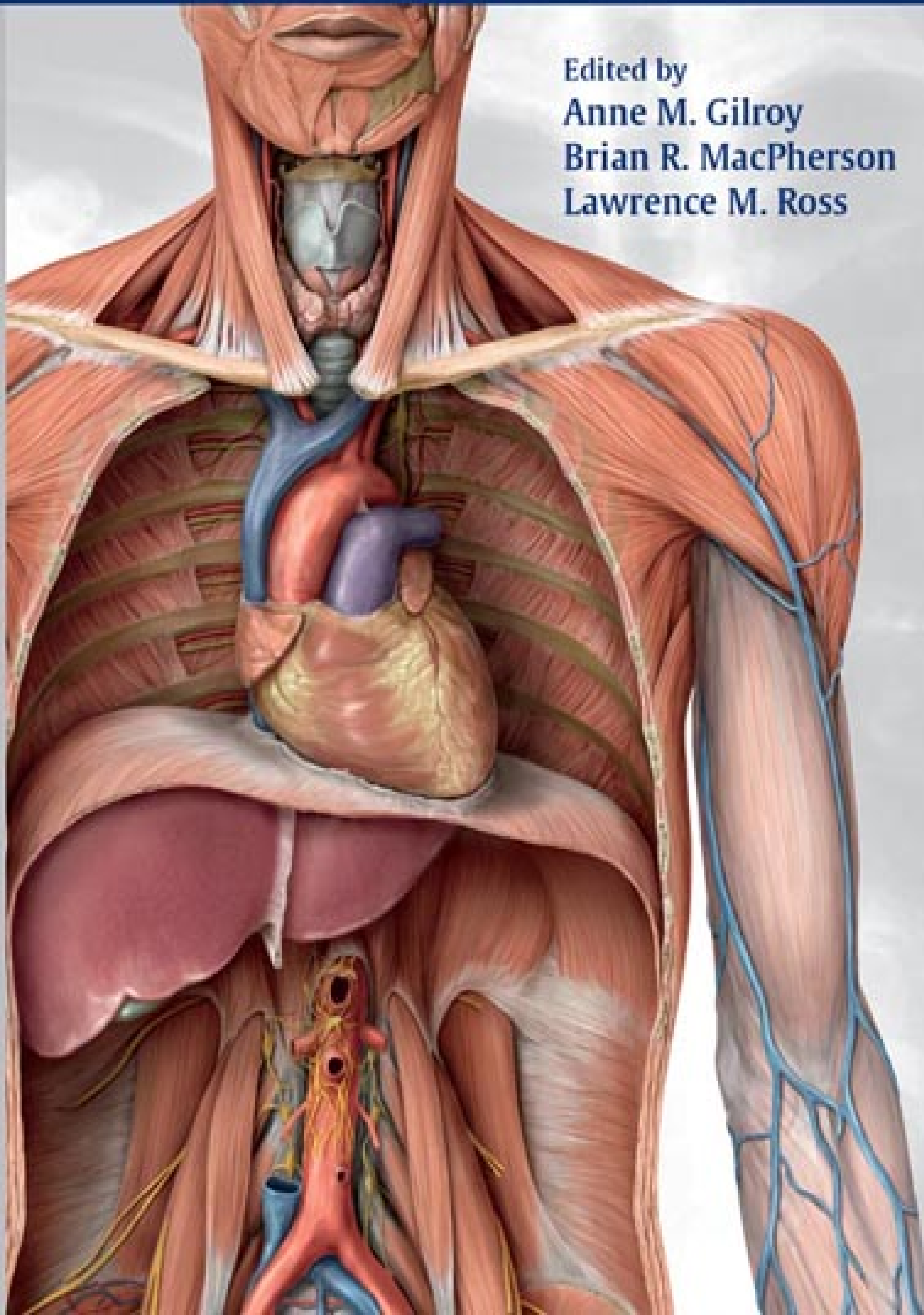
Atlas of Anatomy



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Brian R. MacPherson
Lawrence M. Ross

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Erik Schulte
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Illustrations by
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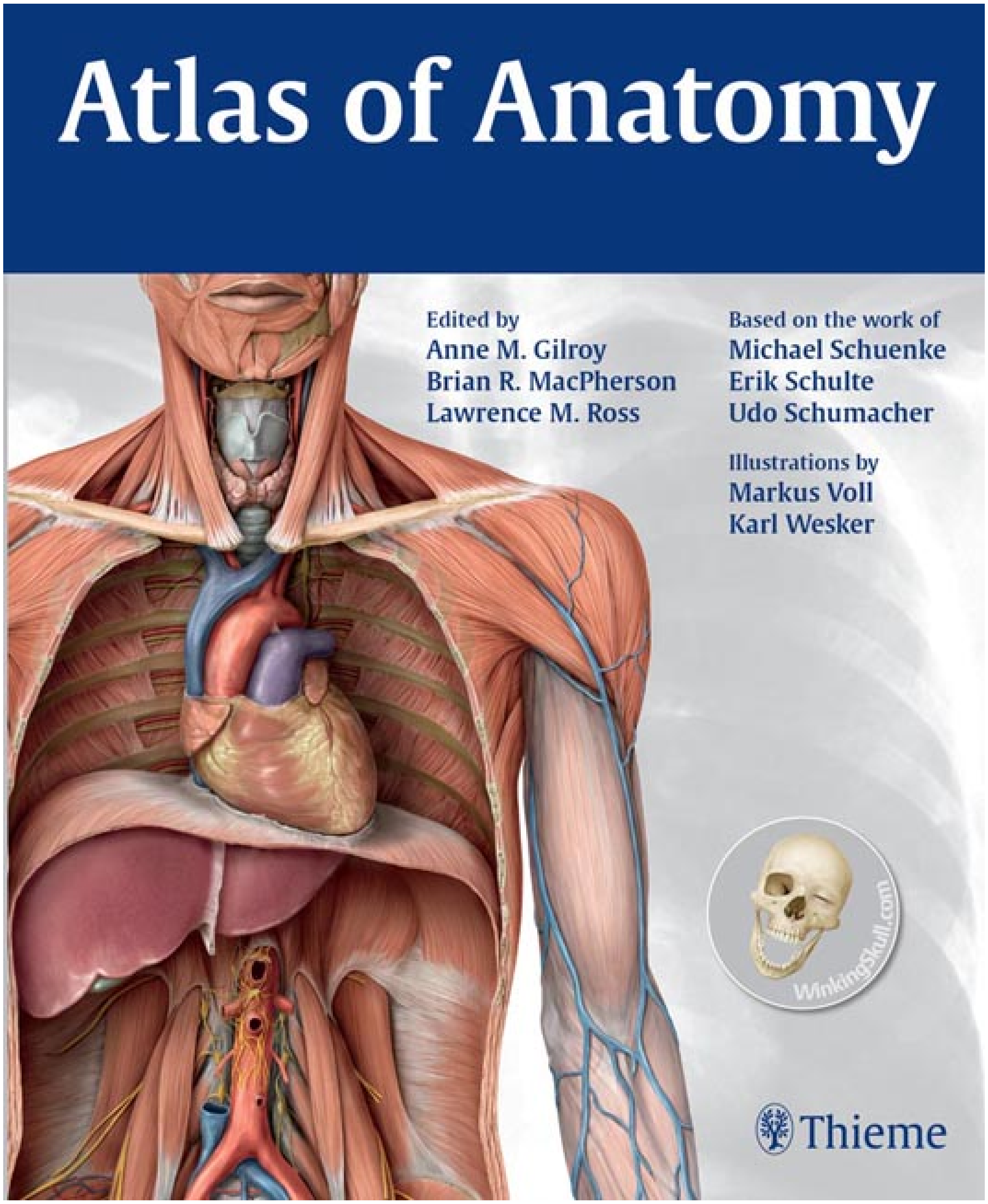
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Based on the work of Michael Schuenke, MD, PhD,
Erik Schulte, MD, and Udo Schumacher, MD

Anne M. Gilroy, MA
Dept. of Cell Biology and Dept. of Surgery
University of Massachusetts Medical School
55 Lake Avenue North
Worcester, MA 01655-0333

Brian R. MacPherson, PhD
Department of Anatomy and Neurobiology
MN225 Chandler Medical Center
University of Kentucky College of Medicine
Lexington, KY 40536-0298

Lawrence M. Ross, MD, PhD
Department of Neurobiology and Anatomy
University of Texas Medical School at Houston
6431 Fannin, Suite 7.046
Houston, TX 77030

Michael Schuenke, MD, PhD
Institute of Anatomy
Christian Albrecht University Kiel
Olshausenstrasse 40
D-24098 Kiel

Erik Schulte, MD
Department of Anatomy and Cell Biology
Johannes Gutenberg University
Saarstrasse 19-21
D-55099 Mainz

Udo Schumacher, MD, FRCPath, CBiol, FIBiol, DSc
Institute of Anatomy II: Experimental Morphology
Center for Experimental Medicine
University Medical Center Hamburg-Eppendorf

Martinistrasse 52
D-20246 Hamburg

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Markus Voll
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Dedication

To my father, Francis Gilroy, whose dedication to medicine has been a greater inspiration to me than he has ever realized; to my students who lovingly tolerate, and sometimes share, my passion for human anatomy; and most of all to my sons, Colin & Bryan, whose love and support I treasure beyond all else.

To my friend and mentor, Dr. Ken McFadden of the Division of Anatomy at the University of Alberta, who ensured I received the training in gross anatomy instruction required to be successful, and to the thousands of professional students who I have taught over the past 30 years honing these skills. However, none of the success I've enjoyed during my time in academia would have been possible without the constant support, participation and encouragement of my wife, Cynthia Long.

To my wife, Irene; to the children, Chip, Jennifer, Jocelyn & Barry, Tricia, Scott, Katie & Snapper, and Trey; and to my students who have taught me so well.

Acknowledgments

We would like to thank the authors of the original award-winning Anatomy Series Michael Schuenke, Erik Schulte, and Udo Schumacher for their work over the course of many years.

We cordially thank the members of the Advisory Board for their contributions.

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Foreword

This Atlas of Anatomy is, in my opinion, the fi nest single volume atlas of human anatomy that has ever been created. Two factors make it so: the images and the way they have been organized.

The artists, Markus Voll and Karl Wesker, have created a new standard of excellence in anatomical art. Their graceful use of transparency and their sensitive representation of light and shadow give the reader an accurate three-dimensional understanding of every structure.

The authors have organized the images so that they give just the flow of information a student needs to build up a clear mental image of the human body. Each two-page spread is a self-contained lesson that unobtrusively shows the hand of an experienced and thoughtful teacher. I wish I could have held this book in my hands when I was a student; I envy any student who does so now.

Robert B. Acland

Louisville,
KY

March 2008

Preface

Each of us was amazed and impressed with the extraordinary detail, accuracy, and beauty of the material that was created for the Thieme Atlas of Anatomy by authors Michael Schuenke, Erik Schulte, and Udo Schumacher and artists Markus Voll and Karl Wesker. We felt these atlases and their pedagogical concepts were one of the most significant additions to anatomical education in the past 50 years. It was our intent to use this exceptional material as the cornerstone of our effort to create a concise single volume Atlas of Anatomy for the curious and eager health science student.

Our challenge was first to select from this extensive collection those images that are most instructive and illustrative of current dissection approaches. Along the way, however, we realized that creating a single volume atlas was much more than choosing images: each image had to convey a significant amount of detail while the appeal and labeling needed to be clean and soothing to the eye. Therefore, hundreds of illustrations were drawn new or modified to fit the approach of this new atlas. In addition, key schematic diagrams and simplified summary-form tables were added wherever needed. Dozens of applicable radiographic images and important clinical correlates have been added where appropriate. Additionally, surface anatomy illustrations are accompanied by questions designed to direct the student's attention to anatomic detail that is most relevant in conducting the physical exam. Elements from each of these features are arranged in a regional format to facilitate common dissection approaches. Within each region the various components are examined systemically, followed by topographical images to tie the systems within the region together. In all of this, a clinical perspective on the anatomical structures is taken. The unique two facing pages “spread” format focuses the user to the area/topic being explored.

We hope these efforts, the results of close to 100 combined years of experience teaching the discipline of anatomy to bright, enthusiastic students, has resulted in a comprehensive, easy-to-use resource and reference.

We would like to thank our colleagues at Thieme Publishers who so professionally facilitated this effort. We cannot thank enough, Cathrin E. Schulz, MD, Editorial Director Educational Products, who so graciously reminded us of deadlines, while always being available to troubleshoot problems. More importantly, she encouraged, helped, and complimented our efforts.

We also wish to extend very special thanks and appreciation to Bridget Queenan, Developmental Editor, who edited and developed the manuscript with an outstanding talent for visualization and intuitive flow of information. We are very grateful to her for catching many details along the way while always patiently responding to requests for artwork and labeling changes.

Cordial thanks to Elsie Starbecker, Senior Production Editor, who with great care and speed produced this atlas with its over 2,200 illustrations. Finally thanks to Rebecca McTavish, Developmental Editor, for joining the team in the correction phase. Their hard work has made the Atlas of Anatomy a reality.

Anne M. Gilroy
Brian R. MacPherson
Lawrence M. Ross

March 2008,
Worcester, MA, Lexington, KY, and Houston, TX

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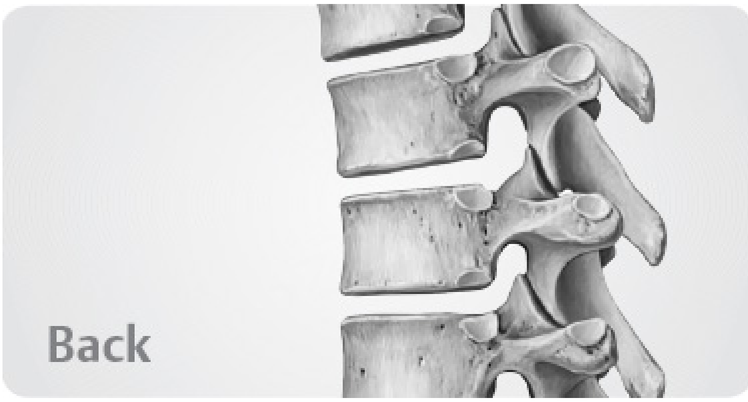

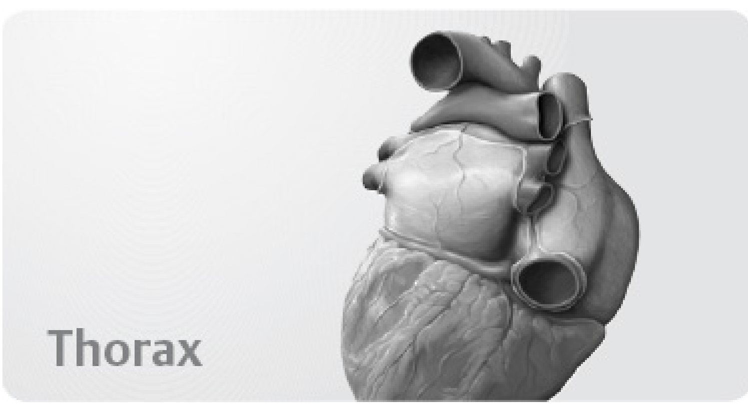
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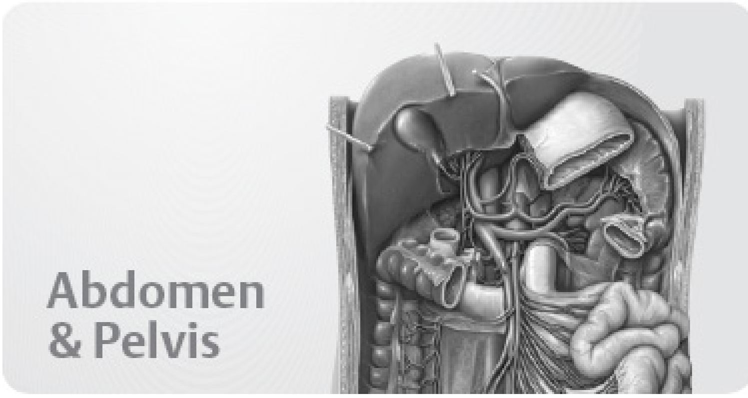
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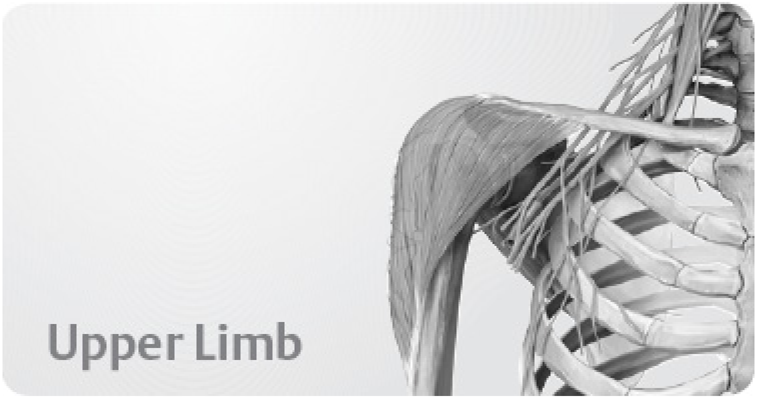

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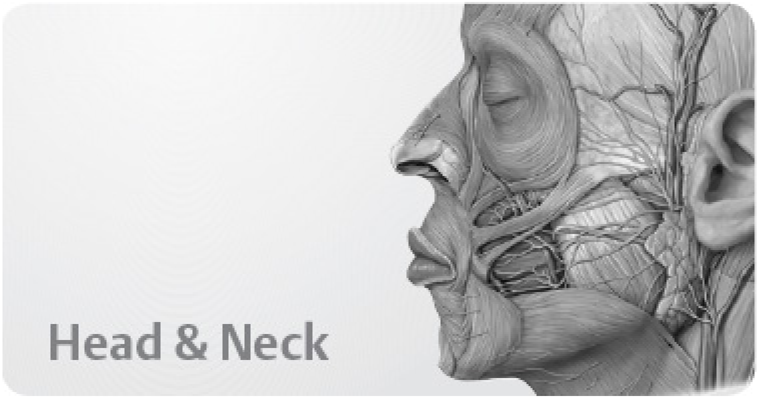
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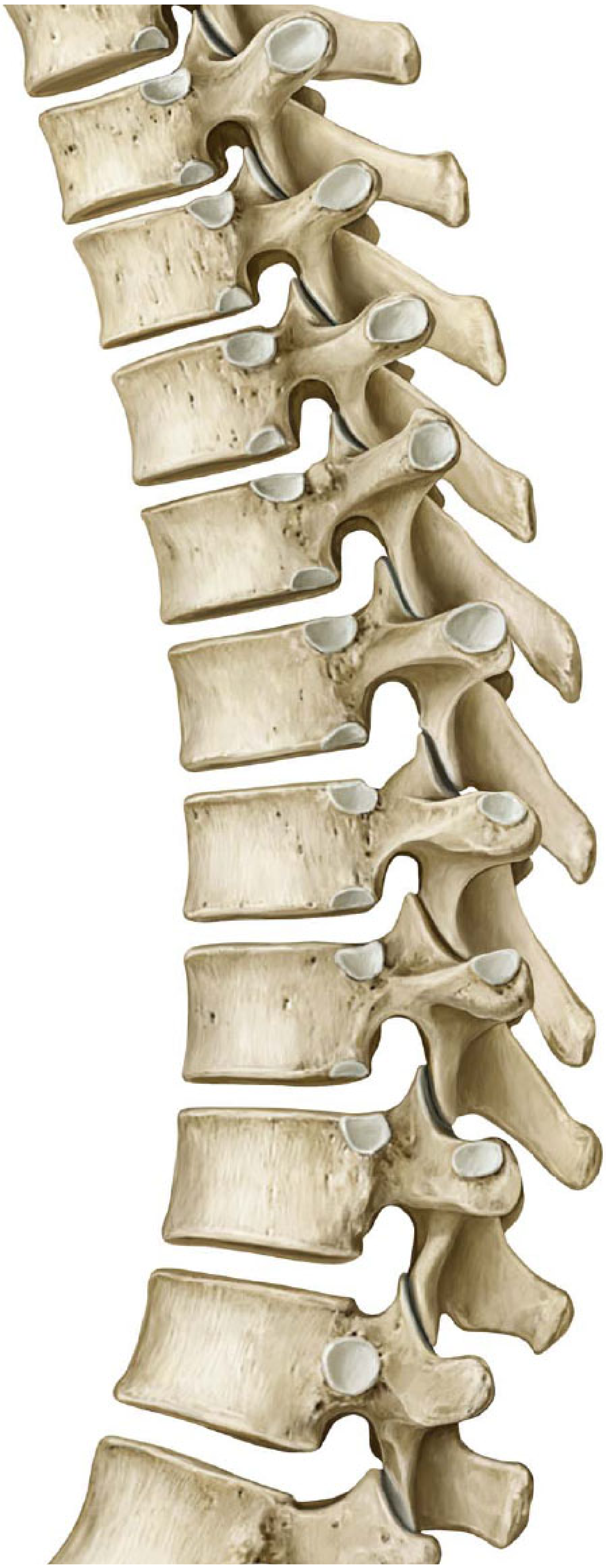


Back

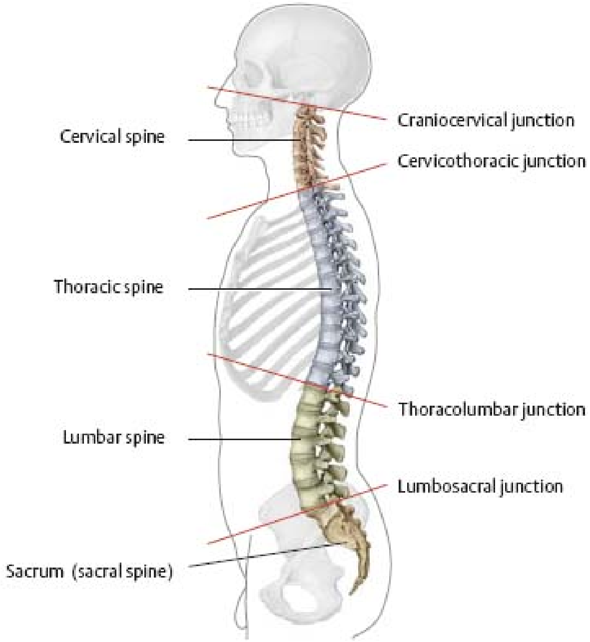
1 Bones, Ligaments & Joints

Vertebral Column: Overview

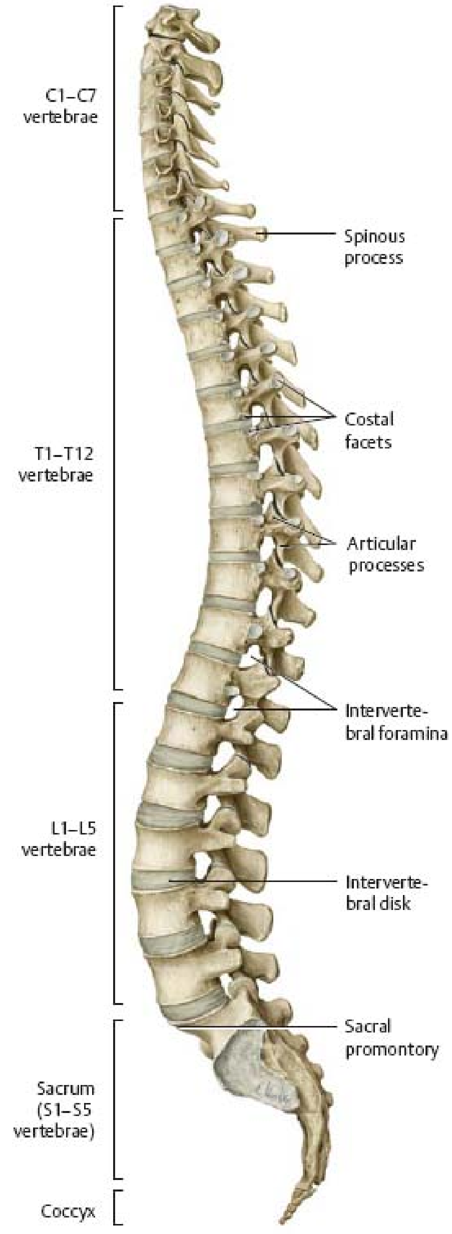
The vertebral column (spine) is divided into four regions: the cervical, thoracic, lumbar, and sacral spines. Both the cervical and lumbar spines demonstrate lordosis (inward curvature); the thoracic and sacral spines demonstrate kyphosis (outward curvature).

Fig. 1.1 Vertebral column

Left lateral view.



A Regions of the spine.



B Bony vertebral column.

Clinical

Spinal development

The characteristic curvatures of the adult spine appear over the course of postnatal development, being only partially present in a newborn. The newborn has a "kyphotic" spinal curvature (**A**); lumbar lordosis develops later and becomes stable at puberty (**C**).

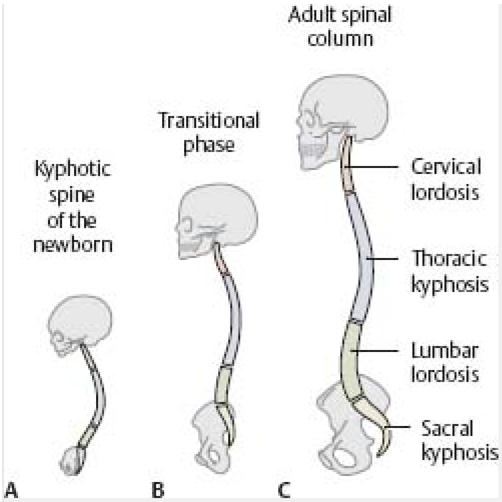
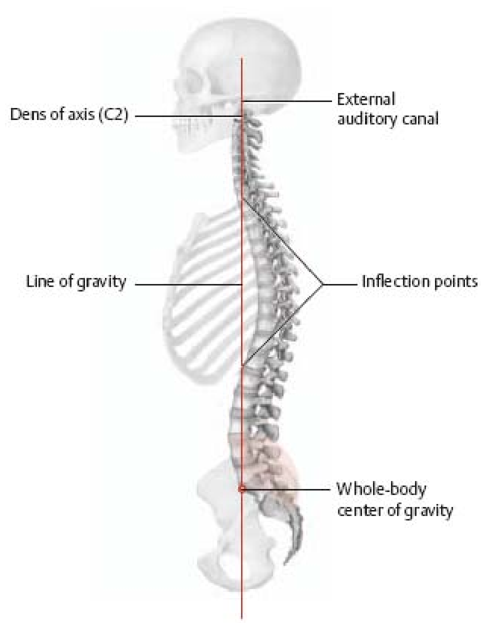
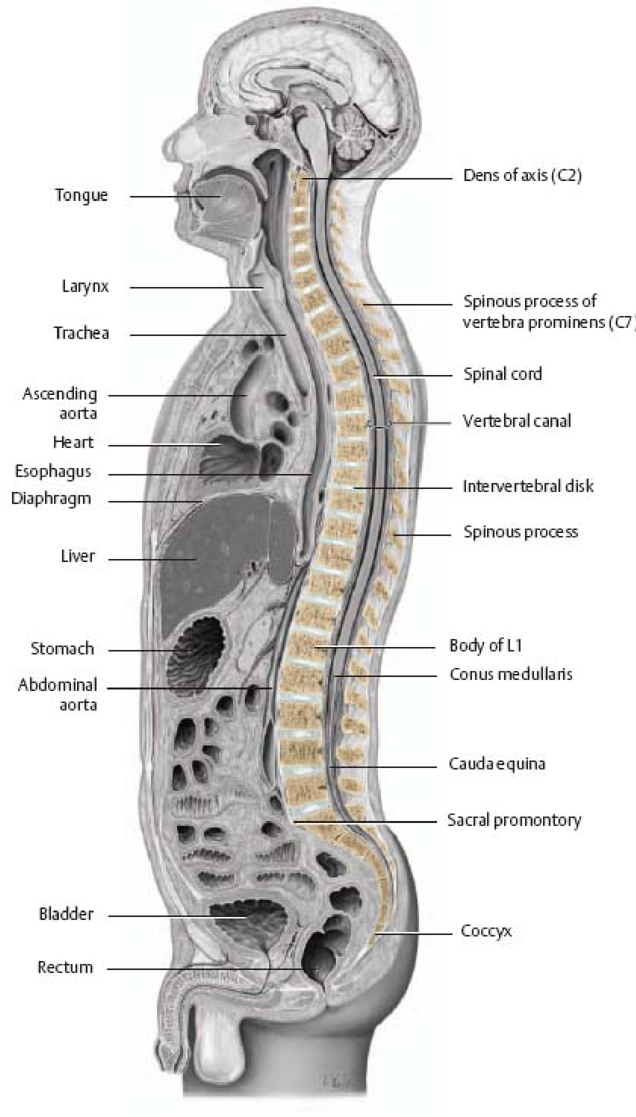


Fig. 1.2 **Normal anatomical position of the spine**
Left lateral view.



A Line of gravity. The line of gravity passes through certain anatomical landmarks, including the inflection points at the cervicothoracic and thoracolumbar junctions. It continues through the center of gravity (anterior to the sacral promontory) before passing through the hip joint, knee, and ankle.



B Midsagittal section through an adult male.

Vertebral Column: Elements

Fig. 1.3 Bones of the vertebral column

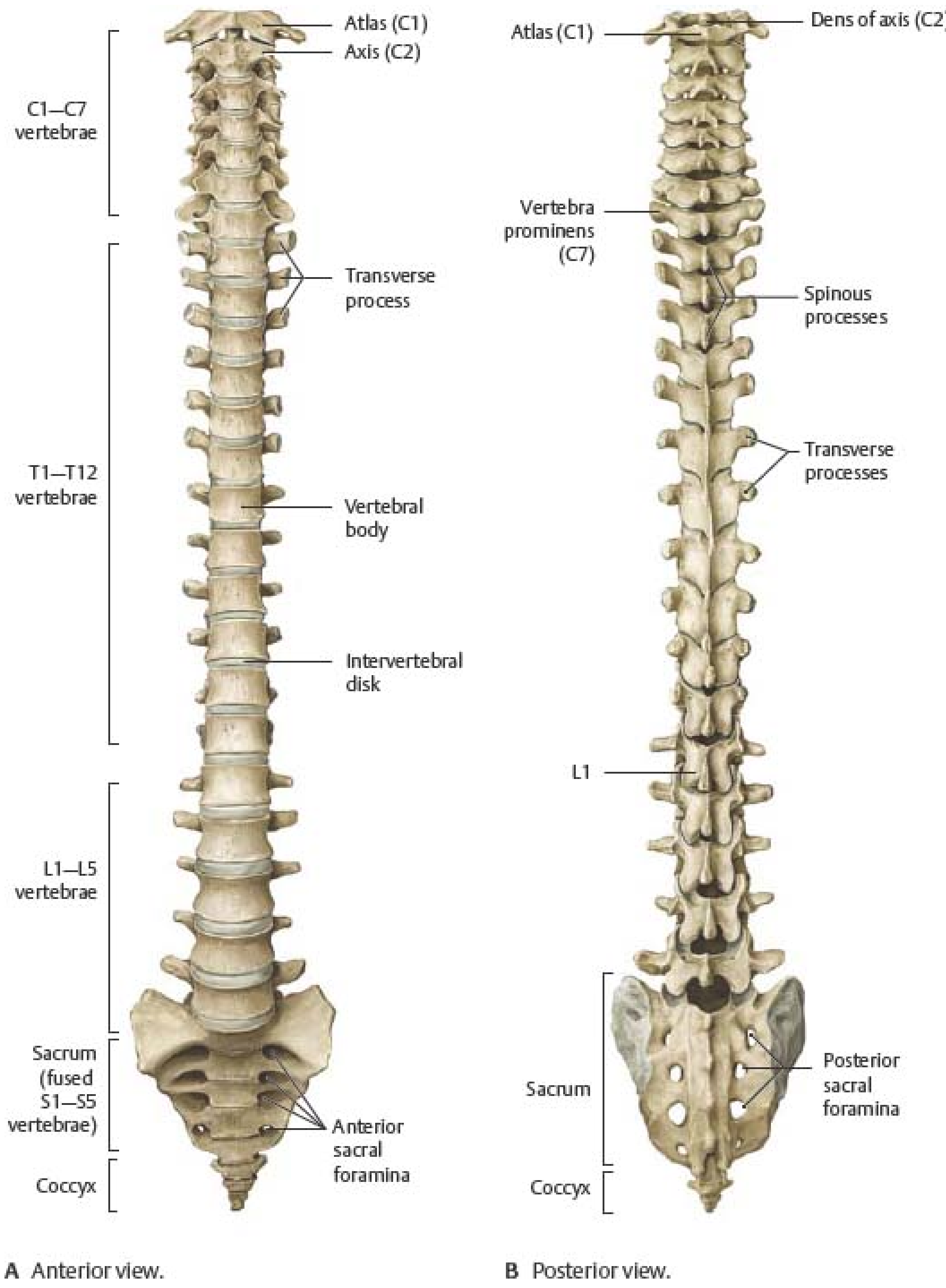


Fig. 1.4 **Palpable spinous processes as landmarks**

Posterior view. The easily palpated spinous processes provide important landmarks during physical examination.

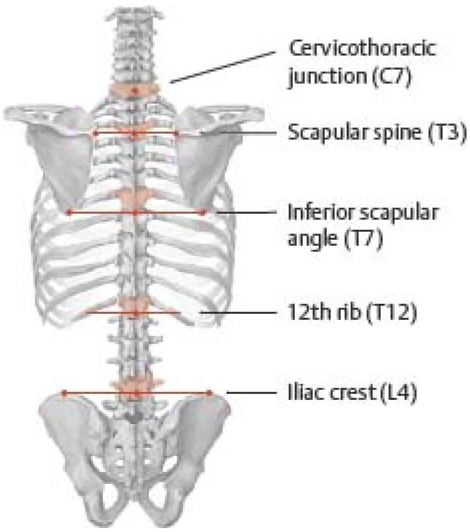


Fig. 1.5 Structural elements of a vertebra

Left posterosuperior view. With the exception of the atlas (C1) and axis (C2), all vertebrae consist of the same structural elements.

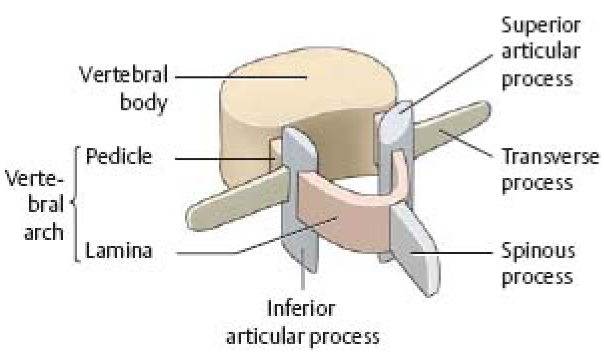
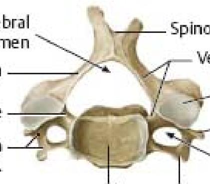
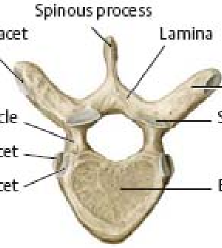


Fig. 1.6 Typical vertebrae

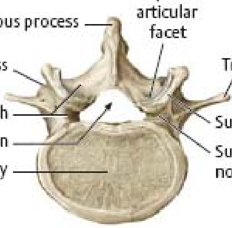
Superior view.



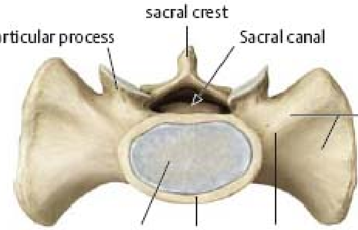
A Cervical vertebra (C4).



B Thoracic vertebra (T6).



C Lumbar vertebra (L4).



D Sacrum.

Table 1.1 Structural elements of vertebrae

Vertebrae	Body	Vertebral foramen	Transverse processes	Articular processes	Spinous process
Cervical vertebrae C3*–C7	Small (kidney-shaped)	Large (triangular)	Small (may be absent in C7); anterior and posterior tubercles enclose transverse foramen	Superoposteriorly and inferoanteriorly; oblique facets: most nearly horizontal	Short (C3–C5); bifid (C3–C6); long (C7)
Thoracic vertebrae T1–T12	Medium (heart-shaped); includes costal facets	Small (circular)	Large and strong; length decreases T1–T12; costal facets (T1–T10)	Posteriorly (slightly laterally) and anteriorly (slightly medially); facets in coronal plane	Long, sloping postero-inferiorly; tip extends to level of vertebral body below
Lumbar vertebrae L1–L5	Large (kidney-shaped)	Medium (triangular)	Long and slender; accessory process on posterior surface	Posteromedially (or medially) and anterolaterally (or laterally); facets nearly in sagittal plane; mammillary process on posterior surface of each superior articular process	Short and broad
Sacral vertebrae (sacrum) S1–S5 (fused)	Decreases from base to apex	Sacral canal	Fused to rudimentary rib (ribs, see pp. 44–47)	Superoposteriorly (SI) superior surface of lateral sacrum-auricular surface	Median sacral crest

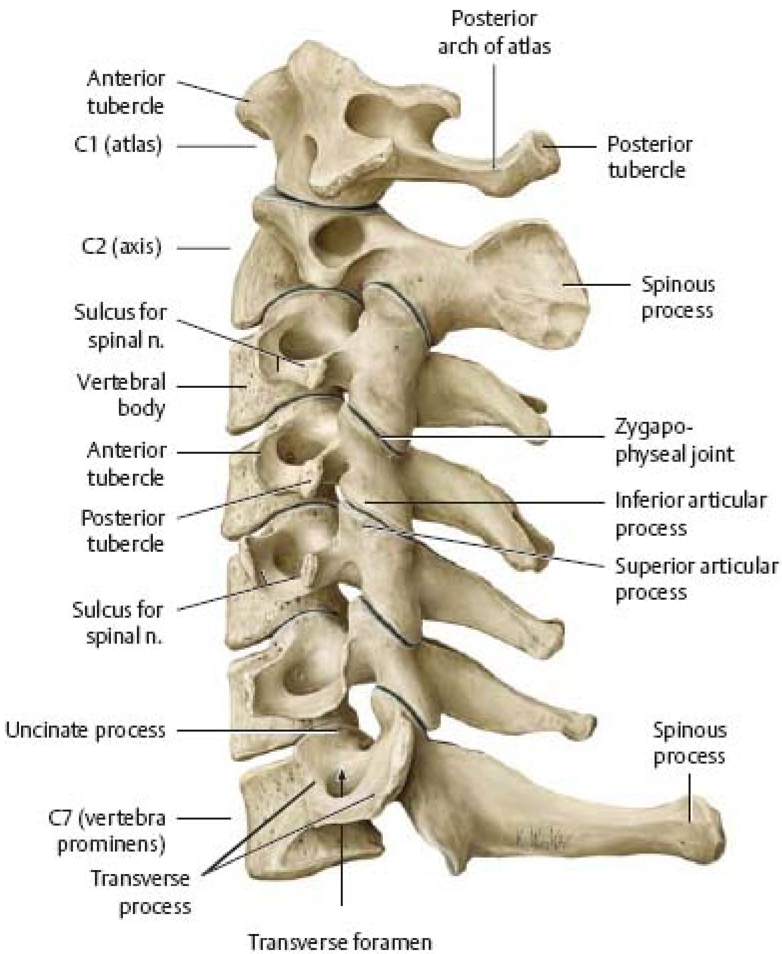
*C1 (atlas) and C2 (axis) are considered atypical (see pp. 6–7).

Cervical Vertebrae

The seven vertebrae of the cervical spine differ most conspicuously from the common vertebral morphology. They are specialized to bear the weight of the head and allow the neck to move in all directions. C1 and C2 are known as the atlas and axis, respectively. C7 is called the vertebra prominens for its long, palpable spinous process.

Fig. 1.7 **Cervical spine**

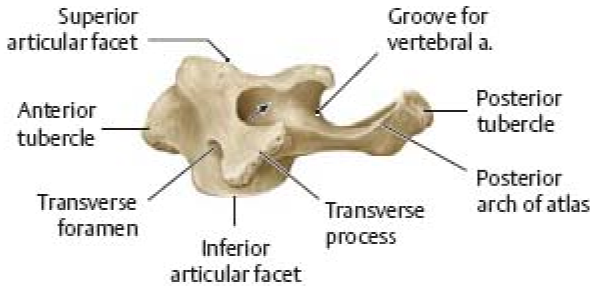
Left lateral view.



A Bones of the cervical spine, left lateral view.

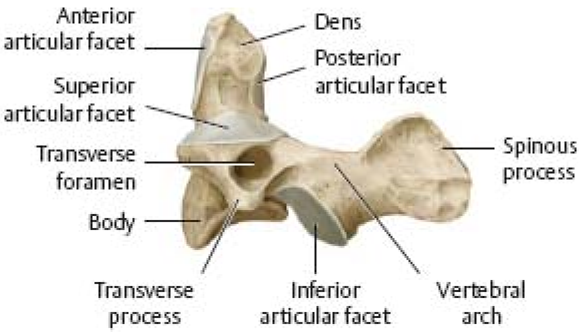
B Radiograph of the cervical spine, left lateral view.

Fig. 1.8 Atlas (C1)



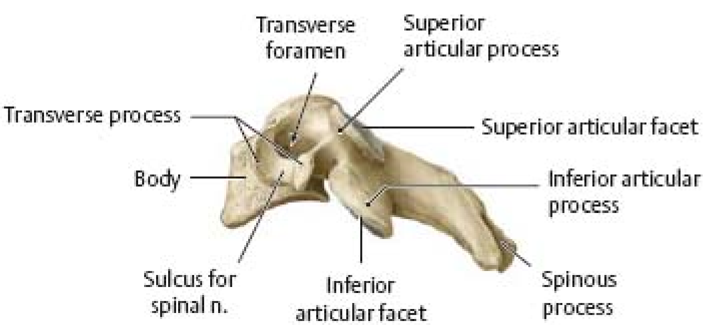
A Left lateral view.

Fig. 1.9 Axis (C2)



A Left lateral view.

Fig. 1.10 Typical cervical vertebra (C4)



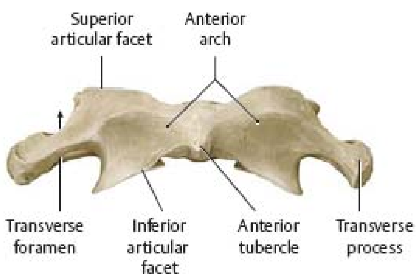
A Left lateral view.

Clinical

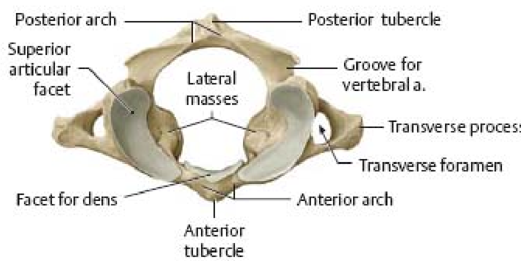
Injuries in the cervical spine

The cervical spine is prone to hyperextension injuries, such as “whiplash,” which can occur when the head extends back much farther than it normally would. The most common injuries of the cervical spine are fractures of the dens of the axis, traumatic spondylolisthesis (ventral slippage of a vertebral body), and atlas fractures. Patient prognosis is largely dependent on the spinal level of the injuries (see p. 600).

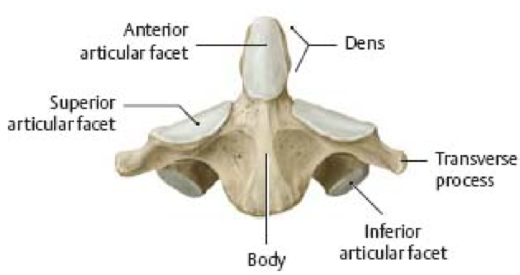
This patient hit the dashboard of his car while not wearing a seat belt. The resulting hyperextension caused the traumatic spondylolisthesis of C2 (axis) with fracture of the vertebral arch of C2, as well as tearing of the ligaments between C2 and C3. This injury is often referred to as “hangman's fracture.”



B Anterior view.



C Superior view.



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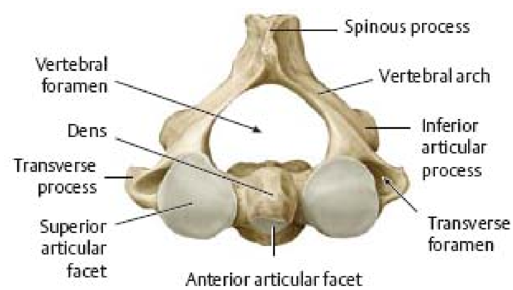
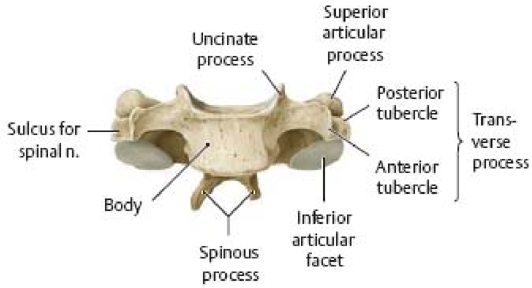
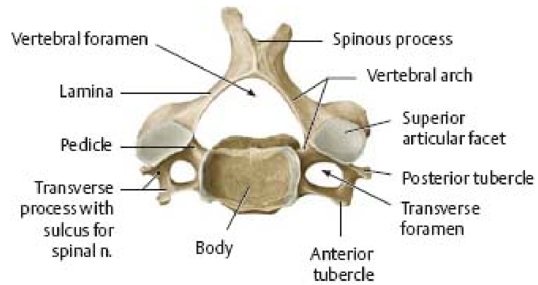


C Superior view.



B Anterior view.



C Superior view.

Thoracic & Lumbar Vertebrae

Fig. 1.11 Thoracic spine

Left lateral view.

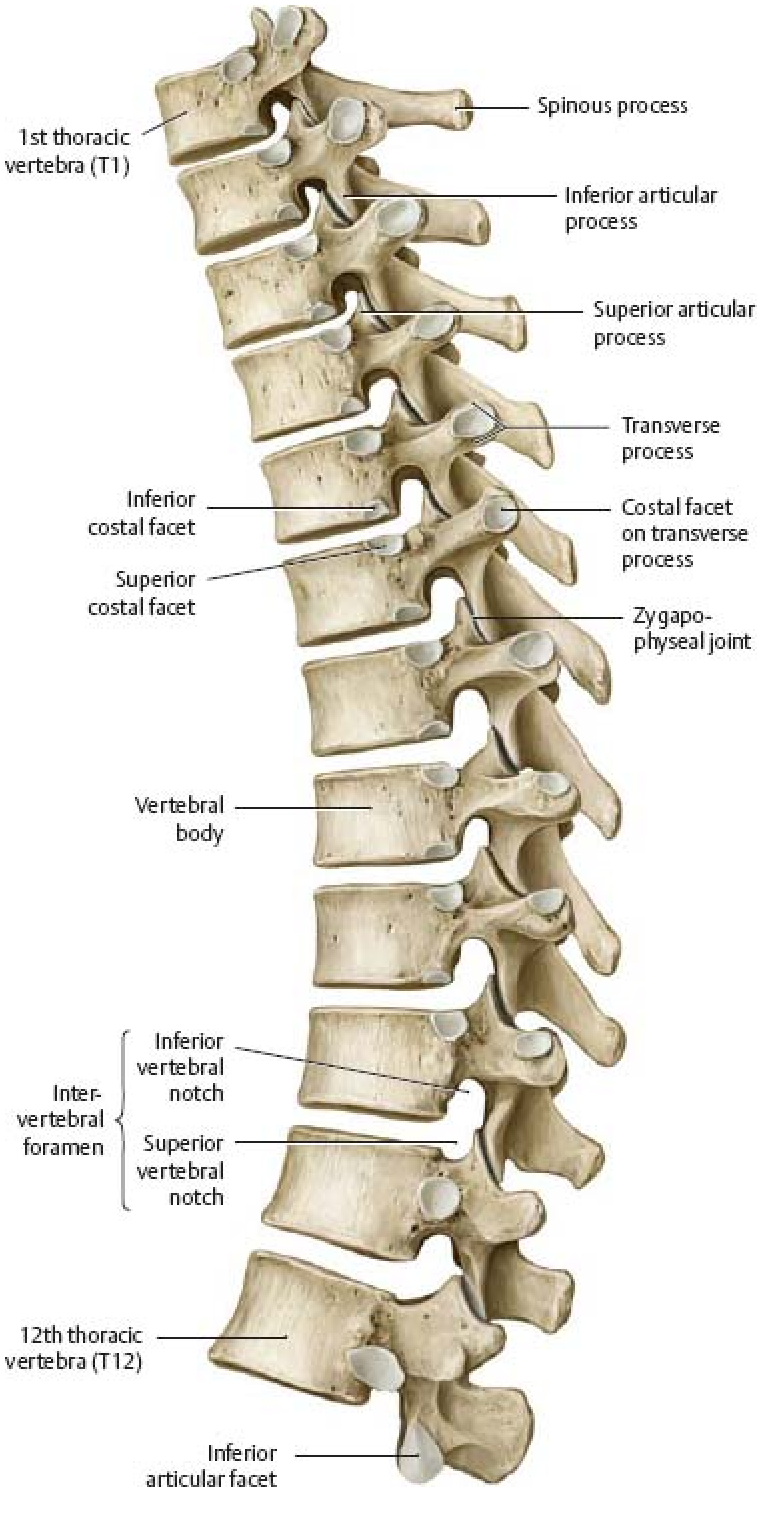
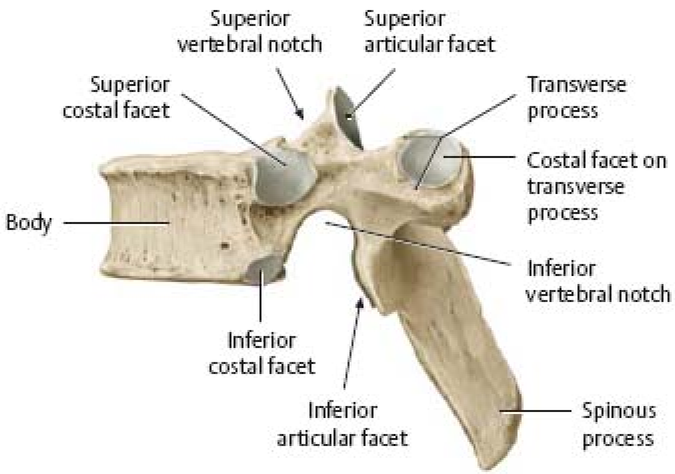
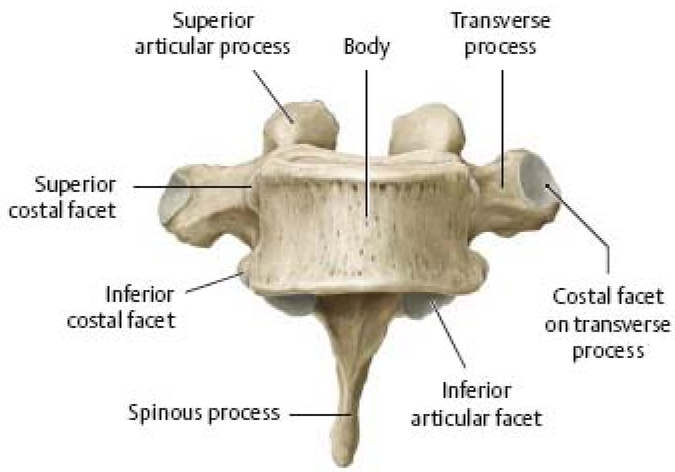


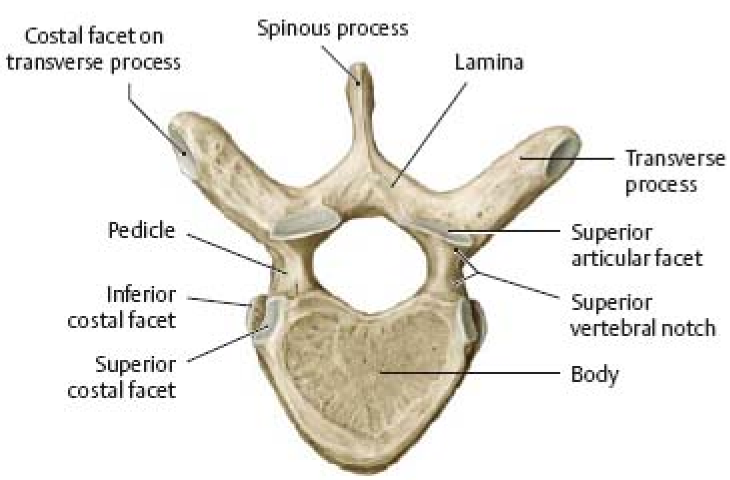
Fig. 1.12 **Typical thoracic vertebra (T6)**



A Left lateral view.



B Anterior view.



C Superior view.

Fig. 1.13 **Lumbar spine**

Left lateral view.

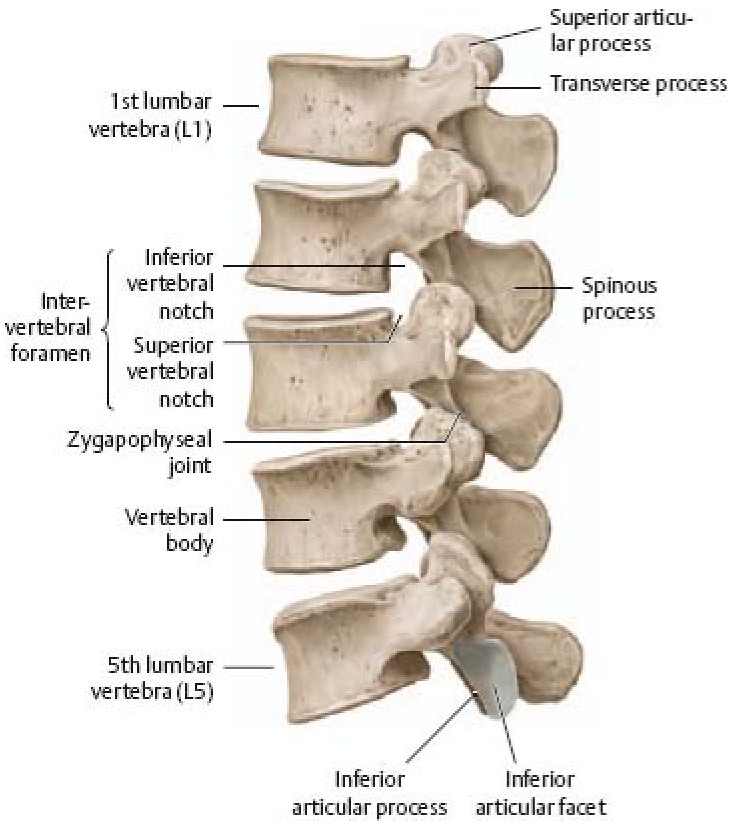
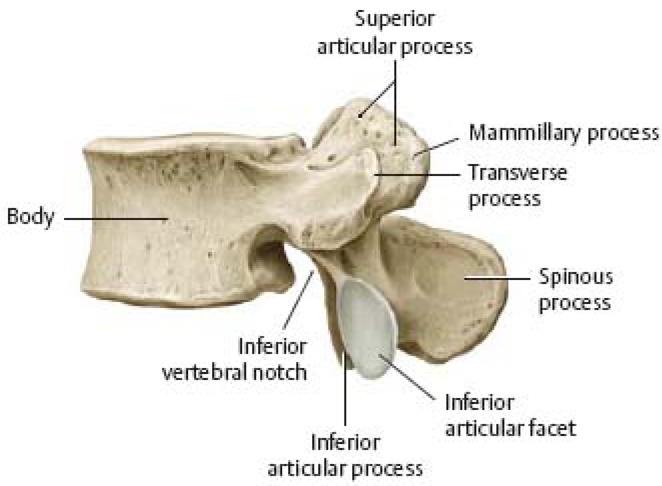
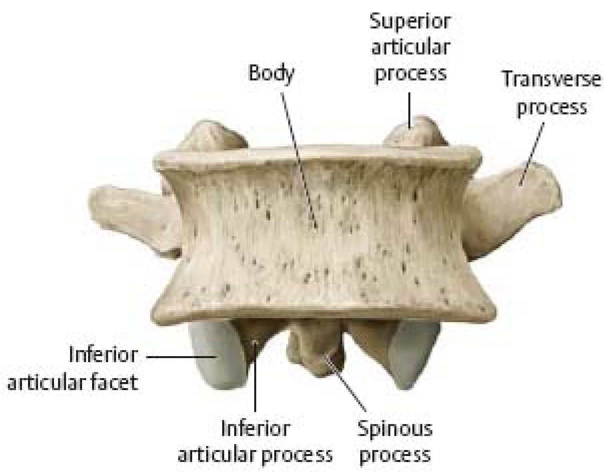


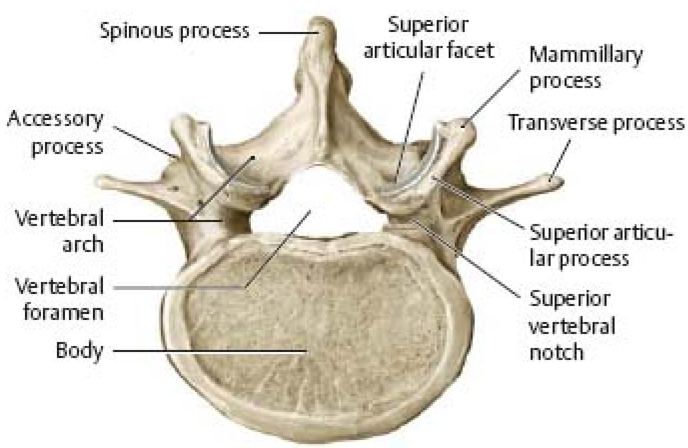
Fig. 1.14 **Typical lumbar vertebra (L4)**



A Left lateral view.



B Anterior view.



C Superior view.

Clinical

Osteoporosis

The spine is the structure most affected by degenerative diseases of the skeleton, such as arthrosis and osteoporosis. In osteoporosis, more bone material gets reabsorbed than built up, resulting in a loss of bone mass. Symptoms include compression fractures and resulting back pain.

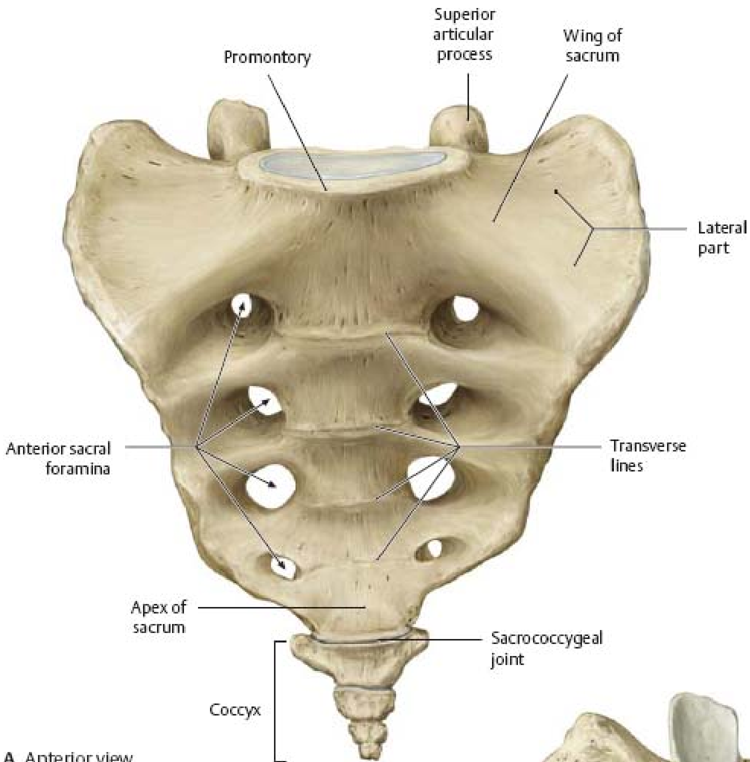
A Radiograph of a normal lumbar spine, left lateral view.

B Radiograph of an osteoporotic spine. The vertebral bodies are decreased in density, and the internal trabecular structure is coarse. Lower and upper end plates are fractured.

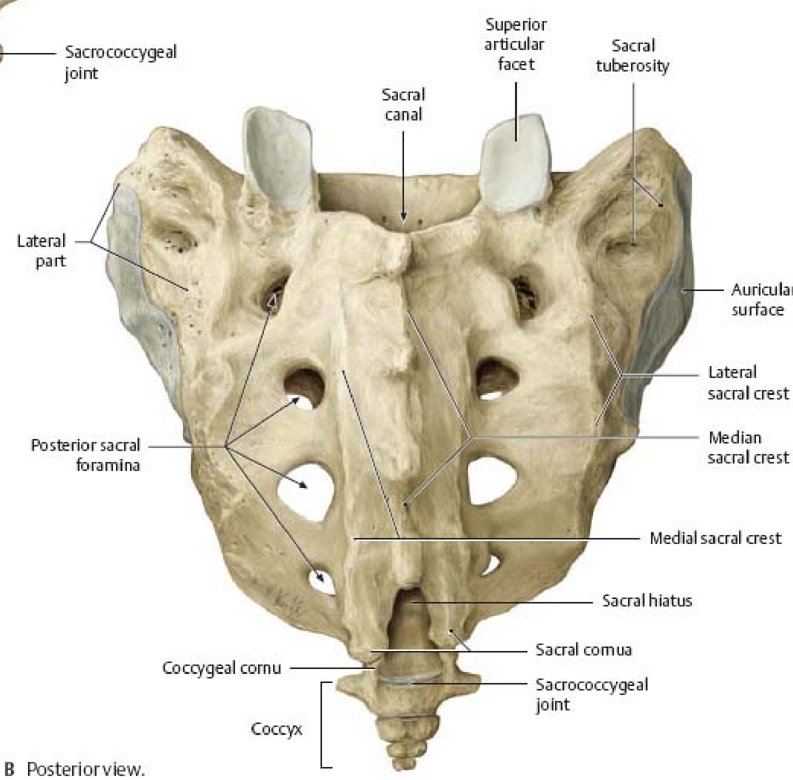
Sacrum & Coccyx

The sacrum is formed from five postnatally fused sacral vertebrae. The base of the sacrum articulates with the fifth lumbar vertebra, and the apex articulates with the coccyx, a series of three or four rudimentary vertebrae.

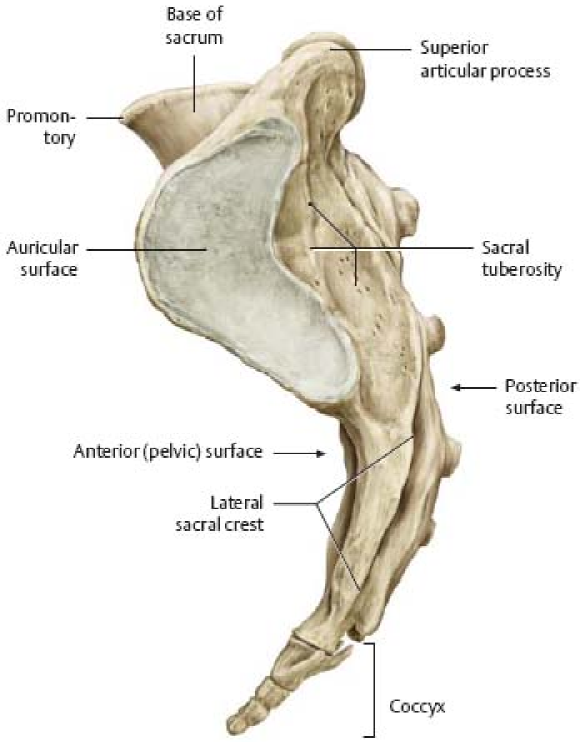
Fig. 1.15 Sacrum and coccyx



A Anterior view.



B Posterior view.

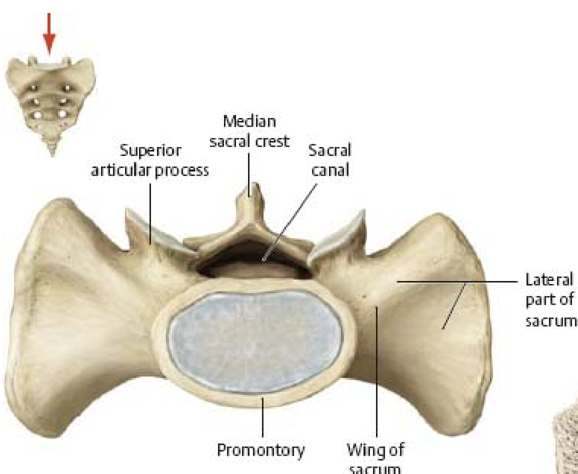


C Left lateral view.

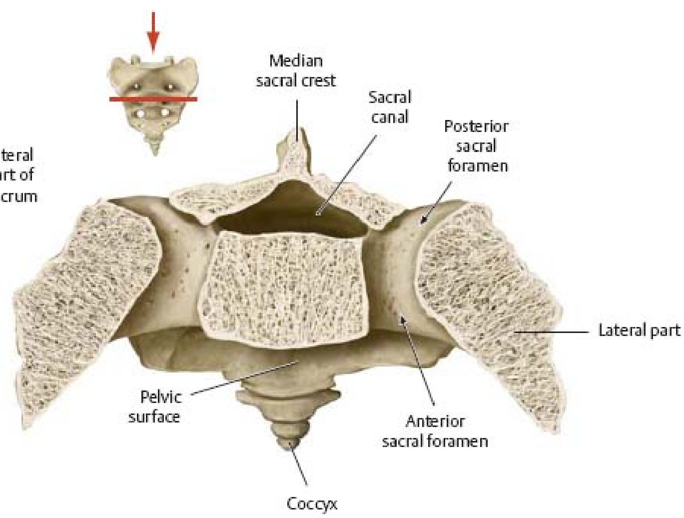
D Radiograph of sacrum, anteroposterior view.

Fig. 1.16 Sacrum

Superior view.



A Base of sacrum, superior view.



B Transverse section through second sacral vertebra demonstrating anterior and posterior sacral foramina, superior view.

Intervertebral Disks

Fig. 1.17 Intervertebral disk in the vertebral column

Sagittal section of T11–T12, left lateral view. The intervertebral disks occupy the spaces between vertebrae (intervertebral joints, see p. 14).

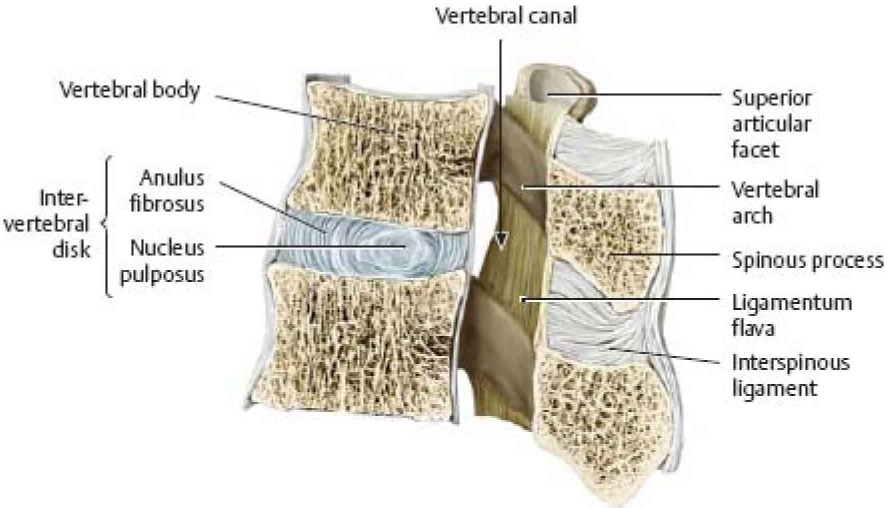


Fig. 1.18 Structure of intervertebral disk

Anterosuperior view with the anterior half of the disk and the right half of the end plate removed. The intervertebral disk consists of an external fibrous ring (anulus fibrosus) and a gelatinous core (nucleus pulposus).

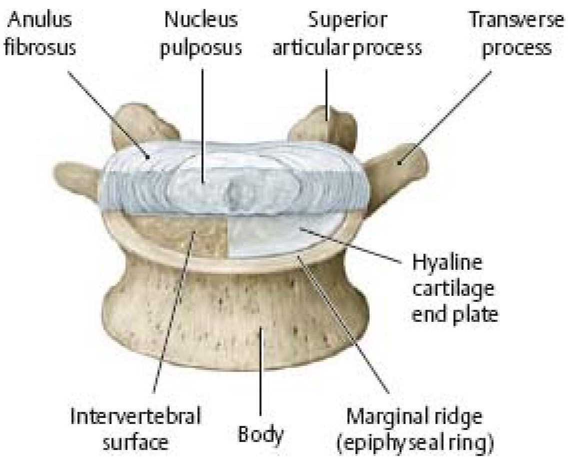


Fig. 1.19 Relation of intervertebral disk to vertebral canal

Fourth lumbar vertebra, superior view.

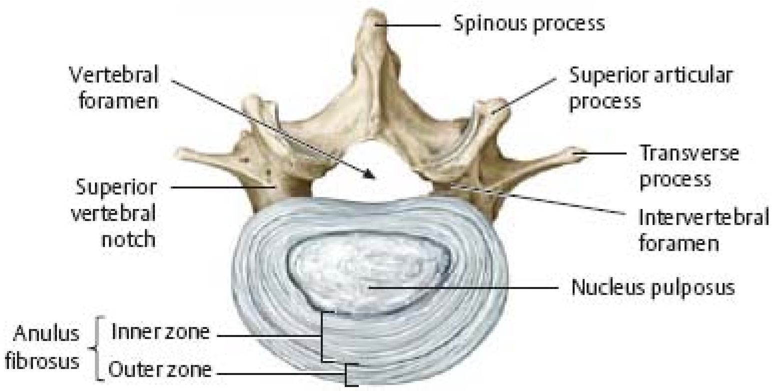
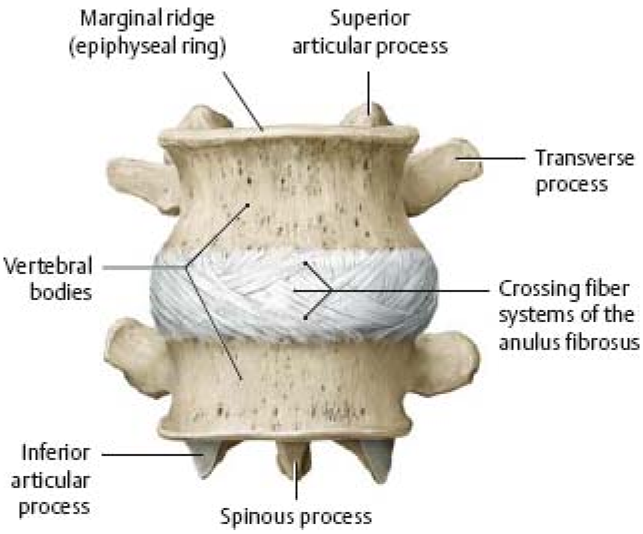


Fig. 1.20 Outer zone of the anulus fibrosus

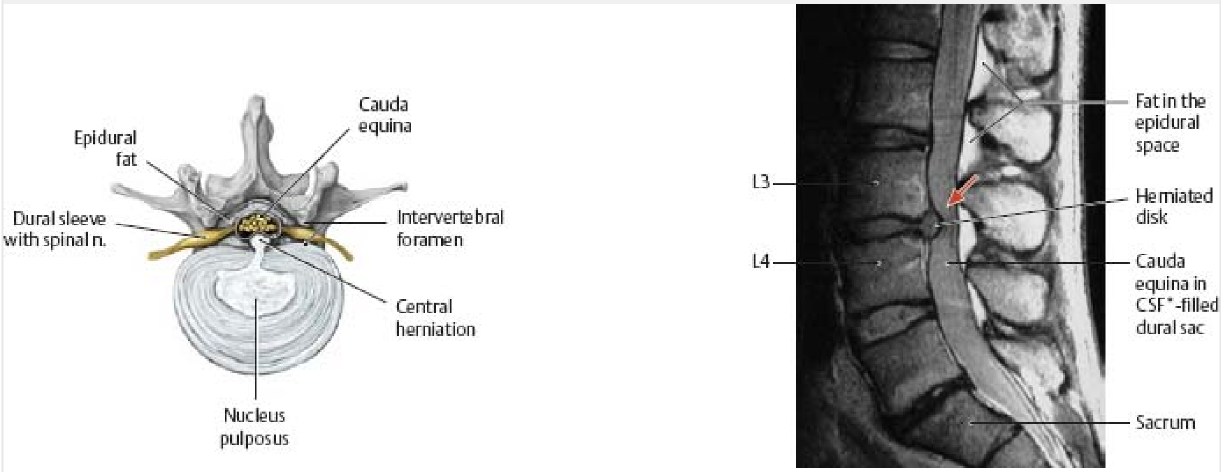
Anterior view of L3–L4 with intervertebral disk.



Clinical

Disk herniation in the lumbar spine

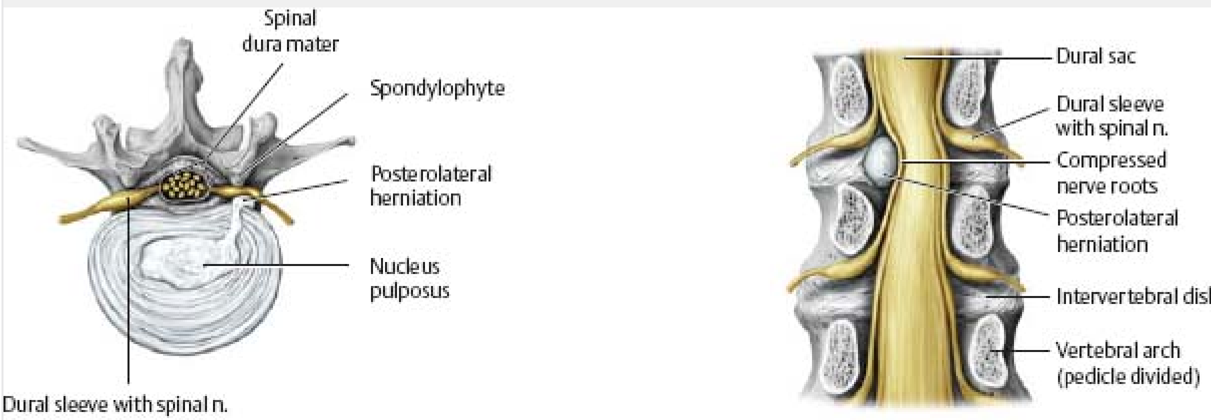
As the stress resistance of the anulus fibrosus declines with age, the tissue of the nucleus pulposus may protrude through weak spots under loading. If the fibrous ring of the anulus ruptures completely, the herniated material may compress the contents of the intervertebral foramen (nerve roots and blood vessels). These patients often suffer from severe local back pain. Pain is also felt in the associated dermatome (see p. 600). When the motor part of the spinal nerve is affected, the muscles served by that spinal nerve will show weakening. It is an important diagnostic step to test the muscles innervated by a nerve from a certain spinal segment, as well as the sensitivity in the specific dermatome. Example: The first sacral nerve root innervates the gastrocnemius and soleus muscles; thus, standing or walking on toes can be affected (see p. 398).



A Superior view.

B Midsagittal T2-weighted MRI (magnetic resonance image).

Posterior herniation (A, B) In the MRI, a conspicuously herniated disk at the level of L3–L4 protrudes posteriorly (transligamentous herniation). The dural sac is deeply indented at that level. *CSF (cerebrospinal fluid).



C Superior view.

D Posterior view, vertebral arches removed.

Posterolateral herniation (C, D) A posterolateral herniation may compress the spinal nerve as it passes through the intervertebral foramen. If more medially positioned, the herniation may spare the nerve at that level, but impact nerves at inferior levels.

Joints of the Vertebral Column: Overview

Table 1.2 **Joints of the vertebral column**

Craniovertebral joints

1 Atlanto-occipital joints	Occiput–C1
2 Atlantoaxial joints	C1–C2
Joints of the vertebral bodies	
3 Uncovertebral joints	C3–C7
4 Intervertebral joints	C1–S1
Joints of the vertebral arch	
5 Zygapophyseal joints	C1–S1

Fig. 1.21 **Joints of the vertebral column**

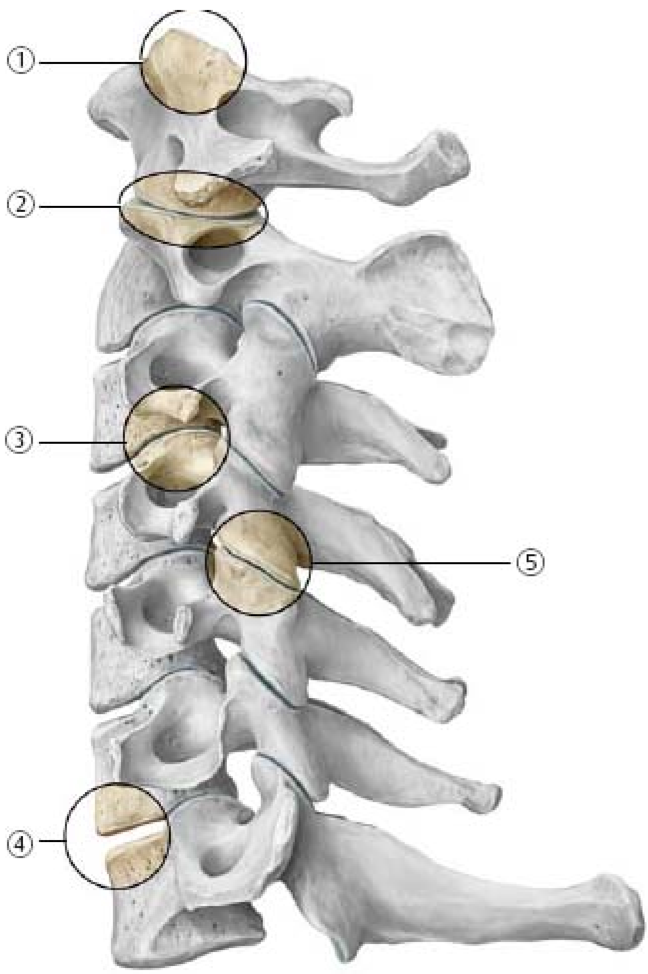
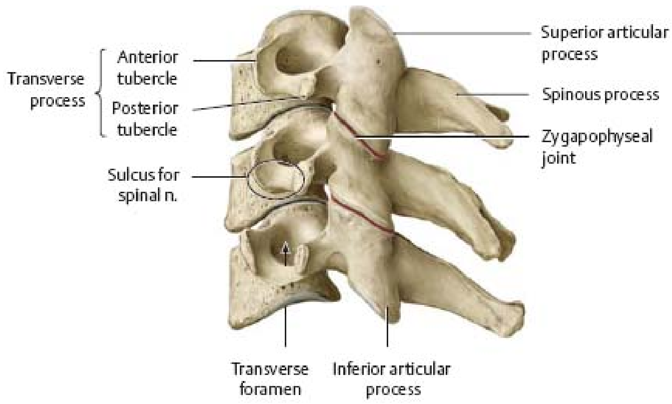
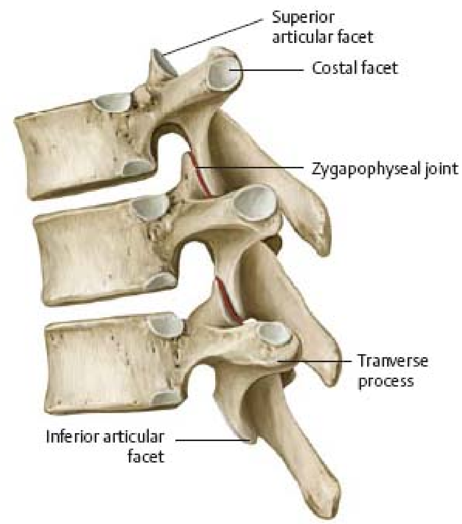


Fig. 1.22 **Zygapophyseal (intervertebral facet) joints**

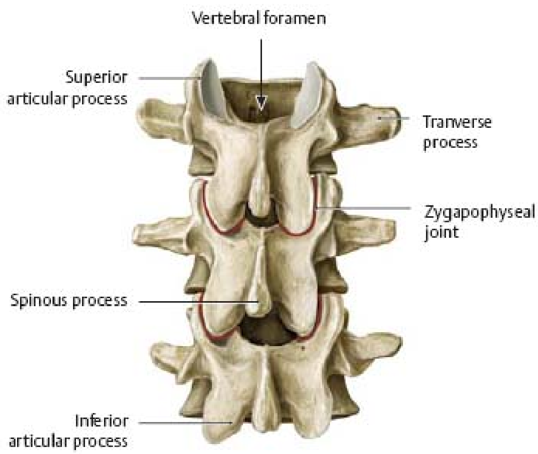
The orientation of the zygapophyseal joints differs between the spinal regions, influencing the degree and direction of movement.



A Cervical region, left lateral view. The zygapophyseal joints lie 45 degrees from the horizontal.



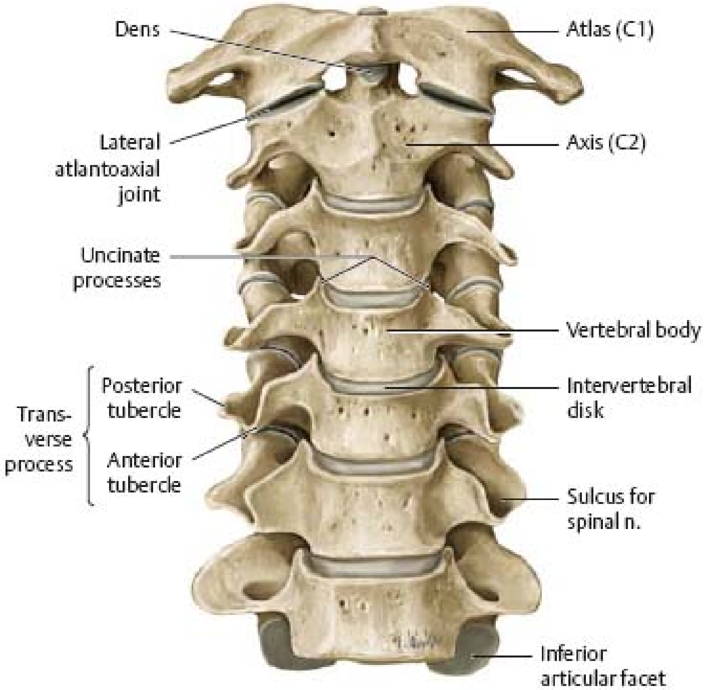
B Thoracic region, left lateral view. The joints lie in the coronal plane.



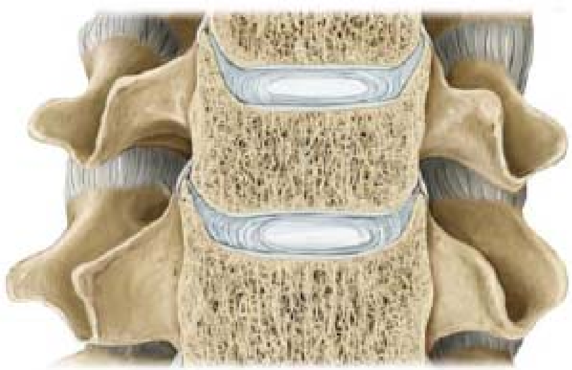
C Lumbar region, posterior view. The joints lie in the sagittal plane.

Fig. 1.23 Uncovertebral joints

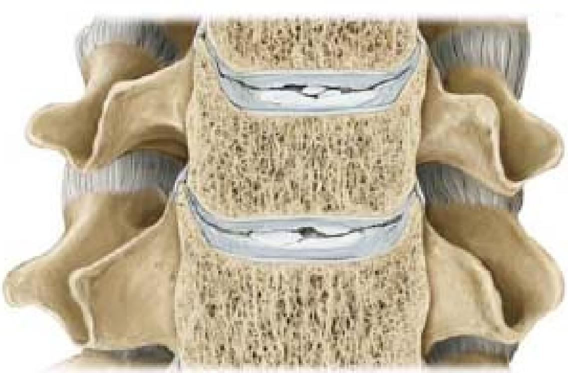
Anterior view. Uncovertebral joints form during childhood between the uncinate processes of C3–C6 and the vertebral bodies immediately superior. The joints may result from fissures in the cartilage of the disks that assume an articular character. If the fissures become complete tears, the risk of pulposus herniation is increased (see p. 13).



A Uncovertebral joints in the cervical spine of an 18-year-old man, anterior view.



B Uncovertebral joint (enlarged), anterior view of coronal section.

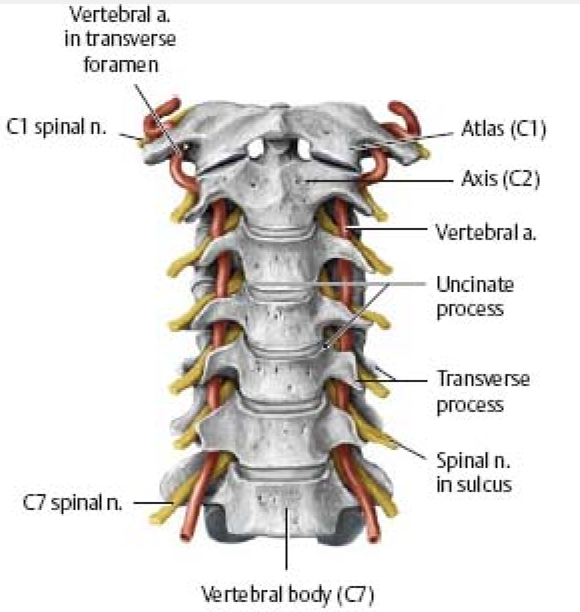


C Split intervertebral disk, anterior view of coronal section.

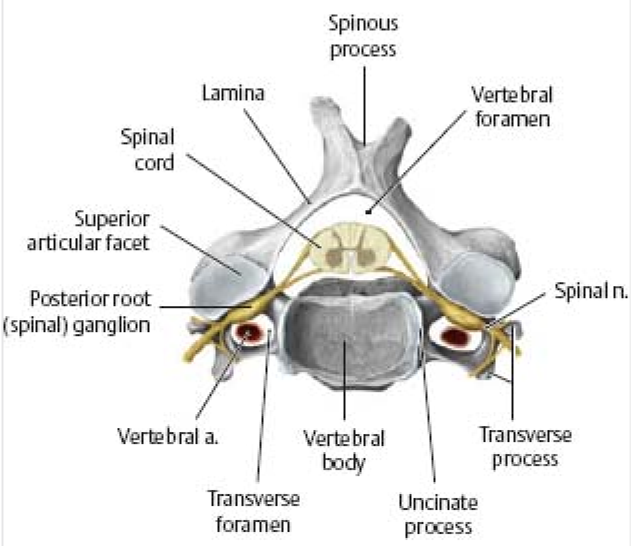
Clinical

Proximity of spinal nerve and vertebral artery to the uncinate process

The spinal nerve and vertebral artery pass through the intervertebral and transverse foramina, respectively. Bony outgrowths (osteophytes) resulting from uncovertebral arthrosis may compress both the nerve and the artery and can lead to chronic pain in the neck.



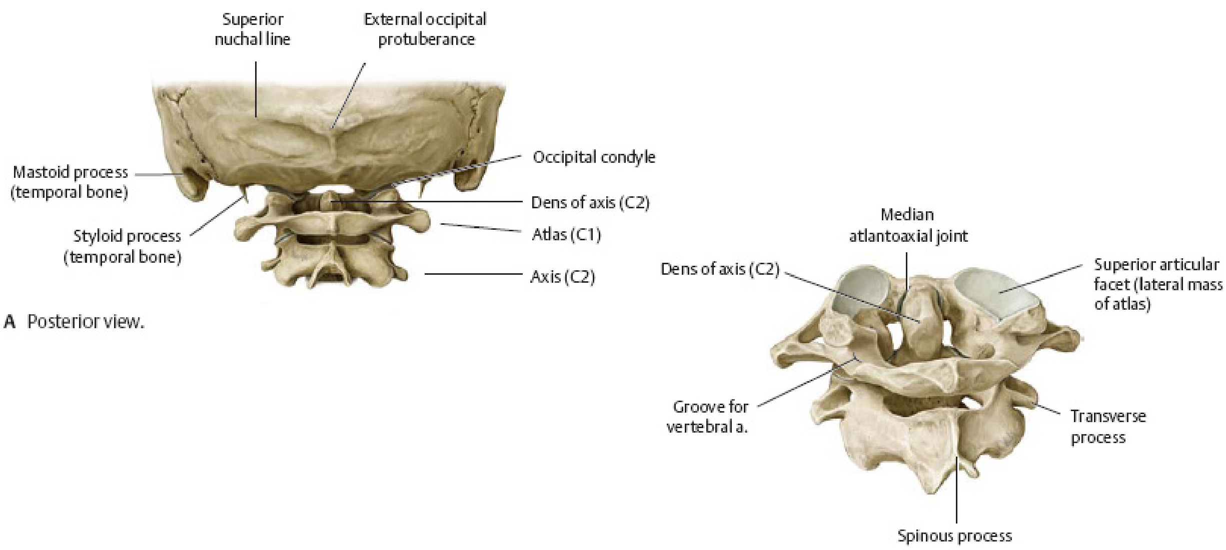
A Cervical spine, anterior view.



B Fourth cervical vertebra, superior view.

Joints of the Vertebral Column: Craniovertebral Region

Fig. 1.24 Craniovertebral joints

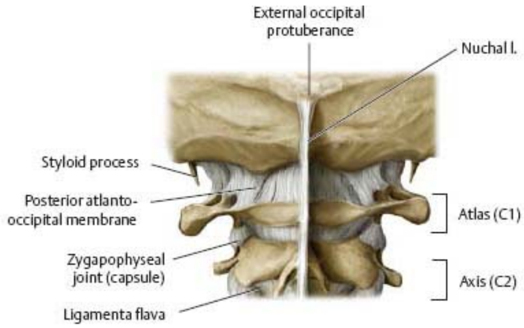


A Posterior view.

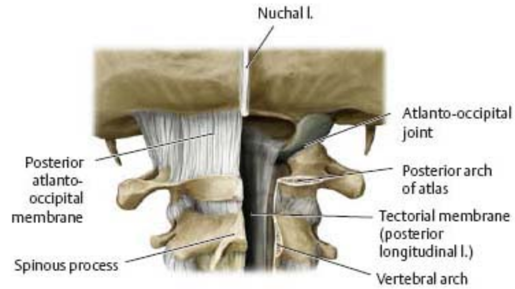
B Atlas and axis, posterosuperior view.

Fig. 1.25 Dissection of the craniovertebral joint ligaments

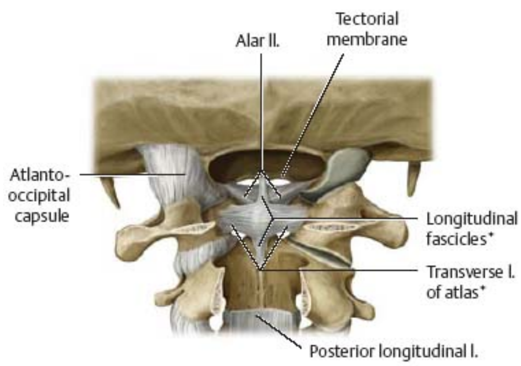
Posterior view.



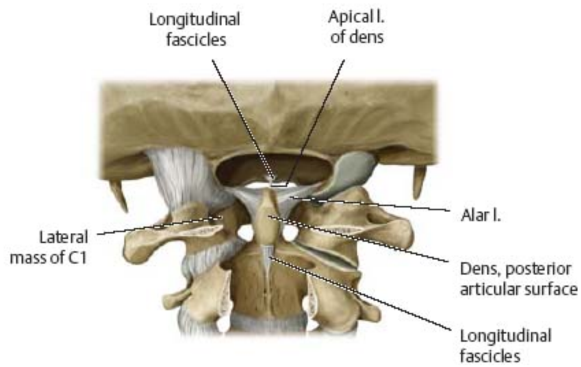
A Nuchal ligament and posterior atlanto-occipital membrane.



B Posterior longitudinal ligament. *Removed:* Spinal cord; vertebral canal windowed.



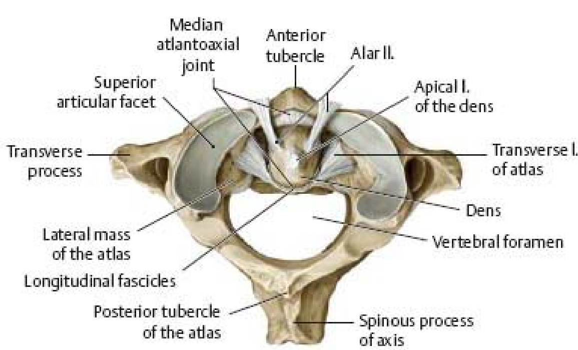
C Cruciform ligament of atlas (*). *Removed:* Tectorial membrane.



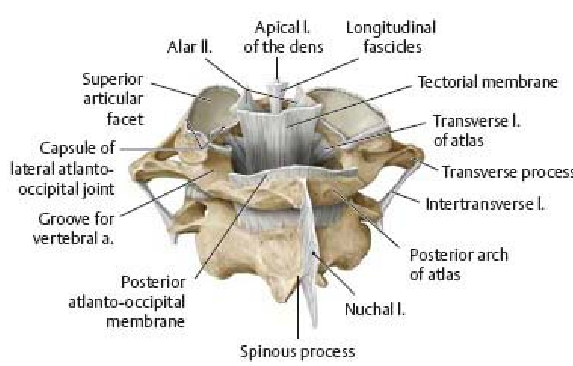
D Alar and apical ligaments. *Removed:* Transverse ligament of atlas, longitudinal fascicles.

The atlanto-occipital joints are the two articulations between the convex occipital condyles of the occipital bone and the slightly concave superior articular facets of the atlas (C1). The atlantoaxial joints are the two lateral and one medial articulations between the atlas (C1) and axis (C2).

Fig. 1.26 Ligaments of the craniovertebral joints



A Ligaments of the median atlantoaxial joint, superior view. The fovea of the atlas is hidden by the joint capsule.



B Ligaments of the craniovertebral joints, posterosuperior view. The dens of the axis is hidden by the tectorial membrane.

Vertebral Ligaments: Overview & Cervical Spine

The ligaments of the spinal column bind the vertebrae and enable the spine to withstand high mechanical loads and shearing stresses and limit the range of motion. The ligaments are subdivided into vertebral body ligaments and vertebral arch ligaments.

Fig. 1.27 Vertebral ligaments

Viewed obliquely from the left posterior view.

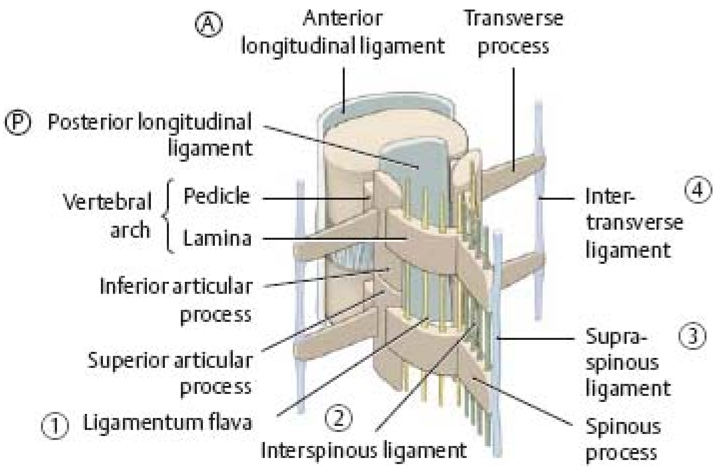


Table 1.3 **Vertebral ligaments**

Ligament		Location
Vertebral body ligaments		
A	Anterior longitudinal ligament	Along anterior surface of vertebral body
P	Posterior longitudinal ligament	Along posterior surface of vertebral body
Vertebral arch ligaments		
1	Ligamenta flava	Between laminae
2	Interspinous ligaments	Between spinous process
3	Supraspinous ligaments	Along posterior ridge of spinous processes
4	Intertransverse ligaments	Between transverse processes

Ligament	Location
Nuchal ligament*	Between external occipital protuberance and spinous process of C7
*Corresponds to a supraspinous ligament that is broadened superiorly.	

Fig. 1.28 Anterior longitudinal ligament

Anterior longitudinal ligament. Anterior view with base of skull removed.

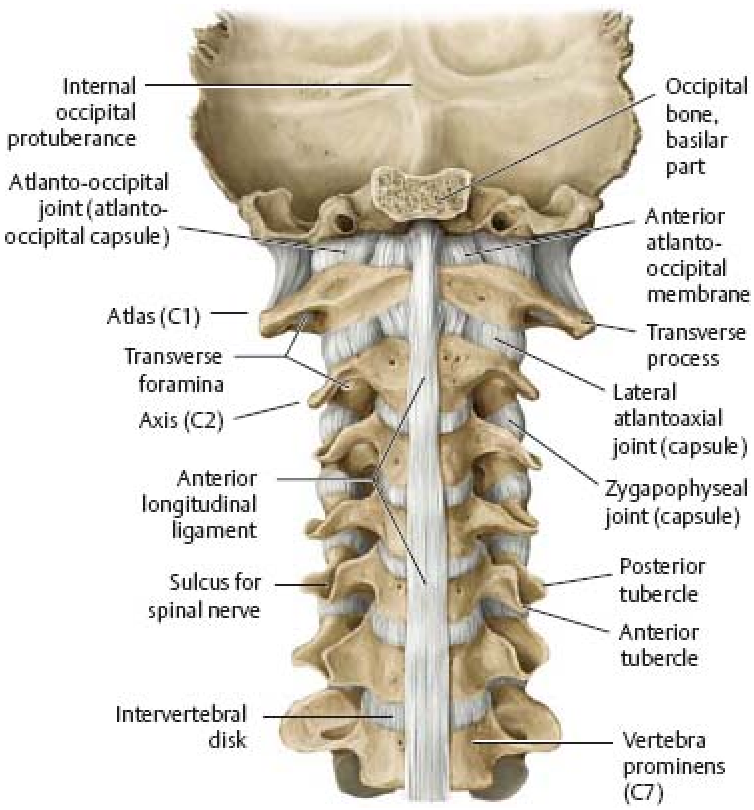


Fig. 1.29 Posterior longitudinal ligament

Posterior view with vertebral canal windowed and spinal cord removed. The tectorial membrane is a broadened expansion of the posterior longitudinal ligament.

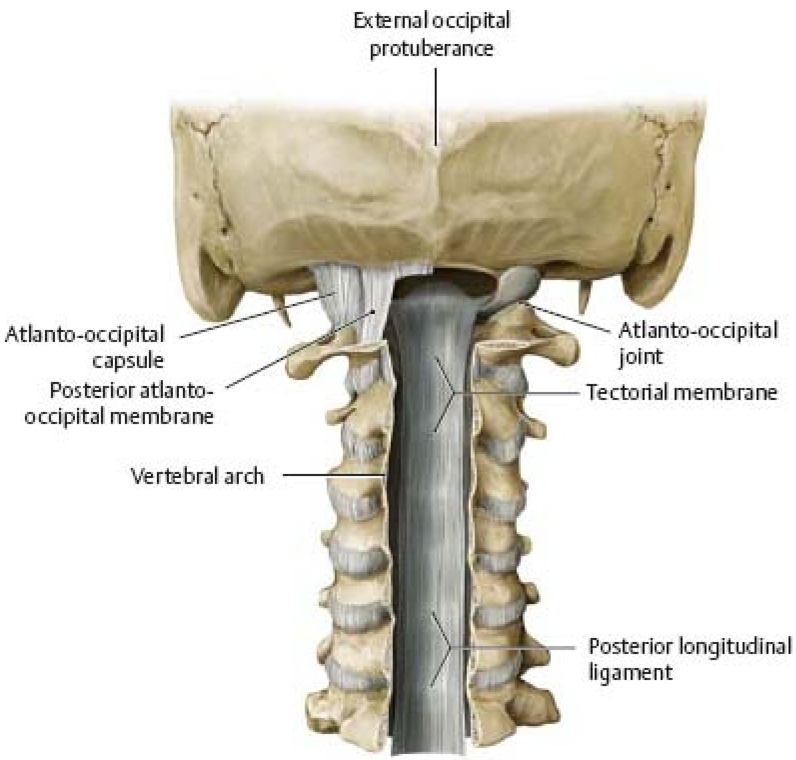
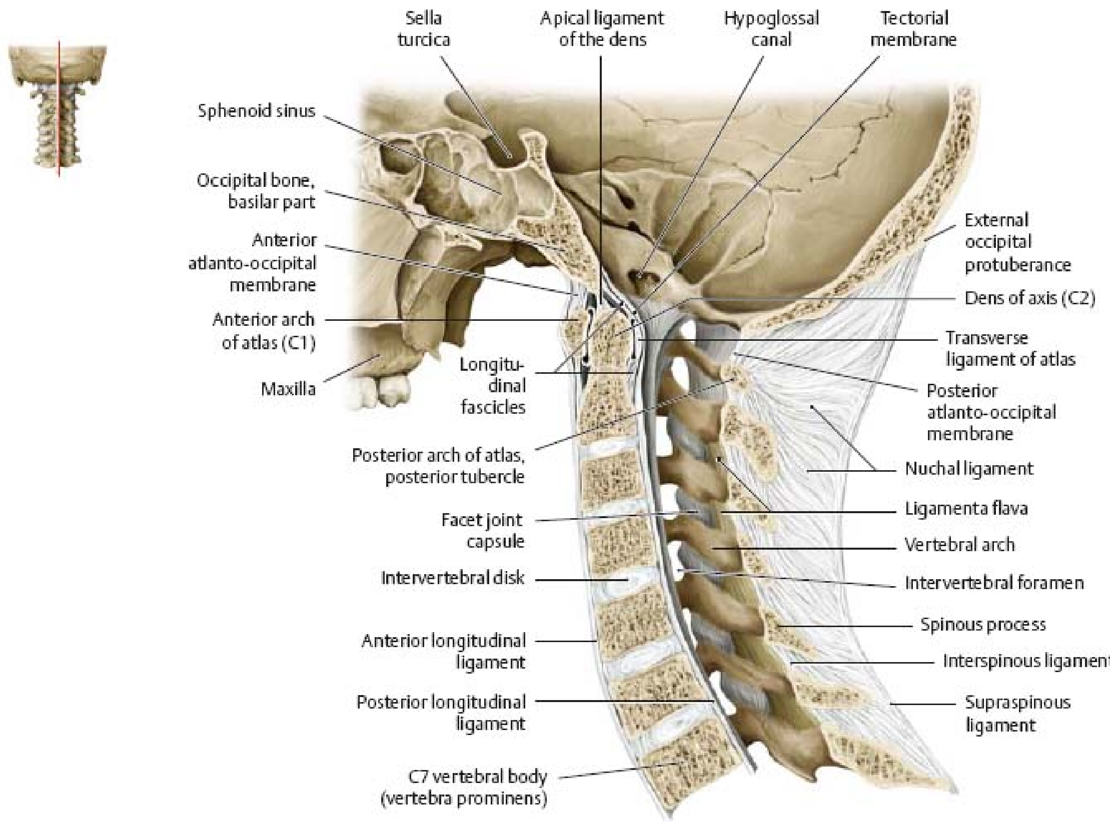
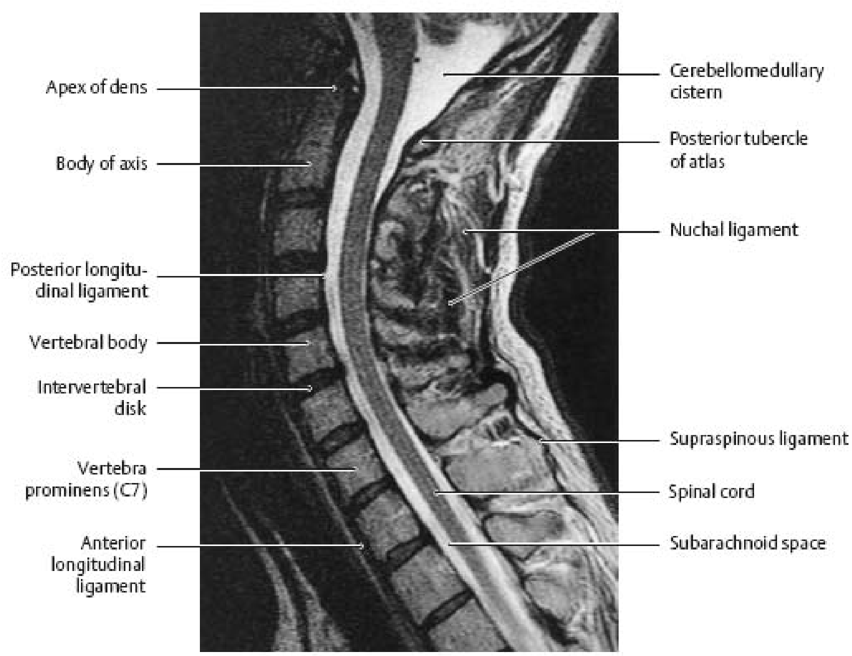


Fig. 1.30 **Ligaments of the cervical spine**



A Midsagittal section, left lateral view. The nuchal ligament is the broadened, sagittally oriented part of the supraspinous ligament that extends from the vertebra prominens (C7) to the external occipital protuberance.

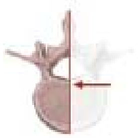


B Midsagittal T2-weighted MRI, left lateral view.

Vertebral Ligaments: Thoracolumbar Spine

Fig. 1.31 Ligaments of the vertebral column: Thoracolumbar junction

Left lateral view of T11–L3, with T11–T12 sectioned in the midsagittal plane.



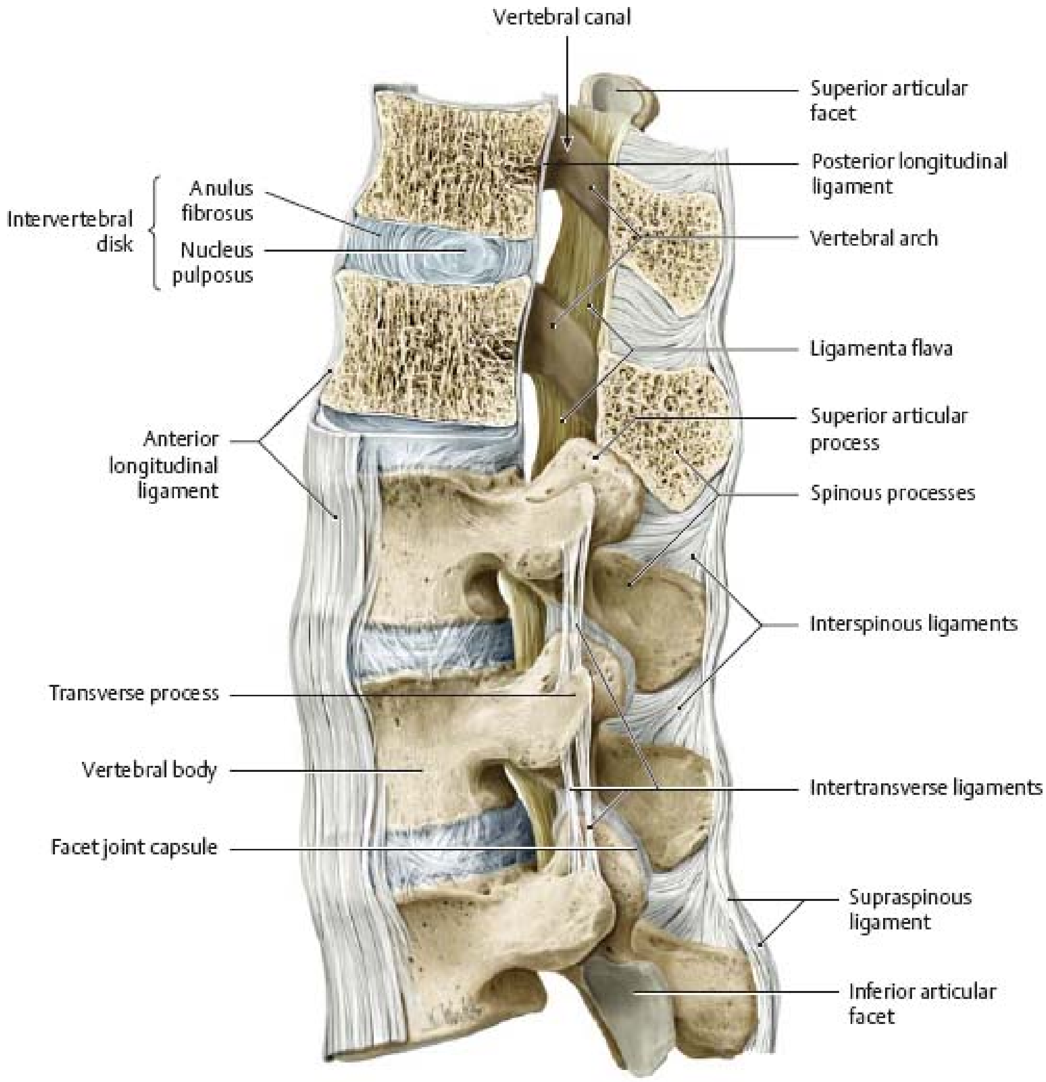


Fig. 1.32 Anterior longitudinal ligament

Anterior view of L3–L5.

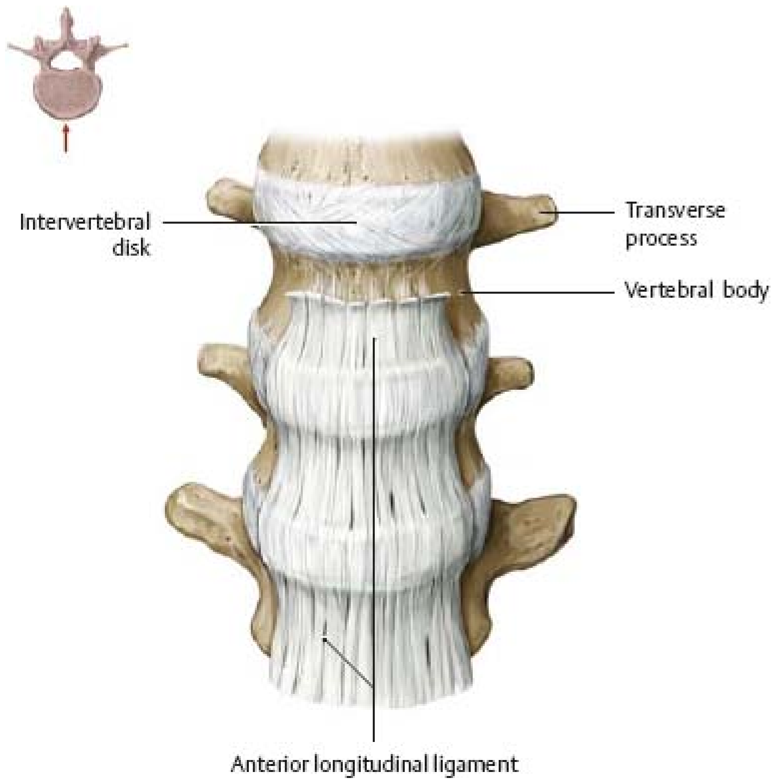


Fig. 1.33 **Ligamentum flavum and intertransverse ligament**
Anterior view of opened vertebral canal at level of L2–L5,Removed: L2–L4 vertebral bodies.

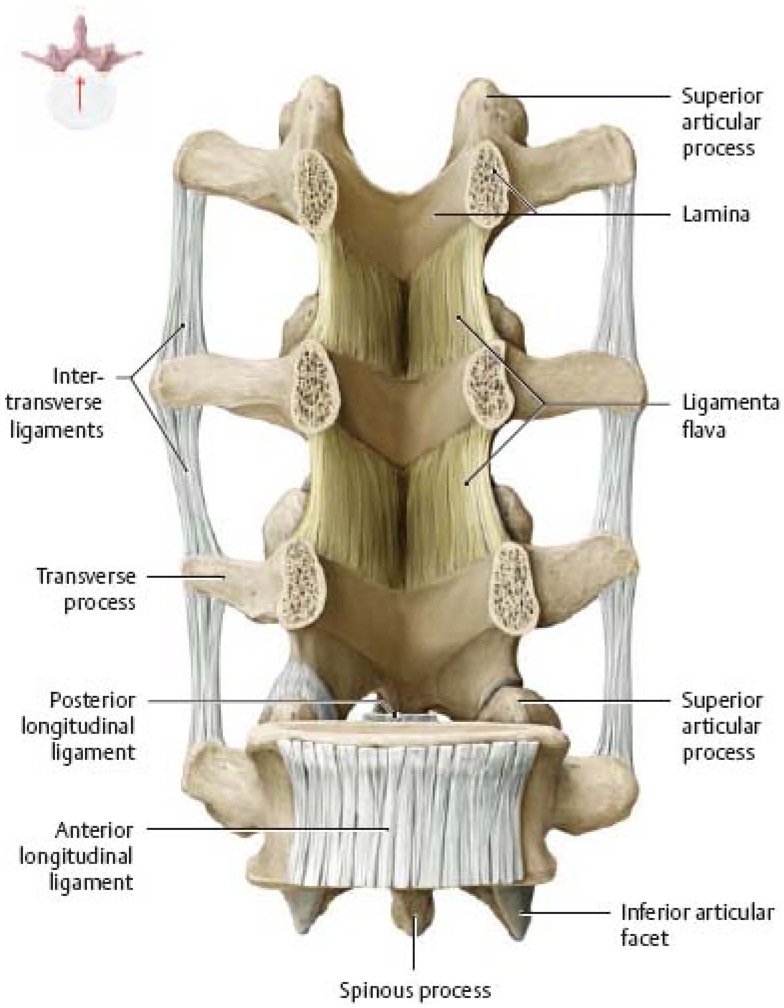
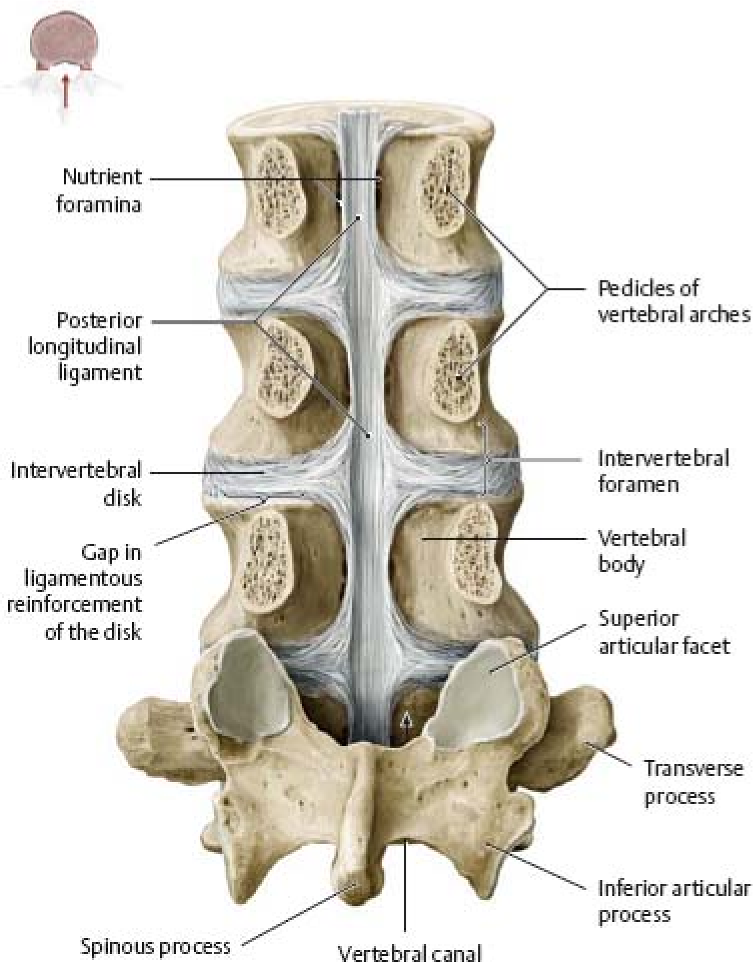


Fig. 1.34 **Posterior longitudinal ligament**

Posterior view of opened vertebral canal at level of L2–L5. *Removed:* L2–L4 vertebral arches at pedicular level.


Nutrient foramina
Posterior longitudinal ligament
Intervertebral disk
Gap in ligamentous reinforcement of the disk
Pedicles of vertebral arches
Intervertebral foramen
Vertebral body
Superior articular facet
Transverse process
Inferior articular process
Spinous process
Vertebral canal

2 Muscles

Muscles of the Back: Overview

The muscles of the back are divided into two groups, the extrinsic and the intrinsic muscles, which are separated by the superficial layer of the thoracolumbar fascia. The superficial extrinsic muscles are considered muscles of the upper limb that have migrated to the back; these muscles are discussed in Unit 4.

Fig. 2.1 Superficial (extrinsic) muscles of the back

Posterior view. *Removed:* Trapezius and latissimus dorsi (right). *Revealed:* Thoracolumbar fascia. *Note:* The superficial layer of the thoracolumbar fascia is reinforced by the aponeurotic origin of the latissimus dorsi.

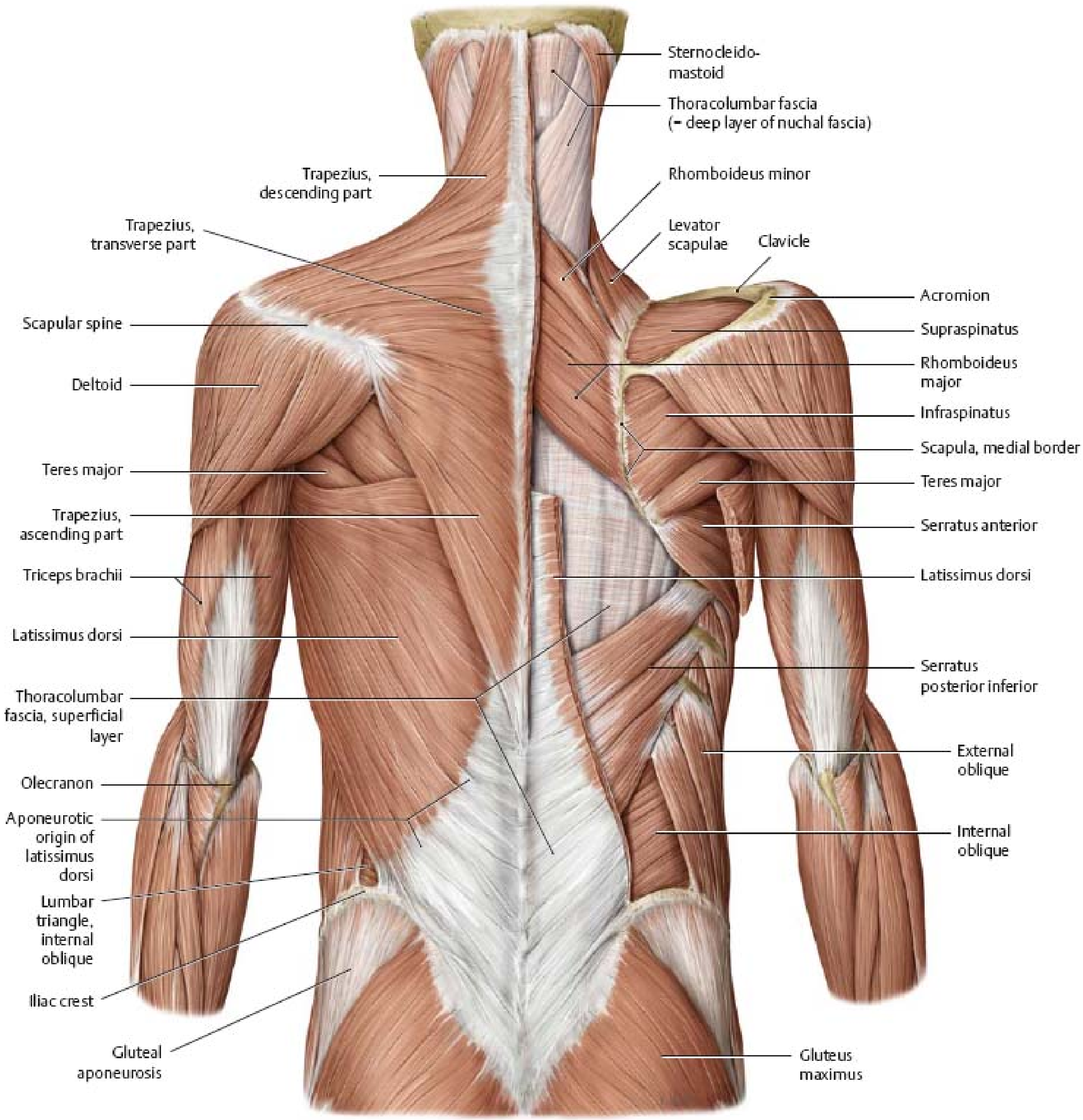
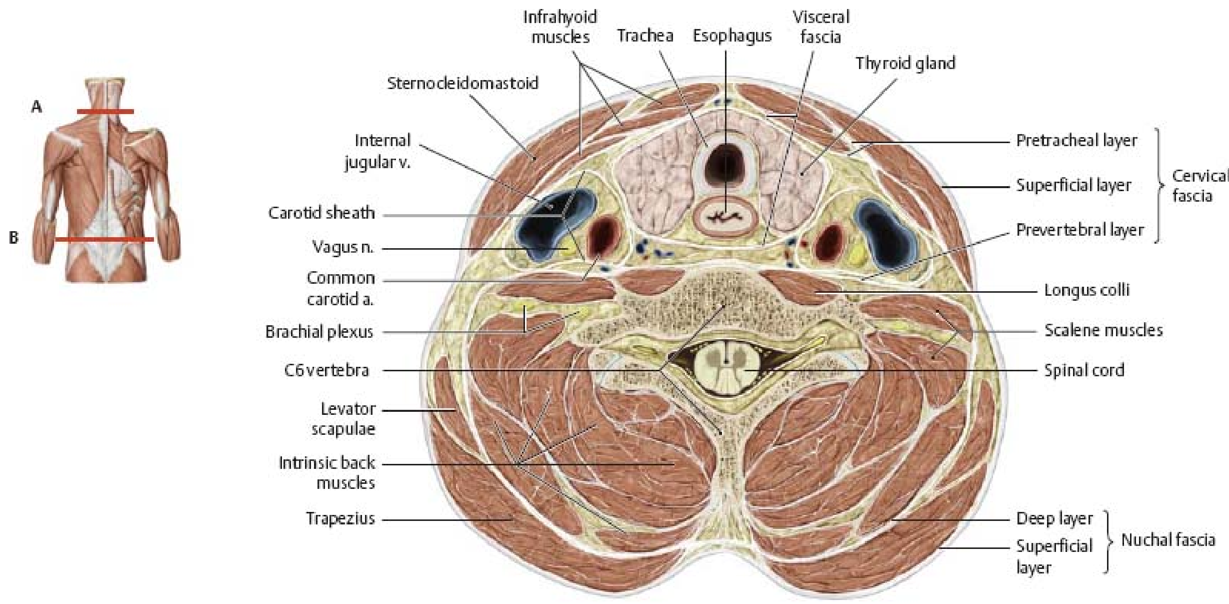
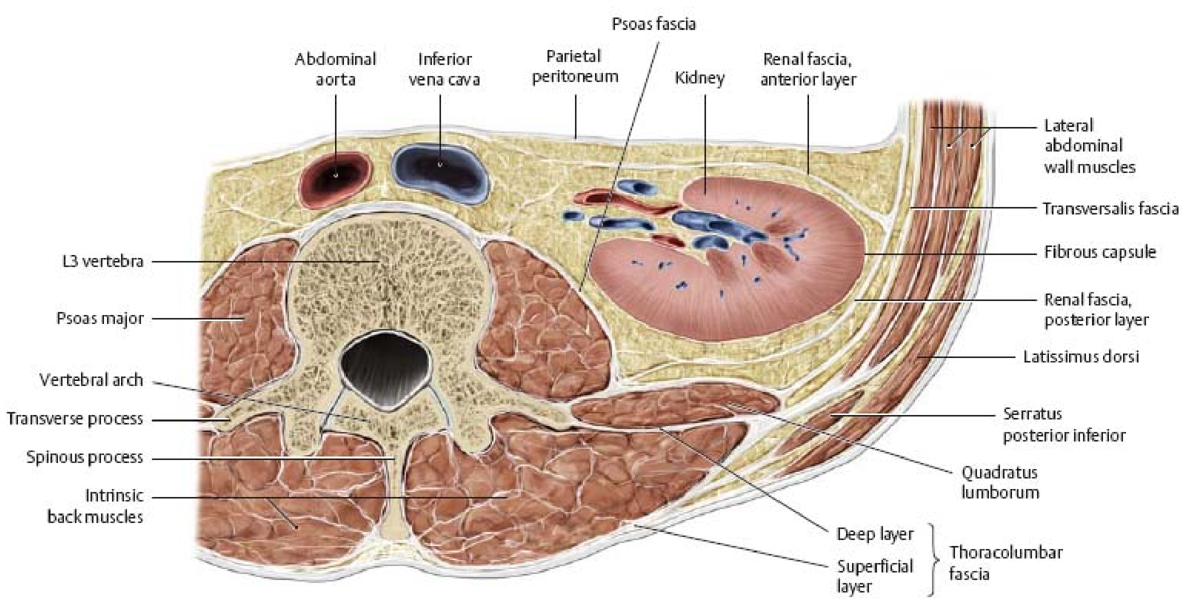


Fig. 2.2 Thoracolumbar fascia

Transverse section, superior view. The intrinsic back muscles are sequestered in an osseofibrous canal, formed by the thoracolumbar fascia, the vertebral arches, and the spinous and transverse processes of associated vertebrae. The thoracolumbar fascia consists of a superficial and a deep layer that unite at the lateral margin of the intrinsic back muscles. In the neck, the superficial layer blends with the nuchal fascia (deep layer), becoming continuous with the cervical fascia (prevertebral layer).



A Transverse section at level of C6 vertebra, superior view.



B Transverse section at level of L3, superior view.
Removed: Cauda equina and anterior trunk wall.

Intrinsic Muscles of the Cervical Spine

Fig. 2.3 Muscles in the nuchal region

Posterior view. *Removed:* Trapezius, sternocleidomastoid, splenius, and semispinalis muscles (right). *Revealed:* Nuchal muscles (right).

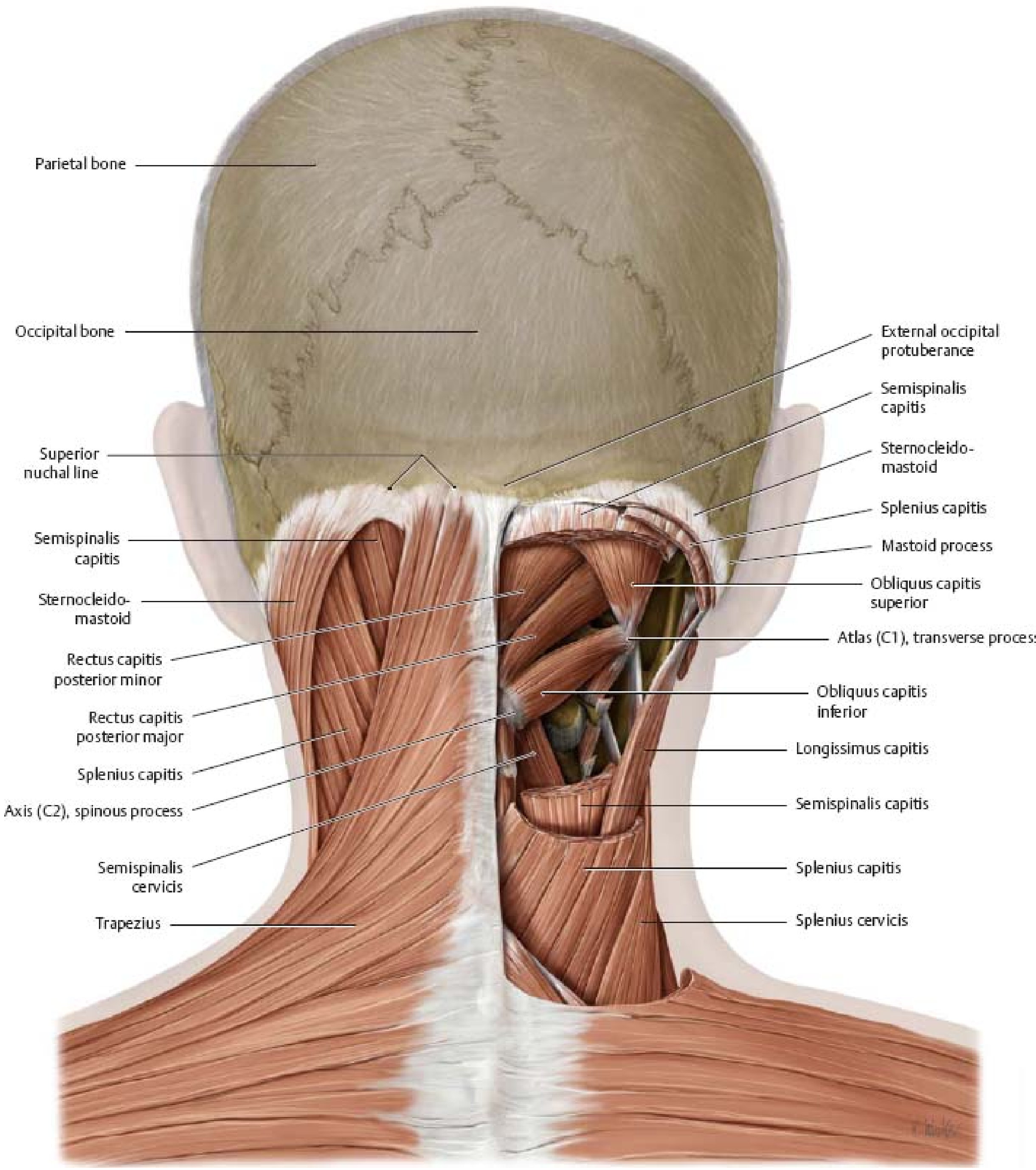
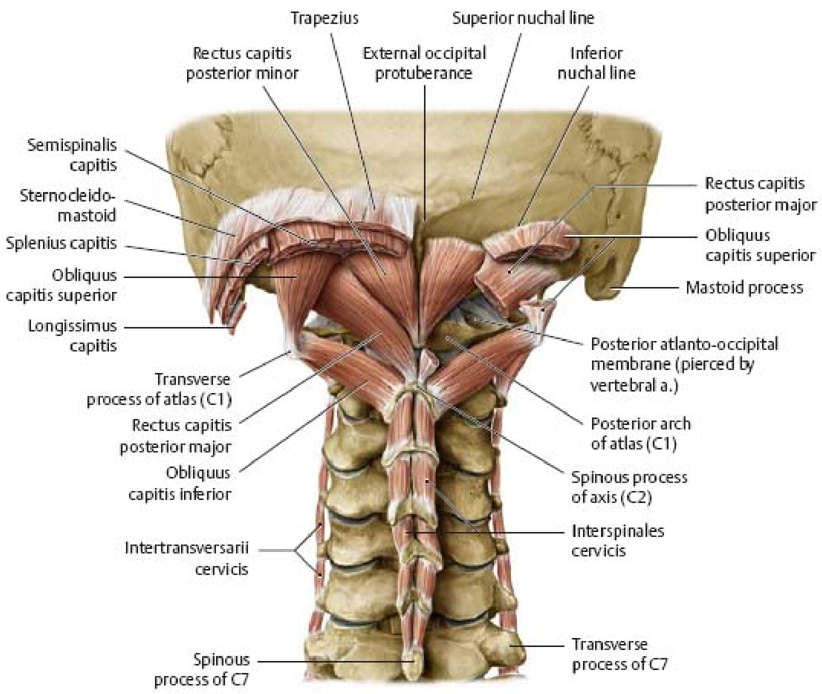
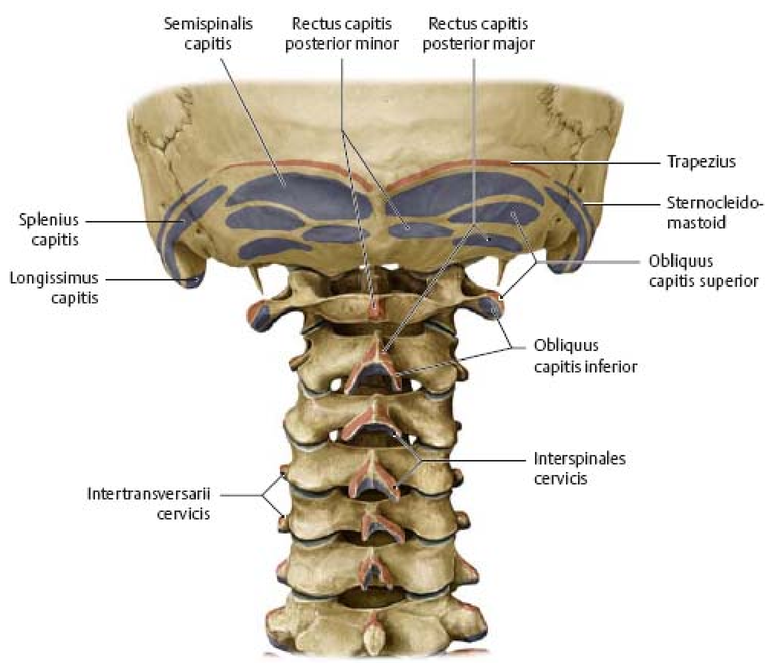


Fig. 2.4 **Short nuchal muscles**

Posterior view. See Fig. 2.6.



A Course of the short nuchal muscles.



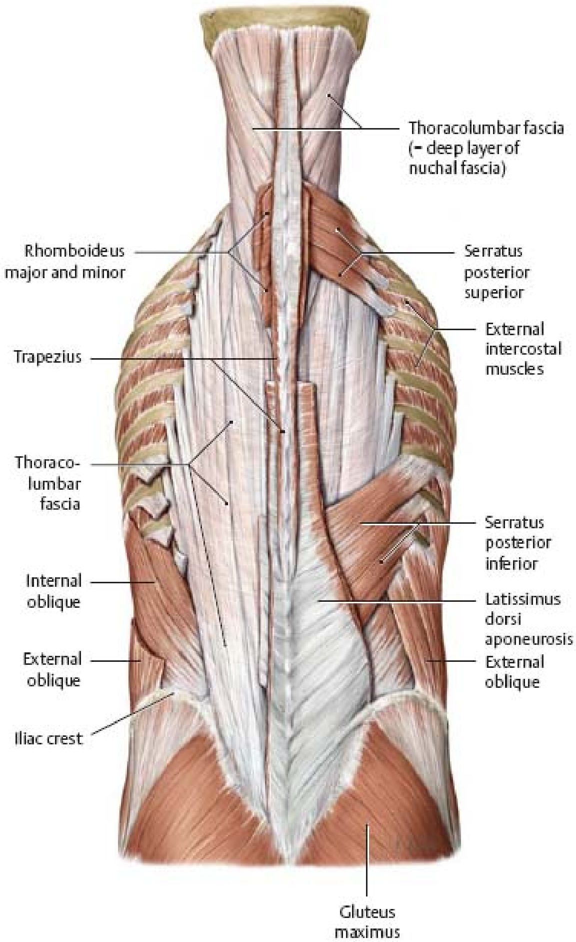
B Origins (red) and insertions (blue) in the suboccipital region.

Intrinsic Muscles of the Back

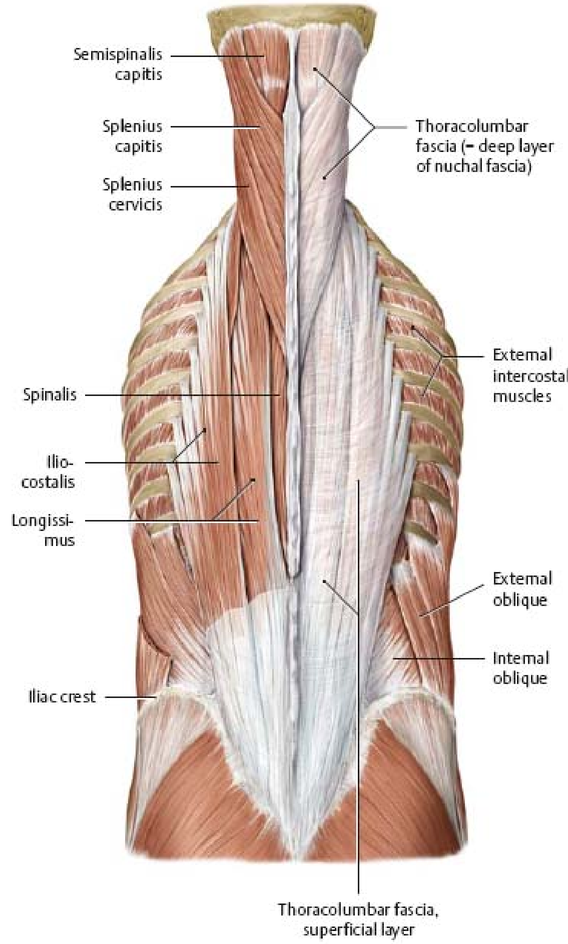
The extrinsic muscles of the back (trapezius, latissimus dorsi, levator scapulae, and rhomboids) are discussed in Unit 4. The serratus posterior, considered an intermediate extrinsic back muscle, has been included with the superficial intrinsic muscles in this unit.

Fig. 2.5 **Intrinsic muscles of the back**

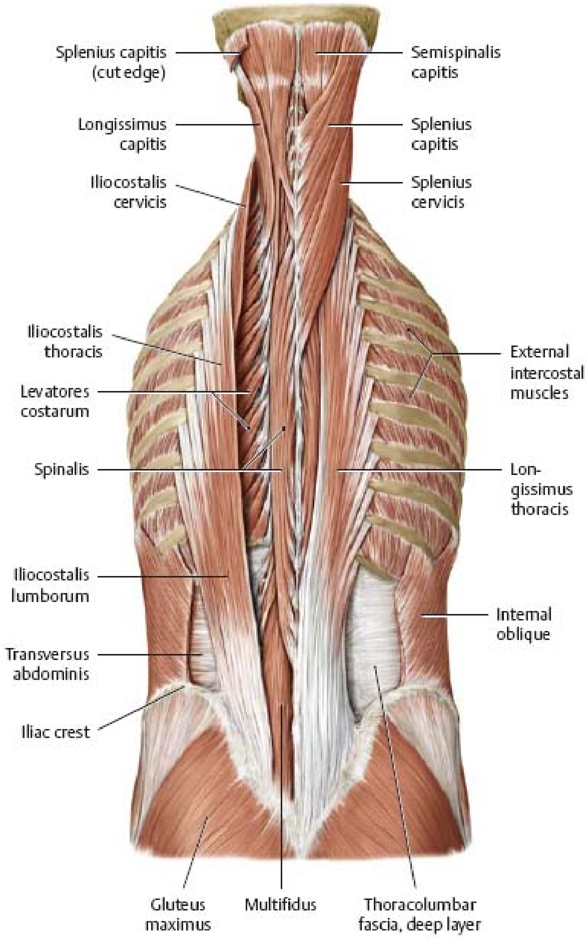
Posterior view. Sequential dissection of the thoracolumbar fascia, superficial intrinsic muscles, intermediate intrinsic muscles, and deep intrinsic muscles of the back.



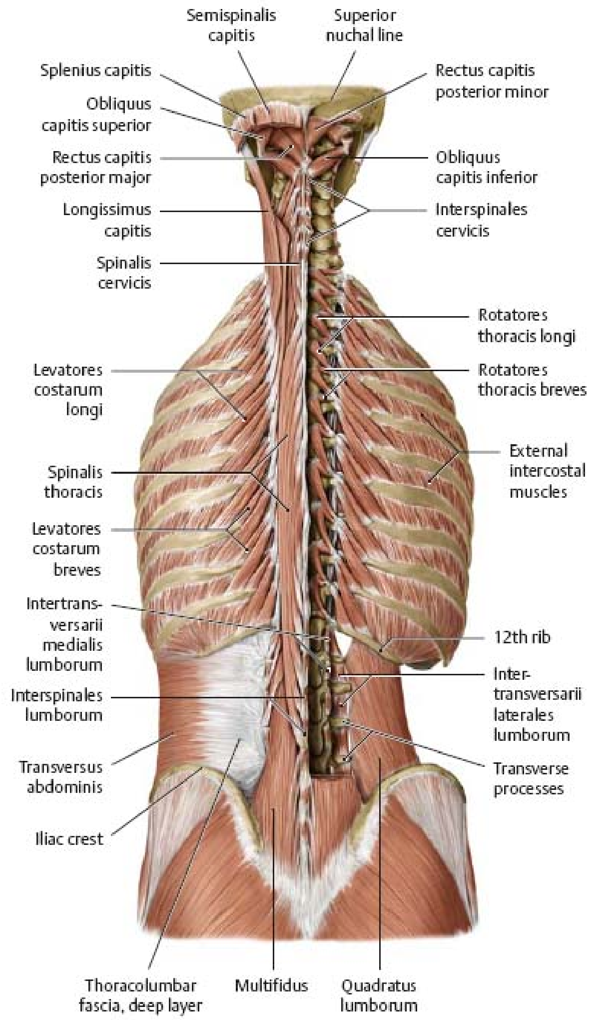
A Thoracolumbar fascia. *Removed:* Shoulder girdles and extrinsic back muscles (except serratus posterior and aponeurotic origin of latissimus dorsi). *Revealed:* Superficial layer of thoracolumbar fascia.



B Superficial and intermediate intrinsic back muscles. *Removed:* Thoracolumbar fascia (left). *Revealed:* Erector spinae and splenius muscles.



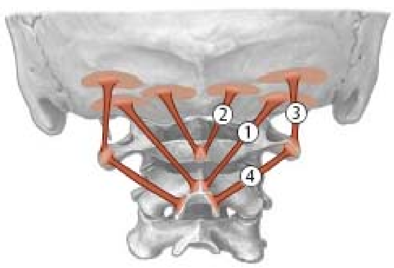
C Intermediate and deep intrinsic back muscles. *Removed:* Longissimus thoracis and cervicis, splenius muscles (left); iliocostalis (right). *Note:* The deep layer of the thoracolumbar fascia gives origin to the internal oblique and transversus abdominus. *Revealed:* Deep muscles of the back.



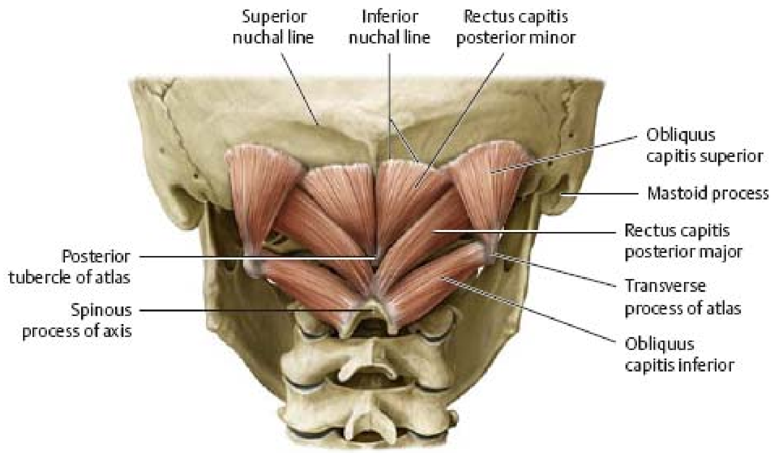
D Deep intrinsic back muscles. *Removed:* Superficial and intermediate intrinsic back muscles (all); deep fascial layer and multifidus (right). *Revealed:* Intertransversarii and quadratus lumborum (right).

Muscle Facts (I)

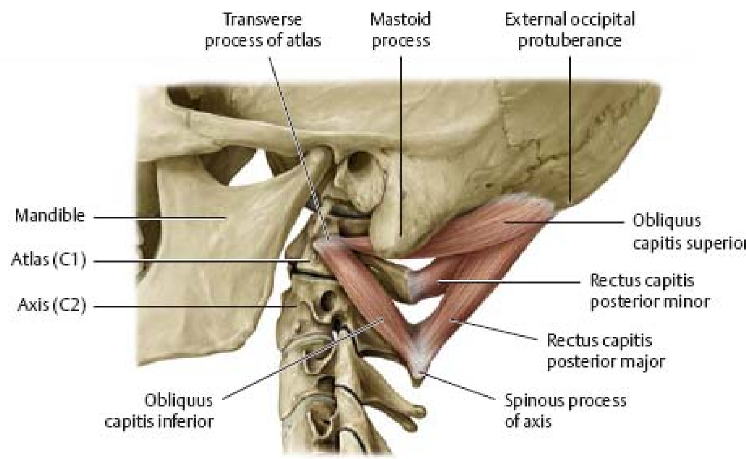
Fig. 2.6 Short nuchal and craniovertebral joint muscles



A Posterior view.



B Suboccipital muscles, posterior view.

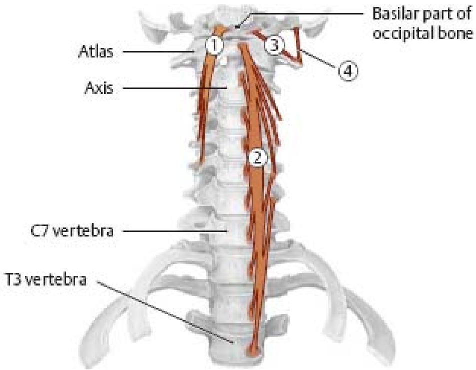


C Suboccipital muscles, left lateral view.

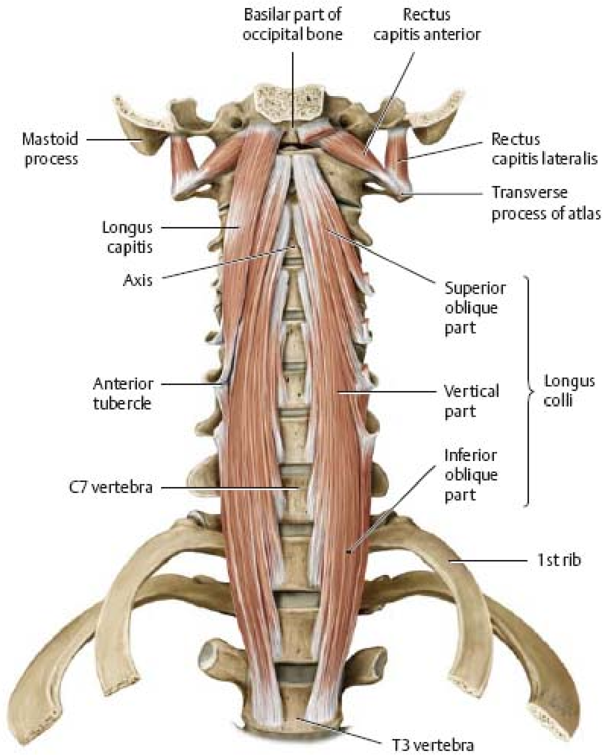
Table 2.1 Short nuchal and craniovertebral joint muscles

Muscle		Origin	Insertion	Innervation	Action
Rectus capitis posterior	① Rectus capitis posterior major	C2 (spinous process)	Occipital bone (inferior nuchal line, middle third)	C1 (posterior ramus = suboccipital n.)	*Bilateral:* Extends head *Unilateral:* Rotates head to same side
	② Rectus capitis posterior minor	C1 (posterior tubercle)	Occipital bone (inferior nuchal line, inner third)		
Obliquus capitis	③ Obliquus capitis superior	C1 (transverse process)	Occipital bone (inferior nuchal line, middle third; above rectus capitis posterior major)		*Bilateral:* Extends head *Unilateral:* Tilts head to same side; rotates to opposite side
	④ Obliquus capitis inferior	C2 (spinous process)	C1 (transverse process)		*Bilateral:* Extends head *Unilateral:* Rotates head to same side

Fig. 2.7 Prevertebral muscles



A Anterior view.



B Prevertebral muscles, anterior view. *Removed:* Longus capitis (left); cervical viscera.

Table 2.2 Prevertebral muscles

Muscle		Origin	Insertion	Innervation	Action
① Longus capitis		C3–C6 (transverse processes, anterior tubercles)	Occipital bone (basilar part)	Direct branches from cervical plexus (C1–C3)	*Bilateral:* Flexes head *Unilateral:* Tilts and slightly rotates head to same side
② Longus colli (cervicis)	Vertical (medial) part	C5–T3 (anterior sides of vertebral bodies)	C2–C4 (anterior sides of vertebral bodies)	Direct branches from cervical plexus (C2–C6)	*Bilateral:* Flexes cervical spine *Unilateral:* Tilts and rotates cervical spine to same side
	Superior oblique part	C3–C5 (transverse processes, anterior tubercles)	C1 (transverse process, anterior tubercle)		
	Inferior oblique part	T1–T3 (anterior sides of vertebral bodies)	C5–C6 (transverse processes, anterior tubercles)		
Rectus capitis	③ Rectus capitis anterior	C1 (lateral mass)	Occipital bone (basilar part)	C1 (anterior ramus)	*Bilateral:* Flexion at atlanto-occipital joint *Unilateral:* Lateral flexion at atlanto-occipital joint
	④ Rectus capitis lateralis	C1 (transverse process)	Occipital bone (basilar part, lateral to occipital condyles)		

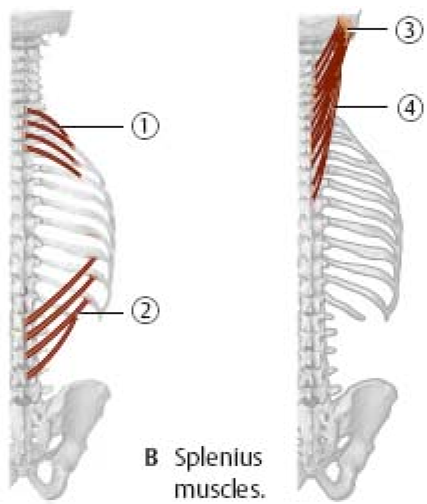
Muscle Facts (II)

The intrinsic back muscles are divided into superficial, intermediate, and deep layers. The posterior serratus muscles are extrinsic back muscles, innervated by the ventral rami of intercostal nerves, not the dorsal rami, which innervate the intrinsic back muscles. They are included here as they are encountered in dissection of the back musculature.

Table 2.3	Superficial intrinsic back muscles				
Muscle		**Origin**	**Insertion**	**Innervation**	**Action**
Posterior serratus	① Posterior serratus superior	Ligamentum nuchae; C7–T3 (spinous processes)	2nd–4th ribs (superior borders)	2nd–5th intercostal nn.	Elevates ribs
	② Posterior serratus inferior	T11–L2 (spinous processes)	8th–12th ribs (inferior borders, near angles)	Spinal nn. T9–T12 (anterior rami)	Depresses ribs
Splenius	③ Splenius capitis	Ligamentum nuchae; C7–T3 (spinous processes)	Occipital bone (lateral superior nuchal line; mastoid process)	Spinal nn. C1–C6 (posterior rami, lateral branches)	*Bilateral:* Extends cervical spine and head *Unilateral:* Flexes and rotates head to the same side
	④ Splenius cervicis	T3–T6 (spinous processes)	C1–C2 (transverse processes)		

Fig. 2.8 Superficial intrinsic back muscles (schematic)

Right side, posterior view.

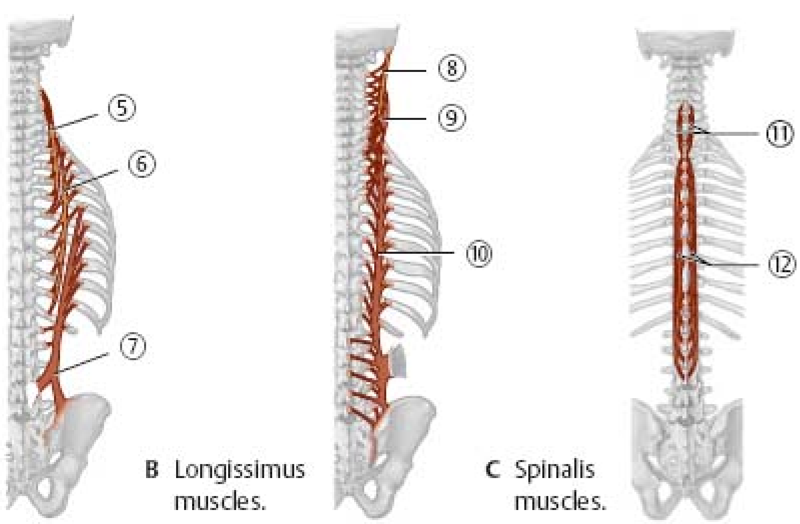


A Posterior serratus.

B Splenius muscles.

Fig. 2.9 Intermediate intrinsic back muscles (schematic)

Right side, posterior view. These muscles are collectively known as the erector spinae.



A Iliocostalis muscles.

B Longissimus muscles.

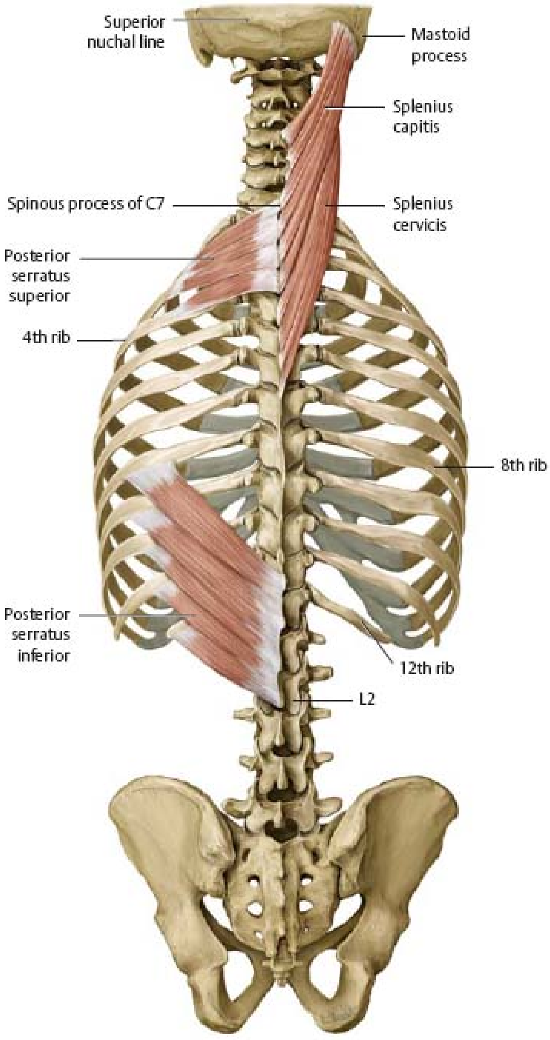
C Spinalis muscles.

Table 2.4 Intermediate intrinsic back muscles

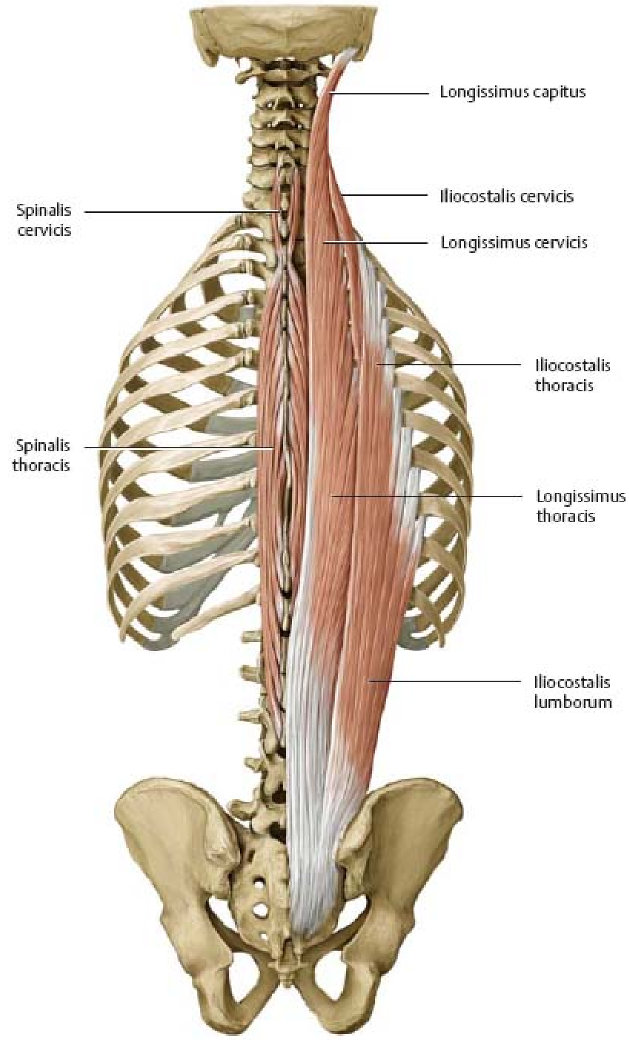
Muscle		Origin	Insertion	Innervation	Action
Iliocostalis	⑤ Iliocostalis cervicis	3rd–7th ribs	C4–C6 (transverse processes)	Spinal nn. C8–L1 (posterior rami, lateral branches)	*Bilateral:* Extends spine *Unilateral:* Bends spine laterally to same side
	⑥ Iliocostalis thoracis	7th–12th ribs	1st–6th ribs		
	⑦ Iliocostalis lumborum	Sacrum; iliac crest; thoracolumbar fascia	6th–12th ribs; thoracolumbar fascia (deep layer); upper lumbar vertebrae (transverse processes)		
Longissimus	⑧ Longissimus capitis	T1–T3 (transverse processes); C4-C7 (transverse and articular processes)	Temporal bone (mastoid process)	Spinal nn. C1–L5 (posterior rami, lateral branches)	*Bilateral:* Extends head *Unilateral:* Flexes and rotates head to same side
	⑨ Longissimus cervicis	T1–T6 (transverse processes)	C2–C5 (transverse processes)		*Bilateral:* Extends spine *Unilateral:* Bends spine laterally to same side
	⑩ Longissimus thoracis	Sacrum; iliac crest; lumbar vertebrae (spinous processes); lower thoracic vertebrae (transverse processes)	2nd–12th ribs; lumbar vertebrae (costal processes); thoracic vertebrae (transverse processes)		
Spinalis	⑪ Spinalis cervicis	C5–T2 (spinous processes)	C2–C5 (spinous processes)	Spinal nn. (posterior rami)	*Bilateral:* Extends cervical and thoracic spine *Unilateral:* Bends cervical and thoracic spine to same side
	⑫ Spinalis thoracis	T10–L3 (spinous processes, lateral surfaces)	T2–T8 (spinous processes, lateral surfaces)		

Fig. 2.10 **Superficial and intermediate intrinsic back muscles**

Posterior view.



A Splenius and posterior serratus muscles.



B Erector spinae: Iliocostalis, longissimus, and spinalis muscles.

Muscle Facts (III)

The deep intrinsic back muscles are divided into two groups: transversospinal and deep segmental muscles. The transversospinalis muscles pass between the transverse and spinous processes of the vertebrae.

Table 2.5 Transversospinalis muscles

Muscle		Origin	Insertion	Innervation	Action
Rotatores	① Rotatores brevis	T1–T12 (between transverse and spinous processes of adjacent vertebrae)		Spinal nn. (posterior rami)	*Bilateral:* Extends throacic spine *Unilateral:* Rotates spine to opposite side
	② Rotatores longi	T1–T12 (between transverse and spinous processes, skipping one vertebra)			
Multifidus ③		C2–sacrum (between transverse and spinous processes, skipping two to four vertebrae)			*Bilateral:* Extends spine *Unilateral:* Flexes spine to same side, rotates to opposite side
Semispinalis	④ Semispinalis capitis	C4–T7 (transverse and articular processes)	Occipital bone (between superior and inferior nuchal lines)		*Bilateral:* Extends thoracic and cervical spines and head (stabilizes craniovertebral joints)
	⑤ Semispinalis cervicis	T1–T6 (transverse processes)	C2–C5 (spinous processes)		*Unilateral:* Bends head, cervical and thoracic spines to same side, rotates to opposite side
	⑥ Semispinalis thoracis	T6–T12 (transverse processes)	C6–T4 (spinous processes)		

Fig. 2.11 Transversospinalis muscles (schematic)

Posterior view.

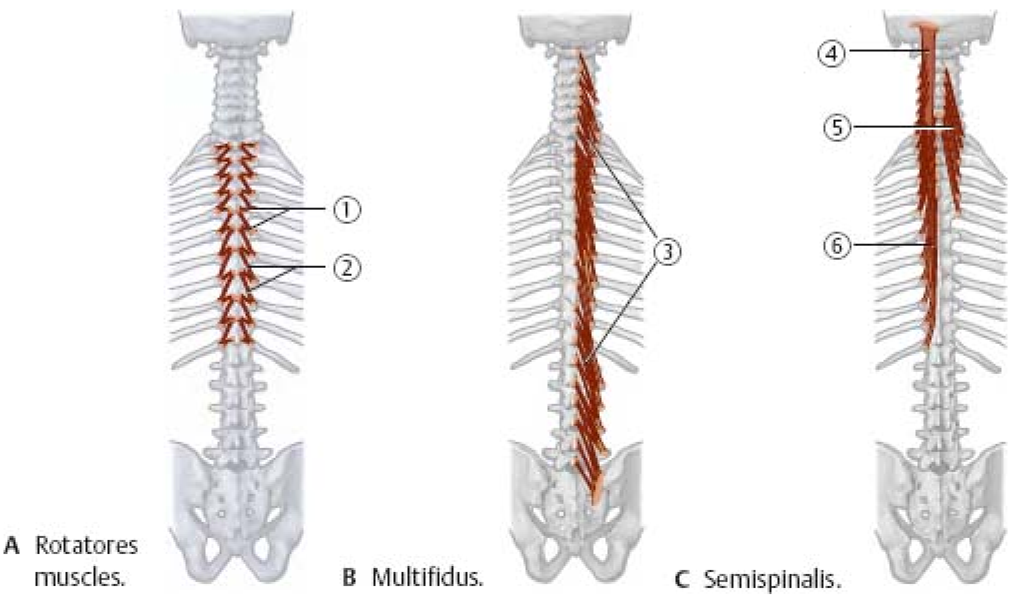


Fig. 2.12 Deep segmental muscles (schematic)

Posterior view.

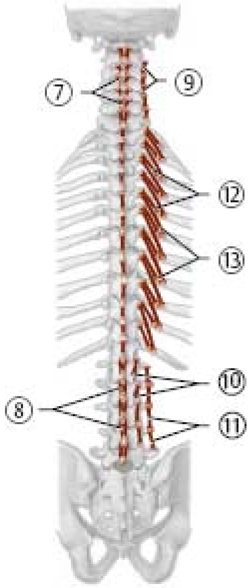
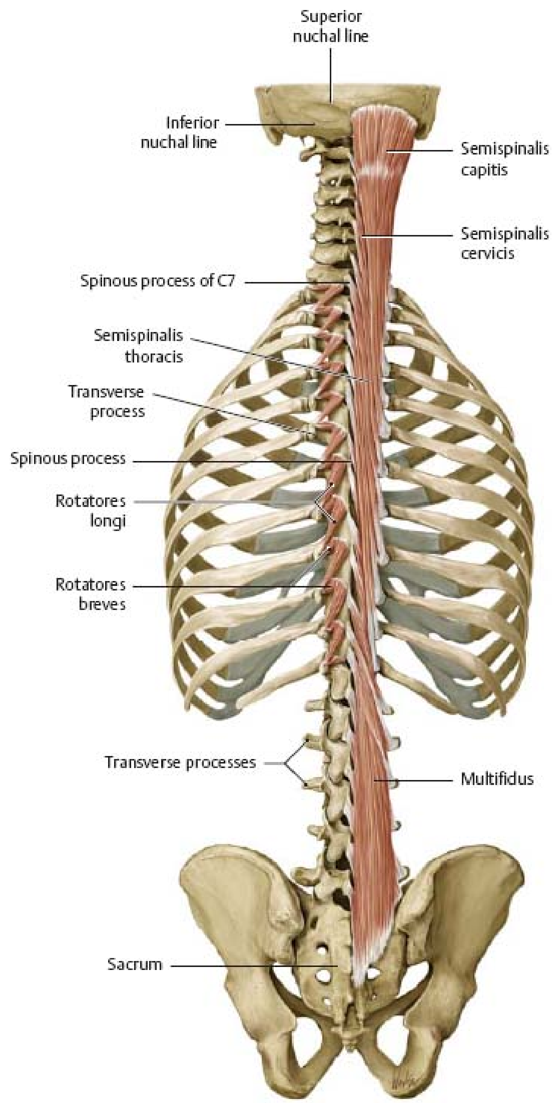


Table 2.6	Deep segmental back muscles				
Muscle		**Origin**	**Insertion**	**Innervation**	**Action**
Interspinales*	⑦ Interspinales cervicis	C1–C7 (between spinous processes of adjacent vertebrae)		Spinal nn. (posterior rami)	Extends cervical and lumbar spines
	⑧ Interspinales lumborum	L1–L5 (between spinous processes of adjacent vertebrae)			*Bilateral:* Stabilizes and extends the cervical and lumbar spines *Unilateral:* Bends the cervical and lumbar spines laterally to same side
Inter-transversarii*	Intertransversarii anteriores cervicis	C2–C7 (between anterior tubercles of adjacent vertebrae)		Spinal nn. (anterior rami)	
	⑨ Intertransversarii posteriores cervicis	C2–C7 (between posterior tubercles of adjacent vertebrae)		Spinal nn. (posterior rami)	
	⑩ Intertransversarii mediales lumborum	L1–L5 (between mammillary processes of adjacent vertebrae)			
	⑪ Intertransversarii laterales lumborum	L1–L5 (between transverse processes of adjacent vertebrae)			
Levatores costarum	⑫ Levatores costarum breves	C7–T11 (transverse processes)	Costal angle of next lower rib		*Bilateral:* Extends thoracic spine *Unilateral:* Bends thoracic spine to same side, rotates to opposite side
	⑬ Levatores costarum longi		Costal angle of rib two vertebrae below		

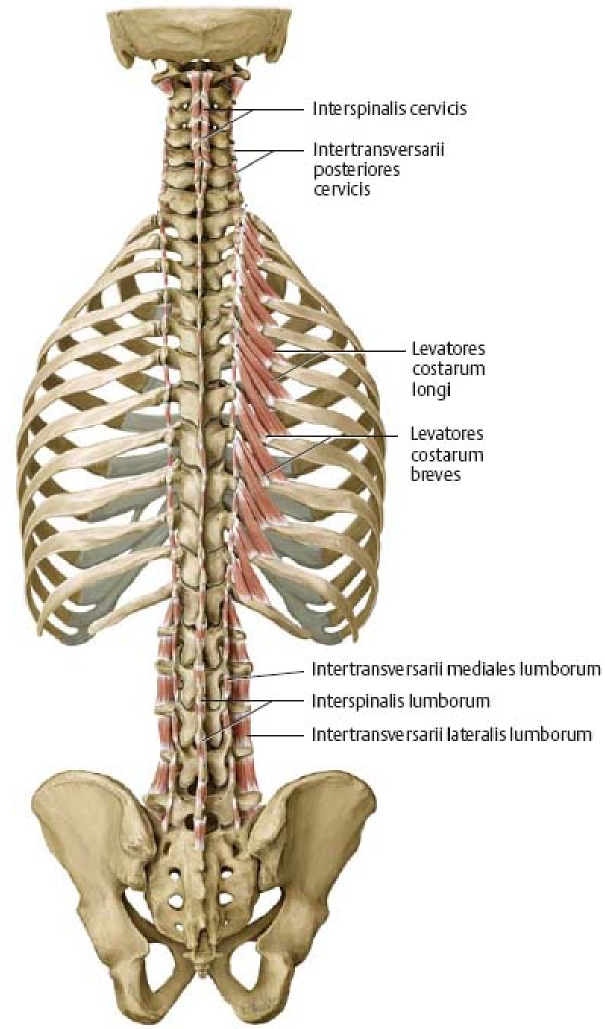
*Both the interspinales and intertransversarii muscles traverse the entire spine; only their clinically relevant components have been included.

Fig. 2.13 Deep intrinsic back muscles

Posterior view.



A Transversospinalis muscles: Rotatores, multifidus, and semispinalis.



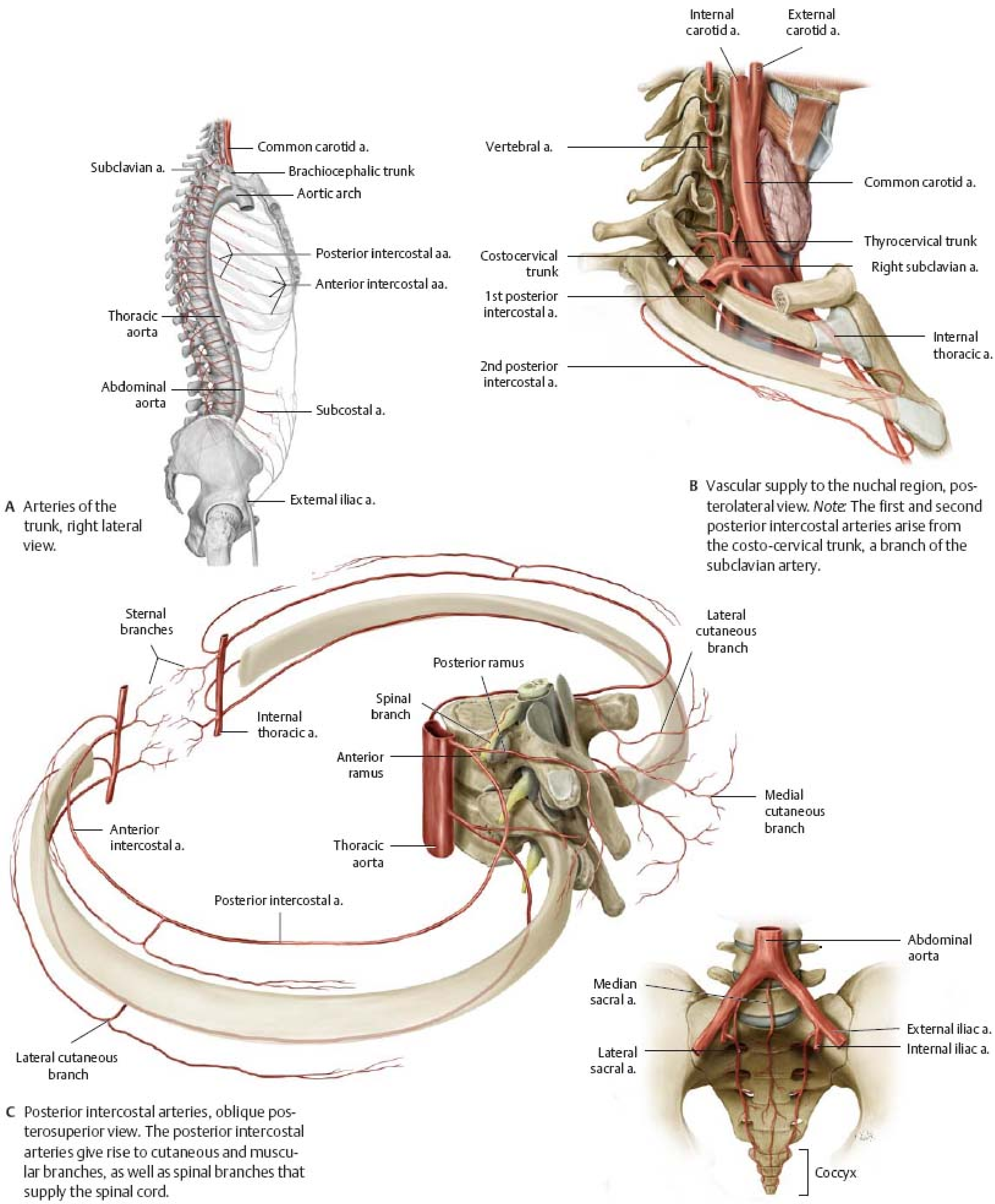
B Deep segmental muscles: Interspinales, intertransversarii, and levatores costarum.

3 Neurovasculature

Arteries & Veins of the Back

Fig. 3.1 Arteries of the back

The structures of the back are supplied by branches of the posterior intercostal arteries, which arise from the thoracic aorta or directly from the subclavian artery.



A Arteries of the trunk, right lateral view.

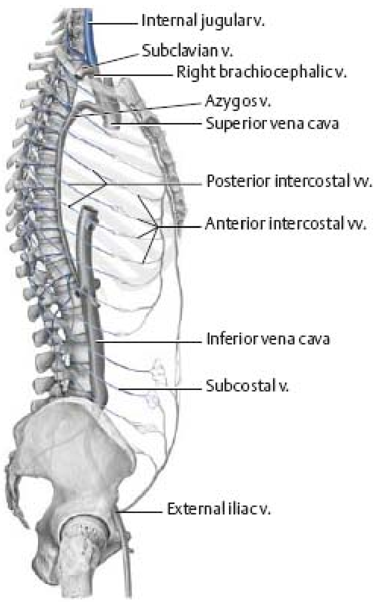
B Vascular supply to the nuchal region, posterolateral view. *Note*: The first and second posterior intercostal arteries arise from the costo-cervical trunk, a branch of the subclavian artery.

C Posterior intercostal arteries, oblique posterosuperior view. The posterior intercostal arteries give rise to cutaneous and muscular branches, as well as spinal branches that supply the spinal cord.

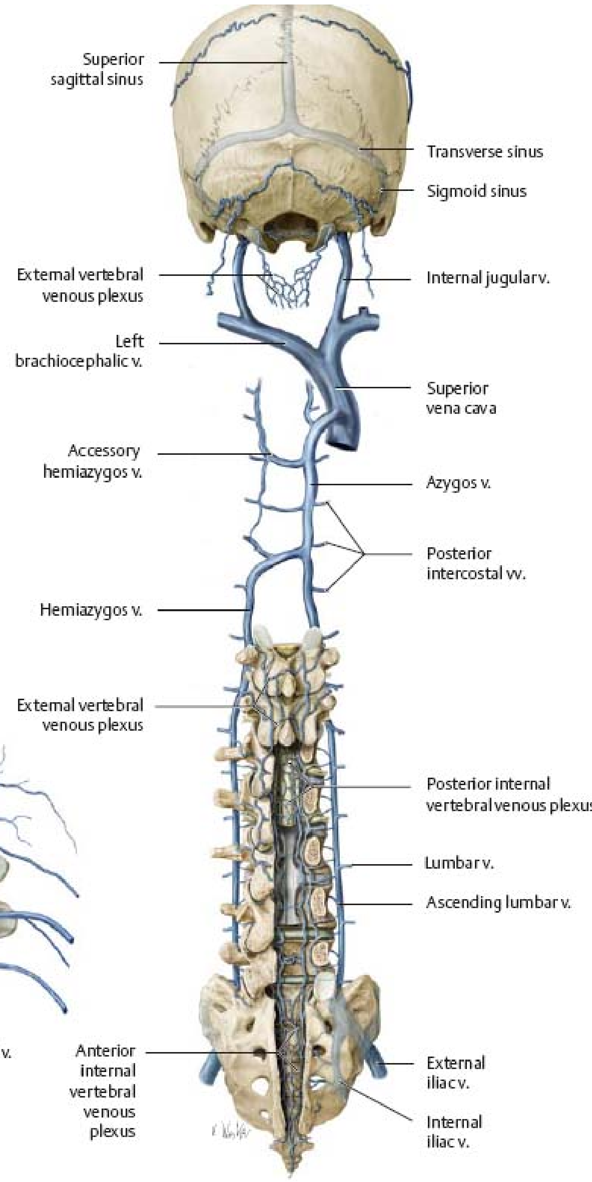
D Vascular supply to the sacrum, anterior view.

Fig. 3.2 Veins of the back

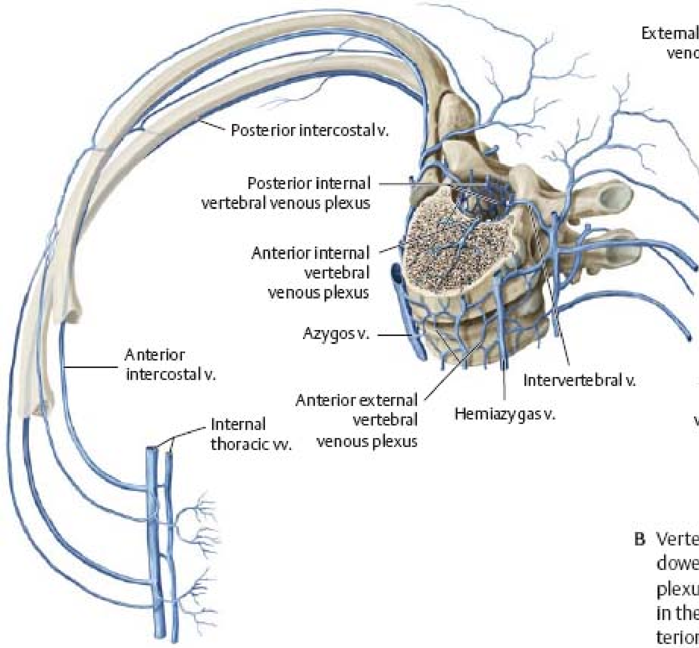
The veins of the back drain into the azygos vein via the superior intercostal veins, hemiazygos veins, and ascending lumbar veins. The interior of the spinal column is drained by the vertebral venous plexus that runs the length of the spine.



A Veins of the trunk, right lateral view.



B Vertebral venous plexus, posterior view with vertebral canal windowed in the lumbar and sacral spine. The external vertebral venous plexus communicates with the sigmoid sinus through emissary veins in the skull. The *external* vertebral venous plexus is divided into an anterior and a posterior portion that run along the exterior of the spinal column. The anterior and posterior *internal* vertebral venous plexus run in the vertebral foramen and drain the spinal cord.



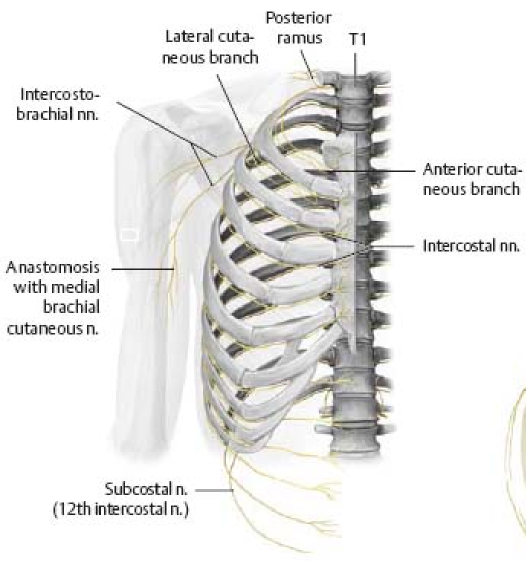
C Intercostal veins and anterior vertebral venous plexus, anterosuperior view. The intercostal veins follow a similar course as the intercostal nerves and arteries (see pp. 34, 36). *Note:* The anterior external vertebral venous plexus can be seen communicating with the azygos vein.

Nerves of the Back

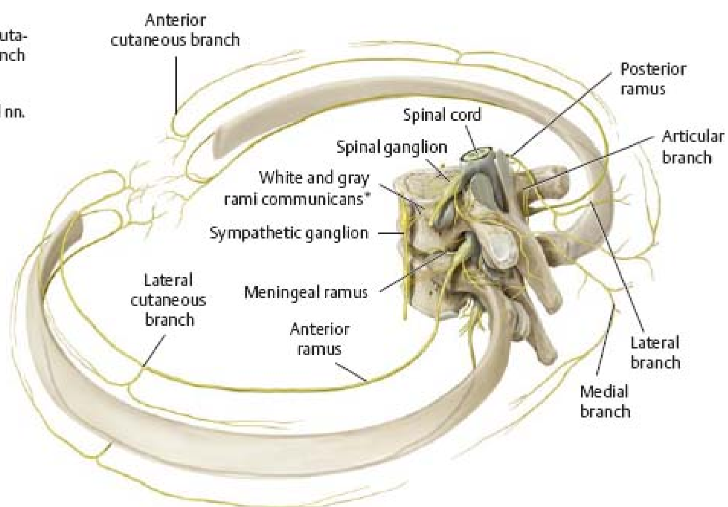
The back receives its innervation from branches of the spinal nerves. The *posterior* rami of the spinal nerves supply most of the intrinsic muscles of the back. The extrinsic muscles of the back are supplied by the *anterior* rami of the spinal nerves.

Fig. 3.3 Nerves of the back

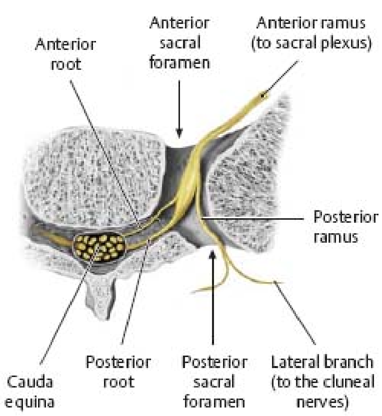
The anterior rami of spinal nerves T1–T11 form the intercostal nerves, which course along the ribs and give rise to lateral and anterior cutaneous branches.



A Course of the intercostal nerves.



B Spinal nerve branches, superior view. The *posterior* rami of the spinal nerves give rise to muscular and cutaneous branches, as well as articular branches to the zygapophyseal joints. The *anterior* rami of spinal nerves T1–T11 produce the intercostal nerves (T12 produces the subcostal nerve).



C Spinal nerve branches in the sacral foramina. Superior view of transverse section through right half of sacrum.

Table 3.1 Branches of a spinal nerve

Branches			Territory
Meningeal ramus			Spinal meninges; ligaments of spinal column
Posterior ramus	Medial branches	Articular branch	Zygapophyseal joints
		Muscular branch	Intrinsic back muscles
		Cutaneous branch	Skin of posterior head, neck, back, and buttocks
	Lateral branches	Cutaneous branch	
		Muscular branch	Intrinsic back muscles
Anterior ramus	Lateral cutaneous branches		Skin of lateral chest wall
	Anterior cutaneous branches		Skin of anterior chest wall

*The white and gray rami communicans carry pre- and postganglionic fibers between the sympathetic trunk and spinal nerve. They are shown on p. 622.

Fig. 3.4 Nerves of the nuchal region

Right side, posterior view. Like the back, the nuchal region receives most of its motor and sensory innervation from the *posterior* rami of the spinal nerves. The posterior rami of C1–C3 have specific names: suboccipital nerve (C1), greater occipital nerve (C2), and third occipital nerve (C3). The lesser occipital and great auricular nerves arise from the *anterior* rami of the C1–C4 spinal nerves and innervate the skin of the anterolateral head and neck. The anterior rami of C1–C4 also give rise to the *ansa cervicalis*, which innervates the infrahyoid muscles (see p. 562).

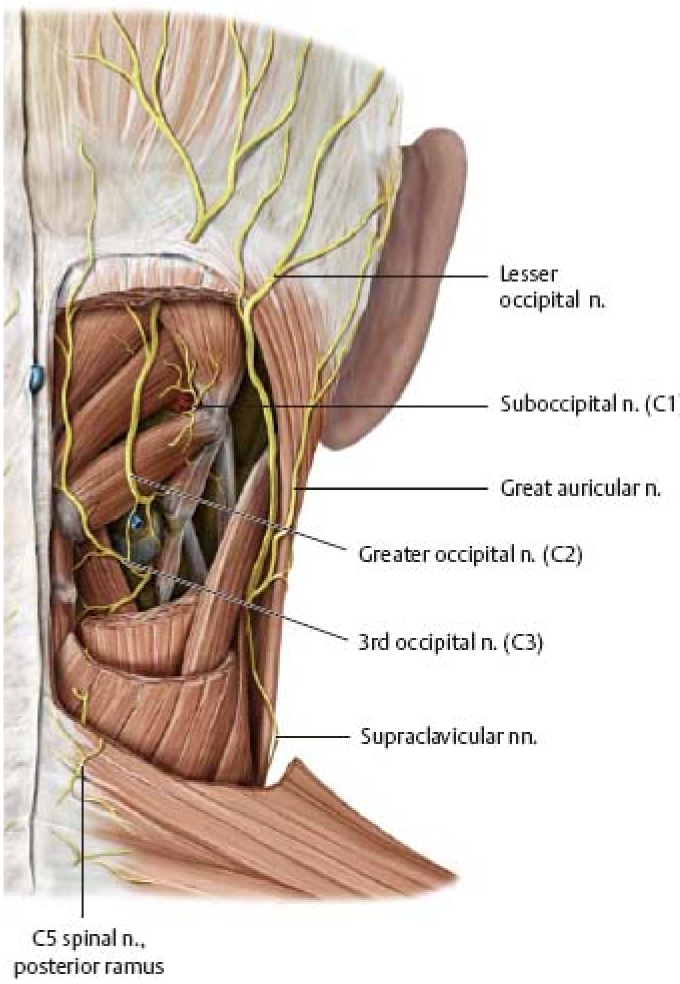
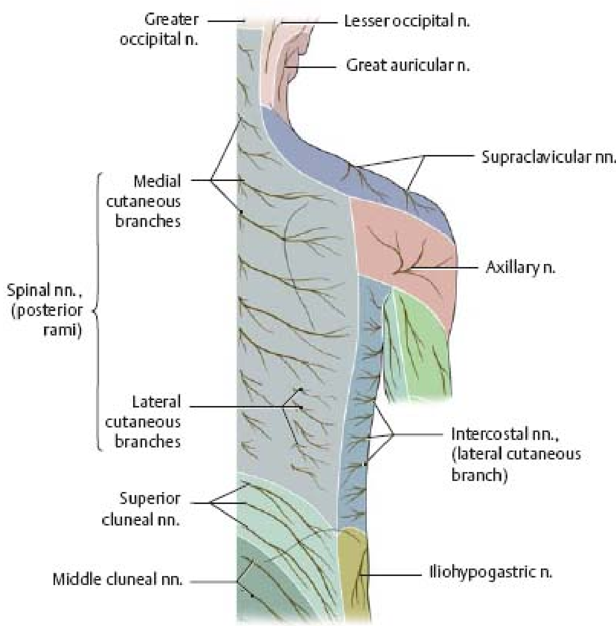
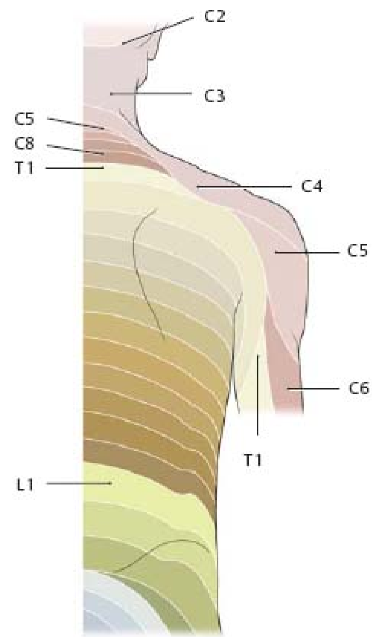


Fig. 3.5 **Cutaneous innervation of the back**



A Peripheral sensory cutaneous innervation of the back.



B Dermatomes: Segmental (radicular) cutaneous innervation of the back. *Note*: The posterior ramus of C1 is purely motor; there is consequently no C1 dermatome.

Neurovascular Topography of the Back

Fig. 3.6 Neurovasculature of the nuchal region

Posterior view. *Removed:* Trapezius, sternocleidomastoid, splenius capitis, and semispinalis capitis. *Revealed:* Suboccipital region. See p. 60 for the course of the intercostal vessels.

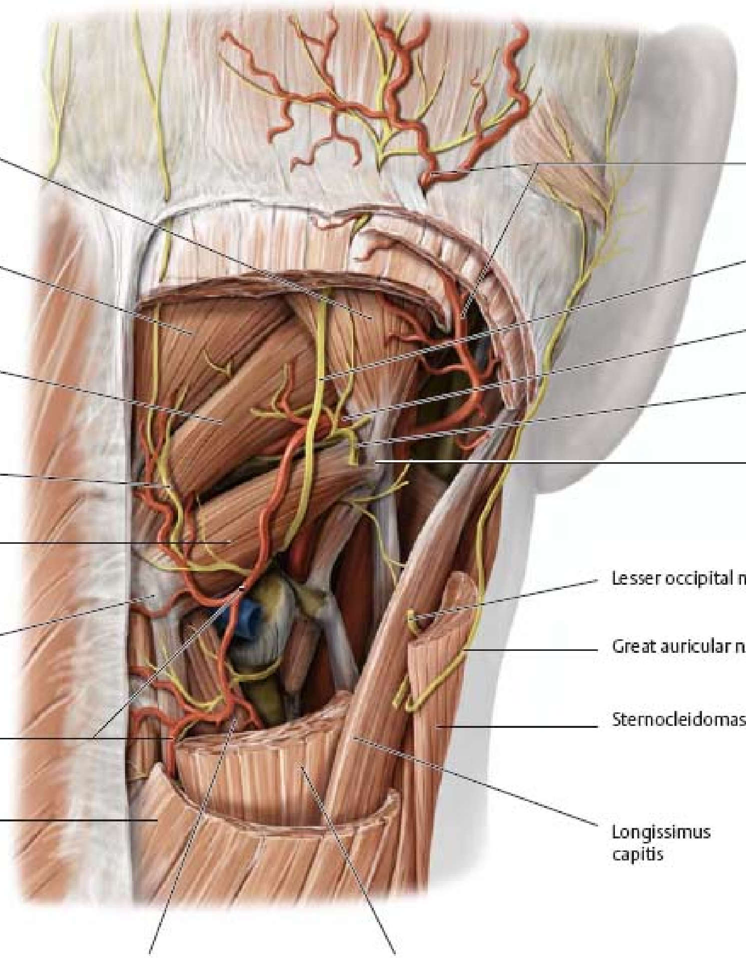
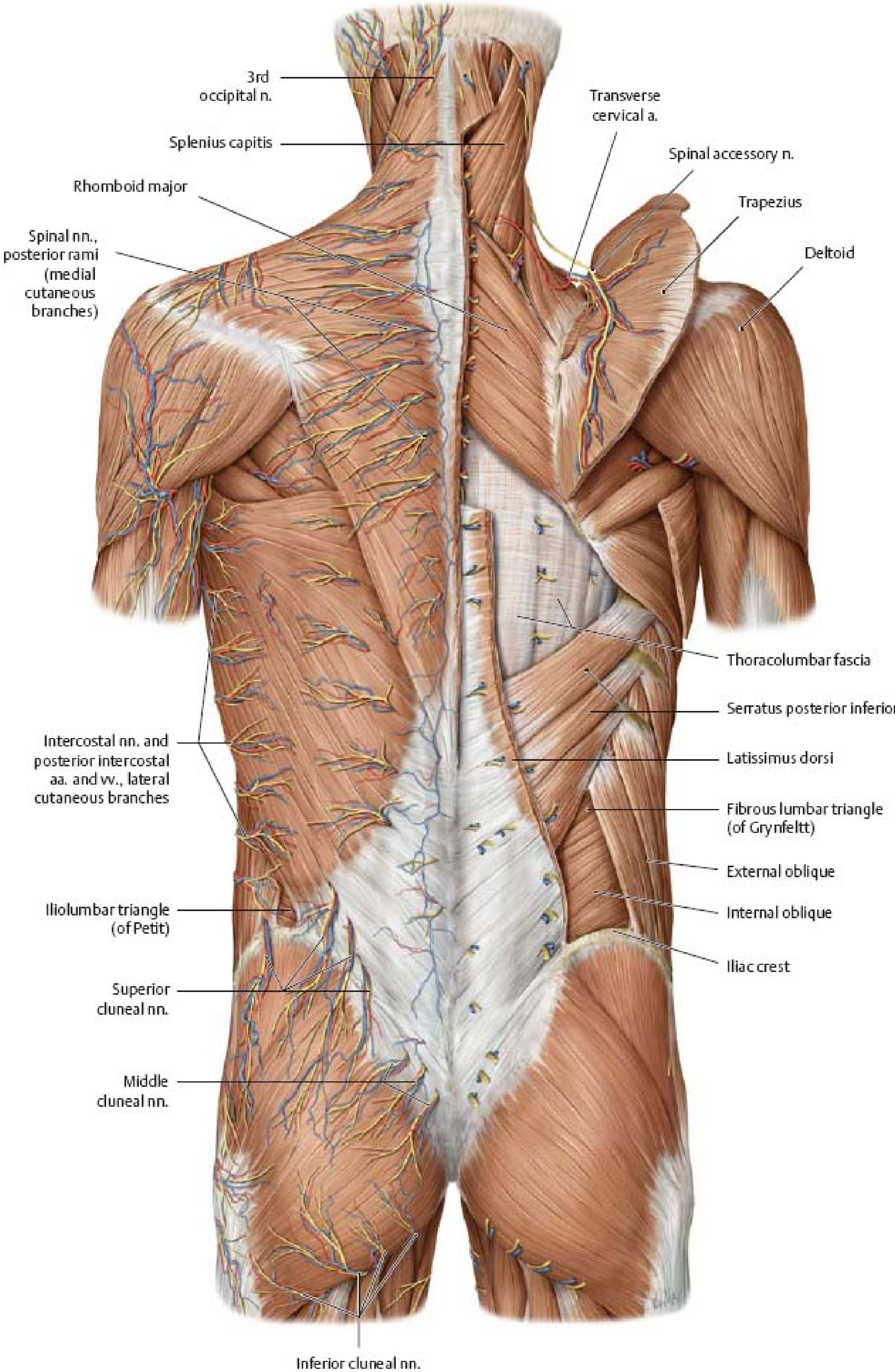


Fig. 3.7 **Neurovasculature of the back**

Posterior view. *Removed:* Muscle fascia (except superficial layer of thoracolumbar fascia); latissimus dorsi (right). *Reflected:* Trapezius (right). *Revealed:* Transverse cervical artery in the deep scapular region.


3rd
occipital n.
Splenius capitis
Rhomboid major
Spinal nn.,
posterior rami
(medial
cutaneous
branches)
Transverse
cervical a.
Spinal accessory n.
Trapezius
Deltoid
Thoracolumbar fascia
Serratus posterior inferior
Latissimus dorsi
Fibrous lumbar triangle
(of Grynfeltt)
External oblique
Internal oblique
Iliac crest
Intercostal nn. and
posterior intercostal
aa. and vv., lateral
cutaneous branches
Iliolumbar triangle
(of Petit)
Superior
cluneal nn.
Middle
cluneal nn.
Inferior cluneal nn.

4 Surface Anatomy

Surface Anatomy

Fig. 4.1 Palpable structures in the back

Posterior view.

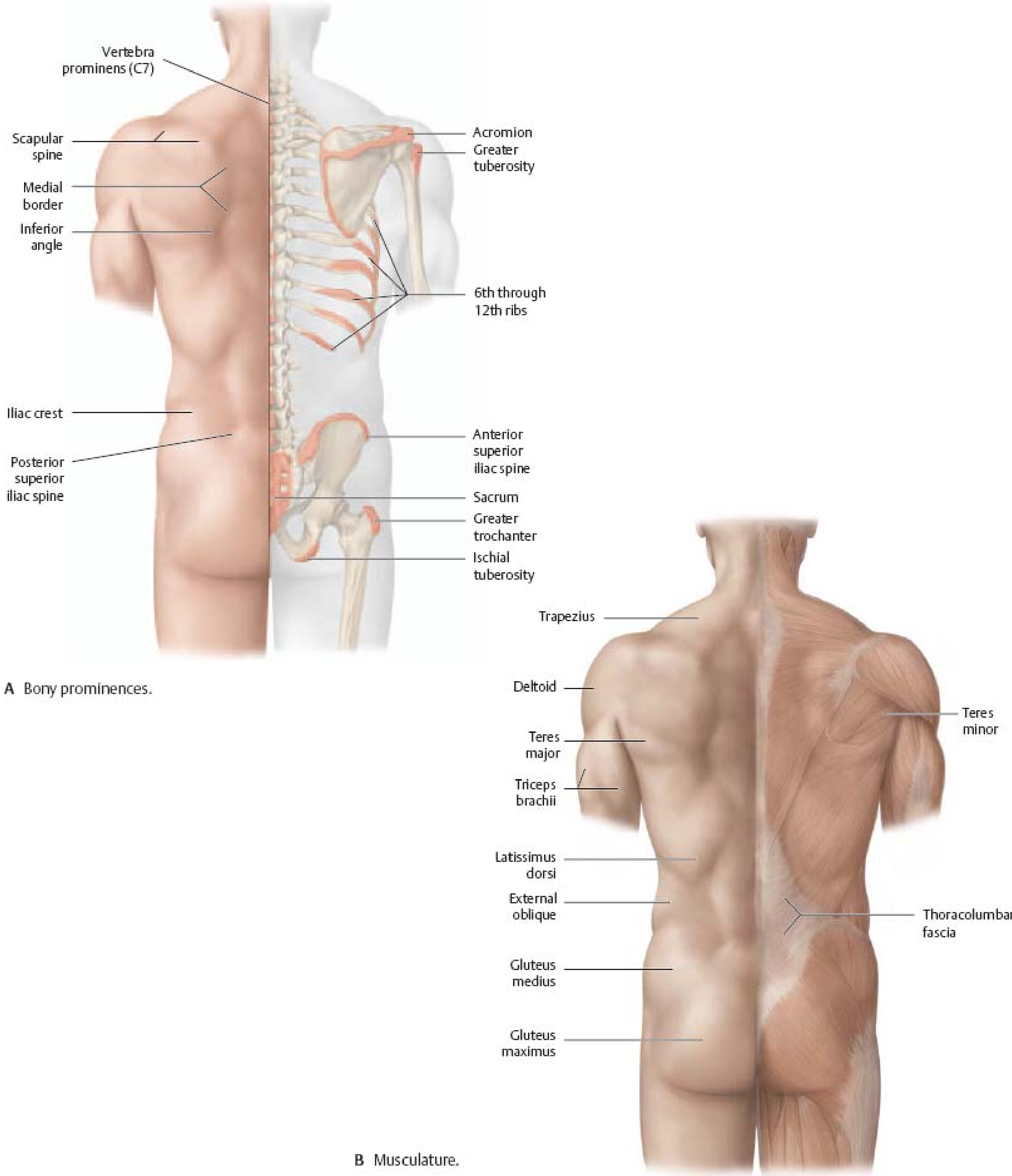
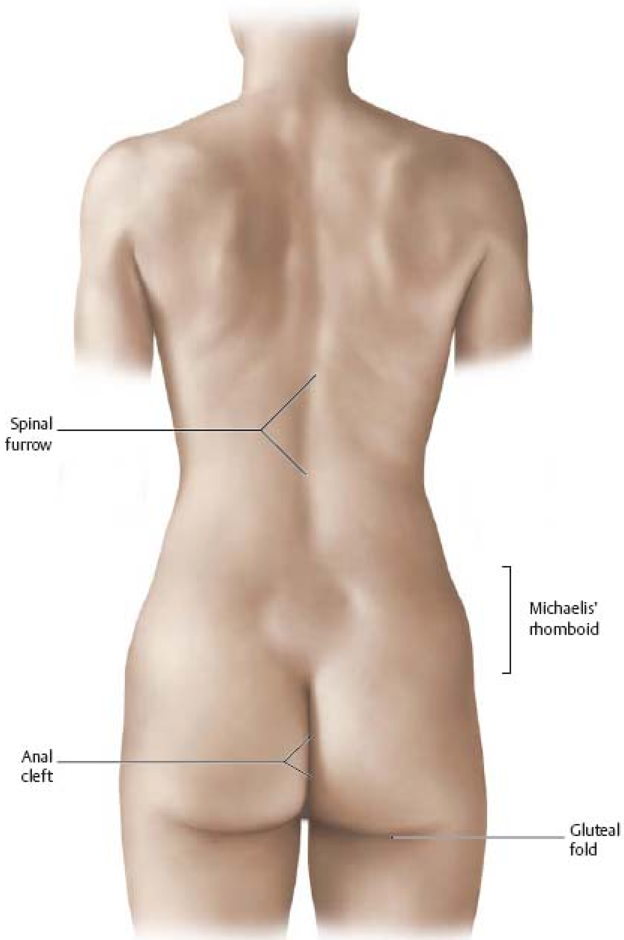


Fig. 4.2 **Surface anatomy of the back**

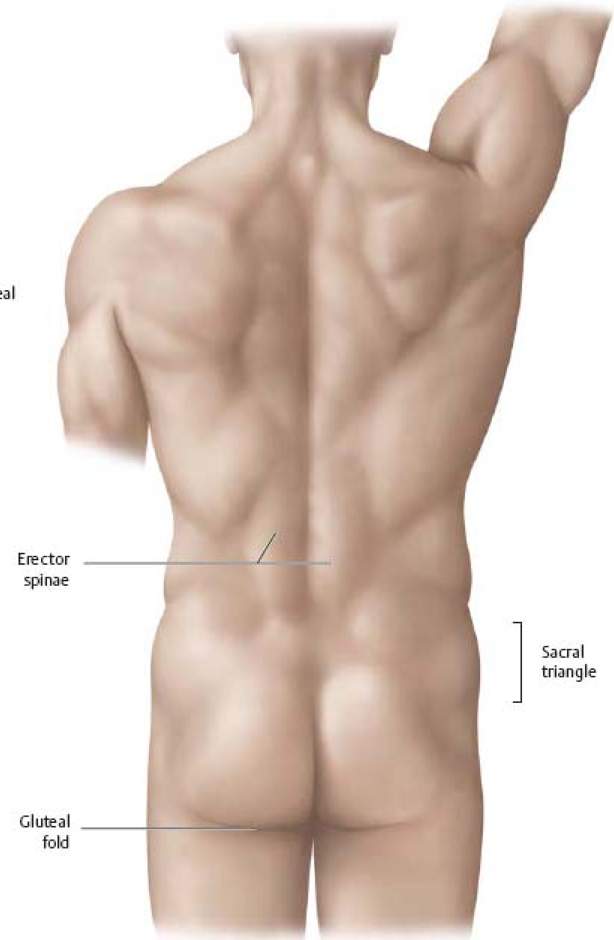
Posterior view.

Q1: Michaelis' rhomboid can be used as an indicator of the width of the female pelvis. What are its boundaries?

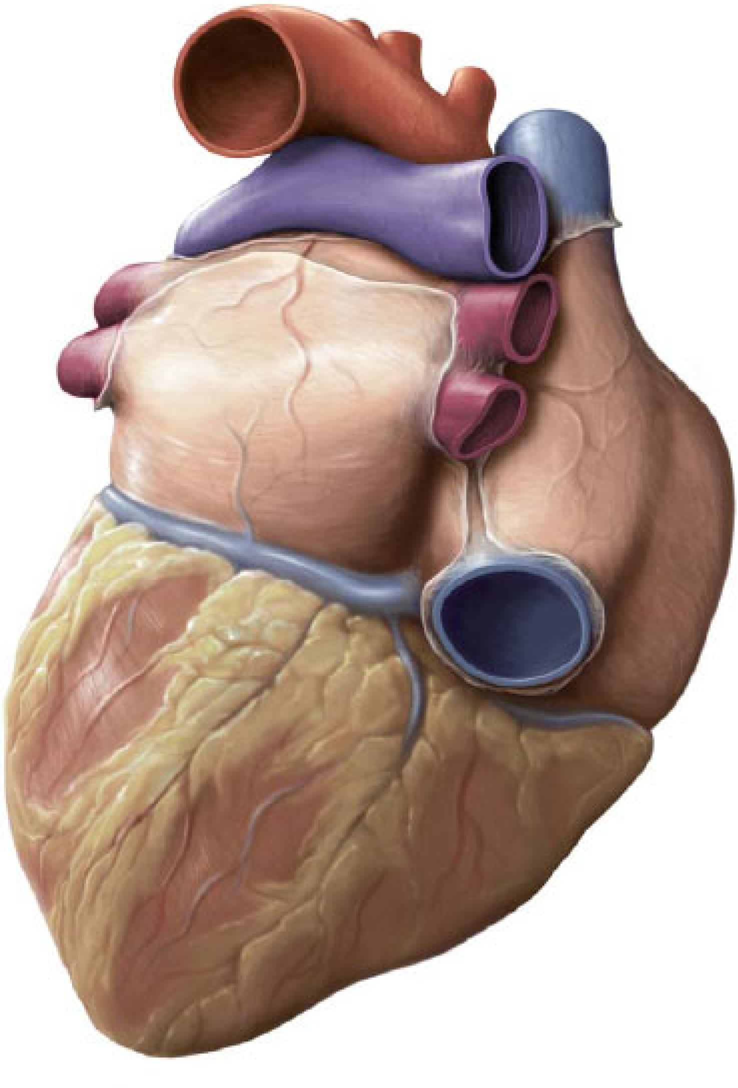


A Female back.

Q2: The limb girdles are reliable indicators of specific vertebral levels. What level corresponds to the inferior angle of the scapula? What level corresponds to the iliac crest?



B Male back.



Thorax

5 Thoracic Wall

Thoracic Skeleton

The thoracic skeleton consists of 12 thoracic vertebrae (p. 8), 12 pairs of ribs with costal cartilages, and the sternum. In addition to participating in respiratory movements, it provides a measure of protection to vital organs. The female thorax is generally narrower and shorter than the male equivalent.

Fig. 5.1 **Thoracic skeleton**

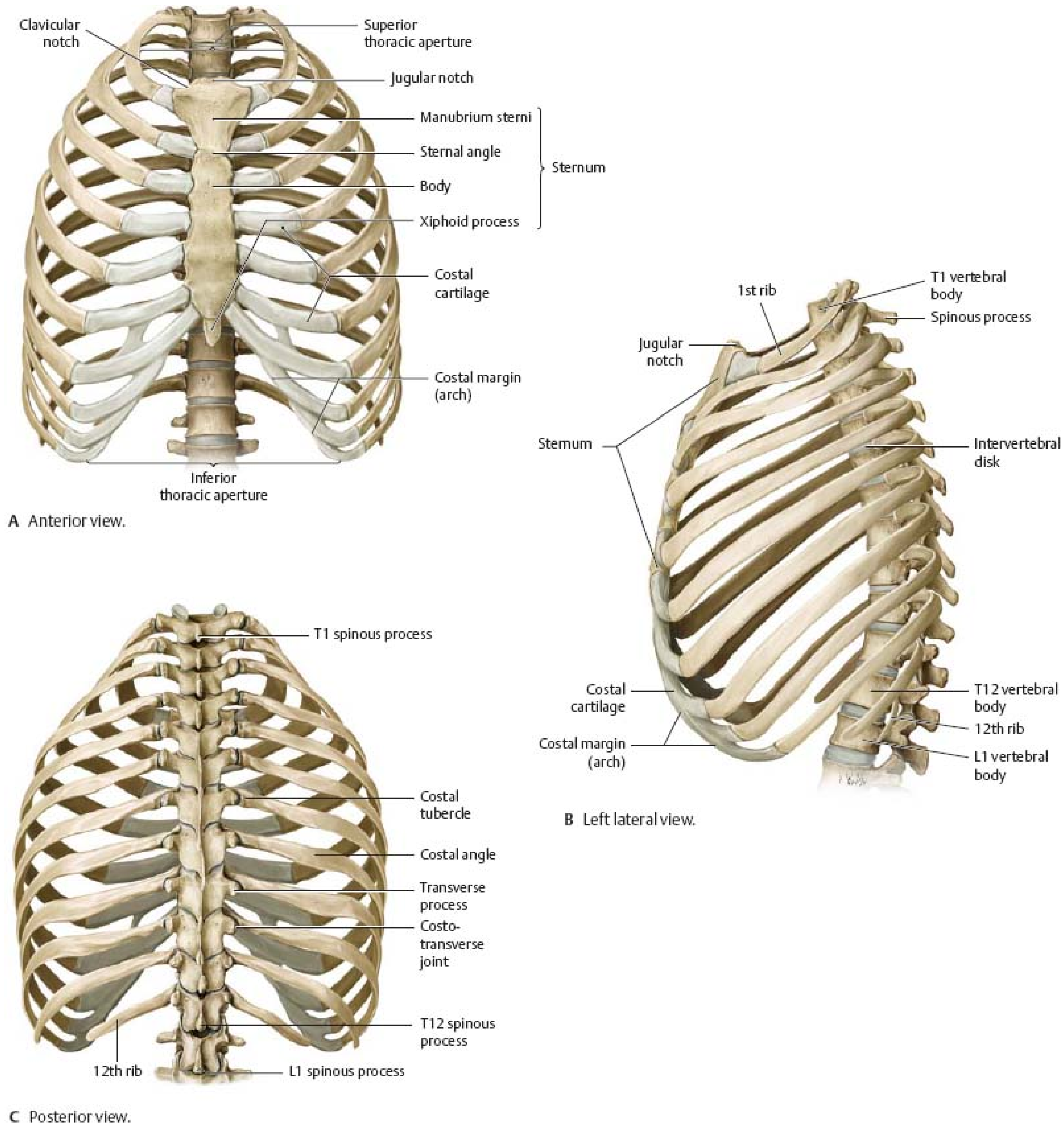


Fig. 5.2 **Structure of a thoracic segment**

Superior view of 6th rib pair.

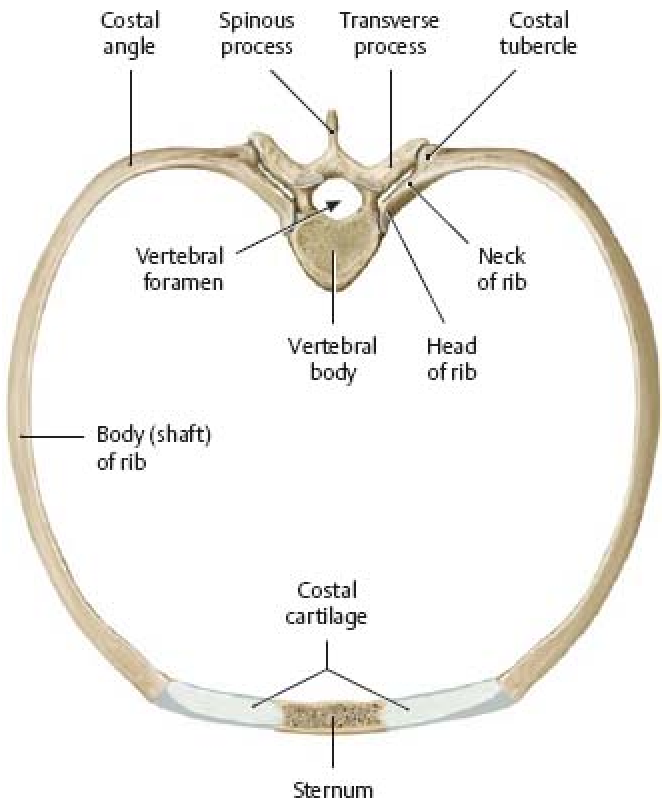
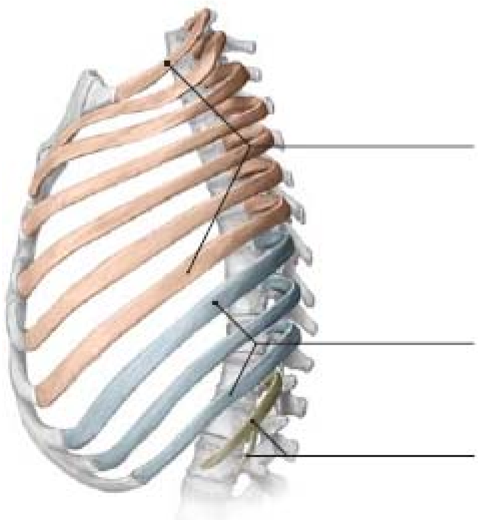


Table 5.1 Elements of a thoracic segment

Vertebra		
Rib	Bony part (costal bone)	Head
		Neck
		Costal tubercle
		Body (including costal angle)
	Costal part (costal cartilage)	
Sternum (articulates with costal cartilage of true ribs only; see Fig. 5.3)		

Fig. 5.3 **Types of ribs**

Left lateral view.

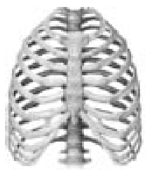


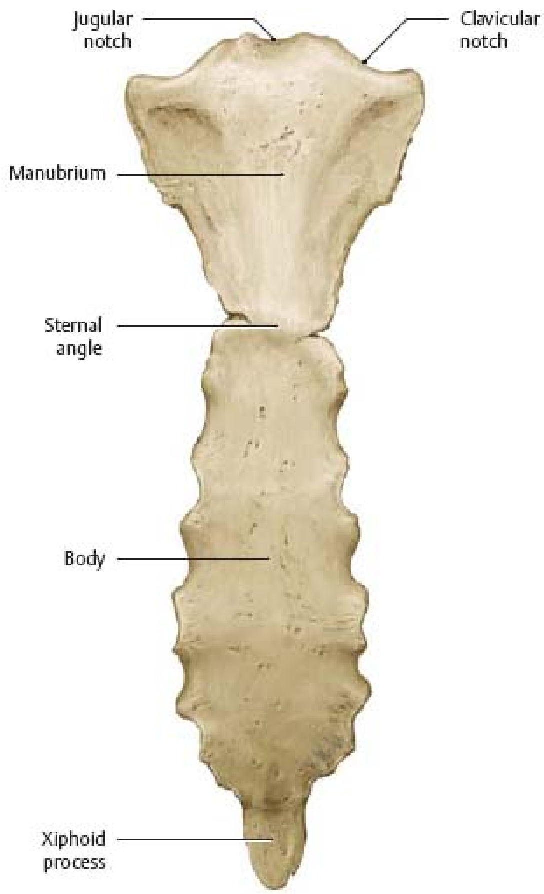
Rib type	Ribs	Anterior articulation
True ribs	1–7	Sternum (costal notches)
False ribs	8–10	Rib above
Floating ribs	11, 12	None

Sternum & Ribs

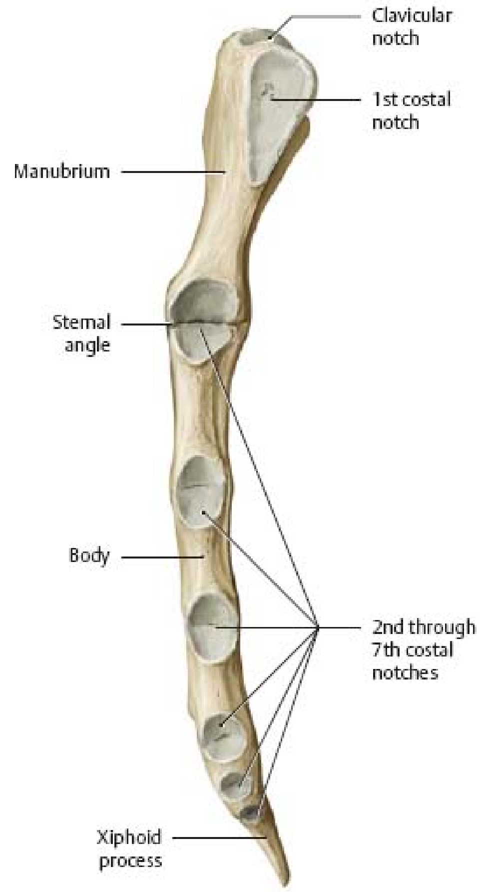
Fig. 5.4 Sternum

The sternum is a bladelike bone consisting of the manubrium, body, and xiphoid process. The junction of the manubrium and body (the sternal angle) is typically elevated and marks the articulation of the second rib. The sternal angle is an important landmark for internal structures.



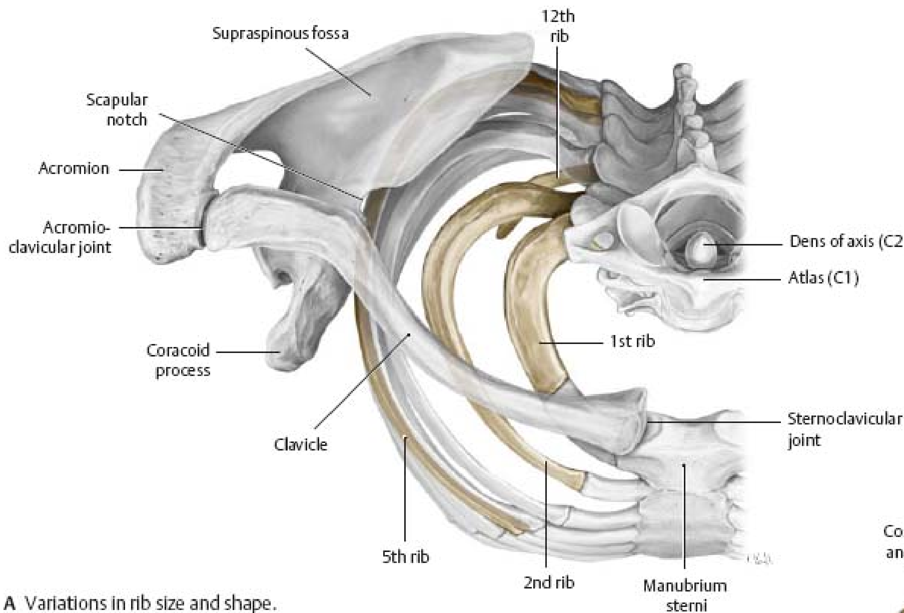


A Anterior view.

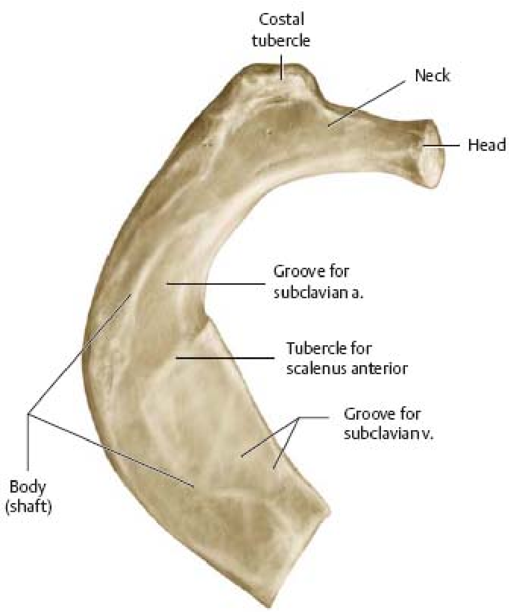


B Left lateral view. The costal notches are sites of articulation with the costal cartilage of the true ribs (see Fig. 5.3).

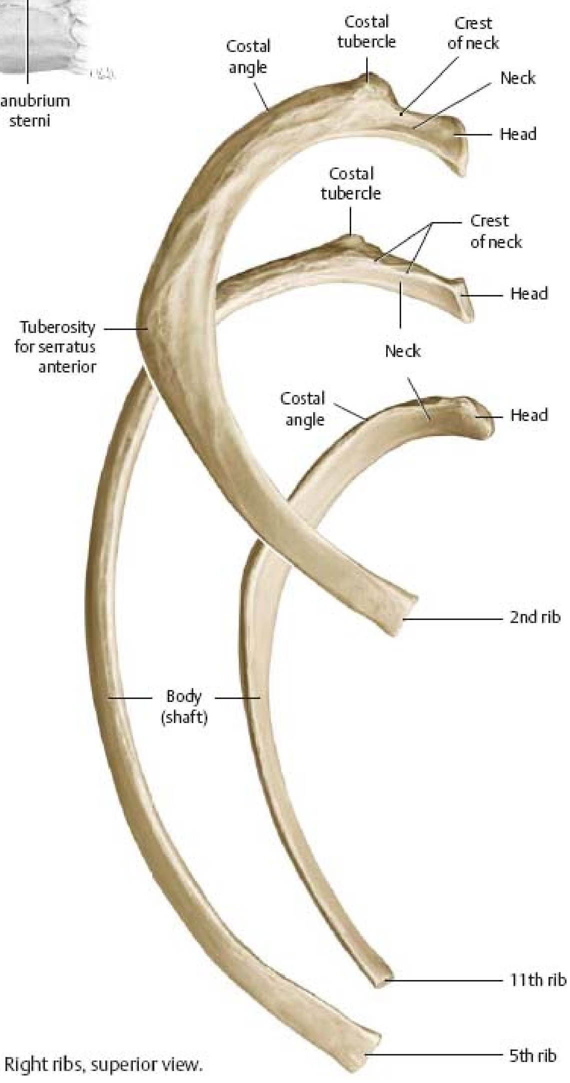
Fig. 5.5 **Ribs** Right ribs, superior view. See pp. 258–259 for joints of the shoulder.



A Variations in rib size and shape.



B 1st rib. *Note:* Most ribs have a costal groove along the inferior border (not shown), which protects the intercostal vessels and nerves.



C Right ribs, superior view.

Joints of the Thoracic Cage

The diaphragm is the chief muscle for quiet respiration (see p. 52). The muscles of the thoracic wall (see p. 50) contribute to deep (forced) inspiration.

Fig. 5.6 Rib cage movement

Full inspiration (red); full expiration (blue). In deep inspiration, there is an increase in transverse and sagittal thoracic diameters, as well as the infrasternal angle. The descent of the diaphragm further increases the volume of the thoracic cavity.

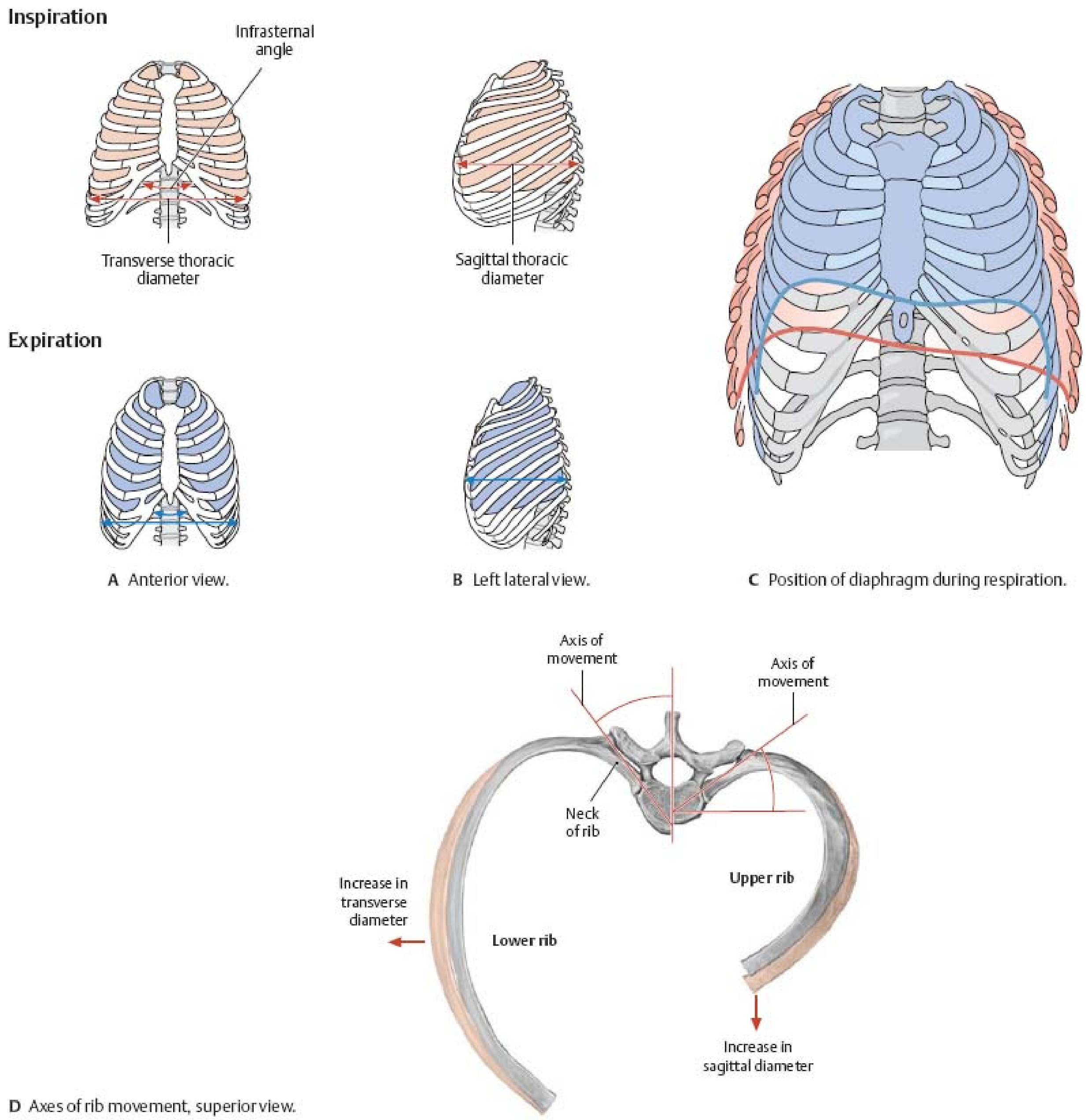


Fig. 5.7 Sternocostal joints

Anterior view with right half of sternum sectioned frontally. True joints are generally found only at ribs 2 to 5; ribs 1, 6, and 7 attach to the sternum by synchondroses.

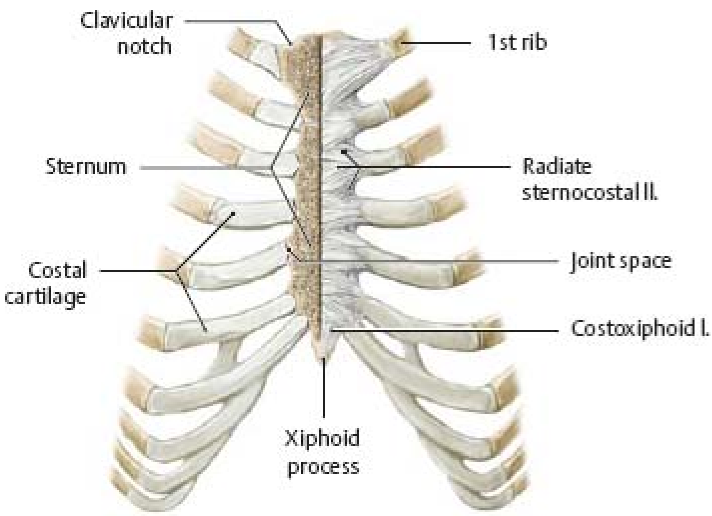
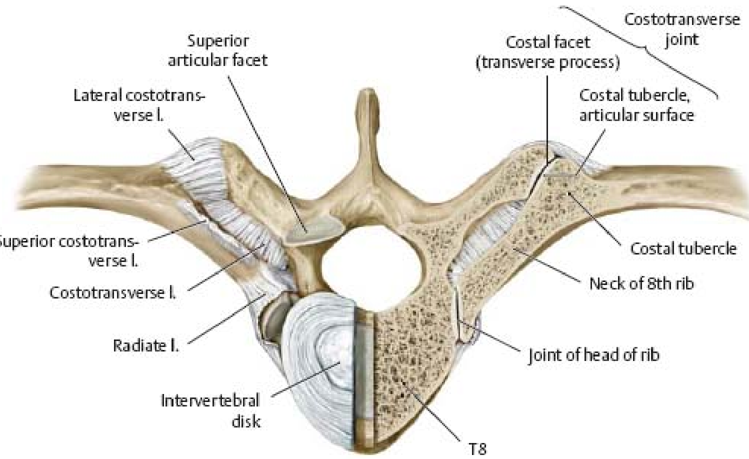
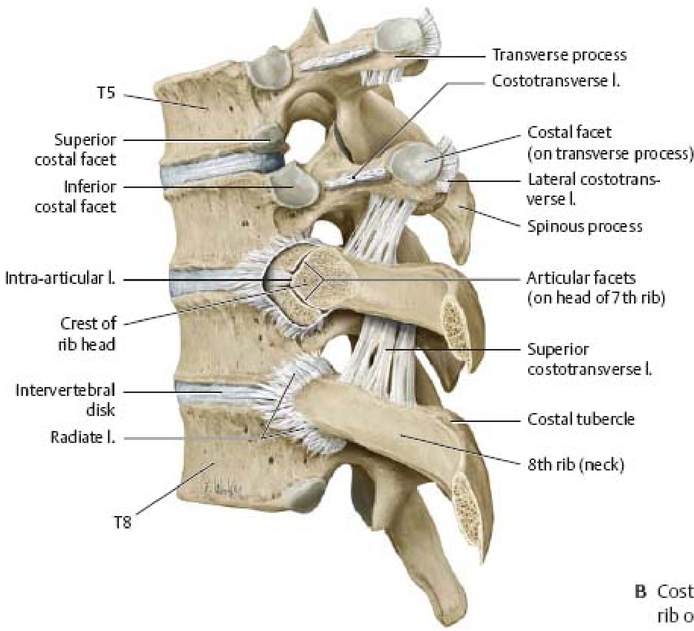


Fig. 5.8 **Costovertebral joints**

Two synovial joints make up the costovertebral articulation of each rib. The costal tubercle of each rib articulates with the costal facet of its accompanying vertebra (**A**). The head of most ribs articulates with the vertebra of its own number and the vertebra immediately superior. Ribs 1, 11, and 12 typically articulate only with their own vertebrae.



A Costotransverse joint. Superior view with joints of the left rib transversely sectioned.

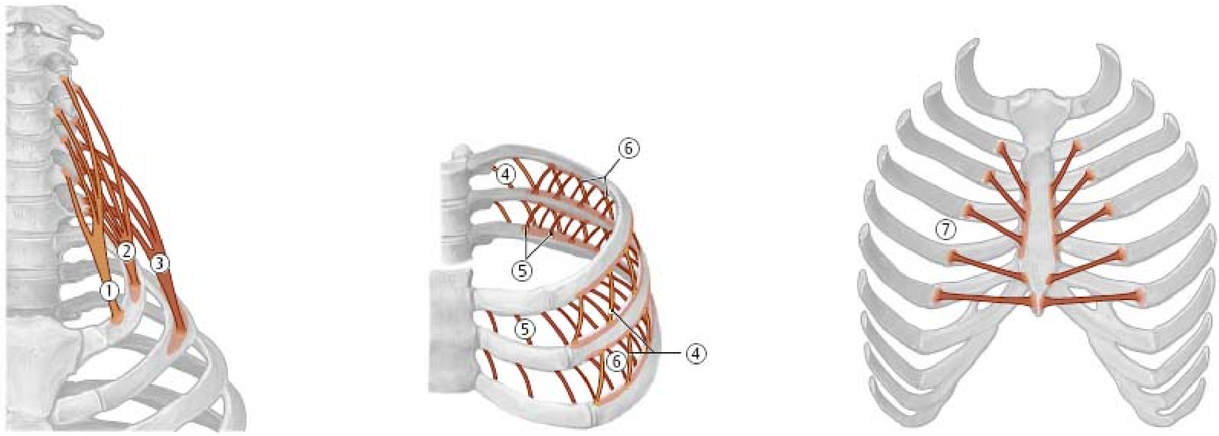


B Costovertebral joints. Left lateral view with the joint head of the 7th rib opened.

Thoracic Wall Muscle Facts

The muscles of the thoracic wall are primarily responsible for chest respiration, although other muscles aid in *deep* inspiration: the pectoralis major and serratus anterior are discussed with the shoulder (see pp. 264–267), and the serratus posterior is discussed with the back (see p. 30).

Fig. 5.9 Muscles of the thoracic wall



A Scalene muscles, anterior view. **B** Intercostal muscles, anterior view. **C** Transversus thoracis, posterior view.

Table 5.2 Muscles of the thoracic wall

Muscle		Origin	Insertion	Innervation	Action
Scalene	① Anterior scalene	C3–C6 (transverse processes, anterior tubercles)	1st rib (scalene tubercle)	Direct branches from cervical and brachial plexus (C3–C6)	*With ribs mobile*: Raises upper ribs (inspiration) *With ribs fixed*: Bends cervical spine to same side (unilateral); flexes neck (bilateral)
	② Middle scalene	C4–C6 (transverse processes, posterior tubercles)	1st rib (posterior to groove for subclavian a.)		
	③ Posterior scalene		2nd rib (outer surface)		
Intercostal	④ External intercostal	Lower margin of rib to upper margin of next lower rib (courses obliquely forward and downward from costal tubercle to chondro-osseous junction)		1st to 11th intercostal nn.	Raises ribs (inspiration); supports intercostal spaces; stabilizes chest wall
	⑤ Internal intercostal	Lower margin of rib to lower margin of next lower rib (courses obliquely forward and upward from costal angle to sternum)			Lowers ribs (expiration); supports intercostal spaces, stabilizes chest wall
	⑥ Innermost intercostal				
Subcostal		Lower margin of lower ribs to inner surface of ribs two to three ribs below		Variable lower intercostal nn.	Raises ribs (inspiration)
⑦ Transversus thoracis		Sternum and xiphoid process (inner surface)	2nd to 6th ribs (costal cartilage, inner surface)	2nd to 7th intercostal nn.	Weakly lowers ribs (expiration)

Fig. 5.10 Muscles of the thoracic wall

Anterior view. The external intercostal muscles are replaced anteriorly by the external intercostal membrane. The internal intercostal muscles are replaced posteriorly by the internal intercostal membrane (removed in Fig. 5.11).

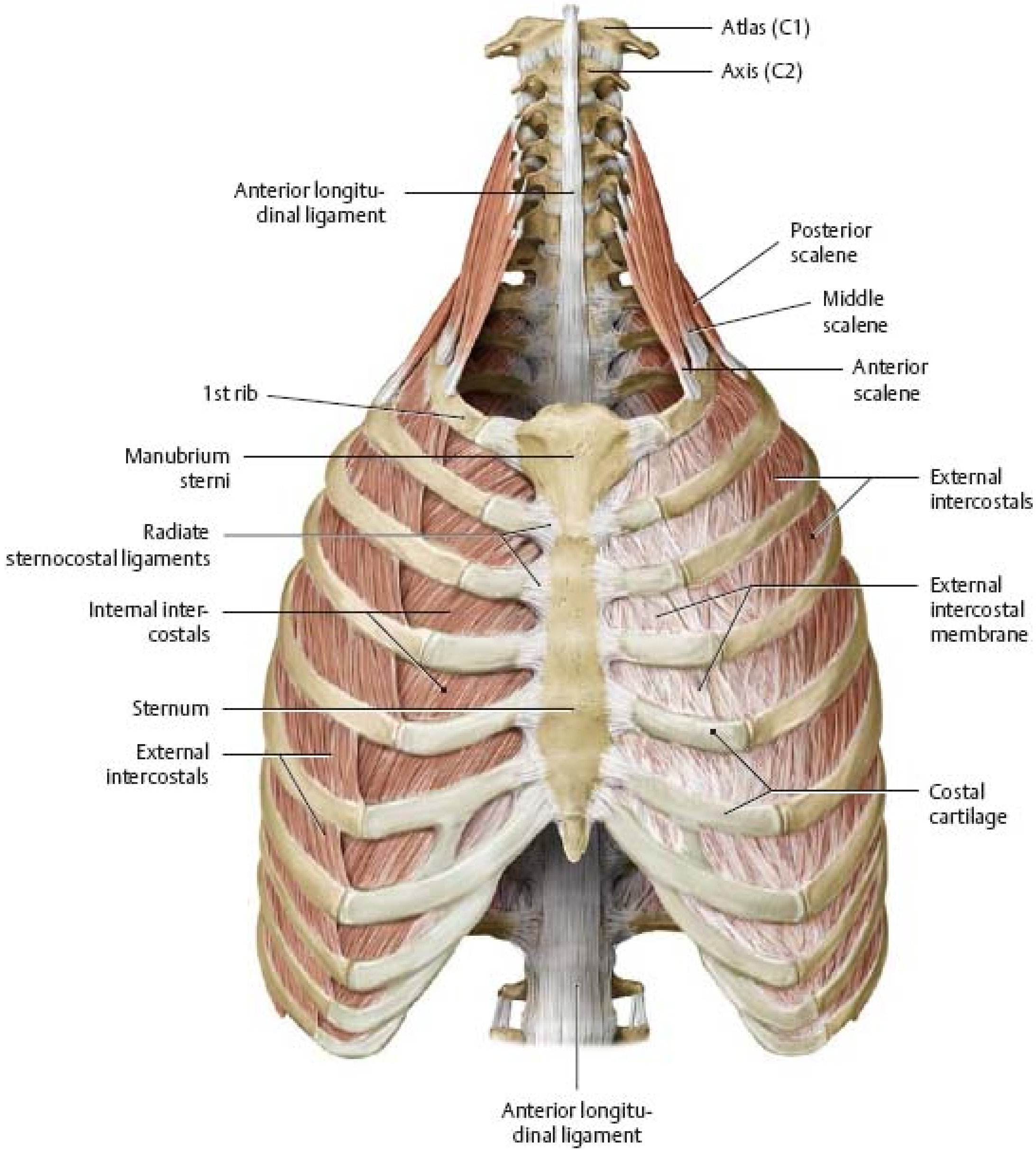
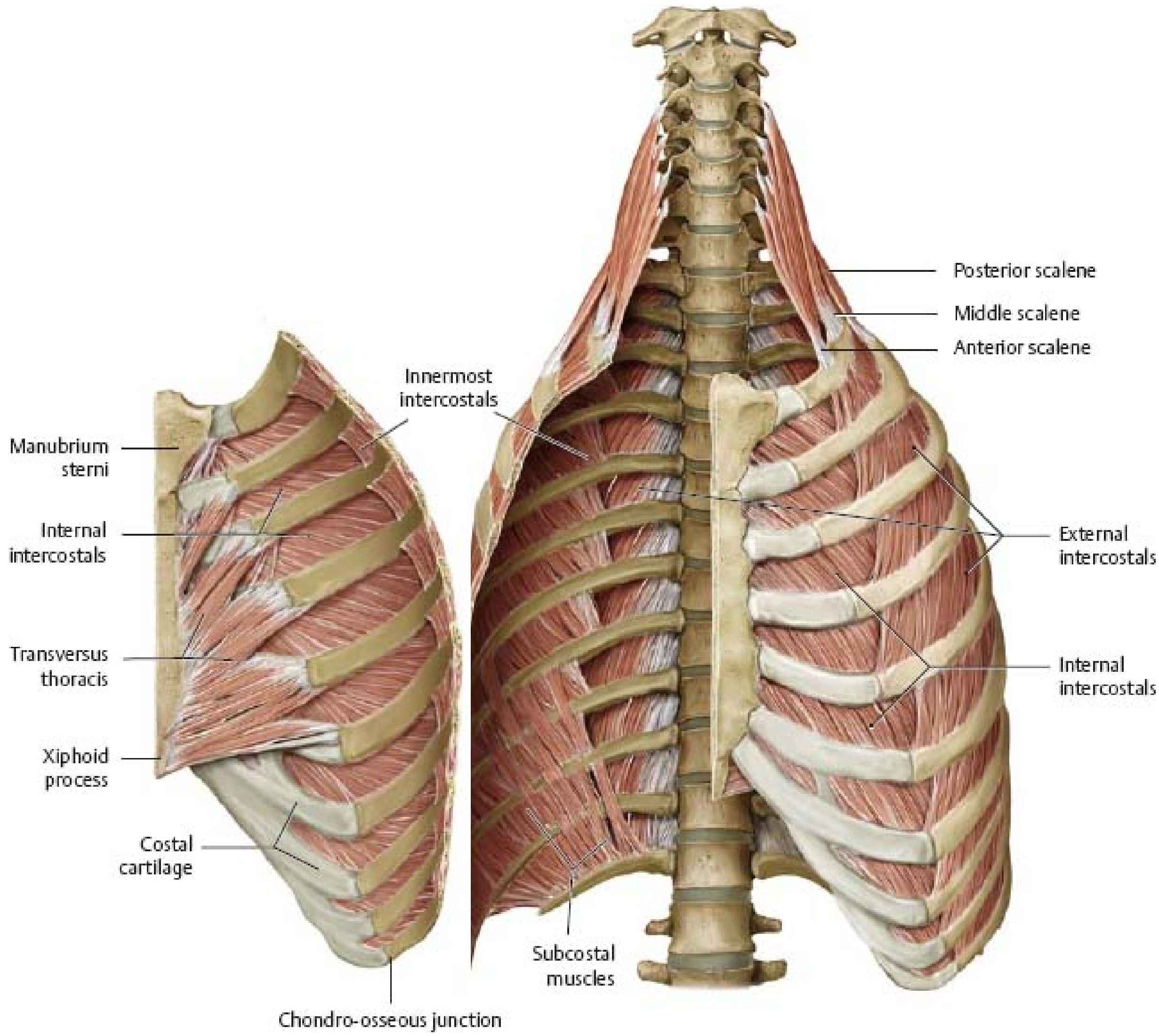


Fig. 5.11 **Transversus thoracis**

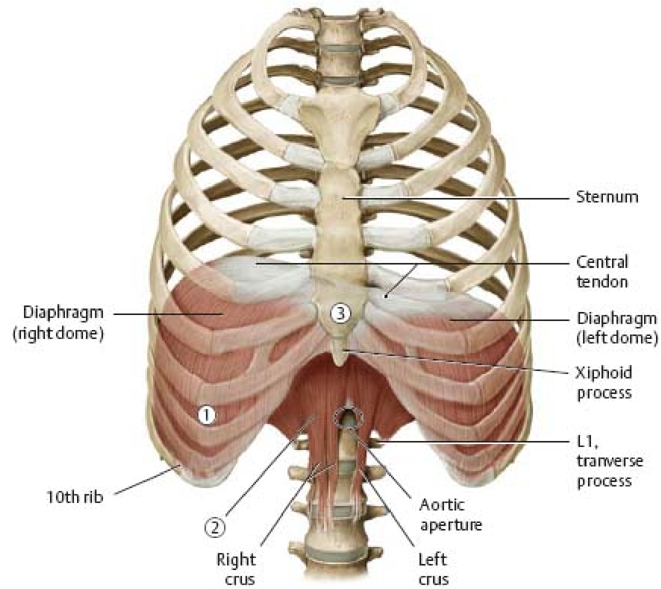
Anterior view with thoracic cage opened to expose posterior surface of anterior wall.



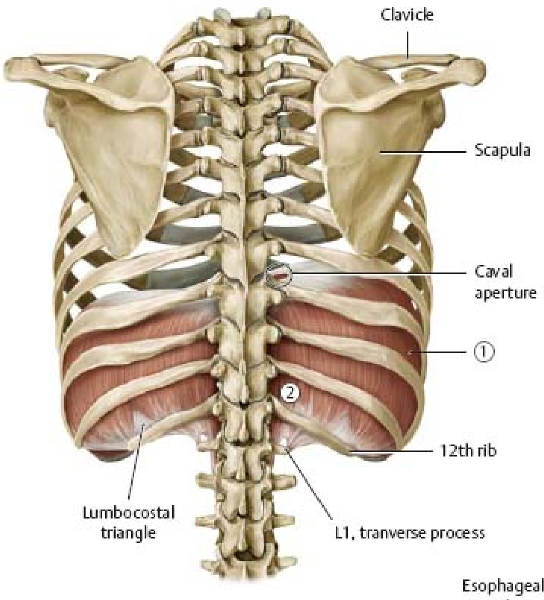
Diaphragm

Fig. 5.12 Diaphragm

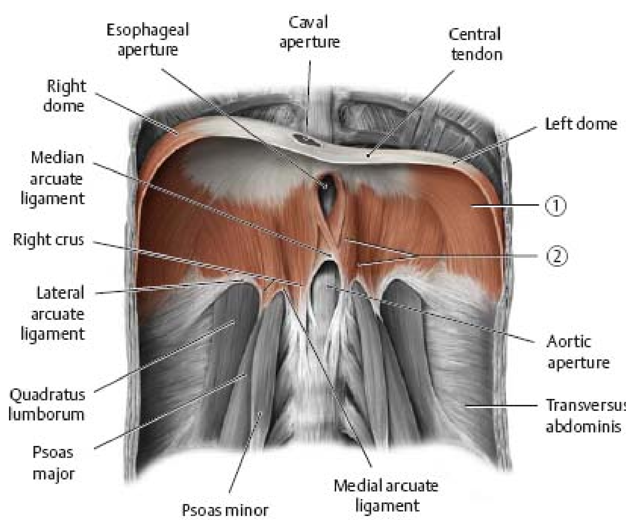
The diaphragm, which separates the thorax from the abdomen, has two asymmetric domes and three apertures (for the aorta, vena cava, and esophagus; see Fig. 5.13B).



A Anterior view.



B Posterior view.

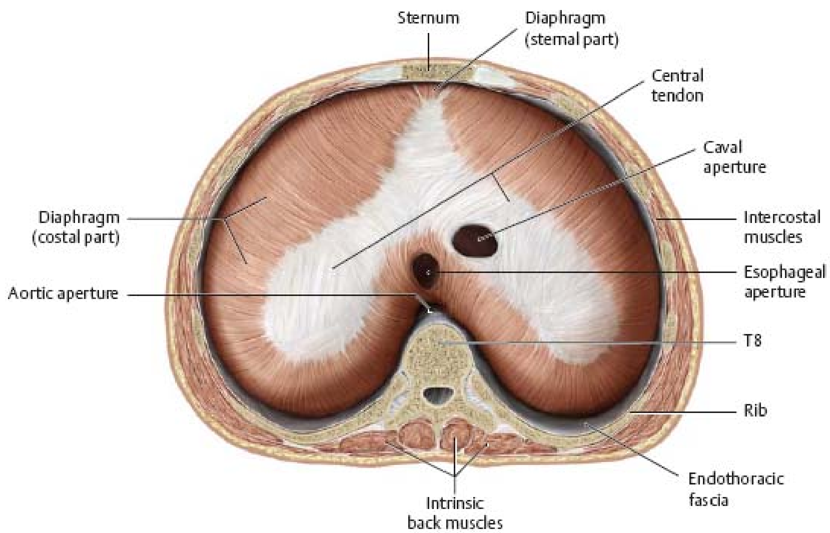


C Coronal section with diaphragm in intermediate position.

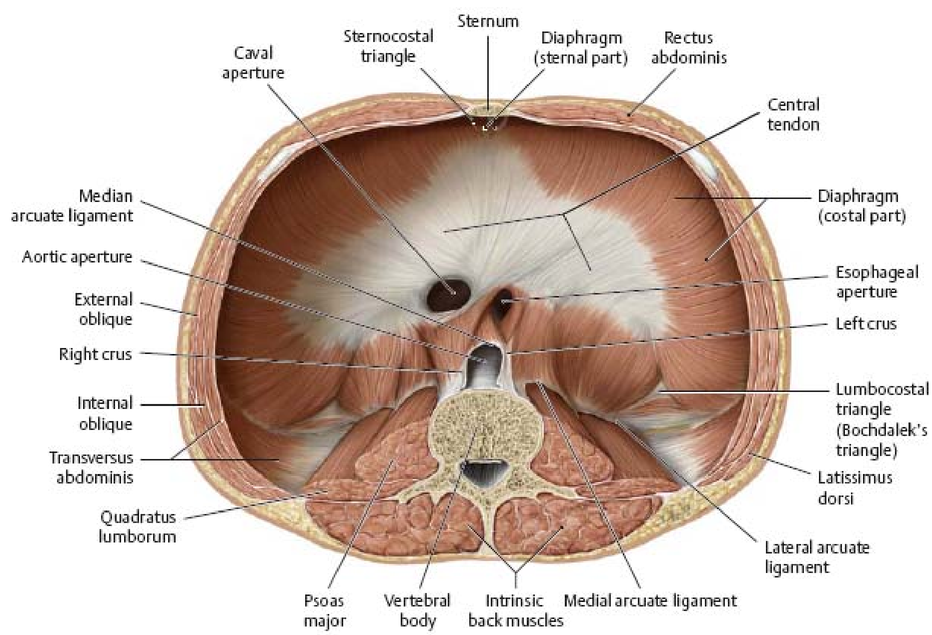
Table 5.3 Diaphragm

Muscle		Origin	Insertion	Innervation	Action
Diaphragm	① Costal part	7th to 12th ribs (inner surface; lower margin of costal arch)	Central tendon	Phrenic n. (C3–C5, cervical plexus)	Principal muscle of respiration (diaphragmatic and thoracic breathing); aids in compressing abdominal viscera (abdominal press)
	② Lumbar part	Medial part: L1–L3 vertebral bodies, intervertebral disks, and anterior longitudinal ligament as right and left crura			
		Lateral parts: lateral and medial arcuate ligaments			
	③ Sternal part	Xiphoid process (posterior surface)			

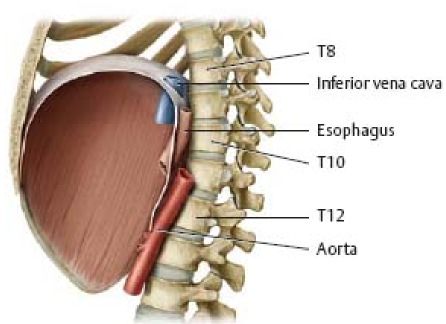
Fig. 5.13 Diaphragm in situ



A Superior view.



B Inferior view.



C Diaphragmatic apertures, left lateral view.

Neurovasculature of the Diaphragm

Fig. 5.14 **Neurovasculature of the diaphragm**

Anterior view of opened thoracic cage.

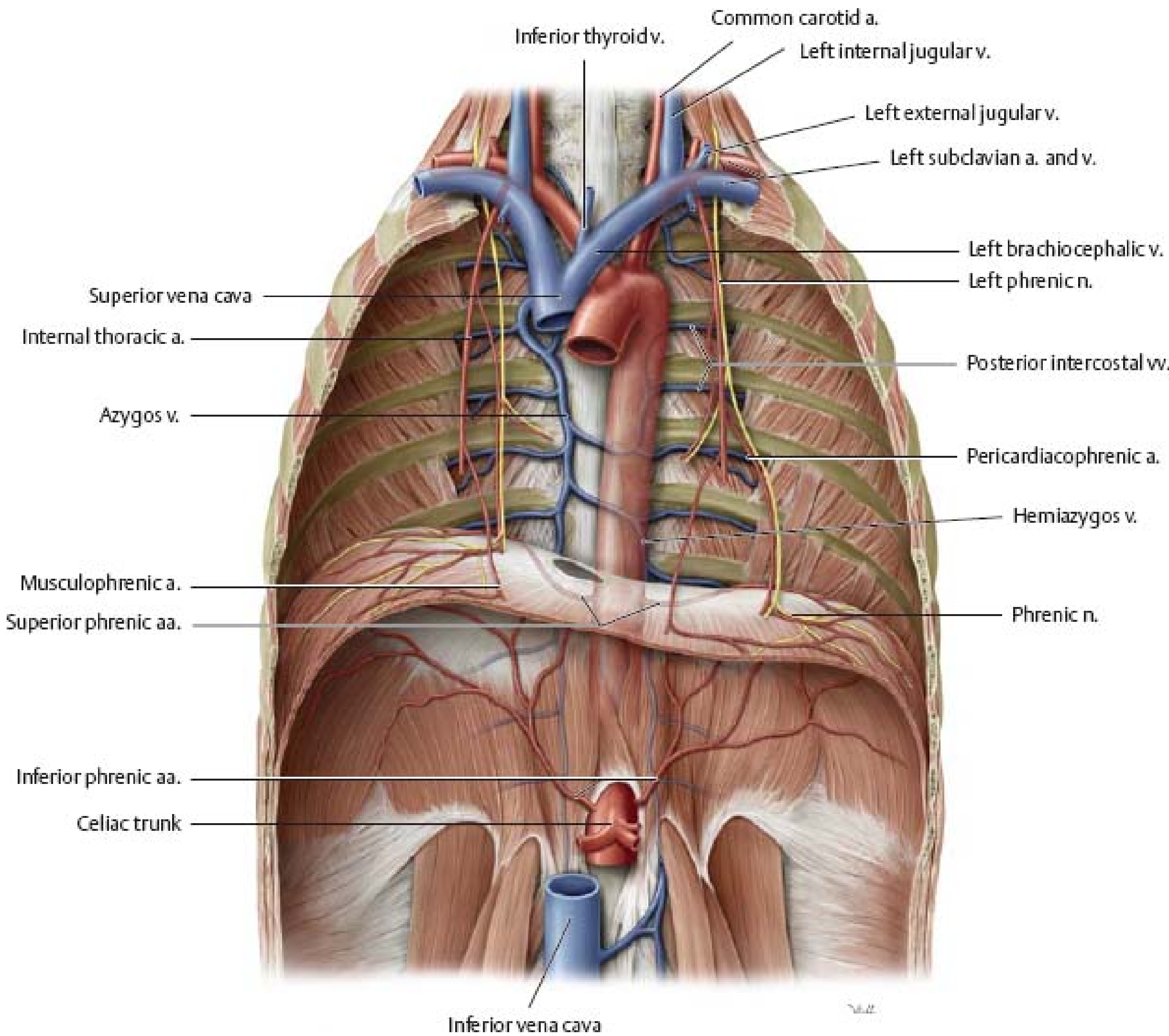


Fig. 5.15 **Innervation of the diaphragm**

Anterior view. The phrenic nerve lies on the lateral surface of the fibrous pericardium together with the pericardiacophrenic arteries and veins. *Note*: The phrenic nerve also innervates the pericardium.

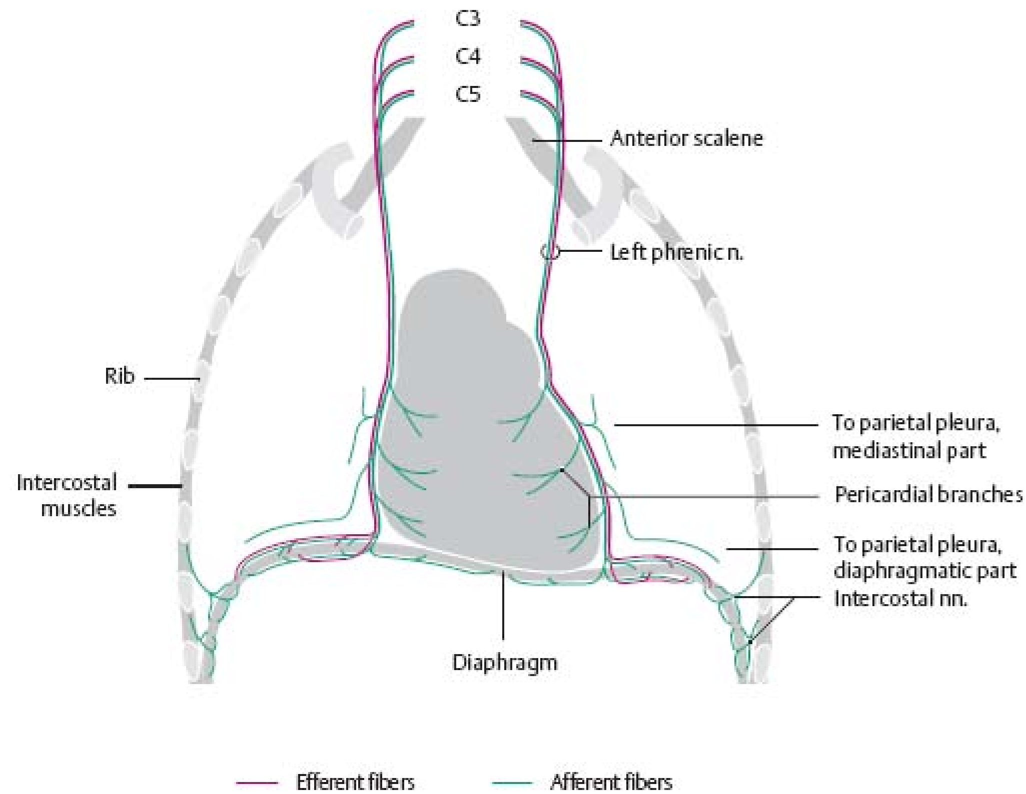
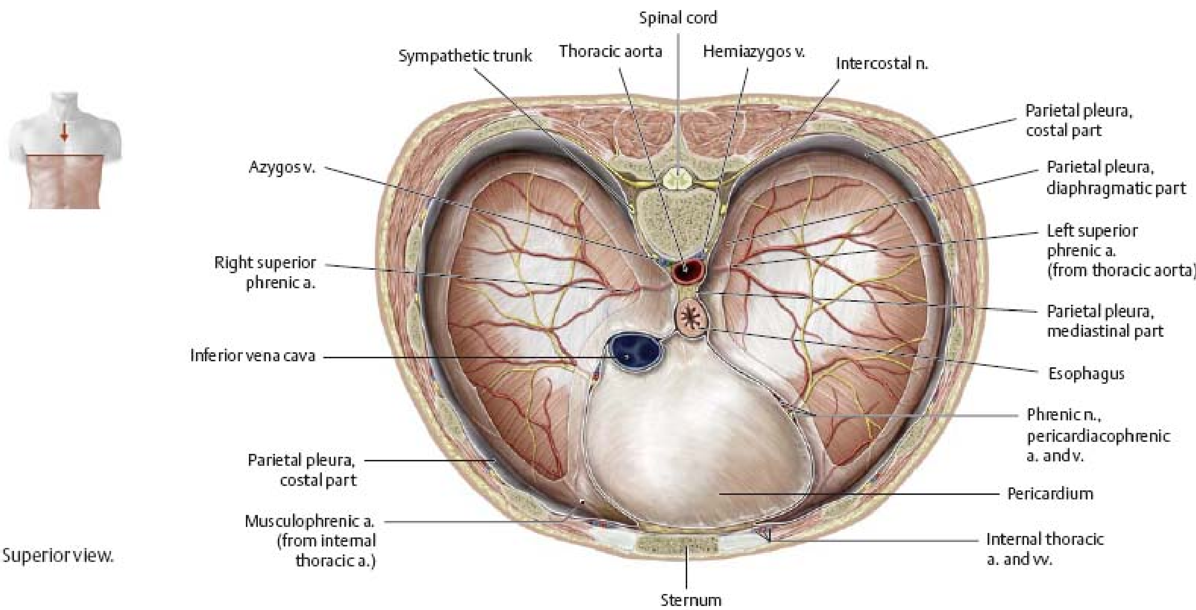


Table 5.4 Blood vessels of the diaphragm

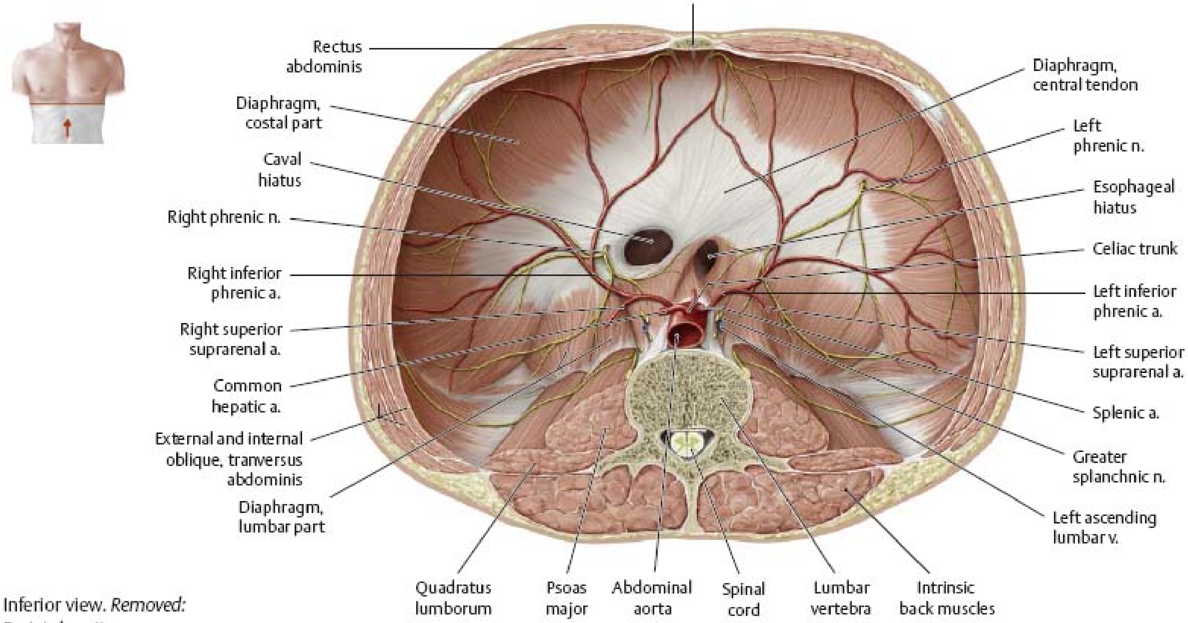
Artery	Origin	Vein	Drainage
Inferior phrenic aa. (chief blood supply)	Abdominal aorta; occasionally from celiac trunk	Posterior intercostal vv.	Right side: Azygos v.; Left side: Hemiazygos v.
Superior phrenic aa.	Thoracic aorta	Superior phrenic vv.	
Pericardiacophrenic aa.	Internal thoracic a.	Right superior intercostal v.	
Musculophrenic aa.			

Fig. 5.16 Arteries and nerves of the diaphragm

Note: The margins of the diaphragm receive sensory innervation from the lowest intercostal nerves.



A Superior view.



B Inferior view. *Removed:* Parietal peritoneum.

Arteries & Veins of the Thoracic Wall

The posterior intercostal arteries anastomose with the anterior intercostal arteries to supply the structures of the thoracic wall. The posterior intercostal arteries branch from the thoracic aorta, with the exception of the 1st and 2nd, which arise from the superior intercostal artery (a branch of the costocervical trunk).

Fig. 5.17 Arteries of the thoracic wall

Anterior view.

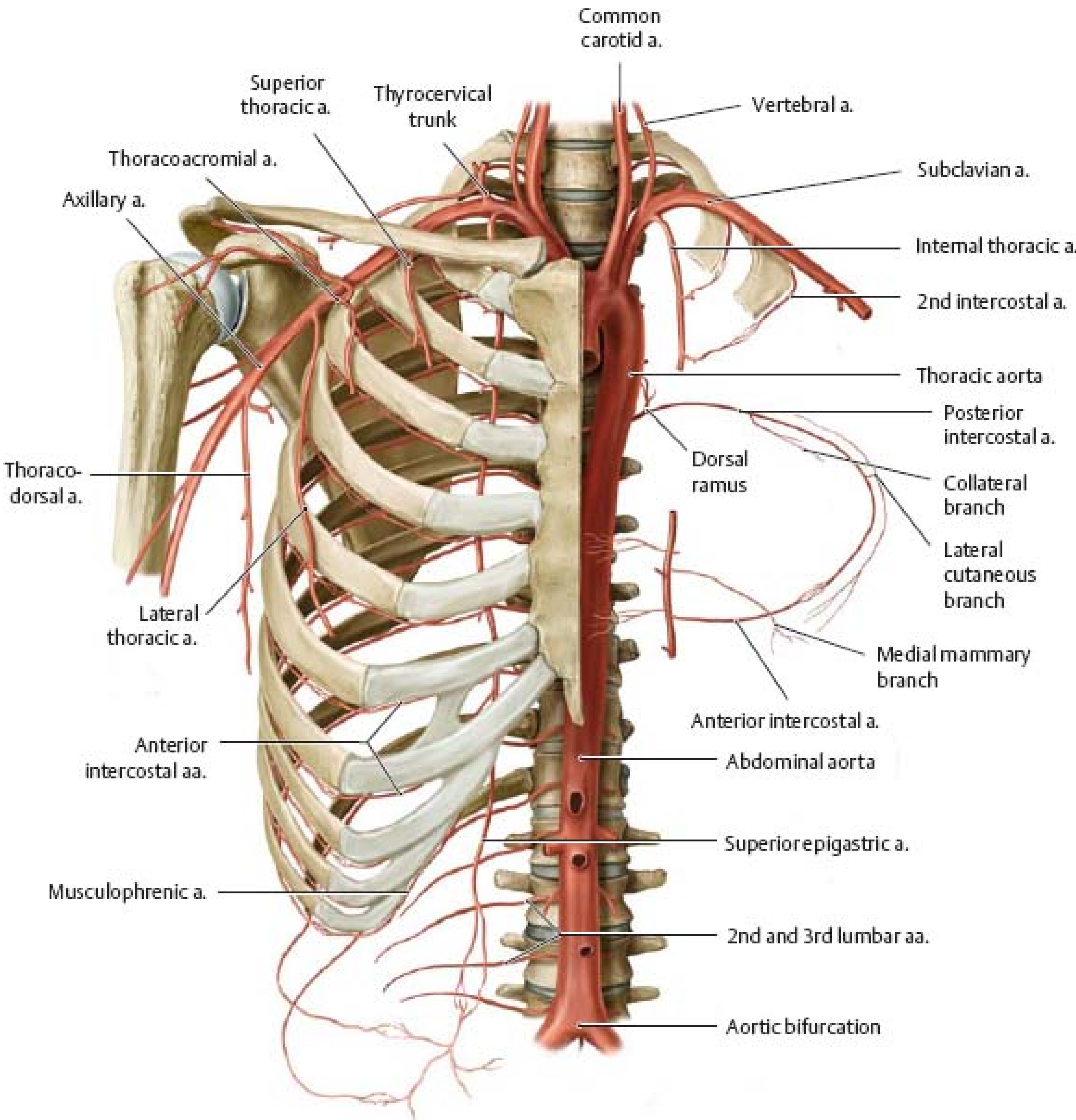


Table 5.5 **Arteries of the thoracic wall**

Origin	Branch
Axillary a.	Lateral thoracic a.

Origin	Branch
	Thoracoacromial a.
Subclavian a.	Posterior intercostal aa. (1st and 2nd; see p. 34)
	Superior thoracic a.
Thoracic aorta	Posterior intercostal aa. (3rd through 12th)
Internal thoracic a.	Anterior intercostal aa.
	Musculophrenic a.
	Superior epigastric a.

Fig. 5.18 Branches of the posterior intercostal arteries

Superior view.

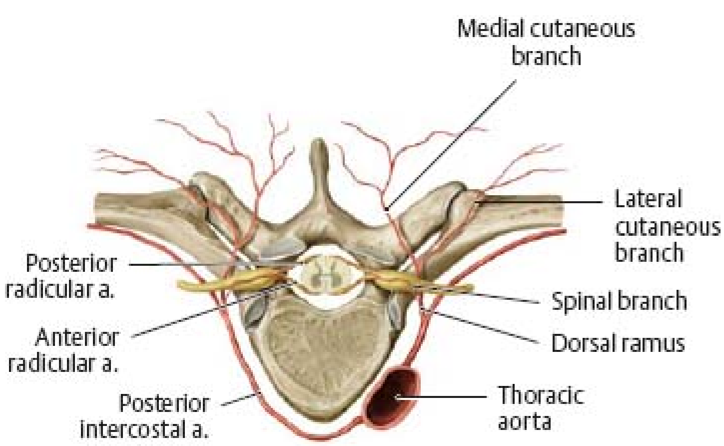


Table 5.6 Branches of the intercostal arteries

Artery	Branches		Supplies
Posterior intercostal aa.	Dorsal branch	Spinal branch	Spinal cord
		Medial cutaneous branch	Posterior thoracic wall
		Lateral cutaneous branch	
	Collateral branch		Lateral thoracic wall
	Lateral cutaneous branch*		
Anterior intercostal aa.			Anterior thoracic wall

*The lateral mammary branch from the lateral cutaneous branch supplies the breast along with the medial mammary branch from the internal thoracic artery.

The intercostal veins drain primarily into the azygos system, but also into the internal thoracic vein. This blood ultimately returns to the heart via the superior vena cava. The intercostal veins follow a similar course to their arterial counterparts. However, the veins of the vertebral column form an external vertebral venous plexus that traverses the entire length of the spine (see p. 35).

Fig. 5.19 Veins of the thoracic wall

Anterior view.

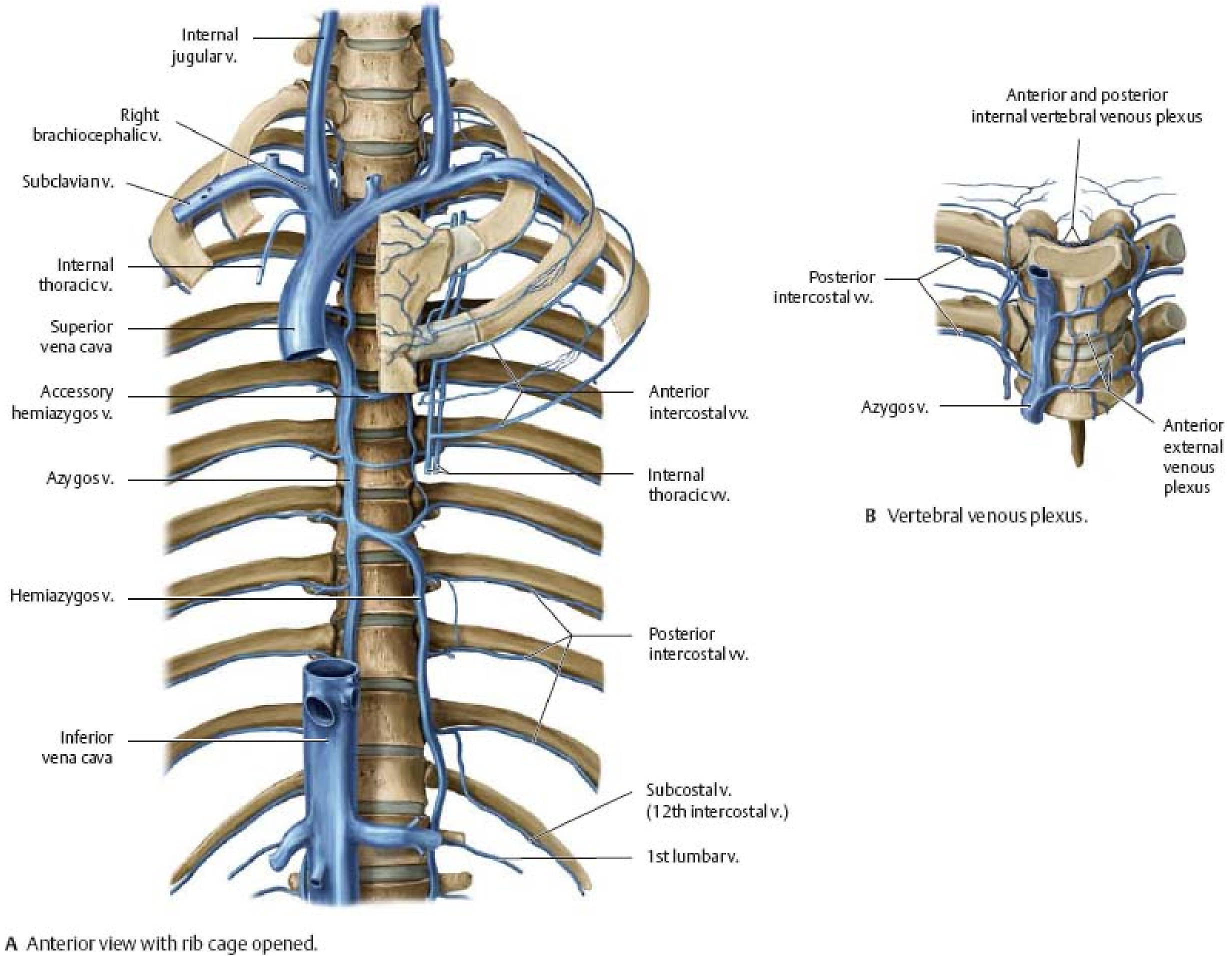
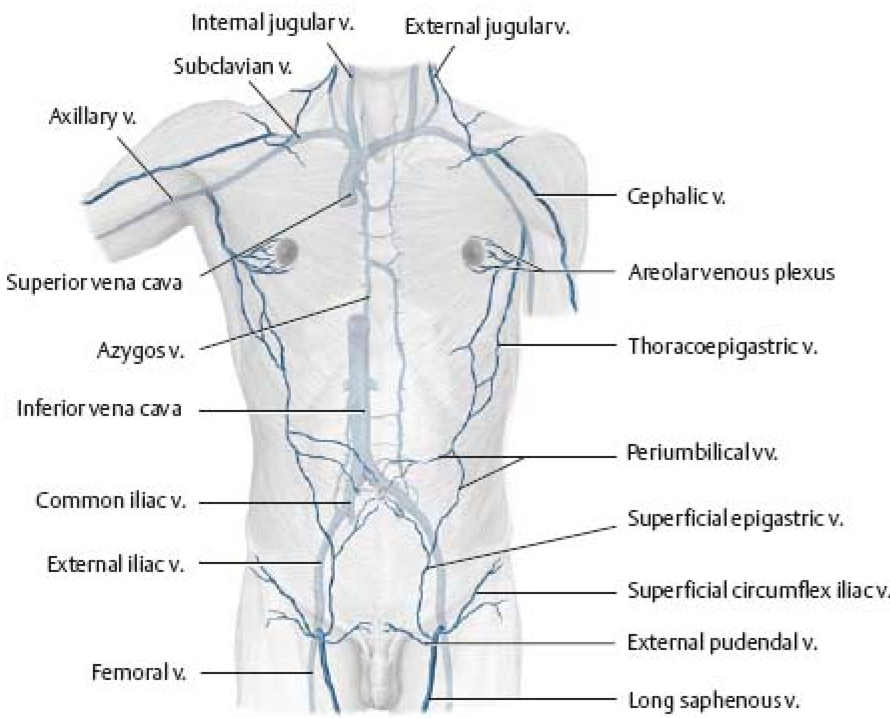


Fig. 5.20 Superficial veins

Anterior view. The thoracoepigastric veins are a potential superficial collateral venous drainage route in the event of superior or inferior vena cava obstruction.



Nerves of the Thoracic Wall

Fig. 5.21 Intercostal nerves

Anterior view. The 1st rib has been removed to reveal the 1st and 2nd intercostal nerves.

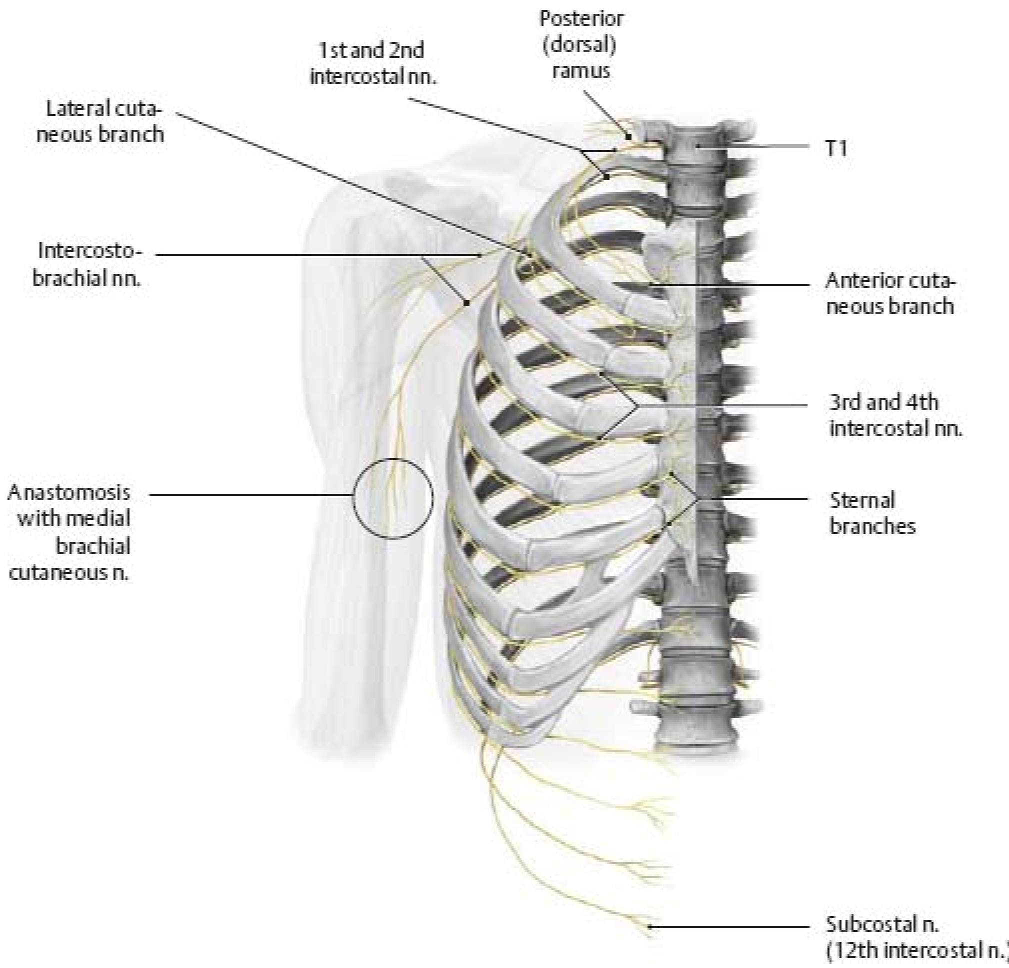


Fig. 5.22 Thoracic wall: Peripheral sensory cutaneous innervation

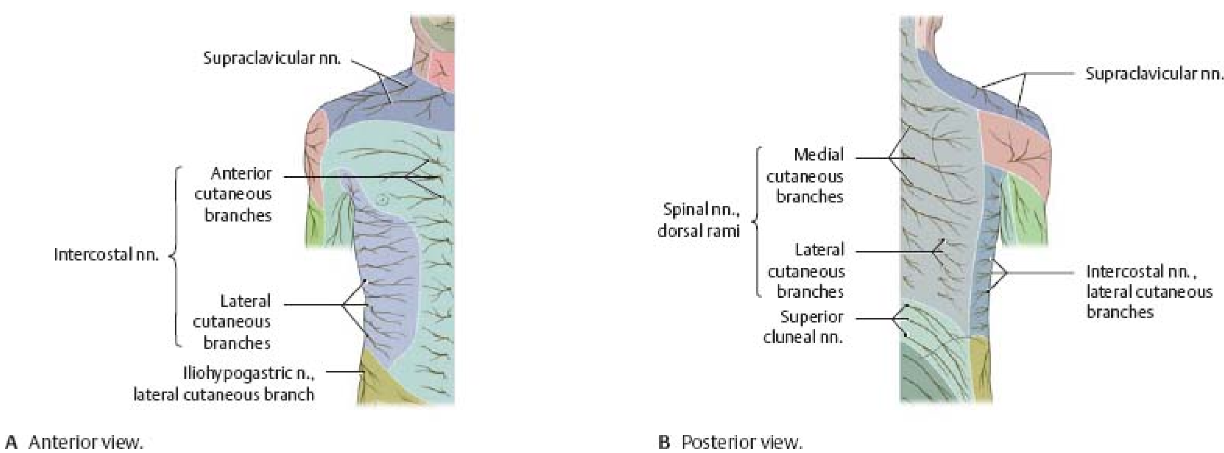


Fig. 5.23 Spinal nerve branches

Superior view. Formed by the union of the posterior (sensory) and anterior (motor) roots, the at-most 1 cm-long spinal nerve courses through the intervertebral foramen and exits the vertebral canal. Its posterior ramus innervates the skin and intrinsic muscles of the back; its anterior ramus forms the intercostal nerves. See p. 36 for more details.

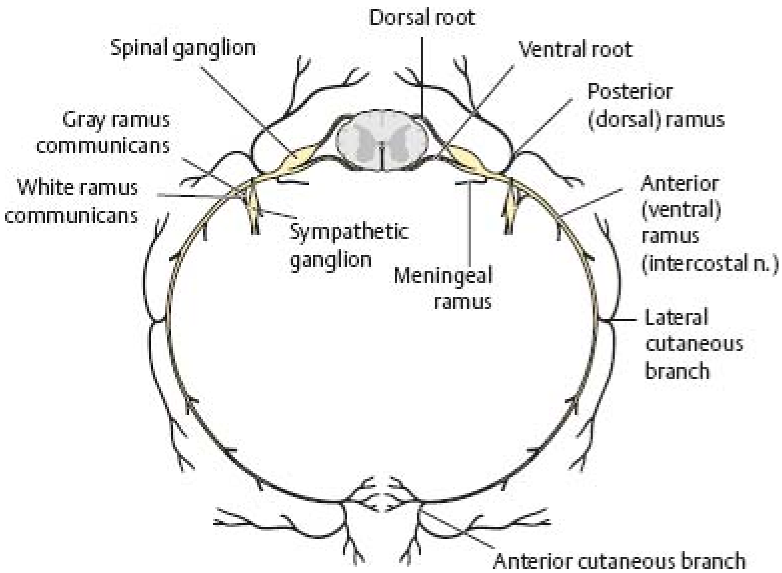


Fig. 5.24 **Course of the intercostal nerves**

Coronal section, anterior view.

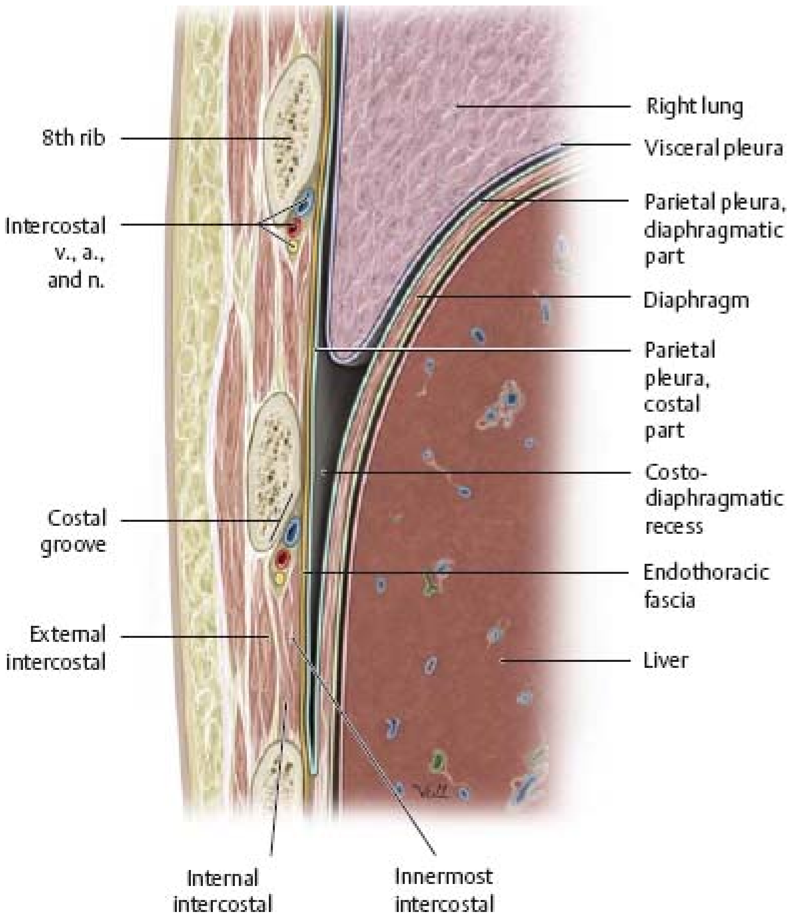
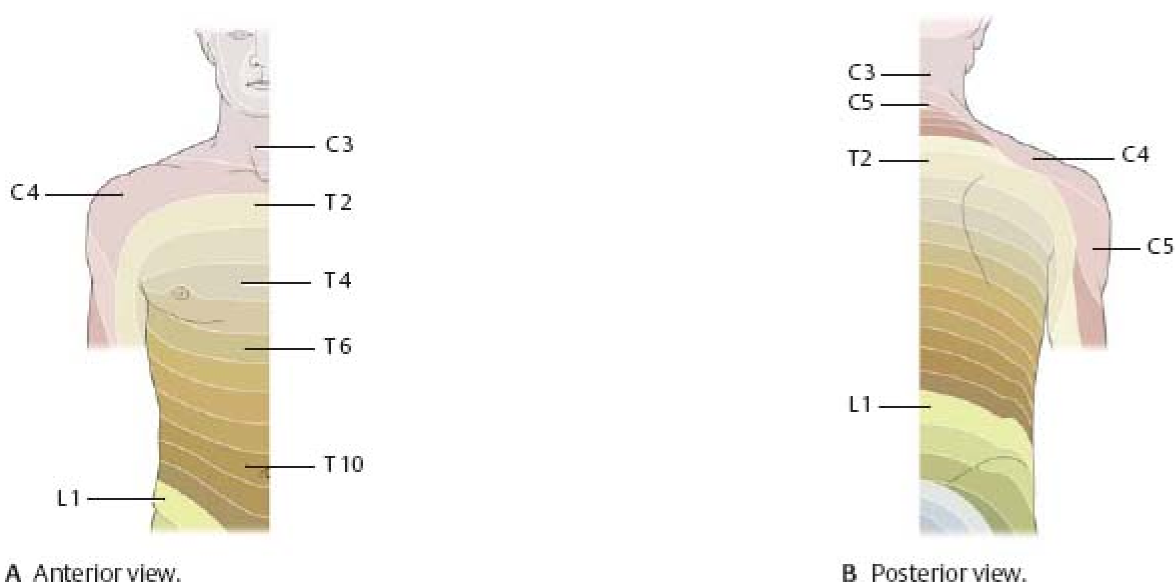


Fig. 5.25 Thoracic wall: Dermatomes

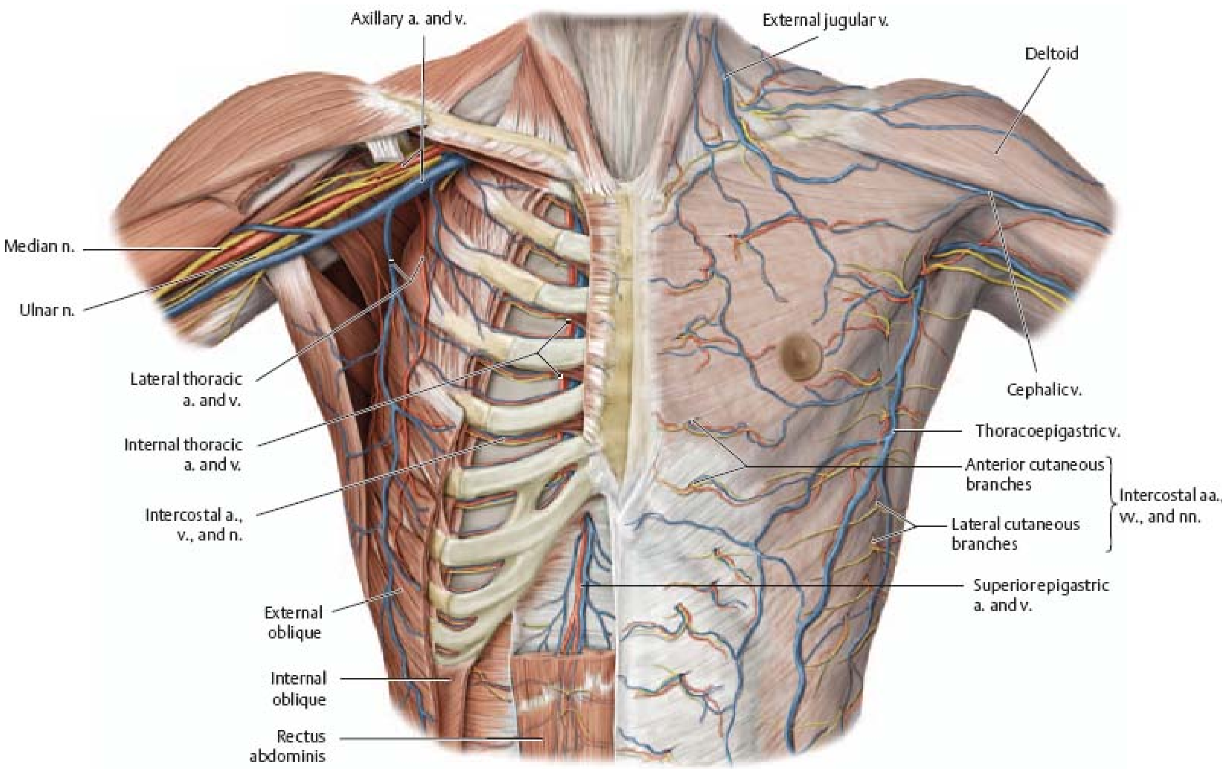
Landmarks: T4 generally includes the nipple; T6 innervates the skin over the xiphoid.



Neurovascular Topography of the Thoracic Wall

Fig. 5.26 Anterior structures

Anterior view (see pp. 34–39 for neurovasculature of the back).



Clinical

Insertion of a chest tube

Abnormal fluid collection in the pleural space (e.g., pleural effusion due to bronchial carcinoma) may necessitate the insertion of a chest tube. Generally, the optimal puncture site in a sitting patient is at the level of the 7th or 8th intercostal space on the posterior axillary line. The drain should always be introduced at the upper margin of a rib to avoid injuring the intercostal vein, artery, and nerve. See p. 113 for details on collapsed lungs.

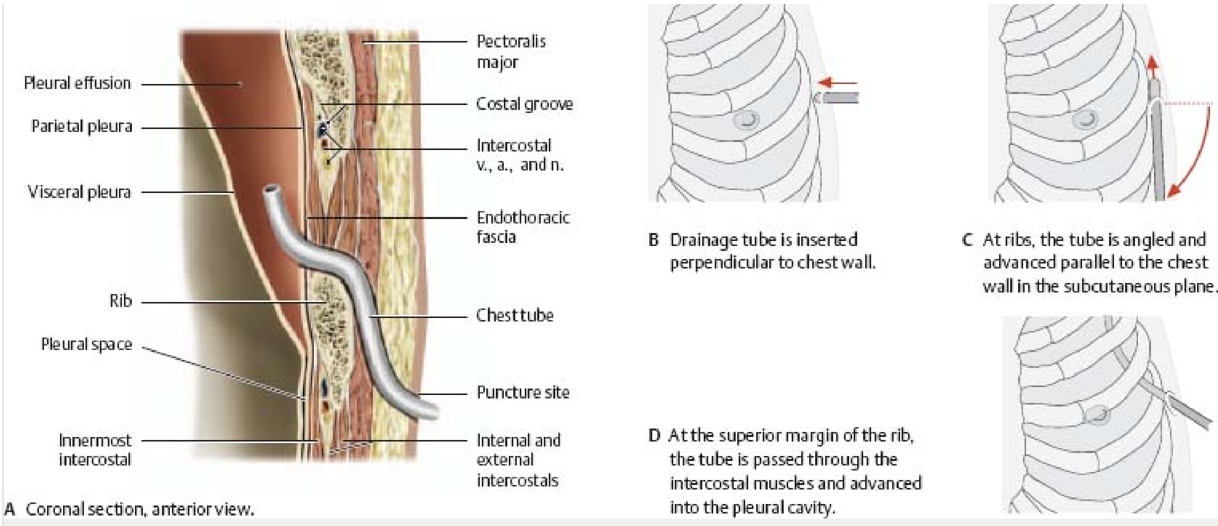
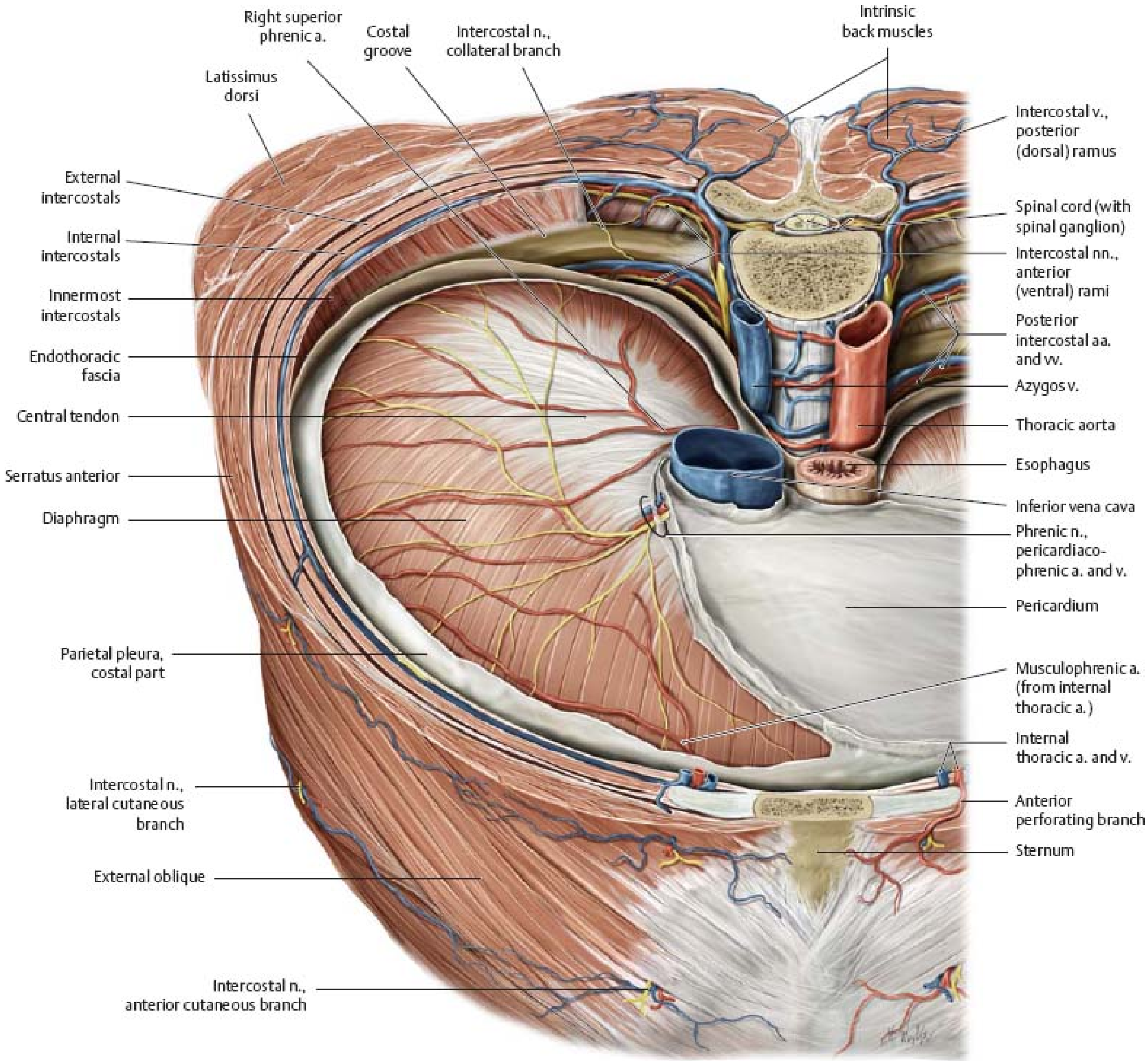


Fig. 5.27 **Intercostal structures in cross section**

Transverse section, anterosuperior view.



Female Breast

The female breast, a modified sweat gland in the subcutaneous tissue layer, consists of glandular tissue, fibrous stroma, and fat. The breast extends from the 2nd to the 6th rib and is loosely attached to the pectoral, axillary, and superficial abdominal fascia by connective tissue. The breast is additionally supported by suspensory ligaments. An extension of the breast tissue into the axilla, the axillary tail, is often present.

Fig. 5.28 **Female breast**

Right breast, anterior view.

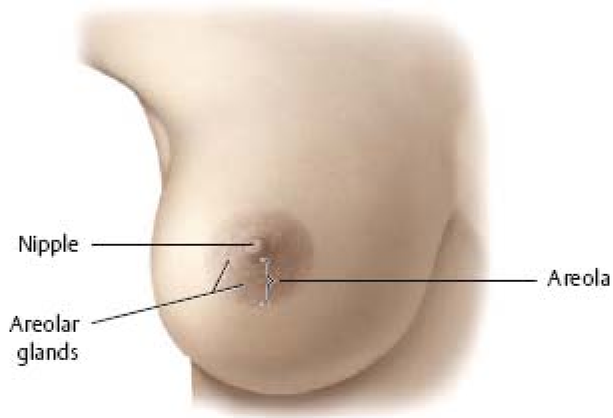


Fig. 5.29 **Mammary ridges**

Rudimentary mammary glands form in both sexes along the mammary ridges. Occasionally, these may persist in humans to form accessory nipples (*polythelia*), although only the thoracic pair normally remains.

Fig. 5.30 **Blood supply to the breast**

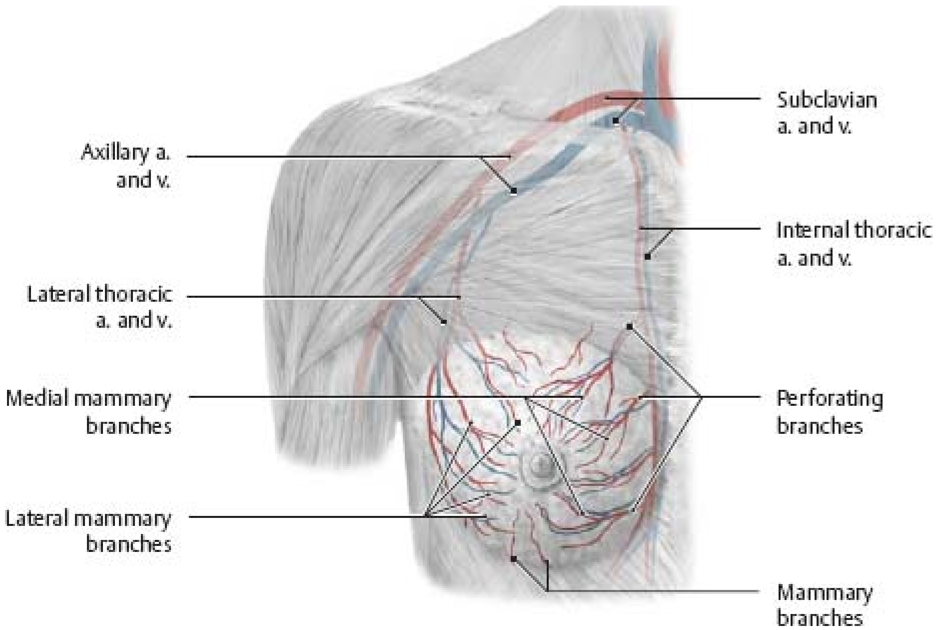
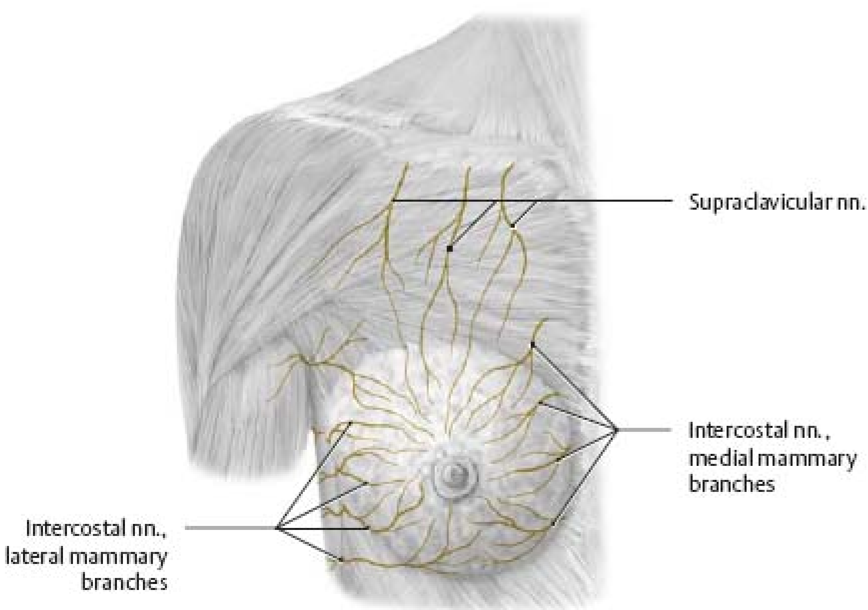
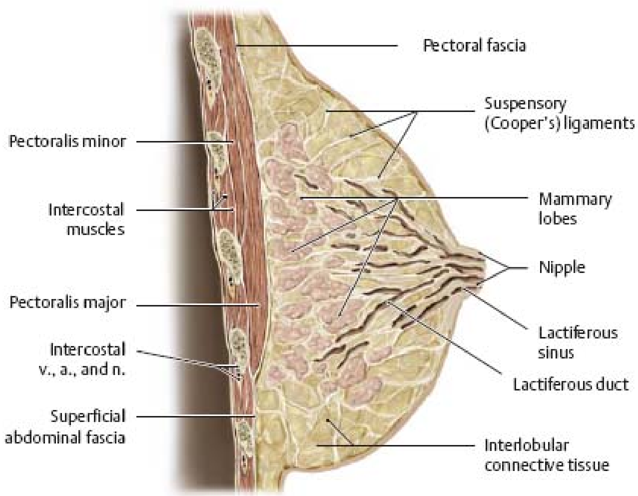


Fig. 5.31 **Sensory innervation of the breast**

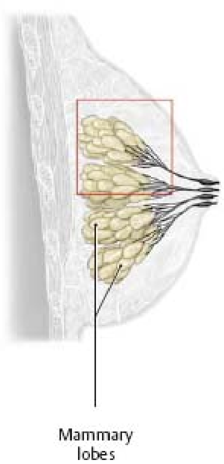


The glandular tissue is composed of 10 to 20 individual lobes, each with its own lactiferous duct. The gland ducts open on the elevated nipple at the center of the pigmented areola. Just proximal to the duct opening is a dilated portion called the lactiferous sinus. Areolar elevations are the openings of the areolar glands (sebaceous). The glands and lactiferous ducts are surrounded by firm, fibrofatty tissue with a rich blood supply.

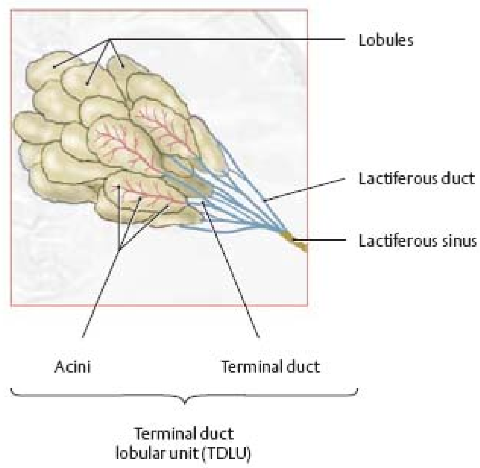
Fig. 5.32 Structures of the breast



A Sagittal section along midclavicular line.



B Duct system and portions of a lobe, sagittal section. In the nonlactating breast (shown here), the lobules contain clusters of rudimentary acini.

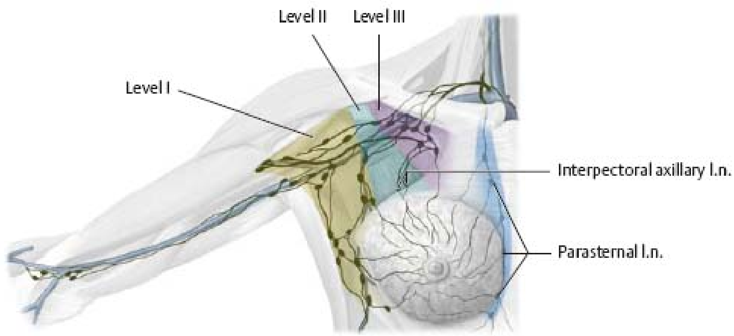


C Terminal duct lobular unit (TDLU). The clustered acini composing the lobule empty into a terminal ductule; these structures are collectively known as the TDLU.

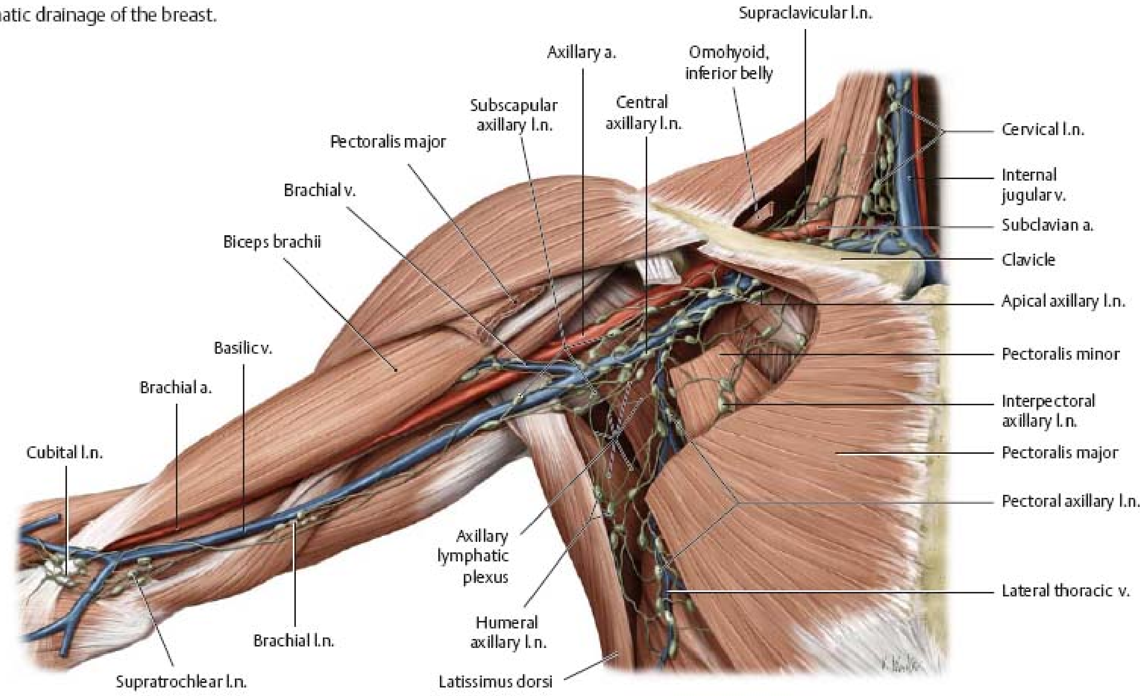
Lymphatics of the Female Breast

The lymphatic vessels of the breast (not shown) are divided into three systems: superficial, subcutaneous, and deep. These drain primarily into the axillary lymph nodes, which are classified based on their relationship to the pectoralis minor (Table 5.7). The medial portion of the breast is drained by the parasternal lymph nodes, which are associated with the internal thoracic vessels.

Fig. 5.33 Axillary lymph nodes



A Lymphatic drainage of the breast.



B Anterior view.

Table 5.7 **Levels of axillary lymph nodes**

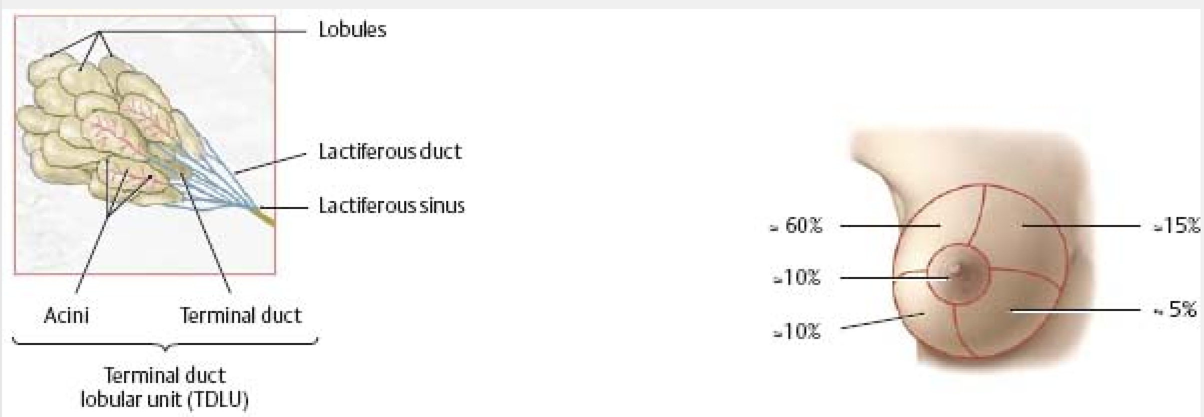
Level		Position	Lymph nodes (l.n.)
I	Lower axillary group	Lateral to pectoralis minor	Pectoral axillary l.n. Subscapular axillary l.n. Humeral axillary l.n. Central l.n.

Level		Position	Lymph nodes (l.n.)
II	Middle axillary group	Along pectoralis minor	Interpectoral axillary l.n.
III	Upper infraclavicular group	Medial to pectoralis minor	Apical axillary l.n.

Clinical

Breast cancer

Stem cells in the intralobular connective tissue give rise to tremendous cell growth, necessary for duct system proliferation and acini differentiation. This makes the terminal duct lobular unit (TDLU) the most common site of origin of malignant breast tumors.



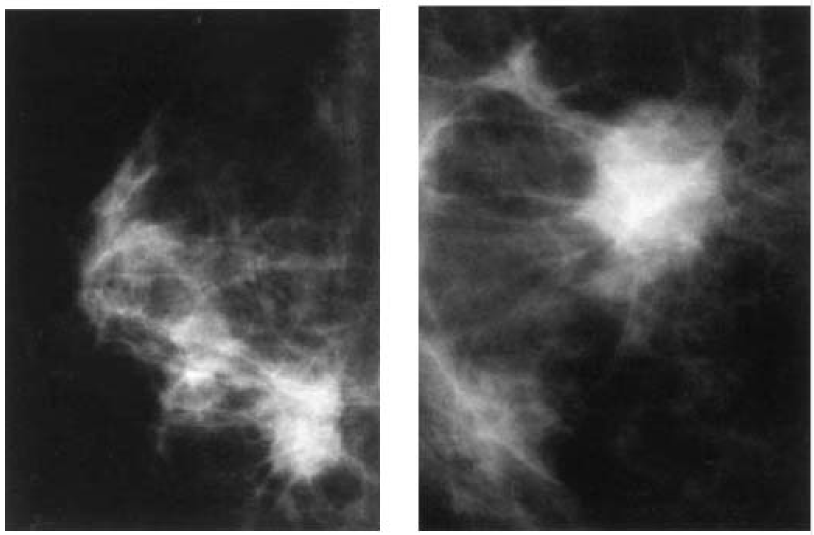
A Terminal duct lobular unit.

B Origin of malignant tumors by quadrant.

Tumors originating in the breast spread via the lymphatic vessels. The deep system of lymphatic drainage (level III) is of particular importance, although the parasternal lymph nodes provide a route by which tumor cells may spread across the midline. The survival rate in breast cancer correlates most strongly with the number of lymph nodes involved at the axillary nodal level. Metastatic involvement is gauged through scintigraphic mapping with radiolabeled colloids (technetium [Tc] 99m sulfur microcolloid). The downstream sentinel node is the first to receive lymphatic drainage from the tumor and is therefore the first to be visualized with radiolabeling. Once identified, it can then be removed (via *sentinel* *lymphadenectomy*) and histologically examined for tumor cells. This method is 98% accurate in predicting the level of axillary nodal involvement.

Metastatic involvement	5-year survival rate
Level I	65%
Level II	31%
Level III	~0%

C Normal mammogram.



D Mammogram of invasive ductal carcinoma. The large lesion has changed the architecture of the neighboring breast tissue.

6 Thoracic Cavity

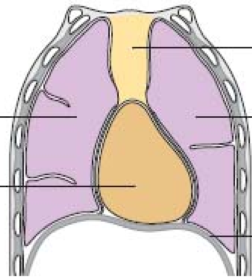
Divisions of the Thoracic Cavity

The thoracic cavity is divided into three large spaces: the mediastinum (p. 76) and the two pleural cavities (p. 102).

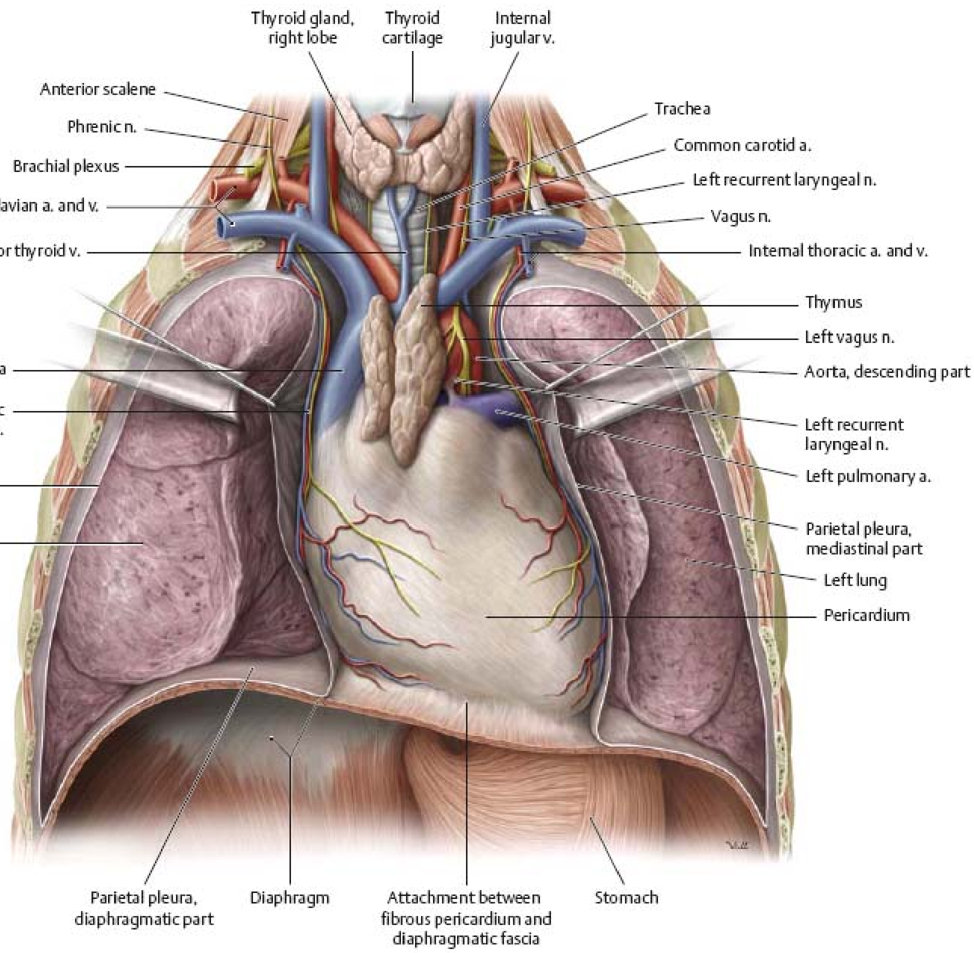
Fig. 6.1 **Thoracic cavity**

Coronal section, anterior view.

Fig. 6.1 Thoracic cavity
Coronal section, anterior view.



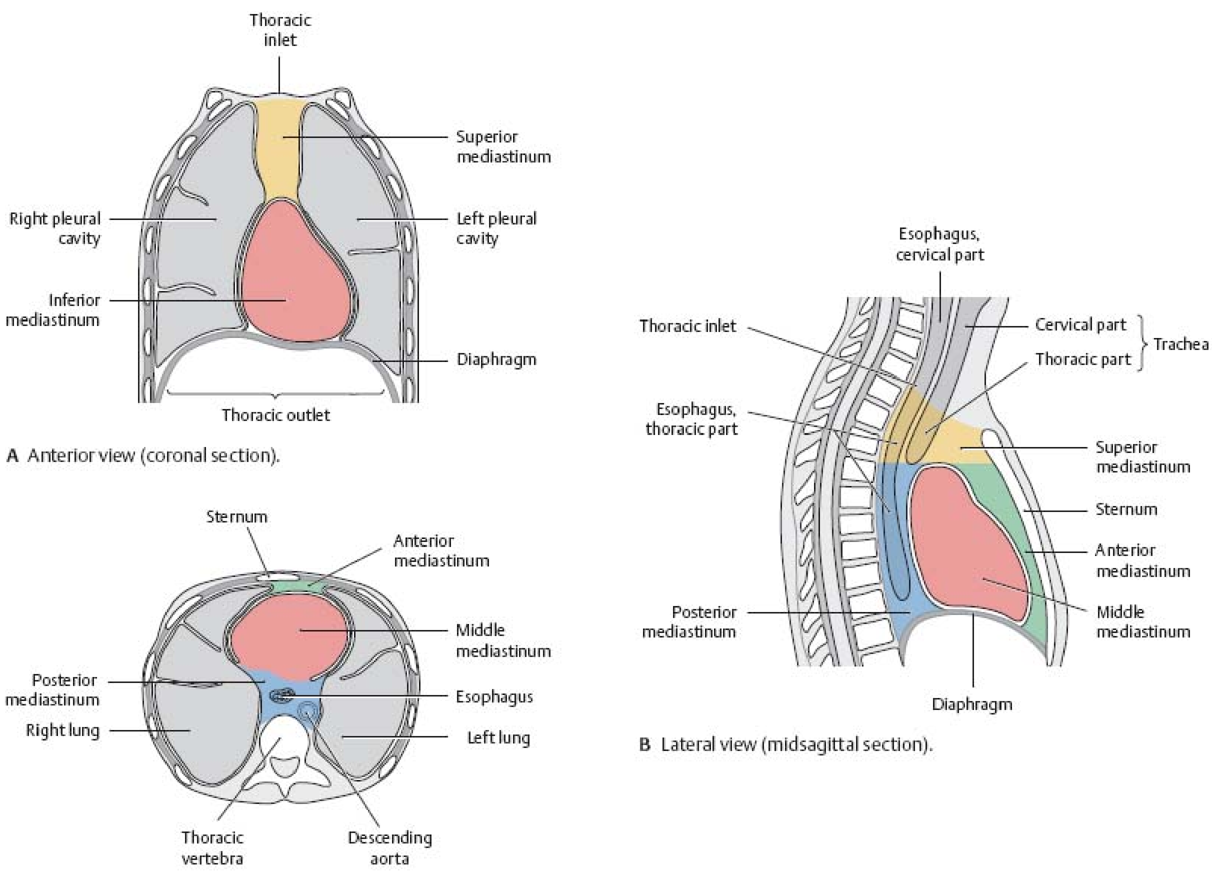
A Divisions of the thoracic cavity.



B Opened thoracic cavity. *Removed:* Thoracic wall; connective tissue of anterior mediastinum.

Table 6.1	Major structures of the thoracic cavity		
Mediastinum	Superior mediastinum		Thymus, great vessels, trachea, esophagus, and thoracic duct
	Inferior mediastinum	Anterior	Thymus
		Middle	Heart, pericardium, and roots of great vessels
		Posterior	Thoracic aorta, thoracic duct, esophagus, and azygos venous system
Pleural cavities	Right pleural cavity		Right lung
	Left pleural cavity		Left lung

Fig. 6.2 Divisions of the mediastinum



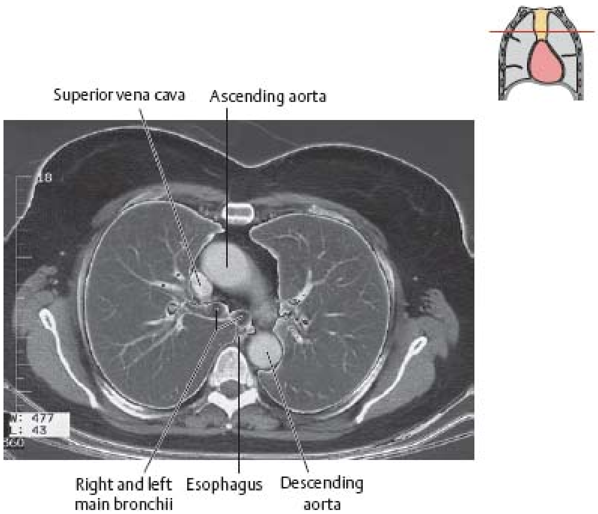
A Anterior view (coronal section).

B Lateral view (midsagittal section).

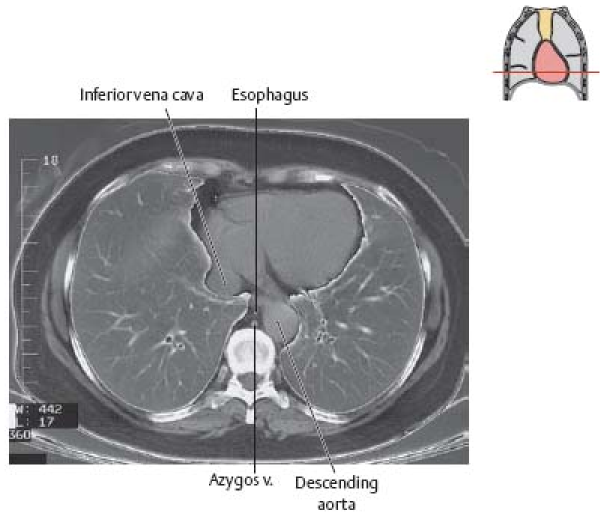
C Inferior view (transverse section).

Fig. 6.3 Transverse sections of the thorax

Computed tomography (CT) scan of thorax, inferior view.



A Superior mediastinum.

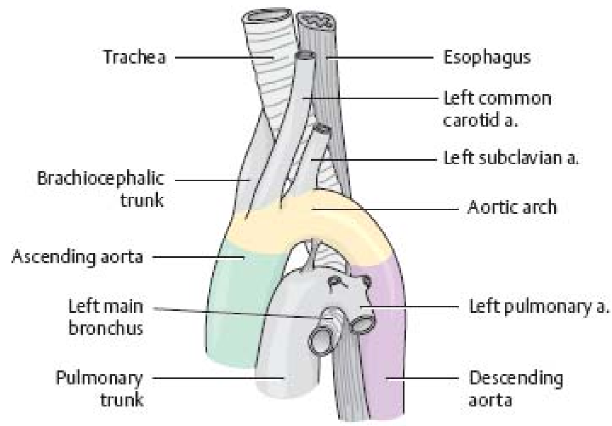


B Inferior mediastinum.

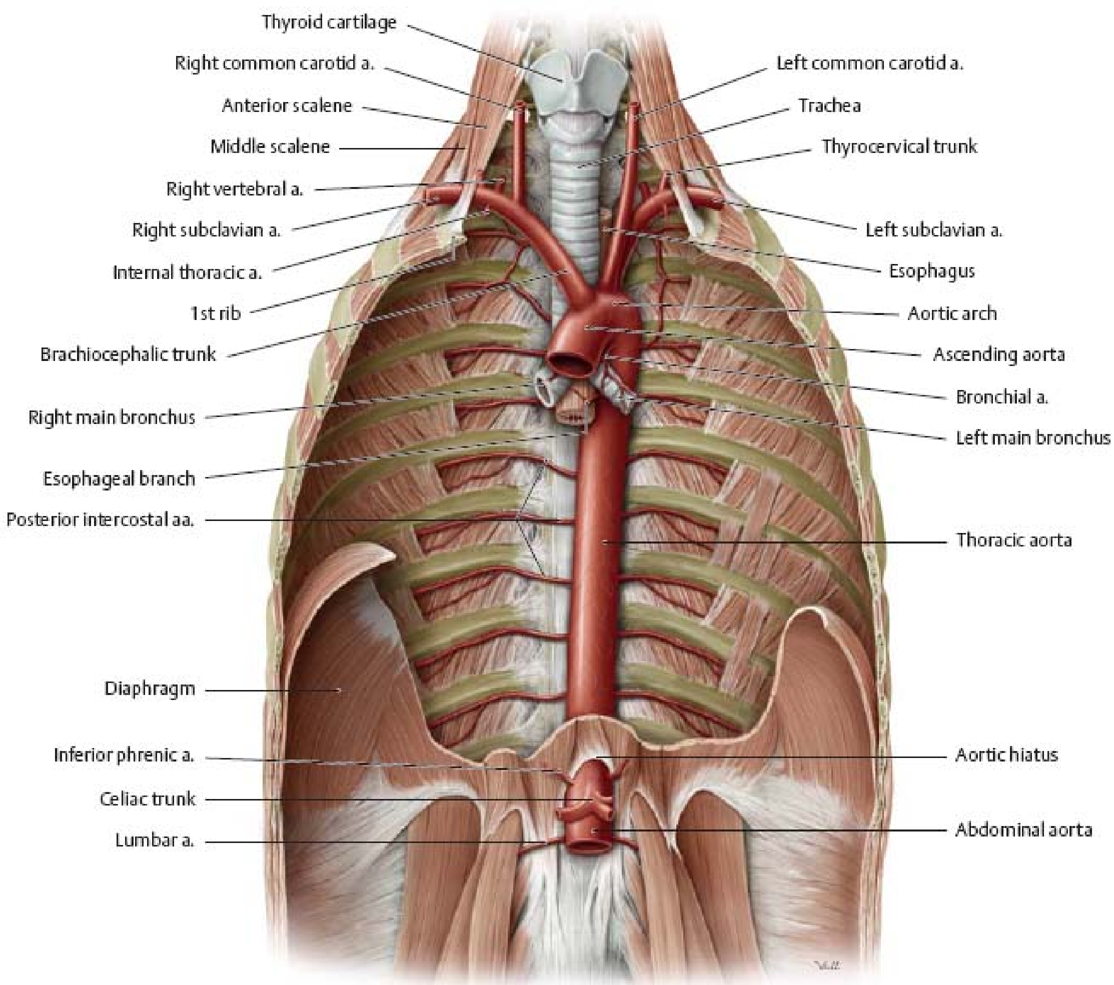
Arteries of the Thoracic Cavity

The arch of the aorta has three major branches: the brachiocephalic trunk, left common carotid artery, and left subclavian artery. After the aortic arch, the aorta begins its descent, becoming the thoracic aorta at the level of the sternal angle and the abdominal aorta once it passes through the aortic hiatus in the diaphragm.

