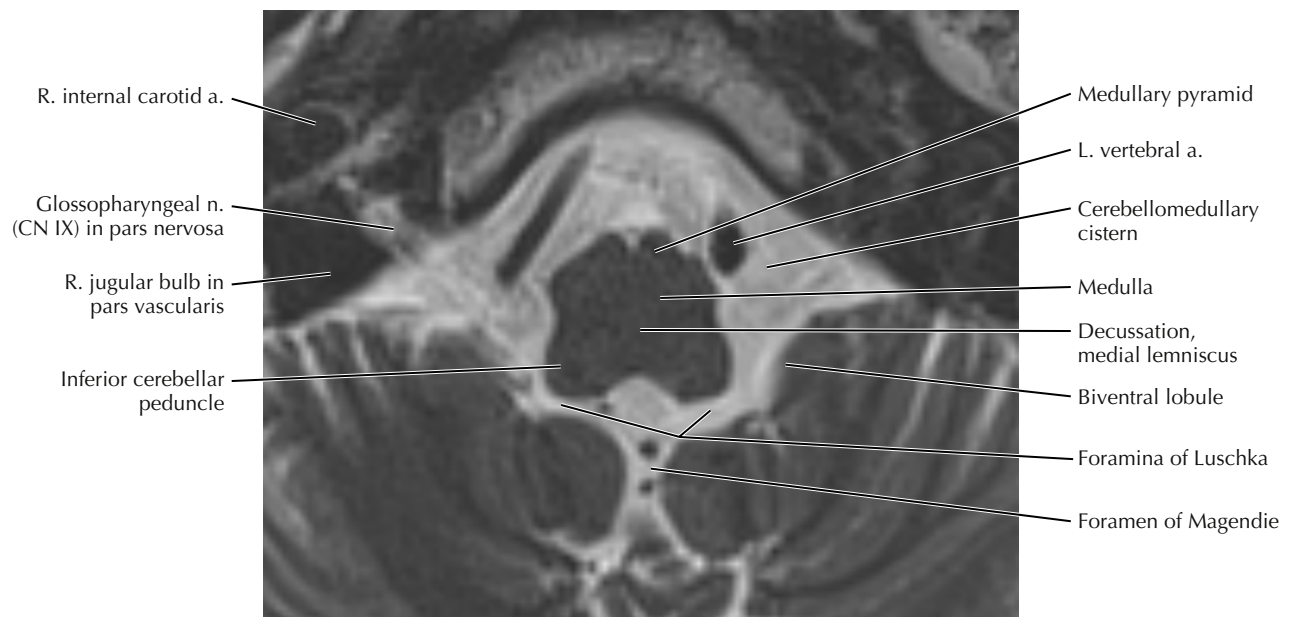
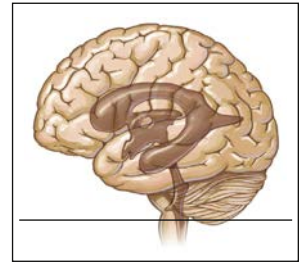
The fluid in the semicircular canal is called *endolymph*.

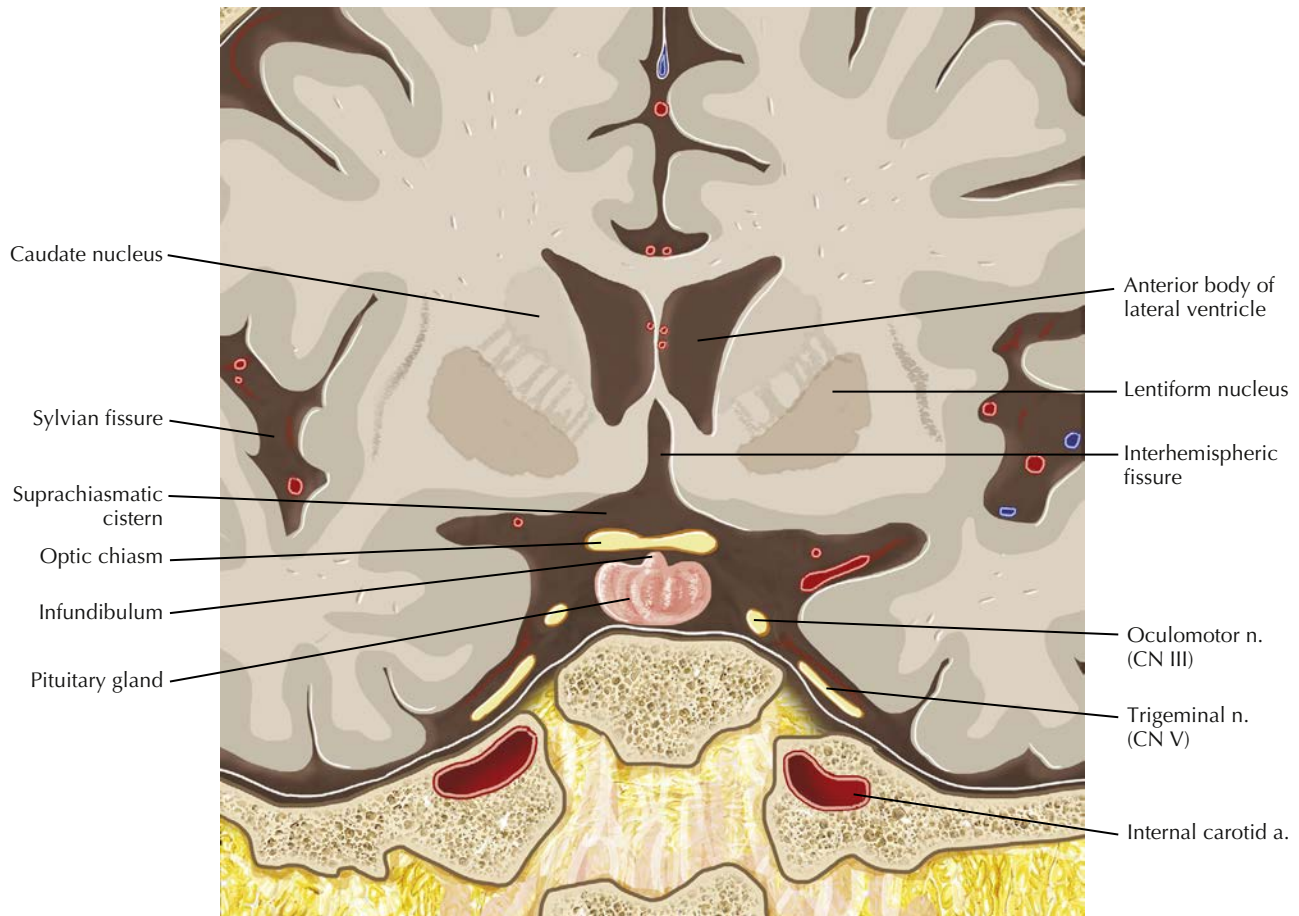




NORMAL ANATOMY

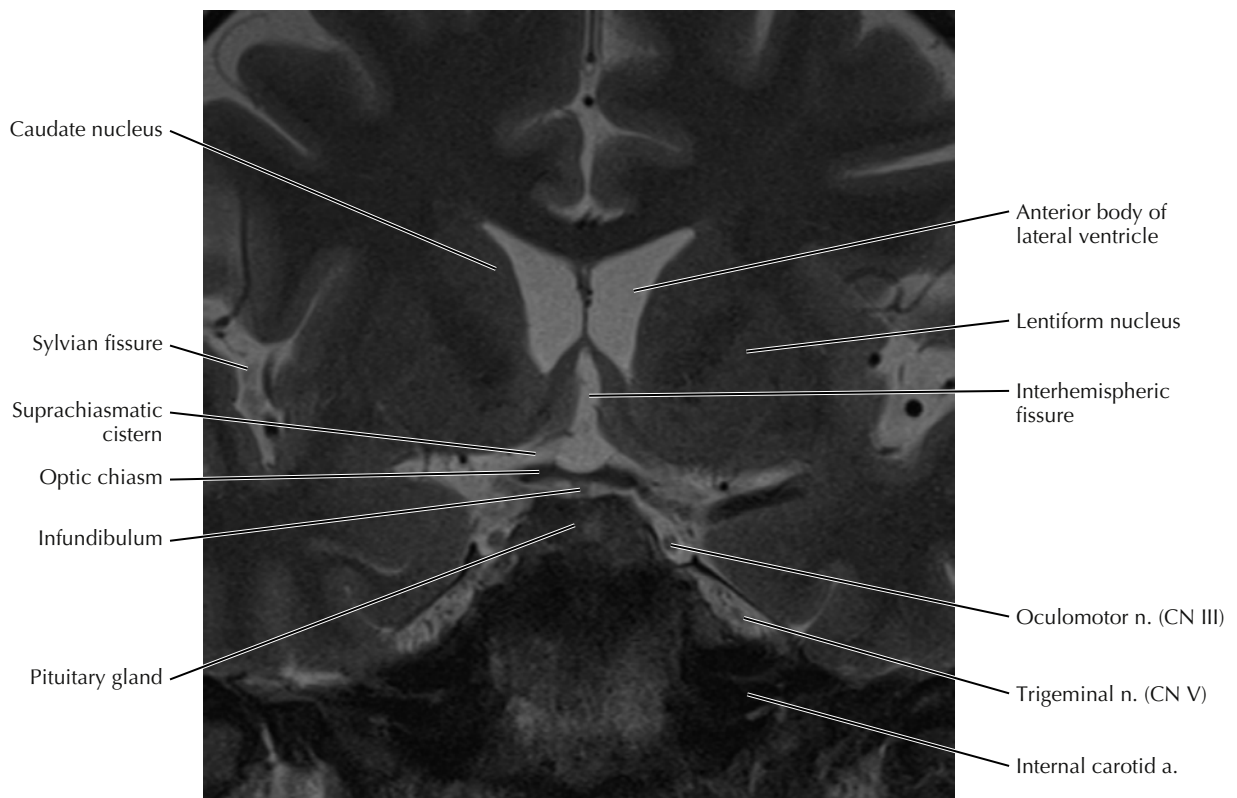
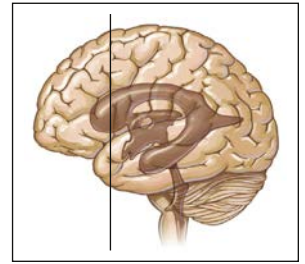
Cerebrospinal fluid produced by the choroid plexus flows downward from the lateral ventricles, third ventricle, aqueduct of Sylvius (cerebral aqueduct), and fourth ventricle. CSF then flows out laterally through the foramina of Luschka or the midline through the foramen of Magendie. From here the CSF flows caudally around the spinal cord or cranially around the brain to the convexity, where it is absorbed by arachnoid granulations.

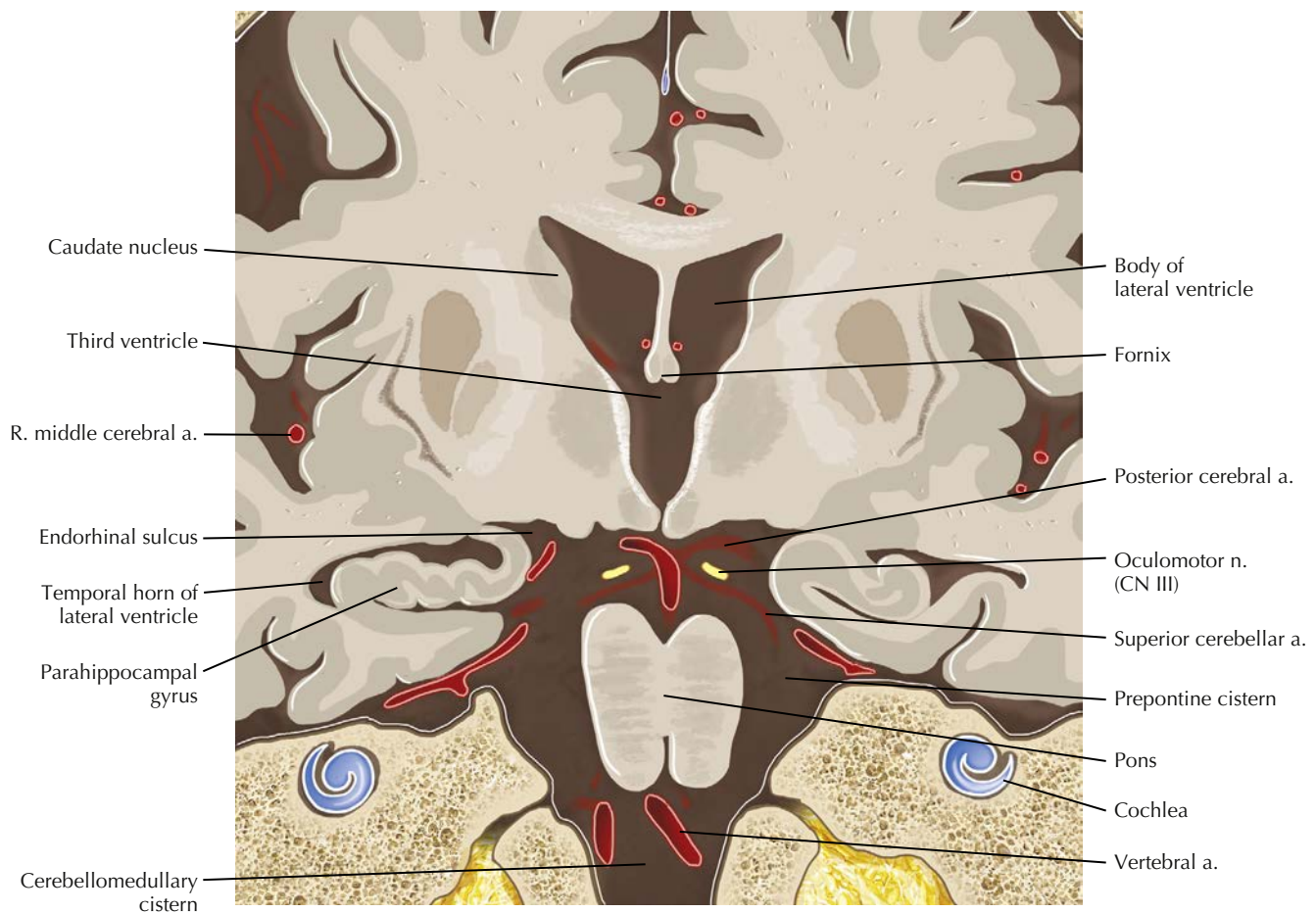


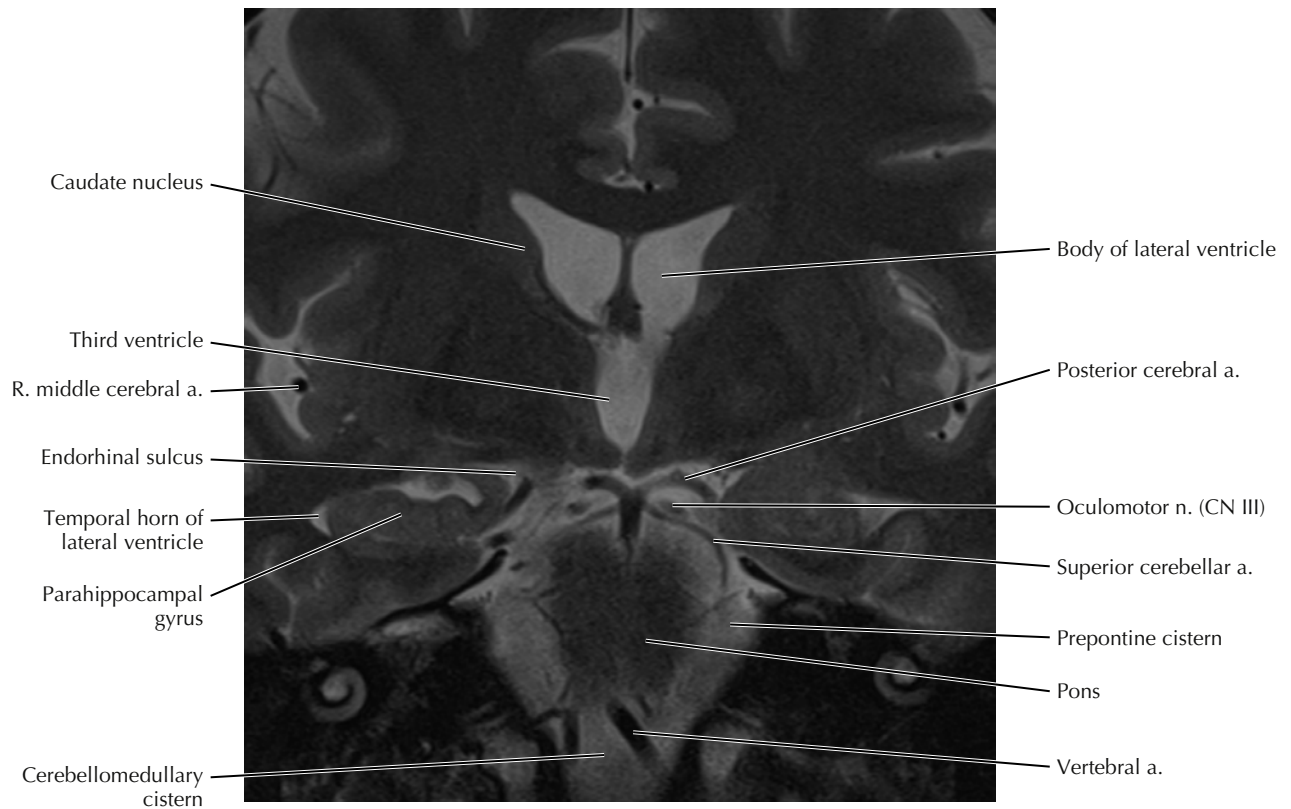
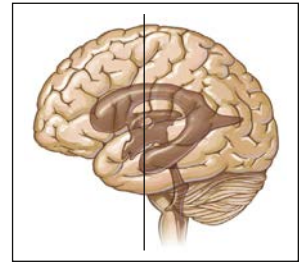


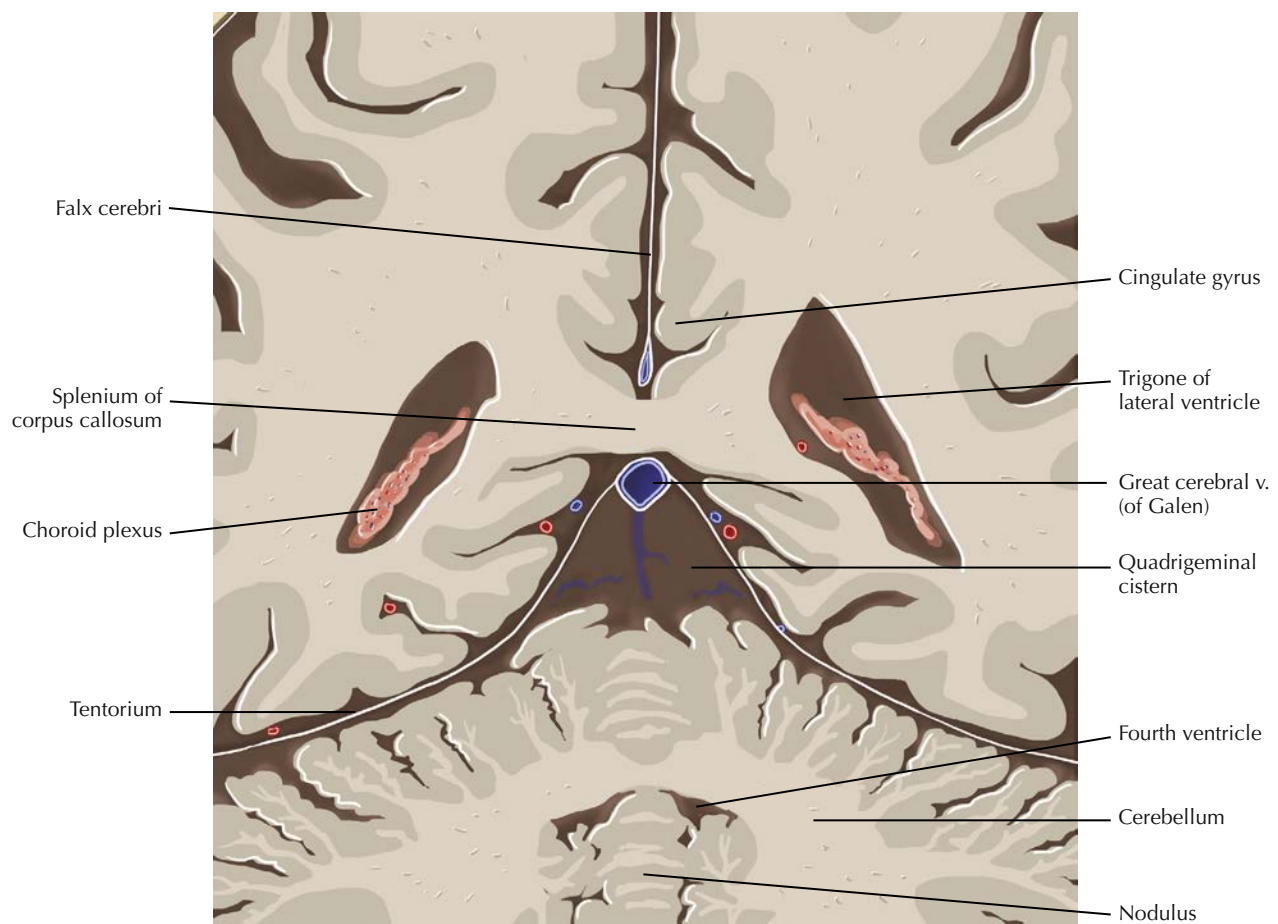
DIAGNOSTIC CONSIDERATION

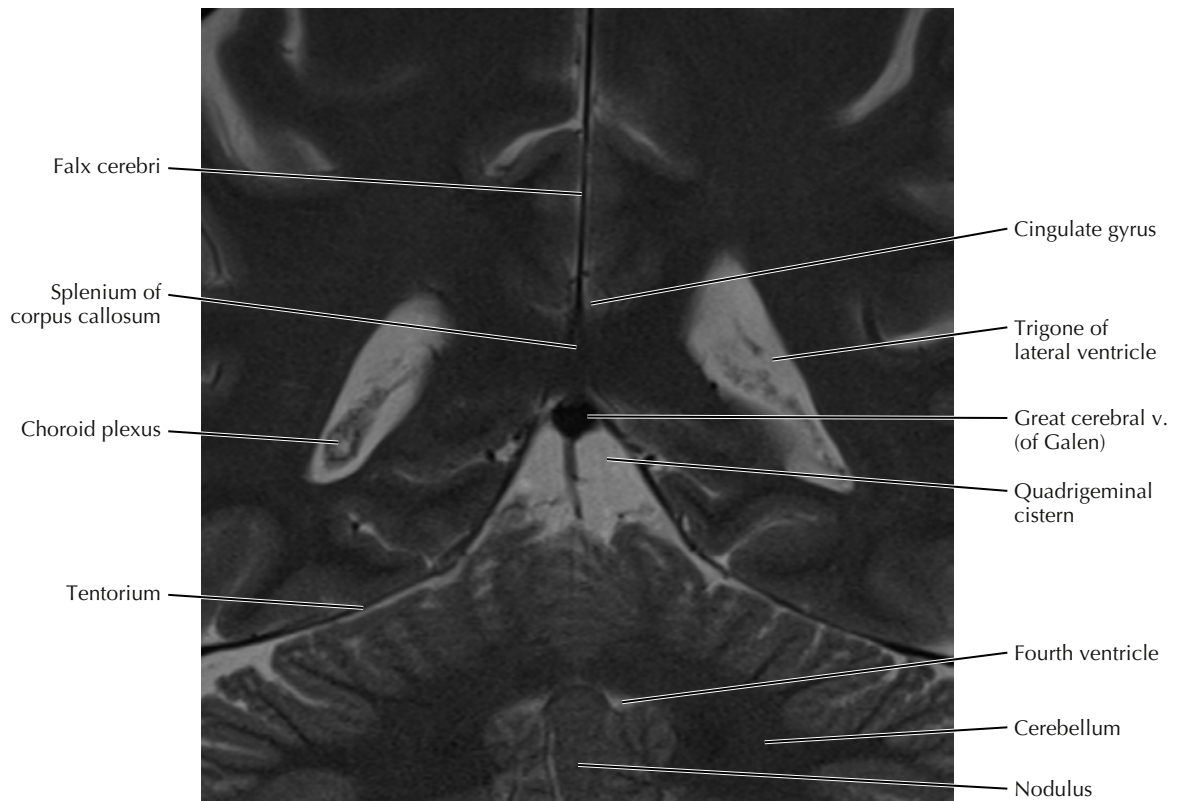
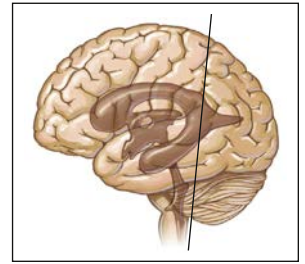
Coronal imaging is not used as often as axial MRI for assessment of the ventricles and cisterns, although the cerebrospinal fluid does provide good contrast in assessment of midline structures such as the optic chiasm, infundibulum, and pituitary gland (hypophysis).

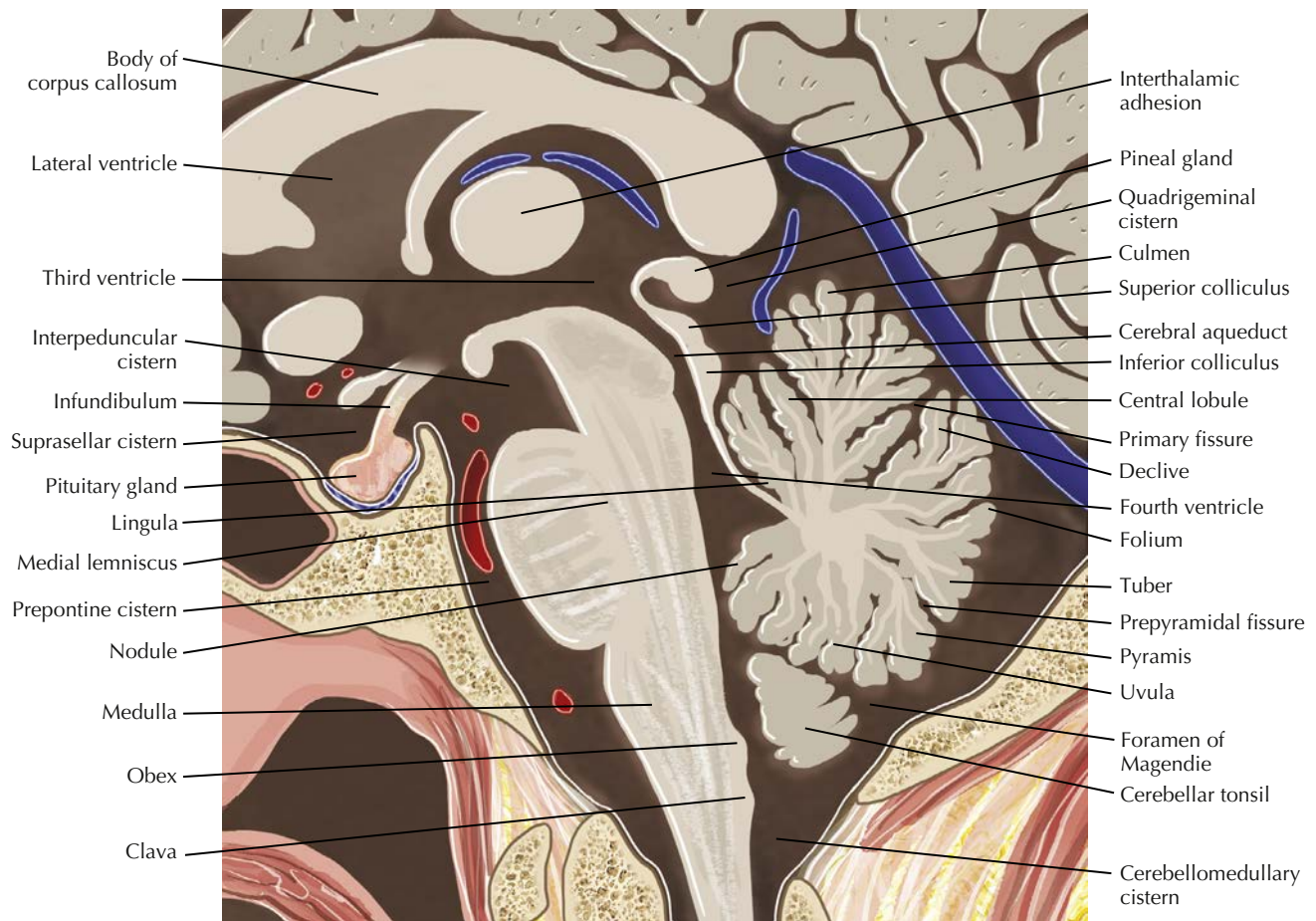






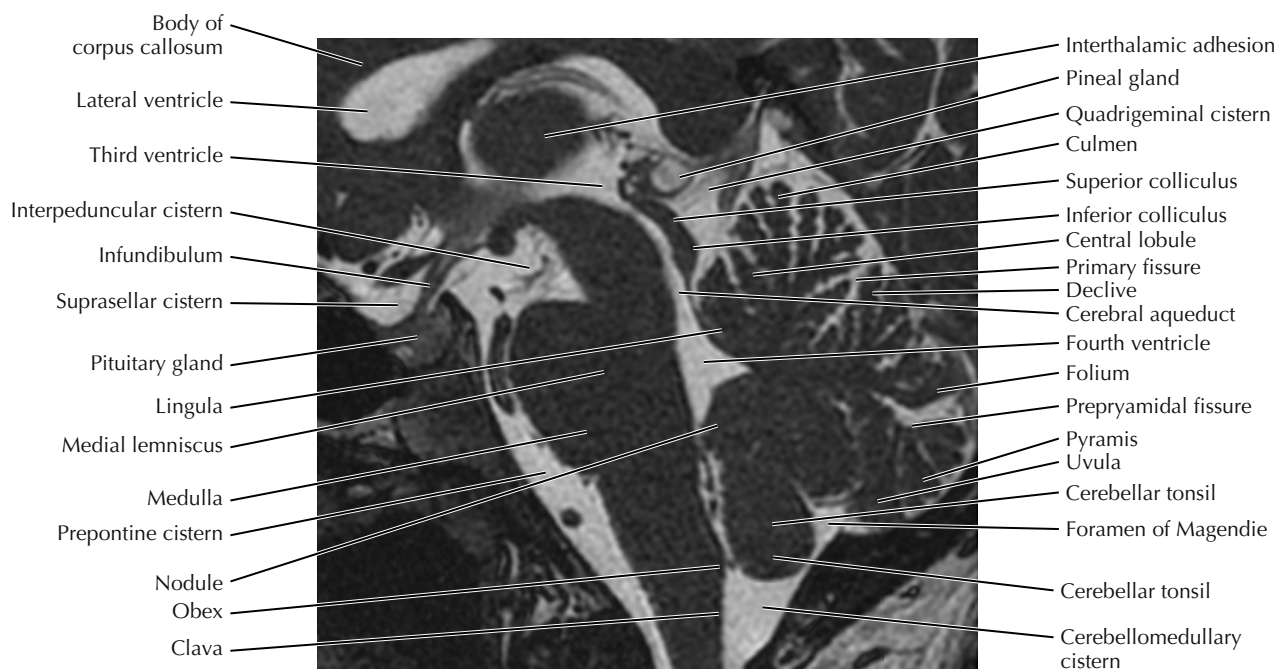
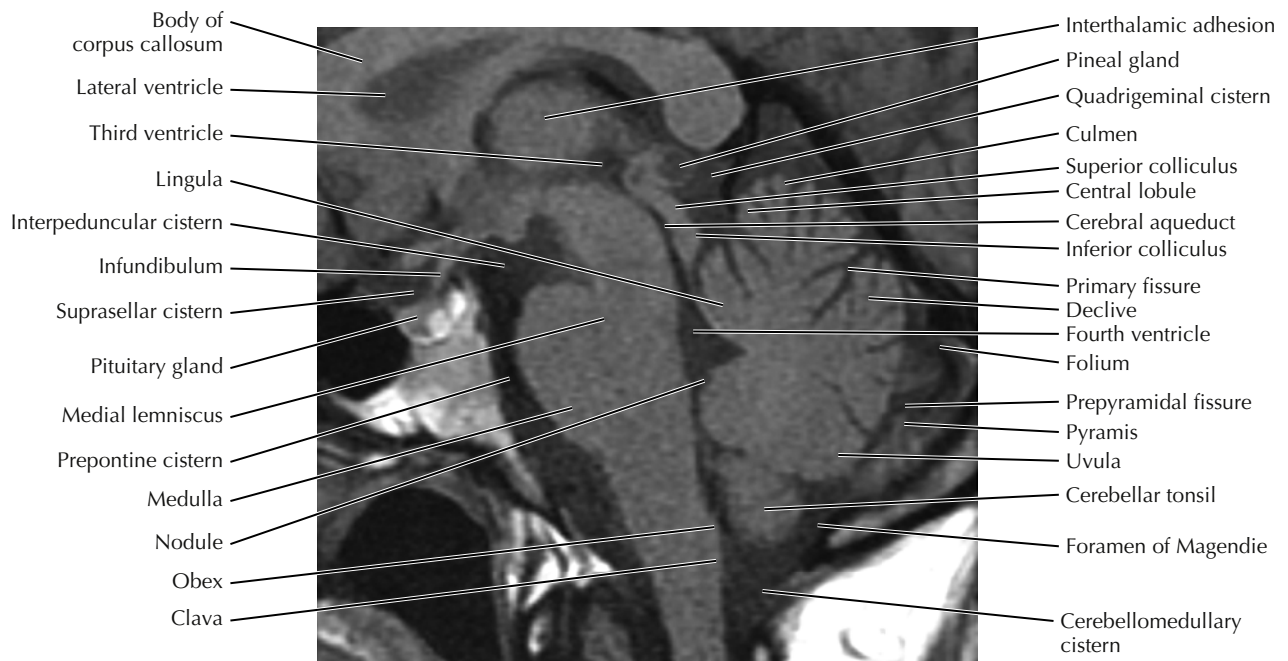






DIAGNOSTIC CONSIDERATION

The midline sagittal plane on MR images provides a good view of the aqueduct of Sylvius (cerebral aqueduct). This long, thin, narrow channel is a relatively easy point for obstruction of CSF flow from a mass or adhesions. Dynamic MRI can be obtained in this sagittal plane to assess whether there is movement of CSF through the cerebral aqueduct.

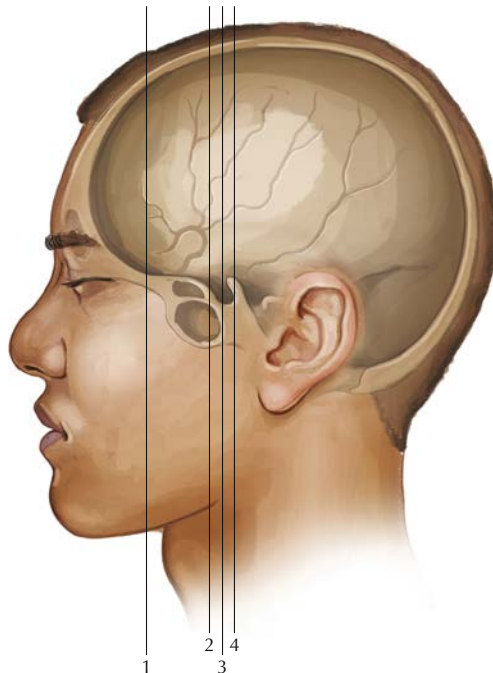


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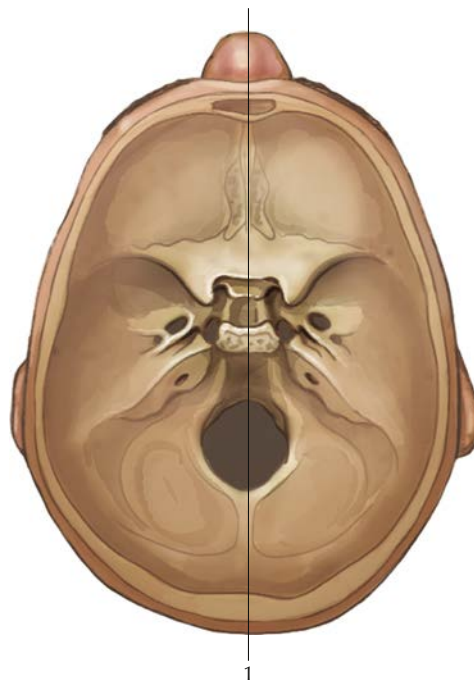
Chapter

7

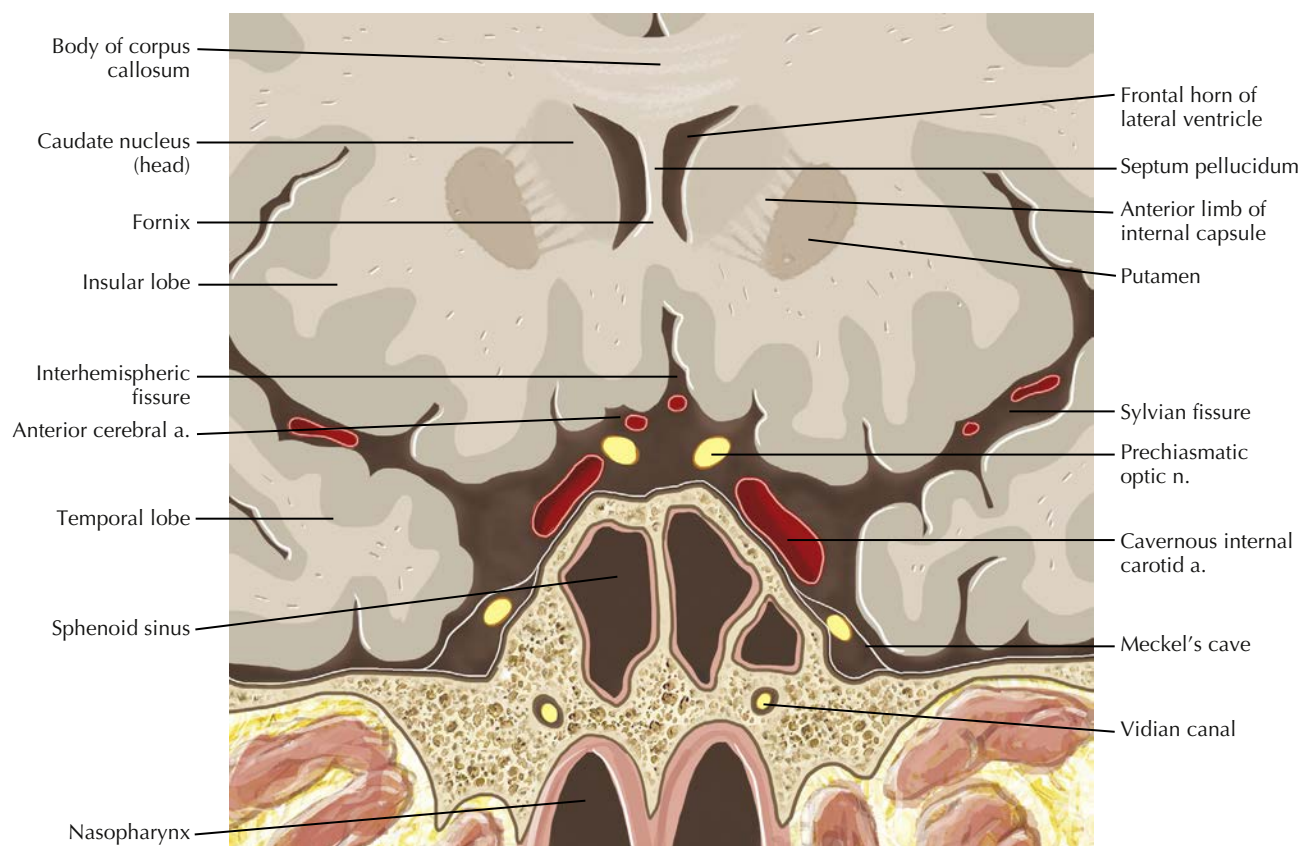
SELLA TURCICA



CORONAL 296

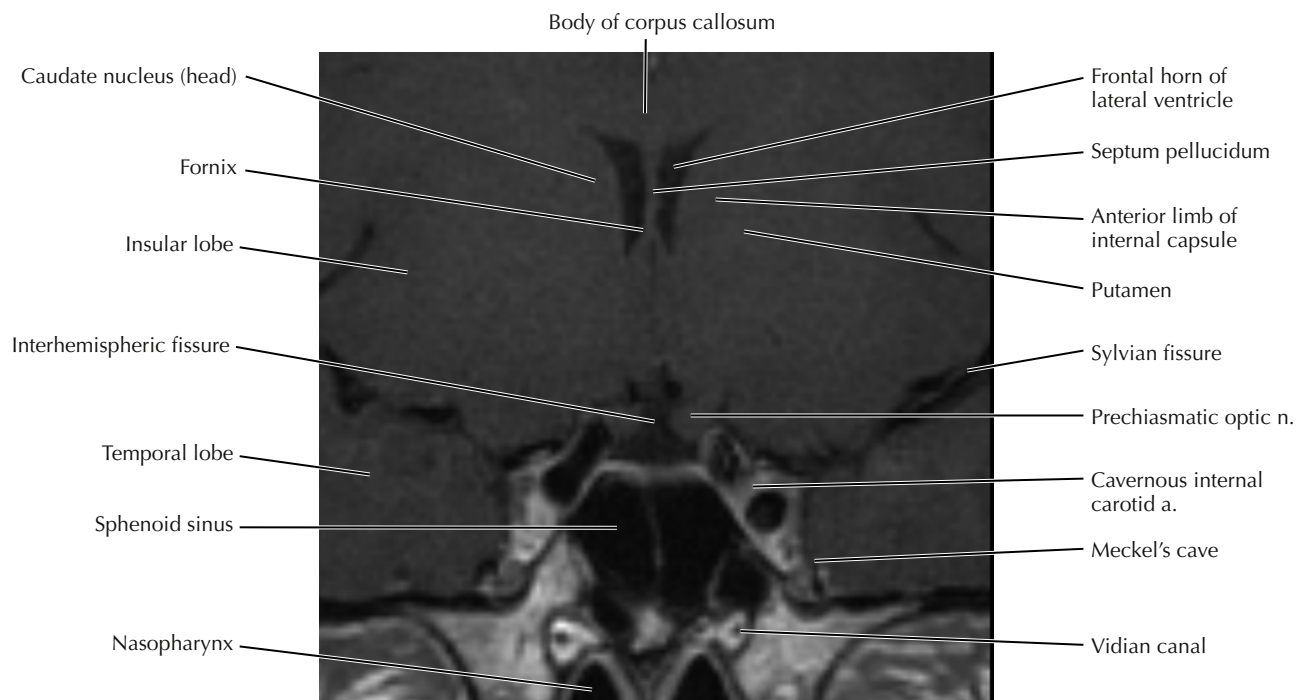
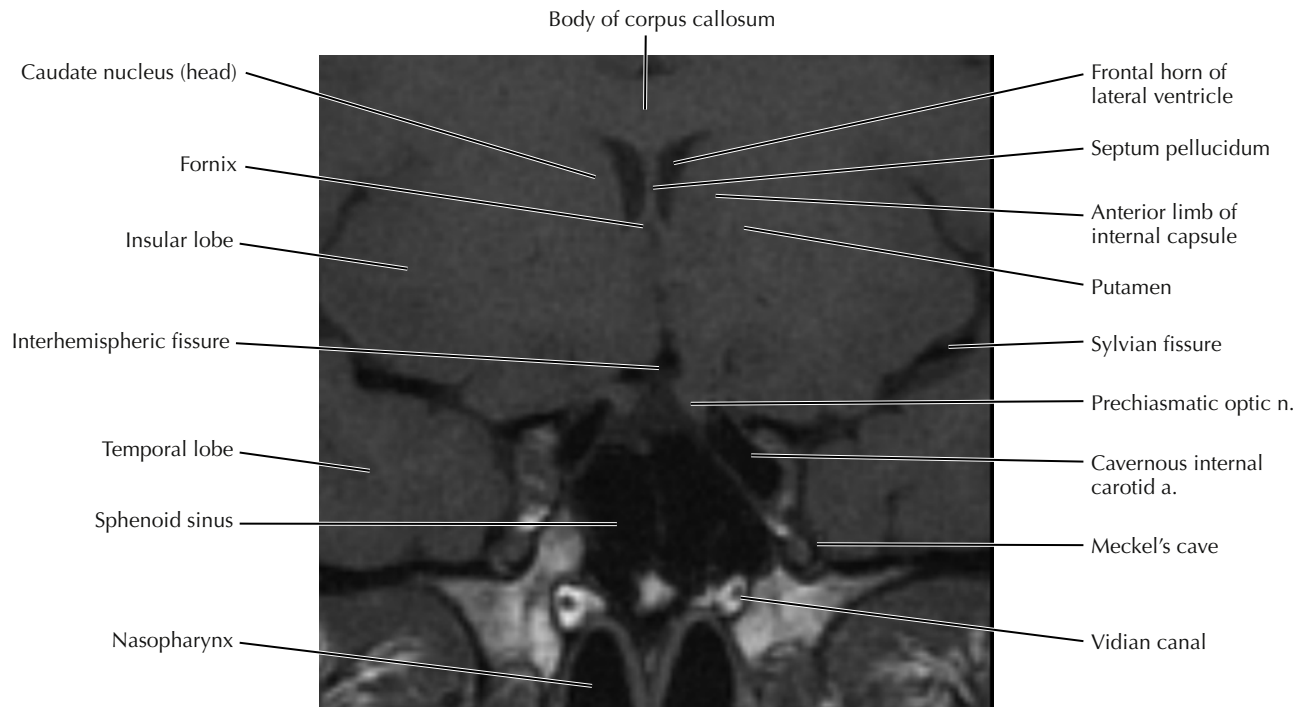
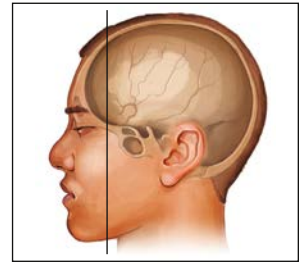


SAGITTAL 304



TECHNICAL NOTE

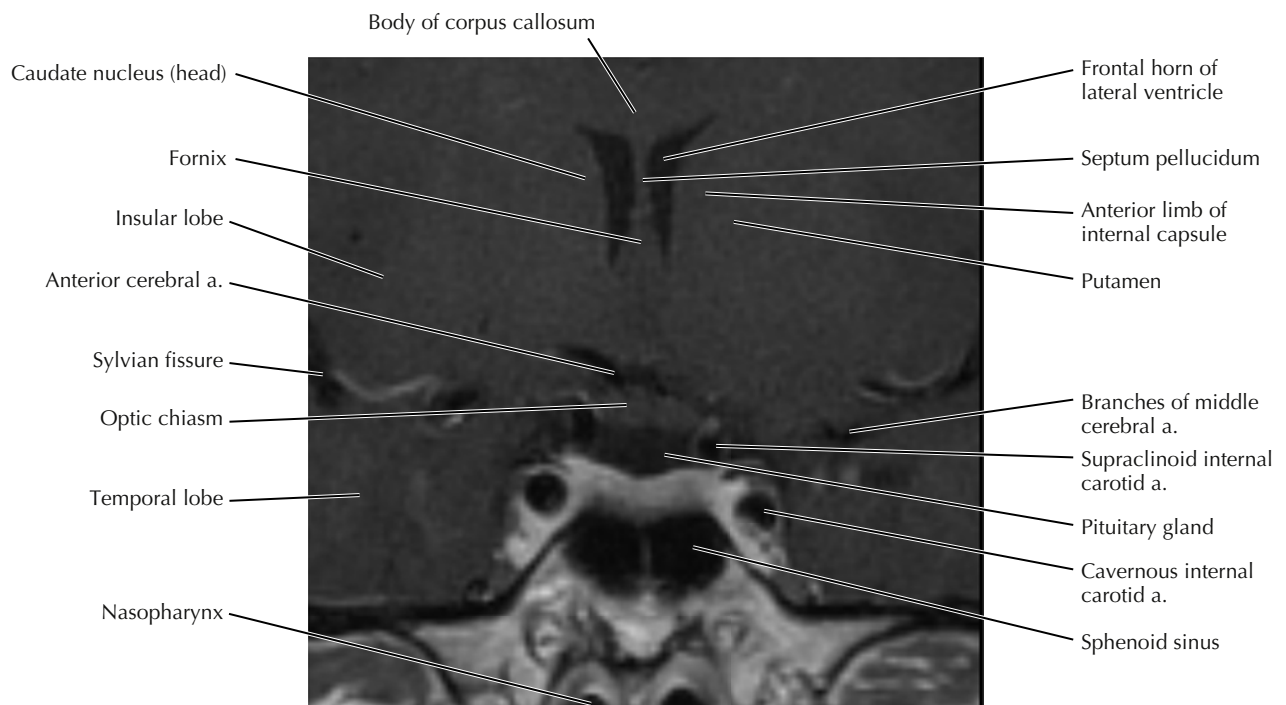
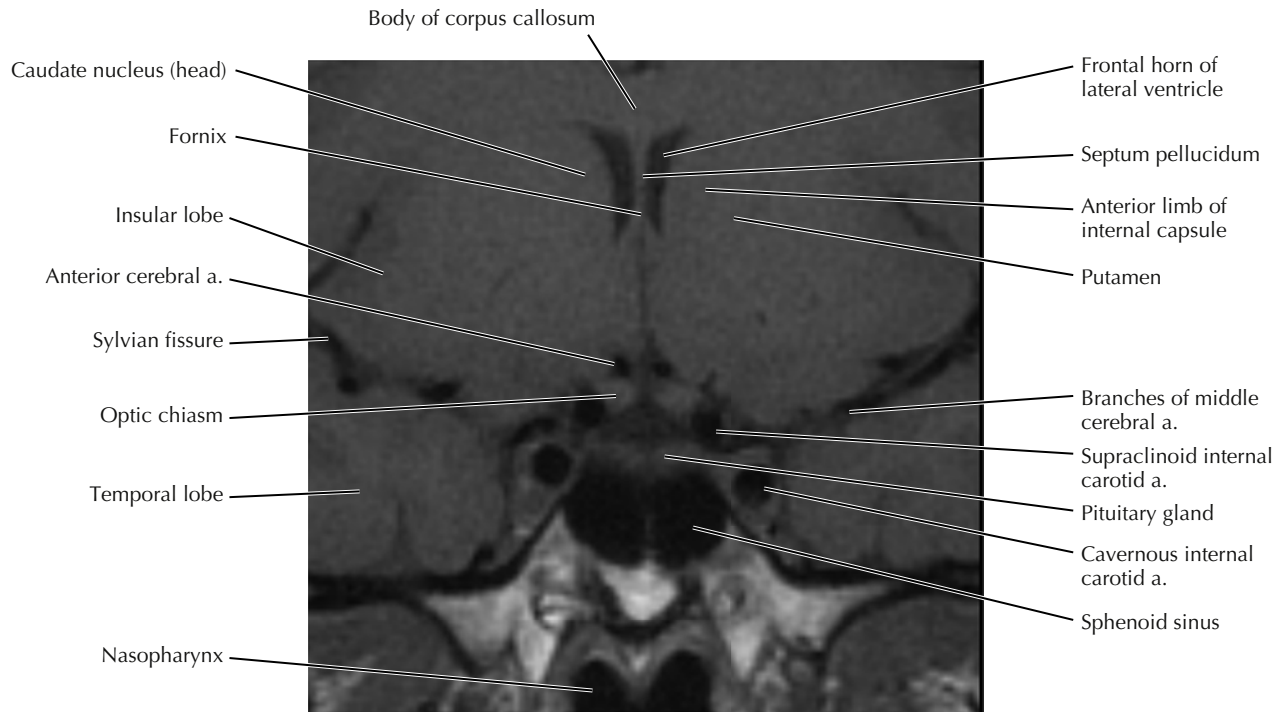
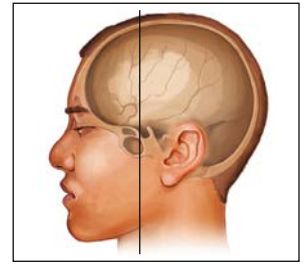
The upper MR image is a coronal T1-weighted pre-contrast sequence and the lower is a coronal T1-weighted post-contrast sequence.





DIAGNOSTIC CONSIDERATIONS

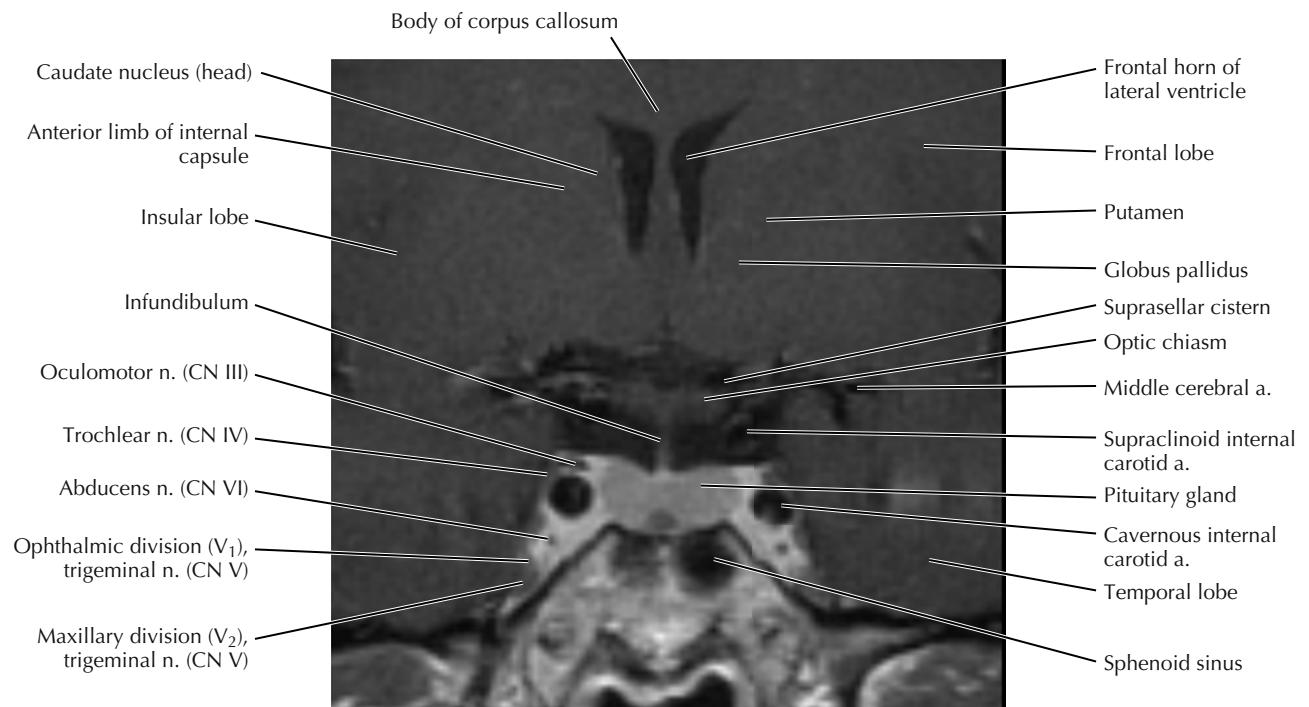
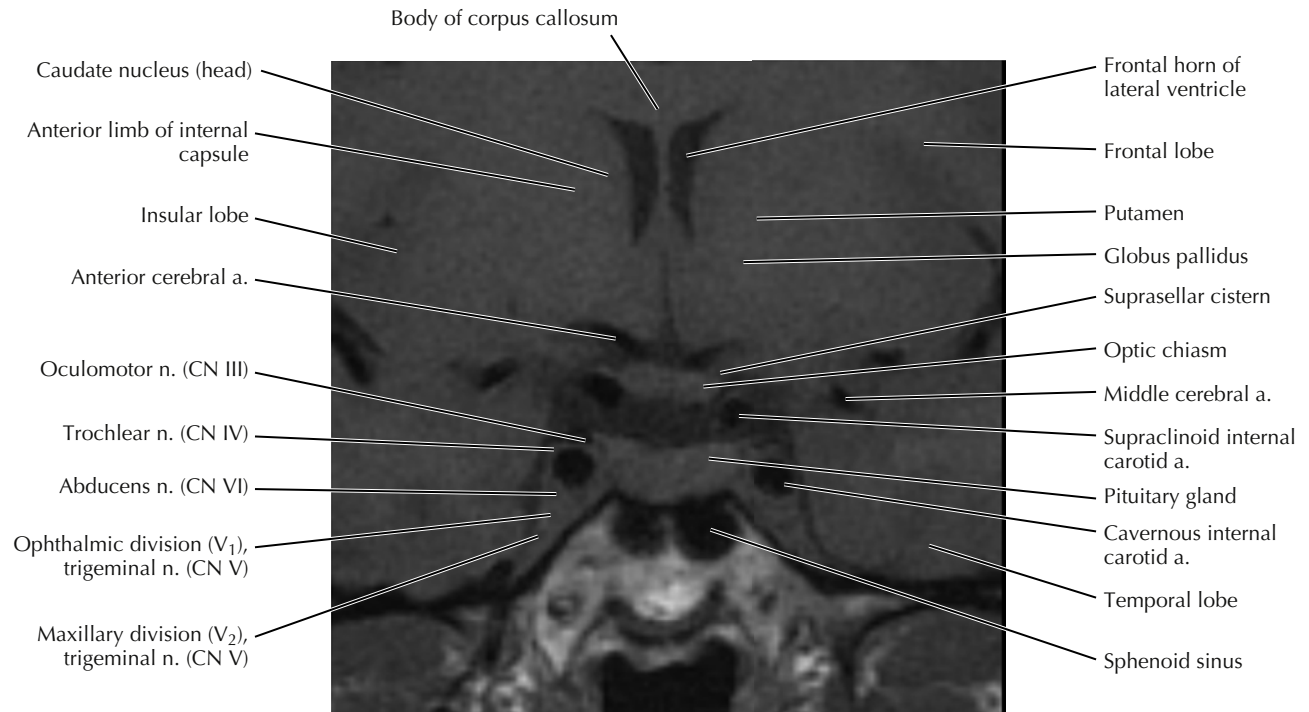
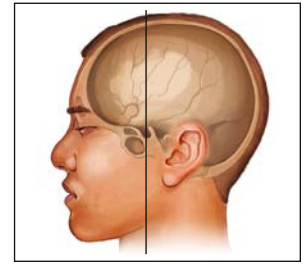
The best magnetic resonance sequence to identify a pituitary lesion is coronal, thin, 3-mm magnified postcontrast images of the sella turcica. The sella is a transverse depression crossing the midline at the superior surface of the sphenoid bone that contains the pituitary gland, or *hypophysis*. Pituitary adenomas are typically less enhancing than the normal gland. Precontrast imaging is used to determine that the apparent enhancement is not intrinsic high T1-weighted signal. Intrinsically high T1 signal is most frequently seen with fat, some forms of protein, acute hemorrhage (methemoglobin), and microcalcifications.

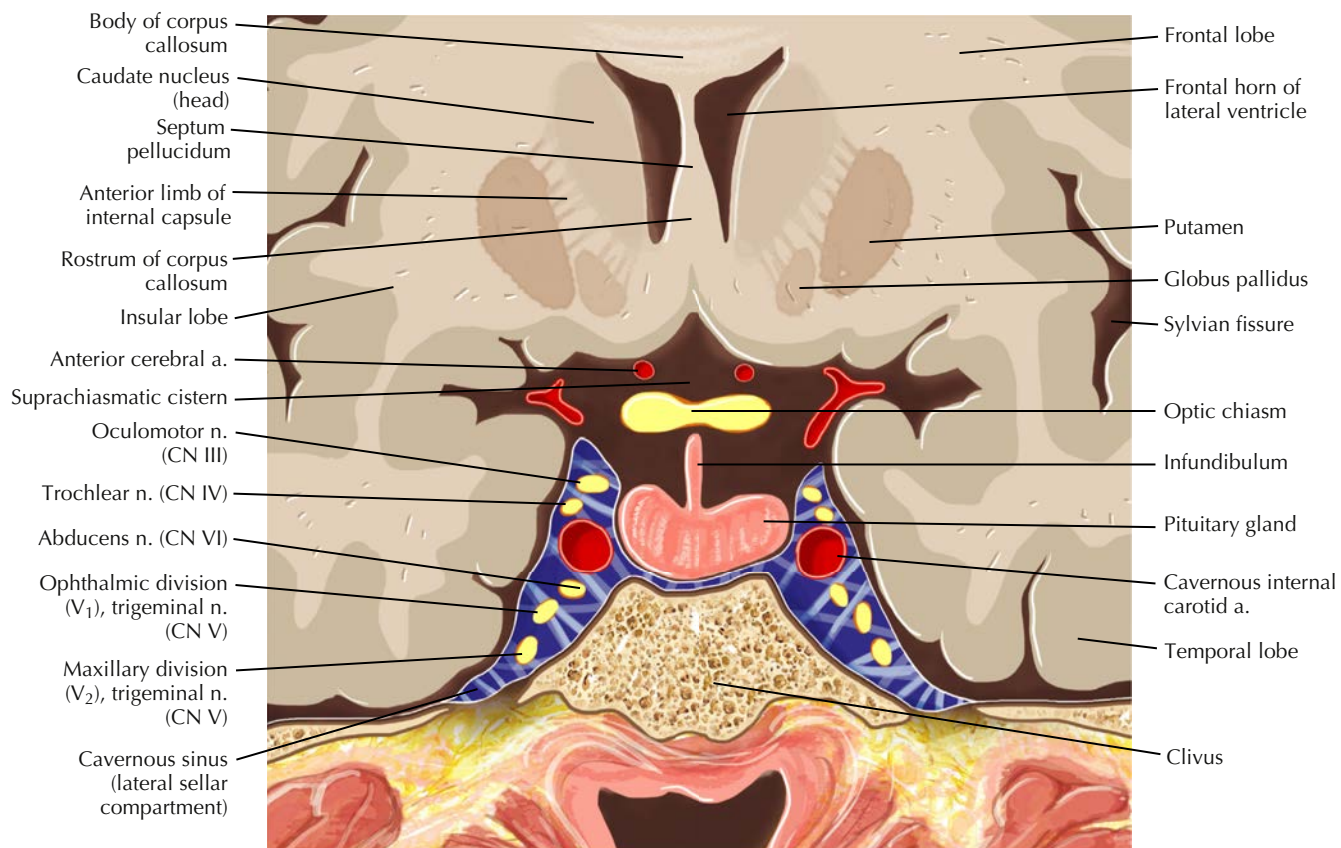


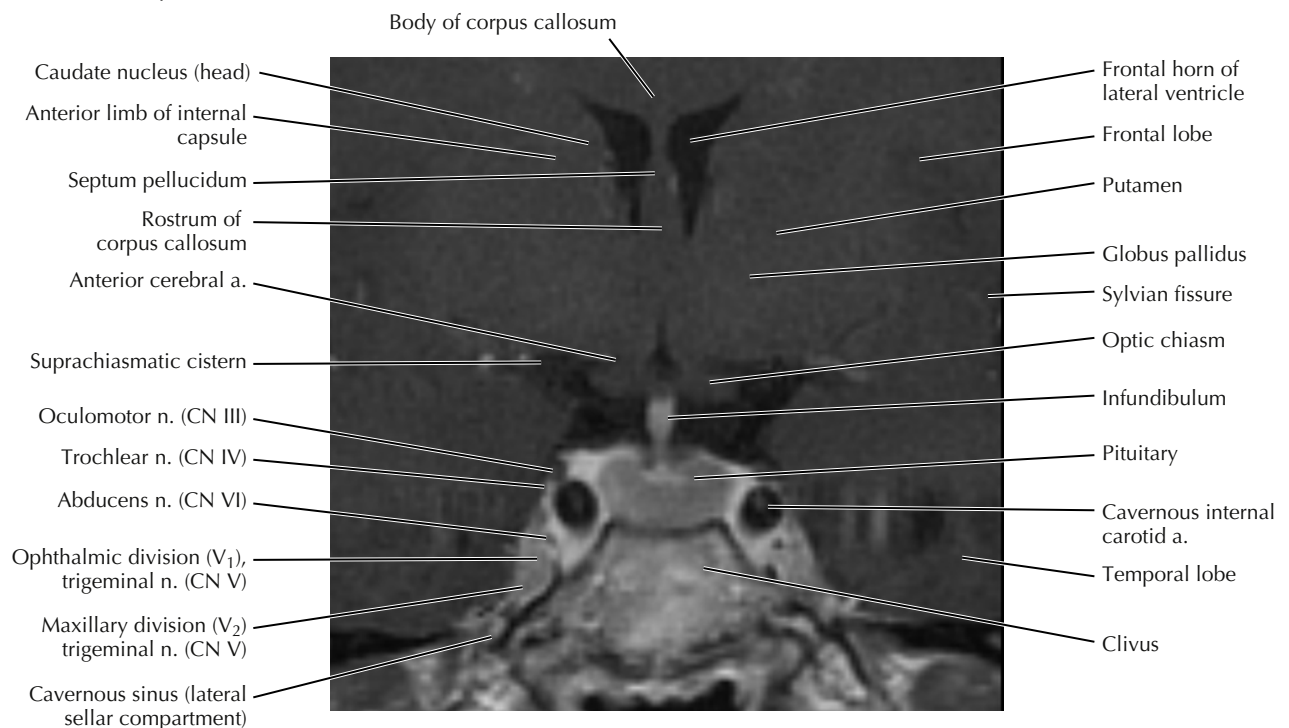
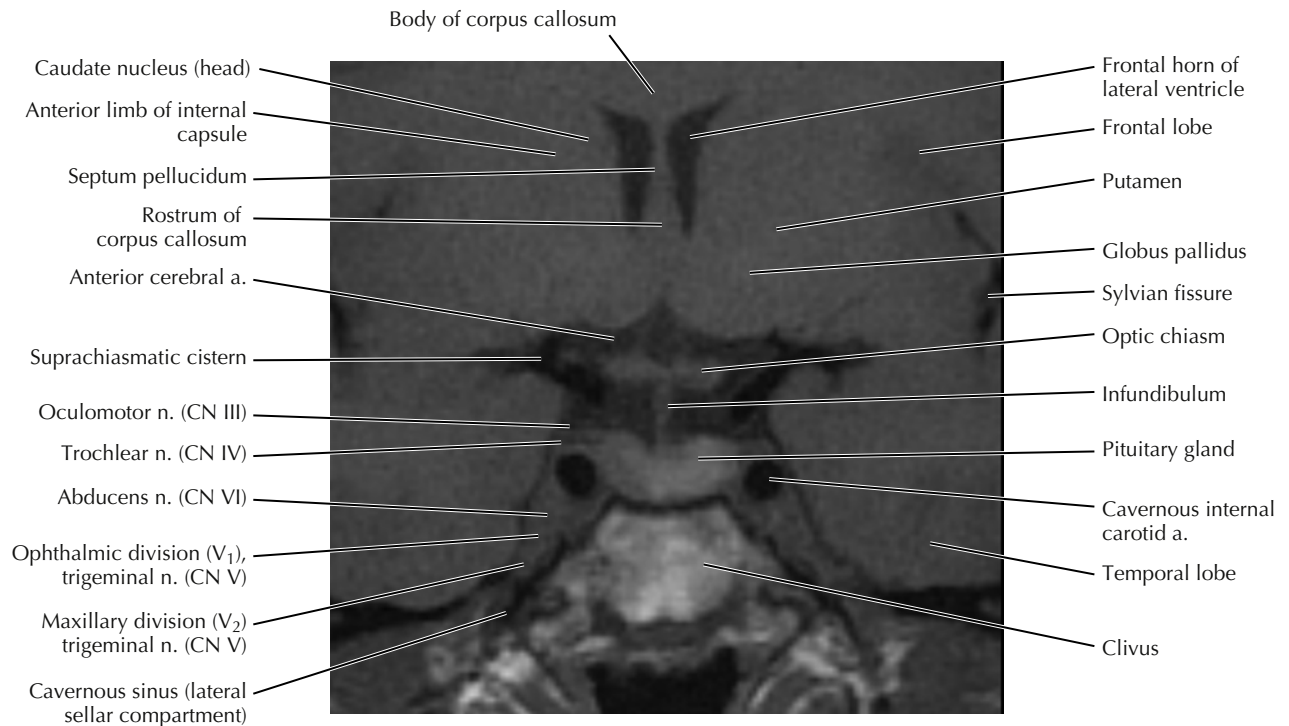
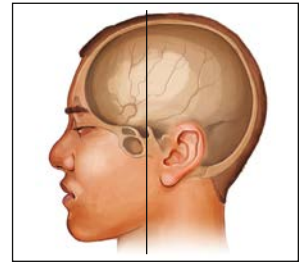


PATHOLOGIC PROCESS

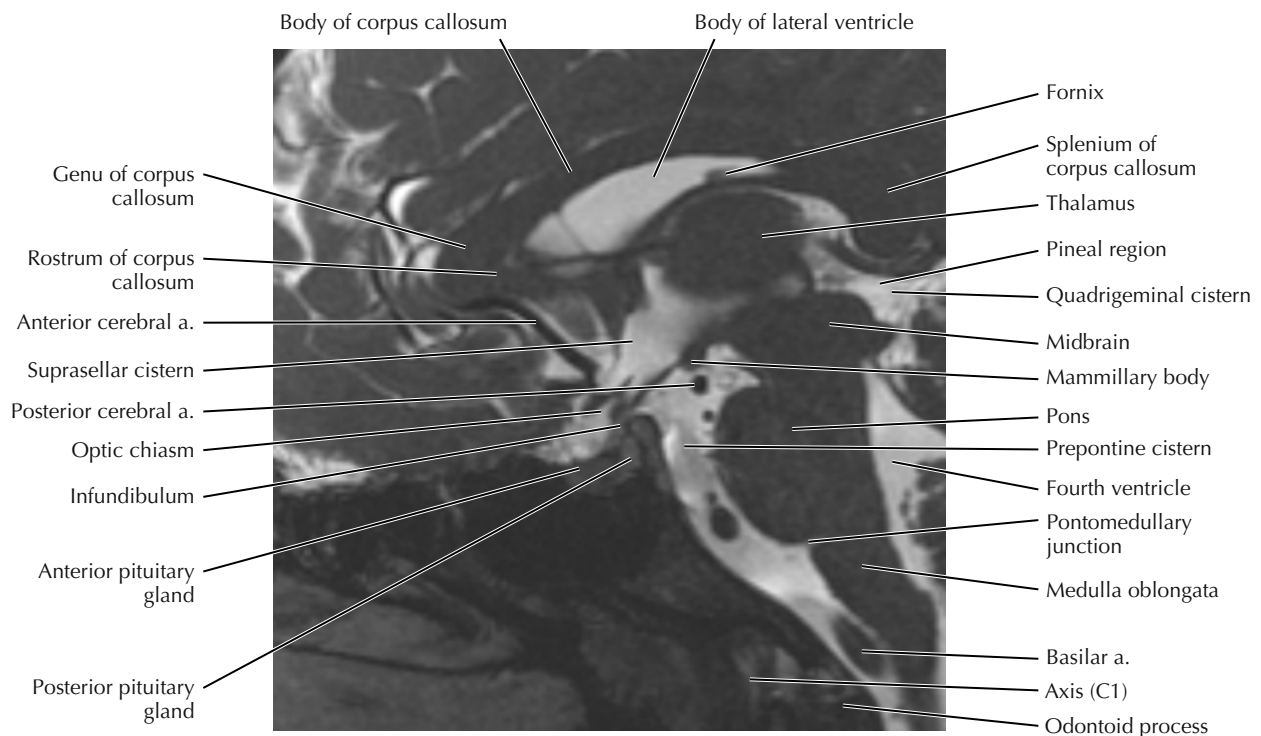
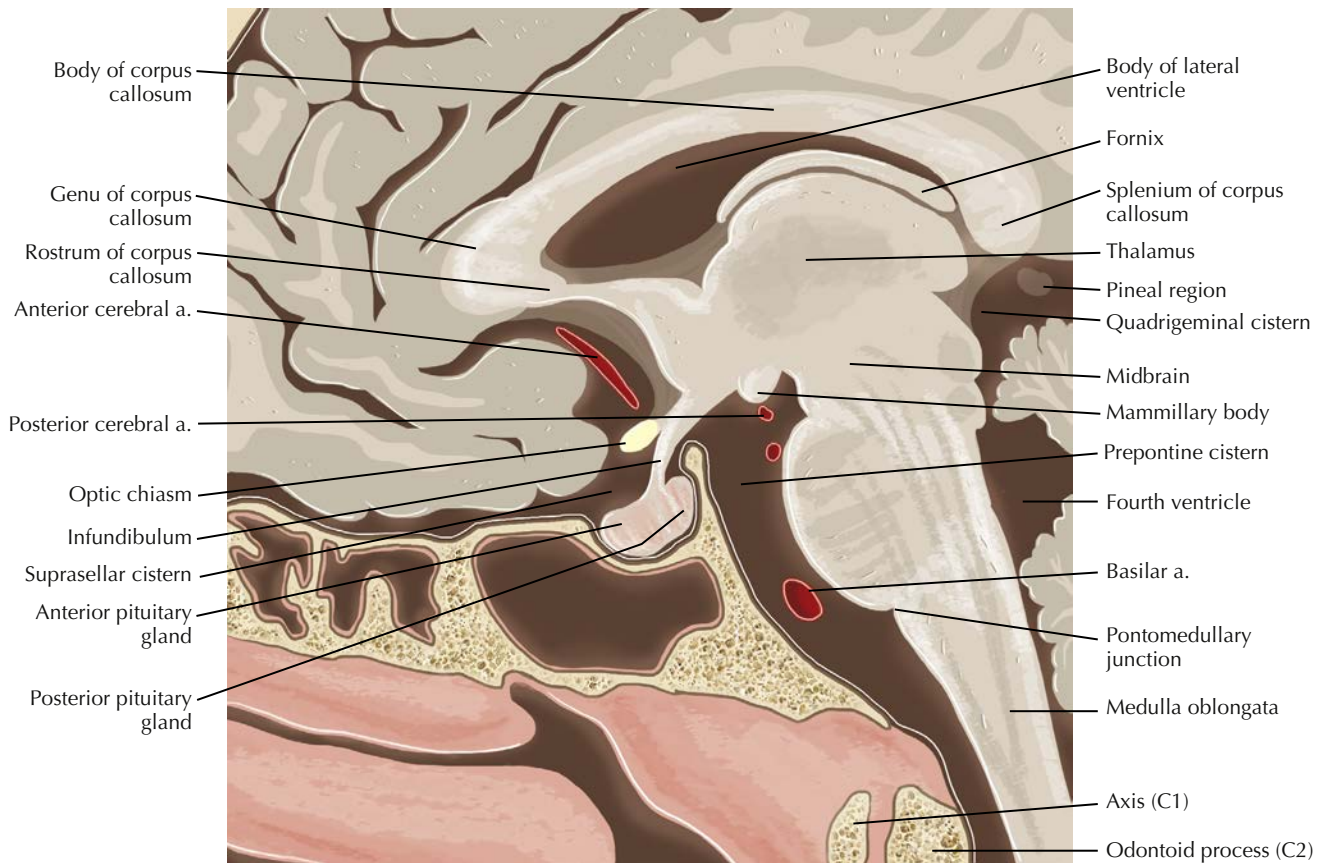
On this coronal MR image, note the 4-mm, ovoid, hypoenhancing lesion within the inferior aspect of the pituitary gland, slightly larger toward the right. The lesion does not cause obvious displacement of the infundibulum or extend into the cavernous sinuses or sphenoid sinuses. This is consistent with a pituitary "microadenoma." This term is a misnomer in that the lesion is not micrometers in size, but rather defined as a lesion less than a centimeter in size, versus a "macroadenoma," which is larger than 1 cm.





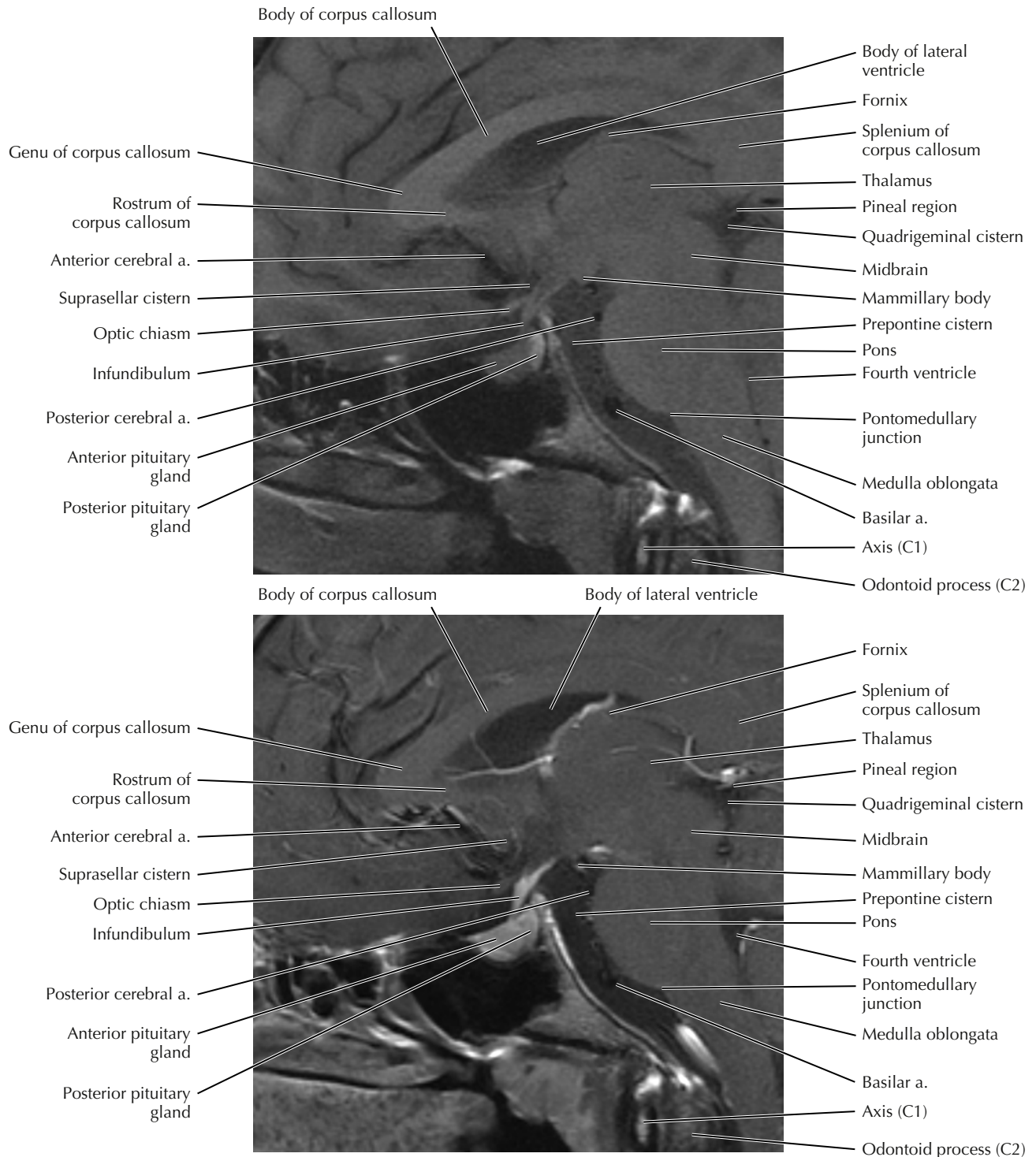
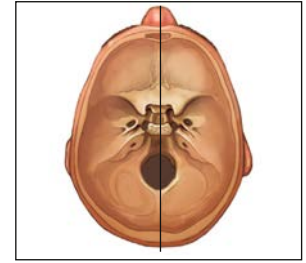


SELLA TURCICA SAGITTAL 1



PATHOLOGIC PROCESS

Acute hemorrhage may be seen with *pituitary apoplexy*. In these patients, attention should focus on the posterior aspect of the clivus for signs of hemorrhage extension. Note that the posterior aspect of the pituitary gland, the *neurohypophysis*, is normally T1 bright, the absence of which may be pathologic.



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PART

2

HEAD AND NECK

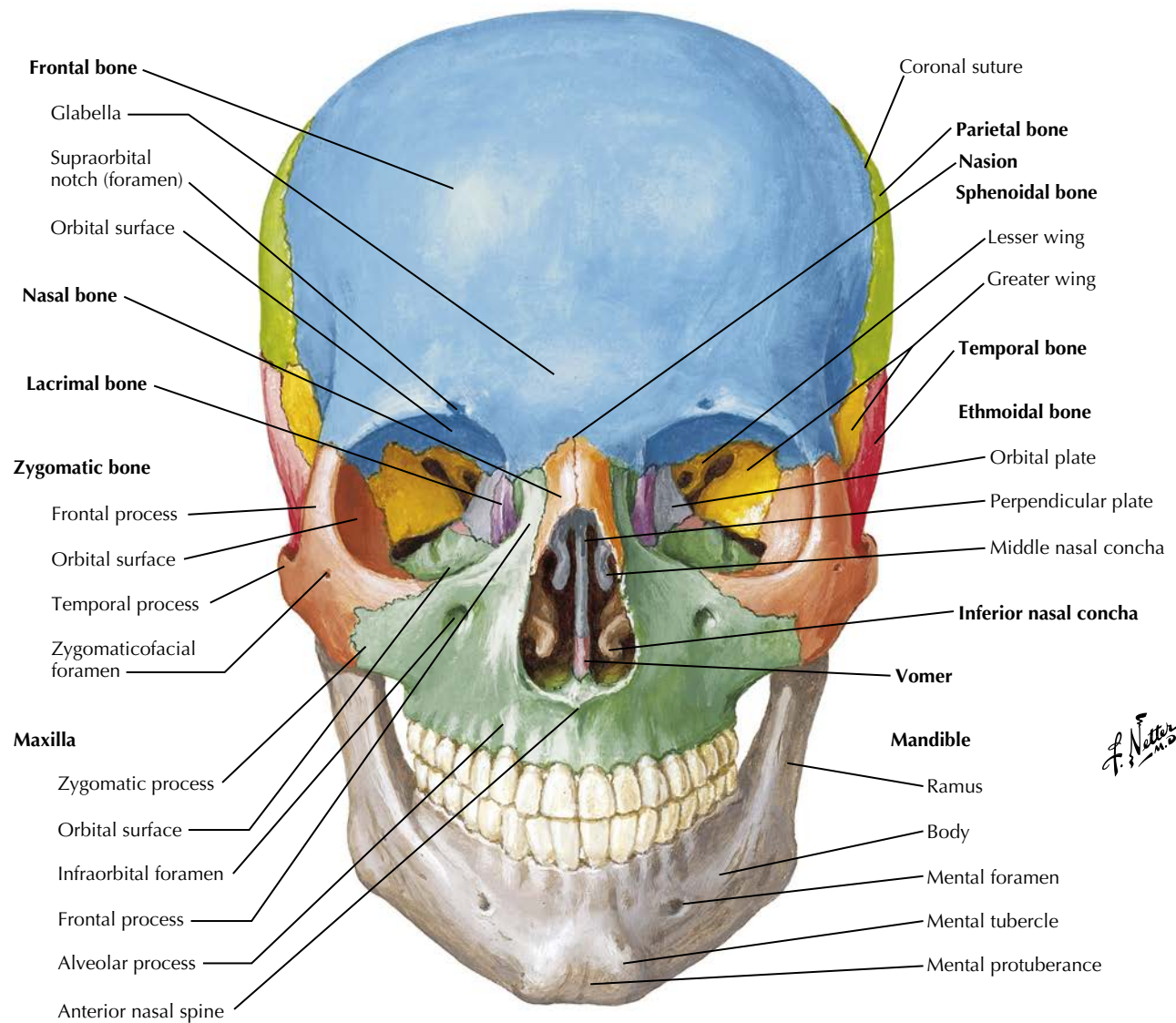
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NECK 308
- CHAPTER 9 PARANASAL SINUSES 321
- CHAPTER 10 ORBITS 355
- CHAPTER 11 MANDIBLE AND MUSCLES OF
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- CHAPTER 12 TEMPORAL BONE (MIDDLE
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- CHAPTER 13 ORAL CAVITY, PHARYNX, AND
SUPRAHYOID NECK 421
- CHAPTER 14 HYPOPHARYNX, LARYNX, AND
INFRAHYOID NECK 471

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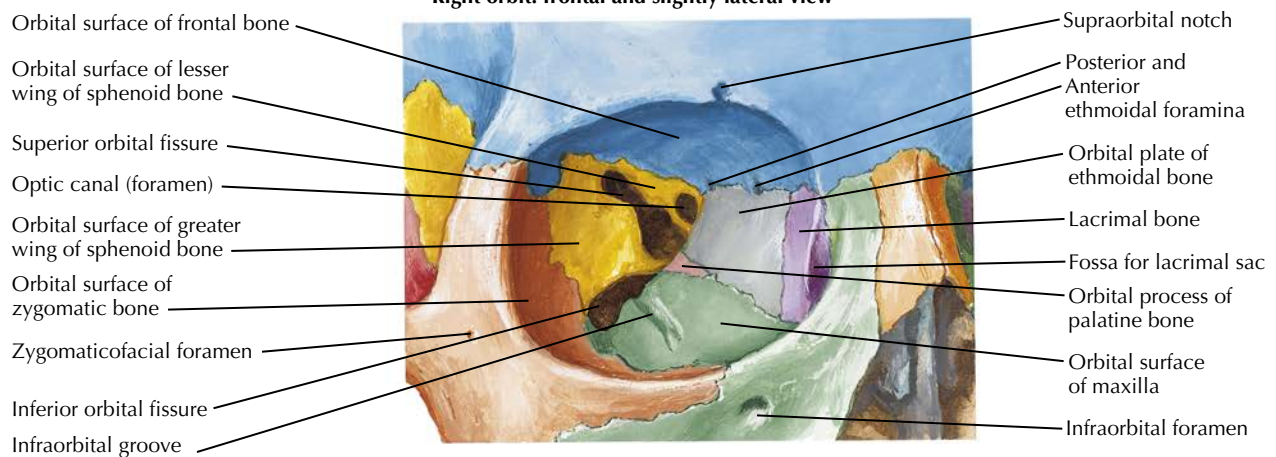
8

OVERVIEW OF HEAD AND NECK

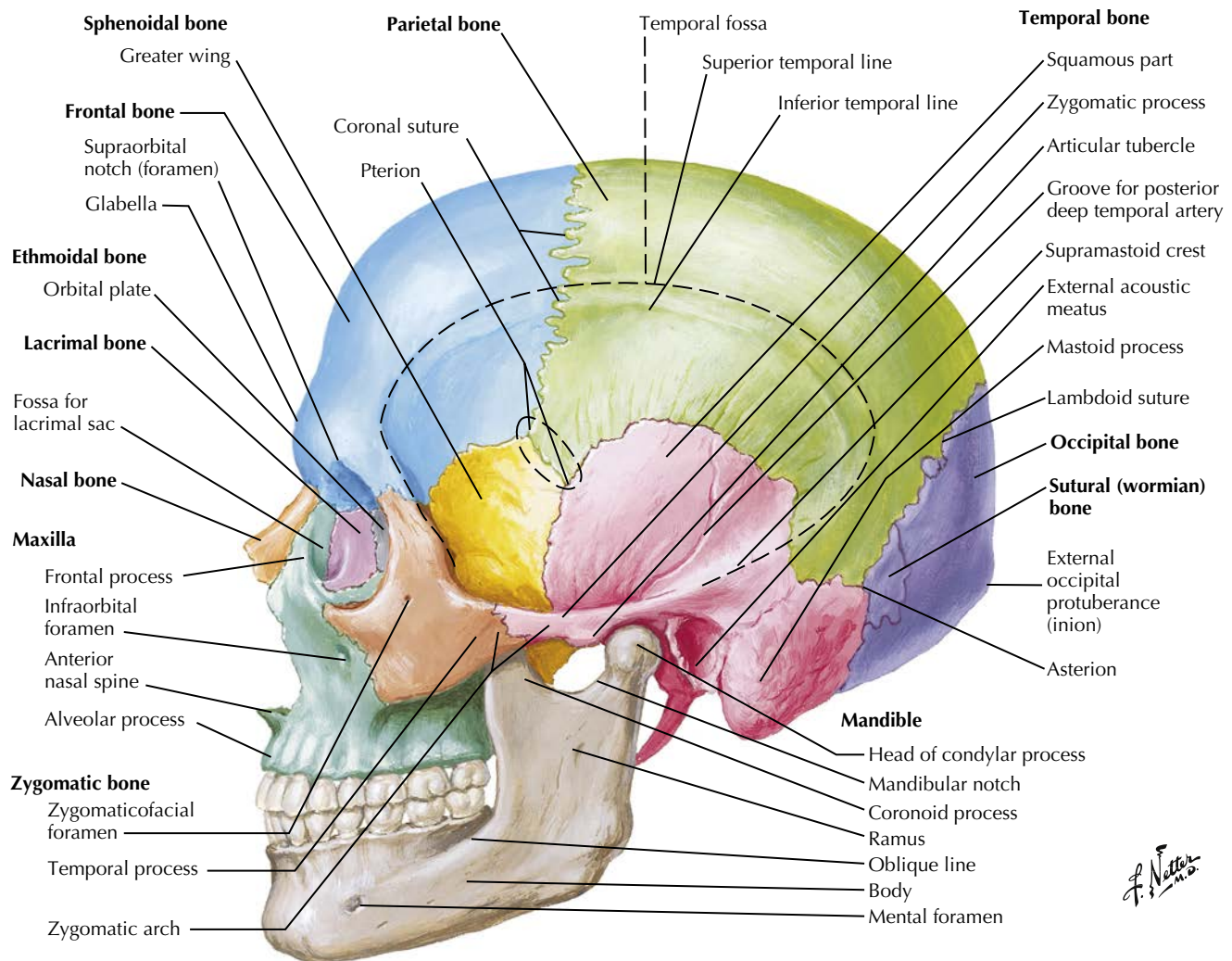
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SKULL: LATERAL ASPECT	310
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BASE OF SKULL: BONES, MARKINGS, AND ORIFICES	312
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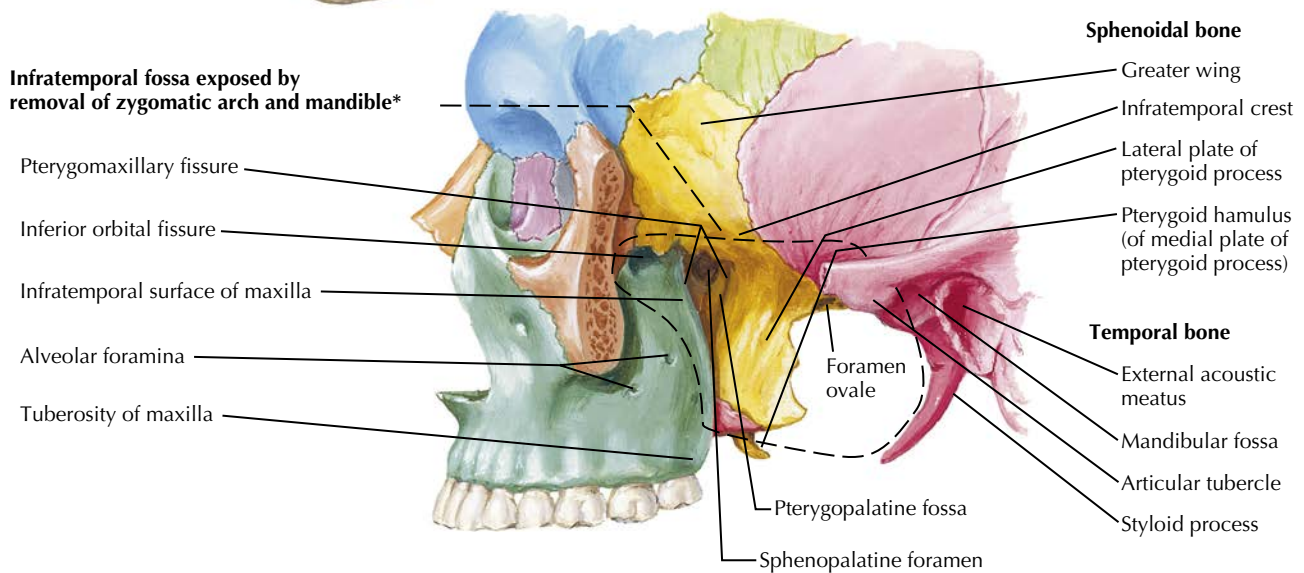
Right orbit: frontal and slightly lateral view



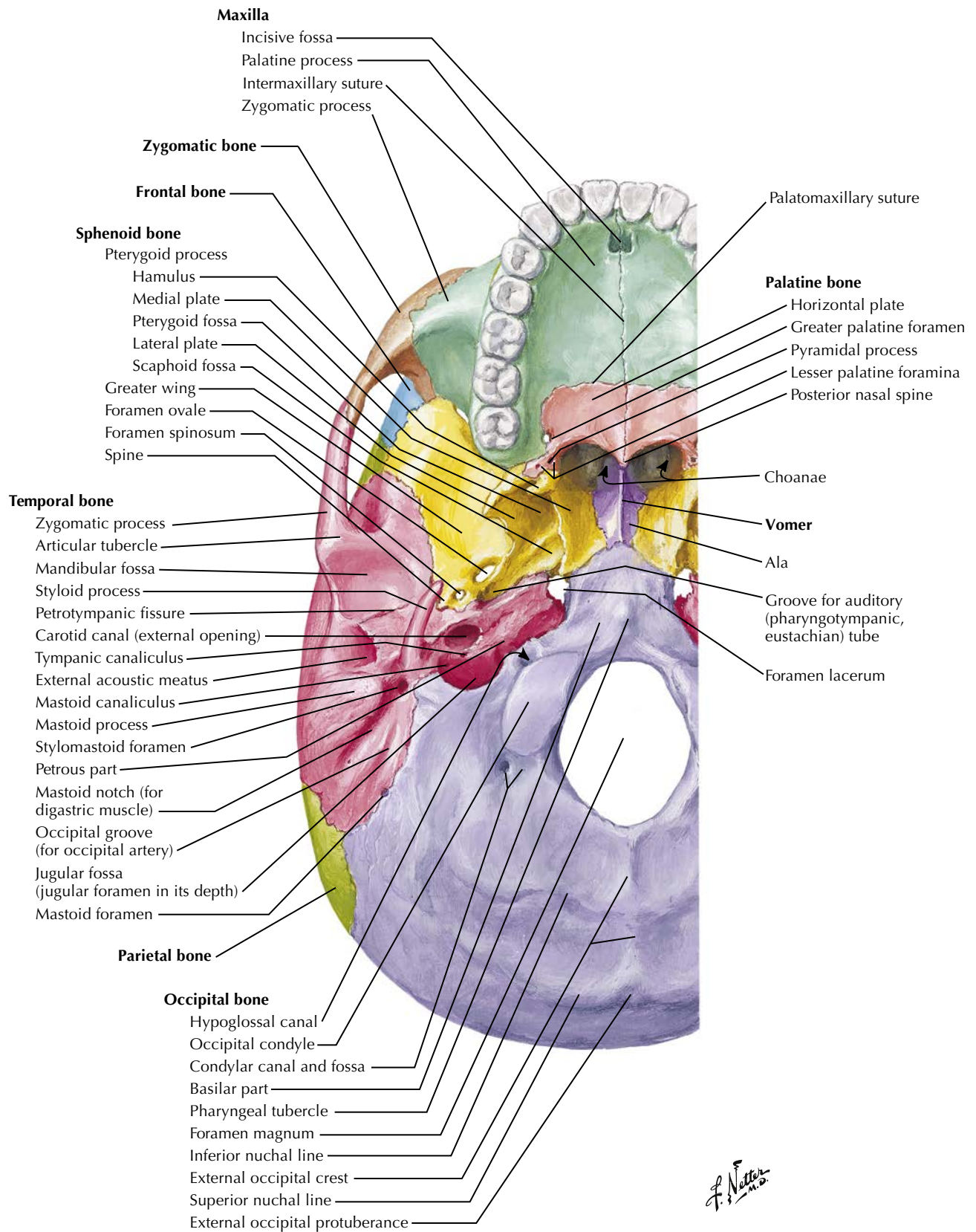
SKULL: LATERAL ASPECT



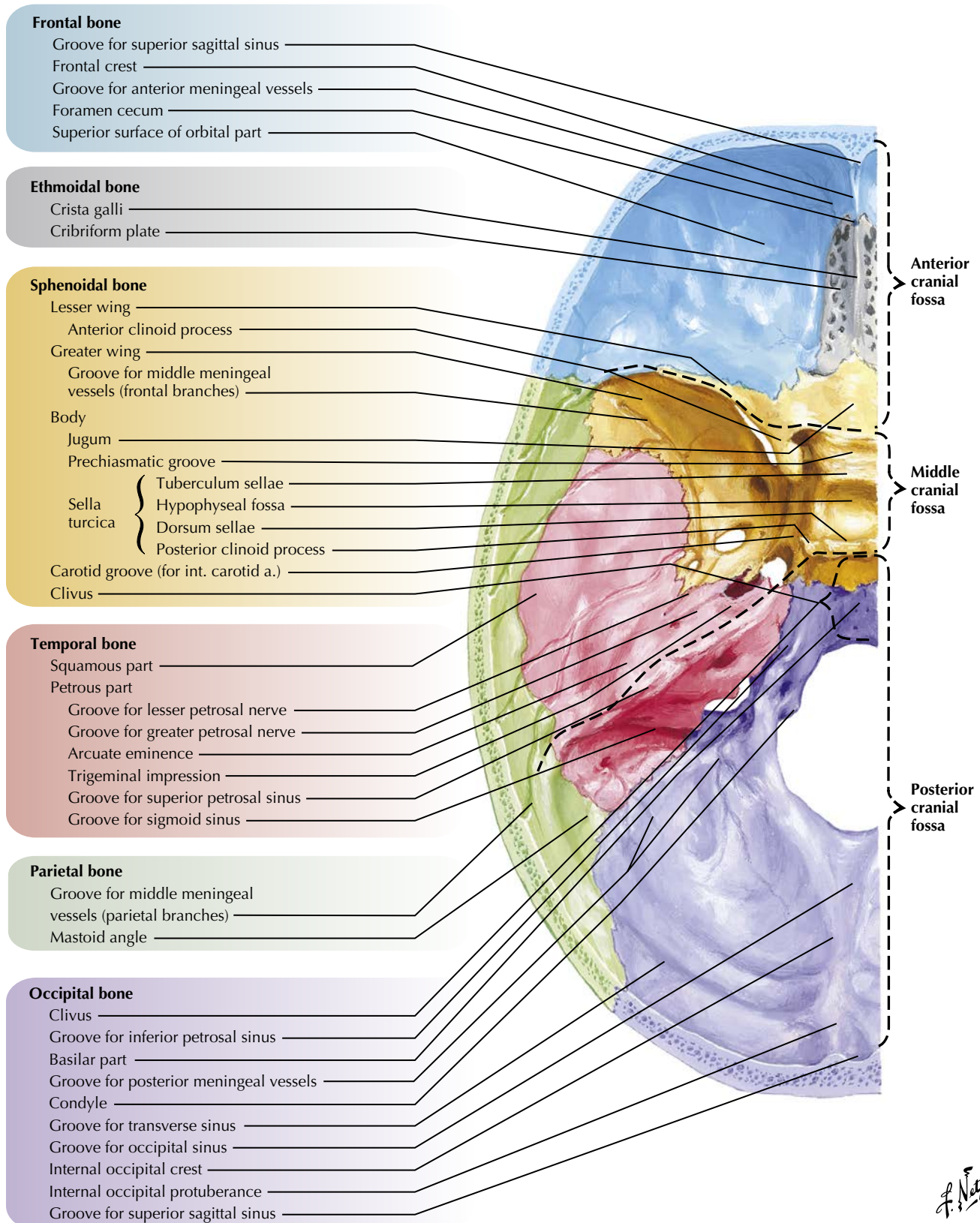
F. Netter M.D.



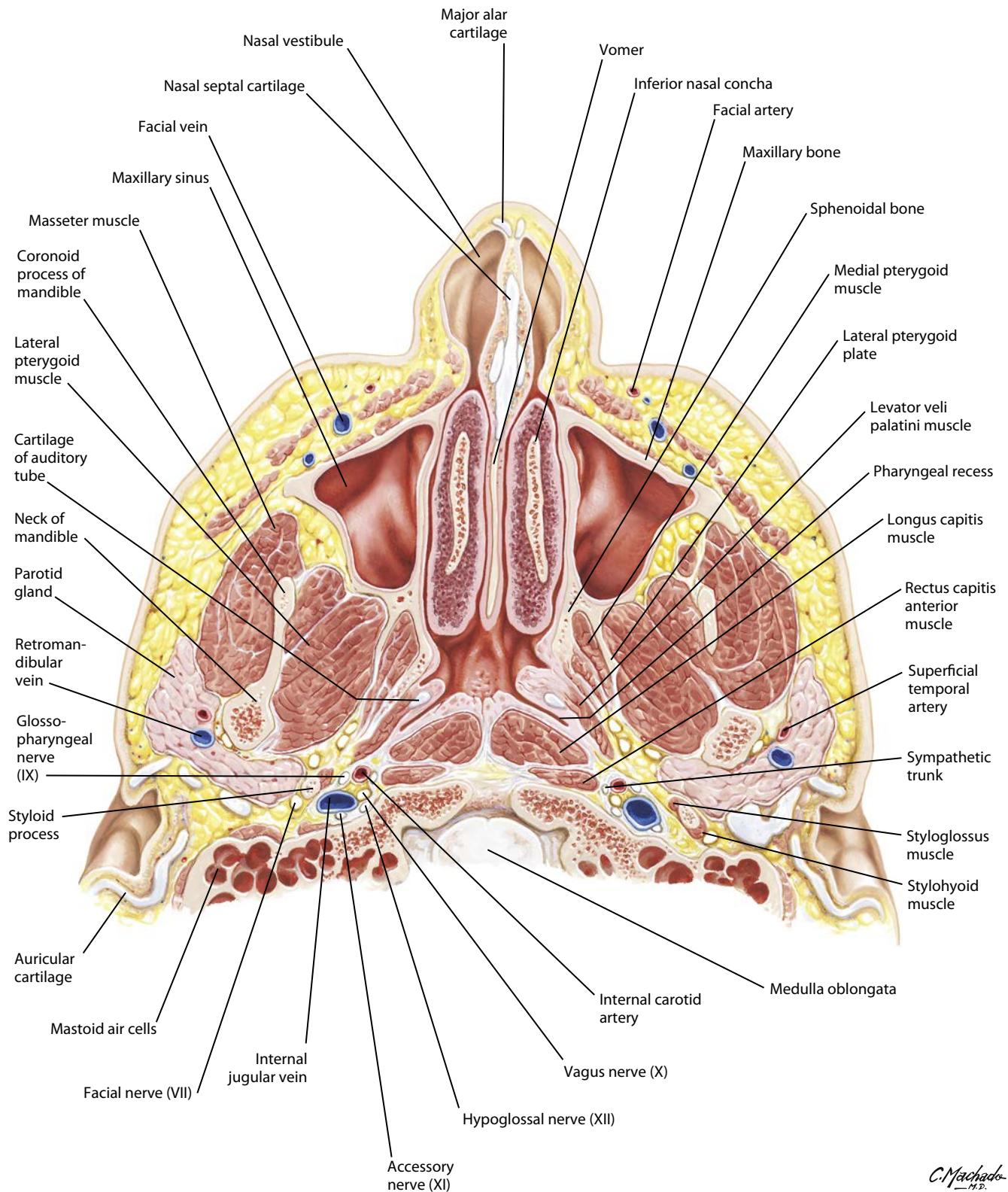
*Superficially, mastoid process forms posterior boundary.



BASE OF SKULL: BONES, MARKINGS, AND ORIFICES

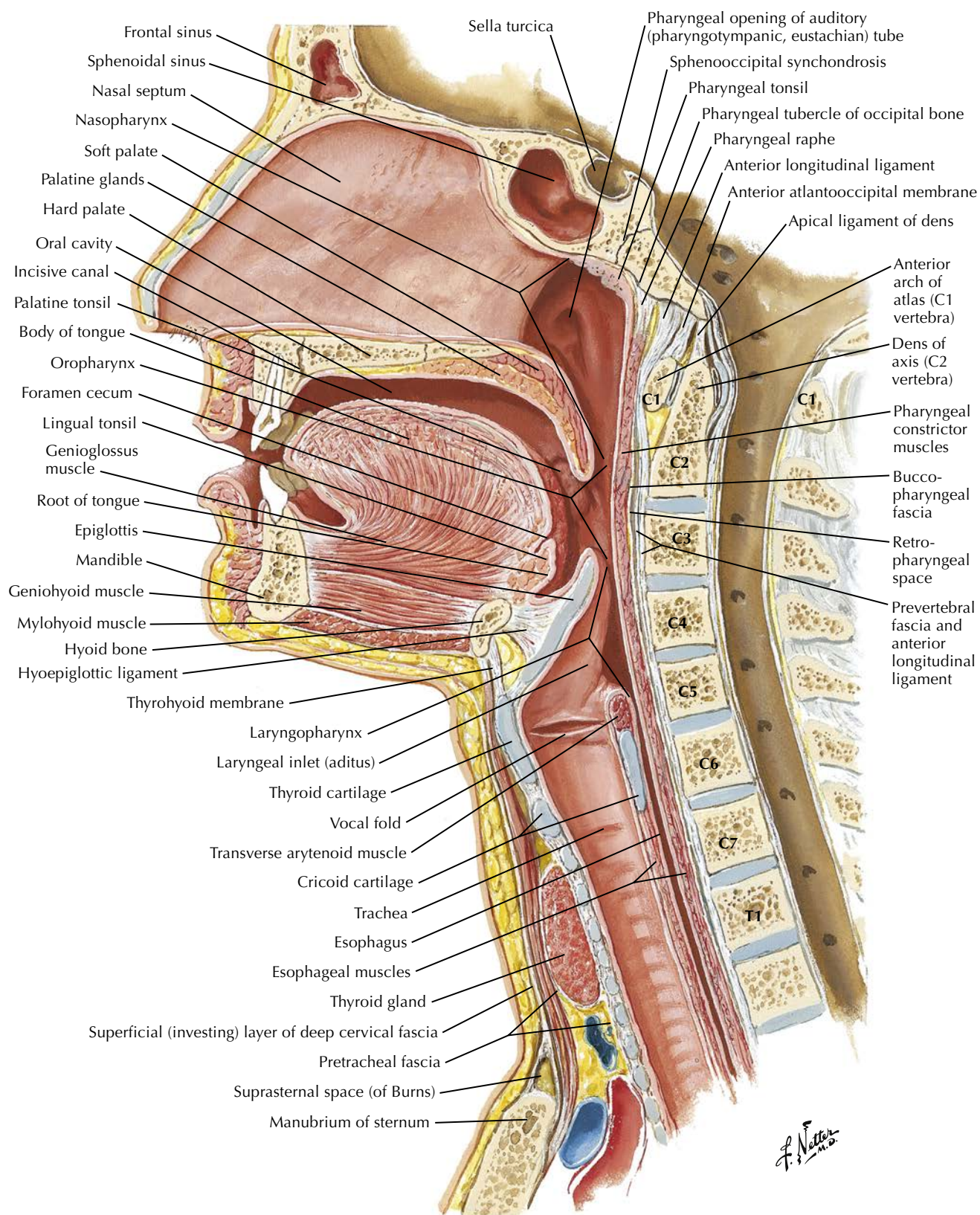


NOSE AND PARANASAL SINUSES: CROSS SECTION

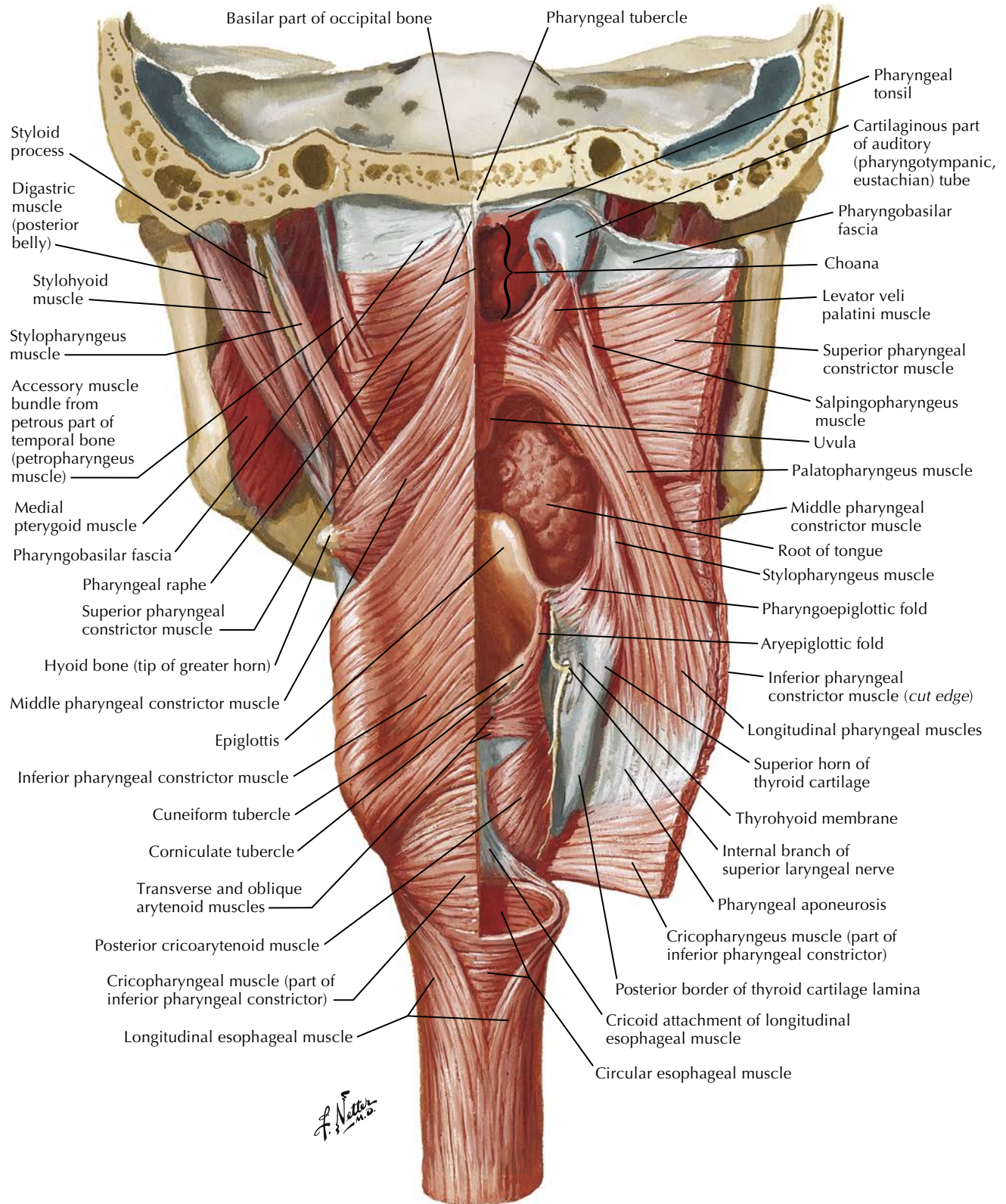


C. Machado
— M.D.

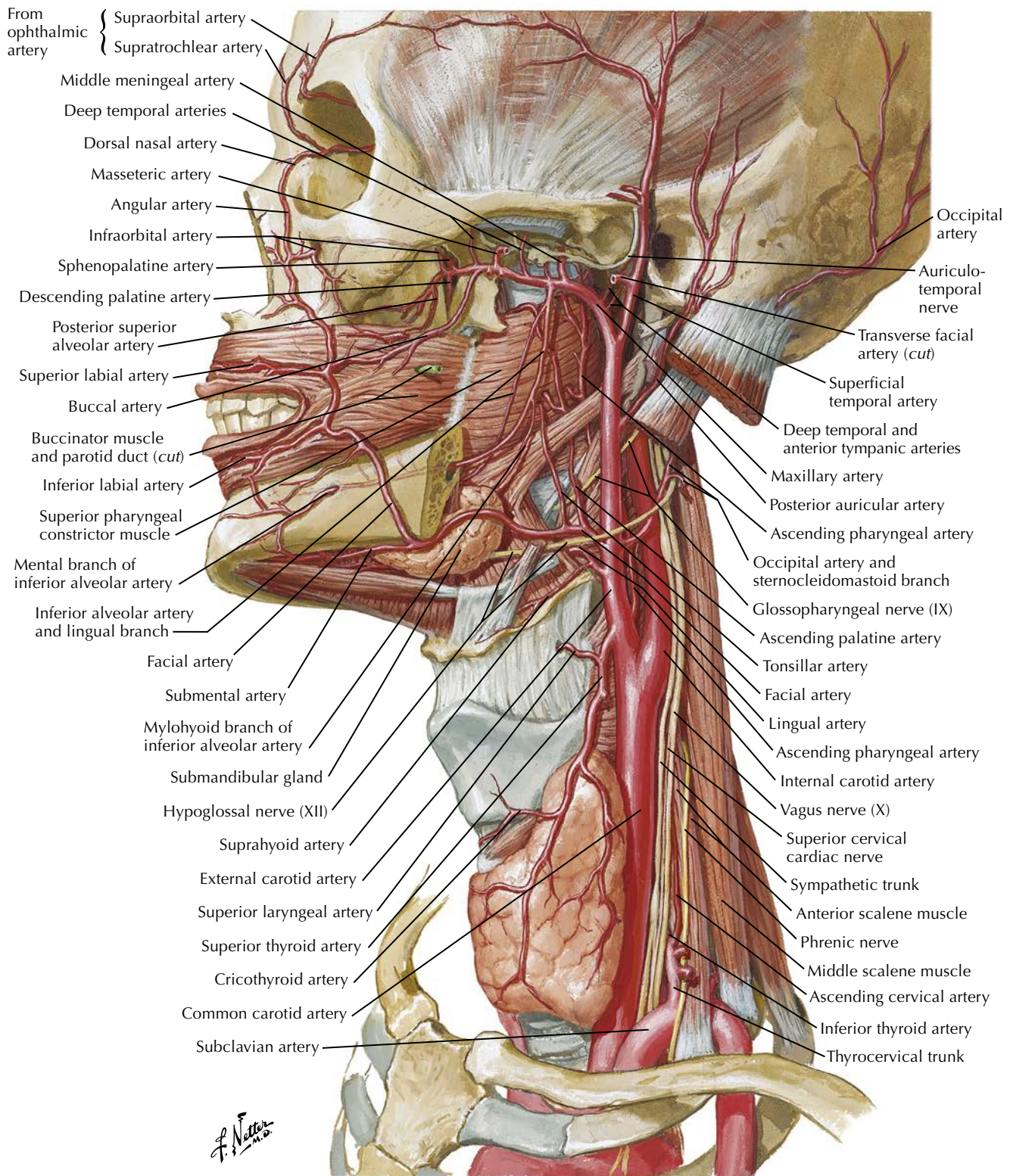
PHARYNX: MEDIAN SECTION

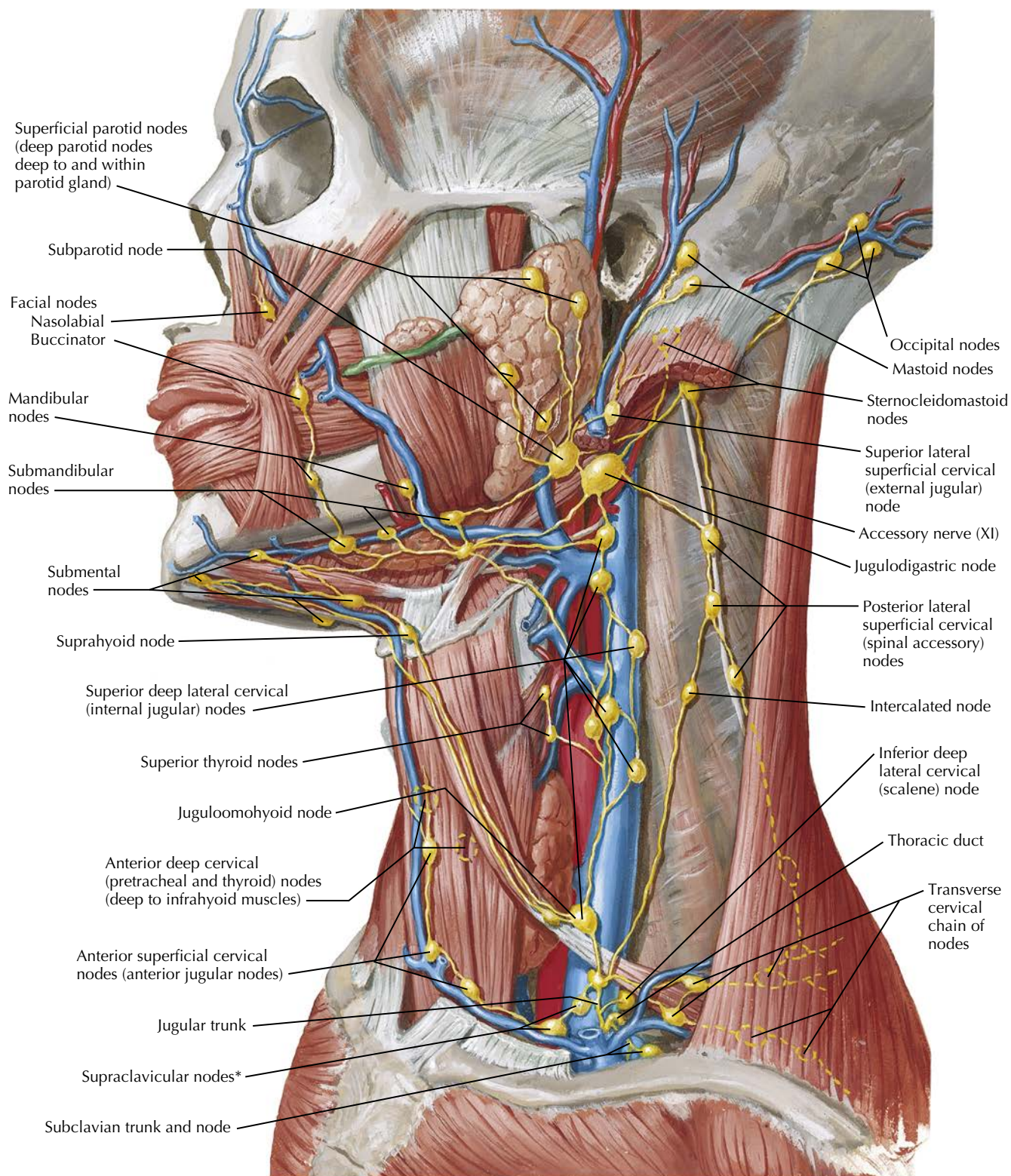


MUSCLES OF PHARYNX: PARTIALLY OPENED POSTERIOR VIEW



ARTERIES OF ORAL AND PHARYNGEAL REGIONS



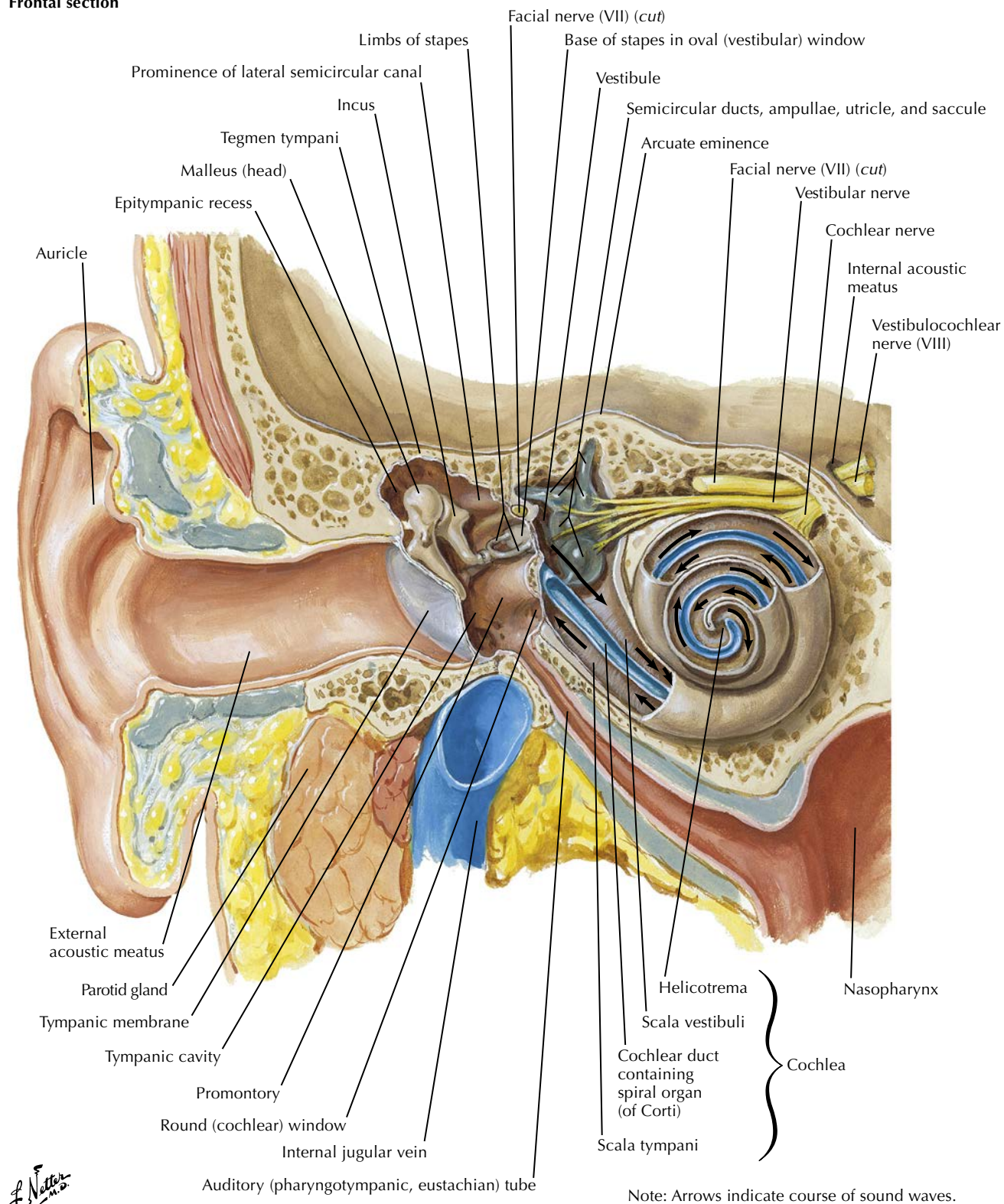


*The supraclavicular group of nodes (also known as the lower deep cervical group), especially on the left, are also sometimes referred to as the signal or sentinel lymph nodes of Virchow or Troisier, especially when sufficiently enlarged and palpable. These nodes (or a single node) are so termed because they may be the first recognized presumptive evidence of malignant disease in the viscera.

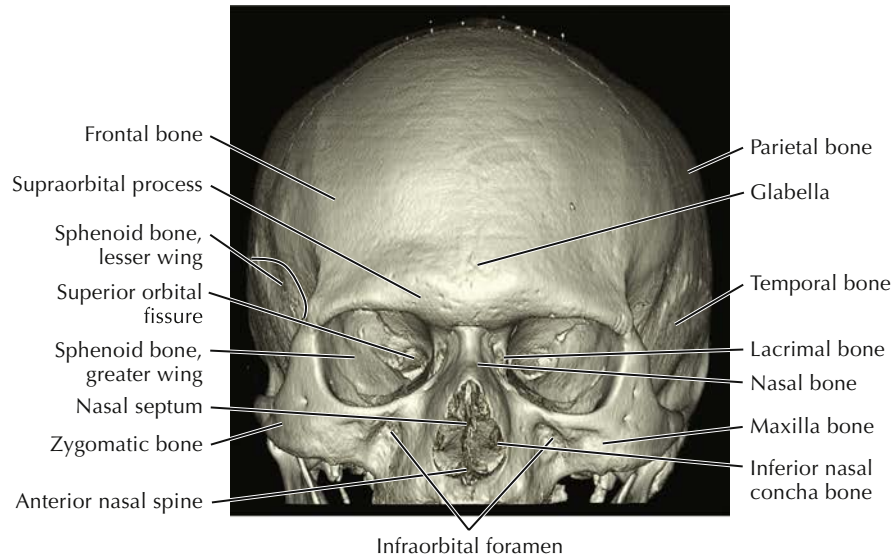
F. Netter M.D.

PATHWAY OF SOUND RECEPTION

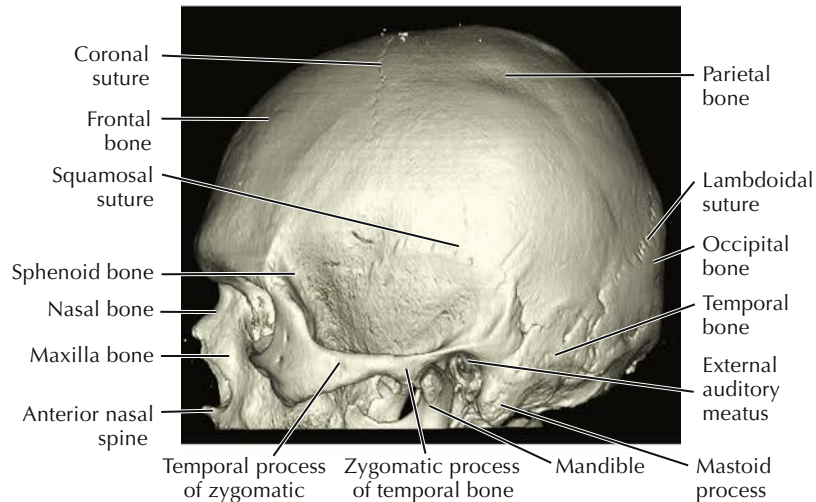
Frontal section



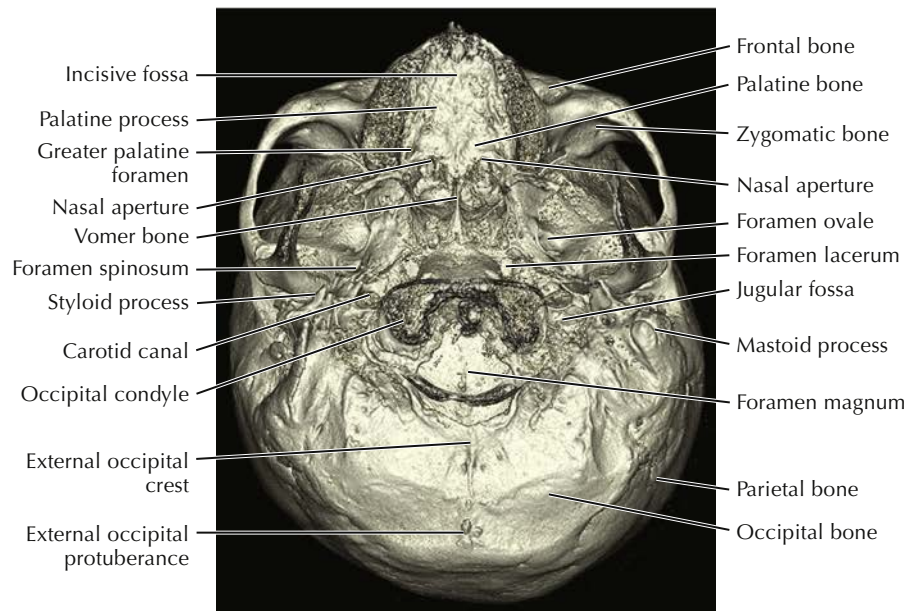
Frontal view of 3D skull reformat



Lateral view of 3D skull reformat

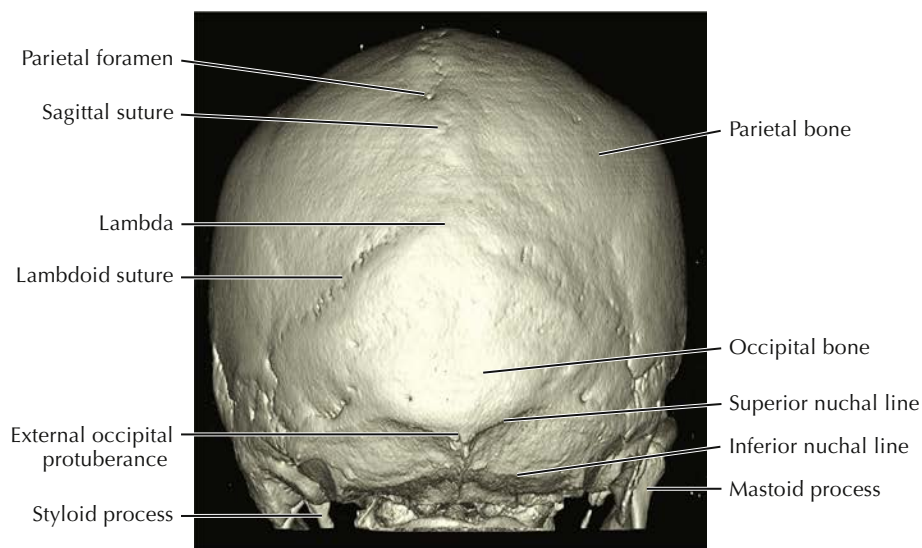


Inferior view of 3D skullbase

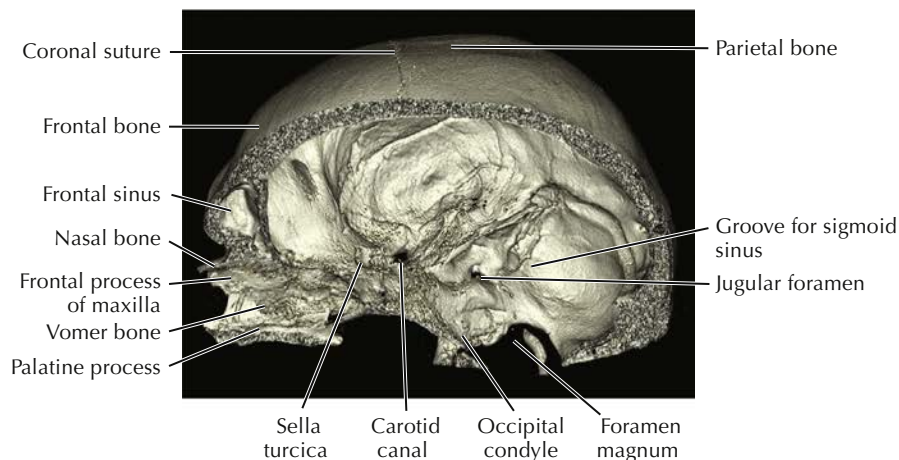


SKULL, SKULL BASE, AND MENINGES (CONTINUED)

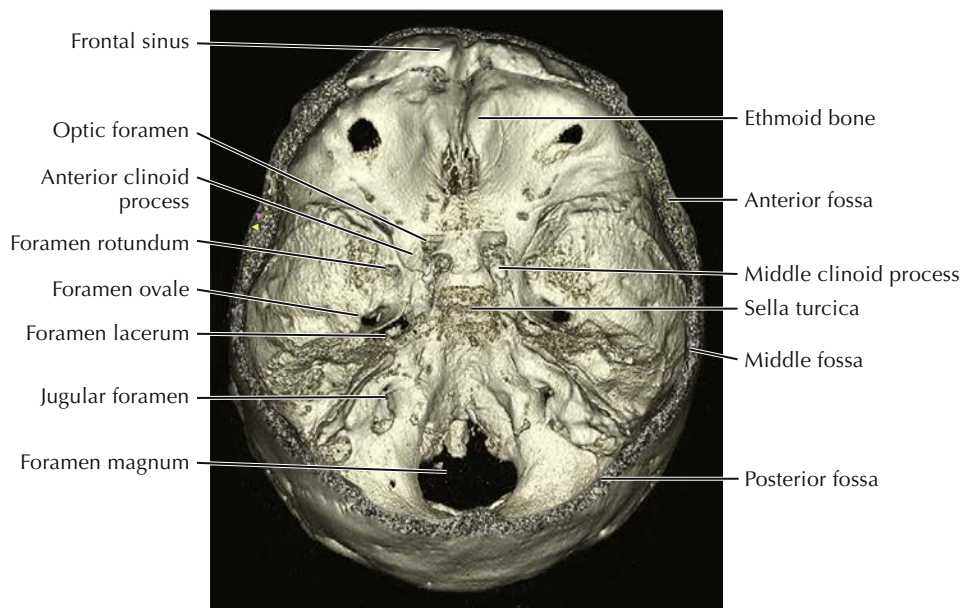
Posterior view of 3D skull reformat



Inferolateral cut view of inside of 3D skull reformat



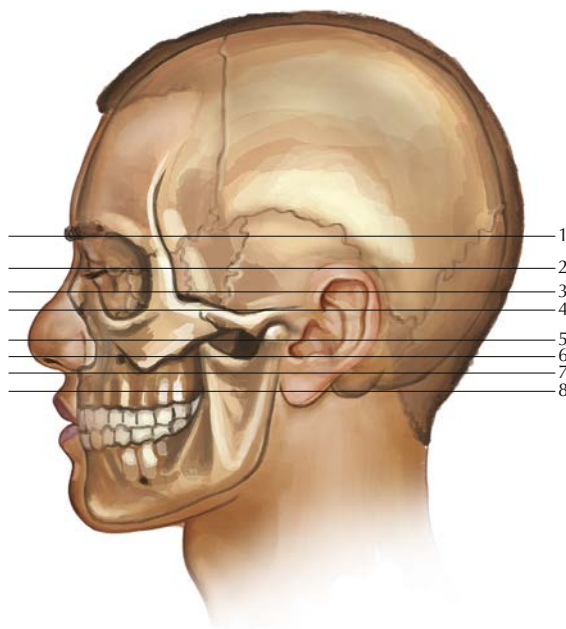
Superior view of cut 3D skull showing inside of skullbase



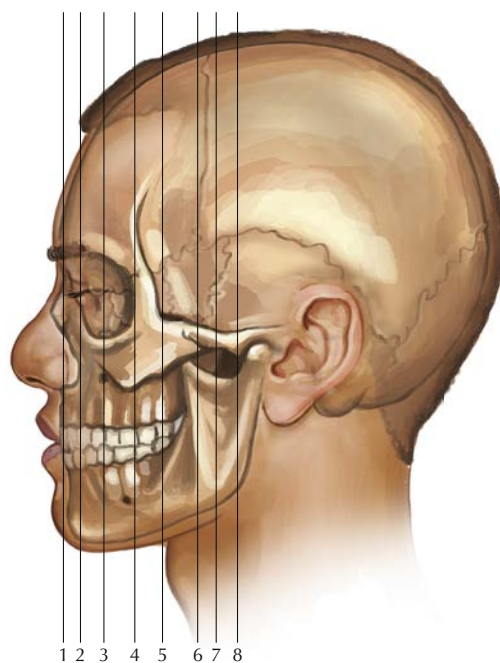
Chapter

9

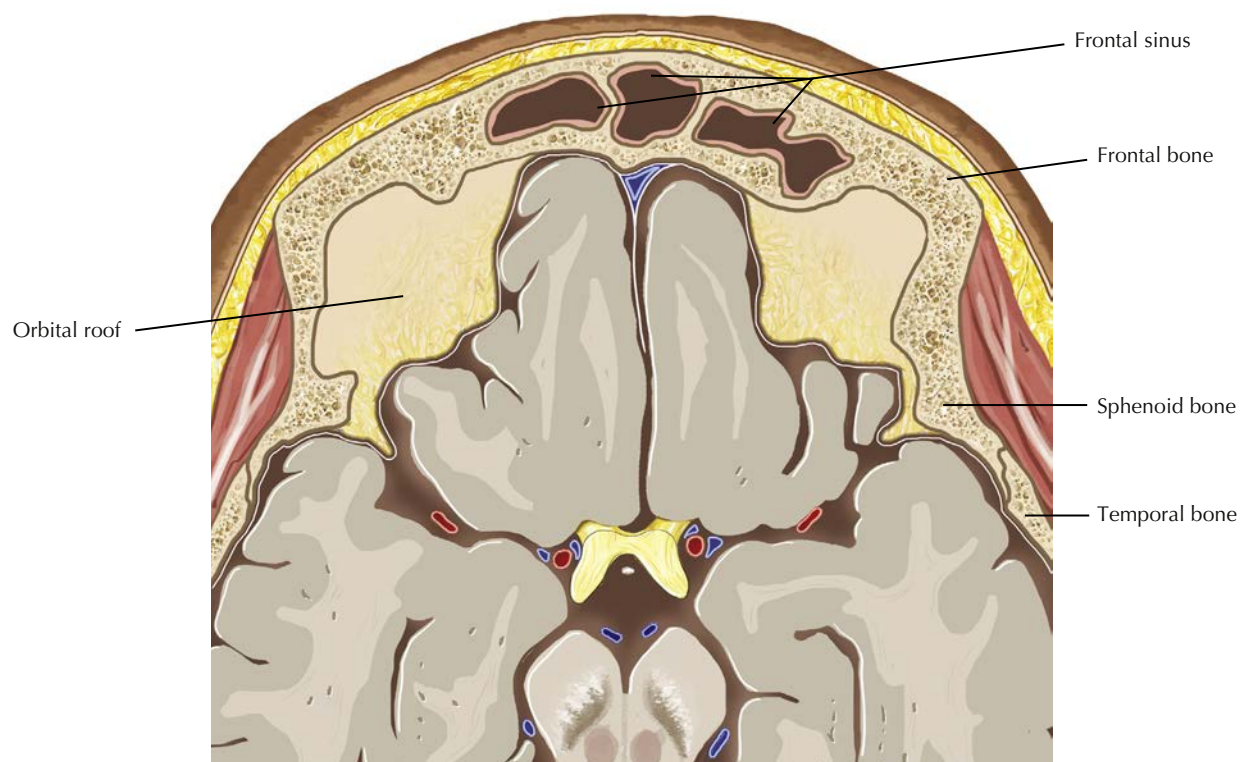
PARANASAL SINUSES



AXIAL 322

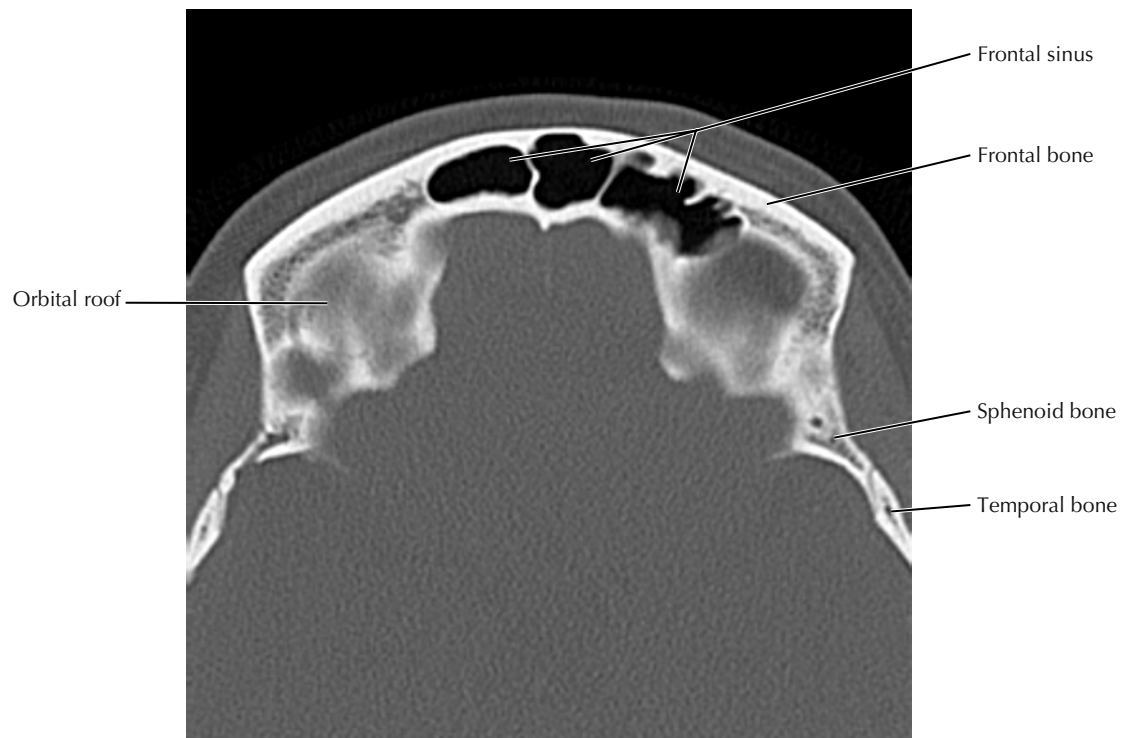
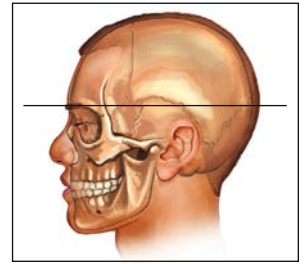


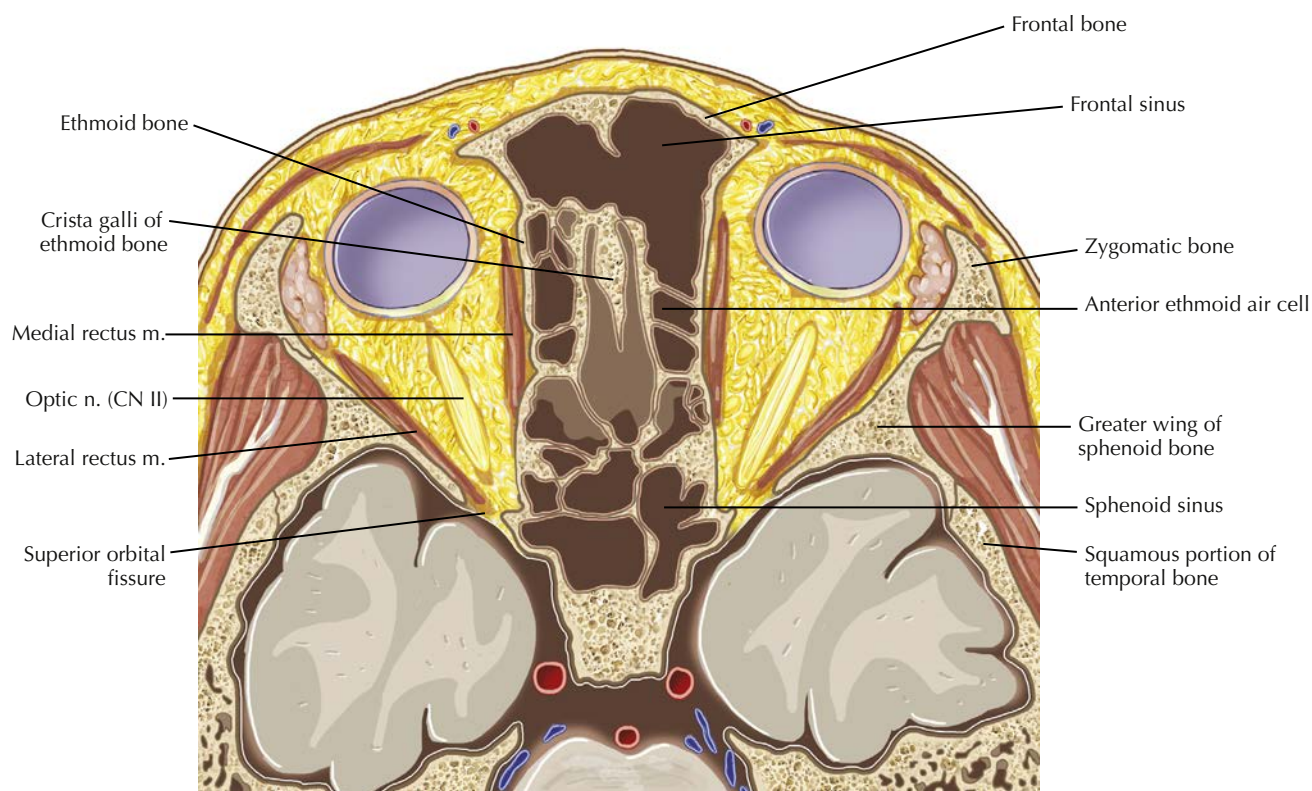
CORONAL 338



NORMAL ANATOMY

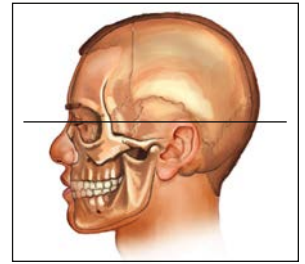
The paranasal sinuses are composed of the *frontal* sinuses, the *ethmoid* sinuses or ethmoid air cells, the *maxillary* sinuses or maxillary antra, and the *sphenoid* sinuses. The names are derived from the bones that form the walls of the sinuses.