Fig. 6.4 Thoracic aorta



A Parts of the aorta, left lateral view. *Note:* The aortic arch begins and ends at the level of the sternal angle (see p. 46).



B Thoracic aorta in situ, anterior view. *Removed:* Heart, lungs, portions of diaphragm.

Table 6.2 Branches of the thoracic aorta

The thoracic organs are supplied by direct branches from the thoracic aorta, as well as indirect branches from the subclavian arteries.

Branches			Region supplied
Brachiocephalic trunk	Right subclavian a.		See left subclavian a.
	Right common carotid a.		Head and neck
Left common carotid a.			
Left subclavian a.	Vertebral a.		
	Internal thoracic a.	Anterior intercostal aa.	Anterior chest wall
		Thymic branches	Thymus
		Mediastinal branches	Posterior mediastinum
		Pericardiacophrenic a.	Pericardium, diaphragm
	Thyrocervical trunk	Inferior thyroid a.	Esophagus, trachea, thyroid gland
	Costocervical trunk	Superior intercostal a.	Chest wall
Descending thoracic aorta	Visceral branches		Bronchi, trachea, esophagus
	Parietal branches	Posterior intercostal aa.	Posterior chest wall
		Superior phrenic aa.	Diaphragm
Ascending aorta	Right and left coronary aa.		Heart

Clinical

Aortic dissection

A tear in the inner wall (intima) of the aorta allows blood to separate the layers of the aortic wall, creating a “false lumen” and potentially resulting in life-threatening aortic rupture. Symptoms are dyspnea (shortness of breath) and sudden onset of excruciating pain. Acute aortic dissections occur most often in the ascending aorta and generally require surgery. More distal aortic dissections may be treated conservatively, provided there are no complications (e.g., obstruction of blood supply to the organs, in which case a stent may be inserted to restore perfusion). Aortic dissections occurring at the base of a coronary artery may cause myocardial infarction.

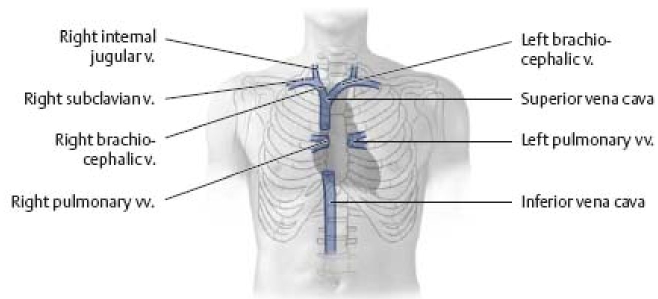
A Aortic dissection. Parts of the intima are still attached to the connective tissue in the wall of the aorta (*arrow*).

B The flow in the coronary arteries is intact (*arrow*).

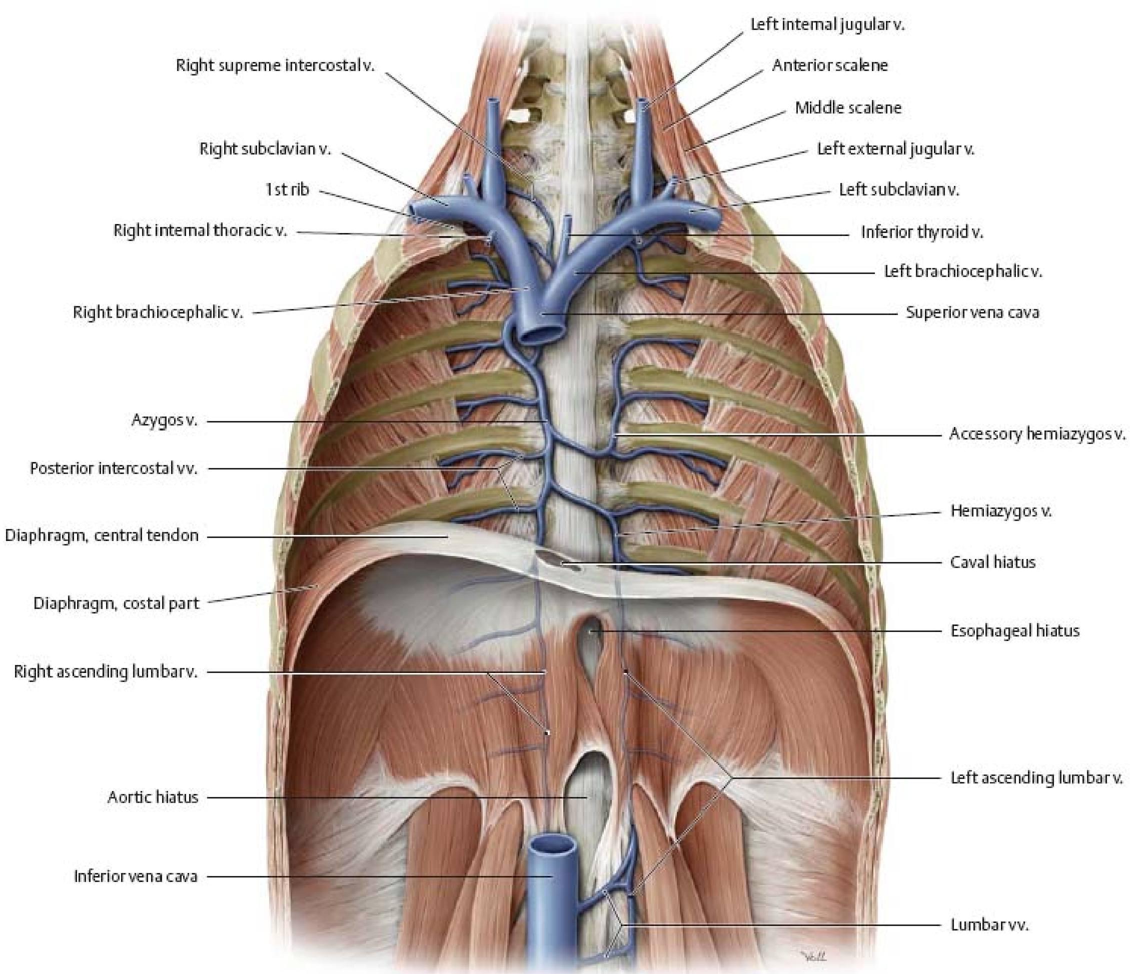
Veins of the Thoracic Cavity

The superior vena cava is formed by the union of the two brachiocephalic veins at the level of the T2-T3 junction. It receives blood drained by the azygos system (the inferior vena cava has no tributaries in the thorax).

Fig. 6.5 Superior vena cava and azygos system



A Projection of venae cavae onto chest, anterior view.



B Veins of the thoracic cavity, anterior view of opened thorax.

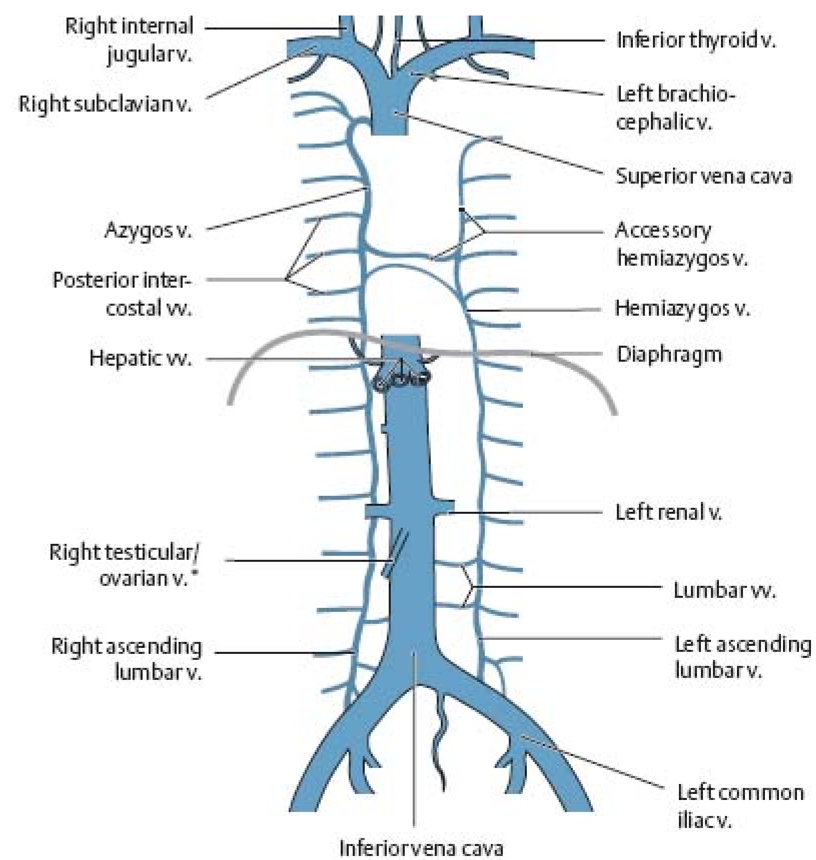
Table 6.3 Thoracic tributaries of the superior vena cava

Major vein	Tributaries		Region drained
Brachiocephalic vv.	Inferior thyroid v.		Esophagus, trachea, thyroid gland
	Internal jugular vv.		Head, neck, upper limb
	External jugular vv.		
	Subclavian vv.		
	Supreme intercostal vv.		
	Pericardial vv.		
	Left superior intercostal v.		
Azygos system (left side: accessory hemiazygos v.; right side: azygos v.)	Visceral branches		Trachea, bronchi, esophagus
	Parietal branches	Posterior intercostal vv.	Inner chest wall and diaphragm
		Superior phrenic vv.	
		Right superior intercostal v.	
Internal thoracic v.	Thymic vv.		Thymus
	Mediastinal tributaries		Posterior mediastinum
	Anterior intercostal vv.		Anterior chest wall
	Pericardiacophrenic v.		Pericardium
	Musculophrenic v.		Diaphragm

Note: Structures of the superior mediastinum may also drain directly to the brachiocephalic veins via the tracheal, esophageal, and mediastinal veins.

Fig. 6.6 Azygos system

Anterior view.



* The left testicular/ovarian vein arises from the left renal vein.

Lymphatics of the Thoracic Cavity

The body's chief lymph vessel is the thoracic duct. Beginning in the abdomen at the level of L1 as the *cisterna chyli*, the thoracic duct empties into the junction of the left internal jugular and subclavian veins. The right lymphatic duct drains to the right junction of the internal jugular and subclavian veins.

Fig. 6.7 Lymphatic trunks in the thorax

Anterior view of opened thorax.

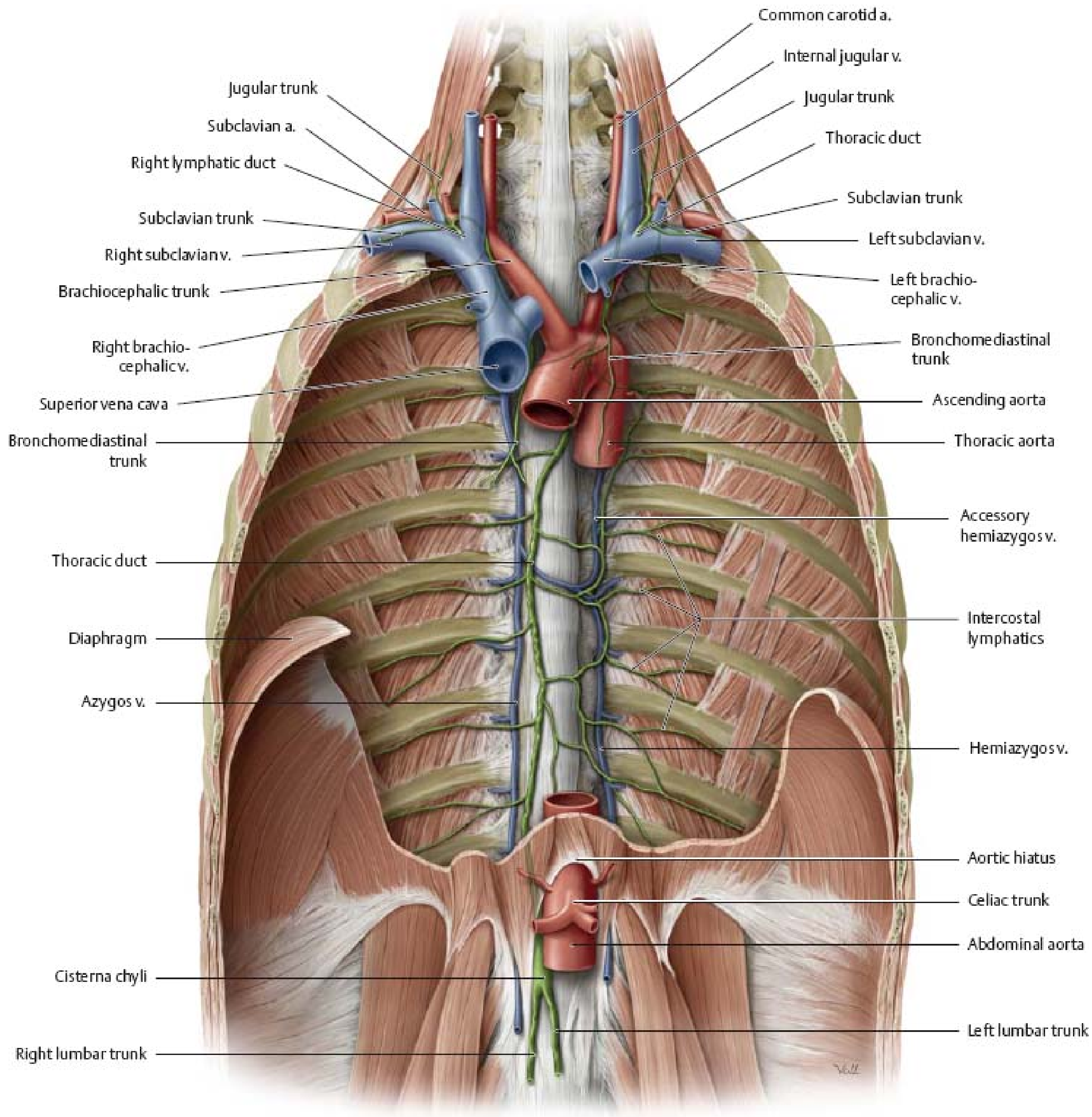


Fig. 6.8 **Lymphatic pathways in the thorax**

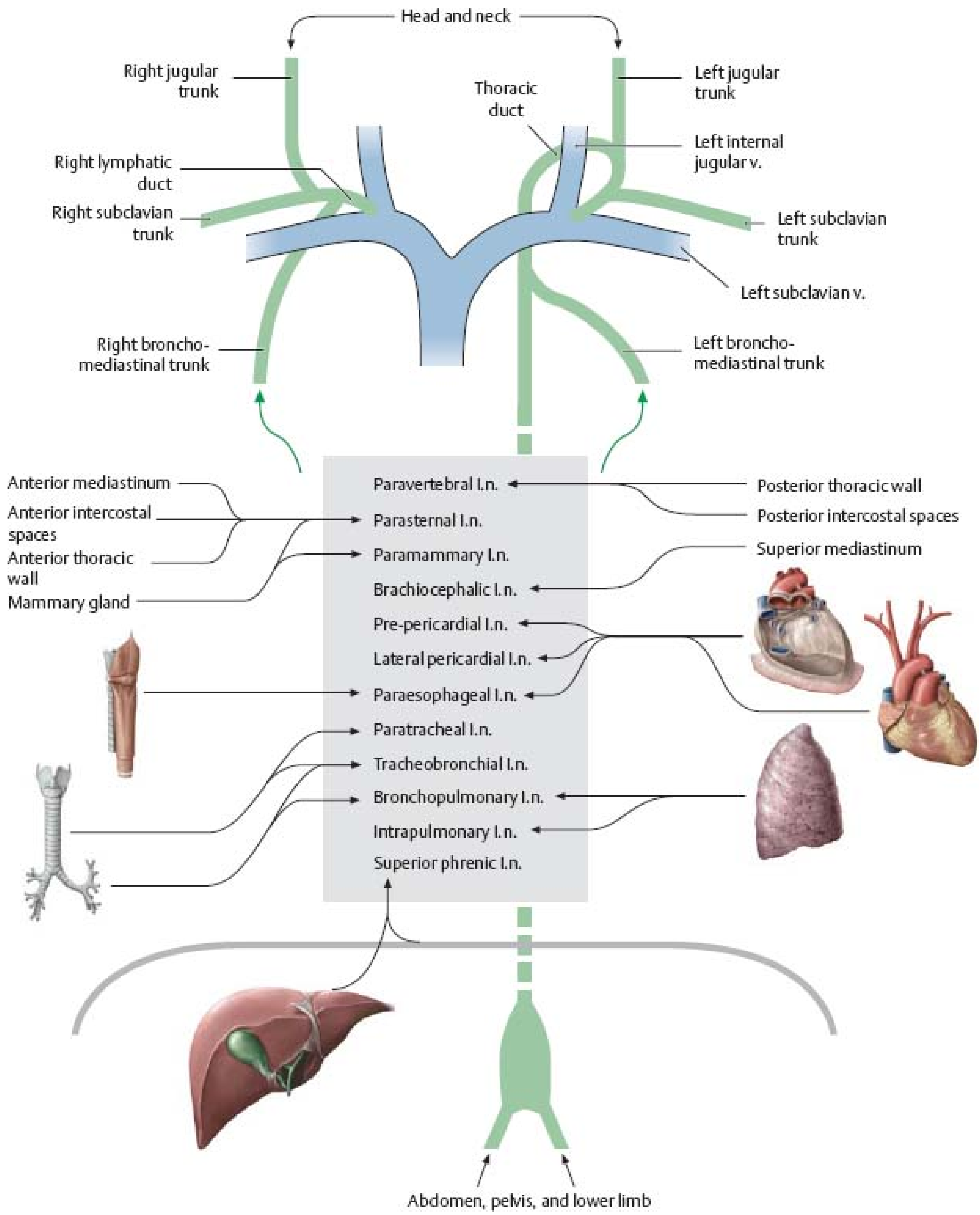


Fig. 6.9 **Lymphatic drainage by quadrants**

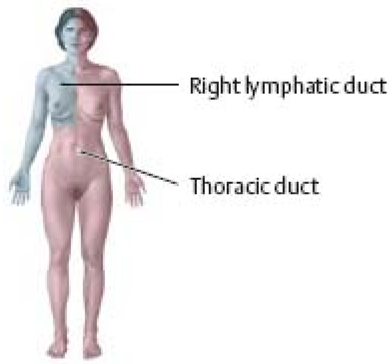
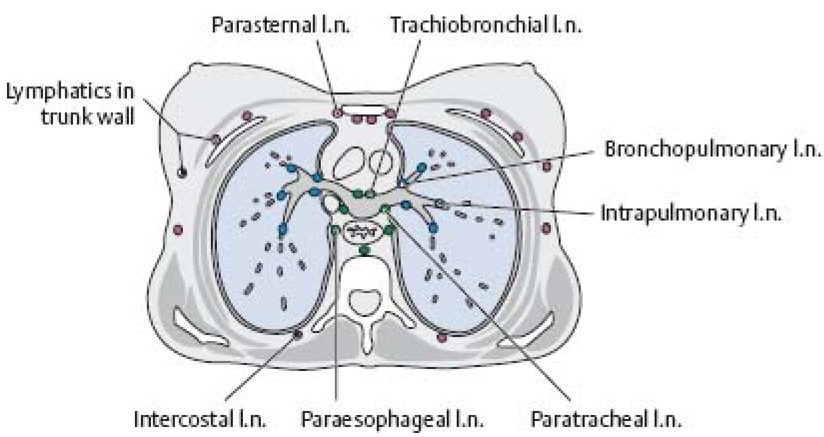


Fig. 6.10 Thoracic lymph nodes

Transverse section at level of tracheal bifurcation (T4), inferior view. The thoracic lymph nodes can be divided into three broad groups: nodes of the thoracic wall (pink), pulmonary nodes (blue), and mediastinal nodes (green). For details of lymphatics of the mediastinum, see pp. 100–101.

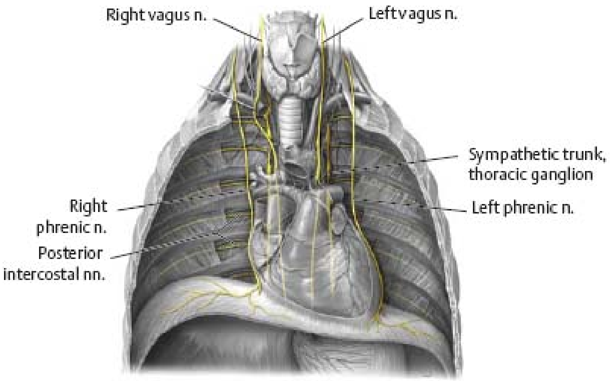


Nerves of the Thoracic Cavity

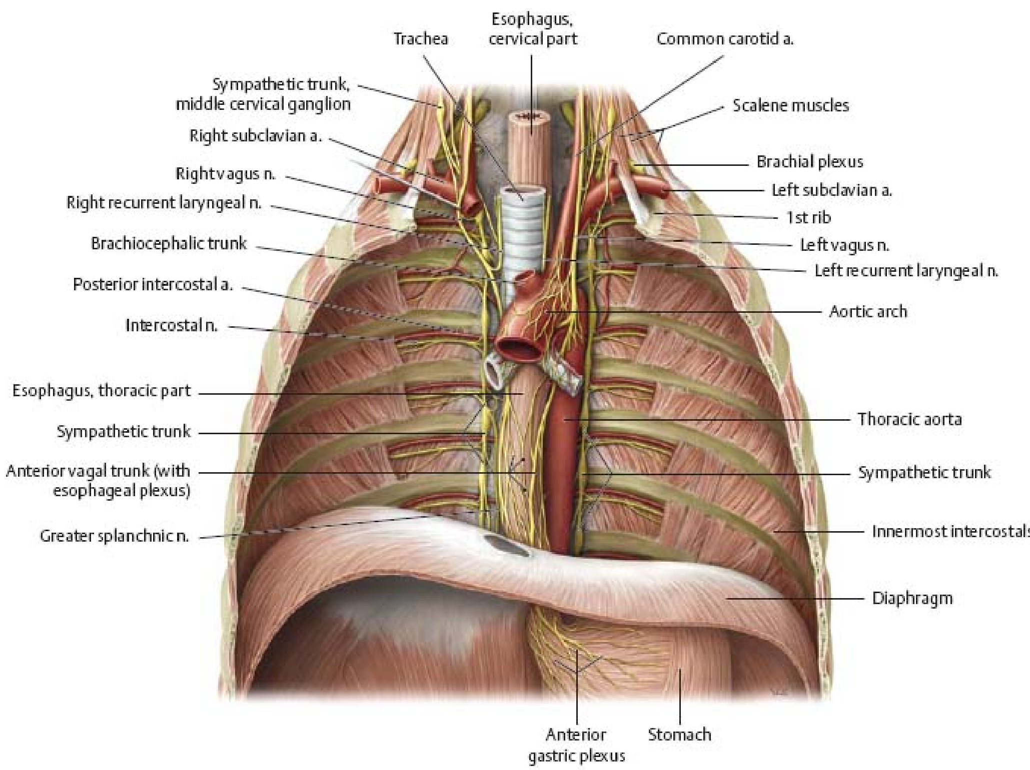
Thoracic innervation is mostly autonomic, arising from the paravertebral sympathetic trunks and parasympathetic vagus nerves. There are two exceptions: the phrenic nerves innervate the pericardium and diaphragm (p. 54), and the intercostal nerves innervate the thoracic wall (p. 58).

Fig. 6.11 Nerves in the thorax

Anterior view of opened thorax.



A Thoracic innervation.



B Nerves of the thorax in situ. *Note:* The recurrent laryngeal nerves have been slightly anteriorly retracted; normally, they occupy the groove between the trachea and the esophagus, making them vulnerable during thyroid gland surgery.

The autonomic nervous system innervates smooth muscle, cardiac muscle, and glands. It is subdivided into the sympathetic (red) and parasympathetic (blue) nervous systems, which together regulates blood flow, secretions, and organ function.

Fig. 6.12 Sympathetic and parasympathetic nervous systems in the thorax

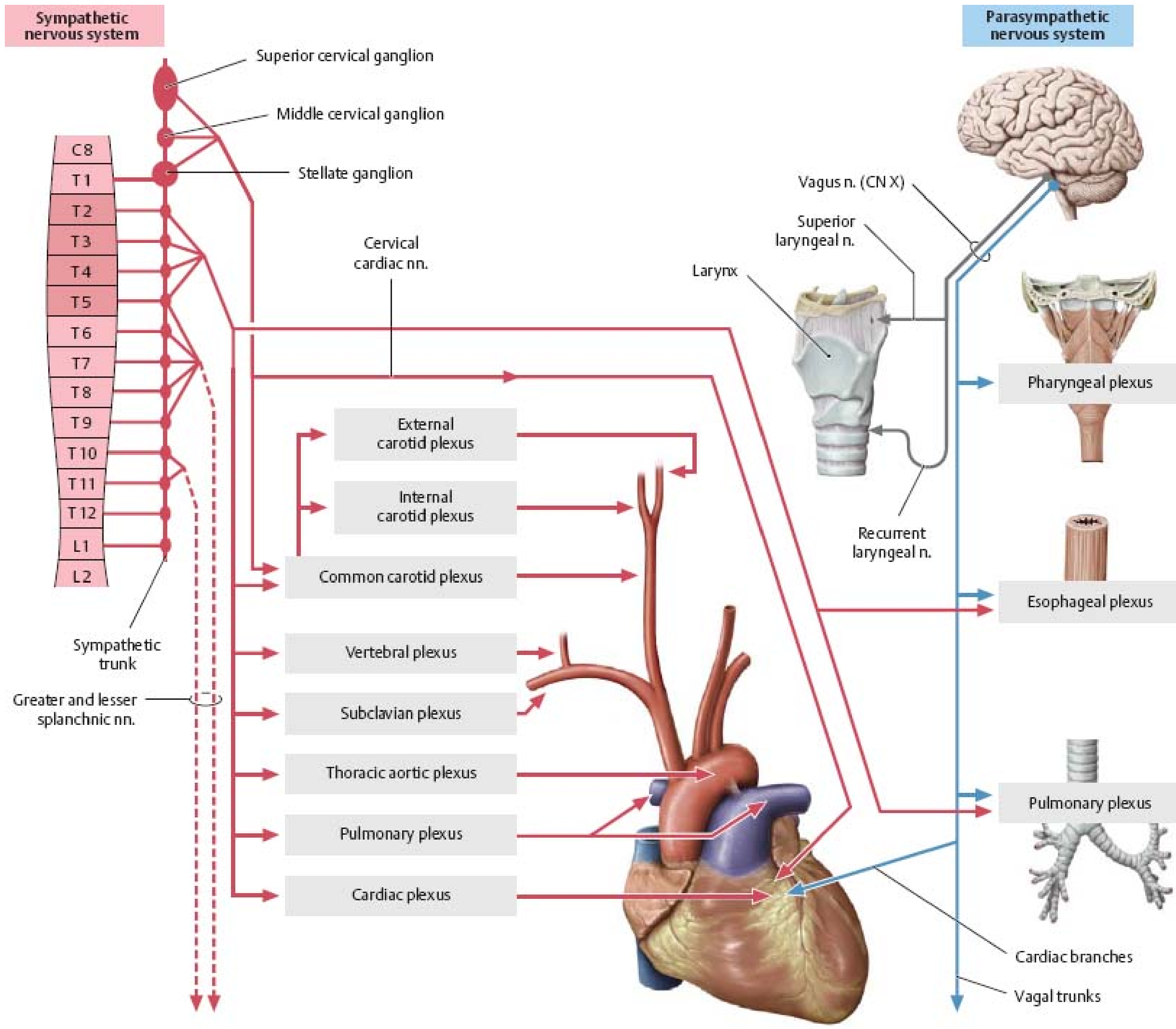


Table 6.4 Peripheral sympathetic nervous system

Origin of presynaptic fibers*	Ganglion cells	Course of postsynaptic fibers	Target
Spinal cord	Sympathetic trunk	Follow intercostal nn.	Blood vessels and glands in chest wall
		Accompany intrathoracic aa.	Visceral targets
		Gather in greater and lesser splanchnic nn.	Abdomen

*The axons of presynaptic neurons exit the spinal cord via the anterior roots and synapse with *postsynaptic* neurons in the sympathetic ganglia.

Table 6.5 Peripheral parasympathetic nervous system			
Origin of presynaptic fibers	Course of presynaptic motor axons*		Target
Brainstem	Vagus n. (CN X)	Cardiac branches	Cardiac plexus
		Esophageal branches	Esophageal plexus
		Tracheal branches	Trachea
		Bronchial branches	Pulmonary plexus (bronchi, pulmonary vessels)

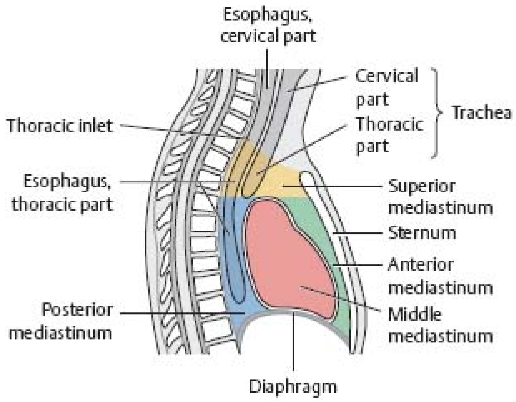
*The ganglion cells of the parasympathetic nervous system are scattered in microscopic groups in their target organs. The vagus nerve thus carries the *pre*synaptic motor axons to these targets.
CN = cranial nerve.

7 Mediastinum

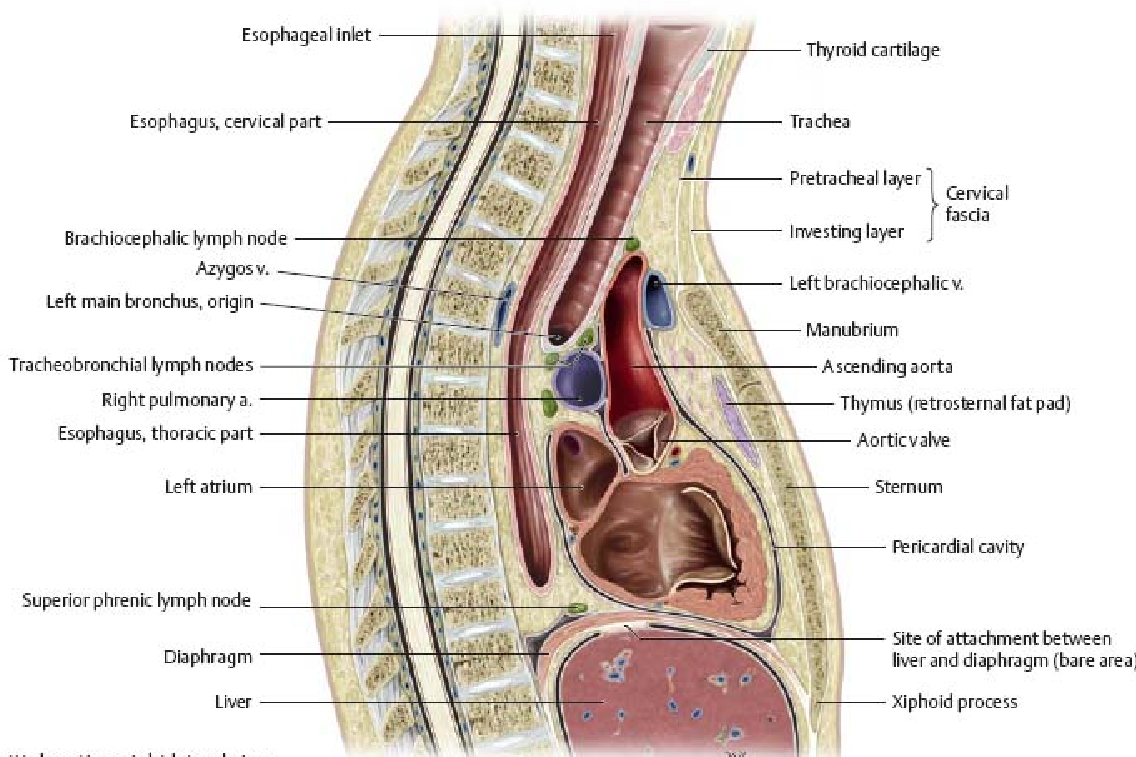
Mediastinum: Overview

The mediastinum is the space in the thorax between the pleural sacs of the lungs. It is divided into two parts: superior and inferior. The inferior mediastinum is further divided into anterior, middle, and posterior portions.

Fig. 7.1 **Divisions of the mediastinum**



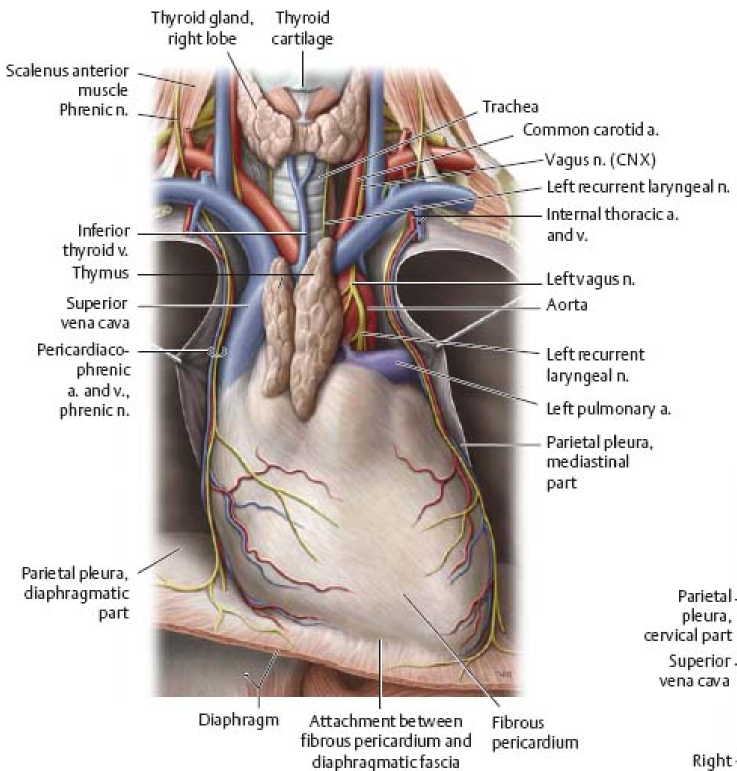
A Schematic.



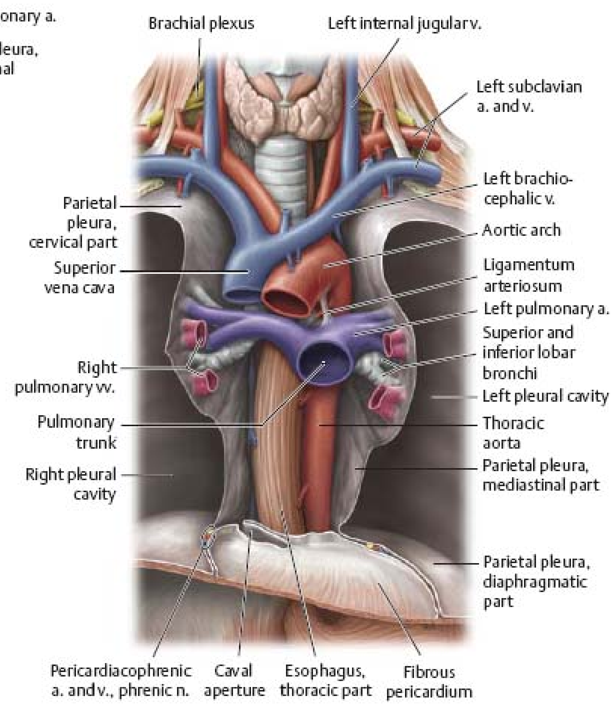
B Midsagittal section, right lateral view.

Table 7.1	Contents of the mediastinum			
	Superior mediastinum	Inferior mediastinum		
		Anterior	*Middle*	*Posterior*
Organs	• Thymus • Trachea • Esophagus • Thoracic duct	• Thymus (in children, see Fig. 7.5)	• Heart • Pericardium	• Esophagus
Arteries	• Aortic arch • Brachiocephalic trunk • Left common carotid a. • Left subclavian a.	• Smaller vessels	• Ascending aorta • Pulmonary trunk and branches • Pericardiacophrenic aa. and vv.	• Thoracic aorta and branches • Thoracic duct
Veins and lymph vessels	• Superior vena cava • Brachiocephalic vv. • Thoracic duct	• Smaller vessels, lymphatics, and lymph nodes	• Superior vena cava • Azygos v. • Pulmonary vv. • Pericardiacophrenic aa. and vv.	• Azygos v. • Hemiazygos v. • Thoracic duct
Nerves	• Vagus nn. • Left recurrent laryngeal n. • Cardiac nn. • Phrenic nn.	• None	• Phrenic nn.	• Vagus nn.

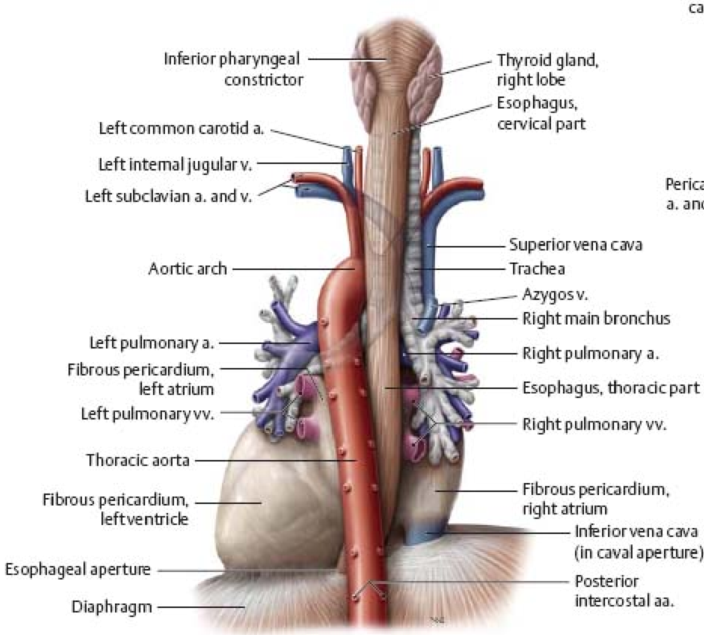
Fig. 7.2 **Contents of the mediastinum**



A Anterior view of mediastinum.



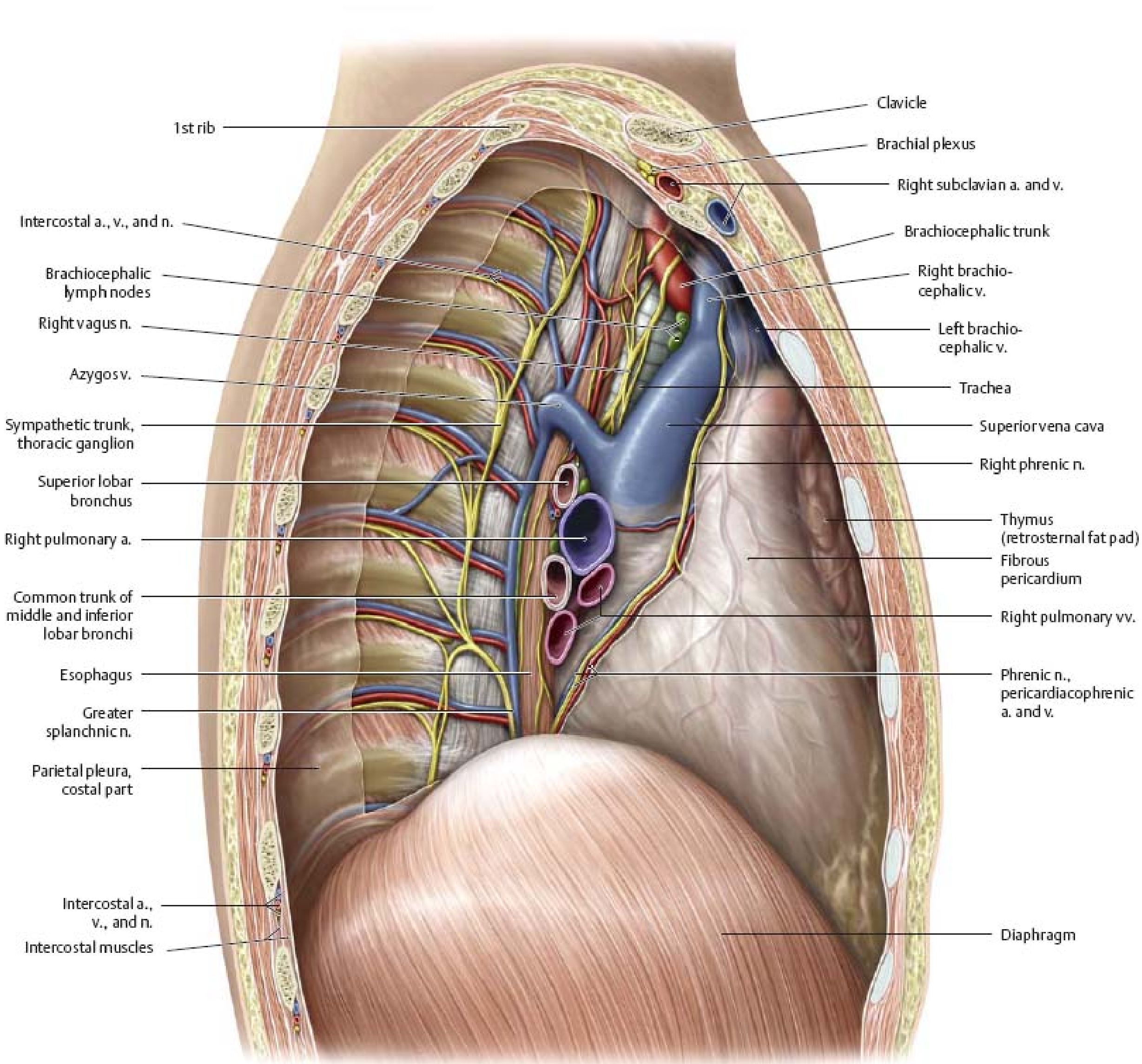
B Anterior view with heart, pericardium, and thymus removed.



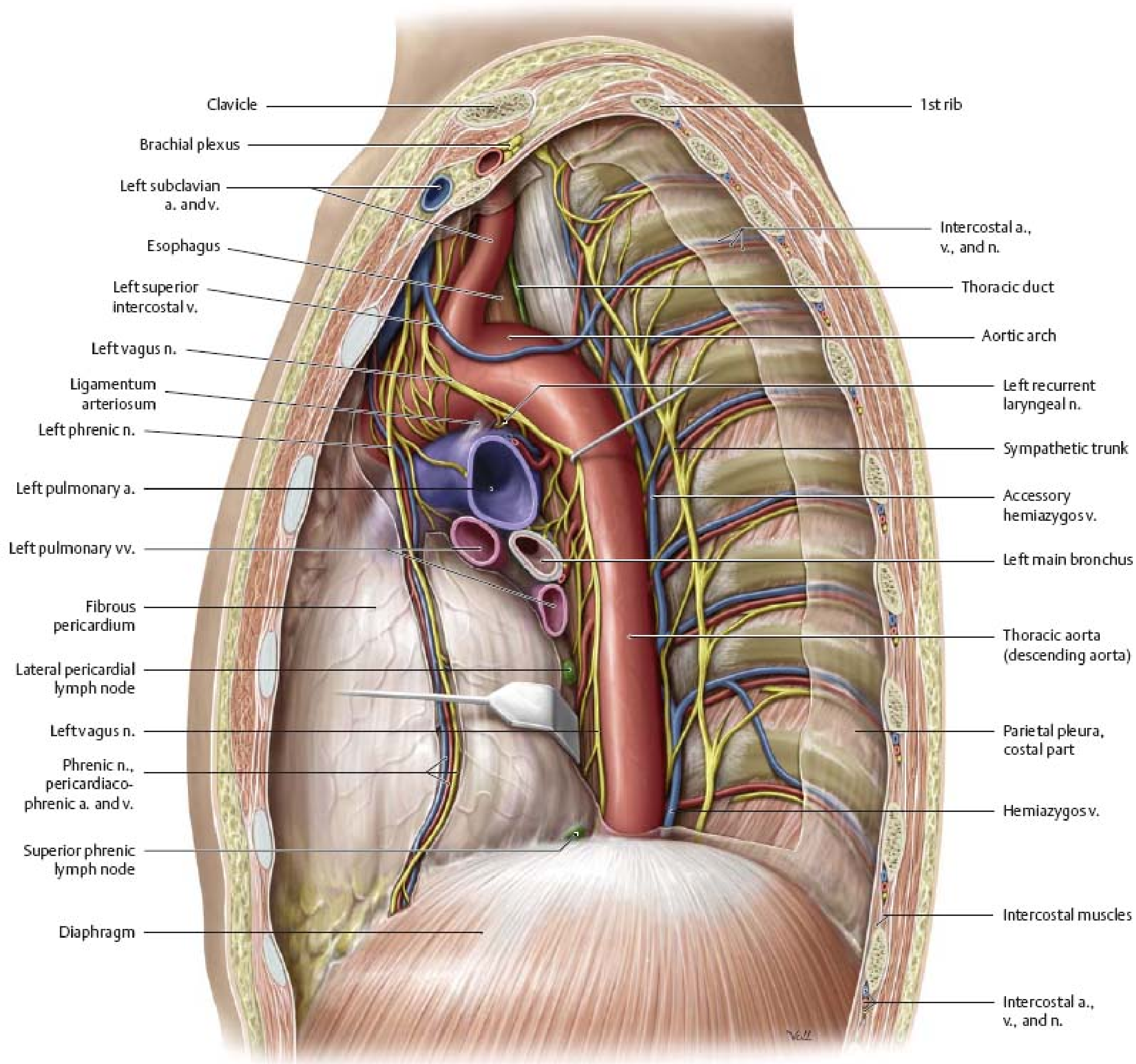
C Posterior view.

Mediastinum: Structures

Fig. 7.3 Mediastinum



A Right lateral view, parasagittal section. Note the many structures passing between the superior and inferior (middle and posterior) mediastinum.



B Left lateral view, parasagittal section. *Removed:* Left lung and parietal pleura. *Revealed:* Posterior mediastinal structures.

Thymus & Pericardium

Fig. 7.4 Thymus and pericardium in situ

Anterior view of coronal section. The thymus lies in the superior mediastinum.

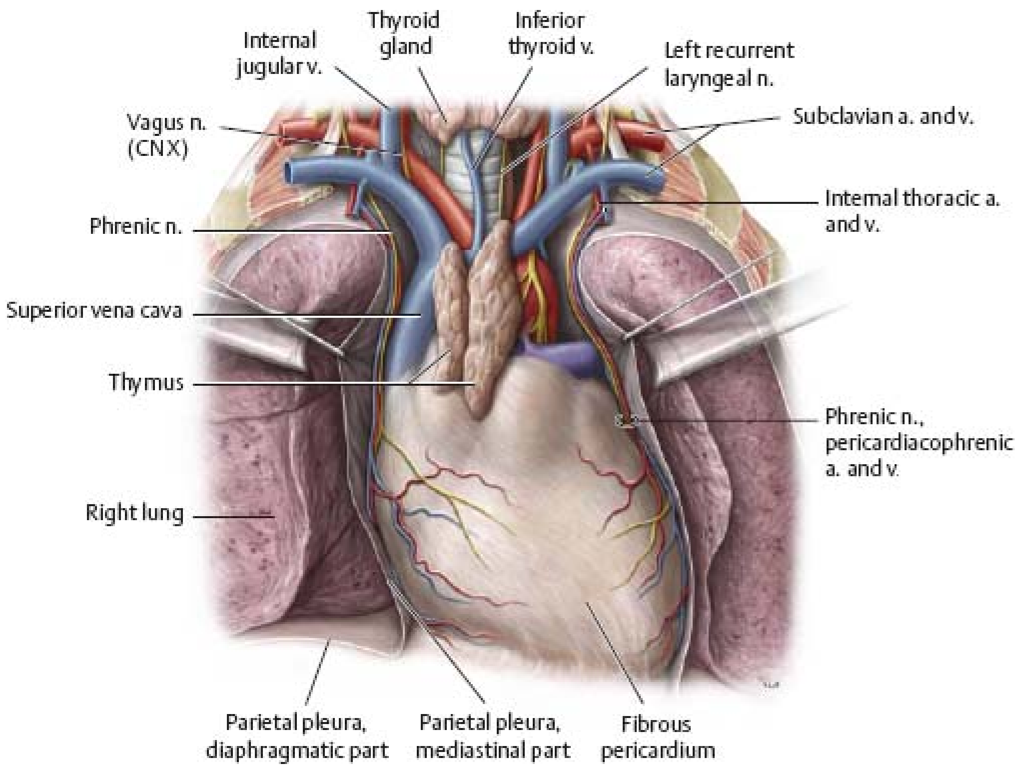


Fig. 7.5 Thymus

Anterior view of opened thorax of a 2-year-old child. The thymus is well developed at this age, extending inferiorly into the anterior mediastinum (compare with Fig. 7.4). The thymus grows throughout childhood; at puberty, high levels of circulating sex hormones cause the thymus to atrophy.

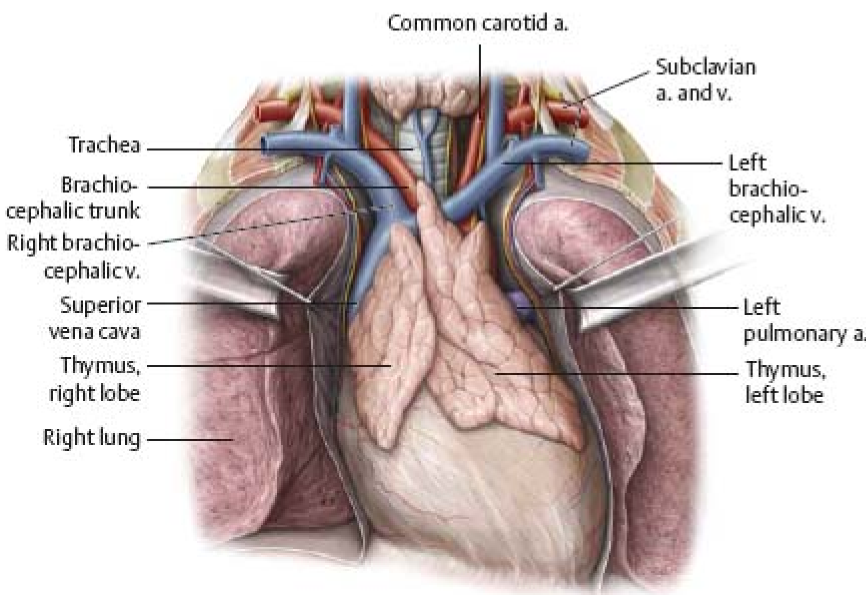


Fig. 7.6 **Pericardium**

Anterior view of opened thorax with flaps of fibrous pericardium reflected.

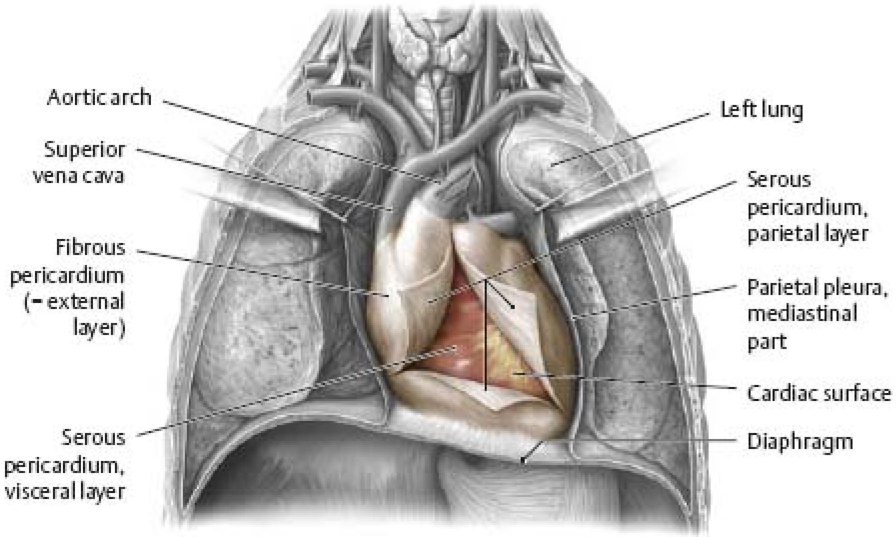
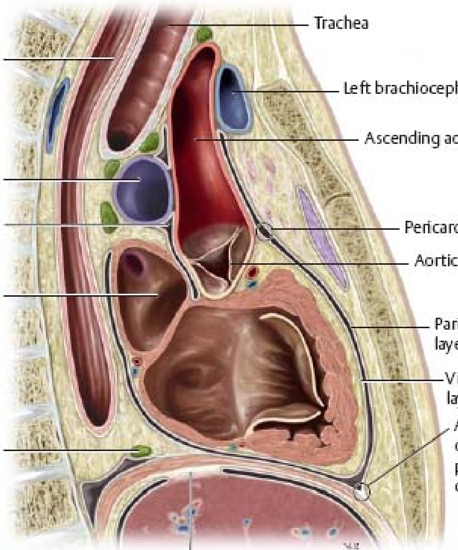
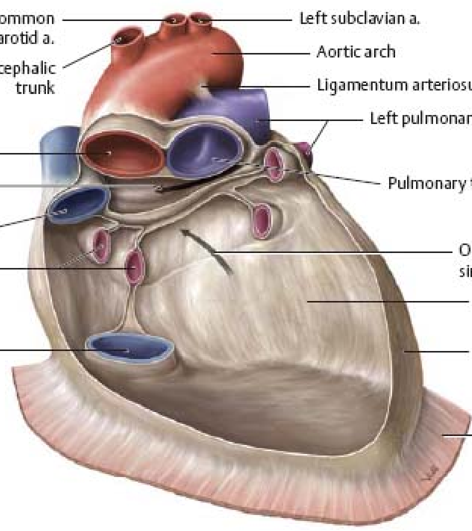


Fig. 7.7 **Serous pericardial reflections**

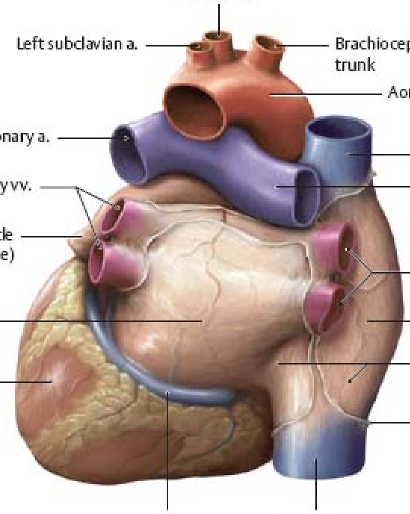
Anterior view. The parietal and visceral serous pericardium are continuous with one another around the great vessels of the heart. The passage between the arterial- and venous-associated reflections is the transverse pericardial sinus (see **B**).



A Sagittal section through the mediastinum. Note the continuity of the parietal serous and visceral serous pericardia.



B Pericardium with heart removed, anterior view.

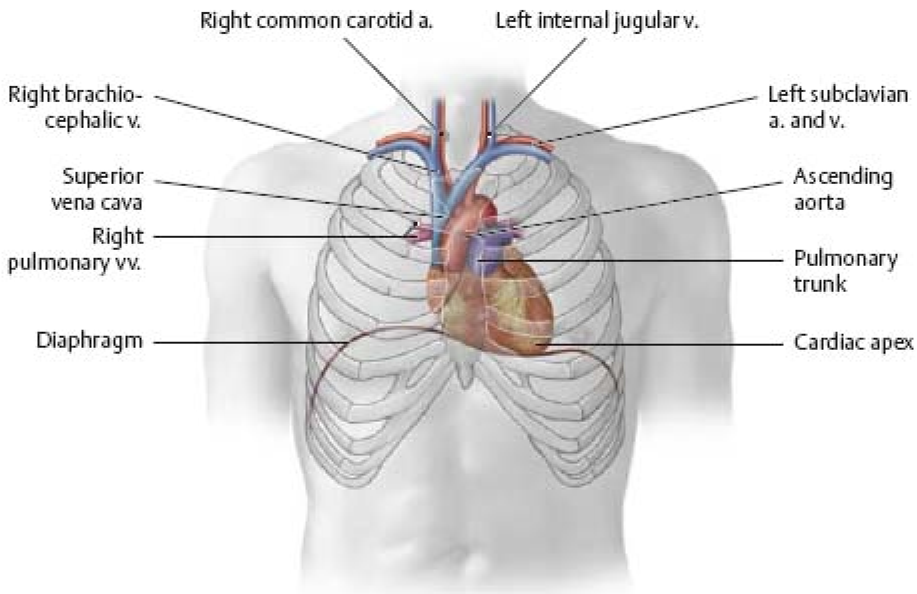


C Heart removed from fibrous pericardium, posterior view. Note the reflection of the visceral layer of serous pericardium (cut edges).

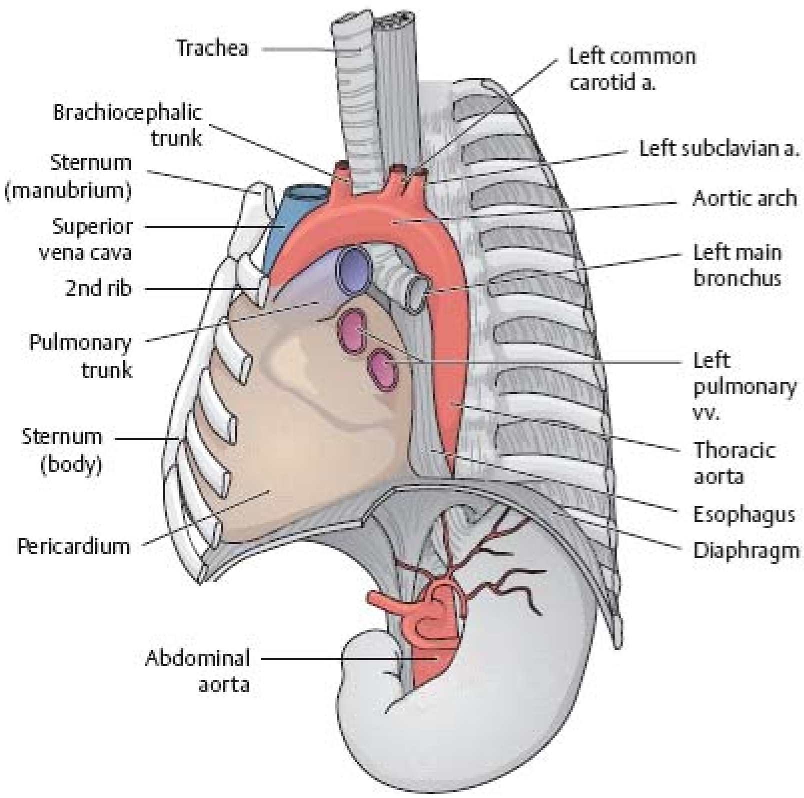
Heart in Situ

The heart is located posterior to the sternum in the middle portion of the inferior mediastinum. The heart projects into the left side of the thoracic cavity.

Fig. 7.8 **Topographical relations of the heart**



A Projection of heart and great vessels onto chest, anterior view.



B Left lateral view.

Fig. 7.9 **Circulation**

Red: Oxygenated blood. Blue: Deoxygenated blood. See p. 94 for prenatal circulation.

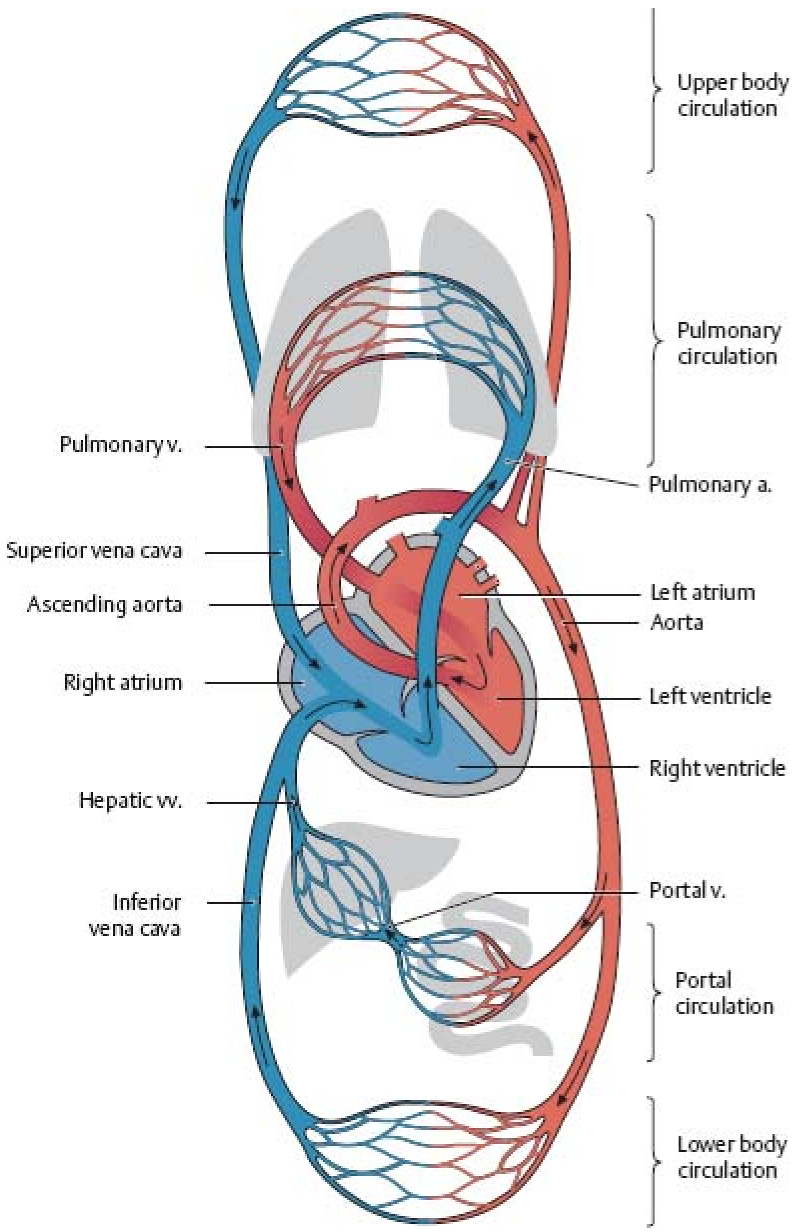
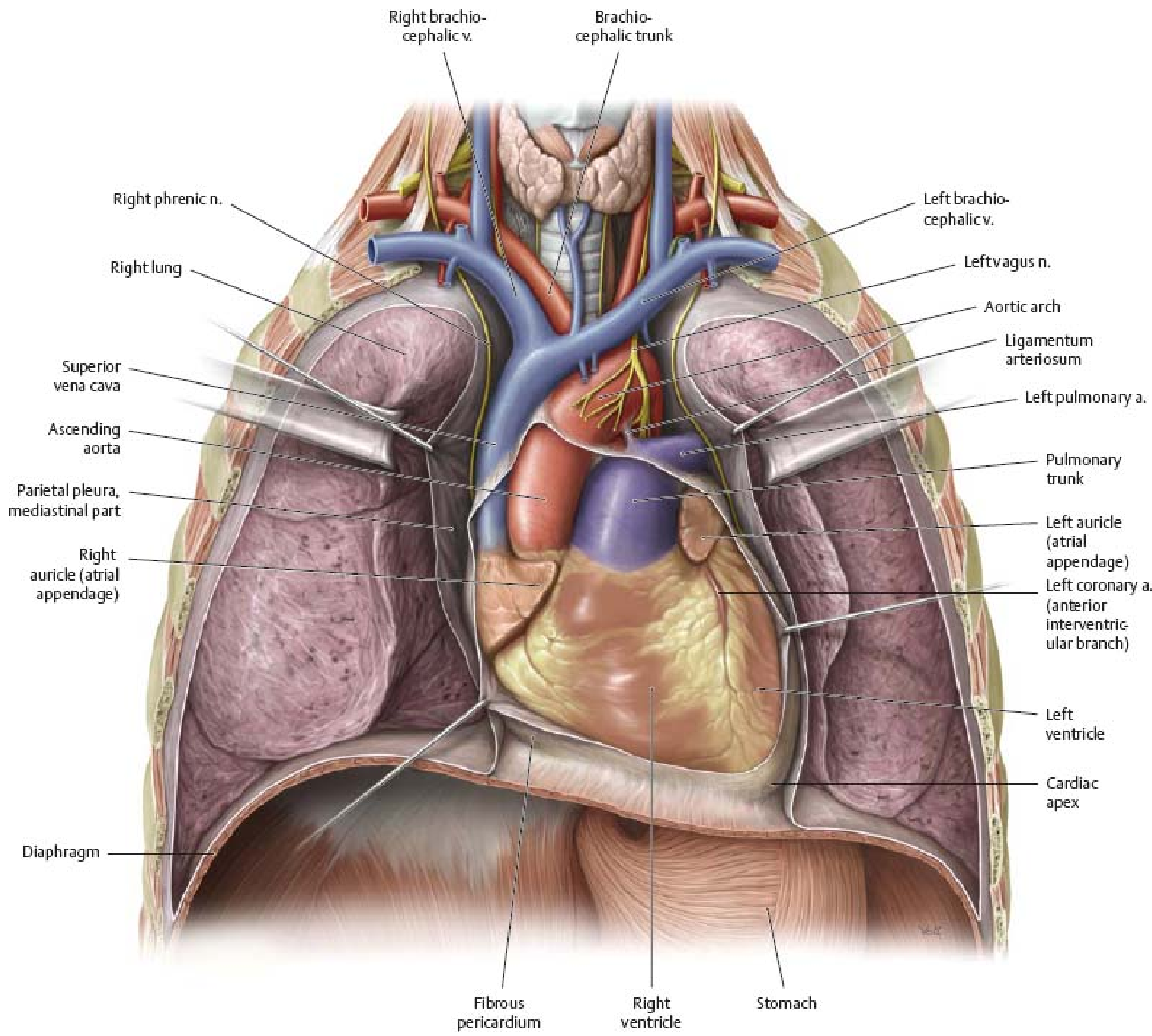


Fig. 7.10 Heart in situ

Anterior view.



Heart: Surfaces & Chambers

Note the reflection of visceral serous pericardium to become parietal serous pericardium.

Fig. 7.11 Surfaces of the heart

The heart has three surfaces: anterior (sternocostal), posterior (base), and inferior (diaphragmatic).

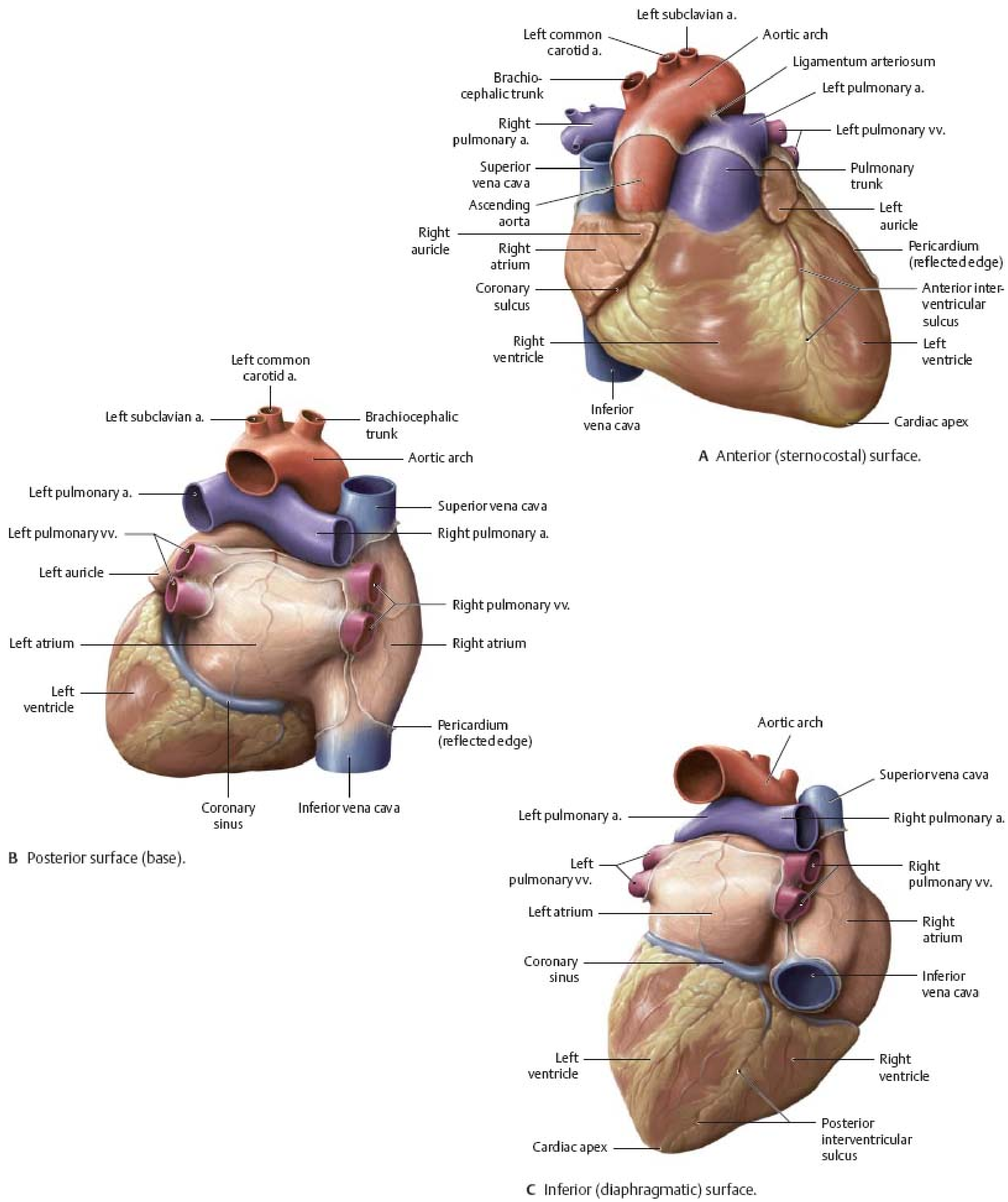
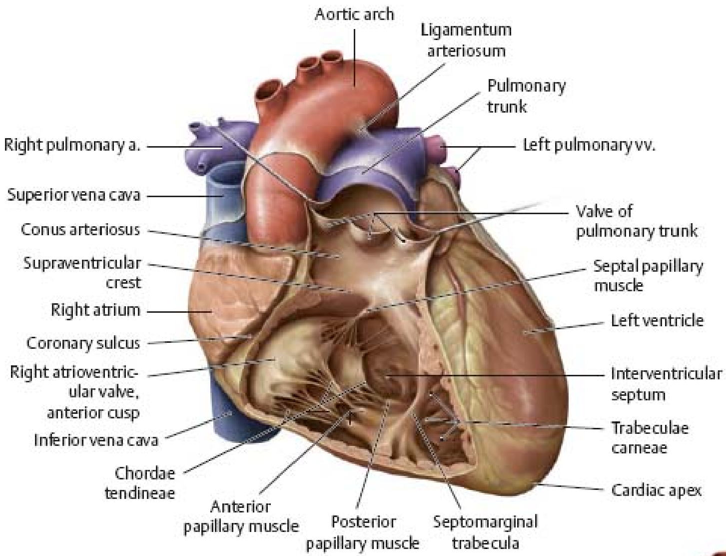
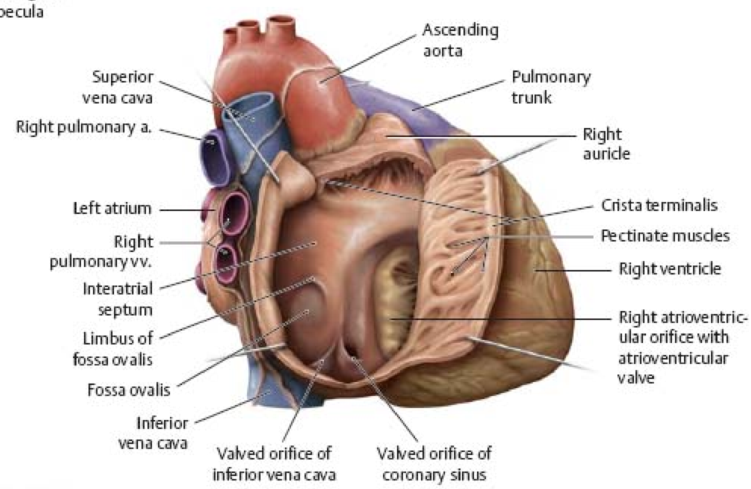


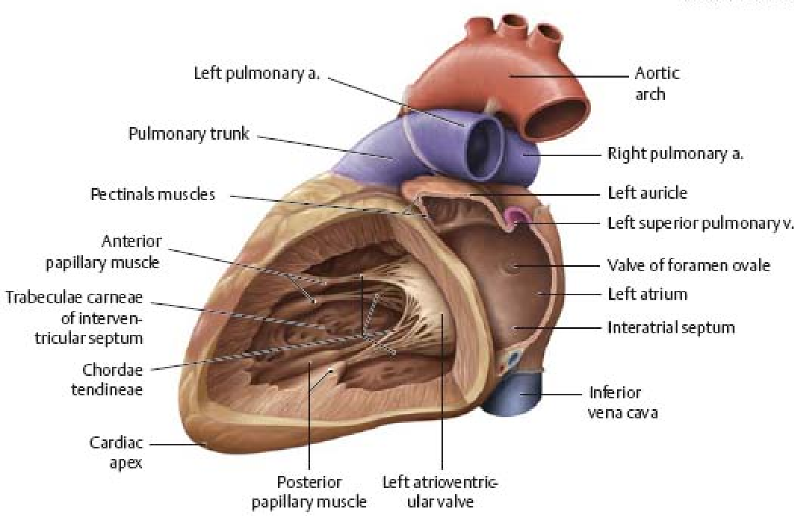
Fig. 7.12 Chambers of the heart



A Right ventricle, anterior view. Note the supraventricular crest, which marks the adult boundary between the embryonic ventricle and the bulbus cordis (now conus arteriosus).



B Right atrium, right lateral view.



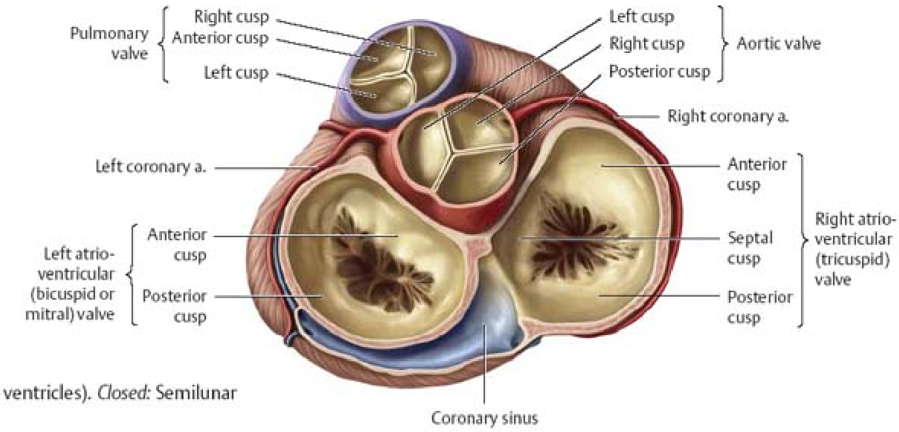
C Left atrium and ventricle, left lateral view. Note the irregular trabeculae carneae characteristic of the ventricular wall.

Heart: Valves

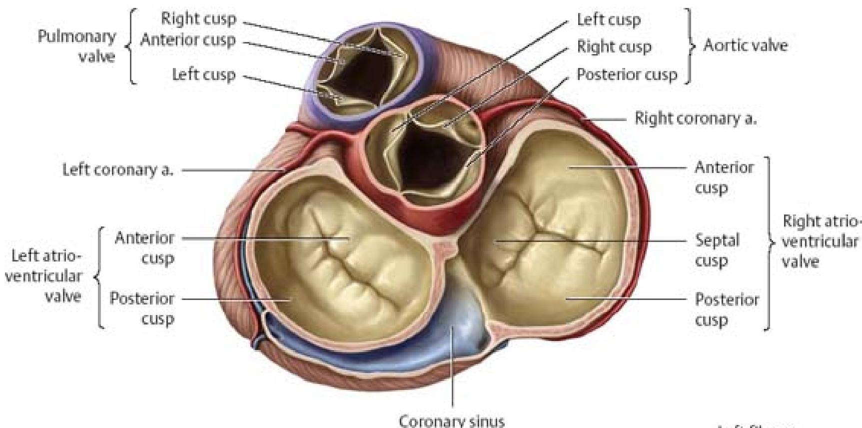
The cardiac valves are divided into two groups: semilunar and atrioventricular. The two semilunar valves (aortic and pulmonary) located at the base of the two great arteries of the heart regulate passage of blood from the ventricles to the aorta and pulmonary trunk. The two atrioventricular valves (left and right) lie at the interface between the atria and ventricles.

Fig. 7.13 Cardiac valves

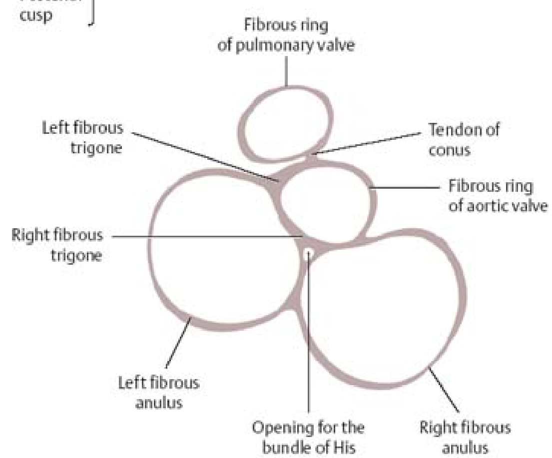
Plane of cardiac valves, superior view. *Removed:* Atria and great arteries.



A Ventricular diastole (relaxation of the ventricles). *Closed:* Semilunar valves. *Open:* Atrioventricular valves.



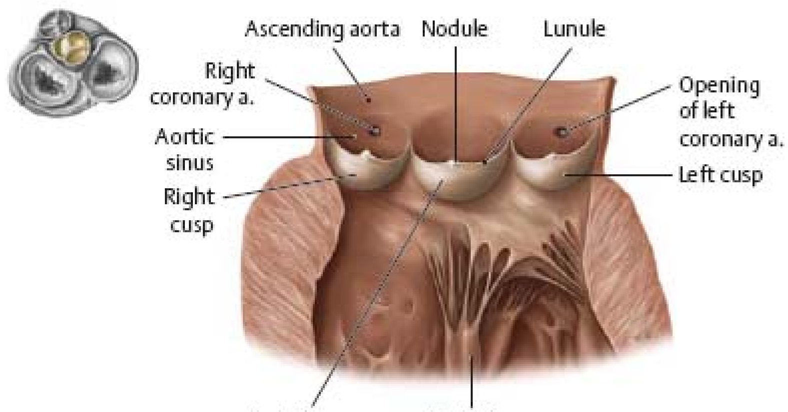
B Ventricular systole (contraction of the ventricles). *Closed:* Atrioventricular valves. *Open:* Semilunar valves.



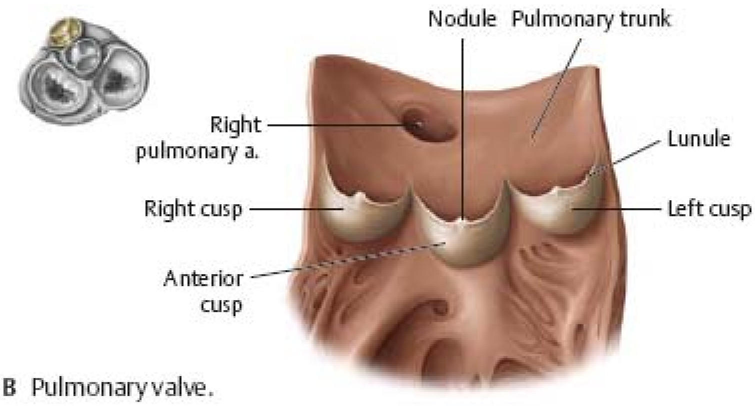
C Cardiac skeleton. The cardiac skeleton is formed by dense fibrous connective tissue. The fibrous anuli (rings) and intervening trigones separate the atria from the ventricles. This provides mechanical stability, electrical insulation (see p. 90 for cardiac conduction system), and an attachment point for the cardiac muscles and valve cusps.

Fig. 7.14 Semilunar valves

Valves have been longitudinally sectioned and opened.



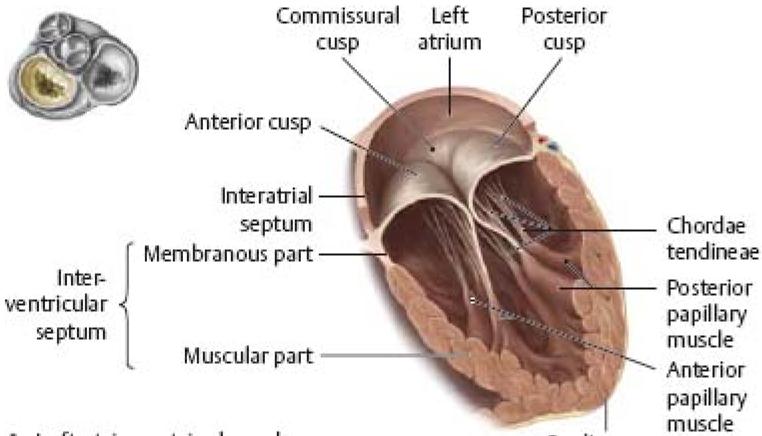
A Aortic valve.



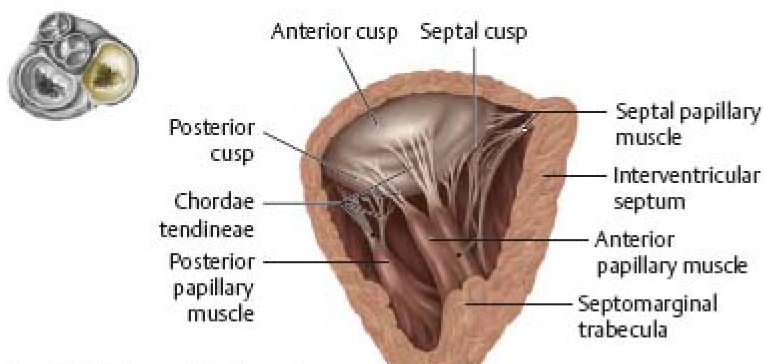
B Pulmonary valve.

Fig. 7.15 Atrioventricular valves

Anterior view during ventricular systole.



A Left atrioventricular valve.



B Right atrioventricular valve.

Clinical

Auscultation of the cardiac valves

Heart sounds, produced by closure of the semilunar and atrioventricular valves, are carried by the blood flowing through the valve. The resulting sounds are therefore best heard "downstream," at defined auscultation sites (dark circles). Valvular heart disease causes turbulent blood flow through the valve; this produces a murmur that may be detected in the colored regions.

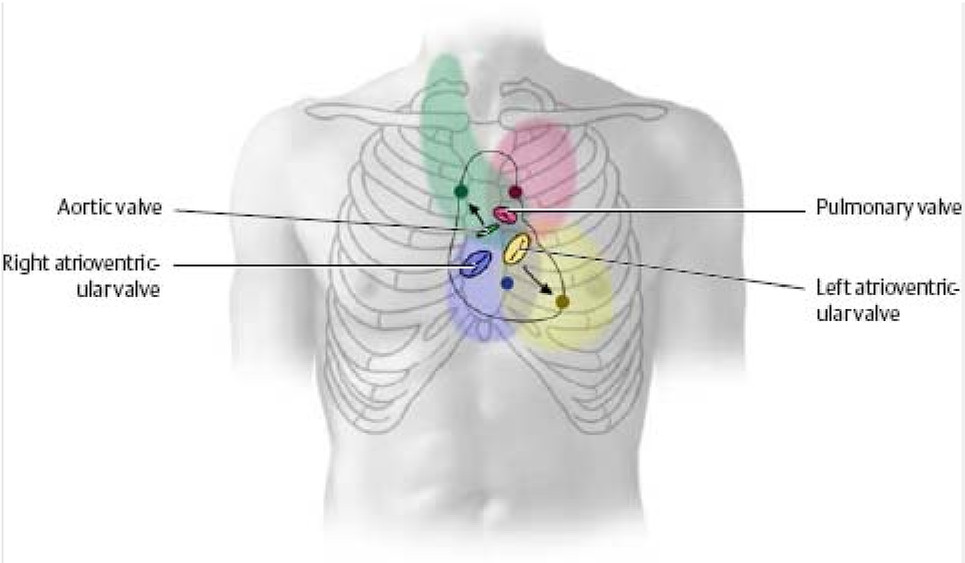
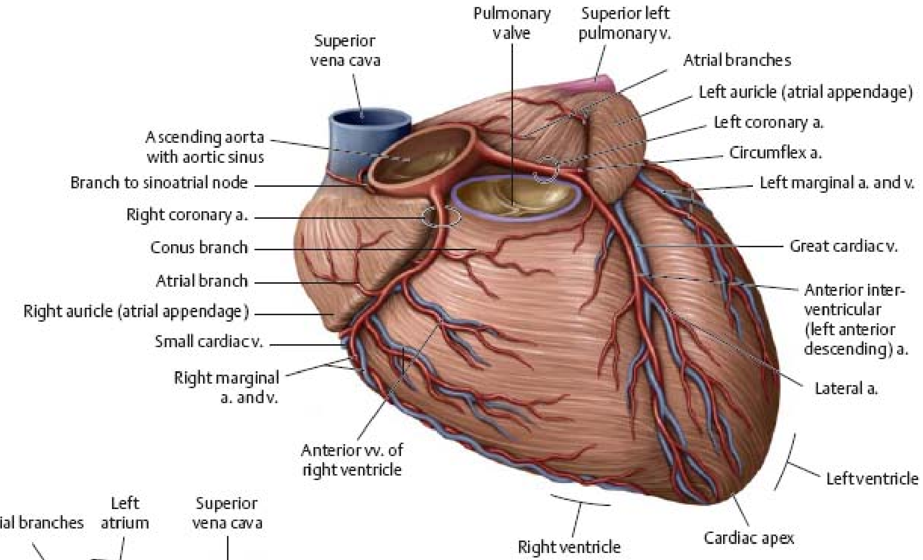


Table 7.2 **Position and auscultation sites of cardiac valves**

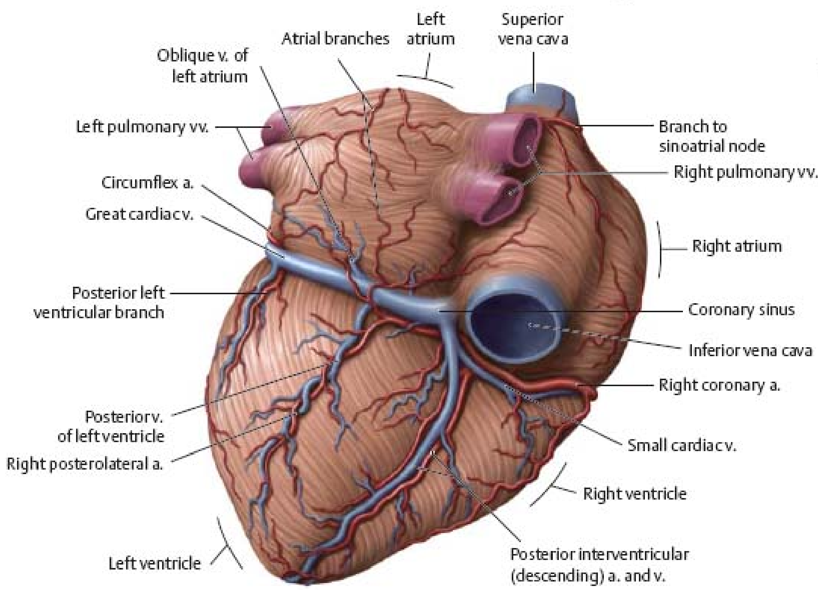
Valve	Anatomical projection	Auscultation site
Aortic valve	Left sternal border (at level of 3rd rib)	Right 2nd intercostal space (at sternal margin)
Pulmonary valve	Left sternal border (at level of 3rd costal cartilage)	Left 2nd intercostal space (at sternal margin)
Left atrioventricular valve	Left 4th/5th costal cartilage	Left 5th intercostal space (at midclavicular line) or cardiac apex
Right atrioventricular valve	Sternum (at level of 3rd costal cartilage)	Left 5th intercostal space (at sternal margin)

Arteries & Veins of the Heart

Fig. 7.16 Coronary arteries and cardiac veins



A Anterior view.



B Posteroinferior view. *Note*: The right and left coronary arteries typically anastomose posteriorly at the left atrium and ventricle.

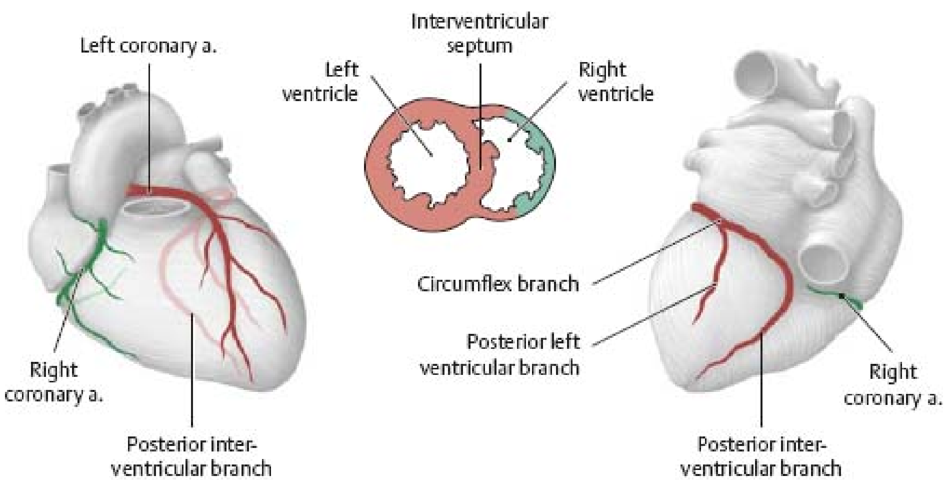
Table 7.3 Branches of the coronary arteries

Left coronary artery	Right coronary artery
Circumflex a. • Atrial branch • Left marginal a. • Posterior left ventricular a.	Branch to SA node Conus branch Atrial branch Right marginal a.
Anterior interventricular a. (left anterior descending a.) • Conus branch • Lateral branch • Interventricular septal branches	Posterior interventricular (descending) a. • Interventricular septal branches Branch to AV node Right posterolateral a.
AV = atrioventricular; SA = sinoatrial.	

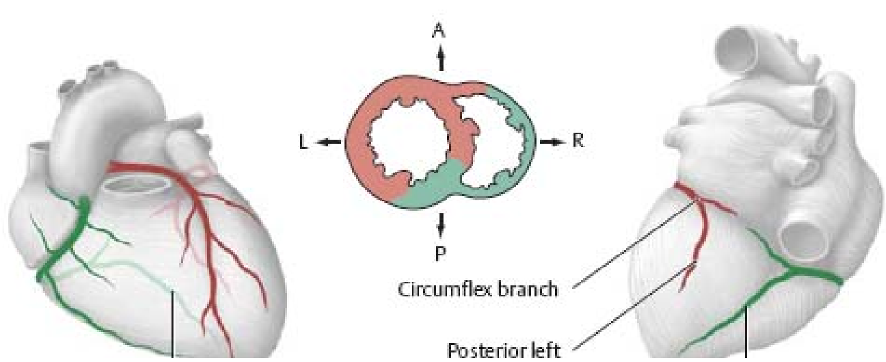
Table 7.4	Divisions of the cardiac veins	
Vein	**Tributaries**	**Drainage**
Anterior cardiac vv. (not shown)		Right atrium
Great cardiac v.	Anterior interventricular v.	Coronary sinus
	Left marginal v.	
	Oblique v. of left atrium	
Left posterior ventricular v.		
Posterior interventricular v. (middle cardiac v.)		
Small cardiac v.	Anterior vv. of right ventricle	
	Right marginal v.	

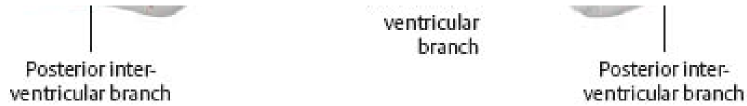
Fig. 7.17 Distribution of the coronary arteries

Anterior and posterior views of the heart, with superior views of transverse sections through the ventricles. The distribution of the coronary arteries differs from person to person. Right coronery artery and branches (green); left coronary artery and branches (red).

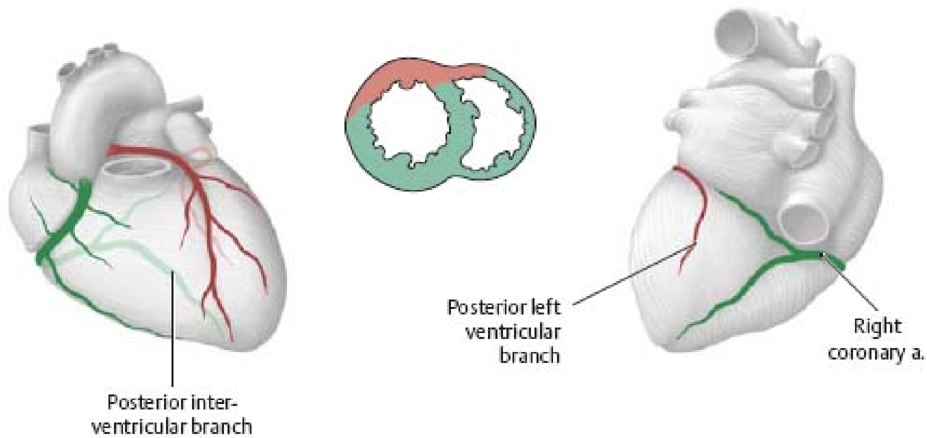


A Left coronary dominance (~15%).





B Balanced distribution (~70%).



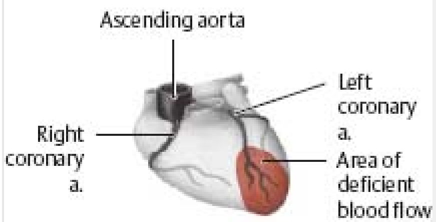
C Right coronary dominance (~15%).

Clinical

Disturbed coronary blood flow

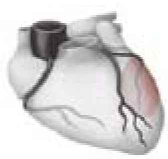
Although the coronary arteries are connected by structural anastomoses, they are end arteries from a functional standpoint. The most frequent cause of deficient blood flow is *athero sclerosis*, a narrowing of the coronary lumen due to plaque-like deposits on the vessel wall. When the decrease in luminal size (stenosis) reaches a critical point, coronary blood flow is restricted, causing chest pain (*angina pectoris*). Initially, this pain is induced by physical effort, but eventually it persists at rest, often radiating to characteristic sites (e.g., left arm, left side of head and neck). A myocardial infarction occurs when deficient blood supply causes myocardial tissue to die (necrosis). The location and extent of the infarction depends on the stenosed vessel (see **A-E**, after Heinecker).

A Supra-apical anterior infarction.



B Apical anterior infarction.

C Anterior lateral infarction.



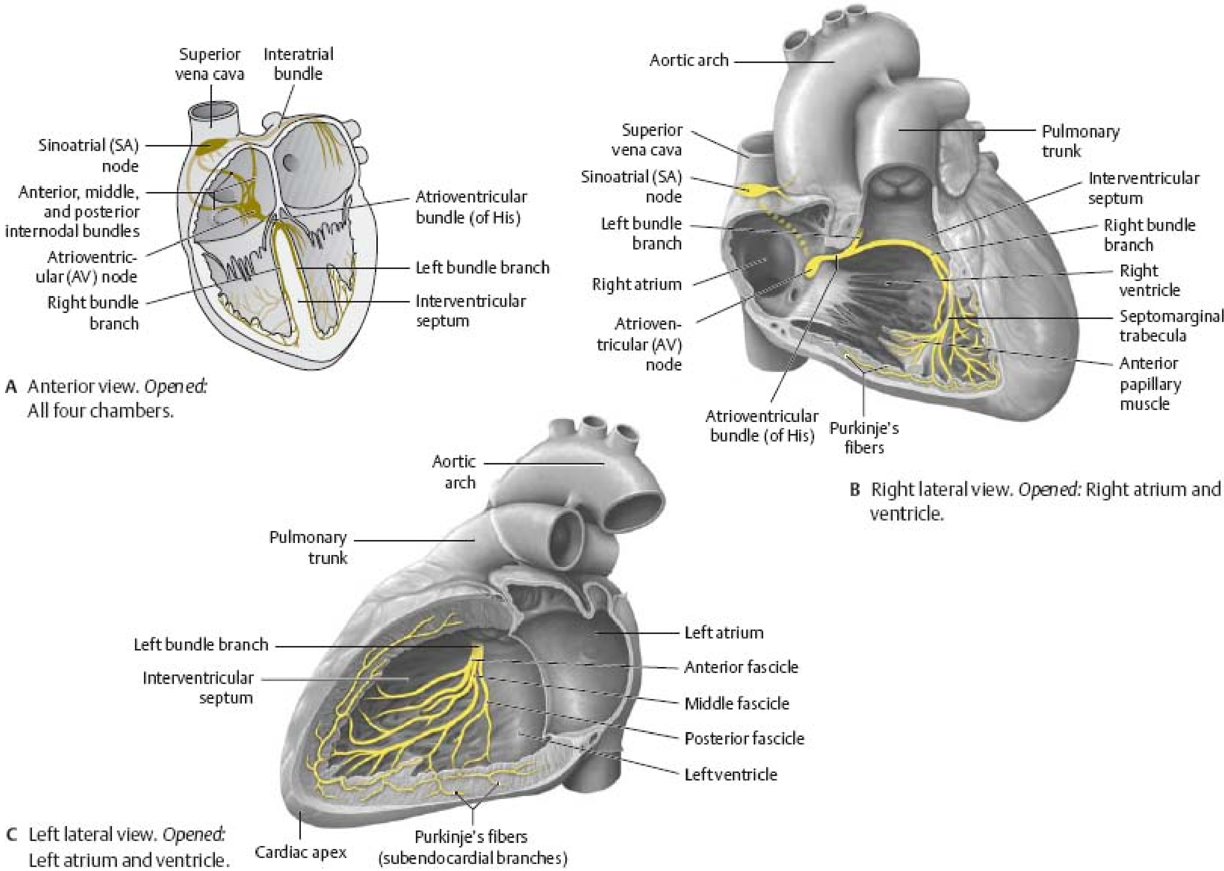
D Posterior lateral infarction.

E Posterior infarction.

Conduction & Innervation of the Heart

Contraction of cardiac muscle is modulated by the cardiac conduction system. This system of specialized myocardial cells generates and conducts excitatory impulses in the heart. The conduction system contains two nodes, both located in the atria: the sinoatrial (SA) node, known as the pacemaker, and the atrioventricular (AV) node.

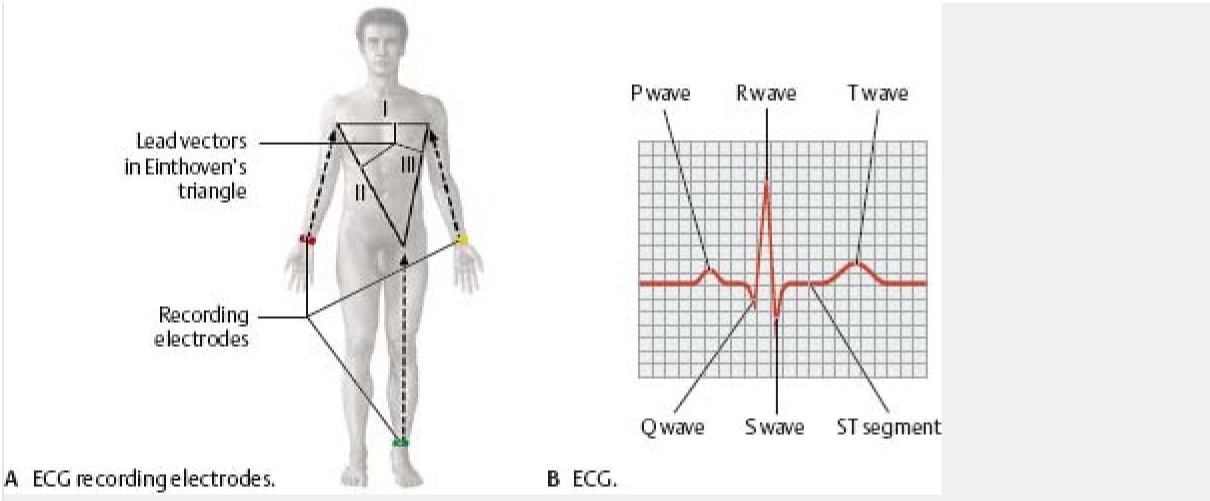
Fig. 7.18 Cardiac conduction system



Clinical

Electrocardiogram (ECG)

The cardiac impulse (a physical dipole) travels across the heart and may be detected with electrodes. The use of three electrodes that separately record electrical activity of the heart along three axes or vectors (Einthoven limb leads) generates an electrocardiogram (ECG). The ECG graphs the cardiac cycle (“heartbeat”), reducing it to a series of waves, segments, and intervals. These ECG components can be used to determine whether cardiac impulses are normal or abnormal (e.g., myocardial infarction, chamber enlargement). *Note:* Although only three leads are required, a standard ECG examination includes at least two others (Goldberger, Wilson leads).

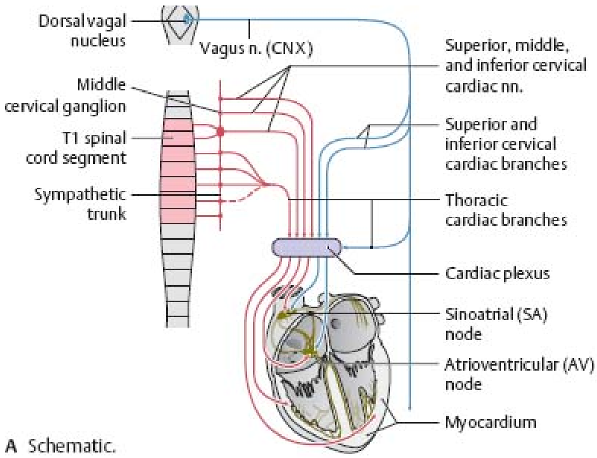


A ECG recording electrodes.

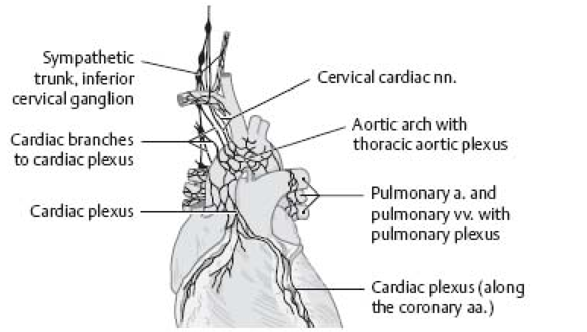
B ECG.

Sympathetic innervation: Presynaptic neurons from T1 to T6 spinal cord segments send fibers to synapse on postsynaptic neurons in the cervical and upper thoracic sympathetic ganglia. The three cervical cardiac nerves and thoracic cardiac branches contribute to the cardiac plexus. Parasympathetic innervation: Presynaptic neurons and fibers reach the heart via cardiac branches, some of which also arise in the cervical region. They synapse on postsynaptic neurons near the SA node and along the coronary arteries.

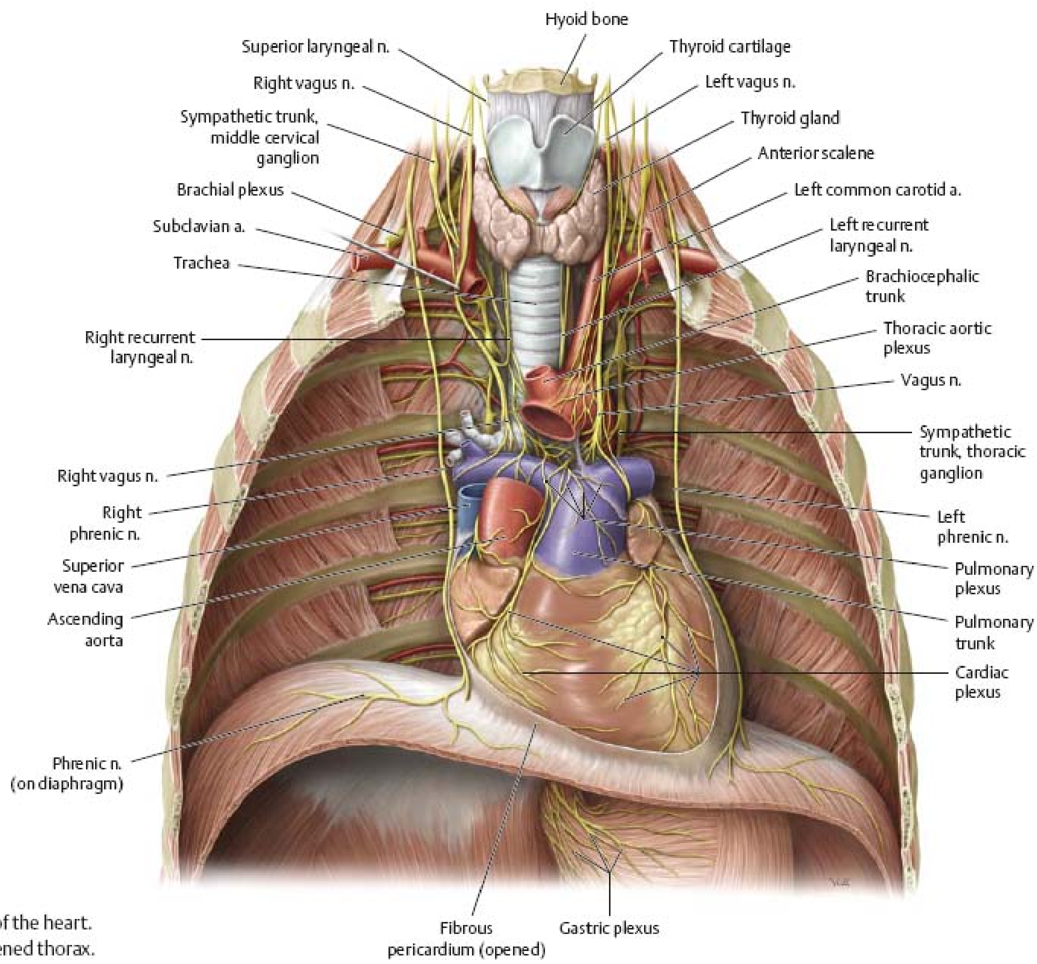
Fig. 7.19 **Autonomic innervation of the heart**



A Schematic.



B Autonomic plexuses of the heart, right lateral view. Note the continuity between the cardiac, aortic, and pulmonary plexuses.



C Autonomic nerves of the heart. Anterior view of opened thorax.

Heart: Radiology

Fig. 7.20 Cardiac borders and configurations

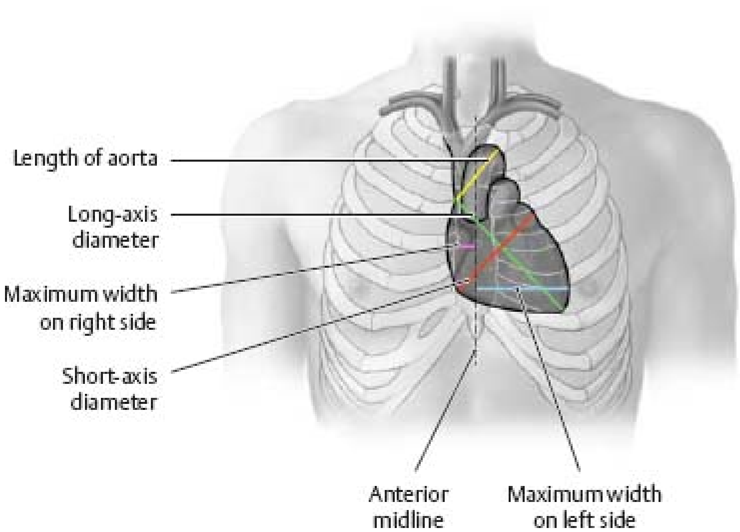
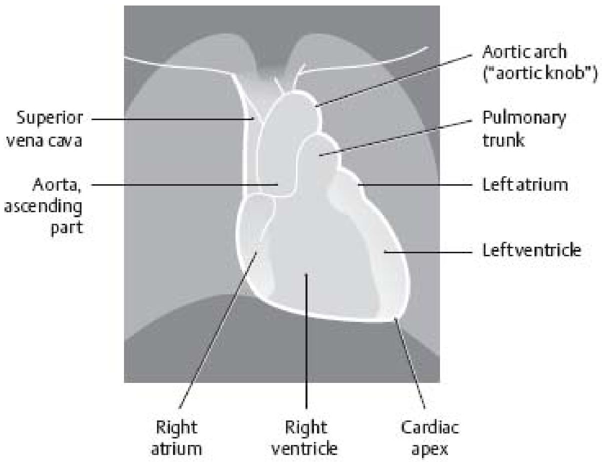


Table 7.5 **Borders of the heart**

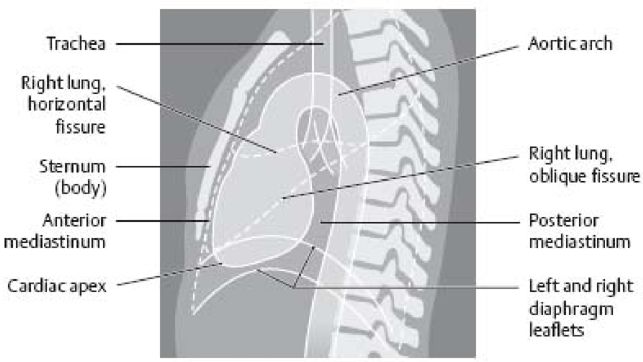
Border	**Defining structures**
Right cardiac border	Right atrium
	Superior vena cava
Apex	Left ventricle
Left cardiac border	Aortic arch (“aortic knob”)
	Pulmonary trunk
	Left atrium
	Left ventricle
Inferior cardiac border	Left ventricle
	Right ventricle

Fig. 7.21 **Radiographic appearance of the heart**



A Anterior view.

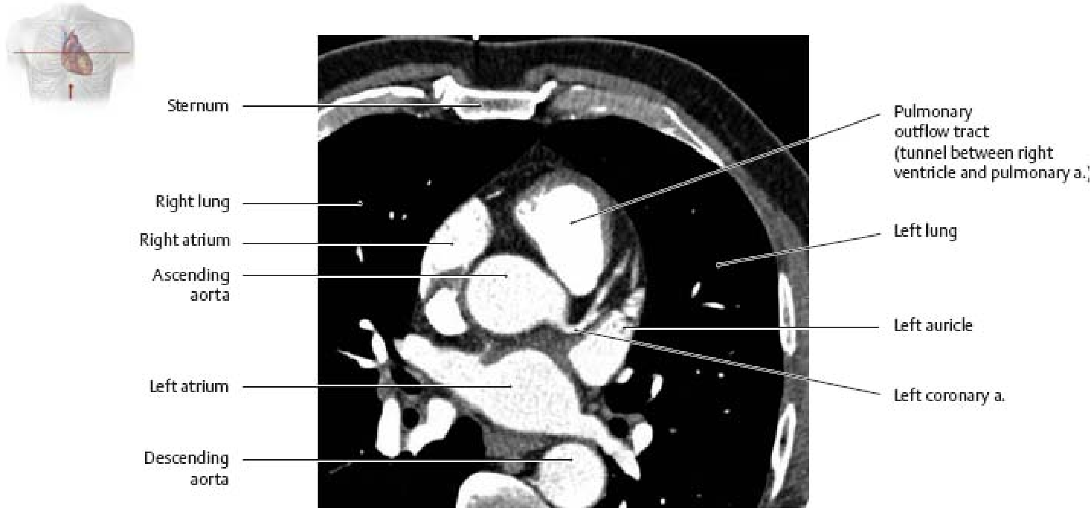
B Anteroposterior chest radiograph.



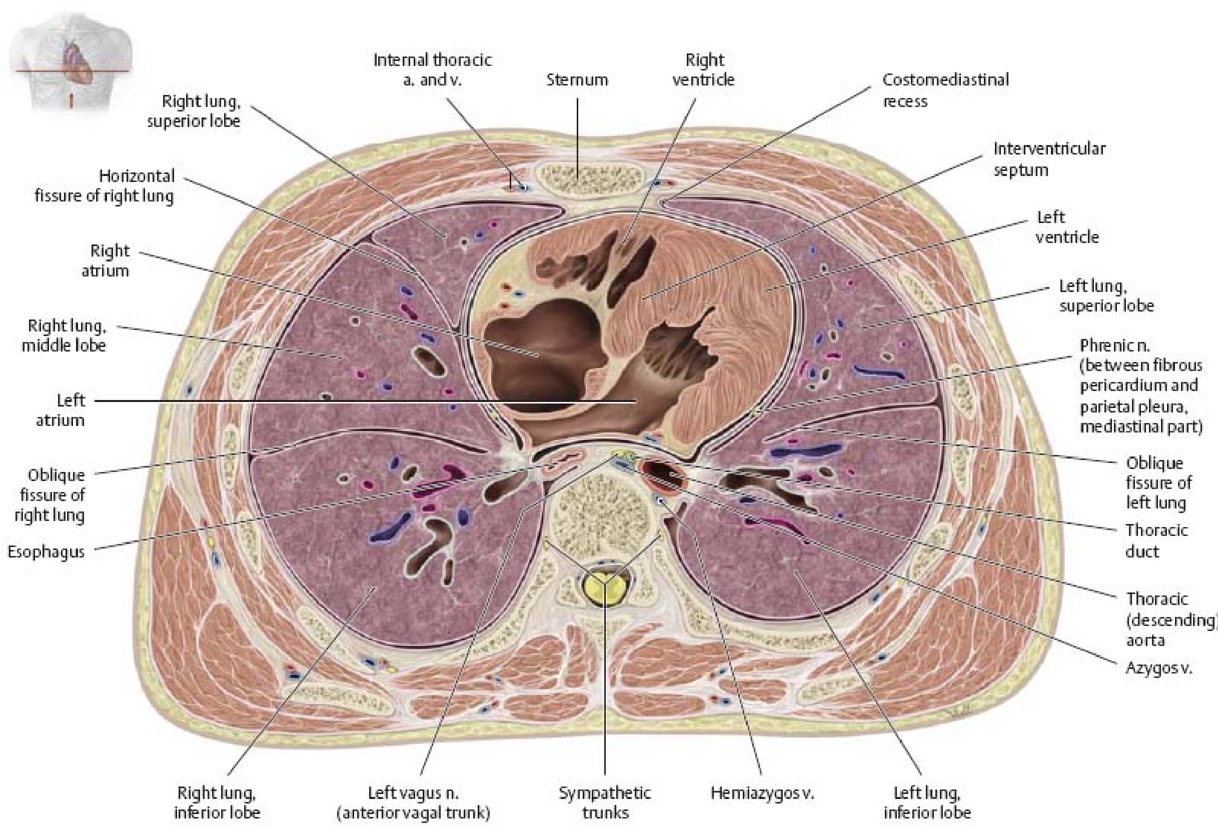
C Lateral view. *Visible*: Diaphragm leaflets and lungs. The aortic arch forms a sling over the left main bronchus. Note the narrowness of the anterior mediastinum relative to the posterior mediastinum.

D Left lateral chest radiograph.

Fig. 7.22 Heart in transverse section



A Heart in normal chest magnetic resonance imaging (MRI). The cardiac chambers are clearly displayed owing to the high signal intensity, and the lungs are not visualized.



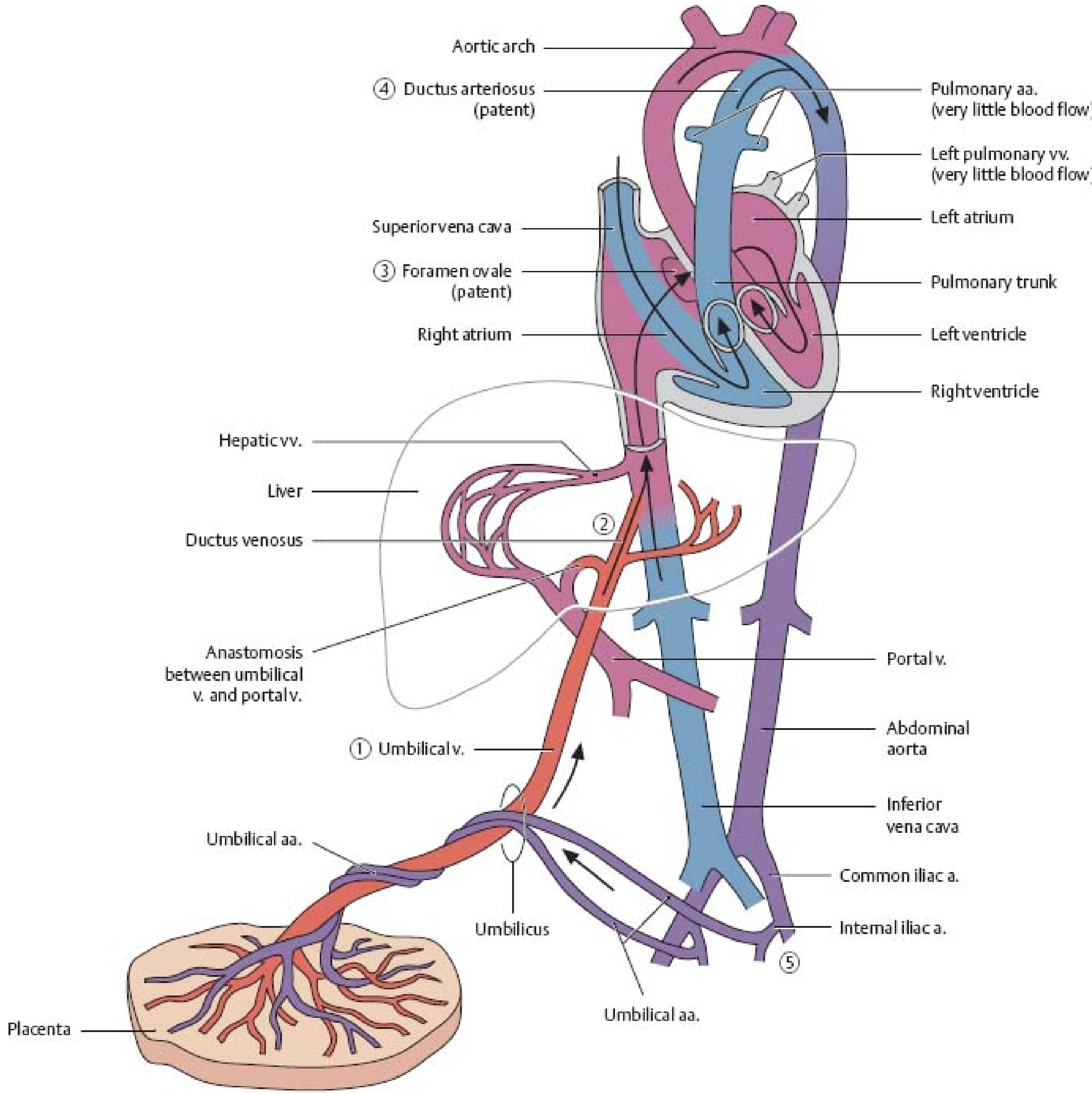
B Transverse section through T8, inferior view.

Pre- & Postnatal Circulation

Fig. 7.23 Prenatal circulation

After Fritsch and Kühnel.

1. Oxygenated and nutrient-rich fetal blood from the placenta passes to the fetus via the umbilical *vein*.
2. Approximately half of this blood bypasses the liver (via the ductus venosus) and enters the inferior vena cava. The remainder enters the portal vein to supply the liver with nutrients and oxygen.
3. Blood entering the right atrium from the inferior vena cava bypasses the right ventricle (as the lungs are not yet functioning) to enter the left atrium via the foramen ovale, a right-to-left shunt.
4. Blood from the superior vena cava enters the right atrium, passes to the right ventricle, and moves into the pulmonary trunk. Most of this blood enters the aorta via the ductus arteriosus, a right-to-left shunt.
5. The partially oxygenated blood in the aorta returns to the placenta via the paired umbilical arteries that arise from the internal iliac arteries.

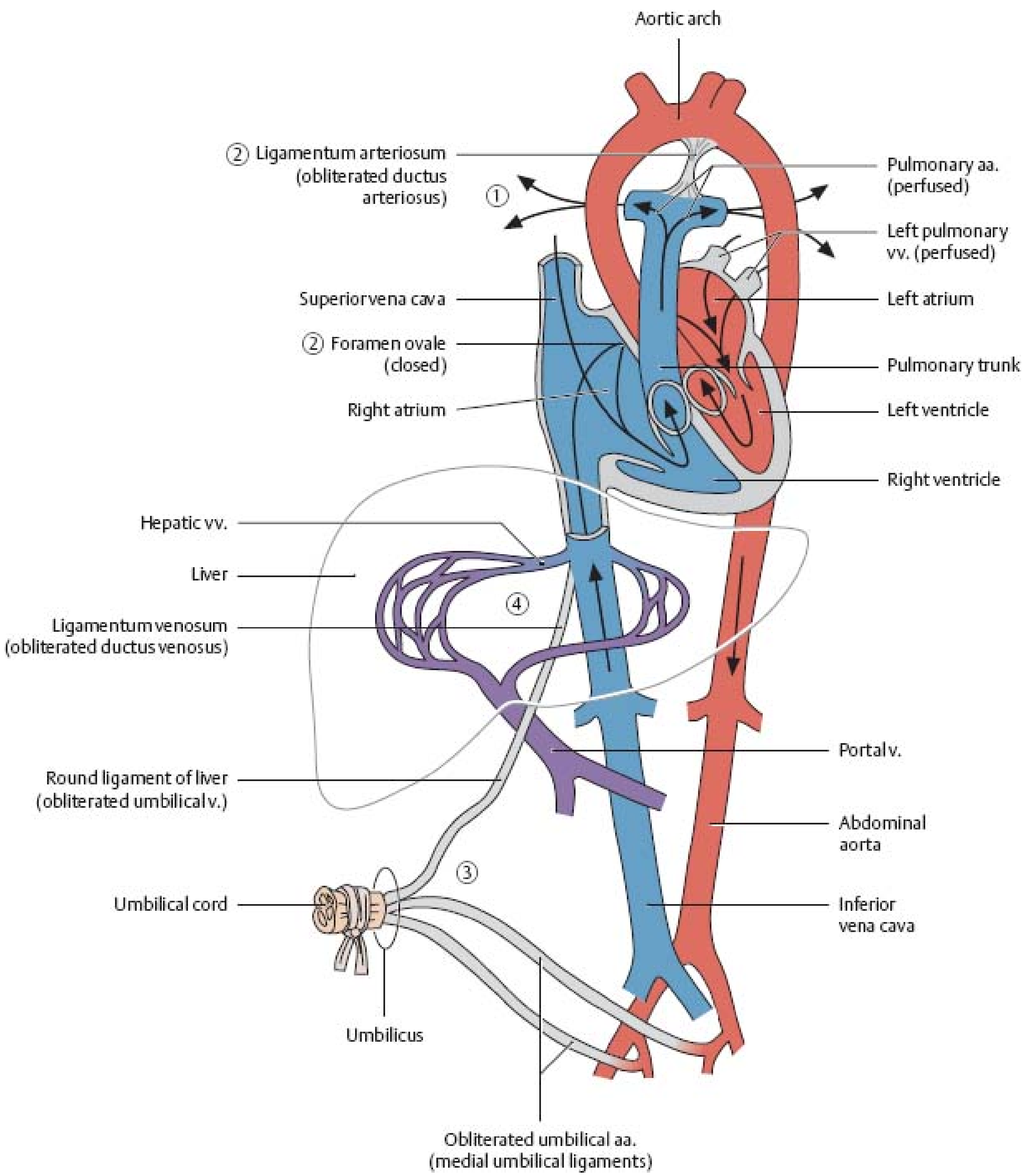


1. As pulmonary respiration begins at birth, pulmonary blood pressure falls, causing blood from the right pulmonary trunk to enter the pulmonary veins.
2. The foramen ovale and ductus arteriosus close, eliminating the fetal right-to-left shunts. The pulmonary and systemic circulations in the heart are now separate.
3. As the infant is separated from the placenta, the umbilical arteries occlude (except for the proximal portions), along with the umbilical vein and ductus venosus.

4. Blood to be metabolized now passes through the liver.

Fig. 7.24 Postnatal circulation

After Fritsch and Kühnel.



Clinical

Septal defects

Septal defects, the most common type of congenital heart defect, allow blood from the left chambers of the heart to improperly pass into the right chambers during systole. Ventrical septal defect (VSD, shown below) is the most common form. Patent foramen ovale, the most prevalent form of *atrial* septal defect (ASD), results from improper closure of the fetal shunt.

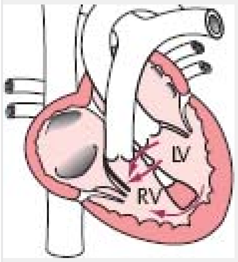


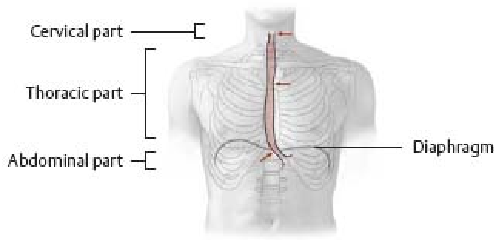
Table 7.6 **Derivatives of fetal circulatory structures**

Fetal structure	**Adult remnant**
Ductus arteriosus	Ligamentum arteriosum
Foramen ovale	Fossa ovalis
Ductus venosus	Ligamentum venosum
Umbilical v.	Round ligament of the liver (ligamentum teres)
Umbilical a.	Medial umbilical ligament

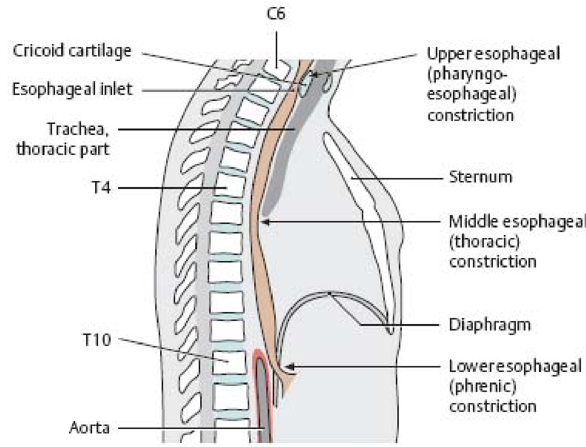
Esophagus

The esophagus is divided into three parts: cervical (C6-T1), thoracic (T1 to the esophageal hiatus of the diaphragm), and abdominal (the diaphragm to the cardiac orifice of the stomach). It descends slightly to the right of the thoracic aorta and pierces the diaphragm slightly to the left, just below the xiphoid process of the sternum.

Fig. 7.25 Esophagus: Location and constrictions



A Projection of esophagus onto chest wall. Esophageal constrictions are indicated with arrows.



B Esophageal constrictions, right lateral view.

Fig. 7.26 Esophagus in situ

Anterior view.

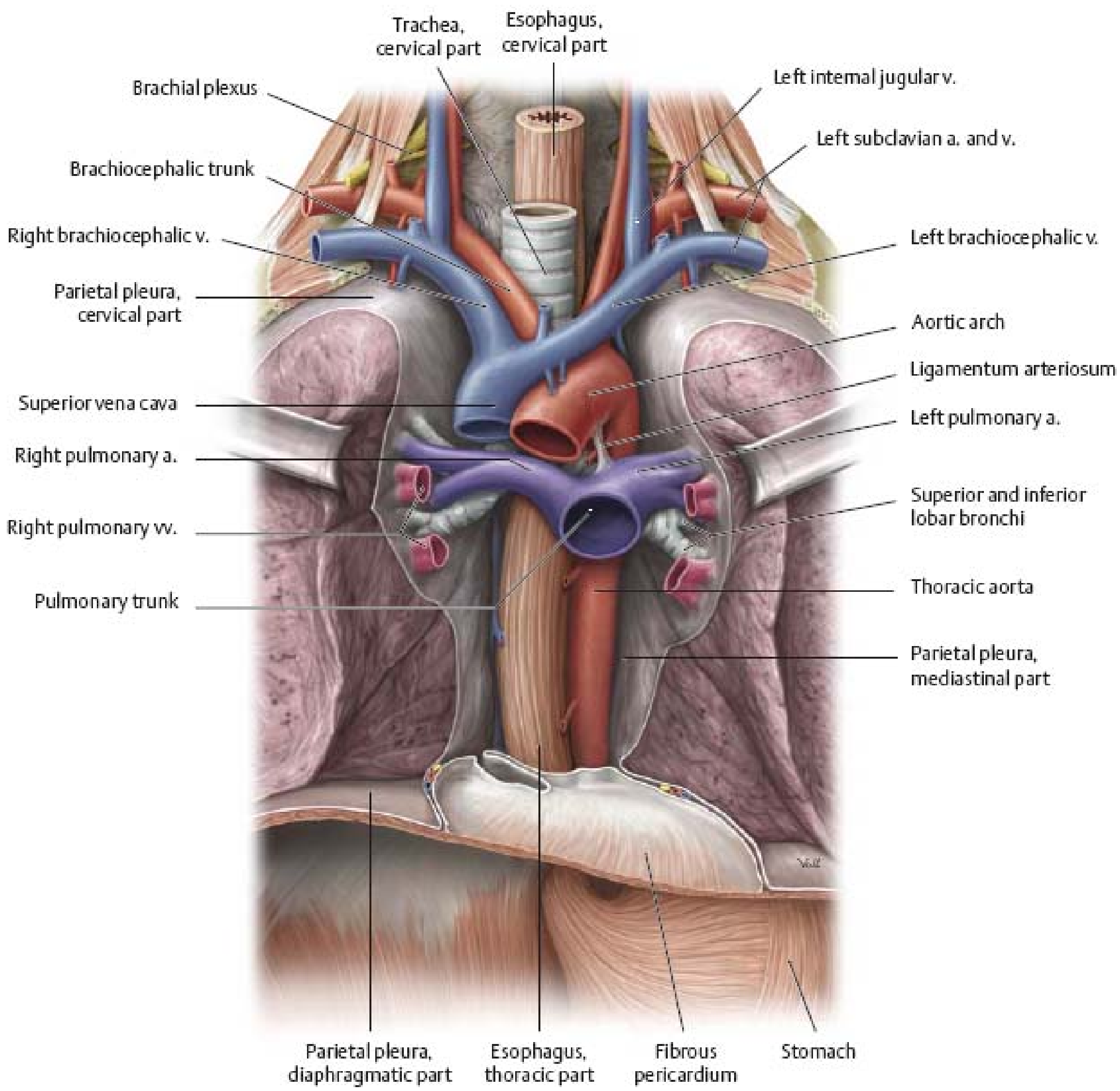
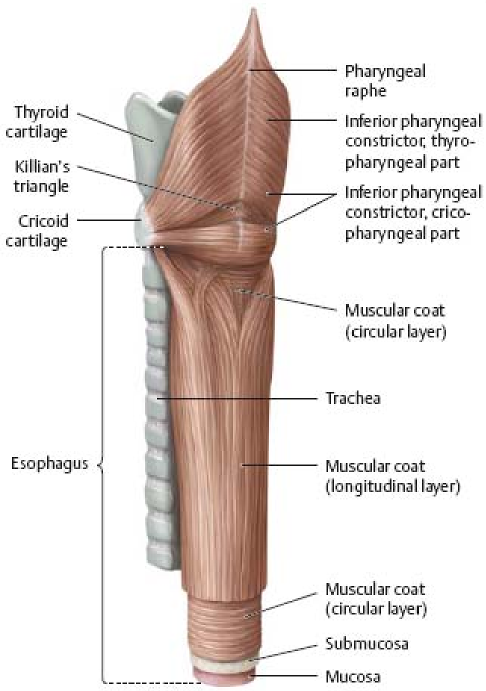
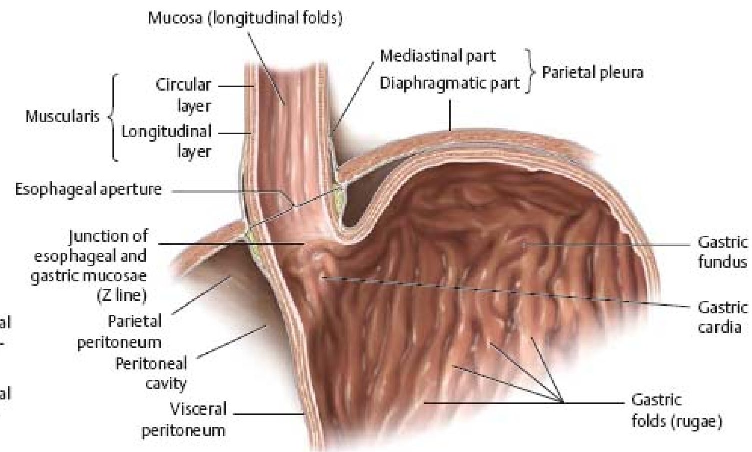
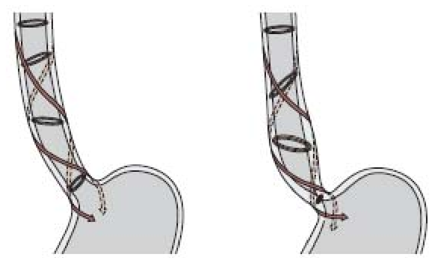


Fig. 7.27 **Structure of the esophagus**





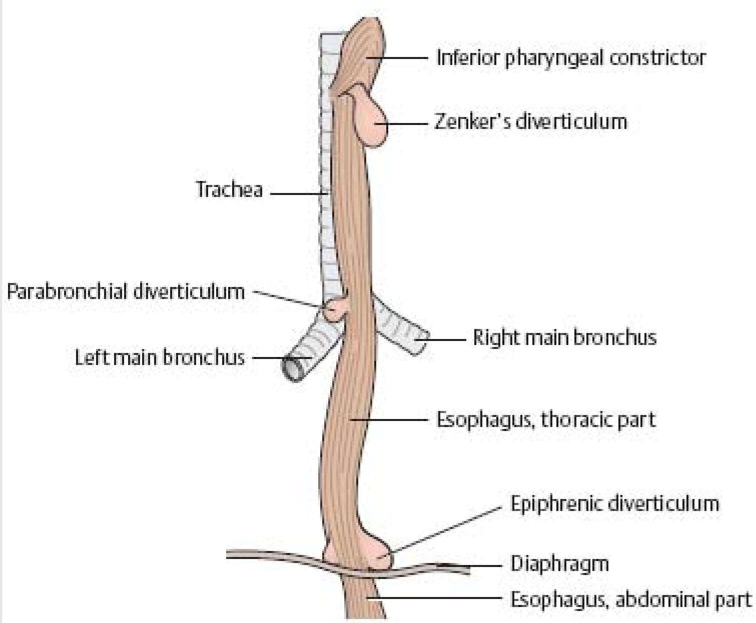
B Esophagogastric junction, anterior view. A true sphincter is not identifiable at this junction; instead, the diaphragmatic muscle of the esophageal aperture functions as a sphincter. It is often referred to as the "Z line" because of its zigzag form.



A Esophageal wall, oblique left posterior view. Pharynx (p. 552); trachea (p. 110).

C Functional architecture of esophageal muscle.

Clinical



Esophageal diverticula

Diverticula (abnormal outpouchings or sacs) generally develop at weak spots in the esophageal wall. There are three main types of esophageal diverticula:

- Hypopharyngeal (pharyngo-esophageal) diverticula: Outpouchings occurring at the junction of the pharynx and the esophagus. These include Zenker's diverticula (70% of cases).
- “True” traction diverticula: Protrusion of all wall layers, not typicallyoccurring at characteristic weak spots. However, they generally result from an inflammatory process (e.g., lymphangitis) and are thus common at sites where the esophagus closely approaches the bronchi and bronchial lymph nodes (thoracic or parabronchial diverticula).
- “False” pulsion diverticula: Herniations of the mucosa and submucosa through weak spots in the muscular coat due to a rise in esophageal pressure (e.g., during normal swallowing). These include parahiatal and epiphrenic diverticula occurring above the esophageal aperture of the diaphragm (10% of cases).

Neurovasculature of the Esophagus

Sympathetic innervation: Presynaptic fibers arise from the T2-T6 spinal cord segments. Postsynaptic fibers arise from the sympathetic chain to join the esophageal plexus. Parasympathetic innervation: Presynaptic fibers arise from the dorsal vagal nucleus and travel in the vagus nerves to form the extensive esophageal plexus. *Note:* The postsynaptic neurons are in the wall of the esophagus. Fibers to the cervical portion of the esophagus travel in the recurrent laryngeal nerves.

Fig. 7.28 Autonomic innervation of the esophagus

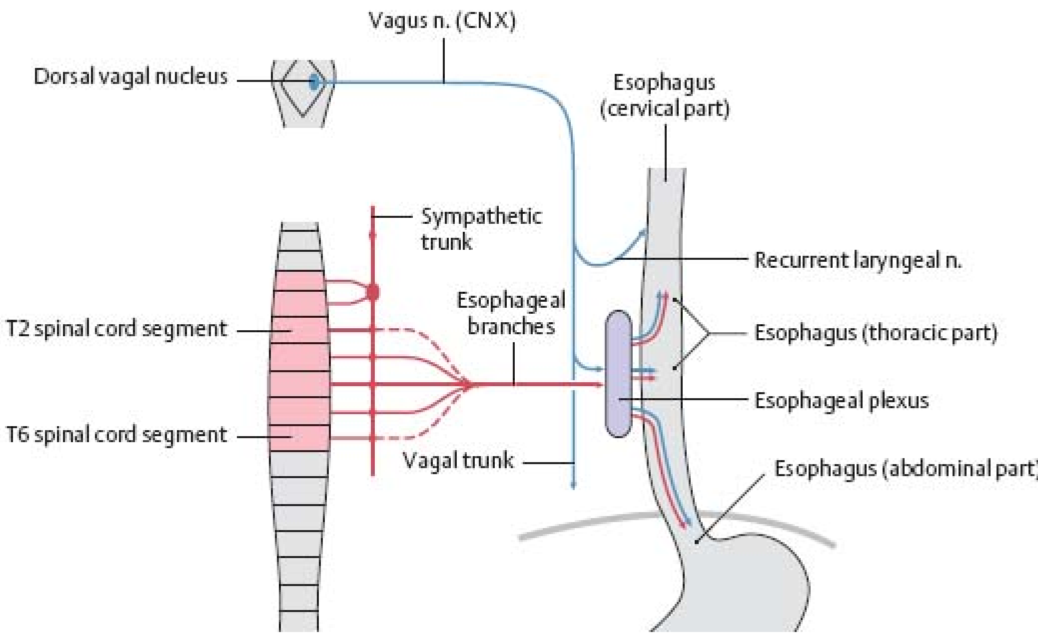
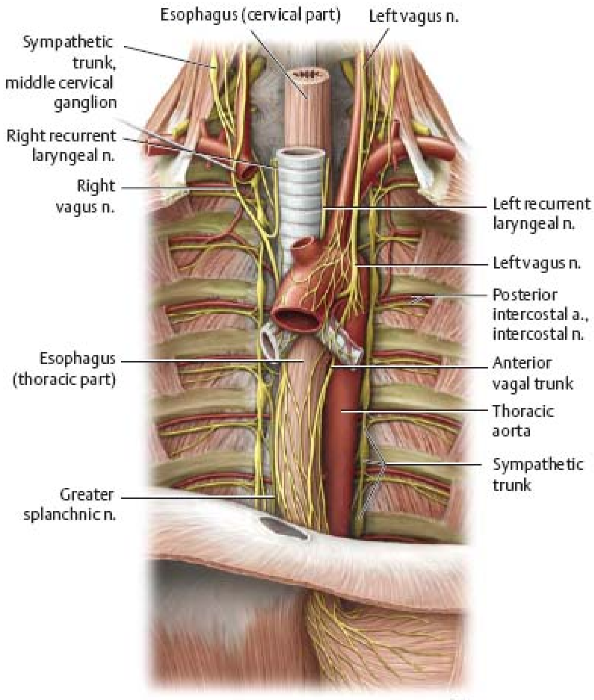
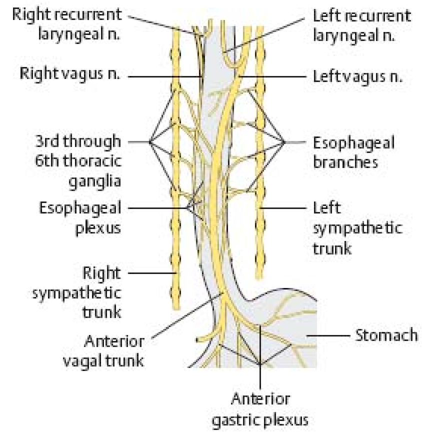


Fig. 7.29 Esophageal plexus

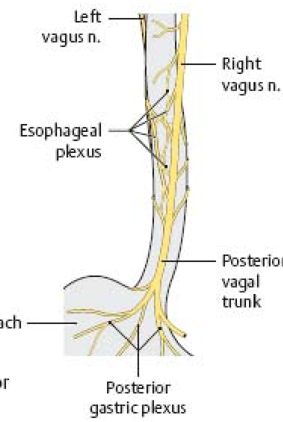
The left and right vagus nerves initially descend on the left and right sides of the esophagus. As they begin to contribute to the esophageal plexus, they shift to anterior and posterior positions, respectively. As the vagus nerves continue into the abdomen, they are named the anterior and posterior vagal trunks.



A Esophageal plexus in situ. Anterior view.



B Anterior view. Note the post-synaptic sympathetic contribution to the esophageal plexus.



C Posterior view.

Fig. 7.30 Esophageal arteries

Anterior view.

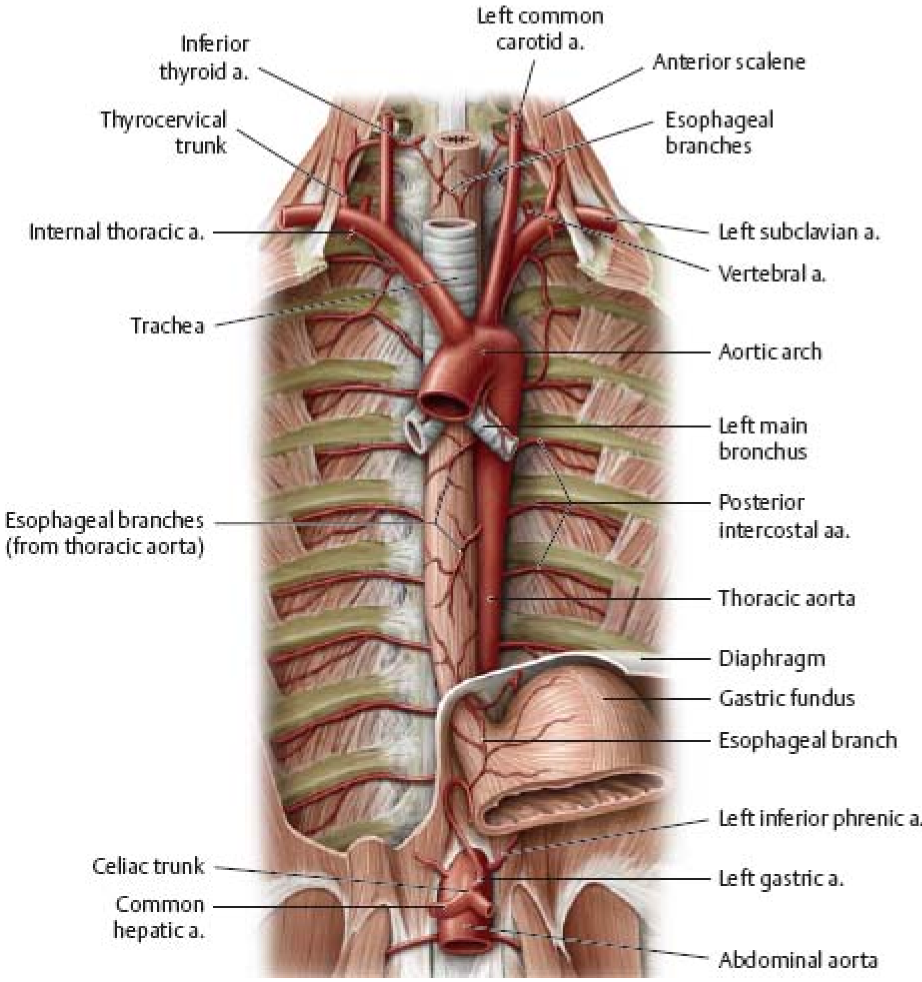


Fig. 7.31 **Esophageal veins**

Anterior view.

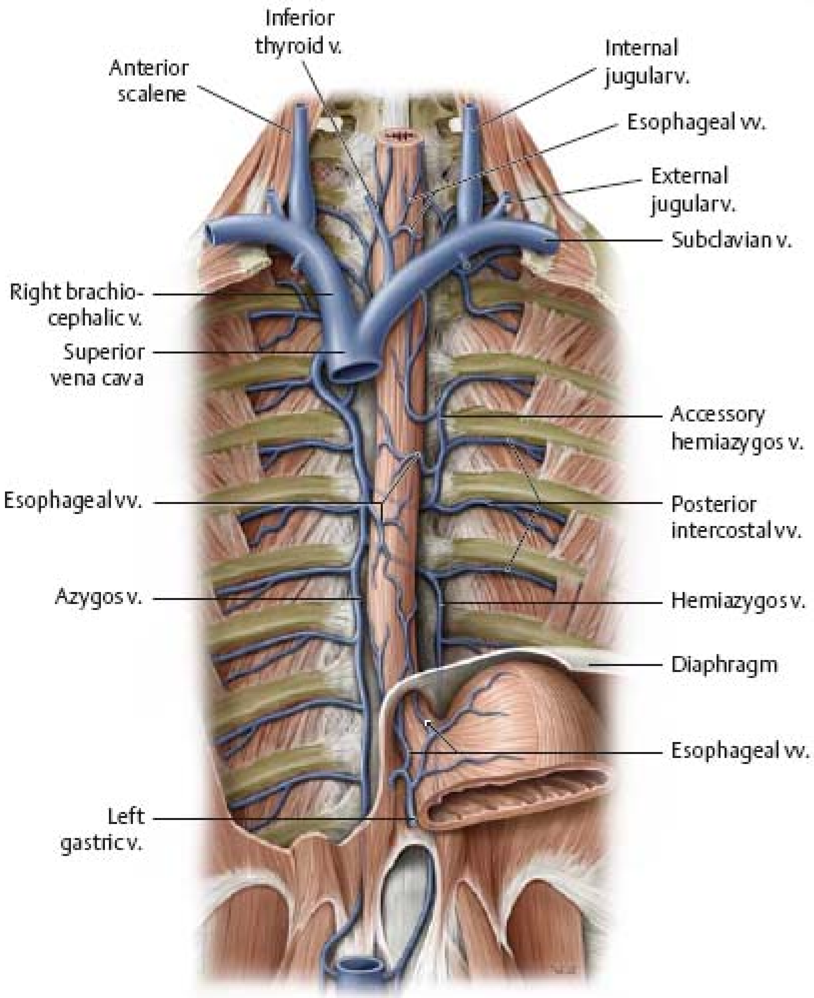


Table 7.7 Blood vessels of the esophagus

Part	Origin of esophageal arteries	Drainage of esophageal veins
Cervical	Inferior thyroid a.	Inferior thyroid v.
	Rarely direct branches from thyrocervical trunk or common carotid a.	Left brachiocephalic v.
Thoracic	Aorta (four or five esophageal aa.)	Upper left: Accessory hemiazygos v. or left brachiocephalic v.
		Lower left: Hemiazygos v.
		Right side: Azygos v.
Abdominal	Left gastric a.	Left gastric v.

Lymphatics of the Mediastinum

The superior phrenic lymph nodes drain lymph from the diaphragm, pericardium, lower esophagus, lung, and liver into the bronchomediastinal trunk. The inferior phrenic lymph nodes, found in the abdomen, collect lymph from the diaphragm and lower lobes of the lung and convey it to the lumbar trunk. *Note:* The pericardium may also drain superiorly to the brachiocephalic lymph nodes.

Fig. 7.32 Lymph nodes of the mediastinum and thoracic cavity

Left anterior oblique view.

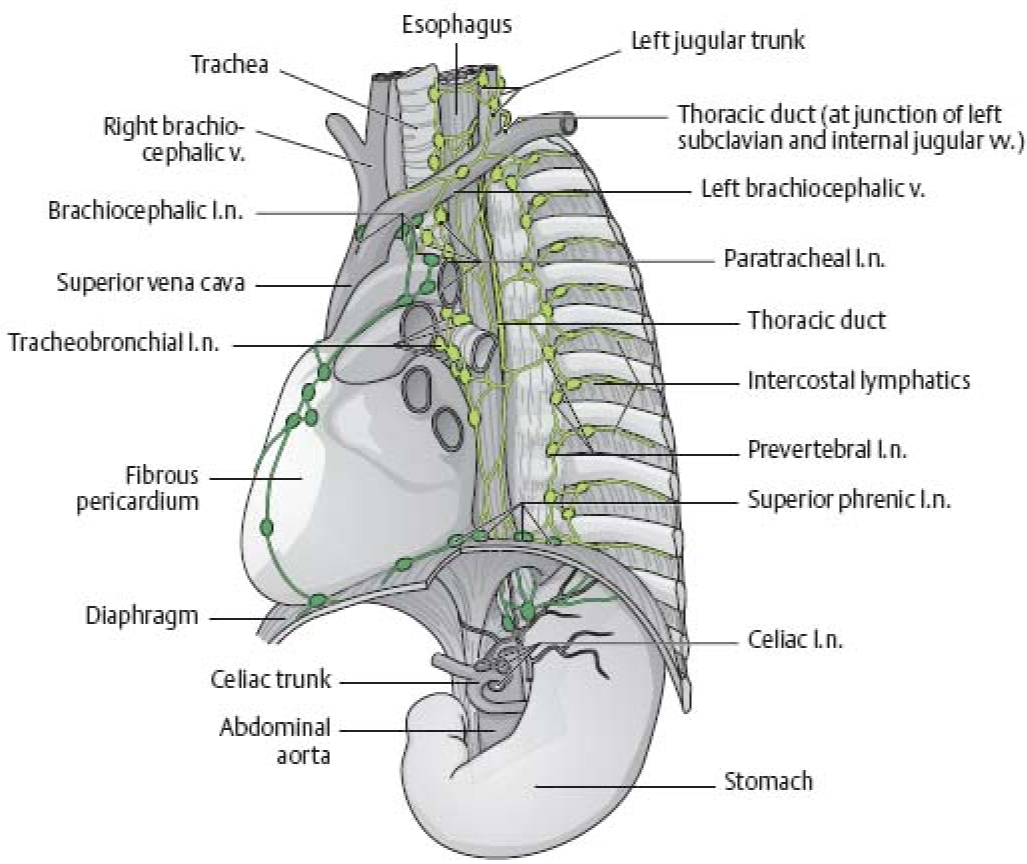
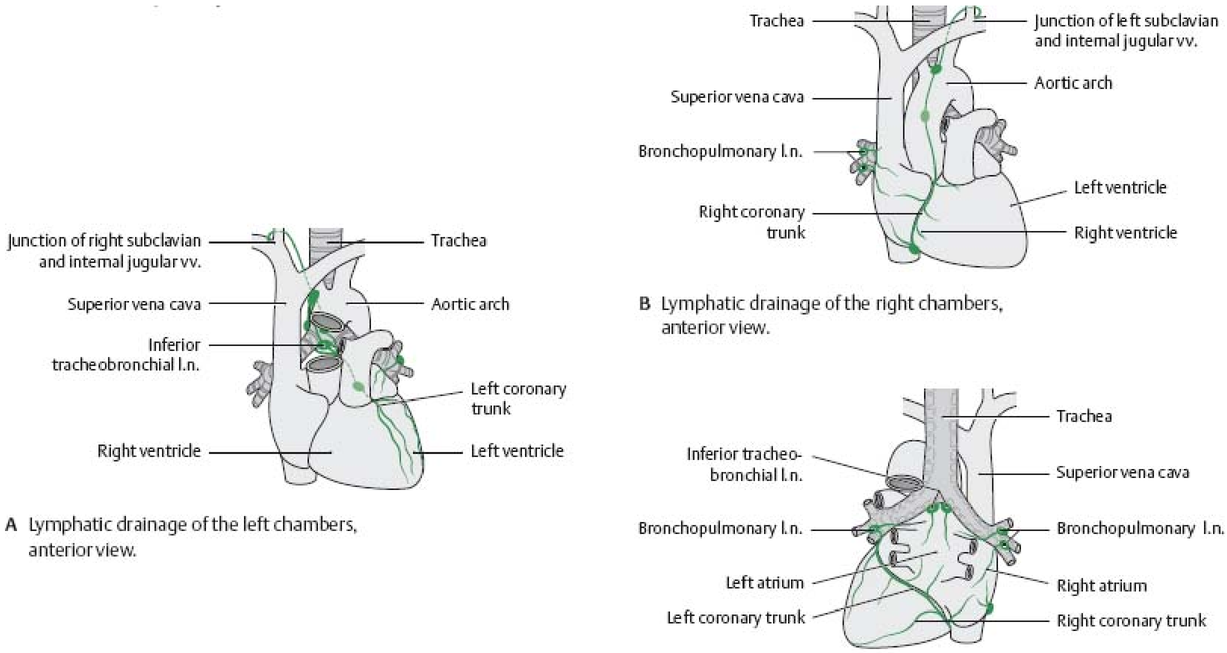


Fig. 7.33 Lymphatic drainage of the heart

A unique “crossed” drainage pattern exists in the heart: lymph from the left atrium and ventricle drains to the right venous junction, whereas lymph from the right atrium and ventricle drains to the left venous junction.



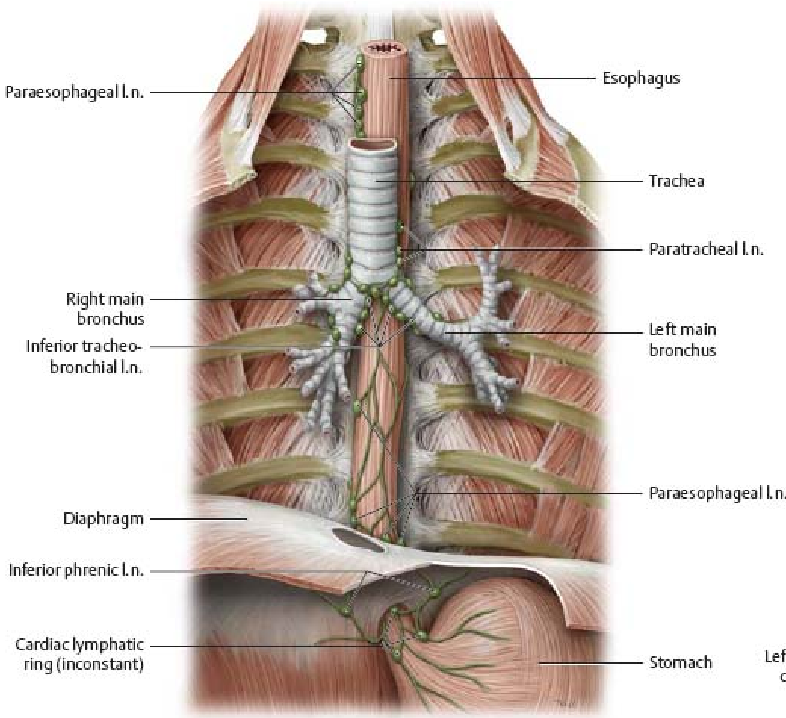
A Lymphatic drainage of the left chambers, anterior view.

B Lymphatic drainage of the right chambers, anterior view.

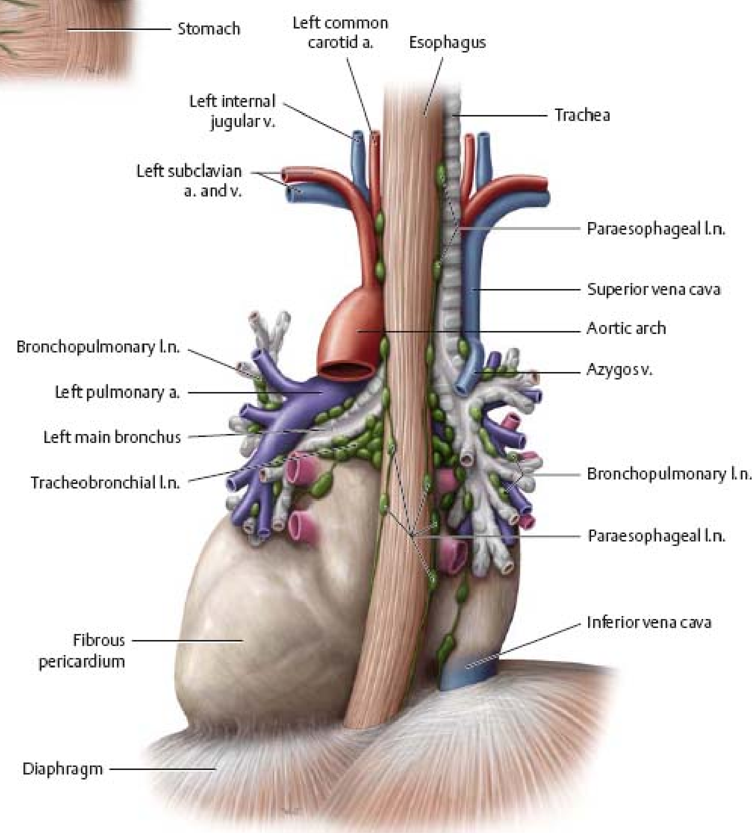
C Posterior view.

The paraesophageal nodes drain the esophagus. Lymphatic drainage of the cervical part of the esophagus is primarily cranial, to the deep cervical lymph nodes and then to the jugular trunk. The thoracic part of the esophagus drains to the bronchomediastinal trunks in two parts: the upper half drains cranially, and the lower half drains inferiorly via the superior phrenic lymph nodes. The bronchopulmonary and paratracheal nodes drain lymph from the lungs, bronchi, and trachea into the bronchomediastinal trunk (see p. 118).

Fig. 7.34 Mediastinal lymph nodes



A Anterior view of opened thorax.



B Posterior view of mediastinal lymph nodes.

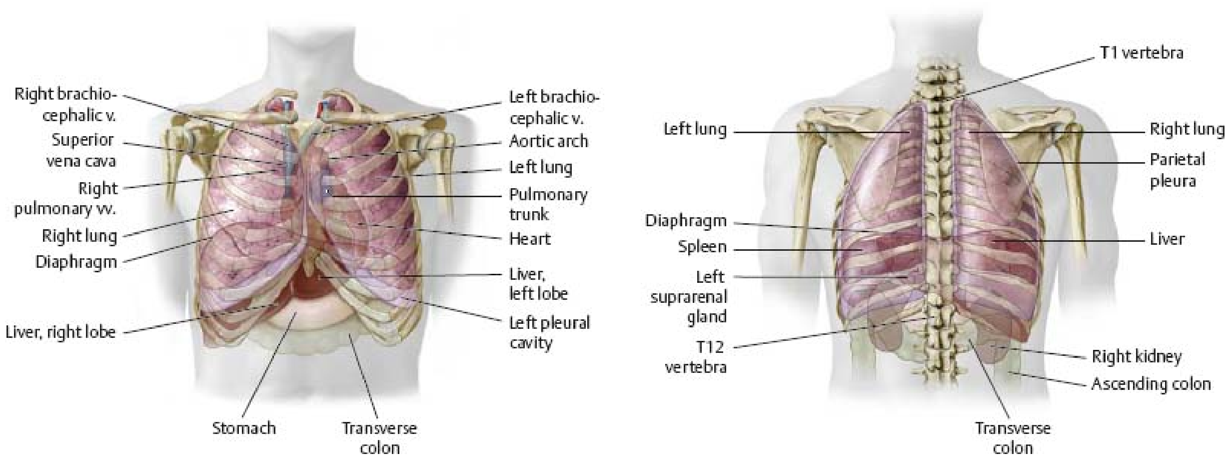
8 Pleural Cavity

Pleural Cavity

The paired pleural cavities contain the left and right lungs. They are completely separated from each other by the mediastinum and are under negative atmospheric pressure (see respiratory mechanics, pp. 112–113).

Fig. 8.1 Pleural cavity

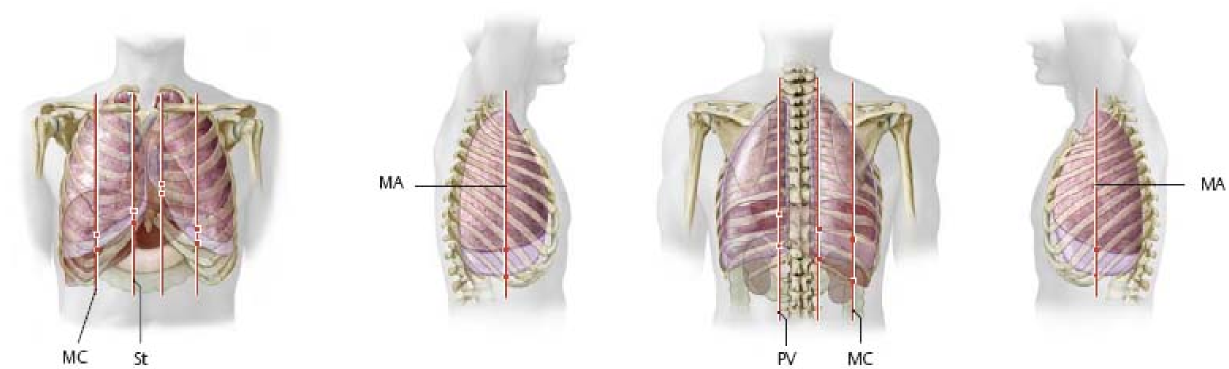
Pleural cavities and lungs projected onto thoracic skeleton.



A Anterior view.

B Posterior view.

Fig. 8.2 Boundaries of the pleural cavities and lungs



A Anterior view.

B Right lateral view.

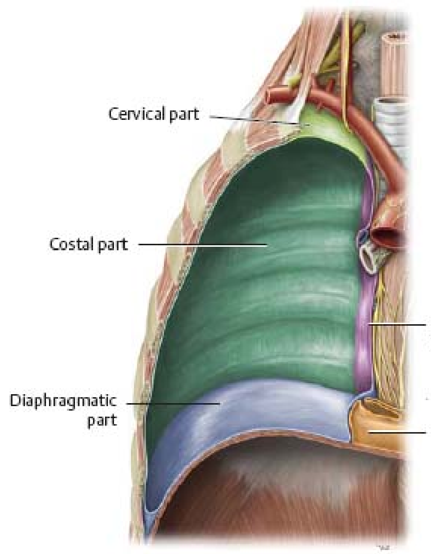
C Posterior view.

D Left lateral view.

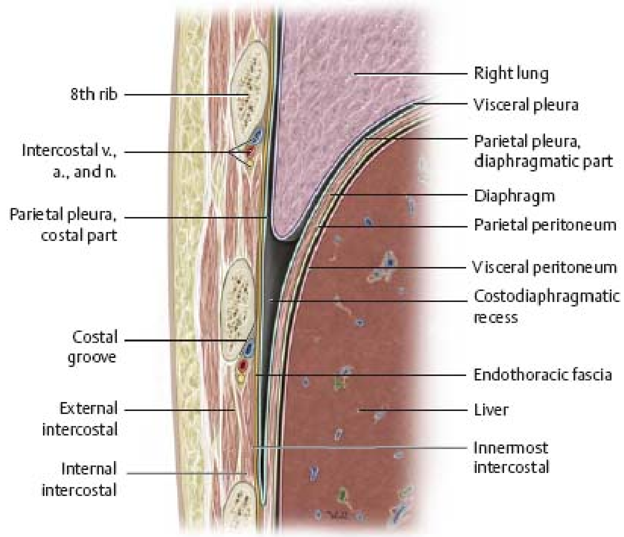
Table 8.1 Pleural cavity boundaries and reference points				
Reference line	Right parietal pleura	Right lung	Left lung	Left parietal pleura
Sternal line (St)	7th rib	6th rib	4th rib	4th rib
Midclavicular line (MC)	8th costal cartilage	6th rib	6th rib	8th rib
Midaxillary line (MA)	10th rib	8th rib	8th rib	10th rib
Paravertebral line (PV)	T12 vertebra	10th rib	10th rib	T12 vertebra

Fig. 8.3 Parietal pleura

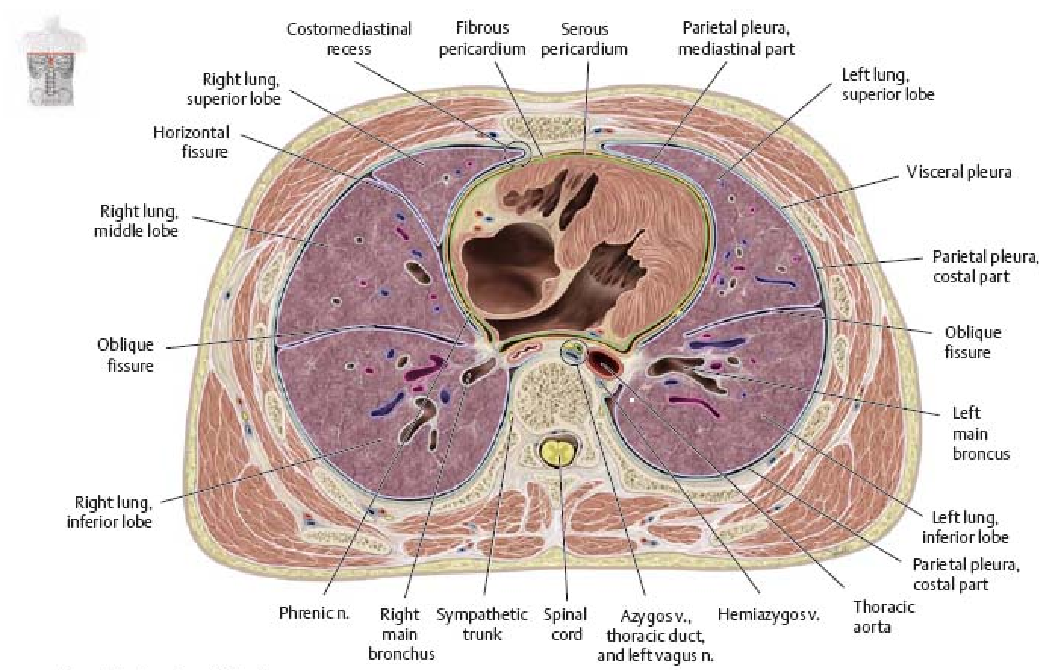
The pleural cavity is bounded by two serous layers. The visceral (pulmonary) pleura covers the lungs, and the parietal pleura lines the inner surface of the thoracic cavity. The four parts of the parietal pleura (costal, diaphragmatic, mediastinal, and cervical) are continuous.



A Parts of the parietal pleura. *Opened:* Right pleural cavity, anterior view.



B Costodiaphragmatic recess, coronal section, anterior view. Reflection of the diaphragmatic pleura onto the inner thoracic wall (becoming the costal pleura) forms the costodiaphragmatic recess.

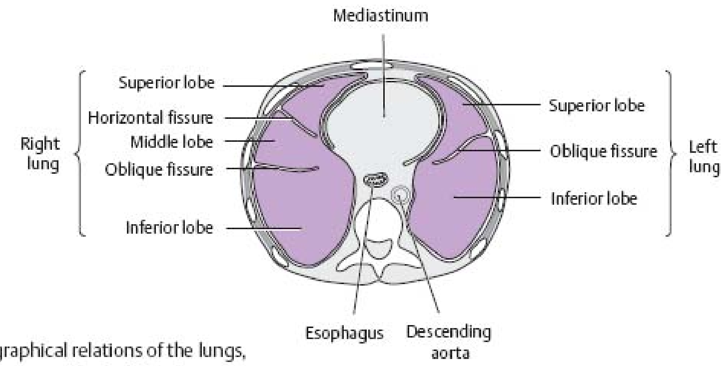


C Transverse section, inferior view. Reflection of the costal pleura onto the pericardium forms the costomediastinal recess.

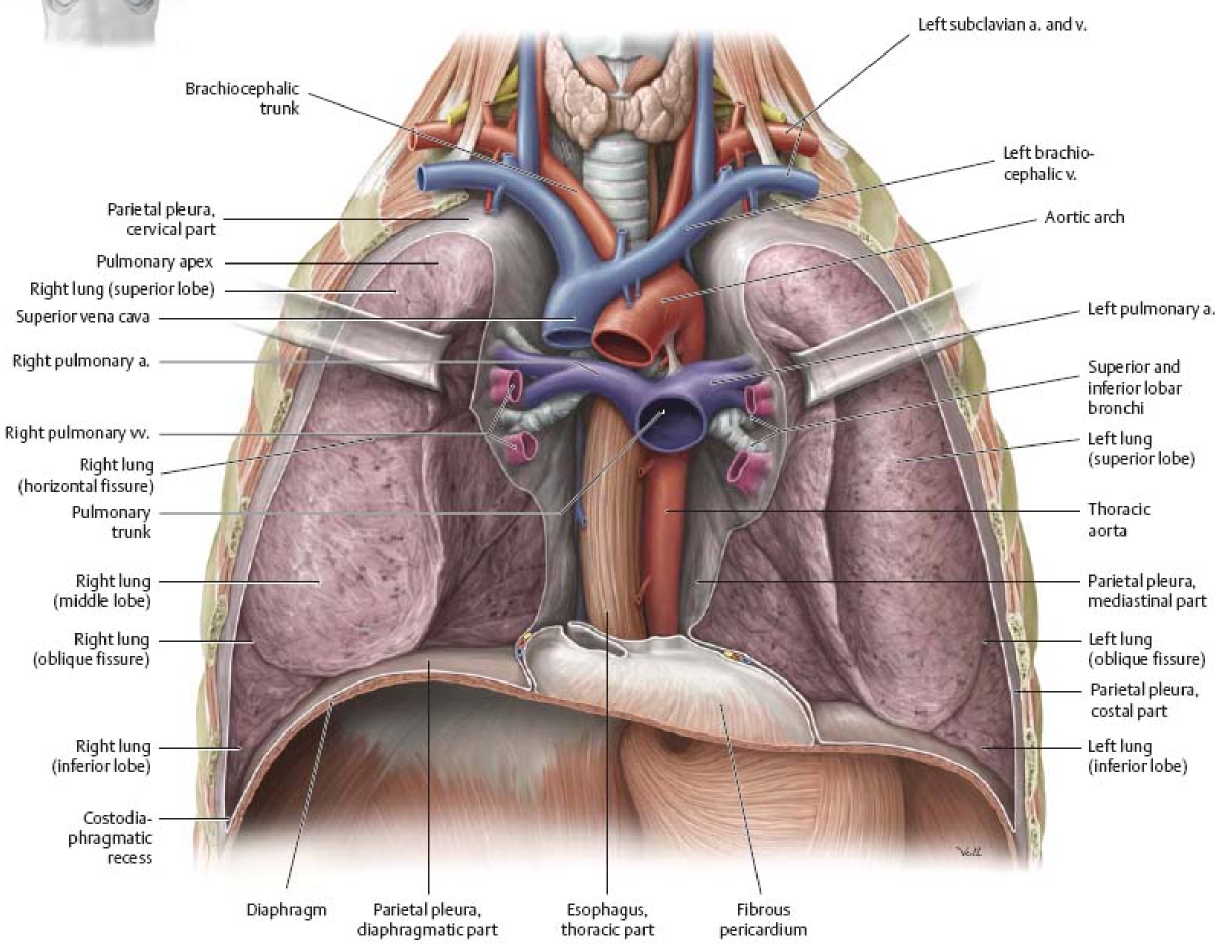
Lungs in Situ

Fig. 8.4 Lungs in situ

The left and right lungs occupy the full volume of the pleural cavity. Note that the left lung is slightly smaller than the right due to the asymmetrical position of the heart.



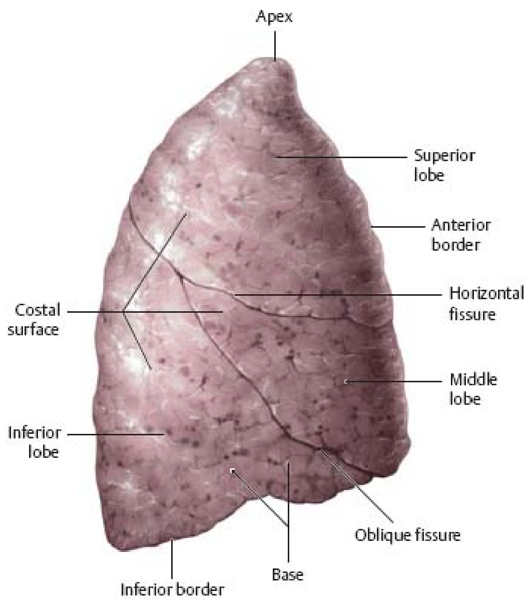
A Topographical relations of the lungs, transverse section, inferior view.



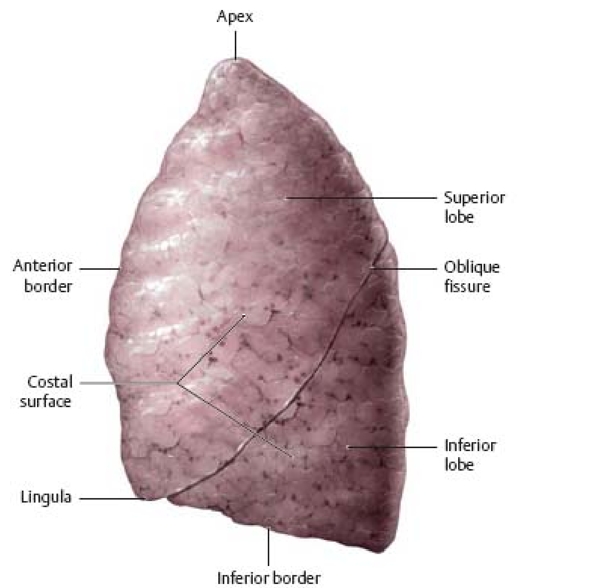
B Anterior view with lungs retracted.

The oblique and horizontal fissures divide the right lung into three lobes: superior, middle, and inferior. The oblique fissure divides the left lung into two lobes: superior and inferior. The apex of each lung extends into the root of the neck. The hilum is the location at which the bronchi and neurovascular structures connect to the lung.

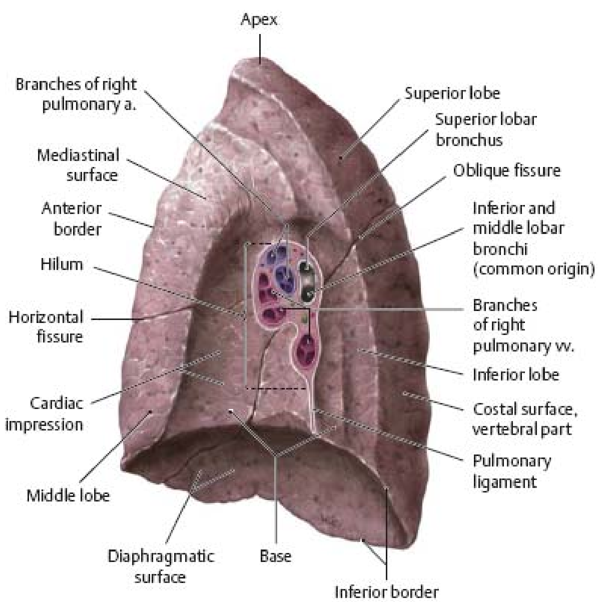
Fig. 8.5 **Gross anatomy of the lungs**



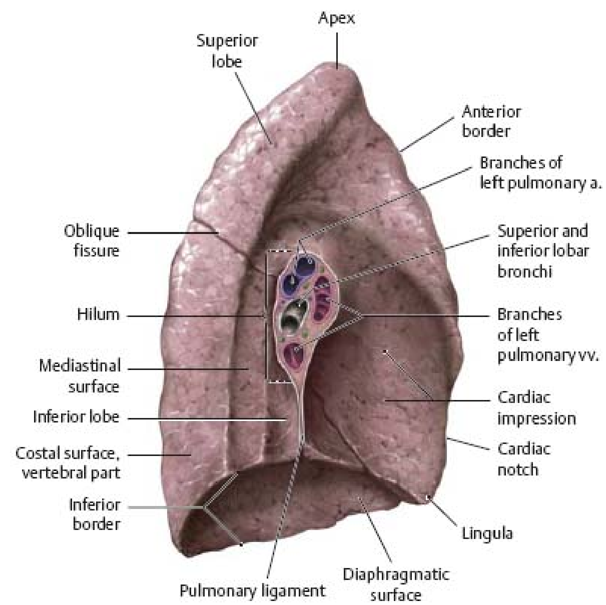
A Right lung, lateral view.



B Left lung, lateral view.



C Right lung, medial view.



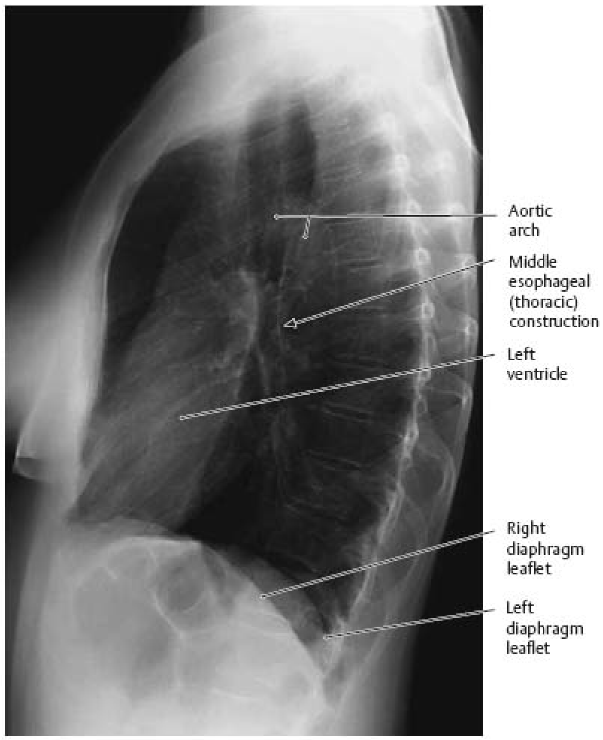
D Left lung, medial view.

Lung: Radiology

The regions of the lungs show varying degrees of lucency in chest radiographs. The perihilar region where the main bronchi and vessels enter and exit the lung is less radiolucent than the peripheral region, which contains small-caliber vascular branches and segmental bronchi. The perihilar lung region is also covered by the heart. These "shadows" appear as white or bright areas on the radiograph (radiographs are negatives: areas that are impermeable to light will appear bright).

Fig. 8.6 Radiographic appearance of the lungs

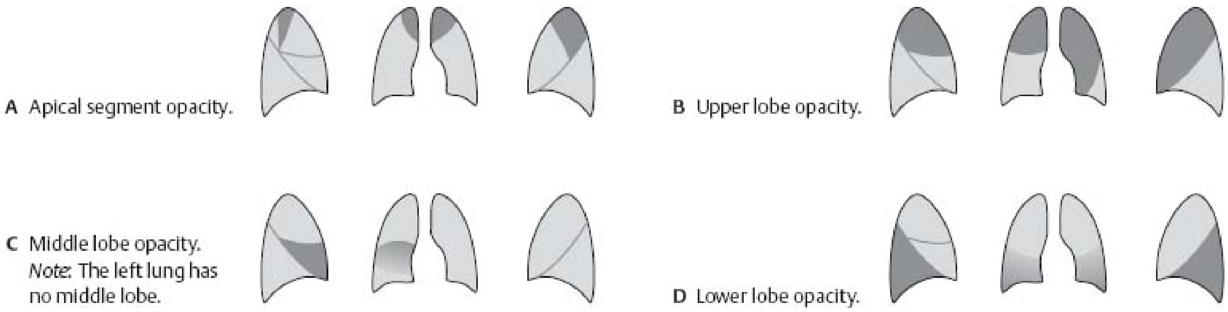
A Normal anteroposterior chest radiograph.



B Normal lateral chest radiograph.

Fig. 8.7 Opacity in lung diseases

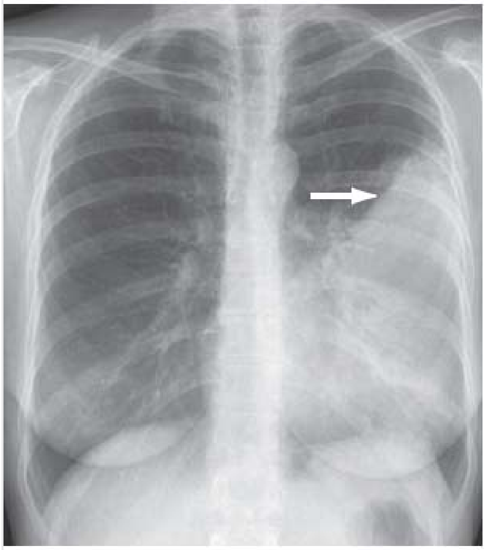
Lateral and anterior views of the right and left lungs. Opacity (decreased radiolucency) may be observed in diseased lung areas. Increased opacity may be due to fluid infiltration (inflammation) or tissue proliferation (neoplasia). These opacities are easier to detect in the peripheral part of the lung, which is inherently more radiolucent. *Note:* Opacities that conform to segmental lung boundaries are almost invariably due to pulmonary inflammation.



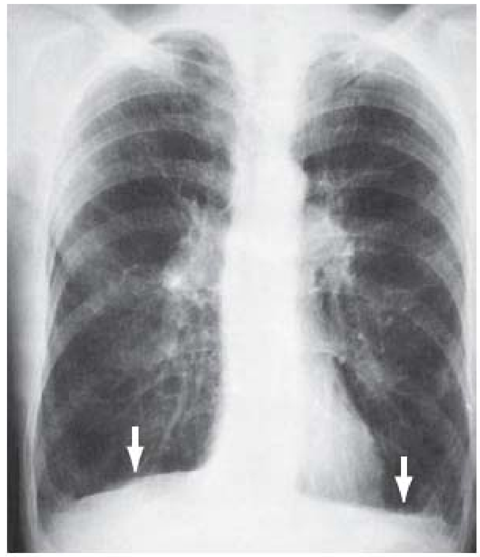
Clinical

Diseases of the lungs

Increased opacity in the lungs does not necessarly correspond to segmental boundaries. Fluid accumulation in the lungs also creates characteristic “shadows” in pulmonary radiographs.

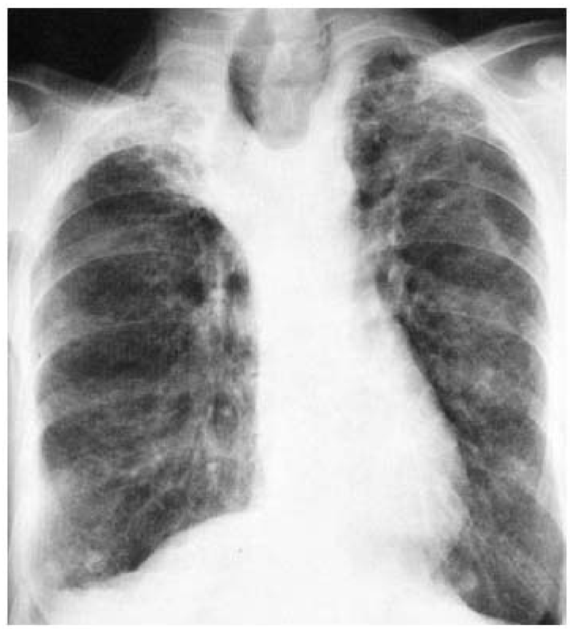


A Lingular pneumonia. The boundary between bronchopulmonary segments III and IV can be seen (arrow). *Note:* The heart is much more difficult to visualize here due to increased opacity of segments IV and V.



B Pulmonary emphysema. The chest radiograph reveals diaphragmatic depression (flattening of the domes of the diaphragm, arrows) with corresponding changes in the orientation of the cardiac shadow. The heart assumes a vertical orientation due to the low diaphragm (a lateral radiograph would reveal an increased retrosternal space). The central pulmonary arteries are dilated but taper dramatically at the segmental level.

C Pulmonary edema complicating acute myocardial infarction. Dilation of vessels increases the number of visible vascular structures. This image shows a butterfly pattern of edema and bilateral pleural effusion.



D Tuberculosis. Note the thickening of the pleura and the radiating fibrous bands. This image does not contain the small pulmonary nodules (tuberculomas) often found in the upper zones of the lung.

Bronchopulmonary Segments of the Lungs

The lung lobes are subdivided into bronchopulmonary segments, each supplied by a tertiary (segmental) bronchus. *Note:* These subdivisions are not defined by surface boundaries but by origin.

Fig. 8.8 Segmentation of the lung

Anterior view. See pp. 110–111 for details of the trachea and bronchial tree.

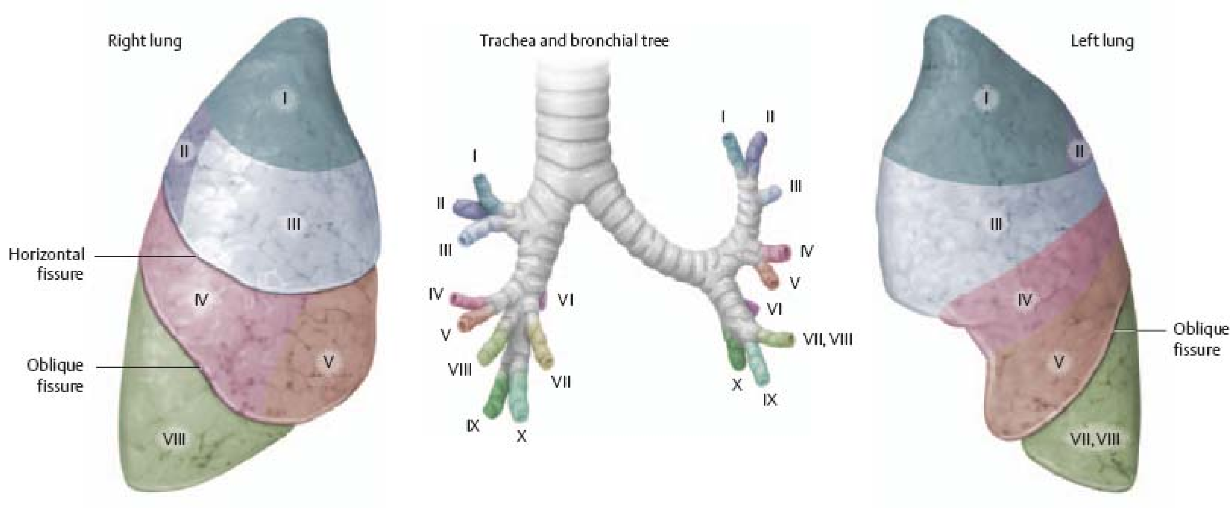


Fig. 8.9 Posteroanterior bronchogram

Anterior view of right lung.

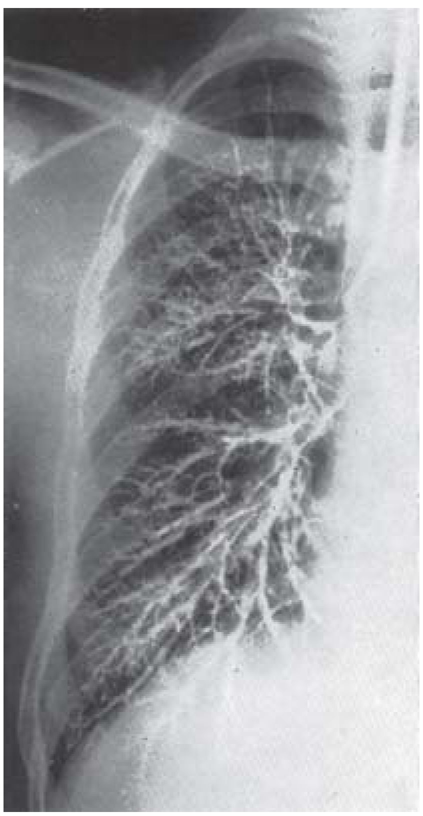


Table 8.2 Segmental architecture of the lungs

Each segment is supplied by a segmental bronchus of the same name (e.g., the apical segmental bronchus supplies the apical segment). See pp. 110–111 for details of the trachea and bronchial tree.

Right lung		Left lung	
Superior lobe			
I	Apical segment	Apicoposterior segment	I
II	Posterior segment		II
III	Anterior segment	Anterior segment	III
Middle lobe		**Lingula**	
IV	Lateral segment	Superior lingular segment	IV
V	Medial segment	Inferior lingular segment	V
Inferior lobe			
VI	Superior segment	Superior segment	VI
VII	Medial basal segment	Medial basal segment	VII
VIII	Anterior basal segment	Anterior basal segment	VIII
IX	Lateral basal segment	Lateral basal segment	IX
X	Posterior basal segment	Posterior basal segment	X

Fig. 8.10 Right lung: Bronchopulmonary segments

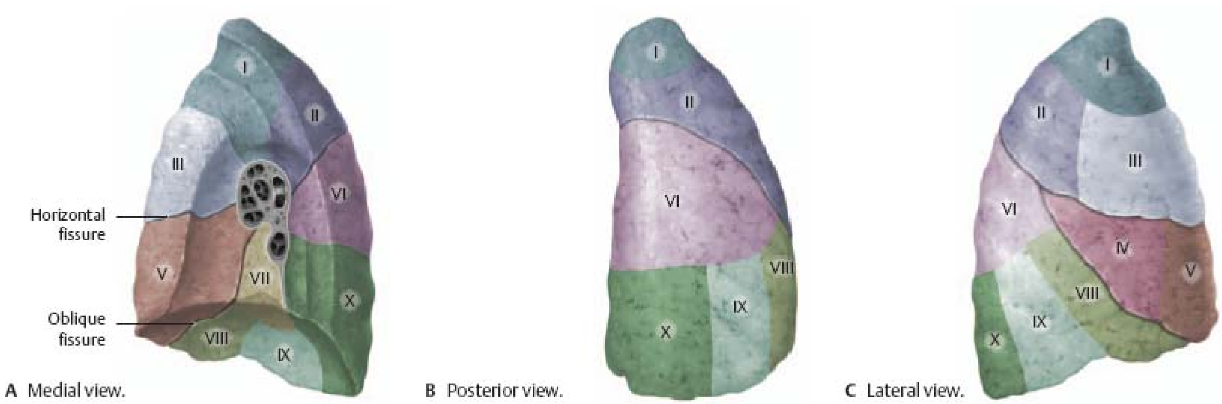
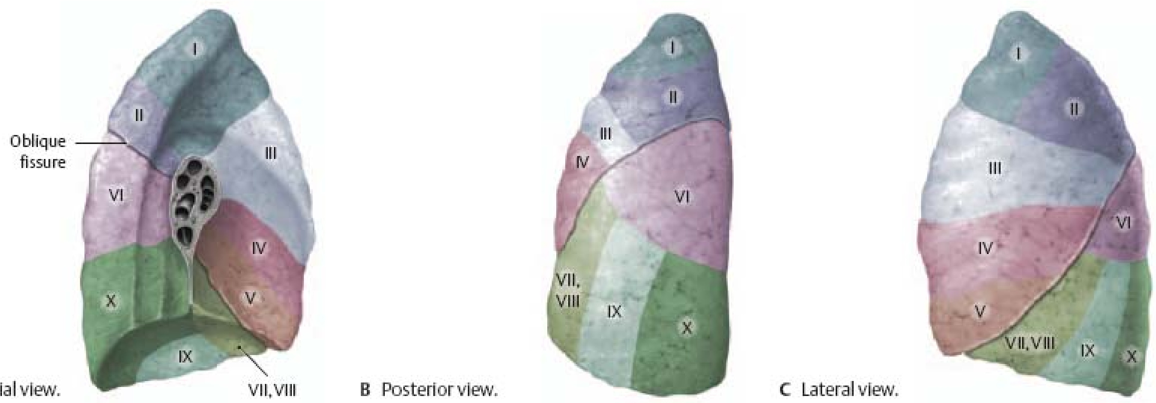


Fig. 8.11 Left lung: Bronchopulmonary segments



A Medial view.
B Posterior view.
C Lateral view.

Clinical

Lung resections

Lung cancer, emphysema, or tuberculosis may necessitate the surgical removal of damaged portions of the lung. Surgeons exploit the anatomical subdivision of the lungs into lobes and segments when excising damaged tissue.

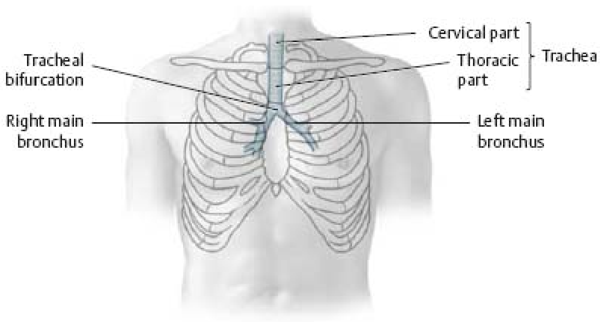
A Segmentectomy (wedge resection): Removal of one or more segments.
B Lobectomy: Removal of lobe.
C Pneumonectomy: Removal of entire lung.

Trachea & Bronchial Tree

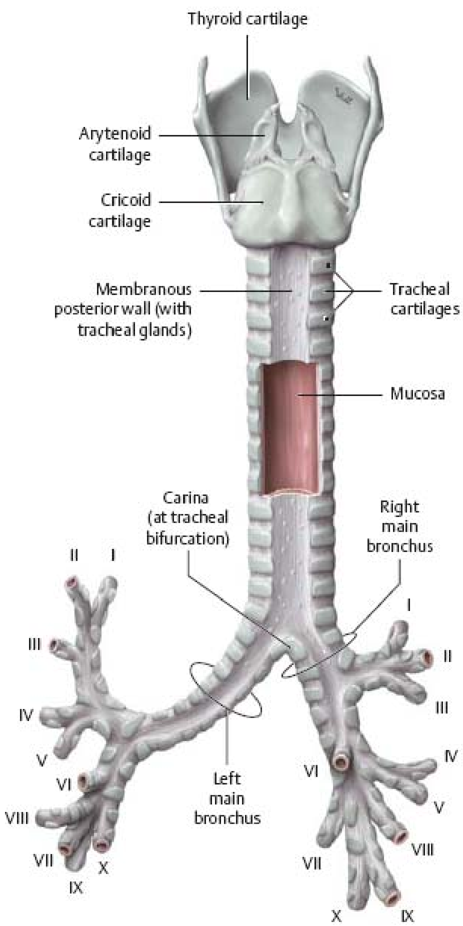
At or near the level of the sternal angle, the lowest tracheal cartilage extends anteroposteriorly, forming the carina. The trachea bifurcates at the carina into the right and left main bronchi. Each bronchus gives off lobar branches to the corresponding lung.

Fig. 8.12 Trachea

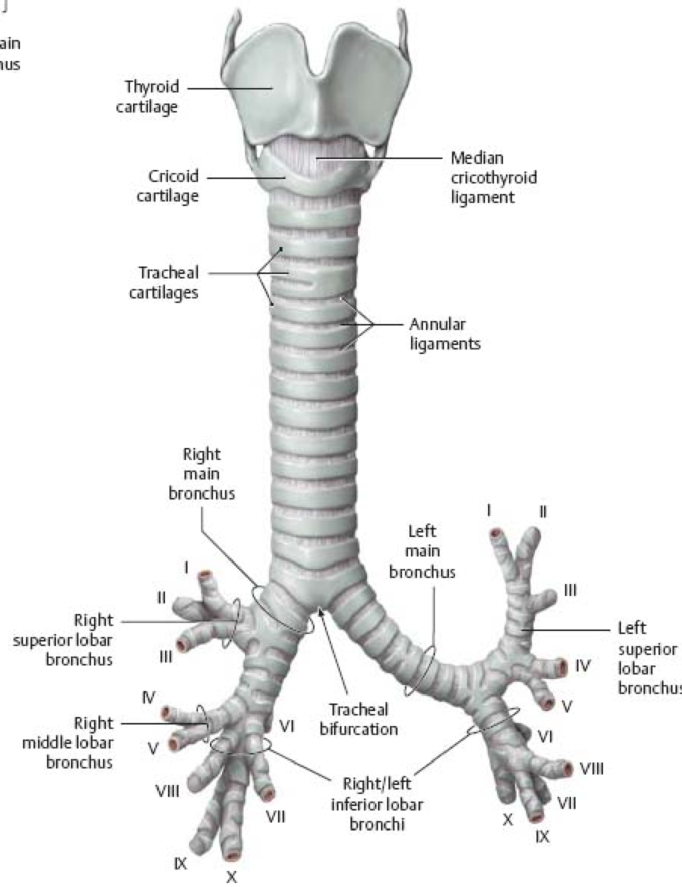
See p. 574 for the structures of the thyroid.



A Projection of trachea onto chest.



C Posterior view with opened posterior wall.



B Anterior view.

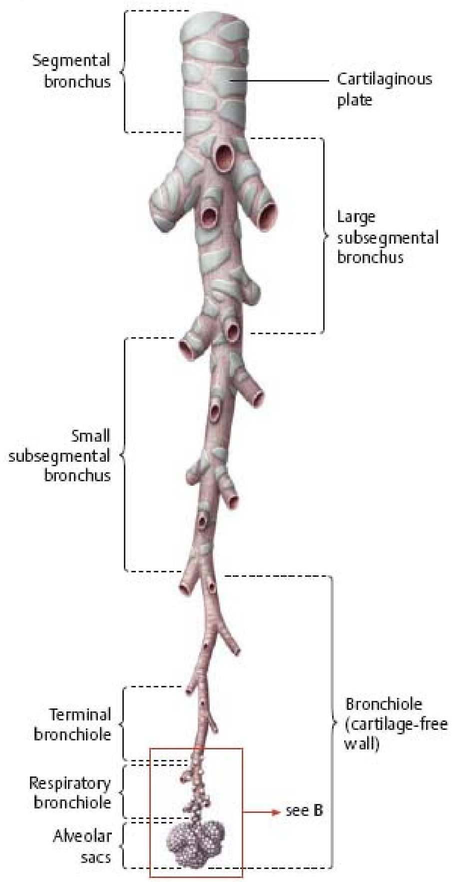
Clinical

Foreign body aspiration

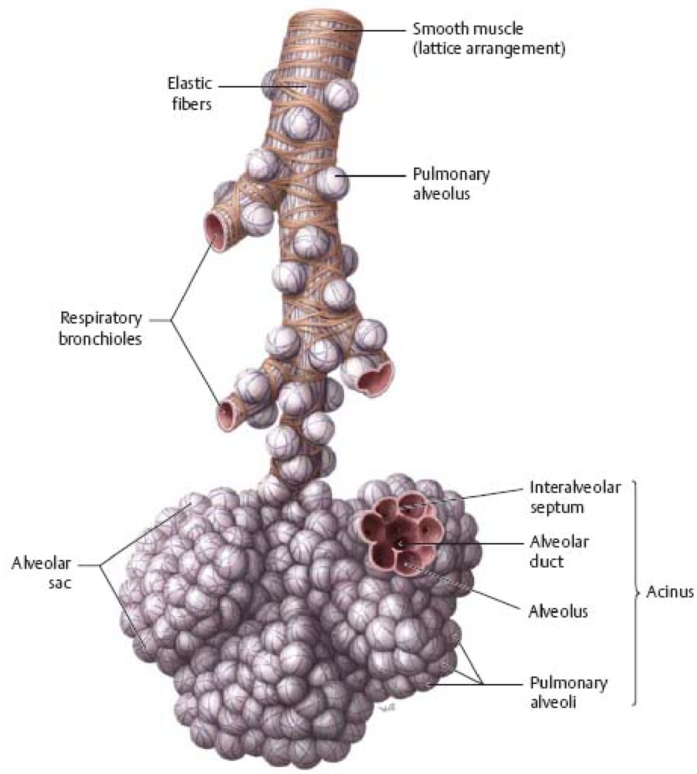
Toddlers are at particularly high risk of potentially fatal aspiration of foreign bodies. In general, foreign bodies are more likely to become lodged in the right main bronchus than the left: the left bronchus diverges more sharply at the tracheal bifurcation, while the right bronchus is relatively straight.

The conducting portion of the bronchial tree extends from the tracheal bifurcation to the terminal bronchiole, inclusive. The respiratory portion consists of the respiratory bronchiole, alveolar ducts, alveolar sacs, and alveoli.

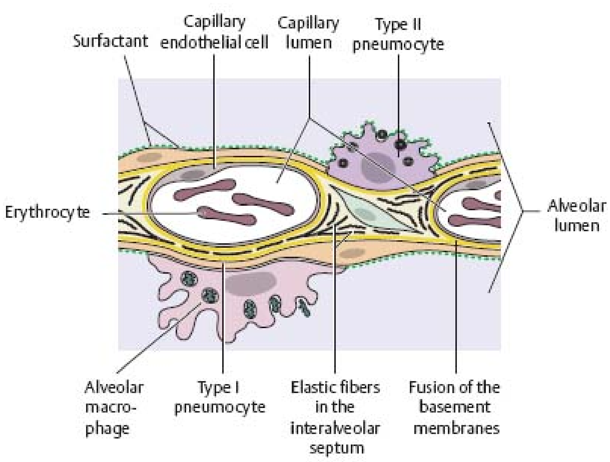
Fig. 8.13 **Bronchial tree**



A Divisions of the bronchial tree.



B Respiratory portion of the bronchial tree.



C Epithelial lining of the alveoli.

Clinical

Respiratory compromise

The most common cause of respiratory compromise at the bronchial level is asthma. Compromise at the alveolar level may result from increased diffusion distance, decreased aeration (emphysema), or fluid infiltration (e.g., pneumonia).

Diffusion distance:
Gaseous exchange takes place between the alveolar and capillary lumens in the alveoli (see Fig. 8.13C). At these sites, the basement membranes of capillary endothelial cells are fused with those of type I alveolar epithelial cells, lowering the exchange distance to 0.5 µm. Diseases that increase this diffusion distance (e.g., edematous fluid collection or inflammation) result in compromised respiration.

Condition of alveoli: In diseases like emphysema, which occurs in chronic obstructive pulmonary disease (COPD), alveoli are destroyed or damaged. This reduces the surface area available for gaseous exchange.

Production of surfactant: Surfactant is a protein-phospholipid film that lowers the surface tension of the alveoli, making it easier for the lung to expand. The immature lungs of a preterm infant often fail to produce sufficient surfactant, leading to respiratory problems. Surfactant is produced and absorbed by alveolar epithelial cells (pneumocytes). Type I alveolar epithelial cells absorb surfactant; type II produce and distribute it.

Respiratory Mechanics

The mechanics of respiration are based on a rhythmic increase and decrease in thoracic volume, with an associated expansion and contraction of the lungs. *Inspiration* (red): Contraction of the diaphragm leaflets lowers the diaphragm into the inspiratory position, increasing the volume of the pleural cavity along the vertical axis. Contraction of the thoracic muscles (external intercostals with the scalene, intercartilaginous, and posterior serratus muscles) elevates the ribs, expanding the pleural cavity along the sagittal and transverse axes (Fig. 8.15A,B). Surface tension in the pleural space causes the visceral and parietal pleura to adhere; thus, changes in thoracic volume alter the volume of the lungs. This is particularly evident in the pleural recesses: at functional residual capacity (resting position between inspiration and expiration), the lung does not fully occupy the pleural cavity. As the pleural cavity expands, a negative intrapleural pressure is generated. The air pressure differential results in an influx of air (inspiration). *Expiration* (blue): During passive expiration, the muscles of the thoracic cage relax and the diaphragm returns to its expiratory position. Contraction of the lungs increases the pulmonary pressure and expels air from the lungs. For forcible expiration, the internal intercostal muscles (with the transverse thoracic and subcostal mucosa) can actively lower the rib cage more rapidly and to a greater extent than through passive elastic recoil.

Fig. 8.14 **Respiratory changes in thoracic volume**

Inspiratory position (red); expiratory position (blue).

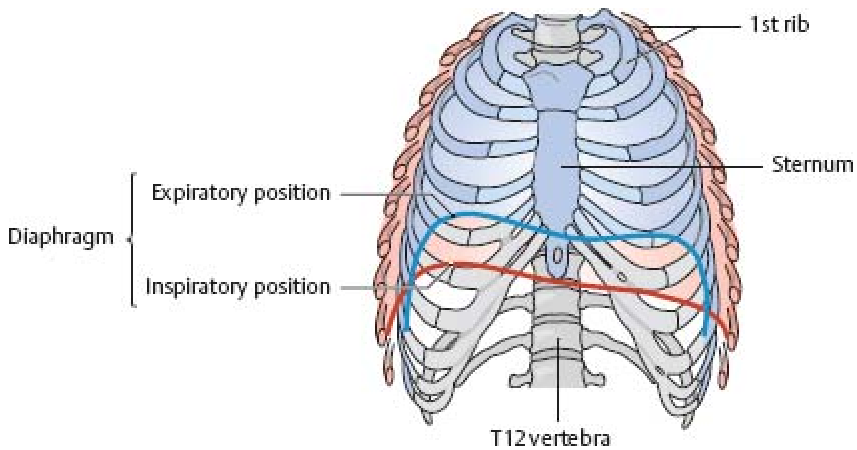


Fig. 8.15 **Inspiration: Pleural cavity expansion**

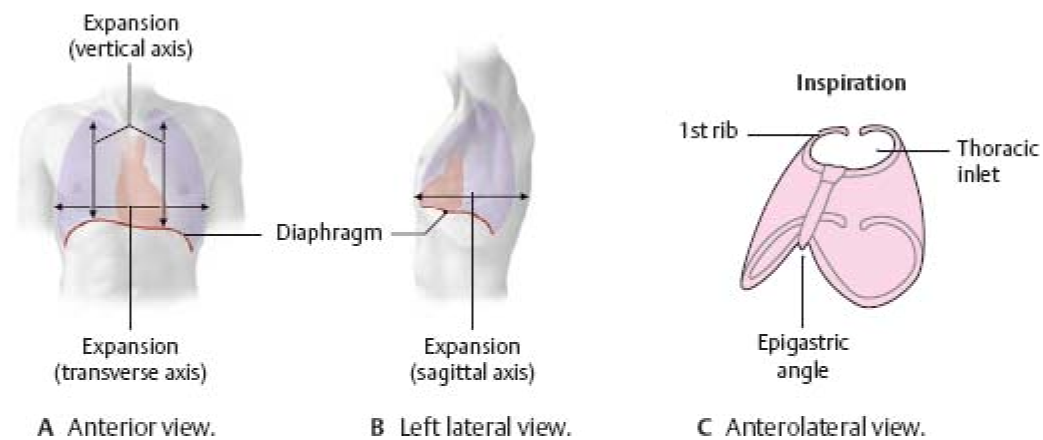


Fig. 8.16 **Expiration: Pleural cavity contraction**

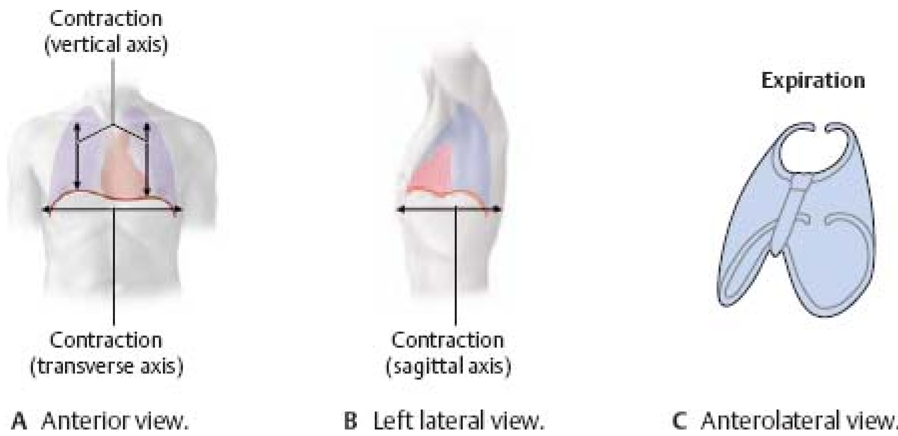


Fig. 8.17 Respiratory changes in lung volume

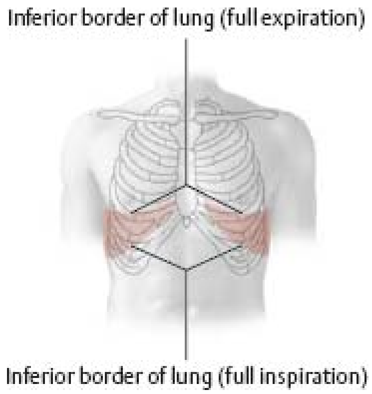


Fig. 8.18 Inspiration: Lung expansion

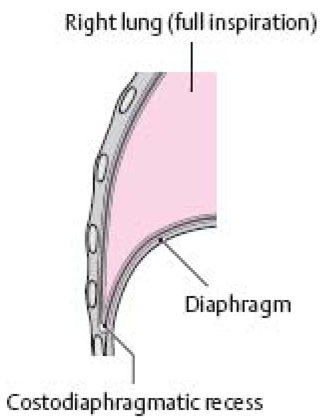


Fig. 8.19 Expiration: Lung contraction

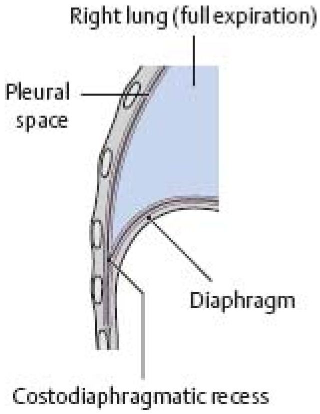
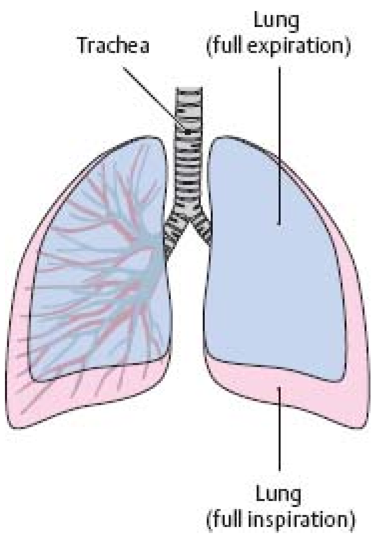


Fig. 8.20 Movements of the lung and bronchial tree

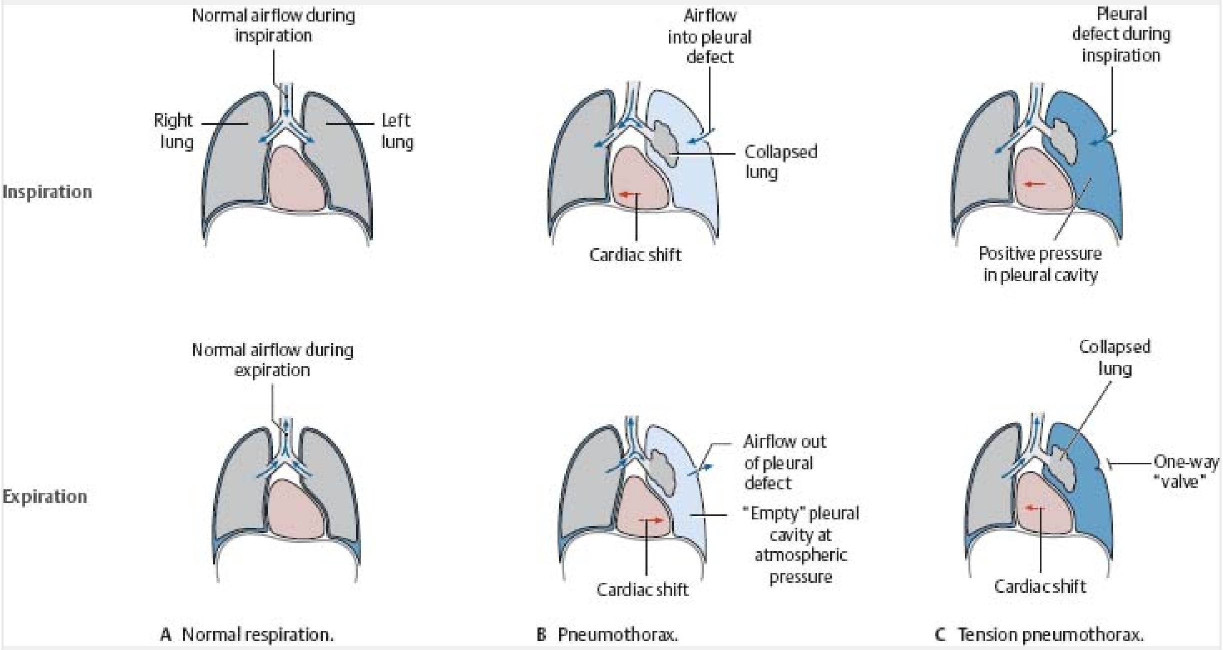
As the volume of the lung changes with the thoracic cavity, the entire bronchial tree moves within the lung. These structural movements are more pronounced in portions of the bronchial tree distant from the pulmonary hilum.



Clinical

Pneumothorax

The pleural space is normally sealed from the outside environment. Injury to the parietal pleura, visceral pleura, or lung allows air to enter the pleural cavity (pneumothorax). The lung collapses due to its inherent elasticity, and the patient's ability to breathe is compromised. The uninjured lung continues to function under normal pressure variations, resulting in “mediastinal flutter”: the mediastinum shifts toward the normal side during inspiration and returns to the midline during expiration. Tension (valve) pneumothorax occurs when traumatically detached and displaced tissure covers the defect in the thoracic wall from the inside. This mobile flap allows air to enter, but not escape, the pleural cavity, causing a pressure buildup. The mediastinum shifts to the normal side, which may cause kinking of the great vessels and prevent the return of venous blood to the heart. Without treatment, tension pneumothorax is invariably fatal.

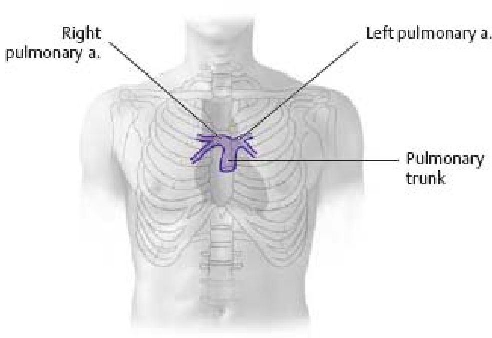


Pulmonary Arteries & Veins

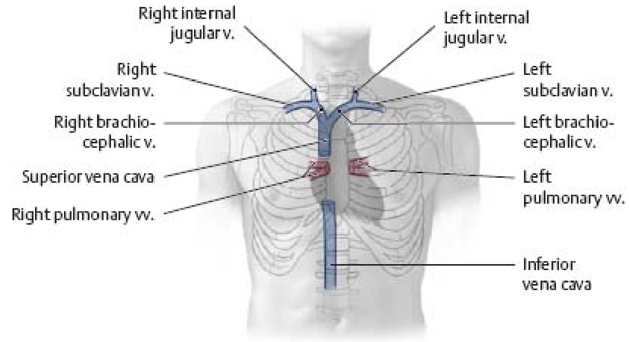
The pulmonary trunk arises from the right ventricle and divides into a left and right pulmonary artery for each lung. The paired pulmonary veins open into the left atrium on each side. The pulmonary arteries accompany and follow the branching of the bronchial tree, whereas the pulmonary veins do not, being located at the margins of the pulmonary lobules.

Fig. 8.21 **Pulmonary arteries and veins**

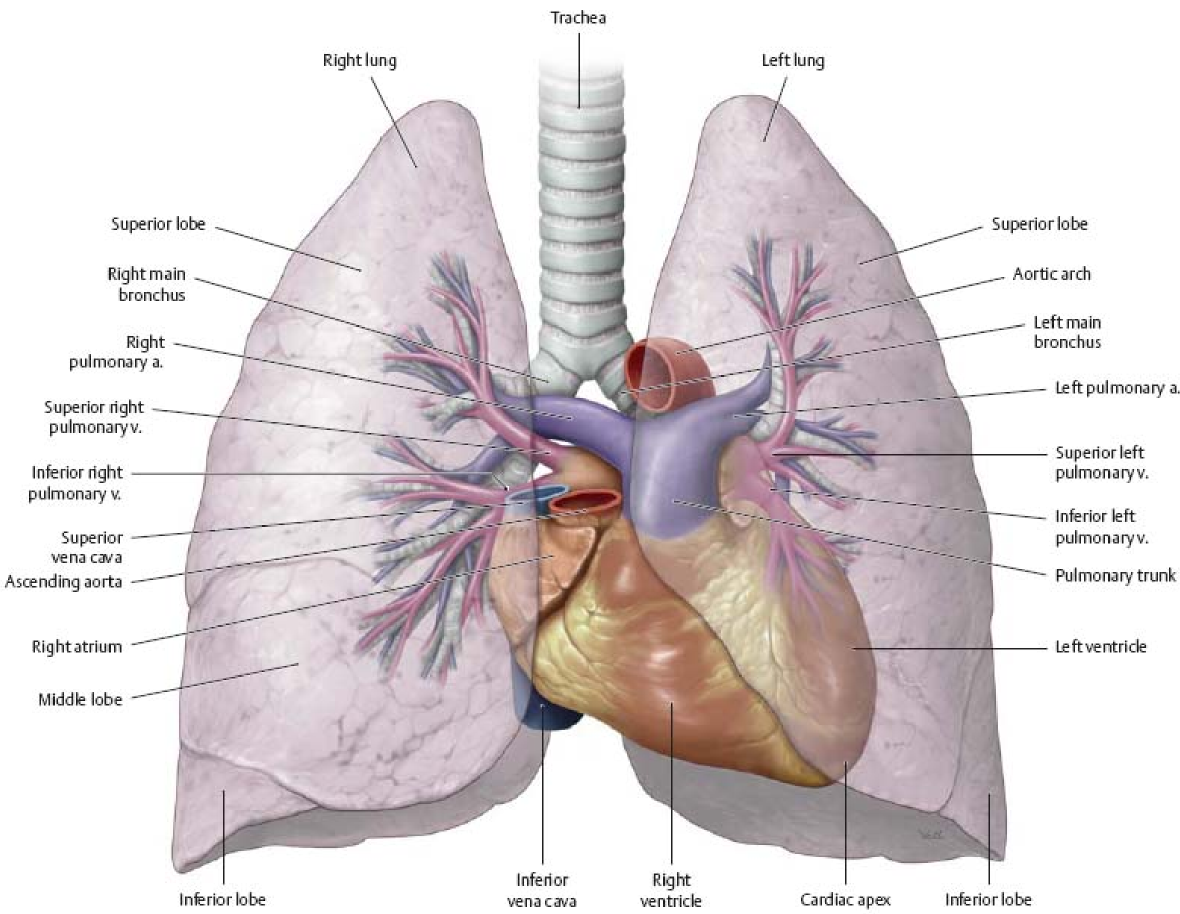
Anterior view.



A Projection of pulmonary arteries on chest wall.

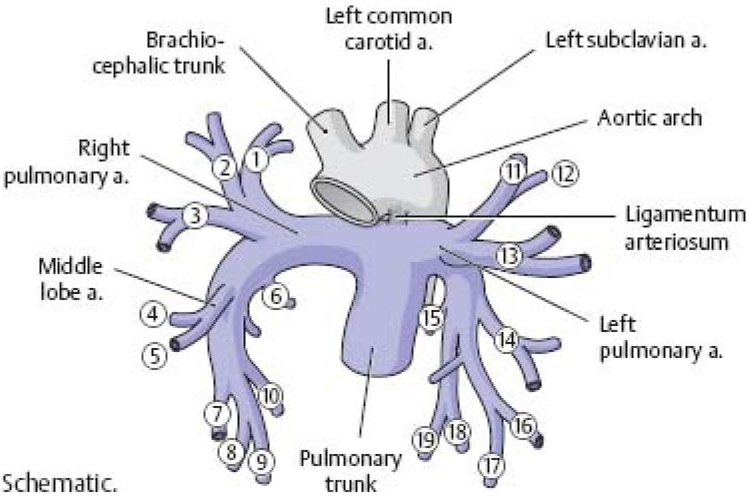


B Projection of pulmonary veins on chest wall.

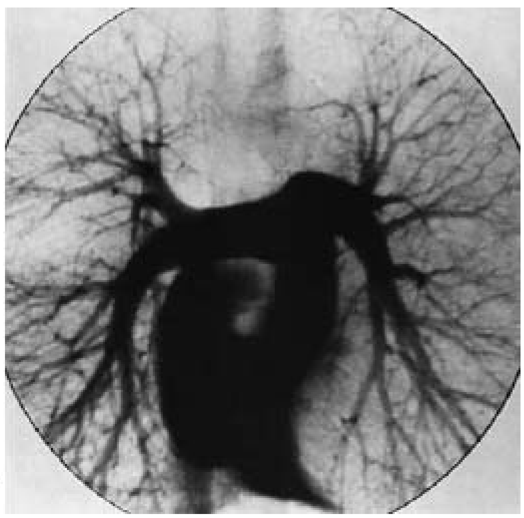


C Distribution of the pulmonary arteries and veins, anterior view.

Fig. 8.22 **Pulmonary arteries**



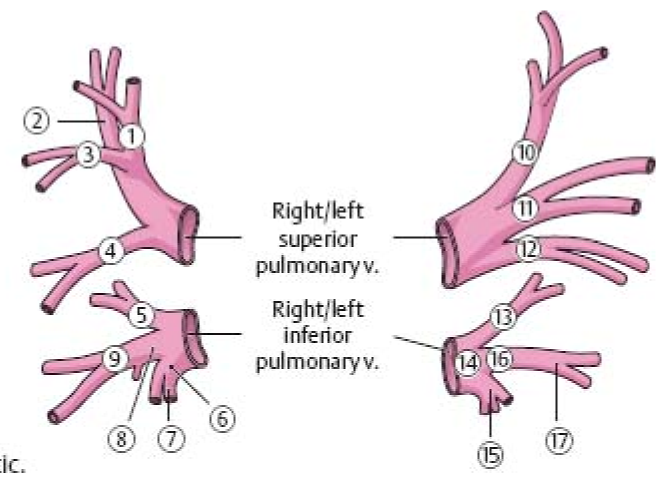
A Schematic.



B Pulmonary arteriogram, arterial phase, anterior view.

Table 8.3	Pulmonary arteries and their branches		
Right pulmonary artery			Left pulmonary artery
Superior lobe arteries			
①	Apical segmental a.		⑪
②	Posterior segmental a.		⑫
③	Anterior segmental a.		⑬
Middle lobe arteries			
④	Lateral segmental a.	Lingular a.	⑭
⑤	Medial segmental a.		
Inferior lobe arteries			
⑥	Superior segmental a.		⑮
⑦	Anterior basal segmental a.		⑯
⑧	Lateral basal segmental a.		⑰
⑨	Posterior basal segmental a.		⑱
⑩	Medial basal segmental a.		⑲

Fig. 8.23 Pulmonary veins



A Schematic.

B Pulmonary arteriogram, venous phase, anterior view.

Table 8.4 Pulmonary veins and their tributaries

Right pulmonary vein		Left pulmonary vein	
Superior pulmonary veins			
①	Apical v.	Apicoposterior v.	⑩
②	Posterior v.		
③	Anterior v.	Anterior v.	⑪
④	Middle lobe v.	Lingular v.	⑫
Inferior pulmonary veins			
⑤	Superior v.		⑬
⑥	Common basal v.		⑭
⑦	Inferior basal v.		⑮
⑧	Superior basal v.		⑯
⑨	Anterior basal v.		⑰

Clinical

Pulmonary embolism

Potentially life-threatening pulmonary embolism occurs when blood clots migrate through the venous system and become lodged in one of the arteries supplying the lungs. Symptoms include dyspnea (difficulty breathing) and tachycardia (increased heart rate). Most pulmonary emboli originate from stagnant blood in the veins of the lower limb and pelvis (venous thromboemboli). Causes include immobilization, disordered blood coagulation, and trauma. *Note:* A thromboembolus is a thrombus (blood clot) that has migrated (embolised).

Neurovasculature of the Tracheobronchial Tree

Fig. 8.24 Pulmonary vasculature

The pulmonary system is responsible for gaseous exchange within the lung. Pulmonary arteries (shown in blue) carry *deoxygenated* blood and follow the bronchial tree. The pulmonary vein (red) is the only vein in the body carrying *oxygenated* blood, which it receives from the alveolar capillaries at the periphery of the lobule.

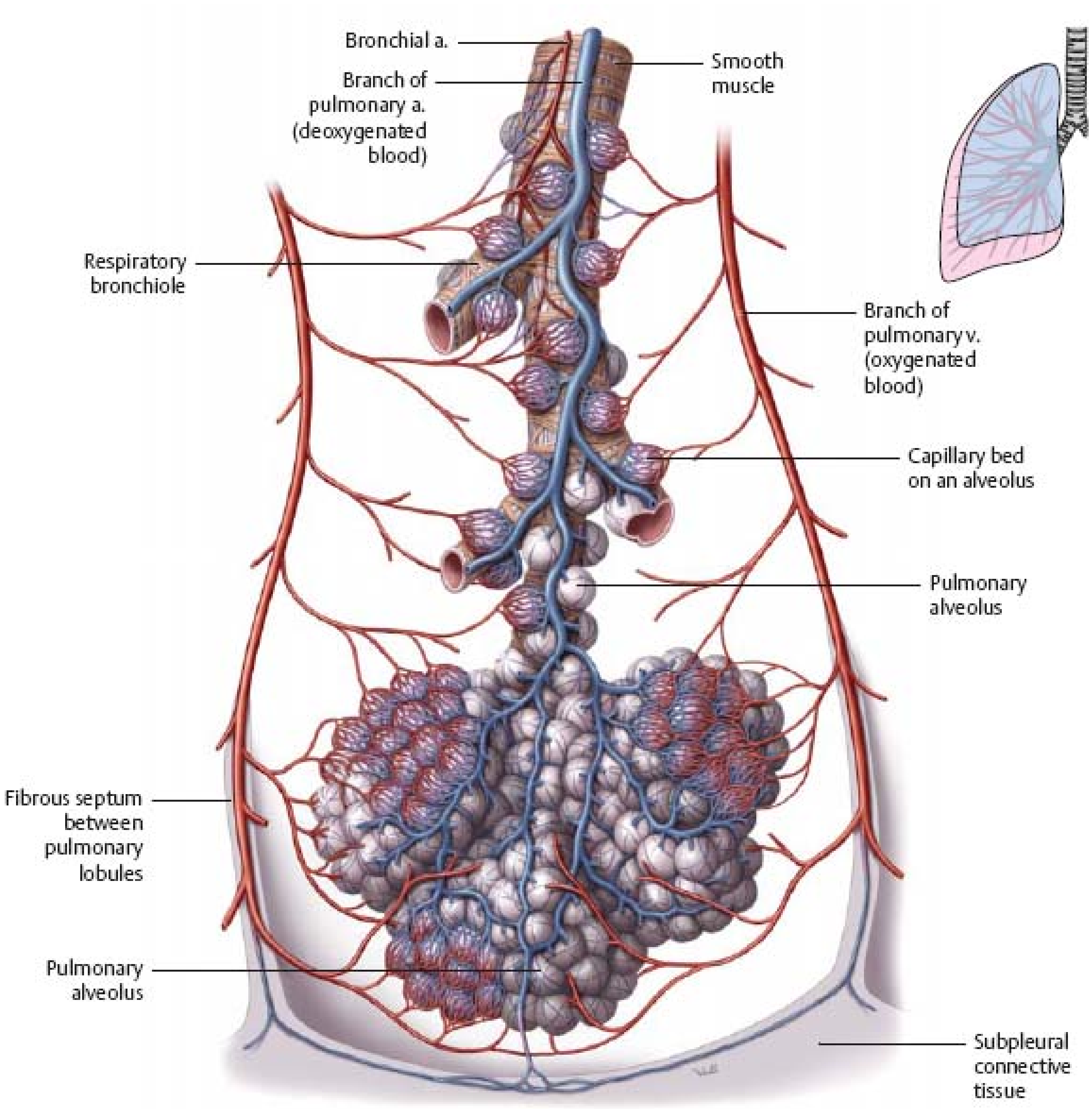


Fig. 8.25 Arteries of the tracheobronchial tree

The bronchial tree receives its nutrients via the bronchial arteries, found in the adventitia of the airways. Typically, there are one to three bronchial arteries arising directly from the aorta. Origin from a posterior intercostal artery may also occur.

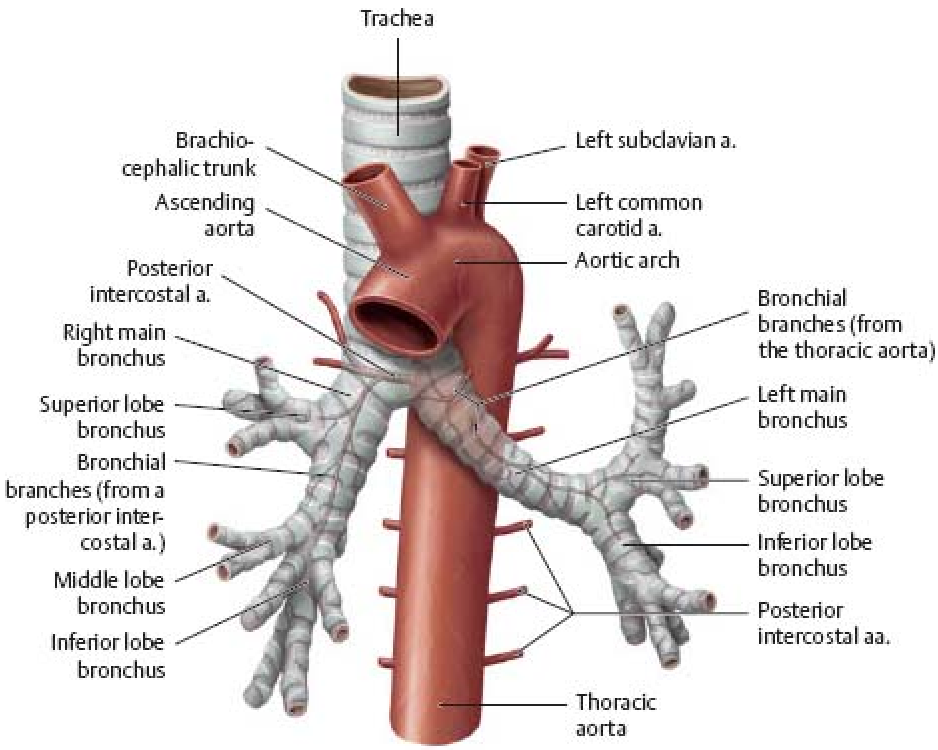


Fig. 8.26 Veins of the tracheobronchial tree

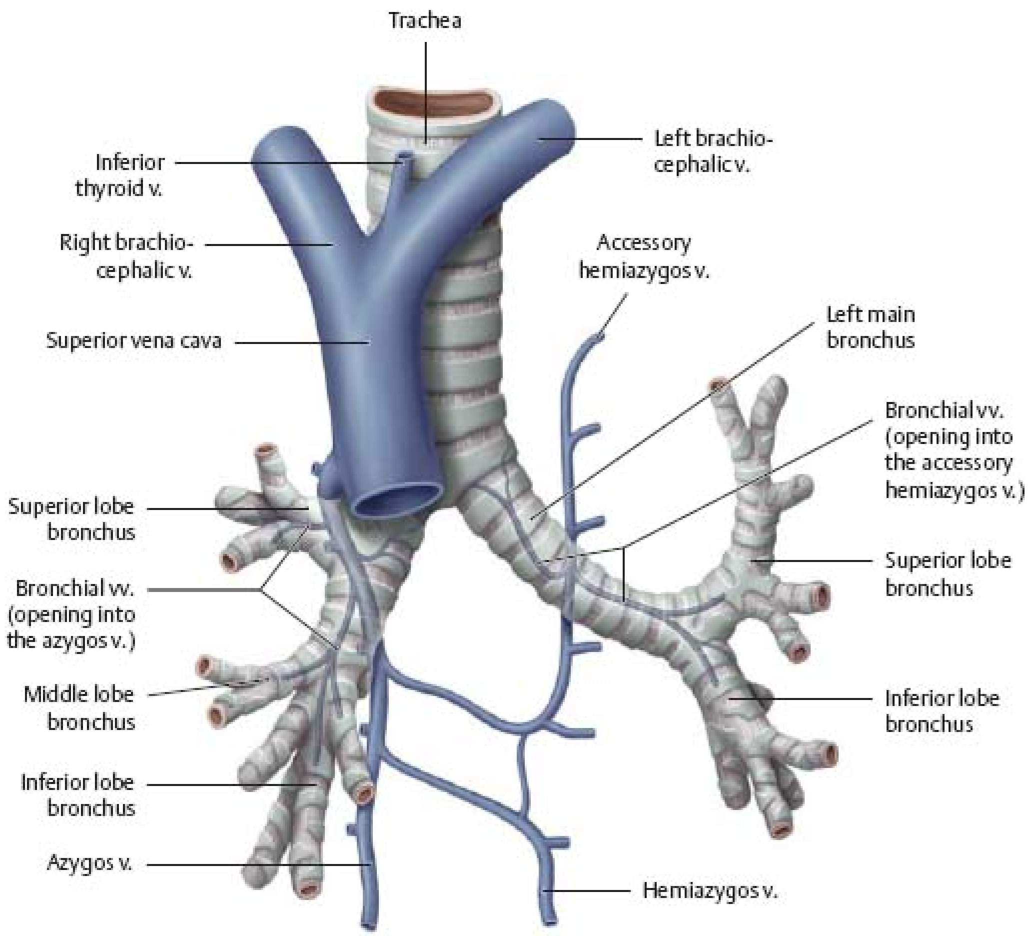
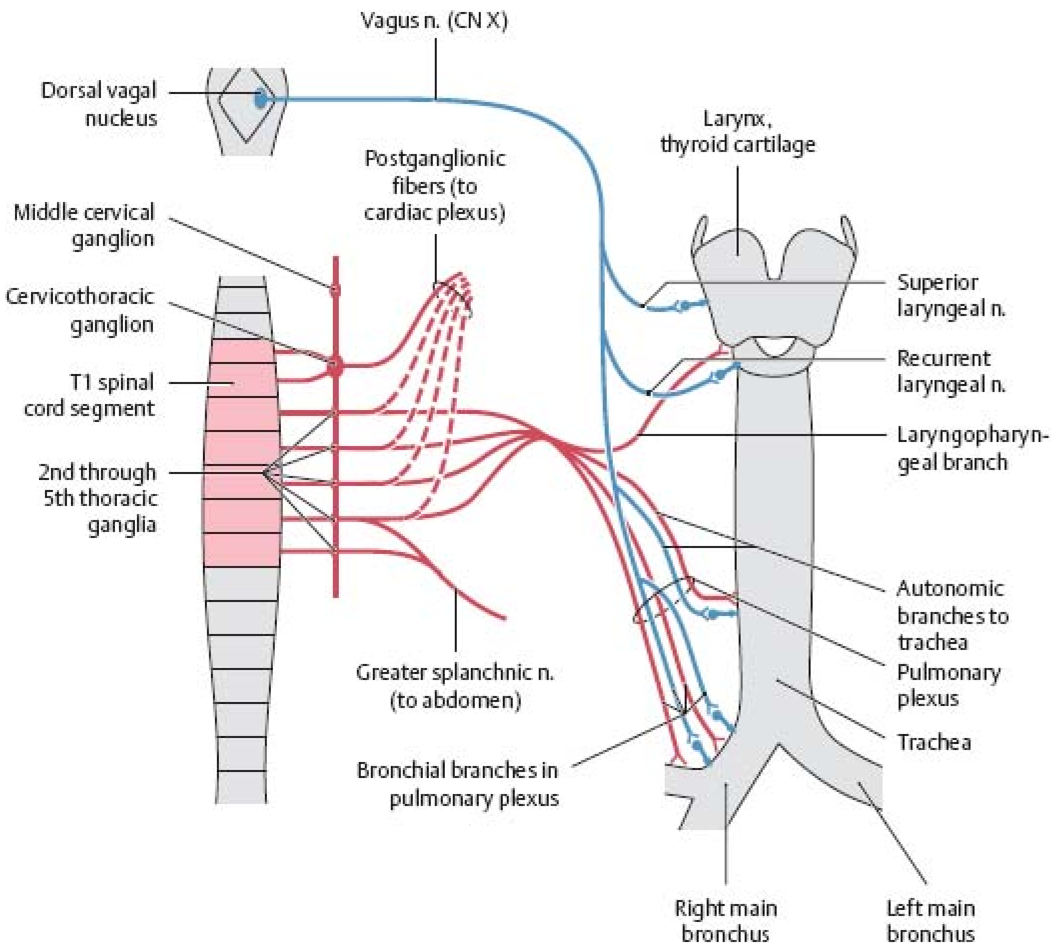


Fig. 8.27 **Autonomic innervation of the tracheobronchial tree**

Sympathetic innervation (red); parasympathetic innervation (blue).

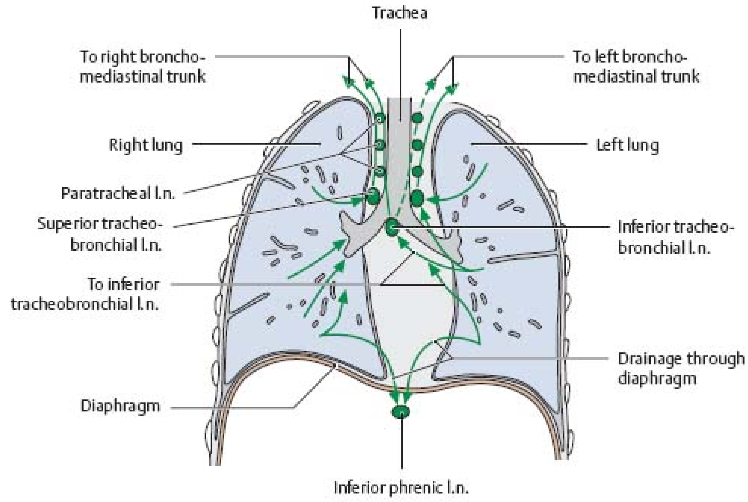


Lymphatics of the Pleural Cavity

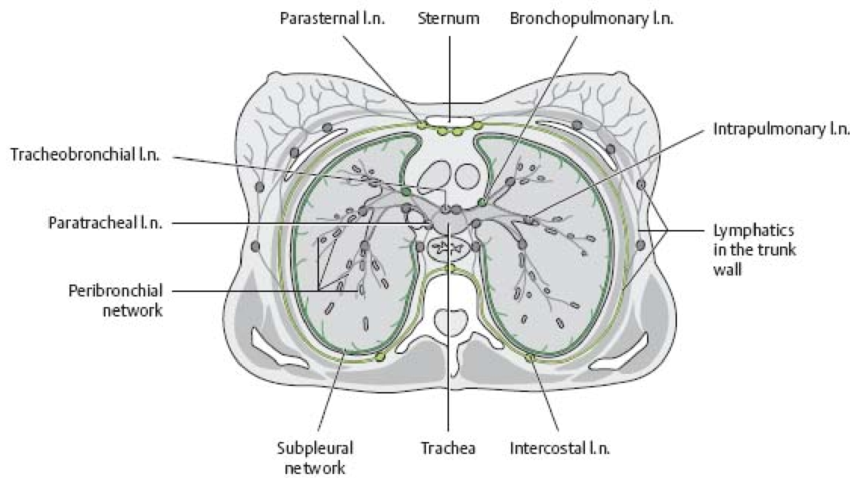
The lungs and bronchi are drained by two lymphatic drainage systems. The peribronchial network follows the bronchial tree, draining lymph from the bronchi and most of the lungs. The subpleural network collects lymph from the peripheral lung and visceral pleura.

Fig. 8.28 Lymphatic drainage of the pleural cavity

Transverse section, inferior view.



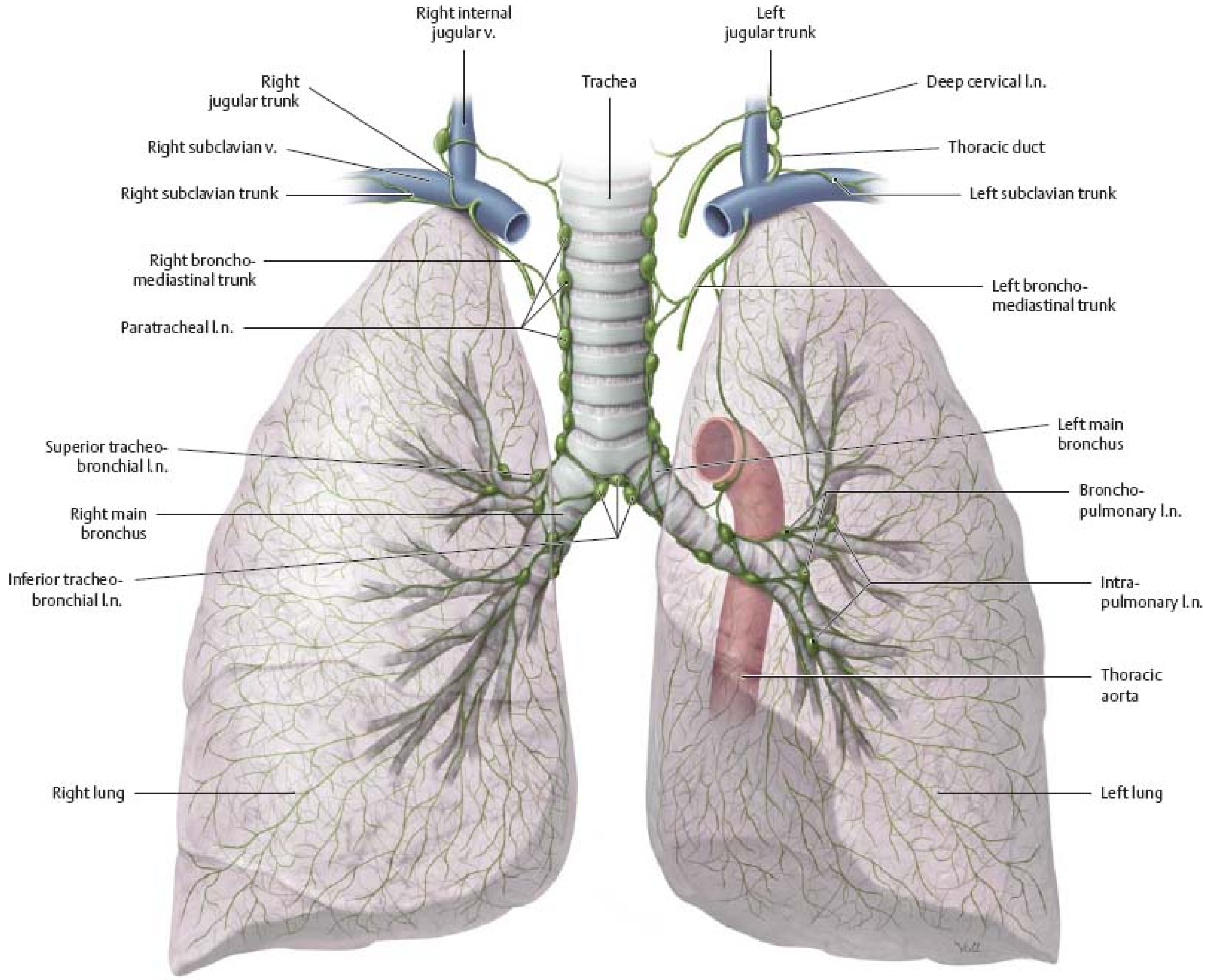
A Peribronchial network, coronal section. (Intra)pulmonary nodes along the bronchial tree drain lymph from the lungs into the bronchopulmonary (hilar) nodes. Lymph then passes sequentially through the inferior and superior tracheobronchial nodes, paratracheal nodes, bronchomediastinal trunk, and finally to the right lymphatic or thoracic duct. *Note:* Significant amounts of lymph from the left lower lobe drain to the right superior tracheobronchial nodes.



B Subpleural network, transverse section, superior view.

Fig. 8.29 Lymph nodes of the pleural cavity

Anterior view of pulmonary nodes.



Right internal jugular v.
Left jugular trunk
Right jugular trunk
Trachea
Deep cervical l.n.
Right subclavian v.
Thoracic duct
Right subclavian trunk
Left subclavian trunk
Right broncho-mediastinal trunk
Left broncho-mediastinal trunk
Paratracheal l.n.
Left main bronchus
Superior tracheo-bronchial l.n.
Broncho-pulmonary l.n.
Right main bronchus
Intra-pulmonary l.n.
Inferior tracheo-bronchial l.n.
Thoracic aorta
Right lung
Left lung

9 Surface Anatomy

Surface Anatomy

Fig. 9.1 Palpable structures in the thorax

Anterior view. See pp. 40–41 for structures of the back.

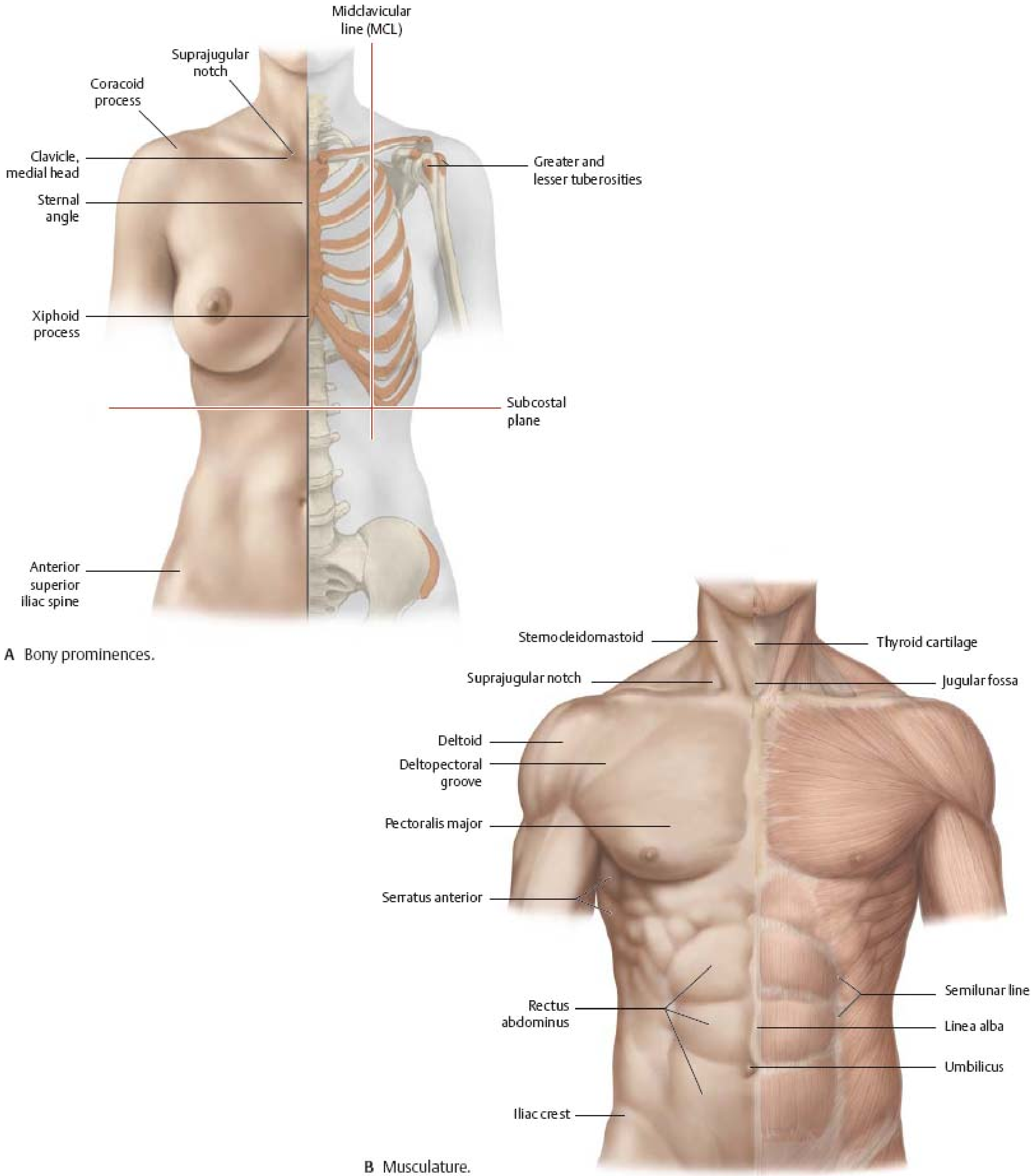
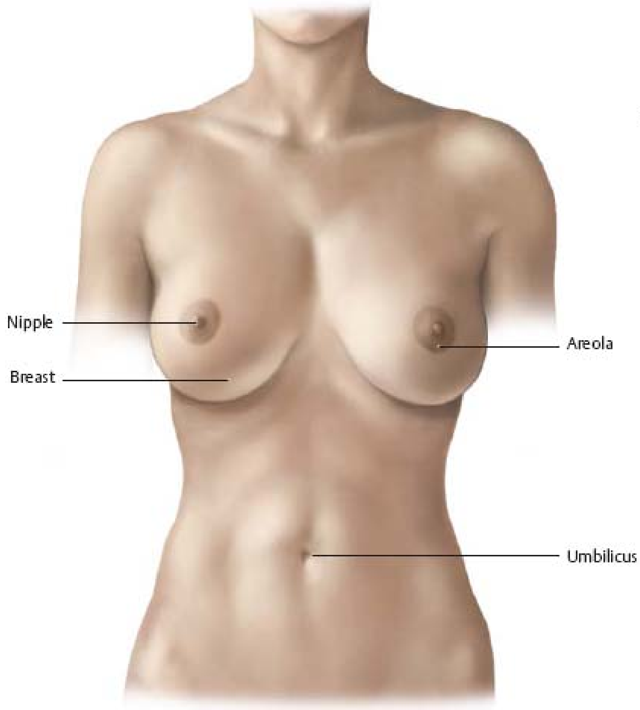


Fig. 9.2 **Surface anatomy of the thorax**

Anterior view. See pp. 40–41 for structures of the back.



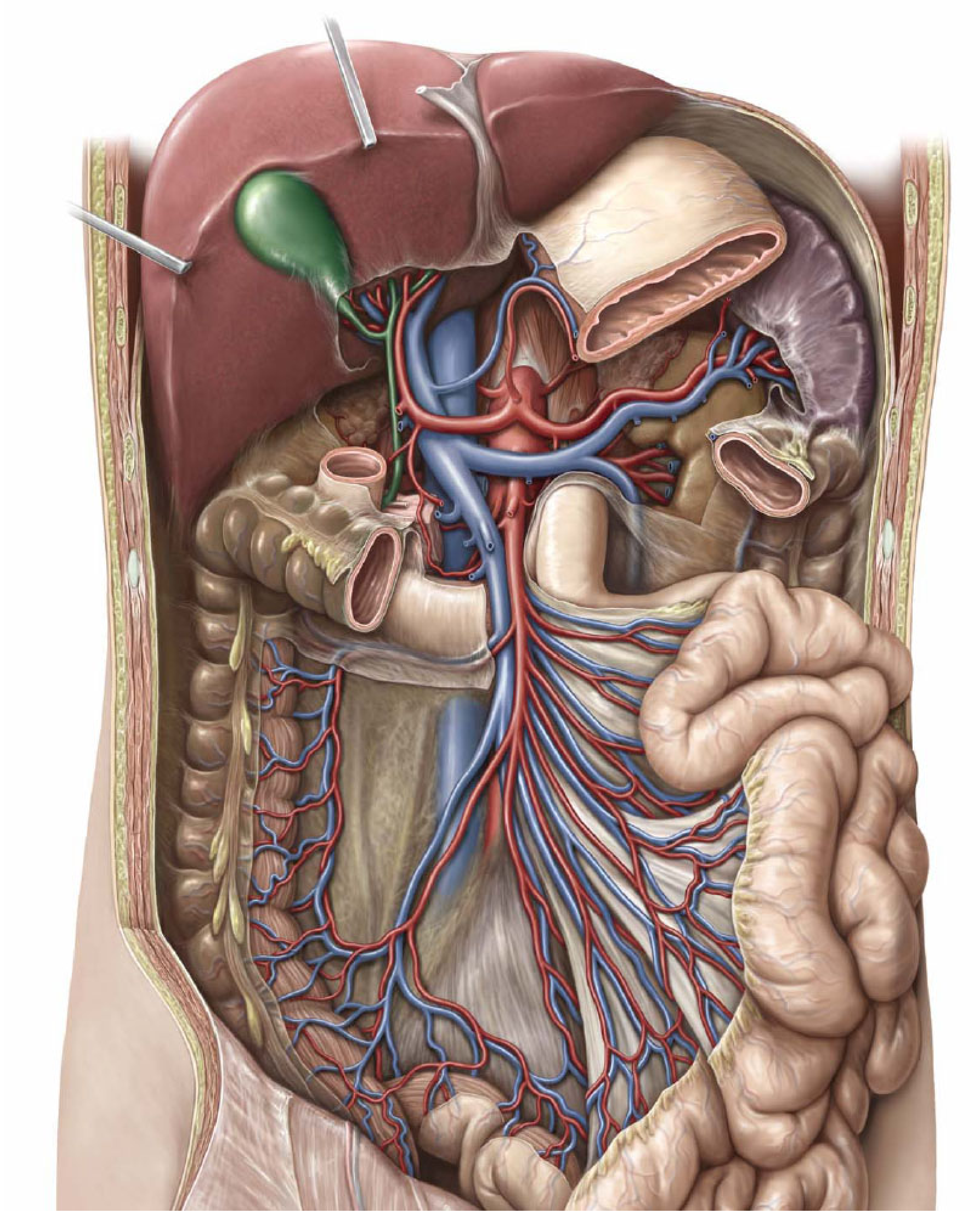
A Female thorax.

Q1: A female patient has given a history of detecting a "lump" during a self-examination. How would you proceed? Where would you palpate for lymph nodes?

Q2: You are presented with the anterior chest of your first hospital patient. How would you formulate a plan to optimally examine the four valves of the heart?

B Male thorax.

See answers beginning on p. 626.



Abdomen & Pelvis

10 Bones, Ligaments & Joints

Pelvic Girdle

Fig. 10.1 Pelvic girdle

Anterosuperior view. The pelvic girdle consists of the two hip bones and the sacrum (see p. 358).

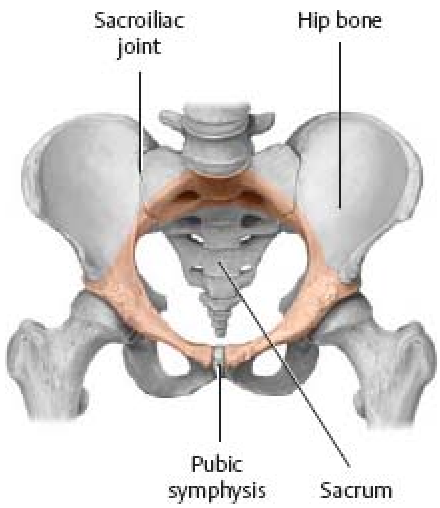


Fig. 10.2 Hip bone

Right hip bone (male).

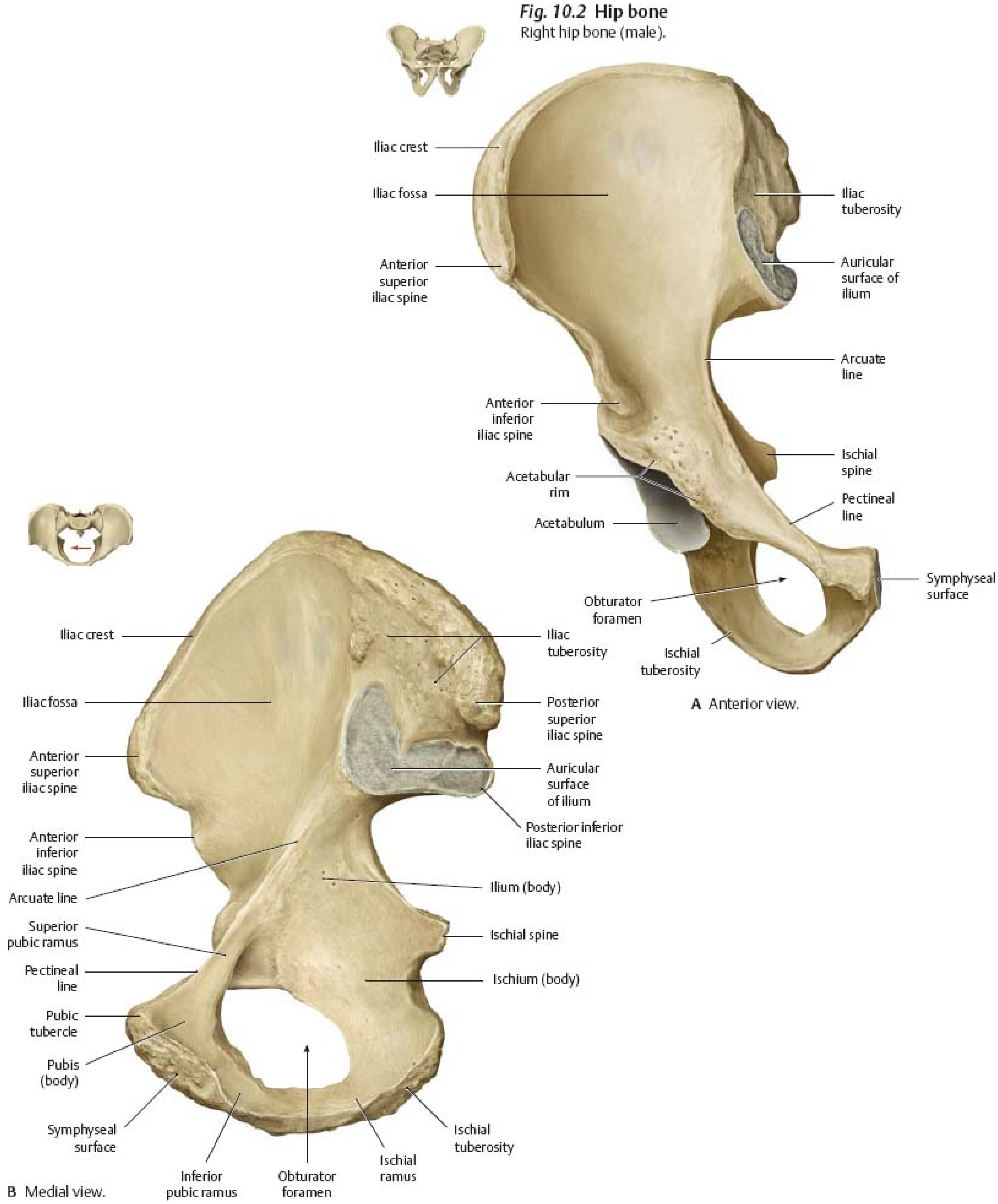
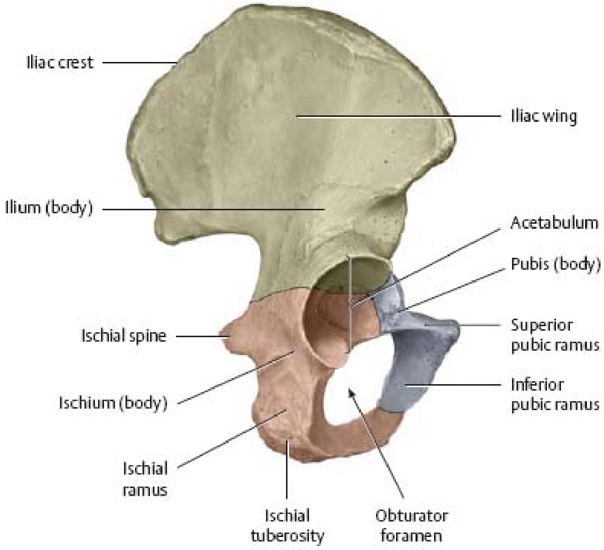


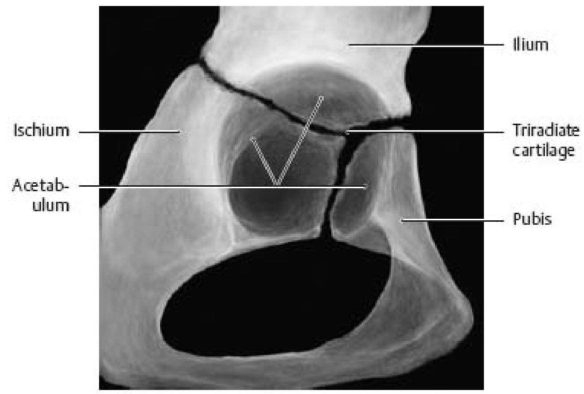
Fig. 10.2 **Hip bone**
Right hip bone (male).

Fig. 10.3 **Triradiate cartilage of the hip bone**

Right hip bone, lateral view. The hip bone consists of the ilium, ischium, and pubis.

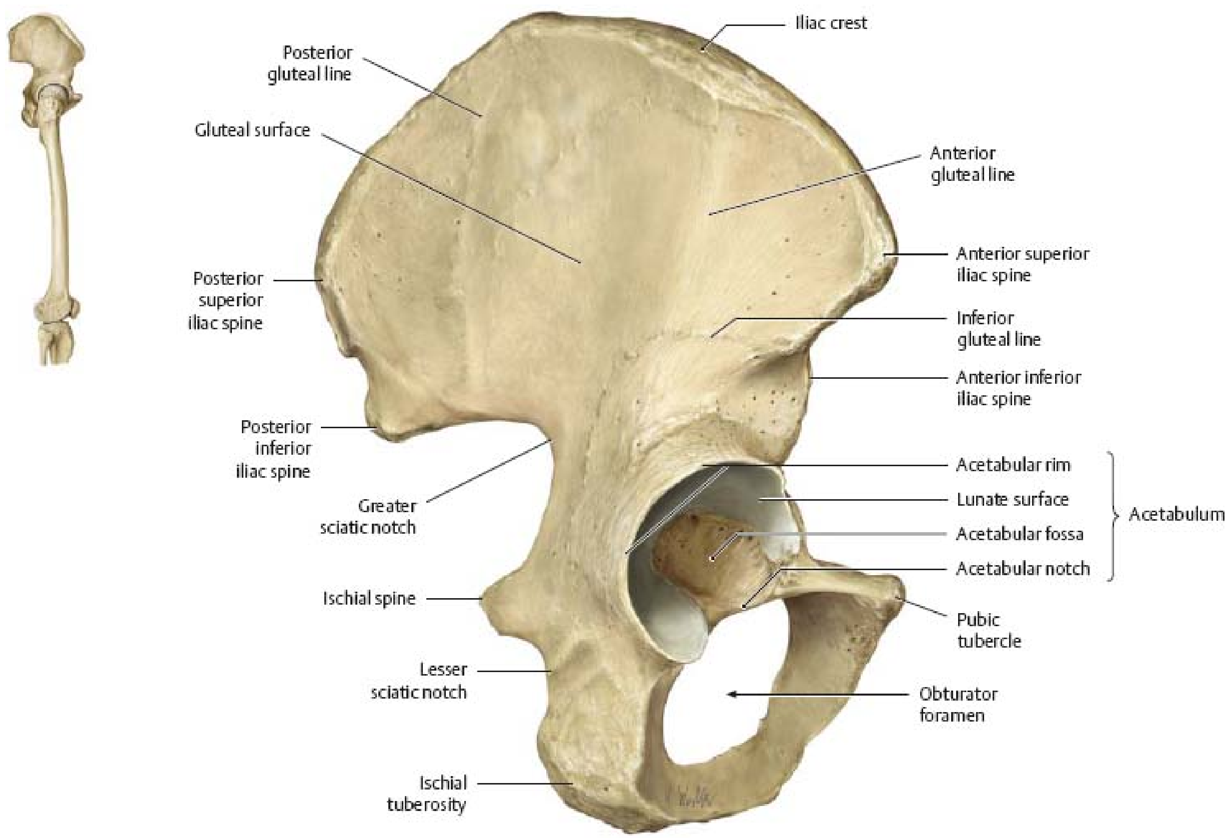


A Junction of the triradiate cartilage.



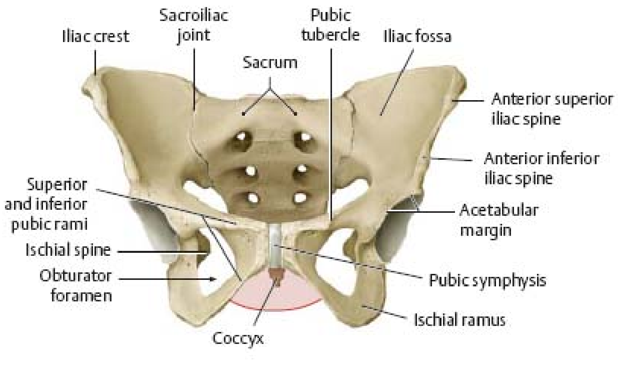
B Radiograph of a child's acetabulum. Right hip bone, lateral view.

Fig. 10.4 **Hip bone: Lateral view**
Right hip bone (male).

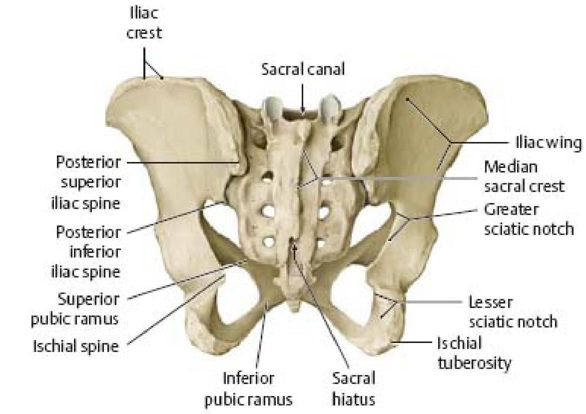


Male & Female Pelvis

Fig. 10.5 Female pelvis

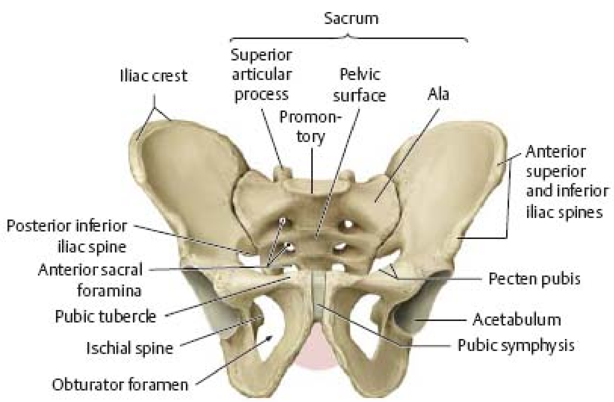


A Anterior view.

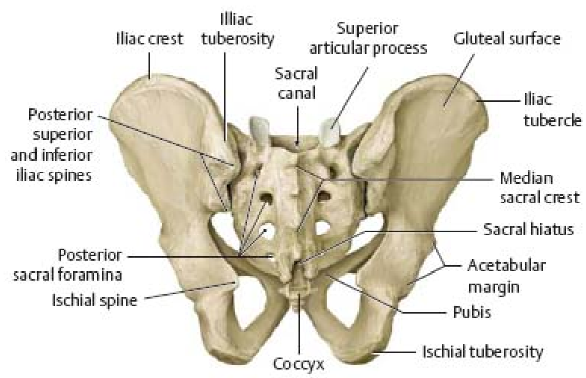


B Posterior view.

Fig. 10.6 Male pelvis

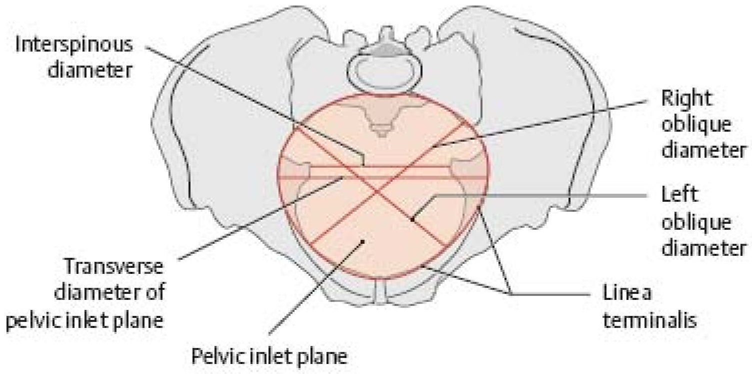


A Anterior view.

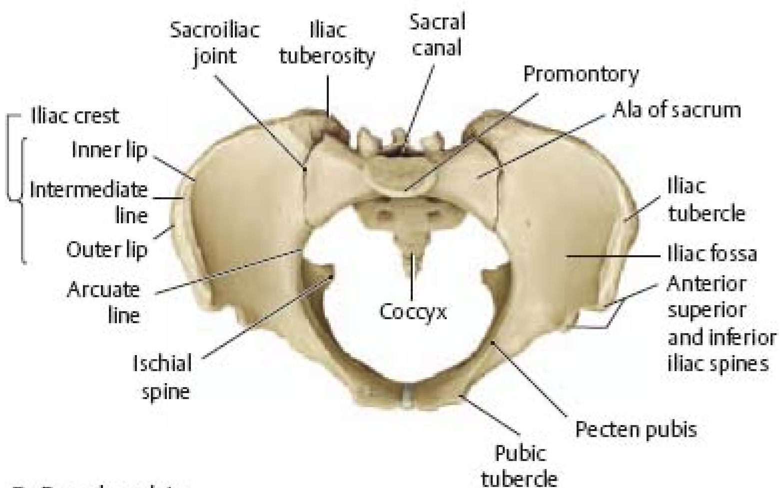


B Posterior view.

Fig. 10.7 Female pelvis: Superior view

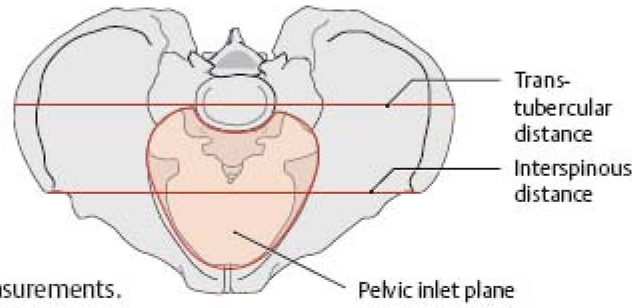


A Pelvic measurements.

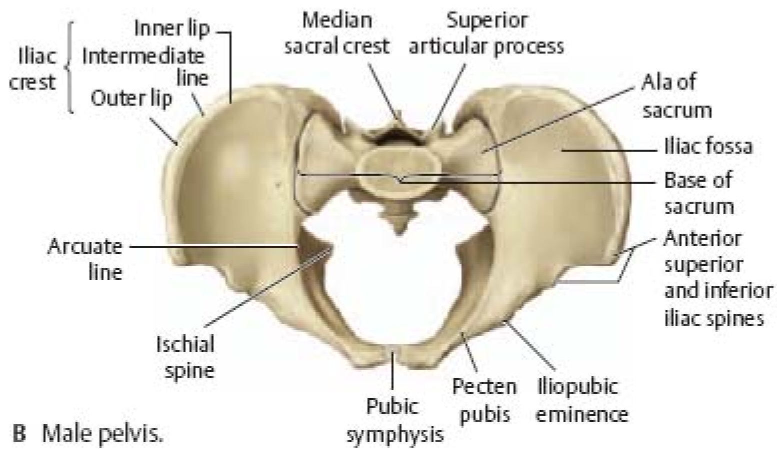


B Female pelvis.

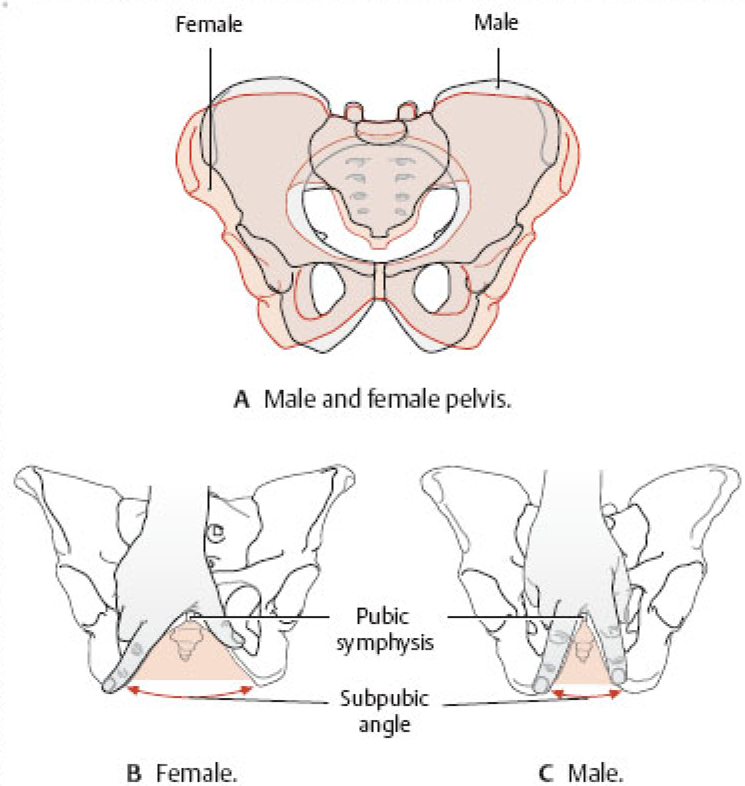
Fig. 10.8 **Male pelvis: Superior view**



A Pelvic measurements.



B Male pelvis.



A Male and female pelvis.

B Female.

C Male.

Table 10.1 Gender-specific features of the pelvis

Structure	♀	♂
False pelvis	Wide and shallow	Narrow and deep
Pelvic inlet	Transversely oval	Heart-shaped
Pelvic outlet	Roomy and round	Narrow and oblong
Ischial tuberosities	Everted	Inverted
Pelvic cavity	Roomy and shallow	Narrow and deep
Sacrum	Short, wide, and flat	Long, narrow, and convex
Subpubic angle	90–100 degrees	70 degrees

Clinical

Childbirth

A non-optimal relation between the maternal pelvis and the fetal head may lead to complications during childbirth, potentially necessitating a caesarean section. Maternal causes include earlier pelvic trauma and innate malformations. Fetal causes include hydrocephalus (disturbed circulation of cerebrospinal fluid, leading to brain dilation and cranial expansion).

Pelvic Ligaments

Fig. 10.9 **Ligaments of the pelvis**

Male pelvis.

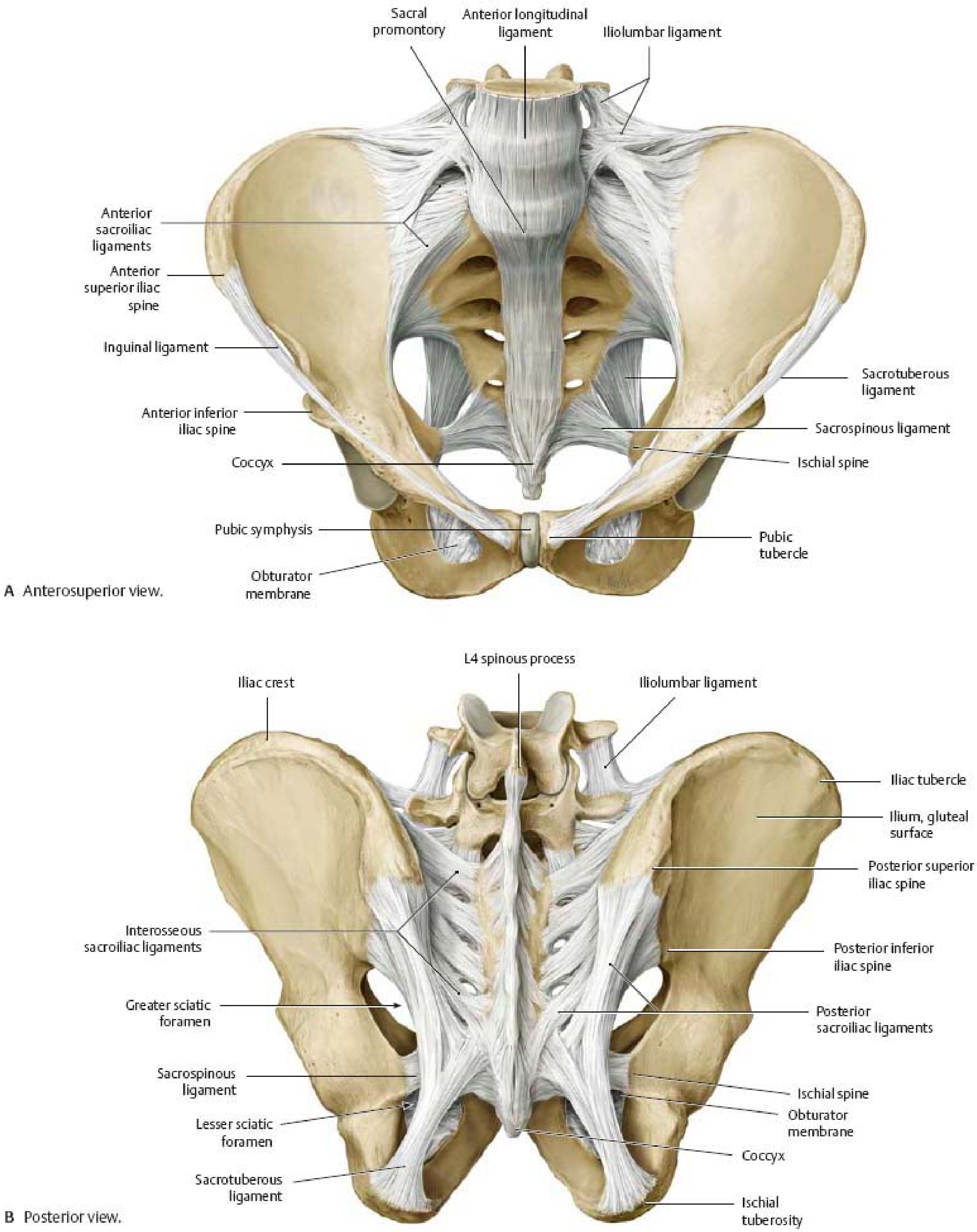


Fig. 10.10 **Ligaments of the sacroiliac joint**

Male pelvis.

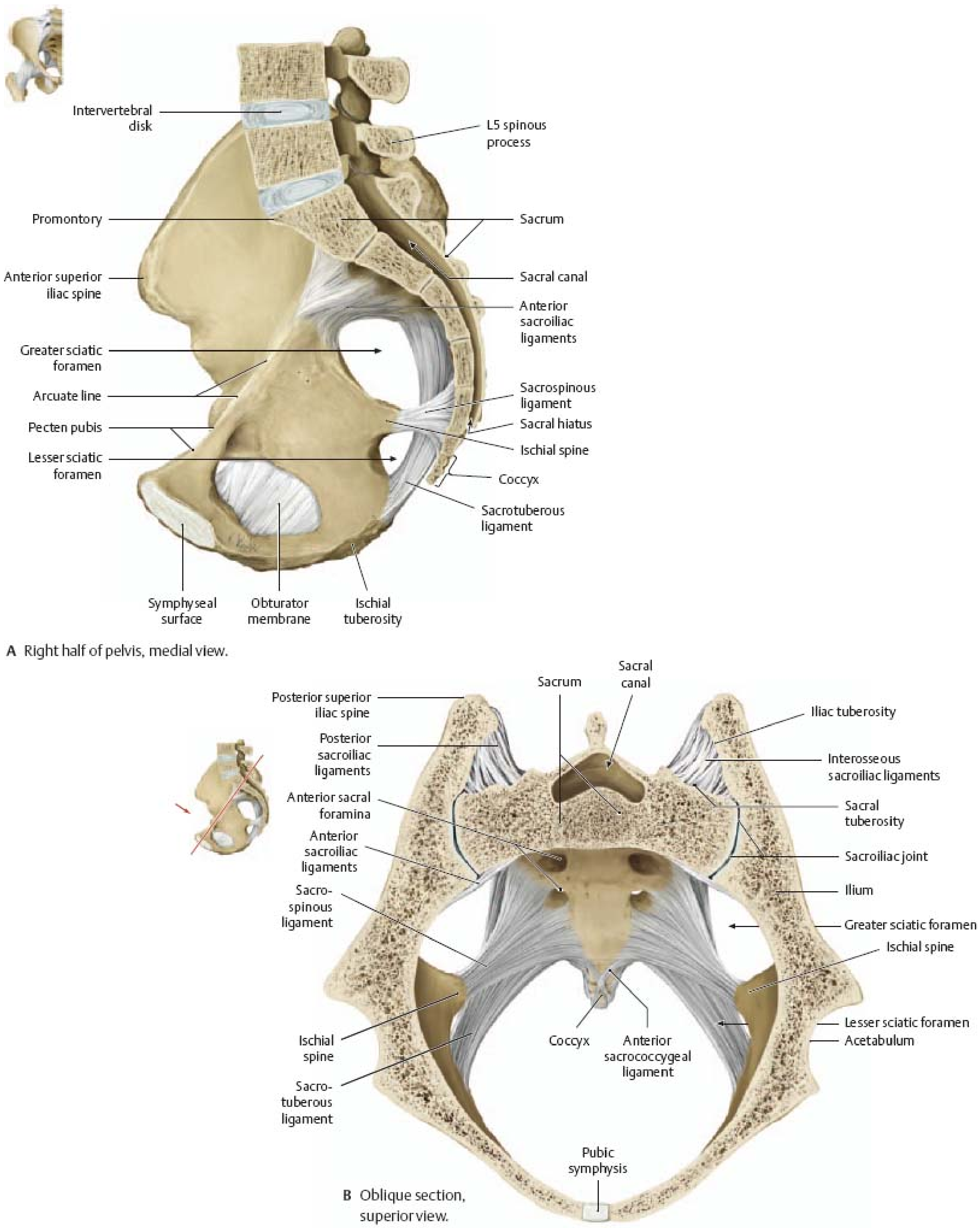
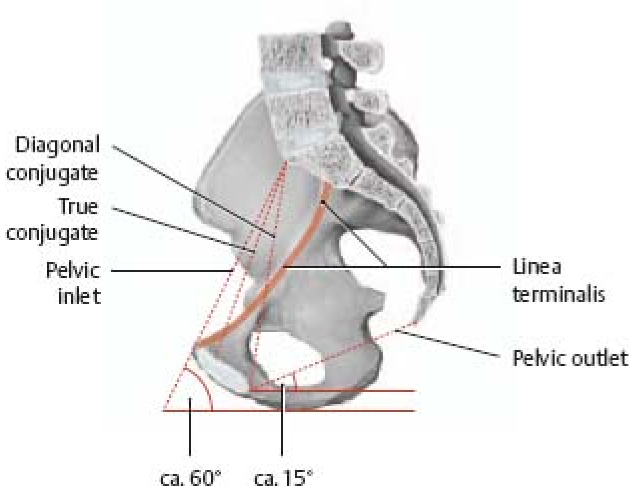


Fig. 10.11 **Pelvic measurements**

Right half of female pelvis, medial view. See Table 10.1.


Diagonal conjugate
True conjugate
Pelvic inlet
Linea terminalis
Pelvic outlet
ca. 60°
ca. 15°

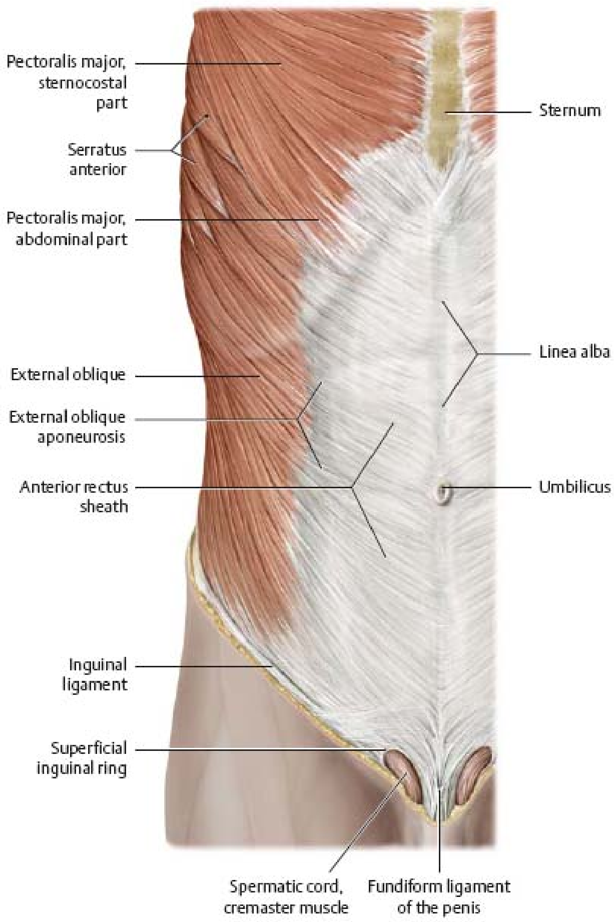
11 Abdominal Wall

Muscles of the Abdominal Wall

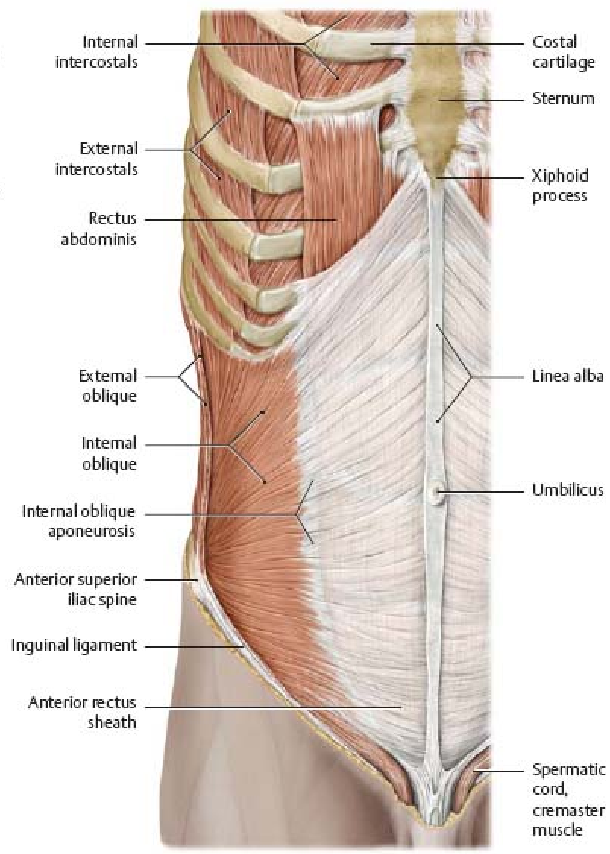
The oblique muscles of the abdominal wall consist of the external and internal obliques and the transversus abdominis. The posterior or deep abdominal wall muscles (notably the psoas major) are functionally hip muscles (see p. 138).

Fig. 11.1 Muscles of the abdominal wall

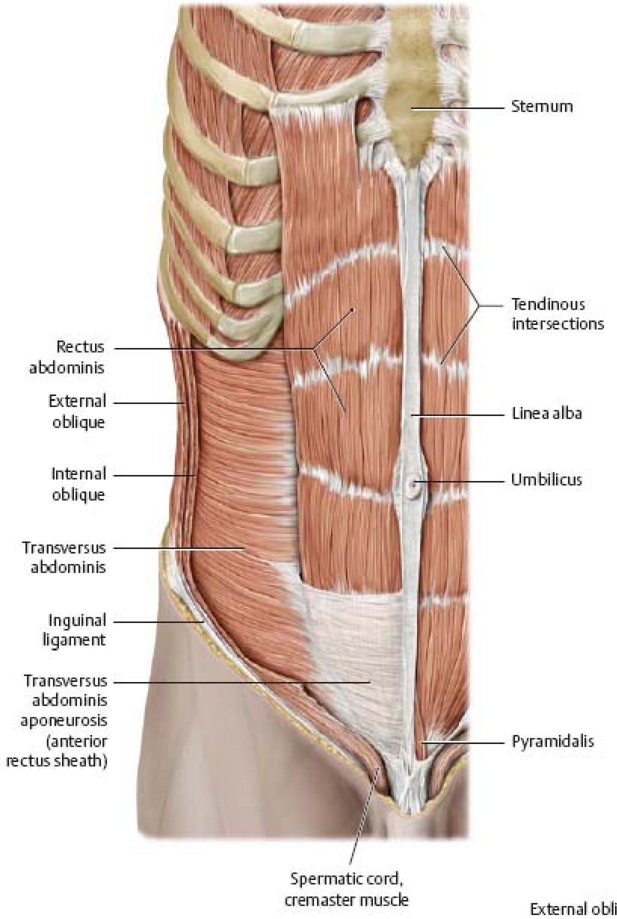
Right side, anterior view.



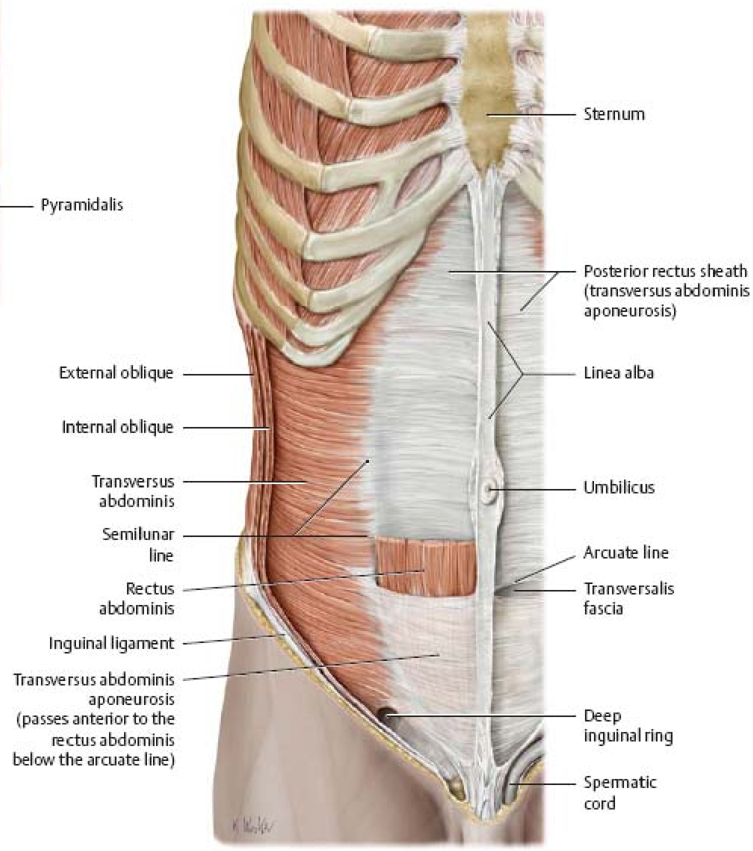
A Superficial abdominal wall muscles.



B *Removed:* External oblique, pectoralis major, and serratus anterior.



C *Removed:* Internal oblique.



D *Removed:* Rectus abdominis.

Inguinal Region & Canal

The inguinal region is the junction of the anterior abdominal wall and the anterior thigh. The inguinal canal is an important site for the passage of structures into and out of the abdominal cavity (e.g., components of the spermatic cord).

Fig. 11.2 Inguinal region

Right side, anterior view.

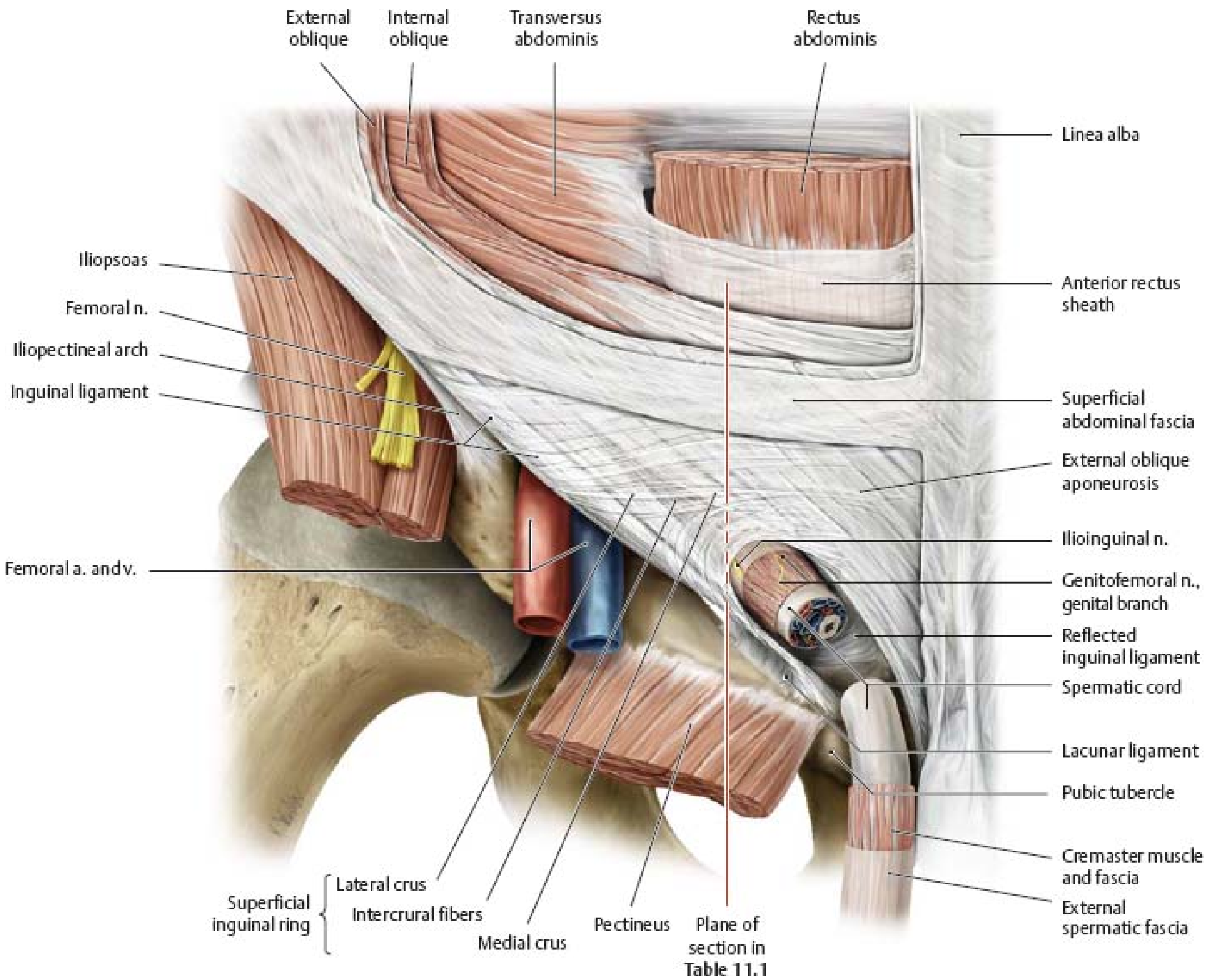


Table 11.1	Structures of the inguinal canal		
Structures			Formed by
Wall	Anterior wall	①	External oblique aponeurosis
	Roof	②	Internal oblique muscles
		③	Transversus abdominis
	Posterior wall	④	Transversalis fascia
		⑤	Parietal peritoneum
	Floor	⑥	Inguinal ligament (densely interwoven fibers of the lower external oblique aponeurosis and adjacent fascia lata of thigh)
Openings	Superficial inguinal ring		Opening in external oblique aponeurosis; bounded by medial and lateral crus, intercrural fibers, and reflected inguinal ligament
	Deep inguinal ring		Outpouching of the transversalis fascia lateral to the lateral umbilical fold (inferior epigastric vessels)
Sagittal section through plane in Fig. 11.2.			

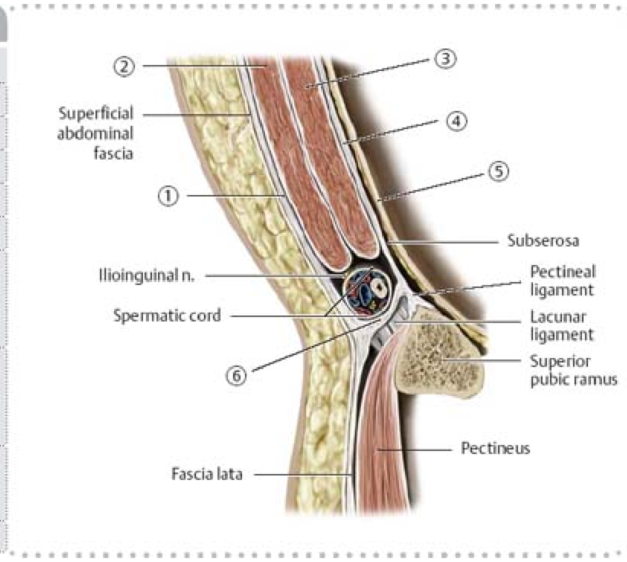


Fig. 11.3 **Dissection of the inguinal region**

Right side, anterior view.

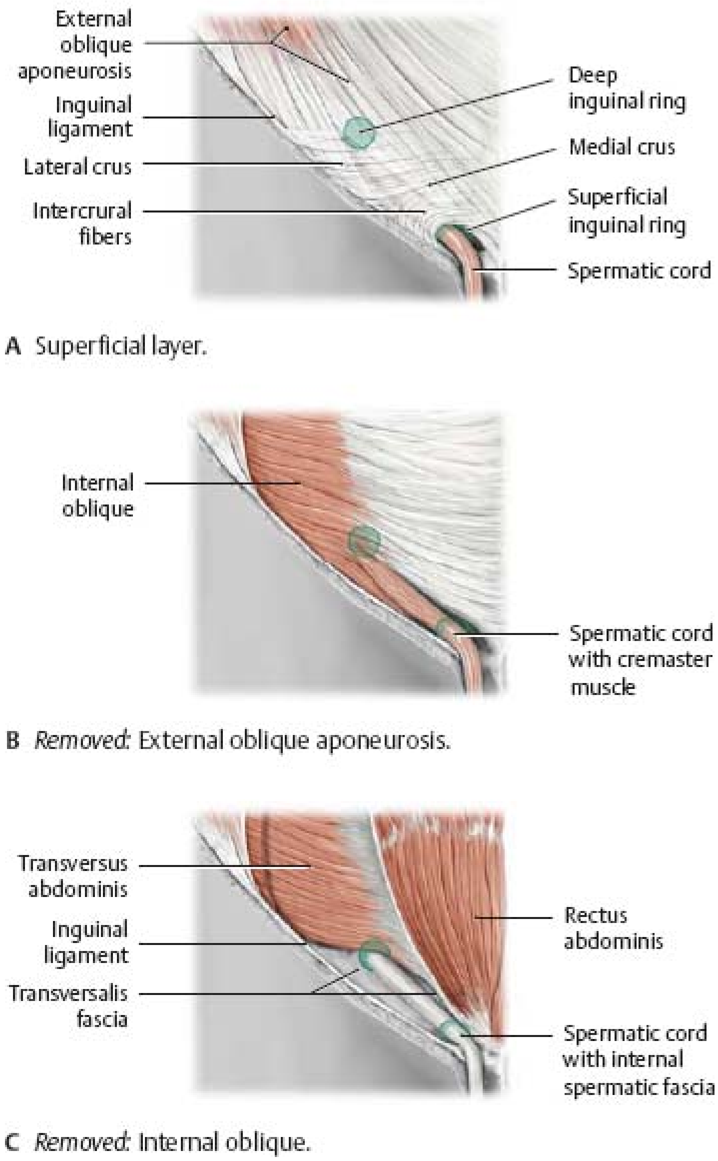
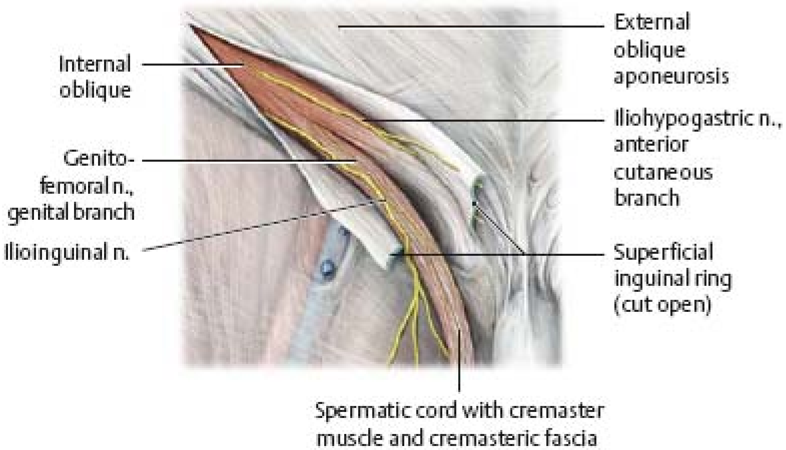
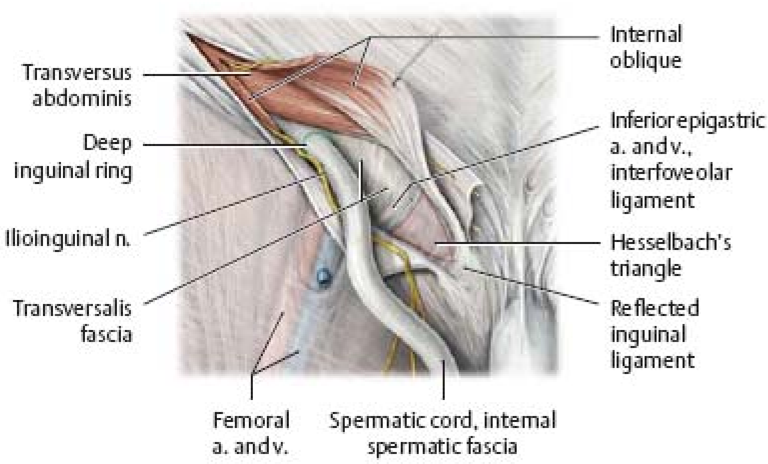


Fig. 11.4 **Opening of the inguinal canal**

Right side, anterior view.



A *Divided:* External oblique aponeurosis.



B *Divided:* Internal oblique and cremaster.

Abdominal Wall & Inguinal Hernias

The rectus sheath is created by fusion of the aponeuroses of the transversus abdominis and abdominal oblique muscles. The inferior edge of the posterior rectus sheath is called the arcuate line.

Fig. 11.5 Abdominal wall and rectus sheath

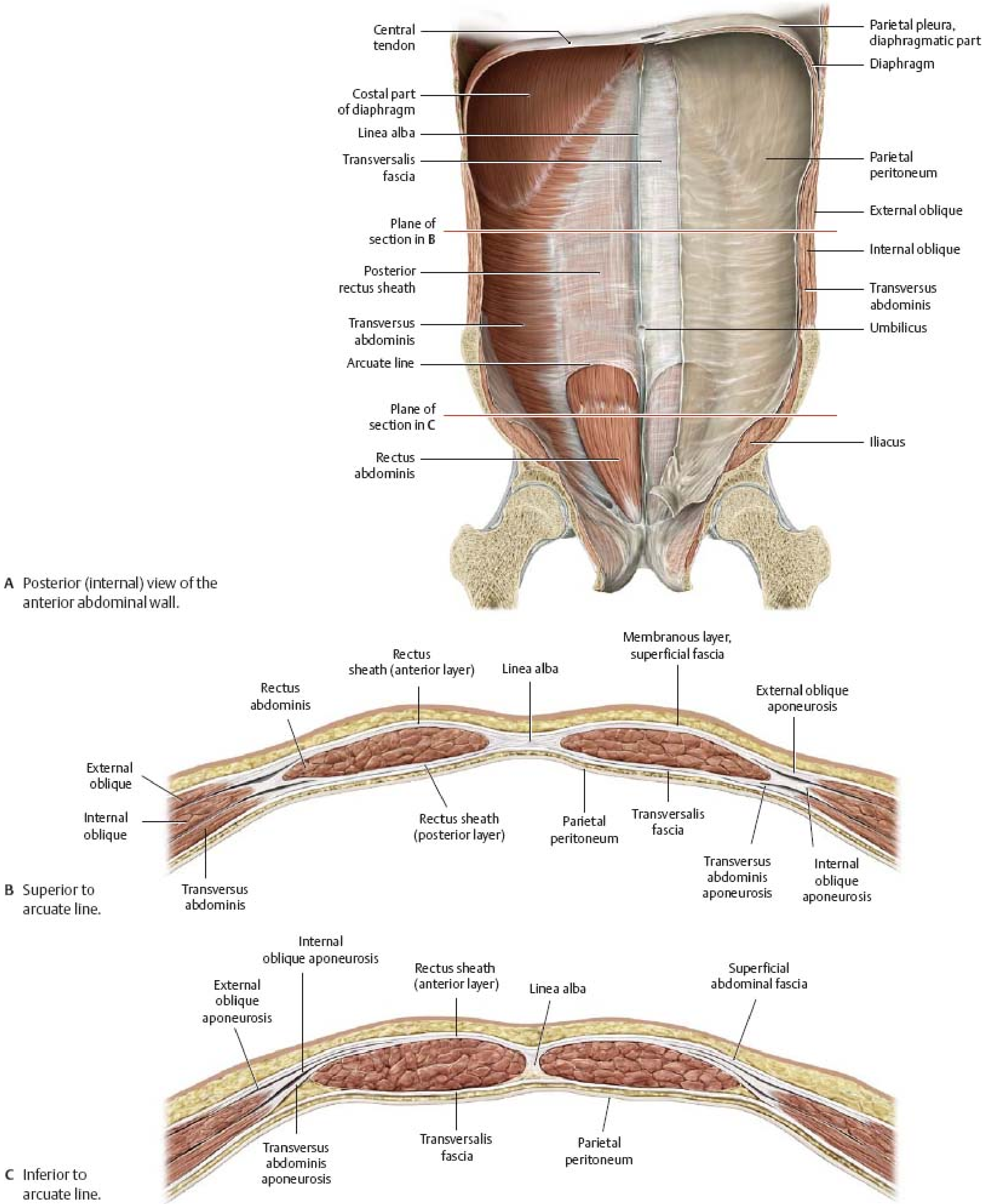
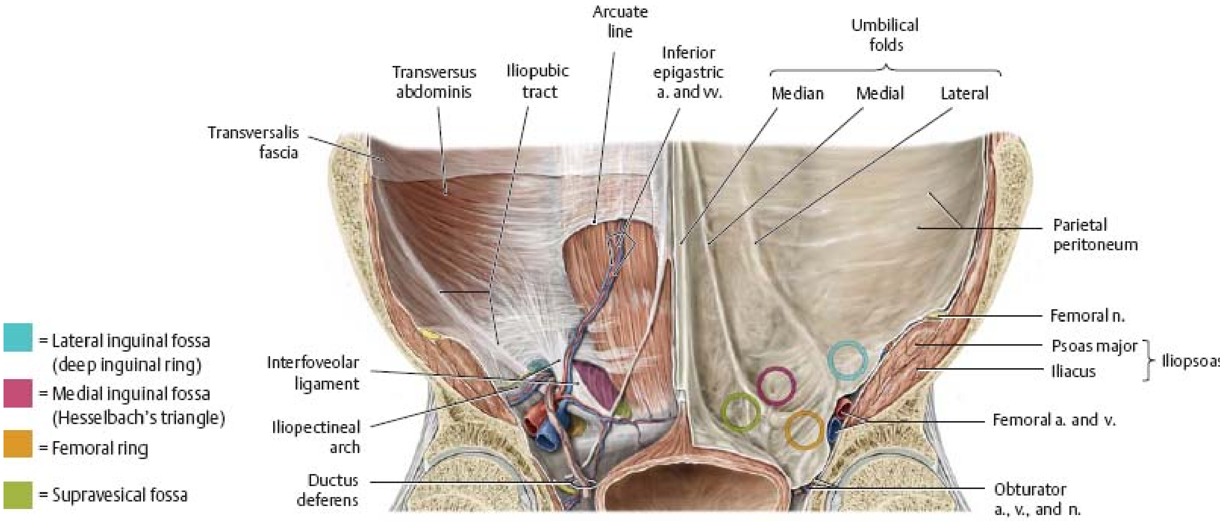


Fig. 11.6 **Abdominal wall: Internal surface anatomy**

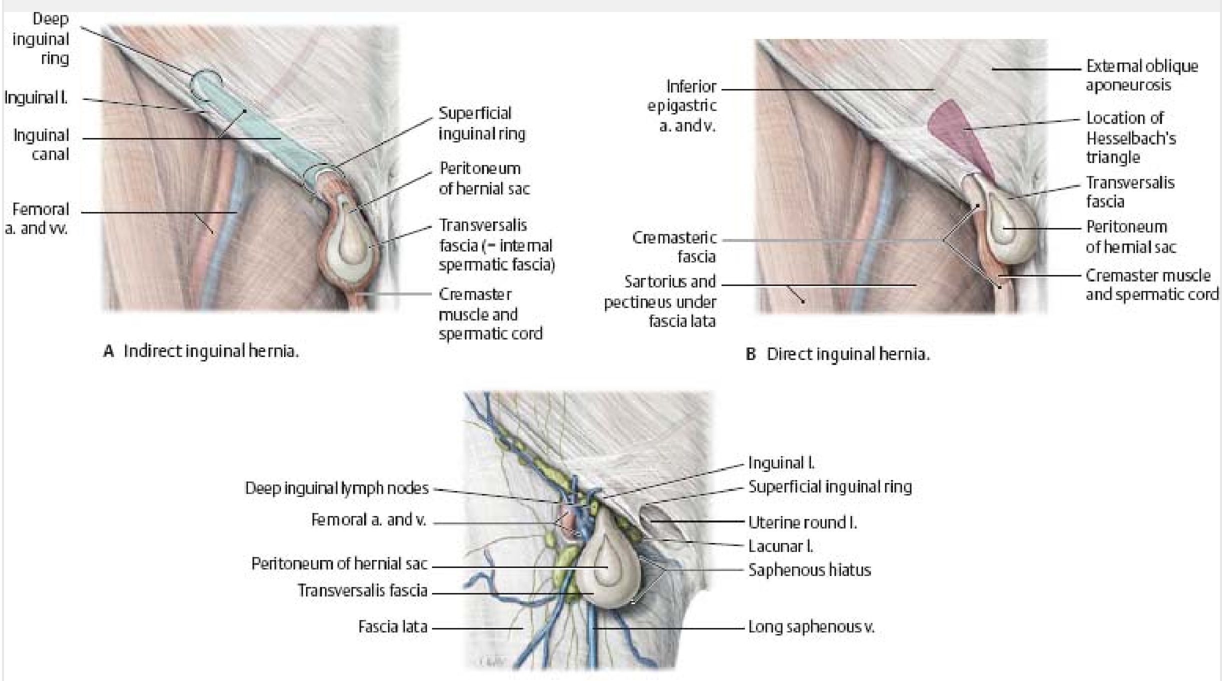
Coronal section, posterior view. The three fossae of the anterior abdominal wall (*circled*) are sites of potential herniation.



Clinical

Inguinal and femoral hernias

Indirect inguinal hernias occur in younger males and may be congenital or acquired; direct inguinal hernias are always acquired. Femoral hernias are acquired and more common in females.



A Indirect inguinal hernia.

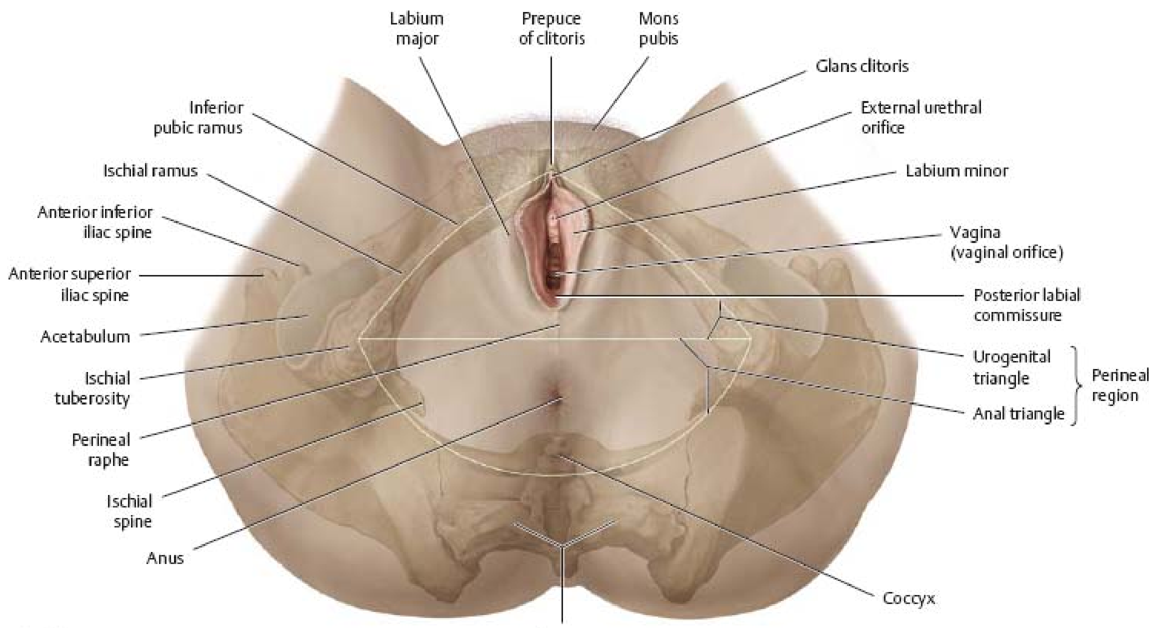
B Direct inguinal hernia.

C Femoral hernia.

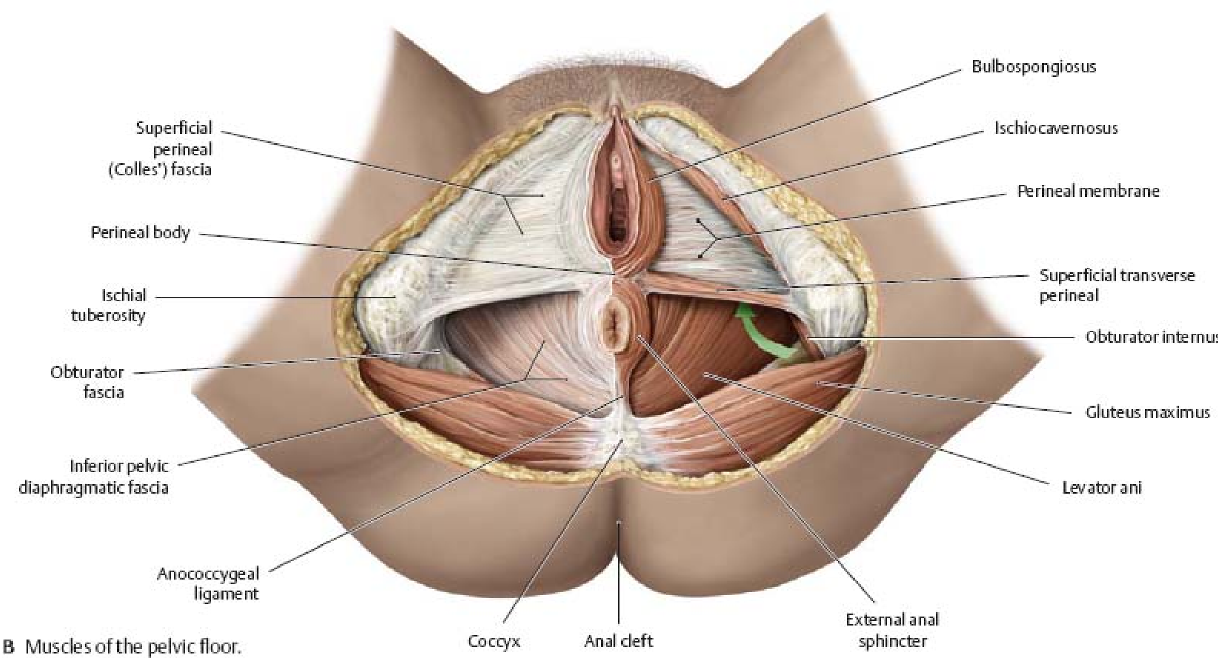
Perineal Region

Fig. 11.7 Perineum and pelvic floor: Female

Lithotomy position, caudal (inferior) view. See p. 192 for the external genitalia.



A Perineal region.

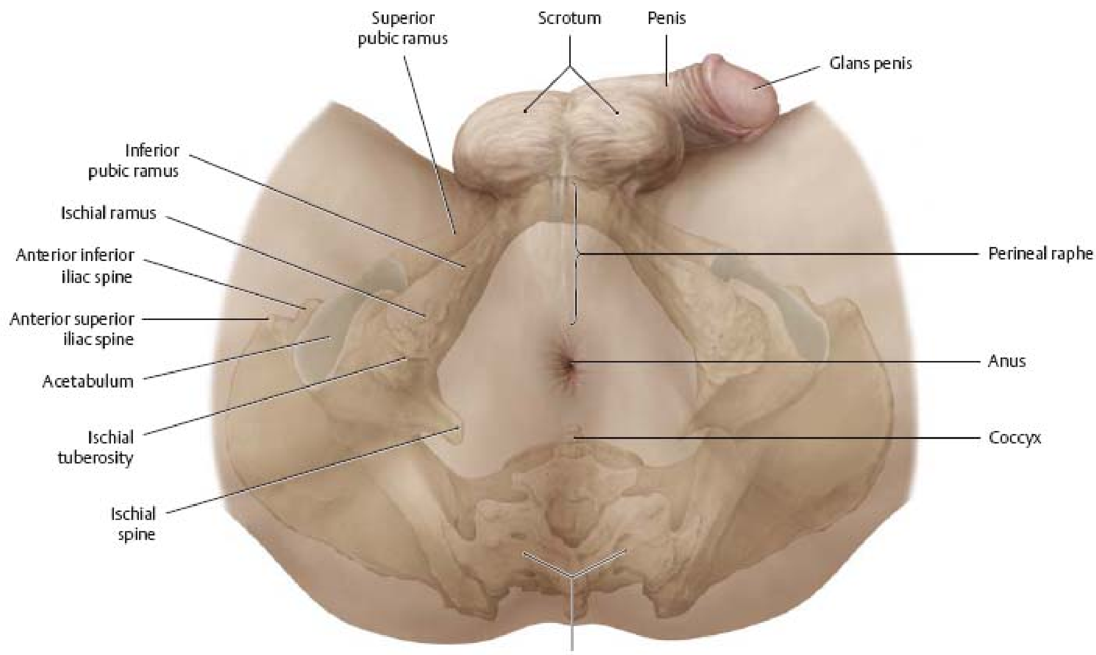


B Muscles of the pelvic floor.

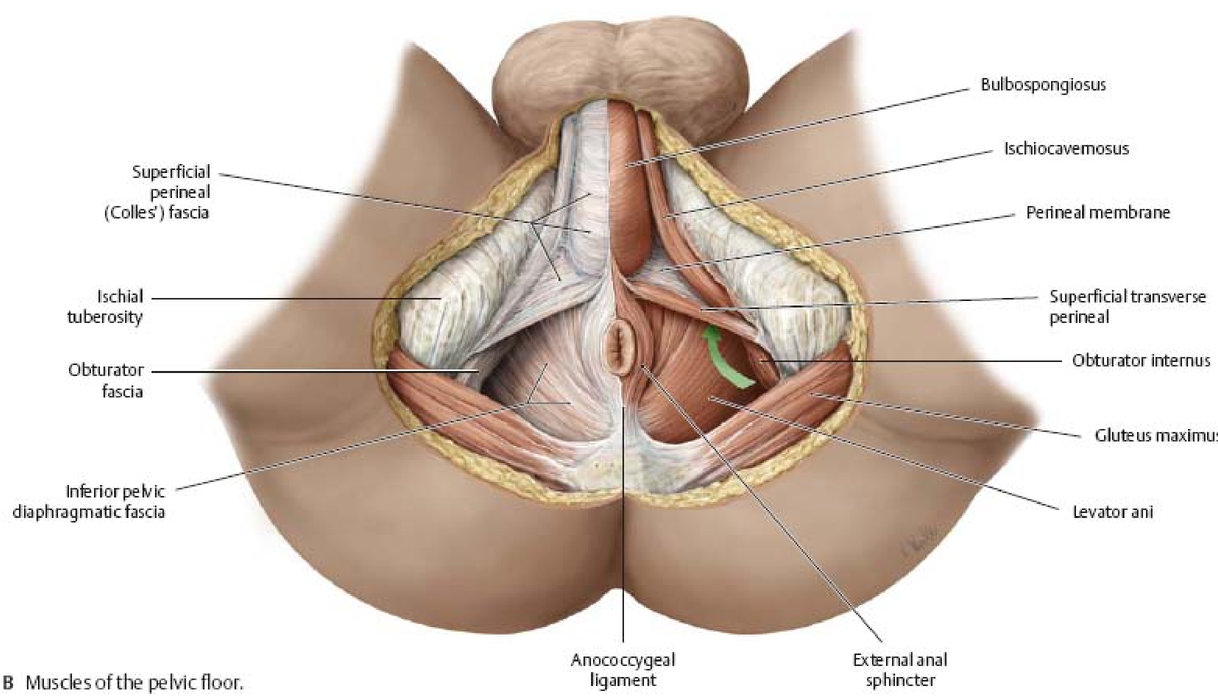
The bilateral boundaries of the perineum in both sexes are the pubic symphysis, ischiopubic ramus, ischial tuberosity, sacrotuberous ligament, and the coccyx. The green arrows indicate the anterior recess of the ischioanal fossa, superior to the urogenital muscles.

Fig. 11.8 Perineum and pelvic floor: Male

Lithotomy position, caudal (inferior) view. See p. 196 for the genitalia.



A Perineal region.



B Muscles of the pelvic floor.

Adominal Wall Muscle Facts

Fig. 11.9 Anterior muscles

Anterior view.

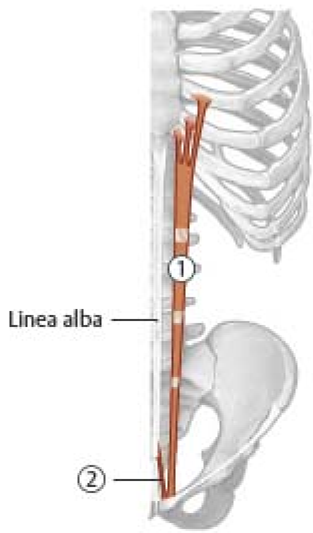
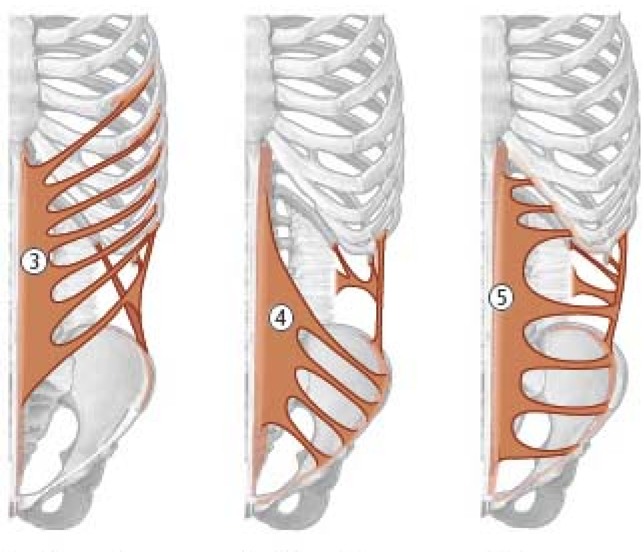


Fig. 11.10 Anterolateral muscles

Anterior view.



A External oblique.

B Internal oblique.

C Transversus abdominis.

Fig. 11.11 Posterior muscles

Anterior view. The psoas major and iliacus are together known as the iliopsoas.

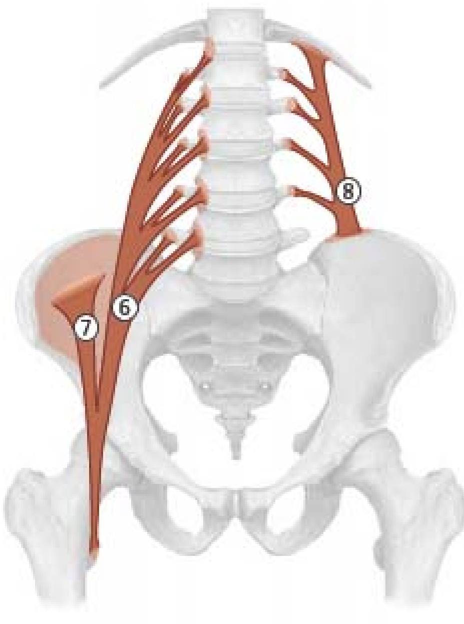
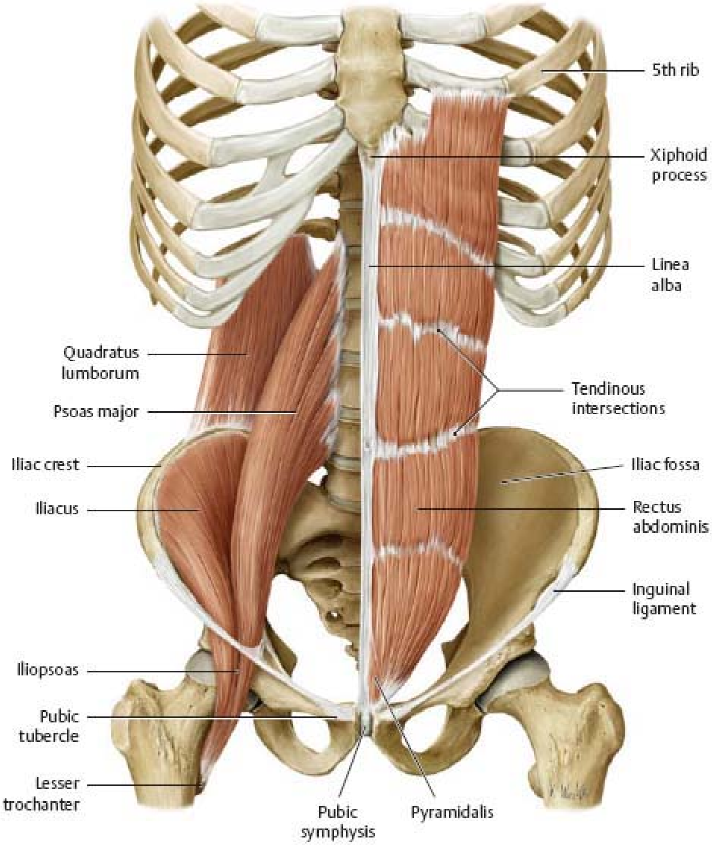
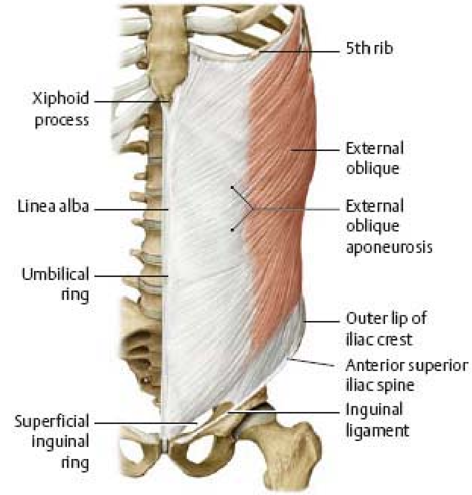


Table 11.2 Abdominal wall muscles				
Muscle	**Origin**	**Insertion**	**Innervation**	**Action**
Anterior abdominal wall muscles				
① Rectus abdominis	Pubis (between pubic tubercle and symphysis)	Cartilages of 5th to 7th ribs, xiphoid process of sternum	Intercostal nn. (T5–T12)	Flexes trunk, compresses abdomen, stabilizes pelvis
② Pyramidalis	Pubis (anterior to rectus abdominis)	Linea alba (runs within the rectus sheath)	Subcostal n. (12th intercostal n.)	Tenses linea alba
Anterolateral abdominal wall muscles				
③ External oblique	5th to 12th ribs (outer surface)	Linea alba, pubic tubercle, anterior iliac crest	Intercostal nn. (T7–T12)	*Unilateral:* Bends trunk to same side, rotates trunk to opposite side *Bilateral:* Flexes trunk, compresses abdomen, stabilizes pelvis
④ Internal oblique	Thoracolumbar fascia (deep layer), iliac crest (intermediate line), anterior superior iliac spine, iliopsoas fascia	10th to 12th ribs (lower borders), linea alba (anterior and posterior layers)	Intercostal nn. (T7–T12), iliohypogastric n., ilioinguinal n.	
⑤ Transversus abdominis	7th to 12th costal cartilages (inner surfaces), thoracolumbar fascia (deep layer), iliac crest, anterior superior iliac spine (inner lip), iliopsoas fascia	Linea alba, pubic crest		*Unilateral:* Rotates trunk to same side *Bilateral:* Compresses abdomen
Posterior abdominal wall muscles				
⑥ Psoas major – Superficial layer	T12–L4 vertebral bodies and associated intervertebral disks (lateral surfaces)	Femur (lesser trochanter), joint insertion as iliopsoas muscle	Direct branches from lumbar plexus (L2–L4)	Hip joint: Flexion and external rotation Lumbar spine (with femur fixed): *Unilateral:* Contraction bends trunk laterally *Bilateral:* Contraction raises trunk from supine position
⑥ Psoas major – Deep layer	L1–L5 (costal processes)			
⑦ Iliacus	Iliac fossa		Femoral n. (L2–L4)	
⑧ Quadratus lumborum	Iliac crest and iliolumbar ligament (not shown)	12th rib, L1–L4 vertebrae (transverse processes)	T12, L1–L4 spinal nn.	*Unilateral:* Bends trunk to same side *Bilateral:* Bearing down and expiration, stabilizes 12th rib

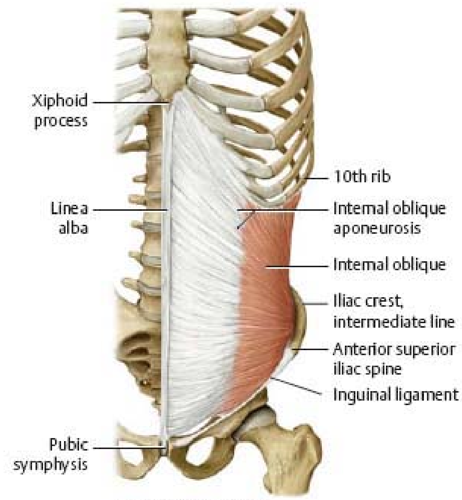
Fig. 11.12 **Anterior and posterior abdominal wall muscles**
Anterior view.



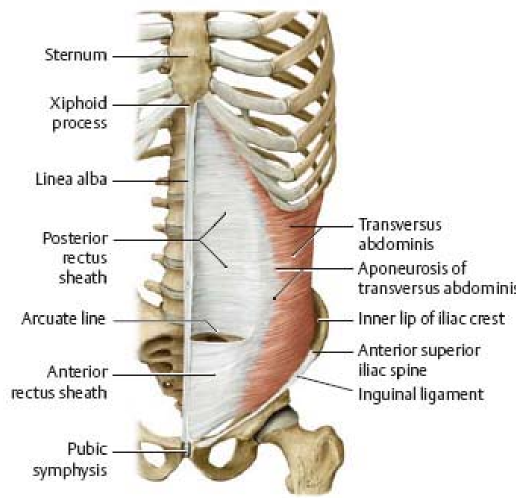
A Anterior and posterior muscles.



B External oblique.



C Internal oblique.

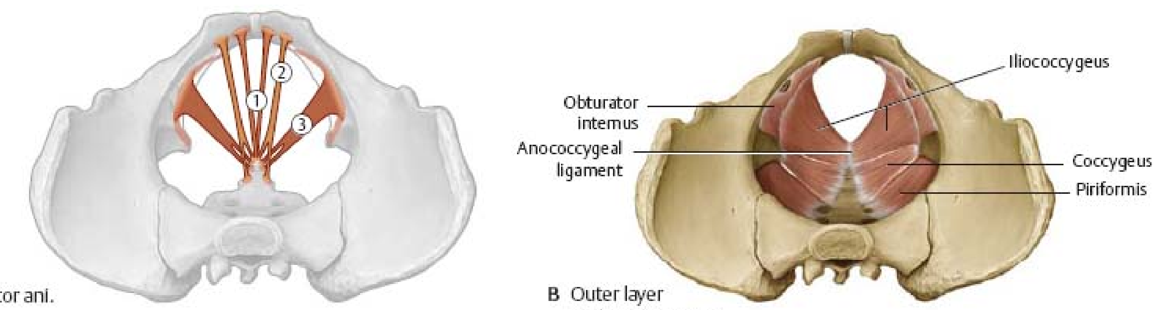


D Transversus abdominis.

Pelvic Floor Muscle Facts

Fig. 11.13 Muscles of the pelvic floor

Superior view.



A Levator ani.

B Outer layer of the pelvic floor.

Table 11.3 Muscles of the pelvic floor

Muscle		Origin	Insertion	Innervation	Action
Muscles of the pelvic diaphragm					
Levator ani	① Puborectalis	Superior pubic ramus (both sides of pubic symphysis)	Anococcygeal ligament	Direct branches of sacral plexus (S4), inferior anal n.	Pelvic diaphragm: Supports pelvic viscera
	② Pubococcygeus	Pubis (lateral to origin of puborectalis)	Anococcygeal ligament, coccyx		
	③ Iliococcygeus	Internal obturator fascia of levator ani (tendinous arch)			
Coccygeus		Sacrum (inferior end)	Ischial spine	Direct branches from sacral plexus (S4–S5)	Supports pelvic viscera, flexes coccyx
Muscles of the pelvic wall (parietal muscles)					
Piriformis*		Sacrum (pelvic surface)	Femur (apex of greater trochanter)	Direct branches from sacral plexus (S1–S2)	Hip joint: External rotation, stabilization, and abduction of flexed hip
Obturator internus*		Obturator membrane and bony boundaries (inner surface)	Femur (greater trochanter, medial surface)	Direct branches from sacral plexus (L5–S1)	Hip joint: External rotation and abduction of flexed hip
Sphincter and erector muscles					
④ External anal sphincter		Encircles anus (runs posteriorly from perineal body to anococcygeal ligament)		Pudendal n. (S2–S4)	Closes anus
⑤ External urethral sphincter		Encircles urethra (division of deep transverse perineal muscle)			Closes urethra
⑥ Bulbospongiosus		Runs anteriorly from perineal body to clitoris (females) or penile raphe (males)			Females: Compresses greater vestibular gland Males: Assists in erection
⑦ Ischiocavernosus		Ischial ramus	Crus of clitoris or penis		Maintains erection by squeezing blood into corpus cavernosum of clitoris or penis

*The piriformis and obturator internus are considered muscles of the hip (see p. 374).
The female and male external genitalia are shown on pp. 194, 203.

Fig. 11.14 Sphincter and erector muscles of the pelvic floor

Inferior view. See pp. 194, 203.

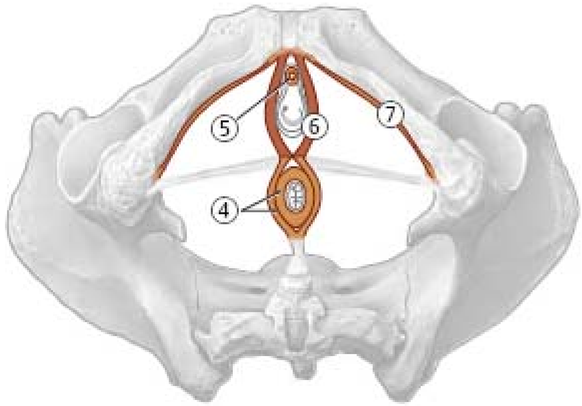
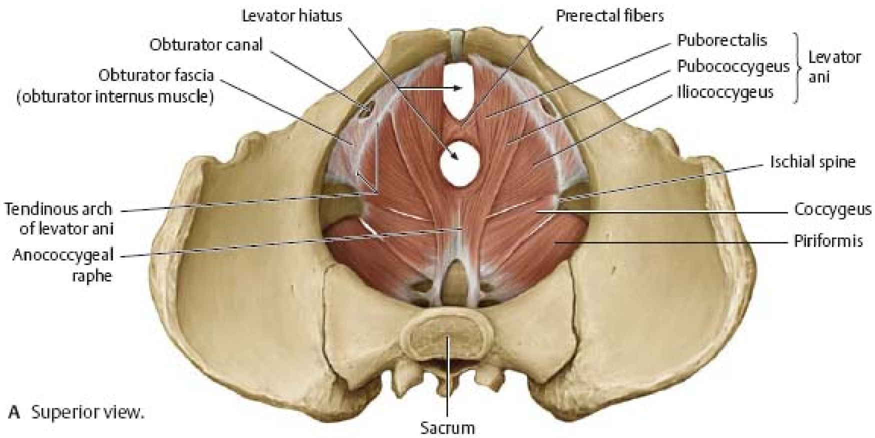
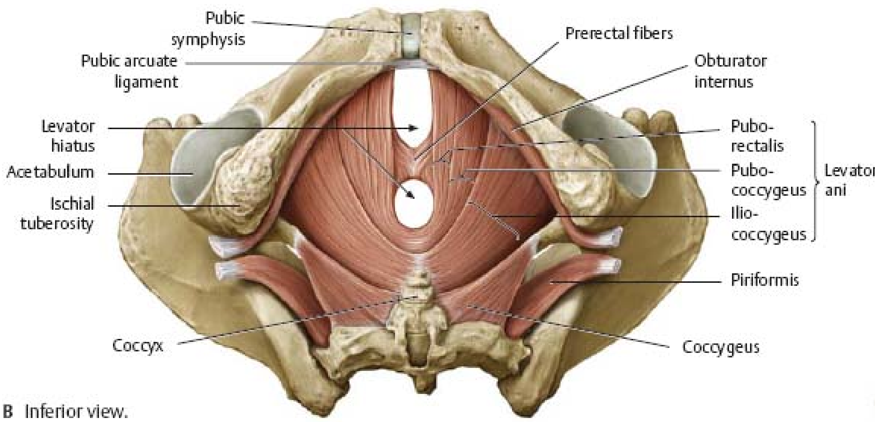


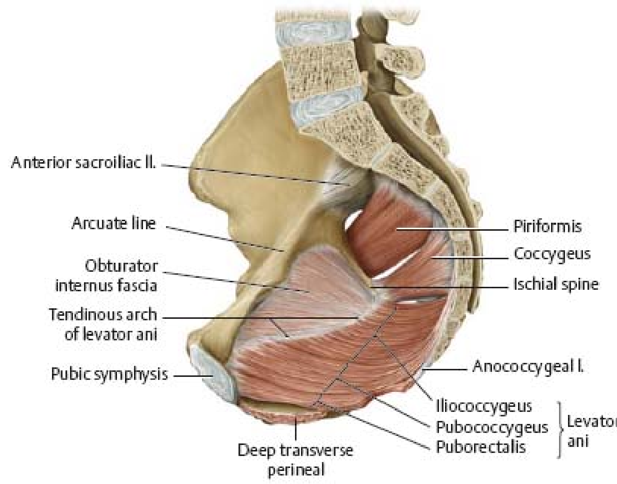
Fig. 11.15 **Pelvic floor**
Female pelvis.



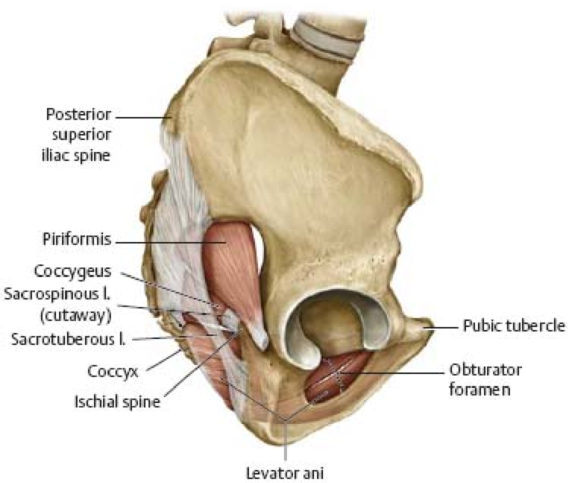
A Superior view.



B Inferior view.



C Medial view of right hemipelvis.



D Right lateral view.

12 Spaces

Divisions of the Abdominopelvic Cavity

Fig. 12.1 Organ layers and quadrants

Anterior view. The organs of the abdomen and pelvis can be classified by layer, by quadrant (using the umbilicus at L4), by level (upper and lower abdomen, and pelvis), or with respect to the presence of a mesentery (Table 12.1).

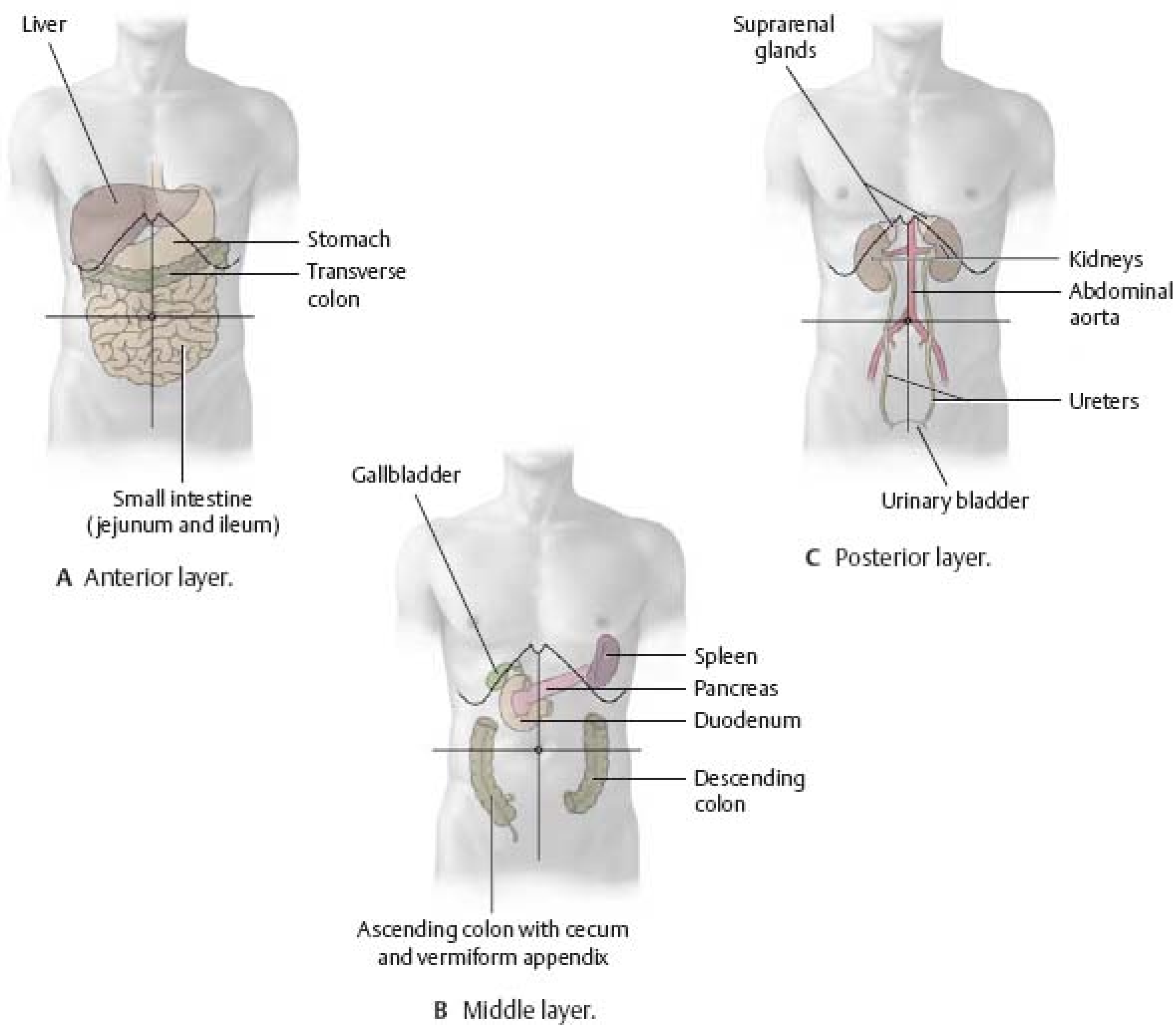


Fig. 12.2 Peritoneum and mesentery

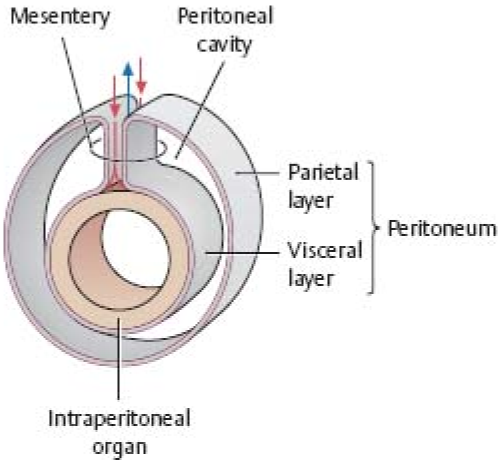
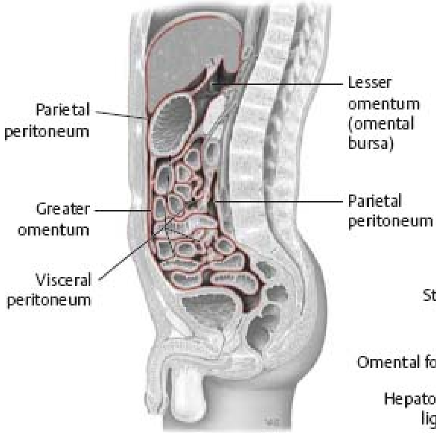


Table 12.1 Organs of the abdomen and pelvis

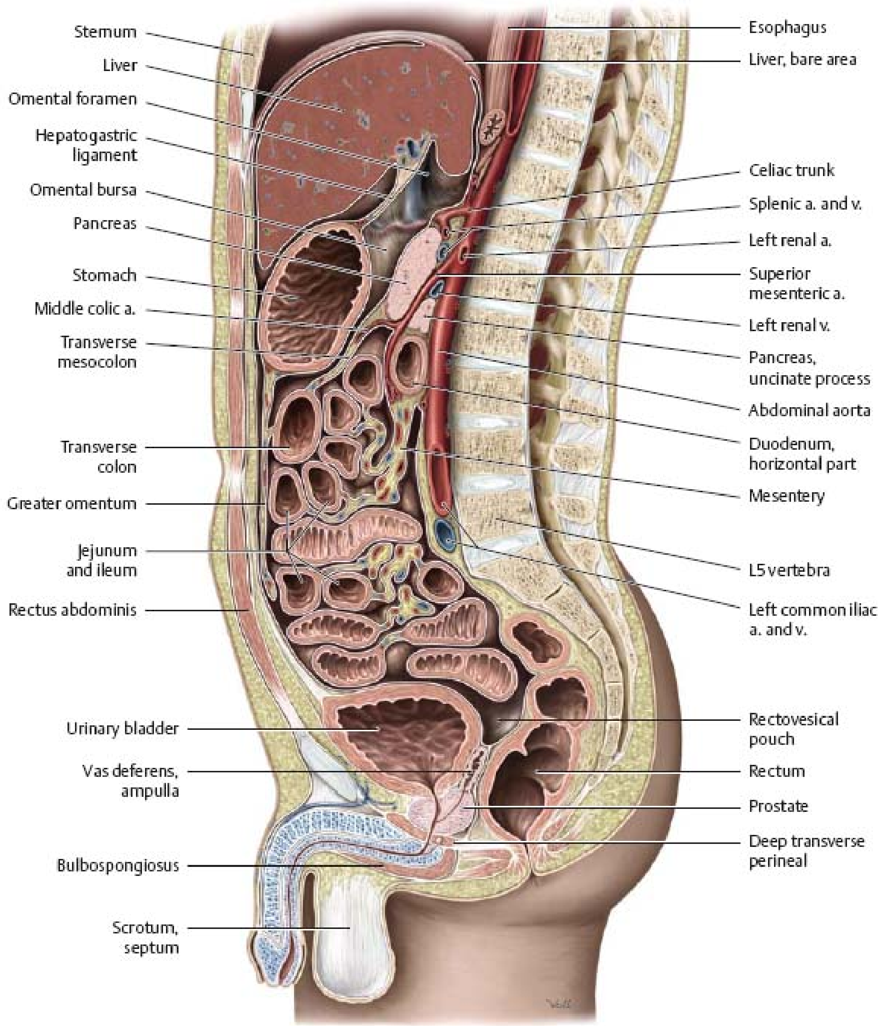
Location		Organs
Intraperitoneal organs: These organs have a mesentery and are completely covered by the peritoneum.		
Abdominal peritoneal cavity		• Stomach • Small intestine (jejunum, ileum, some of the superior part of the duodenum) • Spleen • Liver • Gallbladder • Cecum with vermiform appendix (portions of variable size may be retroperitoneal) • Large intestine (transverse and sigmoid colons)
Pelvic peritoneal cavity		• Uterus (fundus and body) • Ovaries • Uterine tubes
Extraperitoneal organs: These organs either have no mesentery or lost it during development.		
Retroperitoneal	Primarily	• Kidneys • Suprarenal glands • Uterine cervix
	Secondarily	• Duodenum (descending, horizontal, and ascending) • Pancreas • Ascending and descending colon • Rectum (upper 2/3)
Infraperitoneal/subperitoneal		• Urinary bladder • Distal ureters • Prostate • Seminal vesicle • Uterine cervix • Vagina • Rectum (lower 1/3)

Fig. 12.3 Peritoneal relationships

Midsagittal section through male pelvis, viewed from the left side.



A Peritoneal cavity. The peritoneum is shown in red.



B Organs of the abdomen and pelvis.

Clinical

Acute abdominal pain

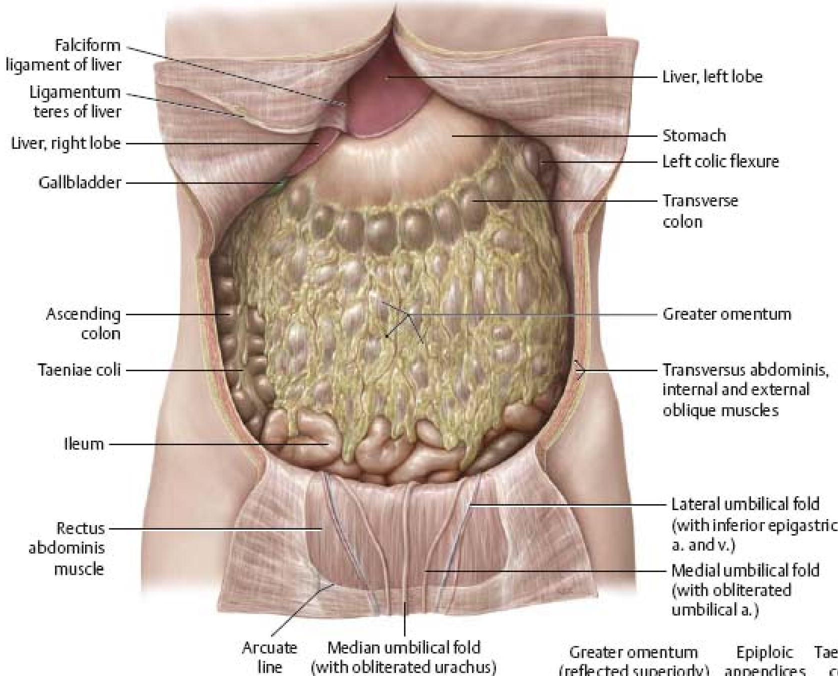
Acute abdominal pain ("acute abdomen") may be so severe that the abdominal wall becomes extremely sensitive to touch ("guarding") and the intestines stop functioning. Causes include organ inflammation such as appendicitis, perforation due to a gastric ulcer (see p. 159), or organ blockage by a stone, tumor, etc. In women, gynecological processes or ectopic pregnancies may produce severe abdominal pain.

Peritoneal Cavity & Greater Sac

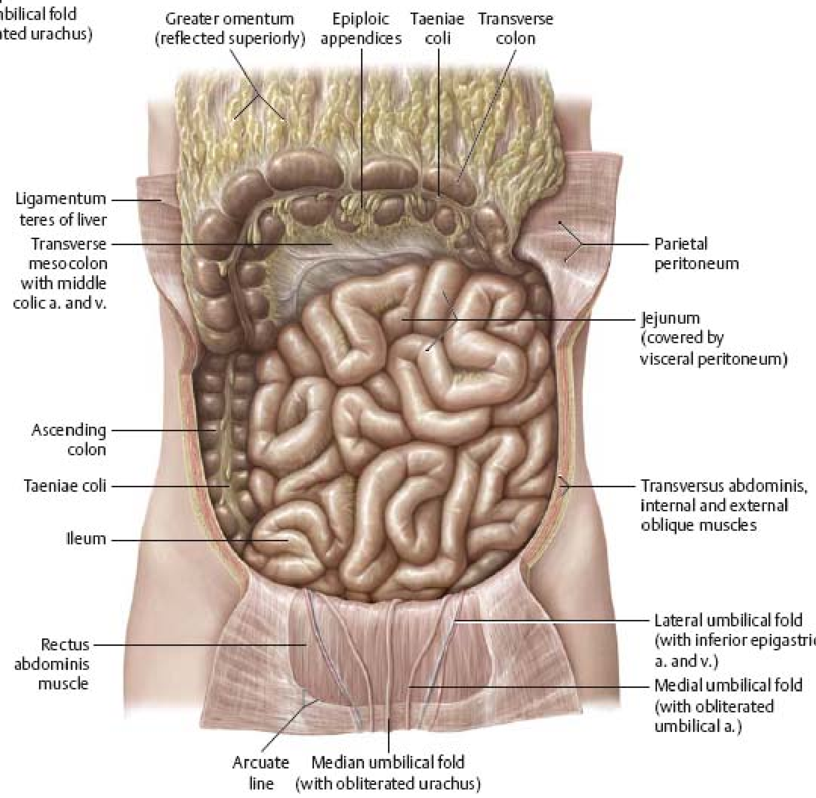
The largest part of the peritoneal cavity is the greater sac. The greater omentum is an apron-like fold of peri toneum suspended from the greater curvature of the stomach and covering the anterior surface of the transverse colon. The transverse colon divides the peritoneal cavity into a supracolic compartment (liver, gallbladder, and stomach) and an infracolic compartment (intestines).

Fig. 12.4 **Dissection of the peritoneal cavity**

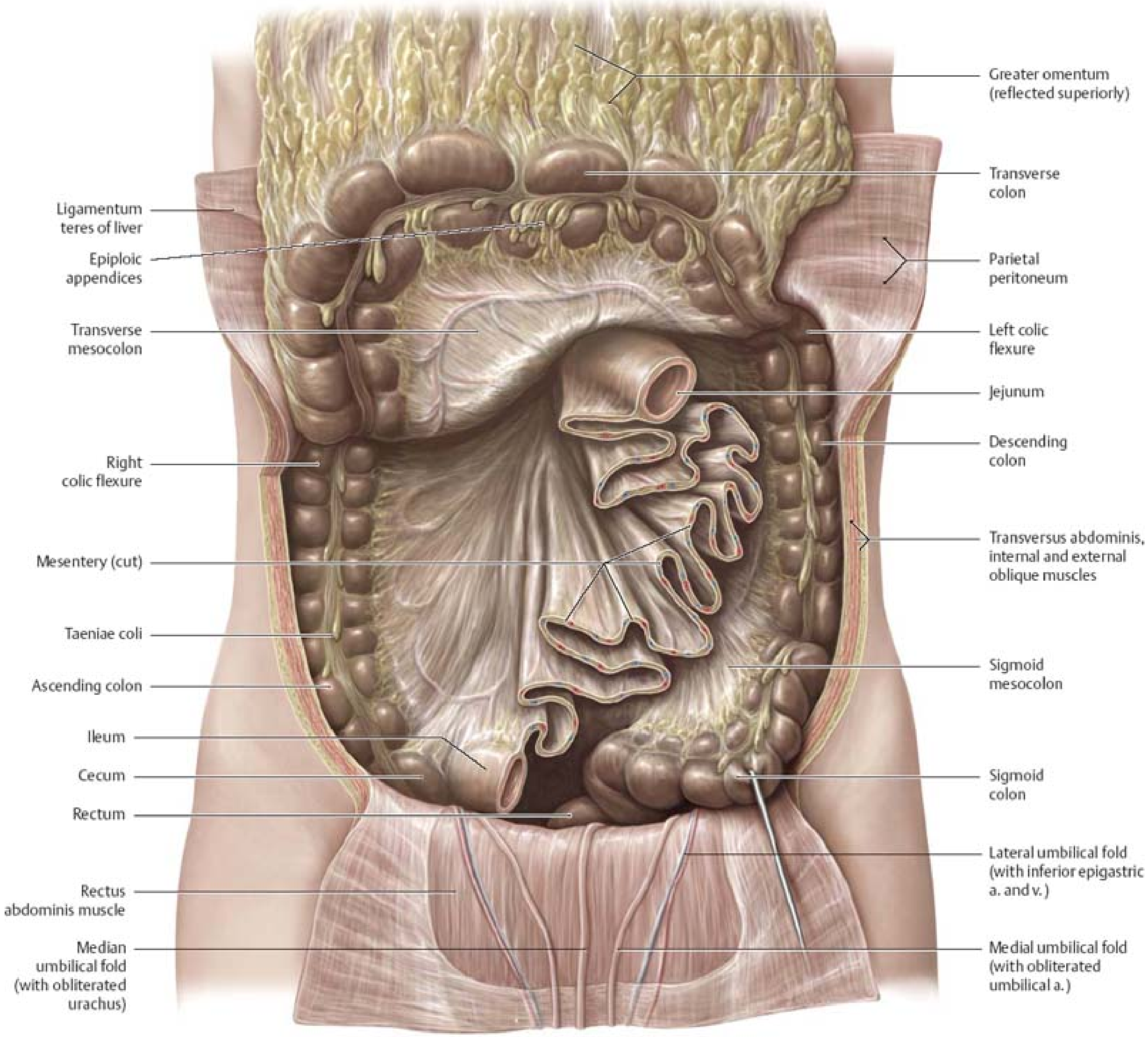
Anterior view.



A Greater sac. *Retracted:* Abdominal wall.



B Infracolic compartment. *Reflected:* Greater omentum and transverse colon.

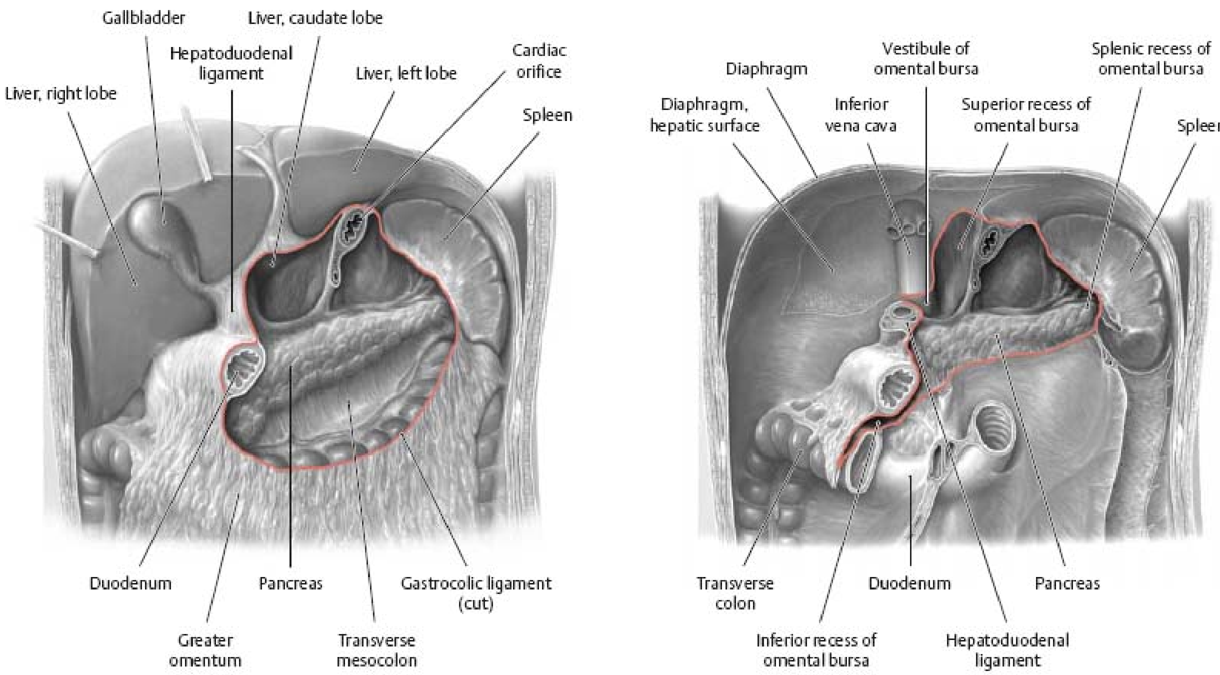


C Mesenteries. *Reflected:* Greater omentum and transverse colon. *Removed:* Intraperitoneal small intestines.

Lesser Sac

Fig. 12.5 Lesser sac (Omental bursa)

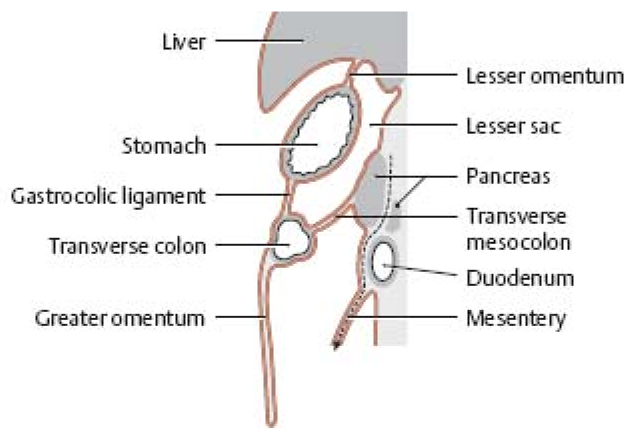
Anterior view. The lesser sac (omental bursa) is the portion of the peritoneal cavity located behind the lesser omentum and stomach.



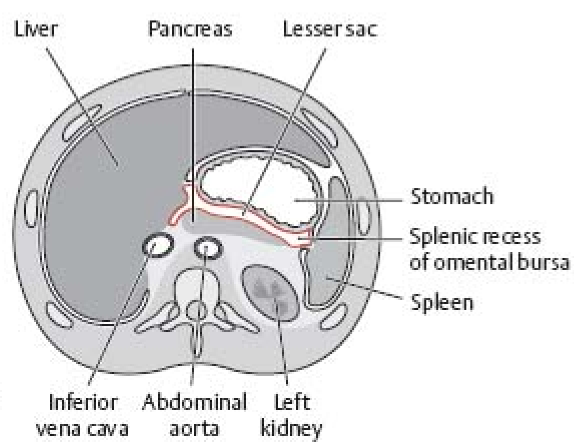
A Boundaries of the lesser sac (omental bursa).

B Posterior wall of the lesser sac (omental bursa).

Fig. 12.6 Location of the lesser sac



A Sagittal section.



B Transverse section, inferior view.

Table 12.2 **Boundaries of the lesser sac (omental bursa)**

Direction	**Boundary**	**Recess**
Anterior	Lesser omentum, gastrocolic ligament	–
Inferior	Transverse mesocolon	Inferior recess
Superior	Liver (with caudate lobe)	Superior recess
Posterior	Pancreas, aorta (abdominal part), celiac trunk, splenic a. and v., gastrosplenic fold, left suprarenal gland, left kidney (superior pole)	–
Right	Liver, duodenal bulb	–
Left	Spleen, gastrosplenic ligament	Splenic recess

Fig. 12.7 **Omental bursa in situ**

Anterior view. *Divided:* Gastrocolic ligament. *Retracted:* Liver. *Reflected:* Stomach.

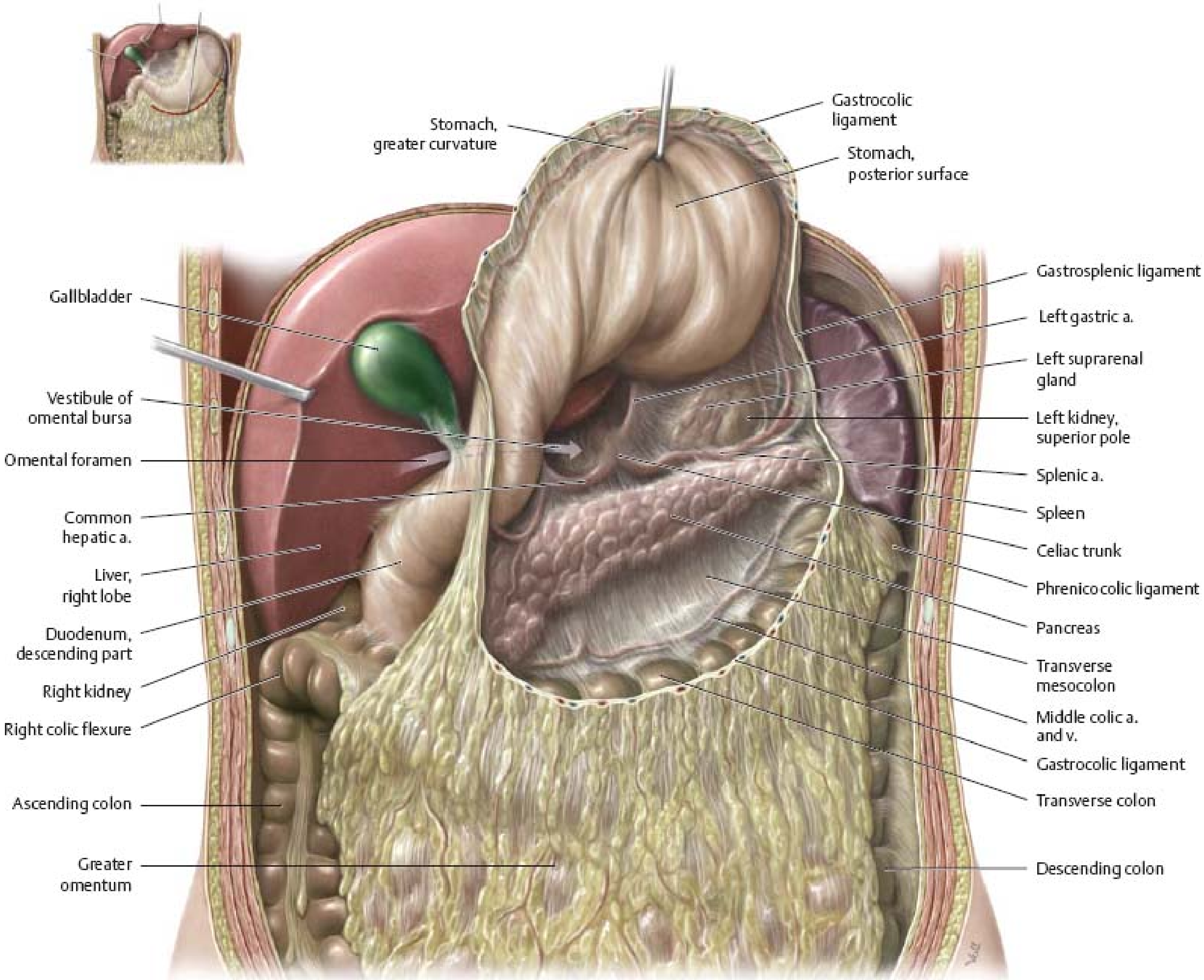


Table 12.3 **Boundaries of the omental foramen**	
The communication between the greater and lesser sacs is the omental (epiploic) foramen (see arrow in Fig. 12.7).	
Direction	**Boundary**
Anterior	Hepatoduodenal ligament with the portal v., proper hepatic a., and bile duct
Inferior	Duodenum (superior part)

The communication between the greater and lesser sacs is the omental (epiploic) foramen (see arrow in Fig. 12.7).	
Direction	**Boundary**
Posterior	Inferior vena cava, diaphragm (right crus)
Superior	Liver (caudate lobe)

Mesenteries & Posterior Wall

Fig. 12.8 Mesenteries and organs of the peritoneal cavity

Anterior view. *Removed:* Stomach, jejunum, and ileum. *Reflected:* Liver.

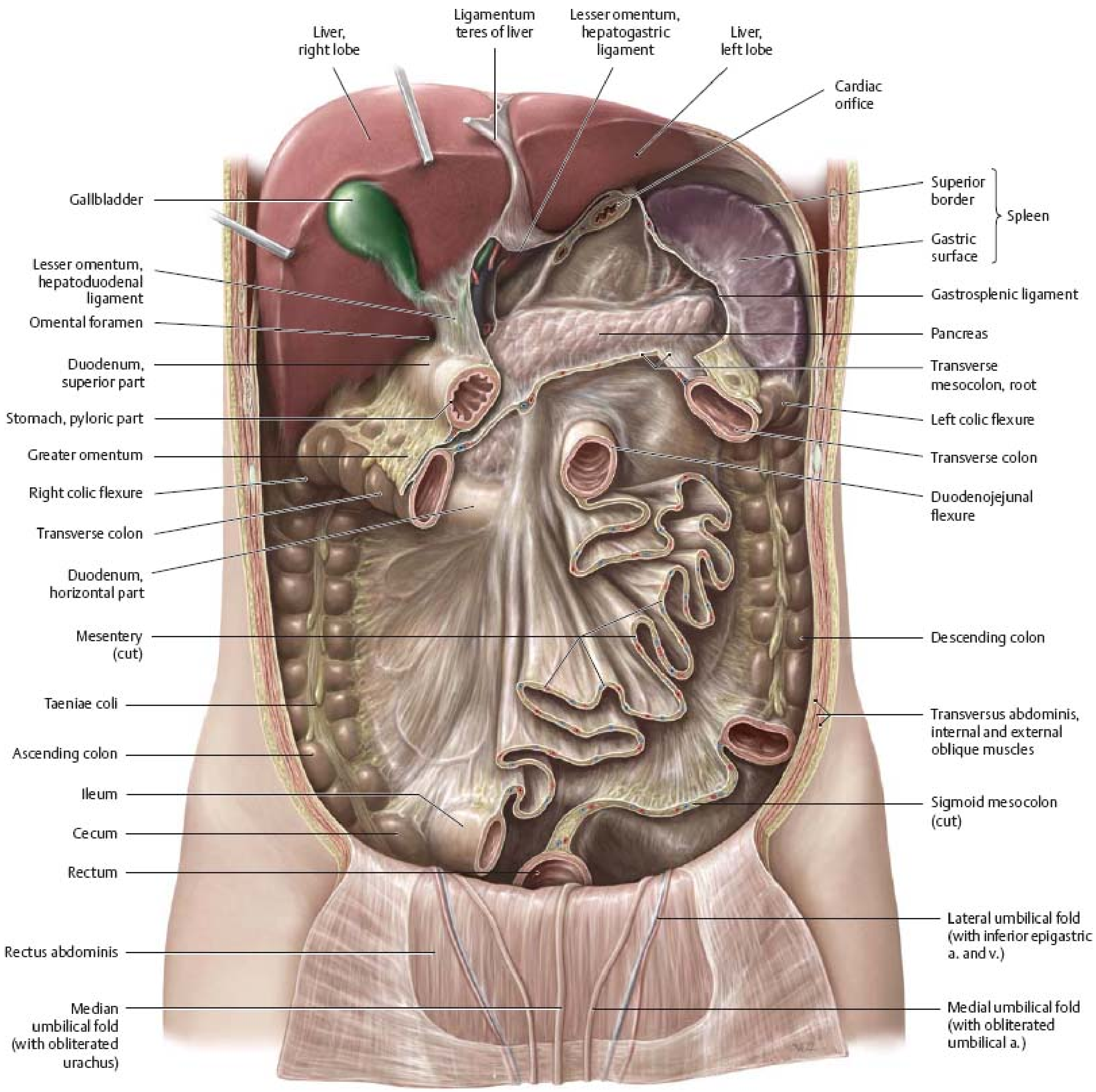


Fig. 12.9 **Posterior wall of the peritoneal cavity**

Anterior view. *Removed:* All intraperitoneal organs. *Revealed:* Structures of the retroperitoneum (see Table 12.4 and p. 180).

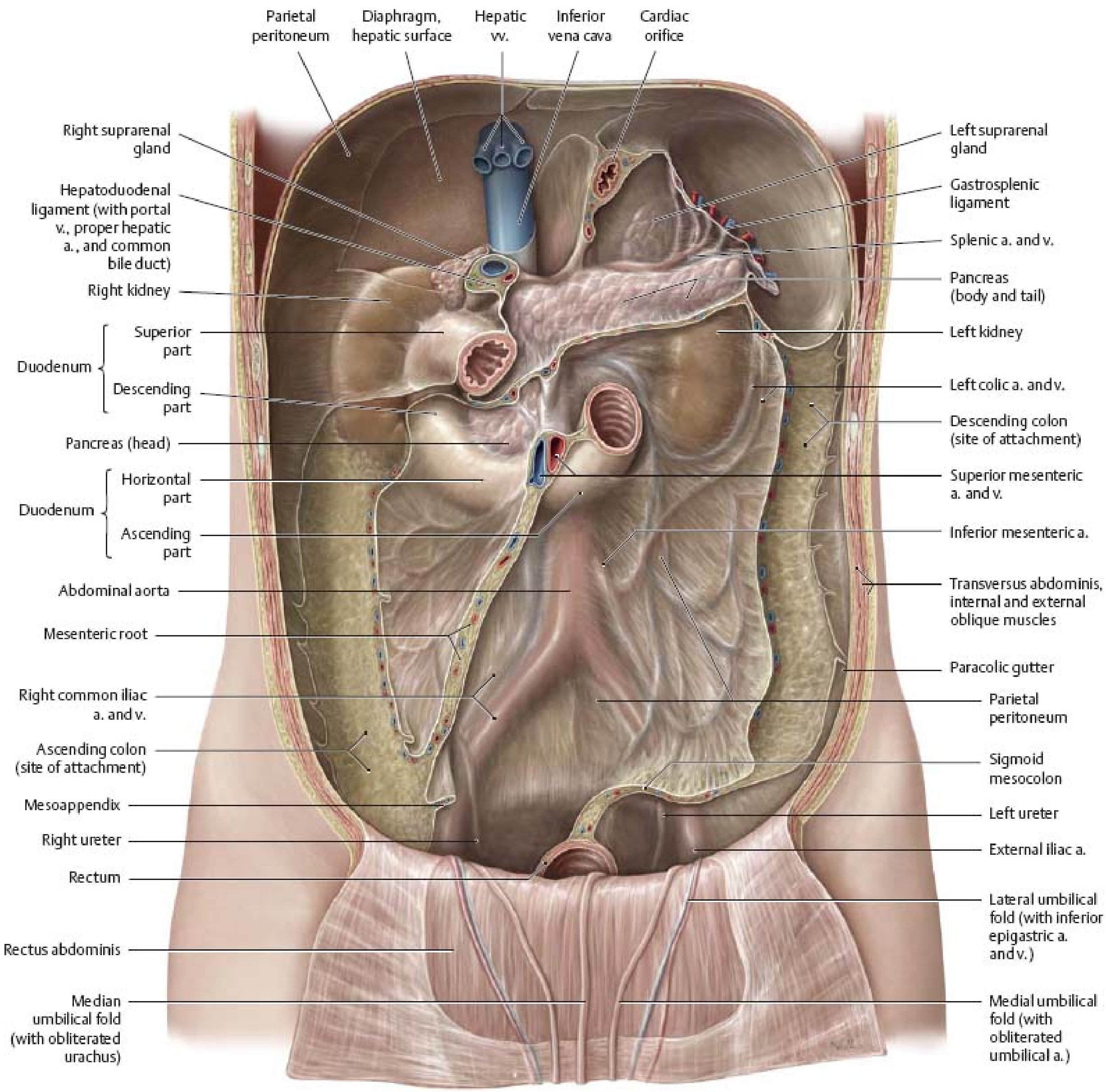


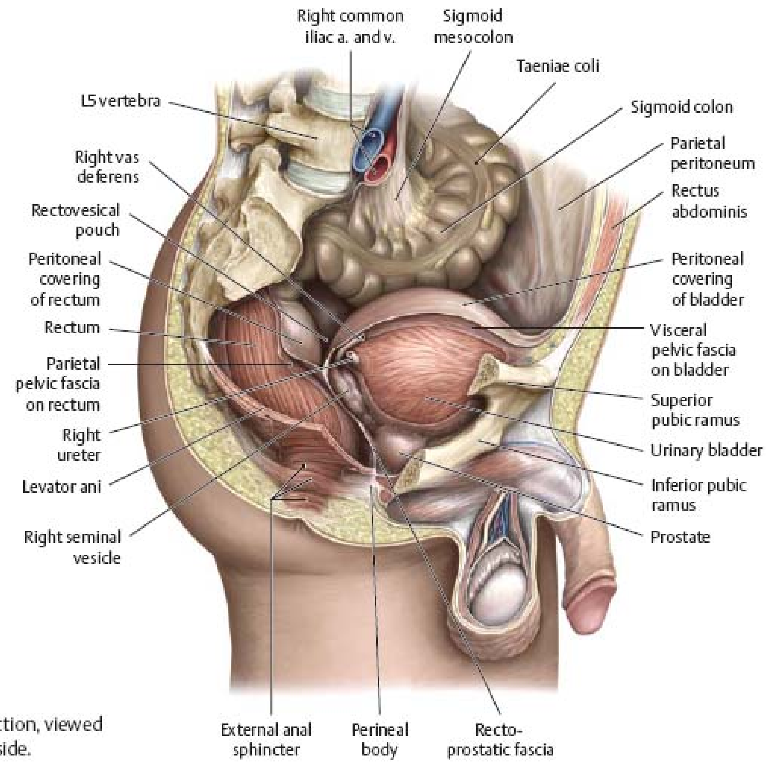
Table 12.4 Structures of the retroperitoneum

See pp. 216, 228, 239 for neurovascular structures of the retroperitoneum.

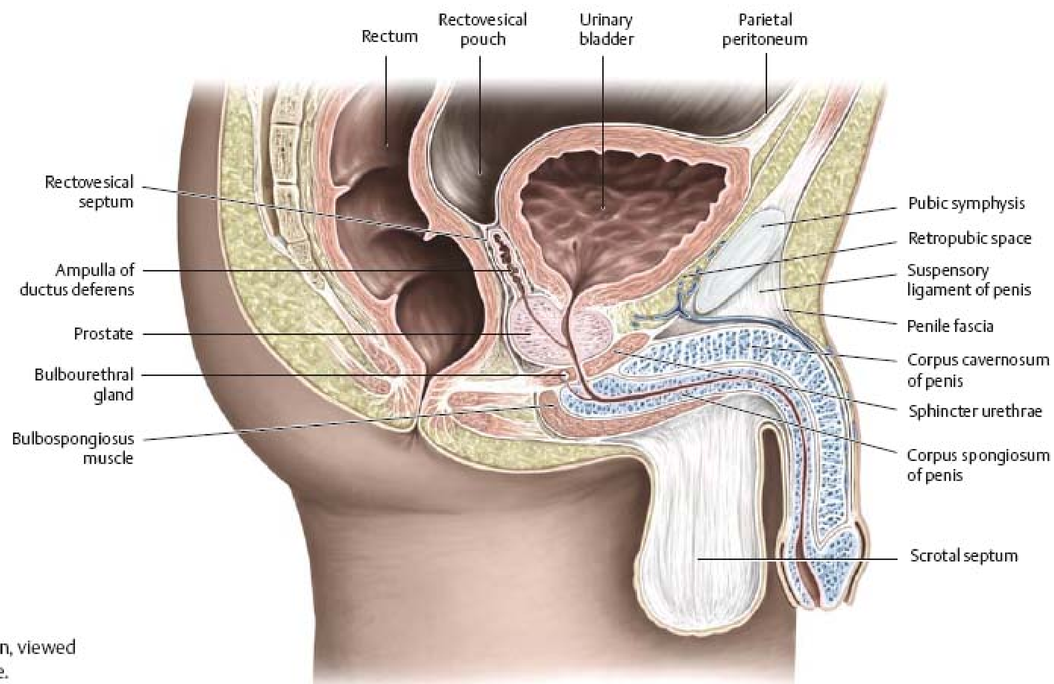
Classification	Organs	Vessels	Nerves
Primarily retroperitoneal (Retroperitoneal when formed)	• Kidneys • Suprarenal glands • Ureters	• Aorta (abdominal part) • Inferior vena cava and tributaries • Ascending lumbar vv. • Portal v. and tributaries • Lumbar, sacral, and iliac lymph nodes • Lumbar trunks and cisterna chyli	• Lumbar plexus branches ∘ Iliohypogastric n. ∘ Ilioinguinal n. ∘ Genitofemoral n. ∘ Lateral femoral cutaneous n. ∘ Femoral n. ∘ Obturator n. • Sympathetic trunk • Autonomic ganglia and plexuses
Secondarily retroperitoneal (Mesentery lost during development)	• Pancreas • Duodenum (descending and horizontal parts; some of ascending part) • Ascending and descending colon • Cecum (portions; variable) • Rectum (upper 2/3)		

Contents of the Pelvis

Fig. 12.10 Male pelvis

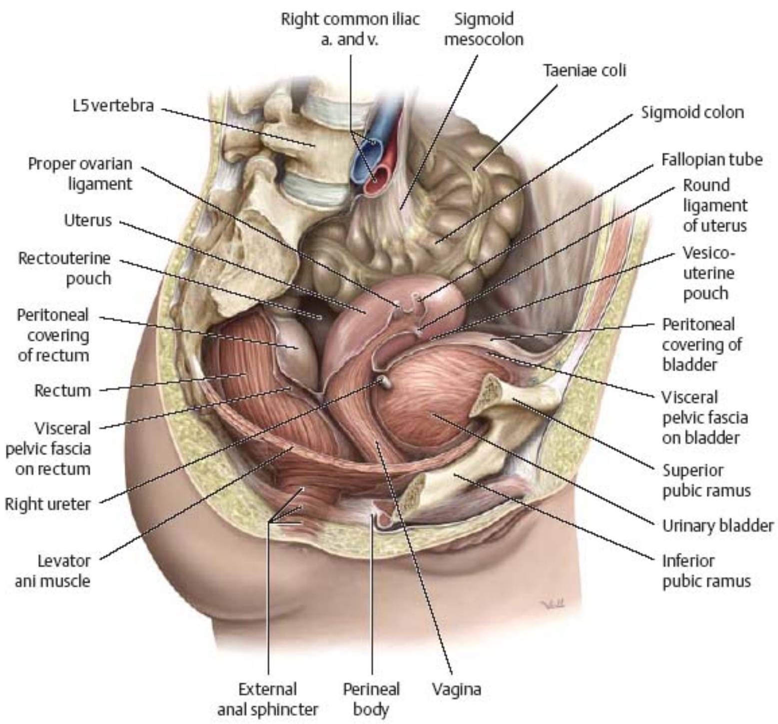


A Parasagittal section, viewed from the right side.

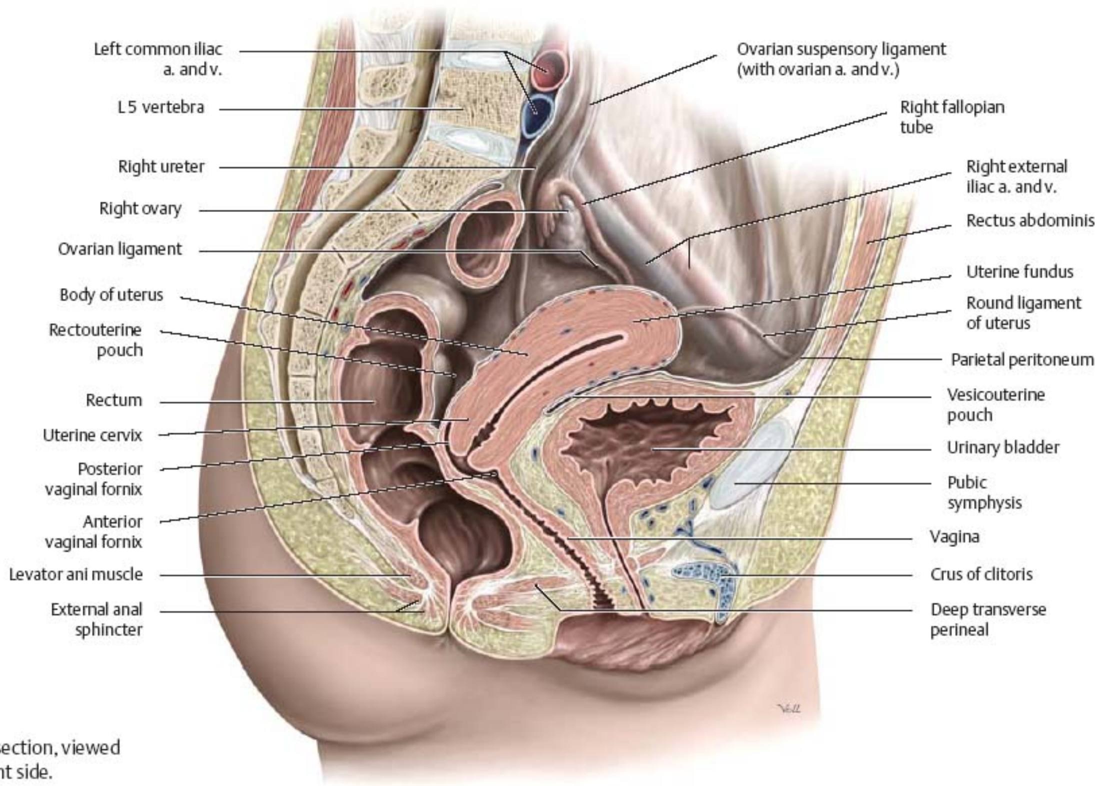


B Midsagittal section, viewed from the right side.

Fig. 12.11 Female pelvis



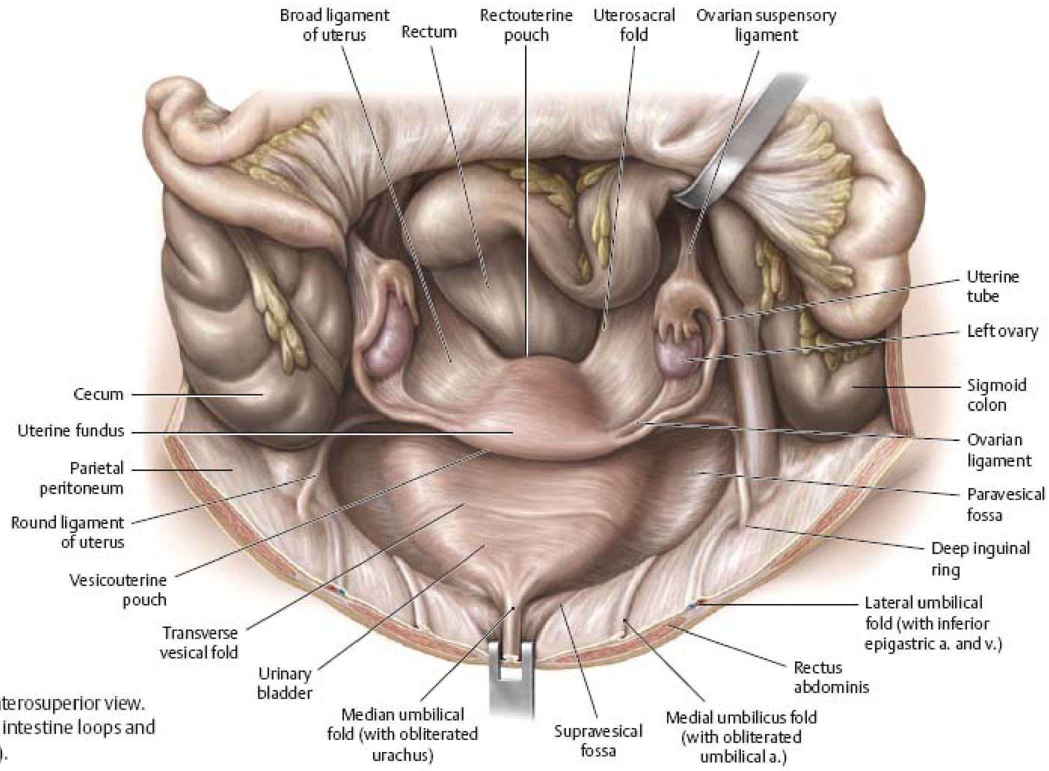
A Parasagittal section, viewed from the right side.



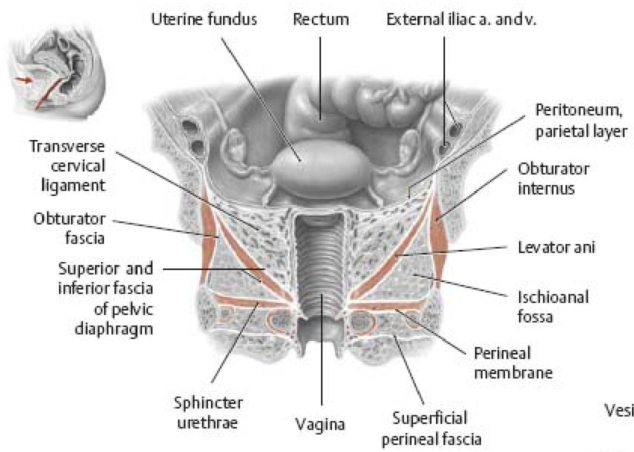
B Midsagittal section, viewed from the right side.

Peritoneal Relationships

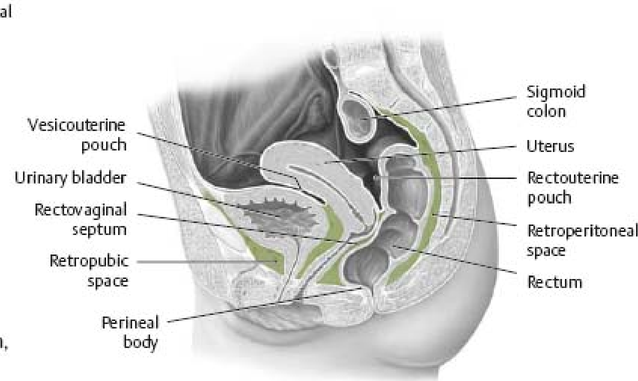
Fig. 12.12 Peritoneal relationships in the pelvis: Female



A Lesser pelvis, anterosuperior view. *Retracted:* Small intestine loops and colon (portions).

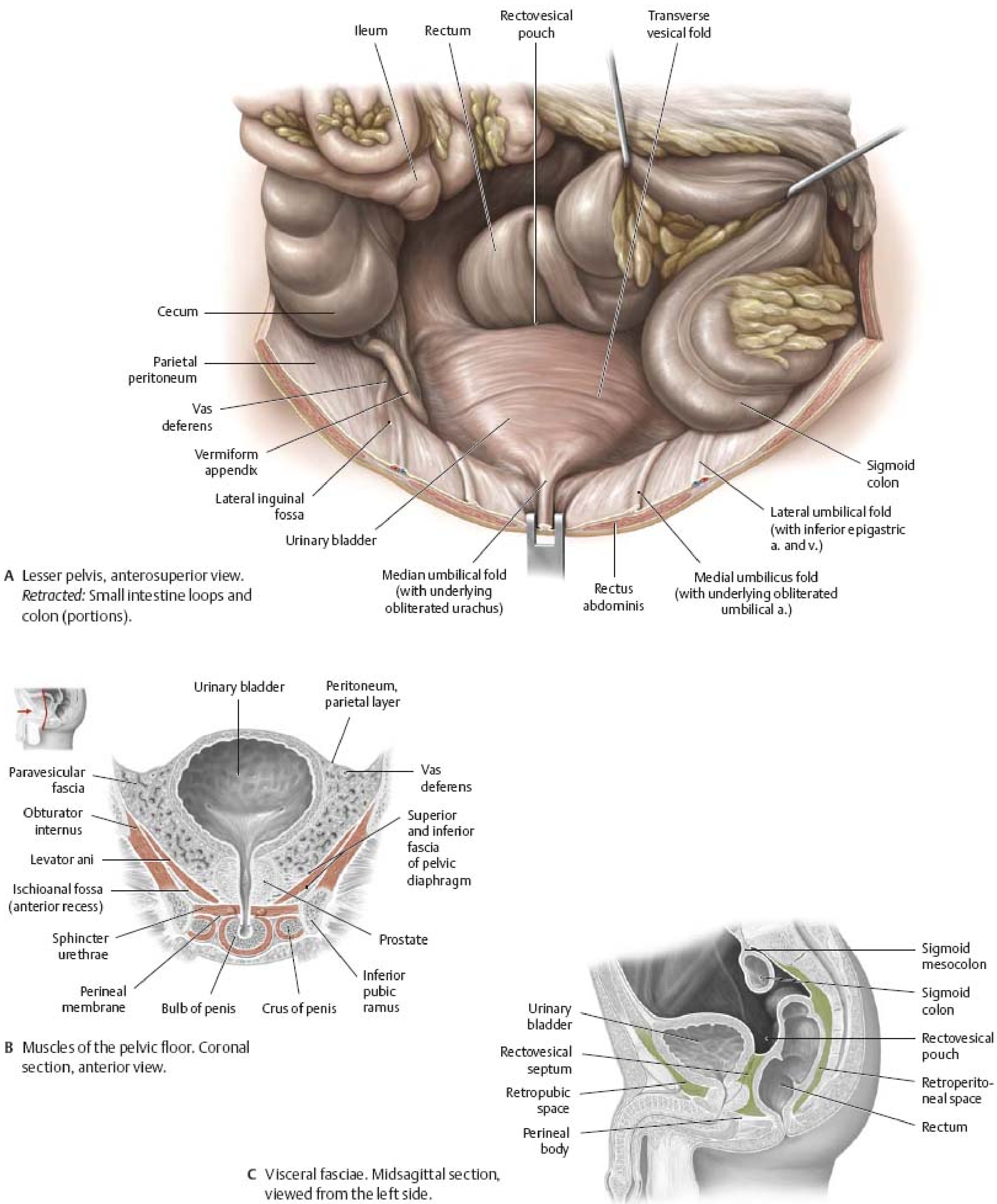


B Muscles of the pelvic floor. Coronal section, anterior view.



C Visceral fasciae. Midsagittal section, viewed from the left side.

Fig. 12.13 Peritoneal relationships in the pelvis: Male



A Lesser pelvis, anterosuperior view. *Retracted:* Small intestine loops and colon (portions).

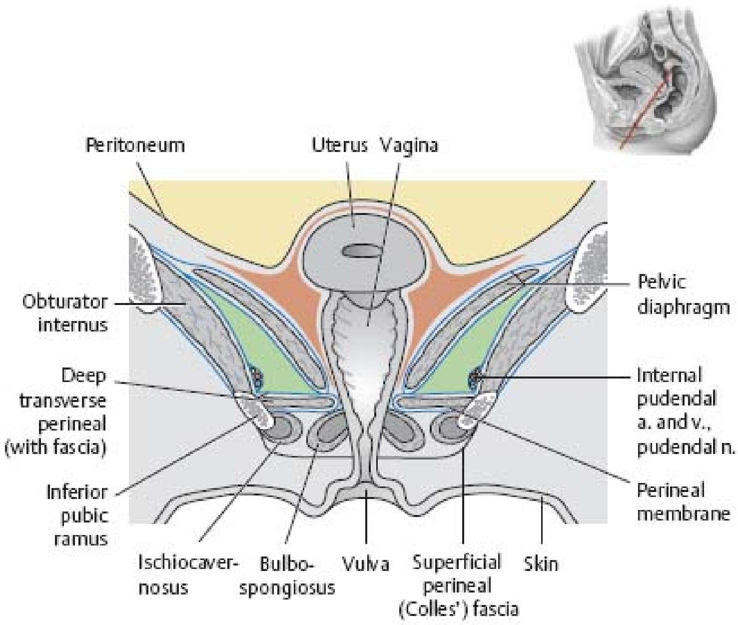
B Muscles of the pelvic floor. Coronal section, anterior view.

C Visceral fasciae. Midsagittal section, viewed from the left side.

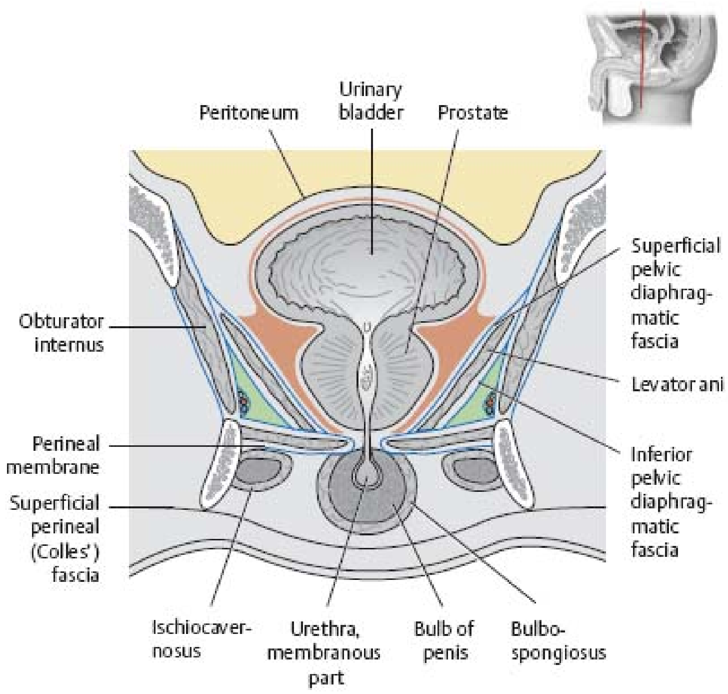
Pelvis & Perineum

Fig. 12.14 Pelvis and urogenital triangle

Coronal section, anterior view.



A Female.



B Male.

Peritoneal cavity

Subperitoneal space

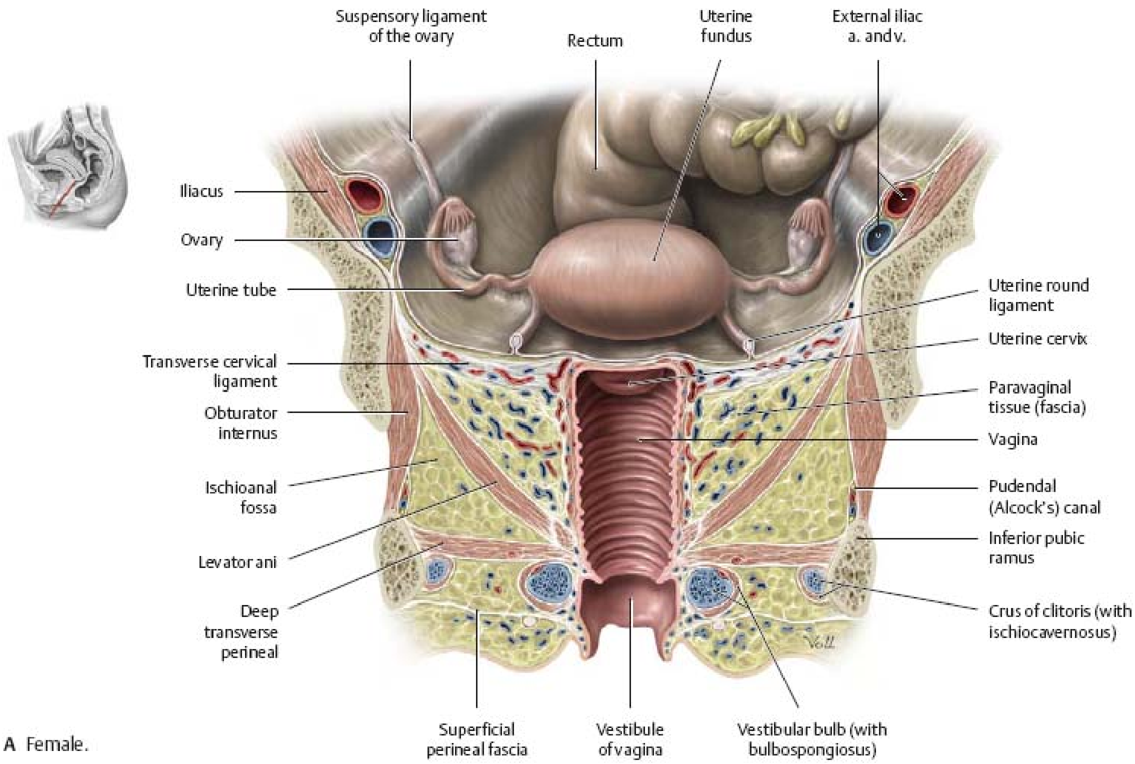
Ischioanal fossa

Visceral pelvic fascia

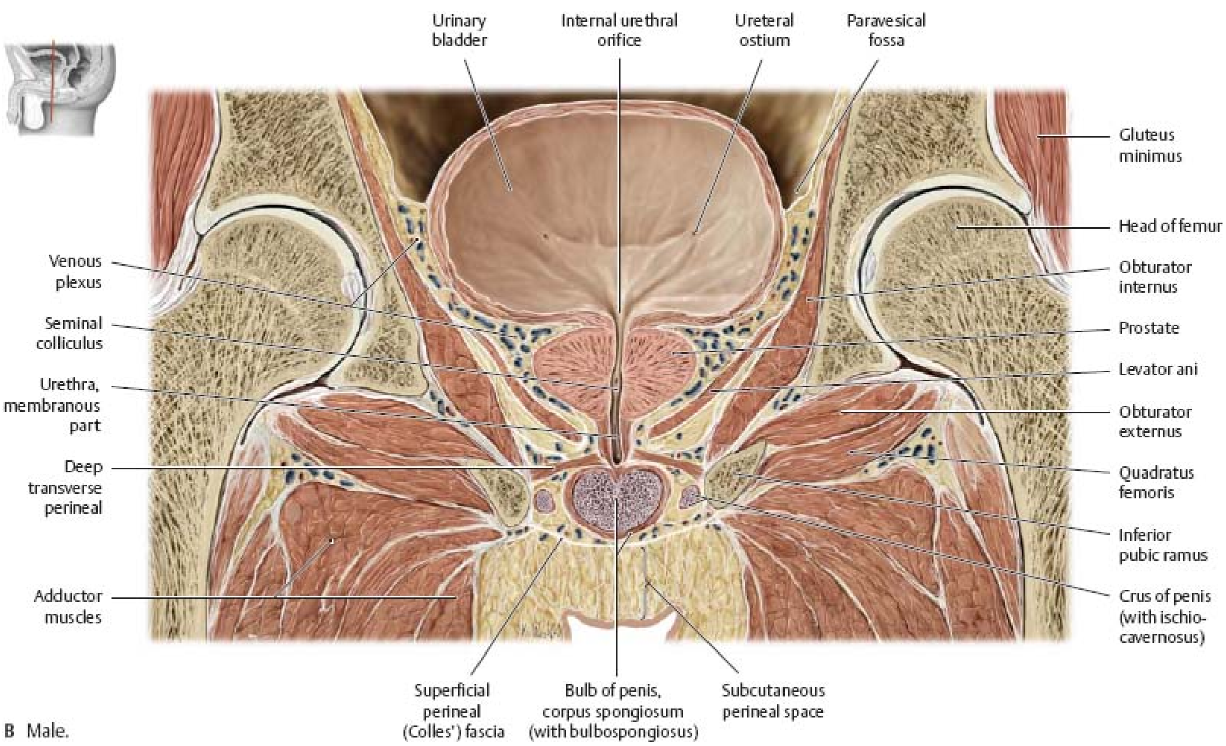
Parietal pelvic fascia

Table 12.5	Divisions of the pelvis and perineum	
The levels of the pelvis are determined by bony landmarks (iliac crest and pelvis inlet, see p. 126). The contents of the perineum are separated by the pelvic diaphragm and two fascial layers.		
Iliac crest		
Pelvis	False pelvis	• Ileum (coils)
		• Cecum and appendix
		• Sigmoid colon
		• Common and external iliac aa. and vv.
		• Lumbar plexus (branches)
	Pelvic inlet	
	Pelvis proper	• Distal ureters
		• Urinary bladder
		• Rectum
		♀: Vagina, uterus, uterine tubes, and ovaries
		♂: Ductus deferens, seminal vesicle, and prostate
		• Internal iliac a. and v. and branches
		• Sacral plexus
		• Inferior hypogastric plexus
Pelvic diaphragm (Levator ani with superficial and inferior pelvic diaphragmatic fascia)		
Perineum	Deep pouch	• Sphincter urethrae and deep transverse perineal mm.
		• Urethra (membranous)
		• Vagina
		• Rectum
		• Bulbourethral gland
		• Ischioanal fossa
		• Internal pudendal a. and v., pudendal n. and branches
	Perineal membrane	
	Superficial pouch	• Ischiocavernosus, bulbocavernosus, and superficial transverse perineal mm.
		• Urethra (penile)
		• Clitoris and penis
		• Internal pudendal a. and v., pudendal n. and branches
	Superficial perineal (Colles') fascia	
	Subcutaneous perineal space	• Fat
Skin		

Fig. 12.15 **Pelvis: Coronal section** Anterior view.



A Female.



B Male.

Transverse Sections

Fig. 12.16 Abdomen: Transverse section

Inferior view.

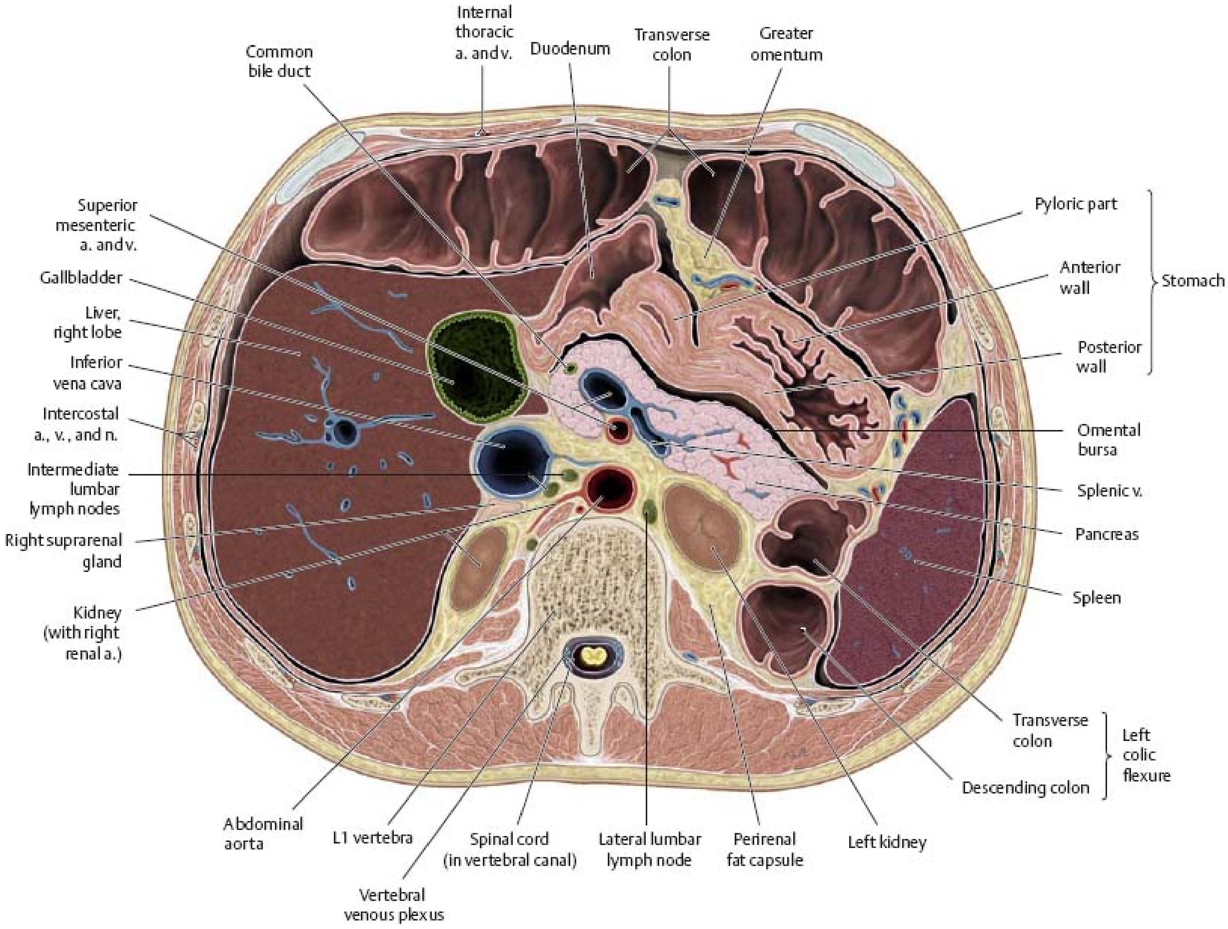
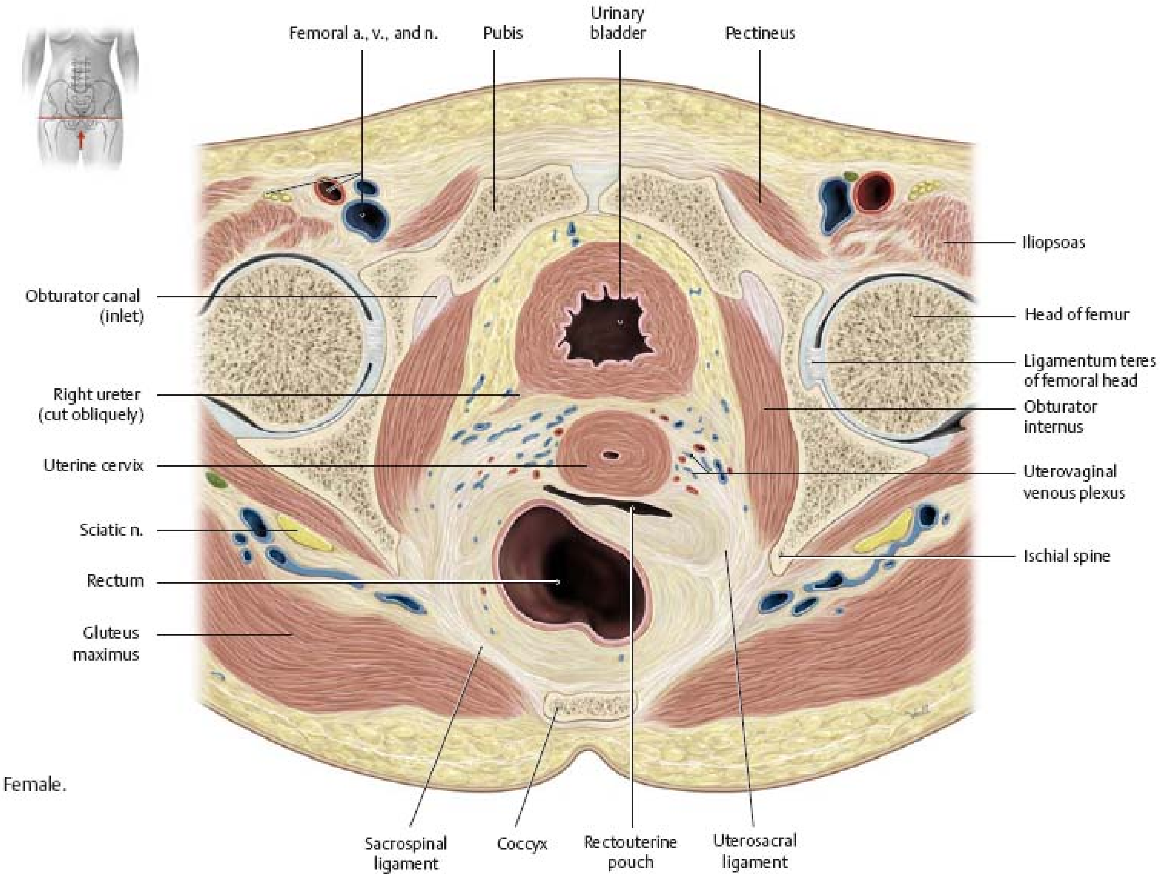
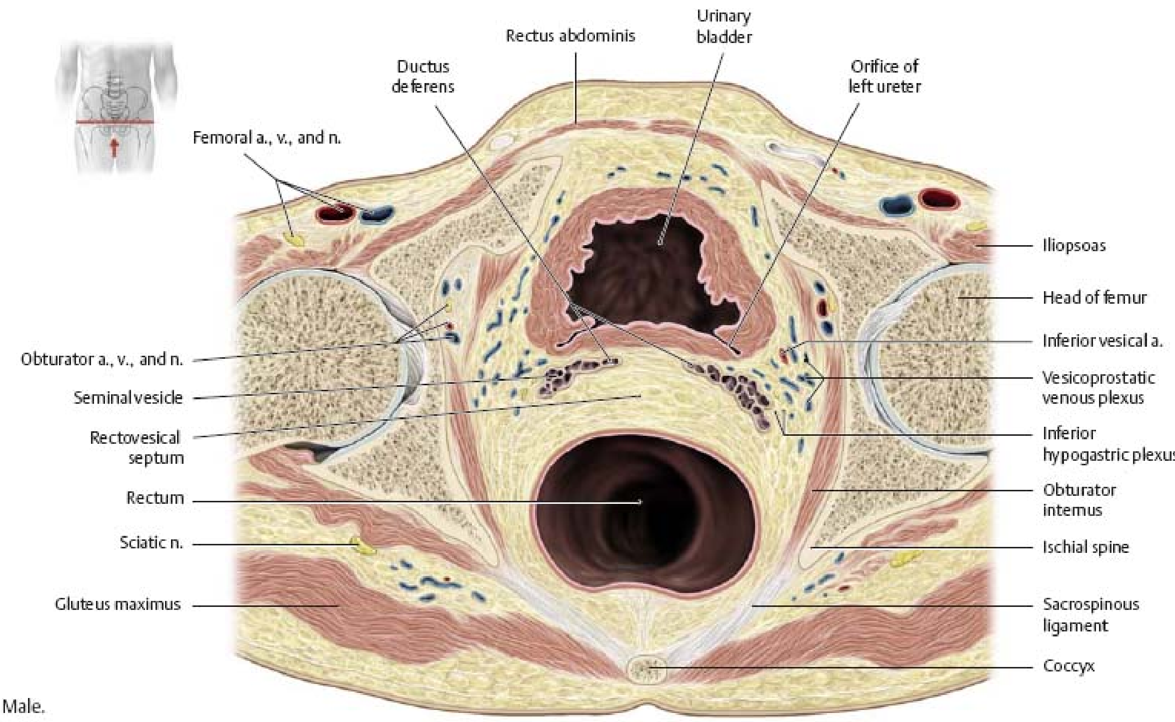


Fig. 12.17 Pelvis: Transverse section

Inferior view.



A Female.

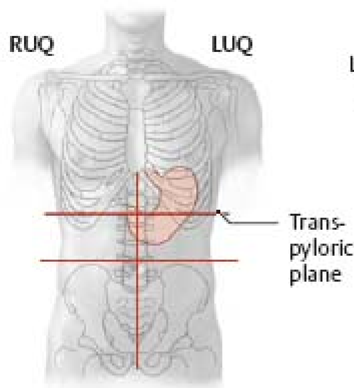


B Male.

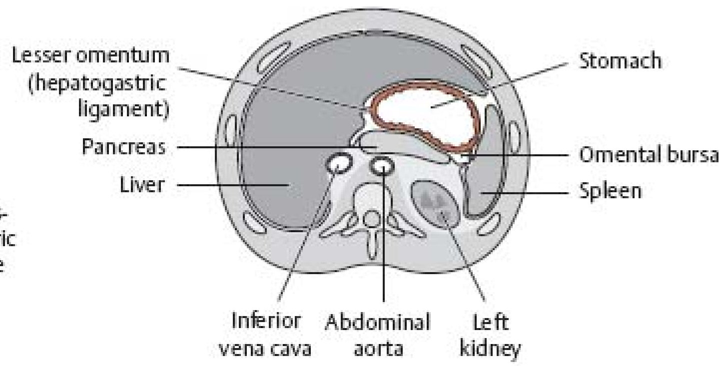
13 Internal Organs

Stomach

Fig. 13.1 Stomach: Location

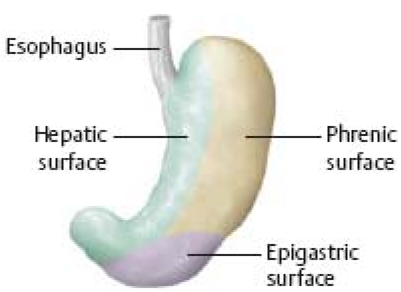


A Anterior view.

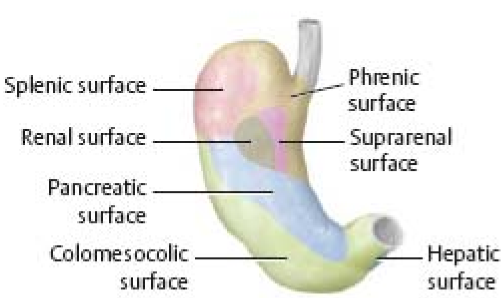


B Transverse section, inferior view.

Fig. 13.2 Surfaces of the stomach



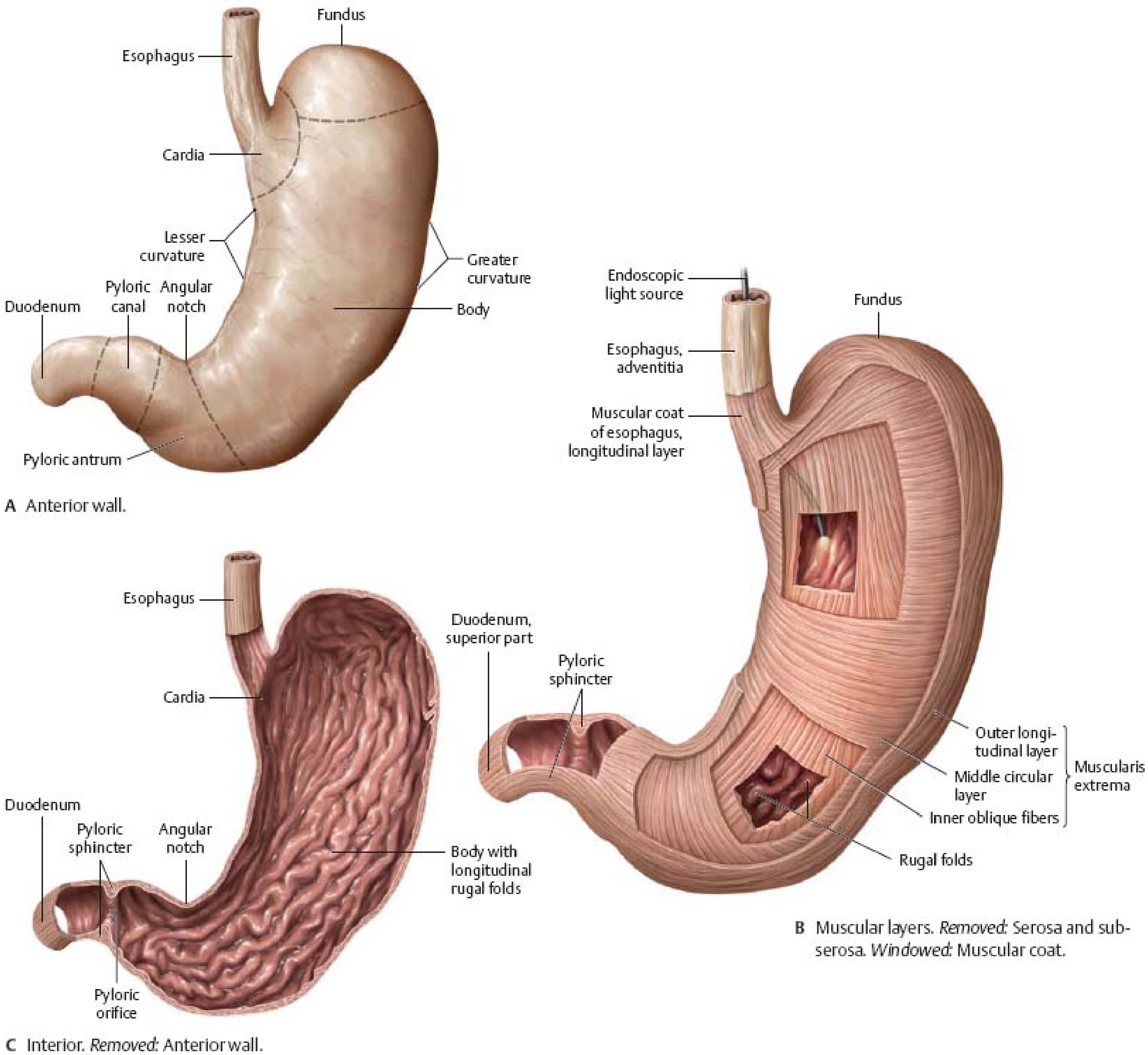
A Anterior view.



B Posterior view.

Fig. 13.3 Stomach

Anterior view.



A Anterior wall.

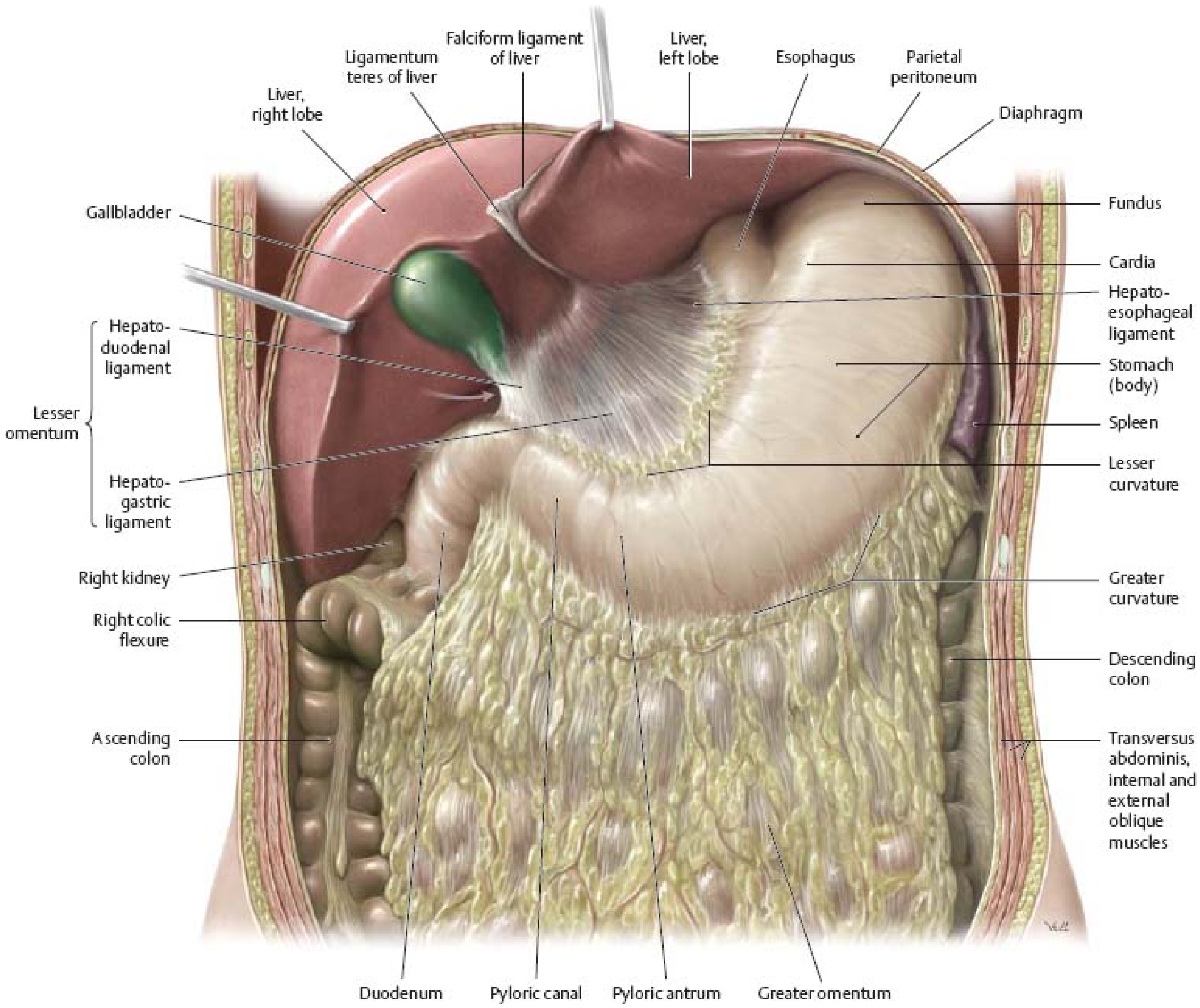
B Muscular layers. *Removed:* Serosa and sub-serosa. *Windowed:* Muscular coat.

C Interior. *Removed:* Anterior wall.

The stomach is found in the right and left upper quadrants. It is intraperitoneal, its mesenteries being the lesser and greater omenta.

Fig. 13.4 Stomach in situ

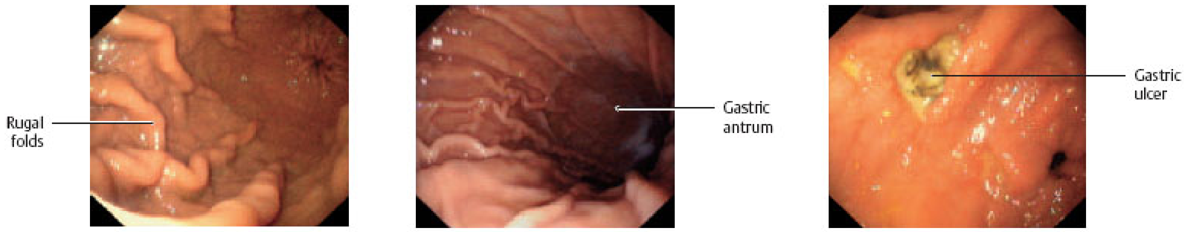
Anterior view of the opened upper abdomen. Arrow indicates the omental foramen.



Clinical

Gastritis and gastric ulcers

Gastritis and gastric ulcers, the two most common diseases of the stomach, are associated with increased acid production and are caused by alcohol, drugs such as aspirin, and the bacterium *Helicobacter pylori*. Symptoms include lessened appetite, pain, and even bleeding, which manifests as black stool or dark brown material in vomit. Gastritis is limited to the inner surface of the stomach, while gastric ulcers extend into the stomach wall. The gastric ulcer in **C** is covered with fibrin and shows hematin spots.



A Body of normal stomach. B Normal pyloric antrum. C Gastric ulcer.

Duodenum

The small intestine consists of the duodenum, jejunum, and ileum (see p. 162). The duodenum is primarily retroperitoneal and divided into four parts: superior, descending, horizontal, and ascending.

Fig. 13.5 Duodenum: Location

Anterior view.

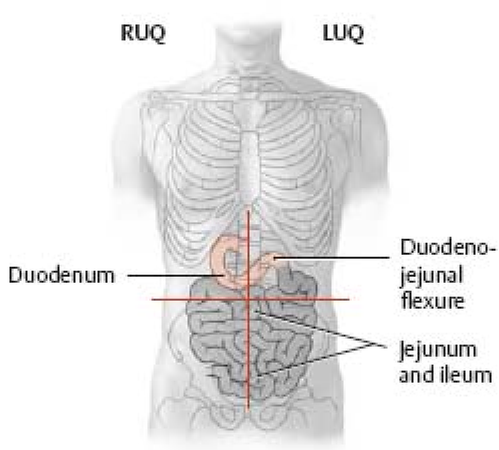


Fig. 13.6 Parts of the duodenum

Anterior view.

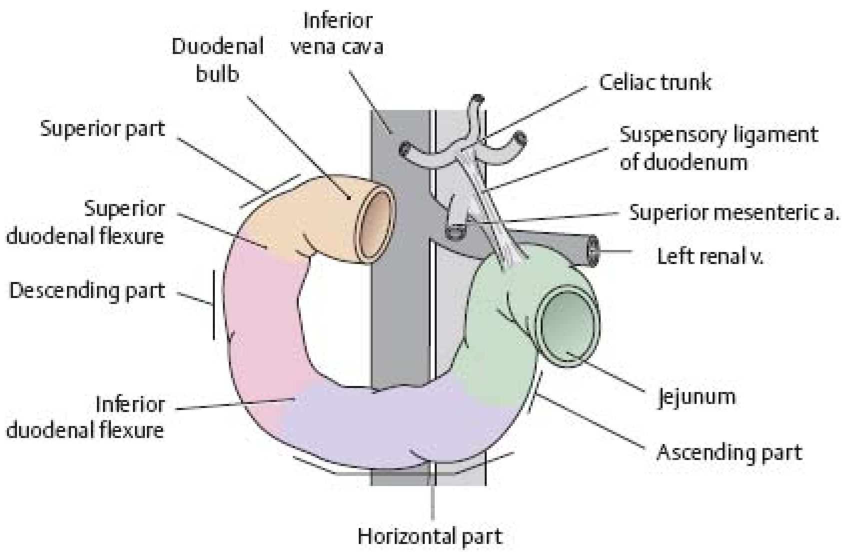


Fig. 13.7 **Duodenum**

Anterior view with the anterior wall opened.

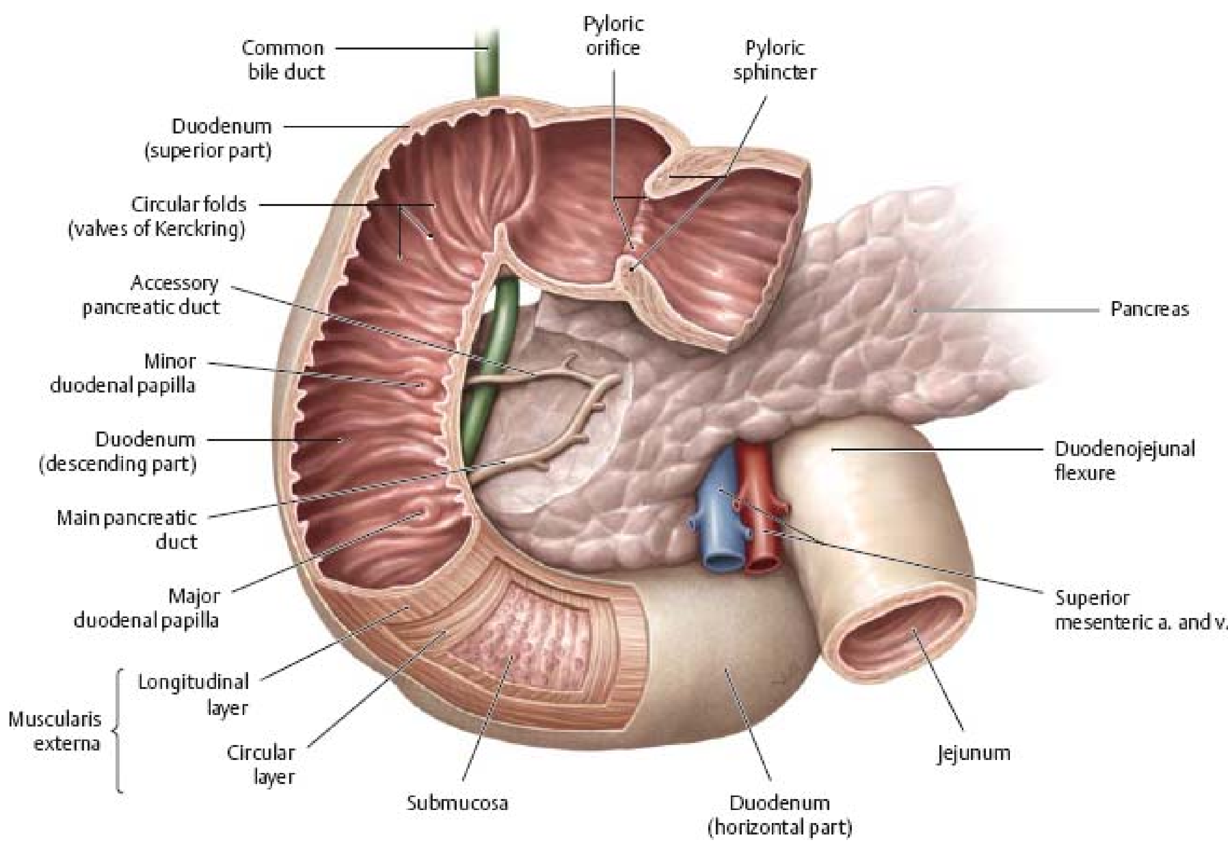
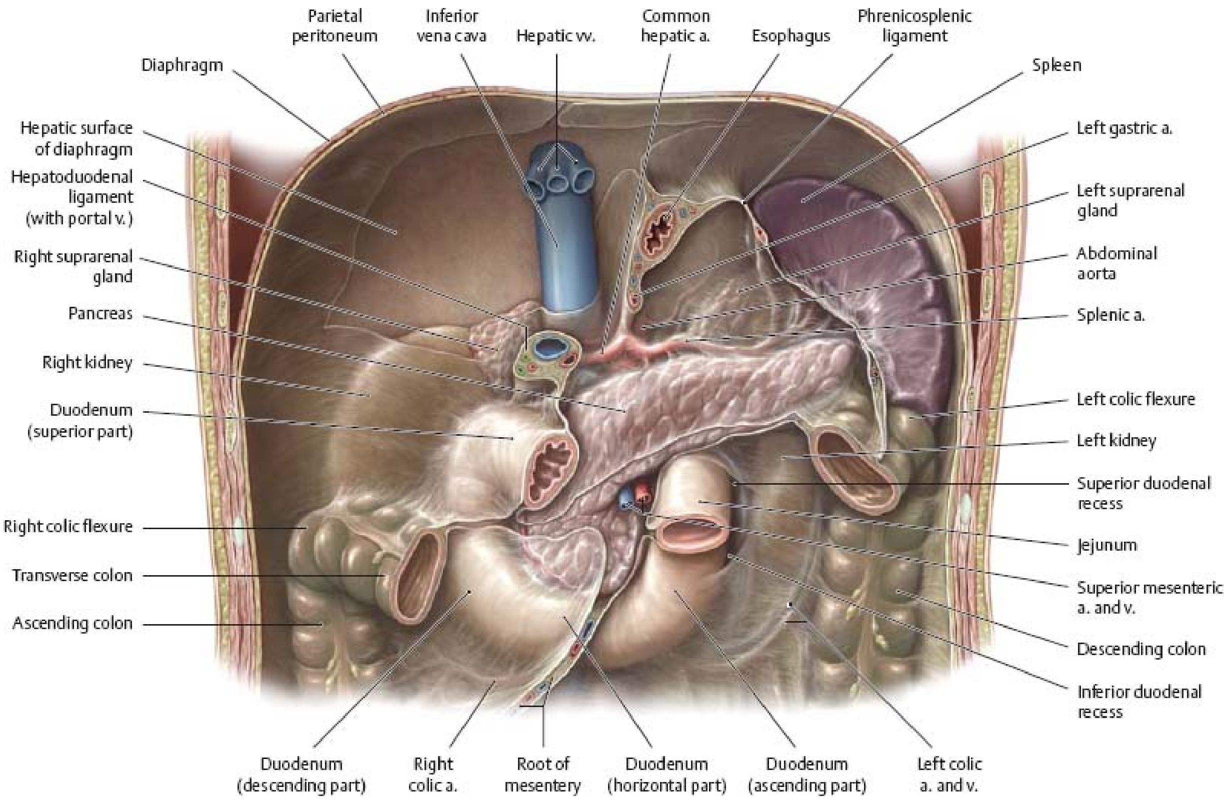


Fig. 13.8 **Duodenum in situ**

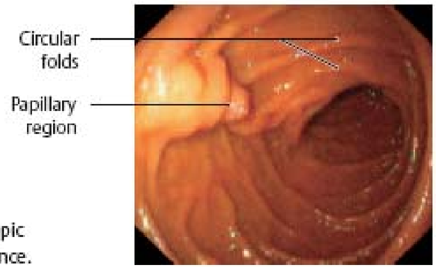
Anterior view. *Removed:* Stomach, liver, small intestine, and large portions of the transverse colon. *Thinned:* Retroperitoneal fat and connective tissue.



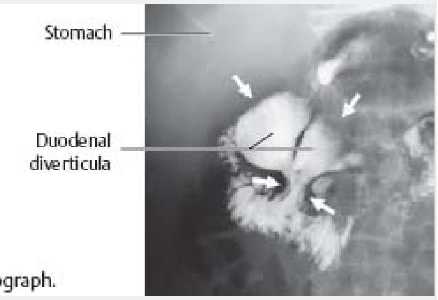
Clinical

Endoscopy of the papillary region

Two important ducts end in the papillary region of the duodenum: the common bile duct and the pancreatic duct (see Fig. 13.7). These ducts may be examined by X-ray through endoscopic retrograde cholangiopancreatography (ERCP), in which dye is injected endoscopically into the duodenal papilla. Duodenal diverticula (generally harmless outpouchings) may complicate the procedure.



A Endoscopic appearance.



B Radiograph.

Jejunum & Ileum

Fig. 13.9 Jejunum and ileum: Location

Anterior view. The intraperitoneal jejunum and ileum are enclosed by the mesentery proper.

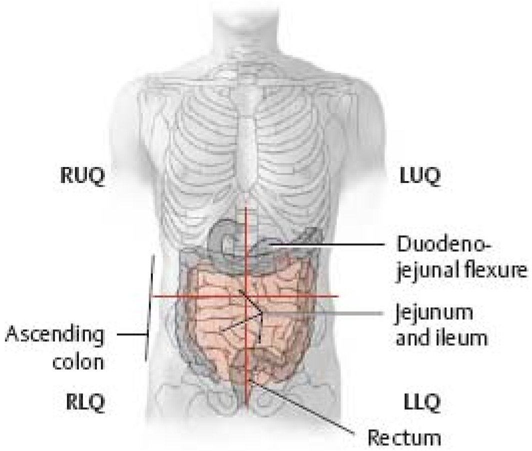
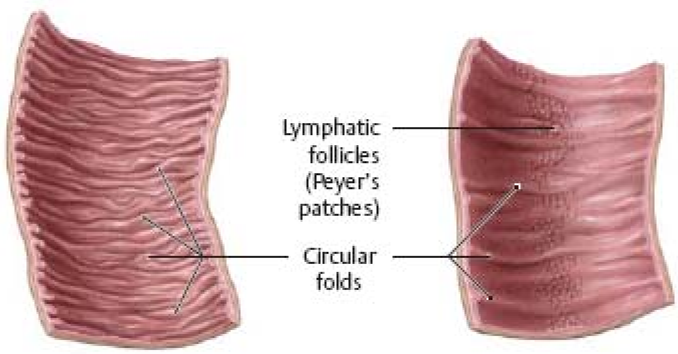


Fig. 13.10 Wall structure of the small intestine

Macroscopic views of the longitudinally opened small intestine.

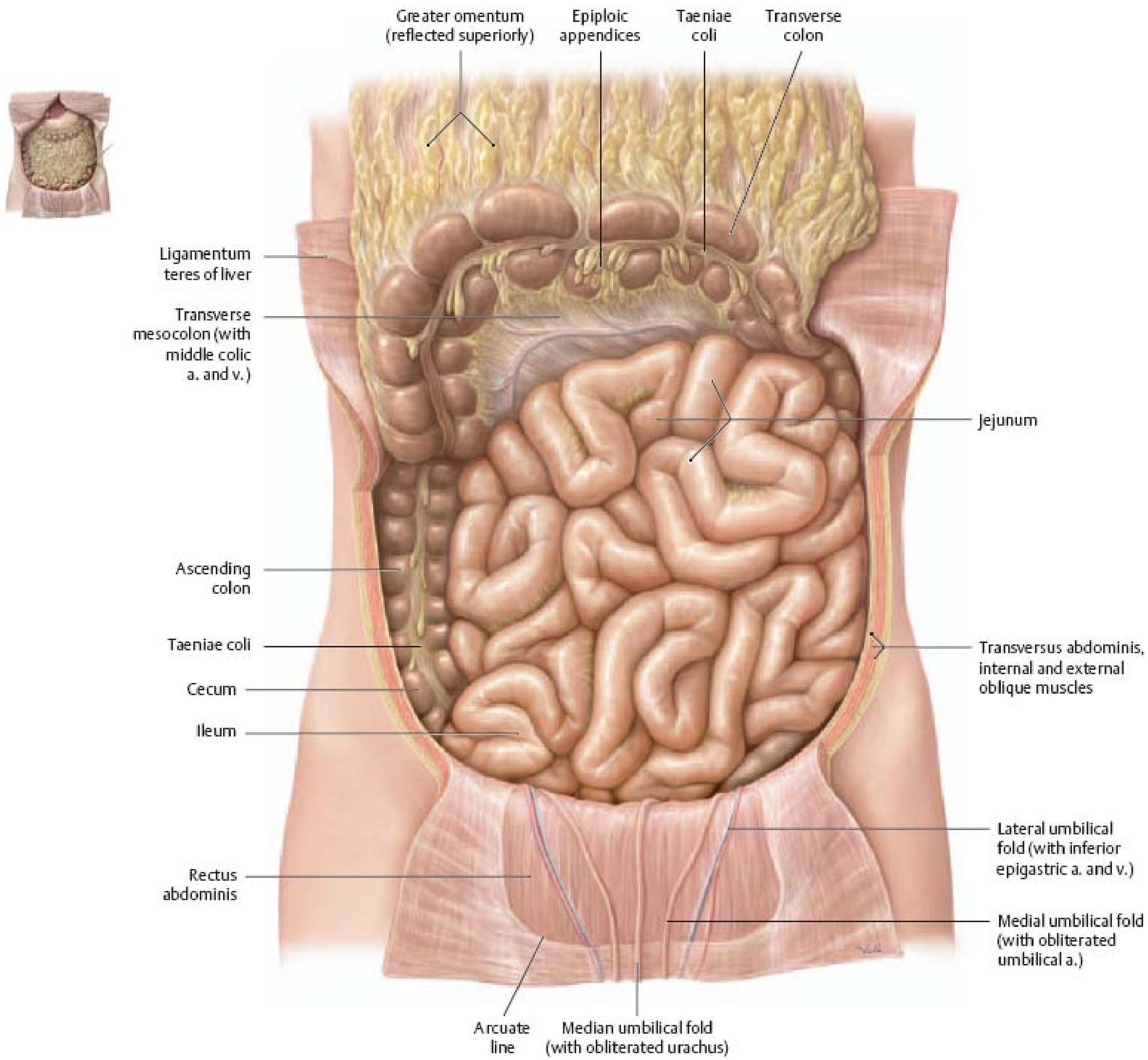


A Jejunum.

B Ileum.

Fig. 13.11 Jejunum and ileum in situ

Anterior view. *Reflected:* Transverse colon.

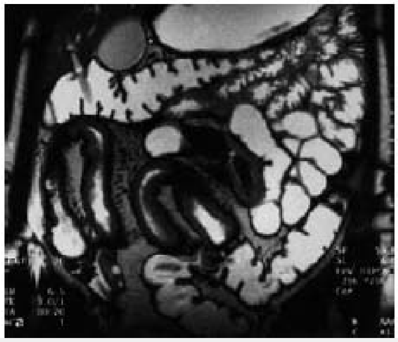


Clinical

Crohn's disease

Crohn's disease, a chronic inflammation of the digestive tract, occurs most often in the terminal ileum (30% of cases). Patients are generally young and suffer from abdominal pain, nausea, elevated body temperature, and diarrhea. Initially, these symptoms can be confused with appendicitis. Complications of Crohn's disease often include anal fistulae (**B**).

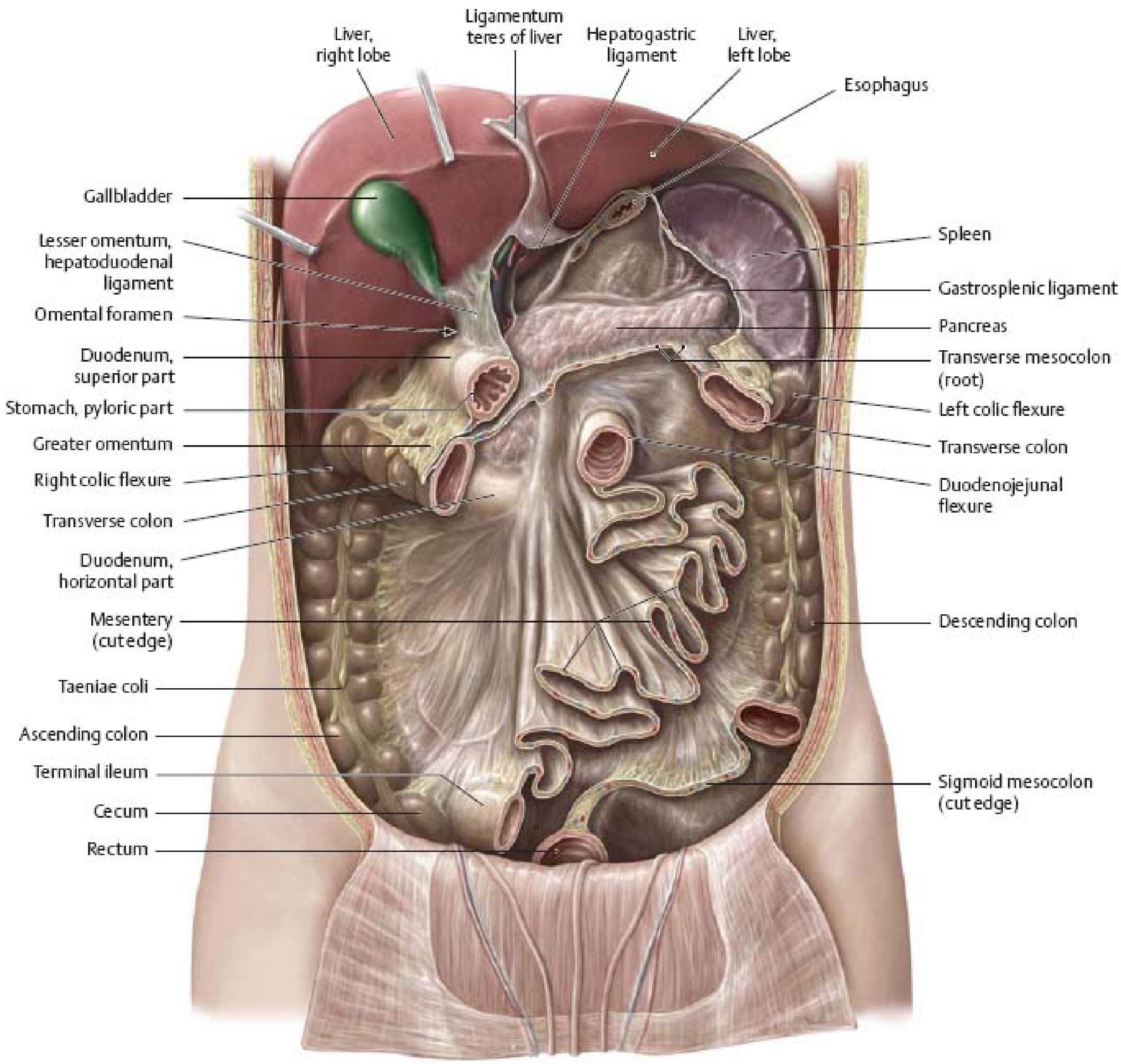
A MRI showing thickened wall of terminal ileum.



B Double-contrast radiograph. Arrow indicates fistula.

***Fig. 13.12* Mesentery of the small intestine**

Anterior view. *Removed:* Stomach, jejunum, and ileum. *Reflected:* Liver.



Cecum, Appendix & Colon

The large intestine consists of the cecum, appendix, colon, and rectum (see p. 166). The colon is divided into four parts: ascending, transverse, descending, and sigmoid. The appendix, transverse colon, and sigmoid colon are intraperitoneal (suspended by the mesoappendix, transverse mesocolon, and sigmoid mesocolon, respectively).

Fig. 13.13 **Large intestine: Location**

Anterior view.

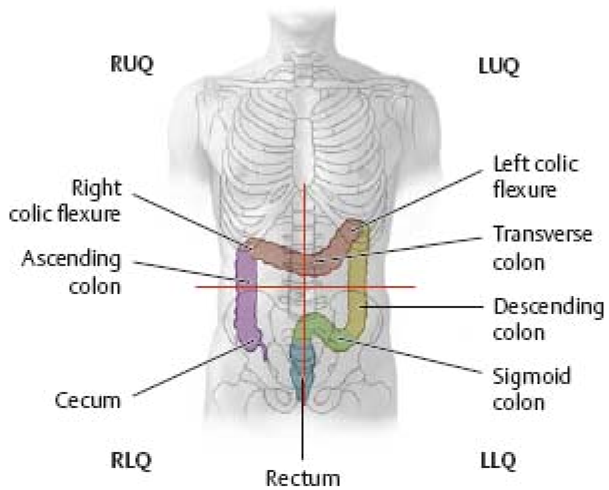


Fig. 13.14 **Ileocecal orifice**
Anterior view of longitudinal coronal section.

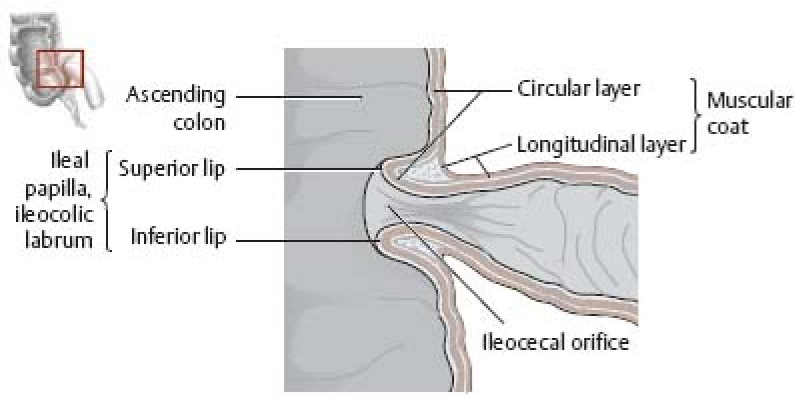


Fig. 13.15 **Large intestine**
Anterior view.

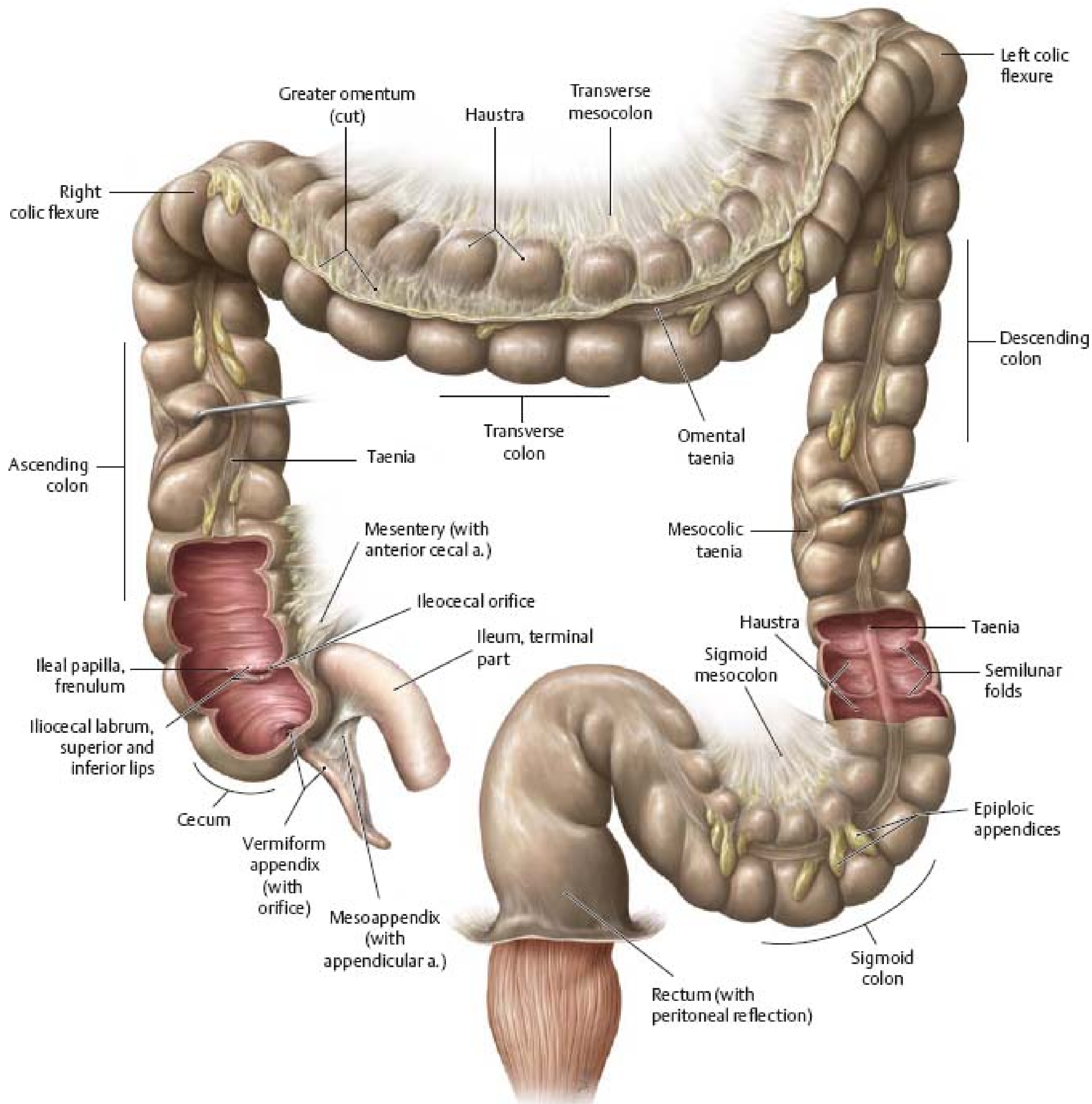
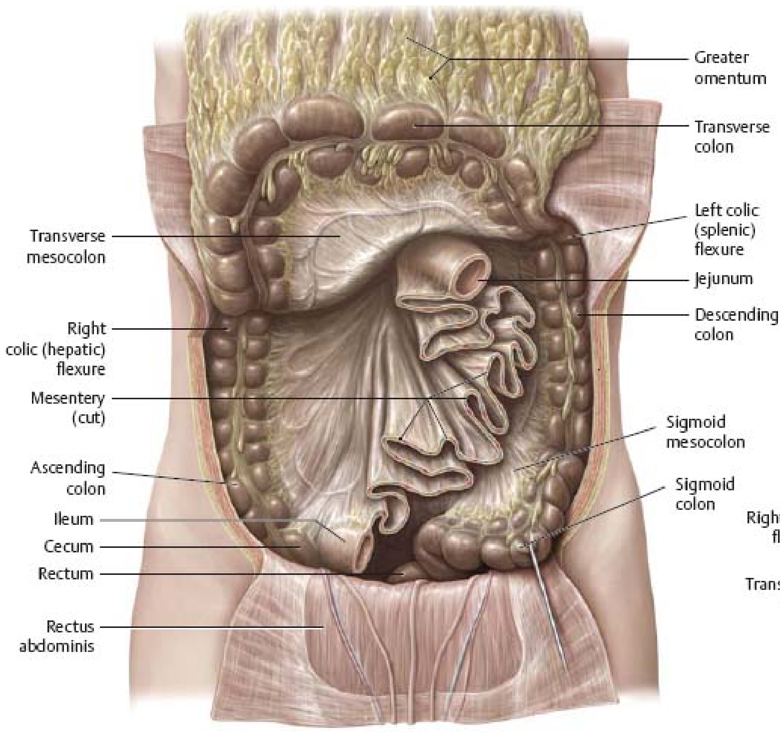
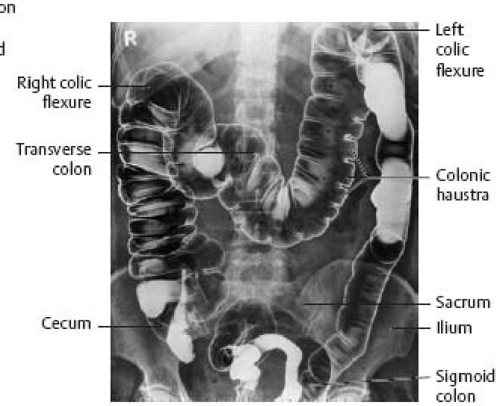


Fig. 13.16 **Large intestine in situ**



A Anterior view. *Reflected:* Transverse colon and greater omentum. *Removed:* Intraperitoneal small intestine.



B Normal radiographic appearance. Double-contrast radiograph, anterior view.

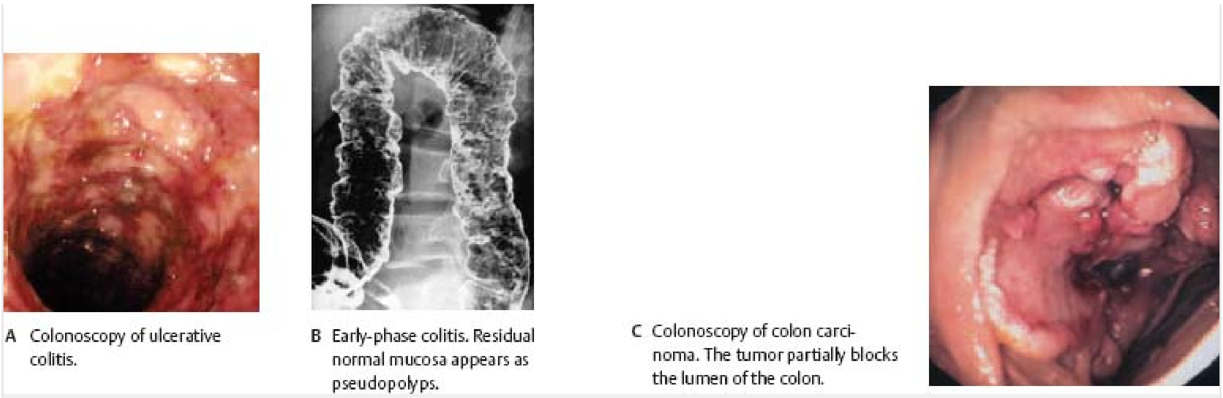
Clinical

Colitis

Ulcerative colitis is a chronic inflammation of the large intestine, often starting in the rectum. Typical symptoms include diarrhea (sometimes with blood), pain, weight loss, and inflammation of other organs. Patients are also at higher risk for colorectal carcinomas.

Colon carcinoma

Malignant tumors of the colon and rectum are among the most frequent solid tumors. More than 90% occur in patients over the age of 50. In early stages, the tumor may be asymptomatic; later symptoms include loss of appetite, changes in bowel movements, and weight loss. Blood in the stools is particularly incriminating, necessitating a thorough examination. Hemorrhoids are not a sufficient explanation for blood in stools unless all other tests (including a colonoscopy) are negative.



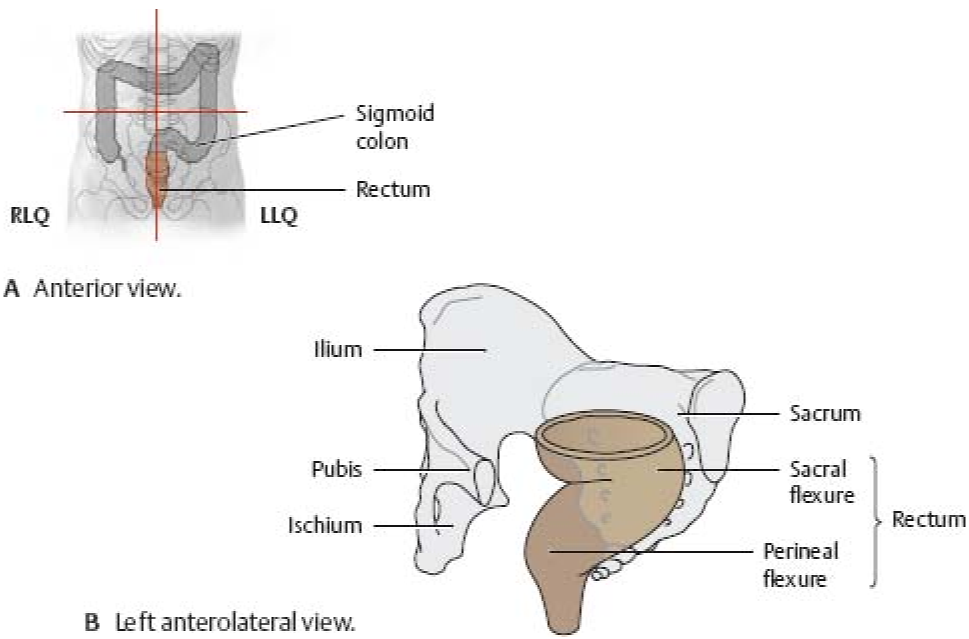
A Colonoscopy of ulcerative colitis.

B Early-phase colitis. Residual normal mucosa appears as pseudopolyps.

C Colonoscopy of colon carcinoma. The tumor partially blocks the lumen of the colon.

Rectum & Anal Canal

Fig. 13.17 Rectum: Location



A Anterior view.

B Left anterolateral view.

Fig. 13.18 Closure of the rectum

Left lateral view. The puborectalis acts as a muscular sling that kinks the anorectal junction. It functions in the maintenance of fecal continence.

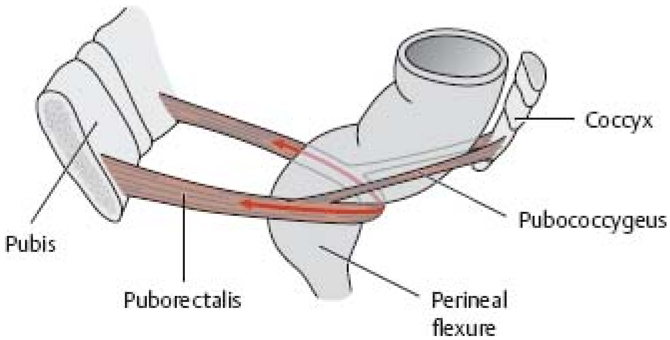


Fig. 13.19 **Rectum in situ**

Coronal section, anterior view of the female pelvis. The upper third of the rectum is covered with visceral peritoneum on its anterior and lateral sides. The middle third is covered only anteriorly and the lower third is inferior to the parietal peritoneum.

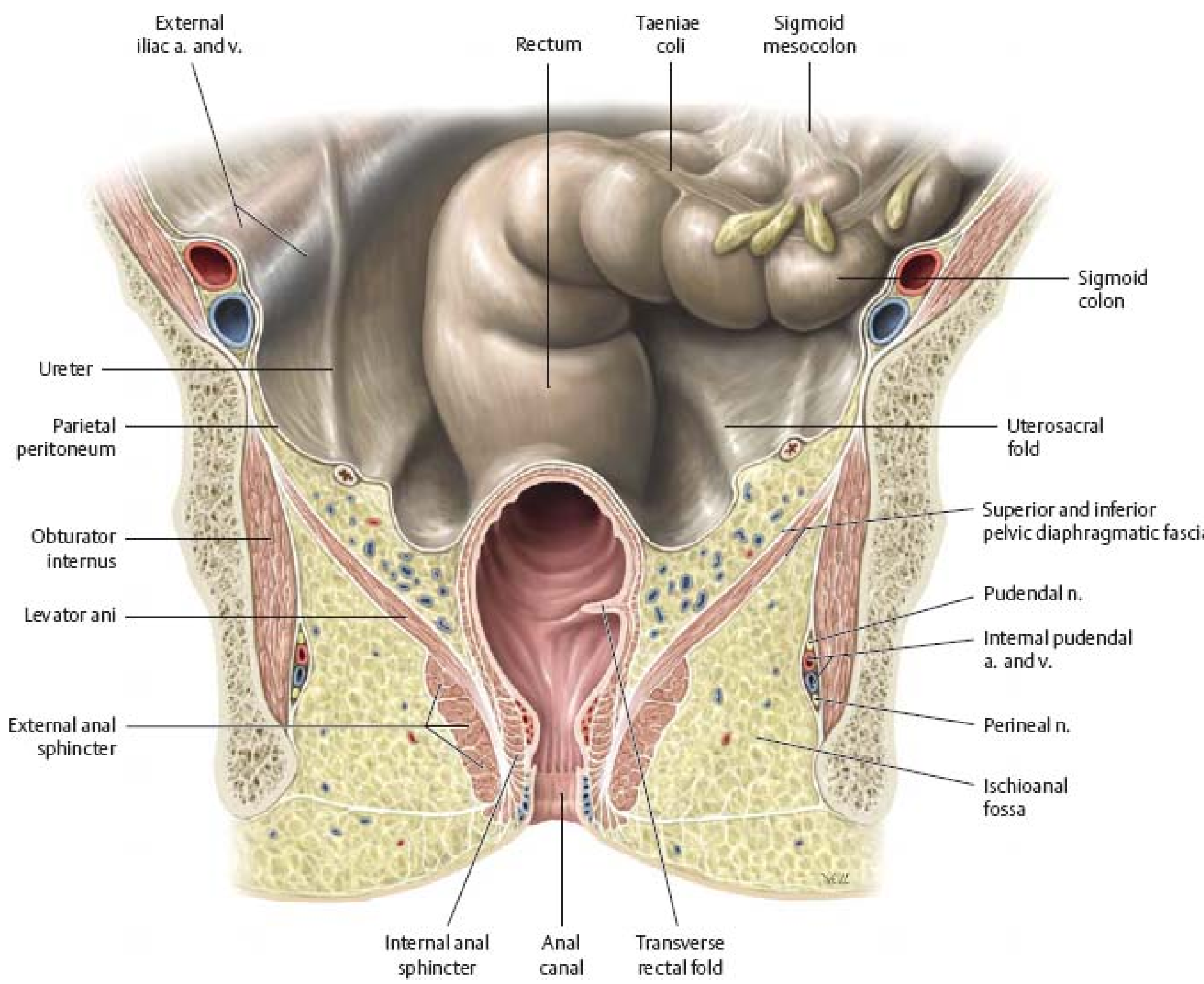
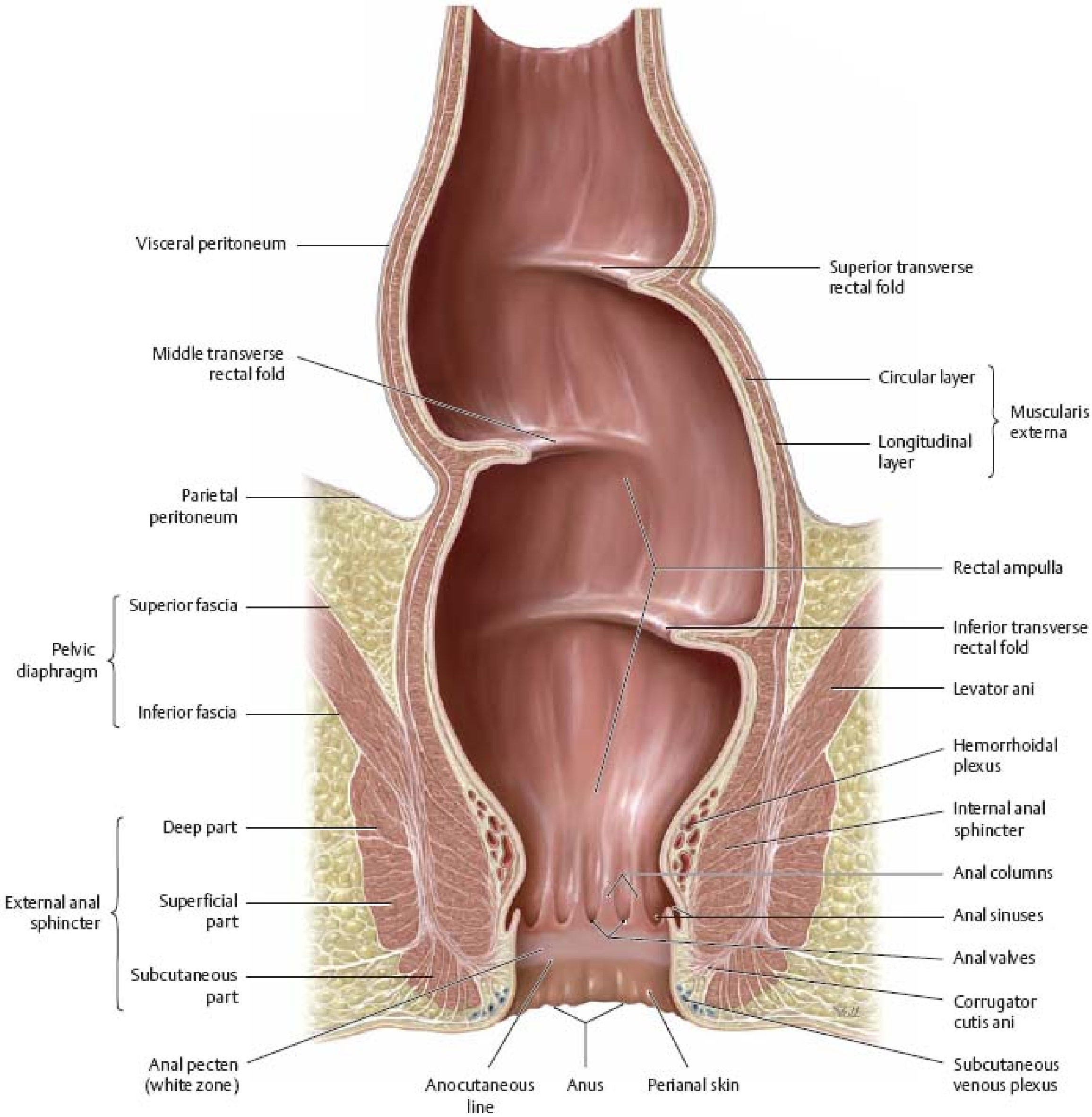


Fig. 13.20 Rectum and anal canal

Coronal section, anterior view with the anterior wall removed.



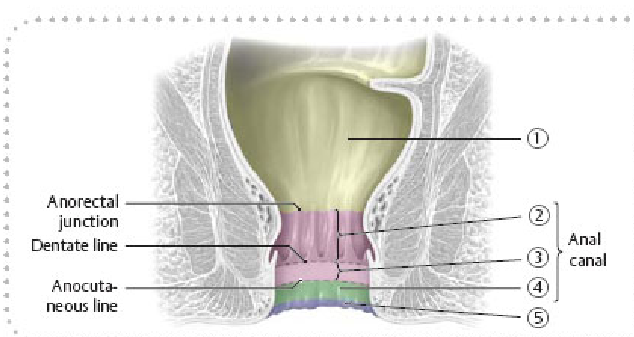


Table 13.1 Regions of the rectum and anal canal

Region		Epithelium
① Rectum		Colon-like with crypts; simple columnar with goblet cells
Anal canal	② Columnar zone	Stratified, nonkeratinized squamous
	③ Anal pecten	
	④ Cutaneous zone	Stratified, keratinized squamous with sebaceous glands
⑤ Perianal skin (pigmented)		Stratified, keratinized squamous with sebaceous glands, hairs, and sweat glands

Liver: Overview

Fig. 13.21 Liver: Location

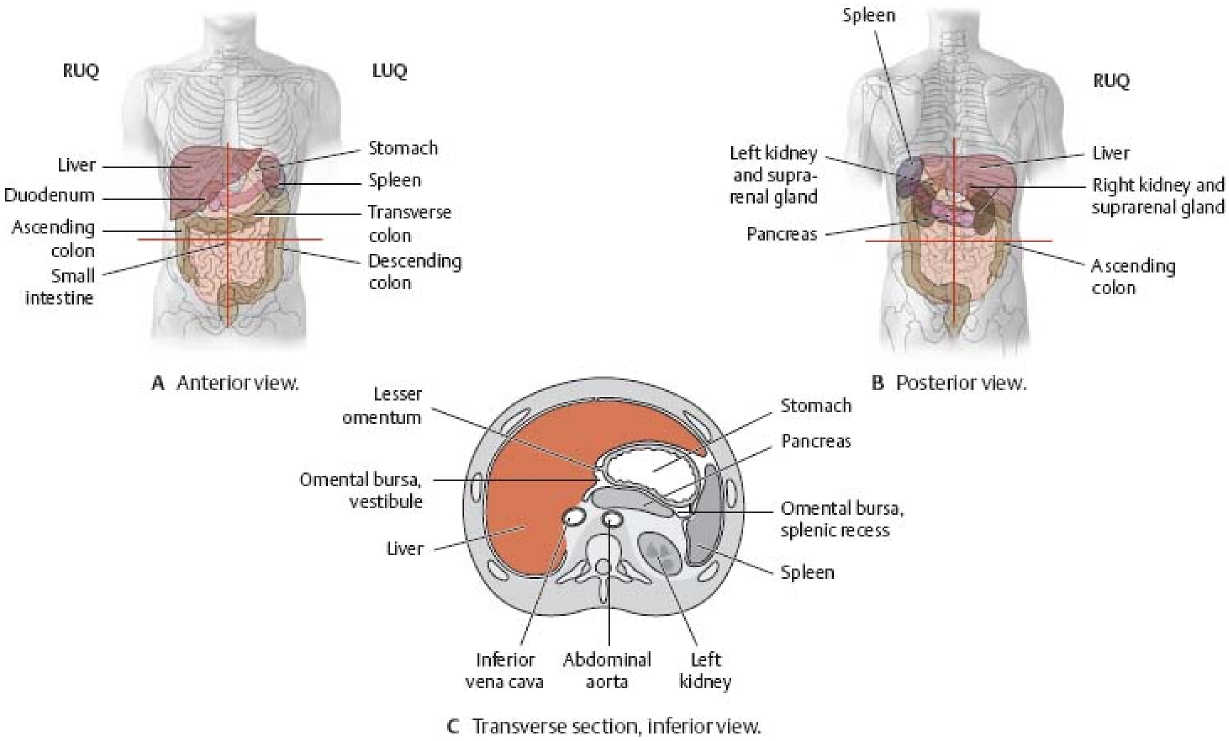


Fig. 13.22 Liver in situ

Anterior view with liver retracted. *Removed:* Stomach, jejunum, and ileum. The liver is intraperitoneal except for its “bare area” (see Fig. 13.26); its mesenteries include the falciform, coronary, and triangular ligaments (See Fig. 13.27).

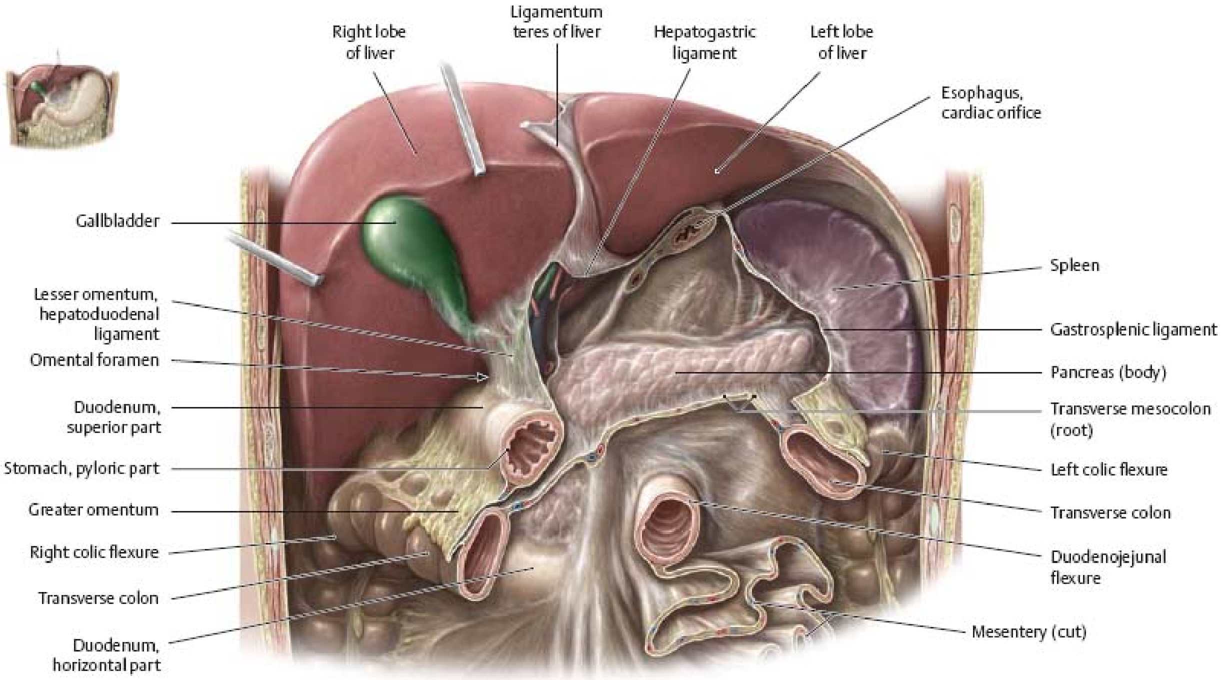
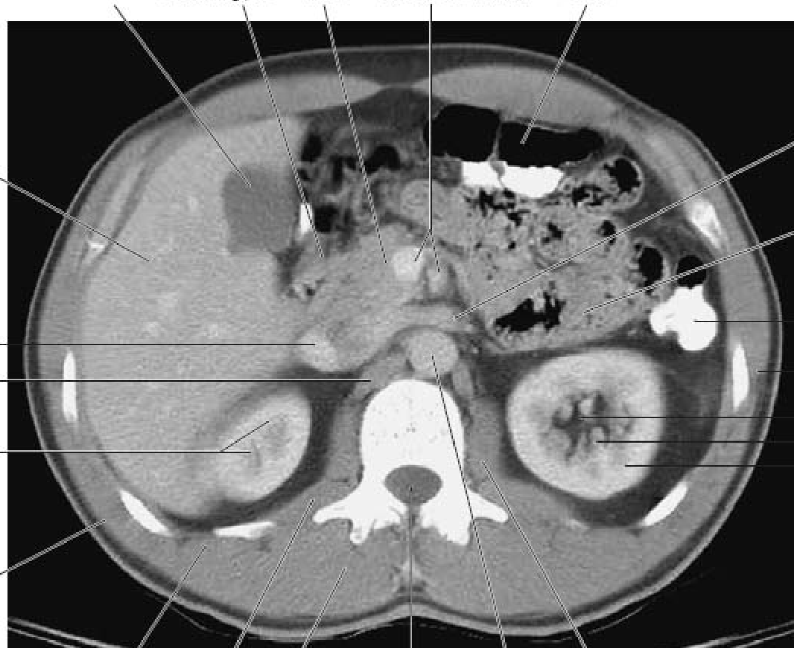


Fig. 13.23 **Abdominal MRI**

Inferior view.

A Transverse section through T12 vertebra.



B Transverse section through L2 vertebra.

Liver: Segments & Lobes

Fig. 13.24 Segmentation of the liver

Anterior view. The components portal triad (hepatic artery, portal vein, and hepatic duct, see pp. 172, 219) divides the liver into hepatic segments (see Table 13.2).

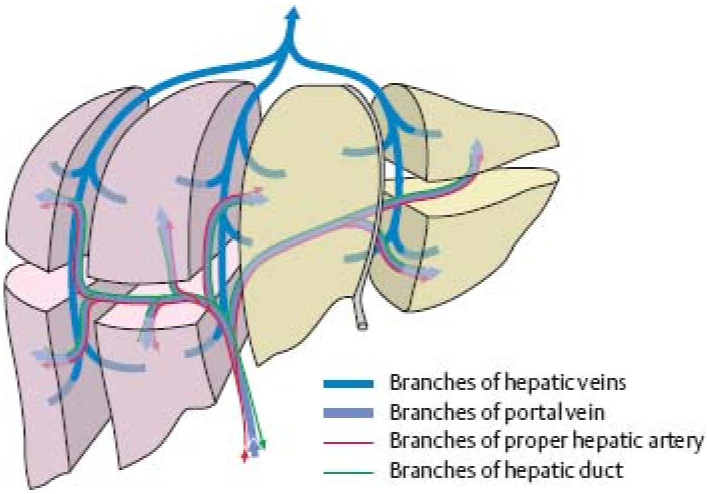


Fig. 13.25 Liver: Areas of organ contact

Visceral surface, inferior view.

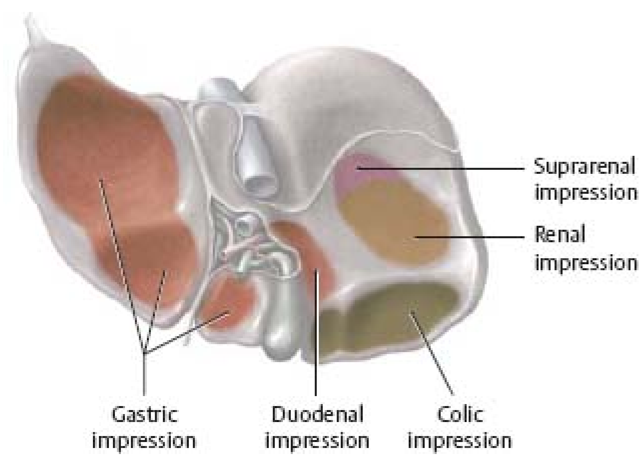
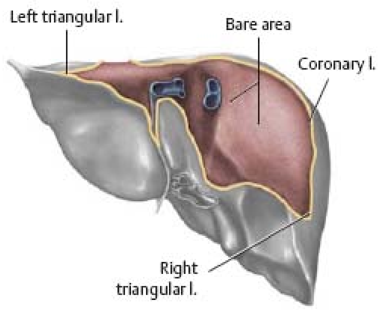
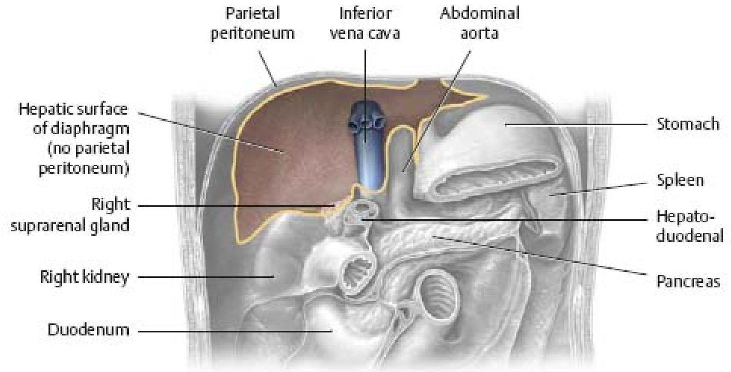


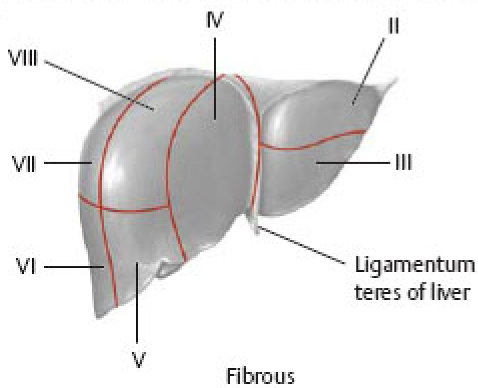
Fig. 13.26 Attachment of liver to diaphragm



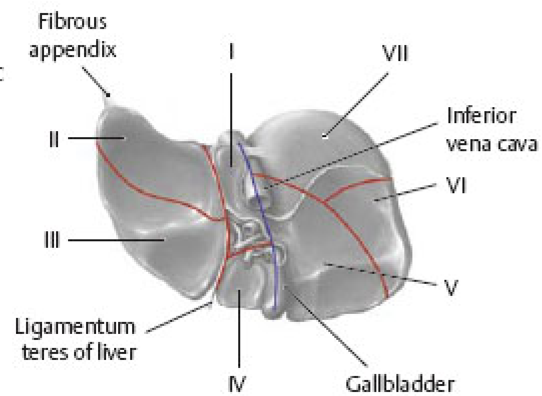
A Diaphragmatic surface of the liver, posterior view.



B Hepatic surface of the diaphragm, anterior view.



A Diaphragmatic surface, anterior view.



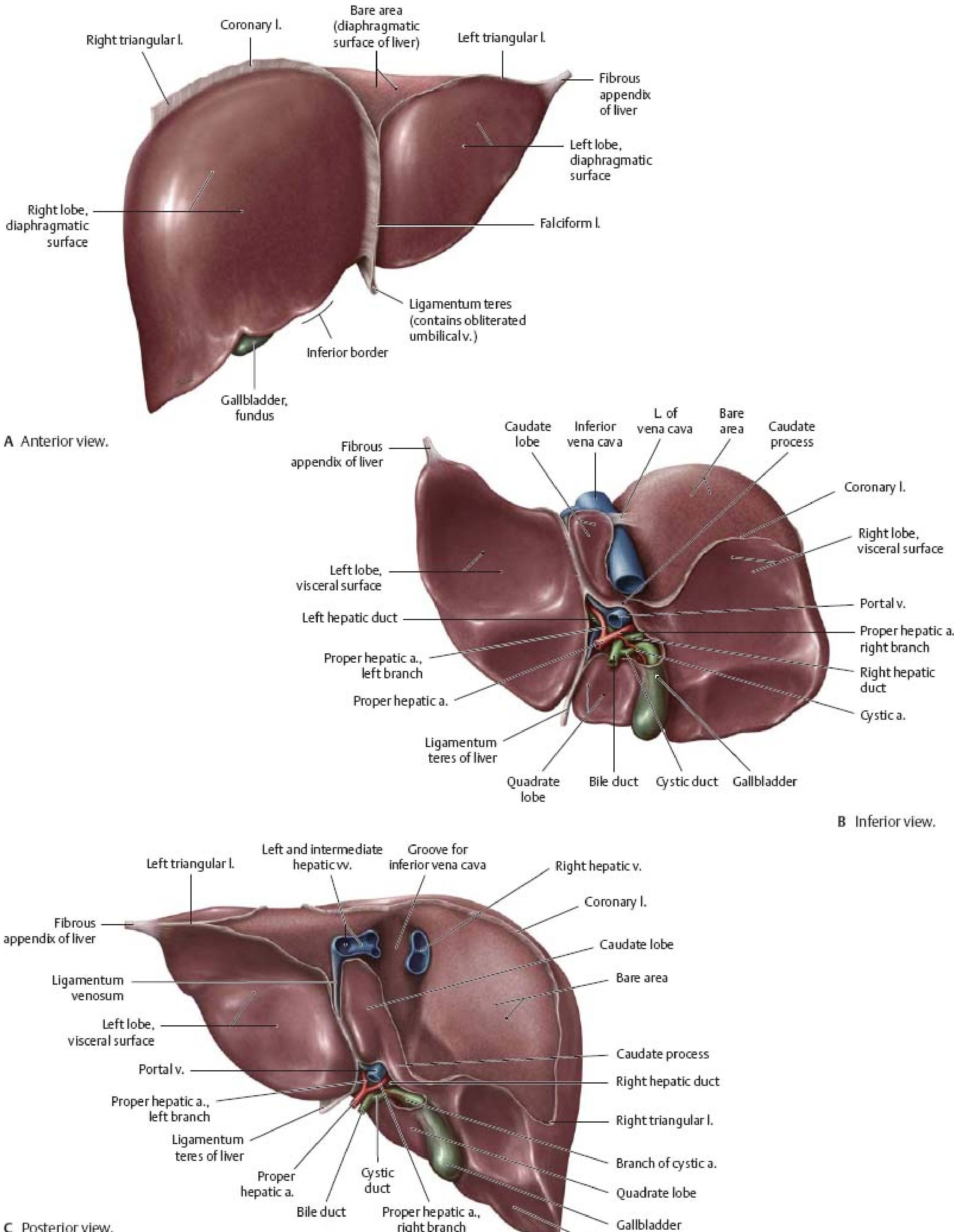
B Visceral surface, inferior view.

Table 13.2 Hepatic segments

Part	Division	Segment	
Left part	Posterior part	I	Caudate lobe
	Left lateral division	II	Left posterolateral
		III	Left anterolateral
	Left medial division	IV	Left medial
Right part	Right medial division	V	Right anteromedial
		VI	Right anterolateral
	Right lateral division	VII	Right posterolateral
		VIII	Right posteromedial

Fig. 13.27 **Surfaces of the liver**

The liver is divided by its ligaments into four lobes: right, left, caudate, and quadrate.



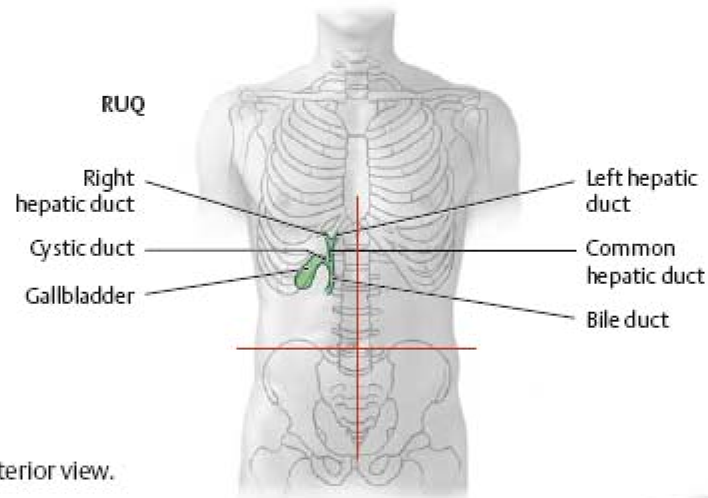
A Anterior view.

B Inferior view.

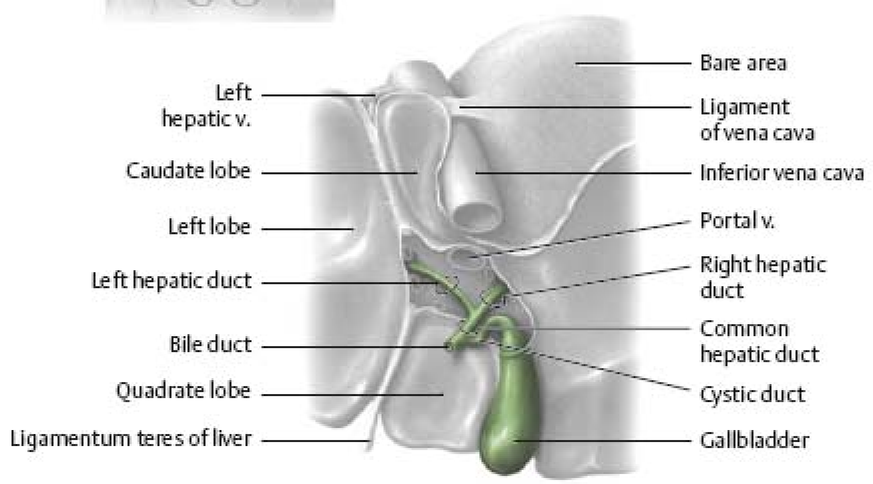
C Posterior view.

Gallbladder & Bile Ducts

Fig. 13.28 Gallbladder: Location



A Anterior view.



B Inferior view.

Fig. 13.29 Hepatic bile ducts: Location

Projection onto surface of the liver, anterior view.

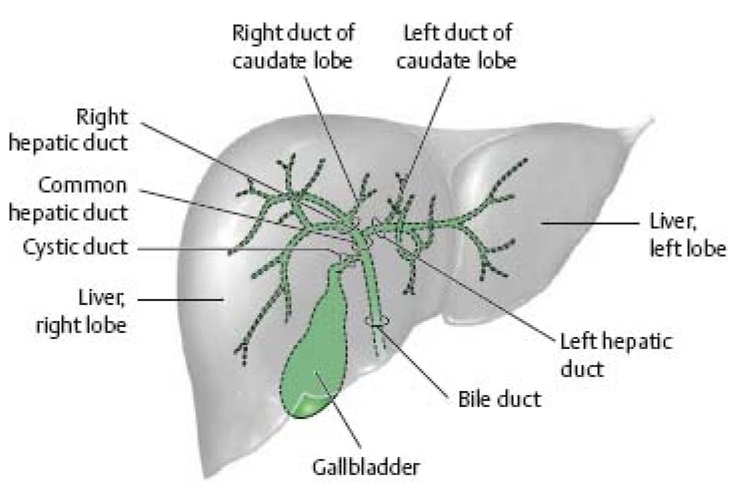
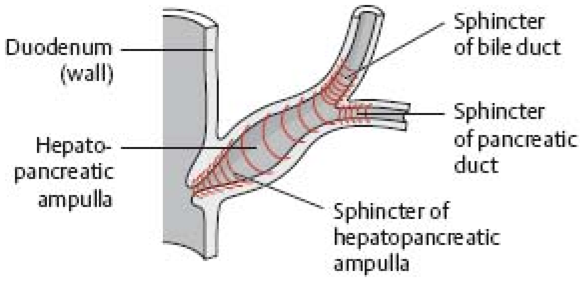
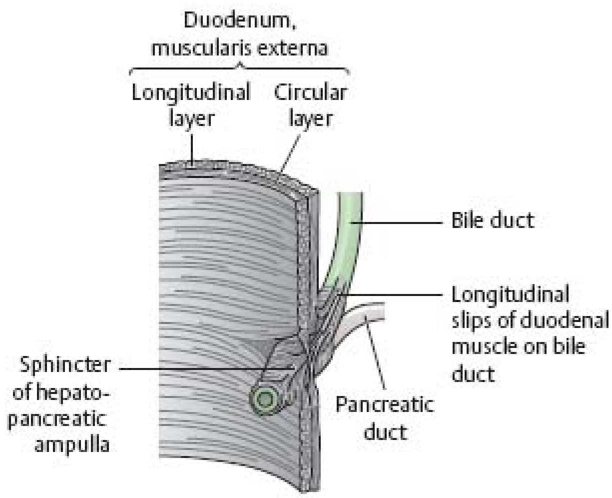


Fig. 13.30 Biliary sphincter system



A Sphincters of the pancreatic and bile ducts.



B Sphincter system in the duodenal wall.

Fig. 13.31 Extrahepatic bile ducts

Anterior view. *Opened:* Gallbladder and duodenum.

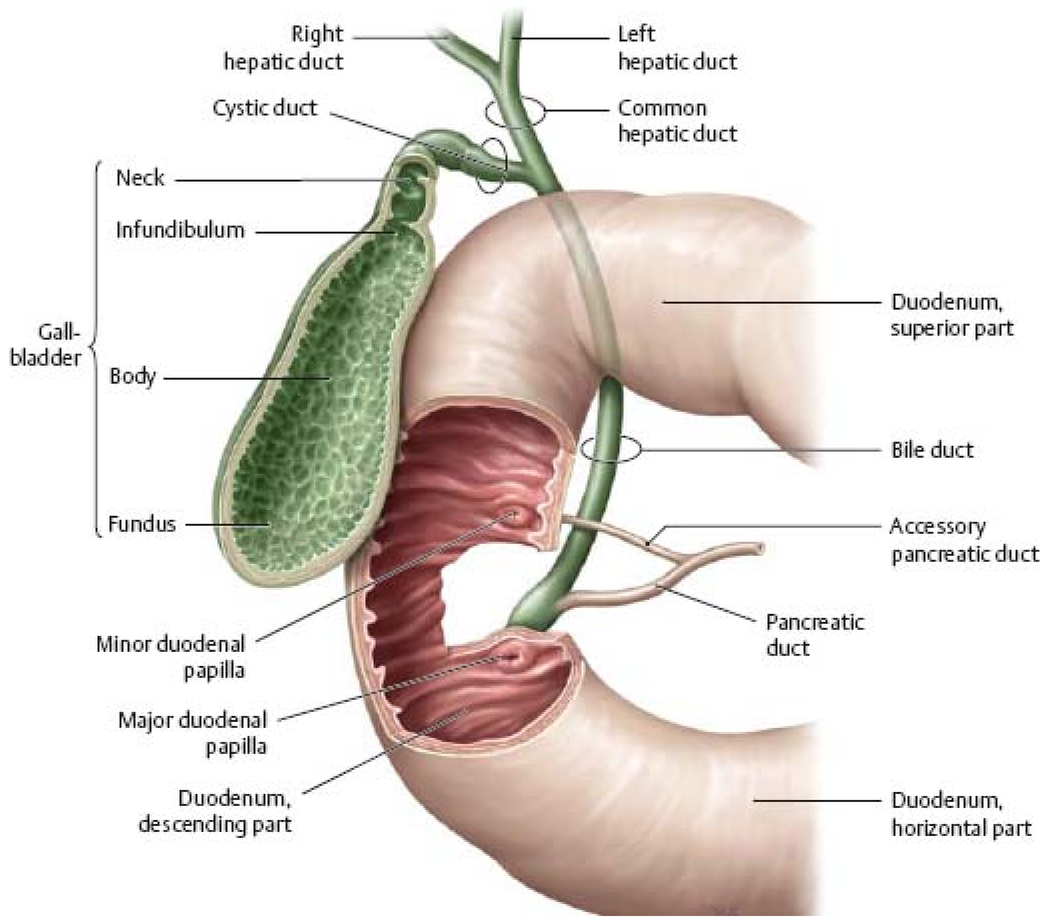
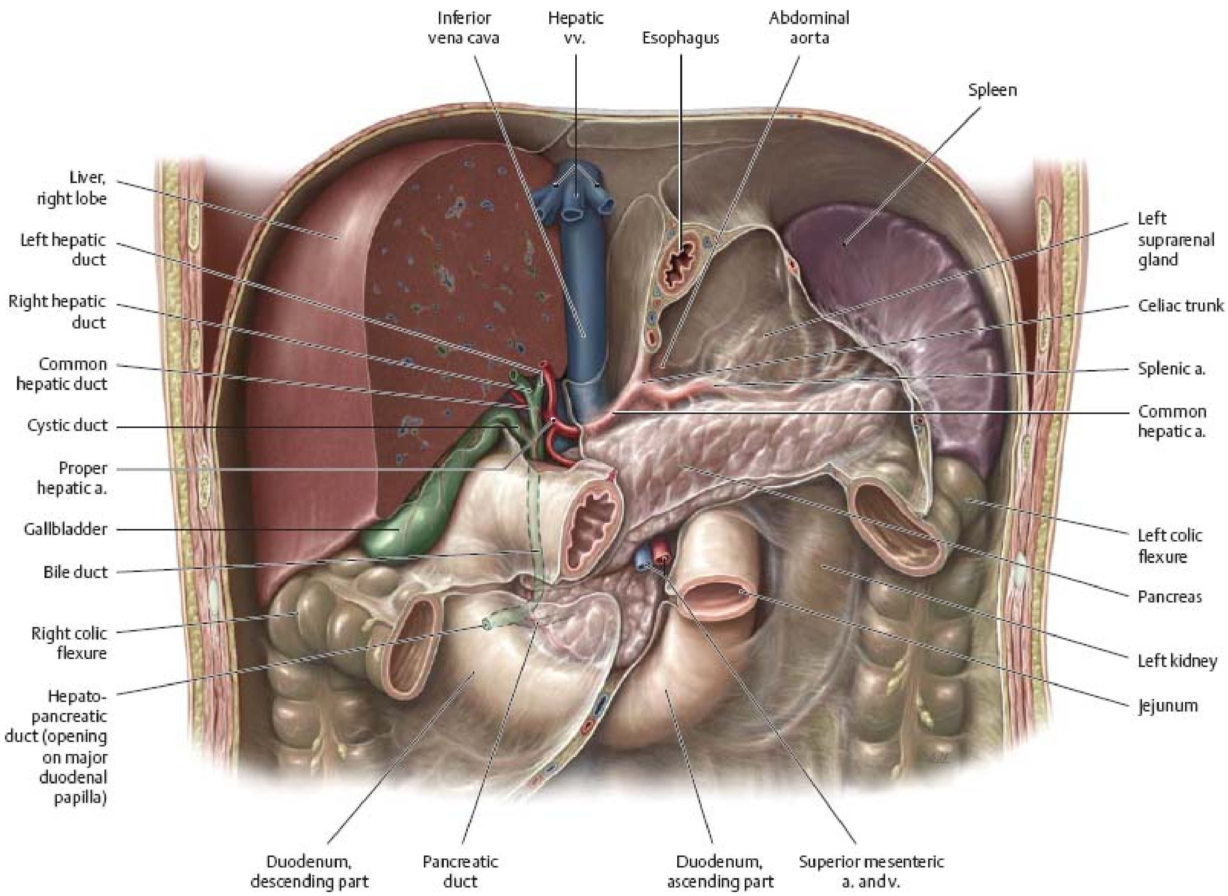


Fig. 13.32 **Biliary tract in situ**

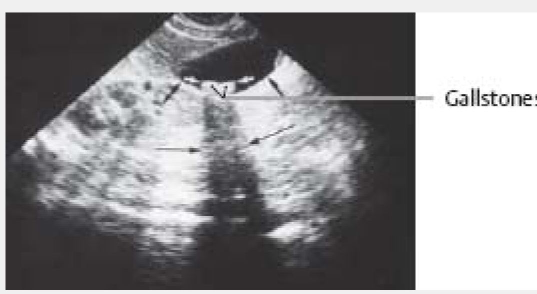
Anterior view. *Removed:* Stomach, small intestine, transverse colon, and large portions of the liver. The gallbladder is intraperitoneal, covered by visceral peritoneum where it is not attached to the liver.



Clinical

Obstruction of the bile duct

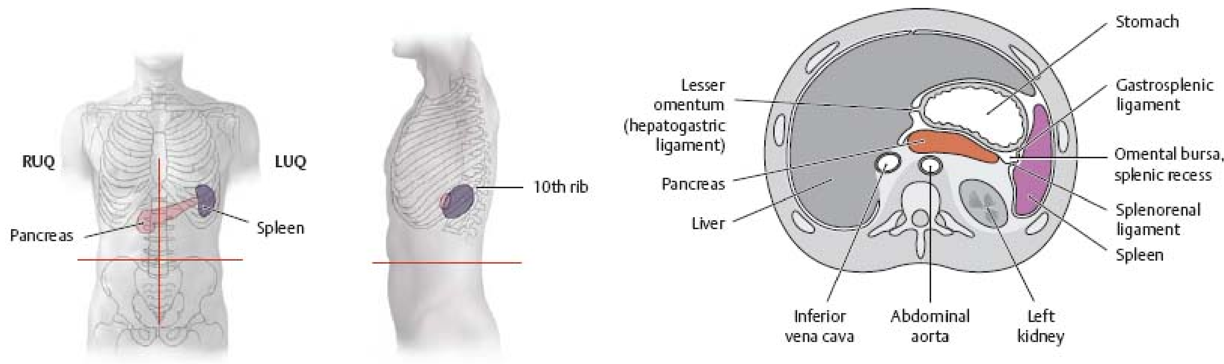
As bile is stored and concentrated in the gallbladder, certain substances, such as cholesterol, may crystallize, resulting in the formation of gallstones. Migration of gallstones into the bile duct causes severe pain (colic). Gallstones may also block the pancreatic duct in the papillary regions, causing highly acute or even life-threatening pancreatitis.



Ultrasound appearance of two gallstones. Black arrows mark the echo-free area behind the stones.

Pancreas & Spleen

Fig. 13.33 Pancreas and spleen: Location



A Anterior view. **B** Left lateral view. **C** Transverse section, inferior view.

Fig. 13.34 Pancreas

Anterior view with dissection of the pancreatic duct.

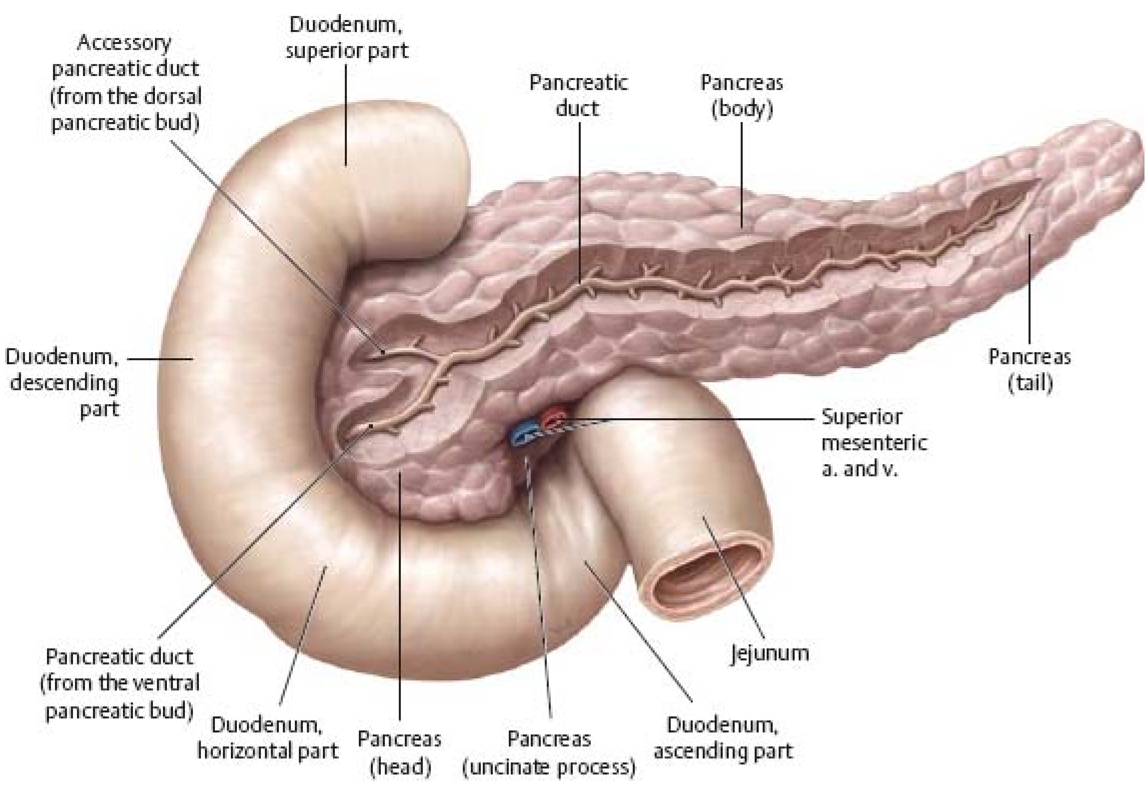
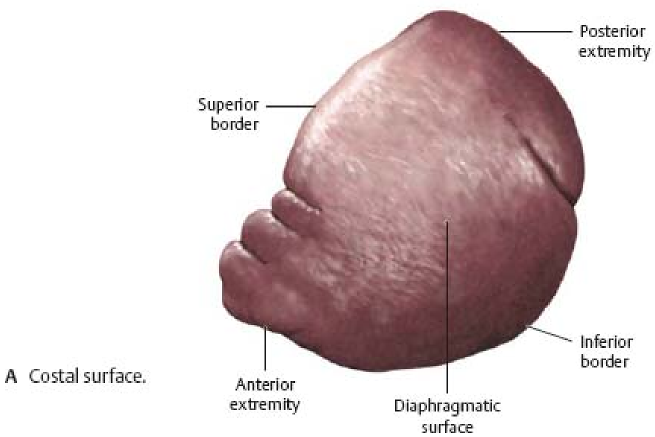
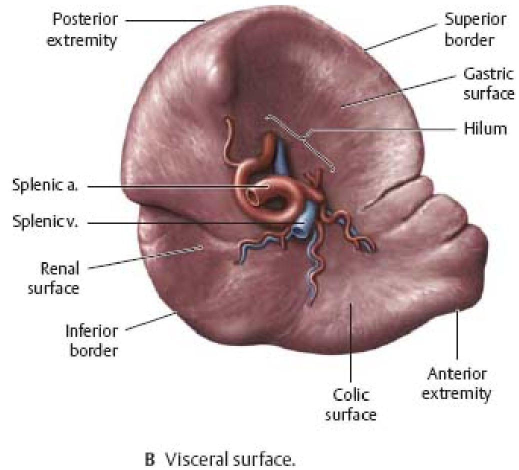


Fig. 13.35 Spleen



A Costal surface.



B Visceral surface.

Fig. 13.36 Pancreas and spleen in situ

Anterior view. *Removed:* Liver, stomach, small intestine, and large intestine. The pancreas is retroperitoneal, while the spleen is intraperitoneal.

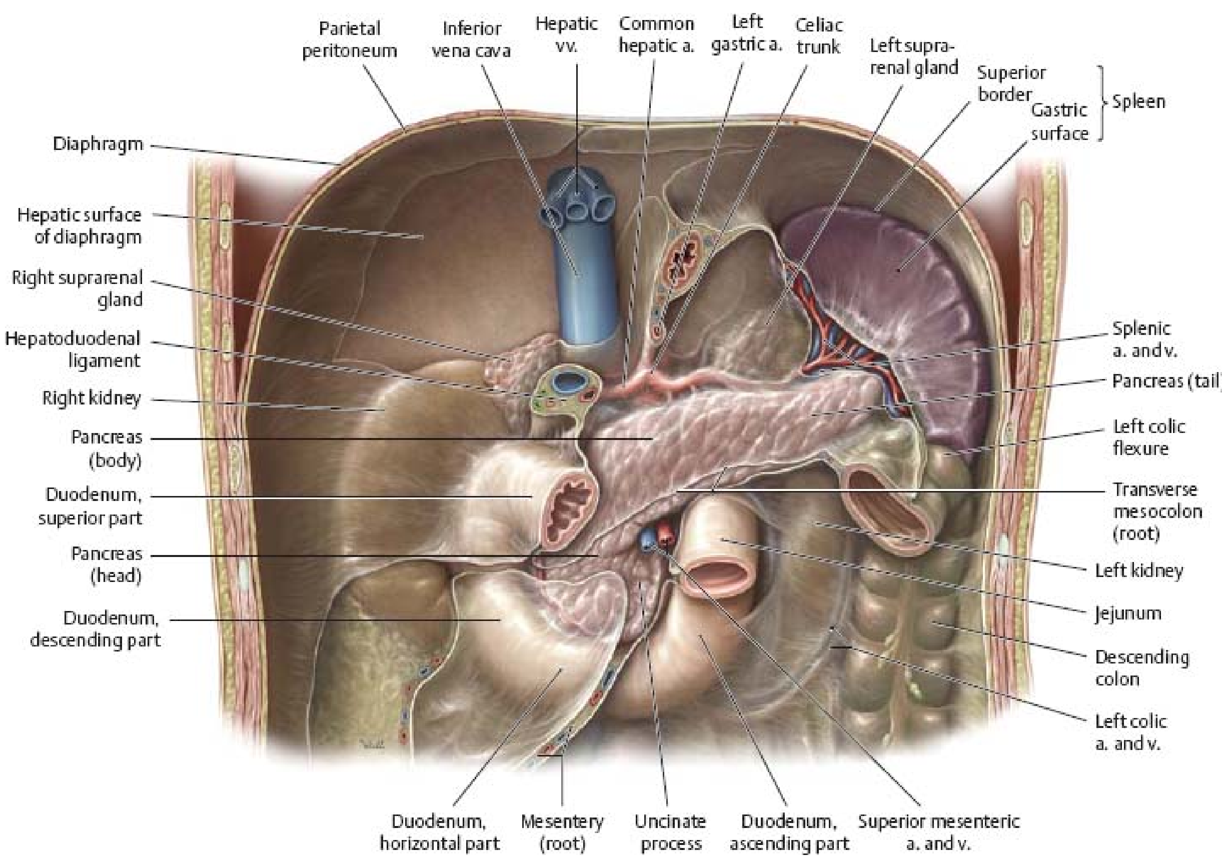
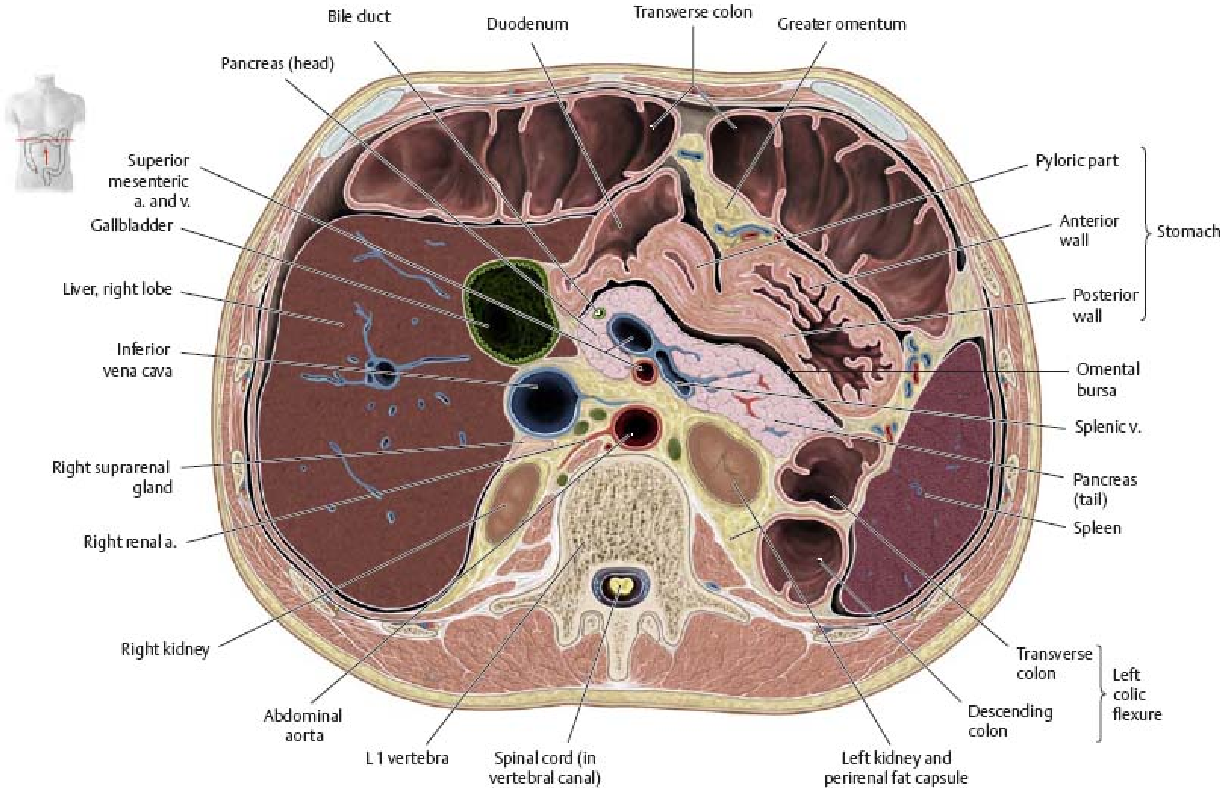


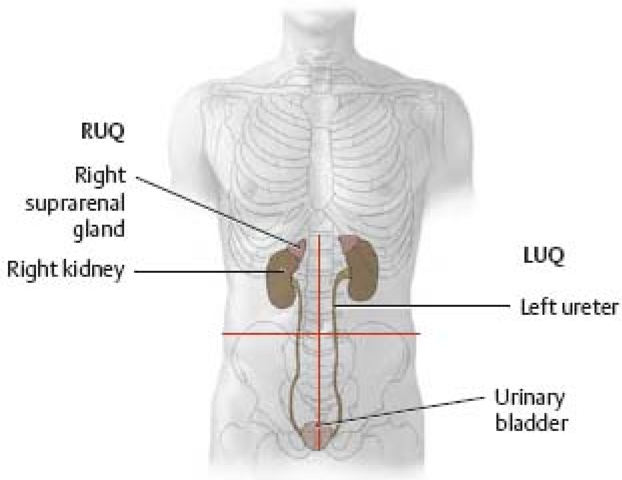
Fig. 13.37 **Pancreas and spleen: Transverse section**

Inferior view. Section through L1 vertebra.

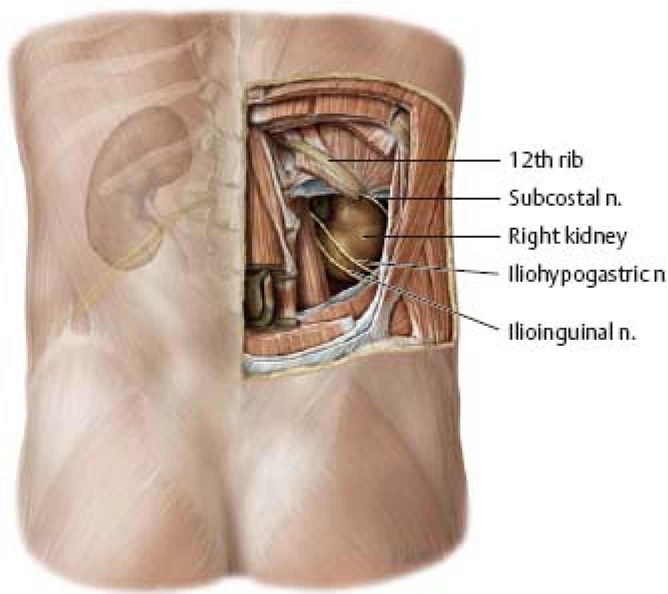


Kidneys & Suprarenal Glands: Overview

Fig. 13.38 Kidneys and suprarenal glands: Location



A Anterior view.



B Posterior view with the trunk wall opened.

Fig. 13.39 **Kidneys: Areas of organ contact**

Anterior view.

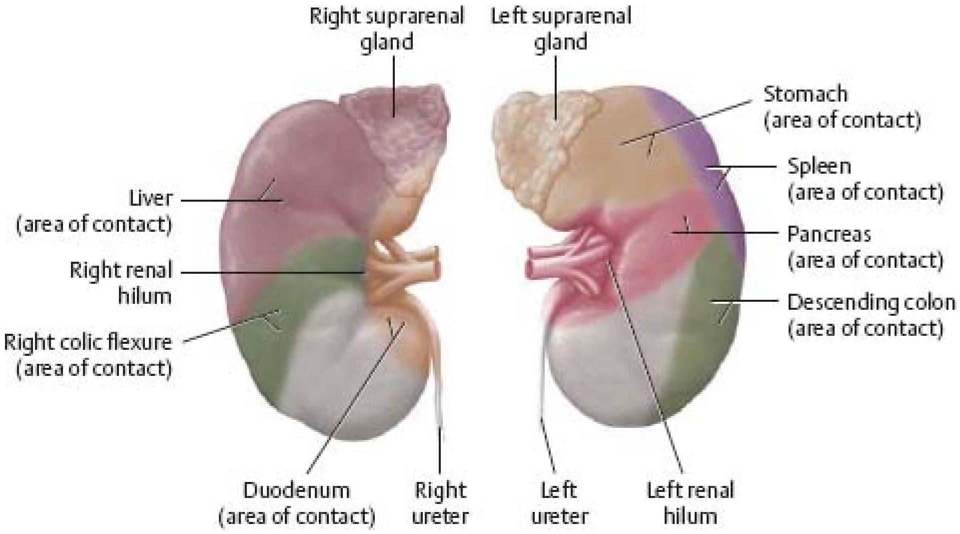


Fig. 13.40 **Right kidney in the renal bed**

Sagittal section through the right renal bed.

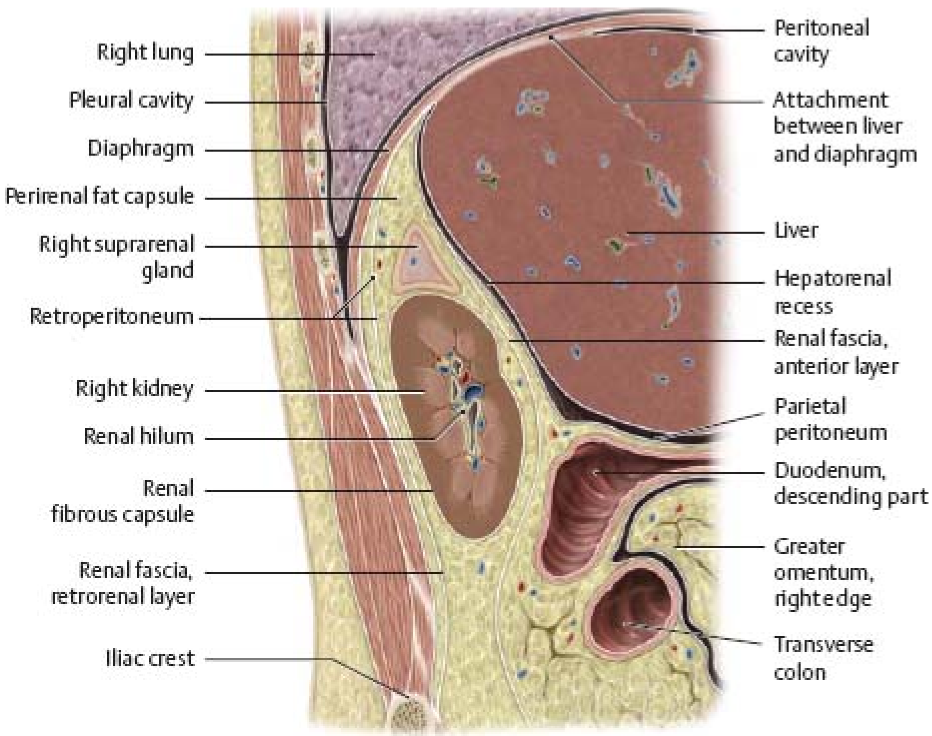


Fig. 13.41 **Suprarenal gland**

Anterior view.

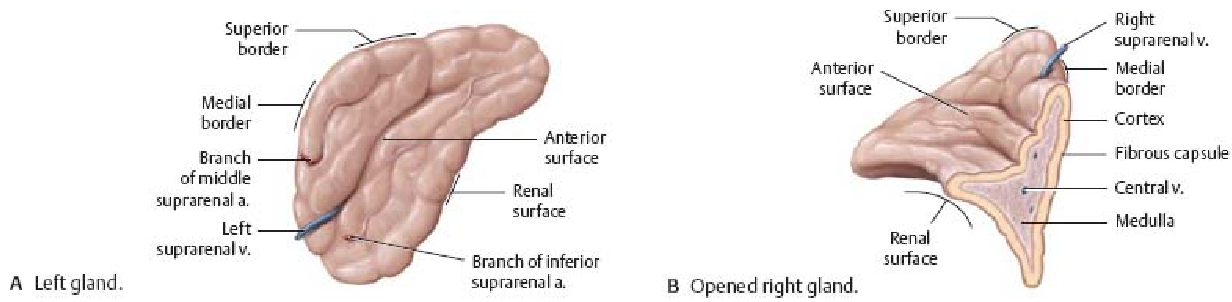
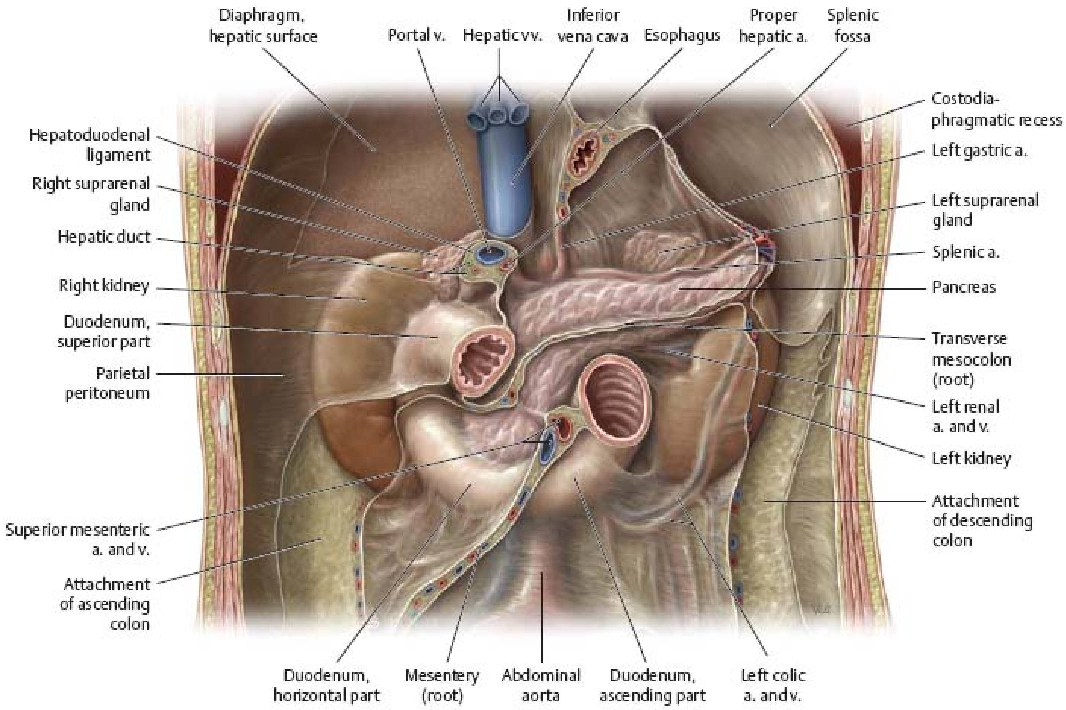
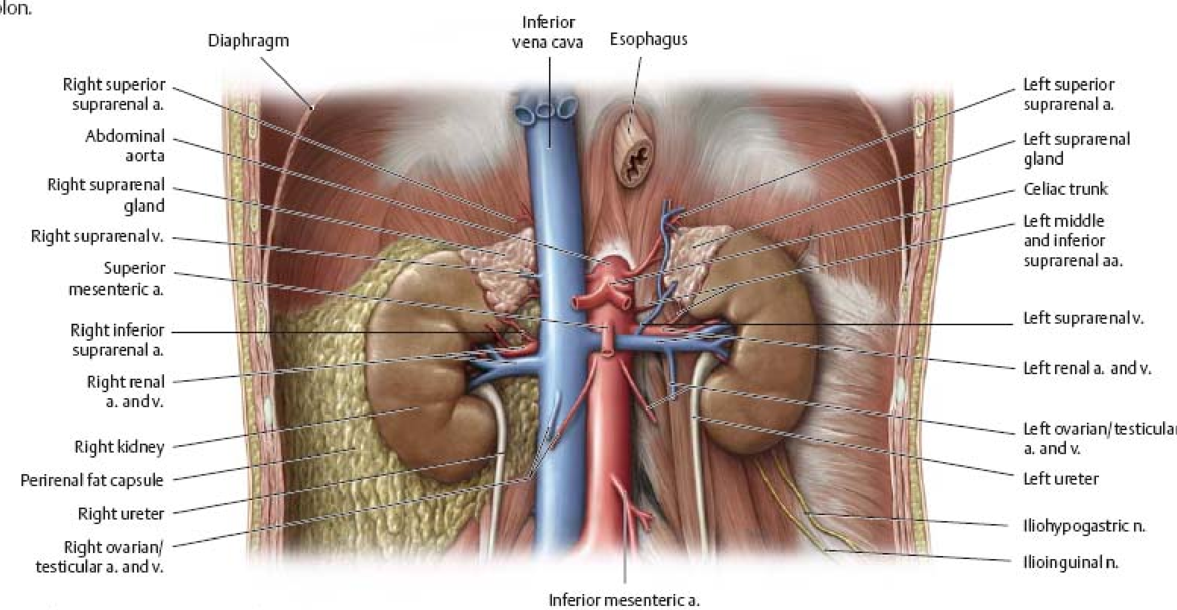


Fig. 13.42 **Kidneys and suprarenal glands in the retroperitoneum**

Anterior view. Both the kidneys and suprarenal glands are retroperitoneal.



A *Removed:* Intraperitoneal organs, along with portions of the ascending and descending colon.



B *Removed:* Peritoneum, spleen, and gastrointestinal organs, along with fat capsule (left side). *Retracted:* Esophagus.

Kidneys & Suprarenal Glands: Features

Fig. 13.43 Right kidney and suprarenal gland

Anterior view. *Removed:* Perirenal fat capsule. *Retracted:* Inferior vena cava.

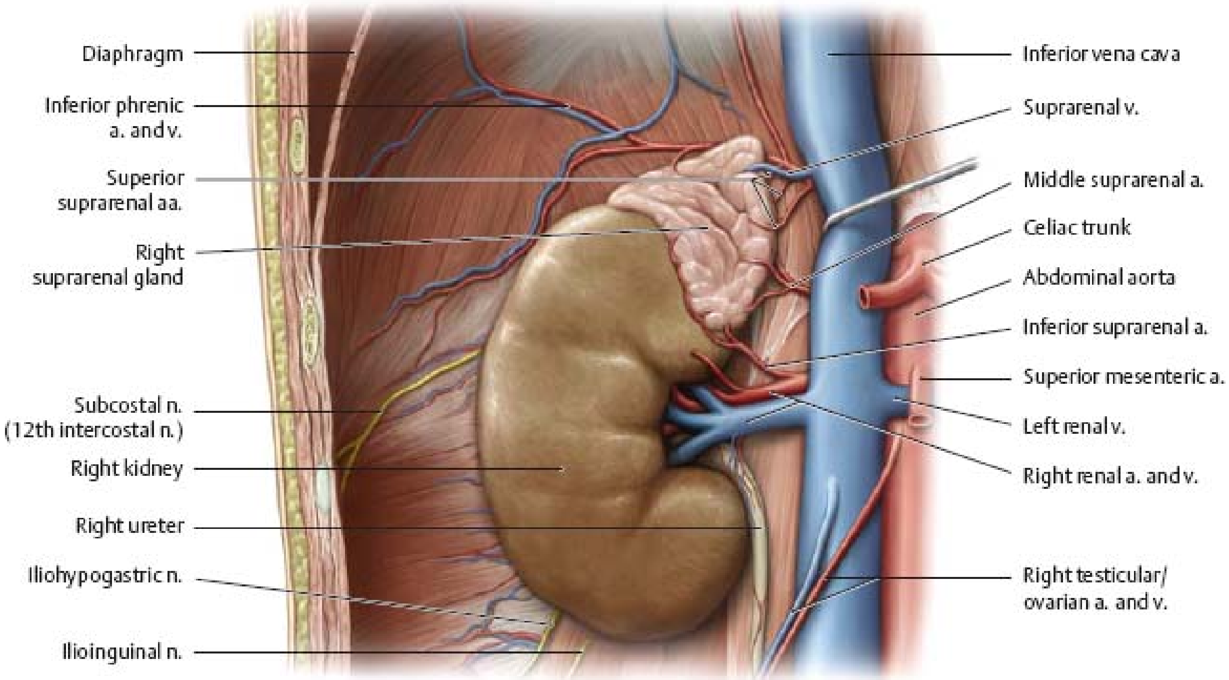


Fig. 13.44 **Left kidney and suprarenal gland**

Anterior view. *Removed:* Perirenal fat capsule. *Retracted:* Pancreas.

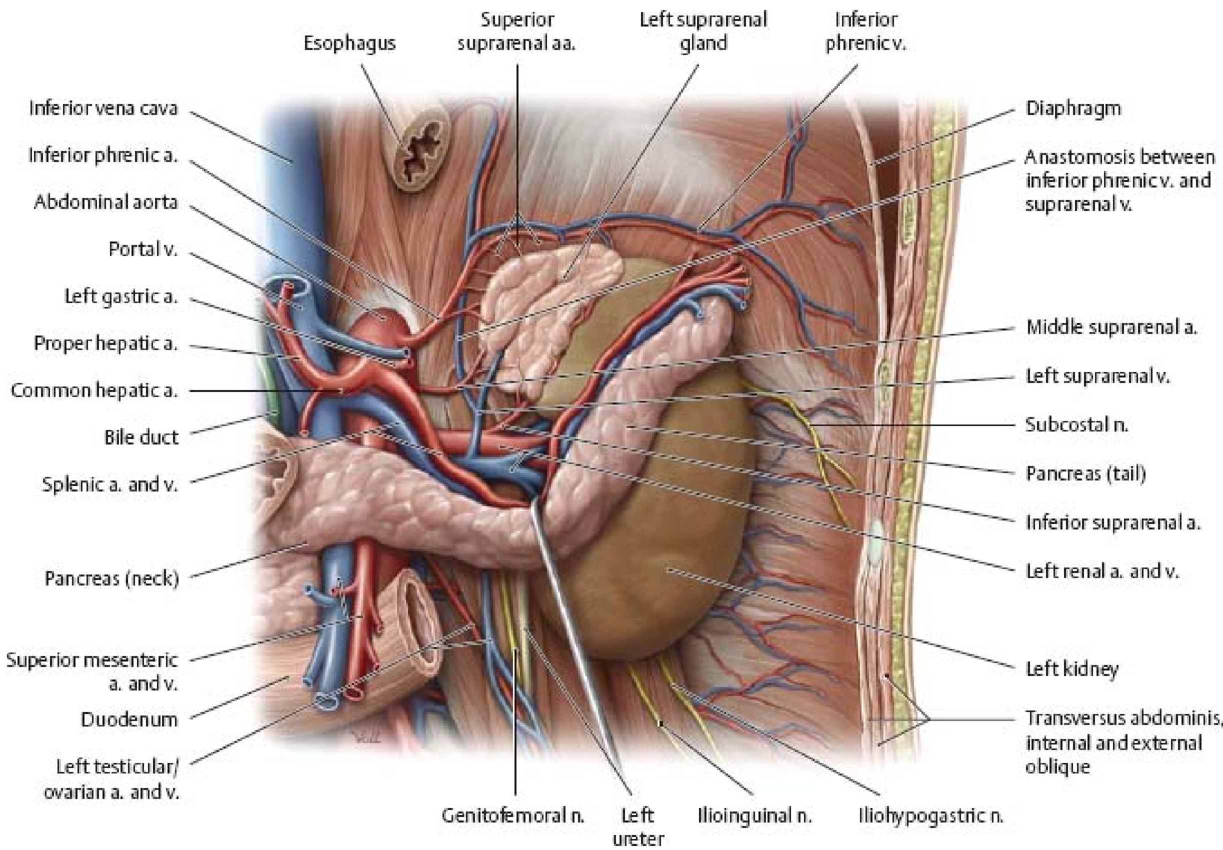
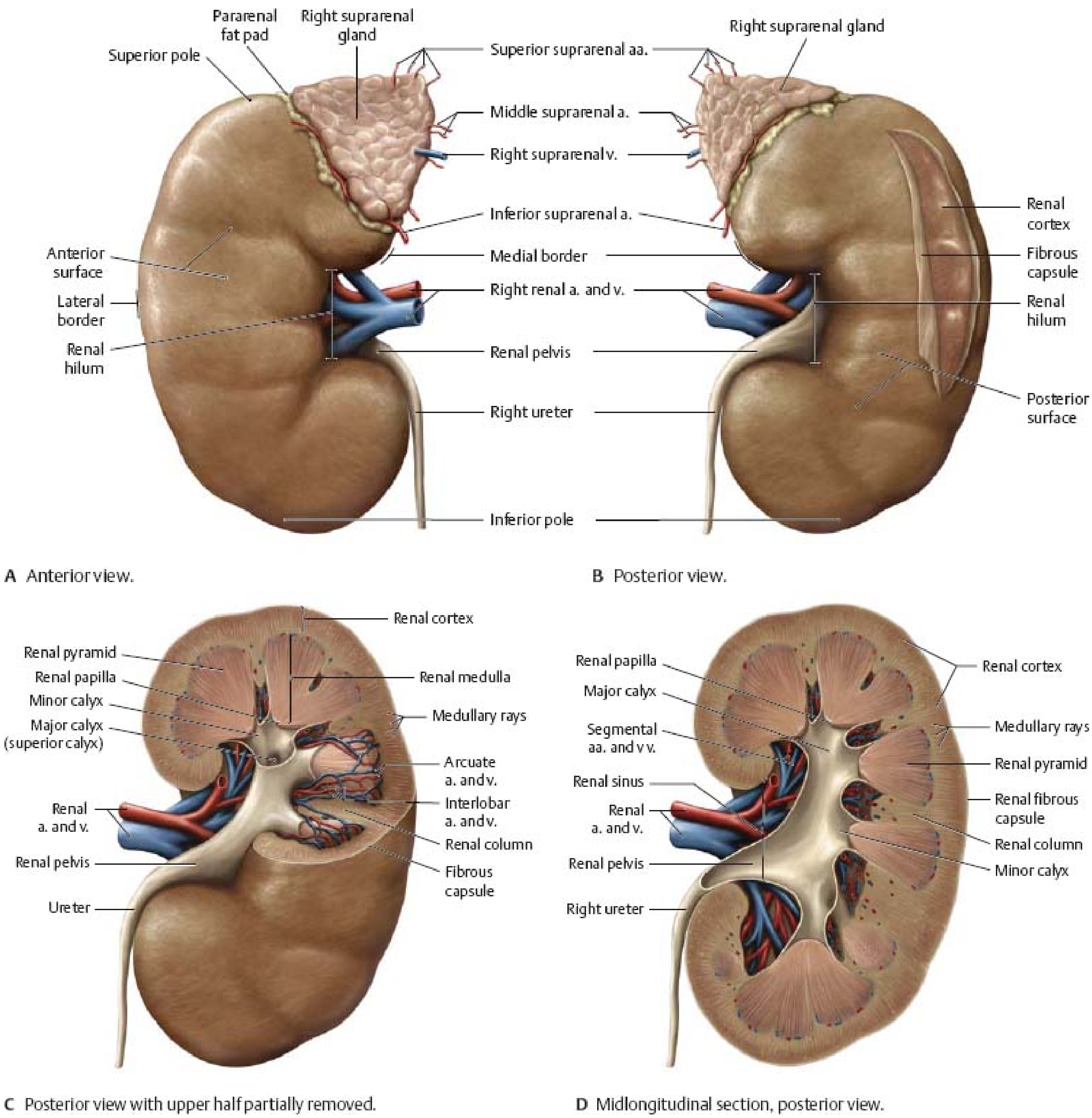


Fig. 13.45 **Kidney: Structure**

Right kidney with suprarenal gland.



A Anterior view.

B Posterior view.

C Posterior view with upper half partially removed.

D Midlongitudinal section, posterior view.

Ureter

The ureters cross the common iliac artery at its bifurcation into the external and internal iliac arteries.

Fig. 13.46 Ureters: Location

Anterior view.

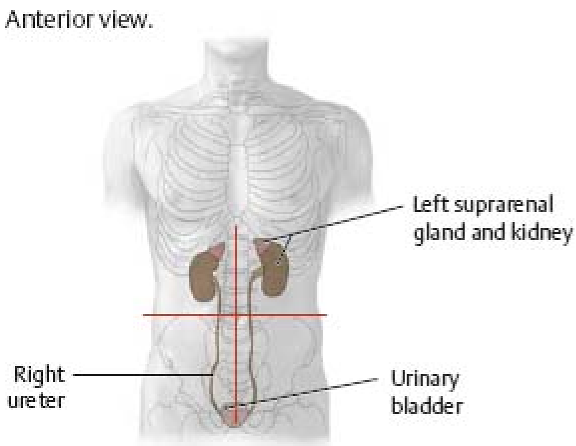


Fig. 13.47 Ureters in situ

Anterior view, male abdomen. Removed: Nonurinary organs and rectal stump. The ureters are retroperitoneal.

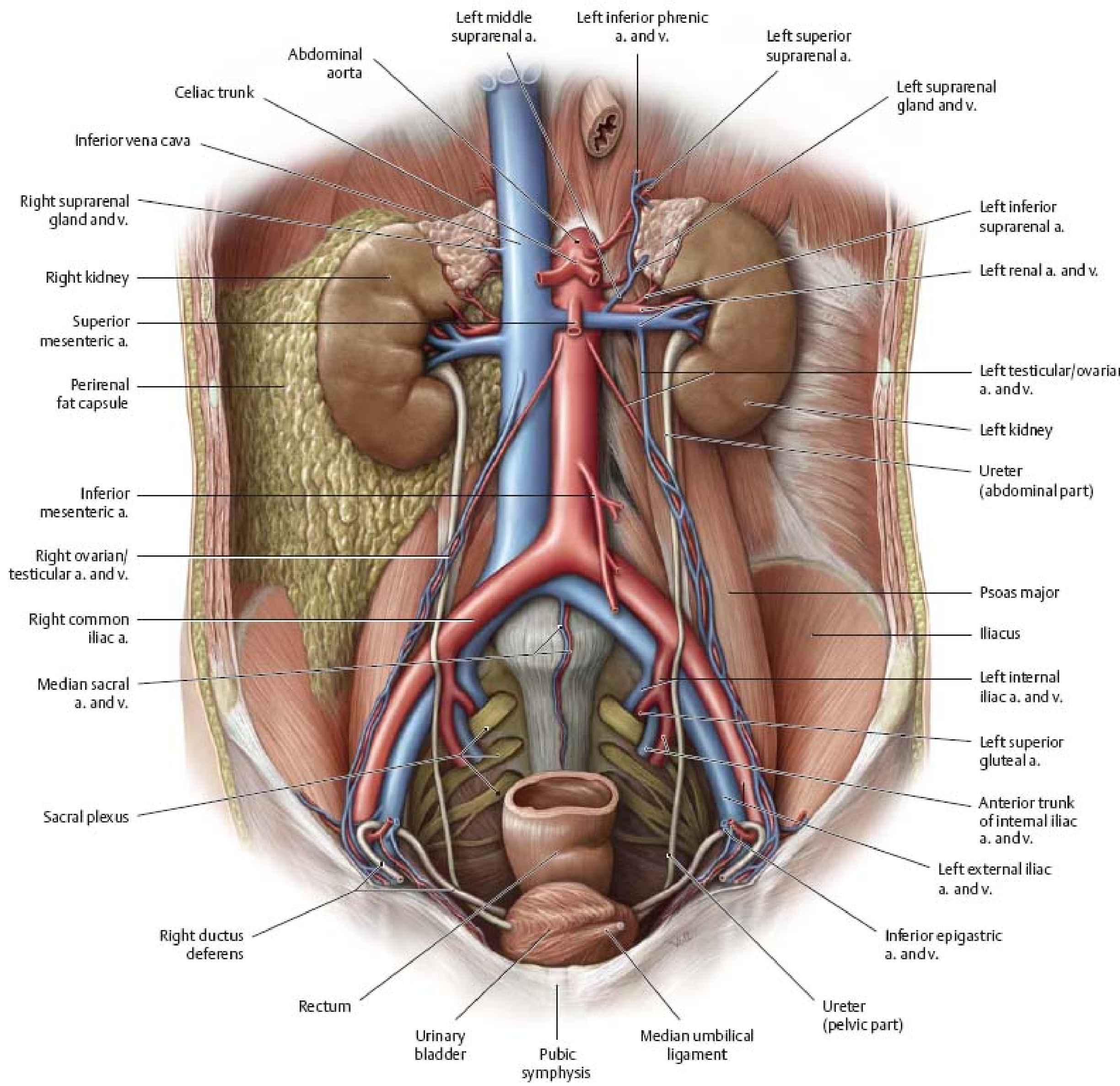


Fig. 13.48 **Ureter in the male pelvis**

Superior view.

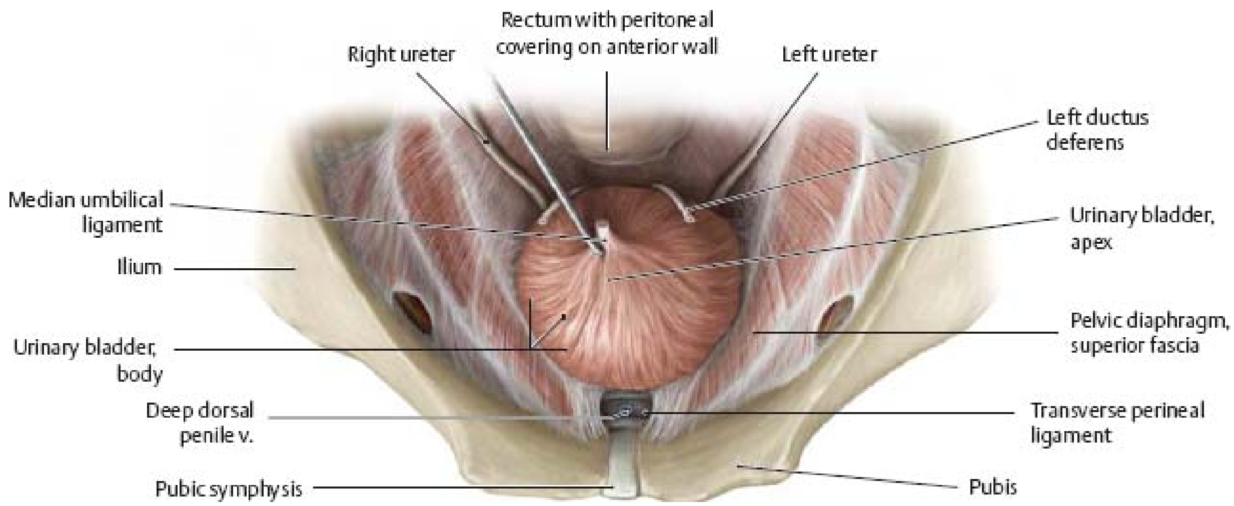
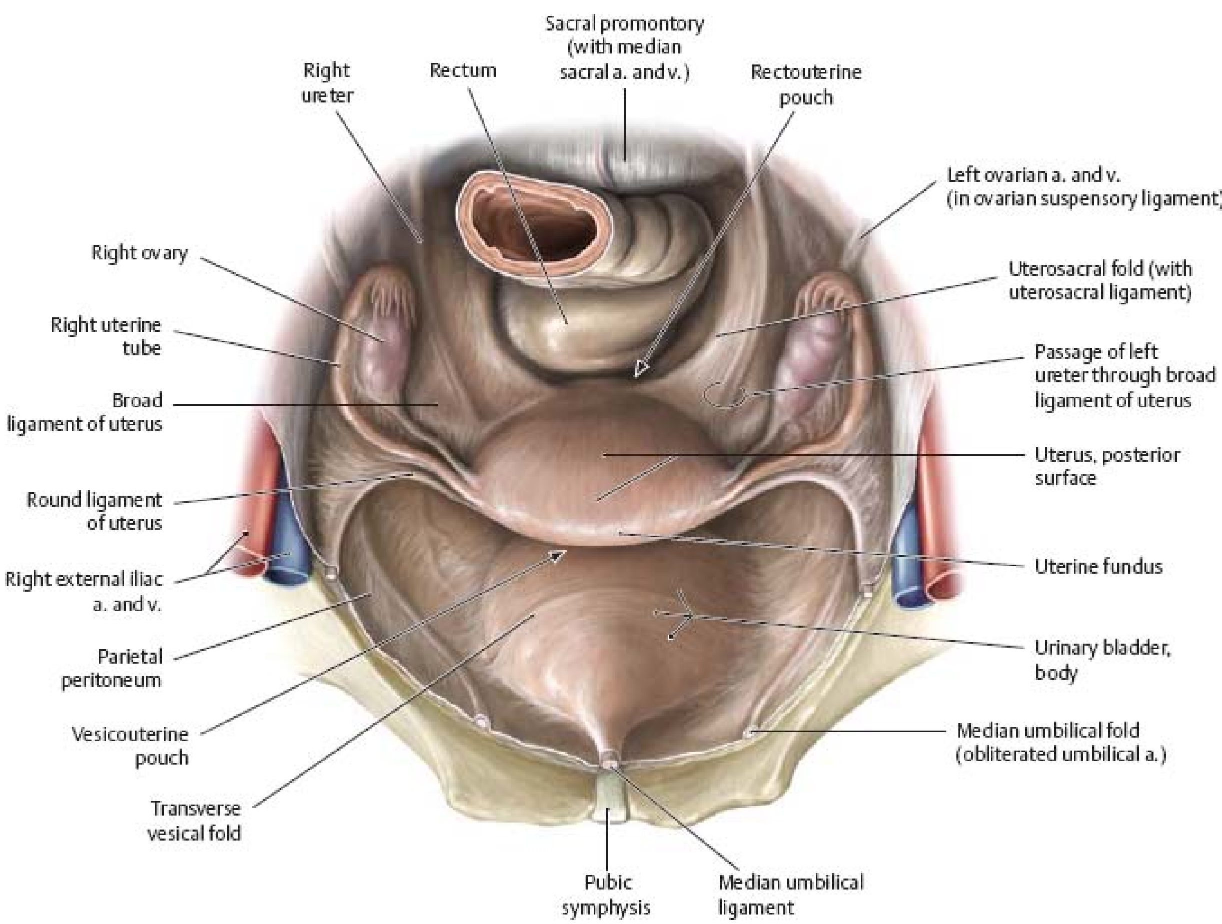
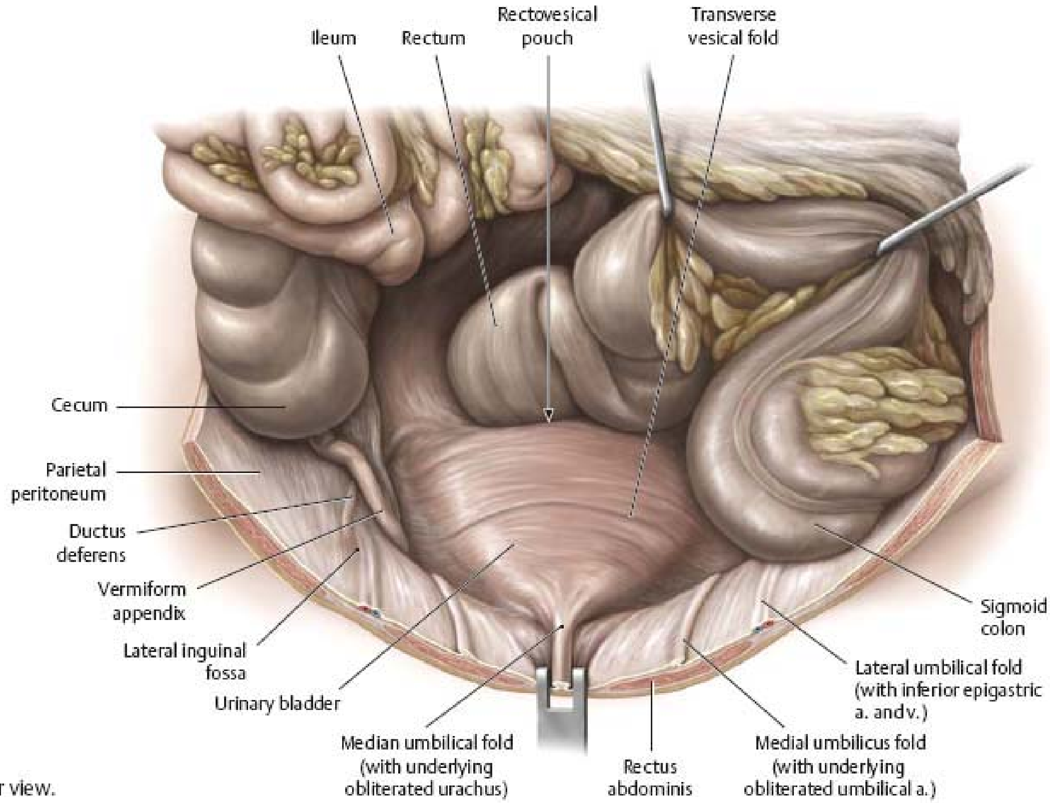


Fig. 13.49 **Ureter in the female pelvis**
Superior view.

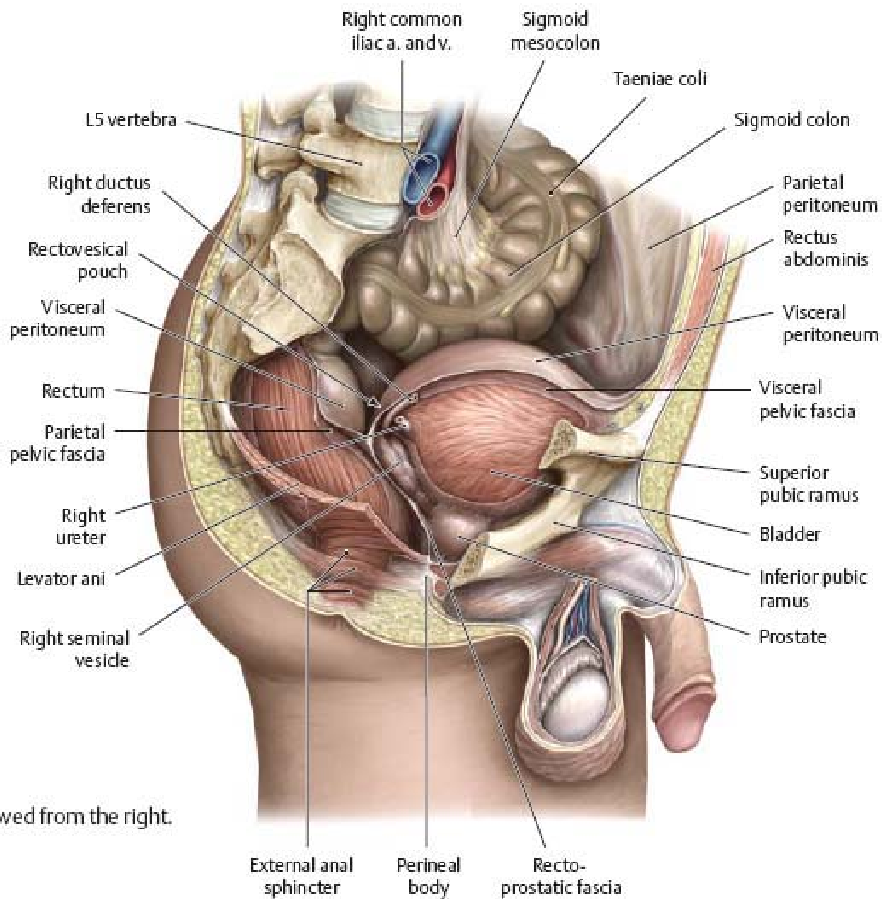


Urinary Bladder

Fig. 13.50 **Male urinary bladder**



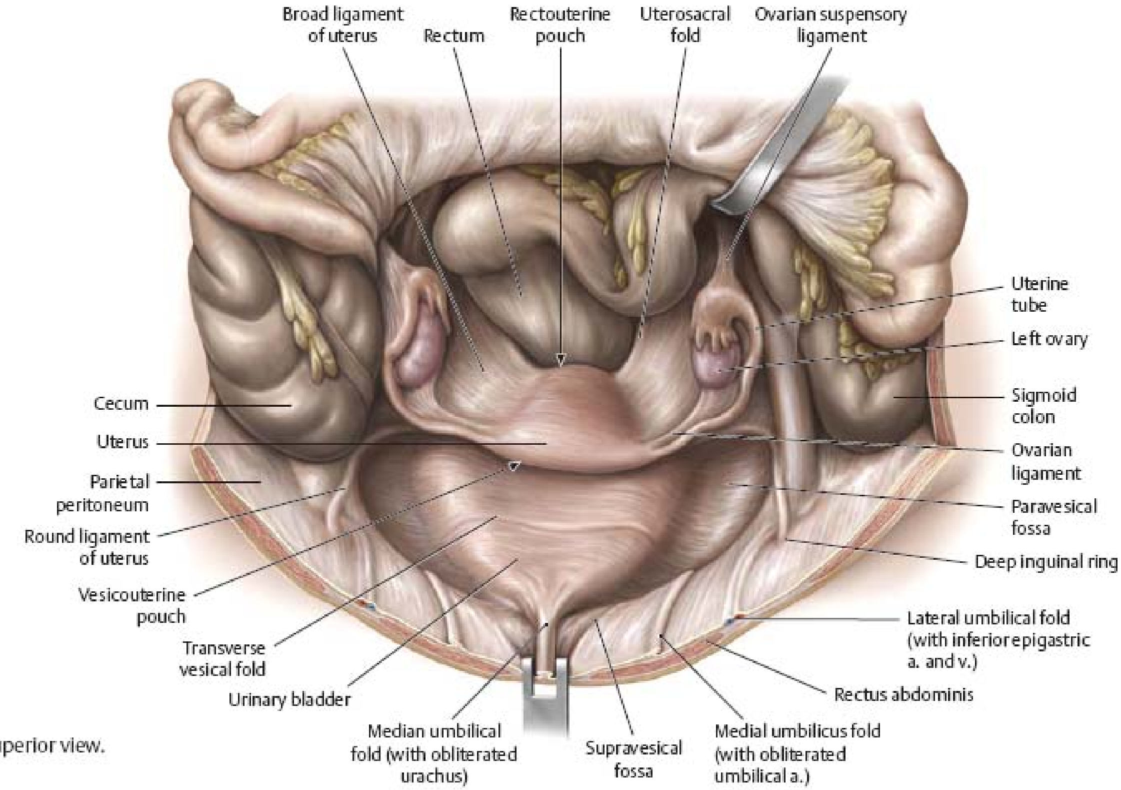
A Anterosuperior view.



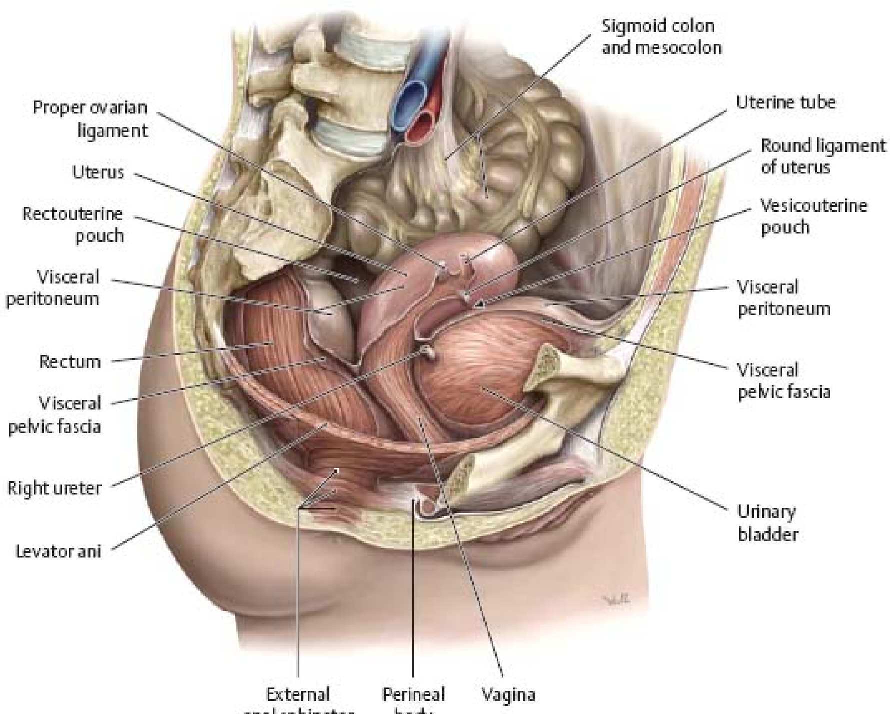
B Parasagittal section, viewed from the right.

The urinary bladder is retropubic and retroperitoneal in location.

Fig. 13.51 **Female urinary bladder**



A Anterosuperior view.



B Parasagittal section, viewed from the right.

Urinary Bladder & Urethra

Fig. 13.52 Female urinary bladder and urethra

Midsagittal section, viewed from the left side.

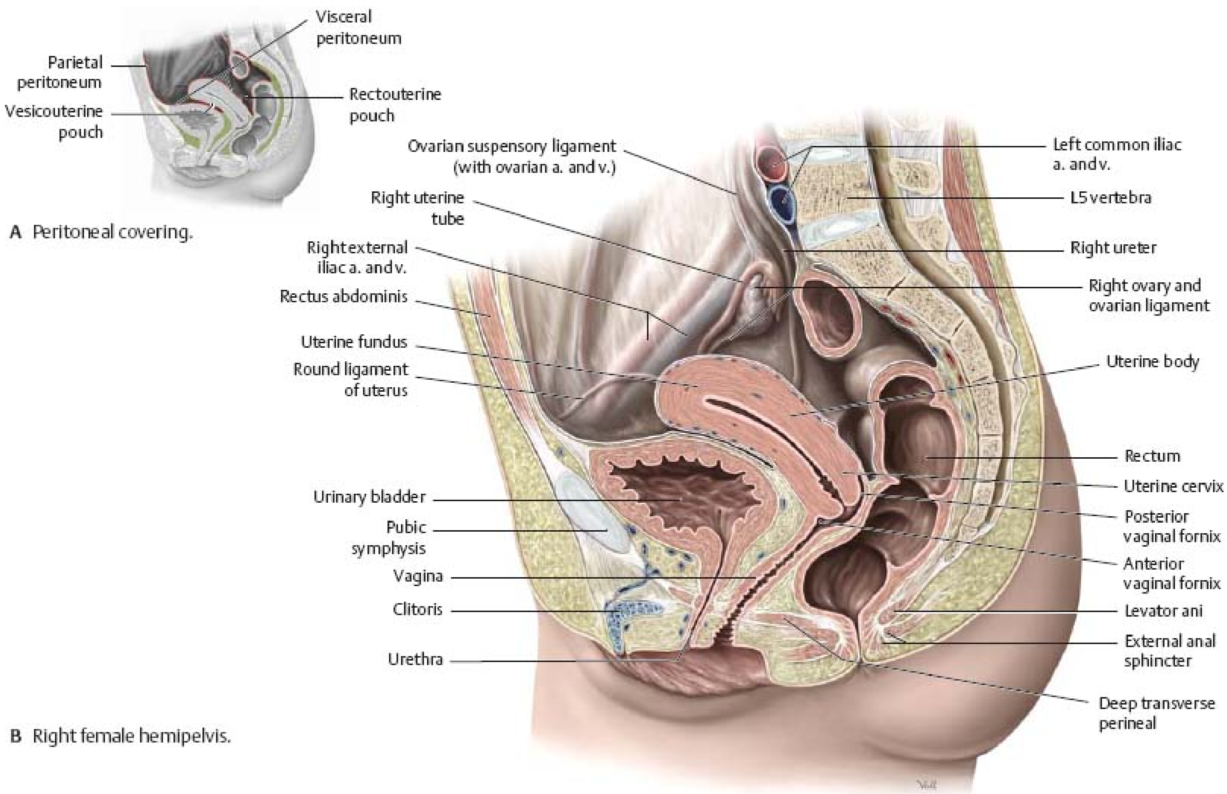
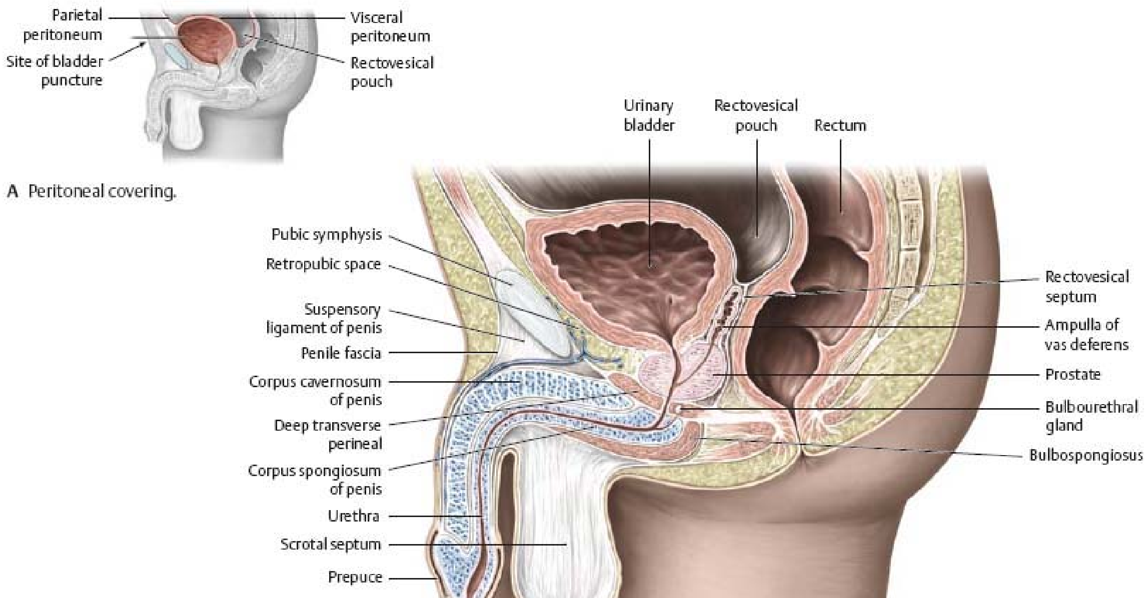


Fig. 13.53 Male urinary bladder and urethra

Midsagittal section, viewed from the left side.



A Peritoneal covering.

B Right male hemipelvis.

Fig. 13.54 Wall structure

Anterior view of coronal section.

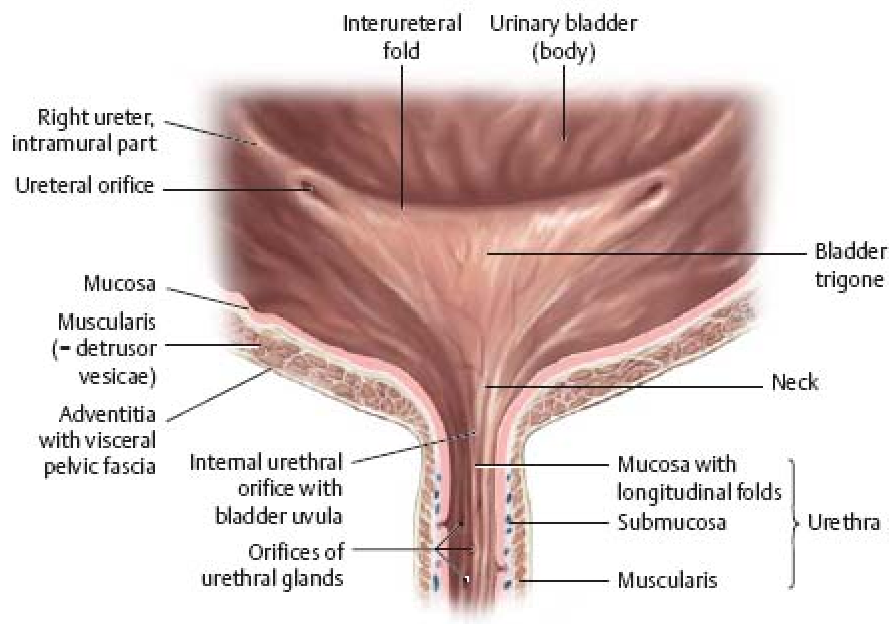
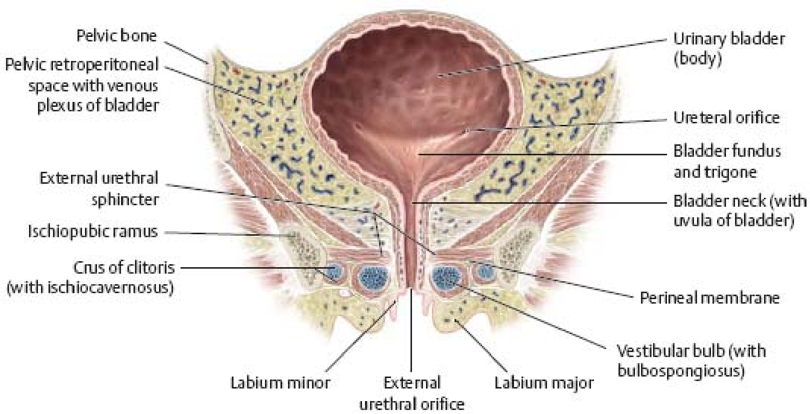
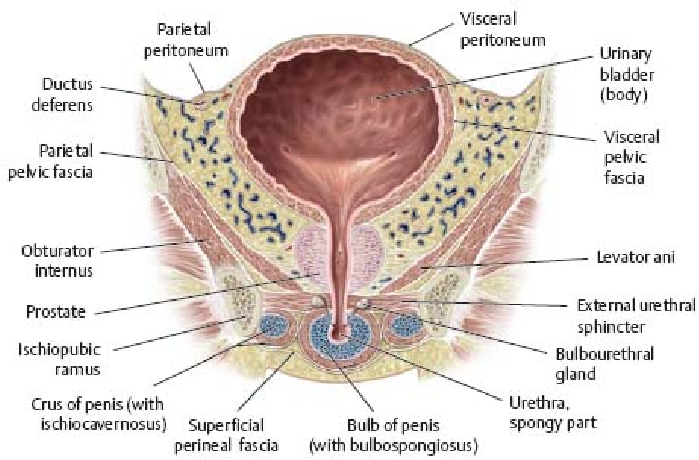


Fig. 13.55 Urinary bladder and urethra

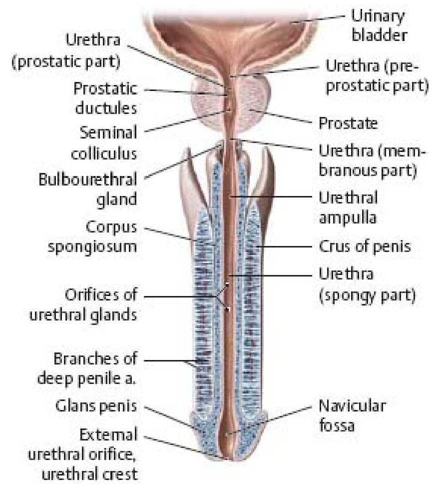
Anterior view.



A Female pelvis in coronal section.



B Male pelvis in coronal section.



C Male urethra in longitudinal section.

14 Reproductive Organs

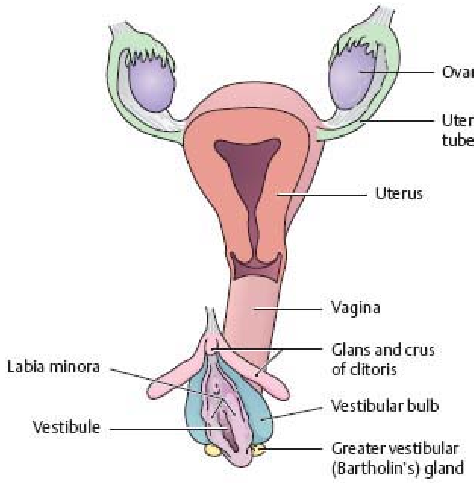
Overview of the Genital Organs

The genital organs can be classified topographically (external versus internal), functionally (Tables 14.1 and 14.2), or ontogenetically (see p. 204).

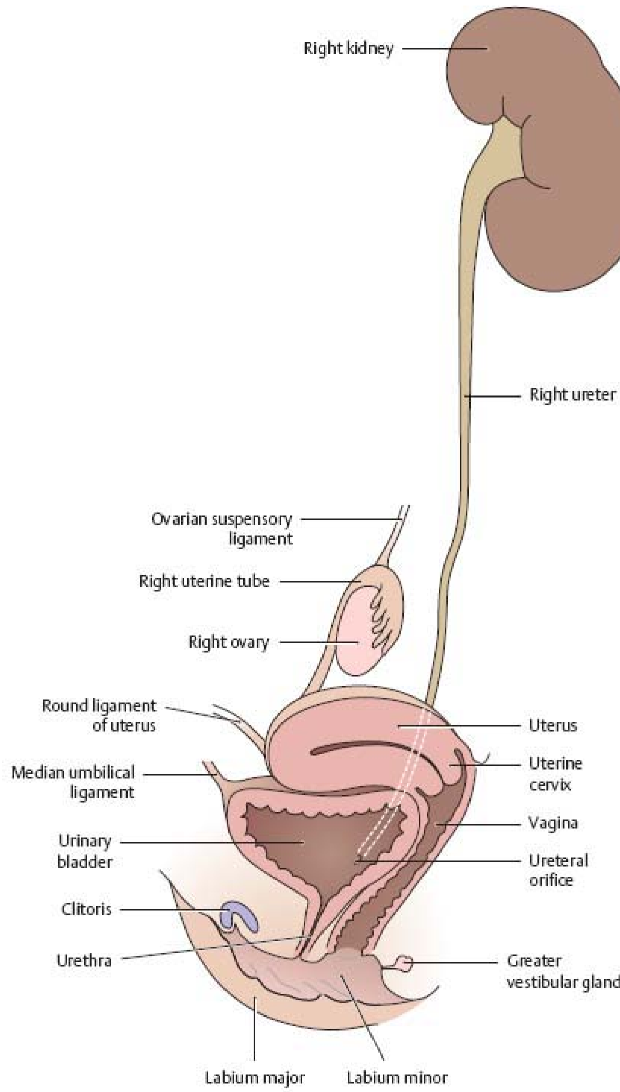
Table 14.1 Female genital organs

	Organ		Function
Internal genitalia	Ovary		Germ cell and hormone production
	Uterine (fallopian) tube		Site of conception and transport organ for zygote
	Uterus		Organ of incubation and parturition
	Vagina (upper portion)		Organ of copulation and parturition
External genitalia	Vulva	Vagina (vestibule)	
		Labia majora and minora	Copulatory organ
		Clitoris	
		Greater and lesser vestibular glands	Production of secretions
		Mons pubis	Protection of the pubic bone

Fig. 14.1 **Female genital organs**



A Internal and external genitalia.

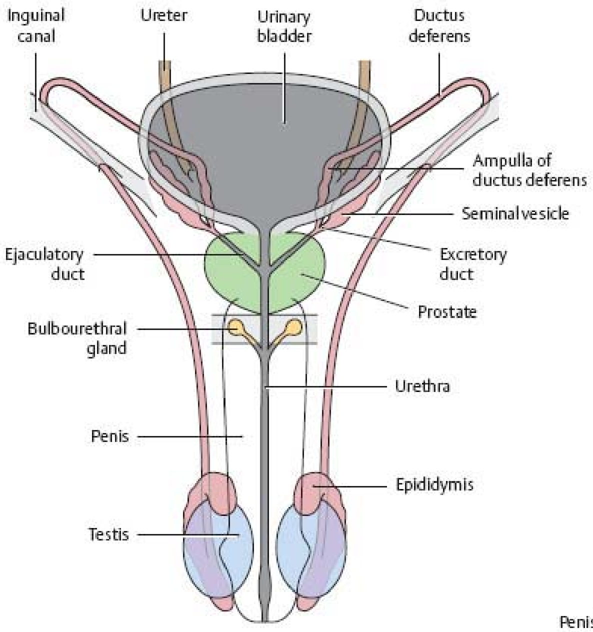


B Urogenital system. *Note:* The female urinary and genital tracts are functionally separate, though topographically close.

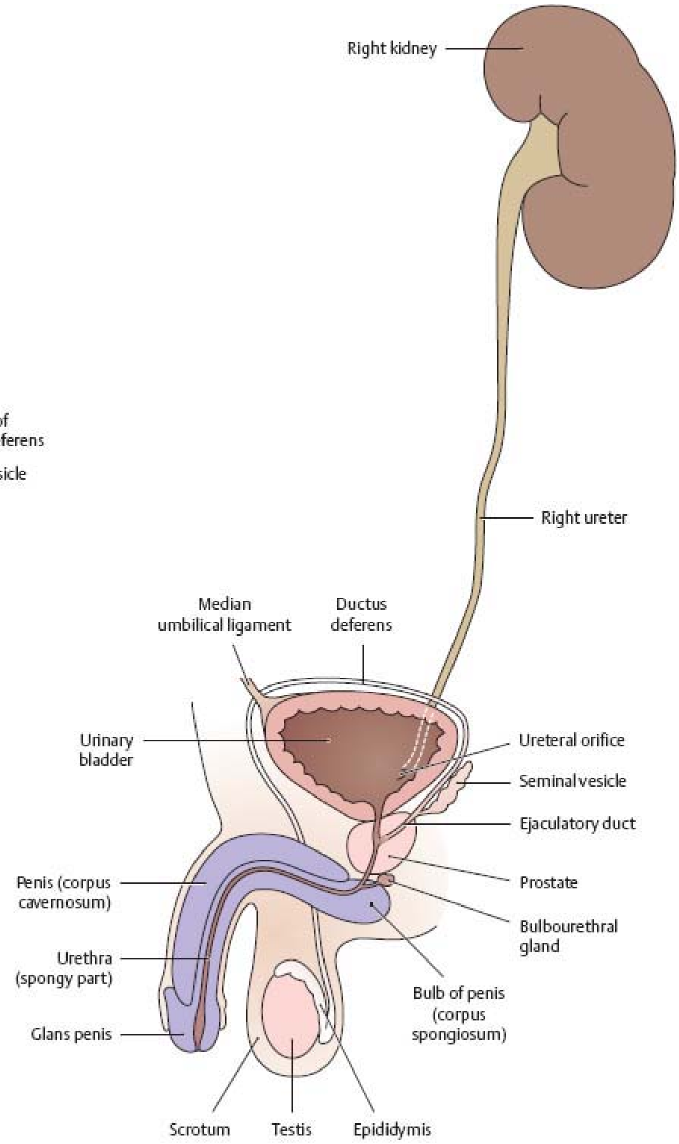
Table 14.2 Male genital organs

	Organ		Function
Internal genitalia	Testis		Germ cell and hormone production
	Epididymis		Reservoir for sperm
	Ductus deferens		Transport organ for sperm
	Accessory sex glands	Prostate	Production of secretions (semen)
		Seminal vesicles	
		Bulbourethral gland	
External genitalia	Penis		Copulatory and urinary organ
	Urethra		Urinary organ and transport organ for sperm
	Scrotum		Protection of testis
	Coverings of the testis		

Fig. 14.2 Male genital organs



A Seminiferous structures.

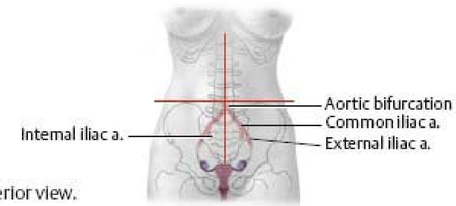


B Urogenital system. *Note:* The male urethra serves as a common urinary and genital passage.

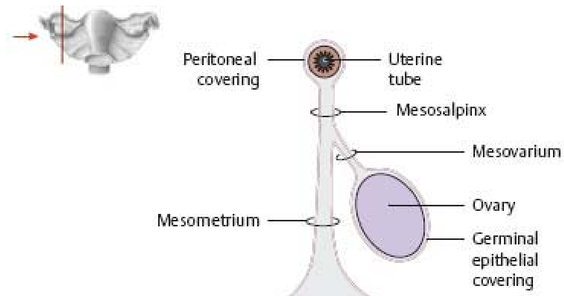
Uterus & Ovaries

Fig. 14.3 Female internal genitalia

The uterus and ovaries are suspended by the mesovarium and mesometrium (portions of the broad ligament).



A Location. Anterior view.



B Mesenteries. Sagittal section. The broad ligament of the uterus is a combination of the mesosalpinx, mesovarium, amd mesometrium.

Fig. 14.4 Ovary

Posterior view of the right ovary.

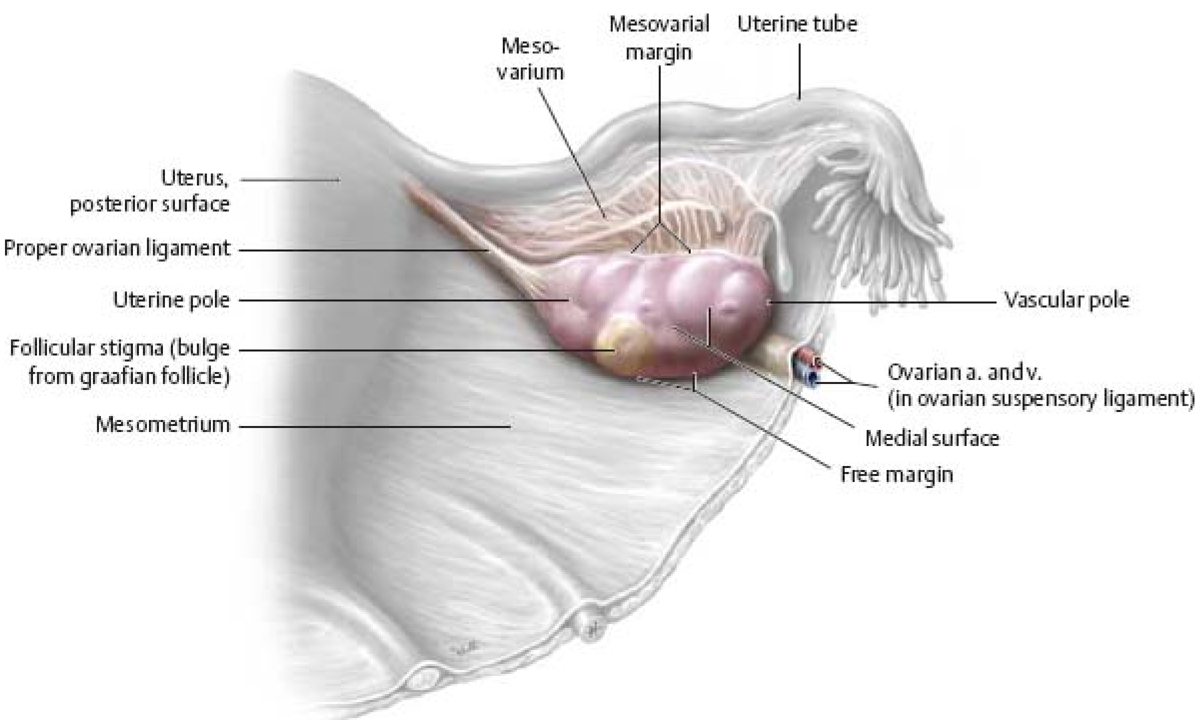


Fig. 14.5 Curvature of the uterus

Midsagittal section, left lateral view. The position of the uterus can be described in terms of flexion (①) and version (②).

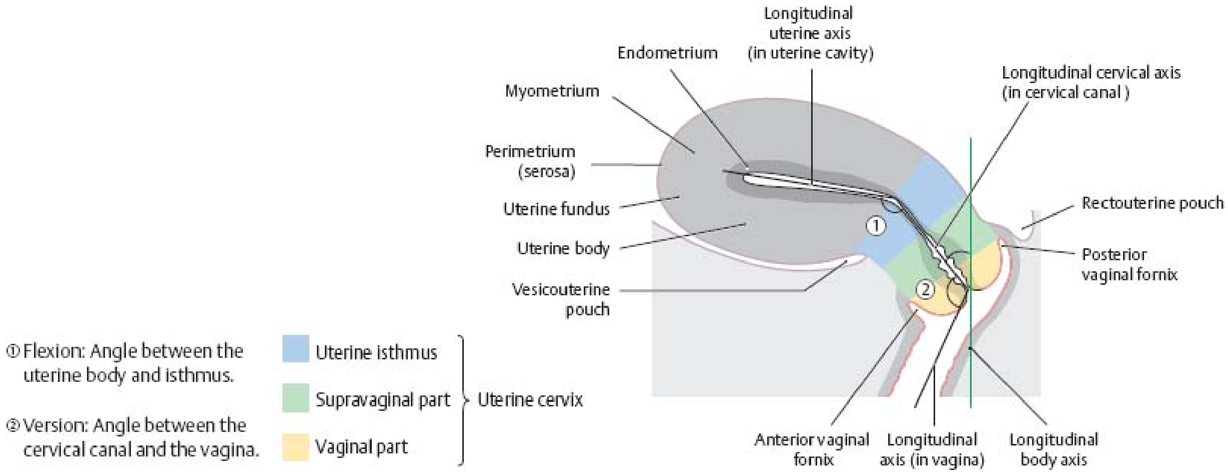
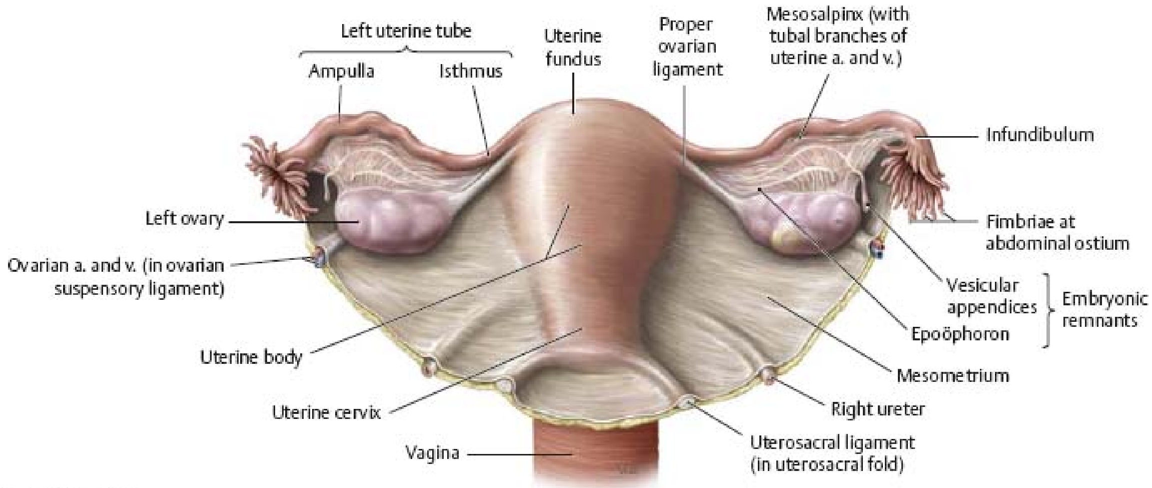
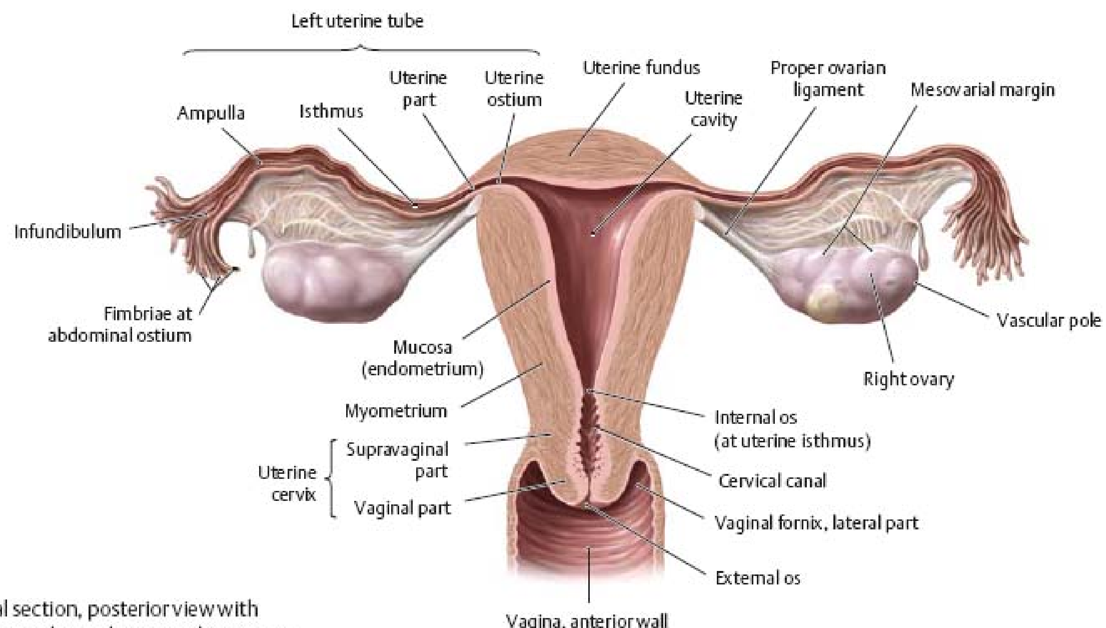


Fig. 14.6 **Uterus and uterine tube**



A Posterosuperior view.



B Coronal section, posterior view with uterus straightened. *Removed:* Mesometrium.

Clinical

Ectopic pregnancy

After fertilization, the ovum usually implants in the wall of the uterine cavity. However, it may become implanted at other sites (e.g., the uterine tube or even the peritoneal cavity). Tubal pregnancies, the most common type of ectopic pregnancy, pose the risk of tubal wall rupture and potentially life-threatening bleeding into the peritoneal cavity. Tubal pregnancies are promoted by adhesion of the tubal mucosa, mostly due to inflammation.

Vagina

Fig. 14.7 Location

Midsagittal section, left lateral view.

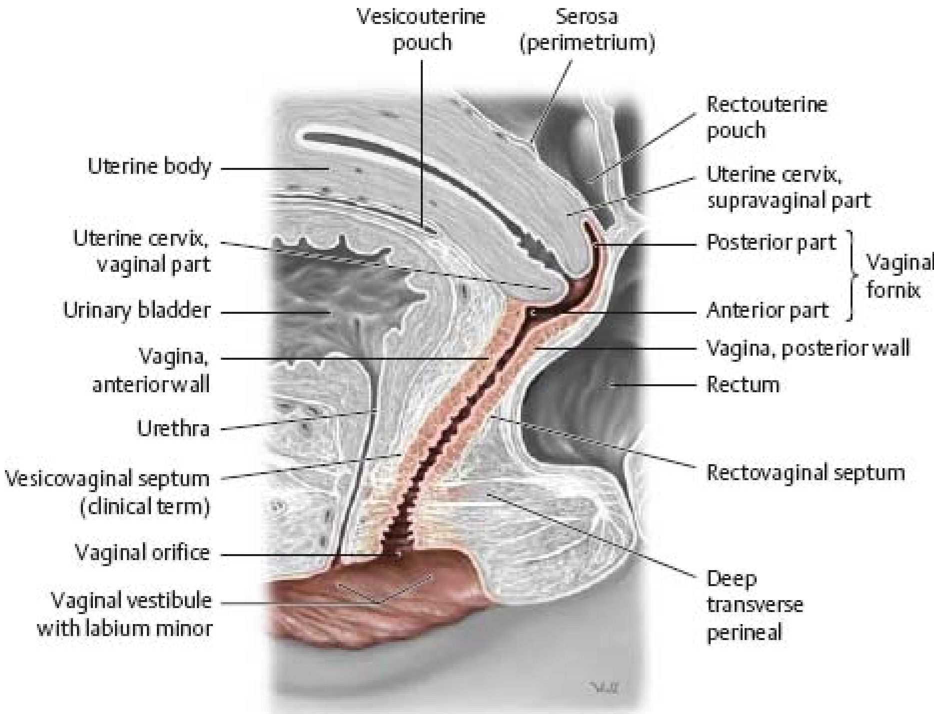


Fig. 14.8 Structure

Posteriorly angled coronal section, posterior view.

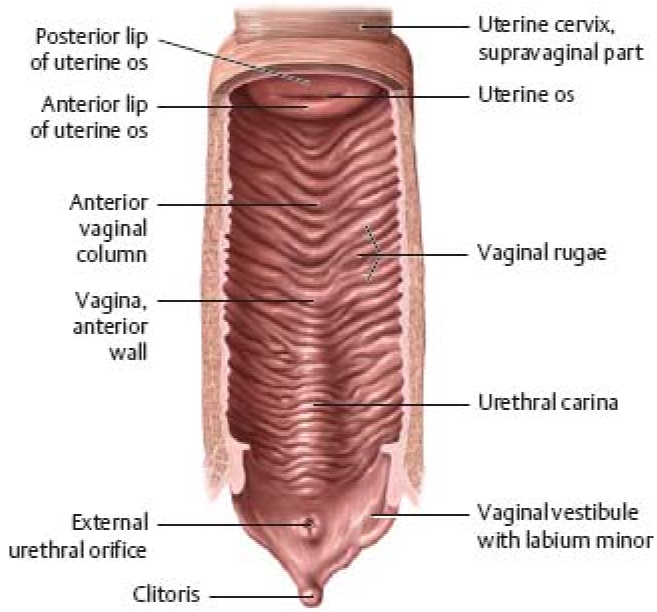


Fig. 14.9 **Uterine cervix: Transverse section**

Inferior view.

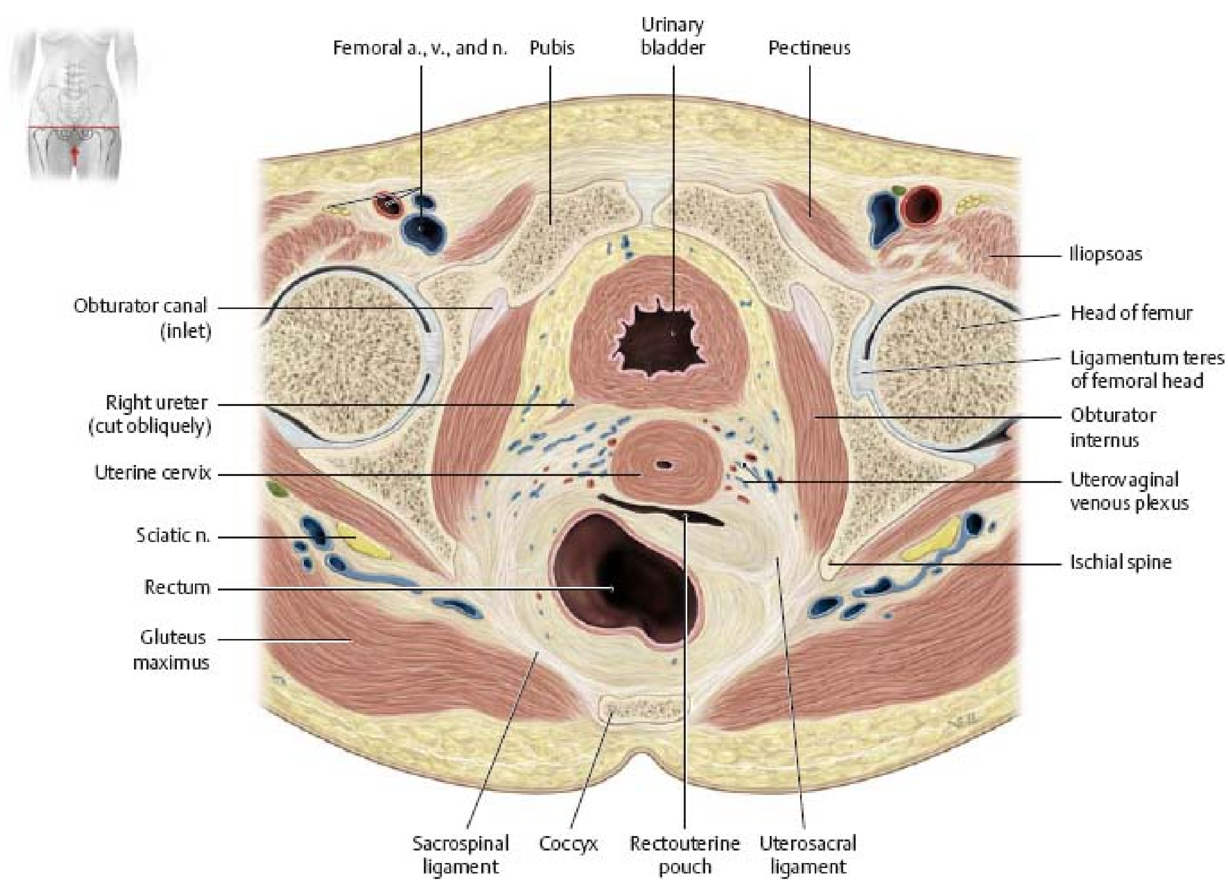


Fig. 14.10 Female genital organs: Coronal section

Anterior view. The vagina is both pelvic and perineal in location. It is also retroperitoneal.

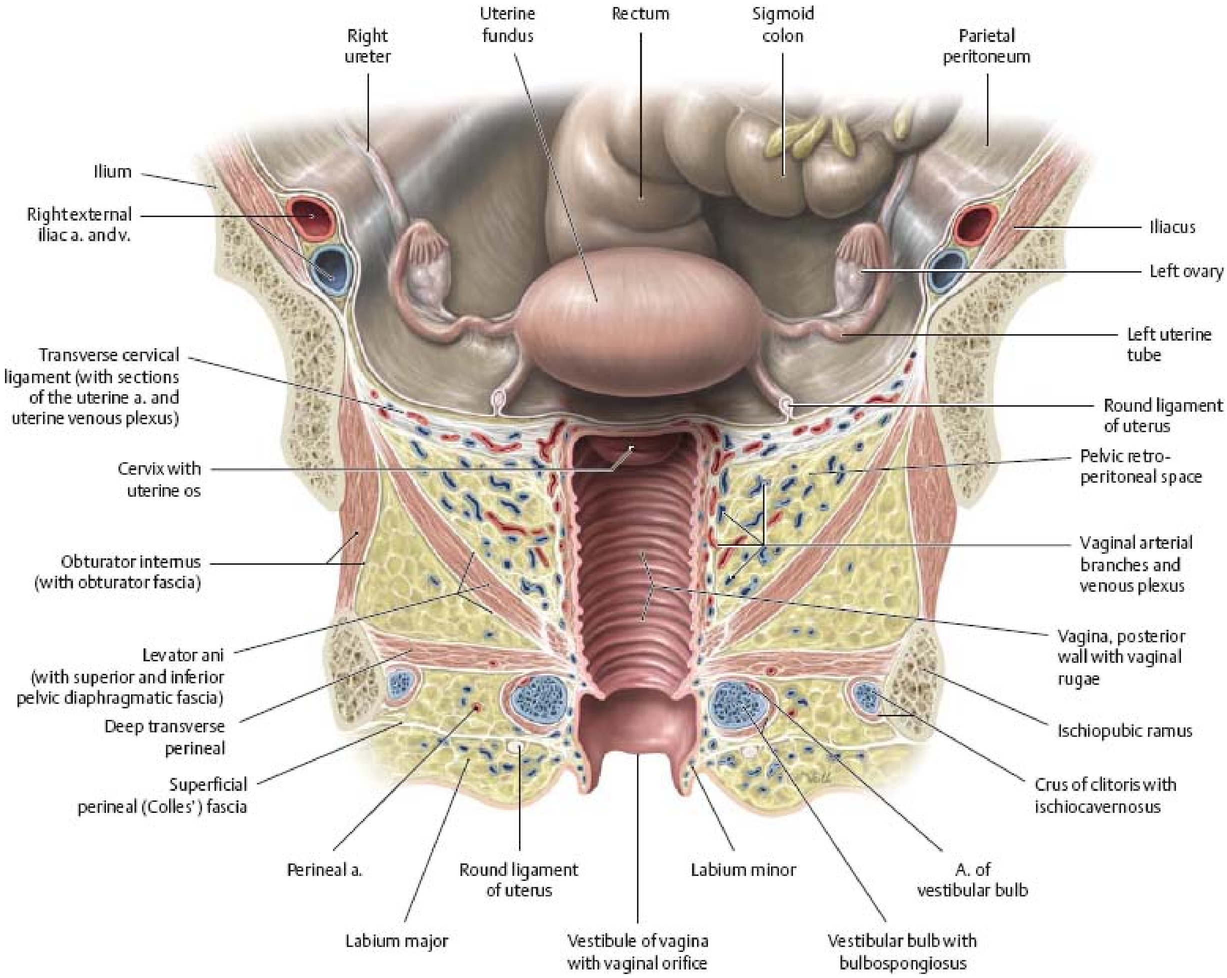
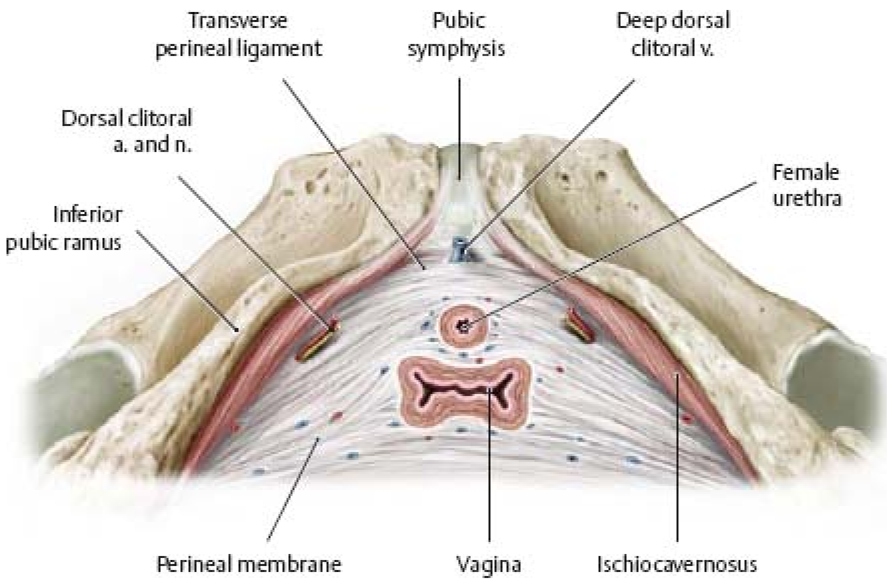


Fig. 14.11 Vagina: Location in the pelvic floor

Inferior view.



Female External Genitalia

Fig. 14.12 Female external genitalia

Lithotomy position with labia minora separated.

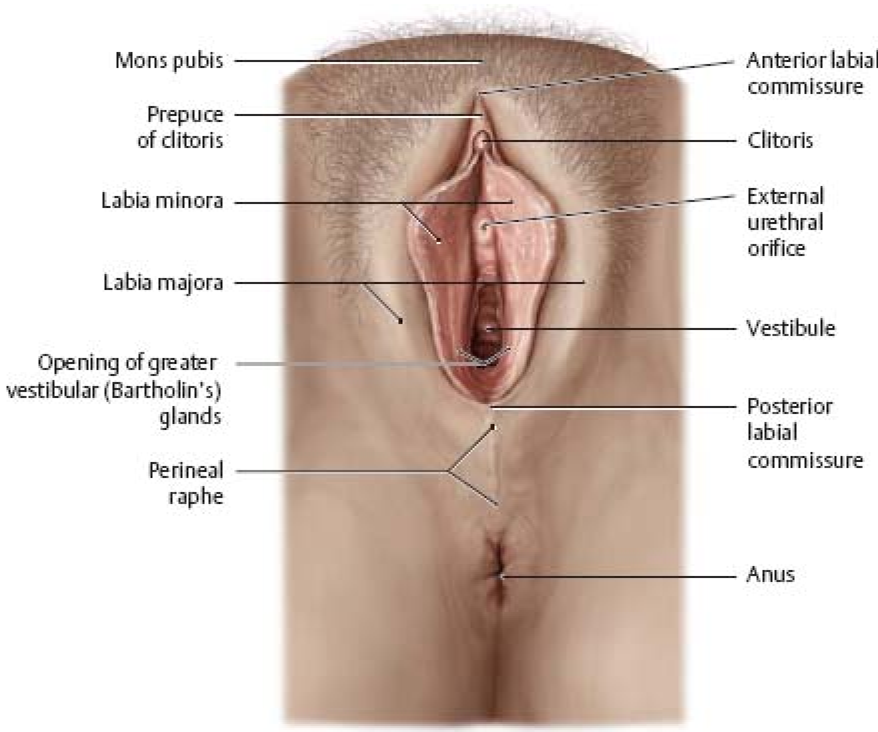


Fig. 14.13 Vestibule and vestibular glands

Lithotomy position with labia separated.

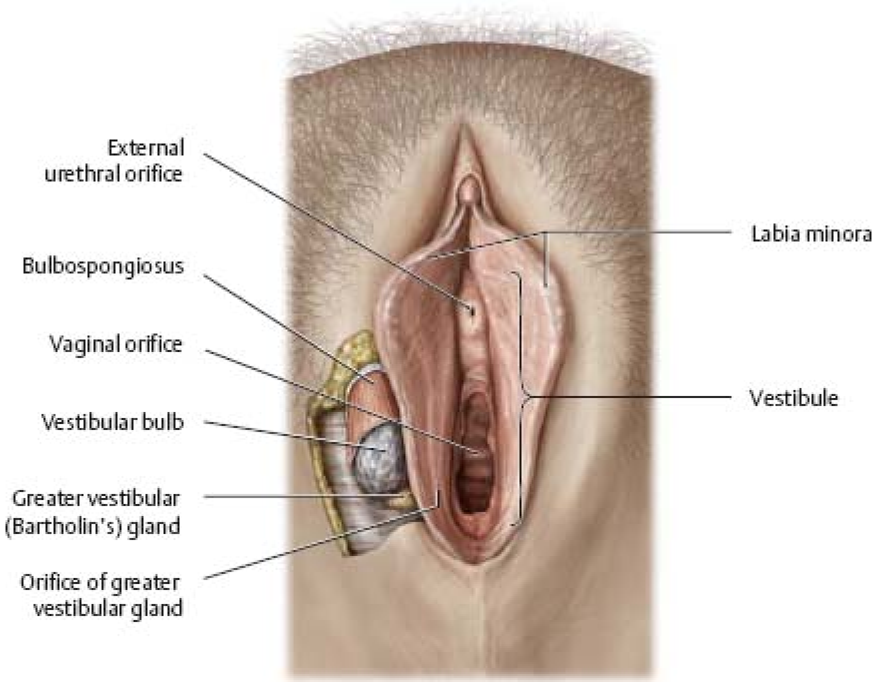
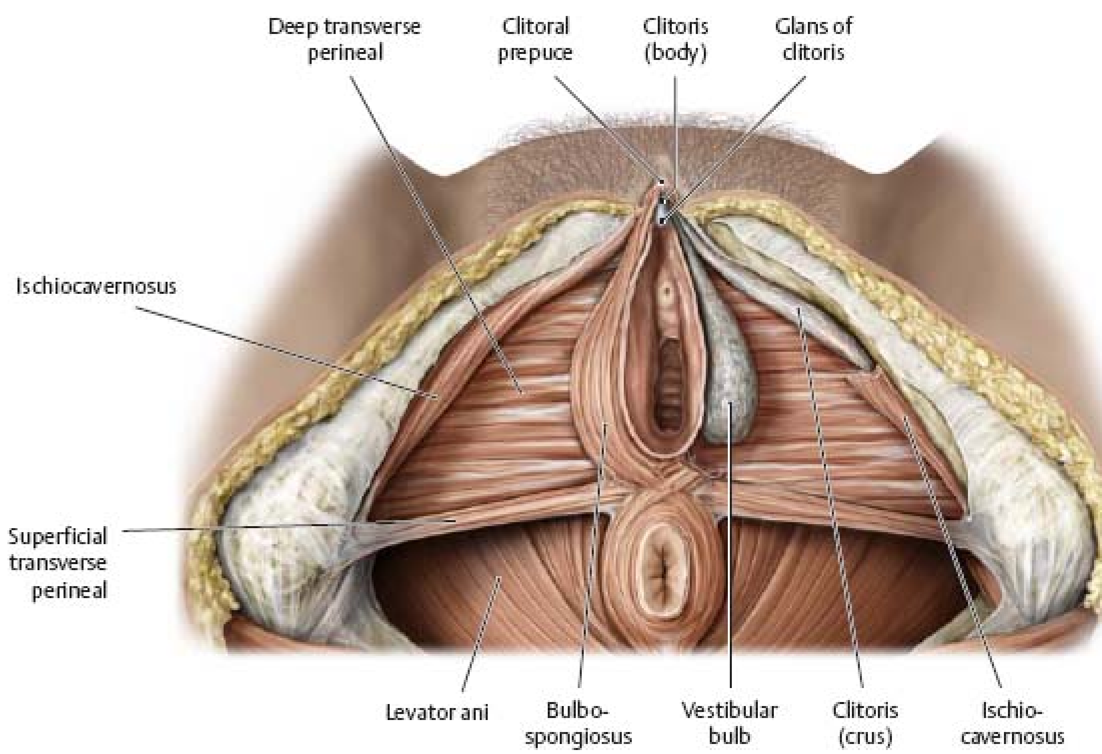


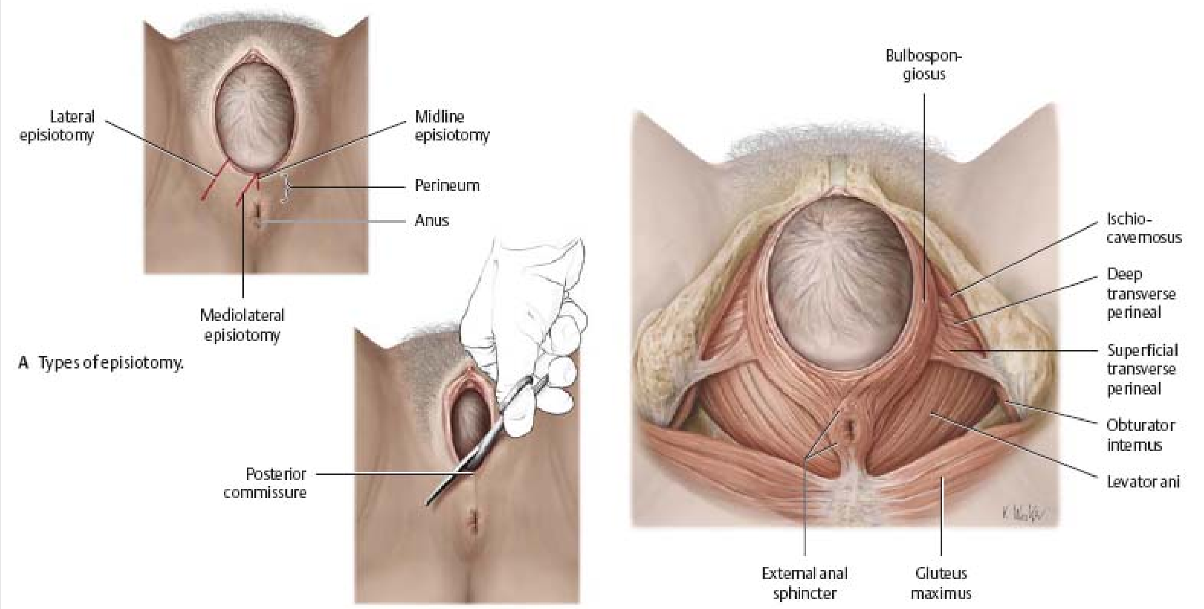
Fig. 14.14 **Erectile muscles and tissue: Female**
Lithotomy position. *Removed:* Labia, skin, and perineal membrane; erectile muscles (left side).



Clinical

Episiotomy

Episiotomy is a common obstetric procedure used to enlarge the birth canal during the expulsive stage of labor. The procedure is generally used to expedite the delivery of a baby at risk for hypoxia during the expulsive stage. Alternately, if the perineal skin turns white (indicating diminished blood flow), there is imminent danger of perineal laceration, and an episiotomy is often performed. More lateral incisions gain more room, but they are more difficult to repair.



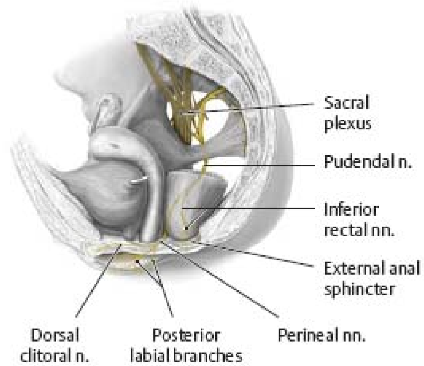
A Types of episiotomy.

B Mediolateral episiotomy at height of contraction.

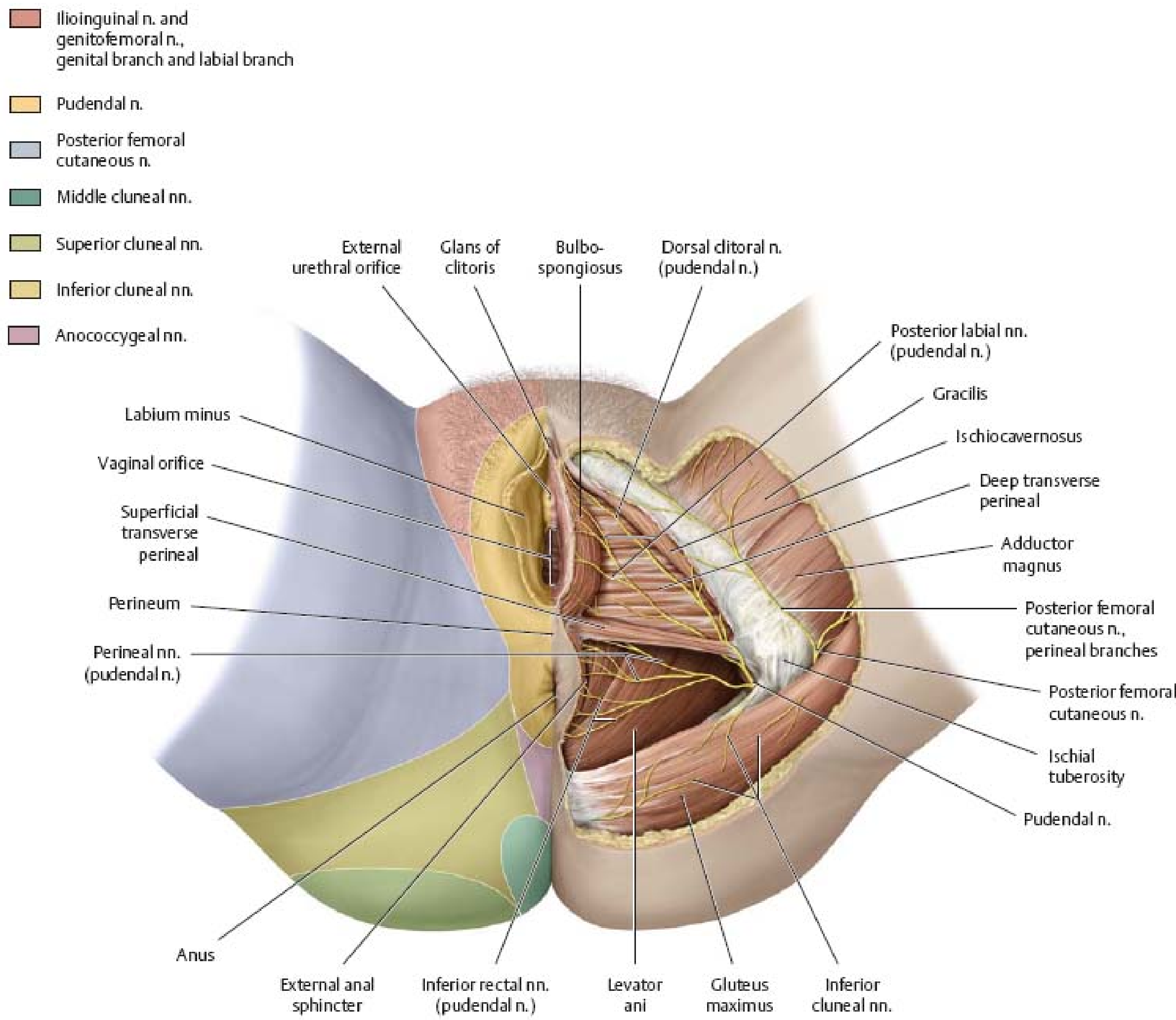
C Pelvic floor with crowning of fetal head.

Neurovasculature of the Female Genitalia

Fig. 14.15 Nerves of the female perineum and genitalia



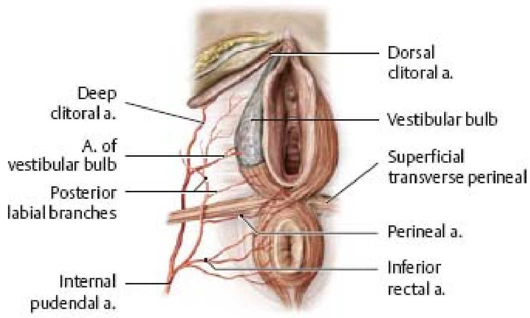
A Nerve supply to the female external genitalia. Lesser pelvis, left lateral view.



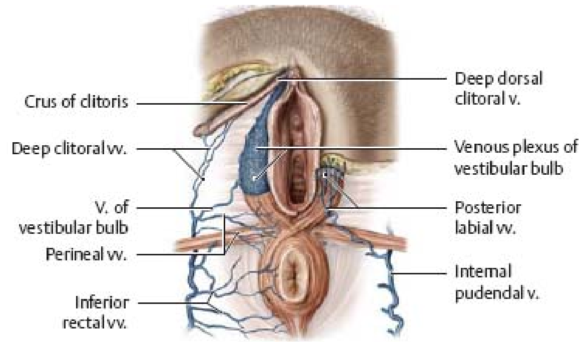
B Sensory innervation of the female perineum. Lithotomy position.

Fig. 14.16 Blood vessels of the female external genitalia

Inferior view.



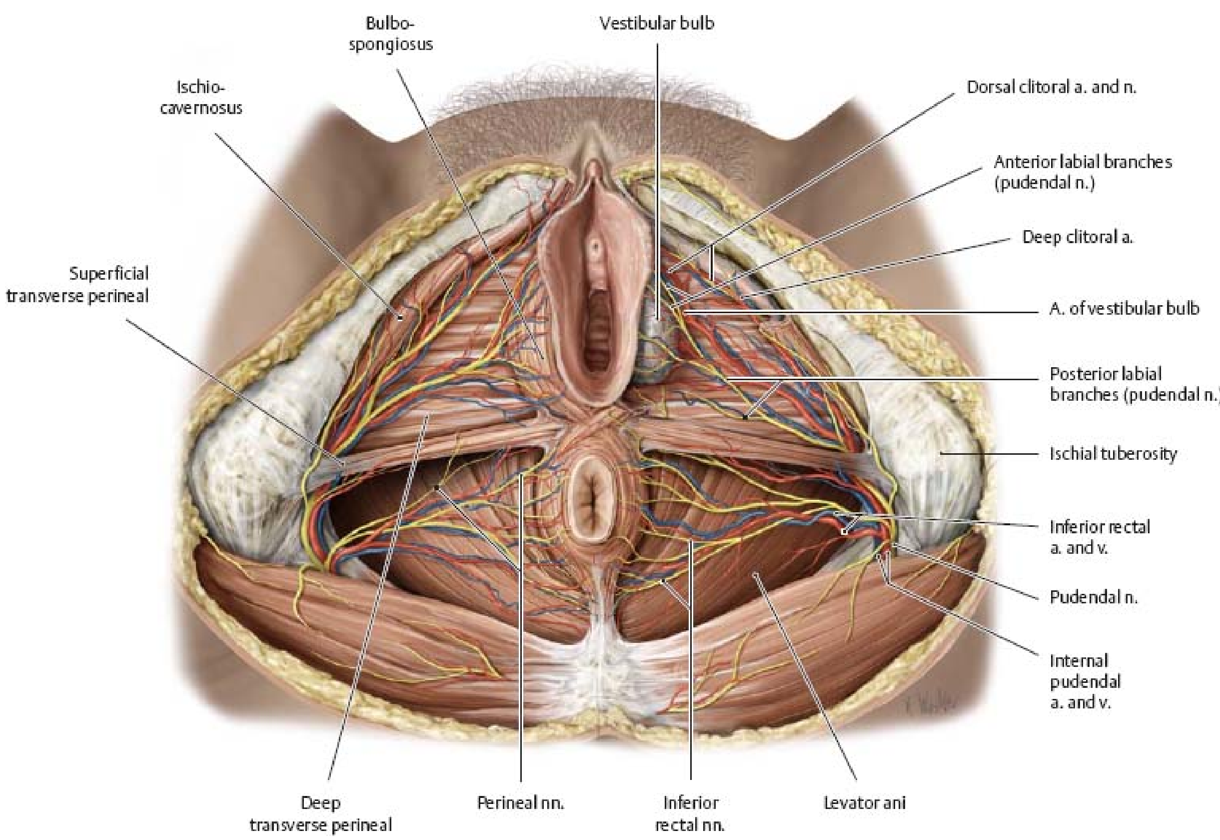
A Arterial supply.



B Venous drainage.

Fig. 14.17 **Neurovasculature of the female perineum**

Lithotomy position.



Penis, Scrotum & Spermatic Cord

Fig. 14.18 Penis, scrotum, and spermatic cord

Anterior view. *Removed:* Skin over the scrotum and spermatic cord.

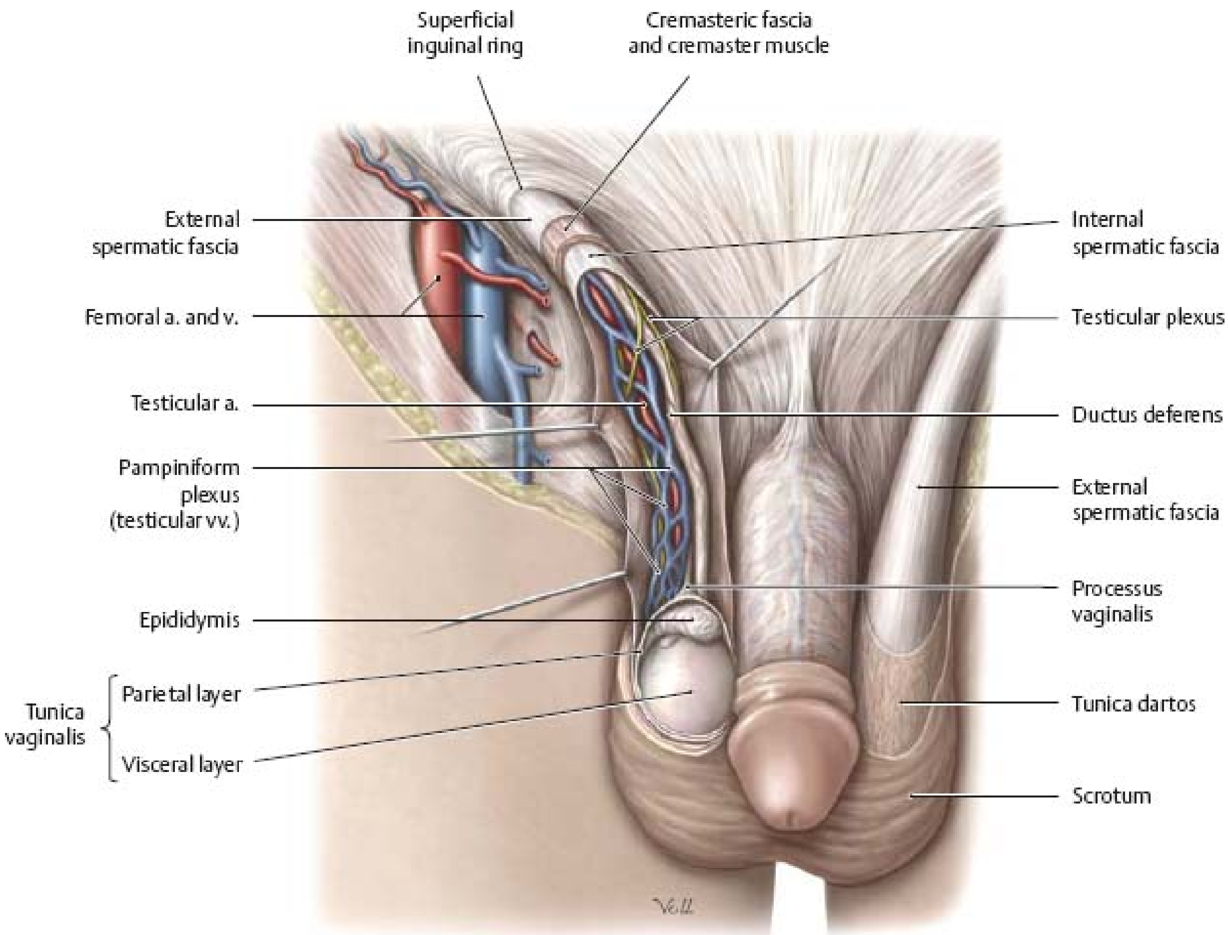


Fig. 14.19 Spermatic cord: Contents

Cross section.

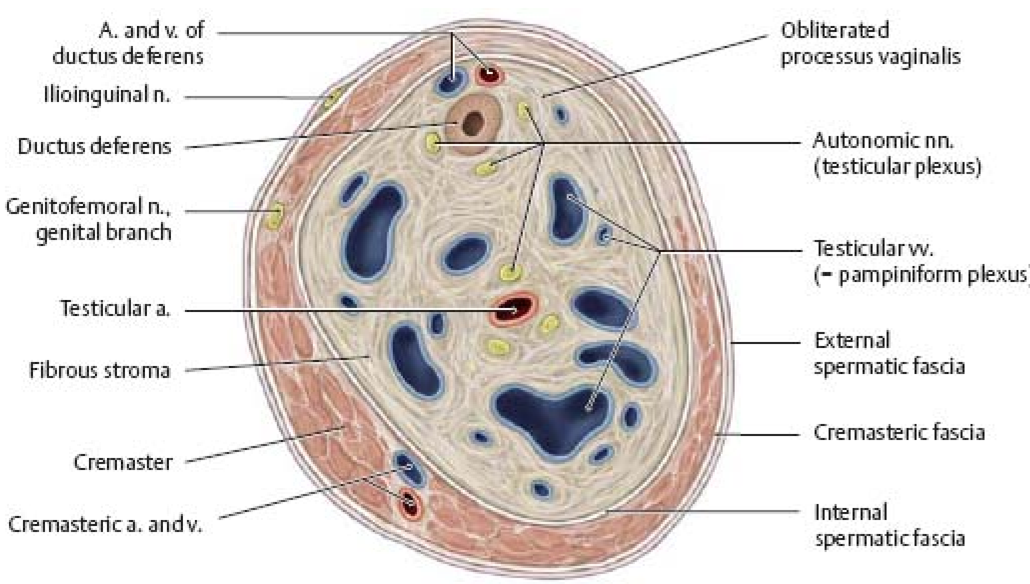
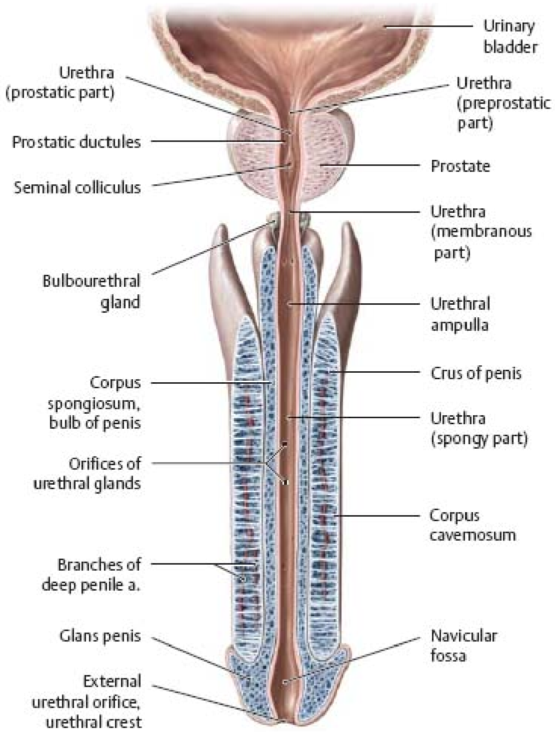
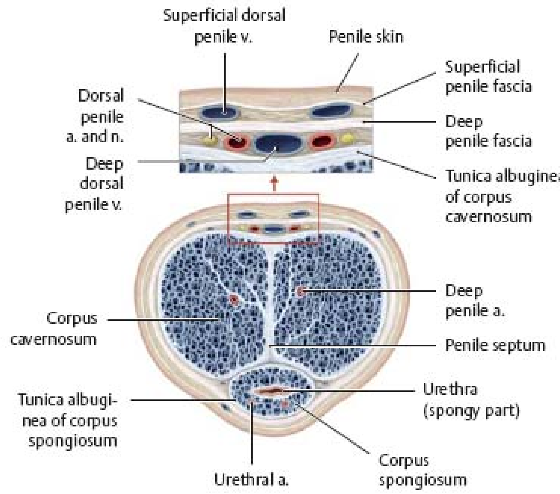


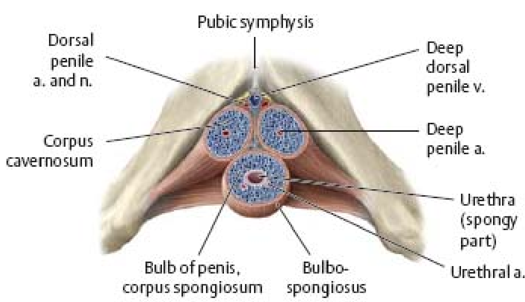
Fig. 14.20 Penis



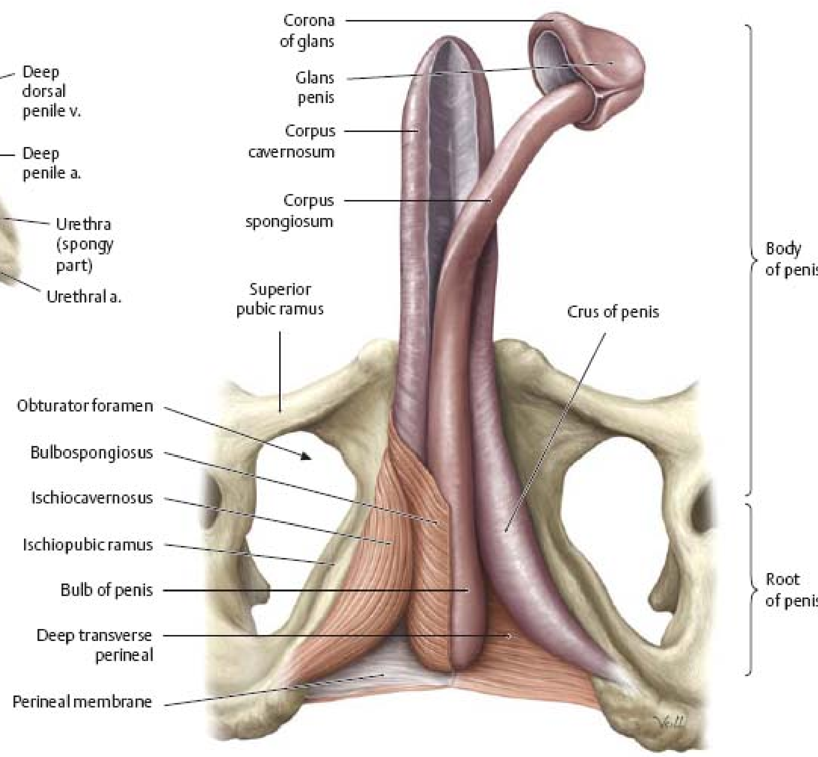
A Longitudinal section.



B Cross section through the shaft of the penis.



C Cross section through the root of the penis.

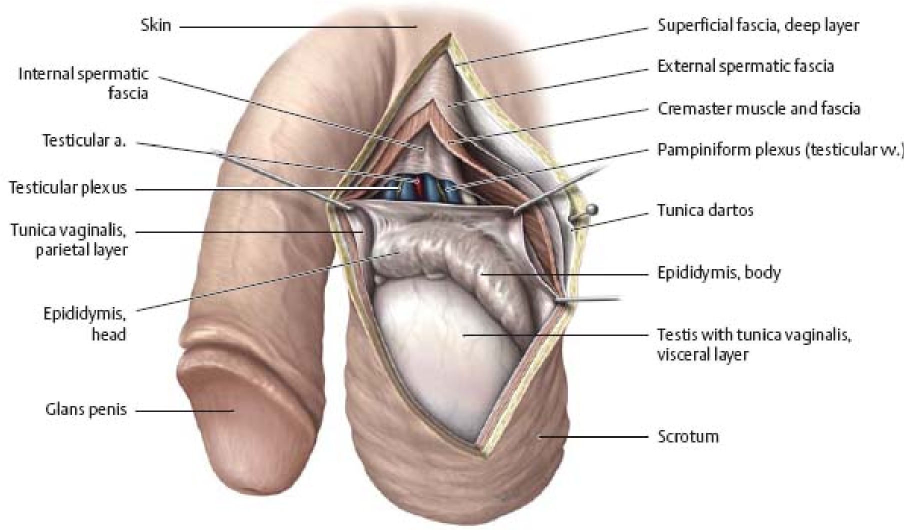


D Inferior view.

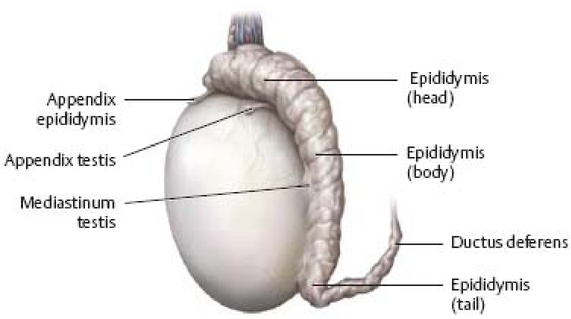
Testis & Epididymis

Fig. 14.21 Testis and epididymis

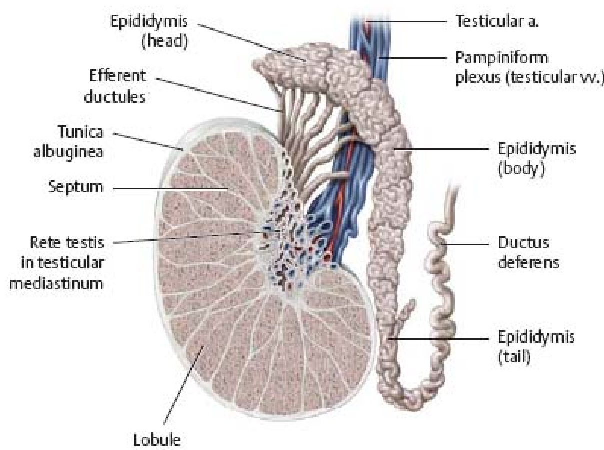
Left lateral view.



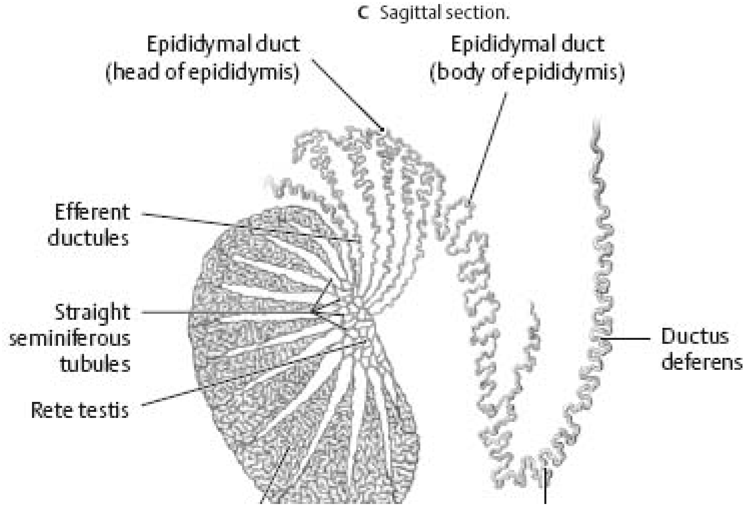
A Testis and epididymis in situ.



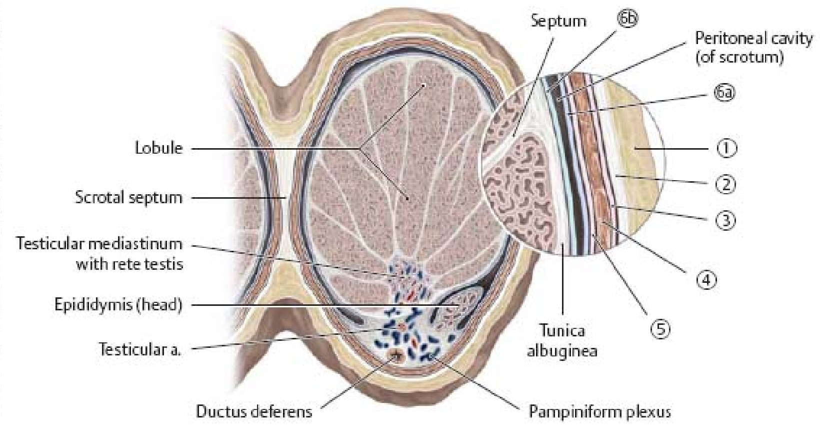
B Surface anatomy of the testis and epididymis.



C Sagittal section.



D Seminiferous tubules.



Transverse section through right testis, superior view.

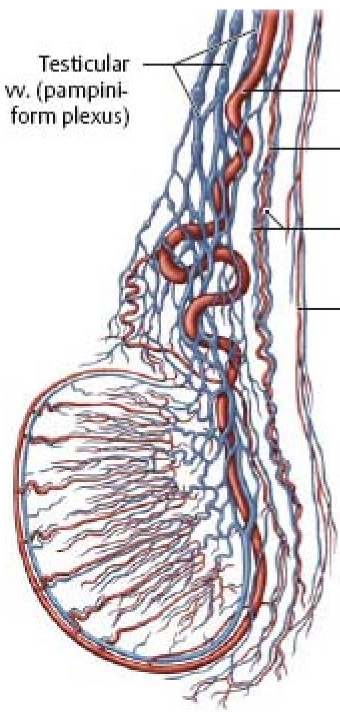
Table 14.3 Coverings of the testis

	Covering of the testis	Abdominal wall derivative
①	Scrotal skin	Abdominal skin
②	Tunica dartos	Dartos fascia and muscle
③	External spermatic fascia	External oblique
④	Cremaster muscle and fascia*	Internal oblique
⑤	Internal spermatic fascia	Transversalis fascia
6a	Tunica vaginalis, parietal layer	Peritoneum
6b	Tunica vaginalis, visceral layer	

* The transversus abdominis has no contribution to the spermatic cord or covering of the testis.

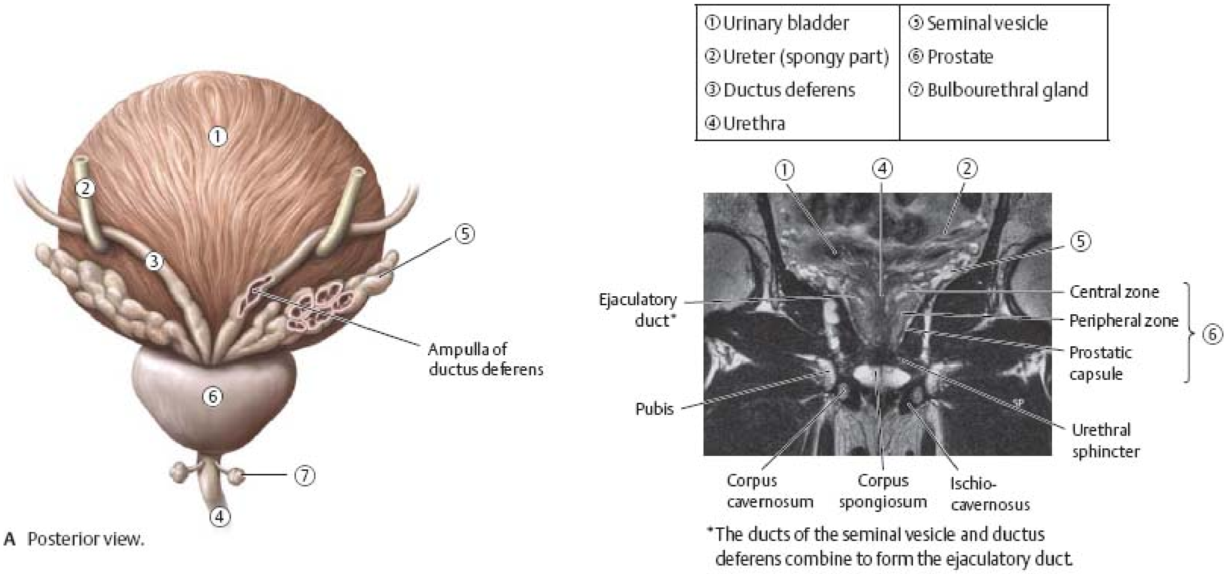
Fig. 14.22 Blood vessels of the testis

Left lateral view.



Male Accessory Sex Glands

Fig. 14.23 Accessory sex glands

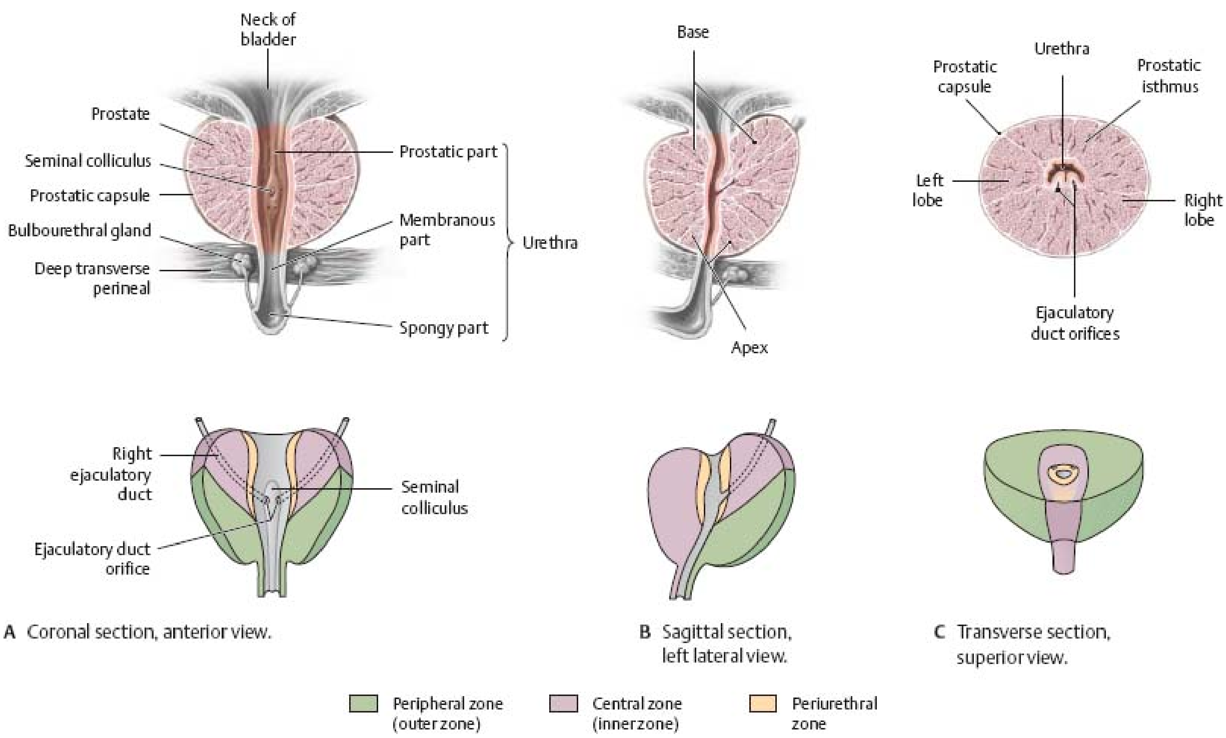


A Posterior view.

B MRI. Coronal section, anterior view.

Fig. 14.24 Prostate

The prostate may be divided anatomically (top row) or clinically (bottom row).



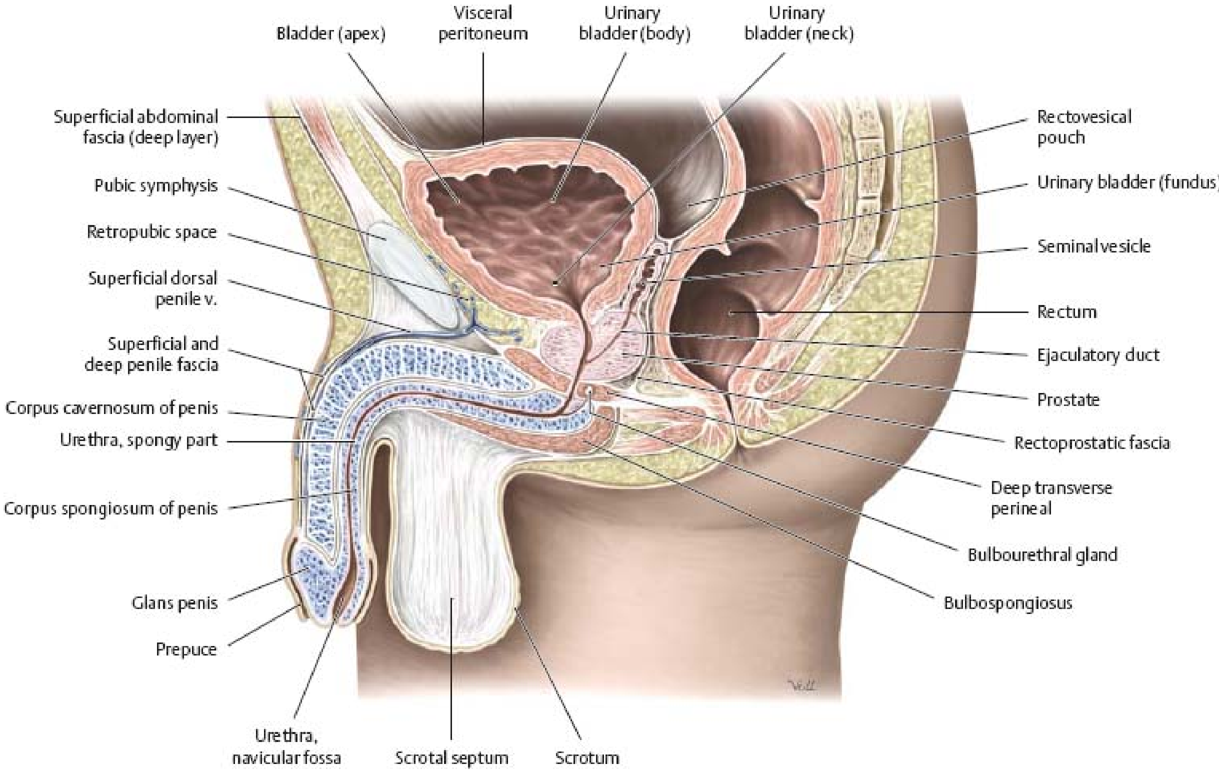
A Coronal section, anterior view.