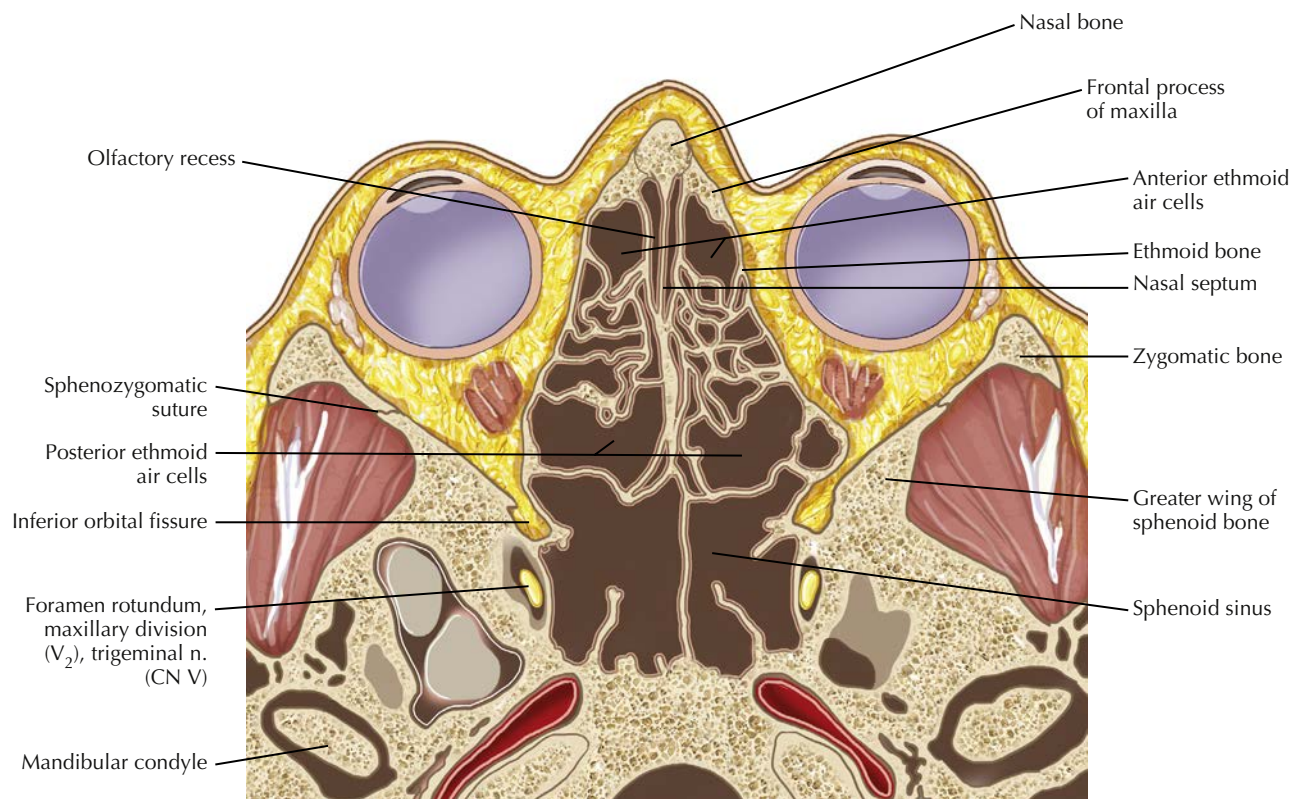




NORMAL ANATOMY

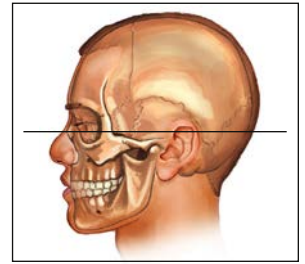
The sphenoid sinuses are at the center of the skull base, immediately below the sella turcica (see Chapter 7). In ancient Egypt, mummification would involve driving a metal hook through the nasal passages and the sphenoid sinuses into the brain, which would be removed through the nostrils. This tract is used in modern days to pass a scope into the sella turcica to remove pituitary adenomas.

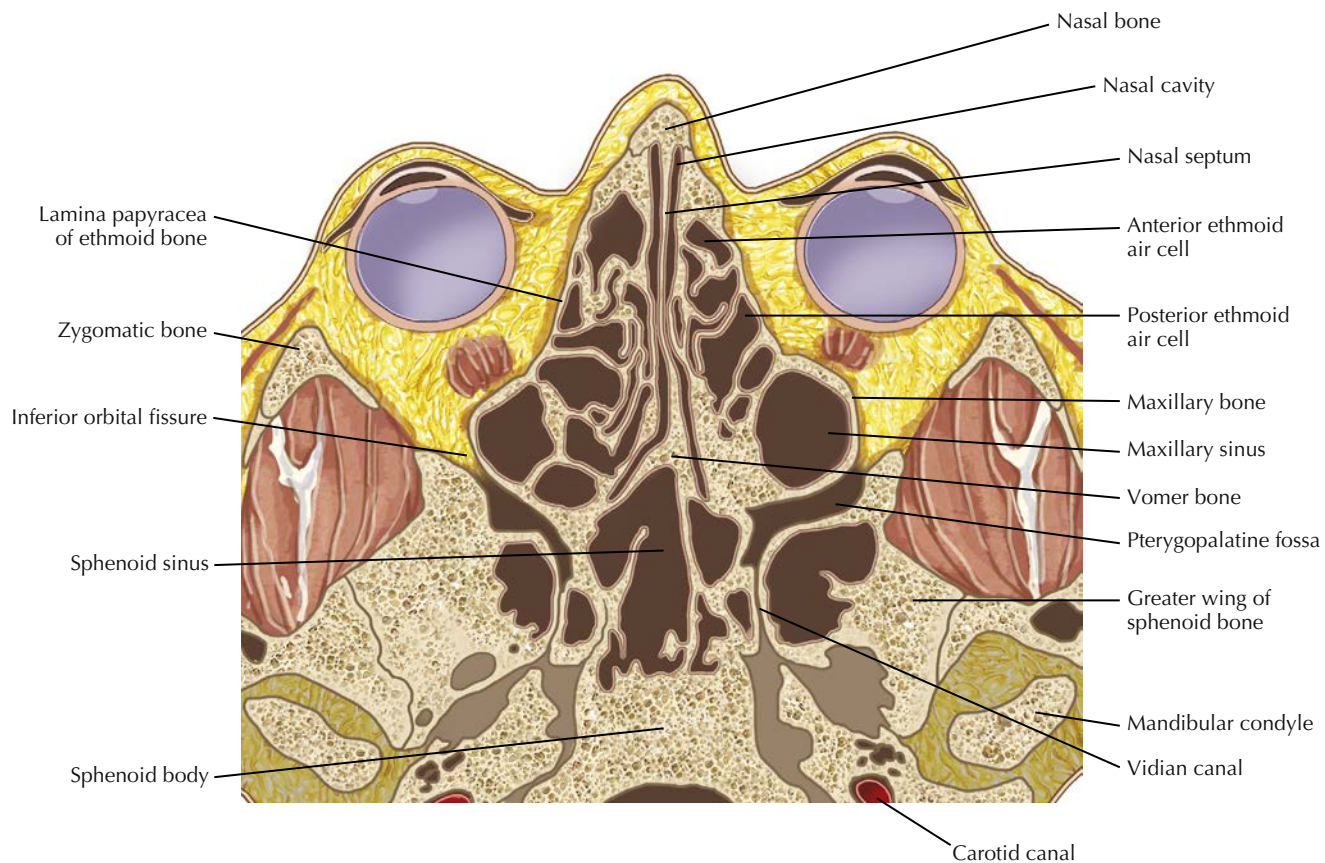




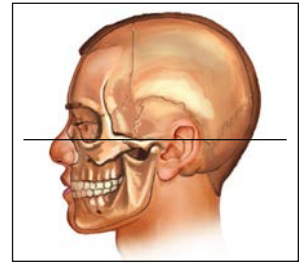
DIAGNOSTIC CONSIDERATION

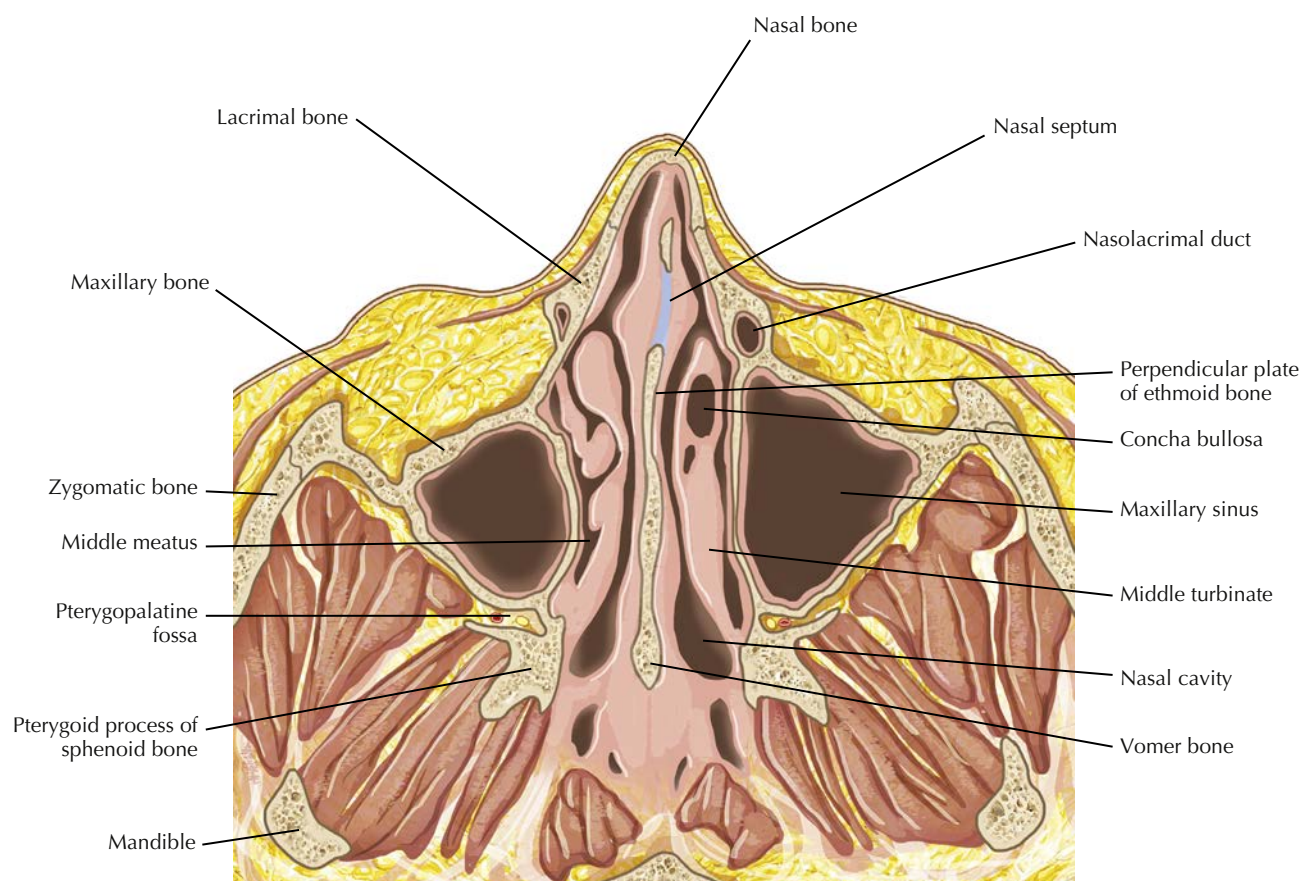
In the setting of trauma, careful evaluation of CT bone windows is important to identify fractures, particularly around critical structures such as the carotid canal. On MRI, subtle bone fractures may not be directly visible; therefore, secondary signs, such as the presence of a hemorrhagic fluid level in the paranasal sinuses may be the only indication of traumatic injury.





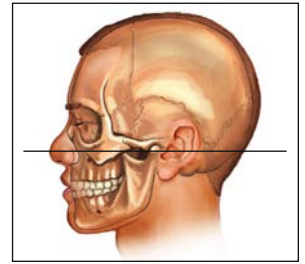
Fracture of the *lamina papyracea*, the thin bone between the orbit and the ethmoid air cells (sinuses), can be subtle. Fat herniating into the ethmoid air cells is a sign of lamina papyracea fracture.

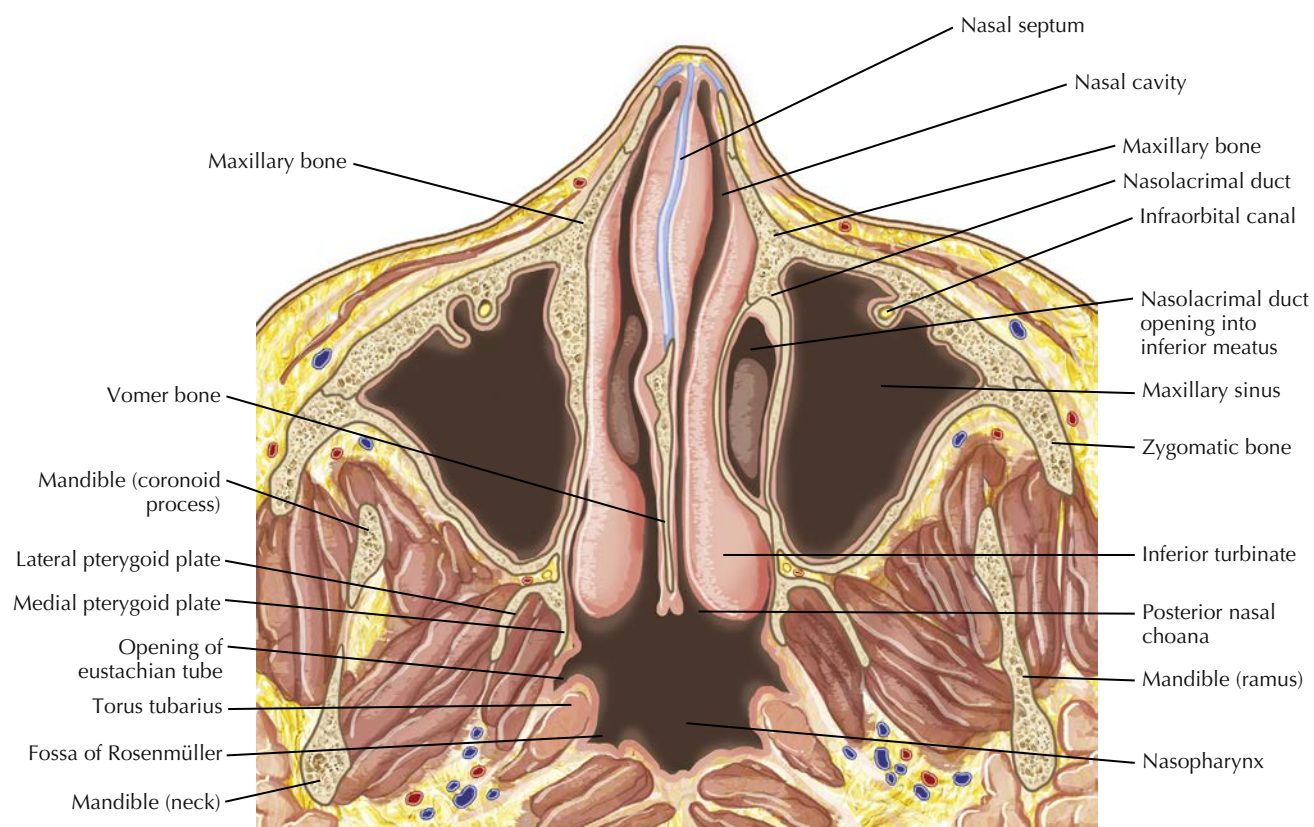


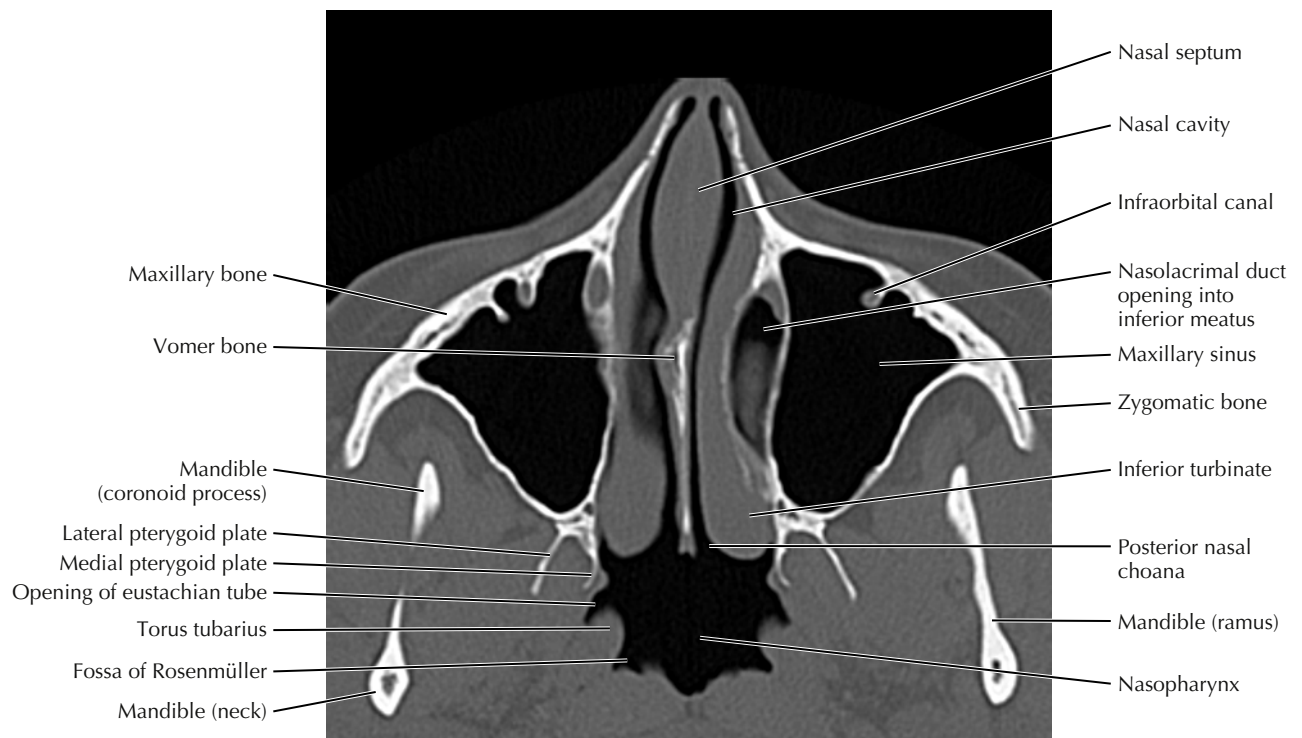
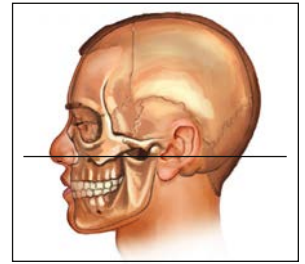


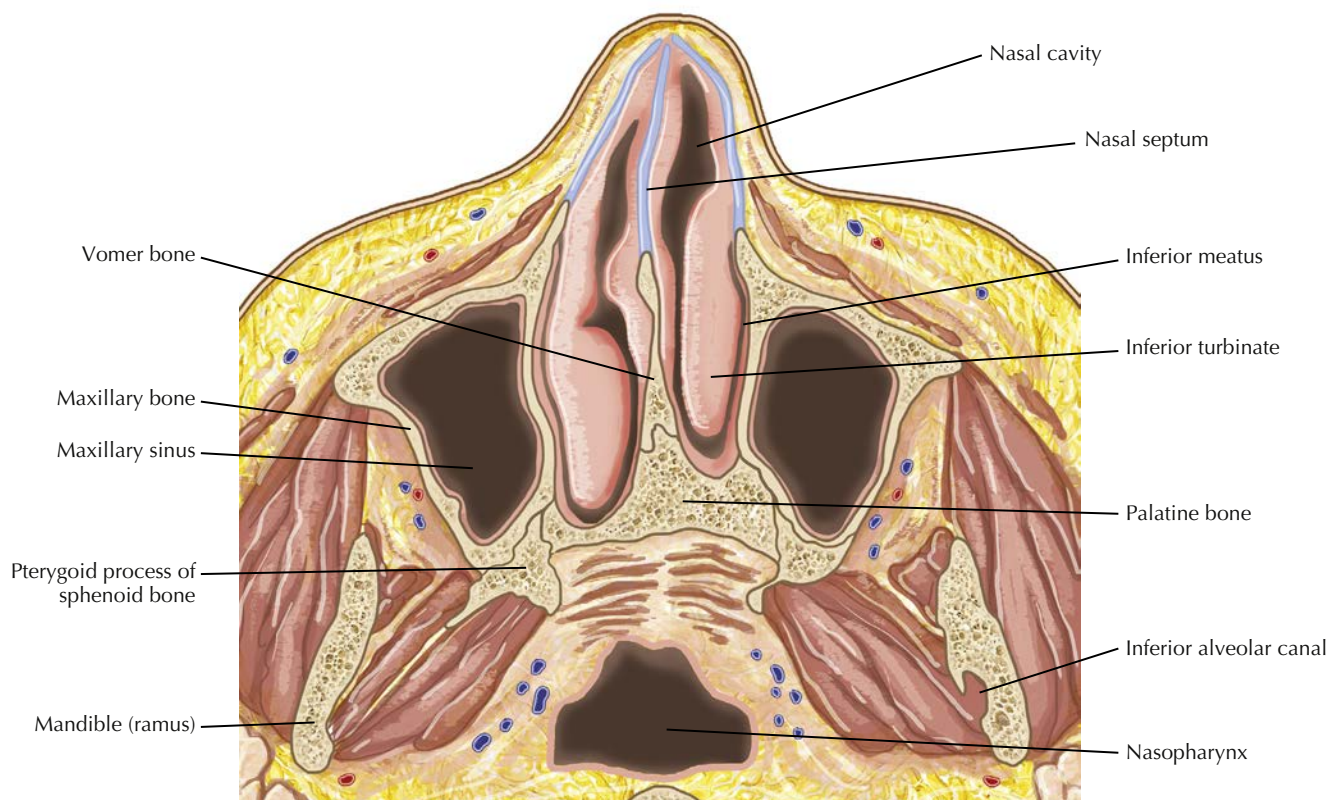
NORMAL ANATOMY

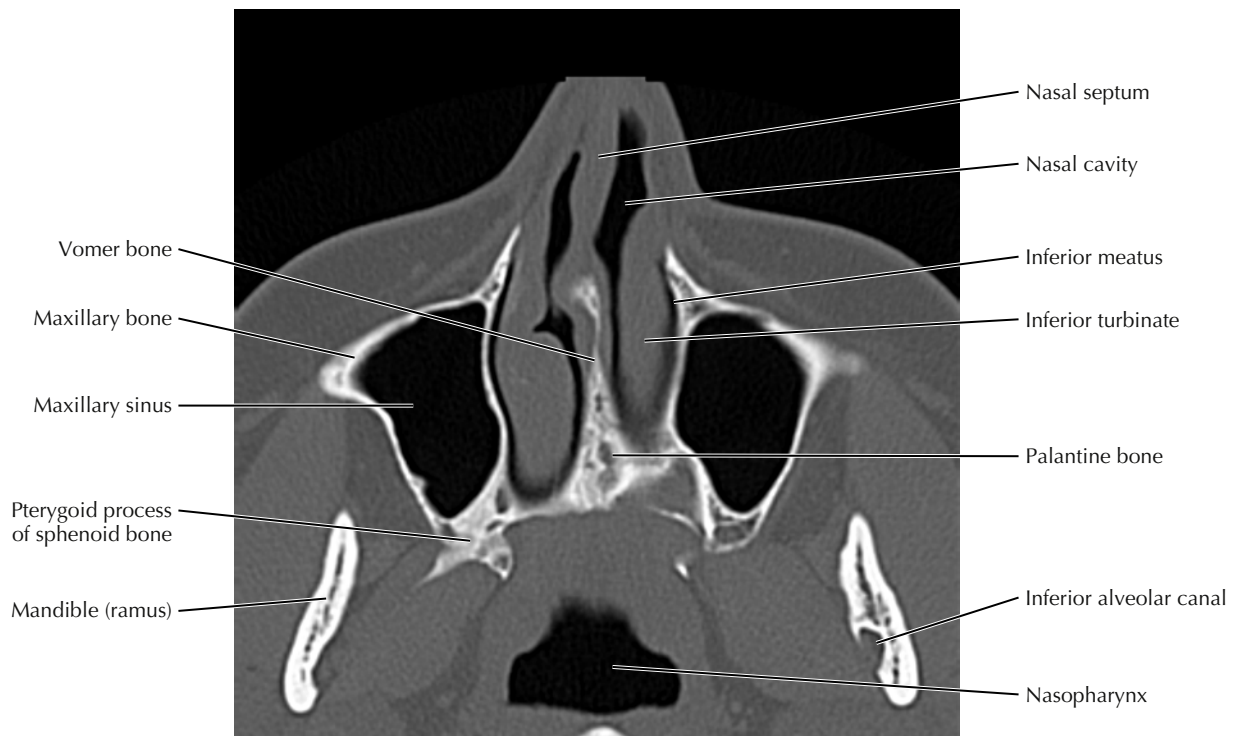
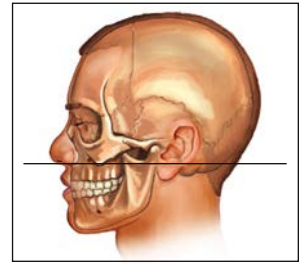
The *pterygopalatine fossa* houses the second division of the fifth cranial nerve (CN V), the maxillary nerve (V_2). The ganglion associated with V_2 lying in this fossa is known as *Meckel's* (pterygopalatine) ganglion, whereas the *Gasserian* (trigeminal) ganglion lies in Meckel's cave. Loss of the fat surrounding the nerve and ganglion is seen in perineural infiltration by malignancy.

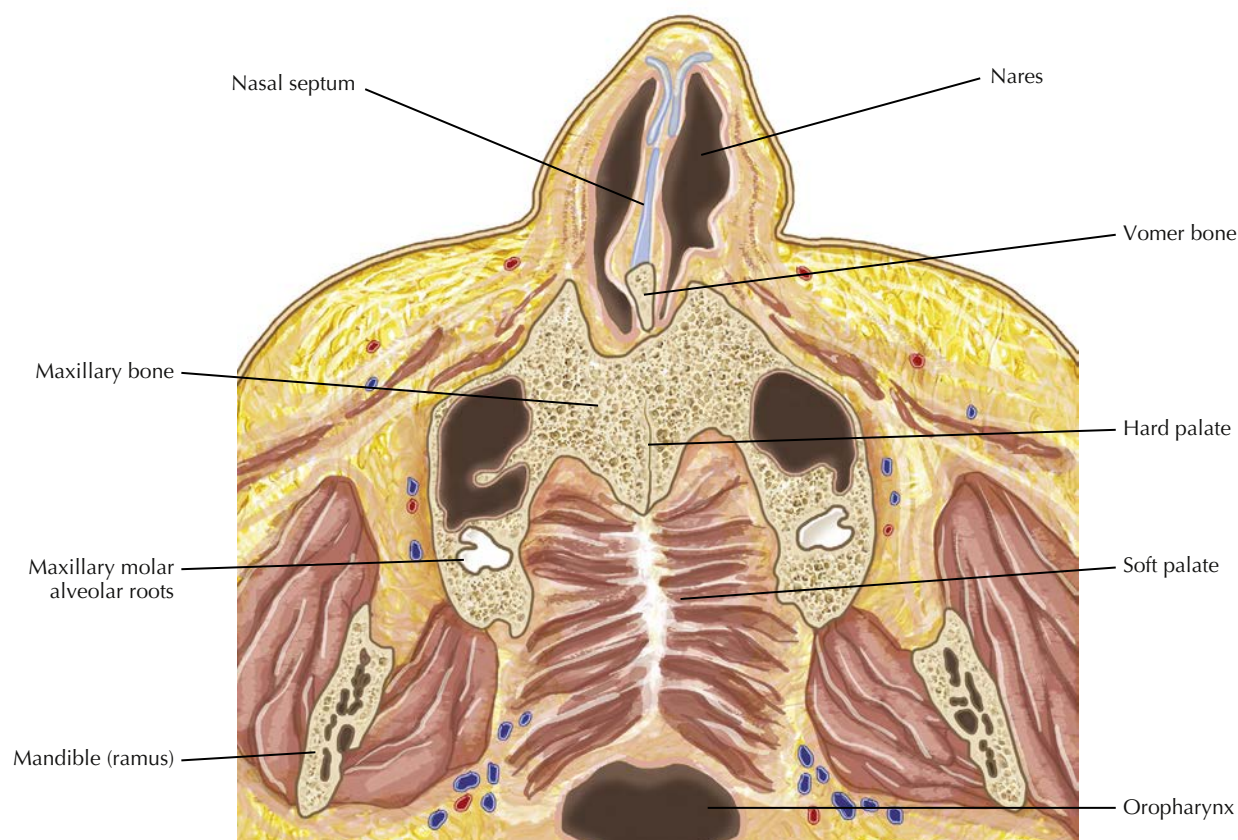






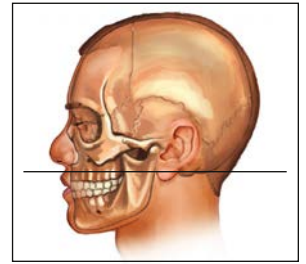


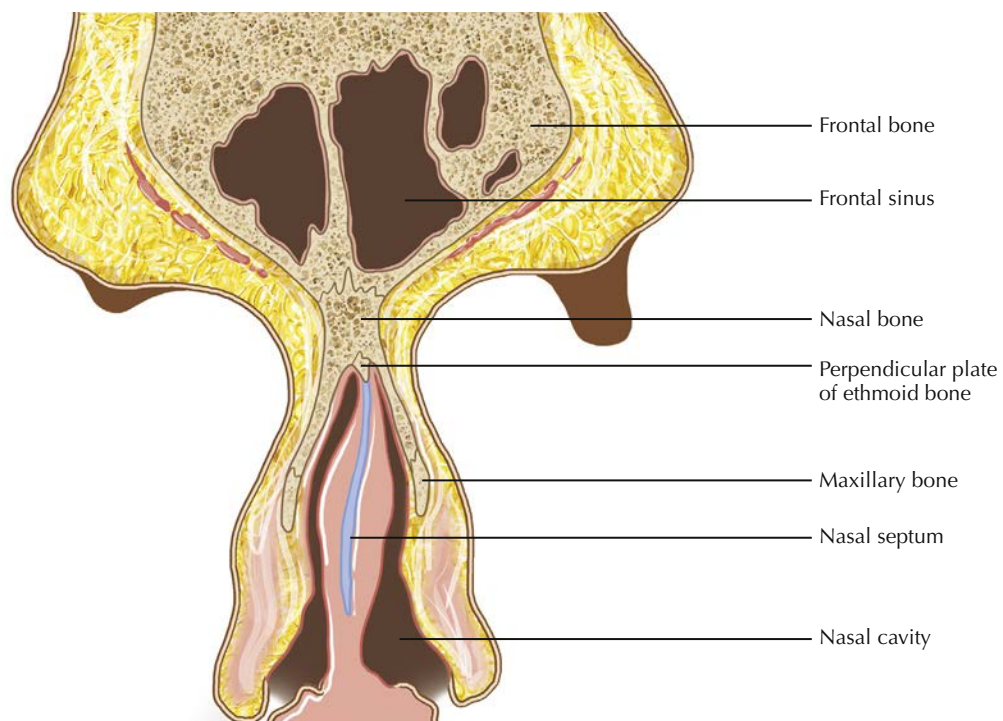




NORMAL ANATOMY

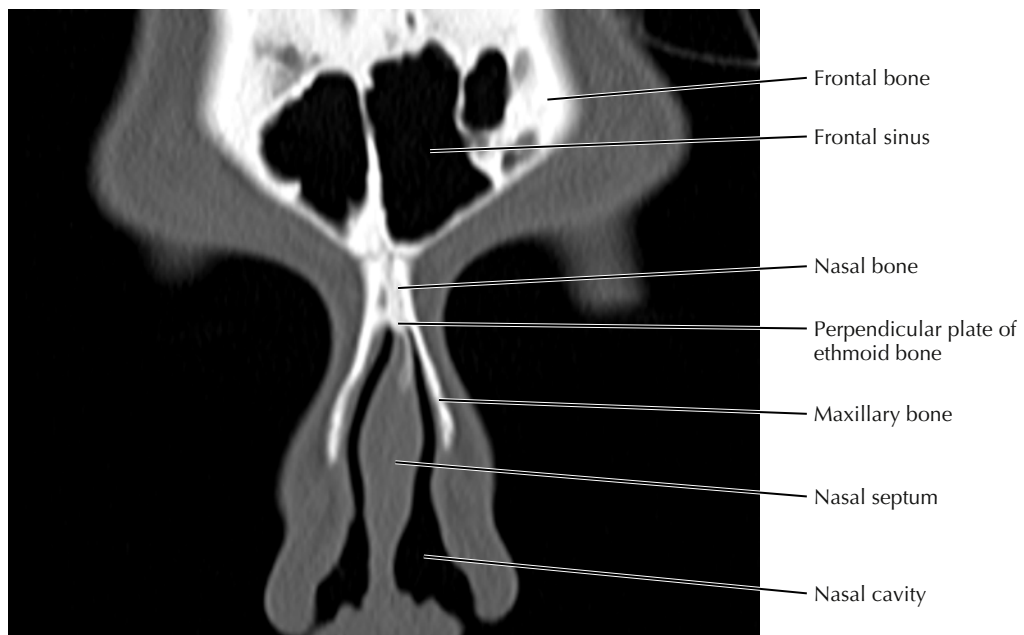
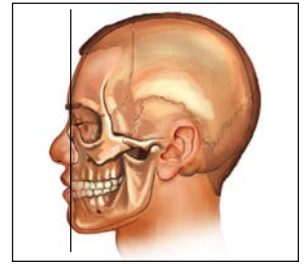
Note that no true boundary exists between the nasopharynx and the oropharynx on axial images. The teeth can provide a helpful anatomic landmark. When the teeth are clearly in view, the lumen is likely that of the oropharynx. On this image, where the alveolar roots of the maxillary molar teeth are visible, along with part of the hard palate and much of the soft palate, the lumen in view is likely junctional between the nasopharynx and the oropharynx.

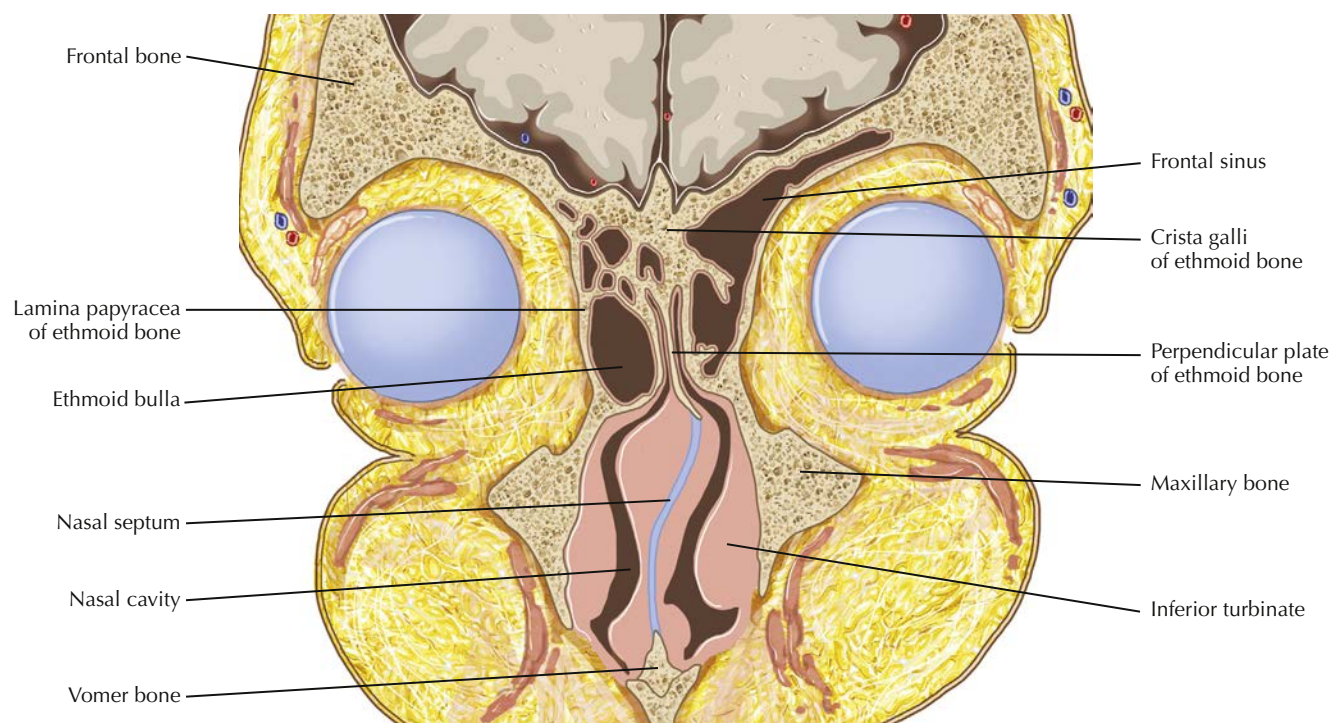




NORMAL ANATOMY

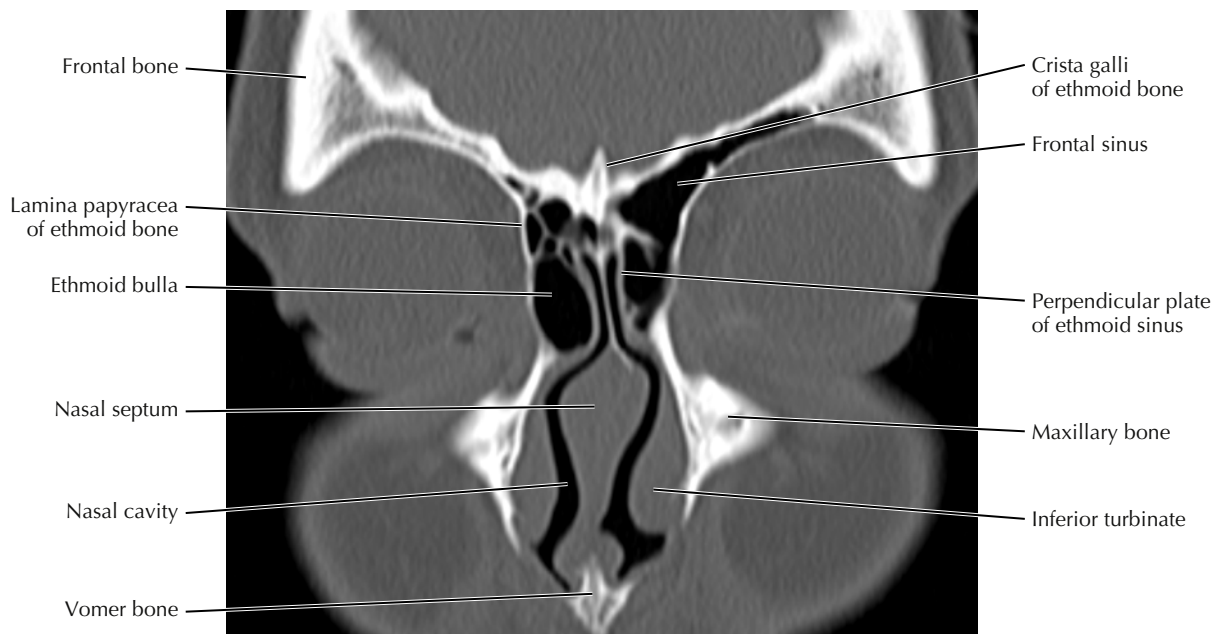
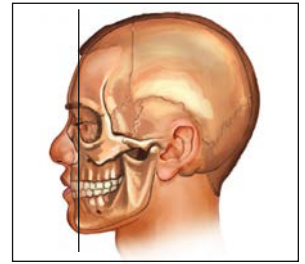
The frontal bone above the level of the sinuses is extremely hard. More inferiorly, however, where the frontal sinuses are located, the walls can be relatively thin.

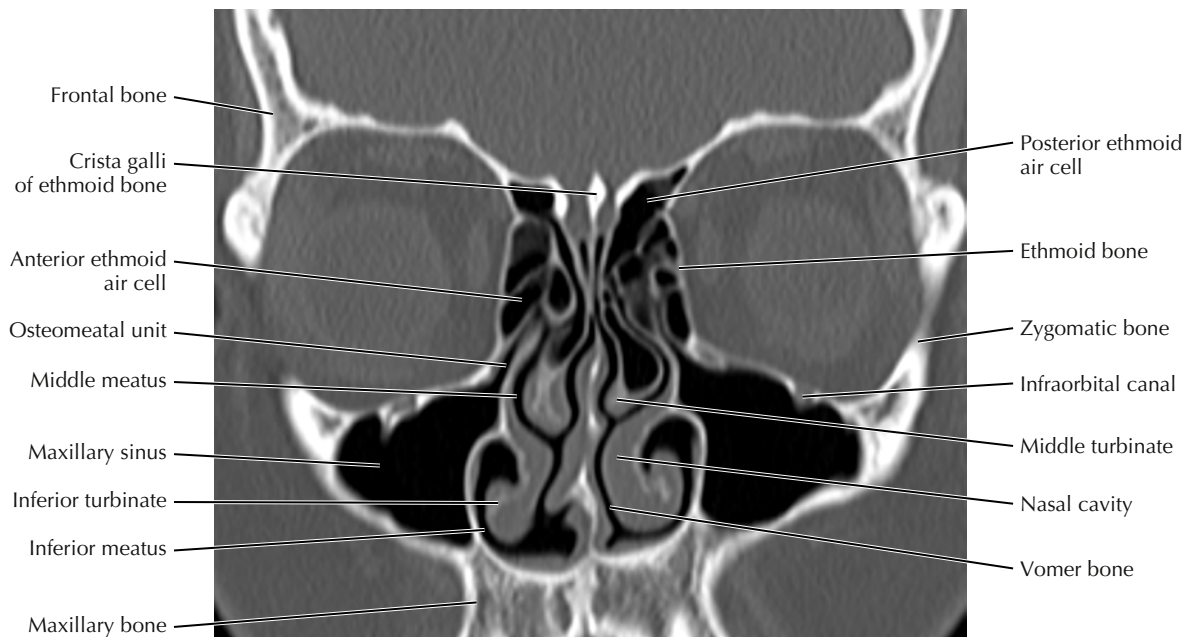
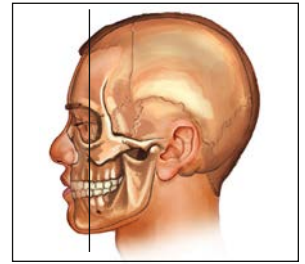




SURGICAL CONSIDERATION

Functional endoscopic sinus surgery can be performed to open the nasal passages when the nasal septum is significantly deviated to one side.

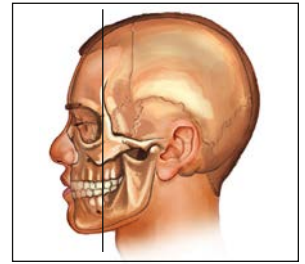


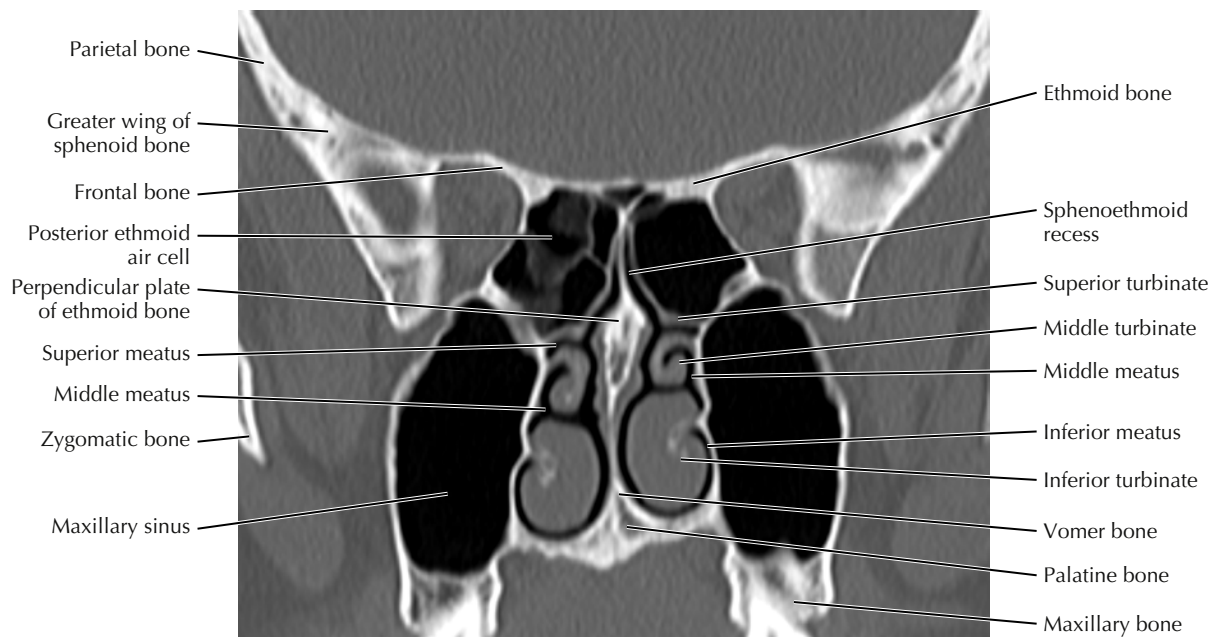
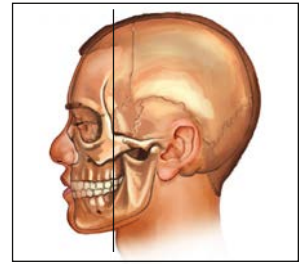


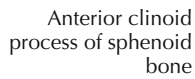


NORMAL ANATOMY

Note the paired olfactory grooves housing the olfactory nerves (cranial nerve I). An asymmetrically low olfactory groove can be important to note in patients who will undergo endoscopic sinus surgery.







Optic canal

Foramen rotundum,
maxillary division -
(V₂), trigeminal n.
(CN V)

Greater wing of sphenoid bone

Pterygopalatine
fossa

Nasal septum

Mandible

Pterygoid process of
sphenoid bone

- Squamous portion of temporal bone

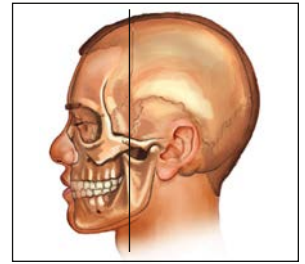
- Sphenosquamosal suture

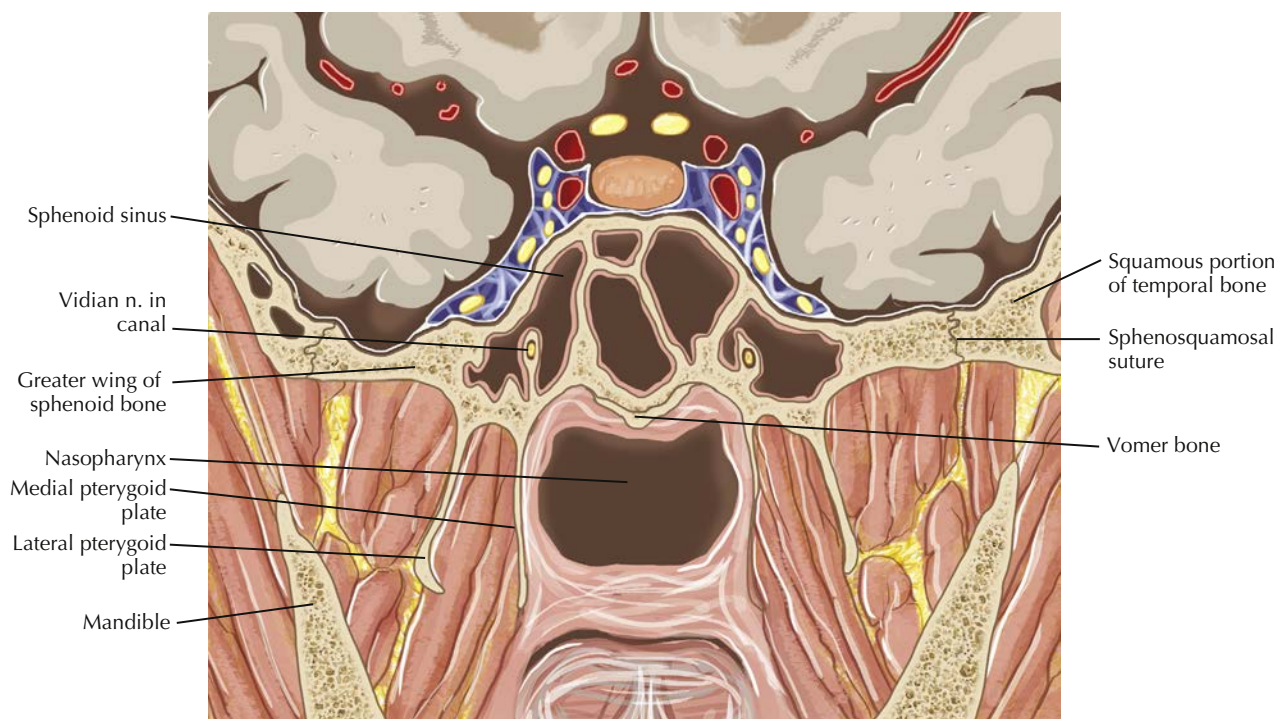
- Vomer bone

- Middle meatus

- Inferior turbinate

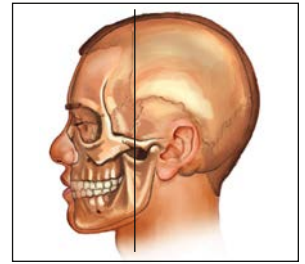
- Inferior meatus

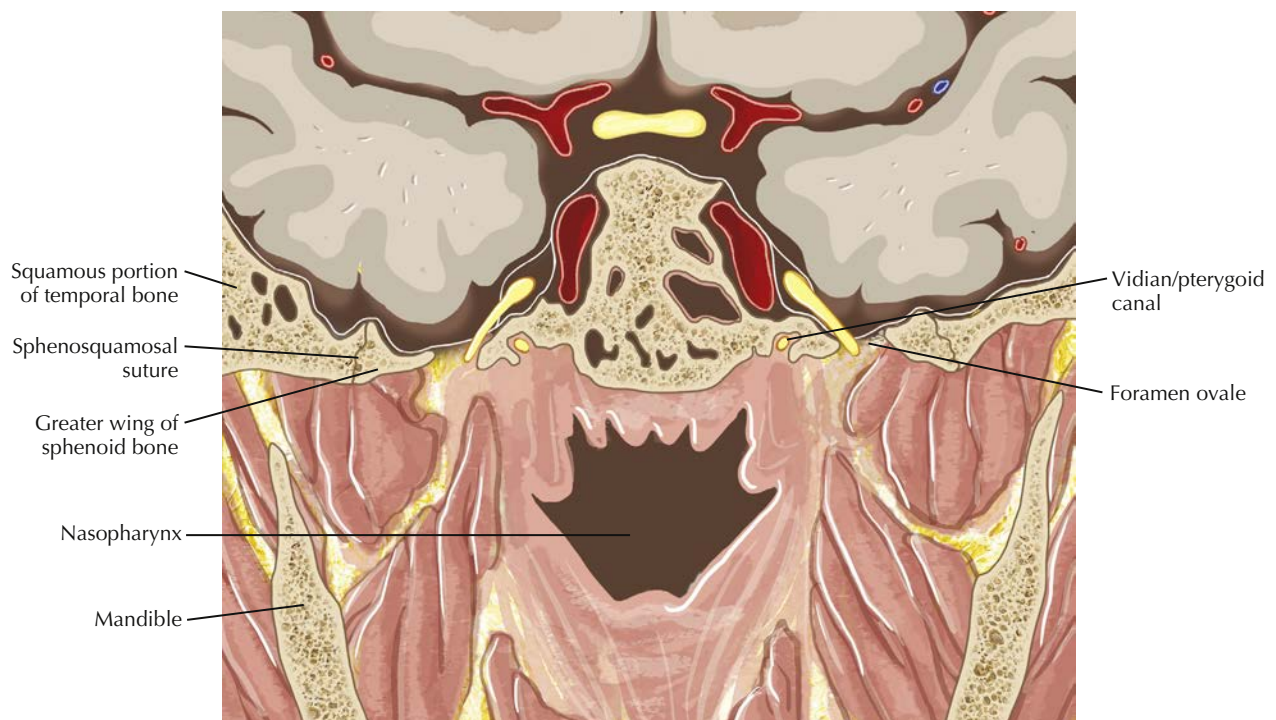


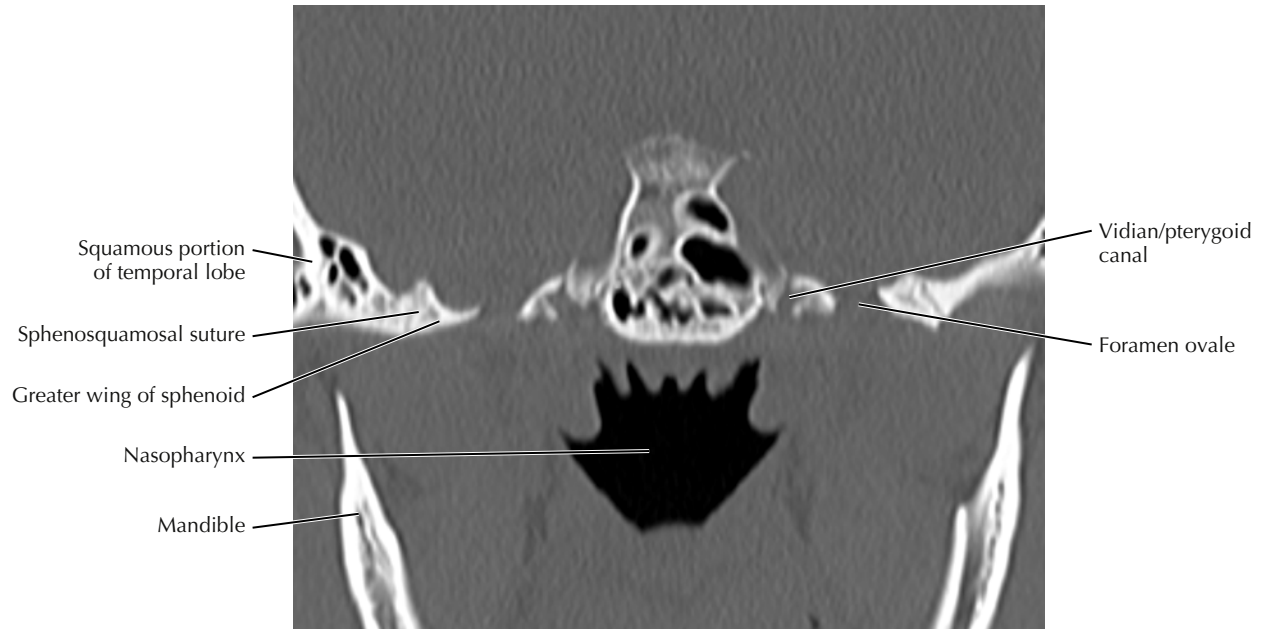
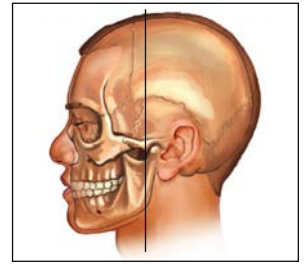


NORMAL ANATOMY

Note that the vidian nerve may often protrude into the sphenoid sinuses, resembling a stalk on coronal images.

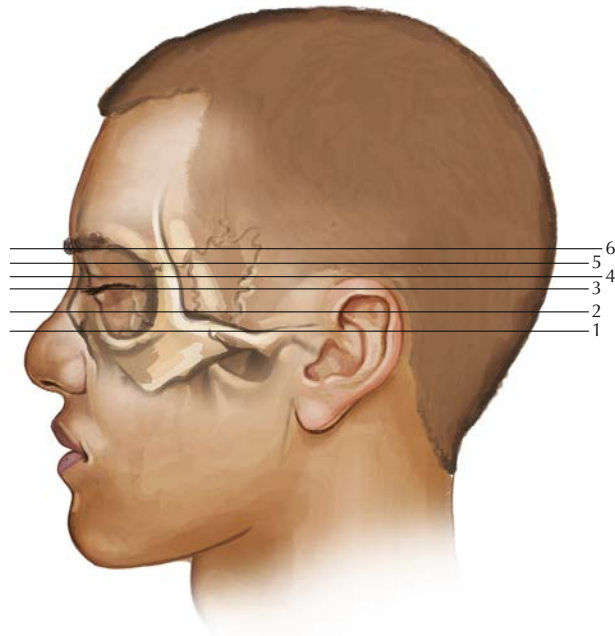




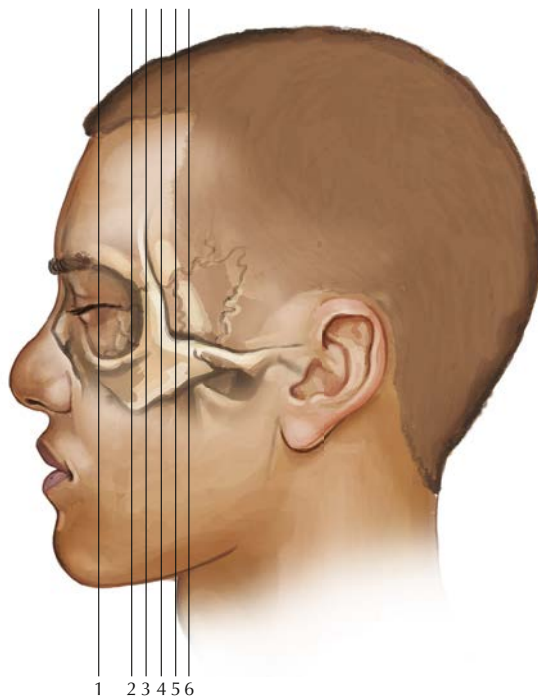


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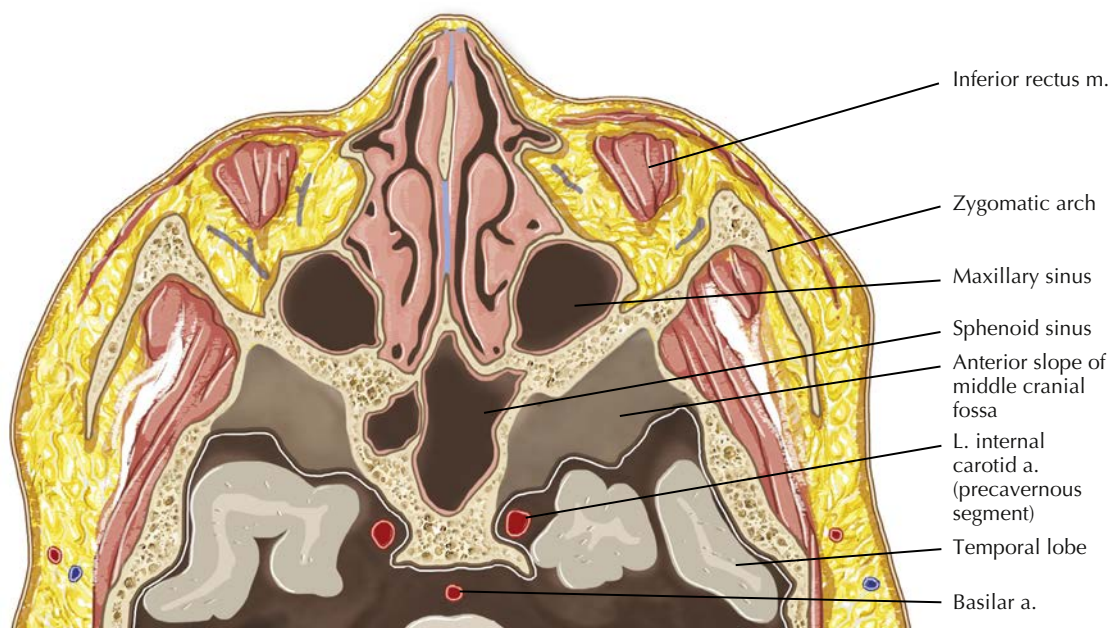
Chapter 10 ORBITS

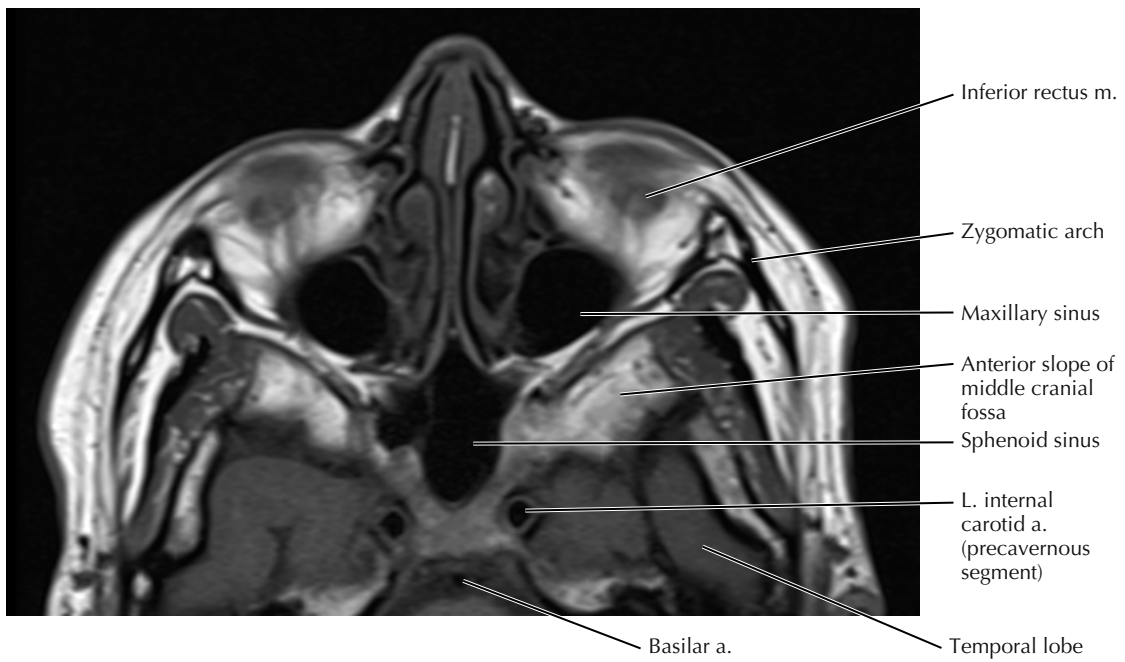
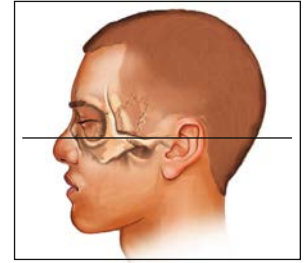


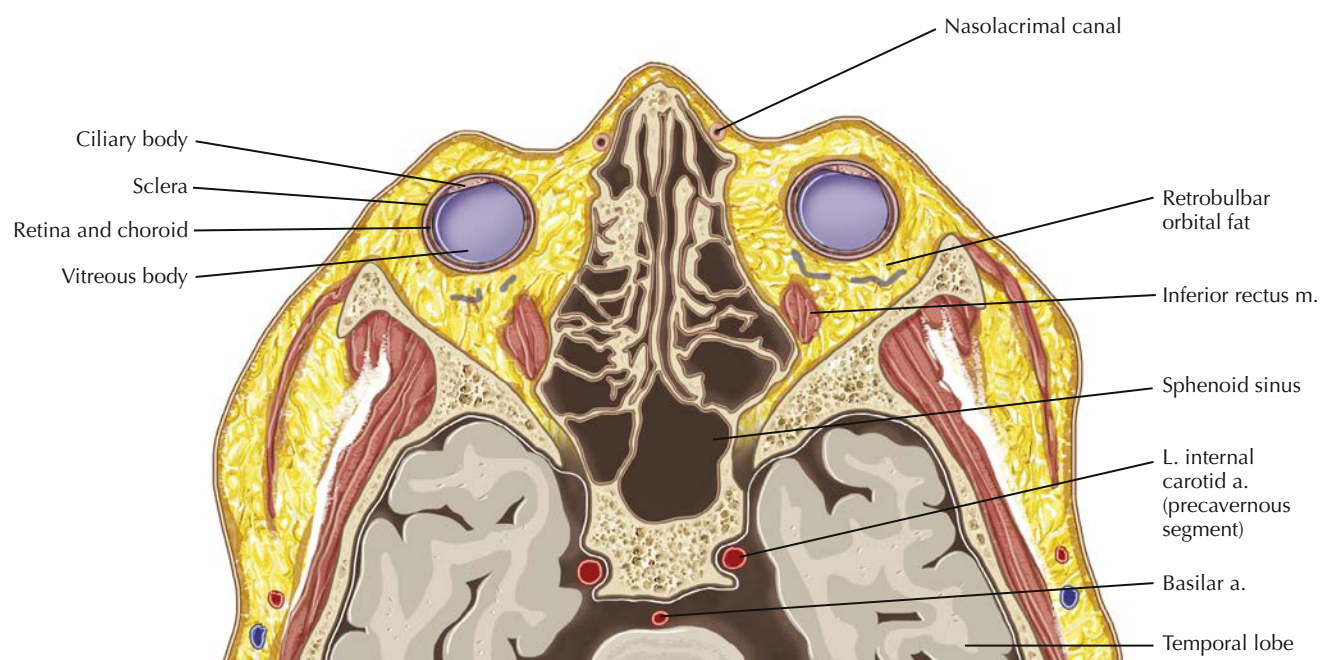
AXIAL 356

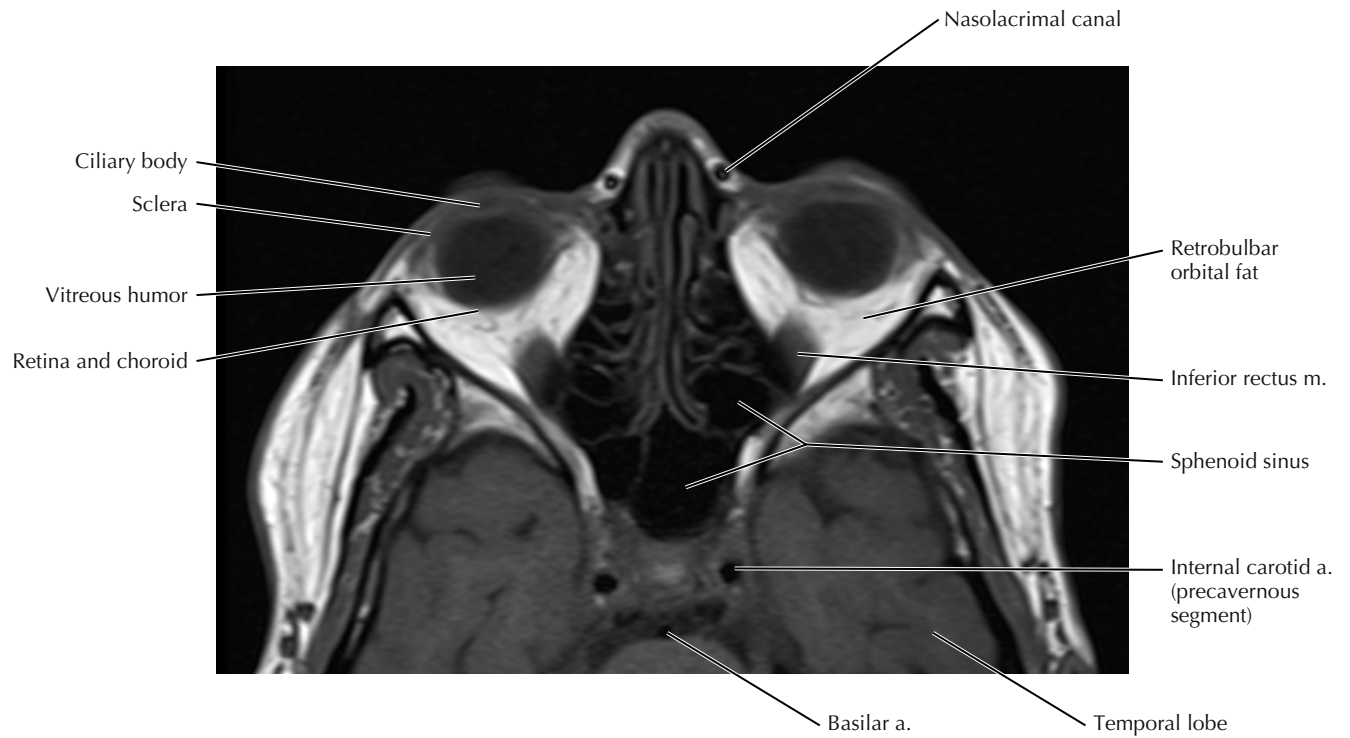
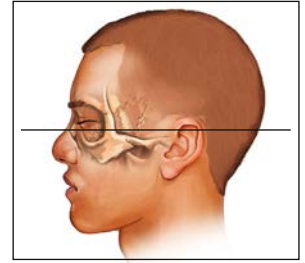


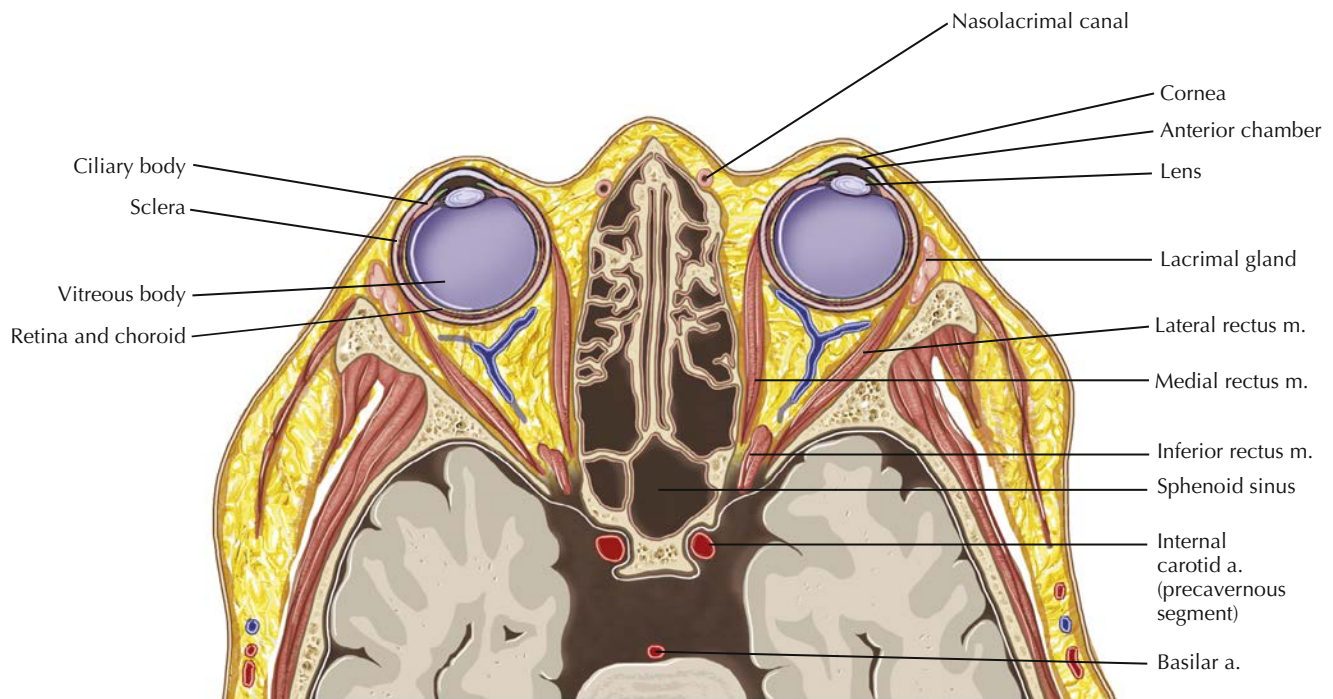
CORONAL 368





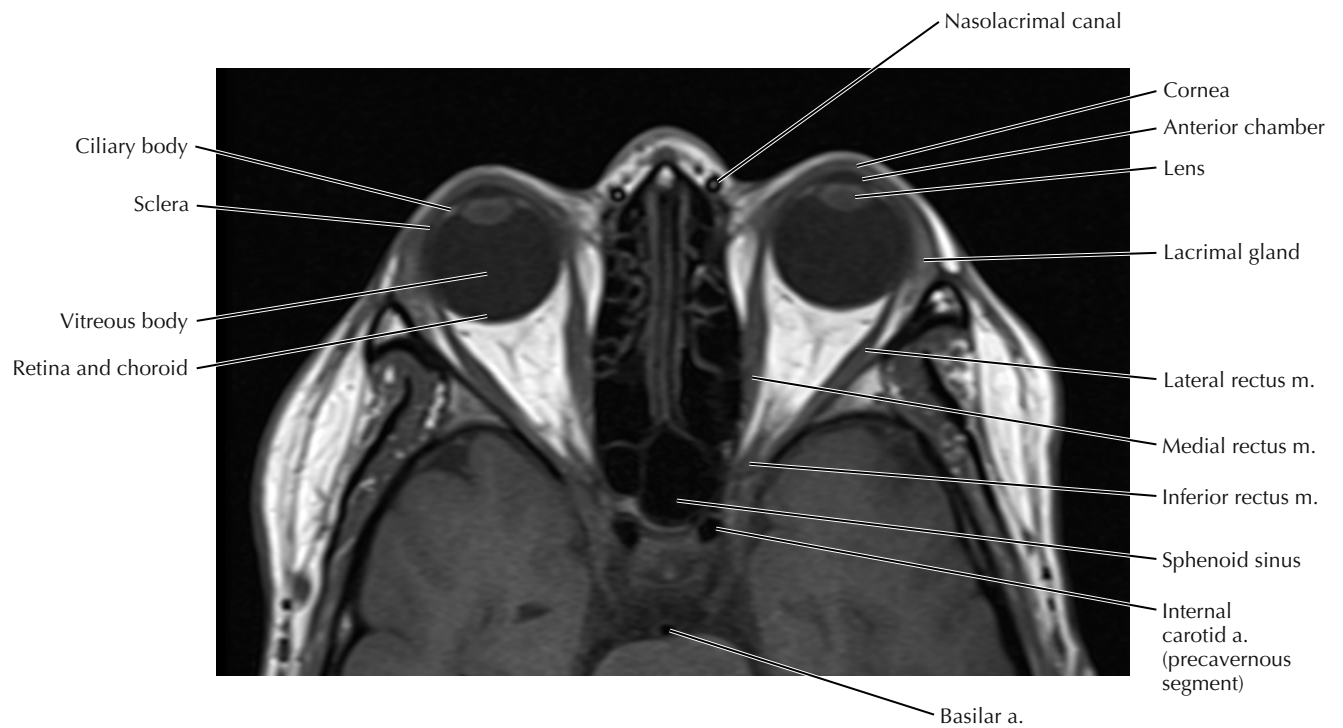
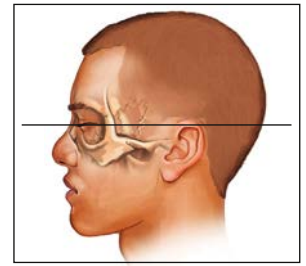


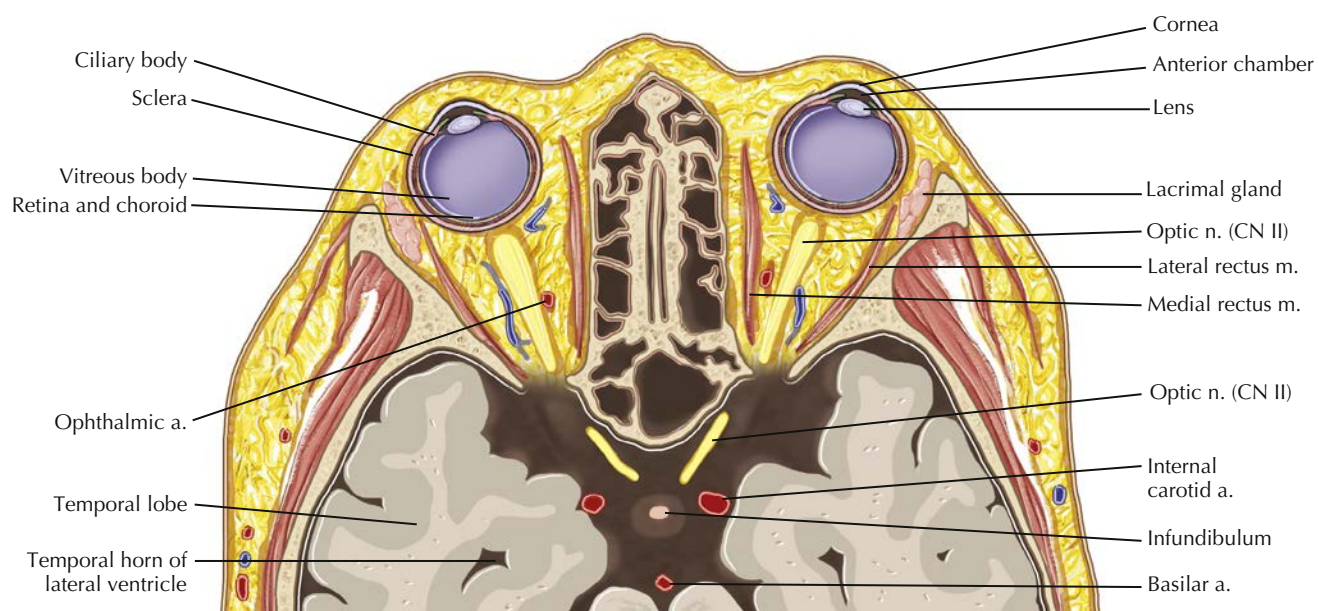


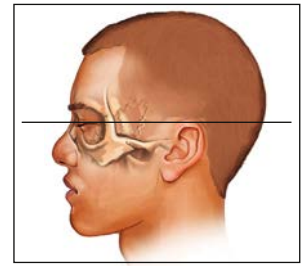


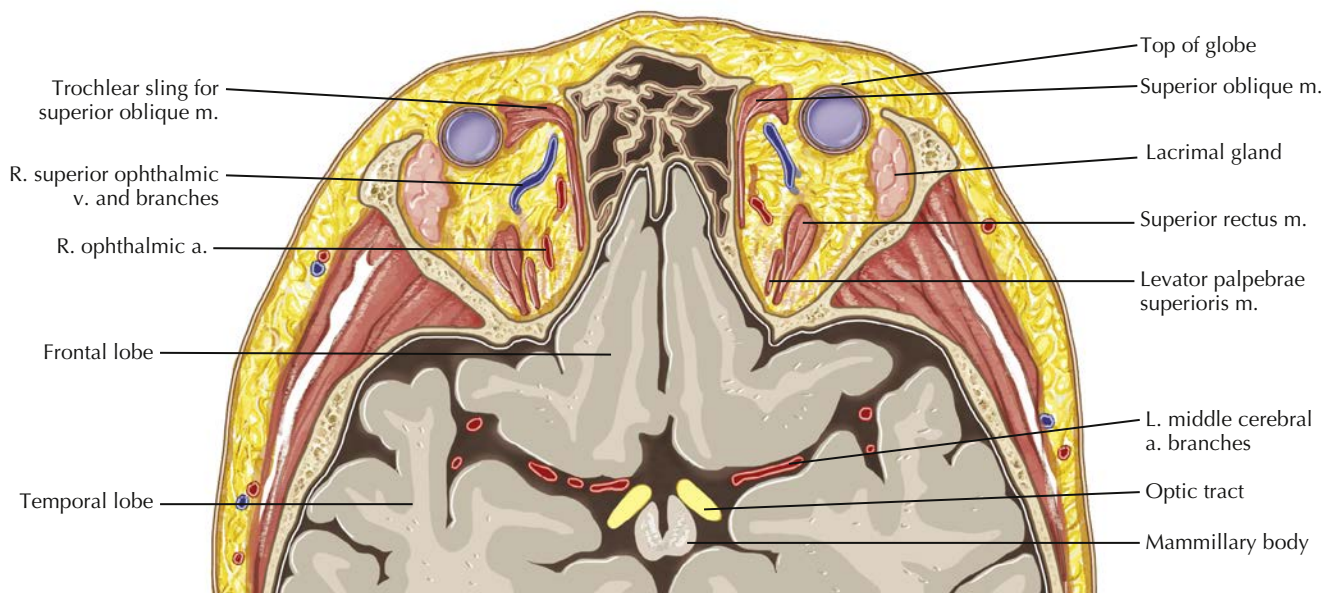
NORMAL ANATOMY

The lenses are normally biconvex in shape. If this configuration is replaced by a thin line, the patient likely has had the lens removed because of cataracts and replaced with an artificial lens.



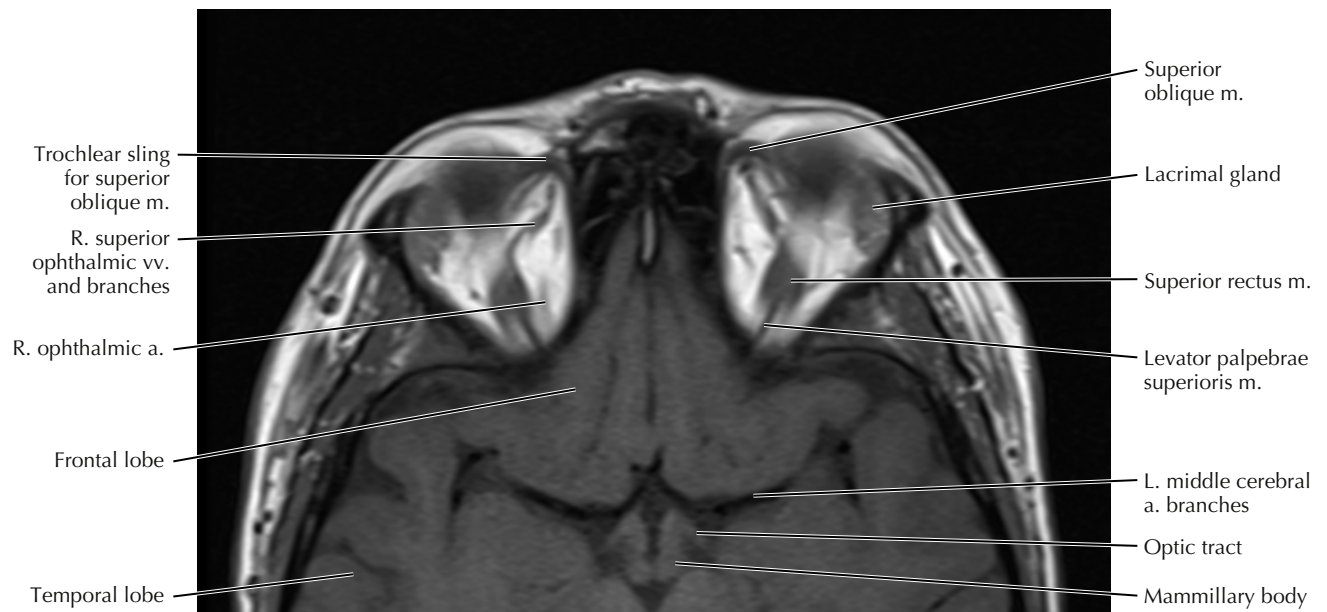
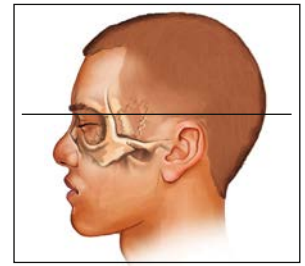


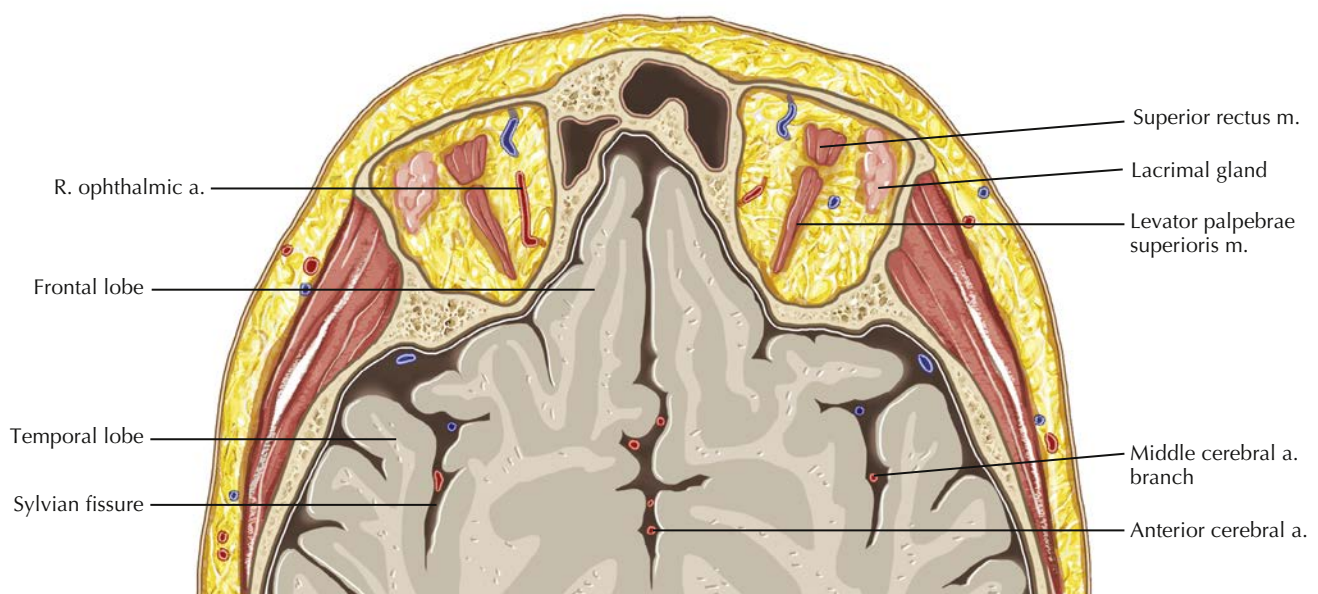




PATHOLOGIC PROCESS

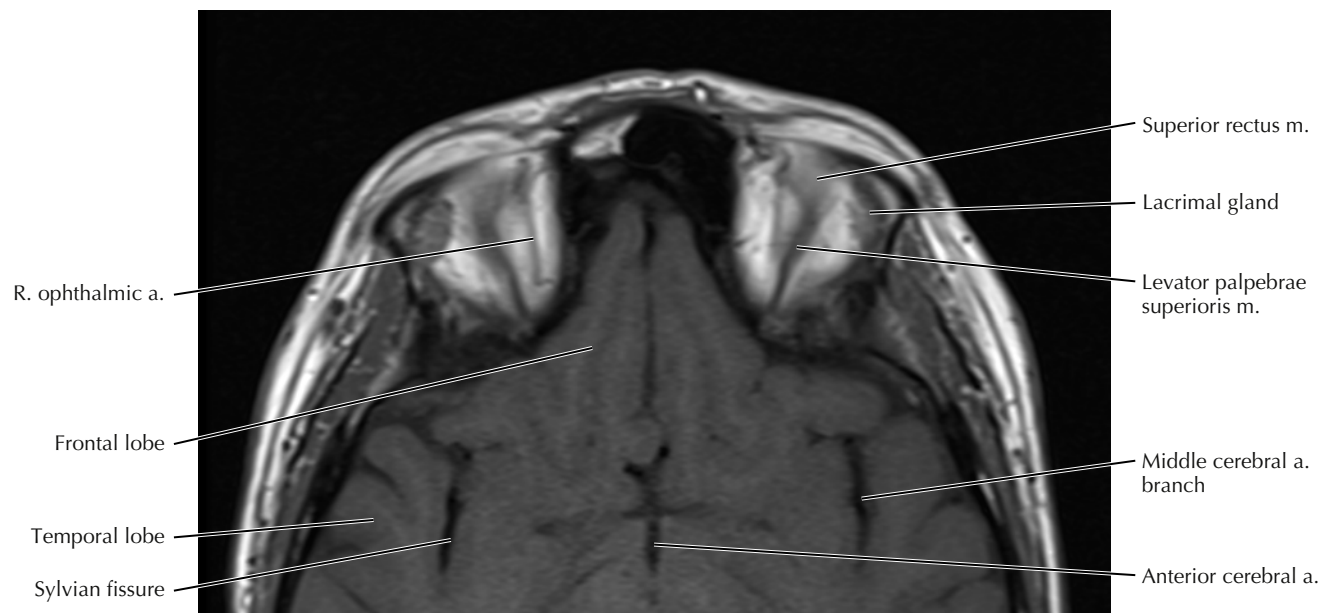
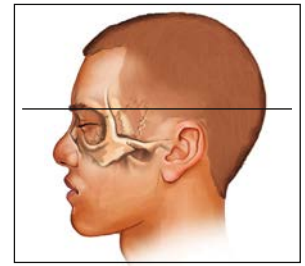
Note the thin superior ophthalmic vein (SOV). Dilatation should lead to consideration of increased pressure within the cavernous sinus, as in carotid cavernous fistula (CCF) following trauma. Early, asymmetric filling of the cavernous sinus in the arterial phase confirms the diagnosis of CCF (see also Orbits Coronal 1).

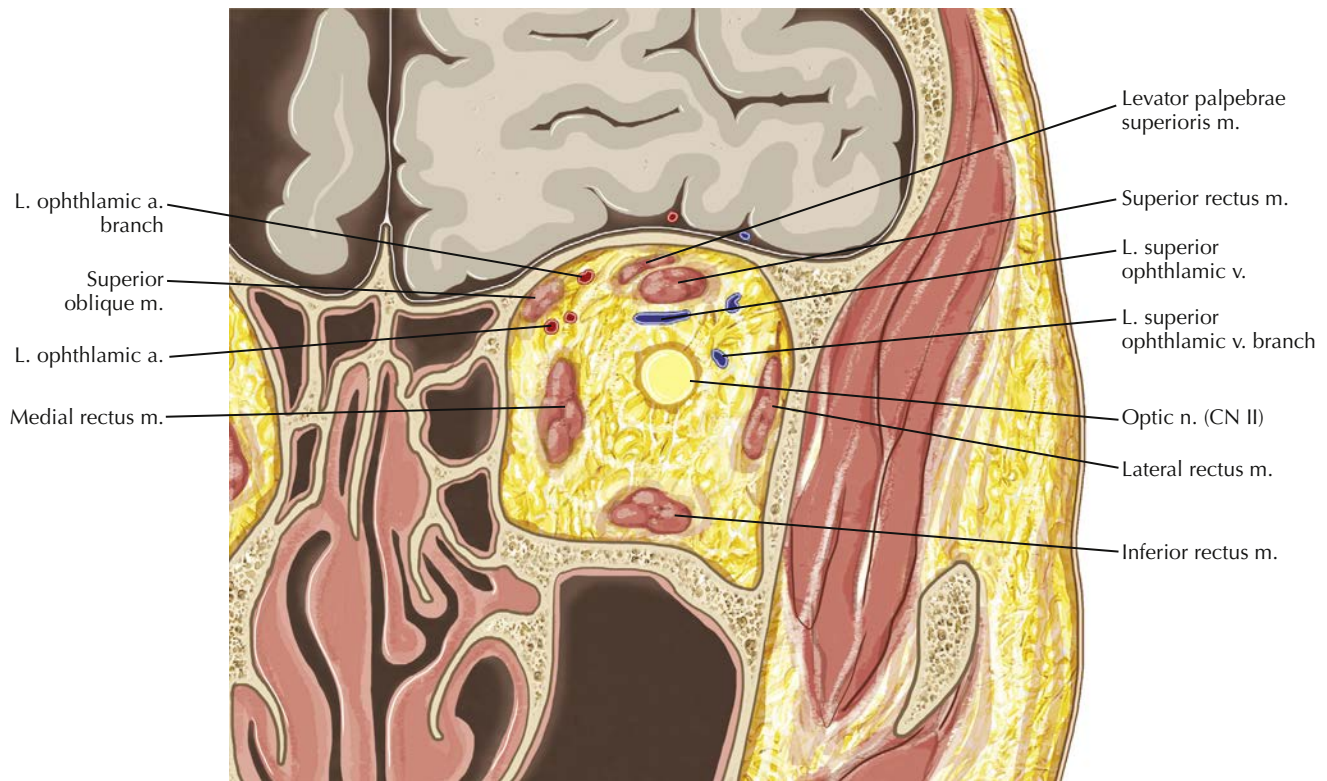




NORMAL ANATOMY

The lacrimal gland is located in the upper outer aspect of the orbit. It produces tears, which coat the eye in a superolateral to inferomedial direction, eventually being drained through the two lacrimal puncta leading to the canaliculi and then the nasolacrimal duct.





NORMAL ANATOMY

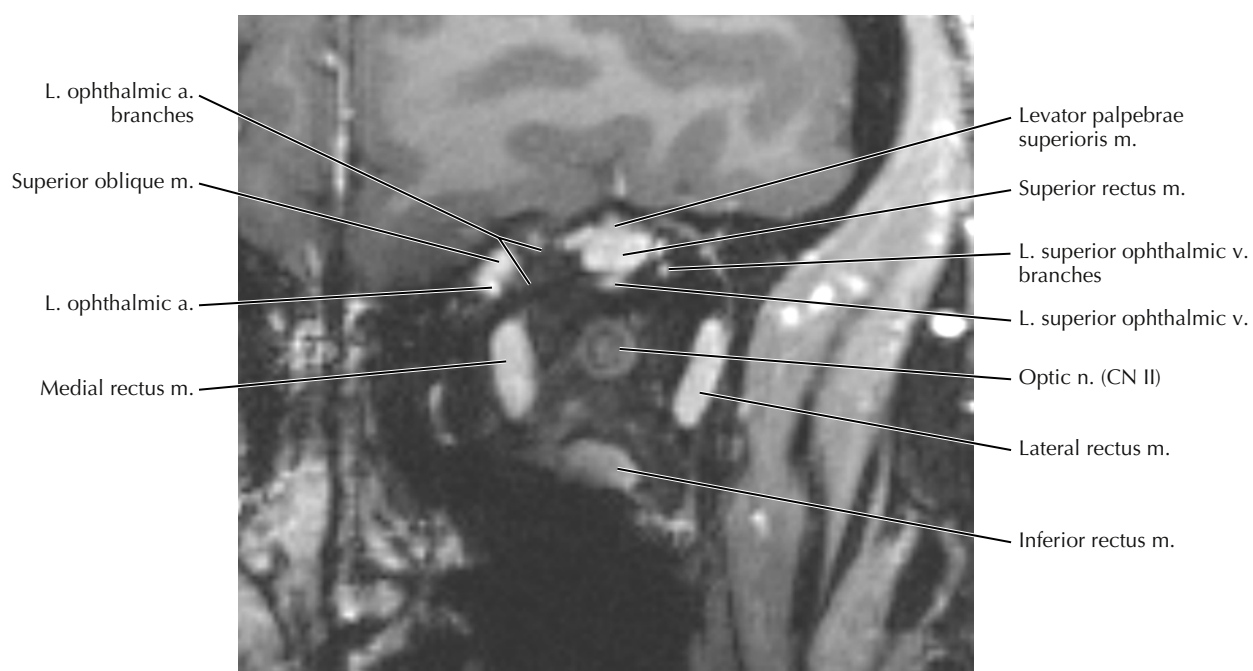
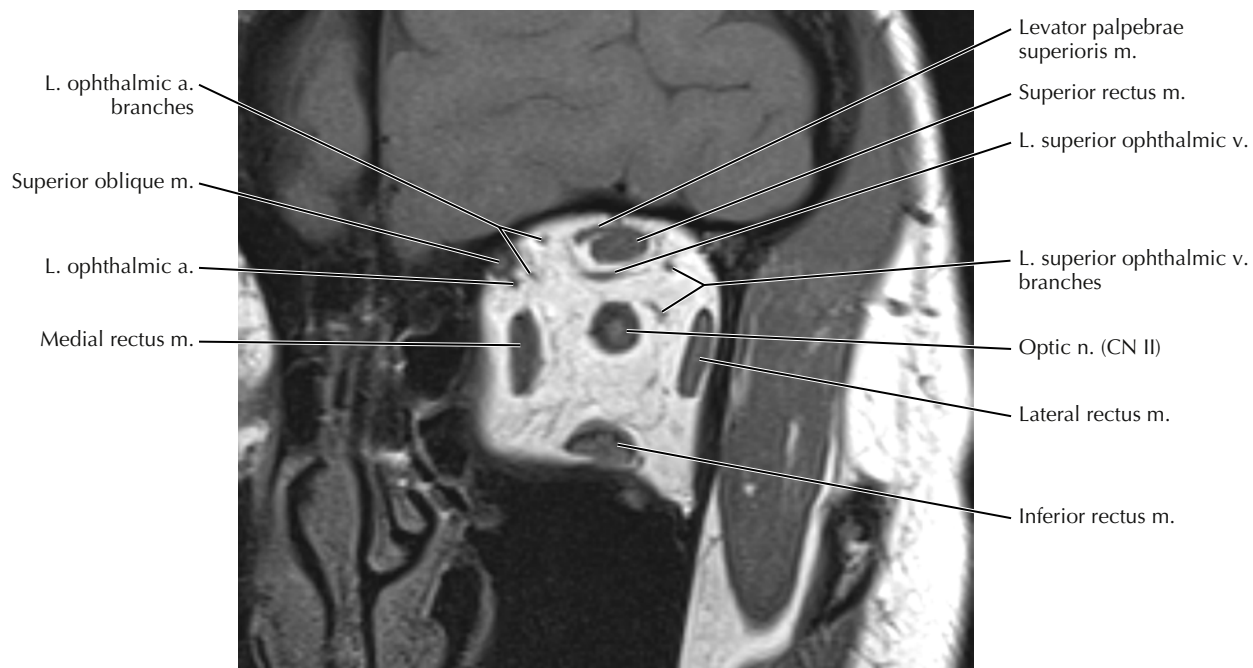
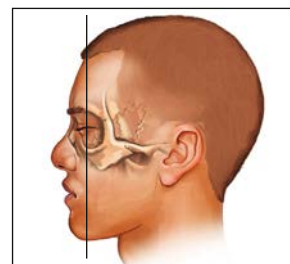
The optic nerve, cranial nerve (CN) II, is the only cranial nerve that is part of the central nervous system in that, like the brain and spinal cord, it has no ability to regenerate, unlike peripheral nerves. CN II is a direct extension of the brain and is surrounded by cerebrospinal fluid (CSF) and dura.

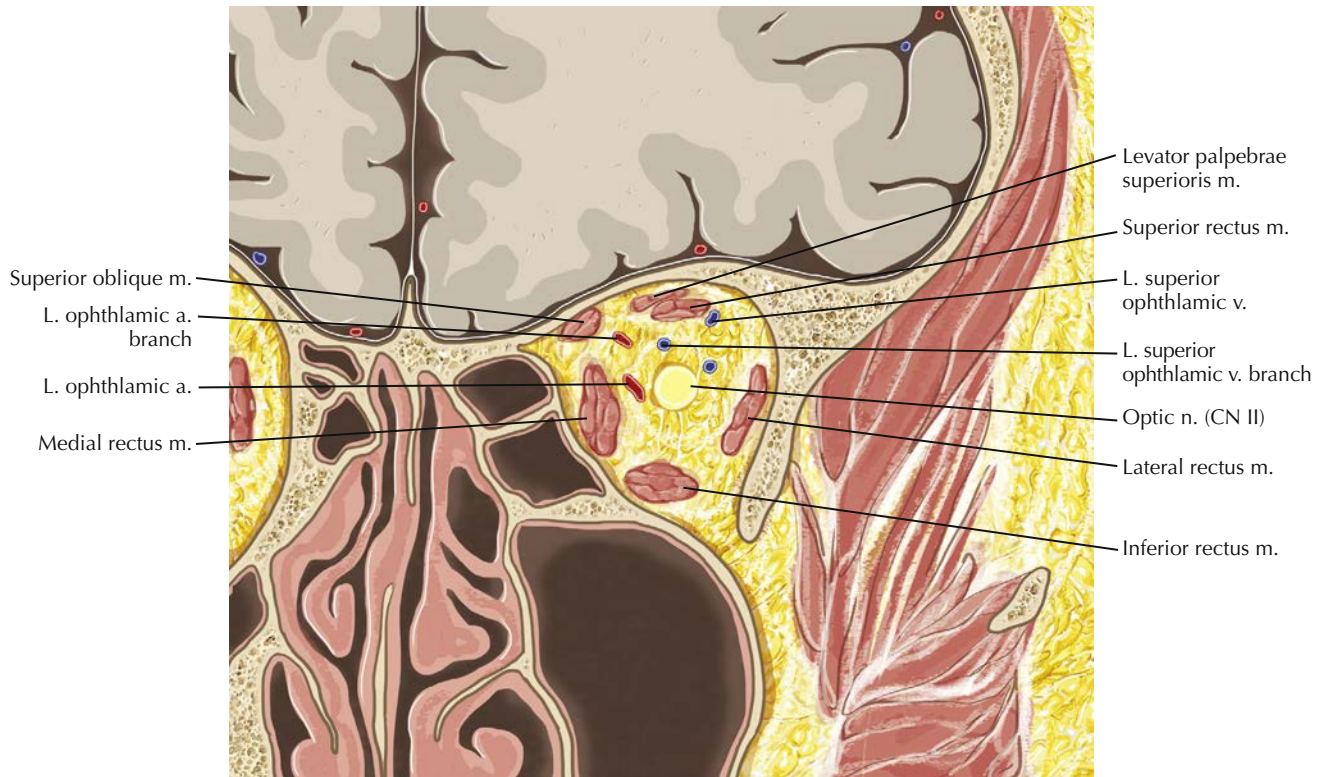
PATHOLOGIC PROCESS

If the normally thin and flat superior ophthalmic vein (SOV) is dilated, rounded, and tortuous, increased pressure within the cavernous sinus should be suspected, as with post-trauma carotid-cavernous fistula (CCF; see also Axial 5).

IMAGING TECHNIQUE CONSIDERATION

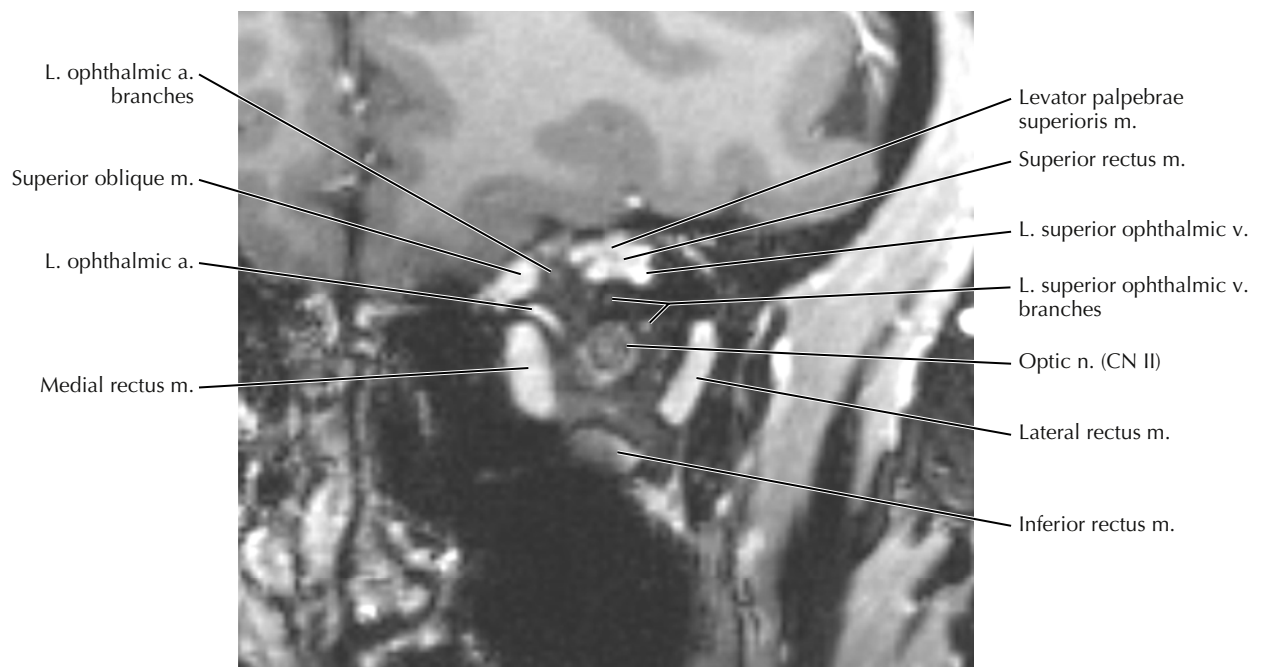
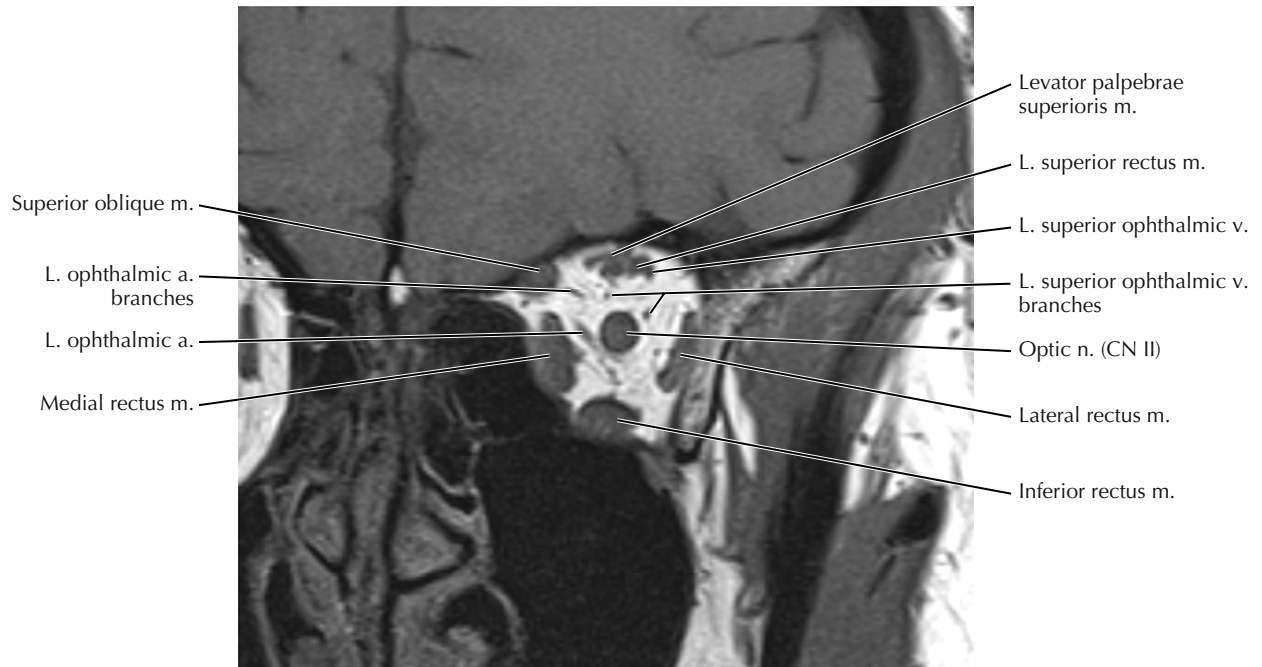
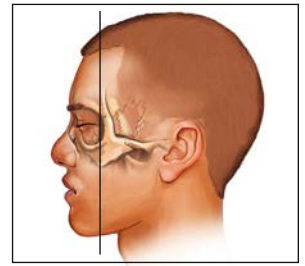
Note that in the bottom MR image of Coronal 1, the white matter is brighter than the gray matter; thus this sequence must be T1 weighted (think of "fatty" myelin being bright on T1). The subcutaneous fat is dark, so this must be a fat-saturated sequence, and the vessels and mucosa are both bright, so contrast has been administered.

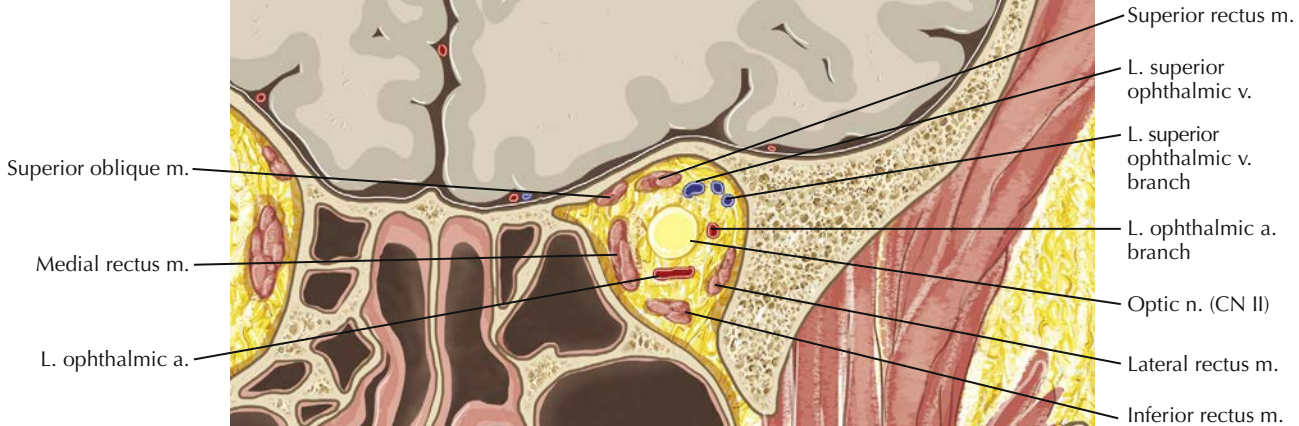


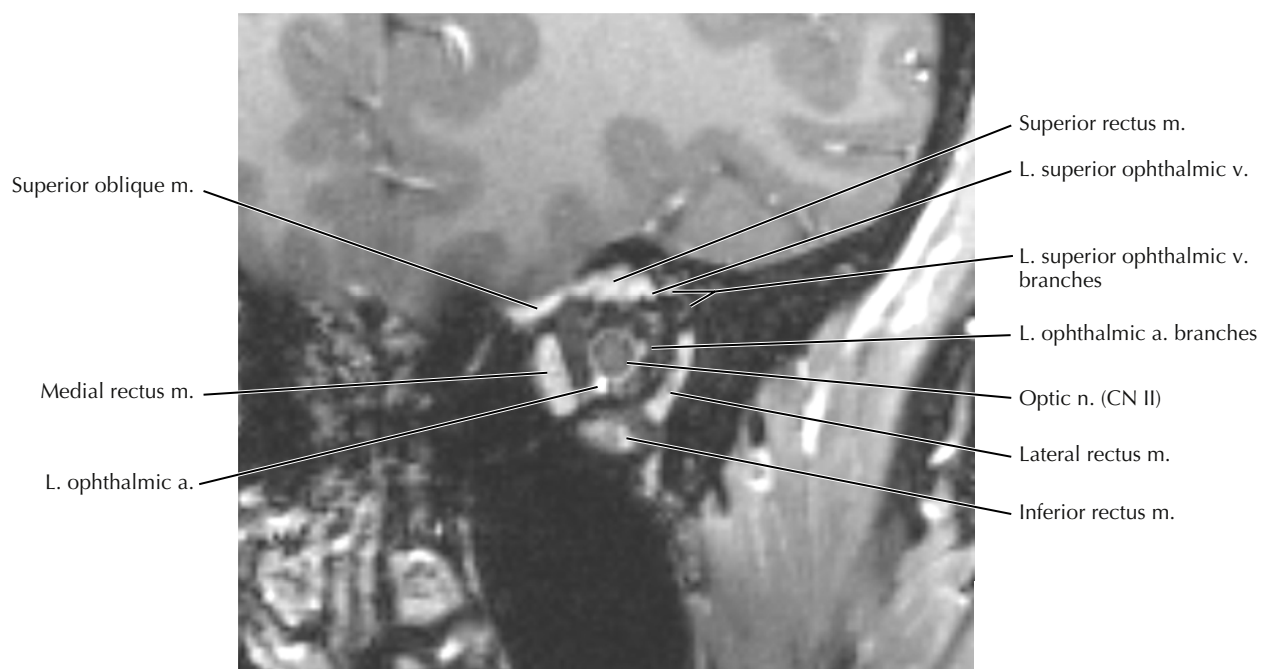
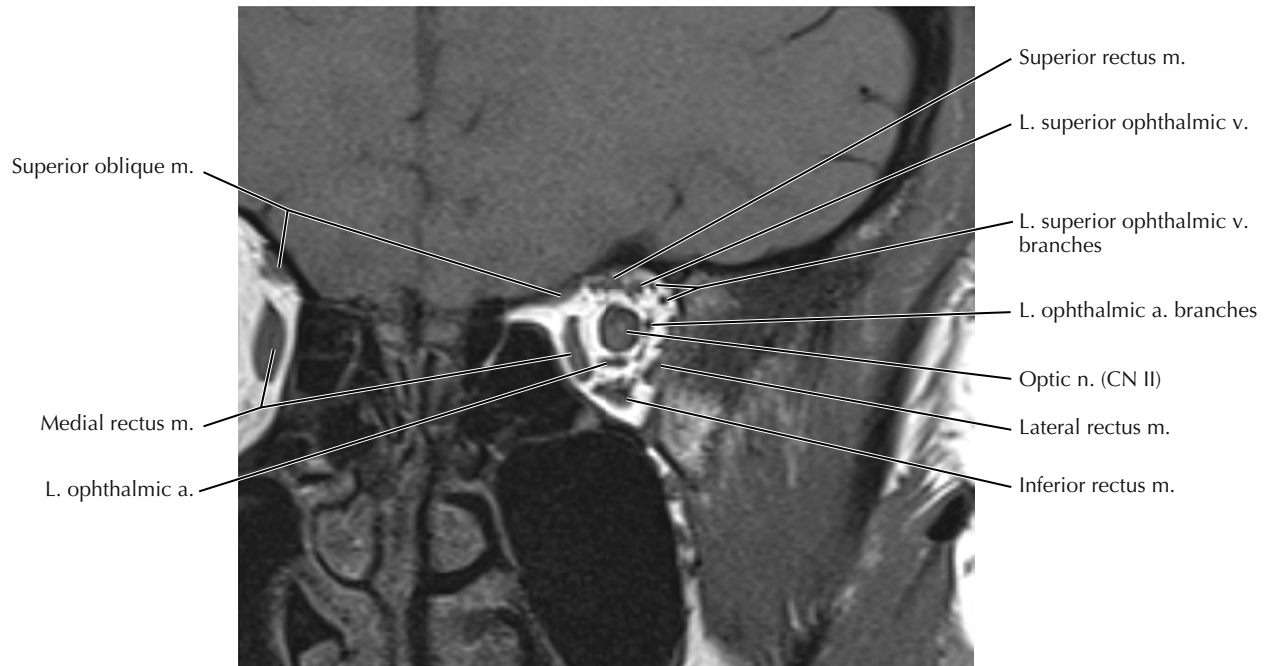
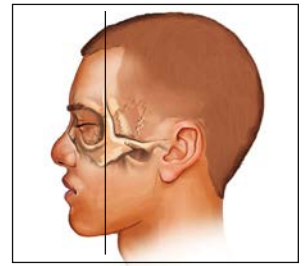


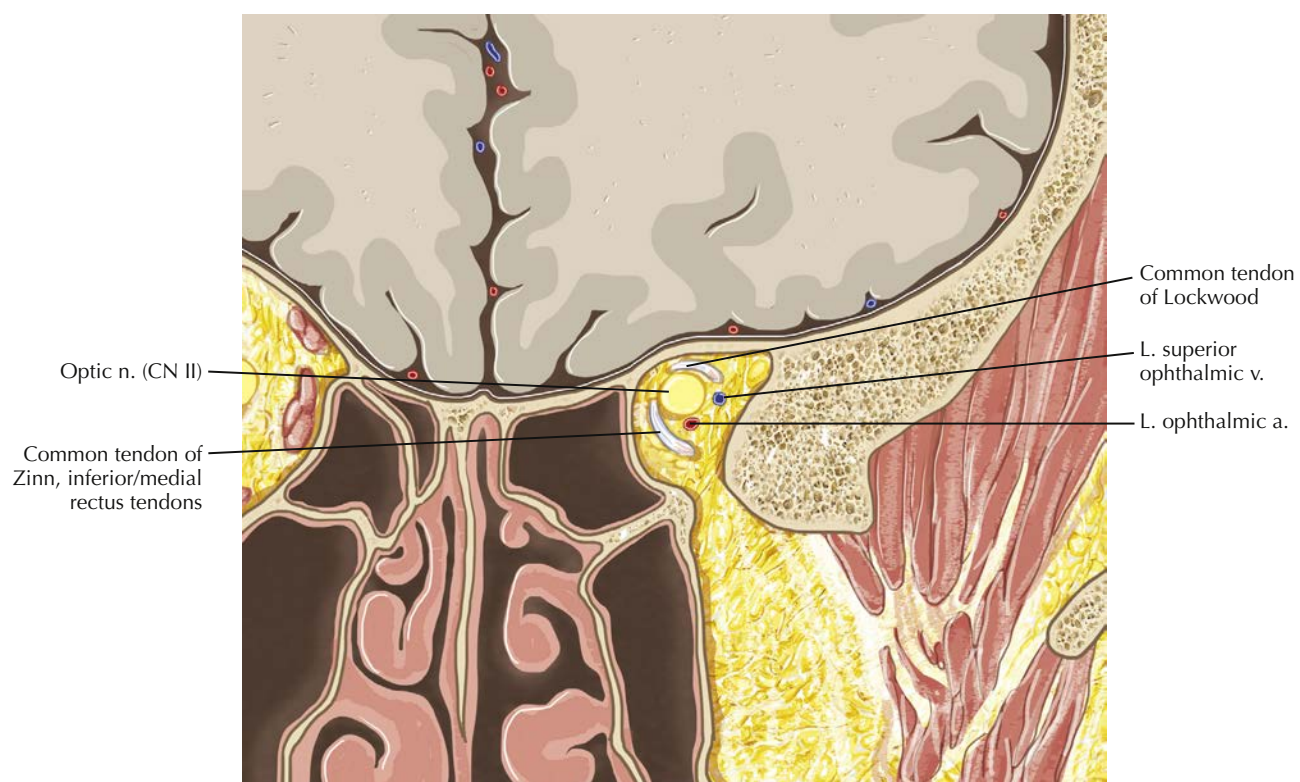
NORMAL ANATOMY

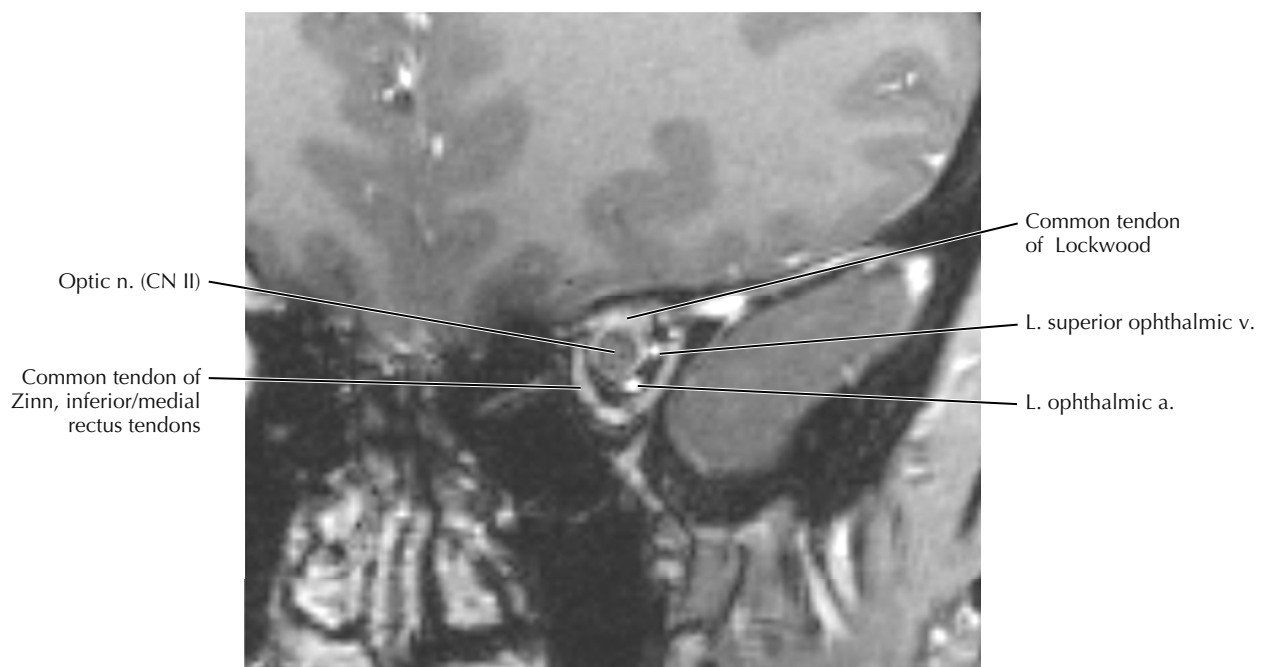
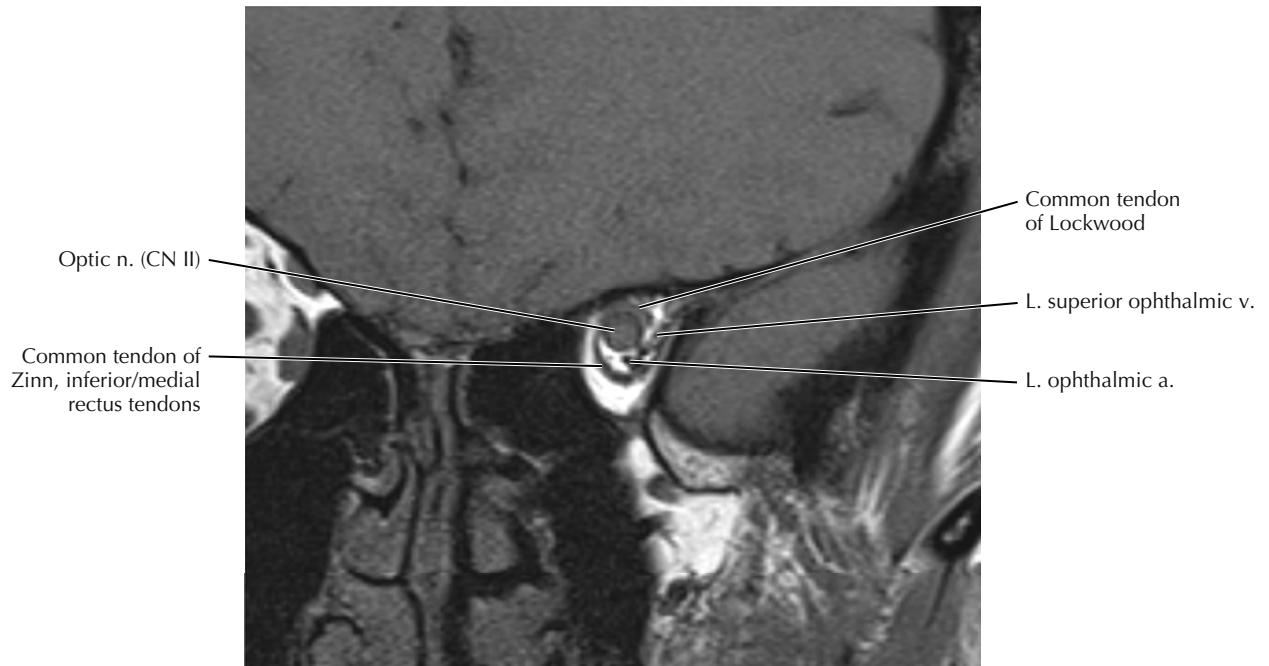
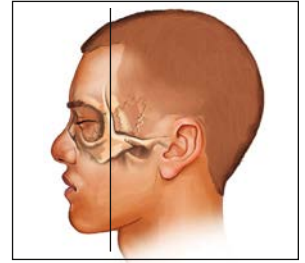
There are five intraorbital muscles that contribute to the annulus of Zinn (the inferior oblique muscle does not). The superior oblique muscle is supplied by the trochlear nerve (CN IV) and causes the eye to point downward and medially toward the tip of the nose. The lateral rectus muscle is supplied by the abducens nerve (CN VI) and points the eye medially. The oculomotor nerve (CN III) supplies the inferior rectus, medial rectus, superior rectus, levator palpebrae superioris, and inferior oblique muscles. When there is diplopia with unilateral palsy of CN III causing the eye to point "down and out," the clinician must consider aneurysm of the posterior communicating artery compressing the oculomotor nerve.

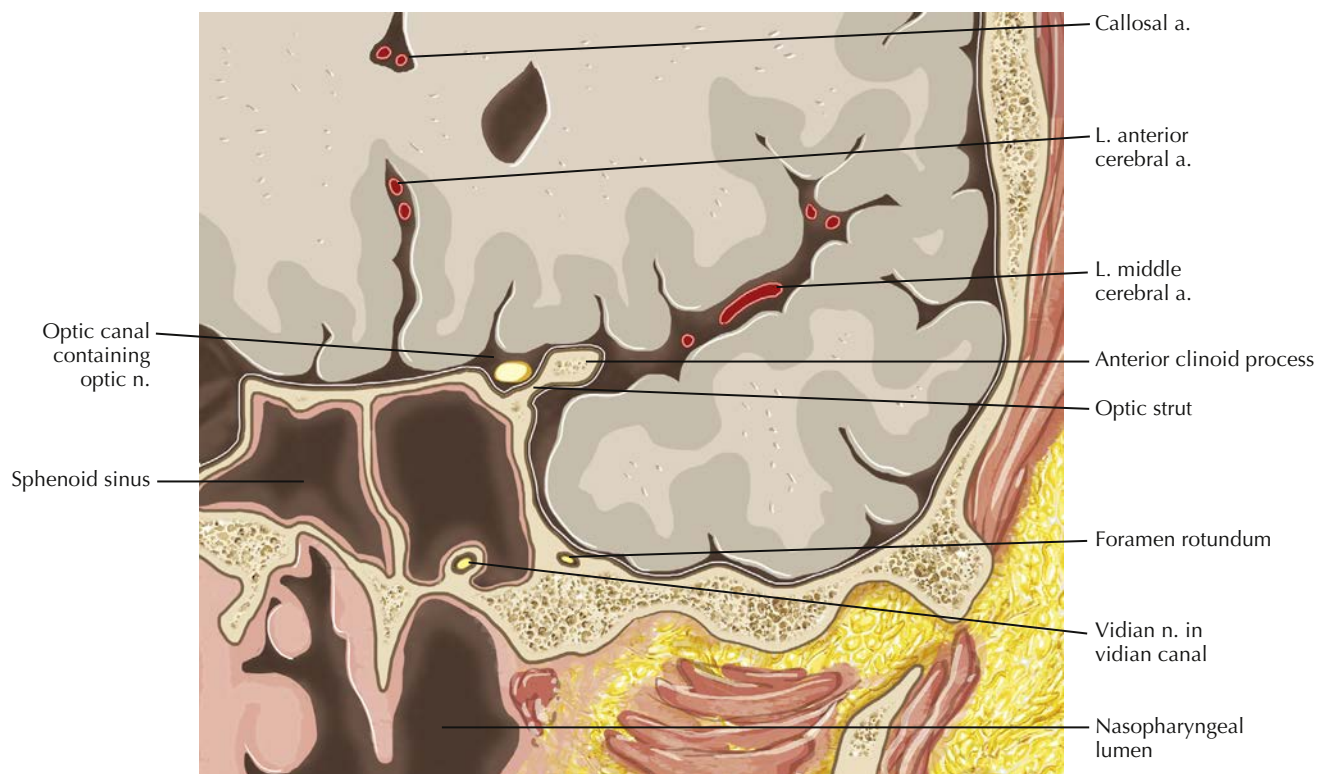






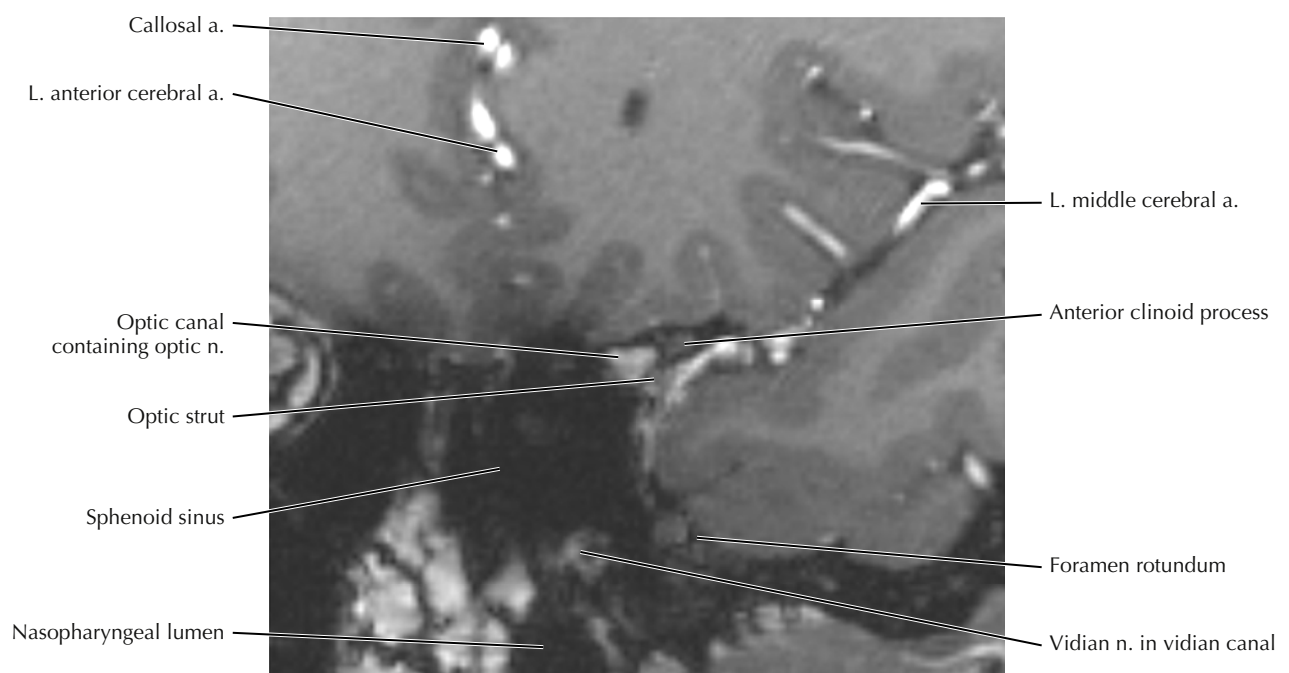
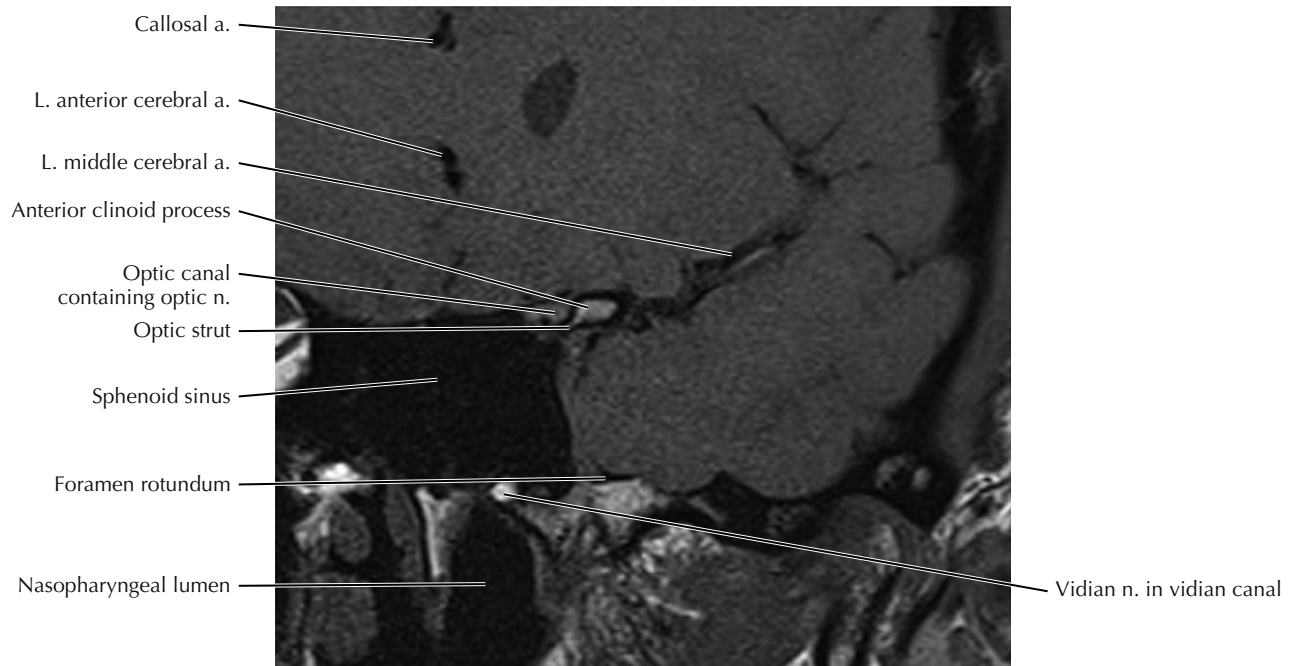
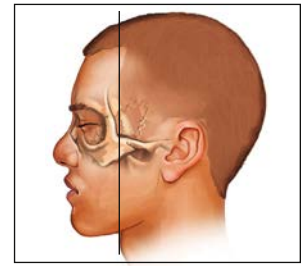


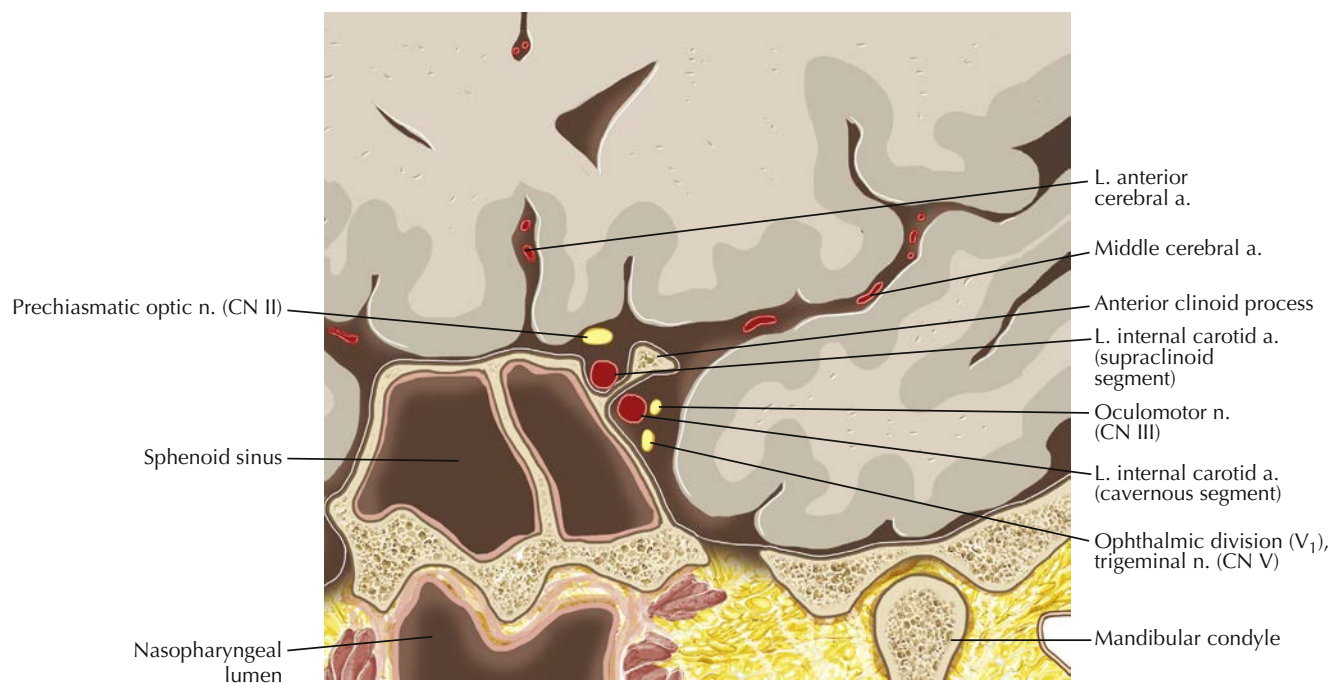


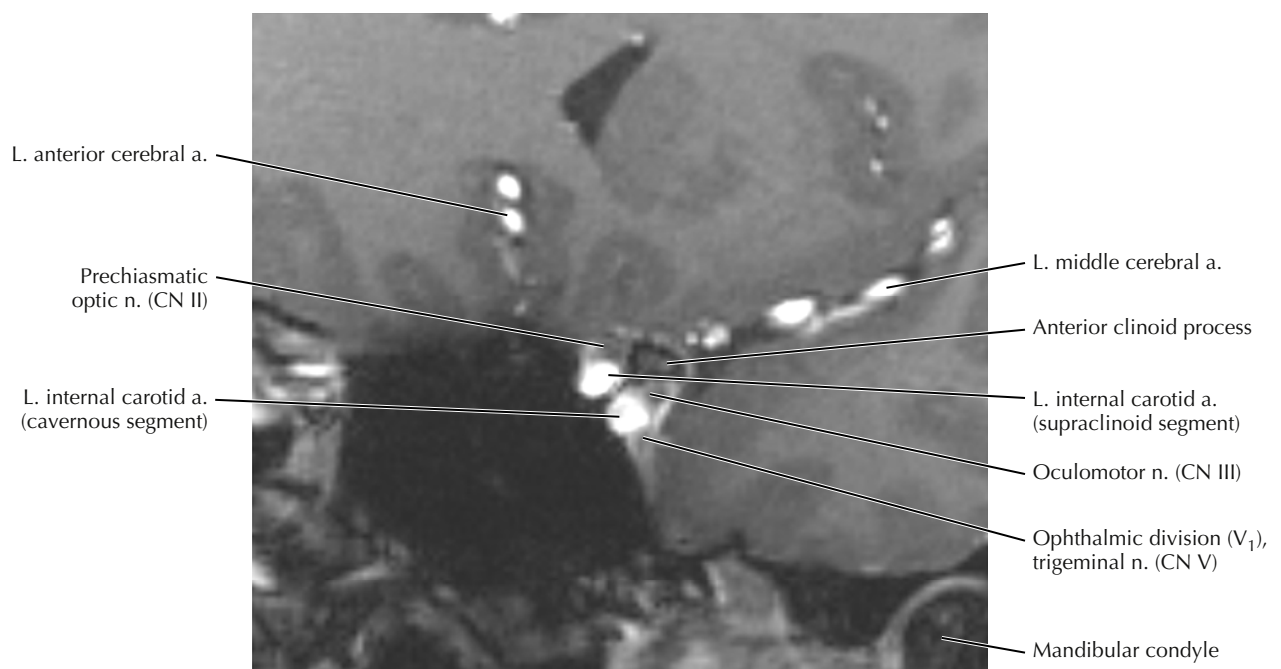
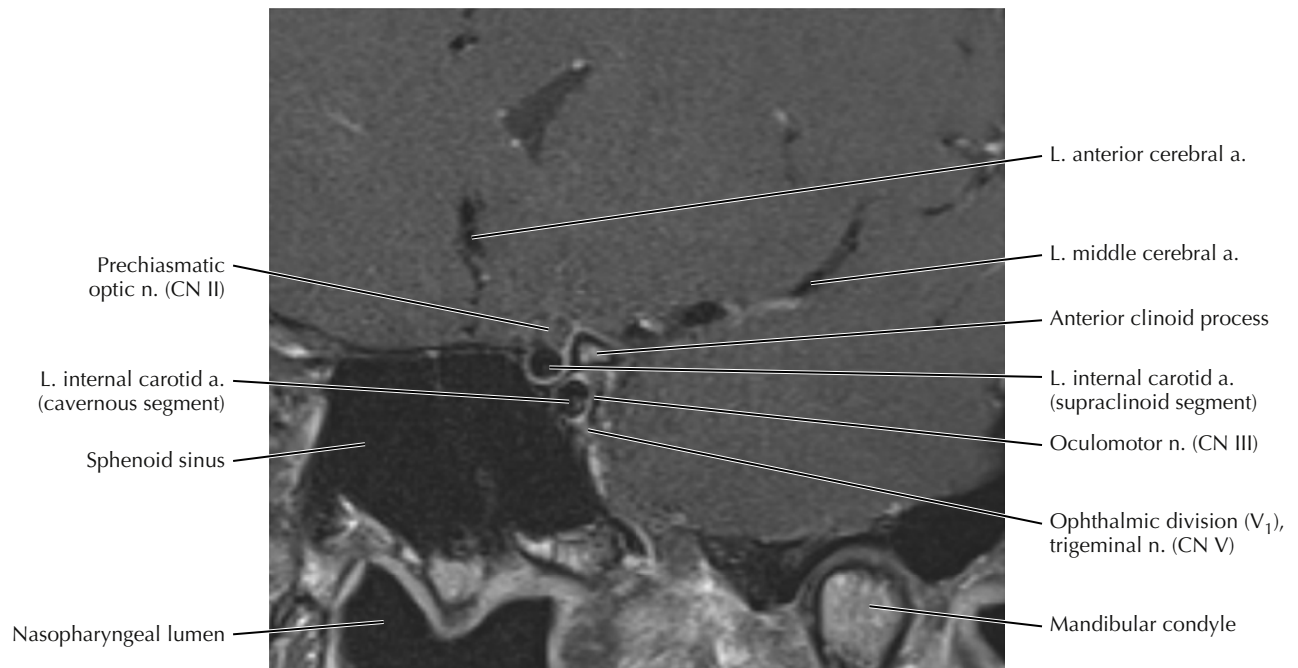
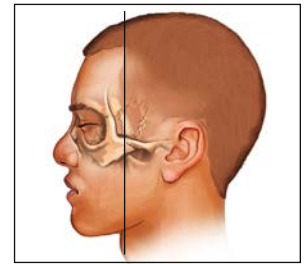


NORMAL ANATOMY

The *optic strut* is a precise landmark between intradural and extradural/intracavernous aneurysms involving the paraclinoid segment of the internal carotid artery.