B Sagittal section, left lateral view.

C Transverse section, superior view.

Fig. 14.25 Prostate in situ

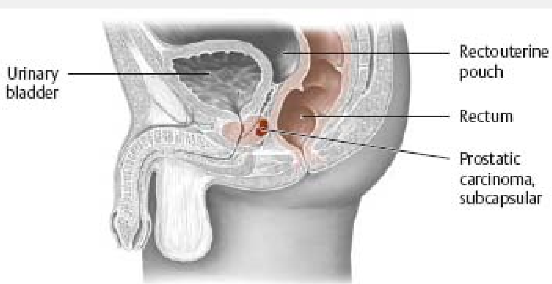
Sagittal section through the male pelvis, left lateral view.



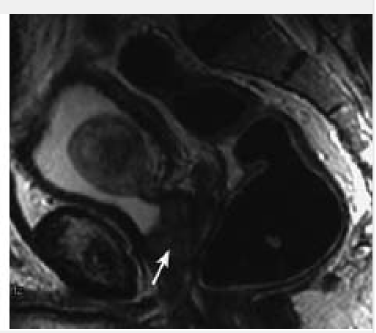
Clinical

Prostatic carcinoma and hypertrophy

Prostatic carcinoma is one of the most common malignant tumors in older men, often growing at a subcapsular location in the peripheral zone of the prostate. Unlike benign prostatic hyperplasia, which begins in the central part of the gland, prostatic carcinoma does not cause urinary outflow obstruction in its early stages. Being in the peripheral zone, the tumor is palpable as a firm mass through the anterior wall of the rectum during rectal examination.



A Common site of prostatic carcinoma.



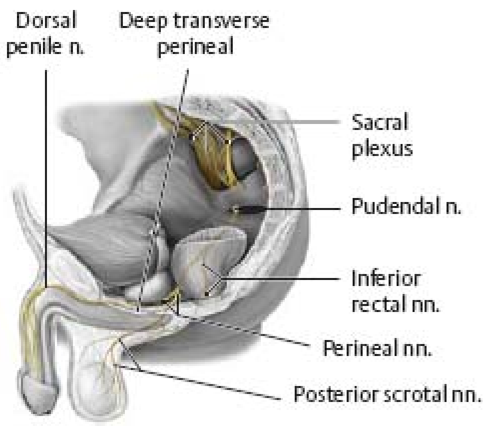
B Prostatic carcinoma (arrow) with bladder infiltration.

In certain prostate diseases, especially cancer, increased amounts of a protein, prostate-specific antigen or PSA, appear in the blood. This protein can be measured by a simple blood test.

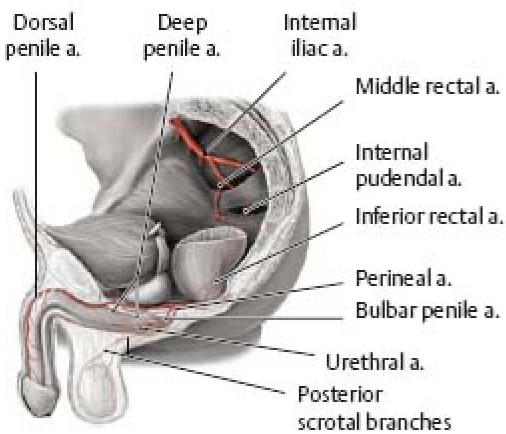
Neurovasculature of the Male Genitalia

Fig. 14.26 Neurovasculature of the male genitalia

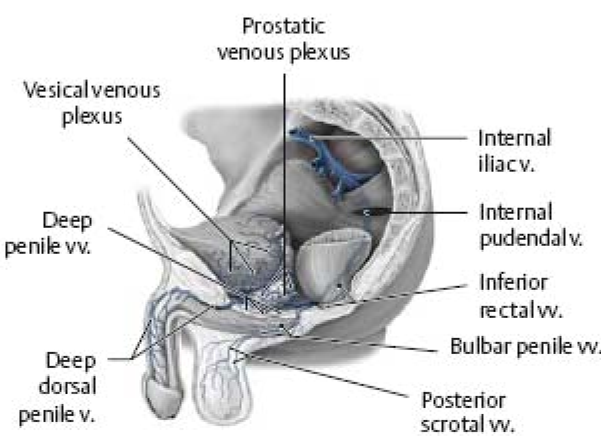
Left lateral view.



A Nerve supply.

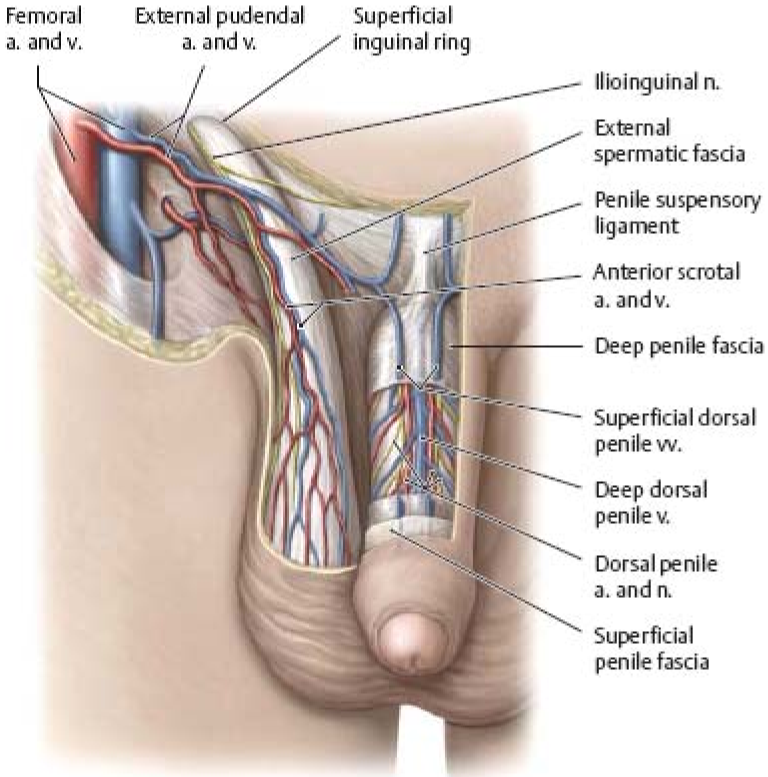


B Arterial supply.

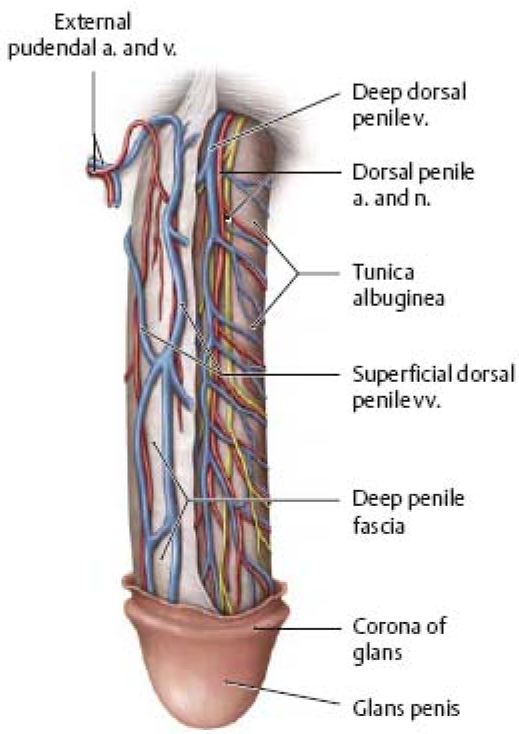


C Venous drainage.

Fig. 14.27 Neurovasculature of the penis and scrotum



A Anterior view. *Partially removed:* Skin and fascia.



B Dorsal vasculature of the penis.

Fig. 14.28 **Nerves of the male perineum and genitalia**
Lithotomy position.

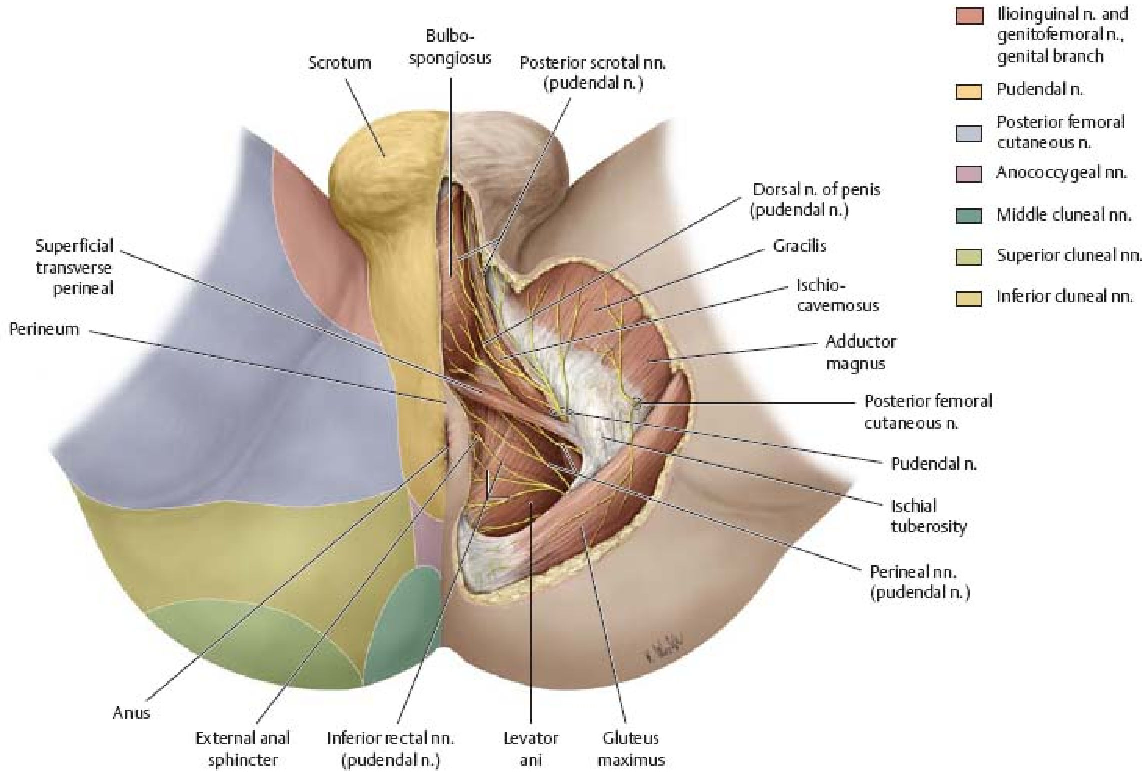
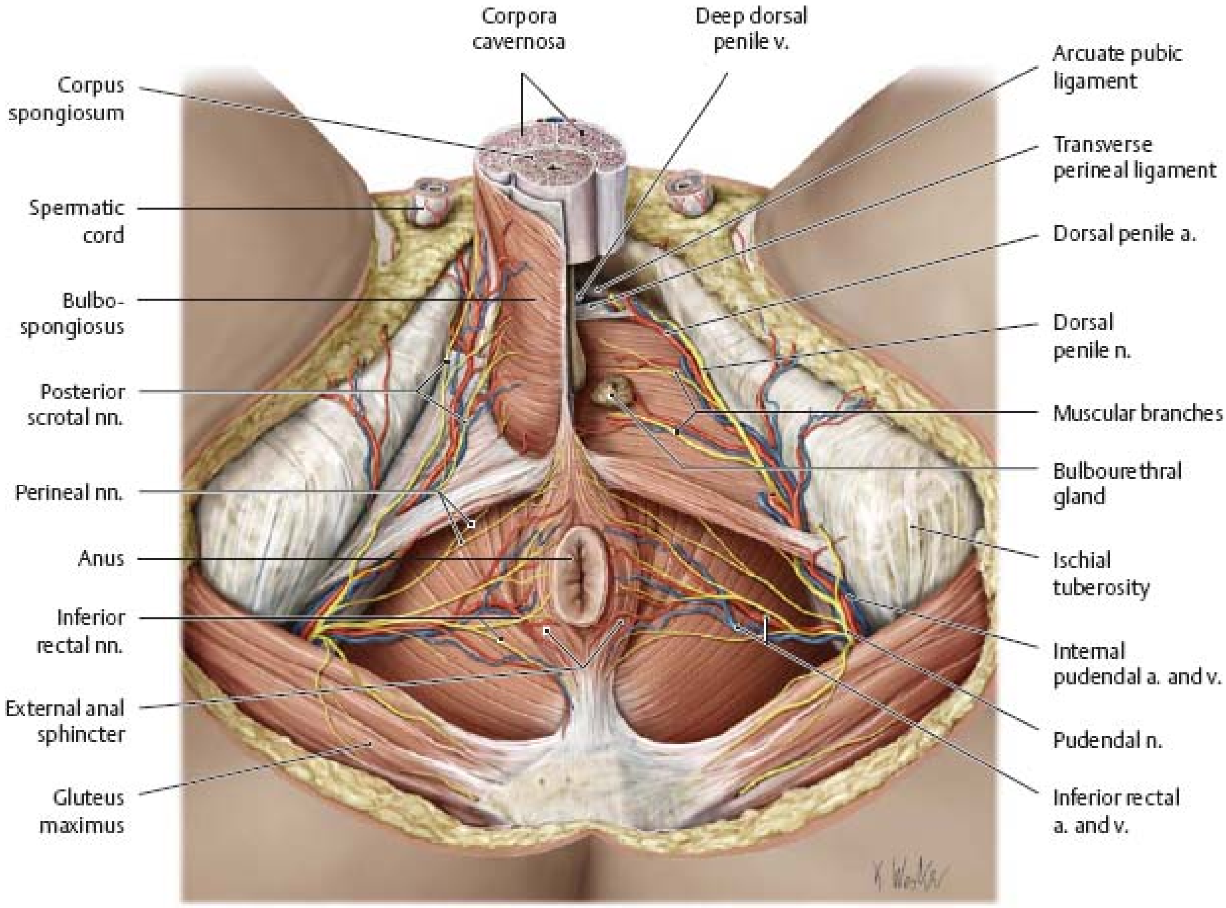


Fig. 14.29 **Neurovasculature of the male perineum**
Lithotomy position.



Development of the Genitalia

The male and female genitalia are derived from a common gonadal primordium.

Fig. 14.30 Development of the external genitalia

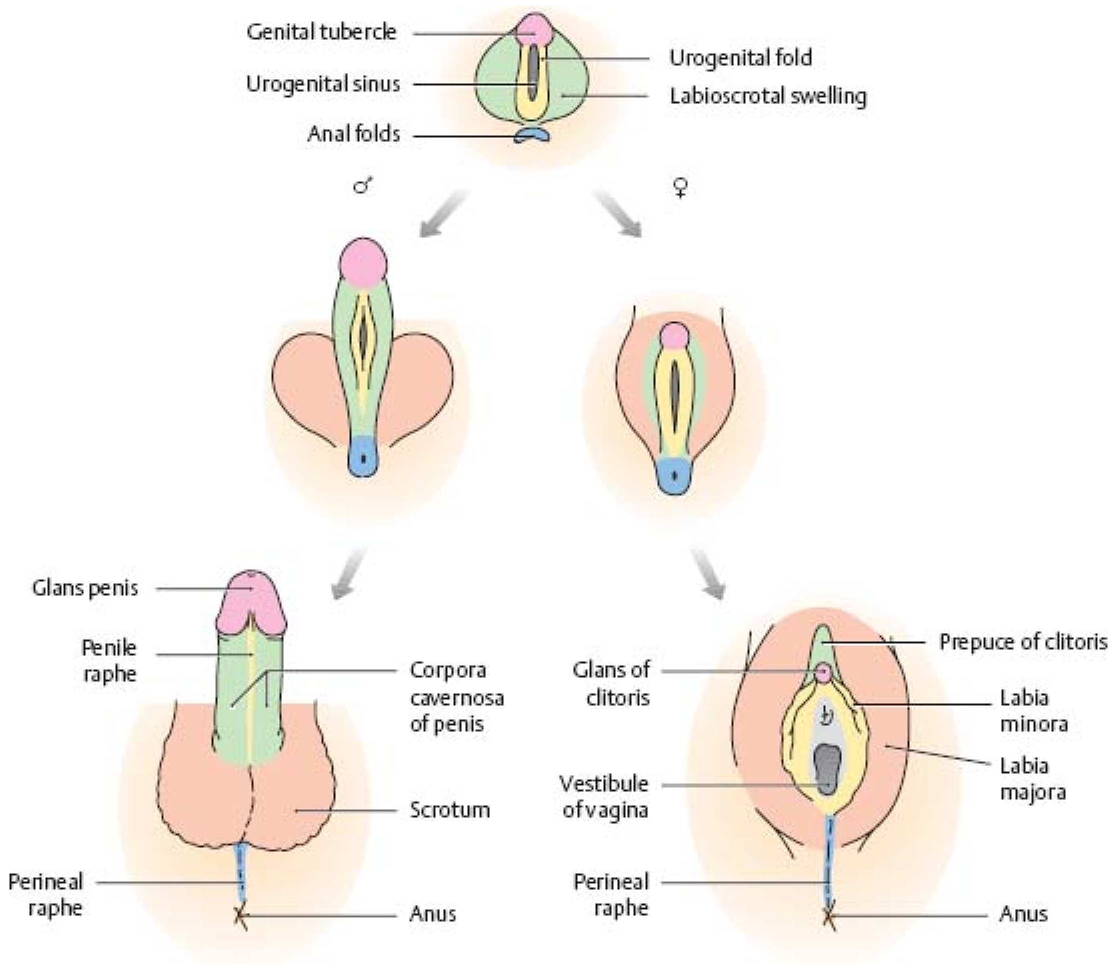


Fig. 14.31 **Descent of the testis**
Left lateral view.

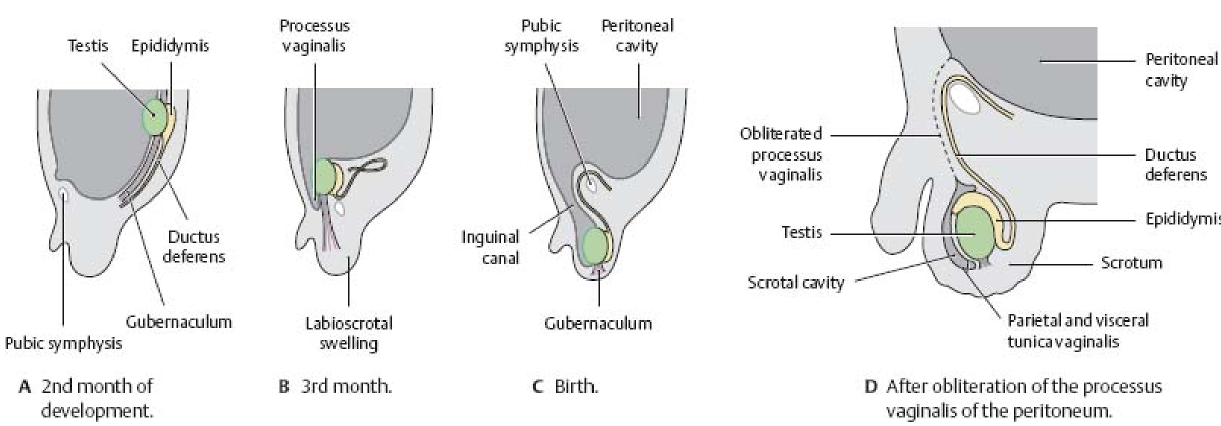
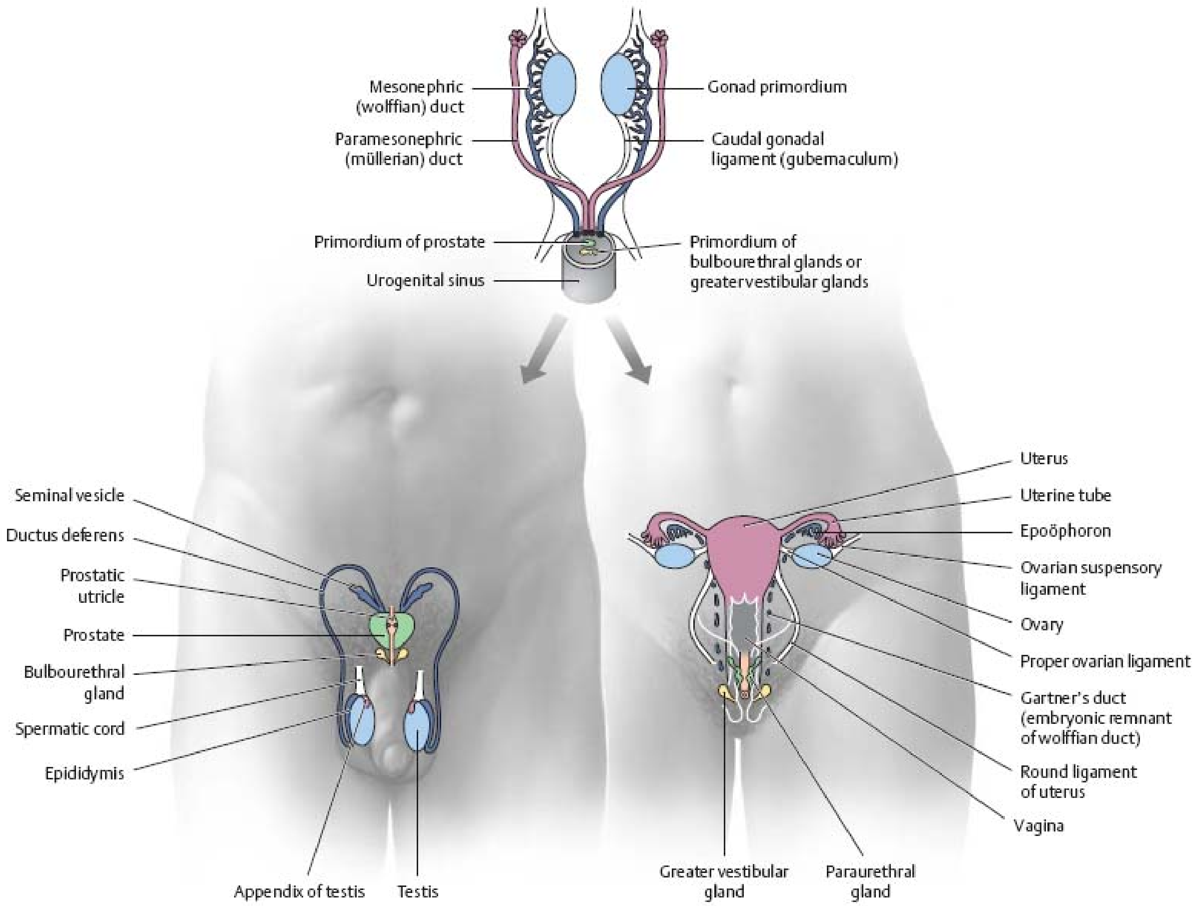


Fig. 14.32 **Development of the internal genitalia**
Anterior view.



A Genetically male embryo (testicular primordium).

B Genetically female embryo (ovarian primordium).

Table 14.4 **Derivatives of embryonic urogenital structures**

Nonfunctioning remnants in italics. Structures common to both sexes in bold.

Rudiment	Male structure	Female structure
Undifferentiated gonad	Testis	Ovary
Cortex	Seminiferous tubules	Follicle
Medulla	Rete testis	Ovarian stroma
Mesonephric ductule	Efferent ductules of testis, *paradidymis*	*Epo- and paroöphoron*
Mesonephric (wolffian) duct	**Ureter, renal pelvis and calices, collecting ducts**	
	Epididymal duct, ductus deferens, ejaculatory duct, seminal vesicle	—
Paramesonephric (müllerian) duct	*Appendix of testis*	Uterine tube, uterus, vagina (superior portion), *Morgagni's hydatids*
Urogenital sinus	**Bladder, urethra**	
	Prostate, bulbourethral gland, *prostatic utricle*	Vagina (inferior portion), greater and lesser vestibular glands
Phallus (genital tubercle)	Corpus cavernosum of penis	Clitoris, glans of clitoris
Genital folds	Glans of penis, *penile raphe*	Labia minora, vestibular bulb
Labioscrotal swellings	Scrotum	Labia majora
Gubernaculum	*Gubernaculum of testis*	Proper ovarian ligament, round ligament of uterus
Genital tubercle (of Müller)	*Seminal colliculus*	*Hymen*

15 Arteries & Veins

Arteries of the Abdomen

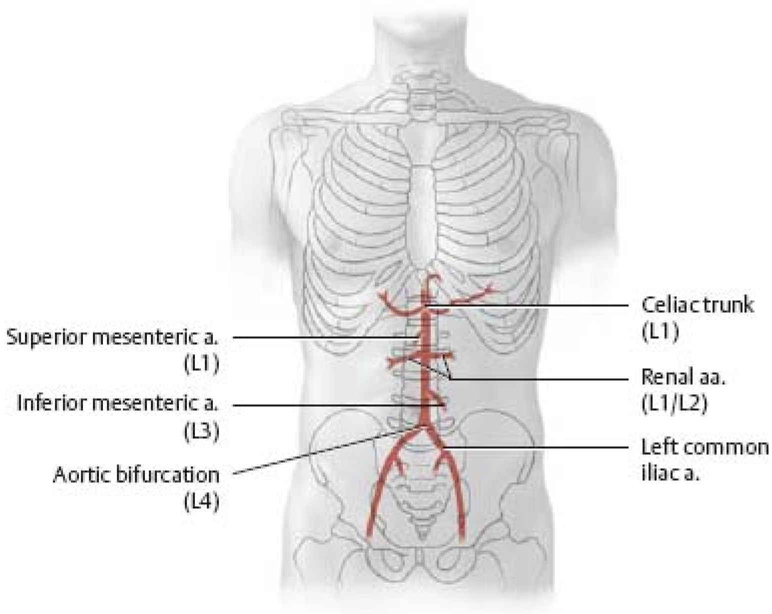
Fig. 15.1 Abdominal aorta and major branches

Anterior view. The abdominal aorta enters the abdomen at the T12 level through the aortic aperture of the diaphragm (see p. 54). Before bifurcating at L4 into its terminal branches, the common iliac arteries, the abdominal aorta gives off the renal arteries (see p. 209) and three major trunks that supply the organs of the alimentary canal:

Celiac trunk: Supplies the structures of the foregut, the anterior portion of the alimentary canal. The foregut consists of the esophagus (distal half), stomach, duodenum (proximal half), liver, gallbladder, and pancreas (superior portion).

Superior mesenteric artery: Supplies the structures of the midgut: the duodenum (distal half), jejunum and ileum, cecum and appendix, ascending and transverse colons, and right colic (hepatic) flexure.

Inferior mesenteric artery: Supplies the structures of the hindgut: the transverse colon (distal third), left colic (splenic) flexure, descending and sigmoid colons, rectum, and anal canal (upper part).



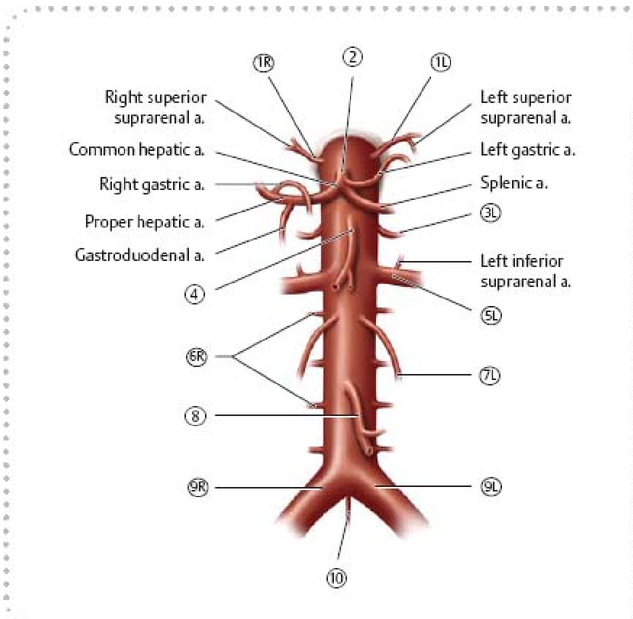


Table 15.1 Branches of the abdominal aorta

The abdominal aorta gives rise to three major unpaired trunks (bold) and the unpaired median sacral artery, as well as six paired branches.

Branch from abdominal aorta			Branches	
1R	1L	Inferior phrenic aa. (paired)	Superior suprarenal aa.	
2		**Celiac trunk**	Left gastric a.	
			Splenic a.	
			Common hepatic a.	Proper hepatic a.
				Right gastric a.
				Gastroduodenal a.
3R	3L	Middle suprarenal aa. (paired)		
4		**Superior mesenteric a.**		
5R	5L	Renal aa. (paired)	Inferior suprarenal aa.	
6R	6L	Lumbar aa. (1st through 4th, paired)		
7R	7L	Testicular/ovarian aa. (paired)		
8		**Inferior mesenteric a.**		
9R	9L	Common iliac aa. (paired)	External iliac a.	
			Internal iliac a.	
10		Median sacral a.		

Fig. 15.2 **Celiac trunk**

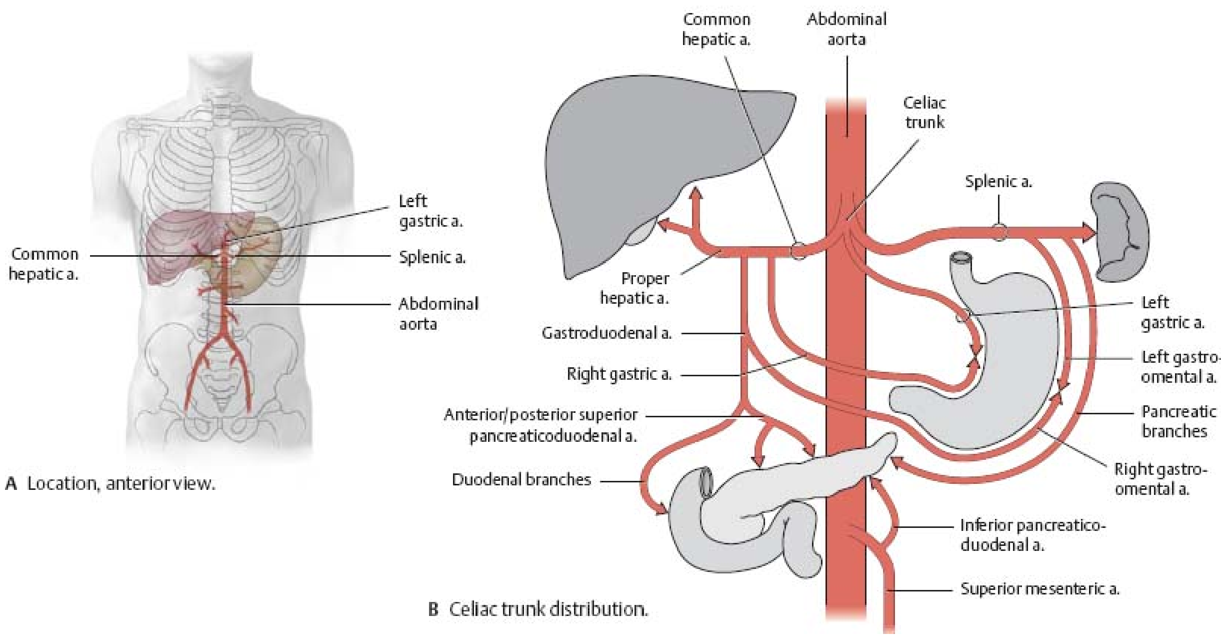


Fig. 15.3 **Superior mesenteric artery**

Anterior view.

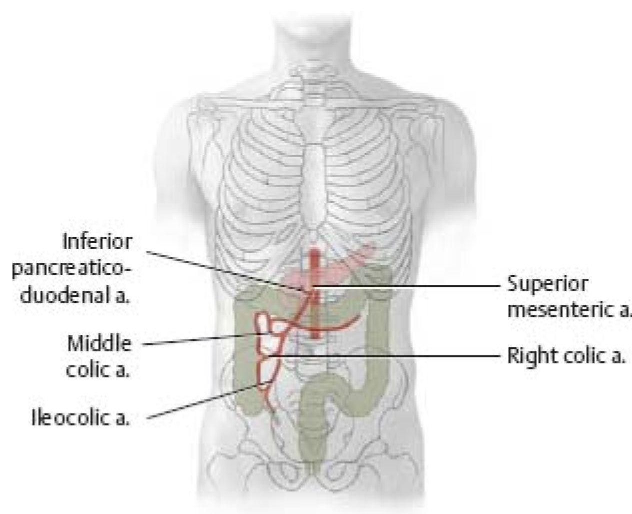


Fig. 15.4 **Inferior mesenteric artery**

Anterior view.

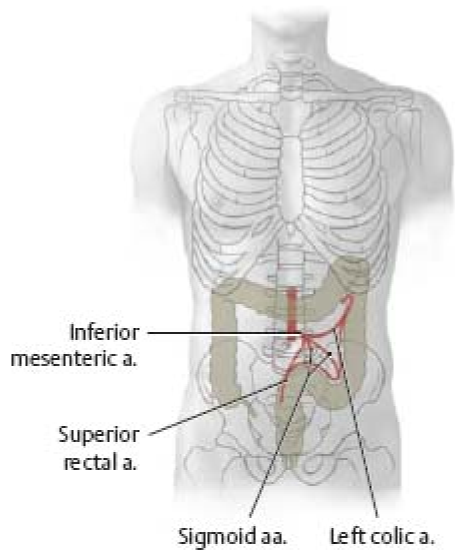
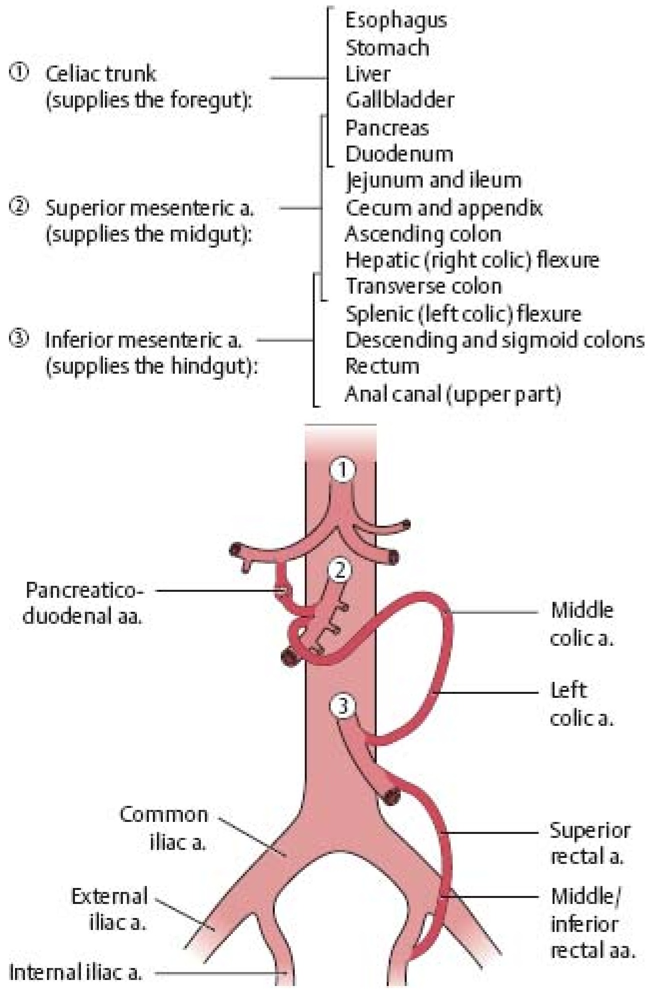


Fig. 15.5 **Abdominal arterial anastomoses**

The three major arterial anastomoses of the abdomen deliver blood to intestinal areas deprived of their normal blood supply.



Abdominal Aorta & Renal Arteries

Fig. 15.6 Abdominal aorta

Anterior view of the female abdomen. *Removed:* Abdominal organs and peritoneum. The abdominal aorta is the distal continuation of the thoracic aorta (see p. 68). It enters the abdomen at the T12 level and bifurcates into the common iliac arteries at L4.

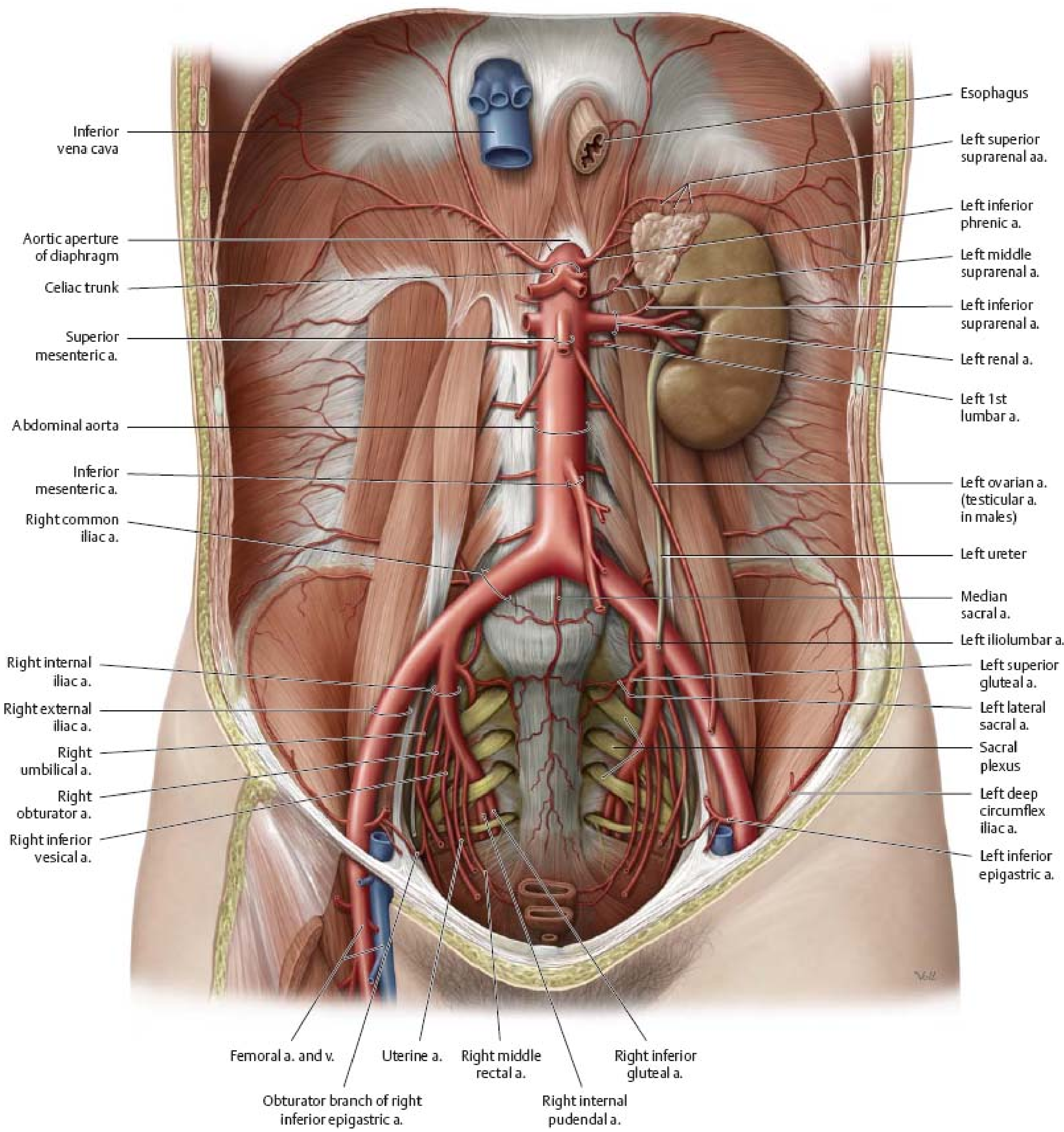
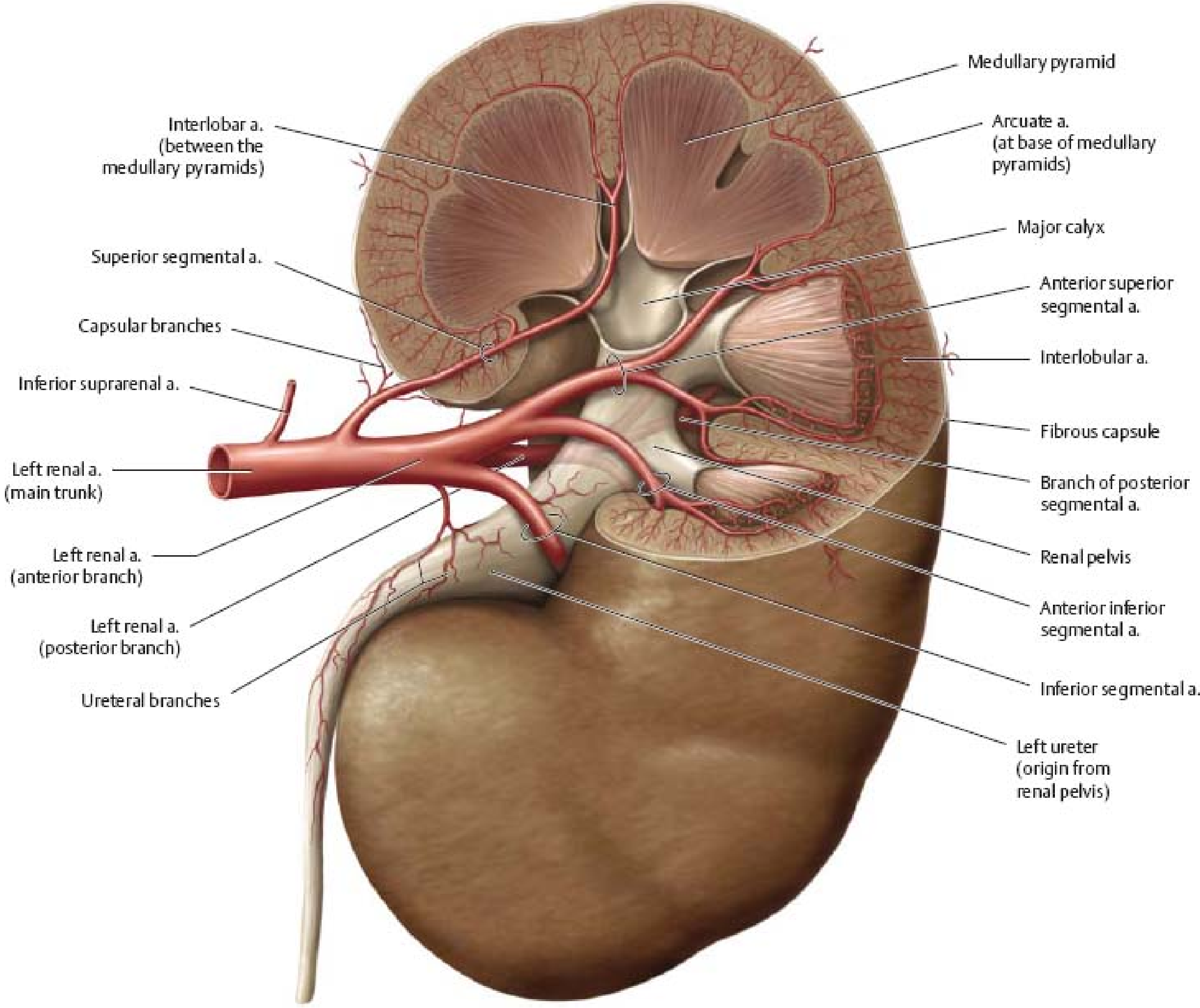


Fig. 15.7 **Renal arteries**

Left kidney, anterior view. The renal arteries arise at approximately the level of L2. Each renal artery divides into an anterior and a posterior branch. The anterior branch further divides into four segmental arteries (circled).



Clinical

Renal hypertension

The kidney is an important blood pressure sensor and regulator. Stenosis of the renal artery reduces blood flow through the kidney and stimulates increased production of renin, a hormone that cleaves angiotensinogen to form angiotensin I. Subsequent cleavage yields angiotensin II, which induces vasoconstriction and an increase in blood pressure. Renal hypertension must be excluded (or confirmed) when diagnosing high blood pressure.

Stenosis of the right renal artery (arrow), visible via arteriography.

Celiac Trunk

The distribution of the celiac trunk is shown on p. 207.

Fig. 15.8 **Celiac trunk: Stomach, liver, and gallbladder**

Anterior view. *Opened:* Lesser omentum. *Incised:* Greater omentum. The celiac trunk arises from the abdominal aorta at about the level of L1.

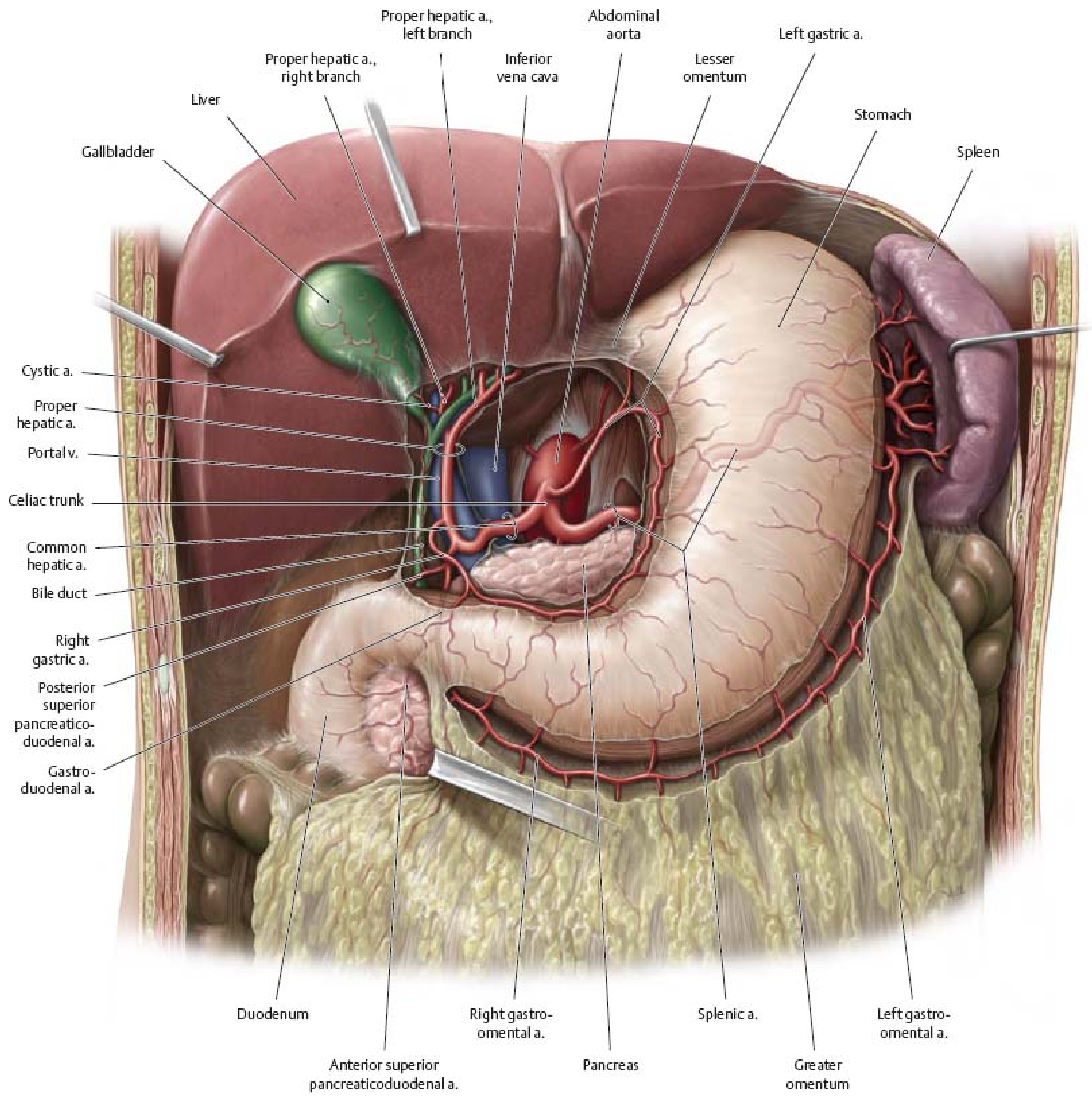
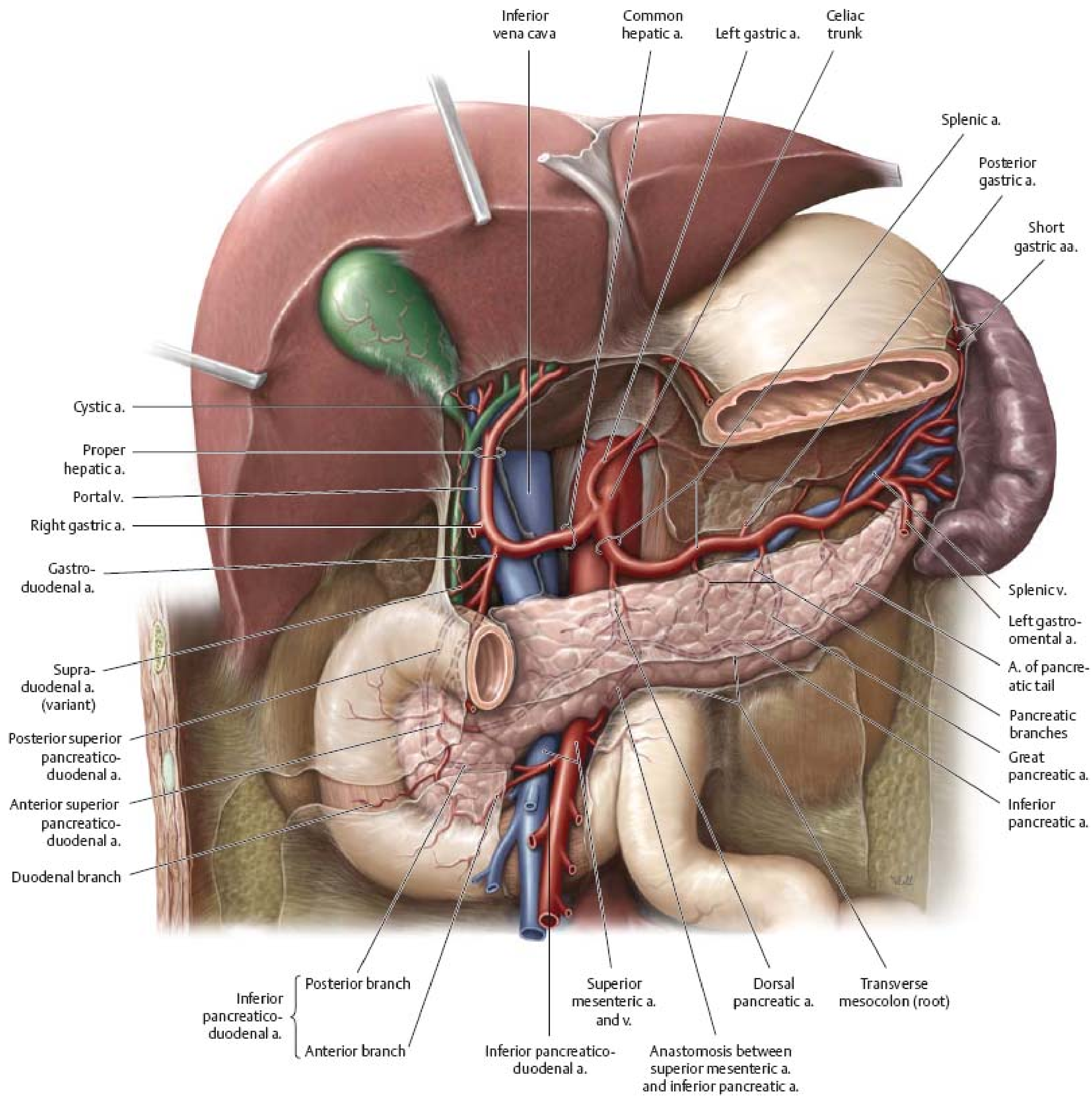


Fig. 15.9 **Celiac trunk: Pancreas, duodenum, and spleen**

Anterior view. *Removed:* Stomach (body) and lesser omentum.



Superior & Inferior Mesenteric Arteries

Fig. 15.10 Superior mesenteric artery

Anterior view. *Partially removed:* Stomach and peritoneum. *Note:* The middle colic artery has been truncated (see Fig. 15.11). The superior and inferior mesenteric arteries arise from the aorta opposite L2 and L3, respectively.

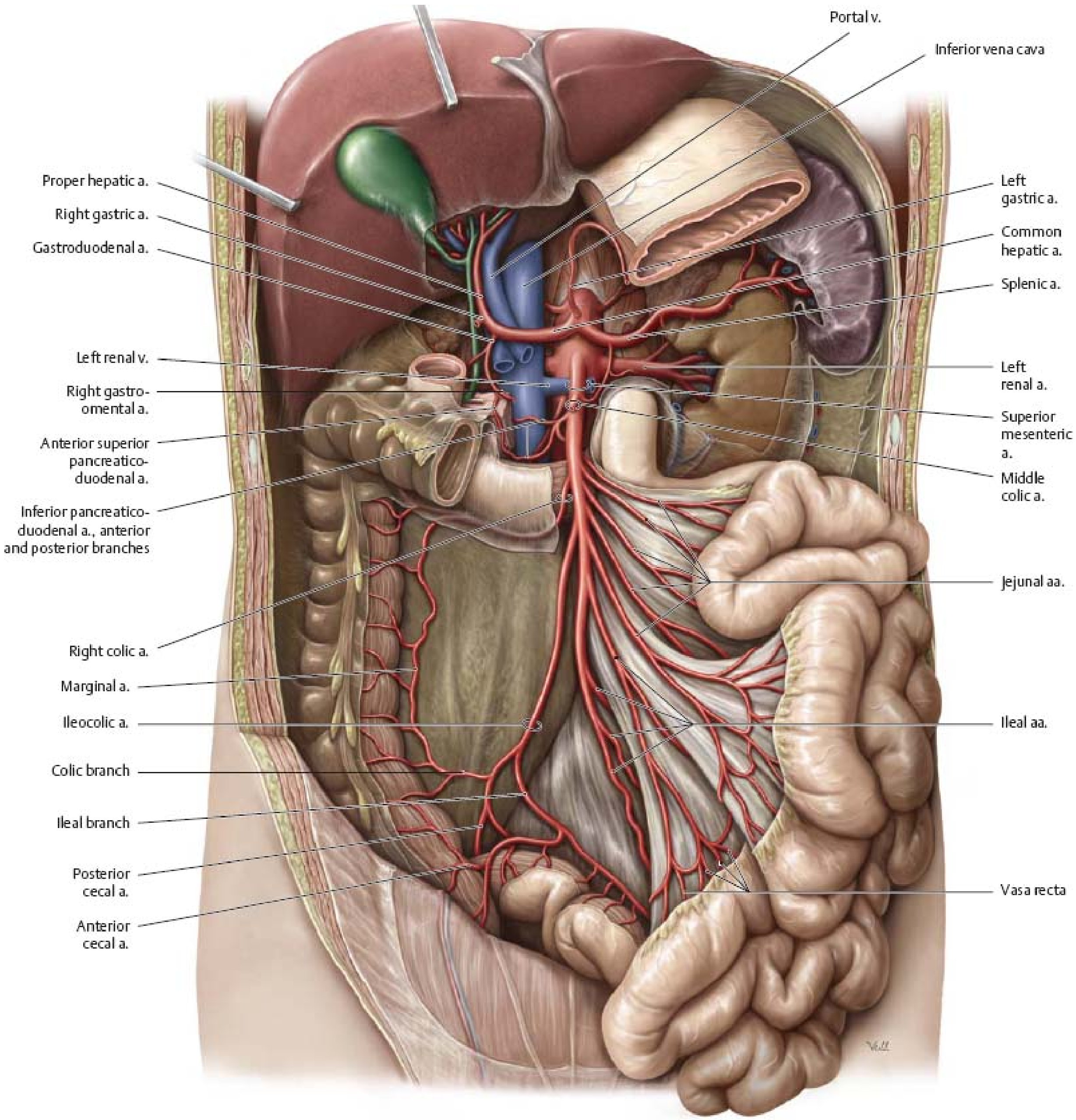
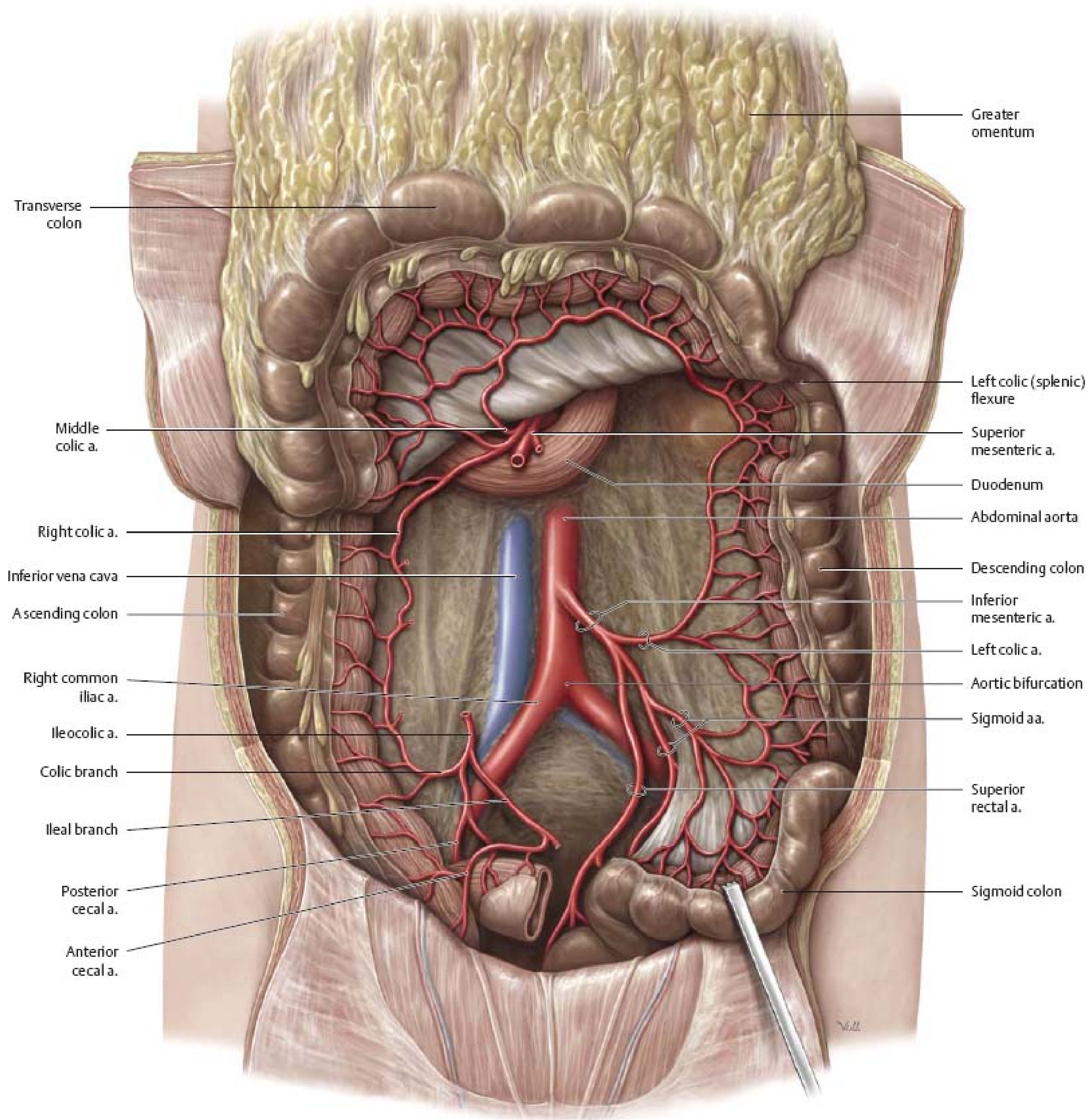


Fig. 15.11 **Inferior mesenteric artery**

Anterior view. *Removed:* Jejunum and ileum. *Reflected:* Transverse colon.



Veins of the Abdomen

Fig. 15.12 Inferior vena cava: Location

Anterior view.

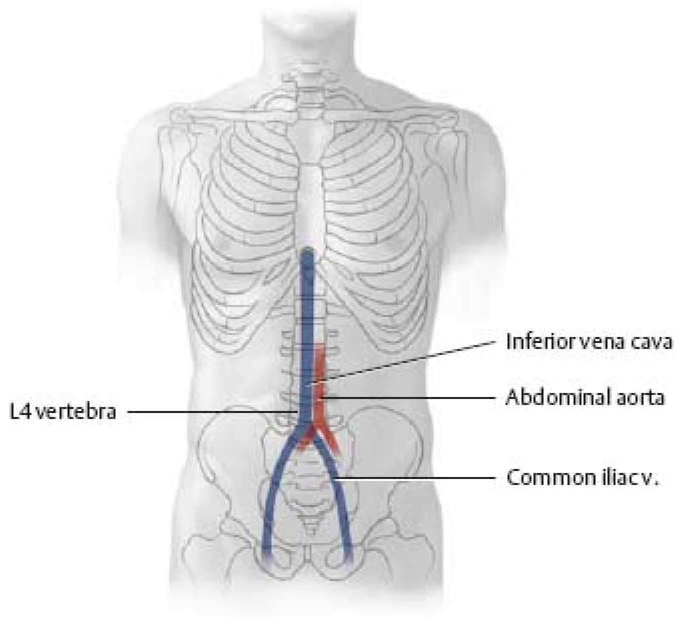
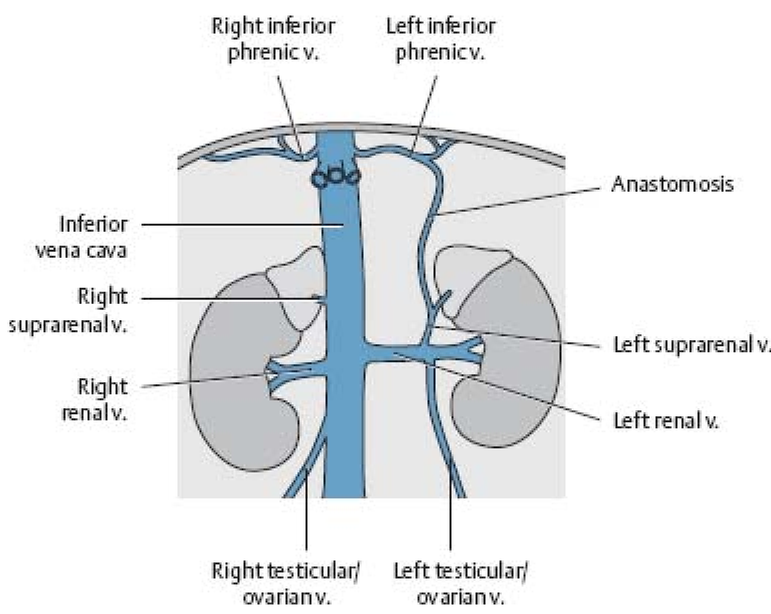
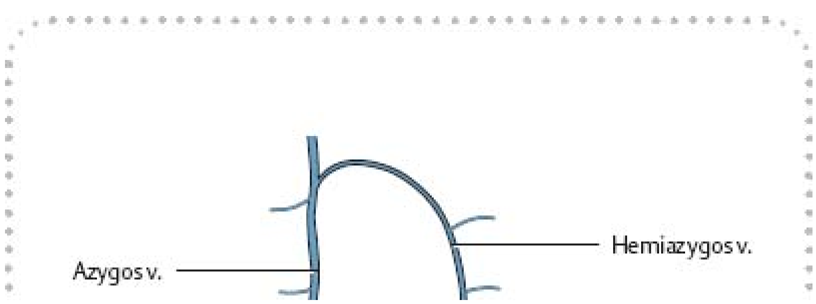


Fig. 15.13 **Tributaries of the renal veins**

Anterior view.





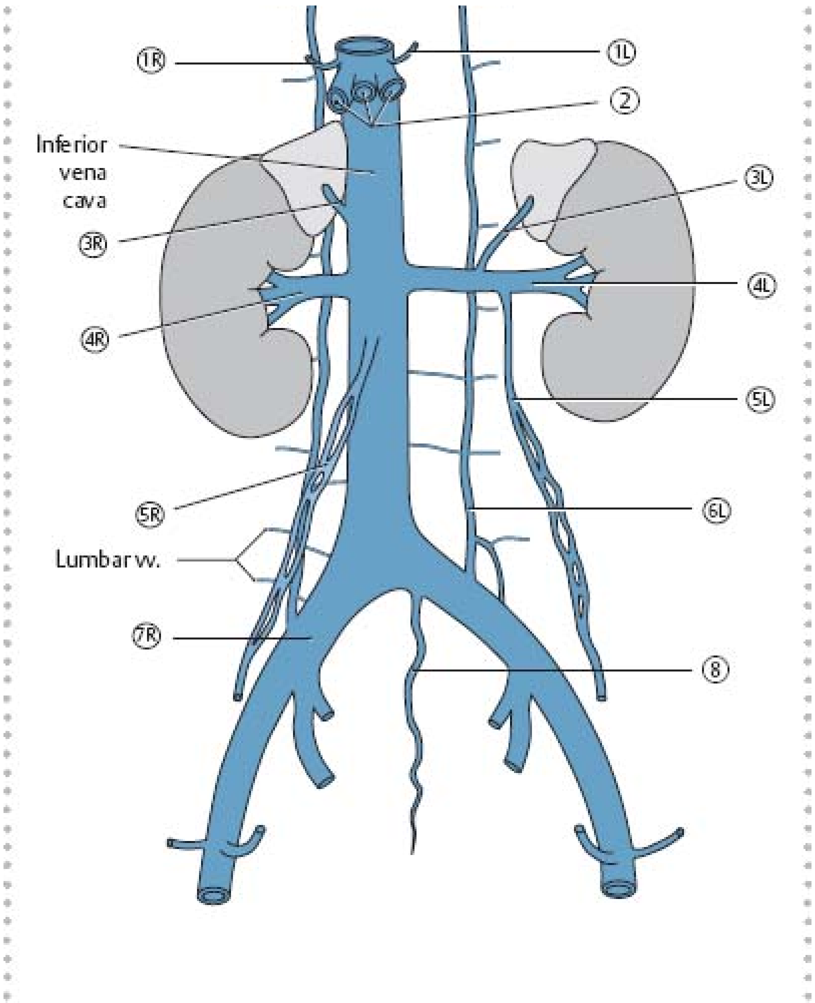
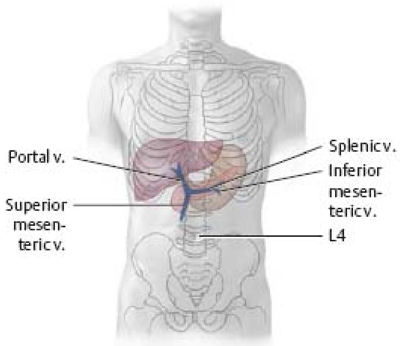


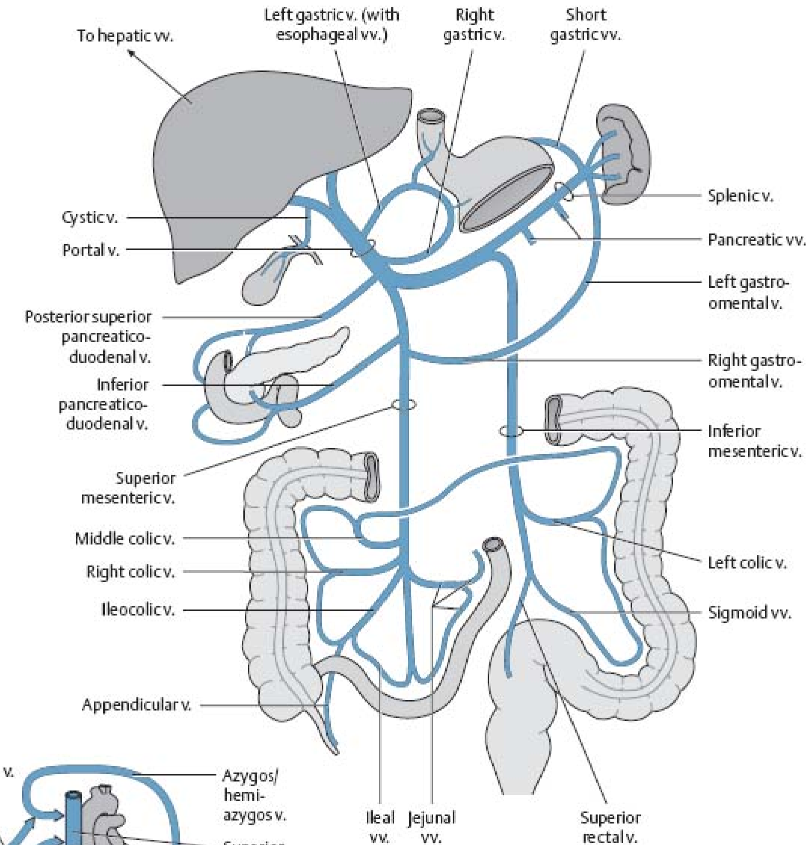
Table 15.2		Tributaries of the inferior vena cava
1R	1L	Inferior phrenic vv. (paired)
2		Hepatic vv. (3)
3R	3L	Suprarenal vv. (the right vein is a direct tributary)
4R	4L	Renal vv. (paired)
5R	5L	Testicular/ovarian vv. (the right vein is a direct tributary)
6R	6L	Ascending lumbar vv. (paired)
7R	7L	Common iliac vv. (paired)
8		Median sacral v.

Fig. 15.14 Portal vein

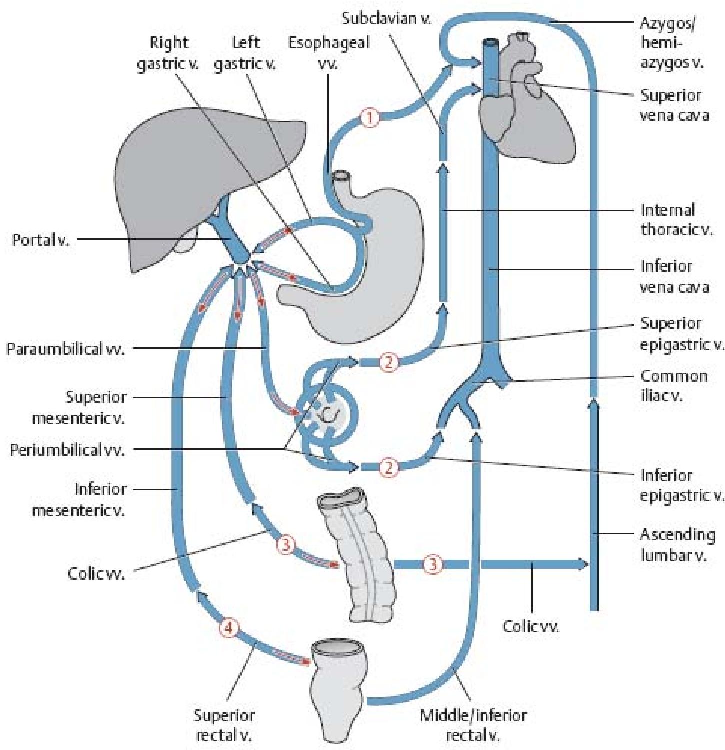
The portal vein (see p. 218) drains venous blood from the abdominopelvic organs supplied by the celiac trunk and superior and inferior mesenteric arteries.



A Location, anterior view.



B Portal vein distribution.



C Collateral pathways (portosystemic collaterals). When the portal system is compromised, nutrient-laden blood may be transported to the heart via the venae cavae without passing through the liver. Red arrows indicate flow reversal.

Clinical

Cancer metastases

Tumors in the region drained by the superior rectal vein may spread through the portal venous system to the capillary bed of the liver (hepatic metastasis). Tumors drained by the middle or inferior rectal veins may metastasize to the capillary bed of the lung (pulmonary metastasis) via the inferior vena cava and right heart.

Inferior Vena Cava & Renal Veins

Fig. 15.15 Inferior vena cava

Anterior view of the female abdomen. *Removed:* All organs (except the left kidney and suprarenal gland).

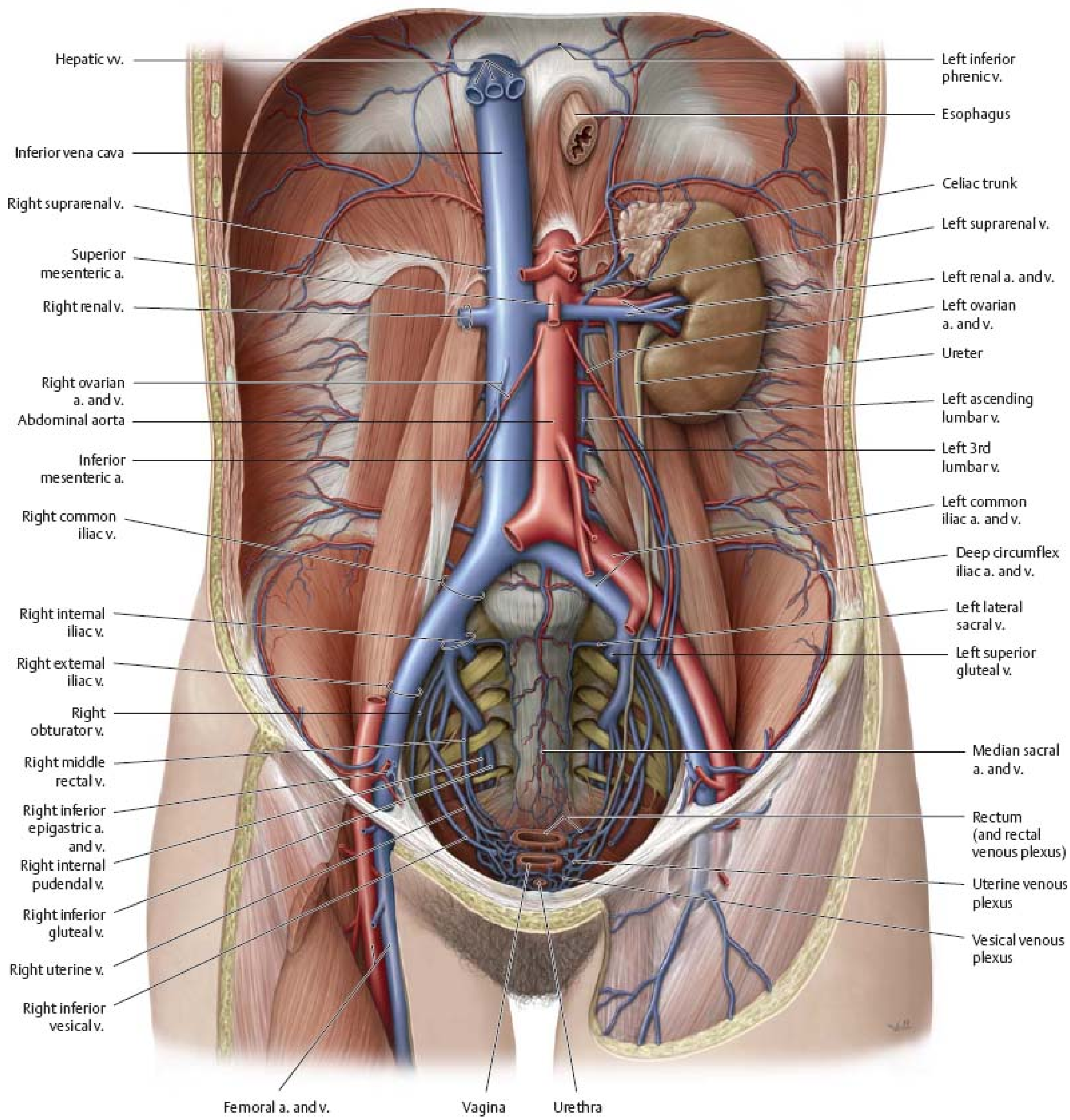
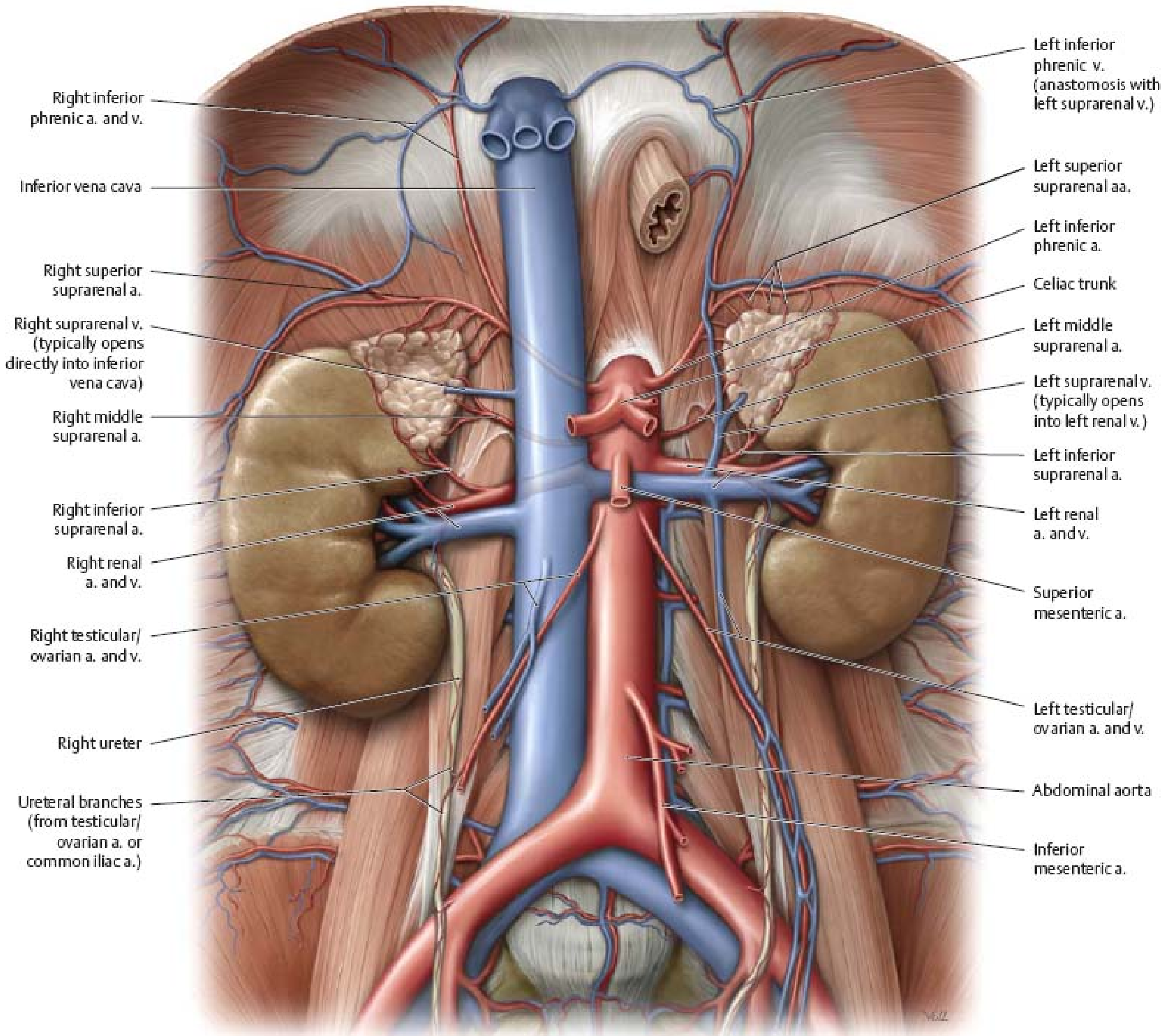


Fig. 15.16 **Renal veins**

Anterior view. See p. 209 for the renal arteries in isolation.



Portal Vein

The portal vein is typically formed by the union of the superior mesenteric and the splenic veins posterior to the neck of the pancreas. The distribution of the portal vein is shown on p. 215.

Fig. 15.17 Portal vein: Stomach and duodenum

Anterior view. *Removed:* Liver, lesser omentum, and peritoneum. *Opened:* Greater omentum.

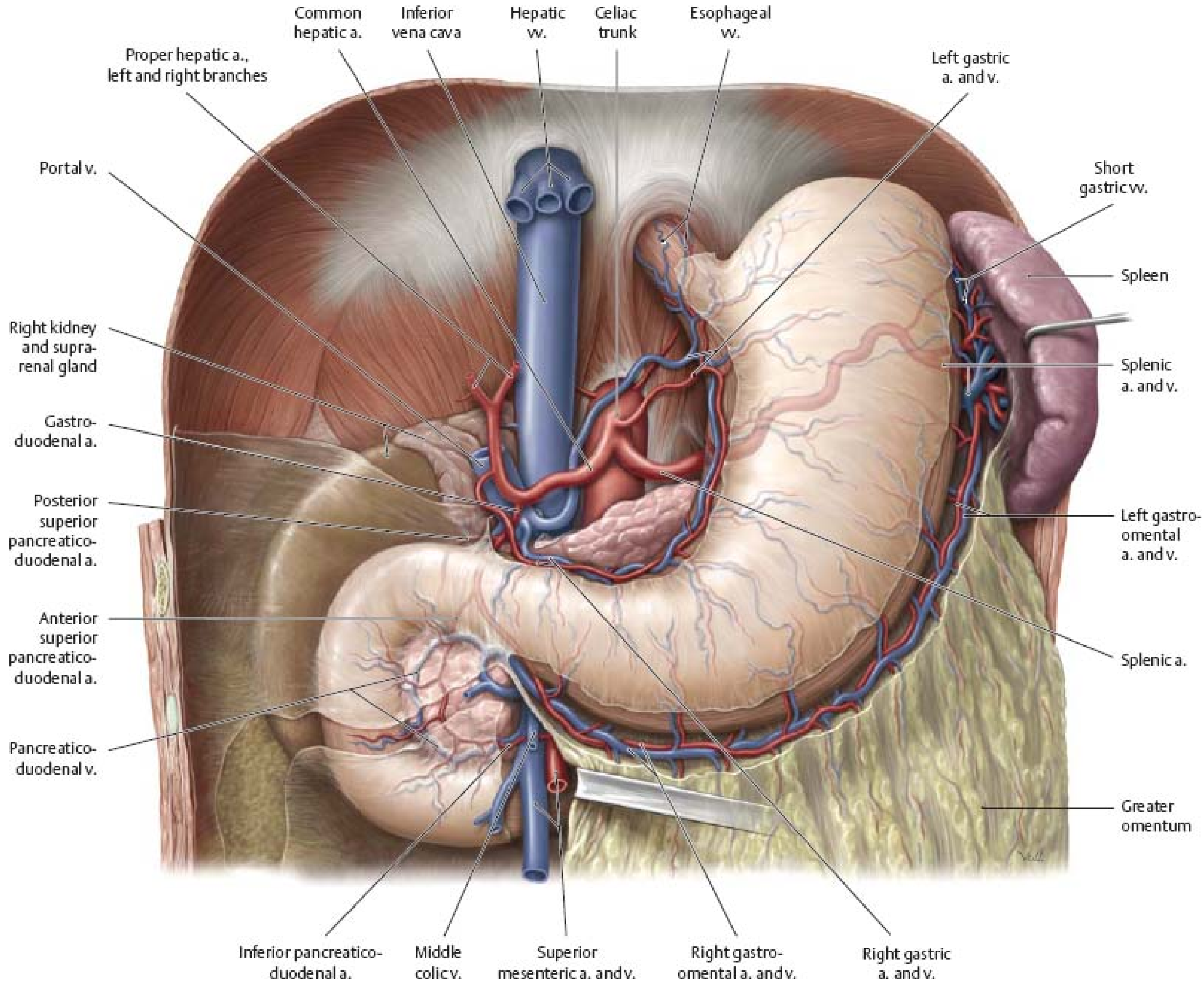
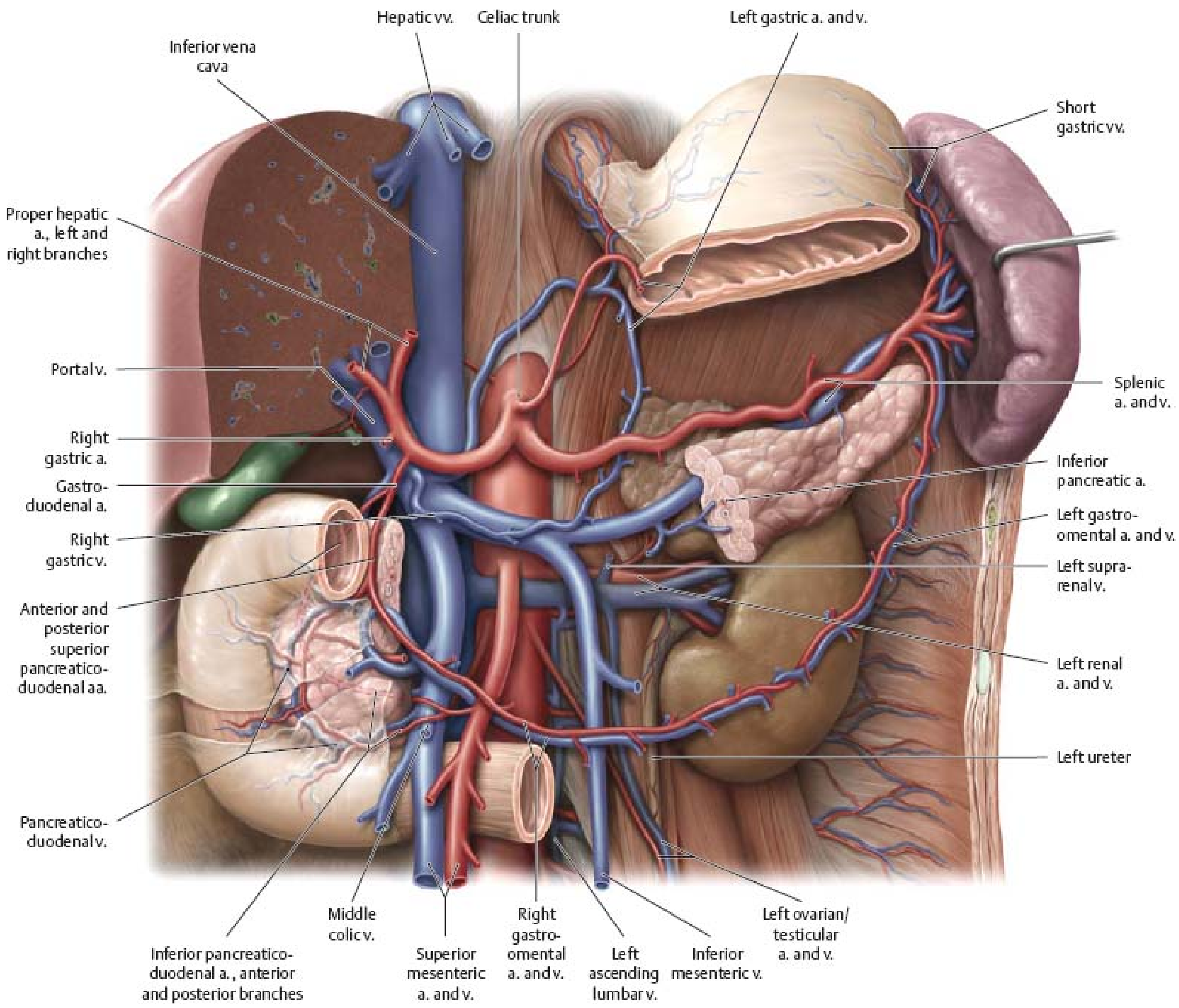


Fig. 15.18 **Portal vein: Pancreas and spleen**

Anterior view. *Partially removed:* Stomach, pancreas, and peritoneum.



Superior & Inferior Mesenteric Veins

Fig. 15.19 Superior mesenteric vein

Anterior view. *Partially removed:* Stomach, pancreas, peritoneum, mesentery, and transverse colon. *Displaced:* Small intestine.

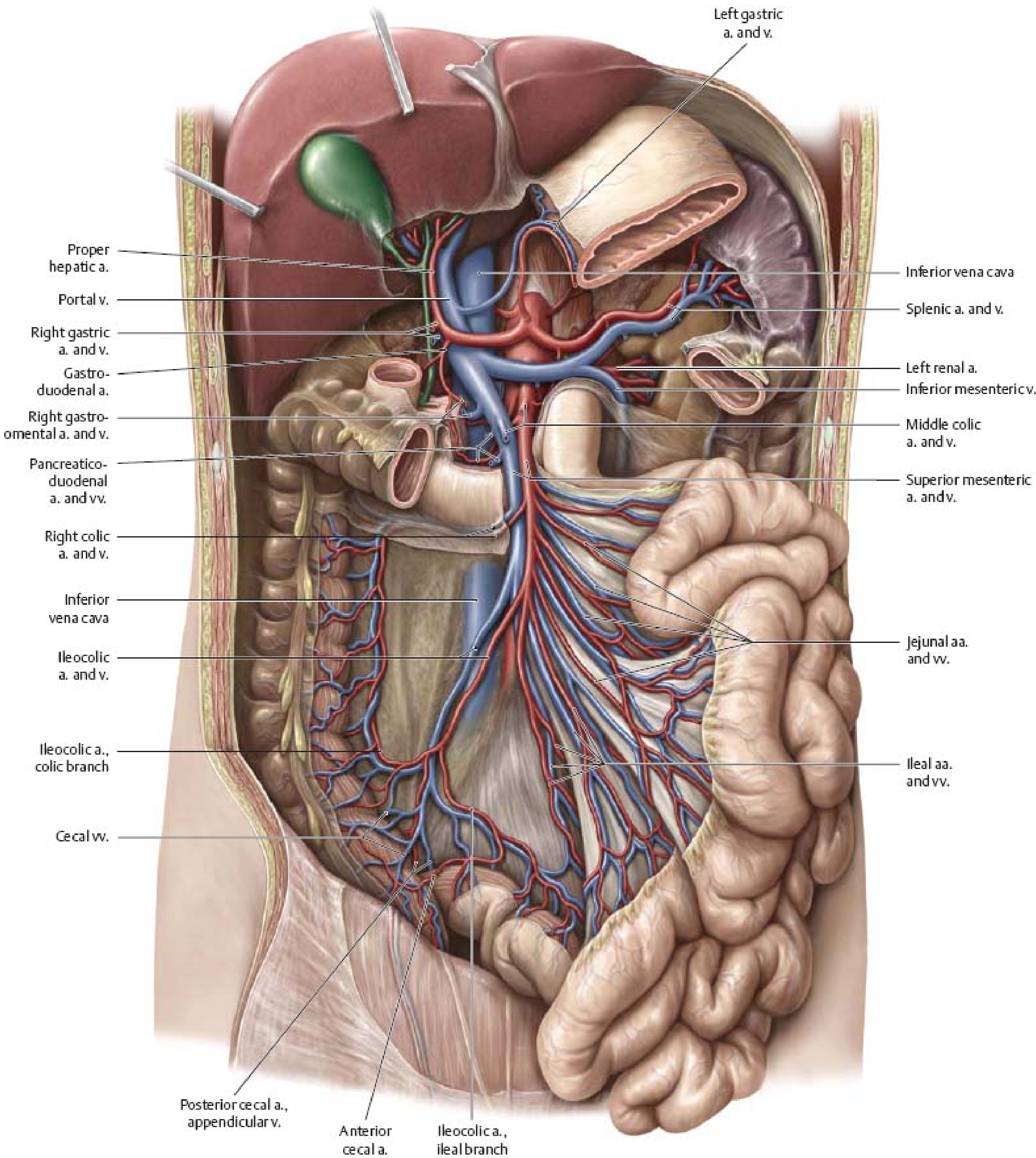
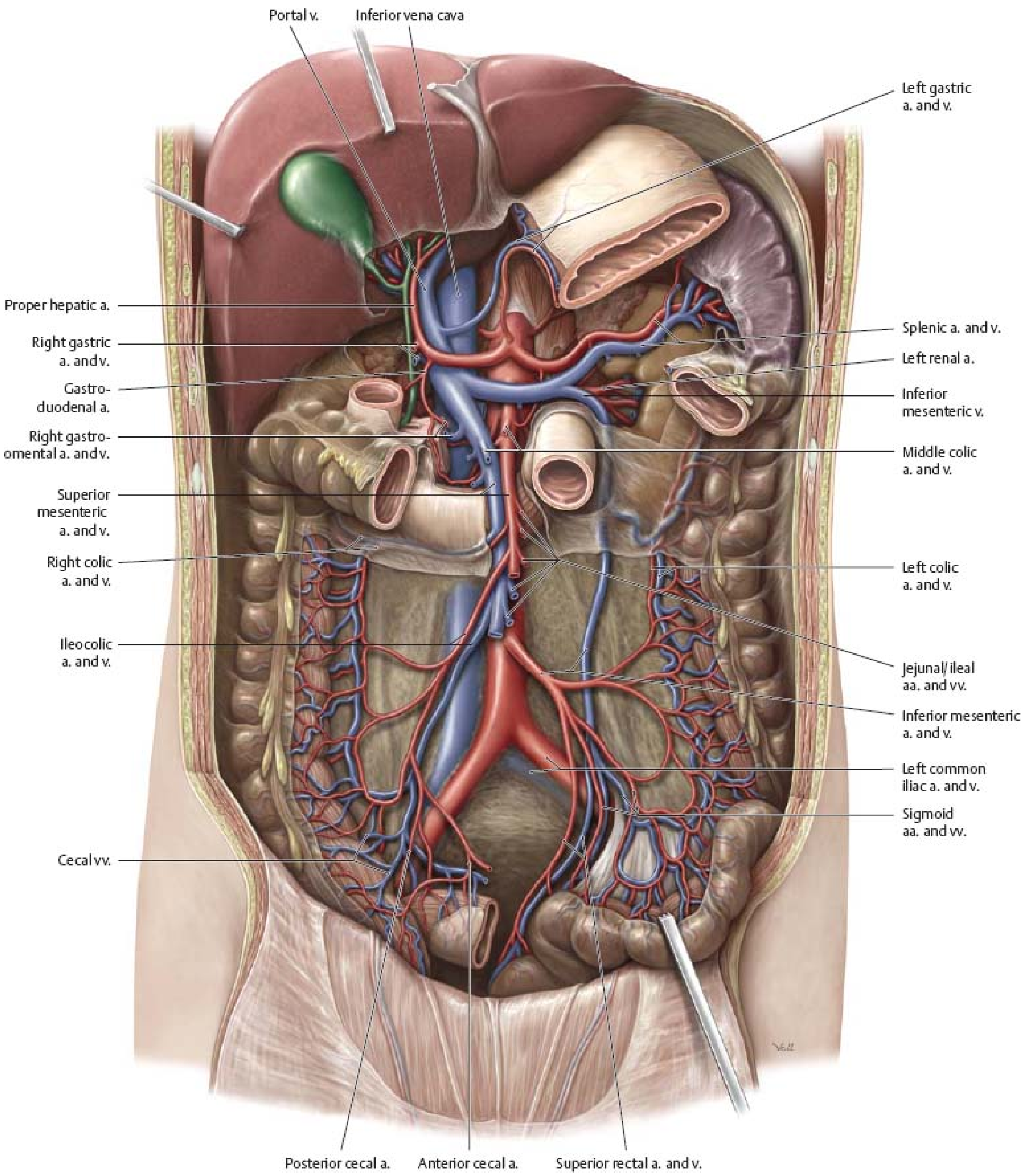
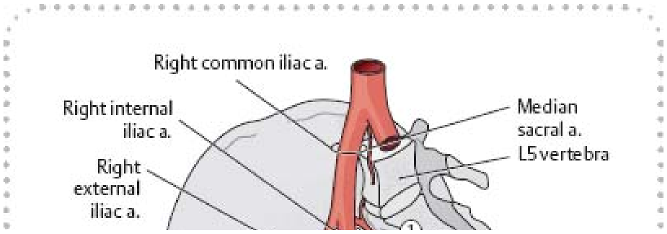


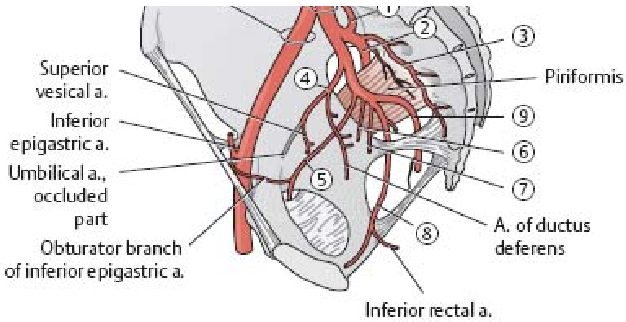
Fig. 15.20 **Inferior mesenteric vein**

Anterior view. *Removed:* Stomach, pancreas, small intestine, and peritoneum.

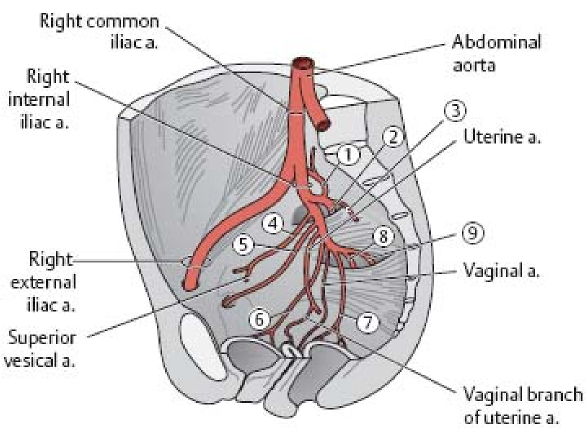


Arteries & Veins of the Pelvis





A Male pelvis.



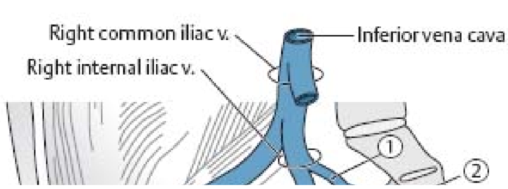
B Female pelvis.

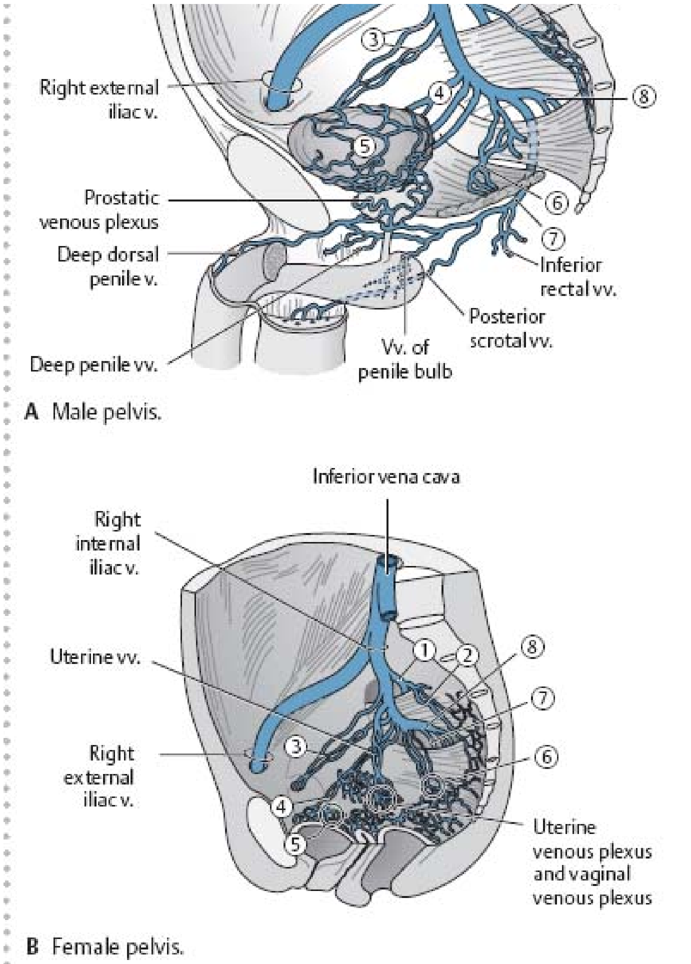
Table 15.3 Branches of the internal iliac artery

The internal iliac artery gives off five parietal (pelvic wall) and four visceral (pelvic organs) branches. * Parietal branches are shown in italics.

Branches		
①	*Iliolumbar a.*	
②	*Superior gluteal a.*	
③	*Lateral sacral a.*	
④	Umbilical a.	A. of ductus deferens
		Superior vesical a.
⑤	*Obturator a.*	
⑥	Inferior vesical a.	
⑦	Middle rectal a.	
⑧	Internal pudendal a.	Inferior rectal a.
⑨	*Inferior gluteal a.*	

* In the female pelvis, the uterine and vaginal arteries may arise directly from the internal iliac artery.





A Male pelvis.

B Female pelvis.

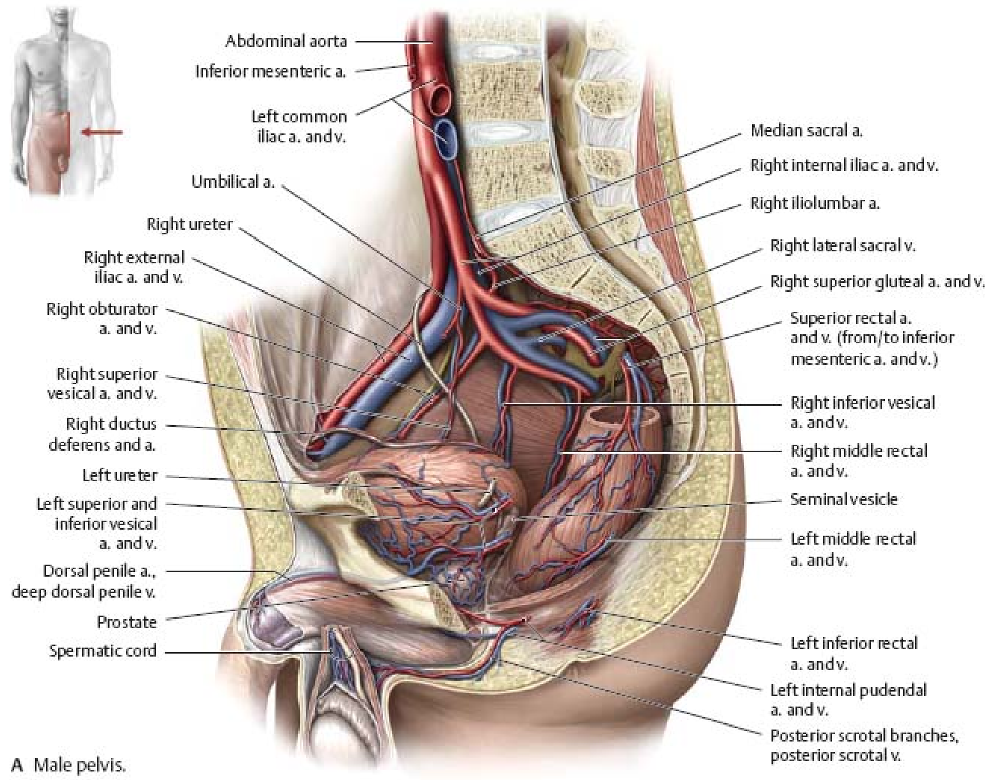
Table 15.4 Venous drainage of the pelvis

Tributaries	
①	Superior gluteal v.
②	Lateral sacral v.
③	Obturator vv.
④	Vesical vv.
⑤	Vesical venous plexus
⑥	Middle rectal vv. (rectal venous plexus) (also superior and inferior rectal vv., not shown)
⑦	Internal pudendal v.
⑧	Inferior gluteal vv.

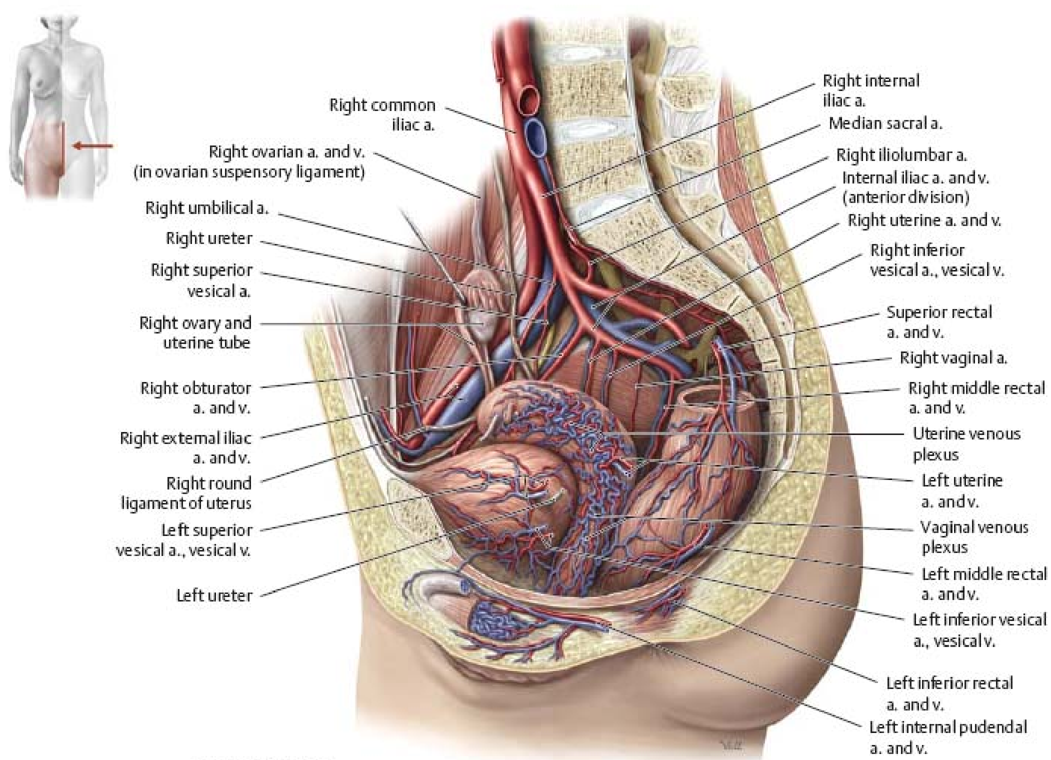
The male pelvis also contains a prostatic venous plexus and veins draining the penis and scrotum. The female pelvis contains the uterine and vaginal venous plexus.

Fig. 15.21 **Blood vessels of the pelvis**

Idealized right hemipelvis, left lateral view.



A Male pelvis.



B Female pelvis.

Arteries & Veins of the Rectum & Genitalia

Fig. 15.22 Blood vessels of the rectum

Posterior view. The main blood supply to the rectum is from the superior rectal arteries; the middle rectal arteries serve as an anastomosis between the superior and inferior rectal arteries.

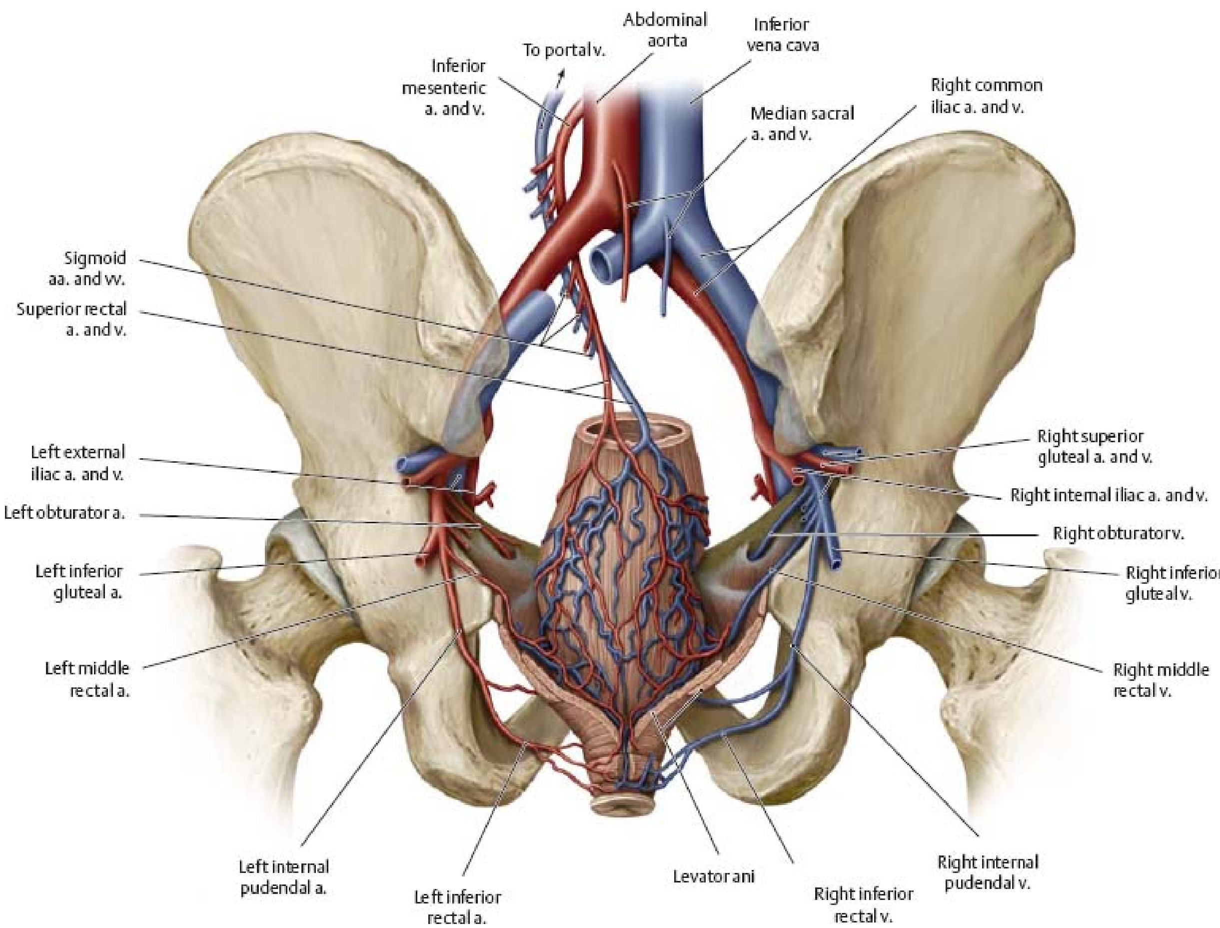
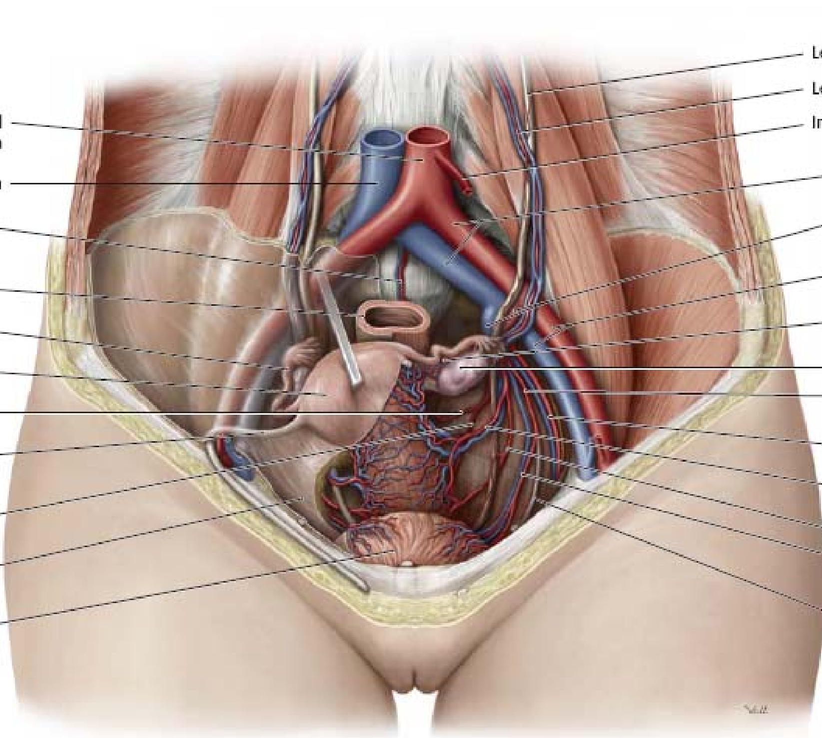
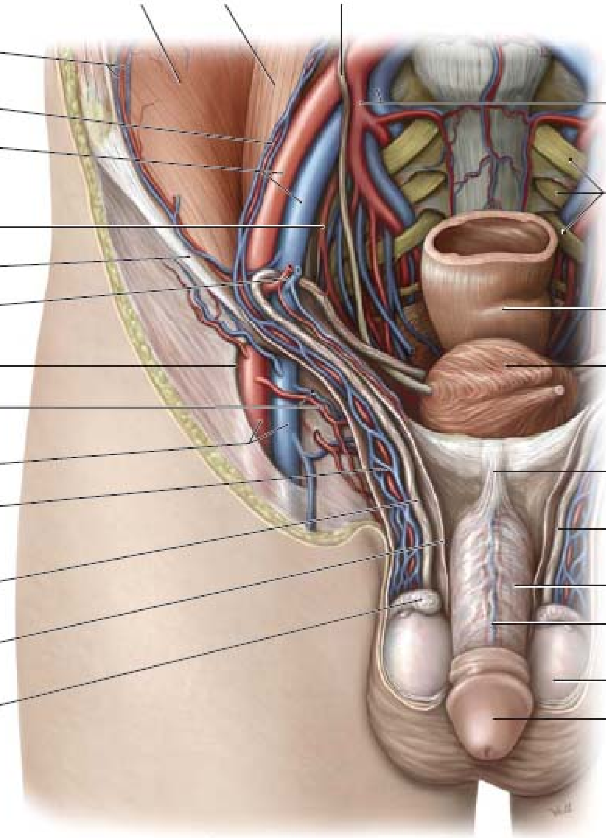


Fig. 15.23 Blood vessels of the genitalia

Anterior view.



A Female pelvis. *Removed:* Peritoneum (left side). *Displaced:* Uterus.



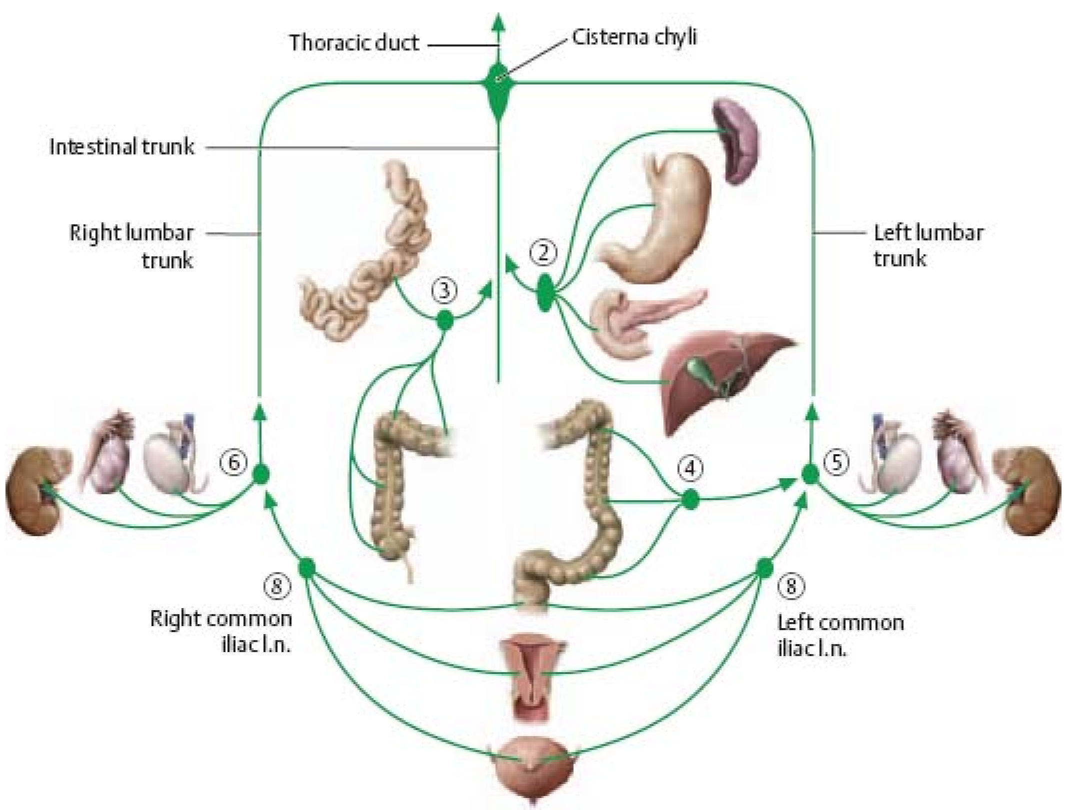
B Male pelvis. *Opened:* Inguinal canal and coverings of the spermatic cord.

16 Lymphatics

Lymph Nodes of the Abdomen & Pelvis

Fig. 16.1 Lymphatic drainage of the internal organs

See Table 16.1 for numbering. Lymph drainage from the abdomen, pelvis, and lower limb ultimately passes through the lumbar lymph nodes (clinically: aortic nodes). The lumbar lymph nodes consist of the right (caval) and left lateral aortic nodes, the preaortic nodes, and the retroaortic nodes. Efferent lymph vessels from the lumbar and preaortic nodes form the lumbar and intestinal trunks, respectively. The lumbar and intestinal trunks terminate into the cisterna chyli.



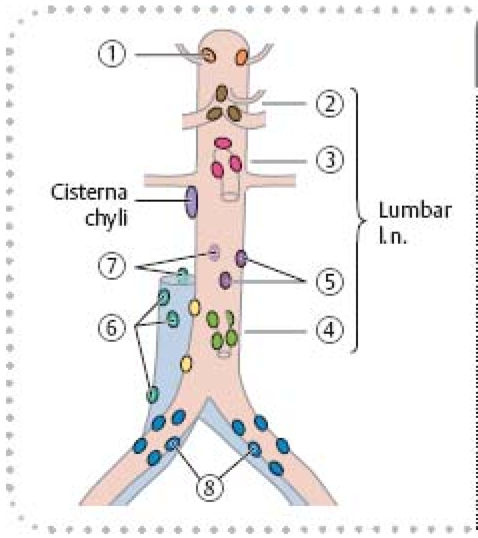


Table 16.1 Lymph nodes of the abdomen

① Inferior phrenic l.n.		
Lumbar l.n.	Preaortic l.n.	② Celiac l.n.
		③ Superior mesenteric l.n.
		④ Inferior mesenteric l.n.
	⑤ Left lateral aortic l.n.	
	⑥ Right lateral aortic (caval) l.n.	
	⑦ Retroaortic l.n.	
⑧ Common iliac l.n.		

Fig. 16.2 Lymphatic drainage of the rectum

Anterior view.

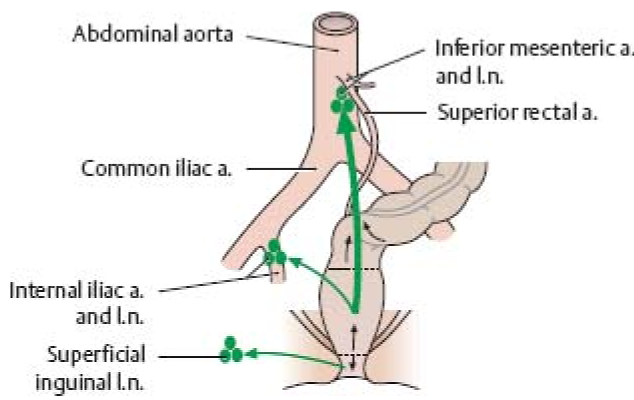


Fig. 16.3 Lymphatic drainage of the bladder and urethra

Anterior view.

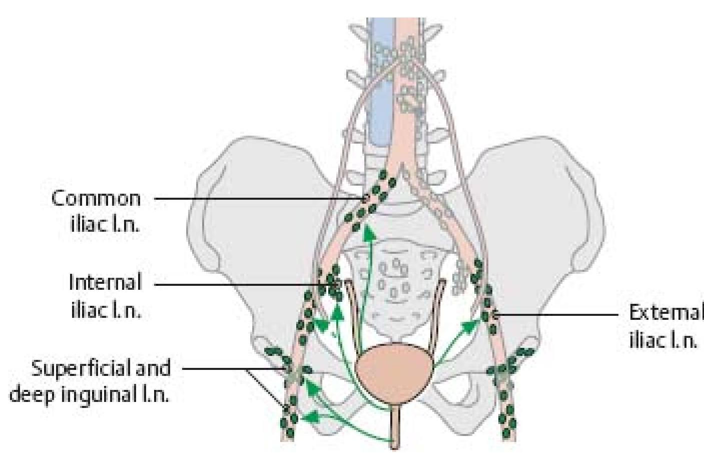


Fig. 16.4 **Lymphatic drainage of the male genitalia**
Anterior view.

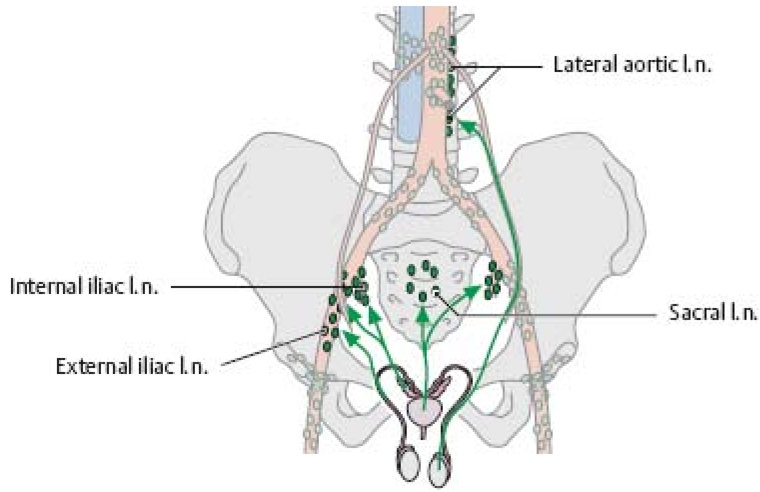
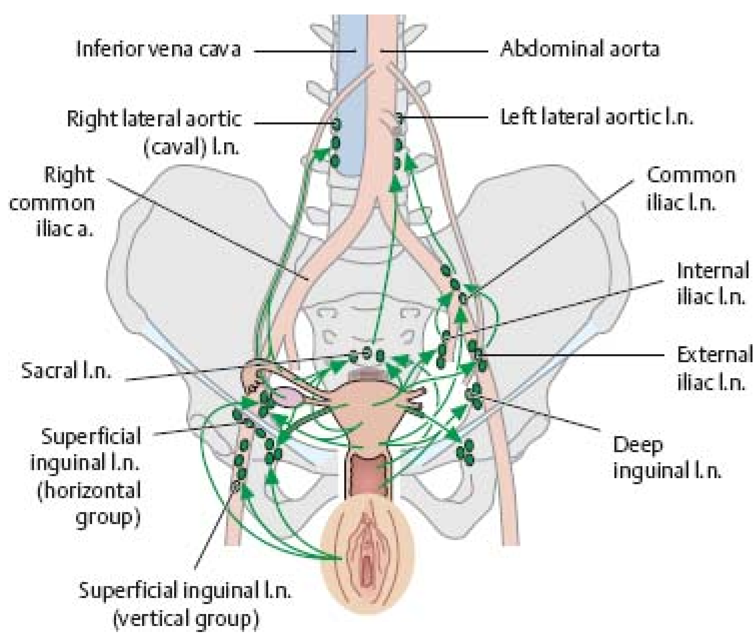


Fig. 16.5 **Lymphatic drainage of the female genitalia**
Anterior view.



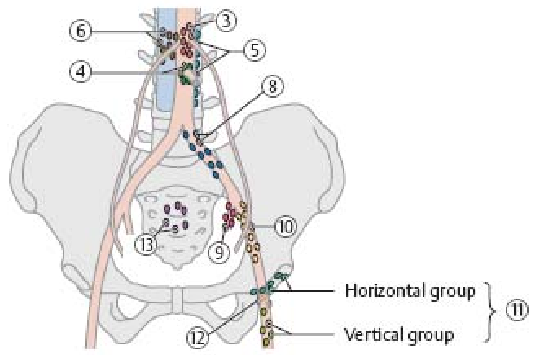


Table 16.2 Lymph nodes of the pelvis

Numbers continued from Table 16.1.	
Preaortic l.n.	③ Superior mesenteric l.n.
	④ Inferior mesenteric l.n.
⑤ Left lateral aortic l.n.	
⑥ Right lateral aortic (caval) l.n.	
⑧ Common iliac l.n.	
⑨ Internal iliac l.n.	
⑩ External iliac l.n.	
⑪ Superficial inguinal l.n.	Horizontal group
	Vertical group
⑫ Deep inguinal l.n.	
⑬ Sacral l.n.	

Lymph Nodes of the Posterior Abdominal Wall

Lymph nodes in the abdomen and pelvis may be classified as either parietal or visceral. The majority of the parietal lymph nodes are located on the posterior abdominal wall.

Fig. 16.6 **Parietal lymph nodes in the abdomen and pelvis**

Anterior view. *Removed:* All visceral structures (except vessels).

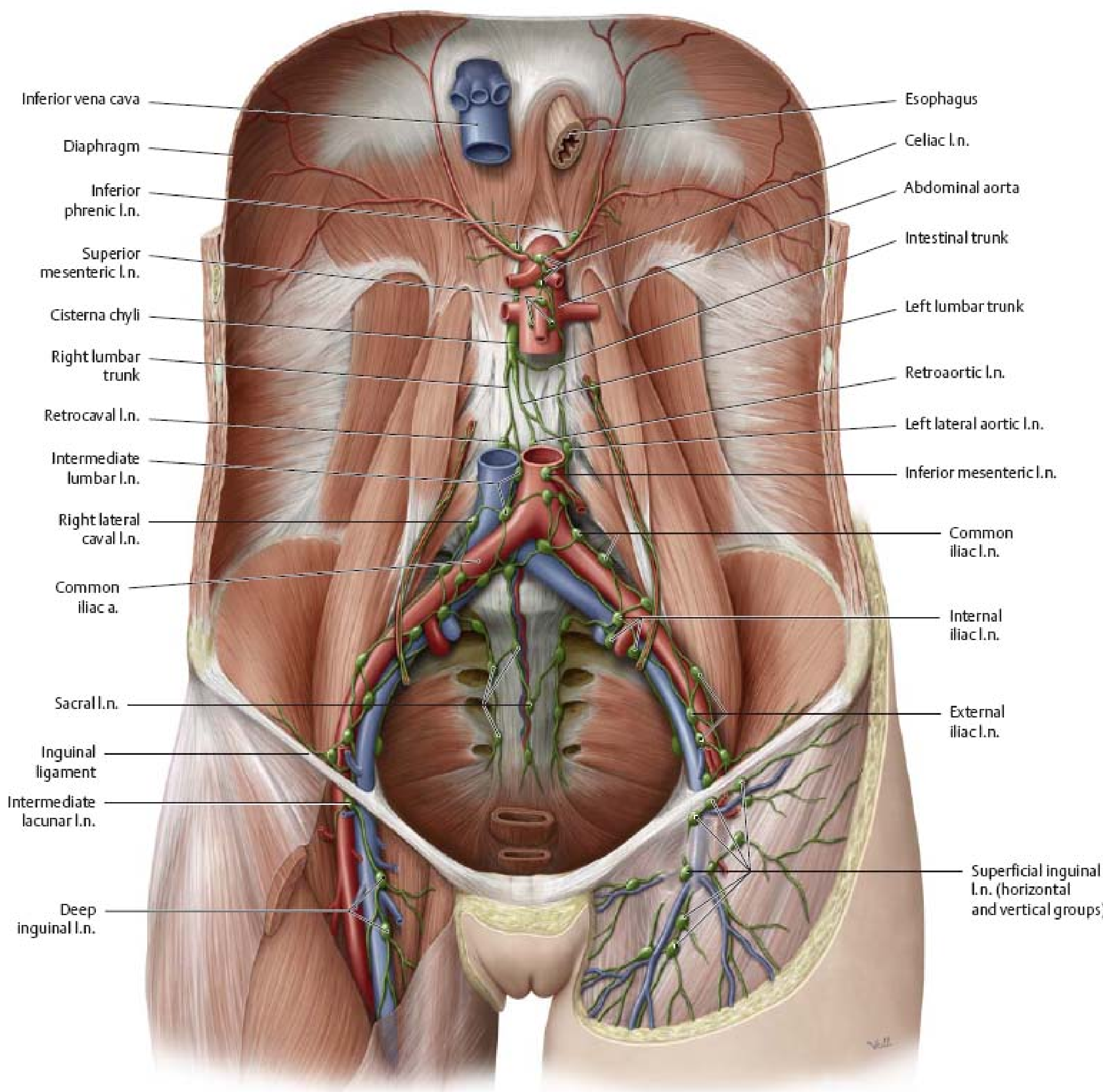


Fig. 16.7 **Lymphatic nodes of the urinary organs**

Anterior view.

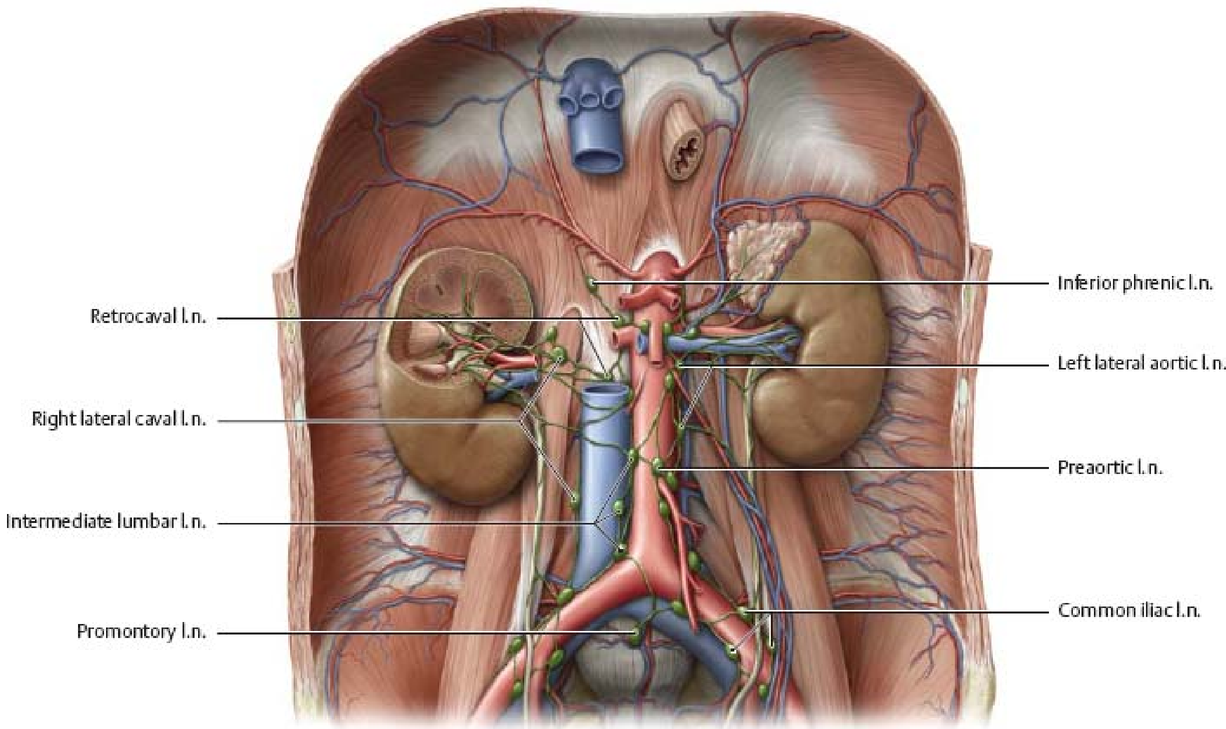
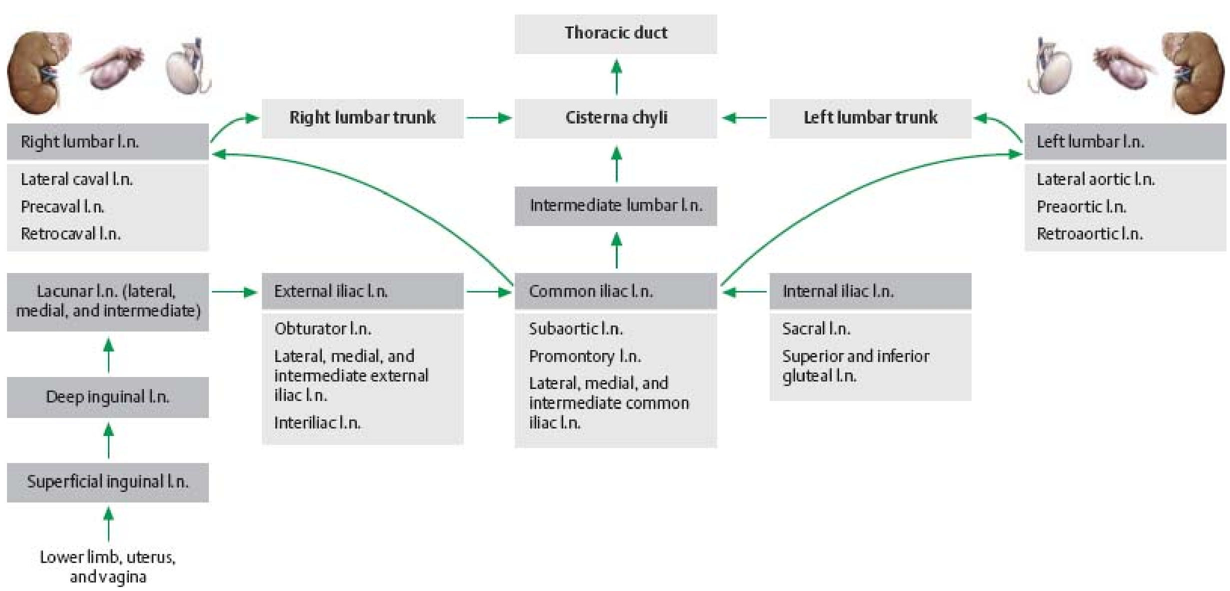


Fig. 16.8 Drainage of the kidneys (with pelvic organs)



Lymph Nodes of the Anterior Abdominal Organs

Fig. 16.9 Lymph nodes of the stomach and liver

Anterior view. *Removed:* Lesser omentum. *Opened:* Greater omentum. Arrows show direction of lymphatic drainage.

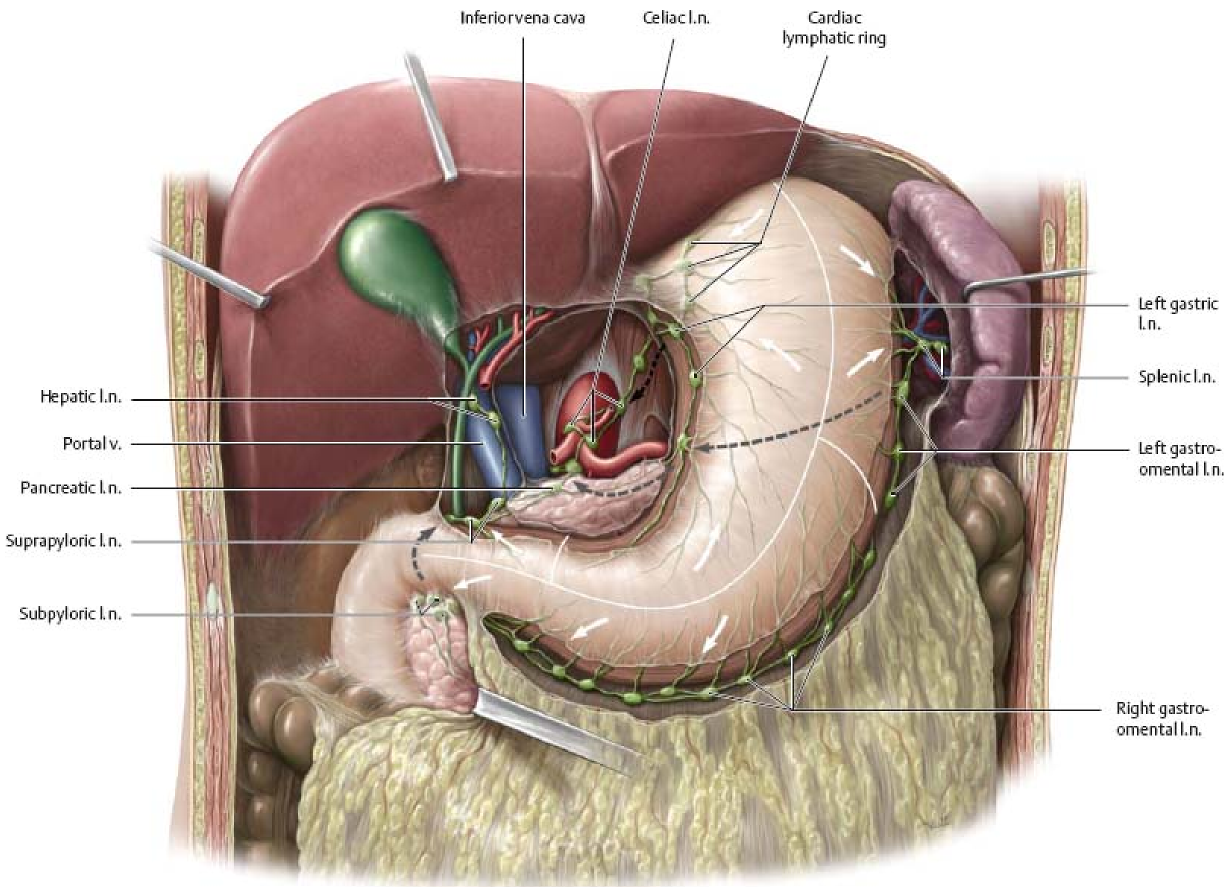


Fig. 16.10 **Lymph nodes of the spleen, pancreas, and duodenum**

Anterior view. *Removed:* Stomach and colon.

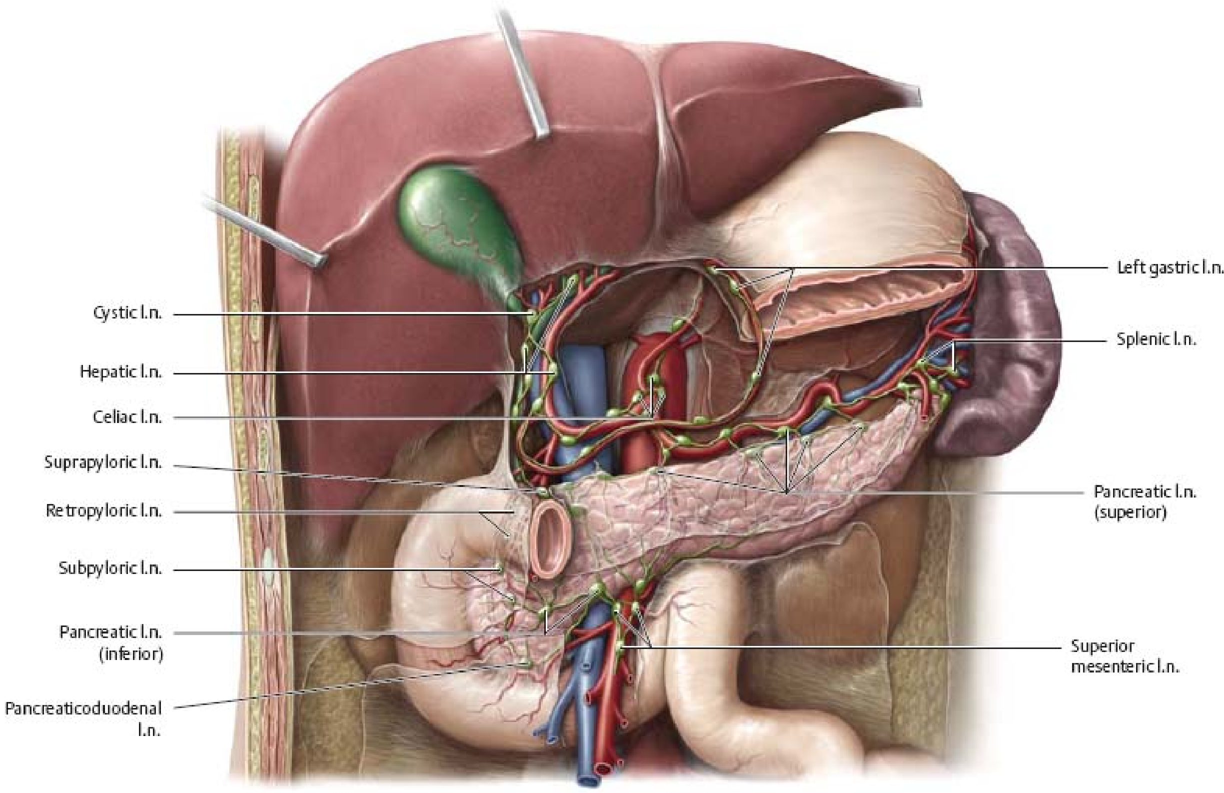
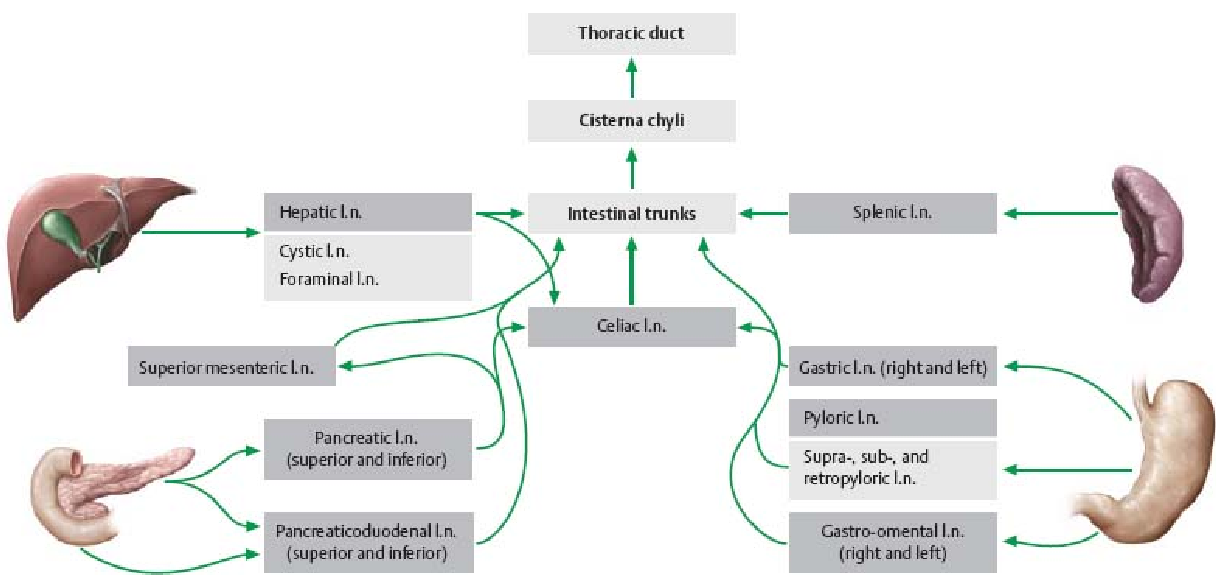


Fig. 16.11 **Lymphatic drainage of the stomach, liver, spleen, pancreas, and duodenum**



Lymph Nodes of the Intestines

Fig. 16.12 Lymph nodes of the jejunum and ileum

Anterior view. *Removed:* Stomach, liver, pancreas, and colon.

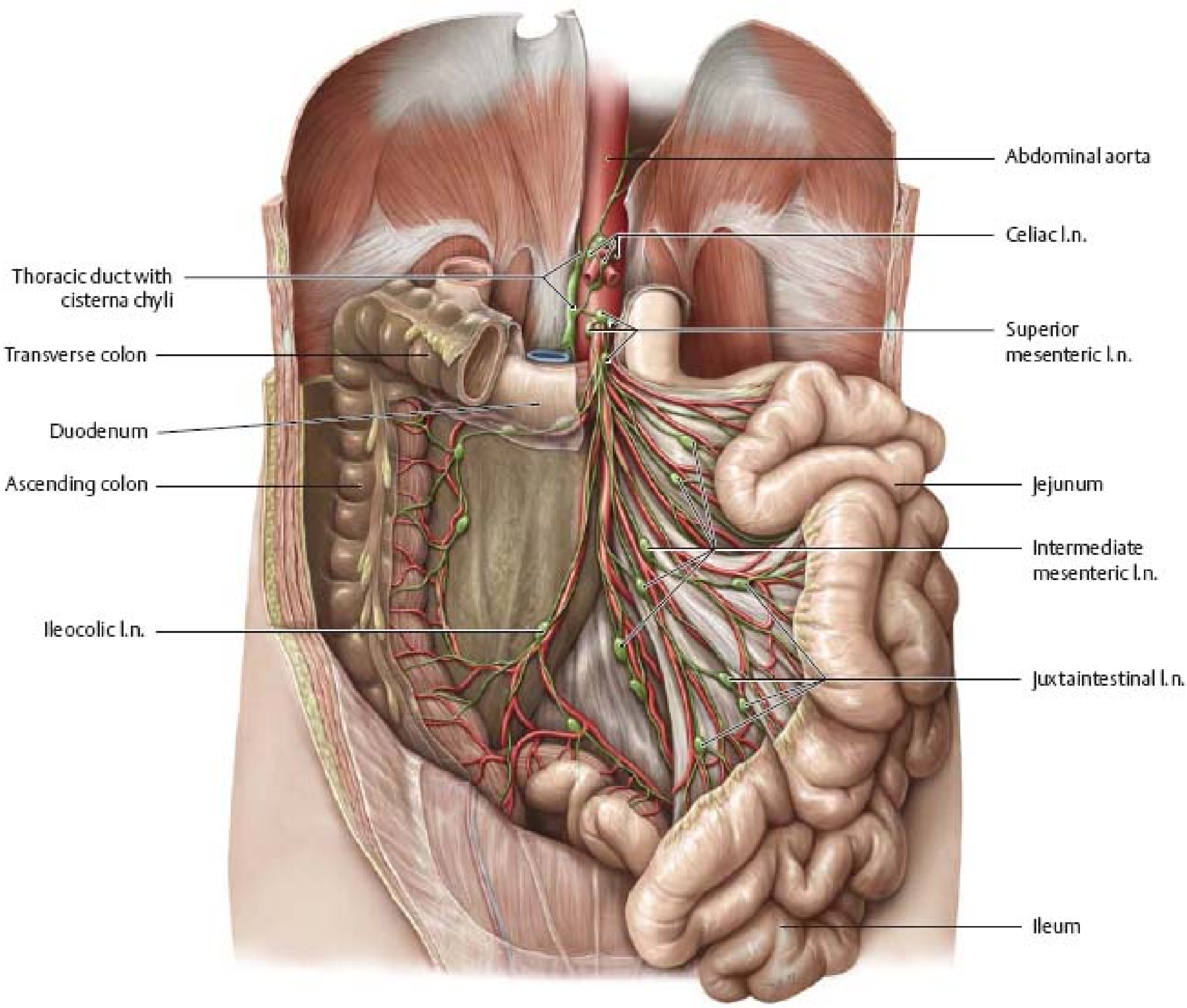


Fig. 16.13 Lymphatic drainage of the intestines

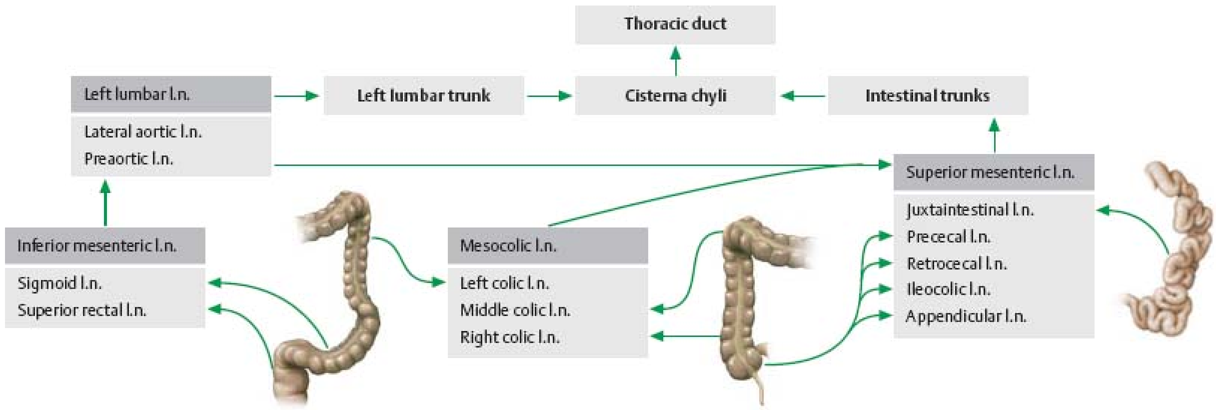
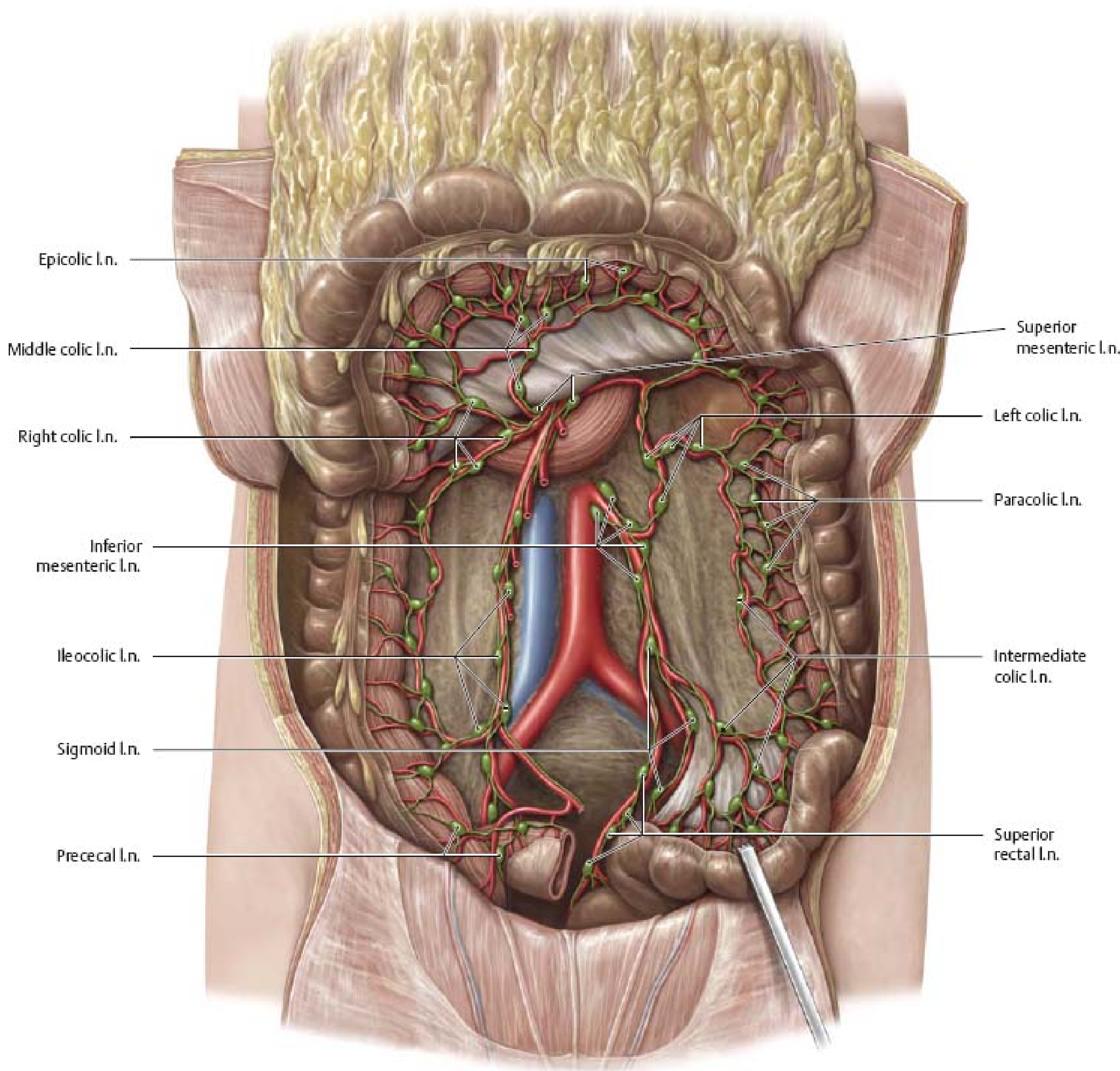


Fig. 16.14 **Lymph nodes of the large intestine**

Anterior view. *Reflected:* Transverse colon and greater omentum.



Lymph Nodes of the Genitalia

Fig. 16.15 Lymph nodes of the male genitalia

Anterior view. *Removed:* Gastrointestinal tract (except rectal stump) and peritoneum.

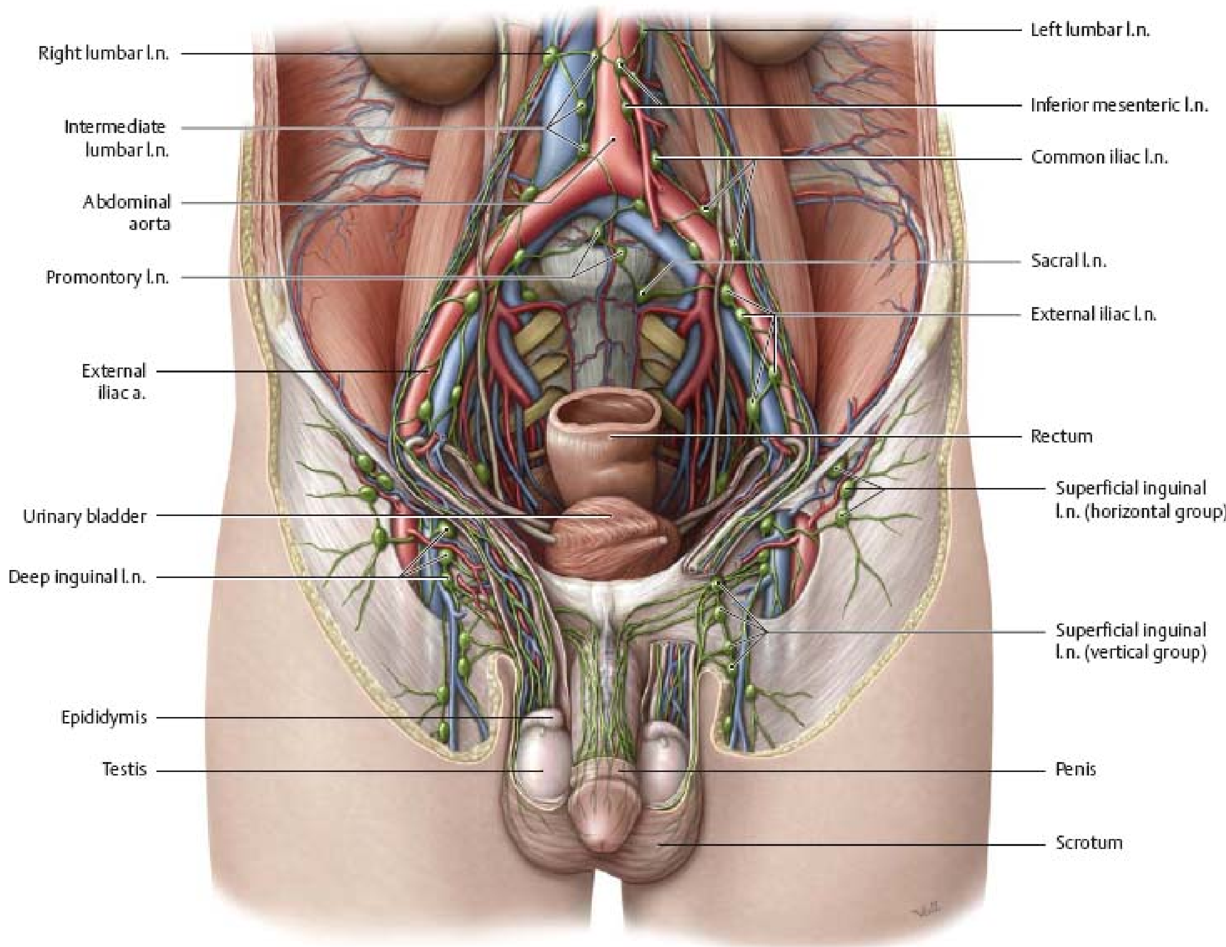


Fig. 16.16 **Lymph nodes of the female genitalia**

Anterior view. *Removed:* Gastrointestinal tract (except rectal stump) and peritoneum. *Retracted:* Uterus.

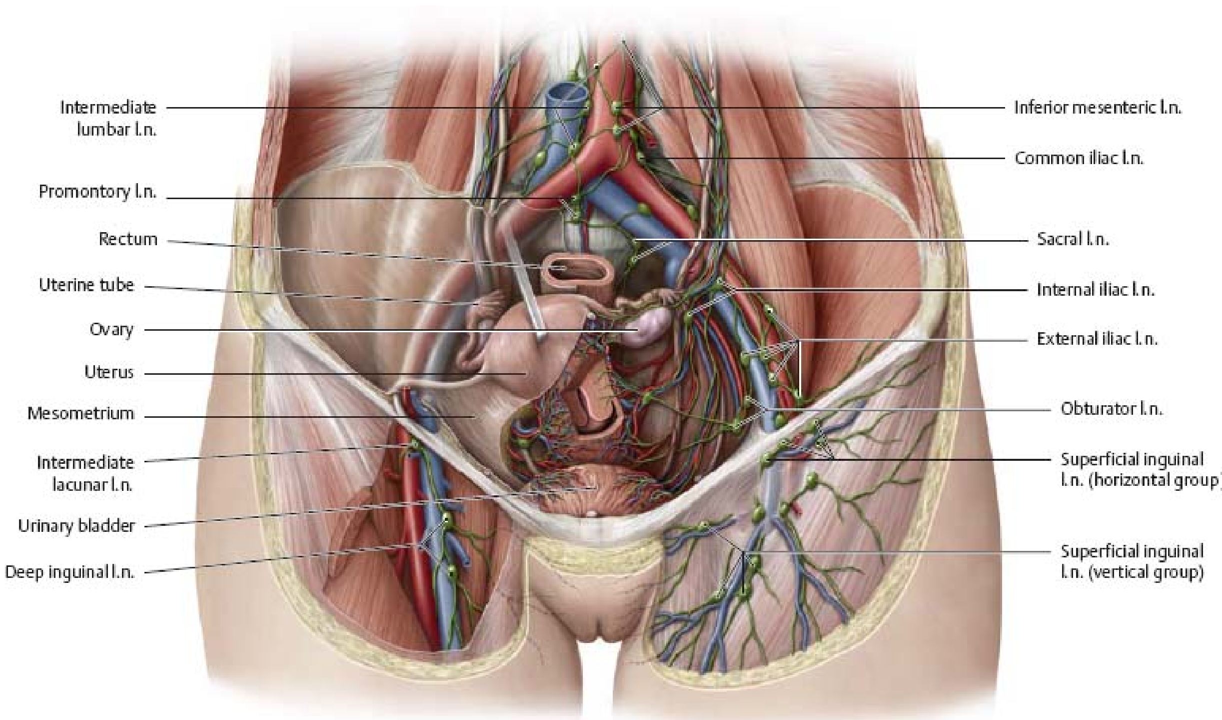
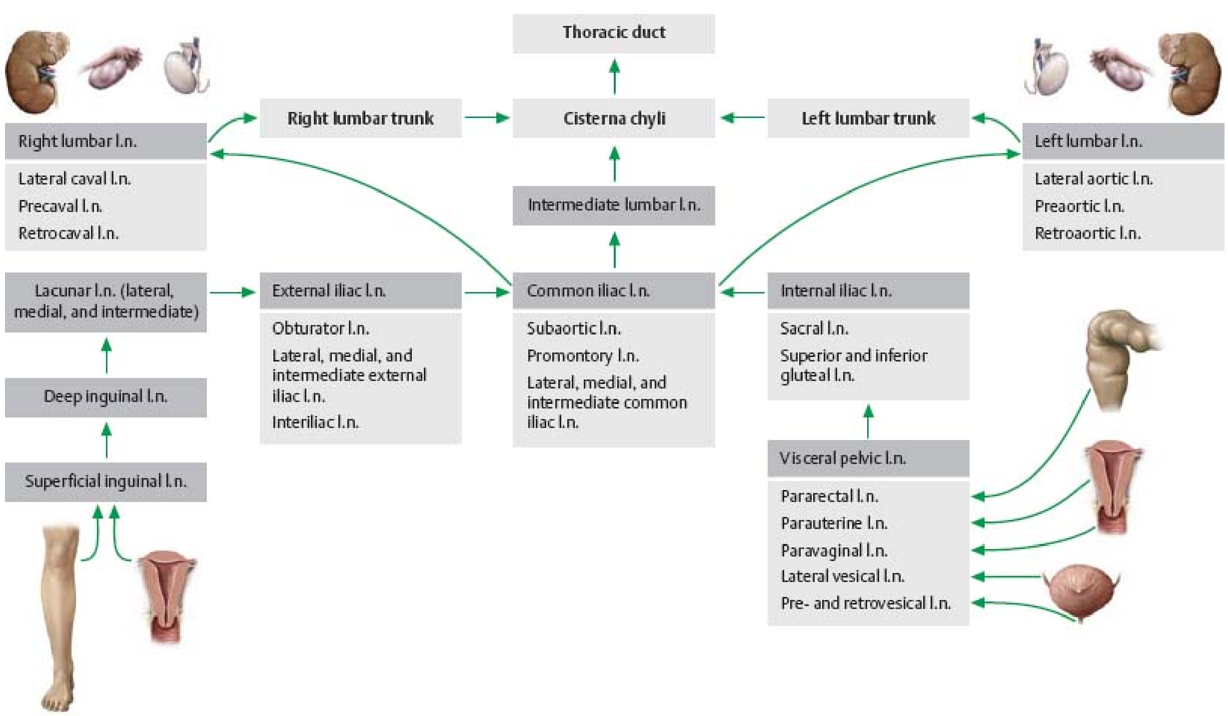


Fig. 16.17 Lymphatic drainage of the pelvic organs



17 Nerves

Autonomic Plexuses

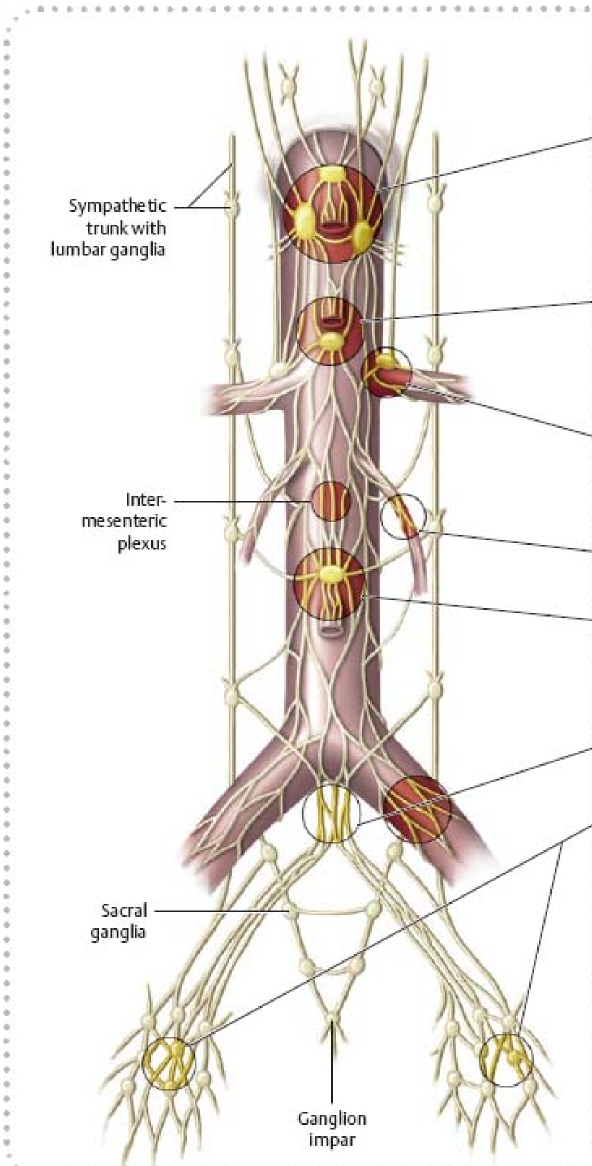
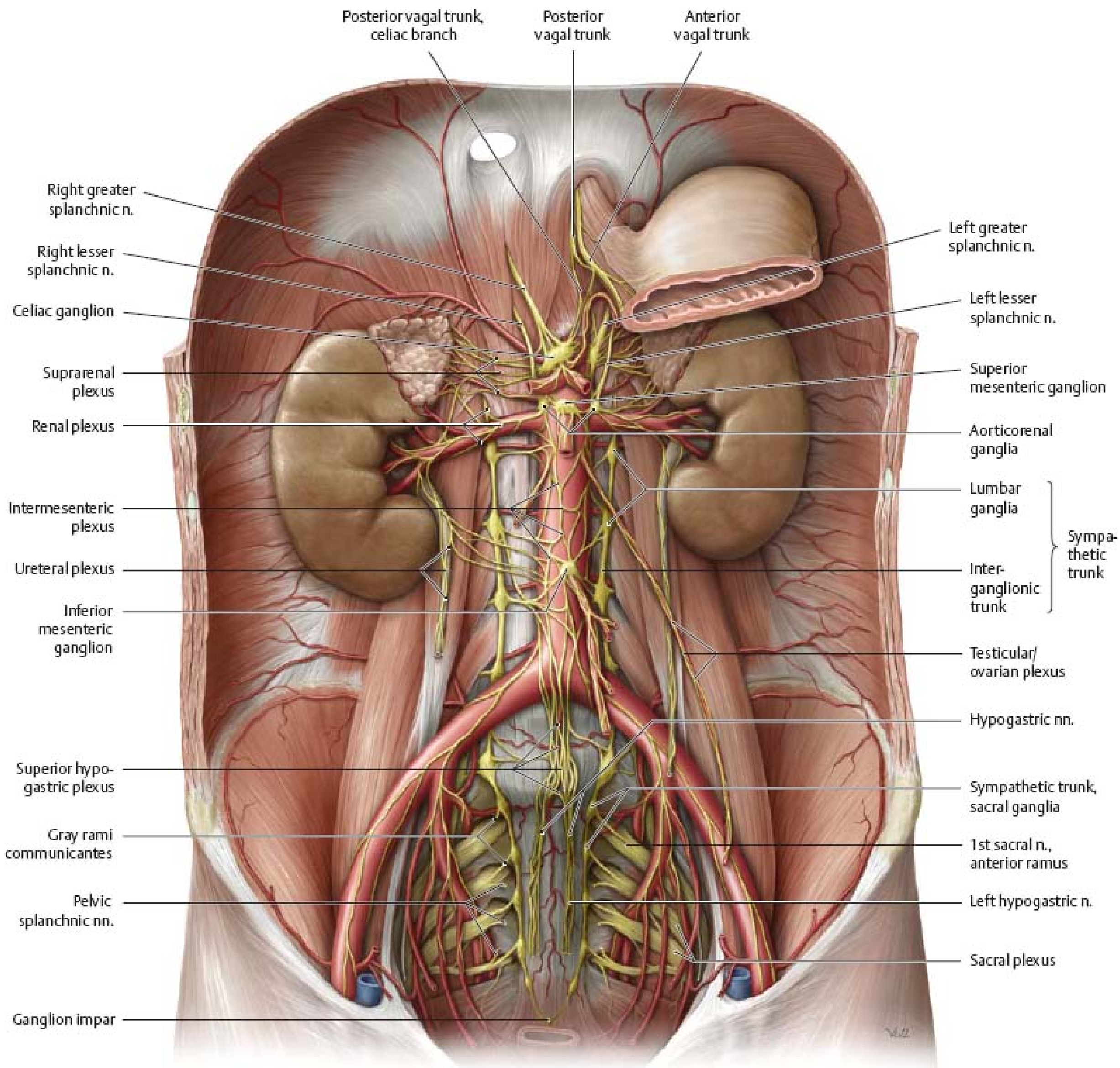


Table 17.1 Autonomic plexuses in the abdomen and pelvis

Ganglia	Subplexus	Distribution	
Celiac plexus			
Celiac ganglia	Hepatic plexus	• Liver, gallbladder	
	Gastric plexus	• Stomach	
	Splenic plexus	• Spleen	
	Pancreatic plexus	• Pancreas	
Superior mesenteric plexus			
Superior mesenteric ganglia	–	• Pancreas (head) • Duodenum • Jejunum • Ileum	• Cecum • Colon (to left colic flexure) • Ovary
Suprarenal and renal plexus			
Aorticorenal ganglion	Ureteral plexus	• Suprarenal gland • Kidney • Proximal ureter	
Ovarian/testicular plexus			
–	–	• Ovary/testis	
Inferior mesenteric plexus			
–	Left colic plexus	• Left colic flexure	
	Superior rectal plexus	• Descending and sigmoid colon • Upper rectum	
Superior hypogastric plexus			
–	Hypogastric nn.	• Pelvic viscera	
Inferior hypogastric plexus			
Pelvic ganglia	Middle and inferior rectal plexus	• Middle and lower rectum	
	Prostatic plexus	• Prostate • Seminal vesicle • Bulbourethral gland	• Ejaculatory duct • Penis • Urethra
	Deferential plexus	• Ductus deferens • Epididymis	
	Uterovaginal plexus	• Uterus • Uterine tube	• Vagina • Ovary
	Vesical plexus	• Urinary bladder	
	Ureteral plexus	• Ureter (ascending from pelvis)	

Fig. 17.1 **Autonomic plexuses in the abdomen and pelvis**
Anterior view of the male abdomen. *Removed:* Peritoneum and majority of the stomach



Innervation of the Abdominal Organs

Fig. 17.2 Innervation of the anterior abdominal organs

Anterior view. *Removed:* Lesser omentum, ascending colon, and parts of the transverse colon. *Opened:* Lesser sac. The anterior and posterior vagal trunks each produce a celiac, hepatic, and pyloric branch, and a gastric plexus. See p. 245 for schematic.

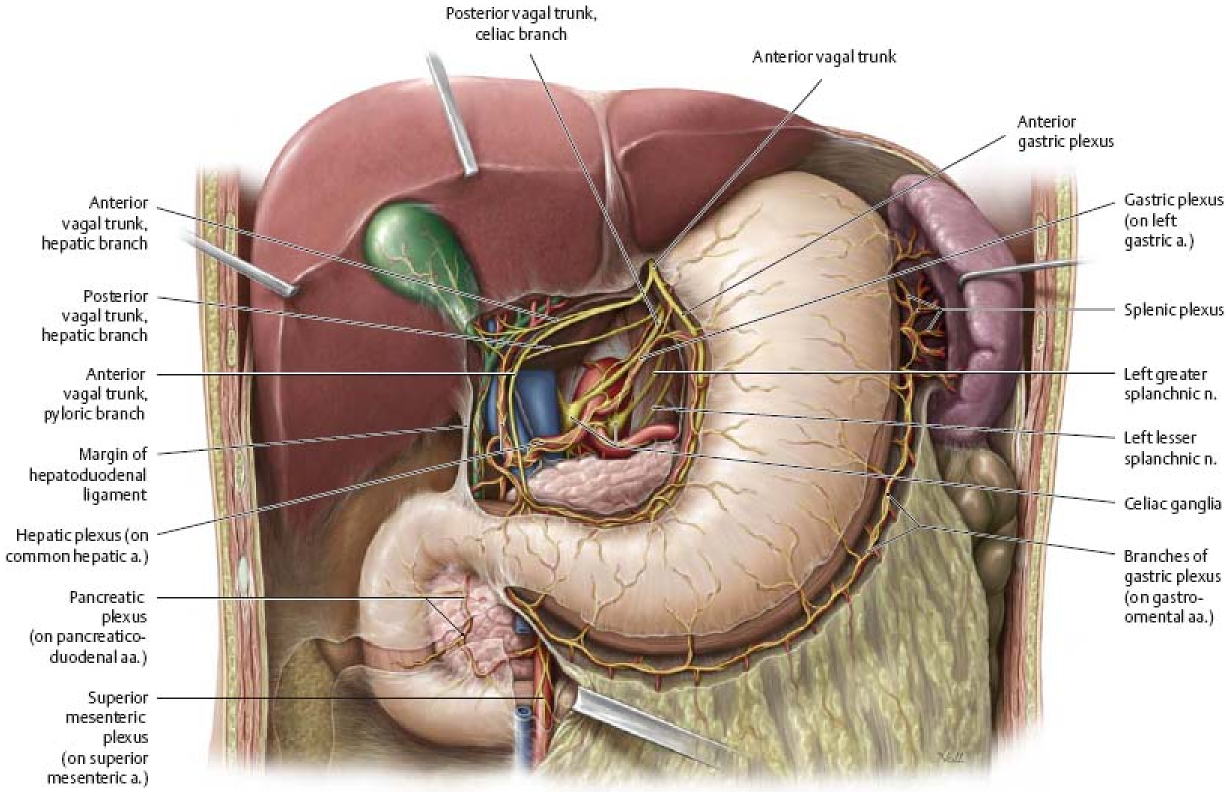
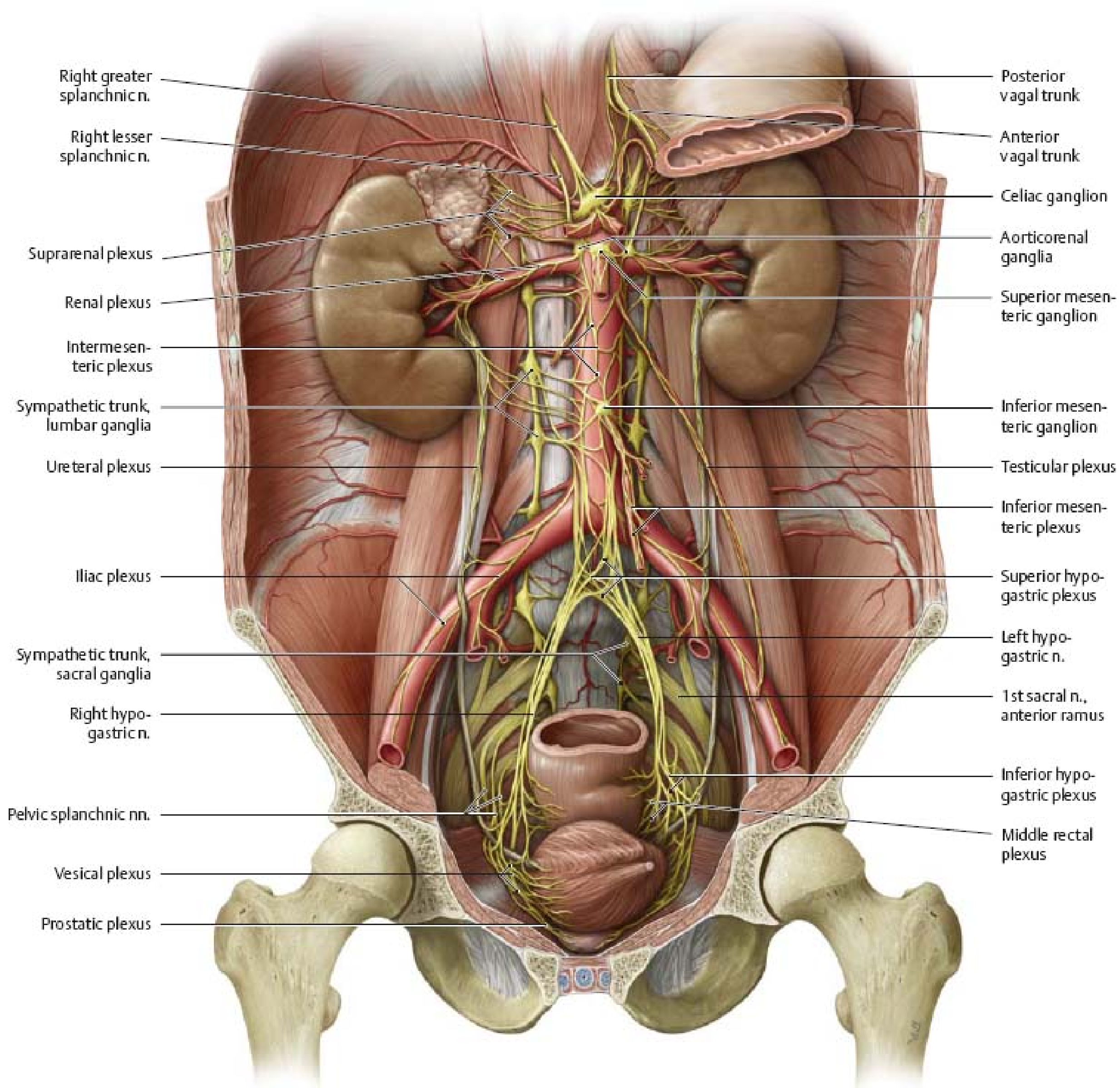


Fig. 17.3 **Innervation of the urinary organs**

Anterior view of the male abdomen and pelvis. *Removed:* Abdominal organs and peritoneum. See p. 246 for schematic.



Innervation of the Intestines

Fig. 17.4 Innervation of the small intestine

Anterior view. *Partially removed:* Stomach, pancreas, and transverse colon (distal part). See p. 245 for schematic.

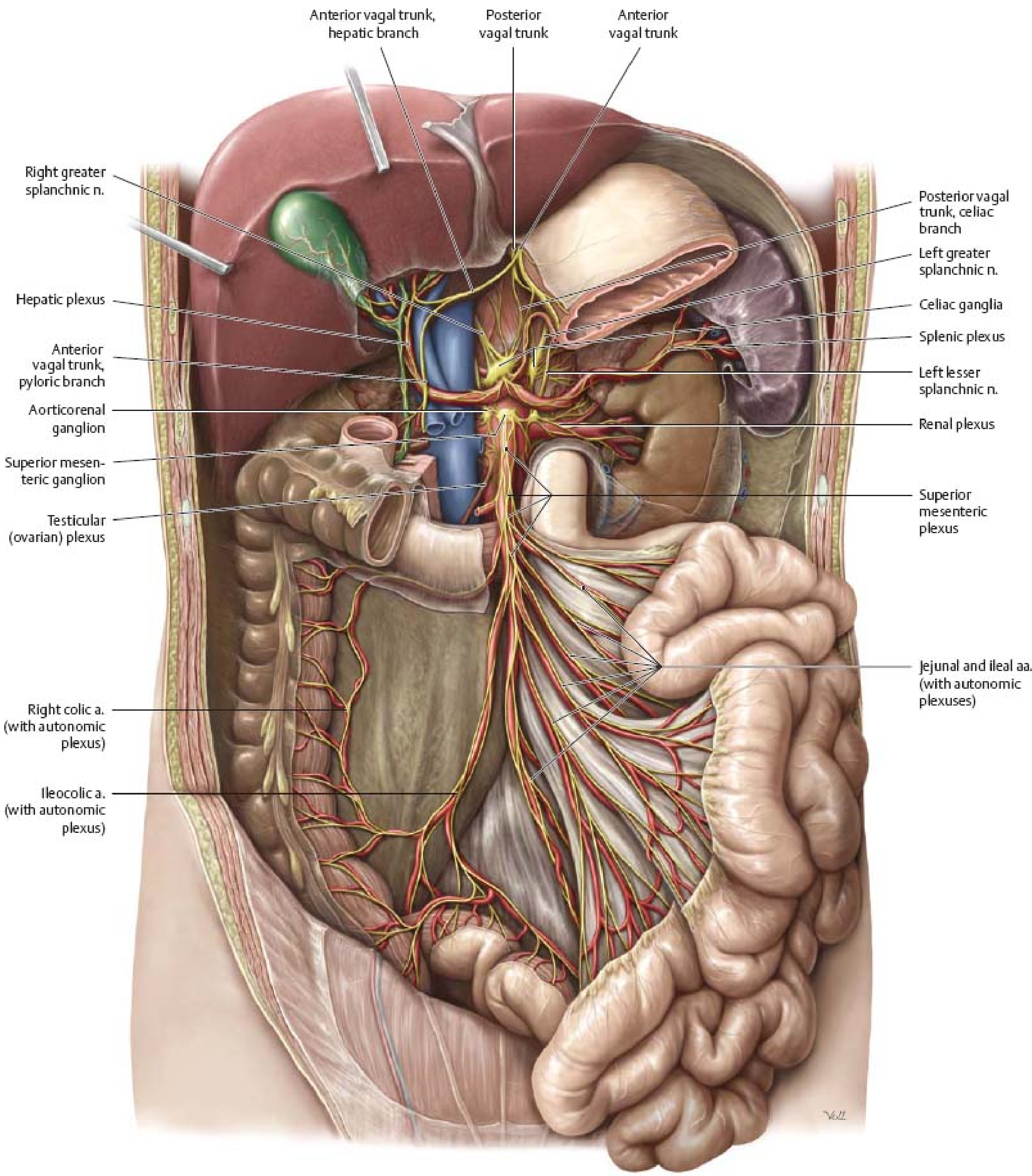
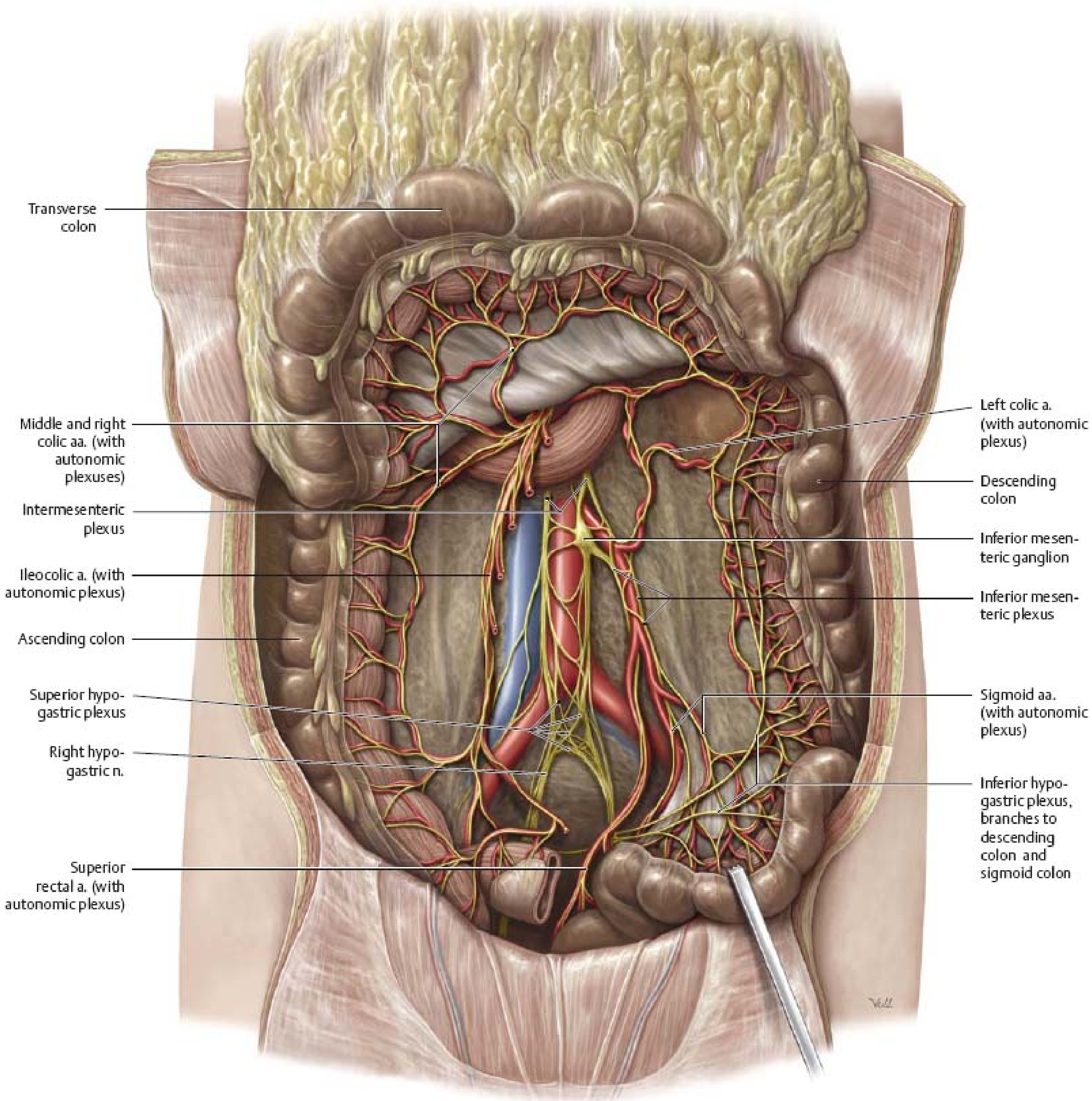


Fig. 17.5 **Innervation of the large intestine**

Anterior view. *Removed:* Jejunum and ileum. *Reflected:* Transverse and sigmoid colons. See p. 245 for schematic.



Innervation of the Pelvis

Fig. 17.6 Innervation of the female pelvis

Right pelvis, left lateral view. *Reflected:* Uterus and rectum. See p. 247 for schematic.

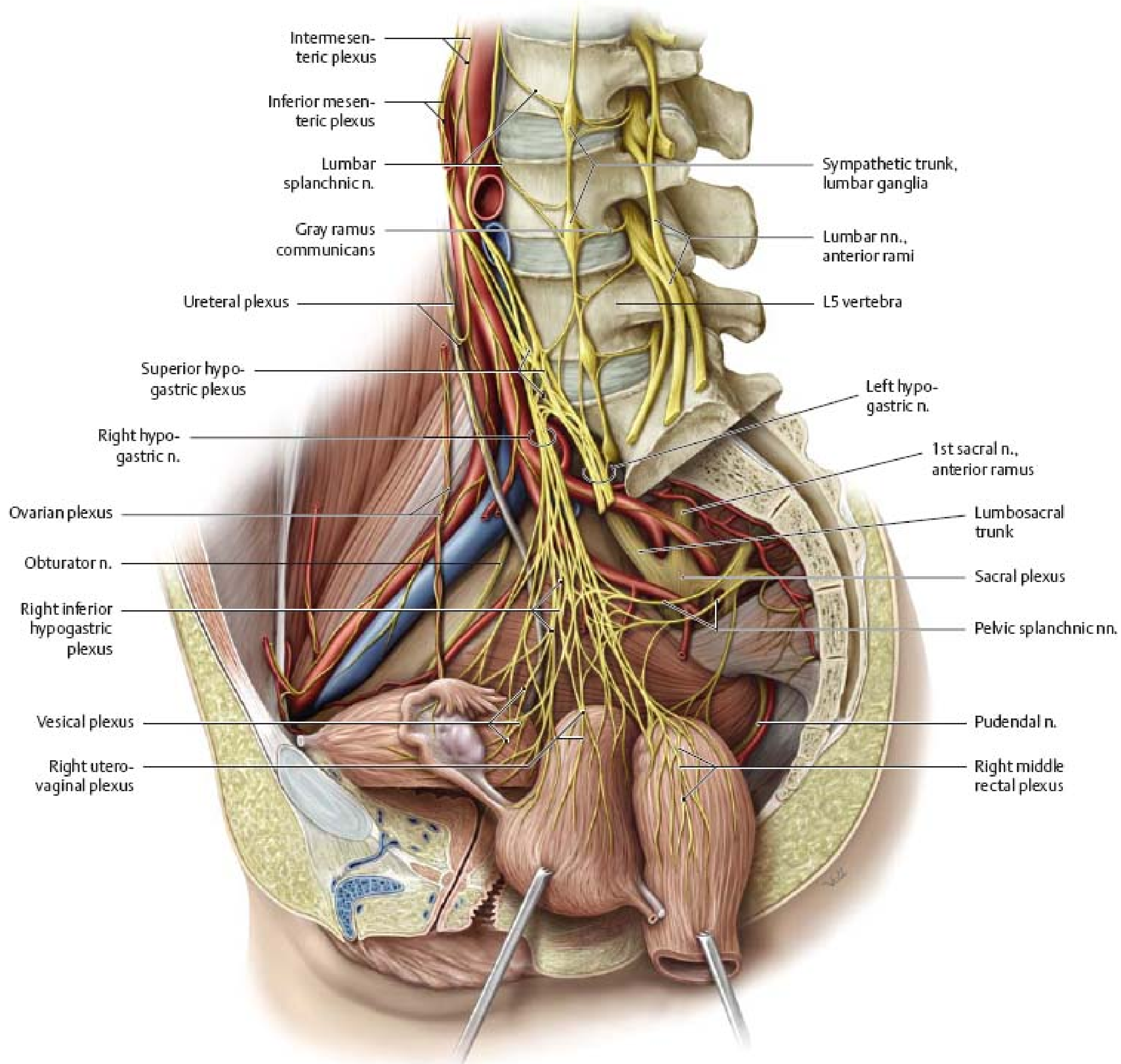
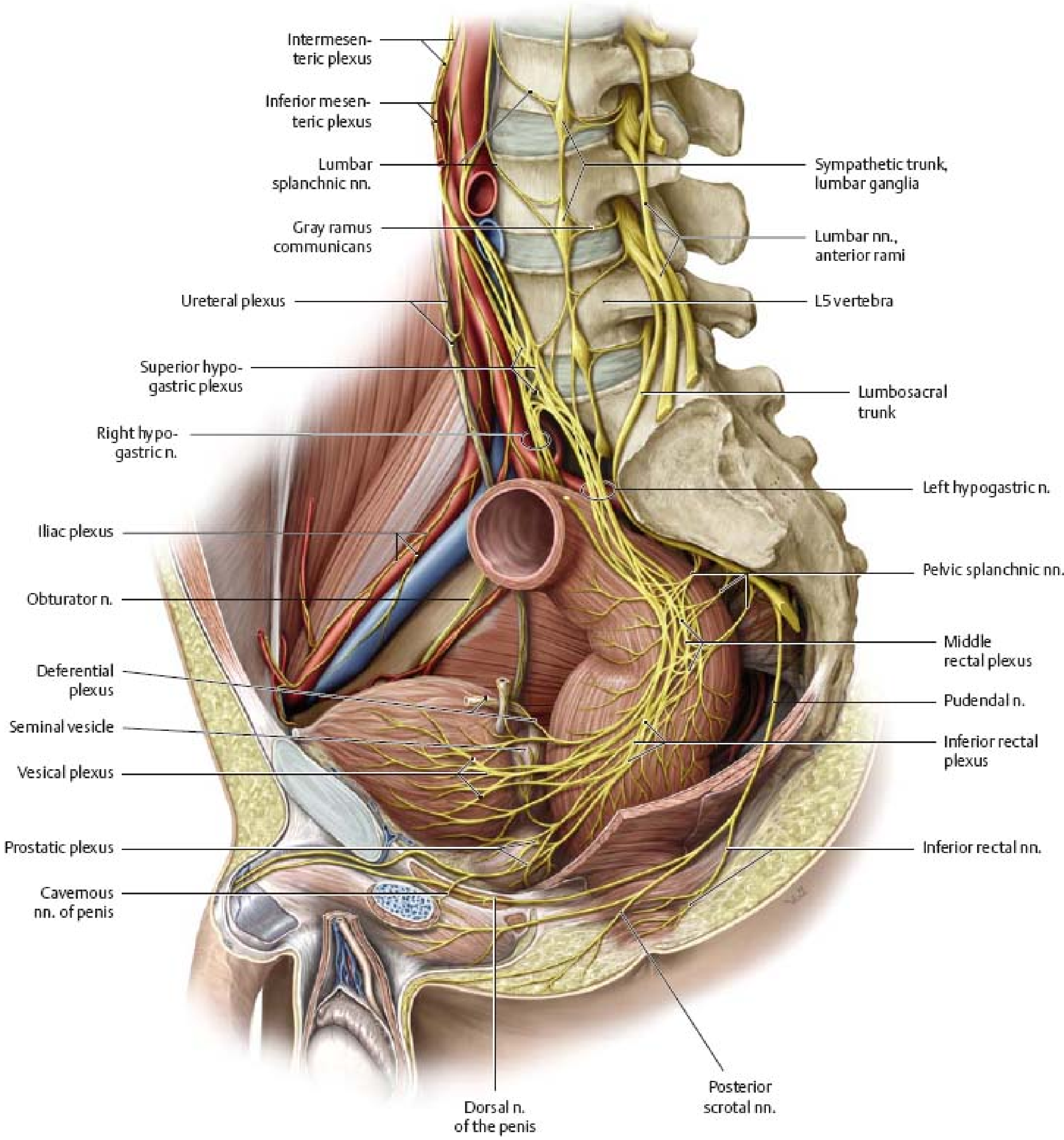


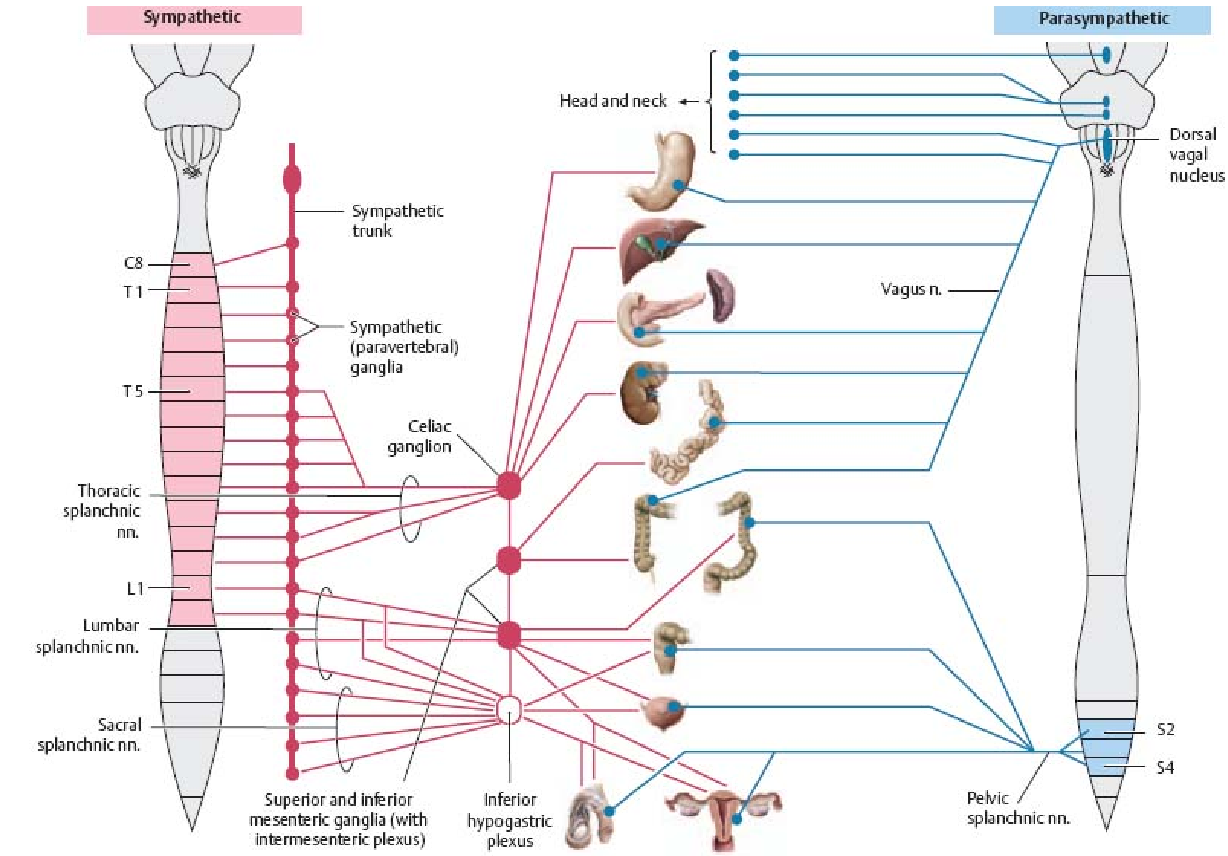
Fig. 17.7 **Innervation of the male pelvis**

Right pelvis, left lateral view. See p. 247 for schematic.



Autonomic Innervation: Overview

Fig. 17.8 **Sympathetic and parasympathetic nervous systems in the abdomen and pelvis**



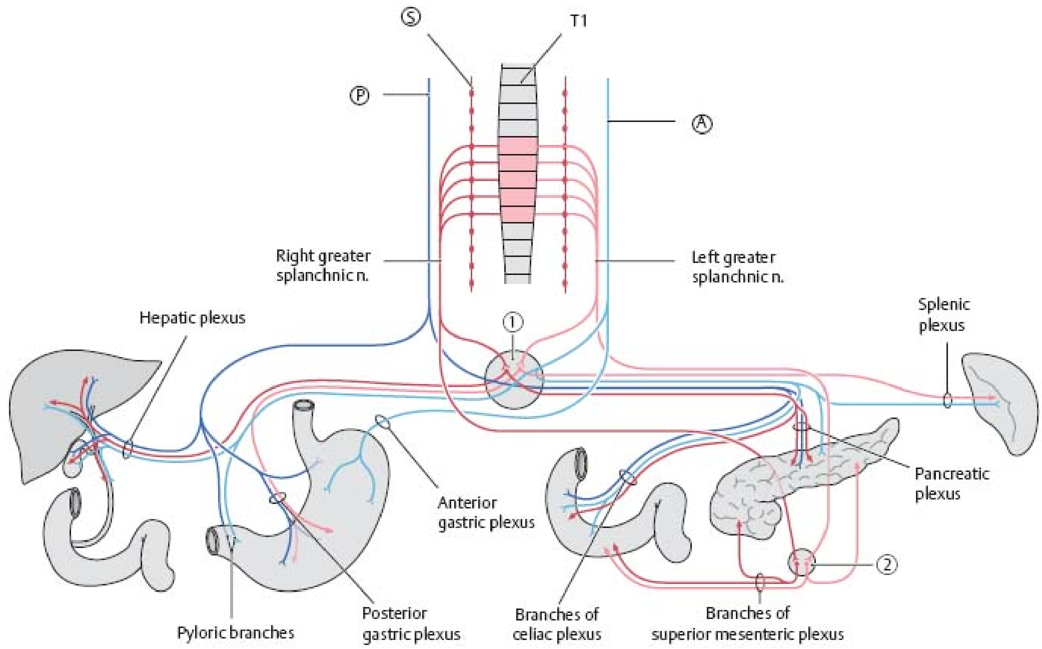
A Sympathetic nervous system.

B Parasympathetic nervous system.

Table 17.2 Effects of the autonomic nervous system in the abdomen and pelvis

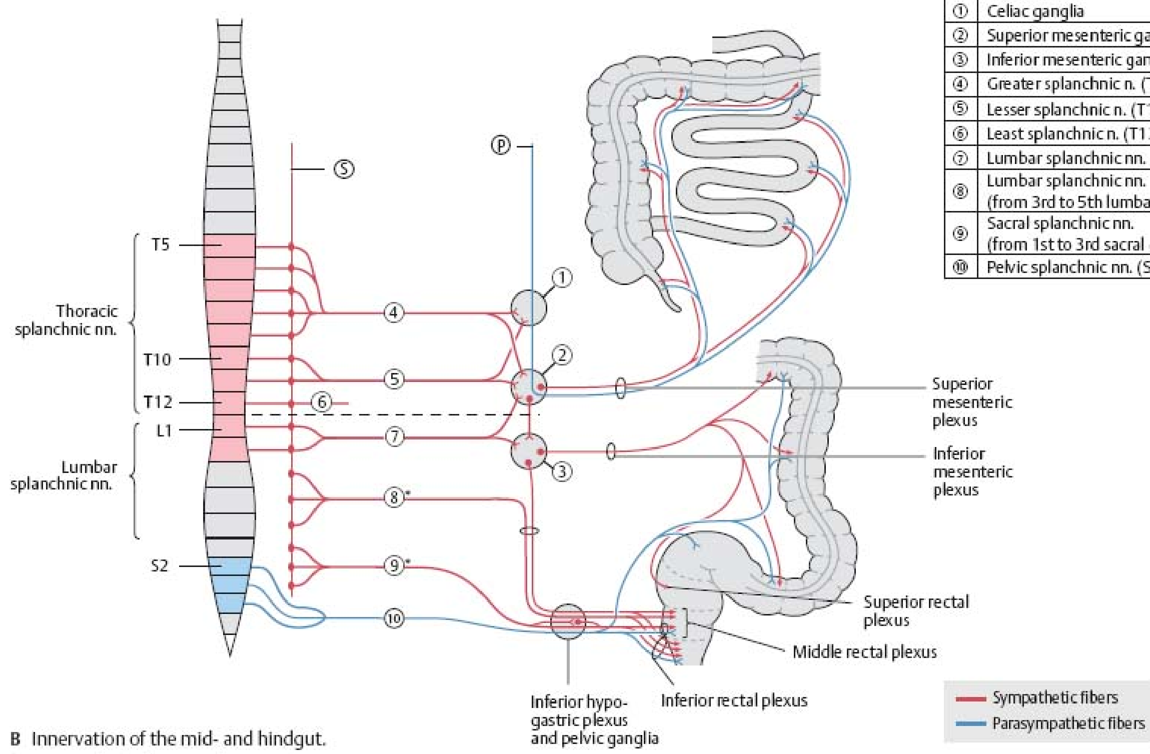
Organ (organ system)		Sympathetic effect	Parasympathetic effect
Gastrointestinal tract	Longitudinal and circular muscle fibers	↓ motility	↑ motility
	Sphincter muscles	Contraction	Relaxation
	Glands	↓ secretions	↑ secretions
Splenic capsule		Contraction	No effect
Liver		↑ glycogenolysis/gluconeogenesis	
Pancreas	Endocrine pancreas	↓ insulin secretion	
	Exocrine pancreas	↓ secretion	↑ secretion
Urinary bladder	Detrusor vesicae	Relaxation	Contraction
	Functional bladder sphincter	Contraction	Inhibits contraction
Seminal vesicle and ductus deferens		Contraction (ejaculation)	No effect
Uterus		Contraction or relaxation, depending on hormonal status	
Arteries		Vasoconstriction	Vasodilation of the arteries of the penis and clitoris (erection)
Suprarenal glands (medulla)		Release of adrenalin	No effect
Urinary tract	Kidney	Vasoconstriction (↓ urine formation)	Vasodilation

Fig. 17.9 **Autonomic innervation of the intraperitoneal organs**



A Innervation of the foregut. As the left and right vagus nerves descend along the esophagus, they become the anterior and posterior vagal trunks, respectively. Each trunk produces a celiac, pyloric, and hepatic branch, and a gastric plexus.

Ⓢ	Sympathetic trunk
Ⓟ	Posterior vagal trunk (from right vagus n.)
Ⓐ	Anterior vagal trunk (from left vagus n.)
①	Celiac ganglia
②	Superior mesenteric ganglion
③	Inferior mesenteric ganglion
④	Greater splanchnic n. (T5–T9)
⑤	Lesser splanchnic n. (T10–T11)
⑥	Least splanchnic n. (T12)
⑦	Lumbar splanchnic nn. (L1–L2)
⑧	Lumbar splanchnic nn. (from 3rd to 5th lumbar ganglia)
⑨	Sacral splanchnic nn. (from 1st to 3rd sacral ganglia)
⑩	Pelvic splanchnic nn. (S2–S4)

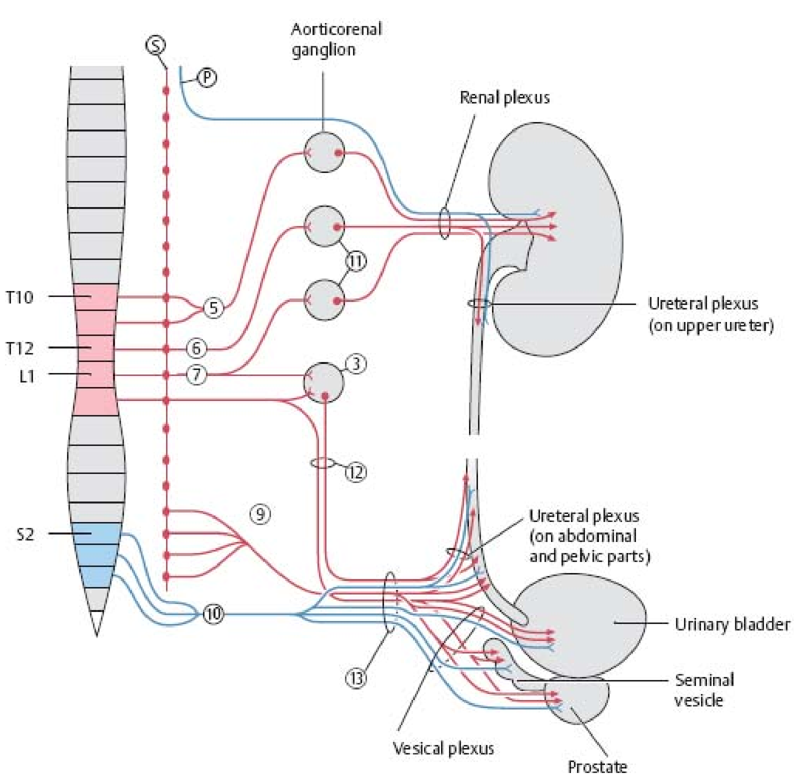


B Innervation of the mid- and hindgut.

*Synapse in the lumbar sympathetic ganglia.

Autonomic Innervation: Urinary & Genital Organs

Fig. 17.10 Autonomic innervation of the urinary organs



Numbering continued from p. 245.	
S	Sympathetic trunk
P	Posterior vagal trunk (from right vagus n.)
3	Inferior mesenteric ganglion
5	Lesser splanchnic n. (T10–T11)
6	Least splanchnic n. (T12)
7	Lumbar splanchnic nn. (L1–L2)
9	Sacral splanchnic nn. (from 1st to 3rd sacral ganglia)
10	Pelvic splanchnic nn. (S2–S4)
11	Renal ganglia
12	Superior hypogastric plexus
13	Inferior hypogastric plexus

Clinical

Referred pain from the internal organs

The convergence of somatic and visceral afferent fibers to a common level of the spinal cord confuses the relationship between the perceived and actual sites of pain, a phenomenon known as referred pain. Pain impulses from a particular organ are consistently projected to the same well-defined skin area.

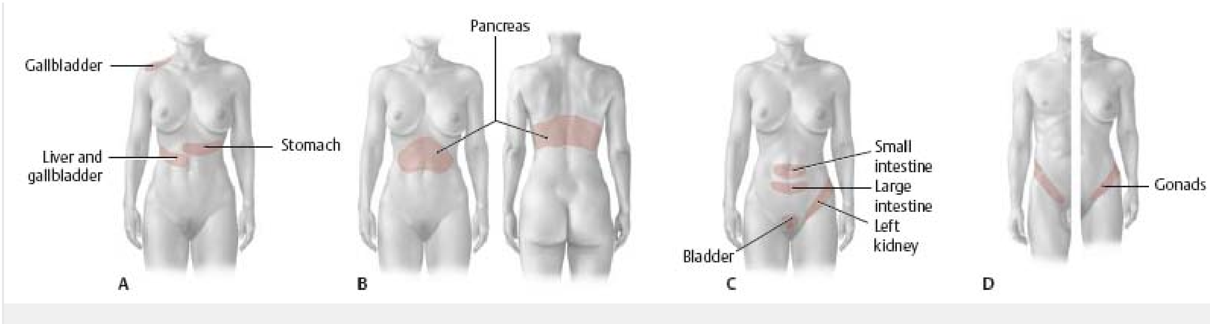
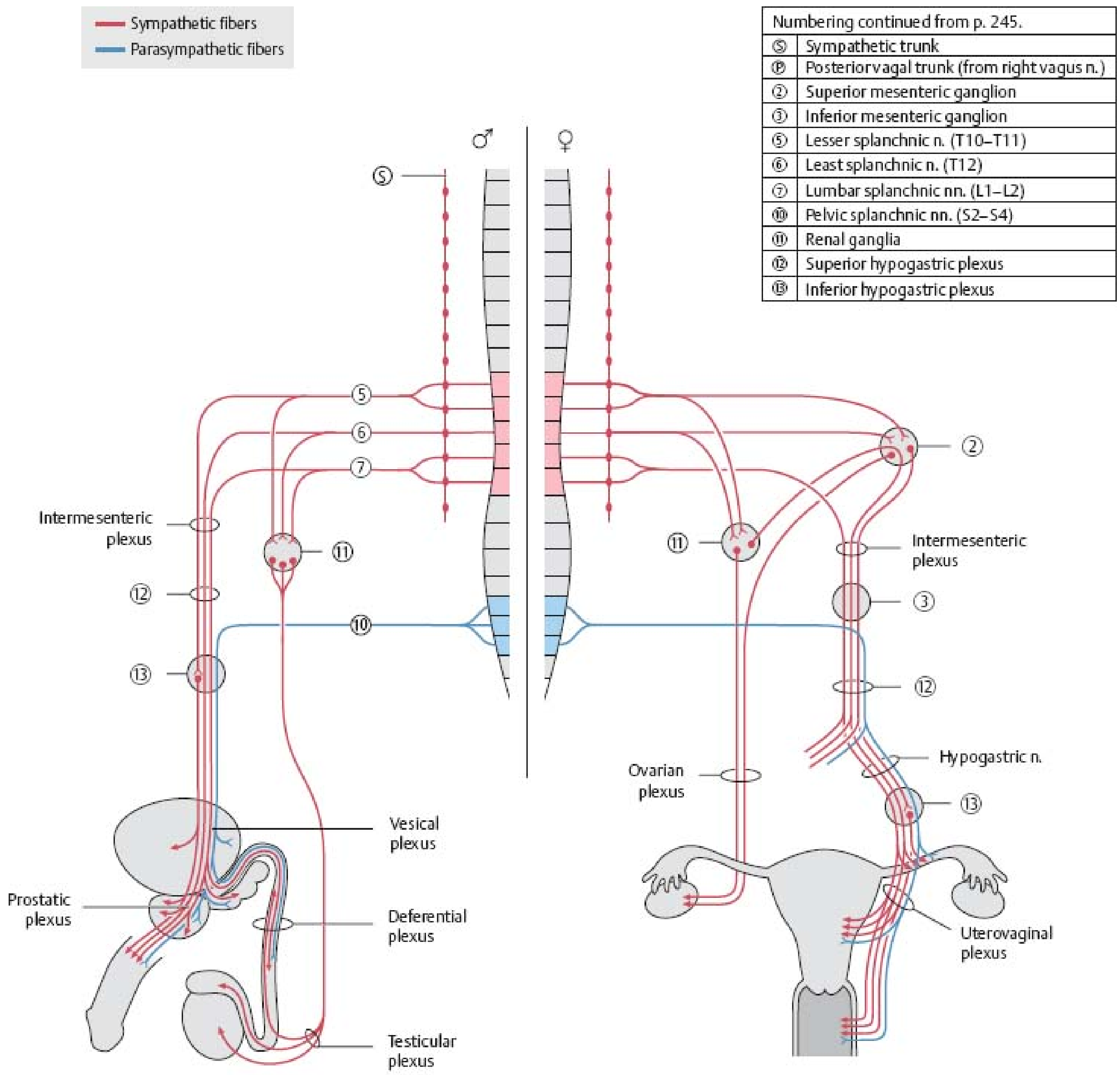


Fig. 17.11 Autonomic innervation of the genitalia



Numbering continued from p. 245.	
Ⓢ	Sympathetic trunk
Ⓟ	Posterior vagal trunk (from right vagus n.)
②	Superior mesenteric ganglion
③	Inferior mesenteric ganglion
⑤	Lesser splanchnic n. (T10–T11)
⑥	Least splanchnic n. (T12)
⑦	Lumbar splanchnic nn. (L1–L2)
⑩	Pelvic splanchnic nn. (S2–S4)
⑪	Renal ganglia
⑫	Superior hypogastric plexus
⑬	Inferior hypogastric plexus

A Male genitalia.

B Female genitalia.

18 Surface Anatomy

Surface Anatomy

Fig. 18.1 Palpable structures in the abdomen and pelvis

Anterior view. See pp. 40–41 for structures of the back.

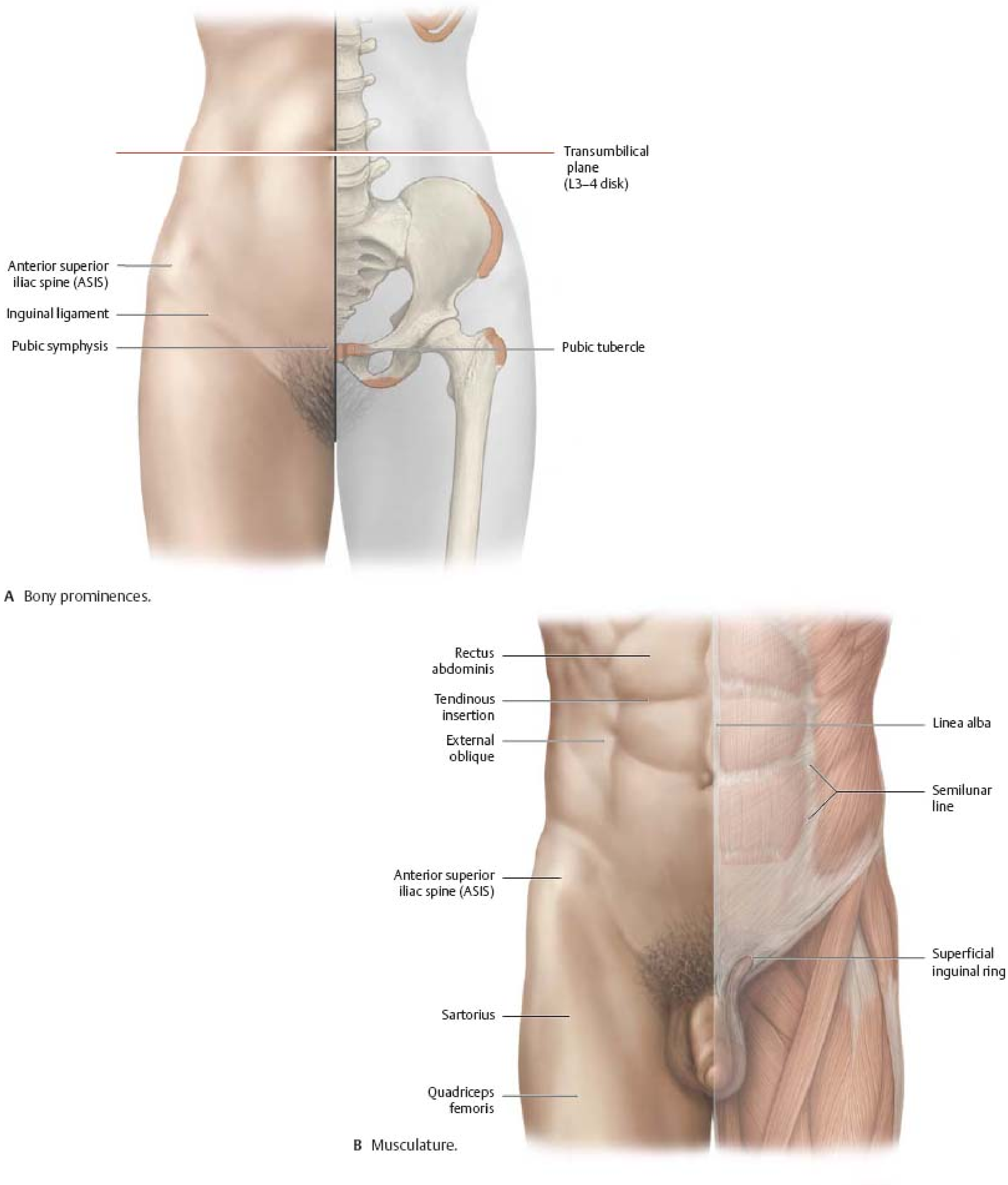


Fig. 18.2 Surface anatomy of the abdomen and pelvis

Anterior view. See pp. 40–41 for structures of the back.

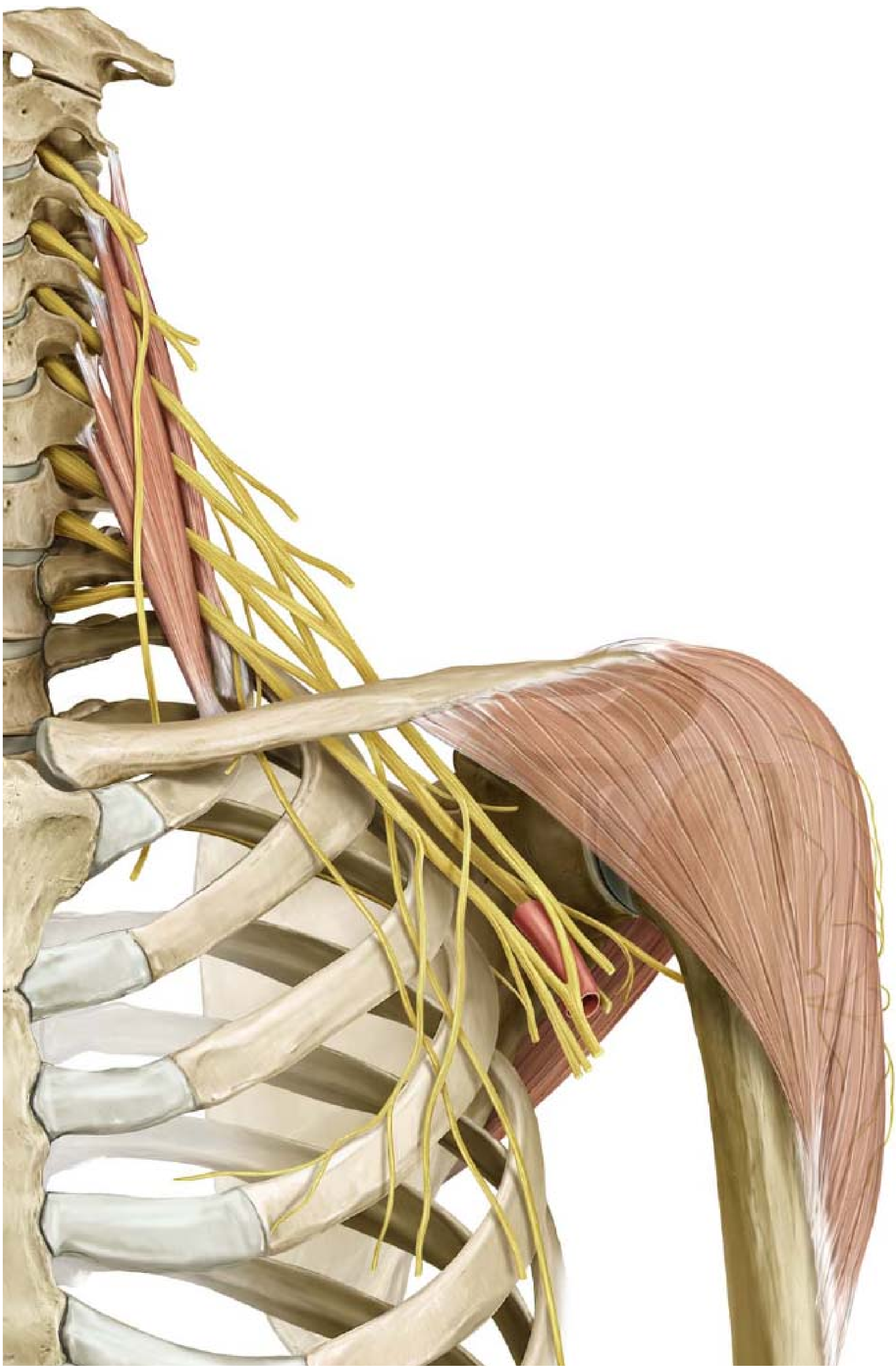
A Female abdomen and pelvis.

Q1: How would this patient's abdomen be subdivided for descriptive purposes into four quadrants? Name five organs in each quadrant.

Q2: A patient's inguinal region shows a slight swelling just superior to the middle of the inguinal region. What factors (age, anatomical) might assist you in determining if this is a direct or indirect inguinal hernia?

B Male abdomen and pelvis.

See answers beginning on p. 626.



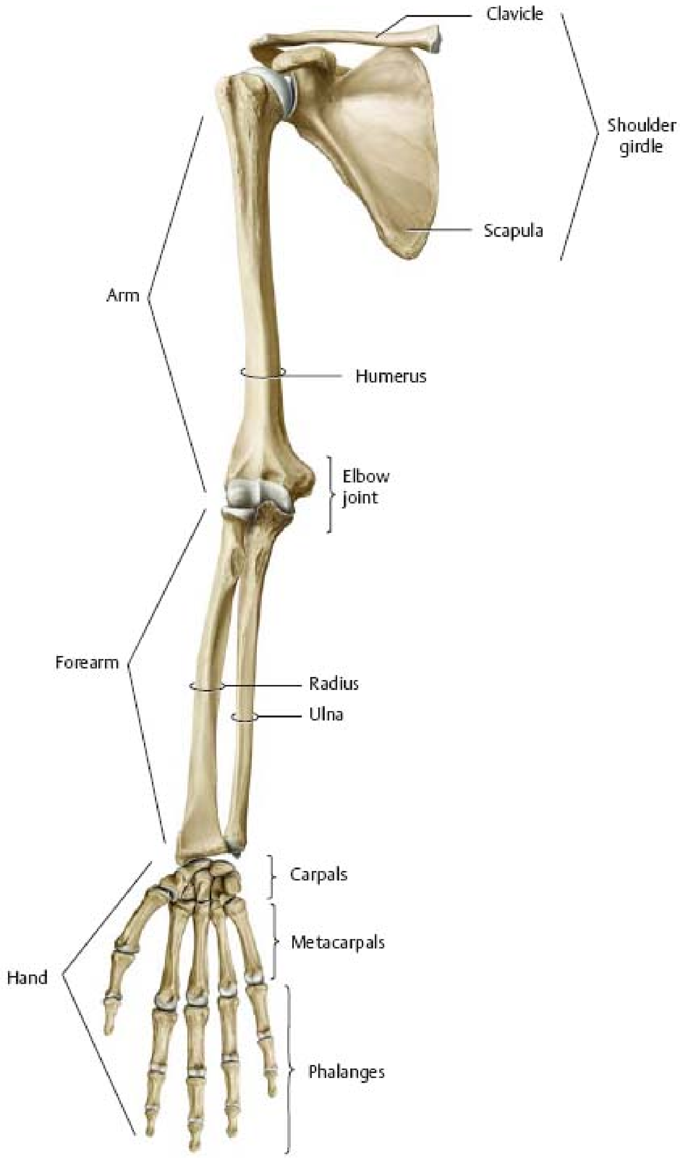
Upper Limb

19 Shoulder & Arm

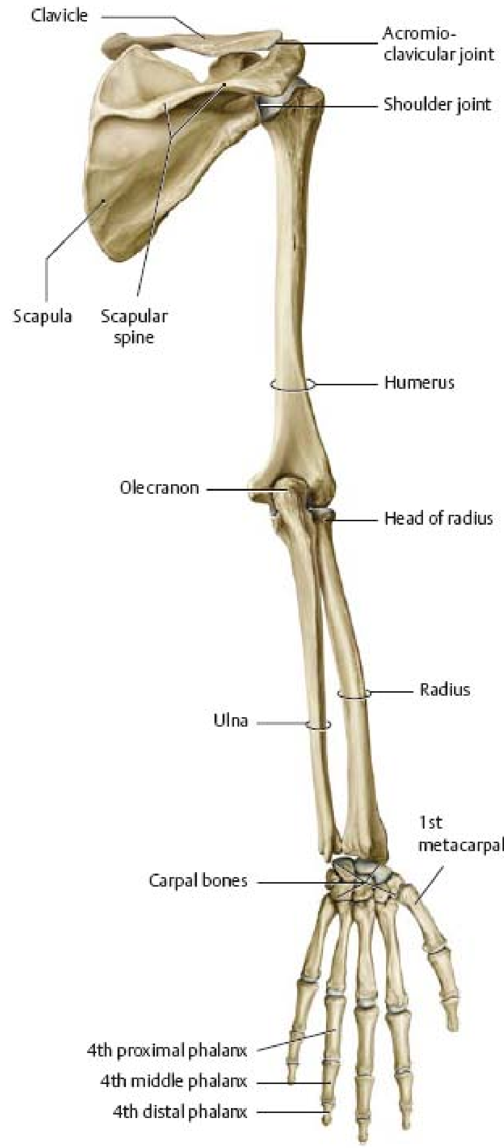
Bones of the Upper Limb

Fig. 19.1 Skeleton of the upper limb

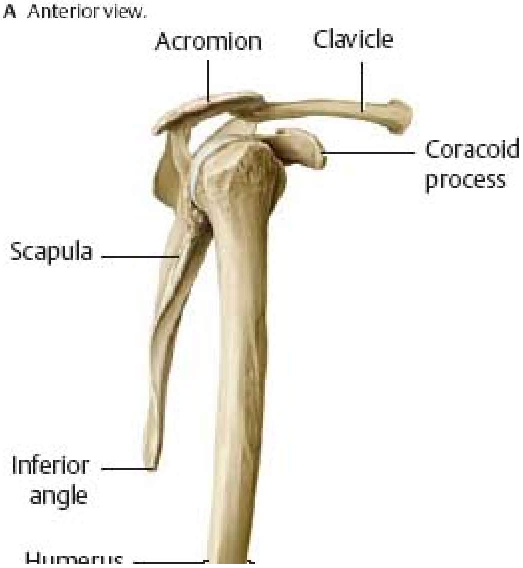
Right limb. The upper limb is subdivided into three regions: arm, forearm, and hand. The shoulder girdle (clavicle and scapula) joins the upper limb to the thorax at the sternoclavicular joint.

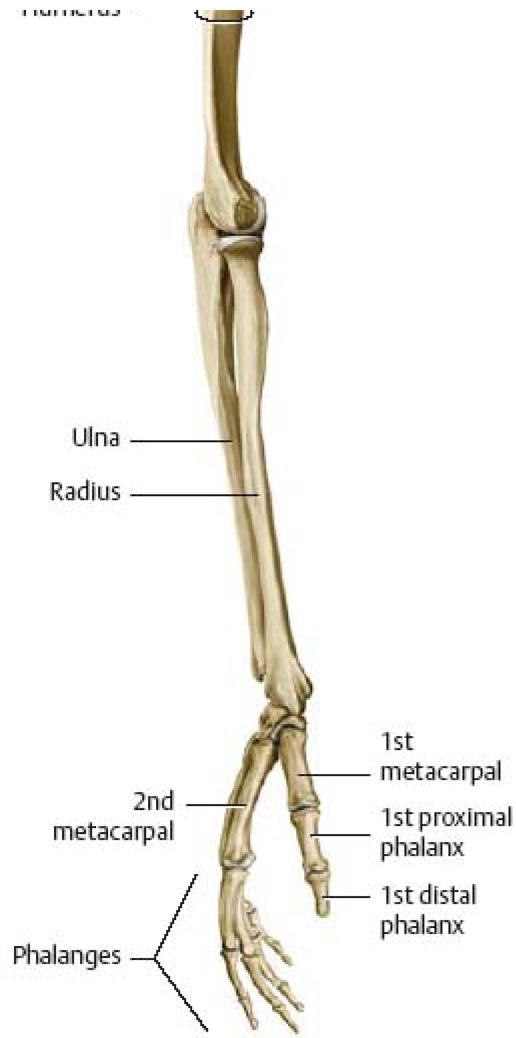


A Anterior view.



B Posterior view.

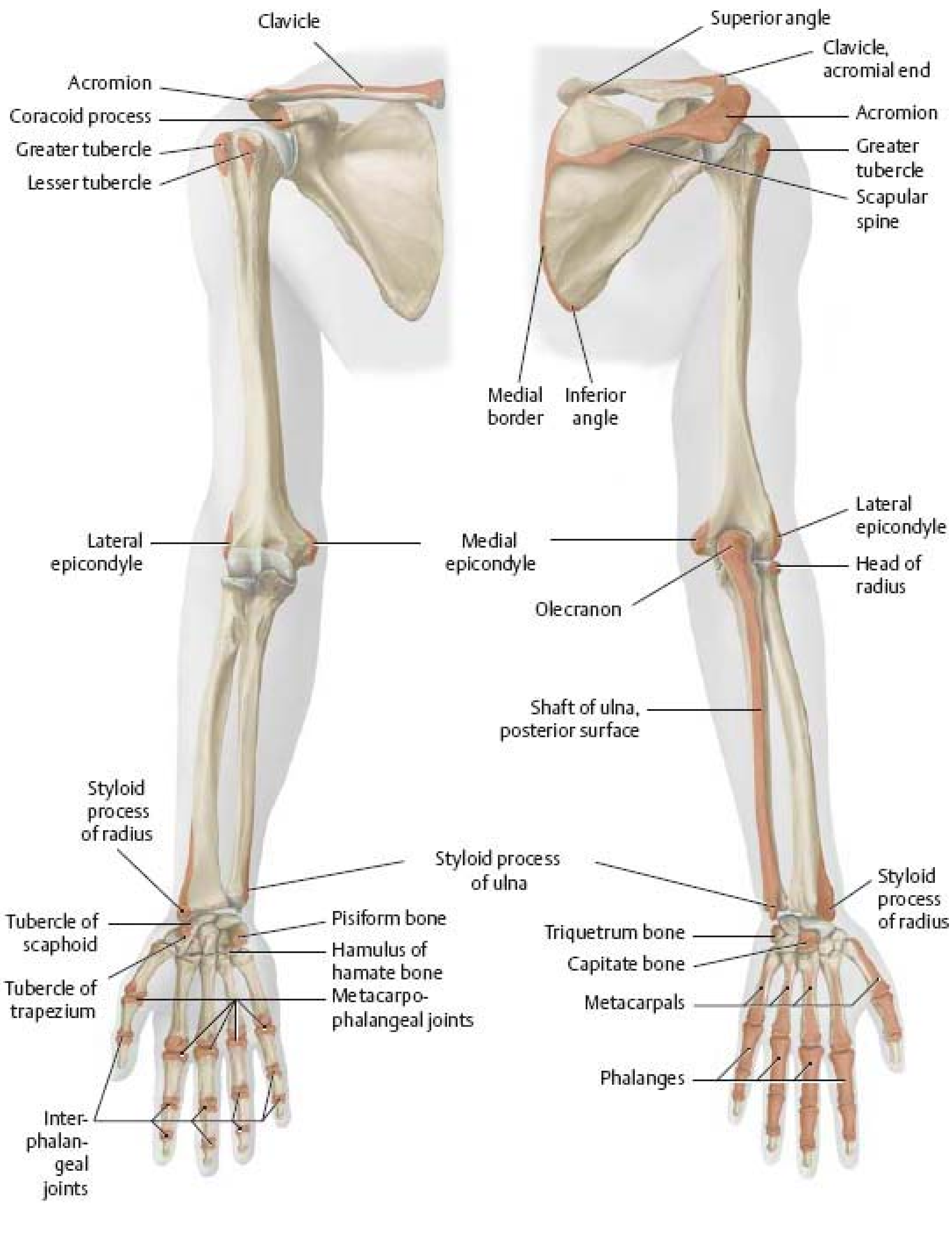




C Lateral view.

Fig. 19.2 **Palpable bony prominences**

Except forthe lunate and trapezoid bones, all of the bones in the upper limb are palpable to some degree through the skin and soft tissues.



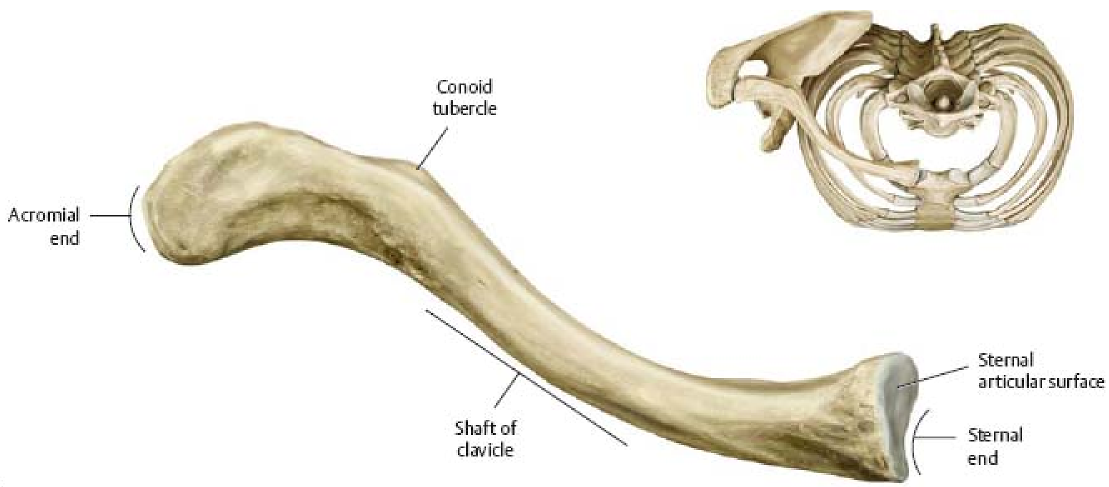
A Anterior view. **B** Posterior view.

Clavicle & Scapula

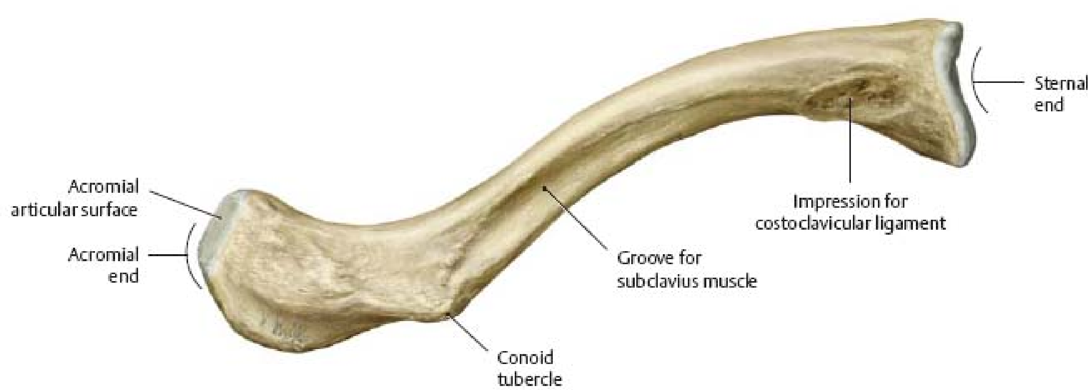
The shoulder girdle (clavicle and scapula) connects the bones of the upper limb to the thoracic cage. Whereas the pelvic girdle (paired hip bones) is firmly integrated into the axial skeleton (see p. 358), the shoulder girdle is extremely mobile.

Fig. 19.3 Clavicle

Right clavicle. The S-shaped clavicle is visible and palpable along its entire length (generally 12 to 15 cm). Its medial end articulates with the sternum at the sternoclavicular joint (see p. 258). Its lateral end articulates with the scapula attheacromioclavicular joint (see p. 259).



A Superior view.



B Inferior view.

Clinical

Scapular foramen

The superior transverse ligament of the scapula (see p. 259) may become ossified, transforming the scapular notch into an anomalous bony canal, the scapular foramen. This can lead to compression of the suprascapular nerve as it passes through the canal (see p. 333).

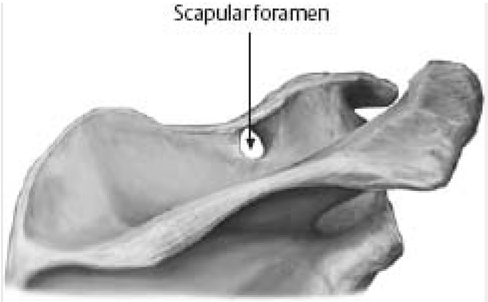
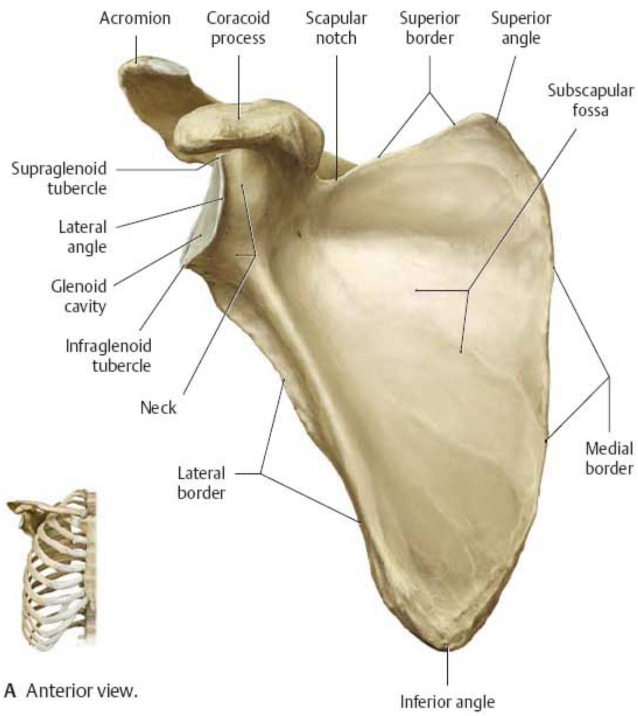
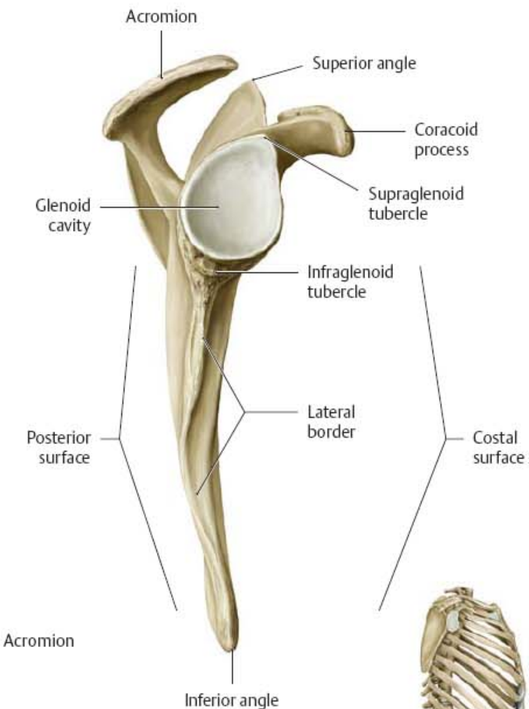


Fig. 19.4 **Scapula**

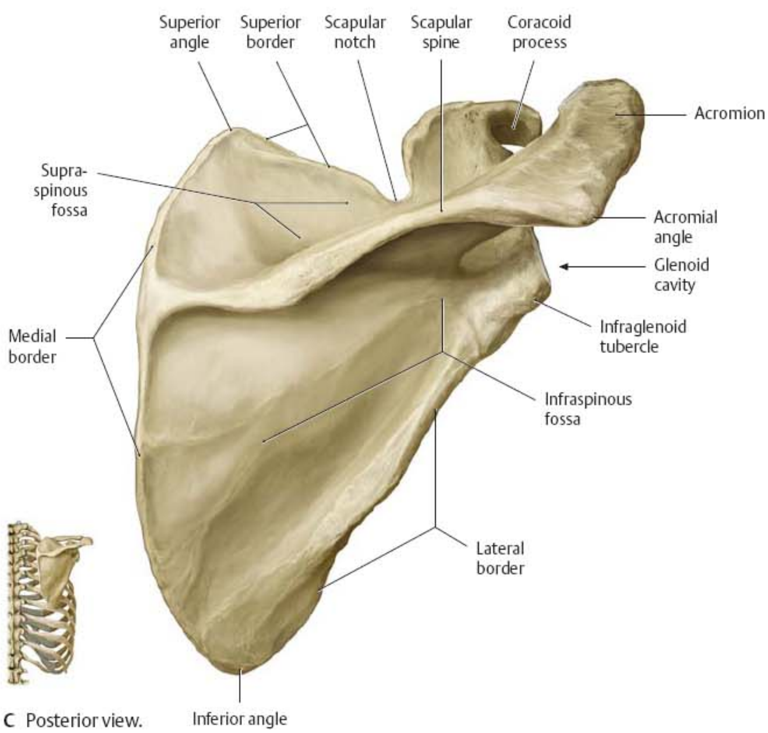
Right scapula. In its normal anatomical position, the scapula extends from the 2nd to the 7th rib.



A Anterior view.



B Right lateral view.

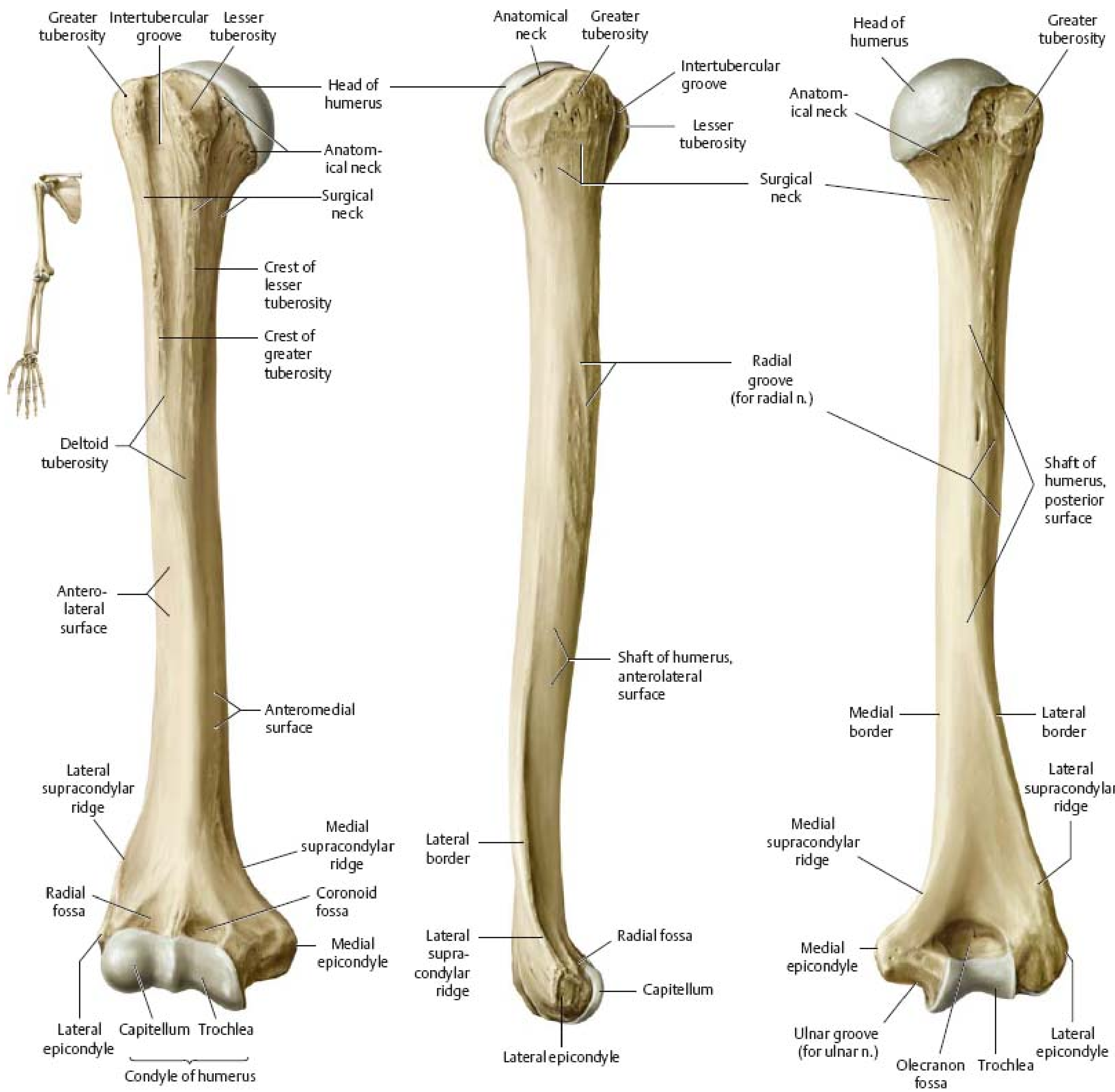


C Posterior view.

Humerus

Fig. 19.5 **Humerus**

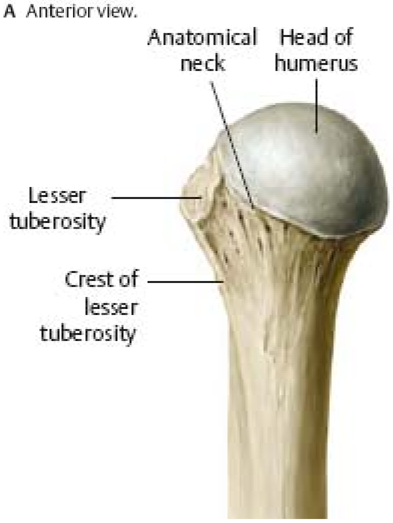
Right humerus. The head of the humerus articulates with the scapula at theglenohumeral joint (see p. 258). Thecapitellum and trochlea of the humerus articulate with the radius and ulna, respectively, at the elbow (cubital) joint (see p. 282).

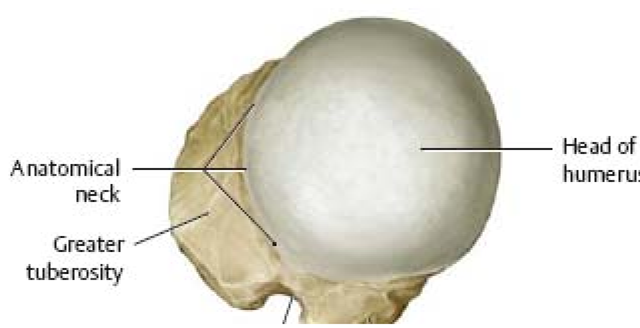


A Anterior view.

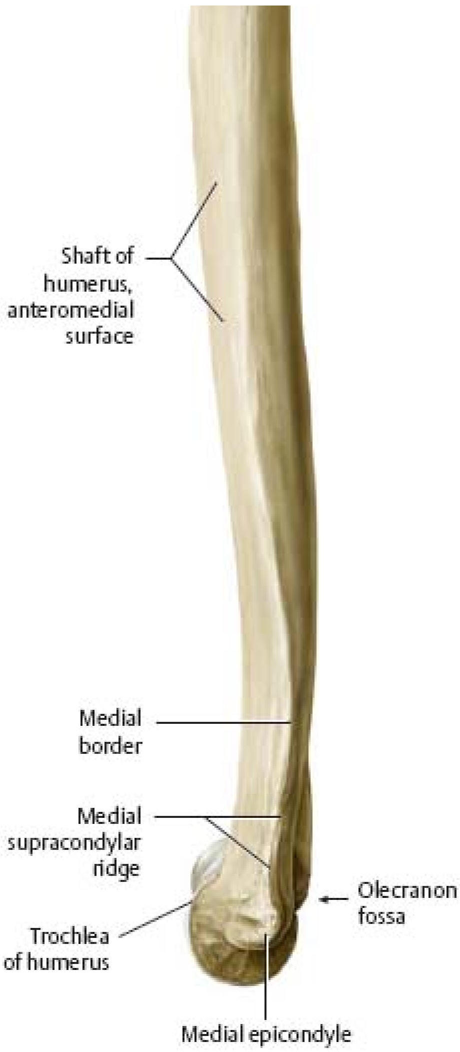
B Lateral view.

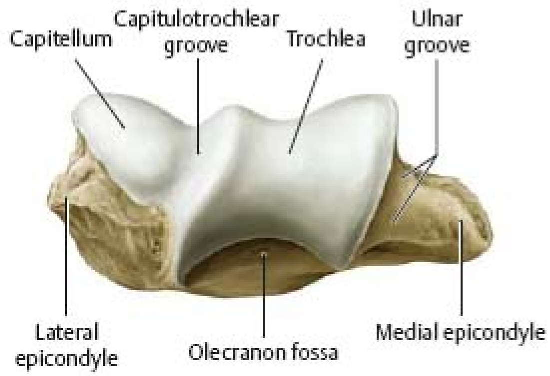
C Posterior view.





E Proximal (superior) view.





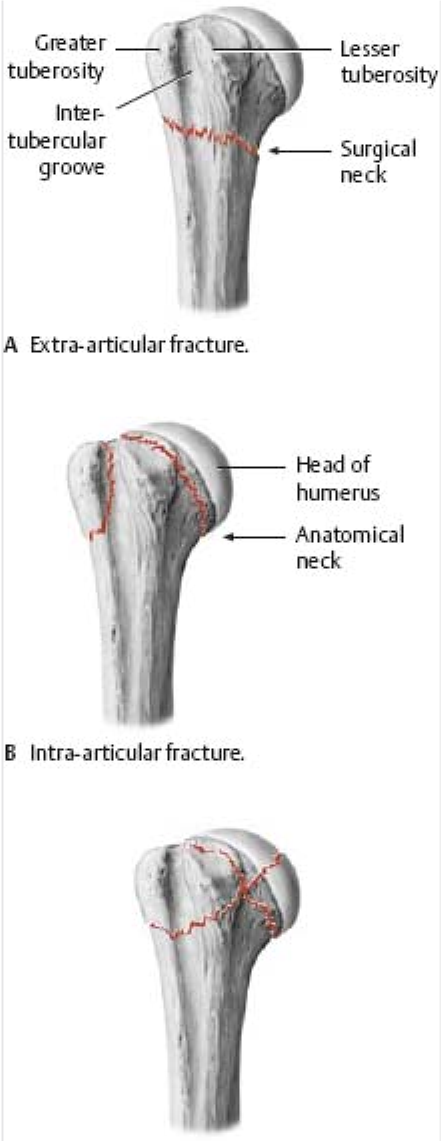
F Distal (inferior) view.

D Medial view.

Clinical

Fractures of the humerus

Anterior view. Fractures of the proximal humerus are very common and occur predominantly in older patients who sustain a fall onto the outstretched arm or directly onto the shoulder. Three main types are distinguished.



A Extra-articular fracture.

B Intra-articular fracture.

C Comminuted fracture.

Extra-articular fractures and intra-articular fractures are often accompanied by injuries of the blood vessels that supply the humeral head (anterior and posterior circumflex humeral arteries), with an associated risk of post-traumatic avascular necrosis.

Fractures of the humeral shaft and distal humerus are frequently associated with damage to the radial nerve.

Joints of the Shoulder

Fig. 19.6 Joints of the shoulder: Overview

Right shoulder, anterior view.

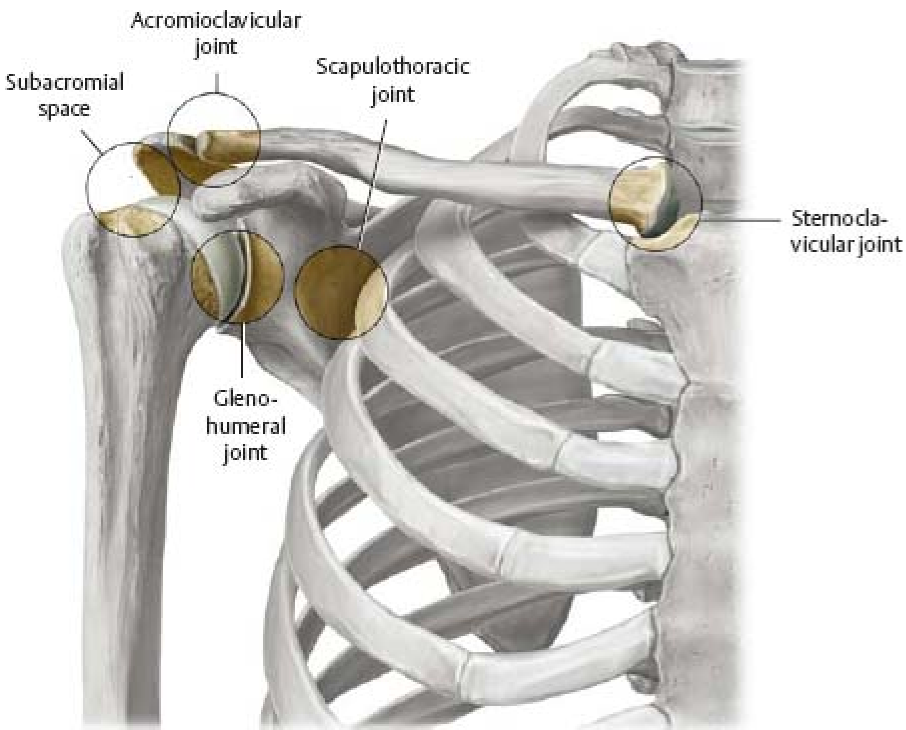


Fig. 19.7 **Joints of the shoulder girdle**
Right side, superior view.

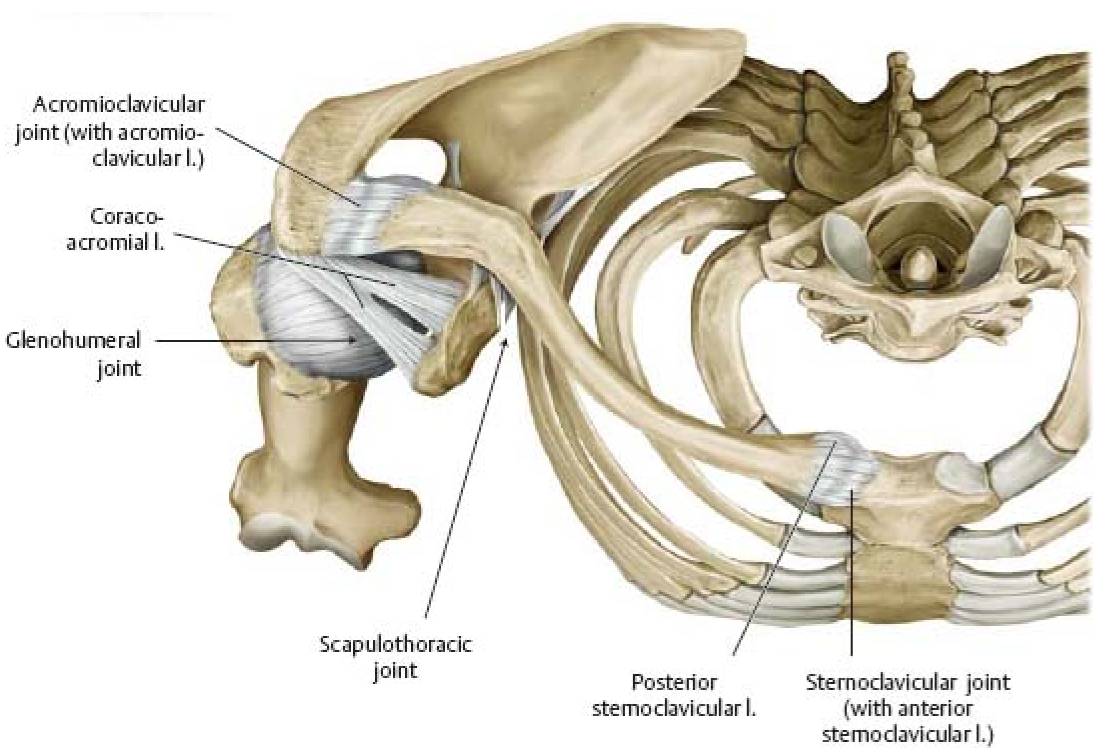


Fig. 19.8 Scapulothoracic joint

Right side, superior view. In all movements of the shoulder girdle, the scapula glides on a curved surface of loose connective tissue between the serratus anterior and the subscapu-laris muscles. This surface can be considered a scapulothoracic joint.

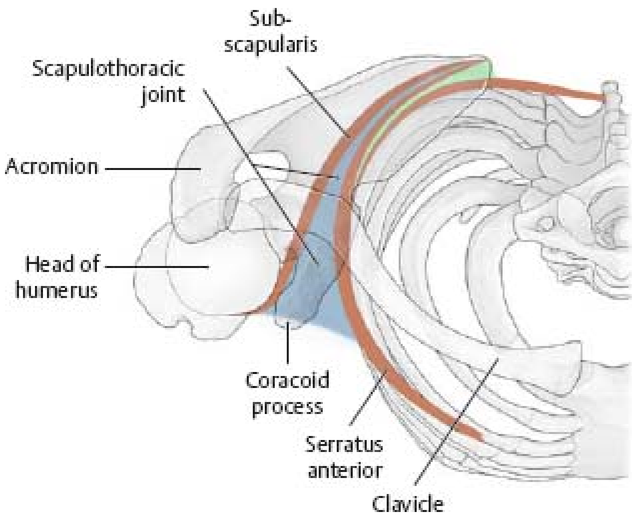


Fig. 19.9 Sternoclavicular joint

Anterior view with sternum coronally sectioned (left). *Note:* A fibrocartilaginous articular disk compensates for the mismatch of surfaces between the two saddle-shaped articular facets of the clavicle and manubrium sterni.

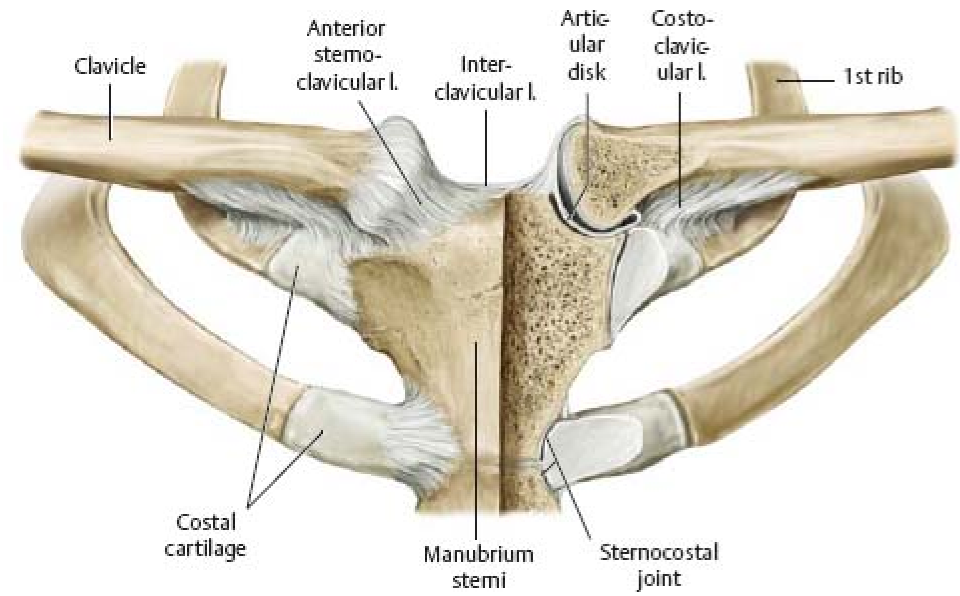
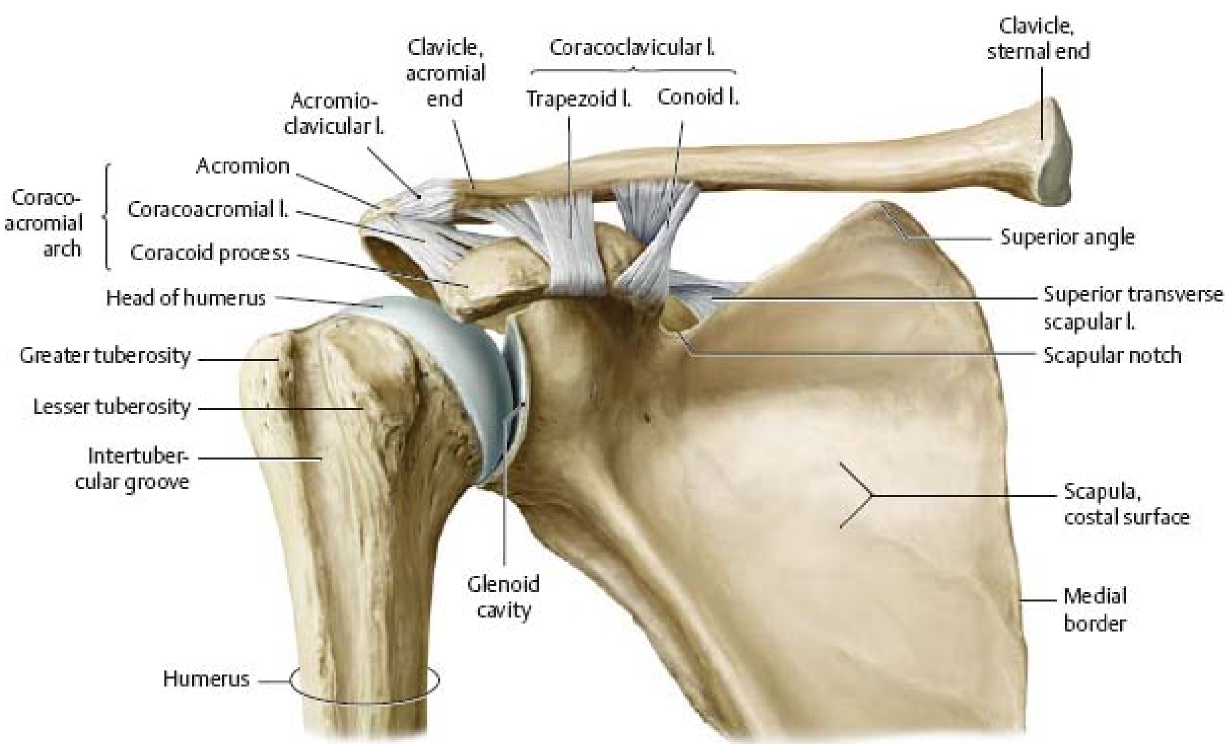


Fig. 19.10 Acromioclavicular joint

Anterior view. The acromioclavicular joint is a plane joint. Because the articulating surfaces are flat, they must be held in place by strong ligaments, greatly limiting the mobility of the joint.



Clinical

Injuries of the acromioclavicular joint

A fall onto the outstretched arm or shoulder frequently causes dislocation of the acromioclavicular joint and damage to the coracoclavicular ligaments.

A Stretching of ligaments.

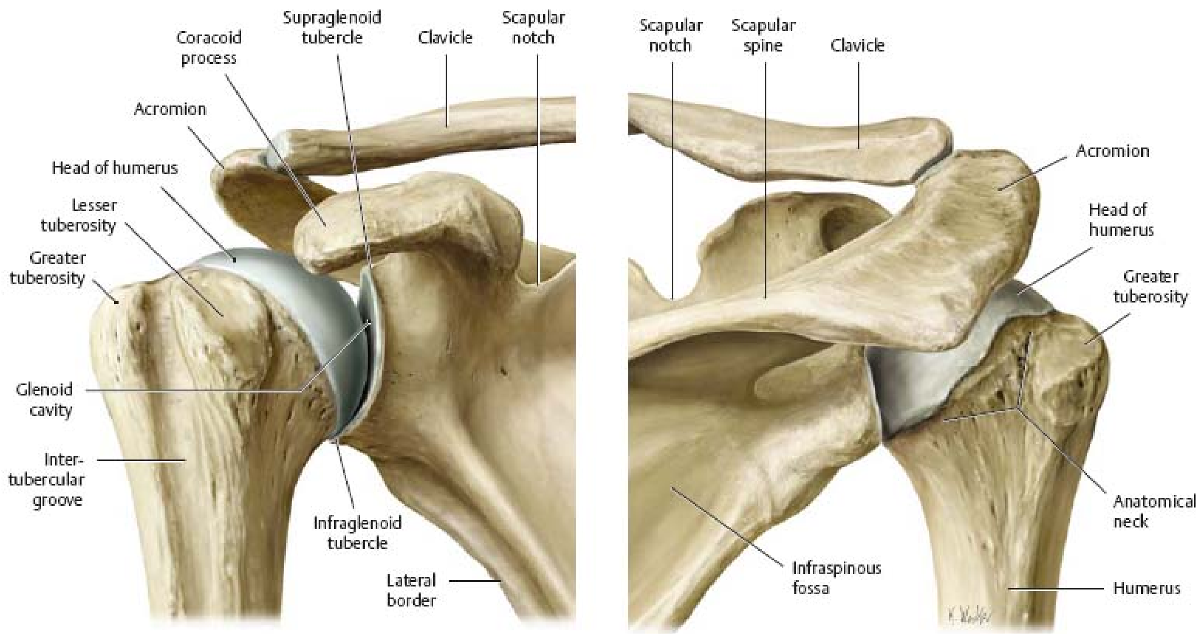
B Rupture of acromioclavicular ligament.

C Complete dislocation of acromioclavicular joint.

Joints of the Shoulder: Glenohumeral Joint

Fig. 19.11 Glenohumeral joint: Bony elements

Right shoulder.



A Anterior view.

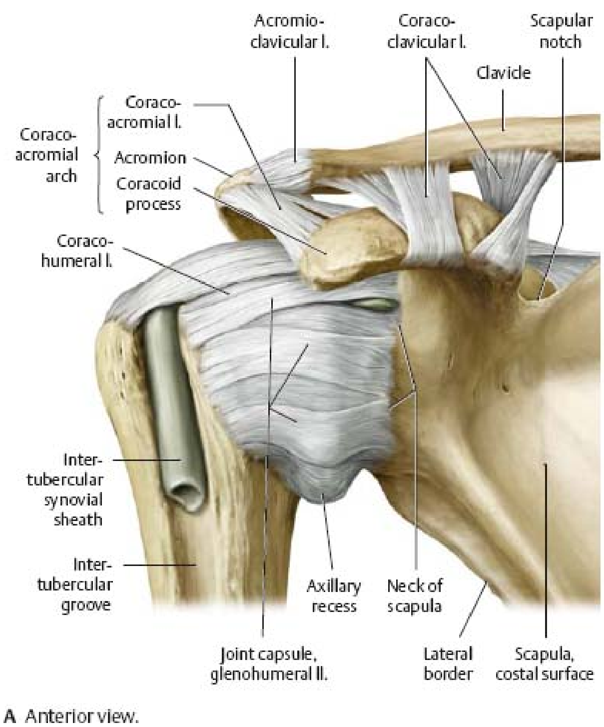
B Posterior view.

Fig. 19.12 Radiograph of the shoulder

Anteroposterior view.

Fig. 19.13 Glenohumeral joint: Capsule and ligaments

Right shoulder.



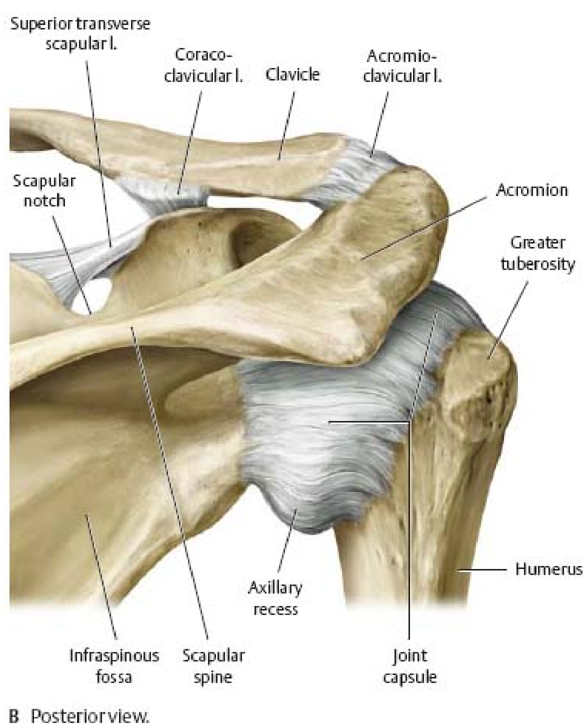


Fig. 19.14 Glenohumeral joint cavity

Anterior view.

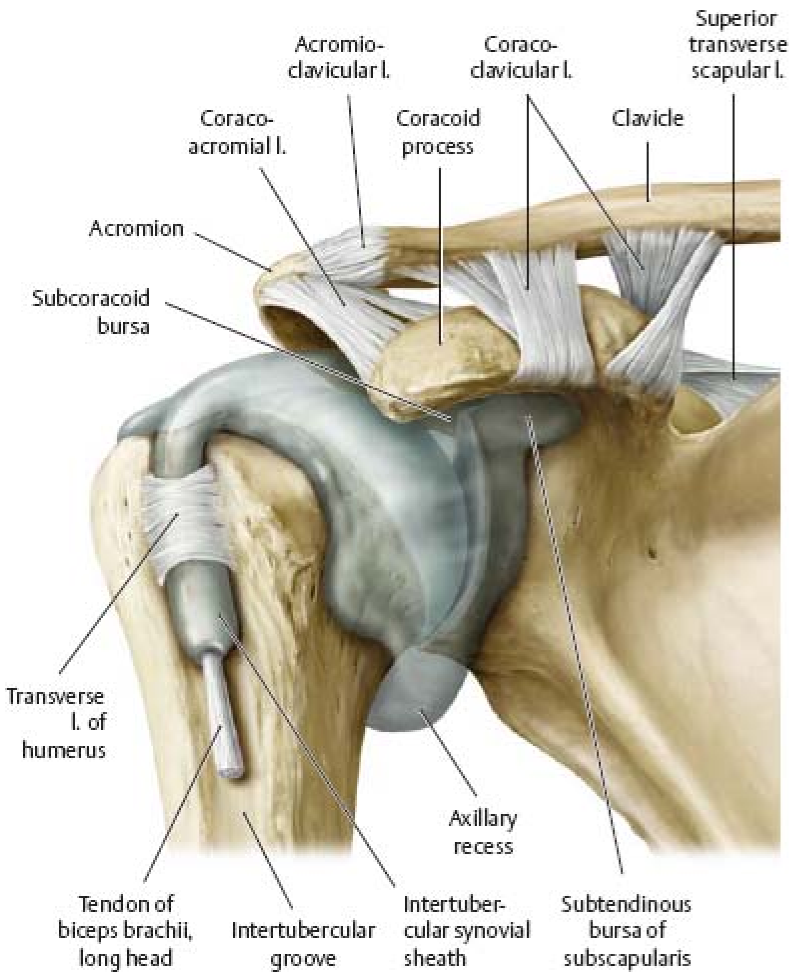
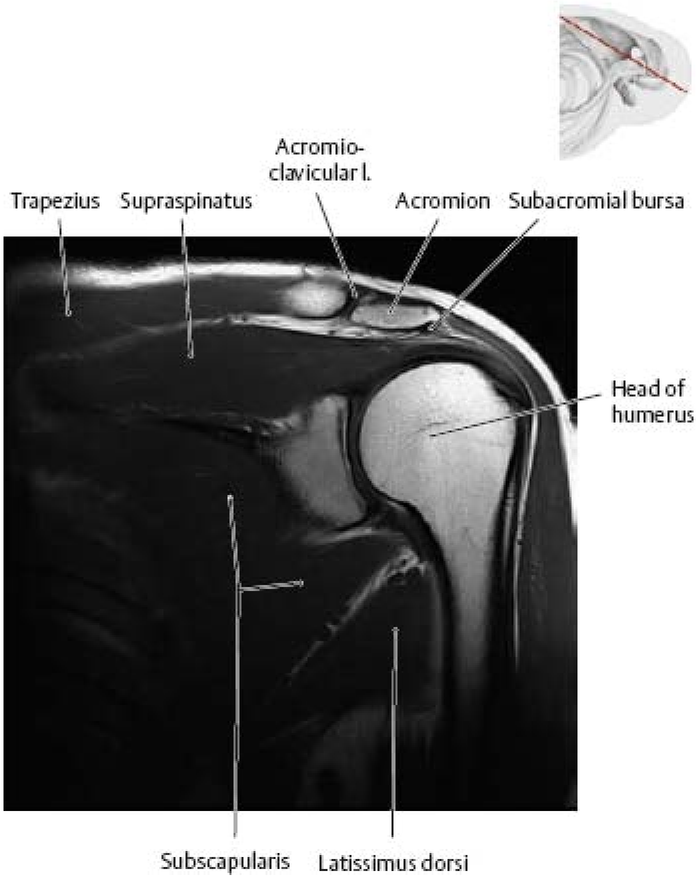


Fig. 19.15 **MRI of the shoulder**

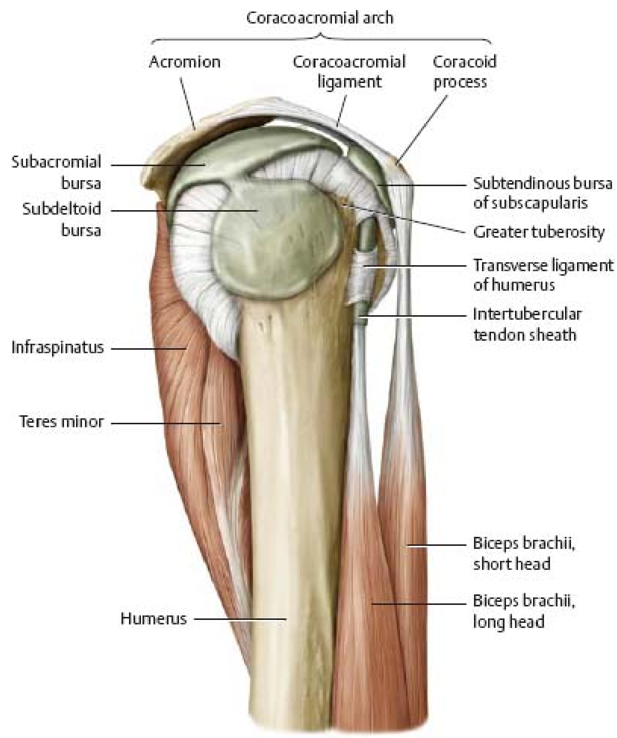
Coronal section, anterior view.



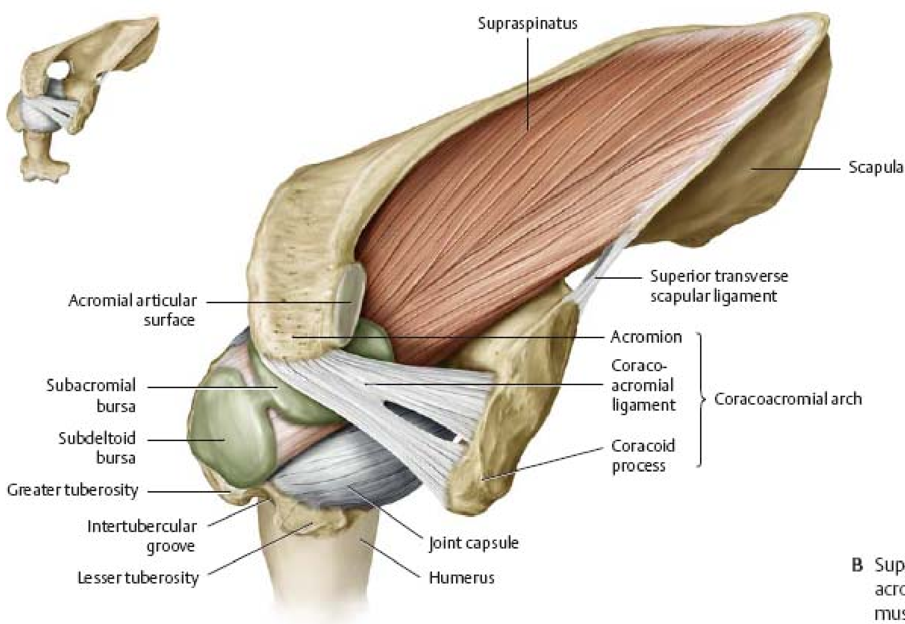
Subacromial Space & Bursae

Fig. 19.16 Subacromial space

Right shoulder.



A Lateral view.



B Superior view. Note the position of the sub-acromial bursa between the supraspinatus muscle and the coracoacromial arch.

Fig. 19.17 Subacromial bursa and glenoid cavity

Right shoulder, lateral view of sagittal section with humerus removed.

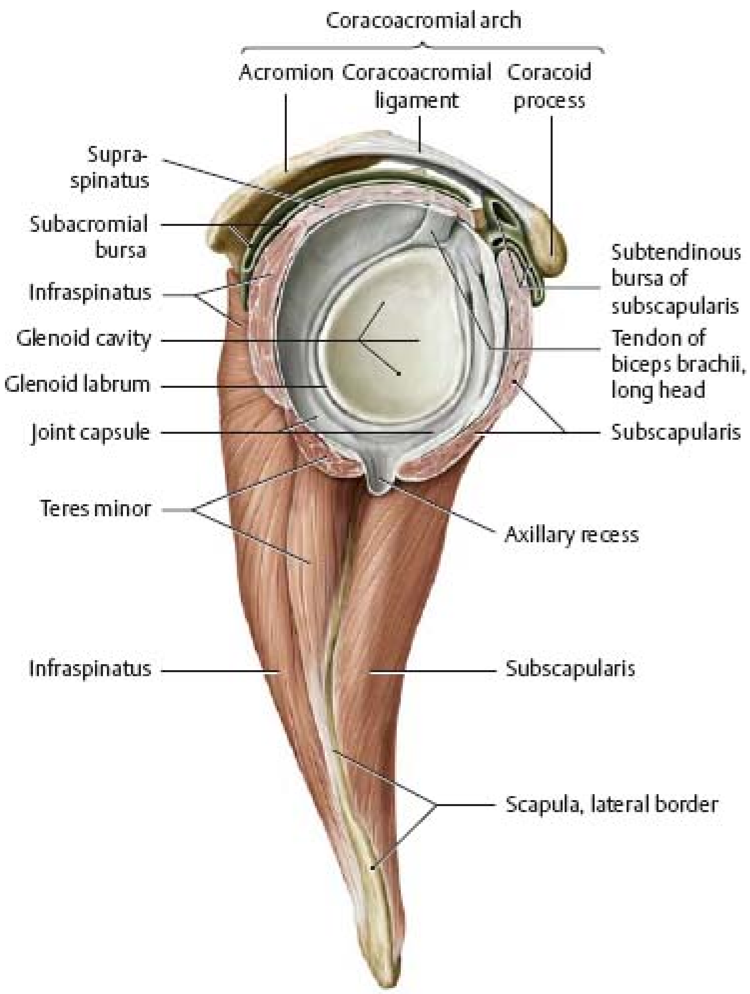
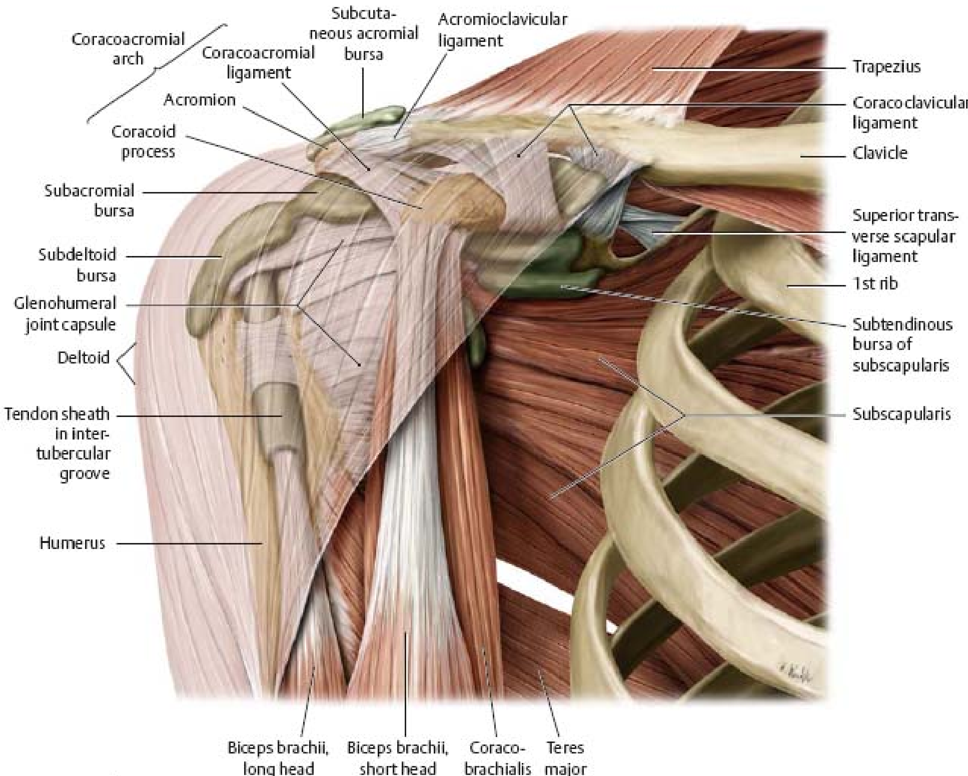
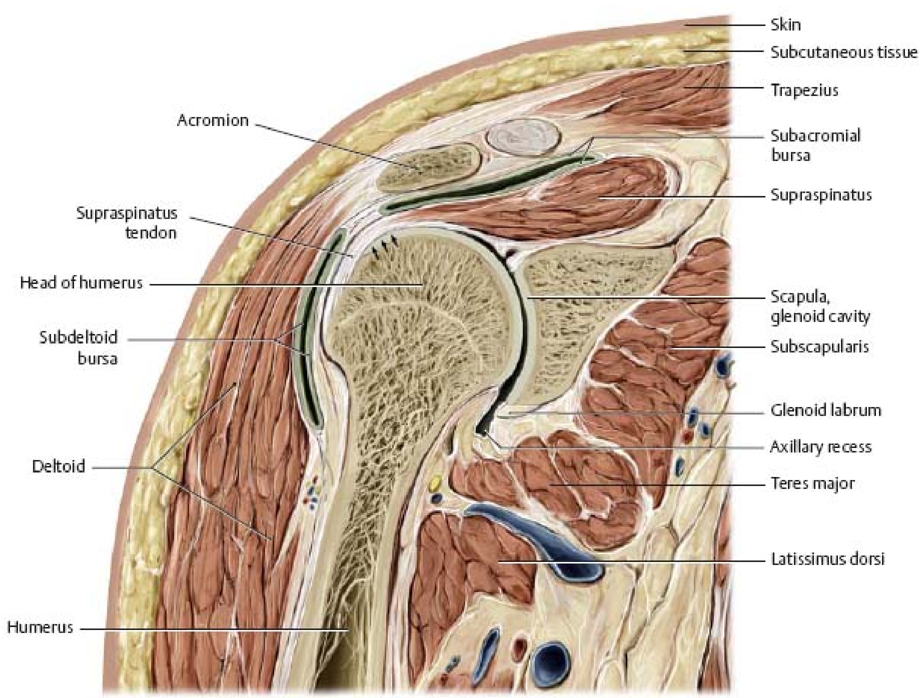


Fig. 19.18 **Subacromial and subdeltoid bursae**

Right shoulder, anterior view.



A Location of bursae.

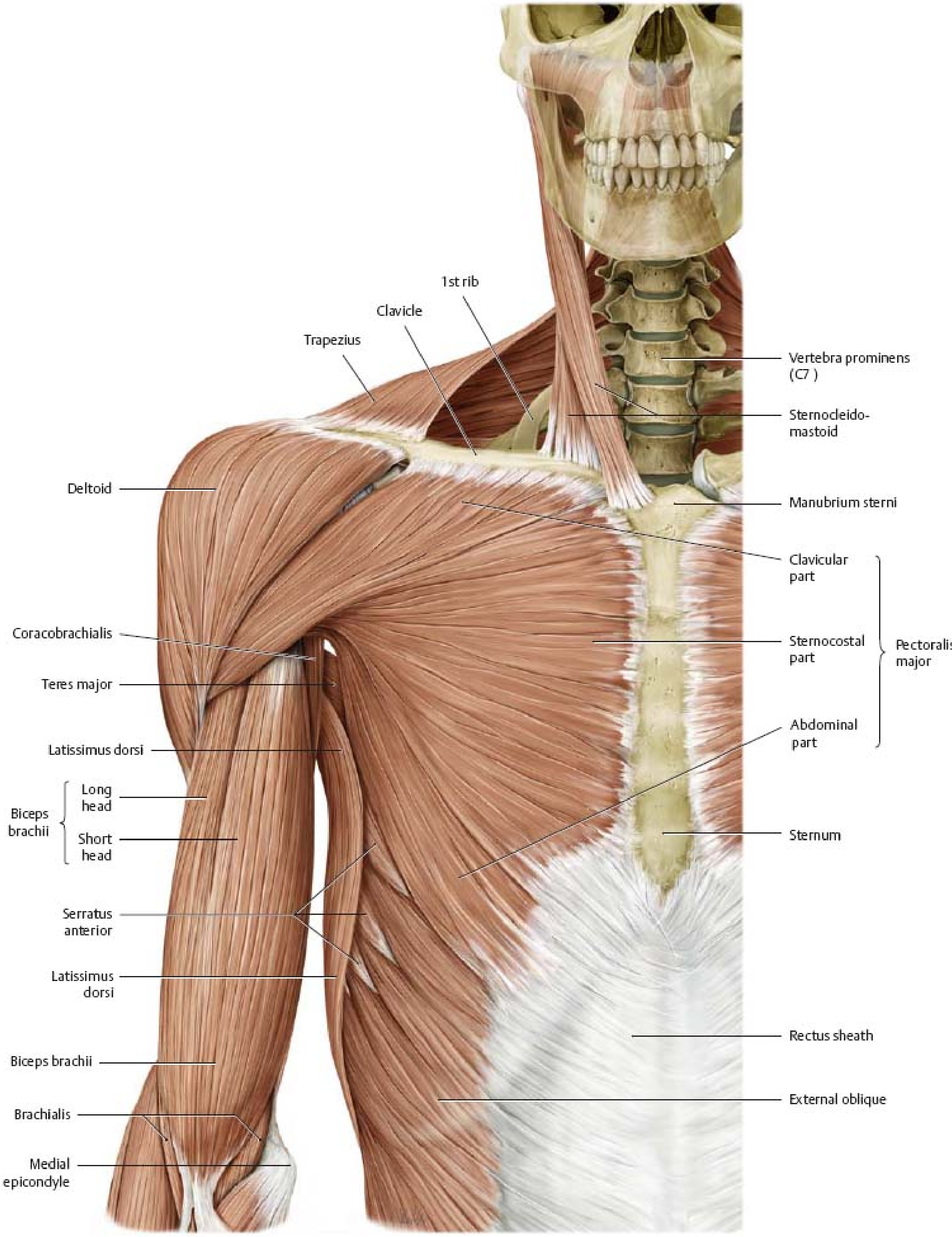


B Coronal section. The arrows are pointing at the supraspinatus tendon, which is frequently injured in a "rotator cuff tear" (for rotator cuff, see p. 273).

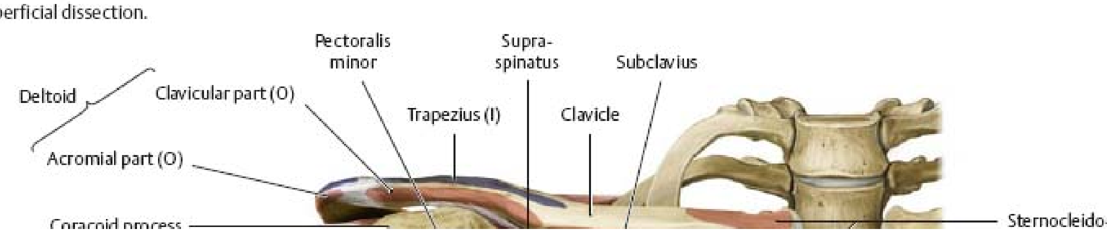
Anterior Muscles of the Shoulder & Arm (I)

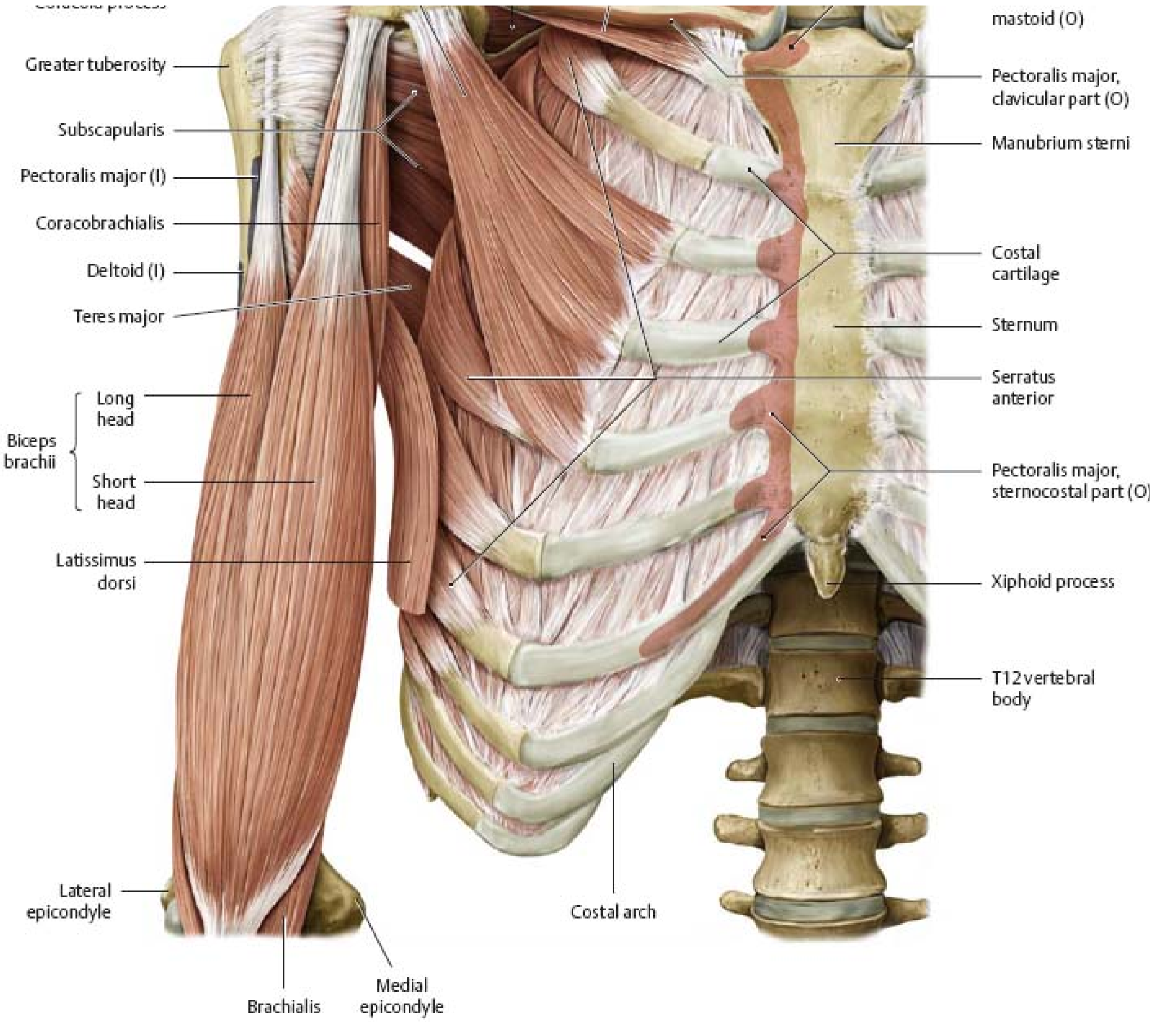
Fig. 19.19 **Anterior muscles**

Right side, anterior view. Muscle origins (O) are shown in red, insertions (I) in blue.



A Superficial dissection.



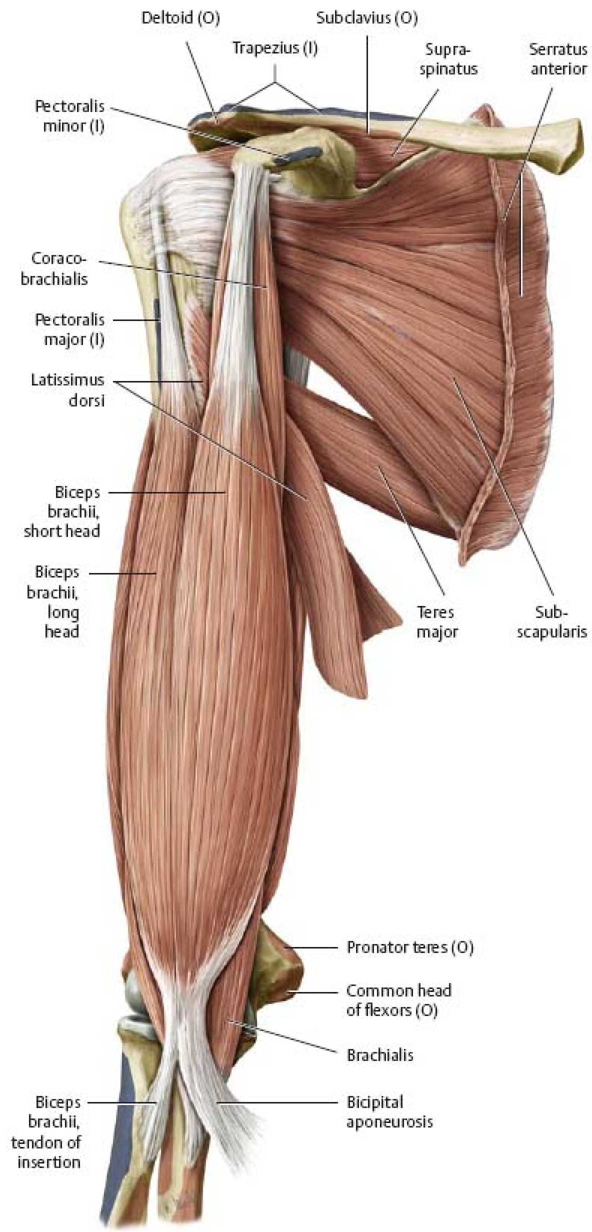


B Deep dissection. *Removed:* Sternocleidomastoid, trapezius, pectoralis major, deltoid, and external oblique muscles.

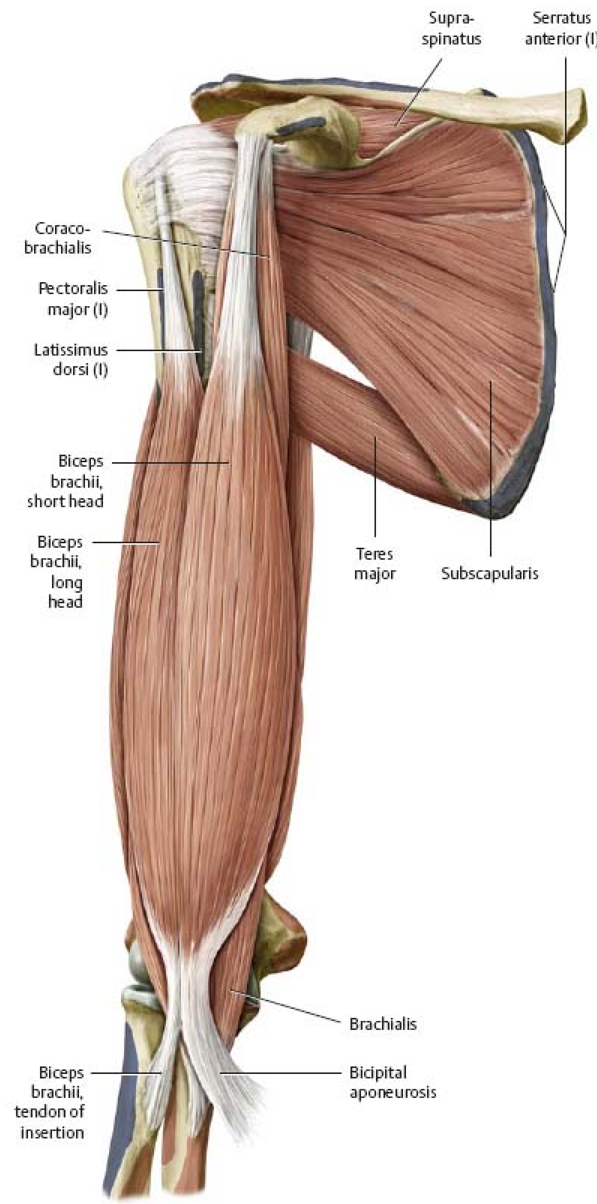
Anterior Muscles of the Shoulder & Arm (II)

Fig. 19.20 Anterior dissection

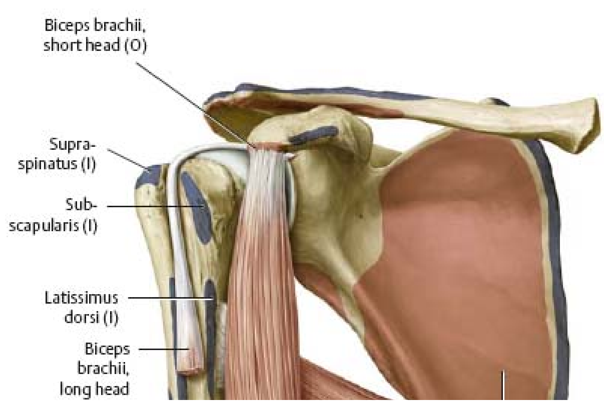
Right arm, anterior view. Muscle origins (O) are shown in red, insertions (I) in blue.

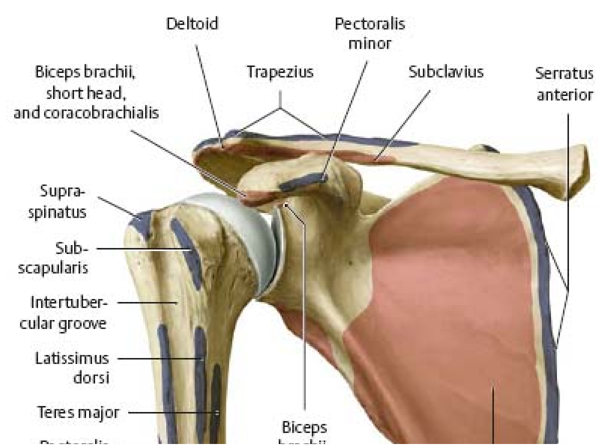


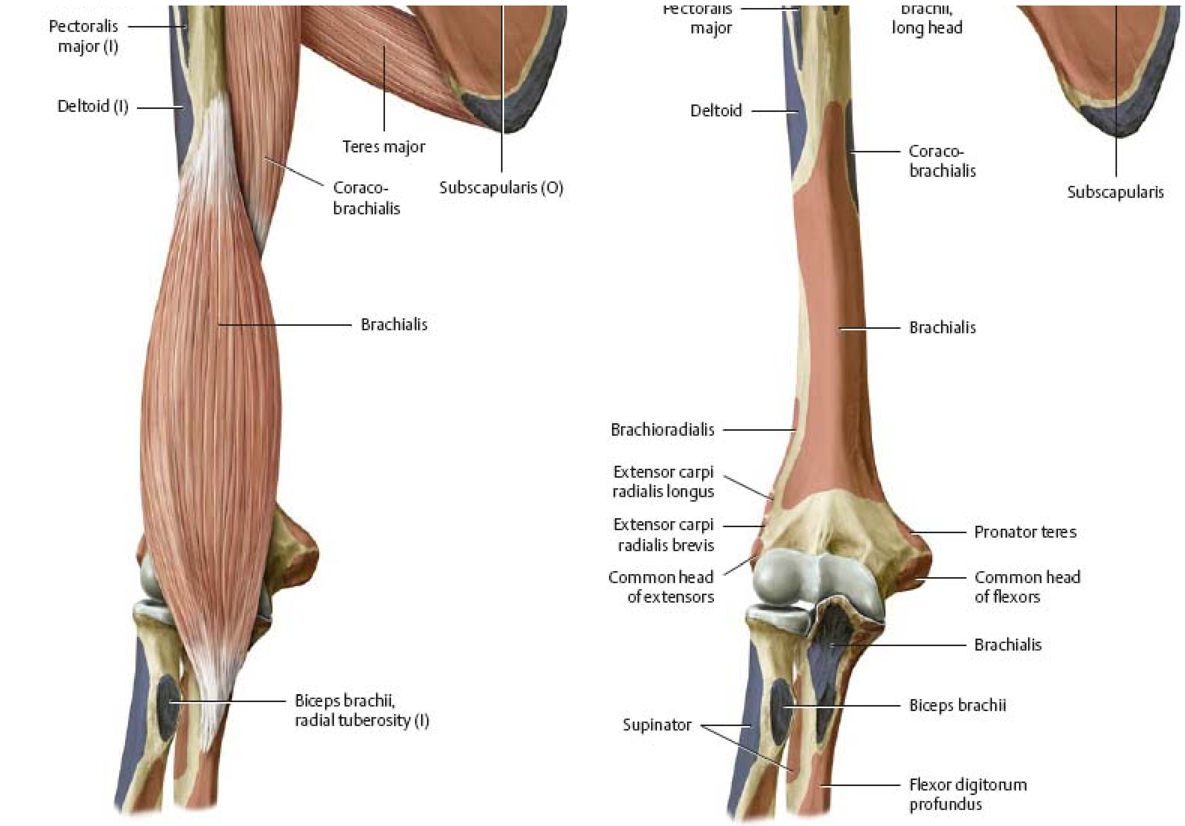
A *Removed:* Thoracic skeleton. *Partially removed:* Latissimus dorsi and serratus anterior.



B *Removed:* Latissimus dorsi and serratus anterior.







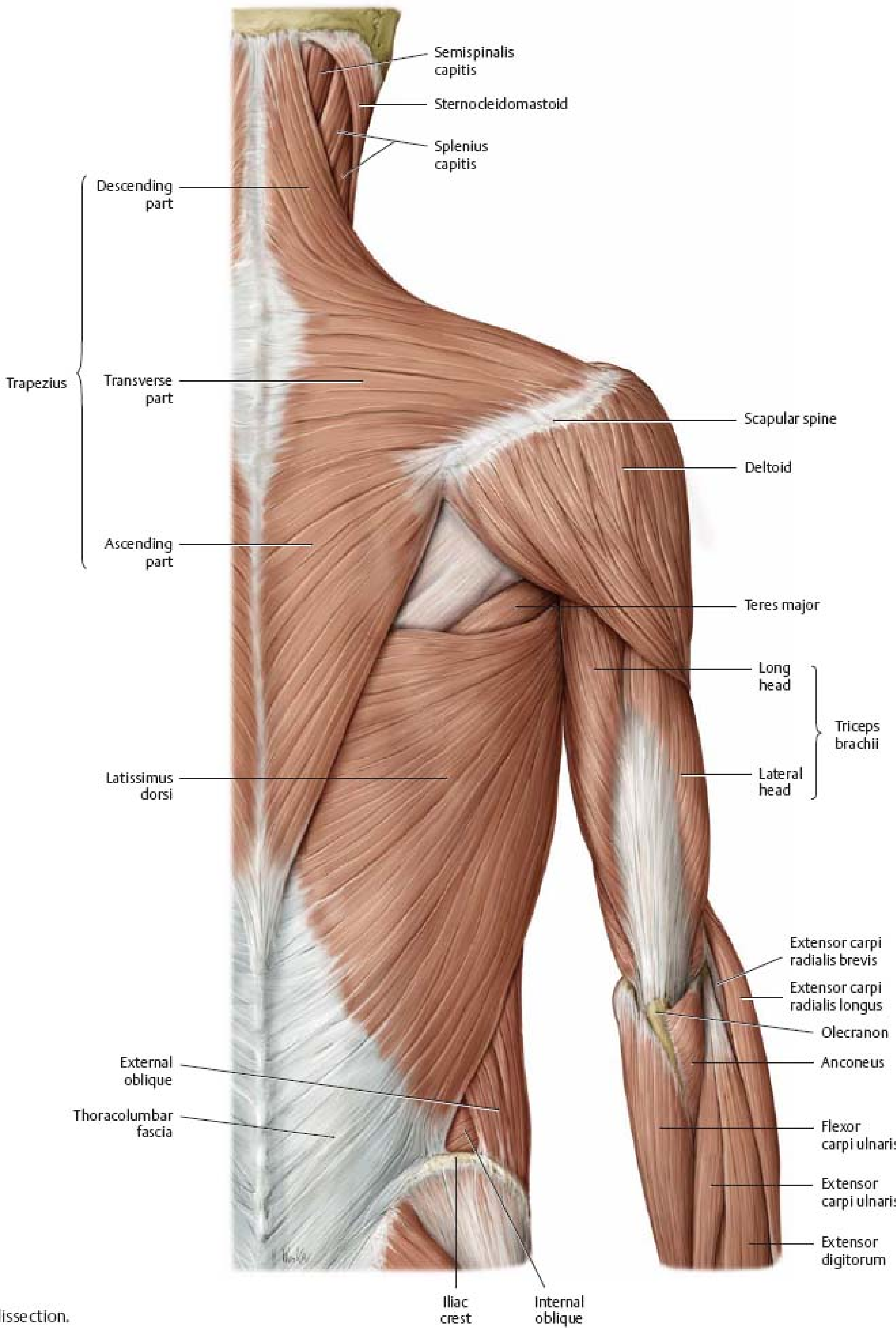
C *Removed:* Subscapularis and supraspinatus muscles. *Partially removed:* Biceps brachii.

D *Removed:* Biceps brachii, coracobrachialis, and teres major.

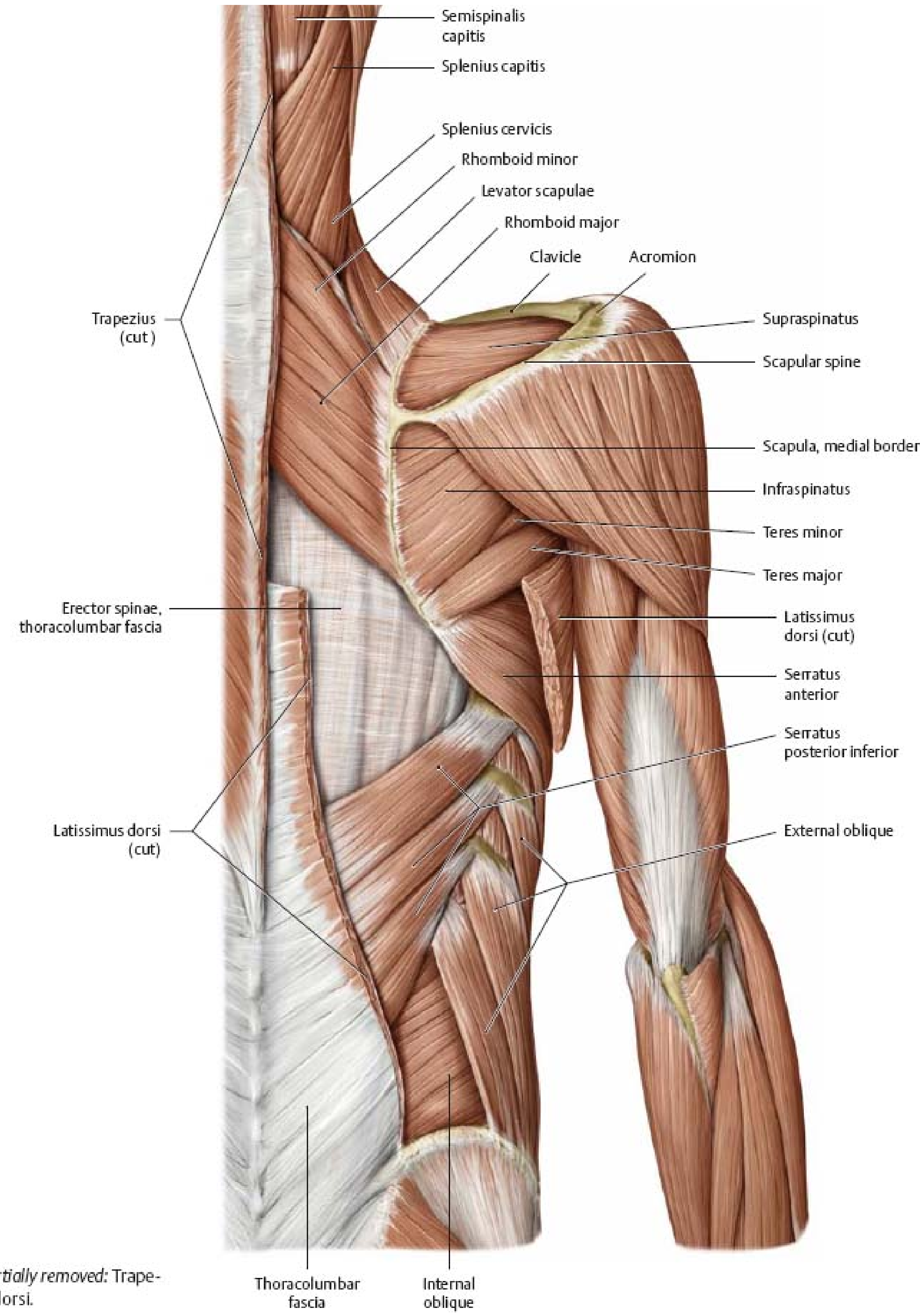
Posterior Muscles of the Shoulder & Arm (I)

Fig. 19.21 Posterior muscles

Right side, posterior view.



A Superficial dissection.



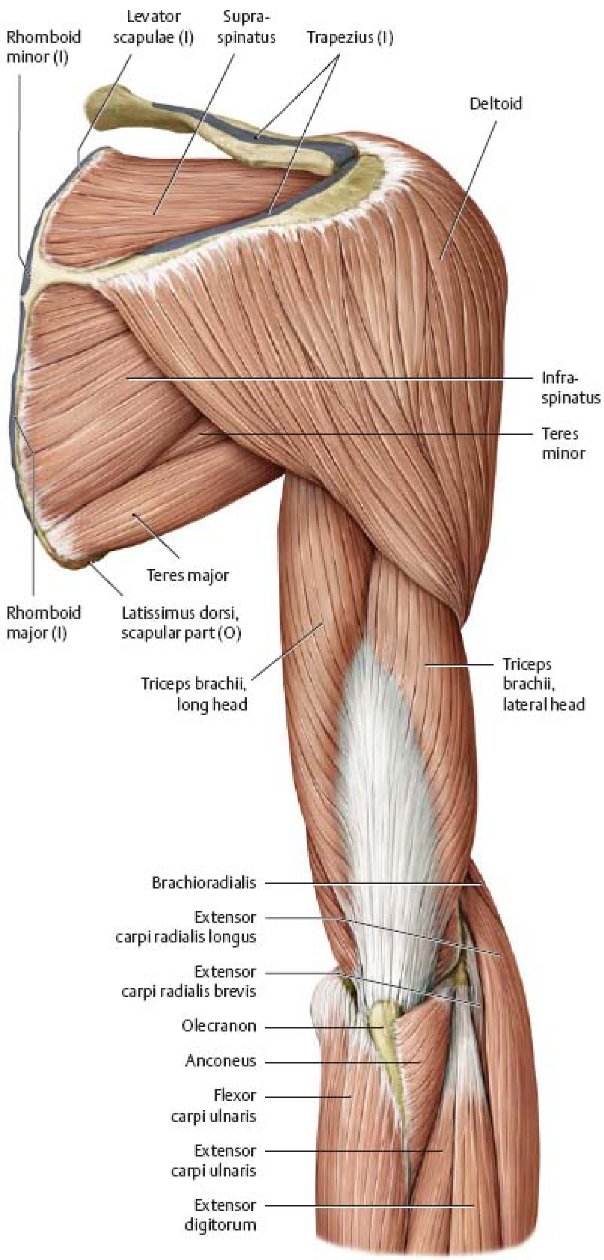
B Deep dissection. *Partially removed:* Trapezius and latissimus dorsi.

Posterior Muscles of the Shoulder & Arm (II)

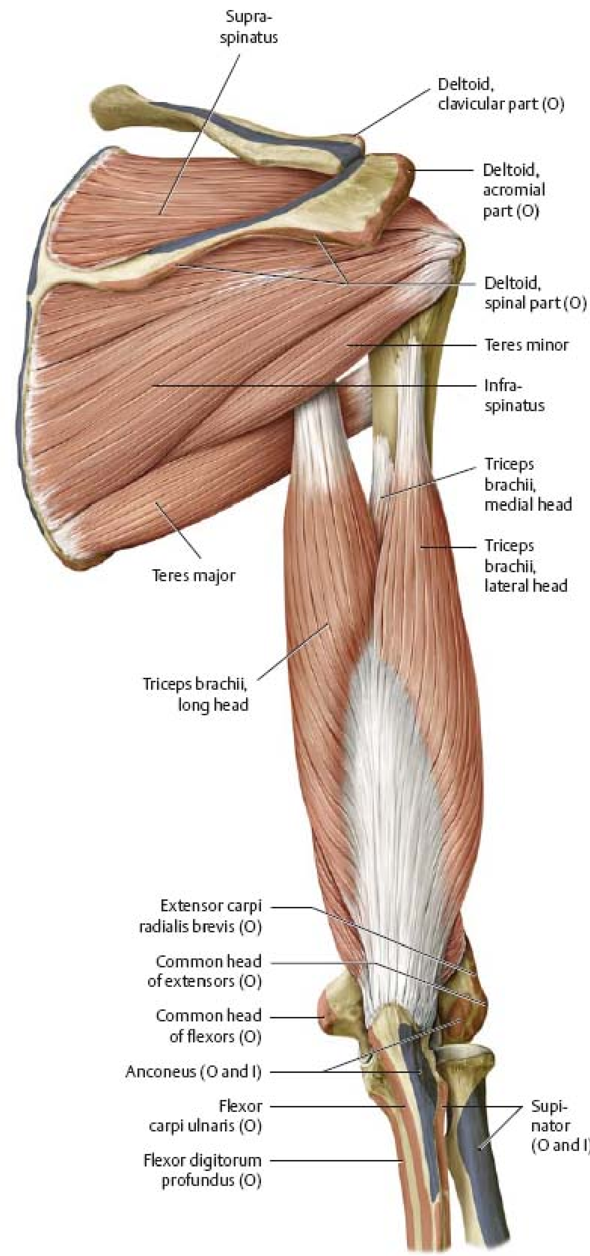
Fig. 19.22 Posterior dissection

Right arm, posterior view. Muscle origins (0) are shown in red, insertions

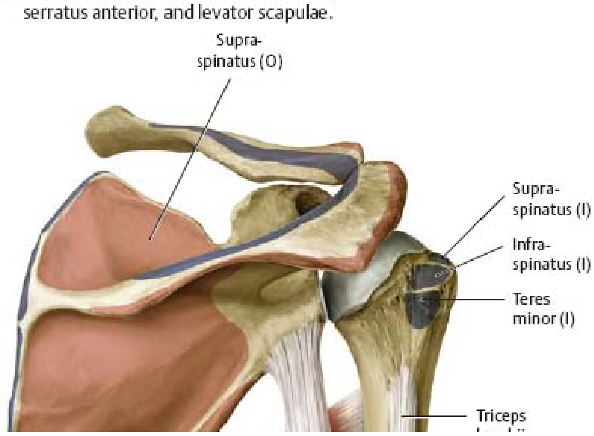
(I) in blue.

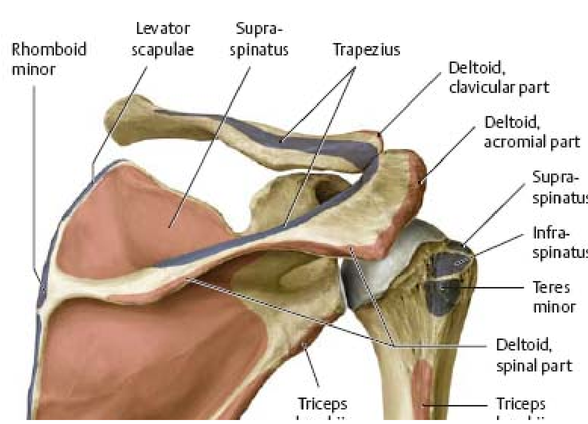


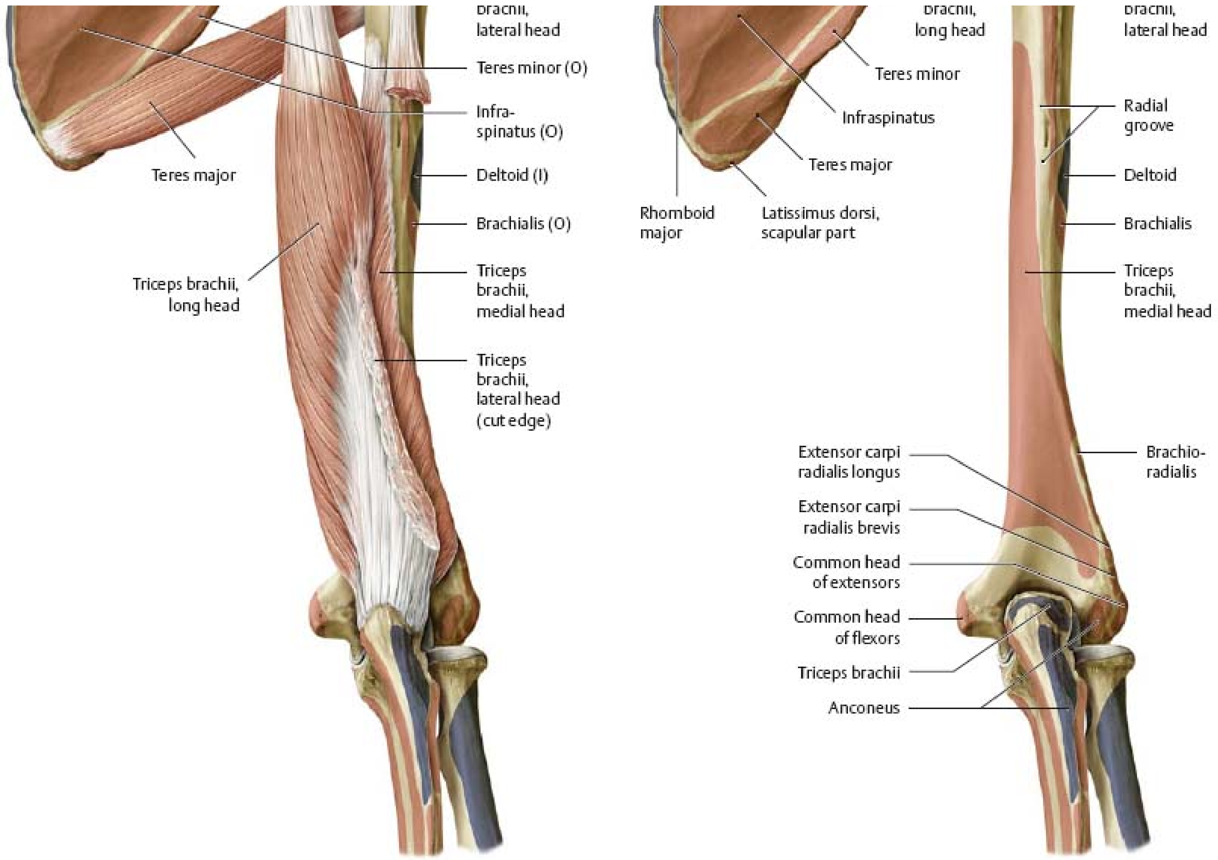
A *Removed:* Rhomboids major and minor, serratus anterior, and levator scapulae.



B *Removed:* Deltoid and forearm muscles.







C *Removed:* Supraspinatus, infraspinatus, and teres minor. *Partially removed:* Triceps brachii.

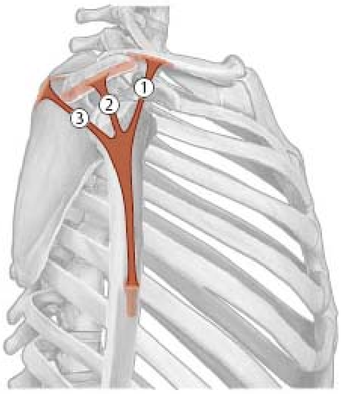
D *Removed:* Triceps brachii and teres major.

Muscle Facts (I)

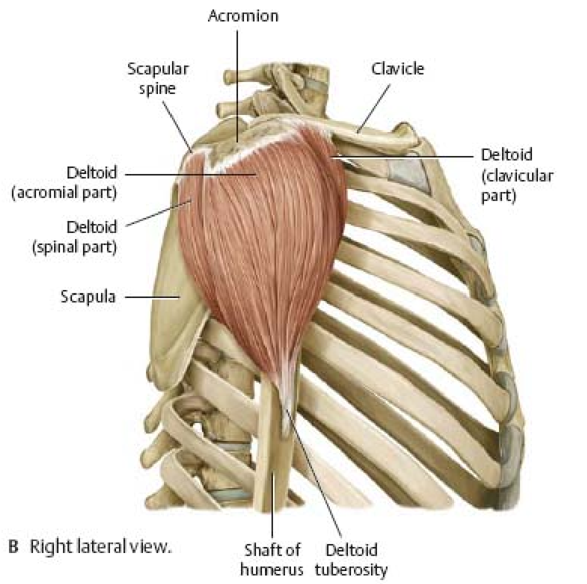
The actions of the three parts of the deltoid muscle depend on their relationship to the position of the humerus and its axis of motion. At less than 60 degrees, the muscles act as adductors, but at greater than 60 degrees, they act as abductors. As a result, the parts of the deltoid can act antagonistically as well as synergistically.

Fig. 19.23 Deltoid

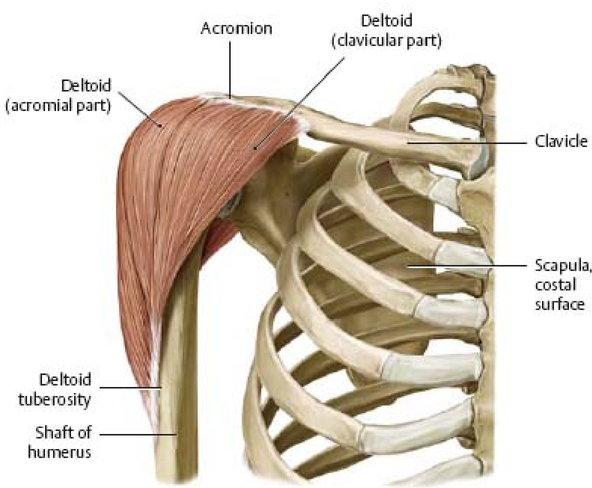
Right shoulder.



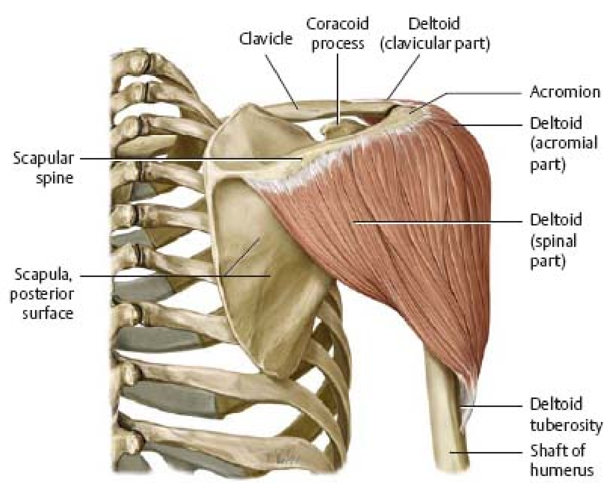
A Parts of the deltoid, right lateral view.



B Right lateral view.



C Anterior view.



D Posterior view.

Table 19.1 Parts of the deltoid

Muscle		Origin	Insertion	Innervation	Action*
Deltoid	① Clavicular part	Lateral one third of clavicle	Humerus (deltoid tuberosity)	Axillary n. (C5, C6)	Flexion, internal rotation, adduction
	② Acromial part	Acromion			Abduction
	③ Spinal part	Scapular spine			Extension, external rotation, adduction

* Between 60 and 90 degrees of abduction, the clavicular and spinal parts assist the acromial part with abduction.

Fig. 19.24 Rotator cuff

Right shoulder. The rotator cuff consists of four muscles: supraspinatus, infraspinatus, teres minor, and subscapularis.

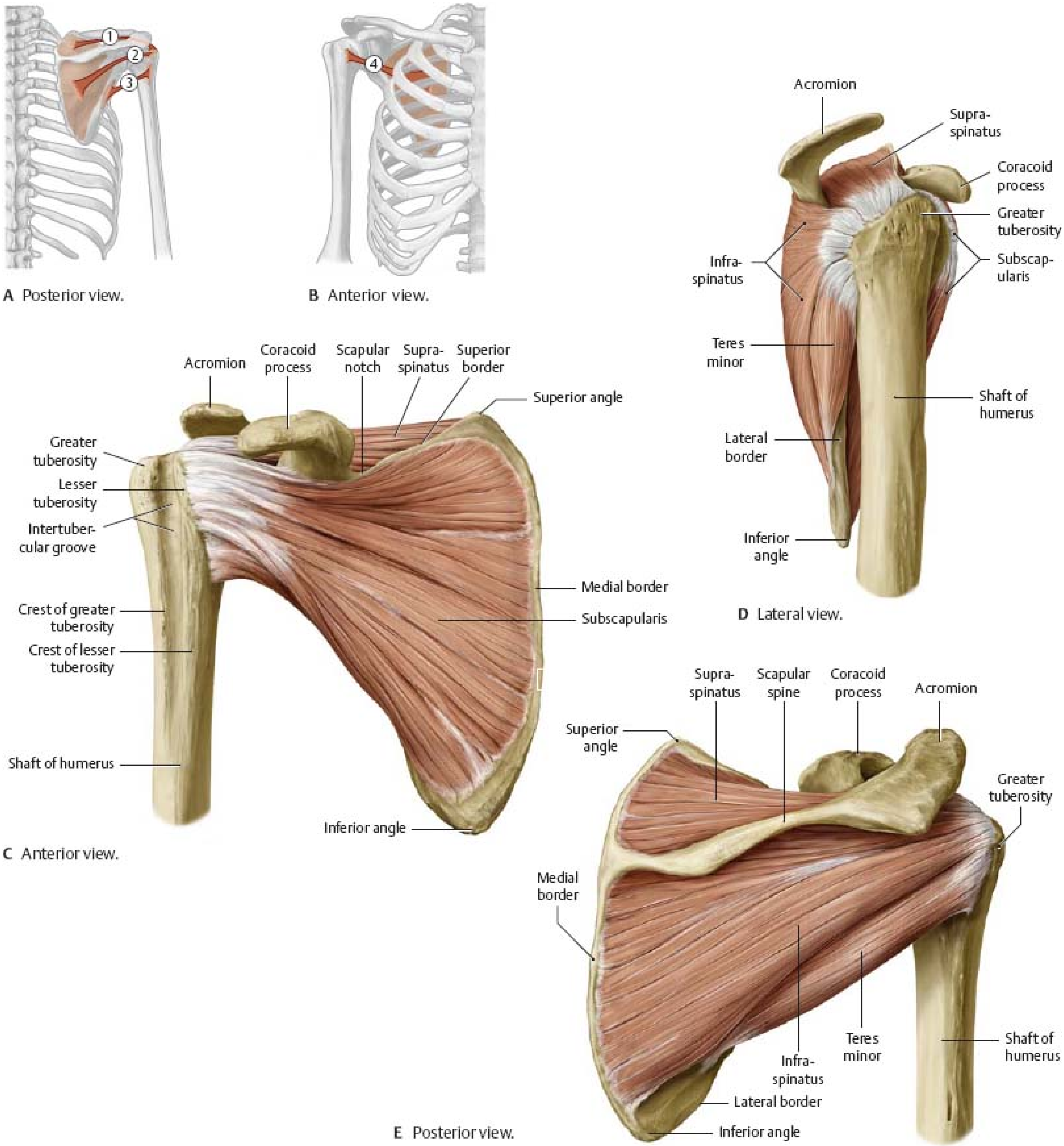


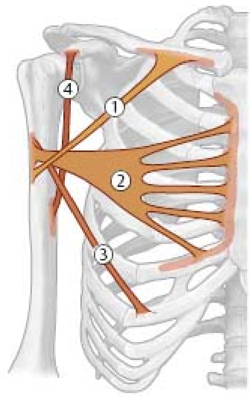
Table 19.2 Muscles of the rotator cuff

Muscle	Origin		Insertion		Innervation	Action
① Supraspinatus	Scapula	Supraspinous fossa	Humerus	Greater tuberosity	Suprascapular n. (C4–C6)	Abduction
② Infraspinatus		Infraspinous fossa				External rotation
③ Teres minor		Lateral border			Axillary n. (C5, C6)	External rotation, weak adduction
④ Subscapularis		Subscapular fossa		Lesser tuberosity	Subscapular n. (C5, C6)	Internal rotation

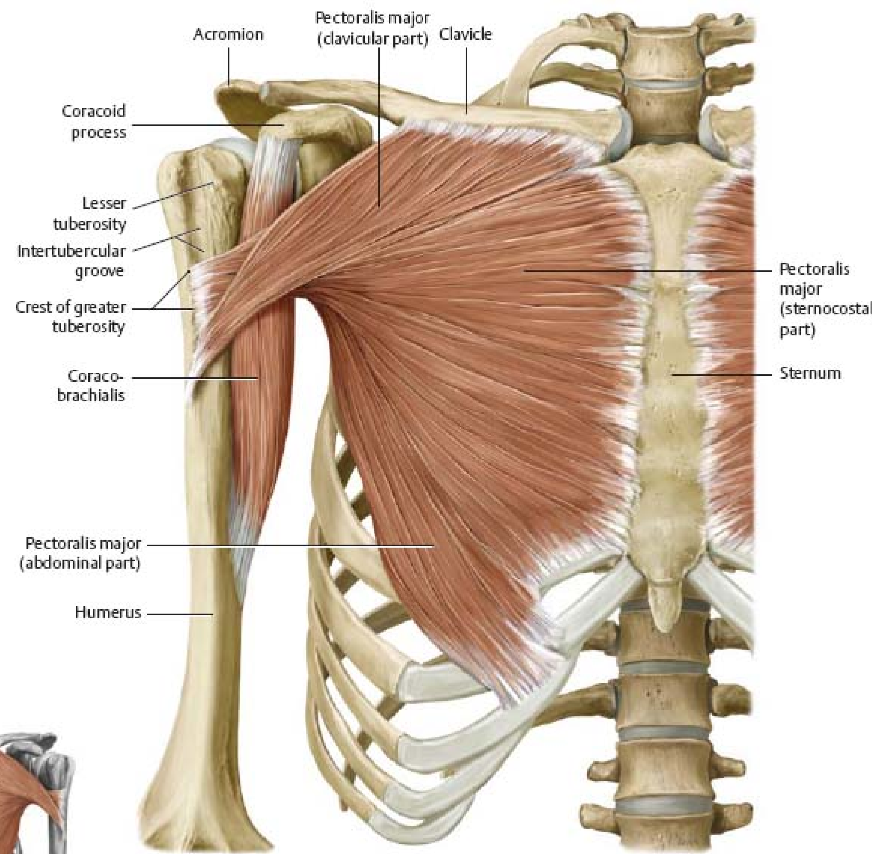
Muscle Facts (II)

Fig. 19.25 Pectoralis major and coracobrachialis

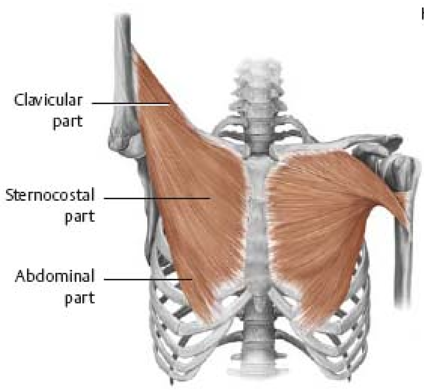
Anterior view.



A Schematic.



C Pectoralis major and coracobrachialis.



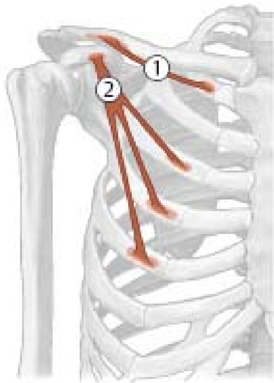
B Pectoralis major in neutral position (left) and elevation (right).

Table 19.3 Pectoralis major and coracobrachialis

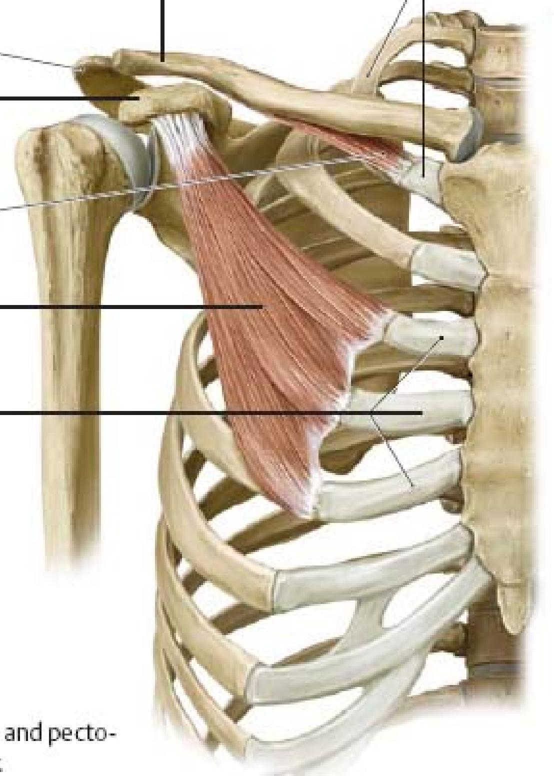
Muscle		Origin	Insertion	Innervation	Action
Pectoralis major	① Clavicular part	Clavicle (medial half)	Humerus (crest of greater tuberosity)	Medial and lateral pectoral nn. (C5–T1)	Entire muscle: adduction, internal rotation Clavicular and sternocostal parts: flexion; assist in respiration when shoulder is fixed
	② Sternocostal part	Sternum and costal cartilages 1–6			
	③ Abdominal part	Rectus sheath (anterior layer)			
④ Coracobrachialis		Scapula (coracoid process)	Humerus (in line with crest of lesser tuberosity)	Musculocutaneous n. (C6, C7)	Flexion, adduction, internal rotation

Fig. 19.26 Subclavius an pectoralis minor

Right side, anterior view.

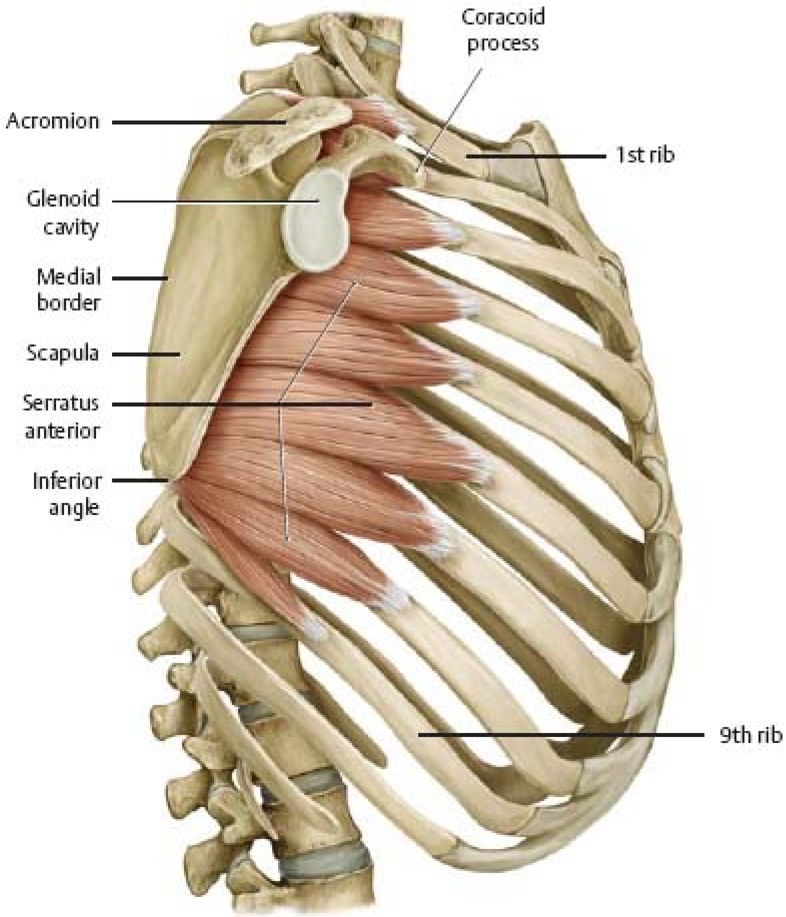


A Schematic.

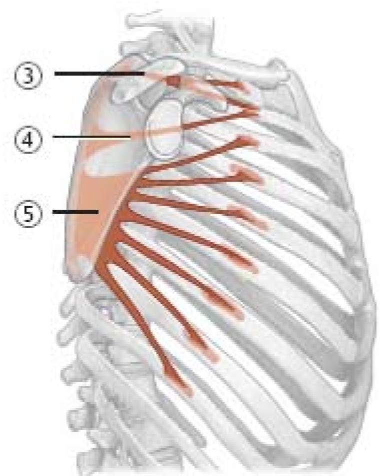


B Subclavius and pectoralis minor.

Fig. 19.27 **Serratus anterior**
Right lateral view.



A Serratus anterior.



B Schematic.

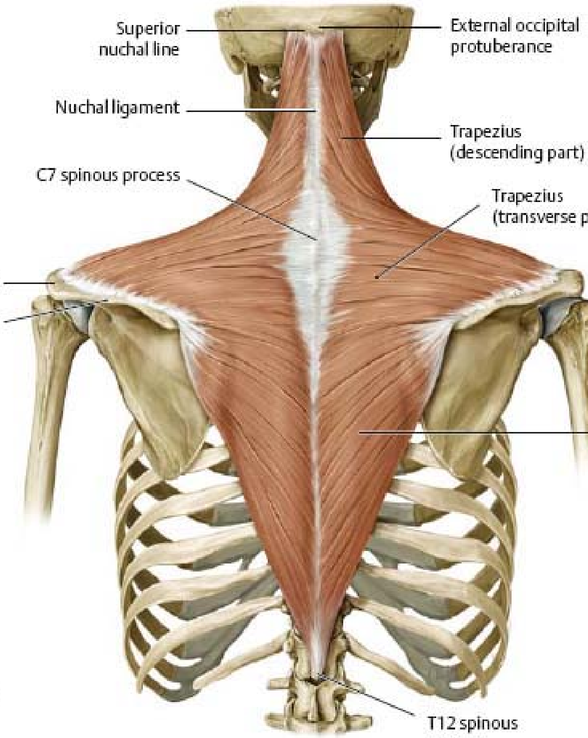
Table 19.4 Subclavius, pectoralis minor, and serratus anterior

Muscle		Origin	Insertion	Innervation	Action
① Subclavius		1st rib	Clavicle (inferior surface)	N. to subclavius (C5, C6)	Steadies the clavicle in the sternoclavicular joint
② Pectoralis minor		3rd to 5th ribs	Coracoid process	Medial and lateral pectoral nn. (C6–T1)	Draws scapula downward, causing inferior angle to move posteromedially; rotates glenoid inferiorly; assists in respiration
Serratus anterior	③ Superior part	1st to 9th ribs	Scapula (medial border)	Long thoracic n. (C5–C7)	Superior part: lowers the raised arm
	④ Intermediate part				Entire muscle: draws scapula laterally forward; elevates ribs when shoulder is fixed
	⑤ Inferior part				Inferior part: rotates scapula laterally

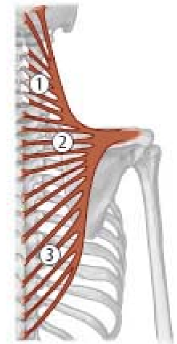
Muscle Facts (III)

Fig. 19.28 Trapezius

Posterior view.



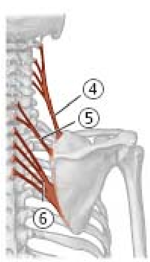
A Trapezius.



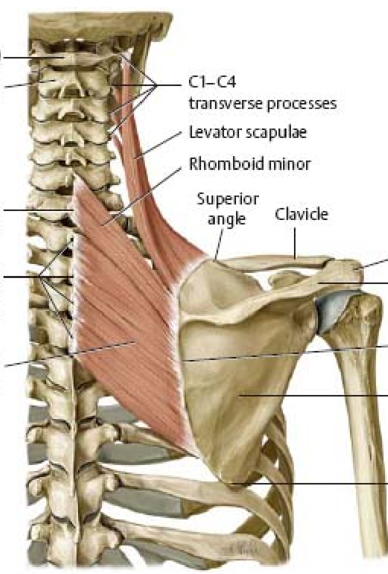
B Schematic.

Fig. 19.29 **Levator scapulae with rhomboids major and minor**

Right side, posterior view.



A Schematic.



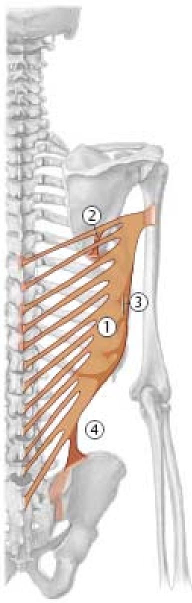
B Levator scapulae with rhomboids major and minor.

Table 19.5	Trapezius, levator scapulae, and rhomboids major and minor				
Muscle		**Origin**	**Insertion**	**Innervation**	**Action**
Trapezius	① Descending part	Occipital bone; spinous process of C1–C7	Clavicle (lateral one third)	Accessory n. (CN XI); cervical plexus (C3–C4)	Draws scapula obliquely upward; rotates glenoid cavity superiorly; tilts head to same side and rotates it to opposite
	② Transverse part	Aponeurosis at T1–T4 spinous processes	Acromion		Draws scapula medially
	③ Ascending part	Spinous process of T5–T12	Scapular spine		Draws scapula medially downward
					Entire muscle: steadies scapula on thorax
④ Levator scapulae		Transverse process of C1–C4	Scapula (superior angle)	Dorsal scapular n. (C4–C5)	Draws scapula medially upward while moving inferior angle medially; inclines neck to same side
⑤ Rhomboid minor		Spinous process of C6, C7	Medial border of scapula above (minor) and below (major) scapular spine		Steadies scapula; draws scapula medially upward
⑥ Rhomboid major		Spinous process of T1–T4 vertebrae			

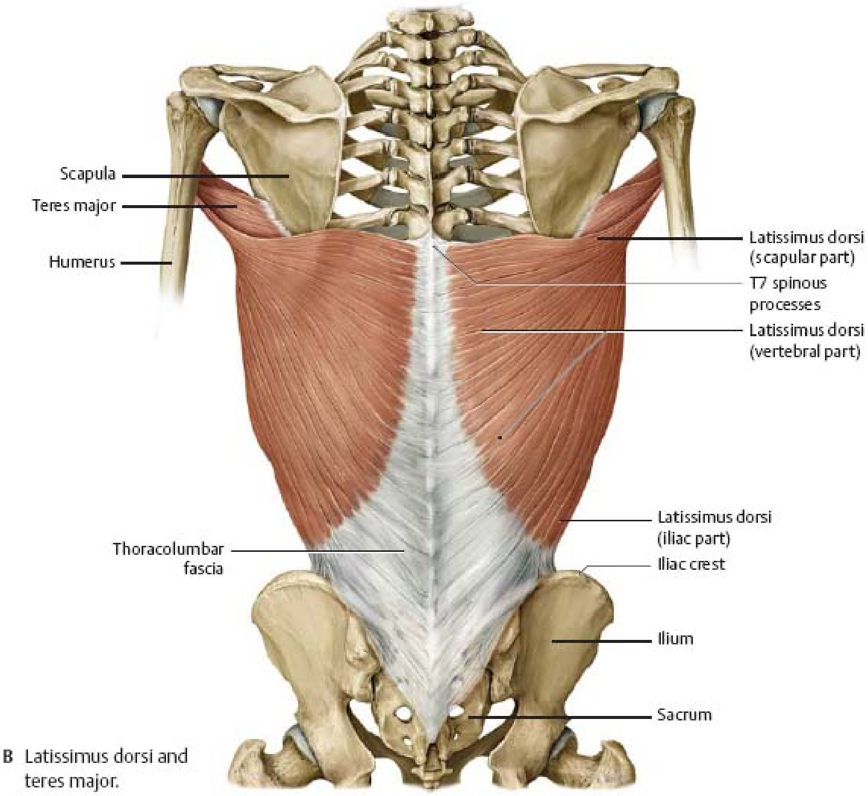
CN = cranial nerve.

Fig. 19.30 **Latissimus dorsi and teres major**

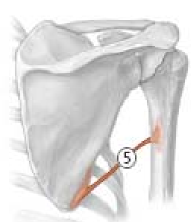
Posterior view.



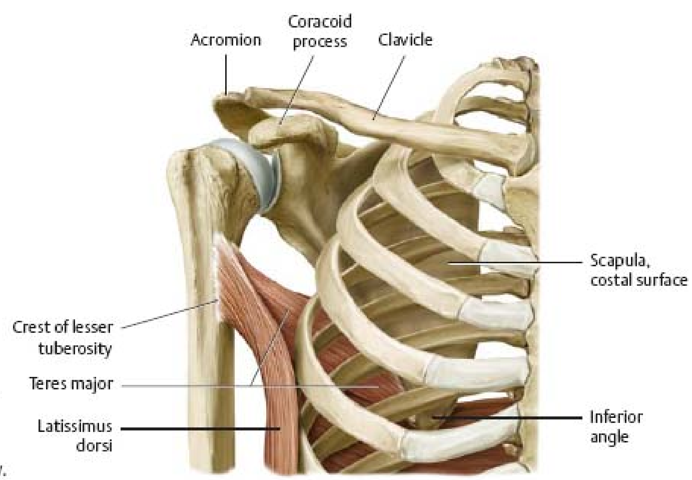
A Latissimus dorsi.



B Latissimus dorsi and teres major.



C Teres major.



D Common insertion of the latissimus dorsi and teres major, anterior view.

Table 19.6 Latissimus dorsi and teres major

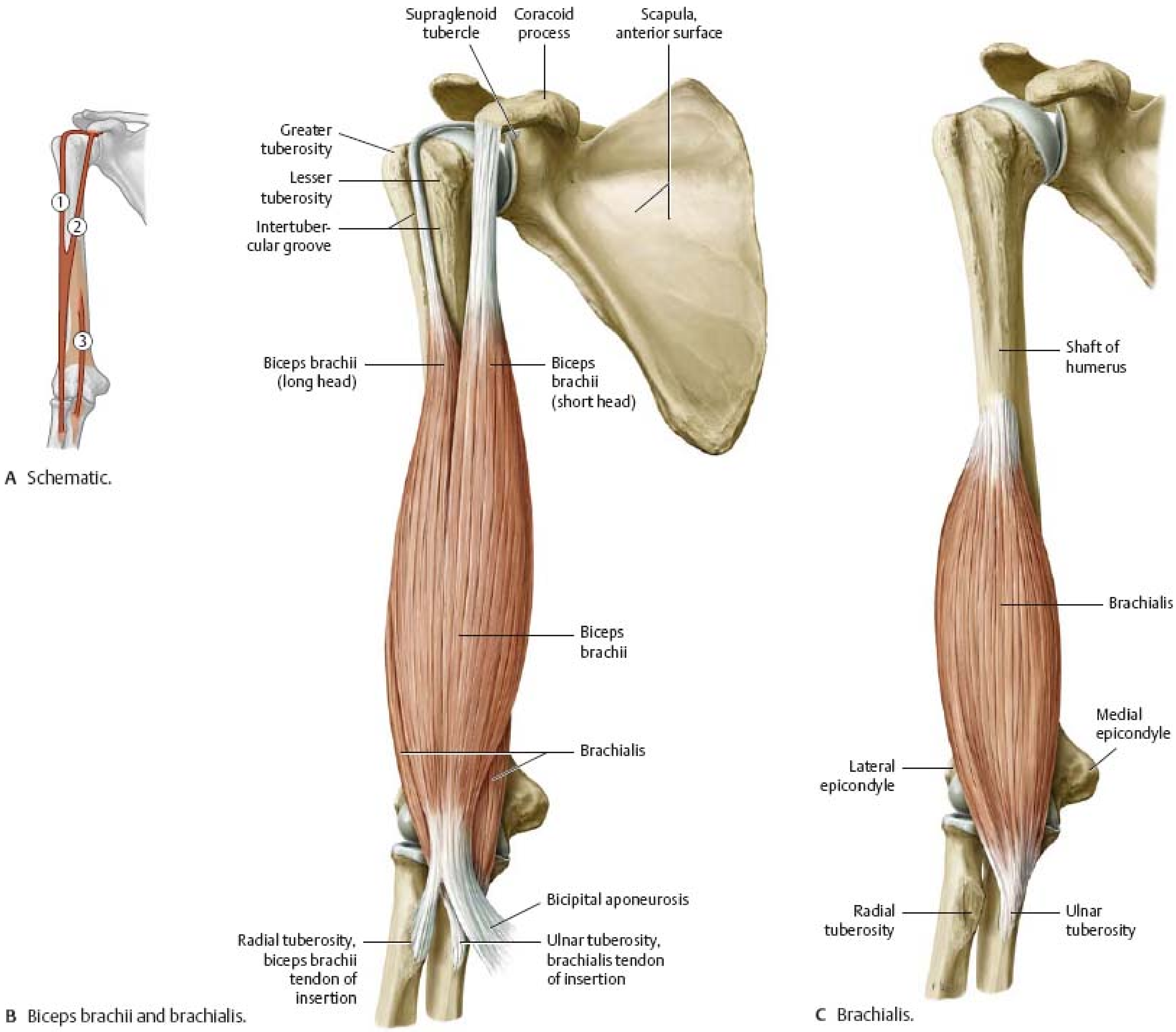
Muscle		Origin	Insertion	Innervation	Action
Latissimus dorsi	① Vertebral part	Spinous process of T7–T12 vertebrae; thoracolumbar fascia	Crest of lesser tuberosity of the humerus (anterior angle)	Thoracodorsal n. (C6–C8)	Internal rotation, adduction, extension, respiration ("cough muscle")
	② Scapular part	Scapula (inferior angle)			
	③ Costal part	9th to 12th ribs			
	④ Iliac part	Iliac crest (posterior one third)			
⑤ Teres major		Scapula (inferior angle)		Lower subscapular n. (C5–C7)	Internal rotation, adduction, extension

Muscle Facts (IV)

The anterior and posterior muscles of the arm may be classified respectively as flexors and extensors relative to the movement of the elbow joint. Although the coracobrachialis is topographically part of the anterior compartment, it is functionally grouped with the muscles of the shoulder (see p. 274).

Fig. 19.31 Biceps brachii and brachialis

Right arm, anterior view.



A Schematic.

B Biceps brachii and brachialis.

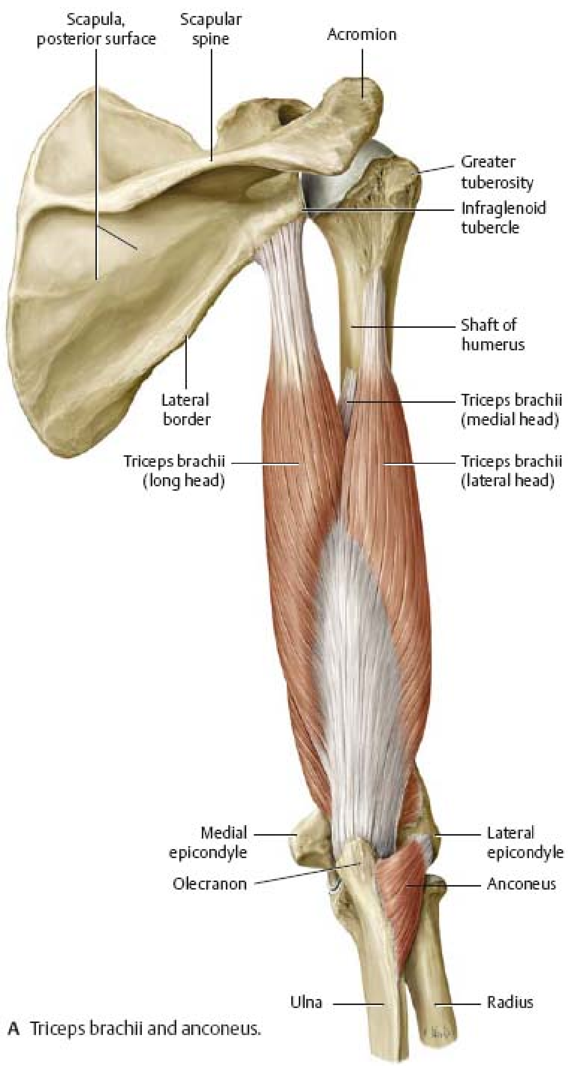
C Brachialis.

Table 19.7		Anterior group: Biceps brachii and brachialis			
Muscle		**Origin**	**Insertion**	**Innervation**	**Action**
Biceps brachii	① Long head	Supraglenoid tubercle of scapula	Radial tuberosity	Musculocutaneous n. (C5–C6)	Elbow joint: flexion; supination* Shoulder joint: flexion; stabilization of humeral head during deltoid contraction; abduction and internal rotation of the humerus
	② Short head	Coracoid process of scapula			
③ Brachialis		Humerus (distal half of anterior surface)	Ulnar tuberosity	Musculocutaneous n. (C5–C6) and radial n. (C7, minor)	Flexion at the elbow joint

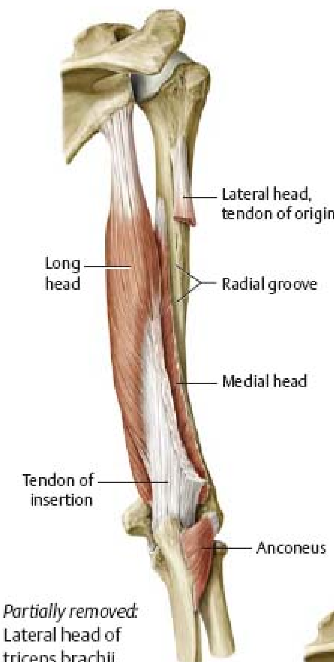
* *Note:* When the elbow is flexed, the biceps brachii acts as a powerful supinator because the lever arm is almost perpendicular to the axis of pronation/supination.

Fig. 19.32 Triceps brachii and anconeus

Right arm, posterior view.

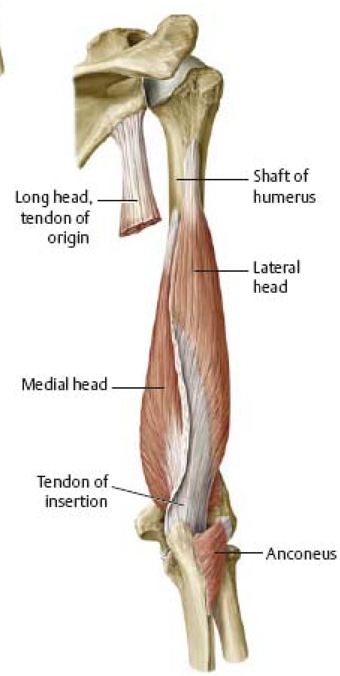


A Triceps brachii and anconeus.



B *Partially removed:* Lateral head of triceps brachii.

D Schematic.



C *Partially removed:* Long head of triceps brachii.

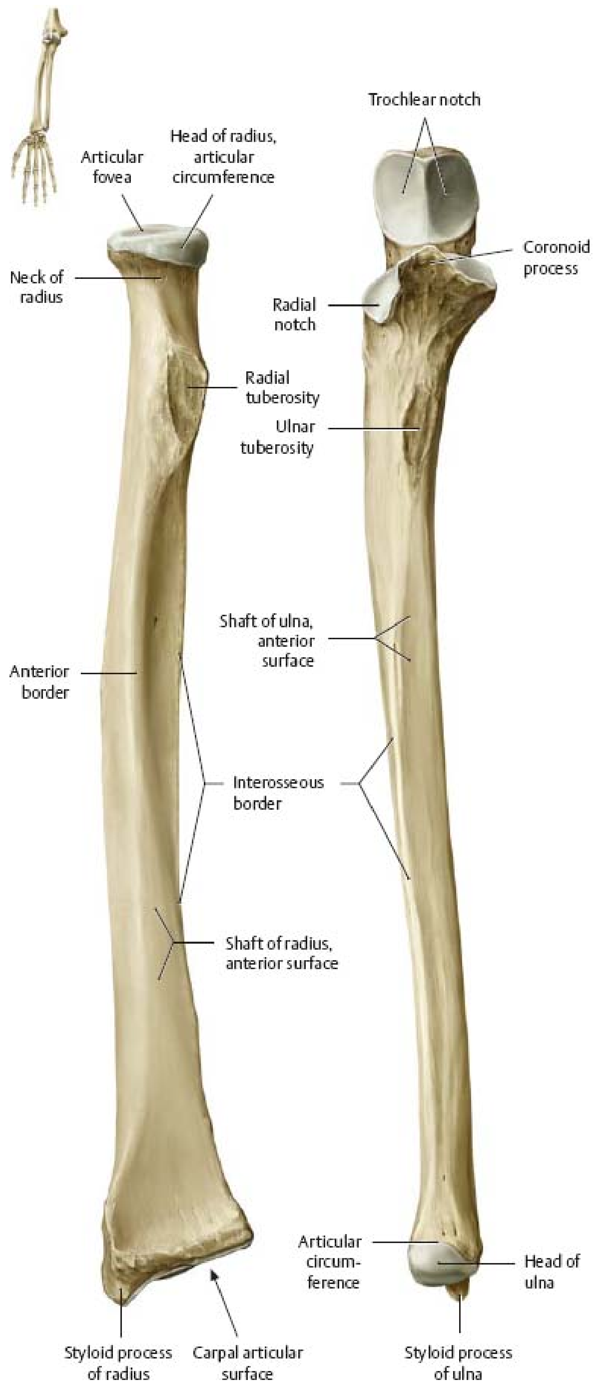
Table 19.8 Posterior group: Triceps brachii and anconeus

Muscle		Origin	Insertion	Innervation	Action
Triceps brachii	① Long head	Scapula (infraglenoid tubercle)	Olecranon of ulna	Radial n. (C6–C8)	Elbow joint: extension Shoulder joint, long head: extension and adduction
	② Medial head	Posterior humerus, distal to radial groove; medial intermuscular septum			
	③ Lateral head	Posterior humerus, proximal to radial groove; lateral intermuscular septum			
④ Anconeus		Lateral epicondyle of humerus (variance: posterior joint capsule)	Olecranon of ulna (radial surface)		Extends the elbow and tightens its joint

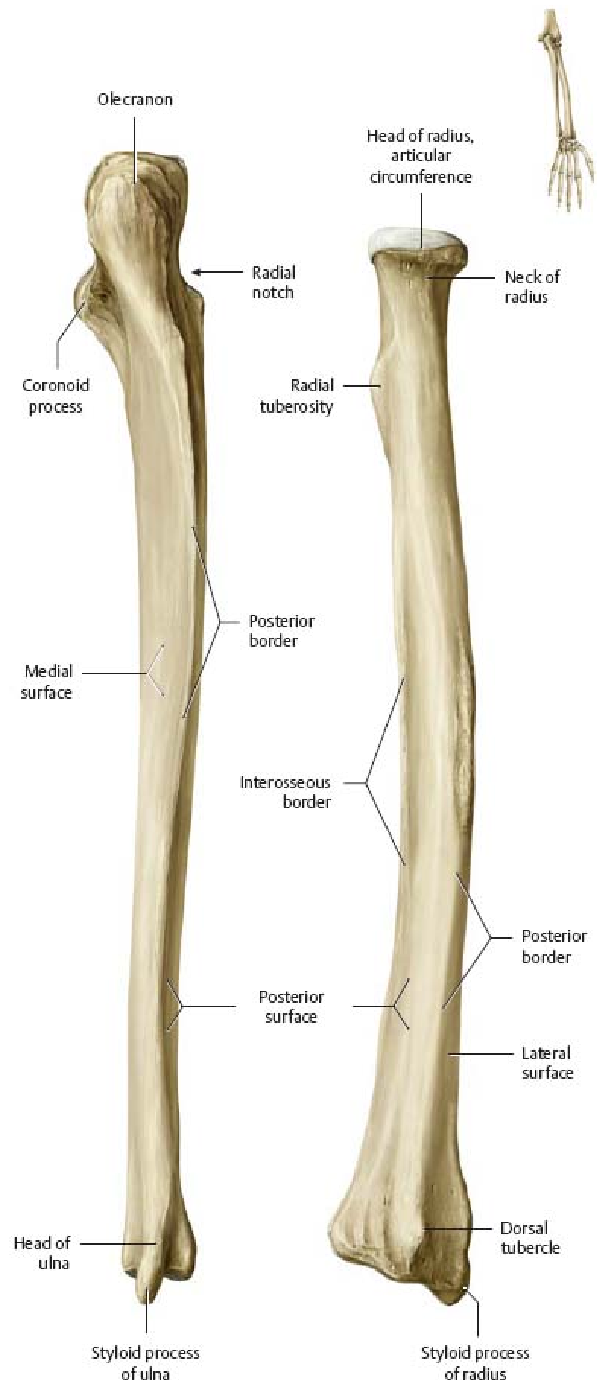
20 Elbow & Forearm

Radius & Ulna

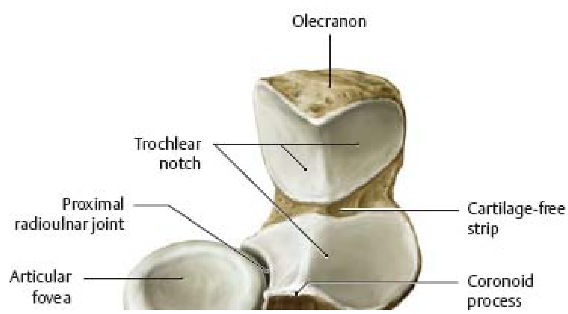
Fig. 20.1 **Radius and ulna**
Right forearm.

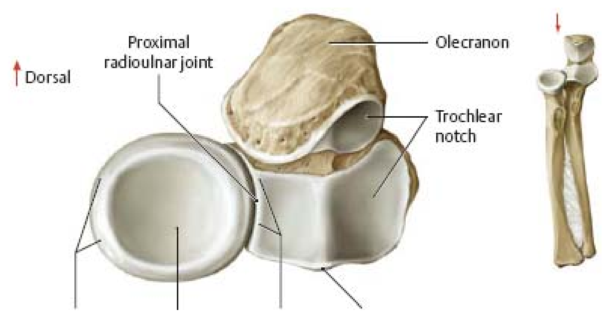


A Anterior view.



B Posterior view.

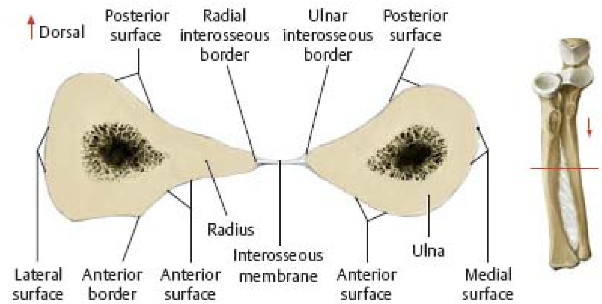




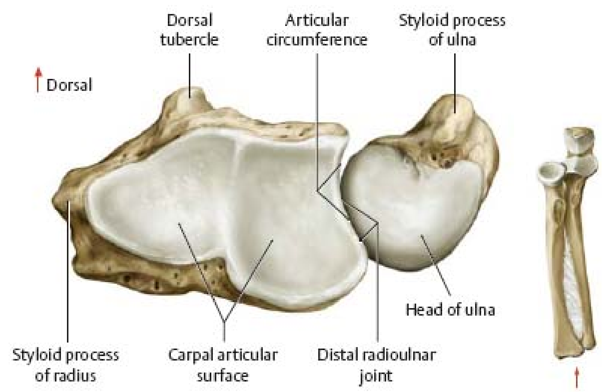
C Anterosuperior view.

Head of radius, articular circumference
Articular fovea
Radial notch
Coronoid process

D Proximal view.



E Transverse section, proximal view.

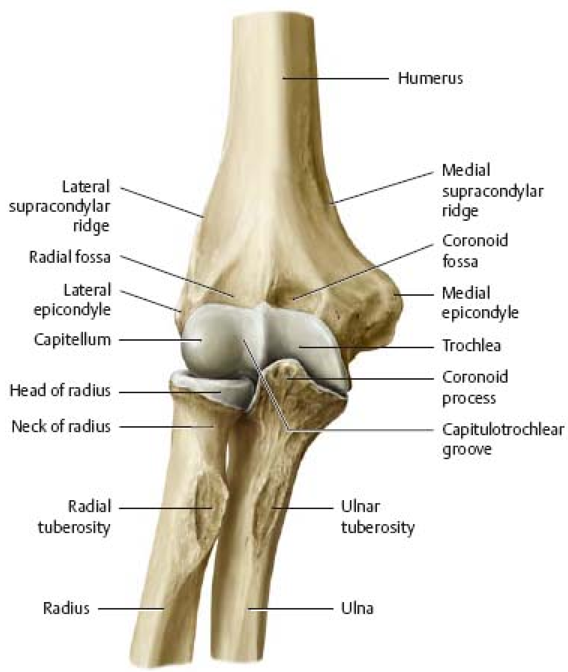


F Distal view.

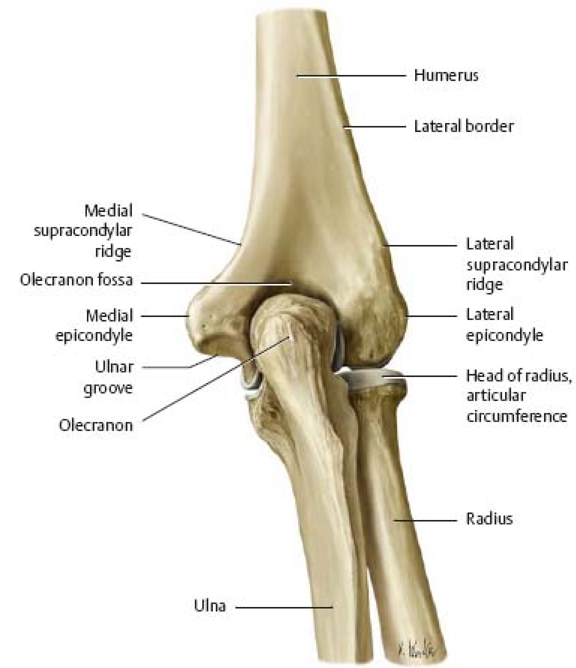
Elbow Joint

Fig. 20.2 Elbow (cubital) joint

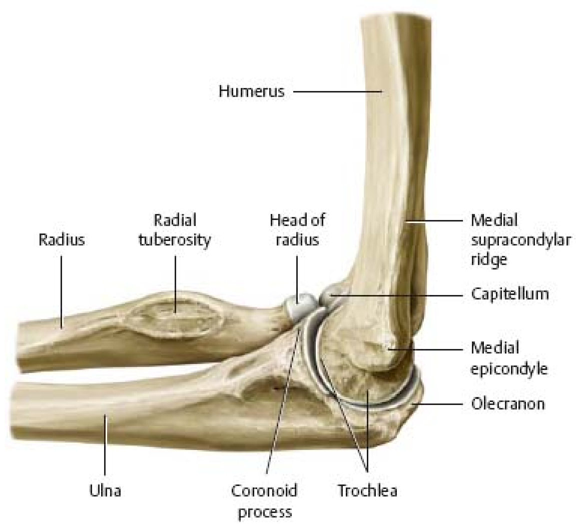
Right limb. The elbow consists of three articulations between the humerus, ulna, and radius: the humeroulnar, humeroradial, and proximal radioulnar joints.



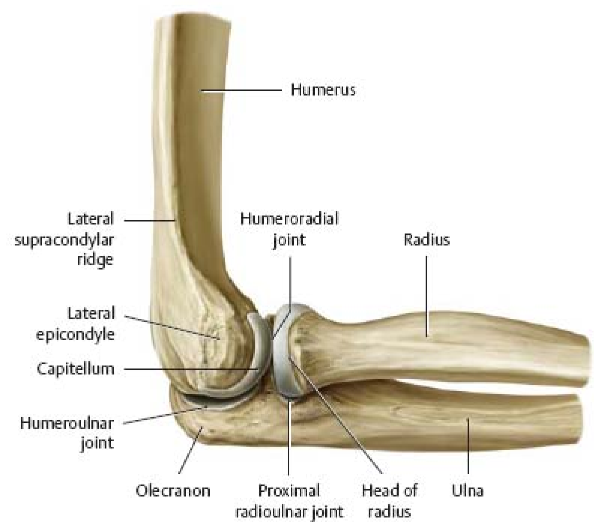
A Anterior view.



B Posterior view.



C Medial view.

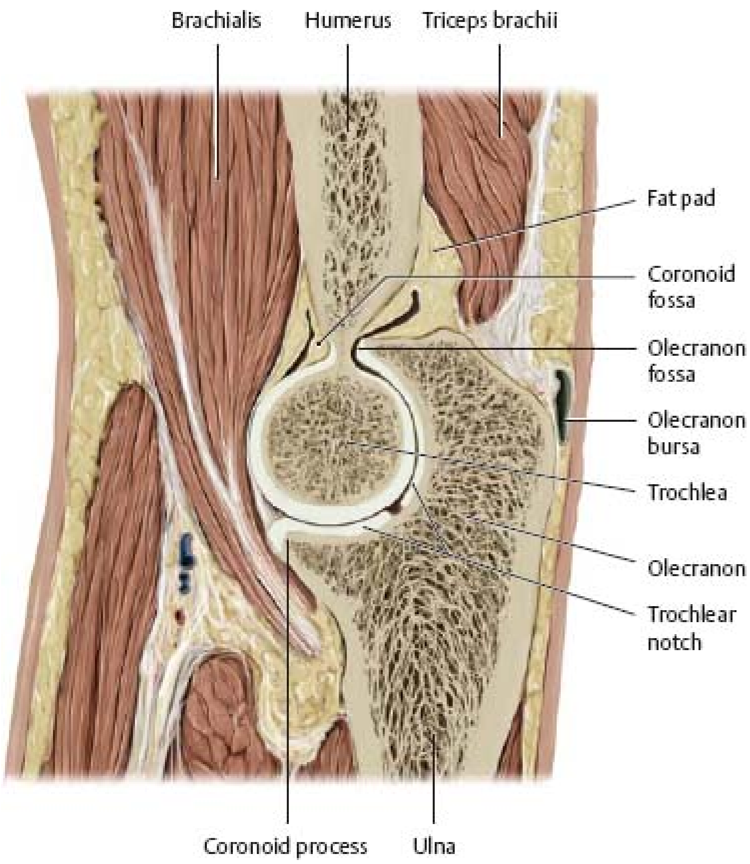


D Lateral view.

Fig. 20.3 **MRI of the elbow joint**

Sagittal section.

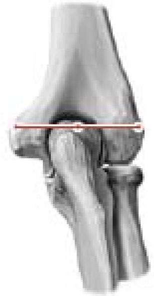
Fig. 20.4 **Humeroulnar joint**
Sagittal section through the humeroulnar joint, medial view.



Clinical

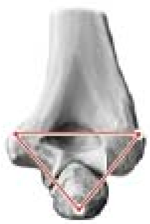
Assessing elbow injuries

The fat pads between the fibrous capsule and synovial membrane are part of the normal anatomy of the elbow joint. The anterior pad is most readily seen on a sagittal MRI while the posterior pad is often hidden within the bony fossa (Fig. 20.3). With an effusion of the joint space, the inferior edge of the anterior pad appears concave as it gets pushed superiorly by the intra-articular fluid. This causes the pad to resemble the shape of a ship's sail, thus creating a characteristic "sail sign." The alignment of the prominences in the elbow also aids in the identification of fractures and dislocations.



A Posterior view of extended elbow: The epicondyles and olecranon lie in a straight line.

B Lateral view of flexed elbow: The epicondyles and olecranon lie in a straight line.

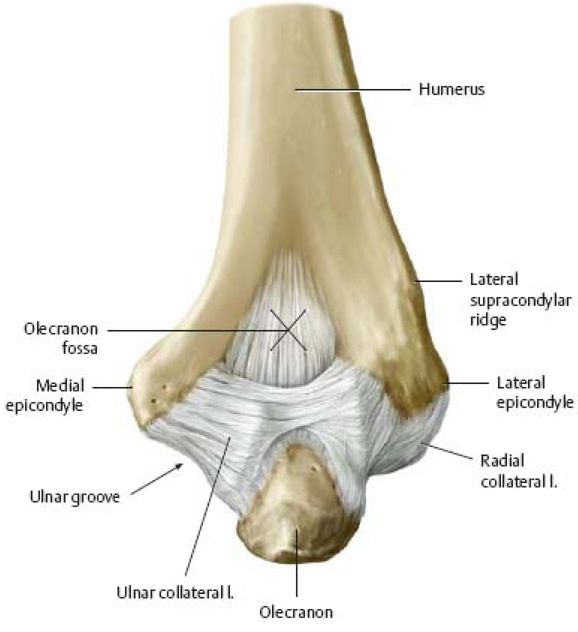


C Posterior view of flexed elbow: The two epicondyles and the tip of the olecranon form an equilateral triangle. Fractures and dislocations alter the shape of the triangle.

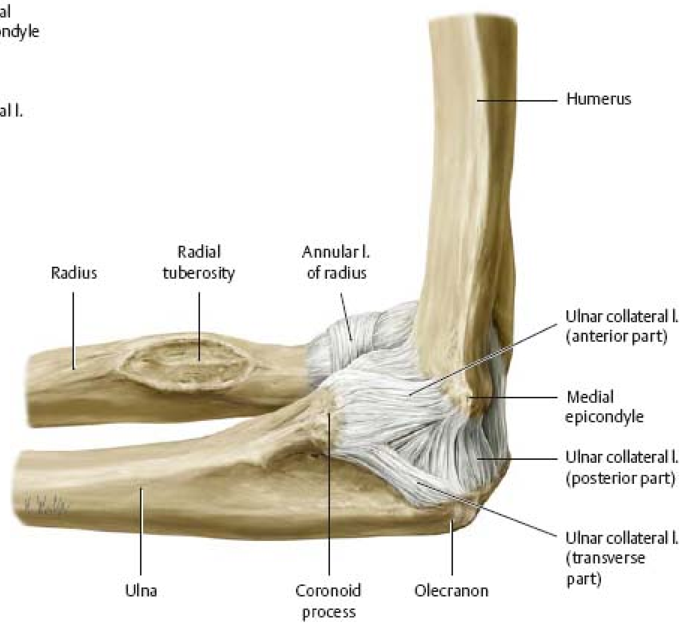
Ligaments of the Elbow Joint

Fig. 20.5 Ligments of the elbow joint

Right elbow in flexion.



A Posterior view.



B Medial view.

C Lateral view.

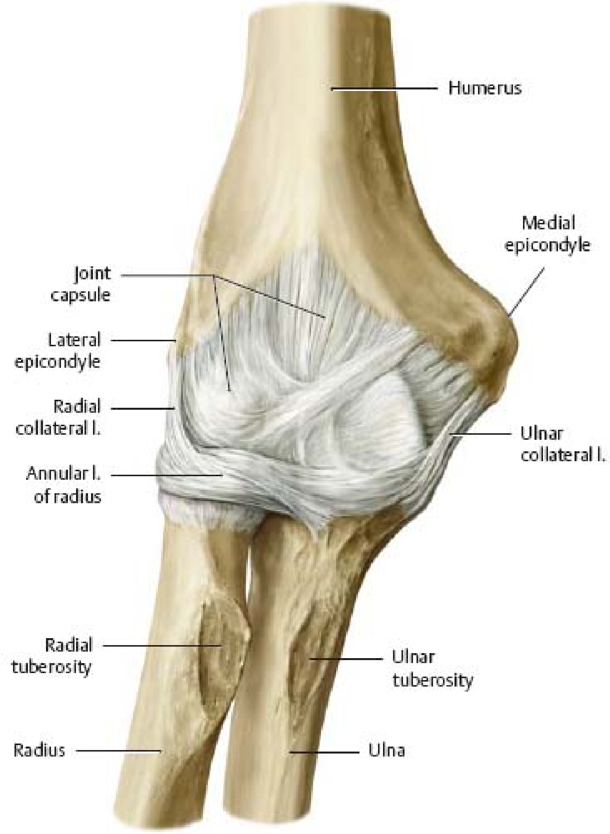
Table 20.1 **Joints and ligaments of the elbow**

Joint	Articulating surfaces	Ligament

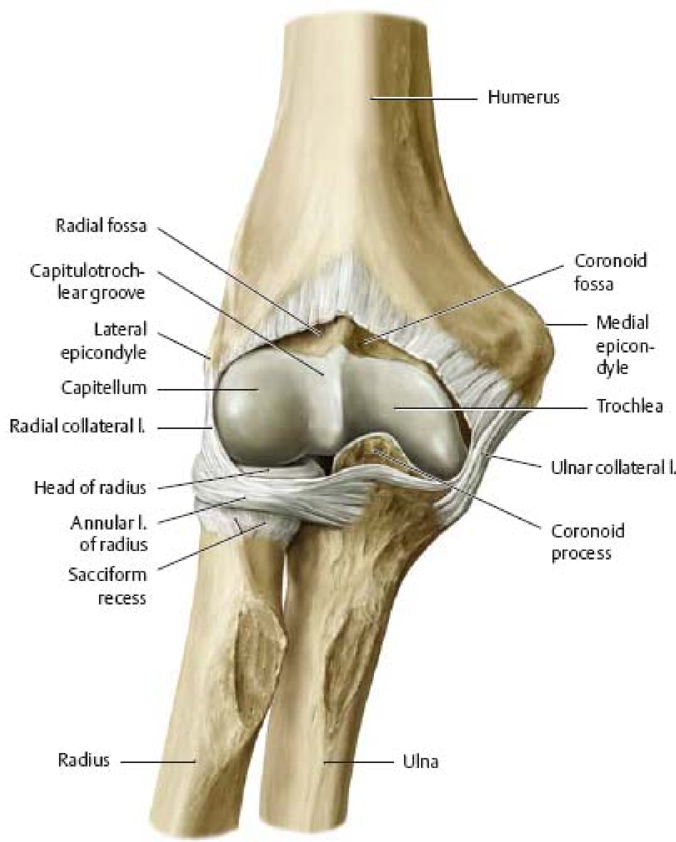
Joint	**Articulating surfaces**		**Ligament**
Humeroulnar joint	Trochlea	Ulna (trochlear notch)	Ulnar collateral l.
Humeroradial joint	Capitellum	Radius (articular fovea)	Radial collateral l.
Proximal radioulnar joint	Radius (articular circumference)	Ulna (radial notch)	Annular l.

Fig. 20.6 **Joint capsule of the elbow**

Right elbow in extension, anterior view.



A Intact joint capsule.



B Windowed joint capsule.

Radioulnar Joints

The proximal and distal radioulnar joints function together to enable pronation and supination movements of the hand. The joints are functionally linked by the interosseous membrane. The axis for pronation and supination runs obliquely from the center of the humeral capitellum through the center of the radial articular fovea down to the styloid process of the ulna.

Fig. 20.7 **Supination**

Right forearm, anterior view.

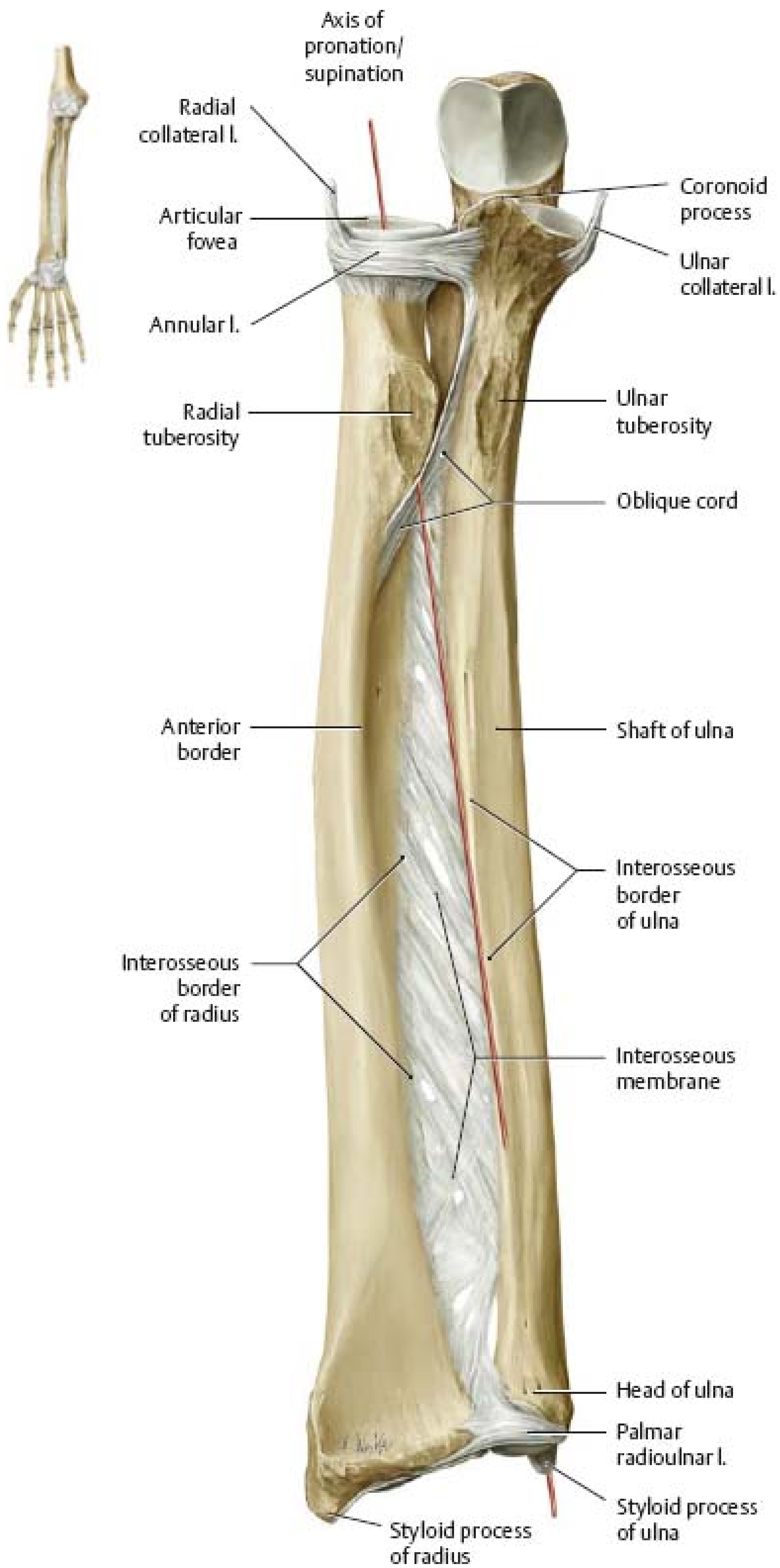
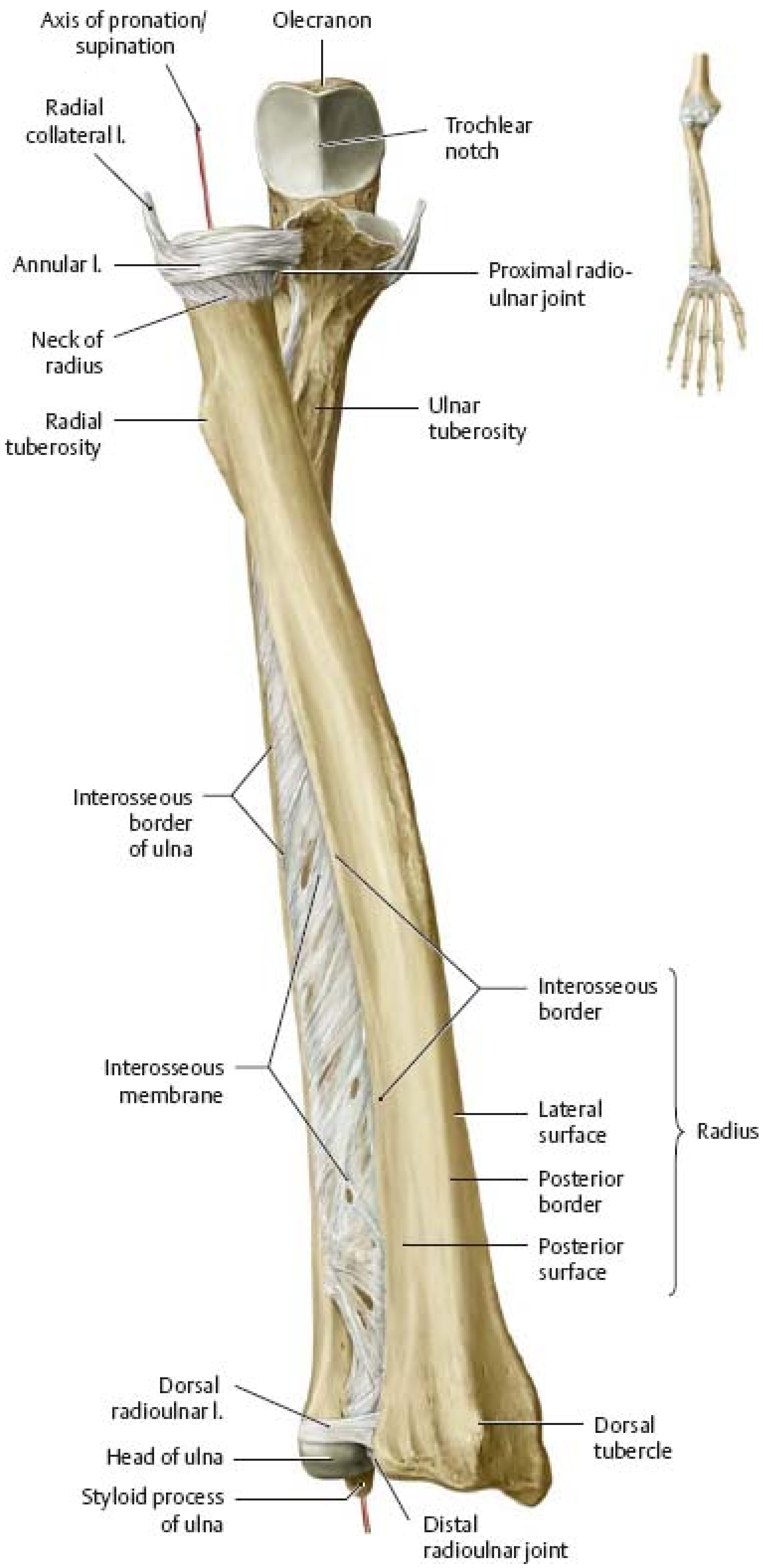


Fig. 20.8 **Pronation**

Right forearm, anterior view.

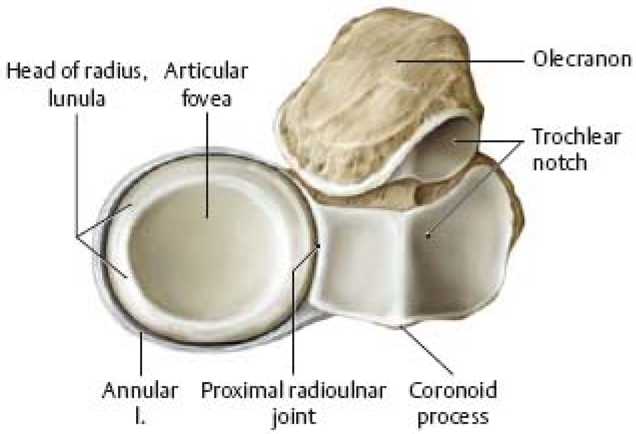

Axis of pronation/ supination
Olecranon
Radial collateral l.
Trochlear notch
Annular l.
Proximal radio-ulnar joint
Neck of radius
Radial tuberosity
Ulnar tuberosity
Interosseous border of ulna
Interosseous border
Interosseous membrane
Lateral surface
Radius
Posterior border
Posterior surface
Dorsal radioulnar l.
Dorsal tubercle
Head of ulna
Styloid process of ulna
Distal radioulnar joint

Clinical

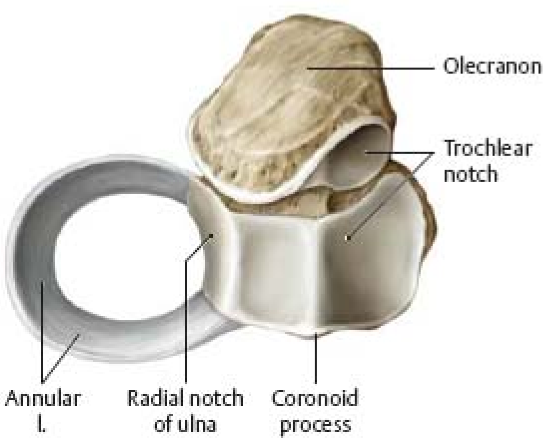
Subluxation of the radial head ("nursemaid's elbow")
When small children are abruptly pulled up by their arm, the immature head of the radius can dislocate from the annular ligament, resulting in painful pronation.

Fig. 20.9 Proximal radioulnar joint

Right elbow, proximal (superior) view.



A Proximal articular surfaces of radius and ulna.



B Radius removed.

Clinical

Radius fracture
Falls onto the outstretched arm often result in fractures of the distal radius. In a "Colles' fracture," the distal fragment is tilted dorsally.

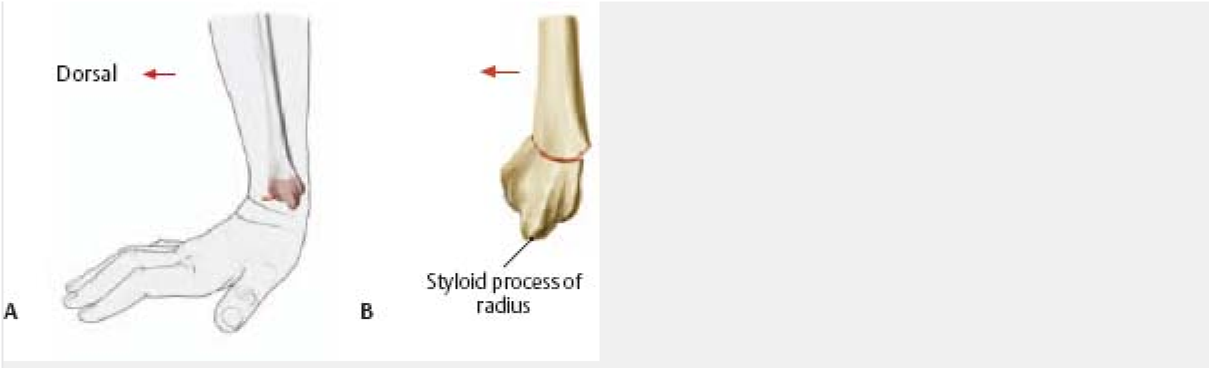
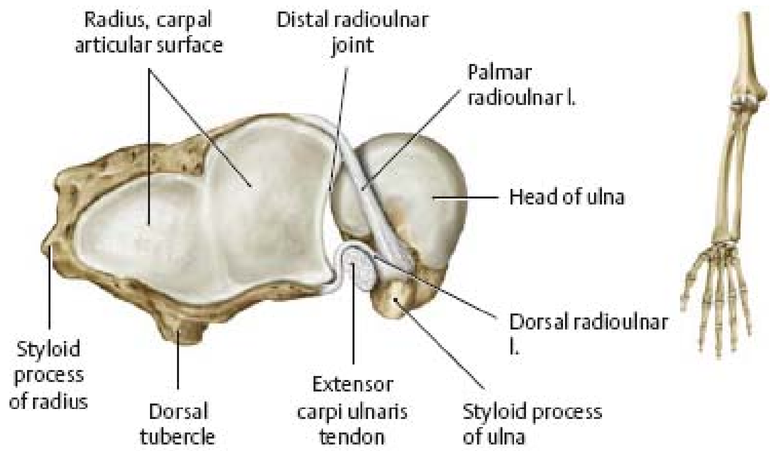
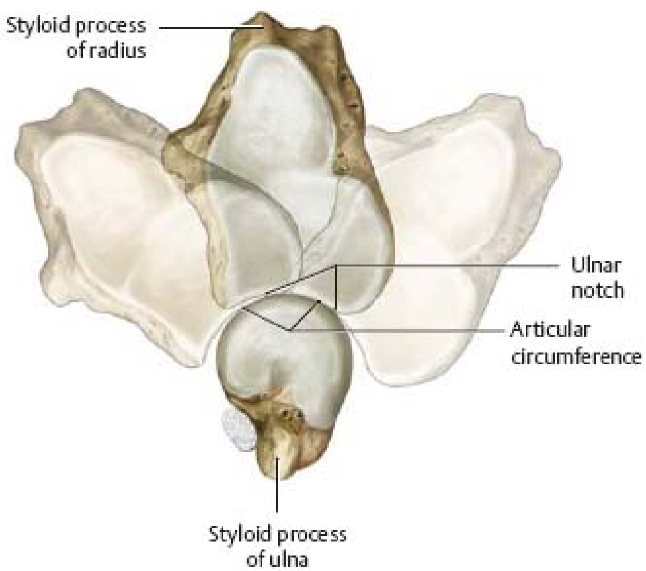


Fig. 20.10 **Distal radioulnar joint rotation**

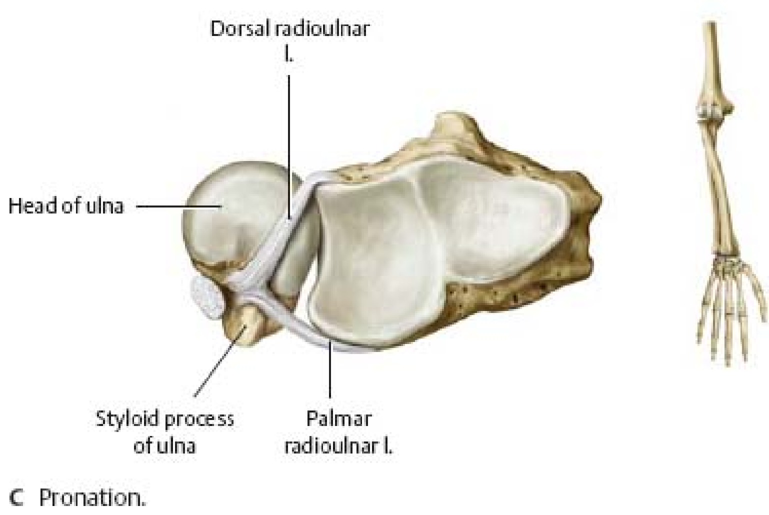
Right forearm, distal view of articular surfaces of radius and ulna. The dorsal and palmar radioulnar ligaments stabilize the distal radioulnar joint.



A Supination.



B Semipronation.

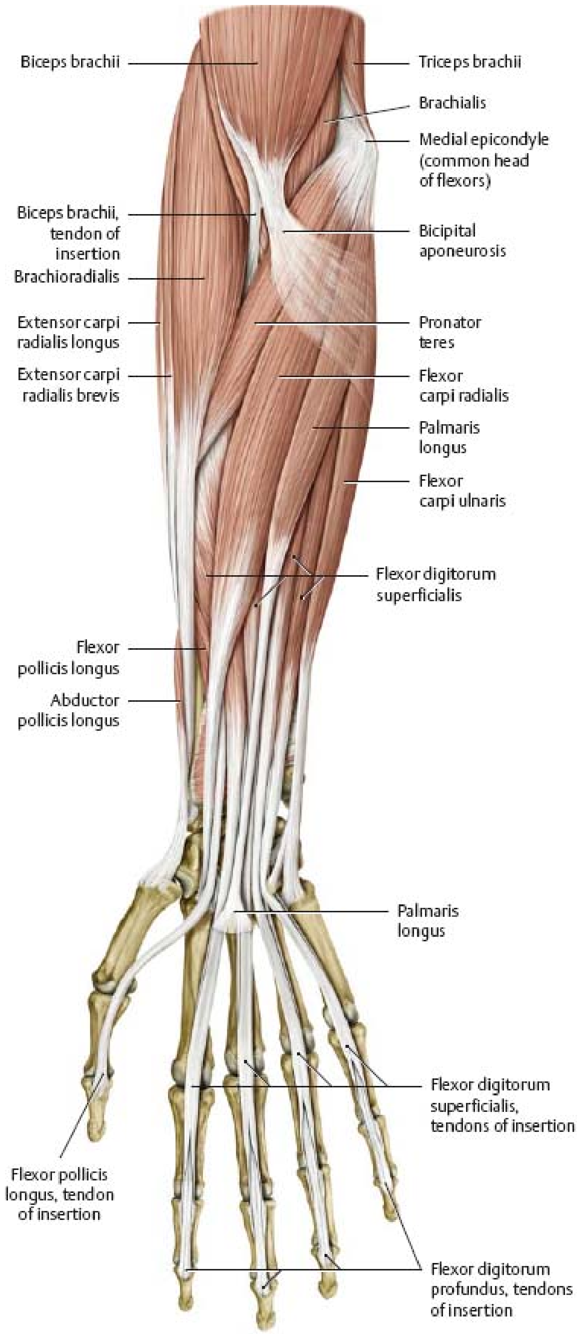


C Pronation.

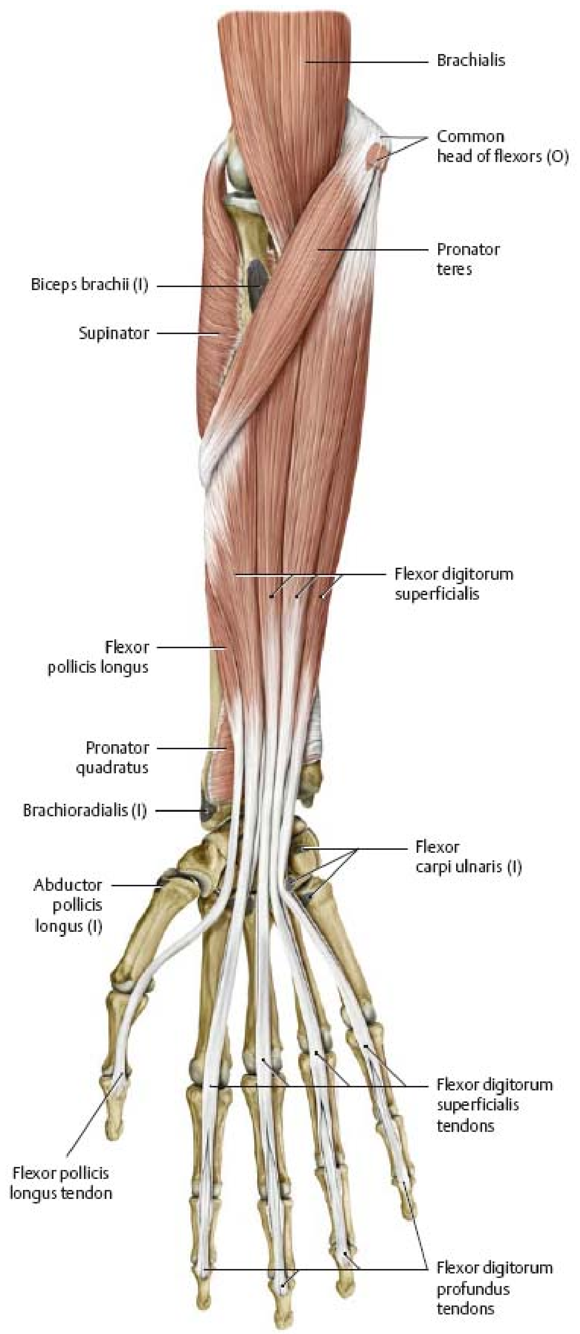
Muscles of the Forearm (I)

Fig. 20.11 Anterior muscles

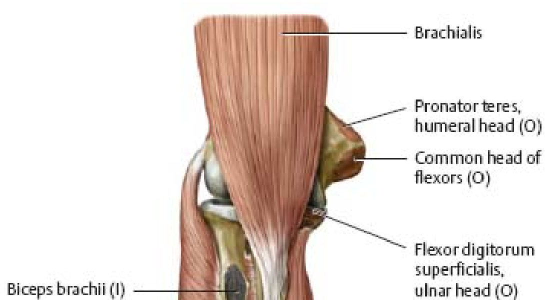
Right forearm, anterior view. Muscle origins (O) are shown in red, insertions (I) in blue.

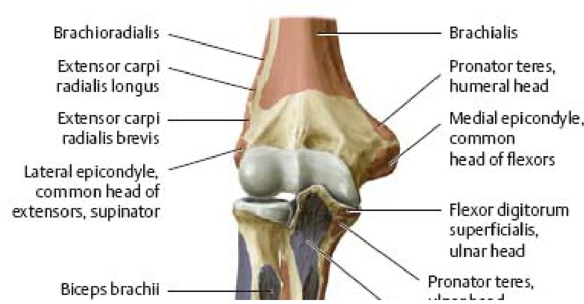


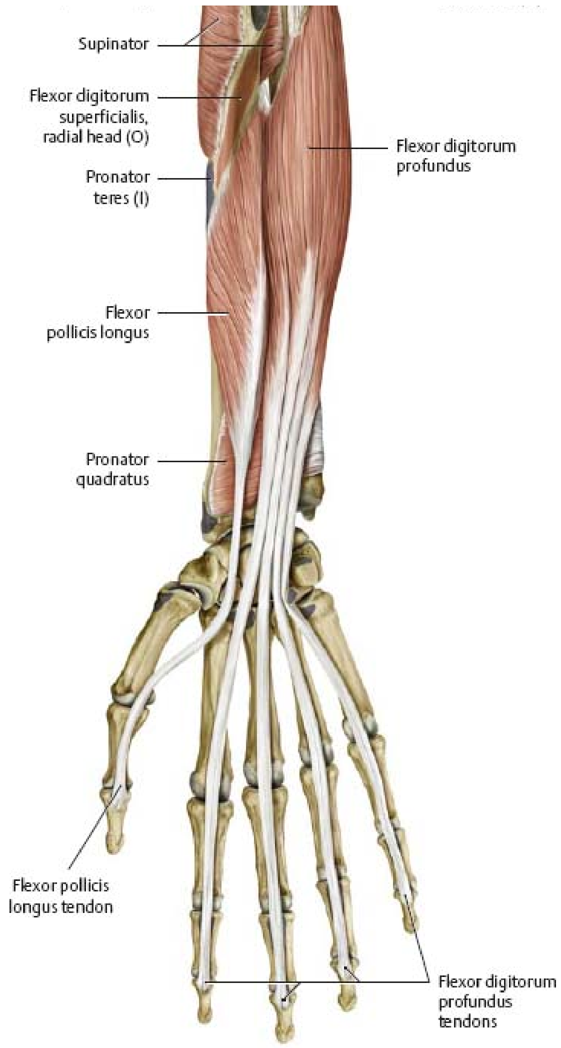
A Superficial flexors and radialis group.



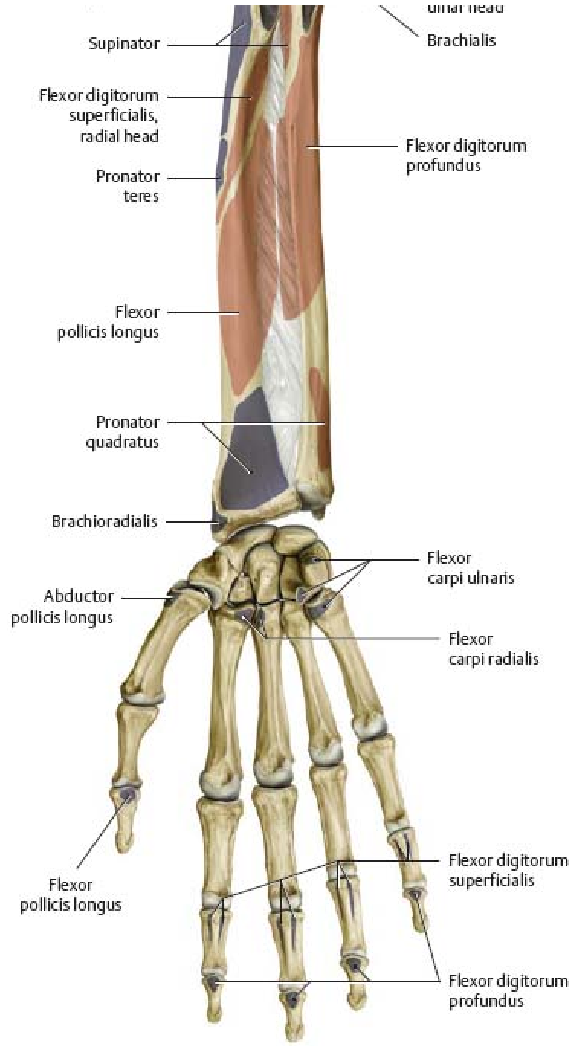
B *Removed:* Radialis group (brachioradialis, extensor carpi radialis longus, and extensor carpi radialis brevis), flexor carpi radialis, flexor carpi ulnaris, abductor pollicis longus, palmaris longus, and biceps brachii.







C *Removed:* Pronator teres and flexor digitorum superficialis.

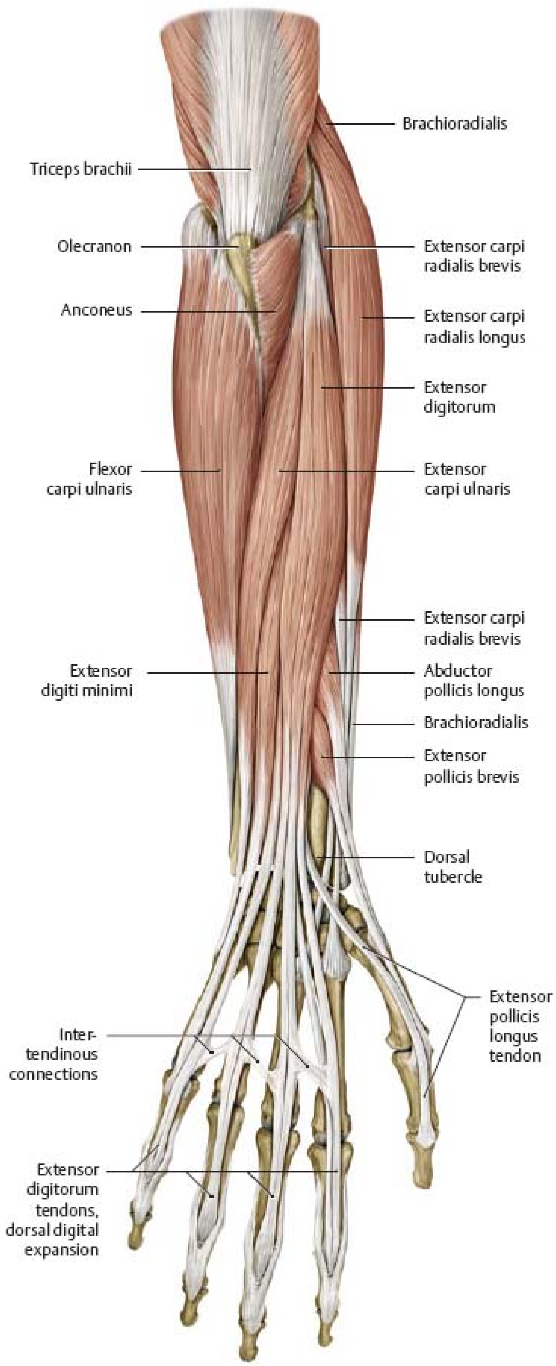


D *Removed:* Brachialis, supinator, pronator quadratus, and deep flexors.

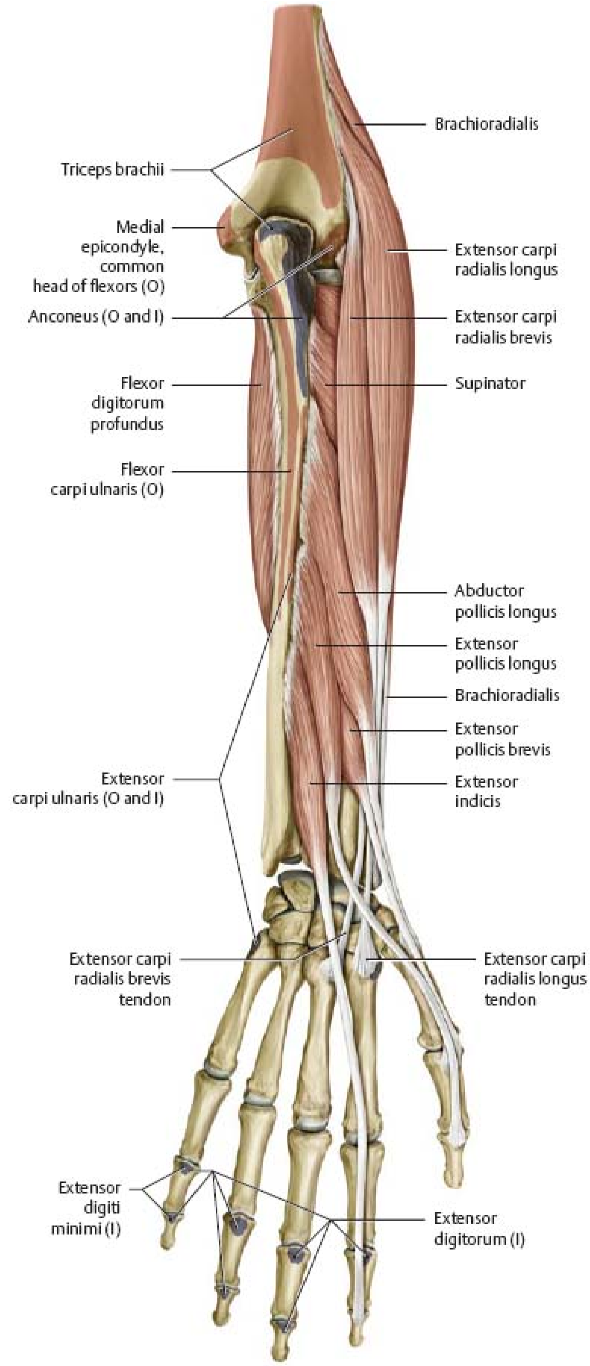
Muscles of the Forearm (II)

Fig. 20.12 Posterior muscles

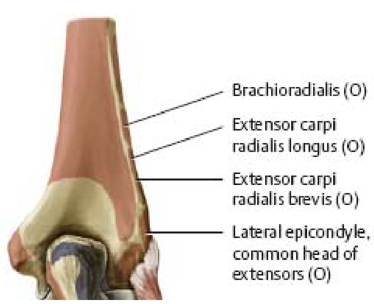
Right forearm, posterior view. Muscle origins (O) are shown in red, insertions (I) in blue.

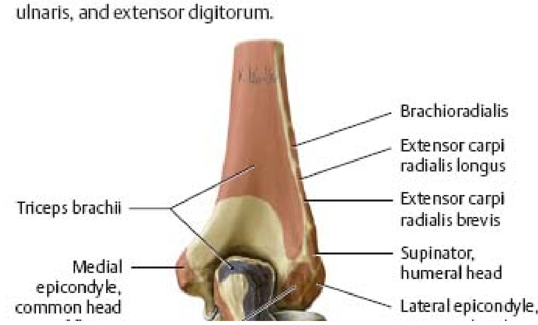


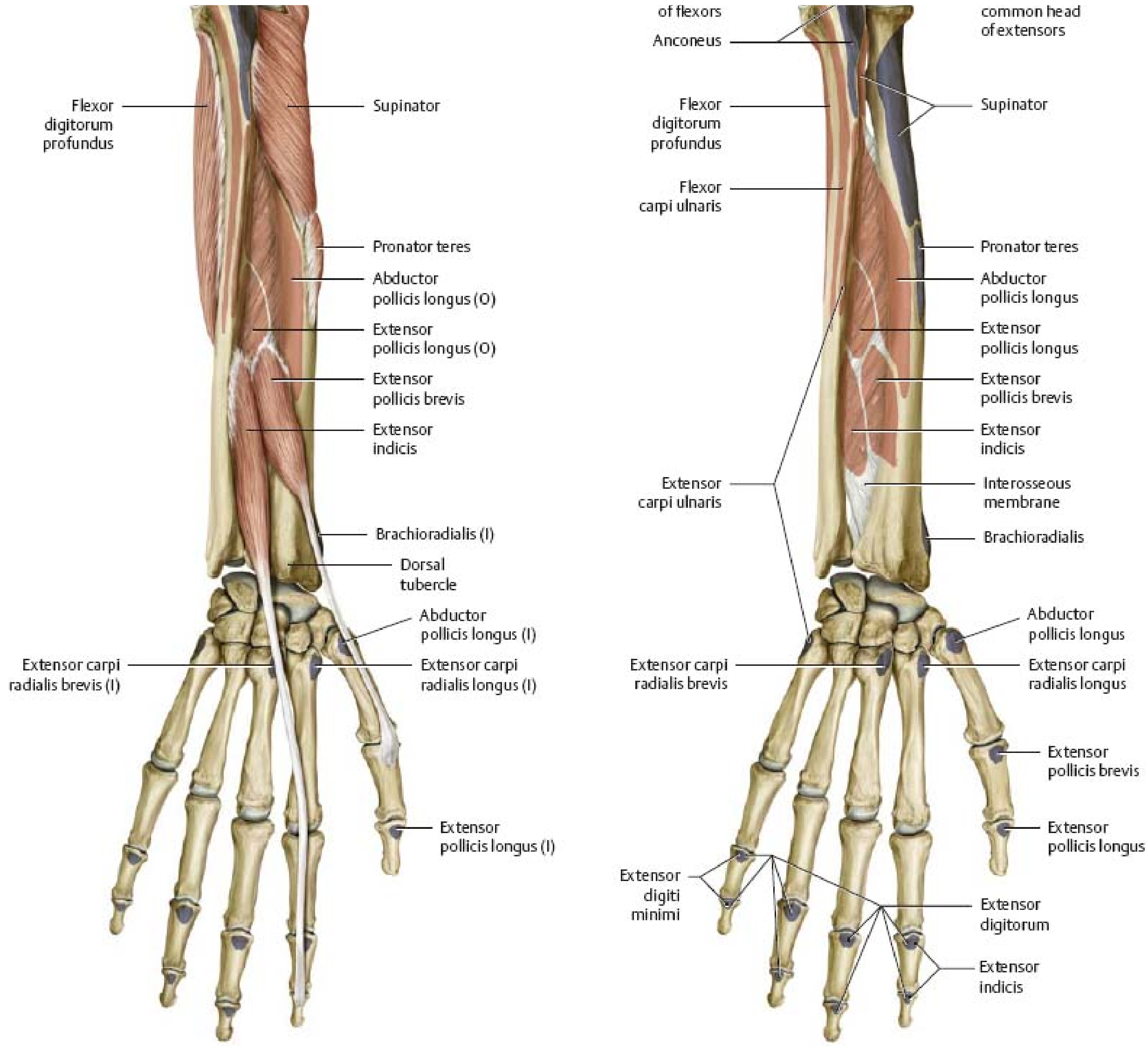
A Superficial extensors and radialis group.



B *Removed:* Triceps brachii, anconeus, flexor carpi ulnaris, extensor carpi ulnaris, and extensor digitorum.







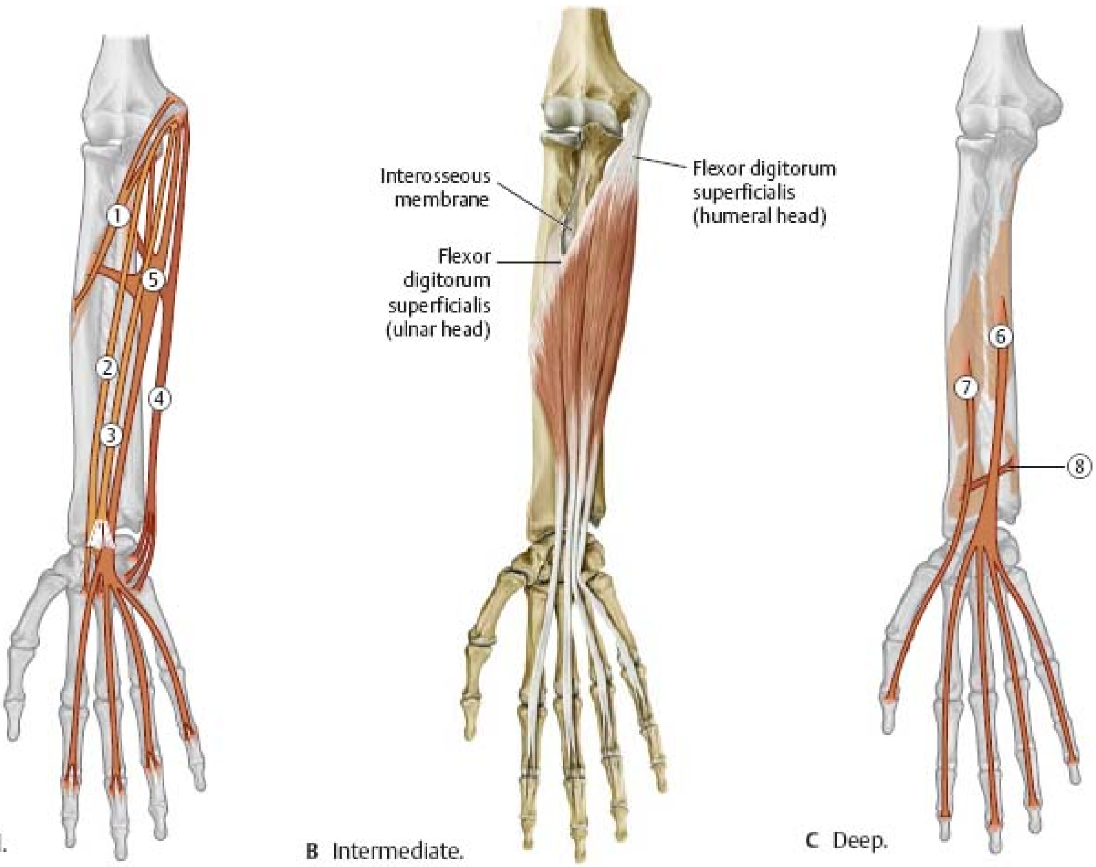
C *Removed:* Abductor pollicis longus, extensor pollicis longus, and radialis group.

D *Removed:* Flexor digitorum profundus, supinator, extensor pollicis brevis, and extensor indicis.

Muscle Facts (I)

Fig. 20.13 Anterior compartment

Right forearm, anterior view.



A Superficial. **B** Intermediate. **C** Deep.

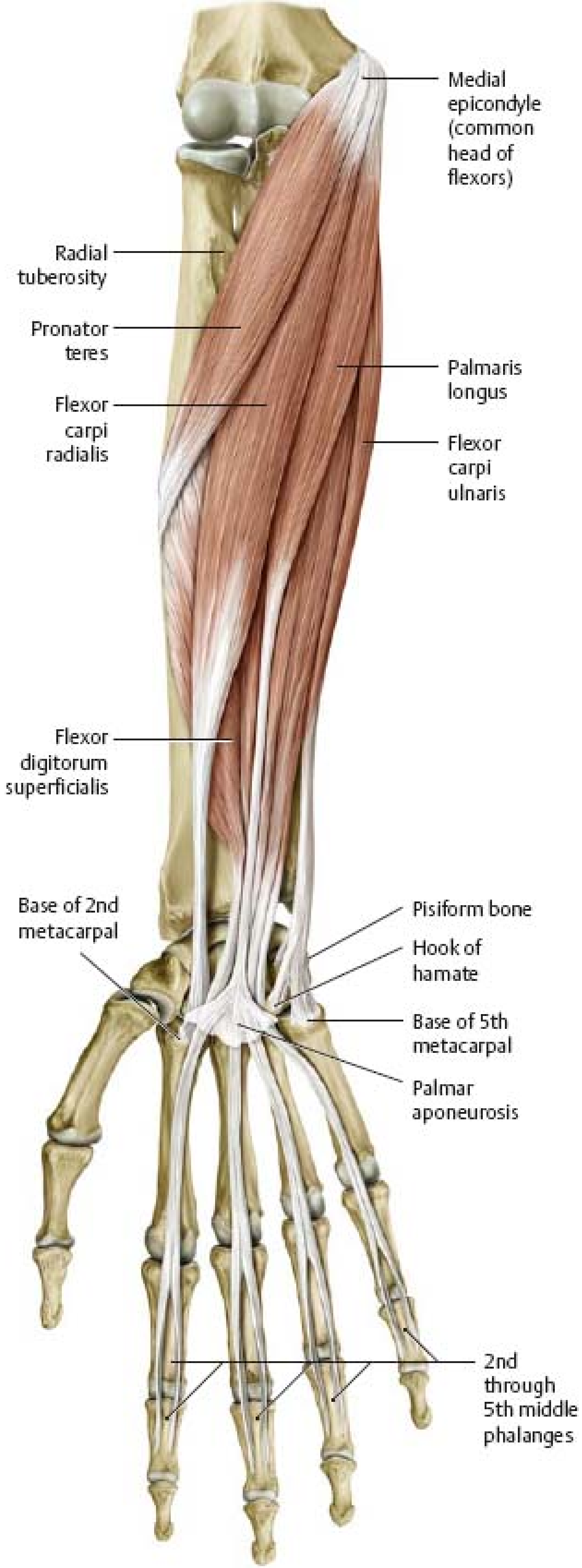
Table 20.2 Anterior compartment of the forearm

Muscle	Origin	Insertion	Innervation	Action
Superficial group				
① Pronator teres	Humeral head: medial epicondyle of humerus Ulnar head: coronoid process	Lateral radius (distal to supinator insertion)	Median n. (C6, C7)	Elbow: weak flexor Forearm: pronation
② Flexor carpi radialis	Medial epicondyle of humerus	Base of 2nd metacarpal (variance: base of 3rd metacarpal)		Wrist: flexion and abduction (radial deviation) of hand
③ Palmaris longus		Palmar aponeurosis	Median n. (C7, C8)	Elbow: weak flexion Wrist: flexion tightens palmar aponeurosis
④ Flexor carpi ulnaris	Humeral head: medial epicondyle Ulnar head: olecranon	Pisiform; hook of hamate; base of 5th metacarpal	Ulnar n. (C7–T1)	Wrist: flexion and adduction (ulnar deviation) of hand
Intermediate group				
⑤ Flexor digitorum superficialis	Humeral head: medial epicondyle Ulnar head: coronoid process	Sides of middle phalanges of 2nd to 5th digits	Median n. (C8, T1)	Elbow: weak flexor Wrist, MCP, and PIP joints of 2nd to 5th digits: flexion
Deep group				
⑥ Flexor digitorum profundis	Ulna (two thirds of flexor surface) and interosseous membrane	Distal phalanges of 2nd to 5th digits (palmar surface)	Median n. (C8, T1) Ulnar n. (C8, T1)	Wrist, MCP, PIP, and DIP of 2nd to 5th digits: flexion
⑦ Flexor pollicis longus	Radius (midanterior surface) and adjacent interosseous membrane	Distal phalanx of thumb (palmar surface)	Median n. (C7, C8)	Wrist: flexion and abduction (radial deviation) of hand Carpometacarpal of thumb: flexion MCP and IP of thumb: flexion
⑧ Pronator quadratus	Distal quarter of ulna (anterior surface)	Distal quarter of radius (anterior surface)		Hand: pronation Distal radioulnar joint: stabilization

DIP = distal interphalangeal; IP = interphalangeal; MCP = metacarpophalangeal; PIP = proximal interphalangeal.

Fig. 20.14 **Superficial and intermediate groups**

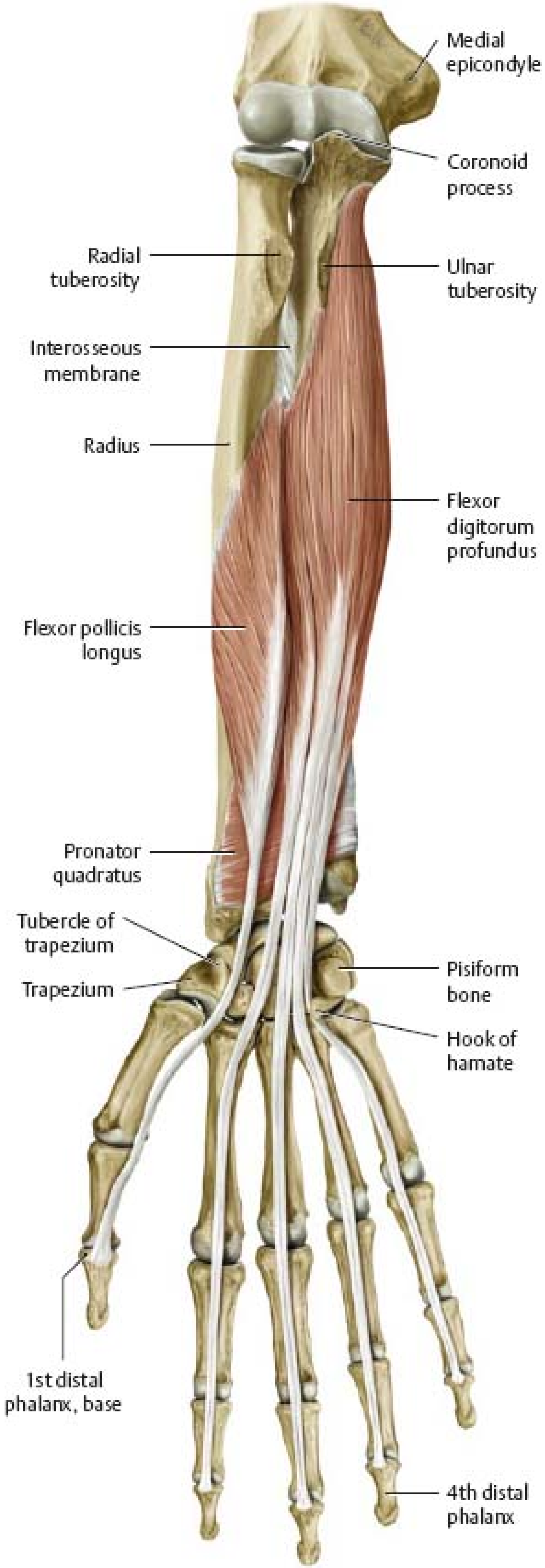
Right forearm, anterior view.



Medial epicondyle (common head of flexors)
Radial tuberosity
Pronator teres
Palmaris longus
Flexor carpi radialis
Flexor carpi ulnaris
Flexor digitorum superficialis
Base of 2nd metacarpal
Pisiform bone
Hook of hamate
Base of 5th metacarpal
Palmar aponeurosis
2nd through 5th middle phalanges

Fig. 20.15 **Deep group**

Right forearm, anterior view.


Medial epicondyle
Coronoid process
Radial tuberosity
Ulnar tuberosity
Interosseous membrane
Radius
Flexor digitorum profundus
Flexor pollicis longus
Pronator quadratus
Tubercle of trapezium
Trapezium
Pisiform bone
Hook of hamate
1st distal phalanx, base
4th distal phalanx

Muscle Facts (II)

Fig. 20.16 Radialis group

Right forearm, posterior view.

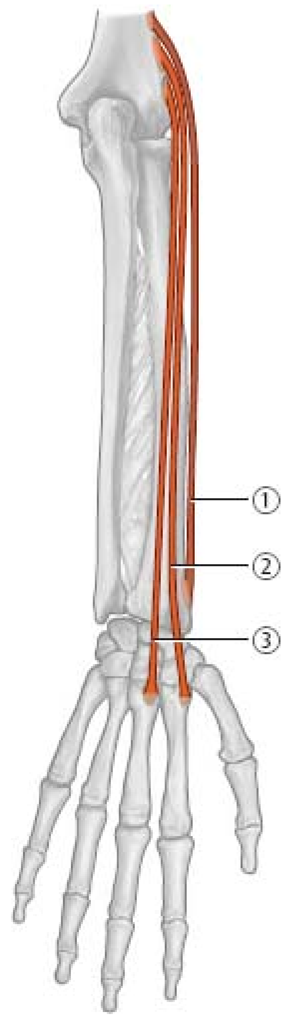


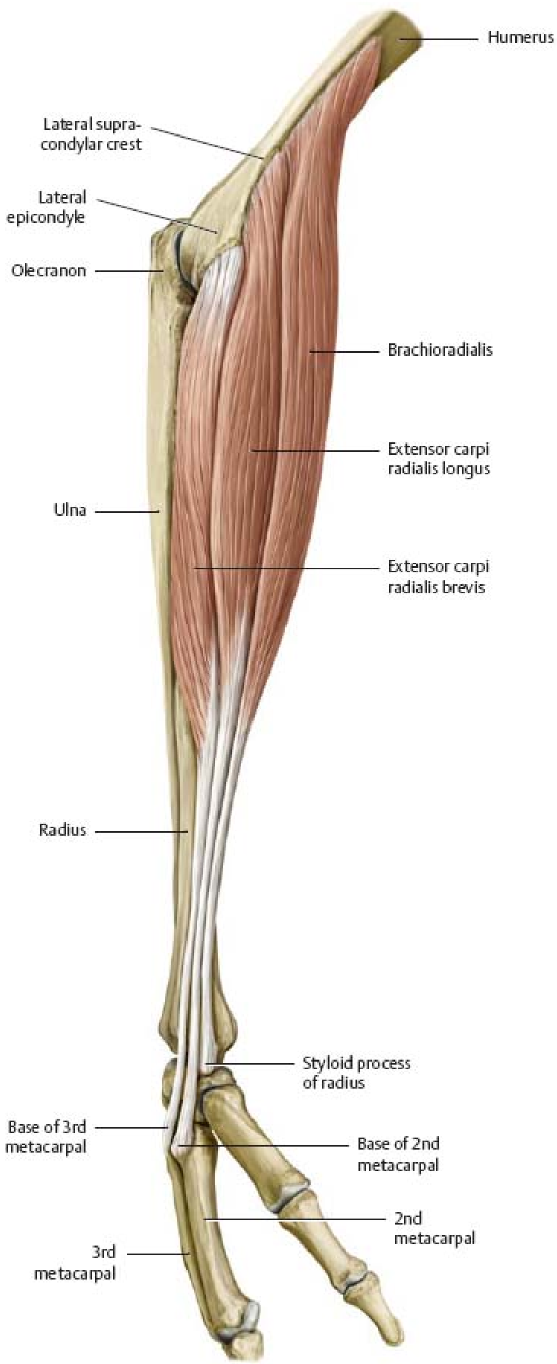
Table 20.3 **Posterior compartment of the forearm: Radialis muscles**

Muscle	Origin	Insertion	Innervation	Action
① Brachioradialis	Distal humerus (distal surface), lateral intermuscular septum	Styloid process of the radius	Radial n. (C5, C6)	Elbow: flexion Forearm: semipronation

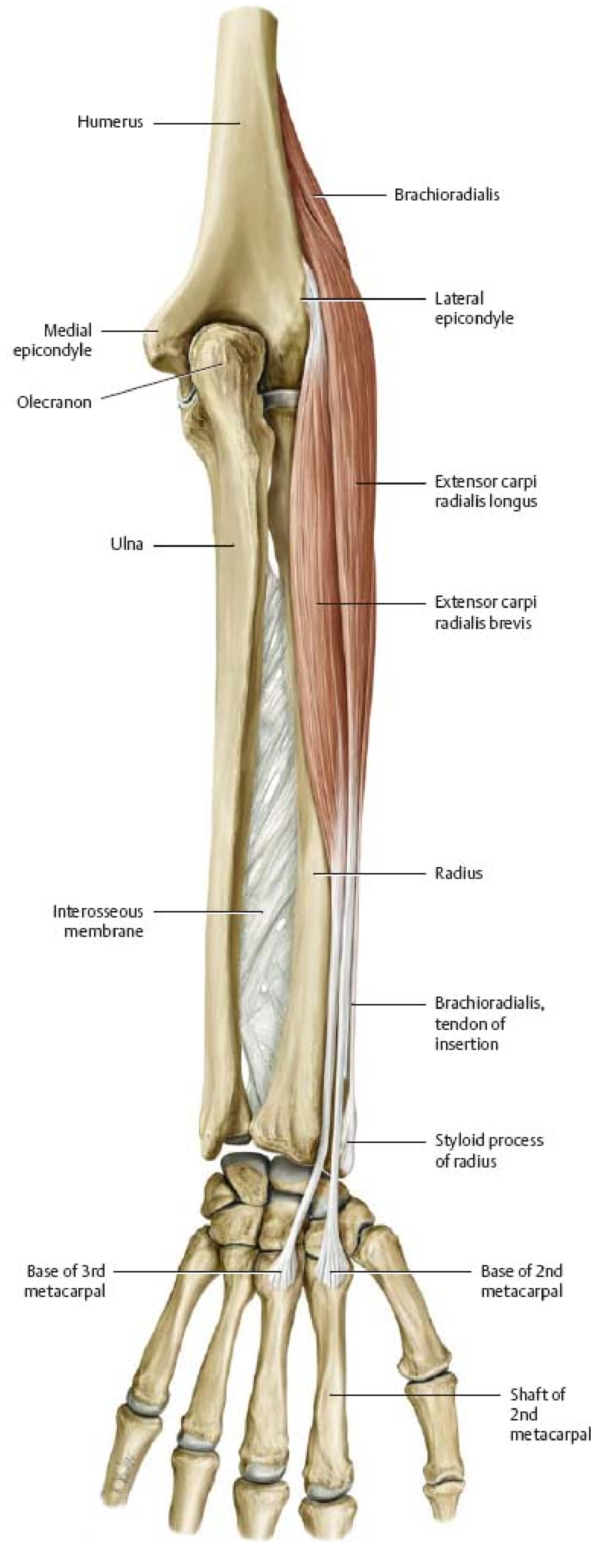
Muscle	Origin	Insertion	Innervation	Action
② Extensor carpi radialis longus	Lateral supracondylar ridge of distal humerus, lateral intermuscular septum	2nd metacarpal (base)	Radial n. (C6, C7)	Elbow: weak flexion Wrist: extension and abduction
③ Extensor carpi radialis brevis	Lateral epicondyle of humerus	3rd metacarpal (base)	Radial n. (C7, C8)	

Fig. 20.17 **Radialis muscles of the forearm**

Right forearm.



A Lateral (radial) view.



B Posterior view.

Muscle Facts (III)

Fig. 20.18 **Superficial group**

Right forearm, posterior view.

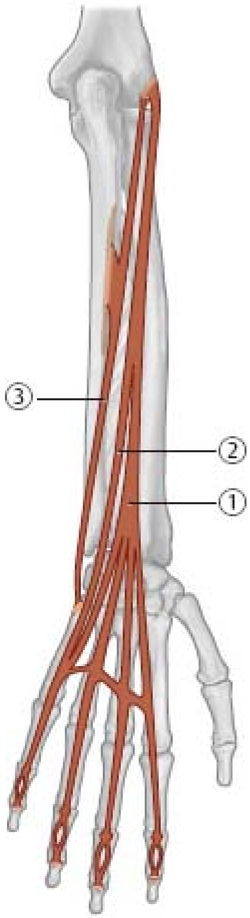


Fig. 20.19 **Deep group**

Right forearm, posterior view.


4
5
6
7
8

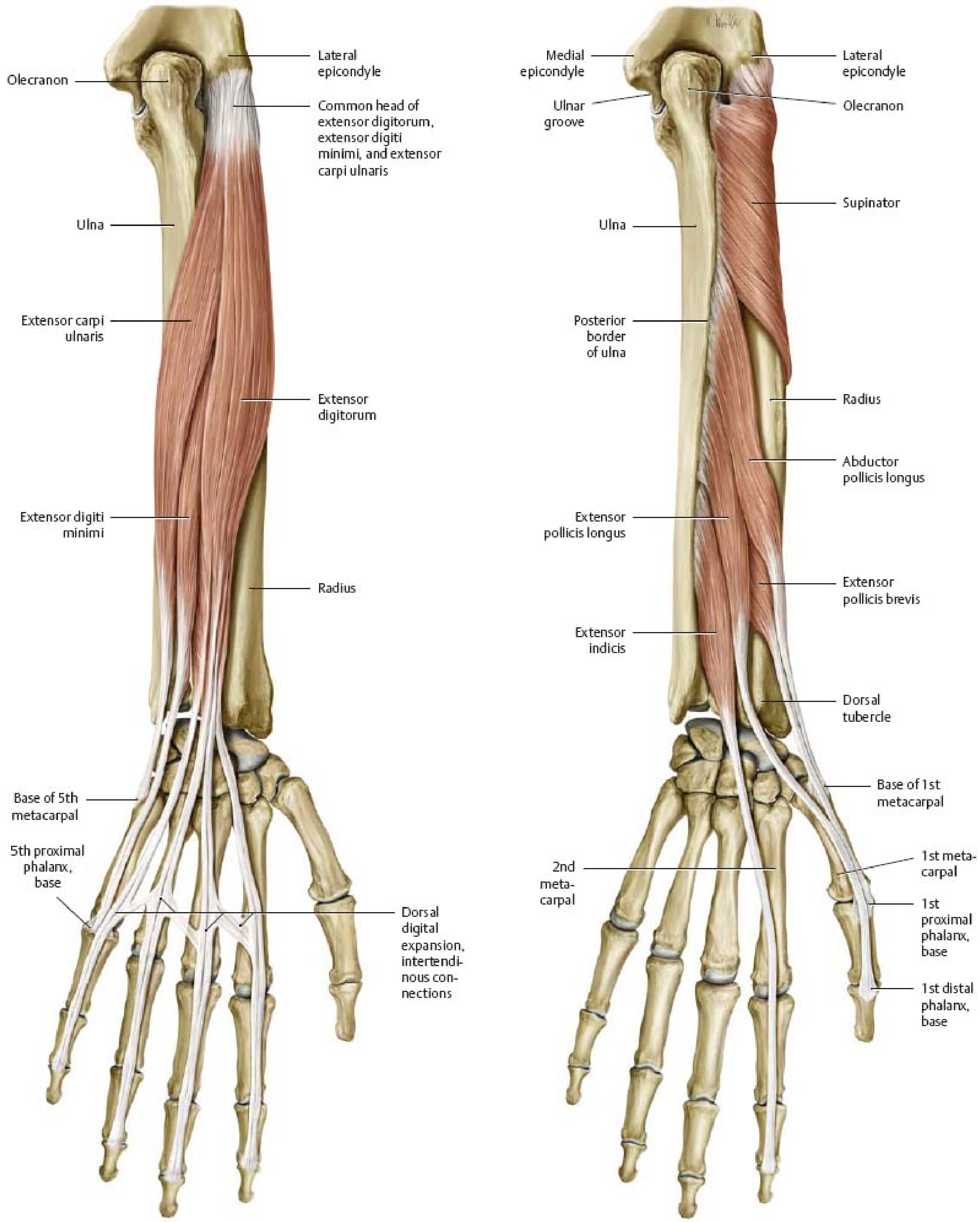
Table 20.4 Posterior compartment of the forearm

Muscle	Origin	Insertion	Innervation	Action
Superficial group				
① Extensor digitorum	Common head (lateral epicondyle of humerus)	Dorsal digital expansion of 2nd to 5th digits	Radial n. (C7, C8)	Wrist: extension MCP, PIP, and DIP of 2nd to 5th digits: extension/abduction of fingers
② Extensor digiti minimi	Common head (lateral epicondyle of humerus)	Dorsal digital expansion of 5th digit	Radial n. (C7, C8)	Wrist: extension, ulnar abduction of hand MCP, PIP, and DIP of 5th digit: extension and abduction of 5th digit
③ Extensor carpi ulnaris	Common head (lateral epicondyle of humerus) Ulnar head (dorsal surface)	Base of 5th metacarpal	Radial n. (C7, C8)	Wrist: extension, adduction (ulnar deviation) of hand
Deep group				
④ Supinator	Olecranon, lateral epicondyle of humerus, radial collateral ligament, annular ligament of radius	Radius (between radial tuberosity and insertion of pronator teres)	Radial n. (C6, C7)	Radioulnar joints: supination
⑤ Abductor pollicis longus	Radius and ulna (dorsal surfaces, interosseous membrane)	Base of 1st metacarpal	Radial n. (C7, C8)	Radiocarpal joint: abduction of the hand Carpometacarpal joint of thumb: abduction
⑥ Extensor pollicis brevis	Radius (posterior surface) and interosseous membrane	Base of proximal phalanx of thumb	Radial n. (C7, C8)	Radiocarpal joint: abduction (radial deviation) of hand Carpometacarpal and MCP of thumb: extension
⑦ Extensor pollicis longus	Ulna (posterior surface) and interosseous membrane	Base of distal phalanx of thumb	Radial n. (C7, C8)	Wrist: extension and abduction (radial deviation) of hand Carpometacarpal of thumb: adduction MCP and IP of thumb: extension
⑧ Extensor indicis	Ulna (posterior surface) and interosseous membrane	Posterior digital extension of 2nd digit	Radial n. (C7, C8)	Wrist: extension MCP, PIP, and DIP of 2nd digit: extension

DIP = distal interphalangeal; IP = interphalangeal; MCP = metacarpophalangeal; PIP = proximal interphalangeal.

Fig. 20.20 Muscles of the posterior forearm

Right forearm, posterior view.



A Superficial extensors.

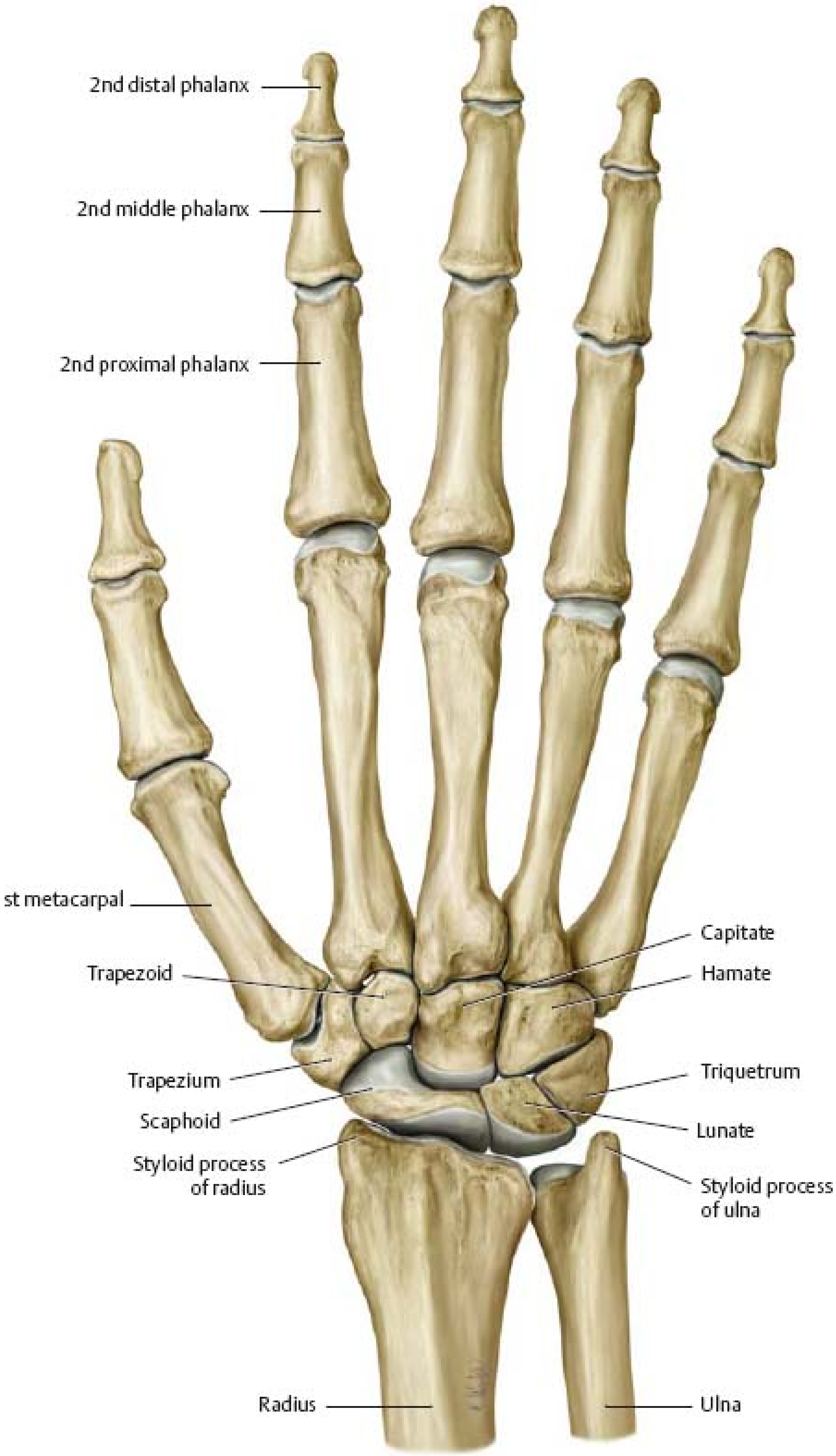
B Deep extensors with supinator.

21 Wrist & Hand

Bones of the Wrist & Hand

Fig. 21.1 **Dorsal view**

Right hand.



2nd distal phalanx
2nd middle phalanx
2nd proximal phalanx
st metacarpal
Trapezoid
Trapezium
Scaphoid
Styloid process
of radius
Radius
Capitate
Hamate
Triquetrum
Lunate
Styloid process
of ulna
Ulna

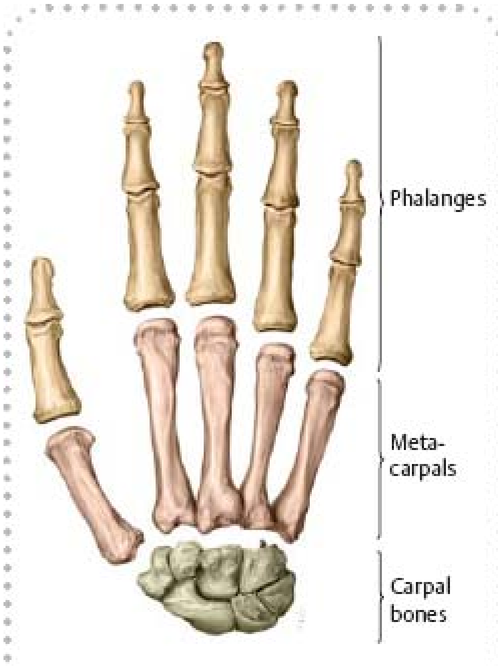


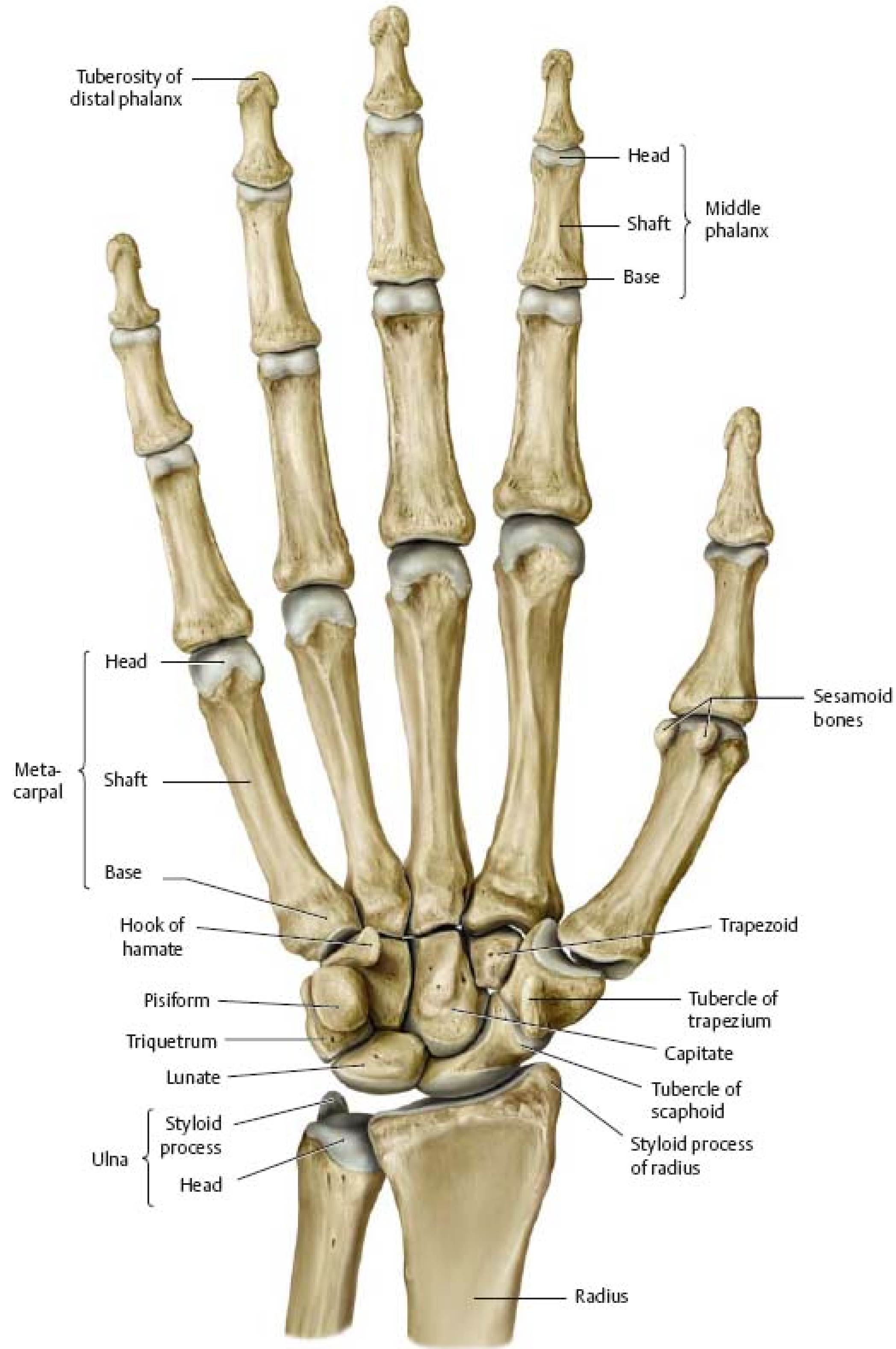
Table 21.1 Bones of the wrist and hand

Phalanges	1st to 5th proximal phalanges	
	2nd to 5th middle phalanges*	
	1st to 5th distal phalanges	
Metacarpal bones	1st to 5th metacarpals	
Carpal bones	Trapezium	Scaphoid
	Trapezoid	Lunate
	Capitate	Triquetrum
	Hamate	

*There are only four middle phalanges (the thumb has only a proximal and a distal phalanx).

Fig. 21.2 **Palmar view**

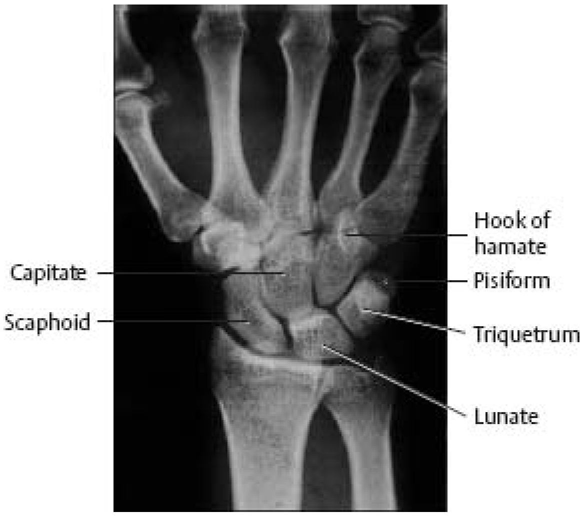
Right hand.



Tuberosity of distal phalanx
Head
Shaft
Base
Middle phalanx
Head
Meta-carpal
Shaft
Base
Sesamoid bones
Hook of hamate
Trapezoid
Pisiform
Tubercle of trapezium
Triquetrum
Capitate
Lunate
Tubercle of scaphoid
Styloid process
Ulna
Head
Styloid process of radius
Radius

Fig. 21.3 Radiograph of the wrist

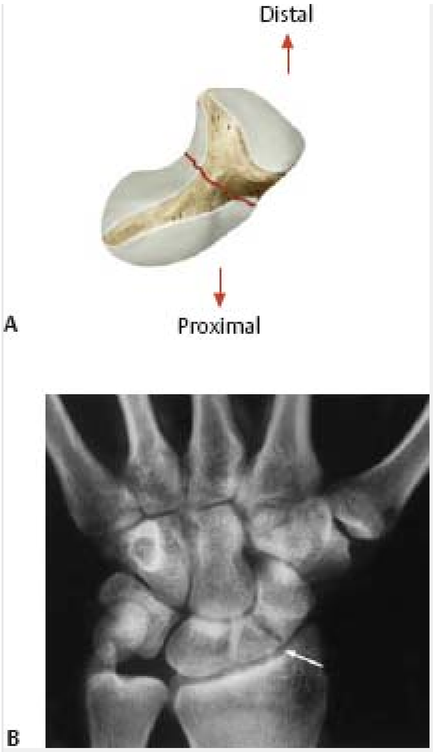
Anteroposterior view of left limb.



Clinical

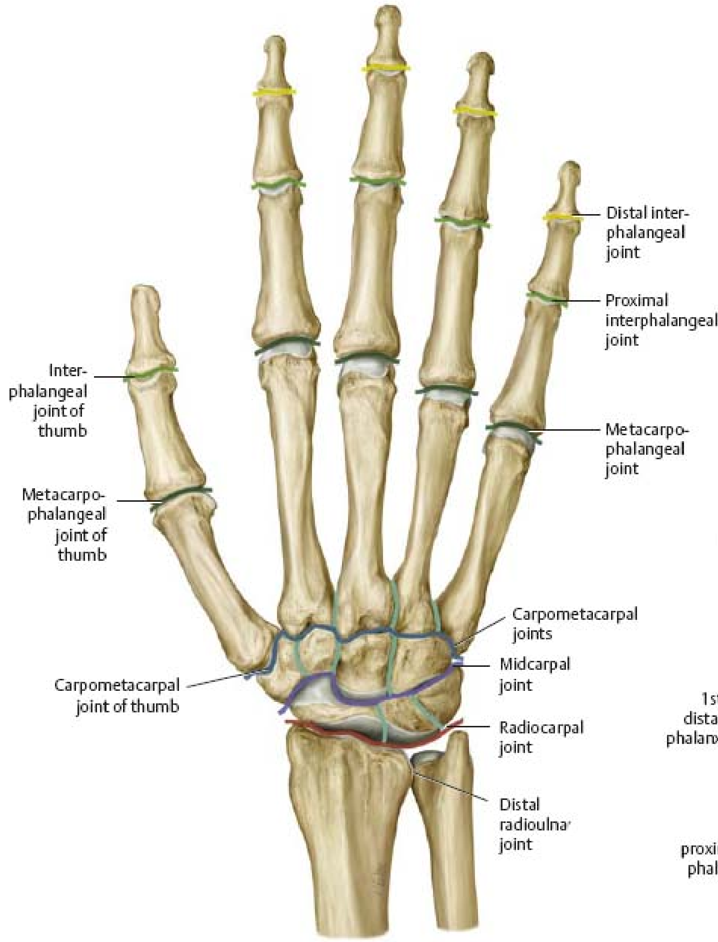
Scaphoid Fractures

Scaphoid fractures are the most common carpal bone fractures, generally occurring at the narrowed waist between the proximal and distal poles (**A**, right scaphoid). Because blood supply to the scaphoid is transmitted via the distal segment, fractures at the waist can compromise the supply to the proximal segment, often resulting in nonunion and avascular necrosis



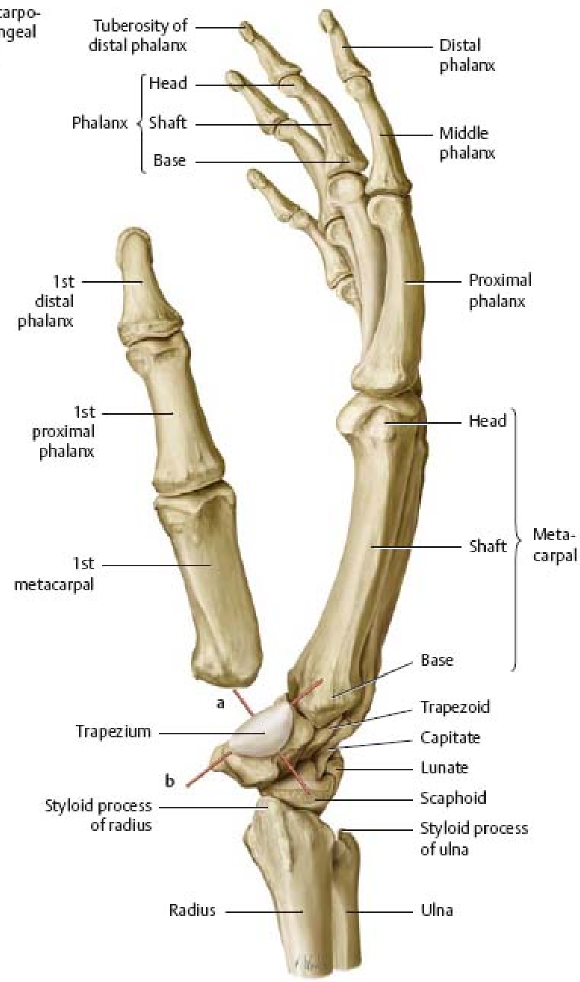
Joints of the Wrist & Hand

Fig. 21.4 Joints of the wrist and hand



A Joints of the wrist and hand. Right hand, posterior (dorsal) view.

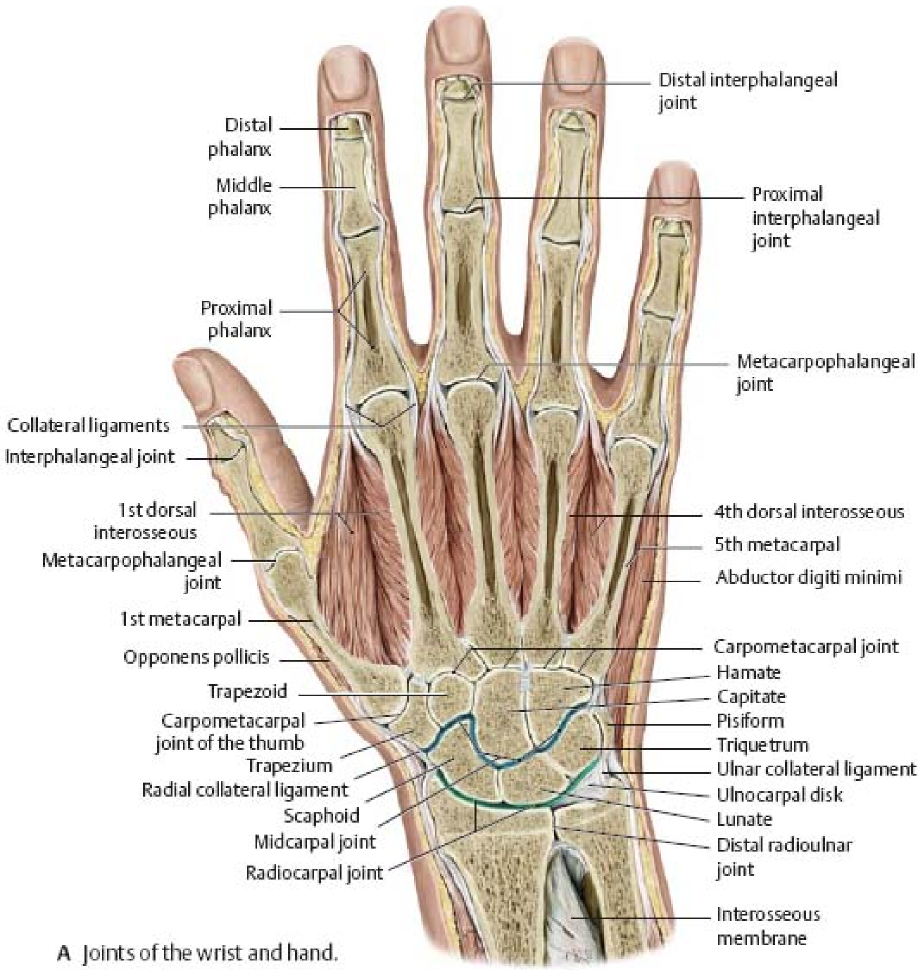
C Radiograph of wrist. Radial view.



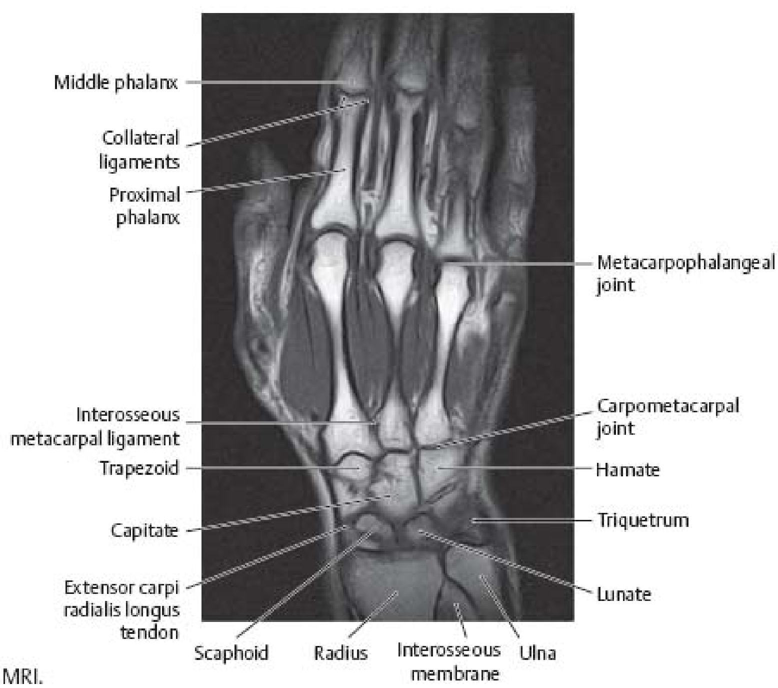
B Carpometacarpal joint of the thumb. Radial view. The 1st metacarpal bone has been moved slightly distally to expose the articular surface of the trapezium. Two cardinal axes of motion are shown here: (**a**) flexion/extension and (**b**) abduction/adduction.

Fig. 21.5 Wrist and hand: Coronal section

Right hand.



A Joints of the wrist and hand.

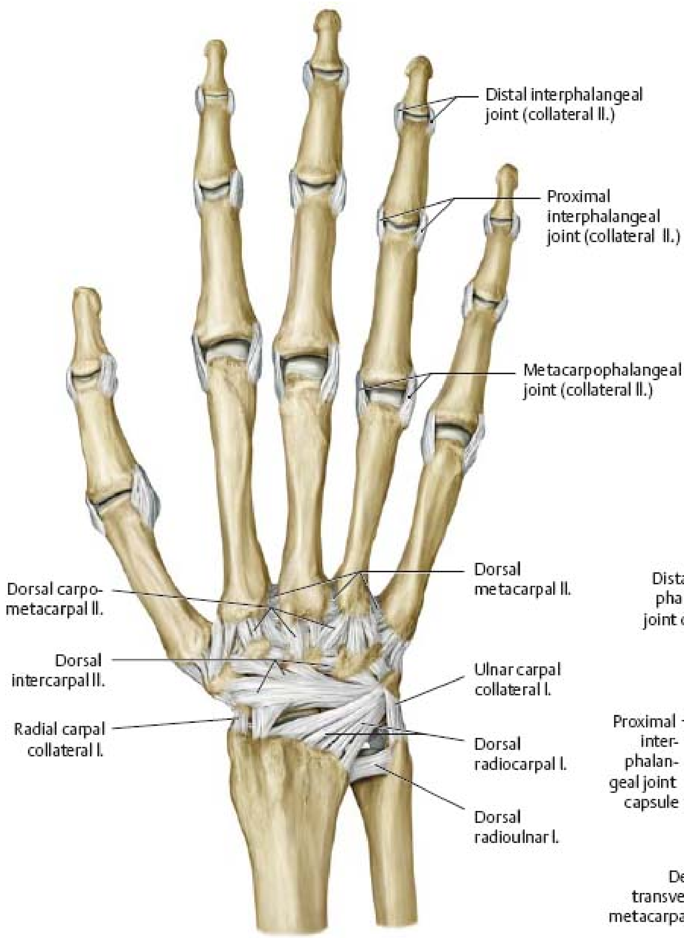


B Coronal MRI.

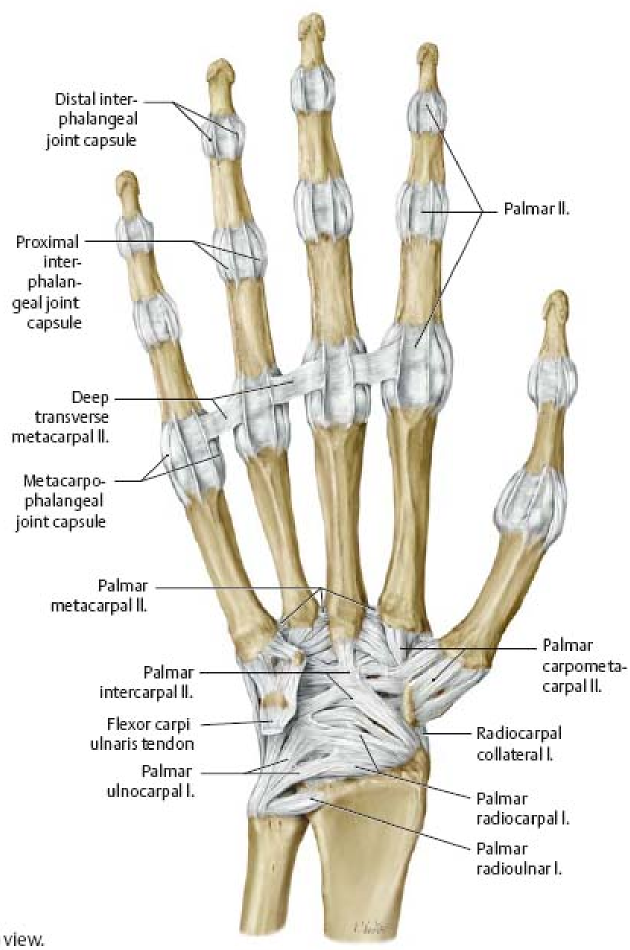
Ligaments of the Wrist & Hand

Fig. 21.6 Ligaments of the hand

Right hand.



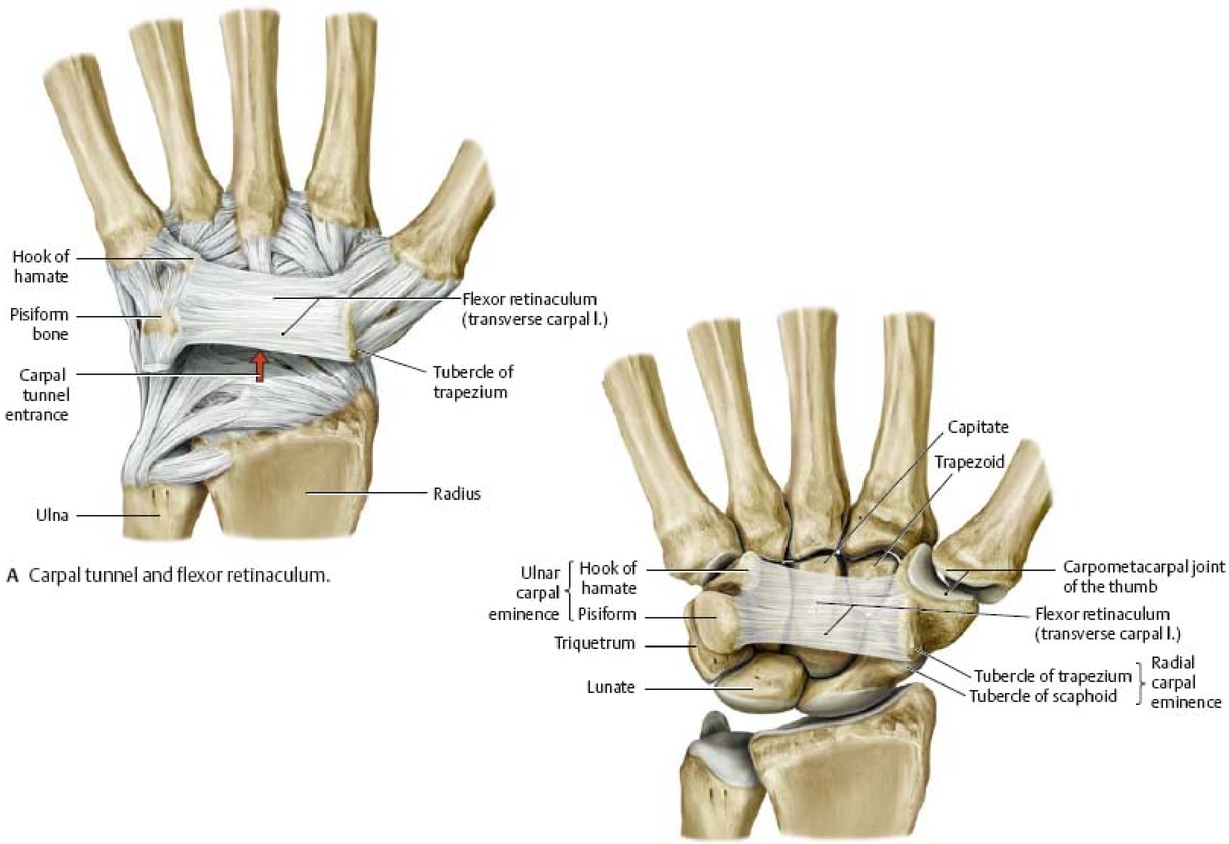
A Posterior (dorsal) view.



B Anterior (palmar) view.

Fig. 21.7 Ligaments of the carpal tunnel

Right hand, anterior view.

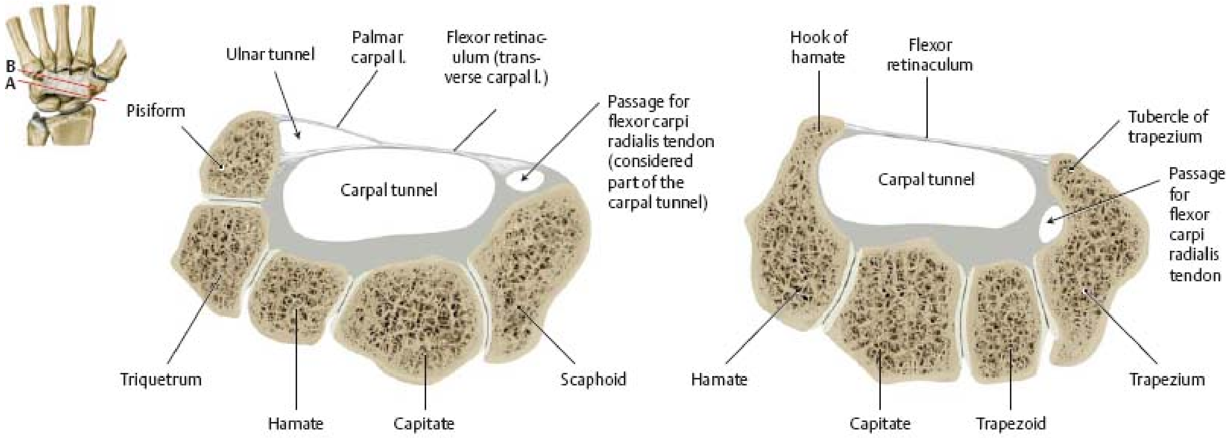


A Carpal tunnel and flexor retinaculum.

B Bony boundaries of the carpal tunnel.

Fig. 21.8 Carpal tunnel

Transverse section. The contents of the carpal tunnel are discussed on p. 342. See p. 343 for the ulnar tunnel and palmar carpal ligment.

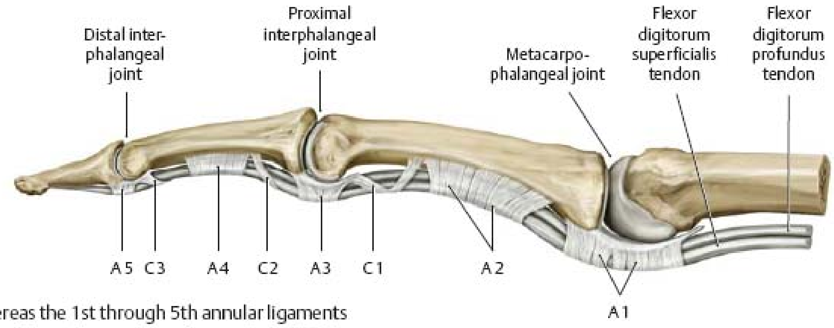


A Proximal part of the carpal tunnel. **B** Distal part of the carpal tunnel.

Ligaments of the Fingers

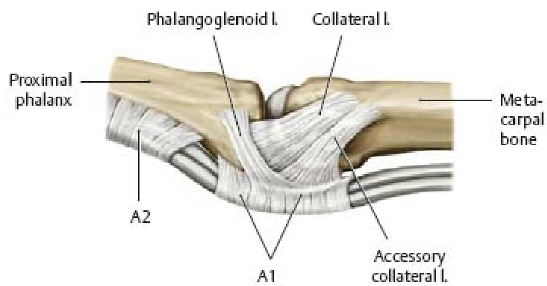
Fig. 21.9 Ligaments of the fingers: Lateral view

Right middle finger. The outer fibrous layer of the tendon sheaths (stratum fibrosum) is strengthened by the annular and cruciform ligaments, which also bind the sheaths to the palmar surface of the phalanx and prevent palmar deviation of the sheaths during flexion.



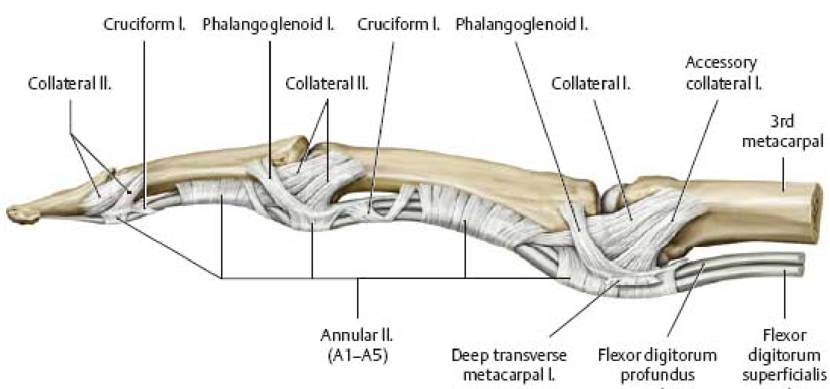
A Extension. *Note:* Whereas the 1st through 5th annular ligaments (A1–A5) have fixed positions, the cruciform ligaments (C1–C3) are highly variable in their course.

B Flexion.



C Extension of the metacarpophalangeal joint. *Note:* The collateral ligament is lax.

D Flexion of the metacarpo-phalangeal joint. *Note:* The collateral ligament is taut.



E Joint capsules, ligaments, and digital tendon sheaths.

Fig. 21.10 **Anterior view**

Right middle finger, palmar view.

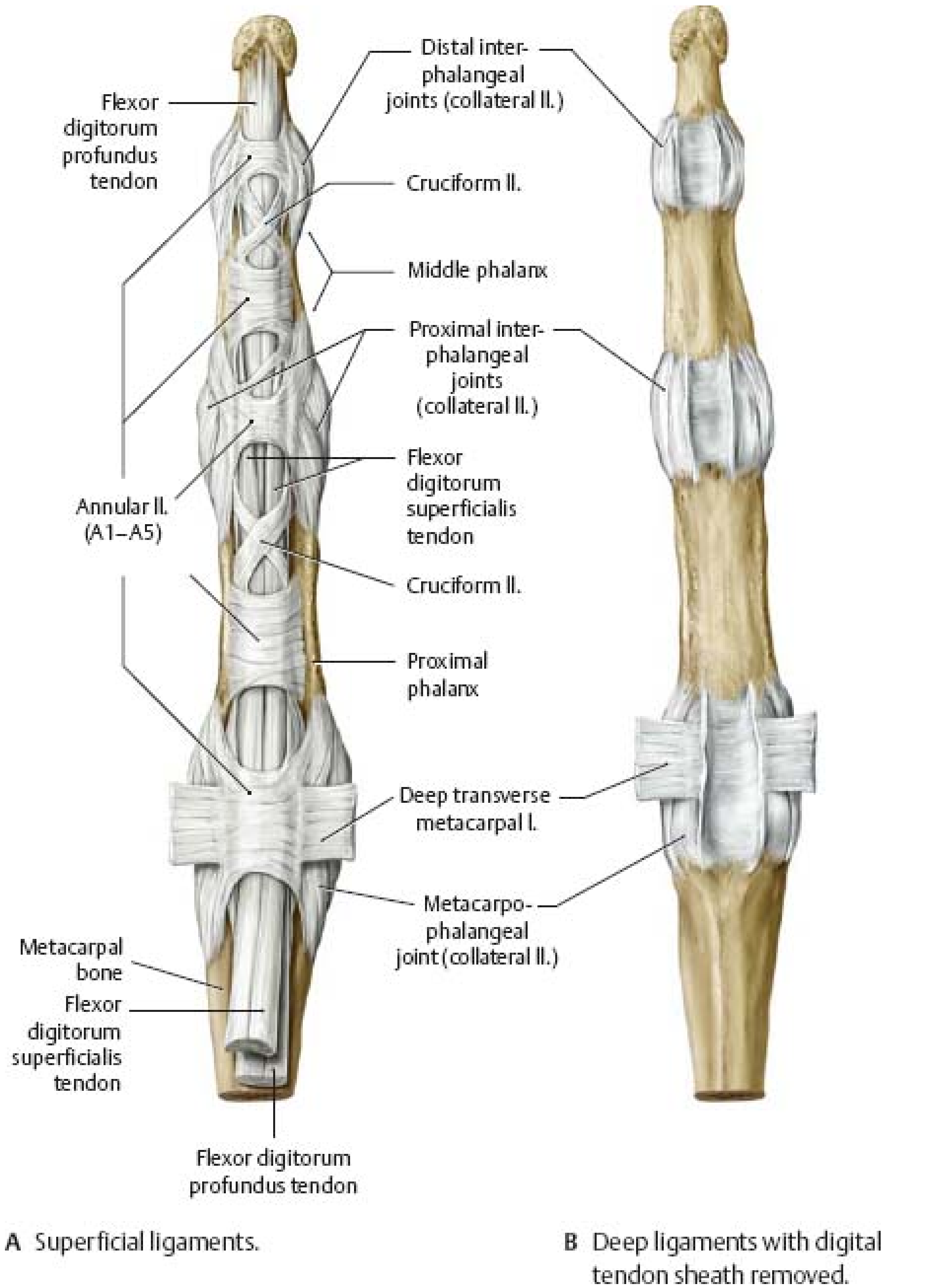


Fig. 21.11 **Third metacarpal: Transverse section**
Proximal view.

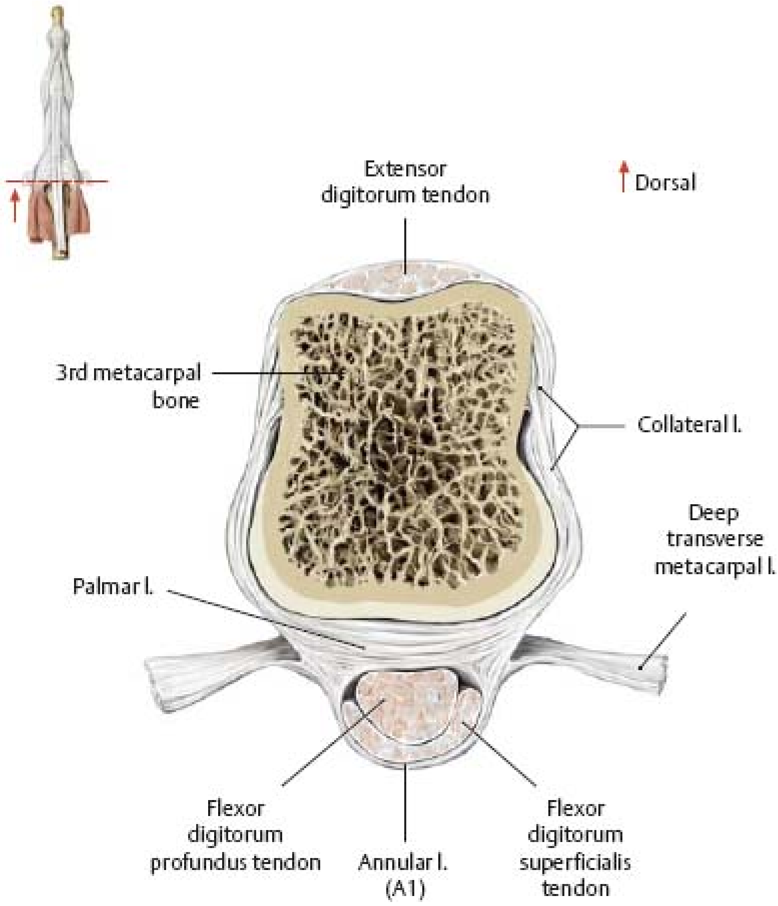
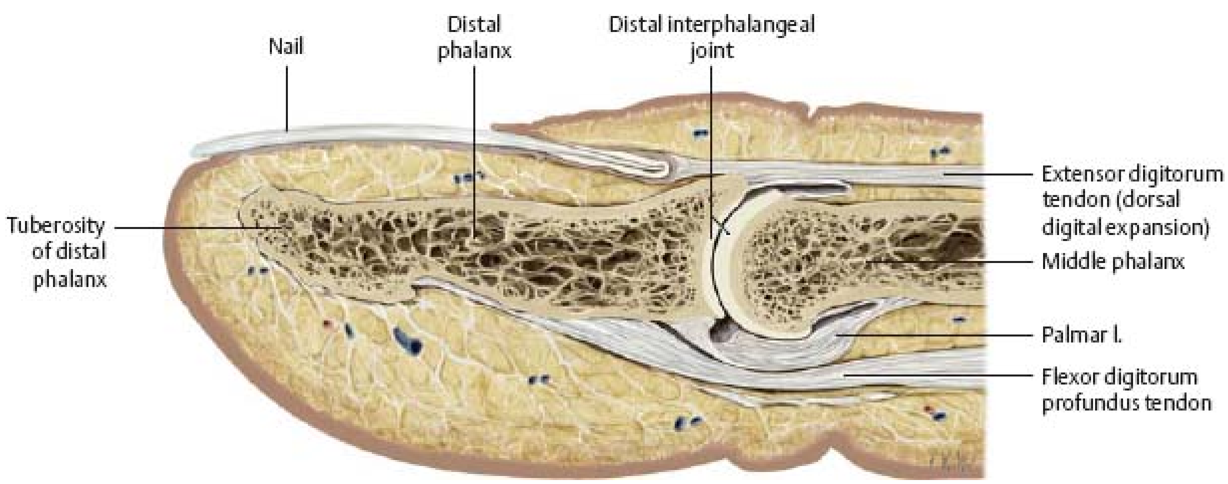


Fig. 21.12 Fingertip: Longitudinal section

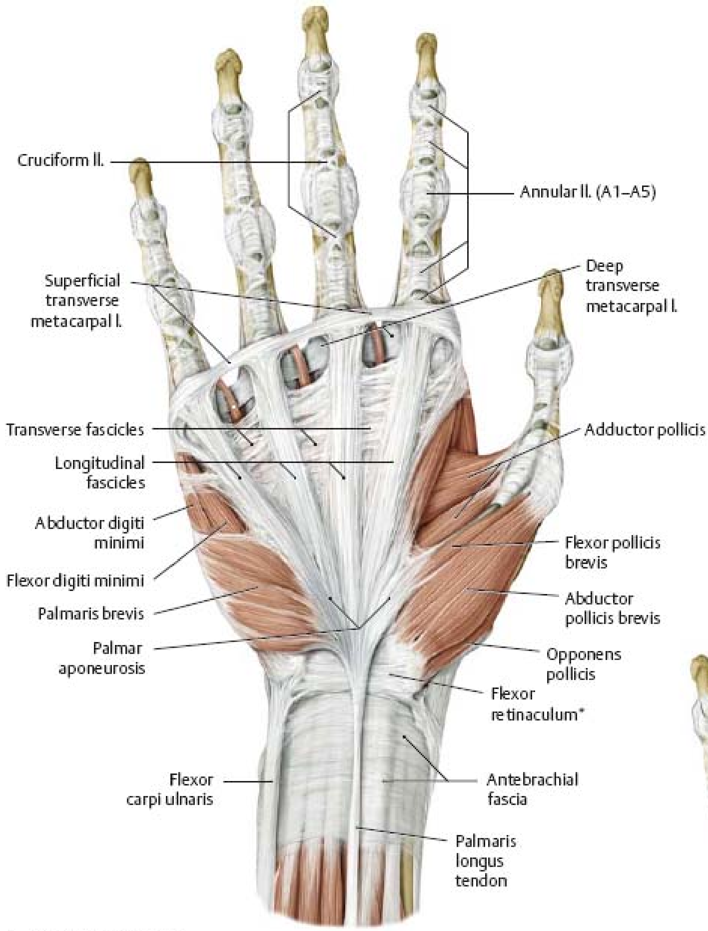
The palmar articular surfaces of the phalanges are enlarged proximally at the joints by the palmar ligament. This fibrocartilaginous plate, also known as the volar plate, forms the floor of the digital tendon sheaths.



Muscles of the Hand: Superficial & Middle Layers

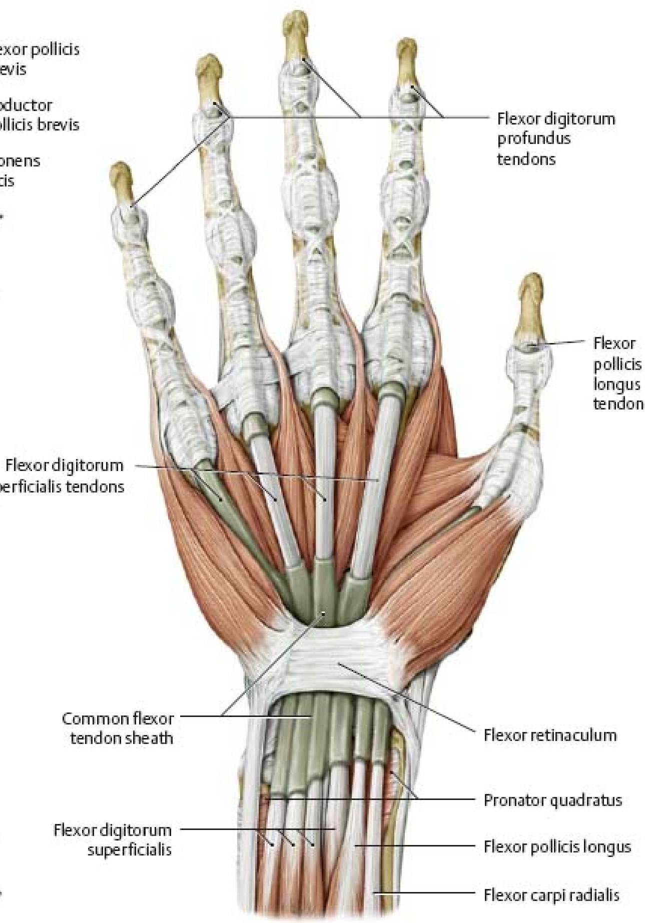
Fig. 21.13 **Intrinsic muscles of the hand: Superficial and middle layers**

Right hand, palmar surface.



A Palmar aponeurosis.

* Also known as transverse carpal ligament.

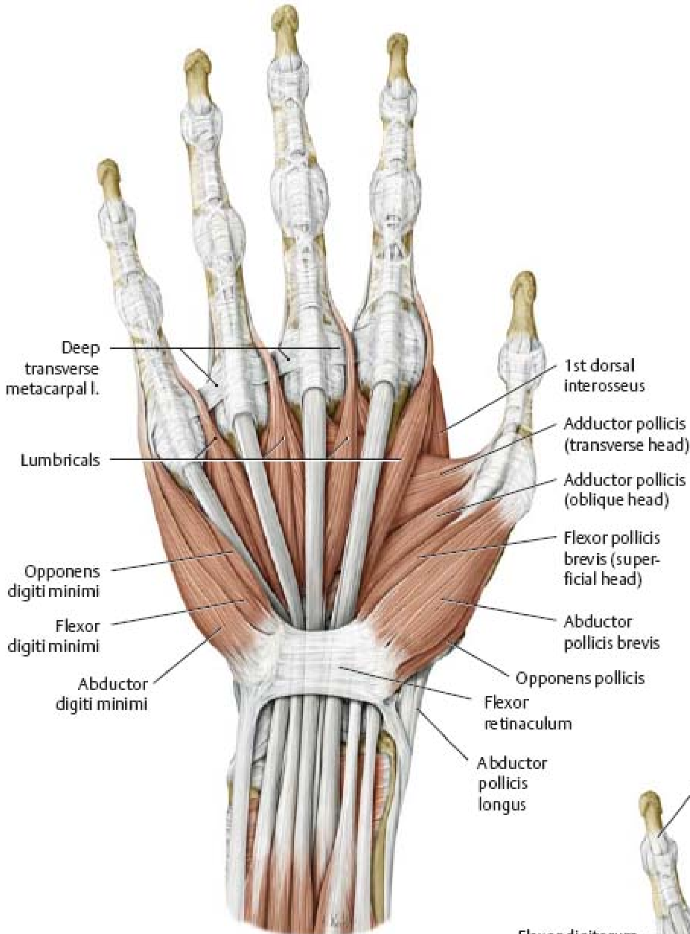


B Carpal and digital tendon sheaths. *Removed:* Palmar aponeurosis, palmaris longus, antebrachial fascia, and palmaris brevis.

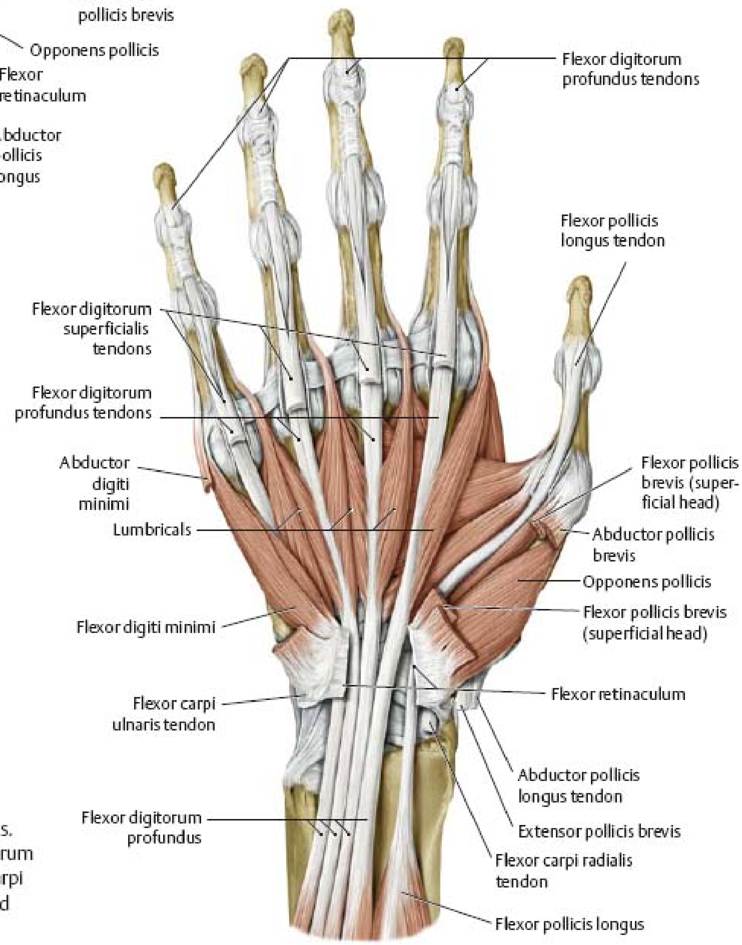
Clinical

Dupuytren's contracture

Gradual atrophy of the palmar aponeurosis leads to progressive shortening of the palmar fascia, chiefly affecting the 4th and 5th digits. Over a period of years, the contracture may become so severe that the fingers assume a flexed position (with fingertips touching the palms), severely compromising the grasping ability of the hand. The causes of Dupuytren's contracture are poorly understood, but it is a relatively common condition, most prevalent in men over 40 and associated with chronic liver disease (i.e., cirrhosis). Treatment generally consists of complete surgical removal of the palmar aponeurosis.



C Superficial muscles of the hand.
Removed: Tendon sheaths.

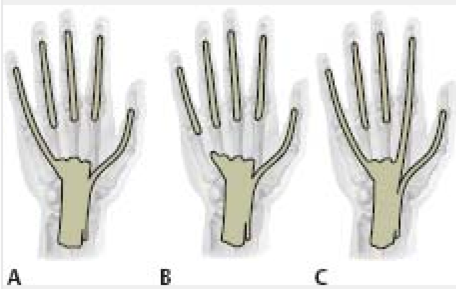


D Middle layer of muscles.
Removed: Flexor digitorum superficialis, flexors carpi radialis and ulnaris, and pronator quadratus.

Clinical

Tendon sheath communication

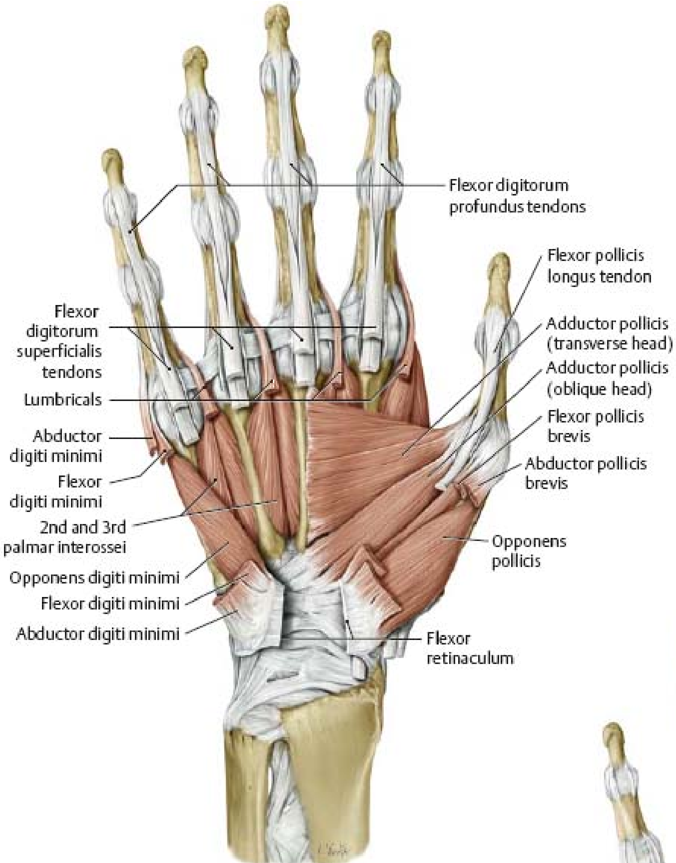
The digital tendon sheath of the thumb is continuous with the carpal tendon sheath of the pollicis longus. The remaining fingers show variable communication with the carpal tendon sheaths (A is the most common variation). Infections within the tendon sheaths from puncture wounds of the fingers can track proximally to communicating spaces of the hand.



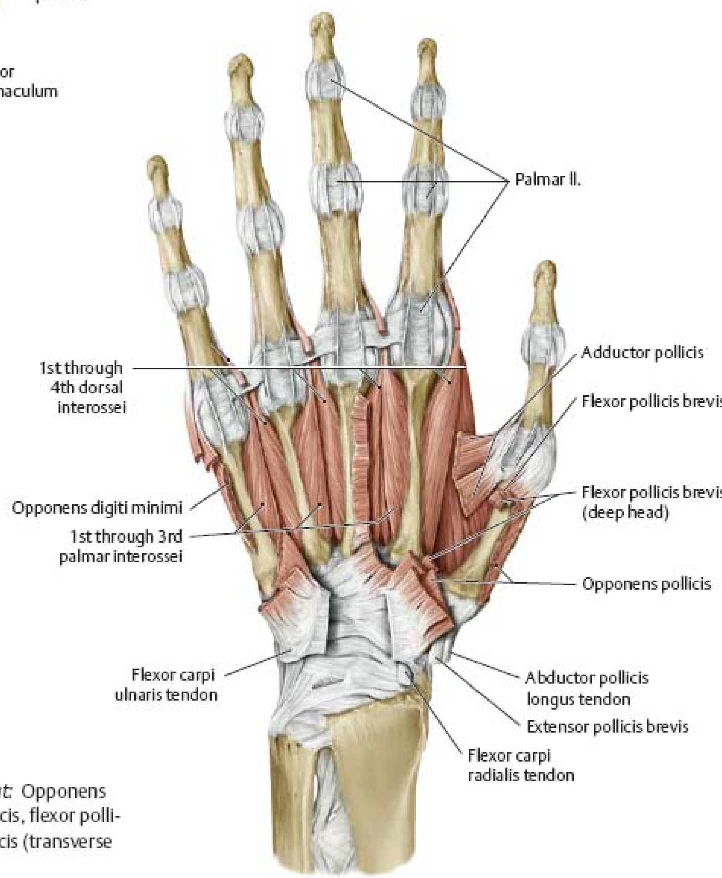
Muscles of the Hand: Middle & Deep Layers

Fig. 21.14 Intrinsic muscles: Middle and deep layers

Right hand, palmar surface.



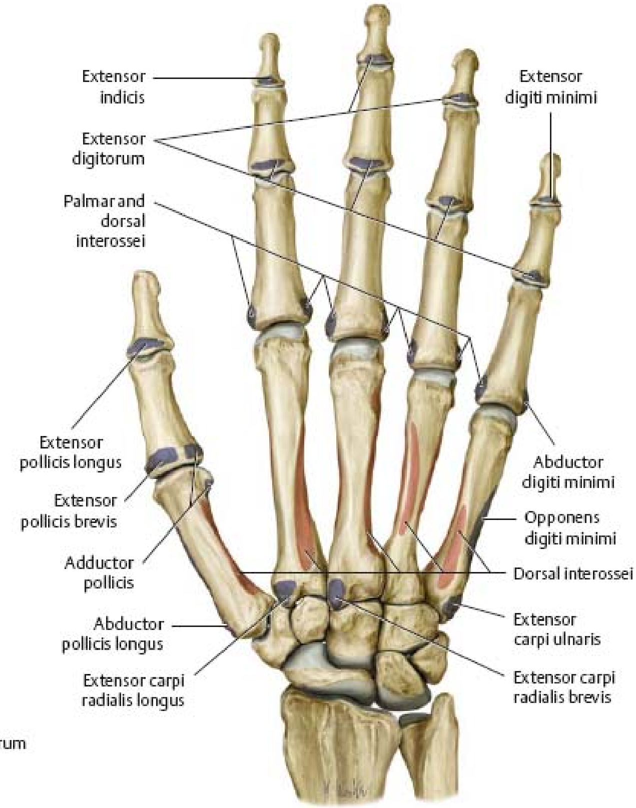
A Middle layer of muscles of the hand. *Cut:* Flexor digitorum profundus, lumbricals, flexor pollicis longus, and flexor digiti minimi.



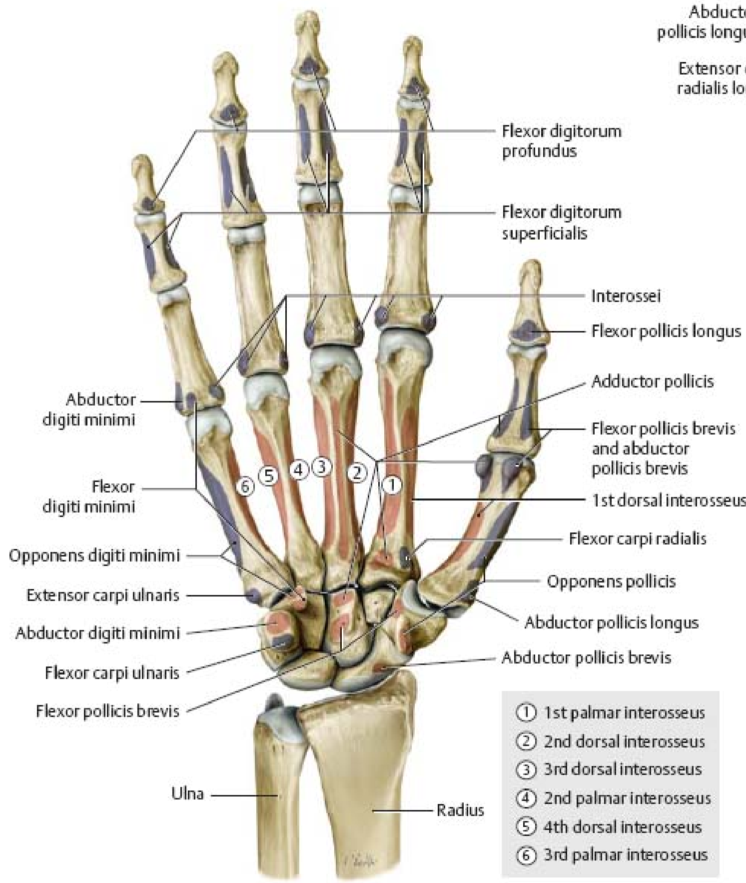
B Deep muscles of the hand. *Cut:* Opponens digiti minimi, opponens pollicis, flexor pollicis brevis, and adductor pollicis (transverse and oblique heads).

Fig. 21.15 **Origins and insertions**

Right hand. Muscle origins shown in red, insertions in blue.



A Dorsal (posterior) view.



B Palmar (anterior) view.

Dorsum of the Hand

Fig. 21.16 **Extensor retinaculum and dorsal carpal tendon sheaths**

Right hand, posterior (dorsal) view.

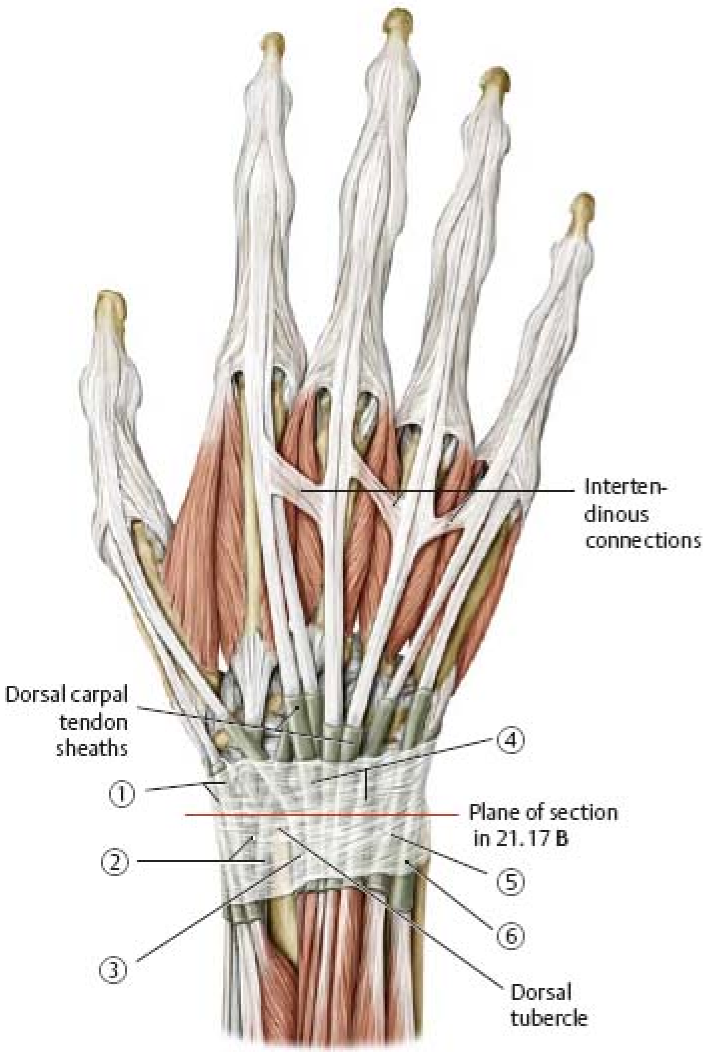
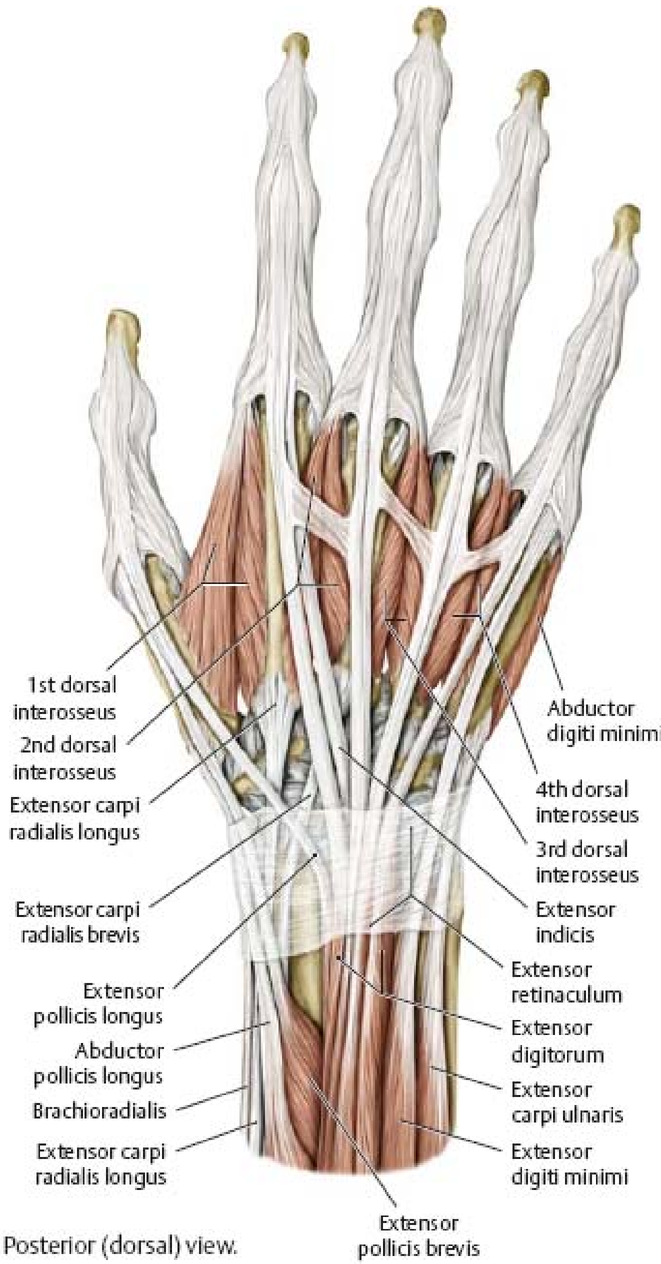


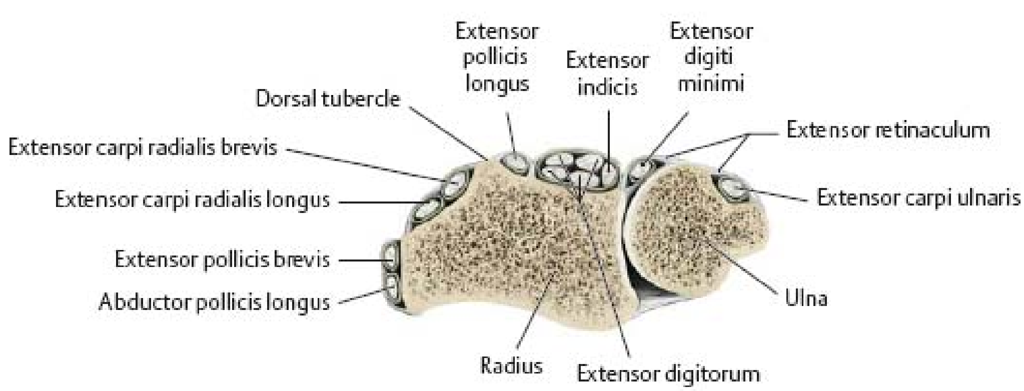
Table 21.2	Dorsal compartments for extensor tendons
①	Abductor pollicis longus
	Extensor pollicis brevis
②	Extensor carpi radialis longus
	Extensor carpi radialis brevis
③	Extensor pollicis longus
④	Extensor digitorum
	Extensor indicis
⑤	Extensor digiti minimi
⑥	Extensor carpi ulnaris

Fig. 21.17 **Muscles and tendons of the dorsum**

Right hand.



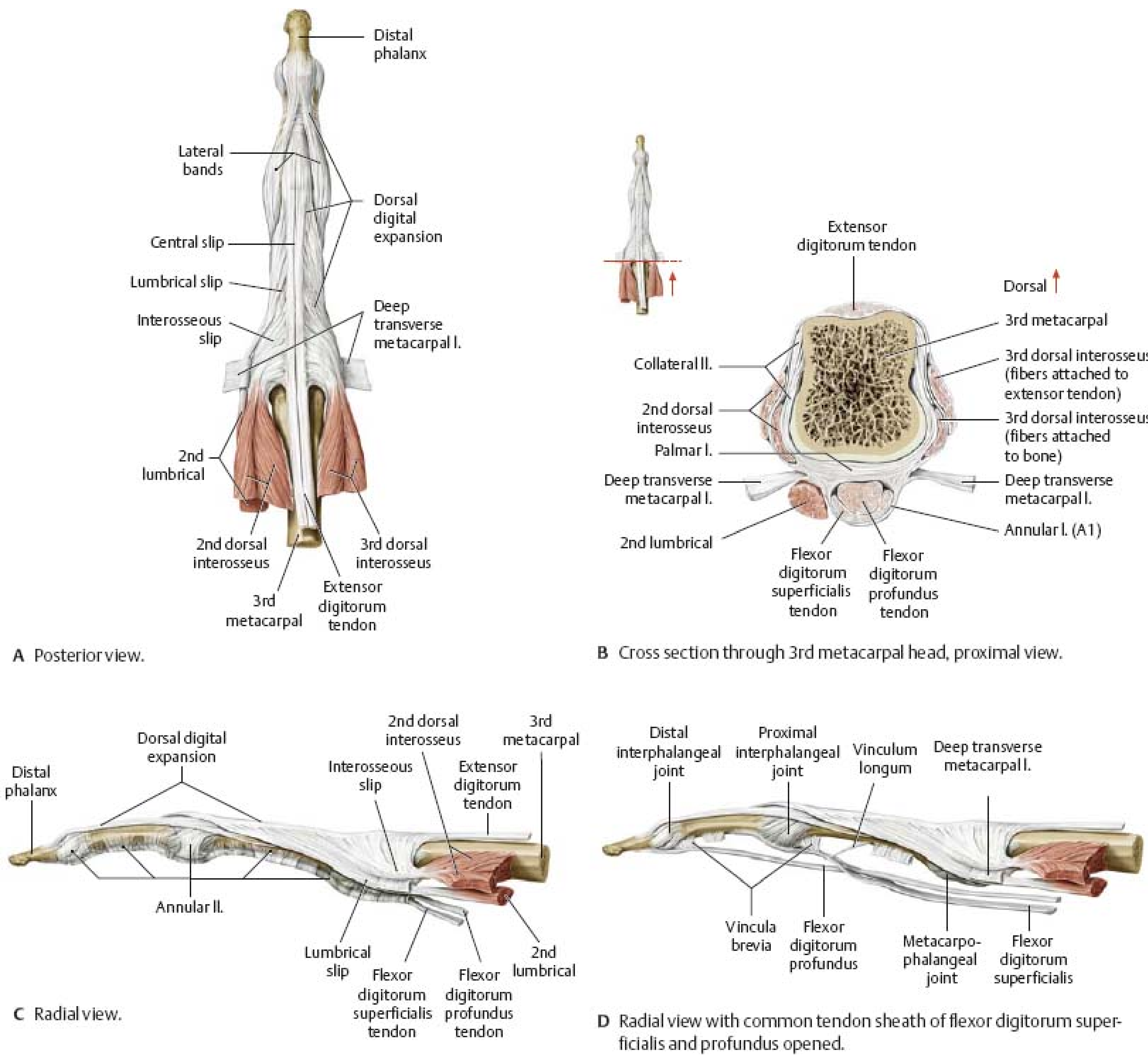
A Posterior (dorsal) view.



B Dorsal compartments, proximal view of section in Fig. 21.16.

Fig. 21.18 **Dorsal digital expansion**

Right hand, middle finger. The dorsal digital expansion permits the long digital flexors and the short muscles of the hand to act on all three finger joints.



A Posterior view.

B Cross section through 3rd metacarpal head, proximal view.

C Radial view.

D Radial view with common tendon sheath of flexor digitorum superficialis and profundus opened.

Muscle Facts (I)

The intrinsic muscles of the hand are divided into three groups: the thenar, hypothenar, and metacarpal muscles (see p. 314). The thenar muscles are responsible for movement of the thumb, while the hypothenar muscles move the 5th digit.

Table 21.3 Thenar muscles

Muscle	Origin	Insertion		Innervation		Action
① Adductor pollicis	Transverse head: 3rd metacarpal (palmar surface)	Thumb (base of proximal phalanx)	Via the ulnar sesamoid	Ulnar n.	C8, T1	CMC joint of thumb: adduction MCP joint of thumb: flexion
	Oblique head: capitate bone, 2nd and 3rd metacarpals (bases)					
② Abductor pollicis brevis	Scaphoid bone and trapezium, flexor retinaculum		Via the radial sesamoid	Median n.		CMC joint of thumb: abduction
③ Flexor pollicis brevis	Superficial head: flexor retinaculum			Superficial head: median n.		CMC joint of thumb: flexion
	Deep head: capitate bone, trapezium			Deep head: ulnar n.		
④ Opponens pollicis	Trapezium	First metacarpal (radial border)		Median n.		CMC joint of thumb: opposition

CMC = carpometacarpal; MCP = metacarpophalangeal.

Fig. 21.19 Thenar and hypothenar muscles

Right hand, palmar (anterior) view.

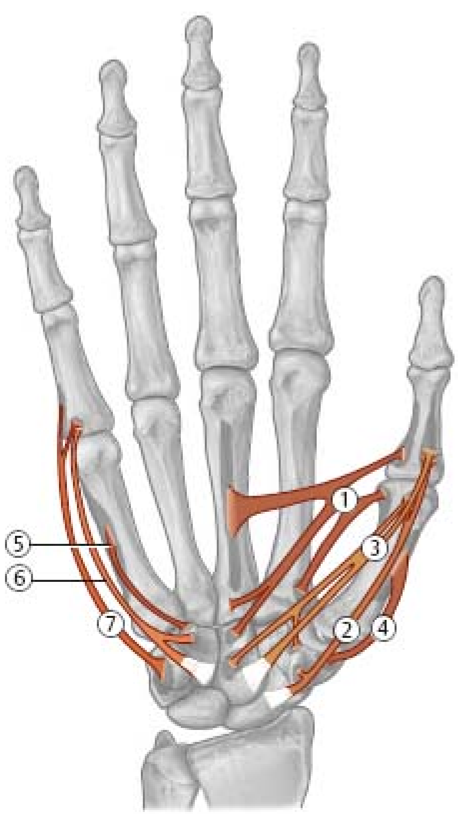
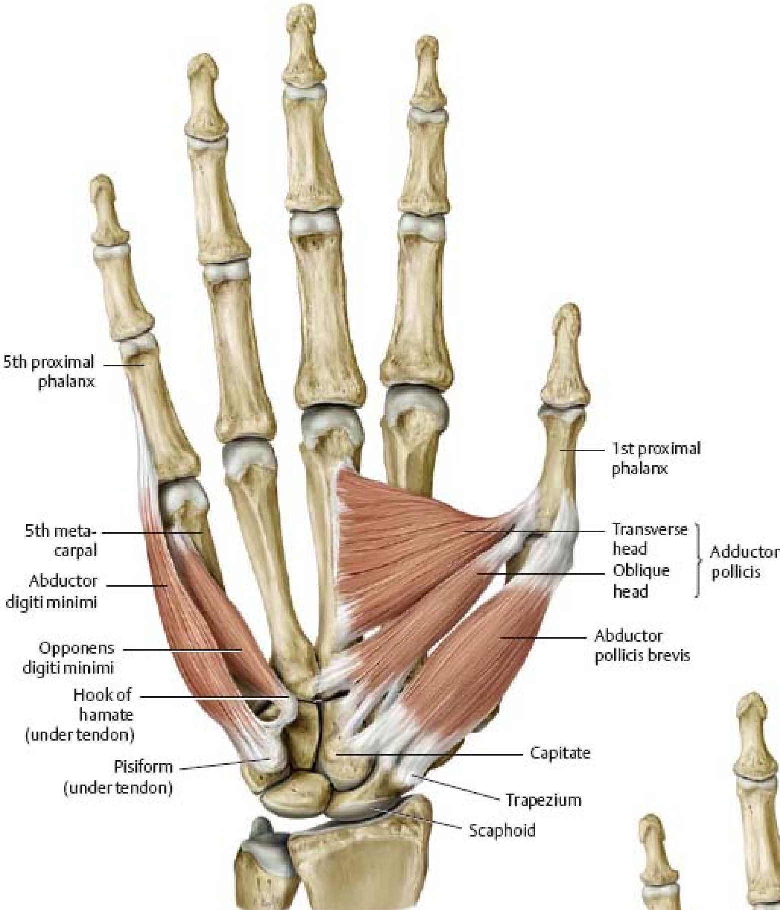


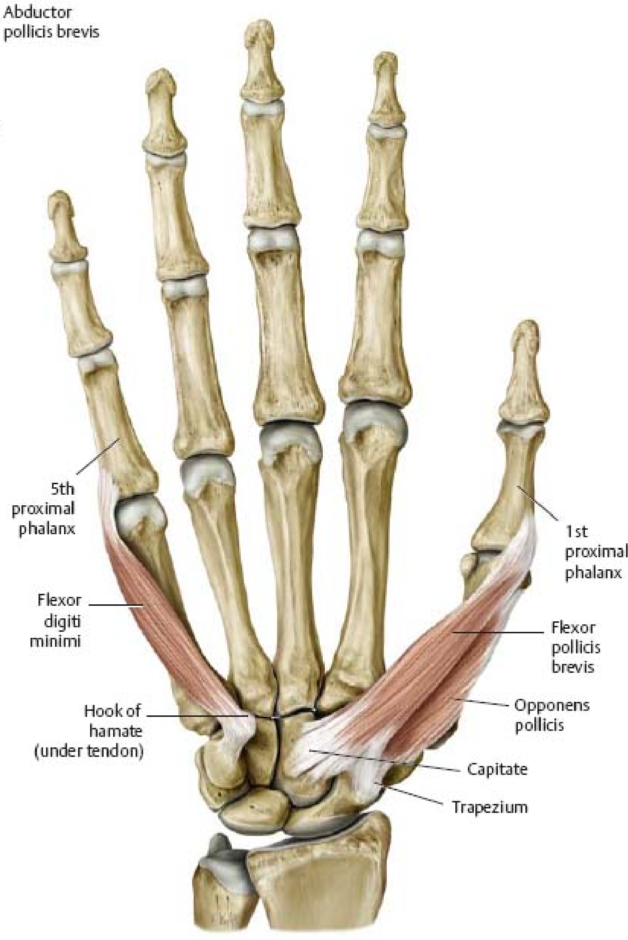
Table 21.4 Hypothenar muscles				
Muscle	**Origin**	**Insertion**	**Innervation**	**Action**
⑤ Opponens digiti minimi	Hook of hamate, flexor retinaculum	5th metacarpal (ulnar border)	Ulnar n. (C8, T1)	Draws metacarpal in palmar direction (opposition)
⑥ Flexor digiti minimi		5th proximal phalanx (base)		MCP joint of little finger: flexion
⑦ Abductor digiti minimi	Pisiform bone	5th proximal phalanx (ulnar base) and dorsal digital expansion of 5th digit		MCP joint of little finger: flexion and abduction of little finger PIP and DIP joints of little finger: extension
Palmaris brevis	Palmar aponeurosis (ulnar border)	Skin of hypothenar eminence		Tightens the palmar aponeurosis (protective function)
DIP = distal interphalangeal; MCP = metacarpophalangeal; PIP = proximal interphalangeal.				

Fig. 21.20 Thenar and hypothenar muscles

Right hand, palmar (anterior) view.



A *Removed:* Flexor pollicis brevis, opponens pollicis, and flexor digiti minimi.



B *Removed:* Adductor pollicis, abductor pollicis brevis, abductor digiti minimi, and opponens digiti minimi.

Muscle Facts (II)

The metacarpal muscles of the hand consist of the lumbricals and interossei. They are responsible for the movement of the digits (with the hypothenars, which act on the 5th digit).

Fig. 21.21 **Lumbricals**

Right hand, palmar view.

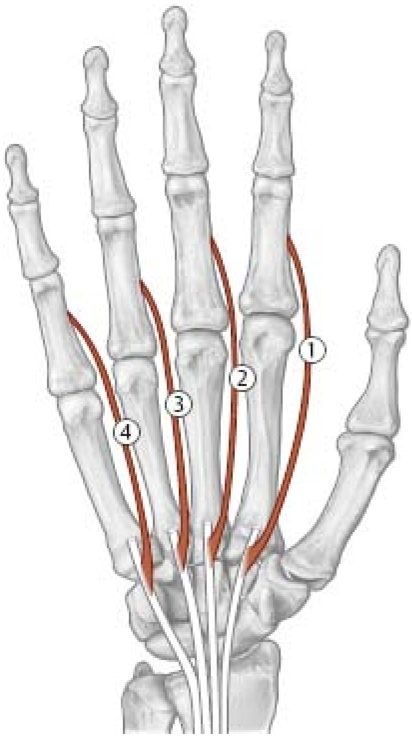


Fig. 21.22 **Dorsal interossei**

Right hand, palmar view.

Fig. 21.23 **Palmar interossei**

Right hand, palmar view.

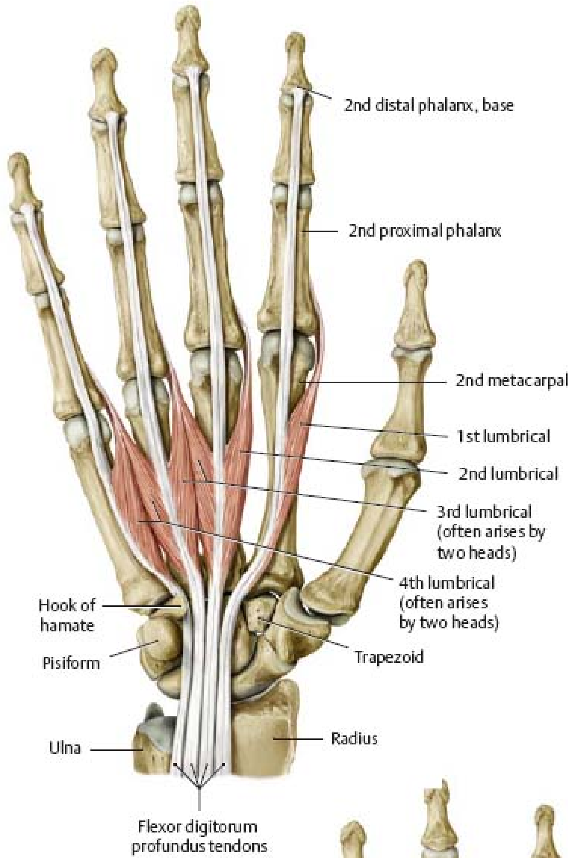
Table 21.5 Metacarpal muscles

Muscle group	Muscle	Origin	Insertion	Innervation	Action
Lumbricals	① 1st	Tendons of flexor digitorum profundus (radial sides)	2nd digit (dde)	Median n. (C8, T1)	2nd to 5th digits: • MCP joints: flexion • Proximal and distal IP joints: extension
	② 2nd		3rd digit (dde)		
	③ 3rd	Tendons of flexor digitorum profundus (bipennate from medial and lateral sides)	4th digit (dde)	Ulnar n. (C8, T1)	
	④ 4th		5th digit (dde)		
Dorsal interossei	⑤ 1st	1st and 2nd metacarpals (adjacent sides, two heads)	2nd digit (dde) 2nd proximal phalanx (radial side)		2nd to 4th digits: • MCP joints: flexion • Proximal and distal IP joints: extension and abduction from 3rd digit
	⑥ 2nd	2nd and 3rd metacarpals (adjacent sides, two heads)	3rd digit (dde) 3rd proximal phalanx (radial side)		
	⑦ 3rd	3rd and 4th metacarpals (adjacent sides, two heads)	3rd digit (dde) 3rd proximal phalanx (ulnar side)		
	⑧ 4th	4th and 5th metacarpals (adjacent sides, two heads)	4th digit (dde) 4th proximal phalanx (ulnar side)		
Palmar interossei	⑨ 1st	2nd metacarpal (ulnar side)	2nd digit (dde) 2nd proximal phalanx (base)		2nd, 4th, and 5th digits: • MCP joints: flexion • Proximal and distal IP joints: extension and adduction toward 3rd digit
	⑩ 2nd	4th metacarpal (radial side)	4th digit (dde) 4th proximal phalanx (base)		
	⑪ 3rd	5th metacarpal (radial side)	5th digit (dde) 5th proximal phalanx (base)		

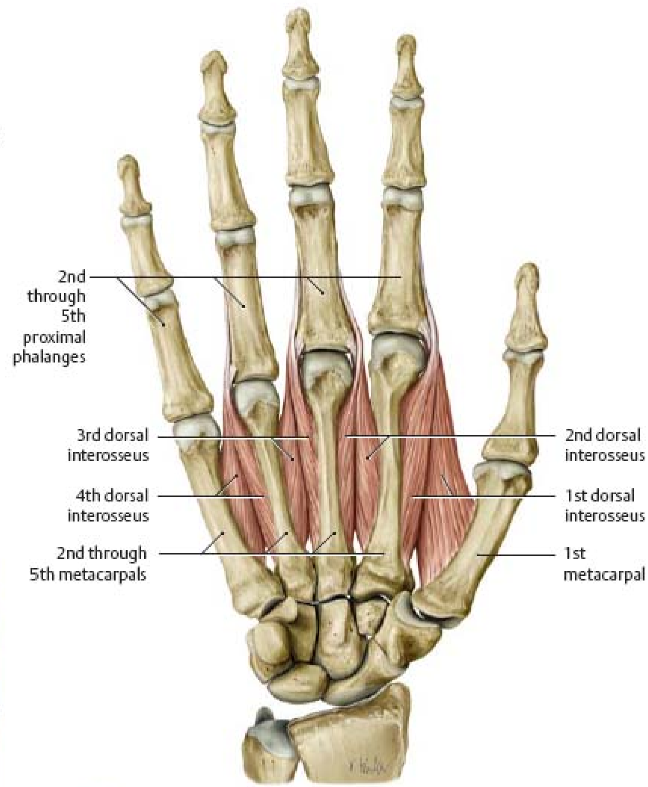
dde = dorsal digital expansion; IP = interphalangeal; MCP = metacarpophalangeal.

Fig. 21.24 **Metacarpal muscles**

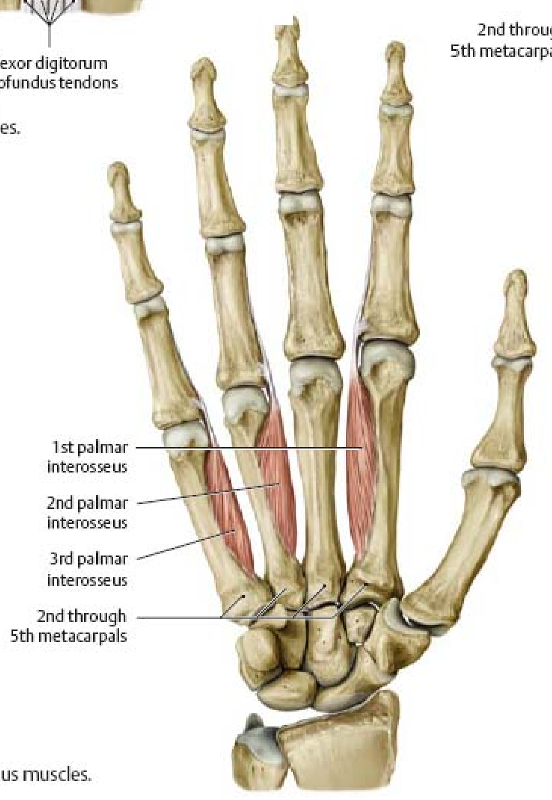
Right hand, palmar (anterior) view.



A Lumbrical muscles.



B Dorsal interosseus muscles.

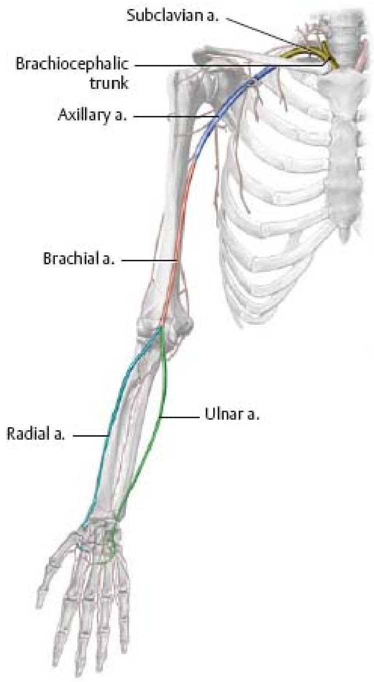


C Palmar interosseus muscles.

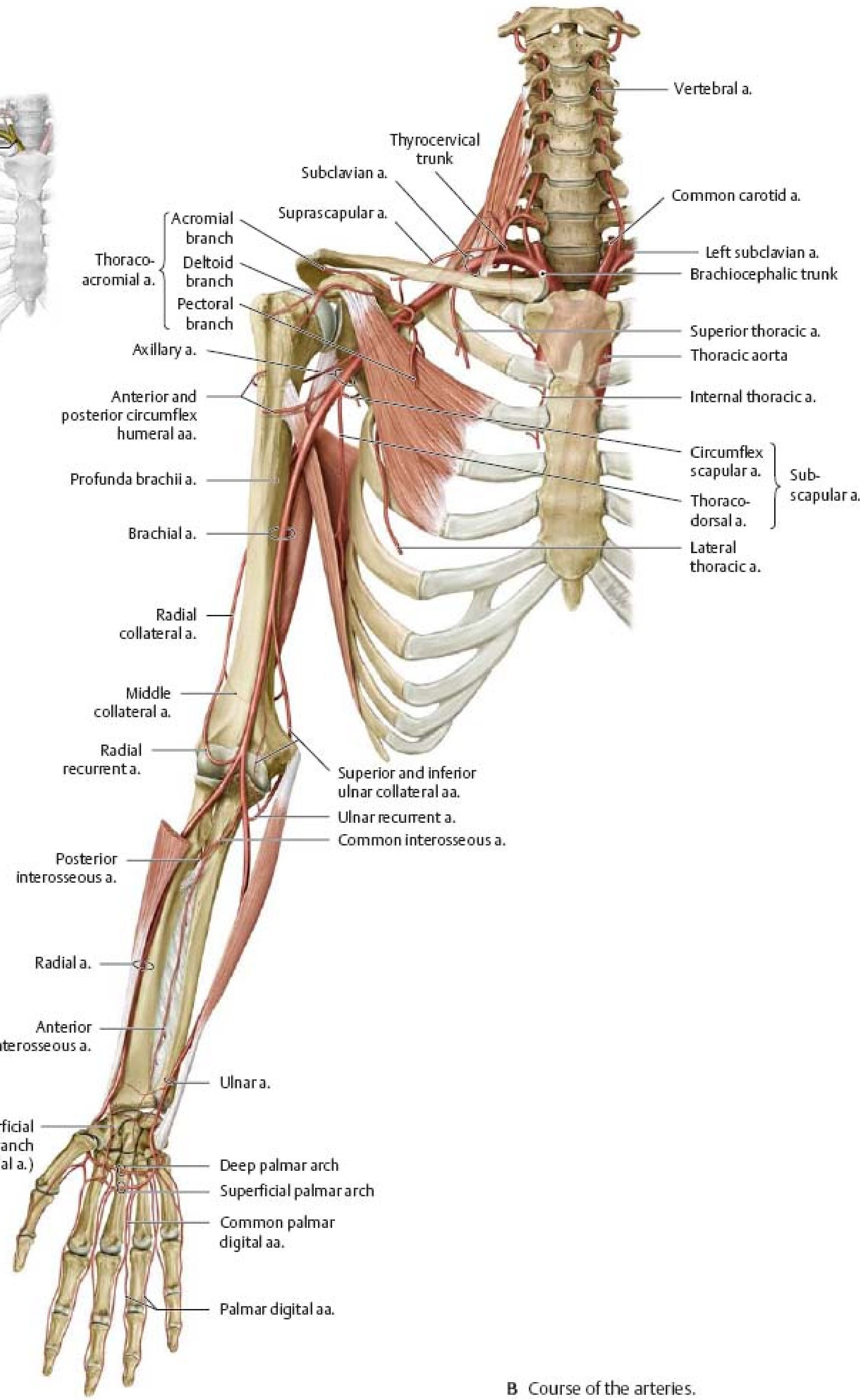
22 Neurovasculature

Arteries of the Upper Limb

Fig. 22.1 **Arteries of the upper limb**
Right side, anterior view.



A Main arterial segments.



B Course of the arteries.

Fig. 22.2 **Branches of the subclavian artery**

Right side, posterior view.

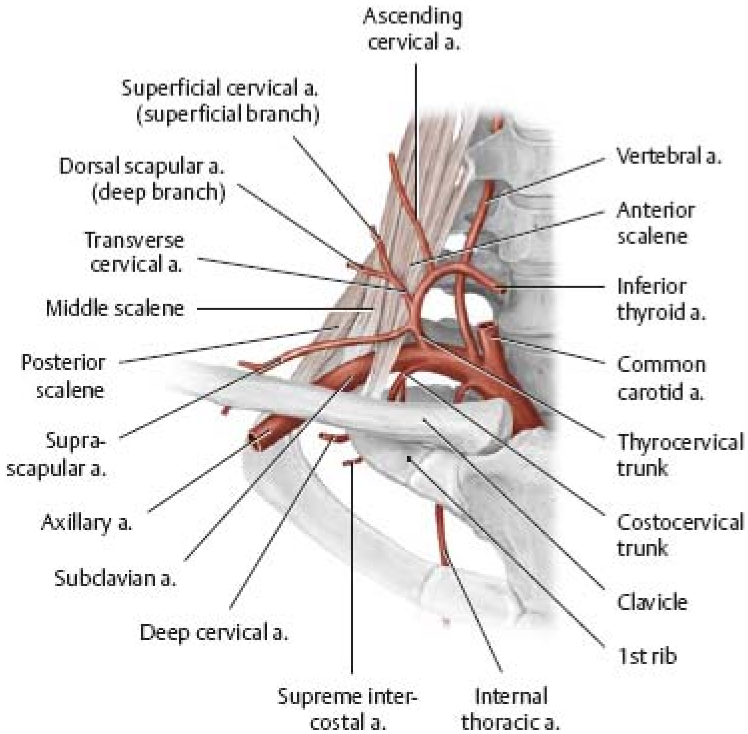


Fig. 22.3 Scapular arcade

Right side, posterior view.

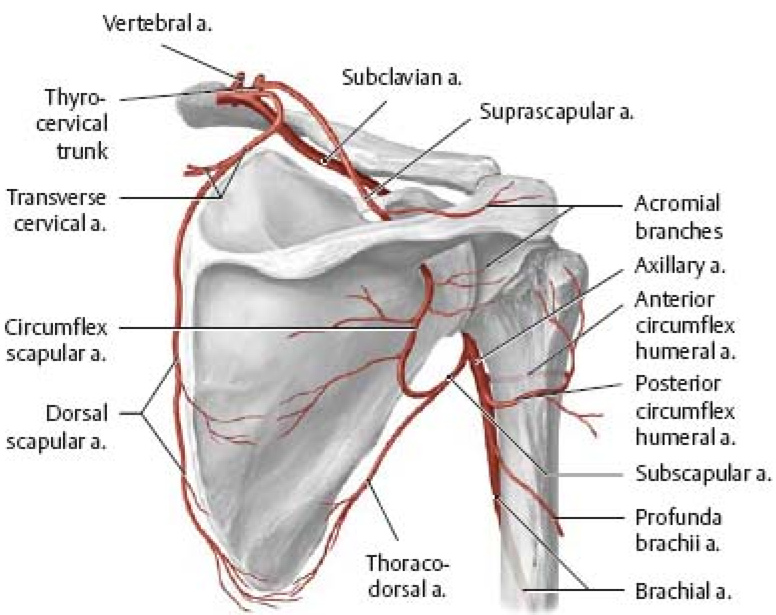
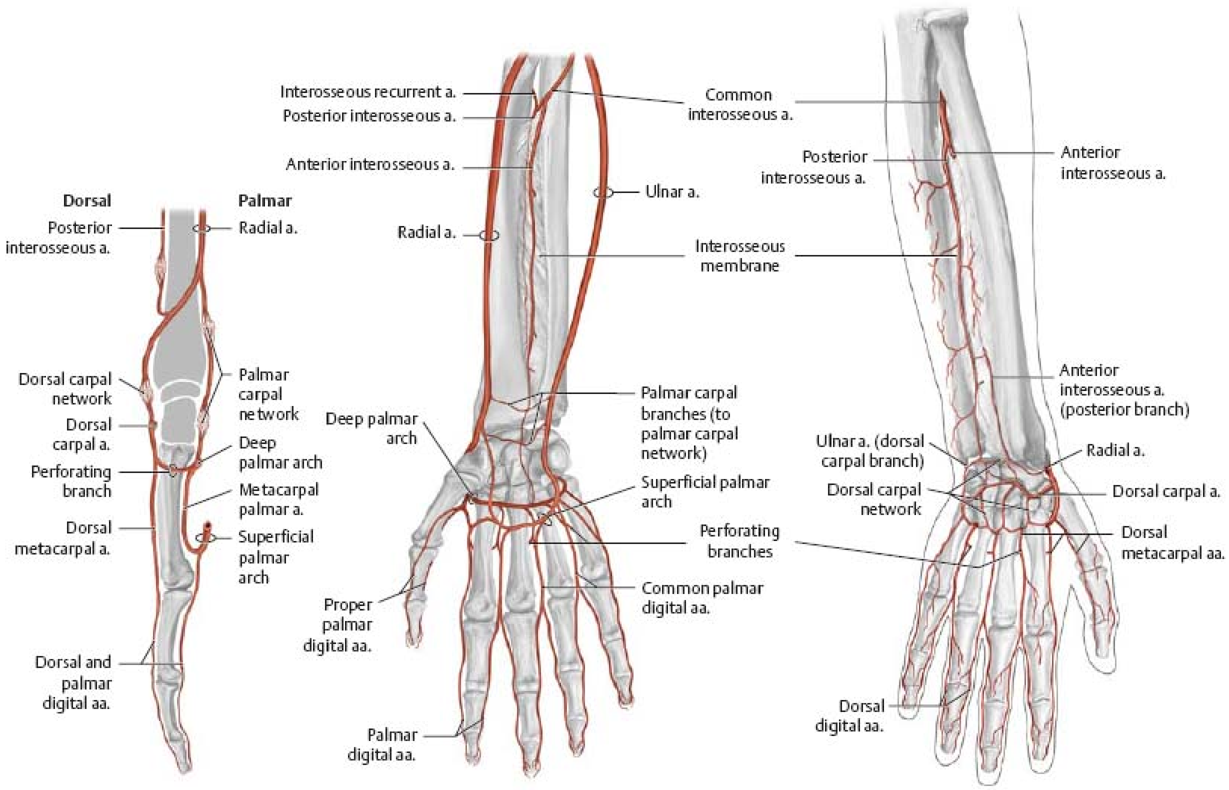


Fig. 22.4 Arteries of the forearm and hand

Right limb. The ulnar and radial arteries are interconnected by the superficial and deep palmar arches, the perforating branches, and the dorsal carpal network.



A Right middle finger, lateral view. B Anterior (palmar) view. C Posterior (dorsal) view.

Veins & Lymphatics of the Upper Limb

Fig. 22.5 Veins of the upper limb

Right limb, anterior view.

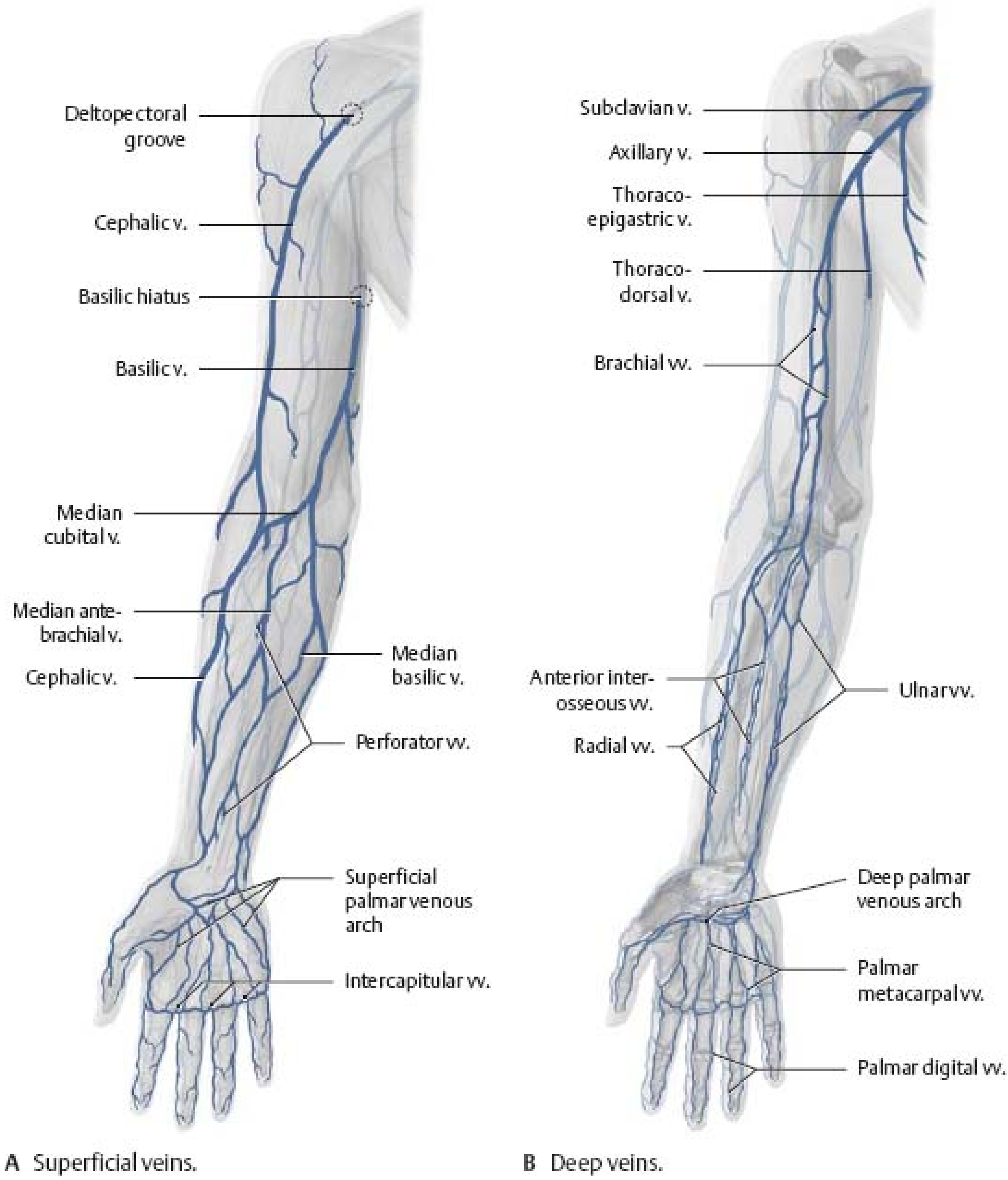


Fig. 22.6 **Veins of the dorsum**

Right hand, posterior view.

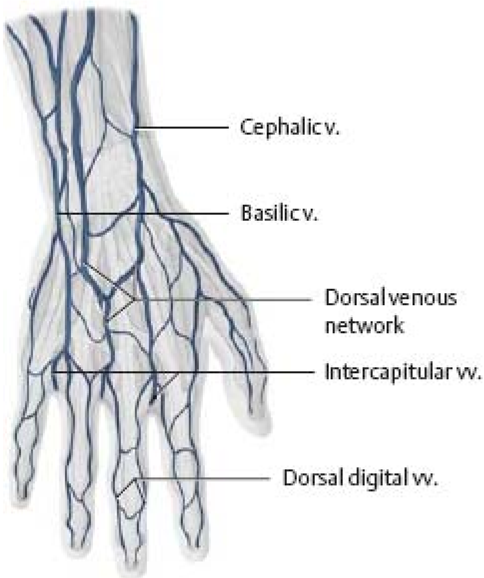
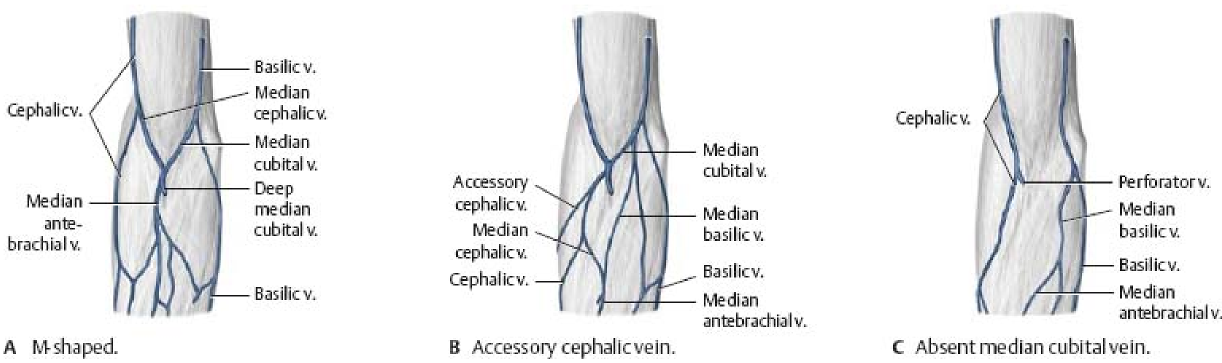


Fig. 22.7 Cubital fossa

Right limb, anterior view. The subcutaneous veins of the cubital fossa have a highly variable course.



Clinical

Venipuncture

The veins of the cubital fossa are frequently used when drawing blood. In preparation, a tourniquet is applied. This allows arterial blood to flow, but blocks the return of venous blood. The resulting swelling makes the veins more visible and palpable.

Lymph from the upper limb and breast drains to the axillary lymph nodes. The superficial lymphatics of the upper limb lie in the subcutaneous tissue, while the deep lymphatics accompany the arteries and deep veins. Numerous anastomoses exist between the two systems.

Fig. 22.8 **Lymph vessels of the upper limb**

Right limb.

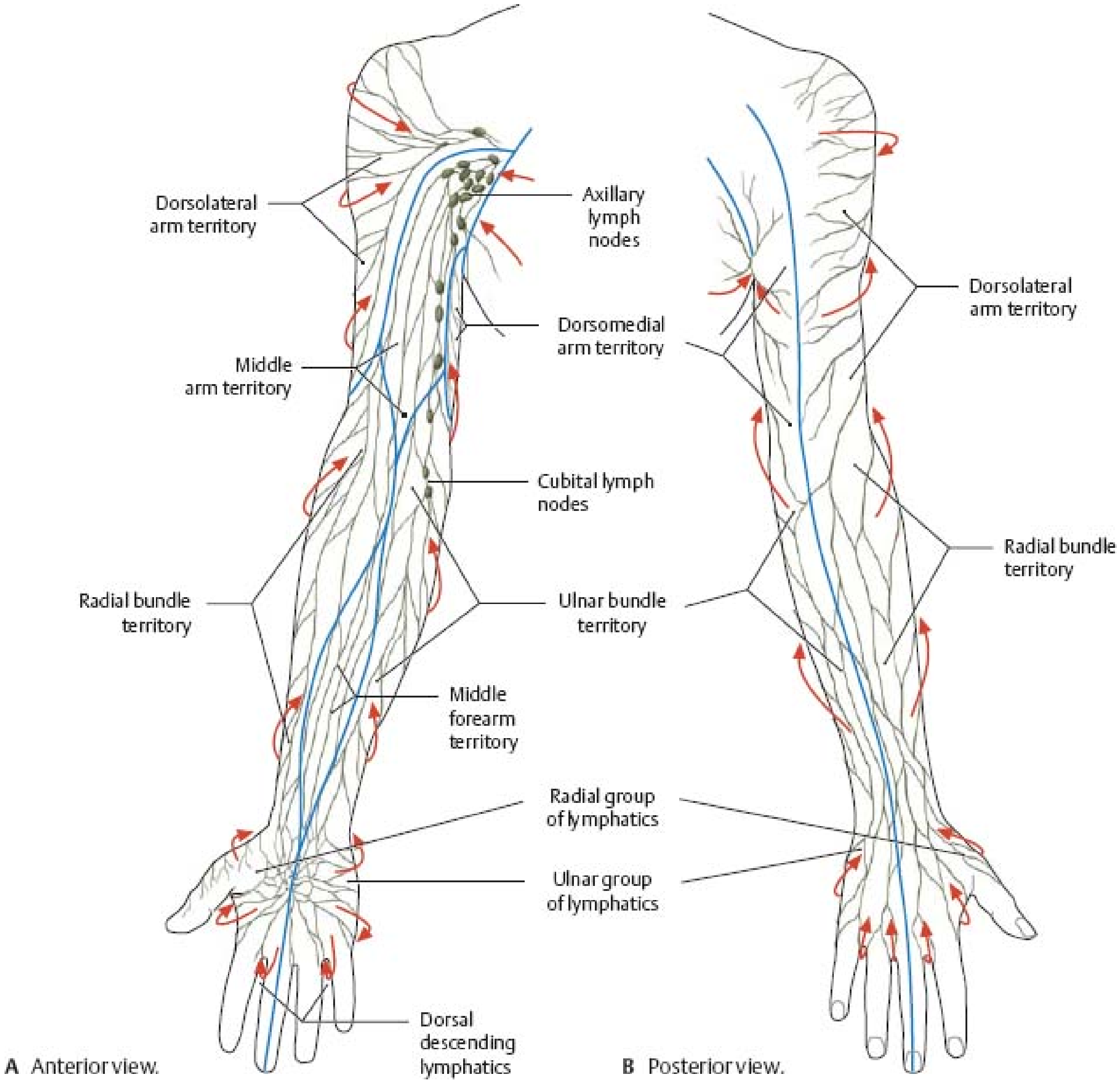


Fig. 22.9 **Lymphatic drainage of the hand**

Right hand, radial view. Most of the hand drains to the axillary nodes via cubital nodes. However, the thumb, index finger, and dorsumofthe hand drain directly.

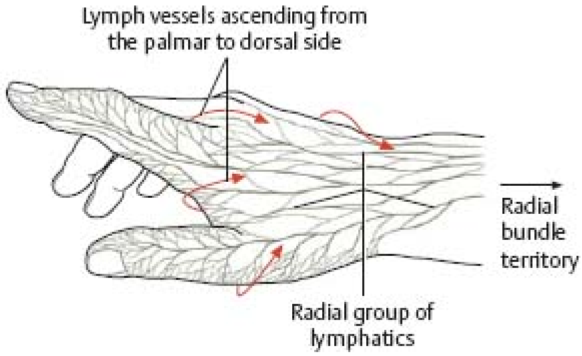
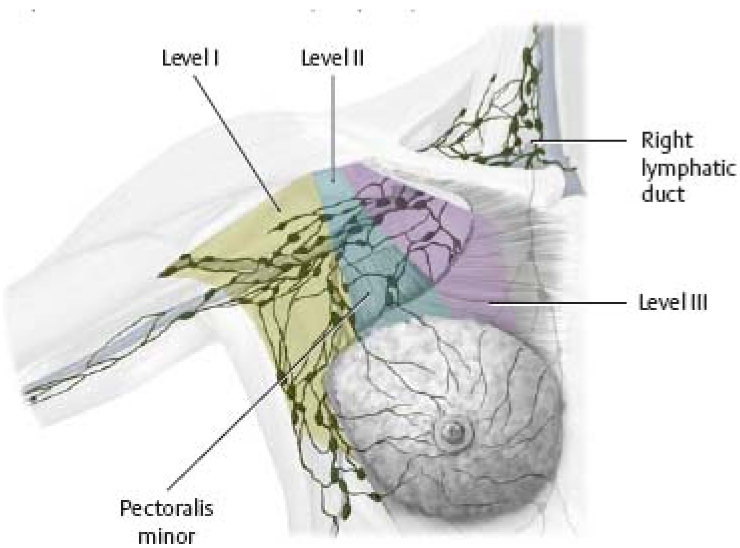


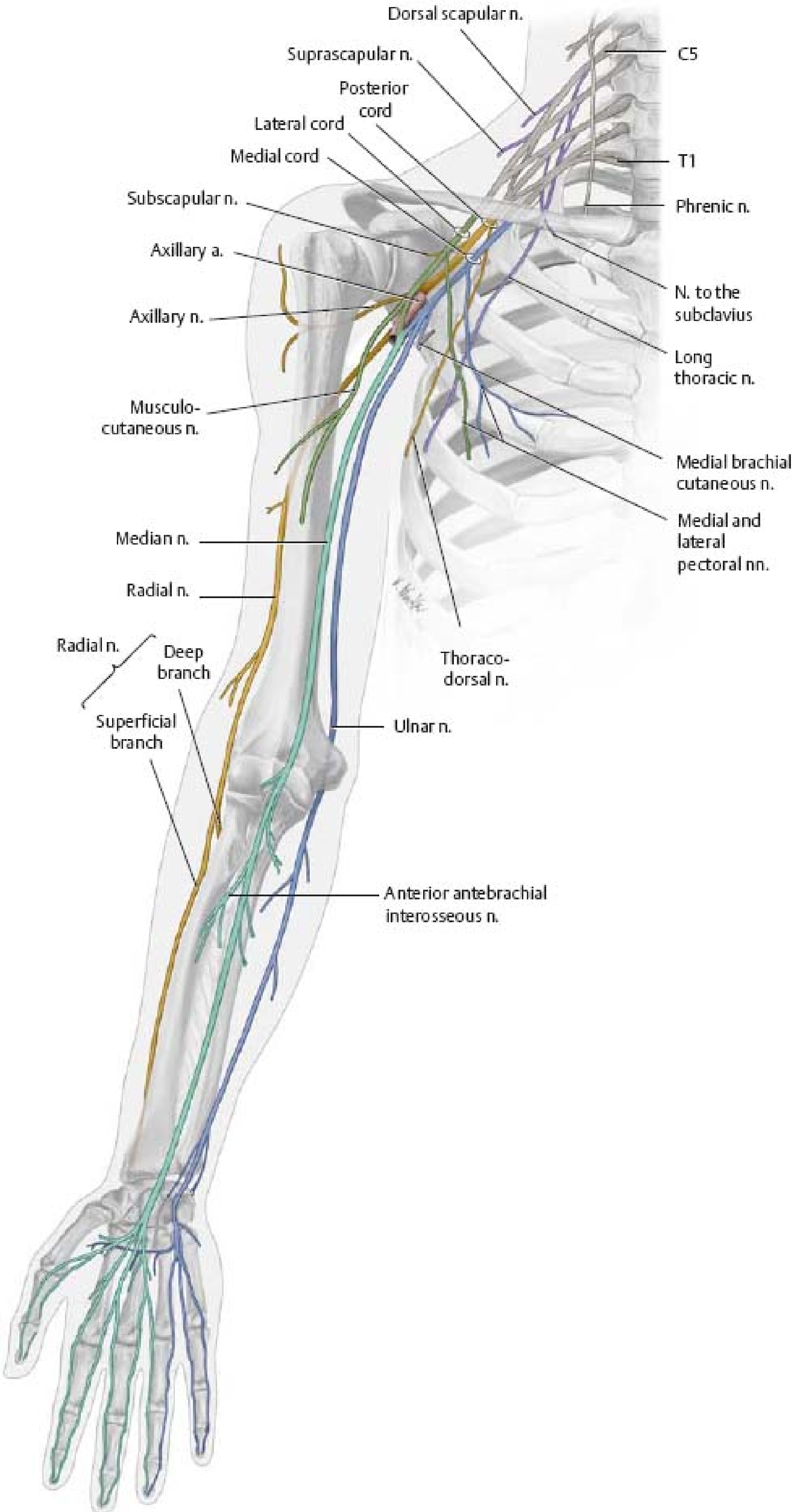
Fig. 22.10 **Axillary lymph nodes**

Right side, anterior view. The axillary lymph nodes are divided into three levels with respect to the pectoralis minor. They have major clinical importance in breast cancer (see p. 65).



Nerves of the Brachial Plexus

Almost all muscles in the upper limb are innervated by the brachial plexus, which arises from spinal cord segments C5 to T1. The anterior rami of the spinal nerves give off direct branches (supraclavicular part of the brachial plexus) and merge to form three trunks, six divisions (three anterior and three posterior), and three cords. The infraclavicular part of the brachial plexus consists of short branches that arise directly from the cords and long (terminal) branches that traverse the limb.



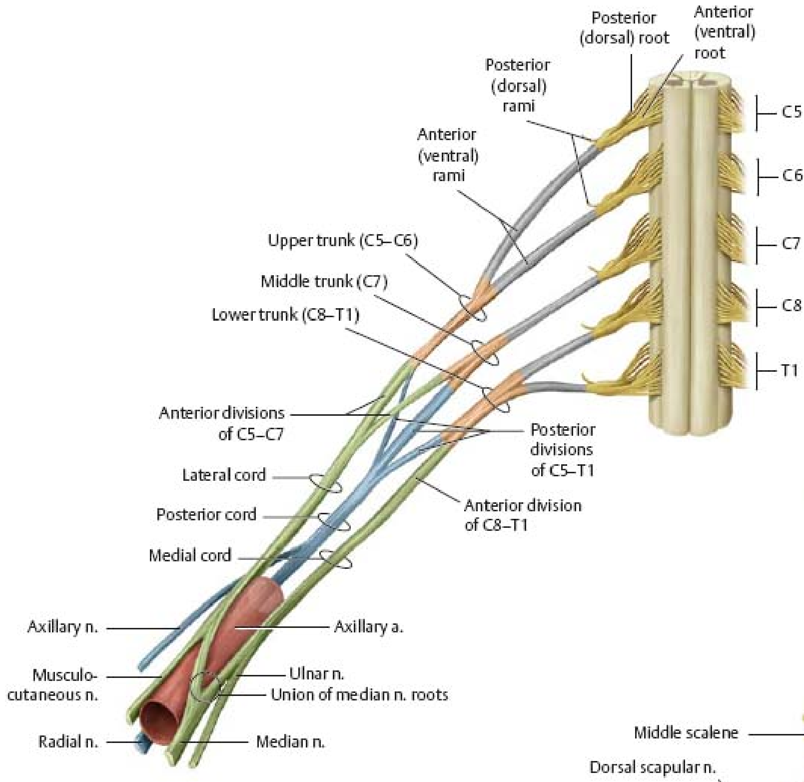
Dorsal scapular n.
Suprascapular n.
C5
Posterior cord
Lateral cord
Medial cord
T1
Subscapular n.
Phrenic n.
Axillary a.
N. to the subclavius
Axillary n.
Long thoracic n.
Musculo-cutaneous n.
Medial brachial cutaneous n.
Medial and lateral pectoral nn.
Median n.
Radial n.
Radial n.
Deep branch
Superficial branch
Thoraco-dorsal n.
Ulnar n.
Anterior antebrachial interosseous n.

Table 22.1 Nerves of the brachial plexus

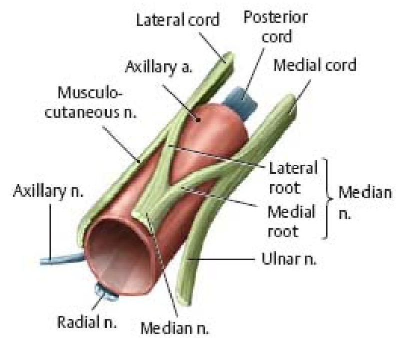
<table>
<tr><th colspan="4">Supraclavicular part</th></tr>
<tr><td colspan="4">Direct branches from the anterior rami or plexus trunks</td></tr>
<tr><td></td><td colspan="2">Dorsal scapular n.</td><td>C4–C5</td></tr>
<tr><td></td><td colspan="2">Suprascapular n.</td><td>C4–C6</td></tr>
<tr><td></td><td colspan="2">N. to the subclavius</td><td>C5–C6</td></tr>
<tr><td></td><td colspan="2">Long thoracic n.</td><td>C5–C7</td></tr>
<tr><th colspan="4">Infraclavicular part</th></tr>
<tr><td colspan="4">Short and long branches from the plexus cords</td></tr>
<tr><td rowspan="3">Lateral cord</td><td colspan="2">Lateral pectoral n.</td><td rowspan="2">C5–C7</td></tr>
<tr><td colspan="2">Musculocutaneous n.</td></tr>
<tr><td rowspan="2">Median n.</td><td>Lateral root</td><td>C6–C7</td></tr>
<tr><td rowspan="5">Medial cord</td><td>Medial root</td><td rowspan="3">C8–T1</td></tr>
<tr><td colspan="2">Medial pectoral n.</td></tr>
<tr><td colspan="2">Median antebrachial cutaneous n.</td></tr>
<tr><td colspan="2">Medial brachial cutaneous n.</td><td>T1</td></tr>
<tr><td colspan="2">Ulnar n.</td><td>C7–T1</td></tr>
<tr><td rowspan="5">Posterior cord</td><td colspan="2">Upper subscapular n.</td><td>C5–C6</td></tr>
<tr><td colspan="2">Thoracodorsal n.</td><td>C6–C8</td></tr>
<tr><td colspan="2">Lower subscapular n.</td><td rowspan="2">C5–C6</td></tr>
<tr><td colspan="2">Axillary n.</td></tr>
<tr><td colspan="2">Radial n.</td><td>C5–T1</td></tr>
</table>

Fig. 22.11 **Brachial plexus**

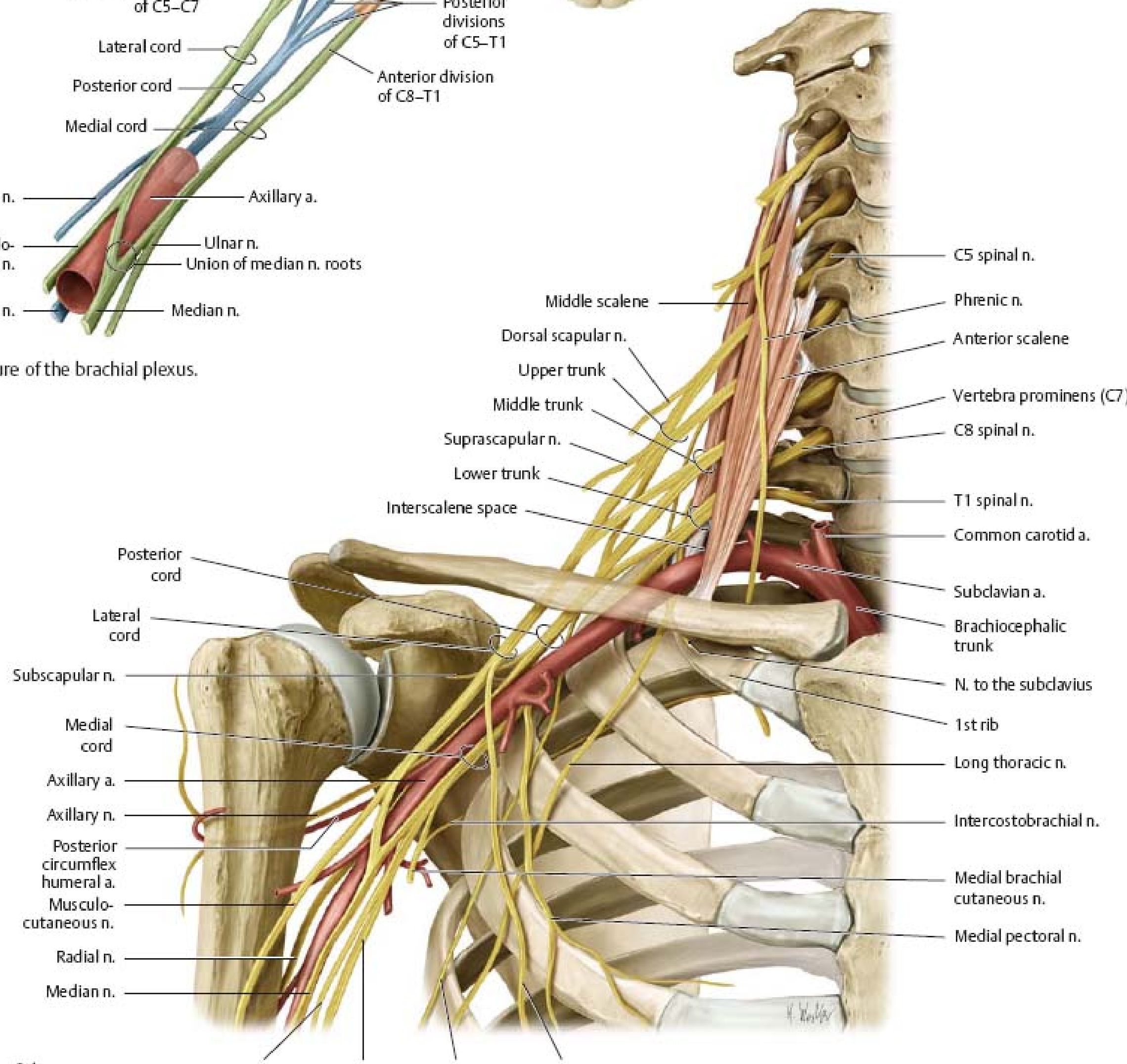
Right side, anterior view.



A Structure of the brachial plexus.



B Division of the cords into terminal branches.

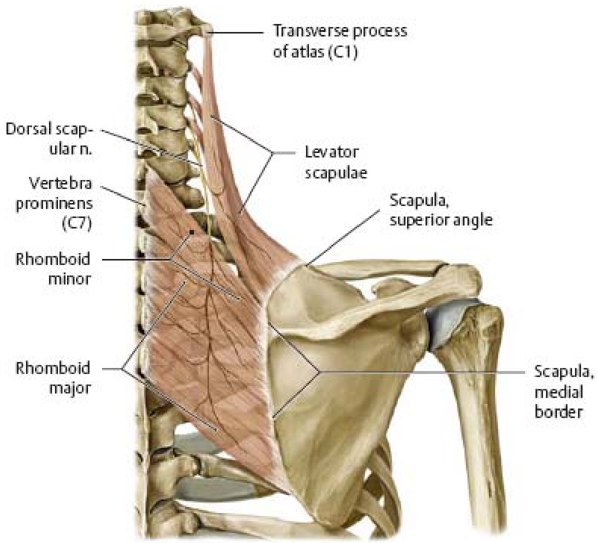


C Course of the brachial plexus.

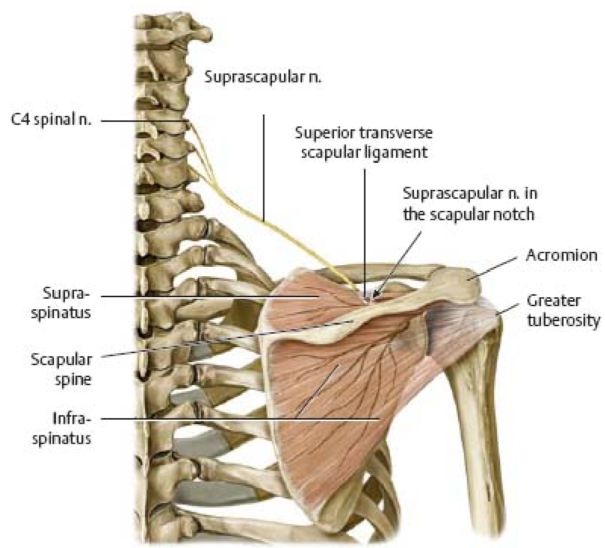
Supraclavicular Branches & Posterior Cord

Fig. 22.12 **Supraclavicular branches**

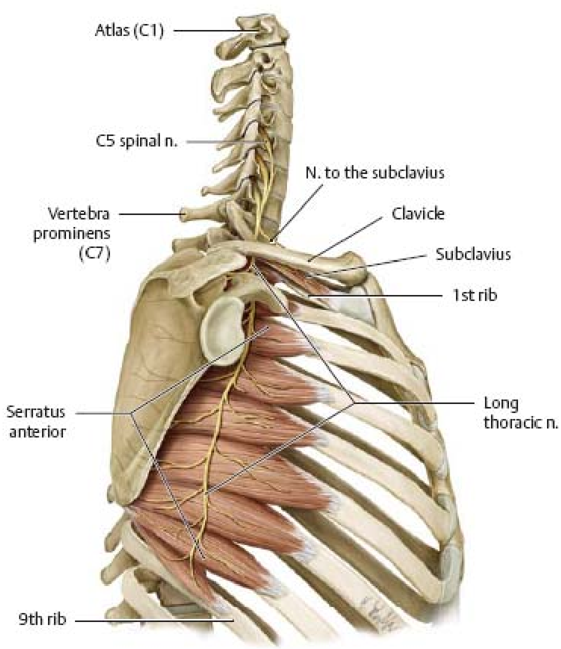
Right shoulder.



A Dorsal scapular nerve. Posterior view.



B Suprascapular nerve. Posterior view.



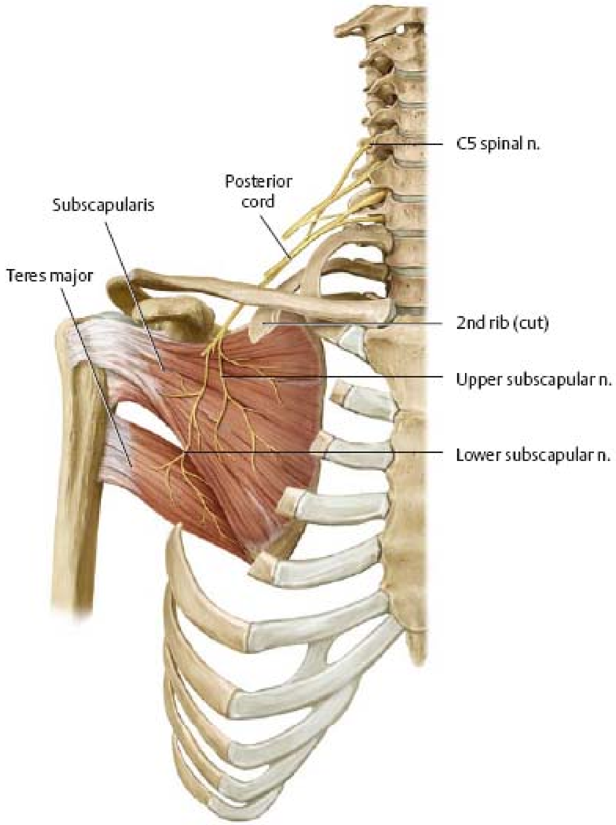
C Long thoracic nerve and nerve to the subclavius. Right lateral view.

The supraclavicular branches of the brachial plexus arise directly from the plexus roots (anterior rami of the spinal nerves) orfrom the plexus trunks in the lateral cervical triangle.

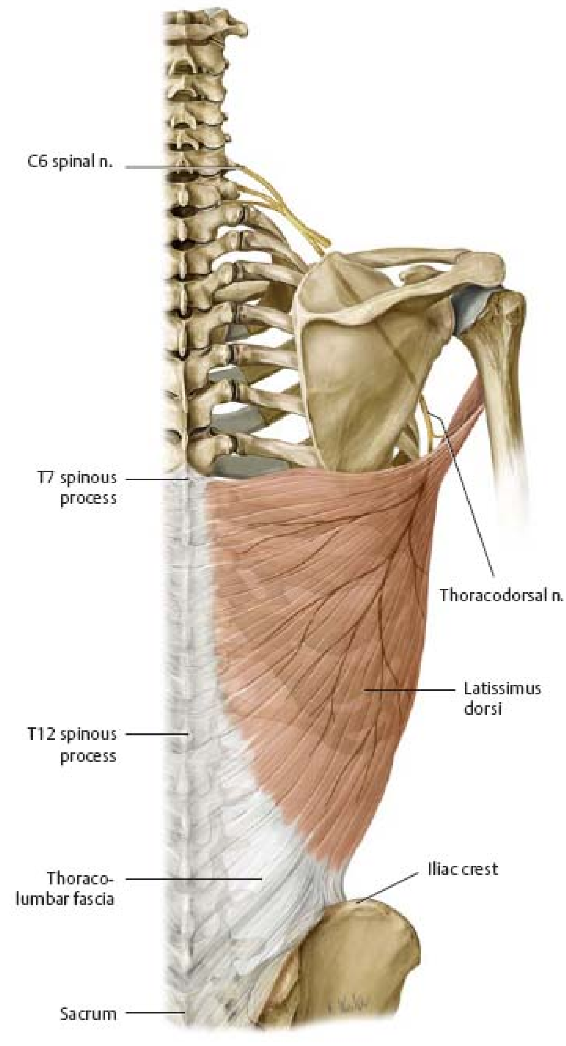
Table 22.2 **Supraclavicular branches**		
Nerve	**Level**	**Innervated muscle**
Dorsal scapular n.	C4–C5	Levator scapulae Rhomboids major and minor
Suprascapular n.	C4–C6	Supraspinatus Infraspinatus
Nerve to the subclavius	C5–C6	Subclavius Intercostobrachial nn.
Long thoracic n.	C5–C7	Serratus anterior

Fig. 22.13 Posterior cord: Short branches

Right shoulder.



A Subscapular nerves. Anterior view.



B Thoracodorsal nerve. Posterior view.

The posterior cord gives off three short branches (arising at the level of the plexus cords) and two long branches (terminal nerves, see pp. 324–325).

Table 22.3 **Branches of the posterior cord**

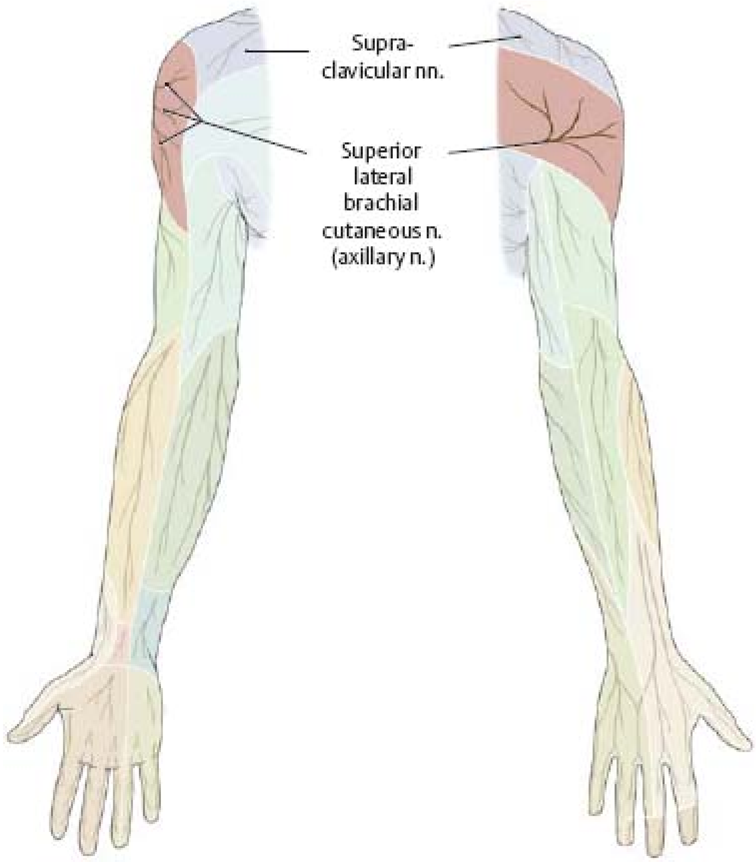
Nerve	Level	Innervated muscle

<table>
<tr><th>Nerve</th><th>Level</th><th>Innervated muscle</th></tr>
<tr><td colspan="3">Short branches</td></tr>
<tr><td>Upper subscapular n.</td><td rowspan="2">C5–C6</td><td>Subscapularis</td></tr>
<tr><td>Lower subscapular n.</td><td>Subscapularis Teres major</td></tr>
<tr><td>Thoracodorsal n.</td><td>C6–C8</td><td>Latissimus dorsi</td></tr>
<tr><td colspan="3">Long (terminal) branches</td></tr>
<tr><td>Axillary n.</td><td>C5–C6</td><td>See p. 324</td></tr>
<tr><td>Radial n.</td><td>C5–T1</td><td>See p. 325</td></tr>
</table>

Posterior Cord: Axillary & Radial Nerves

Fig. 22.14 Axillary nerve: Sensory distribution

Right limb.



A Anterior view.

B Posterior view.

Clinical

The axillary nerve may be damaged in a fracture of the proximal humerus. This results in limited ability to abduct the arm, and may cause a loss of profile of the shoulder.

Fig. 22.15 Axillary nerve

Right side, anterior view.

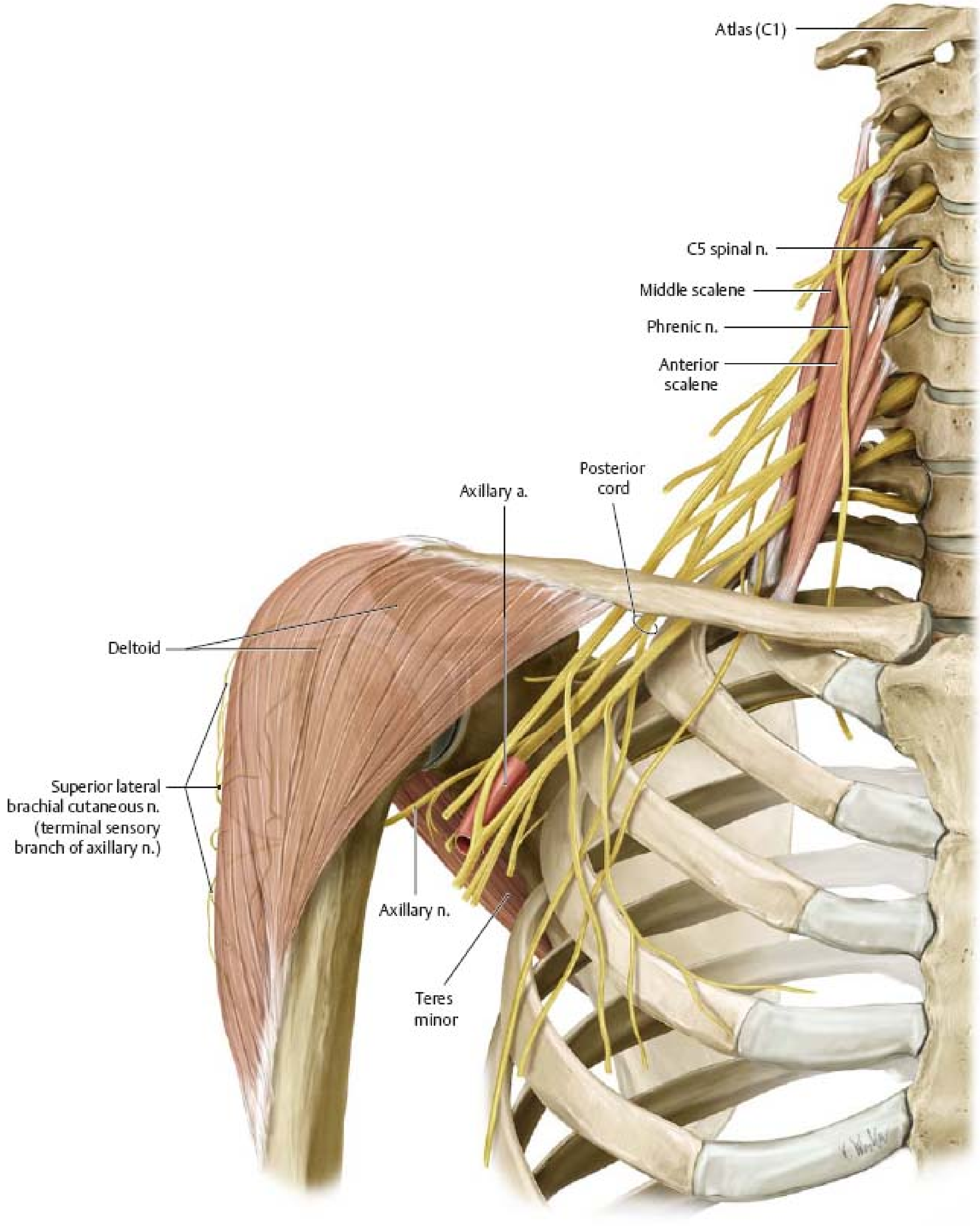
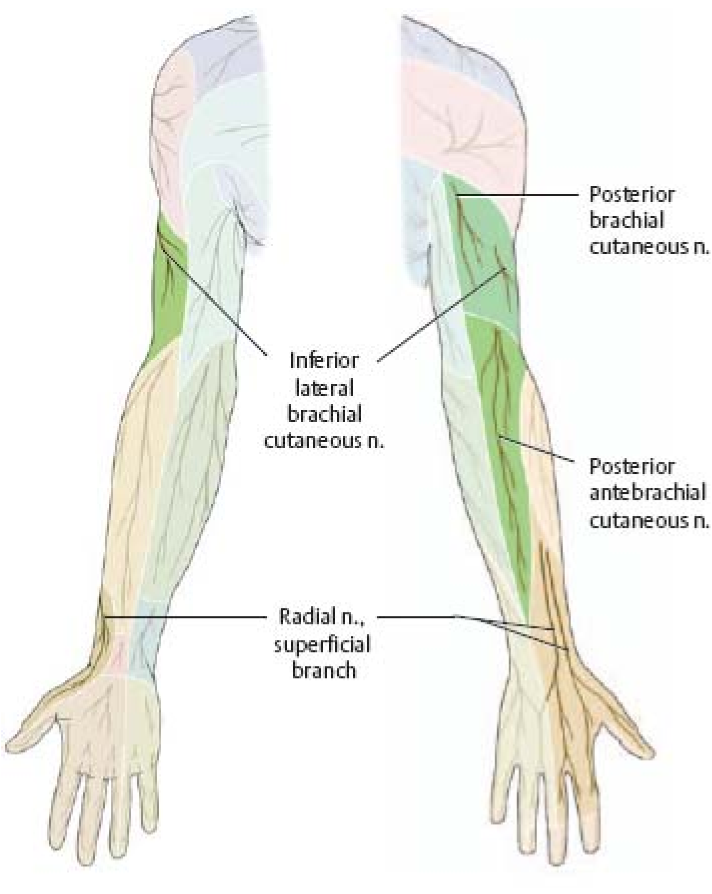


Table 22.4 **Axillary nerve (C5–C6)**	
Motor branches	**Innervated muscles**

Motor branches	**Innervated muscles**
Muscular branches	Deltoid Teres minor
Sensory branch	
Superior lateral cutaneous n.	

Fig. 22.16 Radial nerve: Sensory distribution



A Anterior view. **B** Posterior view.

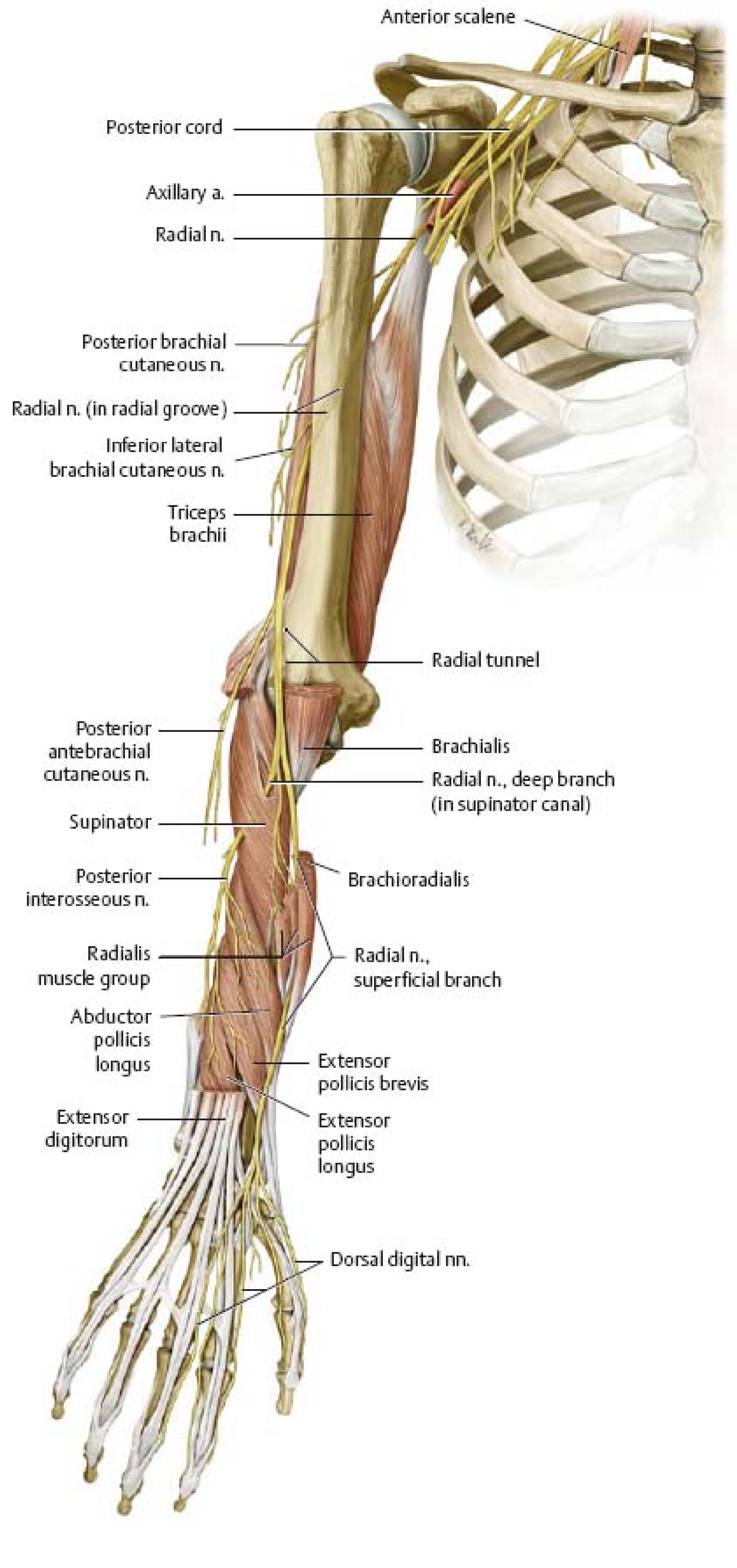
Table 22.5 **Radial nerve (C5–T1)**

Motor branches	**Innervated muscles**
Muscular branches	Brachialis (partial)
	Triceps brachii

Motor branches	**Innervated muscles**
	Anconeus
	Brachioradialis
	Extensors carpi radialis longus and brevis
Deep branch (terminal branch: posterior interosseous n.)	Supinator
	Extensor digitorum
	Extensor digiti minimi
	Extensor carpi ulnaris
	Extensors pollicis brevis and longus
	Extensor indicis
	Abductor pollicis longus
Sensory branches	
Articular branches from radial n.: Capsule of the shoulder joint	
Articular branches from posterior interosseousn.: Joint capsule of the wrist and four radial metacarpophalangeal joints	
Posterior brachial cutaneous n.	
Inferior lateral brachial cutaneous n.	
Posterior antebrachial cutaneous n.	
Superficial branches	Dorsal digital nn.
	Ulnar communicating branch

***Fig. 22.17* Radial nerve**

Right limb, anteriorviewwith forearm pronated.


Anterior scalene
Posterior cord
Axillary a.
Radial n.
Posterior brachial cutaneous n.
Radial n. (in radial groove)
Inferior lateral brachial cutaneous n.
Triceps brachii
Radial tunnel
Posterior antebrachial cutaneous n.
Brachialis
Radial n., deep branch (in supinator canal)
Supinator
Brachioradialis
Posterior interosseous n.
Radialis muscle group
Radial n., superficial branch
Abductor pollicis longus
Extensor pollicis brevis
Extensor digitorum
Extensor pollicis longus
Dorsal digital nn.

Clinical

Chronic radial nerve compression in the axilla (e.g., due to extended/ improper crutch use) may cause loss of sensation or motor function in the hand, forearm, and posterior arm. More distal injuries (e.g., during anesthesia) affect fewer muscles, potentially resulting in wrist drop with intact triceps brachii function.

Medial & Lateral Cords

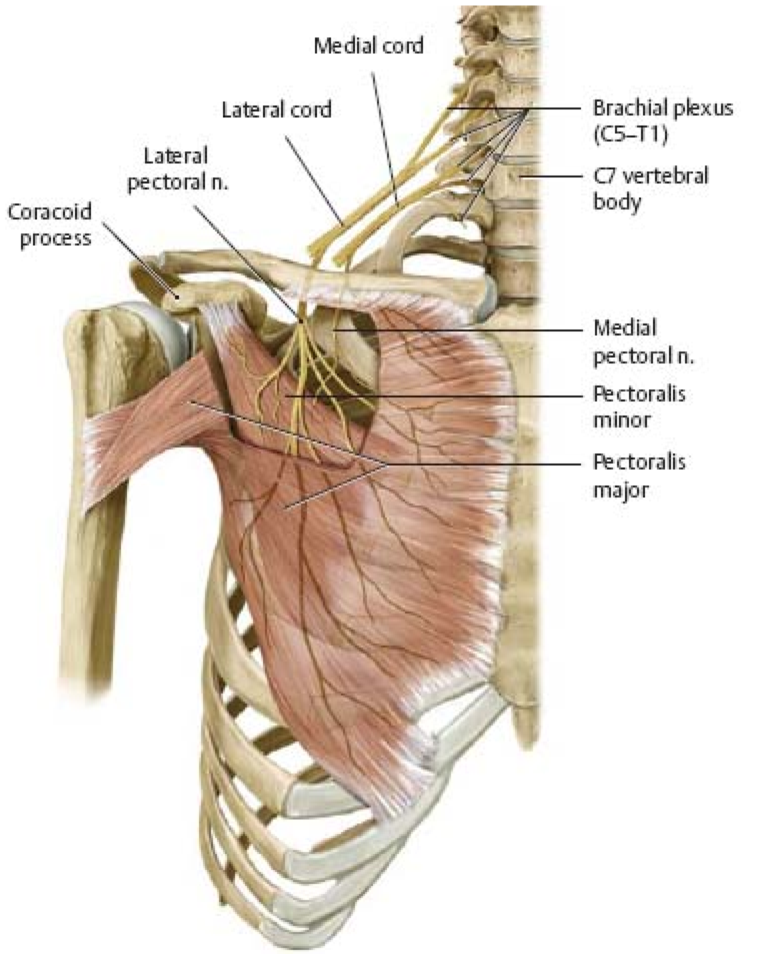
The medial and lateral cords give off four short branches. The intercostobrachial nerves are included with the short branches of the brachial plexus, although they are actually the cutaneous branches of the 2nd and 3rd intercostal nerves.

Table 22.6 Branches of the medial and lateral cords

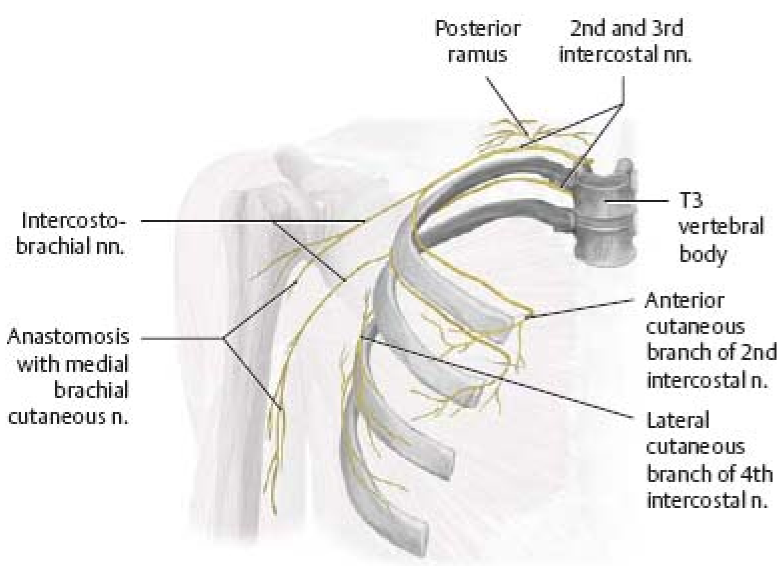
Nerve	Level	Cord	Innervated muscle
Short branches			
Lateral pectoral n.	C5–C7	Lateral cord	Pectoralis major
Medial pectoral n.	C8–T1	Medial cord	Pectoralis major and minor
Medial brachial cutaneous n.	T1		— (sensory branches)
Medial antebrachial cutaneous n.	C8–T1		
Intercostobrachial nn.	T2–T3		
Long (terminal) branches			
Musculocutaneous n.	C5–C7	Lateral cord	Coracobrachialis Biceps brachii Brachialis
Median n.	C6–T1		See p. 328
Ulnar n.	C7–T1	Medial cord	See p. 329

Fig. 22.18 **Medial and lateral cords: Short branches**

Right side, anterior view.



A Medial and lateral pectoral nerves.



B Intercostobrachial nerves.

Fig. 22.19 Short branches: Sensory distribution

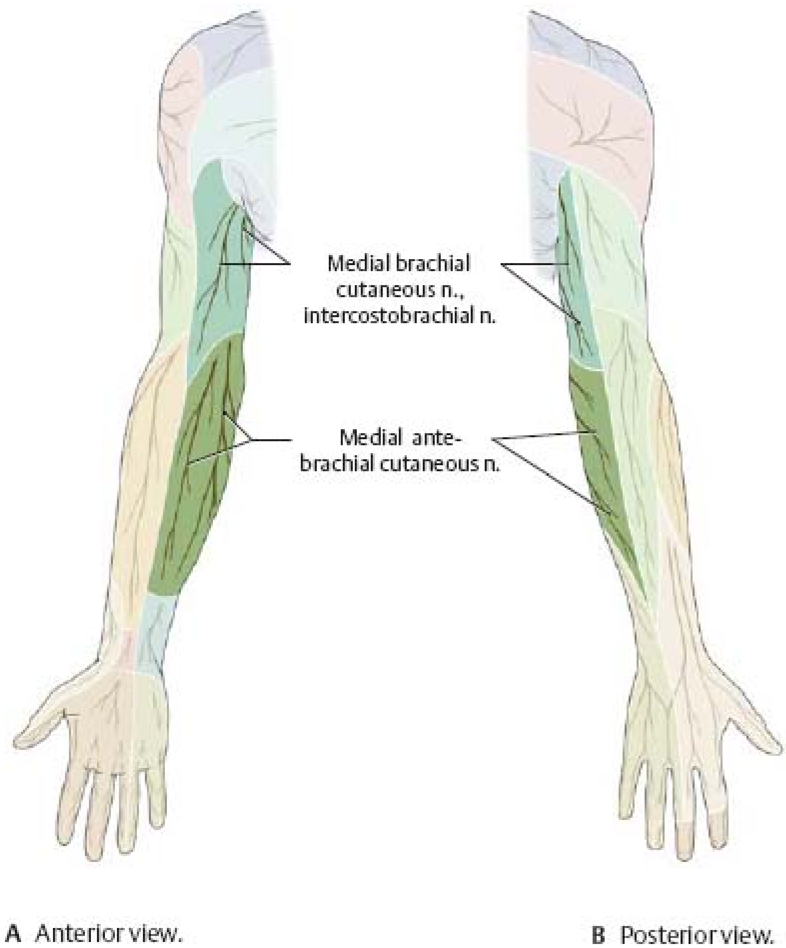


Fig. 22.20 Musculocutaneous nerve

Right limb, anterior view.

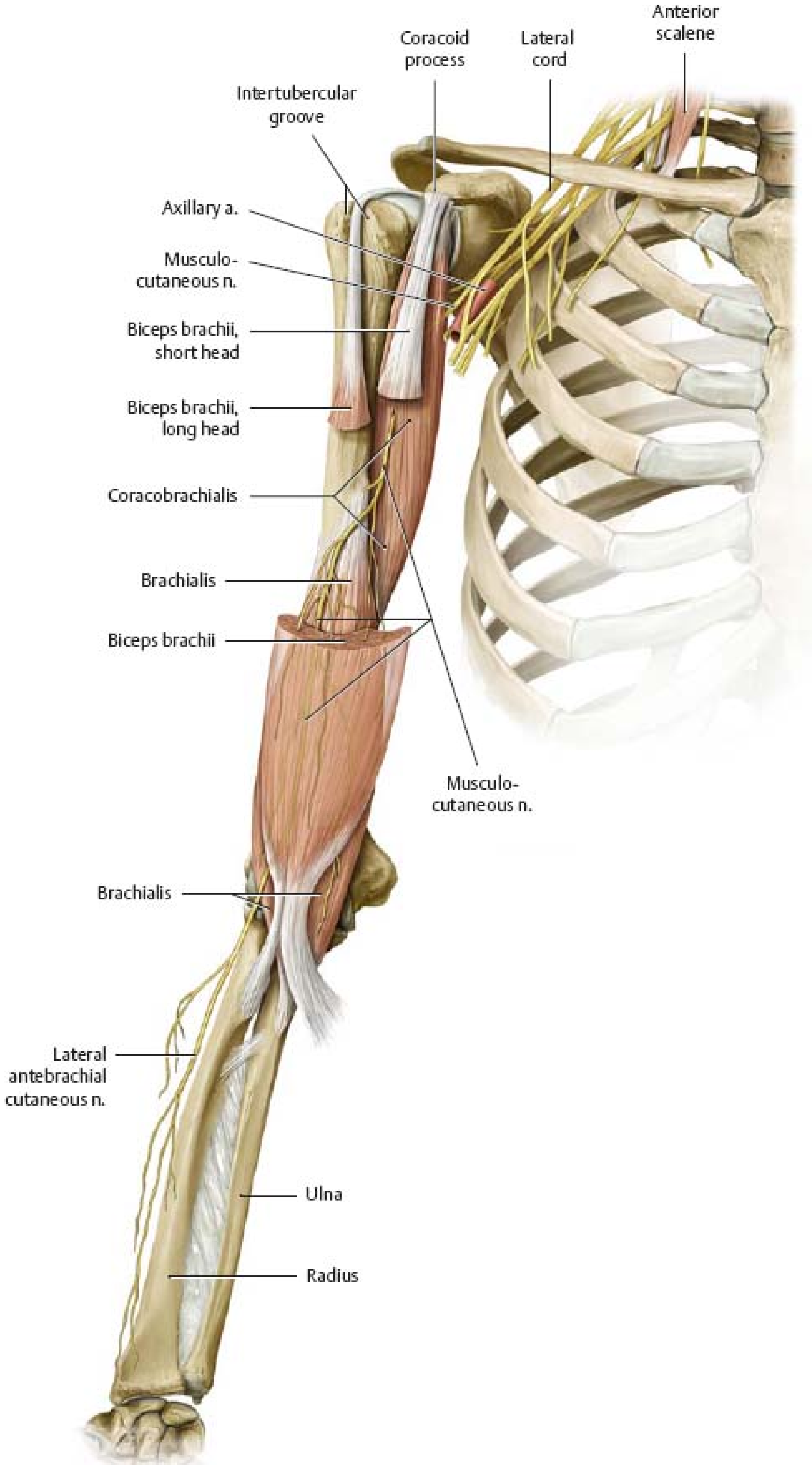
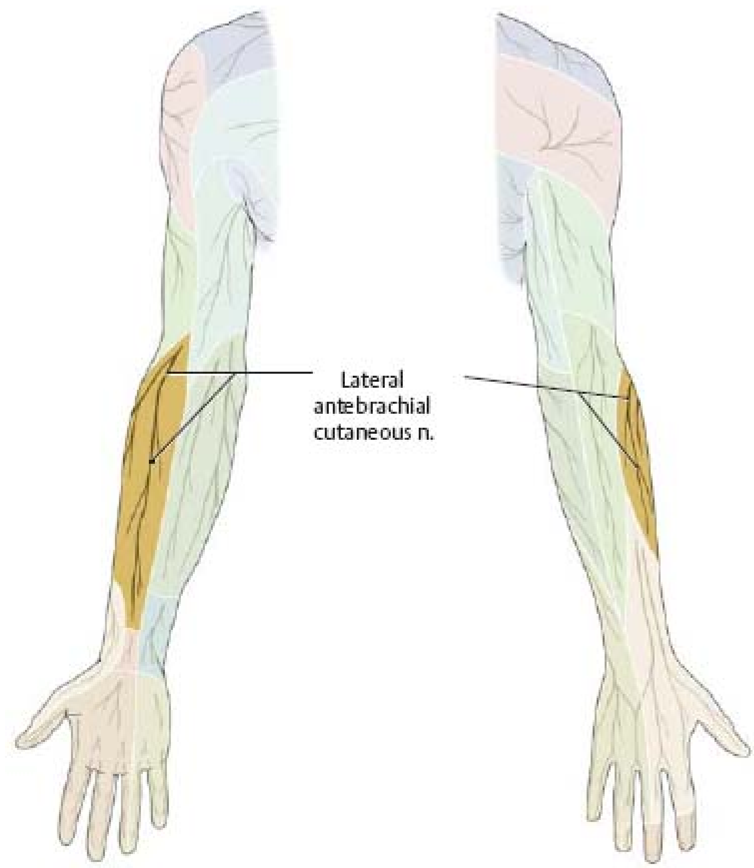

Anterior scalene
Coracoid process
Lateral cord
Intertubercular groove
Axillary a.
Musculo-cutaneous n.
Biceps brachii, short head
Biceps brachii, long head
Coracobrachialis
Brachialis
Biceps brachii
Musculo-cutaneous n.
Brachialis
Lateral antebrachial cutaneous n.
Ulna
Radius

Table 22.7 **Musculocutaneous nerve(C5–C7)**

Motor branches	**Innervated muscles**
Muscular branches	Coracobrachialis
	Biceps brachii
	Brachialis
Sensory branches	
Lateral antebrachial cutaneous n.	
Articular branches: Joint capsule of the elbow (anterior part)	
Note: Musculocutaneous nerve innervation of the arm is purely motor; innervation of the forearm is purely sensory.	

Fig. 22.21 **Musculocutaneous nerve: Sensory distribution**



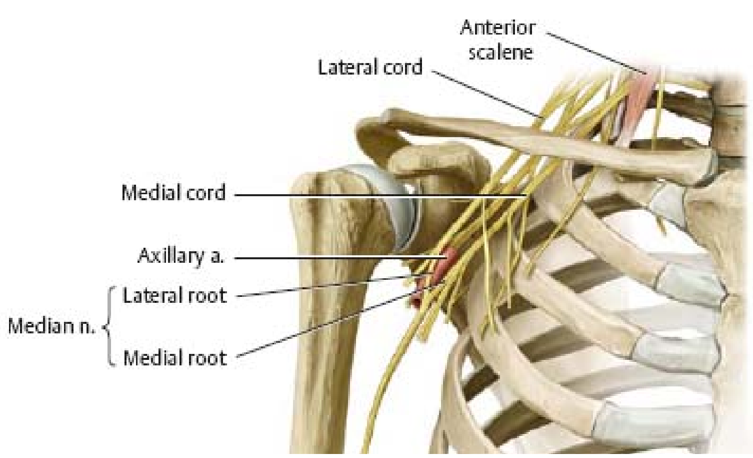
A Anterior view. B Posterior view.

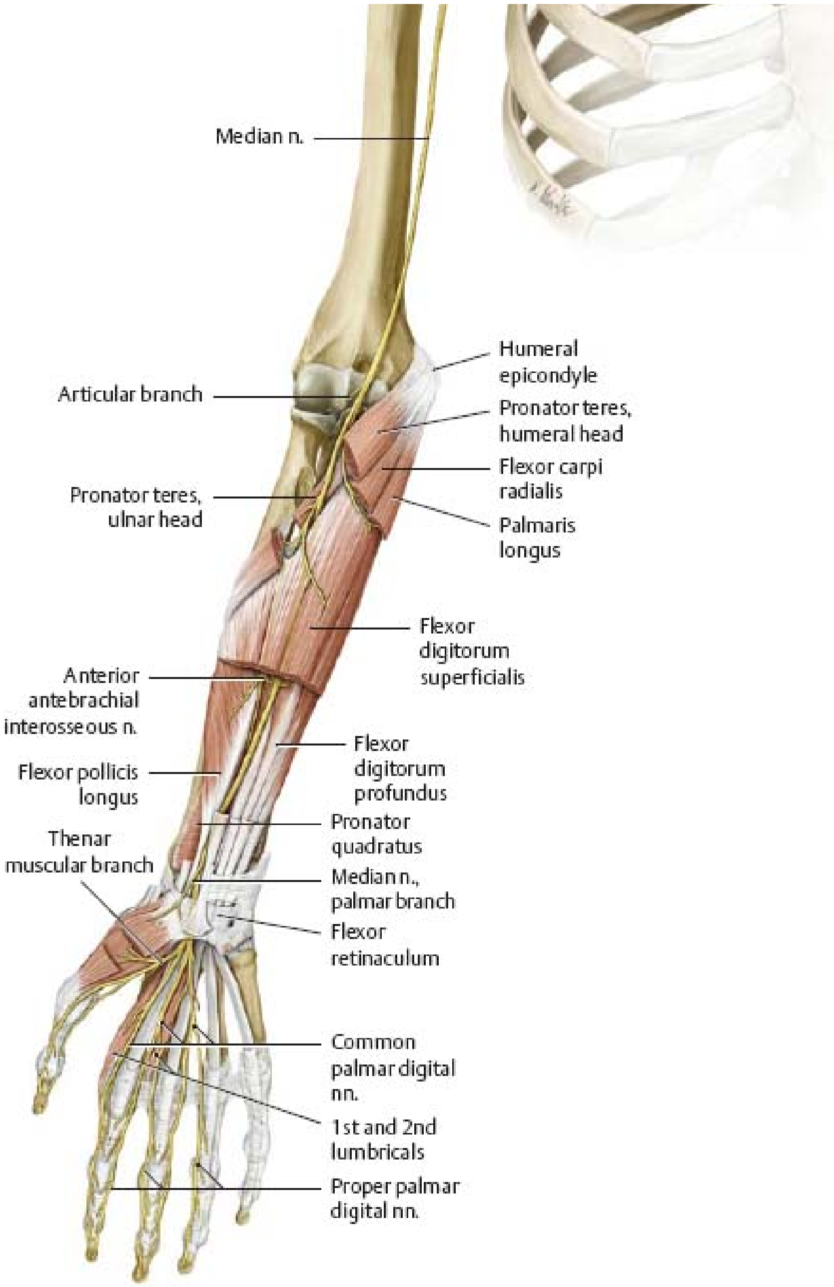
Median & Ulnar Nerves

The median nerve is a terminal branch arising from both the medial and lateral cords. The ulnar nerve arises exclusively from the medial cord.

Fig. 22.22 Median nerve

Right limb, anterior view.

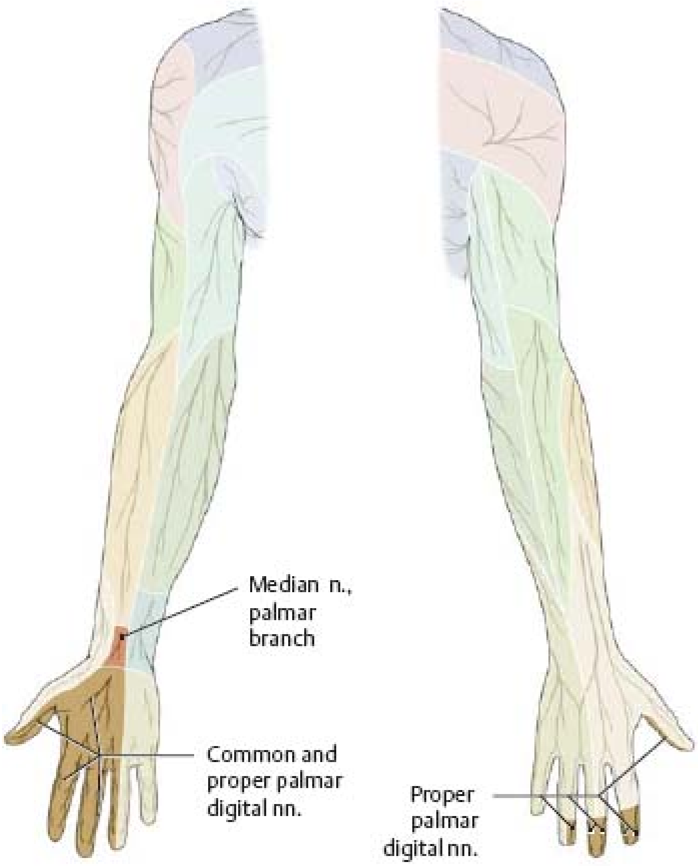




Clinical

Median nerve injury caused by fracture/ dislocation of the elbow joint may result in compromised grasping ability and sensory loss in the fingertips (see Fig. 22.23 forterritories). See also carpal tunnel syndrome (p. 343).

Fig. 22.23 Median nerve: Sensory distribution



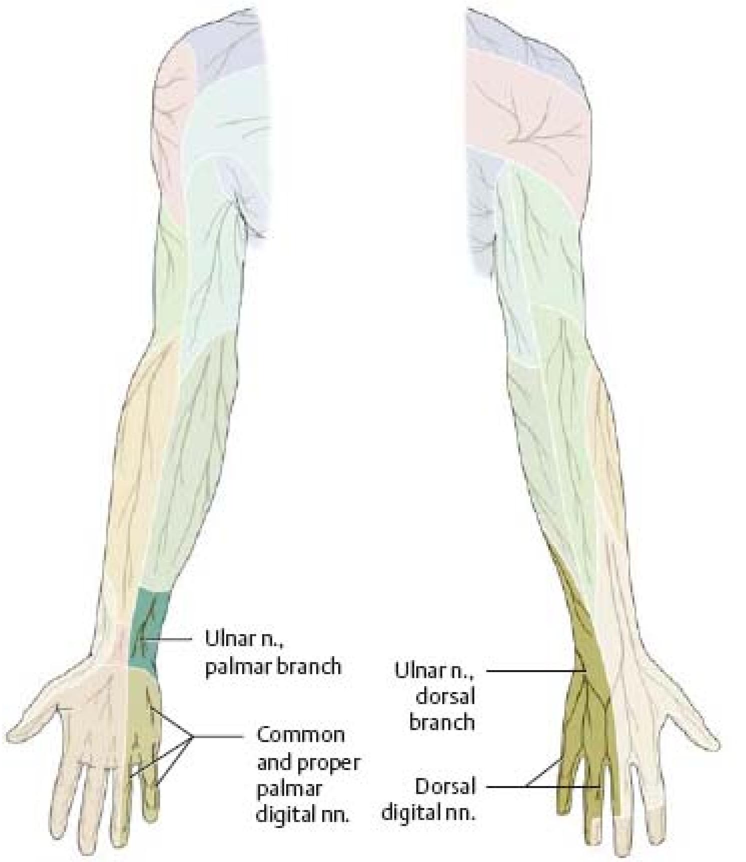
A Anterior view. **B** Posterior view.

Table 22.8 **Median nerve (C6–T1)**

Motor branches	**Innervated muscles**
Direct muscular branches	Pronator teres
	Flexor carpi radialis
	Palmaris longus
	Flexor digitorum superficialis
Muscular branches Pronator from anterior antebrachial Interosseous n.	Pronator quadratus
	Flexor pollicis longus

Motor branches	Innervated muscles
	Flexor digitorum profundus (radial half)
Thenar muscular branch	Abductor pollicis brevis
	Flexor pollicis brevis (superficial head)
	Opponens pollicis
Muscular branches from common palmar digital nn.	1st and 2nd lumbricals
Sensory branches	
Articular branches: Capsules of the elbow and wrist joints	
Palmar branch of median n. (thenar eminence)	
Communicating branch to ulnar n.	
Common palmar digital nn.	

Fig. 22.24 **Ulnar nerve: Sensory distribution**



A Anterior view. B Posterior view.

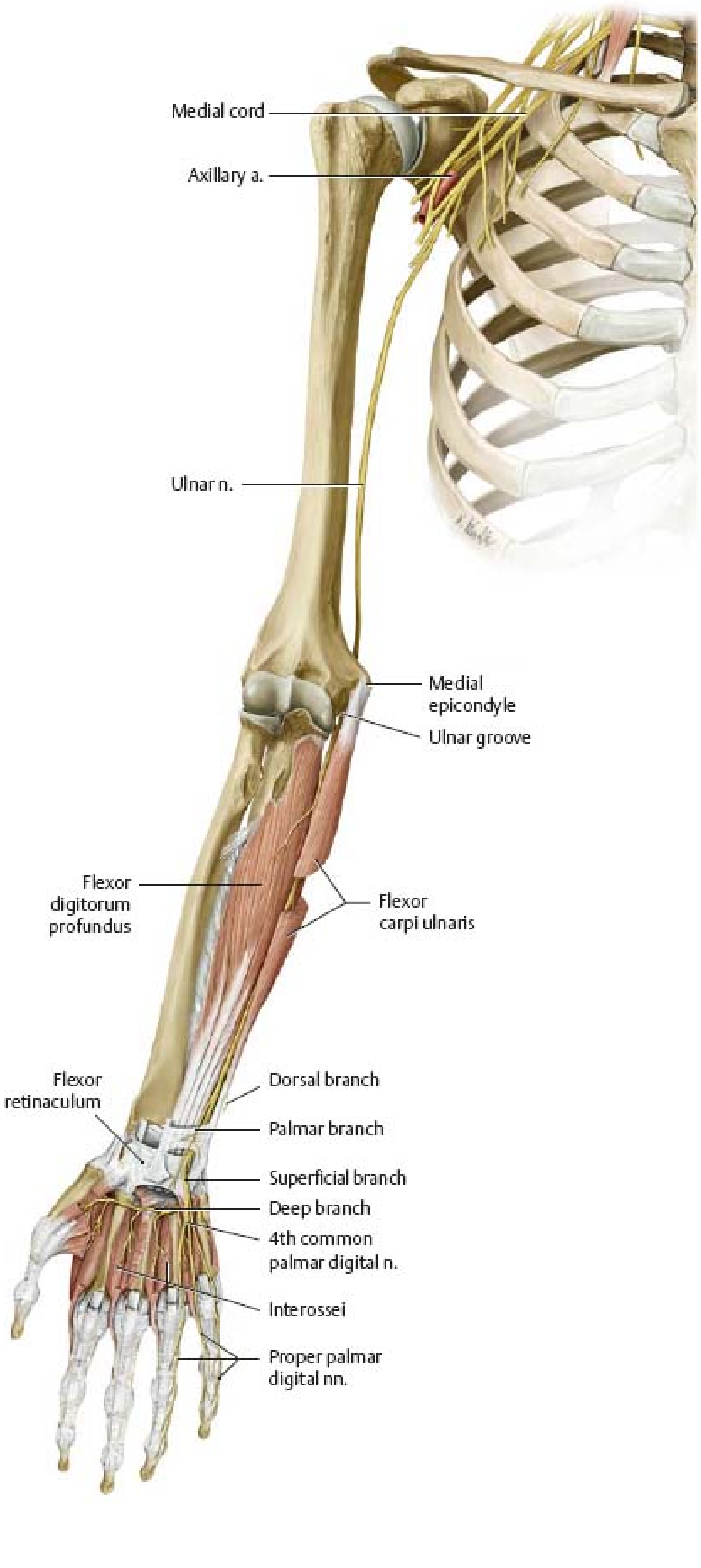
Table 22.9 **Ulnar nerve (C7–T1)**

Motor branches	Innervated muscles
Direct muscular branches	Flexor carpl ulnaris
	Flexor digitorum profundus (ulnar half)
Muscular branch from superior ulnar n.	Palmaris brevis
Muscular branches from deep ulnar n.	Abductor digiti miniml
	Flexor digiti minimi

Motor branches	Innervated muscles
	Opponens digiti miniml
	3 rd and 4th lumbricals
	Palmar and dorsal interosseous muscles
	Adductor policis
	Flexor policis brevis (deep head)
Sensory branches	
Articular branches: Capsules of the elbow, carpal, and metacarpophalangeal joints	
Dorsal branch (terminal branches: dorsal digital nn.)	
Palmar branch	
Proper palmar digital n. (from superficial branch	
Common palmar digital n. (from superficial branch; terminal braches; proper palmar digital nn.)	

Fig. 22.25 **Ulnar nerve**

Right limb, anteriorview.

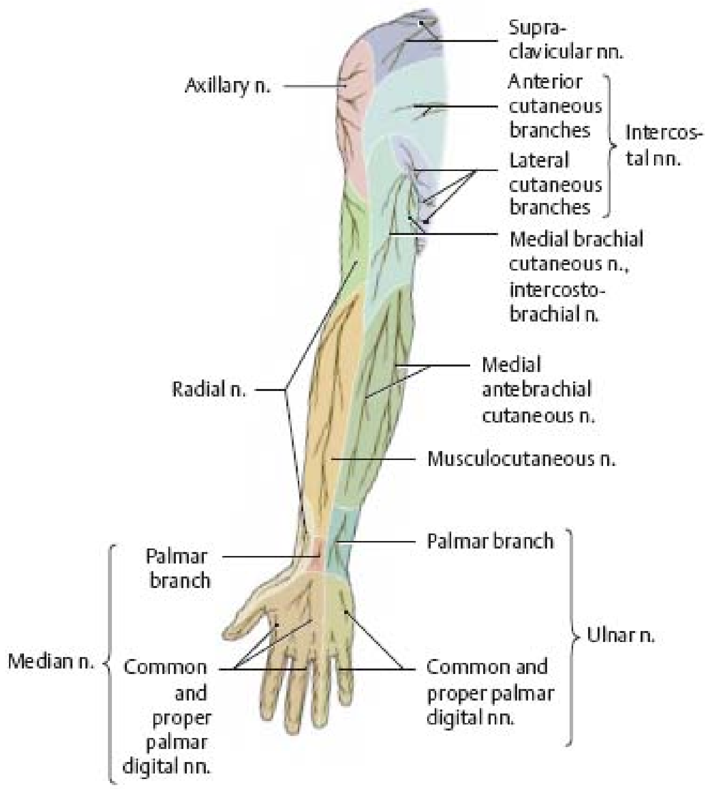

Medial cord
Axillary a.
Ulnar n.
Medial
epicondyle
Ulnar groove
Flexor
digitorum
profundus
Flexor
carpi ulnaris
Flexor
retinaculum
Dorsal branch
Palmar branch
Superficial branch
Deep branch
4th common
palmar digital n.
Interossei
Proper palmar
digital nn.

Clinical

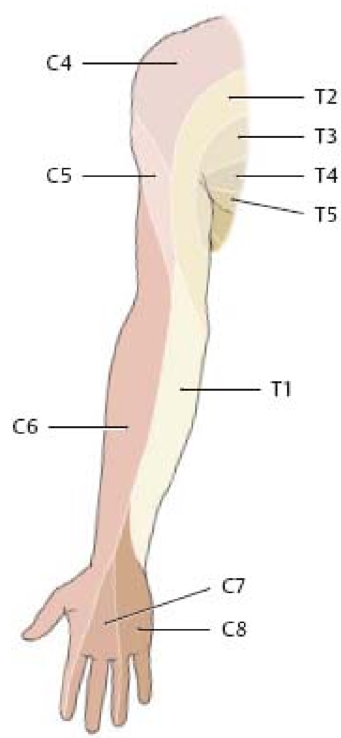
Ulnar nerve palsy is the most common peripheral nerve damage. The ulnar nerve is most vulnerable to trauma or chronic compression in the elbow joint and ulnar tunnel (see p. 343). Nerve damage causes "clawing" of the hand and atrophy of the interossei. Sensory losses are often limited to the 5th digit.

Superficial Veins & Nerves of the Upper Limb

Fig. 22.26 Cutaneous innervation of the upper limb: Anterior view

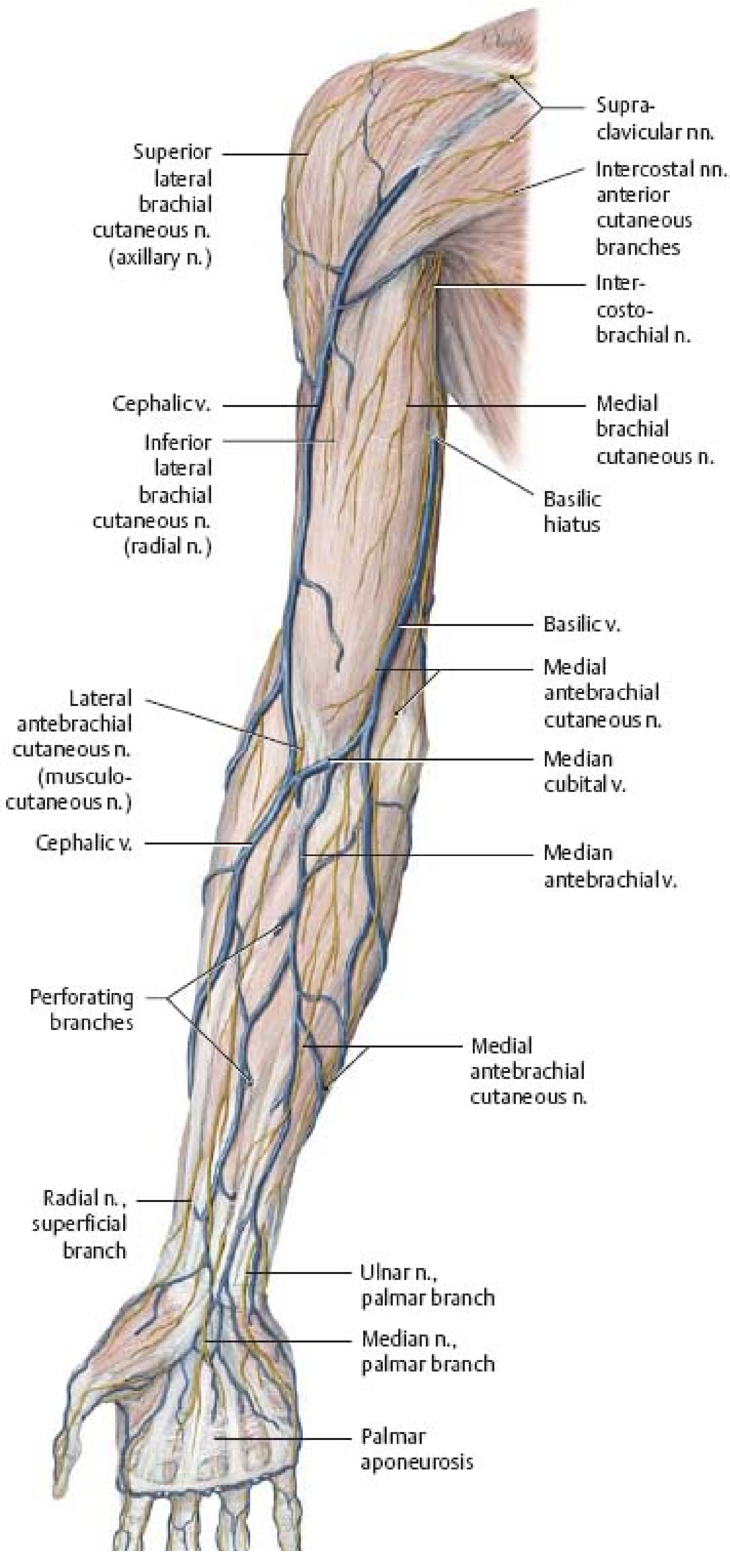


A Peripheral sensory cutaneous innervation.

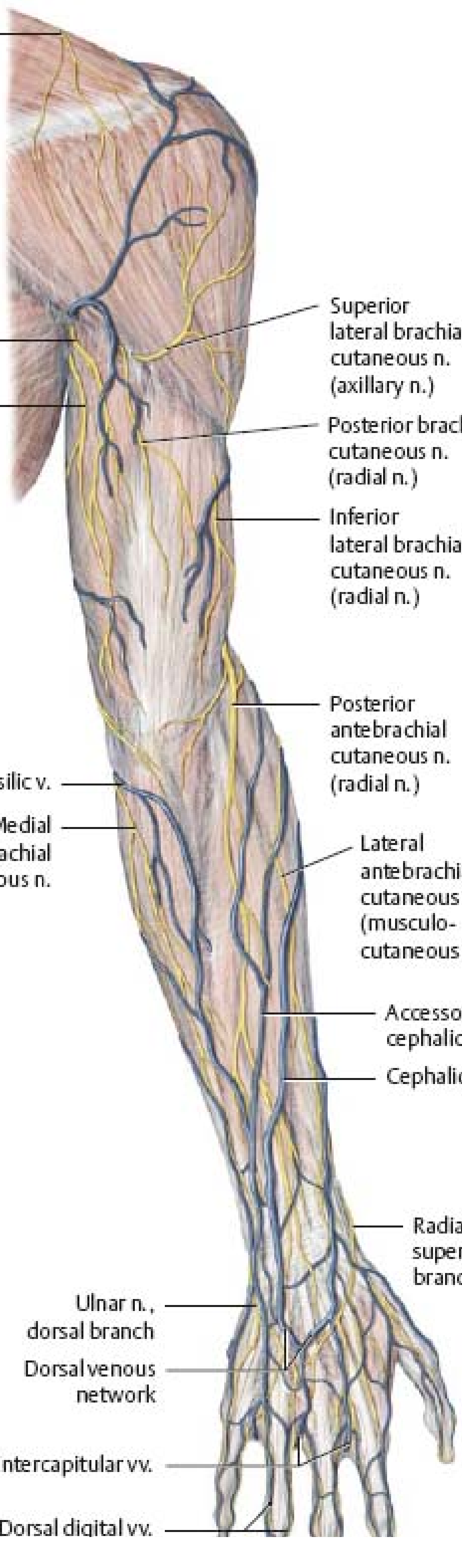


B Segmental, radicular cutaneous innervation (dermatomes).

Fig. 22.27 **Superficial cutaneous veins and nerves of the upper limb**

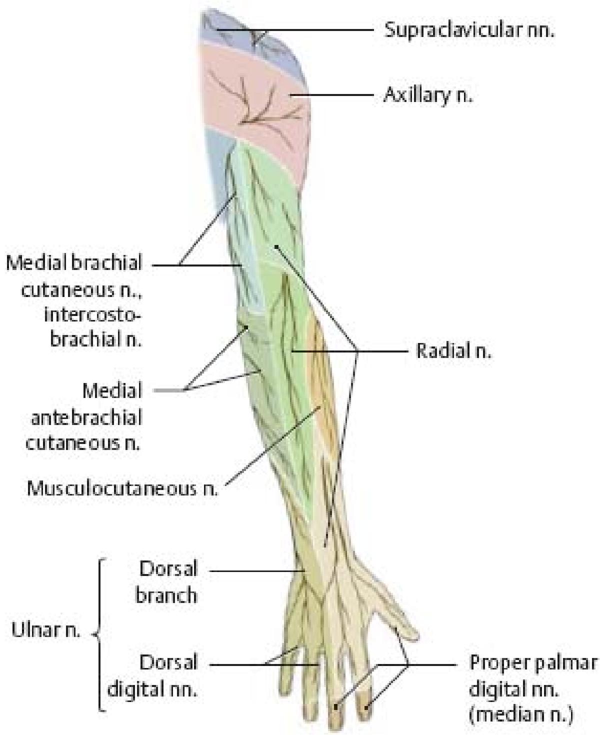


A Anterior view. See p. 344 for nerves of the palm.

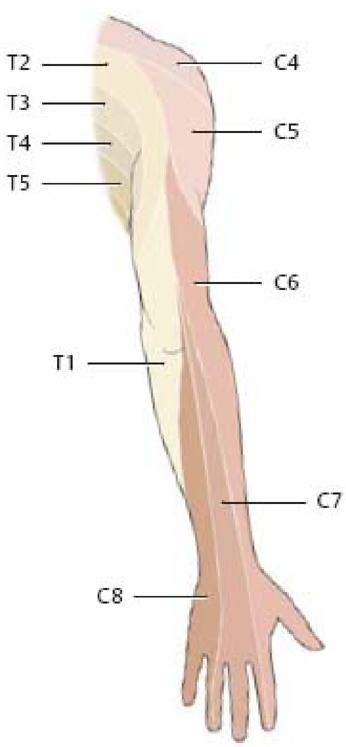


B Posterior view. See p. 346 for nerves of the dorsum.

Fig. 22.28 **Cutaneous innervation of the upper limb: Posterior view**



A Peripheral sensory cutaneous innervation.



B Segmental, radicular cutaneous innervation (dermatomes).

Posterior Shoulder & Axilla

Fig. 22.29 Posterior shoulder

Right shoulder, posterior view. Ro/sed:Trapezius (transverse part). *Windowed:* Supraspinatus. *Revealed:* Suprascapular region.

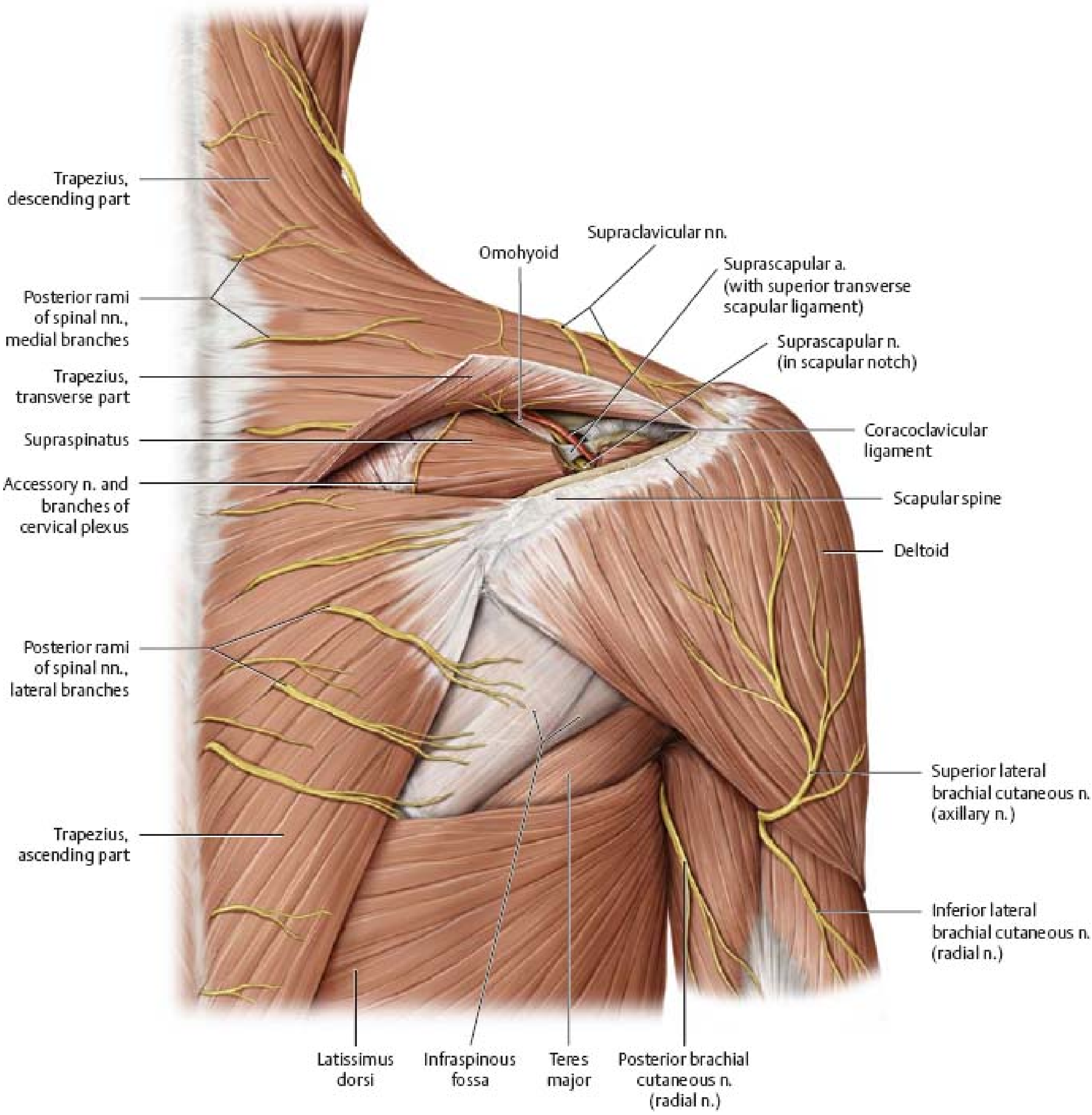


Table 22.10 Neurovascular tracts of the scapula

	Passageway	Boundaries	Transmitted structures
①	Scapular notch	Superior transverse scapular ligament, scapula	Suprascapular a. and n.
②	Medial border	Scapula	Dorsal scapular a. and n.
③	Triangular space	Teres major and minor	Circumflex scapular a.
④	Triceps hiatus	Triceps brachii, humerus, teres major	Profunda brachii a. and radial n.
⑤	Quadrangular space	Teres major and minor, triceps brachii, humerus	Posterior circumflex humeral a. and axillary n.

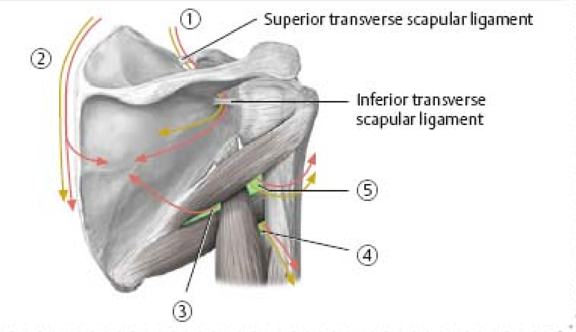
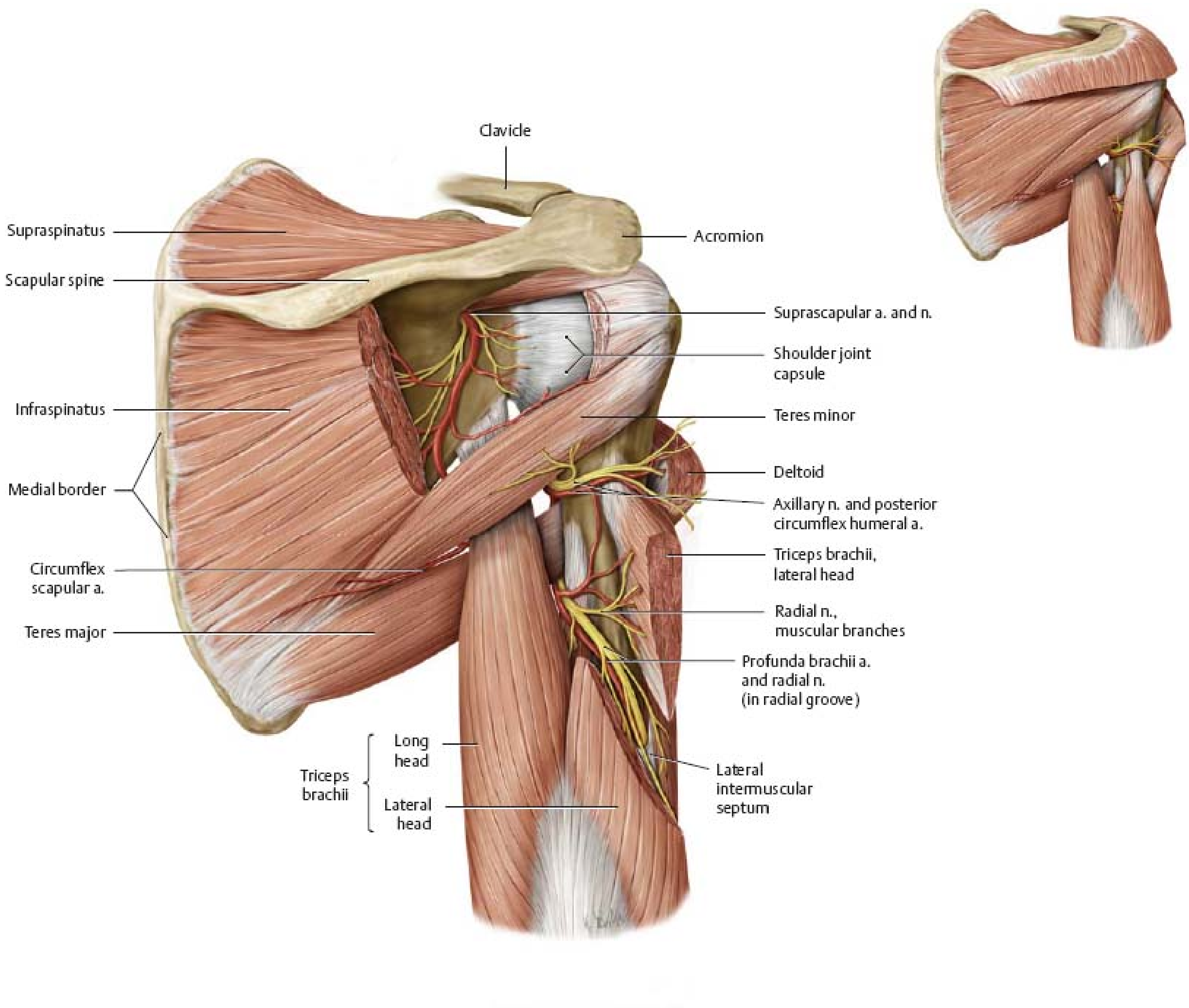


Fig. 22.30 Axilla: Triangular and quadrangular spaces

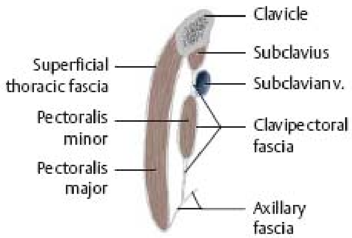
Right shoulder, posterior view.



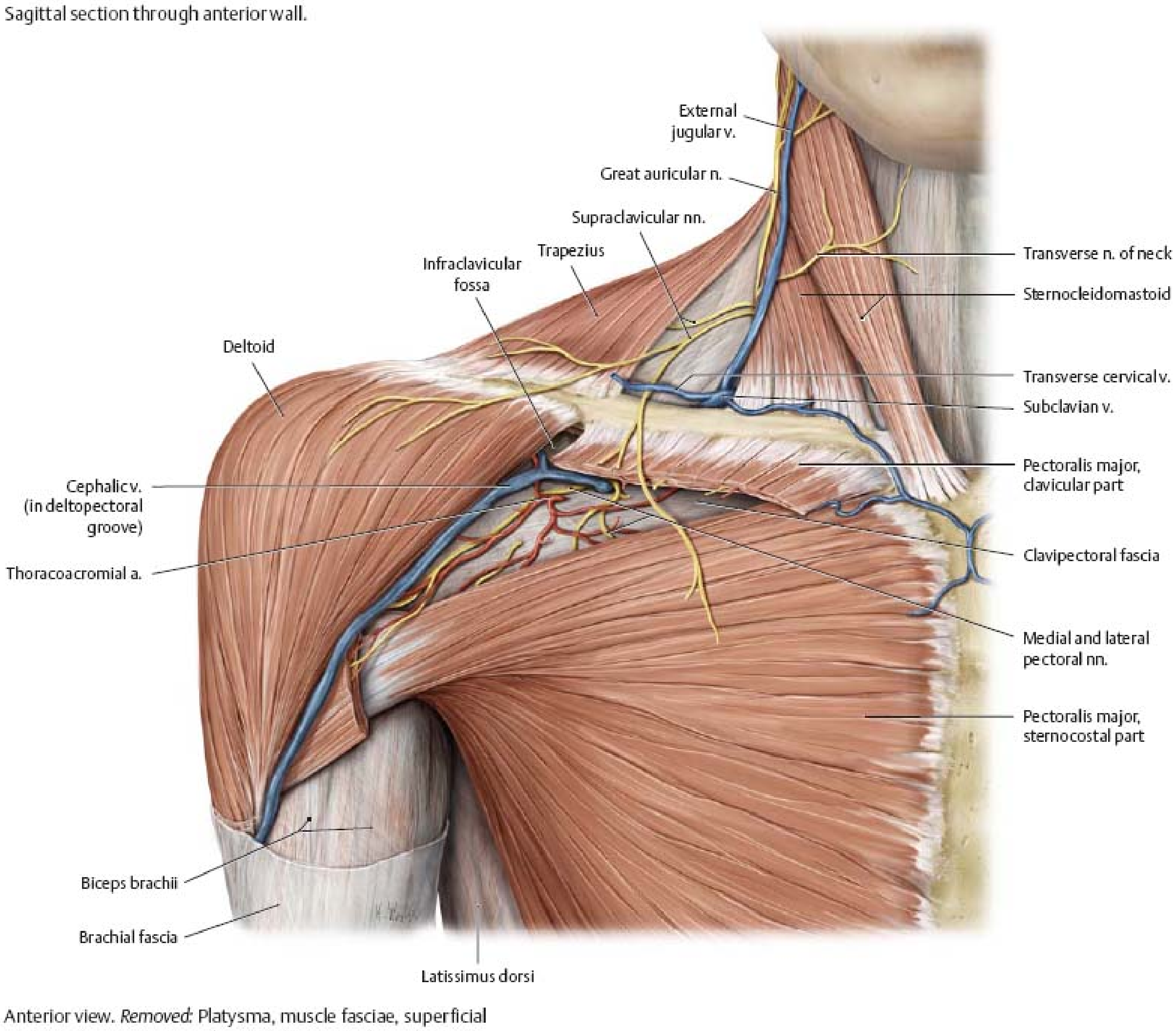
Anterior Shoulder

Fig. 22.31 Anterior shoulder: Superficial dissection

Right shoulder.



A Sagittal section through anterior wall.



B Anterior view. *Removed:* Platysma, muscle fasciae, superficial layer of cervical fascia, and pectoralis major (clavicular part). *Revealed:* Clavipectoral triangle.

Fig. 22.32 Shoulder: Transverse section

Right shoulder, inferior view.