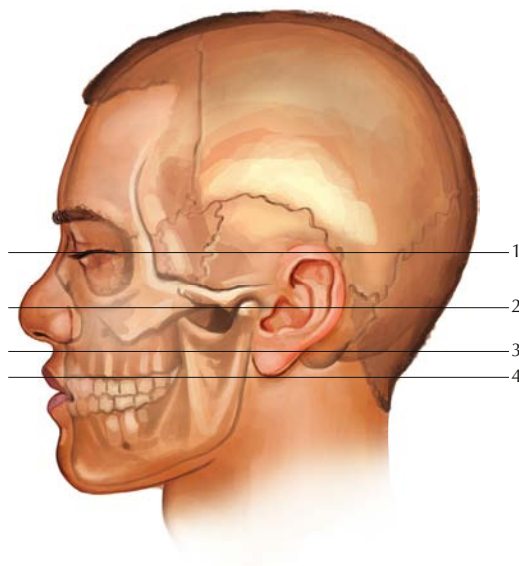


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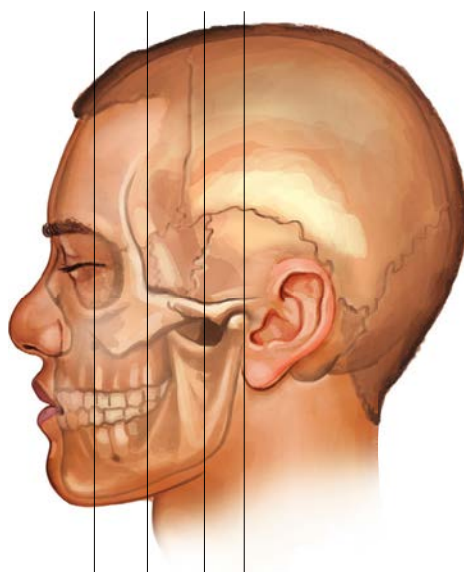
Chapter

11

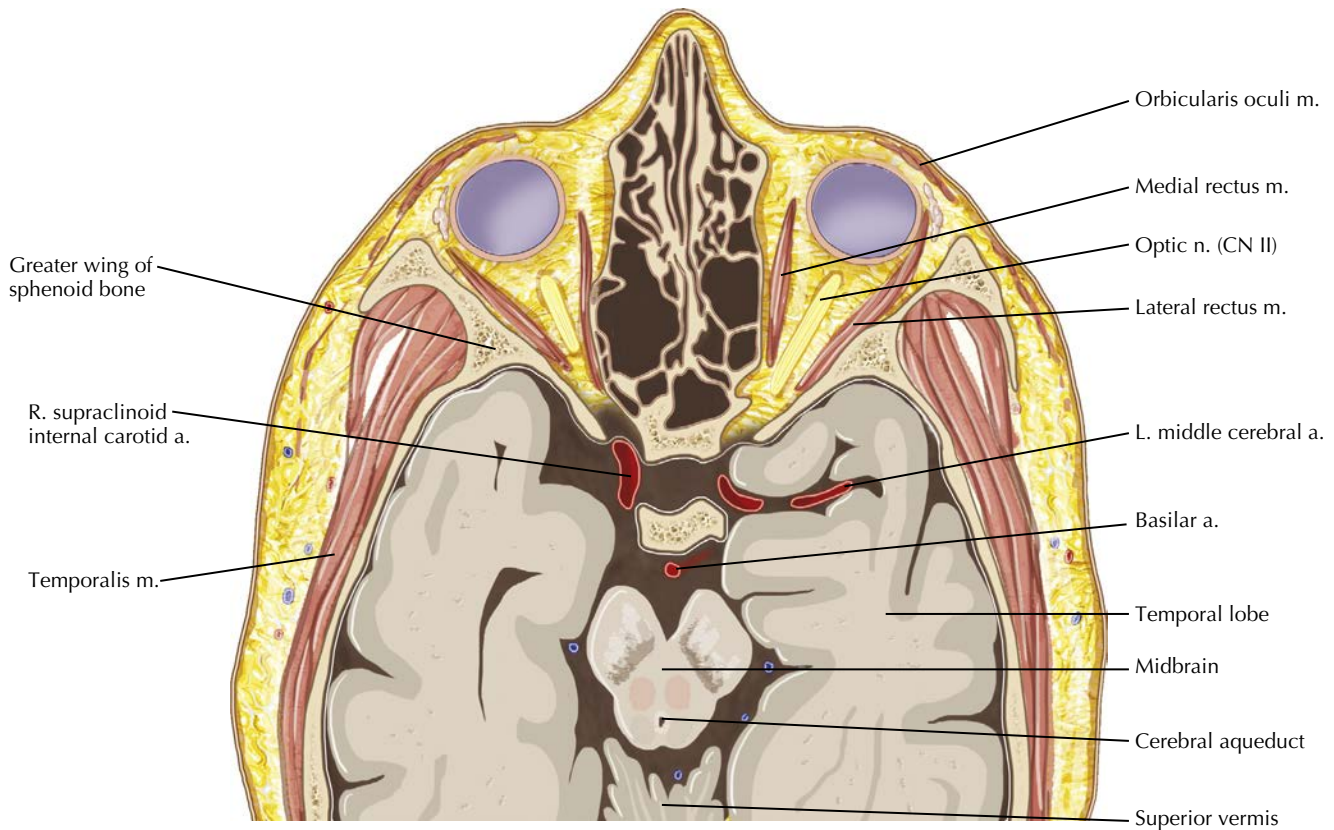
MANDIBLE AND MUSCLES OF MASTICATION



AXIAL 382



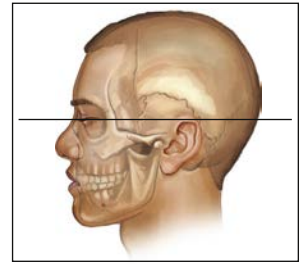
CORONAL 390

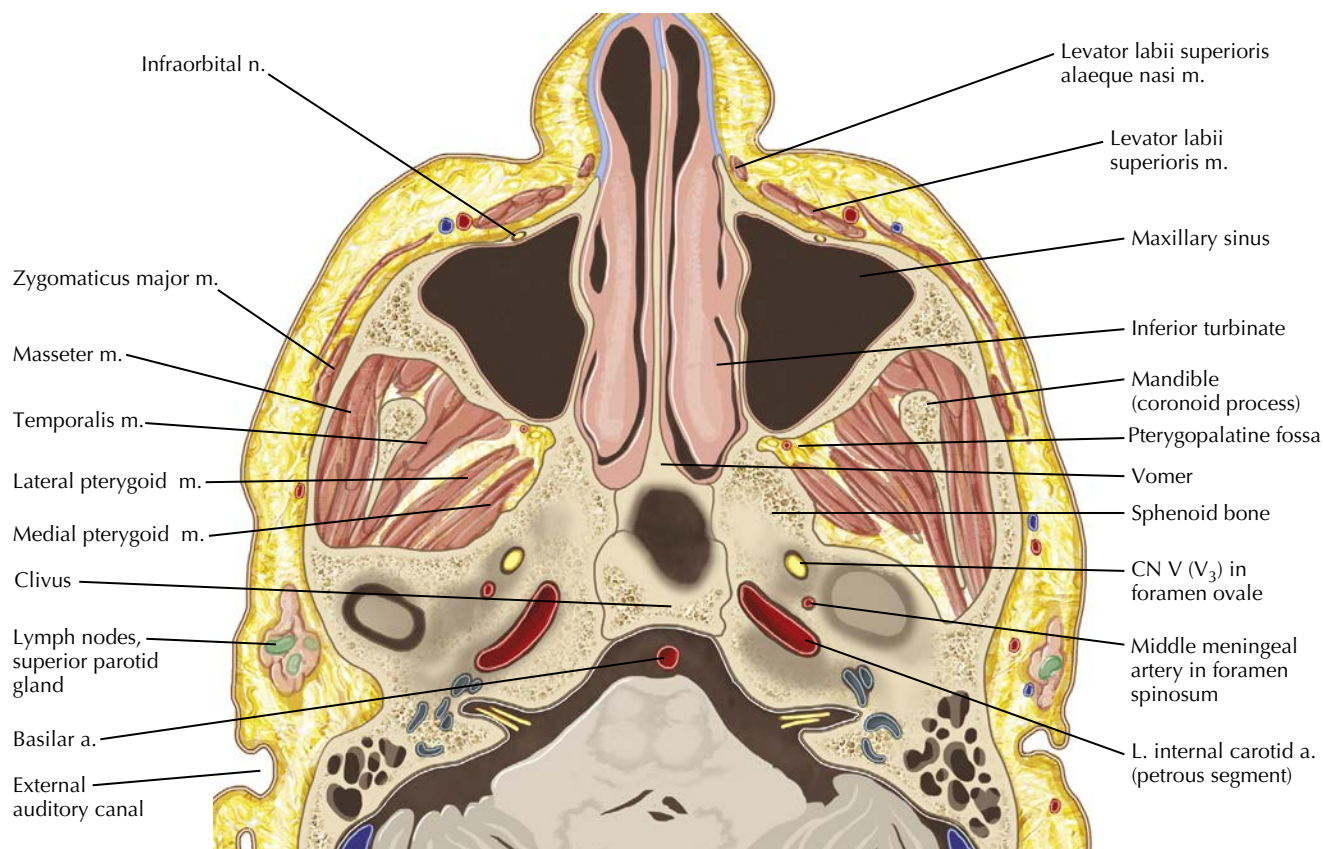


NORMAL ANATOMY

Four paired muscles—temporalis, masseter, medial pterygoid, and lateral pterygoid—are the primary muscles of mastication, responsible for adduction and lateral motion. In the axial MR image on the next page, note the temporalis muscle superficial to the temporal lobe of the brain.

These muscles are innervated by the mandibular branch (V_3) of the trigeminal nerve, cranial nerve (CN) V (see Axial 2). The lateral pterygoid helps open the mouth, and the medial pterygoid helps close the mouth ("lateral lowers and medial munches").



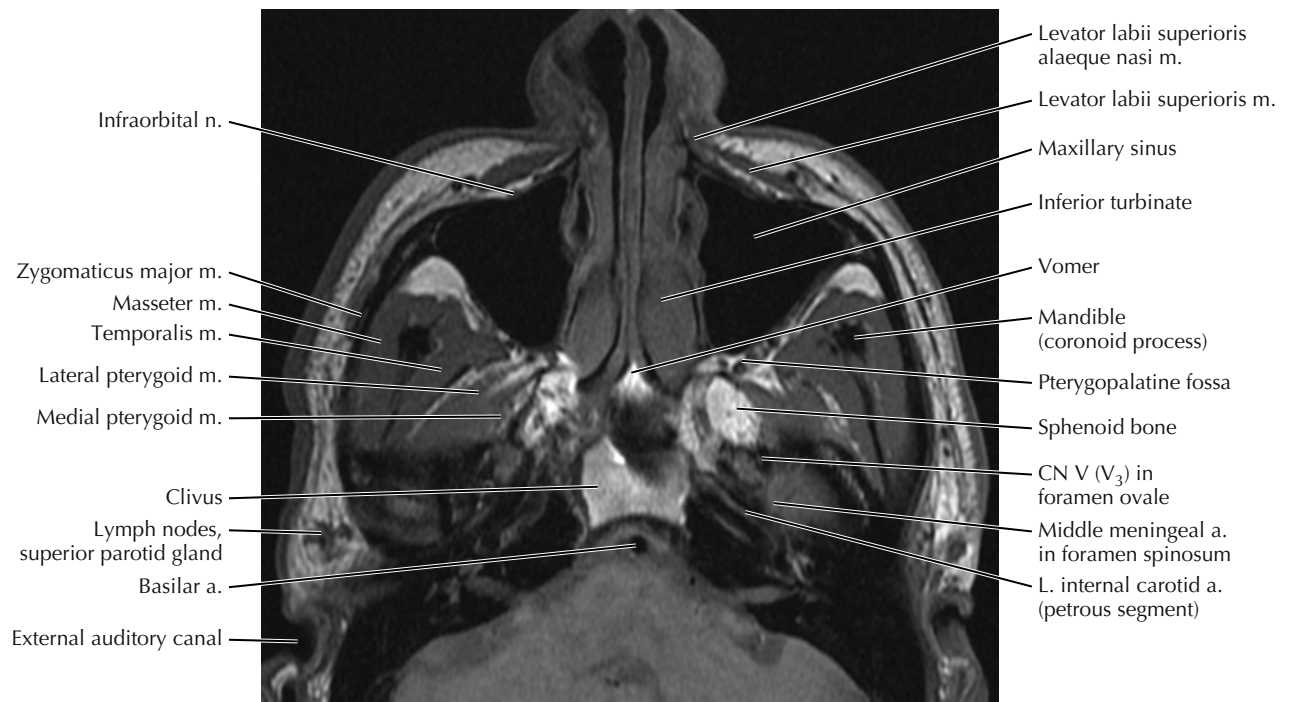
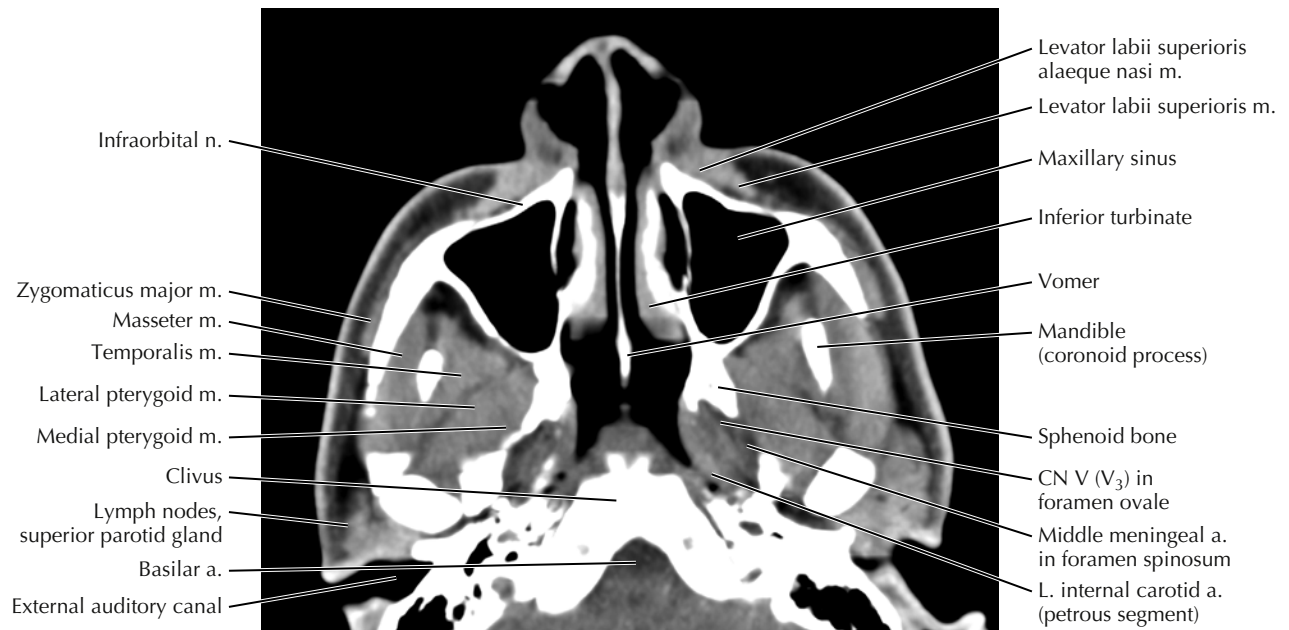
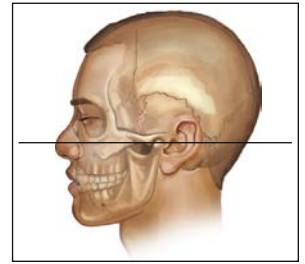


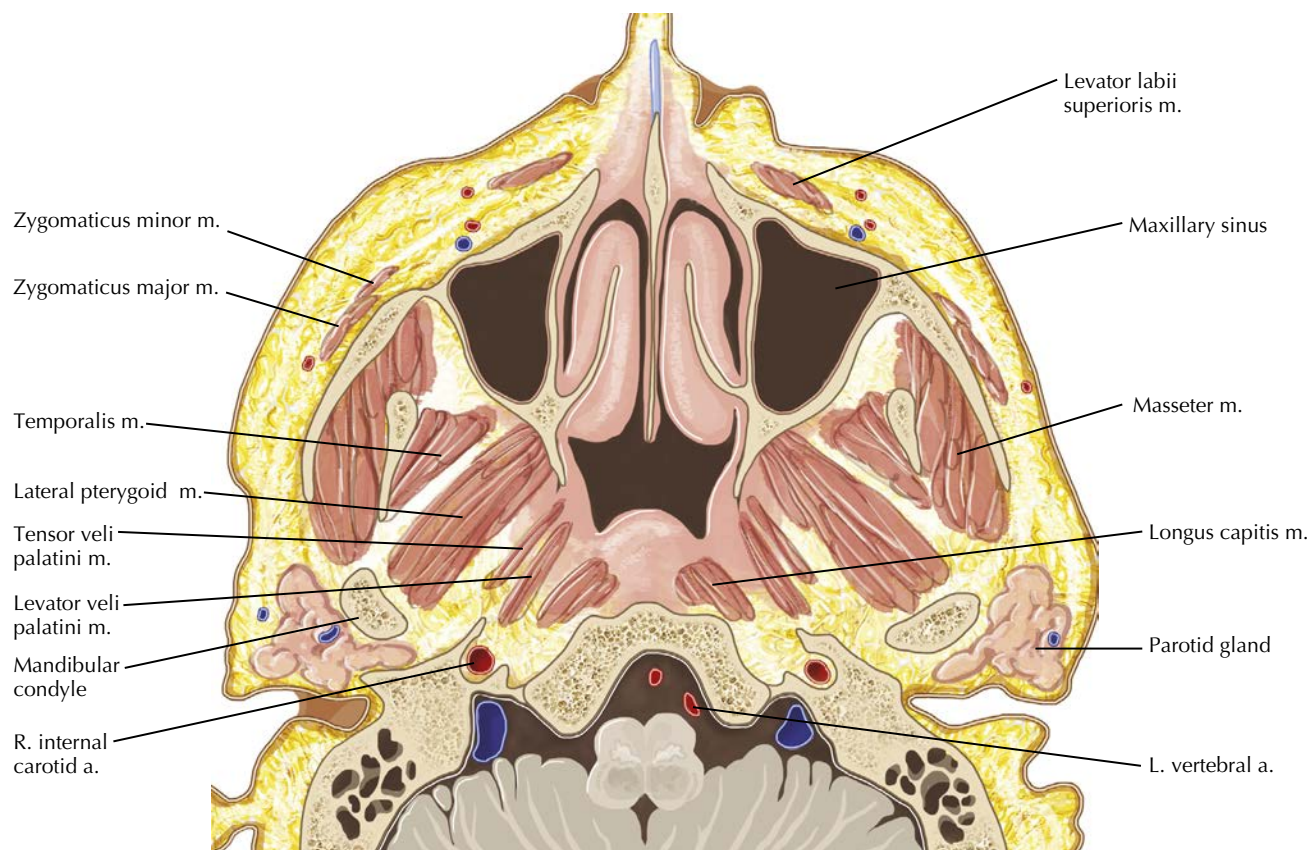
NORMAL ANATOMY

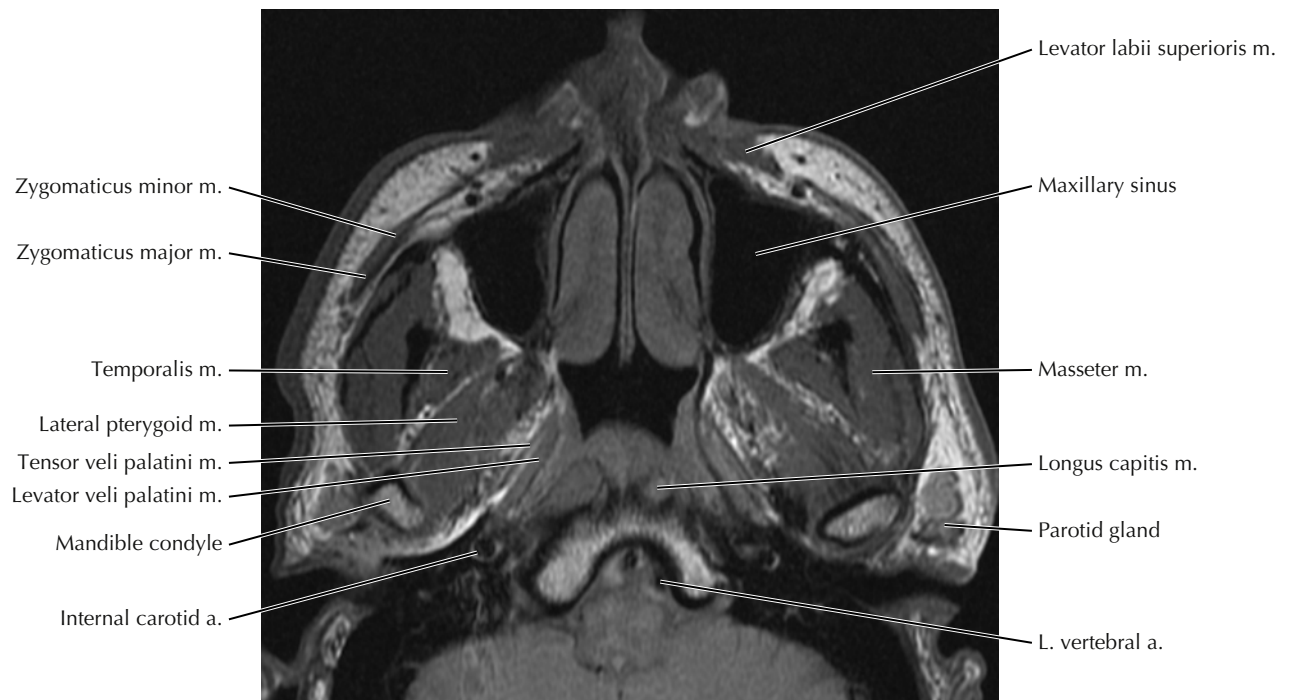
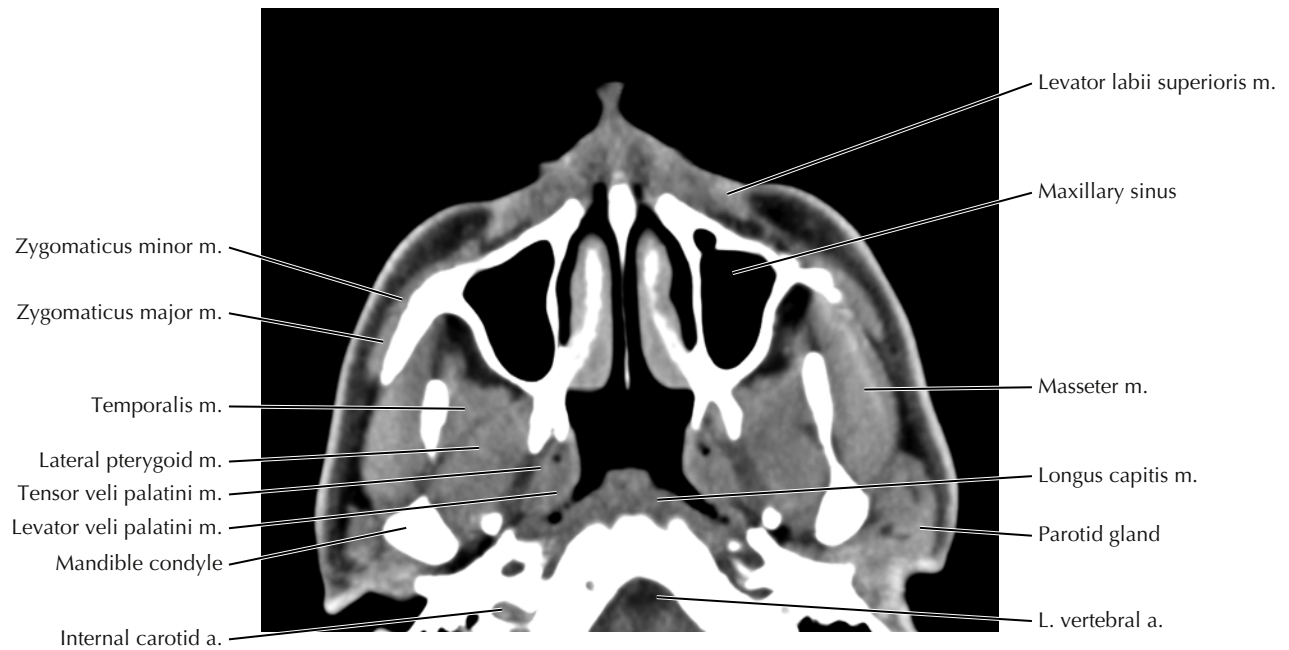
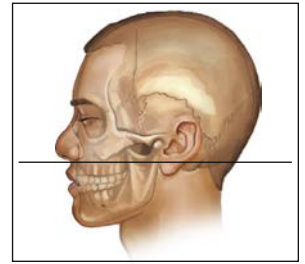
Note that from superficial to deep, the muscles are zygomaticus major, masseter, temporalis, and lateral pterygoid. The medial pterygoid muscle is located deeper and more caudal.

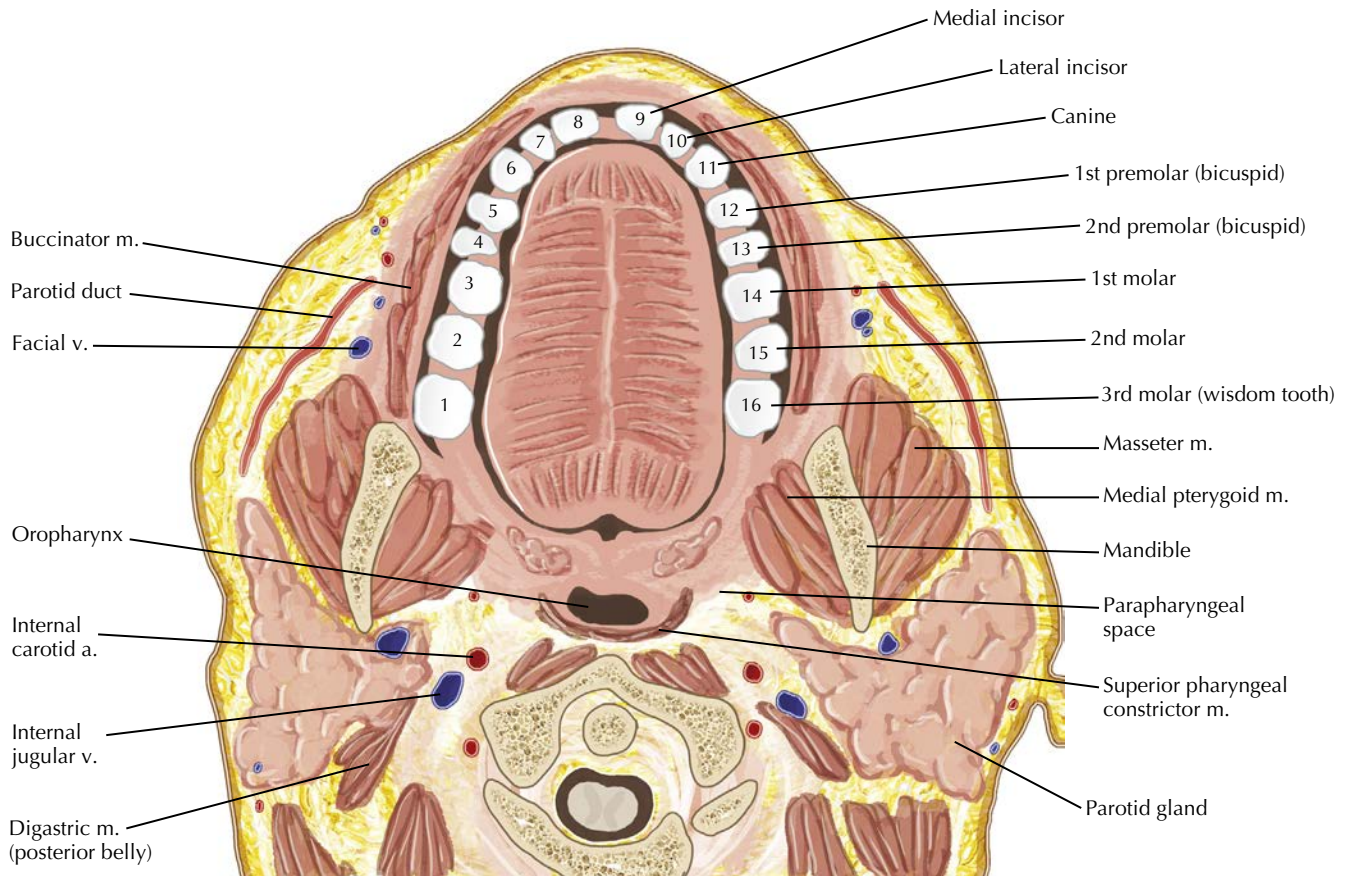
PATHOLOGIC PROCESS

Denervation of the V_3 branch of the trigeminal nerve can lead to atrophy of the ipsilateral muscles of mastication.





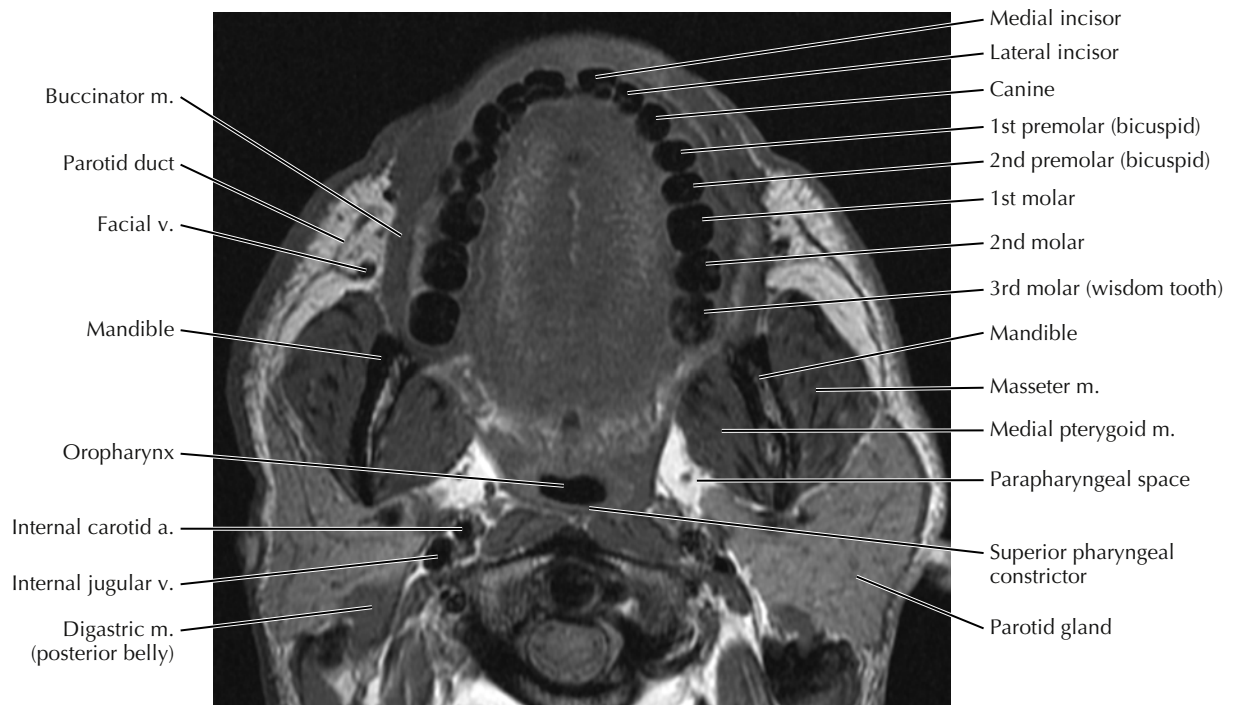
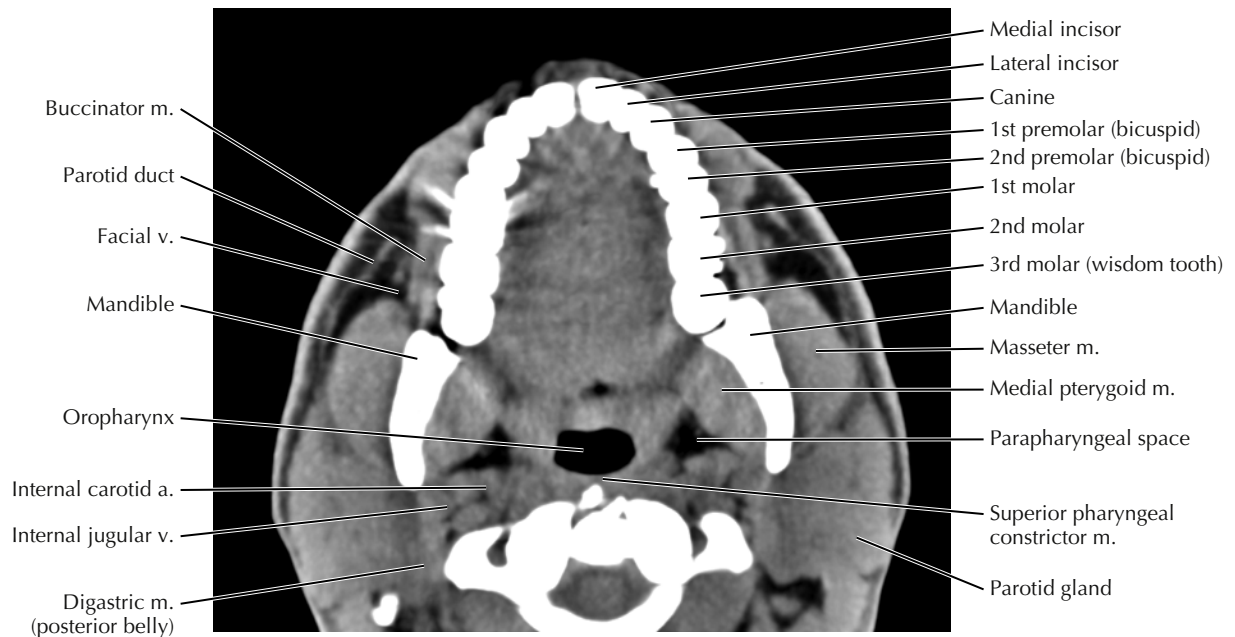
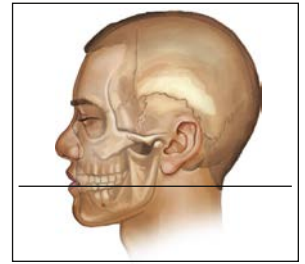


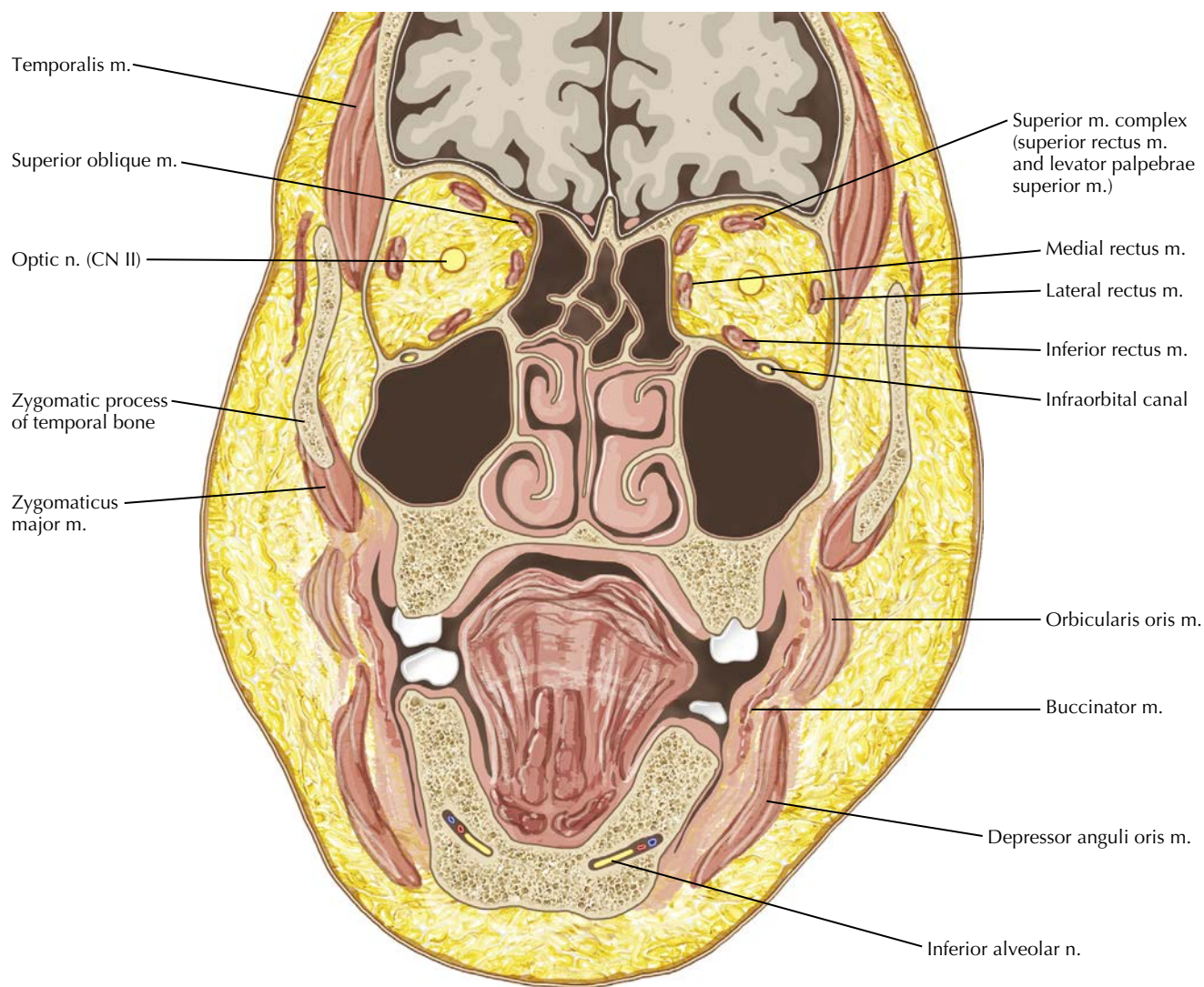


NOMENCLATURE

The two most common dental notation systems are the International Dental Association (Fédération Dentaire Internationale, FDI) notation and the Universal numbering system (dental). The FDI system uses a two-digit numbering system in which the first number represents a tooth's quadrant and the second number represents the number of the tooth from the midline of the face. For permanent teeth, the upper-right teeth begin with 1, the upper-left teeth with 2, the lower-left teeth with 3, and the lower-right teeth with 4. For primary teeth the sequence of numbers is 5, 6, 7, and 8 for the teeth in the upper right, upper left, lower left, and lower right, respectively.

The Universal number system (dental) is used in the United States and begins labeling at the upper-right maxillary wisdom tooth as 1 and continues clockwise (see Axial 4), when viewing the open mouth from a dentist's perspective, up to 32 at the right mandibular wisdom tooth.

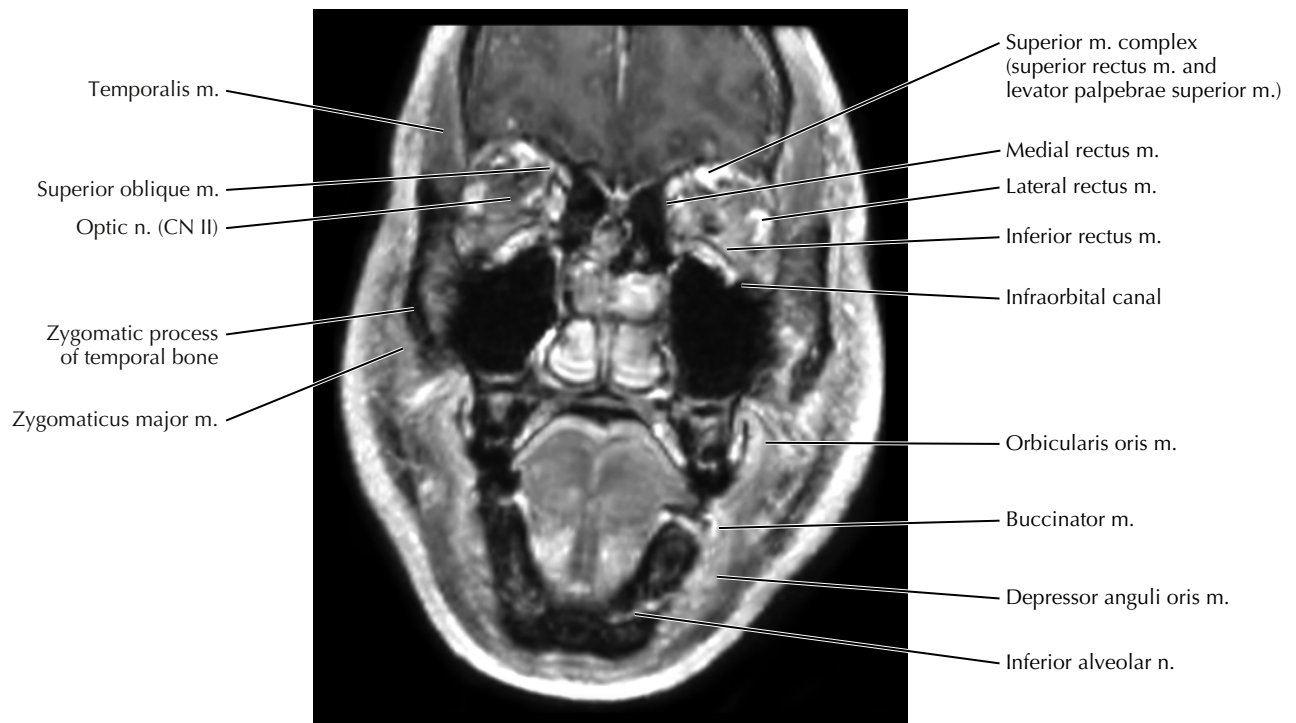
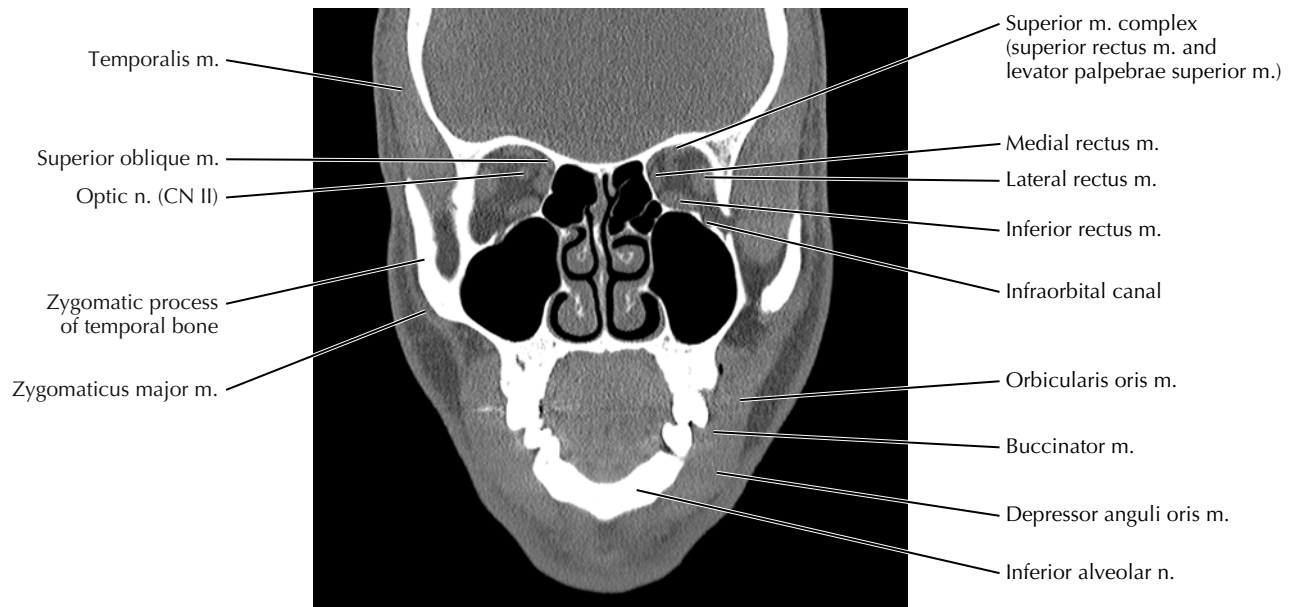
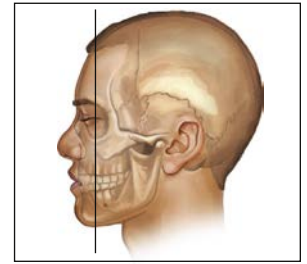


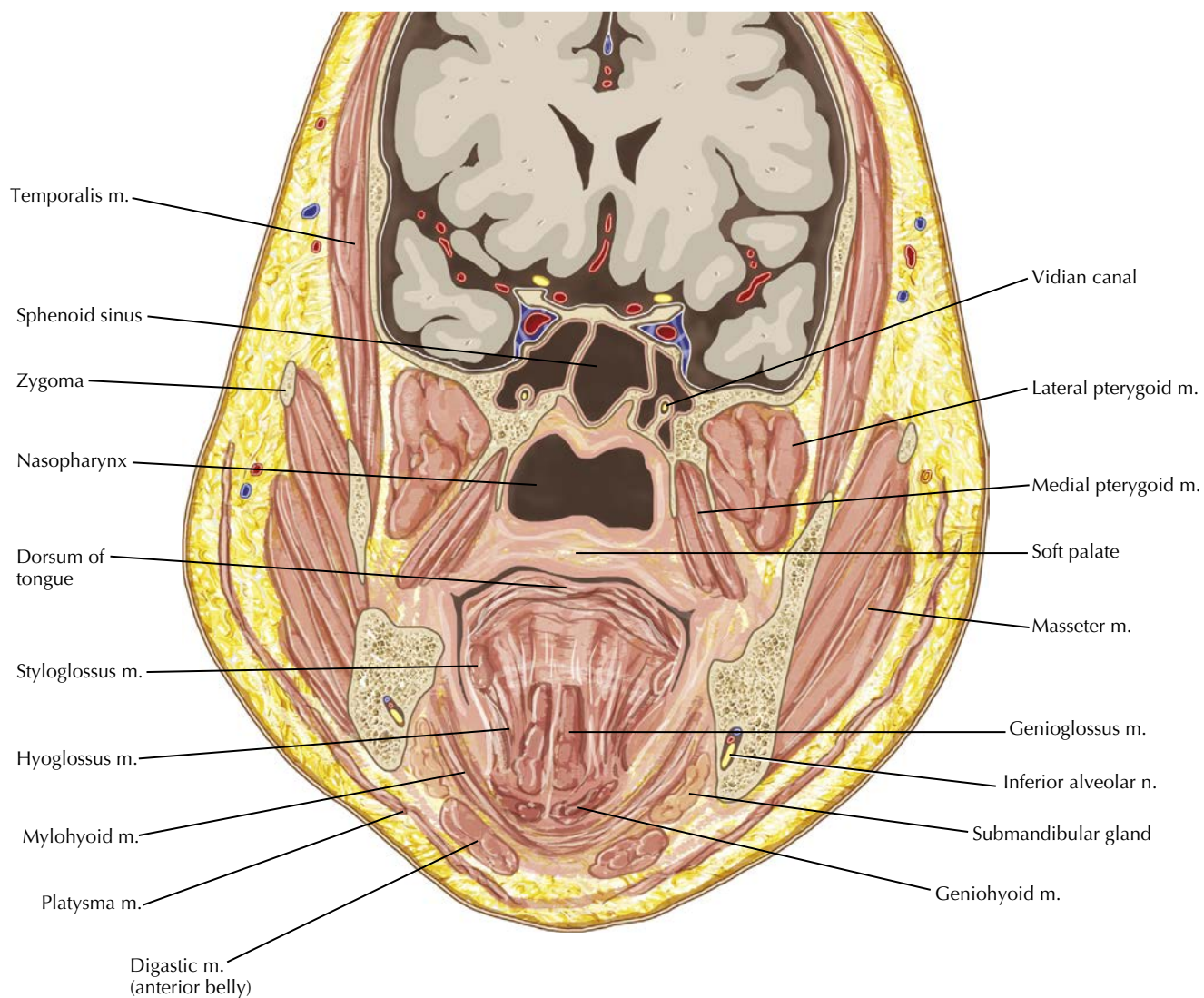


PATHOLOGIC PROCESS

The inferior alveolar nerves course through the mandible in the inferior alveolar canals, exiting superficially at the mental foramina. Squamous cell carcinoma of the mandible can invade the mandible and track perineurally along the inferior alveolar nerve, back to the V₃ branch of the trigeminal nerve and Meckel's cave.

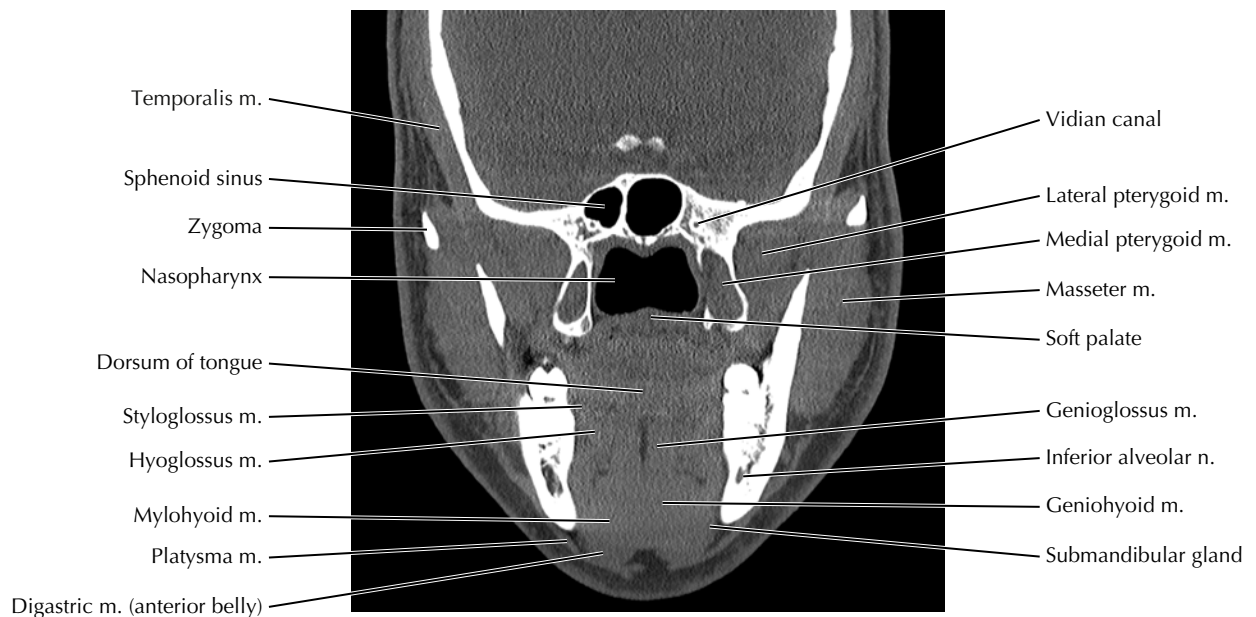
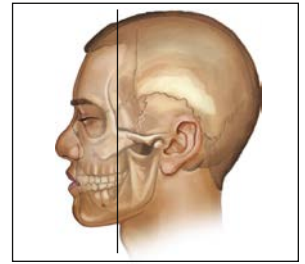
MANDIBLE AND MUSCLES OF MASTICATION CORONAL 1

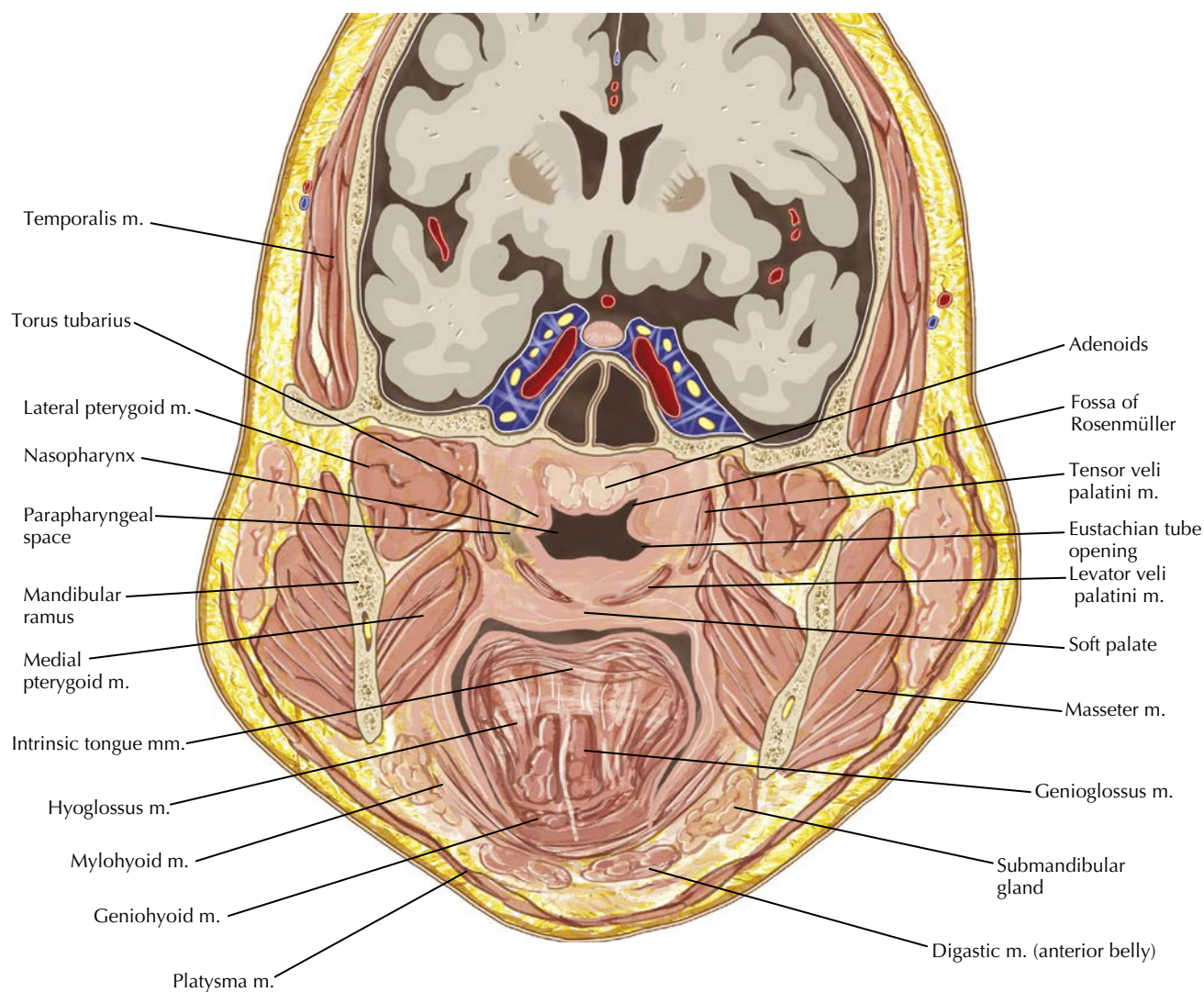




NORMAL ANATOMY

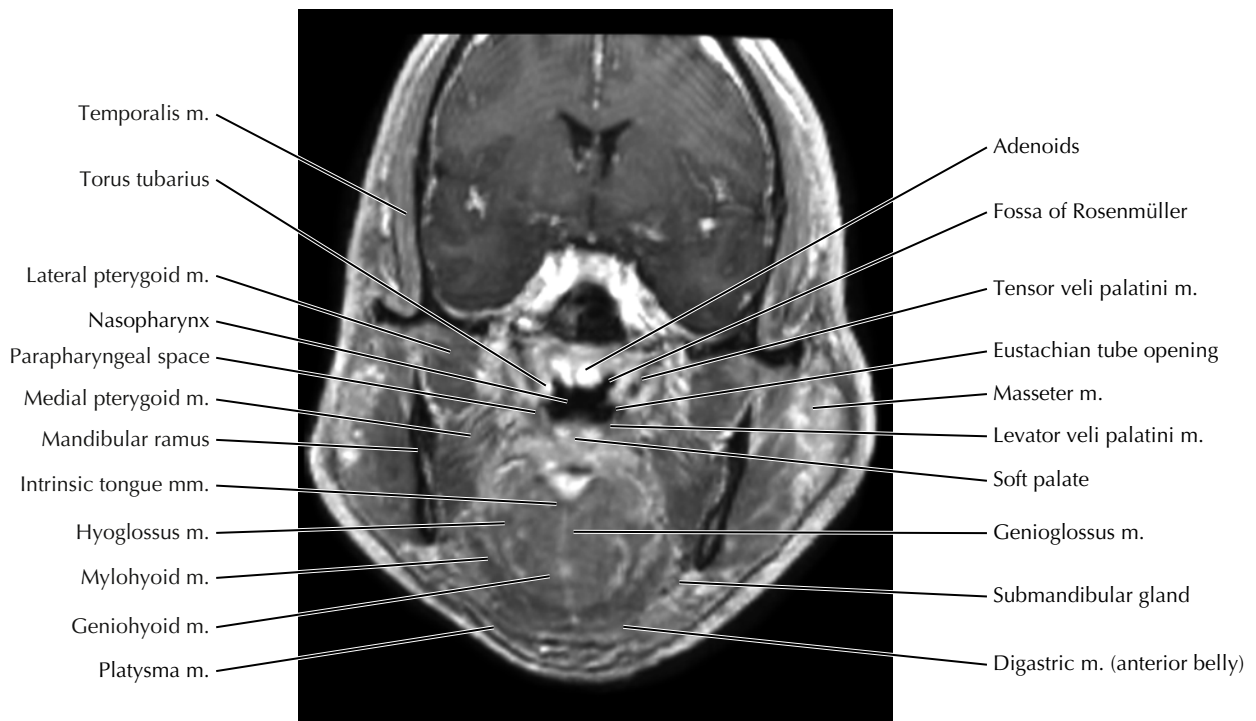
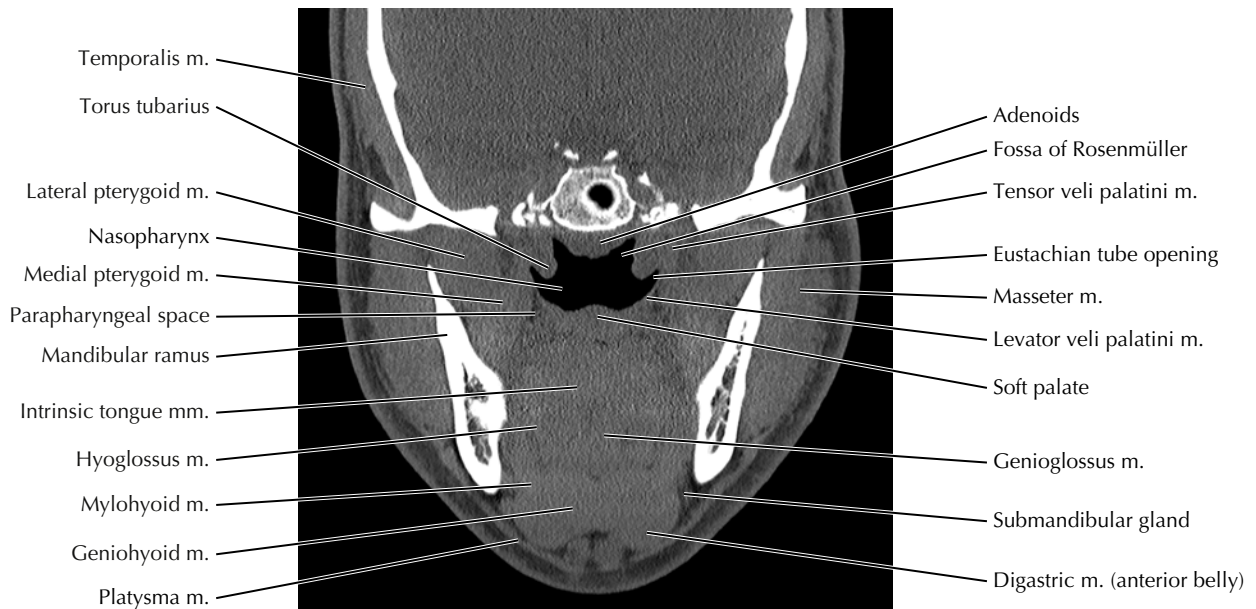
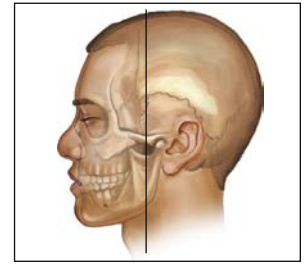
The temporalis muscle has a broad origin from the outer temporal fossa, passes deep to the zygomatic arch, and inserts onto the coronoid process of the mandible to pull back and elevate the mandible. The temporalis muscle can be felt at the temples and can be seen and felt contracting as a person bites down.

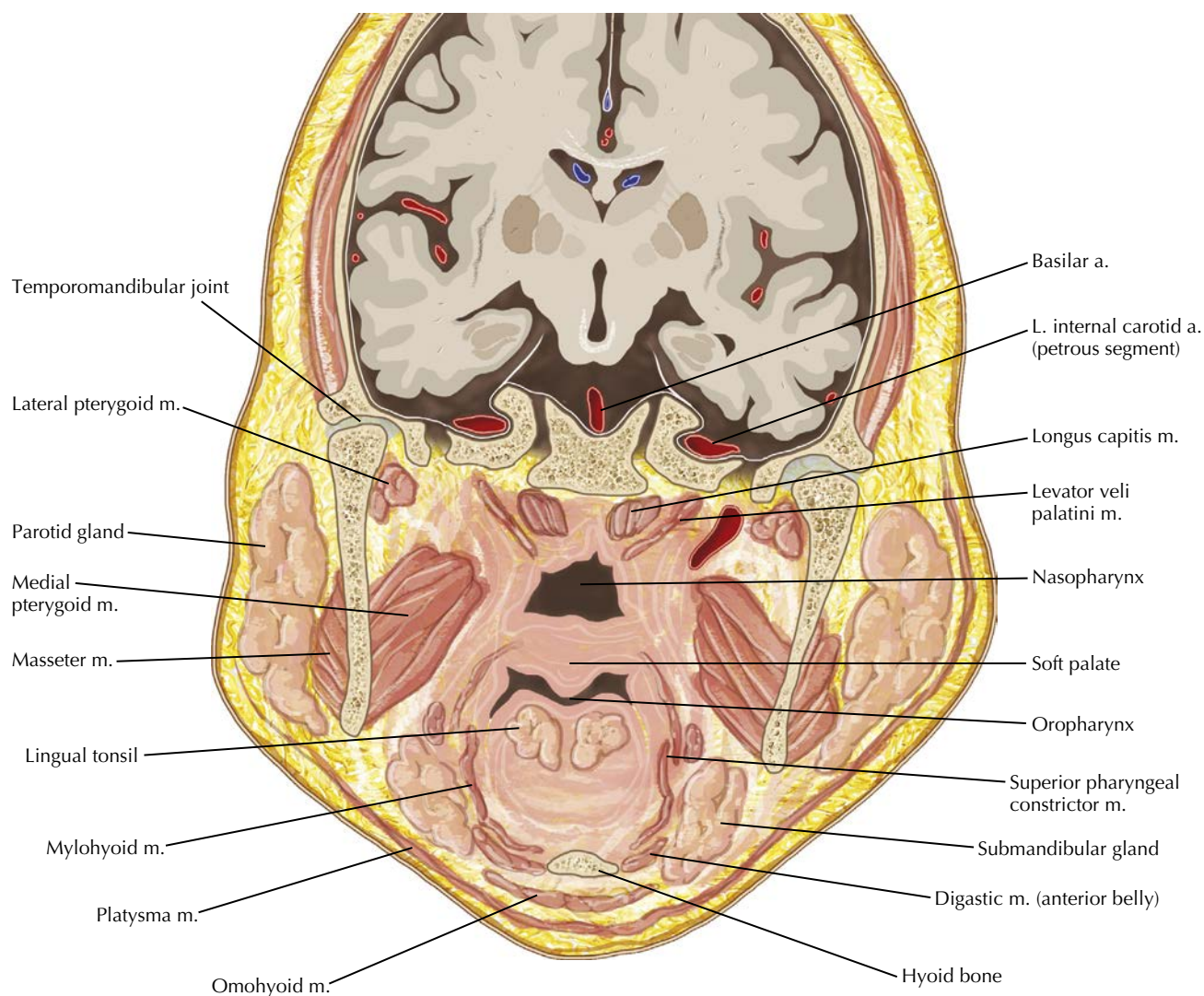




NORMAL ANATOMY

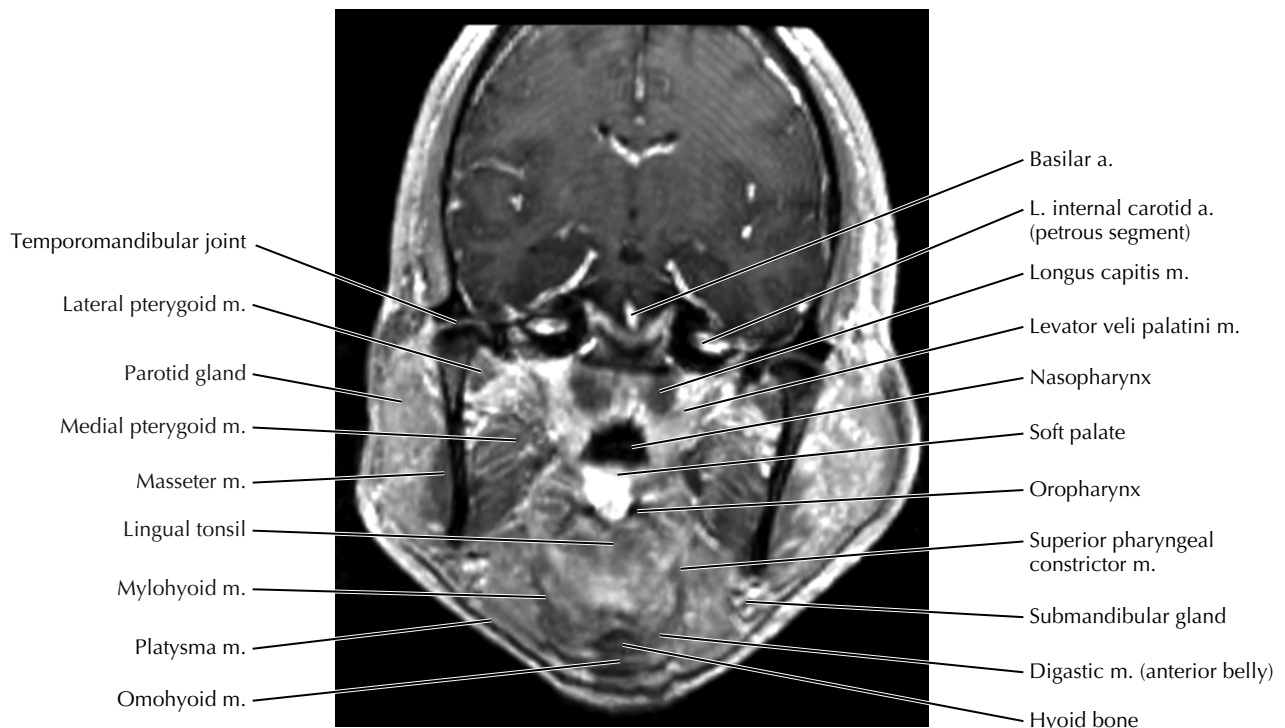
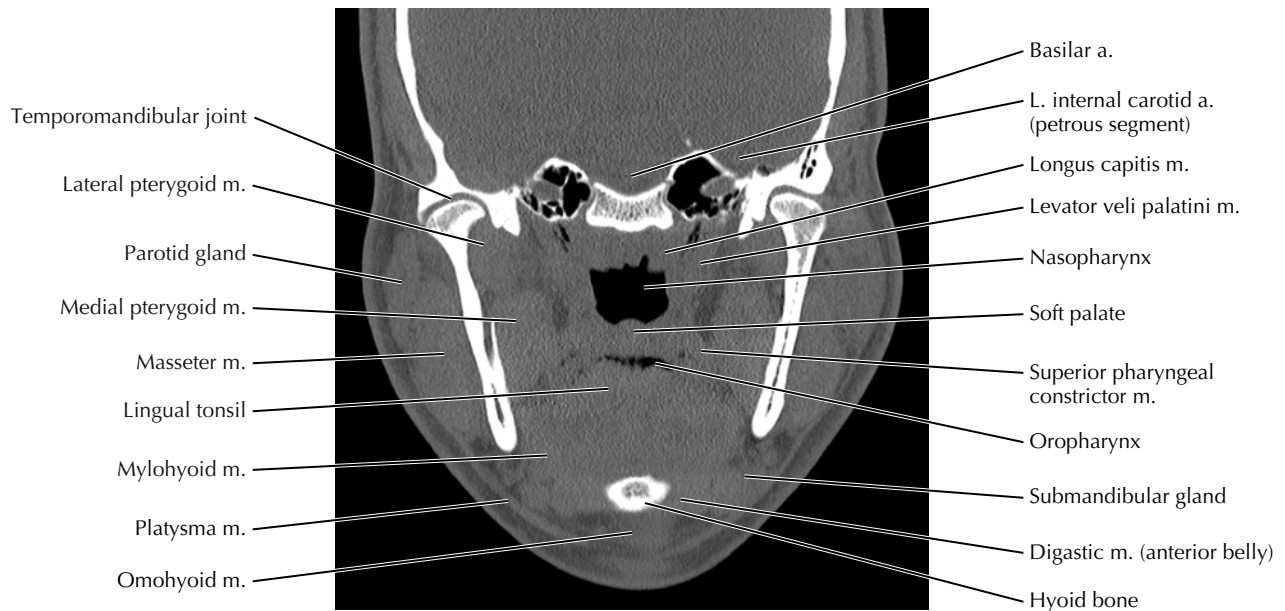
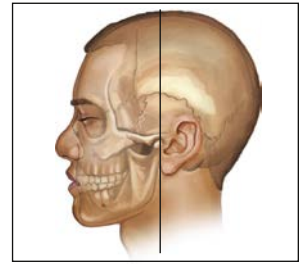
The medial and lateral pterygoid muscles originate from the respective medial and lateral pterygoid bone plates and pass inferiorly and laterally to insert on the inner mandible.





IMAGING TECHNIQUE CONSIDERATION

The temporomandibular joint (TMJ) is formed by two bones, the condyle of the mandible and the glenoid fossa of the temporal bone. The space between these bones contains an articular disc. The TMJ is one of the few synovial joints in the human body with a disc. MR images of different jaw positions can show whether the disc is torn or fails to recapture into normal position between the bones.

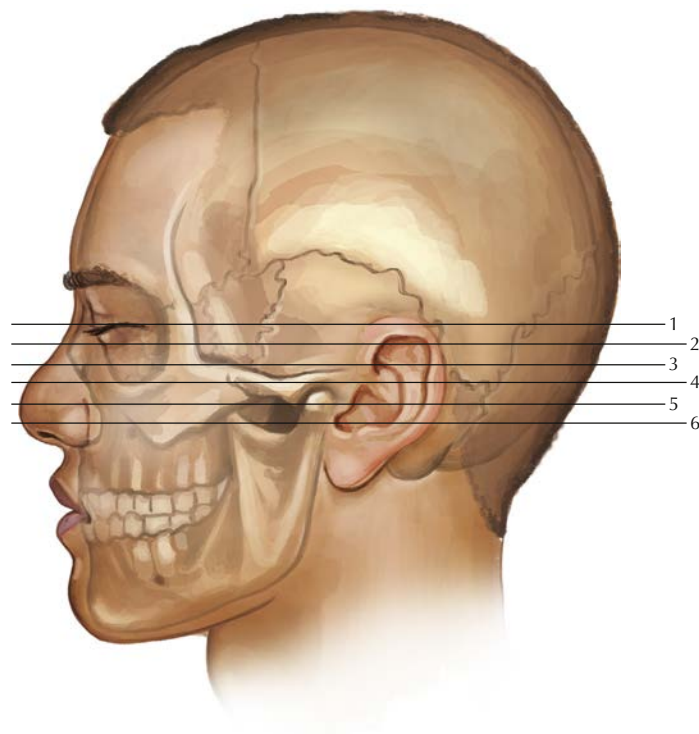


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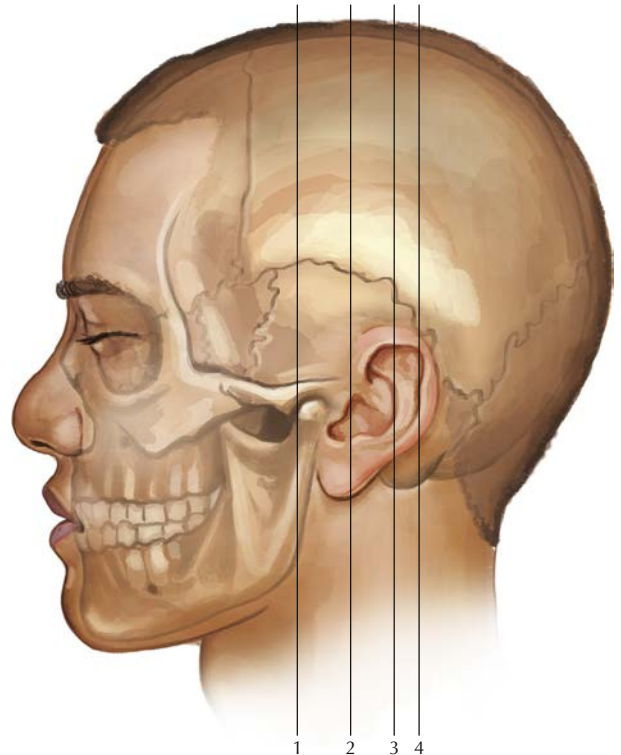
Chapter

12

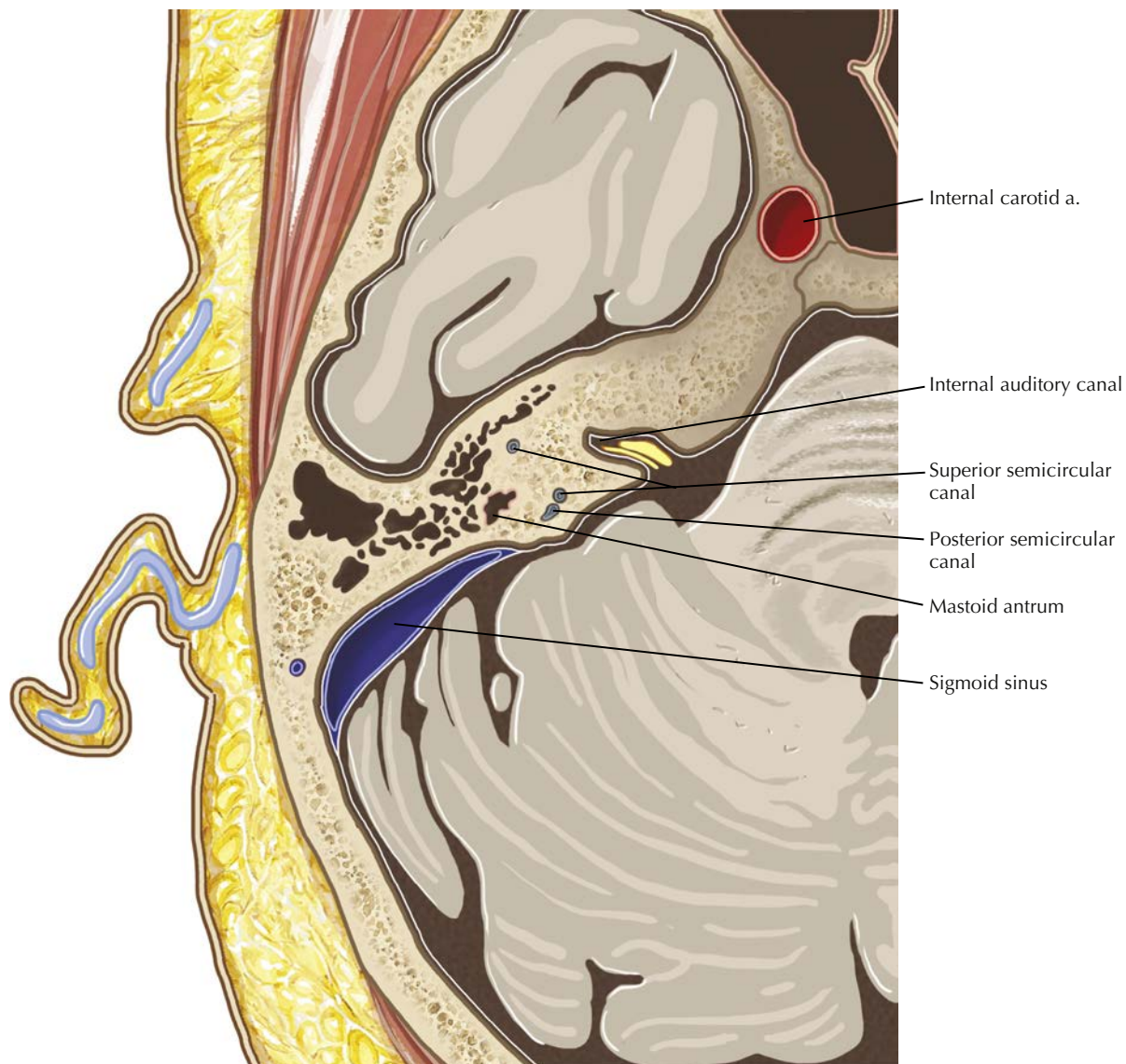
TEMPORAL
BONE
(MIDDLE EAR,
COCHLEA,
VESTIBULAR
SYSTEM)



AXIAL 400



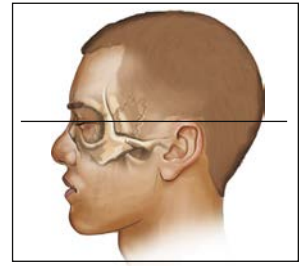
CORONAL 412



NORMAL ANATOMY

The temporal bone initially may seem a daunting area for magnetic resonance imaging because of the apparent structural complexity. To understand the temporal region better, trace the hearing pathway from auricle through external auditory canal, to tympanic membrane attached to small bones (ossicles; malleus, incus, and stapes) in the middle ear cavity, through stapes stirrup on oval window, then vestibule to cochlea to inner auditory canal (IAC). The vestibulocochlear nerve (cranial nerve [CN] VIII) also provides balance with superior and inferior vestibular branches in the IAC, leading to the semicircular canals. Finally, the nearby facial nerve (CN VII) provides motor innervation to the face.

These nerves can be tracked easily on computed tomography (CT) by the corresponding bony canals, although the nerves themselves are best seen on MRI (see also Chapter 5).



Internal carotid a.

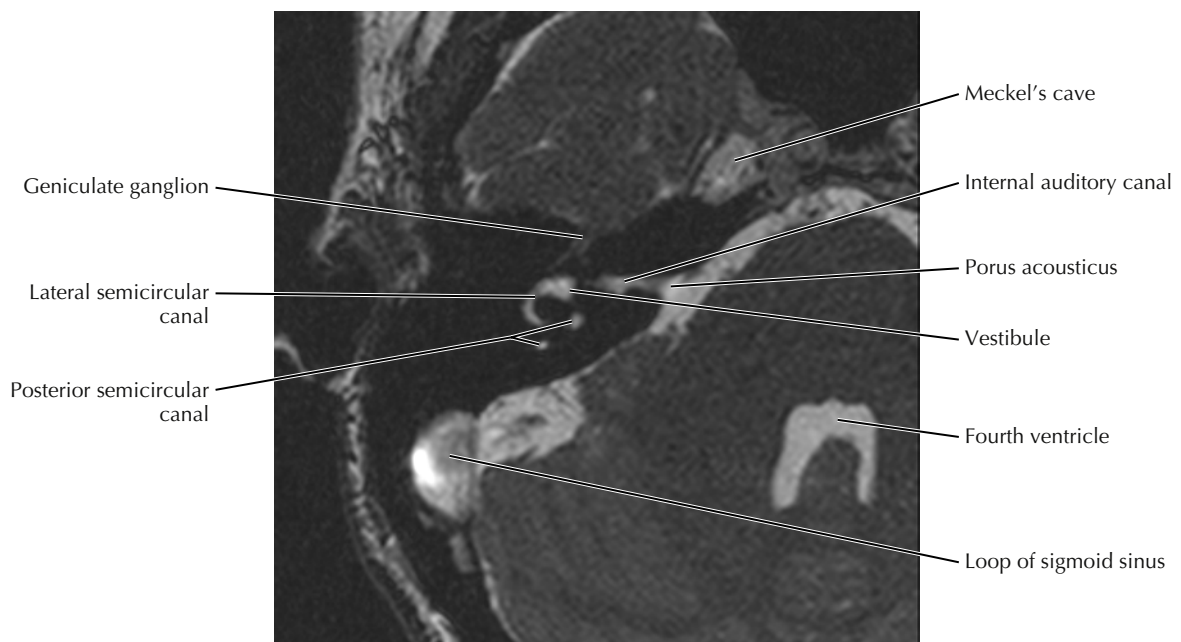
Internal auditory canal

Superior semicircular canal

Posterior semicircular canal

Mastoid antrum

Sigmoid sinus



Geniculate ganglion

Lateral semicircular canal

Posterior semicircular canal

Meckel's cave

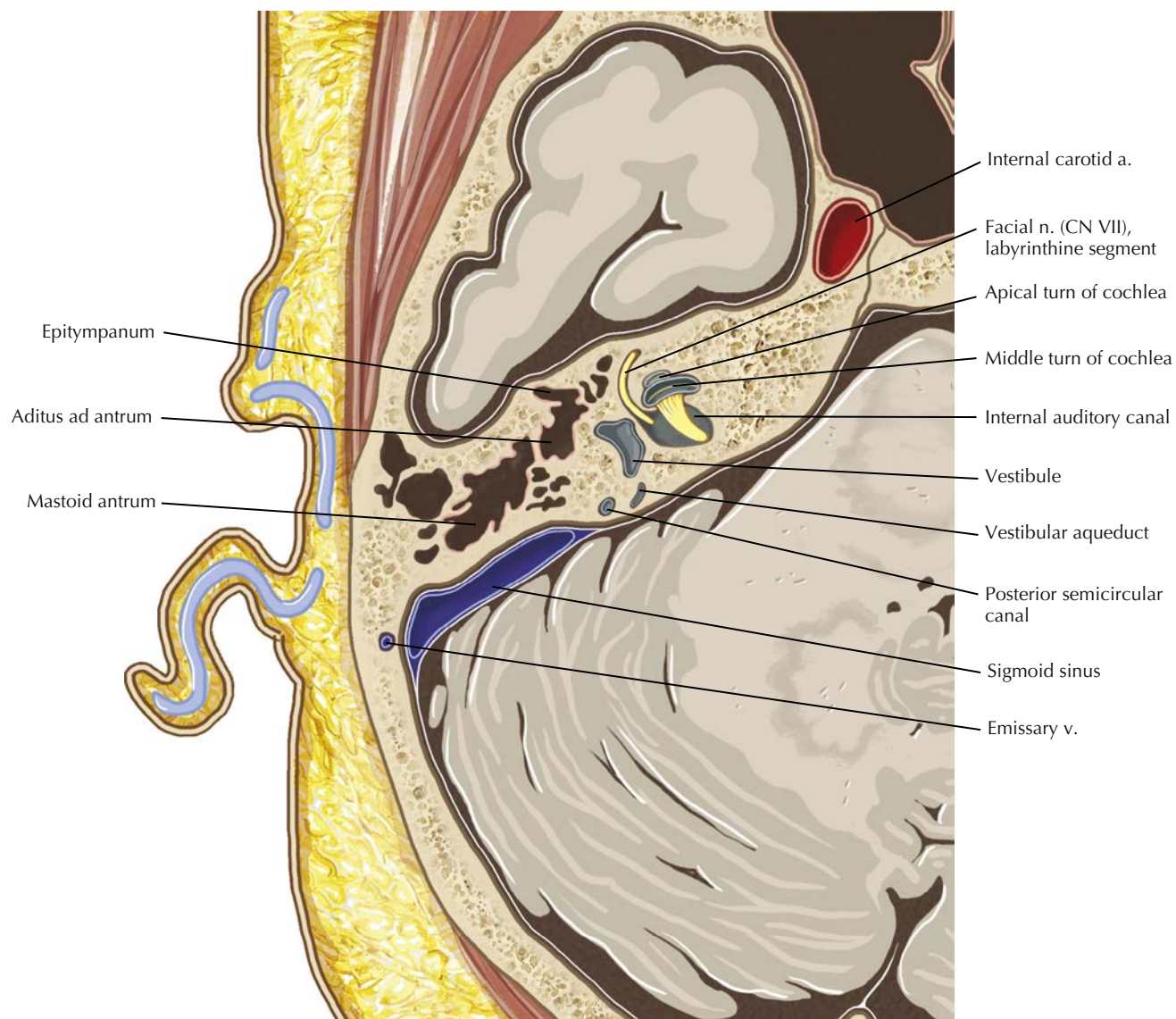
Internal auditory canal

Porus acousticus

Vestibule

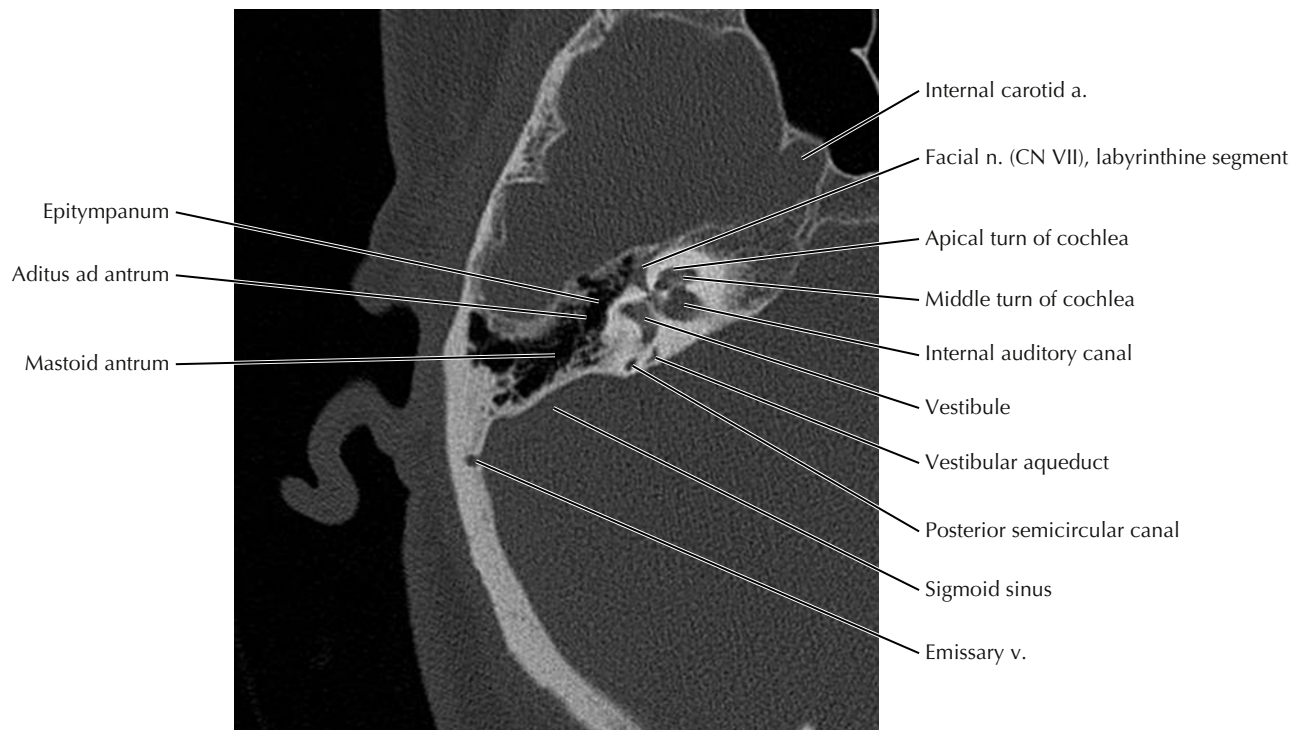
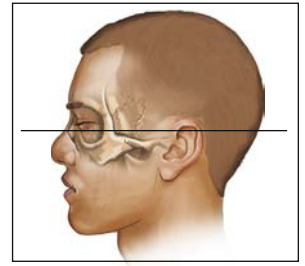
Fourth ventricle

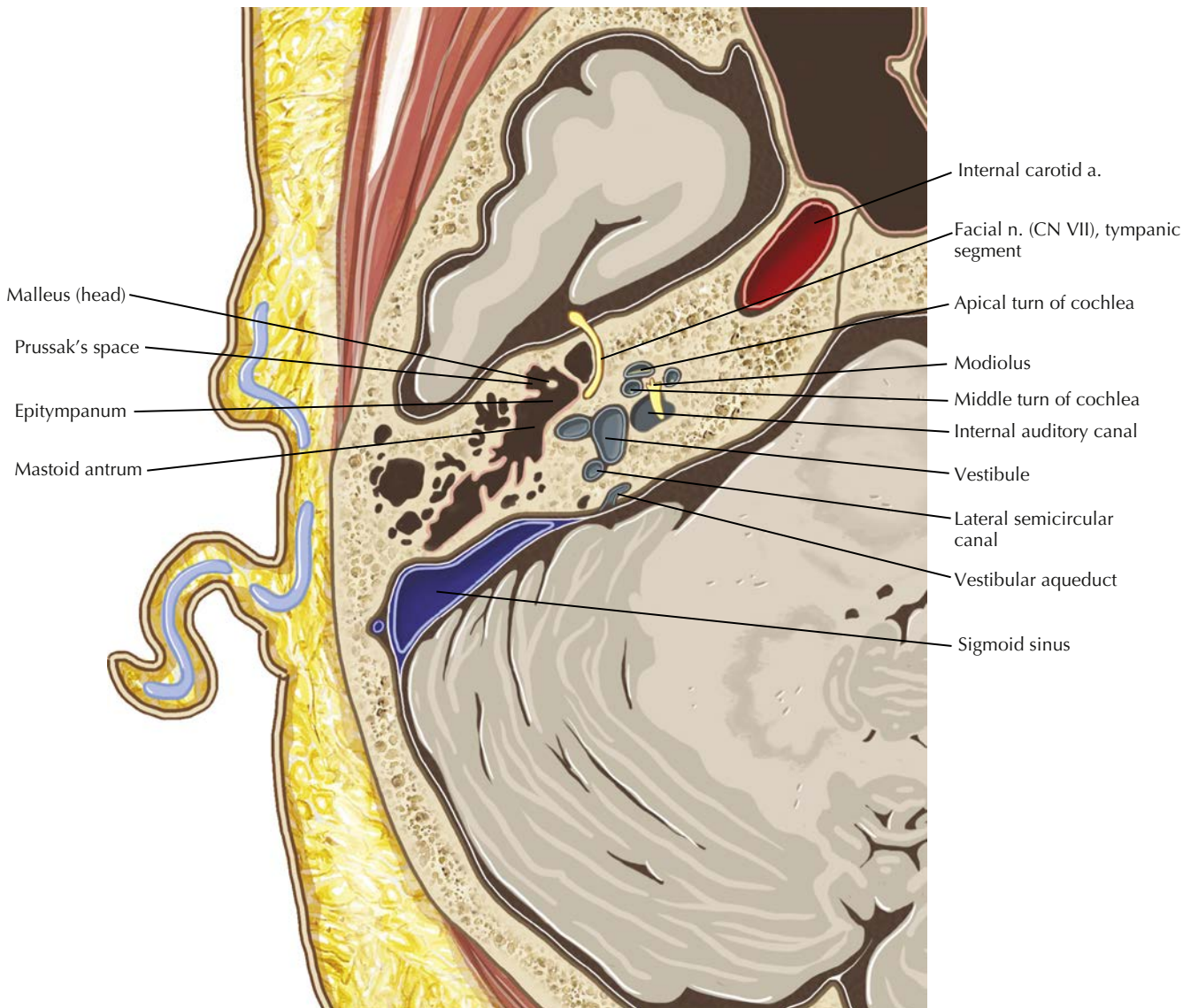
Loop of sigmoid sinus



PATHOLOGIC PROCESS

Note the fan-shaped appearance of the labyrinthine segment of the facial nerve connecting the intracanalicular segment with the geniculate ganglion more anteriorly. Damage to the facial nerve, as occurs with trauma and temporal bone fracture, leads to loss of motor control on the ipsilateral side of the face, mimicking a stroke, with profound social impact given the sensitivity to facial expression. (See facial nerve [CN VII] images in Chapter 5.)





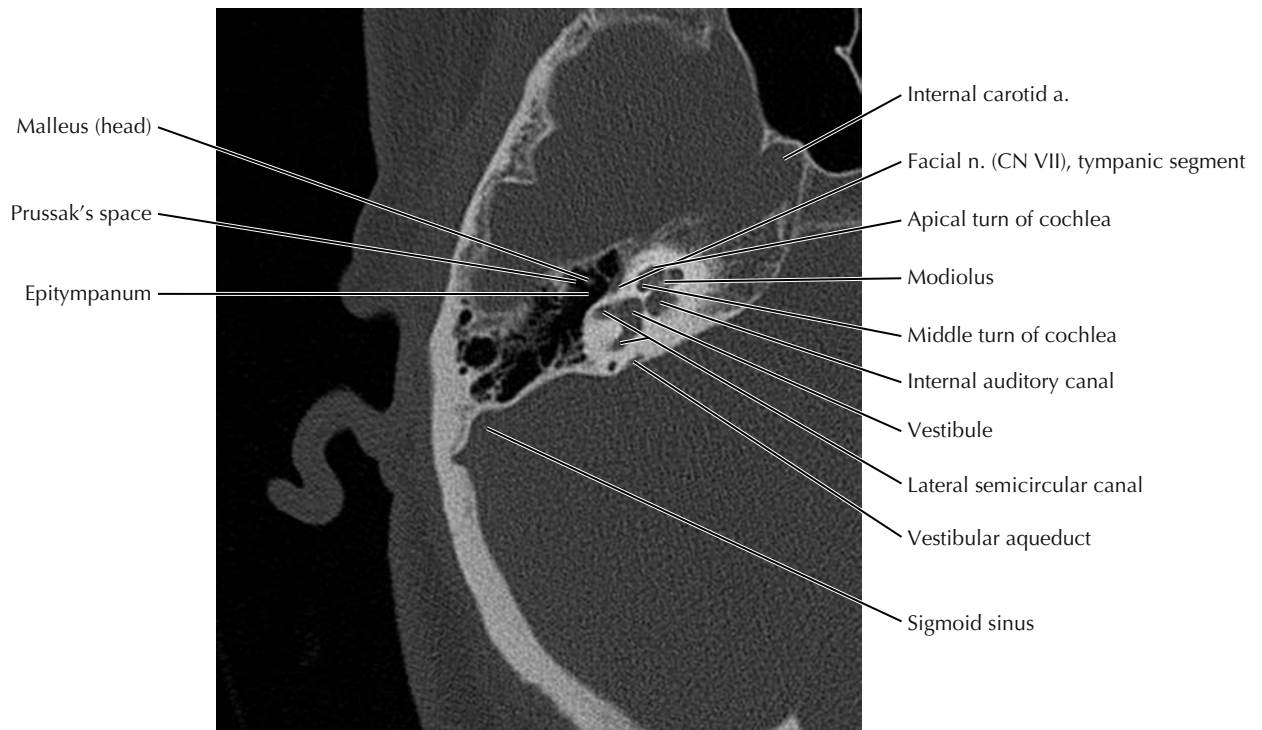
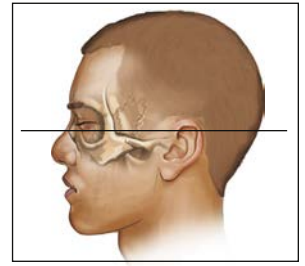
NORMAL ANATOMY

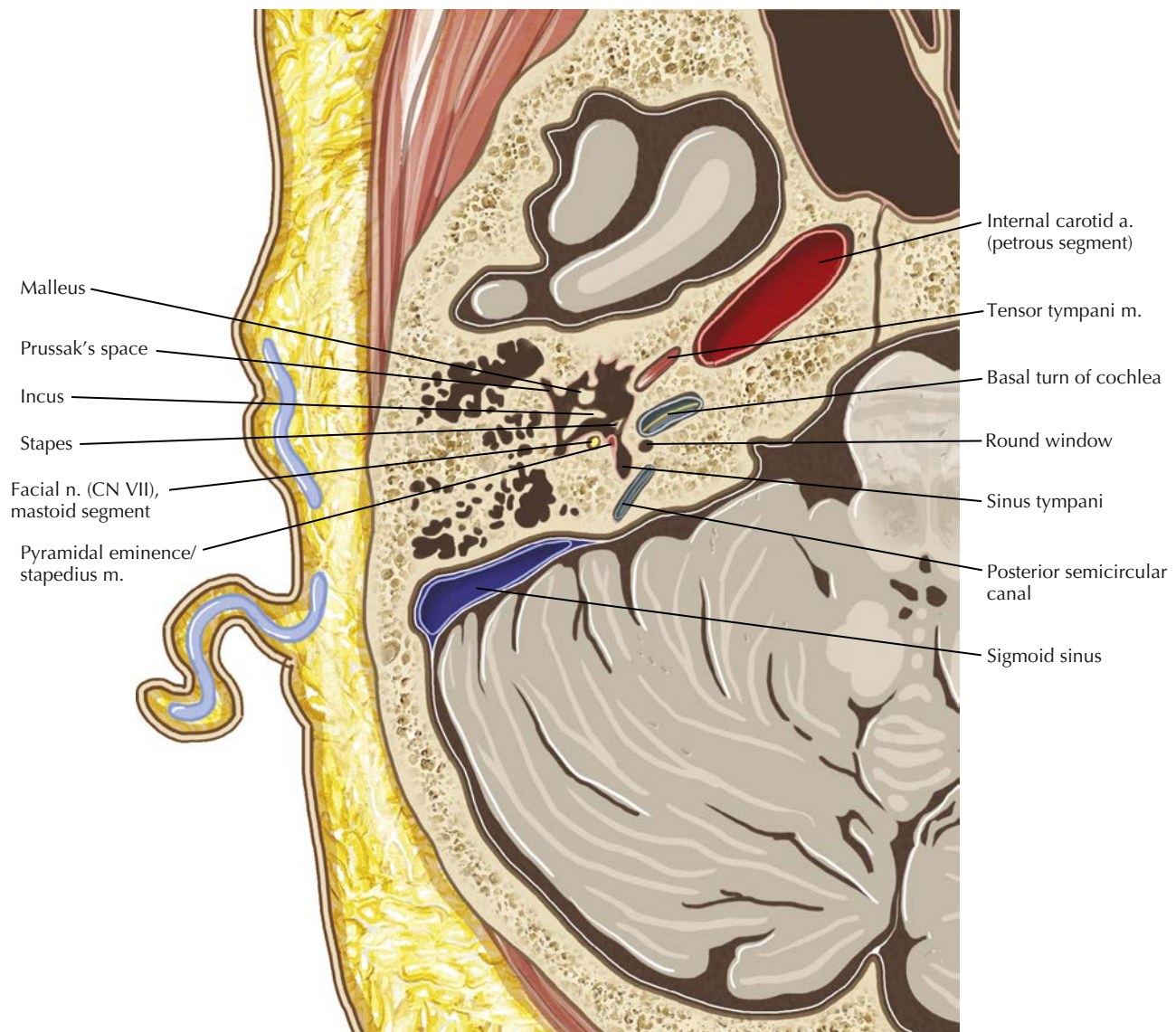
Note the apical and middle turns of the cochlea. Counterintuitively, the tip of the cochlea (the apex) is sensitive to lower frequencies, down to 20 Hz, moving to higher frequencies in the middle turn, and up to 20,000 Hz in the basal turn.

Note also the very thin vestibular aqueduct, which connects the inner ear to a balloon-shaped structure called the *endolymphatic sac*. Although its function is not clearly known, the endolymphatic sac may help to ensure that fluid in the inner ear contains the correct ion concentration. The vestibular aqueduct is normally less than 1 mm in diameter, or smaller than the adjacent medial limb of the superior semicircular canal (a good anatomic reference). Enlarged vestibular aqueducts, associated with hearing loss in children, are thought to be related to the same underlying defect.

PATHOLOGIC PROCESS

Damage to the cochlear nerve, as in trauma with temporal bone fracture, is more classically seen with *transverse* fractures perpendicular to the long axis of the temporal bone, from auricle to petrous apex. Transverse fractures are more frequently associated with sensorineural hearing loss. Practically, however, many fractures combine both conditions.



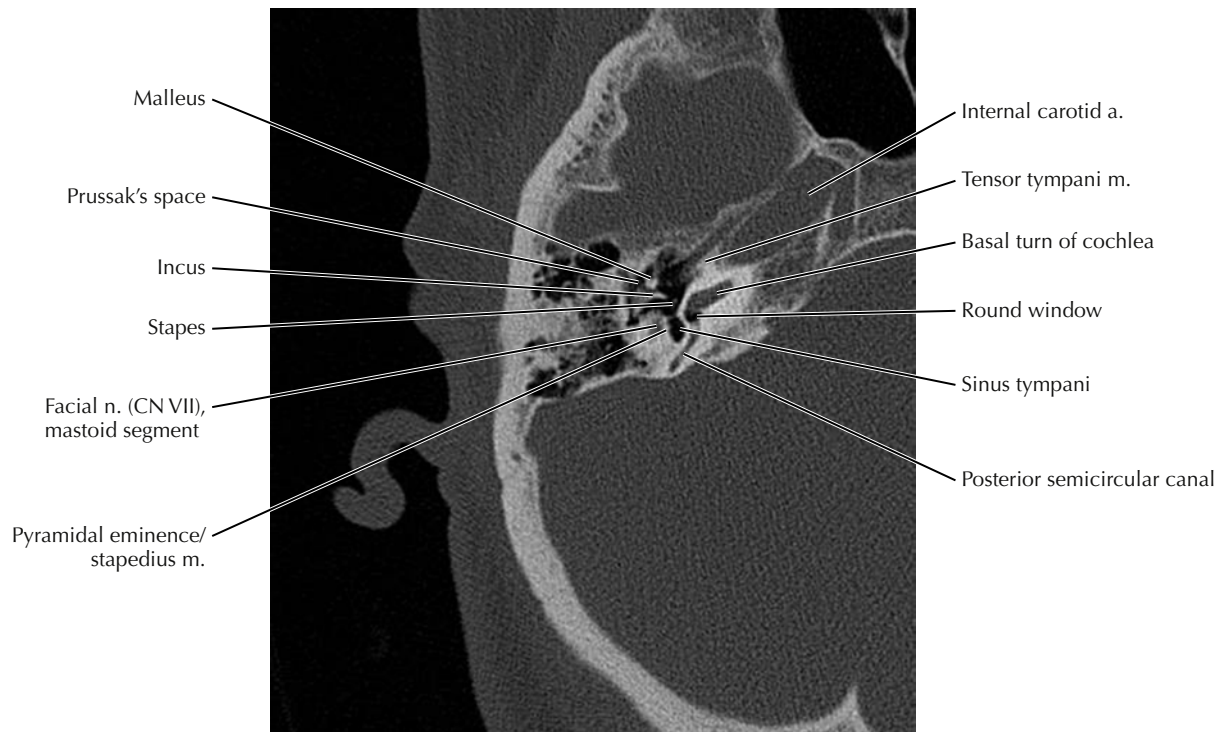
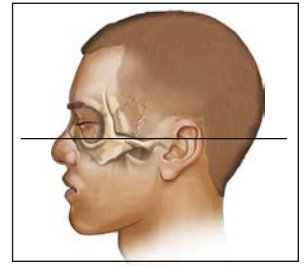


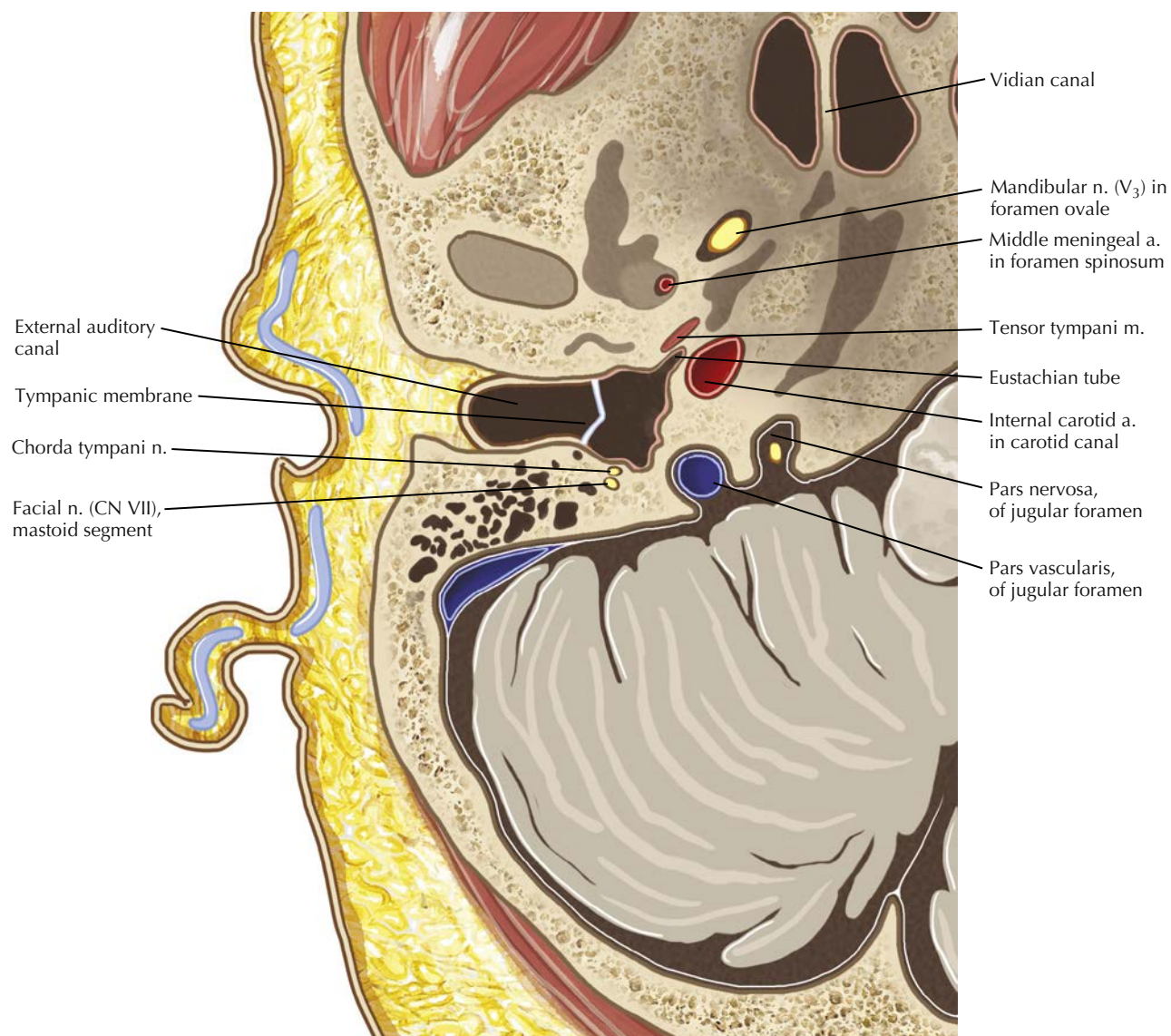
NORMAL ANATOMY

The basal turn of the cochlea is connected to the stapes stirrup through the oval window. Immediately anterior to the oval window is the *fissula ante fenestram*, a small, connective tissue-filled cleft where the tendon of the tensor tympani muscle turns laterally toward the malleus. In otosclerosis, the most common cause of hearing loss in people age 15 to 50, a small lytic lesion often develops at the fissula ante fenestram.

DIAGNOSTIC CONSIDERATION

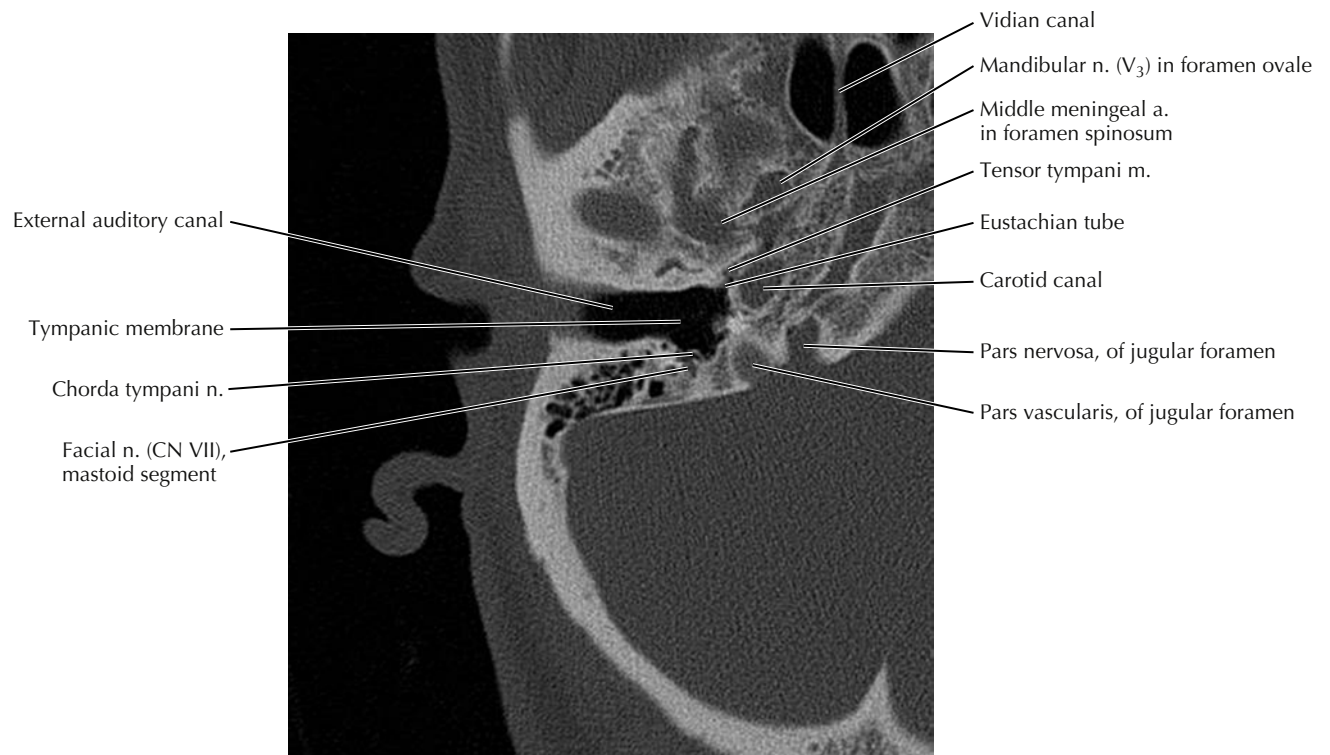
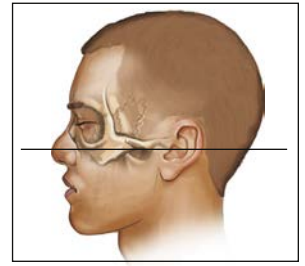
The head of the malleus forms a "scoop of ice cream" on the cone-shaped incus. Loss of this ice cream cone appearance indicates ossicular dislocation.

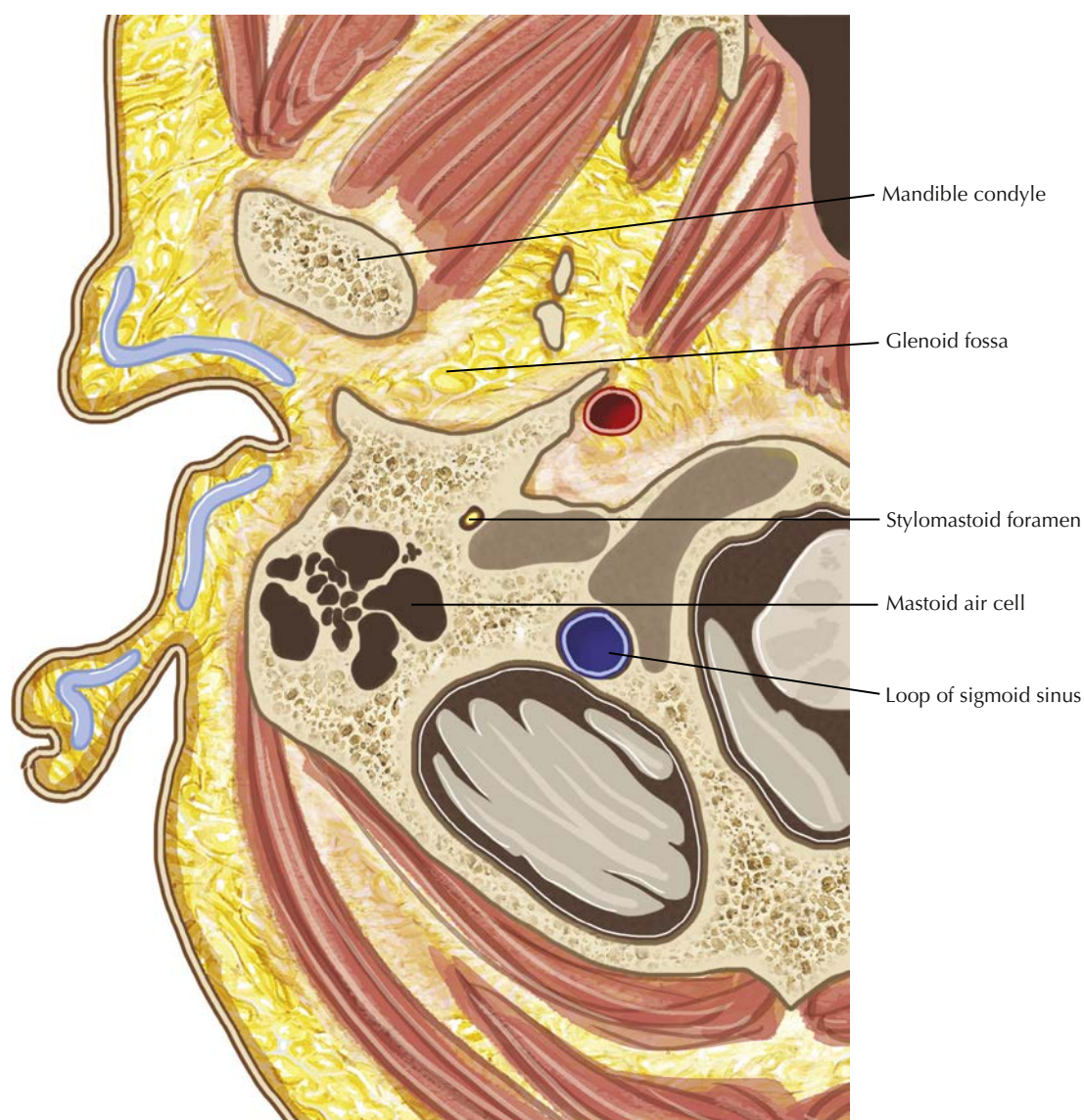




PATHOLOGIC PROCESS

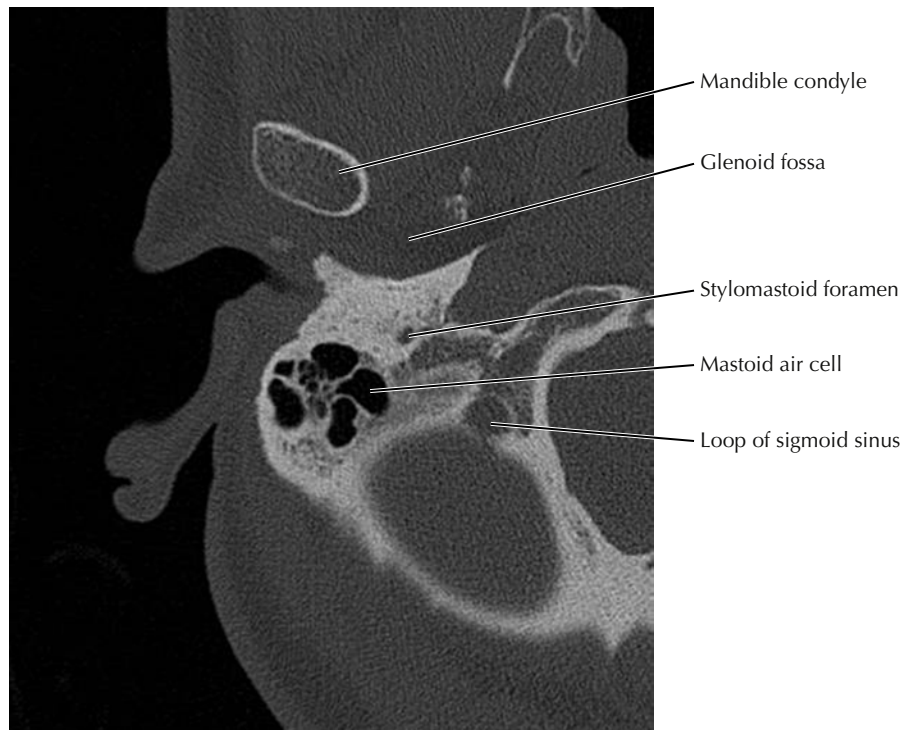
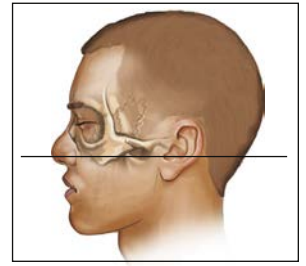
The tympanic membrane separating the external auditory canal from the middle ear cavity is normally extremely thin and barely perceptible on CT. Thickening can often be caused by inflammatory or infectious conditions such as otitis media.

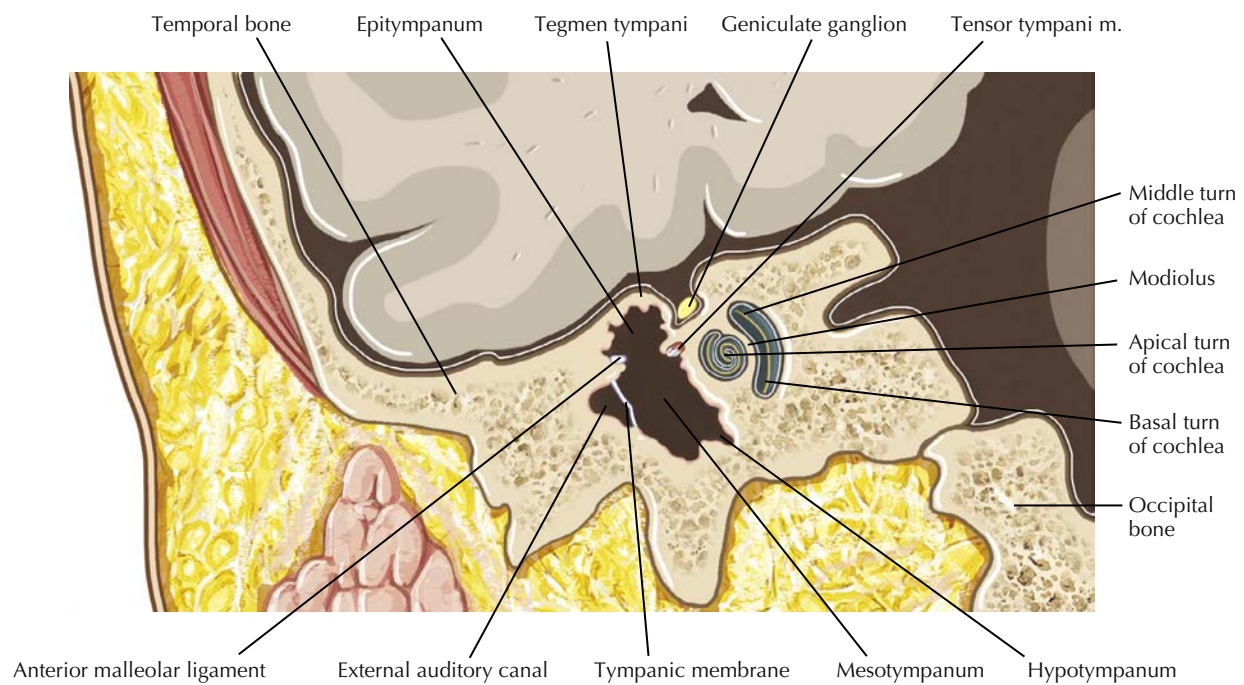


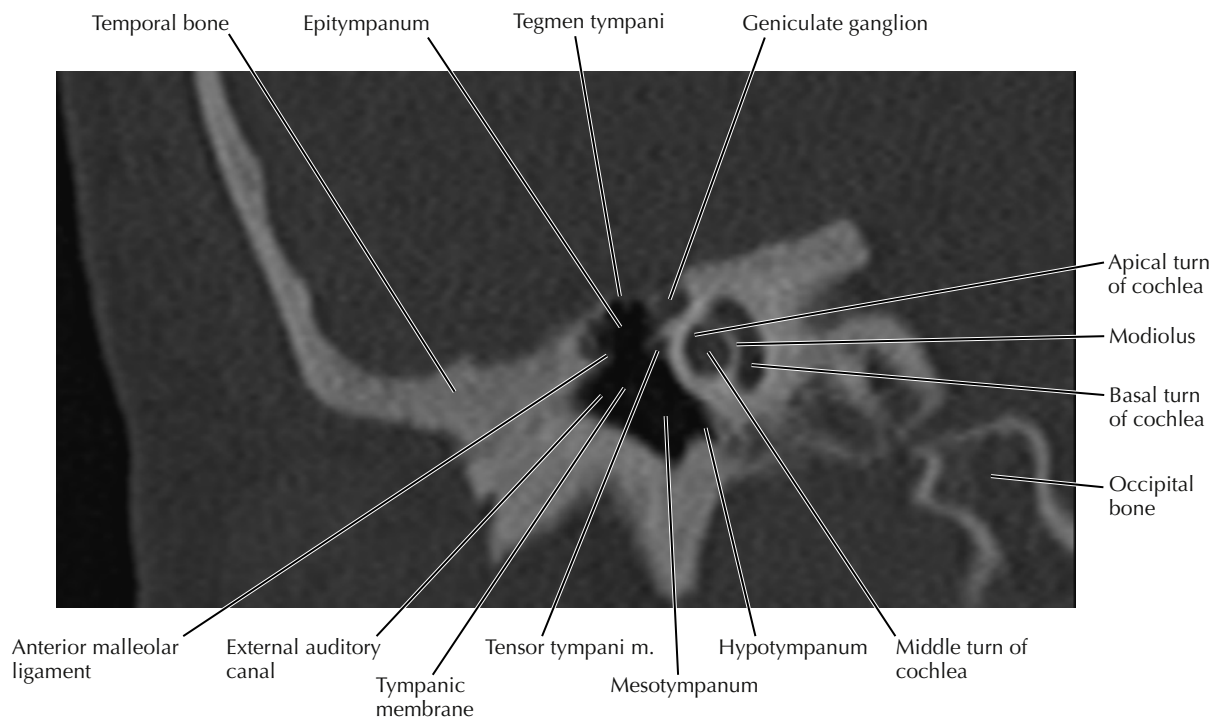
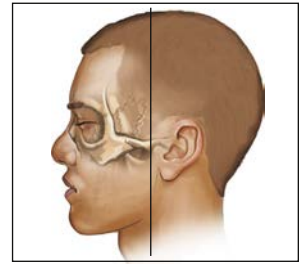


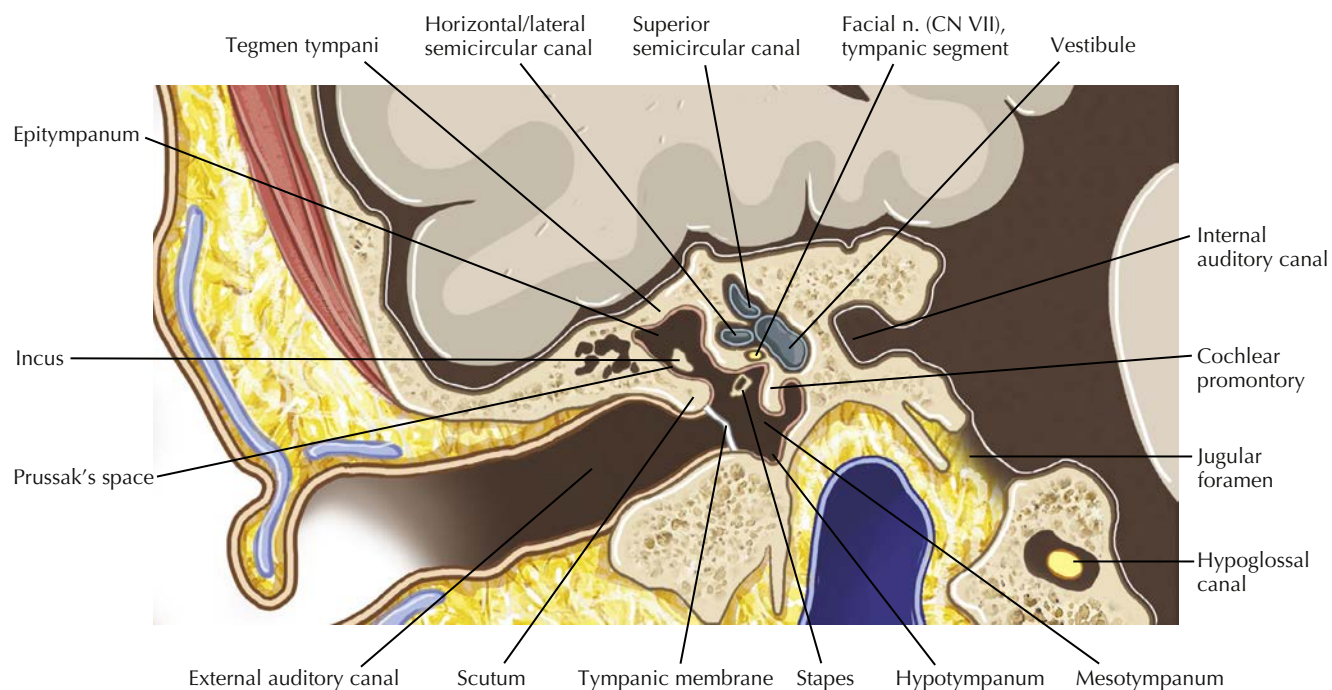
NORMAL ANATOMY

At the bottom of the temporal bone, the only nerve canal visible is the mastoid segment of the facial nerve. The mastoid segment descends vertically from the tympanic segment to the stylomastoid foramen at the skull base, between the styloid process and inferior aspect of the mastoid air cells.



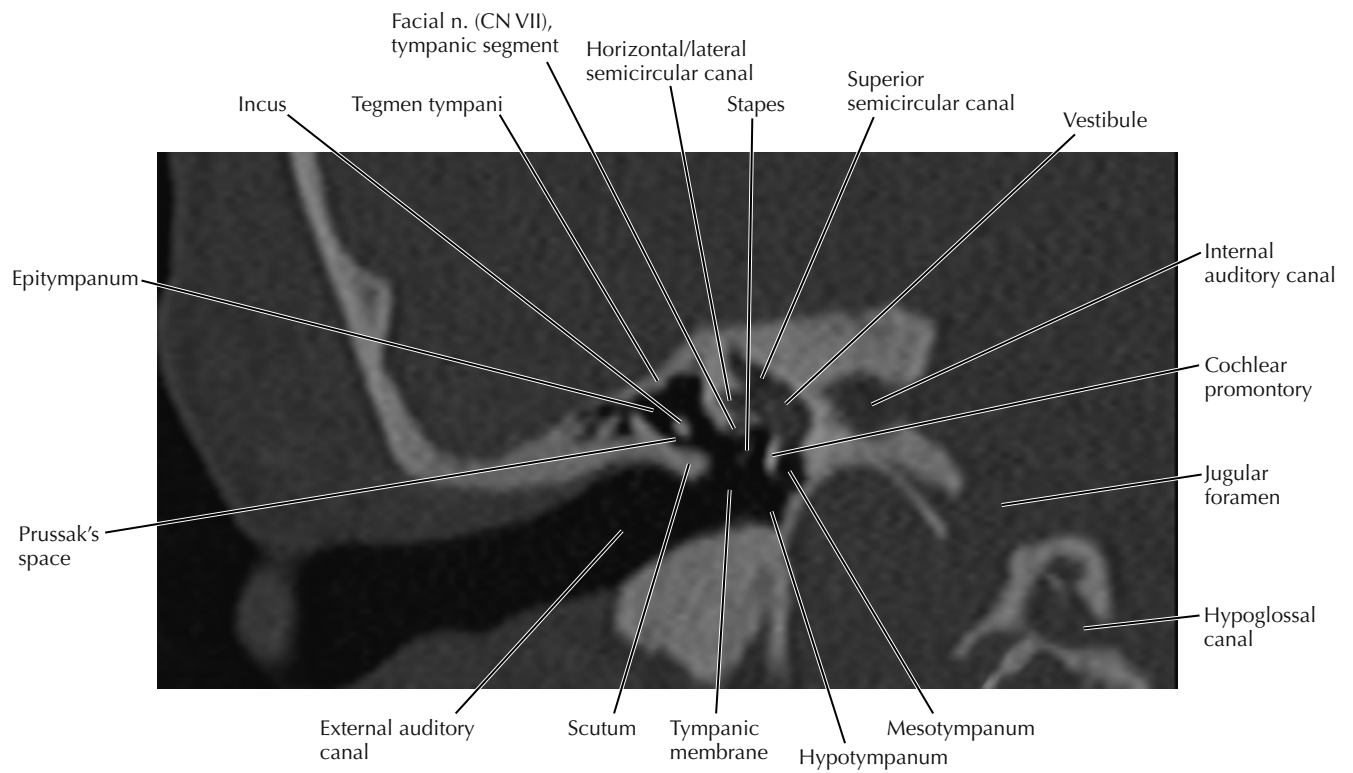
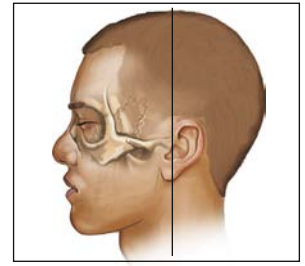


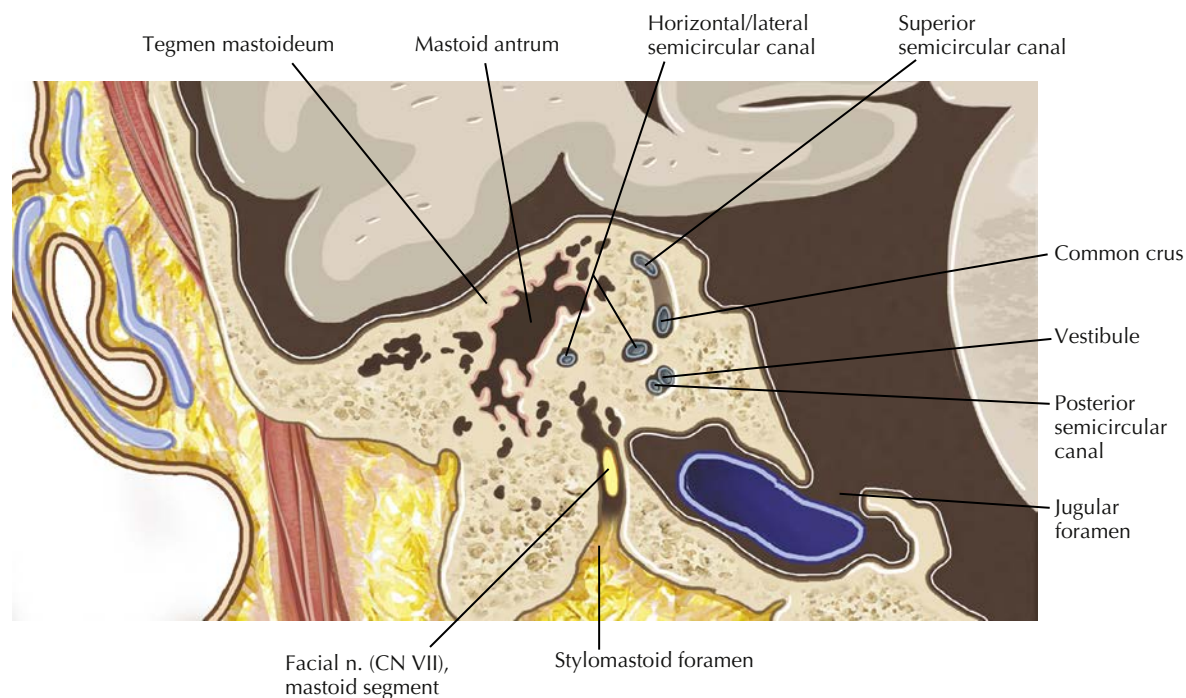




PATHOLOGIC PROCESS

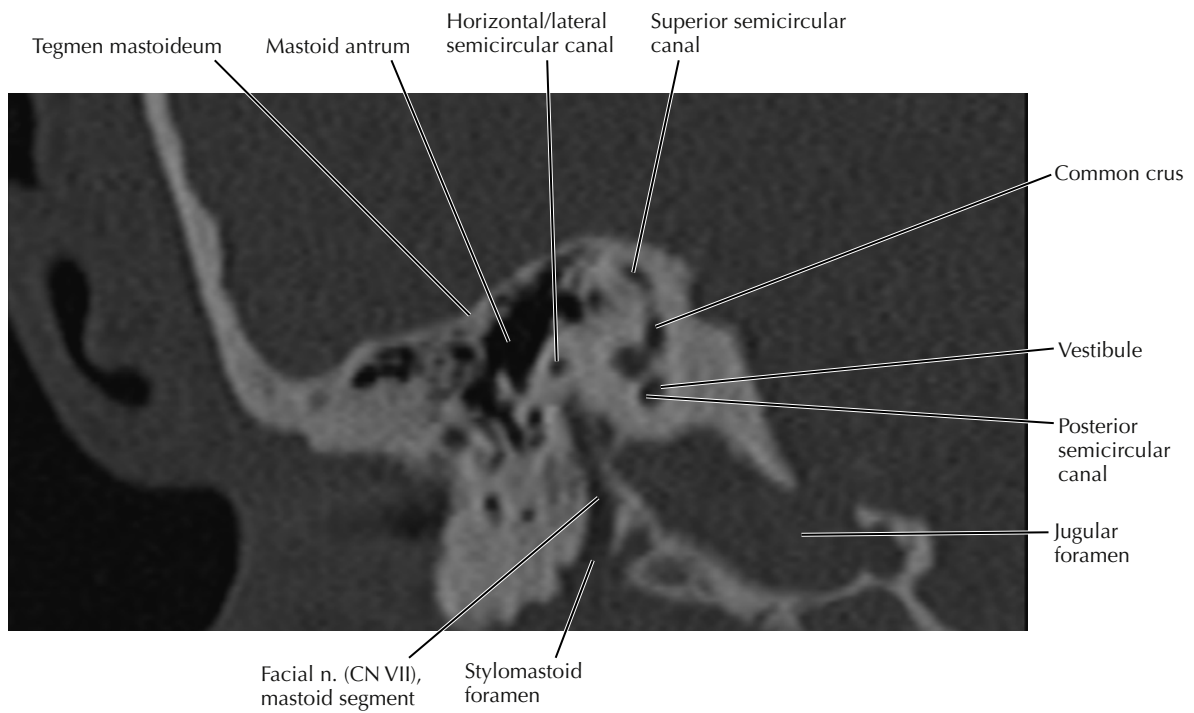
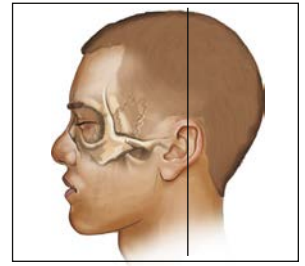
The air space lateral to the neck of the malleus is known as *Prussak's space* (superior recess of tympanic membrane). This space is important because cholesteatoma can occur there. A *cholesteatoma* forms when there is a deep retraction pocket in the tympanic membrane. The lining of the tympanic membrane is shed like skin, but if the membrane is retracted, the dead cells are trapped and can enlarge. This cholesteatoma can eventually erode the surrounding bony structures. One of the early signs differentiating simple middle ear fluid from a cholesteatoma is erosion of the scutum (bony plate) lateral to the Prussak's space at the upper edge of the tympanic membrane. Coronal is the best imaging plane on MRI to evaluate this scutum (tympanic scute).

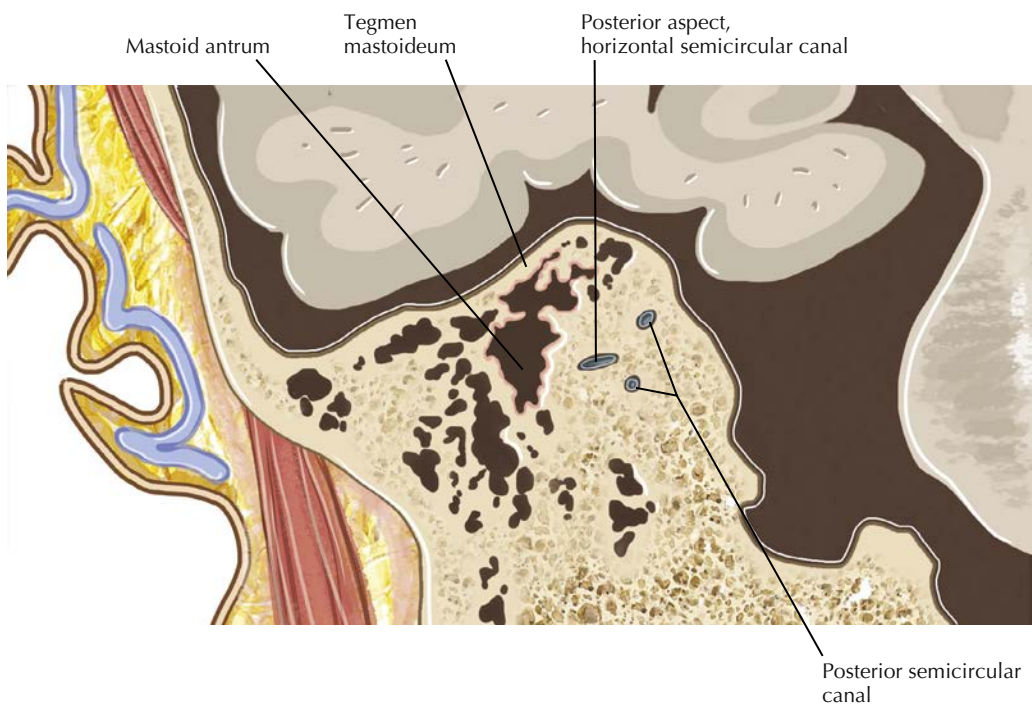


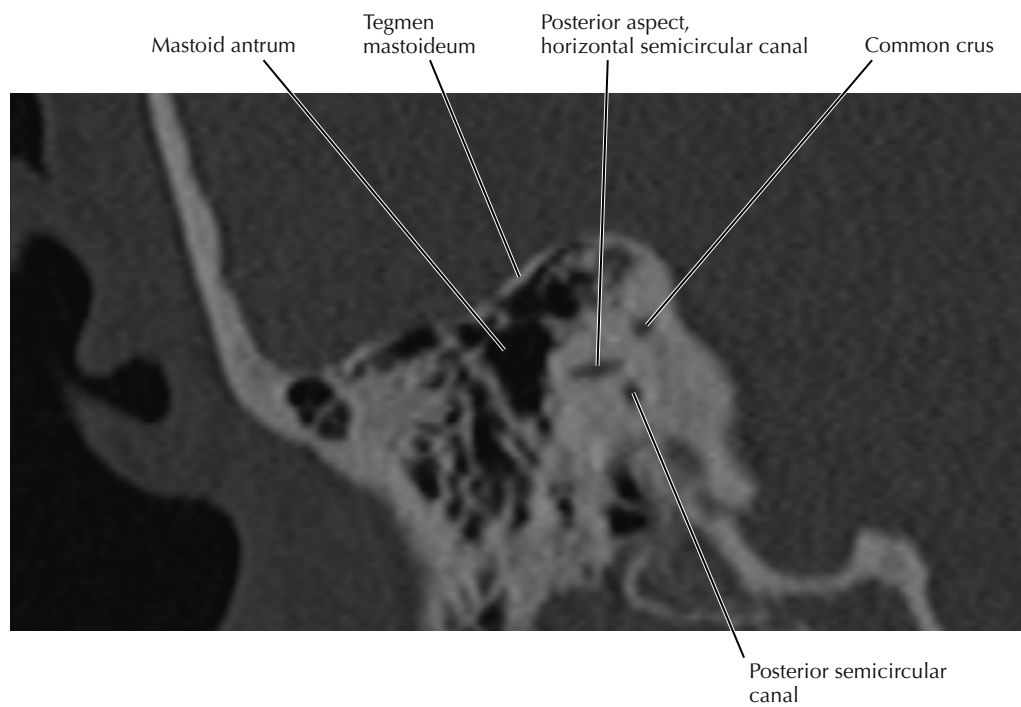
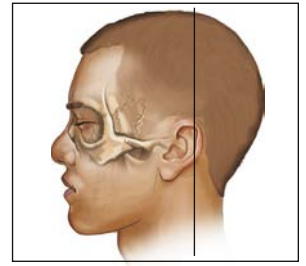


NORMAL ANATOMY

Coronal MR images are useful for assessing the bony roof (tegmen) of the superior semicircular canal. Loss of this roof, or semicircular canal dehiscence and communication with the cerebrospinal fluid around the brain, can lead to disruption of vestibulocochlear nerve function.





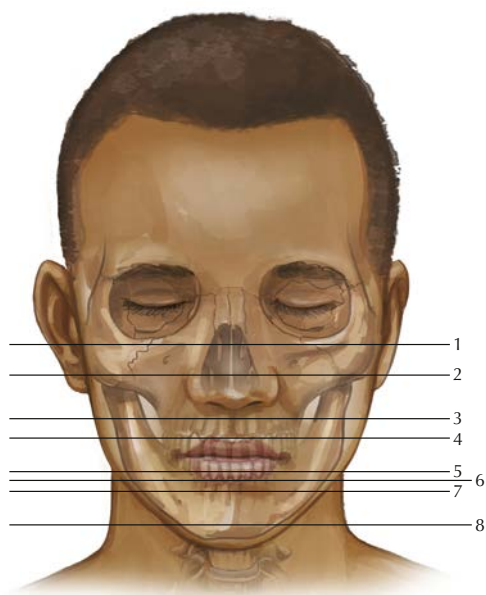


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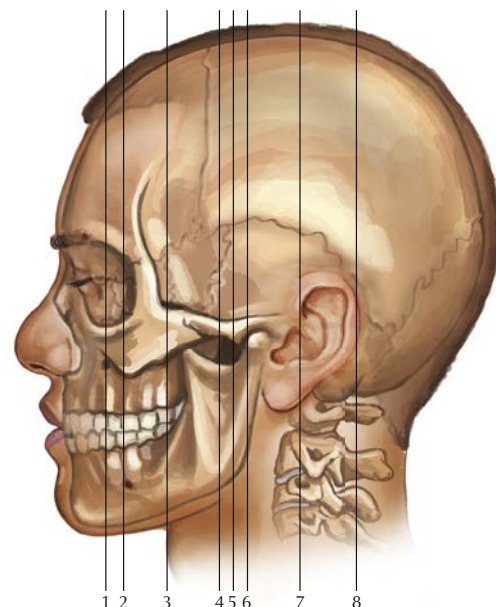
Chapter

13

ORAL CAVITY, PHARYNX, AND SUPRAHYOID NECK



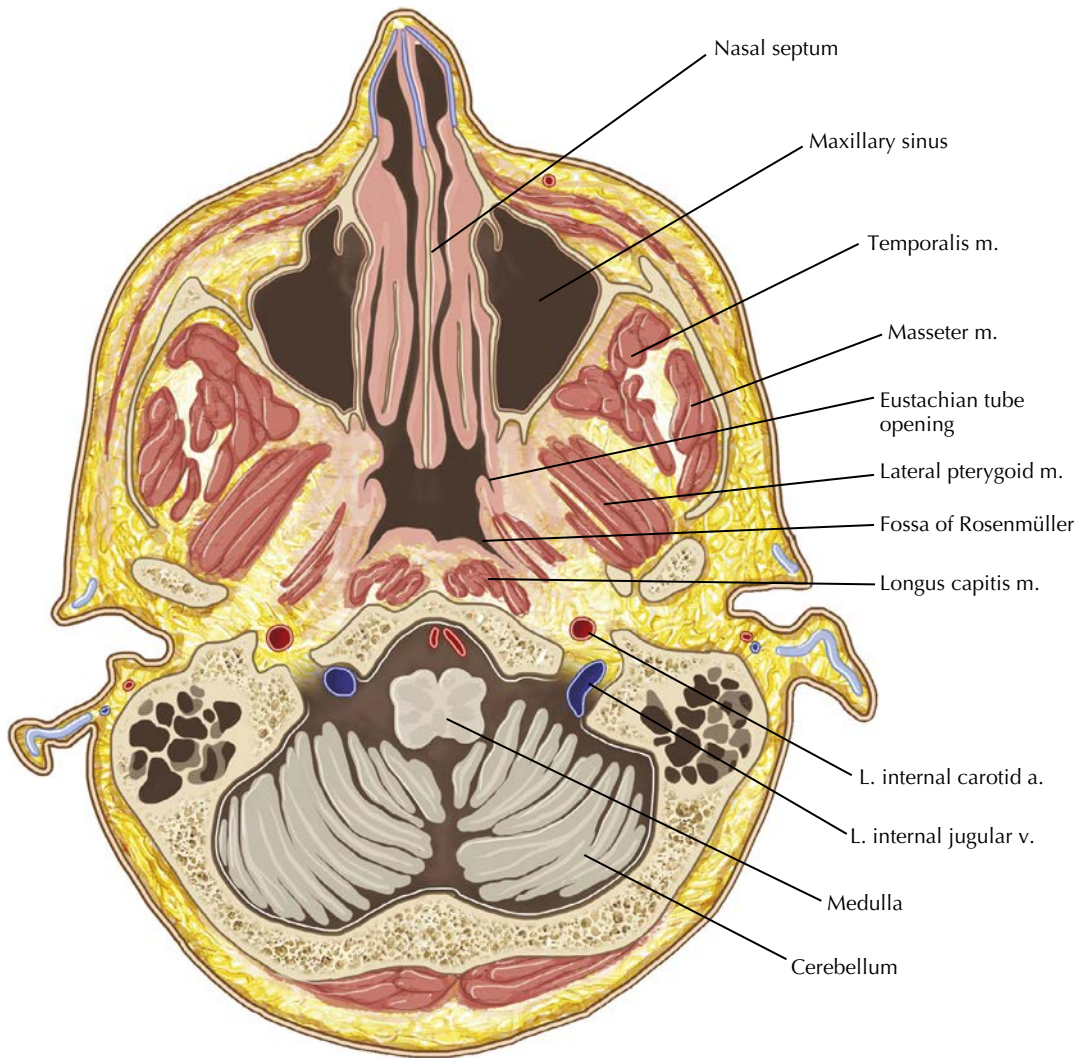
AXIAL 422



CORONAL 438

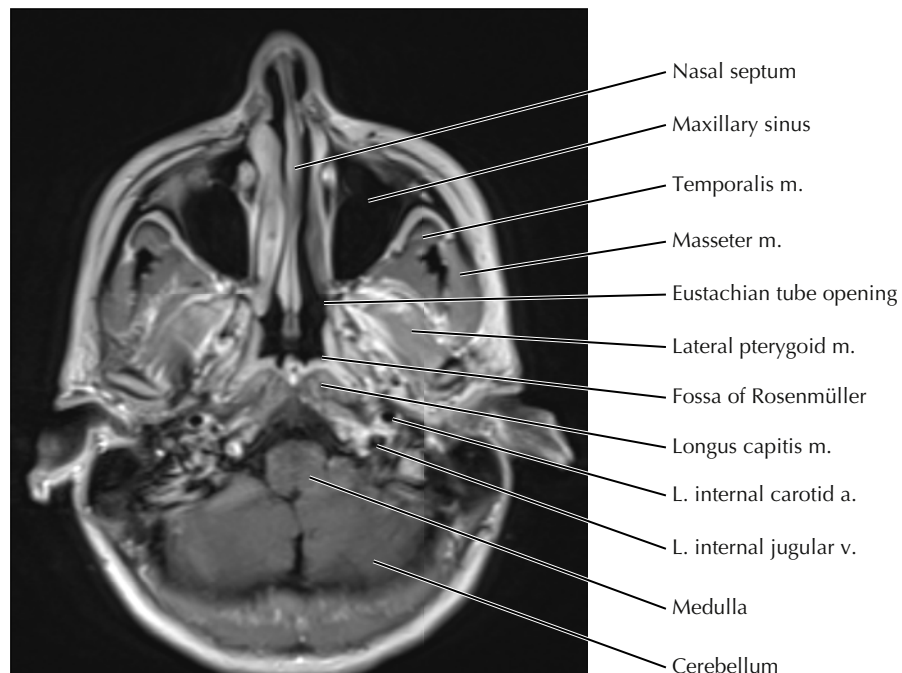
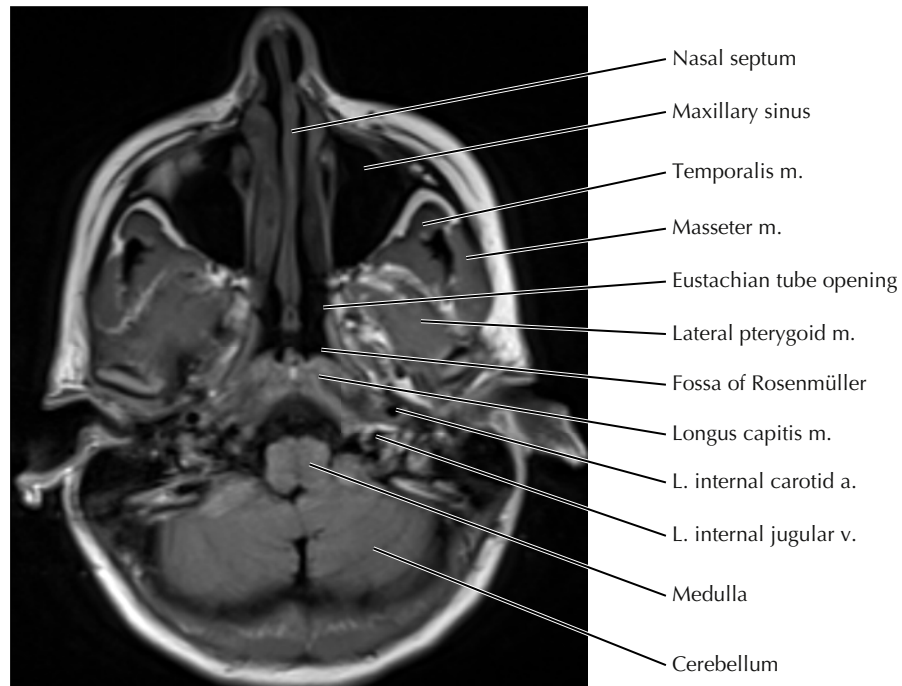
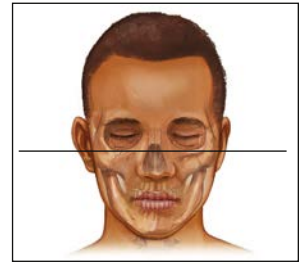


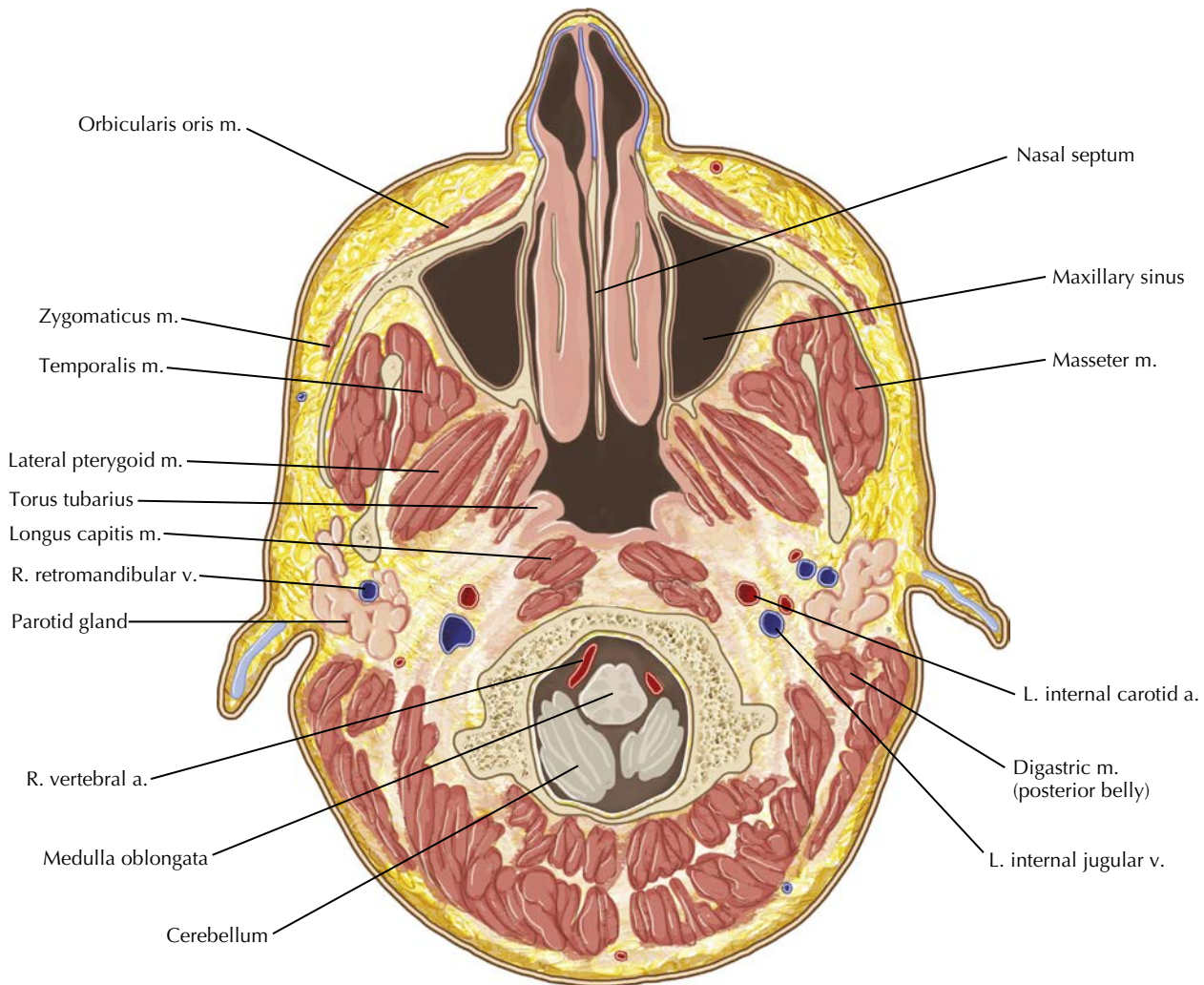
SAGITTAL 454



NORMAL ANATOMY

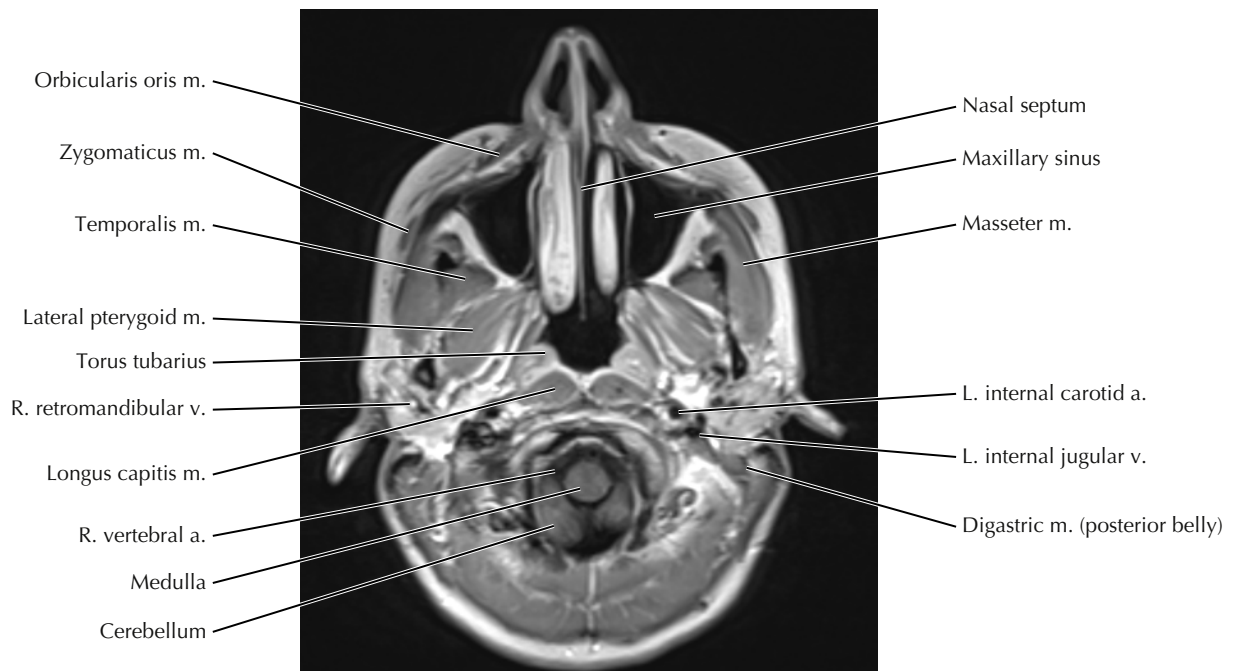
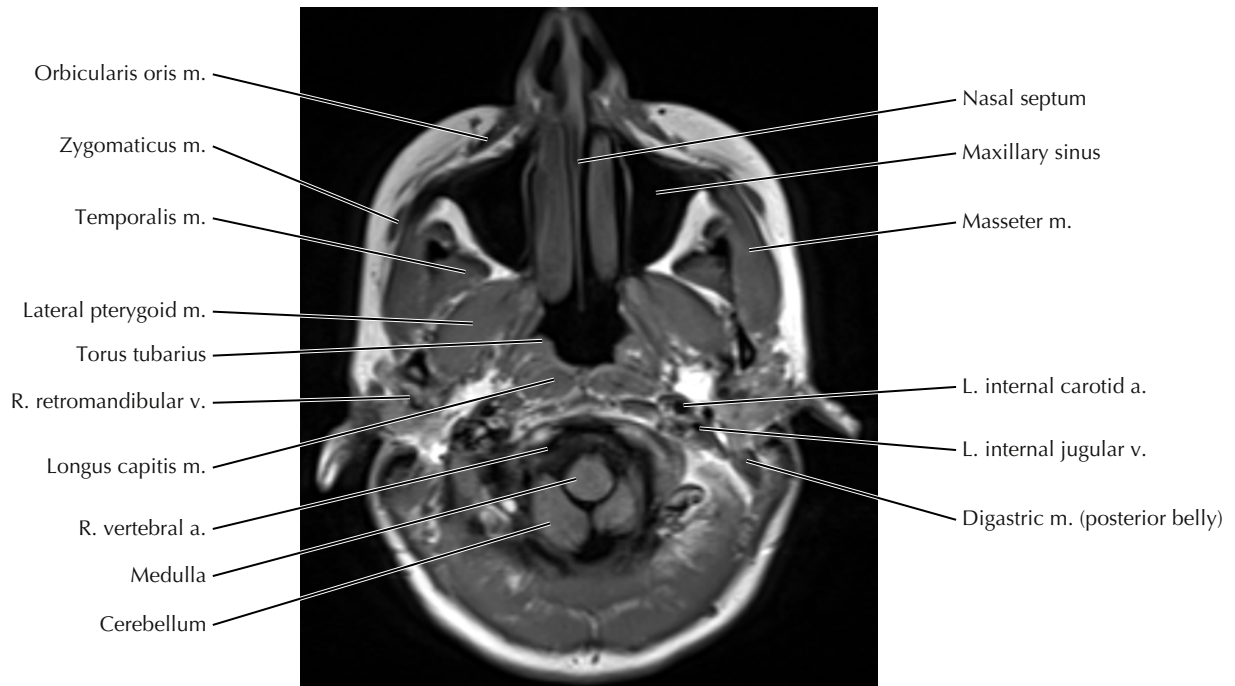
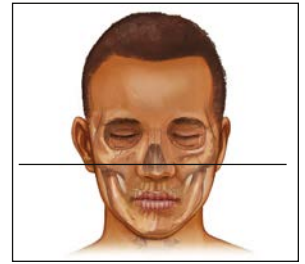
Note the enhancement of the mucosal surfaces of the aerodigestive tract on the lower magnetic resonance (MR) image in Axial 1 after gadolinium contrast administration. The subcutaneous adipose tissue and the adipose planes between the structures in the neck are visible on both the upper pre-contrast T1-weighted MR image and the lower post-contrast T1-weighted MR image.

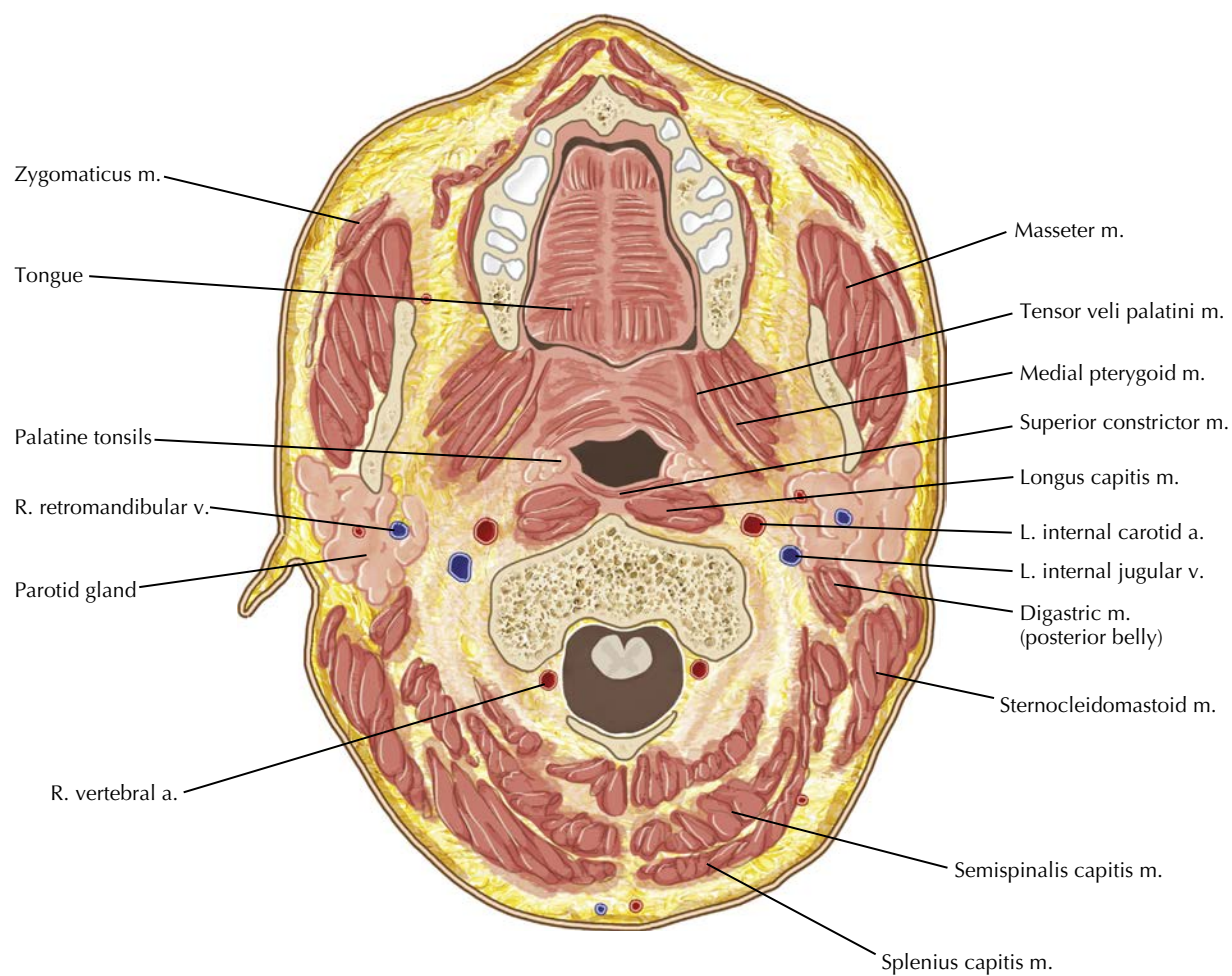


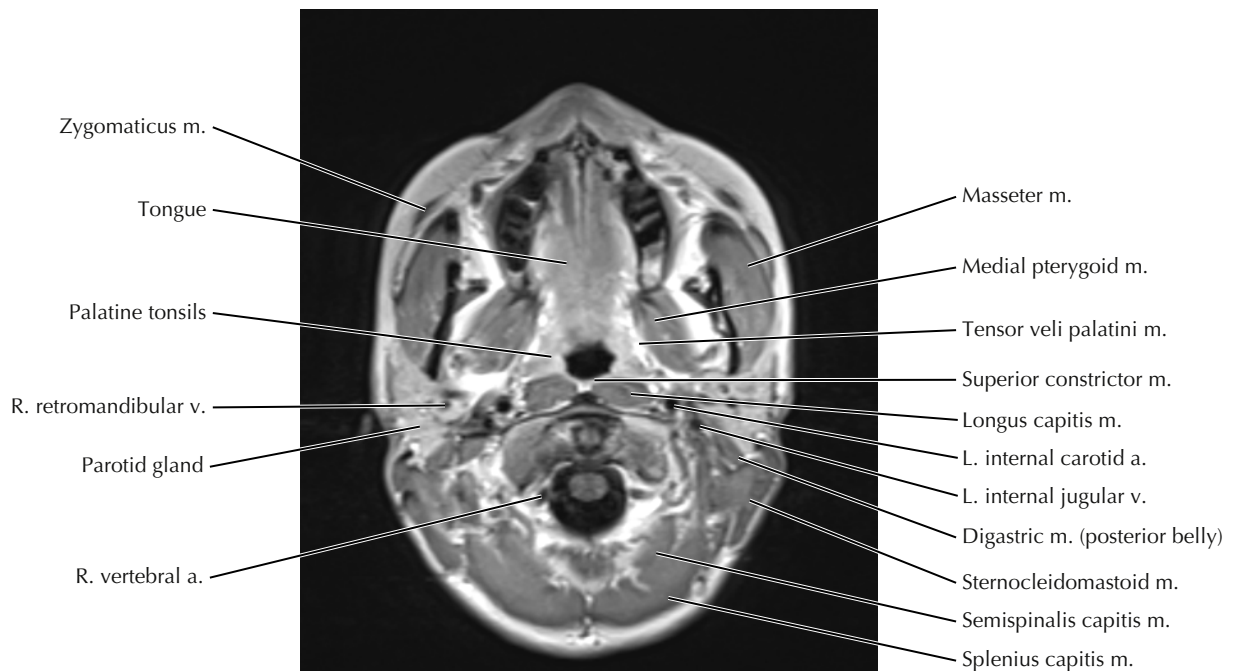
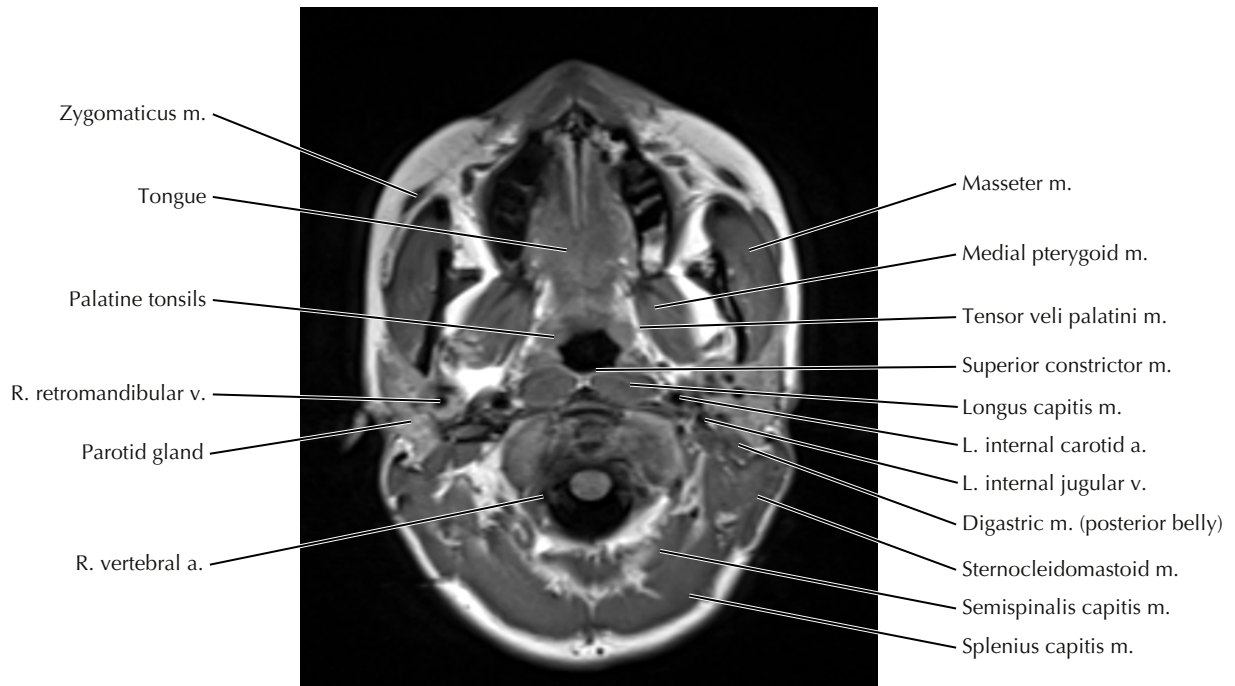
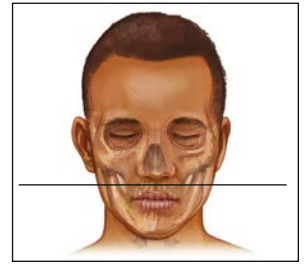


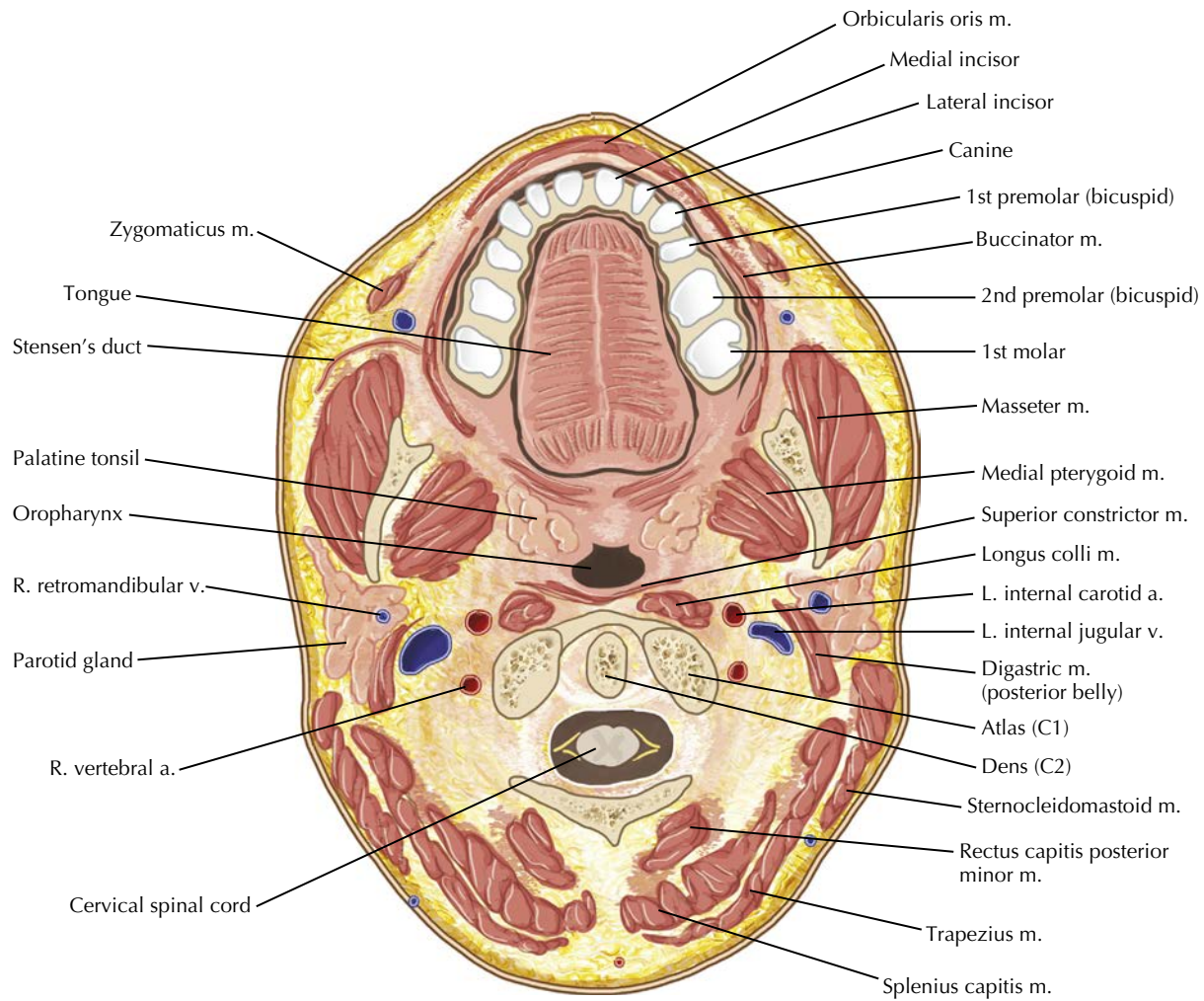
PATHOLOGIC PROCESS

An axial image of the nasopharynx at the level of the foramen magnum is visible on typically every brain study. Fluid in the mastoid air cells on one side may indicate a mass obstructing the Eustachian canal opening anterior to the *torus tubarius* (posterior protuberance of pharyngeal opening of auditory tube). The *fossa of Rosenmüller* is a blind-ending divot between the torus tubarius and the longus capitis muscle more posteriorly. Asymmetric loss of this fossa may be the first sign of a nasopharyngeal lesion. Malignant spread of a nasopharyngeal carcinoma may first reach the retropharyngeal lymph node. This lymph node is normally less than 8 mm in long axis and located between the longus capitis muscle and the internal carotid artery more posterolaterally.



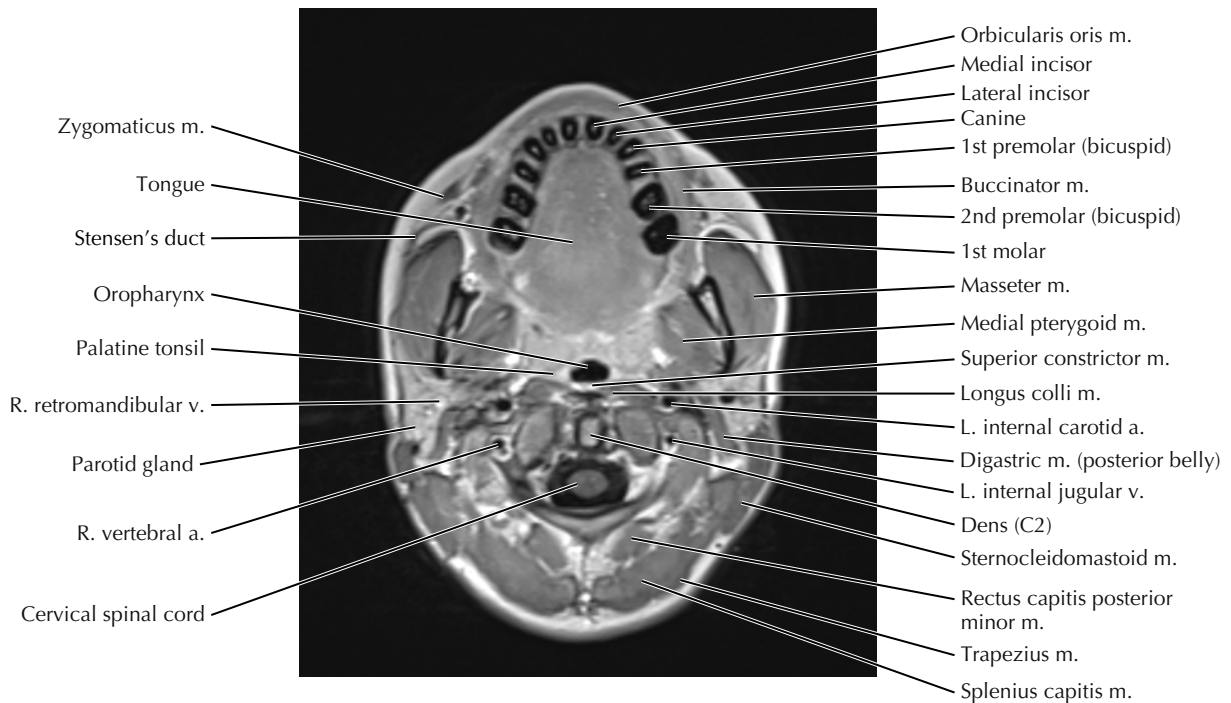
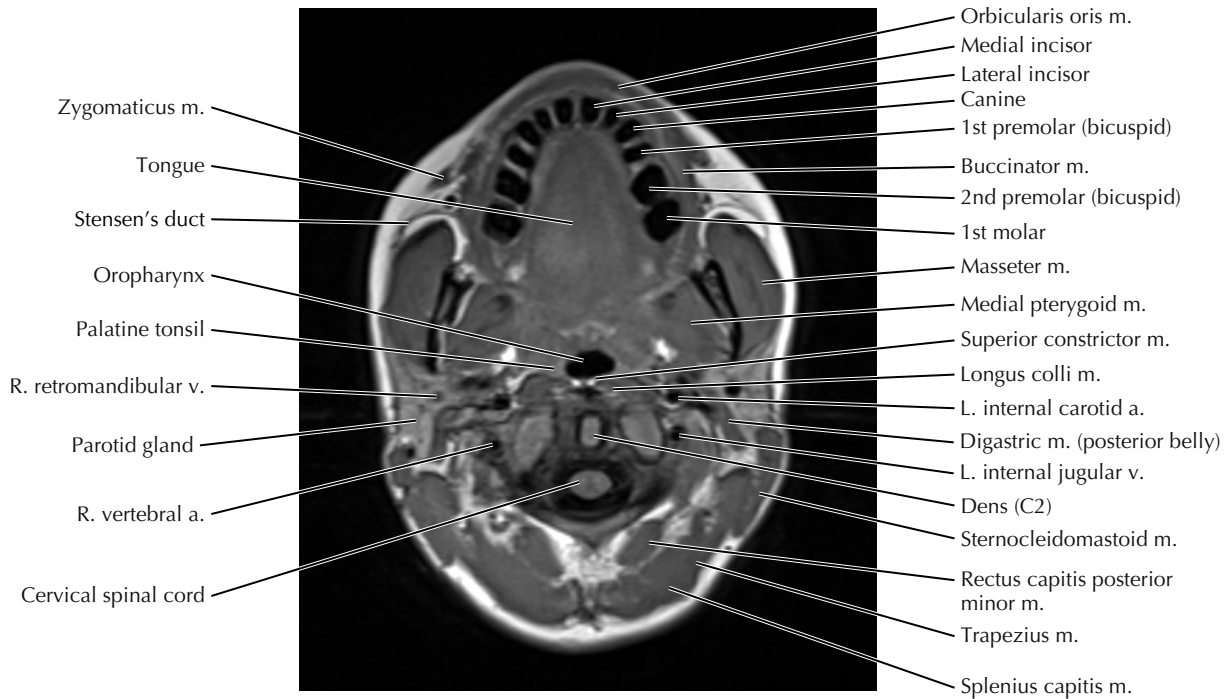
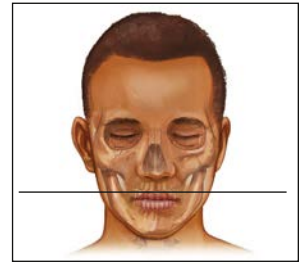


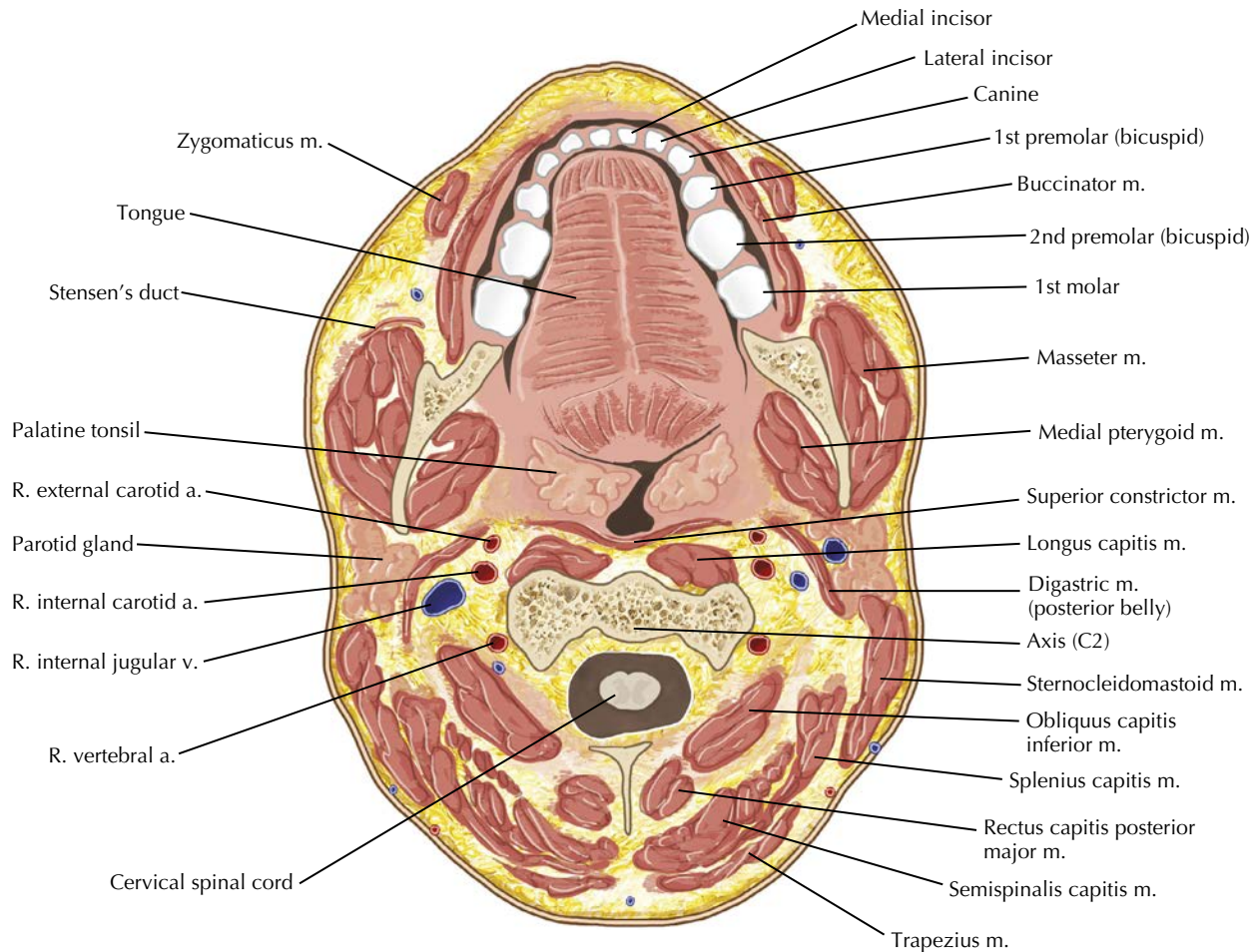




NORMAL ANATOMY

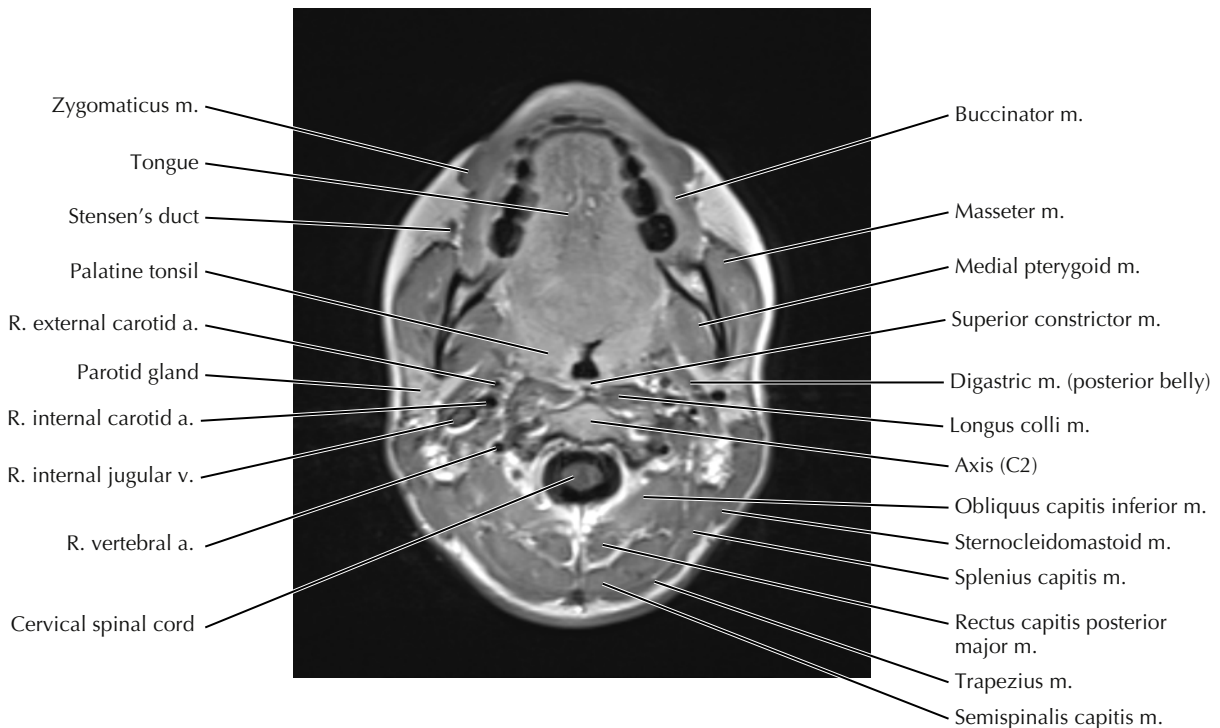
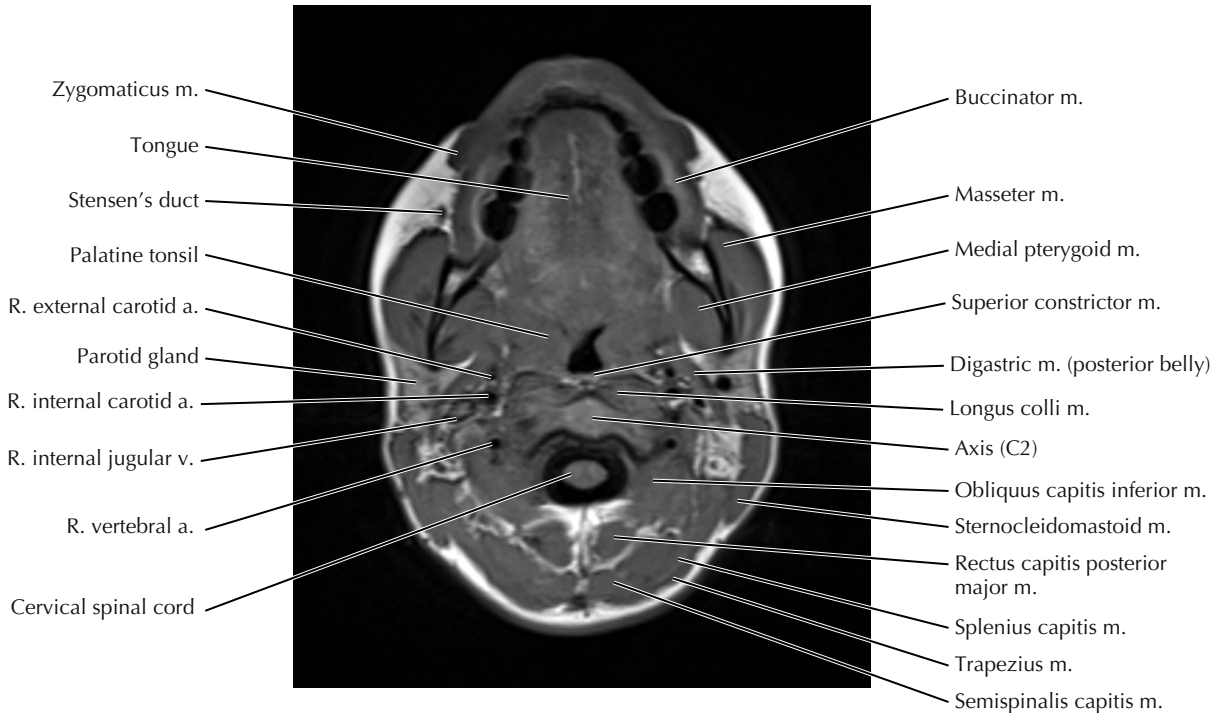
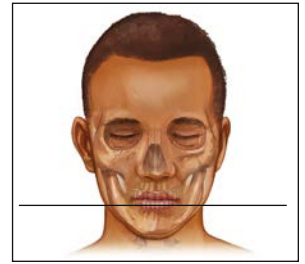
Unlike the nasopharynx cranially or the hypopharynx caudally, the lumen of the oropharynx can be grossly identified on axial MR images by visualization of teeth.

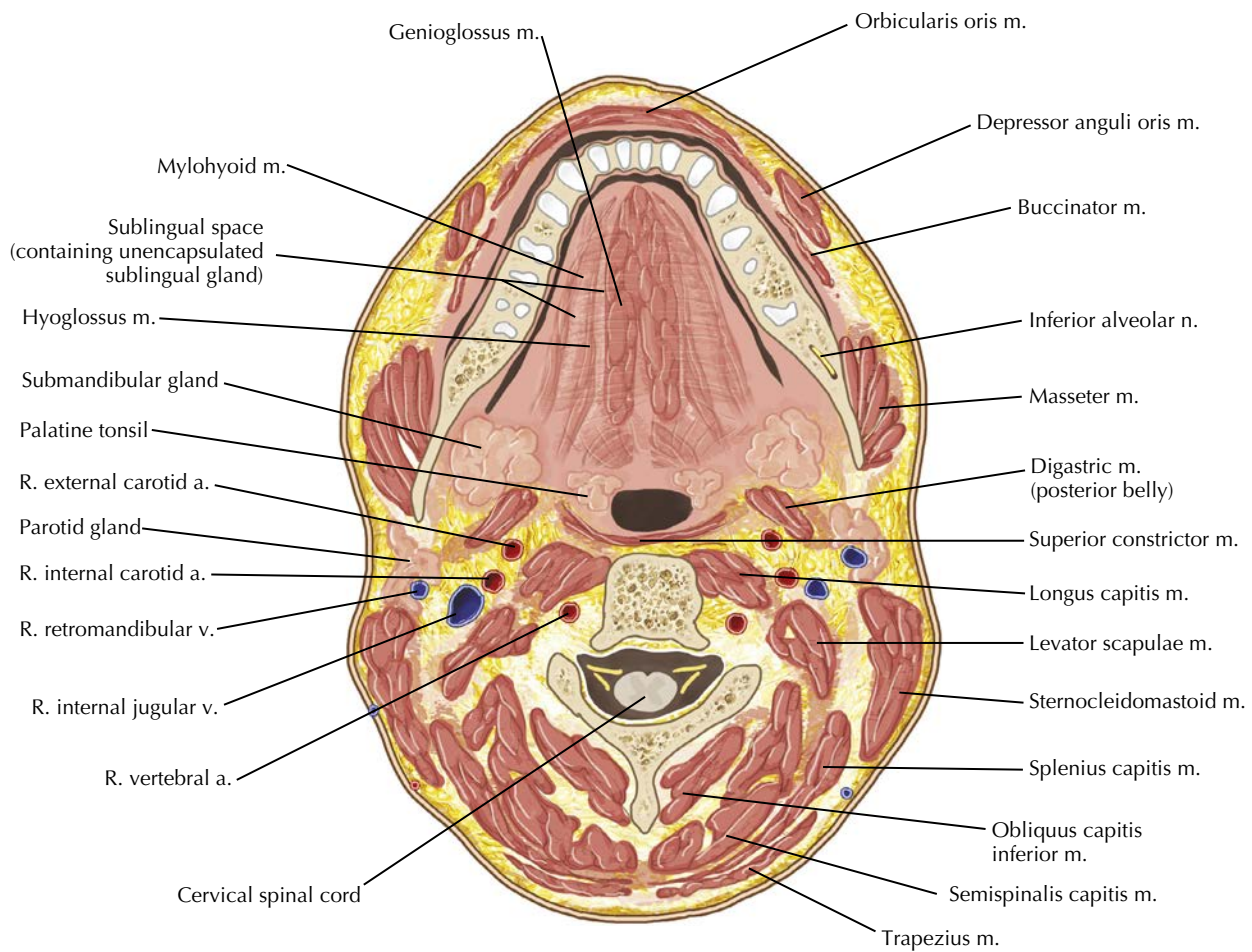


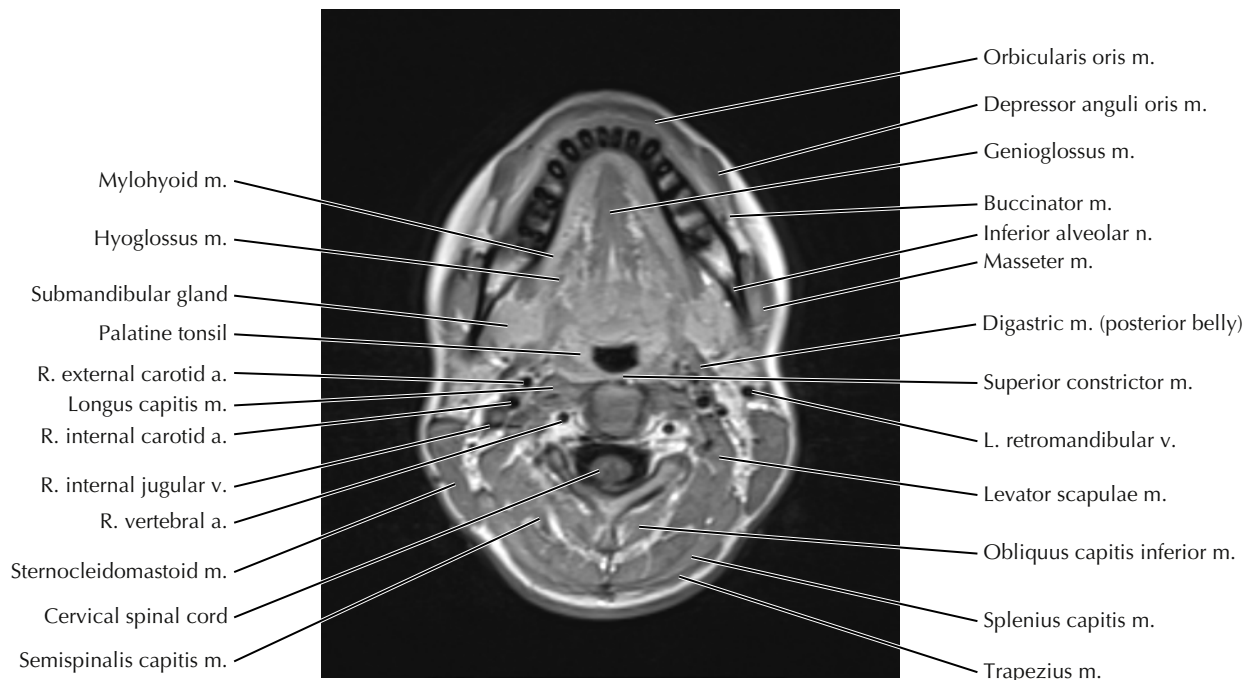
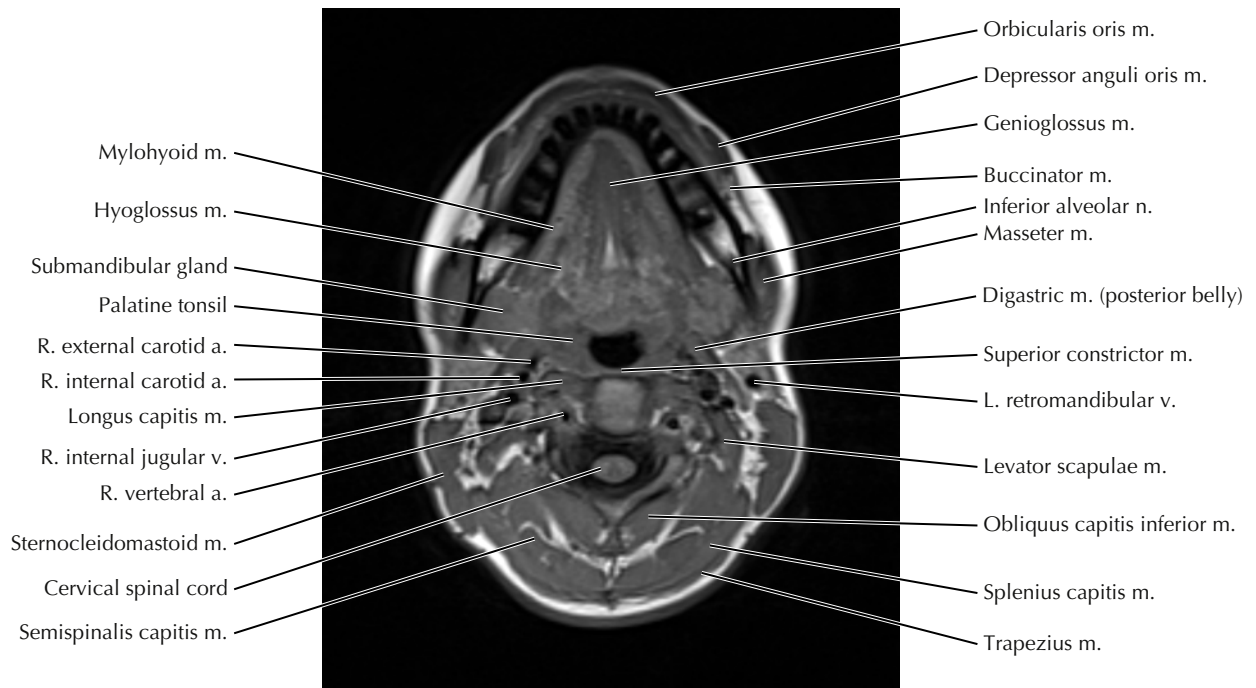
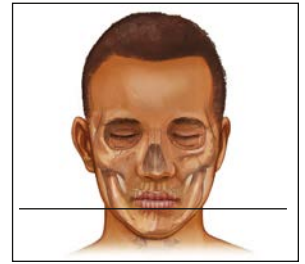


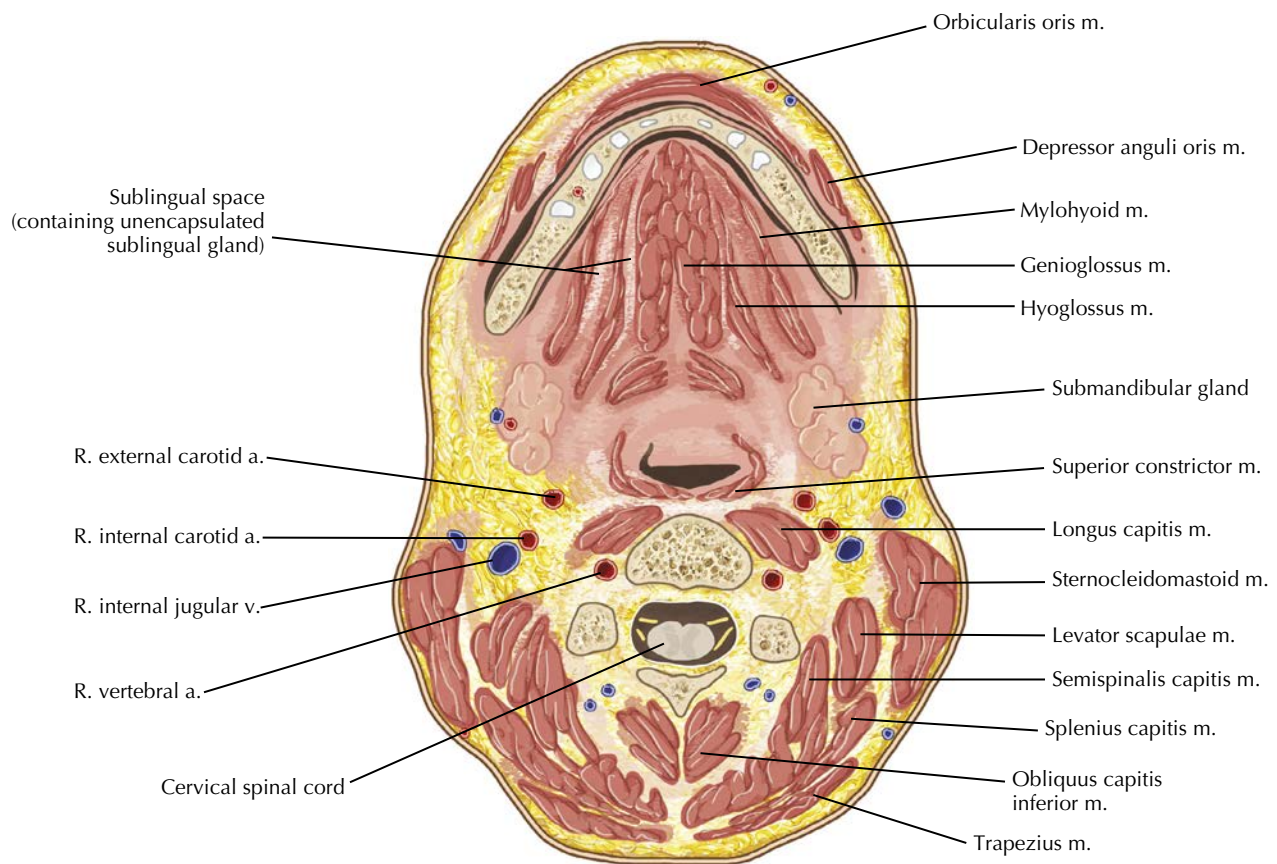
PATHOLOGIC PROCESS

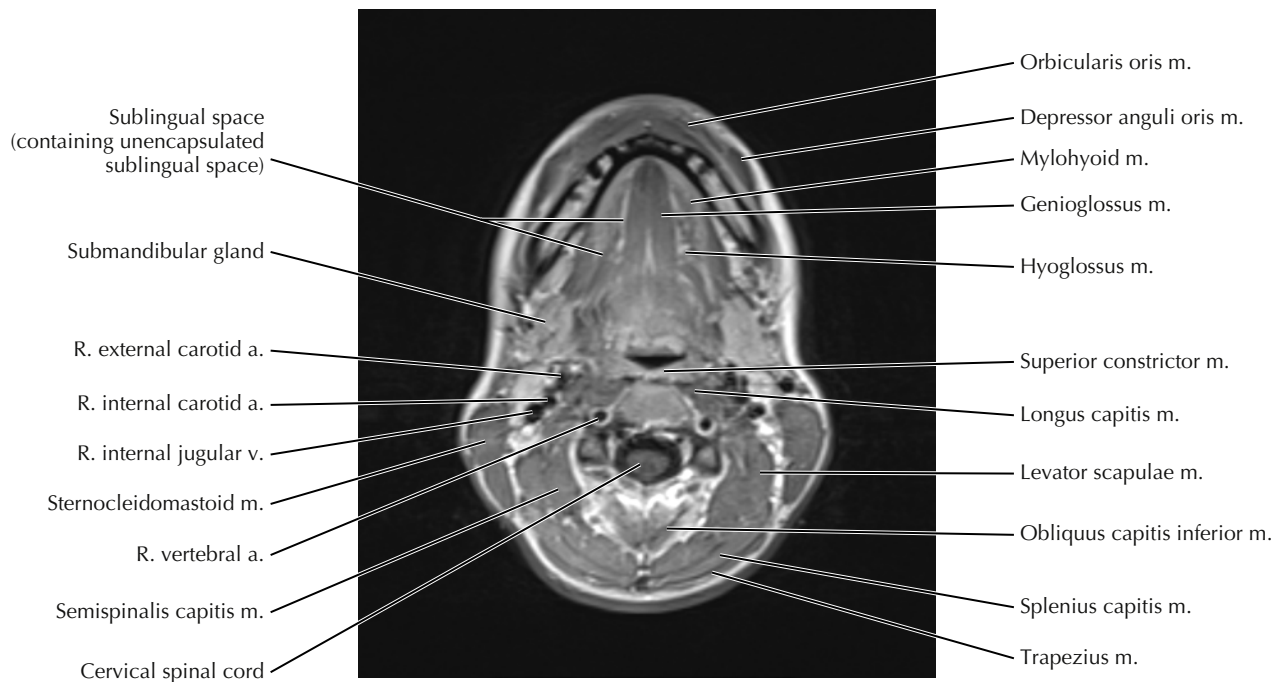
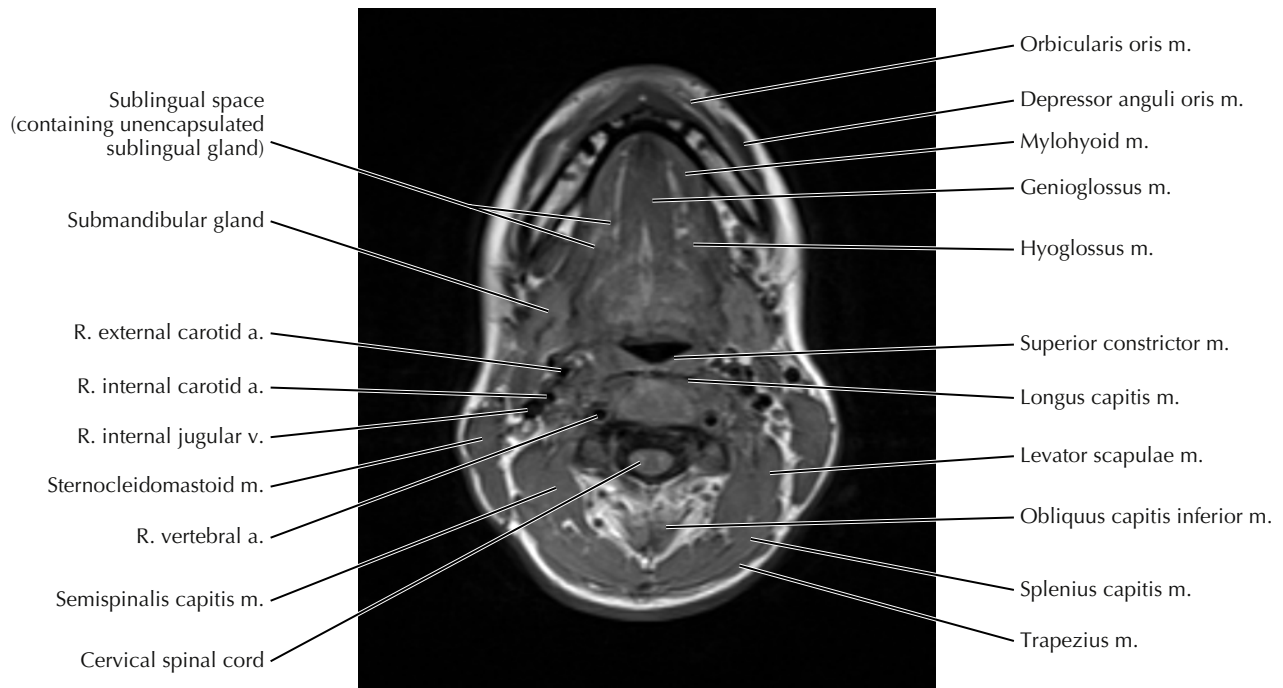
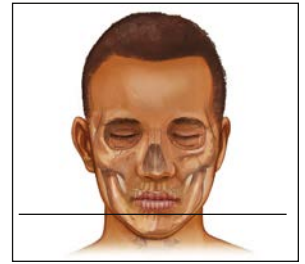
Lesions of the head and neck are often most easily detected by loss of normal fat planes. On these T1-weighted precontrast (upper) and postcontrast (lower) MR images, note the fat within the *retromolar trigone* (retromandibular triangle) located posterior to the third molar. Once a malignancy or infection has reached the parapharyngeal fat located more posteriorly, it has an easy route of spread craniocaudally from the skull base down to the inferior pericardial recess.

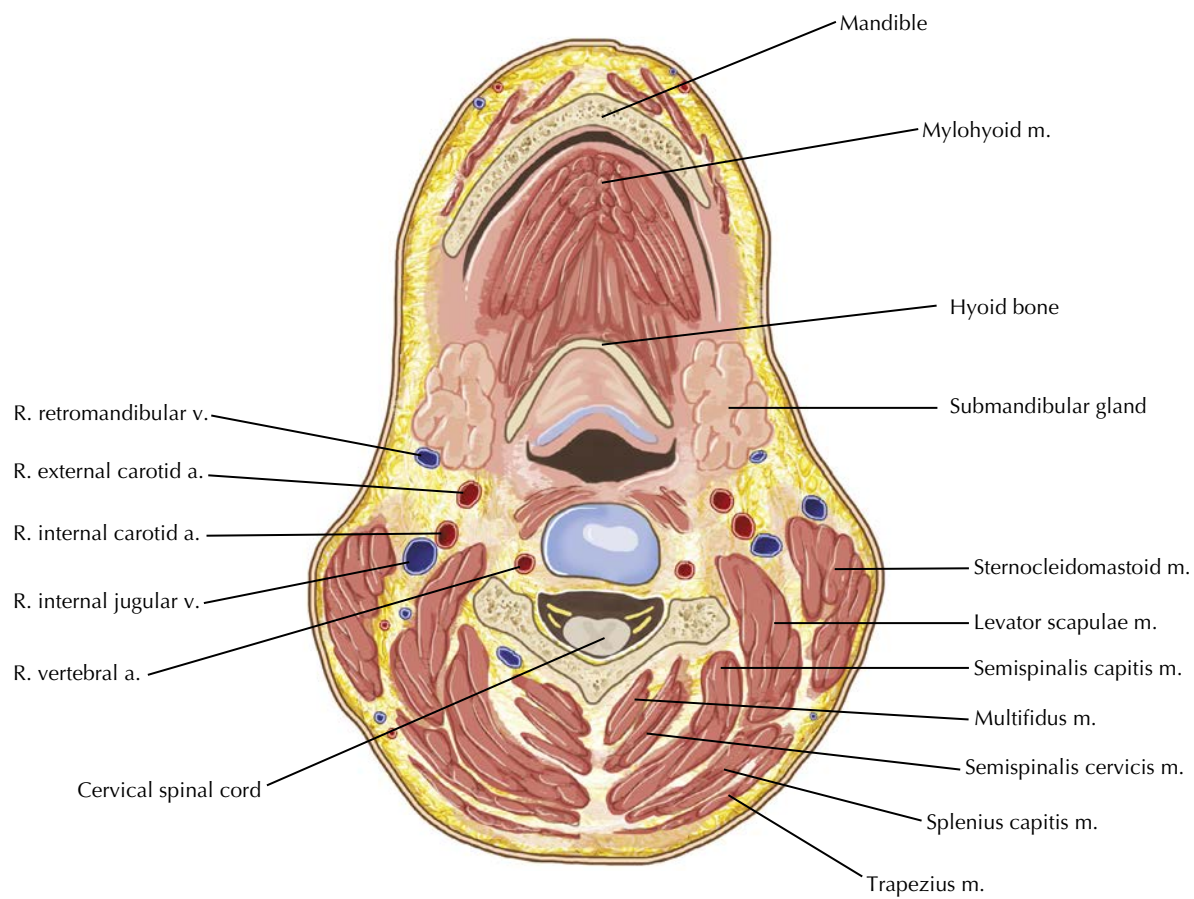


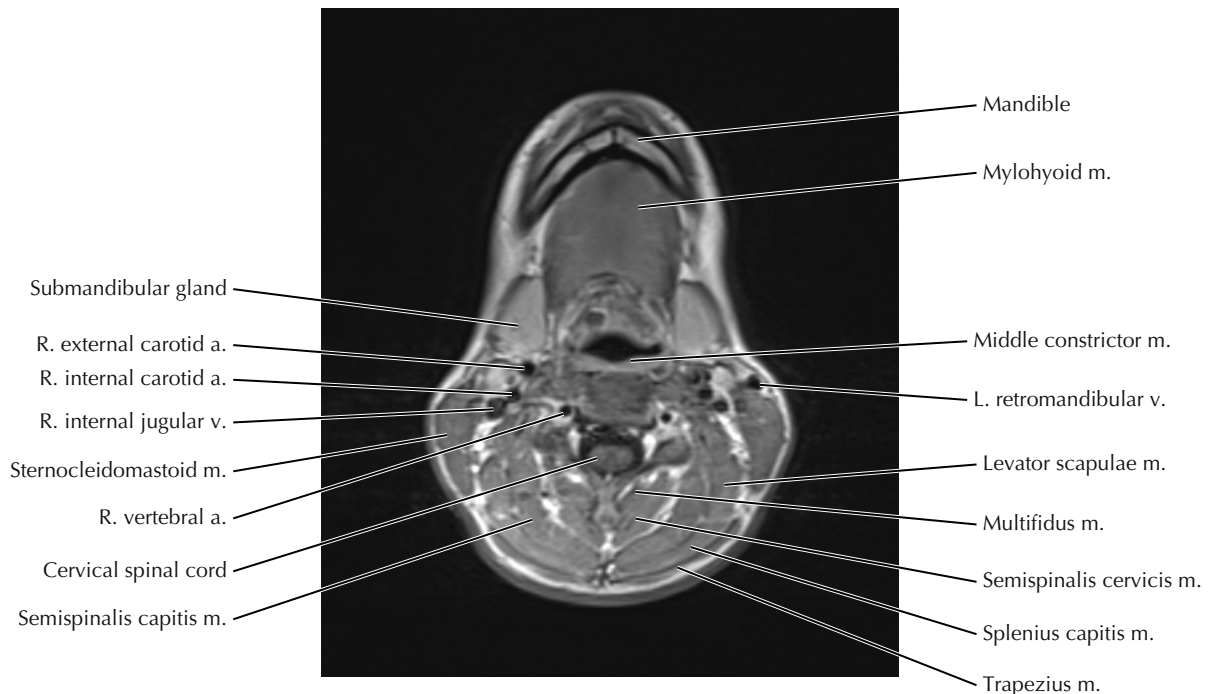
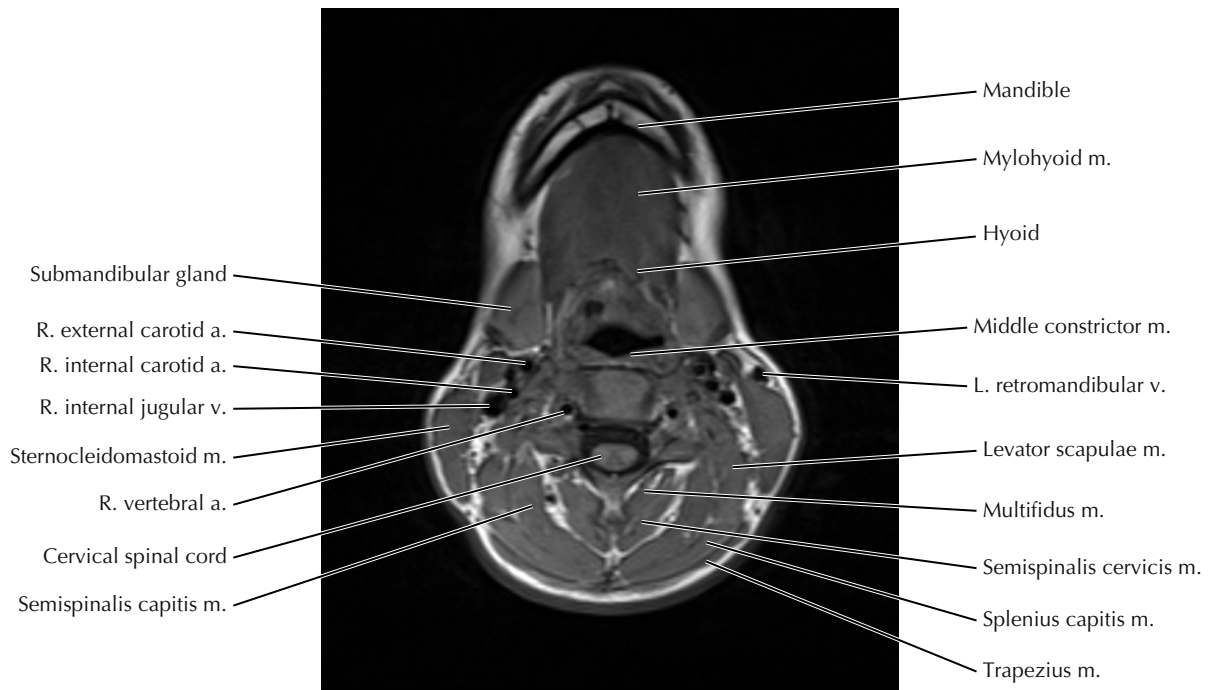
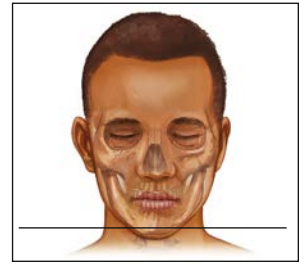


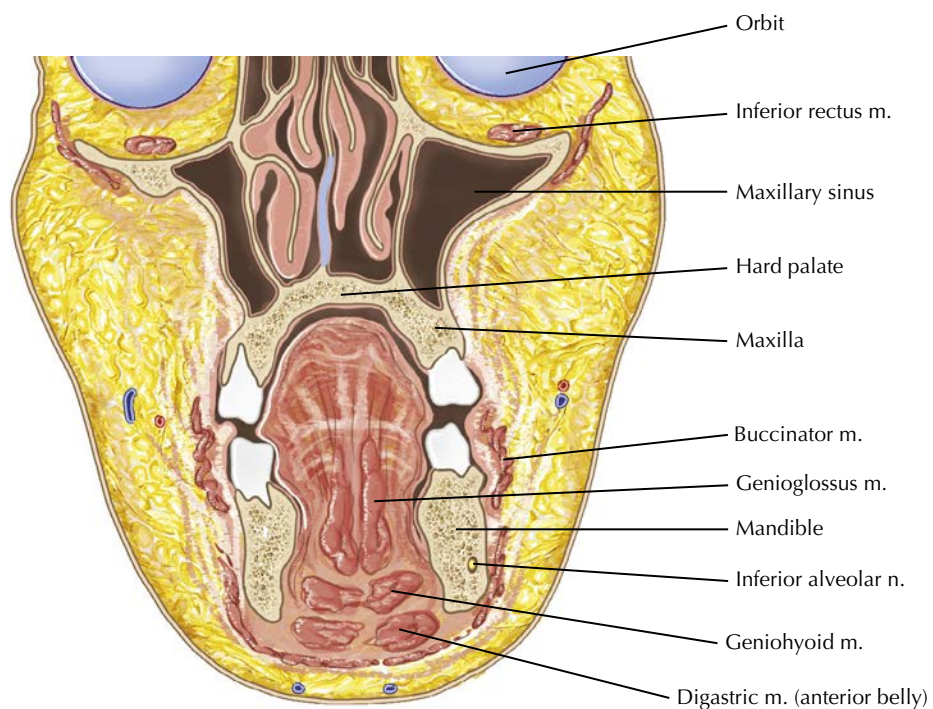








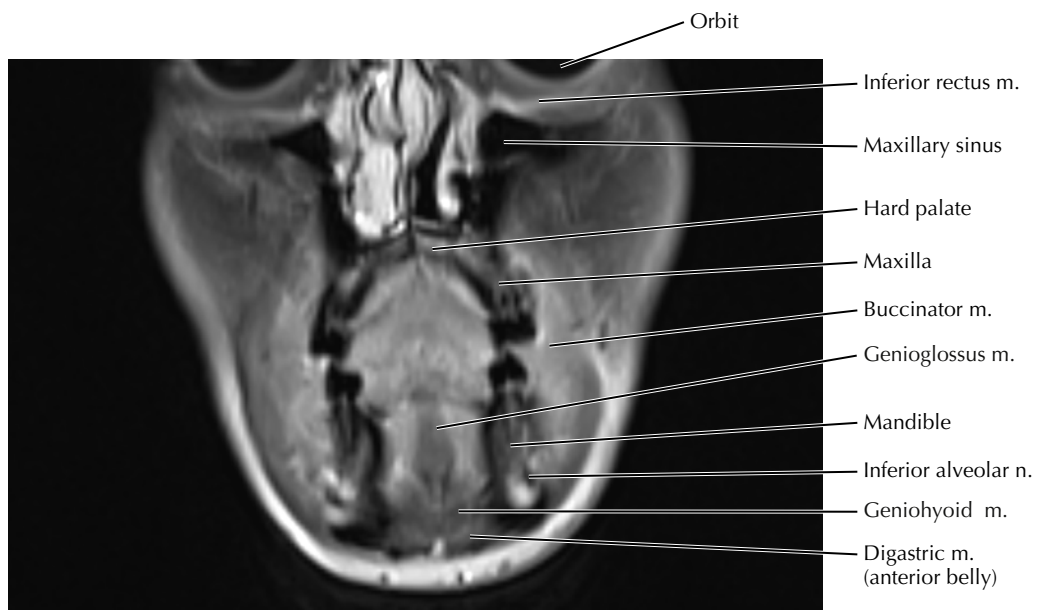
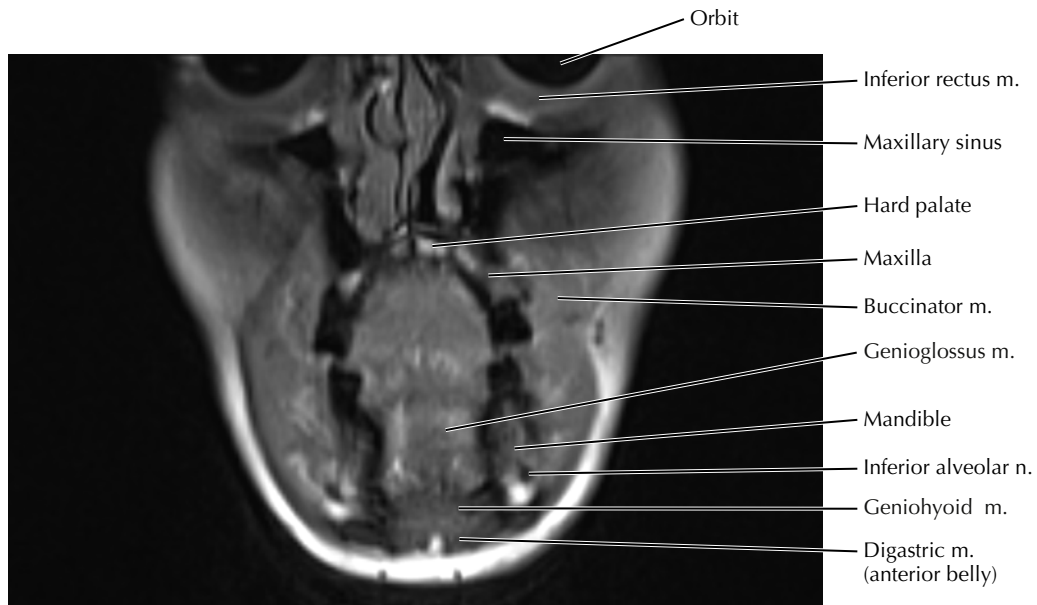
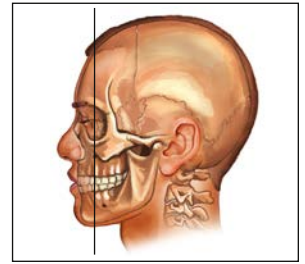


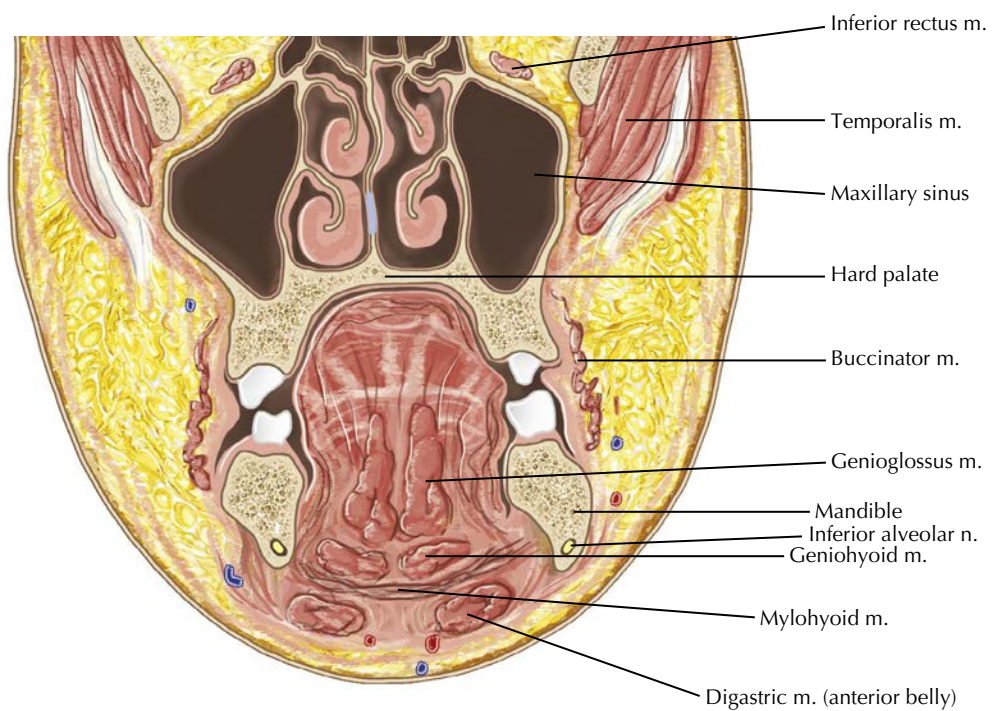


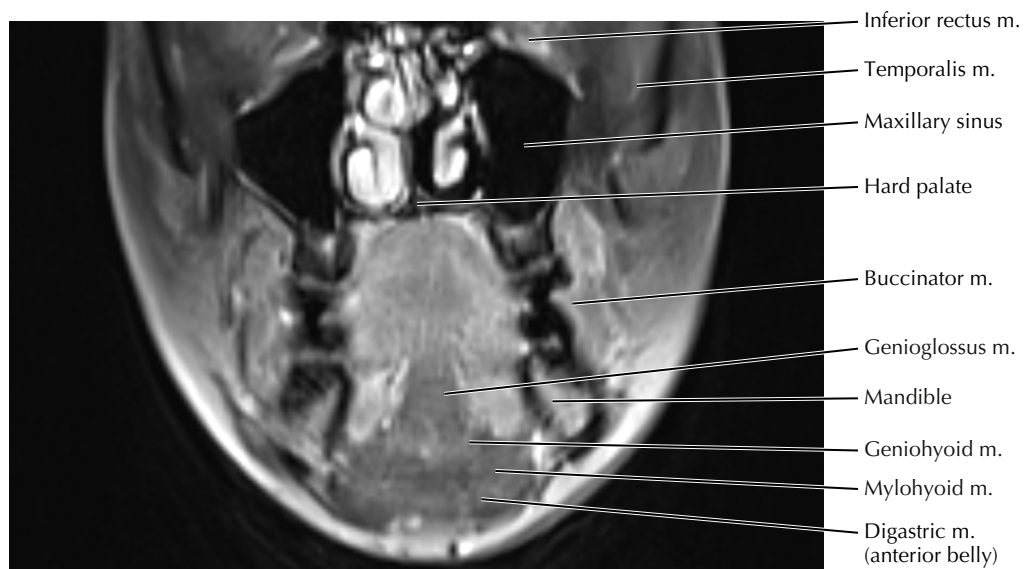
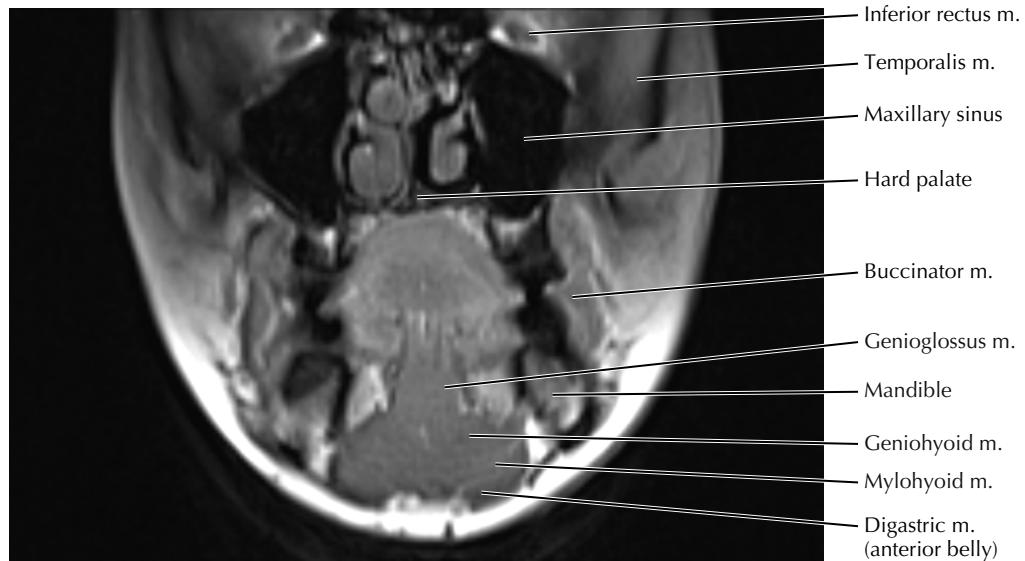
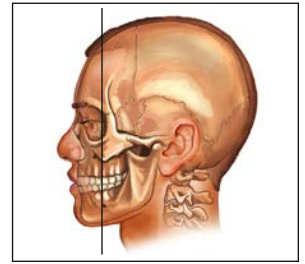
IMAGING TECHNIQUE CONSIDERATION

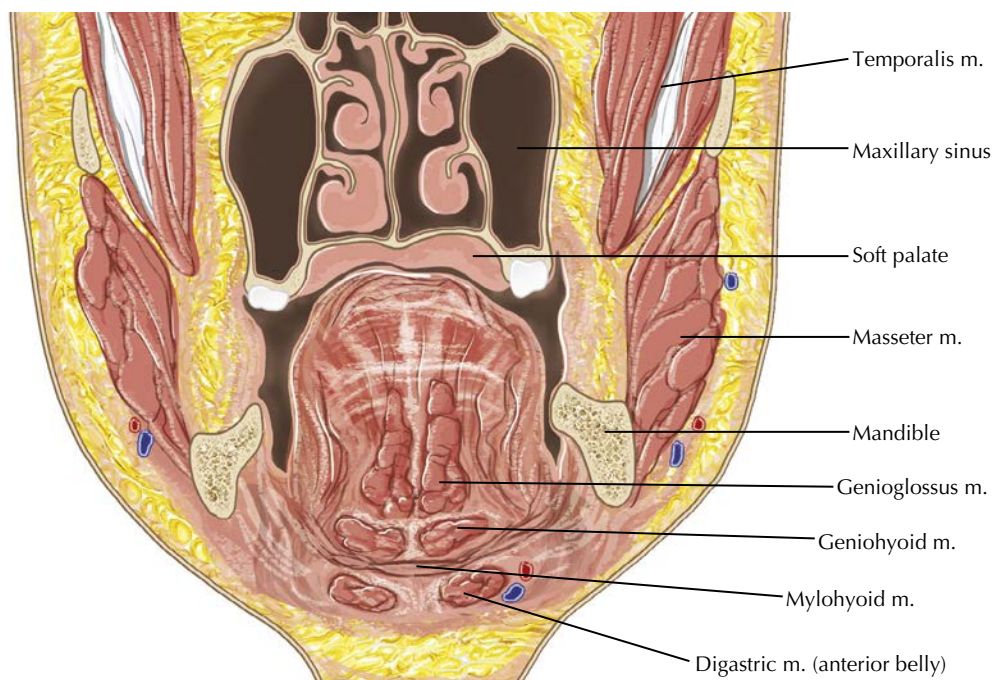
Note the conspicuous contrast enhancement of the mucosal surfaces of the nasal passages on the lower postcontrast T1-weighted MR image in Coronal 1.

ORAL CAVITY, PHARYNX, AND SUPRAHYOID NECK CORONAL 1



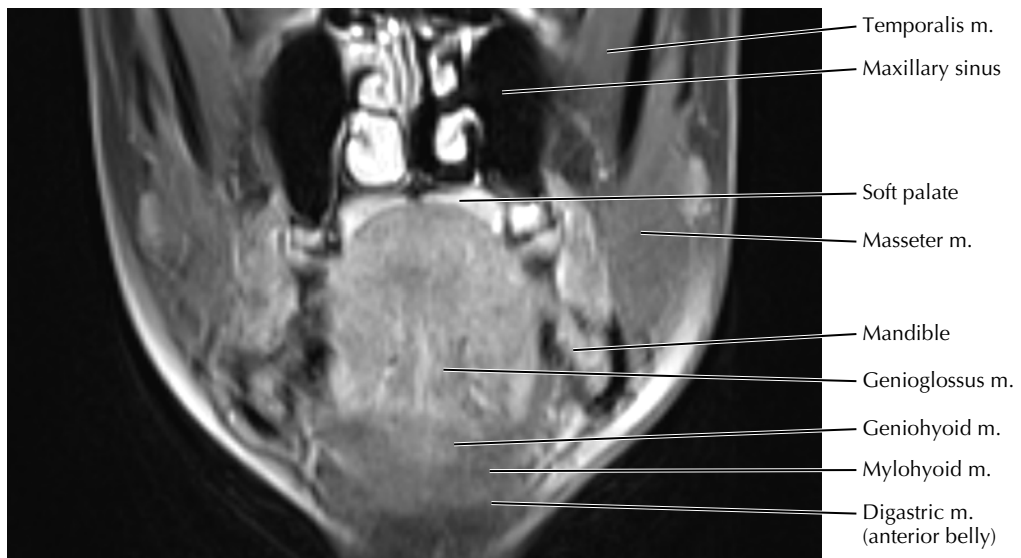
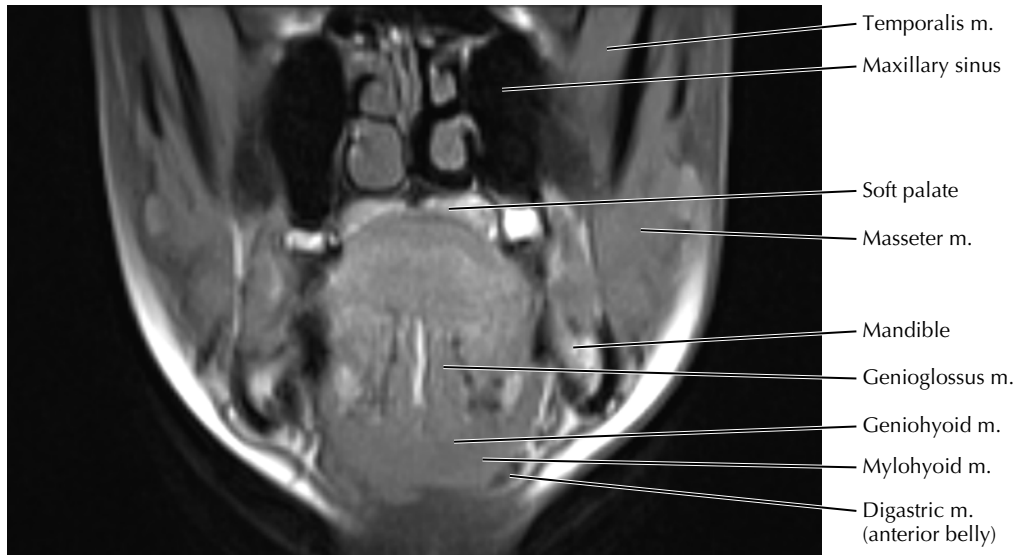
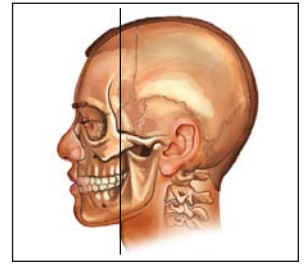


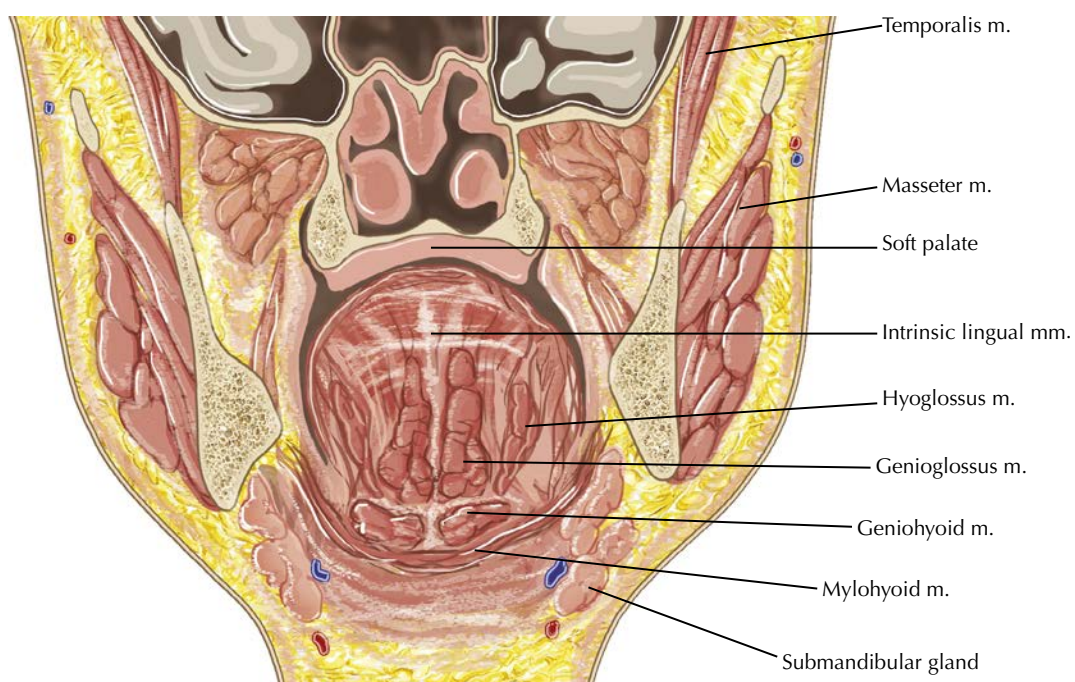


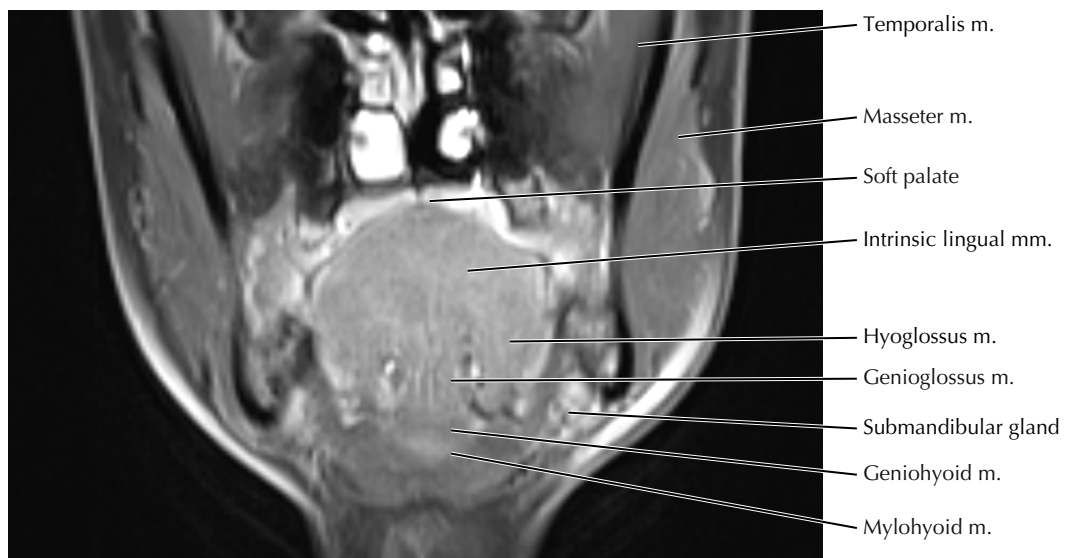
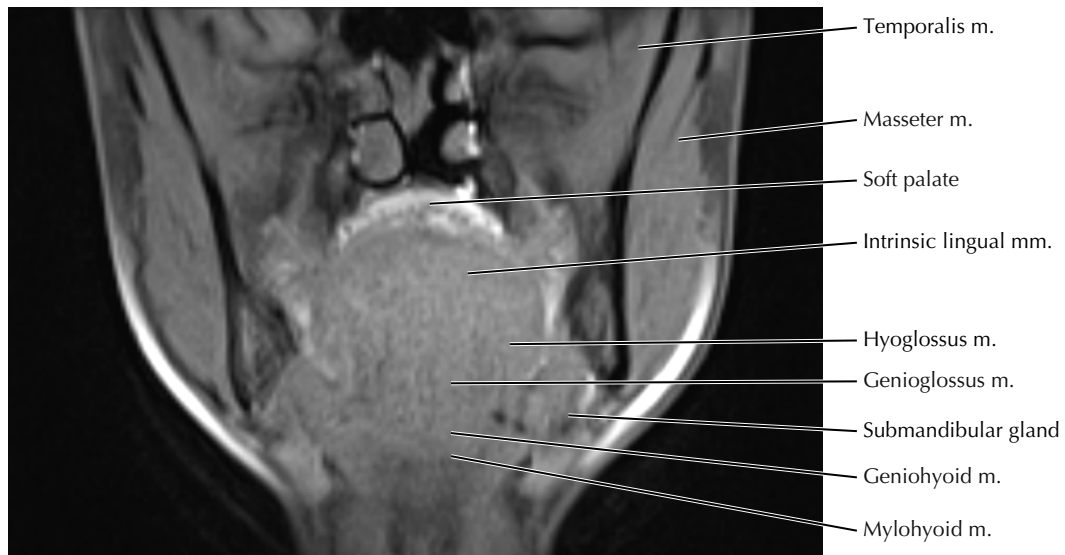
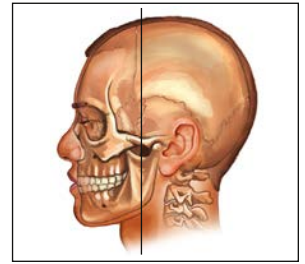


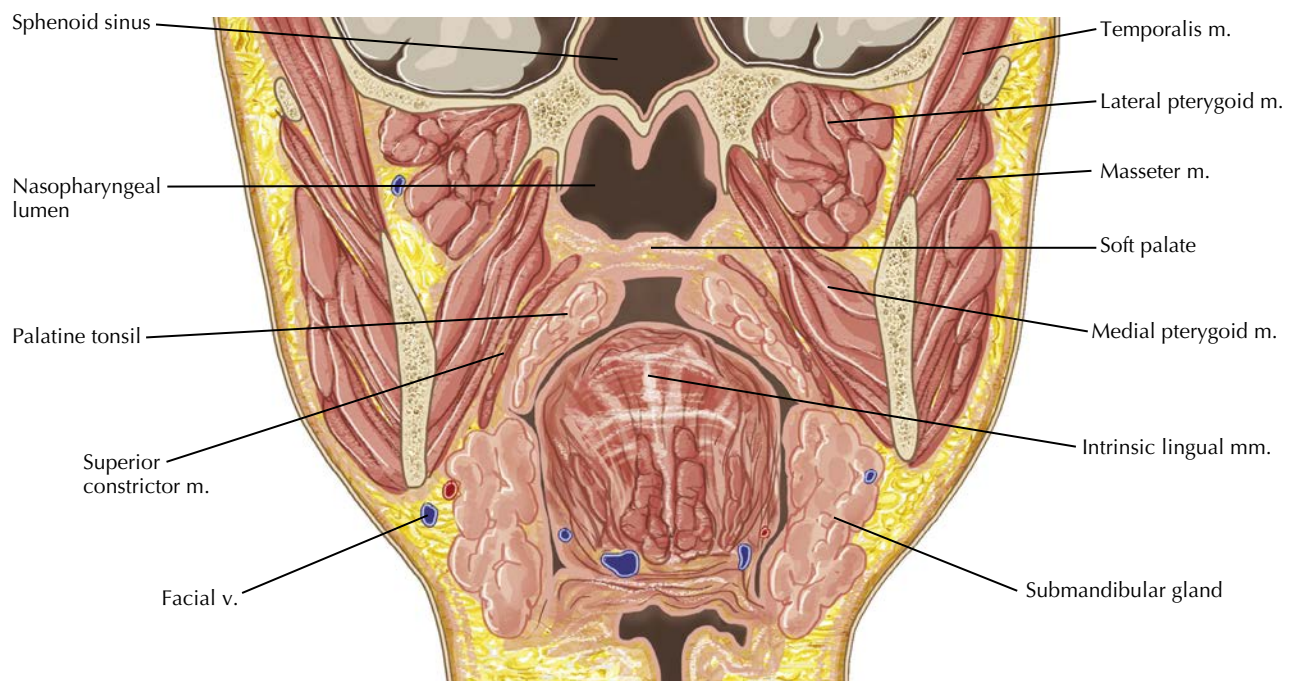
DIAGNOSTIC CONSIDERATION

Coronal imaging is often the best plane on MRI to assess a tongue lesion extending into the floor of mouth. The floor of the mouth is supported by the mylohyoid muscle (Greek *mylai*, "molar teeth"), which courses from the mandible to the hyoid bone.

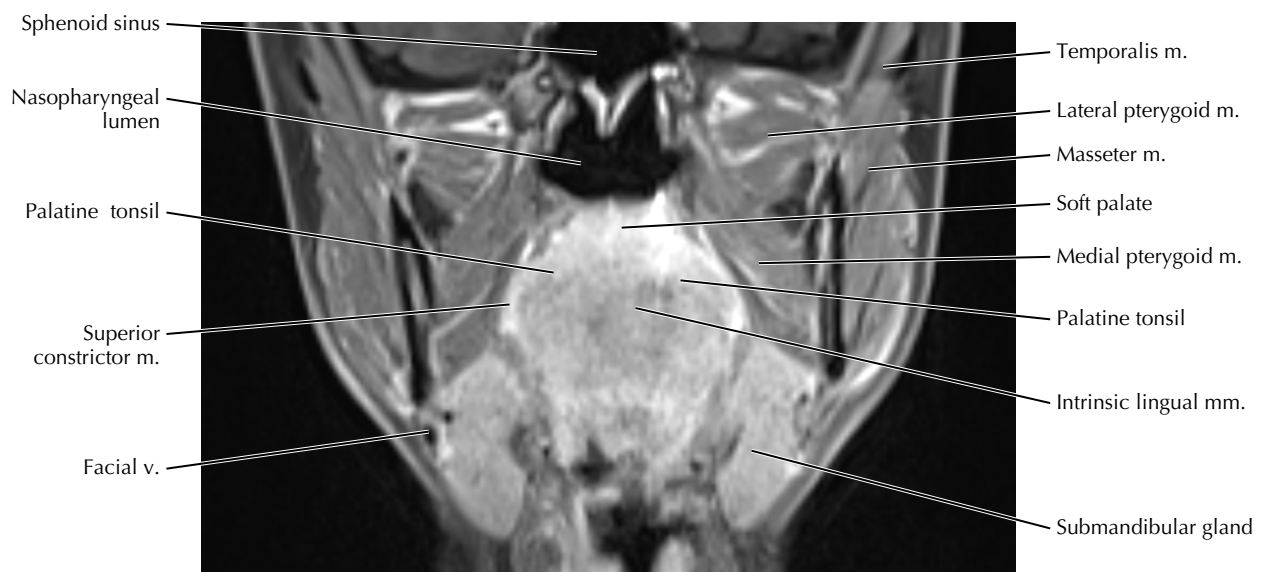
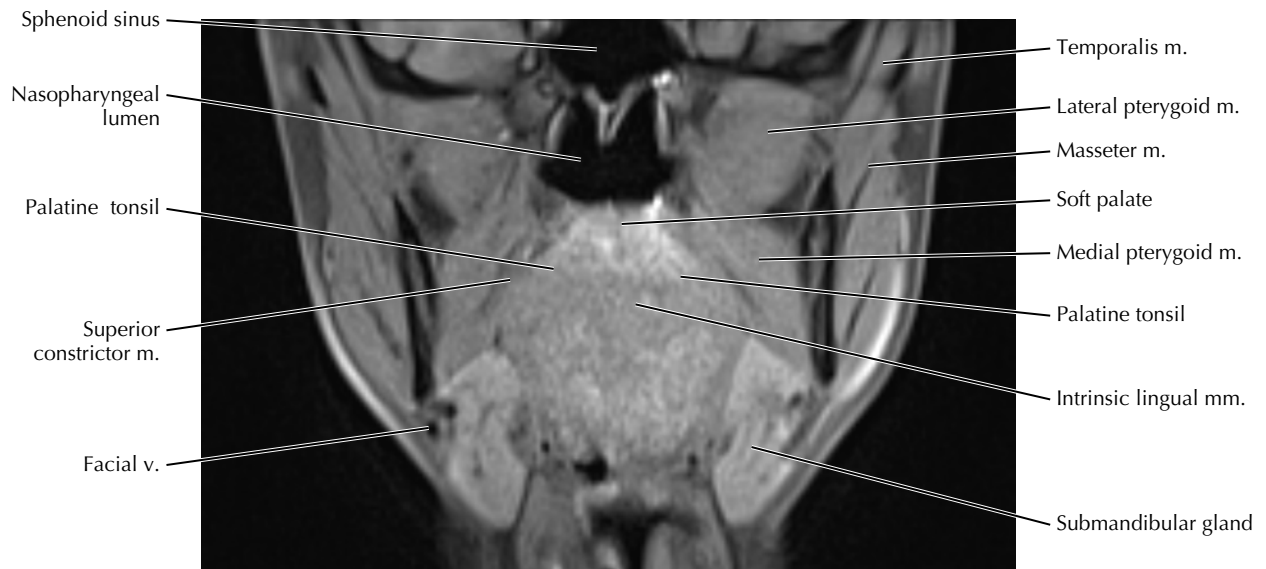
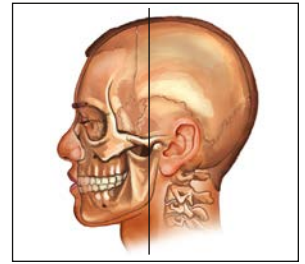


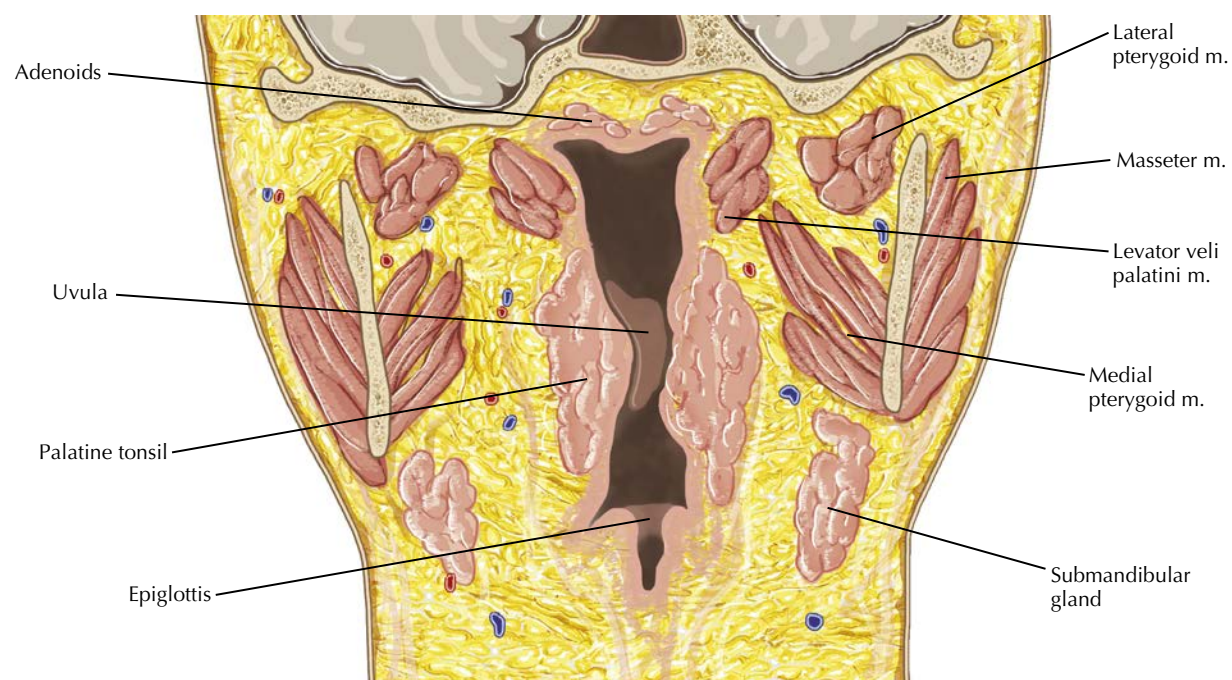


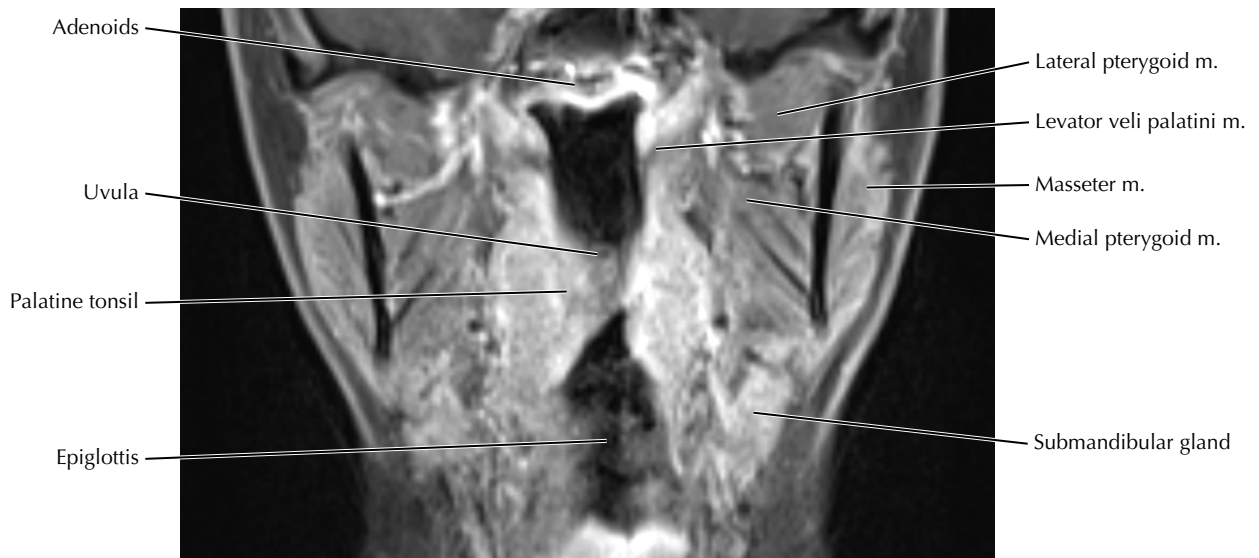
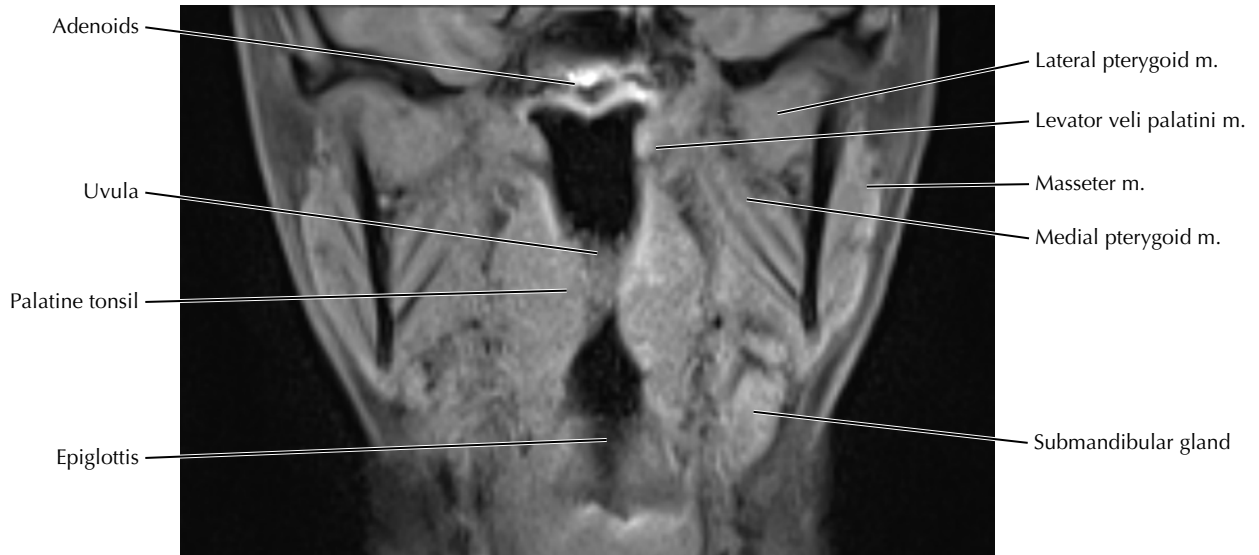
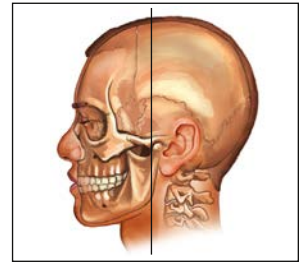


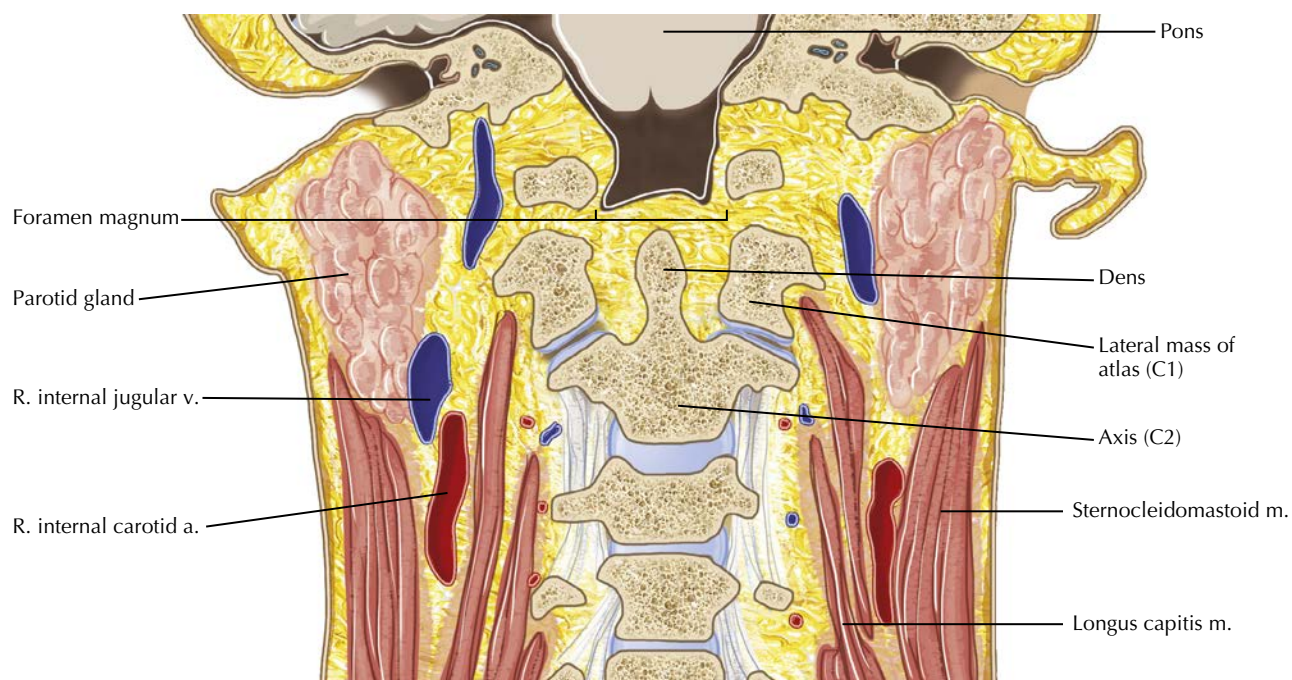


ORAL CAVITY, PHARYNX, AND SUPRAHYOID NECK CORONAL 5



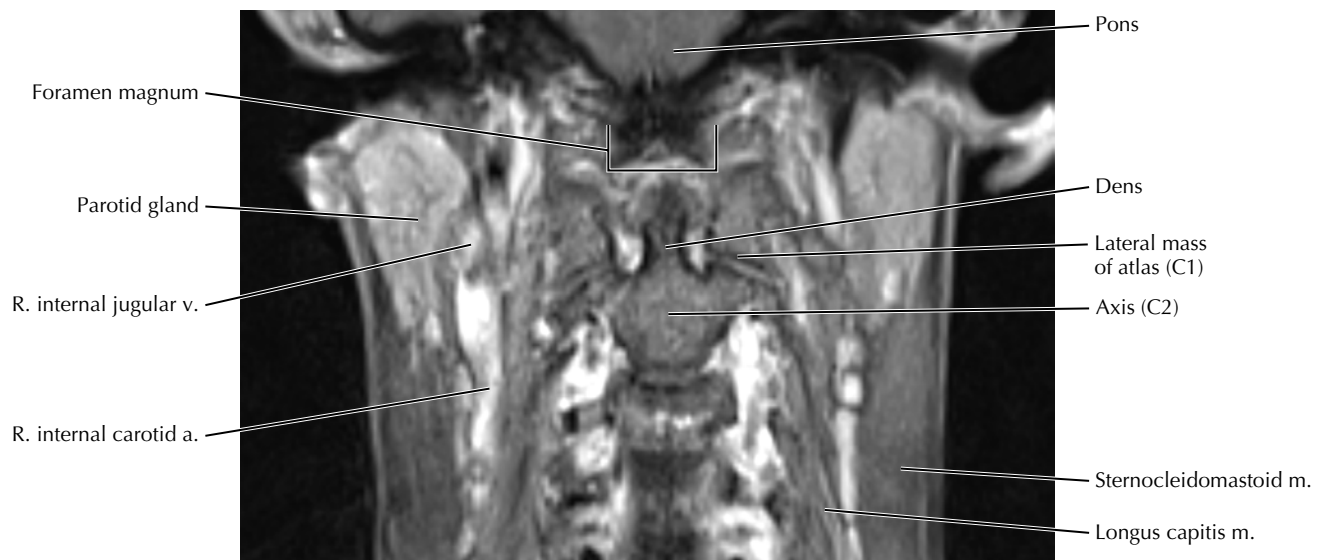
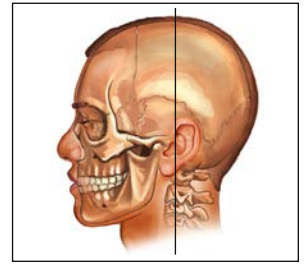


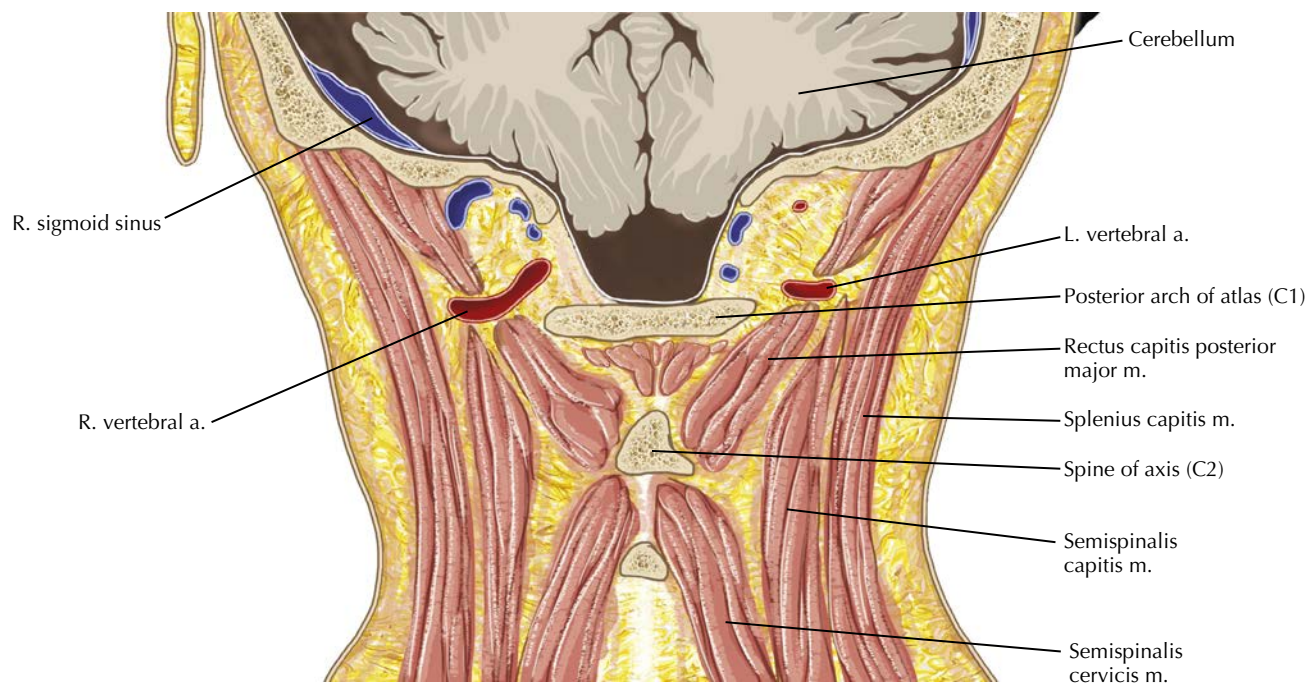




DIAGNOSTIC CONSIDERATION

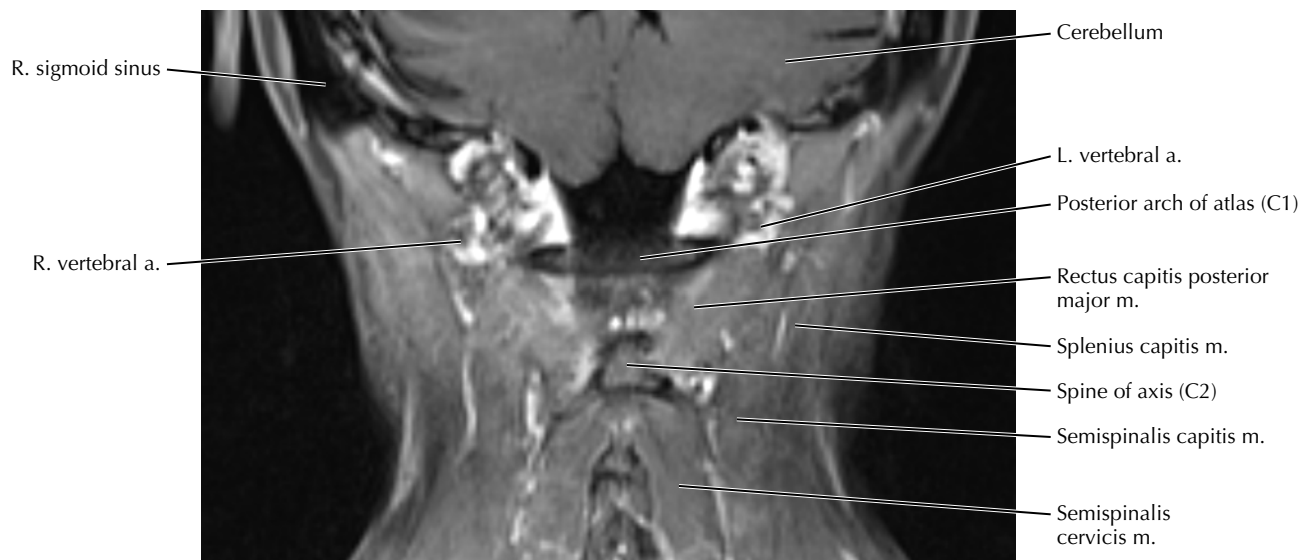
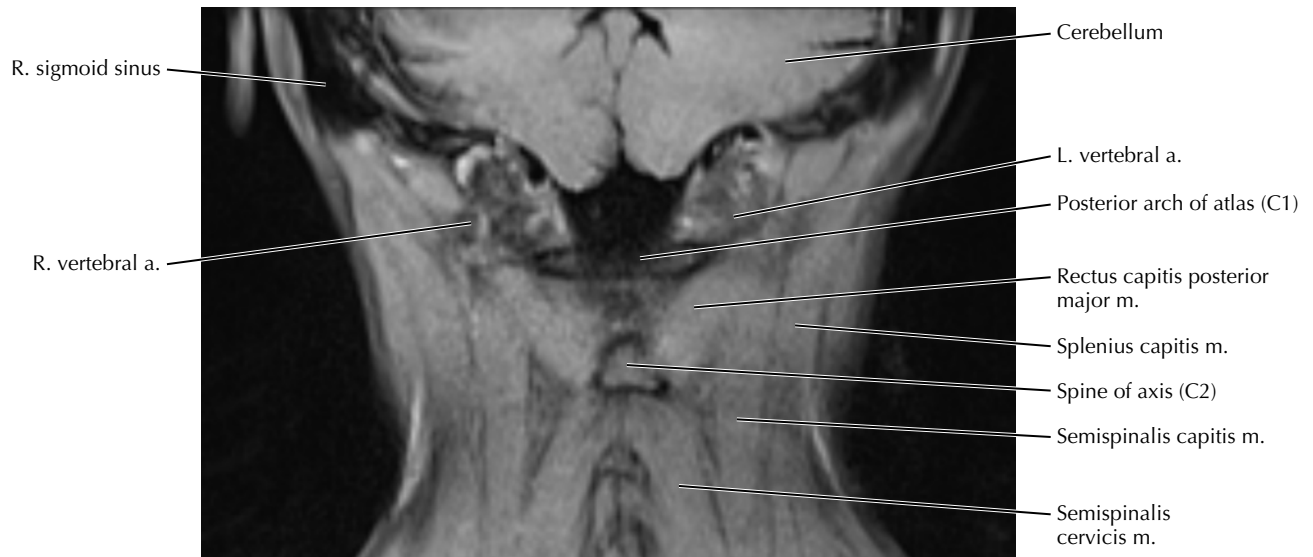
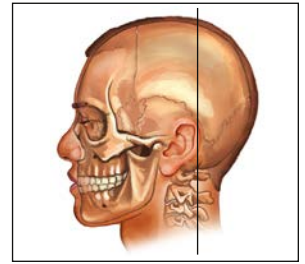
Although axial imaging is the plane conventionally used for measuring the long axis of neck lymph nodes, the coronal plane is often useful for visualizing the entire craniocaudal length of the jugular and spinal accessory lymph node chains.

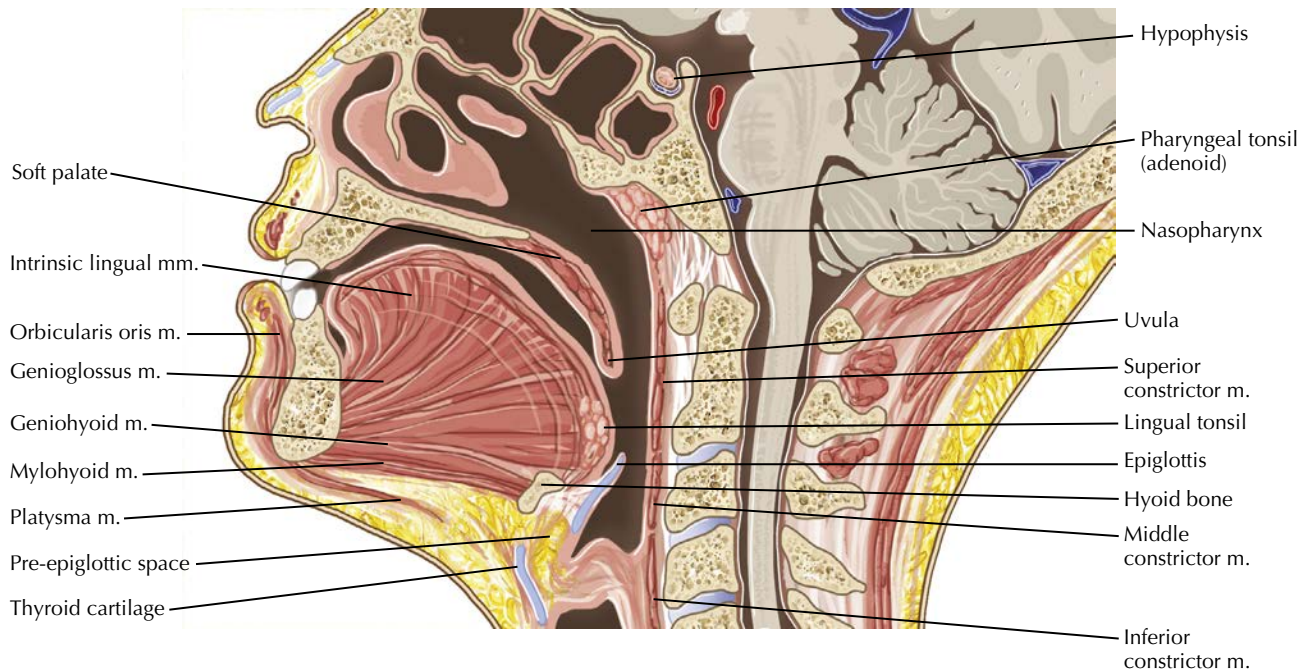




DIAGNOSTIC CONSIDERATION

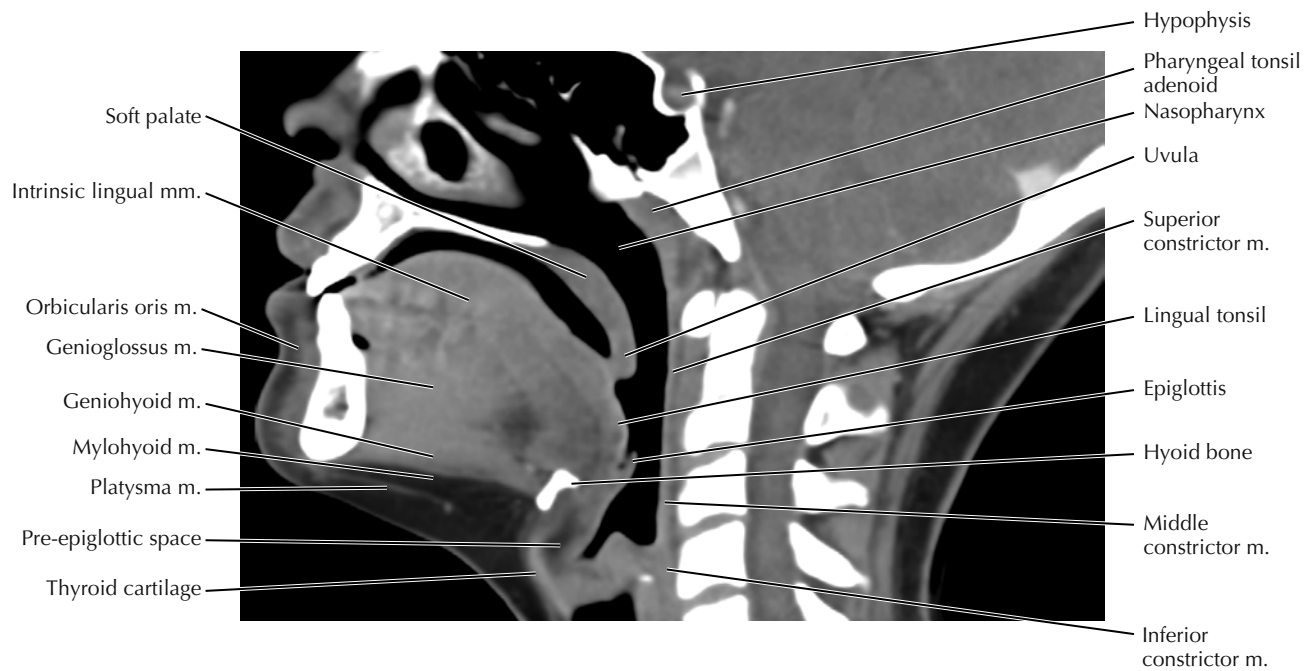
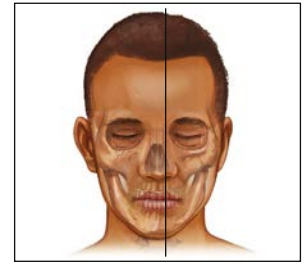
Tumors may arise from muscle, such as leiomyosarcoma, but are relatively rare. Muscles are often a source of pain, but this is usually benign. Bone, however, particularly vertebral body marrow, is a common target for metastases.