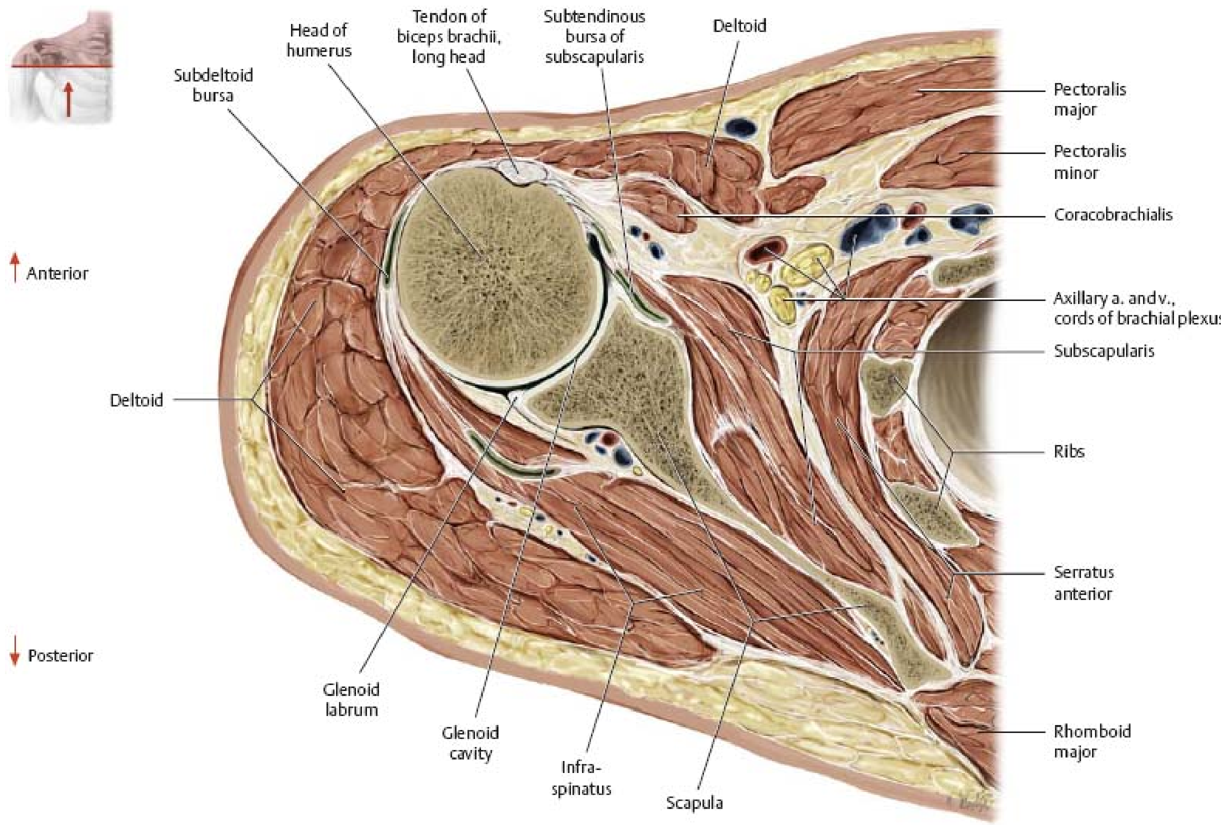
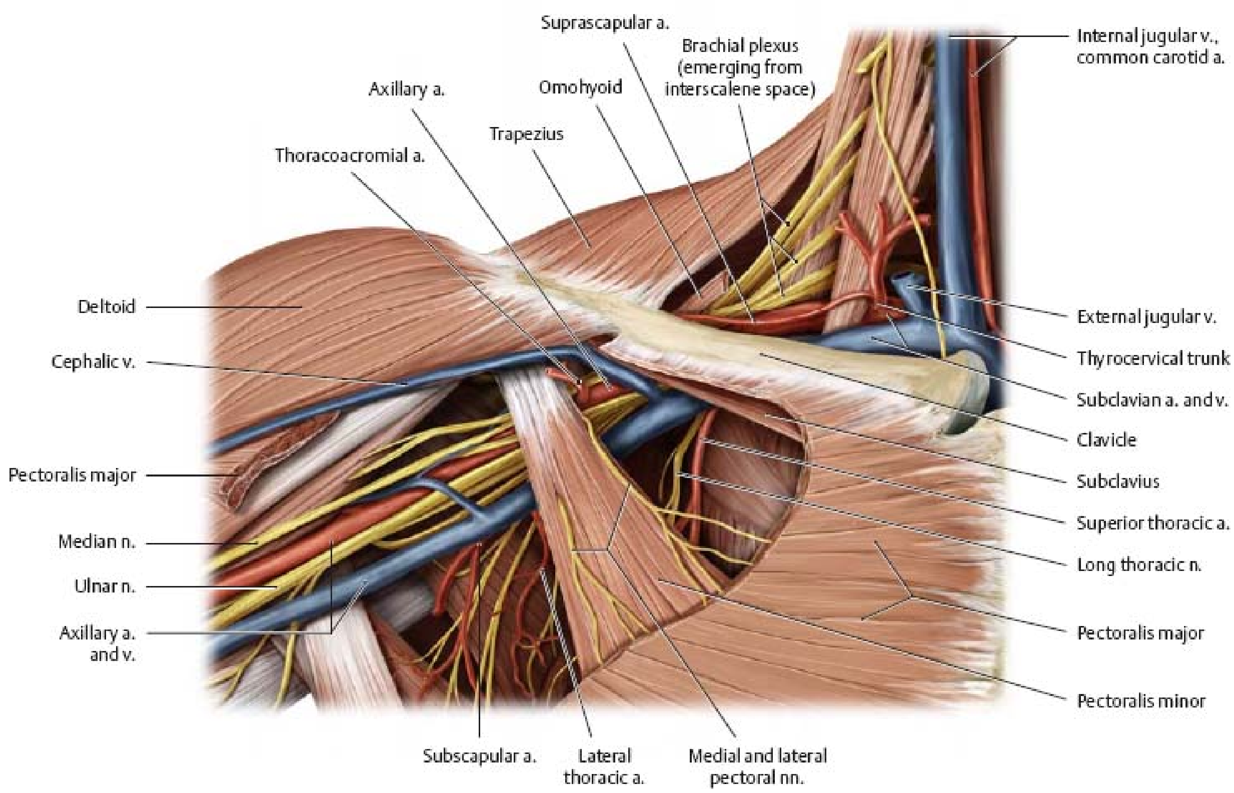


Fig. 22.33 **Anterior shoulder: Deep dissection**

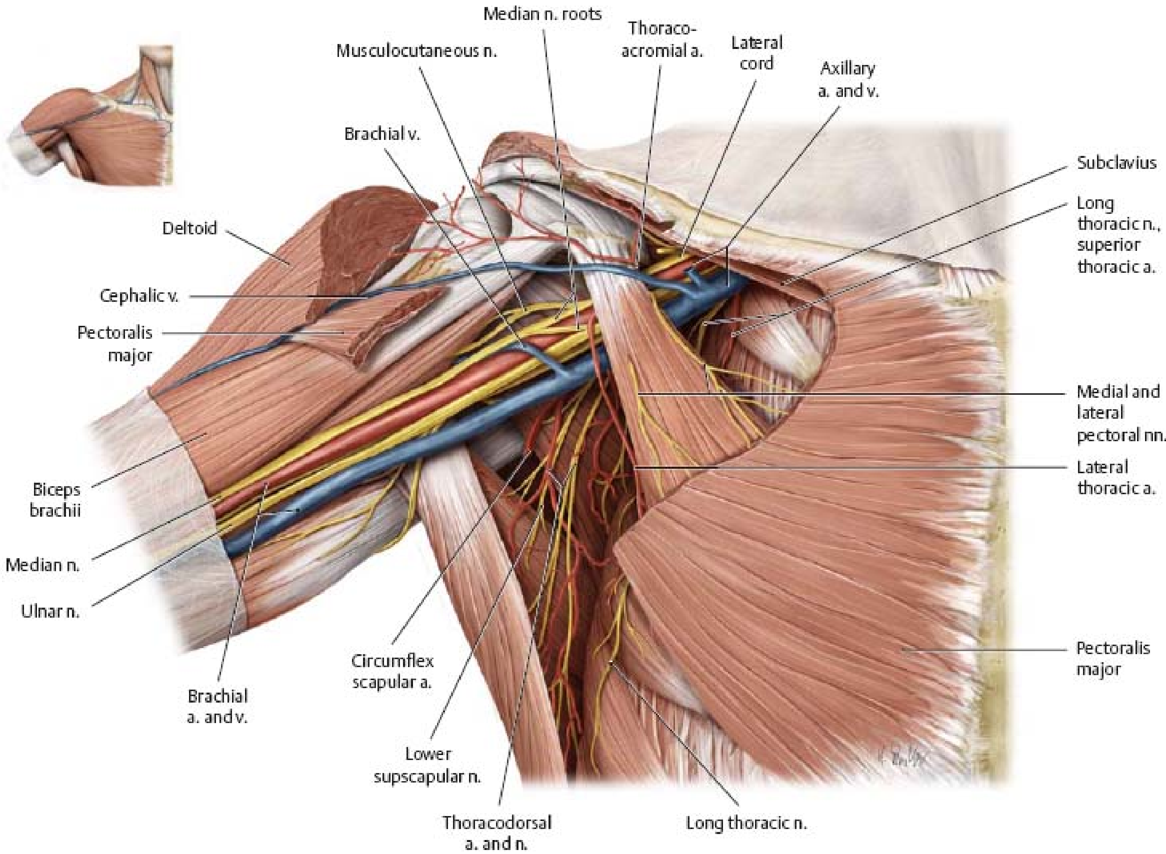
Right limb, anterior view. *Removed:* Sternocleidomastoid, omohyoid, and pectoralis major. This dissection reveals the neurovascular contents of the lateral cervical triangle (see pp. 580–581) and axilla (see pp. 336–337).



Topography of the Axilla

Fig. 22.34 Dissection of the axilla

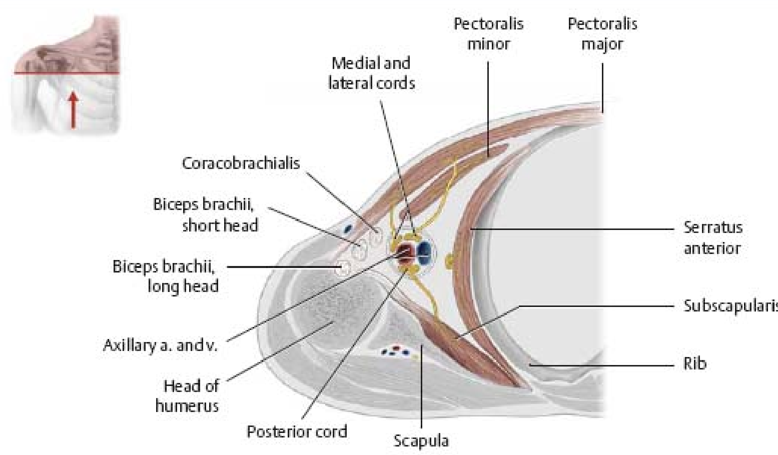
Right shoulder, anterior view.

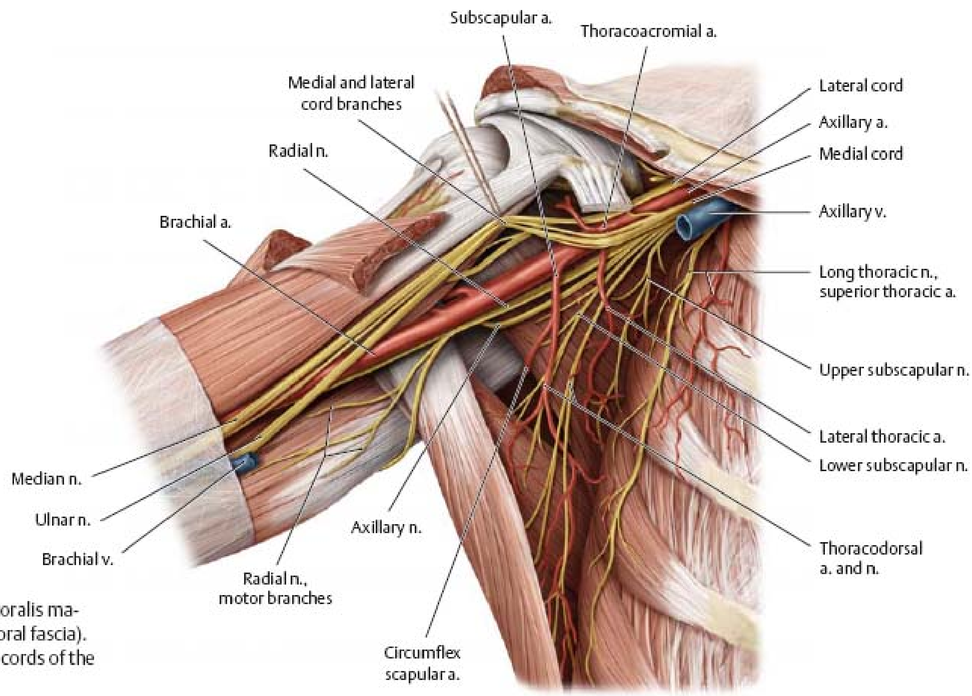


A *Removed:* Pectoralis major and clavipectoral fascia.

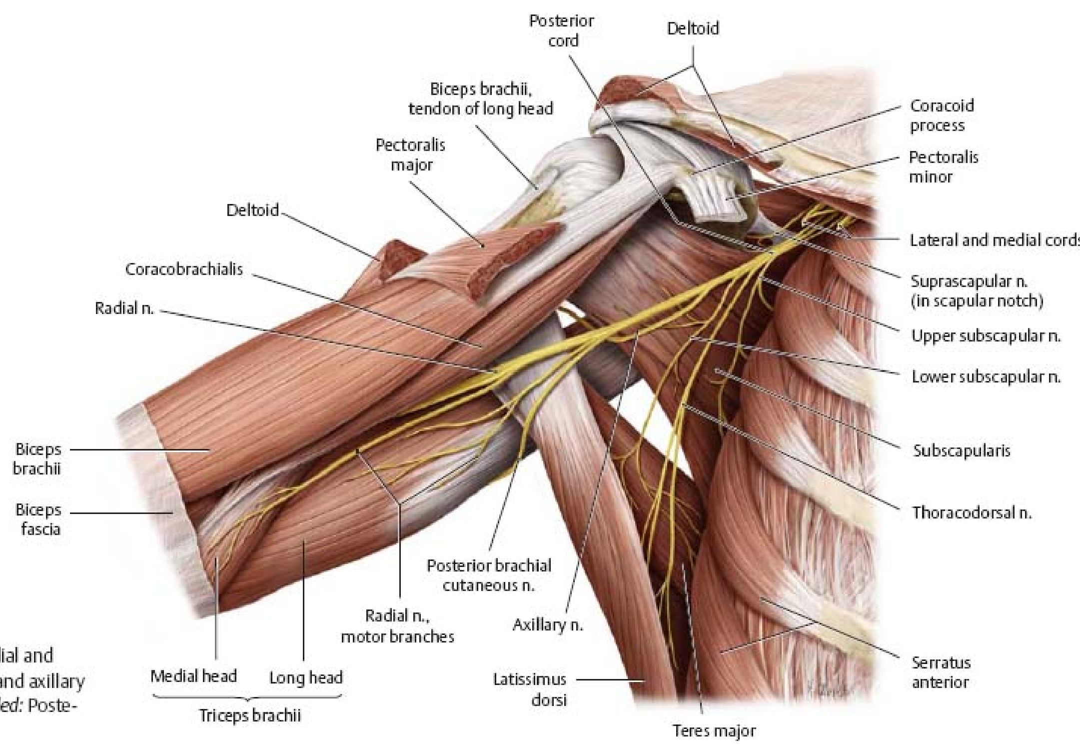
Table 22.11 Walls of the axilla

Anterior wall	Pectoralis major Pectoralis minor Clavipectoral fascia
Lateral wall	Intertubercular groove of humerus
Posterior wall	Subscapularis Teres major Latissimus dorsi
Medial wall	Lateral thoracic wall Serratus anterior





B *Removed:* Anterior wall (pectoralis major and minor, and clavipectoral fascia). *Retracted:* Medial and lateral cords of the brachial plexus.



C *Removed:* Medial and lateral cords, and axillary vessels. *Revealed:* Posterior cord.

Topography of the Brachial & Cubital Regions

Fig. 22.35 Brachial region

Right arm, anterior view. *Removed:* Deltoid, pectoralis major and minor.

Revealed: Medial bicipital groove.

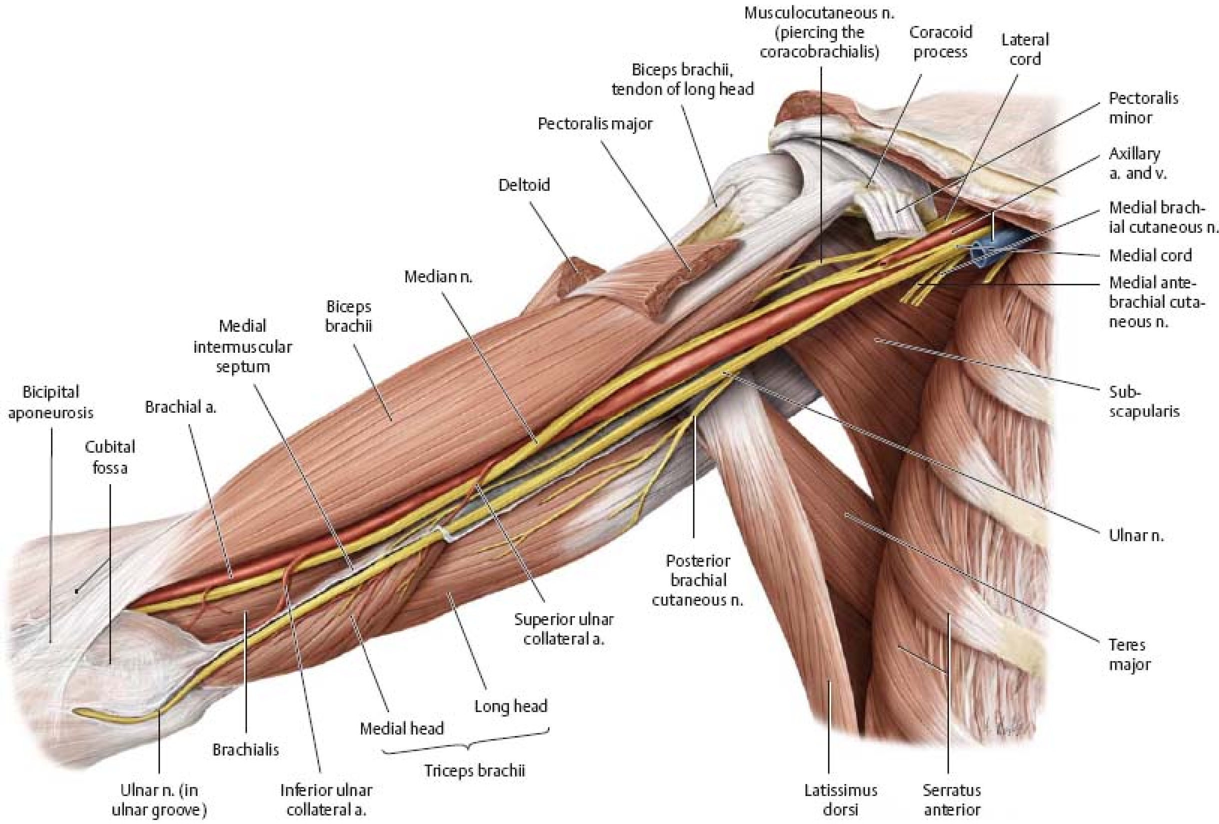
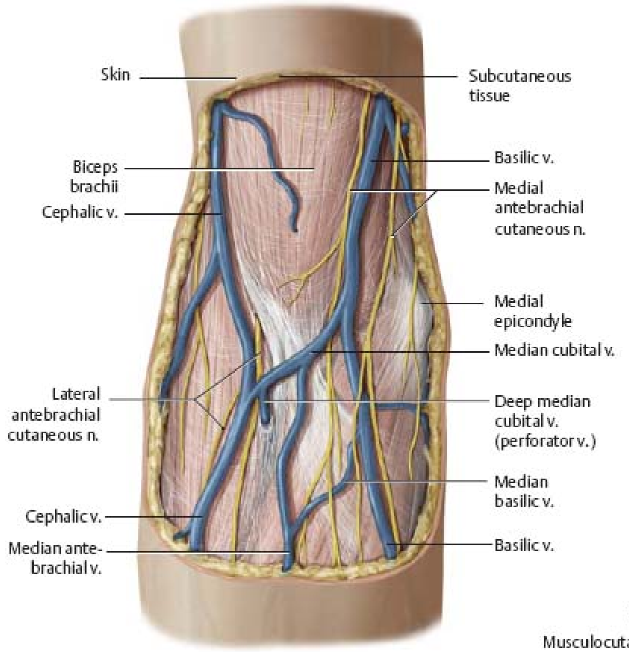
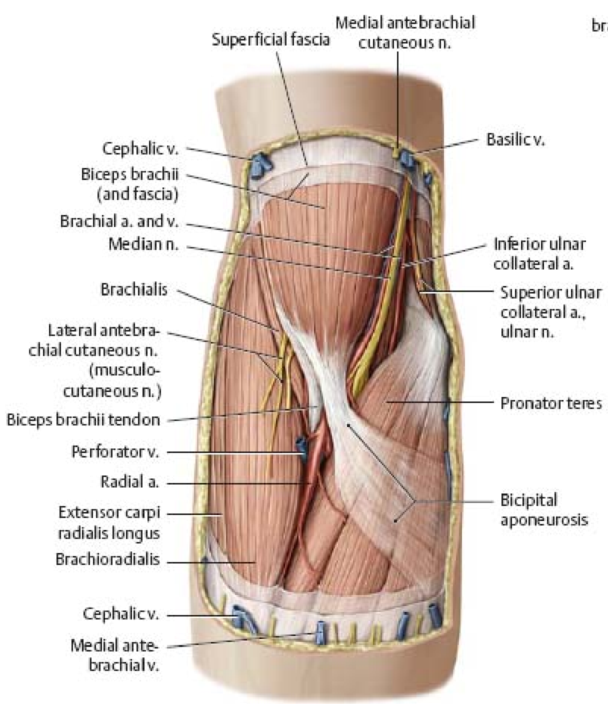


Fig. 22.36 **Cubital region**

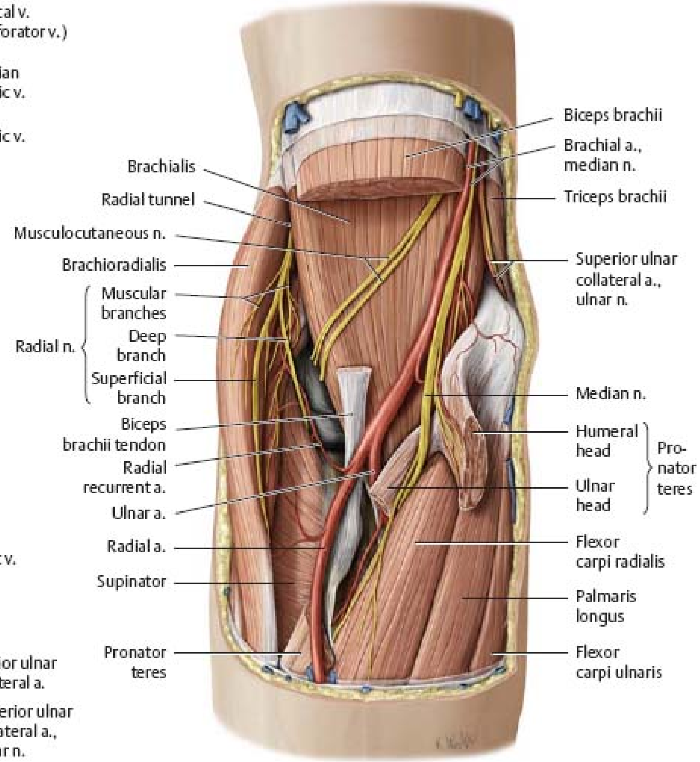
Right elbow, anterior view.



A Cutaneous neurovascular structures in the cubital fossa.



B Superficial cubital fossa. *Removed:* Fasciae and epifascial neurovascular structures.

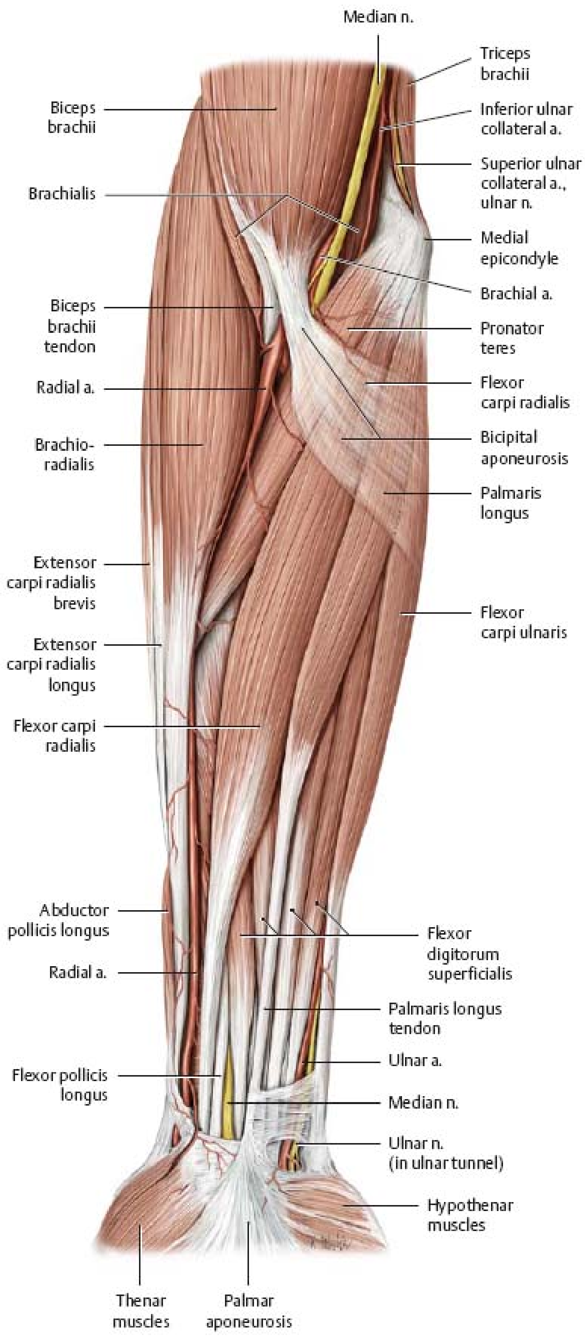


C Deep cubital fossa. *Removed:* Biceps brachii (distal muscle belly). *Retracted:* Brachioradialis.

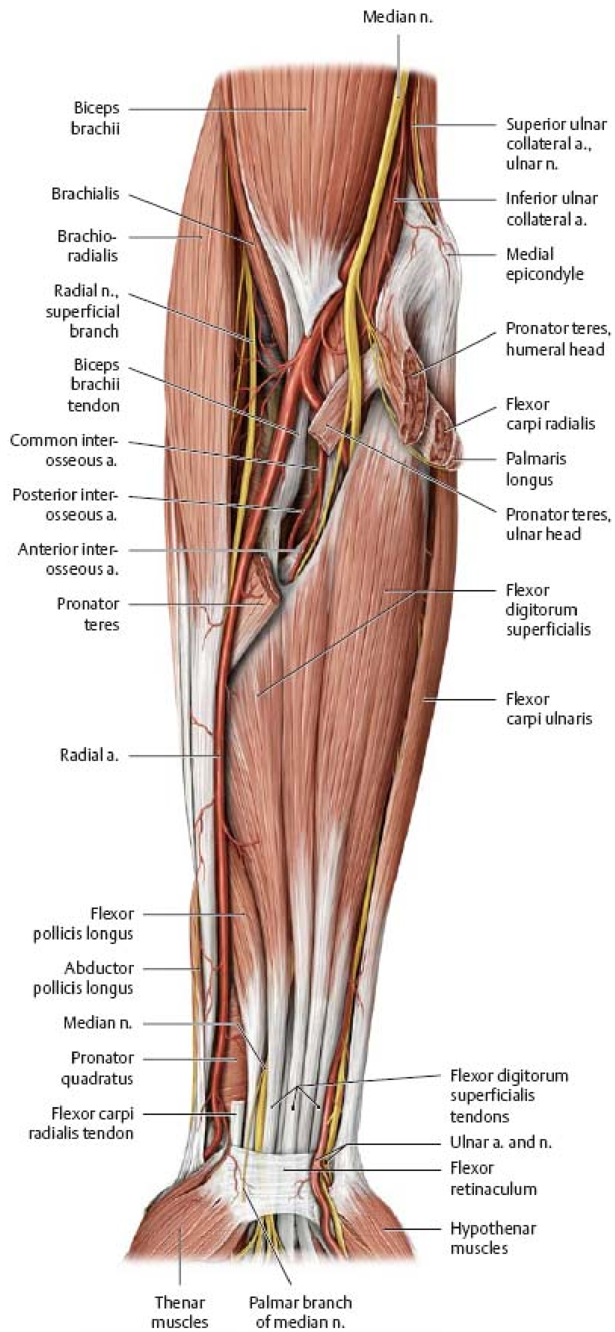
Topography of the Forearm

Fig. 22.37 Anterior forearm

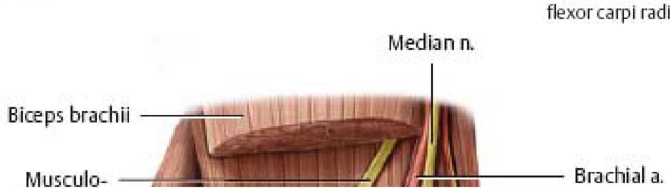
Right forearm, anterior view.

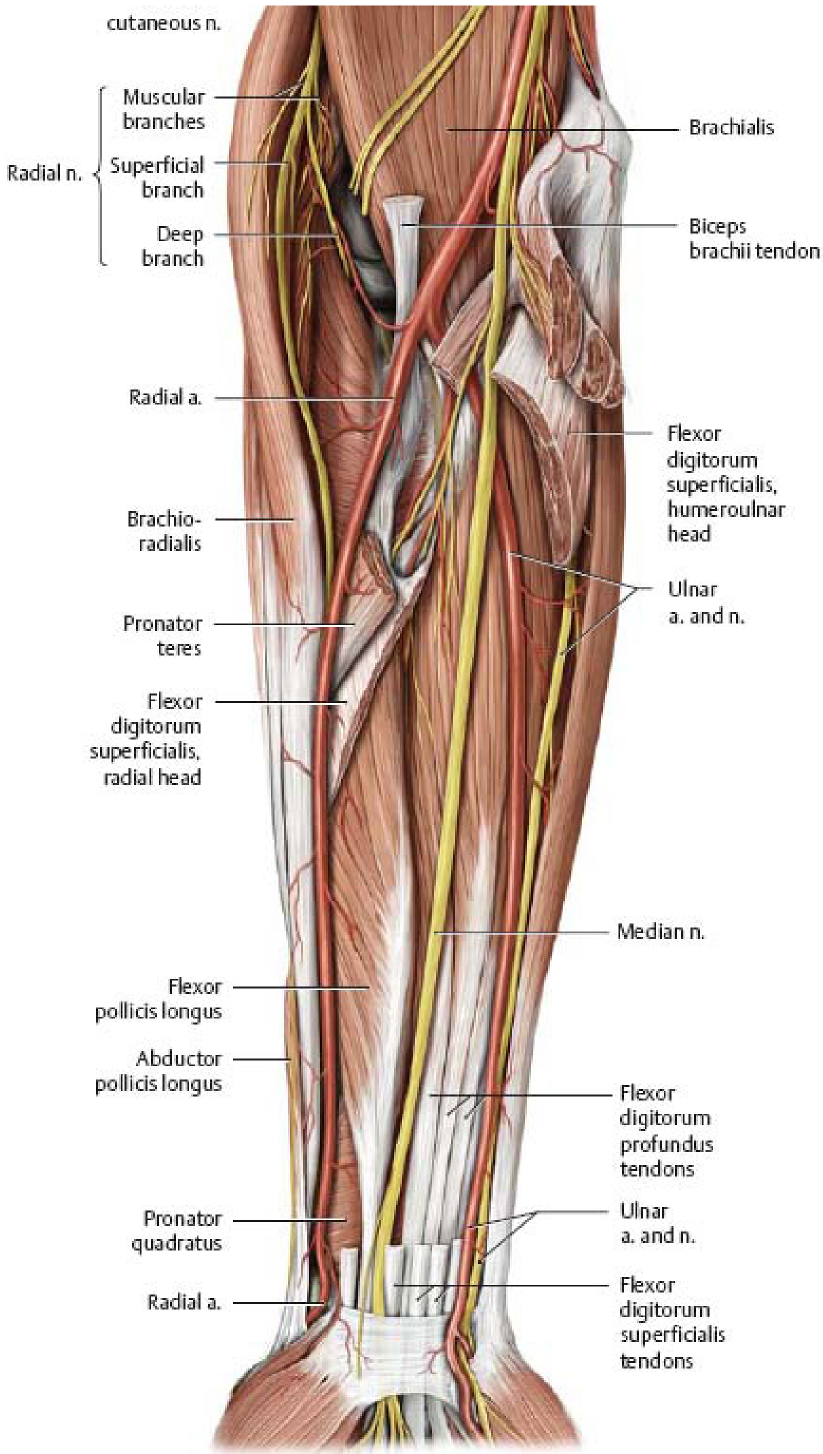


A Superficial layer. *Removed:* Fasciae and superficial neurovasculature.



B Middle layer. *Partially removed:* Superficial flexors (pronator teres, flexor digitorum superficialis, palmaris longus, and flexor carpi radialis).

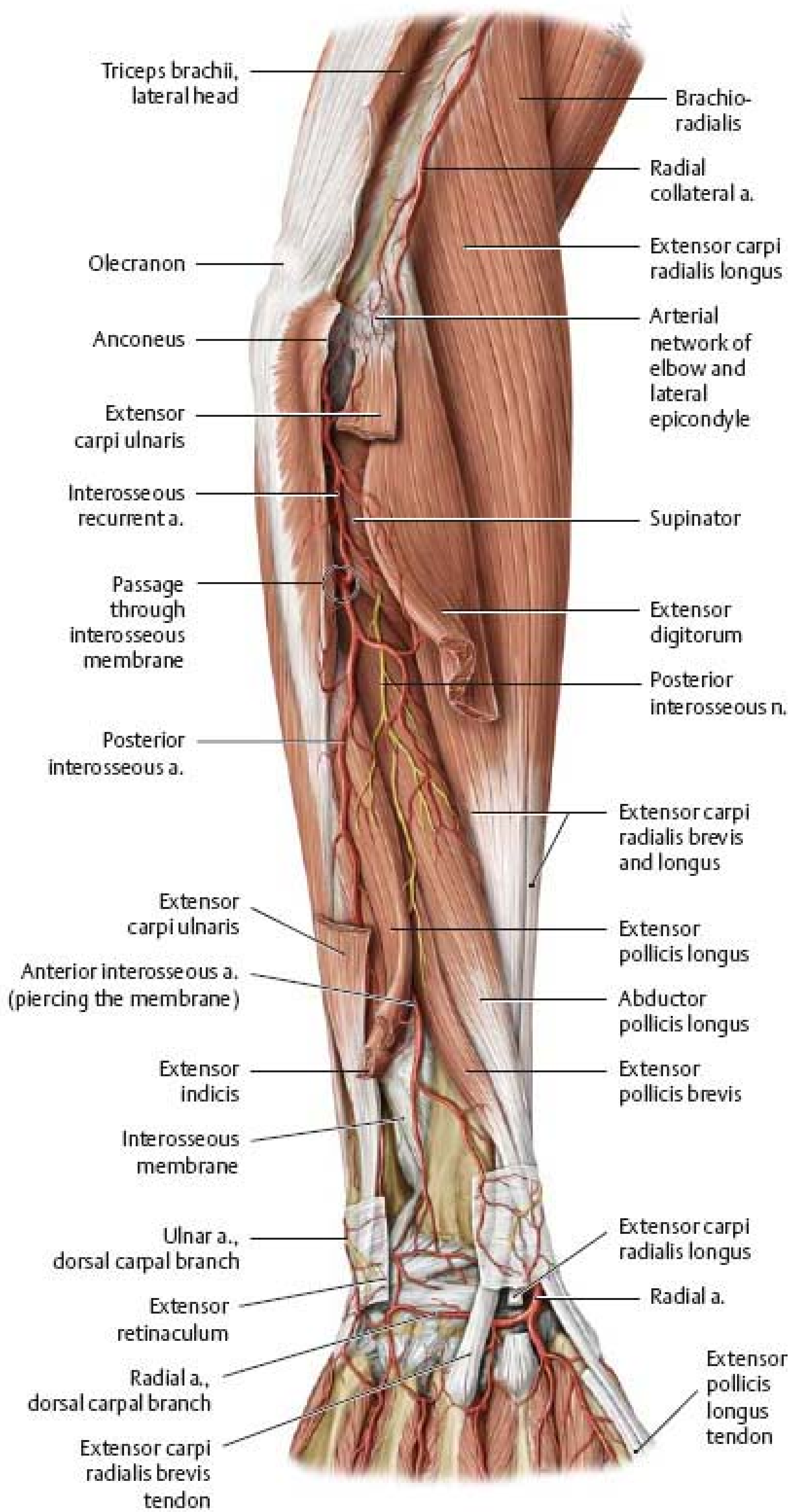




C Deep layer. *Removed:* Deep flexors.

Fig. 22.38 Posterior forearm

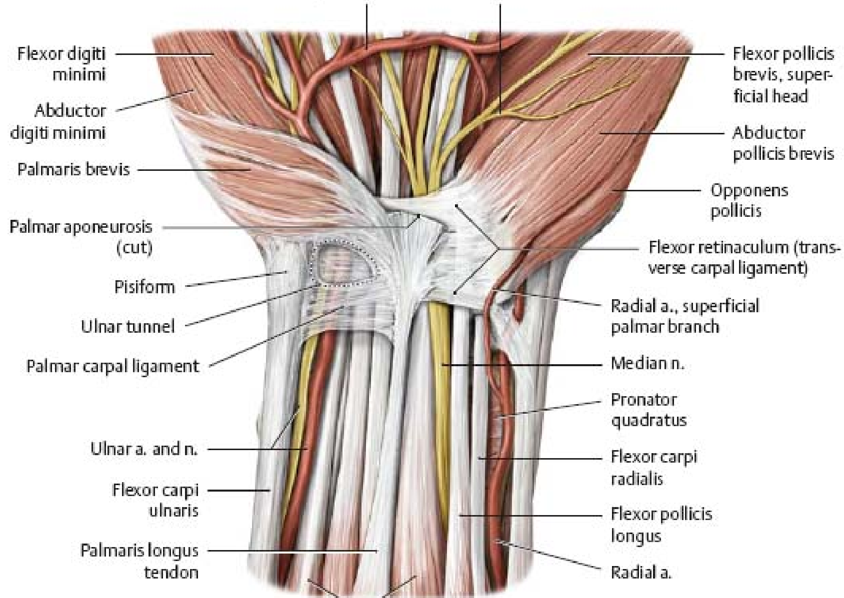
Right forearm, anterior view during pronation. *Reflected:* Anconeus and triceps brachii. *Resected:* Extensor carpi ulnaris and extensor digitorum.



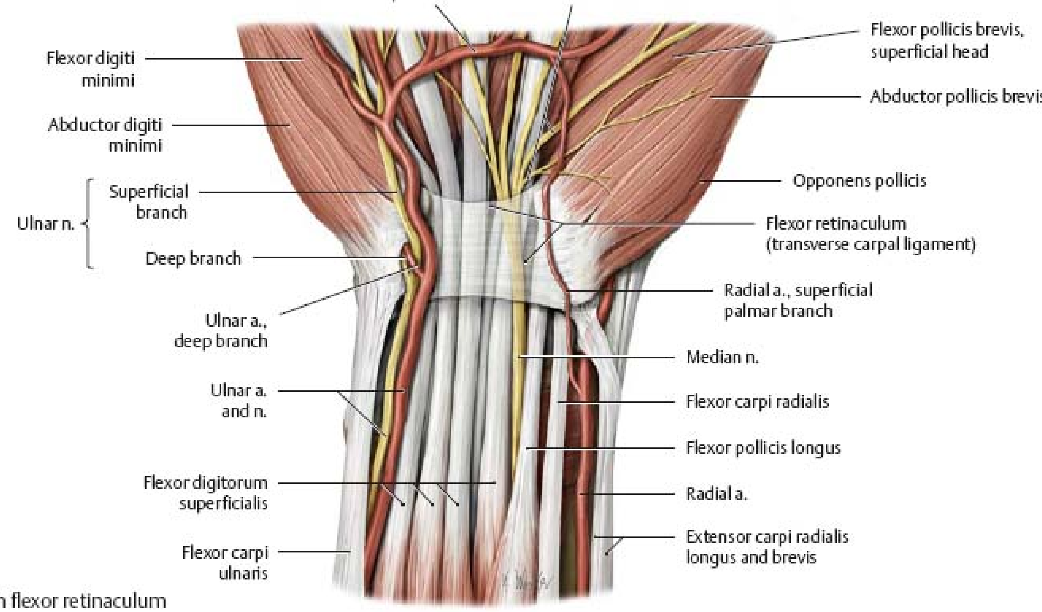
Topography of the Carpal Region

Fig. 22.39 Anterior carpal region

Right hand, anterior (palmar) view.



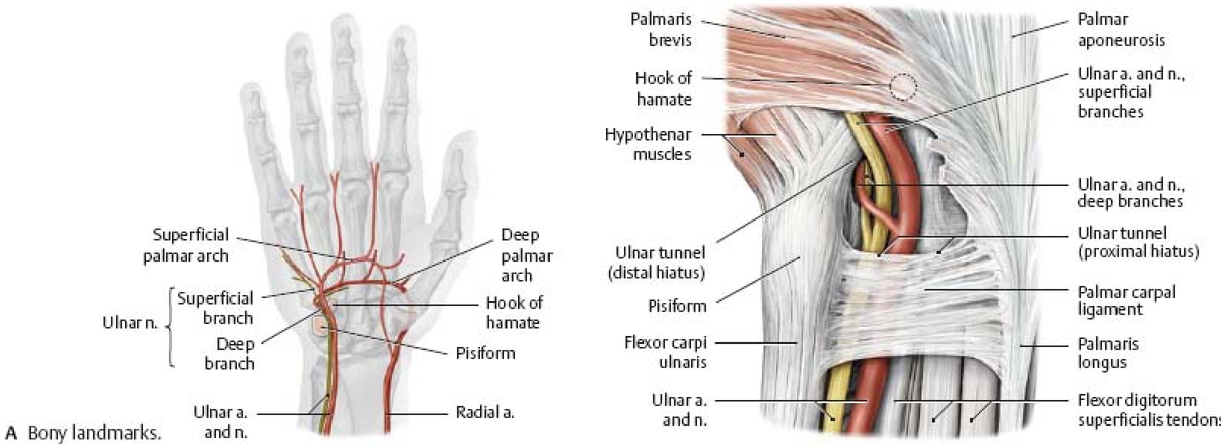
A Ulnar tunnel and deep palm.



B Carpal tunnel with flexor retinaculum windowed.

Fig. 22.40 Ulnar tunnel

Right hand, anterior (palmar) view.

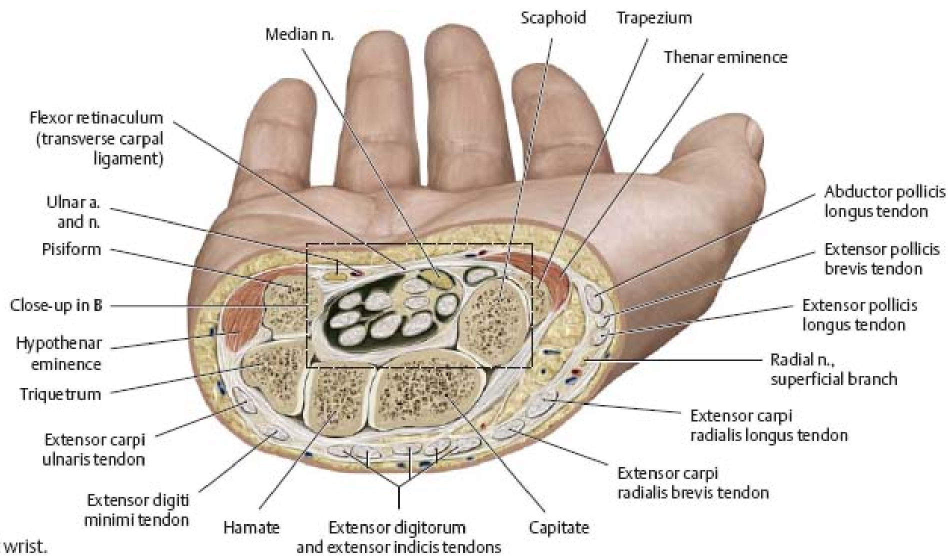


A Bony landmarks.

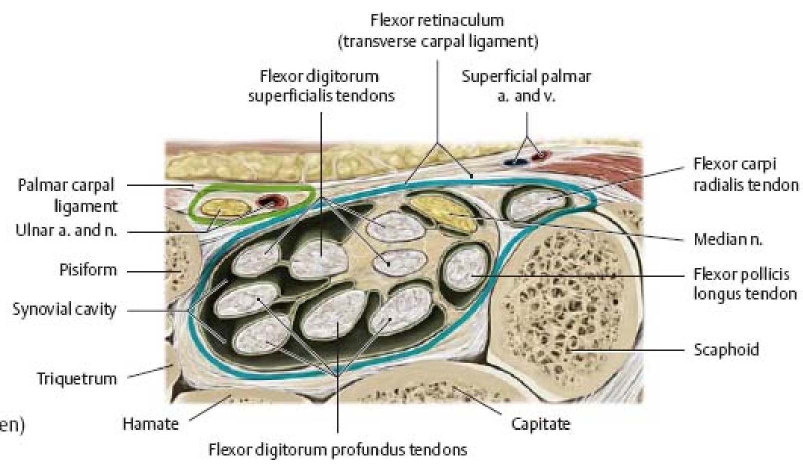
B Apertures and walls of the ulnar tunnel.

Fig. 22.41 Carpal tunnel: Cross section

Right hand, proximal view. The tight fit of sensitive neurovascular structures with closely apposed, frequently moving tendons in the carpal tunnel often causes problems (carpal tunnel syndrome) when any of the structures swell or degenerate.



A Cross section through the right wrist.

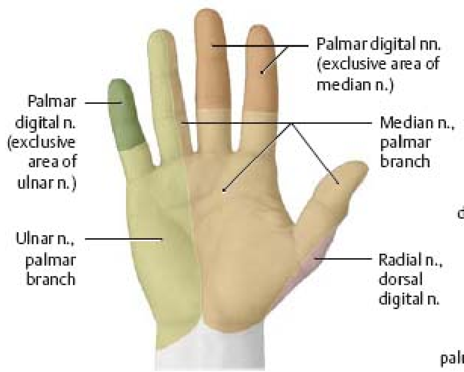


B Structures in the ulnar tunnel (green) and carpal tunnel (blue).

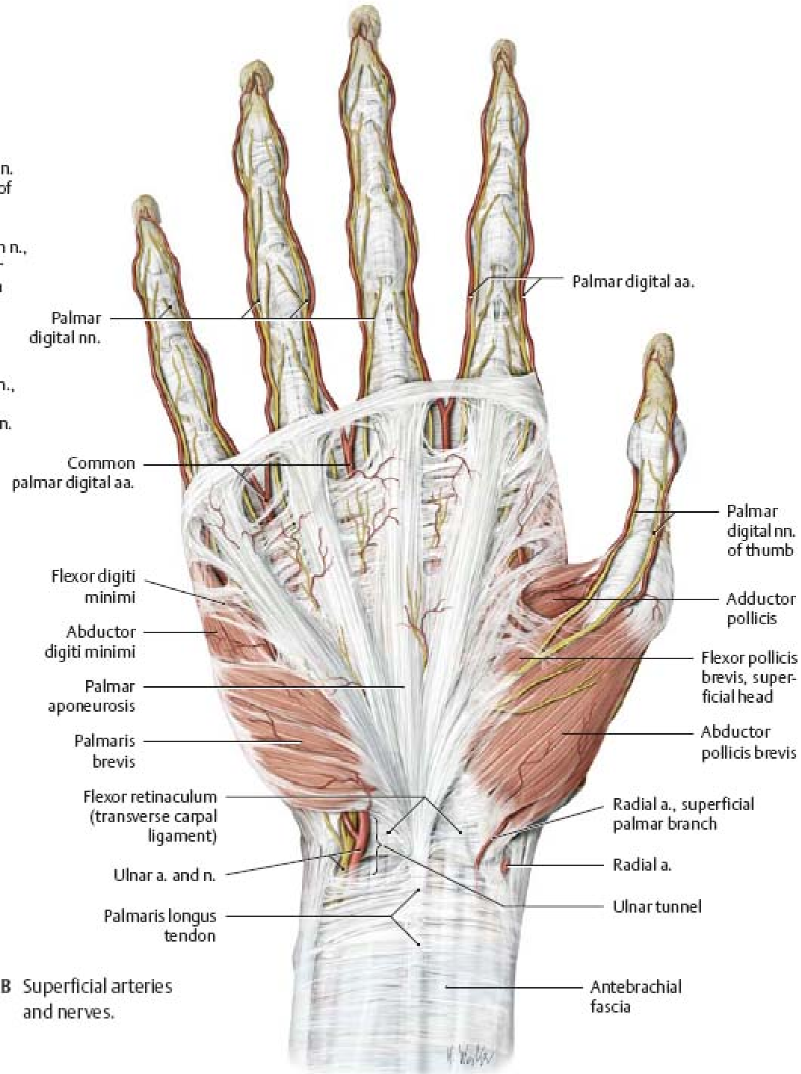
Topography of the Palm of the Hand

Fig. 22.42 Superficial neurovascular structures of the palm

Right hand, anteriorview.



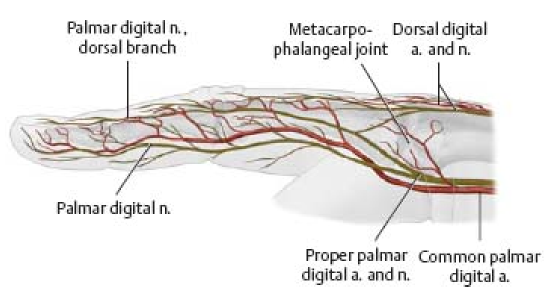
A Sensory territories. Extensive overlap exists between adjacent areas. *Exclusive* nerve territories indicated with darker shading.



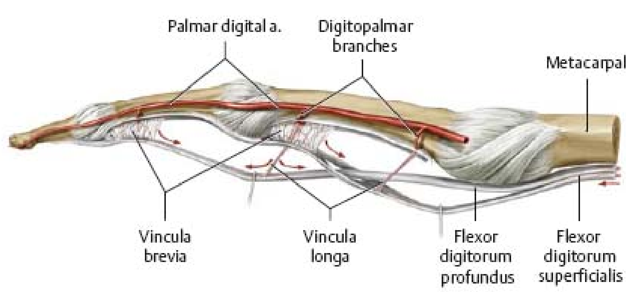
B Superficial arteries and nerves.

Fig. 22.43 Neurovasculature of the finger

Right middle finger, lateral view.

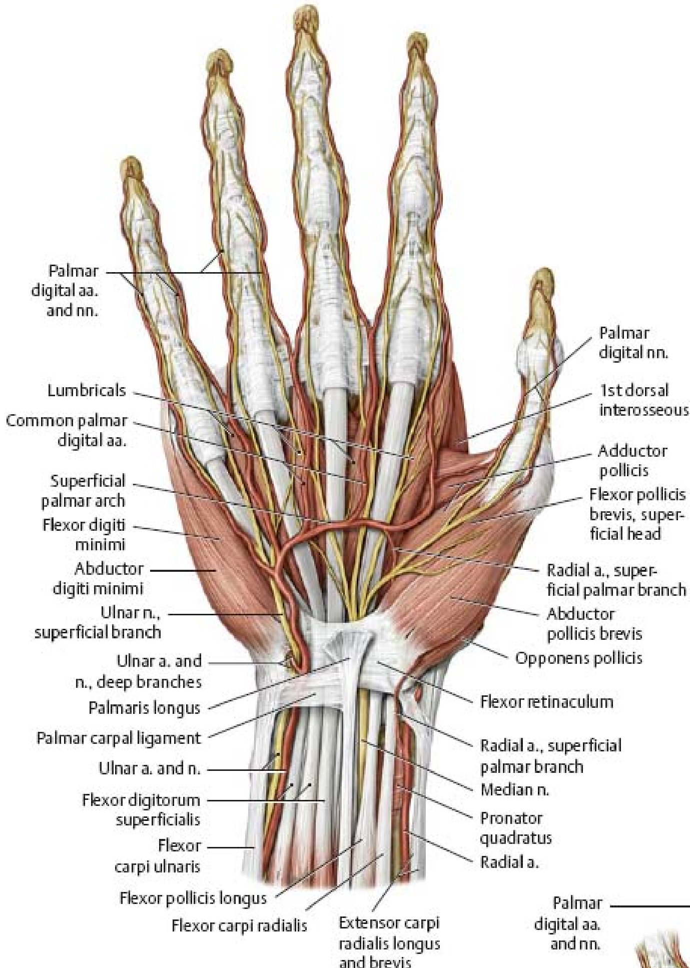


A Nerves and arteries.

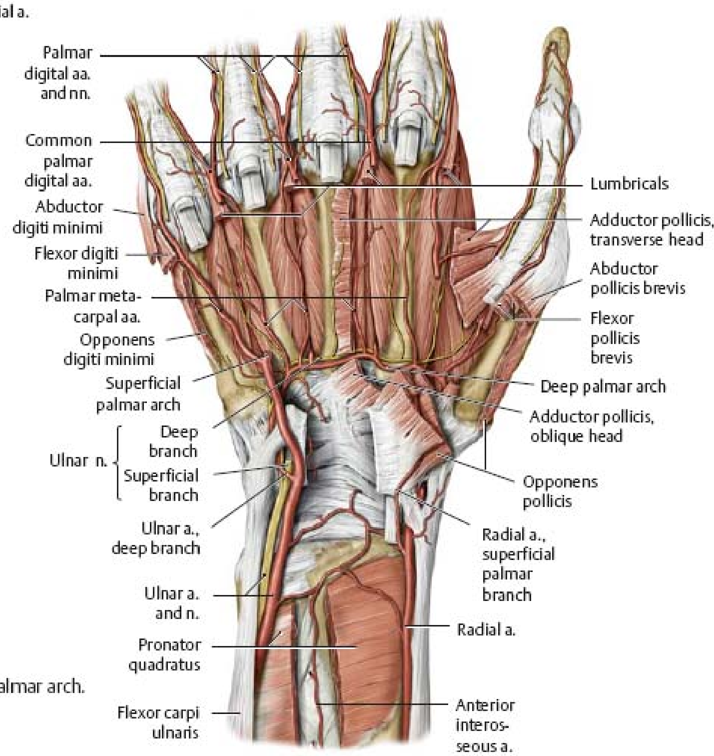


B Blood supply to the flexor tendons in the tendon sheath.

Fig. 22.44 **Deep neuro-vascular structures of the palm**
Right hand, anterior view.



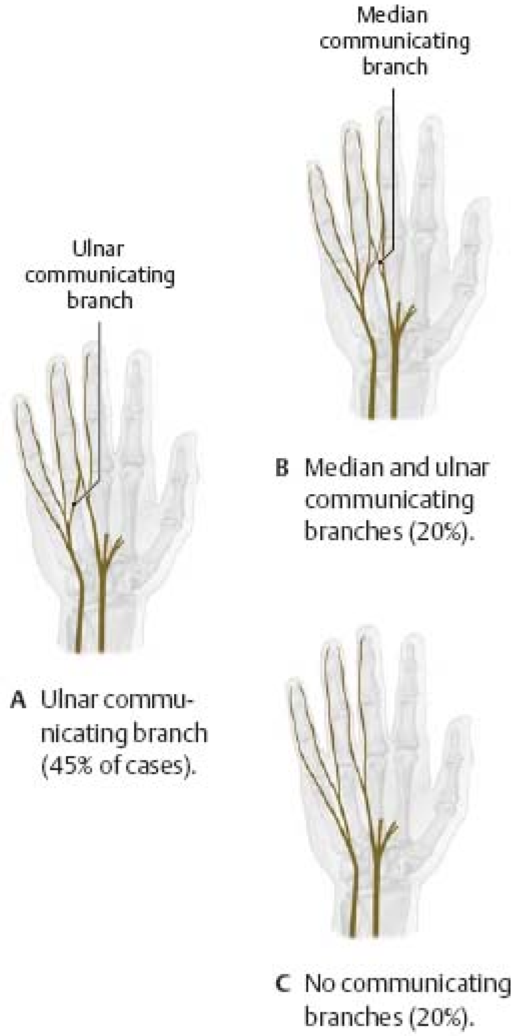
A Superficial palmar arch.



B Deep palmar arch.

Fig. 22.45 **Innervation patterns in the palm**

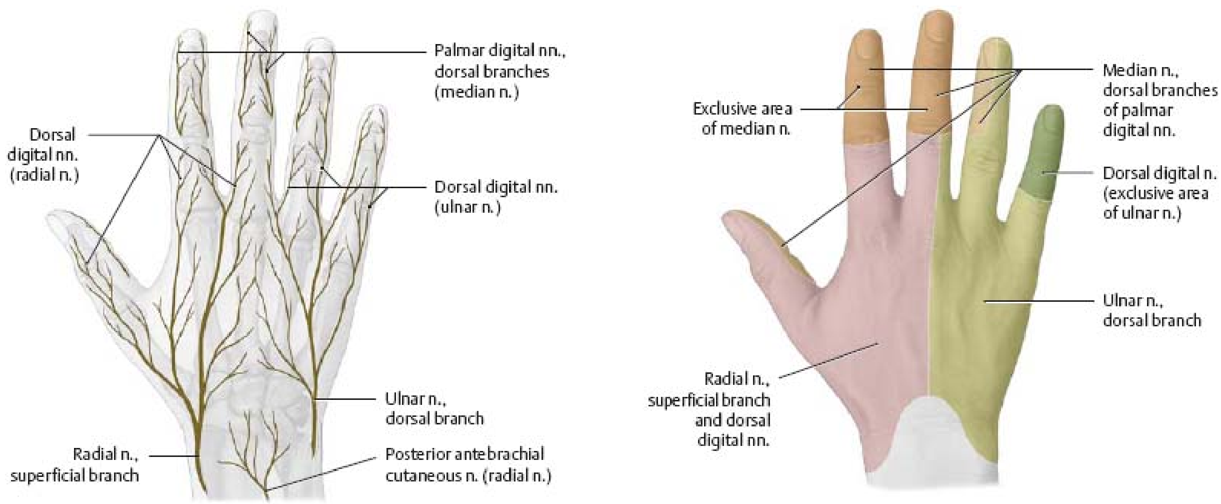
Right hand, anterior view.



Topography of the Dorsum of the Hand

Fig. 22.46 **Sensory innervation of the dorsum**

Right hand, posterior view.



A Nerves of the dorsum.

B Sensory territories. Extensive overlap exists between adjacent areas. *Exclusive* nerve territories indicated with darker shading.

Fig. 22.47 Anatomic snuffbox

Right hand, radial view. The three-sided "anatomic snuffbox" is bounded by the tendons of insertion of the abductor pollicis longus and extensors pollicis brevis and longus.

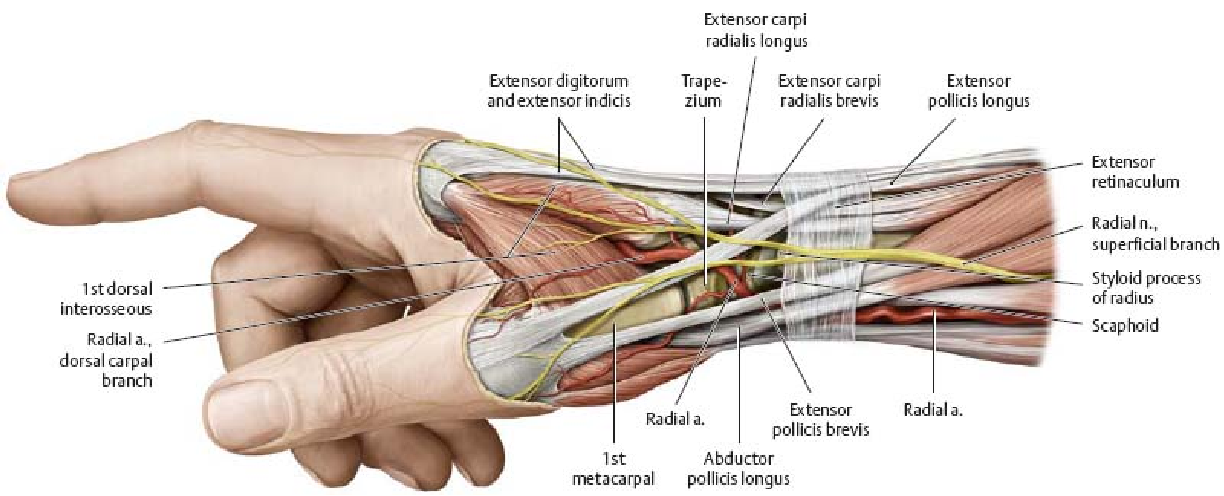
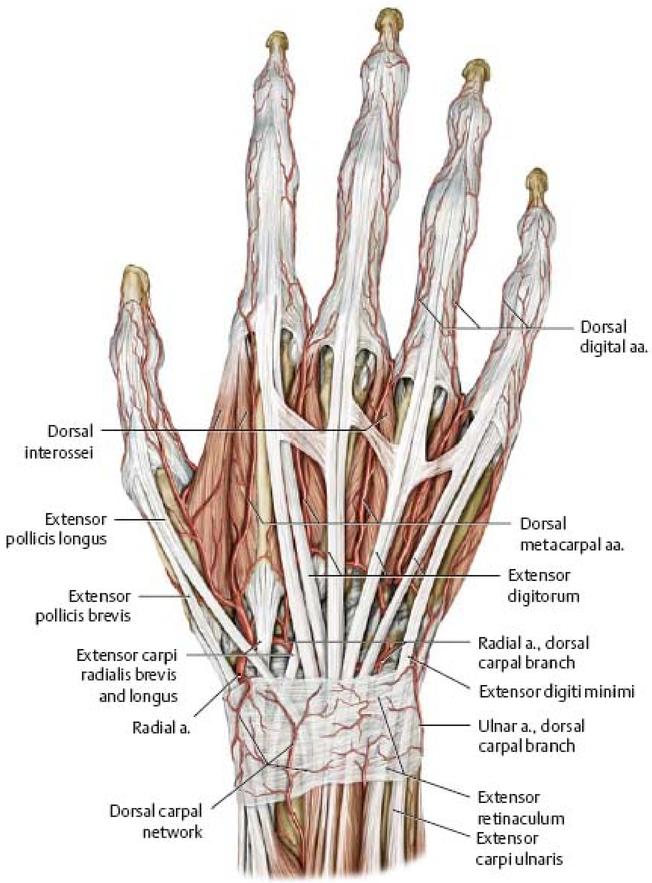
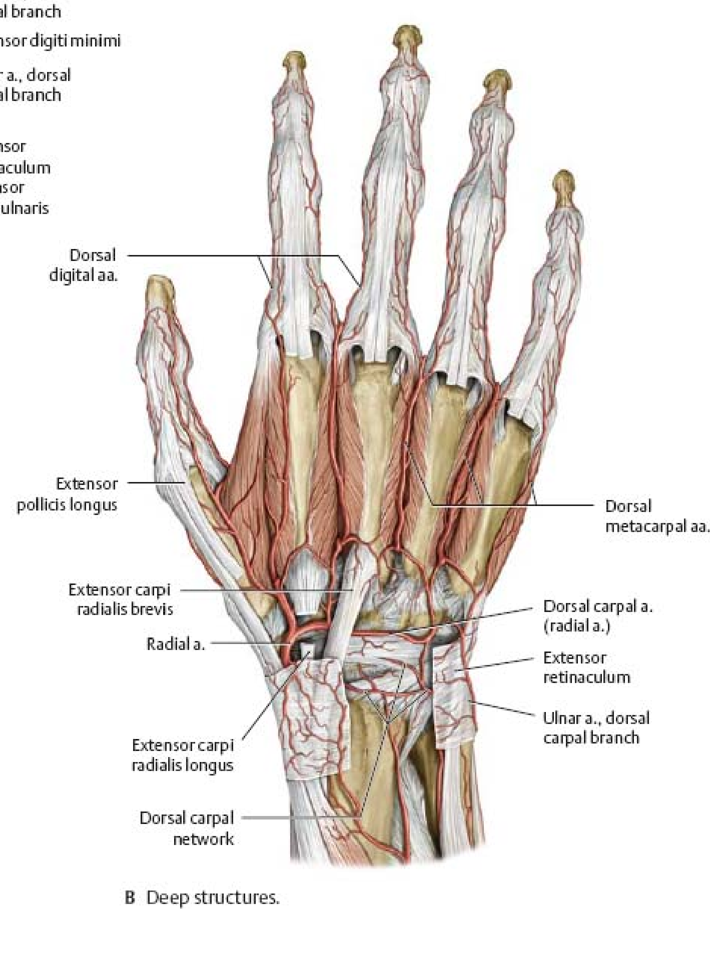


Fig. 22.48 Neurovascular structures of the dorsum



A Superficial structures.

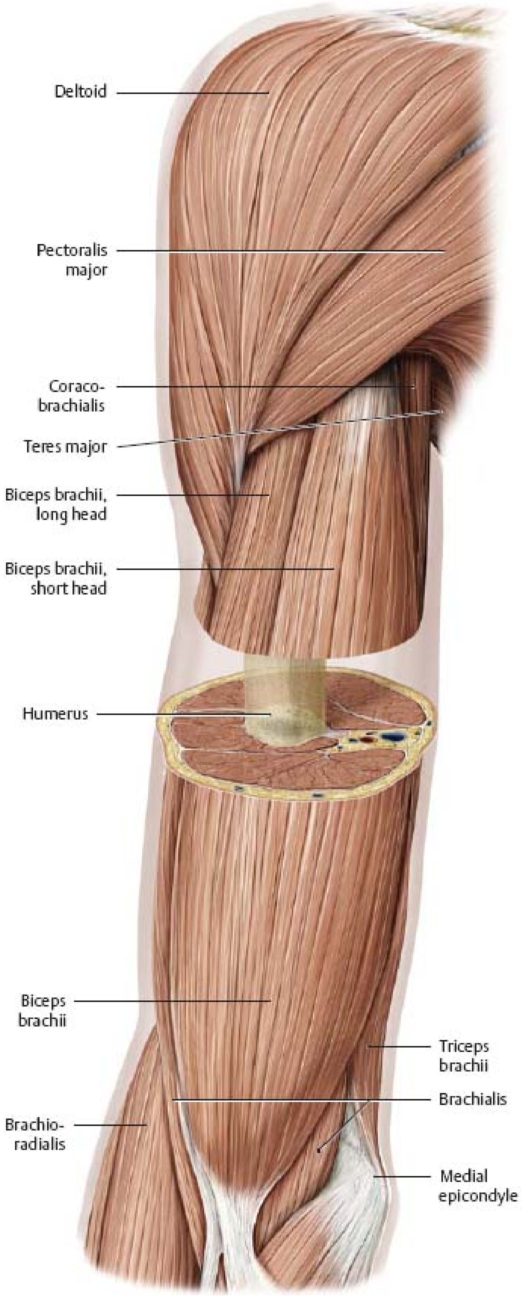


B Deep structures.

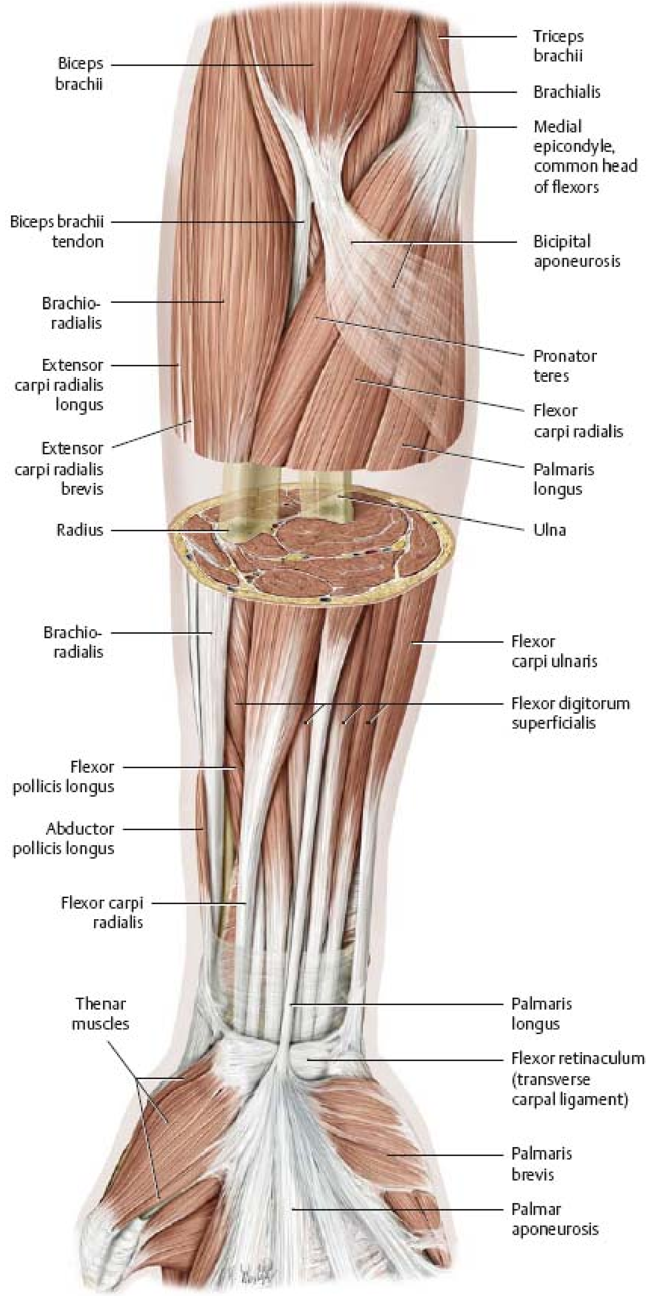
Transverse Sections

Fig. 22.49 **Windowed dissection**

Right limb, anterior view.



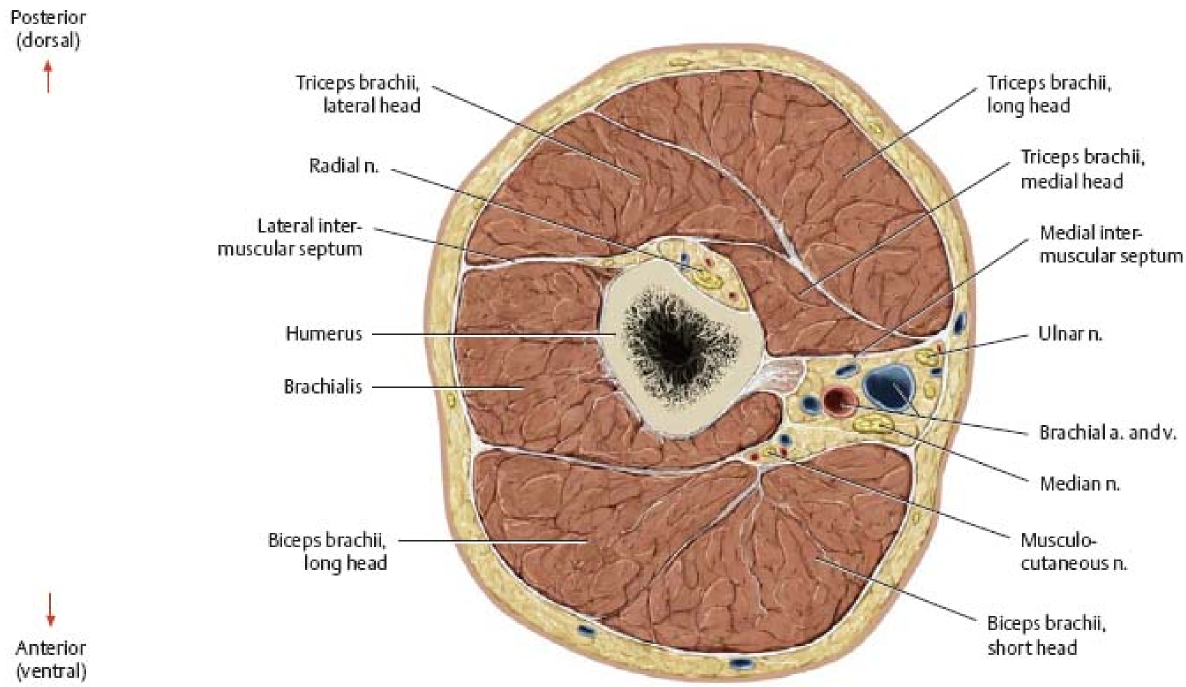
A Dissection of the arm.



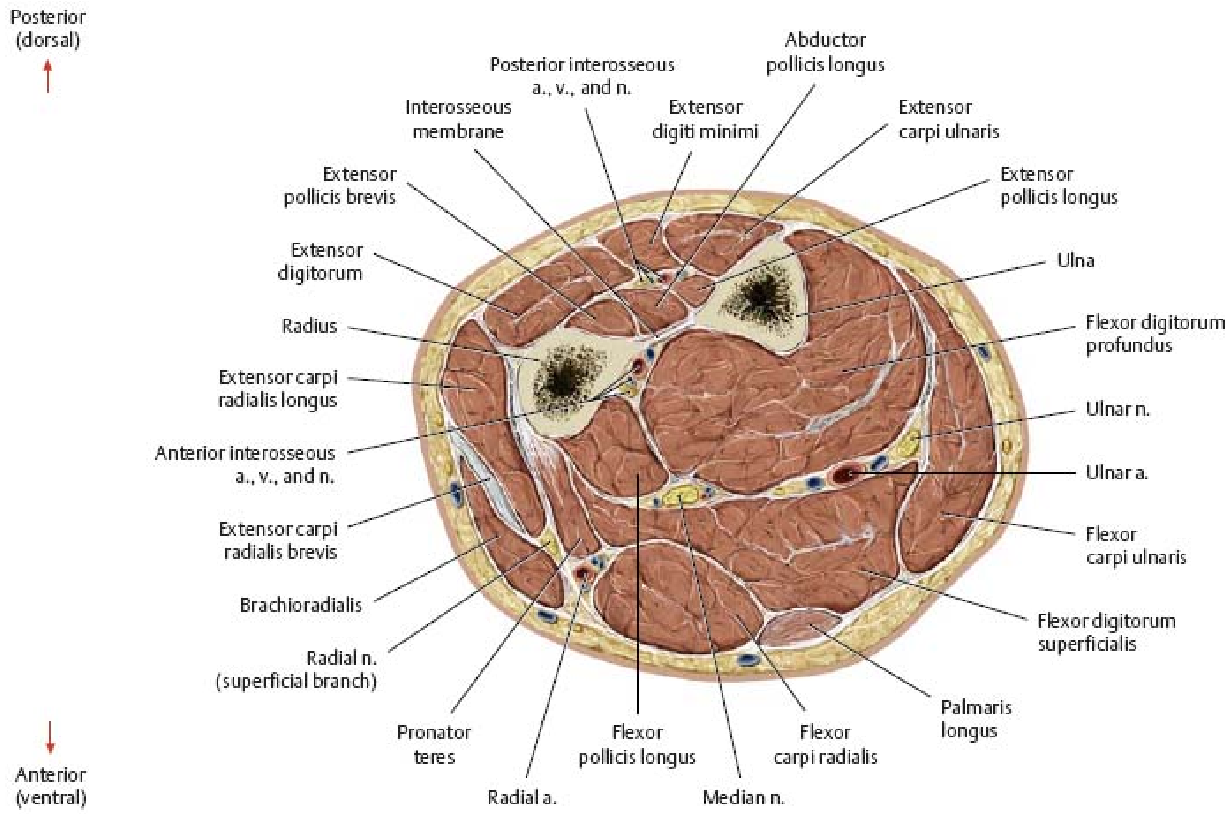
B Dissection of the forearm.

Fig. 22.50 **Transverse sections**

Right limb, proximal (superior) view.



A Arm (plane of section in Fig. 22.49A).

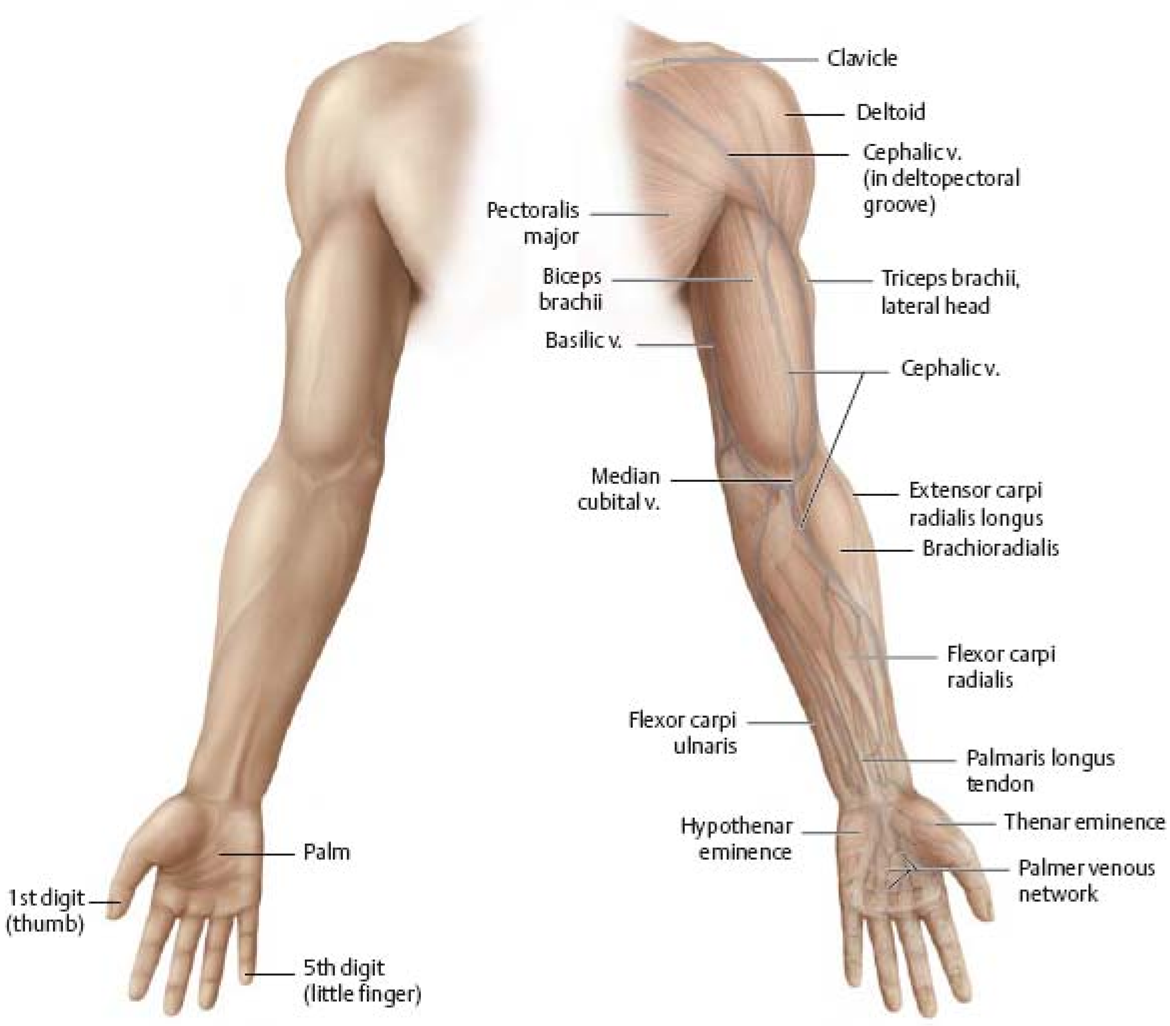


B Forearm (plane of section in Fig. 22.49B).

23 Surface Anatomy

Surface Anatomy (I)

Fig. 23.1 Upper limb: Anterior view



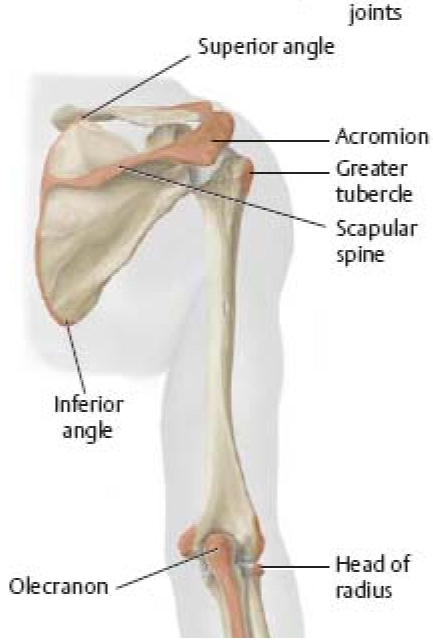
A Surface anatomy, right limb.

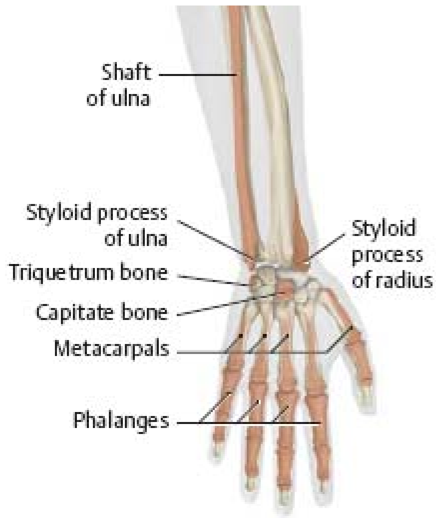
B Musculature, left limb.

Fig. 23.2 Palpable bony prominences

Right limb.

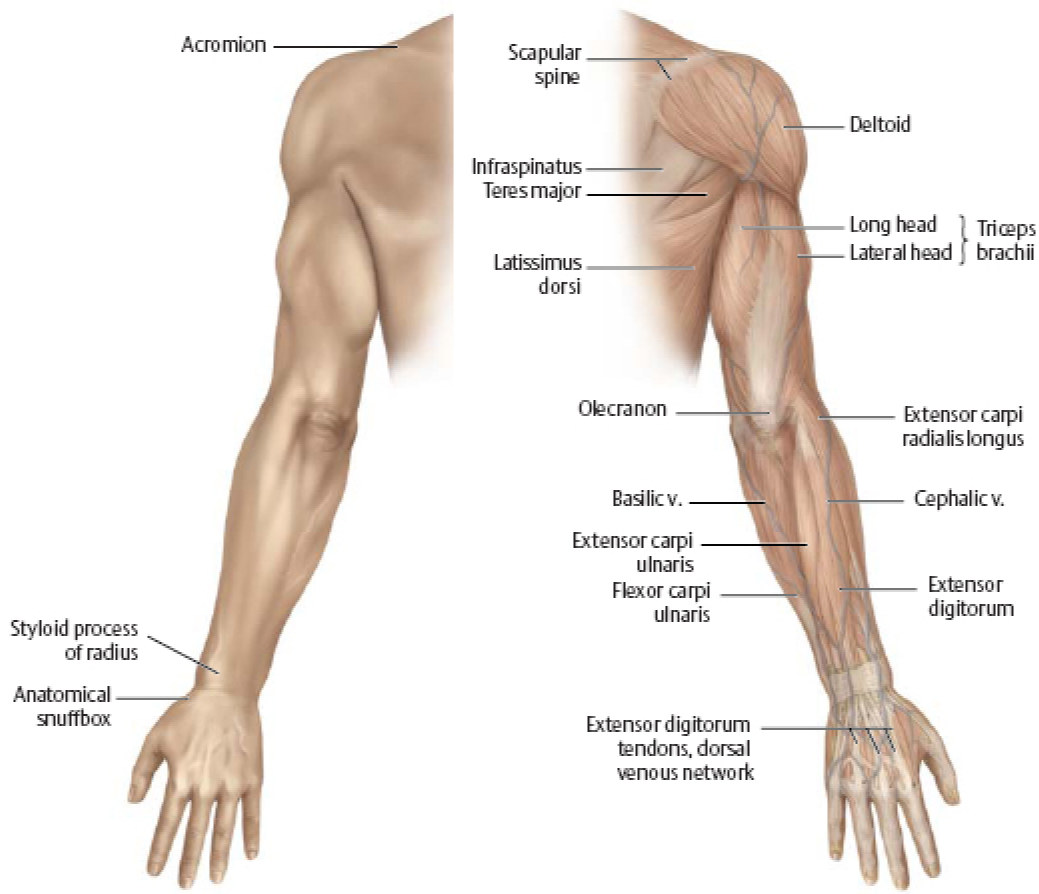
A Anterior view.





B Posterior view.

Fig. 23.3 **Upper limb: Posterior view**



A Surface anatomy, left limb.

B Musculature, right limb.

Q1: Which cutaneous nerves are most vulnerable during intravenous punctures (e.g., drawing blood, injections)?

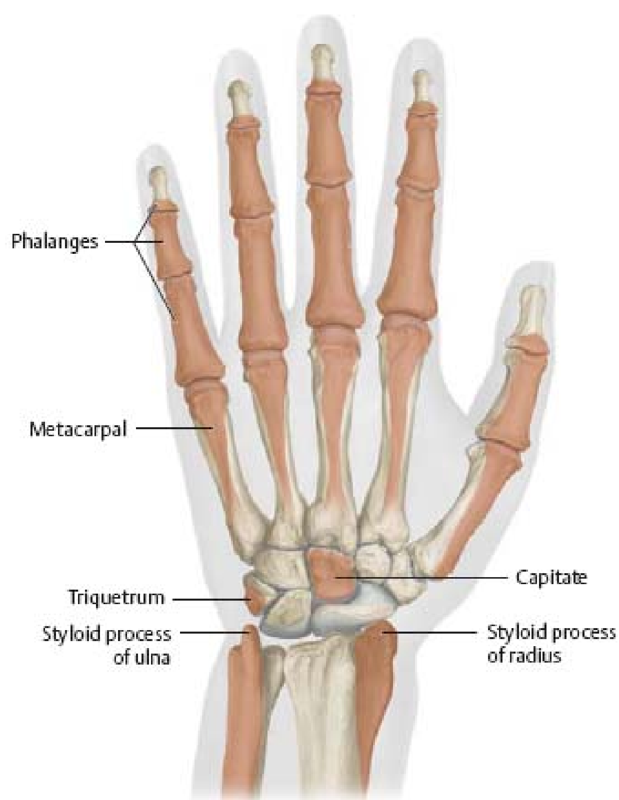
Q2: Palpation of which skeletal landmarks would allow you to locate and examine the collateral ligaments of the elbow?

Surface Anatomy (II)

Fig. 23.4 Palpable bony structures

Left hand.

A Anterior (palmar) view.



B Posterior (dorsal) view.

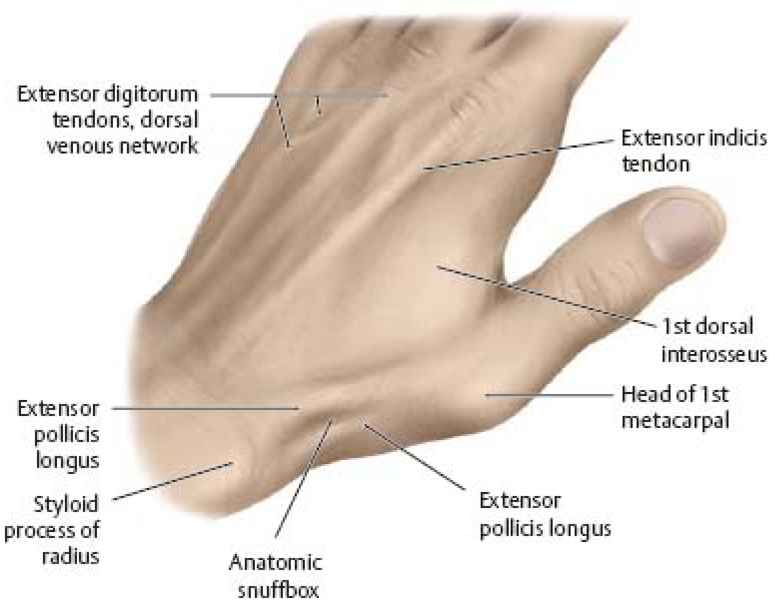
Fig. 23.5 Surface anatomy of the wrist

Left wrist, oblique anterolateral view.

Q3: How can the palpable tendons in the wrist be used to determine the location of key arteries and nerves?

Fig. 23.6 Anatomic snuffbox

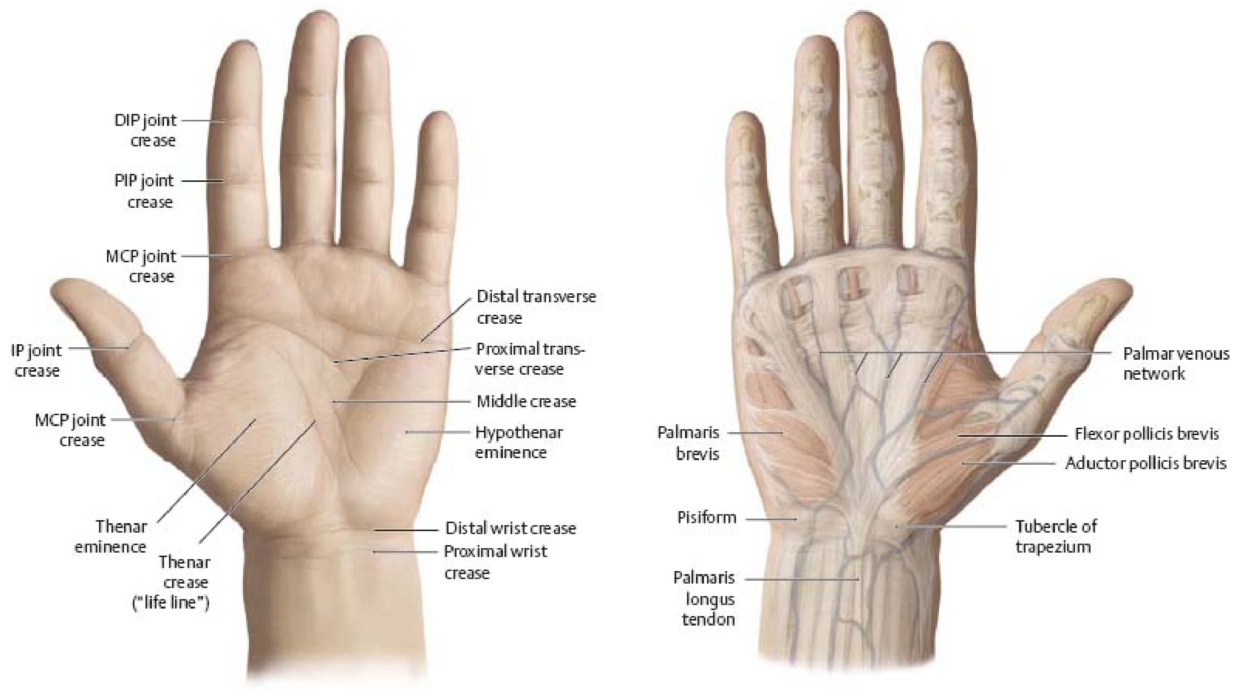
Left hand, oblique posterolateral view.



Q4: Tenderness in the base of the anatomic snuffbox can suggest a fracture of which of the carpal bones?

See answers beginning on p. 626.

Fig. 23.7 Palm

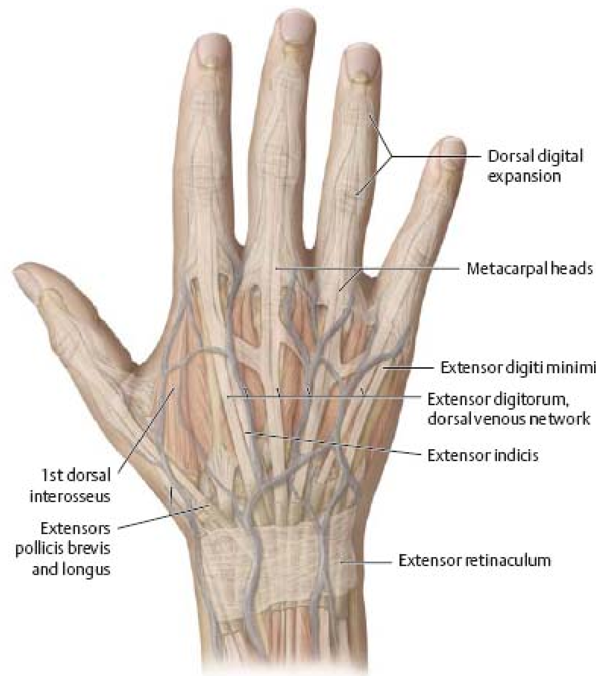


A Surface anatomy, left palm.

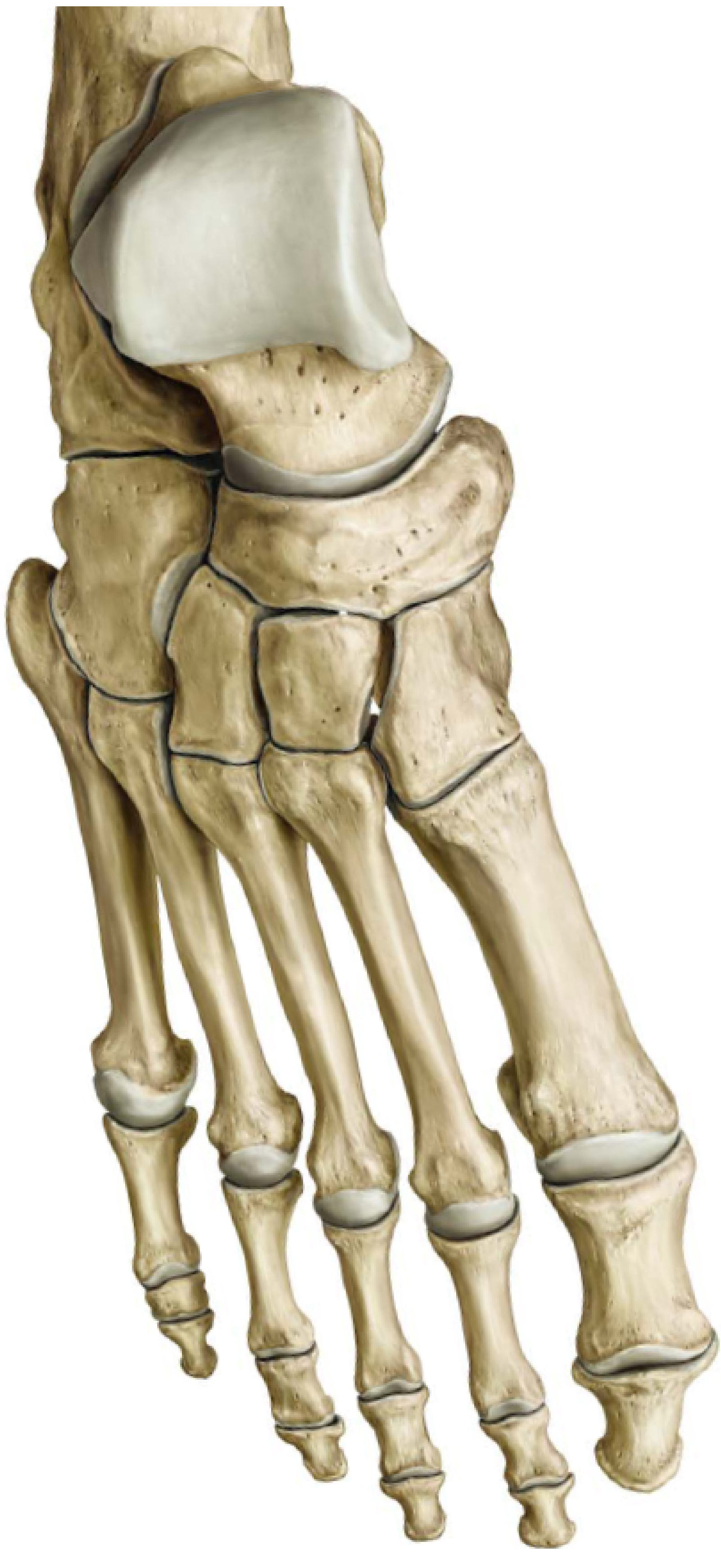
B Musculature, right palm.

Fig. 23.8 Dorsum

A Surface anatomy, left hand.



B Musculature, right hand.



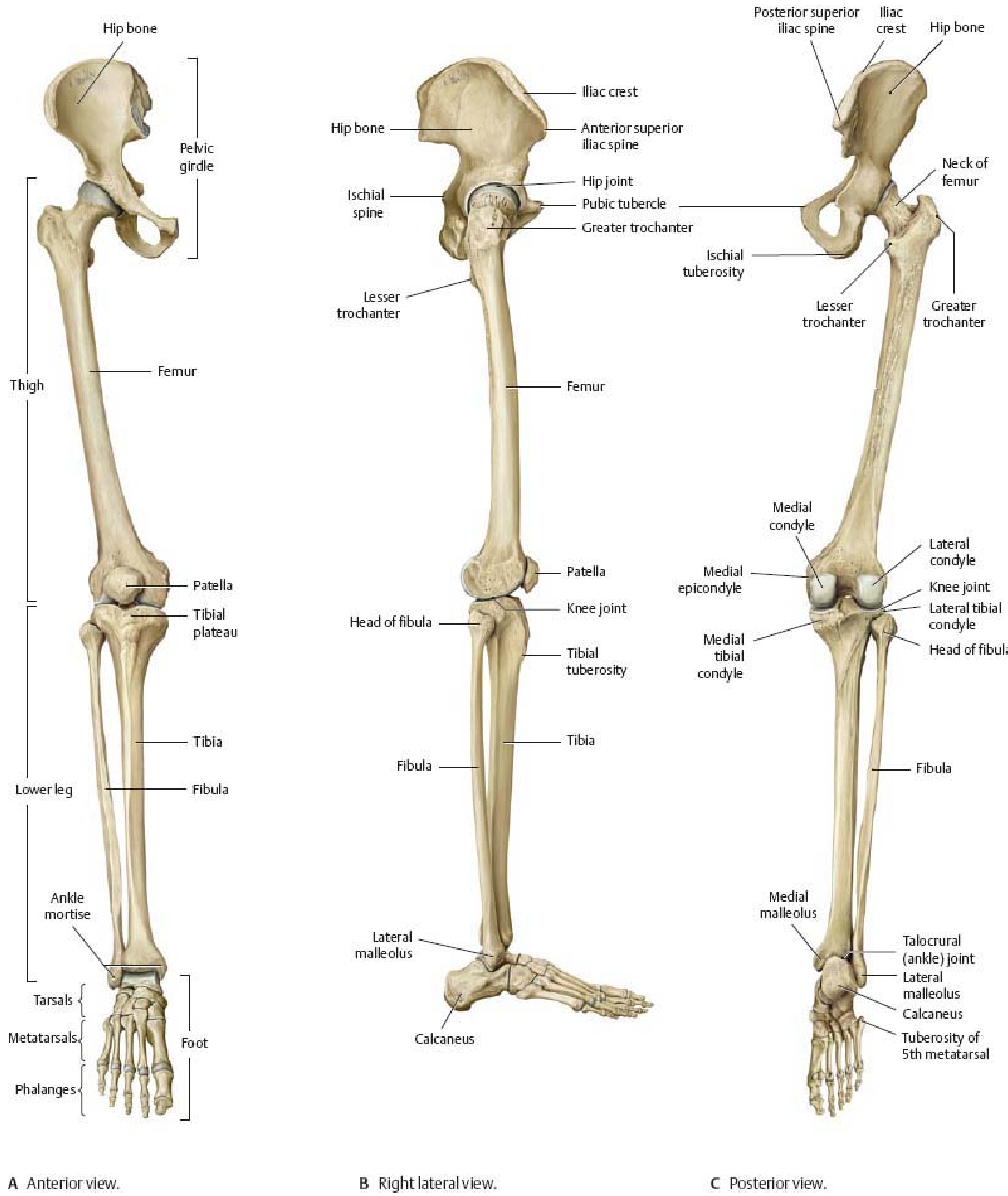
Lower Limb

24 Hip & Thigh

Bones of the Lower Limb

Fig. 24.1 Bones of the lower limb

Right limb. The skeleton of the lower limb consists of a limb girdle and an attached free limb. The free limb is divided into the thigh (femur), leg (tibia and fibula), and foot. It is connected to the pelvic girdle by the hip joint.



A Anterior view. B Right lateral view. C Posterior view.

Fig. 24.2 **Line of gravity**

Right lateral view. The line of gravity runs vertically from the whole-body center of gravity to the ground with characteristic points of intersection.

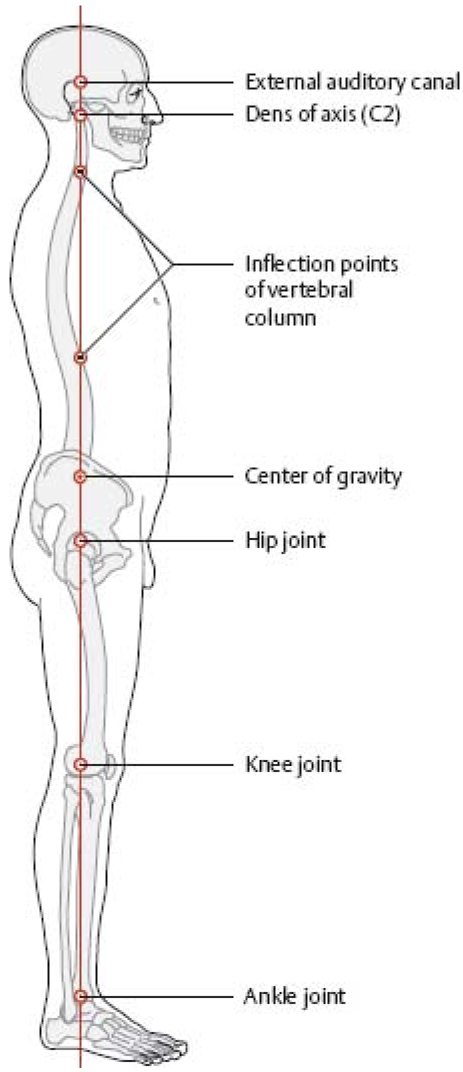
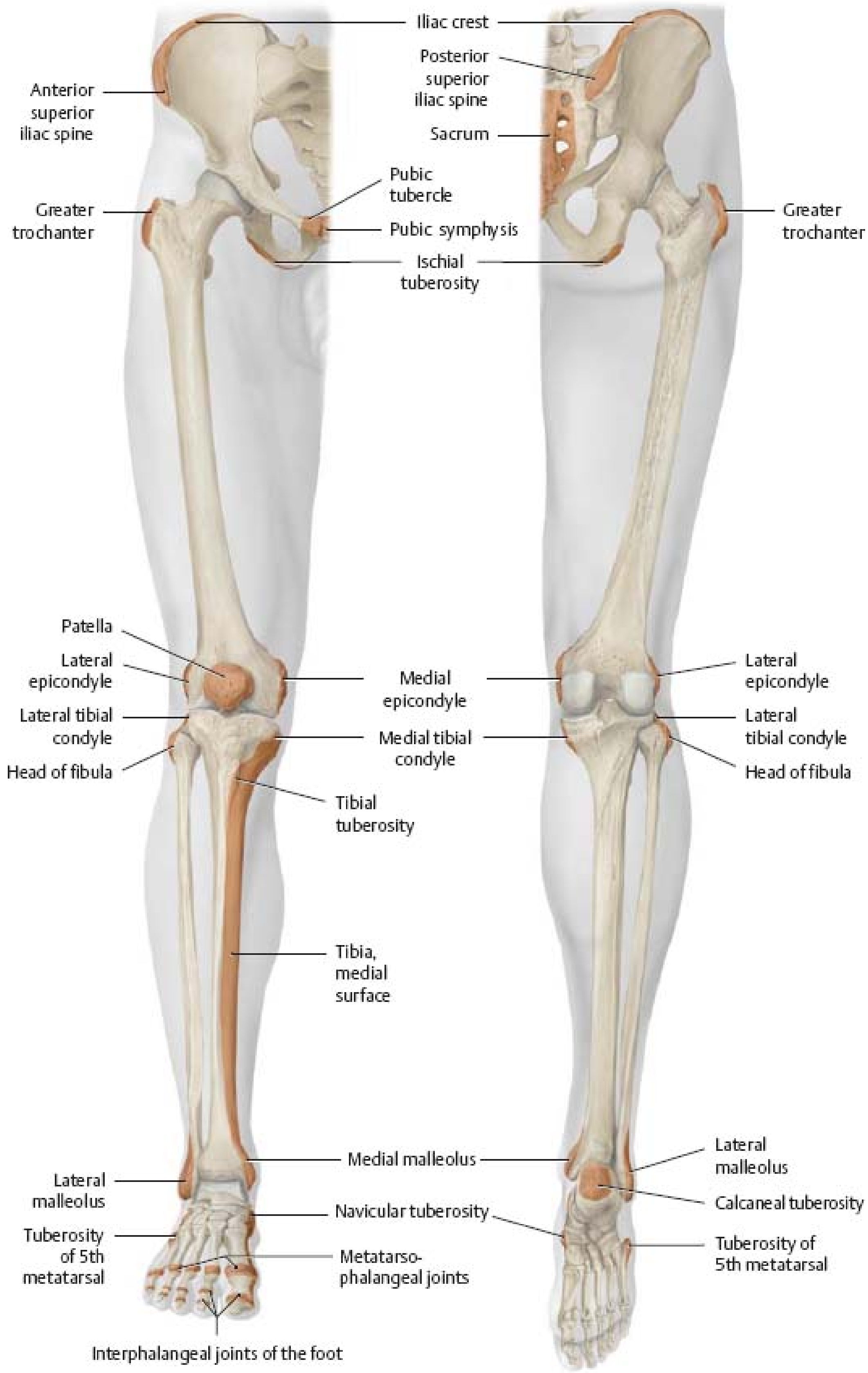


Fig. 24.3 **Palpable bony prominences in the lower limb**

Most skeletal elements of the lower limb have bony prominences, margins, or surfaces (e.g., medial or tibial surfaces) that can be palpated through the skin and soft tissues.



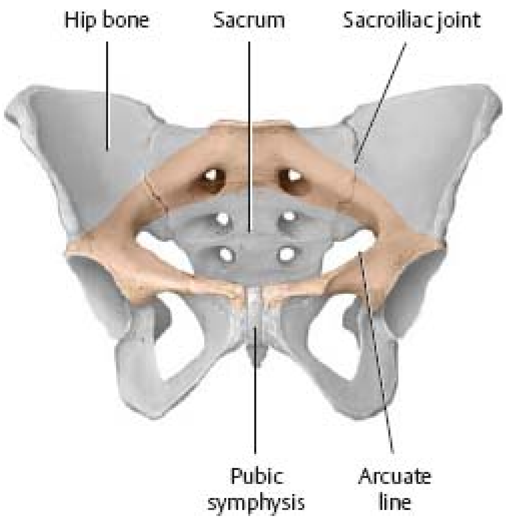
A Anterior view.

B Posterior view.

Pelvic Girdle & Hip Bone

Fig. 24.4 Pelvic girdle

Anterior view. Pelvic ring in red.



Each pelvic girdle consists of a hip bone (coxal bone, innominate bone), which articulates with the head of a femur. Unlike the shoulder girdle, the pelvic girdle is firmly integrated into the axial skeleton: the paired hip bones are connected to each other at the cartilaginous pubic symphysis and to the sacrum via the sacroiliac joints. These attachments create the bony pelvic ring (red), permitting very little motion. This stability is an important prerequisite for the transfer of trunk loads to the lower limb (necessary for normal gait).

Fig. 24.5 Right hip bone

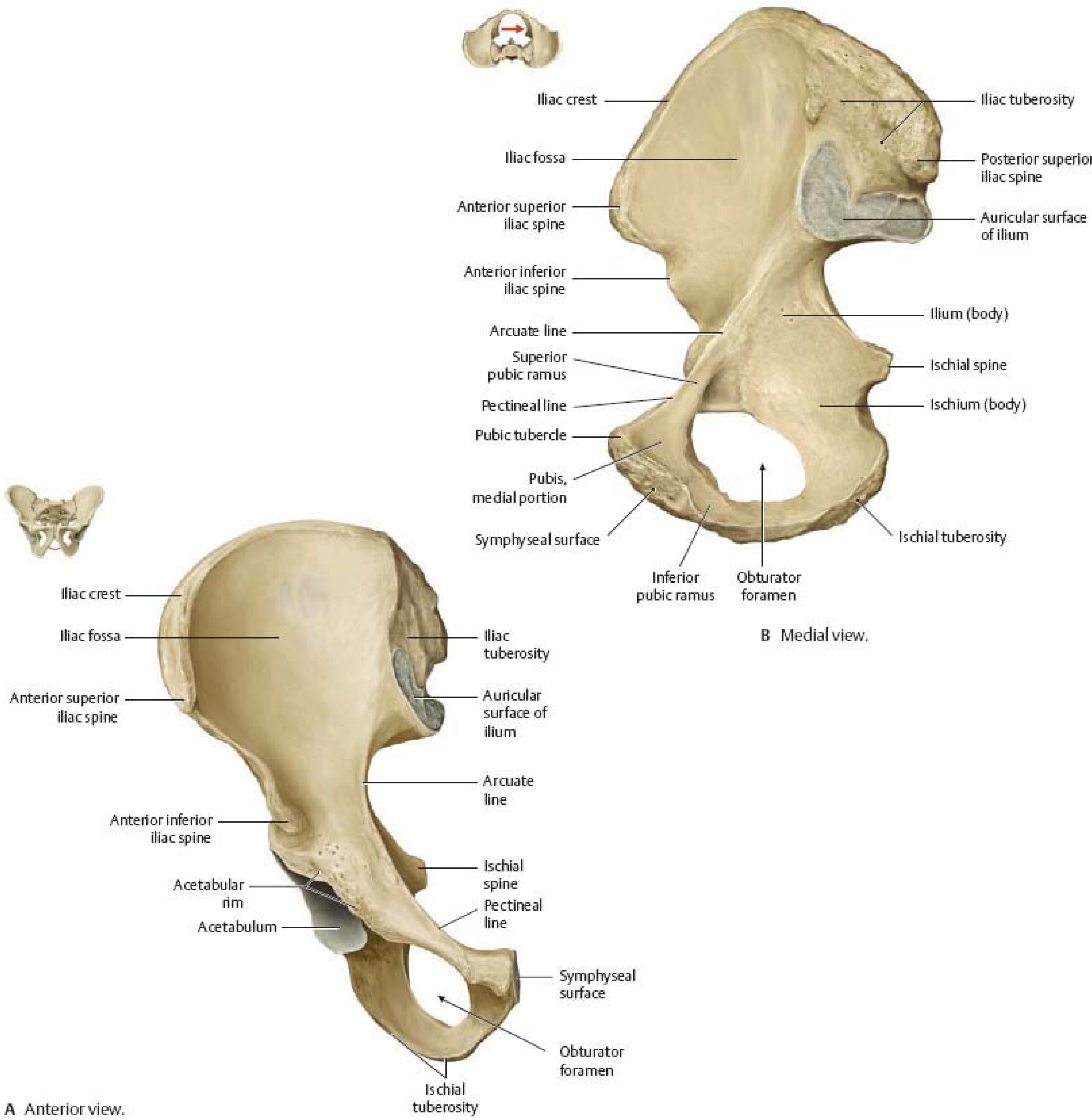
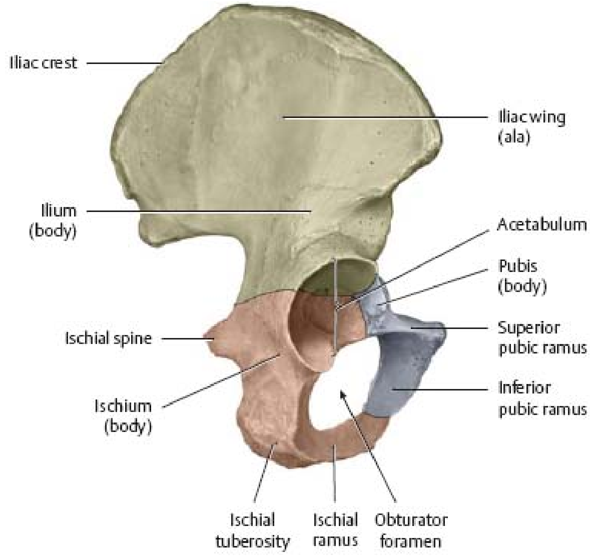
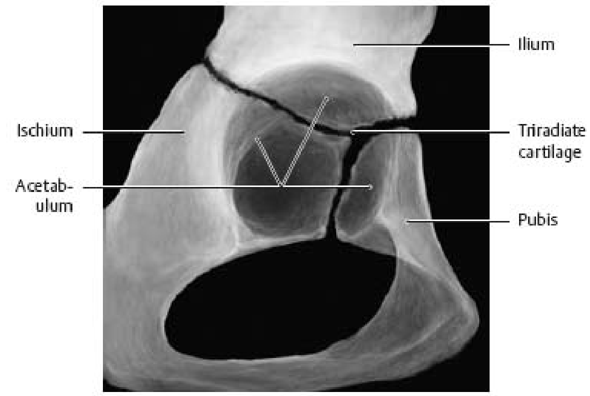


Fig. 24.6 Components of the hip bone

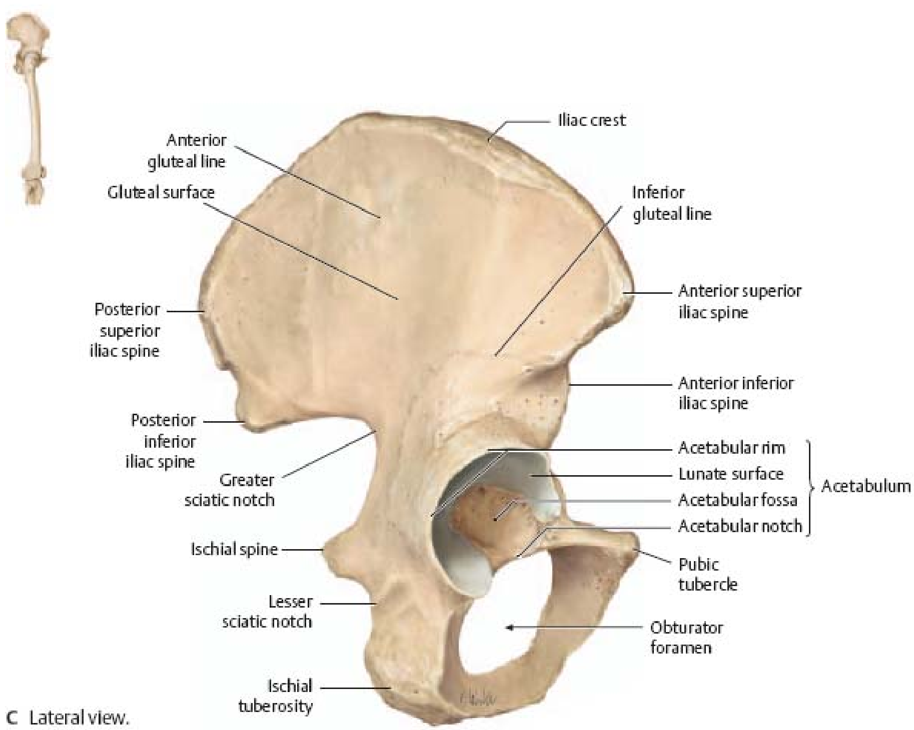
Right hip bone. The three bony elements of the hip bone (ilium, ischium, and pubis) come together at the acetabulum. Definitive fusion of the Y-shaped growth plate (triradiate cartilage) occurs between the 14th and 16th years of life.



A Triradiate cartilage of the hip bone. Lateral view.



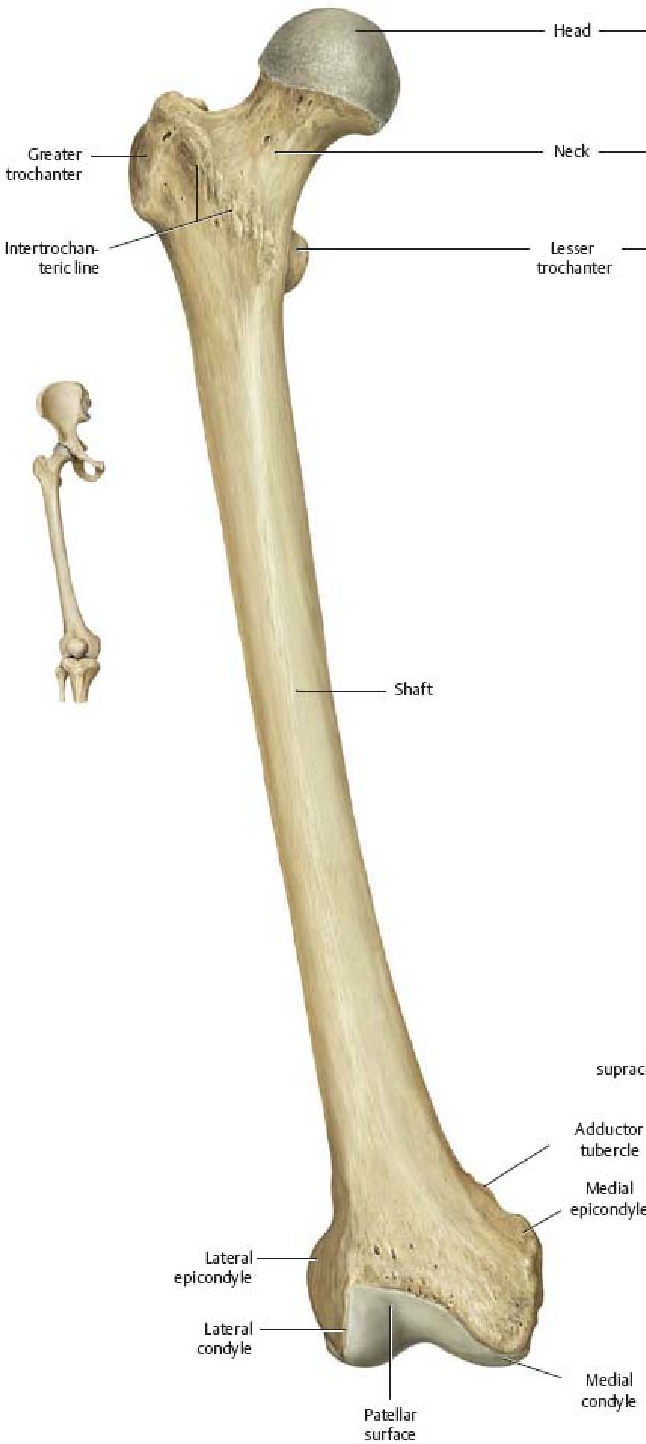
B Radiograph of right acetabulum of a child.



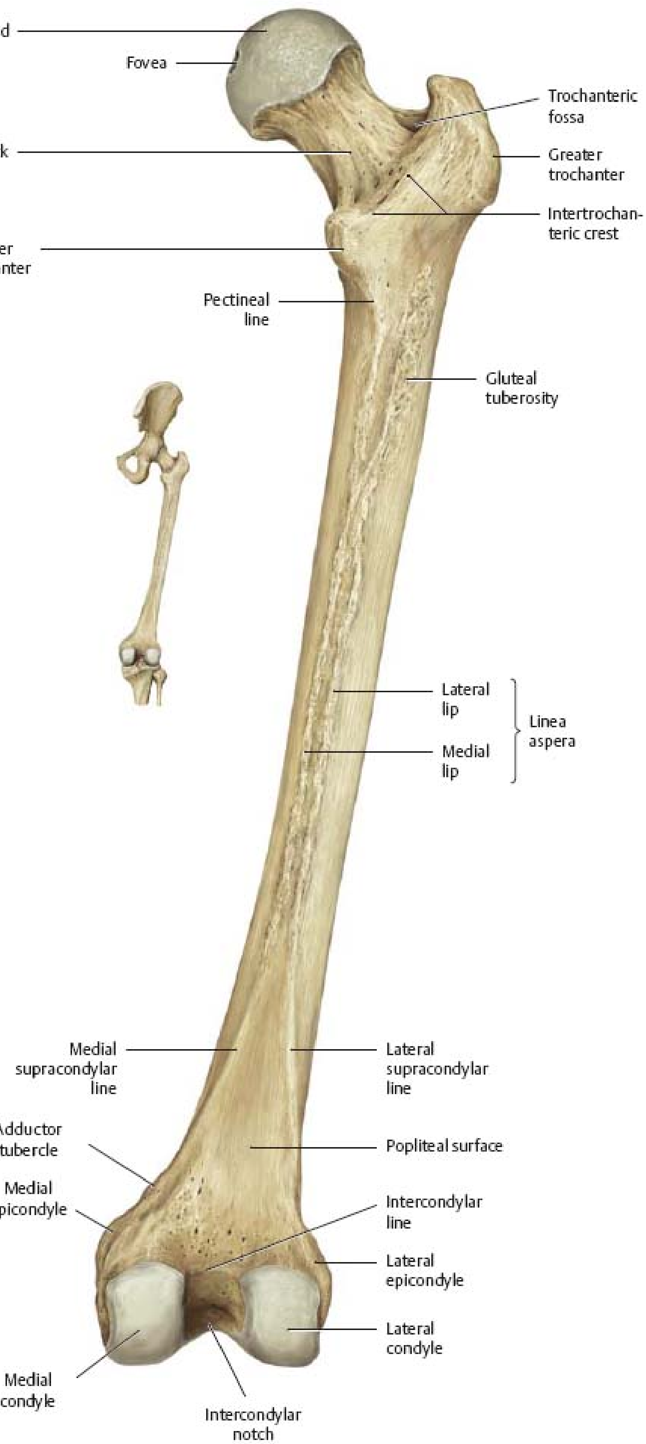
C Lateral view.

Femur

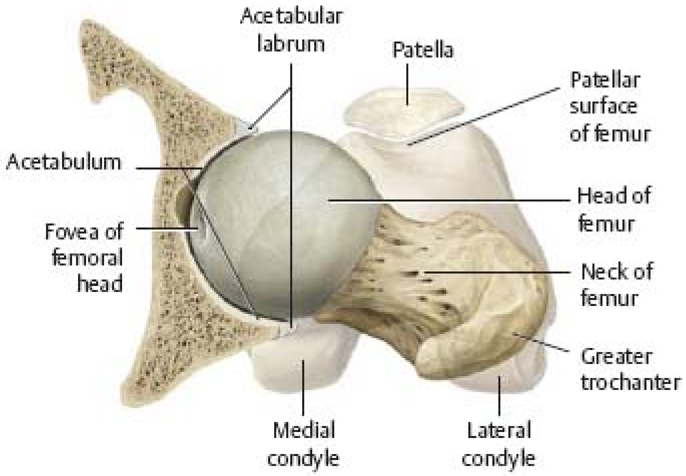
Fig. 24.7 Right femur



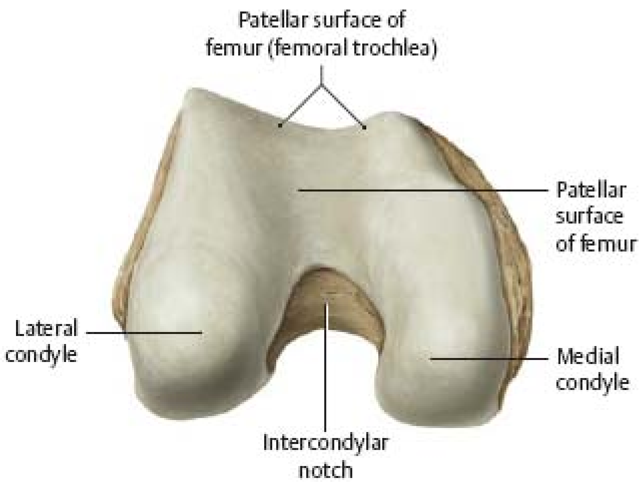
A Anterior view.



B Posterior view.



C Proximal view. The acetabulum has been sectioned in the horizontal plane.



D Distal view. See pp. 382–383 for the knee joint.

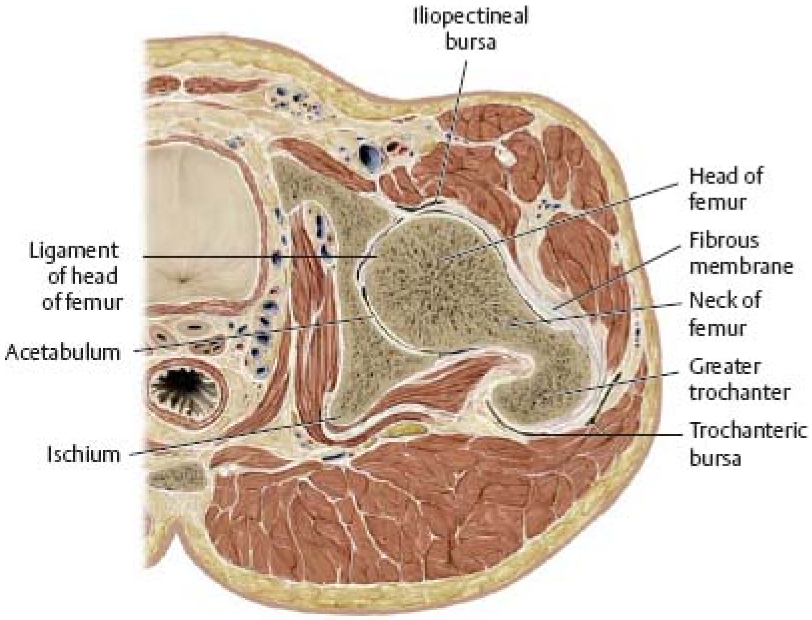
Clinical

Fractures of the femur

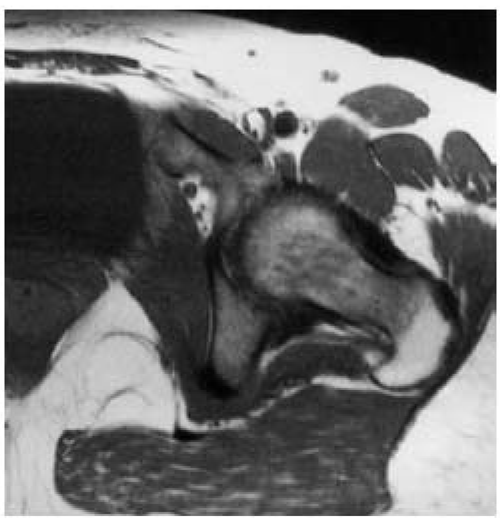
Femoral fractures caused by falls in patients with osteoporosis are most frequently located in the neck of the femur. Femoral shaft fractures are less frequent and are usually caused by strong trauma (e.g., a car accident).

Fig. 24.8 Head of femur in the hip joint

Right hip joint, superior view.



A Transverse section.



B T1-weighted MRI.

Hip Joint: Overview

Fig. 24.9 Right hip joint

The head of the femur articulates with the acetabulum of the pelvis at the hip joint, a special type of spheroidal (ball-and-socket) joint. The roughly spherical femoral head (with an average radius of curvature of approximately 2.5 cm) is largely contained within the acetabulum.

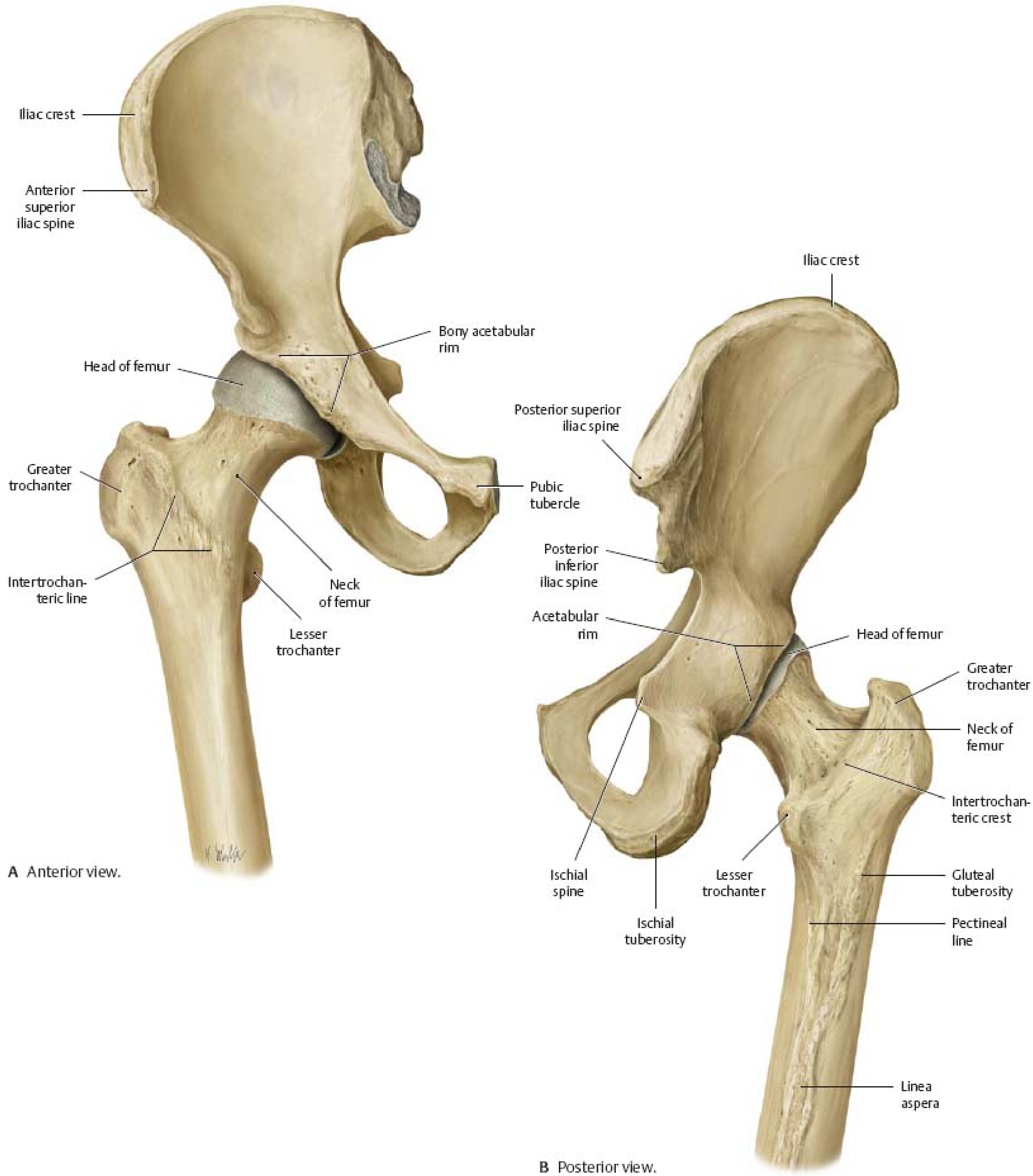
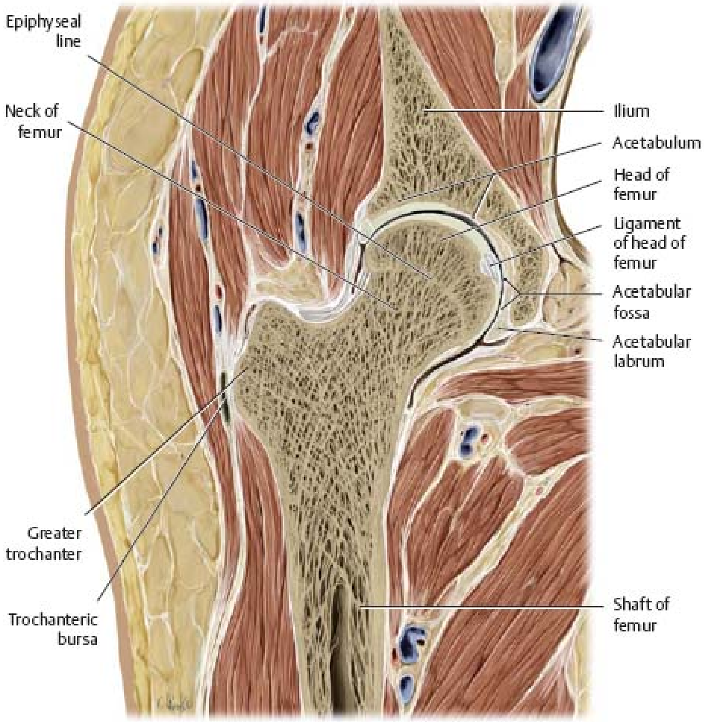


Fig. 24.10 Hip joint: Coronal section

Right hip joint, anterior view.



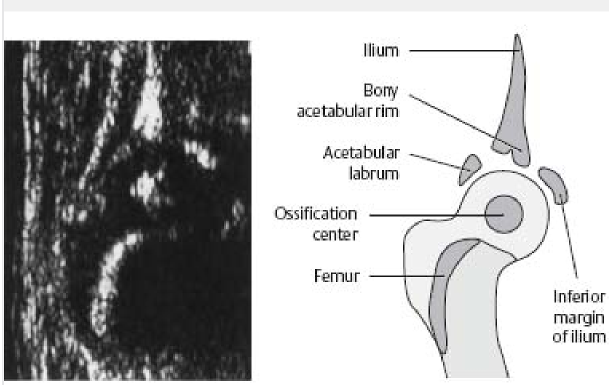
A Coronal section.

B T1-weighted MRI.

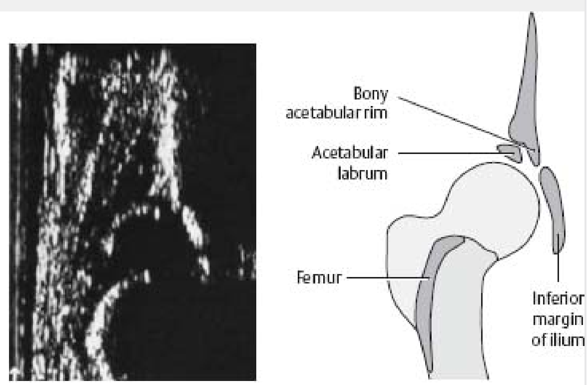
Clinical

Diagnosing hip dysplasia and dislocation

Ultrasonography, the most important imaging method for screening the infant hip, is used to identify morphological changes such as hip dysplasia and dislocation. Clinically, hip dislocation presents itself with instability and limited abduction of the hip joint, and leg shortening with asymmetry of the gluteal folds.



A Normal hip joint in a 5-month-old.

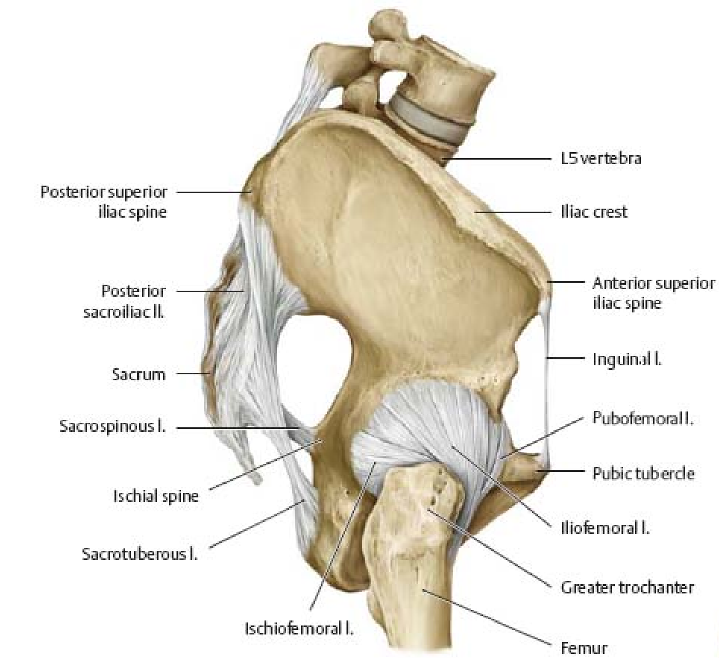


B Hip dislocation and dysplasia in a 3-month-old.

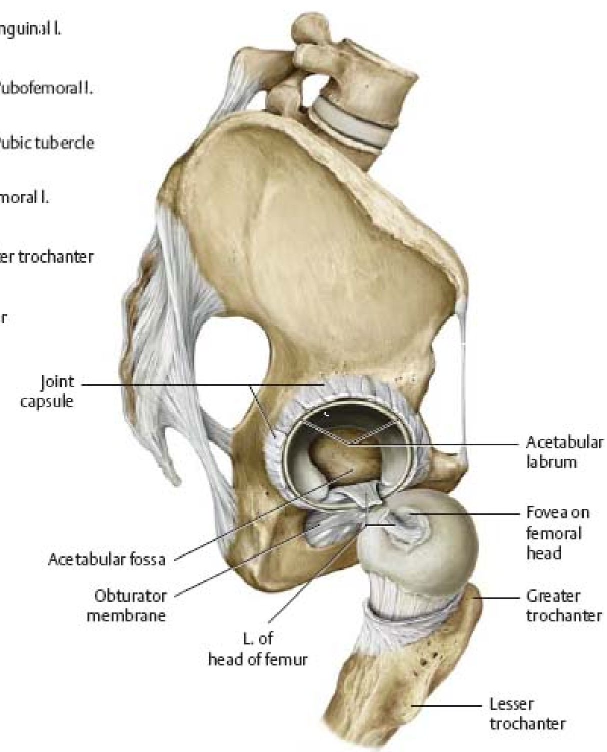
Hip Joint: Ligaments & Capsule

The hip joint has three major ligaments: iliofemoral, pubofemoral, and ischiofemoral. The zona orbicularis (annular ligament) is not visible externally and encircles the femoral neck like a buttonhole.

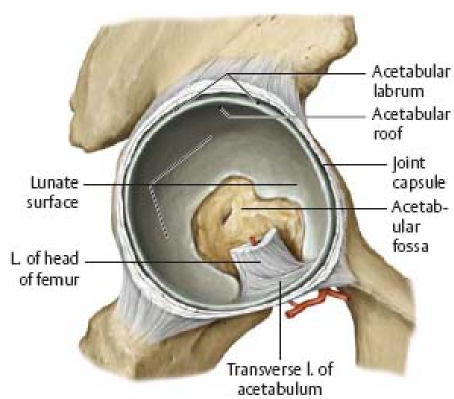
Fig. 24.11 Hip joint: Lateral view



A Ligaments of the hip joint.

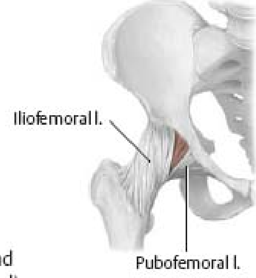


B Joint capsule. The capsule has been divided and the femoral head dislocated to expose the cut ligament of the head of the femur.

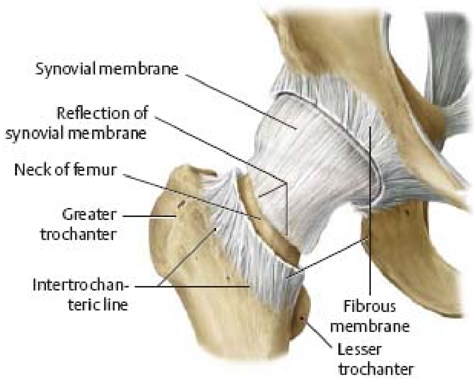


C Acetabulum of right hip joint. *Note:* The ligament of the femoral head (cut) transmits branches from the obturator artery that nourish the femoral head (see p. 421).

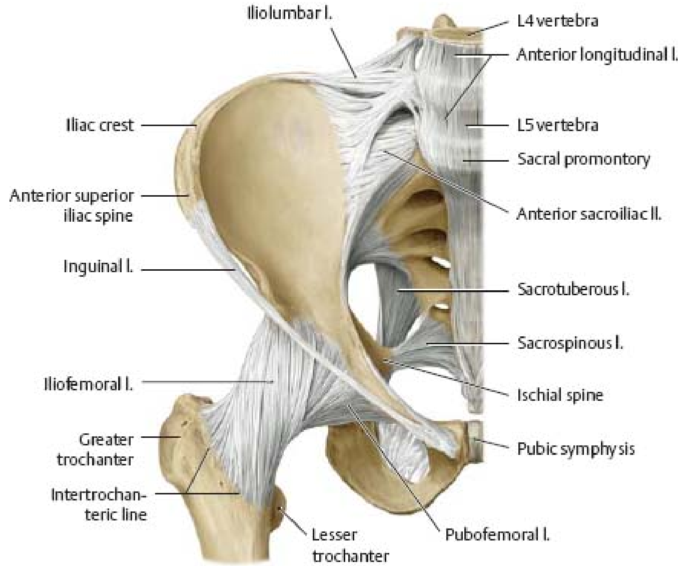
Fig. 24.12 Hip joint: Anterior view



A Ligaments and weak spot (red).

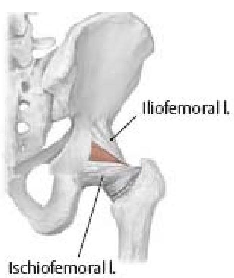


C Joint capsule. *Removed:* Fibrous membrane (at level of femoral neck). *Exposed:* Synovial membrane.

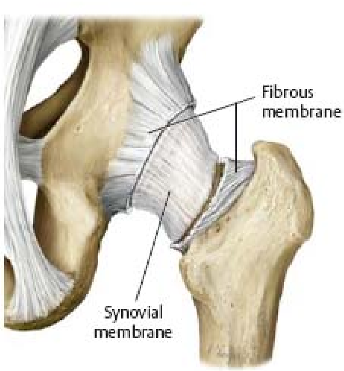


B Ligaments of the hip joint.

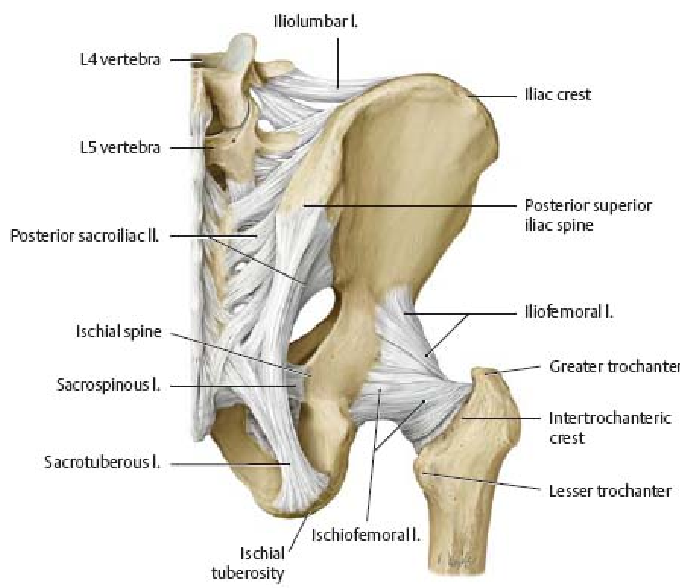
Fig. 24.13 Hip Joint: Posterior view



A Ligaments and weak spot (red).



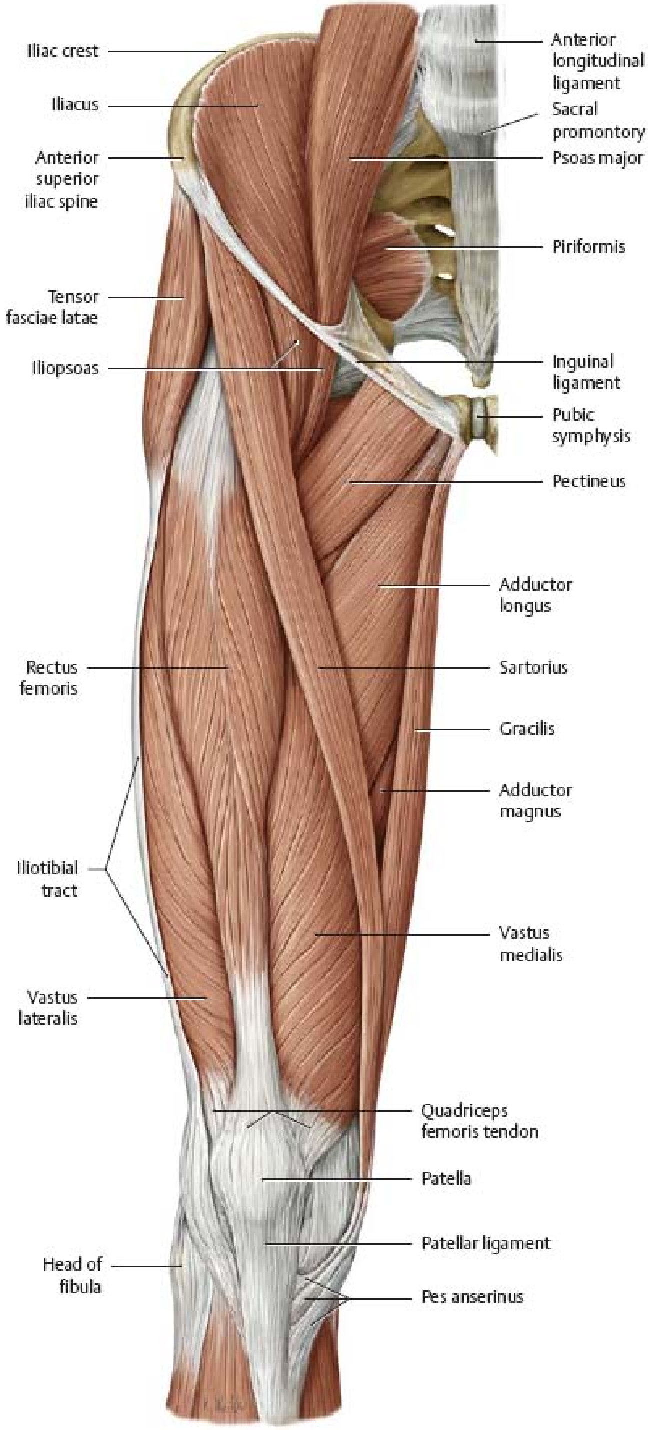
C Joint capsule.



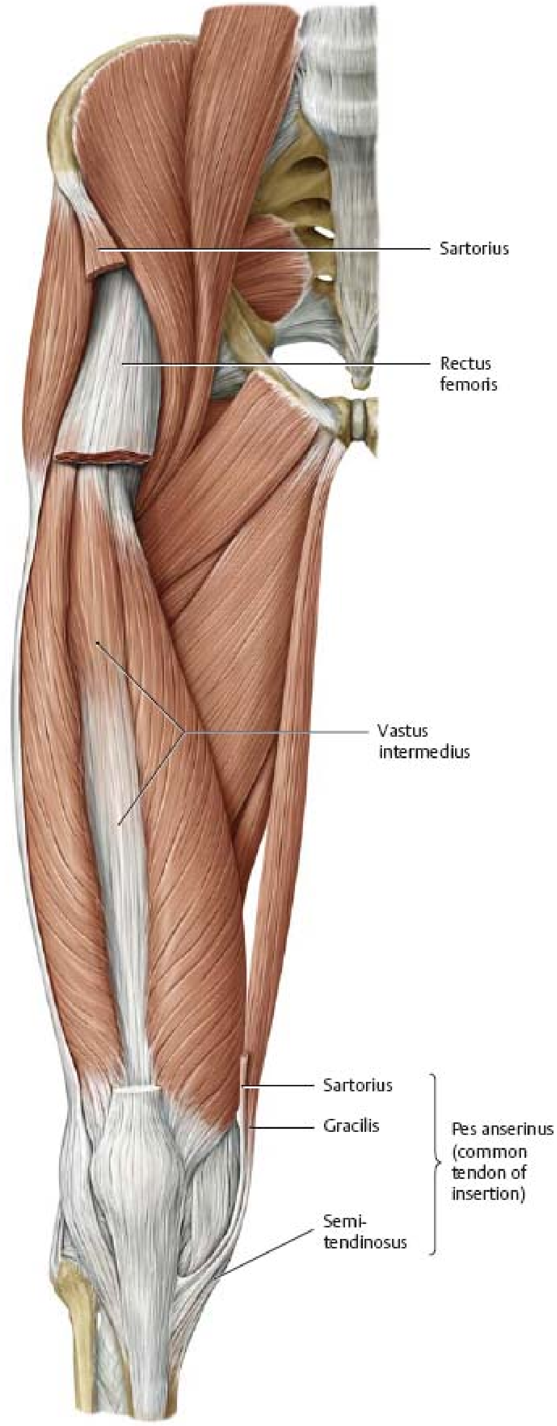
B Ligaments of the hip joint.

Anterior Muscles of the Thigh, Hip & Gluteal Region (I)

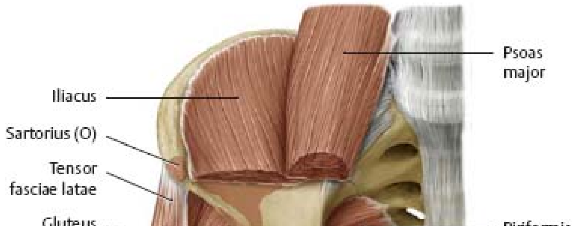
Fig. 24.14 **Muscles of the hip and thigh: Anterior view (I)**
Right limb. Muscle origins (O) are shown in red, insertions (I) in blue.

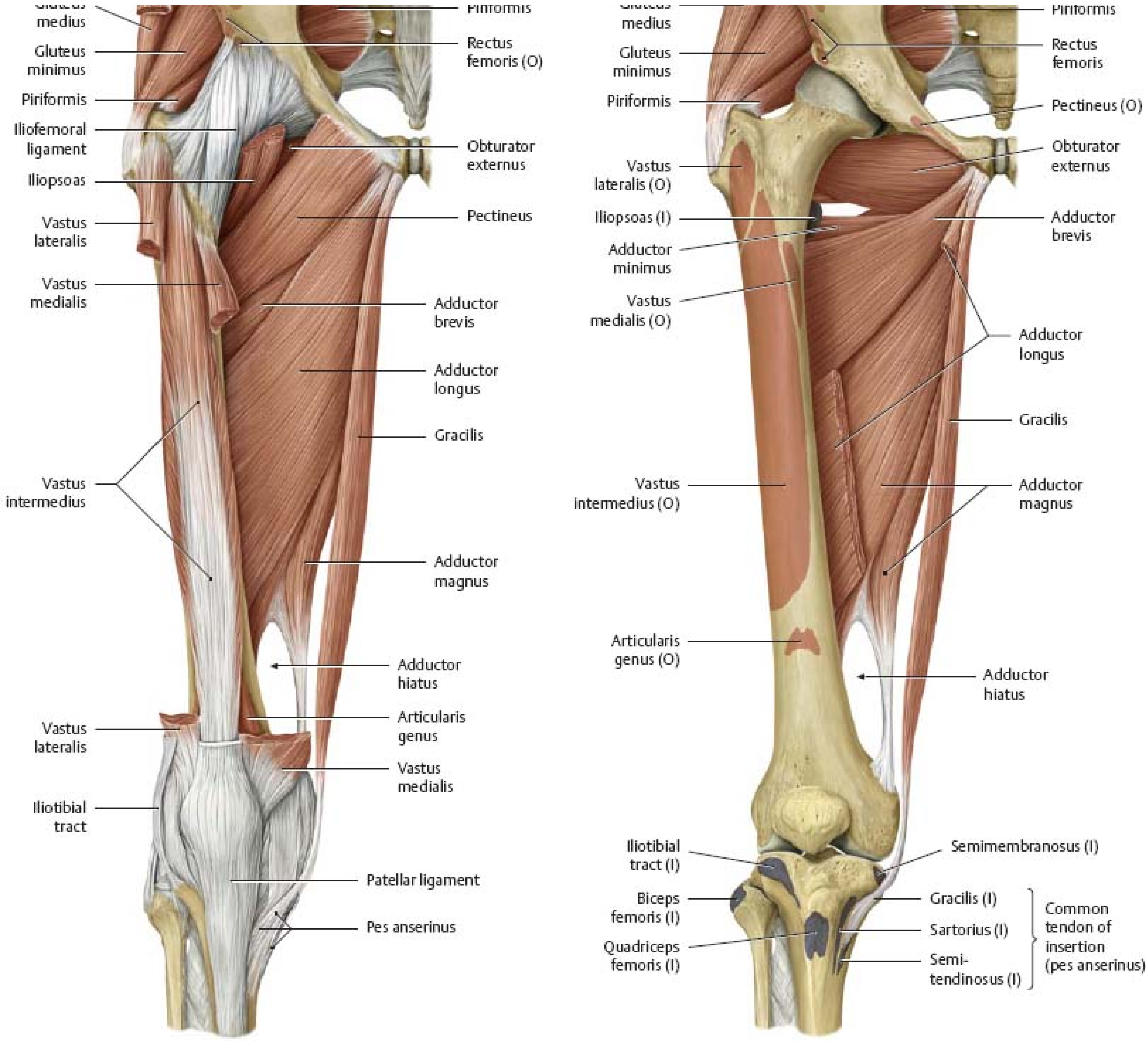


A *Removed:* Fascia lata of thigh (to the lateral iliotibial tract).



B *Removed:* Sartorius and rectus femoris.





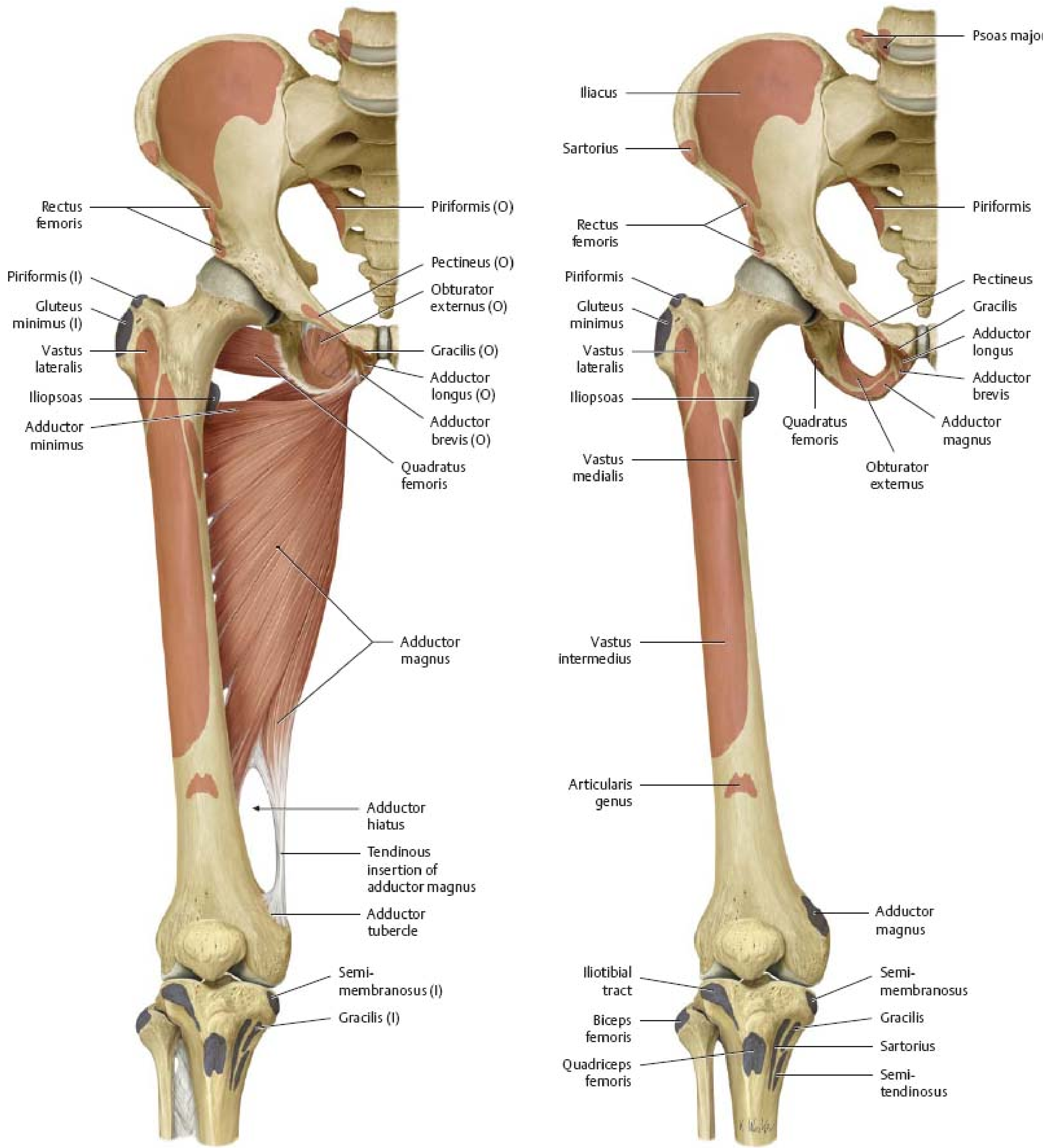
C *Removed:* Rectus femoris (completely), vastus lateralis, vastus medialis, iliopsoas, and tensor fasciae latae.

D *Removed:* Quadriceps femoris (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), iliopsoas, tensor fasciae latae, pectineus, and midportion of adductor longus.

Anterior Muscles of the Thigh, Hip & Gluteal Region (II)

Fig. 24.15 Muscles of the hip and thigh: Anterior view (II)

Right limb. Muscle origins (O) are shown in red, insertions (I) in blue.

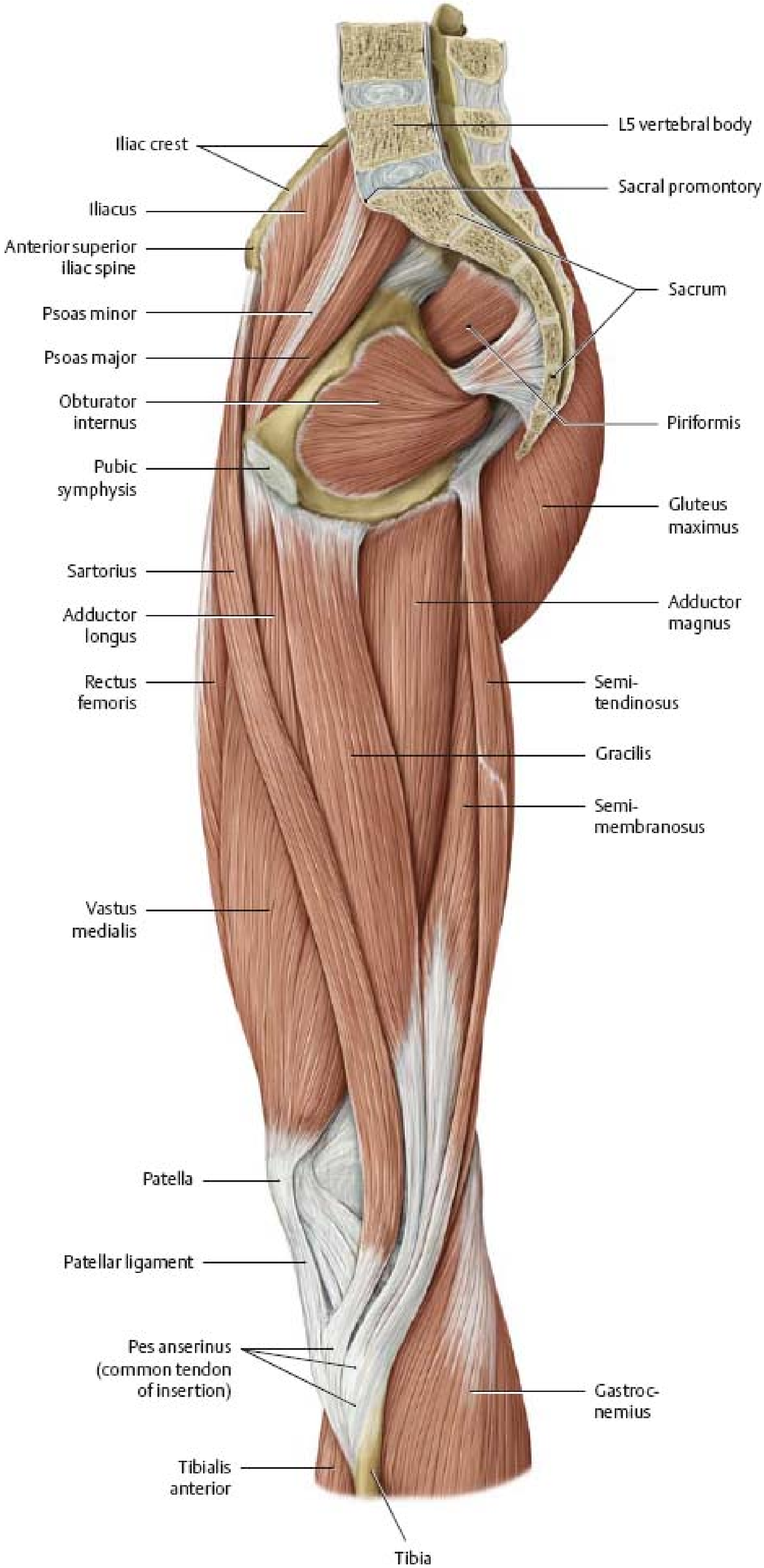


A *Removed:* Gluteus medius and minimus, piriformis, obturator externus, adductor brevis and longus, and gracilis.

B *Removed:* All muscles.

Fig. 24.16 **Muscles of the hip, thigh, and gluteal region: Medial view**

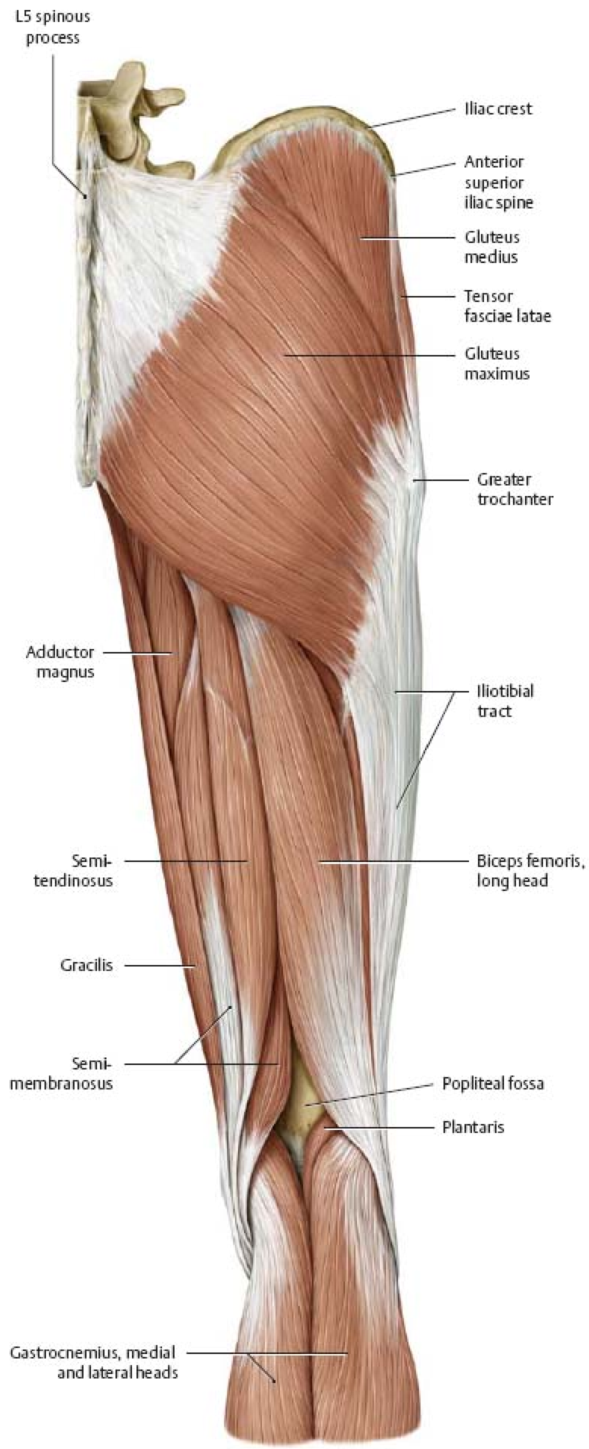
Midsagittal section.


Iliac crest
Iliacus
Anterior superior iliac spine
Psoas minor
Psoas major
Obturator internus
Pubic symphysis
Sartorius
Adductor longus
Rectus femoris
Vastus medialis
Patella
Patellar ligament
Pes anserinus (common tendon of insertion)
Tibialis anterior
Tibia
L5 vertebral body
Sacral promontory
Sacrum
Piriformis
Gluteus maximus
Adductor magnus
Semi-tendinosus
Gracilis
Semi-membranosus
Gastroc-nemius

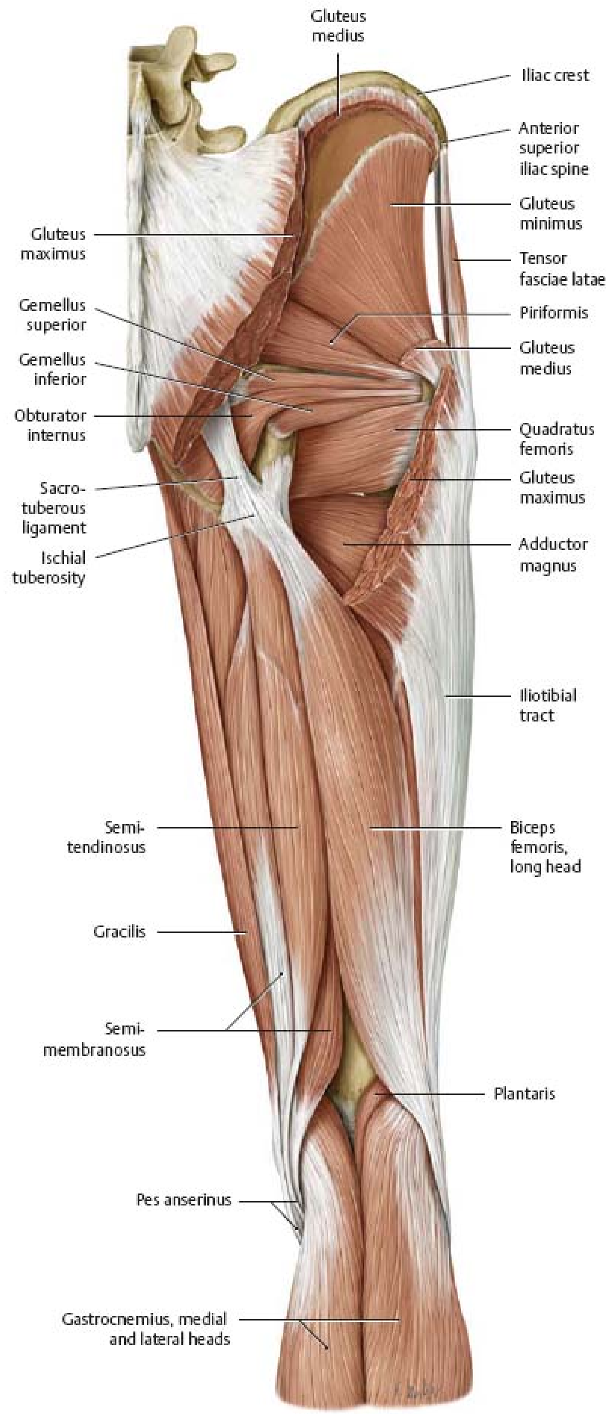
Posterior Muscles of the Thigh, Hip & Gluteal Region (I)

Fig. 24.17 **Muscles of the hip, thigh, and gluteal region: Posterior view (I)**

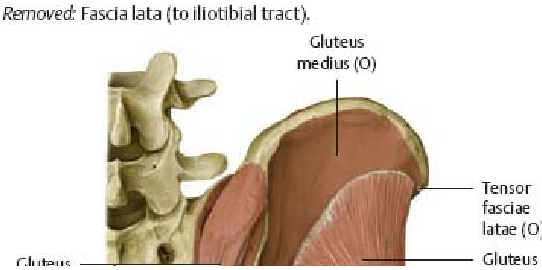
Right limb. Muscle origins (O) are shown in red, insertions (I) in blue.

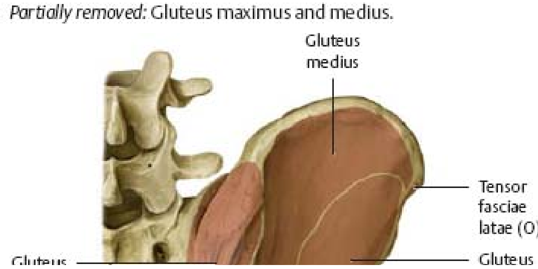


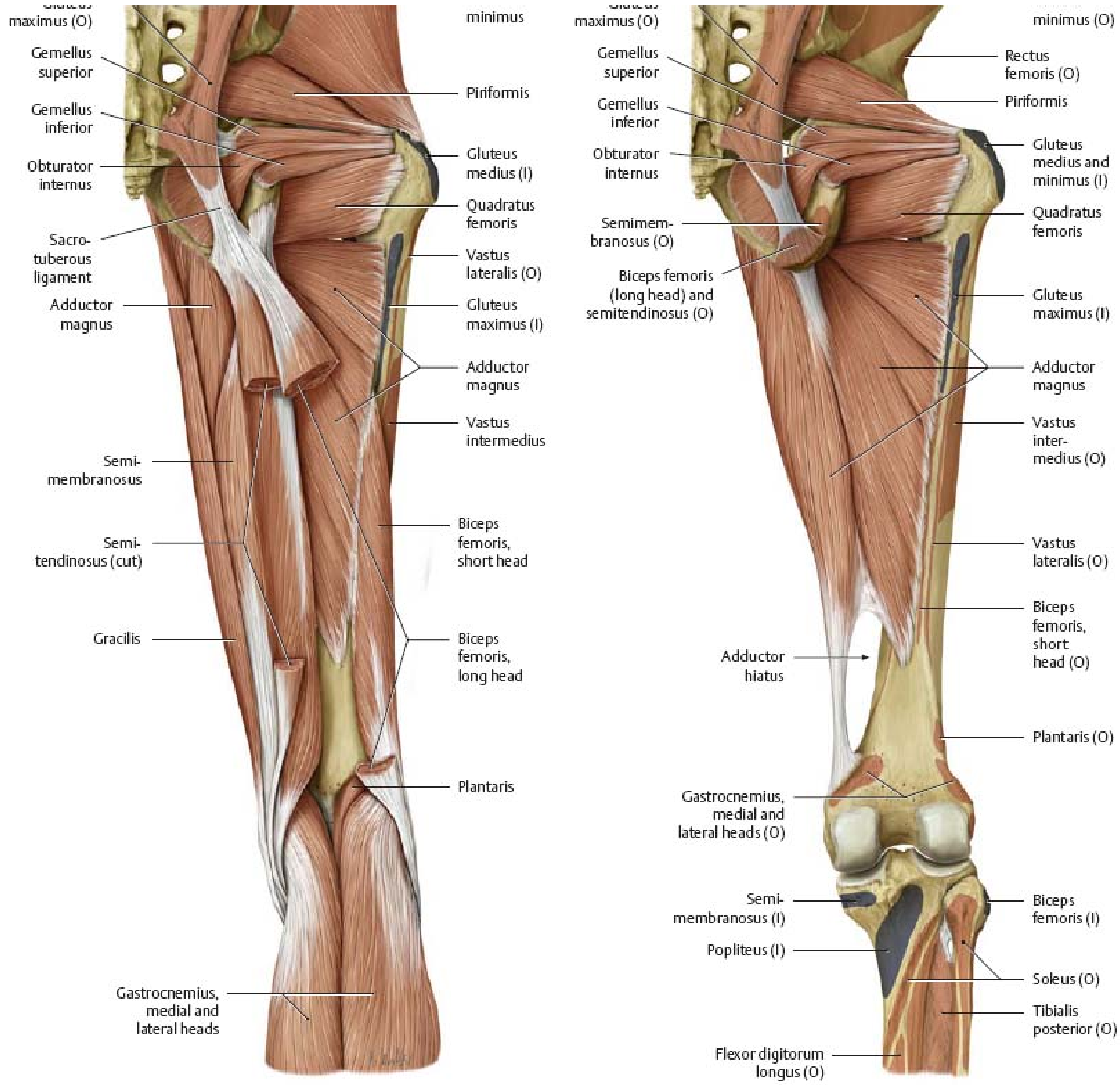
A *Removed:* Fascia lata (to iliotibial tract).



B *Partially removed:* Gluteus maximus and medius.







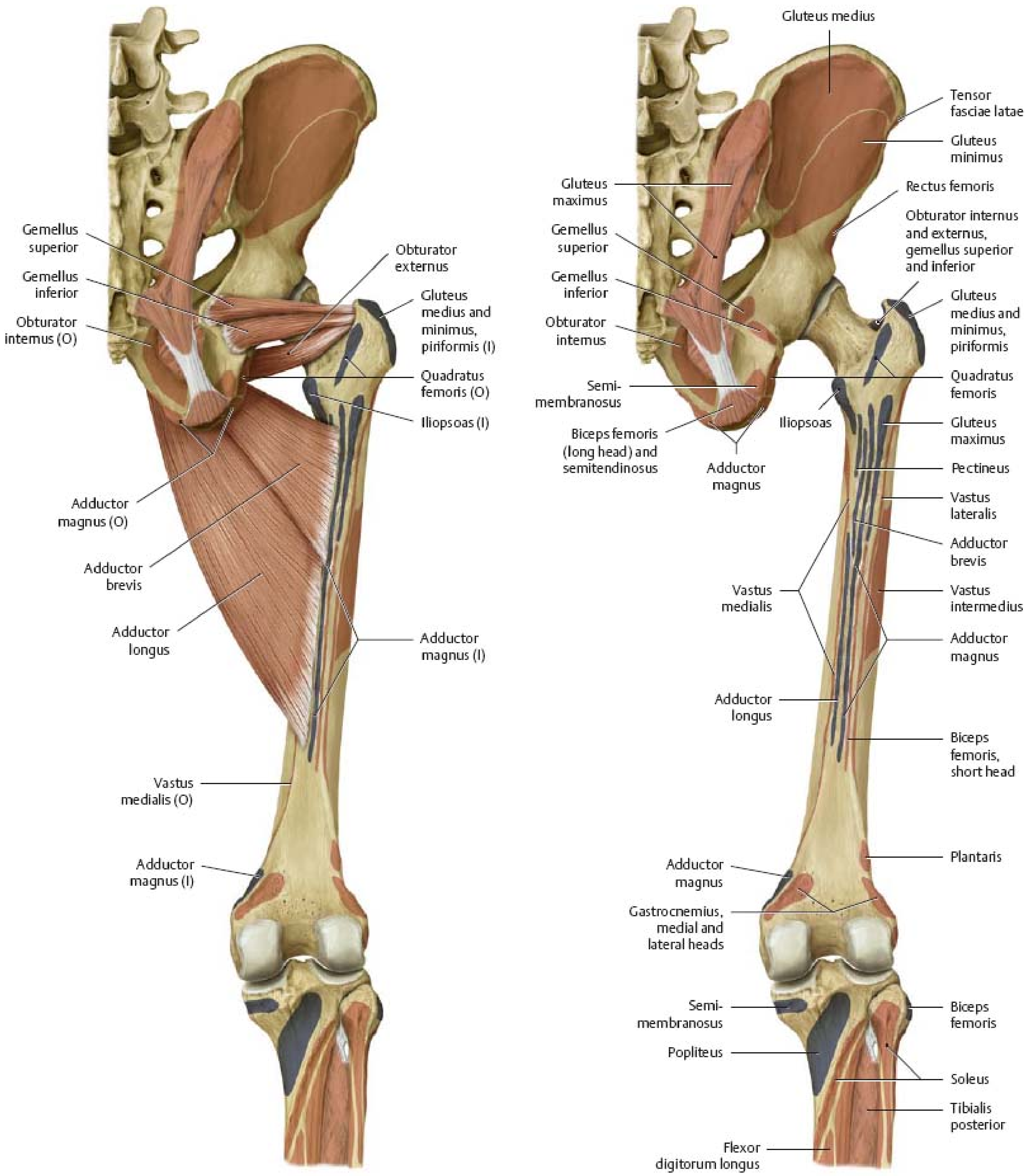
C *Removed:* Semitendinosus and biceps femoris (partially); gluteus maximus and medius (completely).

D *Removed:* Hamstrings (semitendinosus, semimembranosus, and biceps femoris), gluteus minimus, gastrocnemius, and muscles of the leg.

Posterior Muscles of the Thigh, Hip & Gluteal Region (II)

Fig. 24.18 Muscles of the hip, thigh, and gluteal region: Posterior view (II)

Right limb. Muscle origins (O) are shown in red, insertions (I) in blue.

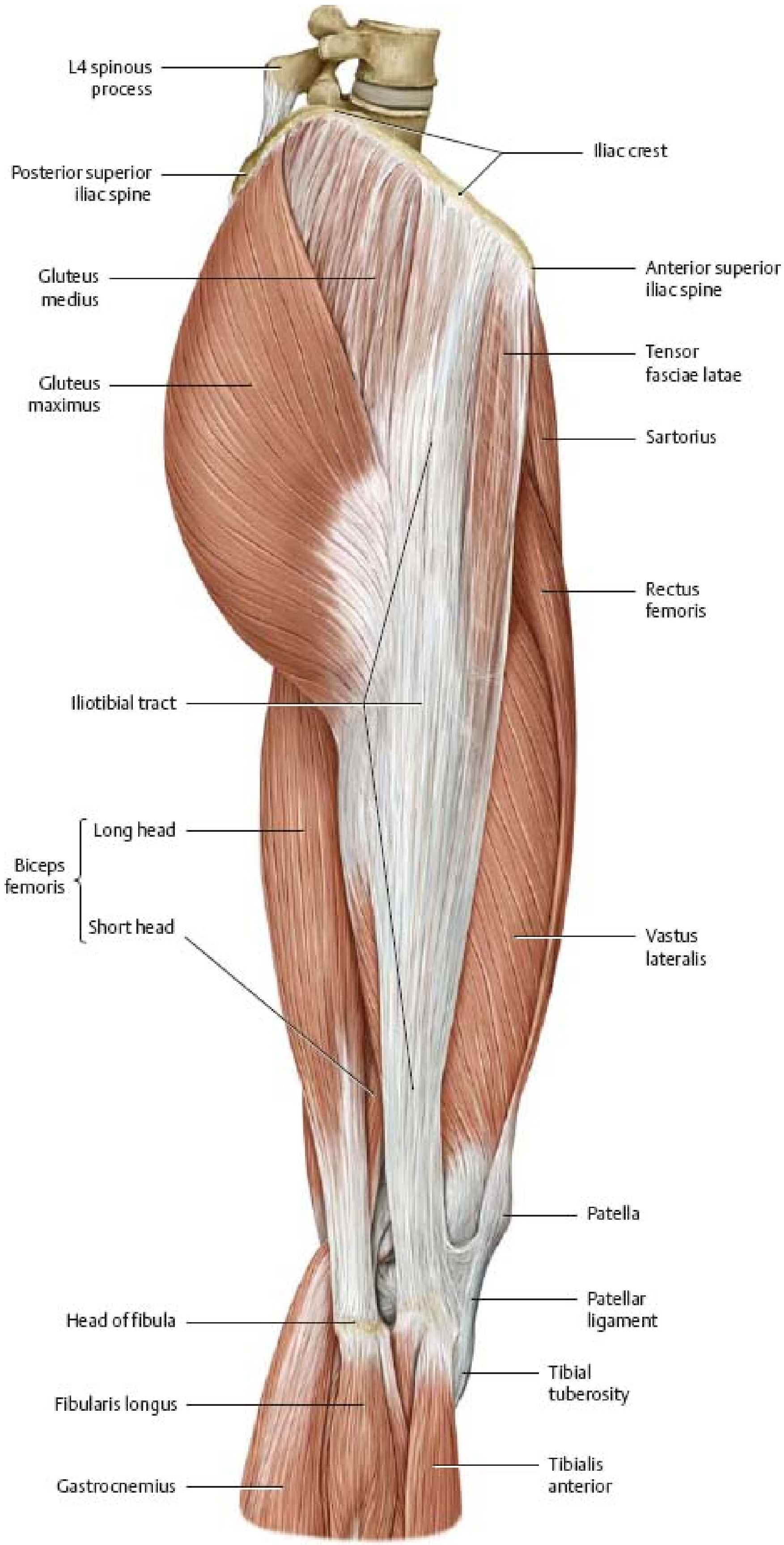


A *Removed:* Piriformis, obturator internus, quadratus femoris, and adductor magnus.

B *Removed:* All muscles.

Fig. 24.19 **Muscles of the hip, thigh, and gluteal region: Lateral view**

Note: The iliotibial tract (the thickened band of fascia lata) functions as a tension band to reduce the bending loads on the proximal femur.


L4 spinous process
Iliac crest
Posterior superior iliac spine
Gluteus medius
Anterior superior iliac spine
Gluteus maximus
Tensor fasciae latae
Sartorius
Rectus femoris
Iliotibial tract
Biceps femoris
Long head
Short head
Vastus lateralis
Patella
Patellar ligament
Head of fibula
Tibial tuberosity
Fibularis longus
Gastrocnemius
Tibialis anterior

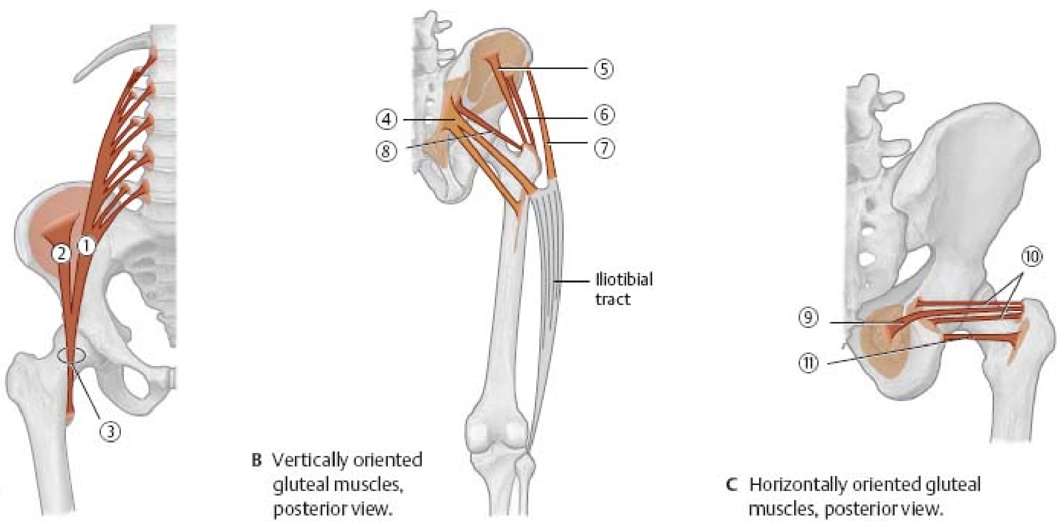
Muscle Facts (I)

Table 24.1 Psoas and iliacus muscles

Muscles		Origin	Insertion	Innervation	Action
③ Iliopsoas	① Psoas minor	T12–L1 vertebrae and intervertebral disk (lateral surfaces)	Iliopectineal arch	Direct branches from the lumbar plexus (psoas) (L2–L4)	Assists in upward rotation of the pelvis
	① Psoas major	*Superficial:* T12–L4 and associated intervertebral disks (lateral surfaces) *Deep:* L1–L5 vertebrae (transverse processes)	Lesser trochanter		• Hip joint: flexion and external rotation • Lumbar spine: *unilateral* contraction (with the femur fixed) bends the trunk laterally to the same side; *bilateral* contraction raises the trunk from the supine position
	② Iliacus	Iliac fossa		Femoral n. (L2–L4)	

Fig. 24.20 Muscles of the hip

Right side.



A Iliopsoas muscle, anterior view.

B Vertically oriented gluteal muscles, posterior view.

C Horizontally oriented gluteal muscles, posterior view.

Table 24.2 Gluteal muscles

Muscle	Origin	Insertion	Innervation	Action
④ Gluteus maximus	Sacrum (dorsal surface, lateral part), ilium (gluteal surface, posterior part), thoracolumbar fascia, sacrotuberous ligament	• Upper fibers: iliotibial tract • Lower fibers: gluteal tuberosity	Inferior gluteal n. (L5–S2)	• Entire muscle: extends and externally rotates the hip in sagittal and coronal planes • Upper fibers: abduction • Lower fibers: adduction
⑤ Gluteus medius	Ilium (gluteal surface below the iliac crest between the anterior and posterior gluteal line)	Greater trochanter of the femur (lateral surface)	Superior gluteal n. (L4–S1)	• Entire muscle: abducts the hip, stabilizes the pelvis in the coronal plane • Anterior part: flexion and internal rotation • Posterior part: extension and external rotation
⑥ Gluteus minimus	Ilium (gluteal surface below the origin of gluteus medius)	Greater trochanter of the femur (anterolateral surface)		
⑦ Tensor fasciae latae	Anterior superior iliac spine	Iliotibial tract		• Tenses the fascia lata • Hip joint: abduction, flexion, and internal rotation
⑧ Piriformis	Pelvic surface of the sacrum	Apex of the greater trochanter of the femur	Direct branches from the sacral plexus (S1–S2)	• External rotation, abduction, and extension of the hip joint • Stabilizes the hip joint
⑨ Obturator internus	Inner surface of the obturator membrane and its bony boundaries	Medial surface of the greater trochanter	Direct branches from the sacral plexus (L5, S1)	External rotation, adduction, and extension of the hip joint (also active in abduction, depending on the joint's position)
⑩ Gemelli	• Gemellus superior: ischial spine • Gemellus inferior: ischial tuberosity	Jointly with obturator internus tendon (medial surface, greater trochanter)		
⑪ Quadratus femoris	Lateral border of the ischial tuberosity	Intertrochanteric crest of the femur		External rotation and adduction of the hip joint

Fig. 24.21 **Psoas and iliacus muscles**

Right side, anterior view.

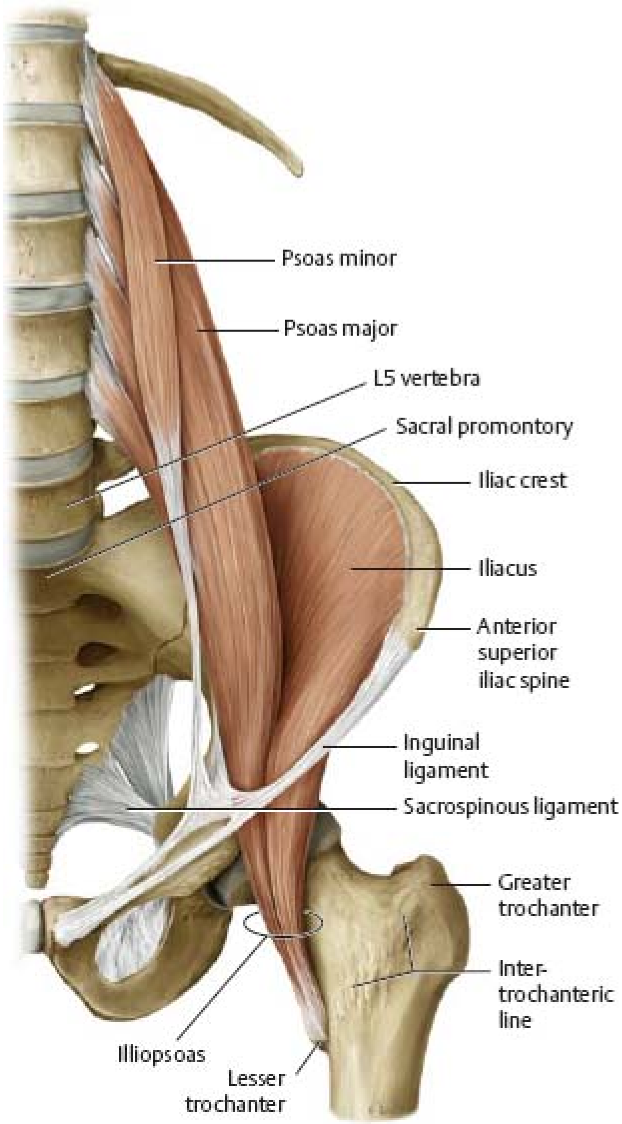


Fig. 24.22 **Superficial muscles of the gluteal region**

Right side, posterior view.

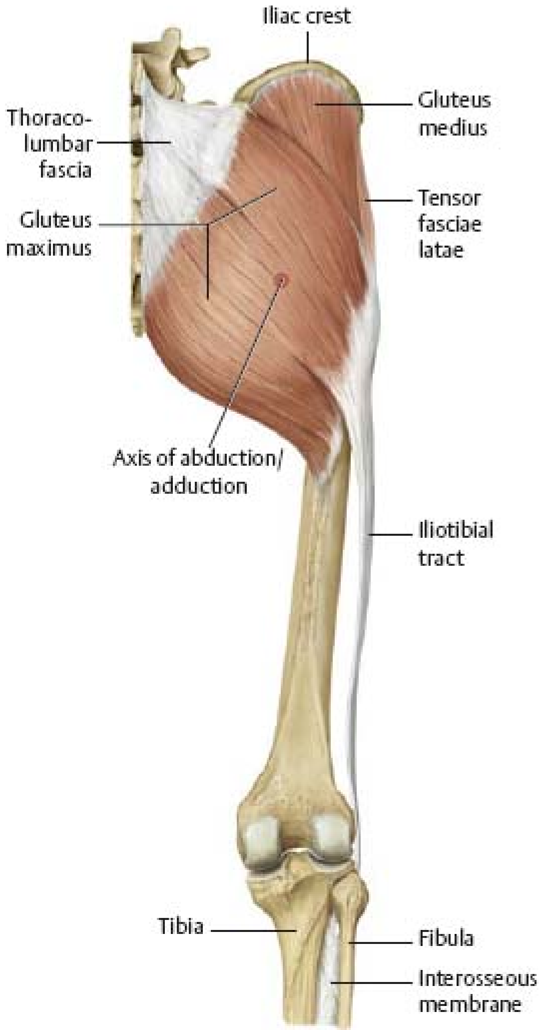
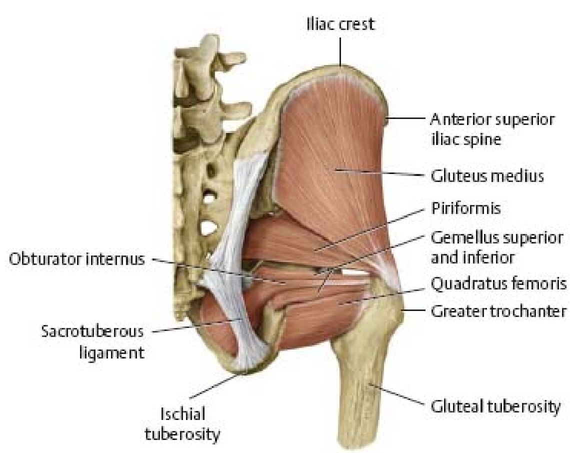
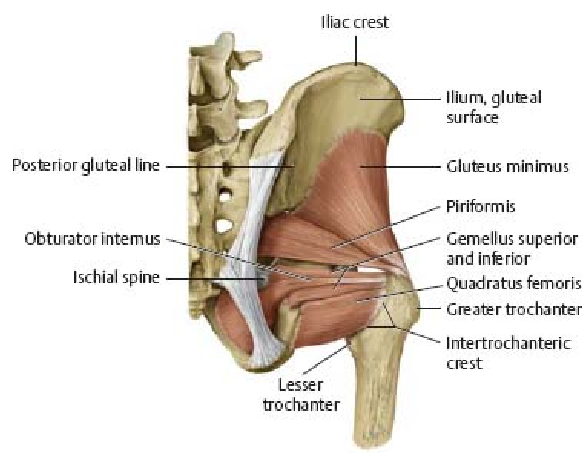


Fig. 24.23 Deep muscles of the gluteal region



A Deep layer with gluteus maximus removed.



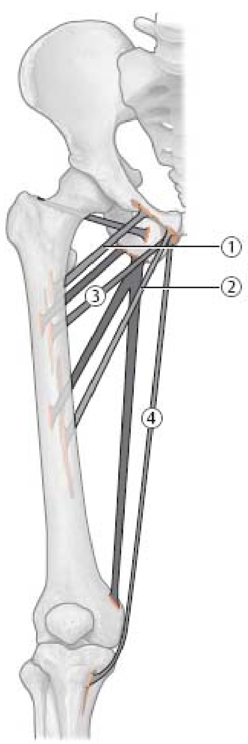
B Deep layer with gluteus medius removed.

Muscle Facts (II)

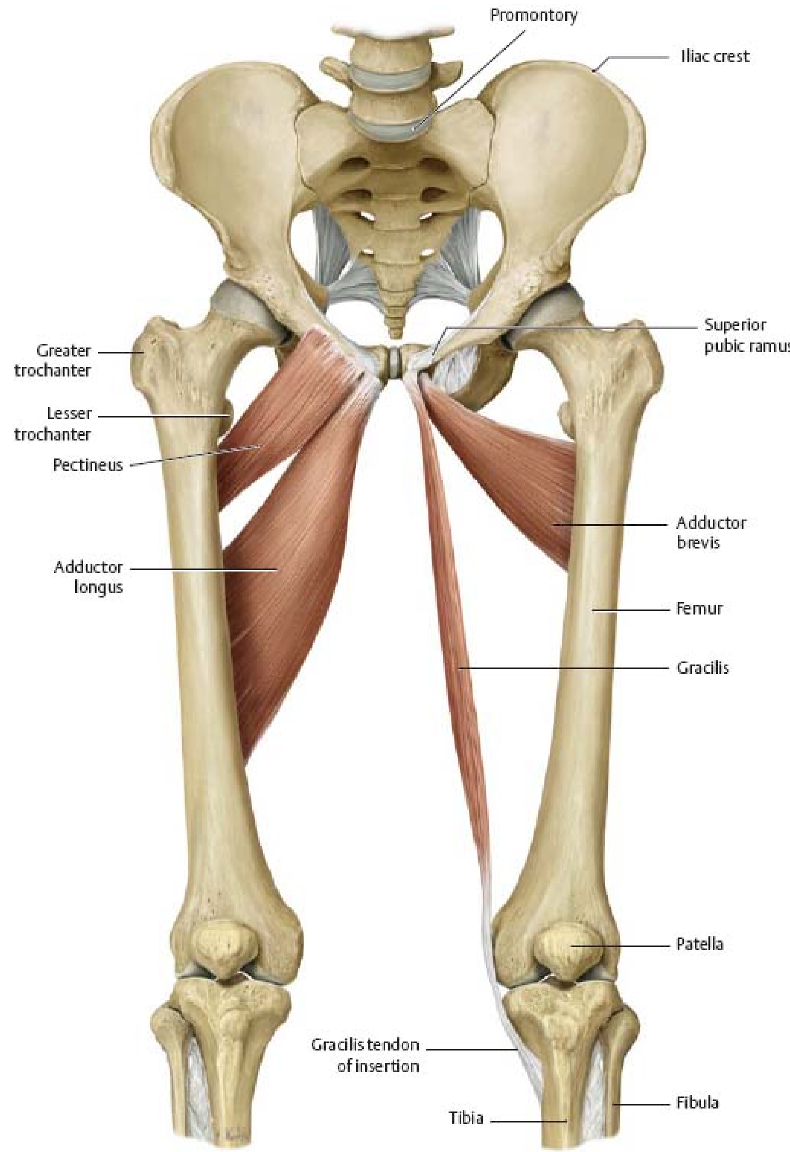
Functionally, the medial thigh muscles are considered the adductors of the hip.

Fig. 24.24 Medial group: Superficial layer

Right side, anterior view.



A Schematic.

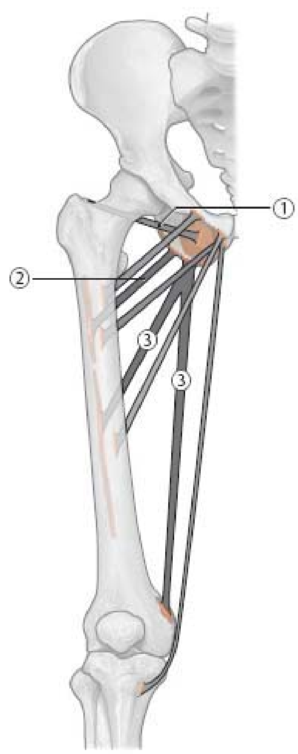


B Superficial adductor group.

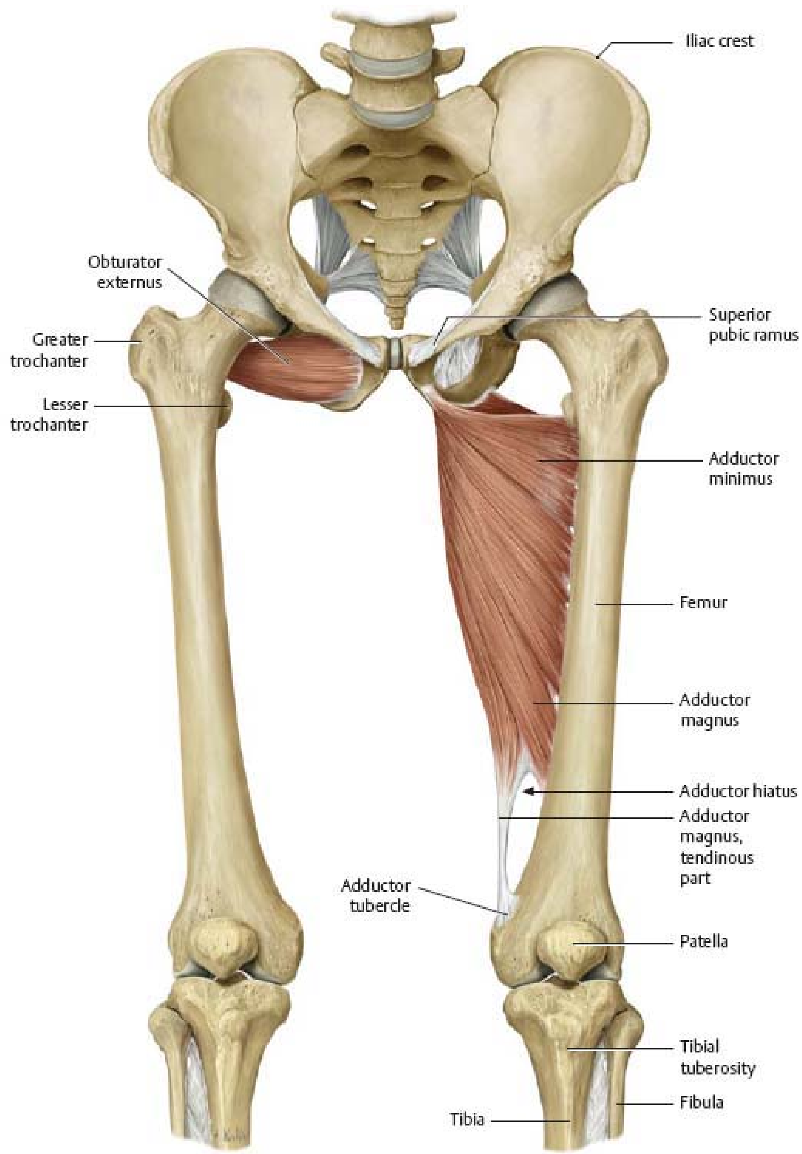
Table 24.3	Medial thigh muscles: Superficial layer			
Muscle	Origin	Insertion	Innervation	Action
① Pectineus	Pecten pubis	Femur (pectineal line and the proximal linea aspera)	Femoral n., obturator n. (L2, L3)	• Hip joint: adduction, external rotation, and slight flexion • Stabilizes the pelvis in the coronal and sagittal planes
② Adductor longus	Superior pubic ramus and anterior side of the symphysis	Femur (linea aspera, medial lip in the middle third of the femur)	Obturator n. (L2–L4)	• Hip joint: adduction and flexion (up to 70 degrees); extension (past 80 degrees of flexion) • Stabilizes the pelvis in the coronal and sagittal planes
③ Adductor brevis	Inferior pubic ramus			
④ Gracilis	Inferior pubic ramus below the symphysis	Tibia (medial border of the tuberosity, along with the tendons of sartorius and semitendinosus)	Obturator n. (L2, L3)	• Hip joint: adduction and flexion • Knee joint: flexion and internal rotation

Fig. 24.25 Medial group: Deep layer

Right side, anterior view.



A Schematic.



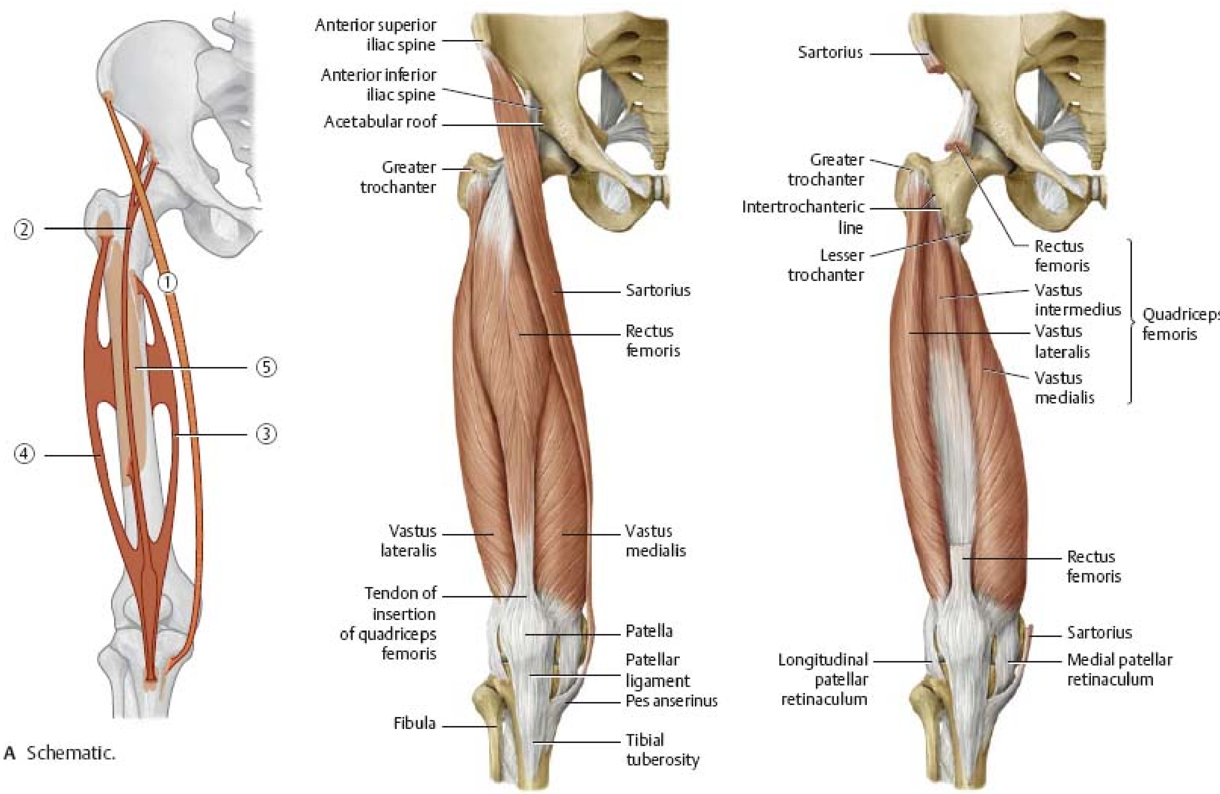
B Deep adductor group.

Table 24.4	Medial thigh muscles: Deep layer			
Muscle	Origin	Insertion	Innervation	Action
① Obturator externus	Outer surface of the obturator membrane and its bony boundaries	Trochanteric fossa of the femur	Obturator n. (L3, L4)	• Hip joint: adduction and external rotation • Stabilizes the pelvis in the sagittal plane
② Adductor minimus	Inferior pubic ramus	Medial lip of the linea aspera	Obturator n. (L2–L4)	Hip joint: adduction extension, and slight flexion of the hip joint
③ Adductor magnus	Inferior pubic ramus, ischial ramus, and ischial tuberosity	• Deep part ("fleshy insertion"): medial lip of the linea spine • Superficial part ("tendinous insertion"): adductor tubercle of the femur	• Deep part: obturator n. (L2–L4) • Superficial part: tibial n. (L4)	• Hip joint: adduction, extention, and slight flexion (the tendinous insertion is also active in internal rotation) • Stabilizes the pelvis in the coronal and sagittal plane

Muscle Facts (III)

Fig. 24.26 Anterior thigh muscles

Right side, anterior view.



A Schematic.

B Superficial group.

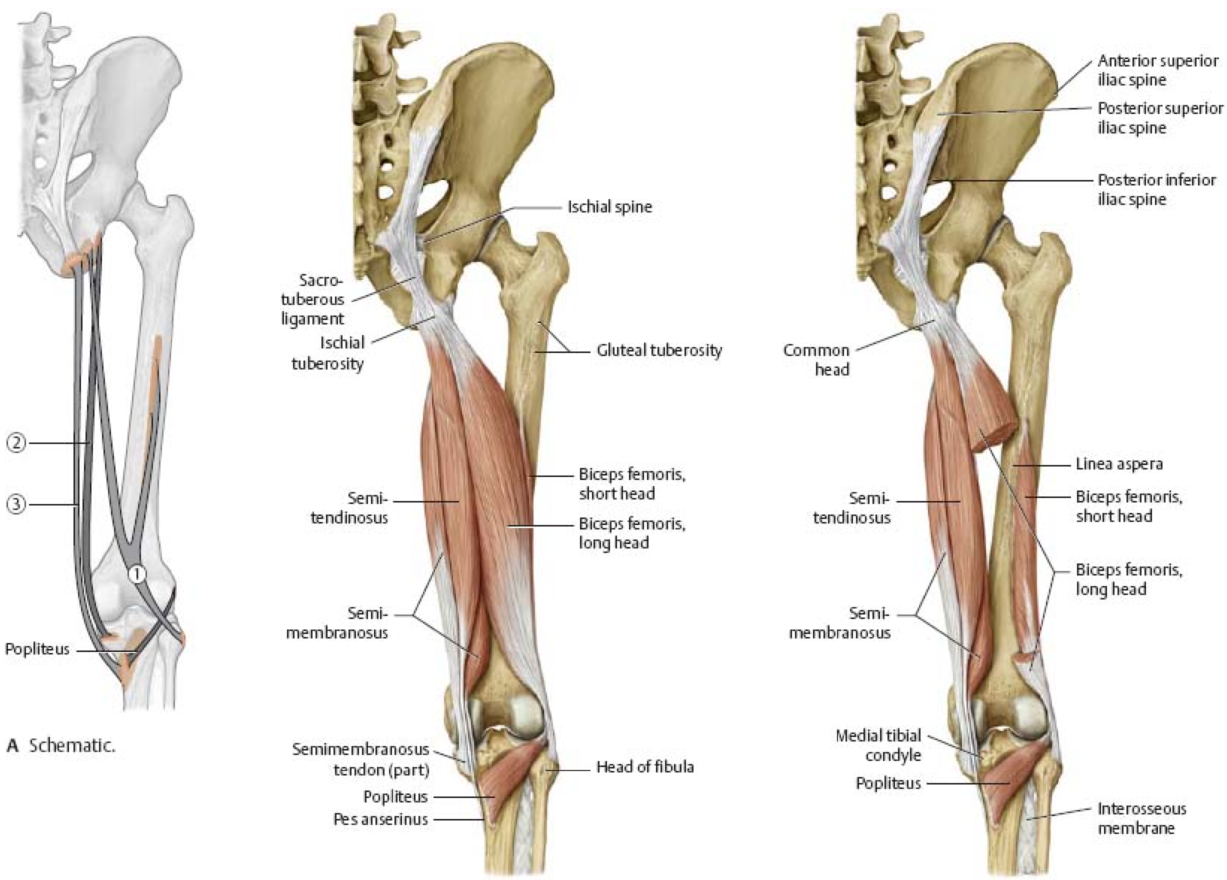
C Deep group. *Removed:* Sartorius and rectus femoris.

Table 24.5	Anterior thigh muscles				
Muscle		**Origin**	**Insertion**	**Innervation**	**Action**
① Sartorius		Anterior superior iliac spine	Medial to the tibial tuberosity (together with gracilis and semitendinosus)	Femoral n. (L2, L3)	• Hip joint: flexion, abduction, and external rotation • Knee joint: flexion and internal rotation
Quadriceps femoris*	② Rectus femoris	Anterior inferior iliac spine, acetabular roof of hip joint	Tibial tuberosity (via patellar ligament)	Femoral n. (L2–L4)	• Hip joint: flexion • Knee joint: extension
	③ Vastus medialis	Linea aspera (medial lip), intertrochanteric line (distal part)	Both sides of tuberosity on the medial and lateral condyles (via the medial and longitudinal patellar retinacula)		Knee joint: extension
	④ Vastus lateralis	Linea aspera (lateral lip), greater trochanter (lateral surface)			
	⑤ Vastus intermedius	Femoral shaft (anterior side)	Tibial tuberosity (via patellar ligament)		
	Articularis genus (distal fibers of vastus intermedius)	Anterior side of femoral shaft at level of the suprapatellar recess	Suprapatellar recess of knee joint capsule		Knee joint: extension; prevents entrapment of capsule

*The entire muscle inserts on the tibial tuberosity via the patellar ligament.

Fig. 24.27 Posterior thigh muscles

Right side, posterior view.



A Schematic.

B Superficial group.

C Deep group. *Removed:* Biceps femoris (long head) and semitendinosus.

Table 24.6 Posterior thigh muscles

Muscle	Origin	Insertion	Innervation	Action
① Biceps femoris	Long head: ischial tuberosity, sacrotuberous ligament (common head with semitendinosus)	Head of fibula	Tibial n. (L5–S2)	• Hip joint (long head): extends the hip, stabilizes the pelvis in the sagittal plane • Knee joint: flexion and external rotation
	Short head: lateral lip of the linea aspera in the middle third of the femur		Common fibular n. (L5–S2)	Knee joint: flexion and external rotation
② Semimembranosus	Ischial tuberosity	Medial tibial condyle, oblique popliteal ligament, popliteus fascia	Tibial n. (L5–S2)	• Hip joint: extends the hip, stabilizes the pelvis in the sagittal plane • Knee joint: flexion and internal rotation
③ Semitendinosus	Ischial tuberosity and sacrotuberous ligament (common head with long head of biceps femoris)	Medial to the tibial tuberosity in the pes anserinus (along with the tendons of gracilis and sartorius)		

See p. 399 for popliteus.

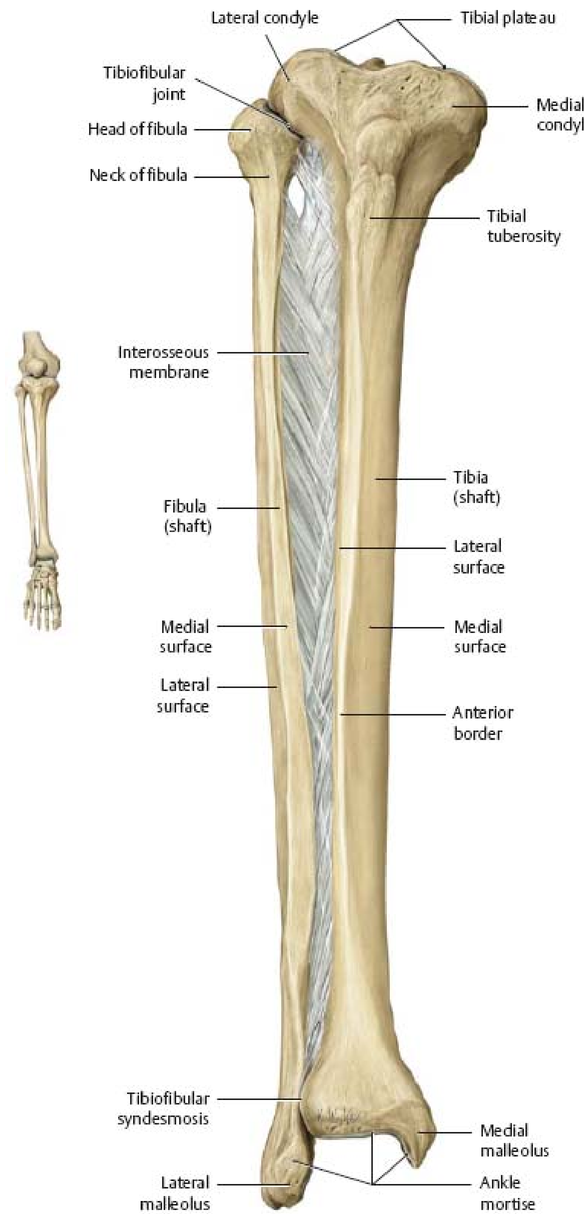
25 Knee & Leg

Tibia & Fibula

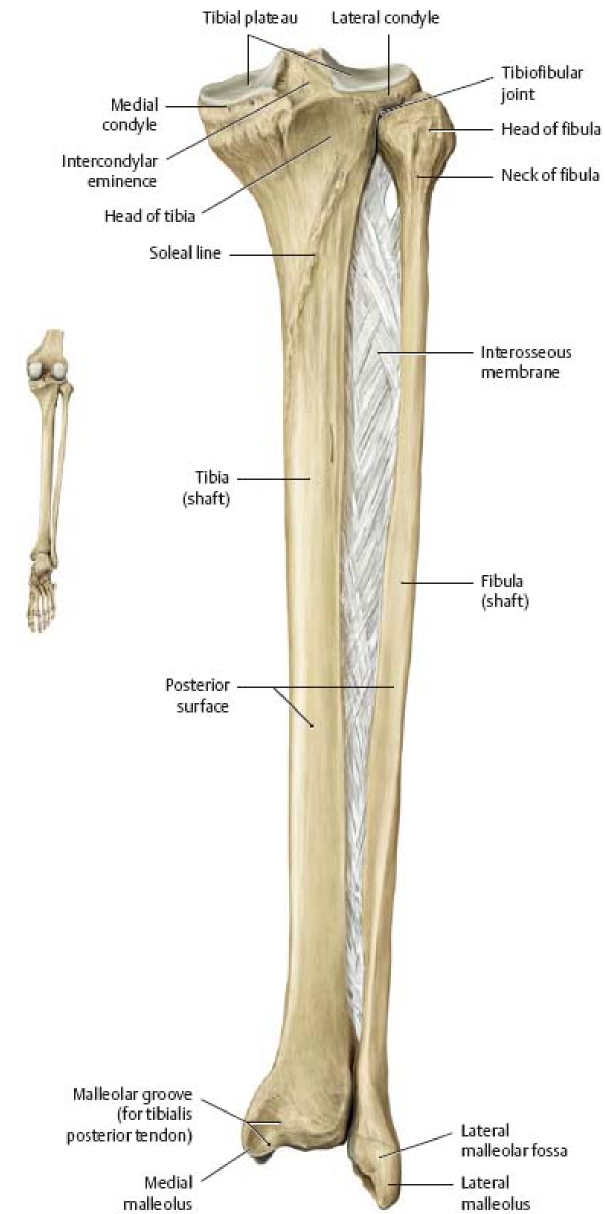
The tibia and fibula articulate at two joints, allowing limited motion (rotation). The crural interosseous membrane is a sheet of tough connective tissue that serves as an origin for several muscles in the leg. It also acts with the tibiofibular syndesmosis to stabilize the ankle joint.

Fig. 25.1 Tibia and fibula

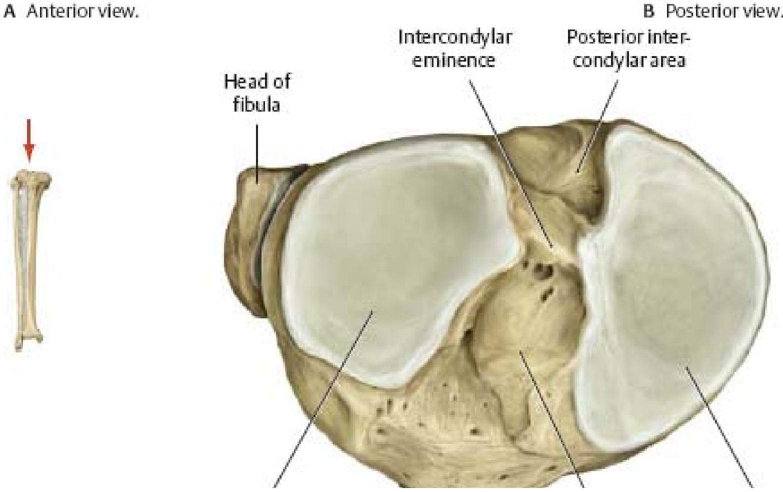
Right leg.

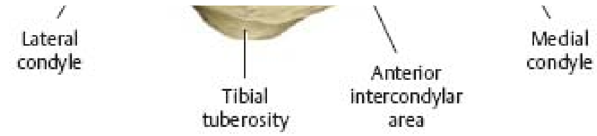


A Anterior view.

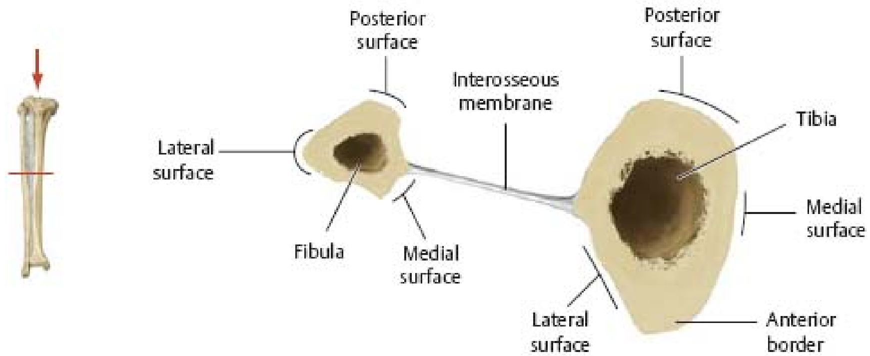


B Posterior view.

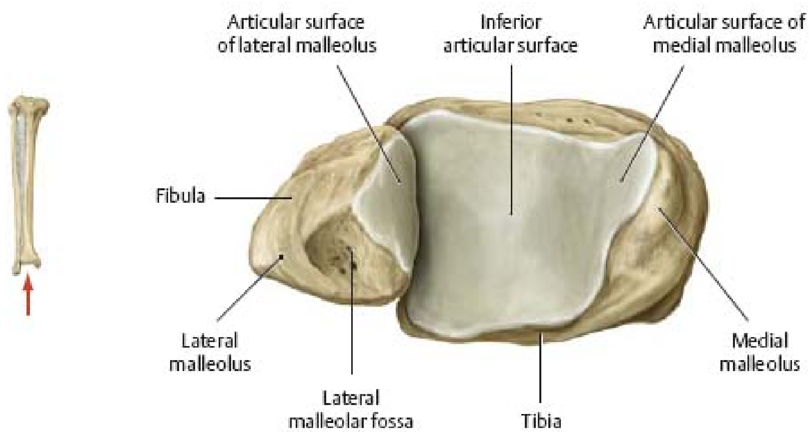




C Proximal view.



D Transverse section, superior view.

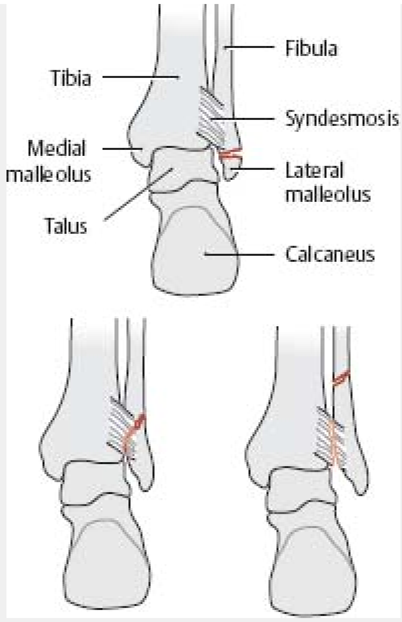


E Distal view.

Clinical

Fibular fracture

When diagnosing a fibular fracture, it is important to determine whether the syndesmosis (see p. 380) is disrupted. Fibular fractures may occur distal to, level with, or proximal to the syndesmosis; the latter two frequently involve tearing of the syndesmosis.



In this fracture, located proximal to the syndesmosis, the syndesmosis is torn, as indicated by the widened medial joint space of the upper ankle joint (see p. 405).

Knee Joint: Overview

In the knee joint, the femur articulates with the tibia and patella. Both joints are contained within a common capsule and have communicating articular cavities. *Note:* The fibula is not included in the knee joint (contrast to the humerus in the elbow; see p. 282). Instead, it forms a separate rigid articulation with the tibia.

Fig. 25.2 Right knee joint

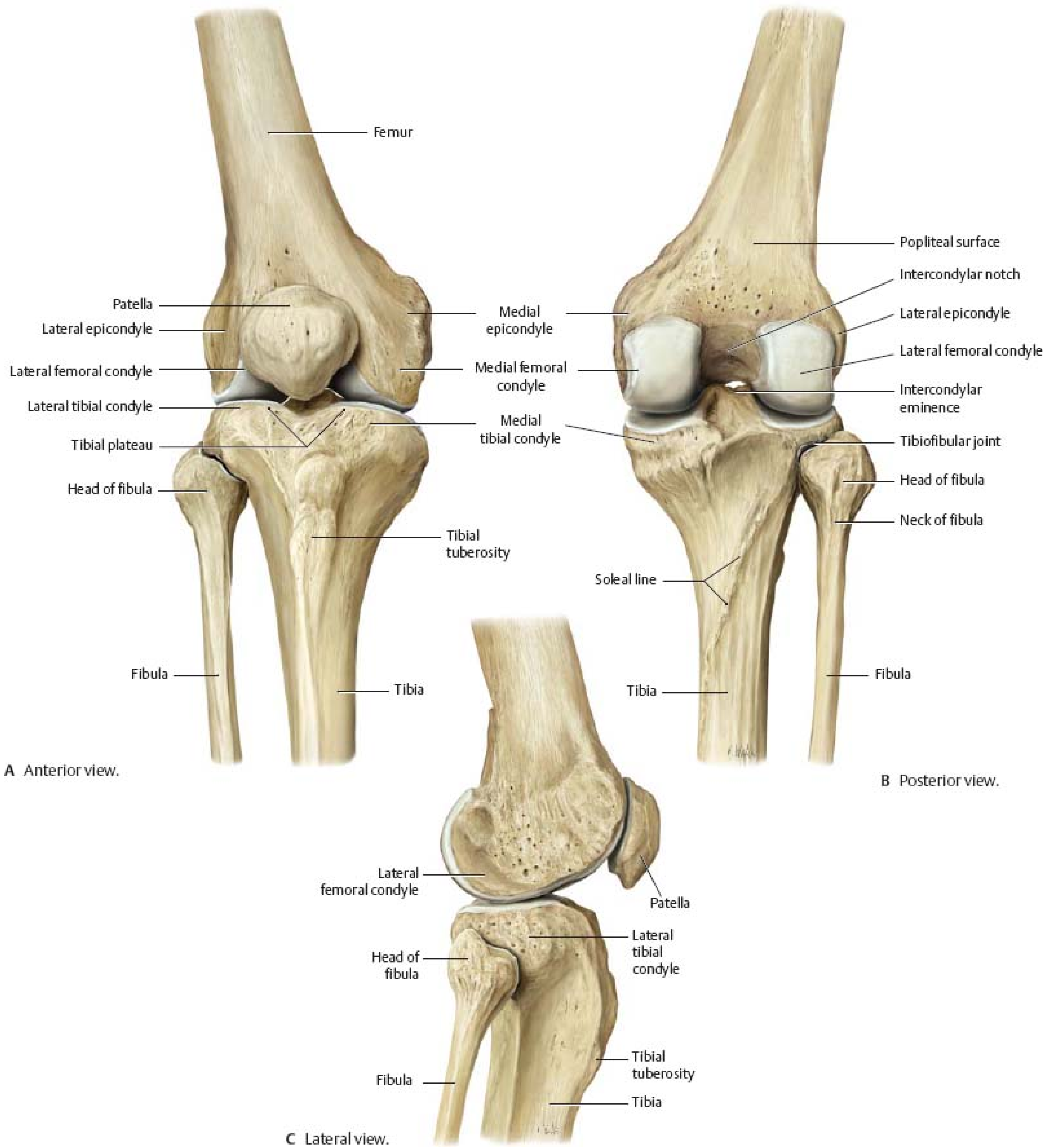
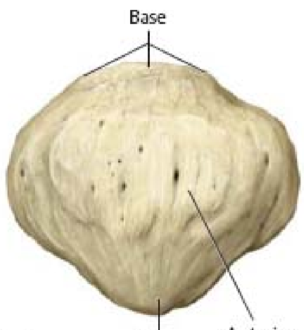


Fig. 25.3 Knee joint: Radiographs

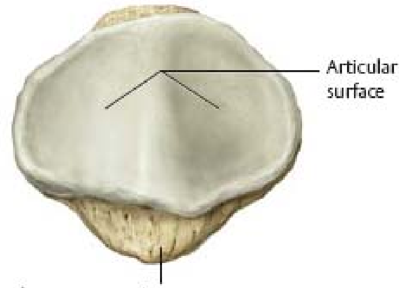
A Anteroposterior projection.

B Lateral projection.

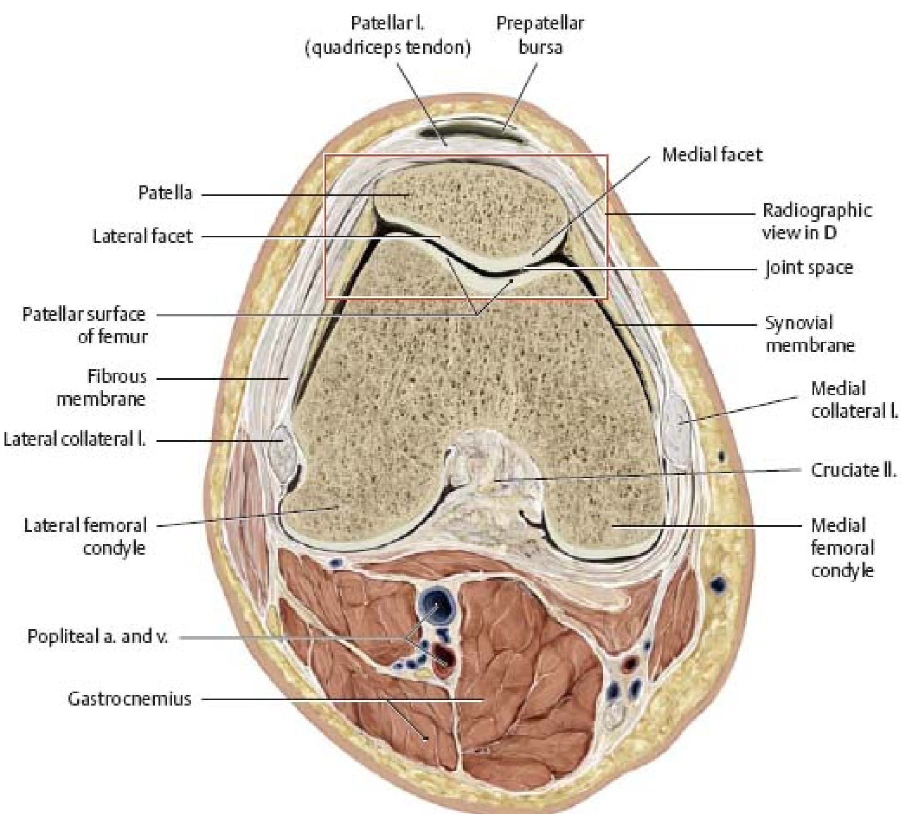
Fig. 25.4 **Patella**



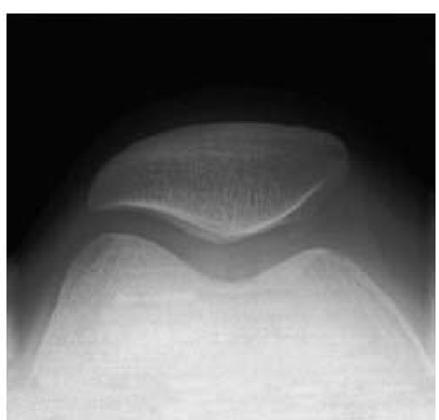
A Anterior view.



B Posterior view.



C Transverse section through femoropatellar joint. Distal view with right knee in slight flexion.



D Radiographic view of patella and femoral trochlea. Tangential radiographic view with right knee in 60 degrees of flexion ("sunrise" view). Note the width of the joint space due to the thick articular cartilage.

Knee Joint: Capsule, Ligaments & Bursae

Table 25.1	**Ligaments of the knee joint**
Extrinsic ligaments	
Anterior side	Patellar l.
	Medial longitudinal patellar retinaculum
	Lateral longitudinal patellar retinaculum
	Medial transverse patellar retinaculum
	Lateral transverse patellar retinaculum
Medial and lateral sides	Medial (tibial) collateral l.
	Lateral (fibular) collateral l.
Posterior side	Oblique popliteal l.
	Arcuate popliteal l.
Intrinsic ligaments	
Anterior cruciate l.	
Posterior cruciate l.	
Transverse l. of knee	
Posterior meniscofemoral l.	

Fig. 25.5 **Ligaments of the knee joint**

Anterior view of right knee.

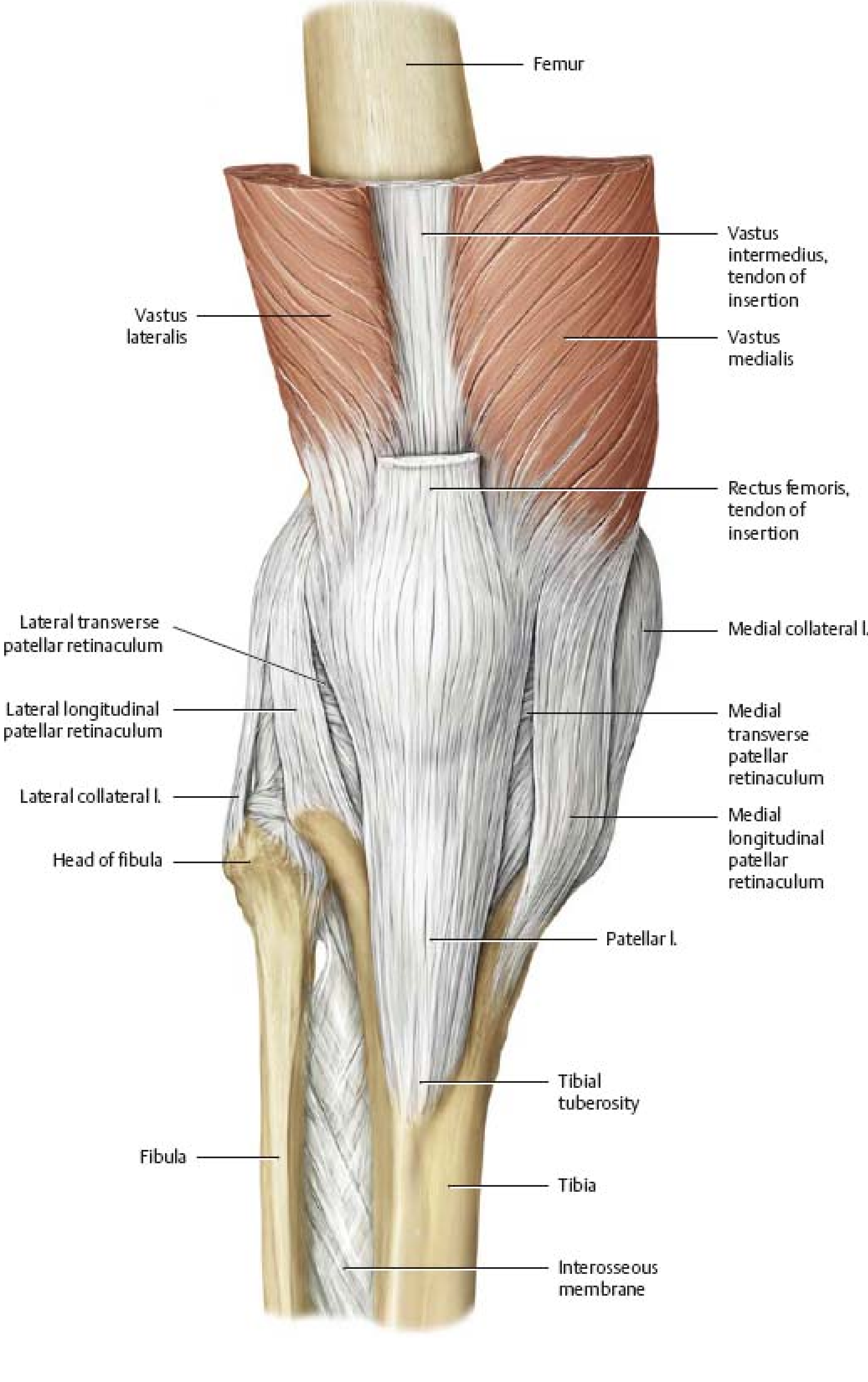
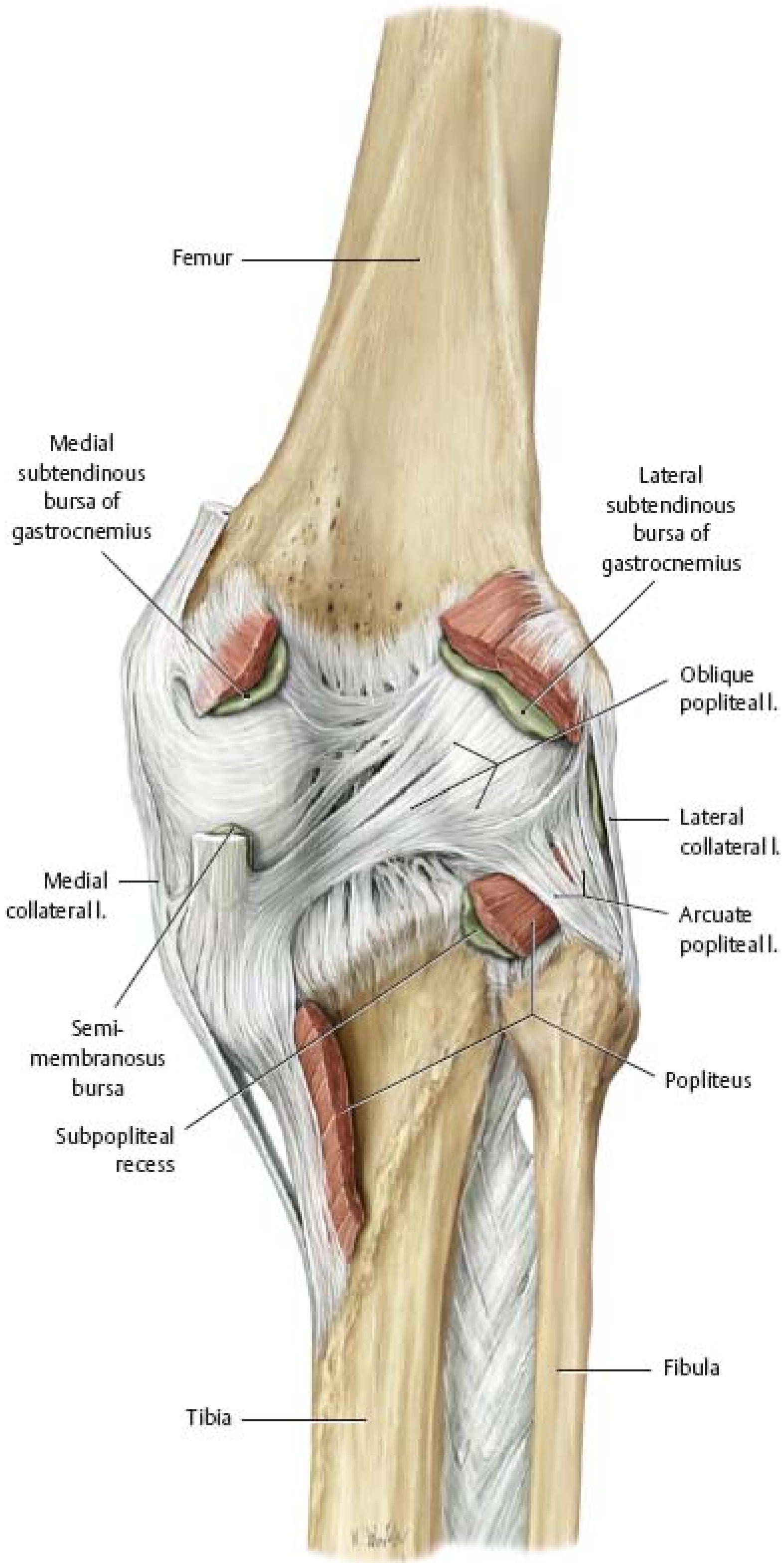

Femur
Vastus intermedius, tendon of insertion
Vastus lateralis
Vastus medialis
Rectus femoris, tendon of insertion
Lateral transverse patellar retinaculum
Medial collateral l.
Lateral longitudinal patellar retinaculum
Medial transverse patellar retinaculum
Lateral collateral l.
Medial longitudinal patellar retinaculum
Head of fibula
Patellar l.
Tibial tuberosity
Fibula
Tibia
Interosseous membrane

Fig. 25.6 **Capsule, ligaments, and periarticular bursae**

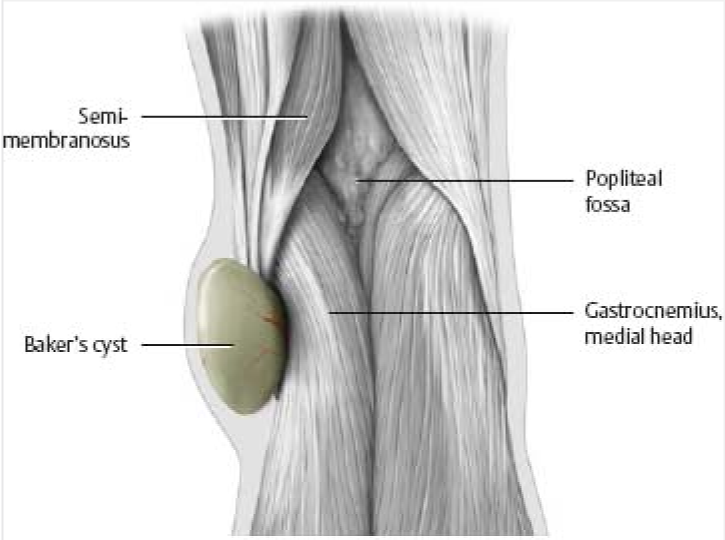
Posterior view of right knee. The joint cavity communicates with periarticular bursae at the subpopliteal recess, semimembranosus bursa, and medial subtendinous bursa of the gastrocnemius.


Femur
Medial subtendinous bursa of gastrocnemius
Lateral subtendinous bursa of gastrocnemius
Oblique popliteal l.
Lateral collateral l.
Medial collateral l.
Arcuate popliteal l.
Semi-membranosus bursa
Popliteus
Subpopliteal recess
Fibula
Tibia

Clinical

Gastrocnemio-semimembranosus bursa (Baker's cyst)

Painful swelling behind the knee may be caused by a cystic outpouching of the joint capsule (synovial popliteal cyst). This frequently results from a rise in intra-articular pressure (e.g., in rheumatoid arthritis).



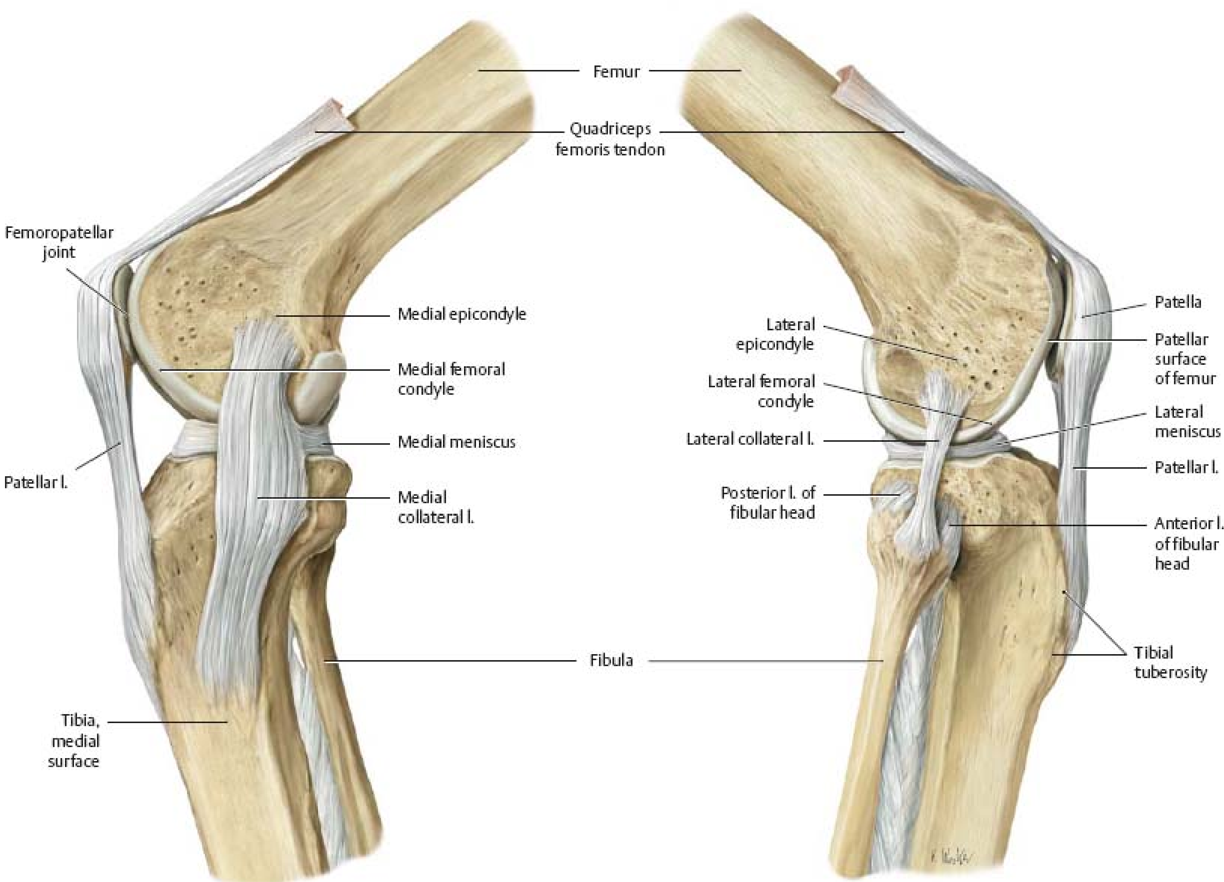
A Baker's cyst in the right popliteal fossa. Baker's cysts often occur in the medial part of the popliteal fossa between the semimembranosus tendon and the medial head of the gastrocnemius at the level of the posteromedial femoral condyle.

B Axial magnetic resonance imaging (MRI) of a Baker's cyst in the popliteal fossa, inferior view.

Knee Joint: Ligaments & Menisci

Fig. 25.7 Collateral and patellar ligaments of the knee joint

Right knee joint. Each knee joint has medial and lateral collateral ligaments. The medial collateral ligament is attached to both the capsule and the medial meniscus, whereas the lateral collateral ligament has no direct contact with either the capsule or the lateral meniscus. Both collateral ligaments are taut when the knee is in extension and stabilize the joint in the coronal plane.

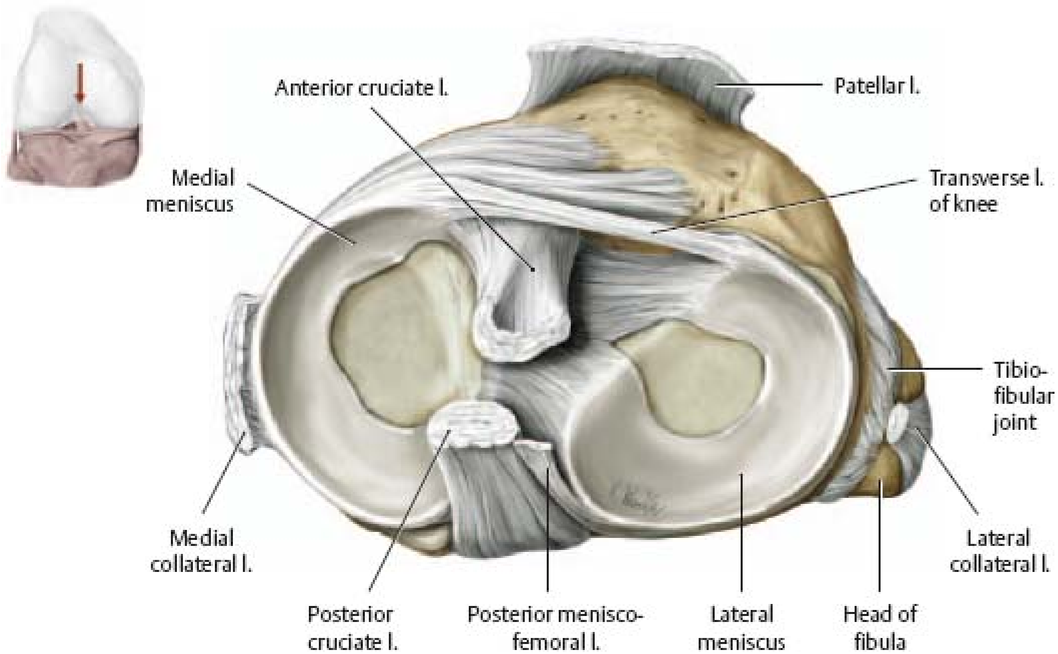


A Medial view.

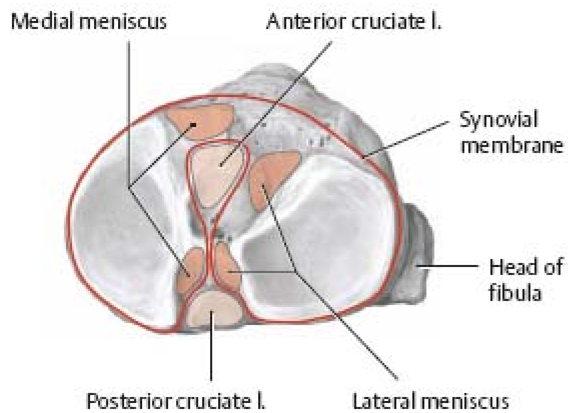
B Lateral view.

Fig. 25.8 Menisci in the knee joint

Right tibial plateau, proximal view.



A Right tibial plateau with cruciate, patellar, and collateral ligaments divided.

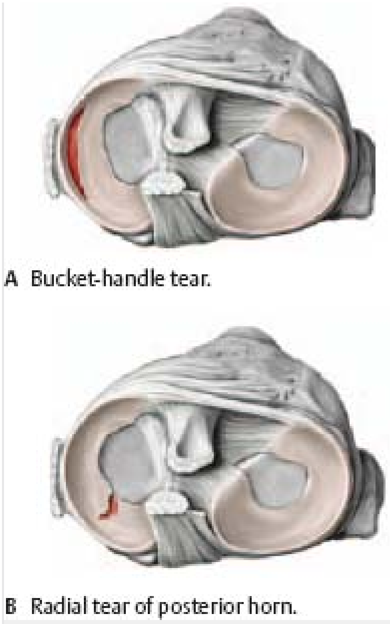


B Attachment sites of menisci and cruciate ligaments. Red line indicates the tibial attachment of the synovial membrane that covers the cruciate ligaments. The cruciate ligaments lie in the subsynovial connective tissue.

Clinical

Injury of the menisci

The less mobile medial meniscus is more susceptible to injury than the lateral meniscus. Trauma generally results from sudden extension or rotation of the flexed knee while the leg is fixed.



A Bucket-handle tear.

B Radial tear of posterior horn.

Fig. 25.9 **Movements of the menisci**

Right knee joint.

A Extension. B Flexion. C Tibial plateau, proximal view.

Cruciate Ligaments

Fig. 25.10 Cruciate and collateral ligaments

Right knee joint. The cruciate ligaments keep the articular surfaces of the femur and tibia in contact, while stabilizing the knee joint primarily in the sagittal plane. Portions of the cruciate ligaments are taut in every joint position.

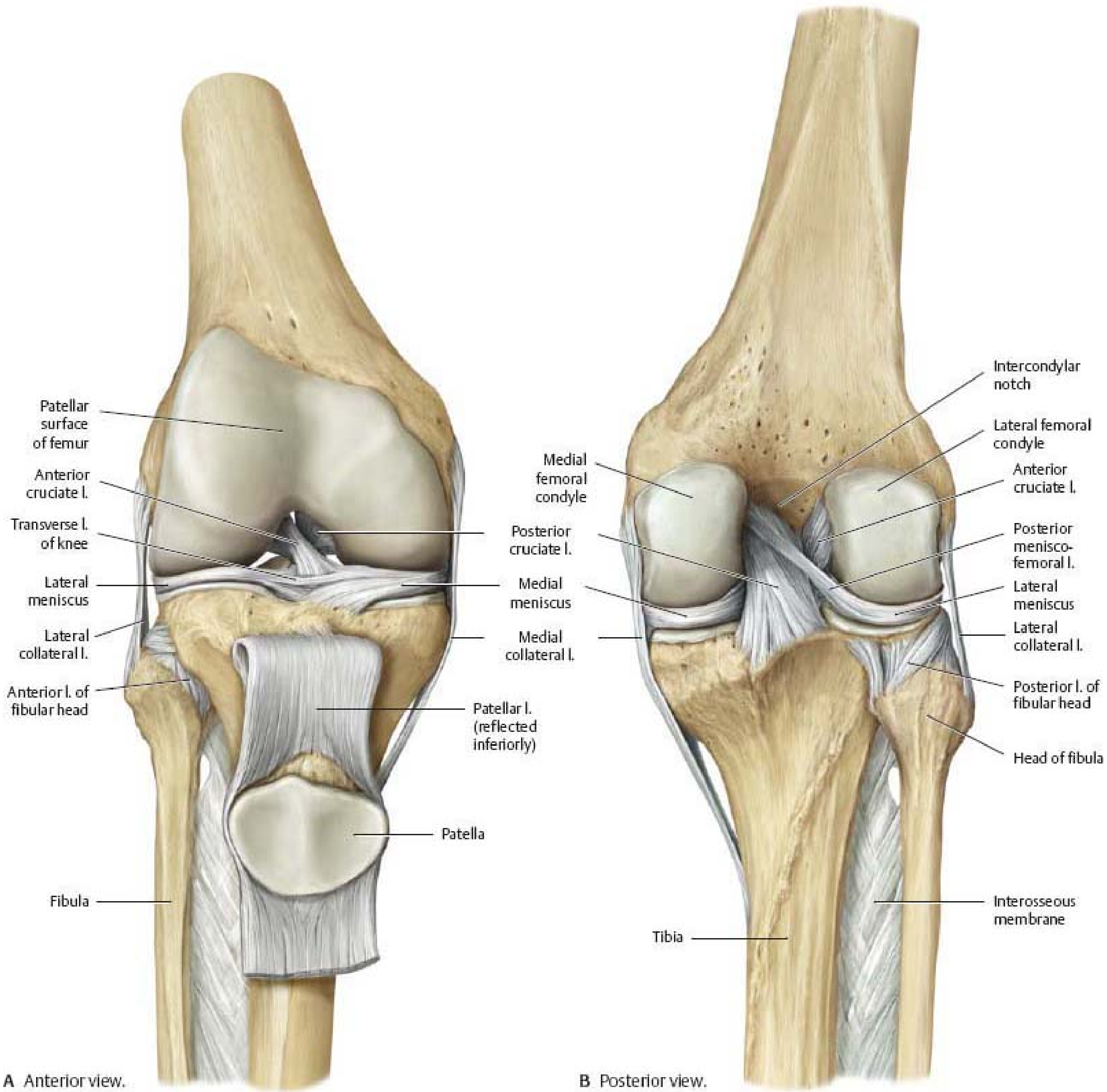
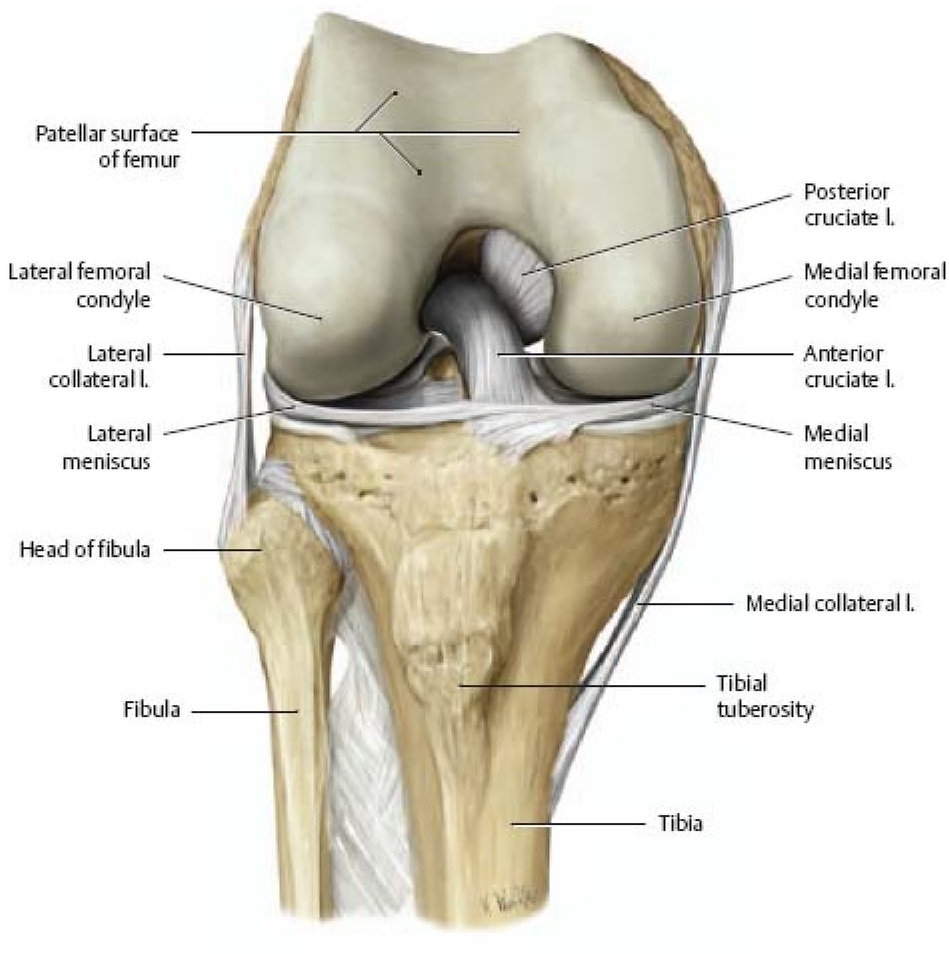


Fig. 25.11 Right knee joint in flexion

Anterior view with joint capsule and patella removed.



Clinical

Rupture of cruciate ligaments

Cruciate ligament rupture destabilizes the knee joint, allowing the tibia to move forward (anterior "drawer sign") or backward (posterior "drawer sign") relative to the femur. *Anterior* cruciate ligament ruptures are approximately 10 times more common than posterior ligament ruptures. The most common mechanism of injury is an internal rotation trauma with the leg fixed. A lateral blow to the fully extended knee with the foot planted tends to cause concomitant rupture of the anterior cruciate and medial collateral ligaments, as well as tearing of the attached medial meniscus.

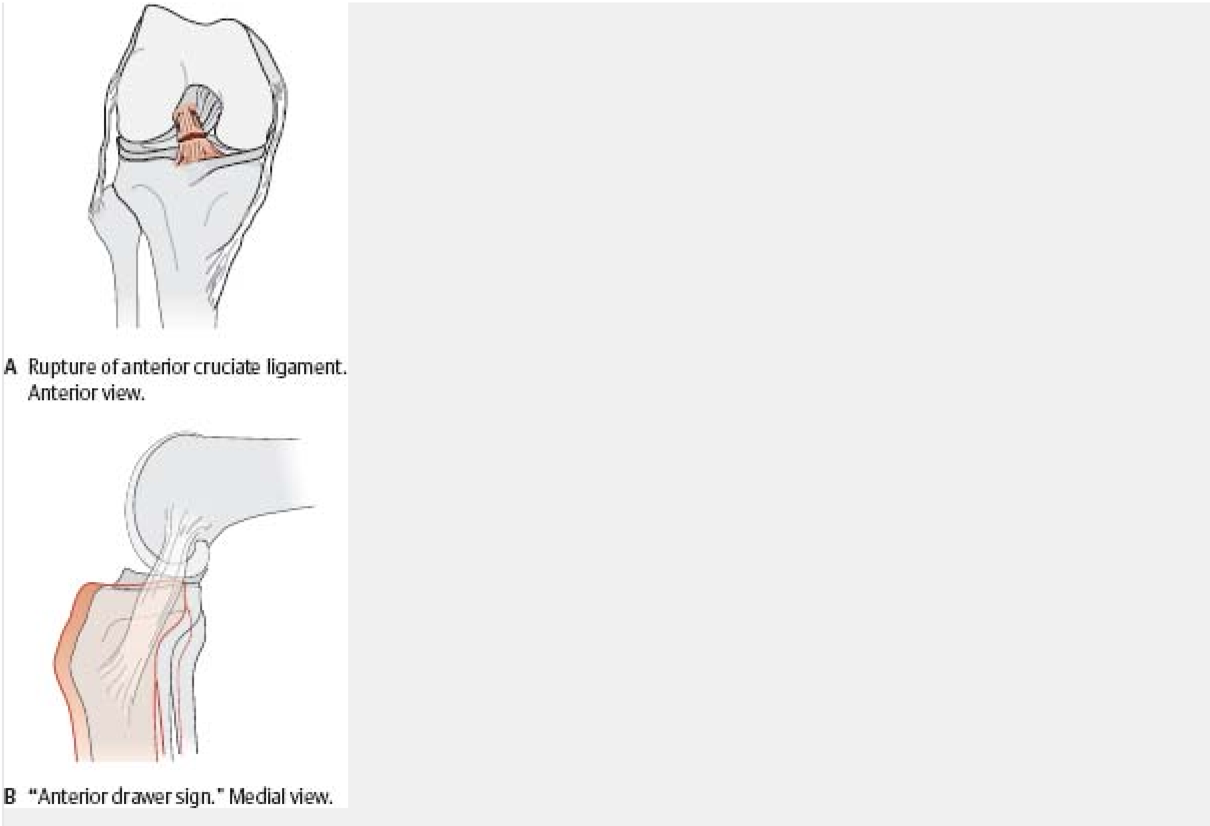
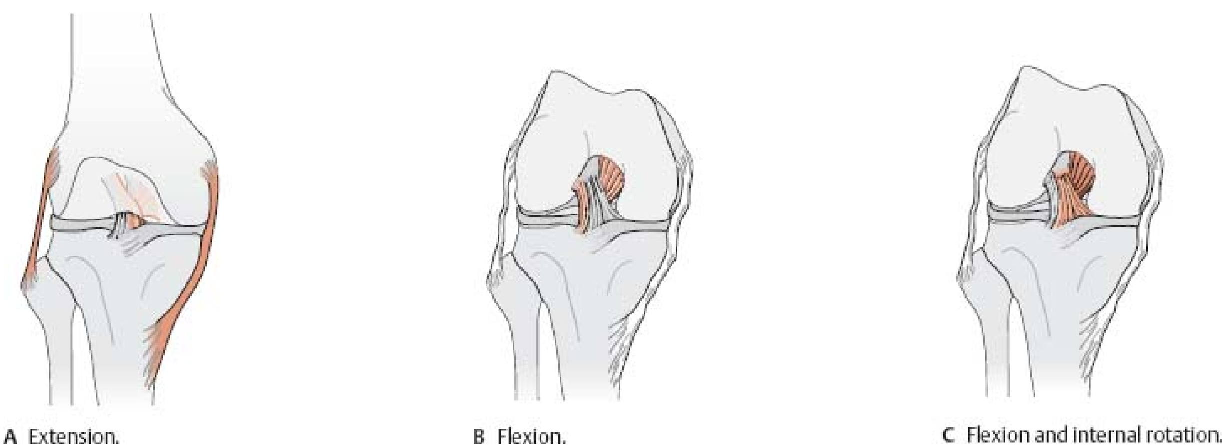


Fig. 25.12 Cruciate and collateral ligaments in flexion and extension

Right knee, anterior view. Taut ligament fibers in red.



Knee Joint Cavity

Fig. 25.13 Joint cavity

Right knee, lateral view. The joint cavity was demonstrated by injecting liquid plastic into the knee joint and later removing the capsule.

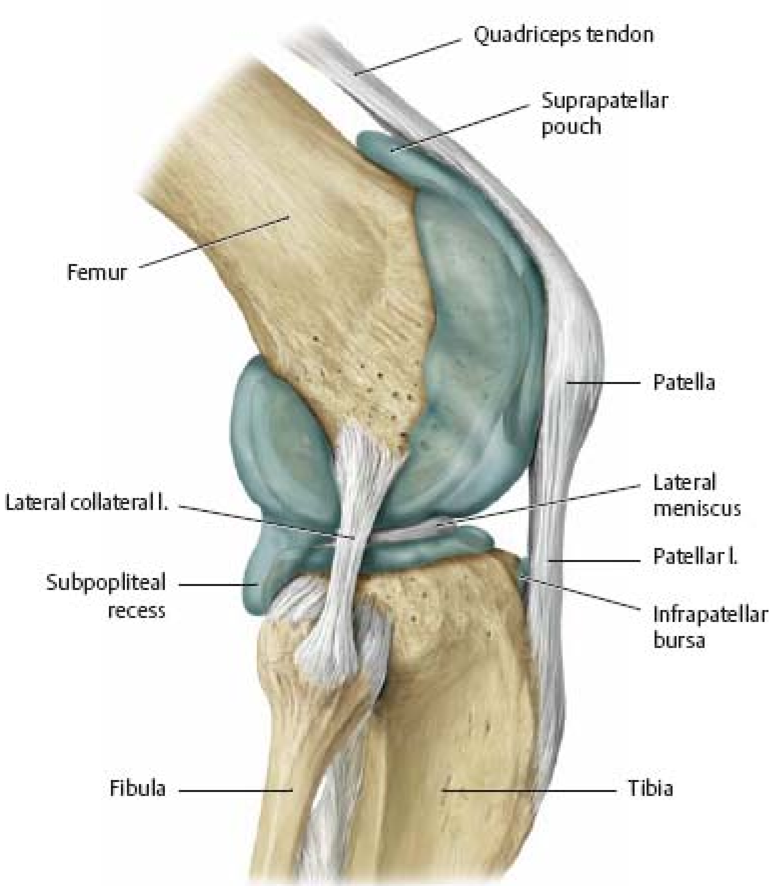


Fig. 25.14 **Opened joint capsule**

Right knee, anterior view with patella reflected downward.

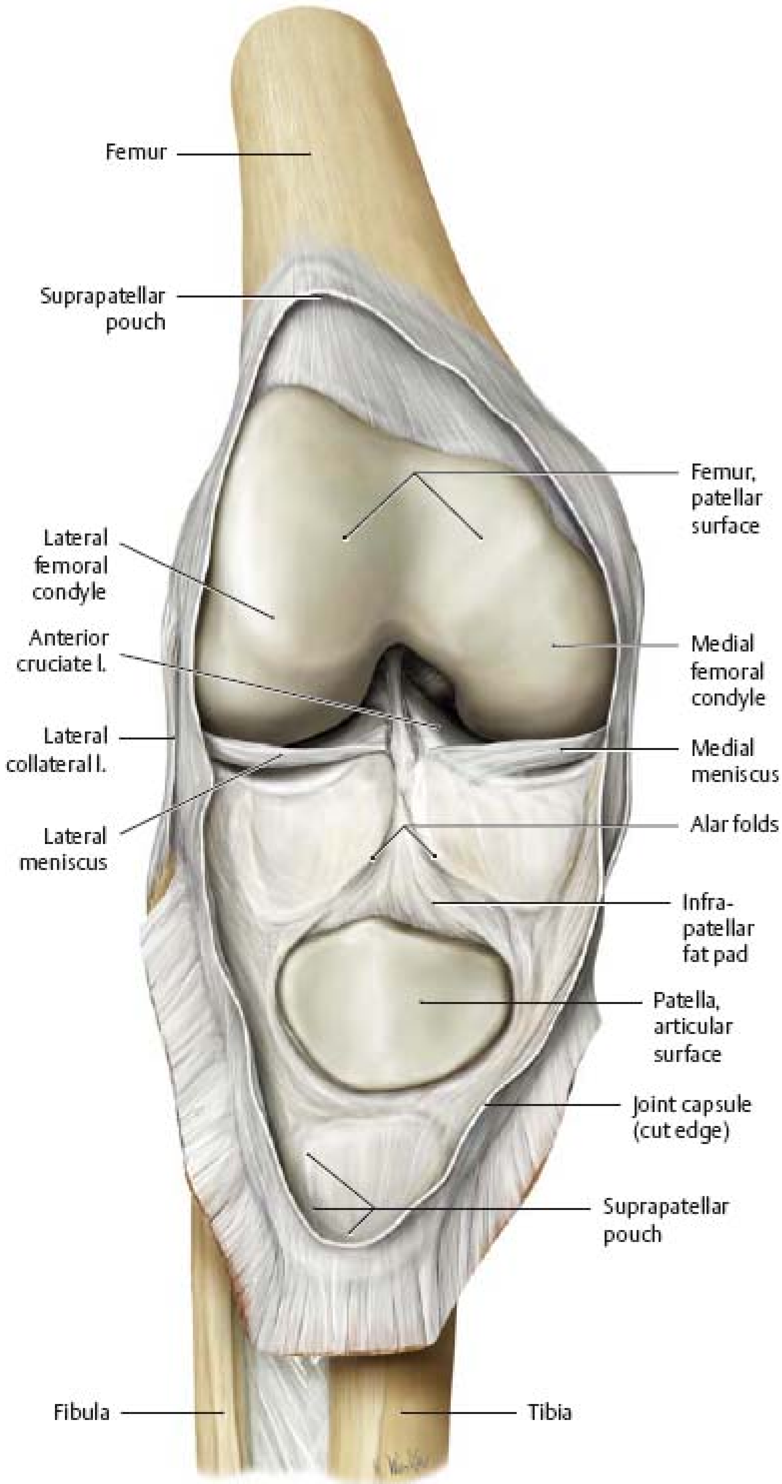


Fig. 25.15 **Attachments of the joint capsule**

Right knee joint, anterior view.

Fig. 25.16 **Suprapatellar pouch during flexion**
Right knee joint, medial view.

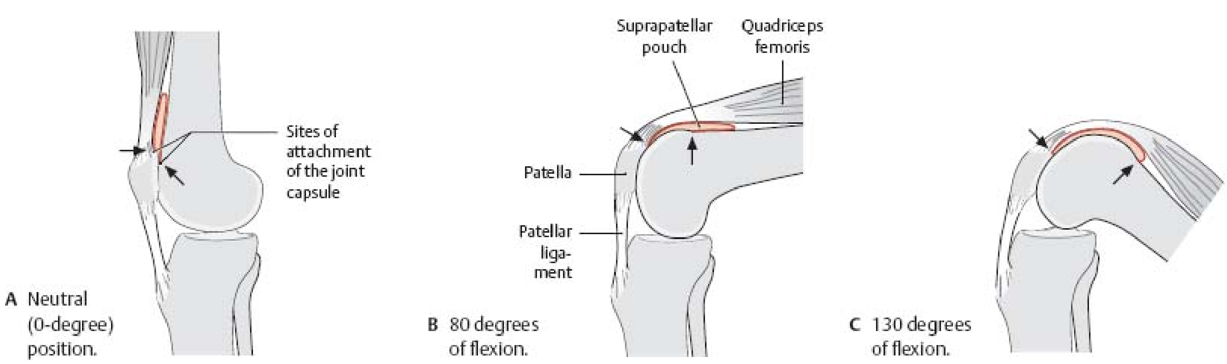


Fig. 25.17 **Right knee joint: Midsagittal section**

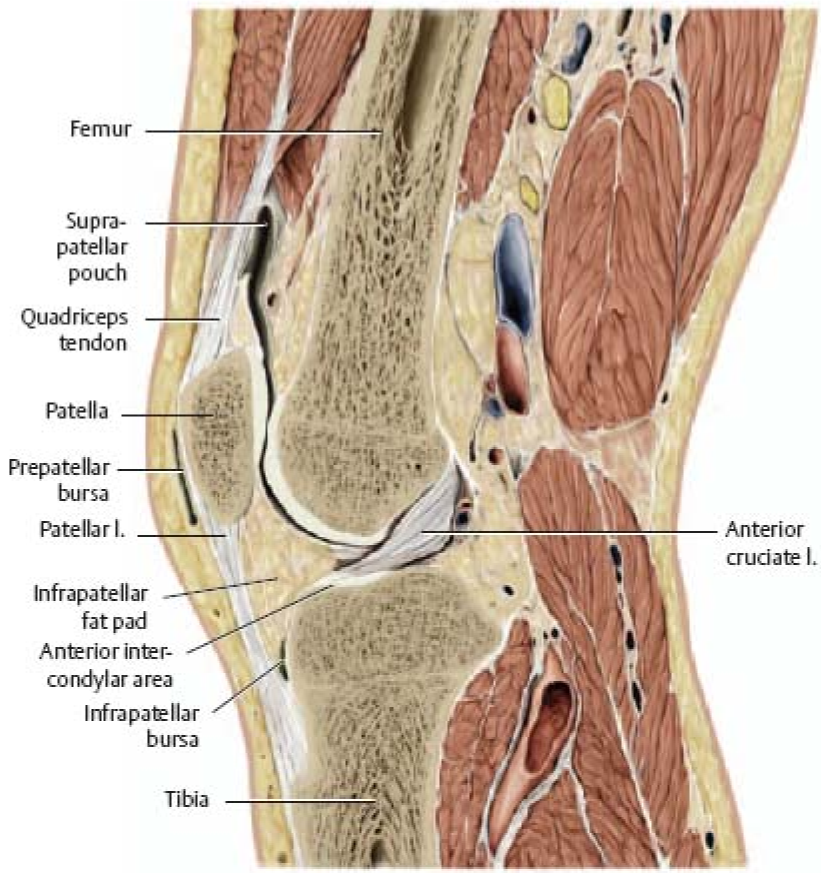
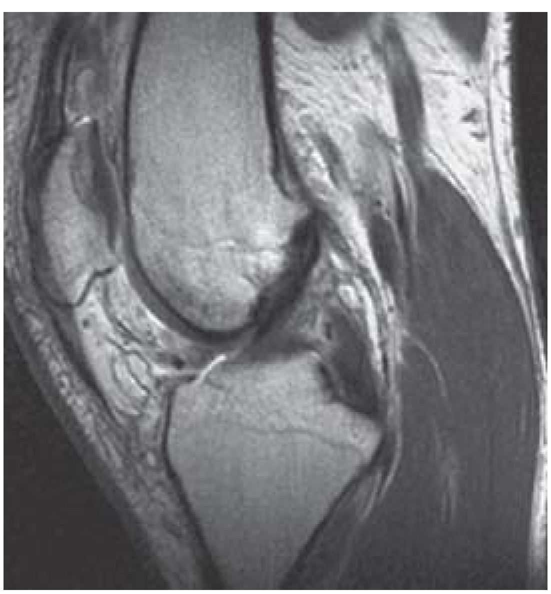


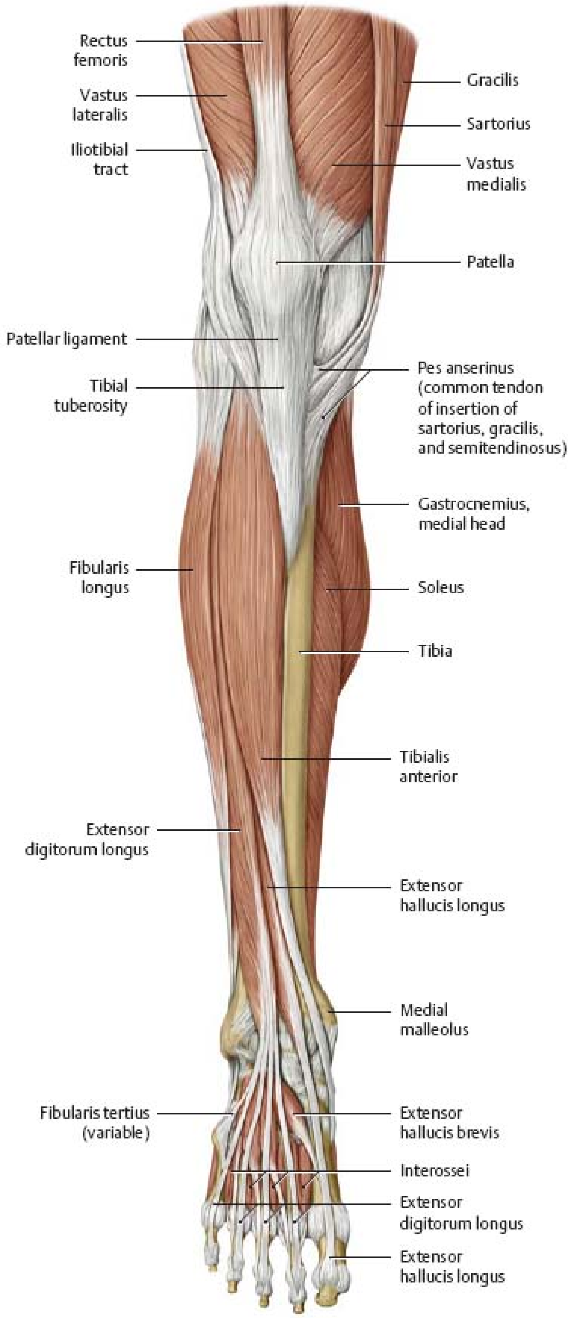
Fig. 25.18 **MRI of knee joint**
Sagittal T2-weighted MRI.



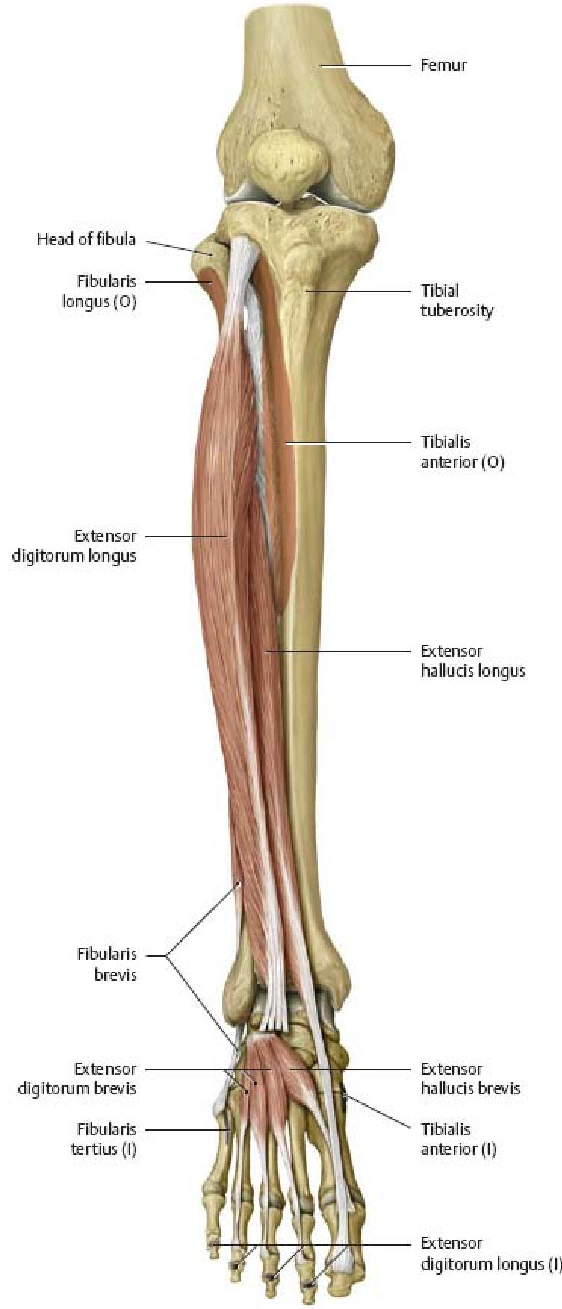
Muscles of the Leg: Anterior & Lateral Views

Fig. 25.19 Muscles of the leg: Anterior view

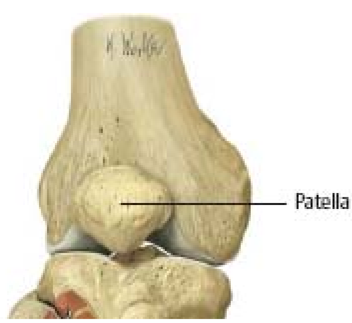
Right leg. Muscle origins (O) shown in red, insertions (I) in blue.

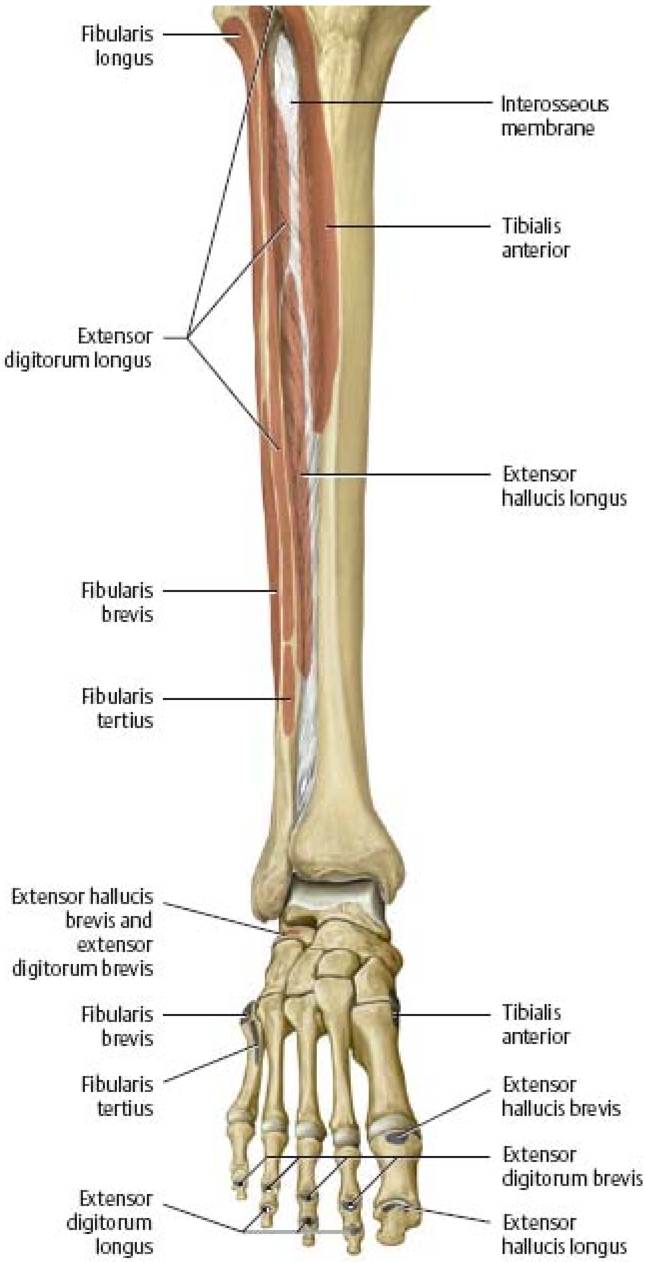


A All muscles shown.



B *Removed:* Tibialis anterior and fibularis longus; extensor digitorum longus tendons (distal portions). *Note:* The fibularis tertius is a division of the extensor digitorum longus.

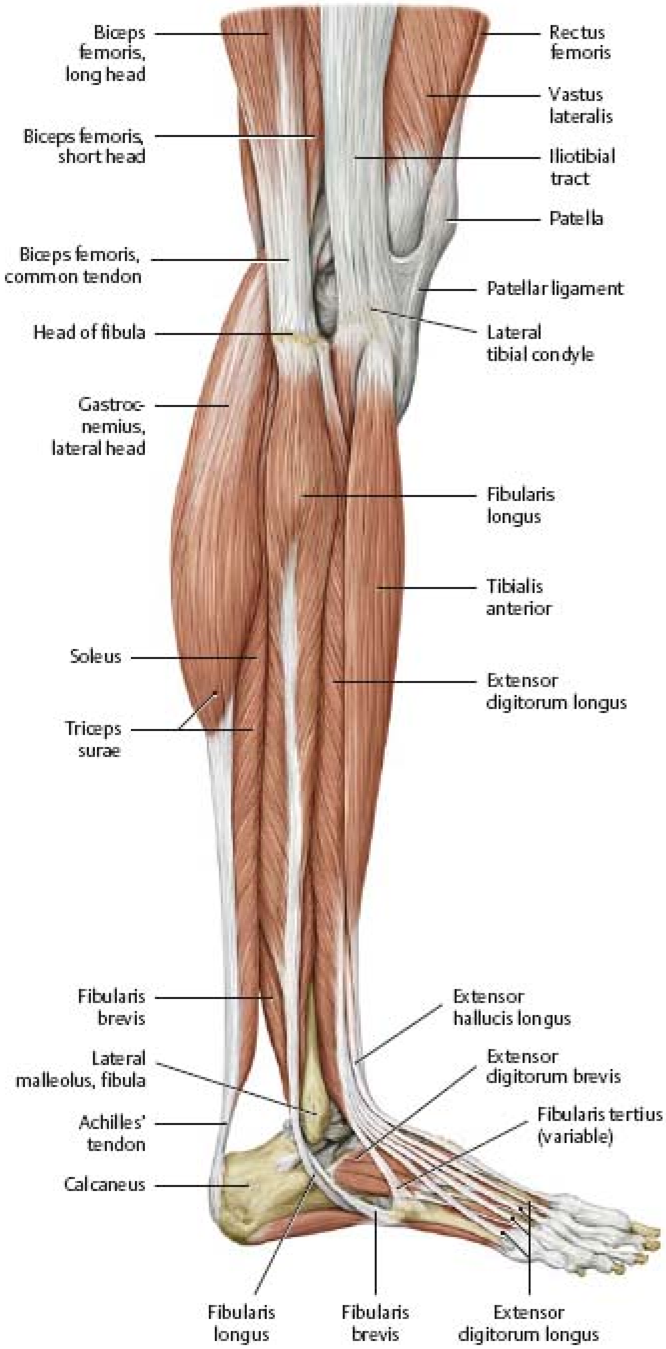




C *Removed:* All muscles.

Fig. 25.20 **Muscles of the leg: Lateral view**

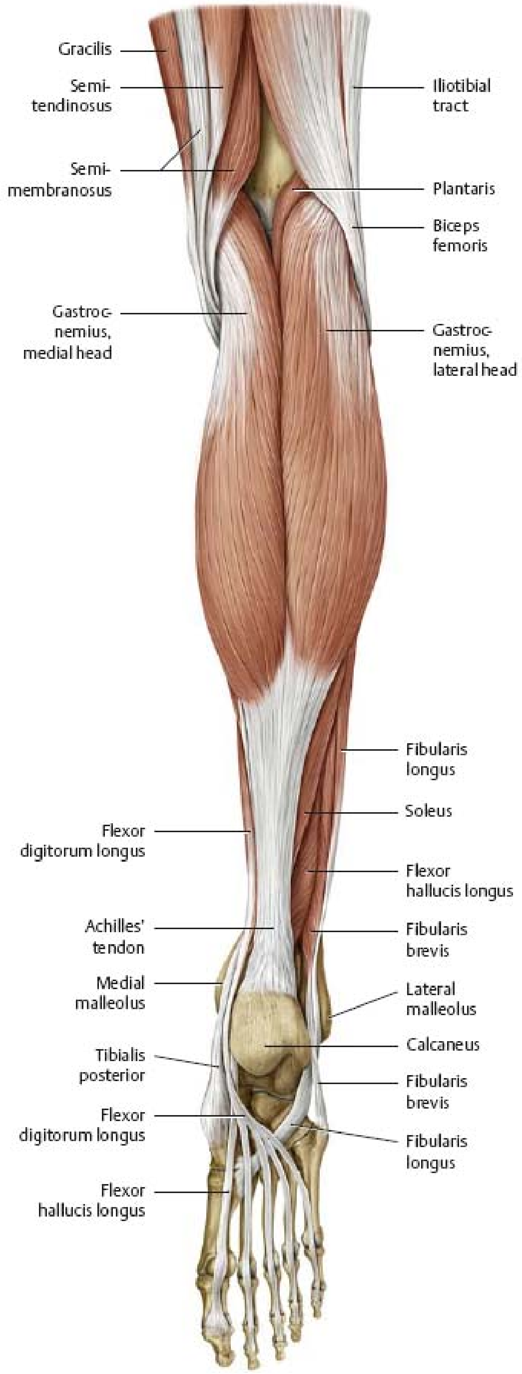
Right leg.



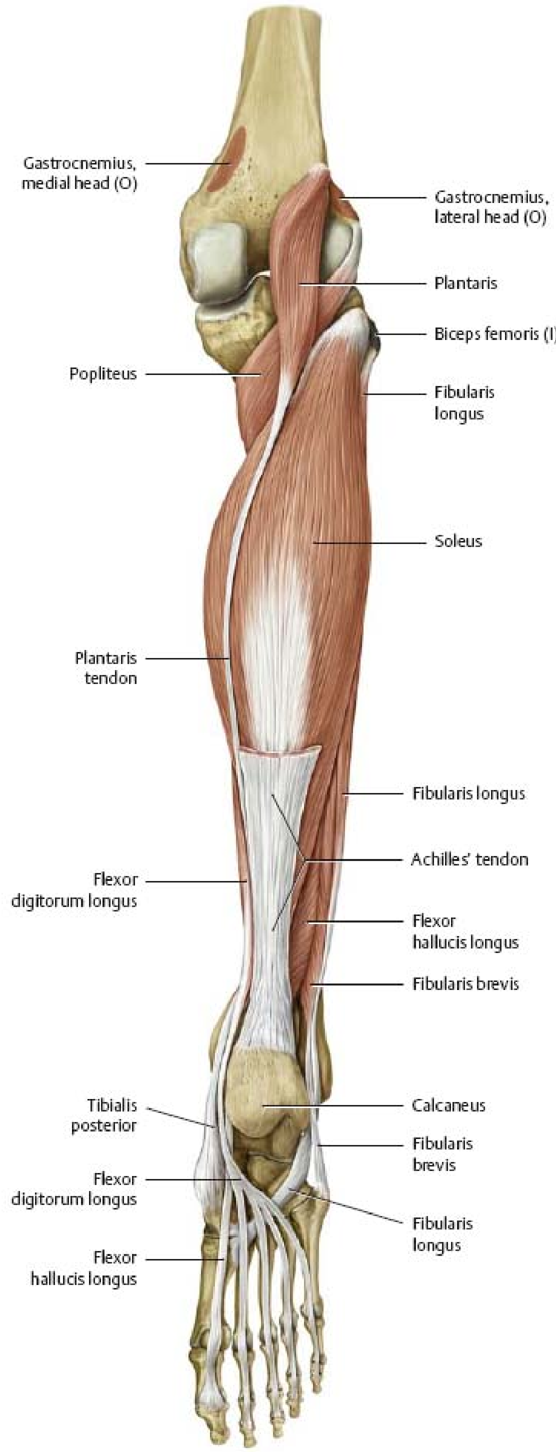
Muscles of the Leg: Posterior View

Fig. 25.21 Muscles of the leg: Posterior view

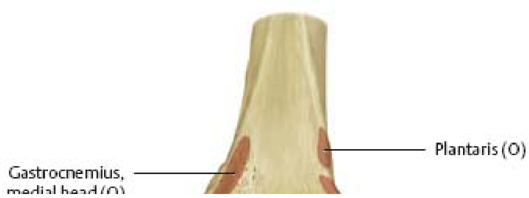
Right leg. Muscle origins (O) shown in red, insertions (I) in blue.

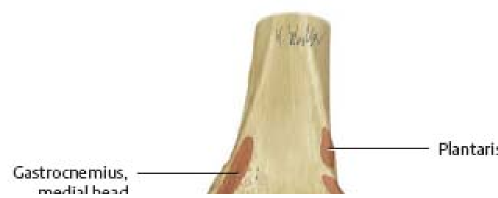


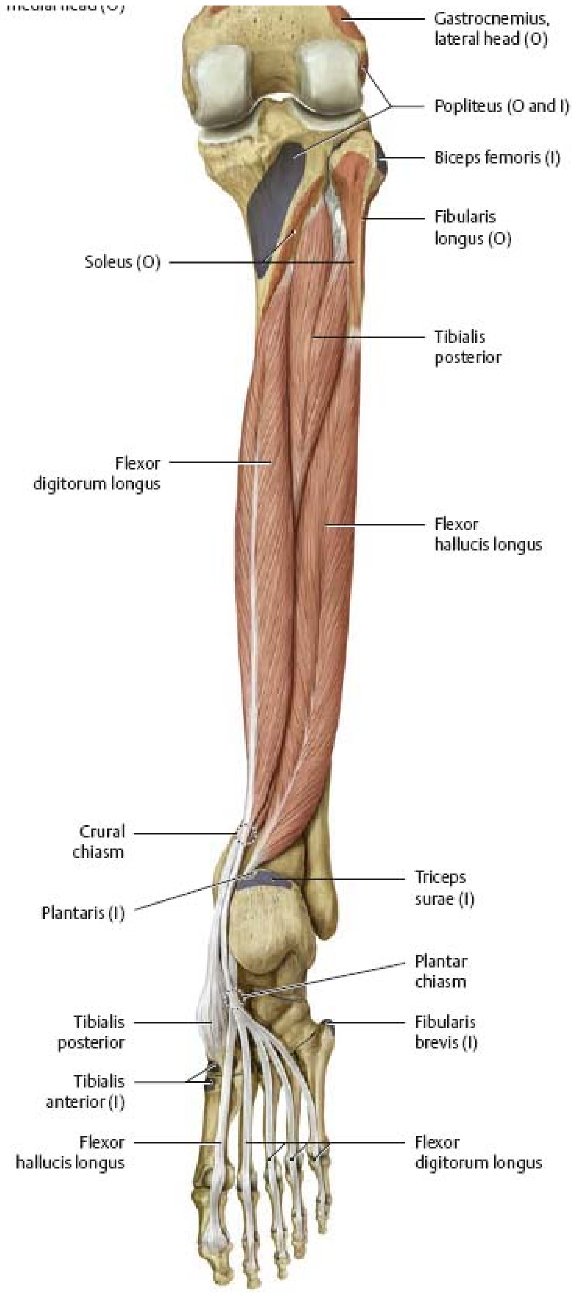
A *Note:* The bulge of the calf is produced mainly by the triceps surae (soleus and the two heads of the gastrocnemius).



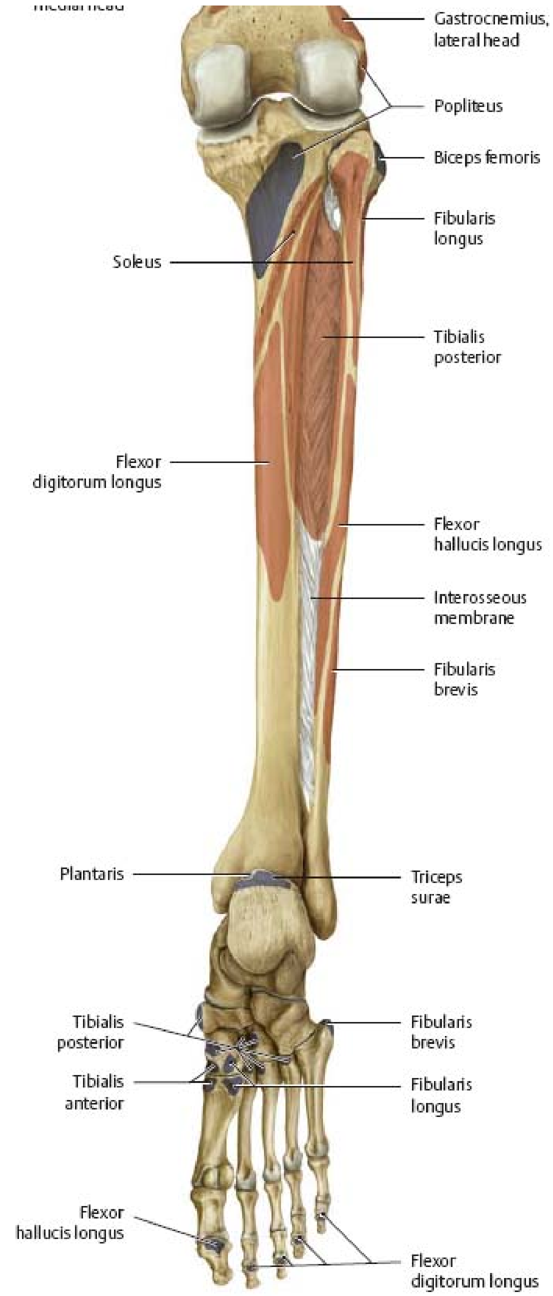
B *Removed:* Gastrocnemius (both heads).







C *Removed:* Triceps surae, plantaris, popliteus, and fibularis longus muscles.



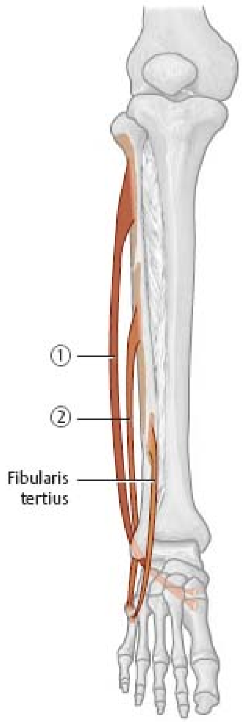
D *Removed:* All muscles.

Muscle Facts (I)

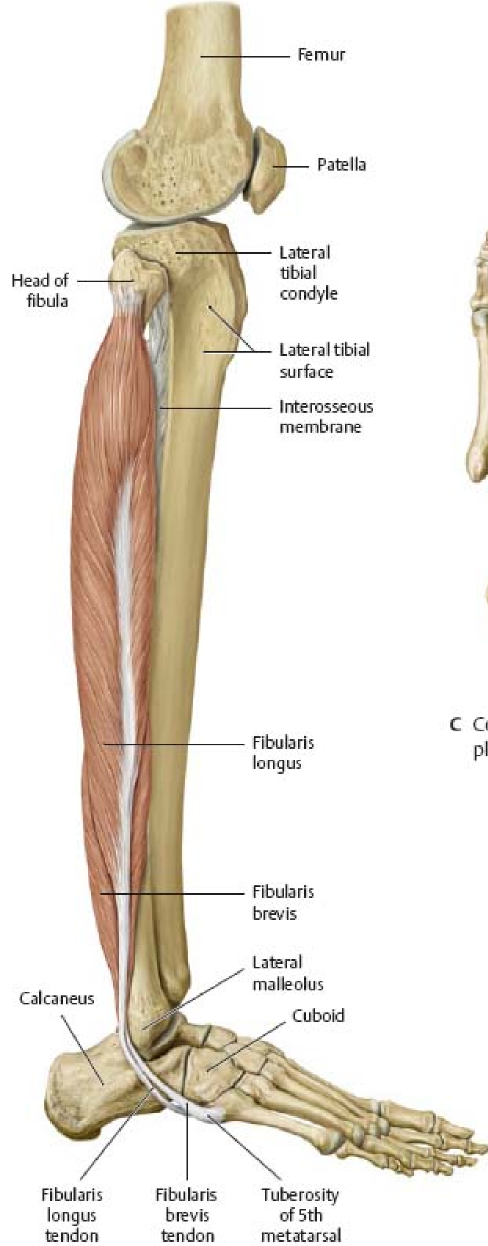
The muscles of the lower leg control the flexion/extension and supination/pronation of the foot as well as provide support for the knee, thigh, hip, and gluteal muscles.

Fig. 25.22 Lateral compartment

Right leg and foot.



A Fibularis group, anterior view.



C Course of the fibularis longus tendon, plantar view.

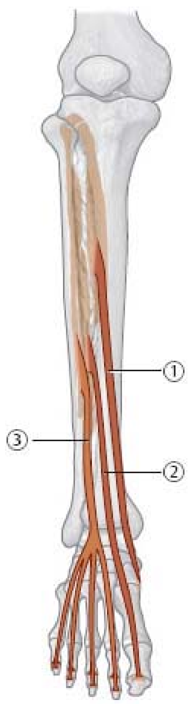
B Lateral compartment, right lateral view.

Table 25.2 Lateral compartment

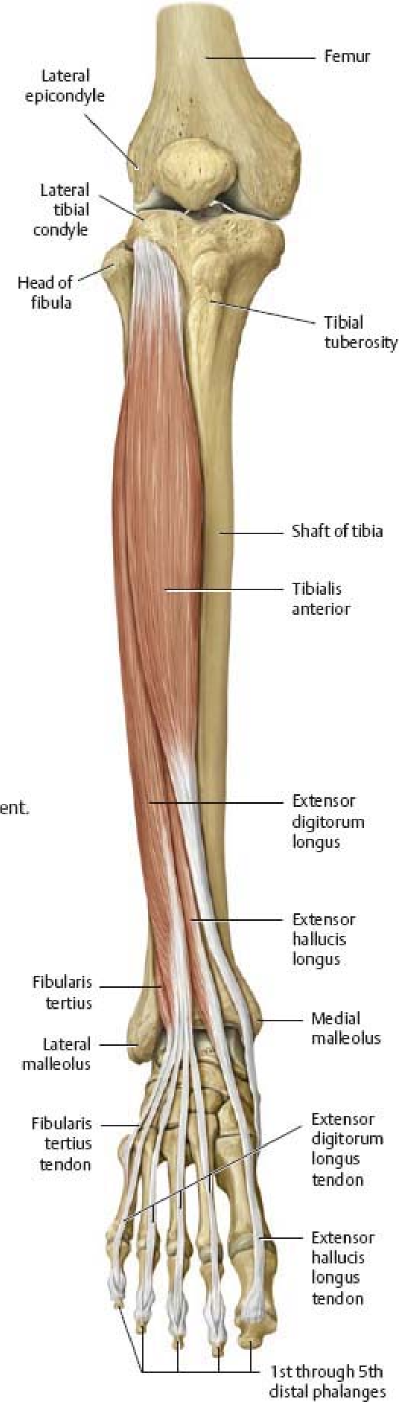
Muscle	Origin	Insertion	Innervation	Action
① Fibularis longus	Fibula (head and proximal two thirds of the lateral surface, arising partly from the intermuscular septa)	Medial cuneiform (plantar side), 1st metatarsal (base)	Superficial fibular n. (L5, S1)	• Talocrural joint: plantar flexion • Subtalar joint: eversion (pronation) • Supports the transverse arch of the foot
② Fibularis brevis	Fibula (distal half of the lateral surface), intermuscular septa	5th metatarsal (tuberosity at the base, with an occasional division to the dorsal aponeurosis of the 5th toe)		• Talocrural joint: plantar flexion • Subtalar joint: eversion (pronation)

Fig. 25.23 Anterior compartment

Right leg, anterior view.



A Schematic.



B Anterior compartment.

Table 25.3	Anterior compartment			
Muscle	**Origin**	**Insertion**	**Innervation**	**Action**
① Tibialis anterior	Tibia (upper two thirds of the lateral surface), interosseous membrane, and superficial crural fascia (highest part)	Medial cuneiform (medial and plantar surface), first metatarsal (medial base)	Deep fibular n. (L4, L5)	• Talocrural joint: dorsiflexion • Subtalar joint: inversion (supination)
② Extensor hallucis longus	Fibula (middle third of the medial surface) interosseous membrane	1st toe (at the dorsal aponeurosis and the base of its distal phalanx)	Deep fibular n. (L5)	• Talocrural joint: dorsiflexion • Subtalar joint: active in both eversion and inversion (pronation/supination), depending on the initial position of the foot • Extends the MTP and IP joints of the big toe
③ Extensor digitorum longus	Fibula (head and anterior border), tibia (lateral condyle), and interosseous membrane	2nd to 5th toes (at the dorsal aponeuroses and bases of the distal phalanges)	Deep fibular n. (L5, S1)	• Talocrural joint: dorsiflexion • Subtalar joint: eversion (pronation) • Extends the MTP and IP joints of the 2nd to 5th toes
Fibularis tertius (see Fig. 25.22A)	Distal fibula (anterior border)	5th metatarsal (base)	Deep fibular n. (L5, S1)	• Talocrural joint: dorsiflexion • Subtalar joint: eversion (pronation)

IP = interphalangeal; MTP = metatarsophalangeal.

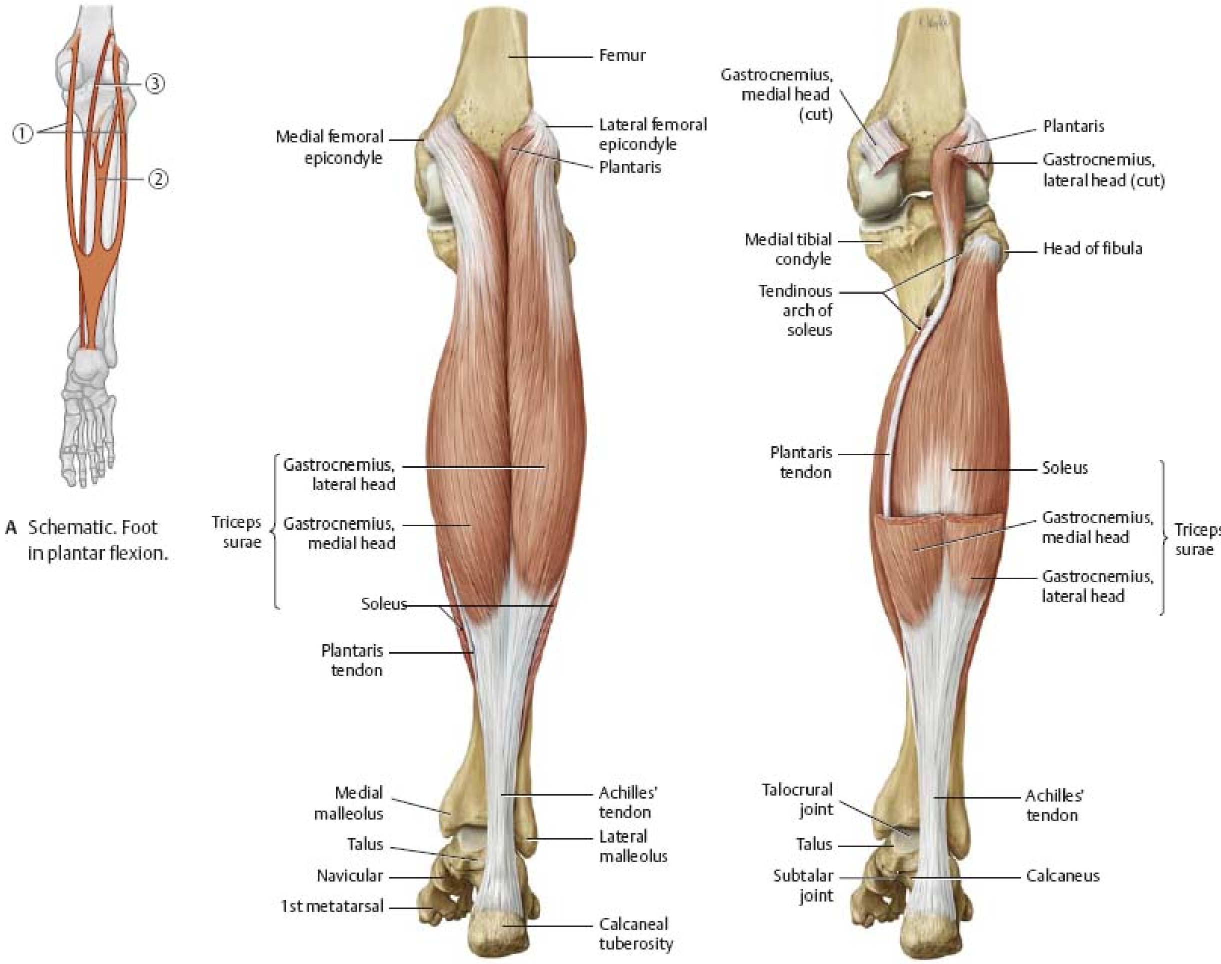
IP = interphalangeal; MTP = metatarsophalangeal.

Muscle Facts (II)

The muscles of the posterior compartment are divided into two groups: the superficial and deep flexors. These groups are separated by the transverse intermuscular septum.

Fig. 25.24 Superficial flexors

Right leg, posterior view.



A Schematic. Foot in plantar flexion.

B Superficial flexors.

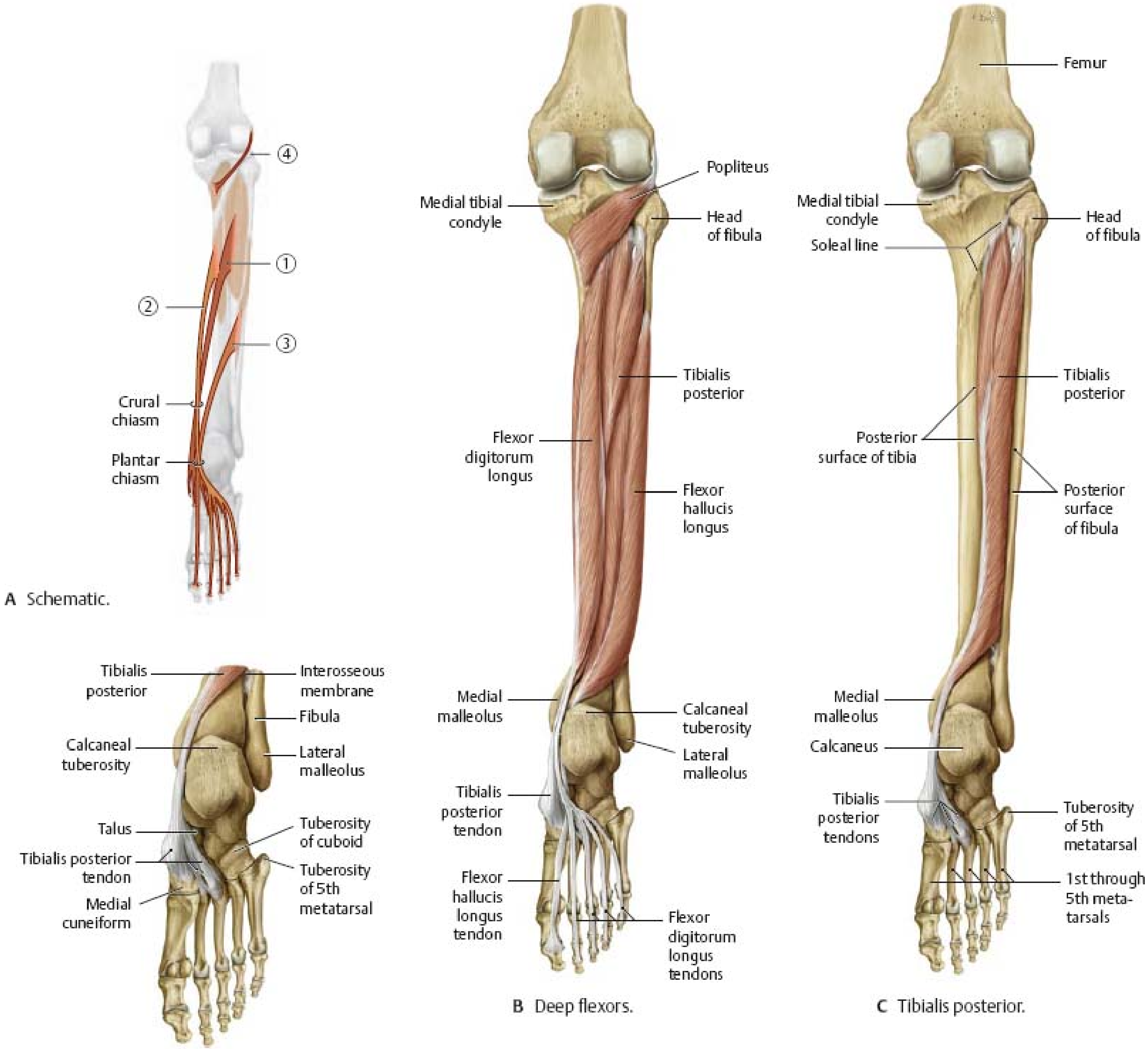
C Superficial flexors with gastrocnemius removed (portions of medial and lateral heads).

Table 25.4 Superficial flexors of the posterior compartment

Muscle		Origin	Insertion	Innervation	Action
Triceps surae	① Gastrocnemius	Femur (medial and lateral epicondyles)	Calcaneal tuberosity via the Achilles' tendon	Tibial n. (S1, S2)	• Talocrural joint: plantar flexion • Knee joint: flexion (gastrocnemius)
	② Soleus	Fibula (head and neck, posterior surface), tibia (soleal line via a tendinous arch)			
③ Plantaris		Femur (lateral epicondyle, proximal to lateral head of gastrocnemius)	Calcaneal tuberosity		Negligible; may prevent compression of posterior leg musculature during knee flexion

Fig. 25.25 Deep flexors

Right leg with foot in plantar flexion, posterior view.



A Schematic.

B Deep flexors.

C Tibialis posterior.

D Insertion of the tibialis posterior.

Table 25.5 Deep flexors of the posterior compartment

Muscle	Origin	Insertion	Innervation	Action
① Tibialis posterior	Interosseous membrane, adjacent borders of tibia and fibula	Navicular tuberosity; cuneiforms (medial, intermediate, and lateral); 2nd to 4th metatarsals (bases)	Tibial n. (L4, L5)	• Talocrural joint: plantar flexion • Subtalar joint: inversion (supination) • Supports the longitudinal and transverse arches
② Flexor digitorum longus	Tibia (middle third of posterior surface)	2nd to 5th distal phalanges (bases)	Tibial n. (L5–S2)	• Talocrural joint: plantar flexion • Subtalar joint: inversion (supination) • MTP and IP joints of the 2nd to 5th toes: plantar flexion
③ Flexor hallucis longus	Fibula (distal two thirds of posterior surface), adjacent interosseous membrane	1st distal phalanx (base)		• Talocrural joint: plantar flexion • Subtalar joint: inversion (supination) • MTP and IP joints of the 2nd to 5th toes: plantar flexion • Supports the medial longitudinal arch
④ Popliteus	Lateral femoral condyle, posterior horn of the lateral meniscus	Posterior tibial surface (above the origin at the soleus)	Tibial n. (L4–S1)	Knee joint: flexion and internal rotation (stabilizes the knee)

IP = interphalangeal; MTP = metatarsophalangeal.

26 Ankle & Foot

Bones of the Foot

Fig. 26.1 Subdivisions of the pedal skeleton

Right foot, dorsal view. Descriptive anatomy divides the skeletal elements of the foot into the tarsus, metatarsus, and forefoot (antetarsus). Functional and clinical criteria divide the pedal skeleton into hindfoot, midfoot, and forefoot.

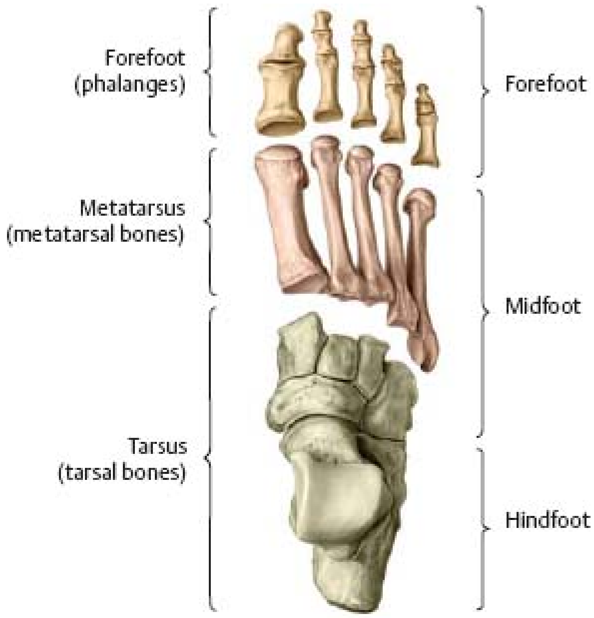
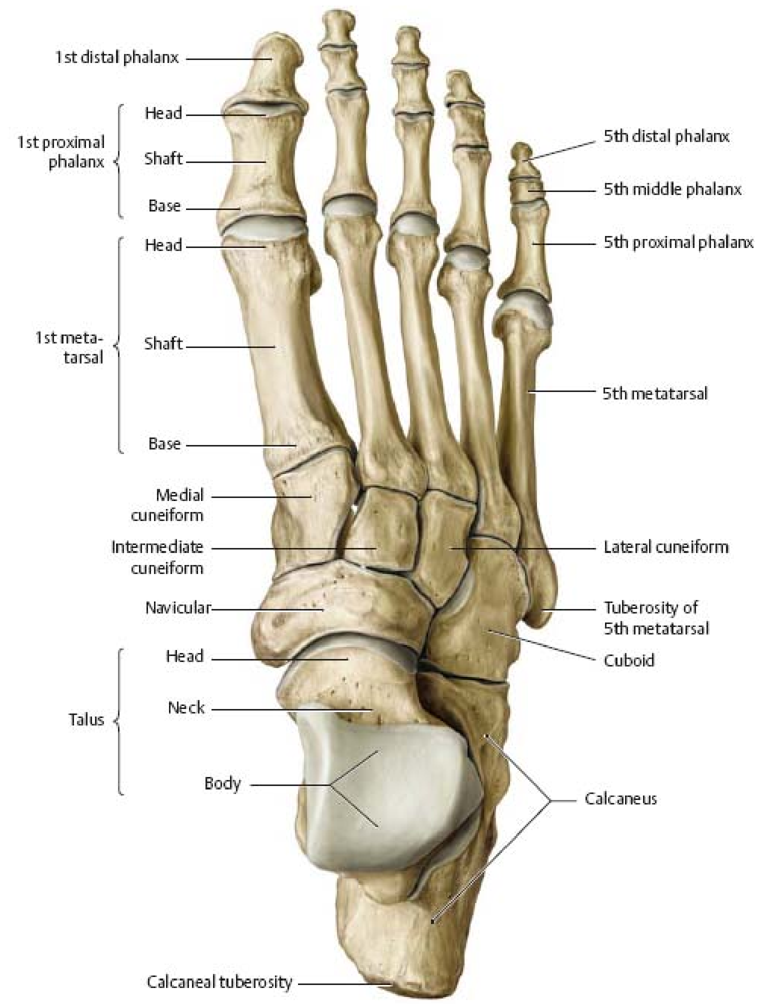
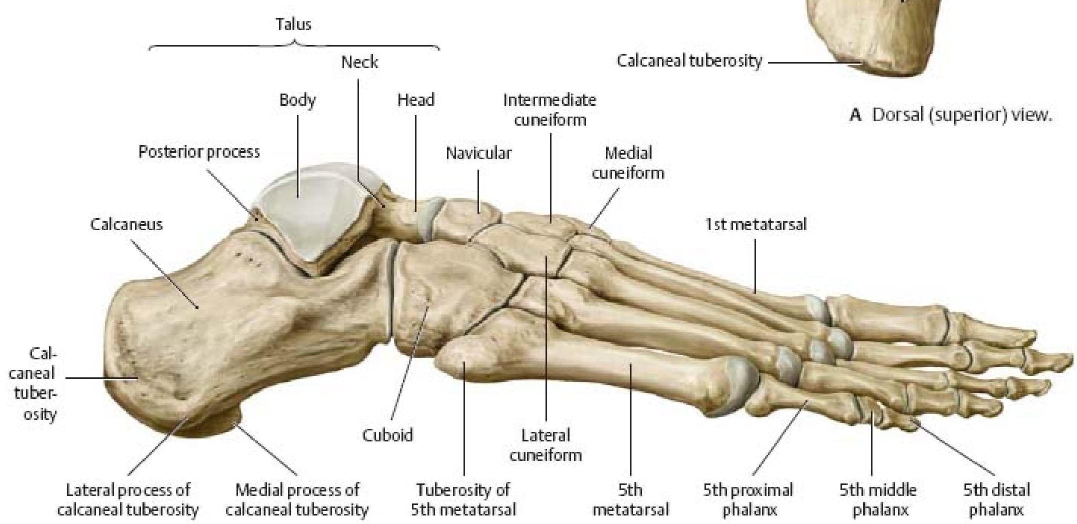


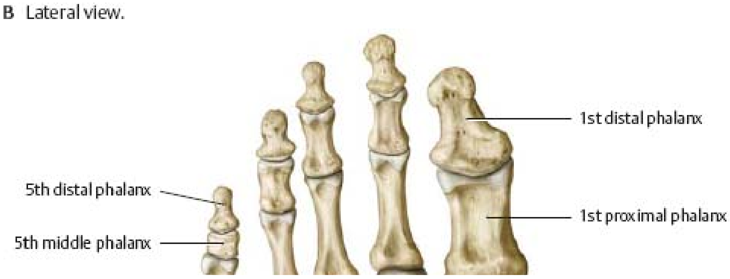
Fig. 26.2 Bones of the right foot

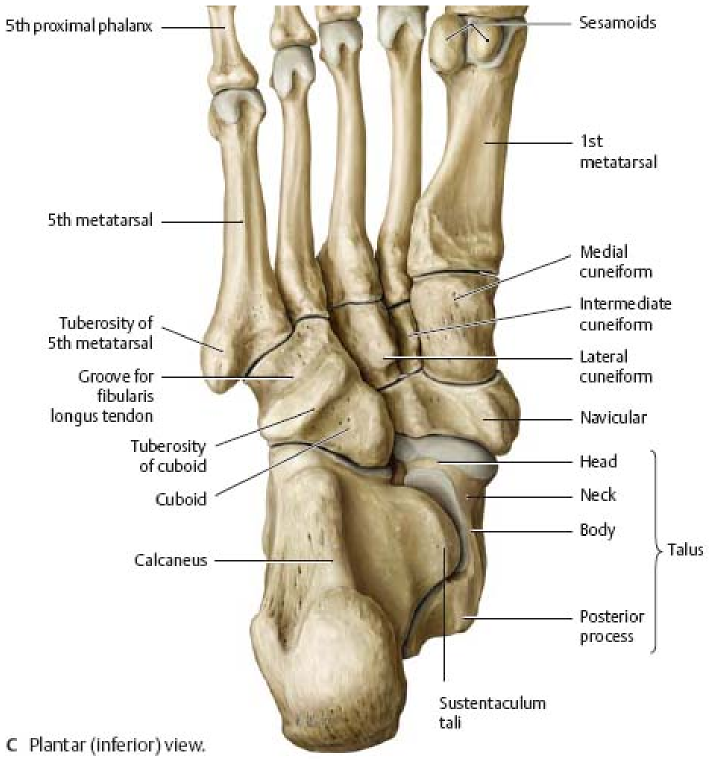


A Dorsal (superior) view.

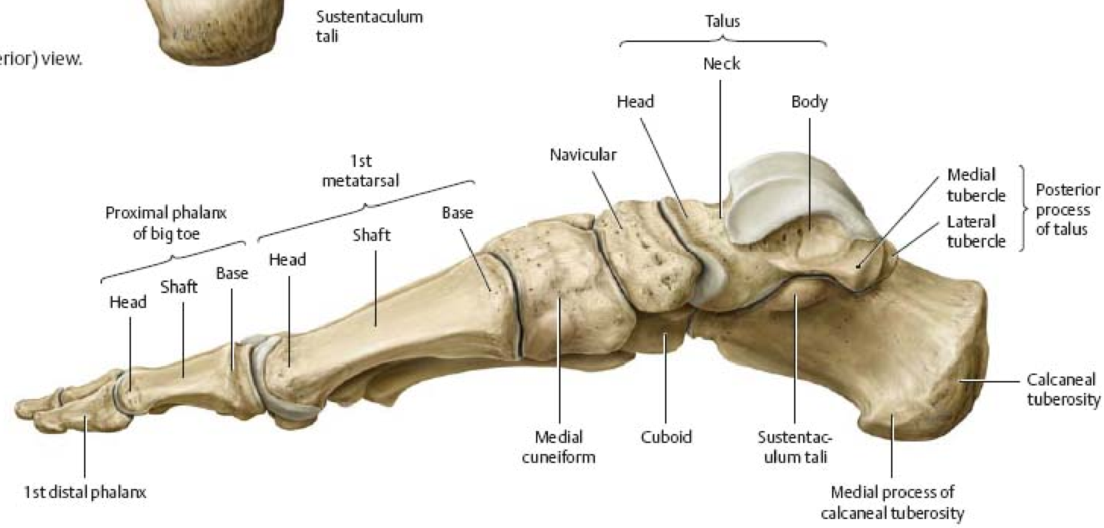


B Lateral view.





C Plantar (inferior) view.

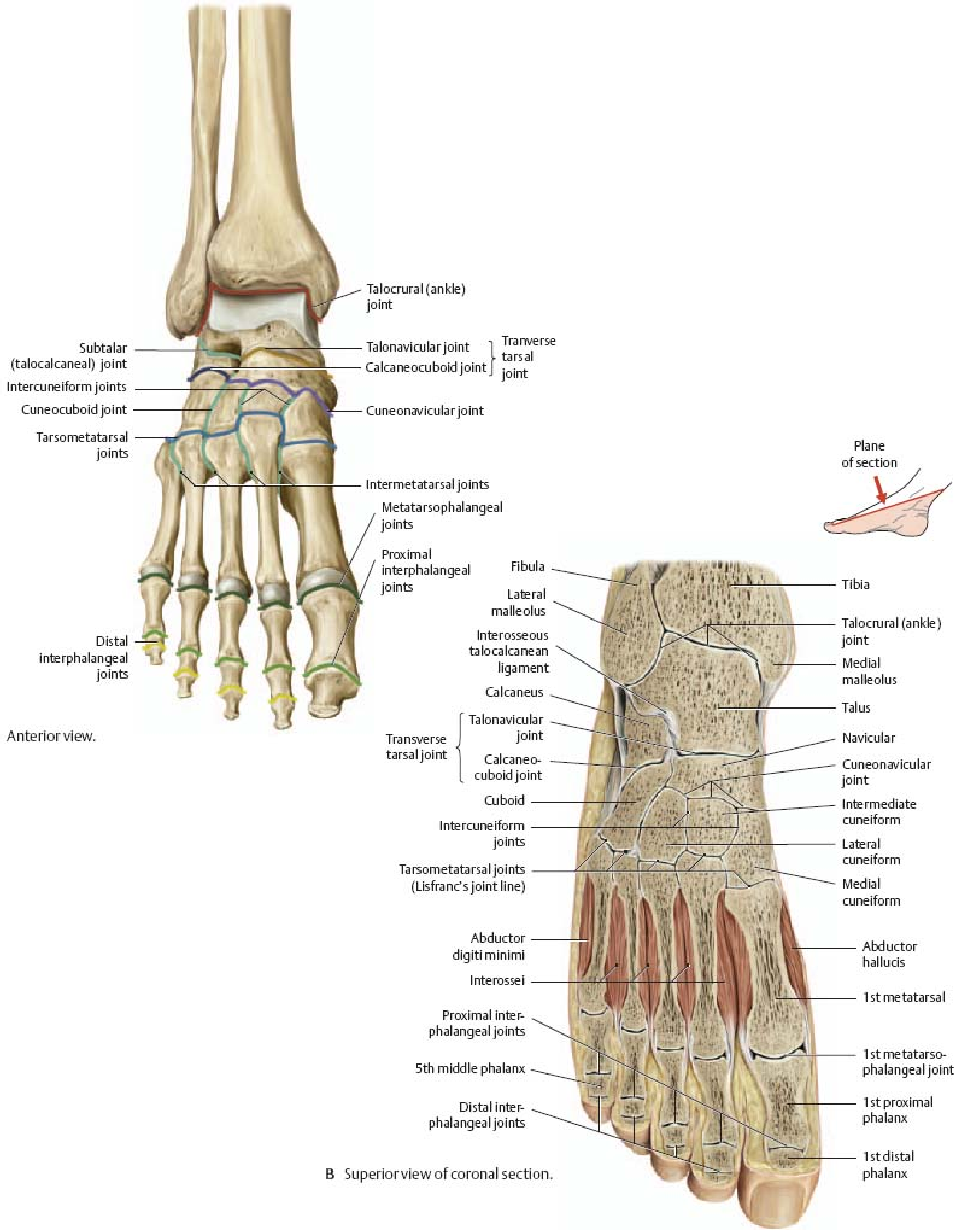


D Medial view.

Joints of the Foot (I)

Fig. 26.3 Joints of the foot

Right foot with talocrural joint in plantar flexion.



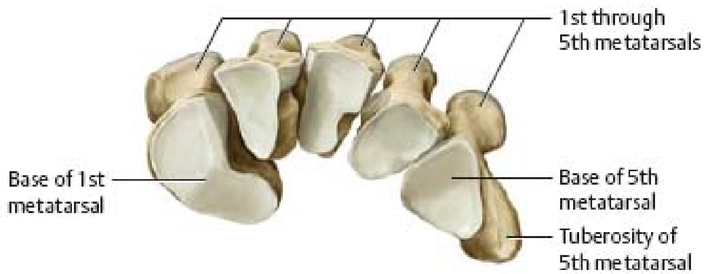
A Anterior view.

B Superior view of coronal section.

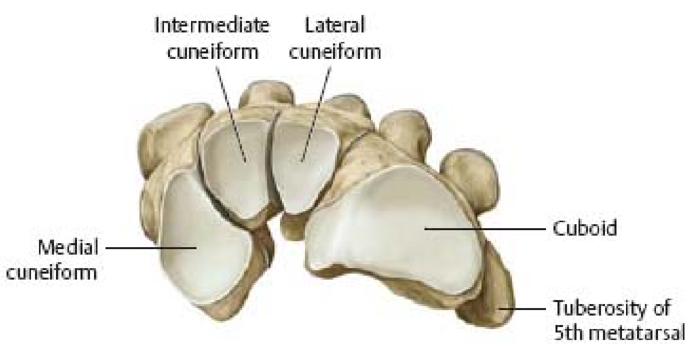
Fig. 26.4 **Proximal articular surfaces**

Right foot, proximal view.

A Metatarsophalangeal joints.



B Tarsometatarsal joints.