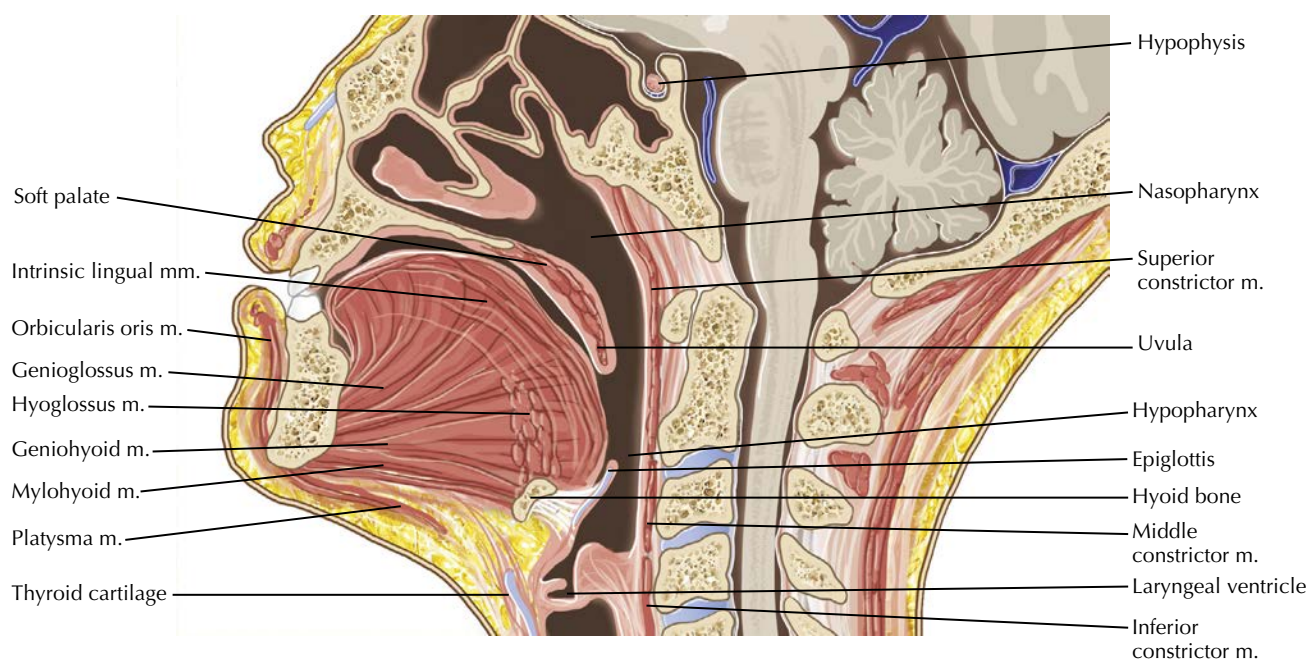




NORMAL ANATOMY

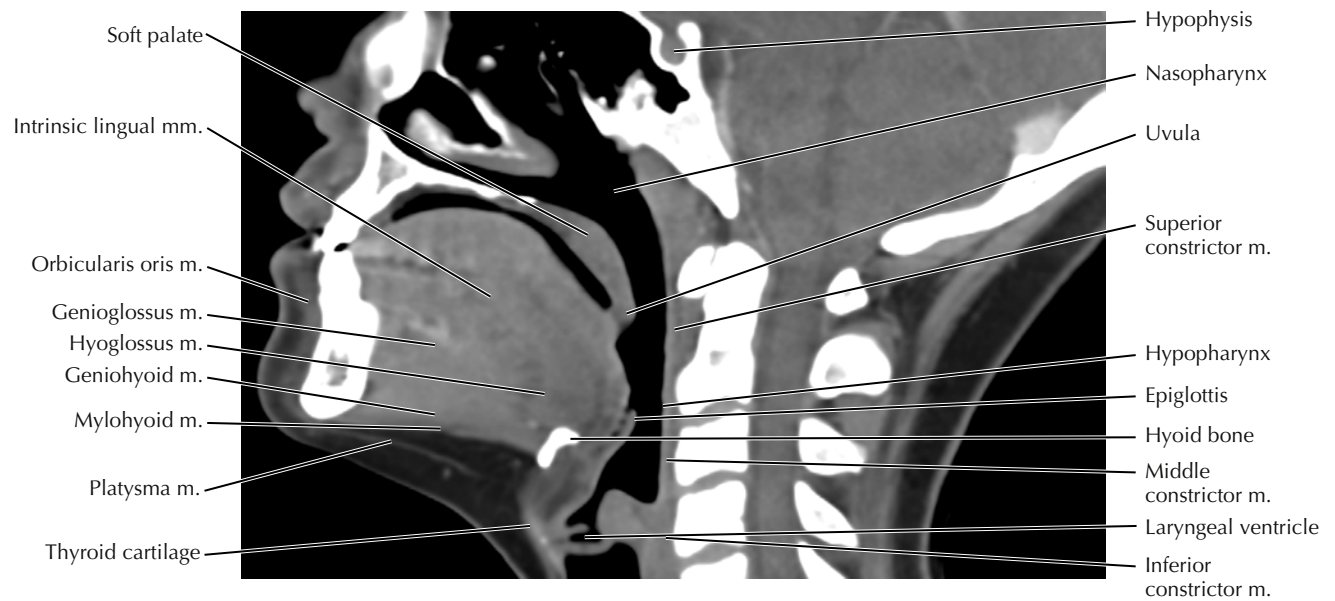
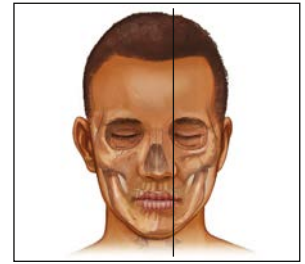
Note that the midline MR image in Sagittal 1 is aligned on the pharynx, which consists of the oropharynx, nasopharynx, and hypopharynx (nose is slightly off midline). The pharyngeal lumen is the common pathway of the respiratory and digestive tracts. Air enters the nose, passes inferiorly and anteriorly to the trachea, crossing over the path of food entering the mouth, which then passes inferiorly and posteriorly to the esophagus. The anterior location of the trachea allows for safe percutaneous access through the cricothyroid membrane in patients with upper airway obstruction at or above the level of the vocal cords.

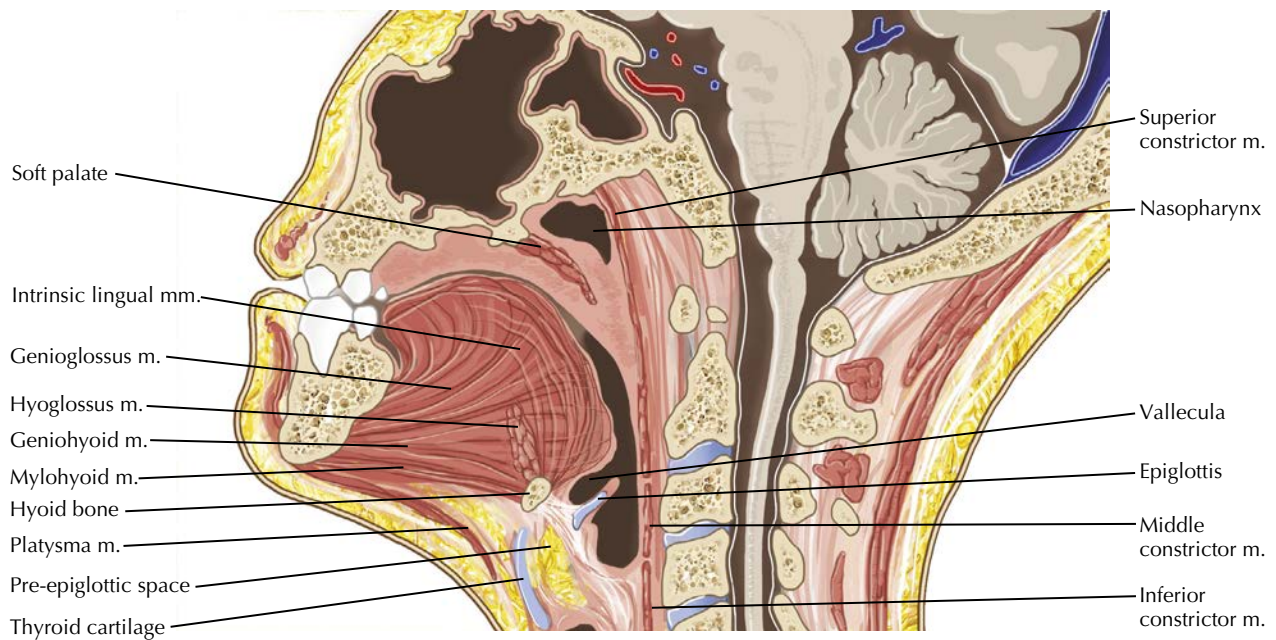




DIAGNOSTIC CONSIDERATION

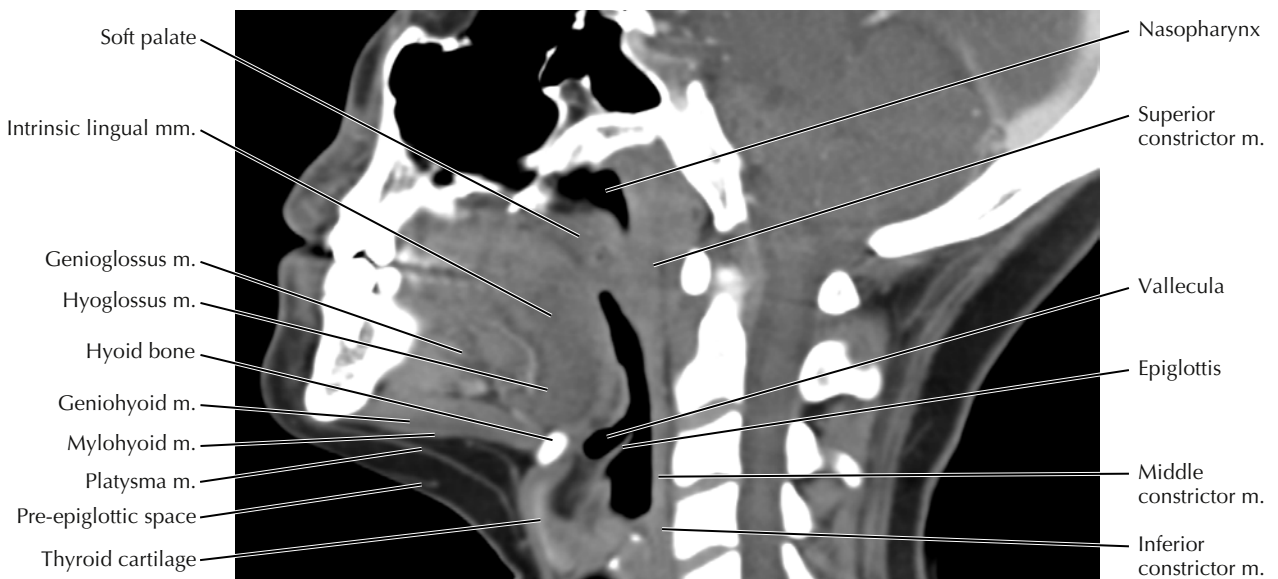
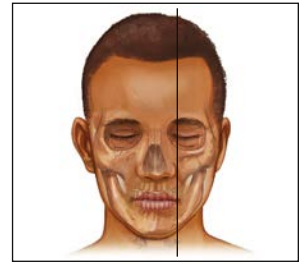
Sagittal imaging may be the best plane for assessing invasion by nasopharyngeal carcinoma into the clivus or incidental metastasis of vertebral bodies.

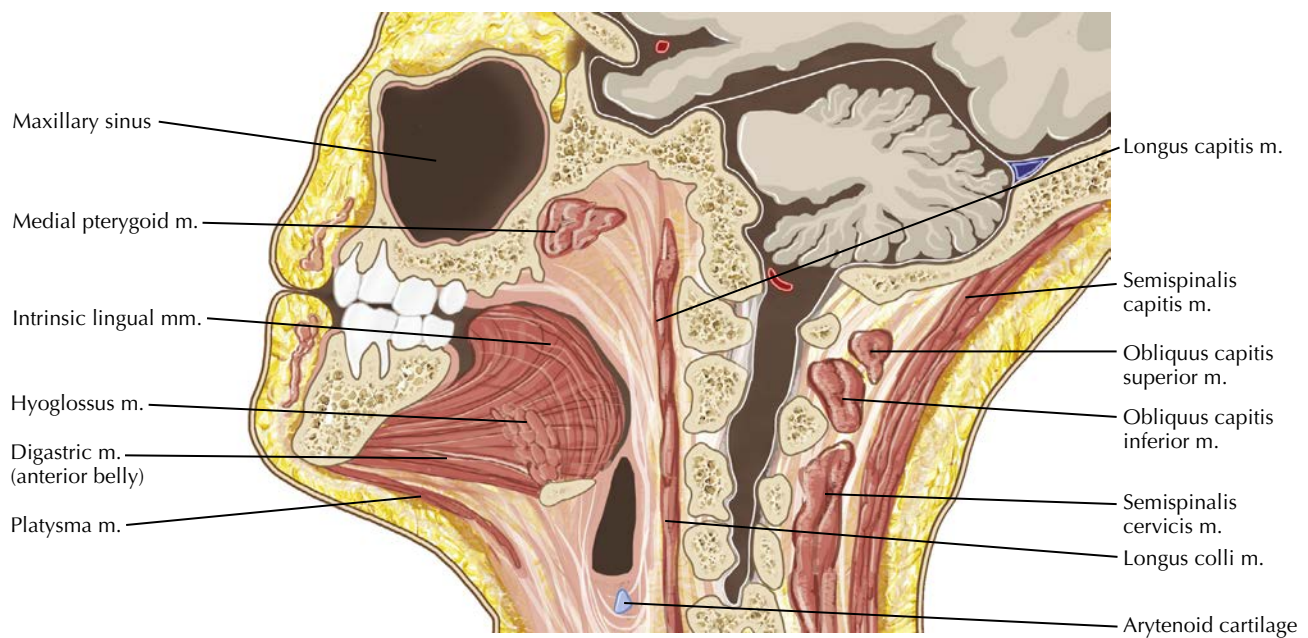


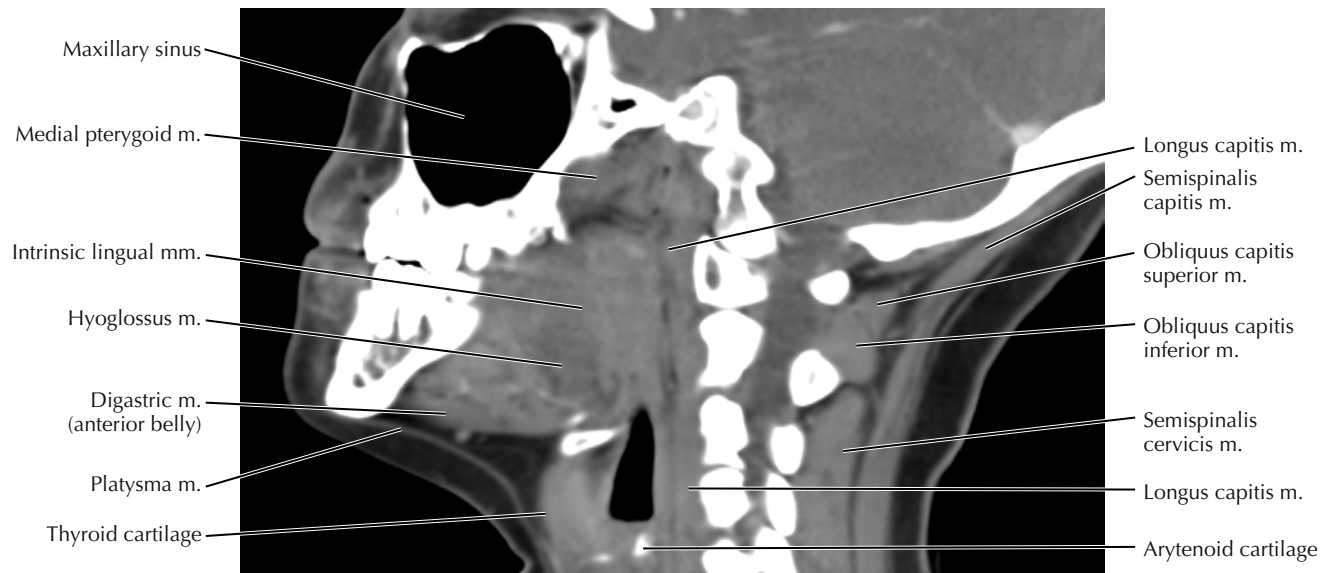
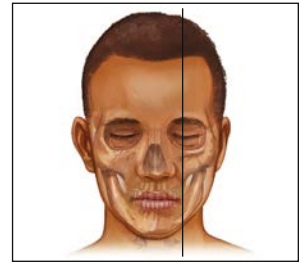


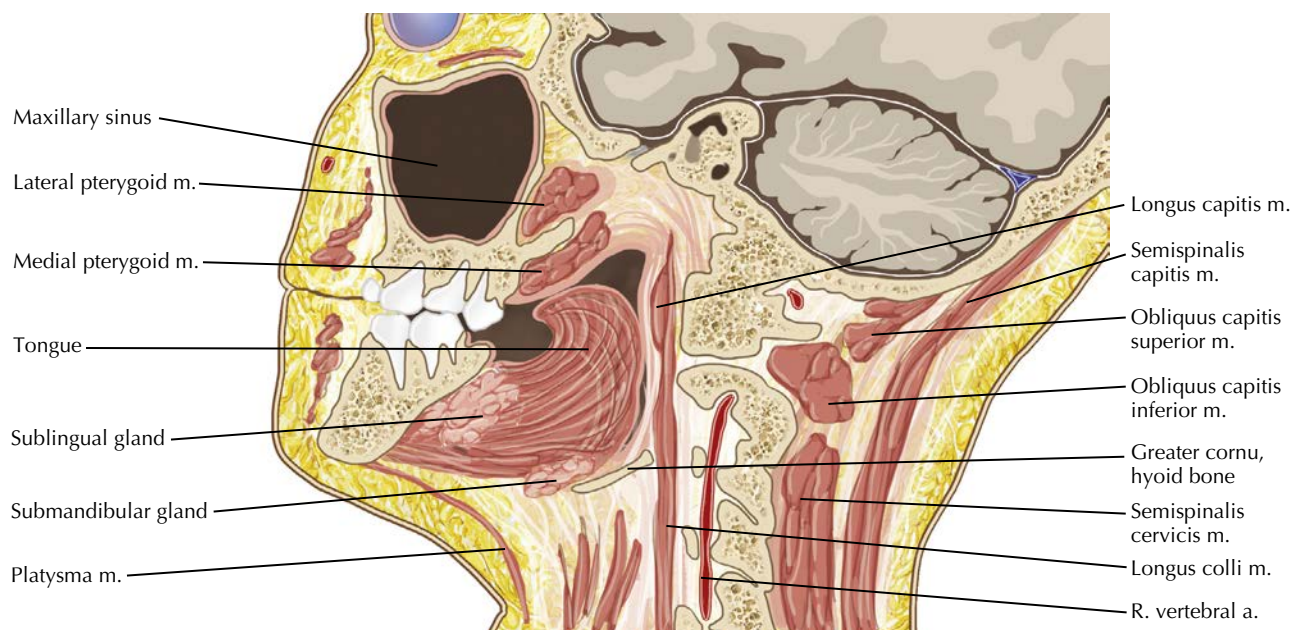
PATHOLOGIC PROCESS

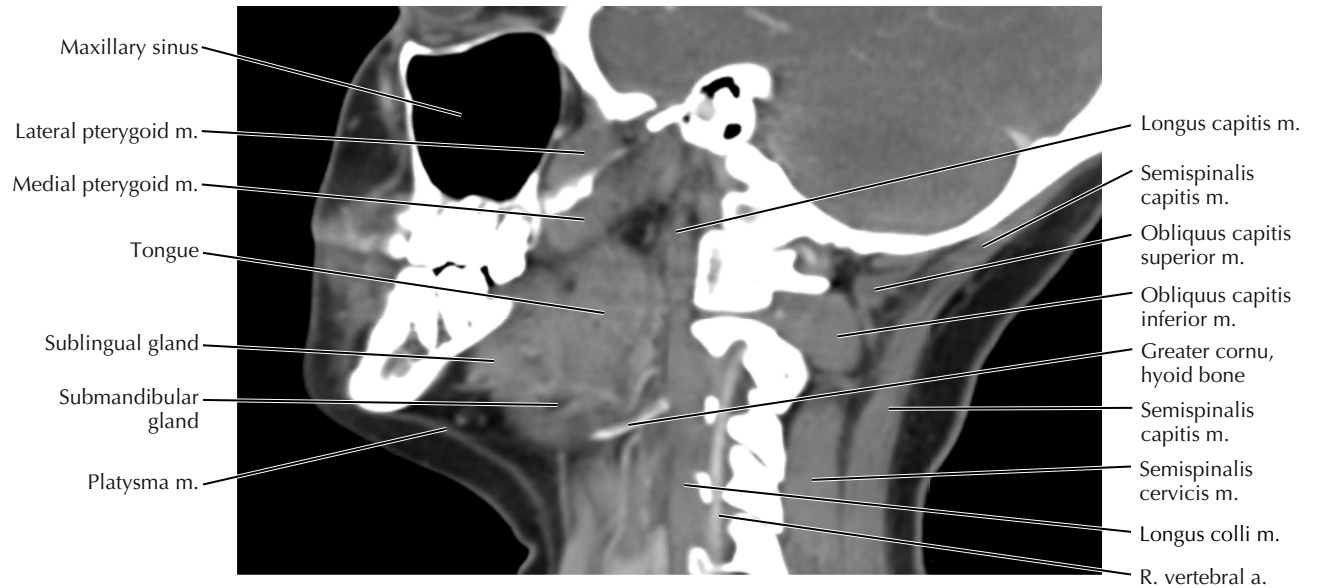
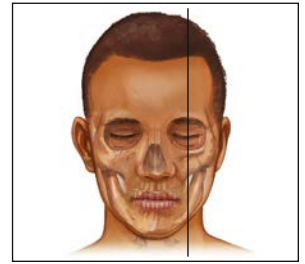
Note the thinness of the epiglottis. Marked thickening of the epiglottis may result from viral infection (supraglottitis, epiglottitis) in children. The "thumbprint" sign on lateral radiographs identifies epiglottic thickening, which can lead to life-threatening airway obstruction. With the advent of *Haemophilus influenzae* type B vaccine, the incidence of supraglottitis has decreased greatly. Currently, the most common reason for epiglottic thickening is post-radiation therapy changes in adult patients.

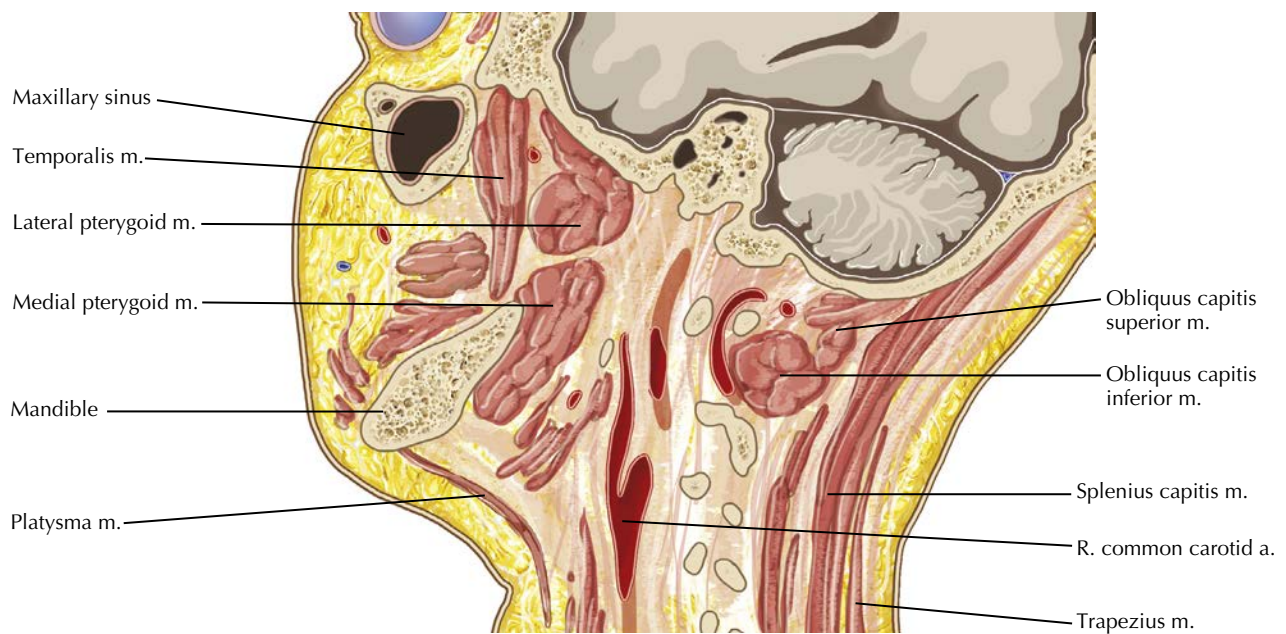


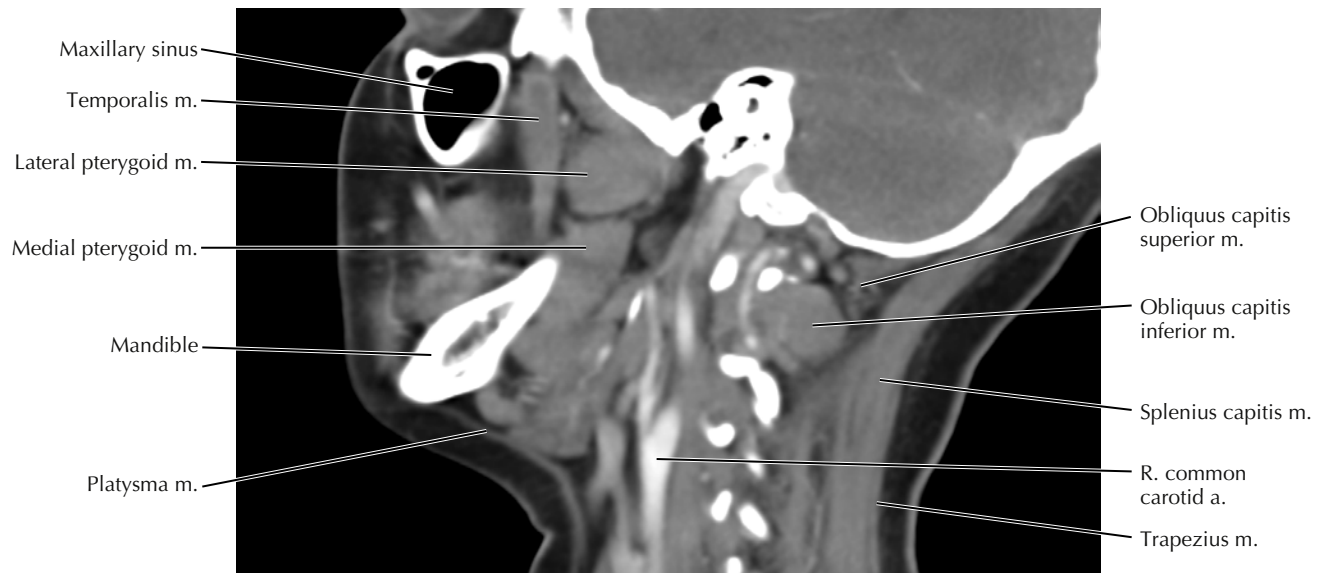
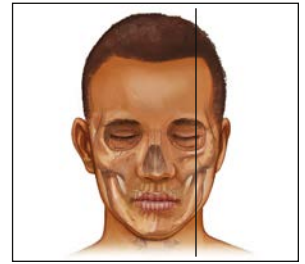


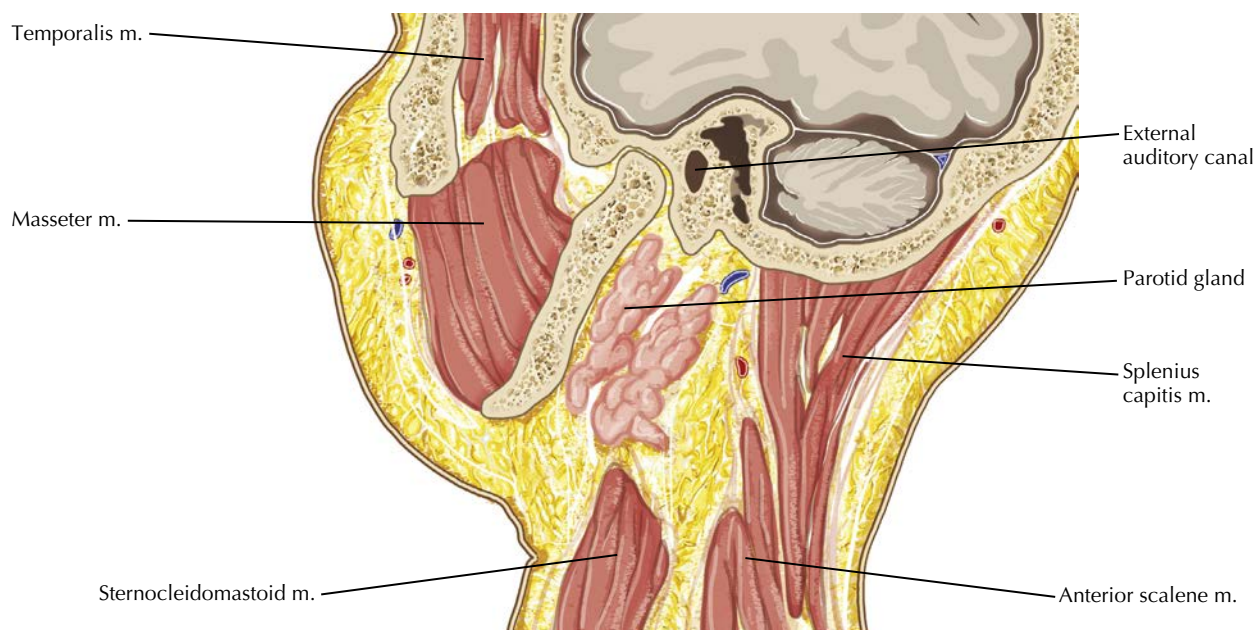






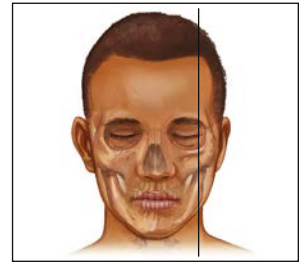


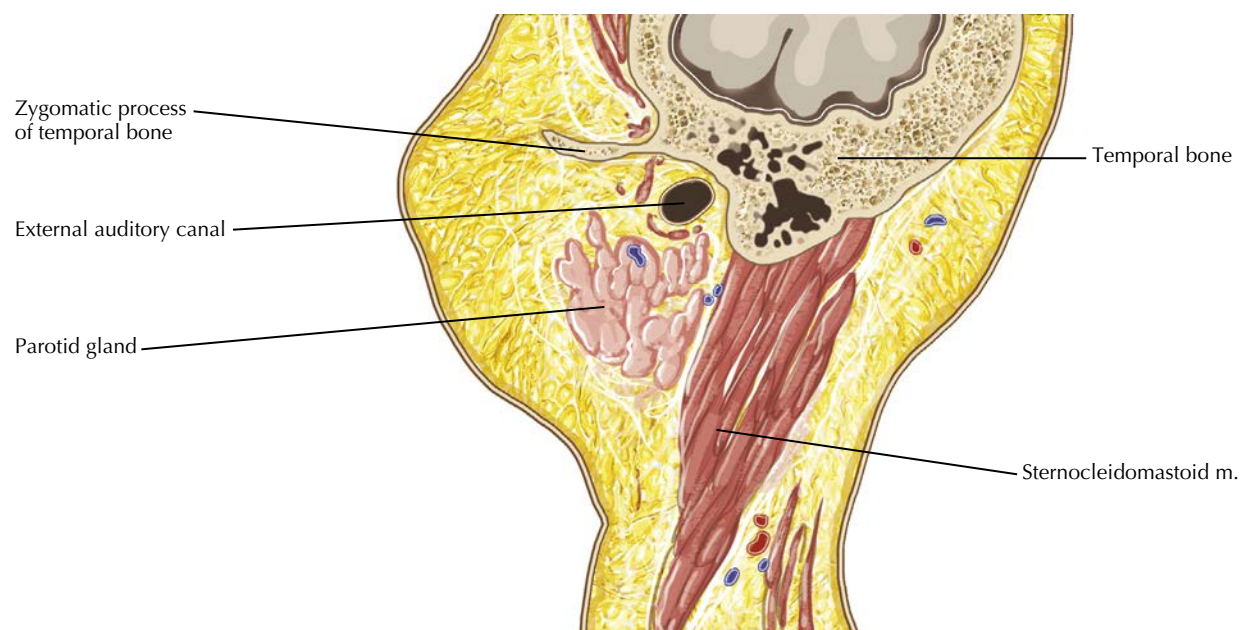


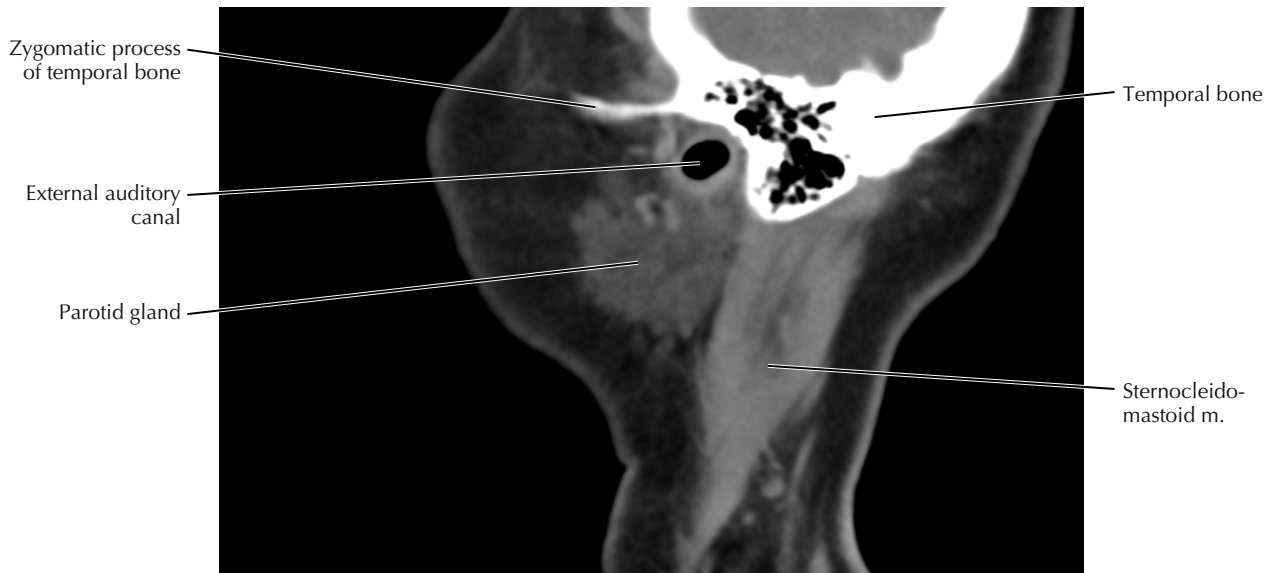
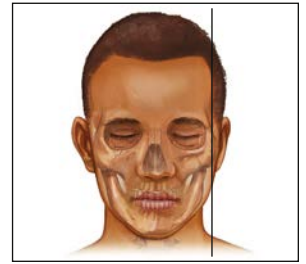


DIAGNOSTIC CONSIDERATION

The off-midline sagittal CT images are typically of limited diagnostic utility given the lack of symmetry as on axial images. Certain structures, however, such as the occipitocervical junction and facet joints, can be better assessed on the sagittal plane.





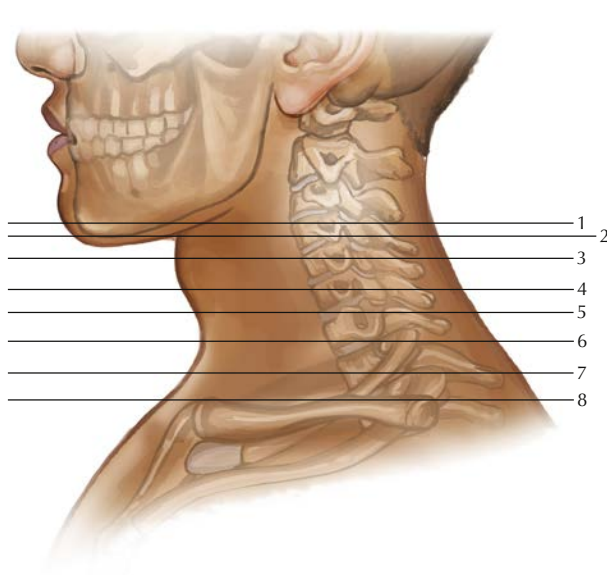


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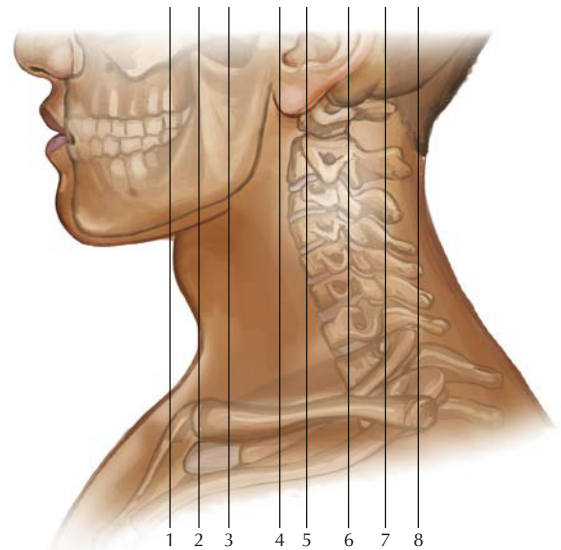
Chapter

14

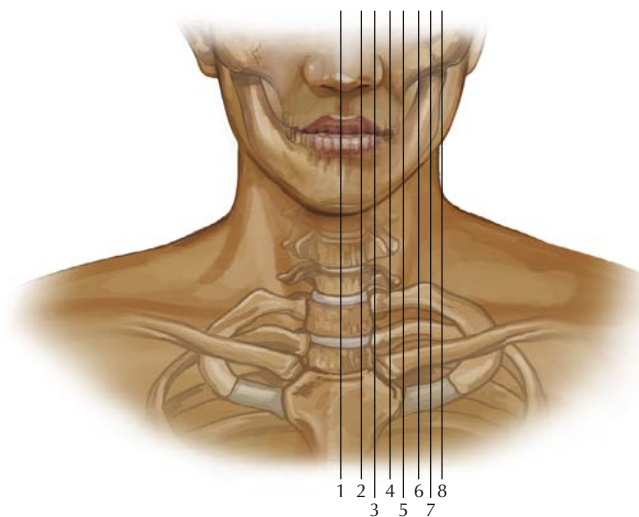
HYPOPHARYNX,
LARYNX, AND
INFRAHYOID
NECK



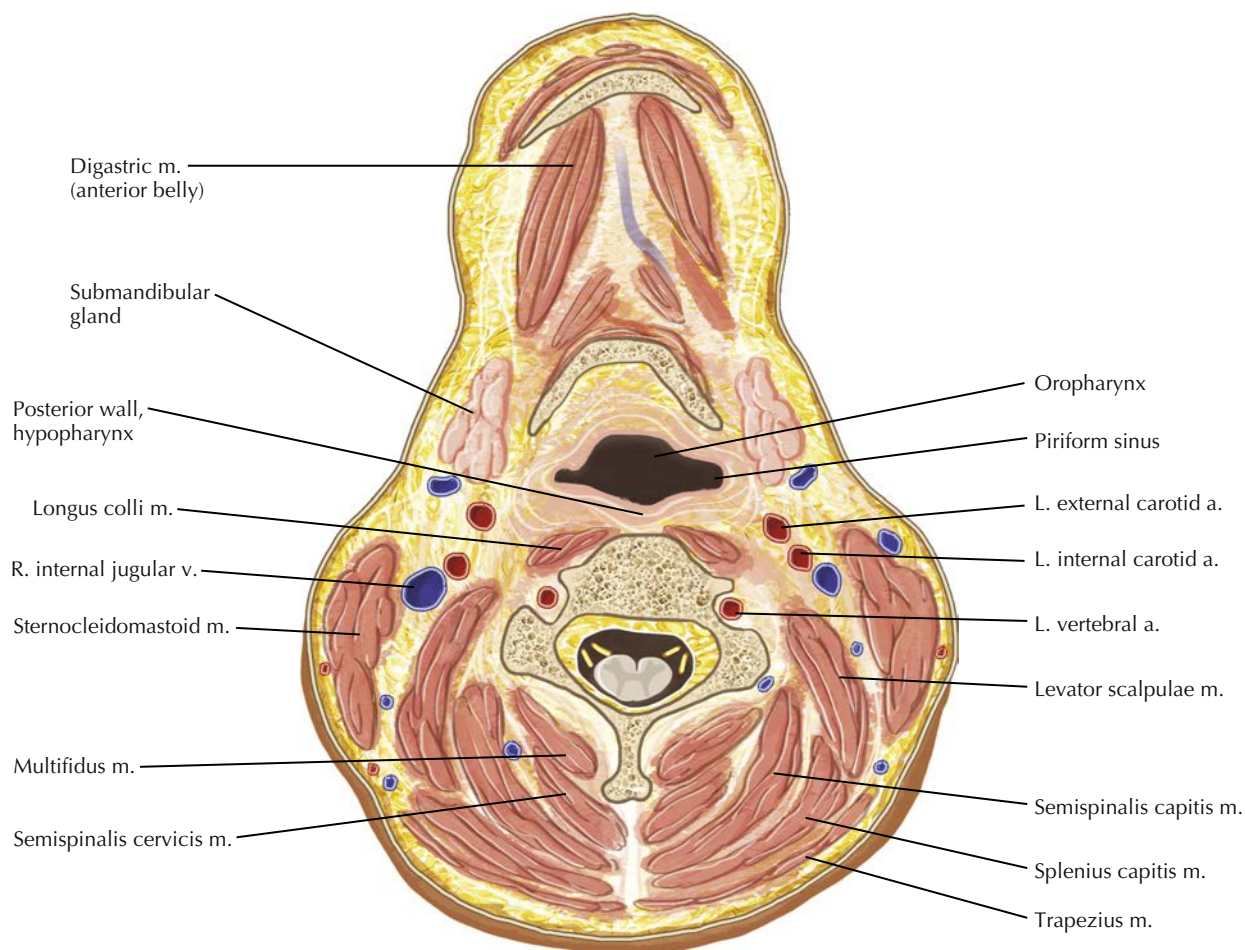
AXIAL 472



CORONAL 488



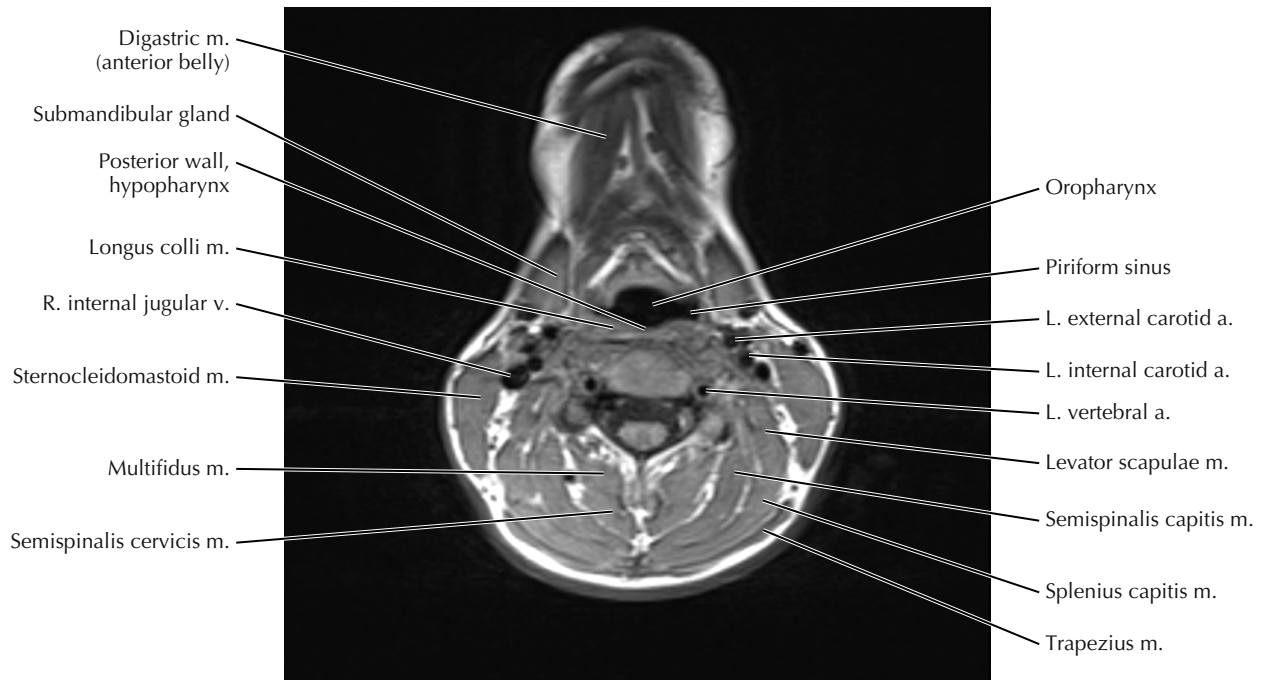
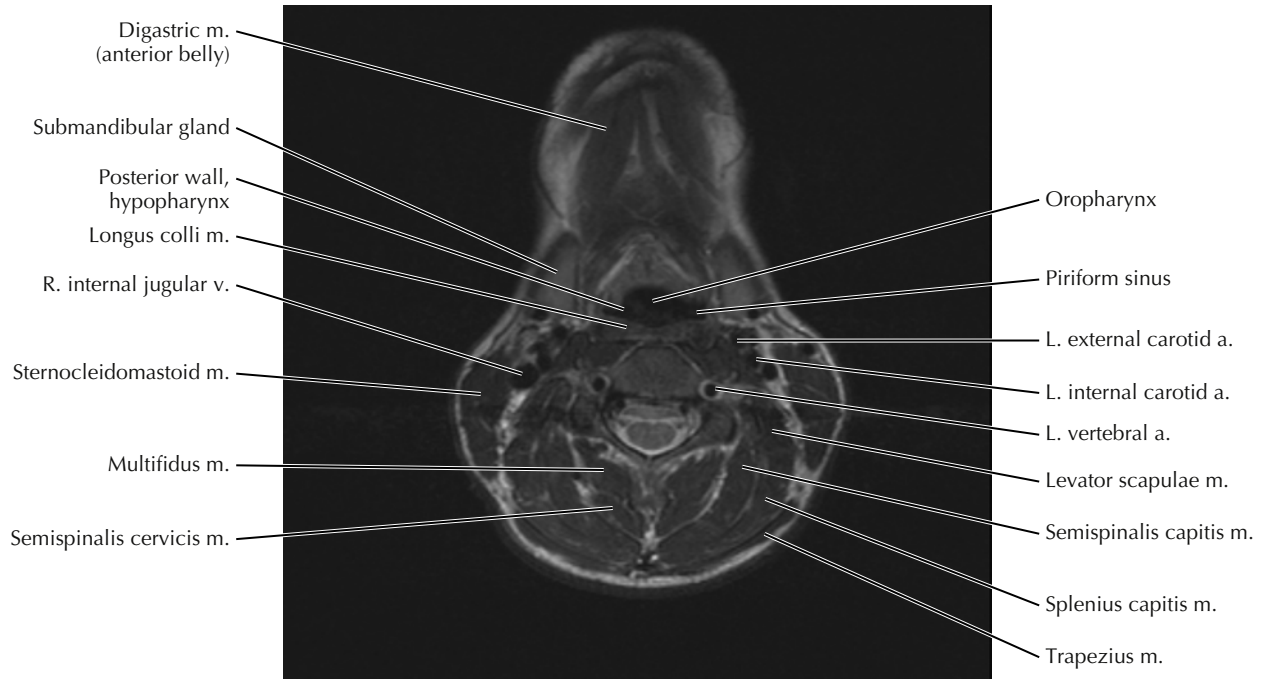
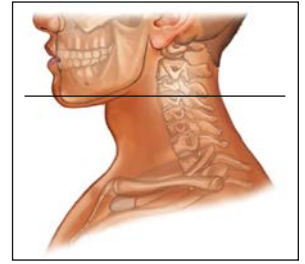
SAGITTAL 504

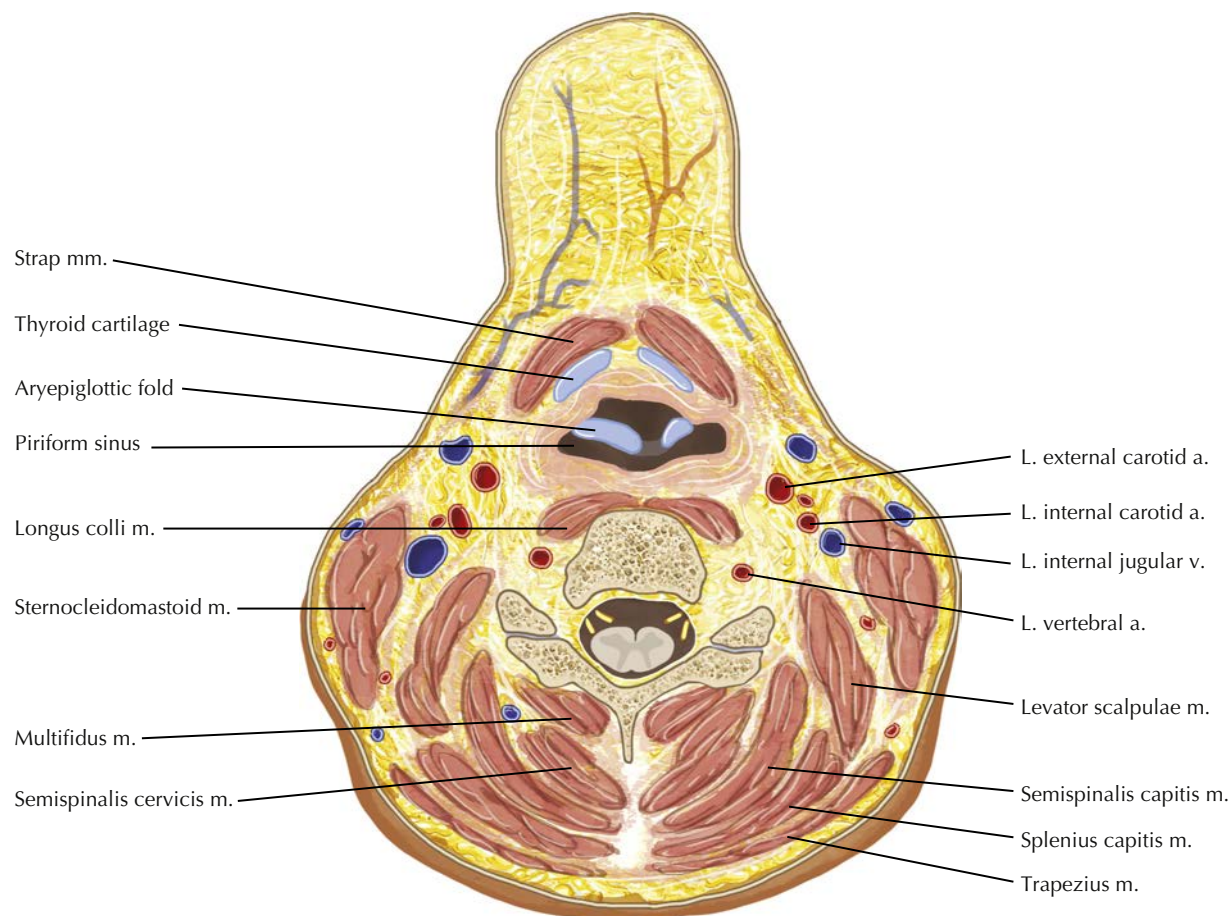


DIAGNOSTIC CONSIDERATION

Axial 1 on the next page shows both a T2-weighted sequence (upper image) and a T1-weighted image (lower). Note that cerebrospinal fluid (CSF) around the spinal cord is bright on T2-weighted magnetic resonance imaging and dark gray on T1-weighted MRI. Usually the brightest structure on T1-weighted imaging is fat. Note that the fat is somewhat bright on T2-weighted imaging because most T2 MRIs are now performed with fast spin-echo or "turbo" spin-echo techniques that use multiple radiofrequency (RF) pulses per echo time and make fat signal appear more like water signal.

HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK AXIAL 1



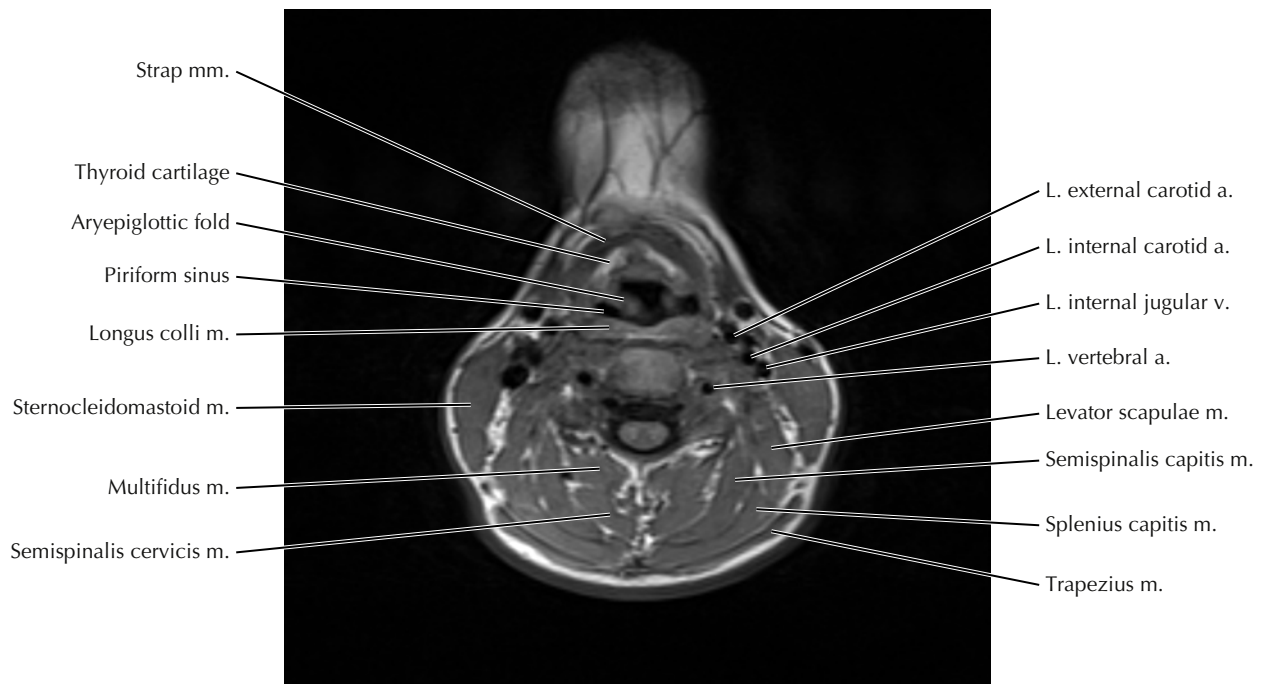
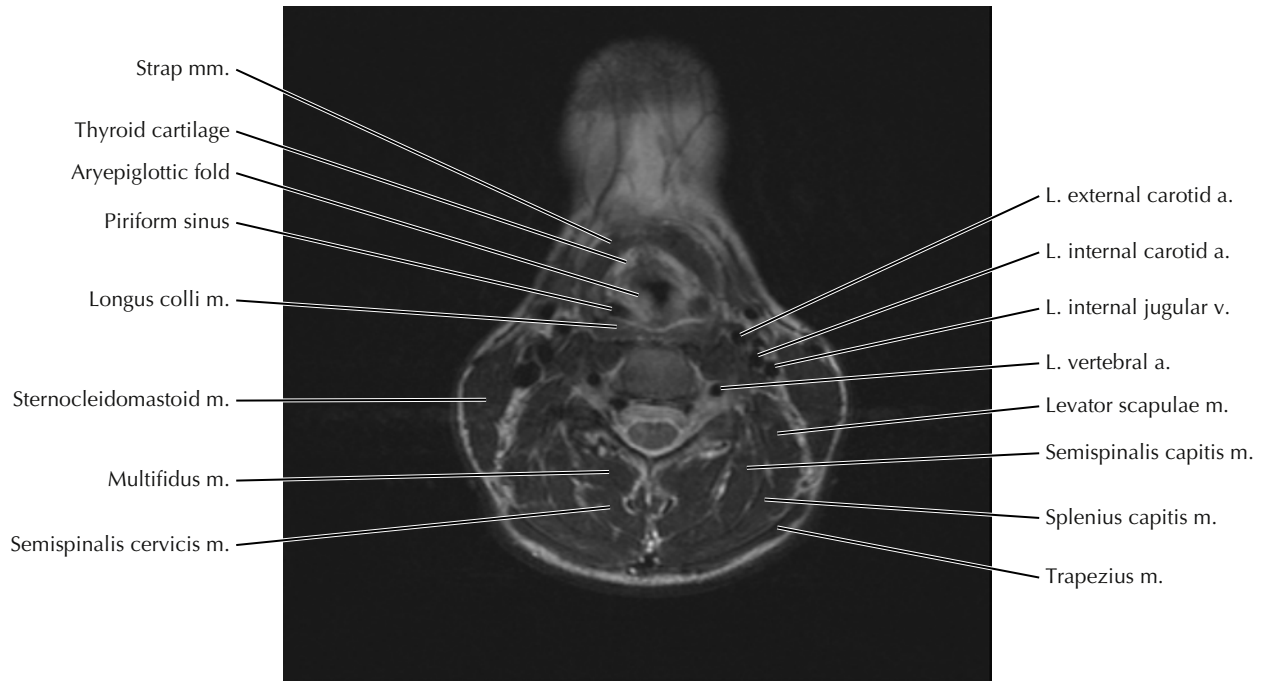
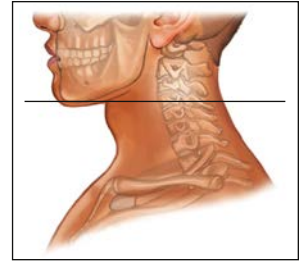


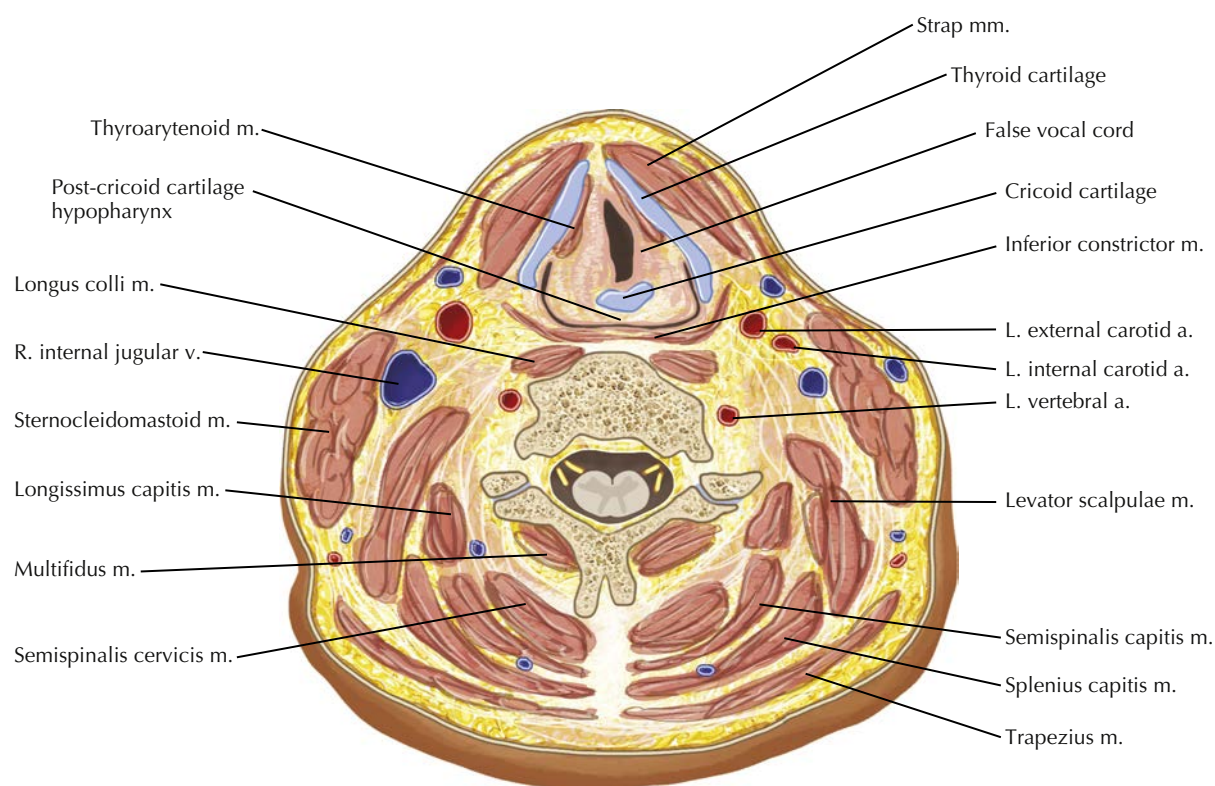
DIAGNOSTIC CONSIDERATION

Imaging of the neck can be difficult because many critical structures are compressed within a relatively small space. One diagnostic approach to MRI and CT of the neck is to assess the structures from central to peripheral, starting with the *airway*. Impending airway obstruction should be recognized early in evaluation of the neck. The airway is often the first structure to be exposed to carcinogenic agents and viruses. A primary hypopharyngeal squamous cell carcinoma may first appear as a slight asymmetry in the mucosal surfaces of the hypopharynx.

The next structure to assess is the usual site of malignancy spread, the *lymph nodes*, which generally follow the venous structures. The largest venous structure in the neck is the internal jugular vein, and thus the jugular lymph node chain typically contains the largest lymph nodes. The largest node is at the top of this chain, the jugulodigastric lymph node, which serves as a common point of lymphatic drainage for the head.

Next, specialized glands of the head and neck can be assessed, including parotid, submandibular, and thyroid glands. Finally, structures are assessed at the edge of a neck study, such as the brain above, the spine and top of the lungs, and structures common to many parts of the body (e.g., vessels, bones, muscles, subcutaneous tissue, skin contours).

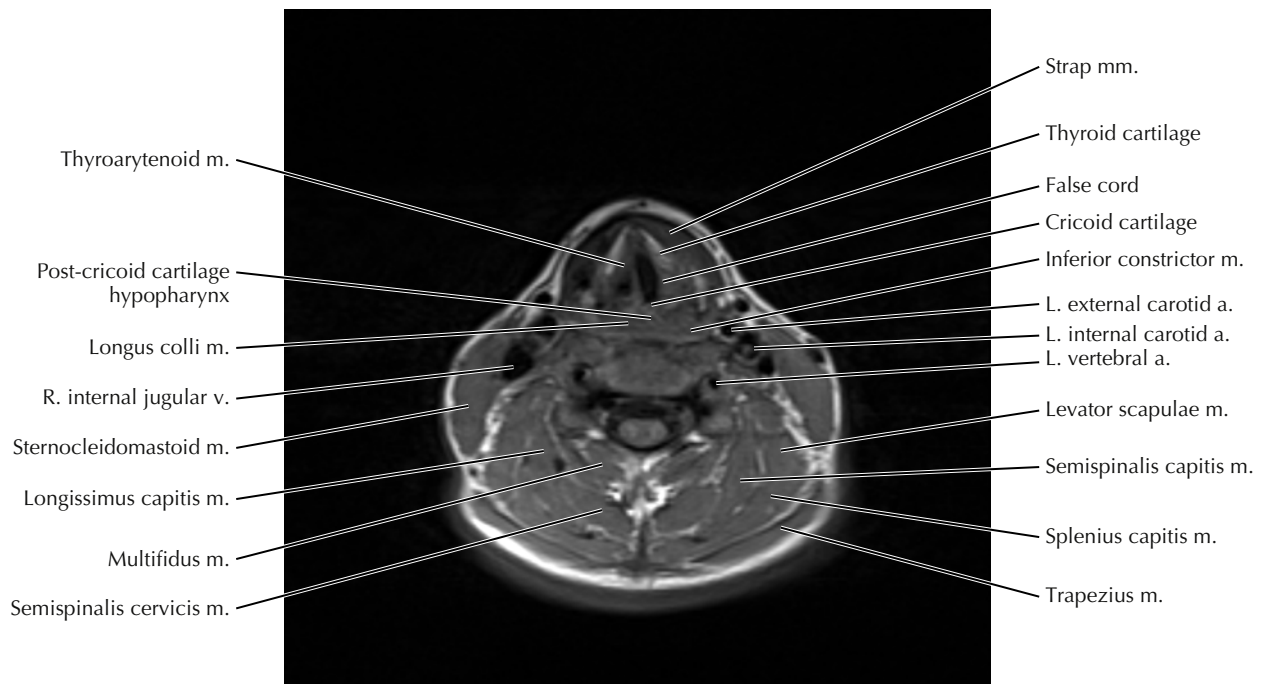
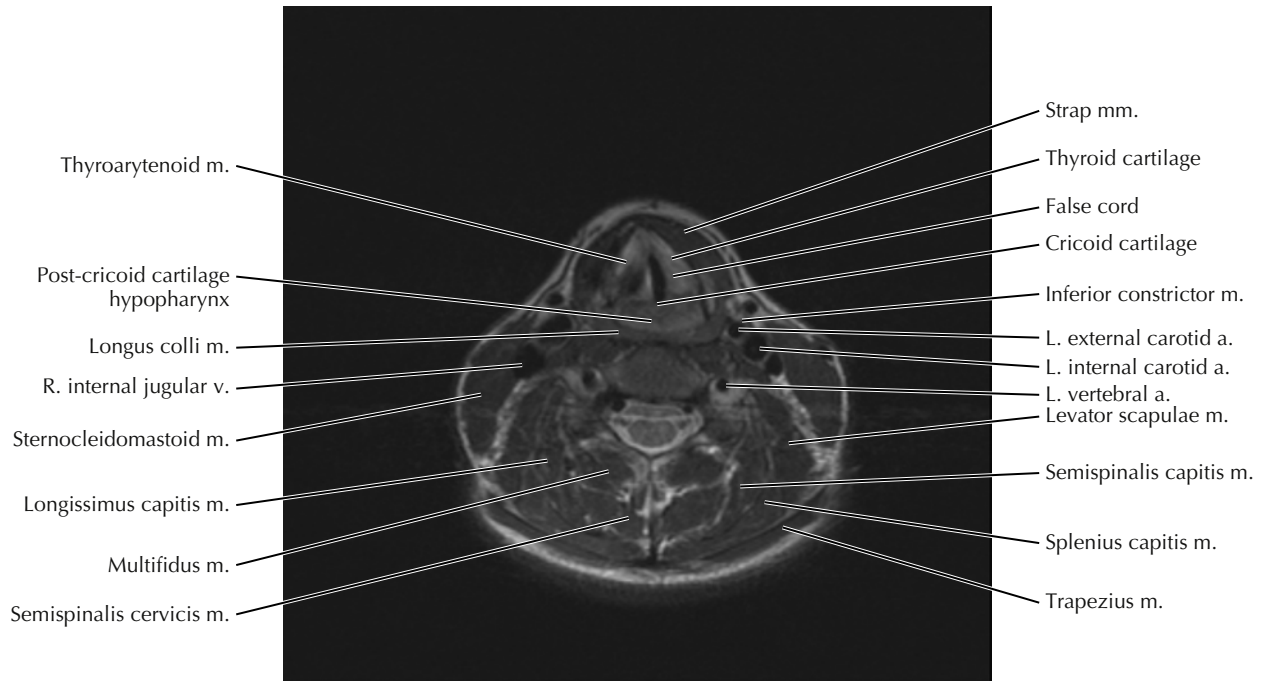
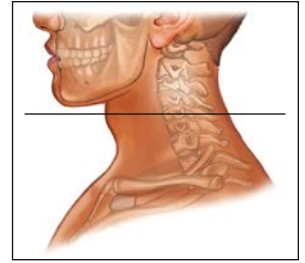


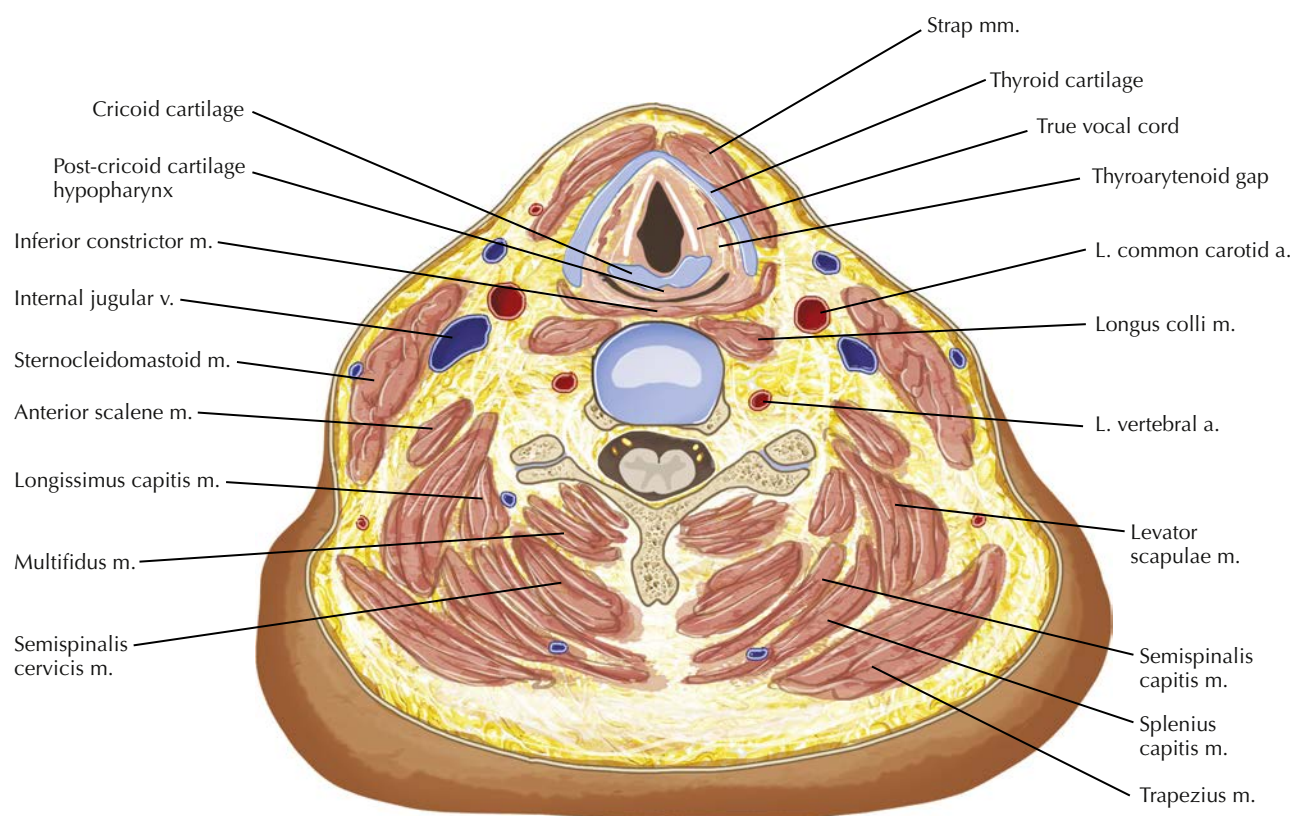


PATHOLOGIC CONSIDERATION

Note the medial deviation of the right vocal cord with a focus of dark signal deep to the mucosal surface. This finding suggests previous Teflon injection for vocal cord paralysis, to help bring one cord in contact with the normal-moving cord.

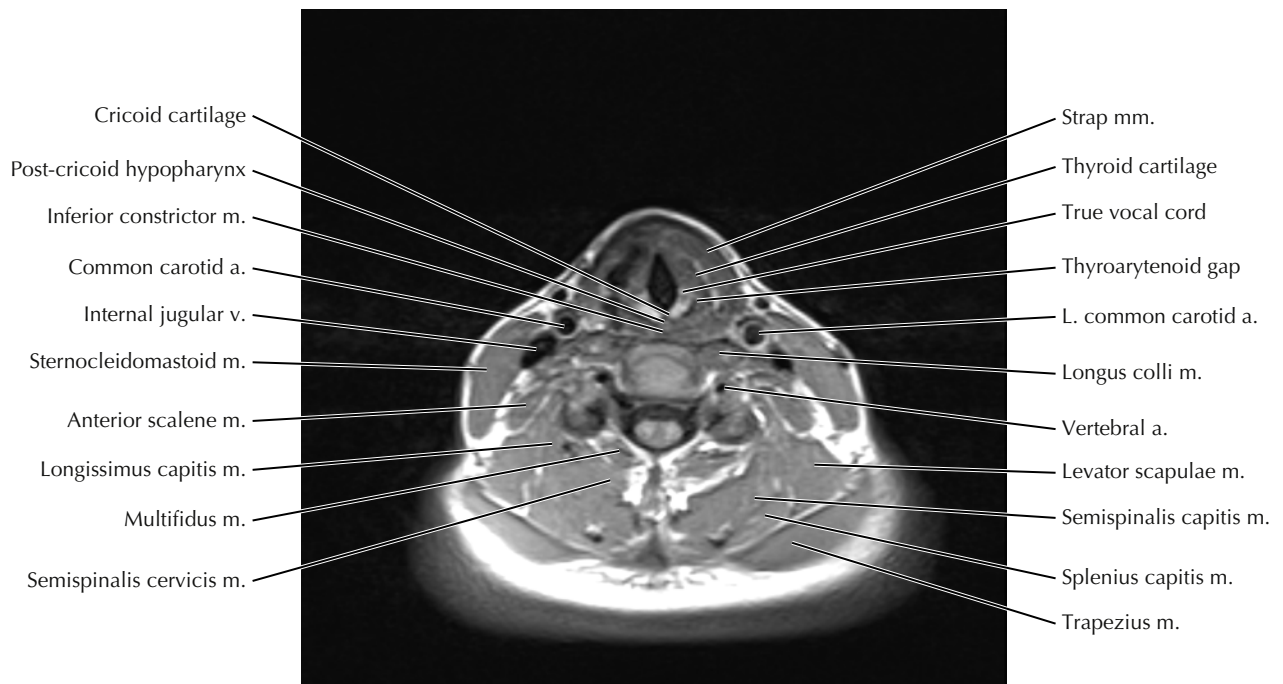
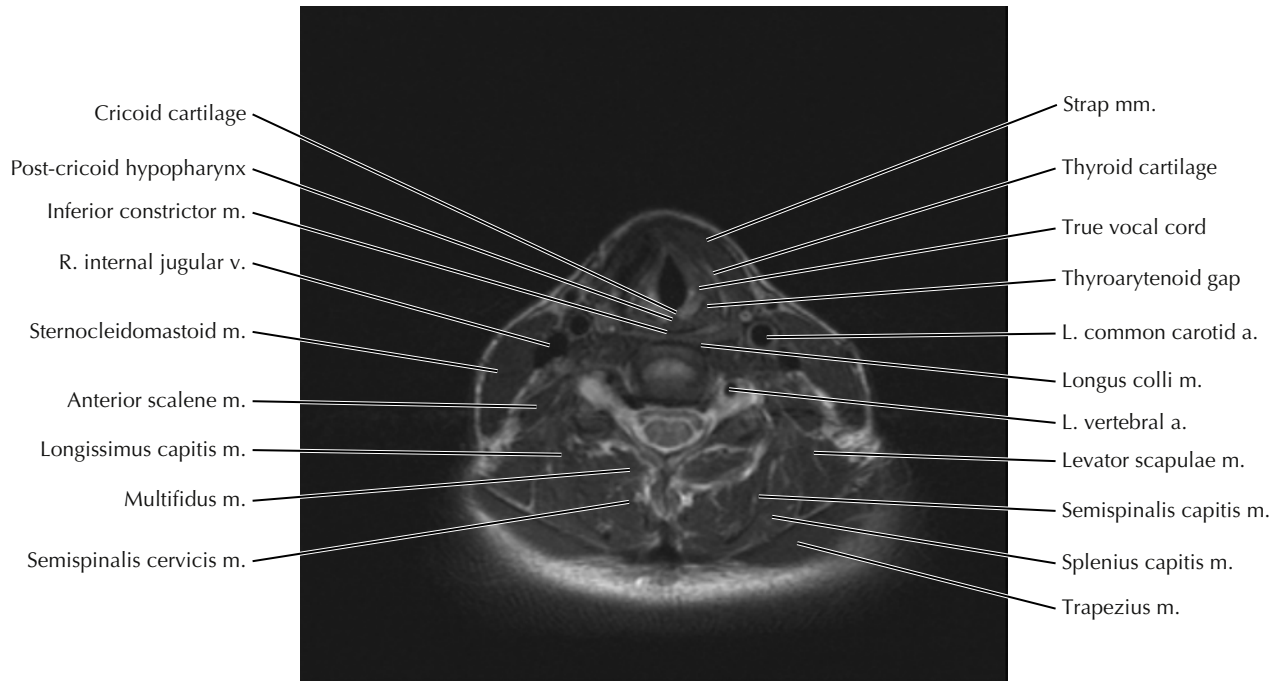
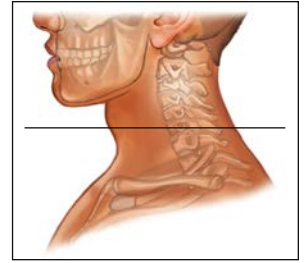
HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK AXIAL 3

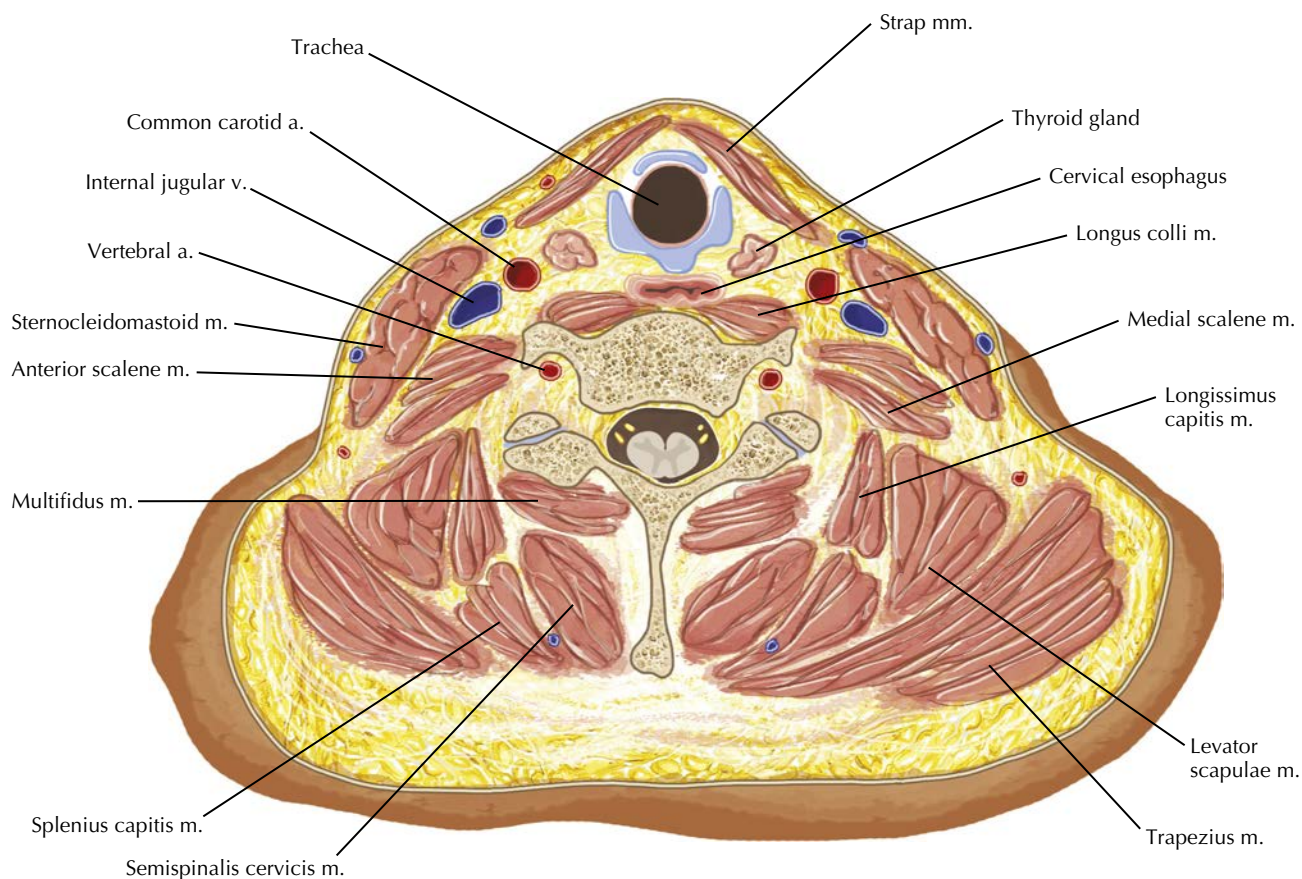




IMAGING TECHNIQUE CONSIDERATION

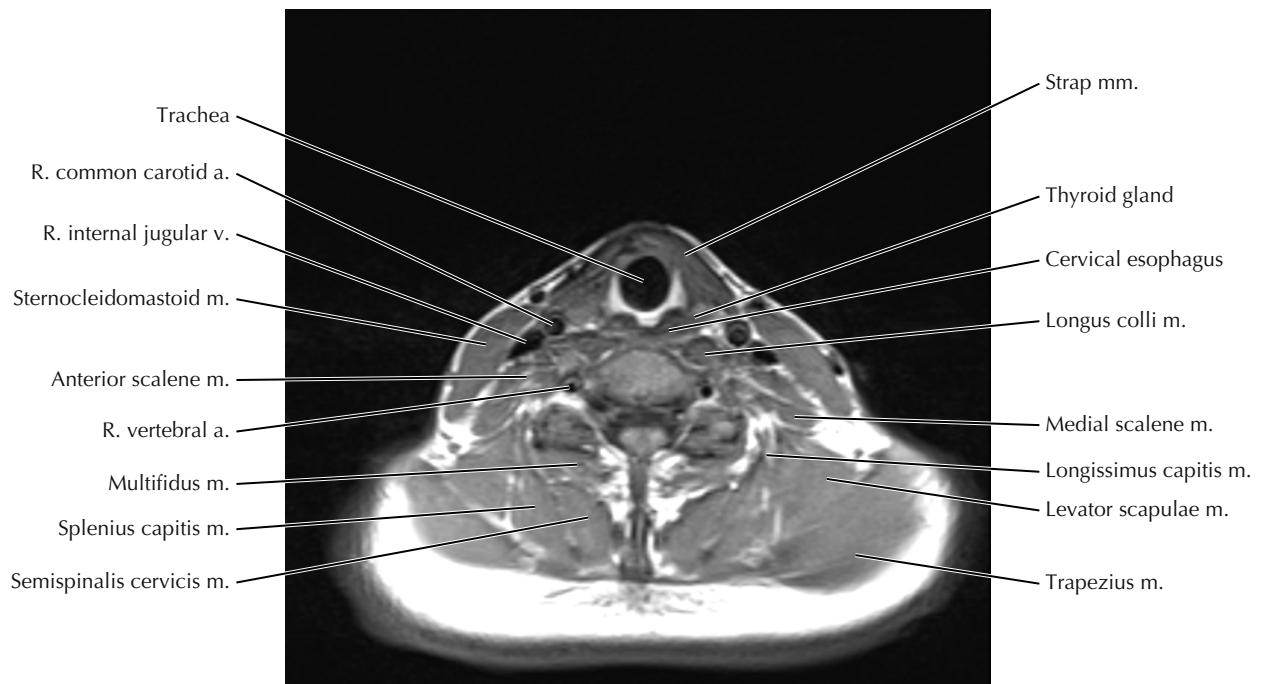
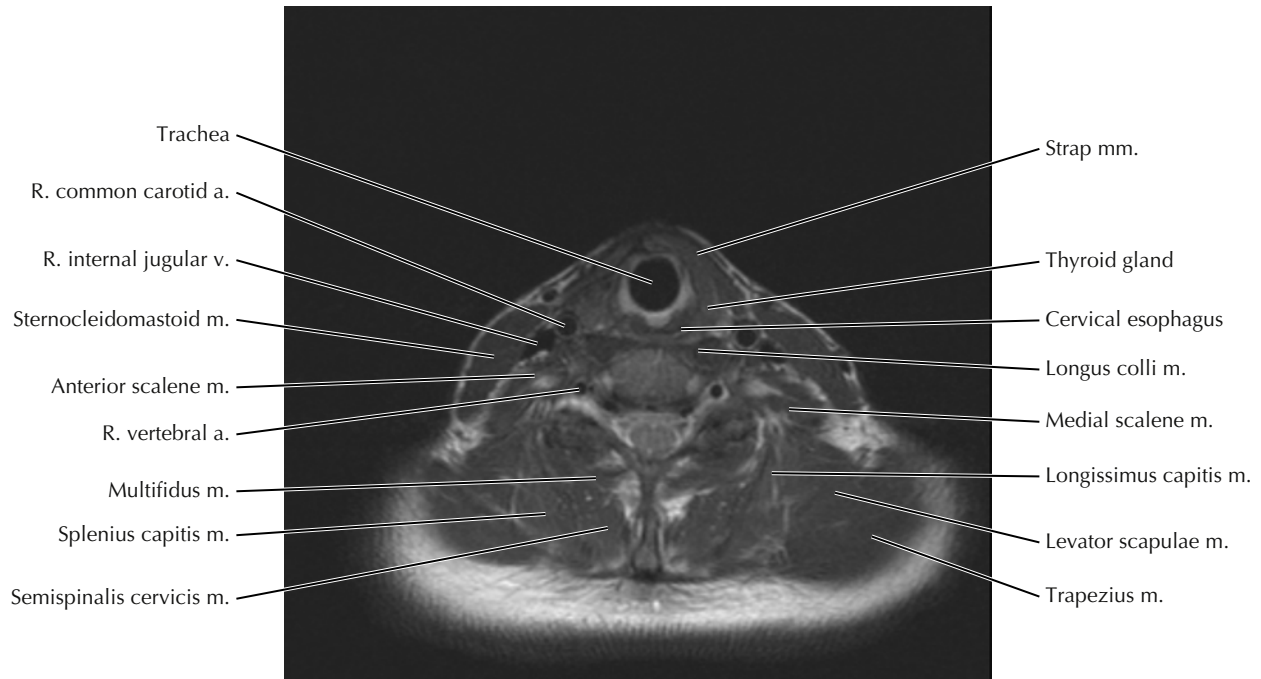
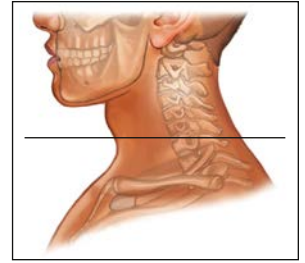
The vocal cords should be symmetric. Medial deviation of one of the vocal cords suggests palsy, and the neuroradiologist should look carefully for a lesion or enlarged lymph node along the course of the recurrent laryngeal nerves.

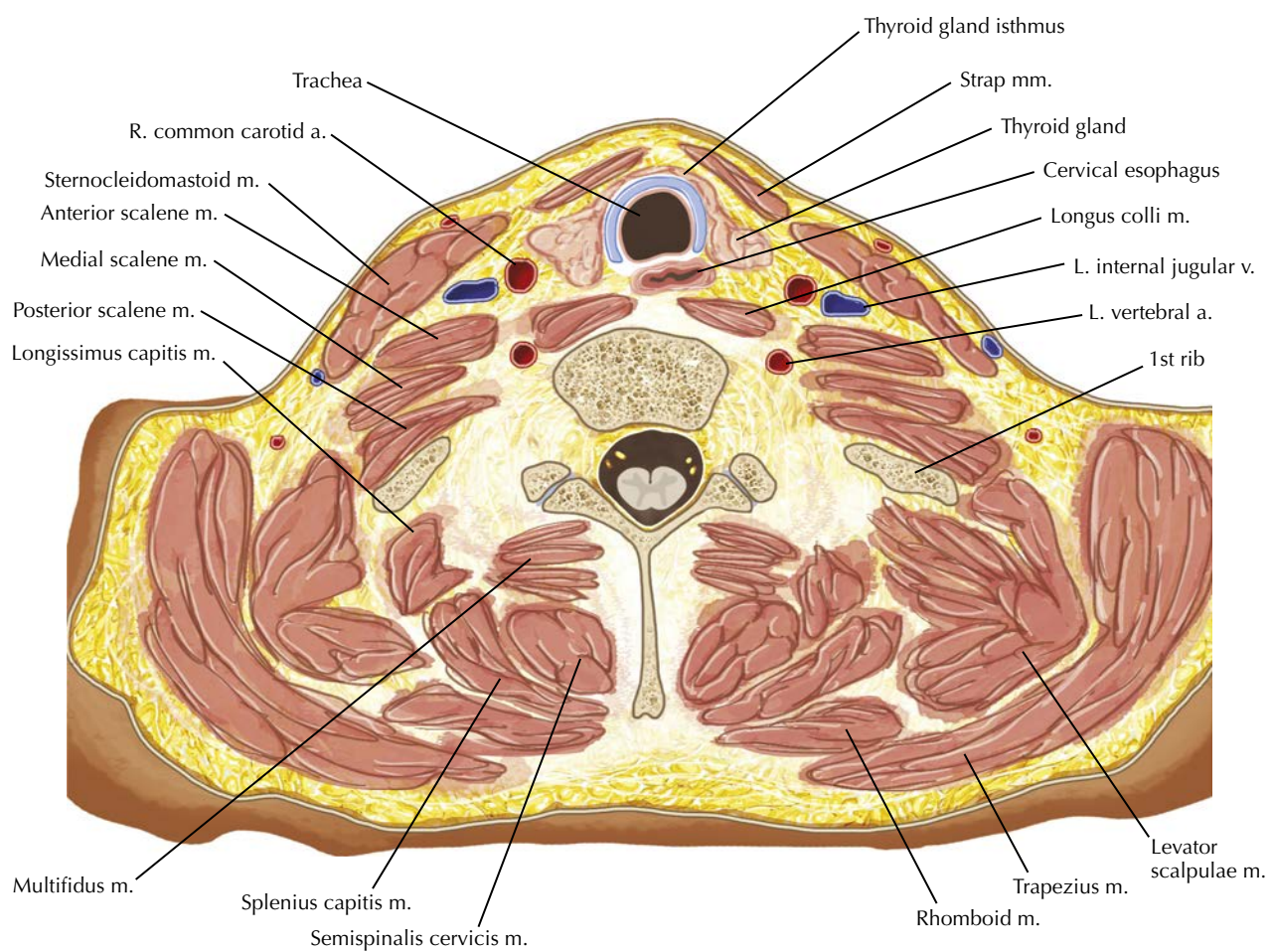


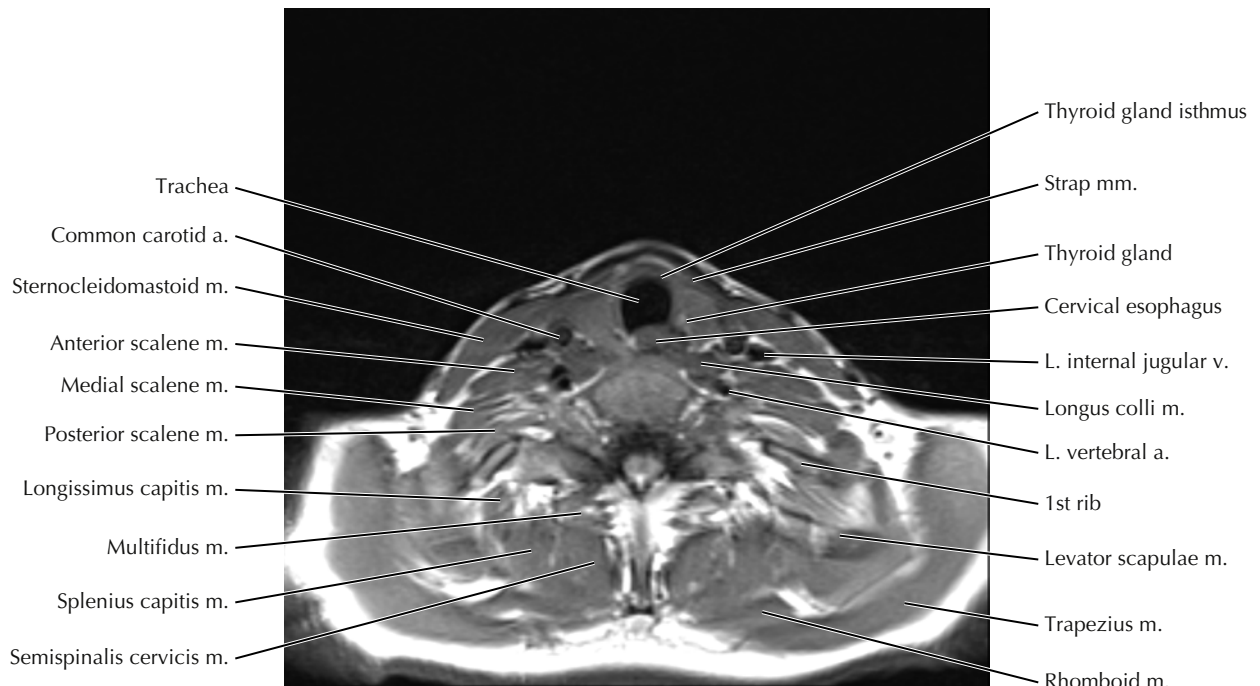
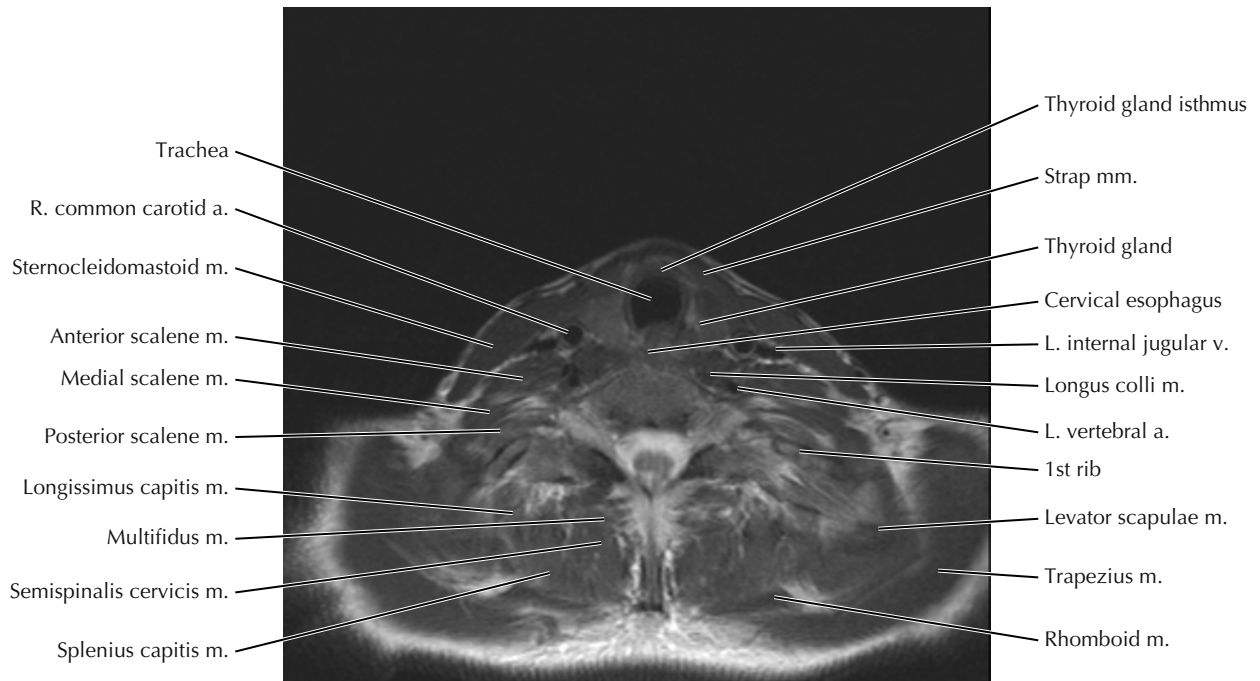
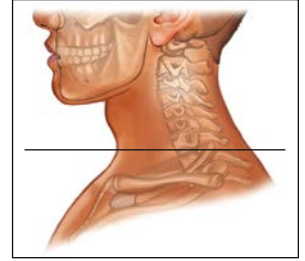


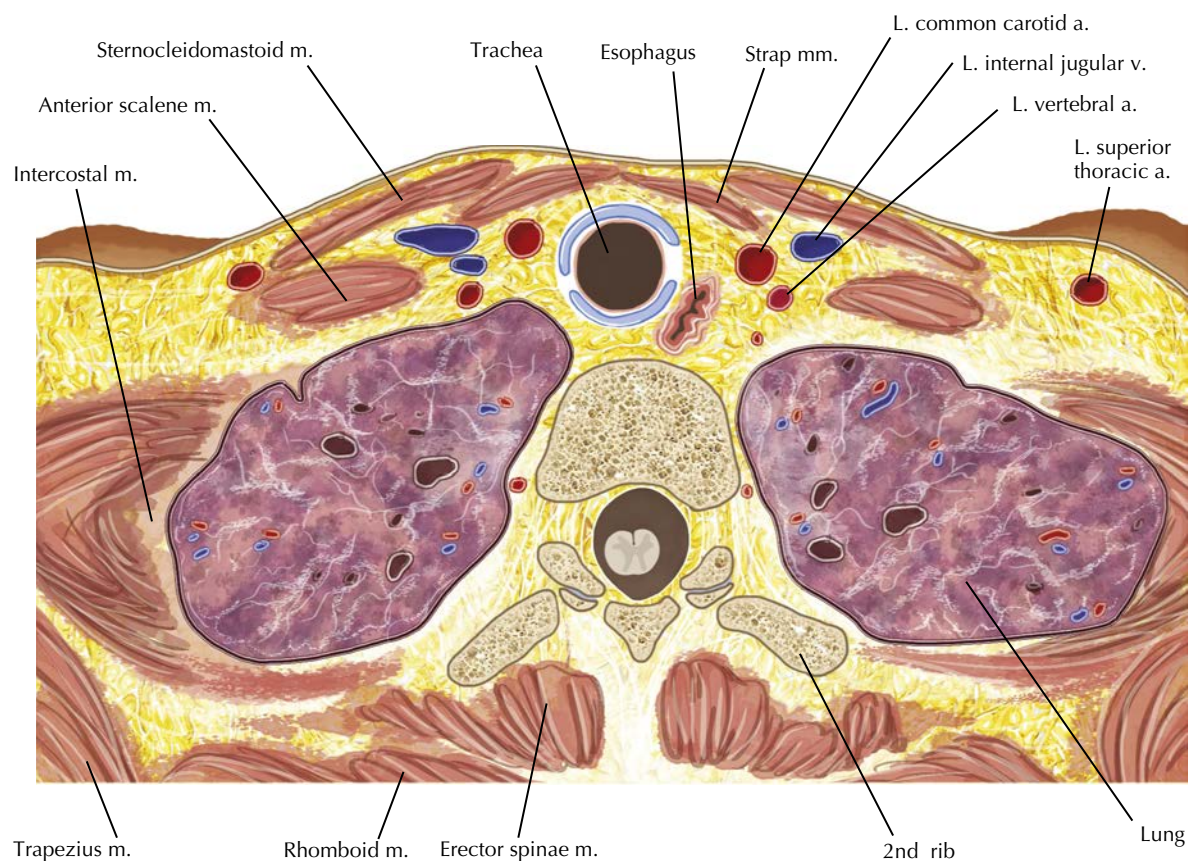
PATHOLOGIC PROCESS

The membranous space in the midline between the thyroid cartilage caudally and the cricoid ring caudally is the site for emergency cricothyrotomy (cricoid tracheotomy). Puncture of the cricothyroid membrane with an angiocatheter allows airway access in cases of obstruction at the level of the vocal cords or higher. The subcutaneous spaces in the midline are relatively avascular.



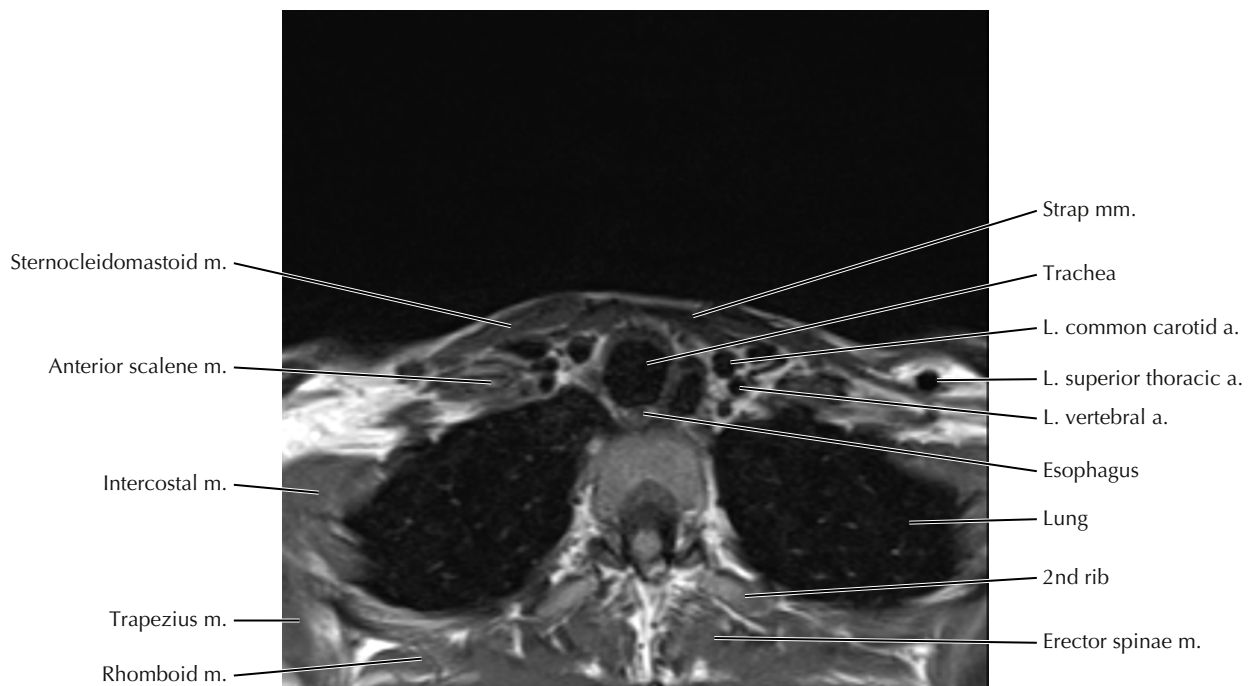
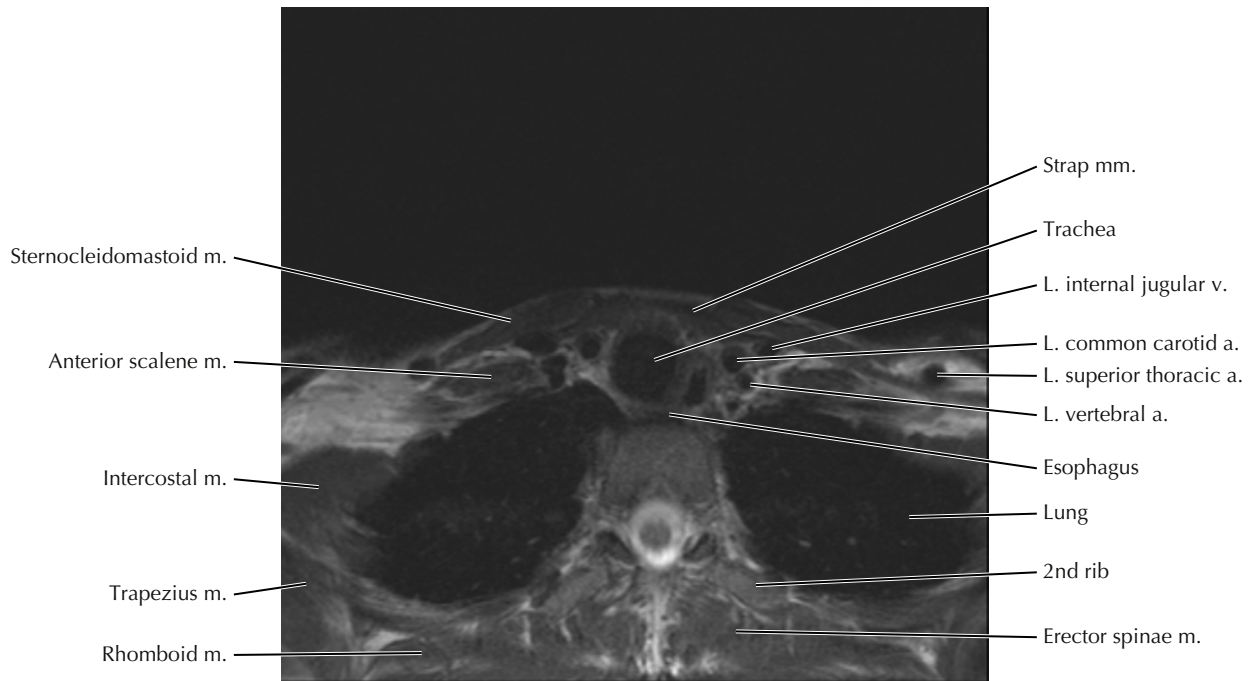
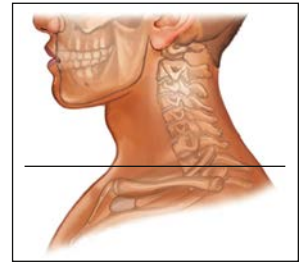


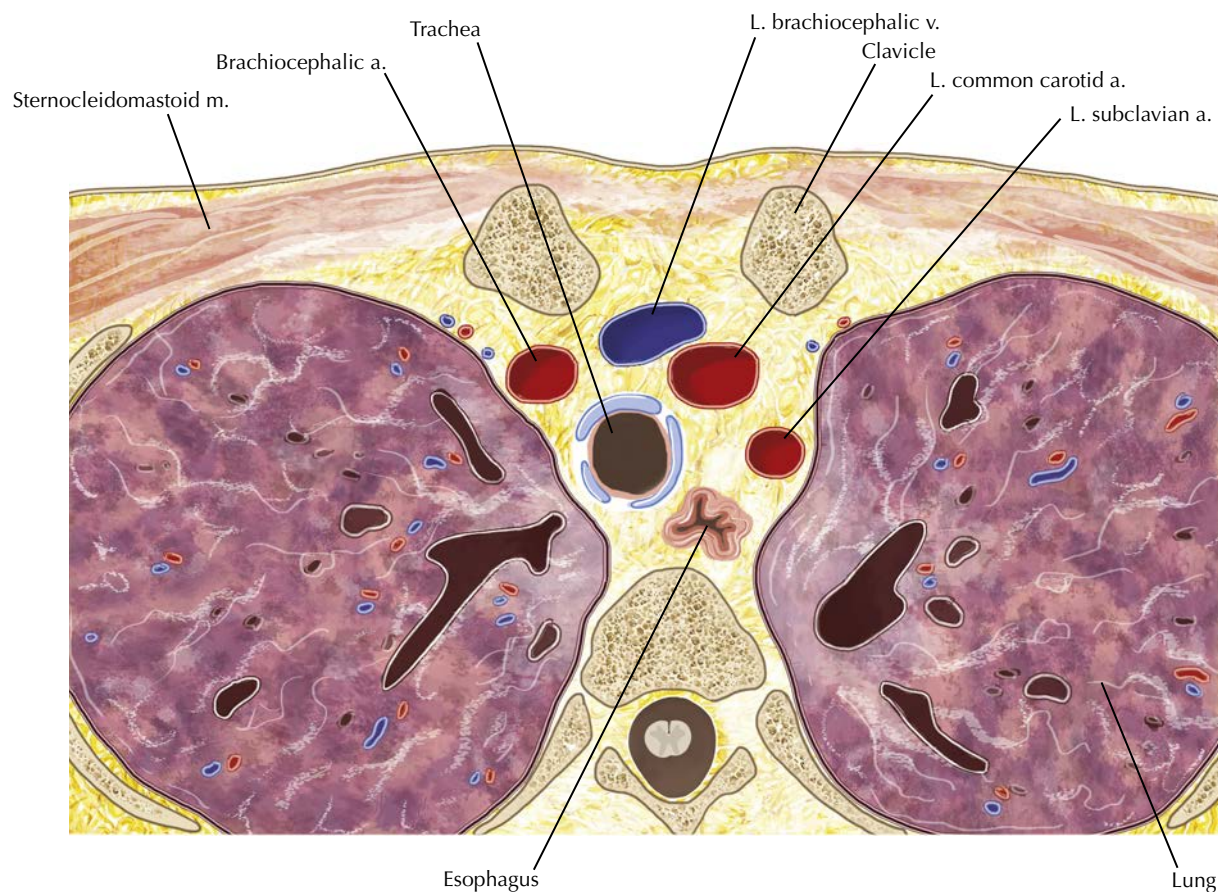




NORMAL ANATOMY

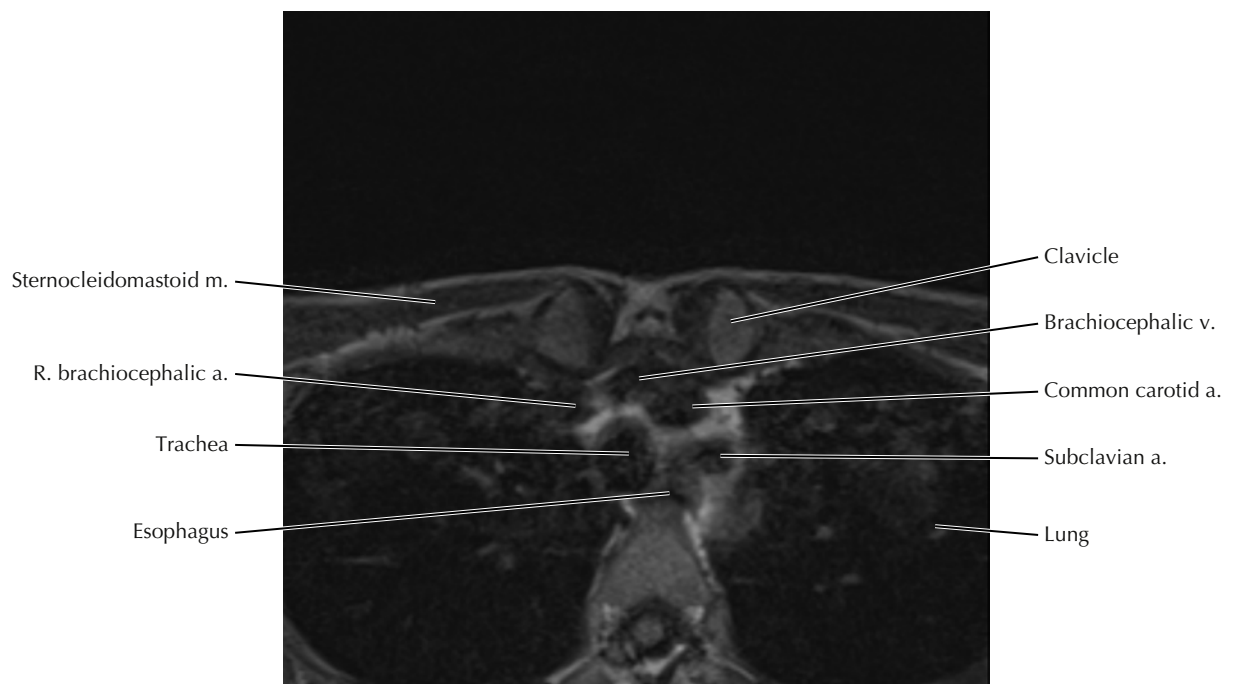
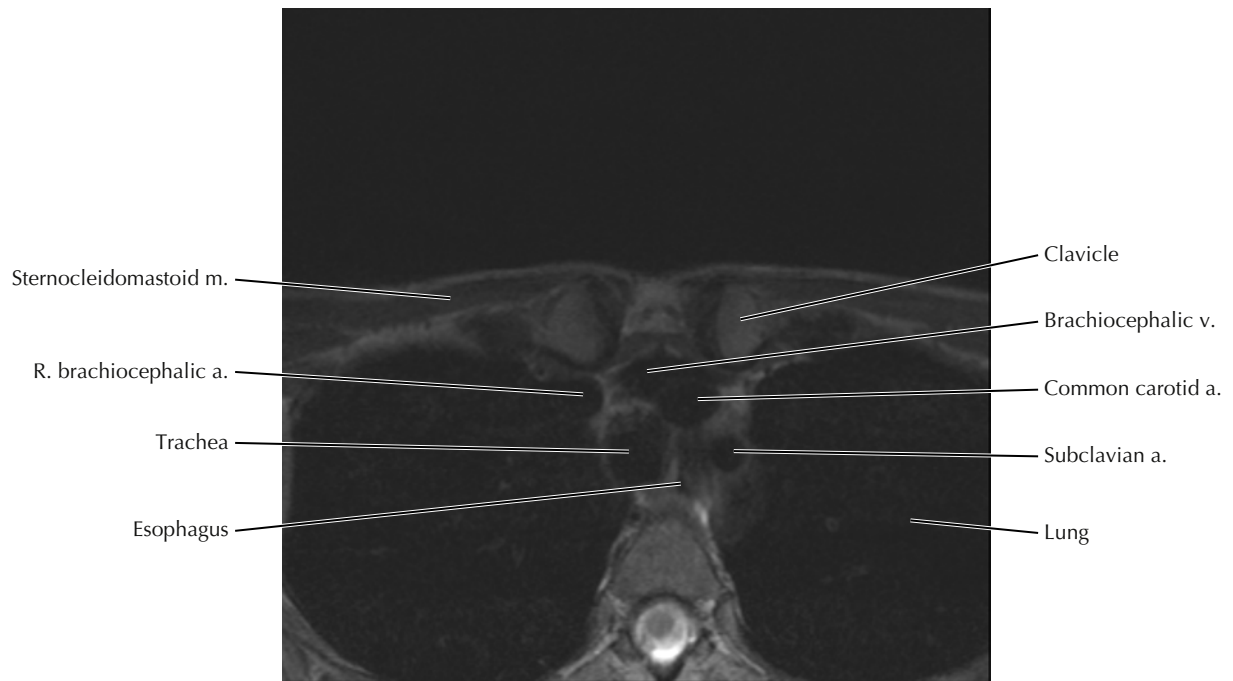
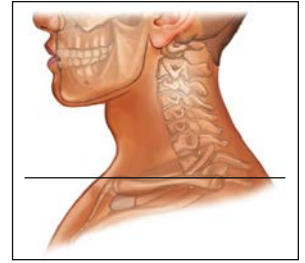
The trachea below the bony cricoid ring has firm, cartilaginous material along the lateral and anterior sides, but a softer, membranous portion that is often straight (or concave) along the posterior wall.

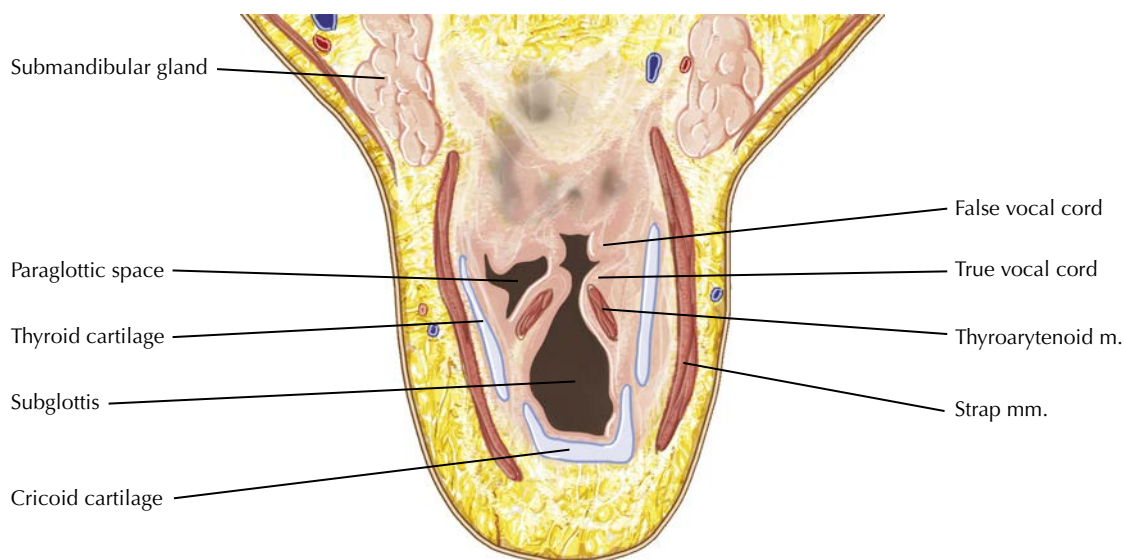




SURGICAL CONSIDERATION

The left innominate (brachiocephalic) vein passes immediately posterior to the suprasternal notch. It drains venous blood from the left internal jugular vein and left subclavian vein, crosses the midline, and joins right innominate vein to form the superior vena cava. In midline sternotomy, when injury involves the left innominate vein, control can be obtained by hooking a finger deep to the suprasternal notch and pulling upward.

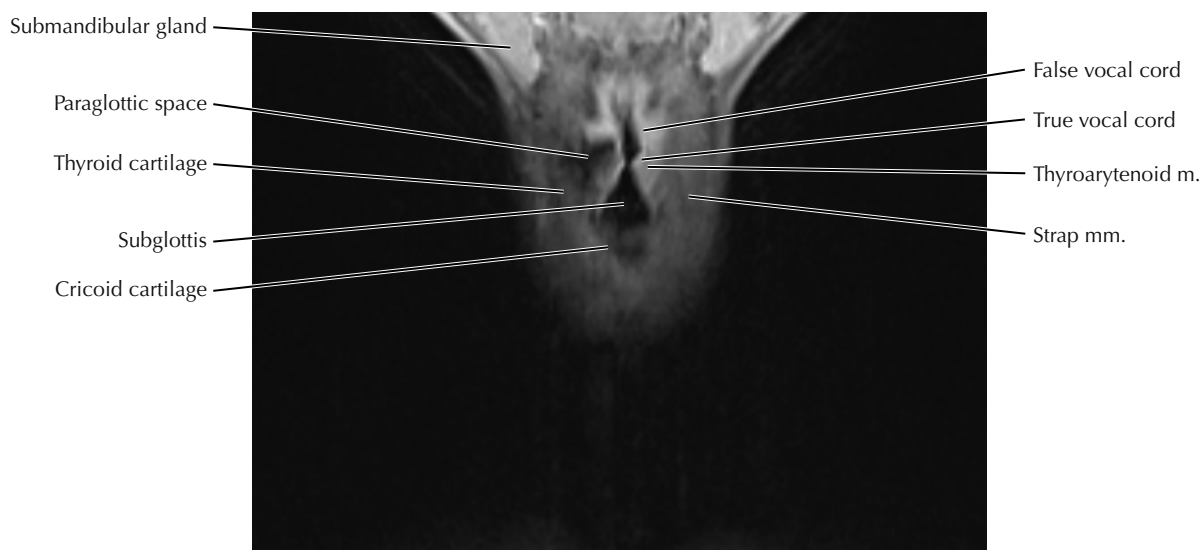
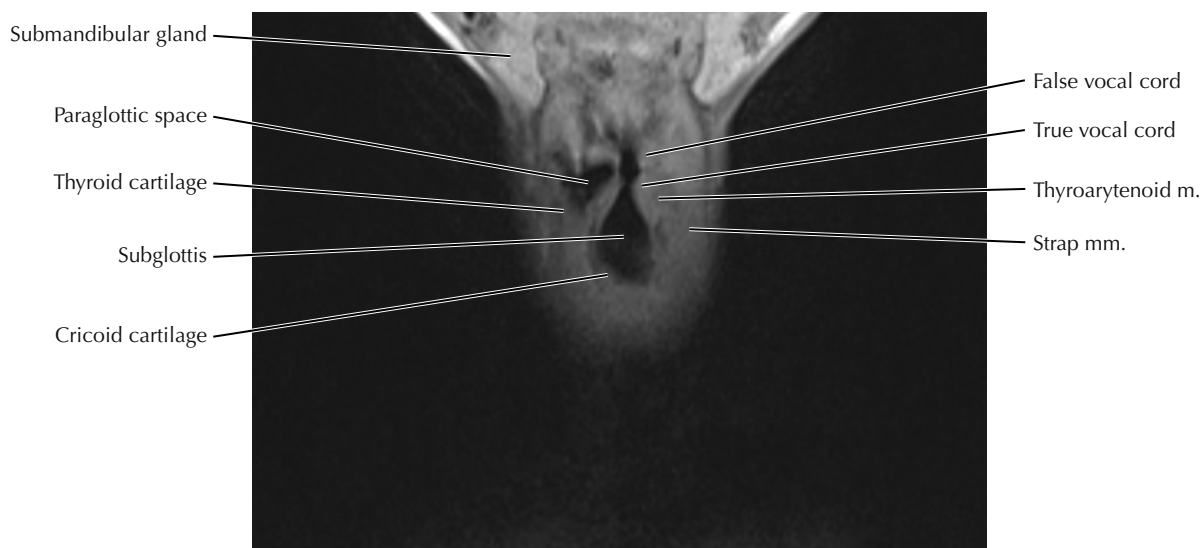
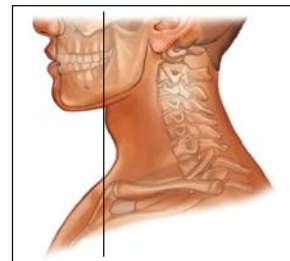


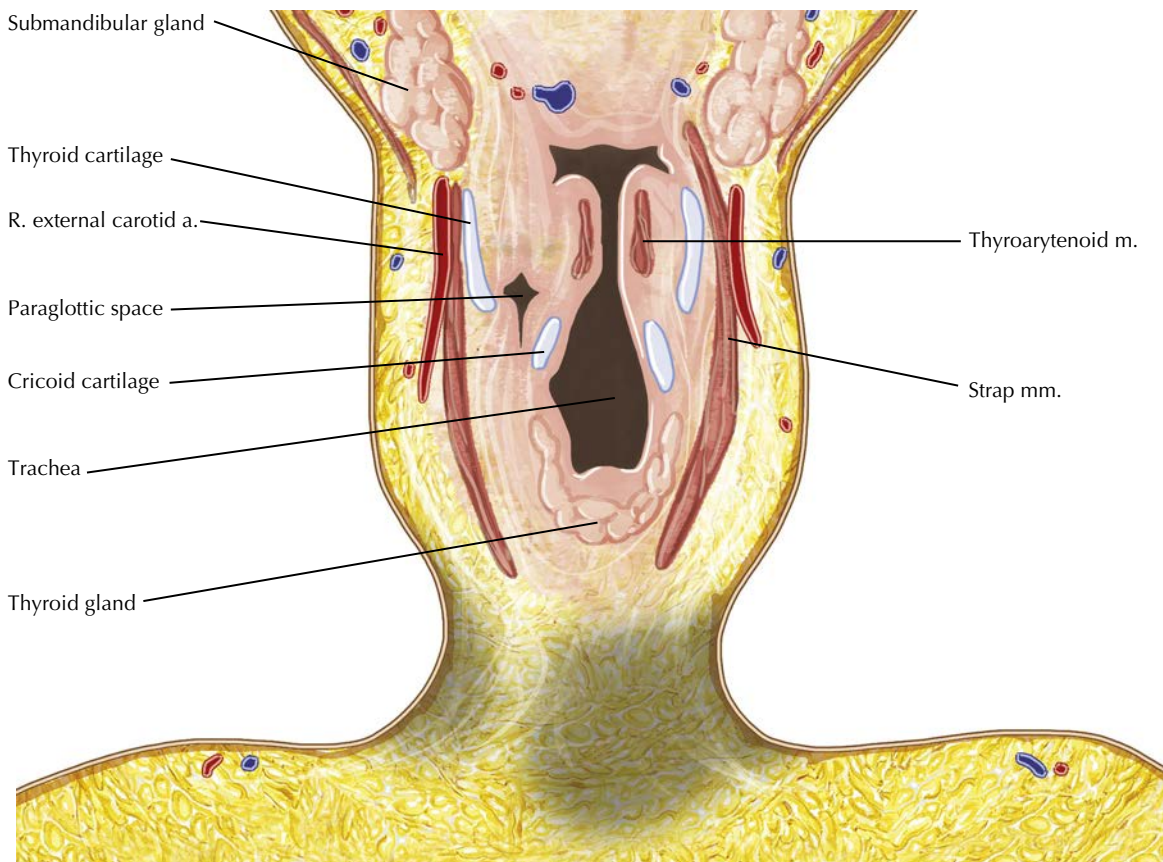


IMAGING TECHNIQUE CONSIDERATION

Coronal imaging is used less often than axial imaging when assessing the neck. However, the ability to see the craniocaudal extent of the jugular lymph node chain in the anterior neck and the spinal accessory lymph node chain in the posterior neck often makes enlarged lymph nodes more conspicuous on coronal MR images.

HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK CORONAL 1

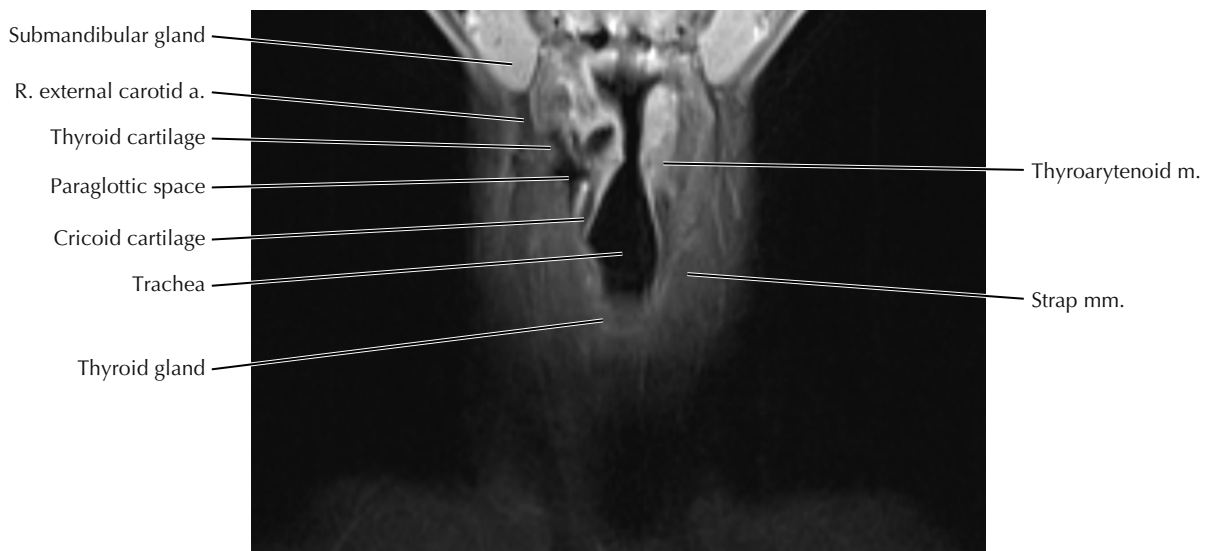
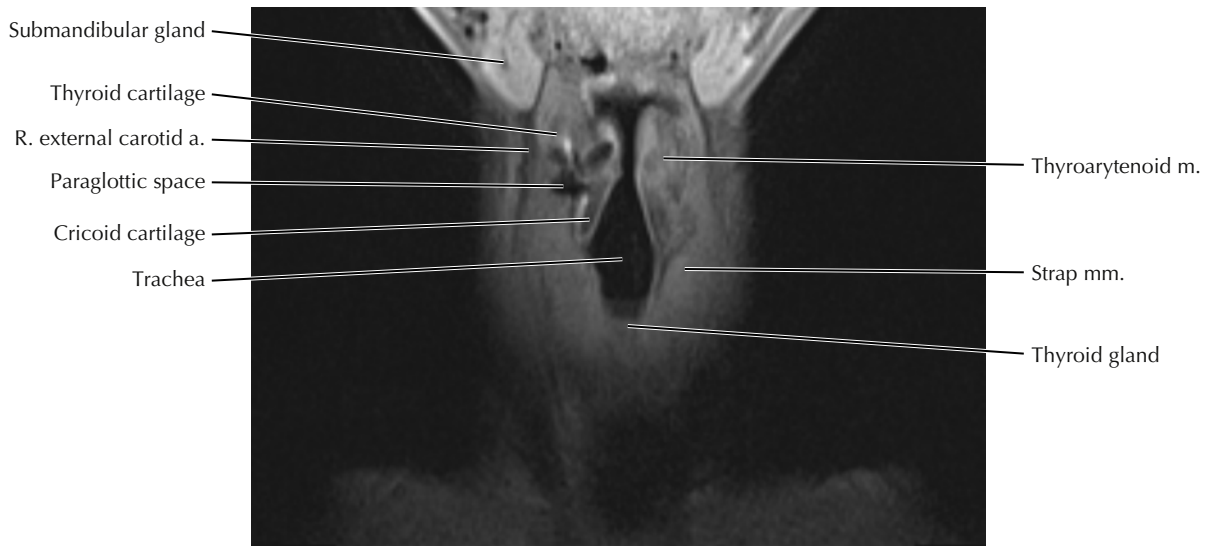
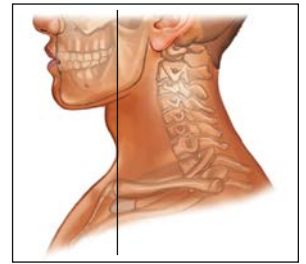


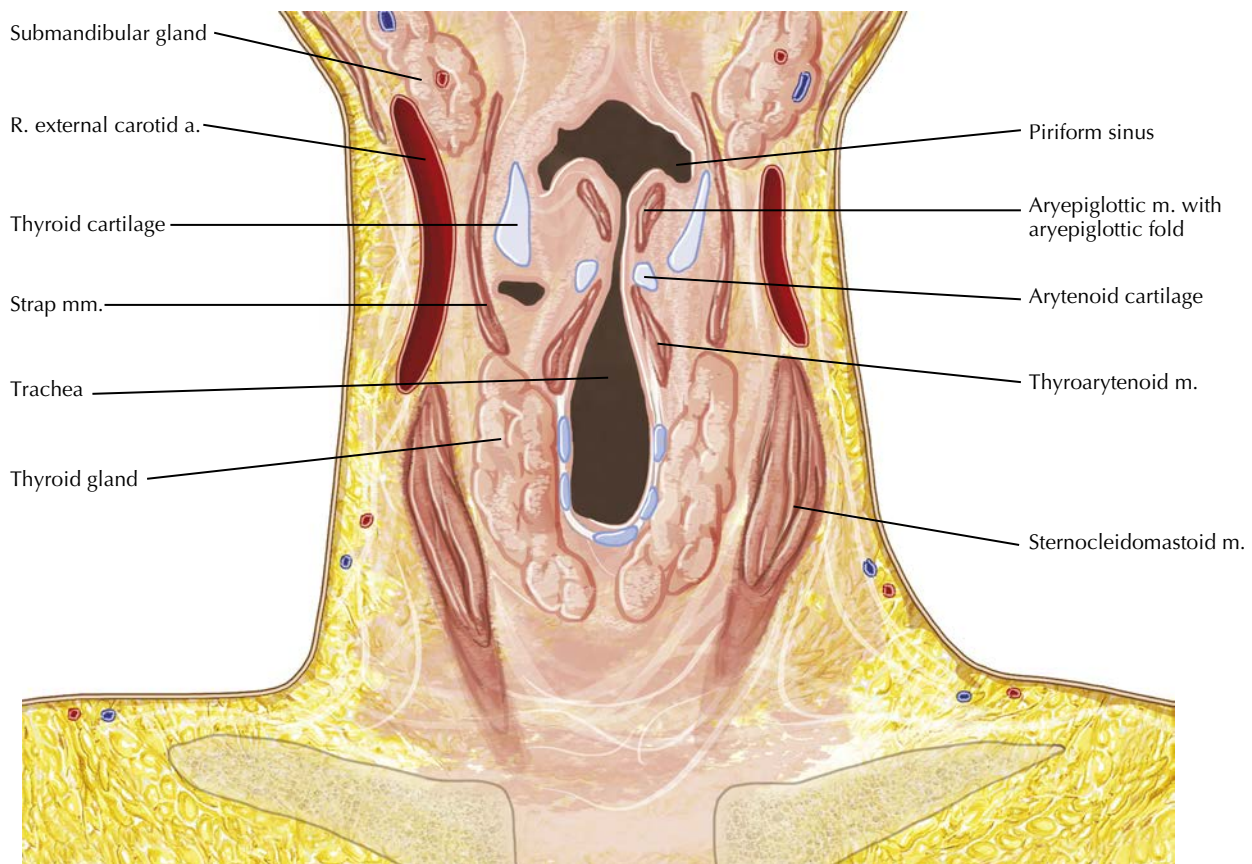


PATHOLOGIC PROCESS

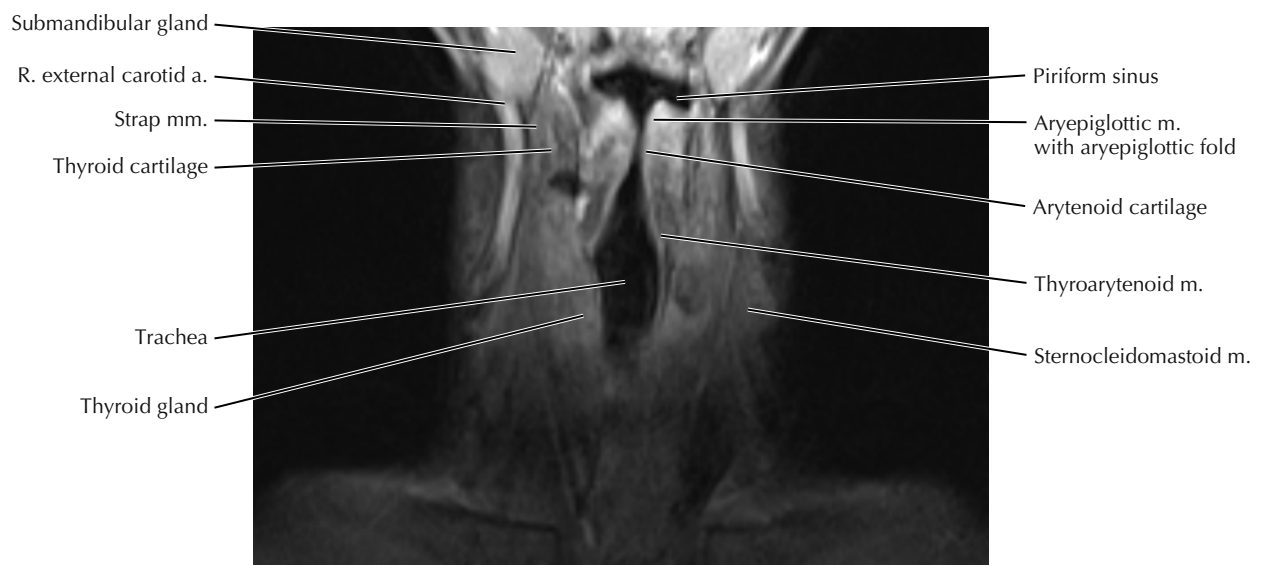
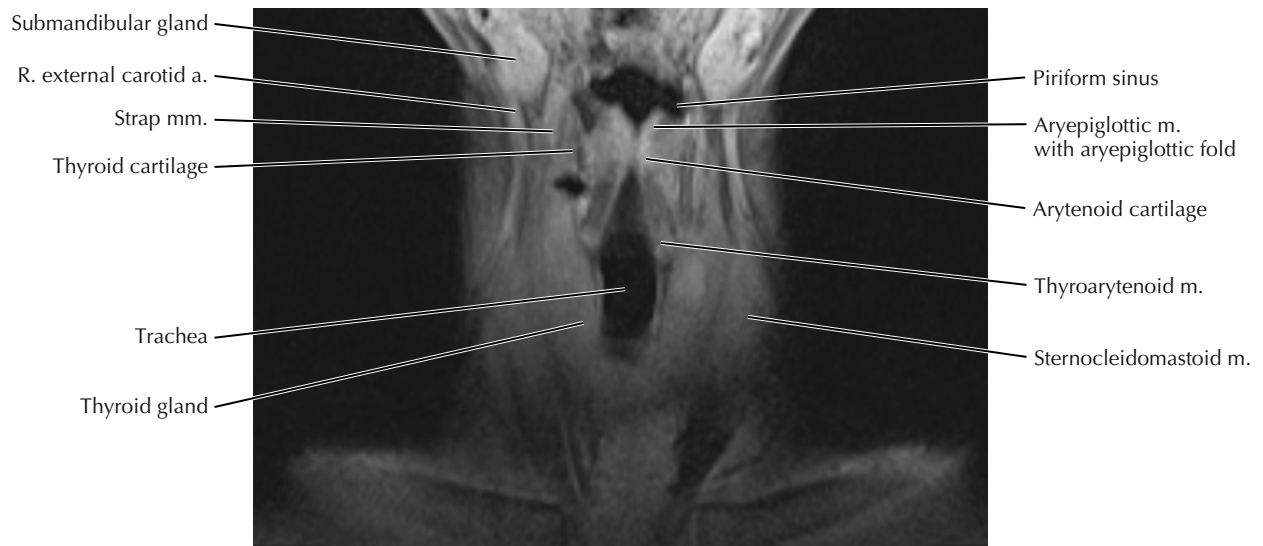
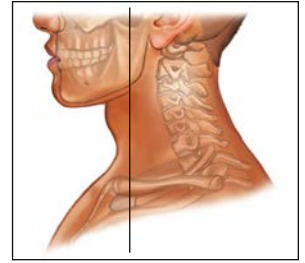
Note the asymmetric dark focus associated with the right vocal cord, suggestive of previous Teflon injection for vocal cord palsy.

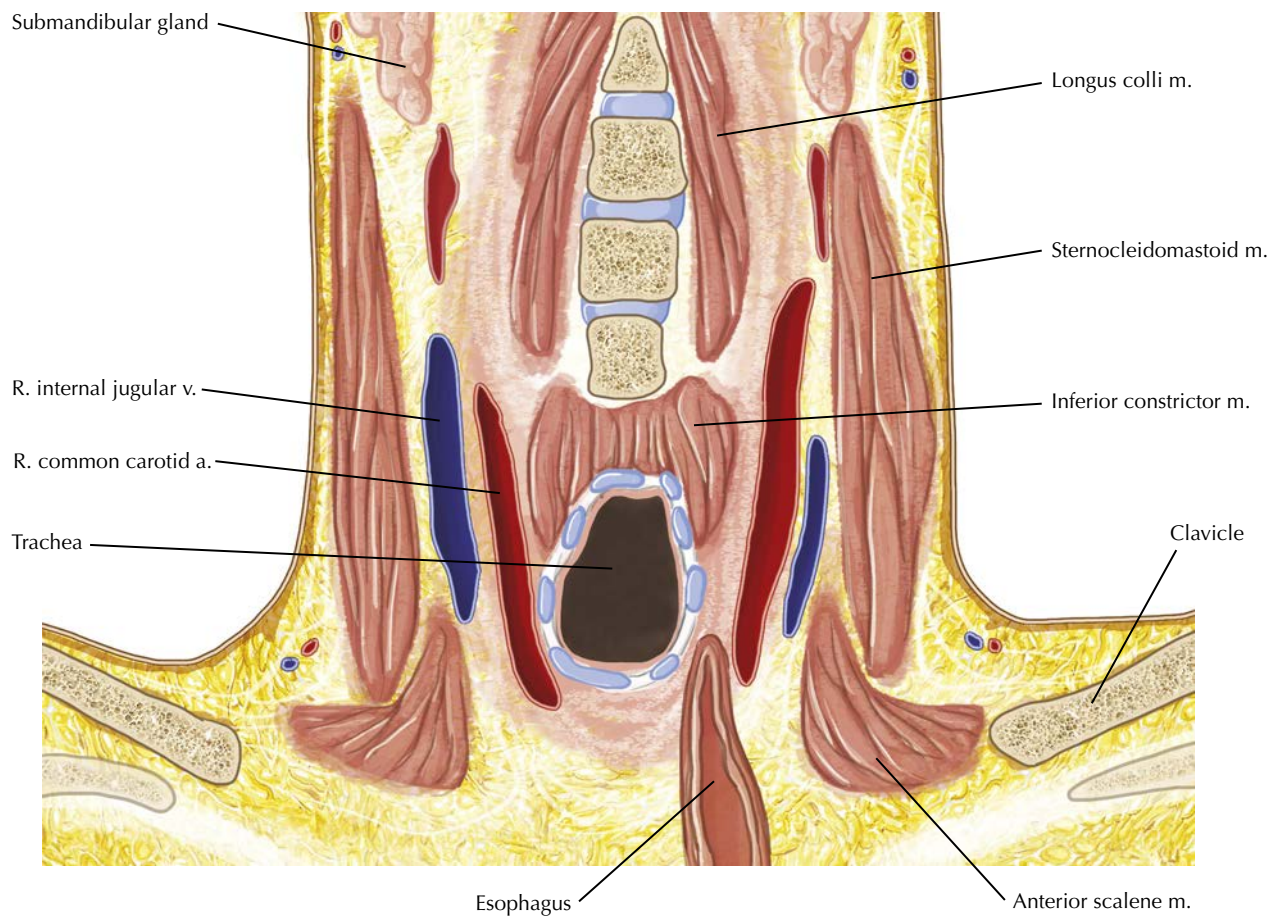
HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK CORONAL 2



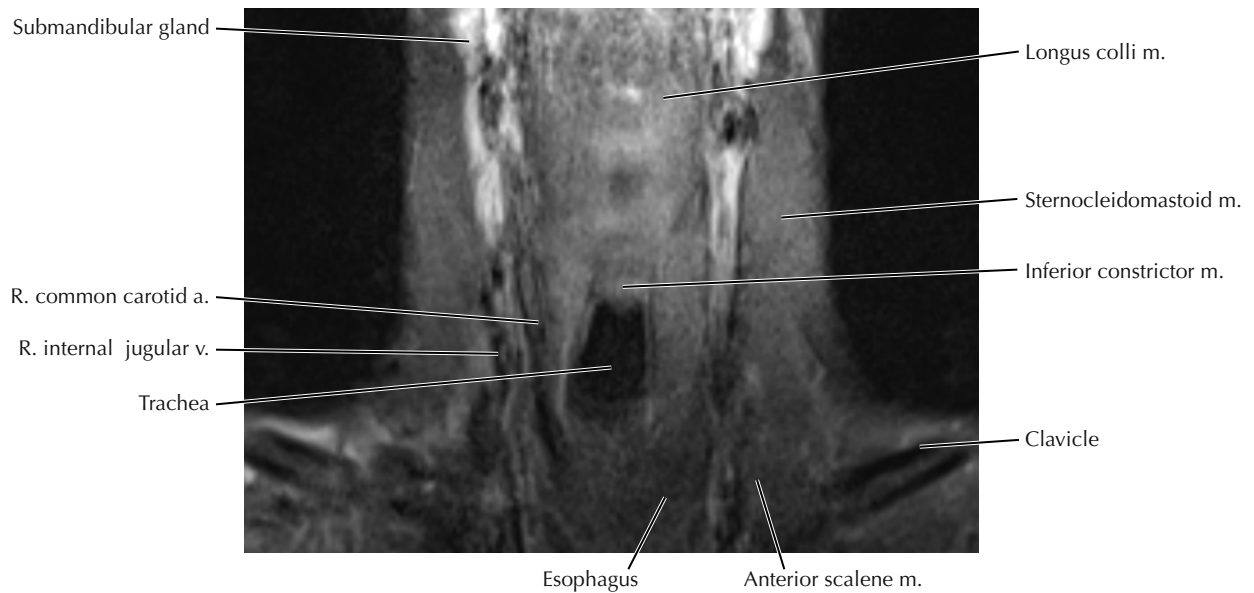
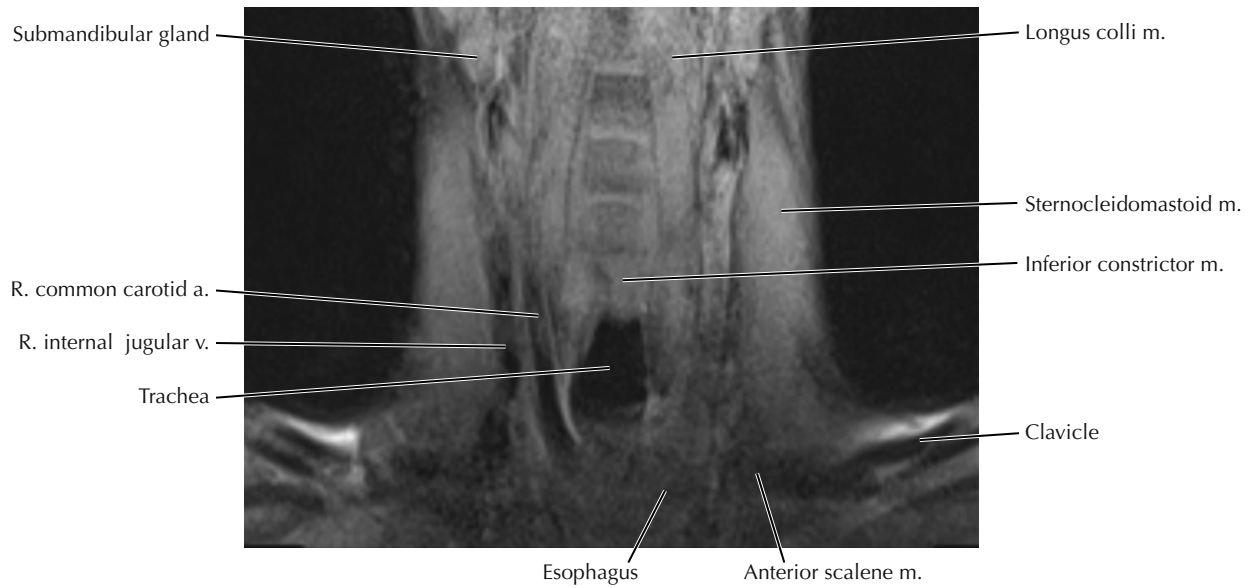
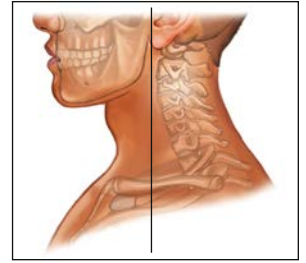


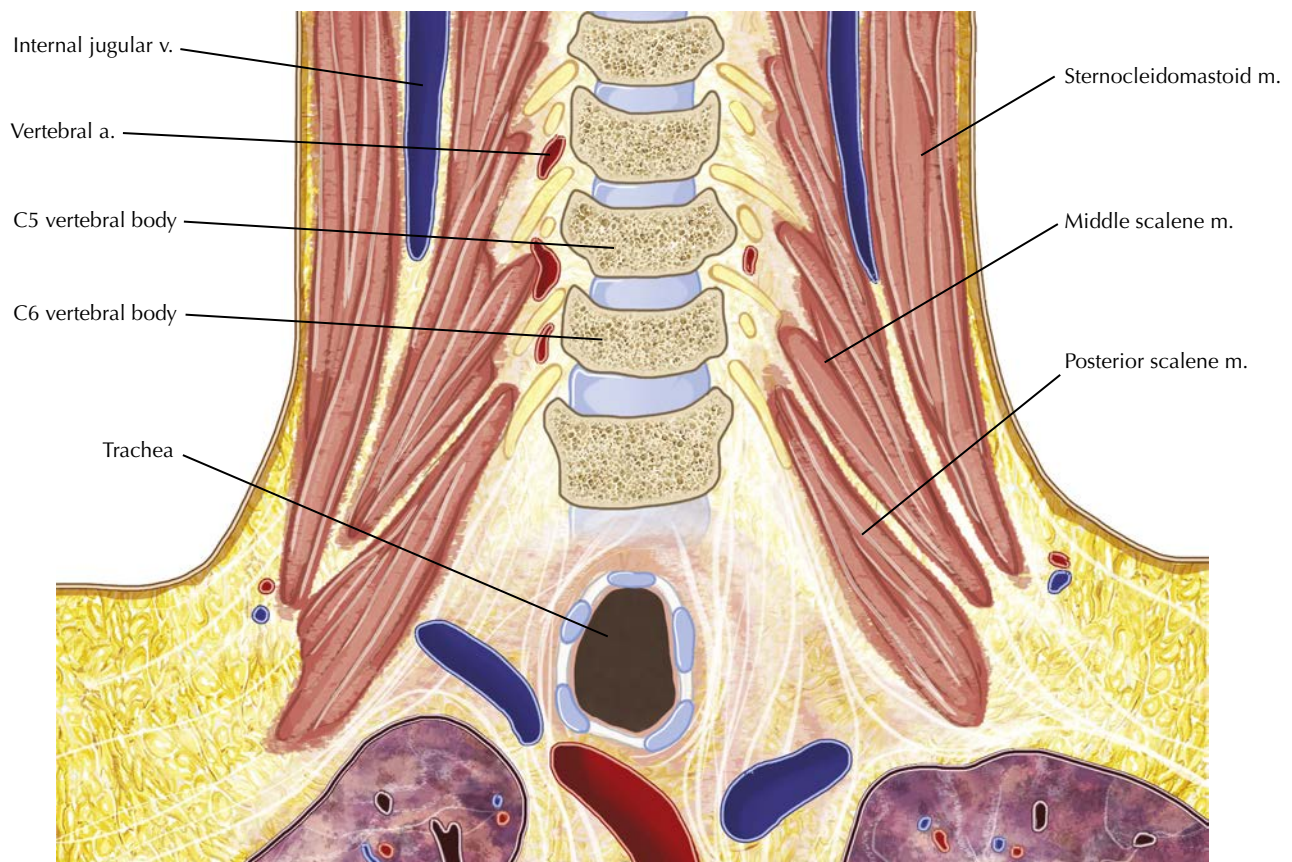
HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK CORONAL 3



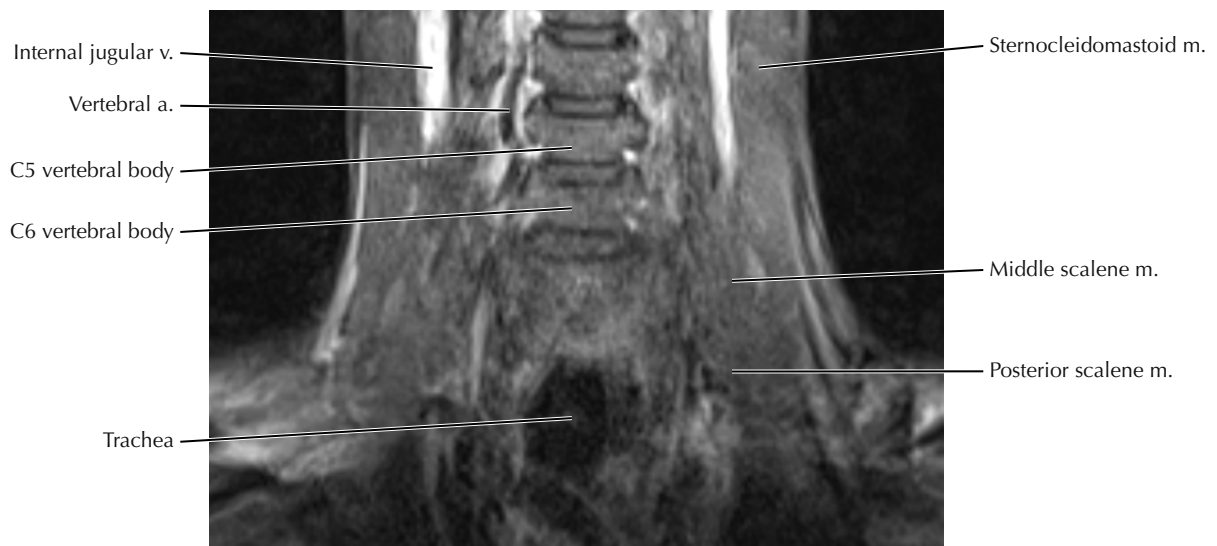
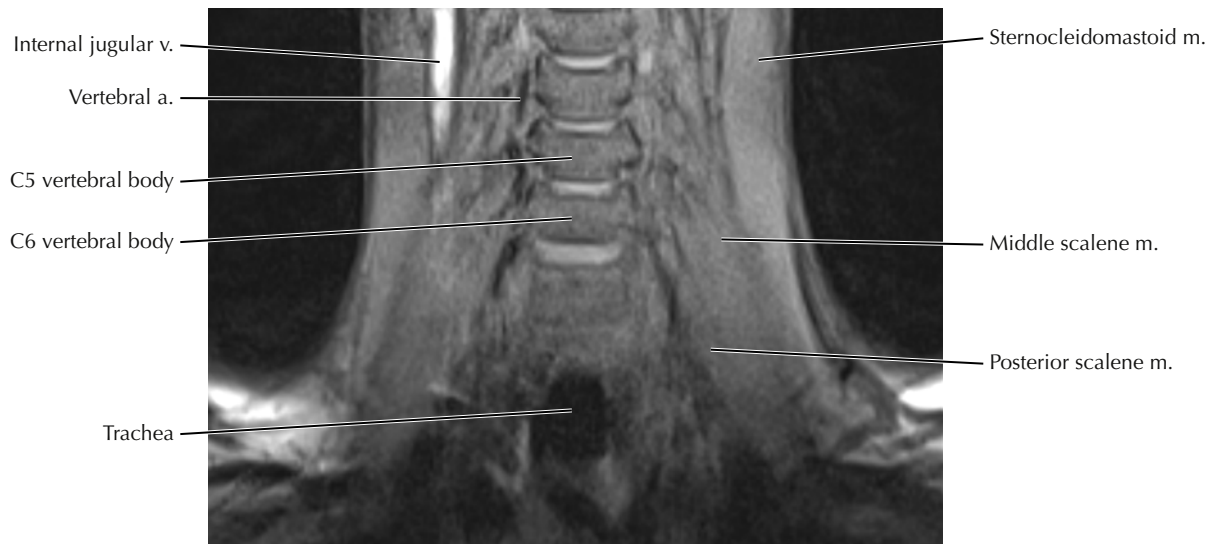
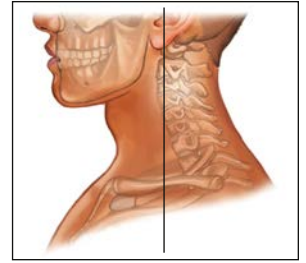


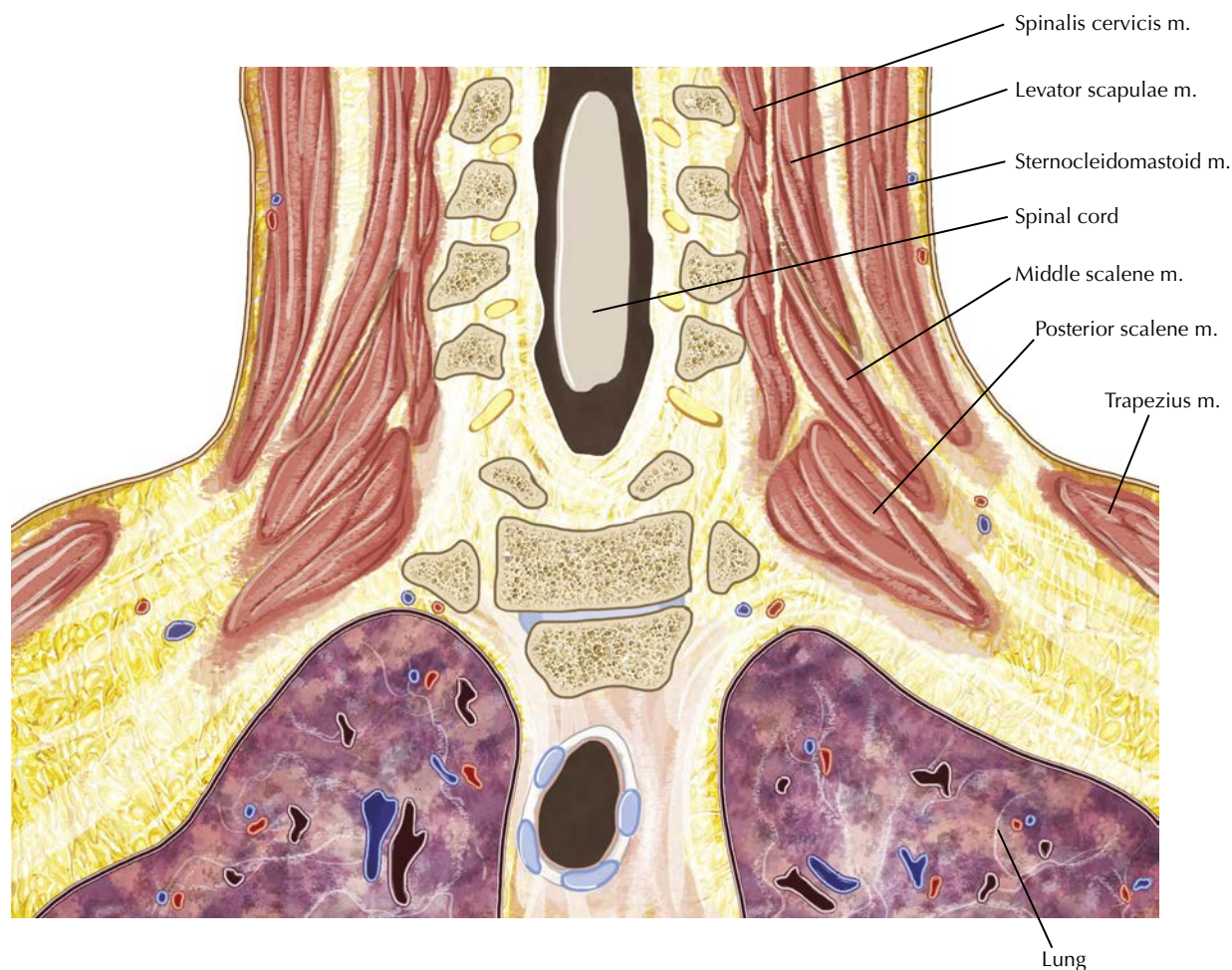
HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK CORONAL 4





HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK CORONAL 5



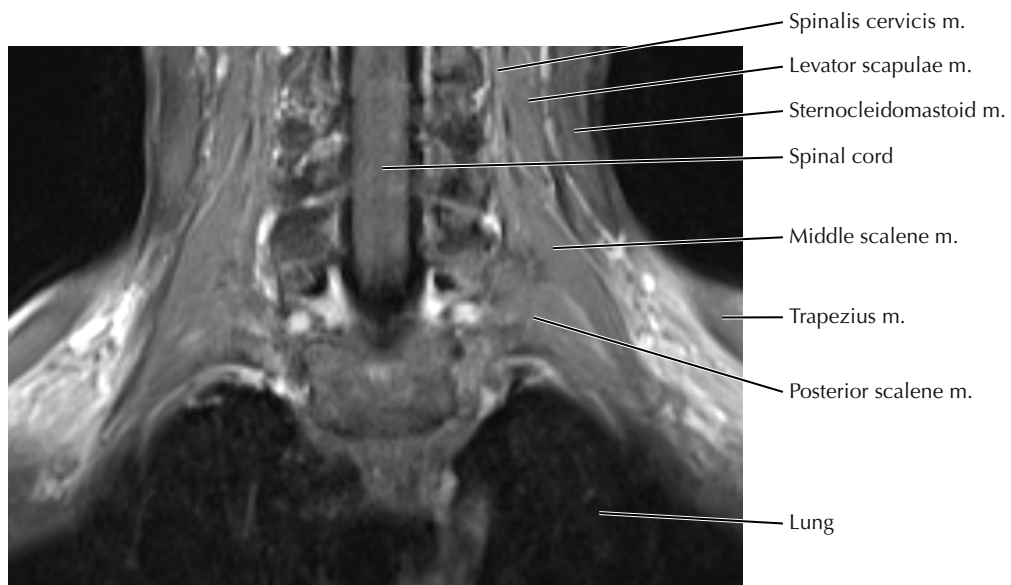
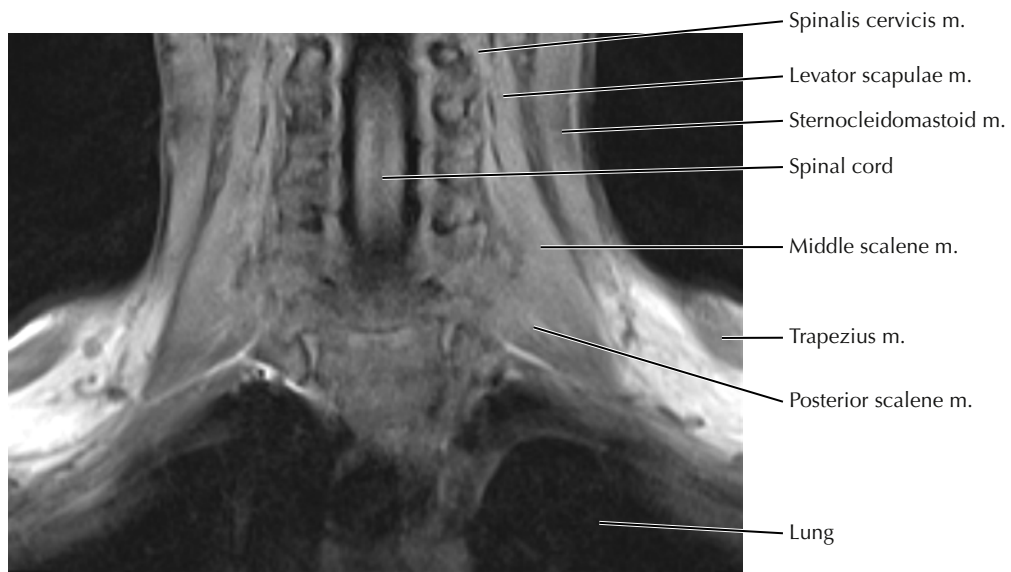
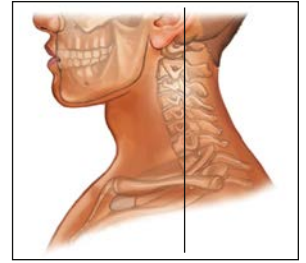


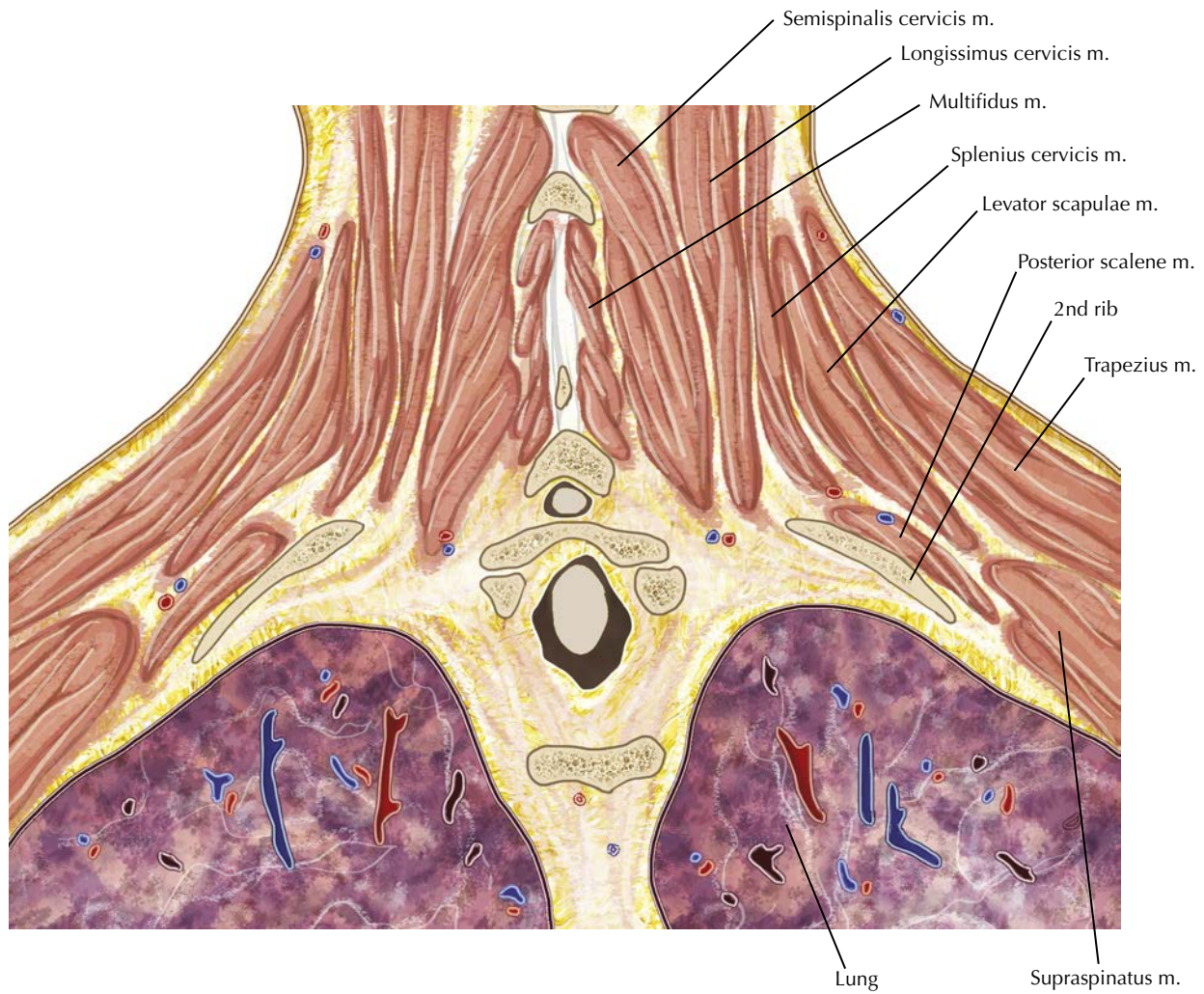
NORMAL ANATOMY

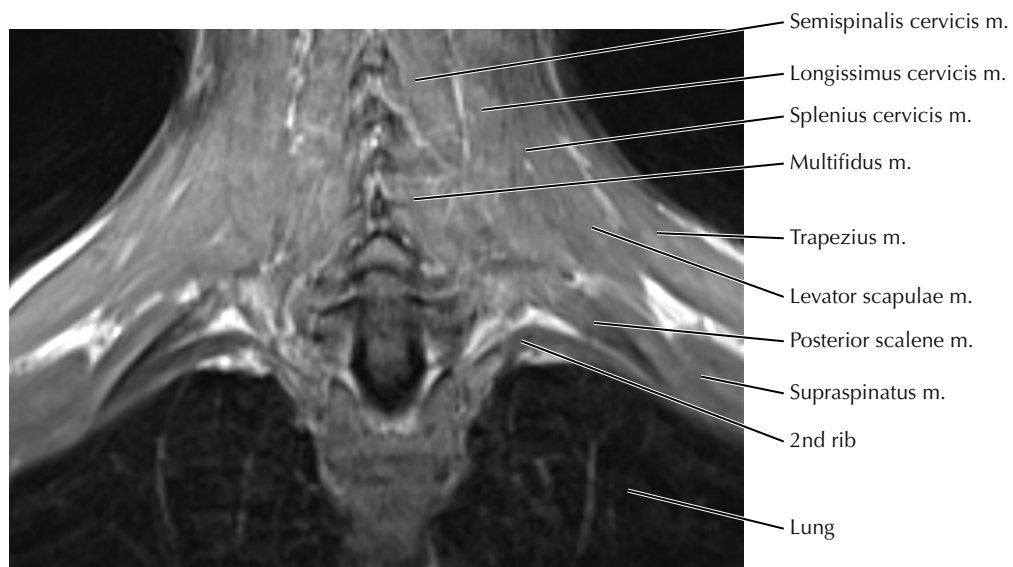
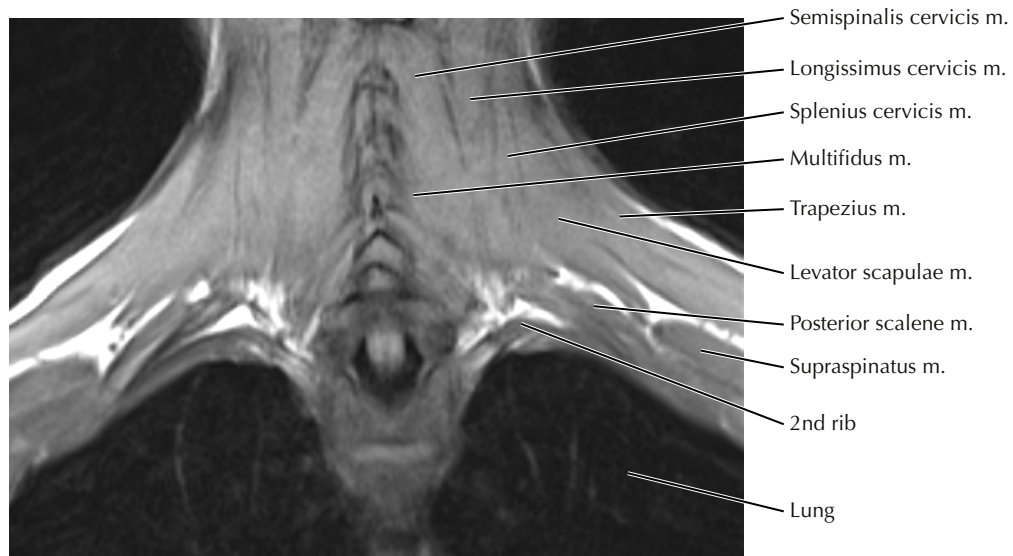
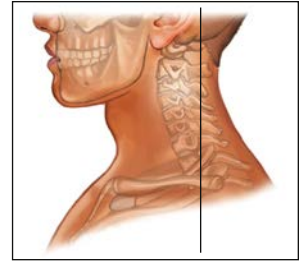
On the Coronal 6 image, cervical nerve roots are seen exiting the foramina to form the brachial plexus. This plexus is formed at cervical vertebrae C5, C6, C7, and C8 and the first thoracic vertebra (T1). Note that C8 is the only nerve without a corresponding vertebra; thus it exits through the C7-T1 foramen. Nerves above this level exit above the corresponding vertebra (e.g., C7 exits spinal canal through C6-C7 foramen), and nerves below this level exit below the corresponding vertebra (e.g., T1 exits through T1-T2 foramen).

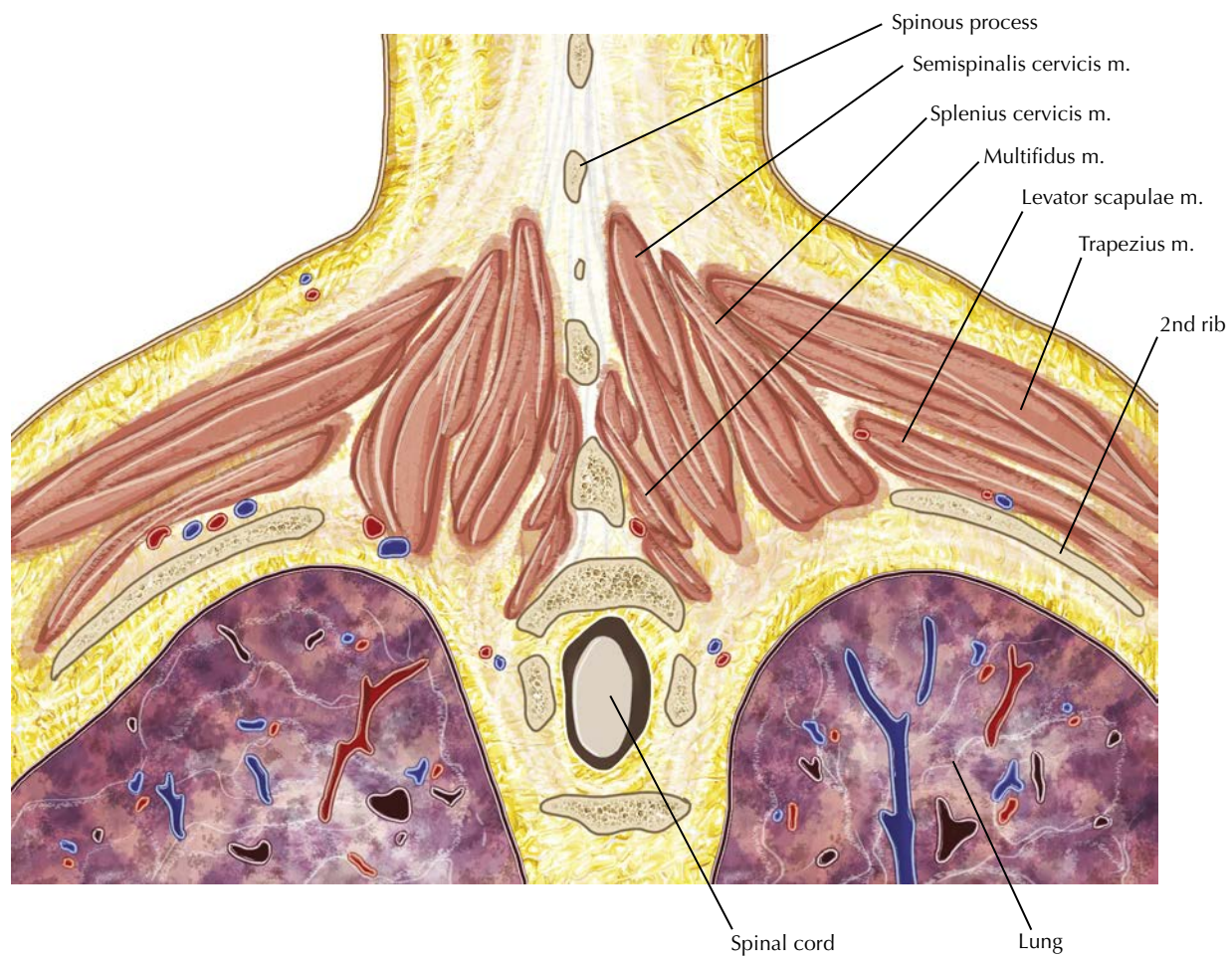
PATHOLOGIC PROCESS

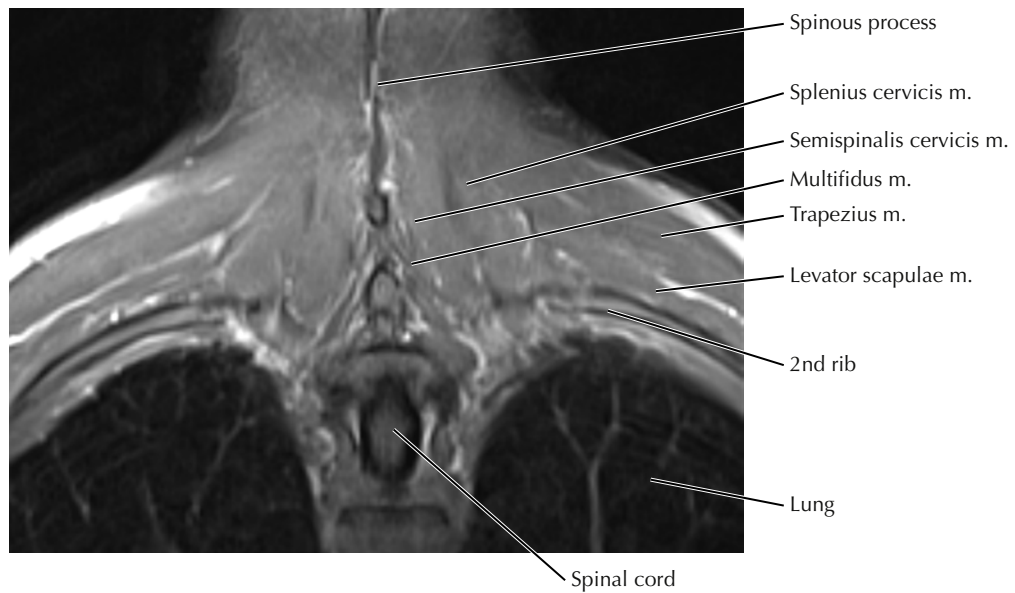
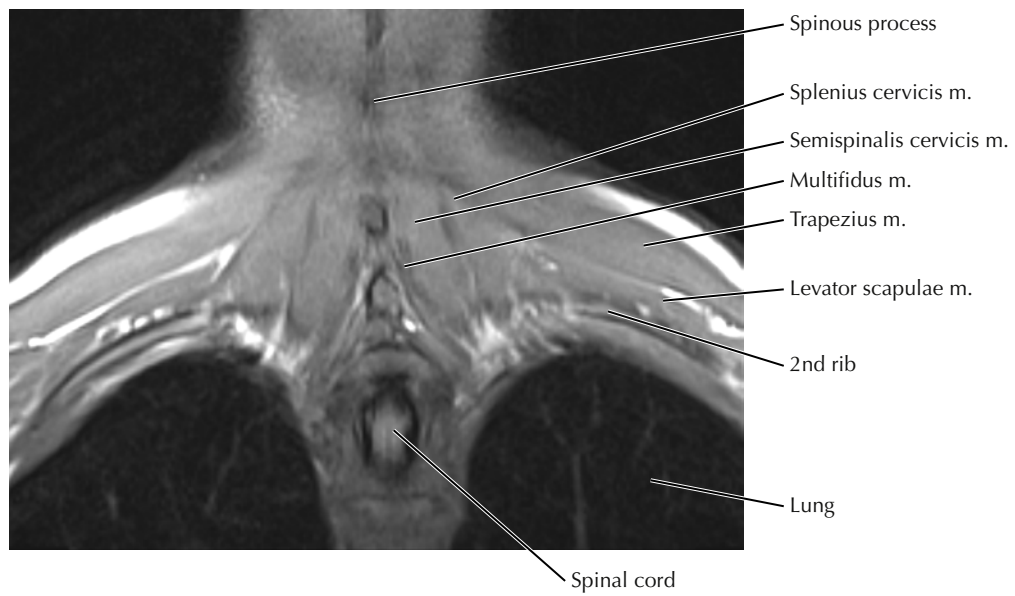
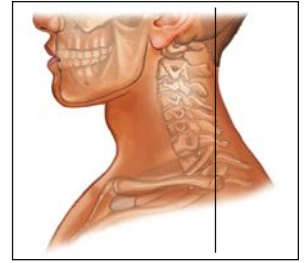
Metastatic lymph nodes in the neck typically are anterior to the spinal column and do not invade the brachial plexus, except in florid disease. More often, a tumor in the top of the lungs may involve the brachial plexus, known as a *Pancoast tumor* (pulmonary sulcus tumor).

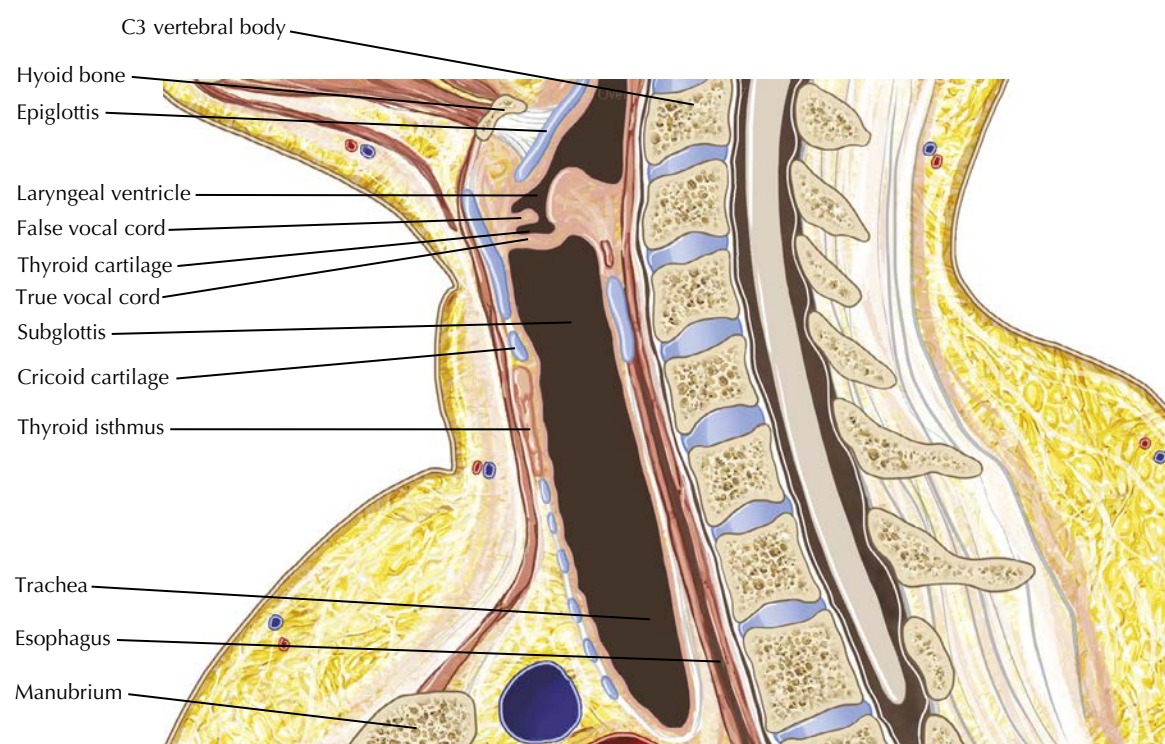






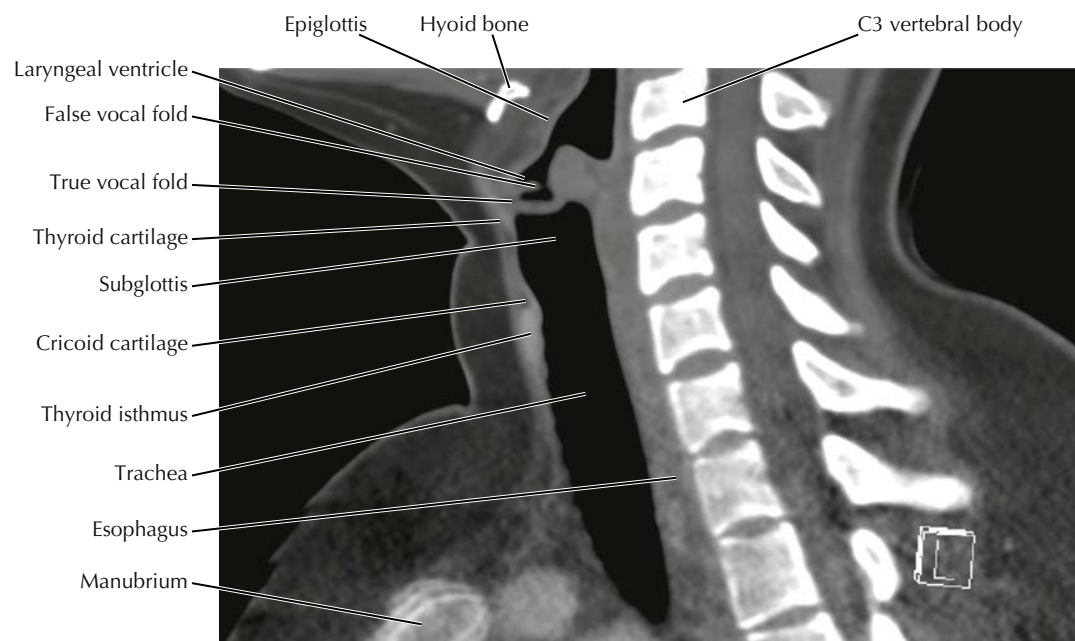
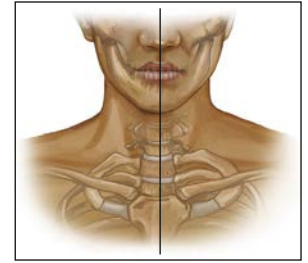


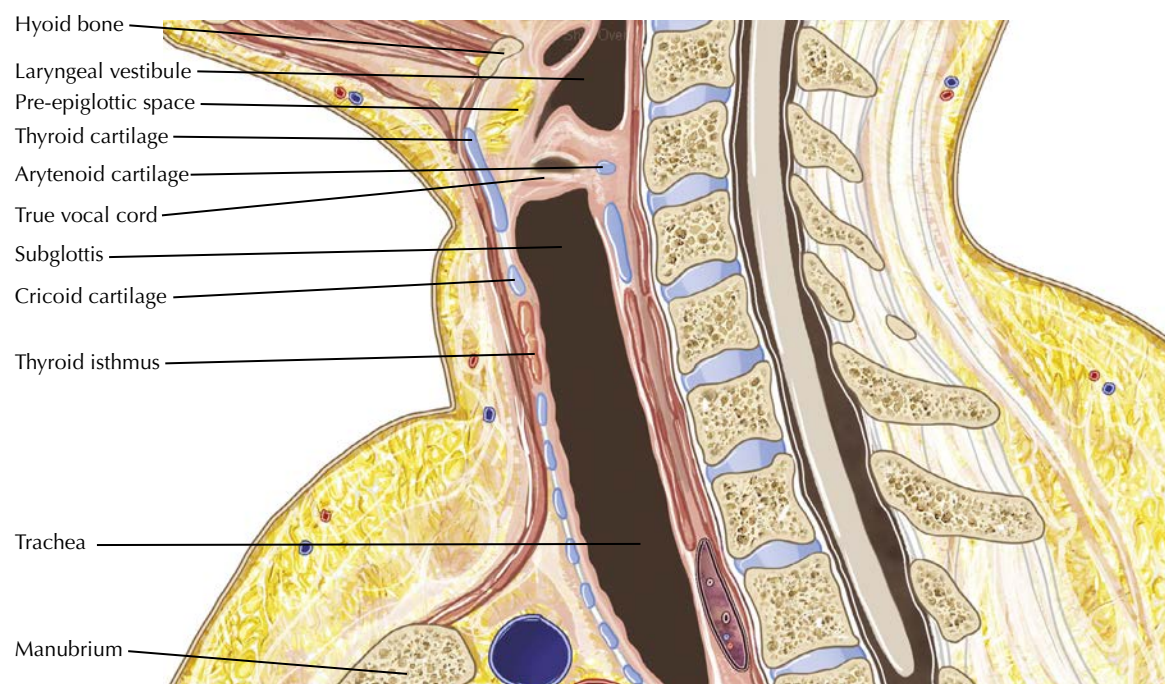




IMAGING TECHNIQUE CONSIDERATION

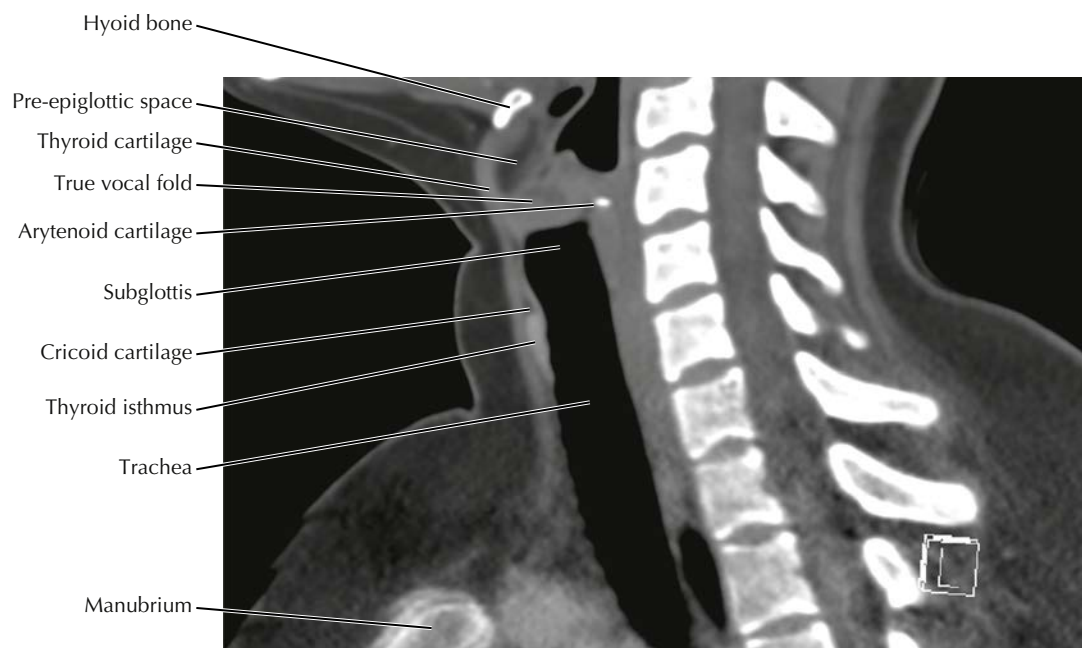
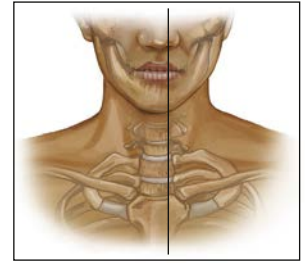
Although the Sagittal 1 plane is ideally a midline image, most patients will show a slight curvature caused by positioning or scoliosis. This sagittal image is fairly well centered on the hypopharynx and upper trachea, although the lower trachea is seen curving off the plane of image, as are the lower cervical and upper thoracic spinous processes.



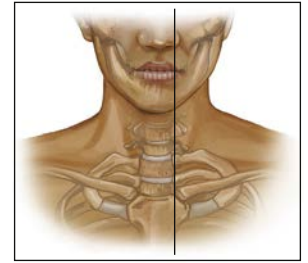


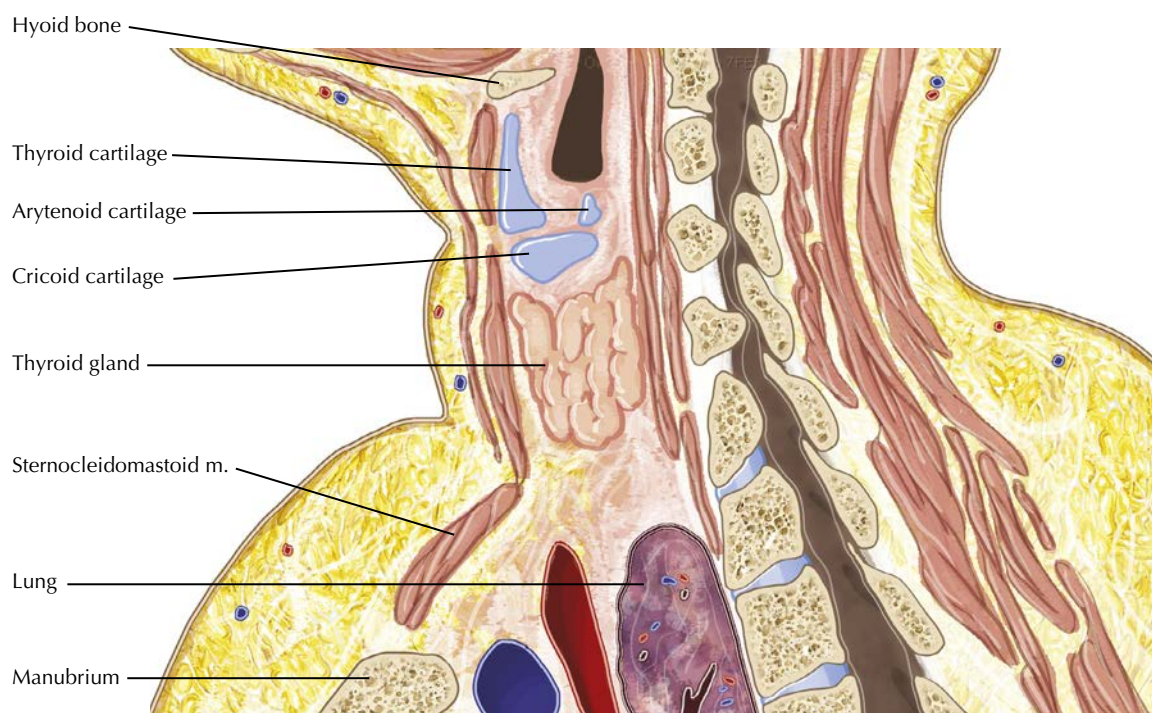
NORMAL ANATOMY

Usually the vertebra with the most palpable spinous process is C7. This patient has subcutaneous tissue that does not allow for palpation of the C7 spinous process tip. However, note how much farther posteriorly the C7 process extends than the tip of C3, C4, C5, or C6. The most accurate way of labeling spine levels is to count from C1. The hyoid bone is anterior to C3.







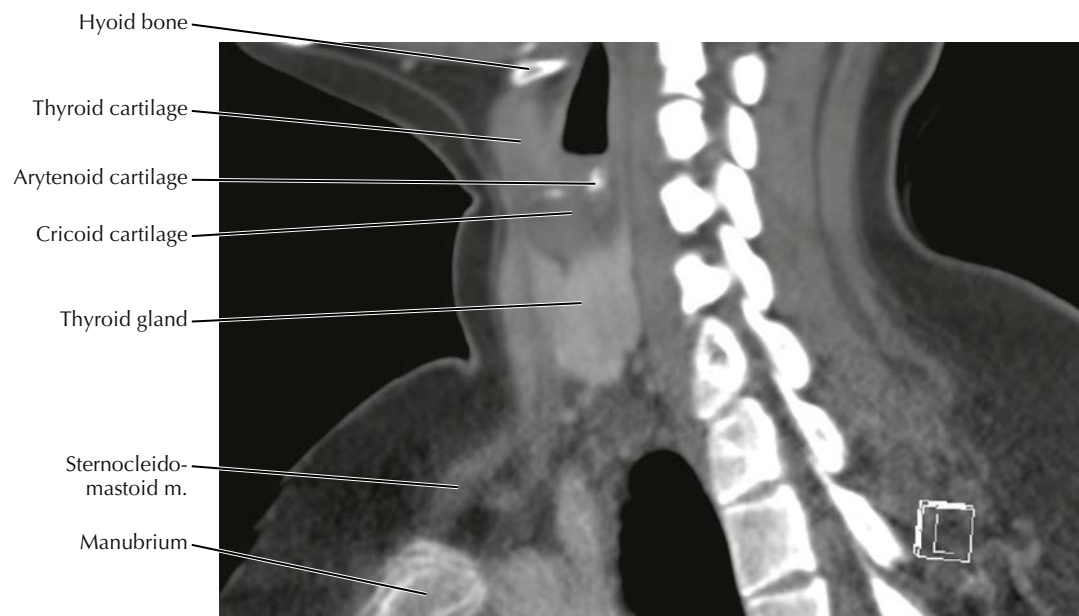
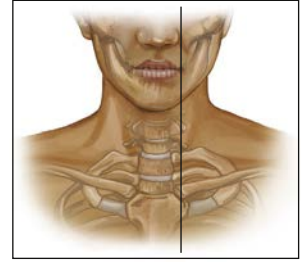


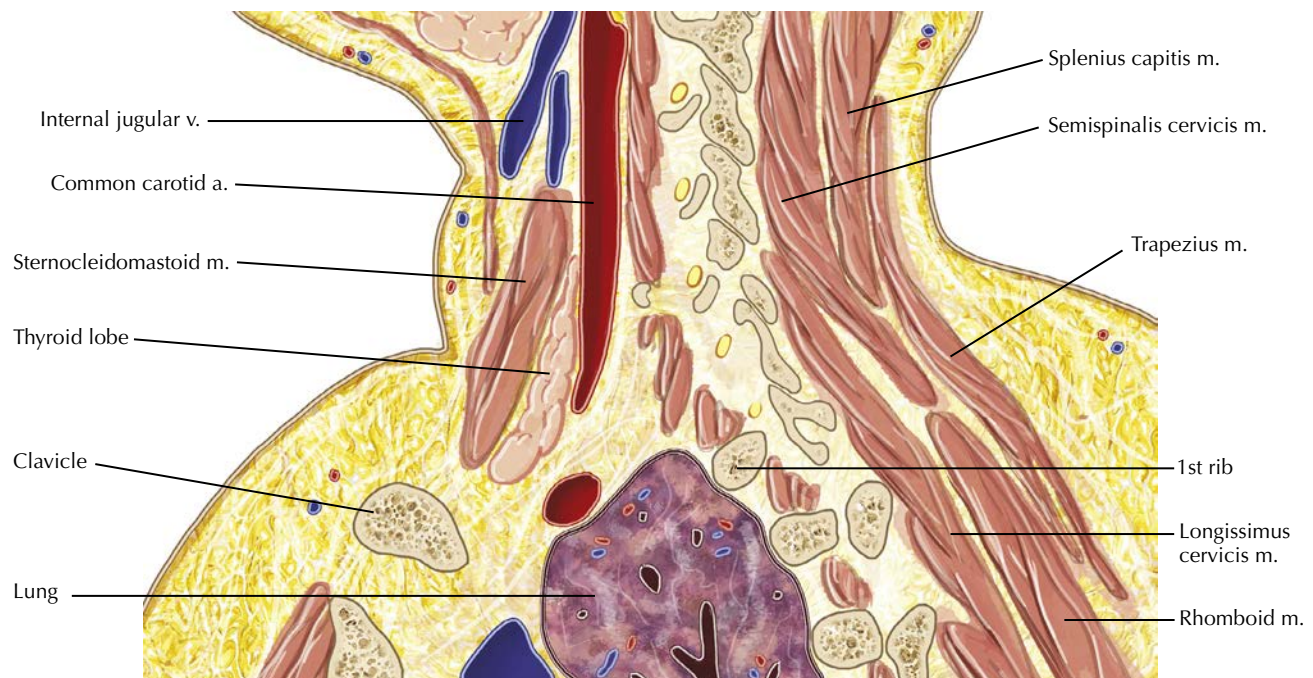
NORMAL ANATOMY

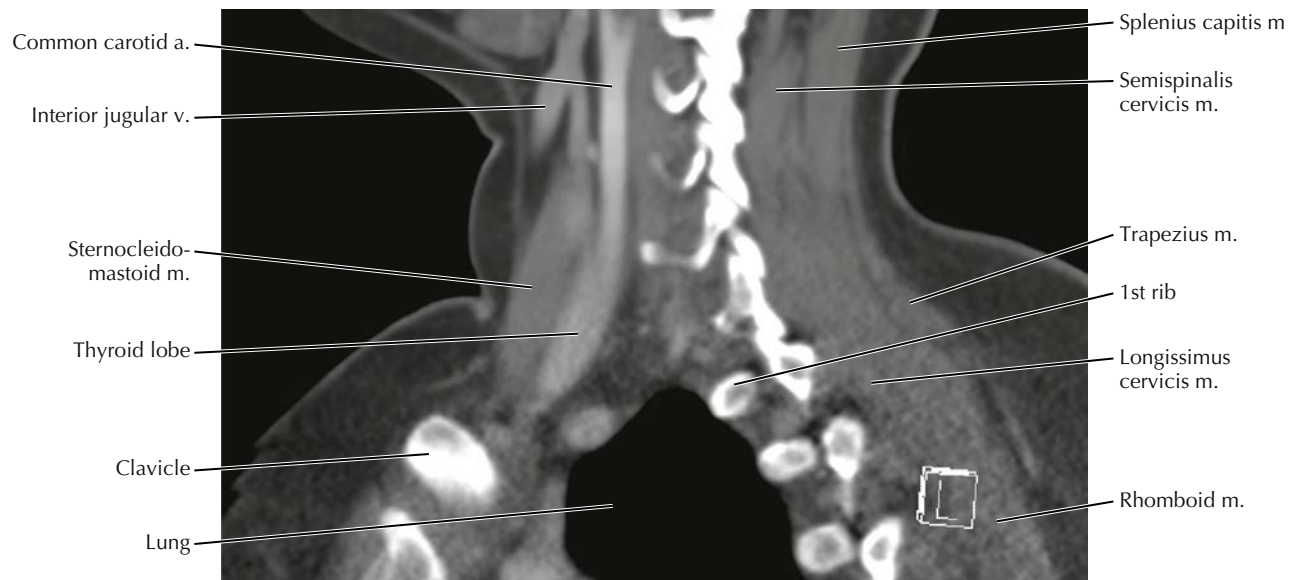
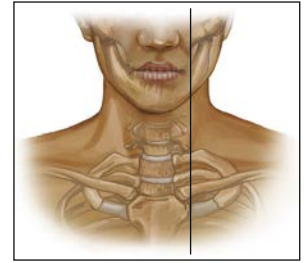
The cervical neural foramina rarely line up on a single plane as in lumbar imaging, where the anatomic structures such as the foramina and pedicles are much larger. In the Sagittal 4 CT image, the upper neural foramina can be seen, but not the lower foramina because of curvature of the cervical spine from positioning or scoliosis. Thus, assessment of cervical foraminal stenosis is often best done on axial images, where there is symmetry for comparison.

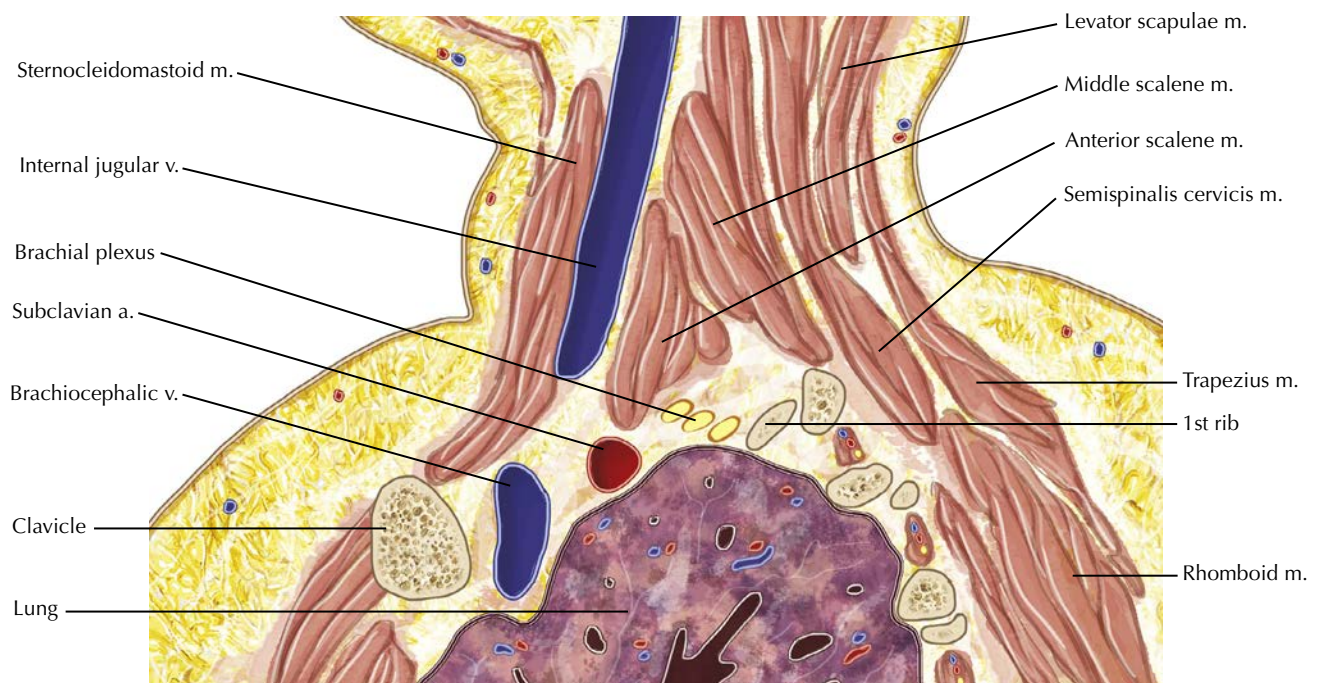
DIAGNOSTIC CONSIDERATION

Although measurement of cervical lymph nodes is performed on axial imaging by convention, the sagittal plane can often increase the conspicuity of an enlarged lymph node, because the internal jugular and spinal accessory lymph node chains can be seen along their entire length.

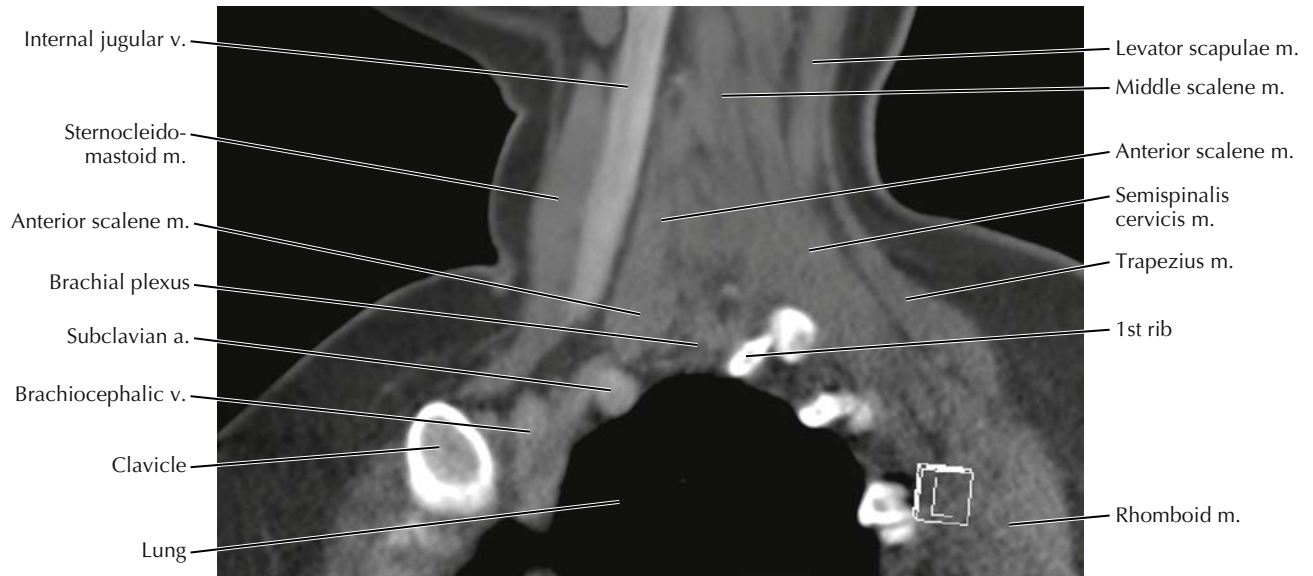
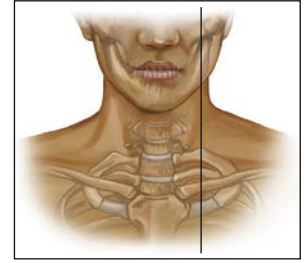


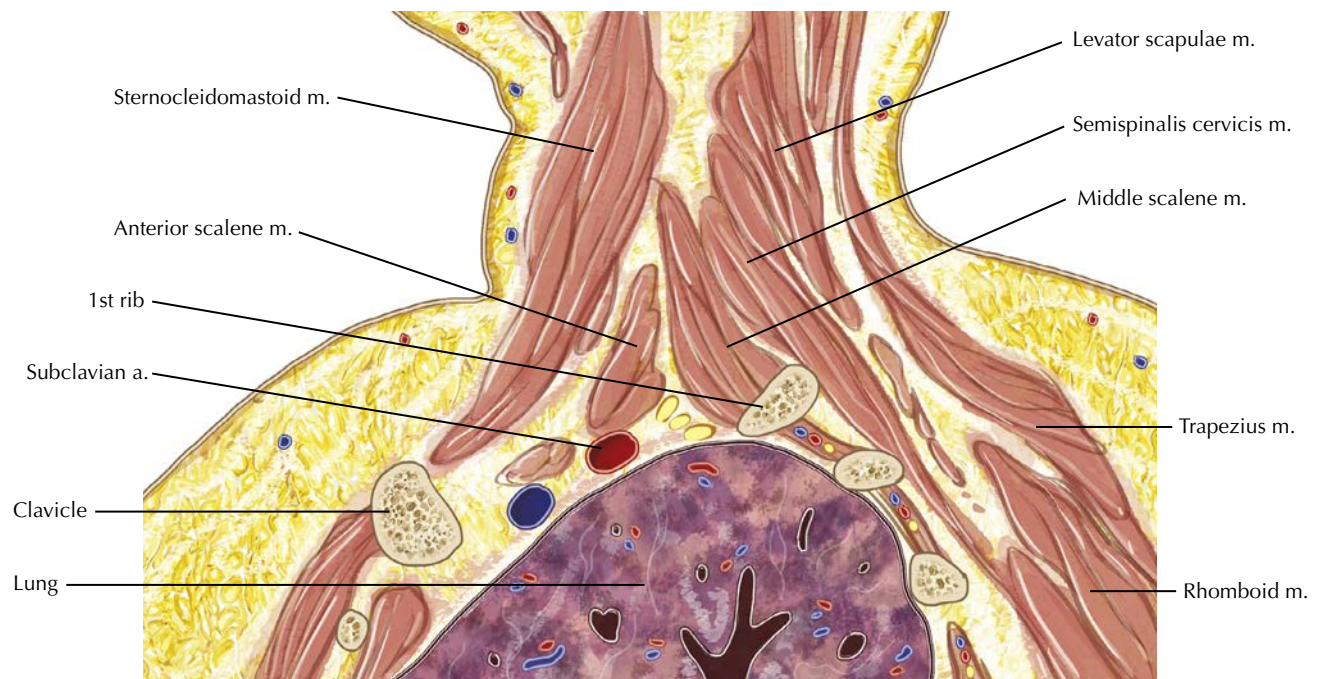


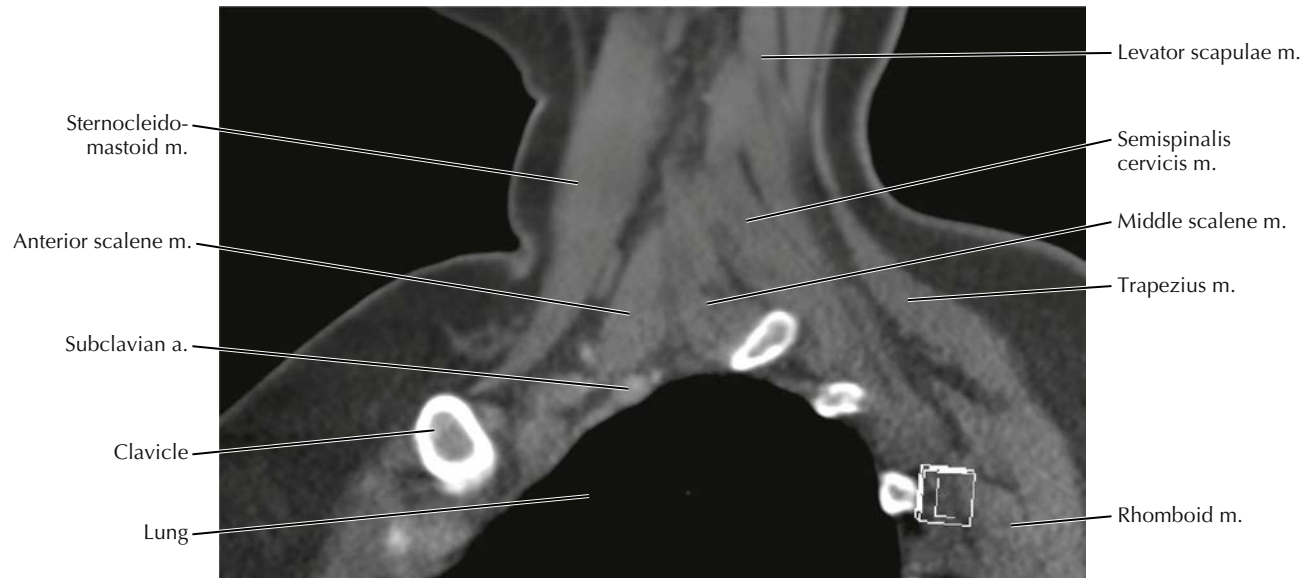
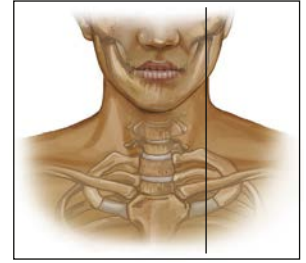


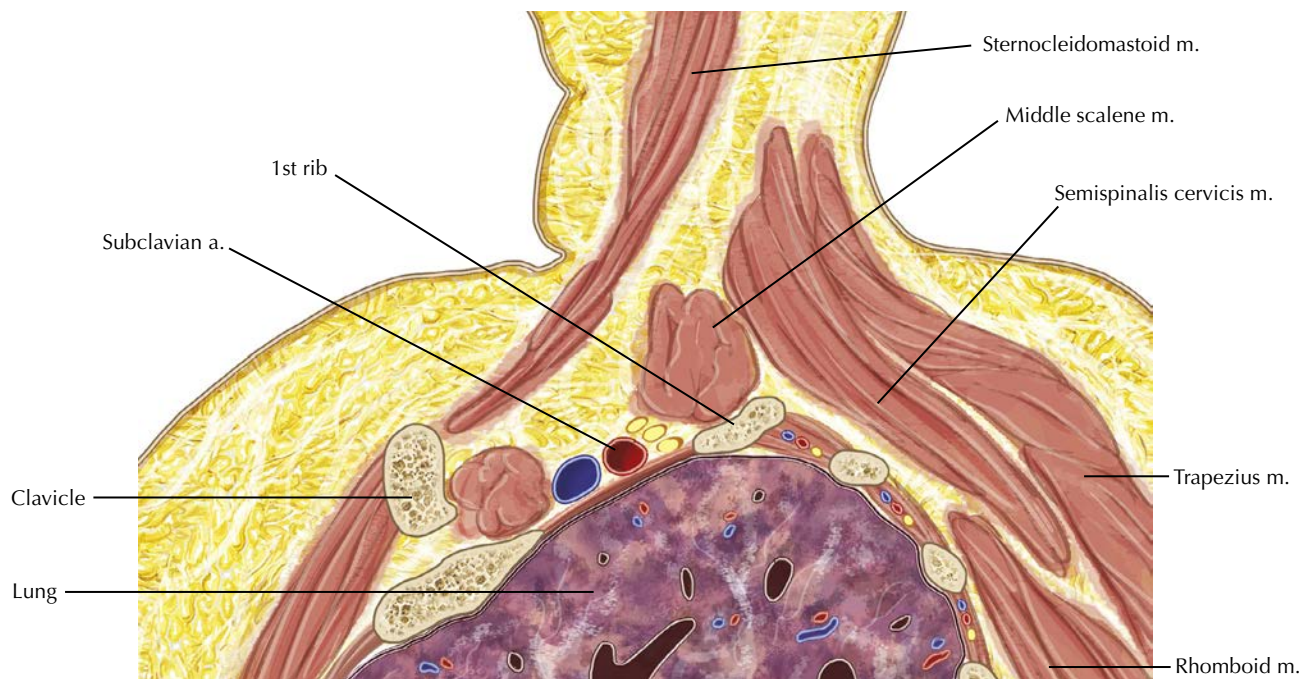


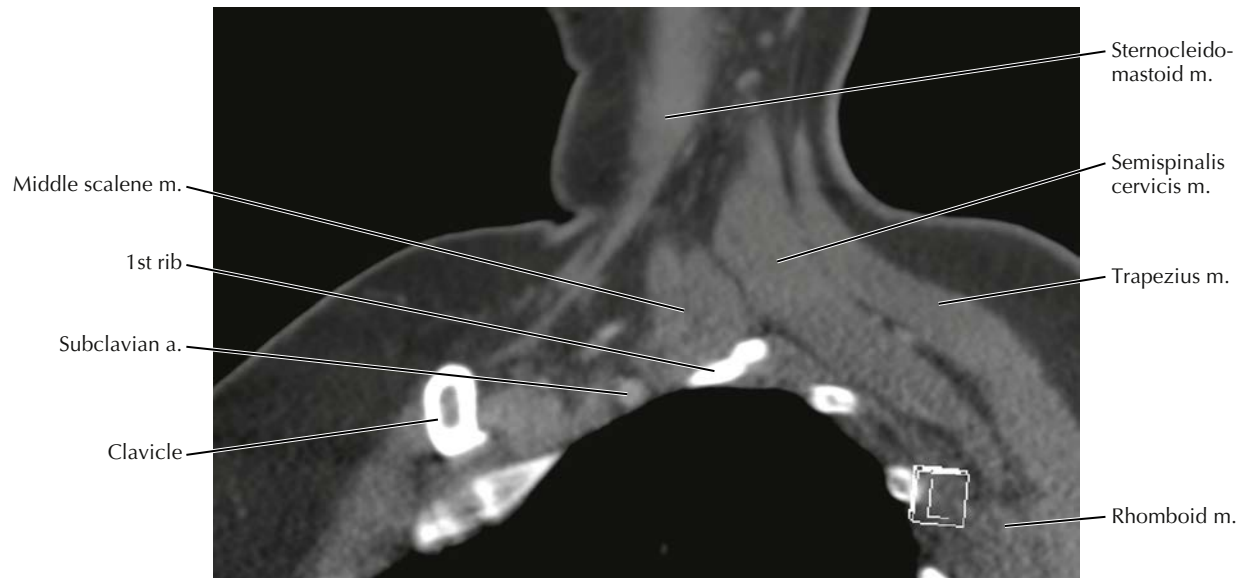
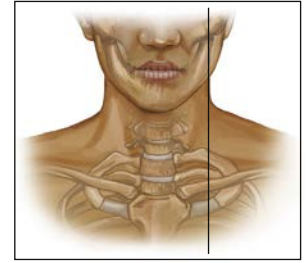
HYPOPHARYNX, LARYNX, AND INFRAHYOID NECK SAGITTAL 6











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PART

3

SPINE

CHAPTER 15 OVERVIEW OF SPINE 523

CHAPTER 16 SPINE 535

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Chapter

15

OVERVIEW OF SPINE

VERTEBRAL COLUMN 524

CERVICAL VERTEBRAE: C1 (ATLAS) AND C2 (AXIS) 525

CERVICAL VERTEBRAE: C3, C4, AND C7 526

EXTERNAL CRANIOCERVICAL LIGAMENTS 527

INTERNAL CRANIOCERVICAL LIGAMENTS 528

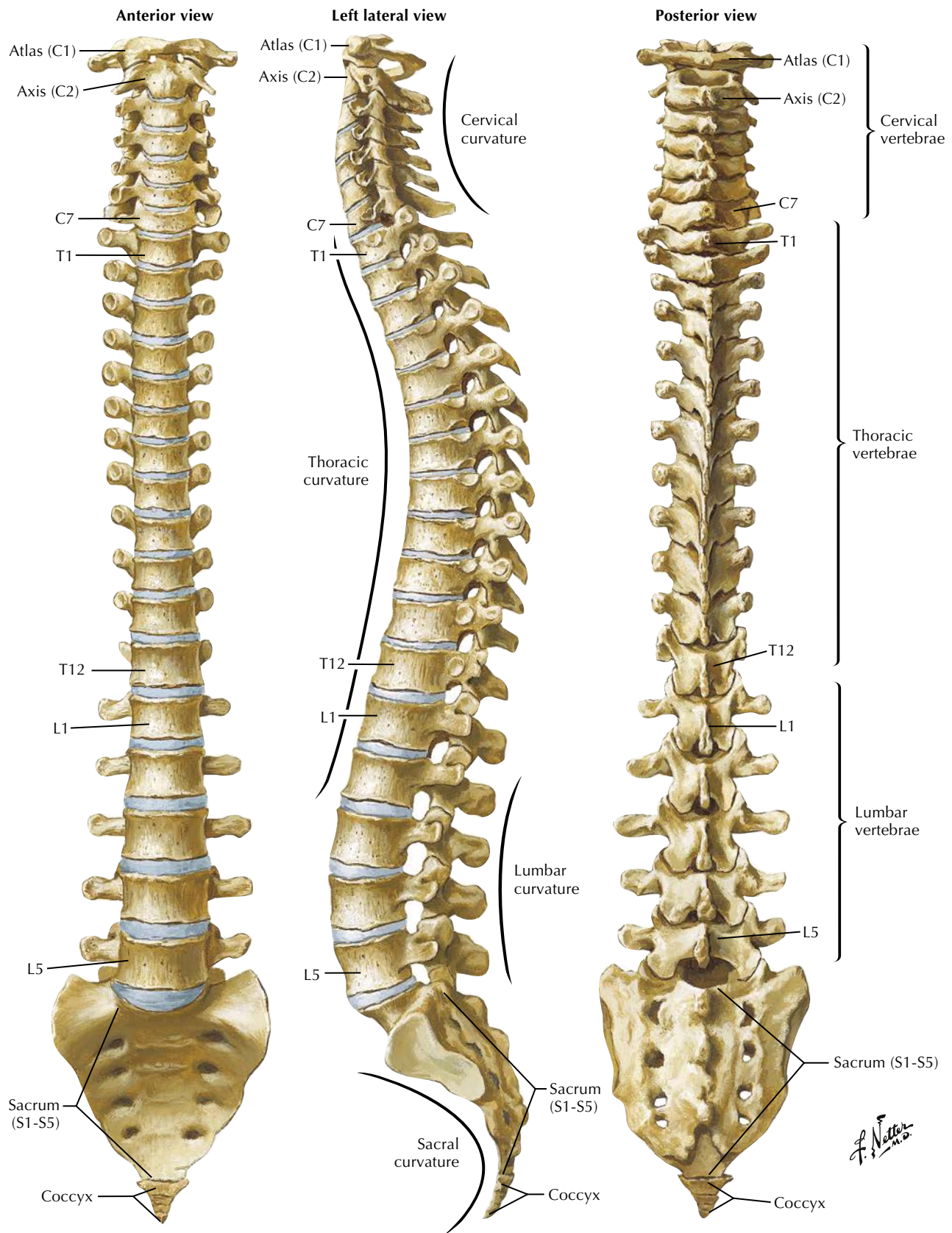
THORACIC VERTEBRAE 529

LUMBAR VERTEBRAE 530

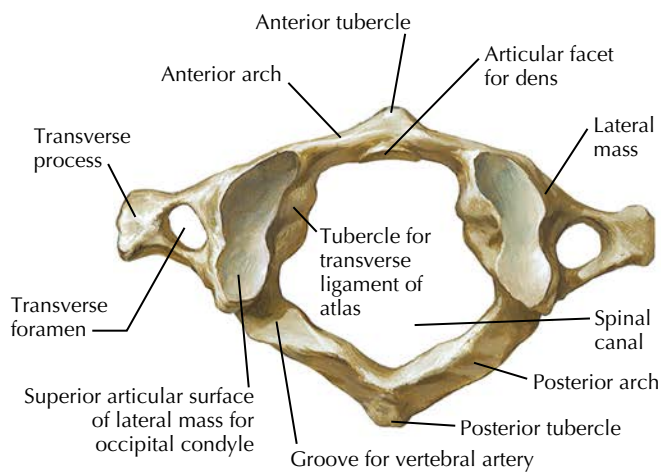
VERTEBRAL LIGAMENTS: LUMBOSACRAL REGION 531

VERTEBRAL LIGAMENTS: LUMBAR REGION 532

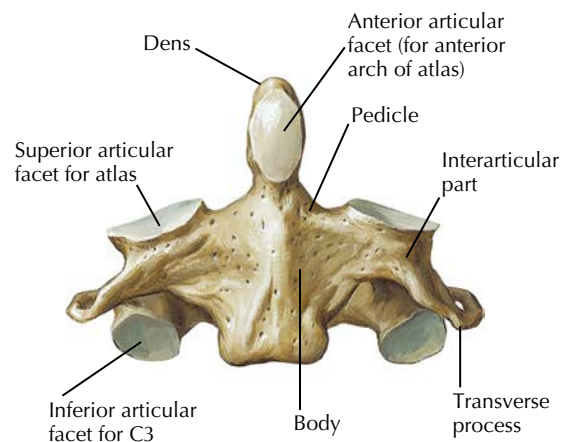
LUMBAR REGION OF BACK: CROSS SECTION 533



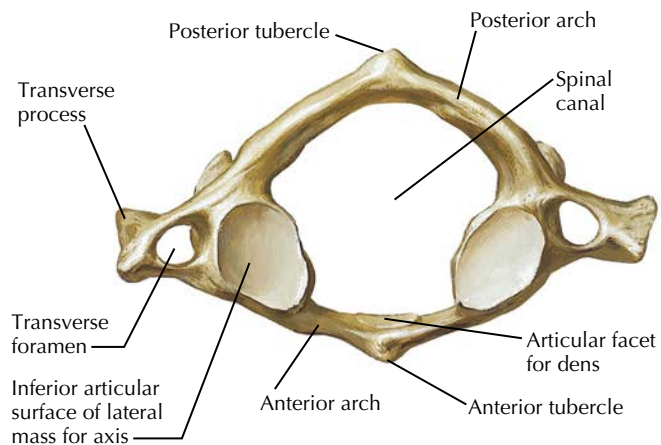
CERVICAL VERTEBRAE: C1 (ATLAS) AND C2 (AXIS)



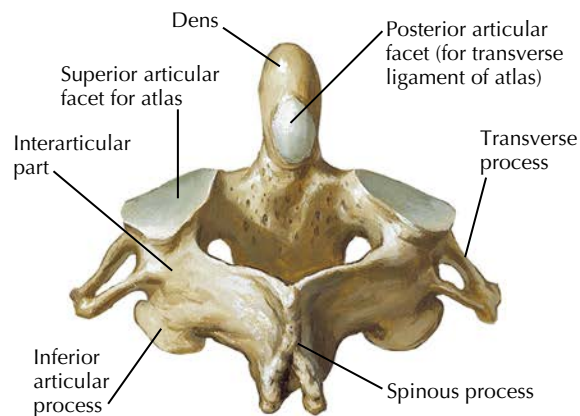
Atlas (C1): superior view



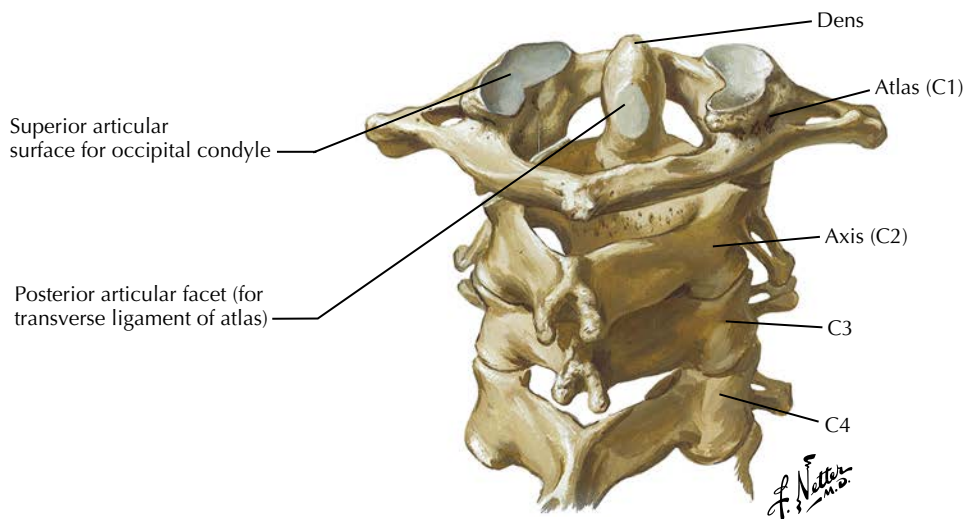
Axis (C2): anterior view



Atlas (C1): inferior view



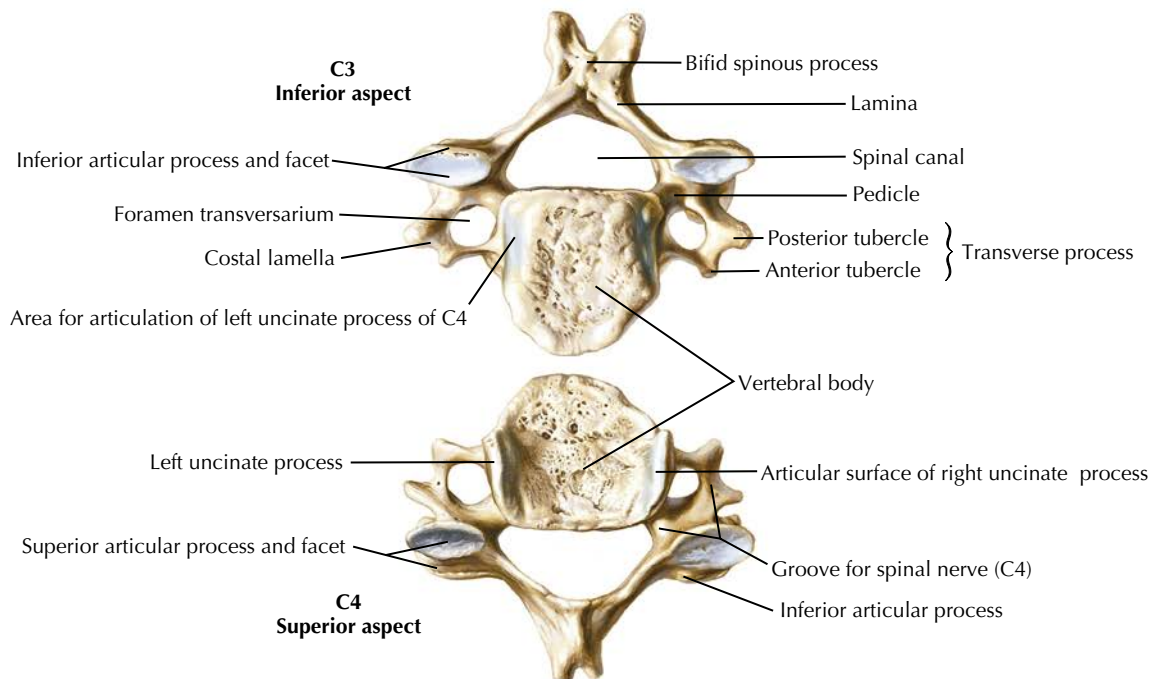
Axis (C2): posterosuperior view



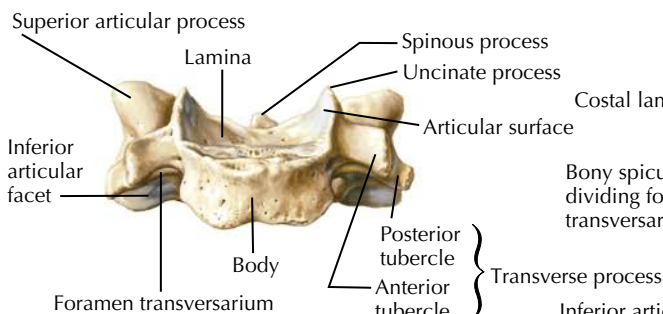
Upper cervical vertebrae, assembled: posterosuperior view

CERVICAL VERTEBRAE: C3, C4, AND C7

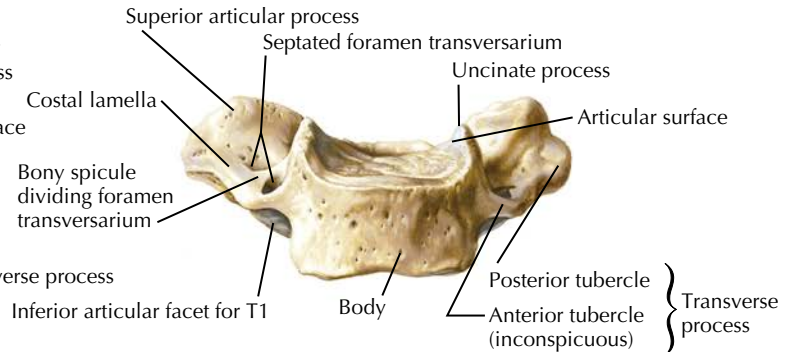
Inferior aspect of C3 and superior aspect of C4 showing the sites of the facet and uncovertebral articulations



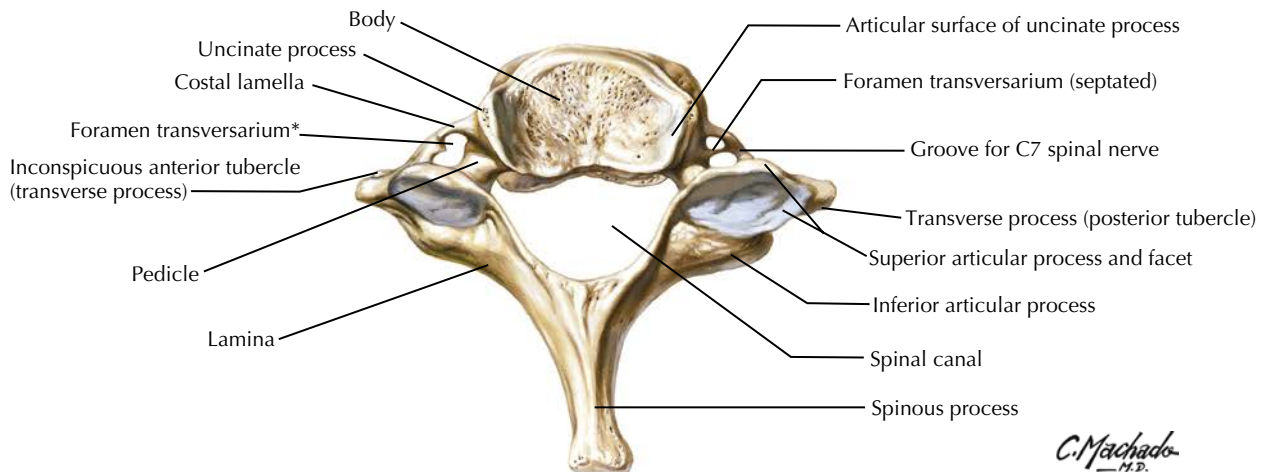
4th cervical vertebra: anterior view



7th cervical vertebra: anterior view

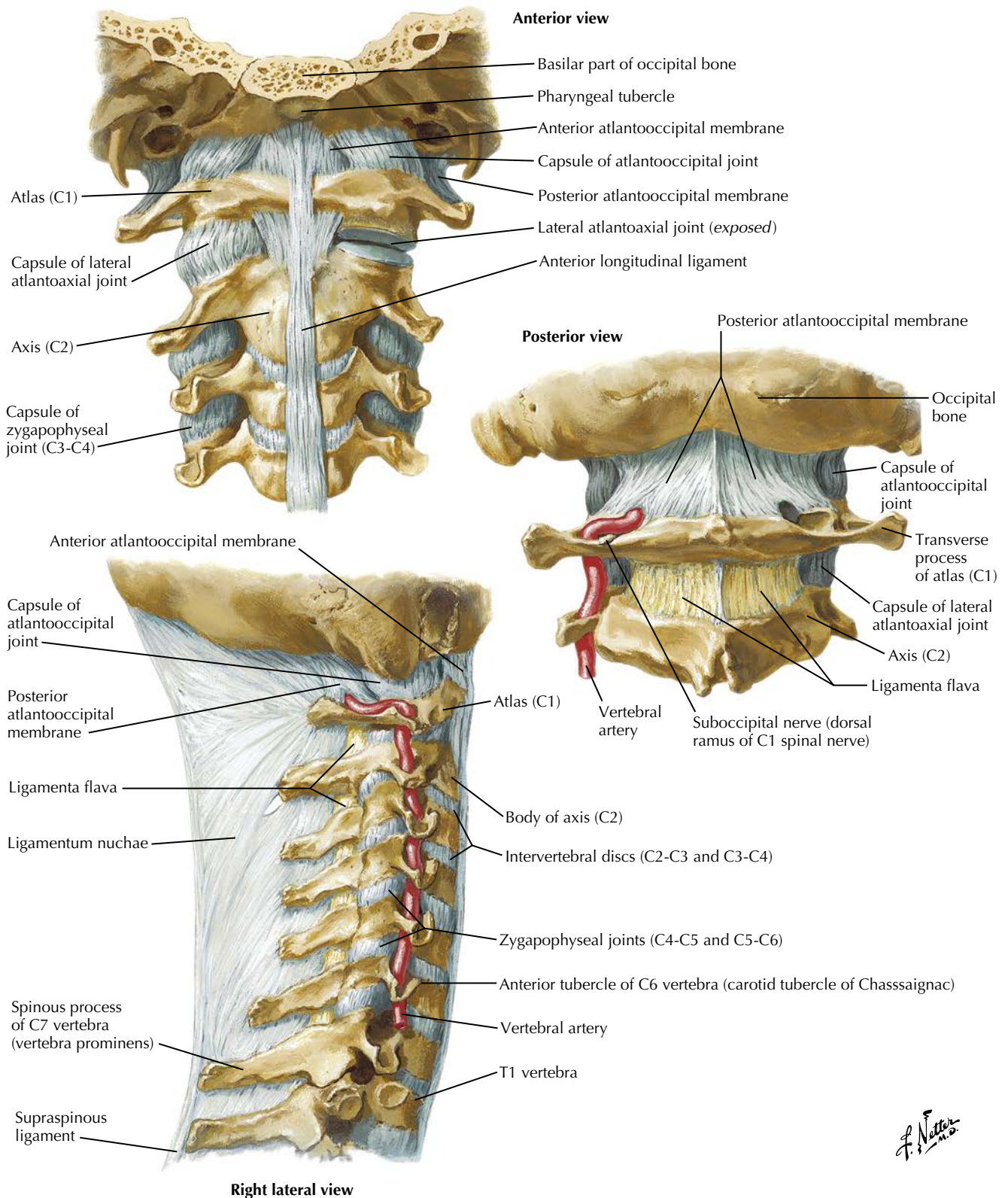


7th cervical vertebra (vertebra prominens): superior view



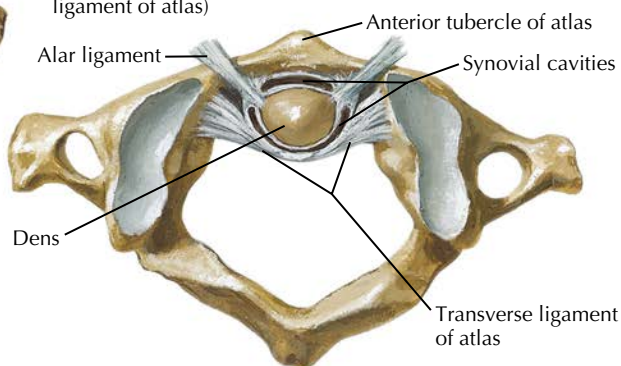
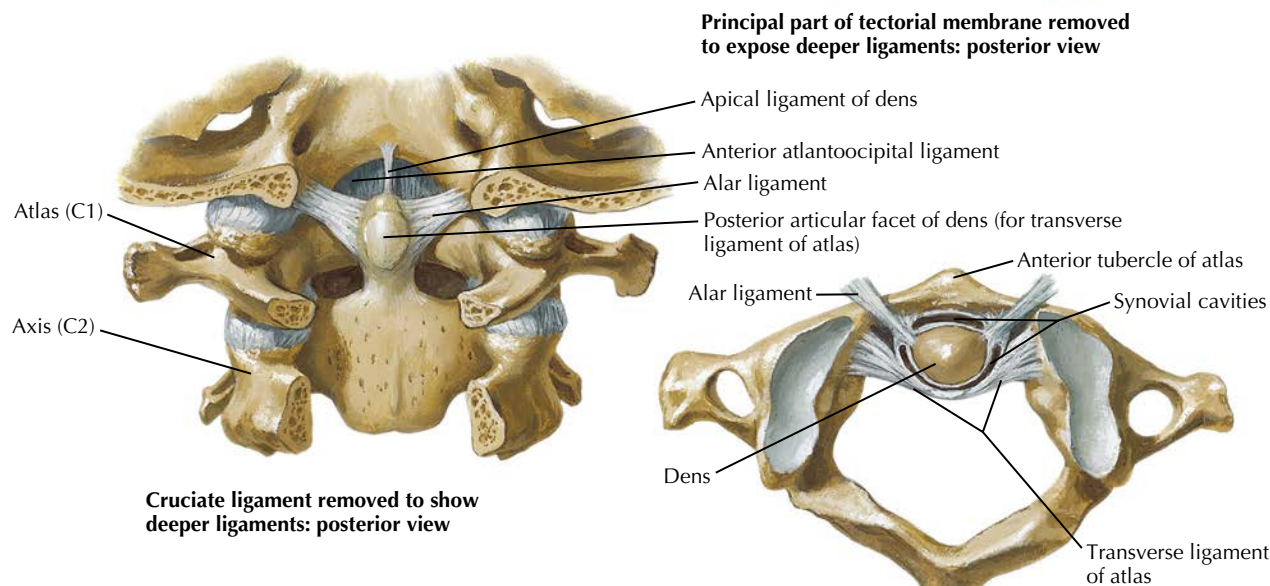
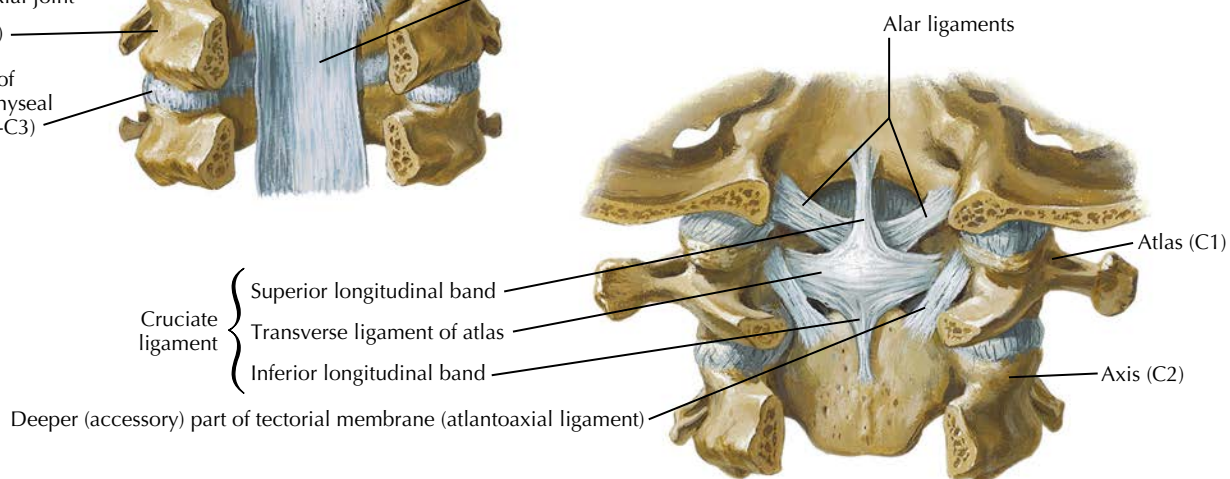
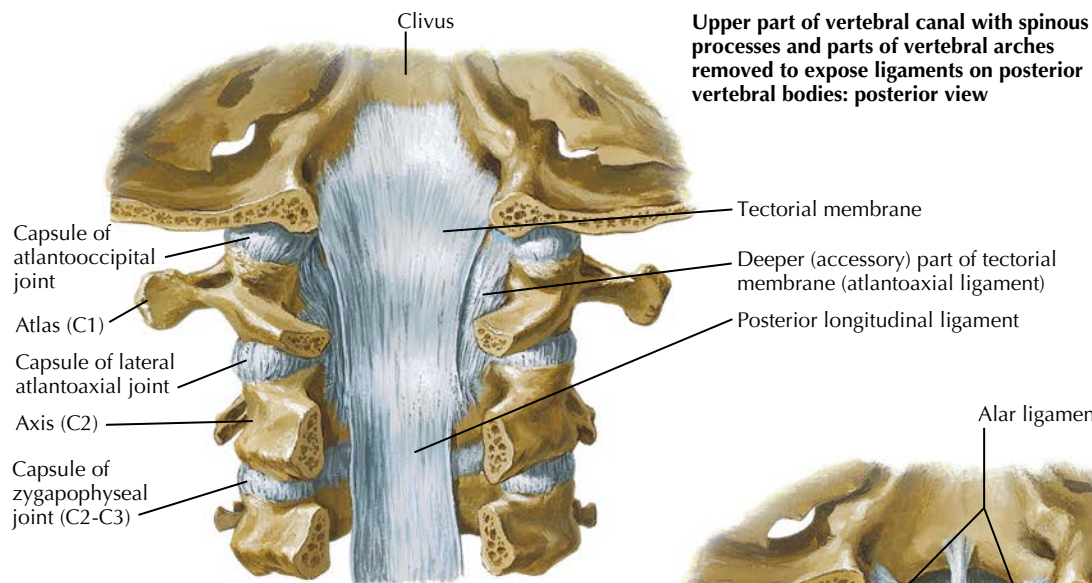
*The foramina transversaria of C7 transmit vertebral veins, but usually not the vertebral artery, and are asymmetric in this specimen.

C. Machado
M.D.



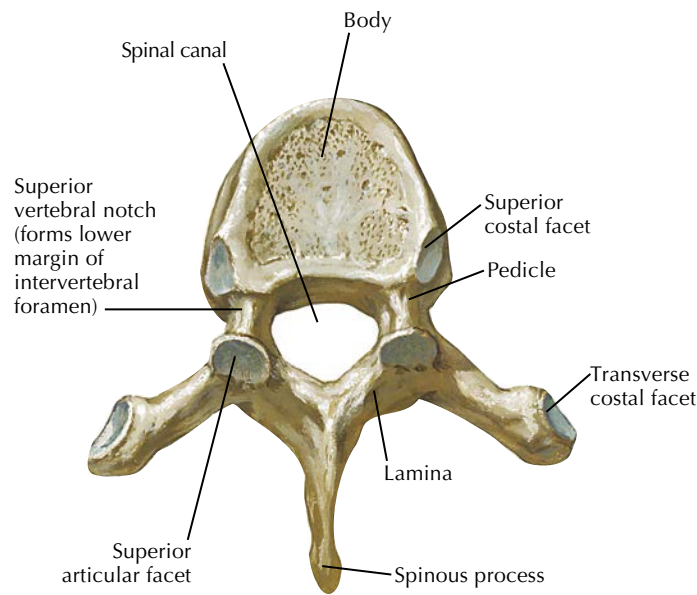
F. Netter M.D.

INTERNAL CRANIOCERVICAL LIGAMENTS

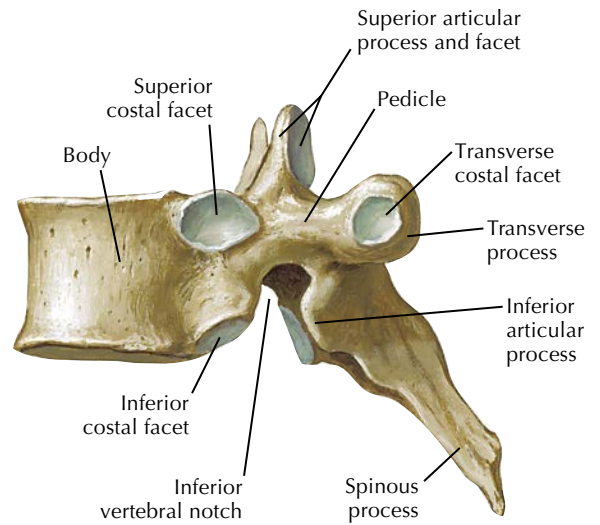


Median atlantoaxial joint: superior view

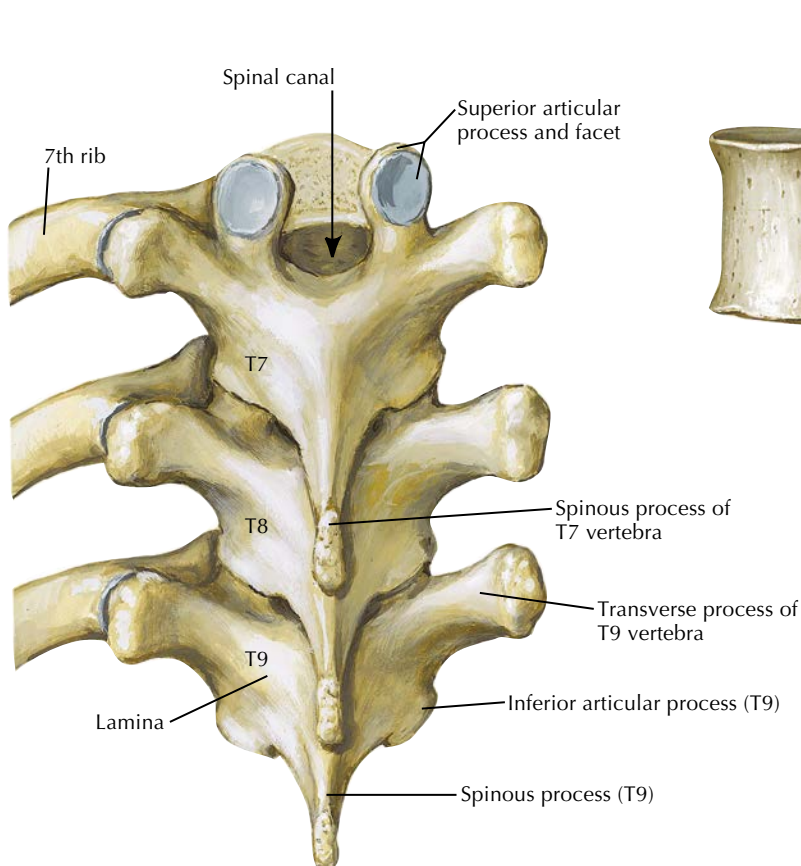
F. Netter M.D.



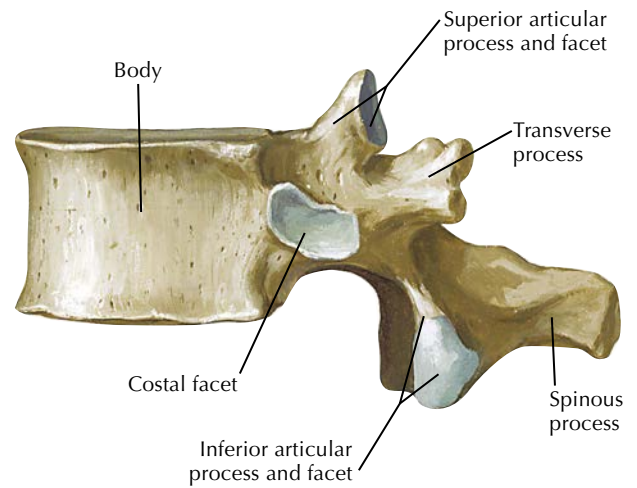
**T6 vertebra:
superior view**



**T6 vertebra:
lateral view**

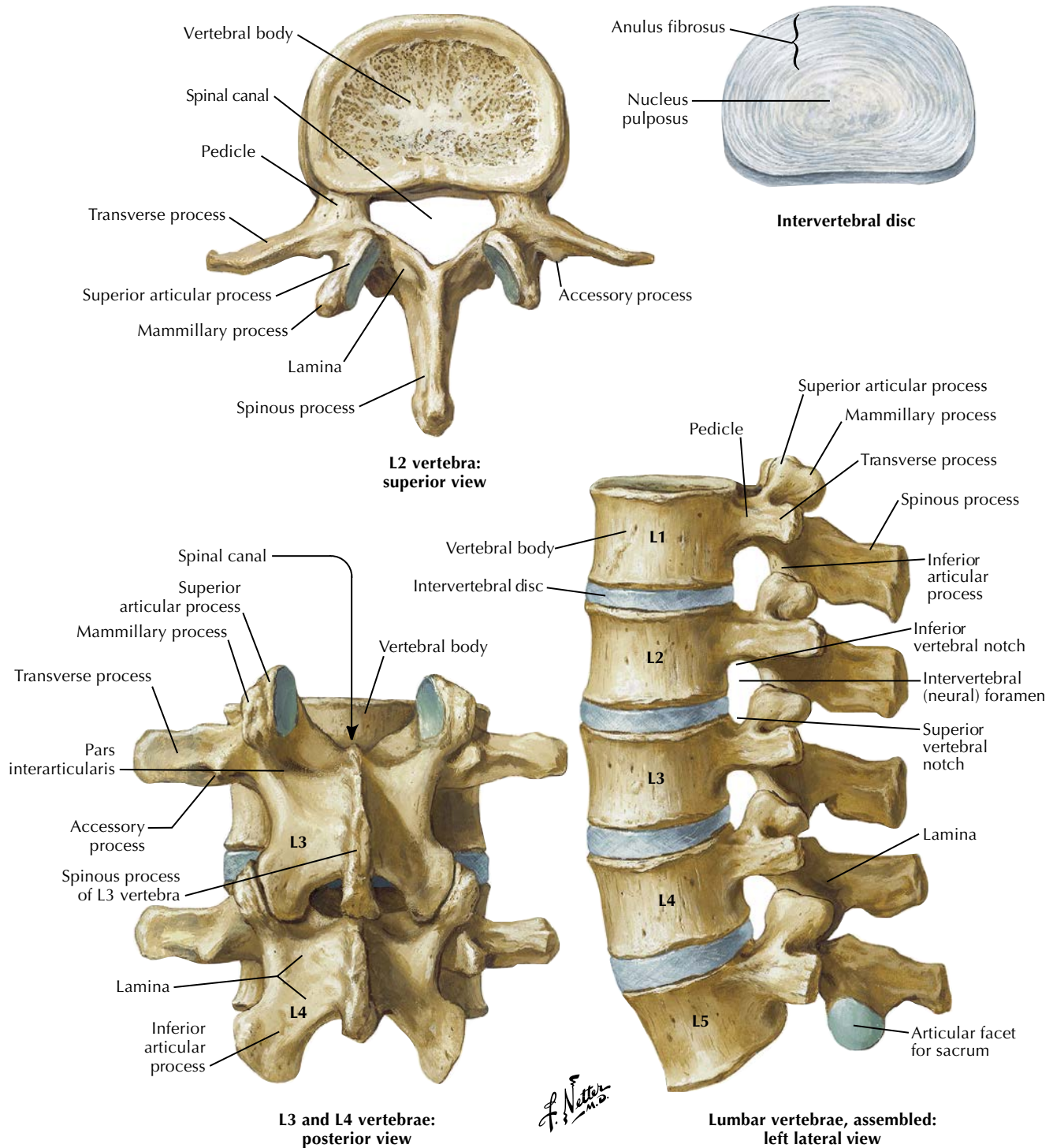


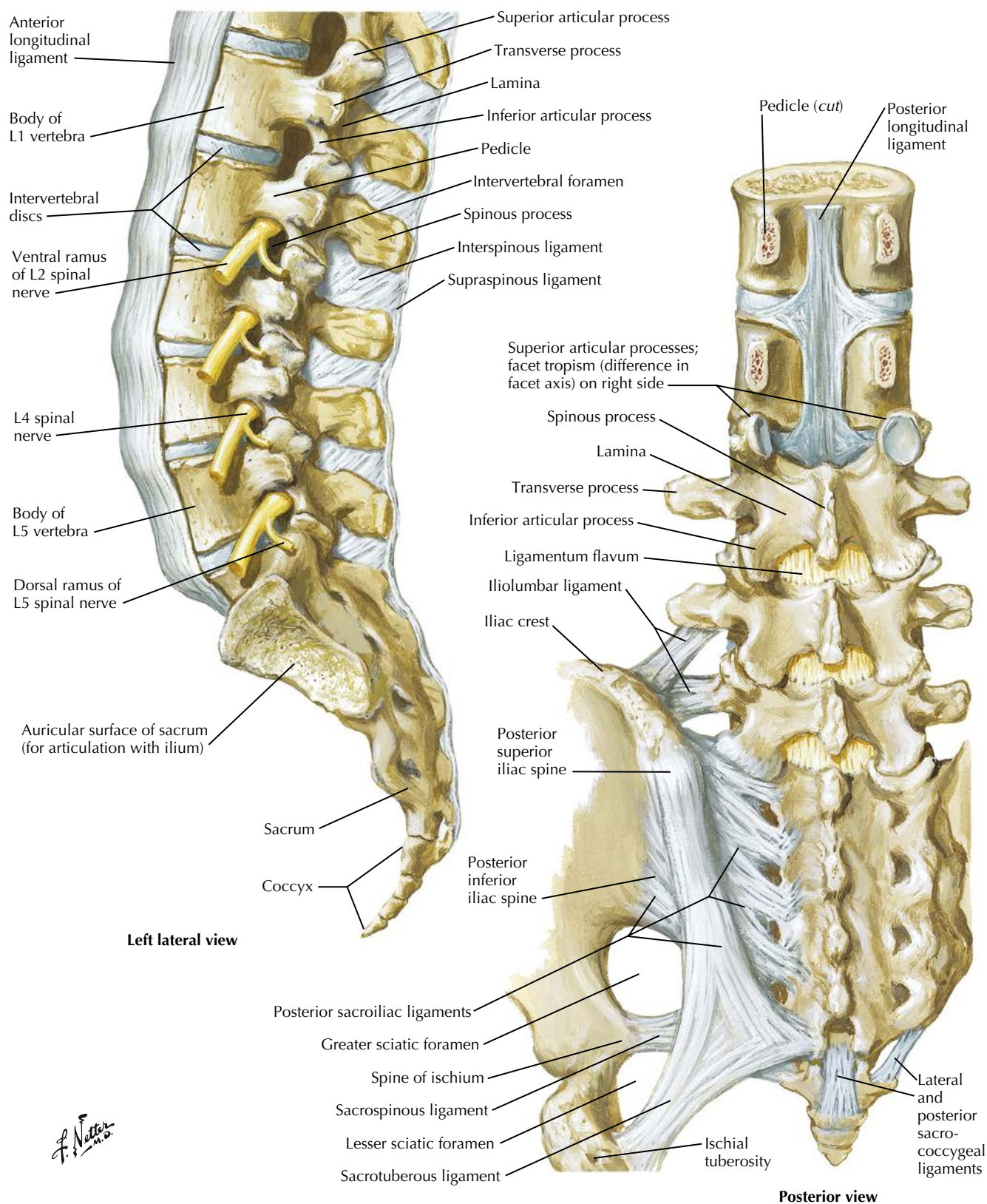
**T7, T8, and T9 vertebrae:
posterior view**



**T12 vertebra:
lateral view**

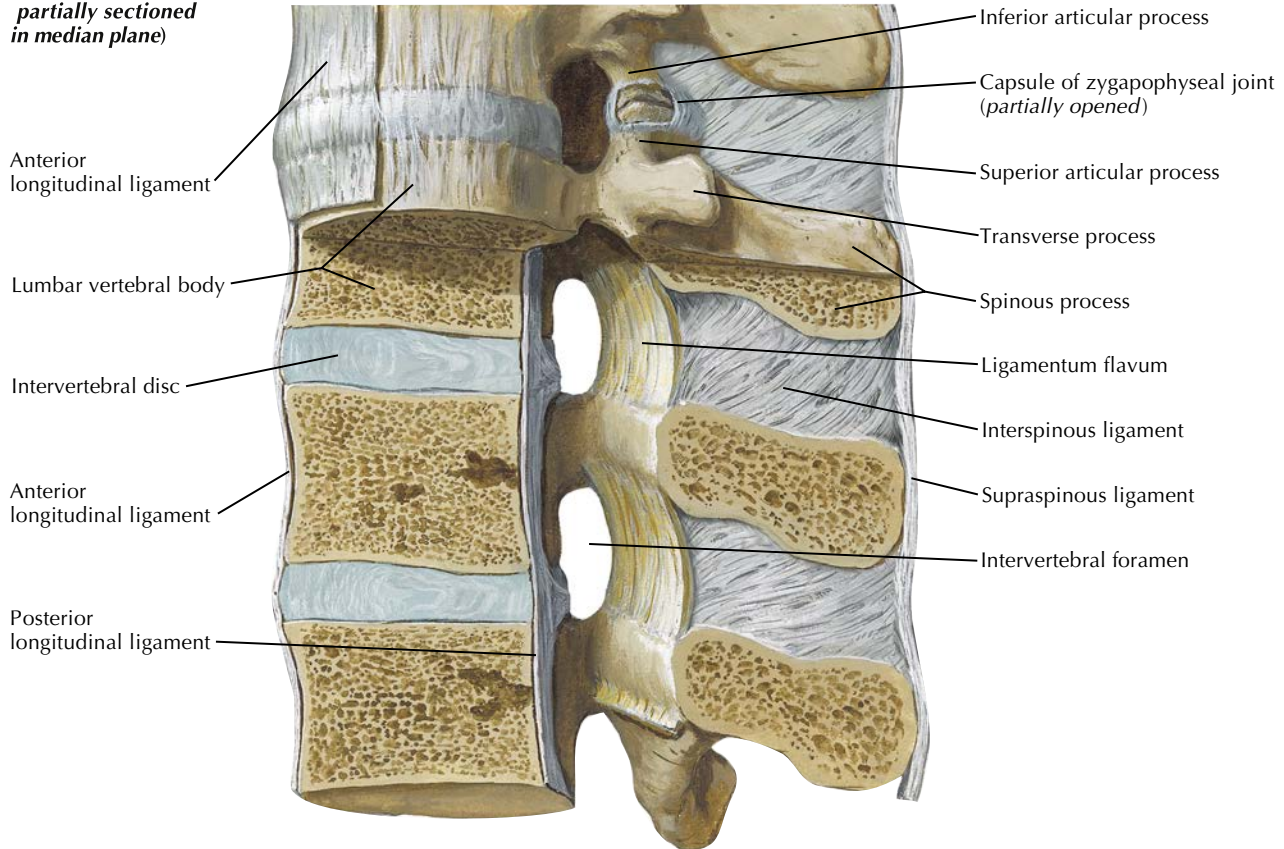
F. Netter M.D.



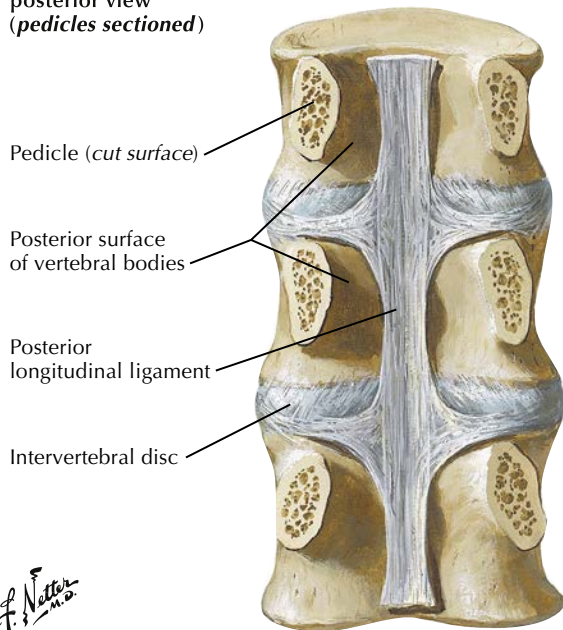


VERTEBRAL LIGAMENTS: LUMBAR REGION

Left lateral view
*partially sectioned
in median plane*

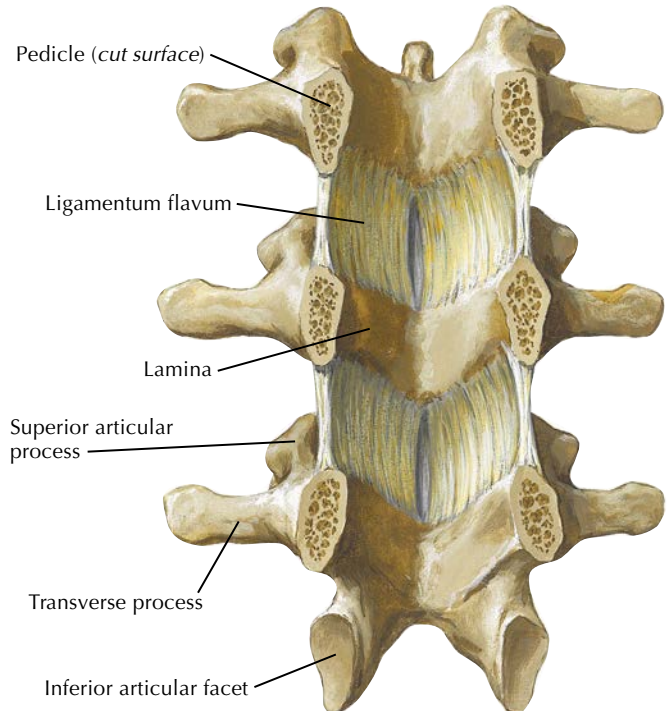


Anterior vertebral segments:
posterior view
(pedicles sectioned)

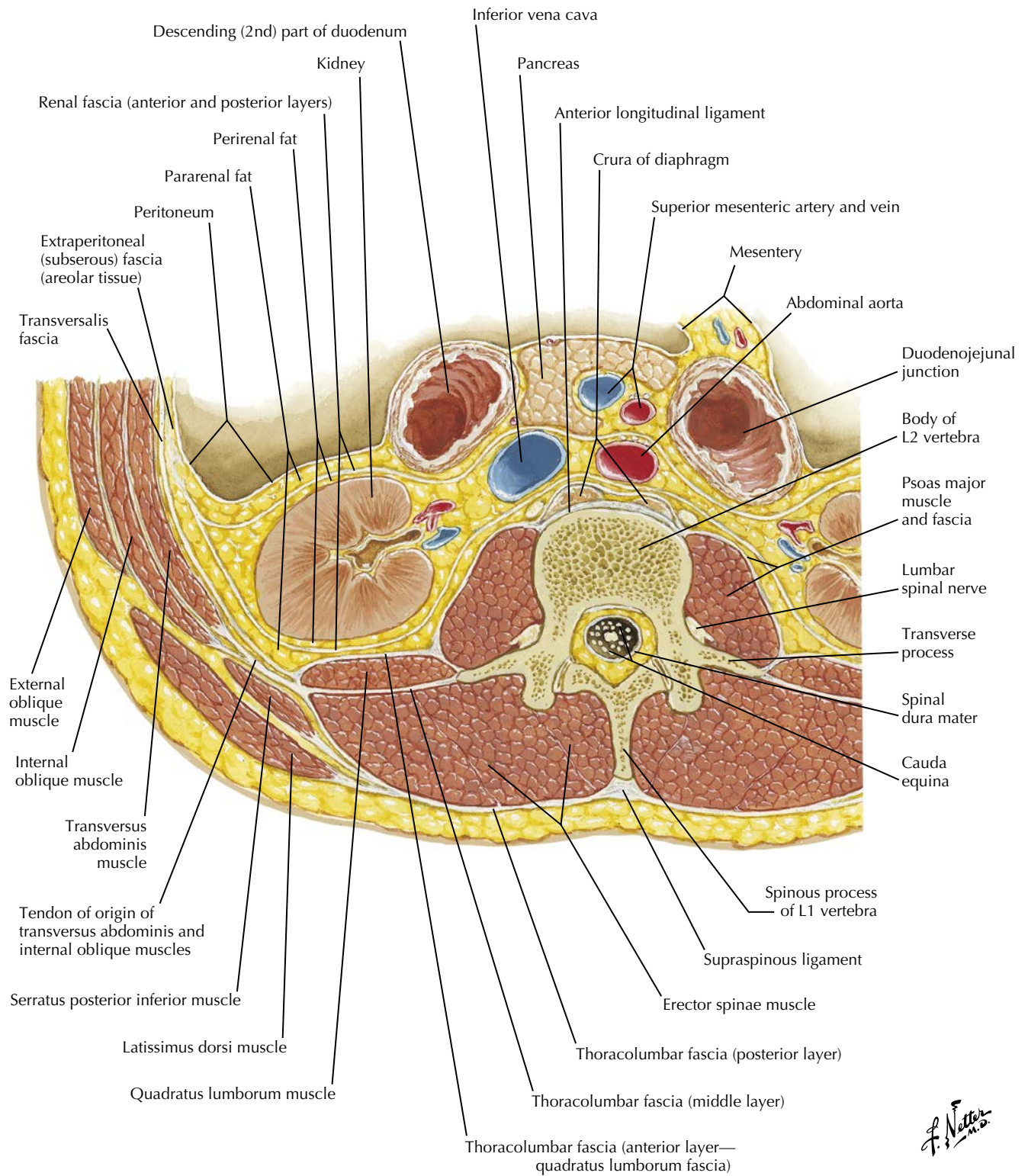


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Posterior vertebral segments:
anterior view



LUMBAR REGION OF BACK: CROSS SECTION



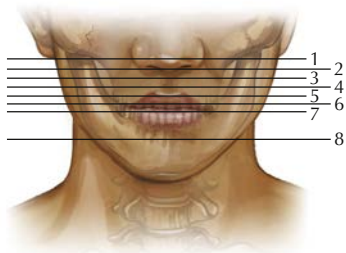
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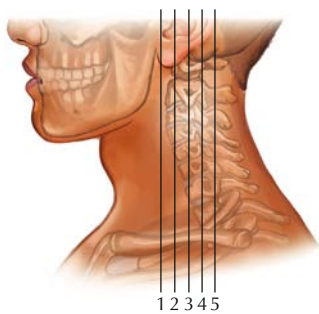
Chapter

16 SPINE

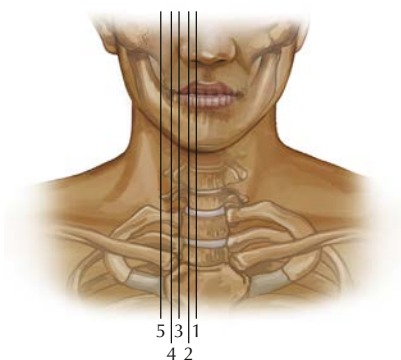
CERVICAL SPINE



AXIAL 536

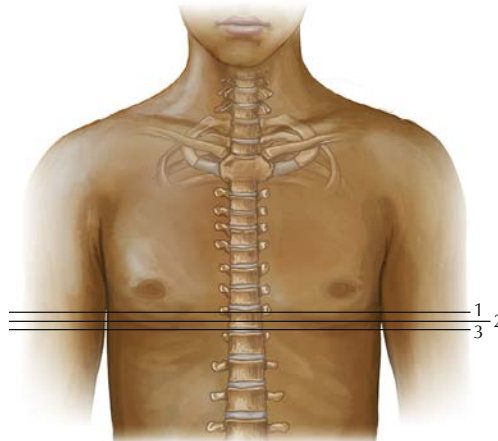


CORONAL 552

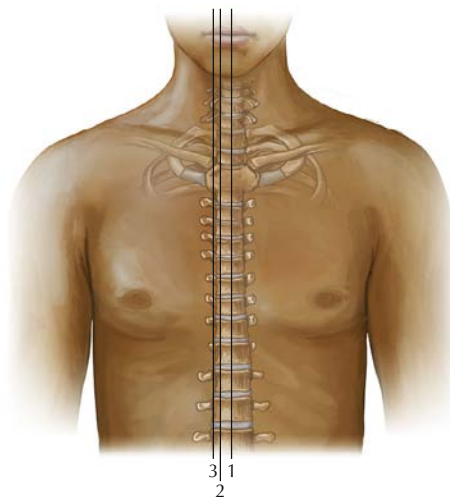


SAGITTAL 562

THORACIC SPINE

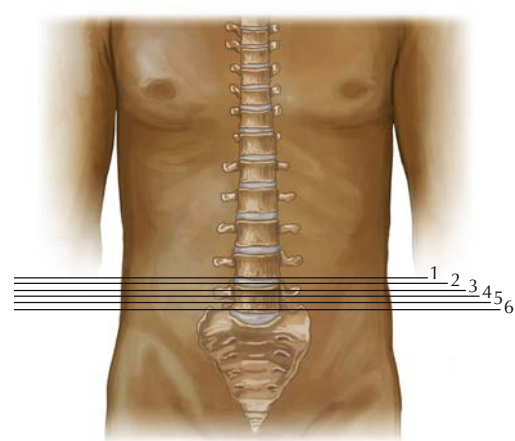


AXIAL 572

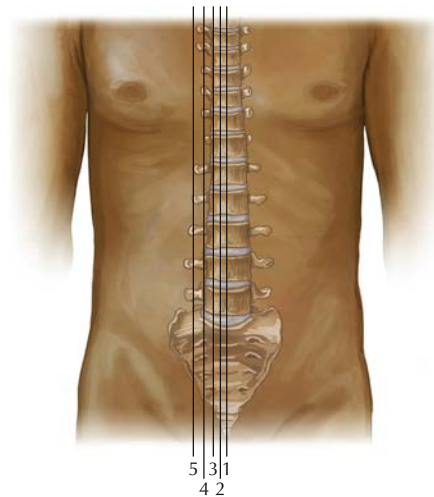


SAGITTAL 578

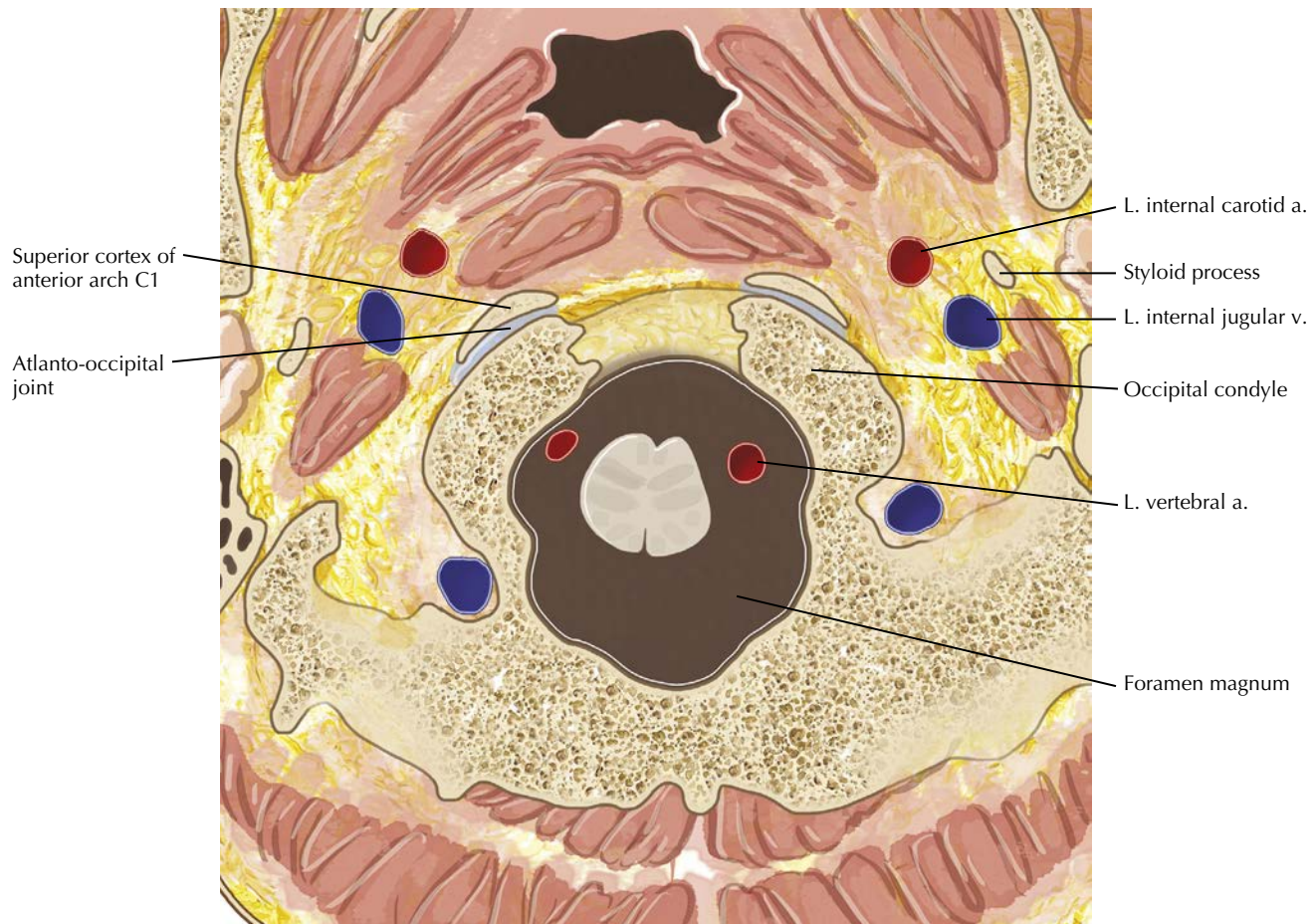
LUMBOSACRAL SPINE



AXIAL 584



SAGITTAL 596



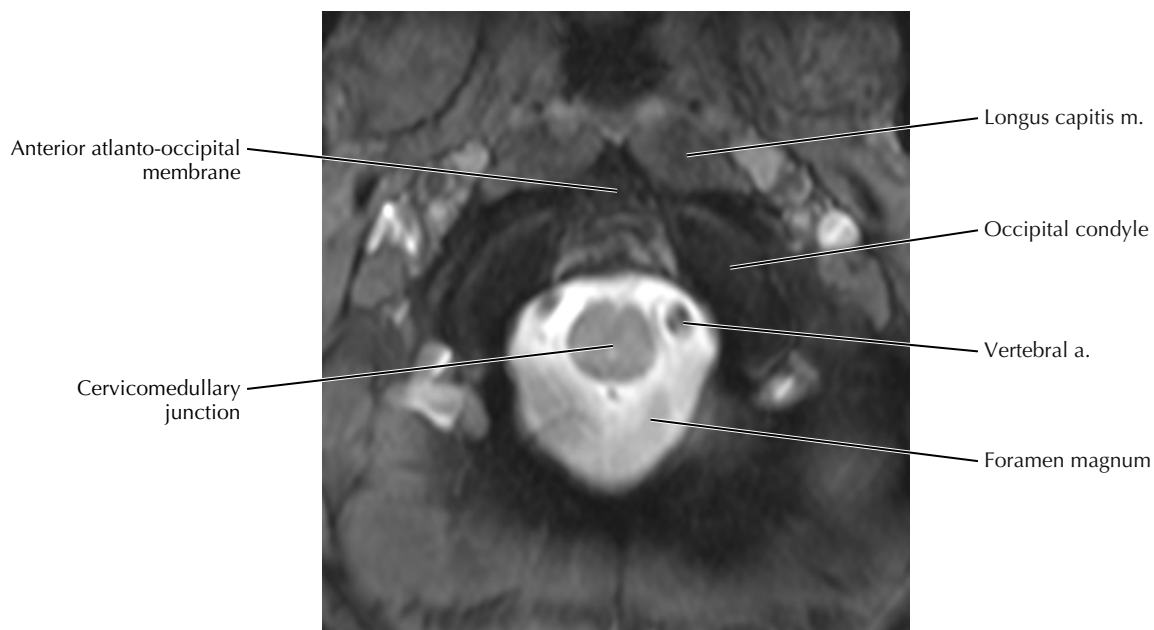
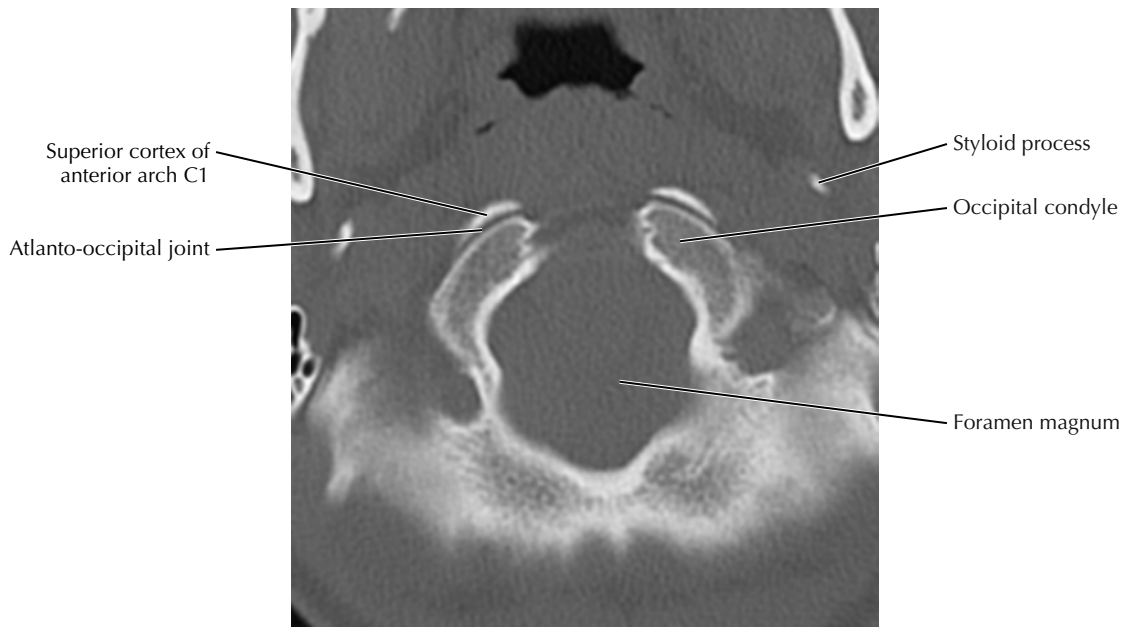
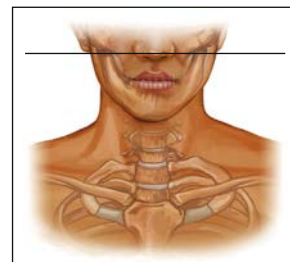
PATHOLOGIC PROCESS

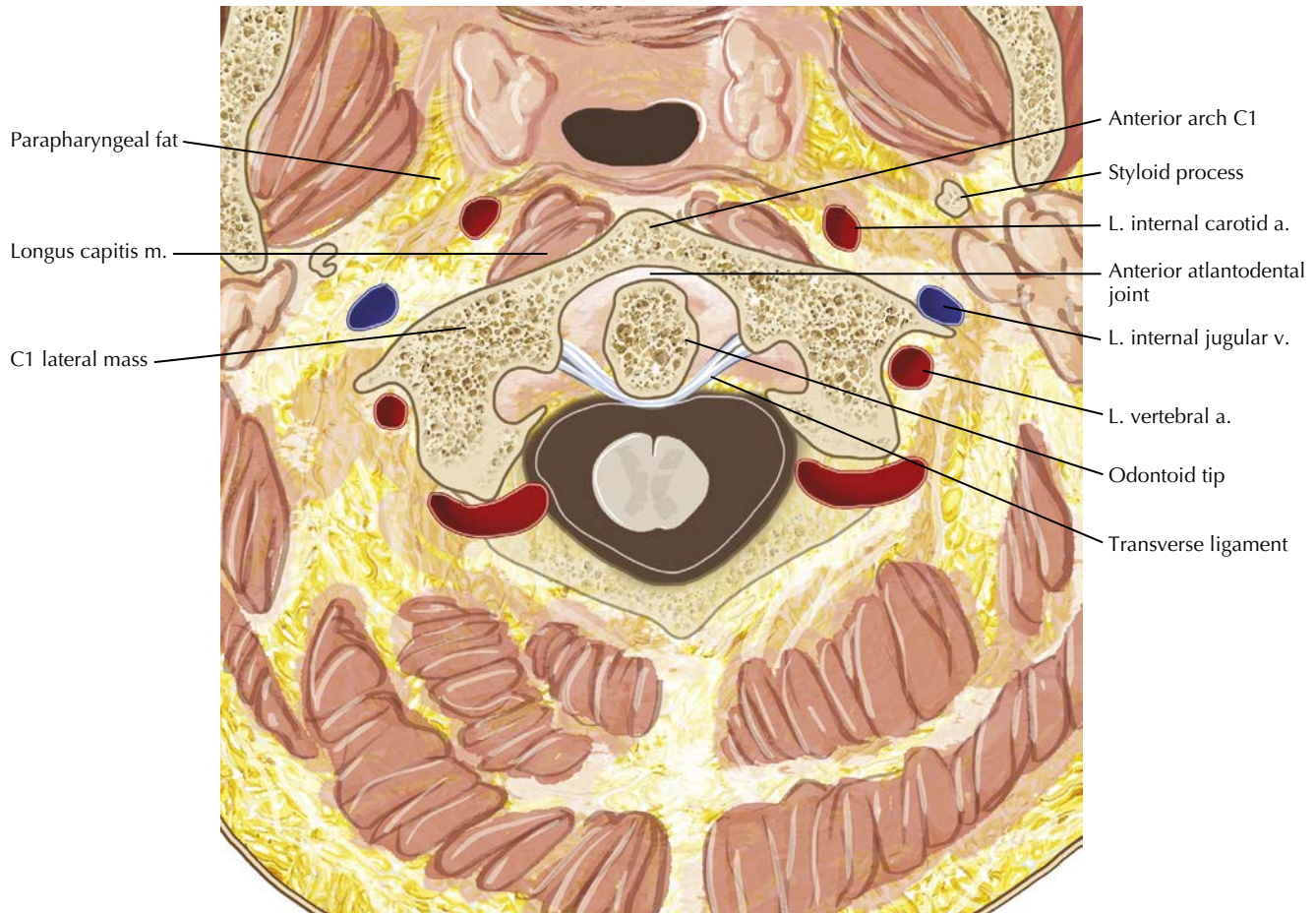
Note on these images that the nasopharynx is often seen on cervical spine imaging. The neuroradiologist should always check for symmetry of the Eustachian tube opening and fossa of Rosenmüller just anterior to the longus capitis muscle to ensure that no nasopharyngeal lesion is present (see Chapter 13).