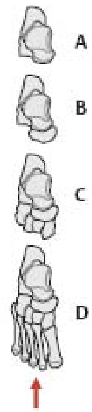


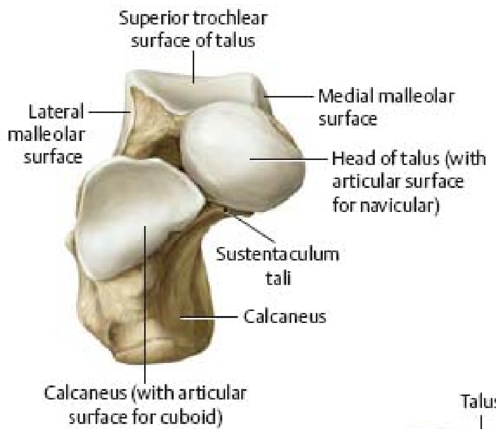
C Cuneonavicular and calcaneocuboid joints.

D Talonavicular and calcaneocuboid joints.

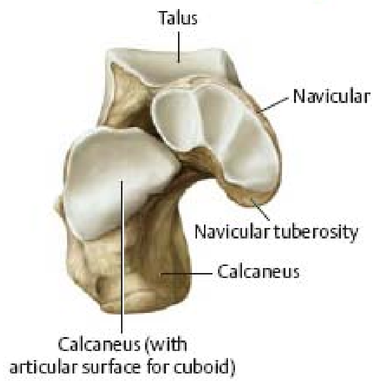
Fig. 26.5 **Distal articular surfaces**

Right foot, distal view.

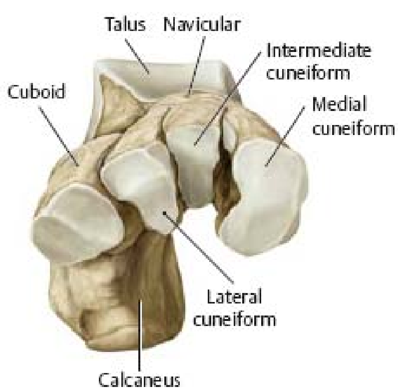




A Talonavicular and calcaneocuboid joints.



B Cuneonavicular and calcaneocuboid joints.



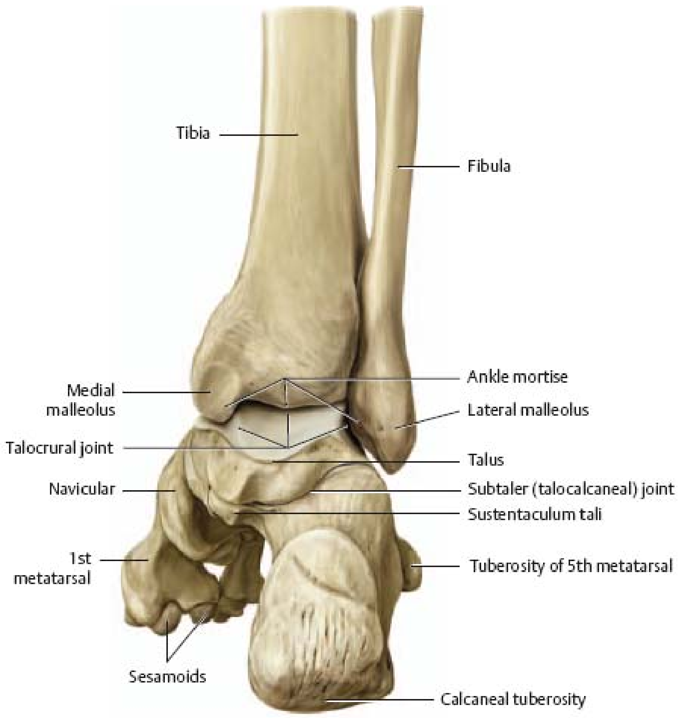
C Tarsometatarsal joints.

D Metatarsophalangeal joints.

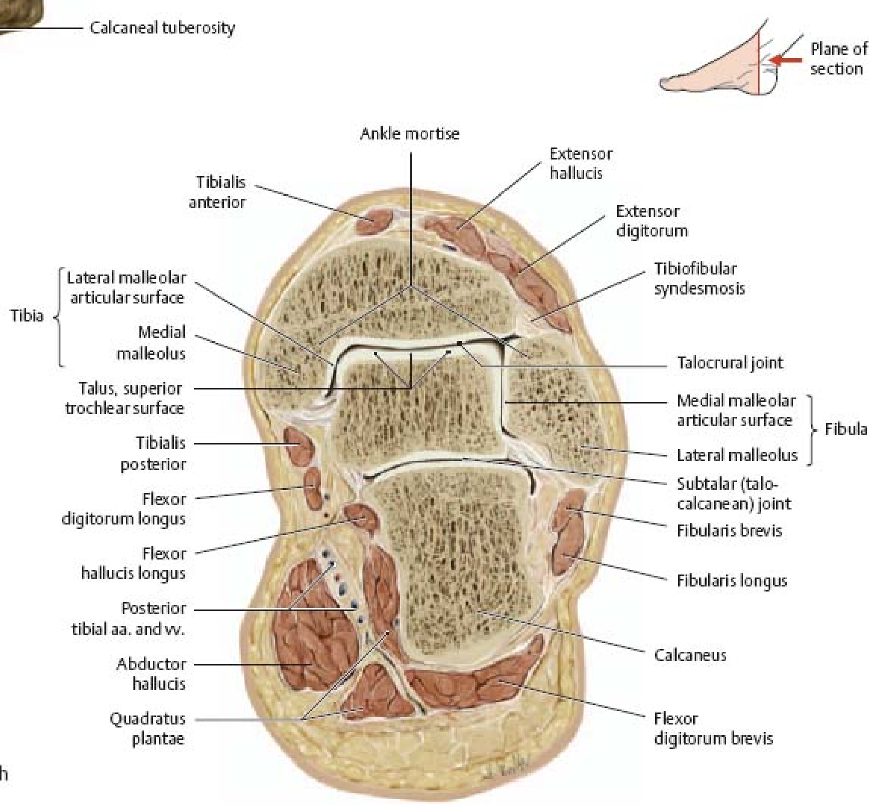
Joints of the Foot (II)

Fig. 26.6 **Talocrural and subtalar joints**

Right foot. The talocrural (ankle) joint is formed by the distal ends of the tibia and fibula (ankle mortise) articulating with the trochlea of the talus. The subtalar joint consists of an anterior and a posterior compartment (the talocalcanean and talocalcaneonavicular joints, respectively)divided by the interosseous talocalcanean ligament (see p. 409).



A Posterior view with foot in neutral (0-degree) position.



B Coronal section, proximal view. The talocrural joint is plantar flexed, and the subtalar joint has been sectioned through its posterior compartment.

Fig. 26.7 **Talocrural and subtaler joints: Sagittal section**

Right foot, medial view.

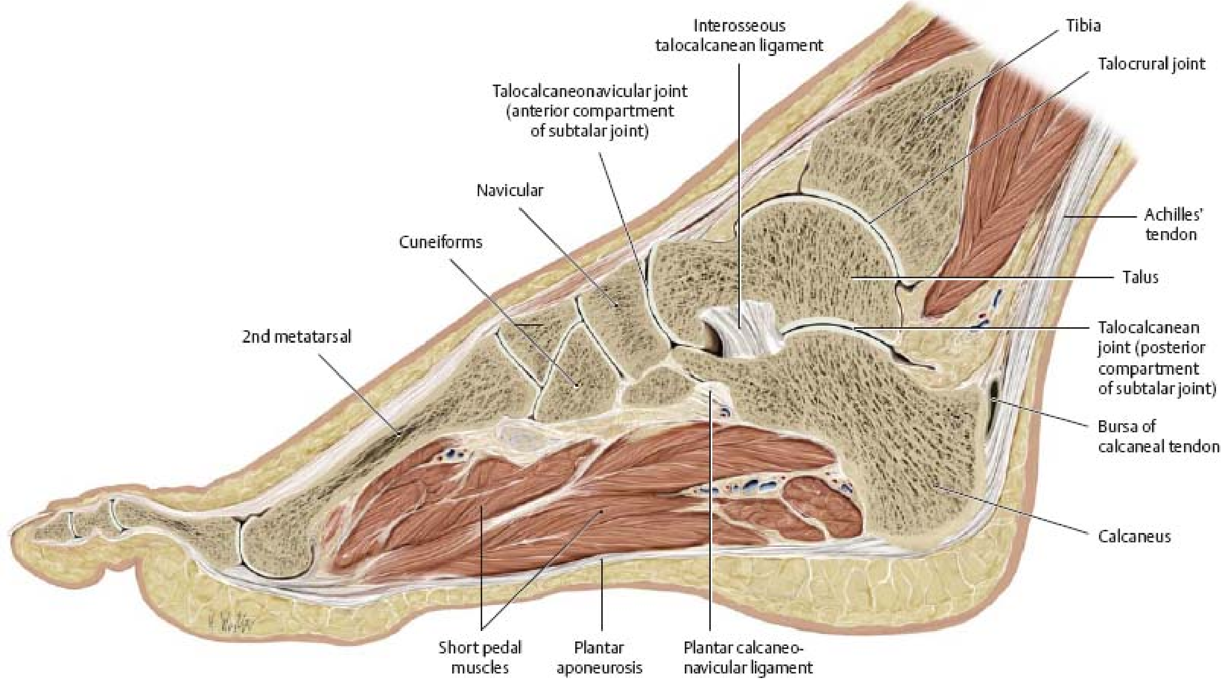
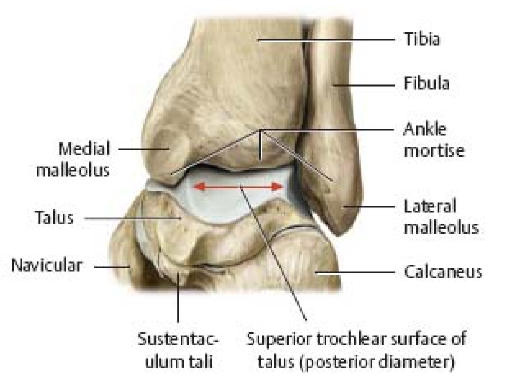


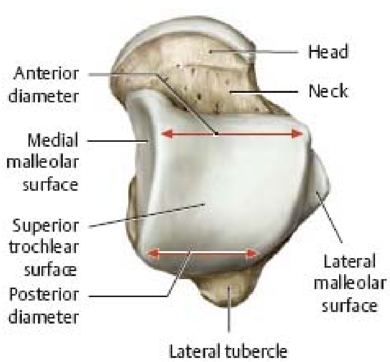
Fig. 26.8 Talocrural joint

Right foot.

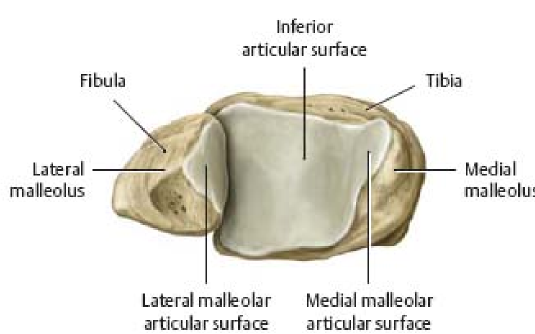
A Anterior view.



B Posterior view.



C Proximal (superior) view of talus.

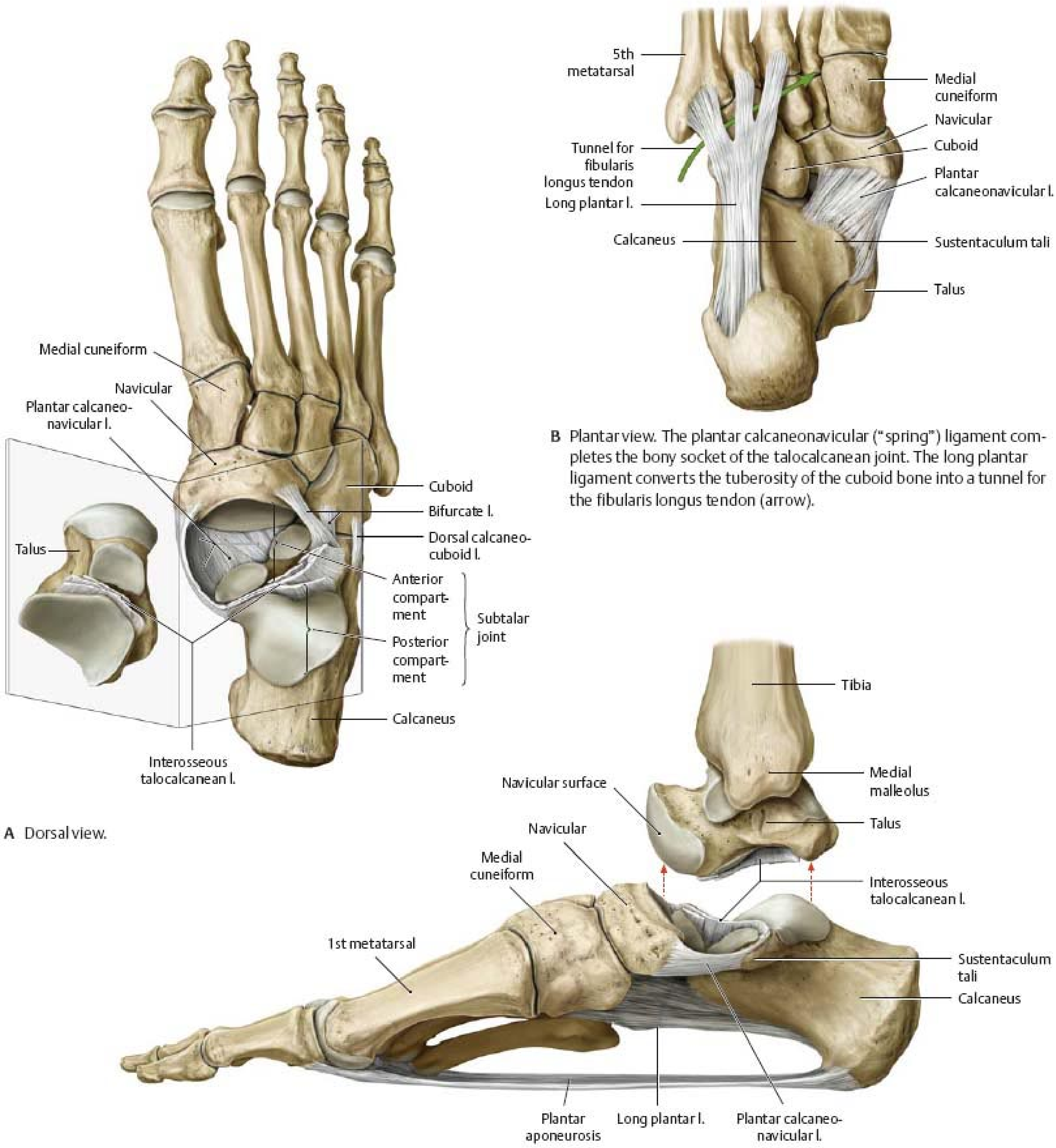


D Distal (inferior) view of ankle mortise.

Joints of the Foot (III)

Fig. 26.9 Subtalar joint and ligaments

Right foot with opened subtalar joint. The subtalar joint consists of two distinct articulations separated by the interosseous talocalcanean ligament: the posterior compartment (talocalcanean joint) and the anterior compartment (talocalcaneonavicular joint).



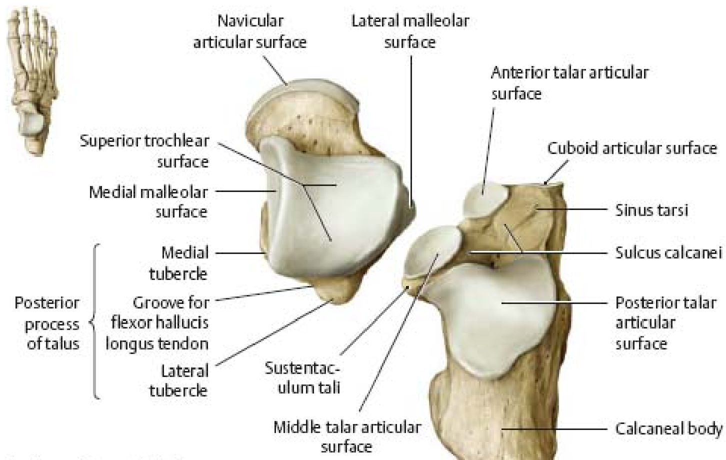
B Plantar view. The plantar calcaneonavicular ("spring") ligament completes the bony socket of the talocalcanean joint. The long plantar ligament converts the tuberosity of the cuboid bone into a tunnel for the fibularis longus tendon (arrow).

A Dorsal view.

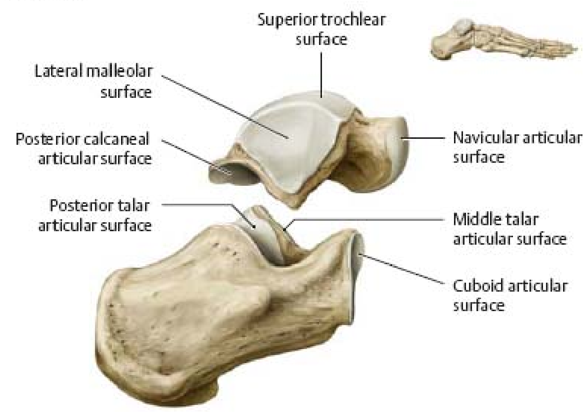
C Medial view. The interosseous talocalcanean ligament has been divided and the talus displaced upward. Note the course of the plantar calcaneonavicular ligament, which functions with the long plantar ligament and plantar aponeurosis to support the longitudinal arch of the foot.

Fig. 26.10 **Talus and calcaneus**

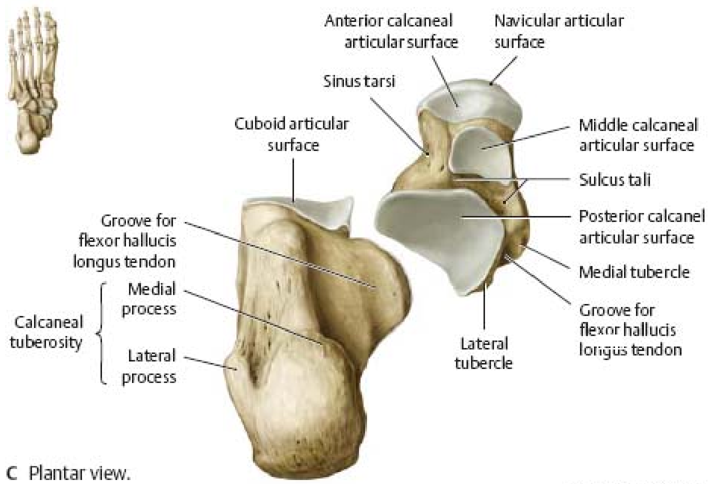
The two tarsal bones have been separated at the subtalar joint to demonstrate their articular surfaces.



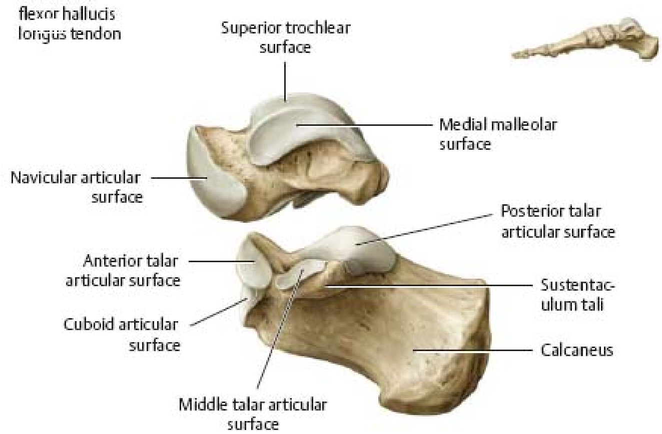
A Dorsal (superior) view.



B Lateral view.



C Plantar view.



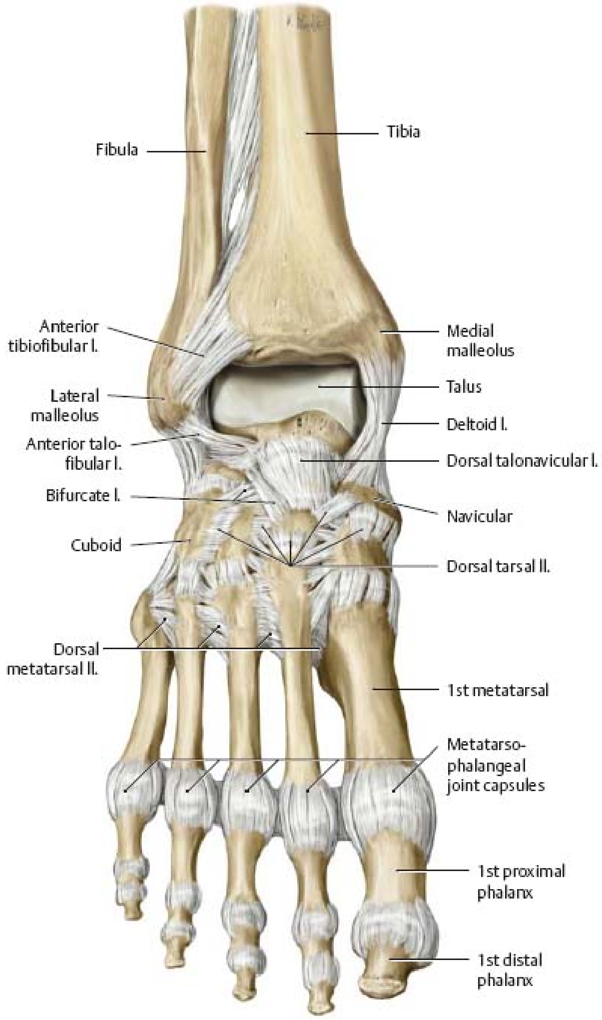
D Medial view.

Ligaments of the Ankle & Foot

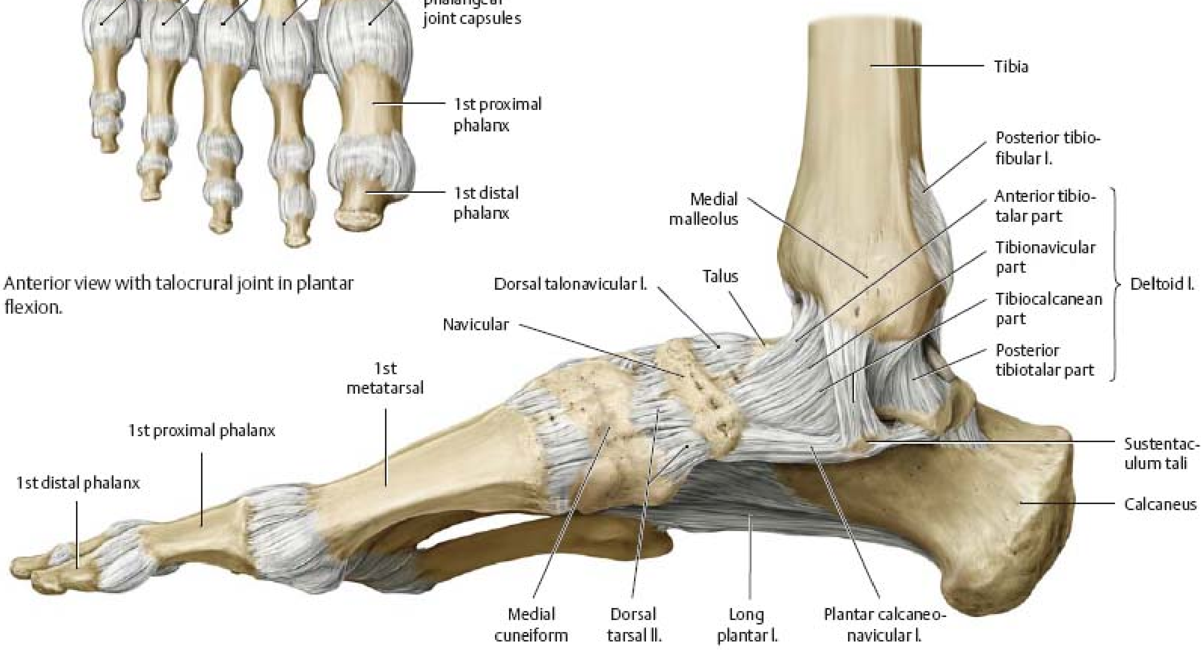
The ligaments of the foot are classified as belonging to the talocrural joint, subtalar joint, metatarsus, forefoot, or sole of the foot. The medial and lateral collateral ligaments, along with the syndesmotic ligaments, are of major importance in the stabilization of the subtalar joint.

Fig. 26.11 **Ligaments of the ankle and foot**

Right foot. See p. 406 for inferior view.



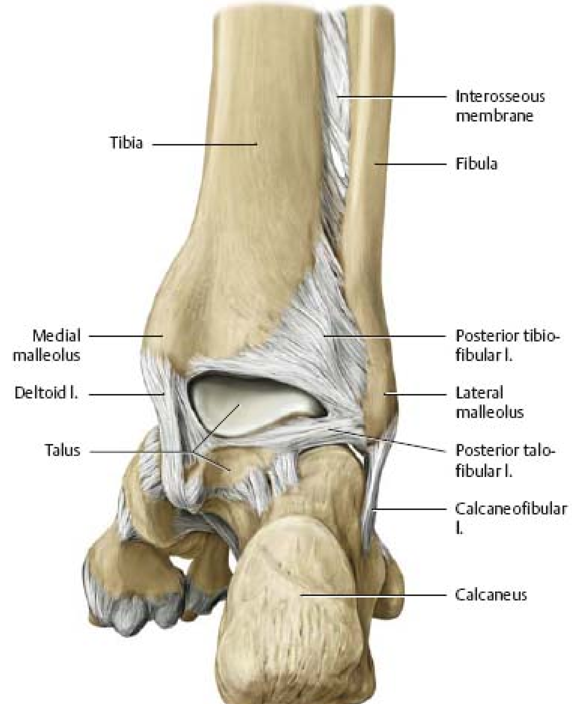
A Anterior view with talocrural joint in plantar flexion.



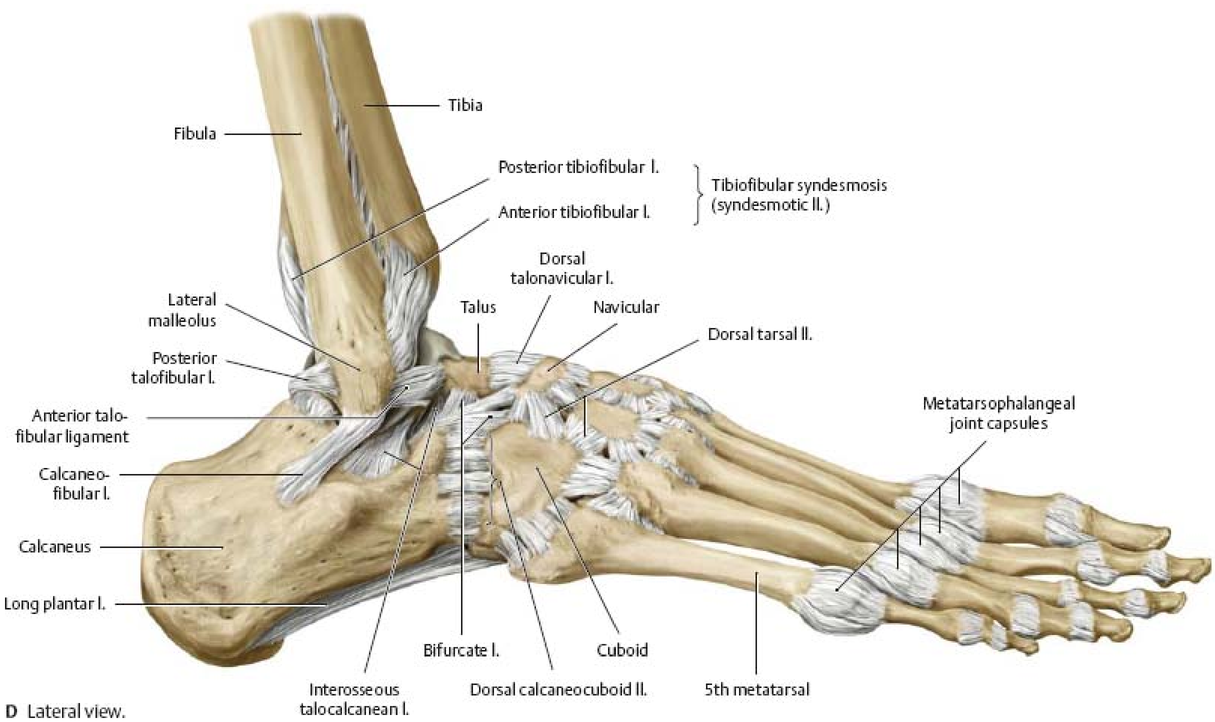
B Medial view.

Table 26.1	Ligaments of the talocrural joint	
Lateral ligaments*	Anterior talofibular l.	
	Posterior talofibular l.	
	Calcaneofibular l.	
Medial ligaments*	Deltoid l.	Anterior tibiotalar part
		Posterior tibiotalar part
		Tibionavicular part
		Tibiocalcanean part
Syndesmotic ligaments of the ankle mortise	Anterior tibiofibular l.	
	Posterior tibiofibular l.	

* The medial and lateral ligaments are also known as the medial and lateral collateral ligaments.



C Posterior view in plantigrade foot position.



D Lateral view.

Plantar Vault & Arches of the Foot

Fig. 26.12 Plantar vault

Right foot. The forces of the foot are distributed among two lateral (fibular) and three medial (tibial) rays. The arrangement of these rays creates a longitudinal and a transverse arch in the sole of the foot, helping the foot absorb vertical loads.

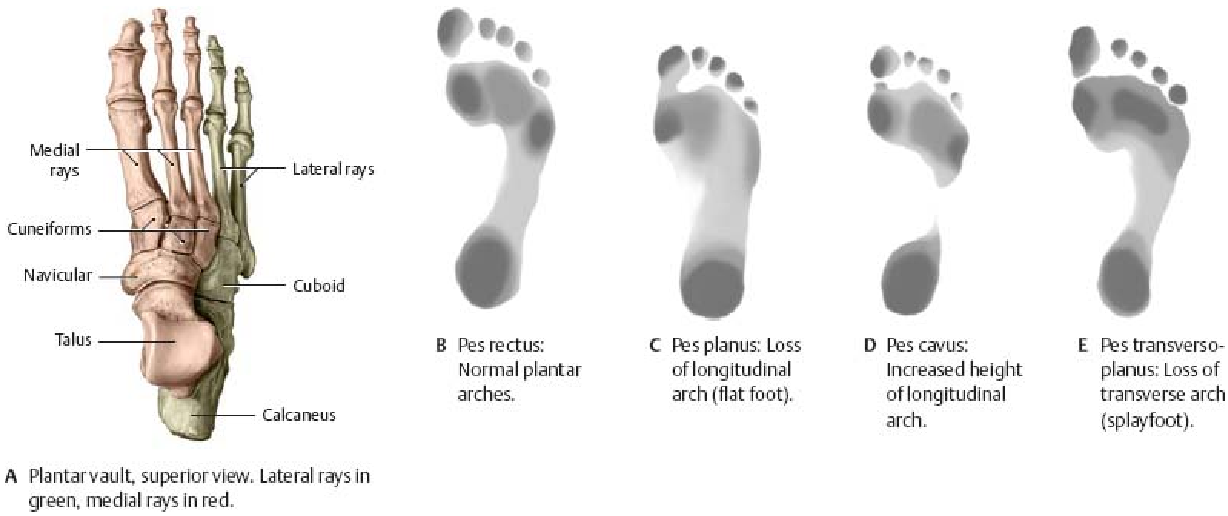


Fig. 26.13 Stabilizers of the transverse arch

Right foot. The transverse pedal arch is supported by both active and passive stabilizing structures (muscles and ligaments, respectively).

Note: The arch of the forefoot has only passive stabilizers, whereas the arches of the metatarsus and tarsus have only active stabilizers.

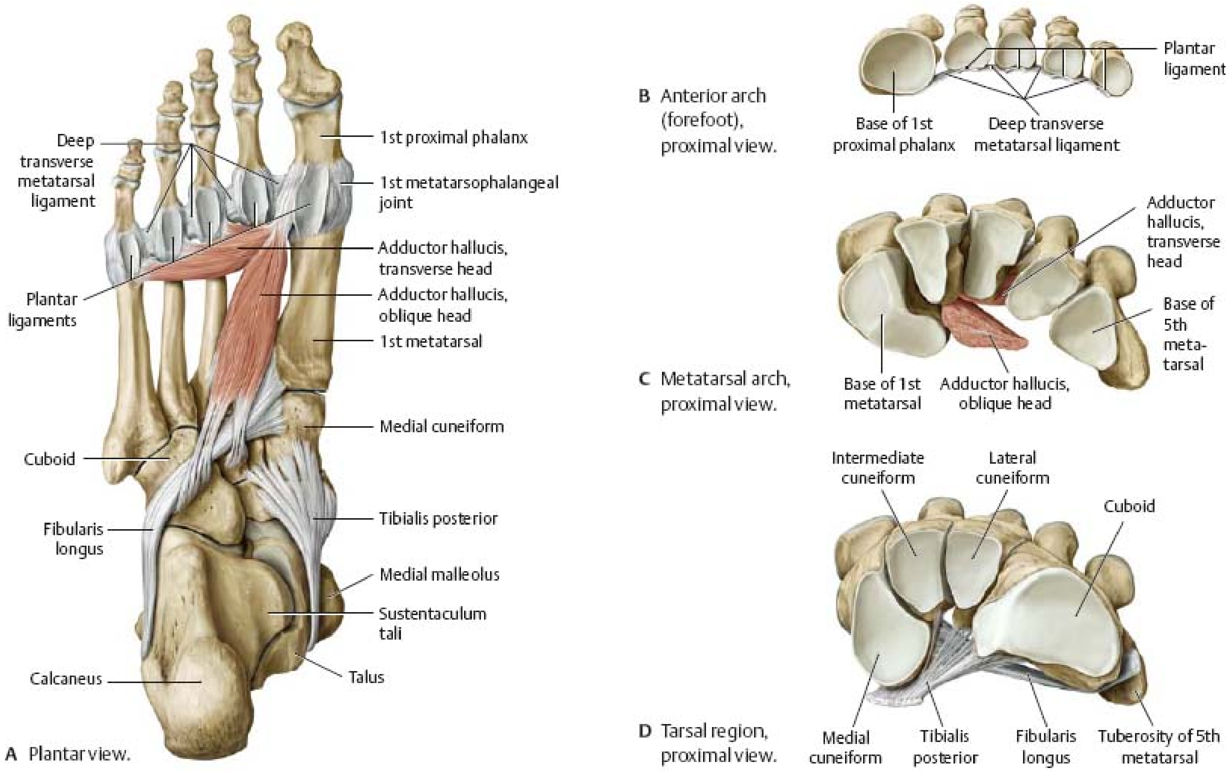
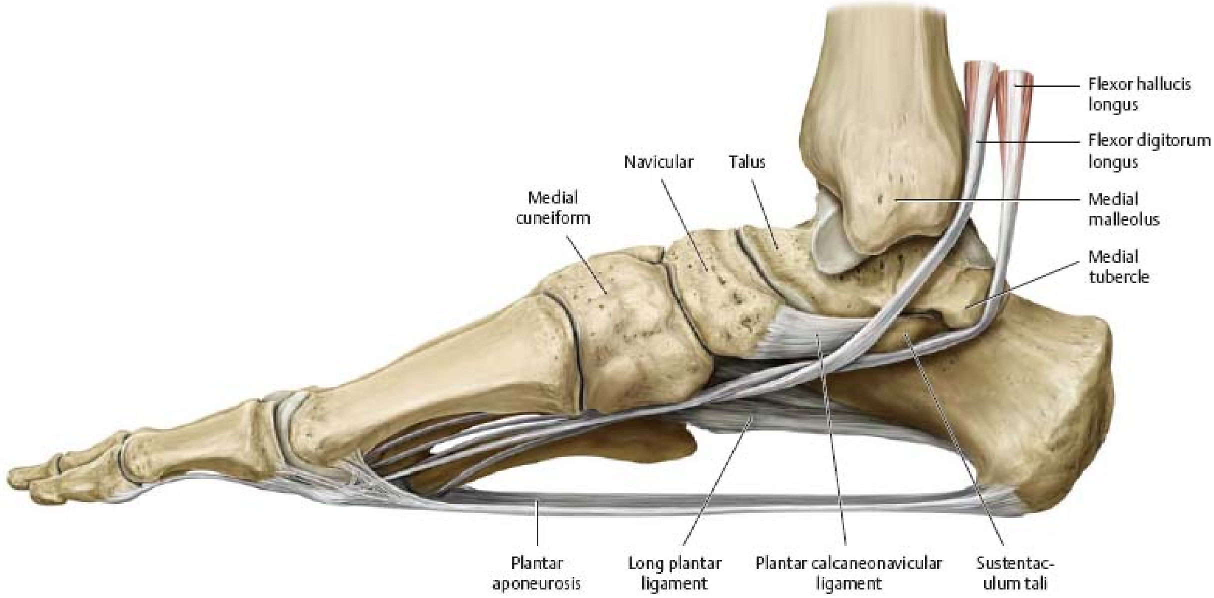
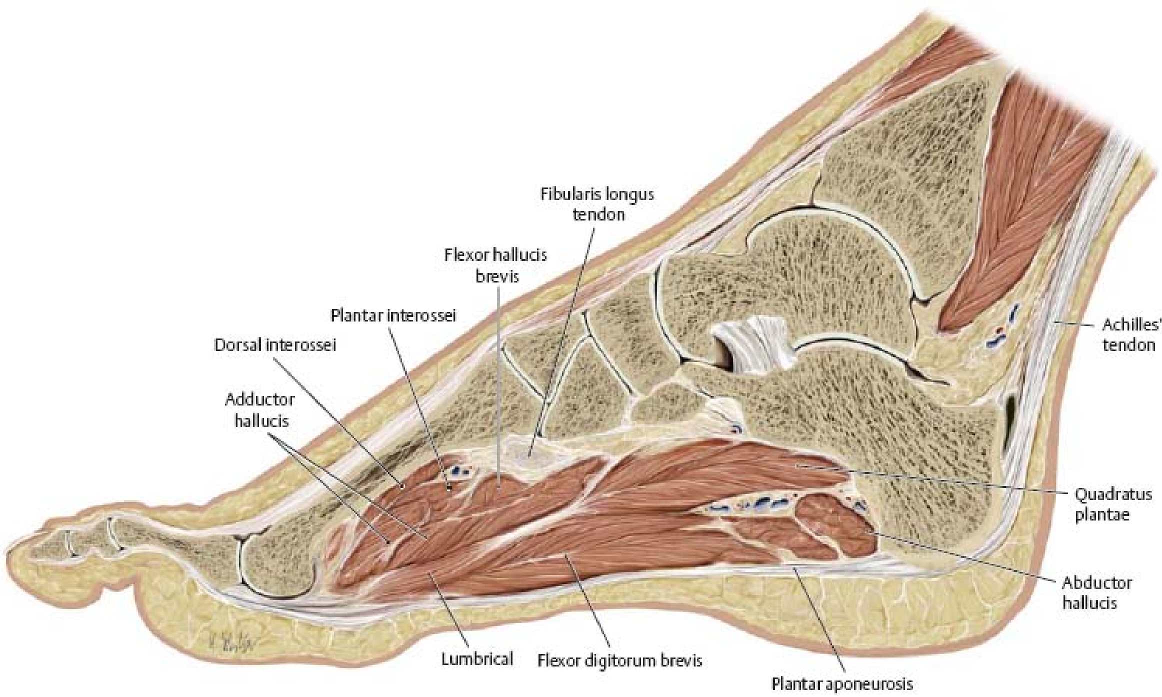


Fig. 26.14 **Stabilizers of the longitudinal arch**

Right foot, medial view.



A Passive stabilizers of the longitudinal arch.



B Active stabilizers of the longitudinal arch. Sagittal section at the level of the second ray. The major active stabilizers of the foot are the abductor hallucis, flexor hallucis brevis, flexor digitorum brevis, quadratus plantae, and abductor digiti minimi.

Muscles of the Sole of the Foot

Fig. 26.15 Plantar aponeurosis

Right foot, plantar view. The plantar aponeurosis is a tough aponeurotic sheet, thickest at the center, that blends with the dorsal fascia (not shown) at the borders of the foot.

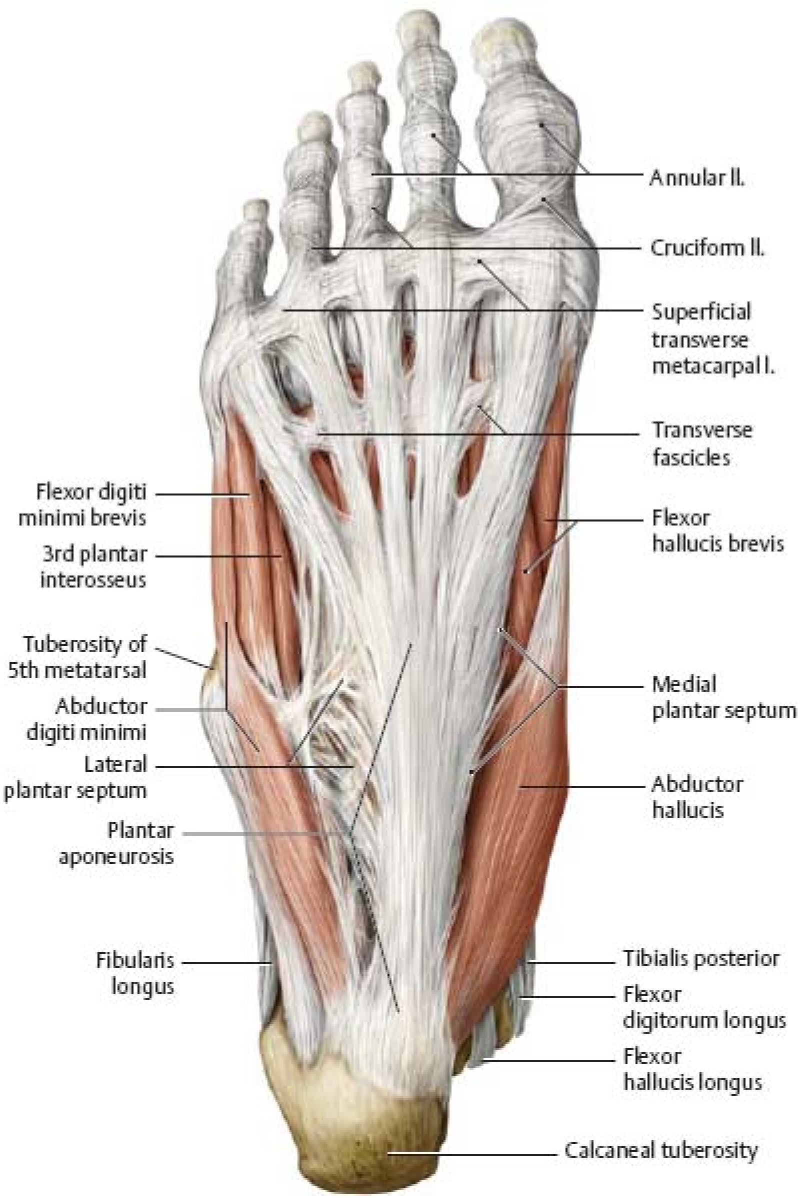
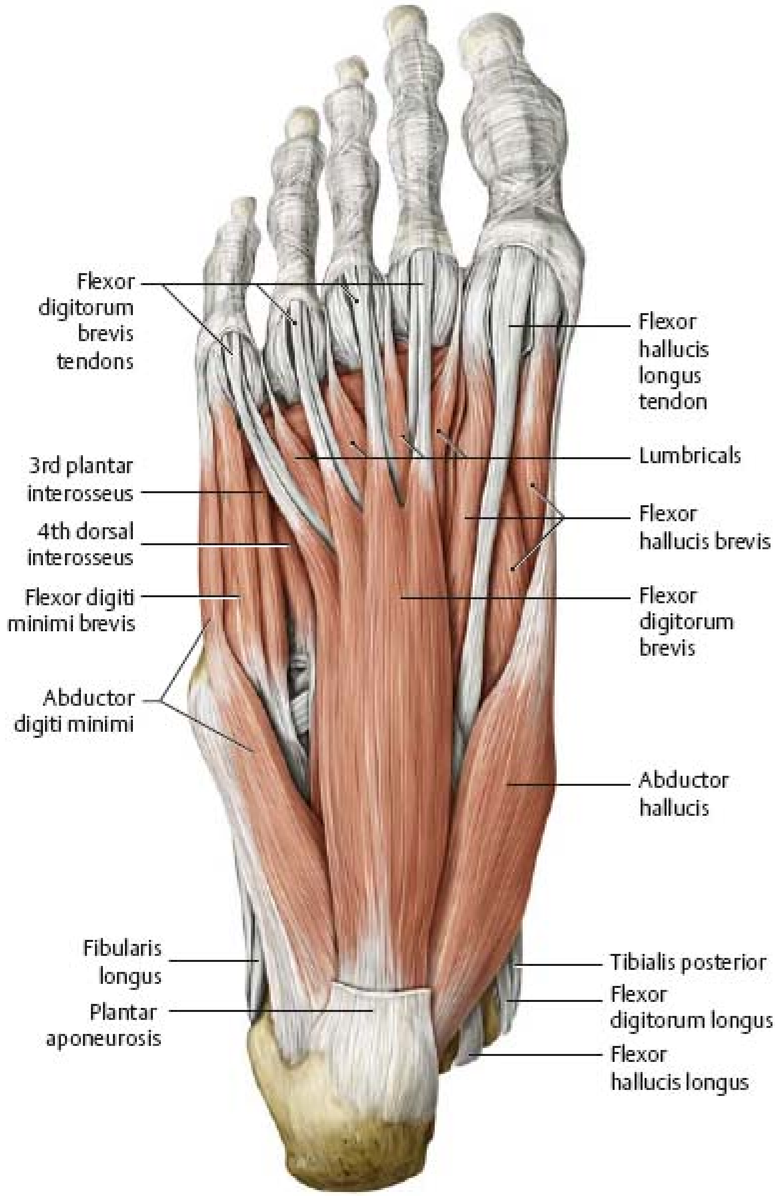
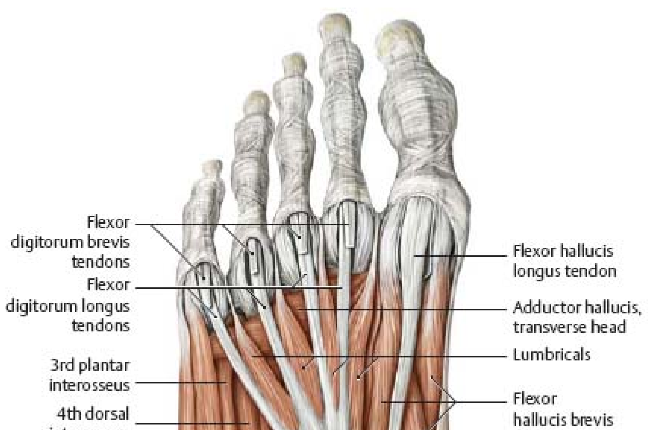


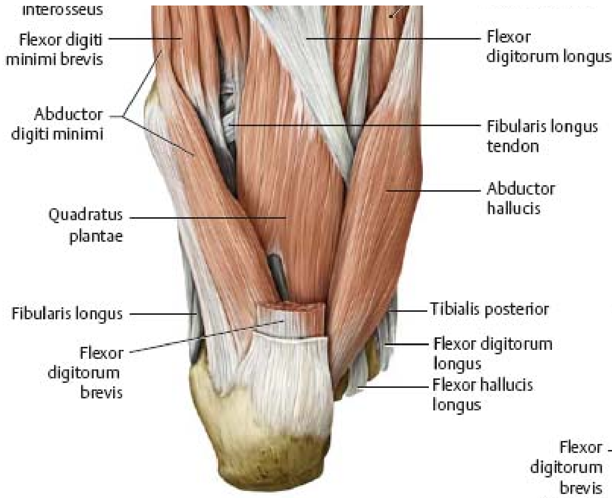
Fig. 26.16 Intrinsic muscles

Right foot, plantar view.

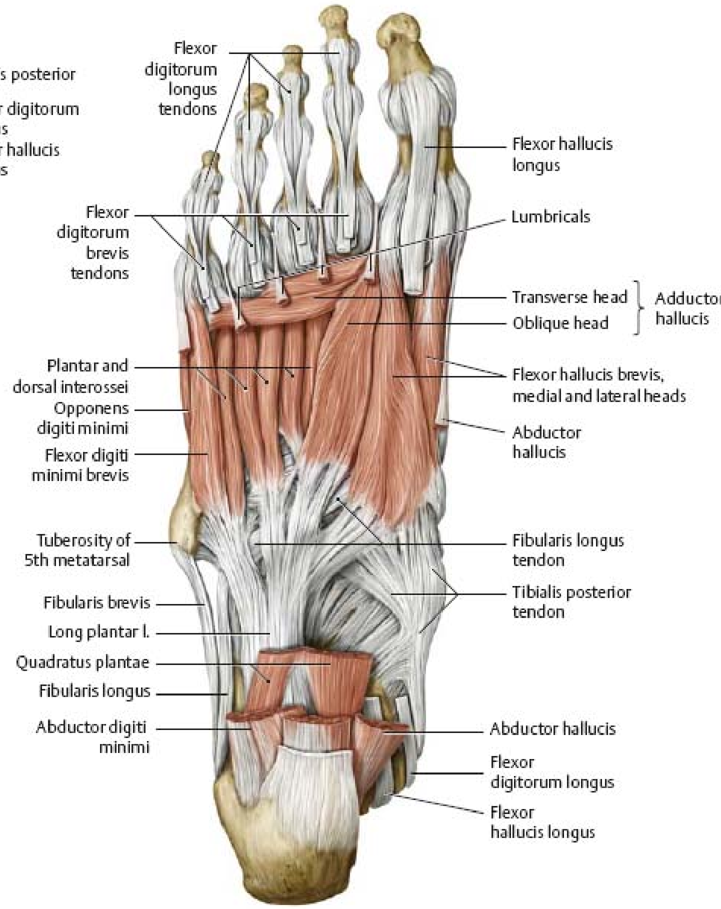


A Superficial (first) layer. *Removed:* Plantar aponeurosis, including the superficial transverse metacarpal ligament.





B Second layer. *Removed:* Flexor digitorum brevis.

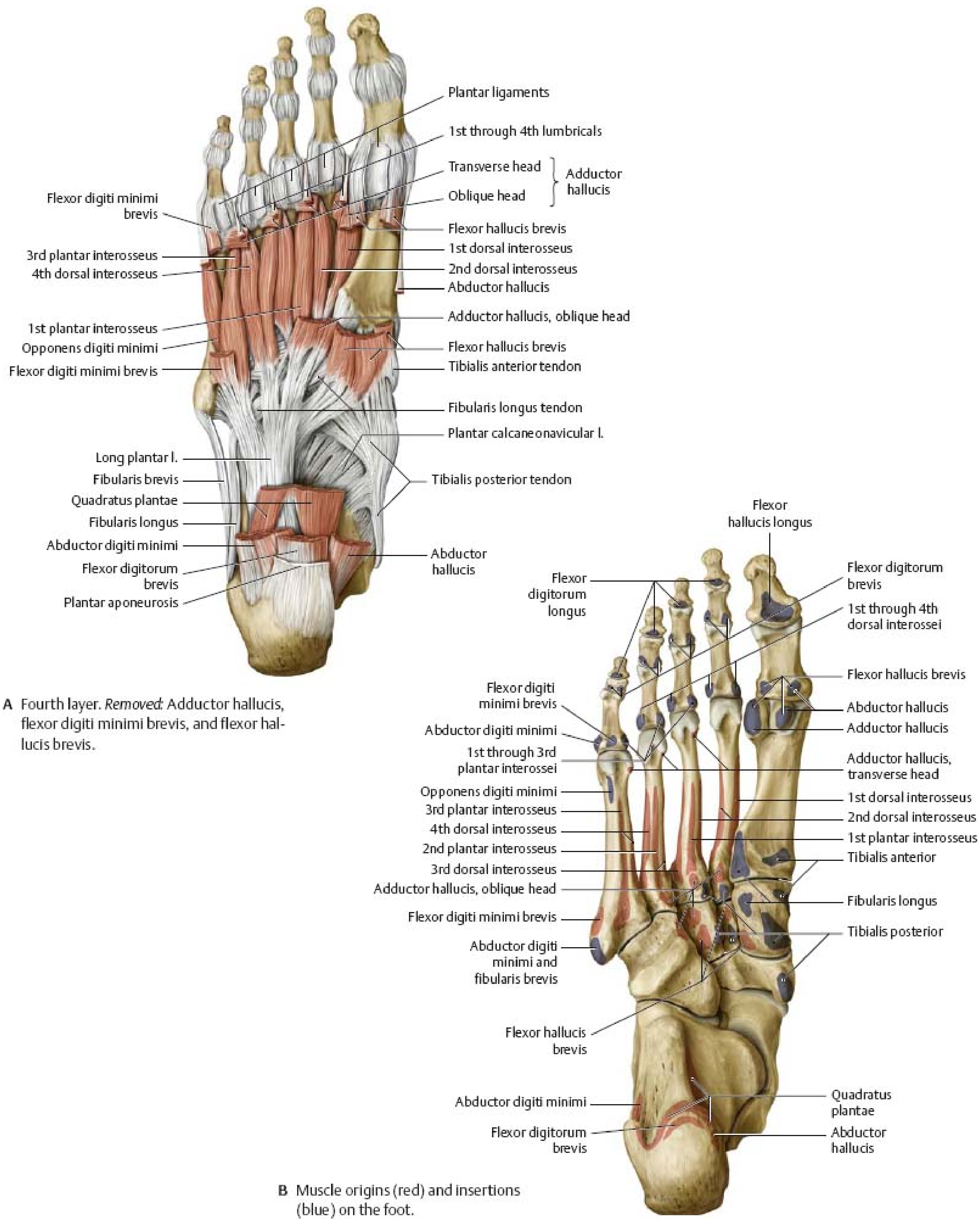


C Third layer. *Removed:* Abductor digiti minimi, abductor hallucis, quadratus plantae, lumbricals, and tendons of insertion of the flexors digitorum and hallucis longus.

Muscles & Tendon Sheaths of the Foot

Fig. 26.17 Deep intrinsic muscles

Right foot, plantar view.

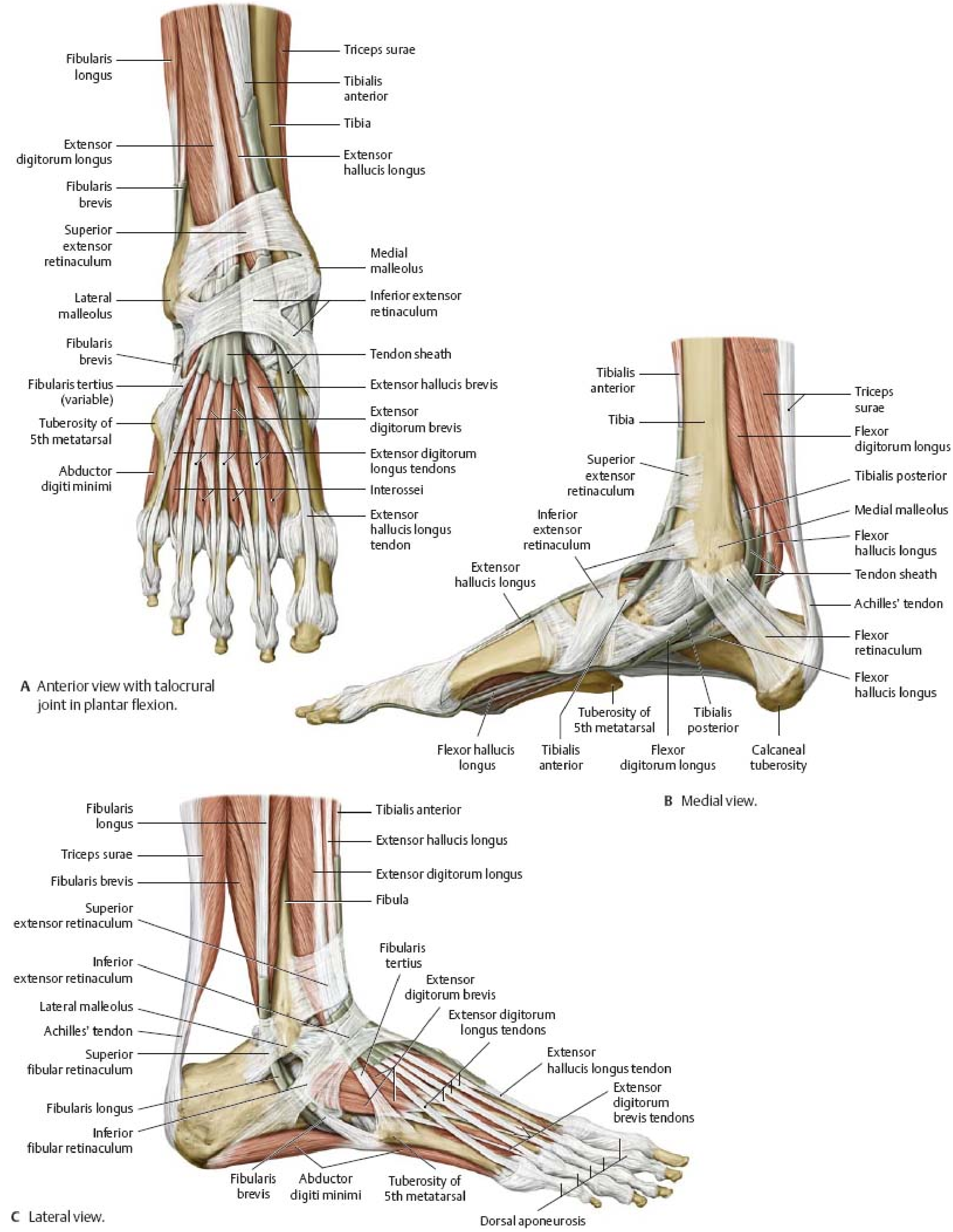


A Fourth layer. *Removed:* Adductor hallucis, flexor digiti minimi brevis, and flexor hallucis brevis.

B Muscle origins (red) and insertions (blue) on the foot.

Fig. 26.18 Tendon sheaths and retinacula of the ankle

Right foot. The superior and inferior extensor retinacula retain the long extensor tendons, the fibularis retinacula hold the fibular muscle tendons in place, and the flexor retinaculum retains the long flexor tendons.



A Anterior view with talocrural joint in plantar flexion.

B Medial view.

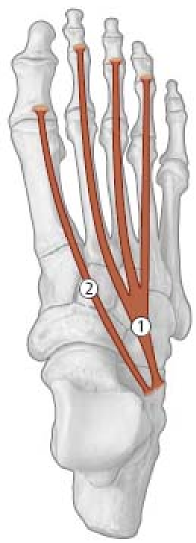
C Lateral view.

Muscle Facts (I)

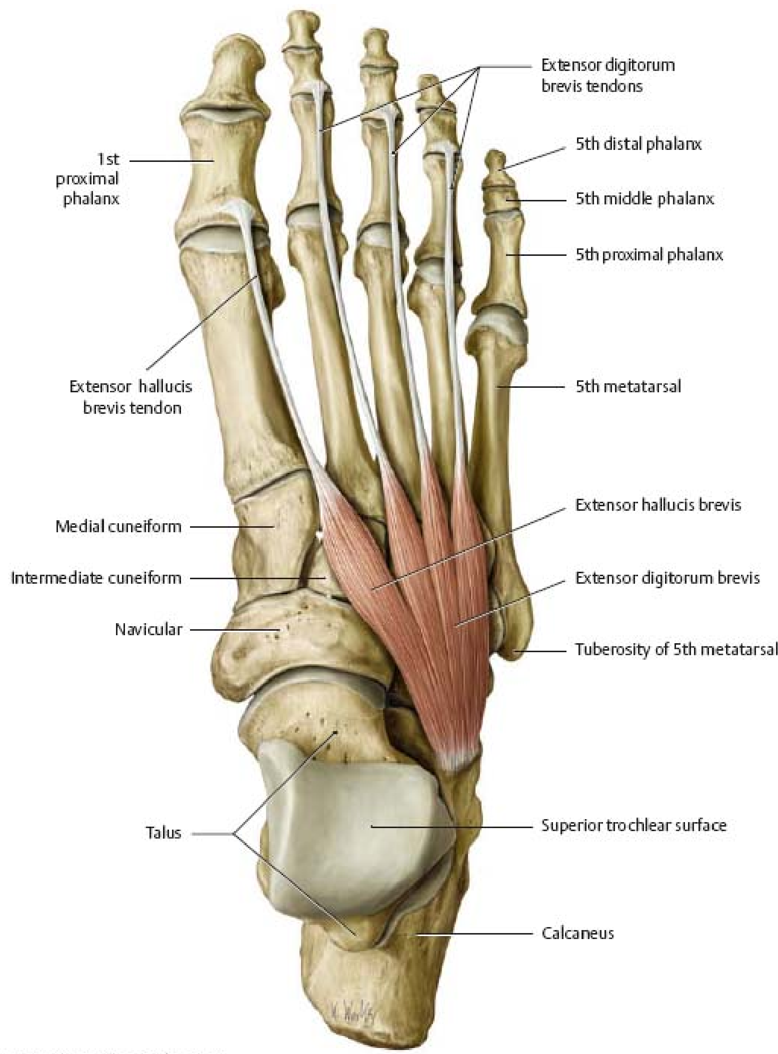
The dorsal surface (dorsum) of the foot contains only two muscles, the extensor digitorum brevis and the extensor hallucis brevis. The sole of the foot, however, is composed of four complex layers that maintain the arches of the foot.

Fig. 26.19 Intrinsic muscles of the dorsum

Right foot, dorsal view.



A Schematic.



B Dorsal muscles of the foot.

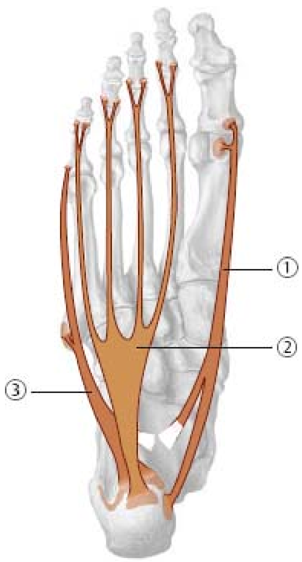
Table 26.2 Intrinsic muscles of the dorsum

Muscle	Origin	Insertion	Innervation	Action
① Extensor digitorum brevis	Calcaneus (dorsal surface)	2nd to 4th toes (at dorsal aponeuroses and bases of the middle phalanges)	Deep fibular n. (L5, S1)	Extension of the MTP and PIP joints of the 2nd to 4th toes
② Extensor hallucis brevis		1st toe (at dorsal aponeurosis and proximal phalanx)		Extension of the MTP joints of the 1st toe

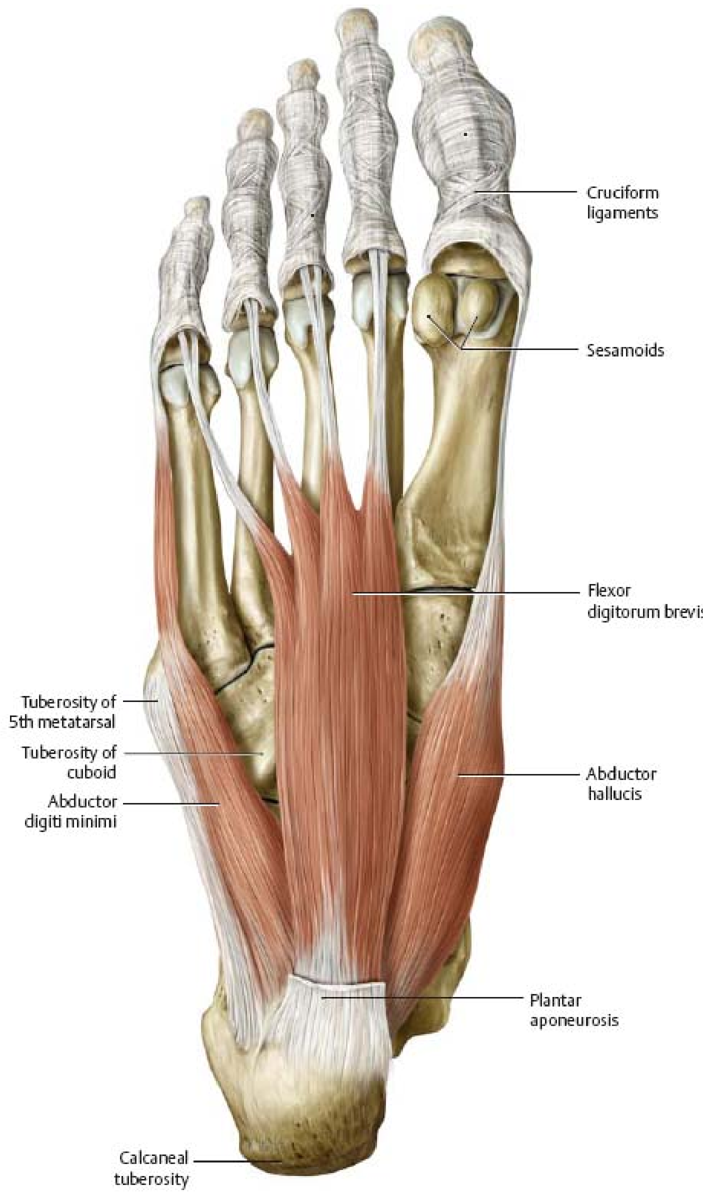
MTP = metatarsophalangeal; PIP = proximal interphalangeal.

Fig. 26.20 Superficial intrinsic muscles of the sole

Right foot, plantar view.



A First layer (schematic).



B Intrinsic muscles of the sole, first layer.

Table 26.3 Superficial intrinsic muscles of the sole

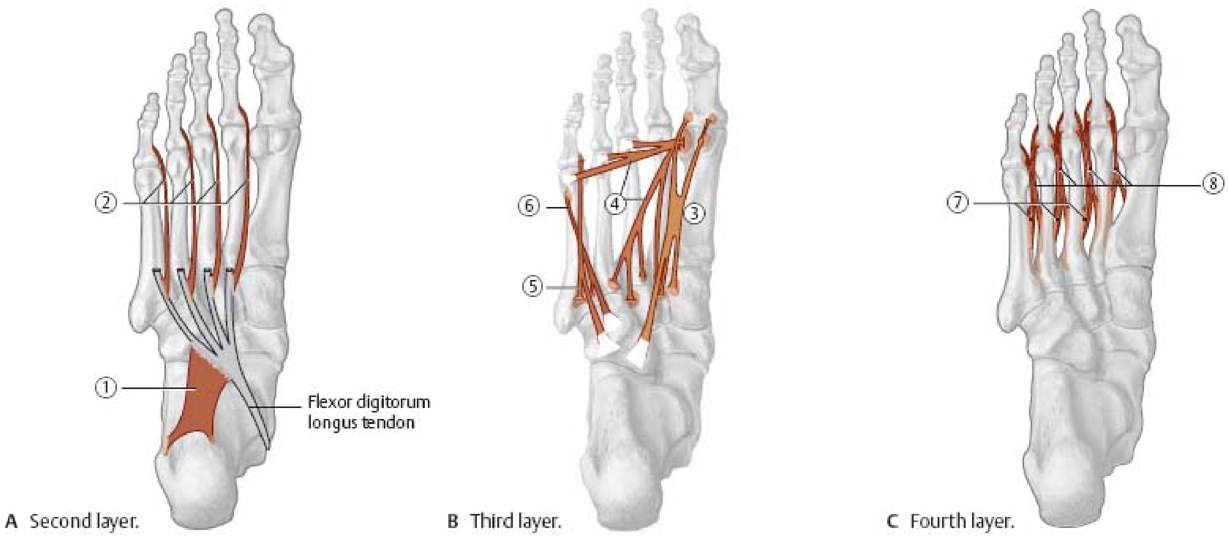
Muscle	Origin	Insertion	Innervation	Action
① Abductor hallucis	Calcaneal tuberosity (medial process)	1st toe (base of proximal phalanx via the medial sesamoid)	Medial plantar n. (S1, S2)	• 1st MTP joint: flexion and abduction of the 1st toe • Supports the longitudinal arch
② Flexor digitorum brevis	Calcaneal tuberosity (medial tubercle), plantar aponeurosis	2nd to 5th toes (sides of middle phalanges)		• Flexes the MTP and PIP joints of the 2nd to 5th toes • Supports the longitudinal arch
③ Abductor digiti minimi		5th toe (base of proximal phalanx), 5th metatarsal (at tuberosity)	Lateral plantar n. (S1–S3)	• Flexes the MTP joint of the 5th toe • Abducts the 5th toe • Supports the longitudinal arch

MTP = metatarsophalangeal; PIP = proximal interphalangeal.

Muscle Facts (II)

Fig. 26.21 Deep intrinsic muscles of the sole

Right foot, plantar view.



A Second layer. B Third layer. C Fourth layer.

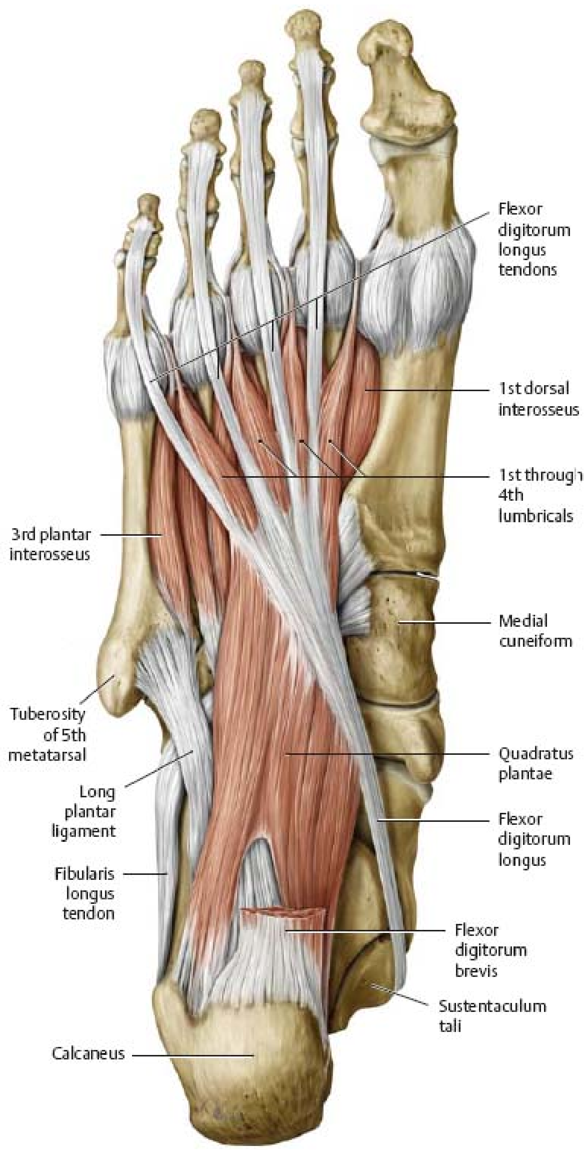
Table 26.4 Deep intrinsic muscles of the sole

Muscle	Origin	Insertion	Innervation	Action
① Quadratus plantae	Calcaneal tuberosity (medial and plantar borders on plantar side)	Flexor digitorum longus tendon (lateral border)	Lateral plantar n. (S1–S3)	Redirects and augments the pull of flexor digitorum longus
② Lumbricals (four muscles)	Flexor digitorum longus tendons (medial borders)	2nd to 5th toes (at dorsal aponeuroses)	1st lumbrical: medial plantar n. (S2, S3) 2nd and 4th lumbrical: lateral plantar n. (S2, S3)	• Flexes the MTP joints of 2nd to 5th toes • Extension of IP joints of 2nd to 5th toes • Adducts 2nd to 5th toes toward the big toe
③ Flexor hallucis brevis	Cuboid, lateral cuneiforms, and plantar calcaneocuboid ligament	1st toe (at base of proximal phalanx via medial and lateral sesamoids)	Medial head: medial plantar n. (S1, S2) Lateral head: lateral plantar n. (S1, S2)	• Flexes the first MTP joint • Supports the longitudinal arch
④ Adductor hallucis	Oblique head: 2nd to 4th metatarsals (at bases) Transverse head: MTPs of 3rd to 5th toes, deep transverse metatarsal ligament	1st proximal phalanx (at base, by a common tendon via the lateral sesamoid)	Lateral plantar n., deep branch (S2, S3)	• Flexes the first MTP joint • Adducts big toe • Transverse head: supports transverse arch • Oblique head: supports longitudinal arch
⑤ Flexor digiti minimi brevis	5th metatarsal (base), long plantar ligament	5th toe (base of proximal phalanx)	Lateral plantar n., superficial branch (S2, S3)	Flexes the MTP joint of the little toe
⑥ Opponens digiti minimi*	Long plantar ligament; fibularis longus (at plantar tendon sheath)	5th metatarsal		Pulls 5th metatarsal in plantar and medial direction
⑦ Plantar interossei (three muscles)	3rd to 5th metatarsals (medial border)	3rd to 5th toes (medial base of proximal phalanx)	Lateral plantar n. (S2, S3)	• Flexes the MTP joints of 3rd to 5th toes • Extension of IP joints of 3rd to 5th toes • Adducts 3rd to 5th toes toward 2nd toe
⑧ Dorsal interossei (four muscles)	1st to 5th metatarsals (by two heads on opposing sides)	1st interosseus: 2nd proximal phalanx (medial base) 2nd to 4th interossei: 2nd to 4th proximal phalanges (lateral base), 2nd to 4th toes (at dorsal aponeuroses)		• Flexes the MTP joints of 2nd to 4th toes • Extension of IP joints of 2nd to 4th toes • Abducts 3rd and 4th toes from 2nd toe

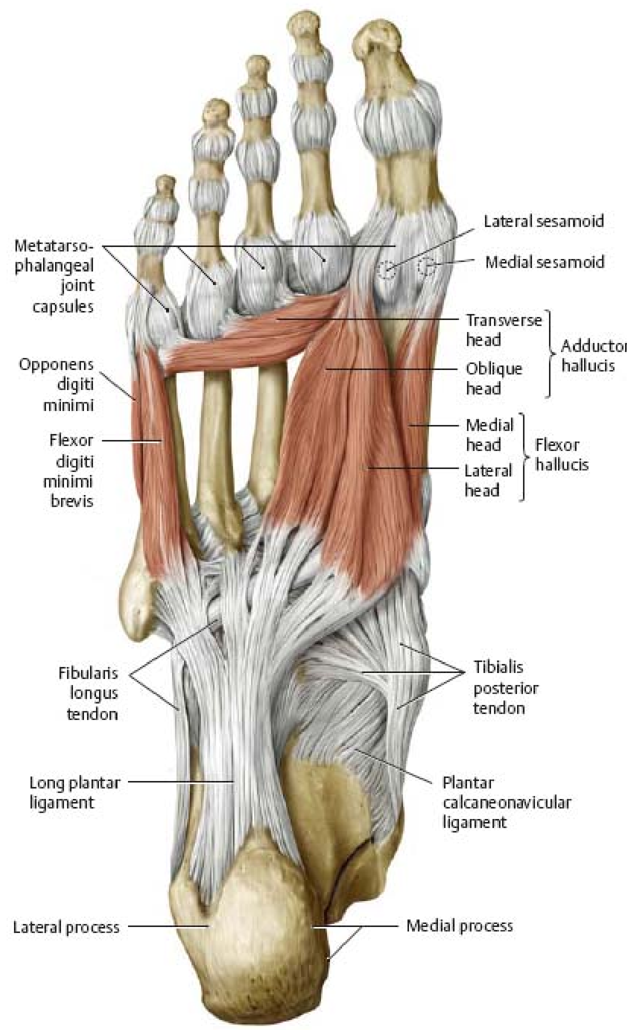
IP = interphalangeal; MTP = metatarsophalangeal. *May be absent.

Fig. 26.22 Deep intrinsic muscles of the sole

Right foot, plantar view.



A Intrinsic muscles of the sole, second and fourth layers.



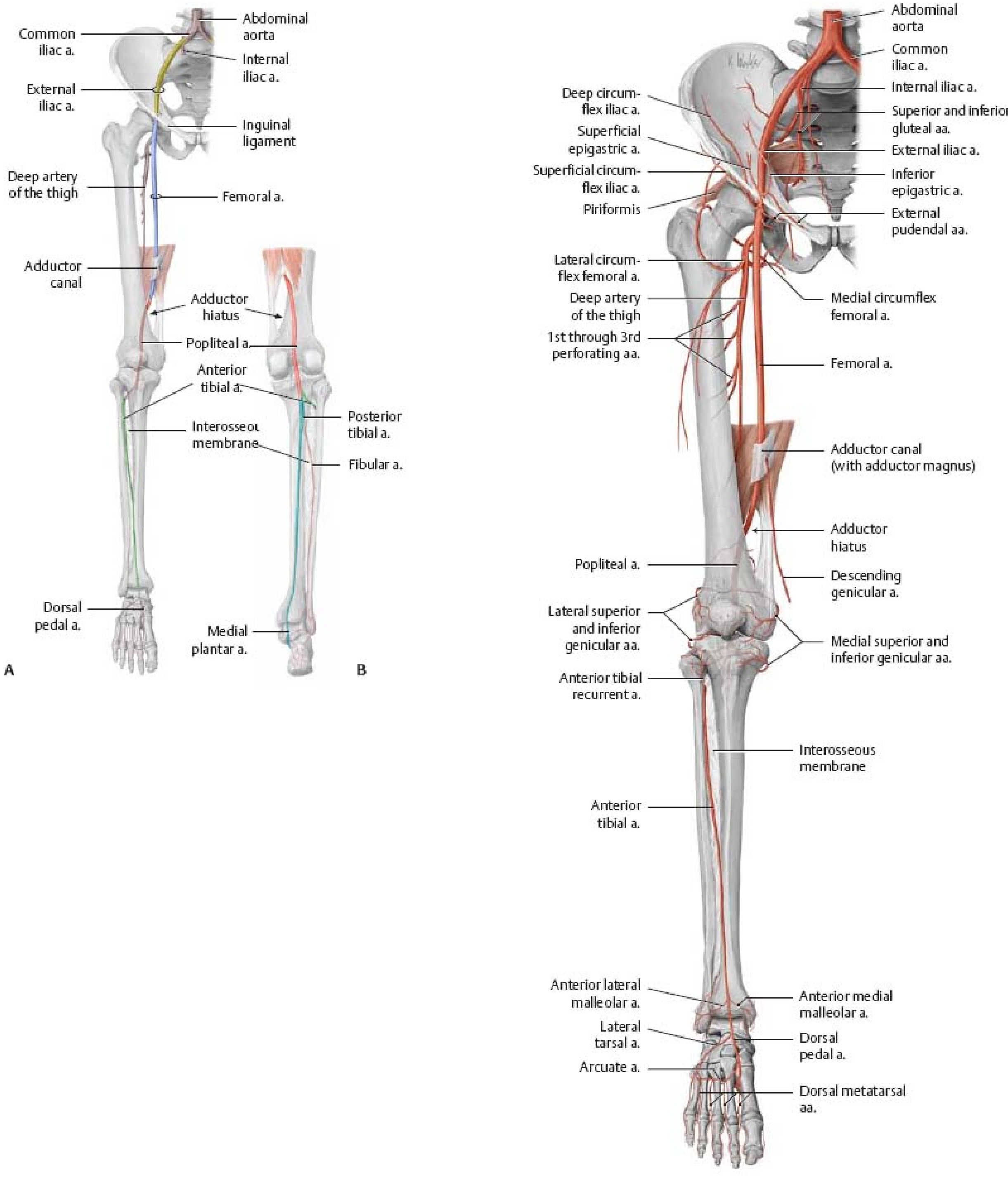
B Intrinsic muscles of the sole, third layer.

27 Neurovasculature

Arteries of the Lower Limb

Fig. 27.1 Arteries of the lower limb

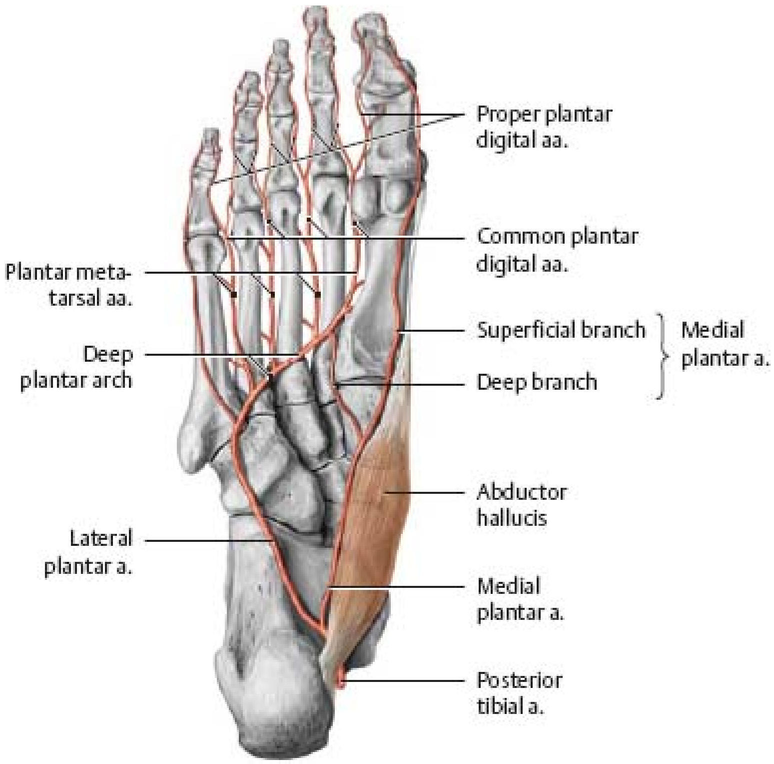
Right limb, anterior (**A**) and posterior (**B**) views.



C Course of the arteries, anterior view.

Fig. 27.2 **Arteries of the sole of the foot**

Right foot, plntar view



Clinical

Femora I head necrosis

Dislocation or fracture of the femoral head (e.g., in patients with osteoporosis) my disrupt the anastomoses between the foveal artery and the femoral neck vessels, resulting in femoral head necrosis.

Fig. 27.3 Arteries of the femoral head

Right hip joint, anterior view.

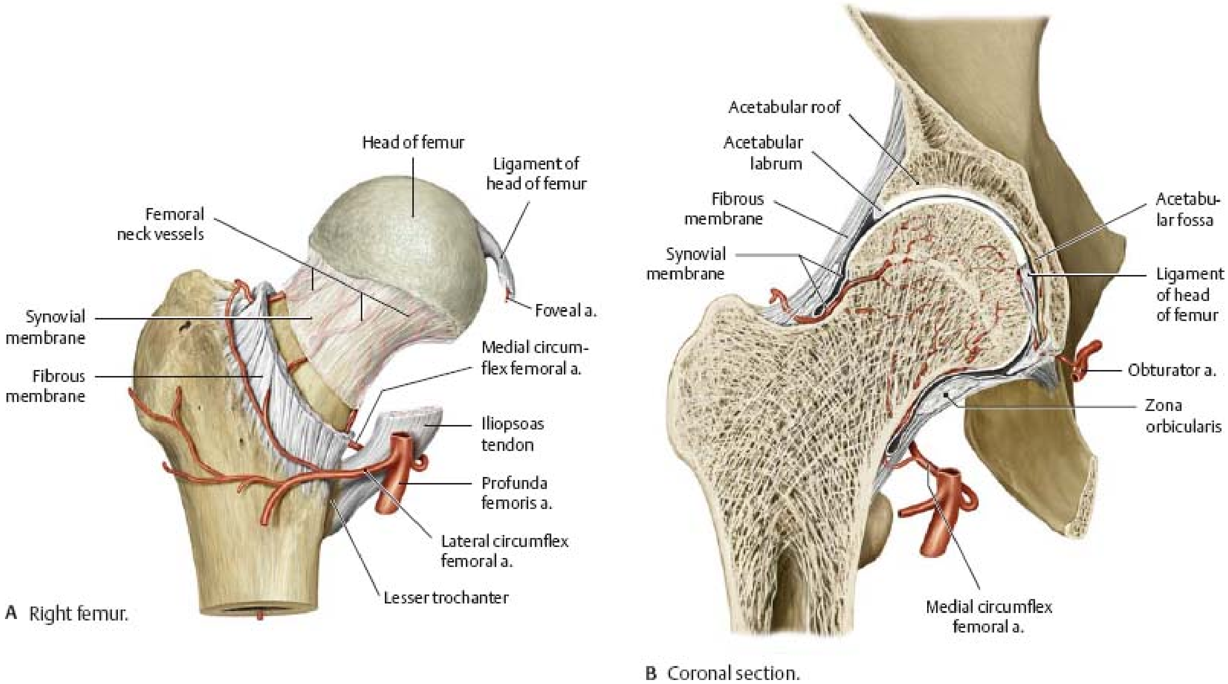
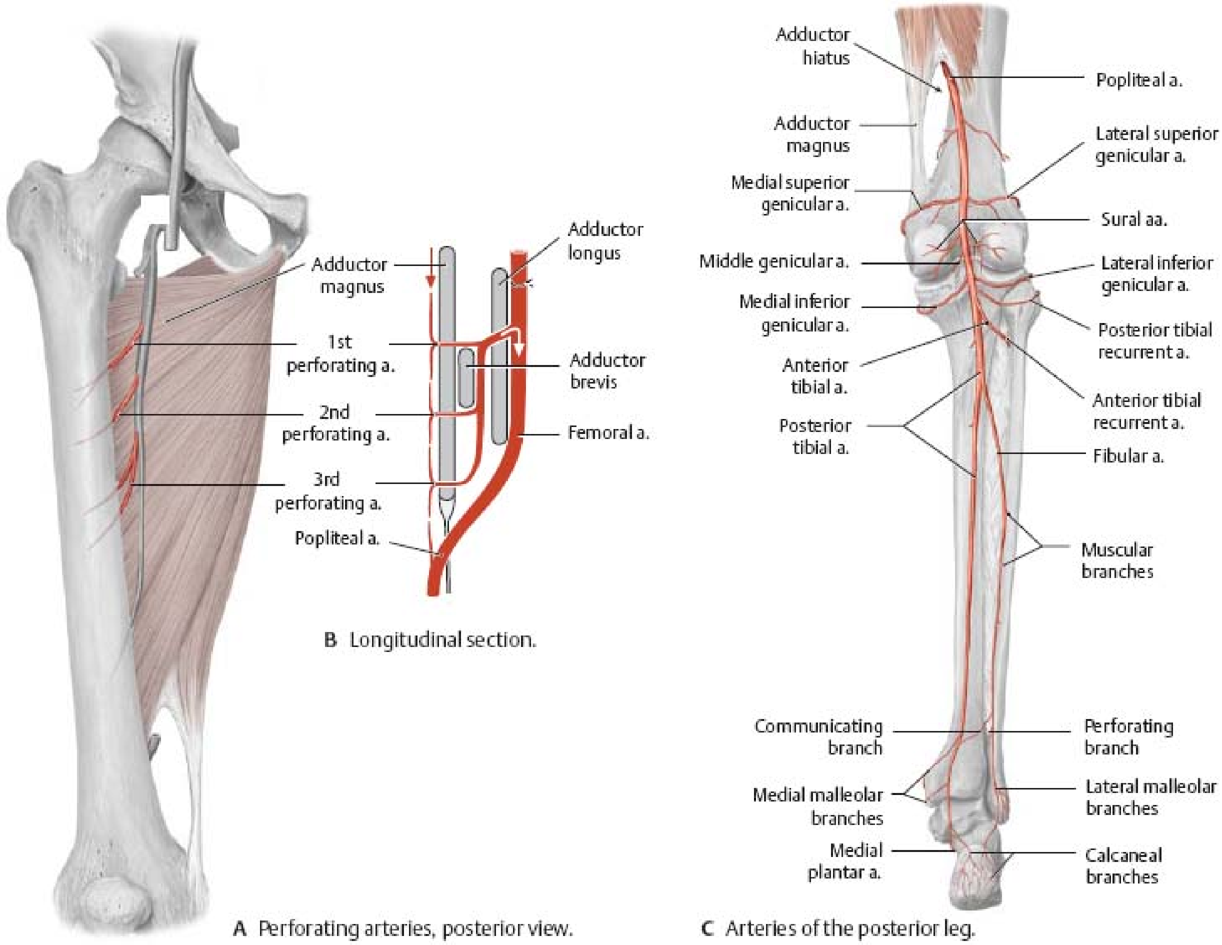


Fig. 27.4 **Arteries of the thigh and leg**

Right leg.



B Longitudinal section.

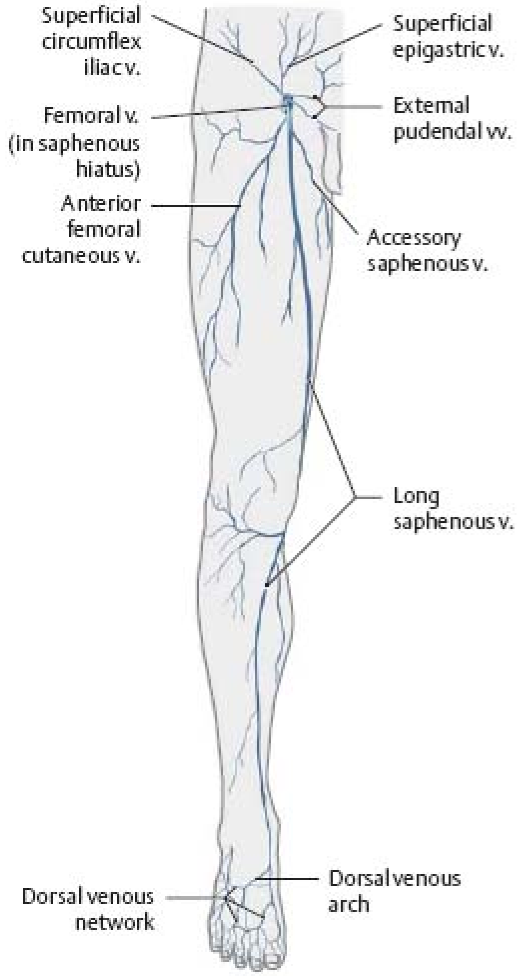
A Perforating arteries, posterior view.

C Arteries of the posterior leg.

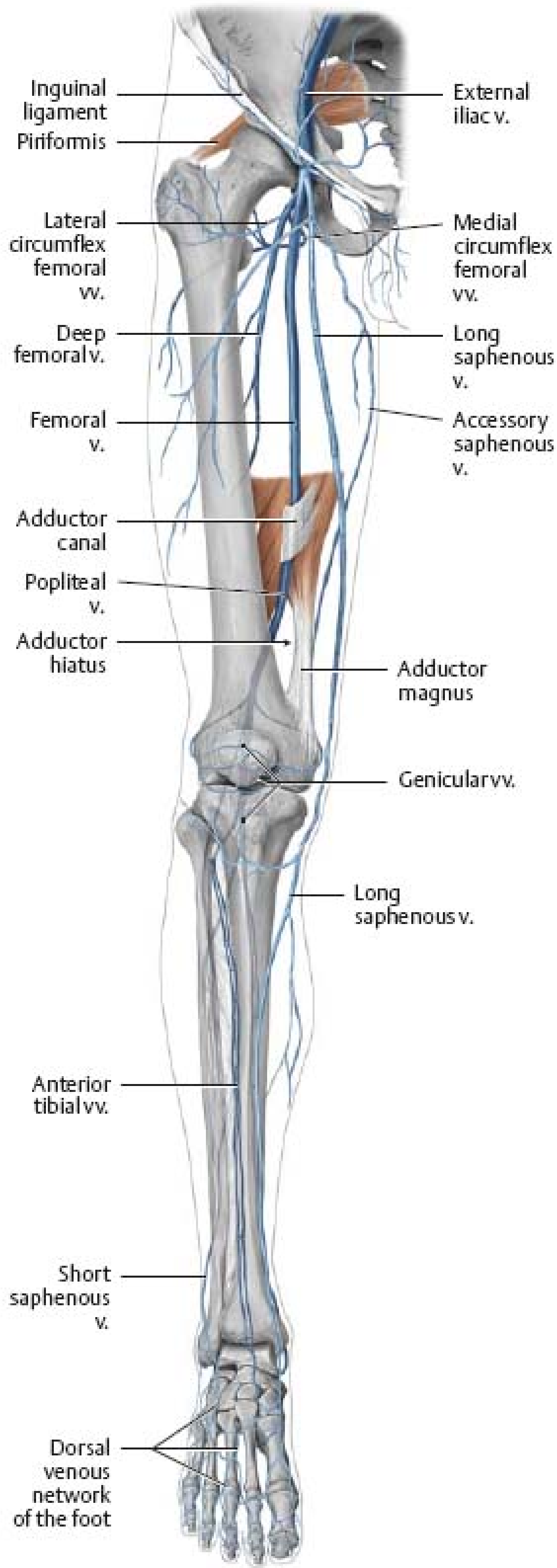
Veins & Lymphatics of the Lower Limb

Fig. 27.5 Veins of the lower limb

Right limb, anterior view.



A Superficial (epifascial) veins.



B Deep veins.

Fig. 27.6 **Veins of the sole of the foot**

Right foot, plantar view.

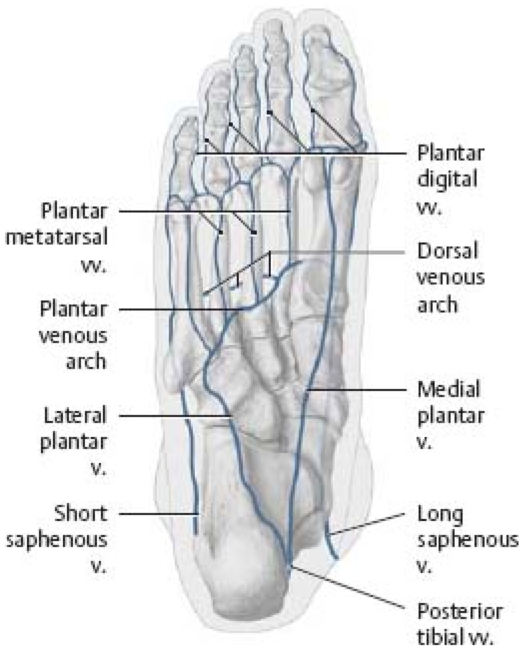
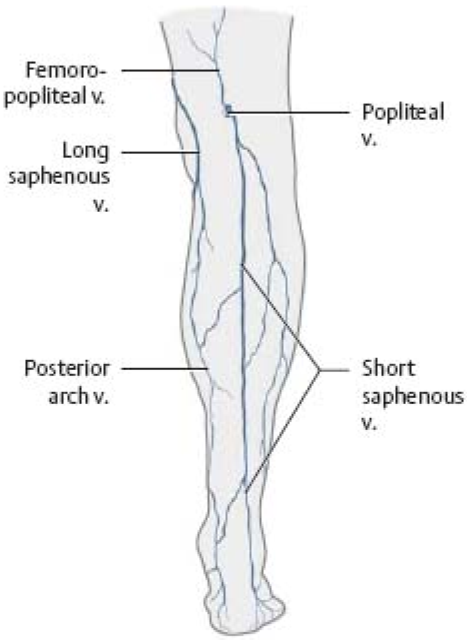
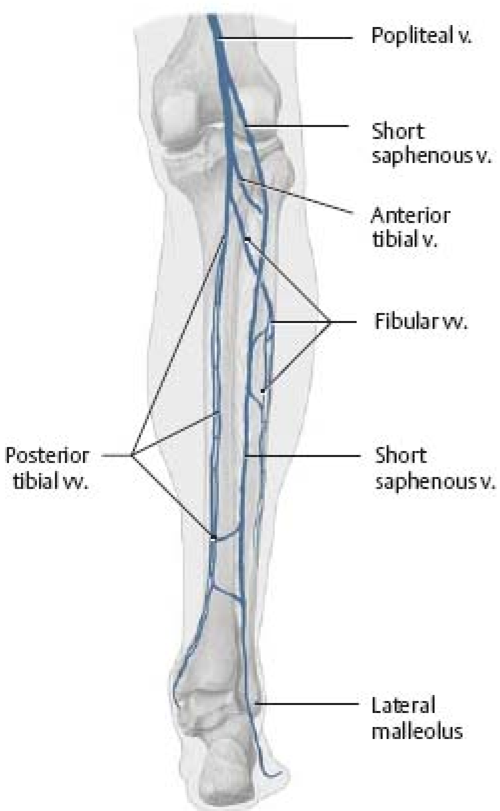


Fig. 27.7 **Veins of the leg**

Right leg, posterior view.



A Superficial (epifascial) veins.



B Deep veins.

Fig. 27.8 **Clinically important perforating veins**

Right leg, medial view.

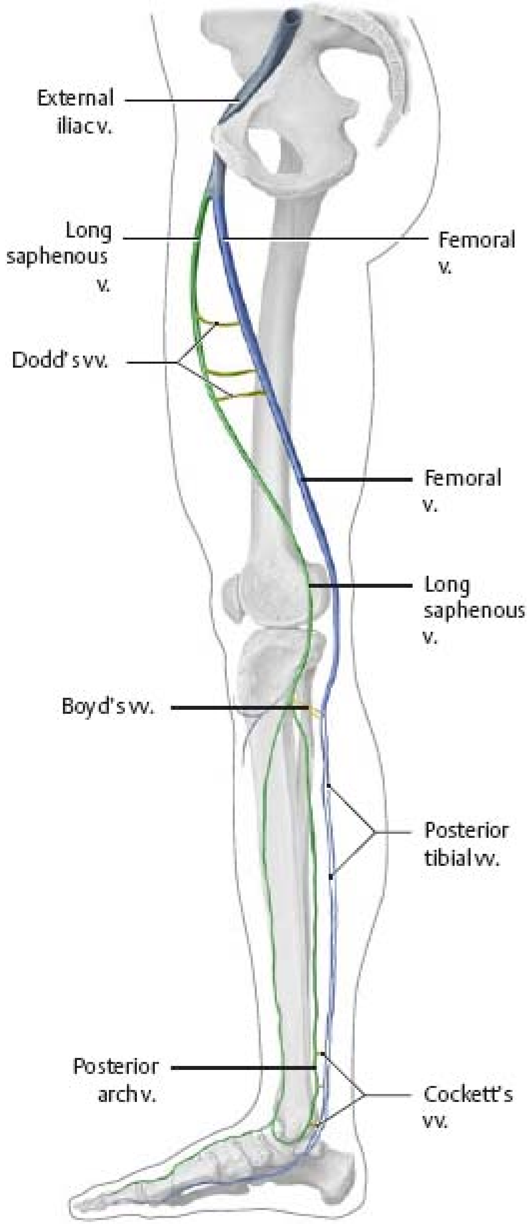


Fig. 27.9 **Superficial lymphatics**

Right limb. Arrows indicate the main directions of lymphatic drainage.

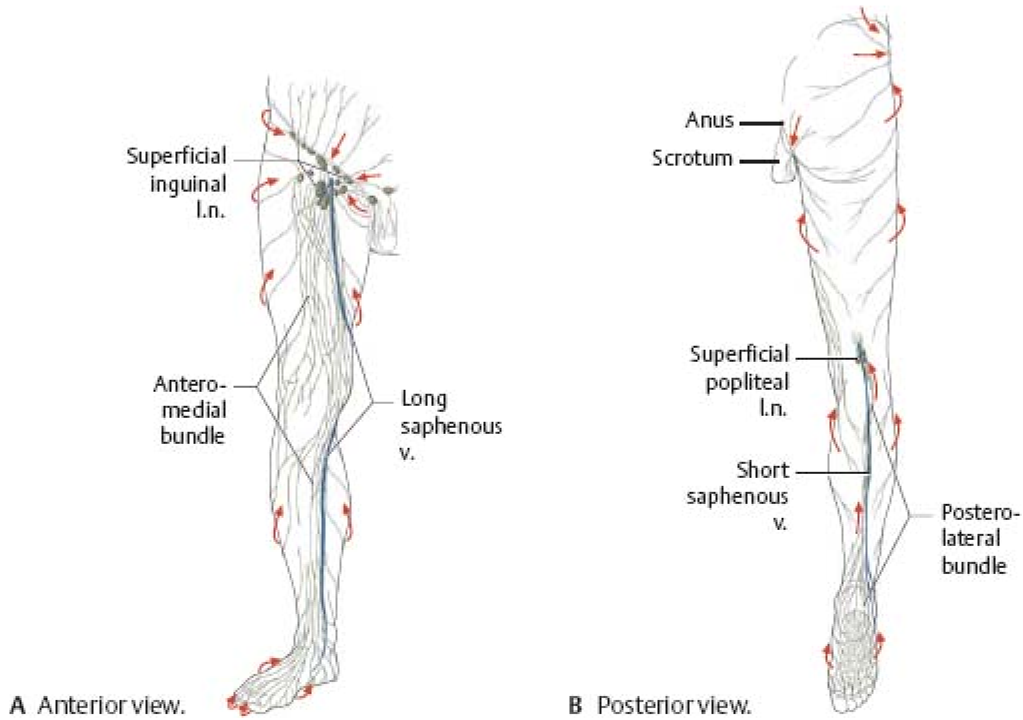
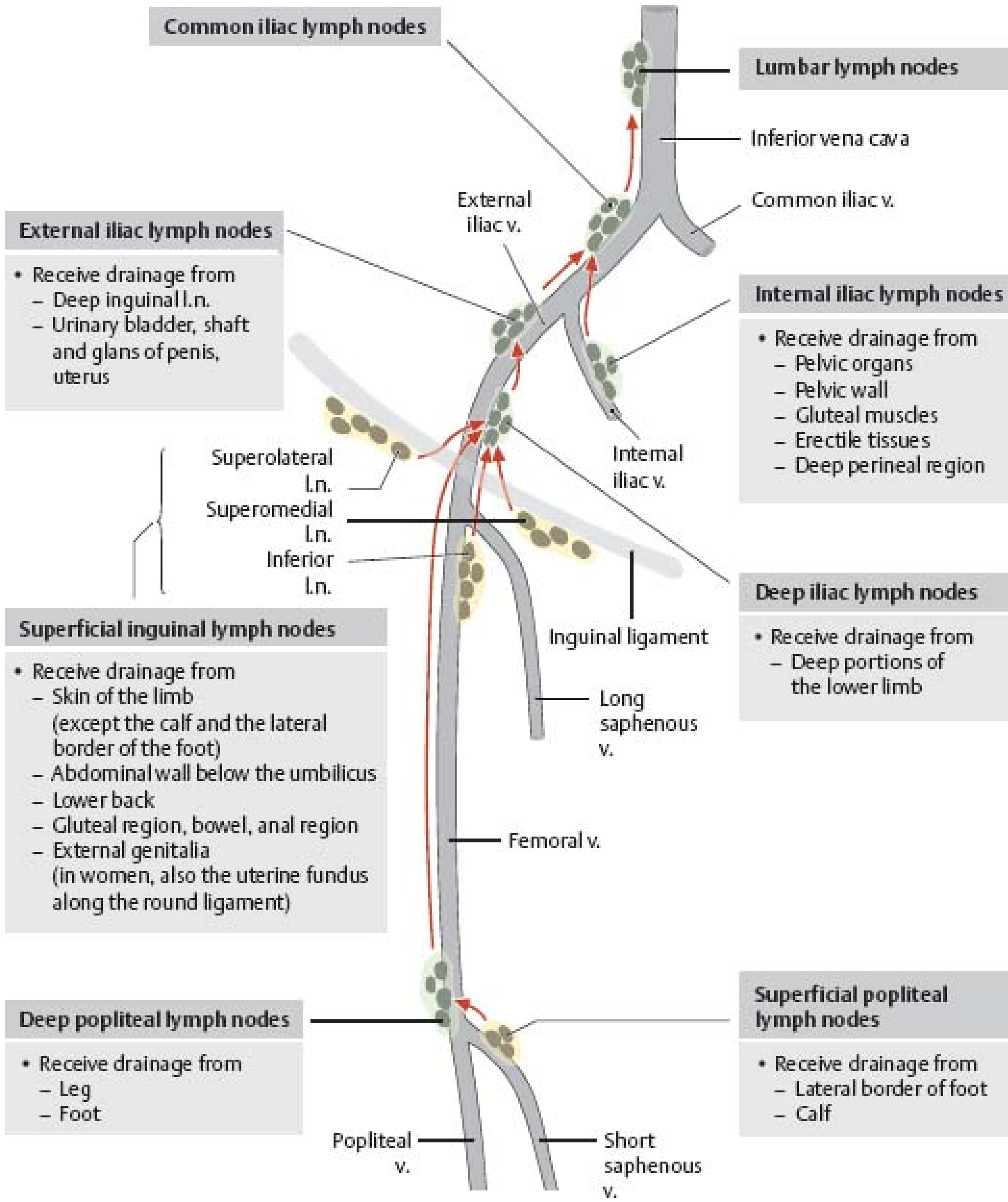


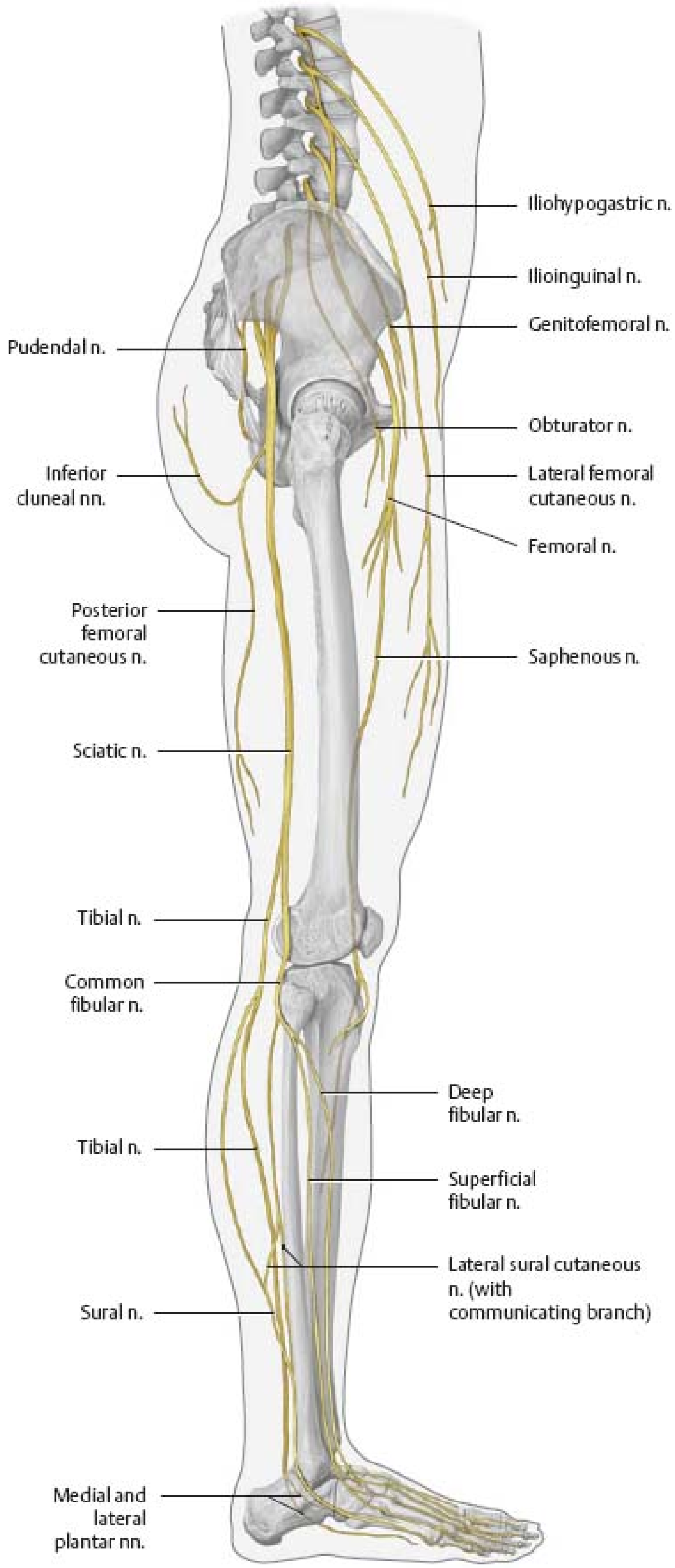
Fig. 27.10 **Lymph nodes and drainage**

Right limb, anterior view.



Lumbosacral Plexus

The lumbosacral plexus supplies sensory and motor innervation to the lower limb. It is formed by the anterior (ventral) rami of the lumbar and sacral spinal nerves, with contributions from the subcostal nerve (T12) and coccygeal nerve (Co1).

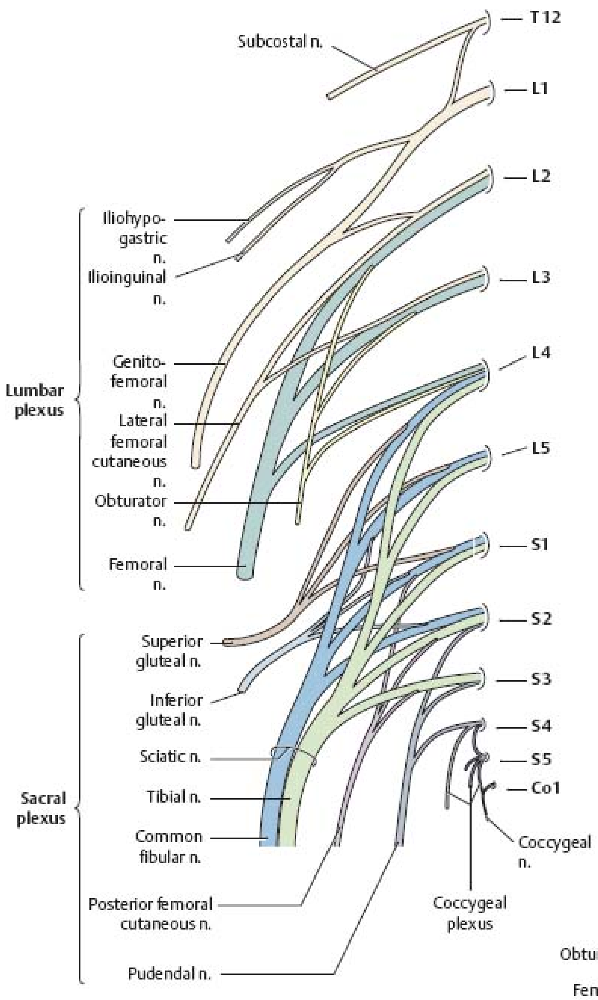


Iliohypogastric n.
Ilioinguinal n.
Genitofemoral n.
Pudendal n.
Obturator n.
Inferior cluneal nn.
Lateral femoral cutaneous n.
Femoral n.
Posterior femoral cutaneous n.
Saphenous n.
Sciatic n.
Tibial n.
Common fibular n.
Deep fibular n.
Tibial n.
Superficial fibular n.
Lateral sural cutaneous n. (with communicating branch)
Sural n.
Medial and lateral plantar nn.

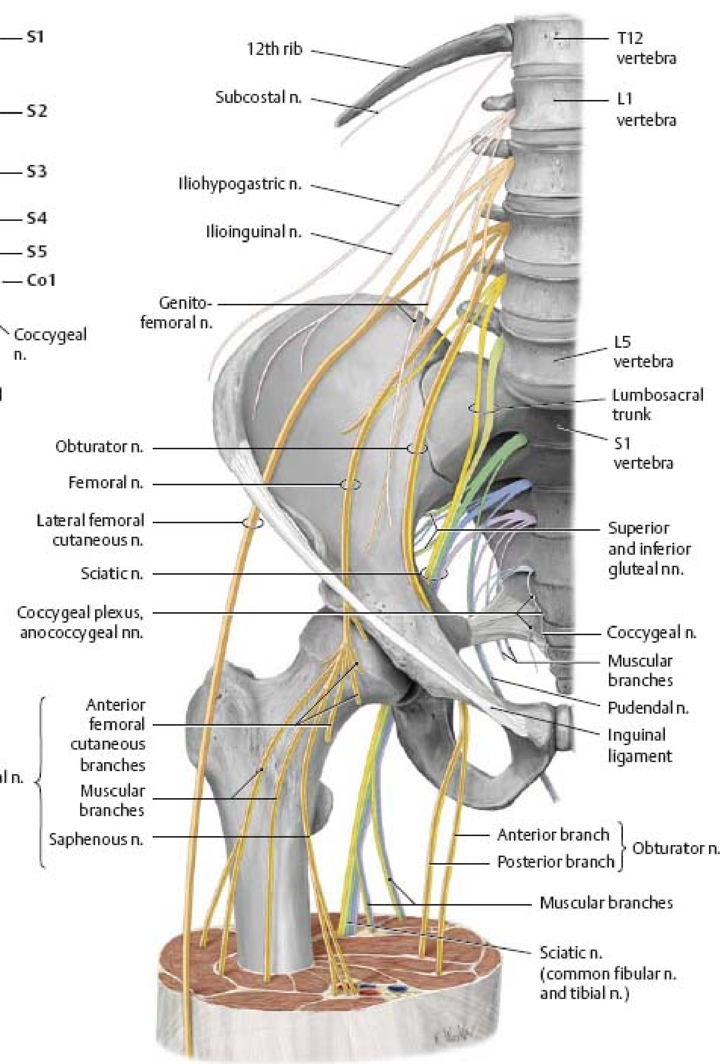
Table 27.1	Nerves of the lumbosacral plexus		
Lumbar plexus			
Iliohypogastric n.		L1	p. 427
Ilioinguinal n.			
Genitofemoral n.		L1–L2	
Lateral femoral cutaneous n.		L2–L3	
Obturator n.		L2–L4	p. 428
Femoral n.			p. 429
Sacral plexus			
Superior gluteal n.		L4–S1	p. 431
Inferior gluteal n.		L5–S2	
Posterior femoral cutaneous n.		S1–S3	p. 430
Sciatic n.	Common fibular n.	L4–S2	p. 432
	Tibial n.	L4–S3	p. 433
Pudendal n.		S2–S4	pp. 194, 202

Fig. 27.11 **Lumbosacral plexus**

Right side, anterior view.



A Structure of the lumbosacral plexus.



B Course of the lumbosacral plexus.

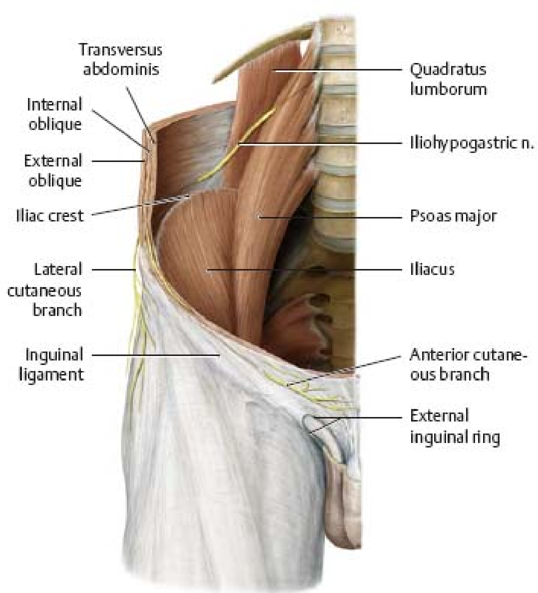
Nerves of the Lumbar Plexus

Table 27.2 Nerves of the lumbar plexus

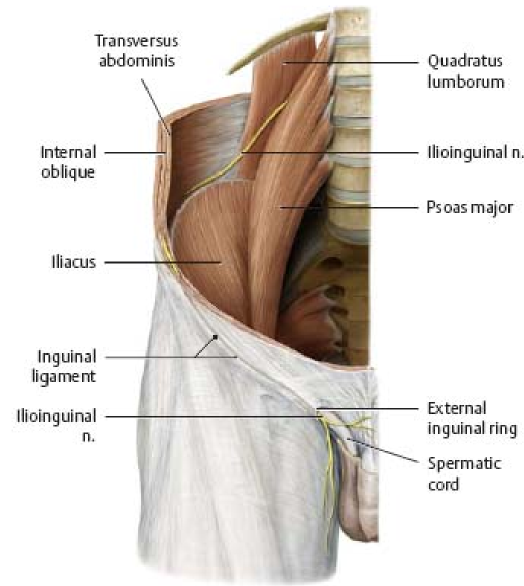
Nerve	Level	Innervated muscle	Cutaneous branches
Iliohypogastric n.	T12–L1	Transversus abdominis and internal oblique (inferior portions)	Anterior and lateral cutaneous branches
Ilioinguinal n.	L1		♂: Anterior scrotal nn. ♀: Anterior labial nn.
Genitofemoral n.	L1–L2	♂: Cremaster (genital branch)	Genital branch Femoral branch
Lateral femoral cutaneous n.	L2–L3	–	Lateral femoral cutaneous n.
Obturator n.	L2–L4	See p. 428	
Femoral n.	L2–L4	See p. 429	
Short, direct muscular branches	T12–L4	Psoas major Quadratus lumborum Iliacus Intertransversarii lumborum	–

Fig. 27.12 **Sensory innervation of the inguinal region**
Right male inguinal region, anterior view.

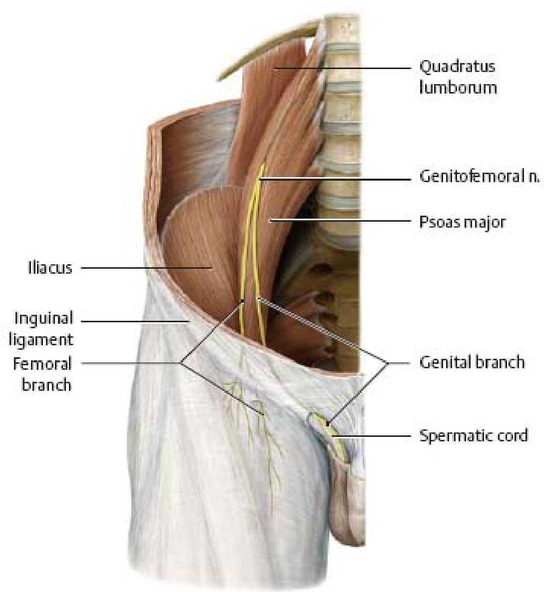
Fig. 27.13 **Nerves of the lumbar plexus**
Right side, anterior view with the anterior abdominal wall removed.



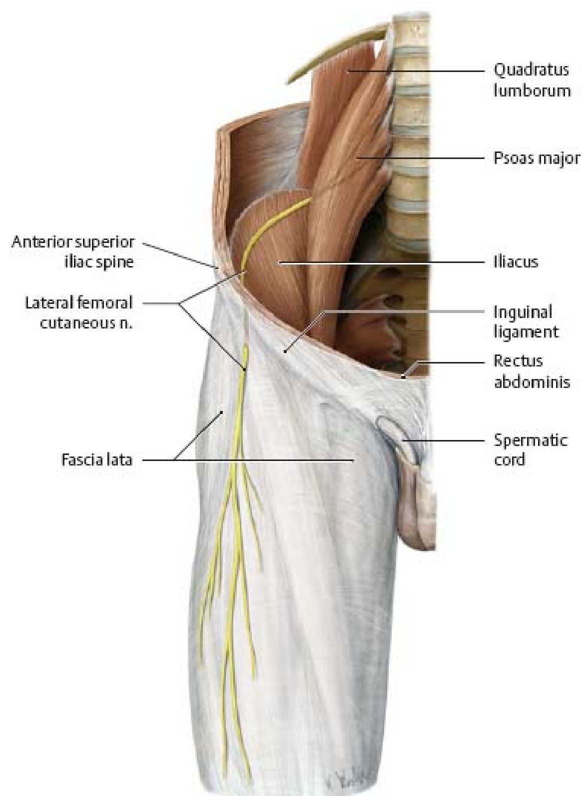
A Iliohypogastric nerve.



B Ilioinguinal nerve.



C Genitofemoral nerve.



D Lateral femoral cutaneous nerve.

Nerves of the Lumbar Plexus: Obturator & Femoral Nerves

Fig. 27.14 **Obturator nerve: Sensory distribution**
Right leg, medial view.

Fig. 27.15 **Obturator nerve**
Right side, anterior view.

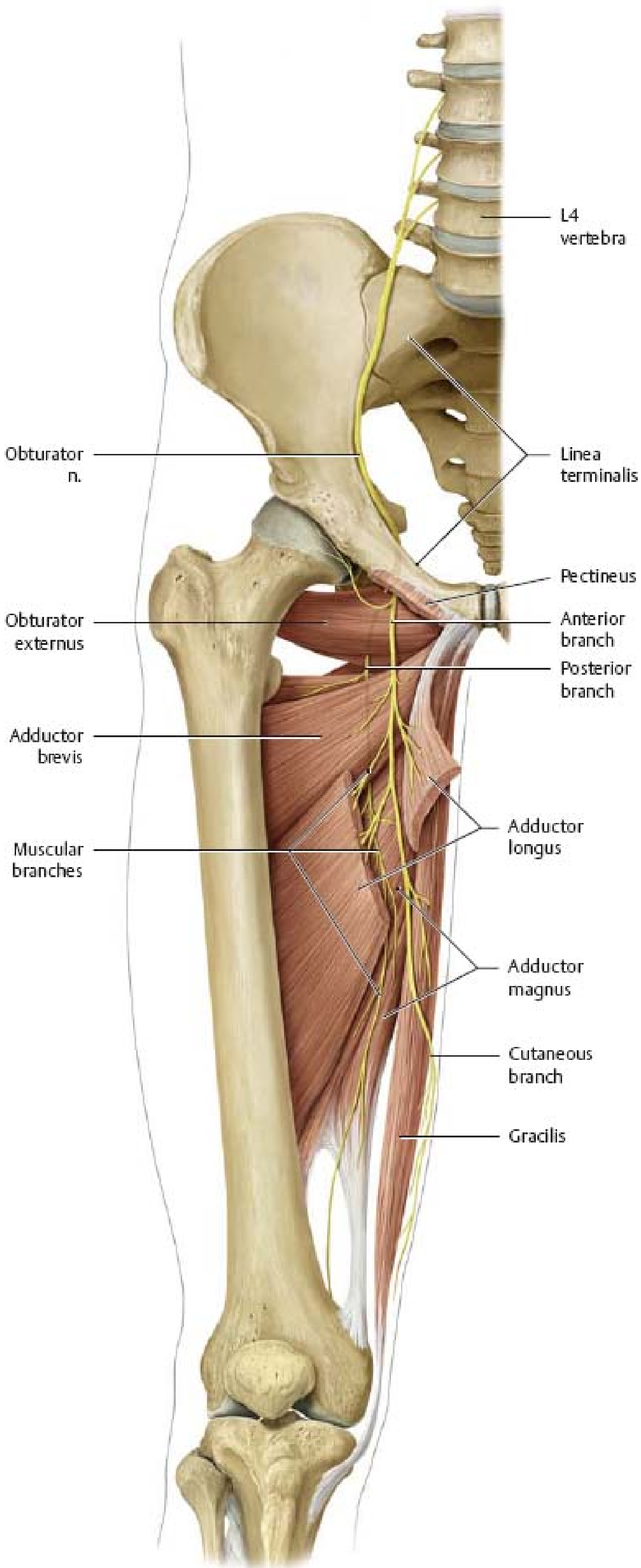

L4 vertebra
Obturator n.
Linea terminalis
Pectineus
Obturator externus
Anterior branch
Posterior branch
Adductor brevis
Adductor longus
Muscular branches
Adductor magnus
Cutaneous branch
Gracilis

Table 27.3 Obturator nerve (L2–L4)	
Motor branches	**Innervated muscles**
Direct branch	Obturator externus
Anterior branch	Adductor longus
	Adductor brevis
	Gracilis
	Pectineus
Posterior branch	Adductor magnus
Sensory branches	
Cutaneous branch	

Fig. 27.16 **Femoral nerve**

Right side, anterior view.

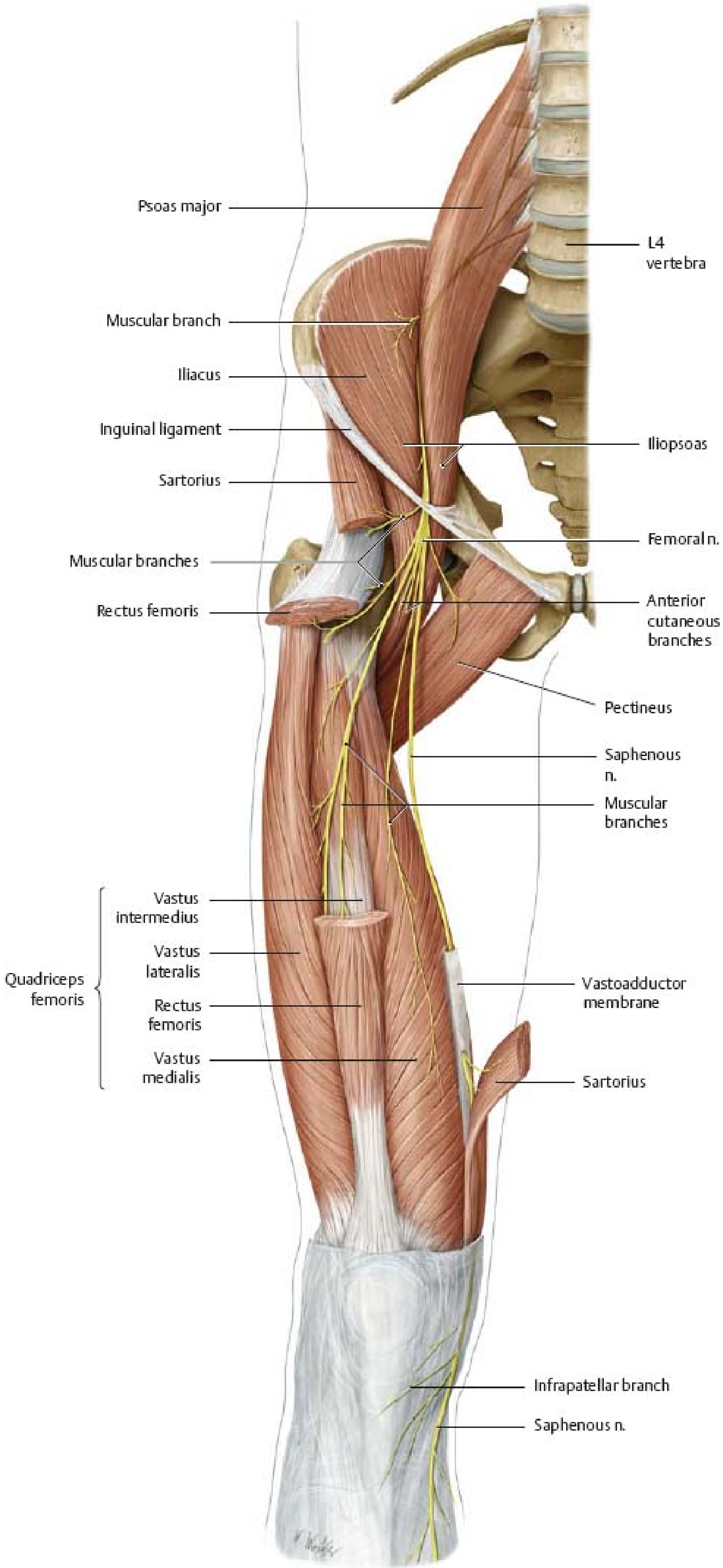

Psoas major
L4 vertebra
Muscular branch
Iliacus
Inguinal ligament
Iliopsoas
Sartorius
Femoral n.
Muscular branches
Rectus femoris
Anterior cutaneous branches
Pectineus
Saphenous n.
Muscular branches
Vastus intermedius
Quadriceps femoris
Vastus lateralis
Vastoadductor membrane
Rectus femoris
Vastus medialis
Sartorius
Infrapatellar branch
Saphenous n.

Fig. 27.17 **Femoral nerve: Sensory distribution**

Right limb, anterior view.

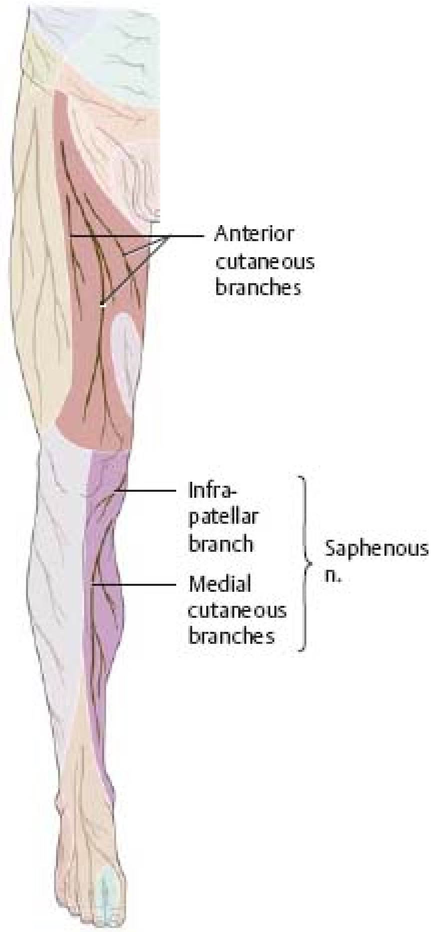


Table 27.4	Femoral nerve (L2–L4)
Motor branches	**Innervated muscles**
Muscular branches	Iliopsoas
	Pectineus
	Sartorius
	Quadriceps femoris
Sensory branches	
Anterior cutaneous branch	
Saphenous n.	

Nerves of the Sacral Plexus

Table 27.5 Nerves of the sacral plexus

Nerve		Level	Innervated muscle	Cutaneous branches	
Superior gluteal n.		L4–S1	Gluteus medius Gluteus minimus Tensor fasciae latae	–	
Inferior gluteal n.		L5–S2	Gluteus maximus	–	
Posterior femoral cutaneous n.		S1–S3	–	Posterior femoral cutaneous n.	Inferior cluneal nn.
					Perineal branches
Direct branches	N. of piriformis	S1–S2	Piriformis	–	
	N. of obturator internus	L5–S1	Obturator internus Gemelli	–	
	N. of quadratus femoris		Quadratus femoris	–	
Sciatic n.	Common fibular n.	L4–S2	See p. 432		
	Tibial n.	L4–S3	See p. 433		

Fig. 27.18 **Sensory innervation of the gluteal region**

Right limb, posterior view.

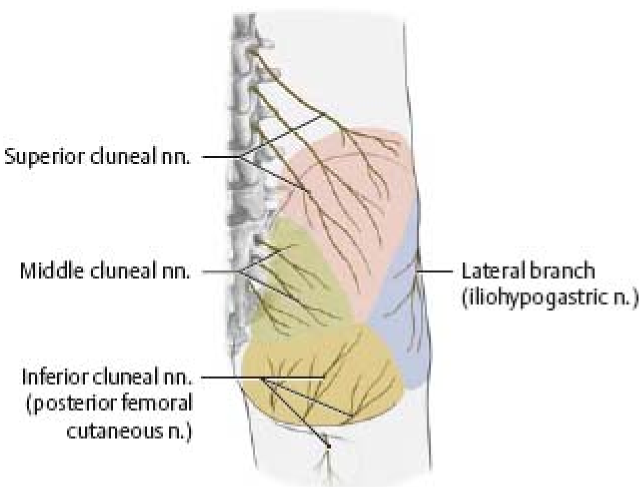


Fig. 27.19 **Posterior femoral cutaneous nerve: Sensory distribution**

Right limb, posterior view.

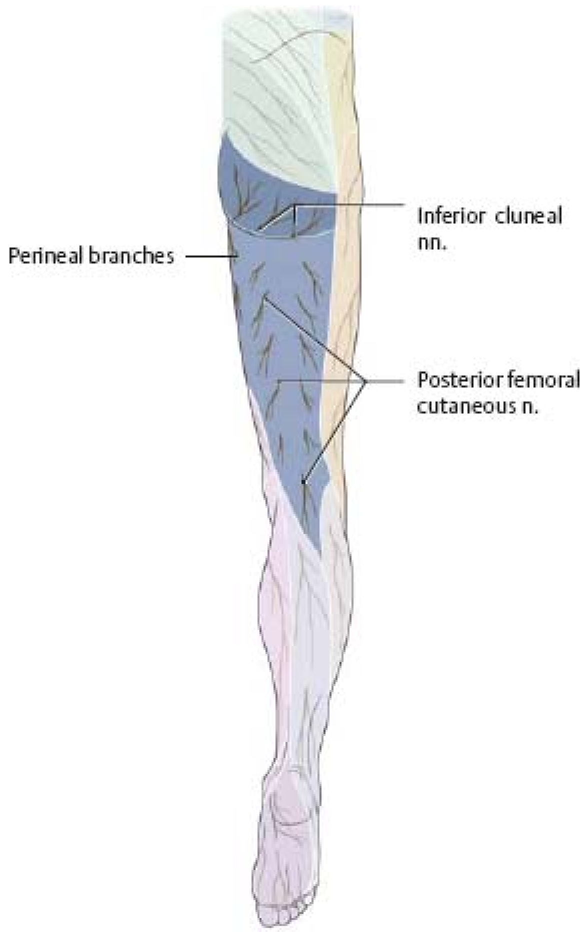


Fig. 27.20 **Emerging sacral nerve**

Horizontal section, superior view.

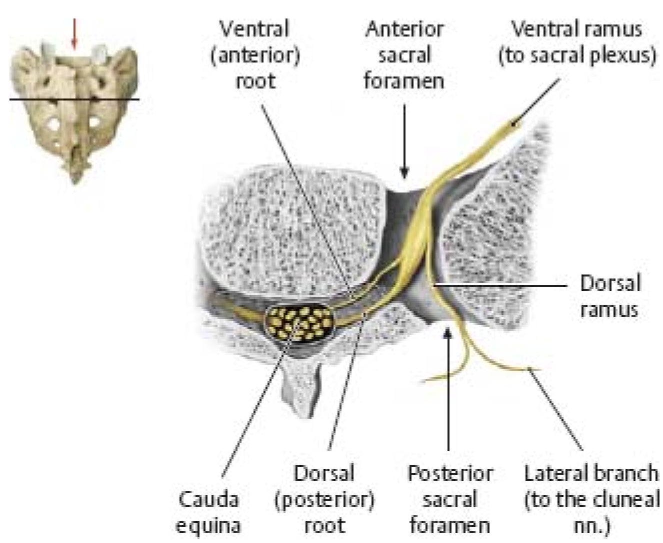
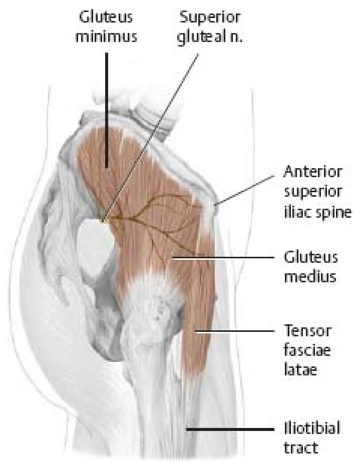
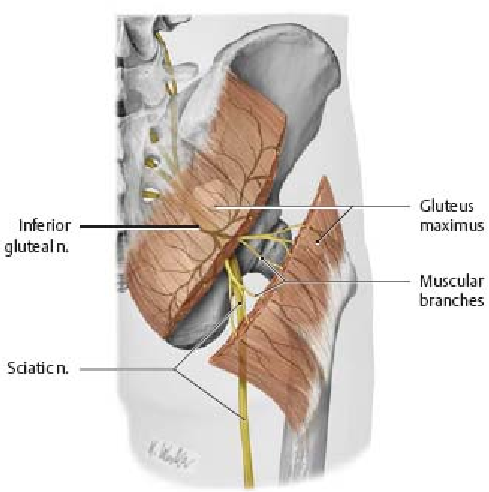


Fig. 27.21 Nerves of the sacral plexus

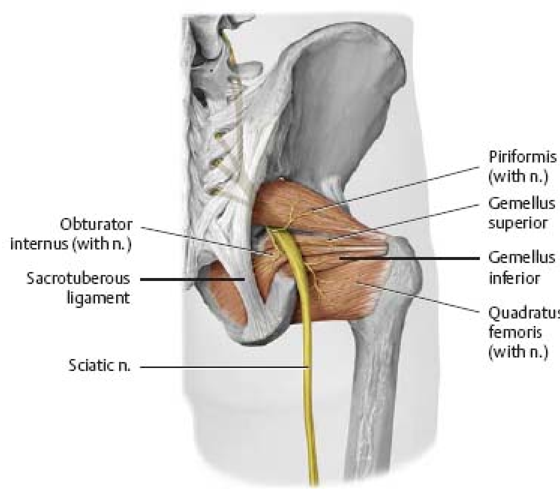
Right limb.



A Superior gluteal nerve. Lateral view.



B Inferior gluteal nerve. Posterior view.

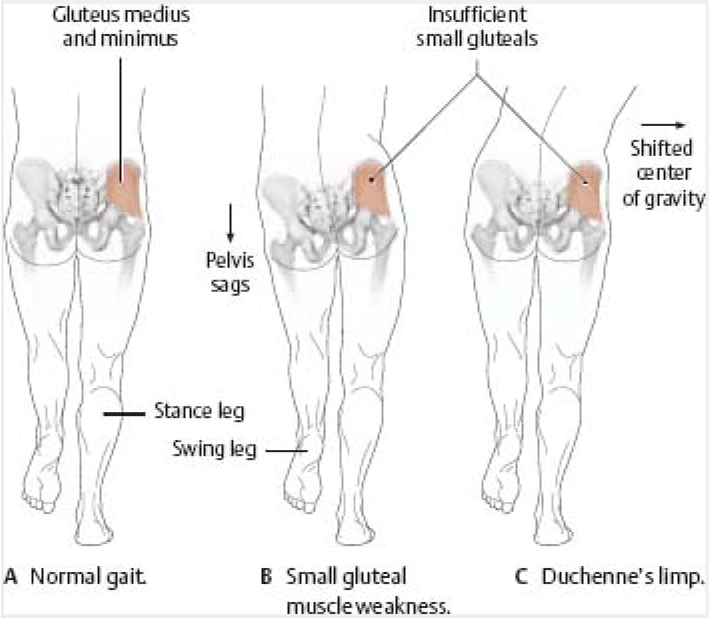


C Direct branches. Posterior view.

Clinical

Small gluteal muscle weakness

The small gluteal muscles on the stance side stabilize the pelvis in the coronal plane. Weakness or paralysis of the small gluteal muscles from damage to the superior gluteal nerve (e.g., due to a faulty intramuscular injection) is manifested by weak abduction of the affected hip joint. In a positive Trendelenburg's test, the pelvis sags toward the normal, unsupported side. Tilting the upper body toward the affected side shifts the center of gravity onto the stance side, thereby elevating the pelvis on the swing side (Duchenne's limp). With bilateral loss of the small gluteals, the patient exhibits a typical waddling gait.



Nerves of the Sacral Plexus: Sciatic Nerve

The sciatic nerve gives off several direct muscular branches before dividing into the tibial and common fibular nerves proximal to the popliteal fossa.

Fig. 27.22 Common fibular nerve: Sensory distribution

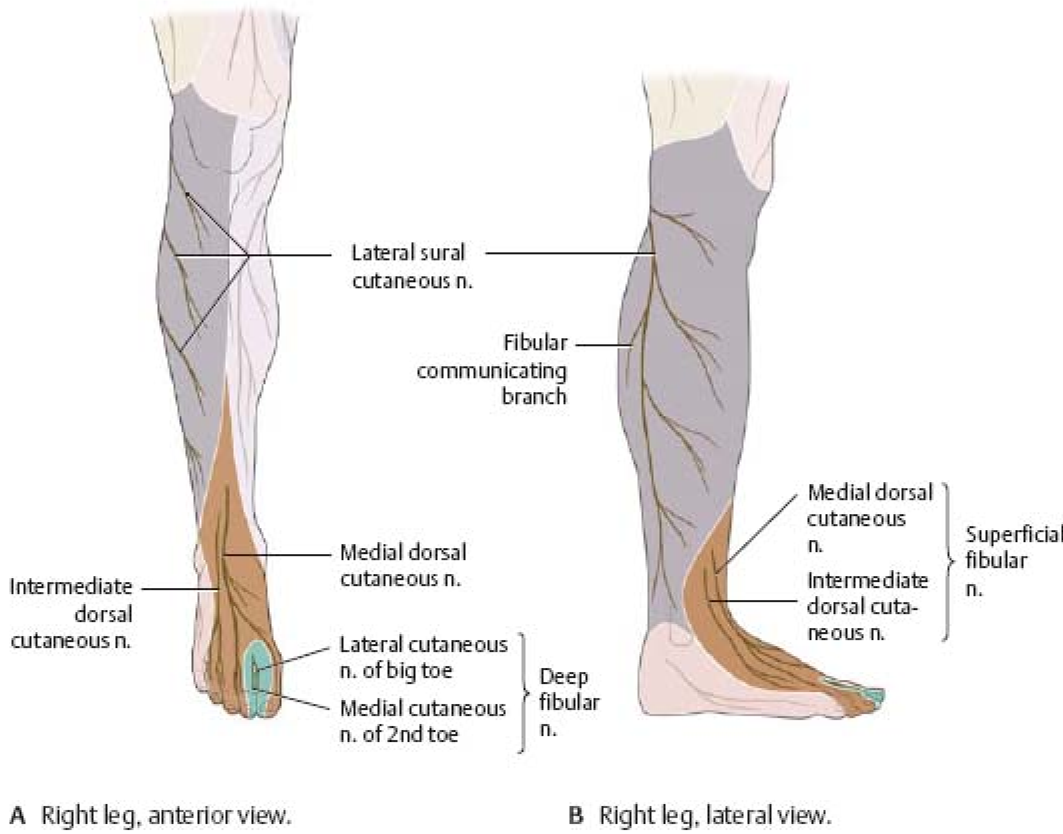
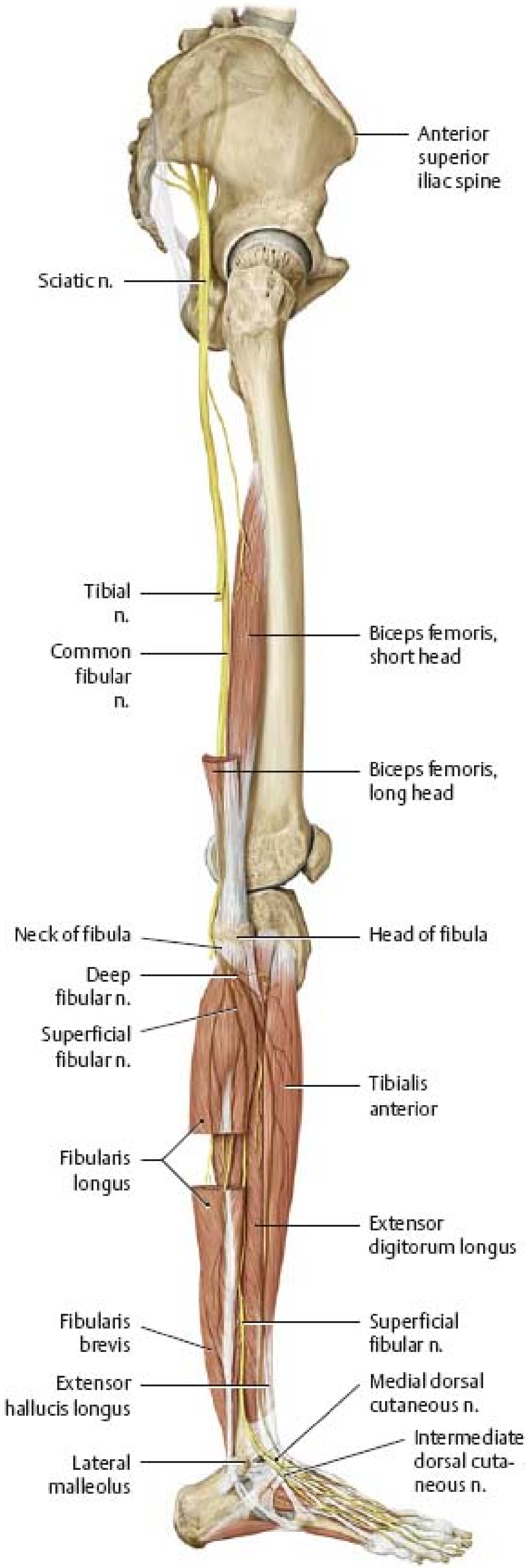


Fig. 27.23 **Common fibular nerve**

Right limb, lateral view.



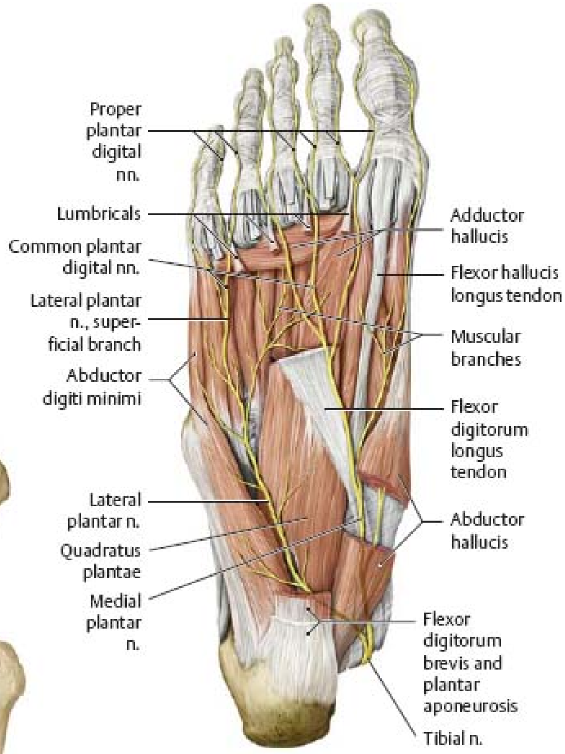
Anterior superior iliac spine
Sciatic n.
Tibial n.
Common fibular n.
Biceps femoris, short head
Biceps femoris, long head
Neck of fibula
Head of fibula
Deep fibular n.
Superficial fibular n.
Tibialis anterior
Fibularis longus
Extensor digitorum longus
Fibularis brevis
Superficial fibular n.
Extensor hallucis longus
Medial dorsal cutaneous n.
Intermediate dorsal cutaneous n.
Lateral malleolus

Table 27.6 **Common fibular nerve (L4-S2)**

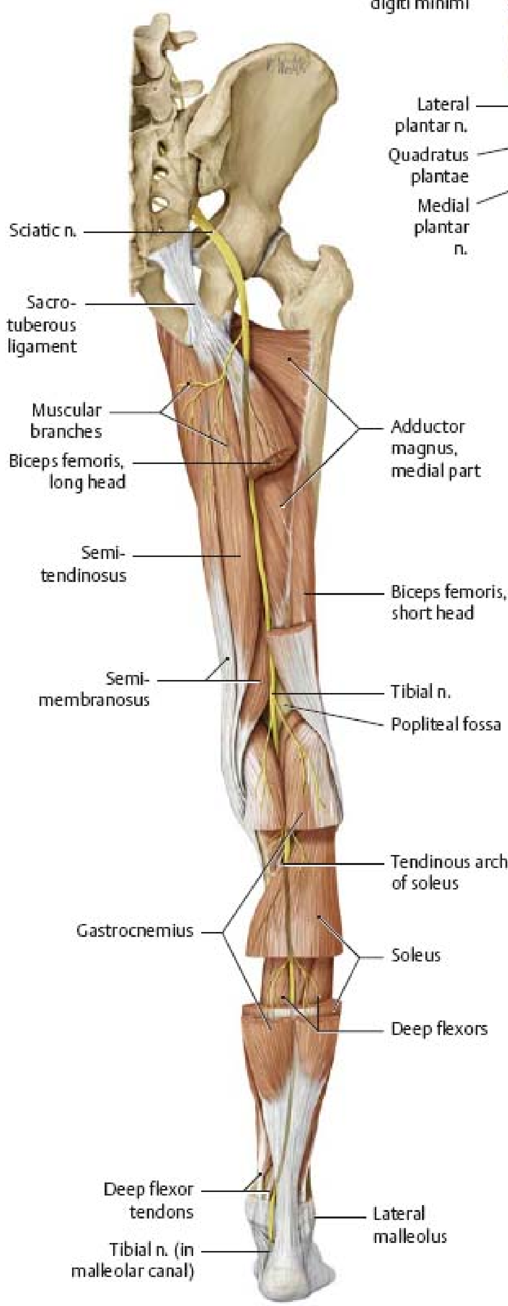
Nerve	Innervated muscles	Sensory branches
Direct branches from Sciatic n.	Biceps femoris (shortsciatic head)	–
Superficial fibular n.	Fibularisbrevisand longus	Medial dorsal cutaneous n. Intermediate dorsal cutaneous n.
Deep fibular n.	Tibialis anterior Extensors digitorum brevis and longus Extensors hallucis brevis and longus Fibularis tertius	Lateral cutaneous n. of big toe Medial cutaneous n. of 2nd toe.

Fig. 27.24 **Tibial nerve**

Right limb.



B Right foot, plantar view.



A Posterior view.

Fig. 27.25 Tibial nerve: Sensory distribution

Right lower limb, posterior view.

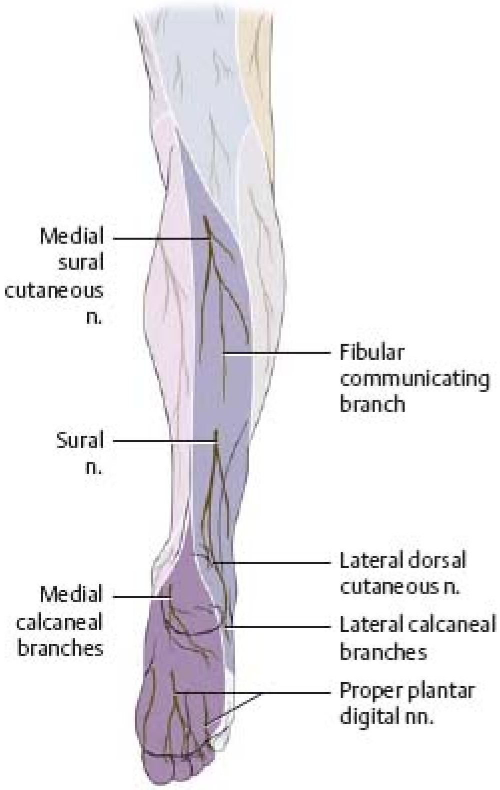


Table 27.7 **Tibial nerve (L4–S3)**

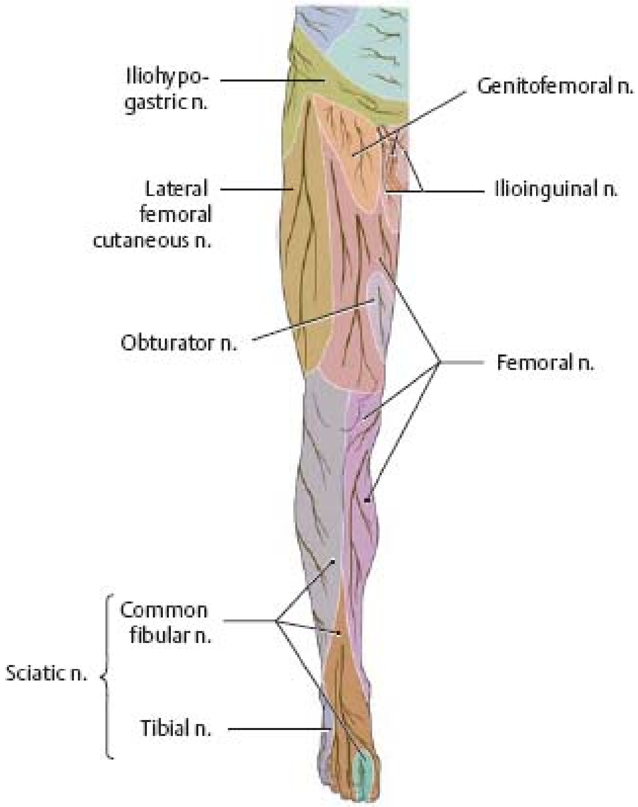
Nerve	Innervated muscles	Sensory branches
Direct branches from sciatic n.	Semitendinosus Semimembranosus Biceps femoris (long head) Adductor magnus (medial part)	–
Tibial n.	Triceps surae Plantaris Popliteus Tibialis posterior Flexor digitorum longus Flexor hallucis longus	Medial sural cutaneous n. Medial and lateral calcaneal branches Lateral dorsal cutaneous n.

Nerve	Innervated muscles	Sensory branches
Medial plantar n.	Adductor hallucis Flexor digitorum brevis Flexor hallucis brevis(medial head) 1st and 2nd lumbricals	Proper plantar digital nn.
Lateral plantar n.	Flexor hallucis brevis (lateral head) Quadratus plantae Abductor digiti minimi Flexor digiti minimi brevis Opponens digiti minimi 3rd and 4th lumbricals 1st and 3rd plantar interossel 1st to 4th doral interossel Adductor hallucis	Proper plantar digital nn.

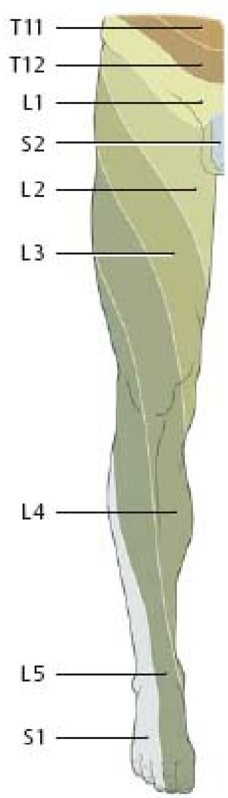
Superficial Nerves & Vessels of the Lower Limb

Fig. 27.26 Cutaneous innervation: Anterior view

Right limb.

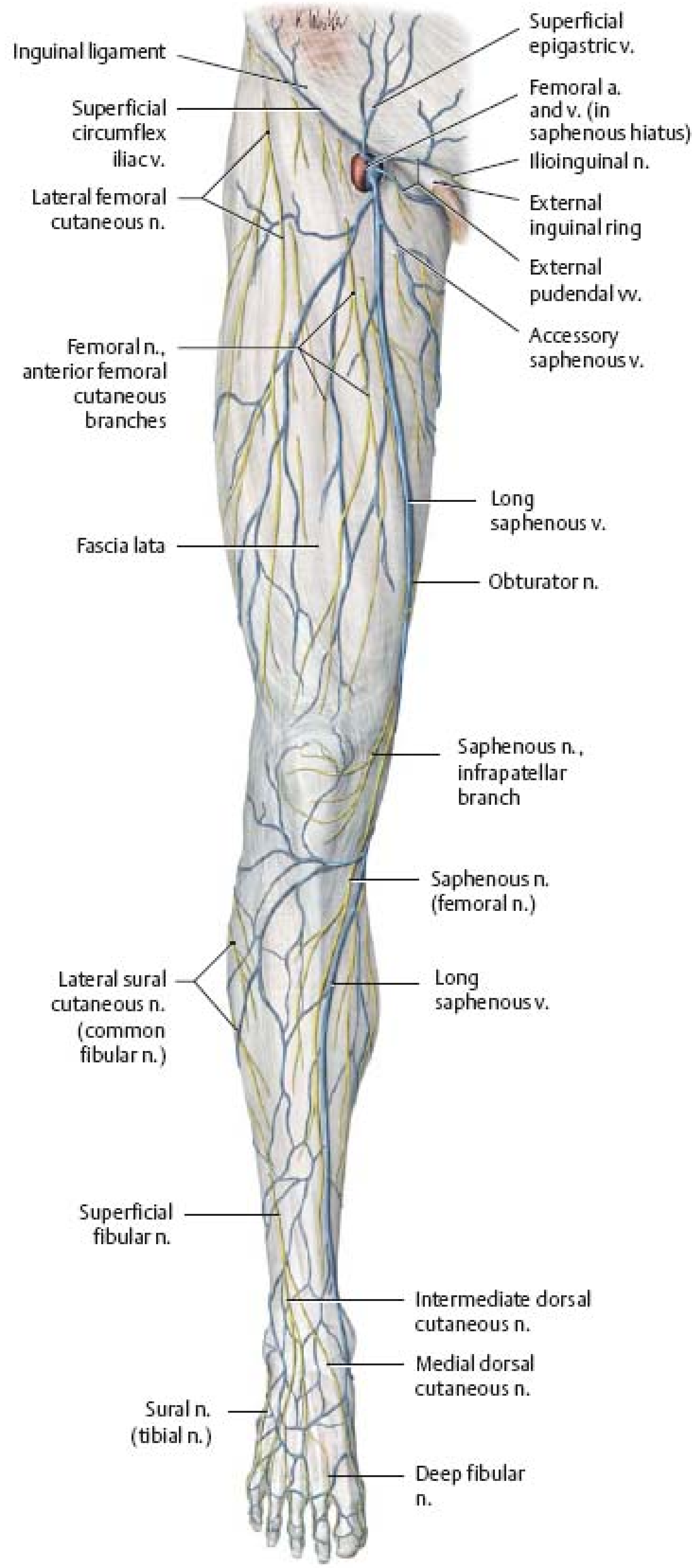


A Peripheral sensory cutaneous innervation.

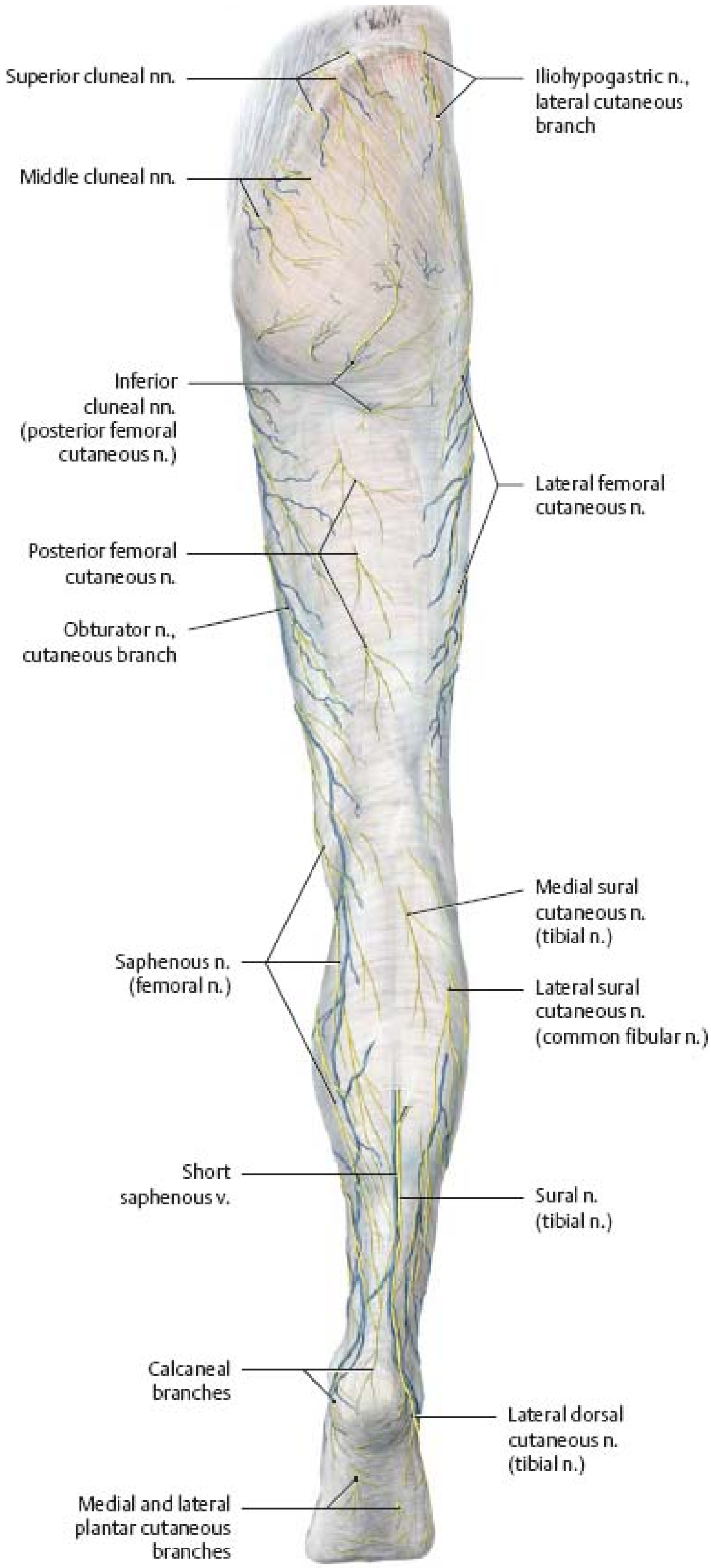


B Segmental, radicular cutaneous innervation (dermatomes).

Fig. 27.27 **Superficial cutaneous veins and nerves**
Right limb.

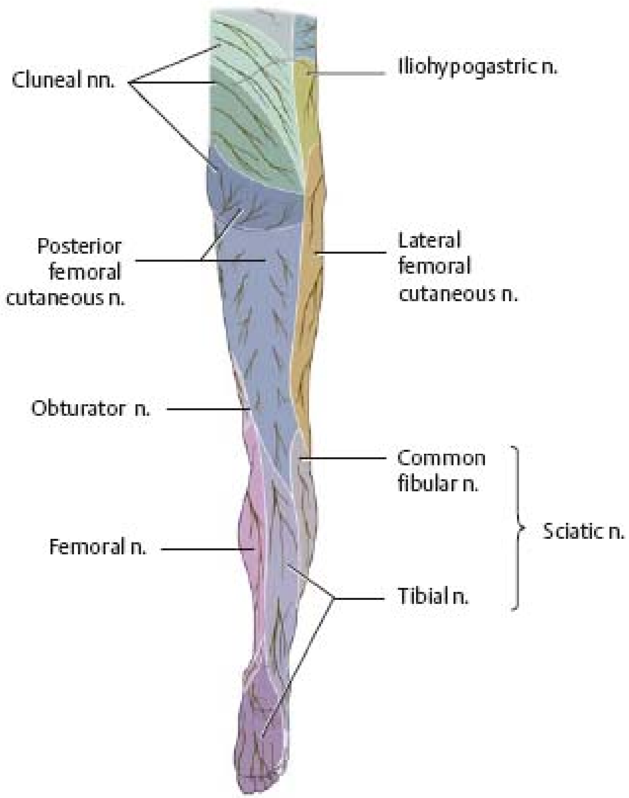


A Anterior view.

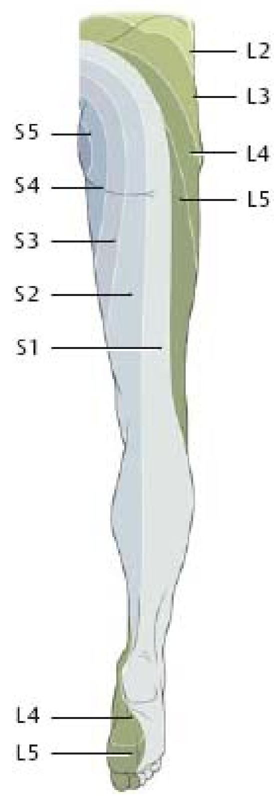


B Posterior view.

Fig. 27.28 **Cutaneous innervation: Posterior view**
Right limb.



A Peripheral sensory cutaneous innervation.



B Segmental, radicular cutaneous innervation (dermatomes).

Topography of the Inguinal Region

Fig. 27.29 Superficial veins and lymph nodes

Right male inguinal region, anterior view. *Removed:* Cribriform fascia about the saphenous hiatus.

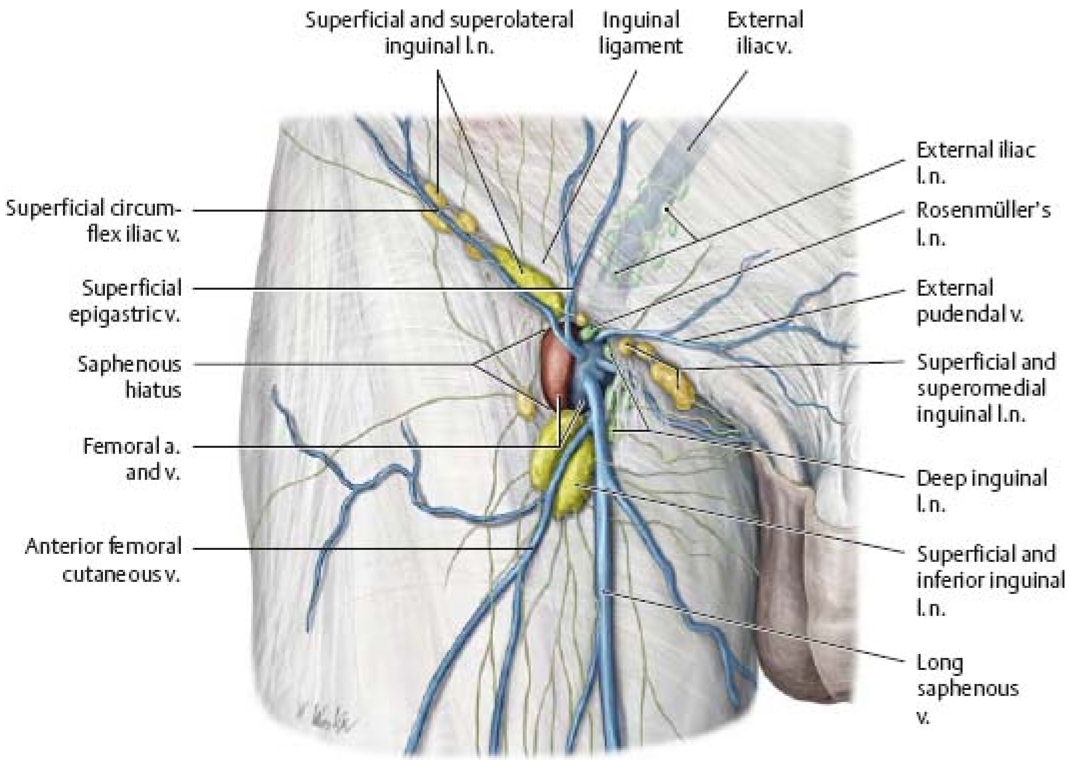


Fig. 27.30 Inguinal region

Right male inguinal region, anterior view.

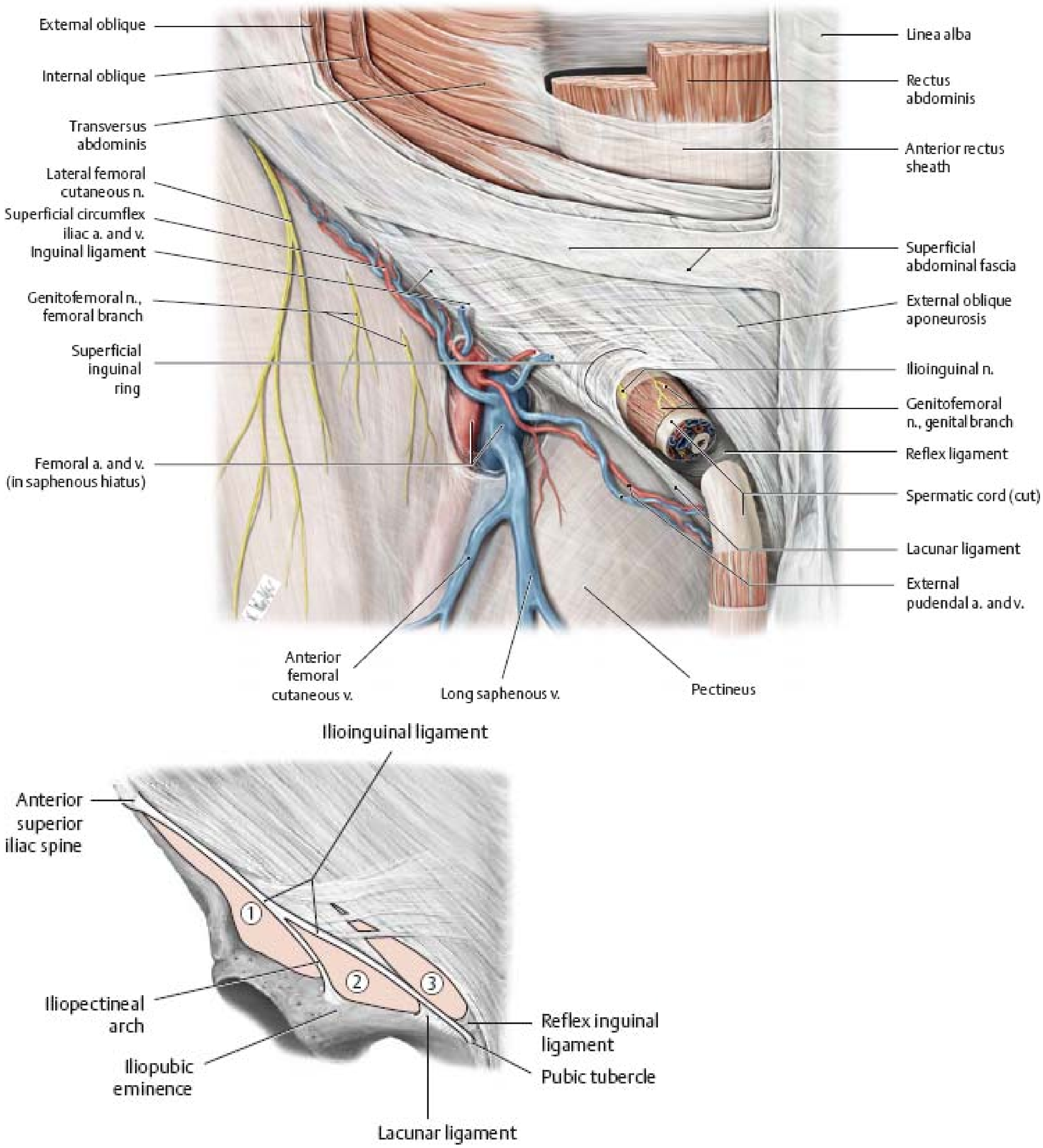


Fig. 27.31 **Lacunae musculorum and vasorum**

Right inguinal region, anterior view.

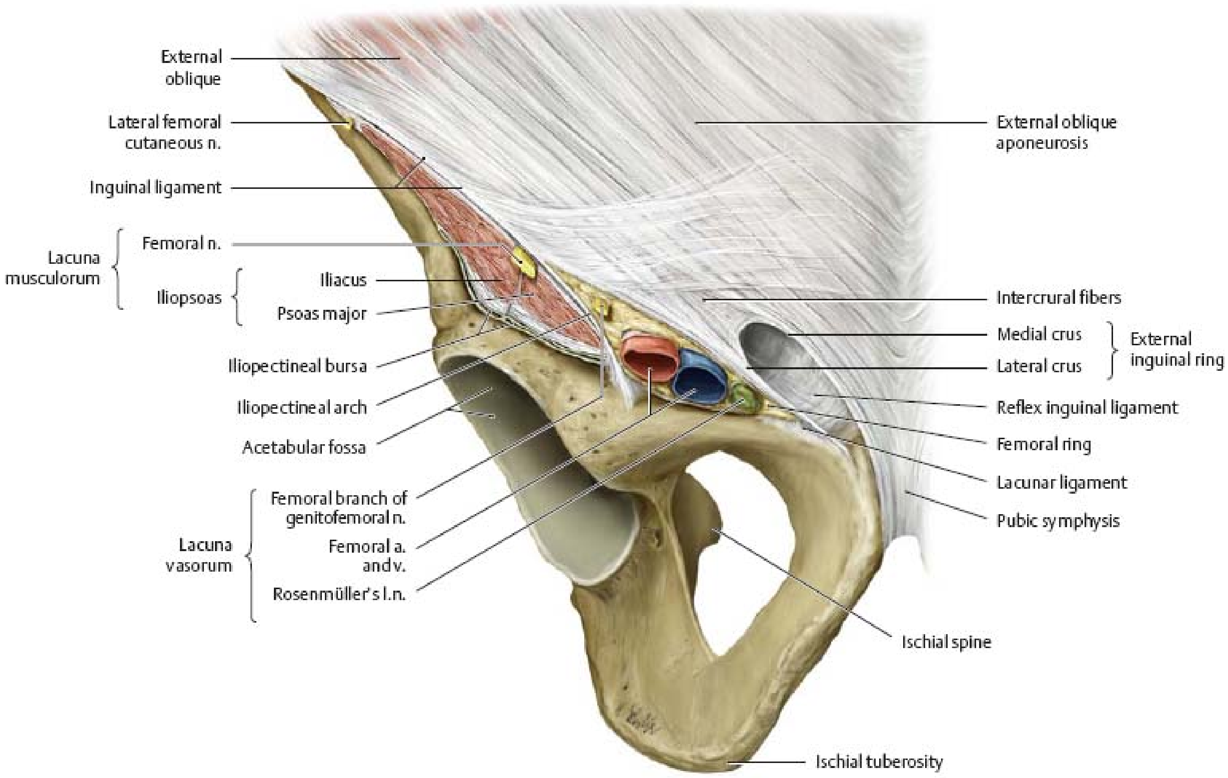


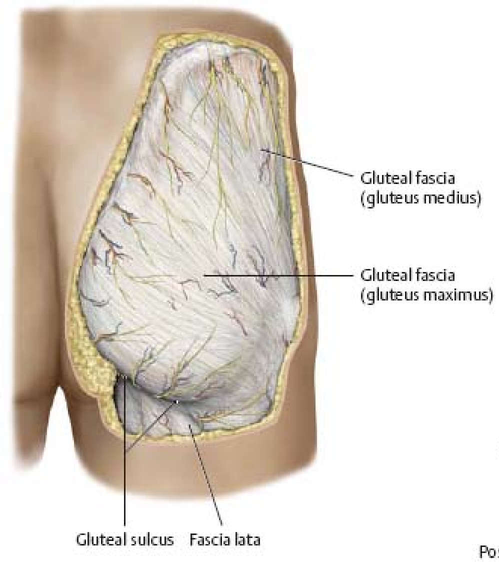
Table 27.8 **Structures in the inguinal region**

Region	Boundaries	Contents
1 Lacuna musculorum	Anterior superior iliac spine Inguinal ligament Iliopectineal arch	Femoral n. Lateral femoral cutaneous n. Iliacus Psoas major
2 Lacuna vasorum	Inguinal ligament Iliopectineal arch Lacunar ligament	Femoral a. and v. Genitofemoral n. (femoral branch) Rosenmiiller's lymph node
3 External inguinal ring	Medial crus Lateral crus Reflex inguinal ligament	Ilioinguinal n. Genitofemoral n. (genital branch) Spermatic cord

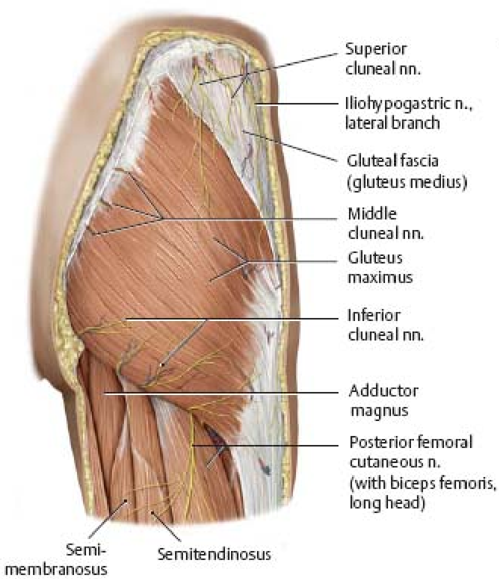
Topography of the Gluteal Region

Fig. 27.32 Gluteal region

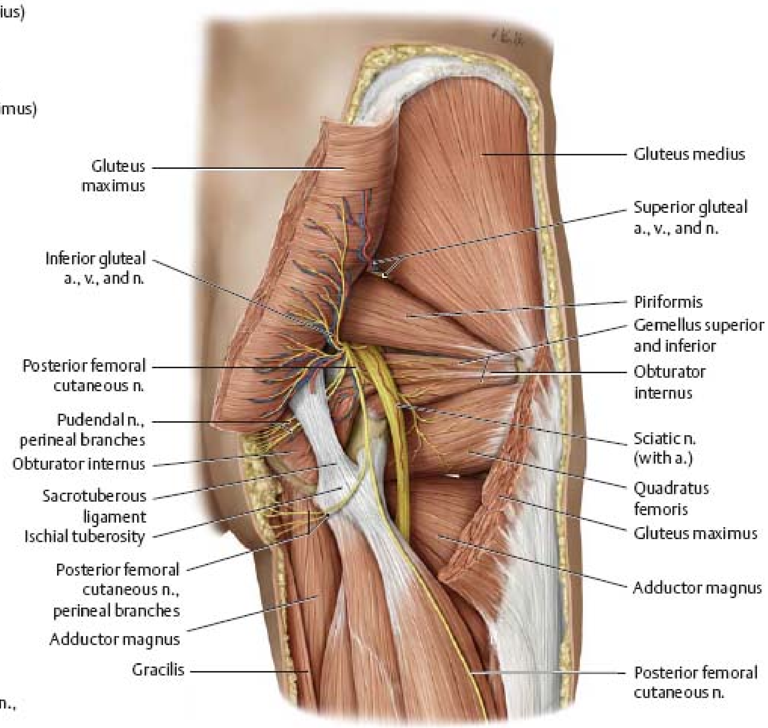
Right gluteal region, posterior view.



A Fasciae and cutaneous neurovasculature.



B Gluteal region. *Removed:* Fascia lata.



C Deep gluteal region. *Partially removed:* Gluteus maximus.

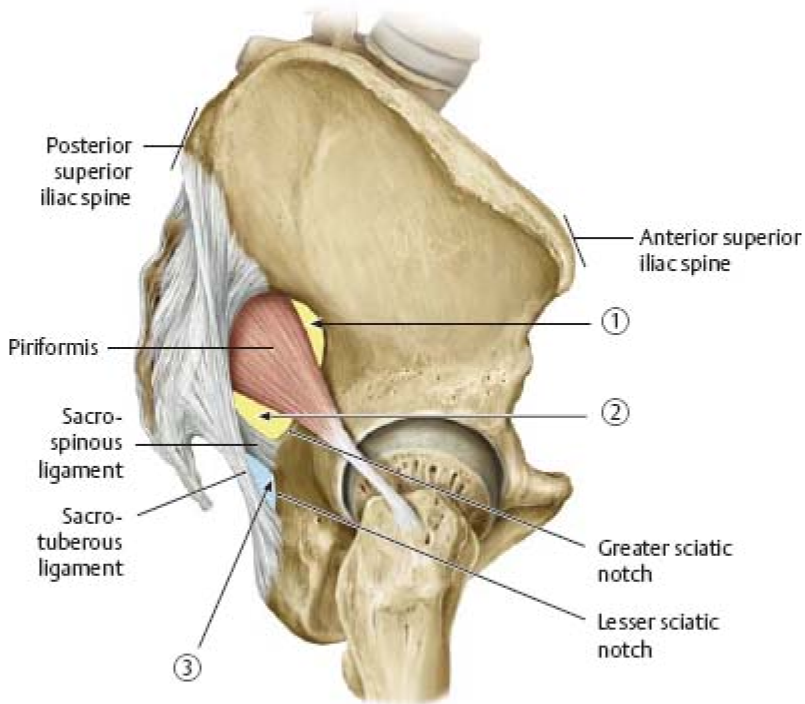
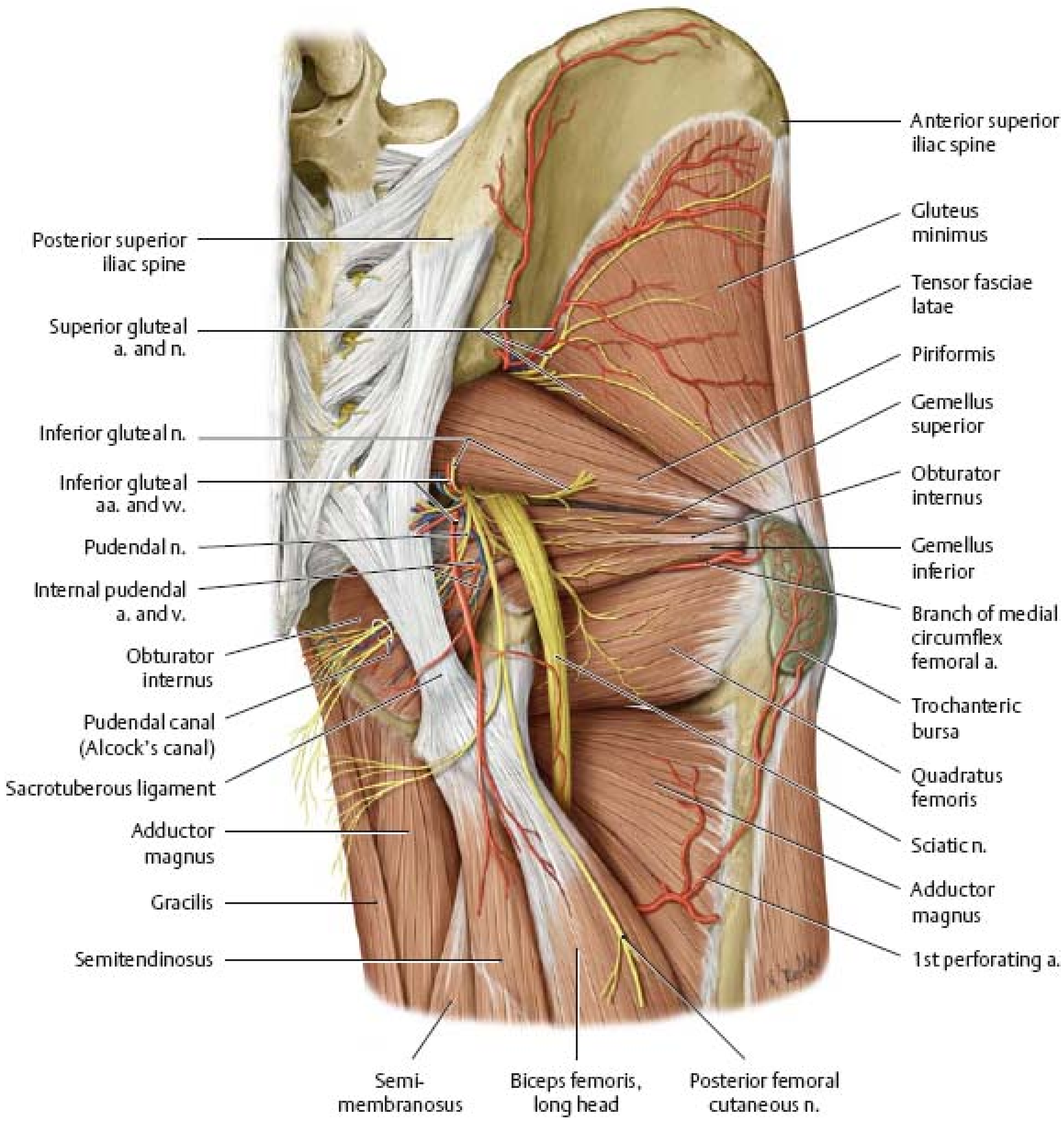


Fig. 27.33 **Gluteal region and ischianal fossa**

Right gluteal region, posterior view. *Removed:* Cluteus maximus and medius.



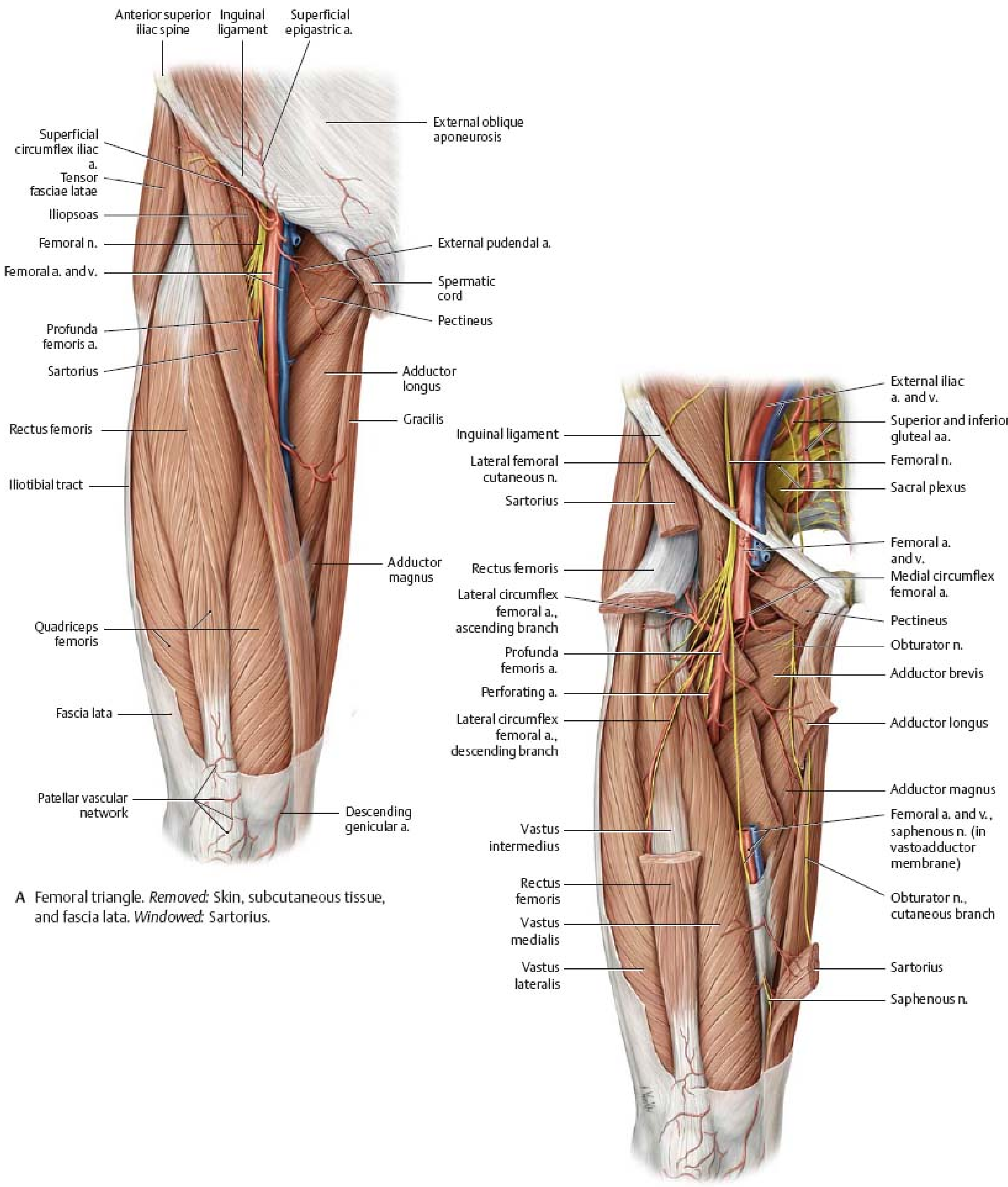
Anterior superior iliac spine
Gluteus minimus
Tensor fasciae latae
Piriformis
Gemellus superior
Obturator internus
Gemellus inferior
Branch of medial circumflex femoral a.
Trochanteric bursa
Quadratus femoris
Sciatic n.
Adductor magnus
1st perforating a.
Posterior superior iliac spine
Superior gluteal a. and n.
Inferior gluteal n.
Inferior gluteal aa. and vv.
Pudendal n.
Internal pudendal a. and v.
Obturator internus
Pudendal canal (Alcock's canal)
Sacrotuberous ligament
Adductor magnus
Gracilis
Semitendinosus
Semi-membranosus
Biceps femoris, long head
Posterior femoral cutaneous n.

Table 27.9	Sciatic foramina		
Foramen		Transmitted structures	Boundaries
Greater sciatic foramen	① Suprapiriform portion	Superior gluteal a., v., and n.	Greater sciatic notch Sacrospinous ligament Sacrum
	② Infrapiriform portion	Inferior gluteal a., v., and n. Internal pudendal a. and v. Pudendal n. Sciatic n. Posterior femoral cutaneous n.	
③ Lesser sciatic foramen		Internal pudendal a. and v. Pudendal n. Obturator internus	Lesser sciatic notch Sacrospinous ligament Sacrotuberous ligament

Topography of the Anterior & Posterior Thigh

Fig. 27.34 Anterior thigh

Right thigh, anterior view.

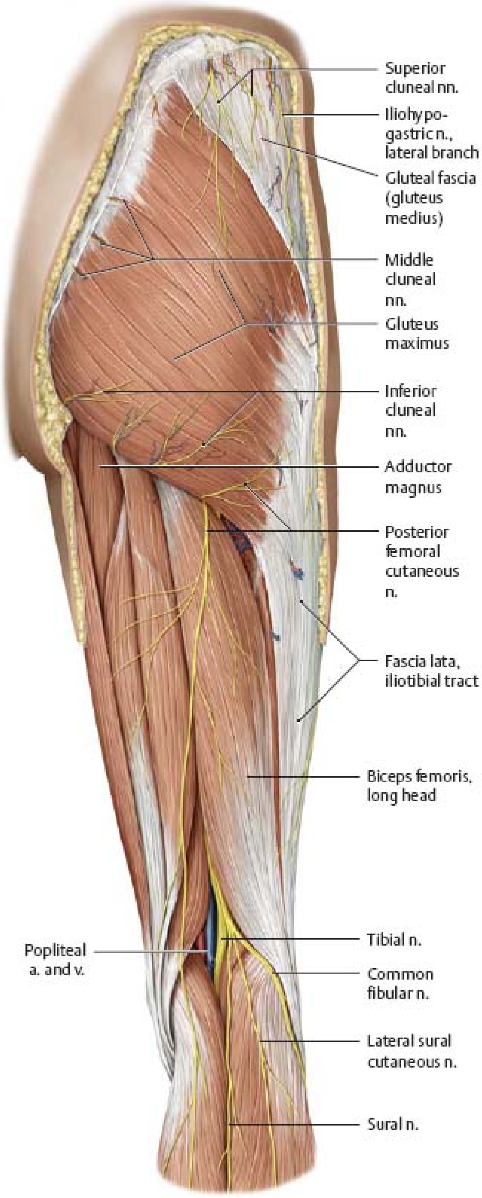


A Femoral triangle. *Removed:* Skin, subcutaneous tissue, and fascia lata. *Windowed:* Sartorius.

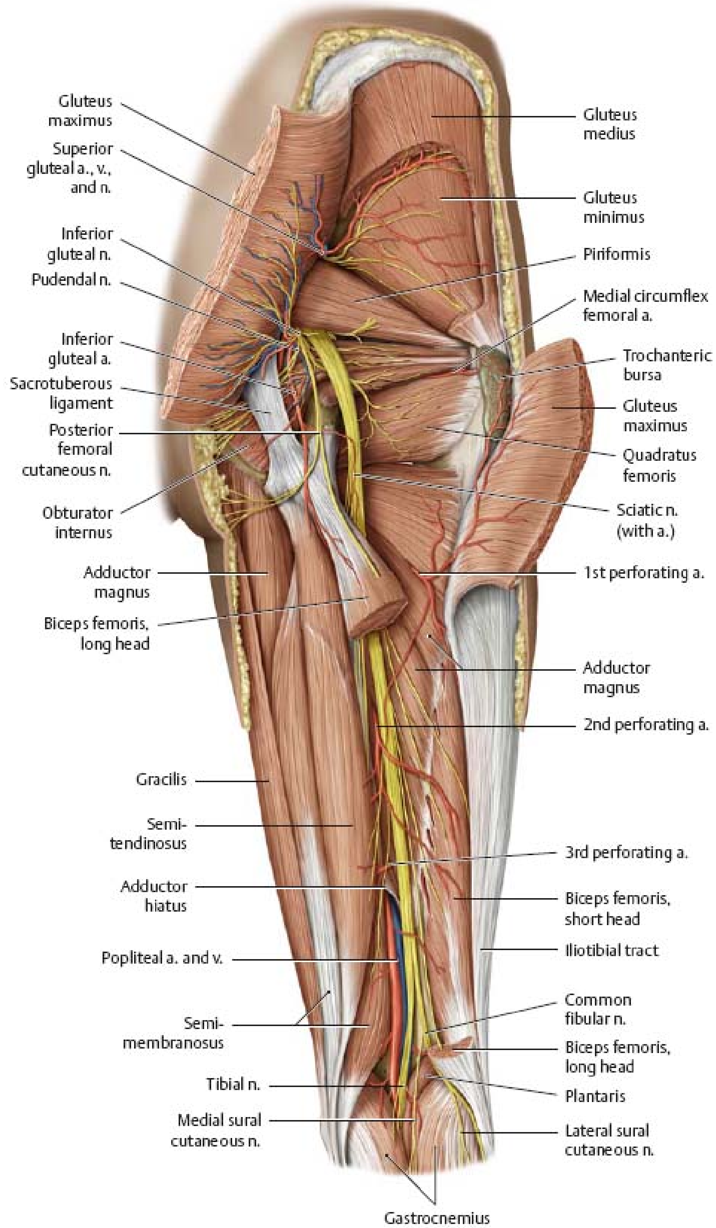
B Neurovasculature of the anterior thigh. *Removed:* Anterior abdominal wall. *Partially removed:* Sartorius, rectus femoris, adductor longus, and pectineus.

Fig. 27.35 **Posterior thigh**

Right thigh, posterior view.



A Gluteal region and thigh. *Removed:* Fascia lata.

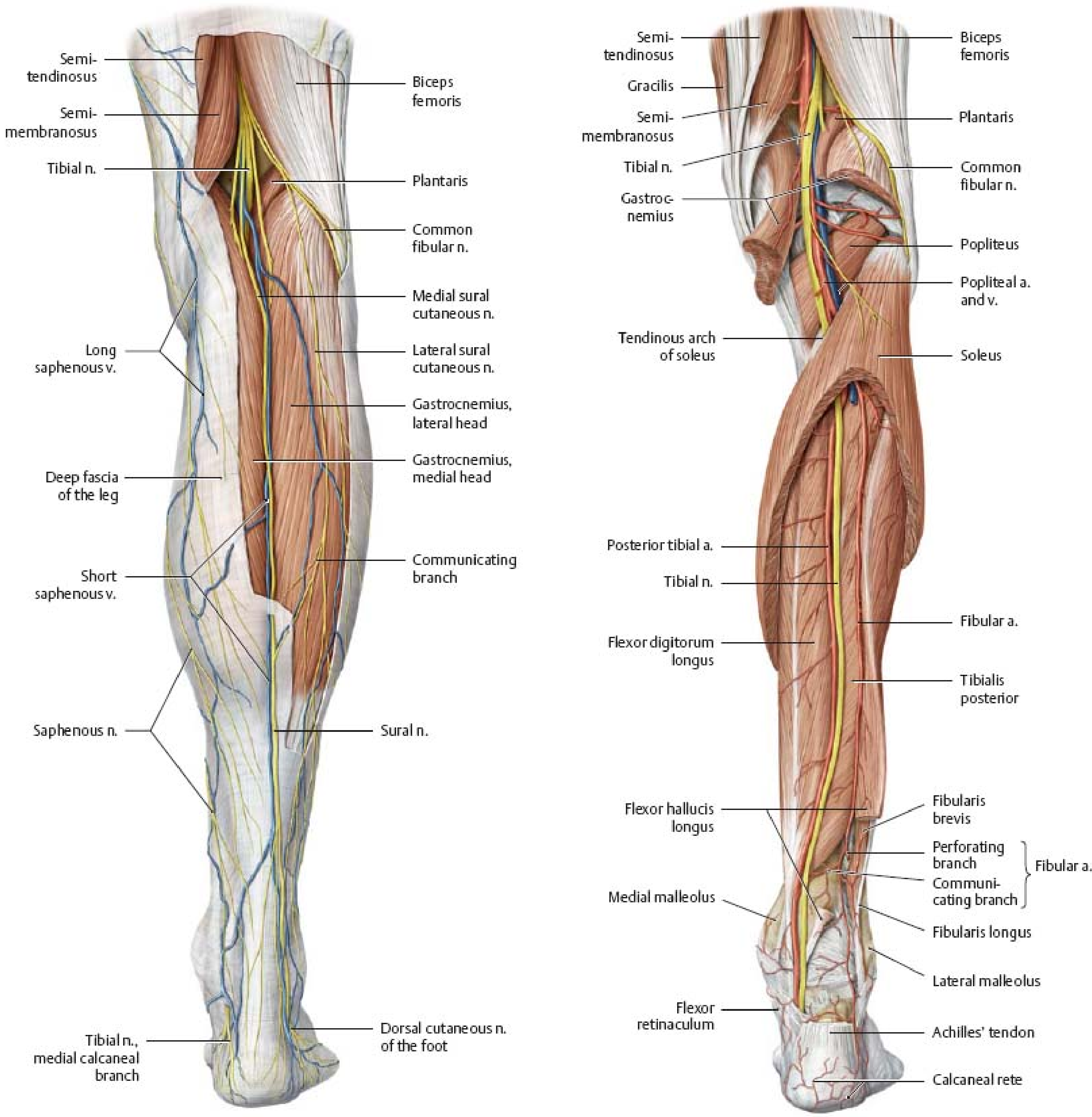


B Neurovasculature of the posterior thigh. *Partially removed:* Gluteus maximus, gluteus medius, and biceps femoris. *Retracted:* Semimembranosus.

Topography of the Posterior & Medial Leg

Fig. 27.36 **Posterior compartment**

Right leg, posterior view.



A Superficial neurovascular structures.

B Deep neurovascular structures.

Fig. 27.37 **Popliteal region**

Right leg, posterior view.

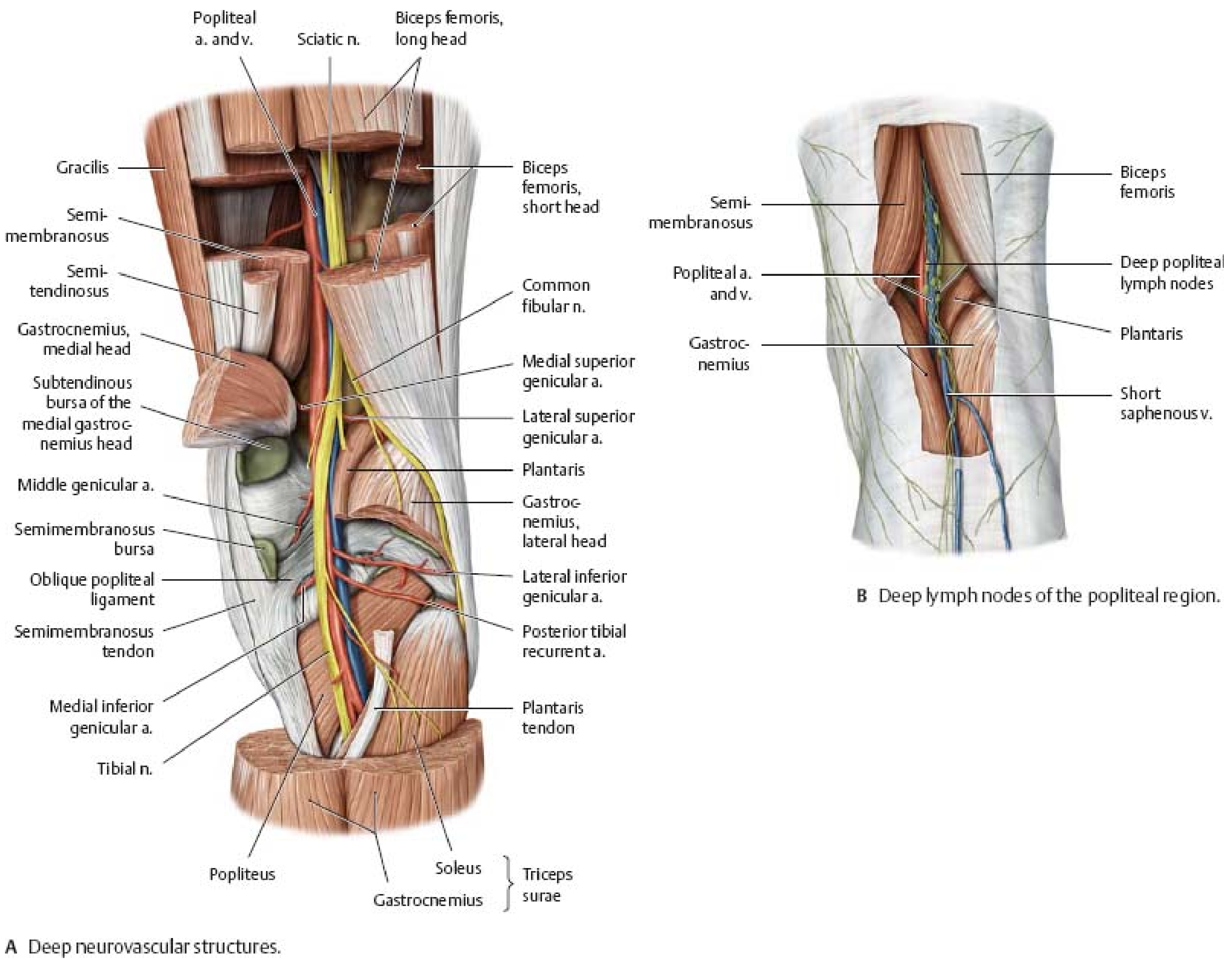
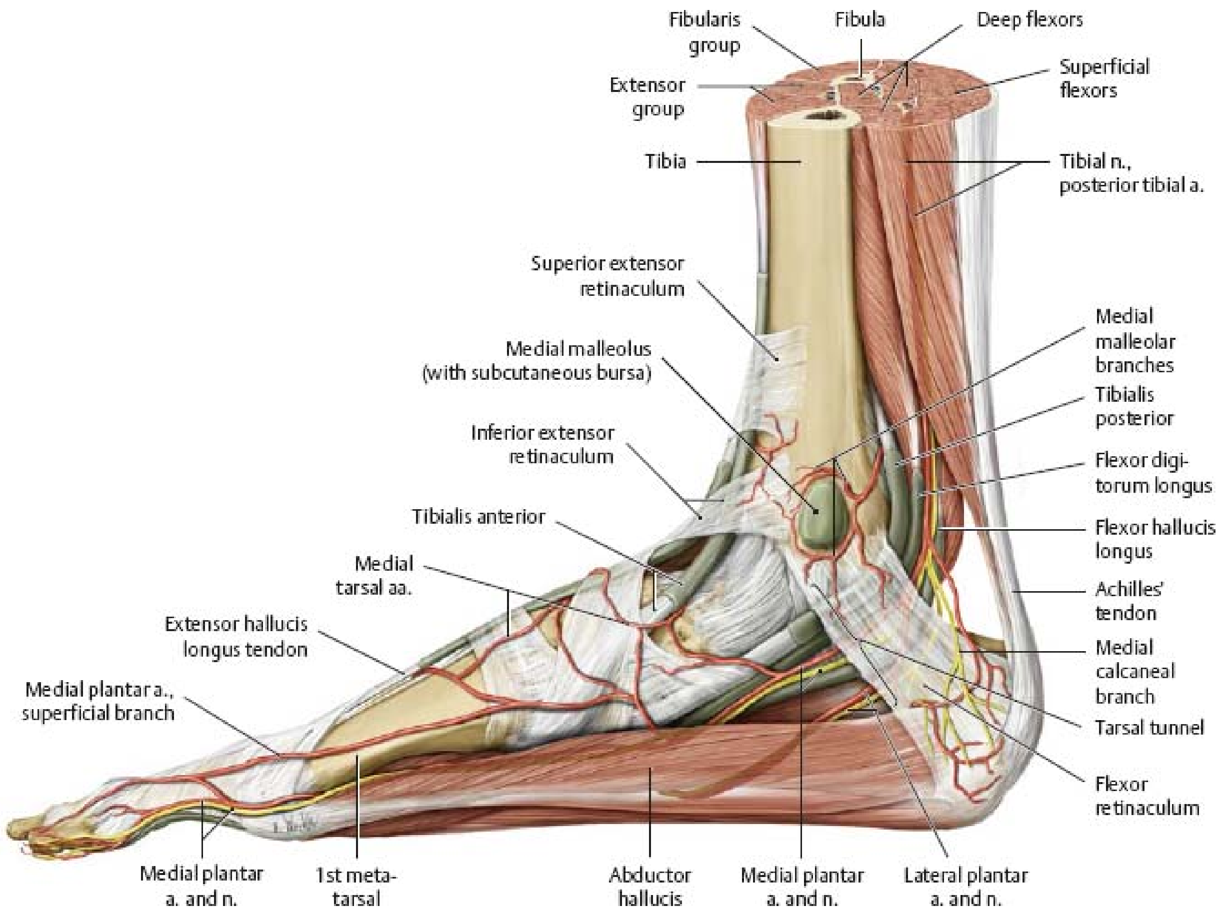


Fig. 27.38 **Posterior compartment: Medial view**

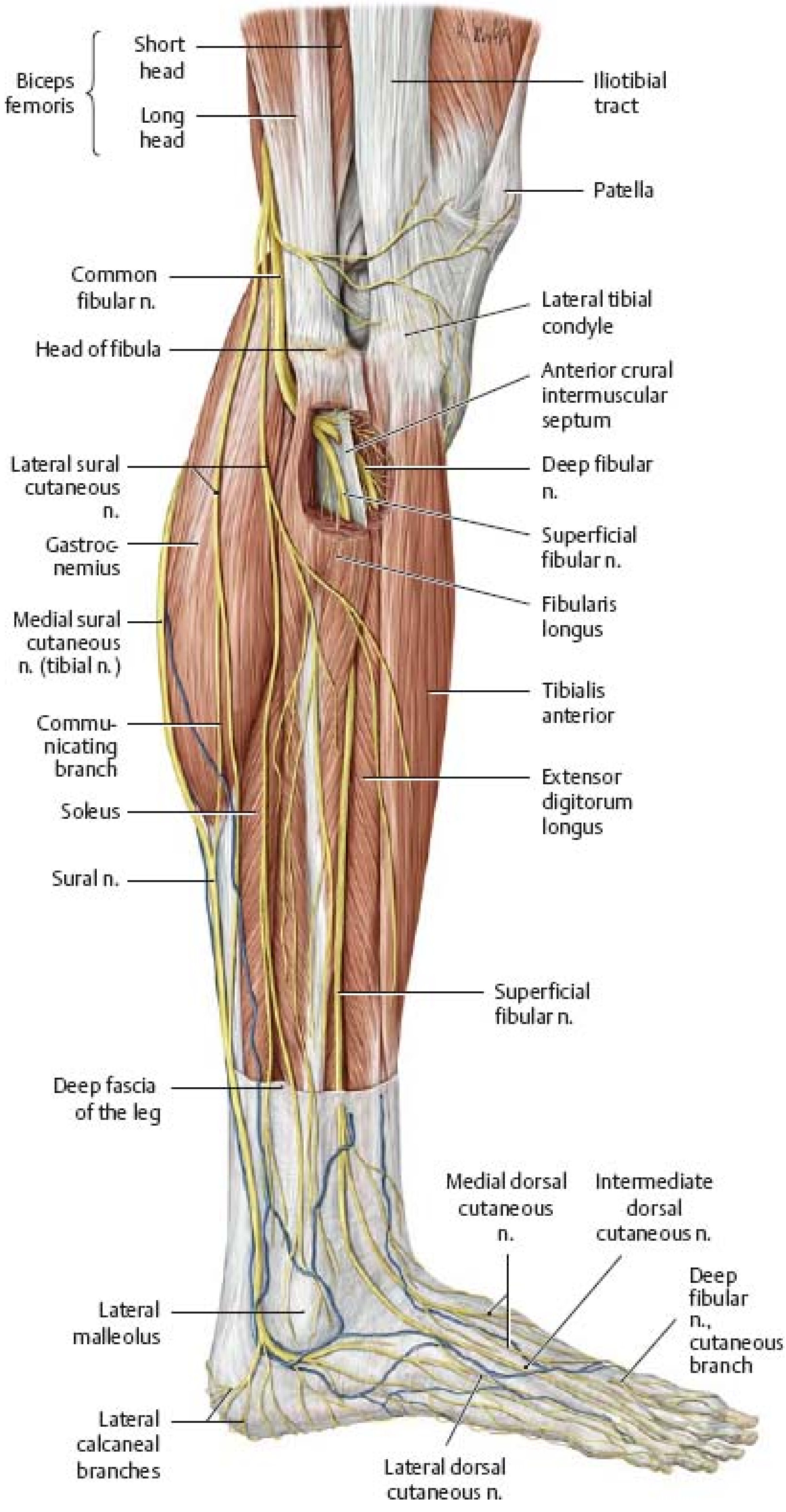
Right foot.



Topography of the Lateral & Anterior Leg

Fig. 27.39 Neurovasculature of the leg: Lateral view

Right limb. *Removed:* Origins of the fibularis longus and extensor digitorum longus.


Biceps femoris
Short head
Long head
Iliotibial tract
Patella
Common fibular n.
Lateral tibial condyle
Head of fibula
Anterior crural intermuscular septum
Lateral sural cutaneous n.
Deep fibular n.
Superficial fibular n.
Gastrocnemius
Fibularis longus
Medial sural cutaneous n. (tibial n.)
Tibialis anterior
Communicating branch
Extensor digitorum longus
Soleus
Sural n.
Superficial fibular n.
Deep fascia of the leg
Medial dorsal cutaneous n.
Intermediate dorsal cutaneous n.
Deep fibular n., cutaneous branch
Lateral malleolus
Lateral calcaneal branches
Lateral dorsal cutaneous n.

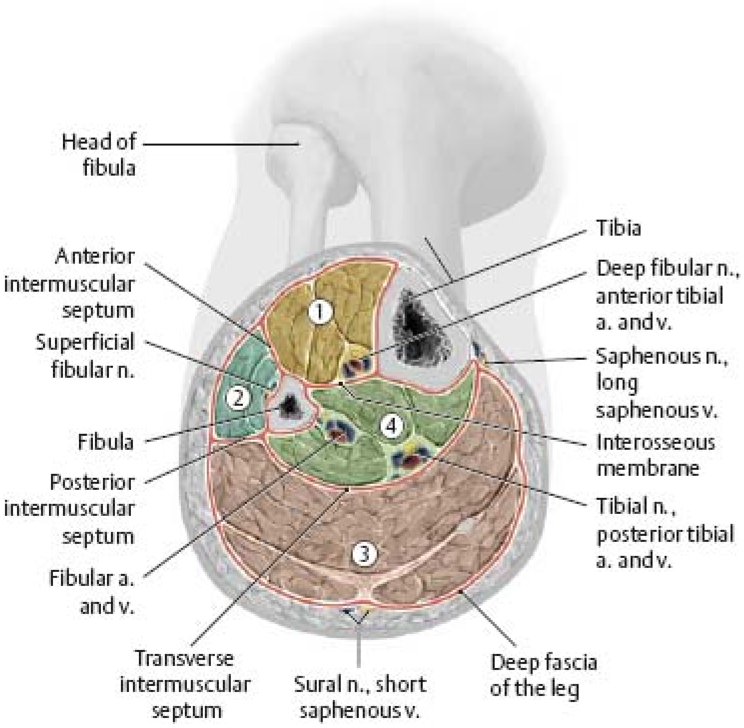


Table 27.10 Compartments of the leg

Compartment		Muscular contents	Neurovascular contents
① Anterior compartment		Tibialis anterior	Deep fibular n. Anterior tibial a. and v.
		Extensor digitorum longus	
		Extensor hallucis longus	
		Fibularis tertius	
② Lateral compartment		Fibularis longus	Superficial fibular n.
		Fibularis brevis	
Posterior compartment	③ Superficial part	Triceps surae (gastrocnemius and soleus)	–
		Plantaris	
	④ Deep part	Tibialis posterior	Tibial n. Posterior tibial a. and v. Fibular a. and v.
		Flexor digitorum longus	
		Flexor hallucis longus	

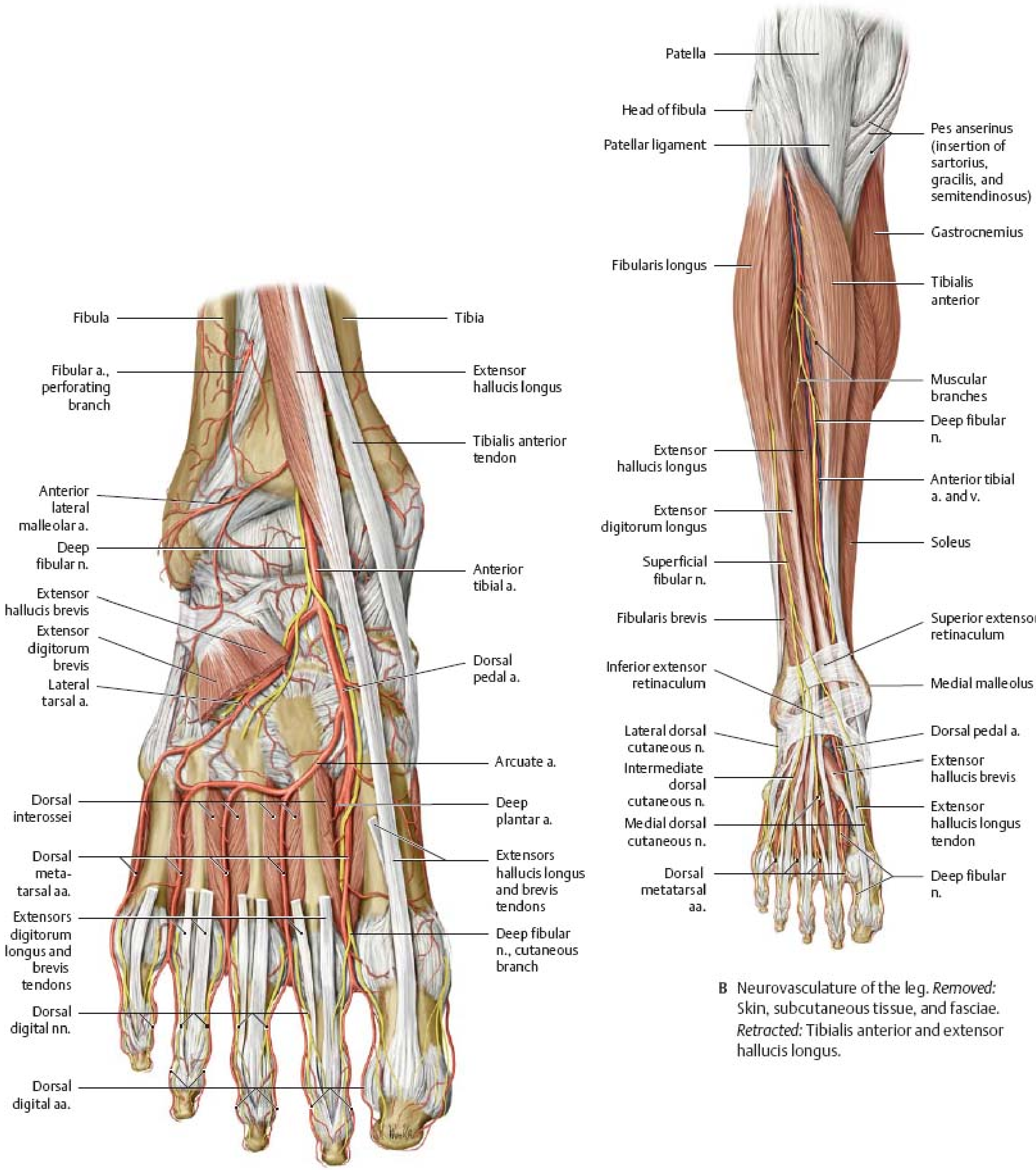
Clinical

Compartment syndrome

Muscle edema or hematoma can lead to a rise in tissue pressure in the compartments of the leg. Subsequent compression of neurovascular structures may cause ischemia and irreversible muscle and nerve damage. Patients with *anterior* compartment syndrome, the most common form, suffer excruciating pain and cannot dorsiflexthe toes. Emergency incision of the fascia of the leg may be performed to relieve compression.

Fig. 27.40 **Neurovasculature of the leg and foot: Anterior view**

Right limb with foot in plantar flexion.



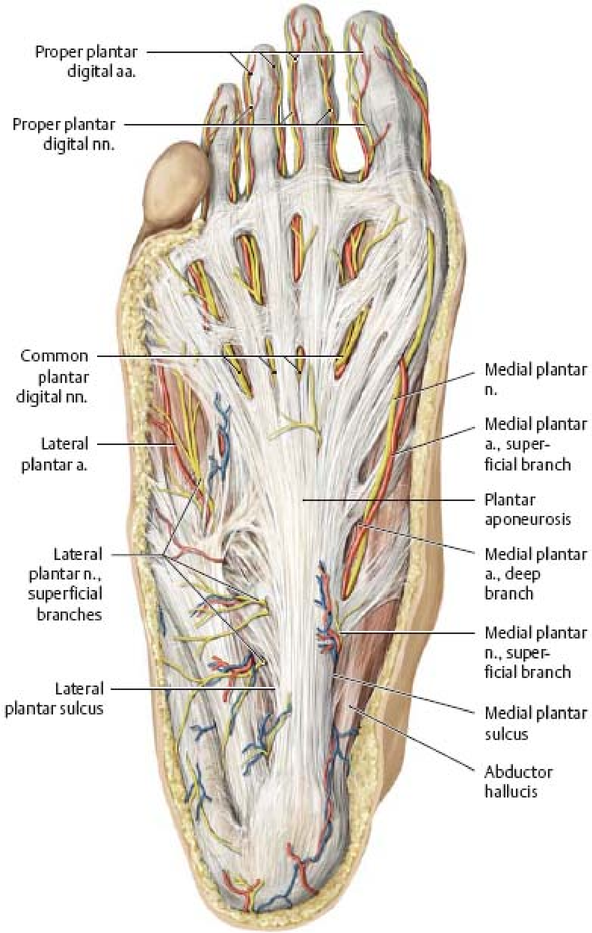
B Neurovasculature of the leg. *Removed:* Skin, subcutaneous tissue, and fasciae. *Retracted:* Tibialis anterior and extensor hallucis longus.

A Neurovasculature of the dorsum.

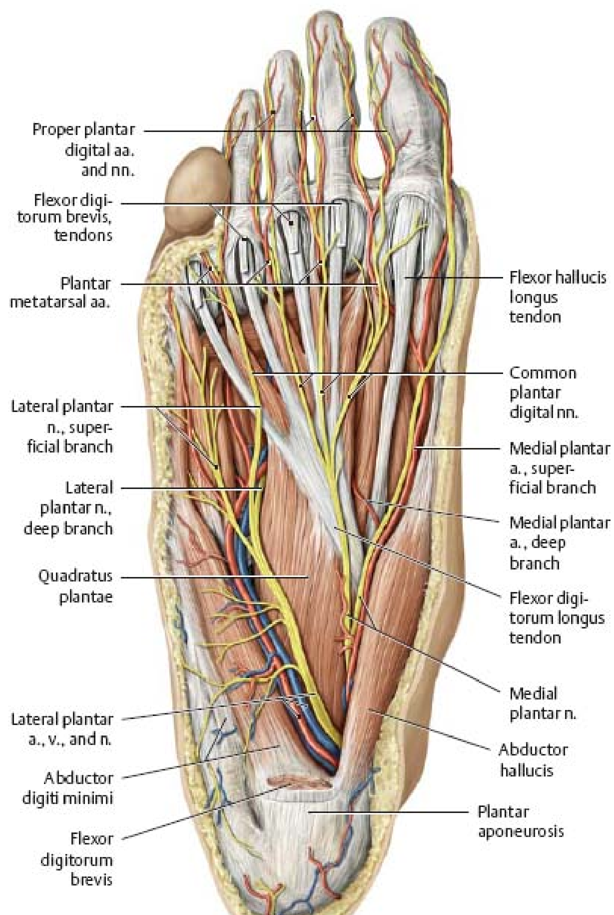
Topography of the Sole of the Foot

Fig. 27.41 Neurovasculature of the foot: Sole

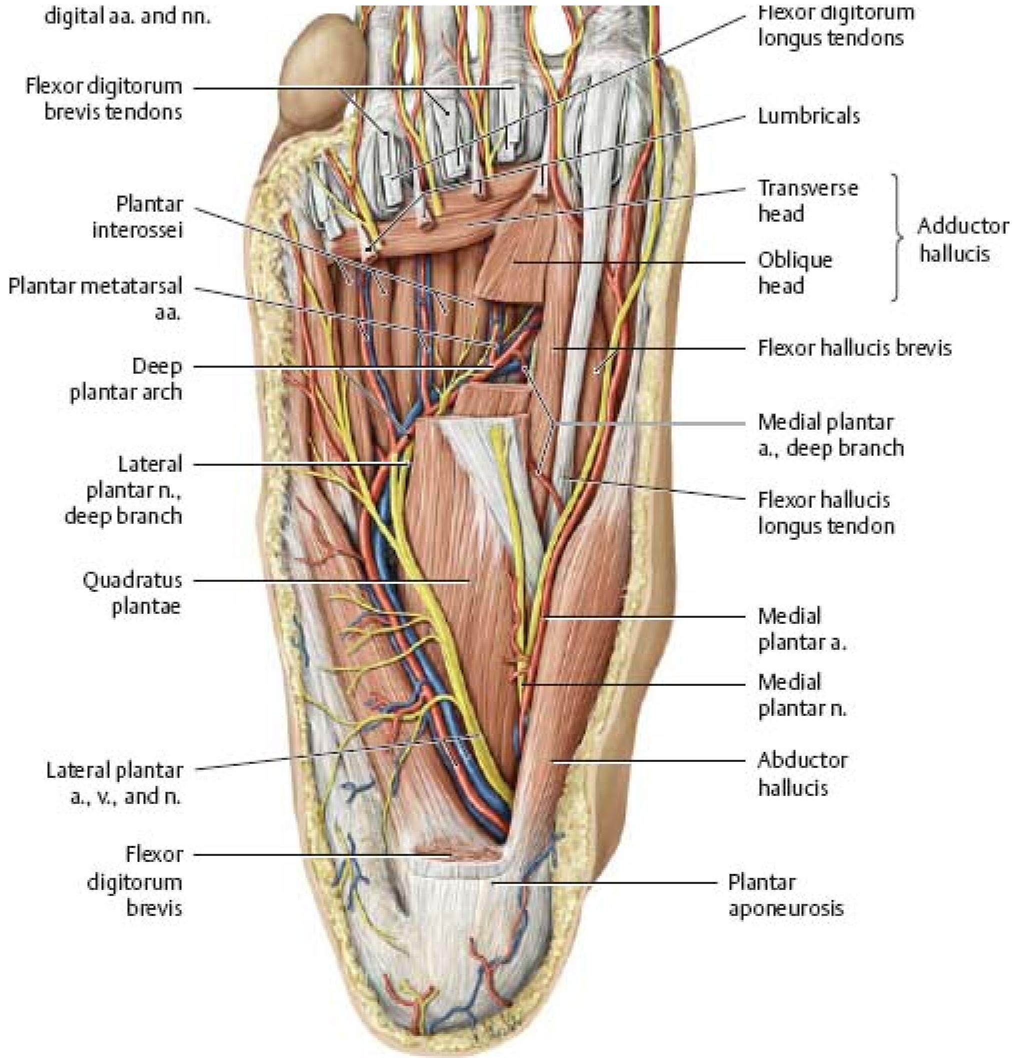
Right foot, plantar view.



A Superficial layer. *Removed:* Skin, subcutaneous tissue, and fascia.



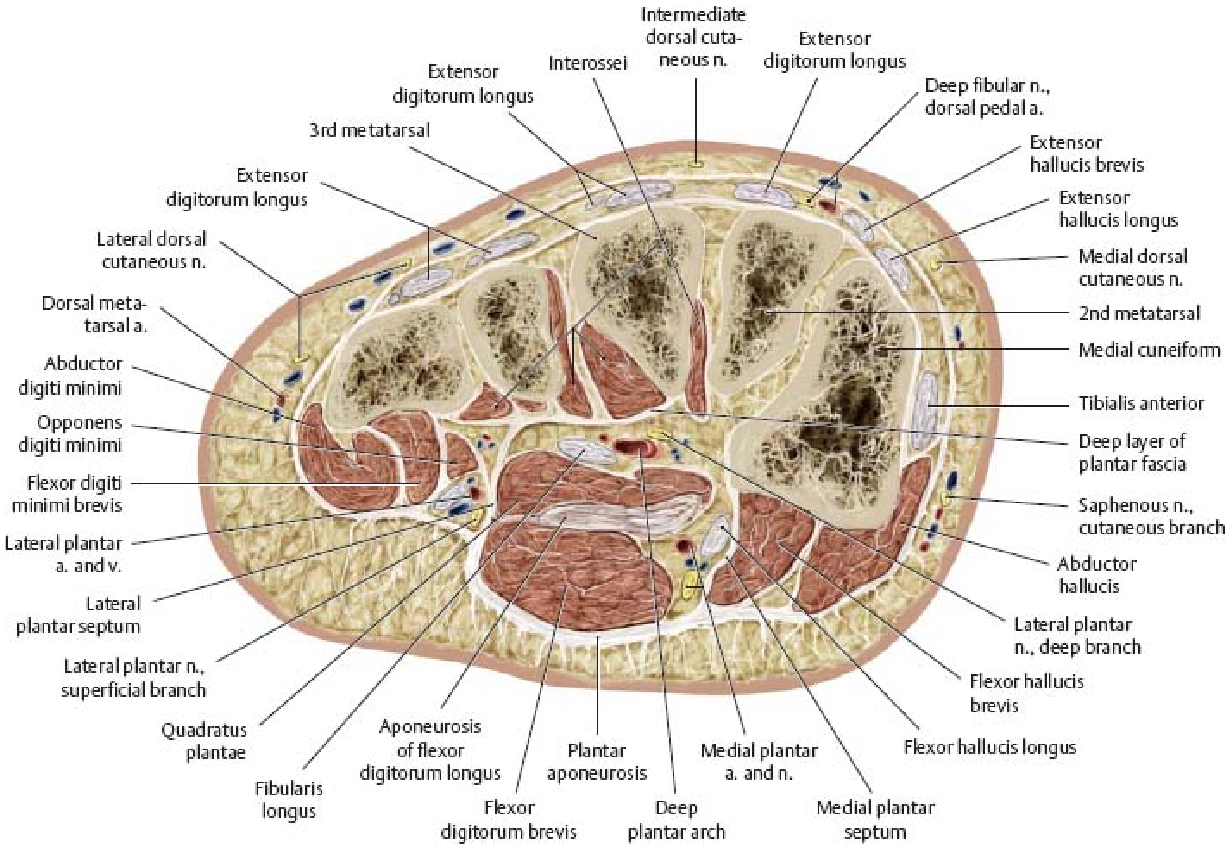
B Middle layer. *Removed:* Plantar aponeurosis and flexor digitorum brevis.



C Deep layer. *Removed:* Flexor digitorum longus. *Windowed:* Adductor hallucis (oblique head).

Fig. 27.42 **Neurovasculature of the foot: Cross section**

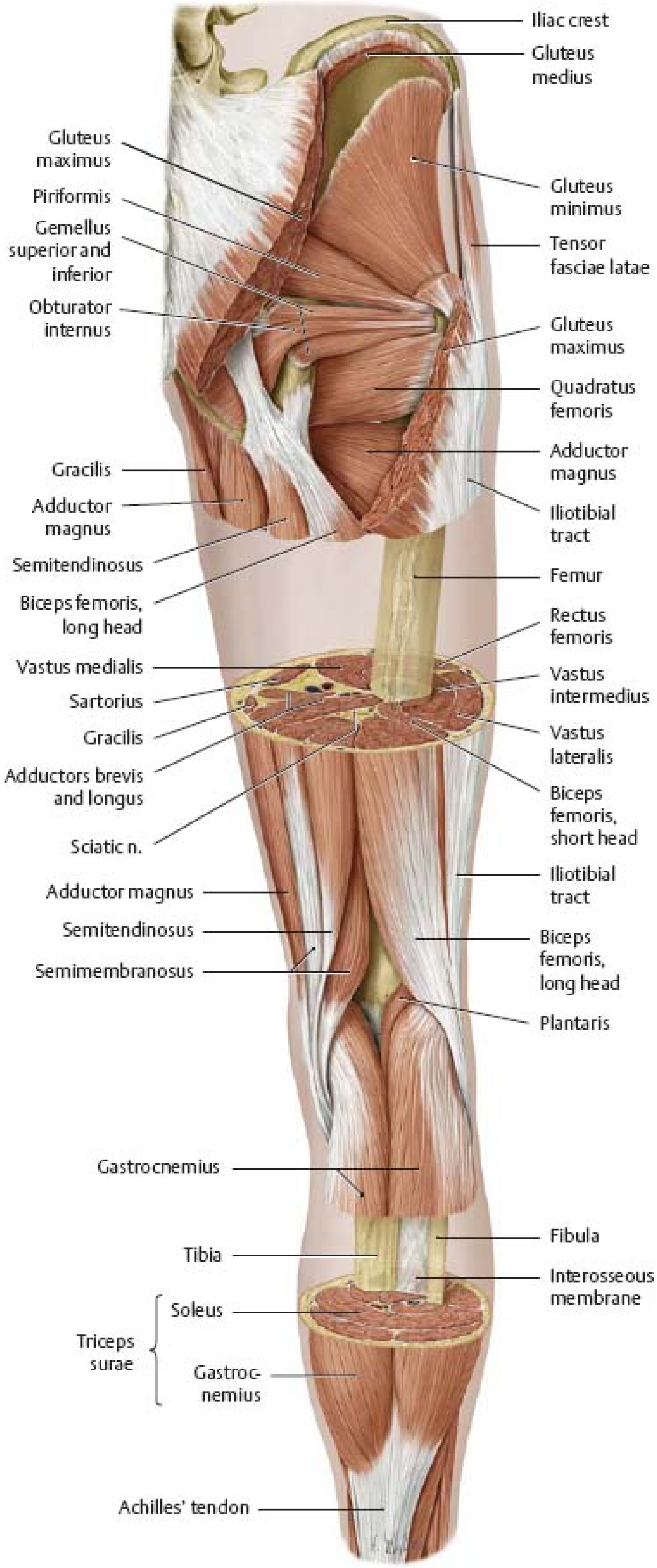
Coronal section, distal view.



Transverse Sections of the Thigh & Leg

Fig. 27.43 Windowed dissection

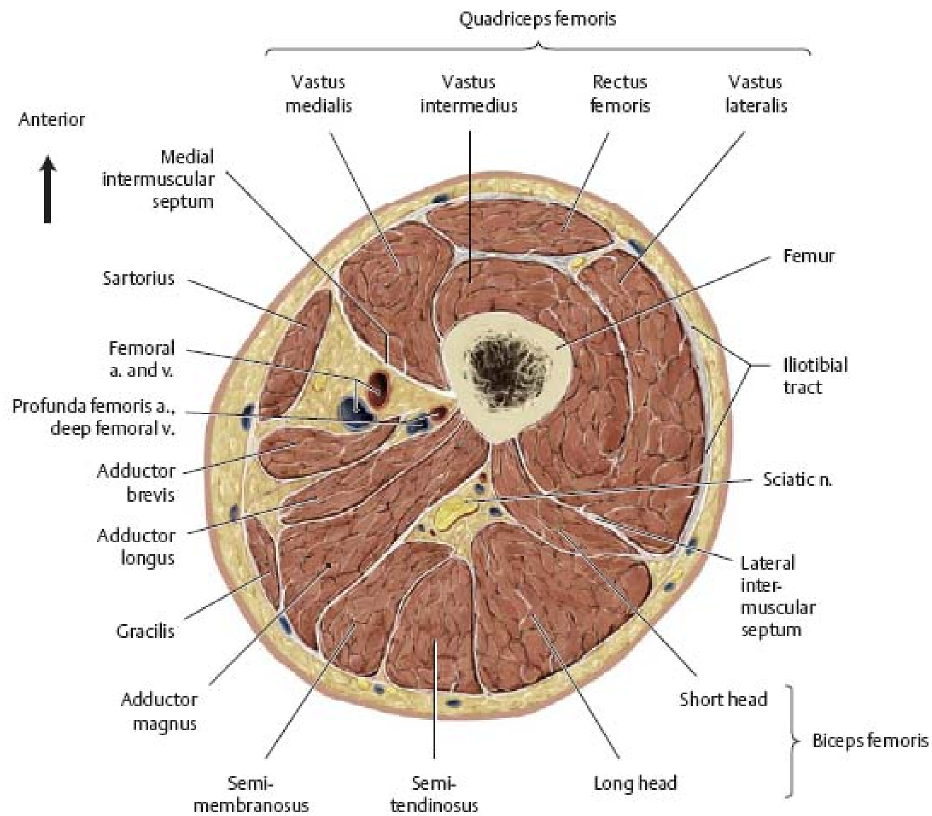
Right limb, posterior view.



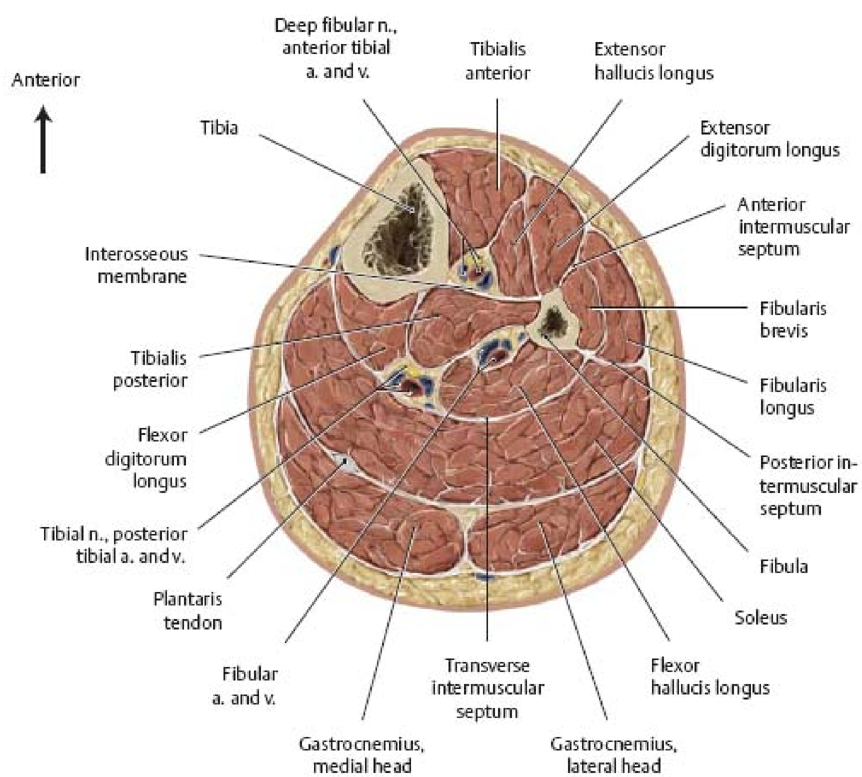
Iliac crest
Gluteus medius
Gluteus maximus
Piriformis
Gemellus superior and inferior
Obturator internus
Gluteus minimus
Tensor fasciae latae
Gluteus maximus
Quadratus femoris
Adductor magnus
Gracilis
Adductor magnus
Iliotibial tract
Semitendinosus
Biceps femoris, long head
Femur
Rectus femoris
Vastus medialis
Sartorius
Gracilis
Adductors brevis and longus
Sciatic n.
Vastus intermedius
Vastus lateralis
Biceps femoris, short head
Iliotibial tract
Adductor magnus
Semitendinosus
Semimembranosus
Biceps femoris, long head
Plantaris
Gastrocnemius
Tibia
Fibula
Interosseous membrane
Triceps surae
Soleus
Gastroc- nemius
Achilles' tendon

Fig. 27.44 **Transverse sections**

Right limb, proximal (superior) view.



A Thigh (plane of section in Fig. 27.43).



B Leg (plane of section in Fig. 27.43).

28 Surface Anatomy

Surface Anatomy

Fig. 28.1 Lower limb: Anterior view

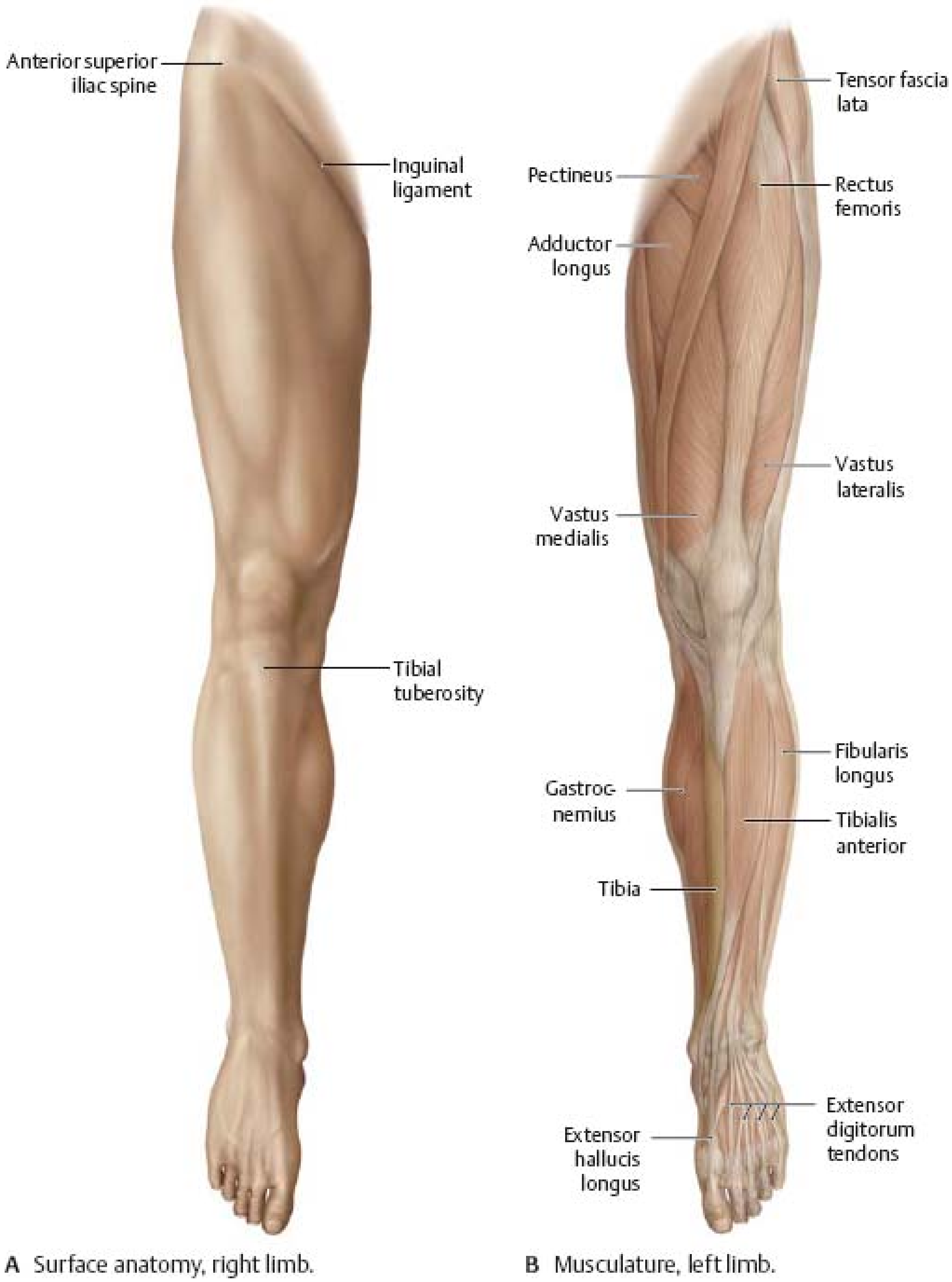
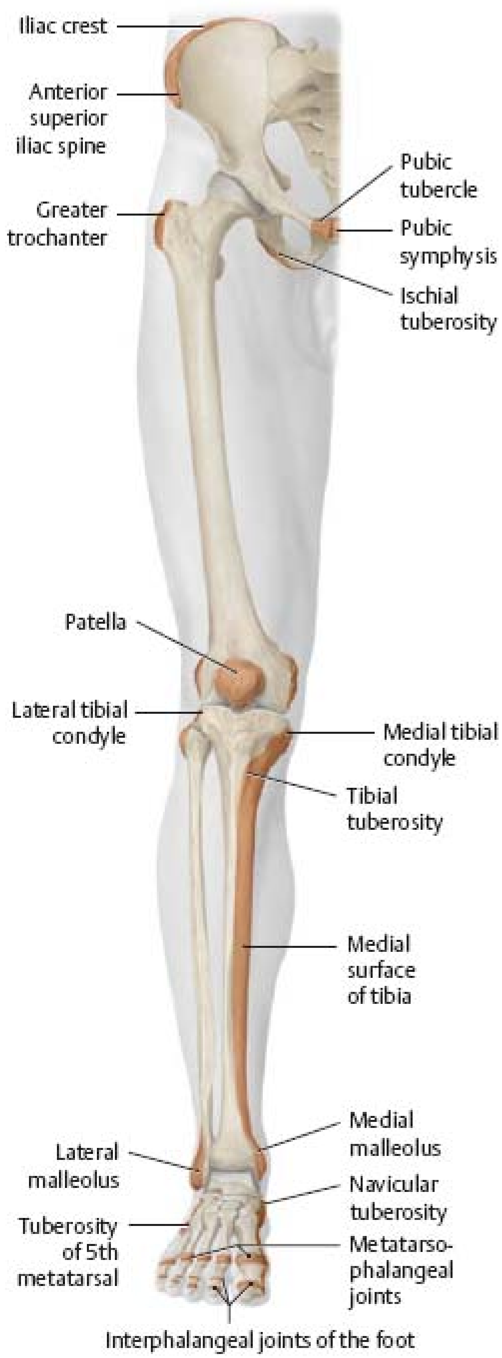


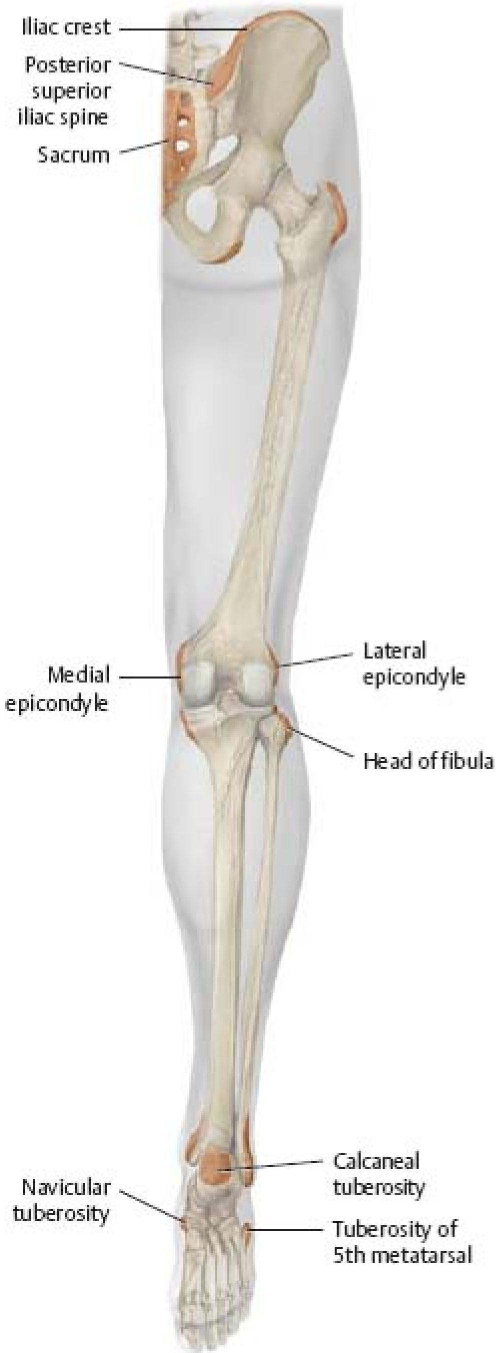
Fig. 28.2 **Palpable bony prominences**

Right limb.



A Anterior view.

Q1: The hip joint is not directly palpable. How would you correctly locate the head of the femur based on surface anatomy?



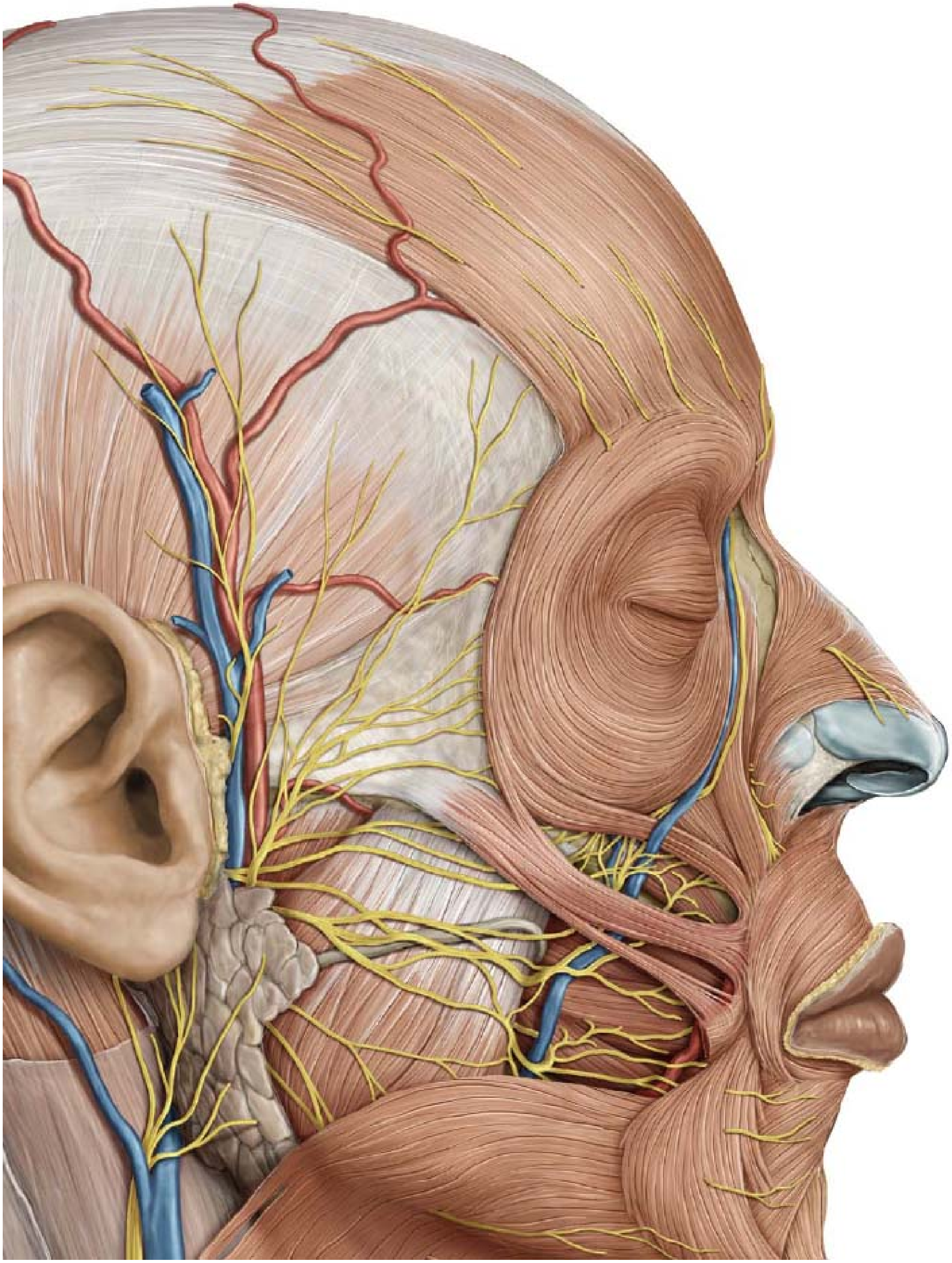
B Posterior view.

Q2: Which palpable landmarks would you use to locate the sciatic nerve (in the gluteal region), the common fibular nerve (at the knee), and the tibial nerve (at the ankle)?

Fig. 28.3 Lower limb: Posterior view

A Surface anatomy, left limb.

B Musculature, right limb.



Head & Neck

29 Bones of the Head

Anterior & Lateral Skull

Fig. 29.1 Lateral skull

Left lateral view.

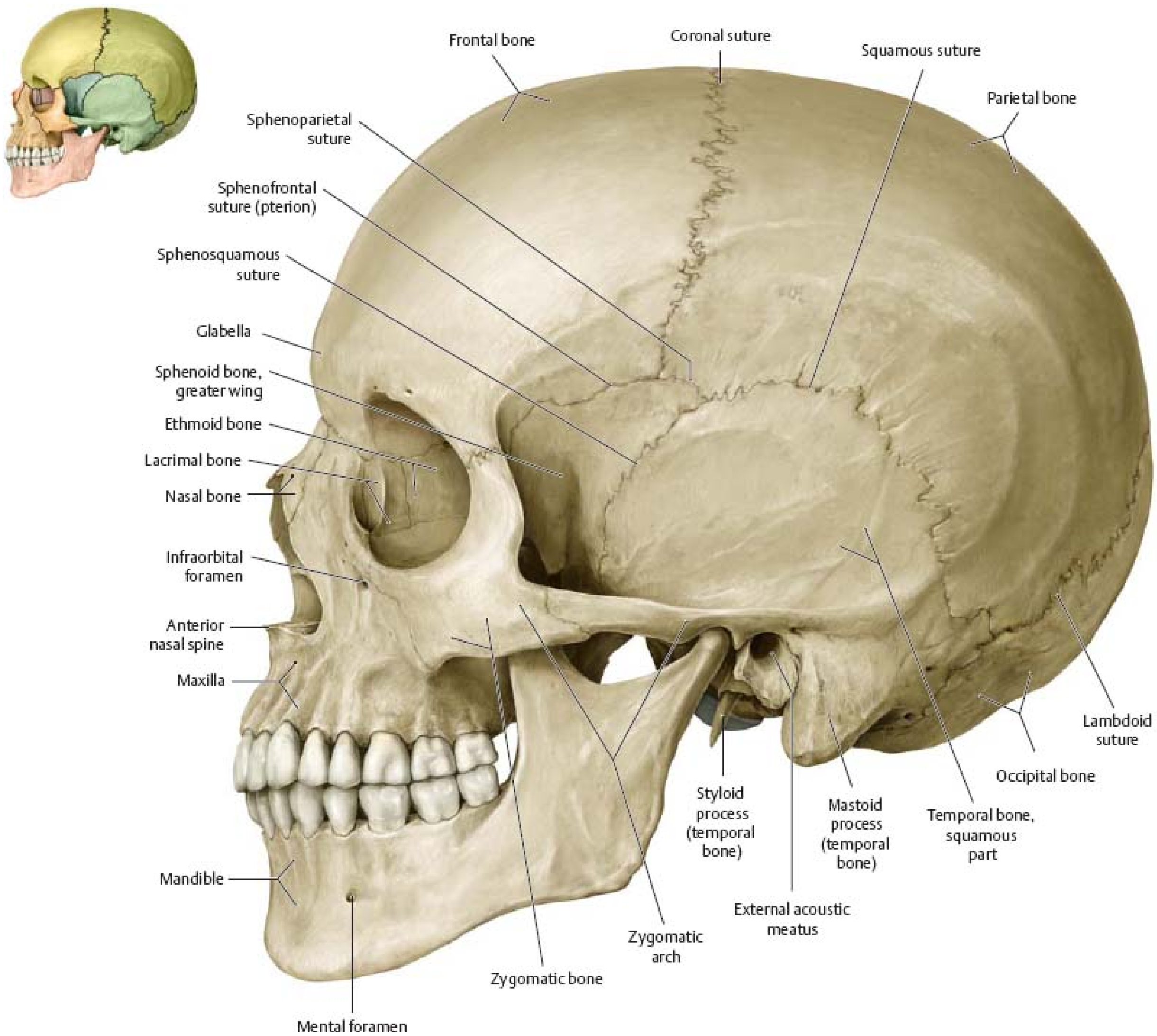


Table 29.1 Bones of the skull

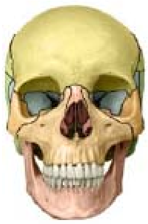
The skull is subdivided into the neurocranium (gray) and viscerocranium (orange). The neurocranium protects the brain, while the viscerocranium houses and protects the facial regions.

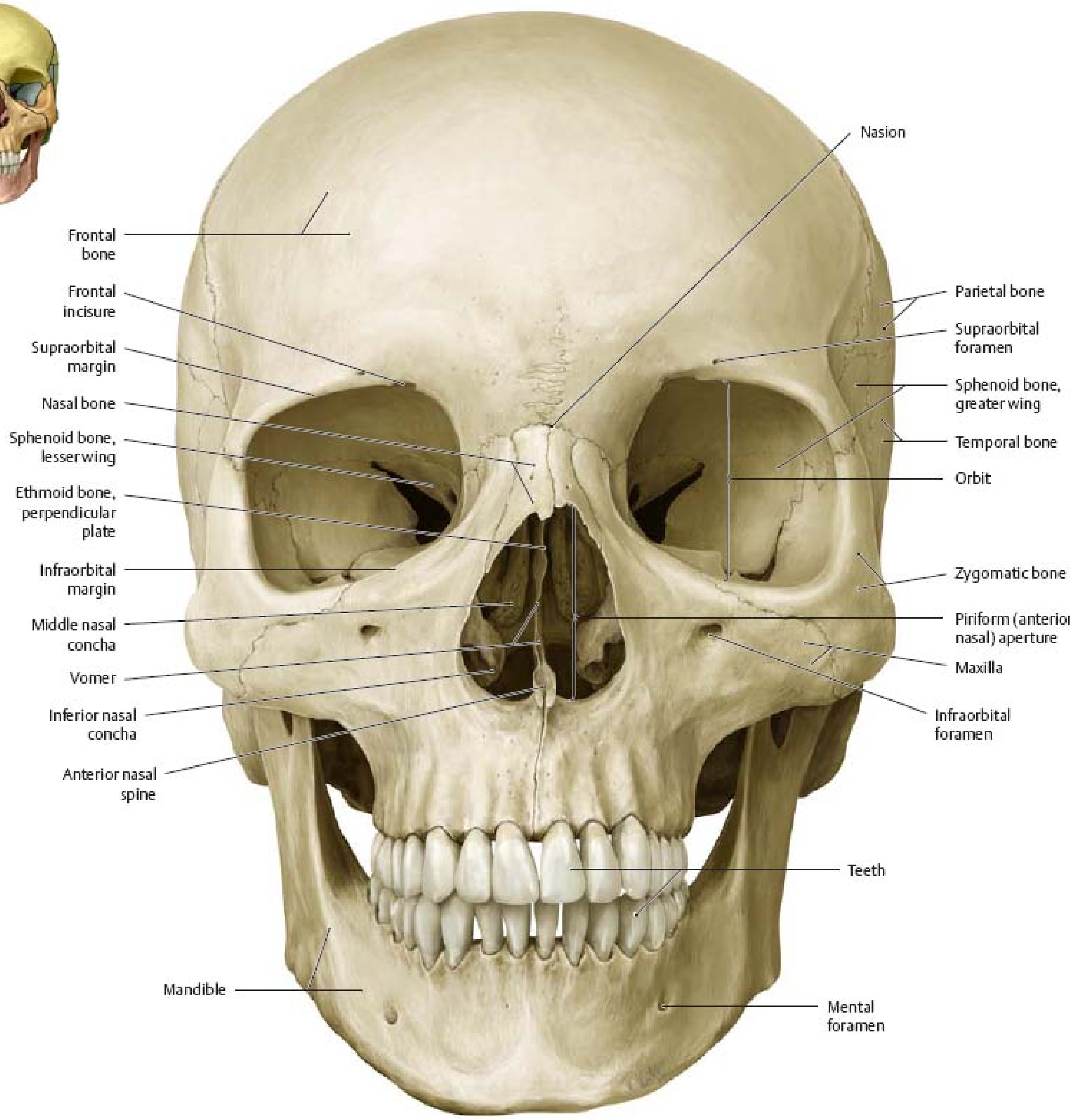
Neurocranium	Viscerocranium	
• Ethmoid bone (cribriform plate)*	• Ethmoid bone	• Mandible
• Frontal bone	• Hyoid bone	• Maxilla
• Occipital bone	• Inferior nasal concha	• Nasal bone
• Parietal bone	• Lacrimal bone	• Palatine bone
• Sphenoid bone	• Sphenoid bone (pterygoid process)	
• Temporal bone (petrous and squamous parts)	• Temporal bone	
	• Vomer	

* Most of the ethmoid bone is in the viscerocranium; most of the sphenoid bone is in the neurocranium. The temporal bone is divided between the two.

Fig. 29.2 Anterior skull

Anterior view.





Clinical

Fractures of the face

The framelike construction of the facial skeleton leads to characteristic patterns for fracture lines (classified as Le Fort I, II, and III fractures).

A Le Fort I. B Le Fort II. C Le Fort III.

Posterior Skull & Calvaria

Fig. 29.3 Posterior skull

Posterior view.

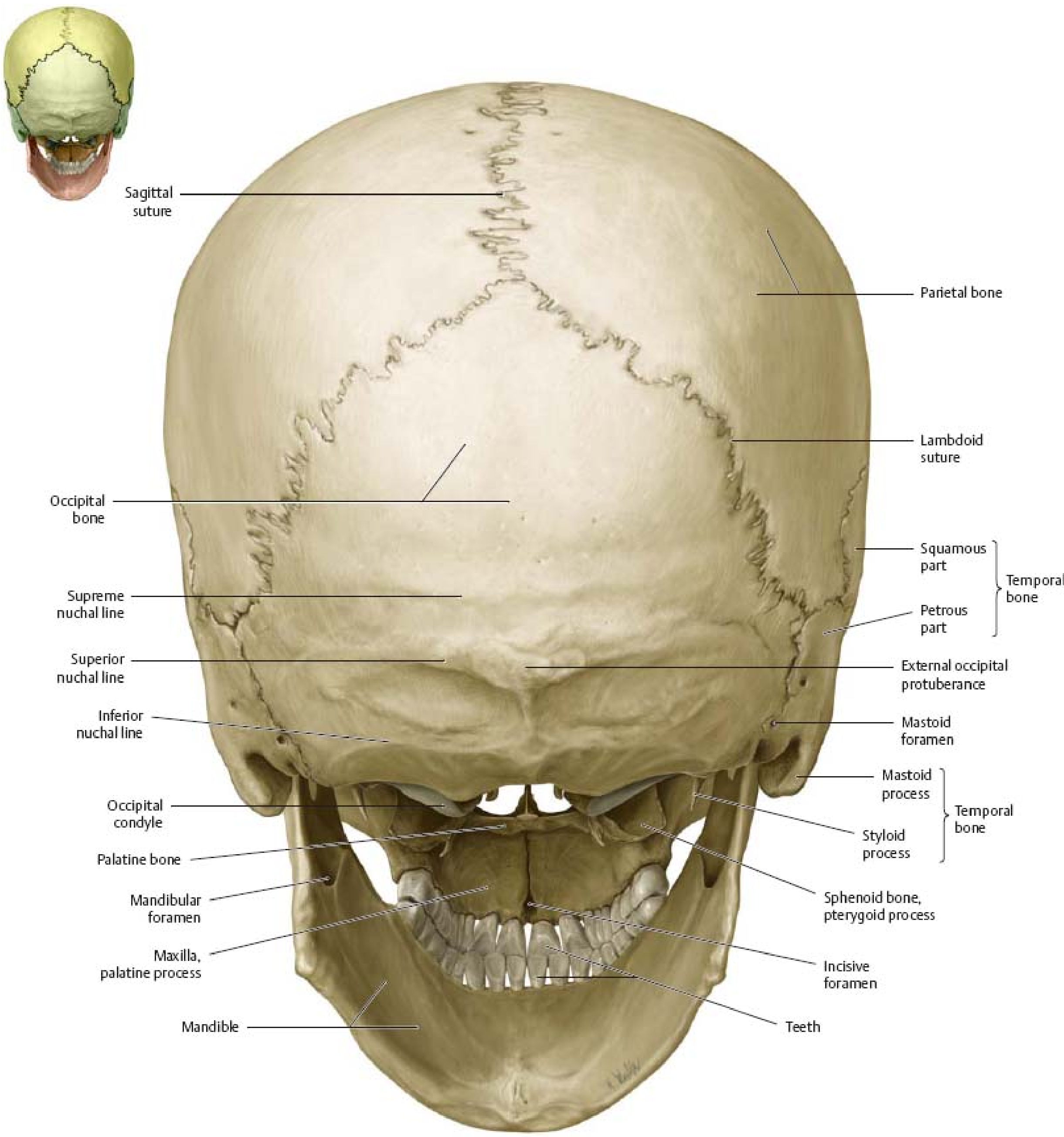


Fig. 29.4 Calvaria

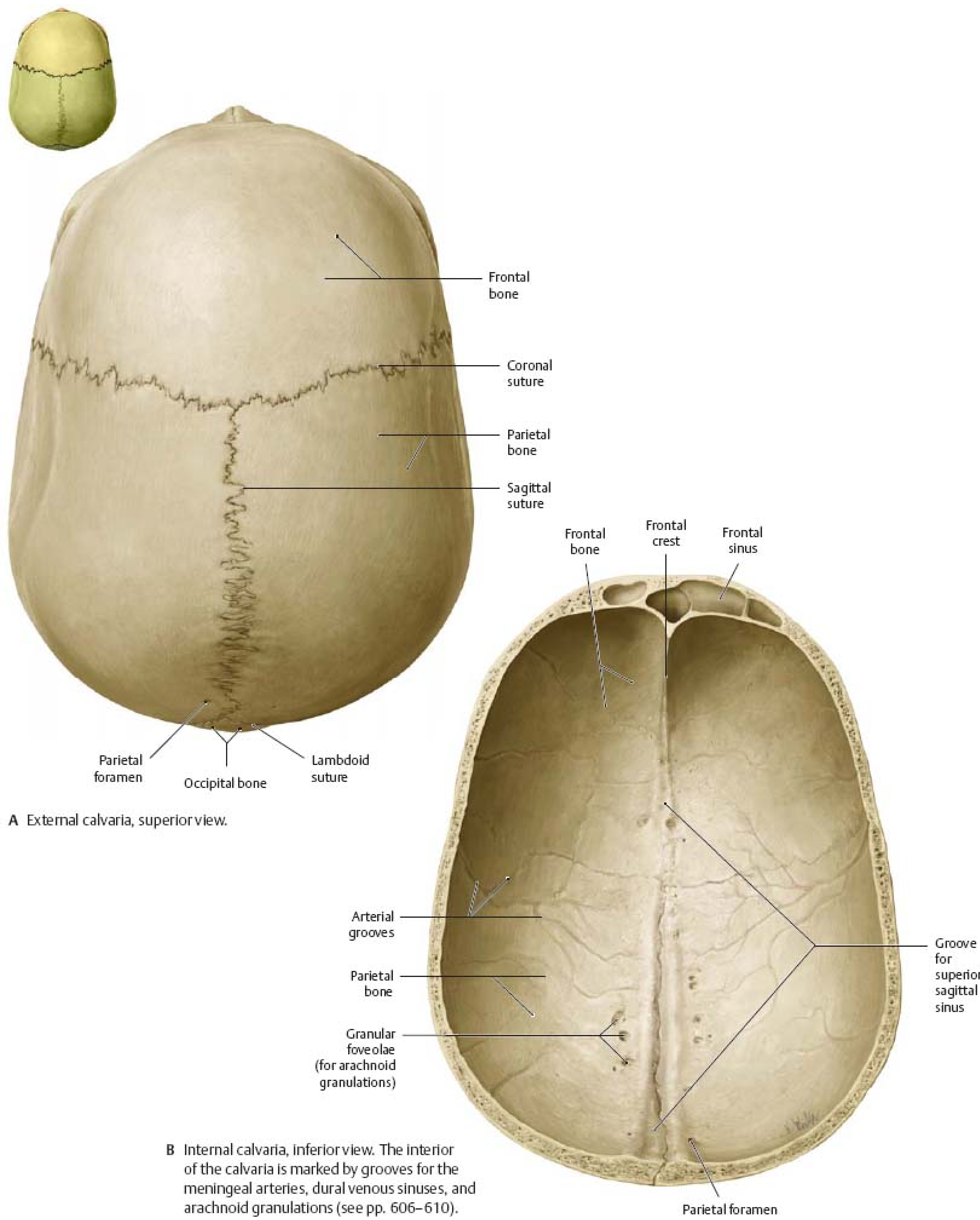
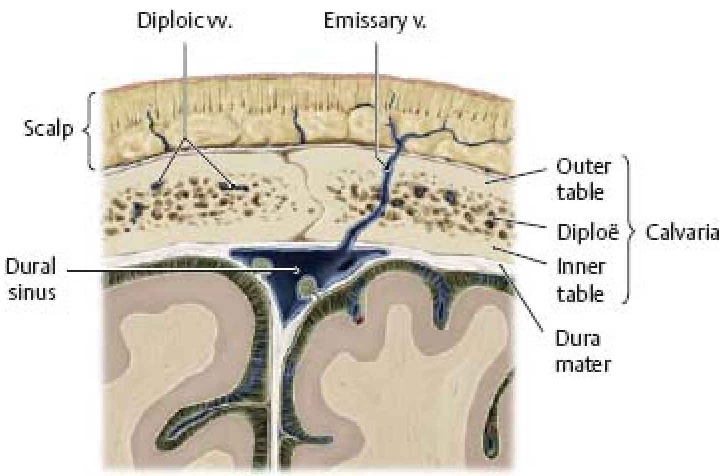


Fig. 29.5 **Structure of the calvaria**

Cross section.



Base of the Skull

Fig. 29.6 Base of the skull: Exterior

Inferior view. *Revealed:* Foramina and canals for blood vessels (see p. 490) and cranial nerves. *Note:* This view allows visual access into the posterior region of the nasal cavity.

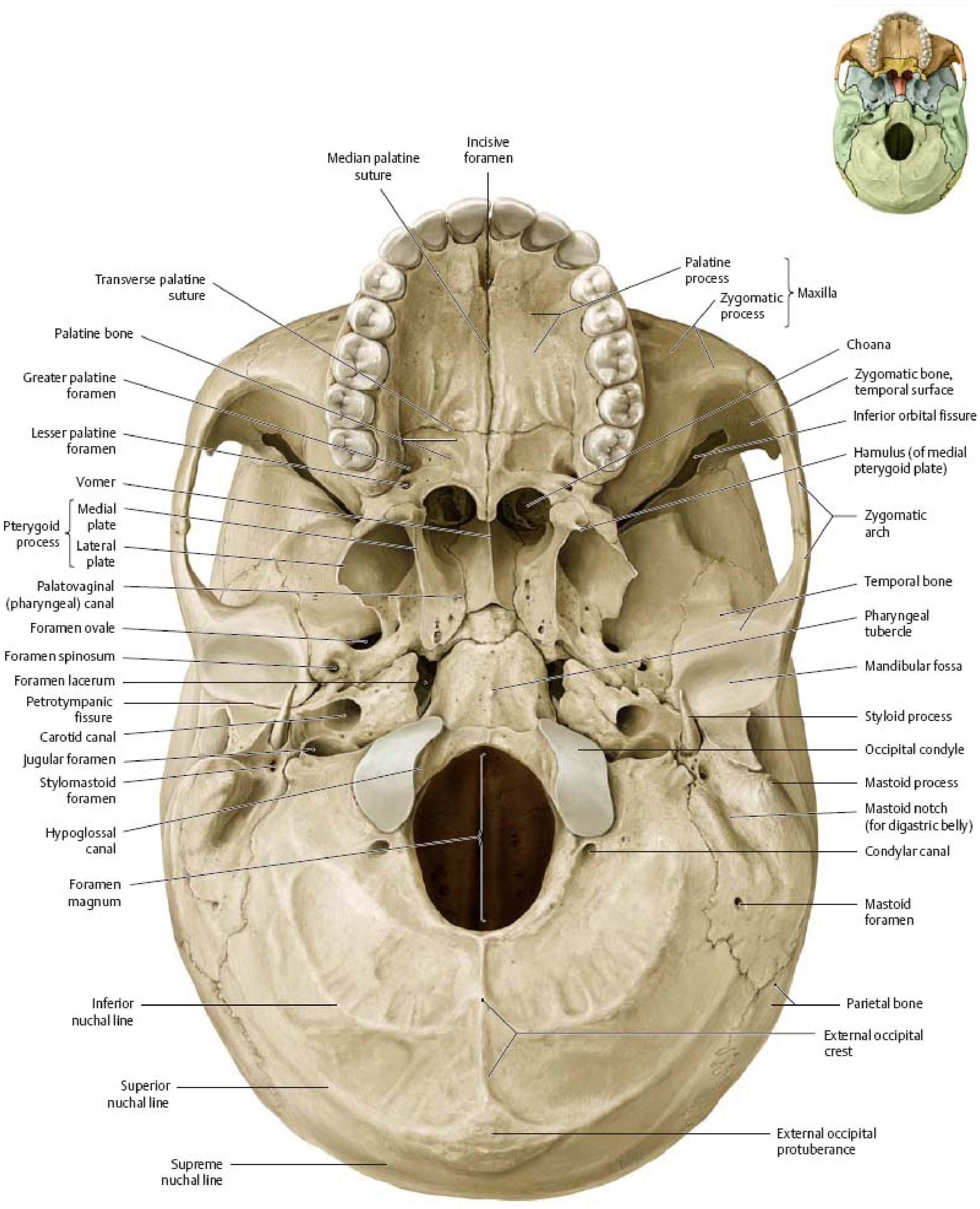
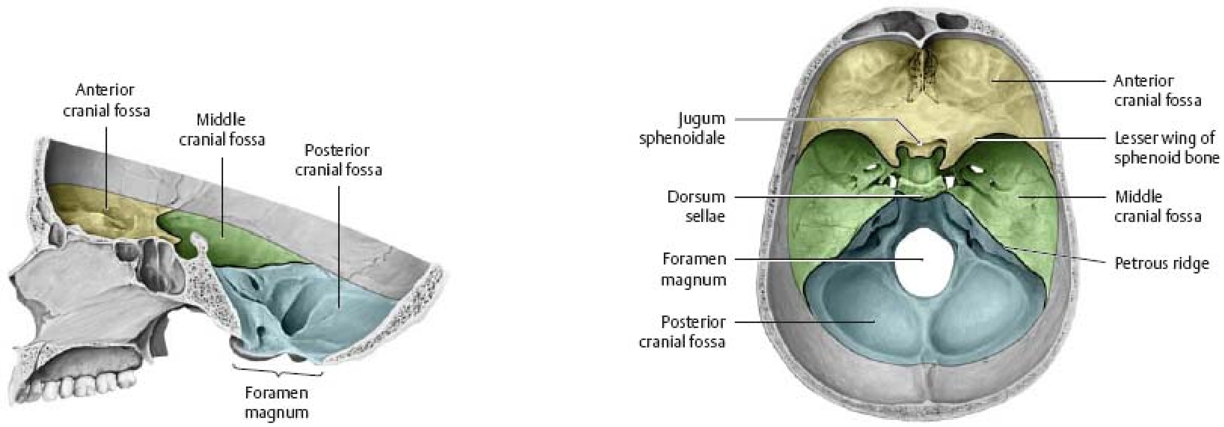


Fig. 29.7 Cranial fossae

The interior of the skull base consists of three successive fossae that become progressively deeper in the frontal-to-occipital direction.

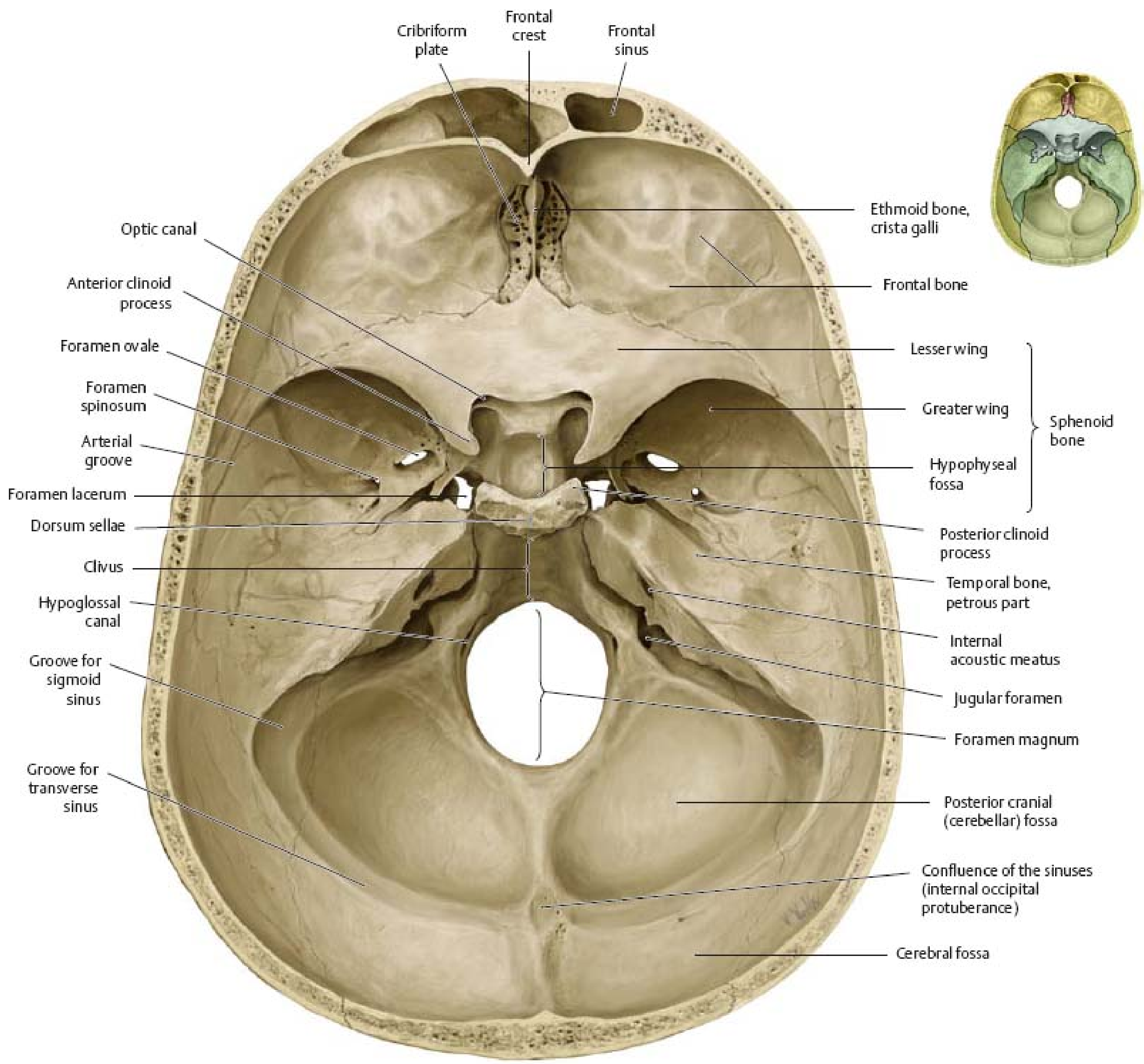


A Midsagittal section, left lateral view.

B Superior view of opened skull.

Fig. 29.8 **Base of the skull: Interior**

Superior view.



Ethmoid & Sphenoid Bones

The structurally complex ethmoid and sphenoid bones are shown here in isolation. The other bones of the skull are shown in their respective regions: orbit (see pp. 506–507), nasal cavity (see pp. 520–521), oral cavity (see pp. 538–539), and ear (see pp. 526–527).

Fig. 29.9 **Ethmoid bone**

The ethmoid bone is the central bone of the nose and paranasal air sinuses (see pp. 520–523).

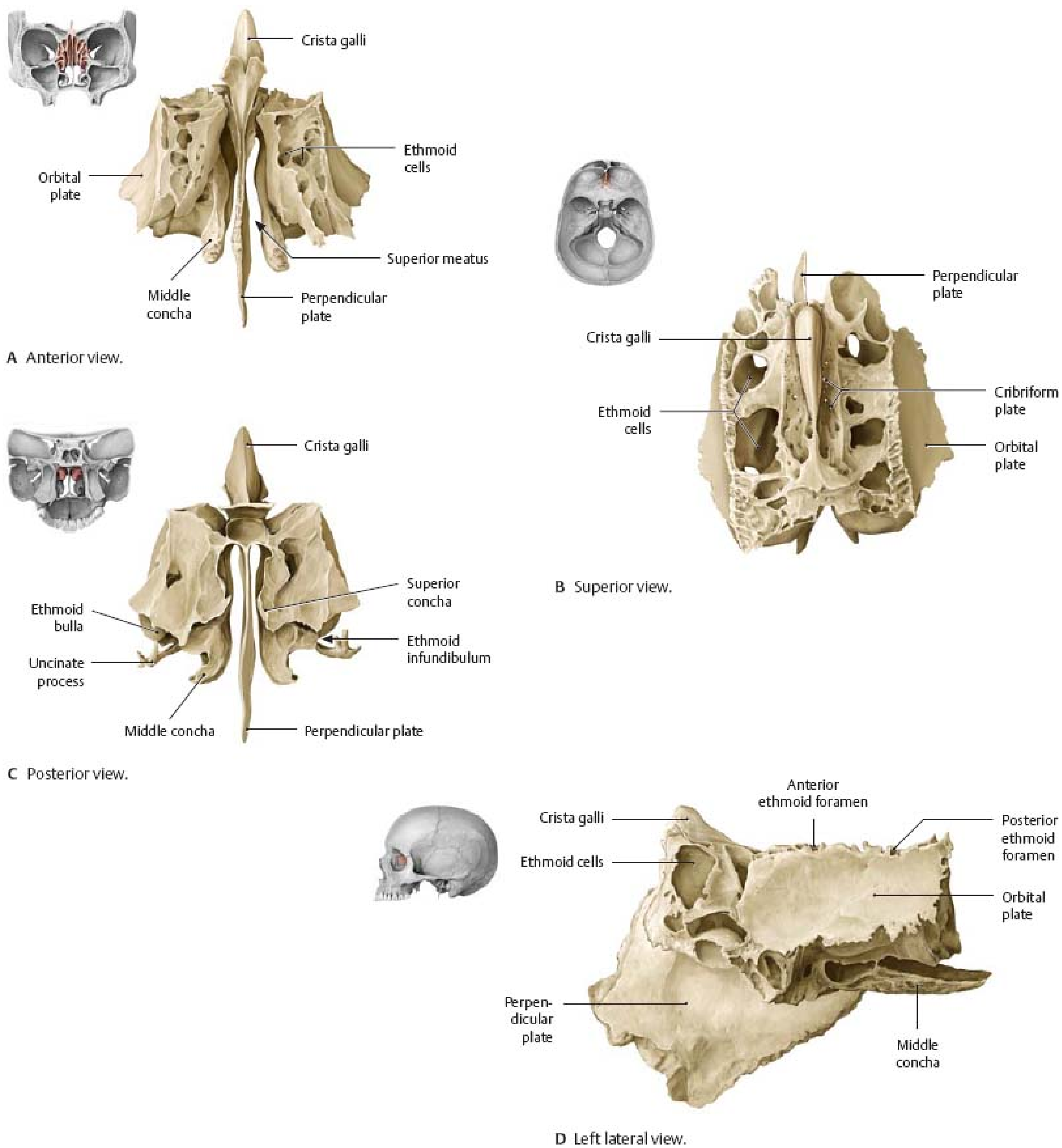
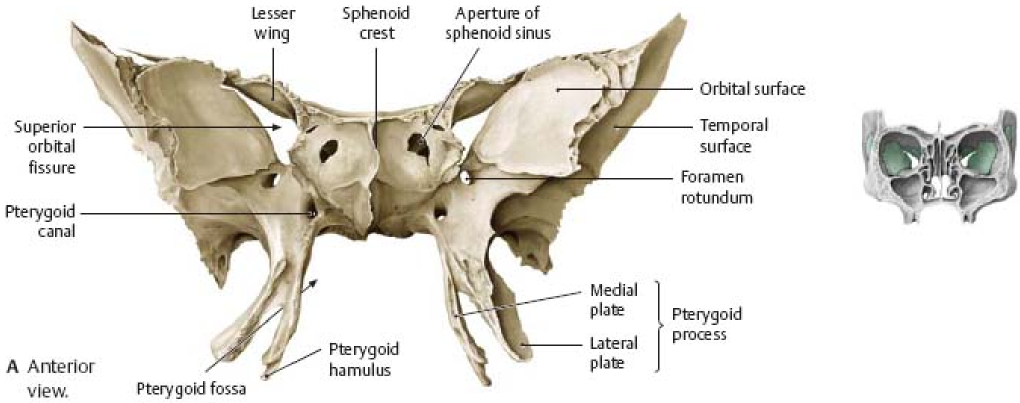
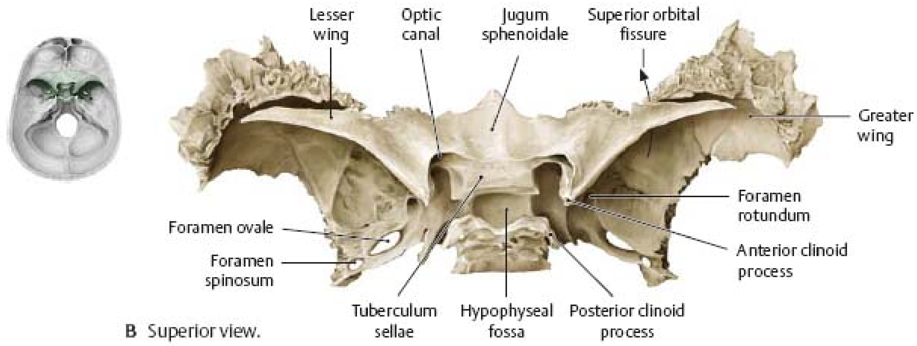


Fig. 29.10 **Sphenoid bone**

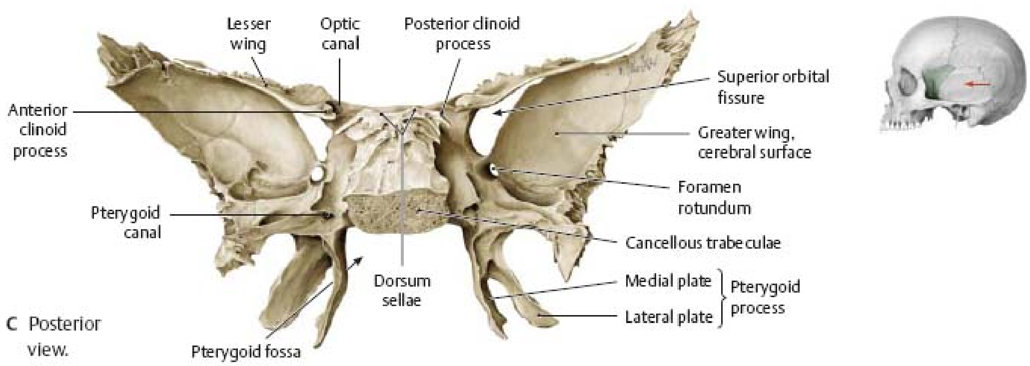
The sphenoid bone is the most structurally complex bone in the human body.



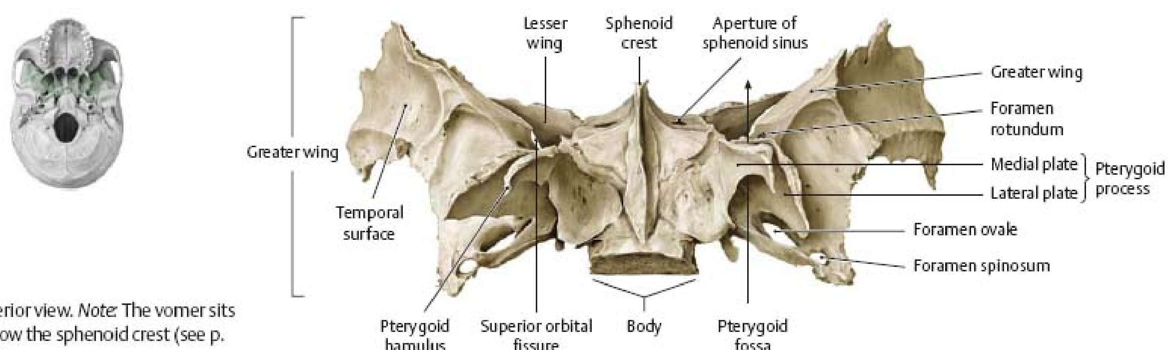
A Anterior view.



B Superior view.



C Posterior view.



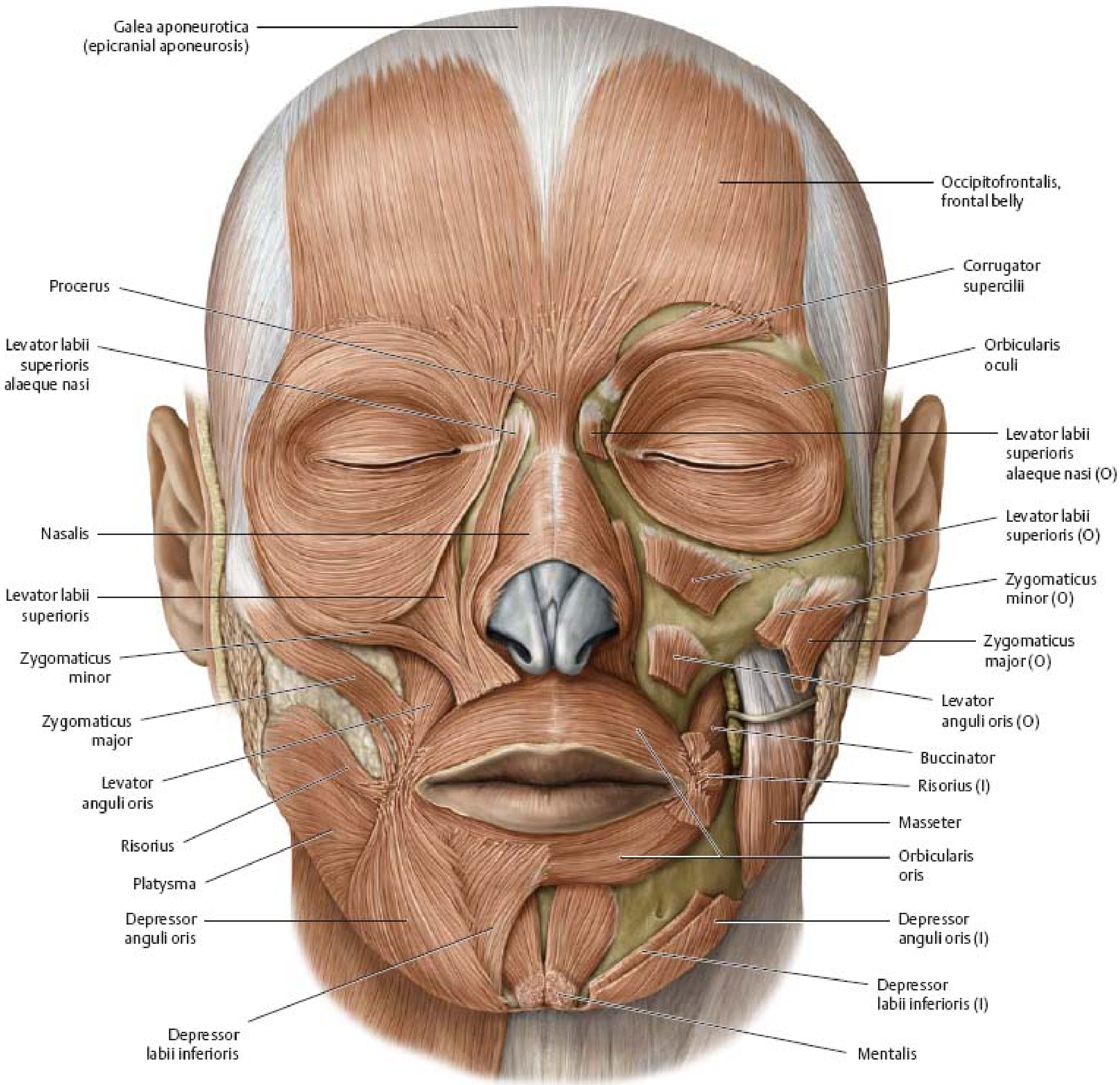
D Inferior view. *Note:* The vomer sits below the sphenoid crest (see p. 538).

30 Muscles of the Skull & Face

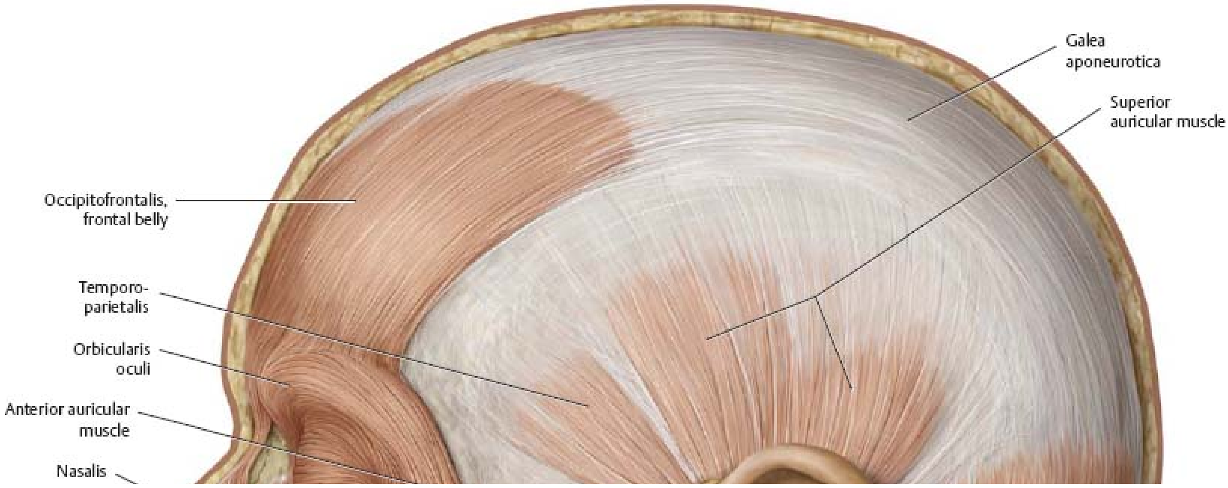
Muscles of Facial Expression & of Mastication

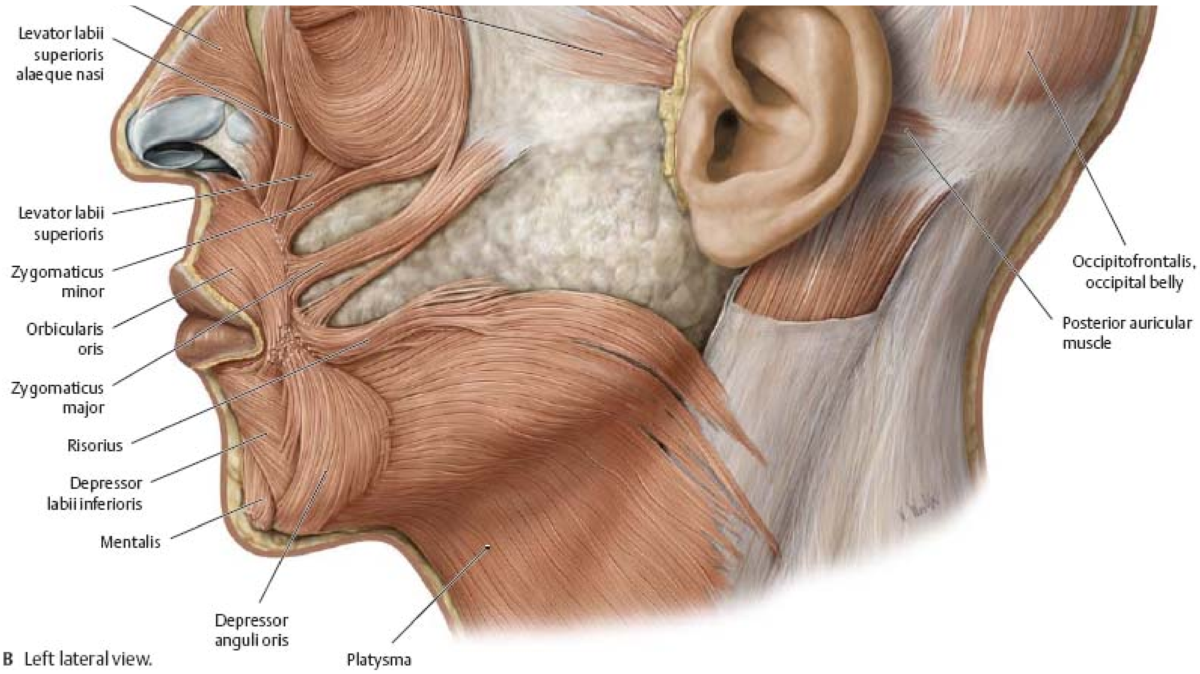
The muscles of the skull and face are divided into two groups. The muscles of facial expression make up the superficial muscle layer in the face. The muscles of mastication are responsible for the movement of the mandible during mastication (chewing).

Fig. 30.1 Muscles of facial expression



A Anterior view. Muscle origins (O) and insertions (I) indicated on left side of face.

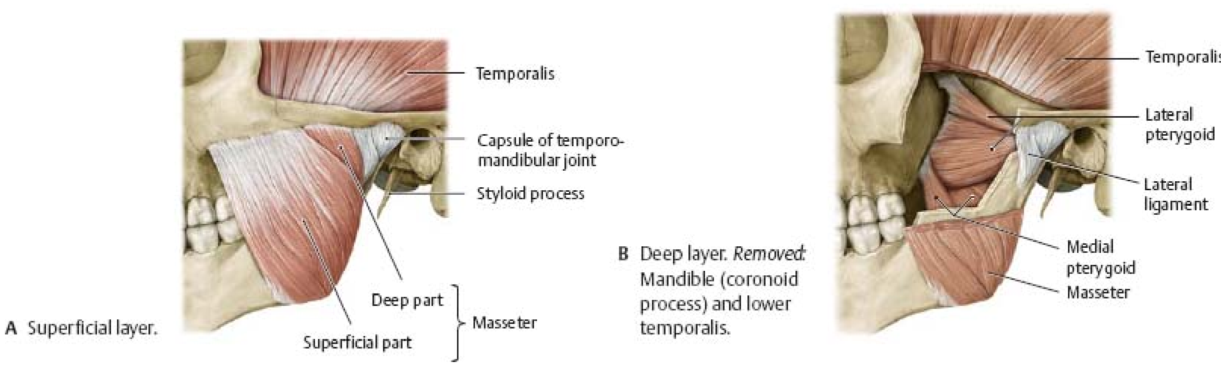




B Left lateral view.

Fig. 30.2 Muscles of mastication

Left lateral view.



Muscle Origins & Insertions on the Skull

Fig. 30.3 Lateral skull: Origins and insertions

Left lateral view. Muscle origins (red), insertions (blue). *Note:* There are generally no bony insertions for the muscles of facial expression. These muscles insert into skin and other muscles of facial expression.

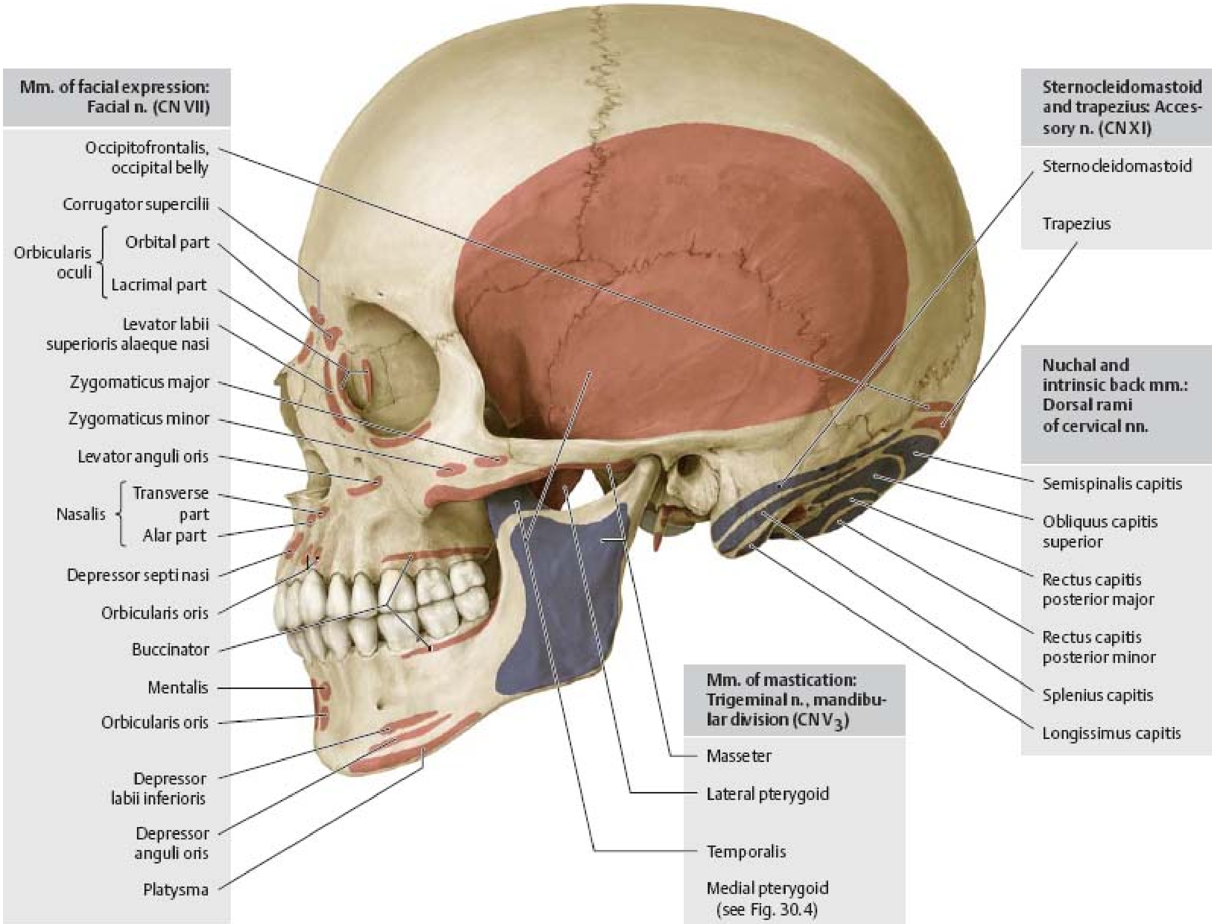


Fig. 30.4 Mandible: Origins and insertions

Medial view of right hemimandible (inner surface). Muscle origins (red), insertions (blue).

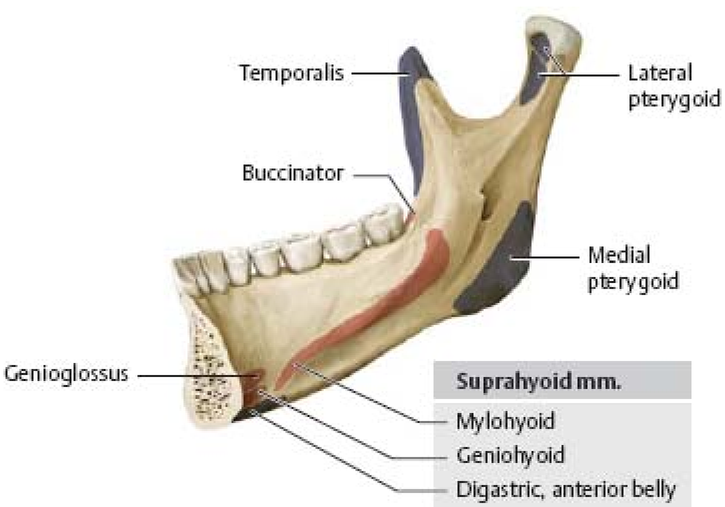


Fig. 30.5 Skull base: Origins and insertions

Inferior view of external skull. Muscle origins (red), insertions (blue).

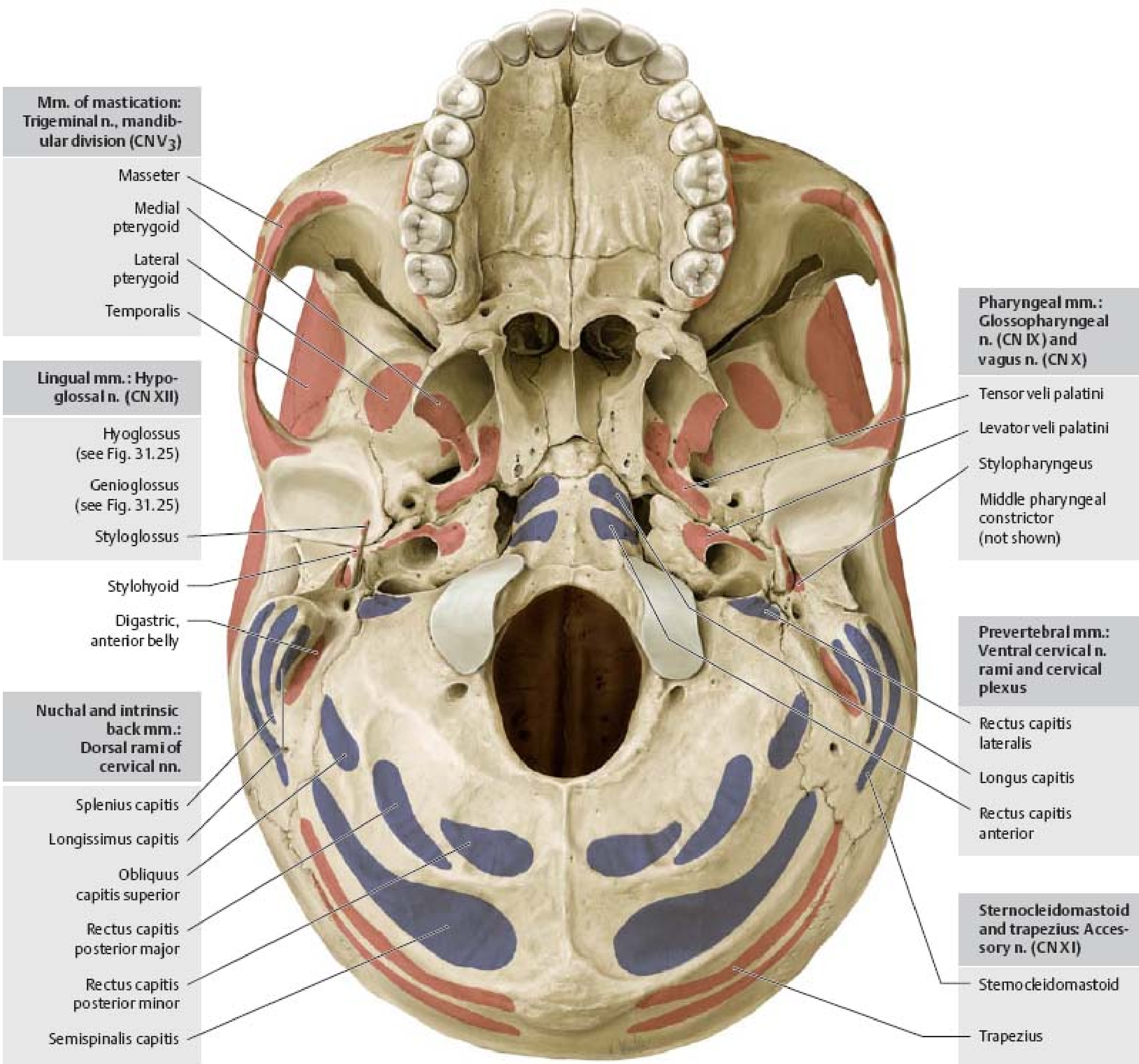
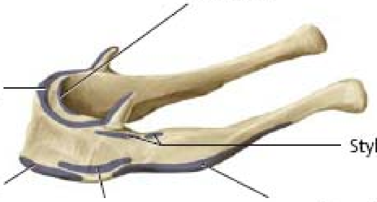


Fig. 30.6 Hyoid bone: Origins and insertions

Muscle origins (red), insertions (blue).

A Anterior view.



B Oblique left lateral view.

Muscle Facts (I)

The muscles of facial expression originate on bone and/or fascia, and insert into the subcutaneous tissue of the face. This allows them to produce their effects by pulling on the skin.

Fig. 30.7 Occipitofrontalis

Anterior view.

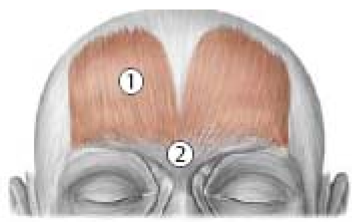
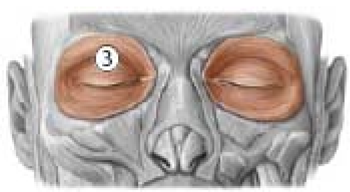
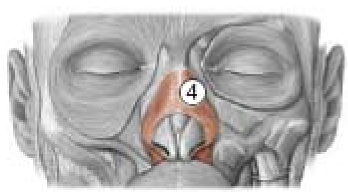


Fig. 30.8 Muscles of the palpebral fissure and nose

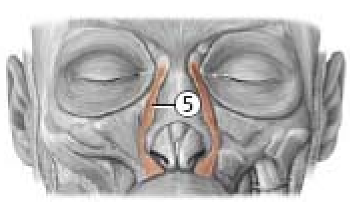
Anterior view.



A Orbicularis oculi.



B Nasalis.



C Levator labii superioris alaeque nasi.

Fig. 30.9 Muscles of the ear

Left lateral view.

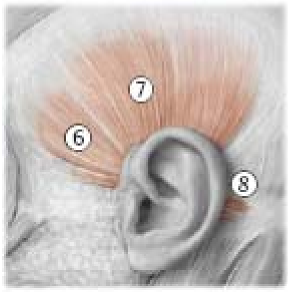


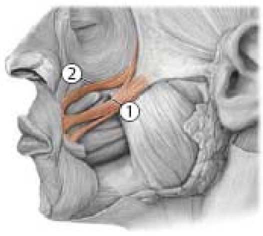
Table 30.1 Muscles of facial expression: Forehead, nose, and ear

Muscle	Origin	Insertion*	Main action(s)**
Calvaria			
① Occipitofrontalis (frontal belly)	Epicranial aponeurosis	Skin and subcutaneous tissue of eyebrows and forehead	Elevates eyebrows, wrinkles skin of forehead
Palpebral fissure and nose			
② Procerus	Nasal bone, lateral nasal cartilage (upper part)	Skin of lower forehead between eyebrows	Pulls medial angle of eyebrows inferiorly, producing transverse wrinkles over bridge of nose
③ Orbicularis oculi	Medial orbital margin, medial palpebral ligament; lacrimal bone	Skin around margin of orbit, superior and inferior tarsal plates	Acts as orbital sphincter (closes eyelids) • Palpebral portion gently closes • Orbital portion tightly closes (as in winking)
④ Nasalis	Maxilla (superior region of canine ridge)	Nasal cartilages	Flares nostrils by drawing ala (side) of nose toward nasal septum
⑤ Levator labii superioris alaeque nasi	Maxilla (frontal process)	Alar cartilage of nose and upper lip	Elevates upper lip, opens nostril
Ear			
⑥ Anterior auricular muscles	Temporal fascia (anterior portion)	Helix of the ear	Pull ear superiorly and anteriorly
⑦ Superior auricular muscles	Epicranial aponeurosis on side of head	Upper portion of auricle	Elevate ear
⑧ Posterior auricular muscles	Mastoid process	Convexity of concha of ear	Pull ear superiorly and posteriorly

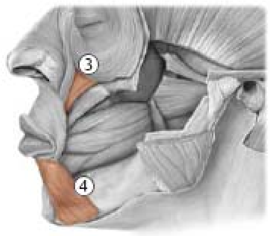
*There are no bony insertions for the muscles of facial expression.
**All muscles of facial expression are innervated by the facial nerve (CN VII) via temporal, zygomatic, buccal, mandibular, or cervical branches arising from the parotid plexus (see p. 478).

Fig. 30.10 Muscles of the mouth

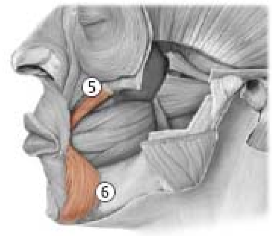
Left lateral view.



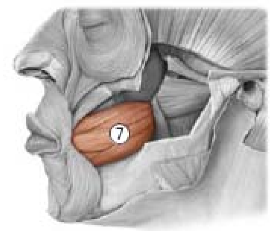
A Zygomaticus major and minor.



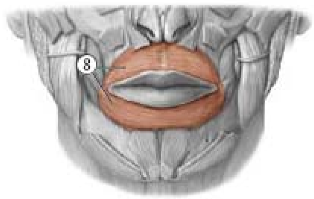
B Levator labii superioris and depressor labii inferioris.



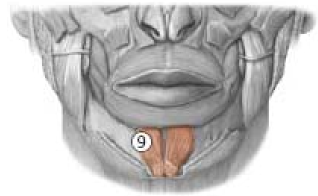
C Levator and depressor anguli oris.



D Buccinator.



E Orbicularis oris, anterior view.



F Mentalis, anterior view.

Table 30.2 Muscles of facial expression: Mouth and neck

Muscle	Origin	Insertion*	Main action(s)**
Mouth			
① Zygomaticus major	Zygomatic bone (lateral surface, posterior part)	Skin at corner of the mouth	Pulls corner of mouth superiorly and laterally
② Zygomaticus minor		Upper lip just medial to corner of the mouth	Pulls upper lip superiorly
Levator labii superioris alaeque nasi (see Fig. 30.8C)	Maxilla (frontal process)	Alar cartilage of nose and upper lip	Elevates upper lip, opens nostril
③ Levator labii superioris	Maxilla (frontal process) and infraorbital region	Skin of upper lip, alar cartilages of nose	Elevates upper lip, dilates nostril, raises angle of the mouth
④ Depressor labii inferioris	Mandible (anterior portion of oblique line)	Lower lip at midline; blends with muscle from opposite side	Pulls lower lip inferiorly and laterally
⑤ Levator anguli oris	Maxilla (below infraorbital foramen)	Skin at corner of the mouth	Raises angle of mouth, helps form nasolabial furrow
⑥ Depressor anguli oris	Mandible (oblique line below canine, premolar, and first molar teeth)	Skin at corner of the mouth; blends with orbicularis oris	Pulls angle of mouth inferiorly and laterally
⑦ Buccinator	Mandible, alveolar processes of maxilla and mandible, pterygo-mandibular raphe	Angle of mouth, orbicularis oris	Presses cheek against molar teeth, working with tongue to keep food between occlusal surfaces and out of oral vestibule; expels air from oral cavity/resists distension when blowing *Unilateral:* Draws mouth to one side
⑧ Orbicularis oris	Deep surface of skin Superiorly: maxilla (median plane) Inferiorly: mandible	Mucous membrane of lips	Acts as oral sphincter • Compresses and protrudes lips (e.g., when whistling, sucking, and kissing) • Resists distension (when blowing)
Risorius (see p. 462)	Fascia over masseter	Skin of corner of the mouth	Retracts corner of mouth as in grimacing
⑨ Mentalis	Mandible (incisive fossa)	Skin of chin	Elevates and protrudes lower lip
Neck			
Platysma (see p. 463)	Skin over lower neck and upper lateral thorax	Mandible (inferior border), skin over lower face, angle of mouth	Depresses and wrinkles skin of lower face and mouth; tenses skin of neck; aids in forced depression of the mandible

*There are no bony insertions for the muscles of facial expression.
**All muscles of facial expression are innervated by the facial nerve (CN VII) via temporal, zygomatic, buccal, mandibular, or cervical branches arising from its parotid plexus.

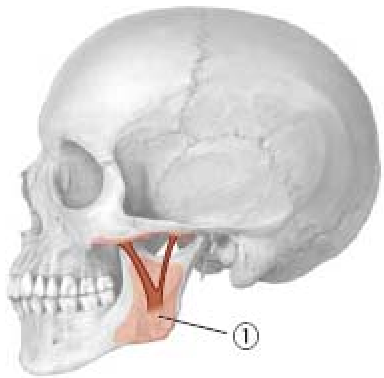
Muscle Facts (II)

The muscles of mastication are located at various depths in the parotid and infratemporal regions of the face. They attach to the mandible and receive their motor innervation from the mandibular division of the trigeminal nerve (CN V_3). The muscles of the oral floor that aid in opening the mouth are found on p. 562.

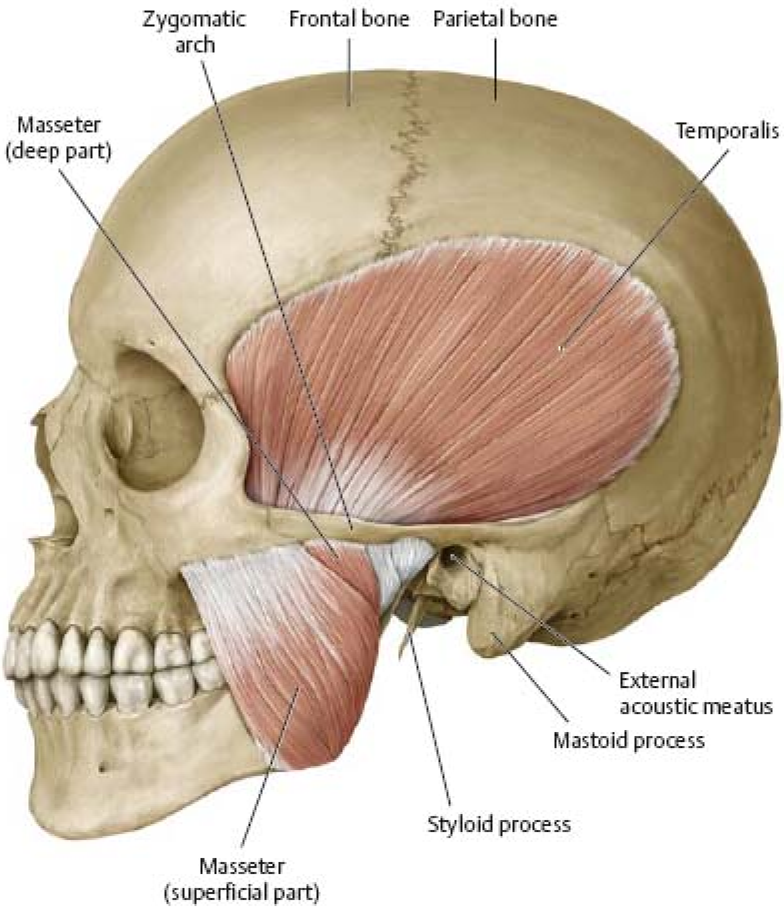
Table 30.3	Muscles of mastication: Masseter and temporalis			
Muscle	**Origin**	**Insertion**	**Innervation**	**Action**
① Masseter	Superficial part: zygomatic arch (anterior two thirds)	Mandibular angle (masseteric tuberosity)	Mandibular n. (CN V_3) via masseteric n.	Elevates (adducts) and protrudes mandible
	Deep part: zygomatic arch (posterior one third)			
② Temporalis	Temporal fossa (inferior temporal line)	Coronoid process of mandible (apex and medial surface)	Mandibular n. (CN V_3) via deep temporal nn.	*Vertical fibers:* Elevate (adduct) mandible *Horizontal fibers:* Retract (retrude) mandible *Unilateral:* Lateral movement of mandible (chewing)

Fig. 30.11 Masseter muscle

Left lateral view.



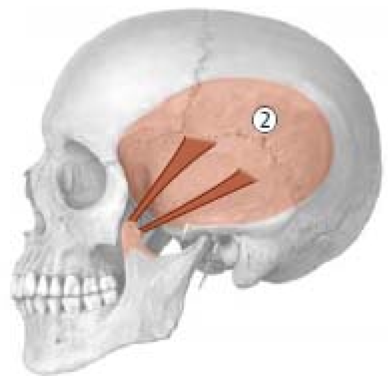
A Schematic.



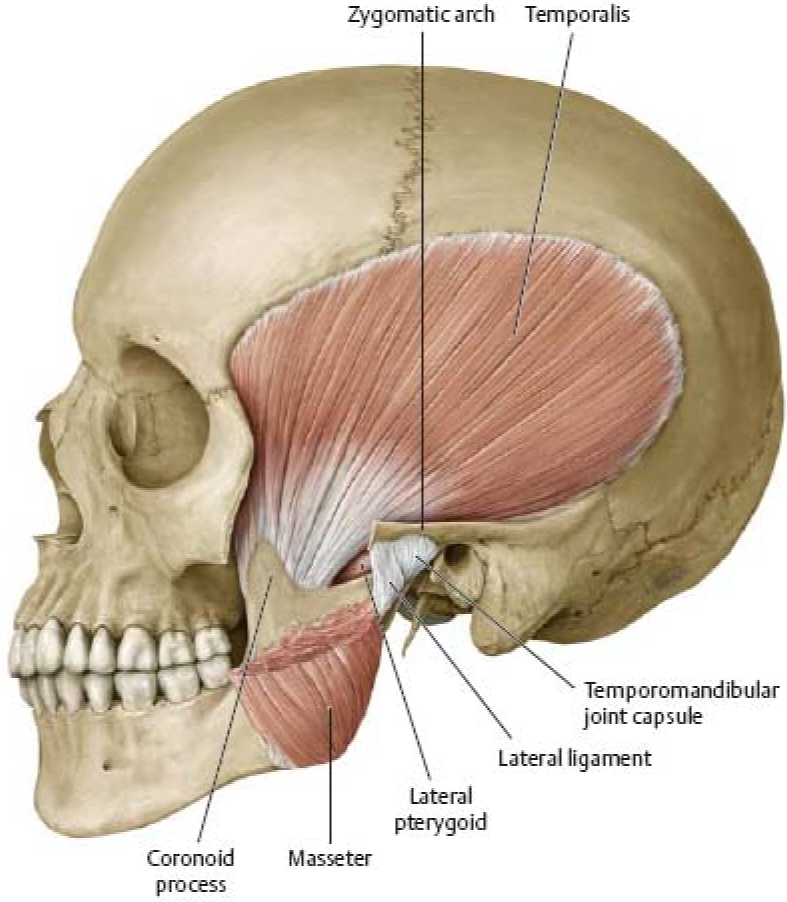
B Masseter with temporalis muscle.

Fig. 30.12 **Temporalis muscle**

Left lateral view.



A Schematic.



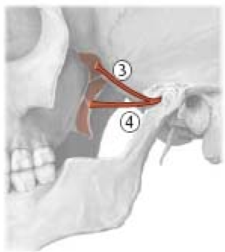
B Temporalis muscle. *Removed:* Masseter and zygomatic arch.

Table 30.4 Muscles of mastication: Pterygoid muscles

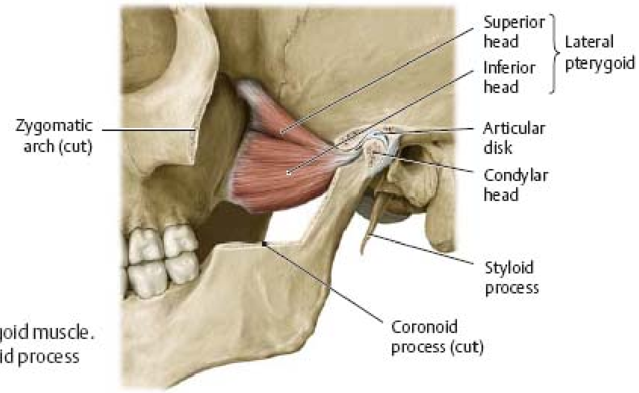
Muscle		Origin	Insertion	Innervation	Action
Lateral pterygoid	③ Superior head	Greater wing of sphenoid bone (infratemporal crest)	Temporomandibular joint (articular disk)	Mandibular n. (CNV_3) via lateral pterygoid n.	*Bilateral:* Protrudes mandible (pulls articular disk forward) *Unilateral:* Lateral movements of mandible (chewing)
	④ Inferior head	Lateral pterygoid plate (lateral surface)	Mandible (condylar process)		
Medial pterygoid	⑤ Superficial head	Maxilla (tuberosity)	Pterygoid tuberosity on medial surface of the mandibular angle	Mandibular n. (CNV_3) via medial pterygoid n.	Elevates (adducts) mandible
	⑥ Deep head	Medial surface of lateral pterygoid plate and pterygoid fossa			

Fig. 30.13 Lateral pterygoid muscle

Left lateral view.



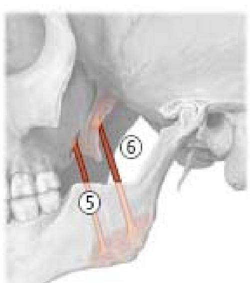
A Schematic.



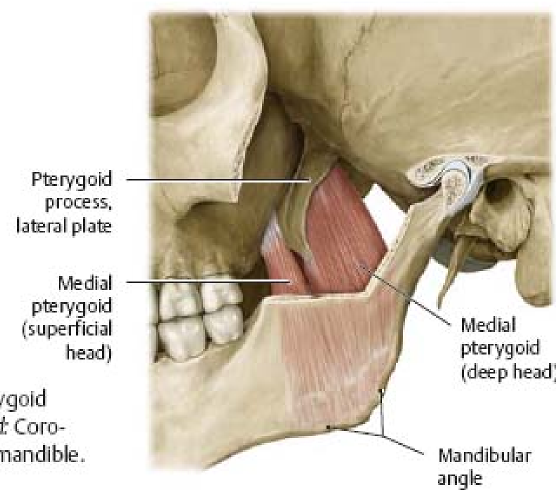
B Left lateral pterygoid muscle. *Removed:* Coronoid process of mandible.

Fig. 30.14 Medial pterygoid muscle

Left lateral view.



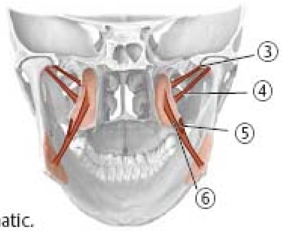
A Schematic.



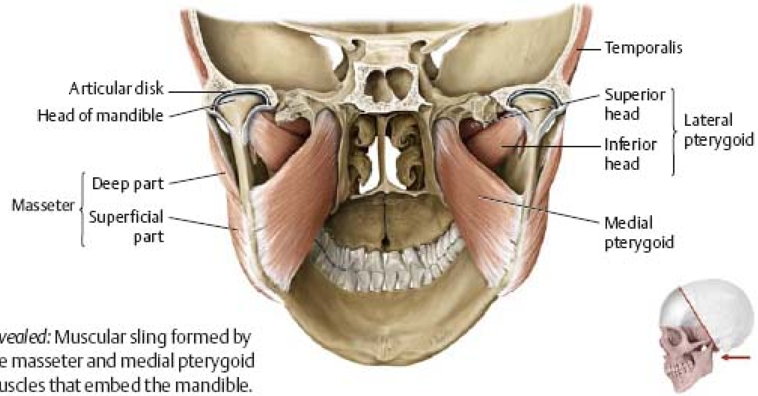
B Left medial pterygoid muscle. *Removed:* Coronoid process of mandible.