IMAGING TECHNIQUE CONSIDERATION

Spinal imaging can be daunting at first due to the complex three-dimensional (3D) anatomy of the vertebrae and the critical implications of damage to the spine. This is particularly true taking into account various signal characteristics on magnetic resonance imaging (MRI) and motion artifact from vessel pulsation and respiration. A good principle is that computed tomography (CT) and MRI are complementary. In general, CT better delineates the architecture of the dense bones, the cortex of which does not provide much MR signal, and MRI is better at providing contrast to the soft tissues, such as the spinal cord. Although CT (top image) would be better at showing a subtle fracture of the vertebral artery foramen, MRI (bottom image) would be better at delineating hematoma in the wall of the vertebral artery from dissection.

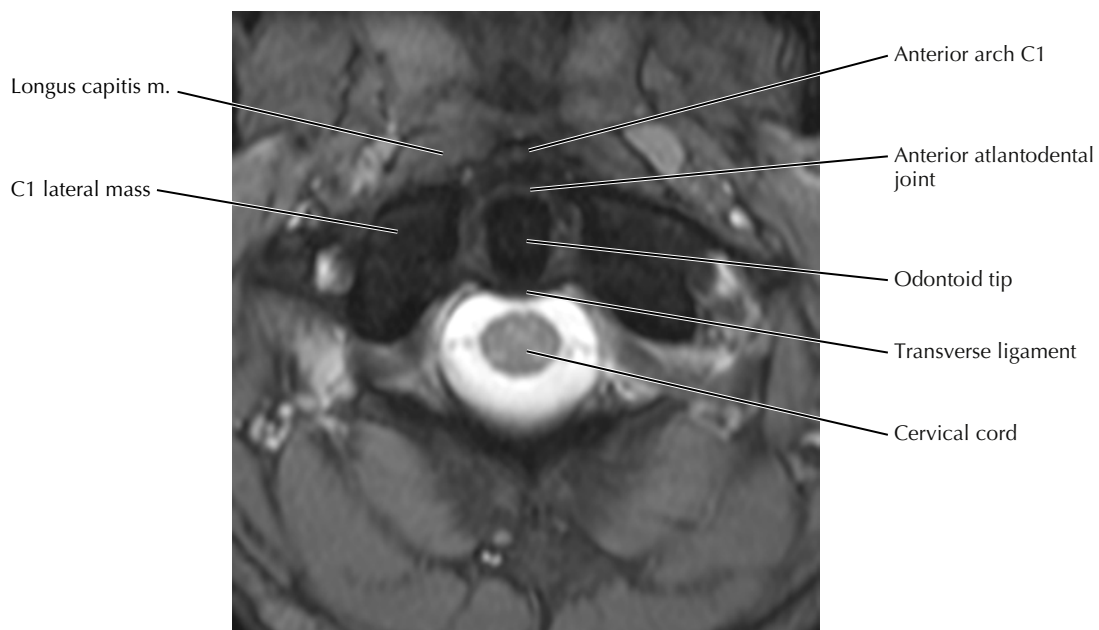
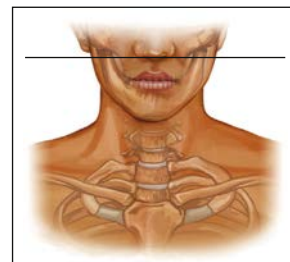
Another good principle for learning spinal anatomy is that the lower the level in the spine, the larger the vertebrae and the easier it is to understand the anatomy. Thus it is often best to start with the lumbar spine, learning both diagnostic principles and image-guided intervention, and to work up the spine as familiarity with spinal anatomy increases.

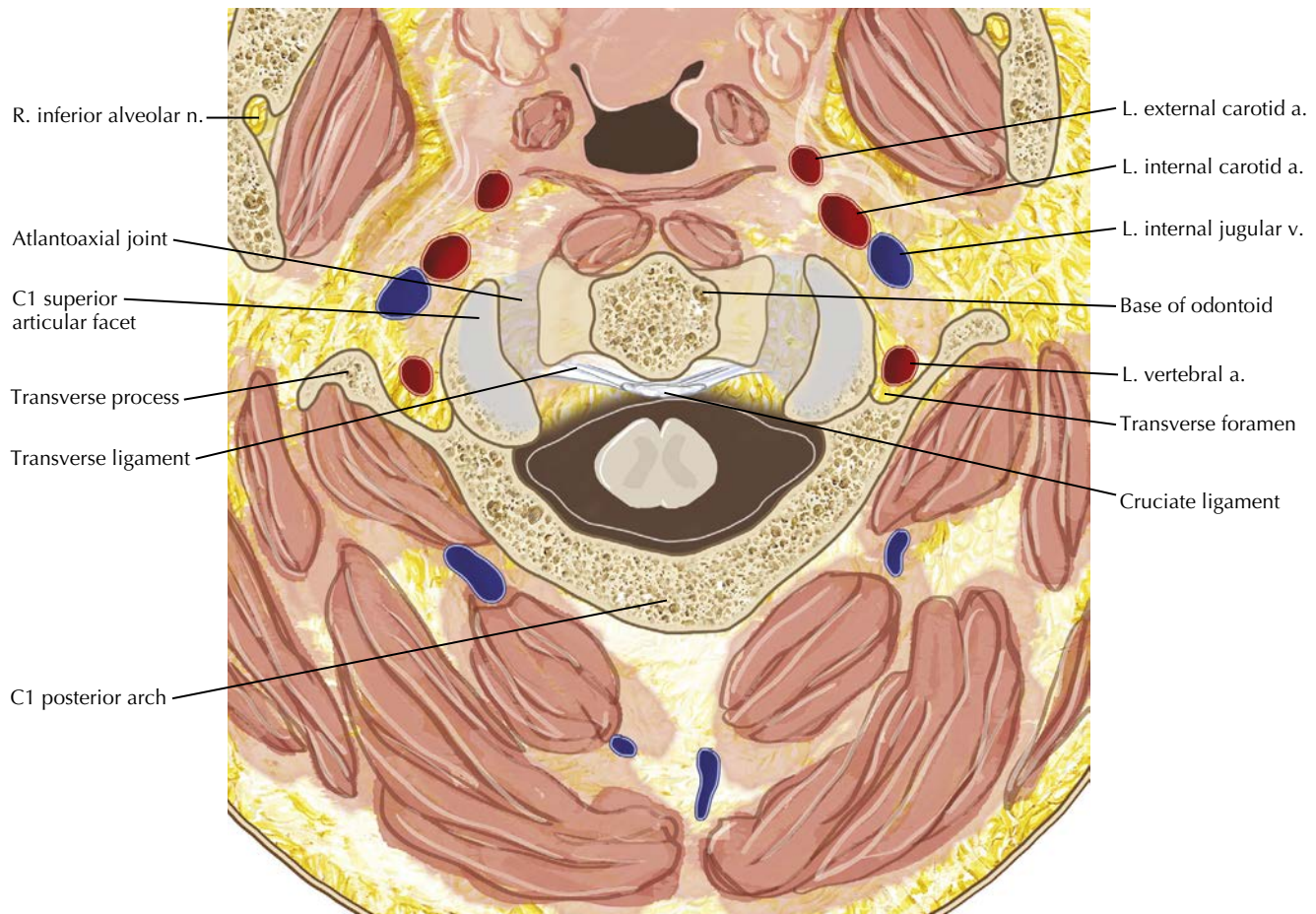




DIAGNOSTIC CONSIDERATION

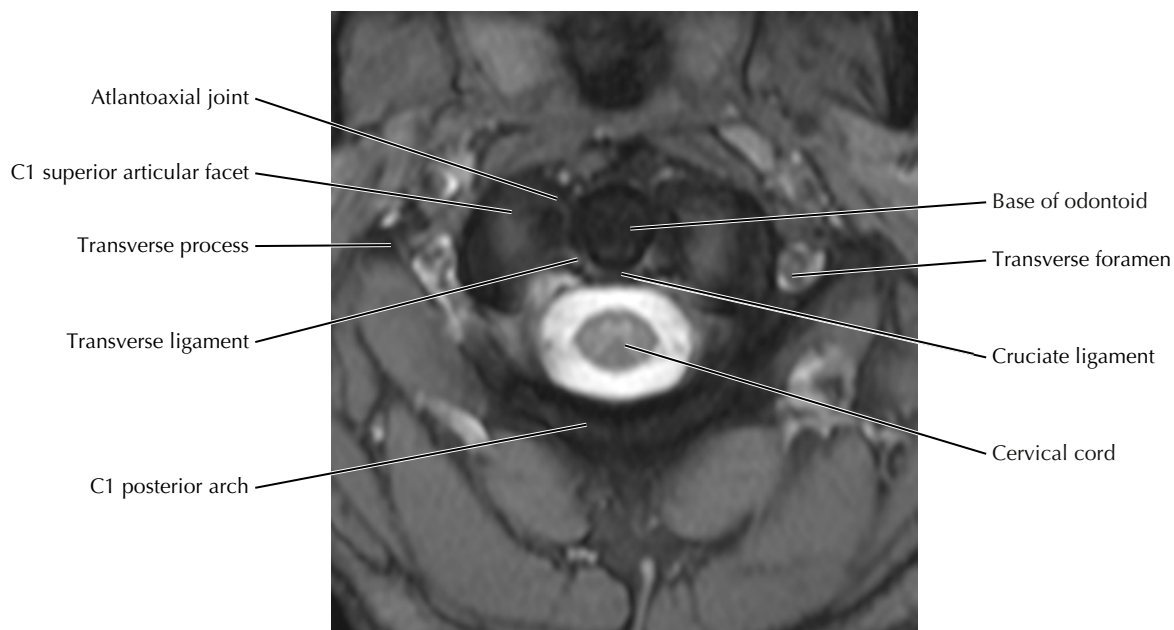
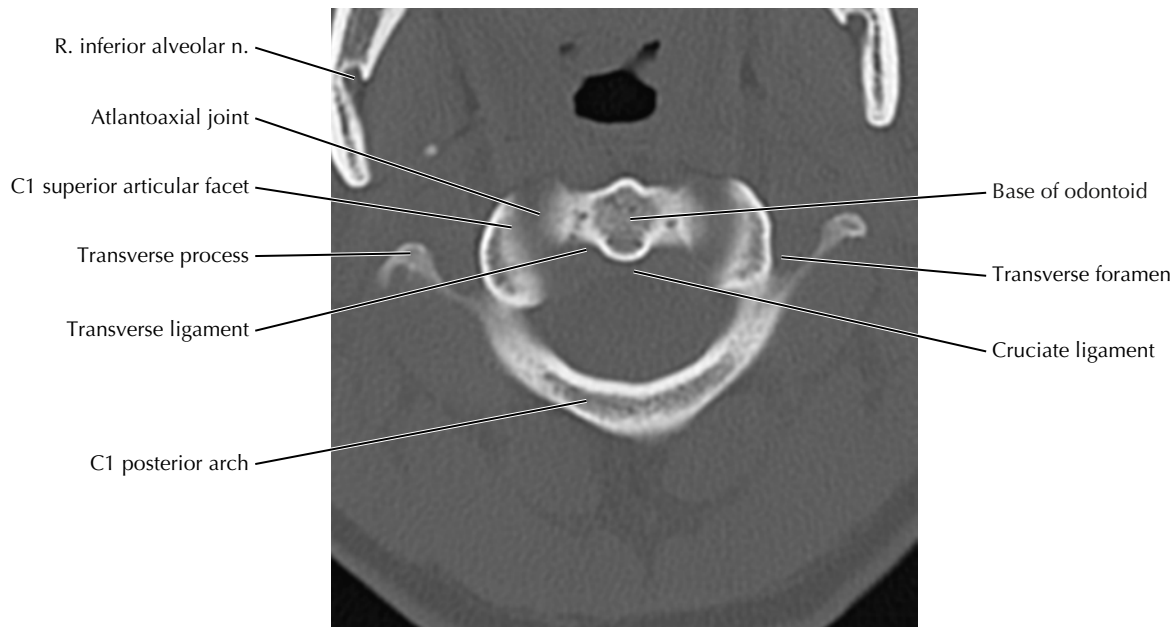
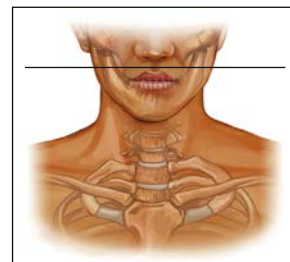
The *predental space*, or distance between the anterior aspect of the dens and the posterior border of the anterior arch of C1 (atlas), should measure 3 mm or less in the adult patient. Widening of this space or asymmetry of soft tissue lateral to the odontoid raises concern for cruciate ligament injury. The best imaging test is voluntary flexion and extension sequences on lateral cervical radiographs to check for change in the predental space measurement. However, in the patient who has pain limiting motion, or in the unconscious patient, CT or MRI can provide secondary signs such as fracture of C1 or C2 (axis), hemorrhage along the dura, and edema within the soft tissues.

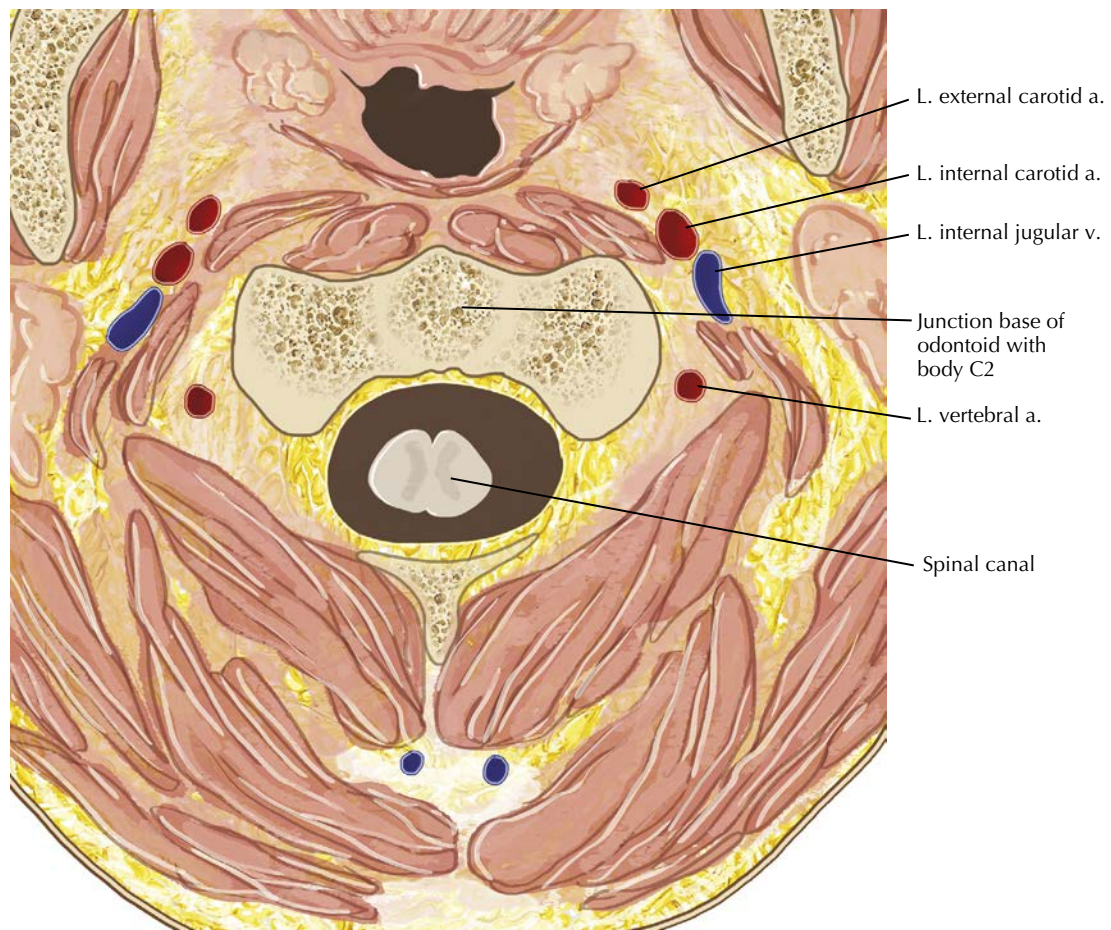


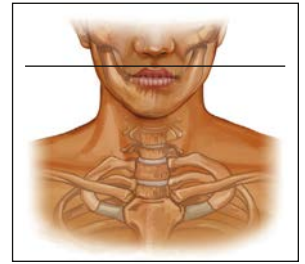


PATHOLOGIC PROCESS

Somewhat counterintuitively, a fracture through the larger base of the odontoid process is less serious than a fracture more superiorly near the tip. The better, more proximal blood supply at the odontoid base allows better healing and less chance of avascular necrosis.

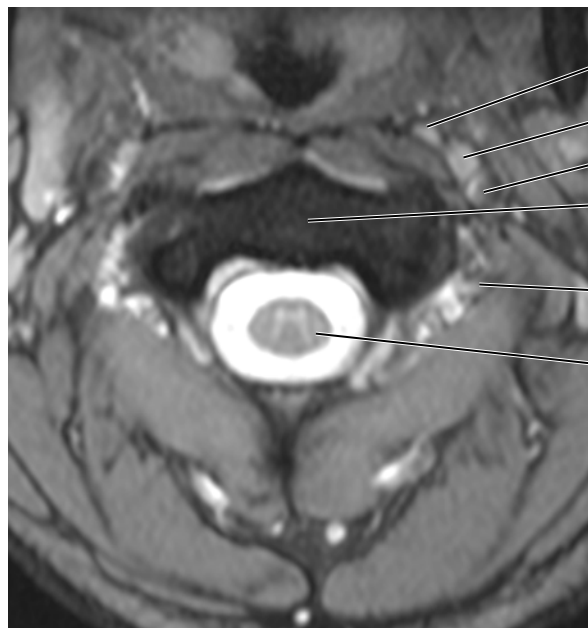






Junction base of
odontoid with body C2

Spinal cord



L. external carotid a.

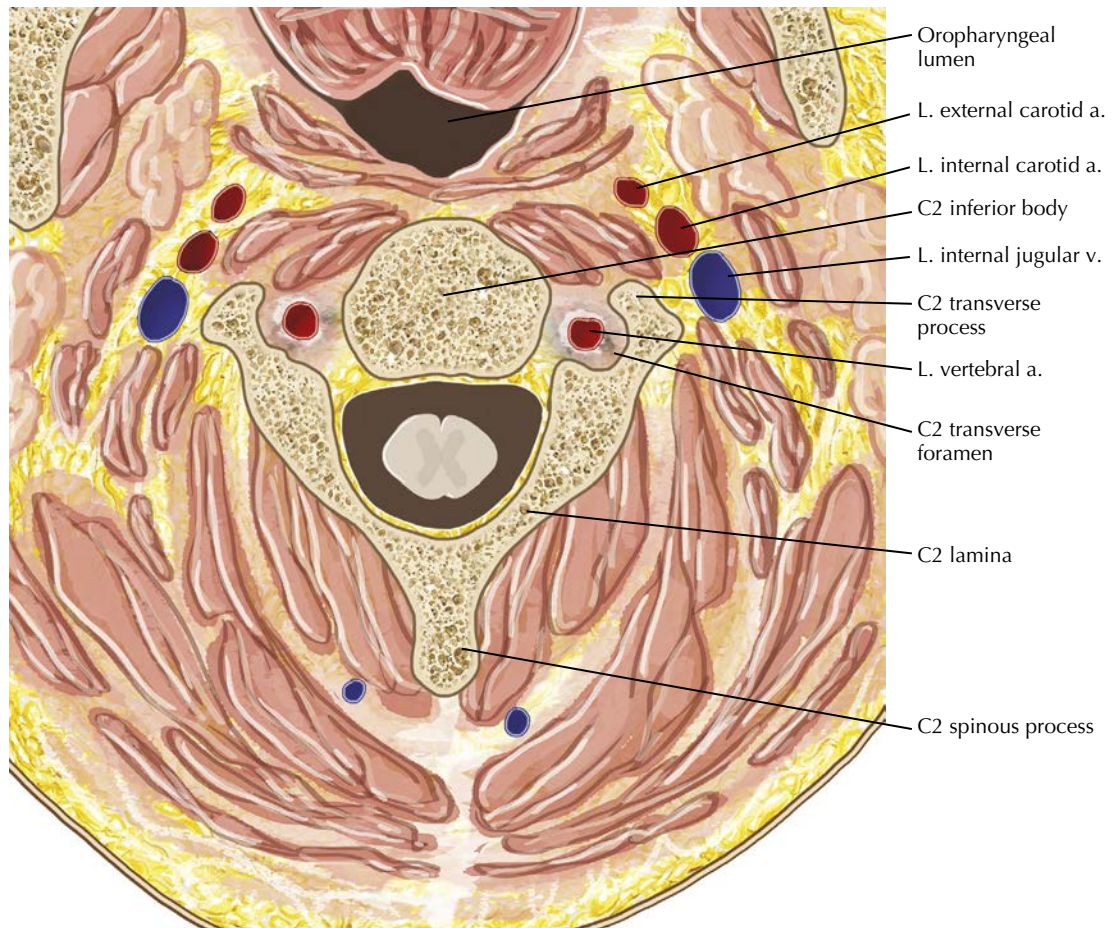
L. internal carotid a.

L. internal jugular v.

Junction base of
odontoid with body C2

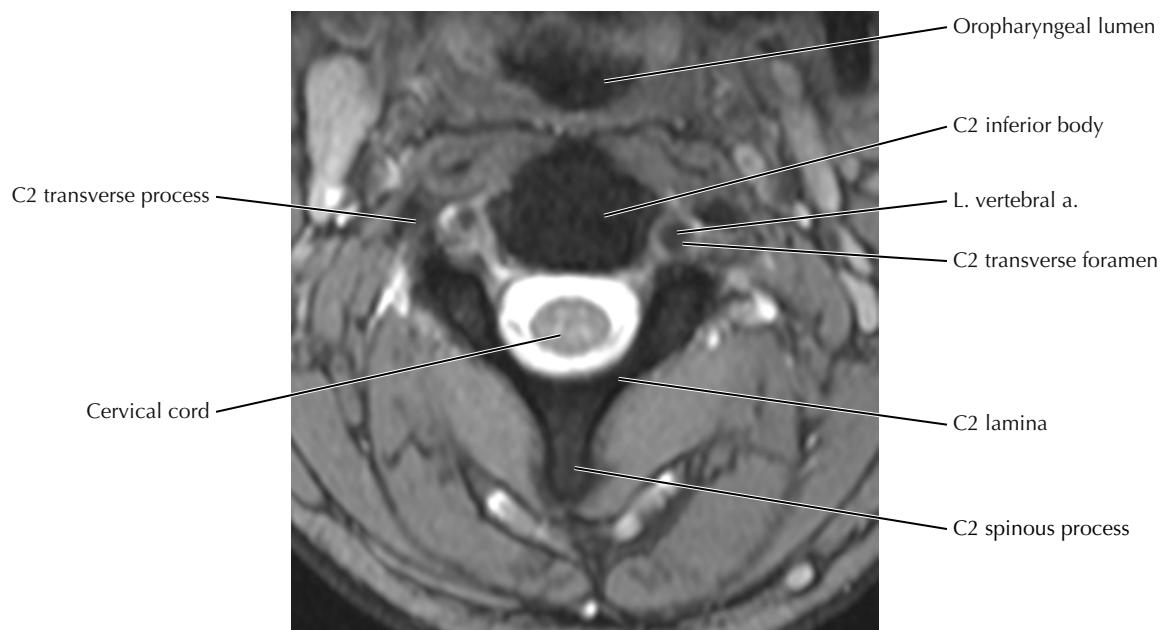
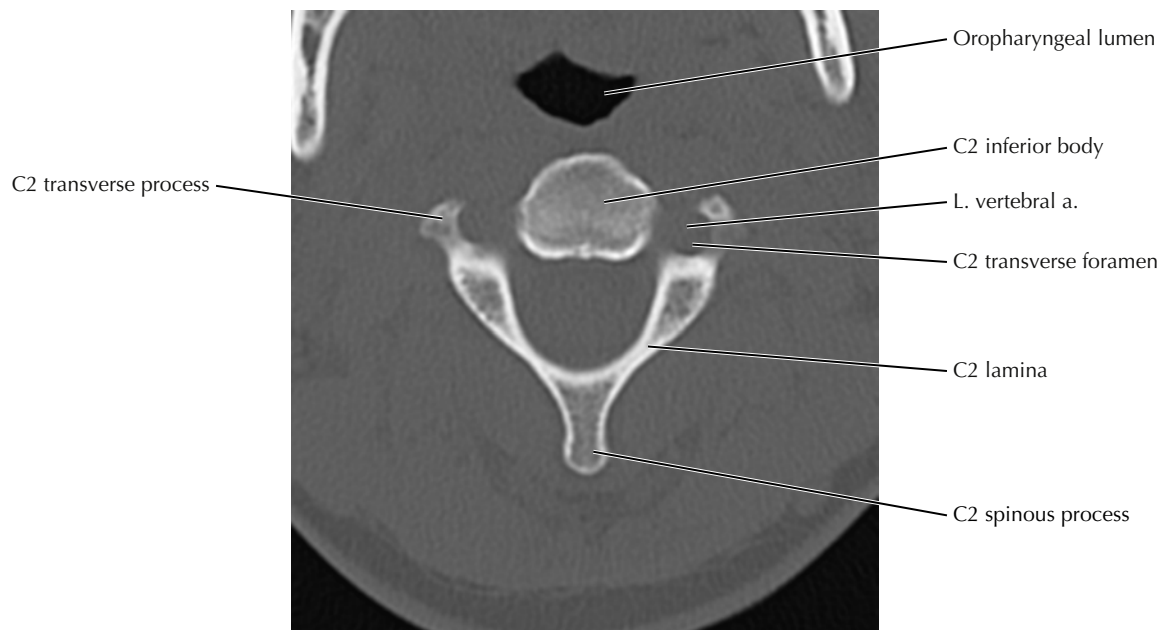
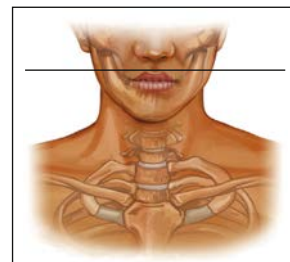
L. vertebral a.

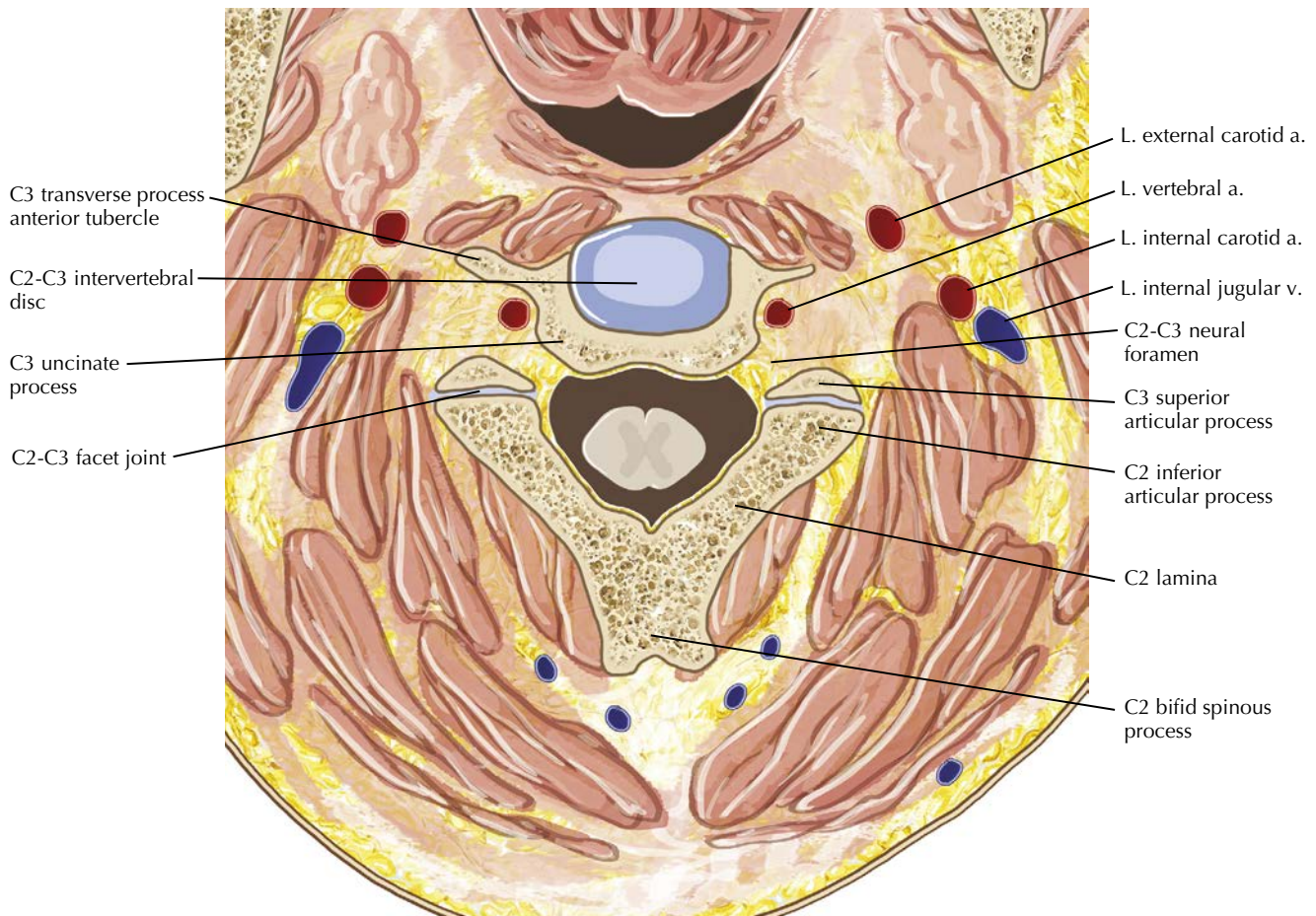
Spinal cord



IMAGING TECHNIQUE CONSIDERATION

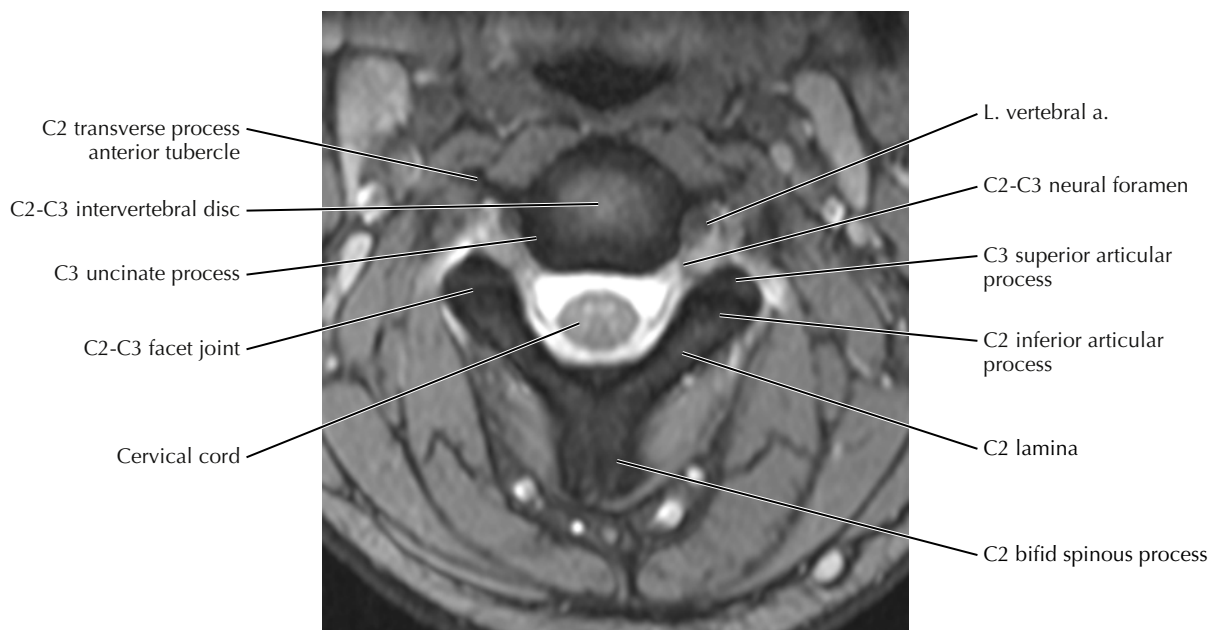
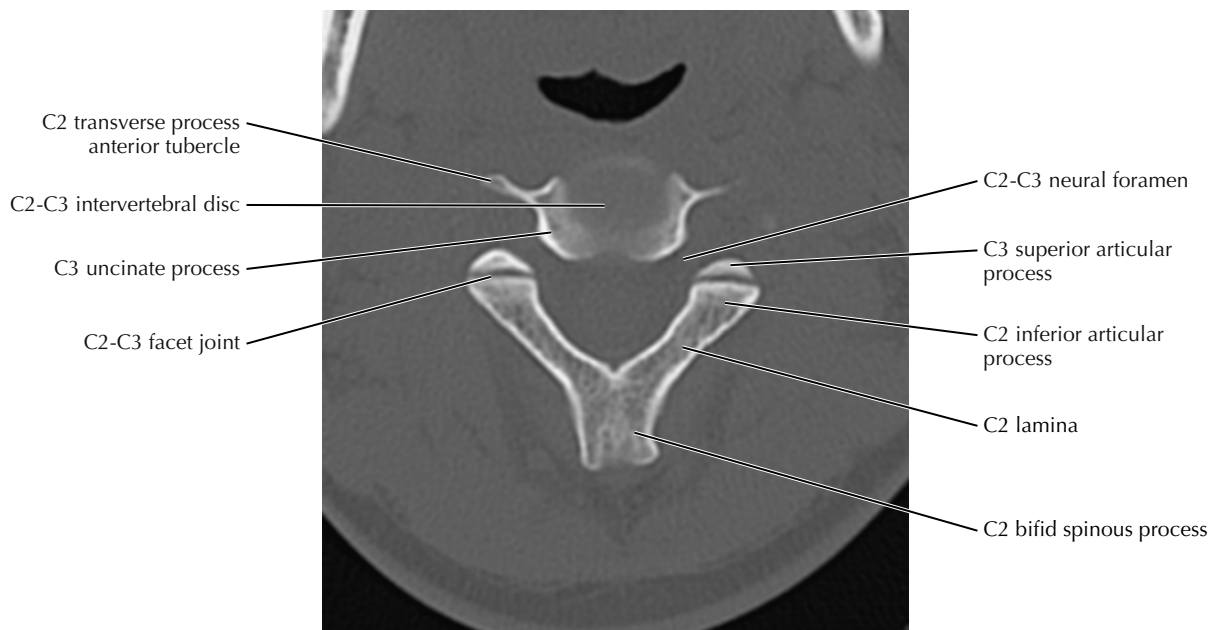
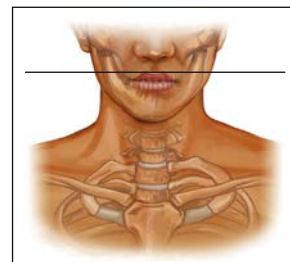
The MR images (lower) are axial 3D T2* gradient images. The advantages over standard 2D spin-echo sequences are the higher spatial resolution and the ability to reformat in any plane. Motion, however, tends to cause all the images of the sequence to become blurred.

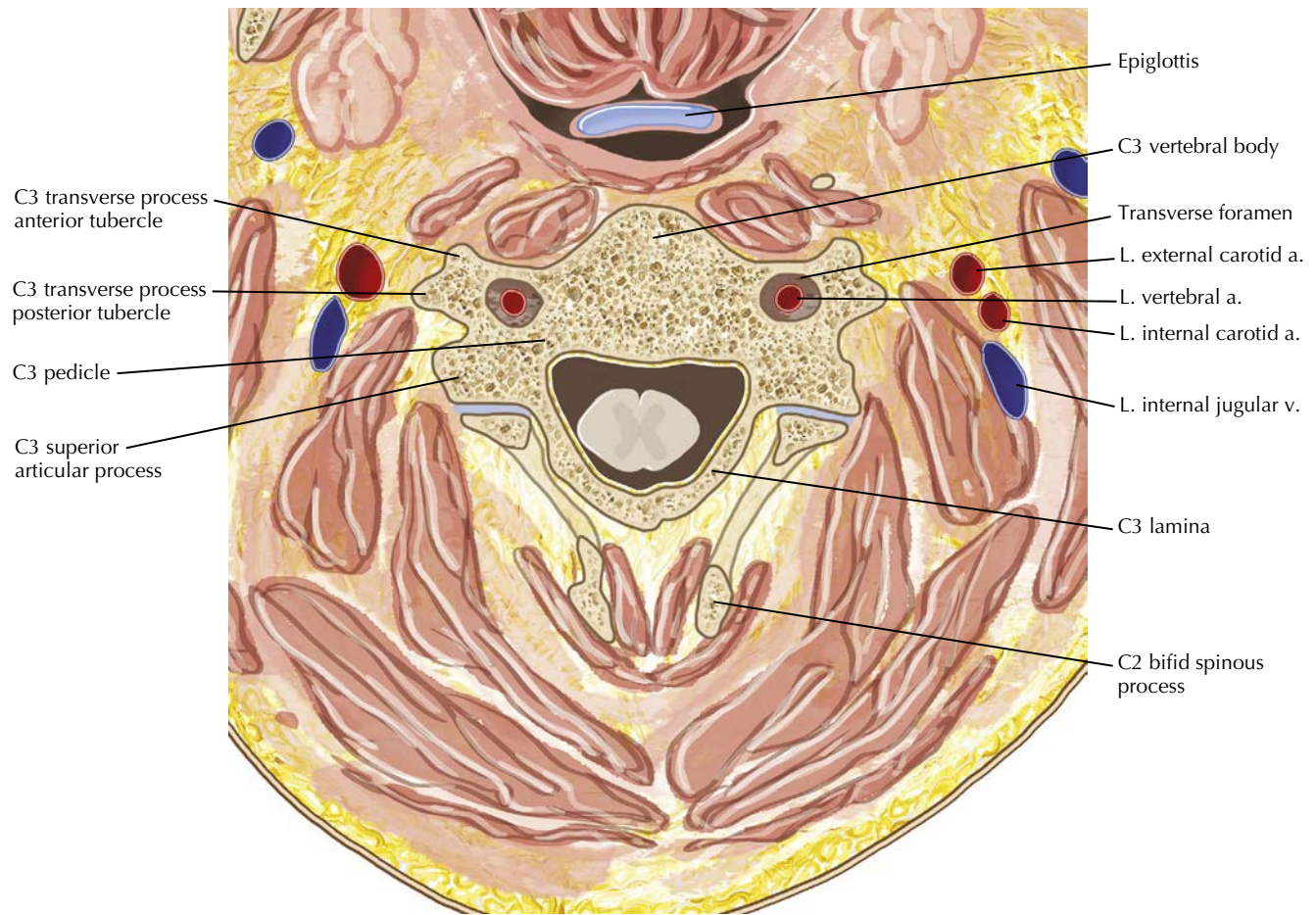




PATHOLOGIC PROCESS

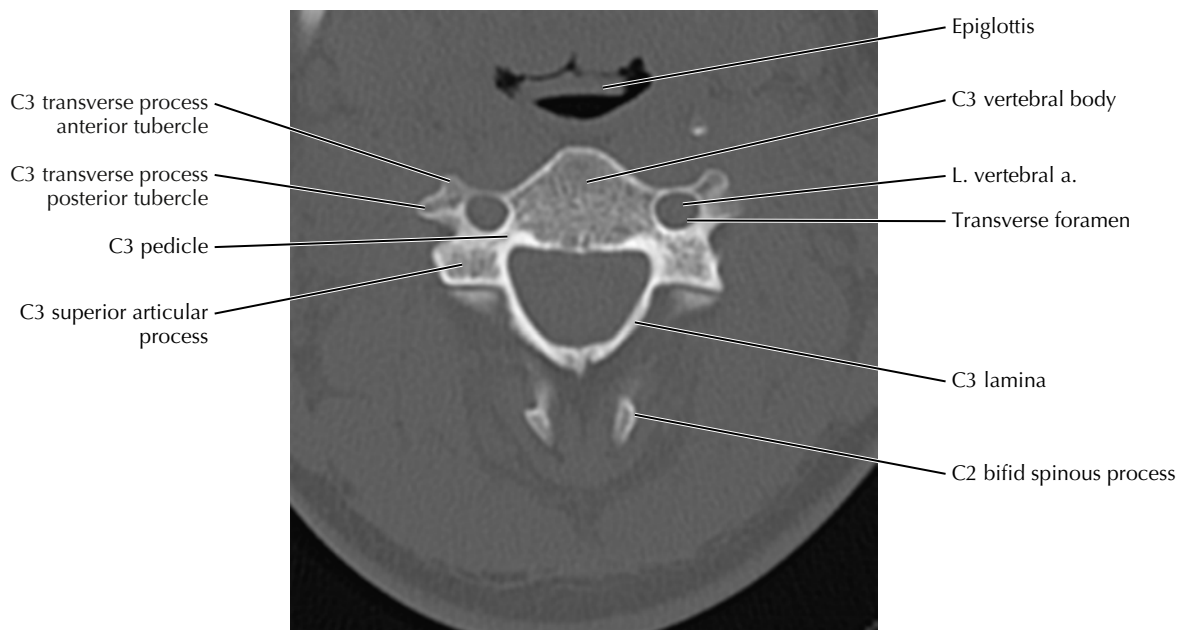
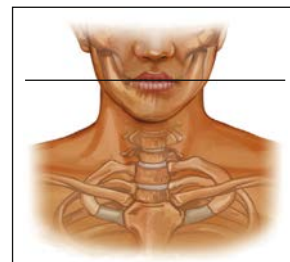
Uncovertebral osteophytes at the posterolateral aspects of the vertebral body can cause narrowing of the foramina and impingement of exiting nerve roots. Some osteophytes may be confluent with a broad-based disc-osteophyte complex across the entire posterior aspect of the vertebral body that can chronically flatten the spinal cord.

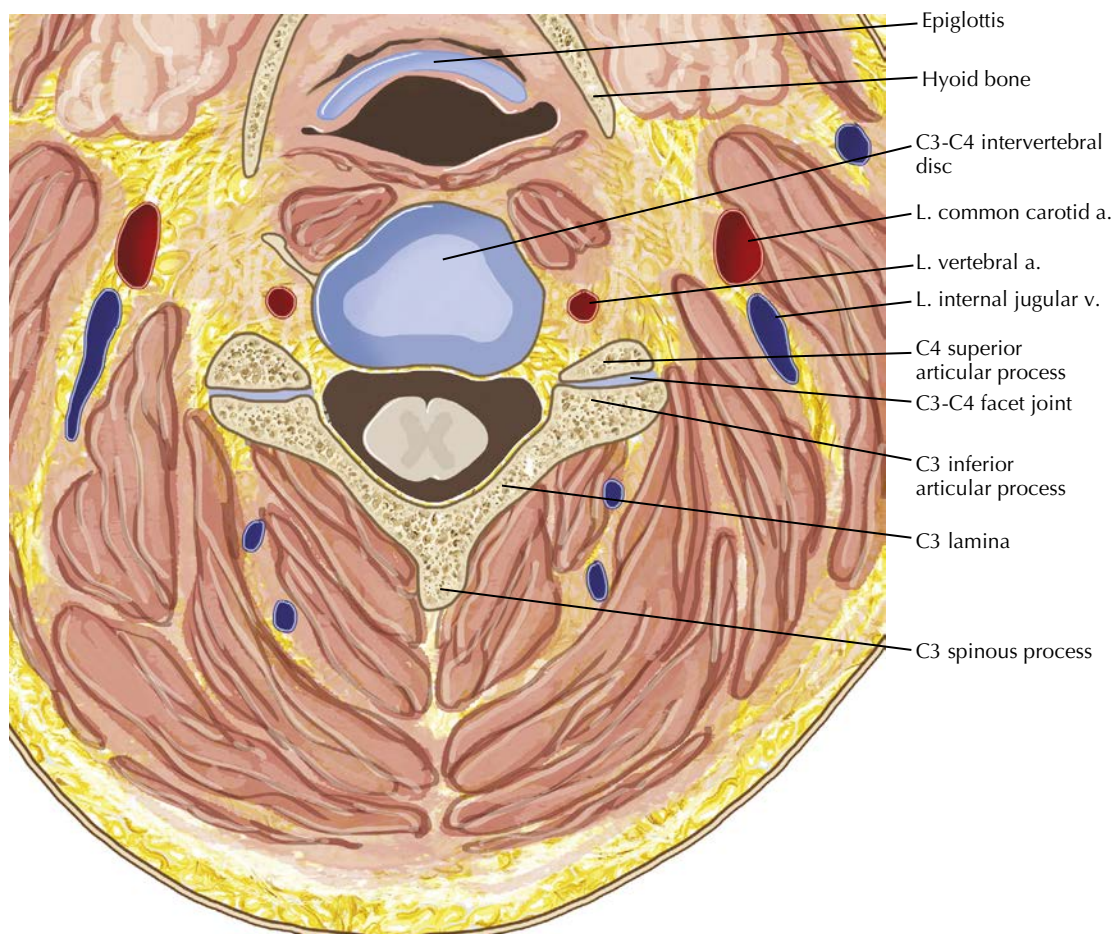


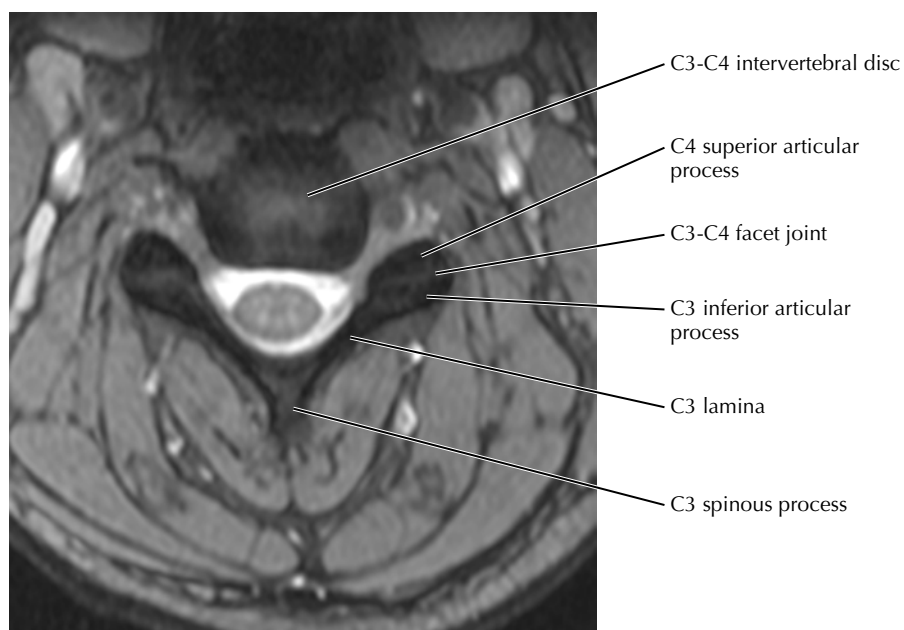
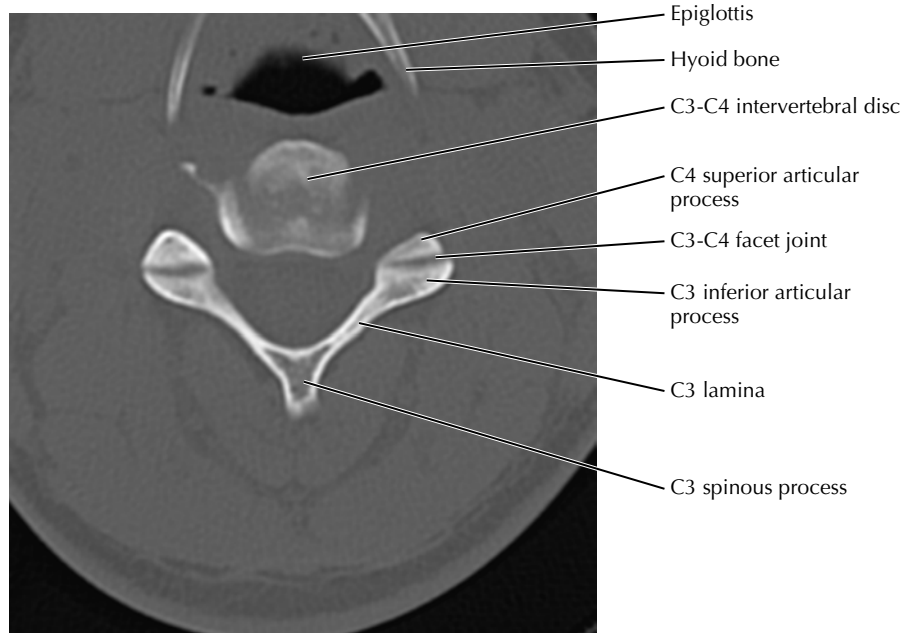
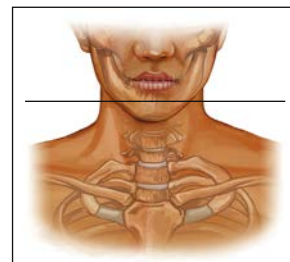


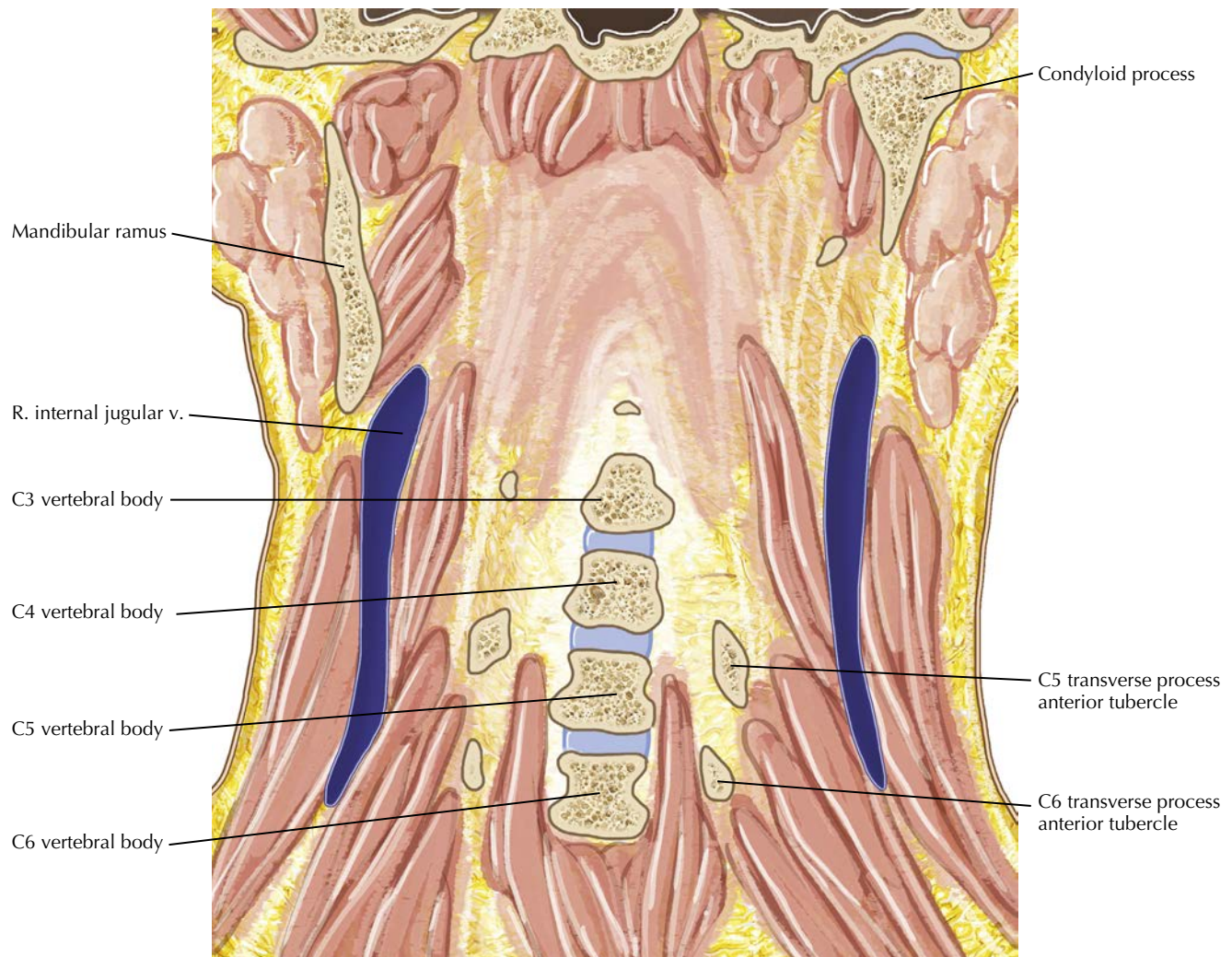
DIAGNOSTIC CONSIDERATION

Note that the bony vertebral artery foramina, also called transverse foramina, are symmetric in this patient (Cervical Axial 7). A careful search for fracture lines across these foramina in the setting of trauma will help reveal vertebral artery dissection. Angiography (CTA or MRA) of the cervical arteries often shows some asymmetry in the lumina. If corresponding asymmetry exists in the bony foramina, the cause is likely a congenitally hypoplastic side rather than a dissection.



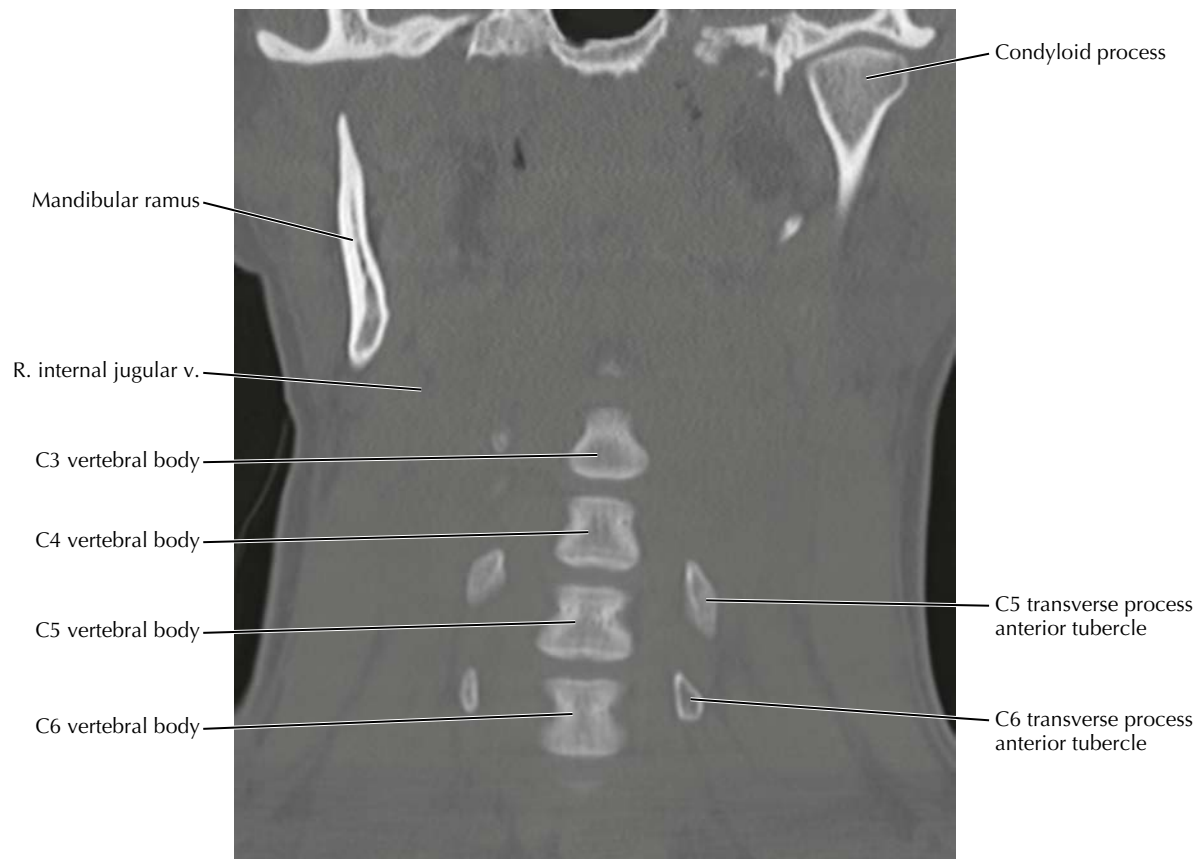
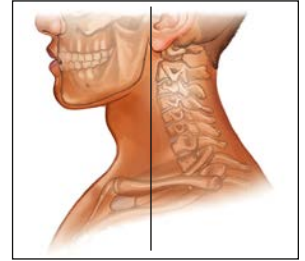


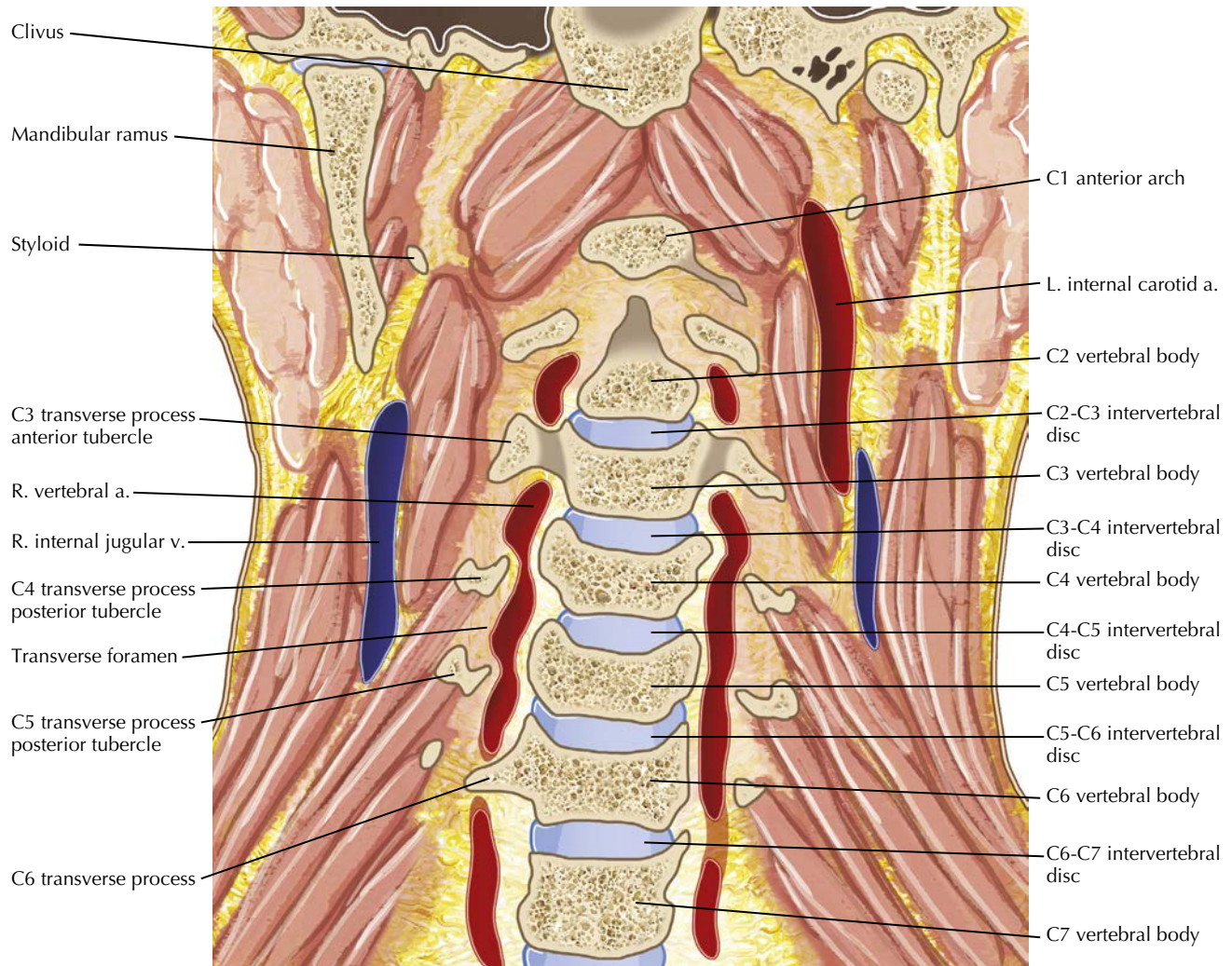


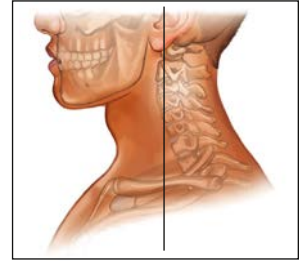


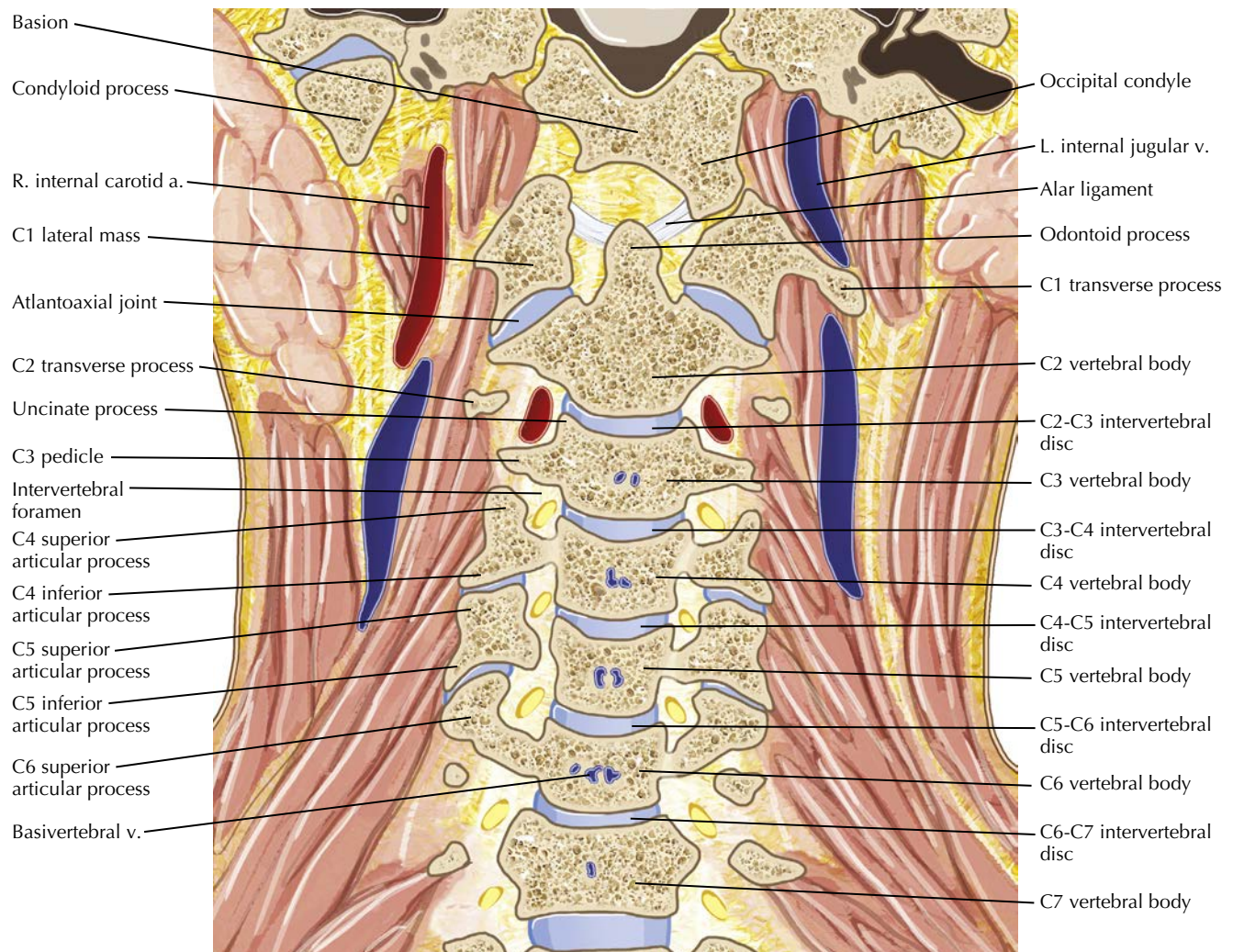
IMAGING TECHNIQUE CONSIDERATION

The temporomandibular joints (TMJs) can often be seen in coronal imaging of the cervical spine. In Cervical Spine Coronal 1, there is slight rotation of positioning such that the patient's left TMJ on the right side of the image is slightly more anterior and better seen than the right TMJ.



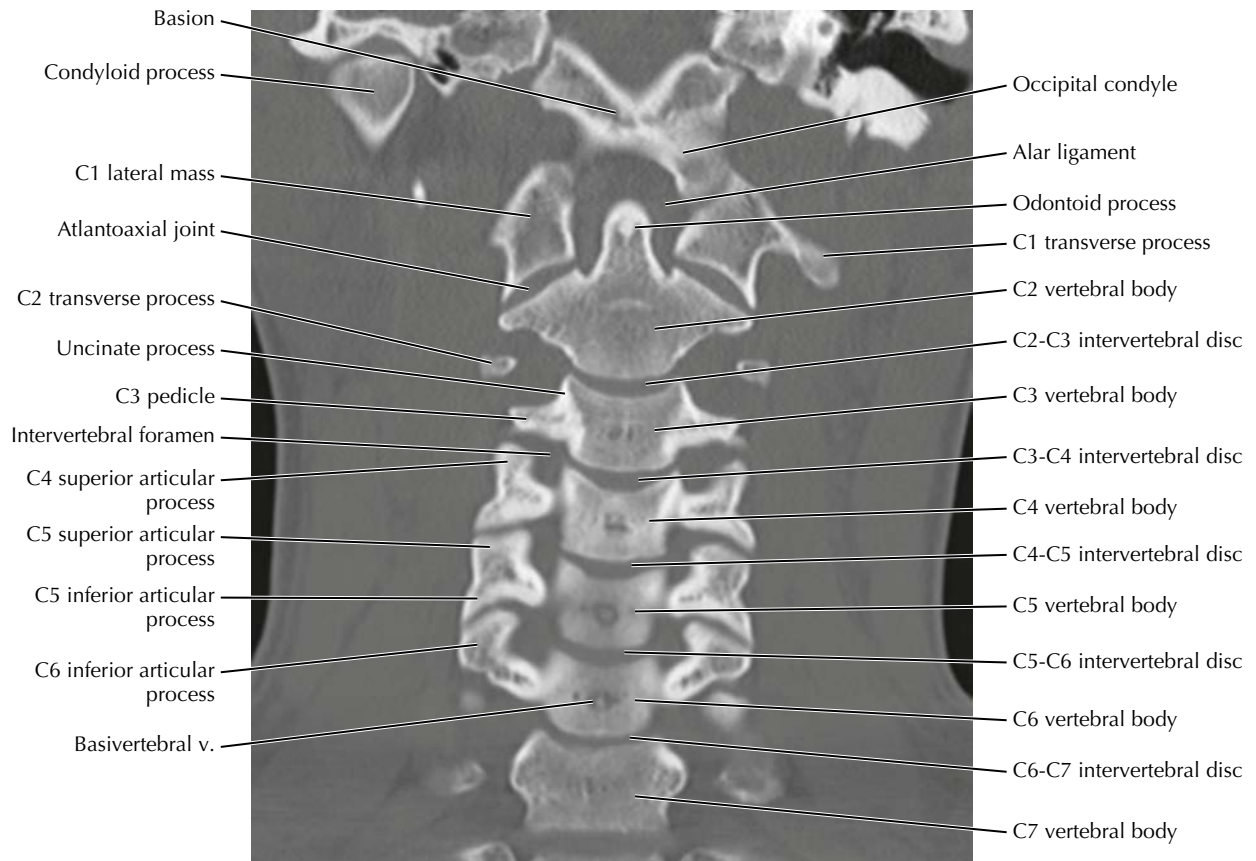
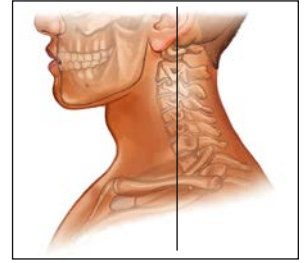


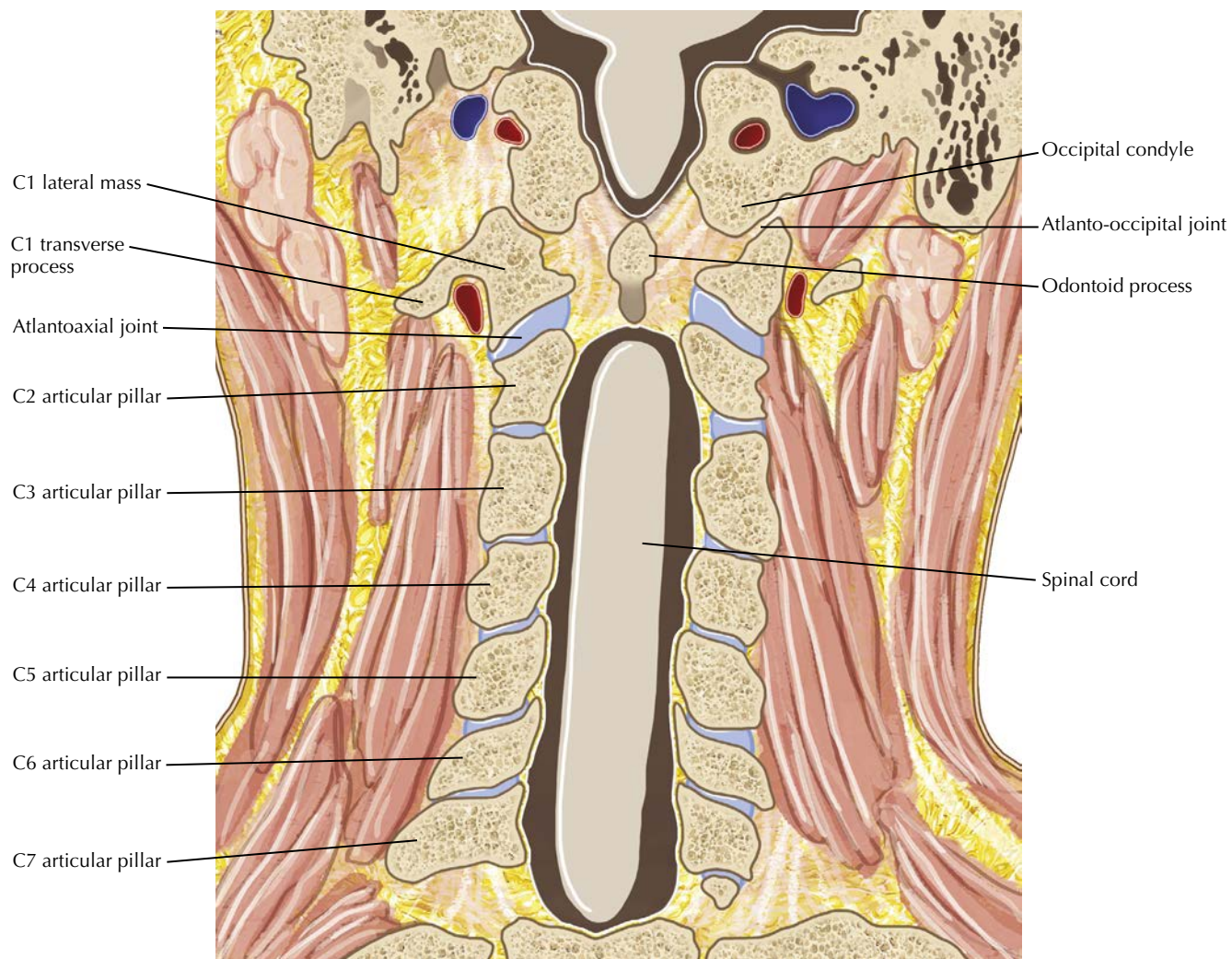


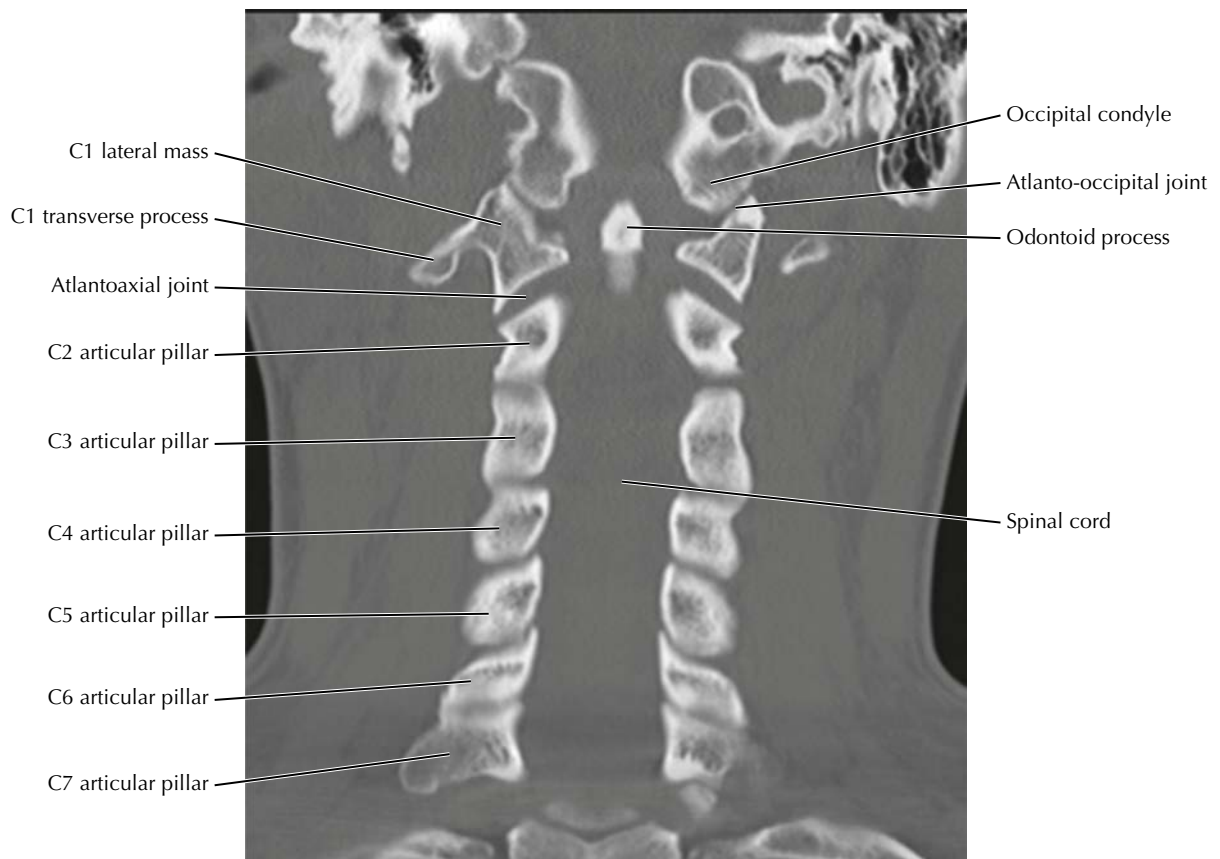
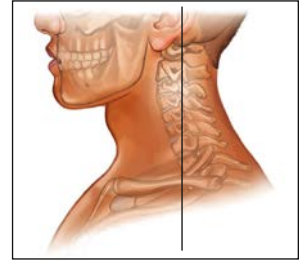


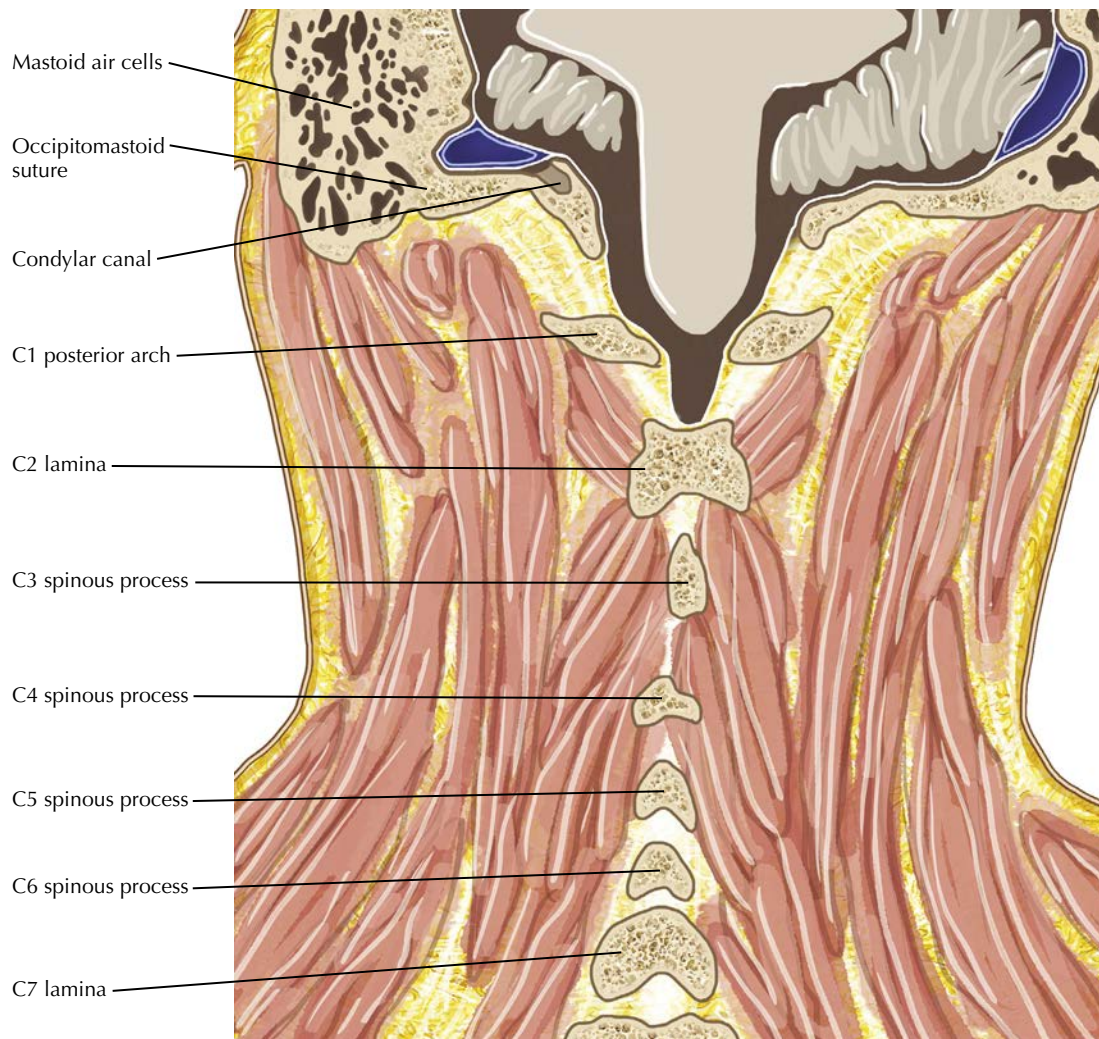
DIAGNOSTIC CONSIDERATION

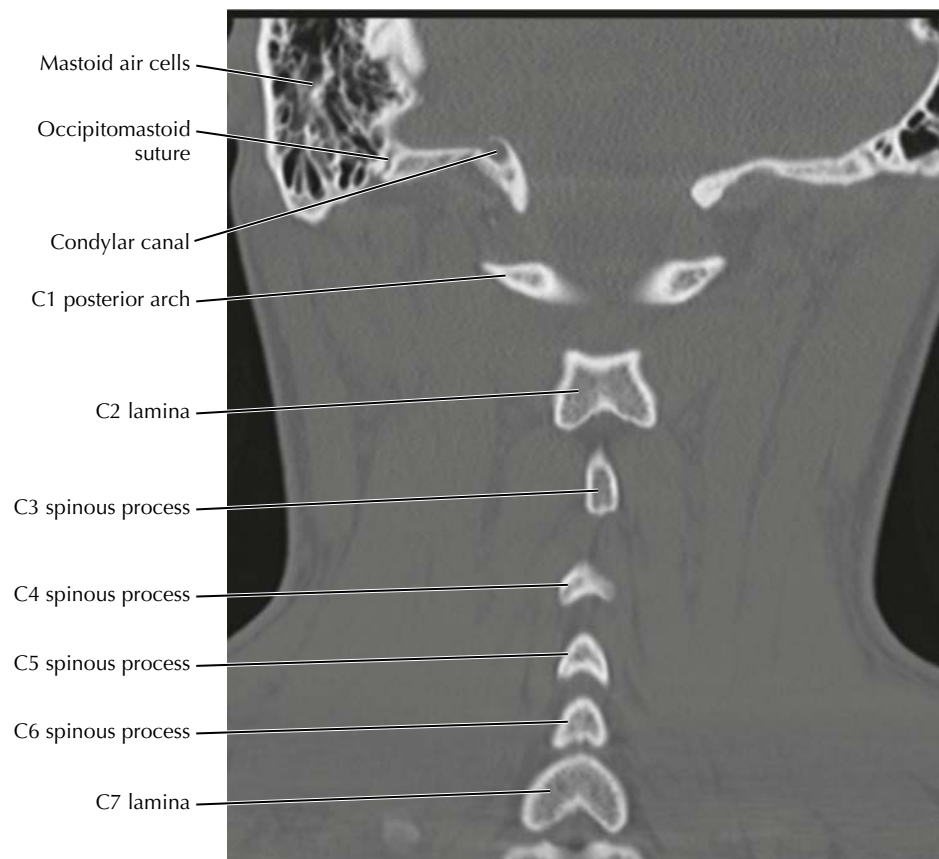
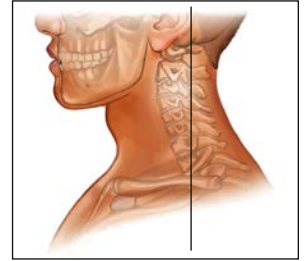
The coronal image is a good plane on which to assess for asymmetric positioning of the odontoid process. Note that in Cervical Spine Coronal 3 there is slightly more space to the right side of the patient's odontoid (left side of the image), although this is likely caused by slight rotation of the patient's neck or perhaps slight normal variation rather than trauma in this patient. The edges of the atlantoaxial joints are shown to be well aligned.

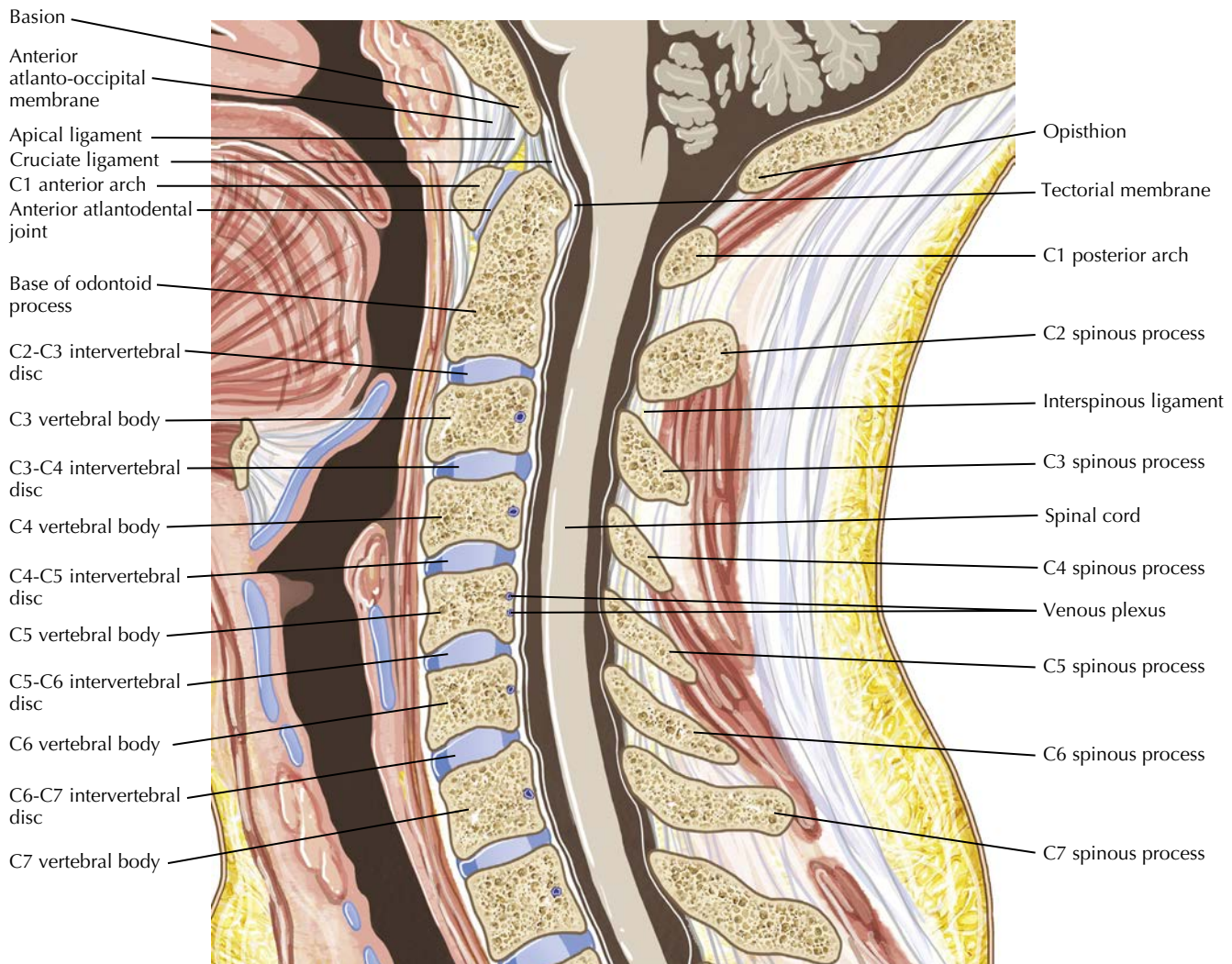










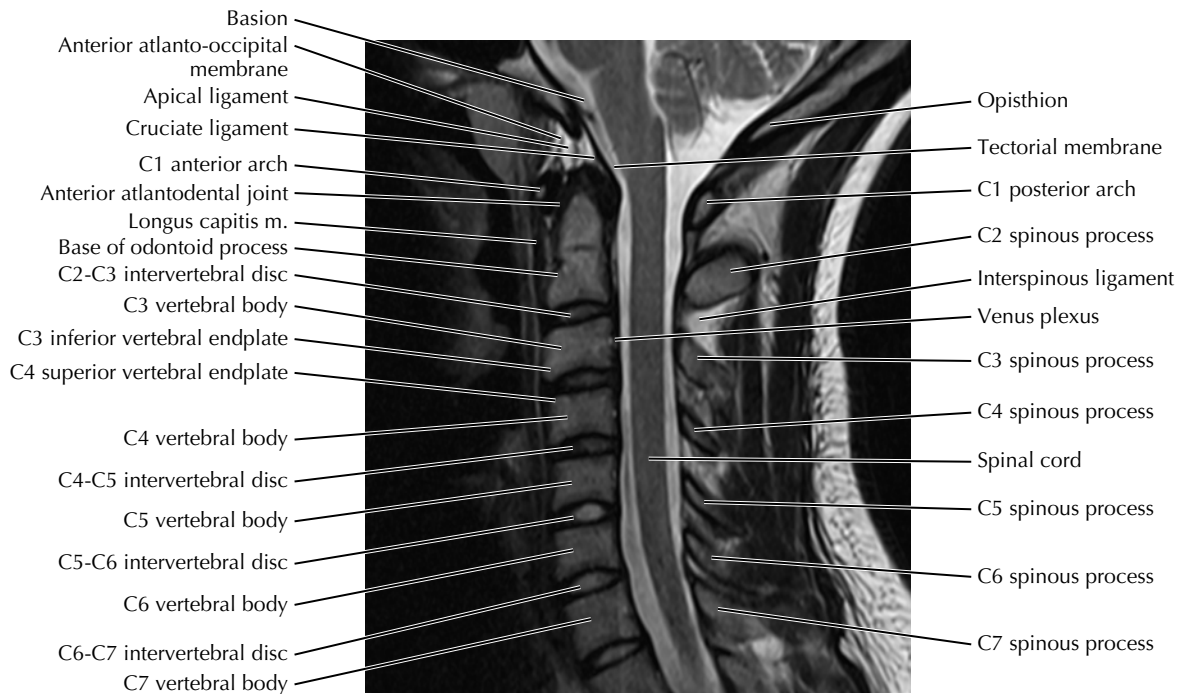
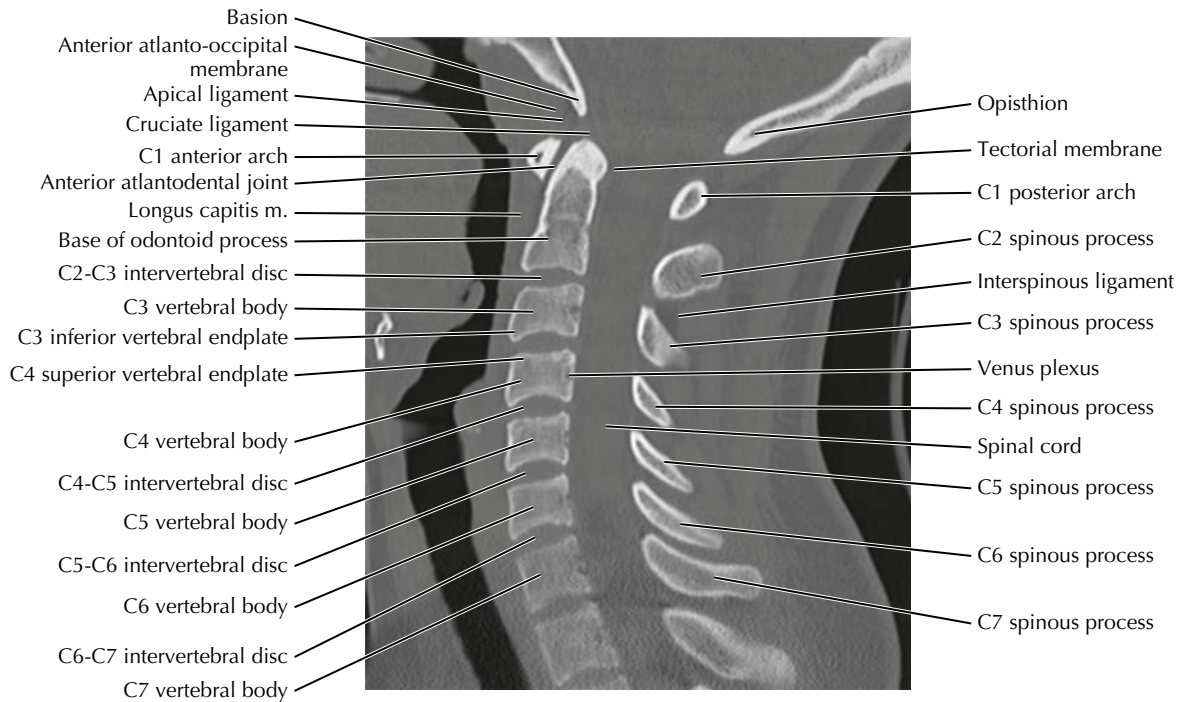
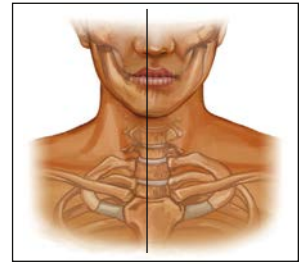


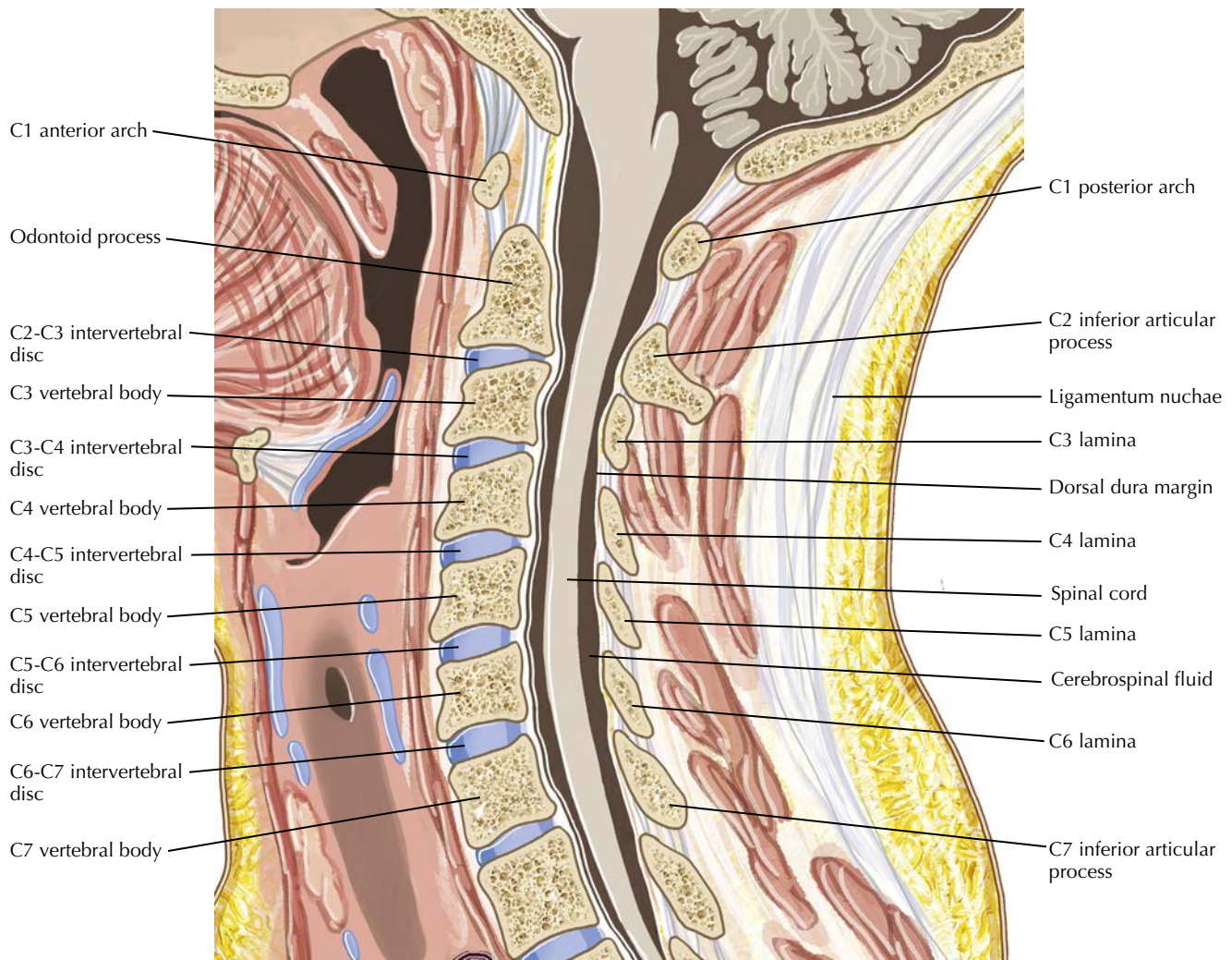
IMAGING TECHNIQUE CONSIDERATION

The midline sagittal cervical image is arguably the most important image in spinal imaging. Injury to the cord above C3 can lead to respiratory loss and death. The diaphragms are innervated by C3, C4, and C5 ("C3, 4, 5 keep the diaphragm alive"), and cord injury below this level can lead to quadriplegia.

The most palpable spinous process is usually that of C7. Recall that there are eight cervical nerves, so in the cervical region, a nerve root exits just above its corresponding vertebral body (e.g., C7 nerve root exits C6-C7 neural foramen). In the thoracic region, where there are typically 12 exiting nerve roots and 12 vertebral bodies, and in the lumbar region, where there are typically five lumbar vertebral bodies and five exiting nerve roots, the nerve root exits just below the corresponding vertebral body (e.g., L5 nerve root exits at L5-S1 neural foramen). Considerable variation exists, however, such as a lumbarized first sacral (S1) vertebral body or an accessory rib; thus, with any spinal imaging analysis, the examiner should declare the numbering of levels used. The best method is to count down from C1.

Note the clear view of the aerodigestive tract lumen, which should always be assessed. Narrowing of the lumen from prevertebral soft tissue swelling may indicate cervical spine injury. Above C4, the prevertebral soft tissue should be not more than one-third the distance of the anterior-to-posterior measurement of the vertebral body. The nasopharynx is somewhat bulky in this case because of normally prominent adenoidal tissue in this relatively young patient, with little cervical degenerative disc disease.

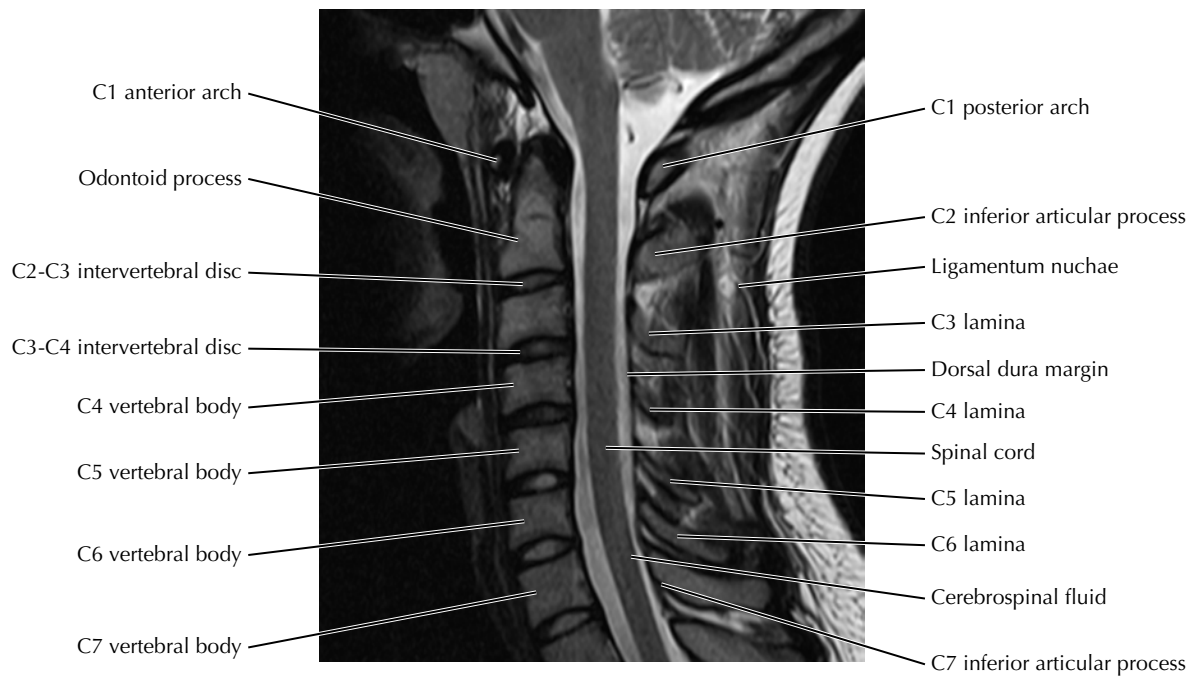
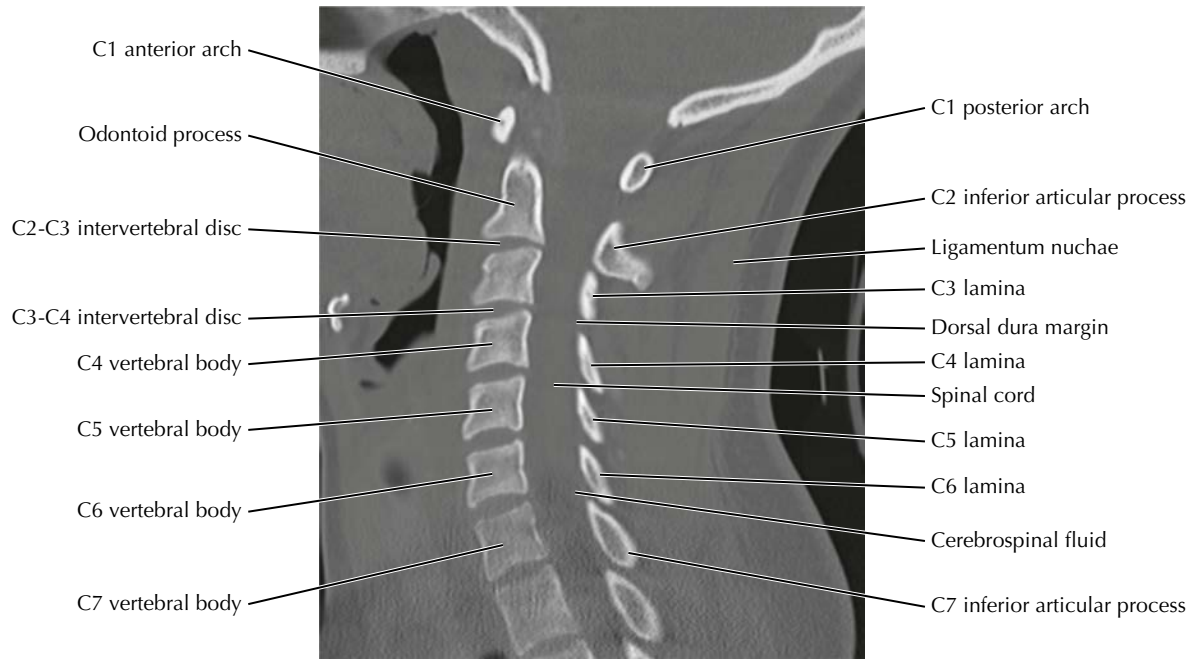
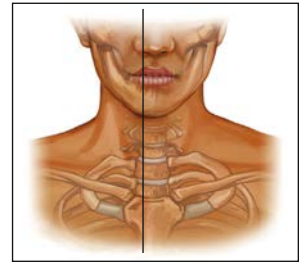


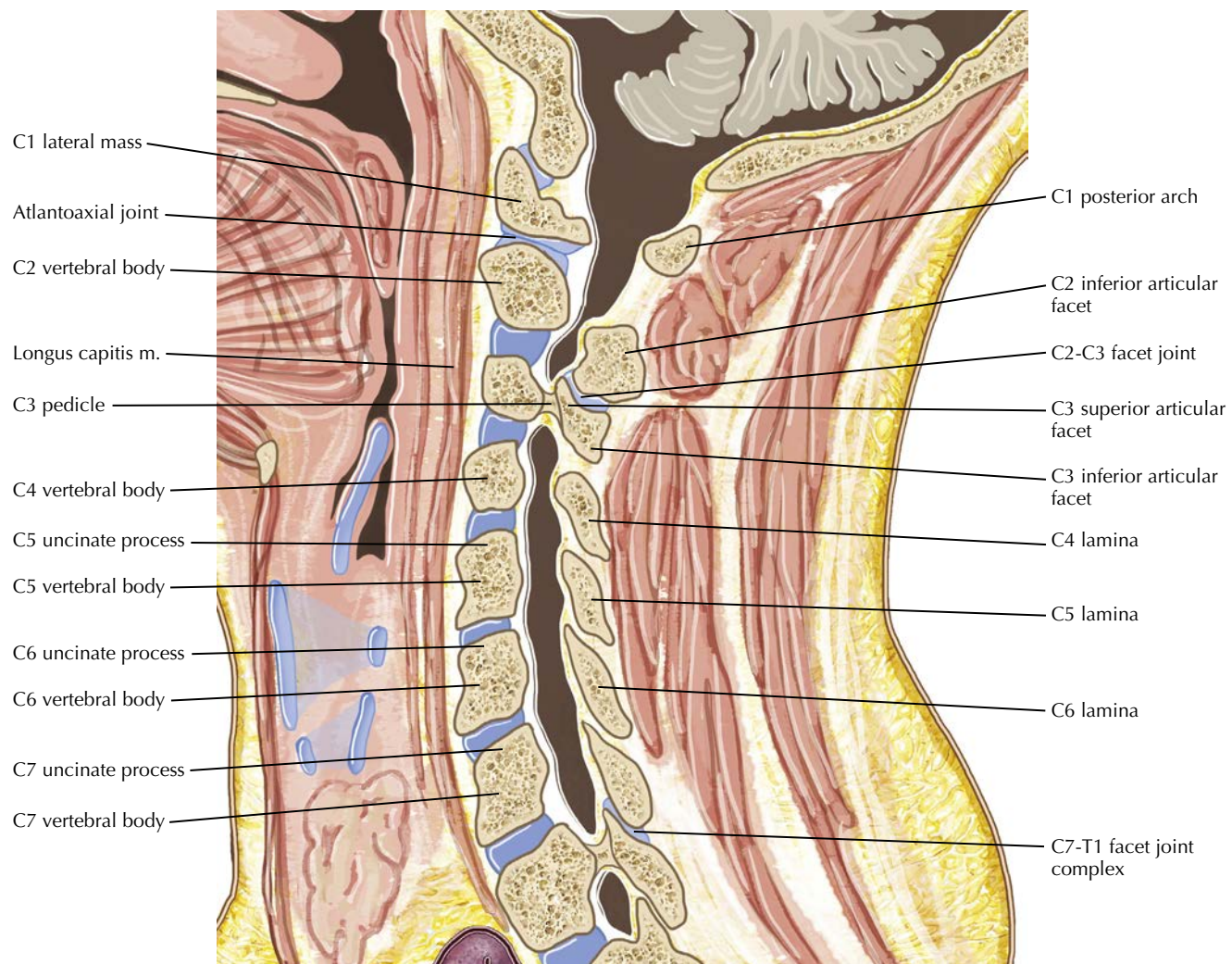


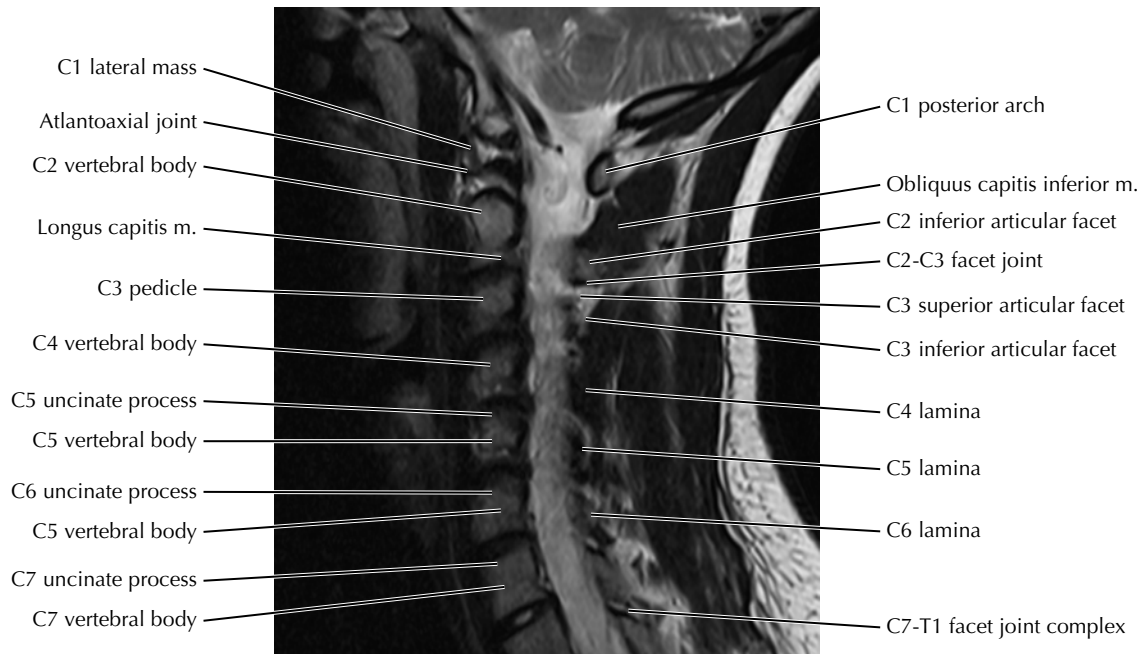
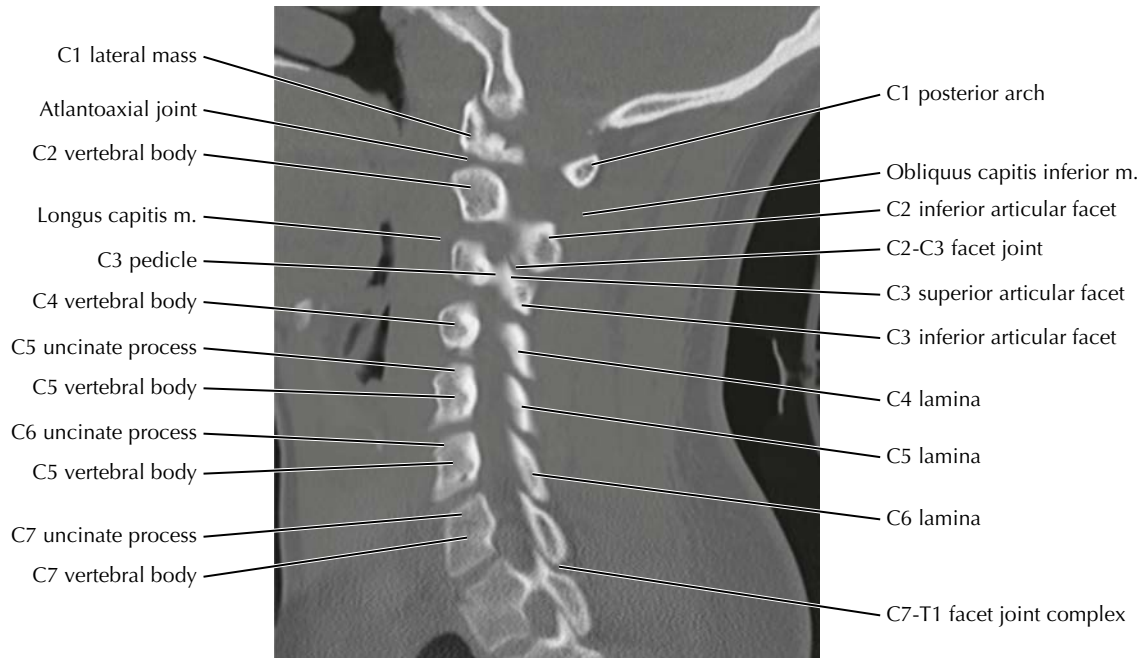
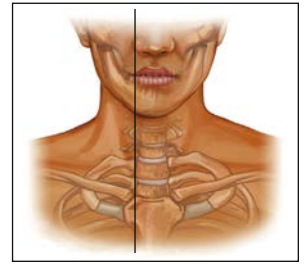
NORMAL ANATOMY

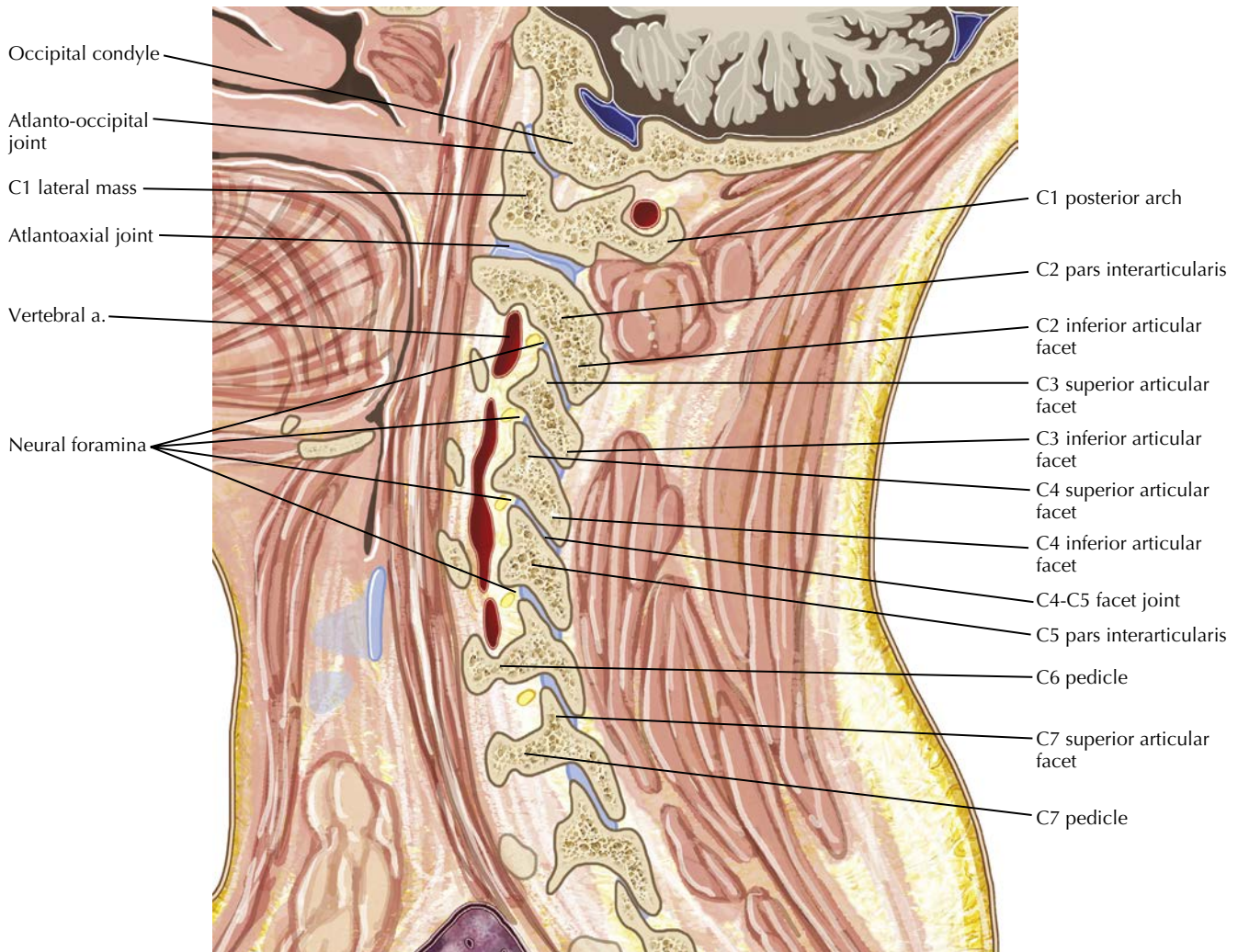
Note the slight spurring of the endplates of the uncovertebral joint at the posterolateral edge of the C2-C3 disc space. This is due to normal aging.

Although generally not present at the level of the foramen magnum, the cerebellar tonsils, if seen, should not protrude more than 5 mm below this foramen best assessed on sagittal images. Tonsils protruding more than 5 mm indicate a Chiari malformation or, more seriously, mass effect in the intracranial vault, causing the cerebellar tonsils to herniate downward.



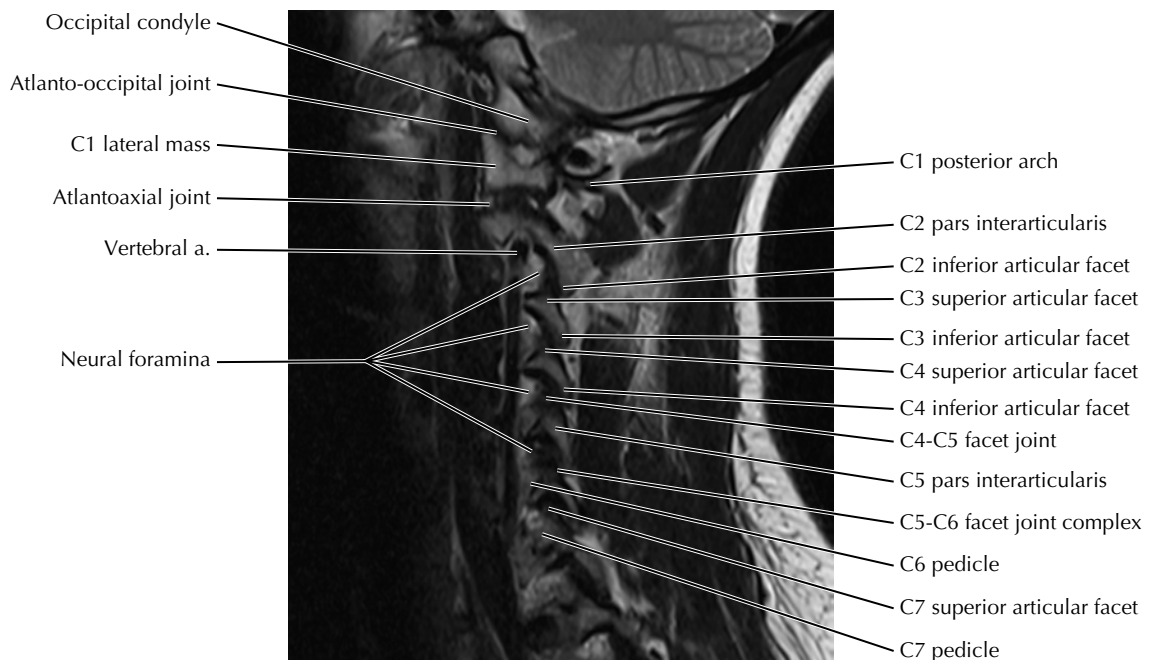
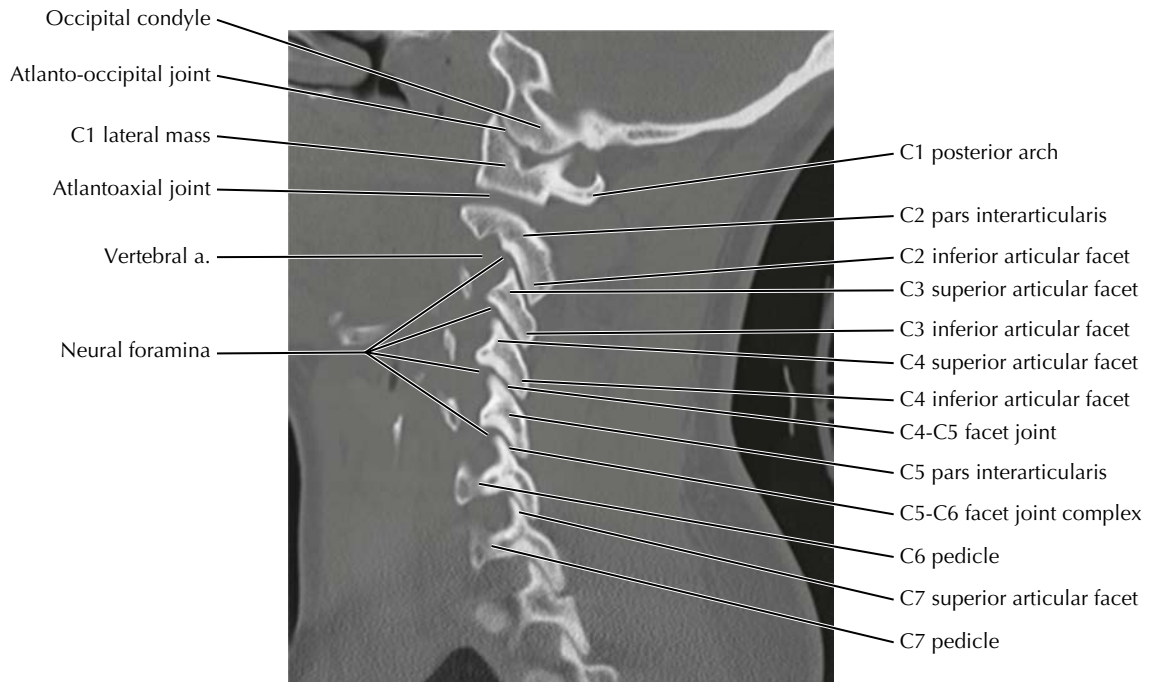
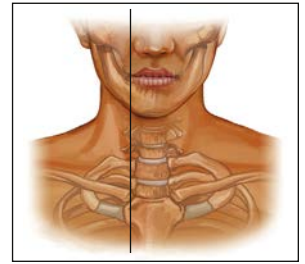


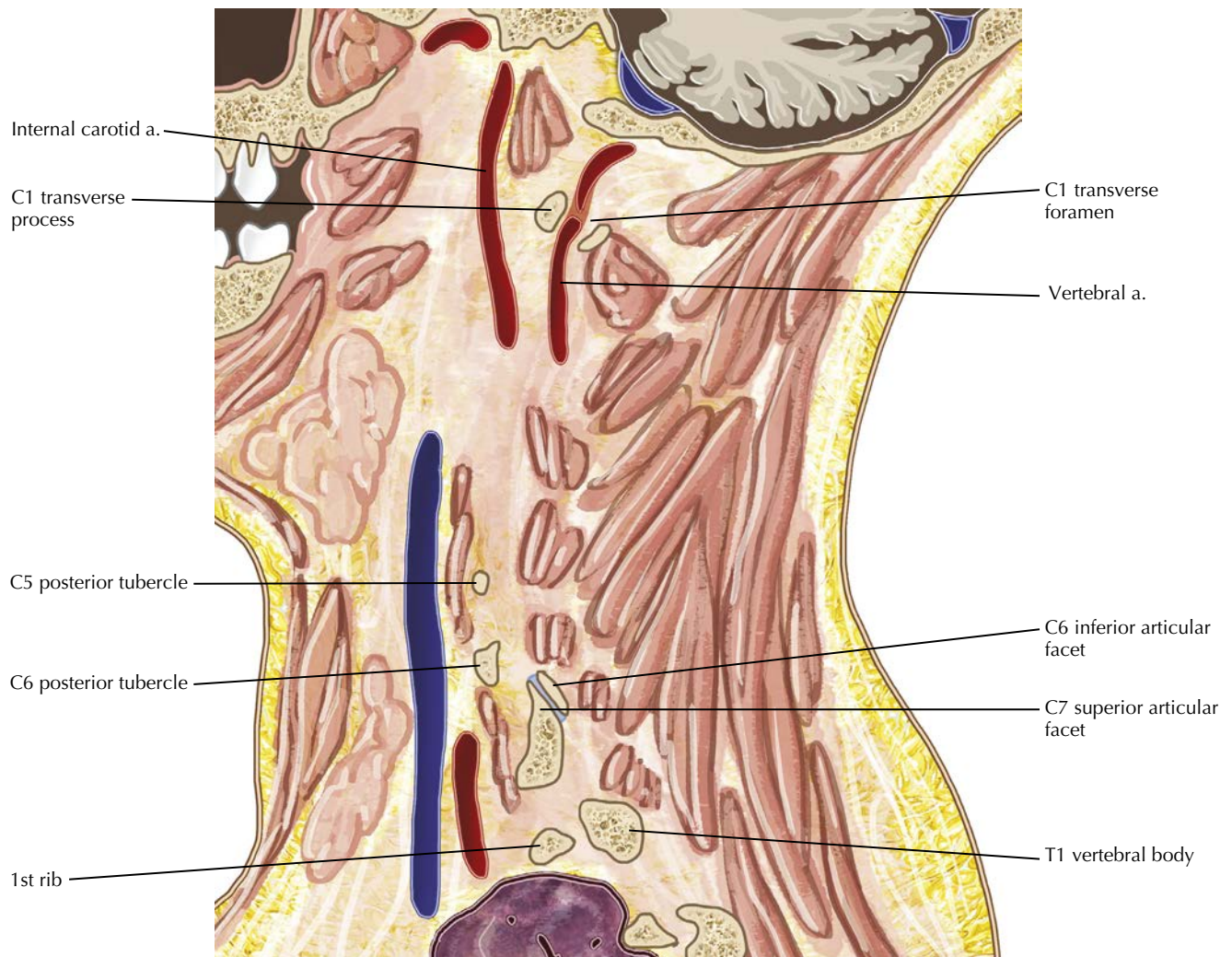


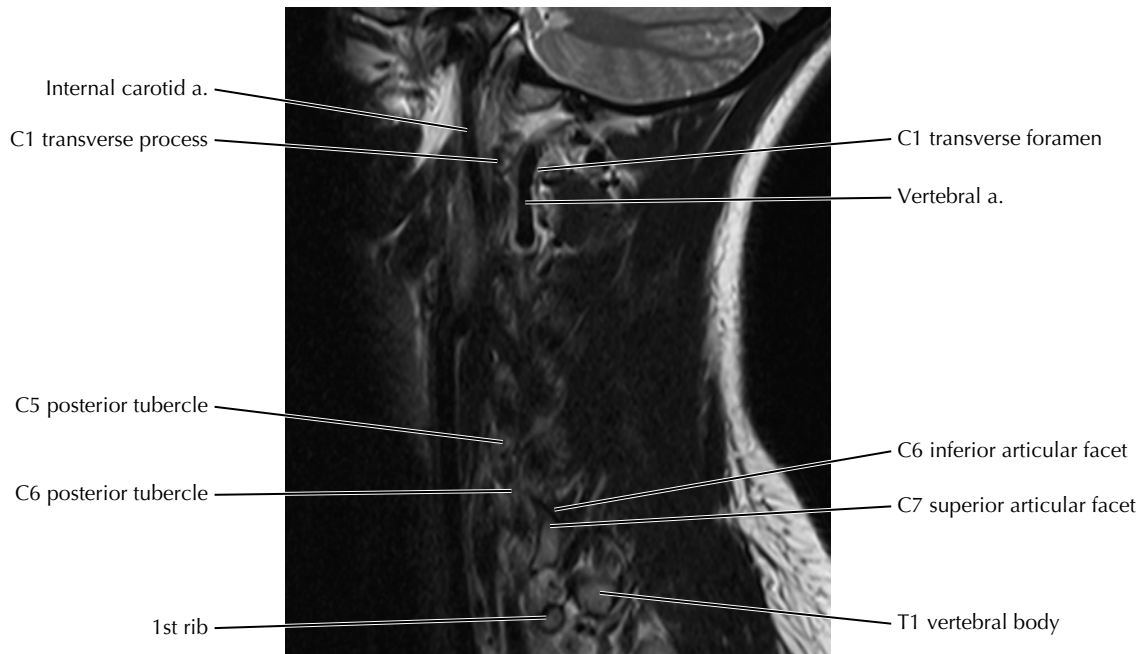
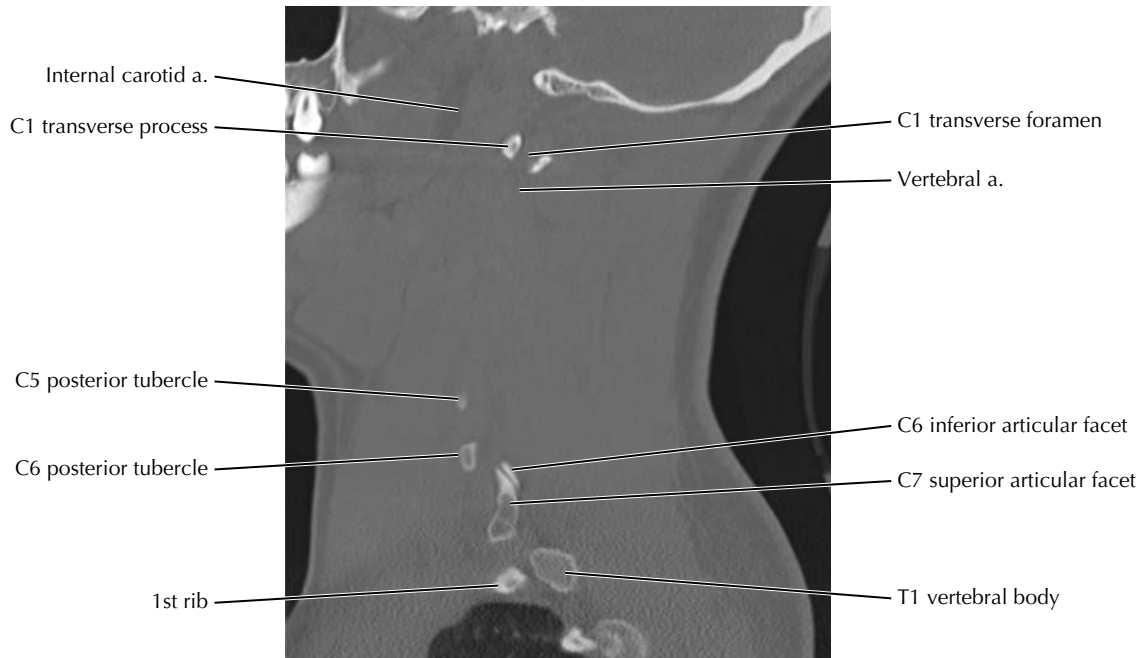
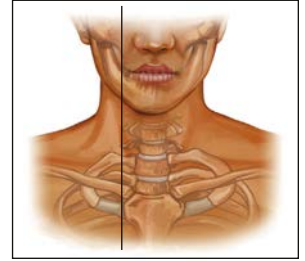


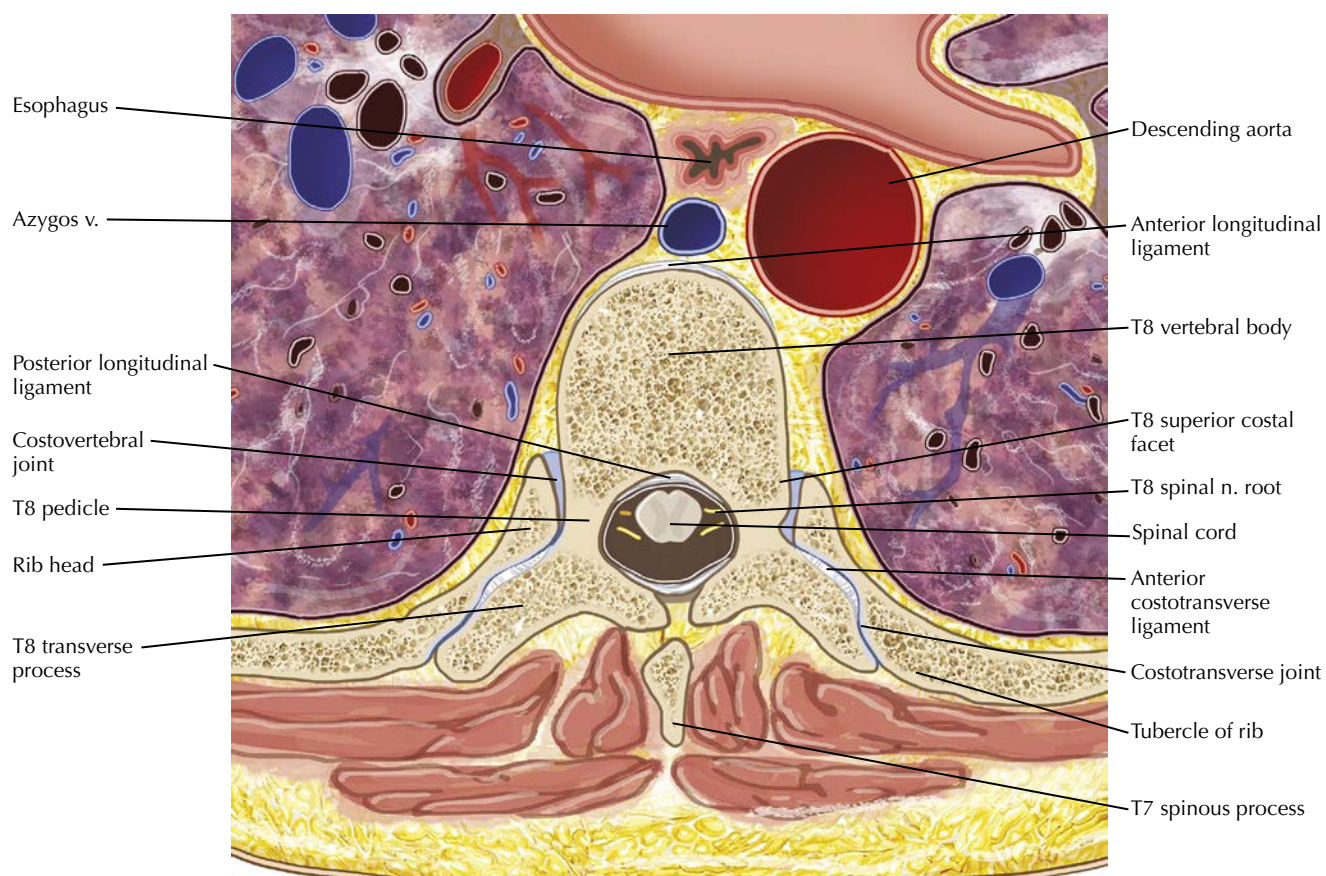
NORMAL ANATOMY

The parasagittal CT (top) and MR (bottom) images in Cervical Spine Sagittal 4 demonstrate the normal relationship of the occipital condyle and atlas (C1) arch, as well as the atlantoaxial joint and cervical facet joints. The foramina are somewhat difficult to assess on these images compared with lumbar imaging because of the smaller nature of the cervical vertebra and confounding vertebral artery foramina. Narrowing of the cervical foramina is therefore often better seen on axial imaging.



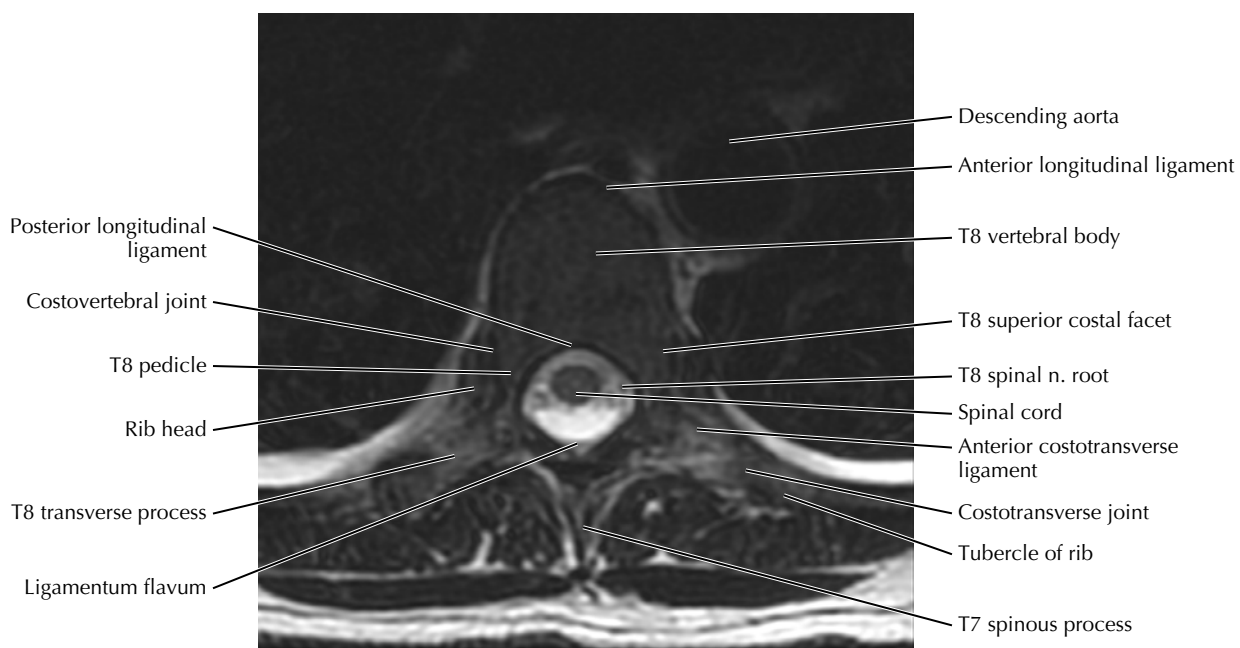
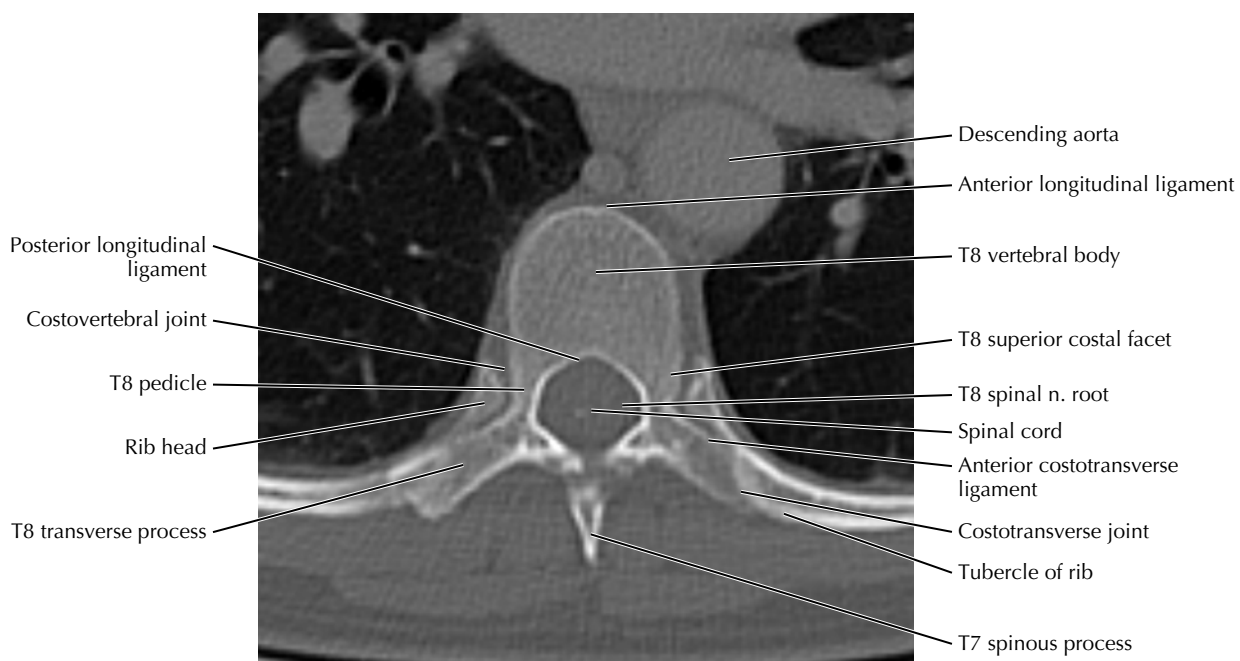
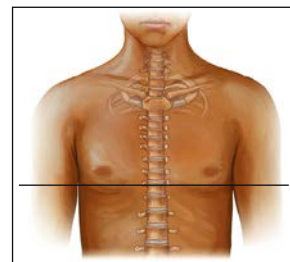


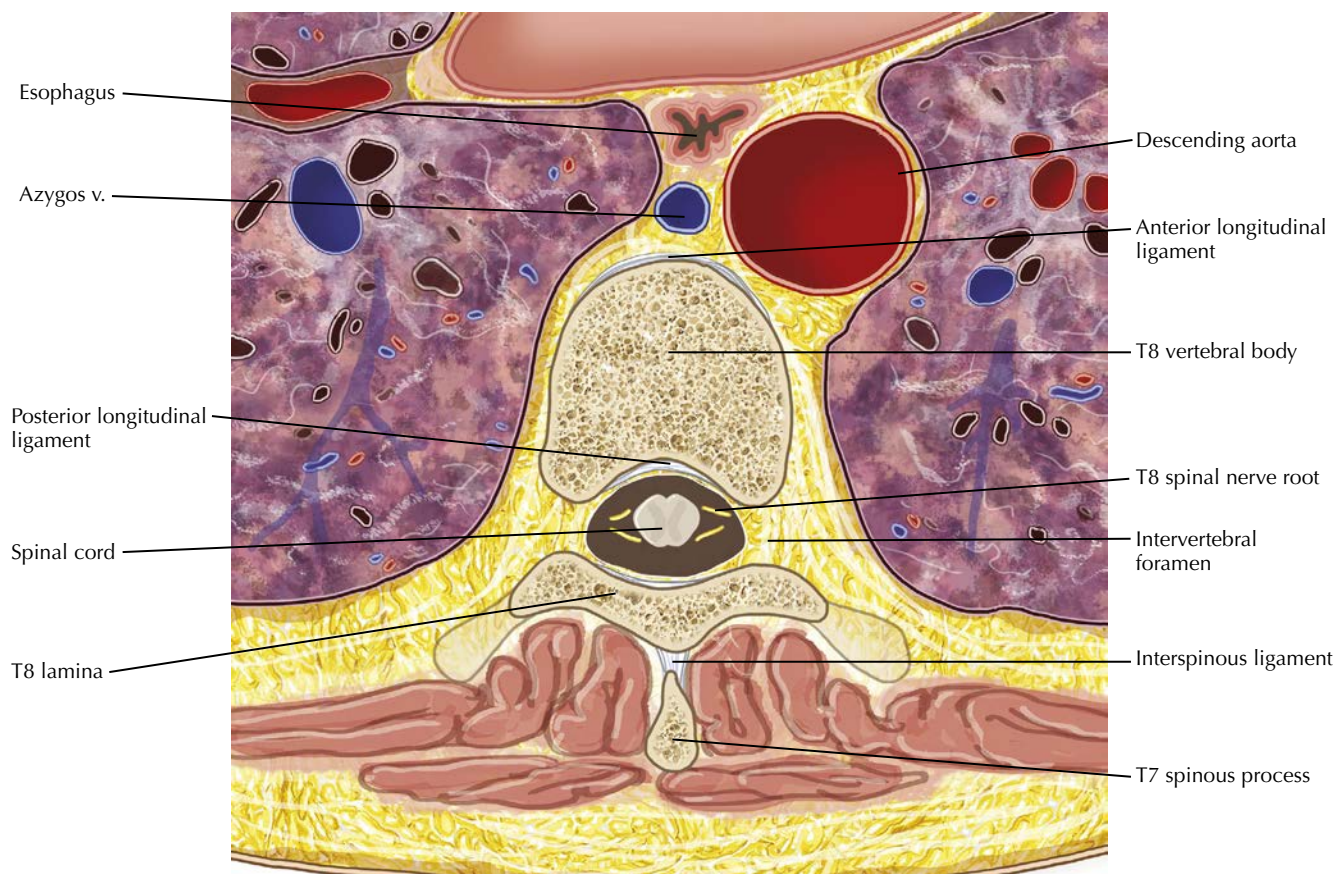




IMAGING TECHNIQUE CONSIDERATION

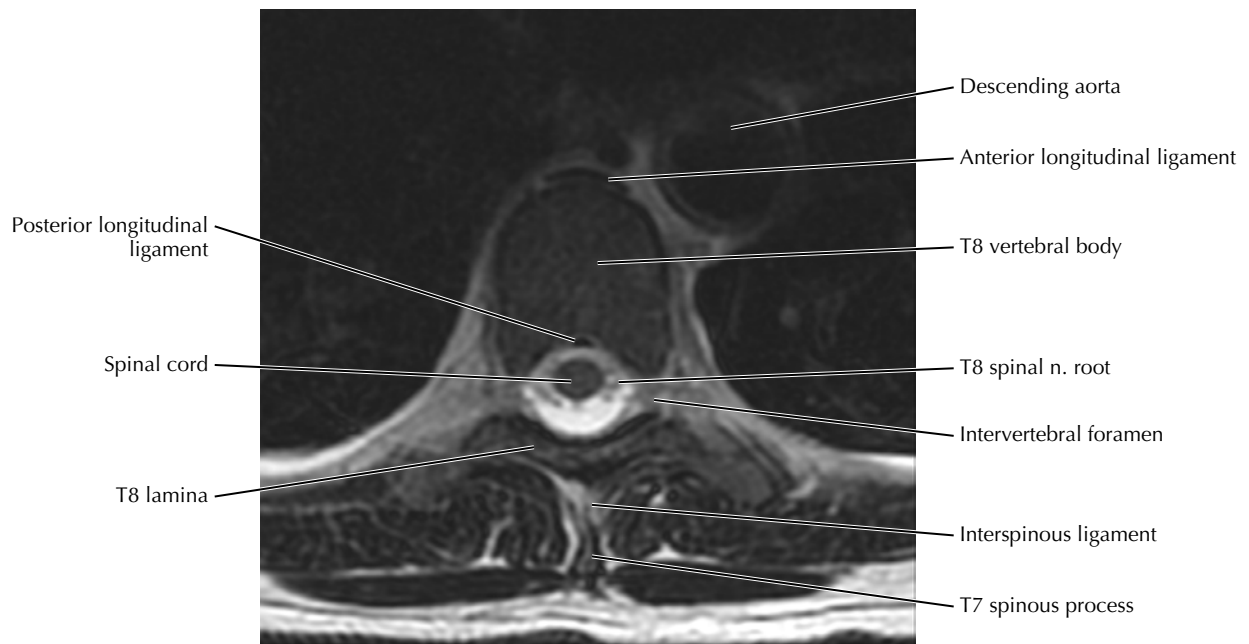
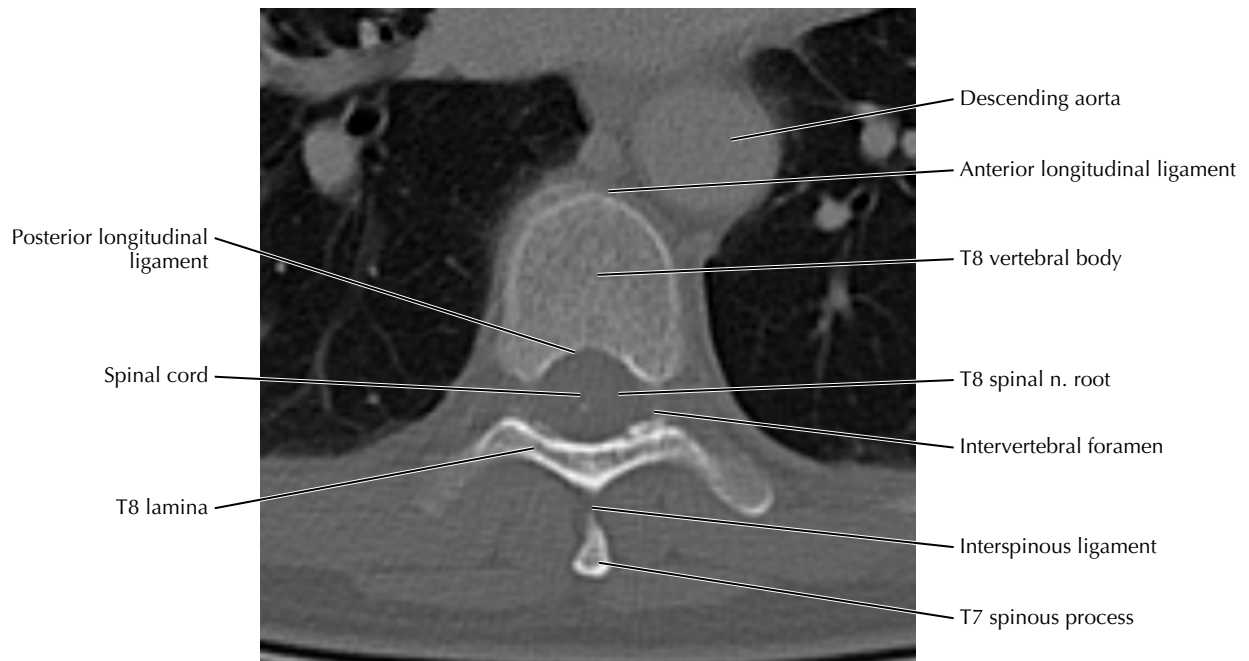
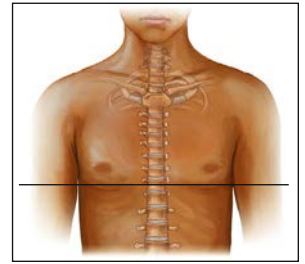
Note that the Thoracic Spine Axial 1 MR image (bottom) is a T2-weighted sequence (CSF is bright) with the now-routine "turbo" or fast spin-echo technique (fat is bright). The thoracic vertebrae are larger and require less spatial resolution than in the cervical region. Unlike the cervical region from the third (C3) through seventh (C7) cervical vertebrae, there are no uncovertebral joints in the thoracic region, but instead costovertebral junctions.

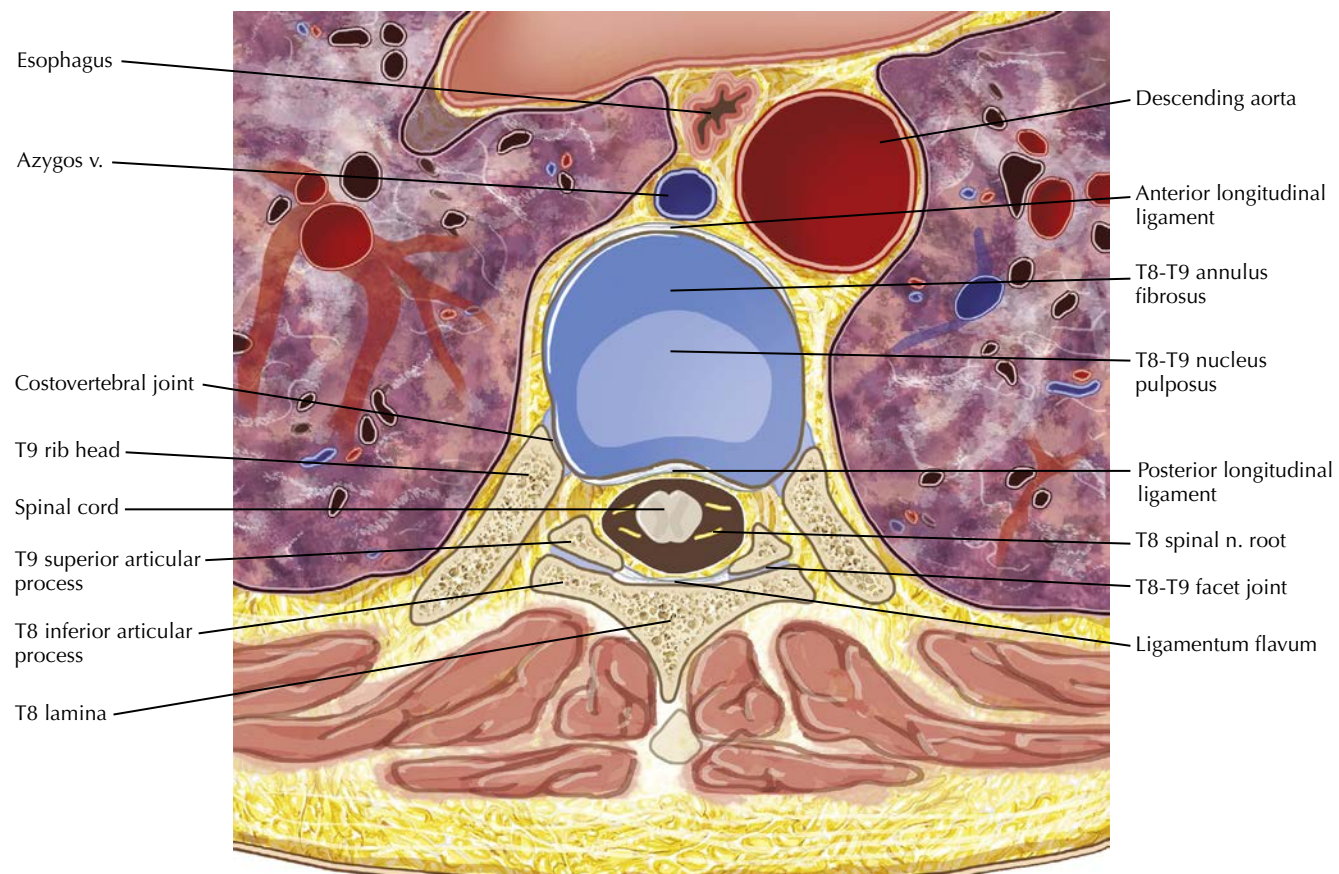




NORMAL ANATOMY

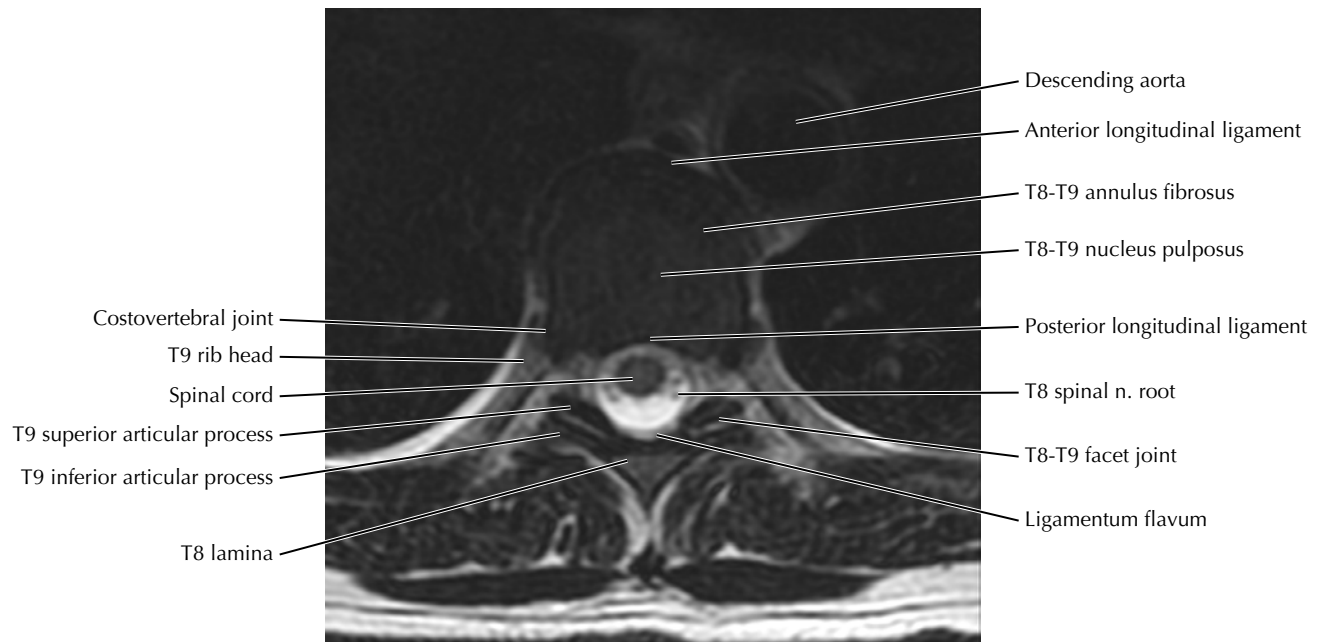
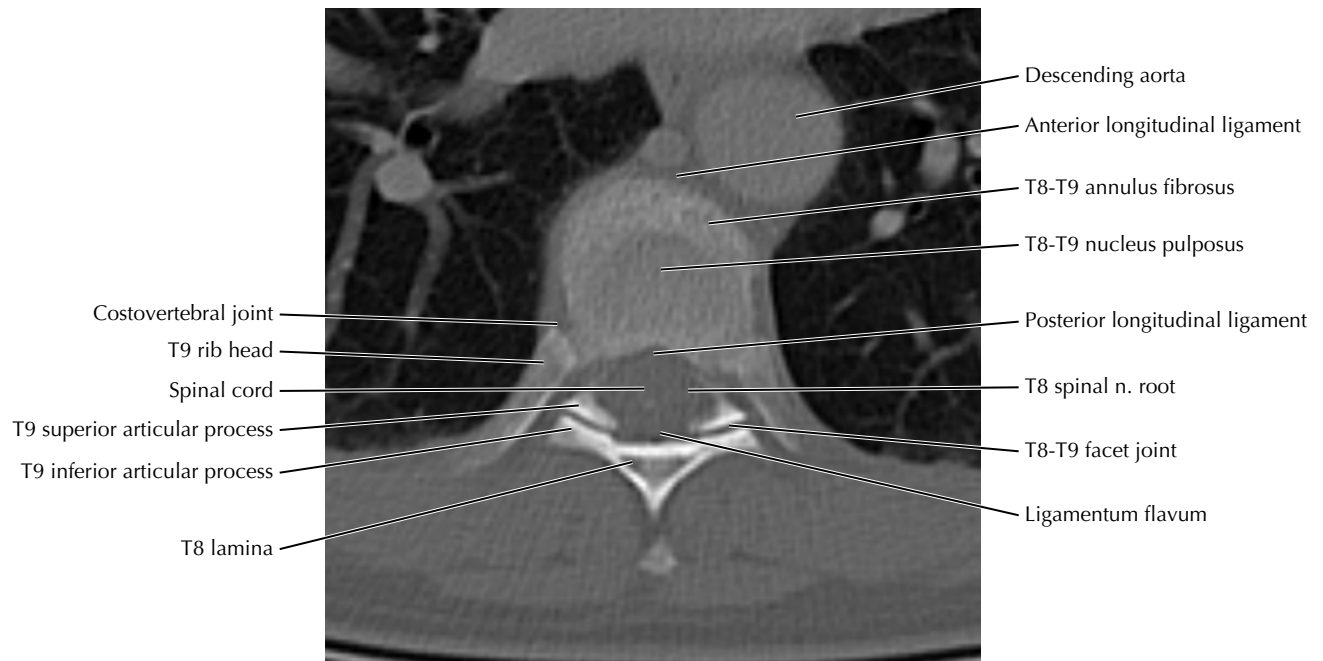
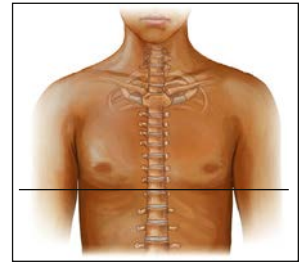
The spinal artery of Adamkiewicz, the major blood supply to the thoracic and lumbar portions of the spinal cord, typically arises from the left T10 intercostal artery and enters the left T10-T11 neural foramen before making a hairpin turn on the anterior surface of the cord. In two thirds of cases, the artery will arise from the same side as the descending aorta, and as a variant arise several levels above or below T10 in a bell curve distribution.

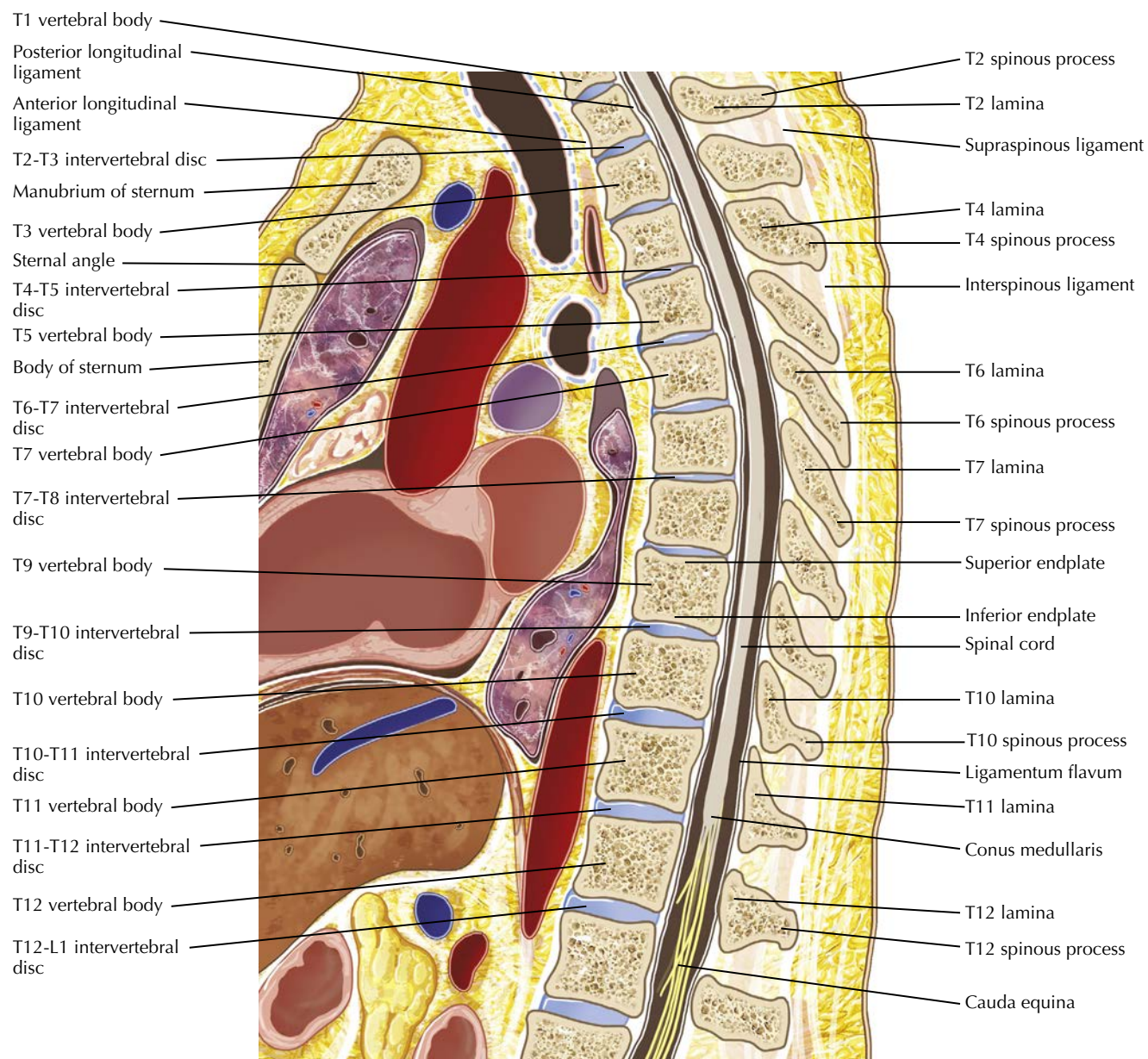




NORMAL ANATOMY

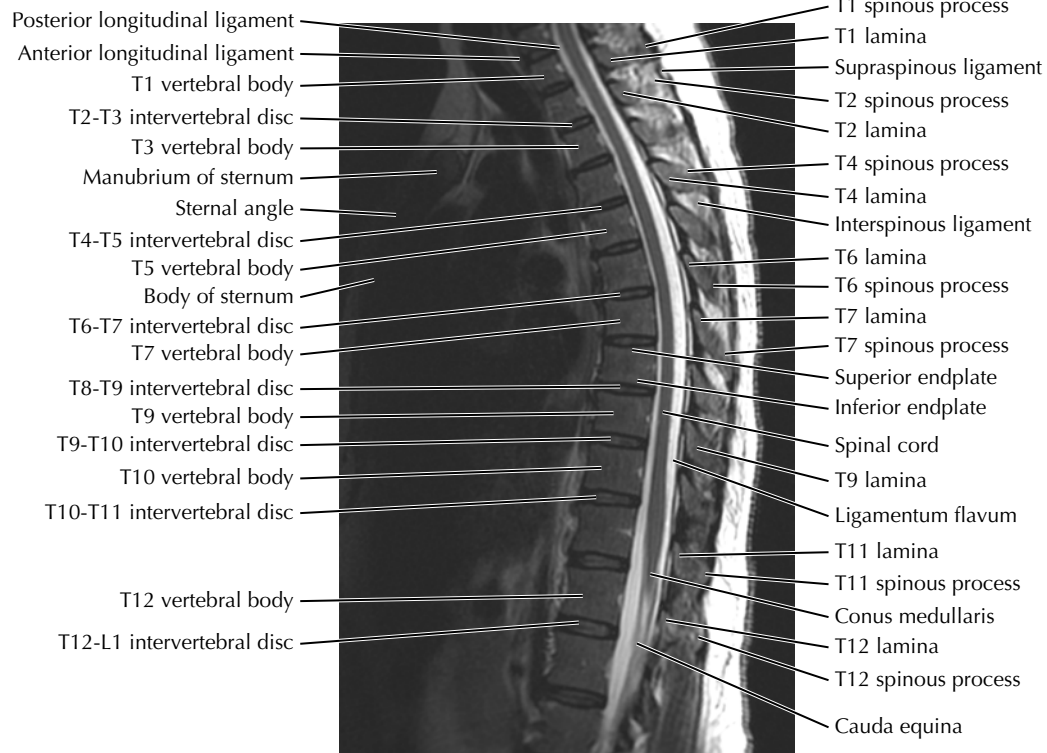
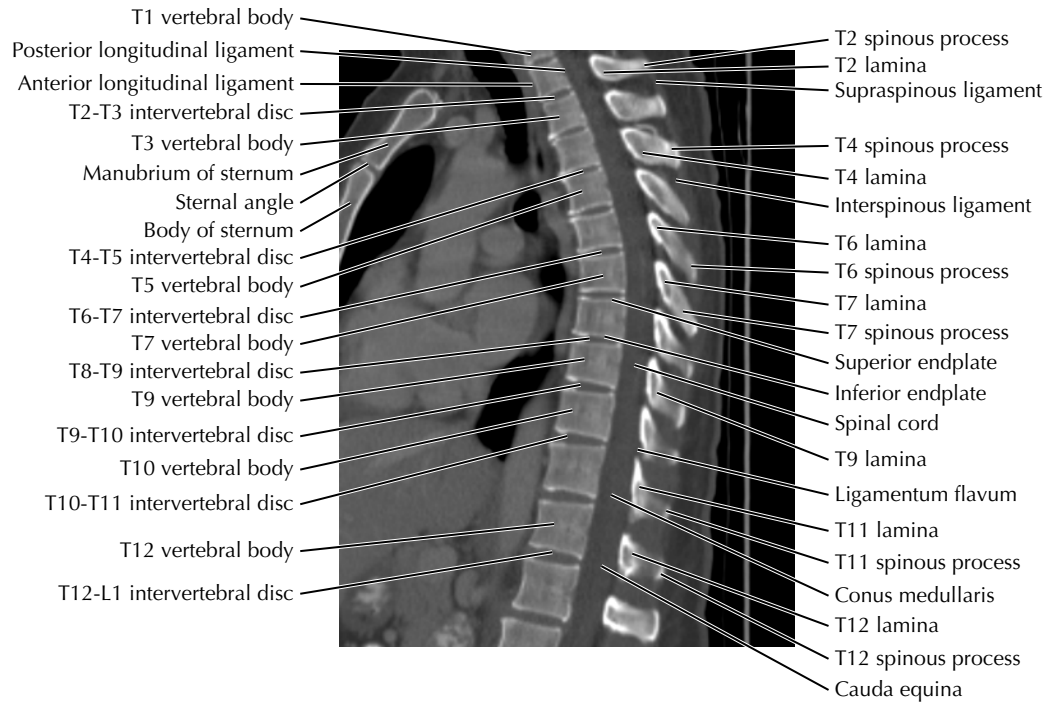
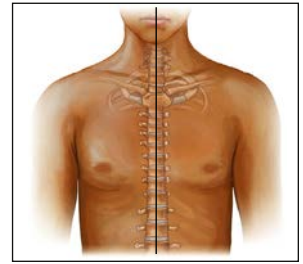
Note the facet joint, which is composed of the superior articular process of the vertebra below, is anterior to the inferior articular process of the vertebra above.

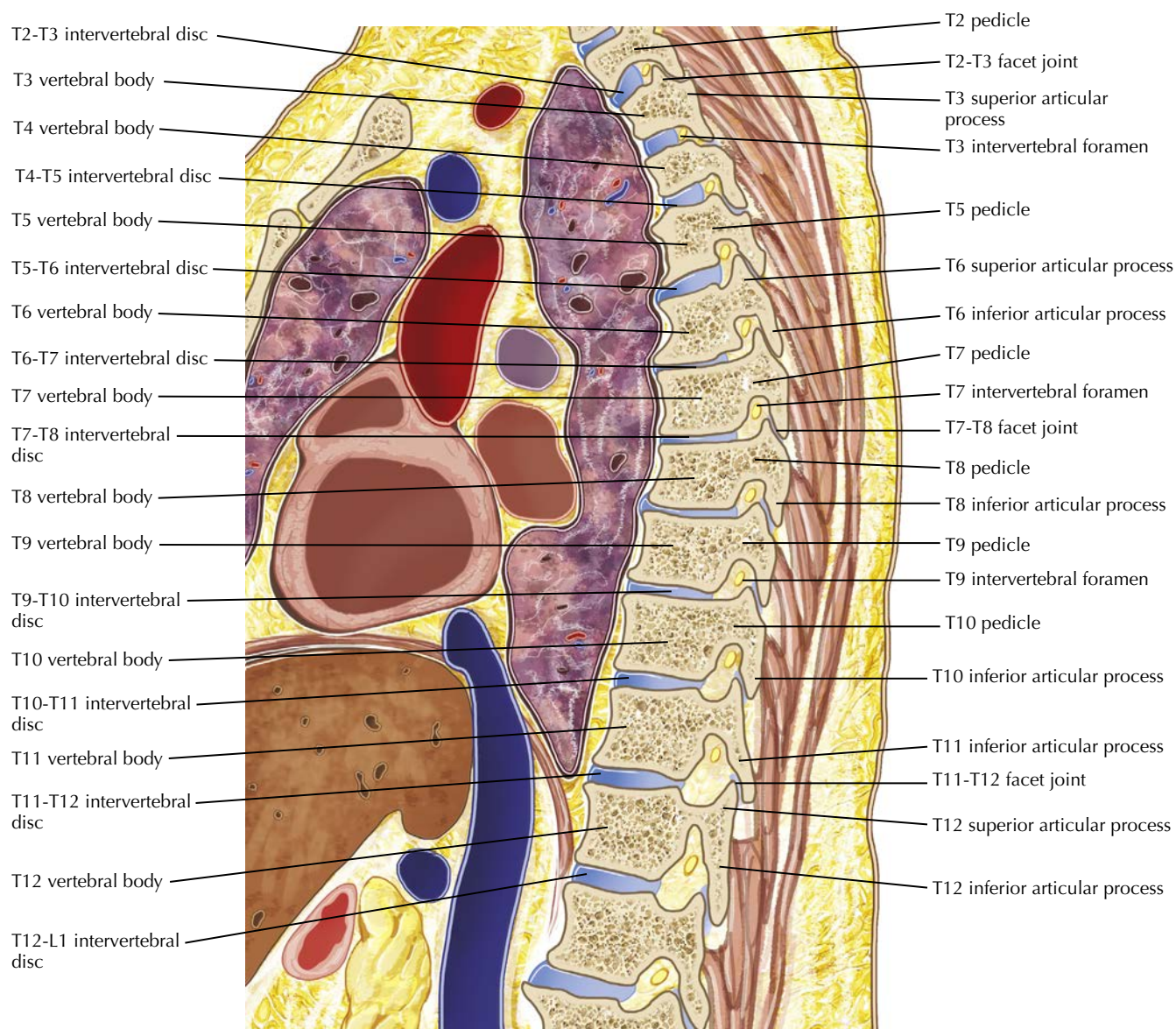




NORMAL ANATOMY

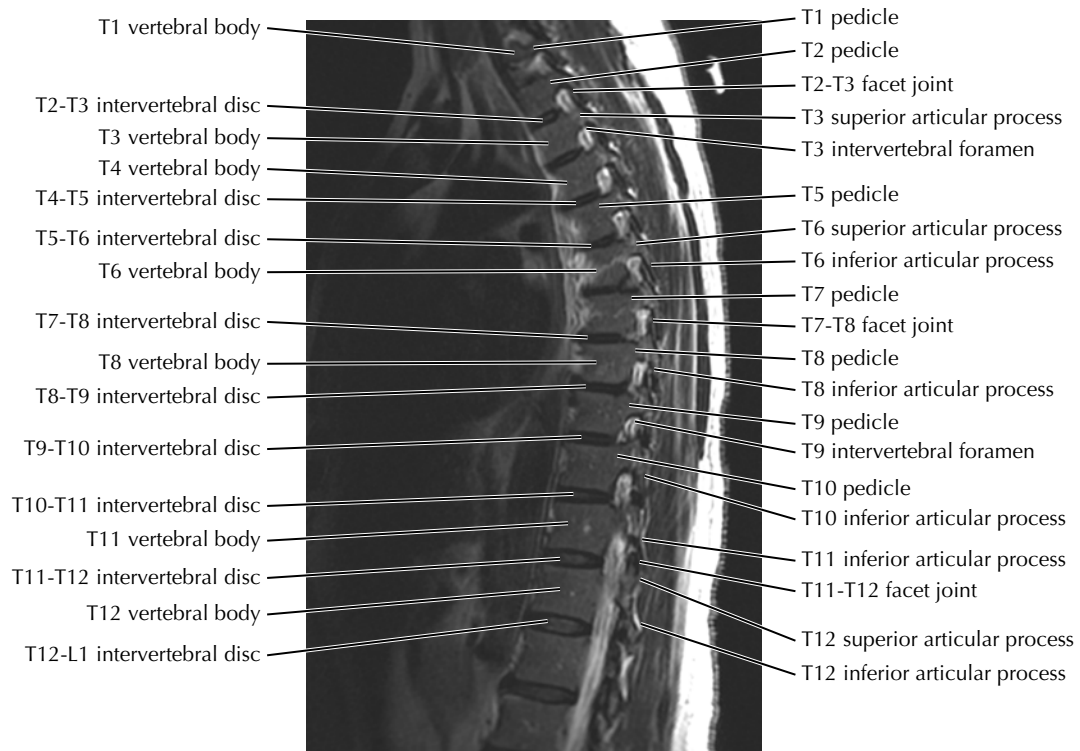
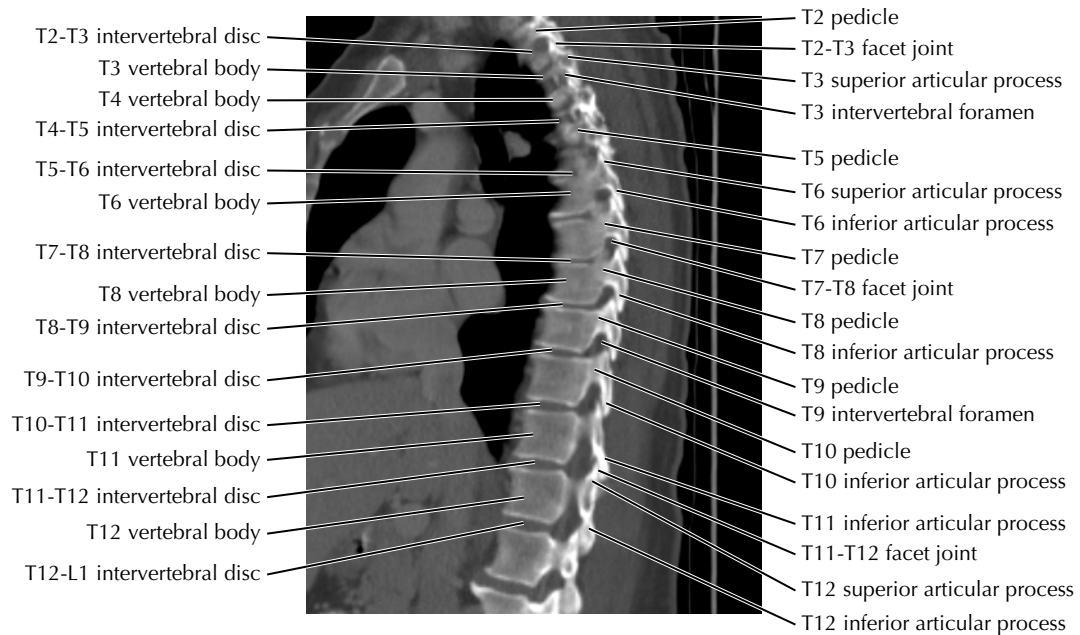
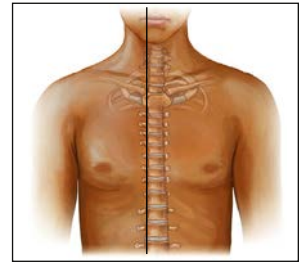
There is a normal anterior-to-posterior expansion of the spinal cord near the conus, just as there is a normal cervical cord expansion where the brachial plexus nerve roots arise. This should not be confused with expansion from an intramedullary lesion.

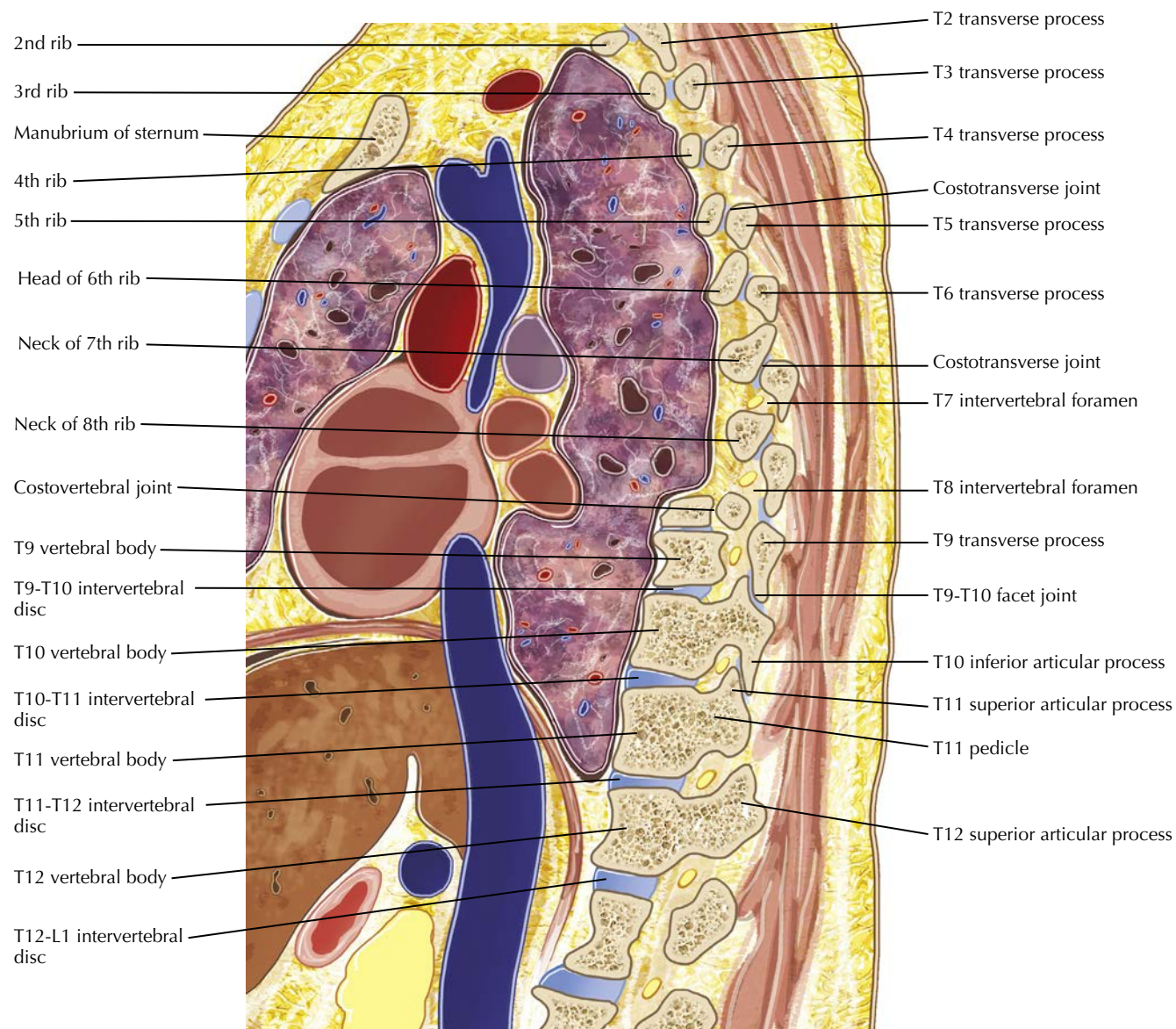


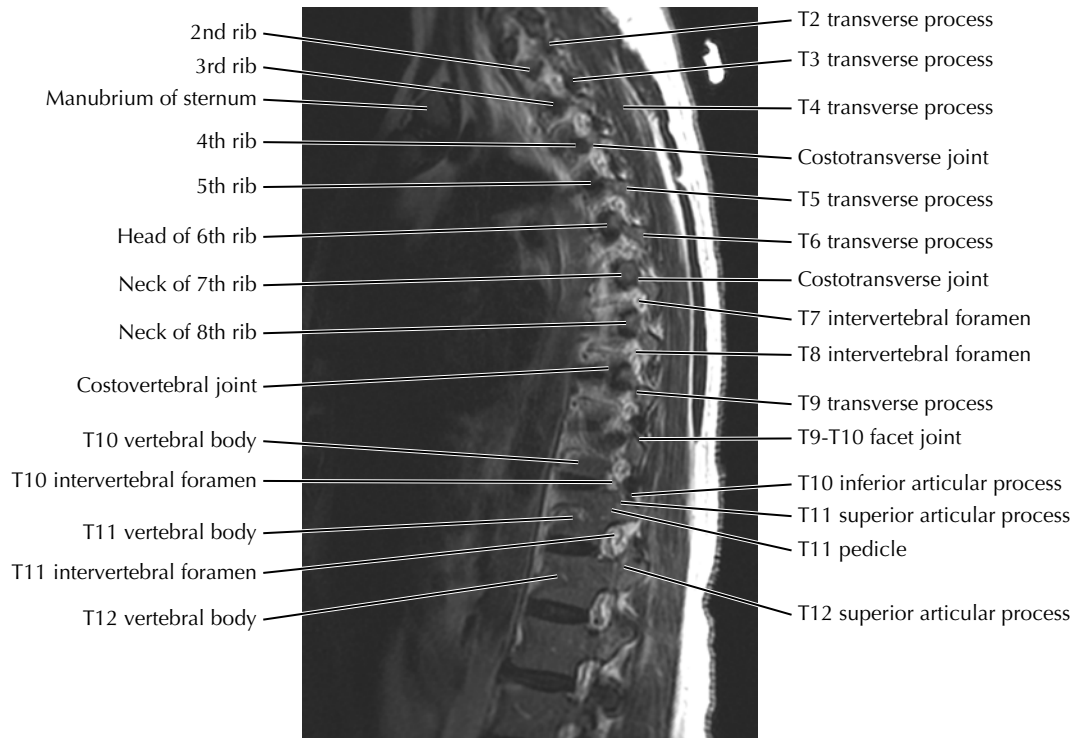
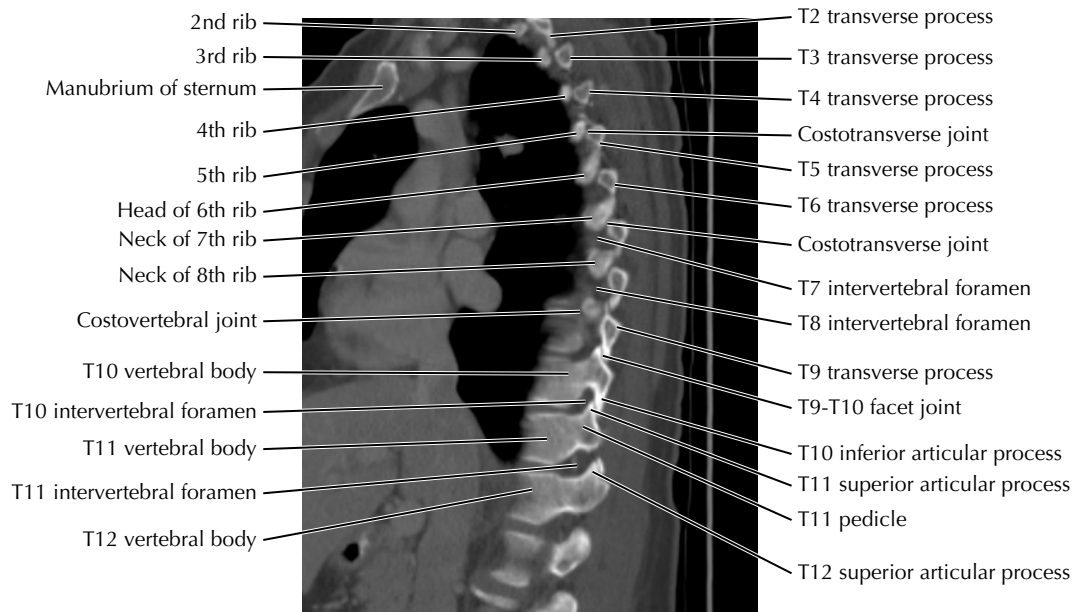
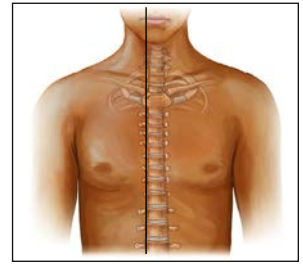


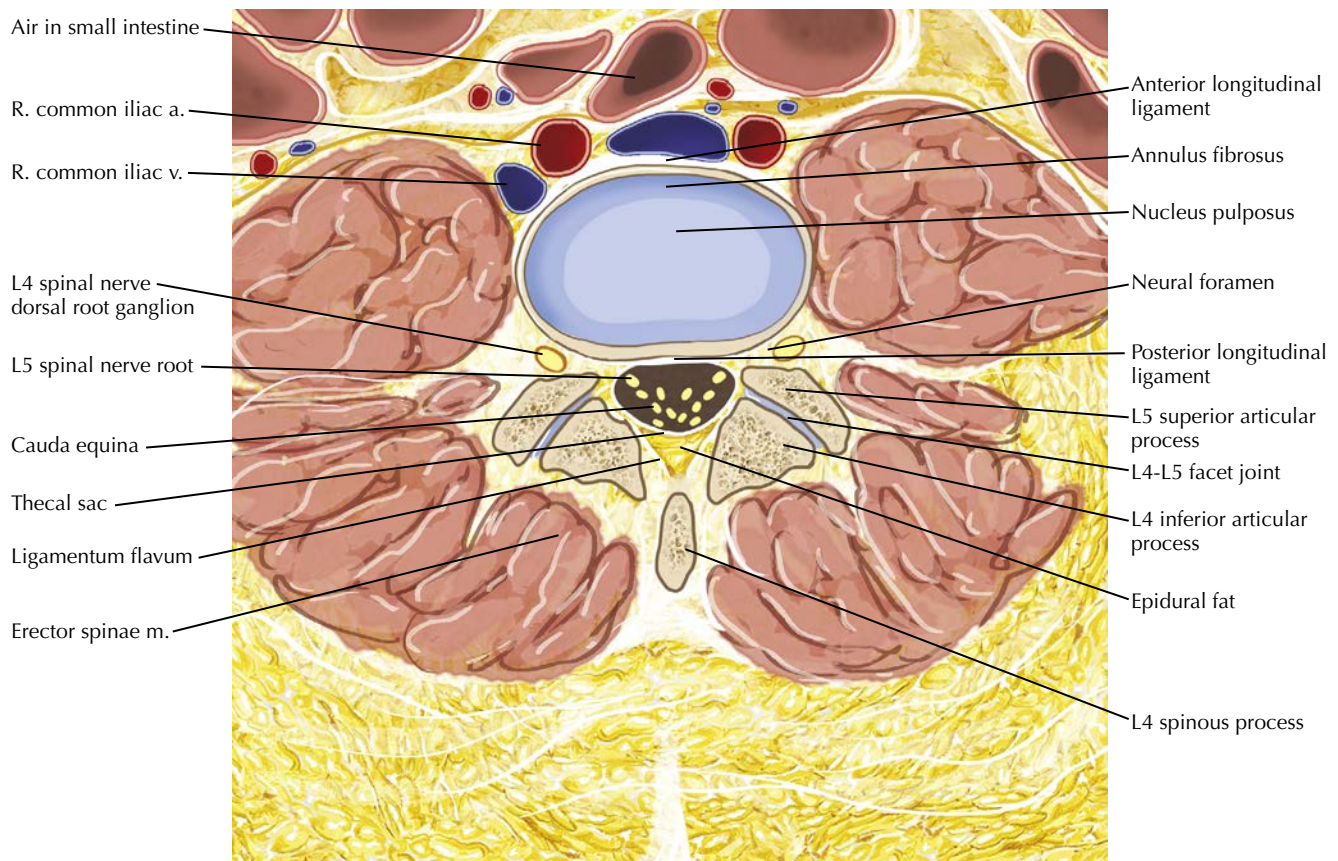
NORMAL ANATOMY

Note that the thoracic vertebral anatomy is larger than the cervical vertebral anatomy, making the foramina much easier to appreciate on parasagittal imaging, along with the absence of the confounding vertebral foramina.





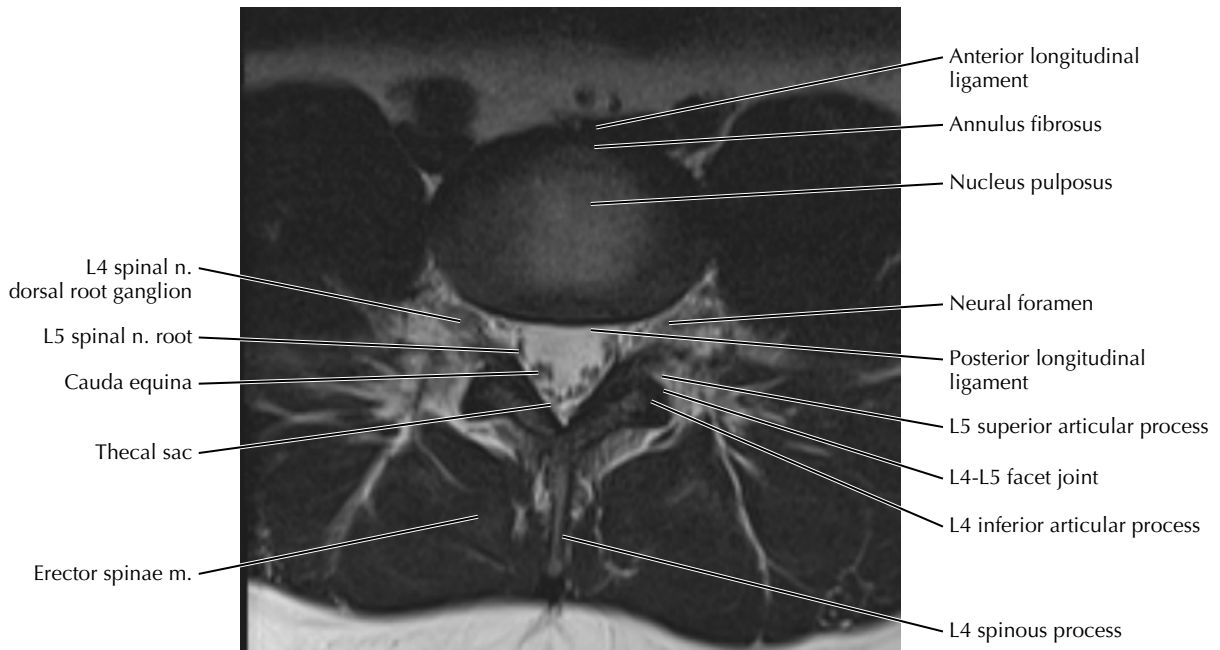
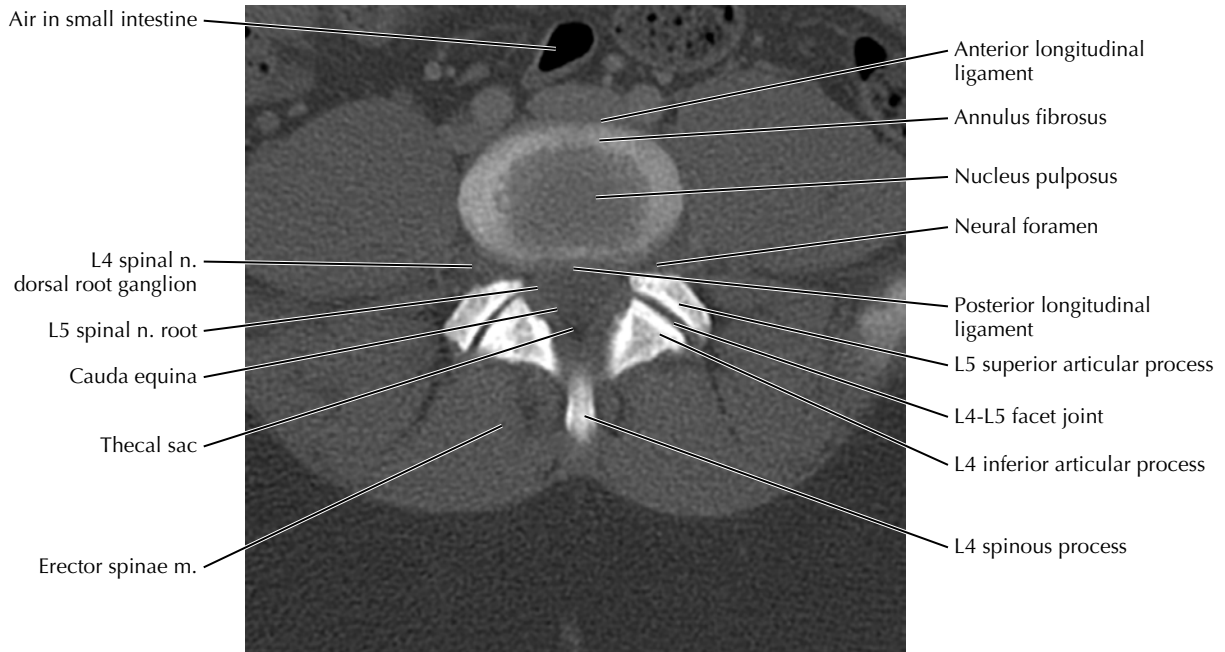
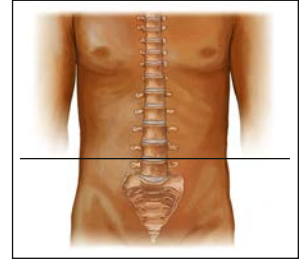


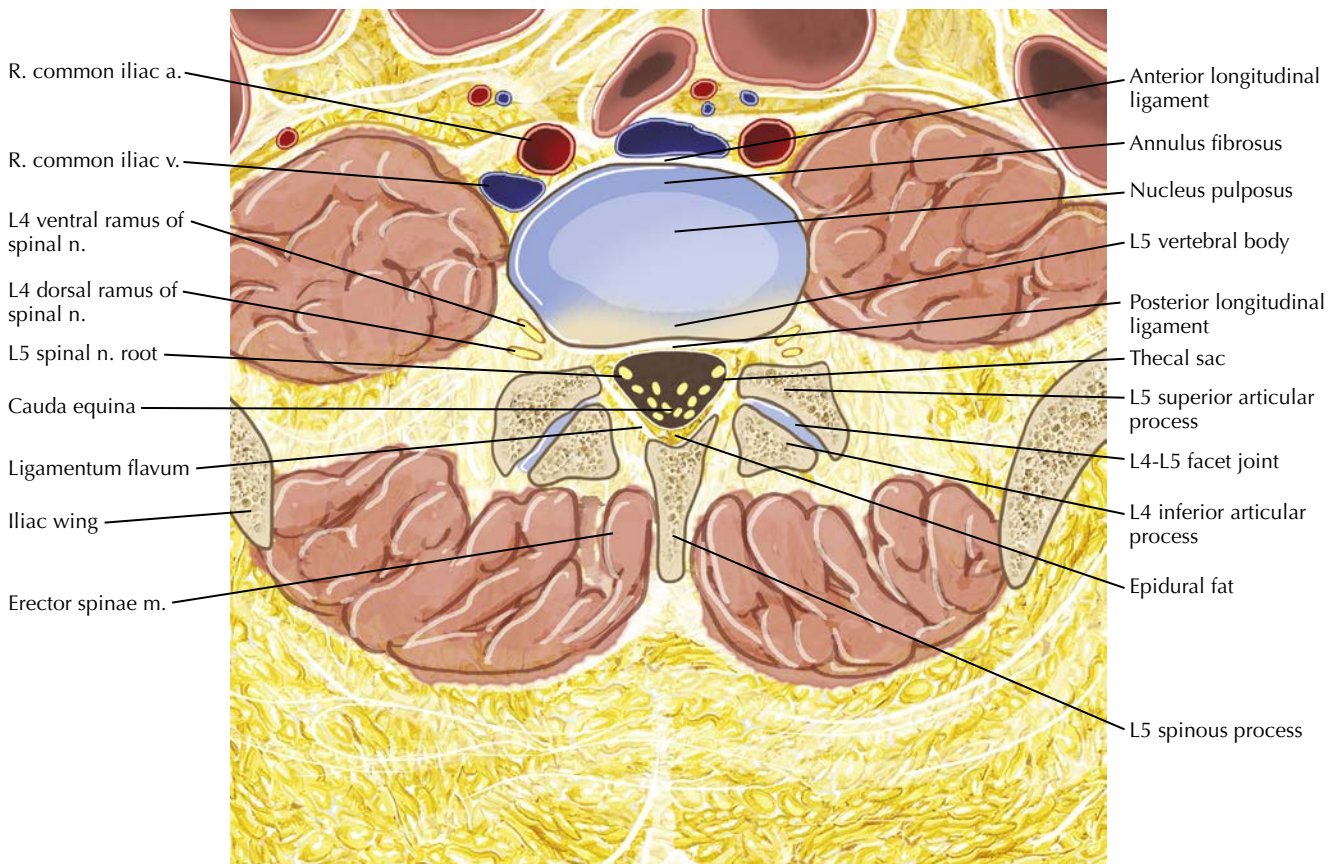


NORMAL ANATOMY

It is easier to see the triangle of posterior epidural fat on the CT image (top) than on the turbo T2-weighted MR sequence (bottom), where both fluid and fat are bright. Fat has a density of about 10 to -50 Hounsfield units (HU), the scale used to measure density on CT, and appears dark gray, whereas the laterally adjacent right and left ligamentum flavum and spinal canal anteriorly are of soft tissue density, measuring about +40 HU.

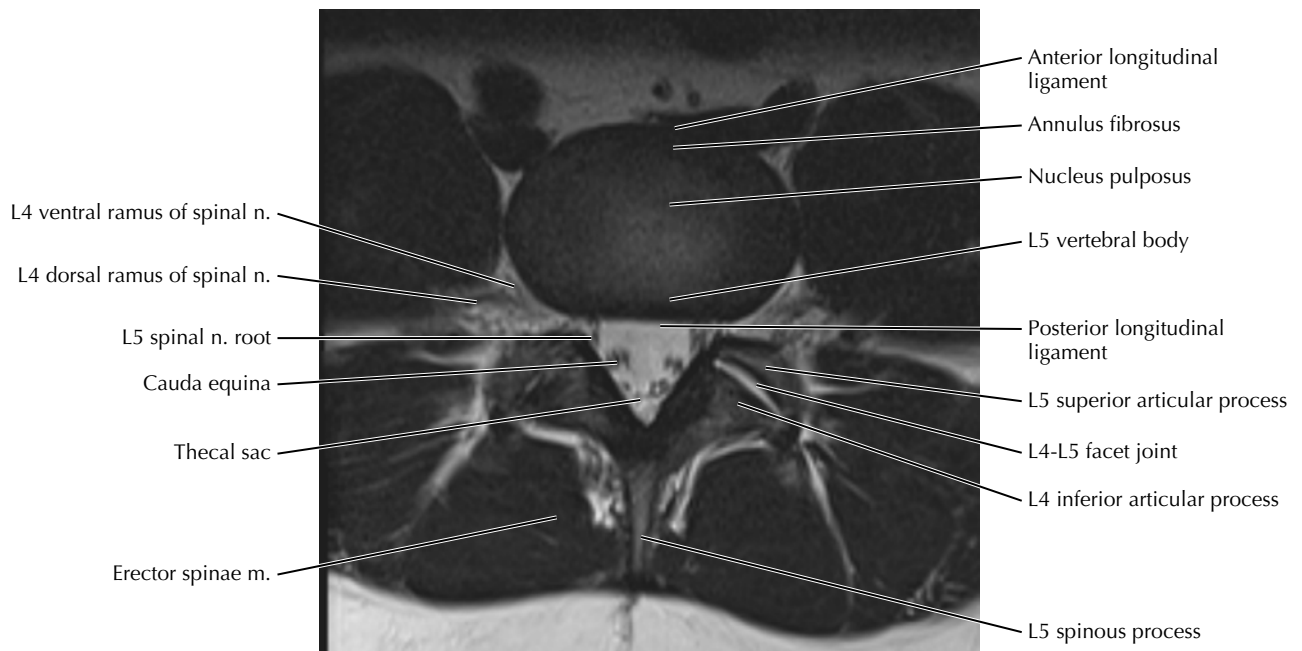
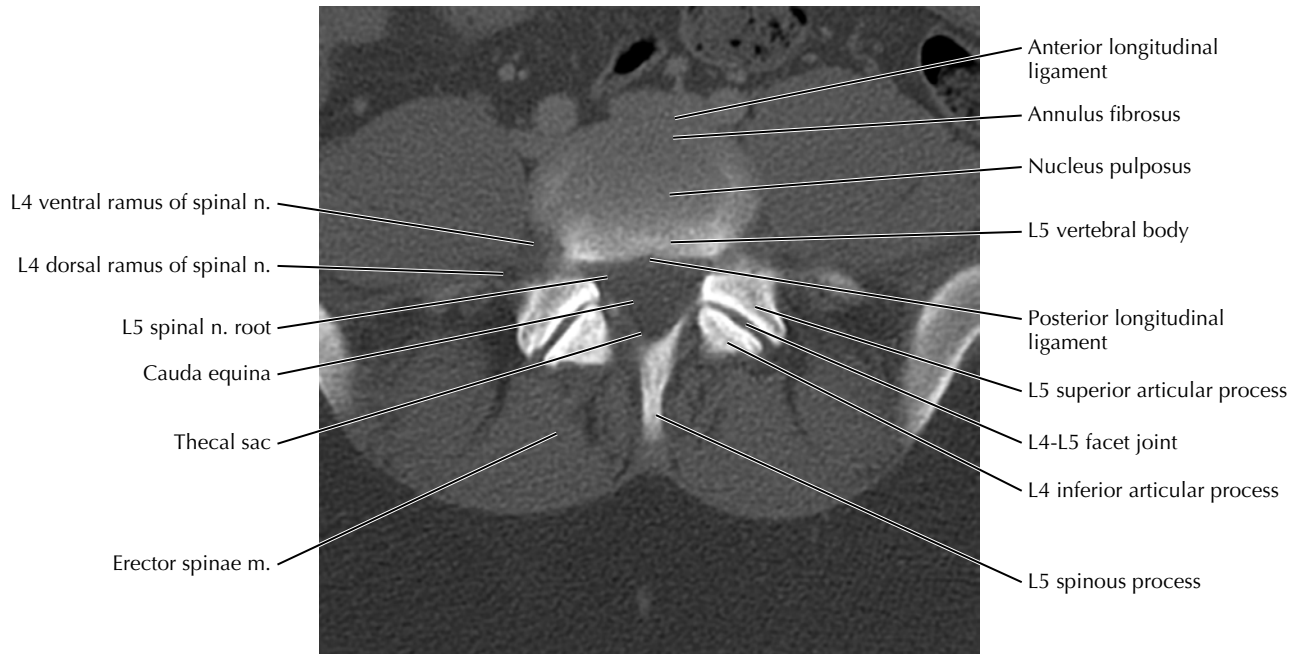
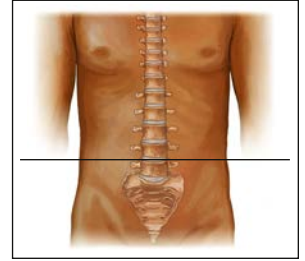
This epidural fat is an important target for steroid injection in patients with lumbar degenerative disease and for anesthetic medication injection in pregnant patients during labor and delivery.

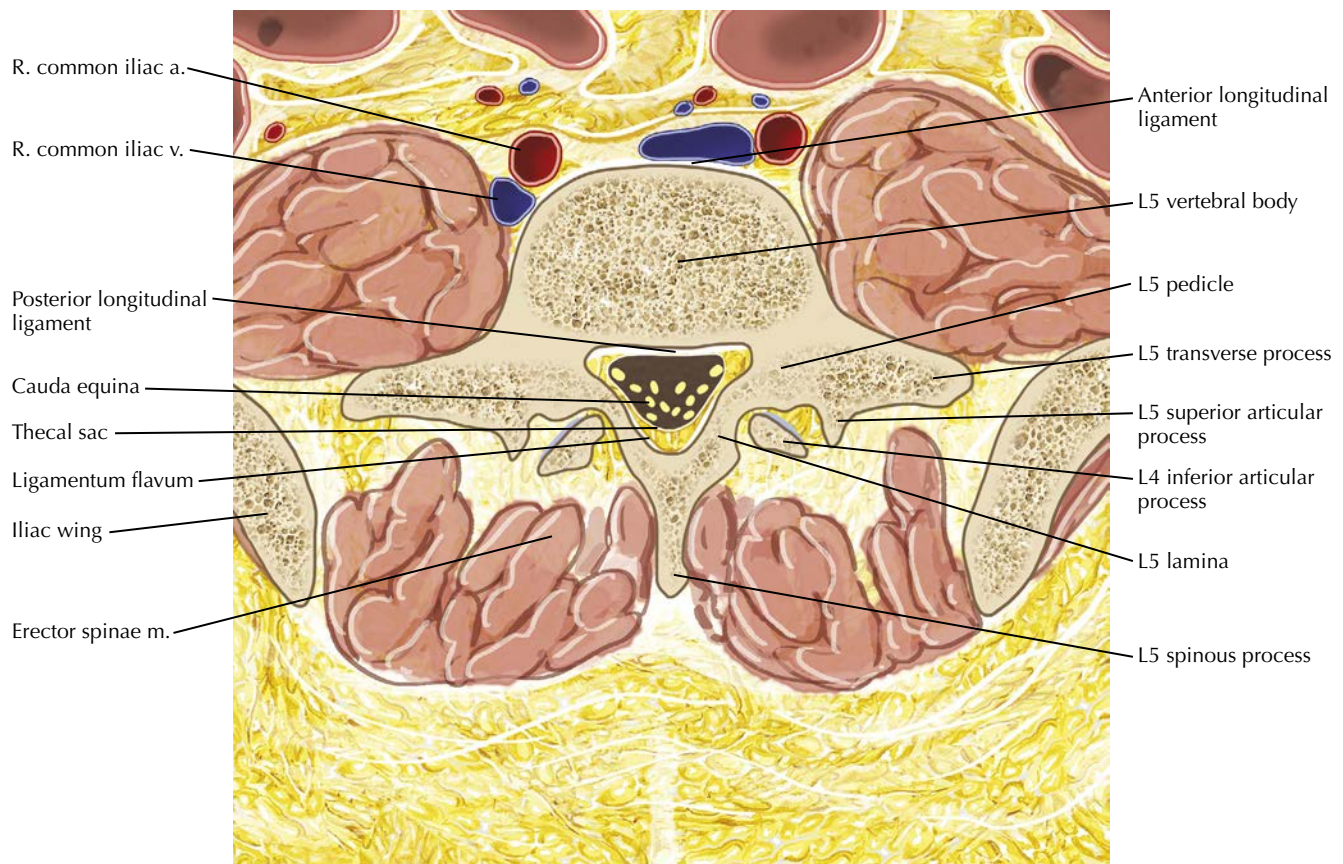


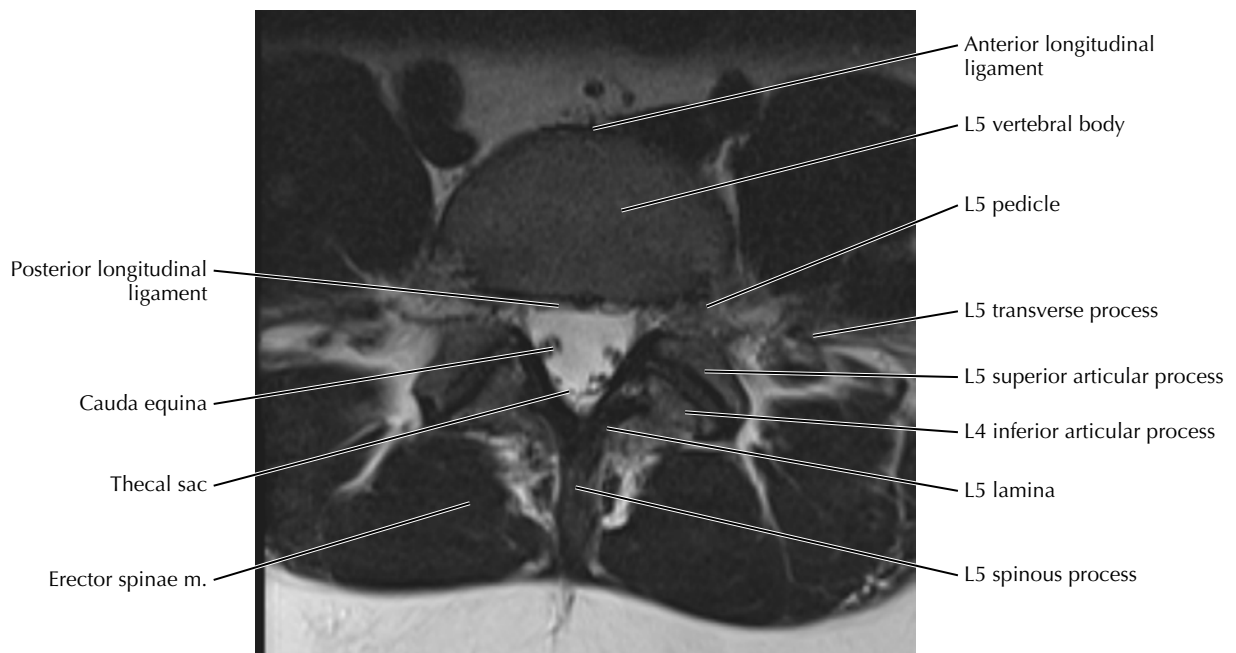
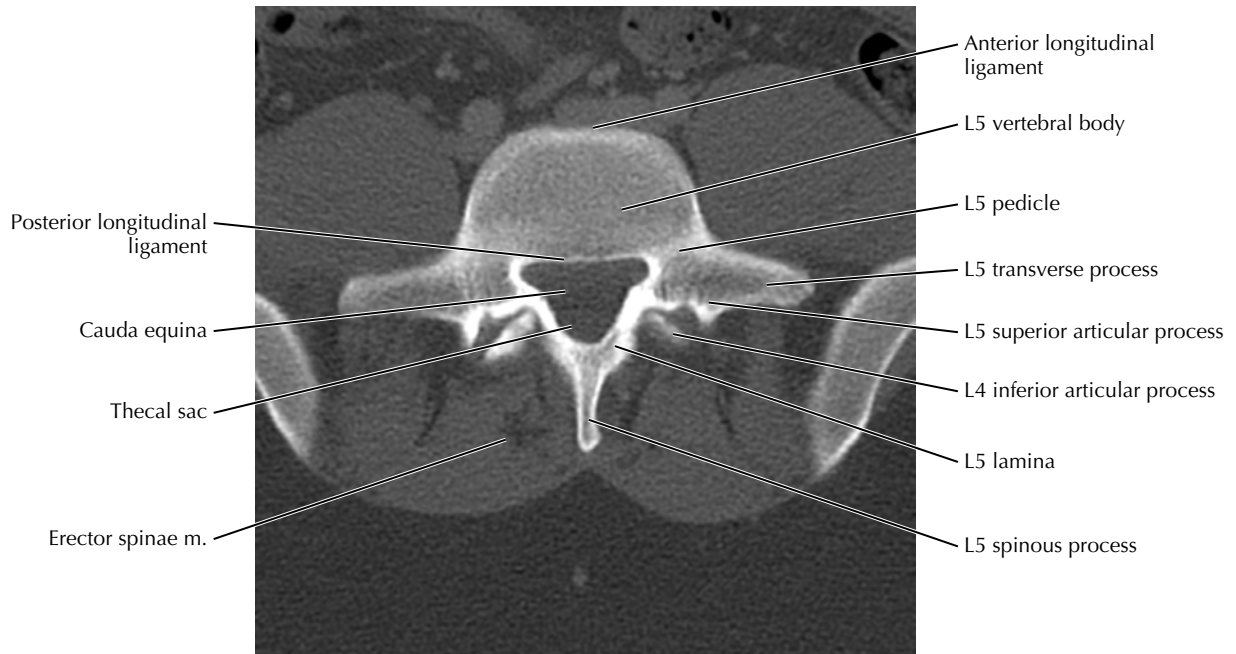
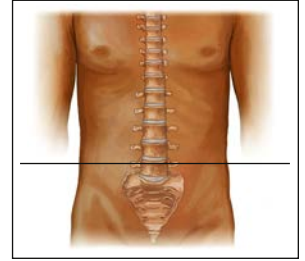


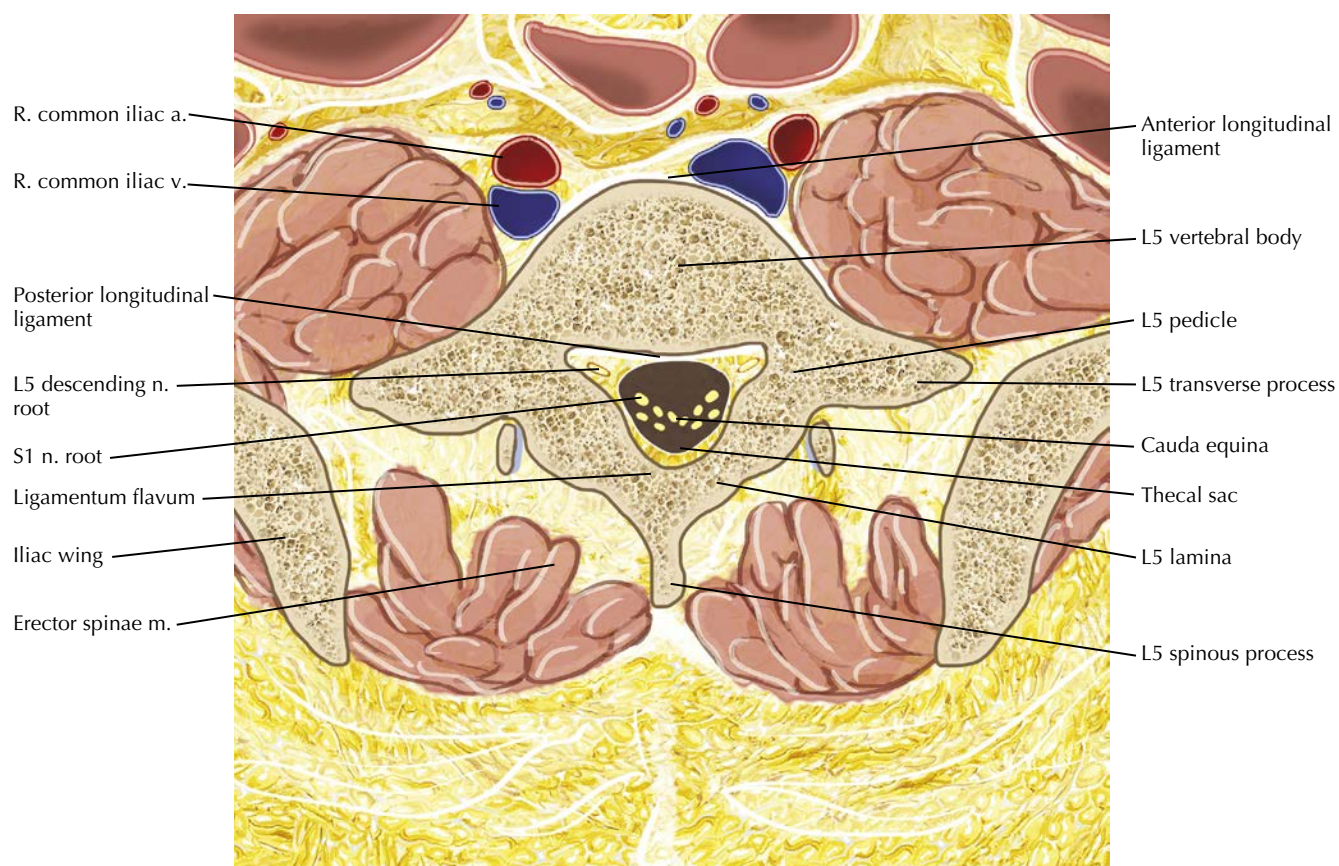
PATHOLOGIC PROCESS

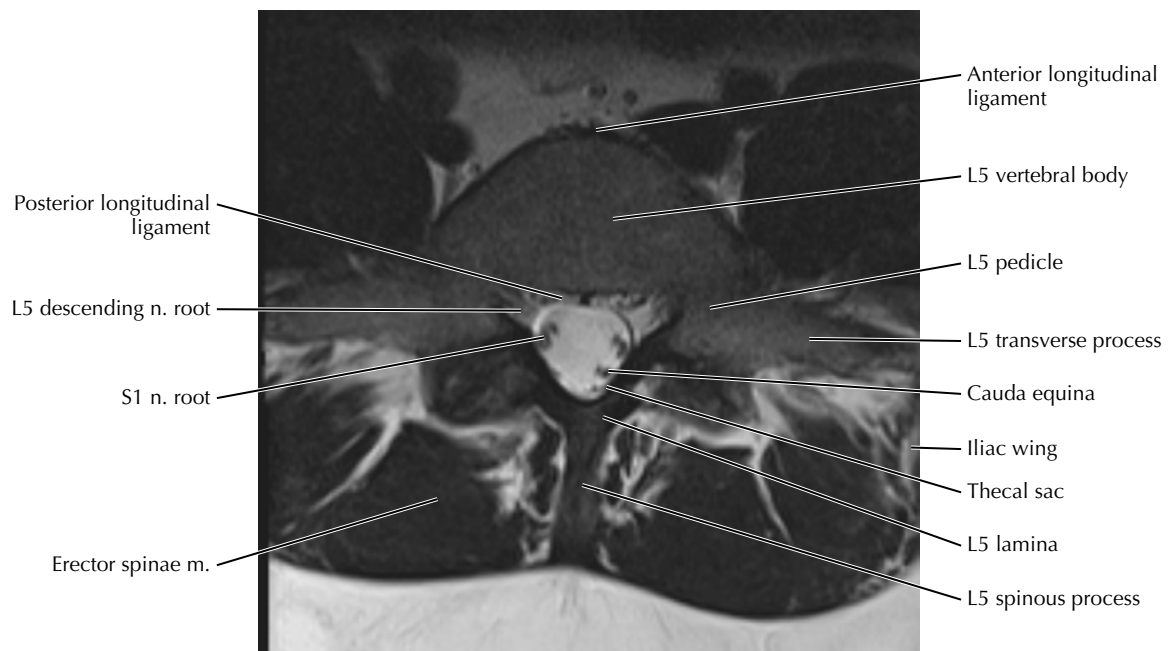
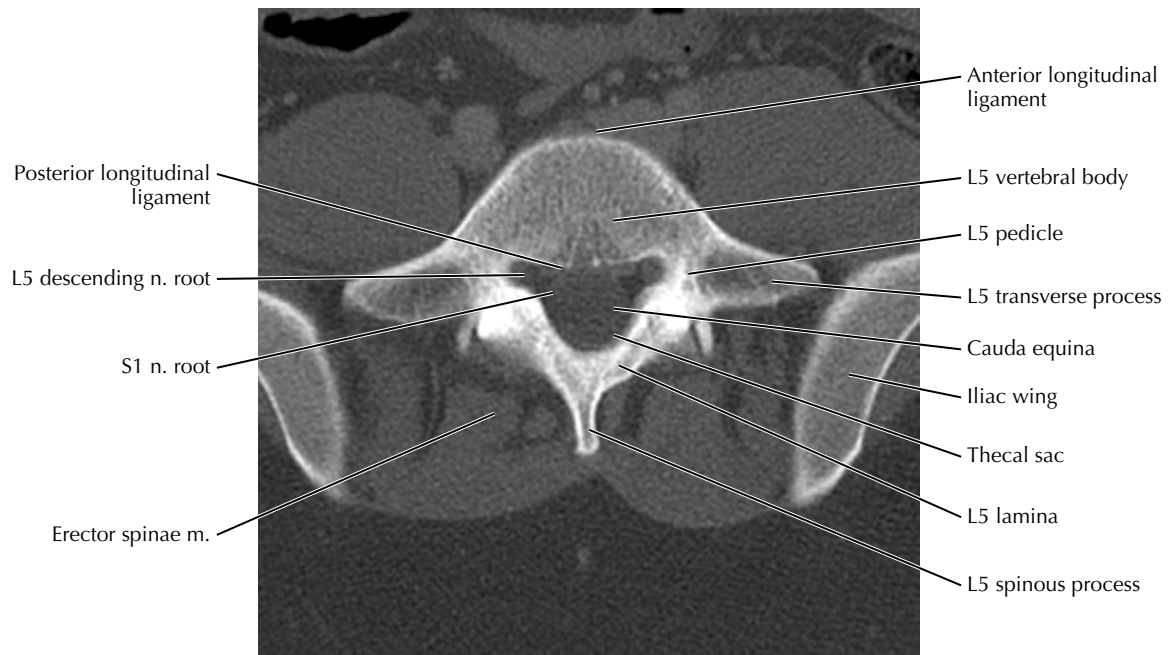
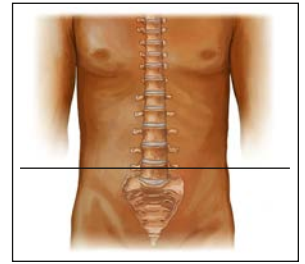
Below the pars of the second lumbar vertebra (L2), the conus gives rise to multiple nerves called the *cauda equina* (Latin, "horse's tail"). A relatively large disc herniation in the lumbar region may not result in significant neural symptoms because these cauda equina nerves may move out of the way, unlike the cord in the thoracic and cervical region. At the lateral aspect of the spinal canal, however, even a small disc protrusion may cause nerve impingement if there is ligamentum flavum hypertrophy that further narrows the lateral recess from posteriorly. With this lateral recess narrowing, the descending L5 nerve that has not yet exited the spinal canal would be impinged, by a lateral L4-5 disc herniation, not the L4 nerve root exiting the neural foramen.

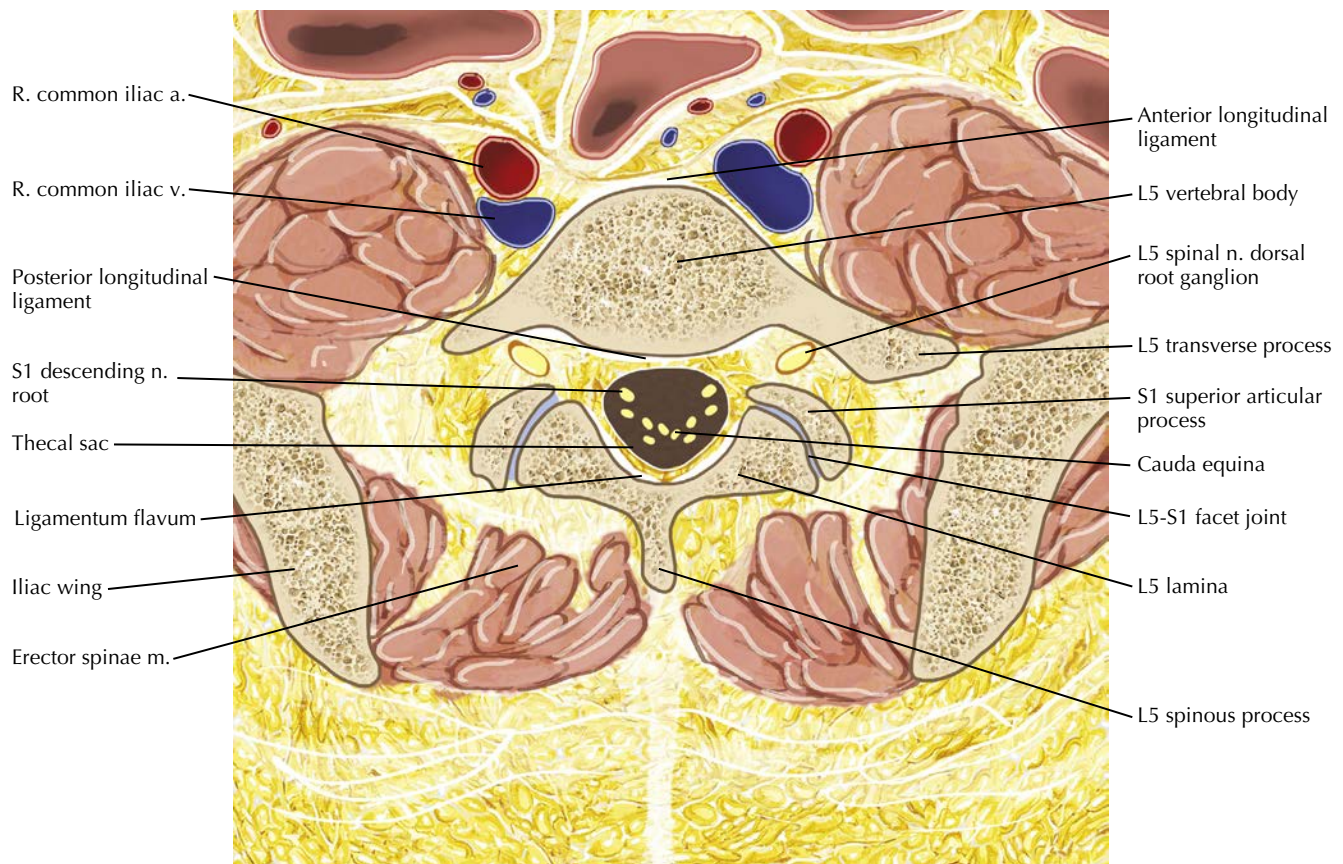


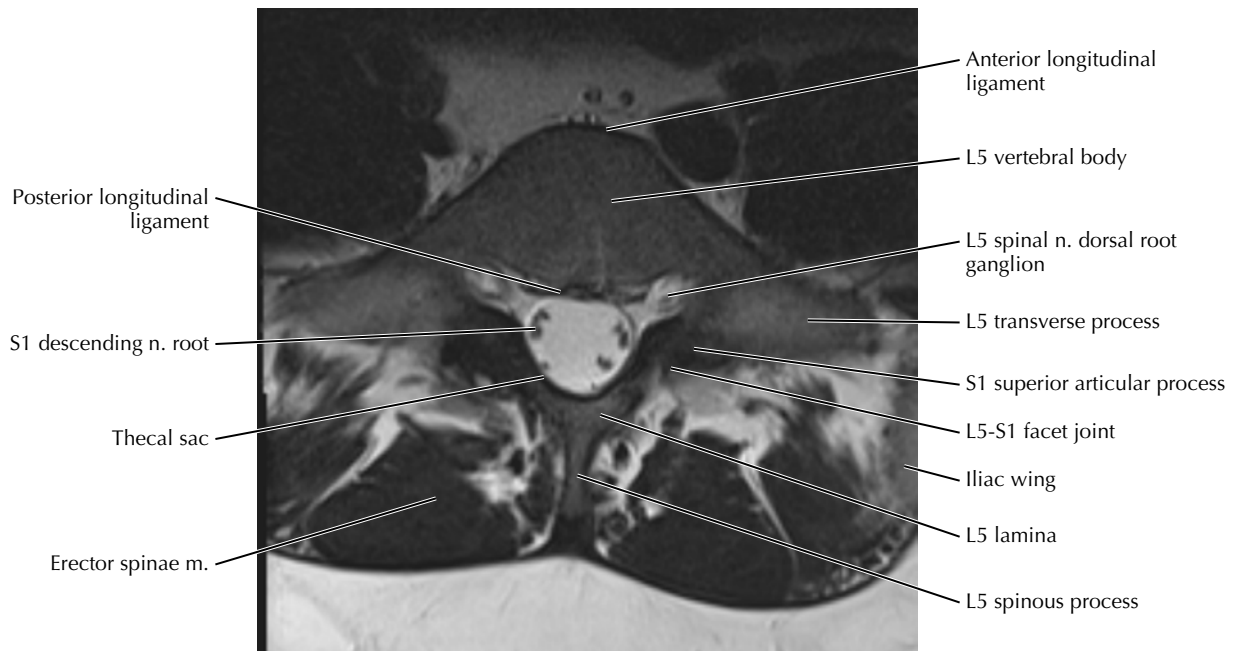
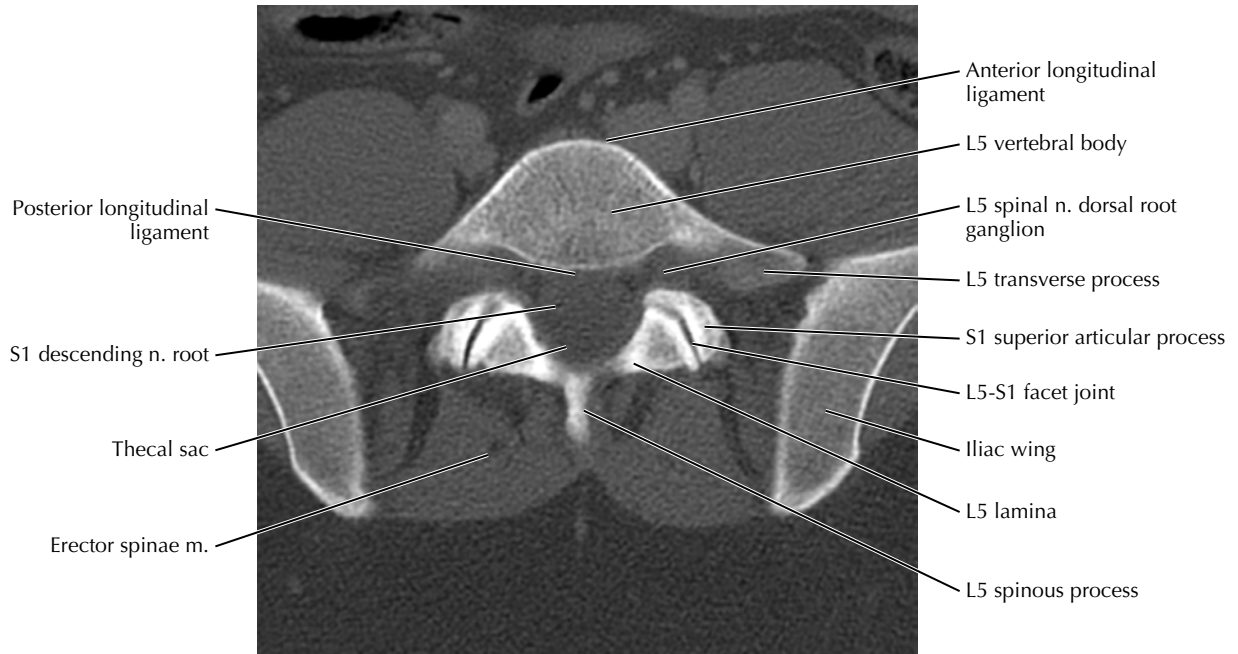
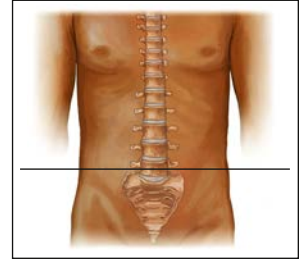




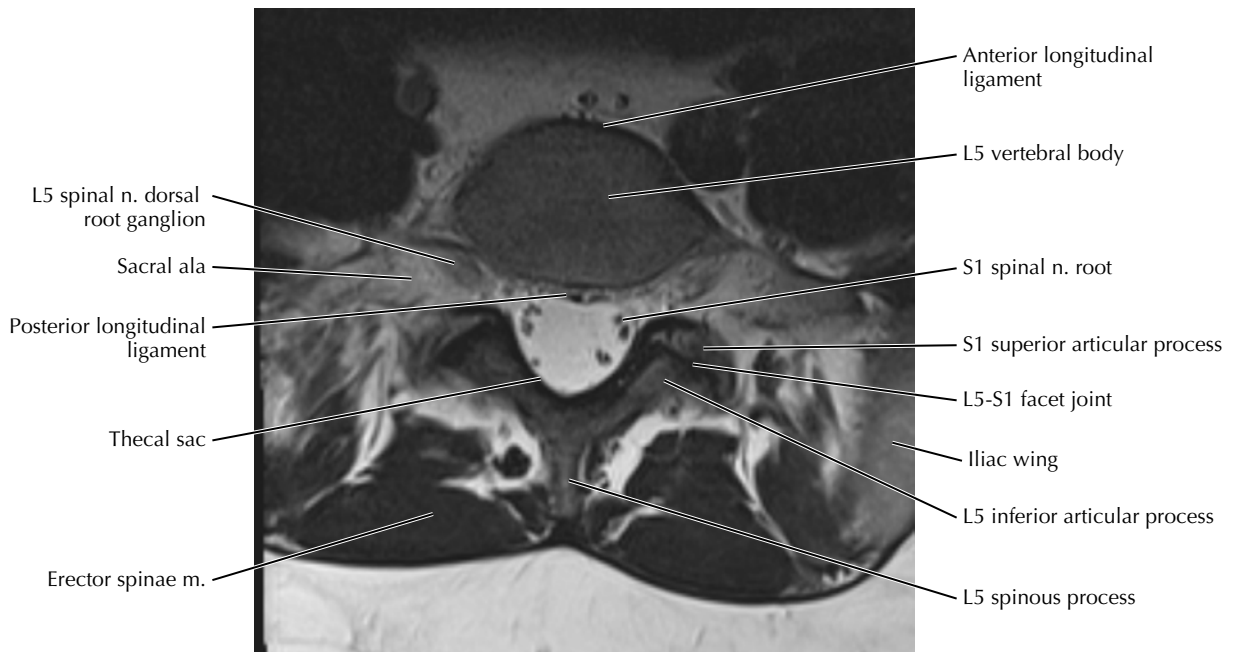
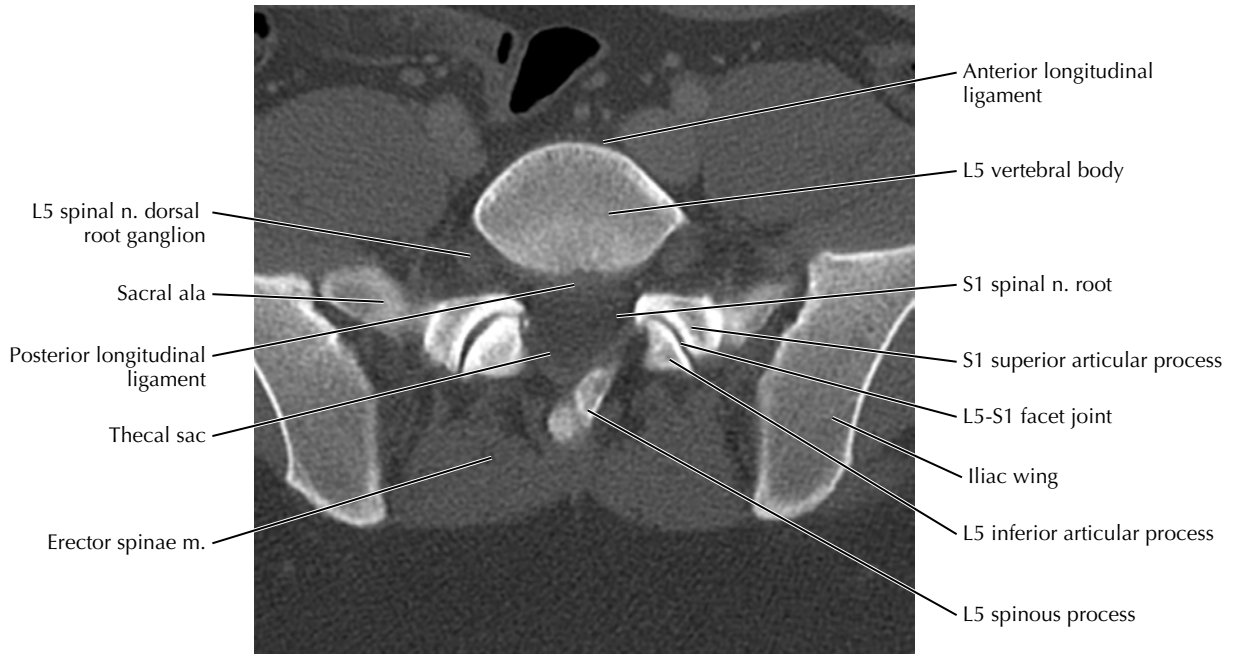
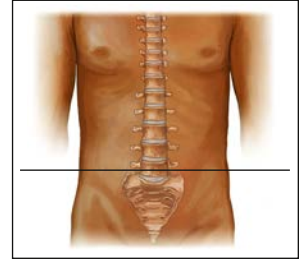


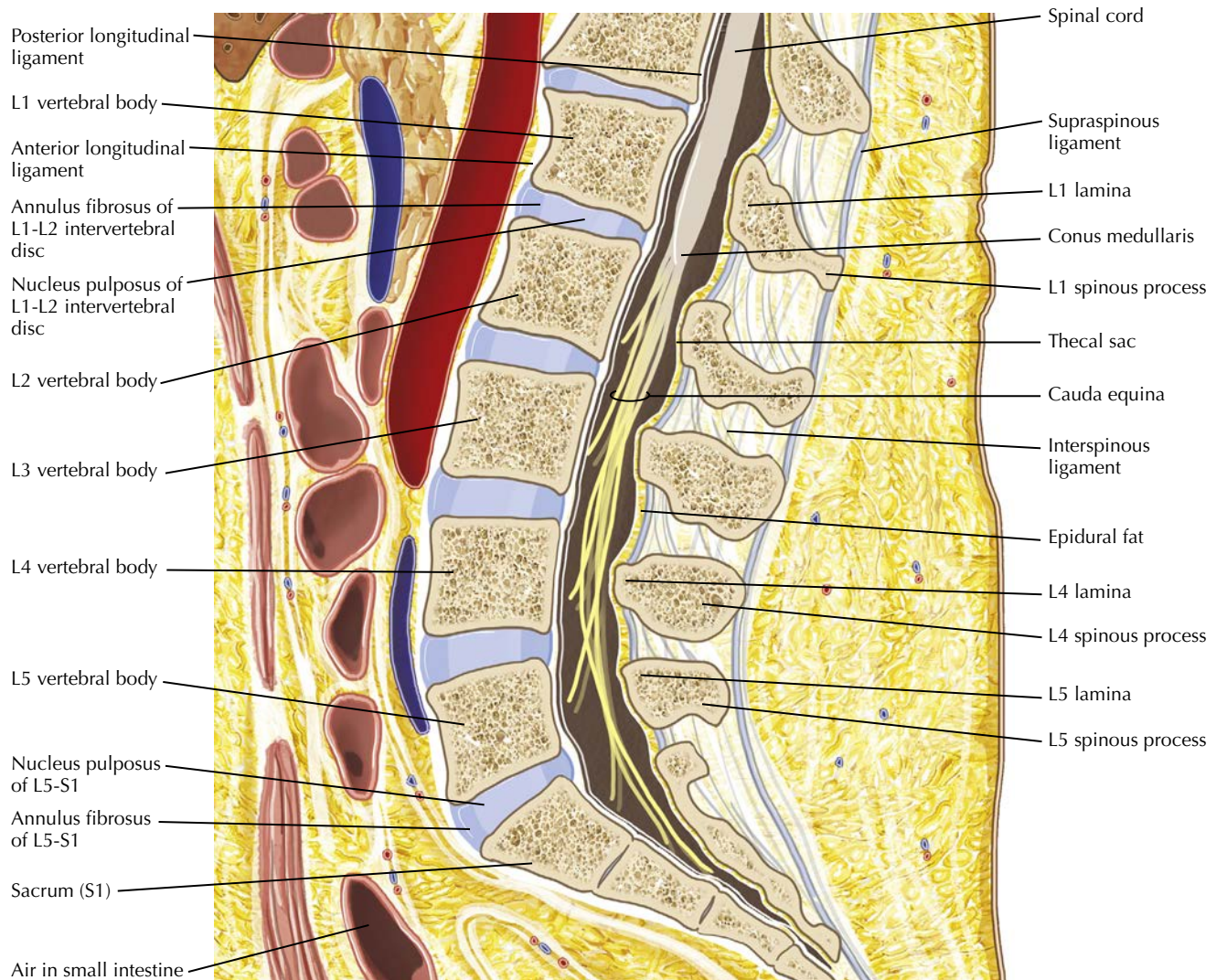












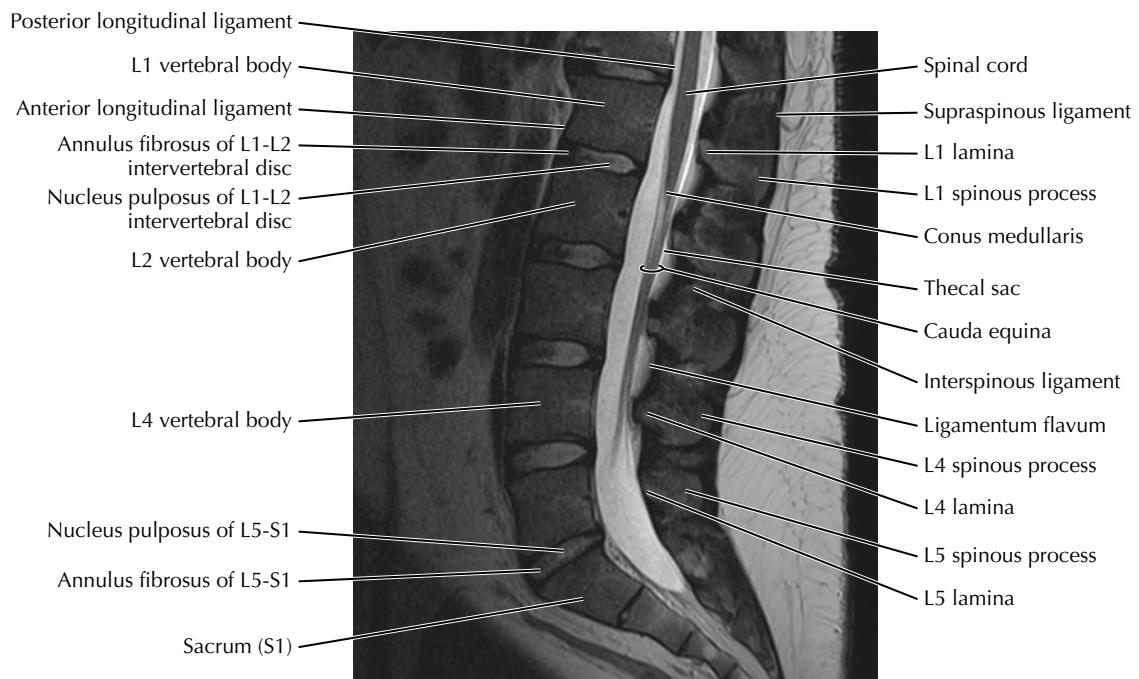
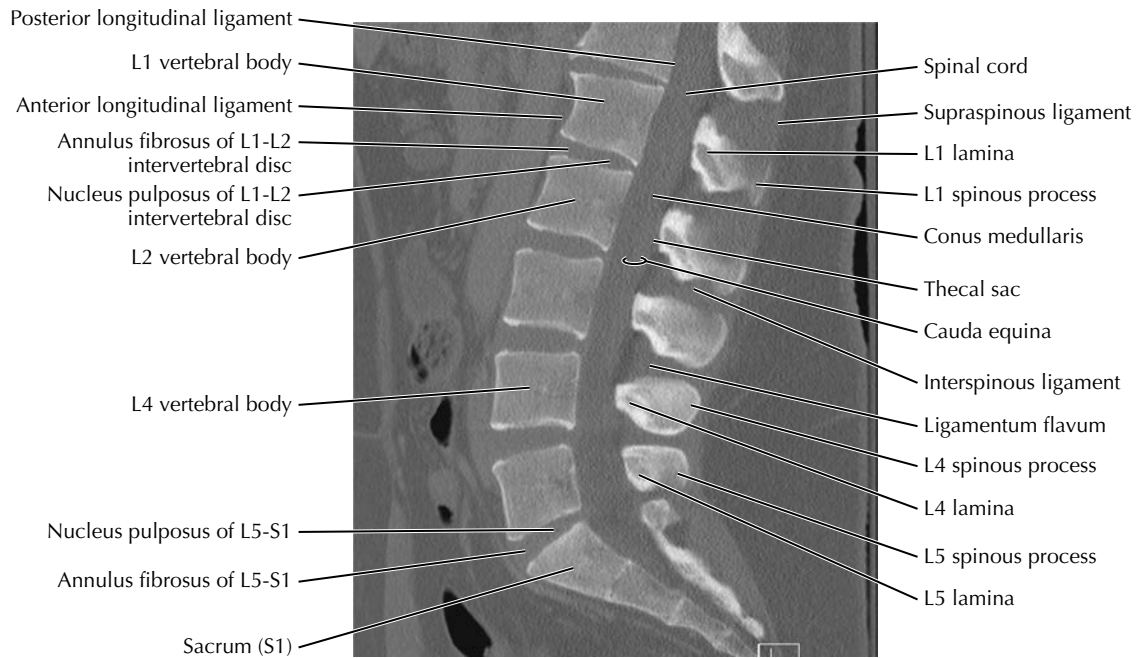
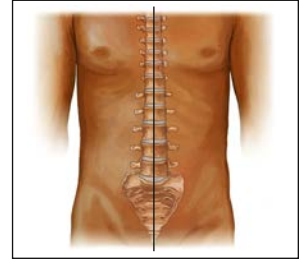
NORMAL ANATOMY

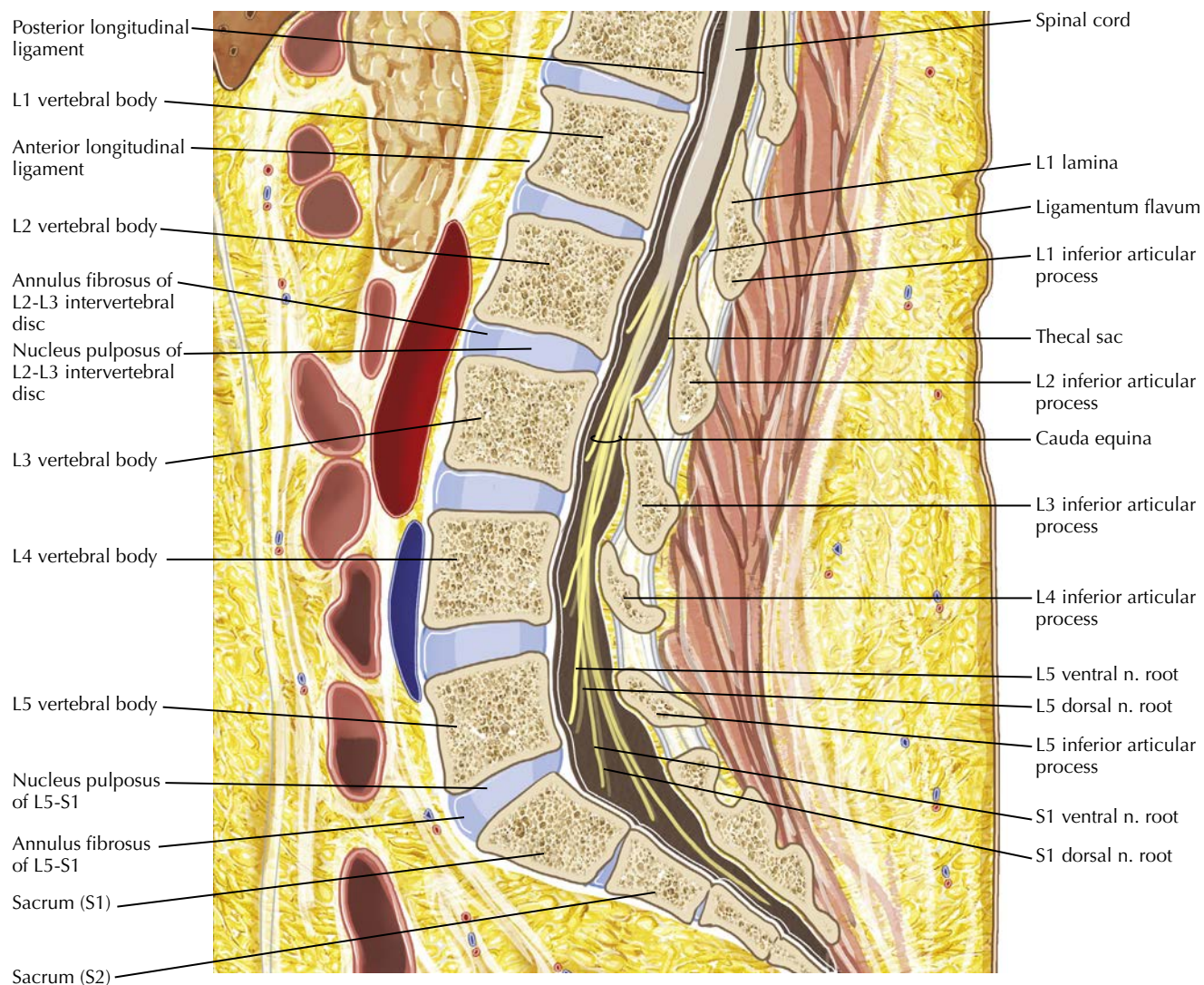
The conus of the spinal cord is typically at or above the pars of L2. A lower location can be seen with a tethered cord and spina bifida.

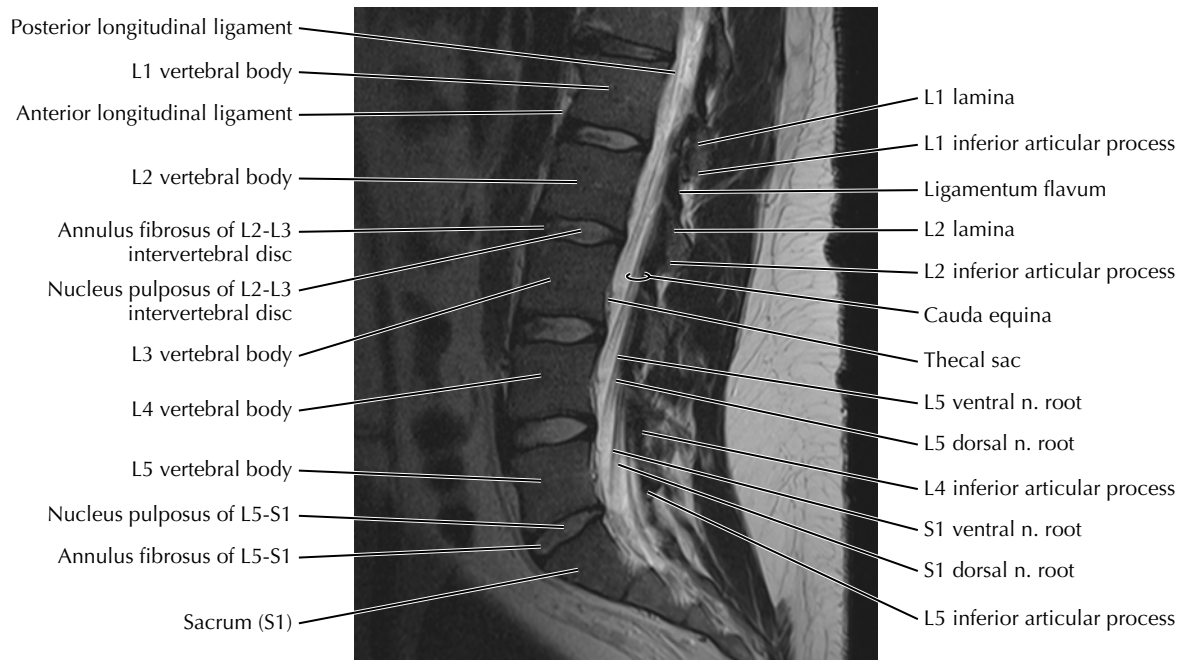
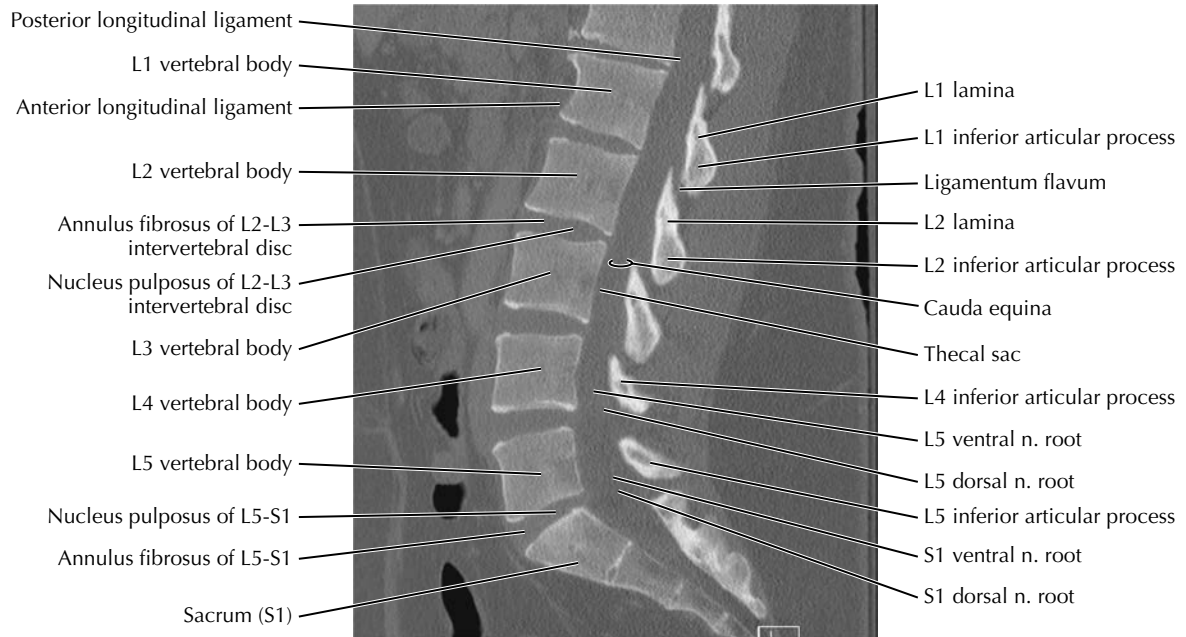
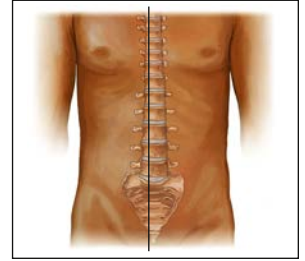
Note that normal, healthy vertebral discs are well hydrated, showing as bright T2 signal, although not as bright as the cerebrospinal fluid.

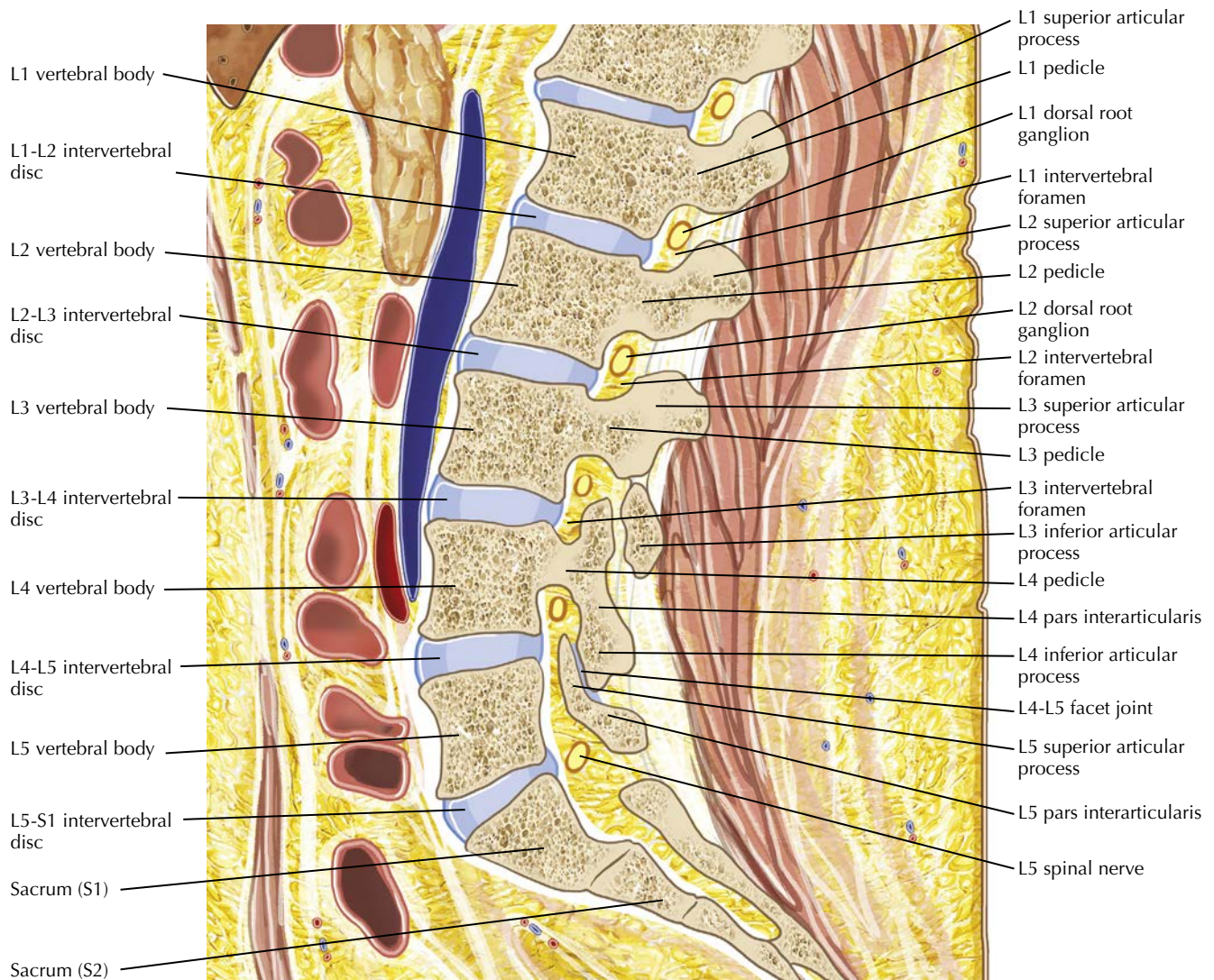
IMAGING TECHNIQUE CONSIDERATION

Recall that on "turbo" or fast spin-echo T2-weighted imaging, unlike nonturbo T2-weighted imaging, the fat is also bright.



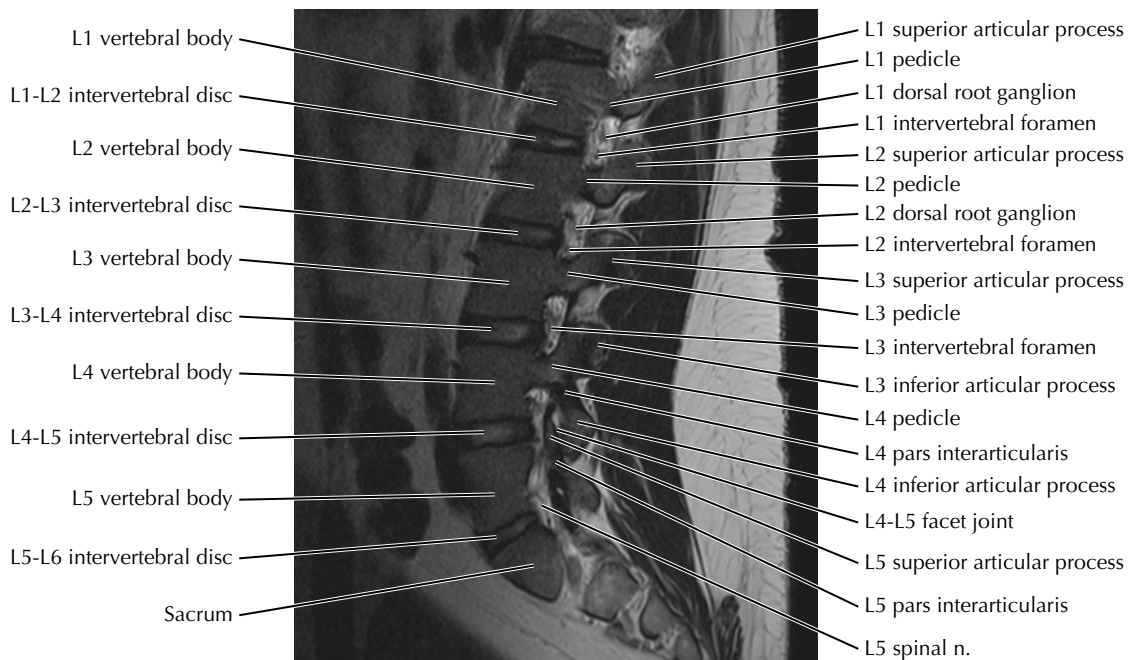
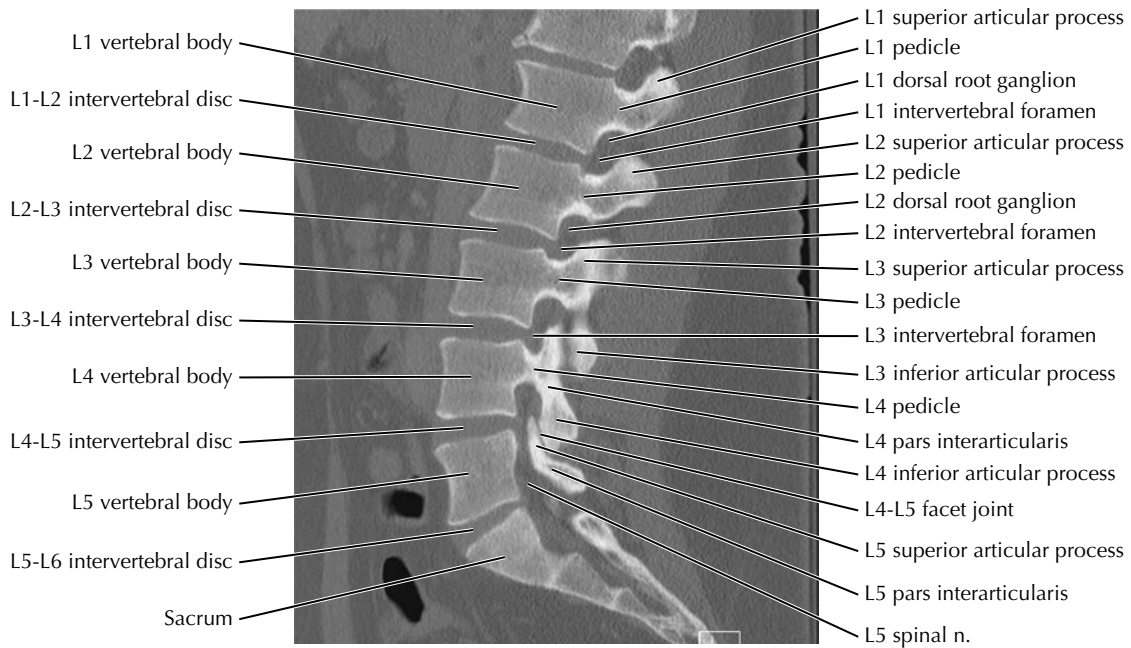
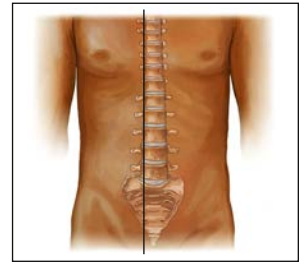


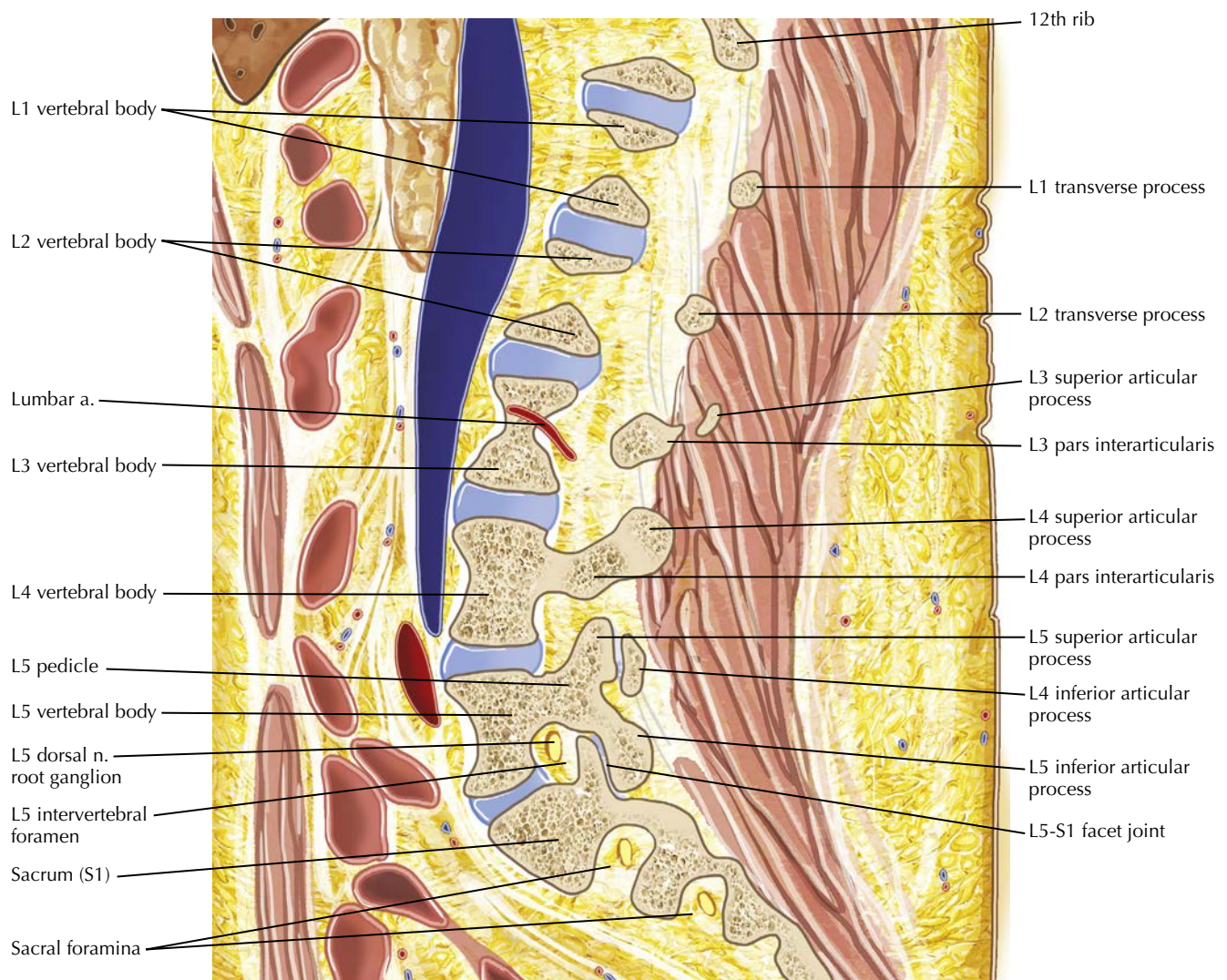


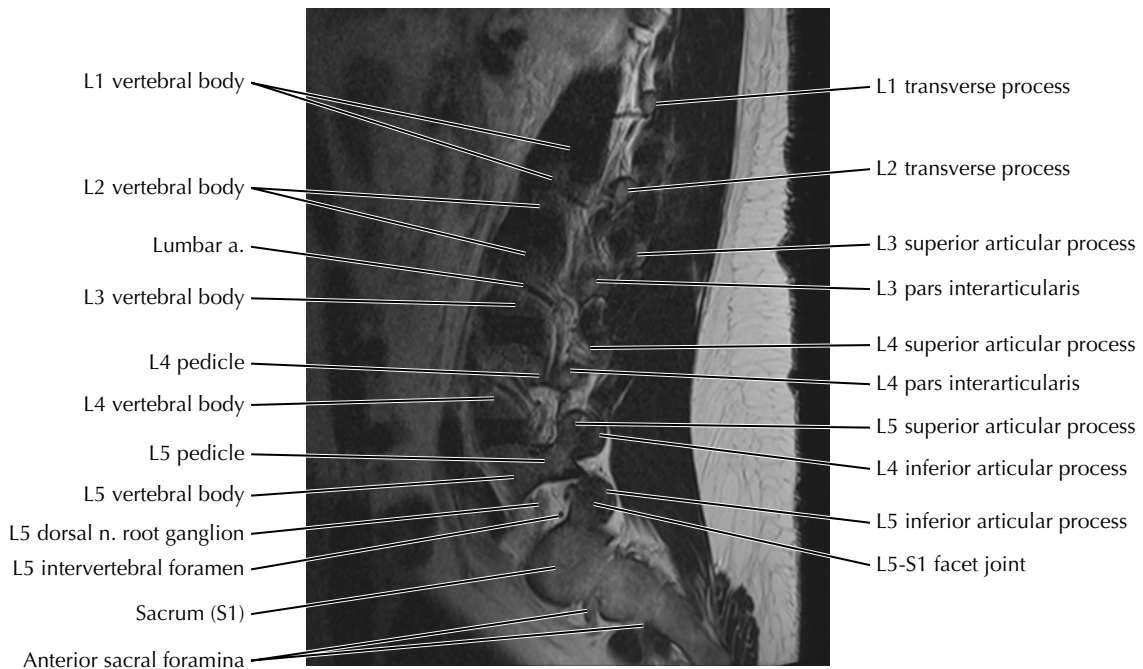
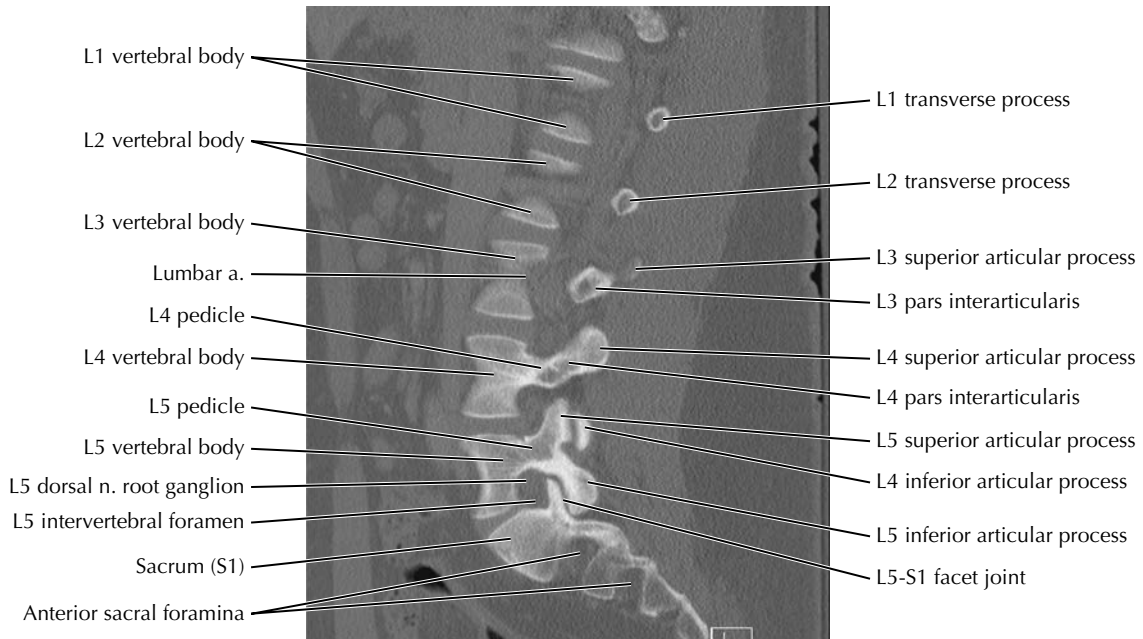


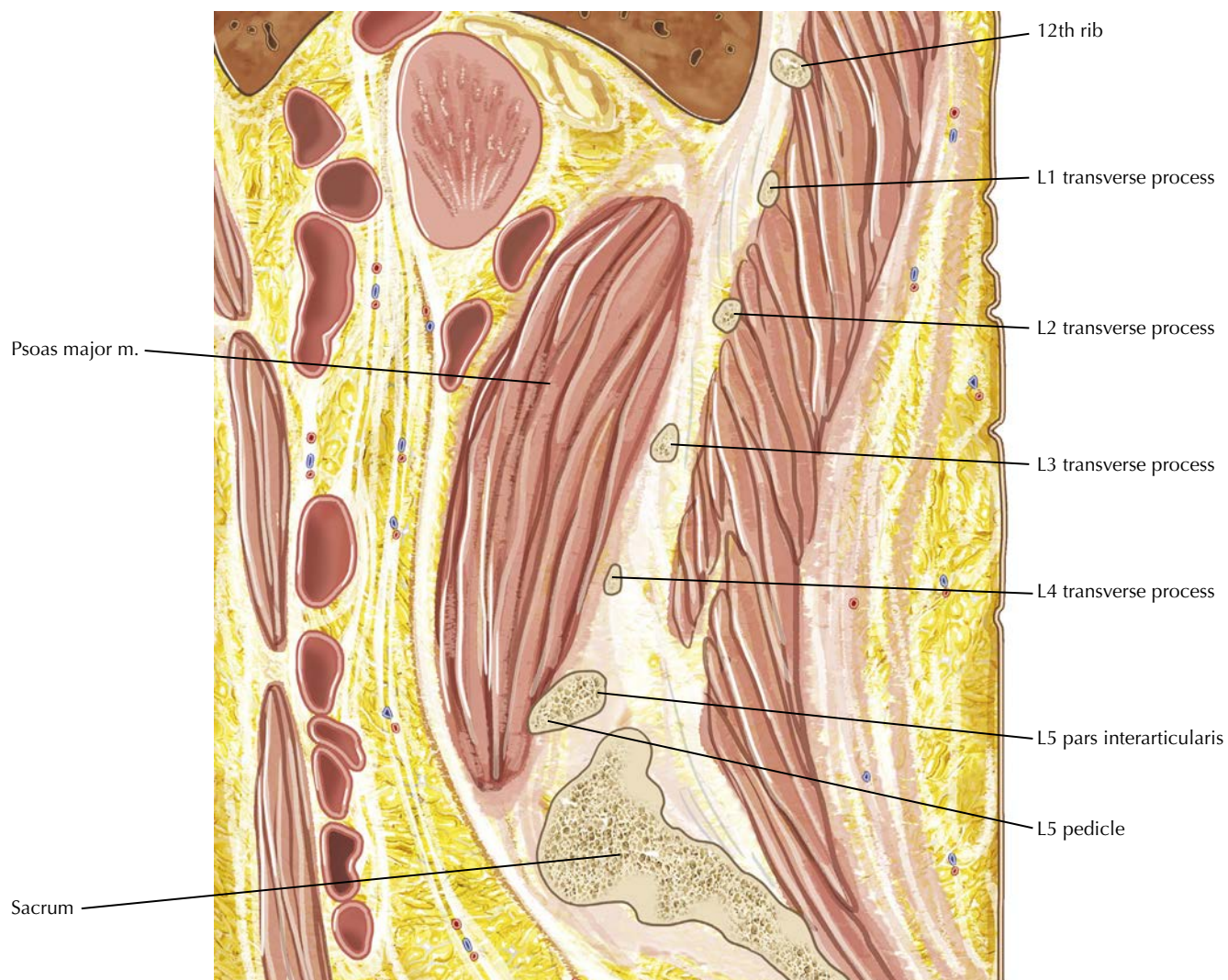
NORMAL ANATOMY

Note how much better the neural foramina are seen in the lumbar region than in the thoracic or cervical region because of the larger size and absence of confounding vertebral artery foramina. The lumbar foramina are typically keyhole shaped on parasagittal imaging, with the exiting nerve root in the larger upper aspect of the foramen.



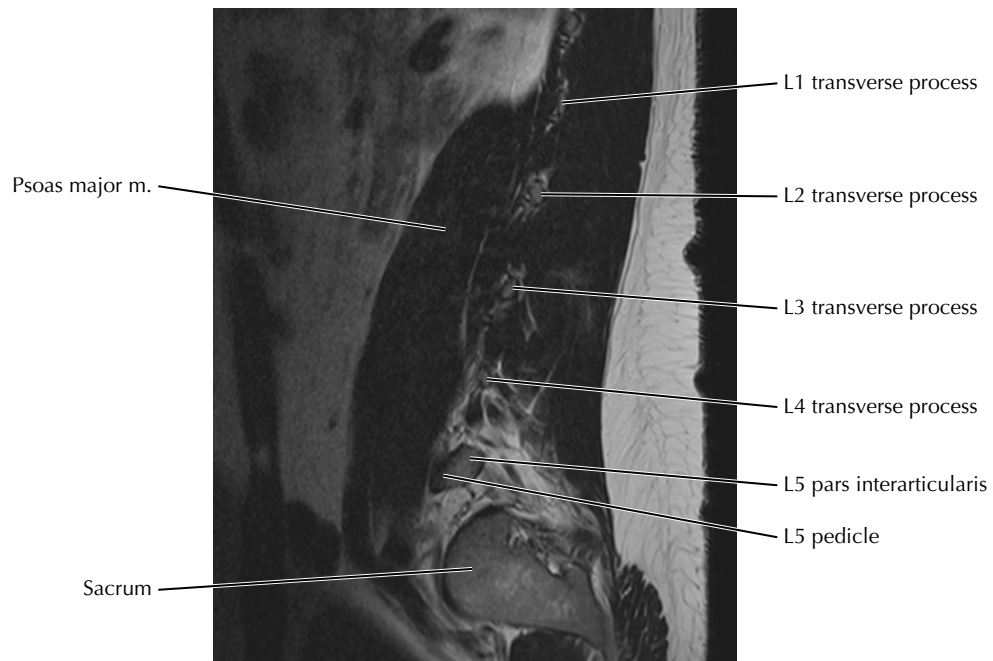
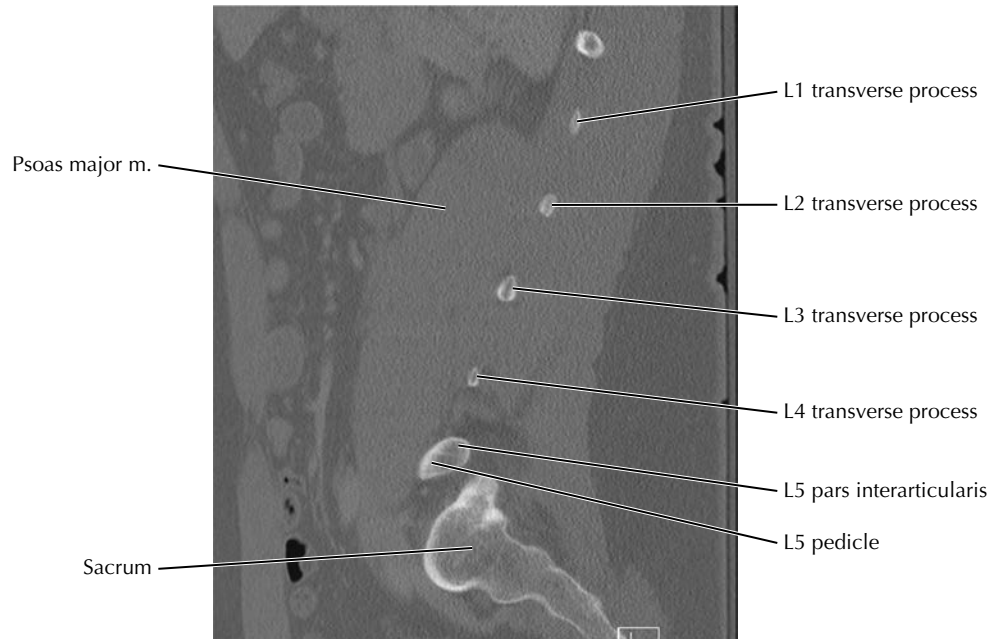






NORMAL ANATOMY

Lumbosacral Spine Sagittal 5 shows the standard five lumbar transverse processes, although variants can include a missing or accessory rib or a lumbarized S1 vertebral segment. Care must always be taken to declare the numbering of levels used when describing pathology in the spine. The best method is counting down from C1 (atlas), but in the absence of whole-spine imaging, a clearly identifiable landmark should be used.



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