Fig. 30.15 Masticatory muscle sling

Oblique posterior view.



A Schematic.



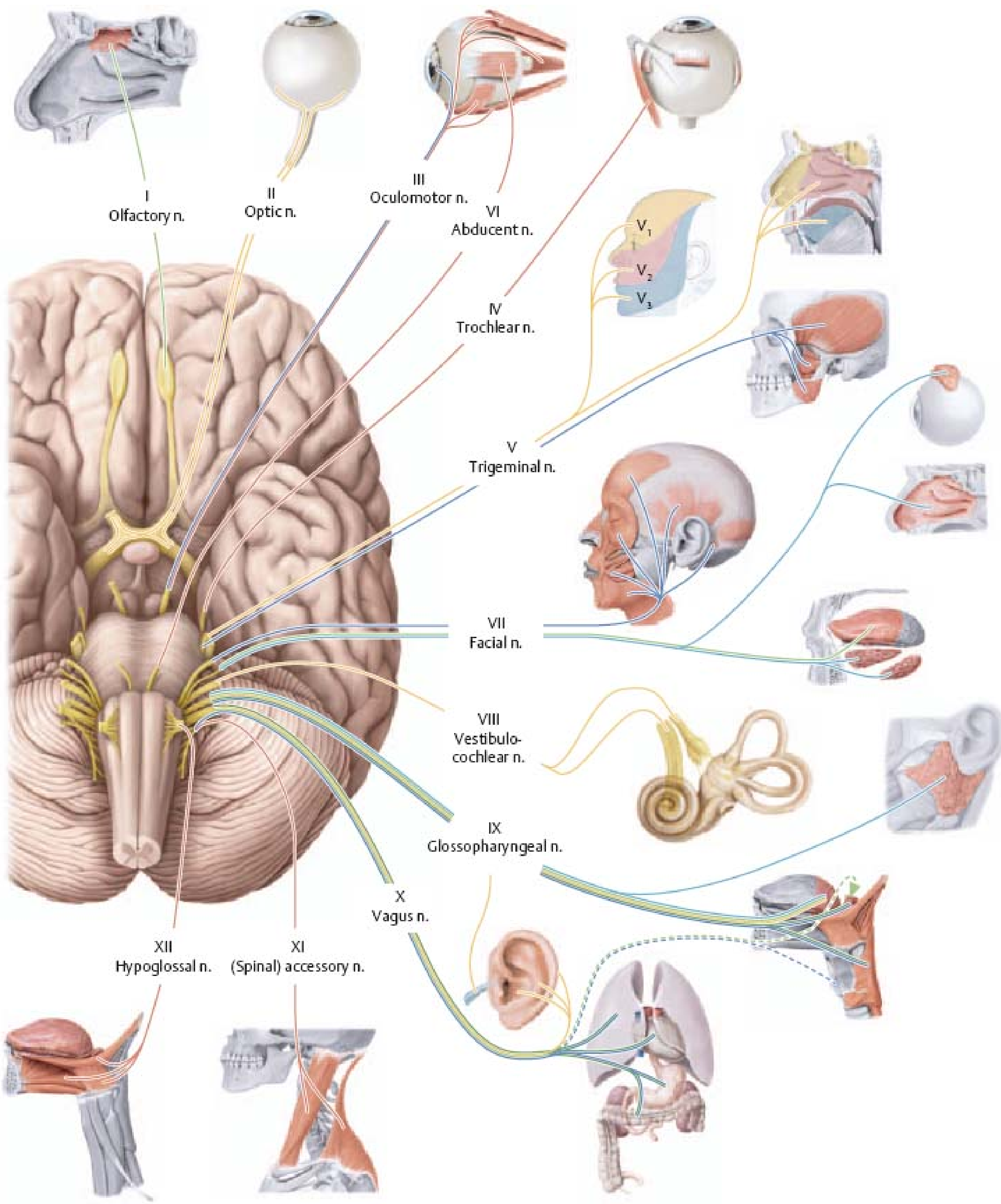
B *Revealed:* Muscular sling formed by the masseter and medial pterygoid muscles that embed the mandible.

31 Cranial Nerves

Cranial Nerves: Overview

Fig. 31.1 Cranial nerves

Inferior (basal) view. The 12 pairs of cranial nerves (CN) are numbered according to the order of their emergence from the brainstem. *Note:* The sensory and motor fibers of the cranial nerves enter and exit the brainstem at the same sites (in contrast to spinal nerves, whose sensory and motor fibers enter and leave through posterior and anterior roots, respectively).



The cranial nerves contain both afferent (sensory) and efferent (motor) axons that belong to either the somatic or the autonomic (visceral) nervous system (see pp. 622–623). The somatic fibers allow interaction with the environment, whereas the visceral fibers regulate the autonomic activity of internal organs. In addition to the general fiber types, the cranial nerves may contain special fiber types associated with particular structures (e.g., auditory apparatus and taste buds). The cranial nerve fibers originate or terminate at specific nuclei, which are similarly classified as either general or special, somatic or visceral, and afferent or efferent.

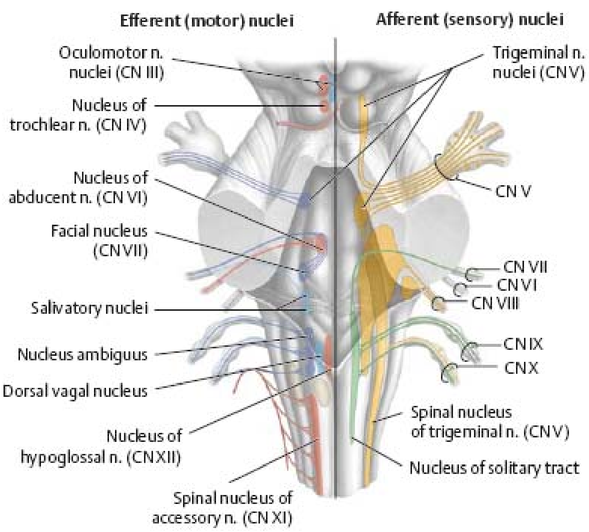
Table 31.1 Classification of cranial nerve fibers and nuclei

This color coding is used in subsequent chapters to indicate fiber and nuclei classifications.

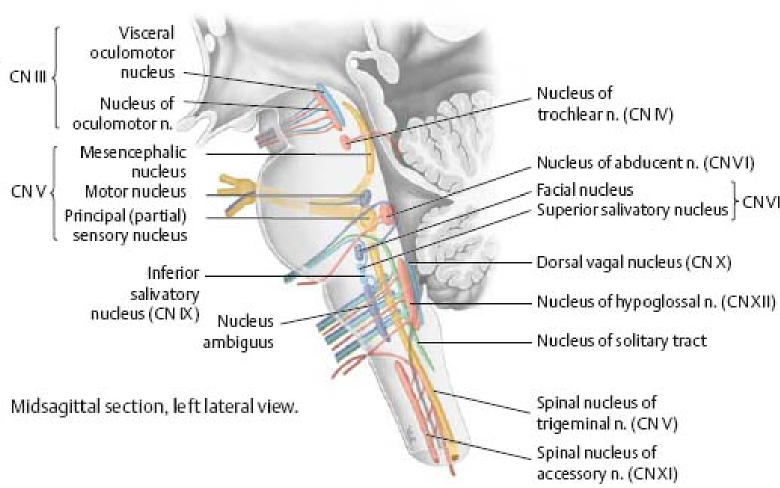
	Fiber type	Example		Fiber type	Example
(red)	General somatic efferent (somatomotor function)	Innervate skeletal muscles	(orange)	General somatic afferent (somatic sensation)	Conduct impulses from skin, skeletal muscle spindles
(blue)	General visceral efferent (visceromotor function)	Innervate smooth muscle of the viscera, intraocular muscles, heart, salivary glands, etc.	(orange)	Special somatic afferent	Conduct impulses from retina, auditory and vestibular apparatuses
(gray-blue)	Special visceral efferent	Innervate skeletal and cardiac muscle derived from branchial arches	(green)	General visceral afferent (visceral sensation)	Conduct impulses from viscera, blood vessels
			(light green)	Special visceral afferent	Conduct impulses from taste buds, olfactory mucosa

Fig. 31.2 Cranial nerve nuclei

The sensory and motor fibers of cranial nerves III to XII originate and terminate in the brainstem at specific nuclei.



A Posterior view with the cerebellum removed.



B Midsagittal section, left lateral view.

Table 31.2 Cranial nerves

Cranial nerve	Origin	Functional fiber types					
CN I: Olfactory n.	Telencephalon*			●			
CN II: Optic n.	Diencephalon*					●	
CN III: Oculomotor n.	Mesencephalon		●				●
CN IV: Trochlear n.							●
CN V: Trigeminal n.	Pons	●				●	
CN VI: Abducent n.							●
CN VII: Facial n.		●	●	●		●	
CN VIII: Vestibulocochlear n.	Medulla oblongata					●	
CN IX: Glossopharyngeal n.		●	●	●	●	●	
CN X: Vagus n.		●	●	●	●	●	
CN XI: Accessory n.		●					●
CN XII: Hypoglossal n.							●

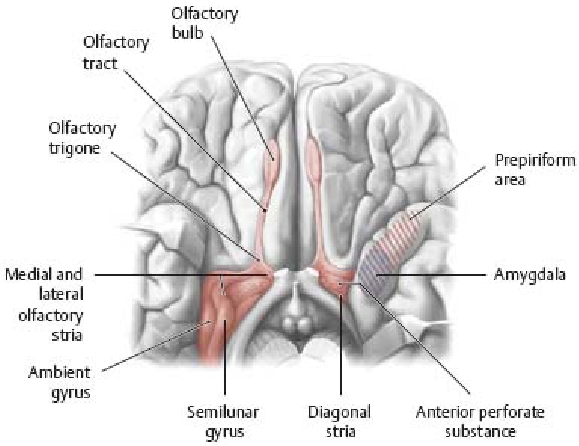
* The olfactory and optic nerves are extensions of the brain rather than true nerves; they are therefore not associated with nuclei in the brainstem.

CN I & II: Olfactory & Optic Nerves

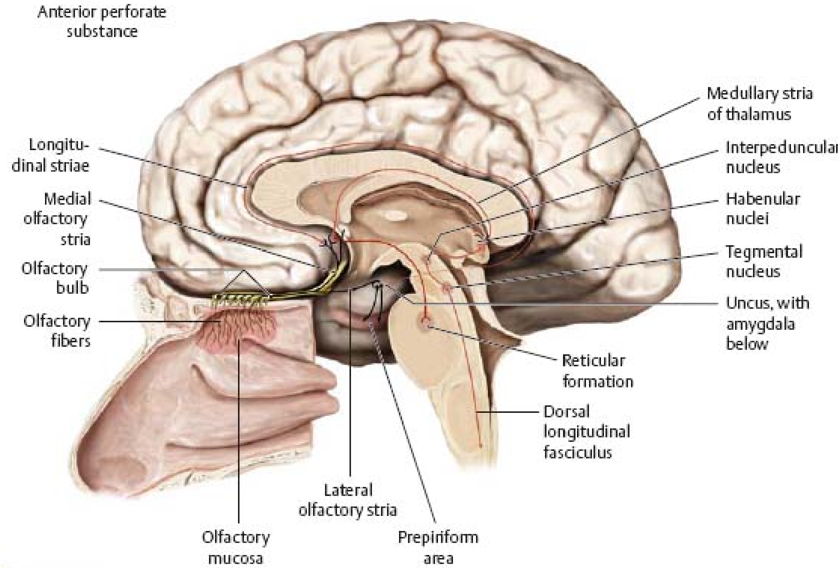
The olfactory and optic nerves are not true peripheral nerves, but extensions (tracts) of the telencephalon and diencephalon, respectively. They are therefore not associated with cranial nerve nuclei in the brainstem.

Fig. 31.3 Olfactory nerve (CN I)

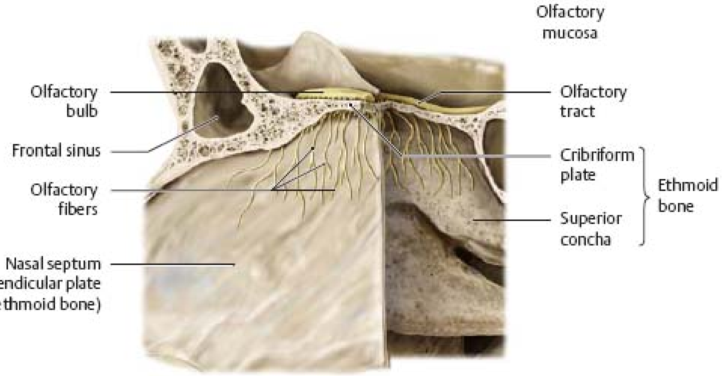
Fiber bundles in the olfactory mucosa pass from the nasal cavity through the cribriform plate of the ethmoid bone into the anterior cranial fossa, where they synapse in the olfactory bulb. Axons from second-order afferent neurons in the olfactory bulb pass through the olfactory tract and medial or lateral olfactory stria, terminating in the cerebral cortex of the prepiriform area, in the amygdala, or in neighboring areas. See p. 617 for the mechanisms of smell.



A Olfactory bulb and tract, inferior view. *Note:* The amygdala and prepiriform area are deep to the basal surface of the brain.



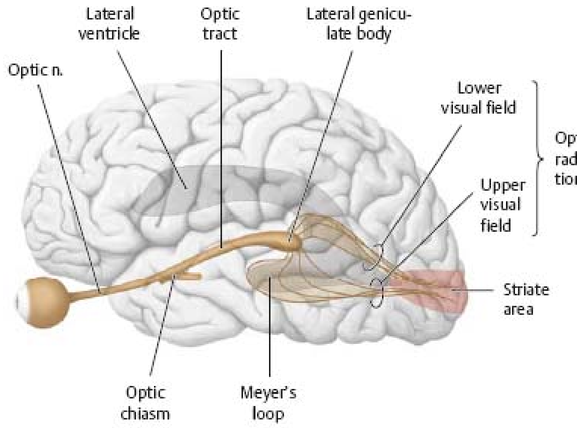
B Course of the olfactory nerve. Parasagittal section, viewed from left side.



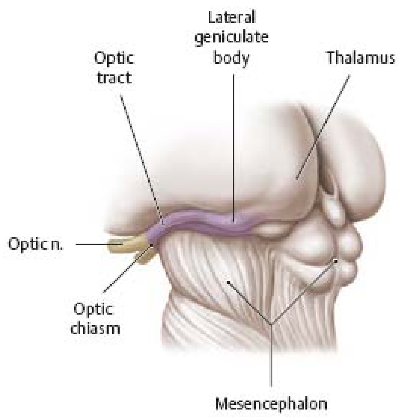
C Olfactory fibers. Portion of left nasal septum and lateral wall of right nasal cavity, left lateral view.

Fig. 31.4 Optic nerve (CN II)

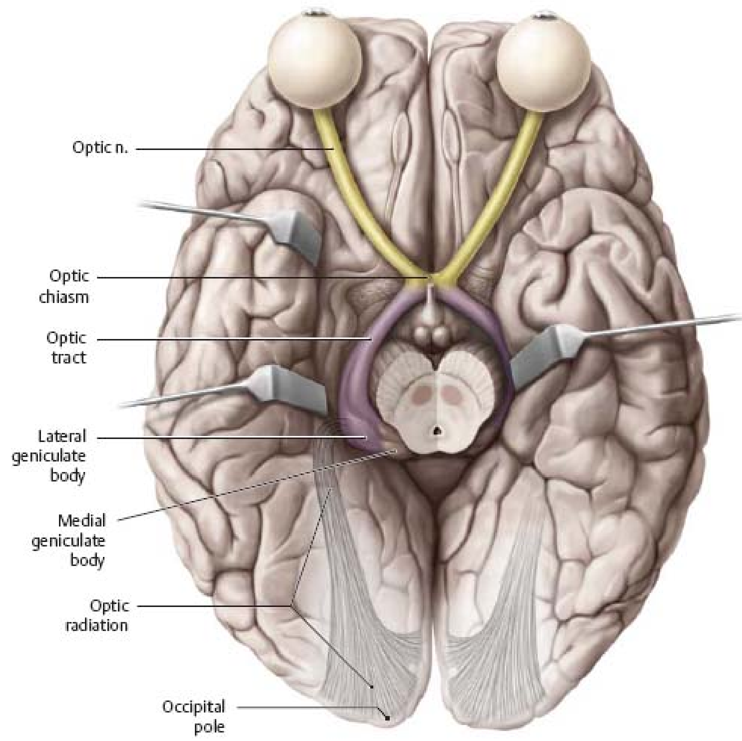
The optic nerve passes from the eyeball through the optic canal into the middle cranial fossa. The two optic nerves join below the base of the diencephalon to form the optic chiasm, before dividing into the two optic tracts. Each of these tracts divides into a lateral and medial root. Many retinal cell ganglion axons cross the midline to the contralateral side of the brain in the optic chiasm. See p. 619 for the mechanisms of sight.



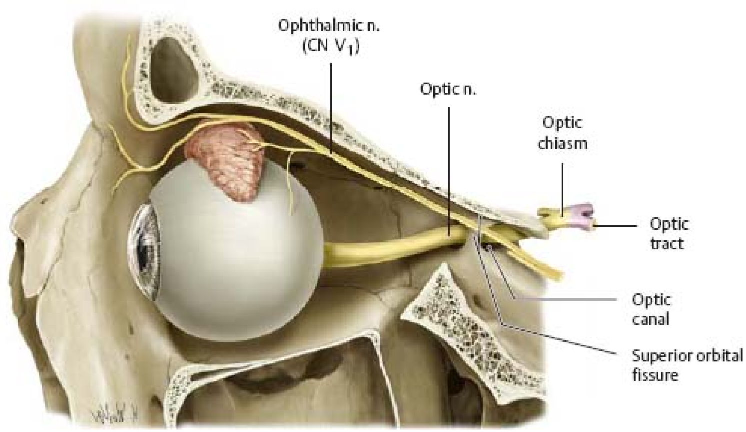
A Optic nerve in the geniculate visual pathway, left lateral view.



B Termination of the optic tract, left posterolateral view of the brainstem. The optic nerve contains the axons of retinal ganglion cells, which terminate mainly in the lateral geniculate body of the diencephalon and in the mesencephalon (superior colliculus).



C Course of the optic nerve, inferior (basal) view.



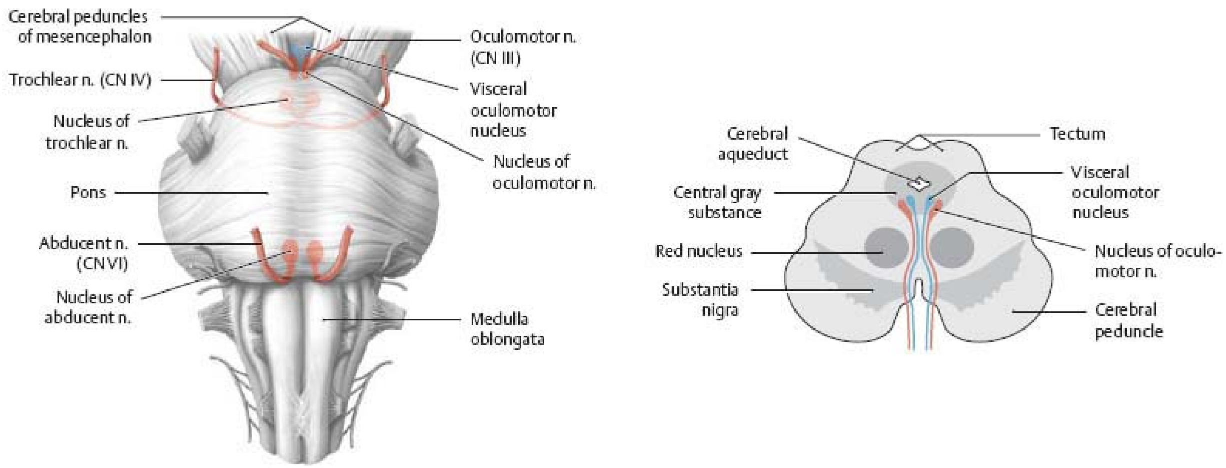
D Optic nerve in the left orbit, lateral view. The optic nerve exits the orbit via the optic canal. *Note*: The other cranial nerves entering the orbit do so via the superior orbital fissure.

CN III, IV & VI: Oculomotor, Trochlear & Abducent Nerves

Cranial nerves III, IV, and VI innervate the extraocular muscles (see p. 509). Of the three, only the oculomotor nerve (CN III) contains both somatic and visceral efferent fibers; it is also the only cranial nerve of the extraocular muscles to innervate multiple extra- and intraocular muscles.

Fig. 31.5 Nuclei of the oculomotor, trochlear, and abducent nerves

The trochlear nerve (CN IV) is the only cranial nerve in which all the fibers cross to the opposite side. It is also the only cranial nerve to emerge from the dorsal side of the brainstem and, consequently, has the longest intradural (intracranial) course of any cranial nerve.



A Emergence of the cranial nerves of the extraocular muscles. Anterior view of the brainstem.

B Oculomotor nerve nuclei. Transverse section, superior view.

Table 31.3 Cranial nerves of the extraocular muscles

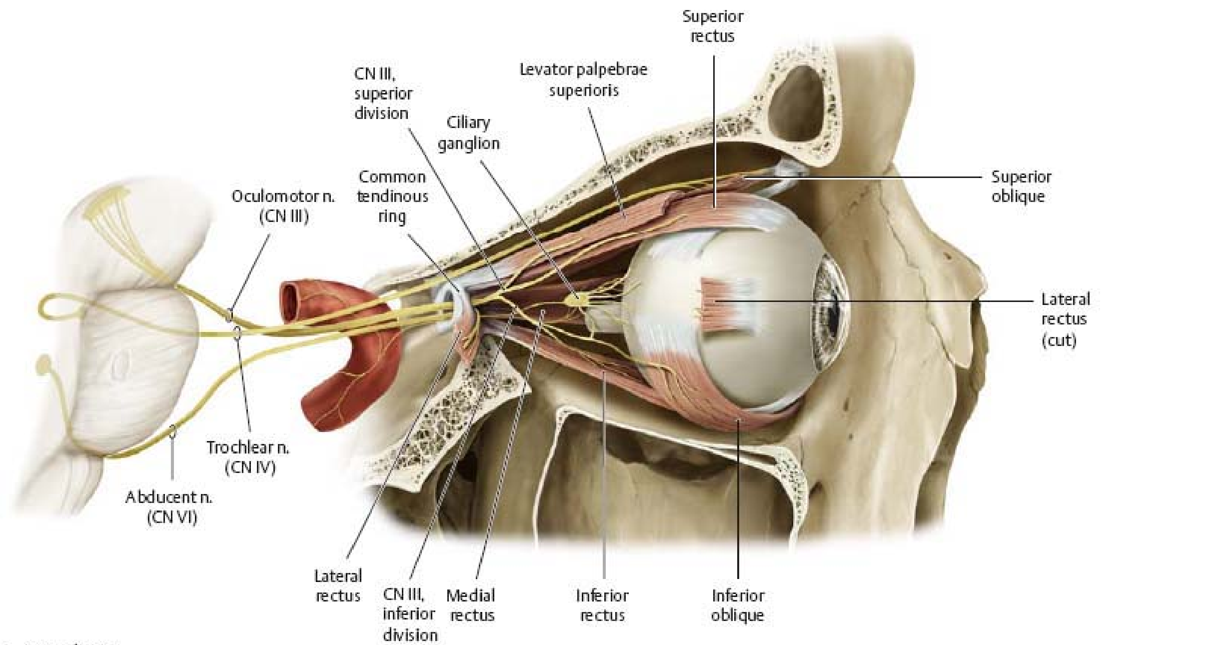
Course*	Fibers	Nuclei	Function	Effects of nerve injury
Oculomotor nerve (CN III)				
Runs anteriorly from mesencephalon	Somatic efferent	Oculomotor nucleus	Innervates: • Levator palpebrae superioris • Superior, medial, and inferior rectus • Inferior oblique	Complete oculomotor palsy (paralysis of extra- and intraocular muscles): • Ptosis (drooping of eyelid) • Downward and lateral gaze deviation • Diplopia (double vision) • Mydriasis (pupil dilation) • Accommodation difficulties (ciliary paralysis)
	Visceral efferent	Visceral oculomotor (Edinger-Westphal) nucleus	Synapse with neurons in ciliary ganglia. Innervates: • Pupillary sphincter • Ciliary muscle	
Trochlear nerve (CN IV)				
Emerges from posterior surface of brainstem near midline, courses anteriorly around the cerebral peduncle	Somatic efferent	Nucleus of the trochlear n.	Innervates: • Superior oblique	• Diplopia • Affected eye is higher and deviated medially (dominance of inferior oblique)
Abducent nerve (CN VI)				
Follows a long extradural path**	Somatic efferent	Nucleus of the abducent n.	Innervates: • Lateral rectus	• Diplopia • Affected eye is deviated superiorly

* All three nerves enter the orbit through the superior orbital fissure; CN III and CN VI pass through the common tendinous ring of the extraocular muscles.
** The abducent nerve follows an extradural course; abducent nerve palsy may therefore develop in association with meningitis and subarachnoid hemorrhage.

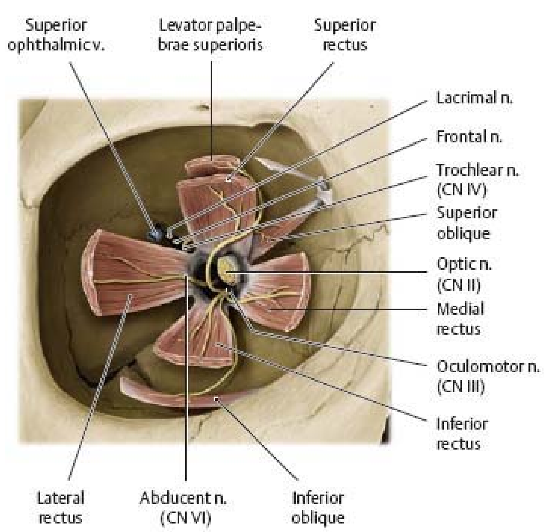
Note: The oculomotor nerve supplies parasympathetic innervation to the intraocular muscles and somatic motor innervation to most of the extraocular muscles (also the levator palpebrae superioris). Its parasympathetic fibers synapse in the ciliary ganglion. Oculomotor nerve palsy may affect exclusively the parasympathetic or somatic fibers, or both concurrently.

***Fig. 31.6* Course of the nerves innervating the extraocular muscles**

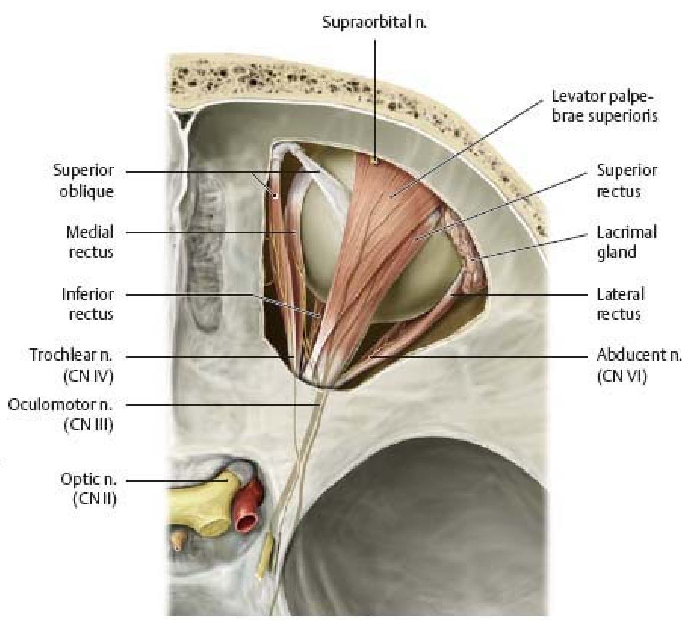
Right orbit.



A Lateral view.



B Anterior view. CN II exits the orbit via the optic canal, which lies medial to the superior orbital fissure (site of emergence of CN III, IV, and VI).

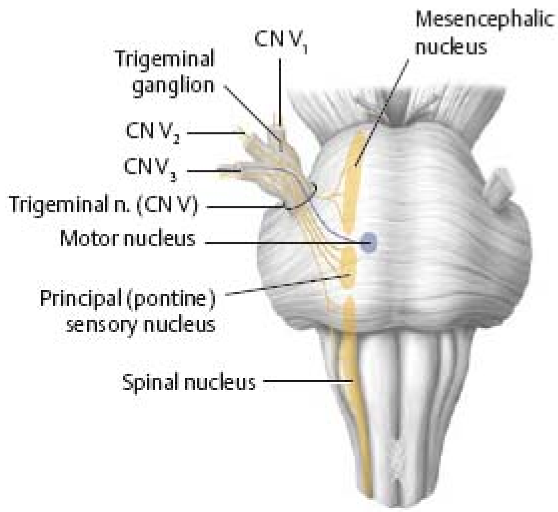


C Superior view of the opened orbit. Note the relationship between the optic canal and the superior orbital fissure.

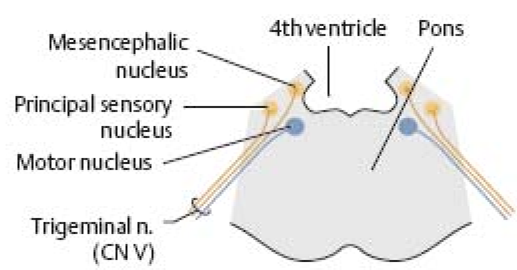
CN V: Trigeminal Nerve

The trigeminal nerve, the sensory nerve of the head, has three somatic afferent nuclei: the mesencephalic nucleus, which receives proprioceptive fibers from the muscles of mastication; the principal (pontine) sensory nucleus, which chiefly mediates touch; and the spinal nucleus, which mediates pain and temperature sensation. The motor nucleus supplies motor innervation to the muscles of mastication.

Fig. 31.7 **Trigeminal nerve nuclei**



A Anterior view of the brainstem.



B Cross section through the pons, superior view.

Fig. 31.8 **Divisions of the trigeminal nerve (CN V)**

Right lateral view.

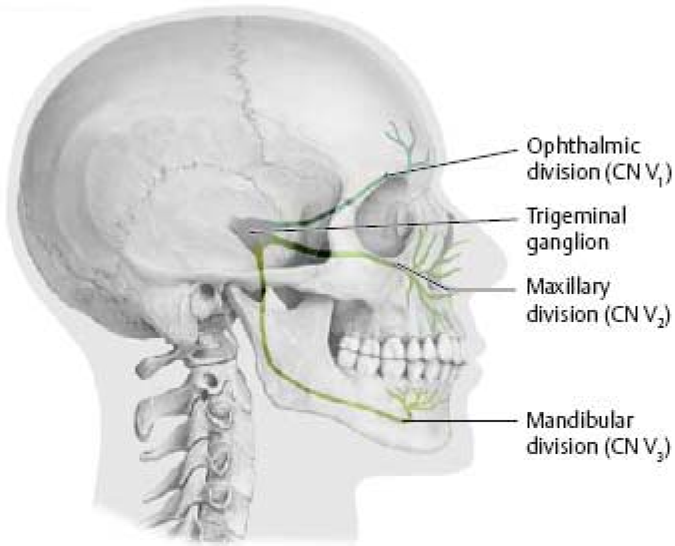
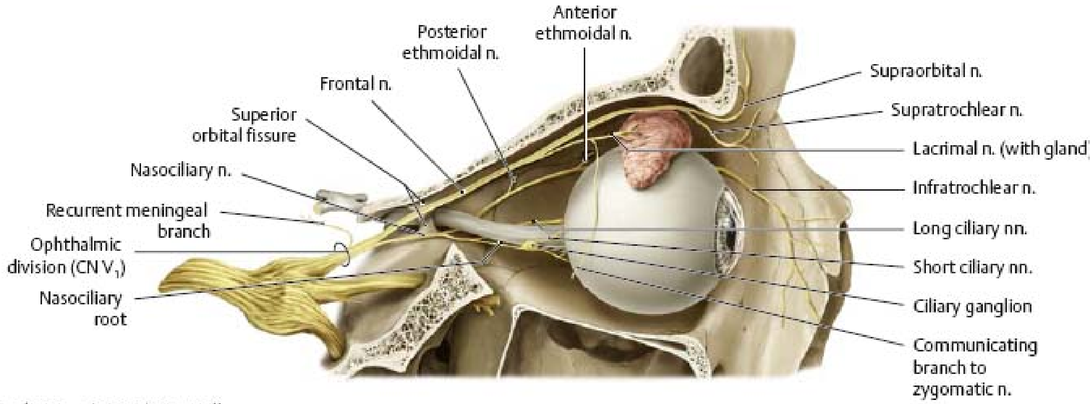


Table 31.4 Trigeminal nerve (CN V)

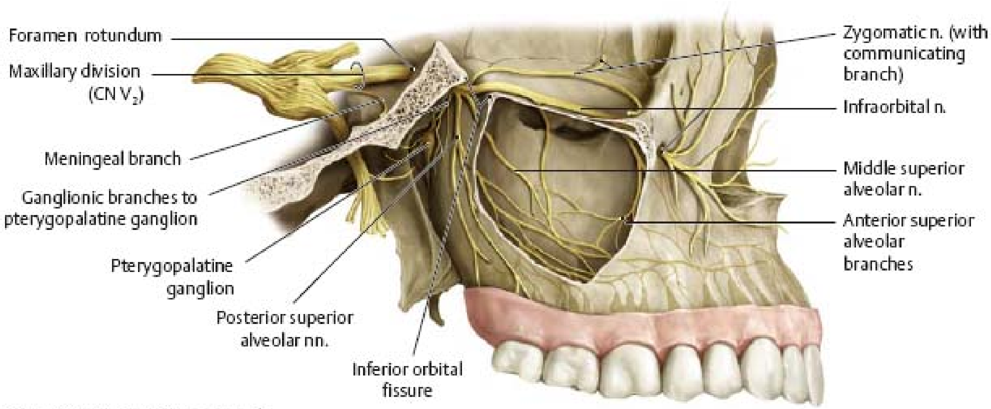
Course	Fibers	Nuclei	Function	Effects of nerve injury
Exits from the middle cranial fossa. **Ophthalmic division (CN V_1):** Enters orbit through superior orbital fissure **Maxillary division (CN V_2):** Enters pterygopalatine fossa through foramen rotundum **Mandibular division (CN V_3):** Passes through foramen ovale to inferior surface of base of the skull	Somatic afferent	• Principal (pontine) sensory nucleus of the trigeminal n. • Mesencephalic nucleus of the trigeminal n. • Spinal nucleus of the trigeminal n.	Innervates: • Facial skin (**A**) • Nasopharyngeal mucosa (**B**) • Tongue (anterior two thirds) (**C**) Involved in the corneal reflex (reflex closure of eyelid)	• Sensory loss (traumatic nerve lesions) • Herpes zoster ophthalmicus (varicella-zoster virus); herpes zoster of the face
	Special visceral efferent	Motor nucleus of the trigeminal n.	Innervates (via CN V_3): • Muscles of mastication (temporalis, masseter, medial and lateral pterygoids (**D**)) • Oral floor muscles (mylohyoid, anterior digastric) • Tensor tympani • Tensor veli palatini	
	Visceral efferent pathway*	• Lacrimal n. (CN V_1) conveys parasympathetic fibers from CN VII along the zygomatic n. (CN V_2) to the lacrimal gland • Lingual n. (CN V_3) conveys parasympathetic fibers from CN VII (via the chorda tympani) to the submandibular and sublingual glands • Auriculotemporal n. (CN V_3) conveys parasympathetic fibers from CN IX to the parotid gland		
	Visceral afferent pathway*	Gustatory (taste) fibers from CN VII (via chorda tympani) travel with the lingual n. (CN V_3) to the anterior two thirds of the tongue		

* Fibers of certain cranial nerves adhere to divisions or branches of the trigeminal nerve, by which they travel to their destination.

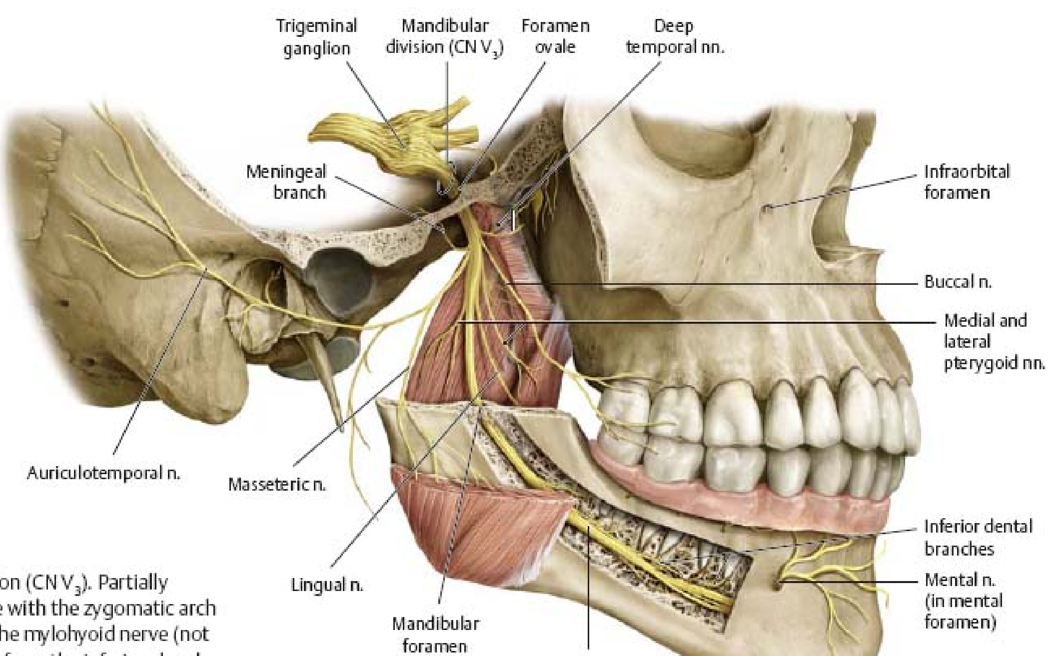
Fig. 31.9 **Course of the trigeminal nerve divisions**
Right lateral view.



A Ophthalmic division (CN V_1). Partially opened right orbit.



B Maxillary division (CN V_2). Partially opened right maxillary sinus with the zygomatic arch removed.

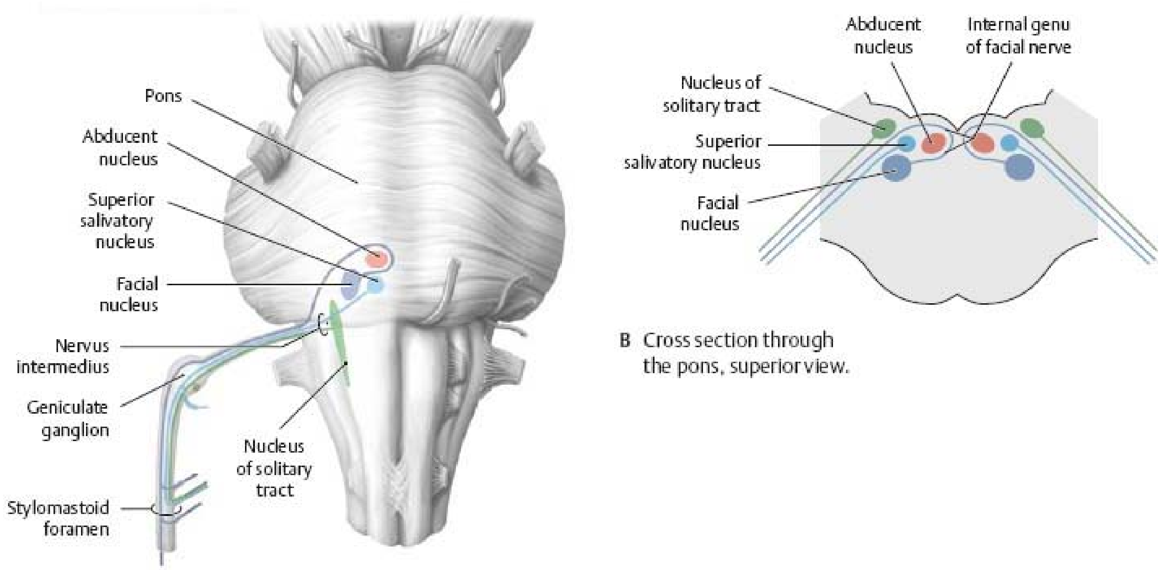


C Mandibular division (CN V_3). Partially opened mandible with the zygomatic arch removed. *Note:* The mylohyoid nerve (not shown) branches from the inferior alveolar nerve just before the mandibular foramen.

CN VII: Facial Nerve

The facial nerve mainly conveys special visceral efferent (branchiogenic) fibers from the facial nerve nucleus to the muscles of facial expression. The other visceral efferent (parasympathetic) fibers from the superior salivatory nucleus are grouped with the visceral afferent (gustatory) fibers to form the nervus intermedius.

Fig. 31.10 Facial nerve nuclei

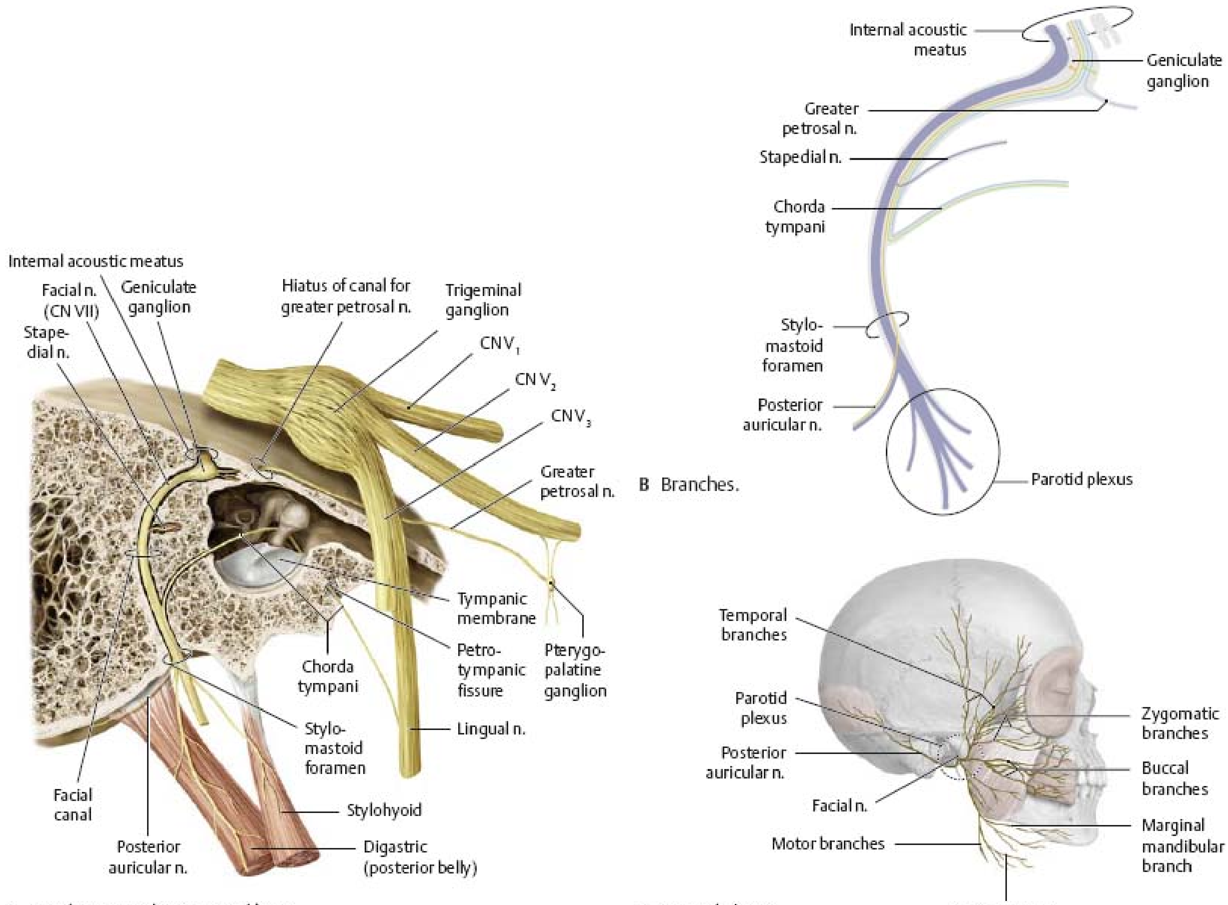


A Anterior view of the brainstem.

B Cross section through the pons, superior view.

Fig. 31.11 Branches of the facial nerve

Right lateral view.



A Facial nerve in the temporal bone.

B Branches.

C Parotid plexus.

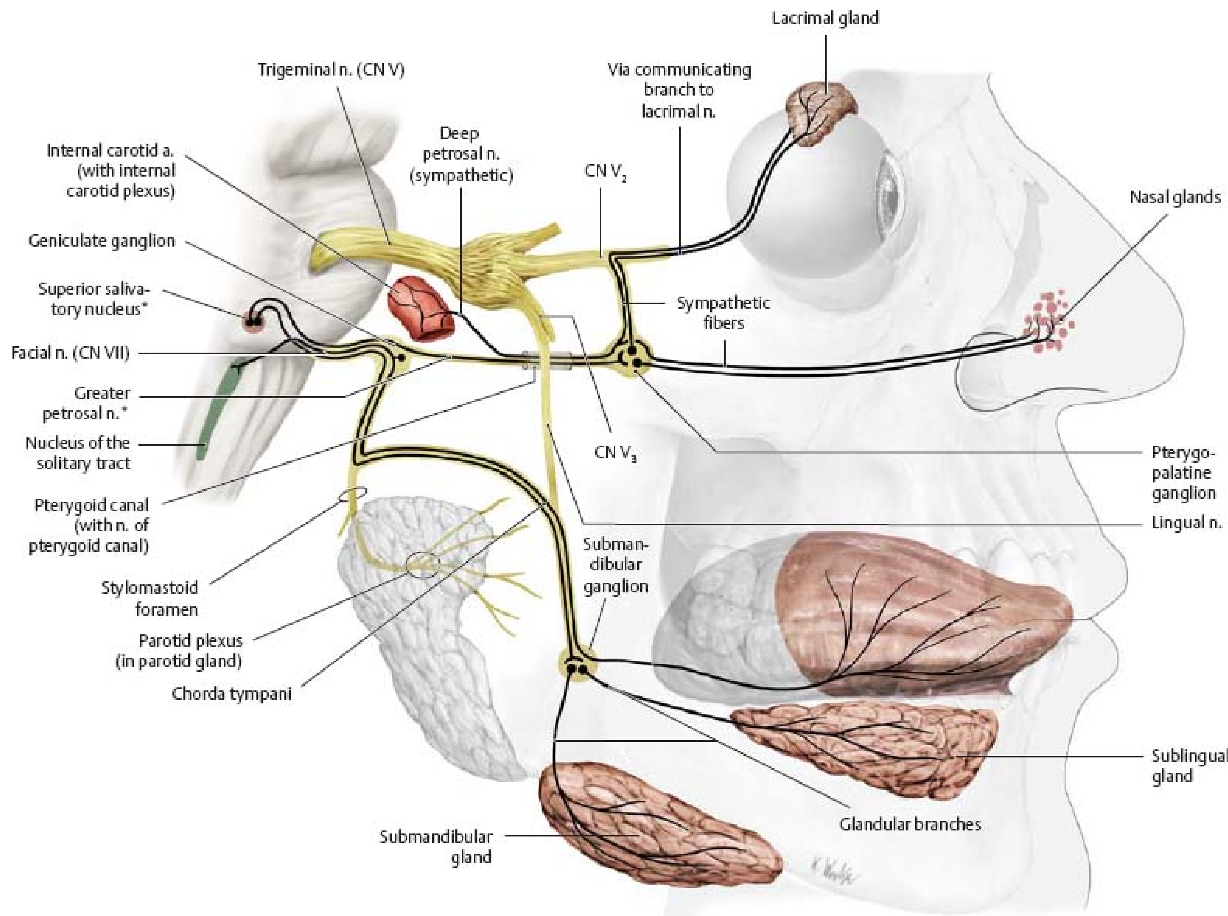
Table 31.5 Facial nerve (CN VII)

Course	Fibers	Nuclei	Function	Effects of nerve injury
Emerges in the cerebellopontine angle between the pons and olive; passes through the internal acoustic meatus into the temporal bone (petrous part), where it divides into: • Greater petrosal nerve • Stapedial nerve • Chorda tympani Certain visceral efferent fibers pass through the stylomastoid foramen to the skull base, forming the intraparotid plexus	Special visceral efferent	Facial nucleus	Innervate: • Muscles of facial expression • Stylohyoid • Digastric (posterior belly) • Stapedius	Peripheral facial nerve injury: paralysis of muscles of facial expression on affected side Associated disturbances of taste, lacrimation, salivation, etc.
	Visceral efferent (para-sympathetic)*	Superior salivatory nucleus	Synapse with neurons in the pterygopalatine or submandibular ganglion. Innervate: • Lacrimal gland • Small glands of nasal mucosa, hard and soft palate • Submandibular gland • Sublingual gland • Small salivary glands of tongue (dorsum)	
	Special visceral afferent*	Nucleus of the solitary tract	Peripheral processes of fibers from geniculate ganglion form the chorda tympani (gustatory fibers from tongue)	
	Somatic afferent	Sensory fibers from the auricle, skin of the auditory canal, and outer surface of the tympanic membrane travel via CN VII to the principal sensory nucleus of the trigeminal nerve		

* Grouped to form nervus intermedius, which aggregates with the visceral efferent fibers from the facial nerve nucleus.

Fig. 31.12 Course of the facial nerve

Right lateral view. Visceral efferent (parasympathetic) and special visceral afferent (taste) fibers shown in black.

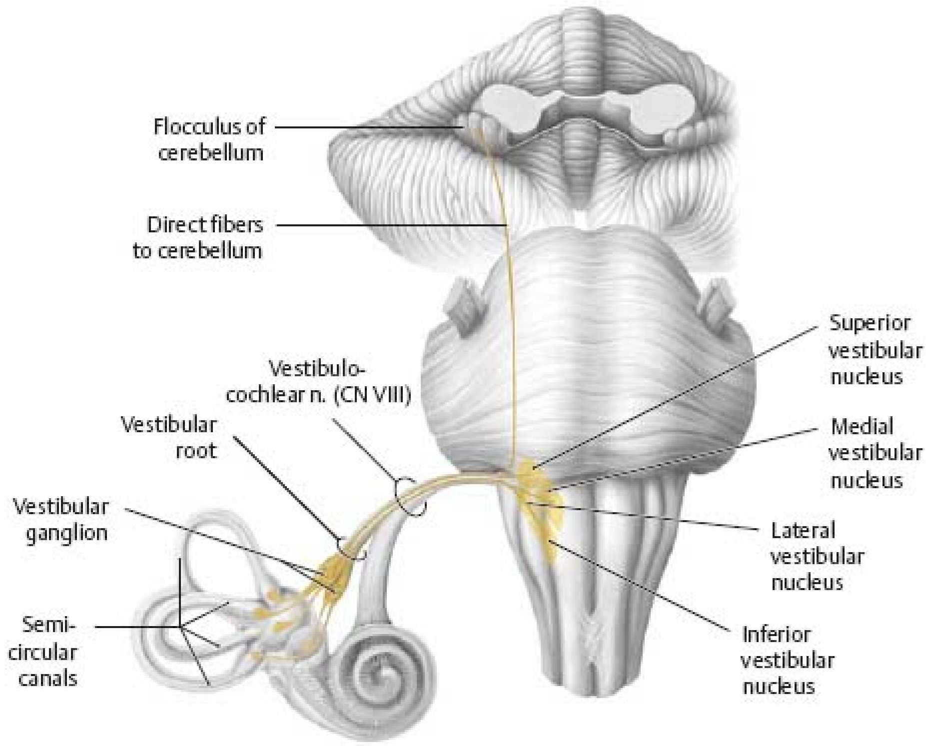


* Parasympathetic

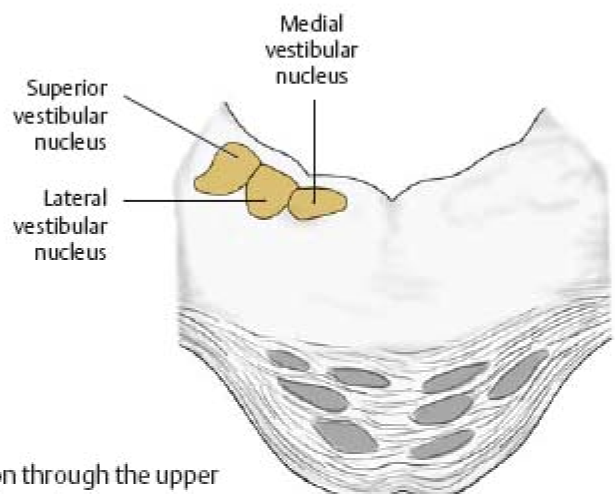
CN VIII: Vestibulocochlear Nerve

The vestibulochochlear nerve is a special somatic afferent nerve that consists of two roots. The vestibular root transmits impulses from the vestibular apparatus (balance, see p. 618); thecochlear root transmits impulses from the auditory apparatus (hearing, see p. 616).

Fig. 31.13 Vestibulocochlear nerve: Vestibular part

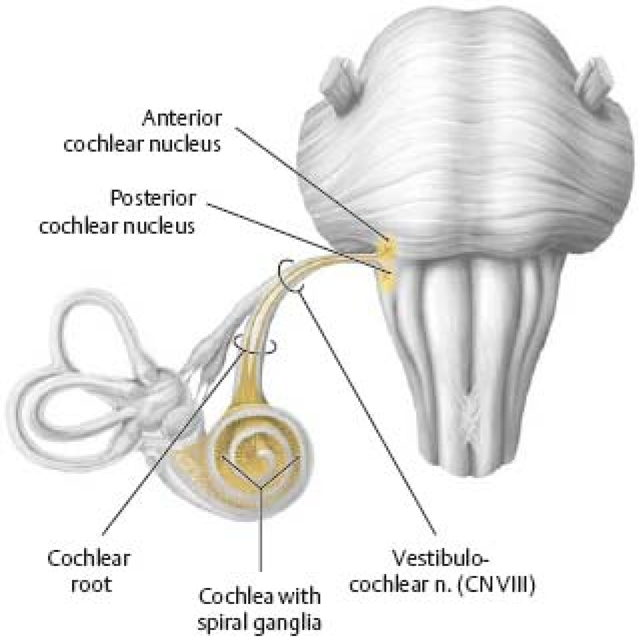


A Anterior view of the medulla oblongata and pons with cerebellum.

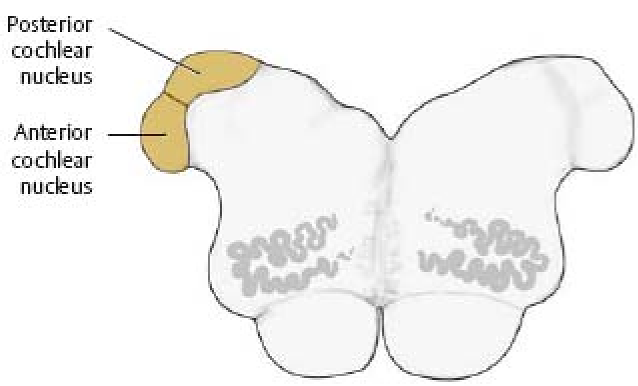


B Cross section through the upper medulla oblongata.

Fig. 31.14 **Vestibulocochlear nerve: Cochlear part**



A Anterior view of the medulla oblongata and pons.



B Cross section through the upper medulla oblongata.

Table 31.6 Vestibulocochlear nerve (CN VIII)

Part	Course	Fibers	Nuclei	Function	Effects of nerve injury
Vestibular part	Pass from the inner ear through the internal acoustic meatus to the cerebellopontine angle, where they enter the brain	Special somatic afferent	Superior, lateral, medial, and inferior vestibular nuclei	Peripheral processes from the semicircular canals, saccule, and utricle pass to the vestibular ganglion and then to the four vestibular nuclei	Dizziness
Cochlear part			Anterior and posterior cochlear nuclei	Peripheral processes beginning at the hair cells of the organ of Corti pass to the spiral ganglion and then to the two cochlear nuclei	Hearing loss

Fig. 31.15 Vestibular and cochear (spiral) ganglia

Note: The vestibular and cochlear roots are still separate structures in the petrous part of the temporal bone.

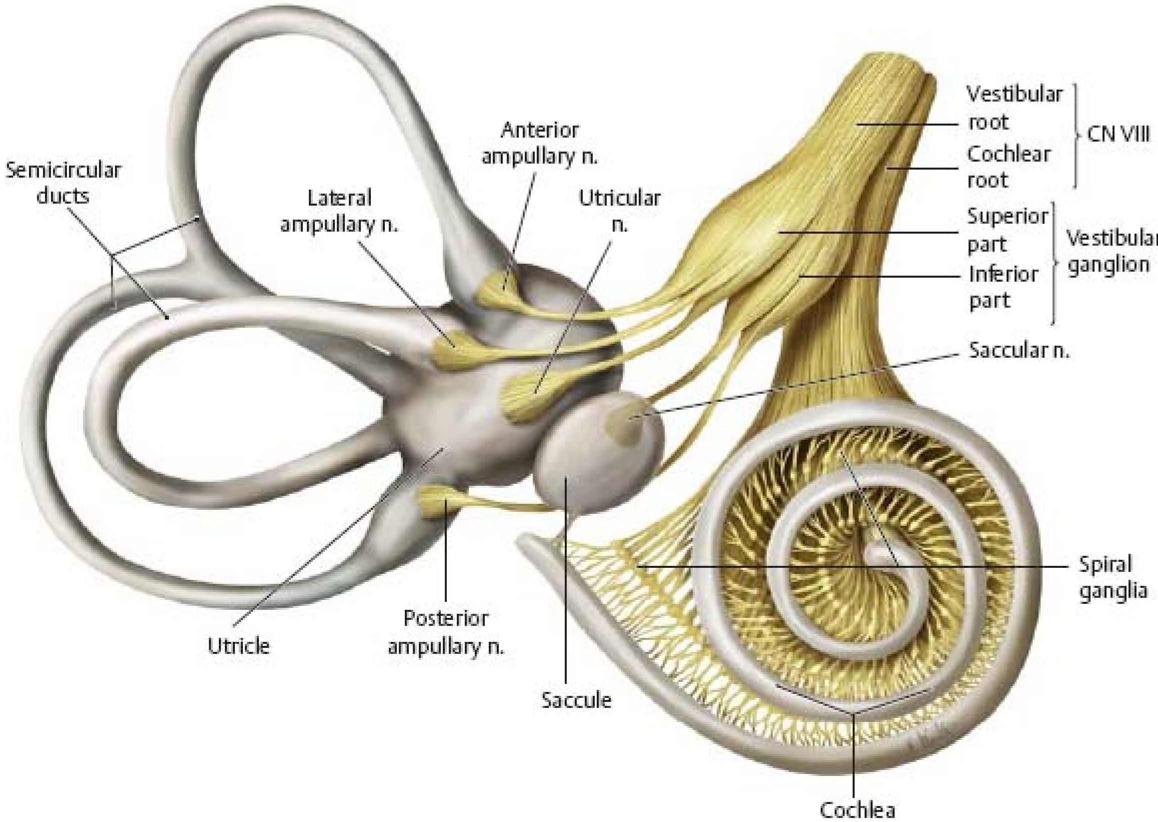
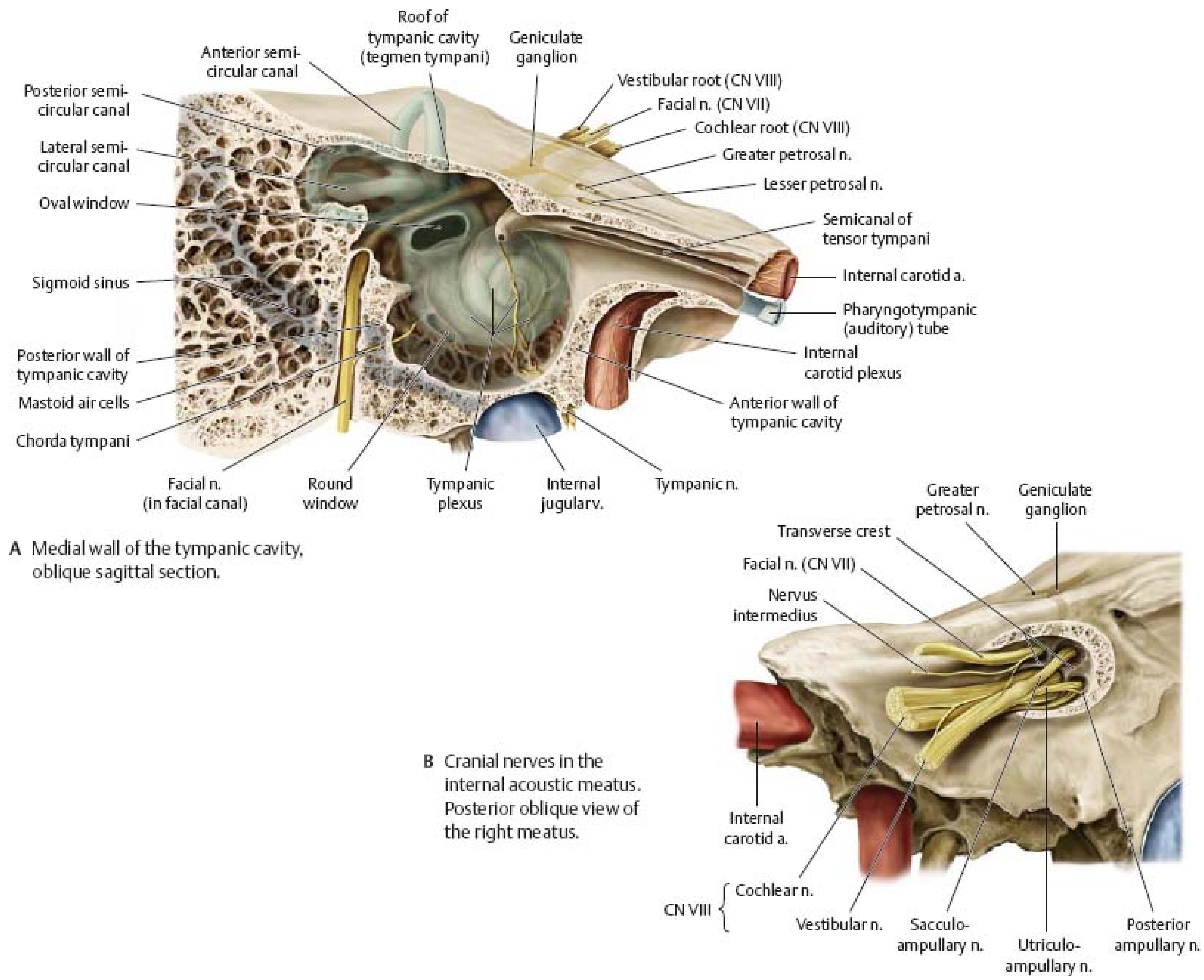


Fig. 31.16 **Vestibulocochlear nerve in the temporal bone**

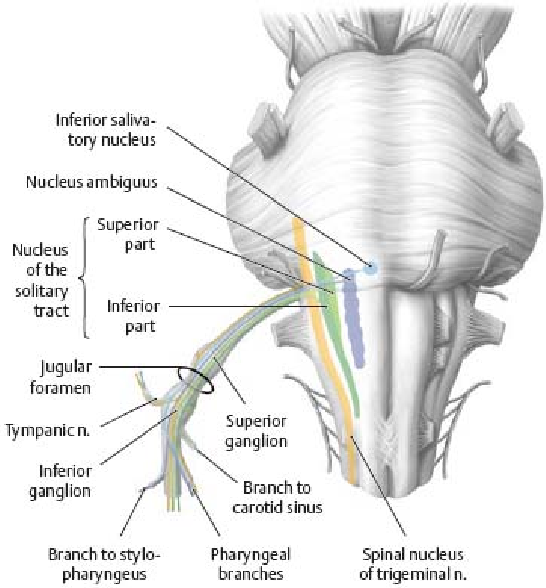


A Medial wall of the tympanic cavity, oblique sagittal section.

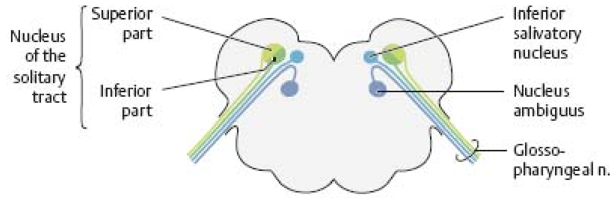
B Cranial nerves in the internal acoustic meatus. Posterior oblique view of the right meatus.

CN IX: Glossopharyngeal Nerve

Fig. 31.17 Glossopharyngeal nerve nuclei



A Anterior view of the medulla oblongata.



B Cross section through the medulla oblongata, superior view. *Not shown:* Nuclei of the trigeminal nerve.

Fig. 31.18 **Course of the glossopharyngeal nerve**

Left lateral view. *Note:* Fibers from the vagus nerve (CN X) cornbine with fibers from CN IX to form the pharyngeal plexus and supply the carotid sinus.

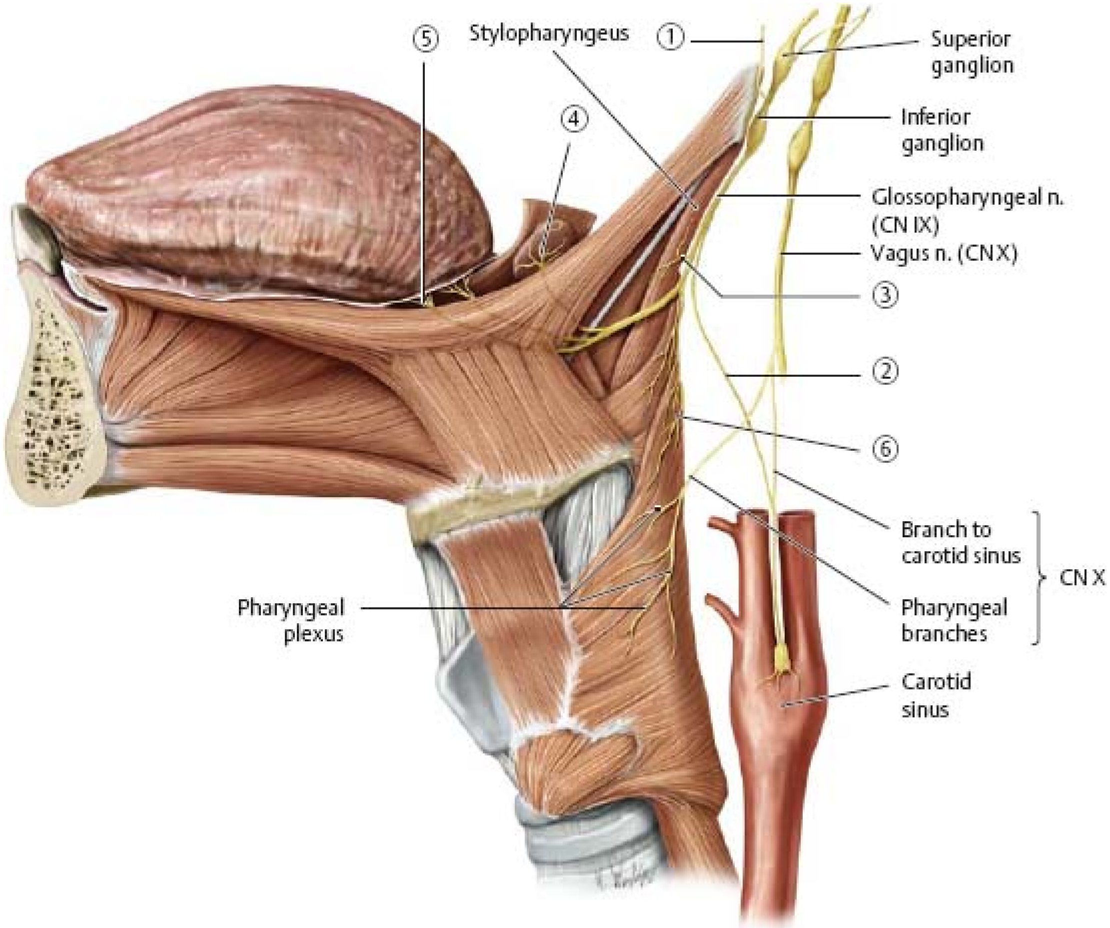


Table 31.7 **Glossopharyngeal nerve branches**	
1	Tympanic n.
2	Branch to carotid sinus
3	Branch to stylopharyngeus muscle
4	Tonsillar branches
5	Lingual branches
6	Pharyngeal branches

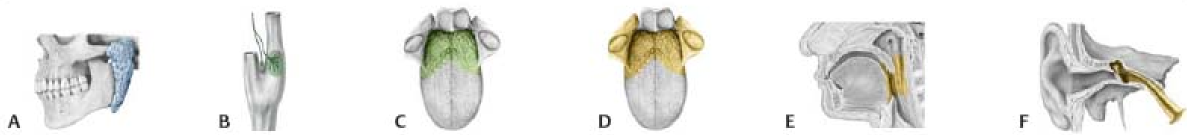


Table 31.8	**Glossopharyngeal nerve (CN IX)**			
Course	**Fibers**	**Nuclei**	**Function**	**Effects of nerve injury**
Emerges from the medulla oblongata; leaves cranial cavity through the jugular foramen	Visceral efferent (parasympathetic)	Inferior salivatory nucleus	Parasympathetic presynaptic fibers are sent to the otic ganglion; postsynaptic fibers are distributed to • Parotid gland (**A**) • Buccal gland • Labial gland	Isolated lesions of CN IX are rare. Lesions are generally accompanied by lesions of CN X and CN XI (cranial part), as all three emerge jointly from the jugular foramen and are susceptible to injury in basal skull fractures.
	Special visceral efferent (branchiogenic)	Nucleus ambiguus	Innervate: • Constrictor muscles of the pharynx (pharyngeal branches join with the vagus nerve to form the pharyngeal plexus) • Stylopharyngeus	
	Visceral afferent	Nucleus of the solitary tract (inferior part)	Receive sensory information from • Chemoreceptors in the carotid body (**B**) • Pressure receptors in the carotid sinus	
	Special visceral afferent	Nucleus of the solitary tract (superior part)	Receives sensory information from the posterior third of the tongue (via the inferior ganglion) (**C**)	
	Somatic afferent	Spinal nucleus of trigeminal nerve	Peripheral processes of the intracranial superior ganglion or the extracranial inferior ganglion arise from • Tongue, soft palate, pharyngeal mucosa, and tonsils (**D, E**) • Mucosa of the tympanic cavity, internal surface of the tympanic membrane, pharyngotympanic tube (tympanic plexus) (**F**) • Skin of the external ear and auditory canal (blends with the vagus nerve)	

Fig. 31.19 **Glossopharyngeal nerve in the tympanic cavity**

Left anterolateral view. The tympanic nerve contaqins visceral efferent (presynaptic parasympathetic) fibers for the otic ganglion, as well as somatic afferent fibers for the tympanic cavity and pharyngotympanic tube. It joint with sympathetic fibers from the internal carotid plexus (via the carticotympanic nerve) to from the tympanic plexus.

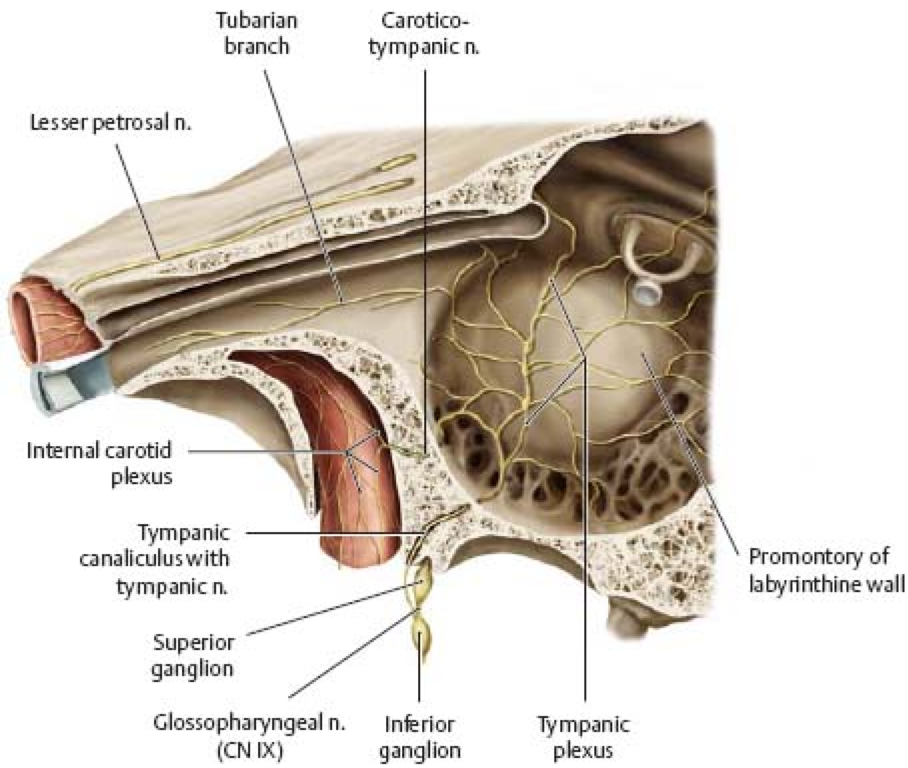
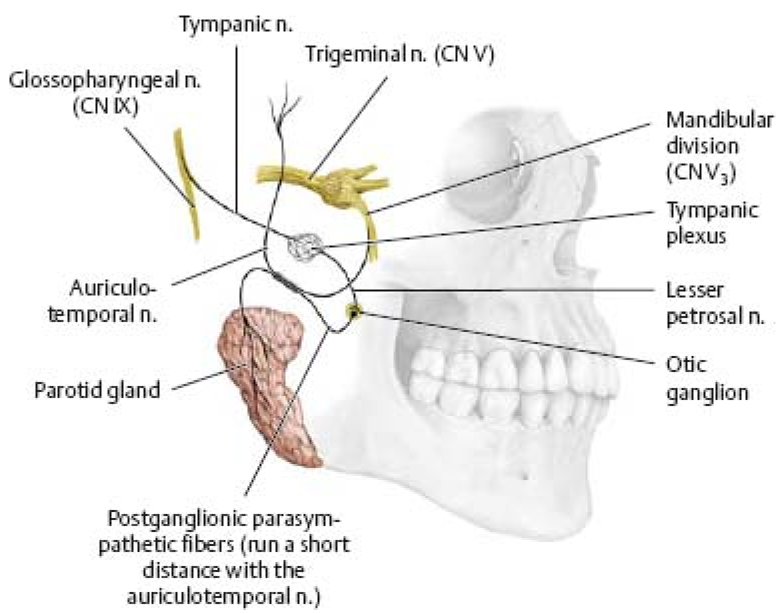
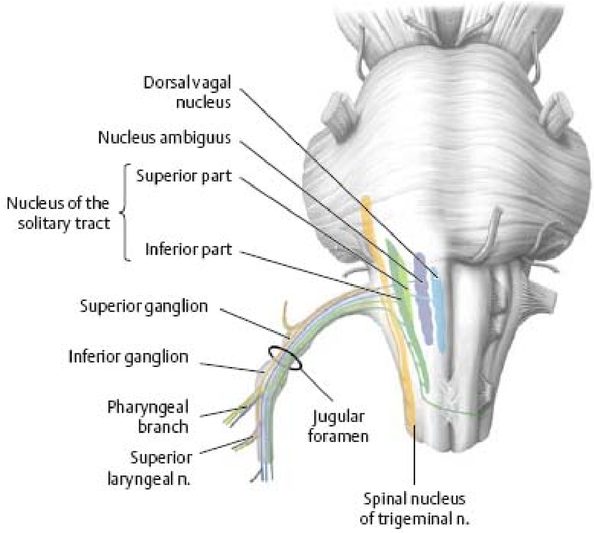


Fig. 31.20 **Visceral efferent (parasympathetic) fibers of CNIX**

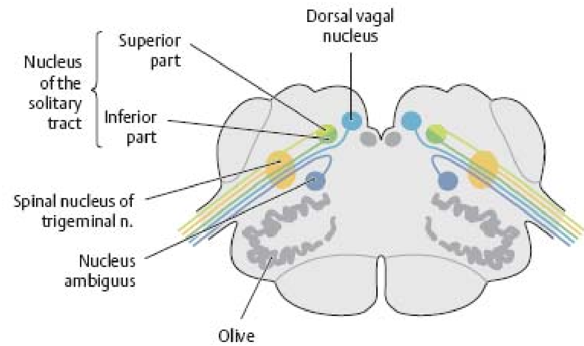


CN X: Vagus Nerve

Fig. 31.21 **Vagus nerve nuclei**



A Anterior view of the medulla oblongata.



B Cross section through the medulla oblongata, superior view.

Table 31.9 Vagus nerve (CN X)

Course	Fibers	Nuclei	Function	Effects of nerve injury
Emerges from the medulla oblongata; leaves the cranial cavity through the jugular foramen. CN X has the most extensive distribution of all the cranial nerves (vagus = "vagabond"), consisting of cranial, cervical, thoracic (see p. 91), and abdominal (see p. 237) parts.	Special visceral efferent (branchiogenic)	Nucleus ambiguus	Innervate: • Pharyngeal muscles (via pharyngeal plexus with CN IX) • Muscles of the soft palate • Laryngeal muscles (superior laryngeal n. supplies the cricothyroid; inferior laryngeal n. supplies all other laryngeal muscles)	The recurrent laryngeal nerve supplies visceromotor innervation to the only muscle abducting the vocal cords, the posterior cricoarytenoid. Unilateral destruction of this nerve leads to hoarseness; bilateral destruction leads to respiratory distress (dyspnea).
	Visceral efferent (parasympathetic)	Dorsal vagal nucleus	Synapse in prevertebral or intramural ganglia. Innervate smooth muscle and glands of • Thoracic viscera (**A**) • Abdominal viscera (**A**)	
	Somatic afferent	Spinal nucleus of trigeminal nerve	Superior (jugular) ganglion receives peripheral fibers from • Dura in posterior cranial fossa (**C**) • Skin of ear (**D**), external auditory canal (**E**)	
	Special visceral afferent	Nucleus of solitary tract (superior part)	Inferior nodose ganglion receives peripheral processes from • Taste buds on the epiglottis (**F**)	
	Visceral afferent	Nucleus of solitary tract (inferior part)	Inferior ganglion receives peripheral processes from • Mucosa of lower pharynx at its esophageal junction (**G**) • Laryngeal mucosa above (superior laryngeal n.) and below (inferior laryngeal n.) the vocal fold (**G**) • Pressure receptors in the aortic arch (**B**) • Chemoreceptors in the para-aortic body (**B**) • Thoracic and abdominal viscera (**A**)	

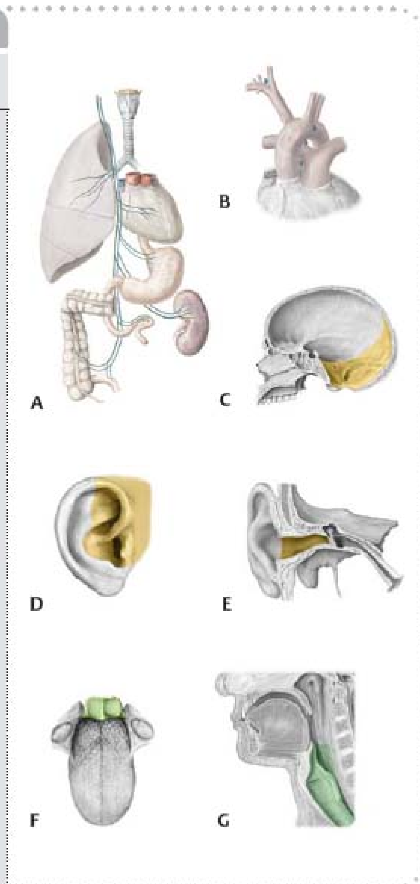
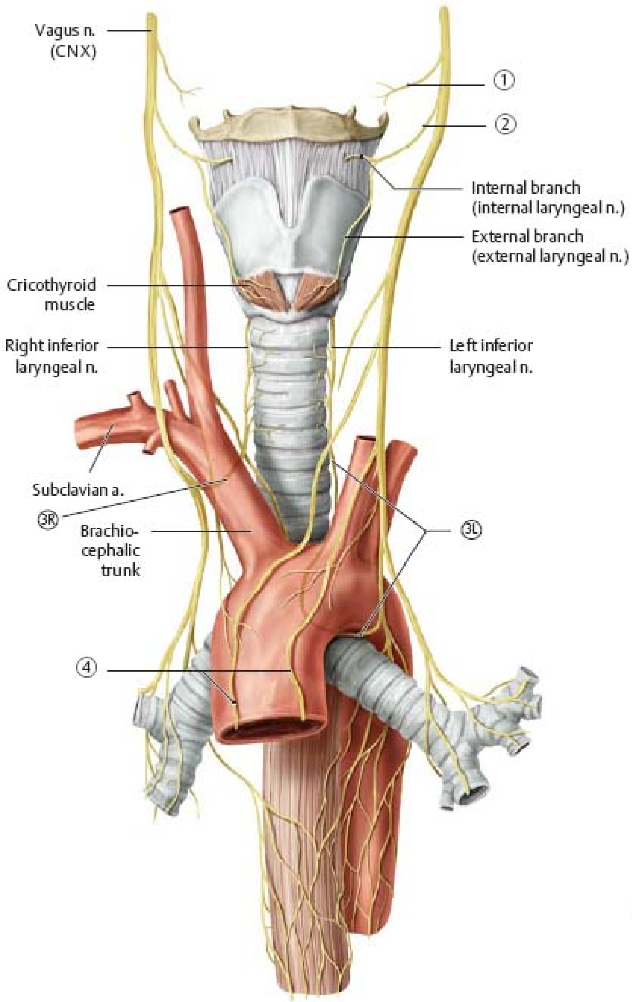


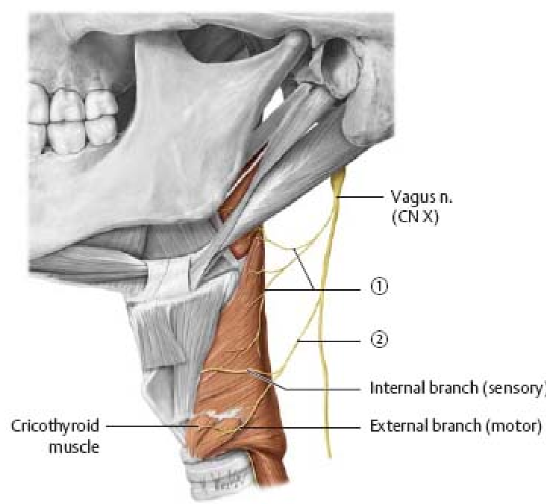
Fig. 31.22 Course of the vagus nerve

The vagus nerve gives off four major branches in the neck. The inferior laryngeal nerves are the terminal branches of the recurrent laryngeal nerves.

Note: The left recurrent laryngeal nerve winds around the aortic arch, while the right nerve winds around the subclavian artery.



A Branches of the vagus nerve in the neck. Anterior view.



B Innervation of the pharyngeal and laryngeal muscles. Left lateral view.

Table 31.10 **Vagus nerve branches in the neck**

1	Pharyngeal branches
2	Superior laryngeal n.
3R	Right recurrent laryngeal n.
3L	Left recurrent laryngeal n.
4	Cervical cardiac branches

CN XI & XII: Accessory & Hypoglossal Nerves

The traditional "cranial root" of the accessory nerve (CN XI) is now considered a part of the vagus nerve (CN X) that travels with the spinal root for a short distance before splitting. The cranial fibers are distributed via the vagus nerve while the spinal root fibers continue on as the (spinal) accessory nerve (CN XI).

Fig. 31.23 Accessory nerve

Posteriorview of the brainstem with the cerebellum removed. *Note:* For didactic reasons, the muscles are displayed from the right side.

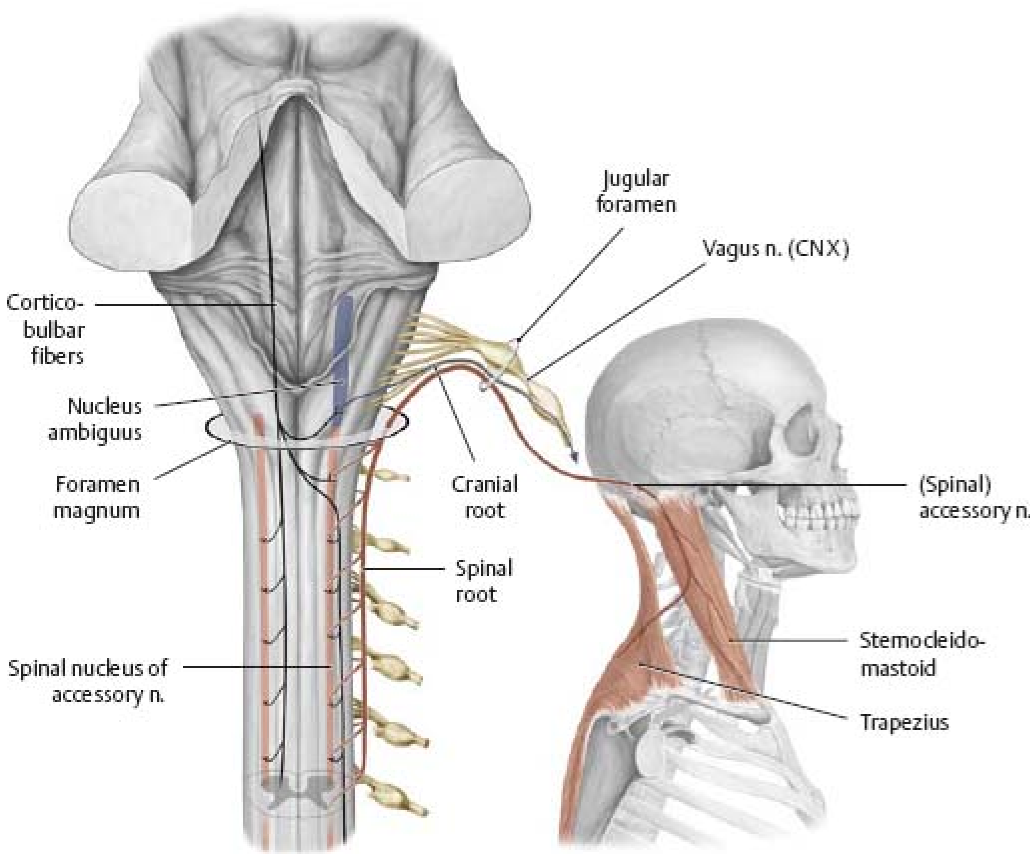
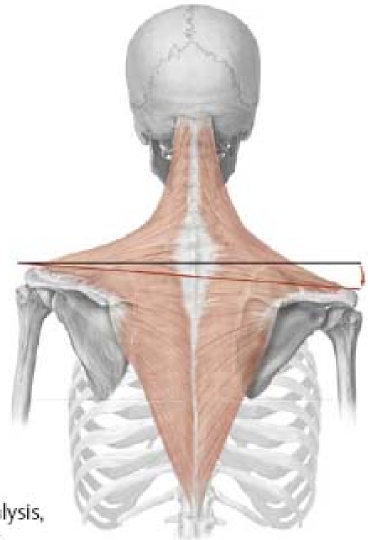


Fig. 31.24 Accessory nerve lesions

Lesion of the right accessory nerve.



A Trapezius paralysis, posterior view.

B Sternocleidomastoid paralysis, right anterolateral view.

Table 31.11 (Spinal) accessory nerve (CN XI)

Course	Fibers	Nuclei	Function	Effects of nerve injury
The spinal root emerges from the spinal cord (at the level of C1–C5/6), passes superiorly, and enters the skull through the foramen magnum, where it joins with the cranial root from the medulla oblongata. Both roots leave the skull through the jugular foramen. Within the jugular foramen, fibers from the cranial root pass to the vagus nerve (internal branch). The spinal portion descends to the nuchal region as the external branch.	Special visceral efferent	Nucleus ambiguus (caudal part)	Join CN X and are distributed with the recurrent laryngeal nerve. Innervate: • All laryngeal muscles (except cricothyroid)	*Trapezius paralysis:* drooping of shoulder on affected side and difficulty raising arm above horizontal plane. This paralysis is a concern during neck operations (e.g., lymph node biopsies). An injury of the accessory nerve will not result in complete trapezius paralysis (the muscle is also innervated by segments C3 and C4/5). *Sternocleidomastoid paralysis:* torticollis (wry neck, i.e., difficulty turning head). Unilateral lesions cause flaccid paralysis (the muscle is supplied exclusively by the accessory nerve). Bilateral lesions make it difficult to hold the head upright.
	Somatic efferent	Spinal nucleus of accessory n.	Form the external branch of the accessory nerve. Innervate: • Trapezius • Sternocleidomastoid	

Fig. 31.25 Hypoglossal nerve

Posterior view of the brainstem with the cerebellum removed. *Note:* C1, which innervates the thyrohyoid and geniohyoid, runs briefly with the hypoglossal nerve.

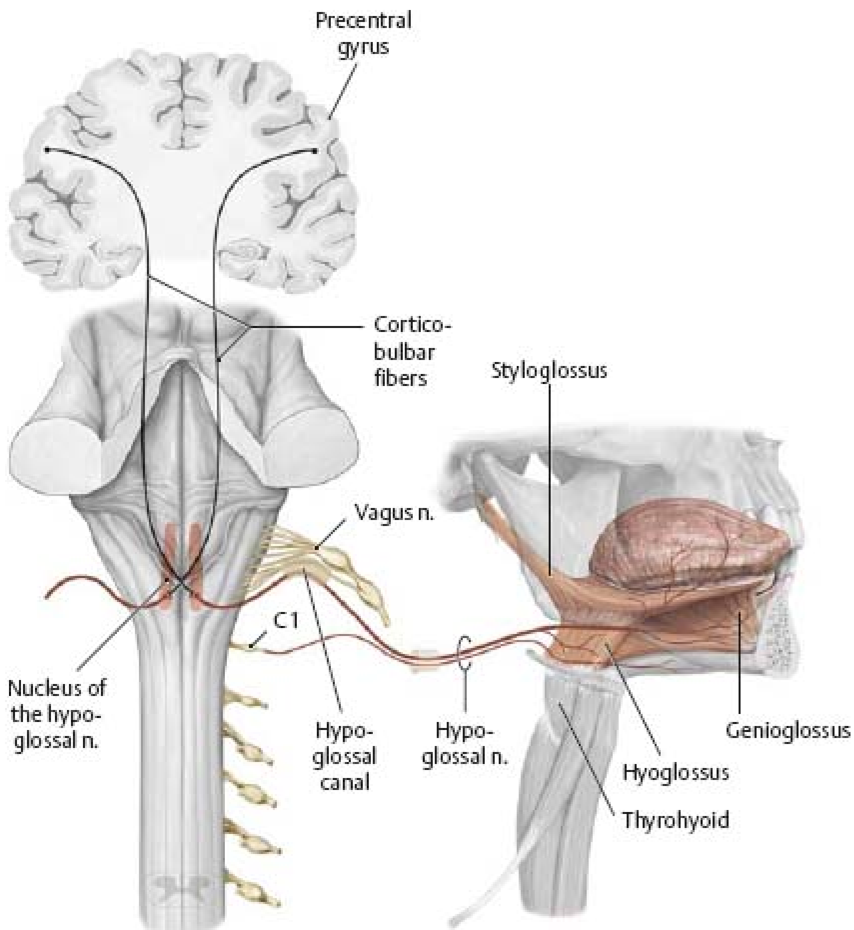


Fig. 31.26 **Hypoglossal nerve nuclei**

Note: The nucleus of the hypoglossal nerve is innervated by cortical neurons from the contralateral side.

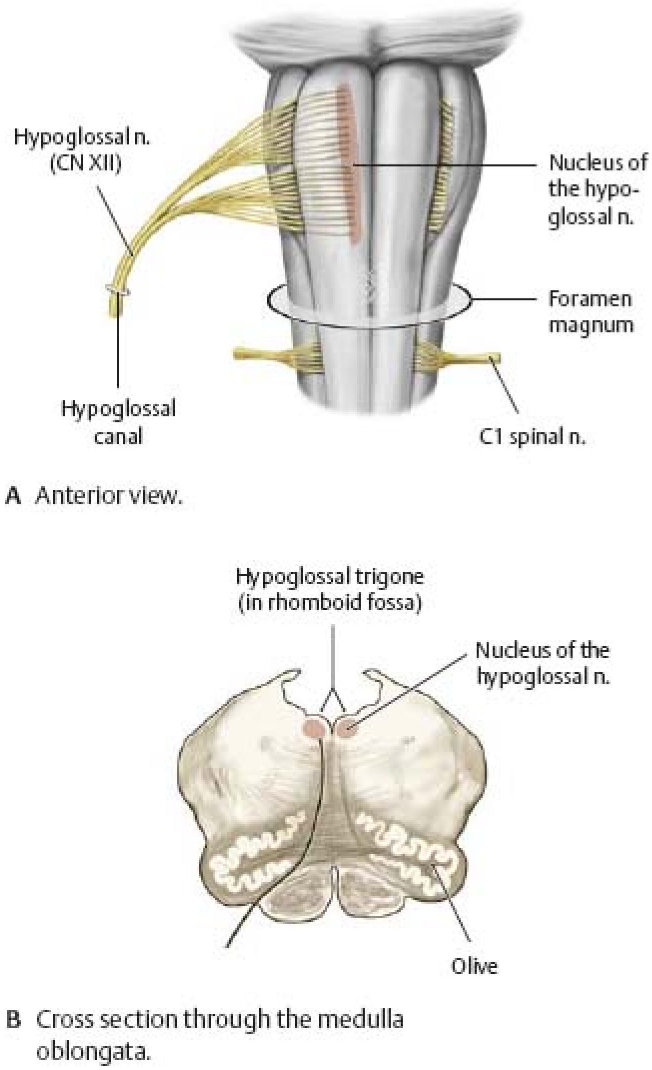
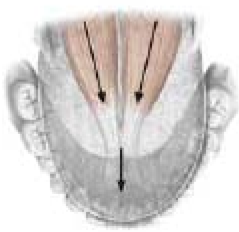
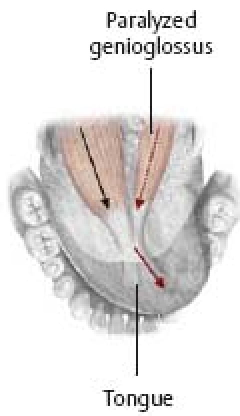


Fig. 31.27 **Hypoglossal nerve lesions**

Superior view.



A Normal genioglossus muscles.



B Unilateral nuclear or peripheral lesion.

Table 31.12 Hypoglossal nerve (CN XII)

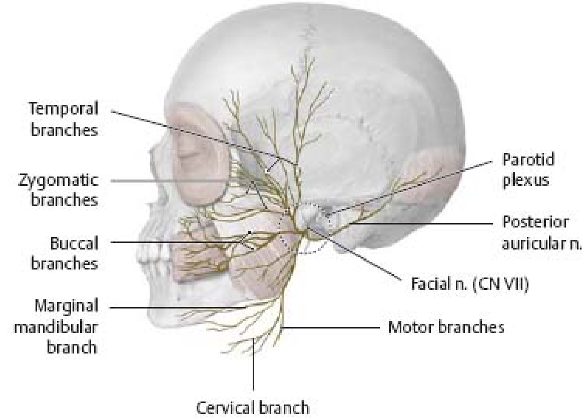
Course	Fibers	Nuclei	Function	Effects of nerve injury
Emerges from the medulla oblongata, leaves the cranial cavity through the hypoglossal canal, and descends laterally to the vagus nerve. CN XII enters the root of the tongue above the hyoid bone.	Somatic efferent	Nucleus of the hypoglossal n.	Innervates: • Intrinsic and extrinsic muscles of the tongue (except the palatoglossus, supplied by CN X)	Central hypoglossal paralysis (supranuclear): tongue deviates *away* from the side of the lesion Nuclear or peripheral paralysis: tongue deviates *toward* the affected side (due to preponderance of muscle on healthy side) Flaccid paralysis: both nuclei injured; tongue cannot be protruded

32 Neurovasculature of the Skull & Face

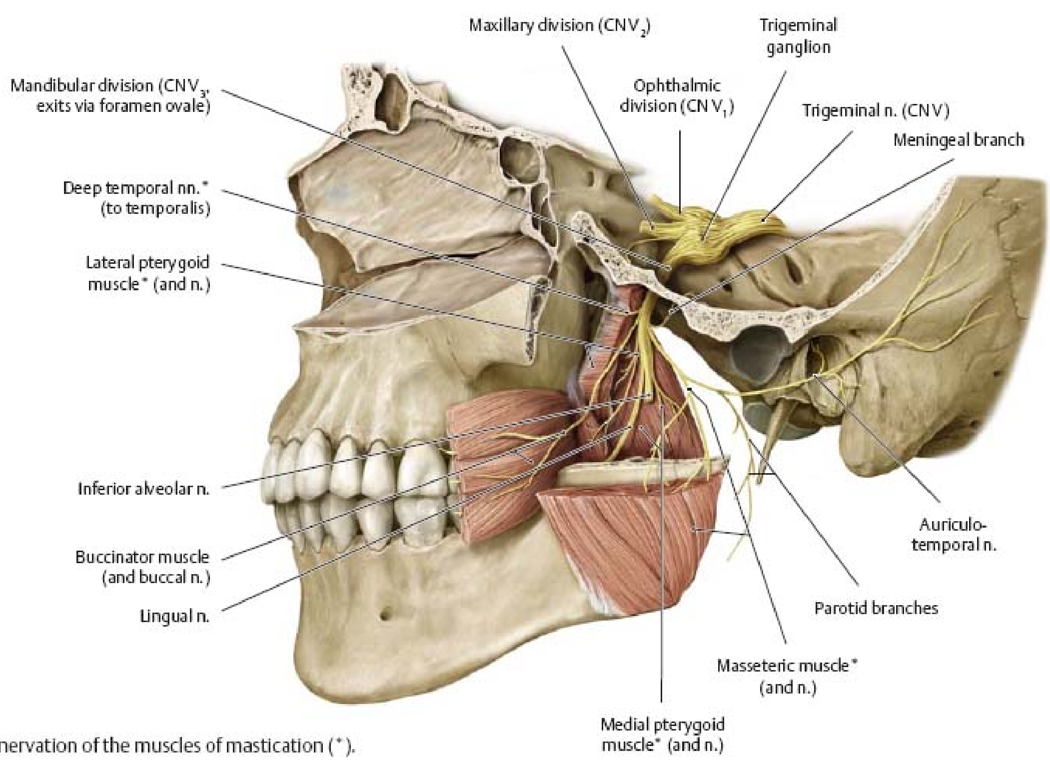
Innervation of the Face

Fig. 32.1 Motor innervation of the face

Left lateral view. Five branches of the facial nerve (CN VII) provide motor innervation to the muscles of facial expression. The mandibular division of the trigeminal nerve (CN V_3) supplies motor innervation to the muscles of mastication.

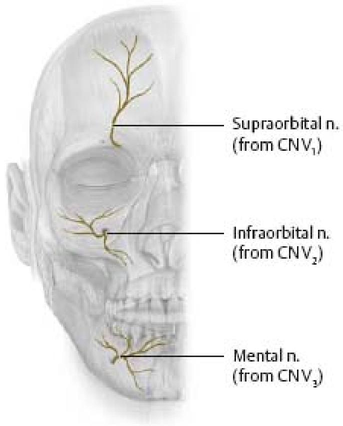


A Motor innervation of the muscles of facial expression.

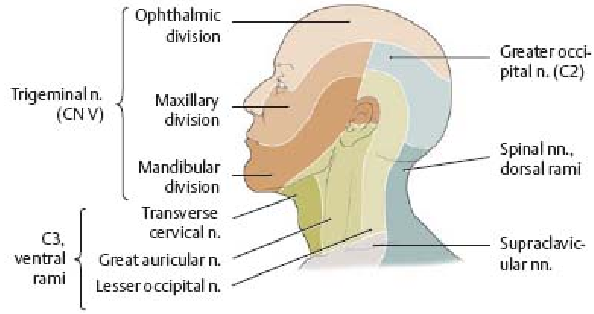


B Motor innervation of the muscles of mastication (*).

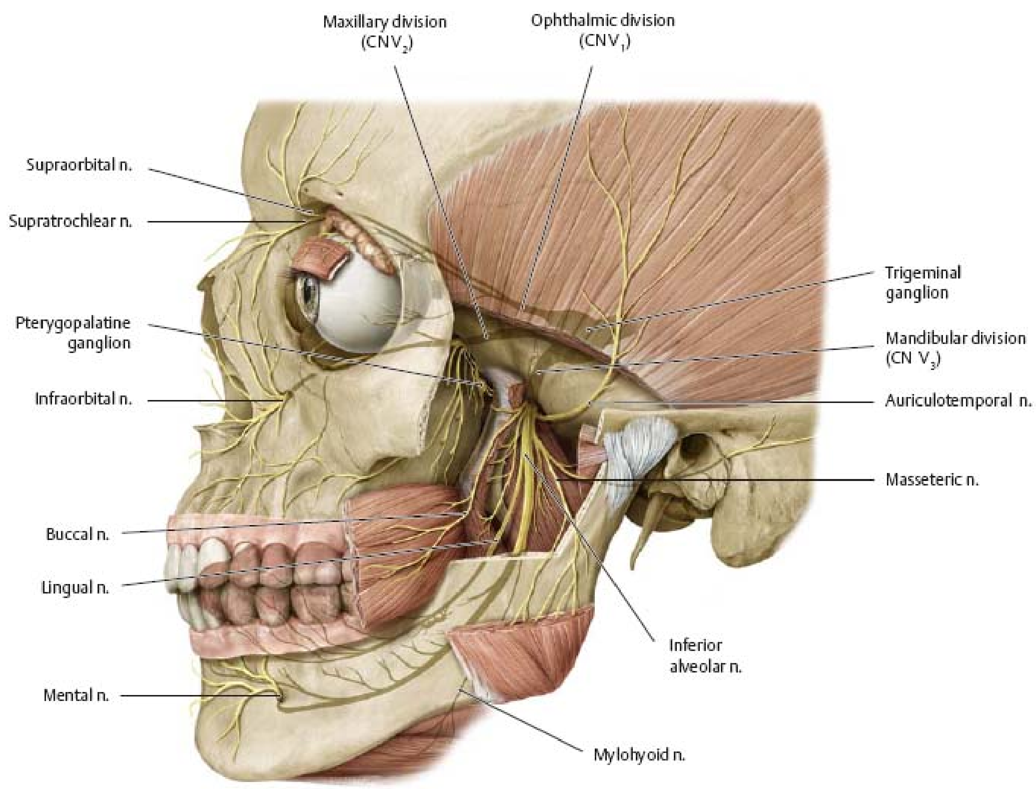
Fig. 32.2 Sensory innervation of the face



A Sensory branches of the trigeminal nerve, anterior view. The sensory branches of the three divisions emerge from the supraorbital, infraorbital, and mental foramina, respectively.



B Sensory innervation of the head and neck, left lateral view. The occiput and nuchal regions are supplied by the dorsal rami (blue) of the spinal nerves (the greater occipital nerve is the dorsal ramus of C2).



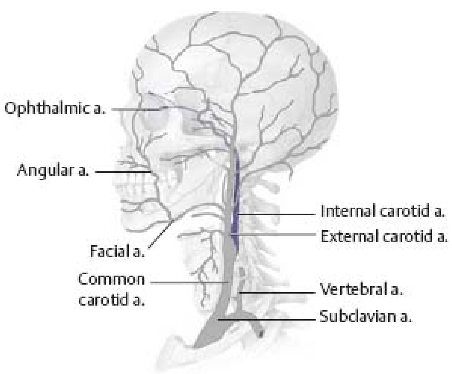
C Divisions of the trigeminal nerve, left lateral view.

Arteries of the Head & Neck

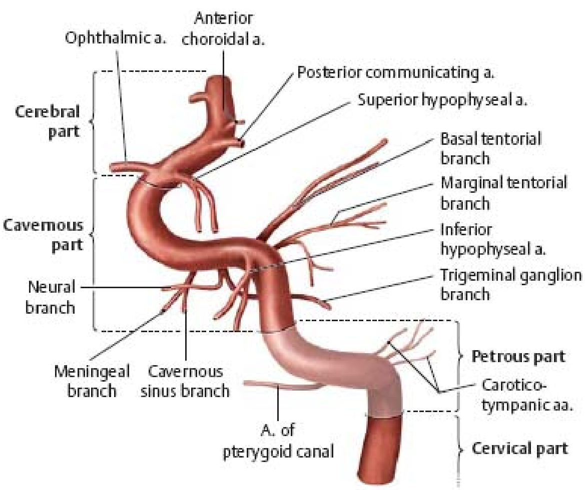
The head and neck are supplied by branches of the common carotid artery. The common carotid splits at the carotid bifurcation into two branches: the internal and external carotid arteries. The internal carotid chiefly supplies the brain (p. 606), although its branches anastomose with the external carotid in the orbit and nasal septum. The external carotid is the major supplier of structures of the head and neck.

Fig. 32.3 **Internal carotid artery**

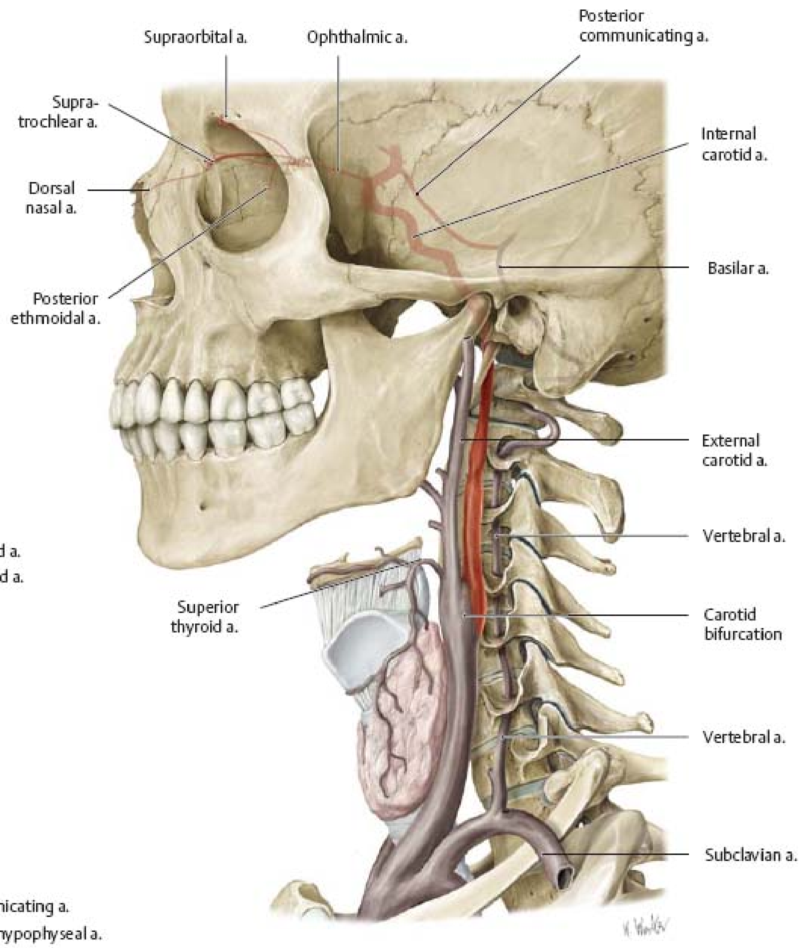
Left lateral view. The most important extra-cerebral branch of the internal carotid artery is the ophthalmic artery, which supplies the upper nasal septum (p. 524) and the orbit (p. 512). See pp. 608–609 for arteries of the brain.



A Schematic.



B Parts and branches of the internal carotid artery.

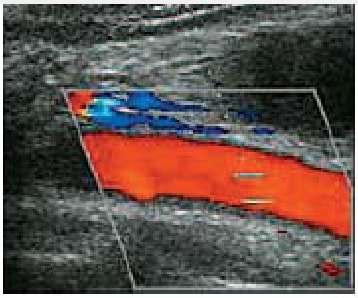


C Course of the internal carotid artery.

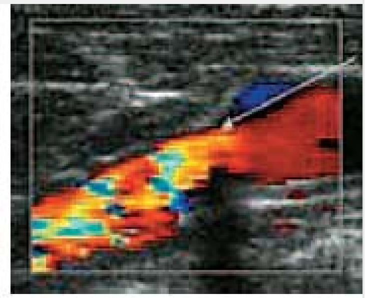
Clinical

Carotid artery atherosclerosis

The carotid artery is often affected by atherosclerosis, a hardening of arterial walls due to plaque formation. The examiner can determine the status of the arteries using ultrasound. *Note:* The absence of atherosclerosis in the carotid artery does not preclude coronary heart disease or atherosclerotic changes in other locations.



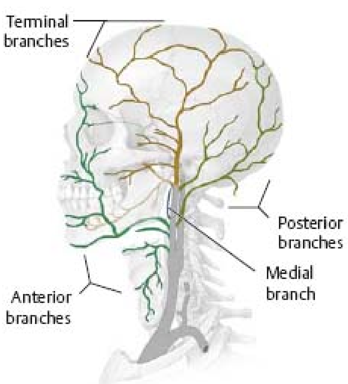
A Common carotid artery with "normal" flow.



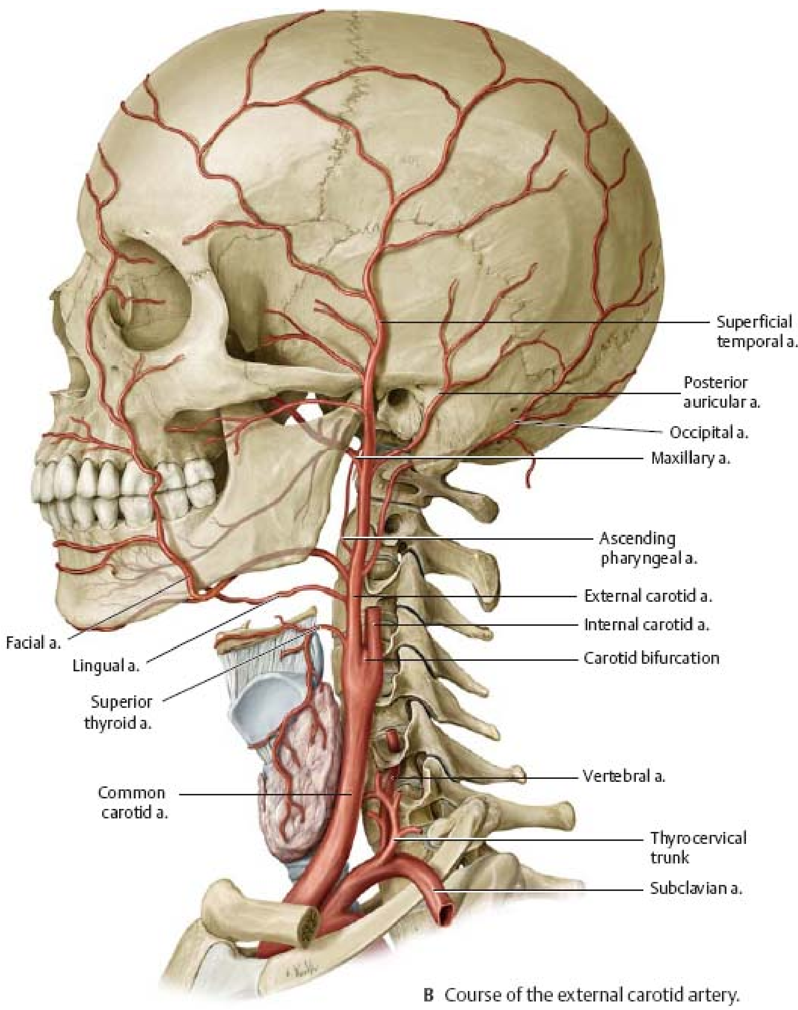
B Calcified plaque in the carotid bulb.

Fig. 32.4 External carotid artery: Overview

Left lateral view.



A Schematic of the external carotid artery.



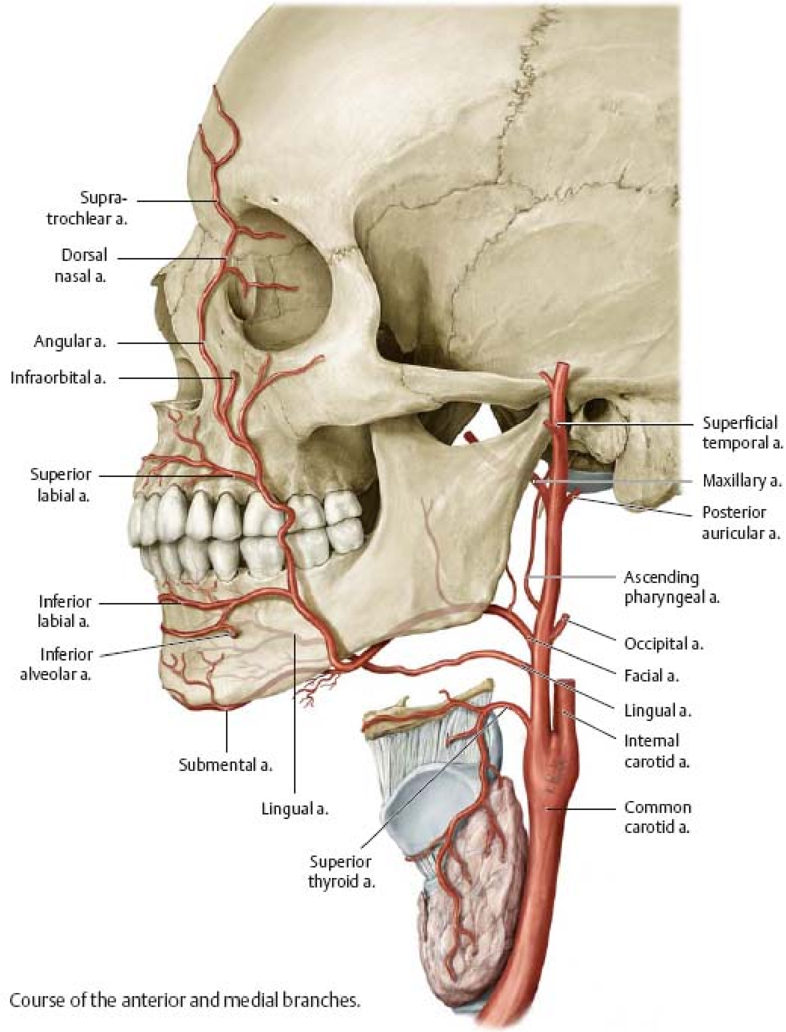
B Course of the external carotid artery.

Table 32.1	Branches of the external carotid artery
Group	**Artery**
Anterior (p. 492)	Superior thyroid a.
	Lingual a.
	Facial a.
Medial (p. 492)	Ascending pharyngeal a.
Posterior (p. 493)	Occipital a.
	Posterior auricular a.
Terminal (p. 494)	Maxillary a.
	Superficial temporal a.

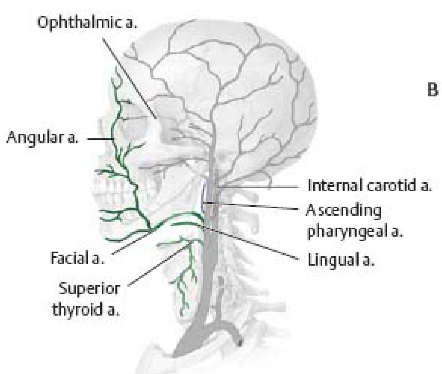
External Carotid Artery: Anterior, Medial & Posterior Branches

Fig. 32.5 Anterior and medial branches

Left lateral view. The arteries of the anterior aspect supply the anterior structures of the head and neck, including the orbit (p. 540), ear (p. 534), larynx (p. 575), pharynx (p. 556), and oral cavity. *Note:* The angular artery anastomoses with the dorsal nasal artery of the internal carotid (via the ophthalmic artery).



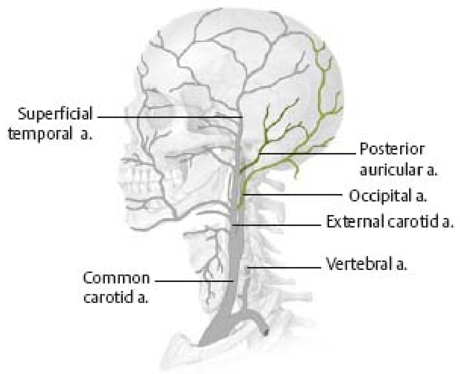
B Course of the anterior and medial branches.



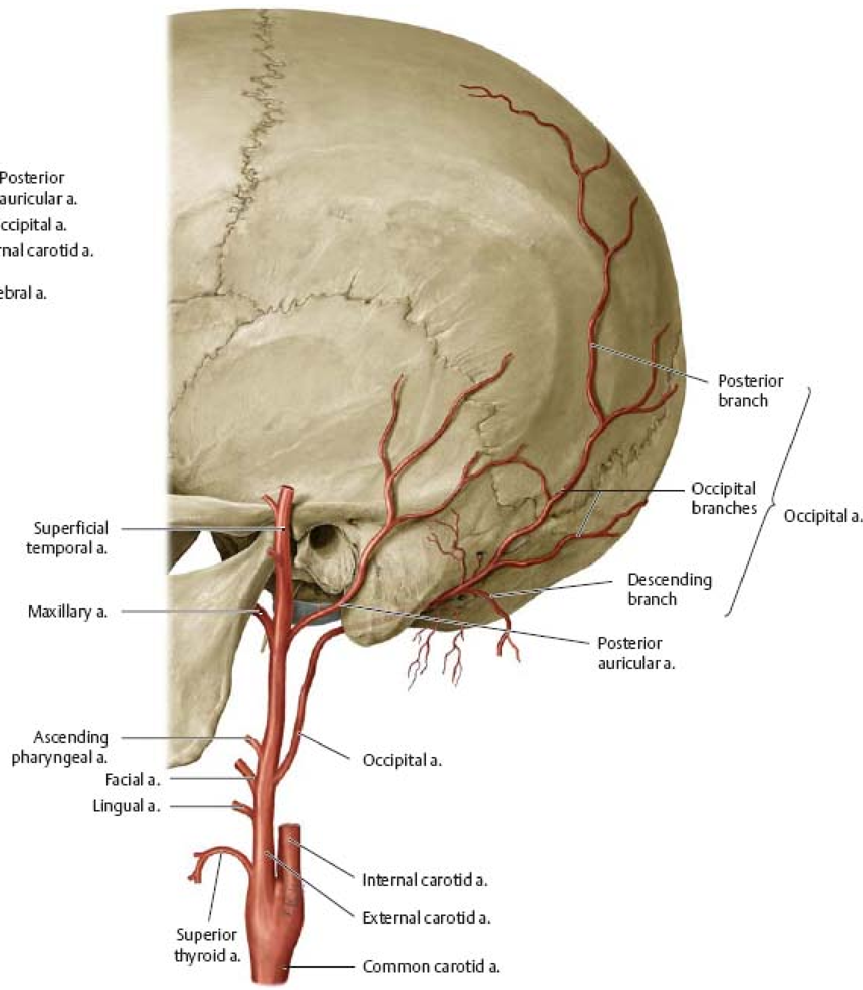
A Arteries of the anterior and medial branches. The copious blood supply to the face makes facial injuries bleed profusely, but heal quickly. There are extensive anastomoses between branches of the external carotid, and between the external carotid artery and branches of the ophthalmic artery.

Fig. 32.6 Posterior branches

Left lateral view. The posterior branches of the external carotid artery supply the ear (p. 534), posterior skull (p. 499), and posterior neck muscles (p. 585).



A Arteries of the posterior branch.



B Course of the posterior branches.

Table 32.2 Anterior, medial, and posterior branches of the external carotid artery

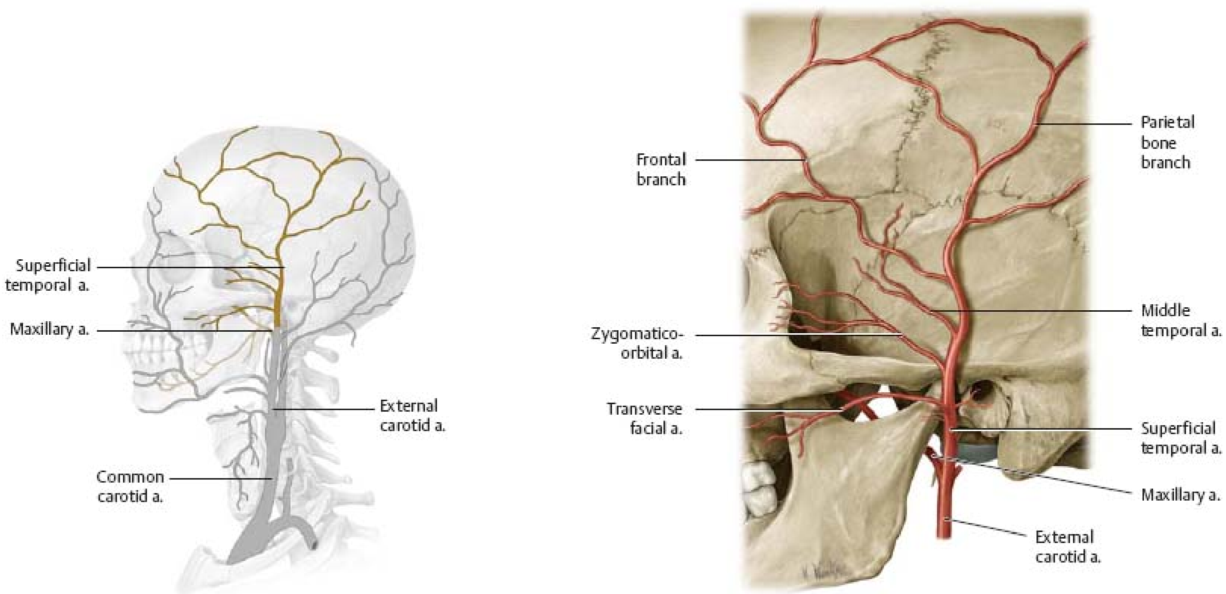
Branch	Artery	Divisions and distribution
Anterior branch	Superior thyroid a.	Glandular branch (to thyroid gland); superior laryngeal a.; sternocleidomastoid branch
	Lingual a.	Dorsal lingual branches (to base of tongue, epiglottis); sublingual a. (to sublingual gland, tongue, oral floor, oral cavity)
	Facial a.	Ascending palatine a. (to pharyngeal wall, soft palate, pharyngotympanic tube); tonsillar branch (to palatine tonsils); submental a. (to oral floor, submandibular gland); labial aa.; angular a. (to nasal root)
Medial branch	Ascending pharyngeal a.	Pharyngeal branches; interior tympanic a. (to mucosa of inner ear); posterior meningeal a.
Posterior branches	Occipital a.	Occipital branches; descending branch (to posterior neck muscles)
	Posterior auricular a.	Stylomastoid a. (to facial nerve in facial canal); posterior tympanic a.; auricular branch; occipital branch; parotid branch
For terminal branches, see Table 32.3.		

External Carotid Artery: Terminal Branches

The terminal branches of the external carotid artery consist of two major arteries: superficial temporal and maxillary. The superficial temporal artery supplies the lateral skull. The maxillary artery is a major artery for internal structures of the face.

Fig. 32.7 Superficial temporal artery

Left lateral view. Inflammation of the superficial temporal artery due to temporal arteritiscan cause severe headaches. The course of the frontal branch of the artery can often be seen superficially under the skin of elderly patients.



A Arteries of the terminal branch.

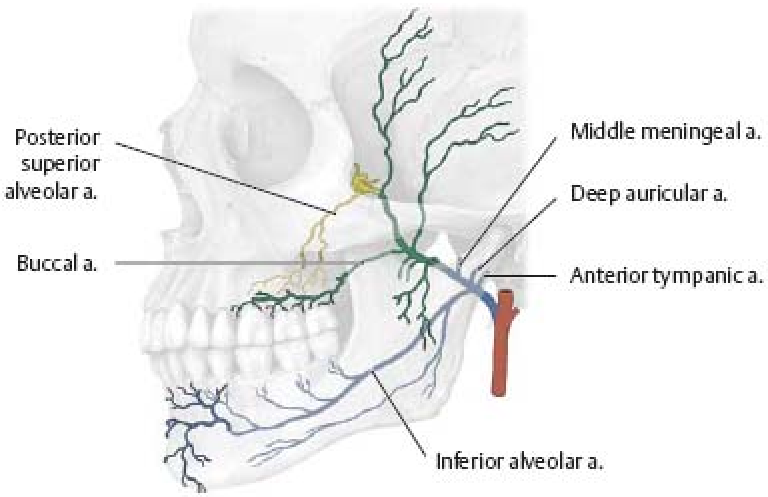
B Course of the superficial temporal artery.

Table 32.3 Terminal branches of the external carotid artery

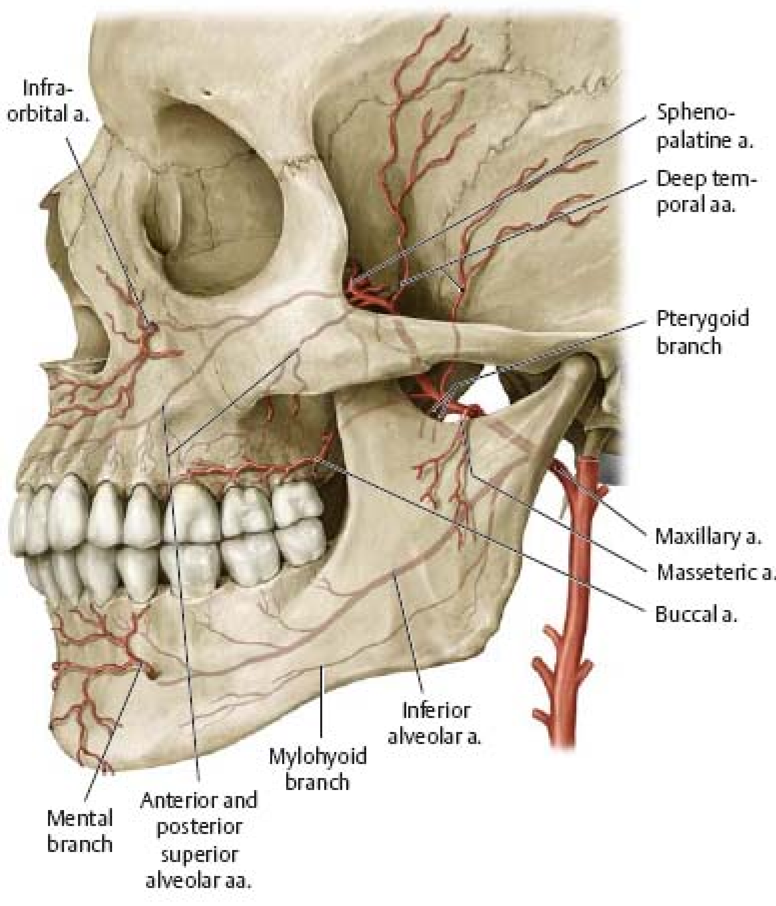
Branch	Artery		Divisions and distribution	
Terminal branches	Superficial temporal a.		Transverse facial a. (to soft tissues below the zygomatic arch); frontal branches; parietal branches; zygomatico-orbital a. (to lateral orbital wall)	
	Maxillary a.	Mandibular part	Inferior alveolar a. (to mandible, teeth, gingiva); middle meningeal a.; deep auricular a. (to temporomandibular joint, external auditory canal); anterior tympanic a.	
		Pterygoid part	Masseteric a.; deep temporal branches; pterygoid branches; buccal a.	
		Pterygopalatine part	Posterosuperior alveolar a. (to maxillary molars, maxillary sinus, gingiva); infraorbital a. (to maxillary alveoli)	
			Descending palatine a.	Greater palatine a. (to hard palate)
				Lesser palatine a. (to soft palate, palatine tonsil, pharyngeal wall)
			Sphenopalatine a.	Lateral posterior nasal aa. (to lateral wall of nasal cavity, conchae)
				Posterior septal branches (to nasal septum)

Fig. 32.8 Maxillary artery

Left lateral view. The maxillary artery consists of three parts: mandibular (blue), pterygoid (green), and pterygopalatine (yellow).



A Divisions of the maxillary artery.

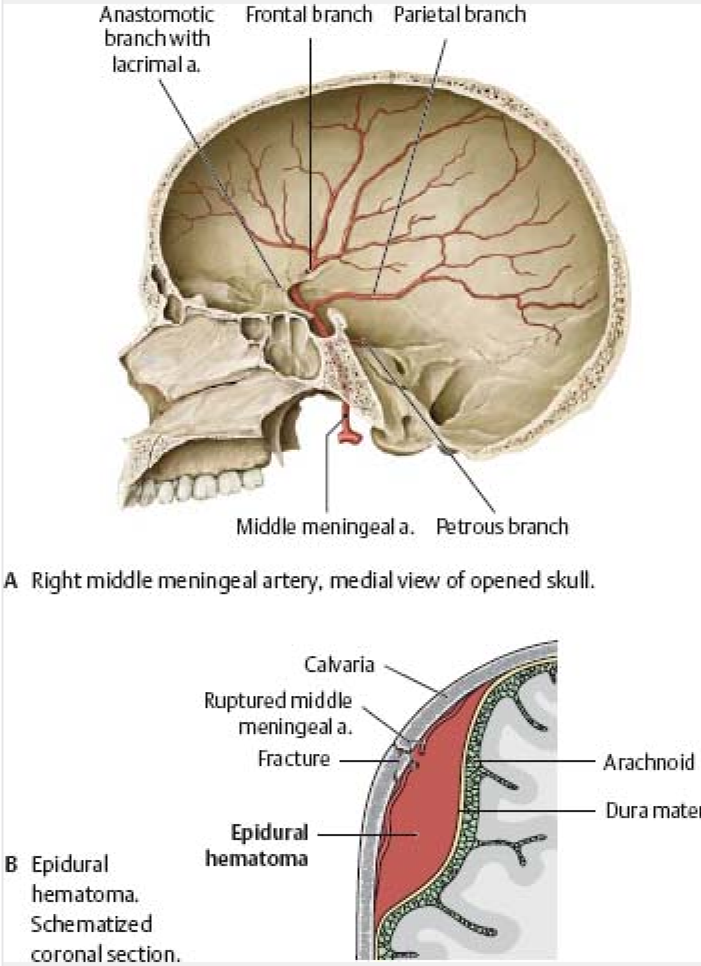


B Course of the maxillary artery.

Clinical

Middle meningeal artery

The middle meningeal artery supplies the meninges and overlying calvaria. Rupture of the artery (generally due to head trauma) results in an epidural hematoma.

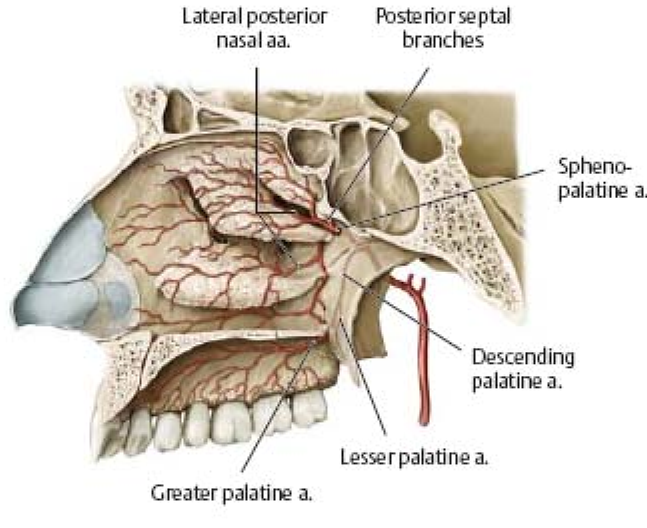


A Right middle meningeal artery, medial view of opened skull.

B Epidural hematoma. Schematized coronal section.

Sphenopalatine artery

The sphenopalatine artery supplies the wall of the nasal cavity. Excessive nasopharyngeal bleeding from the branches of the sphenopalatine artery may necessitate ligationofthe maxillary artery in the pterygopalatine fossa.

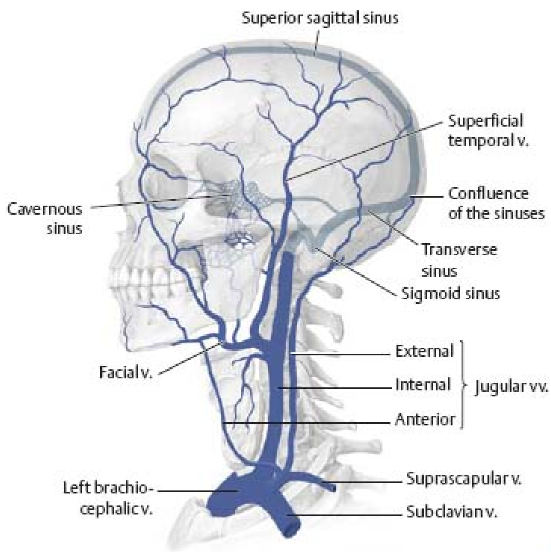


C Lateral wall of nasal cavity, left lateral view.

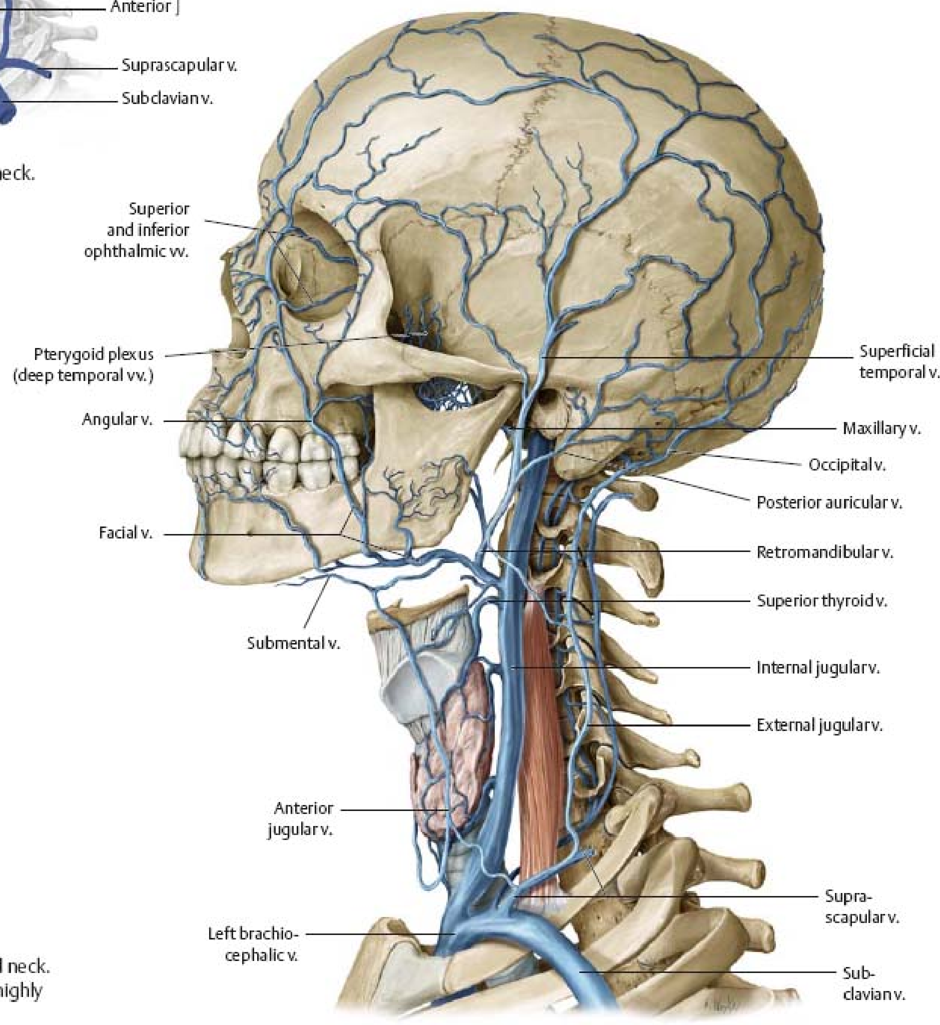
Veins of the Head & Neck

Fig. 32.9 Veins of the head and neck

Left lateral view. The veins of the head and neck drain into the brachio-cephalicvein. *Note:* The left and right brachiocephalic veins are not symmetrical.



A Principal veins of the head and neck.



B Superficial veins of the head and neck. *Note*: The course of the veins is highly variable.

Table 32.4 Principal superficial veins

Vein	Region drained	Location
Internal jugular v.	Interior of skull (including brain)	Within carotid sheath
External jugular v.	Superficial head	Within superficial cervical fascia
Anterior jugular v.	Neck, portions of head	

Fig. 32.10 Deep veins of the head

Left lateral view. *Removed:* Upper ramus, condylar and coronoid processes of mandible. The pterygoid plexus is a venous network situated between the mandibular ramus and the muscles of mastication. The cavernous sinus connects branches of the facial vein to the sigmoid sinuses.

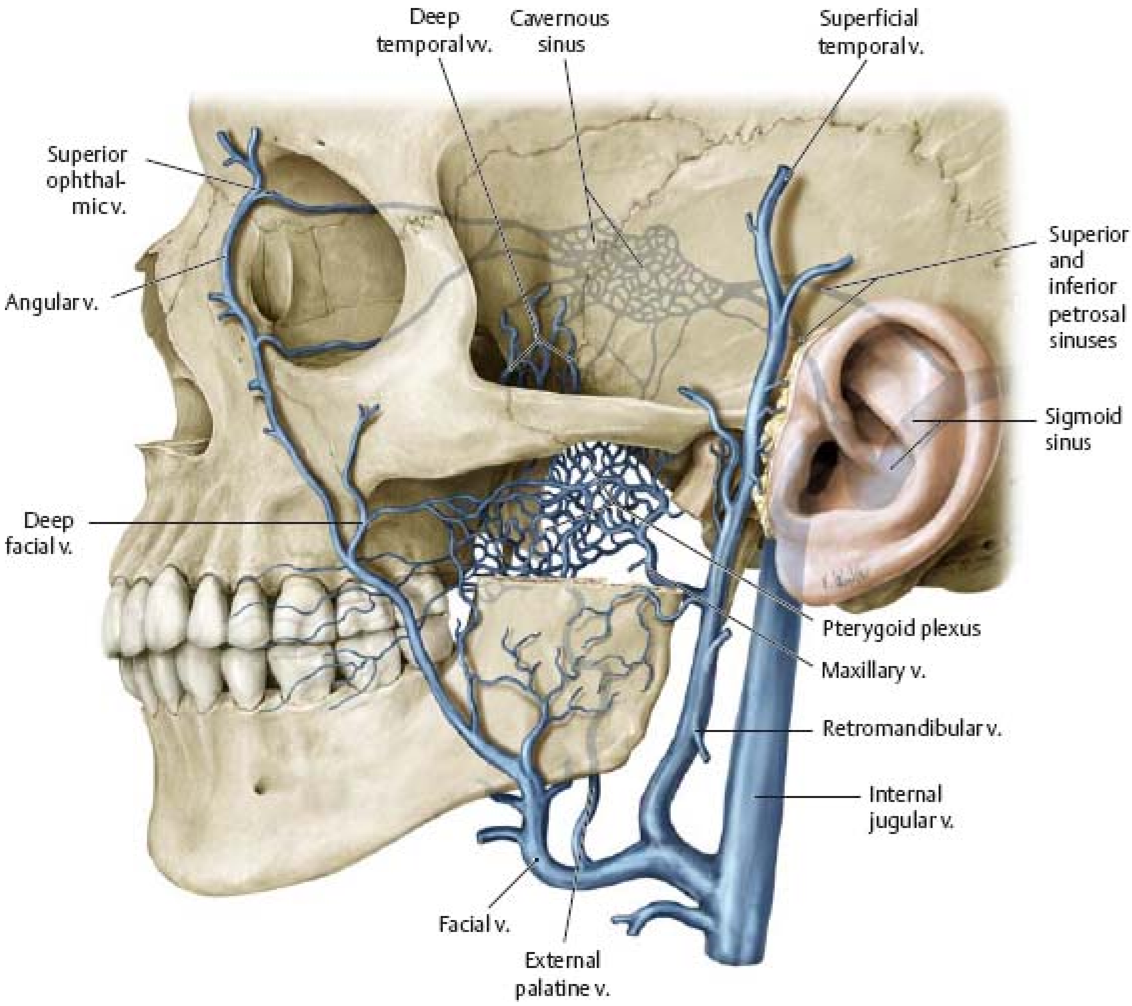


Fig. 32.11 Veins of the occiput

Posterior view. The superficial veins of the occiput communicate with the dural venous sinuses via emissary veins that drain to diploic veins (calvaria, p. 457). *Note:* The external vertebral venous plexus traverses the entire length of the spine (p. 611).

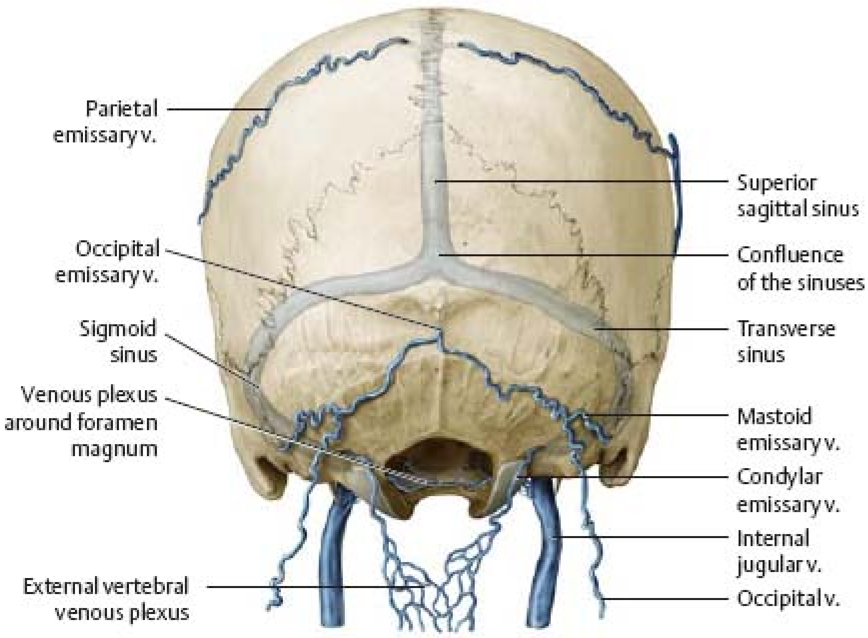


Table 32.5 Venous anastomoses

The extensive venous anastomoses in this region provide routes for the spread of infections.

Extracranial vein	Connecting vein	Venous sinus
Angular v.	Superior and inferior ophthalmic vv.	Cavernous sinus*
Vv. of palatine tonsil	Pterygoid plexus; inferior ophthalmic v.	
Superficial temporal v.	Parietal emissary vv.	Superior sagittal sinus
Occipital v.	Occipital emissary v.	Transverse sinus, confluence of the sinuses
Posterior auricular v.	Mastoid emissary v.	Sigmoid sinus
External vertebral venous plexus	Condylar emissary v.	

*Deep spread of bacterial infection from the facial region may result in cavernous sinus thrombosis.

Topography of the Superficial Face

Fig. 32.12 Superficial neurovasculature of the face

Anterior view. *Removed:* Skin and fatty subcutaneous tissue; muscles of facial expression (leftside).

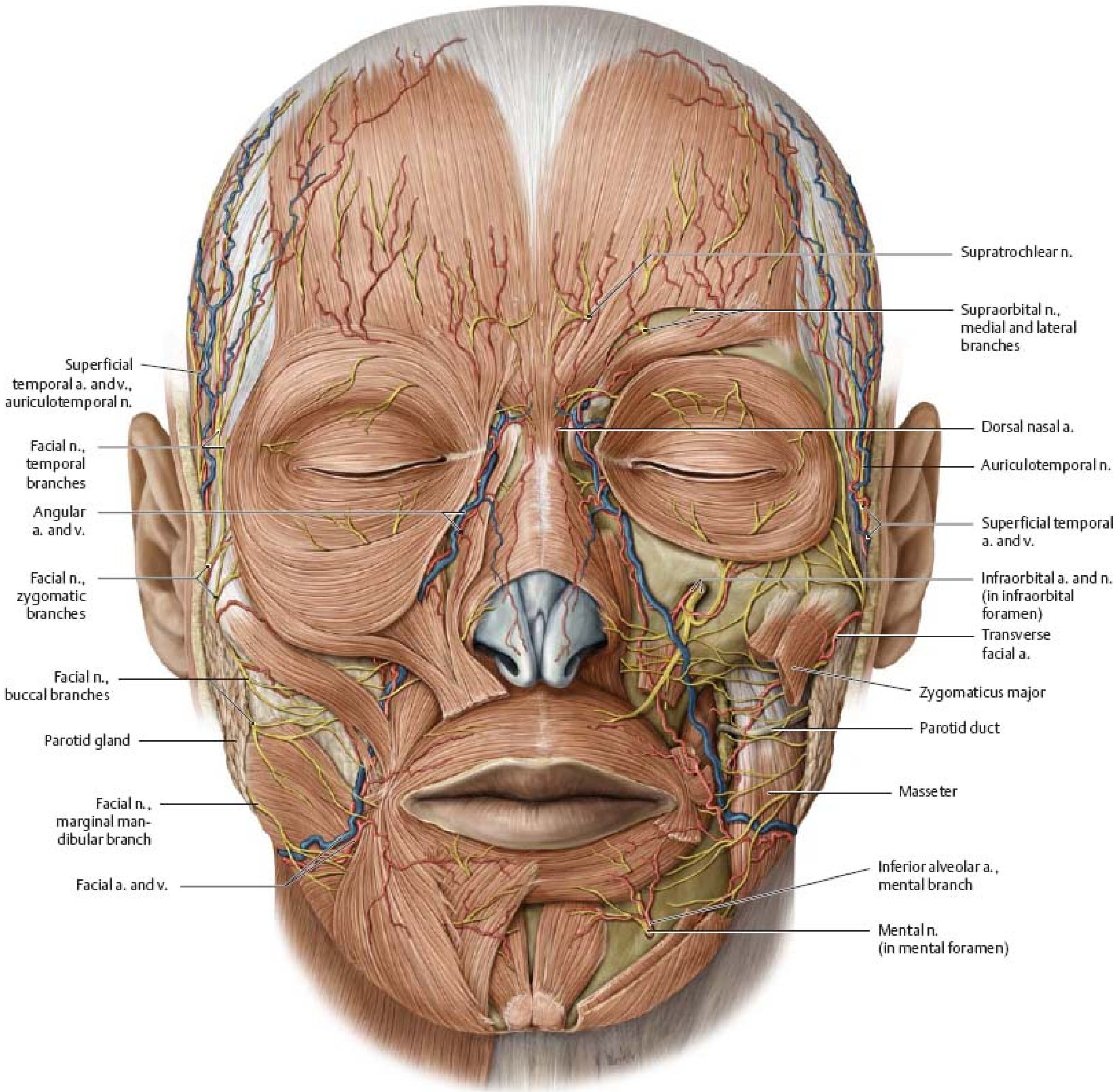
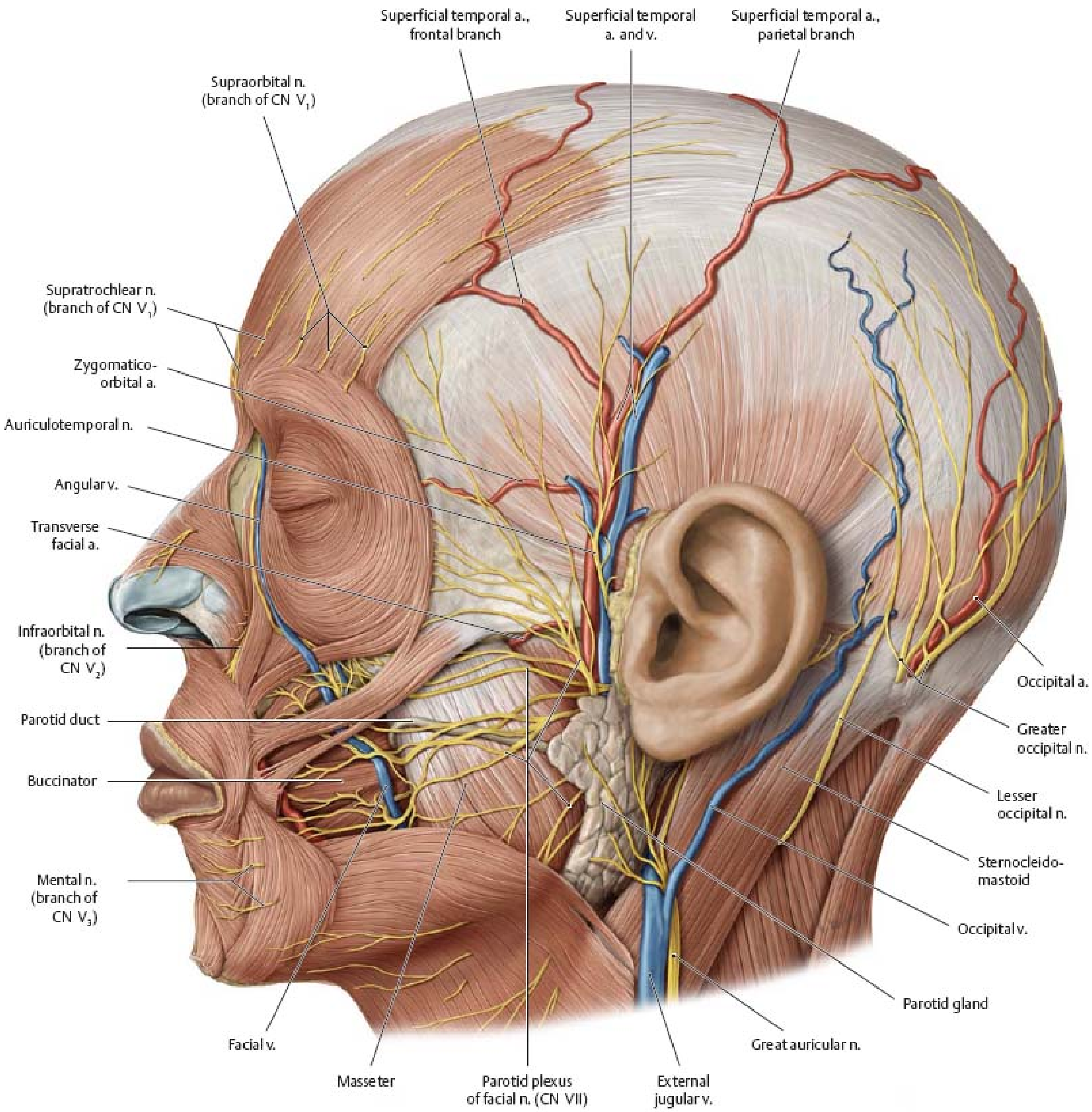


Fig. 32.13 **Superficial neurovasculature of the head**
Left lateral view.



Topography of the Parotid Region & Temporal Fossa

Fig. 32.14 Parotid region

Left lateral view. *Removed:* Parotid gland, sternocleidomastoid, and veins of the head. *Revealed:* Parotid bed and carotid triangle.

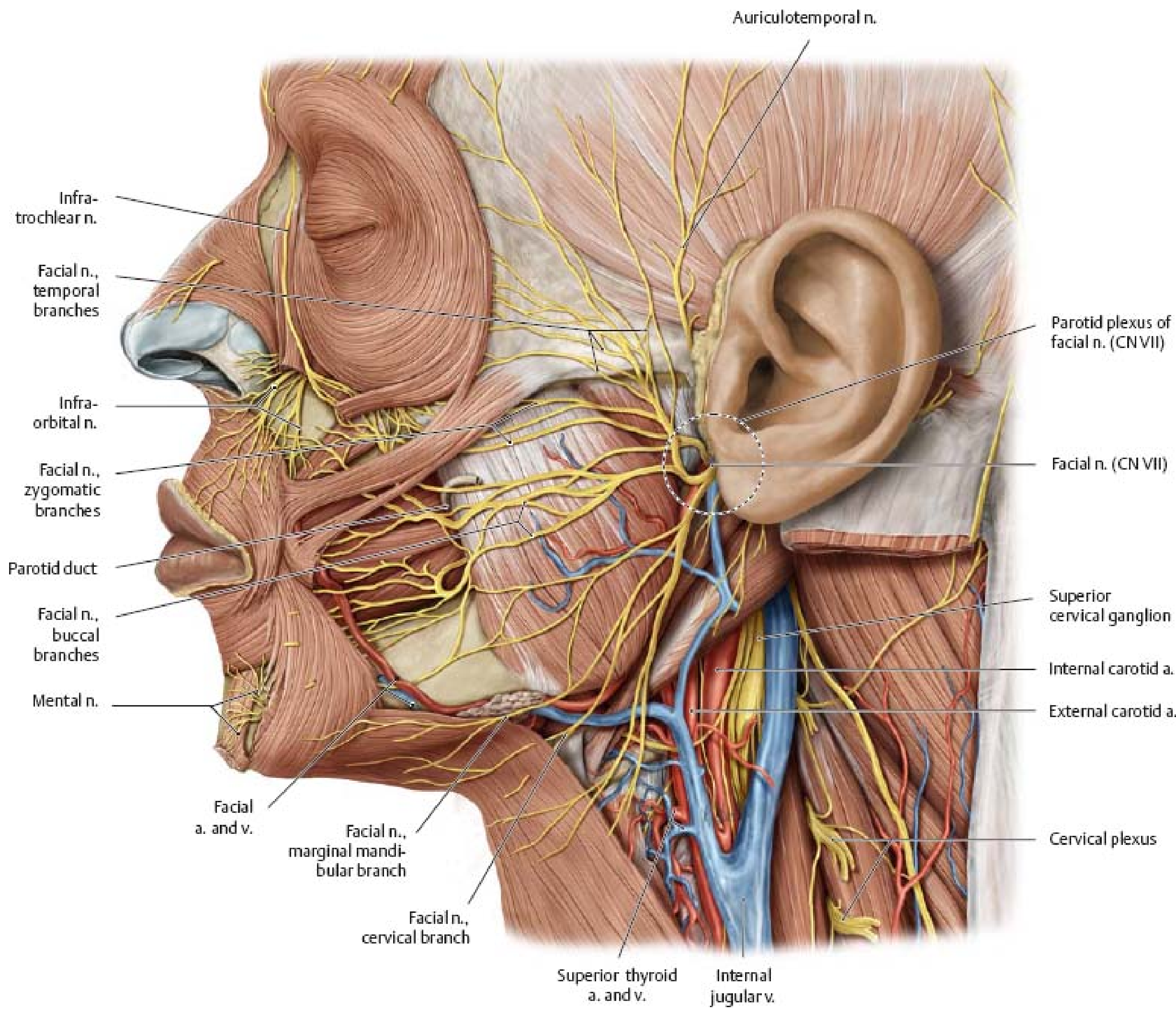
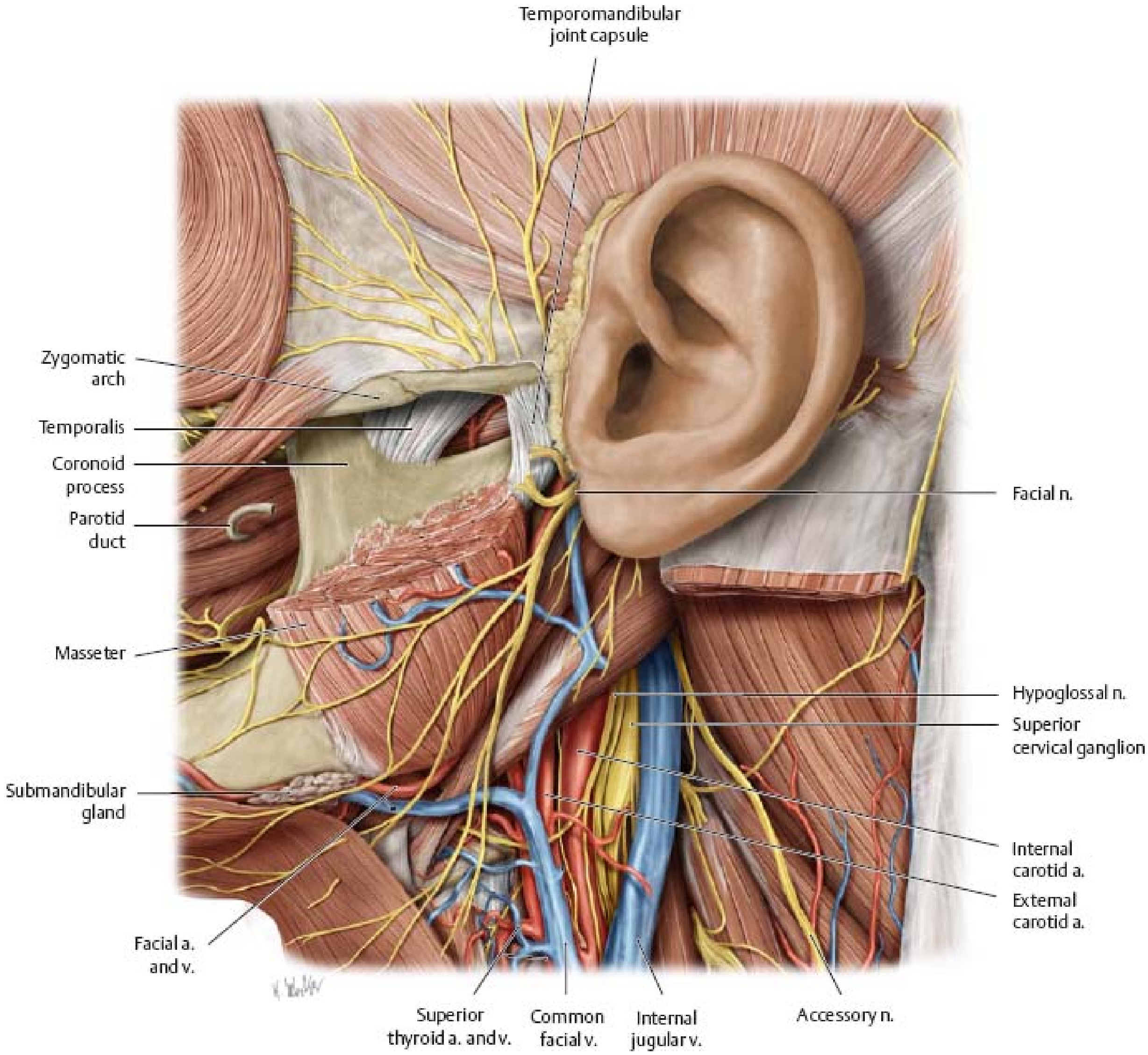


Fig. 32.15 Temporal fossa

Left lateral view. *Removed*: Sternocleidomastoid and masseter. *Revealed*: Temporal fossa and temporomandibular joint (p. 540).



Topography of the Infratemporal Fossa

Fig. 32.16 Infratemporal fossa: Superficial layer

Left lateral view. *Removed*: Ramus of mandible. *Note*: The mylohyoid nerve (see p. 547) branches from the inferior alveolar nerve just before the mandibular foramen.

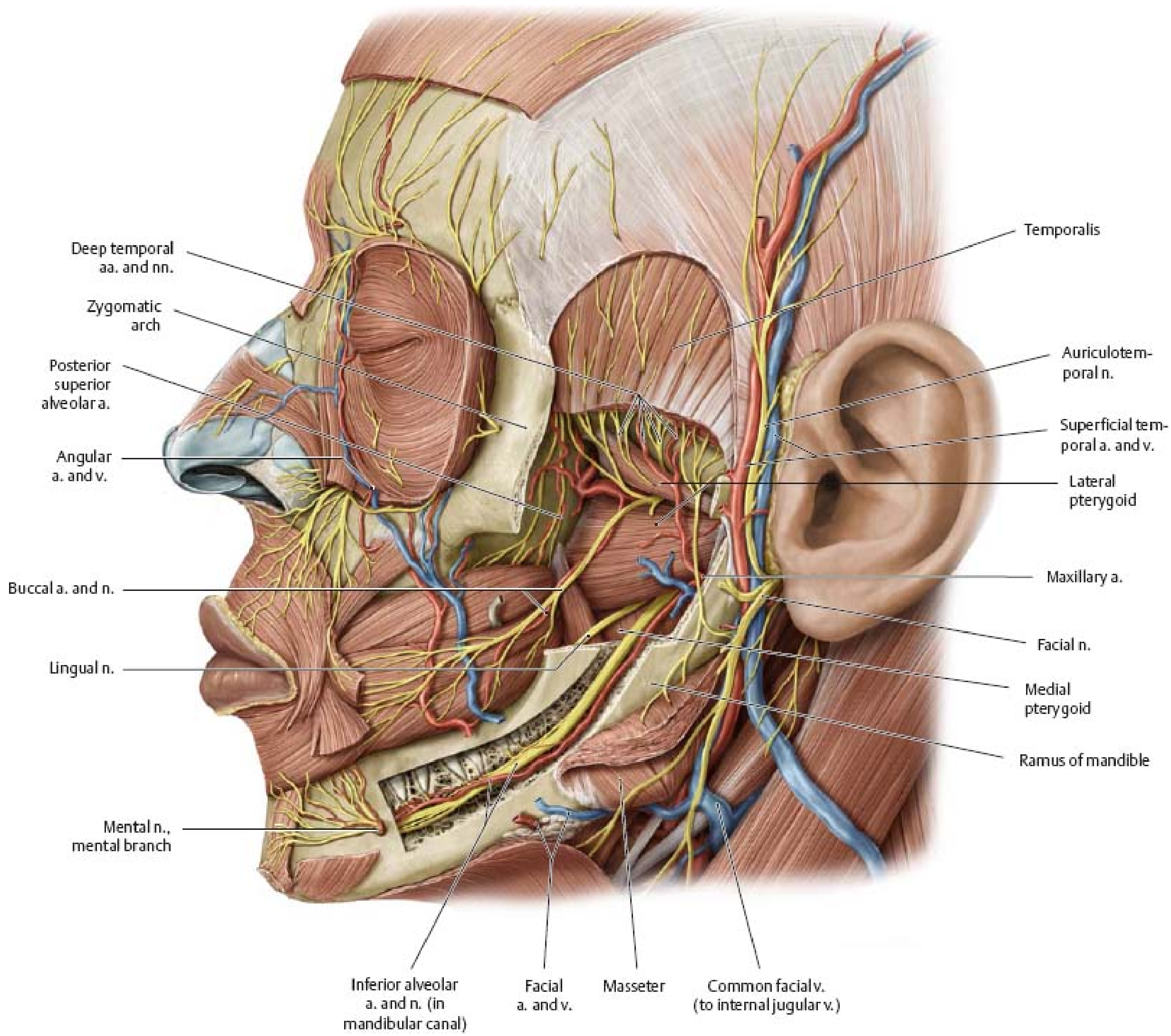


Fig. 32.17 Deep layer

Left leteral view. *Removed*: Lateral pterygold muscle (both heads). *Revealed*: Deep infratemporal fossa and mandibular nerve as it enters the mandibular canal via the foramen ovale in the roof of the fossa.

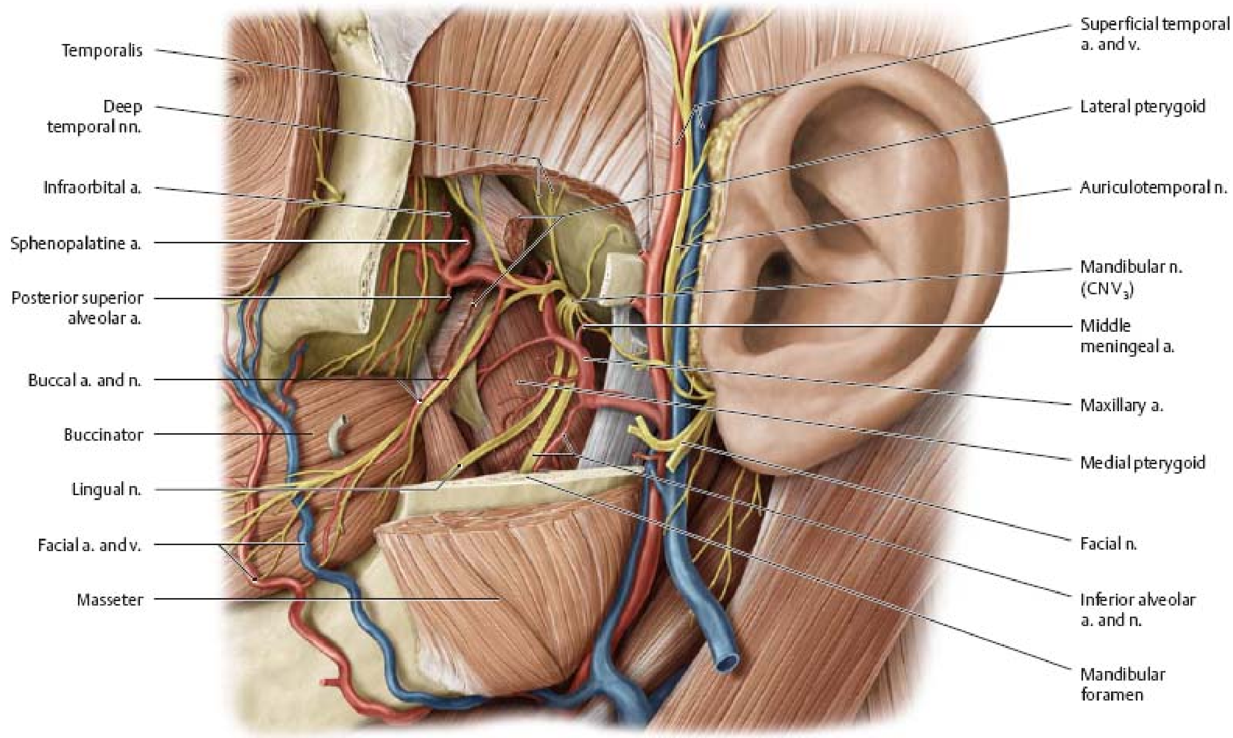
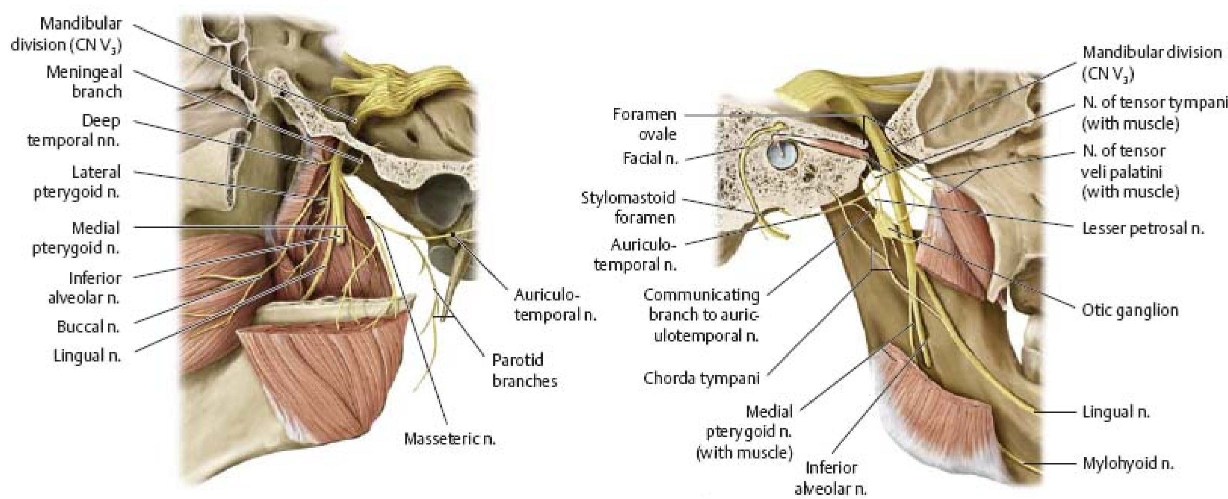


Fig. 32.18 **Mandibular nerve (CN V_3) in the infratemporal fossa**



A Left lateral view. **B** Medial view.

Topography of the Pterygopalatine Fossa

The pterygopalatine fossa is a small pyramidal space just inferior to the apex of the orbit. It is continuous with the infratemporal fossa, with no clear line of demarcation between them. The pterygopalatine fossa is a crossroads for neurovascular structures traveling between the middle cranial fossa, orbit, nasal cavity, and oral cavity.

Table 32.6 Borders of the pterygopalatine fossa

Direction	Boundaries	Direction	Boundaries
Superior	Sphenoid bone (greater wing), junction with inferior orbital fissure	Posterior	Pterygoid process (lateral plate)
Anterior	Maxillary tuberosity	Lateral	Communicates with the infratemporal fossa via the pterygomaxillary fissure
Medial	Palatine bone (perpendicular plate)	Inferior	None; opens into the retropharyngeal space

Fig. 32.19 Arteries in the pterygopalatine fossa

Left lateral view into area. The maxillary artery passes over the lateral pterygoid in the infratemporal fossa (see Fig. 32.16) and enters the pterygopalatine fossa through the pterygomaxillary fissure.

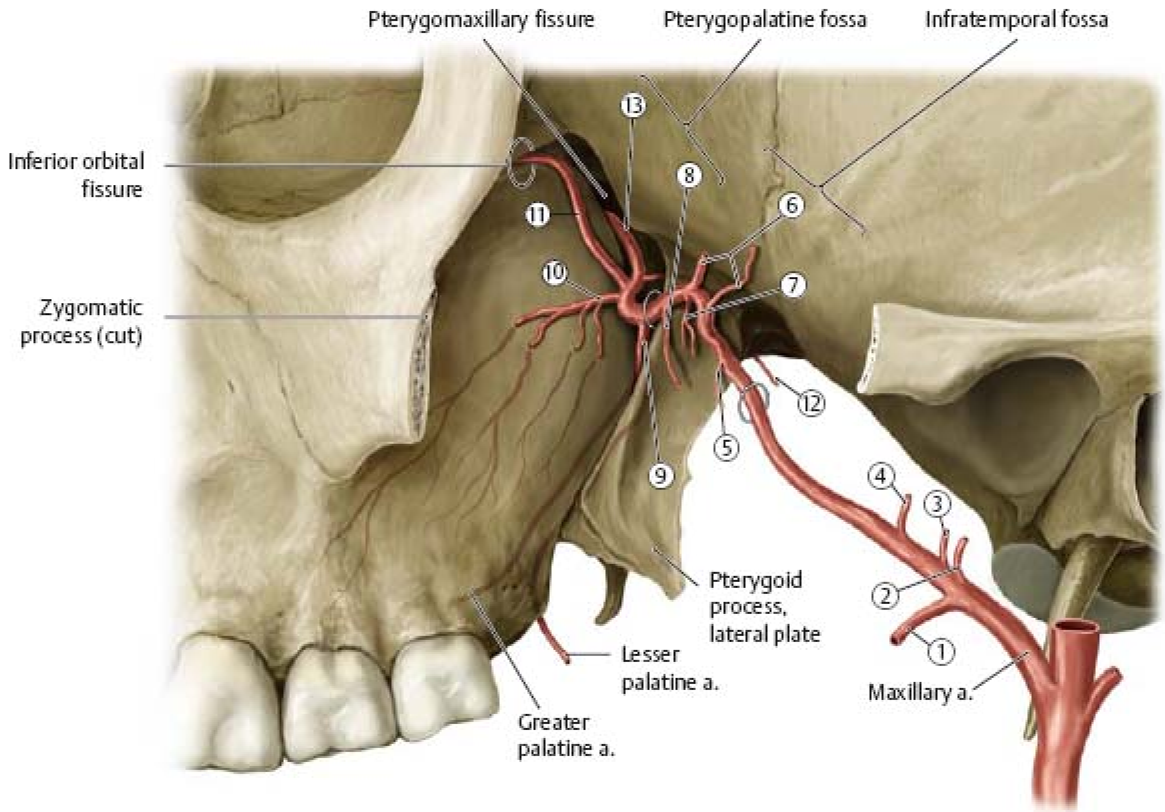


Table 32.7 Branches of the maxillary artery

Part	Artery		Distribution
Mandibular part	① Inferior alveolar a.		Mandible, teeth, gingiva
	② Anterior tympanic a.		Tympanic cavity
	③ Deep auricular a.		Temporomandibular joint, external auditory canal
	④ Middle meningeal a.		Calvaria, dura, anterior and middle cranial fossae
Pterygoid part	⑤ Masseteric a.		Masseter muscle
	⑥ Deep temporal aa.		Temporalis muscle
	⑦ Pterygoid branches		Pterygoid muscles
	⑧ Buccal a.		Buccal mucosa
Pterygopalatine part	⑨ Descending palatine a.	Greater palatine a.	Hard palate
		Lesser palatine a.	Soft palate, palatine tonsil, pharyngeal wall
	⑩ Posterosuperior alveolar a.		Maxillary molars, maxillary sinus, gingiva
	⑪ Infraorbital a.		Maxillary alveoli
	⑫ A. of pterygoid canal		
	⑬ Sphenopalatine a.	Lateral posterior nasal aa.	Lateral wall of nasal cavity, choanae
		Posterior septal branches	Nasal septum

The maxillary division of the trigeminal nerve (CN V_2, see p. 477) passes from the middle cranial fossa through the foramen rotundum into the pterygopalatine fossa. The parasympathetic pterygopalatine ganglion receives presynaptic fibers from the greater petrosal nerve (the parasympathetic root of the nervus intermedius branch of the facial nerve). The preganglionic fibers of the pterygopalatine ganglion synapse with ganglion cells that innervate the lacrimal, small palatal, and small nasal glands. The sympathetic fibers of the deep petrosal nerve (sympathetic root) and sensory fibers of the maxillary nerve (sensory root) pass through the pterygopalatine ganglion without synapsing.

Fig. 32.20 Nerves in the pterygopalatine fossa

Left lateral view.

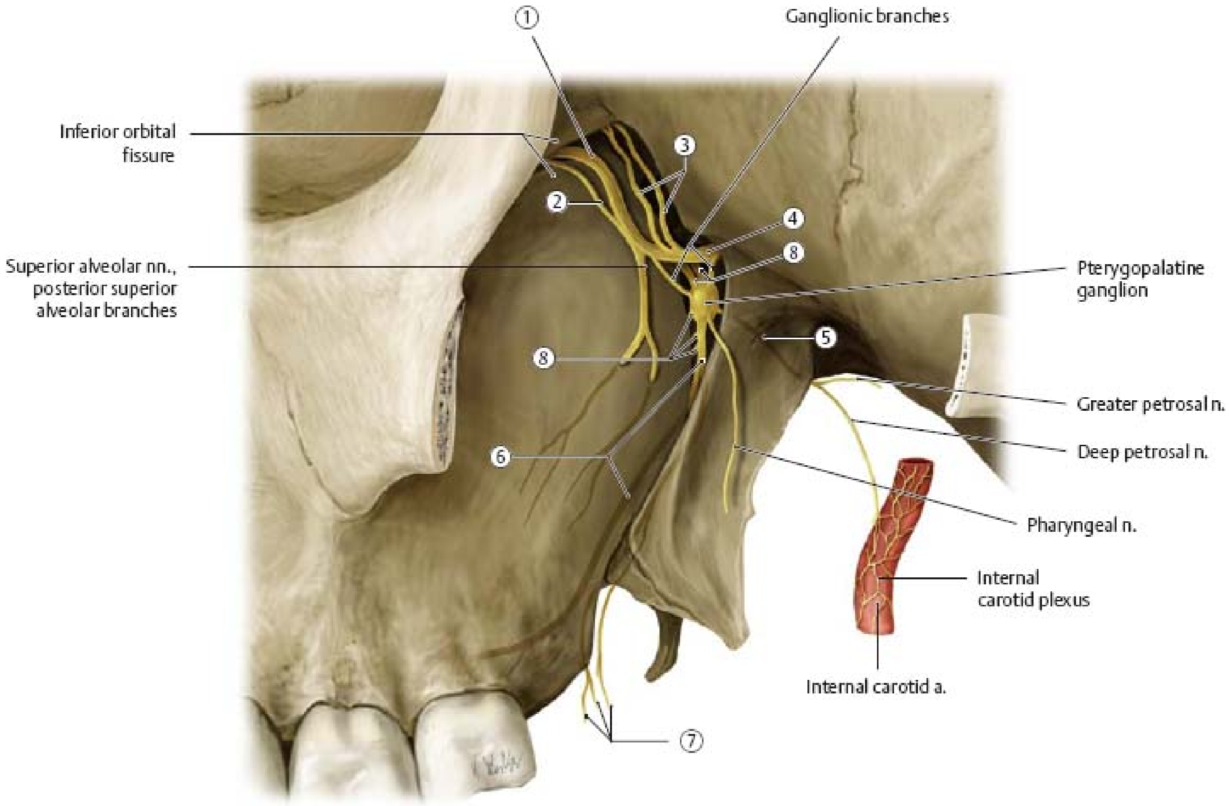


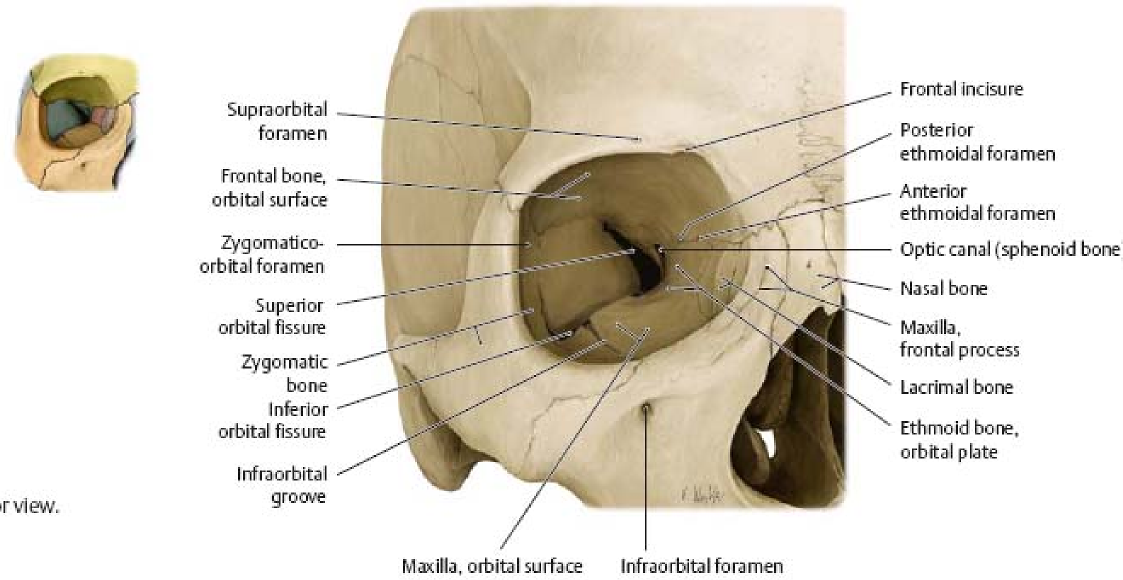
Table 32.8 Passage of neurovascular structures into pterygopalatine fossa

Origin of structures	Passageway	Transmitted nerves	Transmitted vessels
Orbit	Inferior orbital fissure	① Infraorbital n.	Infraorbital a. (and accompanying vv.)
		② Zygomatic n.	Inferior ophthalmic v.
		③ Orbital branches (from CN V_2)	
Middle cranial fossa	Foramen rotundum	④ Maxillary n. (CN V_2)	
Base of skull	Pterygoid canal	⑤ N. of pterygoid canal (greater and deep petrosal nn.)	A. of pterygoid canal (with accompanying vv.)
Palate	Greater palatine canal	⑥ Greater palatine n.	Descending palatine a.
			Greater palatine a.
	Lesser palatine canals	⑦ Lesser palatine nn.	Lesser palatine aa. (terminal branches of descending palatine a.)
Nasal cavity	Sphenopalatine foramen	⑧ Medial and lateral posterior superior and posterior inferior nasal branches (from nasopalatine n., CN V_2)	Sphenopalatine a. (with accompanying vv.)

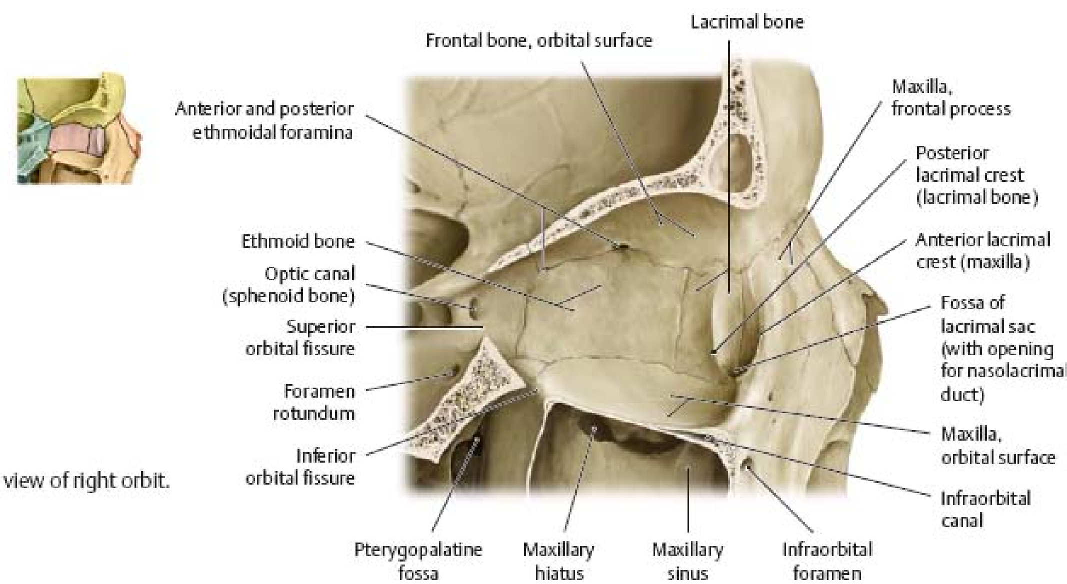
33 Orbit & Eye

Bones of the Orbit

Fig. 33.1 Bones of the Orbit



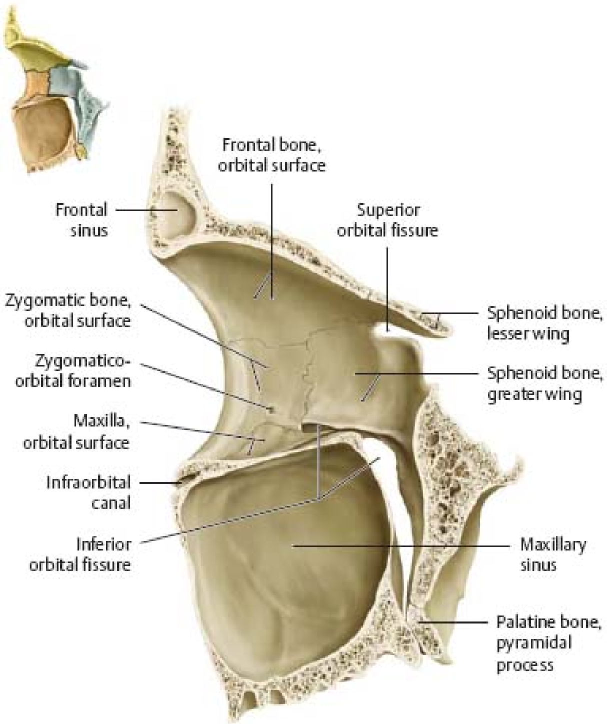
A Anterior view.



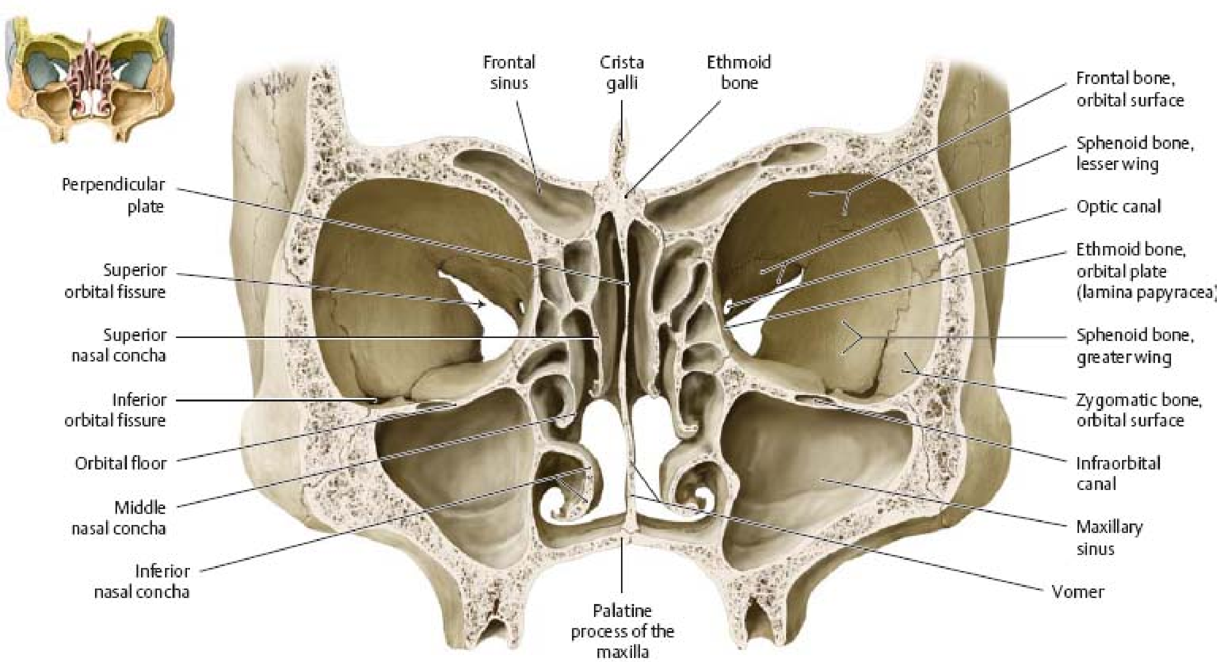
B Lateral view of right orbit.

Table 33.1	Openings in the orbit for neurovascular structures		
Opening*	**Nerves**		**Vessels**
Optic canal	Optic n. (CN II)		Ophthalmic a.
Superior orbital fissure	Oculomotor n. (CN III) Trochlear n. (CN IV) Abducent n. (CN VI)	Trigeminal n., ophthalmic division (CN V_1) • Lacrimal n. • Frontal n. • Nasociliary n.	Superior ophthalmic v.
Inferior orbital fissure	Infraorbital n. (CN V_2) Zygomatic n. (CN V_2)		Infraorbital a. and v., inferior ophthalmic v.
Infraorbital canal	Infraorbital n. (CN V_2), a., and v.		
Supraorbital foramen	Supraorbital n. (lateral branch)		Supraorbital a.
Frontal incisure	Supraorbital n. (medial branch)		Supratrochlear a.
Anterior ethmoidal foramen	Anterior ethmoidal n., a., and v.		
Posterior ethmoidal foramen	Posterior ethmoidal n., a., and v.		

* The nasolacrimal canal transmits the nasolacrimal duct.



C Medial view of right orbit.



D Coronal section, anterior view.

Table 33.2 **Structures surrounding the orbit**

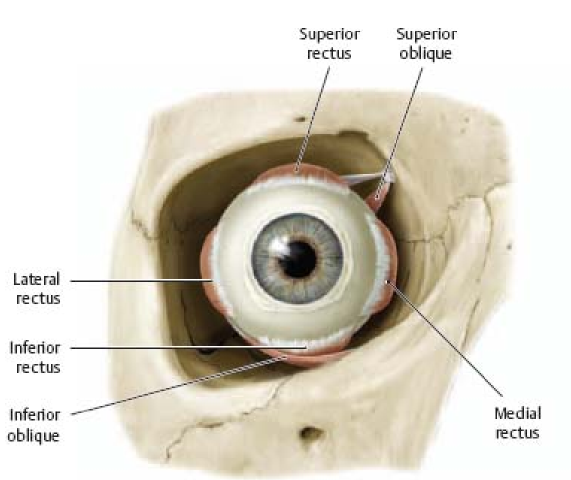
Direction	**Bordering structure**

Direction	Bordering structure
Superior	Frontal sinus Anterior cranial fossa
Medial	Ethmoid sinus
Inferior	Maxillary sinus
Certain deeper structures also have a clinically important relationship to the orbit:	
Sphenoid sinus	Hypophysis (pituitary)
Middle cranial fossa	Cavernous sinus
Optic chiasm	Pterygopalatine fossa

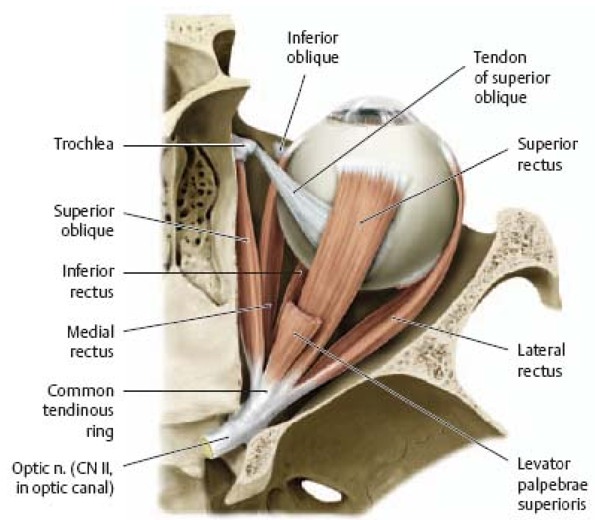
Muscles of the Orbit

Fig. 33.2 Extraocular muscles

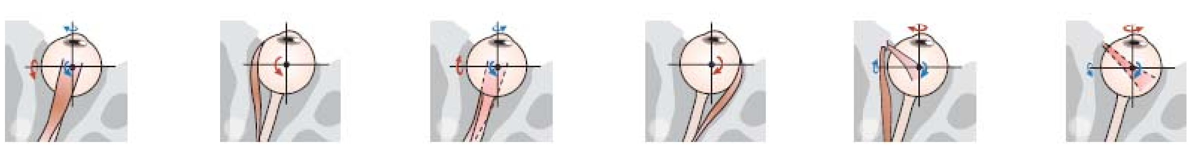
Right eye, superior view (except **A**). The eyeball is moved by six extrinsic muscles: four rectus (superior, inferior, medial, and lateral) and two oblique (superior and inferior).



A Anterior view.



B Superior view of opened orbit.



C Superior rectus. **D** Medial rectus. **E** Inferior rectus. **F** Lateral rectus. **G** Superior oblique. **H** Inferior oblique.

Table 33.3	Extraocular muscles				
Muscle	**Origin**	**Insertion**	**Primary action (red)**	**Secondary action (blue)**	**Innervation**
Superior rectus	Common tendinous ring (common annular tendon)	Sclera of the eye	Elevation	Adduction and medial rotation	Oculomotor n. (CN III), superior branch
Medial rectus			Adduction	—	Oculomotor n. (CN III), inferior branch
Inferior rectus			Depression	Adduction and lateral rotation	
Lateral rectus			Abduction	—	Abducent n. (CN VI)
Superior oblique	Sphenoid bone*		Depression and abduction	Medial rotation	Trochlear n. (CN IV)
Inferior oblique	Medial orbital margin		Elevation and abduction	Lateral rotation	Oculomotor n. (CN III), inferior branch

* The tendon of insertion of the superior oblique passes through a tendinous loop (trochlea) attached to the superomedial orbital margin.

Fig. 33.3 Cardinal directions of gaze

There are six cardinal directions of gaze, all of which are tested during clinical evaluation of ocular motility. *Note:* Each gaze requires activation of two different muscles (not a muscle pair) and therefore two cranial nerves.

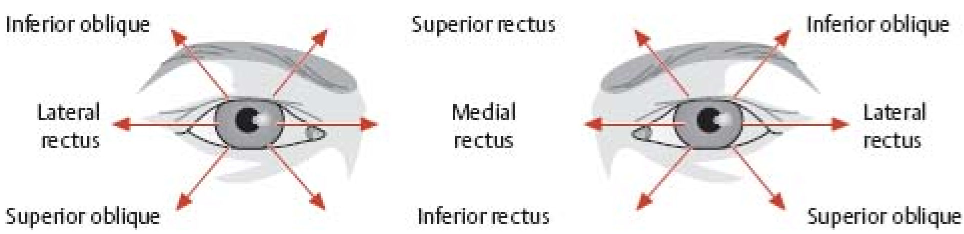
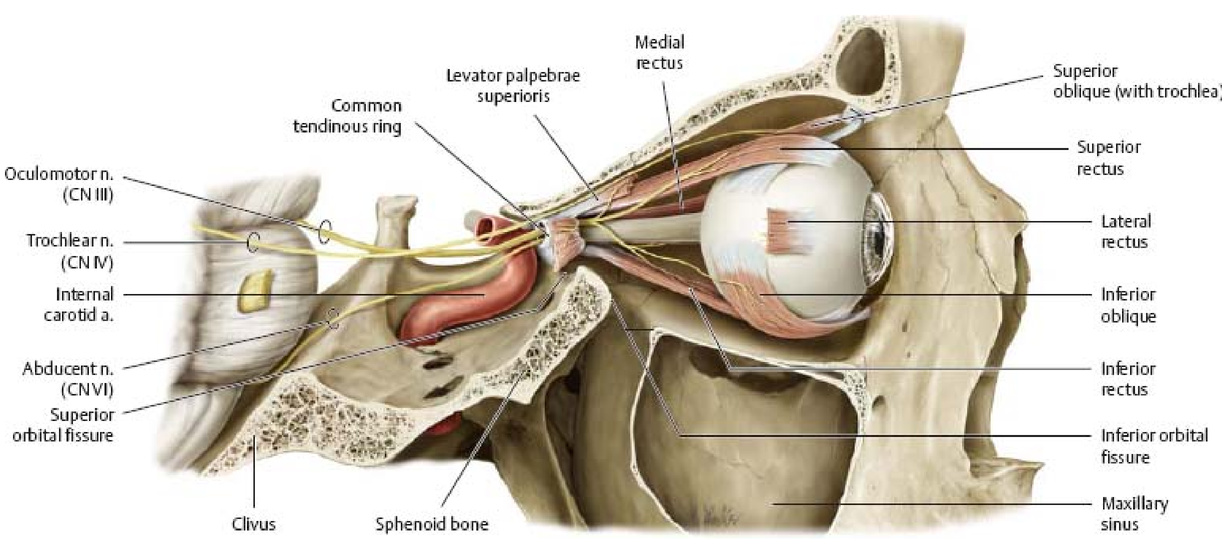


Fig. 33.4 Innervation of the extraocular muscles

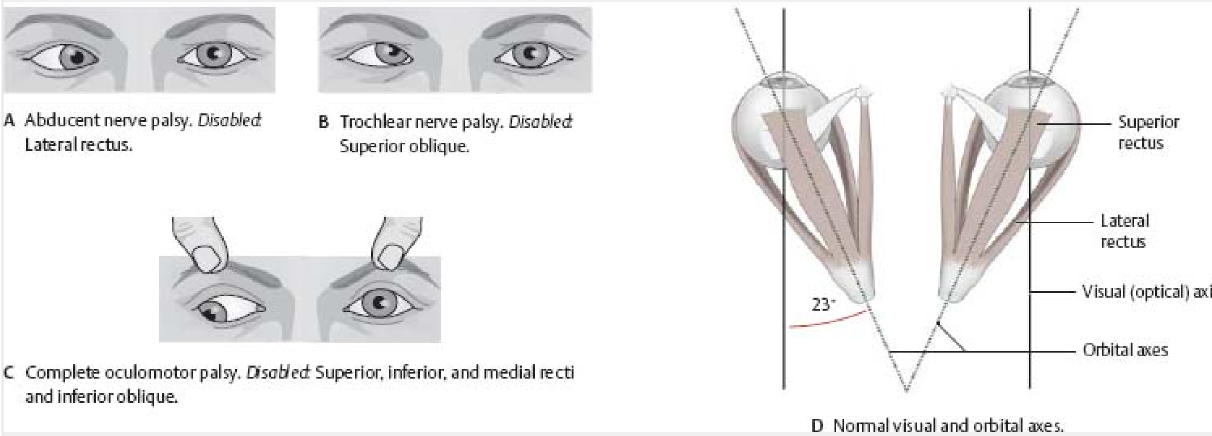
Right eye, lateral view with the temporal wall of the orbit removed.



Clinical

Oculomotor palsies

Oculomotor palsies may result from a lesion involving an eye muscle or its associated cranial nerve (at the nucleus or along the course of the nerve). If one extraocular muscle is weak or paralyzed, deviation of the eye will be noted. Impairment of the coordinated actions of the extraocular muscles may cause the visual axis of one eye to deviate from its normal position. The patient will therefore perceive a double image (diplopia).



Neurovasculature of the Orbit

Fig. 33.5 Veins of the orbit

Lateral view of the right orbit. *Removed:* Lateral orbital wall. *Opened:* Maxillary sinus.

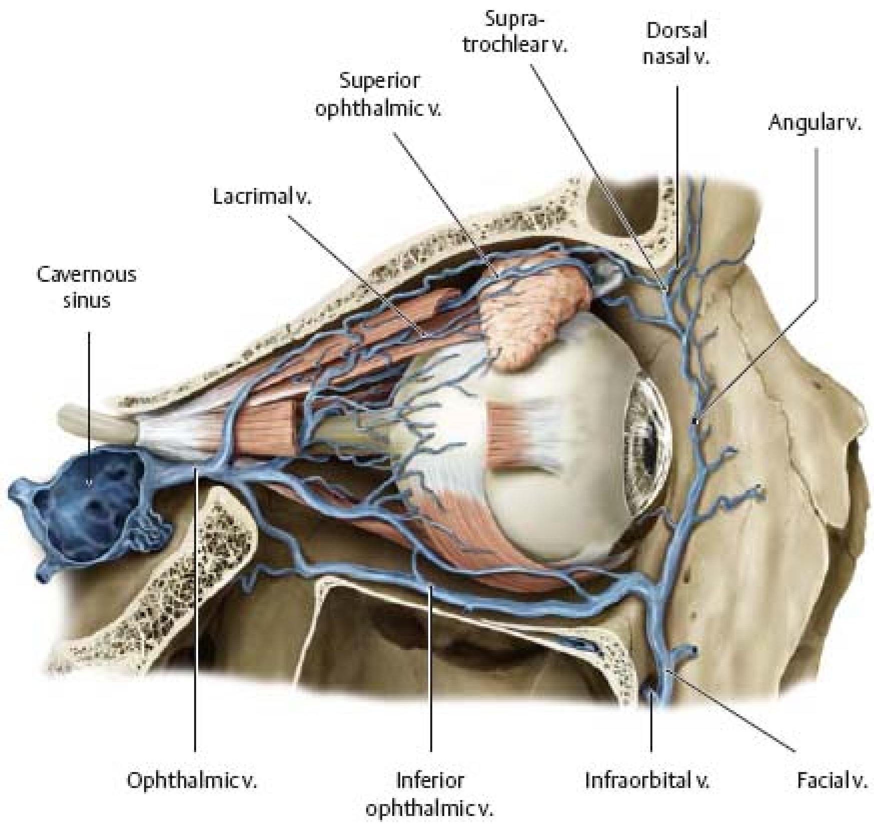


Fig. 33.6 **Arteries of the orbit**

Superior view of the right orbit. *Opened: Optic canal and orbital roof.*

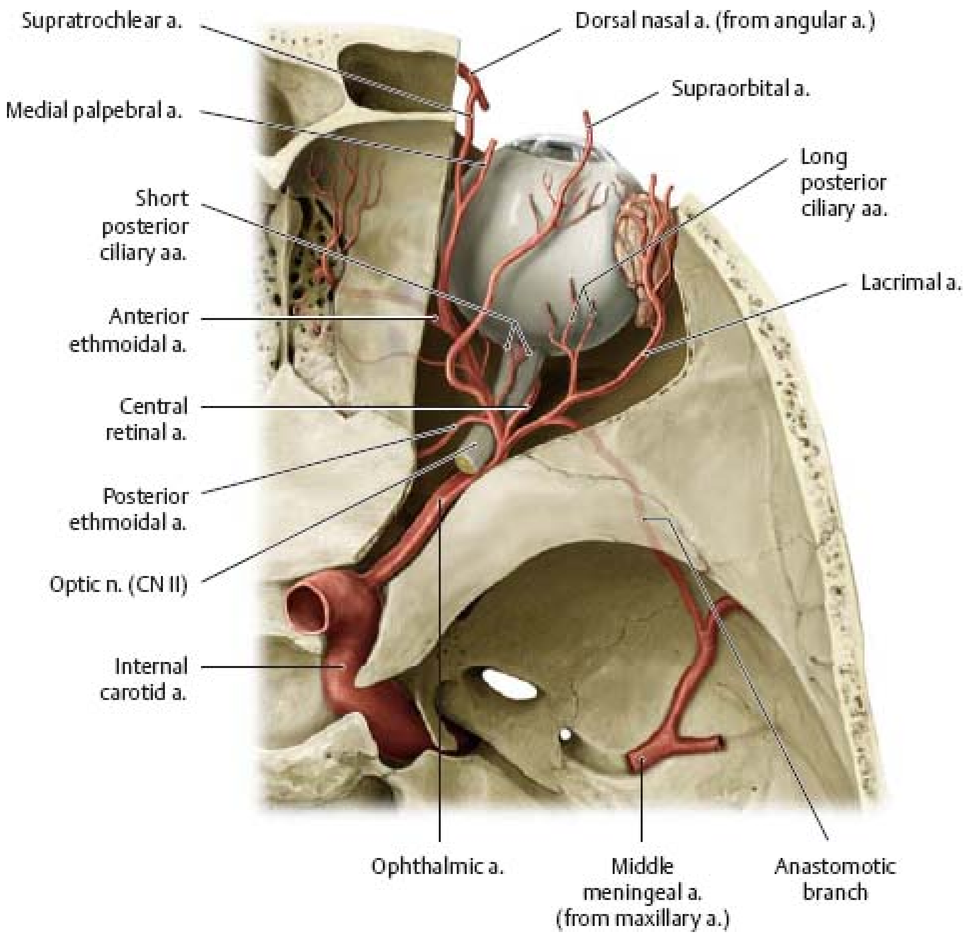


Fig. 33.7 **Innervation of the orbit**

Lateral view of the right orbit. *Removed:* Temporal bony wall.

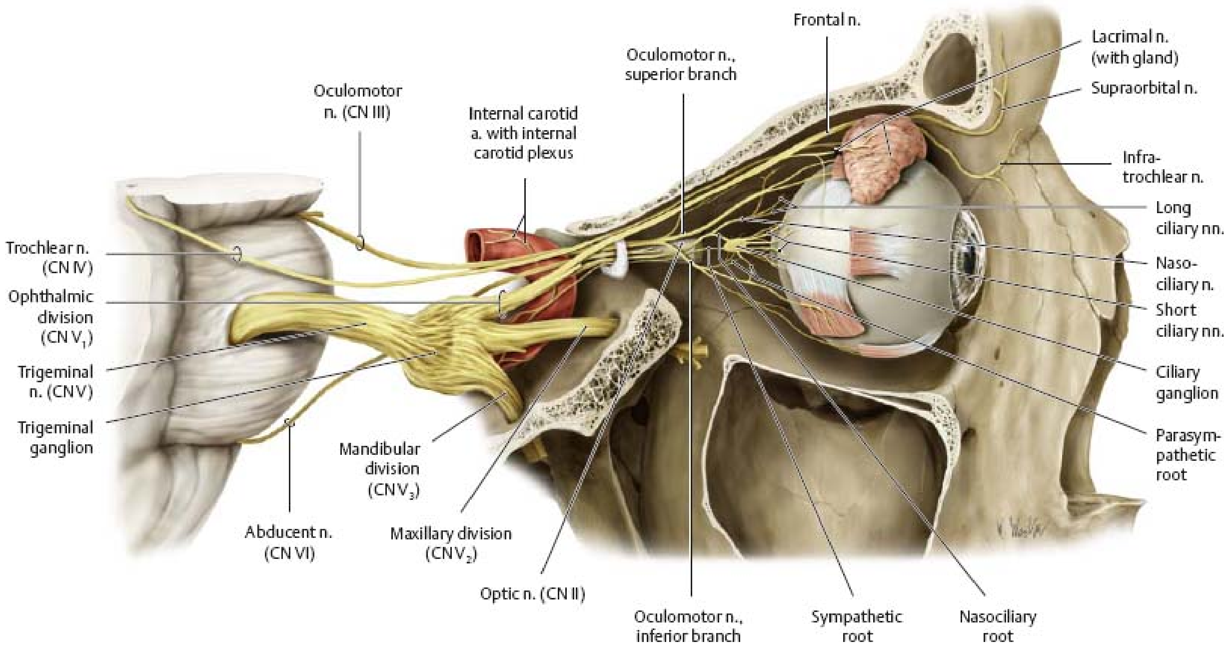
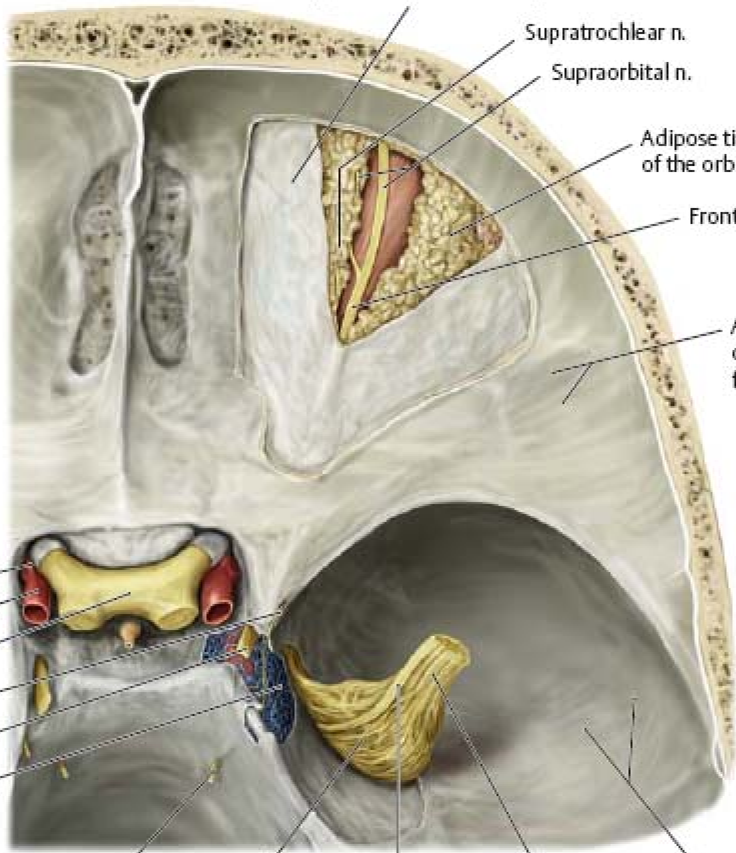


Fig. 33.8 **Cranial nerves in the orbit**

Superior view of the anterior and middle cranial fossae. *Removed:* Cavernous sinus (lateral and superior walls), orbital roof, and periorbita (portions). The trigeminal ganglion has been retracted laterally.



Topography of the Orbit

Fig. 33.9 Neurovascular structures of the orbit

Anterior view. *Right side:* Orbicularis oculi removed. *Left side:* Orbital septum partially removed.

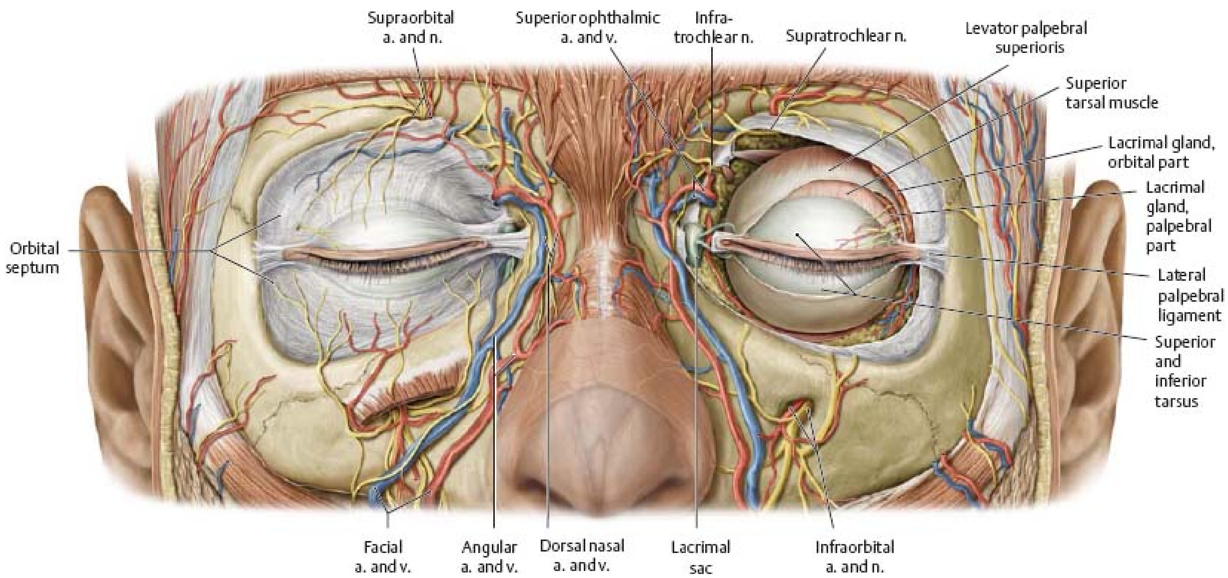


Fig. 33.10 **Passage of neurovascular structures through the orbit**

Anterior view. *Removed:* Orbital contents. *Note:* The optic nerve and ophthalmic artery travel in the optic canal. The remaining structures pass through the superior orbital fissure.

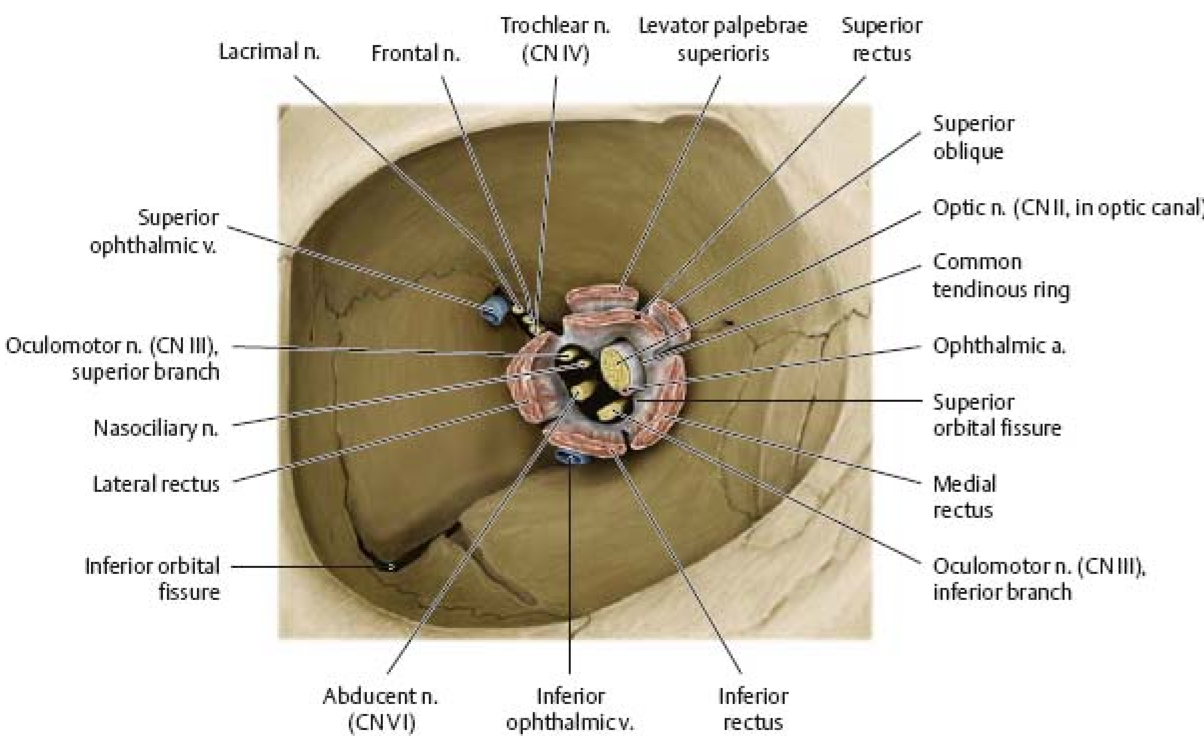
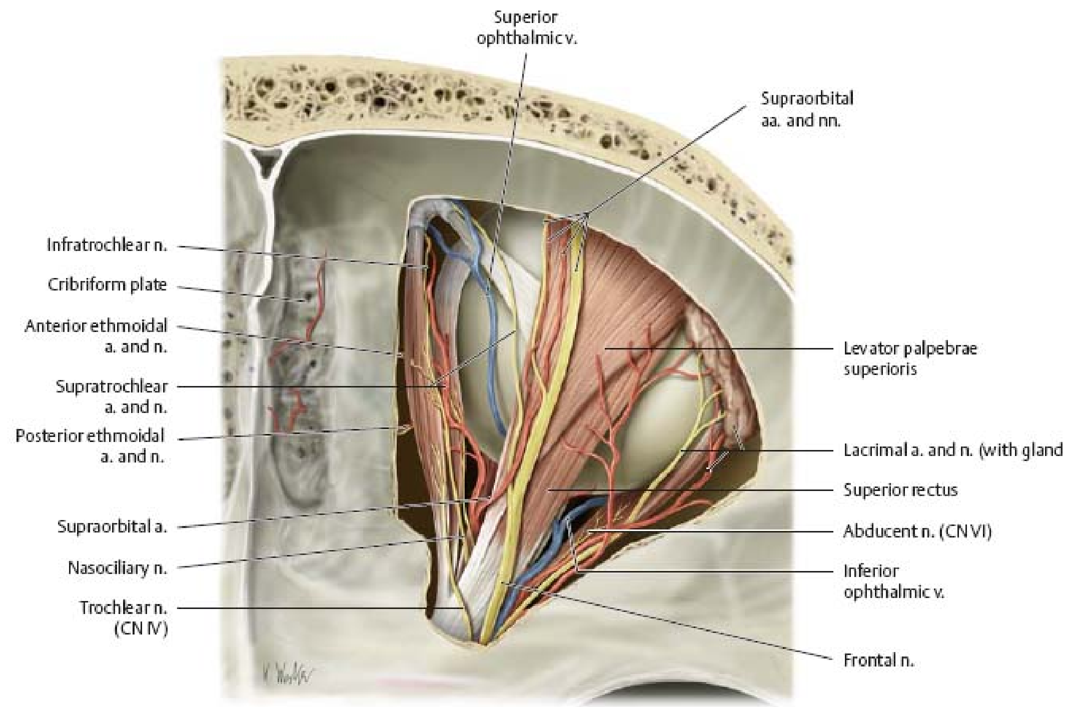
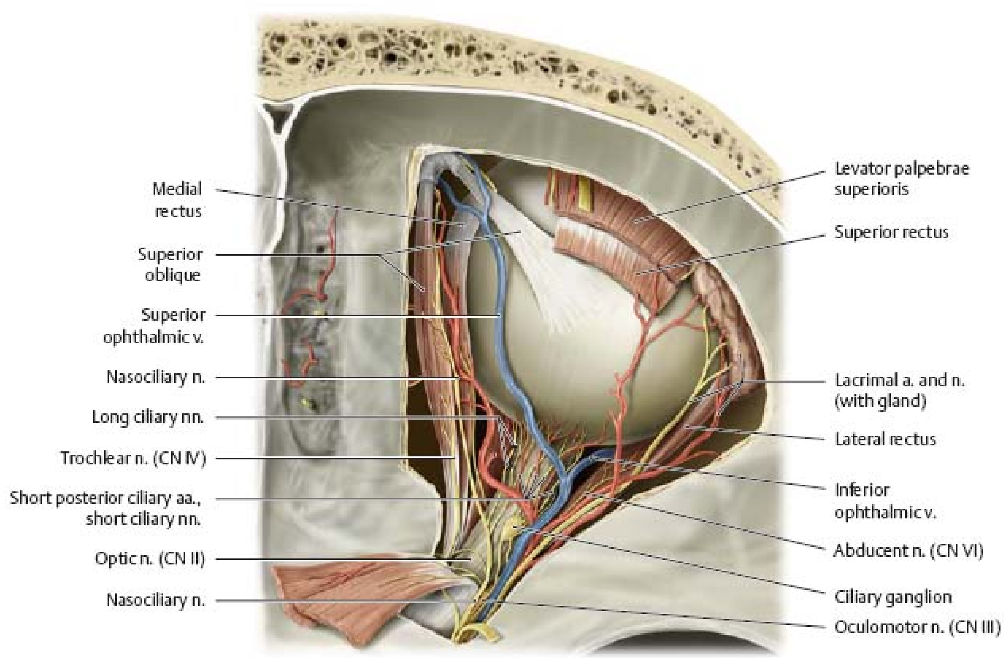


Fig. 33.11 **Neurovascular contents of the orbit**

Superior view. *Removed:* Bony roof of orbit, peritorbita, and retro-orbital fat.



A Upper level.



B Middle level. *Reflected:* Levator palpebrae superioris and superior rectus. *Revealed:* Optic nerve.

Orbit & Eyelid

Fig. 33.12 Topography of the orbit

Sagittal section through the right orbit, medial view.

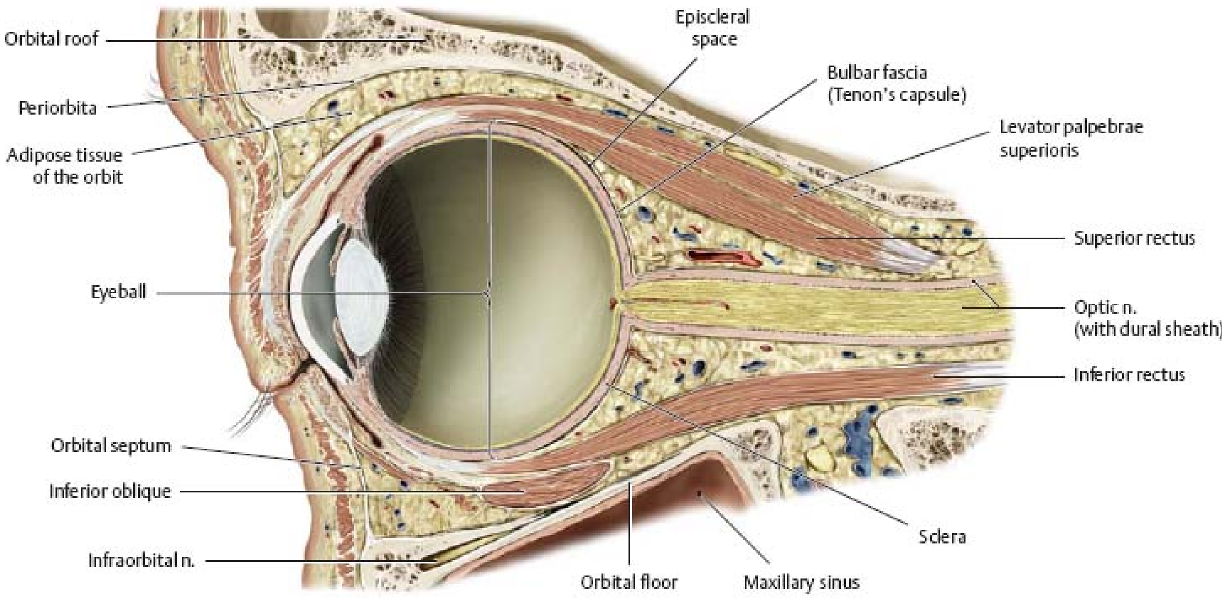


Fig. 33.13 Eyelids and conjuctiva

Sagittal section through the anterior orbital cavity.

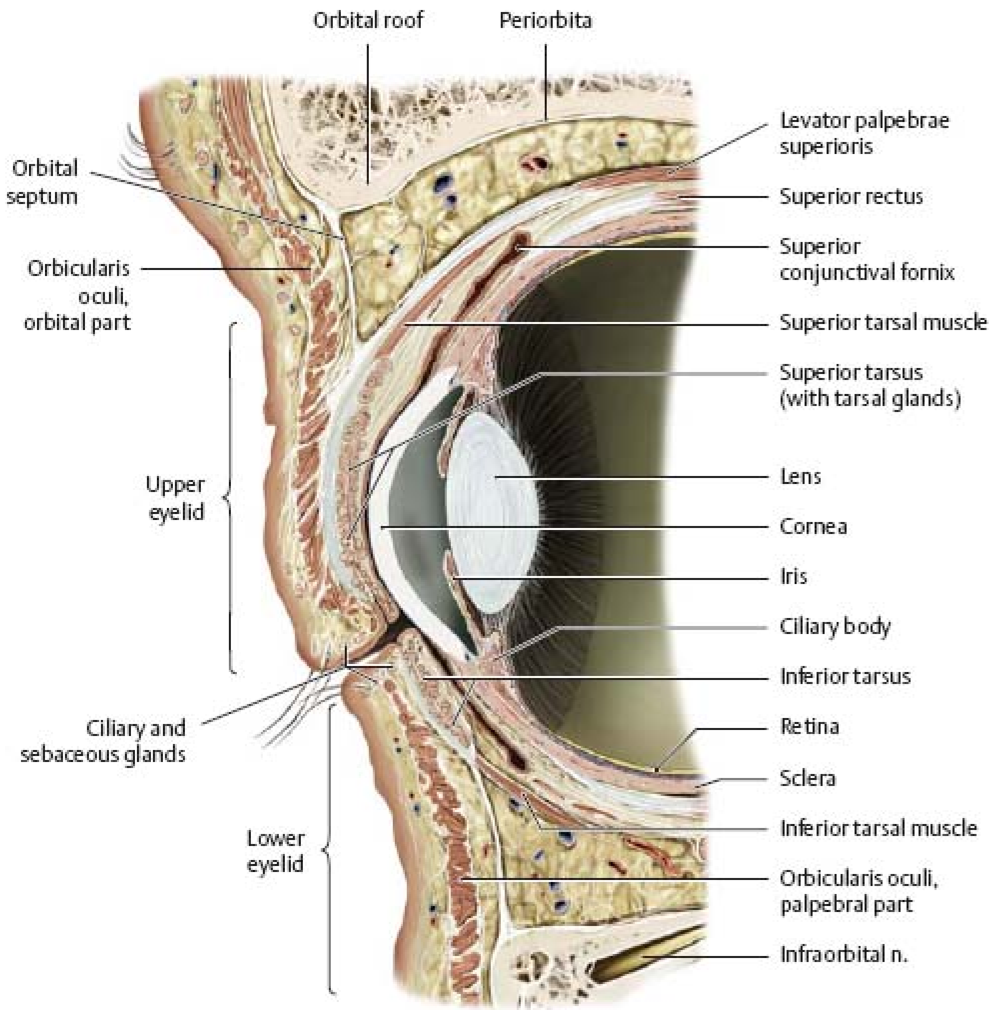
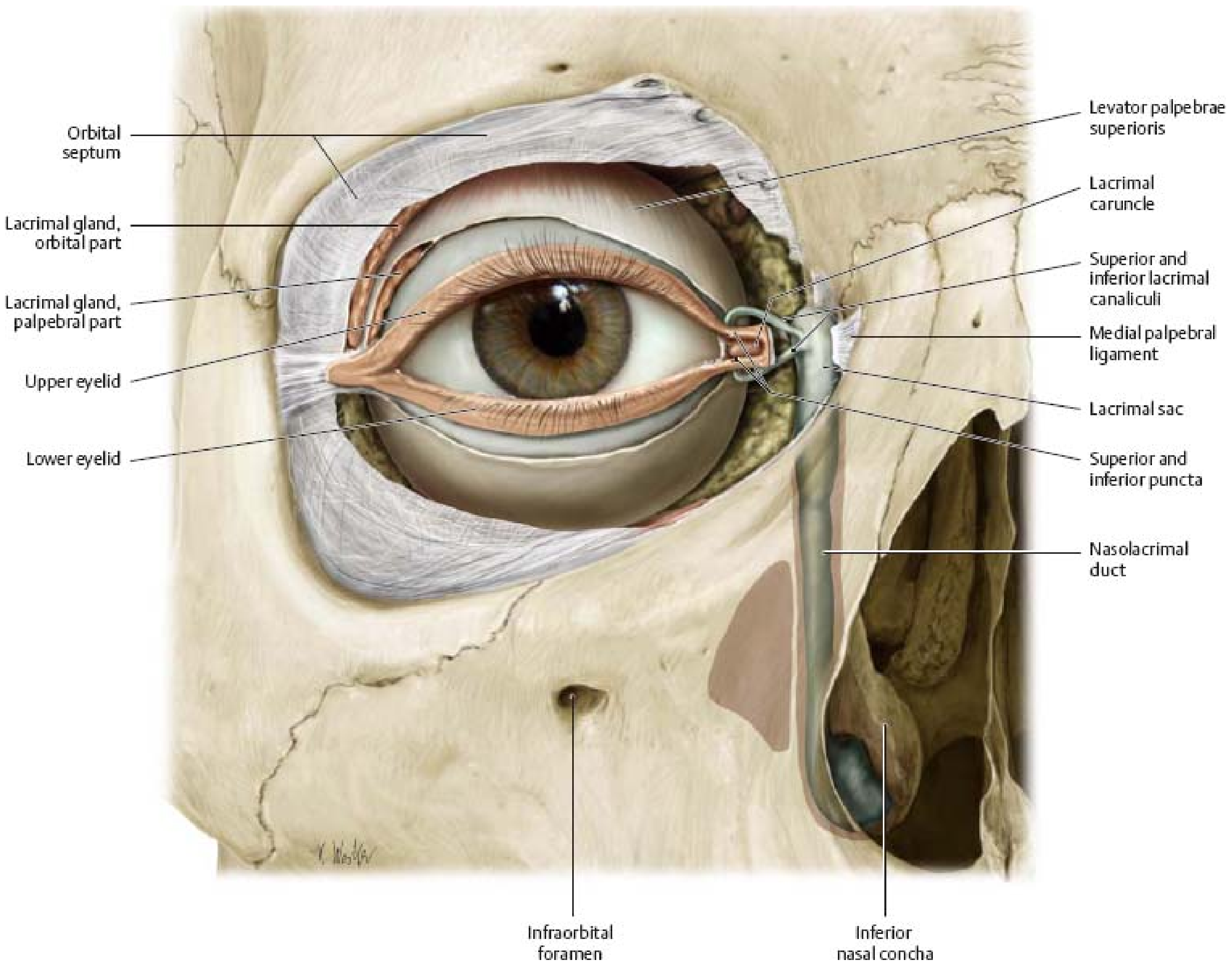


Fig. 33.14 **Lacrimal apparatus**

Right eye, anterior view. *Removed:* Orbital septum (partial). *Divided:* Levator palpebrae superioris (tendon of insertion).



Clinical

Lacrimal drainage

Perimenopausal women are frequently subject to chronically dry eyes (*keratoconjunctivitis sicca*), due to insufficient tear production by the lacrimal gland. Acute inflammation of the lacrimal gland (due to bacteria) is less common and characterized by intense inflammation and extreme tenderness to palpation. The upper eyelid shows a characteristic S-curve.

Eyeball

Fig. 33.15 Structure of the eyeball

Transverse section through right eyeball, superior view. *Note:* The orbital axis (running along the optic nerve through the optic disk) deviates from the optical axis (running down the center of the eye to the fovea centralis) by 23 degrees.

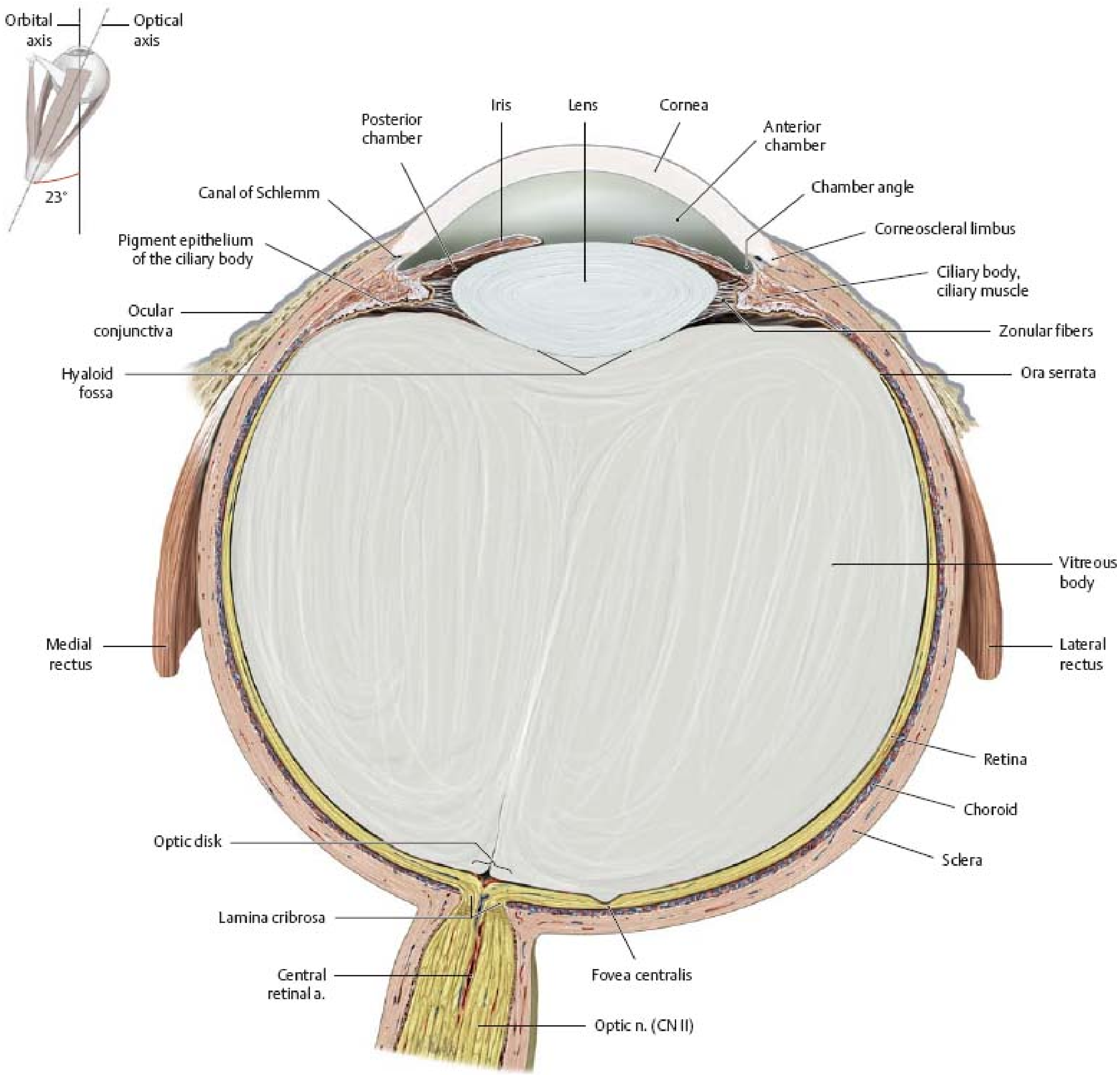
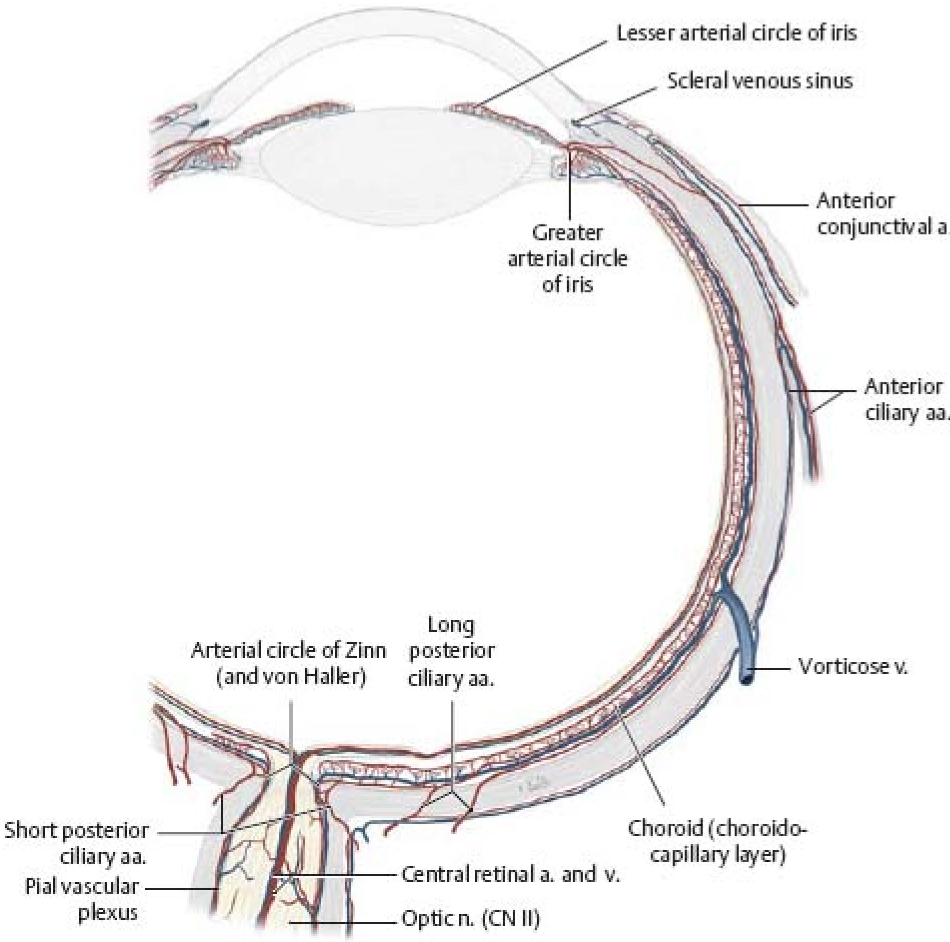


Fig. 33.16 Blood vessels of the eyeball

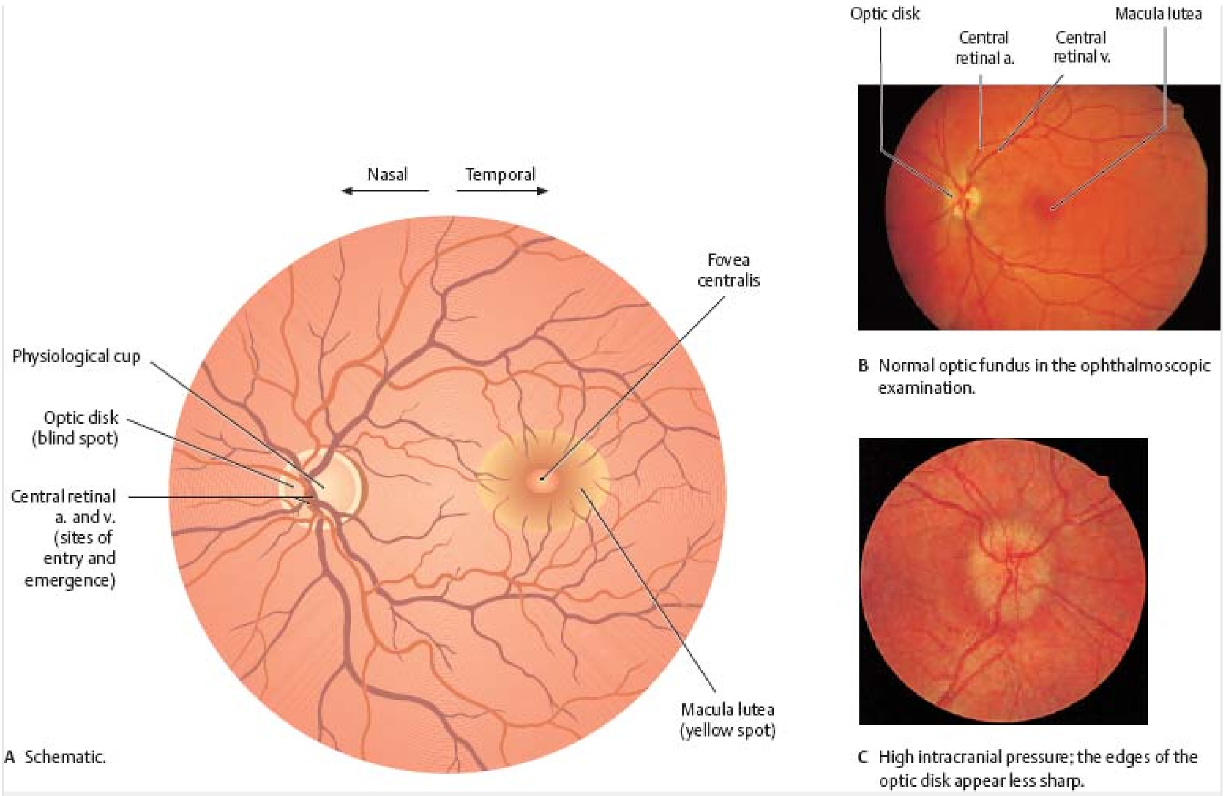
Transverse section at the level of the optic nerve, superior view. The arteries of the eye arise from the ophthalmic artery, a terminal branch of the internal carotid artery. Blood is drained by four to eight vorticose veins that open into the superior and inferior ophthalmic veins.



Clinical

Optic fundus

The optic fundus is the only place in the body where capillaries can be examined directly. Examination of the optic fundus permits observation of vascular changes that may be caused by high blood pressure or diabetes. Examination of the optic disk is important in determining intracranial pressure and diagnosing multiple sclerosis.



A Schematic.

B Normal optic fundus in the ophthalmoscopic examination.

C High intracranial pressure; the edges of the optic disk appear less sharp.

Cornea, Iris & Lens

Fig. 33.17 Cornea, iris, and lens

Transverse section through the anterior segment of the eye. Anterosuperior view.

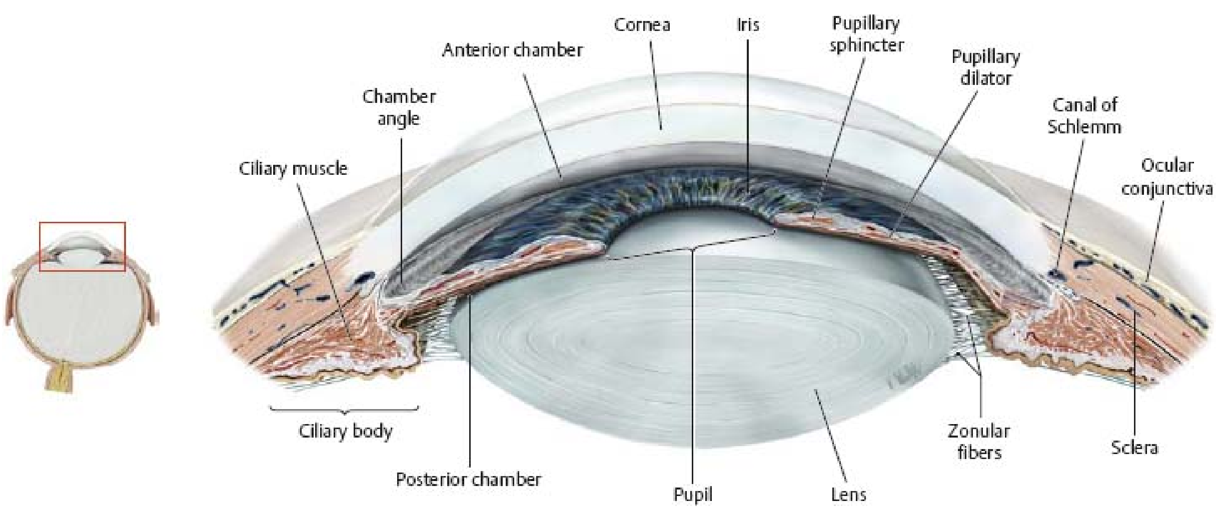
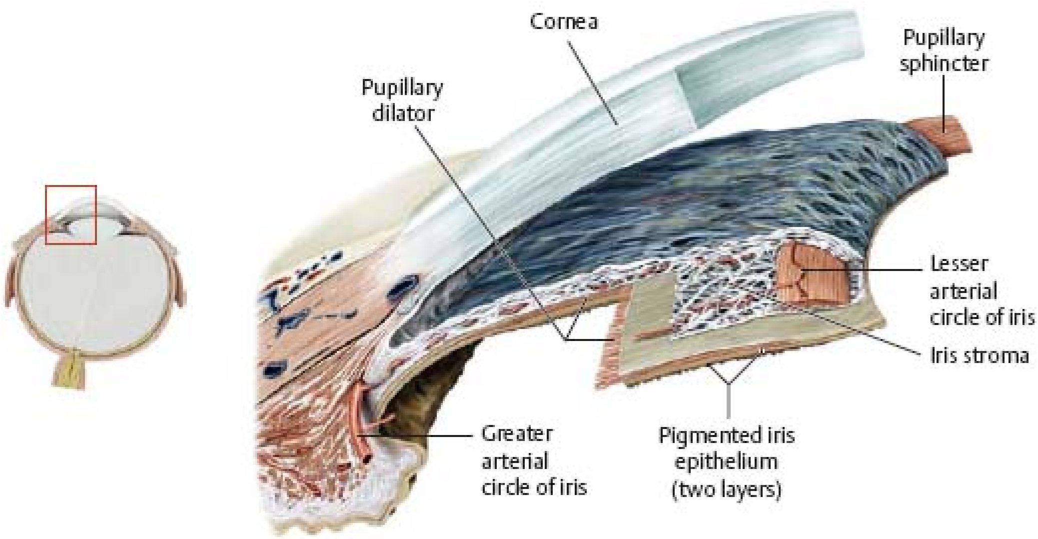


Fig. 33.18 Iris

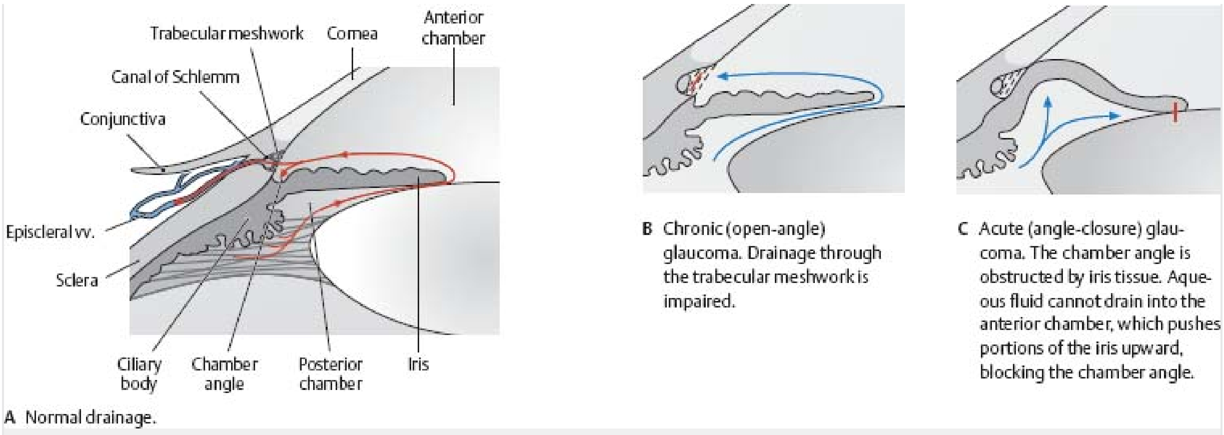
Transverse section through the anterior segment of the eye. Anterosuperior view.



Clinical

Glaucoma

Aqueous humor produced in the posterior chamber passes through the pupil into the anterior chamber. It seeps through the spaces of the trabecular meshwork into the canal of Schlemm and enters the venous sinus of the sclera before passing into the episcleral veins. Obstruction of aqueous humor drainage causes an increase in intraocular pressure (glaucoma), which constricts the optic nerve in the lamina cribrosa. This constriction eventually leads to blindness. The most common glaucoma (approximately 90% of cases) is chronic (open-angle) glaucoma. The more rare acute glaucoma is characterized by red eye, strong headache and/or eye pain, nausea, dilated episcleral veins, and edema of the cornea.



A Normal drainage.

B Chronic (open-angle) glaucoma. Drainage through the trabecular meshwork is impaired.

C Acute (angle-closure) glaucoma. The chamber angle is obstructed by iris tissue. Aqueous fluid cannot drain into the anterior chamber, which pushes portions of the iris upward, blocking the chamber angle.

Fig. 33.19 Pupil

Pupil size is regulated by two intraocular muscles of the iris: the pupillary sphincter, which narrows the pupil (parasympathetic innervation), and the pupillary dilator, which enlarges it (sympathetic innervation).

A Normal pupil size.

B Maximum constriction (miosis).

C Maximum dilation (mydriasis).

Fig. 33.20 Lens and ciliary body

Posterior view. The curvature of the lens is regulated by the muscle fibers of the annular ciliary body.

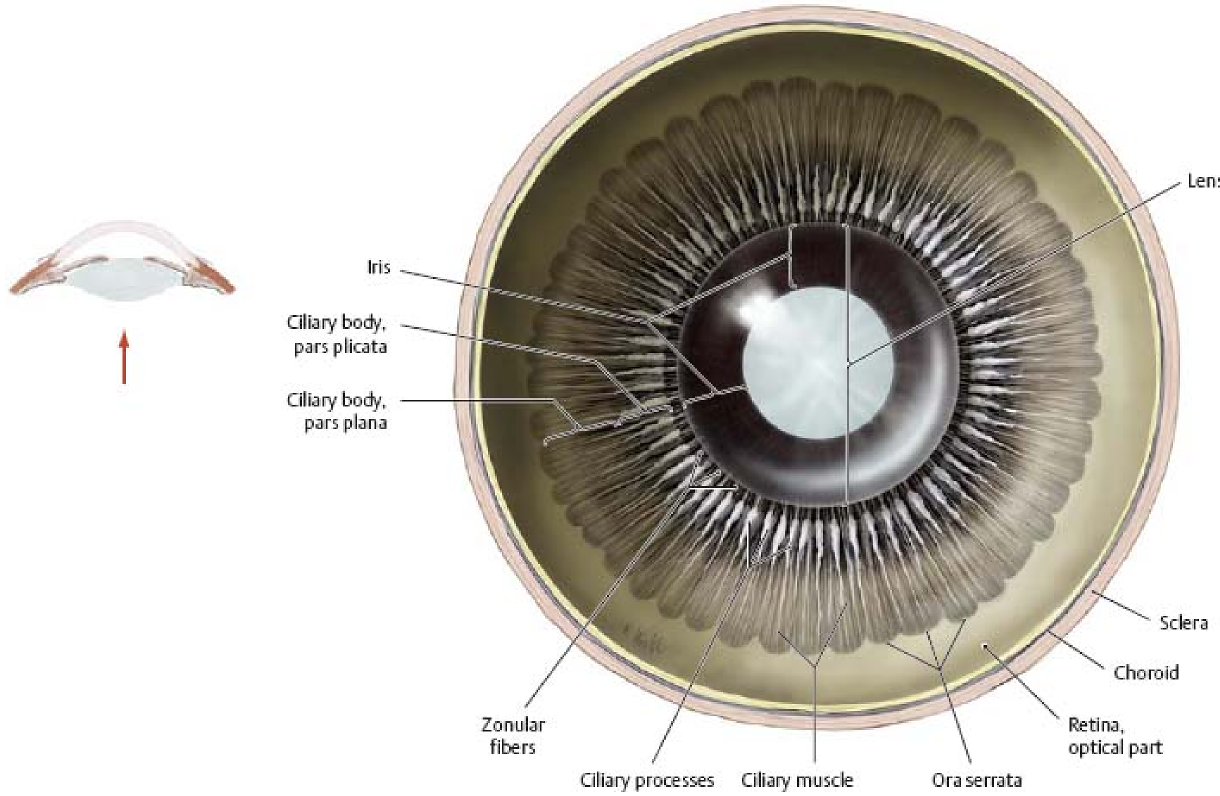
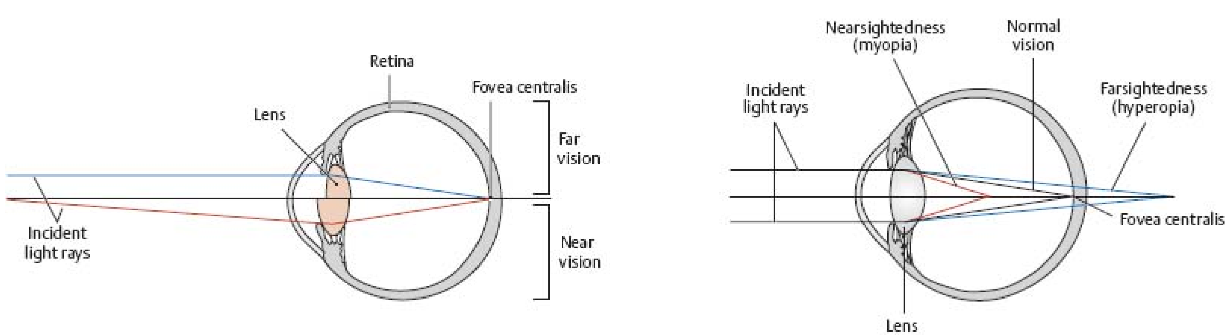


Fig. 33.21 **Light refraction by the lens**

Transverse section, superior view. In the normal (emmetropic) eye, light rays are refracted by the lens (and cornea) to a focal point on the retinal surface (fovea centralis). Tensing of the zonular fibers, with ciliary muscle relaxation, flattens the lens in response to parallel rays arriving from a distant source (far vision). Contraction of the ciliary muscle, with zonular fiber relaxation, causes the lens to assume a more rounded shape (near vision).



A Normal dynamics of the lens.

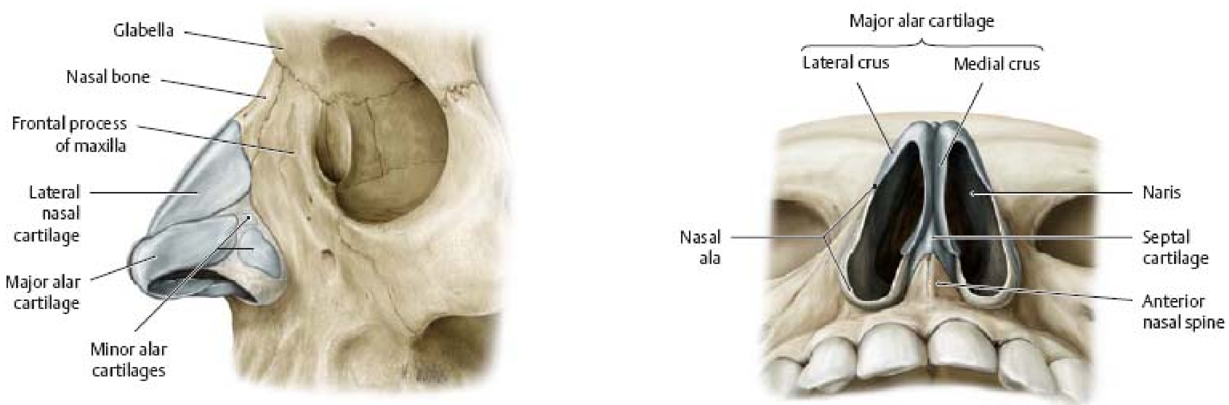
B Abnormal lens dynamics.

34 Nasal Cavity & Nose

Bones of the Nasal Cavity

Fig. 34.1 Skeleton of the nose

The skeleton of the nose is composed of an upper bony portion and a lower cartilaginous portion. The proximal portions of the nostrils (alae) are composed of connective tissue with small embedded pieces of cartilage.

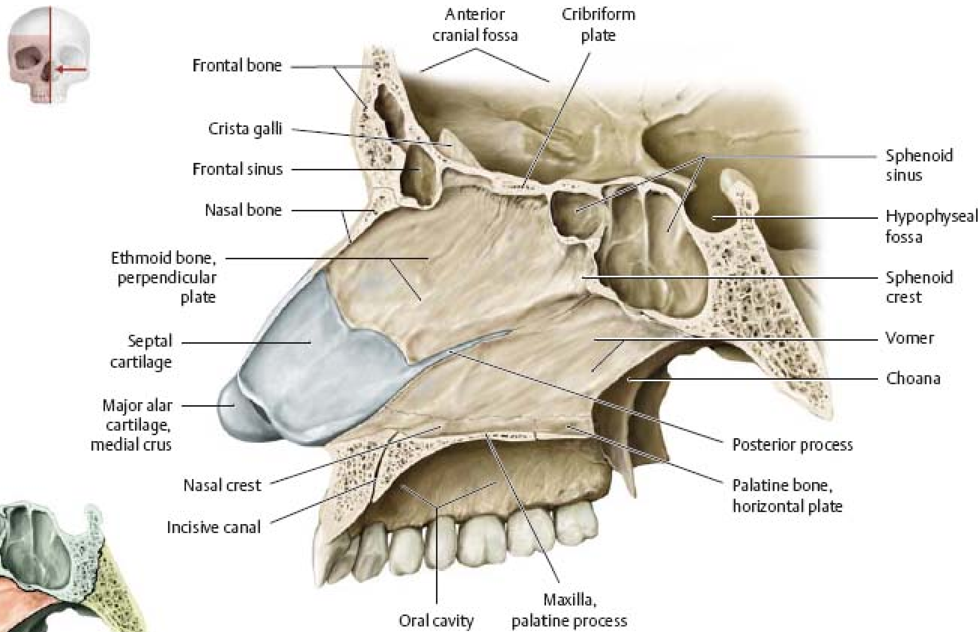


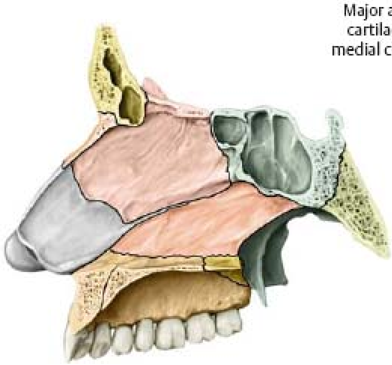
A Left lateral view.

B Inferior view.

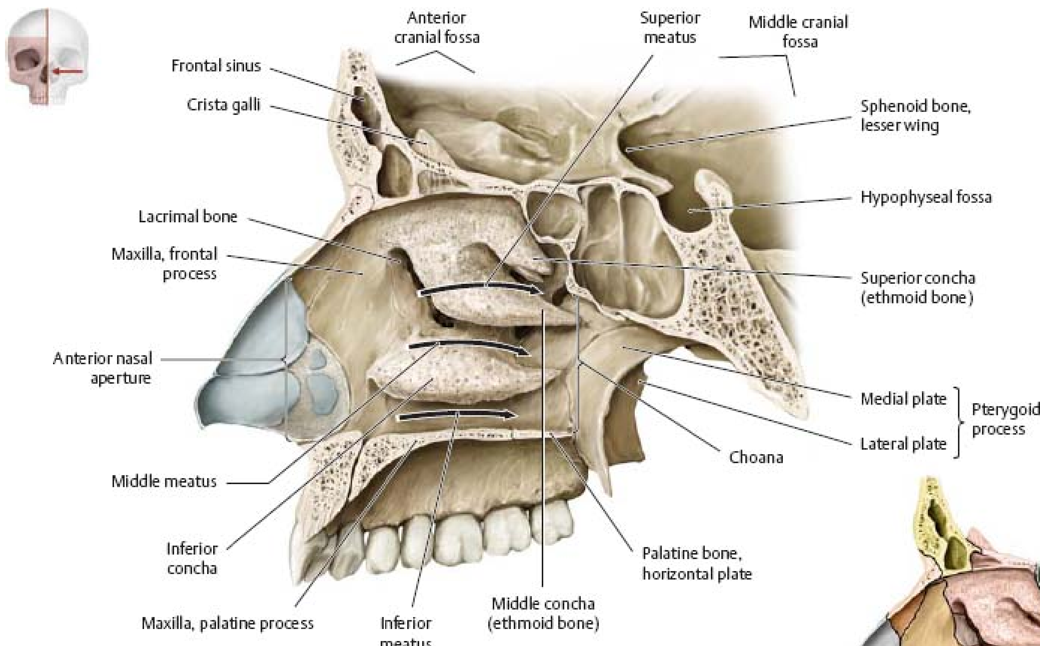
Fig. 34.2 Bones of the nasal cavity

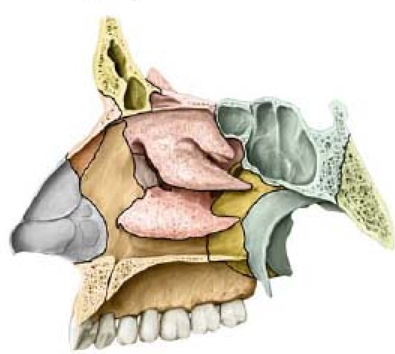
The left and right nasal cavities are flanked by lateral walls and separated by the nasal septum. Air enters the nasal cavity through the anterior nasal aperture and travels through three passages: the superior, middle, and inferior meatuses (arrows). These passages are separated by the superior, middle, and inferior conchae. Air leaves the nose through the choanae, entering the nasopharynx.



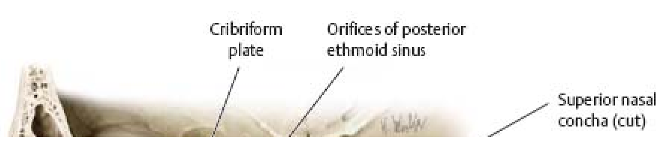


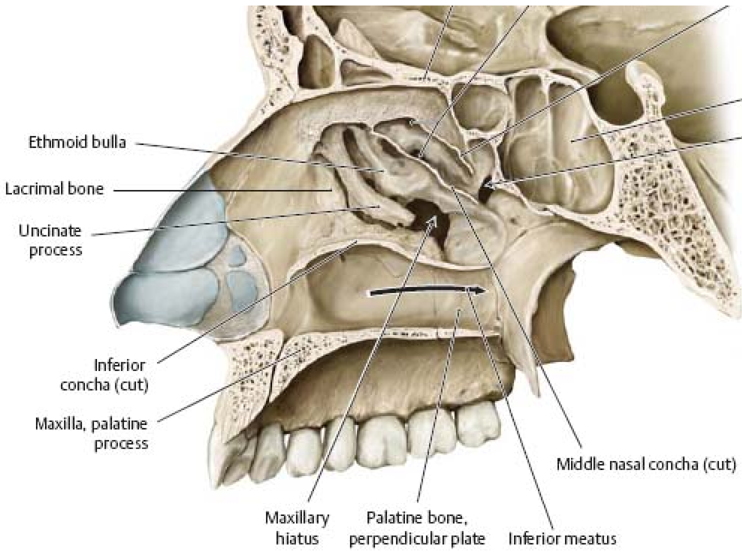
A Nasal septum in left nasal cavity. Parasagittal section, viewed from left side.

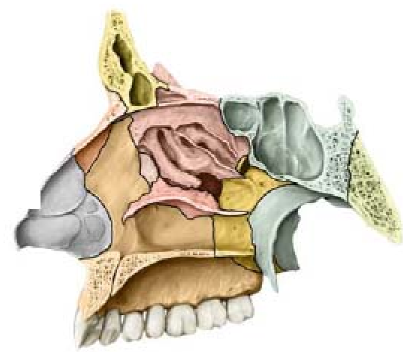




B Lateral wall of the right nasal cavity. Sagittal section, medial view. *Removed:* Nasal septum. *Note:* The superior and middle conchae are parts of the ethmoid bone, whereas the inferior nasal conchae is a separate bone.





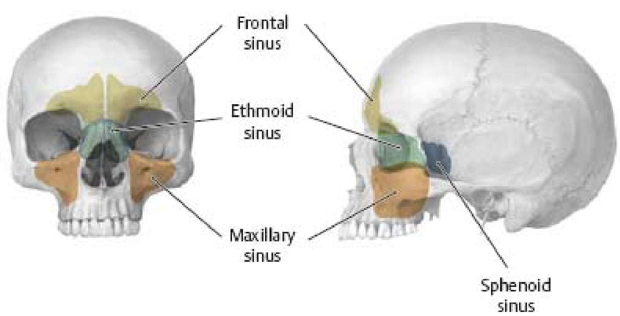


C Lateral wall of the right nasal cavity with the conchae removed. Sagittal section, medial view. *Revealed:* Paranasal sinuses (p. 522).

Paranasal Air Sinuses

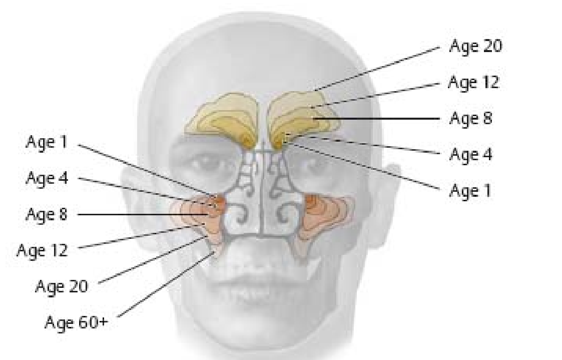
Fig. 34.3 Location of the paranasal sinuses

The paranasal sinuses (frontal, ethmoid, maxillary, and sphenoid) are air-filled cavities that reduce the weight of the skull.



A Anterior view.

B Left lateral view.



C Pneumatization of the sinuses. The frontal and maxillary sinuses develop gradually over the course of cranial growth.

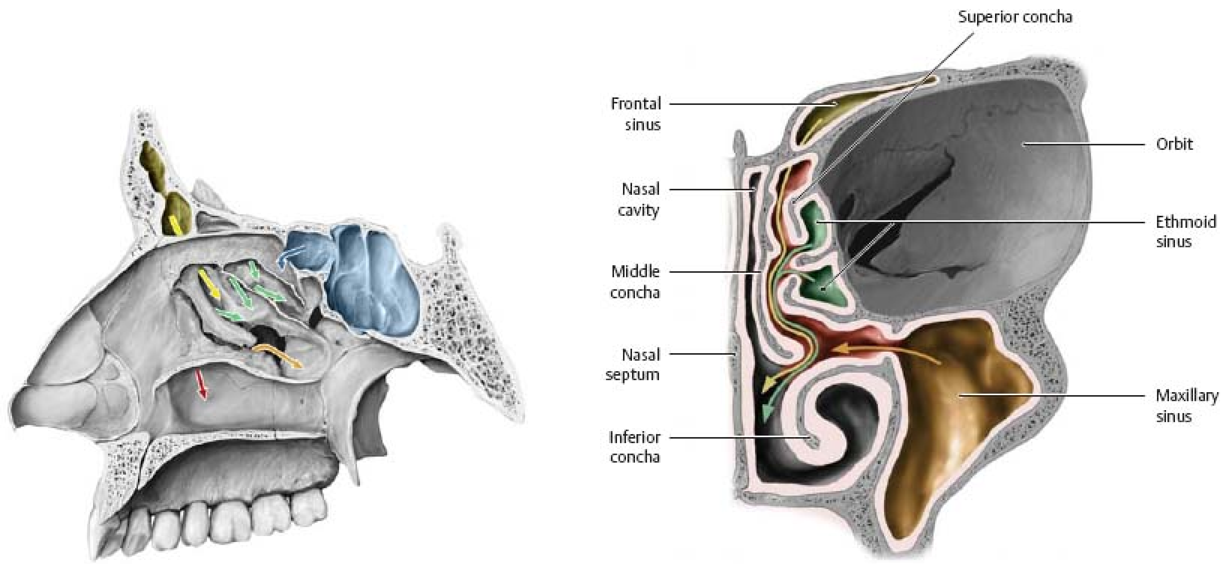
Table 34.1 **Opening of nasal structures into the nose**

Nasal passage	Sinuses/duct
Sphenoethmoid recess	Sphenoid sinus (blue)
Superior meatus	Posterior ethmoid sinus (green)

Nasal passage	**Sinuses/duct**
Middle meatus	Anterior and middle ethmoid sinus (green)
	Frontal sinus (yellow)
	Maxillary sinus (orange)
Inferior meatus	Nasolacrimal duct (red)

Fig. 34.4 Paranasal sinuses

Mucosal secretions from the sinuses and nasolacrimal duct open into the nose.

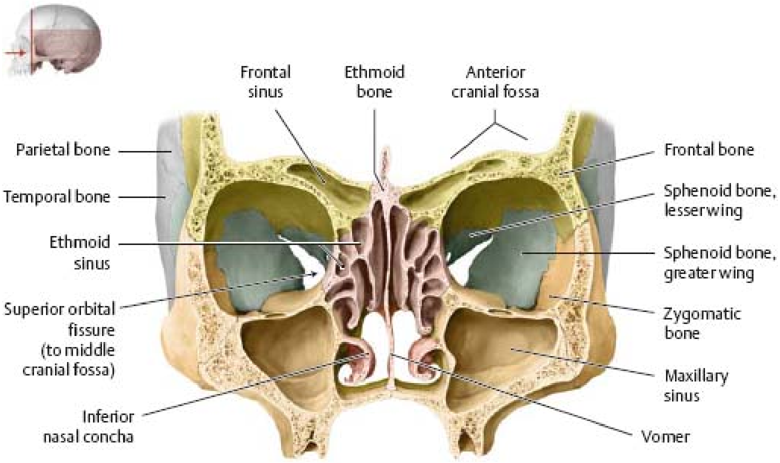


A Openings of the paranasal sinuses and nasolacrimal duct. Sagittal section, medial view of the right nasal cavity.

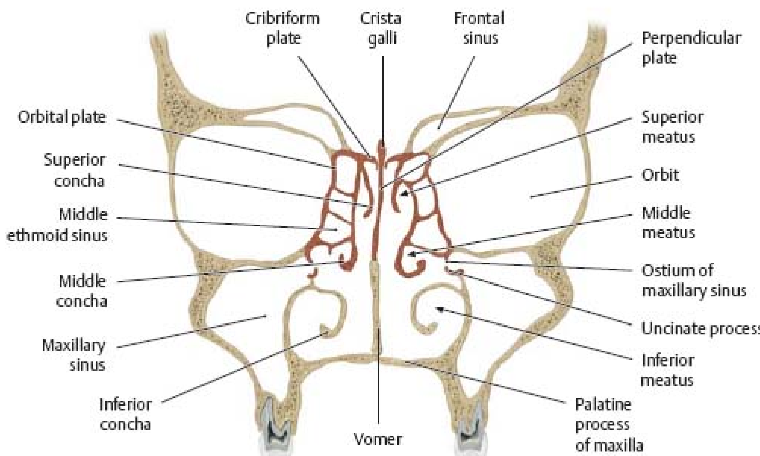
B Paranasal sinuses and osteomeatal unit in the left nasal cavity. Coronal section, anterior view.

Fig. 34.5 Bony structure of the paranasal sinuses

Coronal section, anterior view.



A Bones of the paranasal sinuses.



B Ethmoid bone (red) in the paranasal sinuses.

C MRI through the paranasal sinuses.

Clinical

Deviated septum

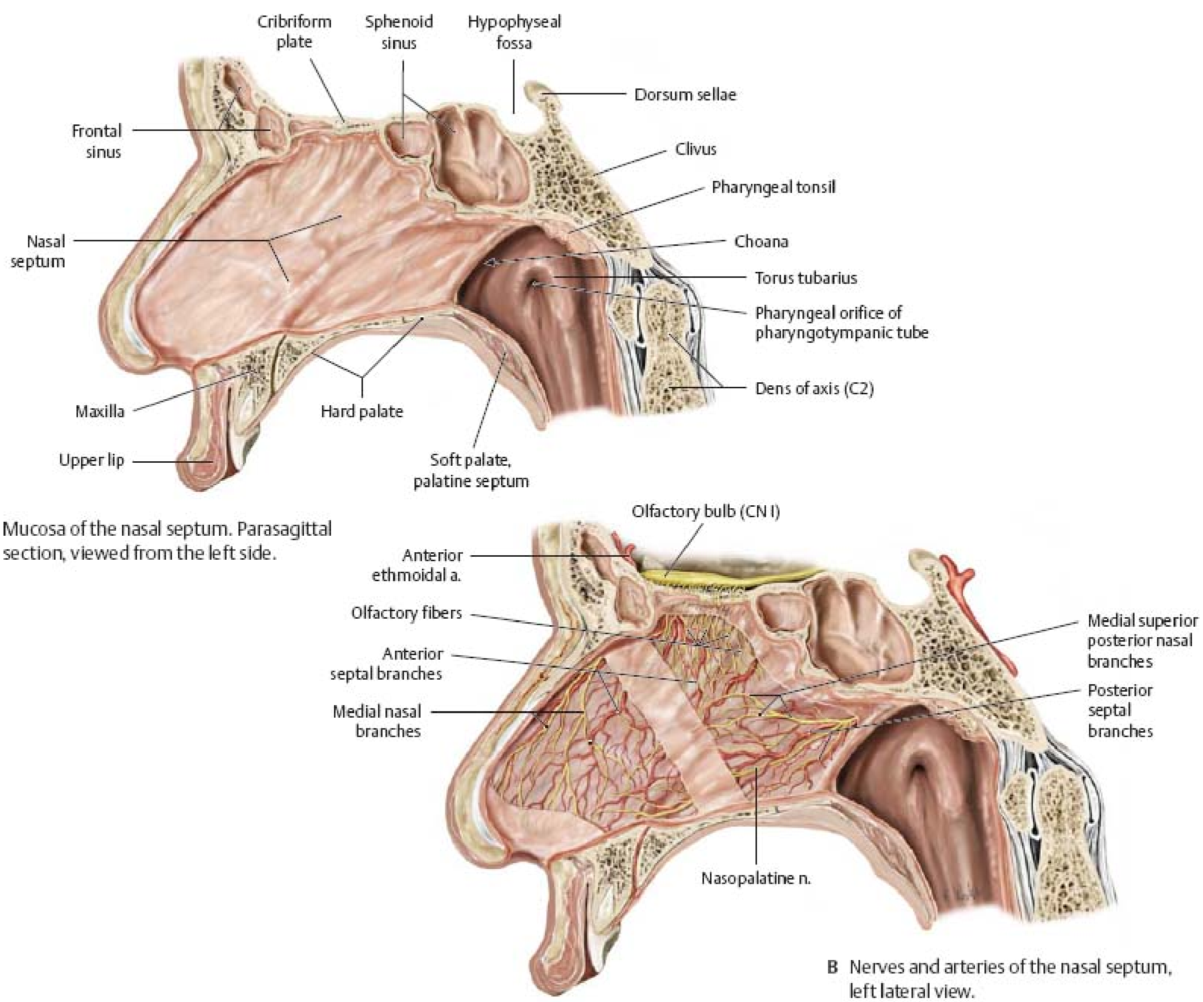
The normal position of the nasal septum creates two roughly symmetrical nasal cavities. Extreme lateral deviation of the septum may result in obstruction of the nasal passages. This may be corrected by removing portions of the cartilage (septoplasty).

Sinusitis

When the mucosa in the ethmoid sinuses becomes swollen due to inflammation (sinusitis), it blocks the flow of secretions from the frontal and maxillary sinuses in the osteomeatal unit (see Fig. 34.4). This may cause microorganisms to become trapped, causing secondary inflammations. In patients with chronic sinusitis, the narrow sites can be surgically widened to establish more effective drainage routes.

Neurovasculature of the Nasal Cavity

Fig. 34.6 Nasal septum

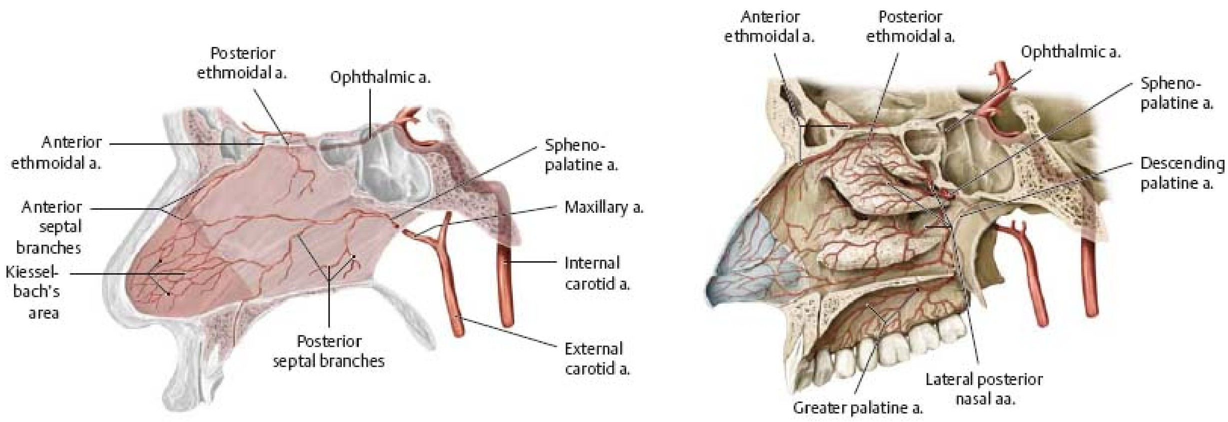


A Mucosa of the nasal septum. Parasagittal section, viewed from the left side.

B Nerves and arteries of the nasal septum, left lateral view.

Fig. 34.7 Arteries of the nasal cavity

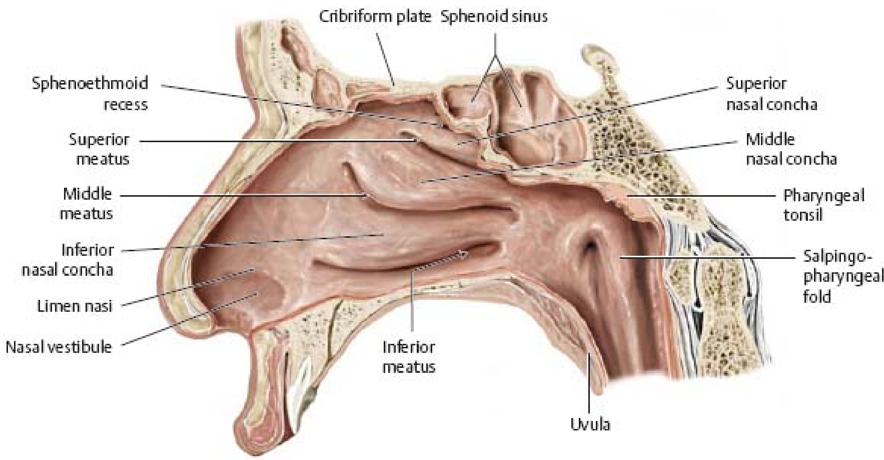
Left lateral view. *Note:* The venous drainage of the nasal cavity is into the anterior facial and ophthalmic veins.



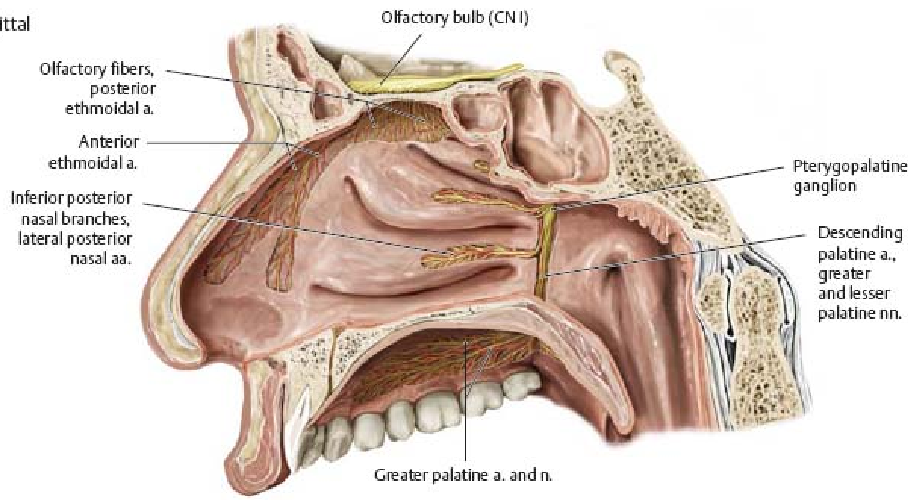
A Arteries of the nasal septum.

B Arteries of the right lateral nasal wall.

Fig. 34.8 Lateral nasal wall



A Mucosa of the lateral nasal wall. Sagittal section, viewed from the left side.



B Nerves and arteries of the lateral nasal wall, left lateral view.

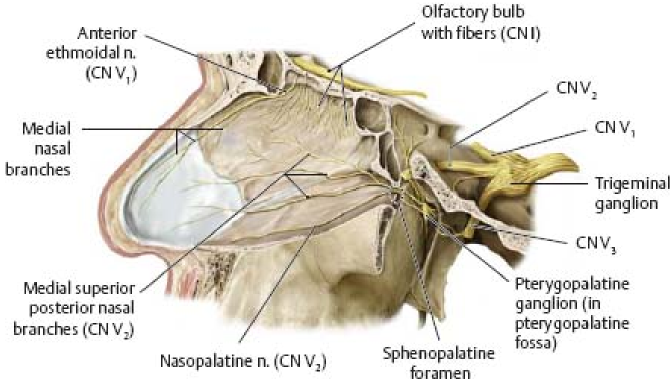
Clinical

Noseble eds

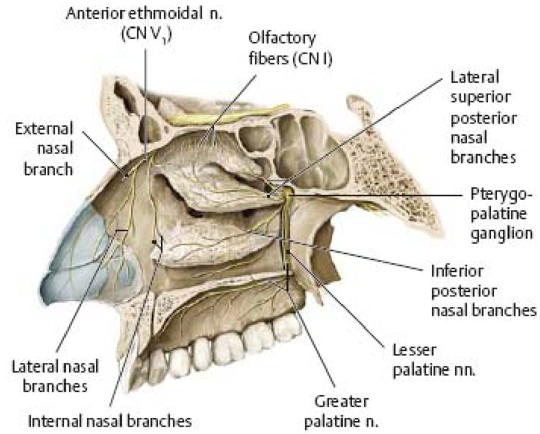
Vascular supply to the nasal cavity arises from both the internal and external carotid arteries. The anterior part of the nasal septum contains a very vascularized region referred to as Kiesselbach's area. This area is the most common site of significant nosebleeds.

Fig. 34.9 Nerves of the nasal cavity

Left lateral view.



A Nerves of the nasal septum.



B Nerves of the lateral nasal wall.

35 Temporal Bone & Ear

Temporal Bone

Fig. 35.1 Temporal bone

Left bone. The temporal bone consists of three major parts: squamous, petrous, and tympanic (see Fig. 35.2).

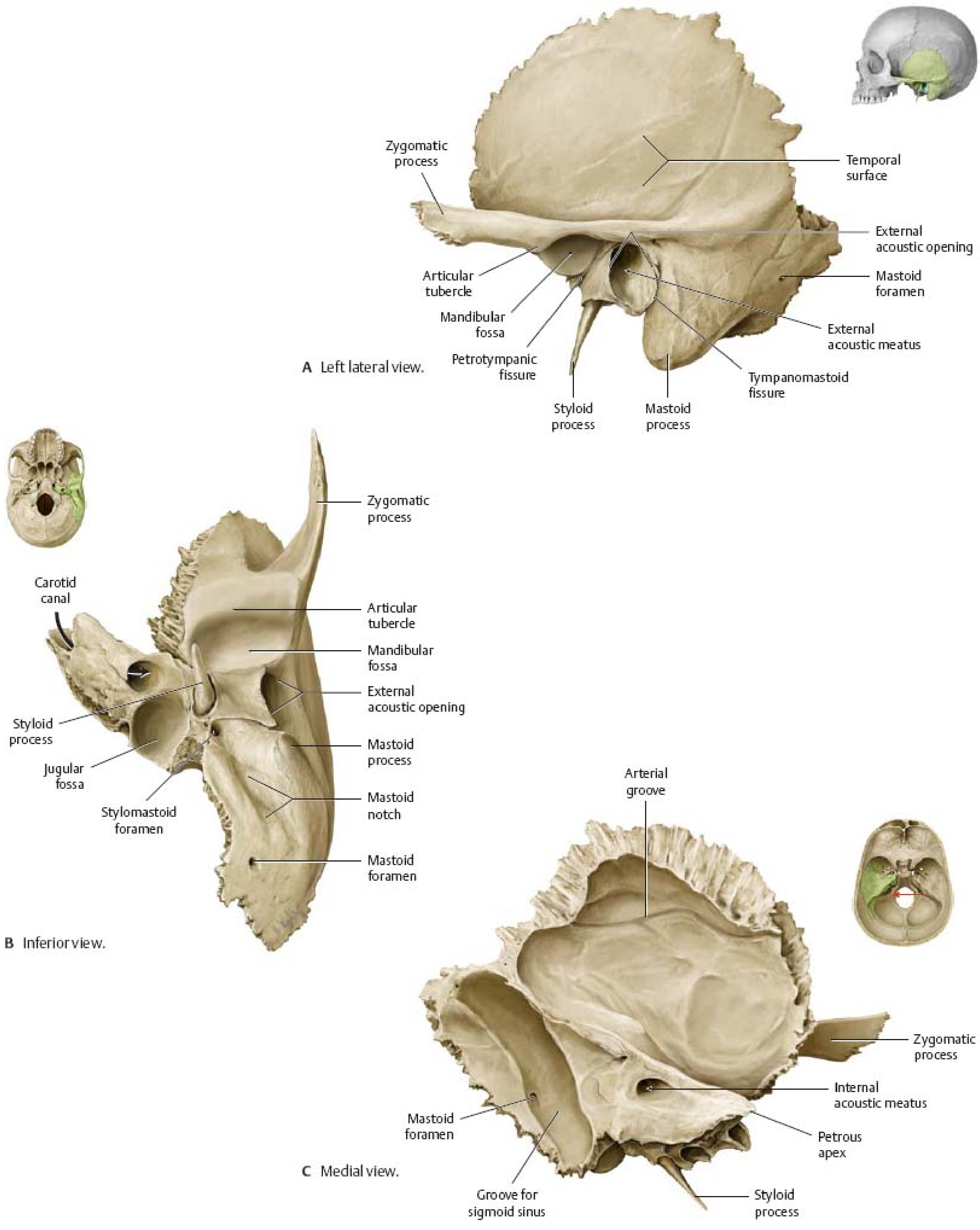
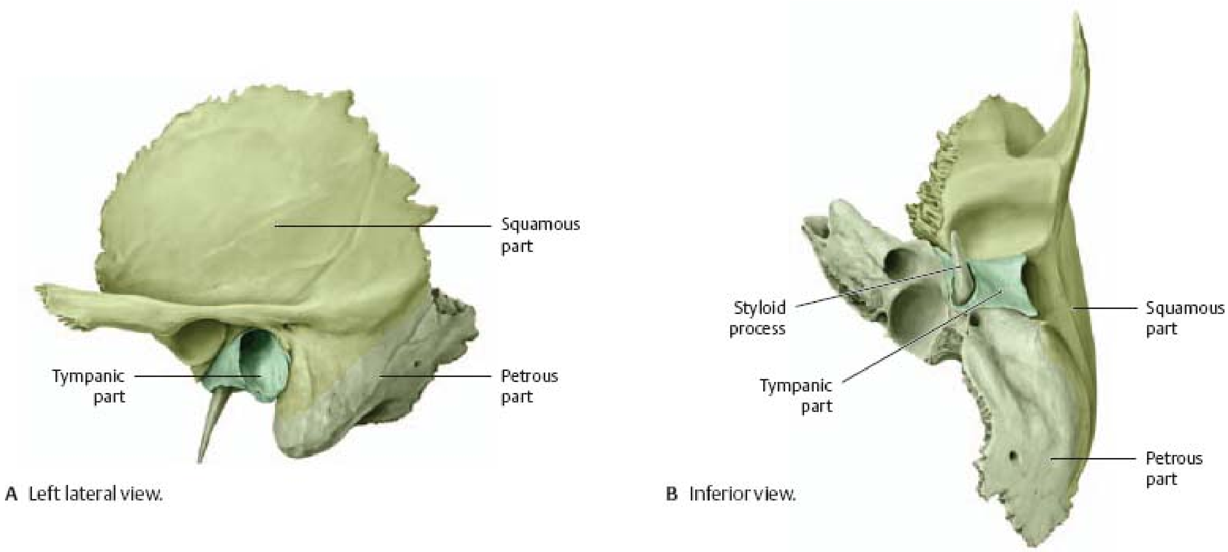


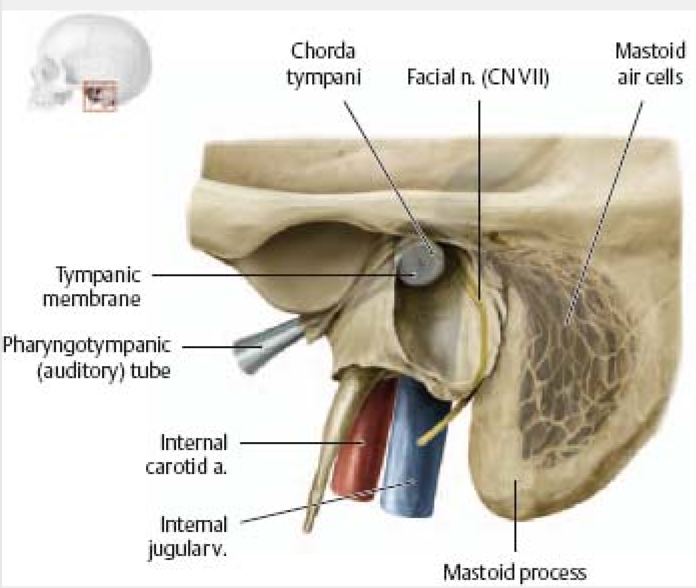
Fig. 35.2 **Parts of the temporal bone**



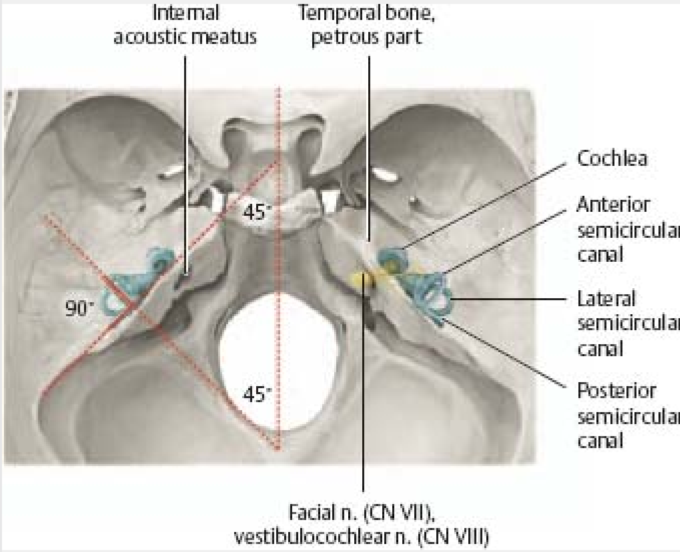
Clinical

Structures in the temporal bone

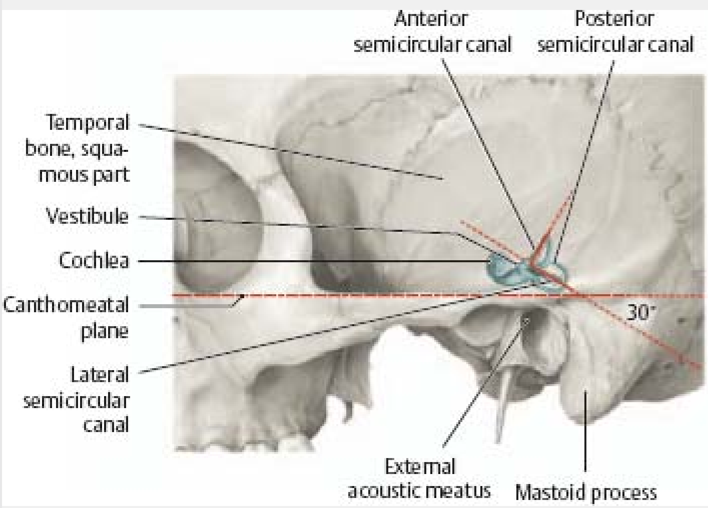
The mastoid process contains mastoid air cells that communicate with the middle ear; the middle ear in turn communicates with the nasopharynx via the pharyngotympanic (auditory) tube. Bacteria may use this pathway to move from the nasopharynx into the middle ear. In severe cases, bacteria may pass from the mastoid air cells into the cranial cavity, causing meningitis.



The petrous portion of the temporal bone contains the middle and inner ear as well as the tympanic membrane. The bony semicircular canals are oriented at an approximately 45-degree angle from the coronal, transverse, and sagittal planes.



Irrigation of the auditory canal with warm (44°C) or cool (30°C) water can induce a thermal current in the endolymph of the semicircular canal, causing the patient to manifest vestibular nystagmus (jerky eye movements, vestibulo-ocular reflex). This caloric testing is important in the diagnosis of unexplained vertigo. The patient must be oriented so that the semicircular canal of interest lies in the vertical plane.



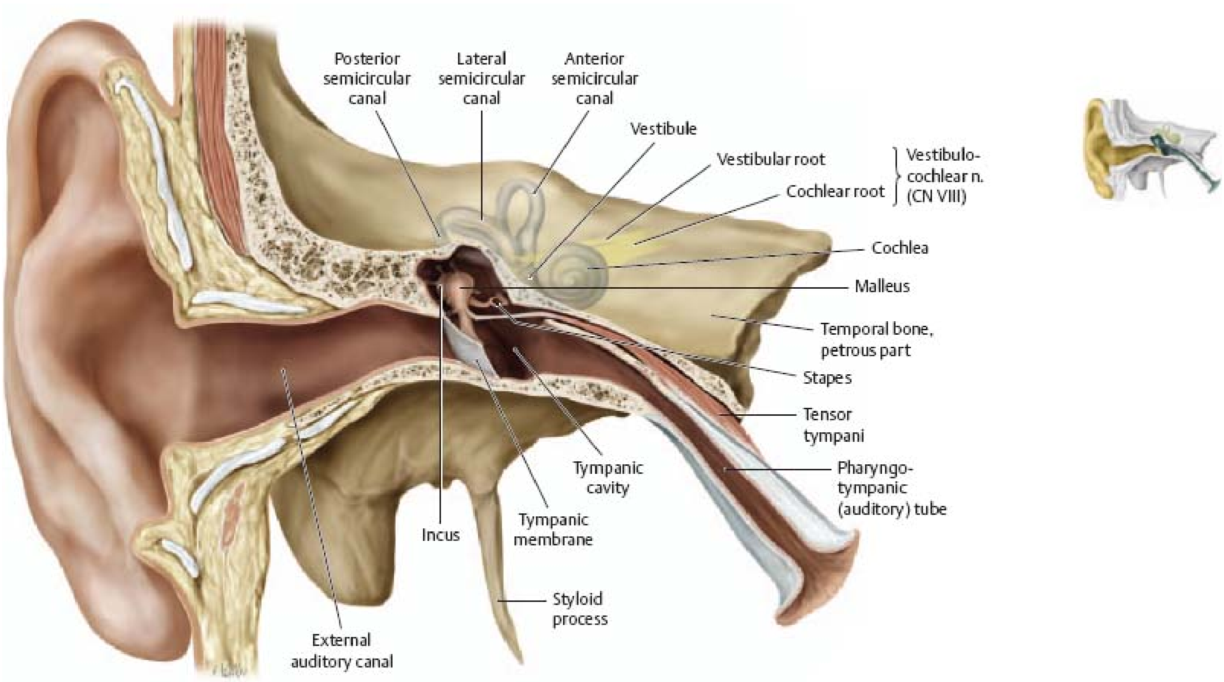
External Ear & Auditory Canal

The auditory apparatus is divided into three main parts: external, middle, and inner ear. The external and middle ear are part of the sound conduction apparatus, and the inner ear is the actual organ of hearing (see p.

619). The inner ear also contains the vestibular apparatus, the organ of balance (see p. 618).

Fig. 35.3 Ear: Overview

Coronal section through right ear, anterior view.



Clinical

Curvature of the external auditory canal

The external auditory canal is most curved in its cartilaginous portion. When an otoscope is being inserted, the auricle should be pulled backward and upward so the speculum can Fig. 35.4 External auditory canal be introduced into a straightened canal.

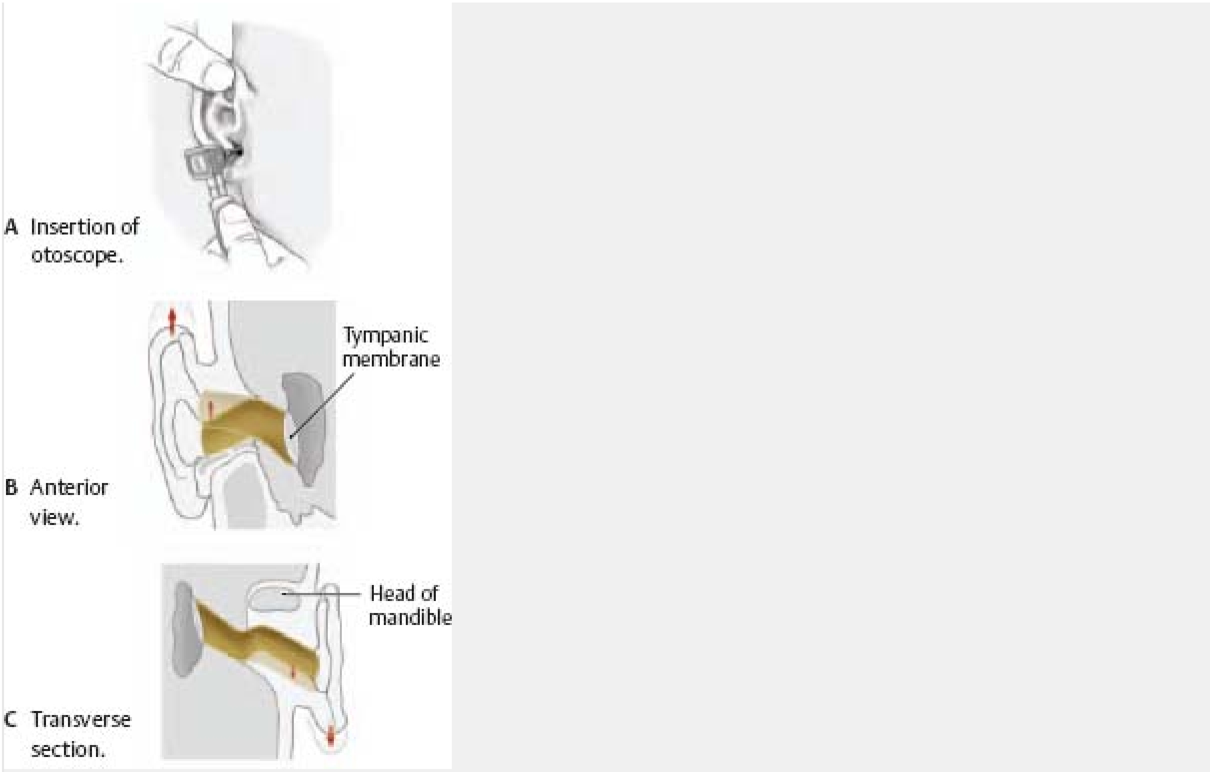


Fig. 35.4 External auditory canal

Coronal section through right ear, anterior view. The tympanic membrane separates the external auditory canal from the tympanic cavity (middle ear). The outer third of the auditory canal is cartilaginous, and the inner two thirds are osseous (tympanic part of temporal bone).

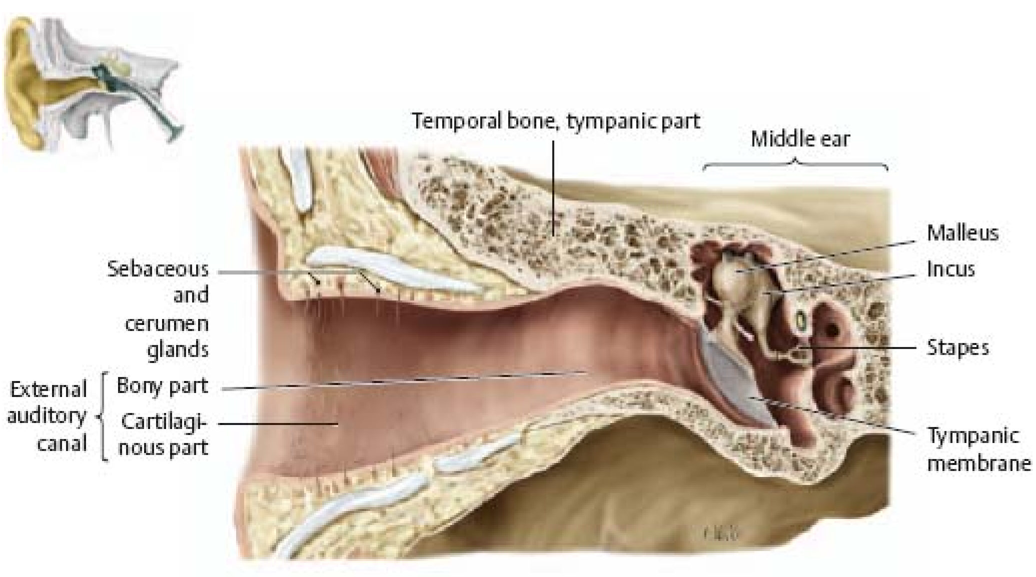
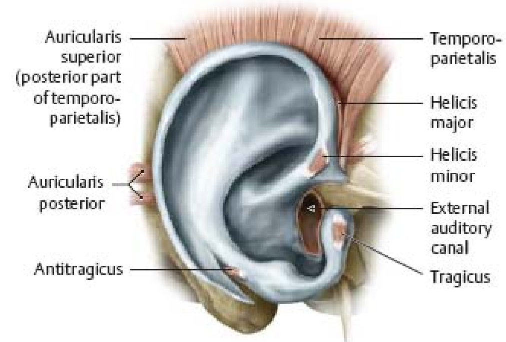


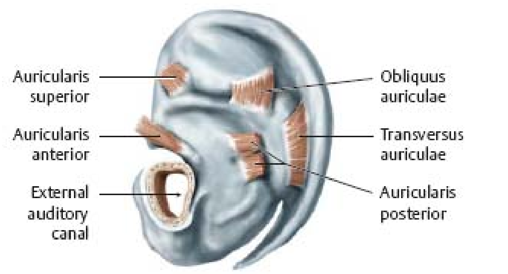
Fig. 35.5 Structure of the auricle

The auricle of the ear encloses a cartilaginous framework that forms a funnel-shaped receptor for acoustic vibrations. The muscles of the auricle are considered muscles of facial expression, although they are vestigial in humans.

A Right auricle, right lateral view.

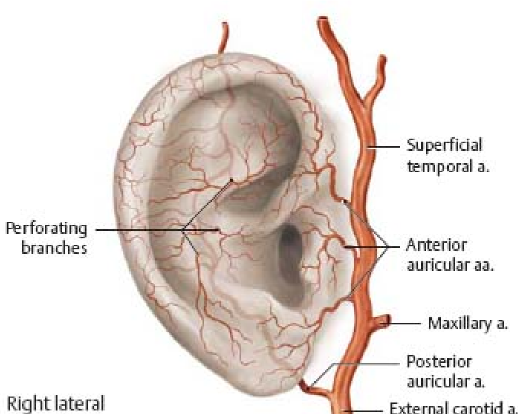


B Cartilage and muscles of the auricle, right lateral view.

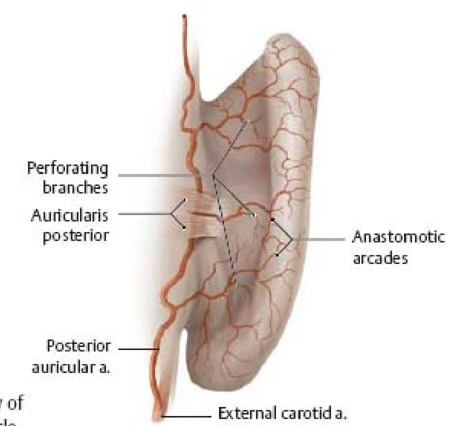


C Cartilage and muscles of the auricle, medial view of posterior surface.

Fig. 35.6 Arteries of the auricle

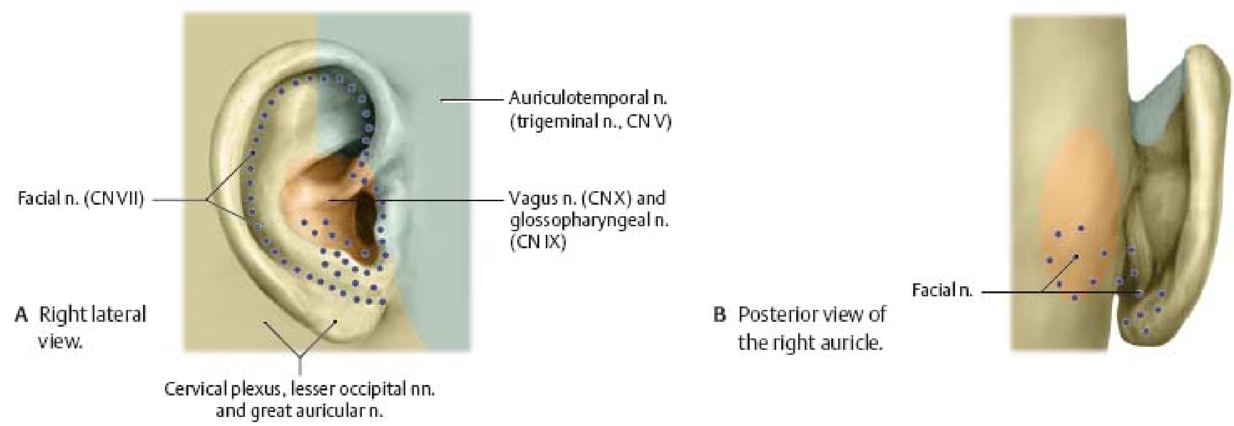


A Right lateral view.



B Posterior view of the right auricle.

Fig. 35.7 Innervation of the auricle



Middle Ear: Tympanic Cavity

Fig. 35.8 Middle ear

Right petrous bone, superior view. The tympanic cavity of the middle ear communicates anteriorly with the pharynx via the pharyngotympanic (auditory) tube and posteriorly with the mastoid air cells.

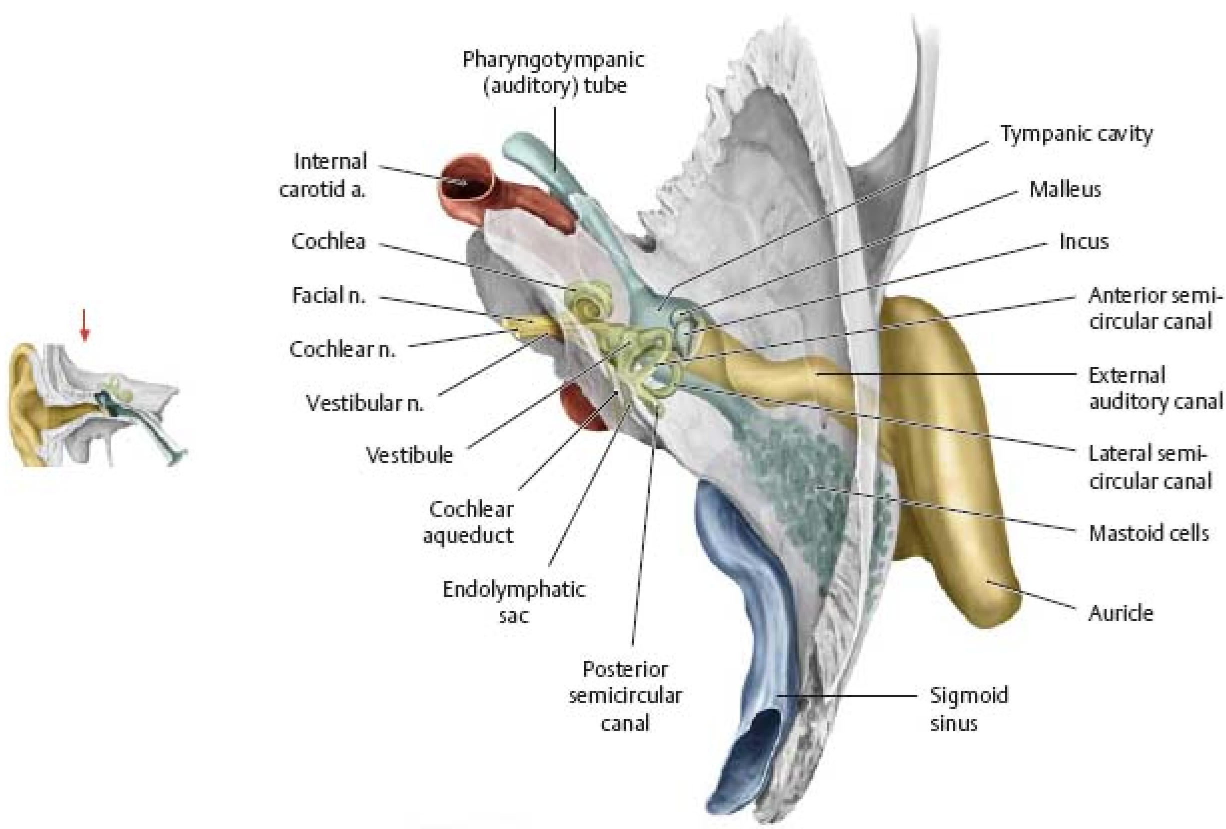


Fig. 35.9 Tympanic cavity and pharyngotympanic tube

Medial view of opened tympanic cavity.

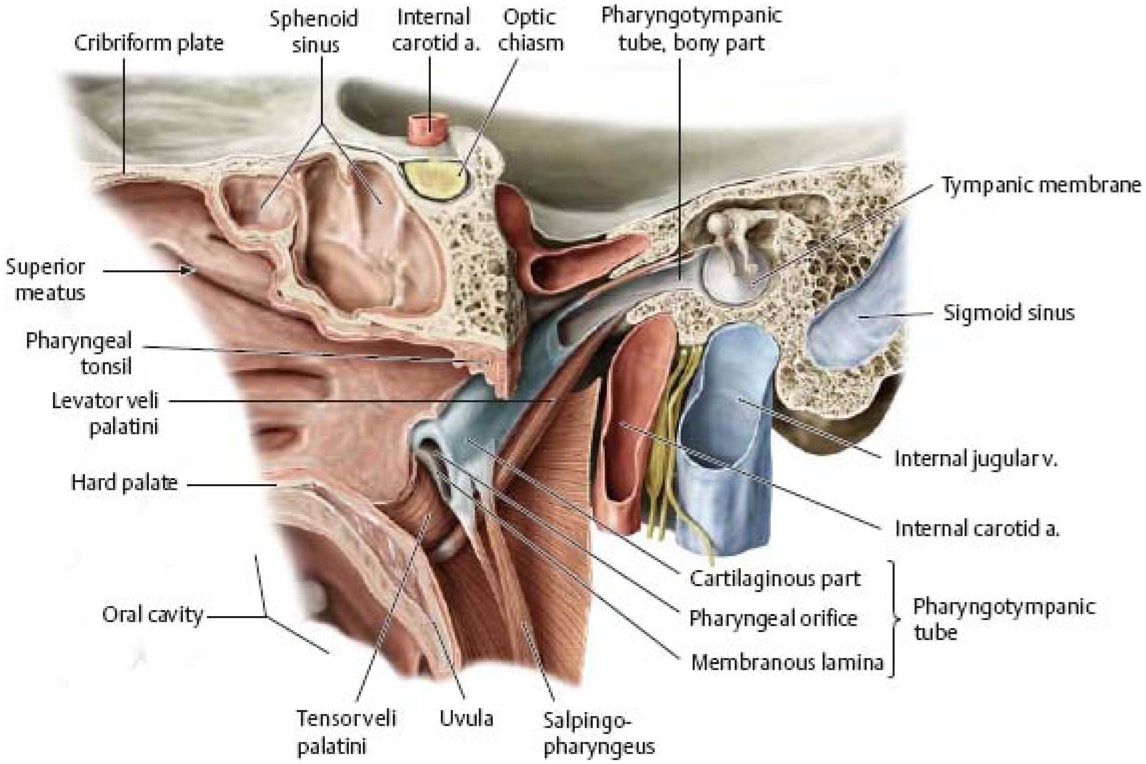


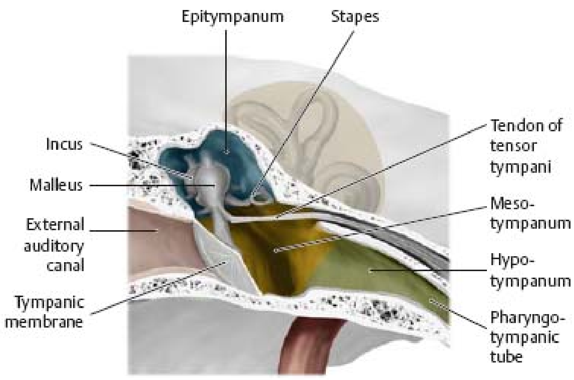
Table 35.1 Boundaries of the tympanic cavity

During chronic suppurative otitis media (inflammation of the middle ear), pathogenic bacteria may spread to adjacent regions.

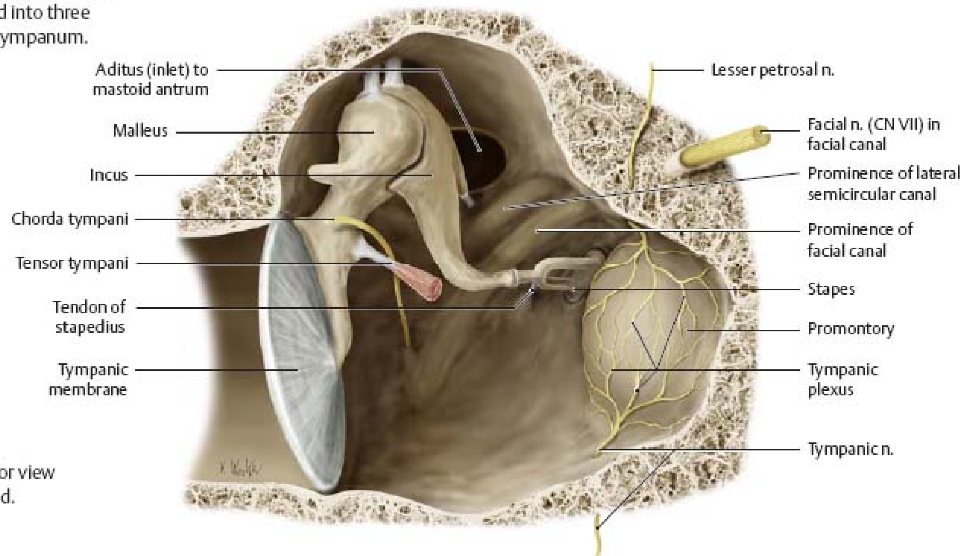
Direction	Wall	Anatomical boundary	Neighboring structures	Infection
Anterior	Carotid	Opening to pharyngotympanic tube	Carotid canal	
Lateral	Membranous	Tympanic membrane	External ear	
Superior	Tegmental	Tegmen tympani	Middle cranial fossa	Meningitis, cerebral abscess (especially of temporal lobe)
Medial	Labyrinthine	Promontory overlying basal turn of cochlea	Inner ear	
			CSF space (via petrous apex)	Abducent paralysis, trigeminal nerve irritation, visual disturbances (Gradenigo's syndrome)
Inferior	Jugular	Temporal bone, tympanic part	Bulb of jugular vein	
			Sigmoid sinus	Sinus thrombosis
Posterior	Mastoid	Aditus to mastoid antrum	Air cells of mastoid process	Mastoiditis
			Facial nerve canal	Facial paralysis

CSF = cerebrospinal fluid.

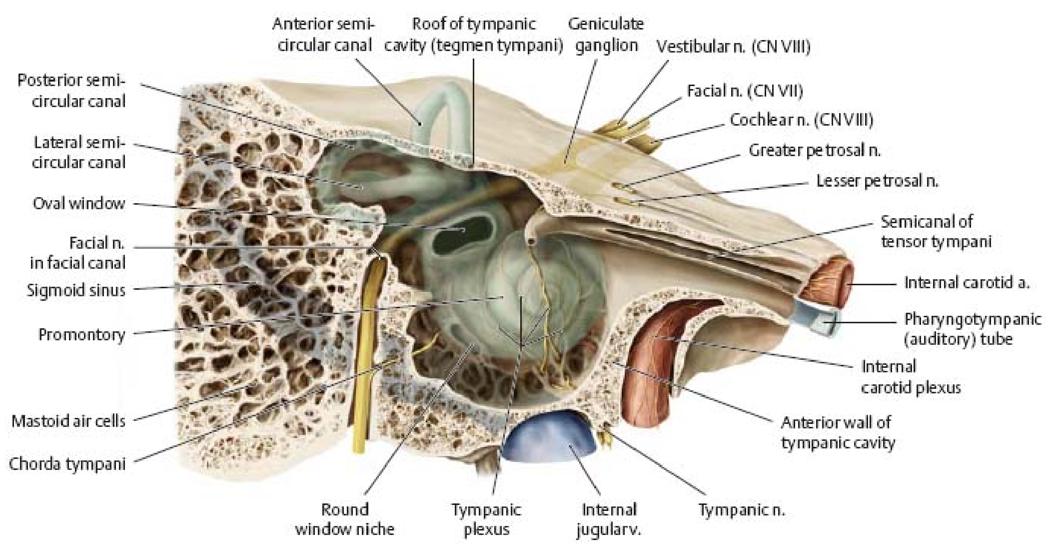
Fig. 35.10 Tympanic cavity



A Levels of the tympanic cavity. Anterior view. The tympanic cavity is divided into three levels: epi-, meso-, and hypotympanum.



B Right tympanic cavity. Anterior view with the anterior wall removed.

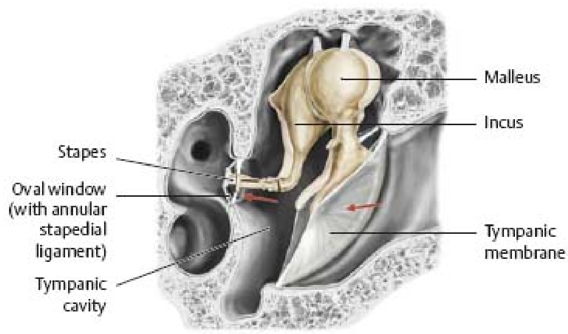


C Anatomical relationships of the tympanic cavity. Oblique sagittal section showing the medial wall.

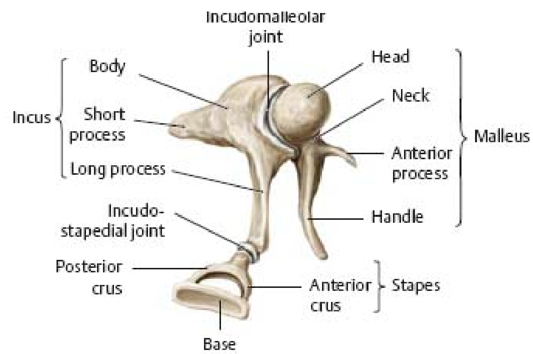
Middle Ear: Ossicular Chain & Tympanic Membrane

Fig. 35.11 Auditory ossicles

Left ear. The ossicular chain consists of three small bones that establish an articular connection between the tympanic membrane and the oval window.



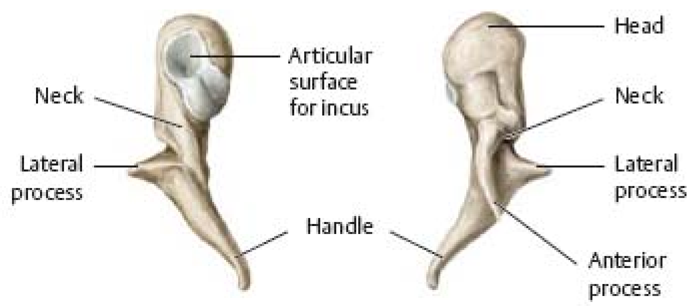
A Auditory ossicles in the middle ear. Anterior view of the left ear.



B Bones of the ossicular chain. Medial view of the left ossicular chain.

Fig. 35.12 Malleus ("hammer")

Left ear.



A Posterior view. B Anterior view.

Fig. 35.13 Incus ("anvil")

Left ear.

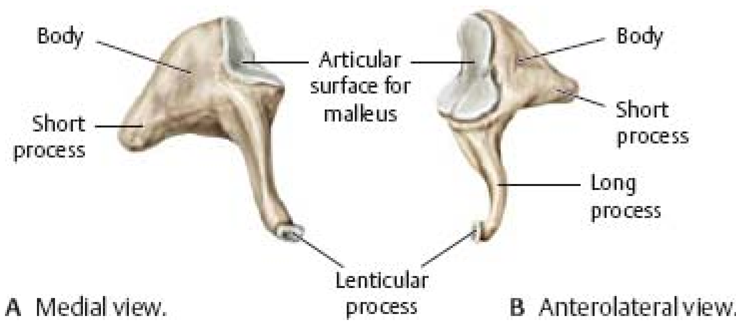


Fig. 35.14 **Stapes (“stirrup”)**

Left ear.

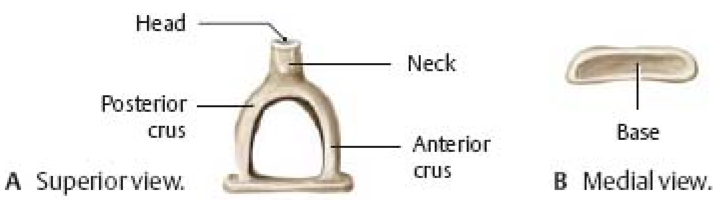
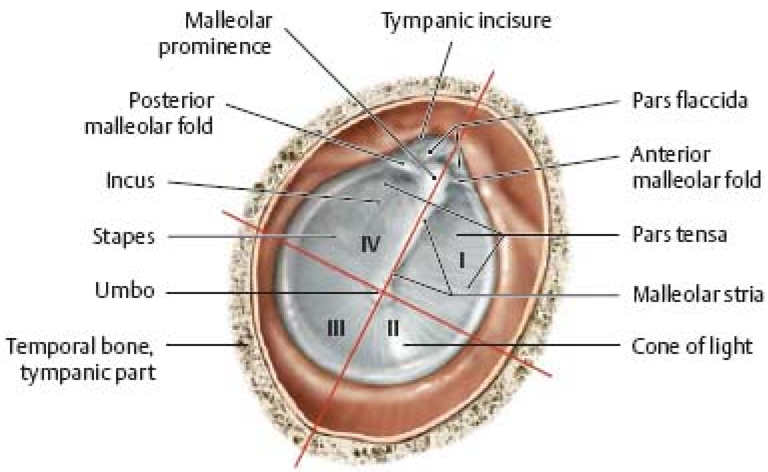
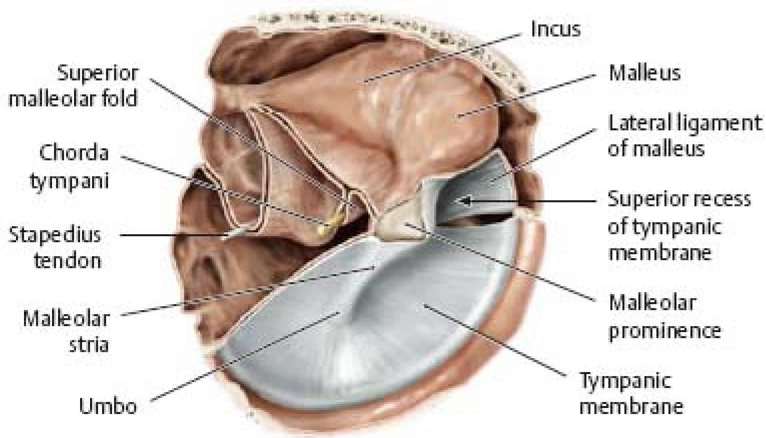


Fig. 35.15 **Tympanic membrane**

Right tympanic membrane. The tympanic membrane is divided into four quadrants: anterosuperior (I), anteroinferior (II), posteroinferior (III), and posterosuperior (IV).



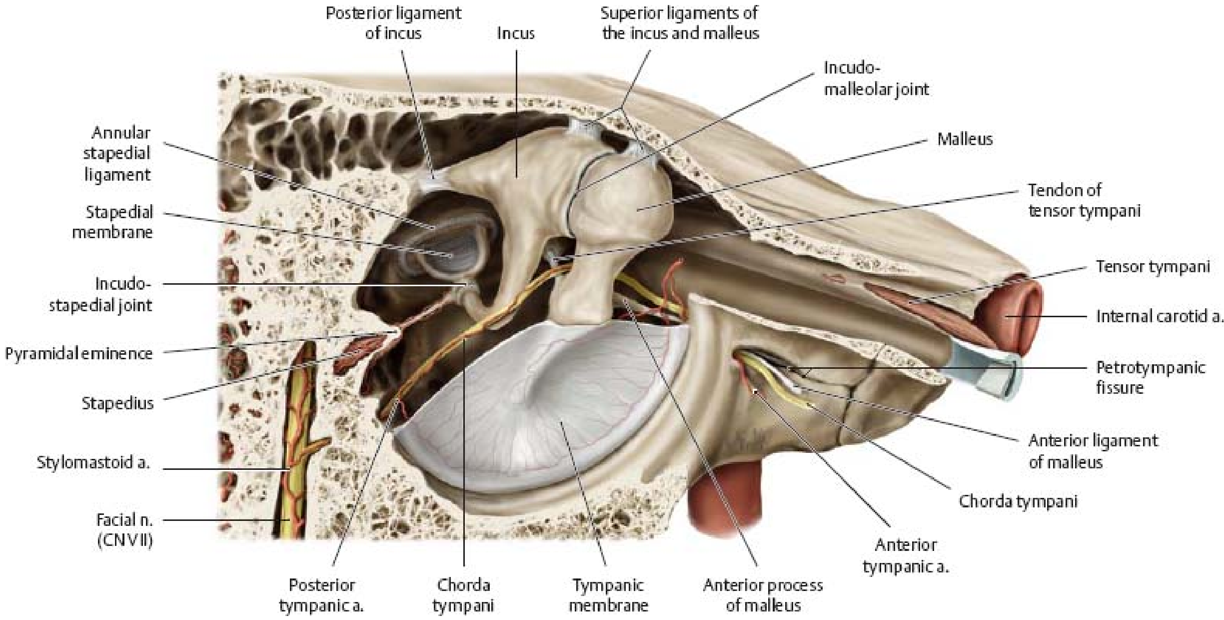
A Lateral view of the right tympanic membrane.



B Mucosal lining of the tympanic cavity. Posterolateral view with the tympanic membrane partially removed.

Fig. 35.16 Ossicular chain in the tympanic cavity

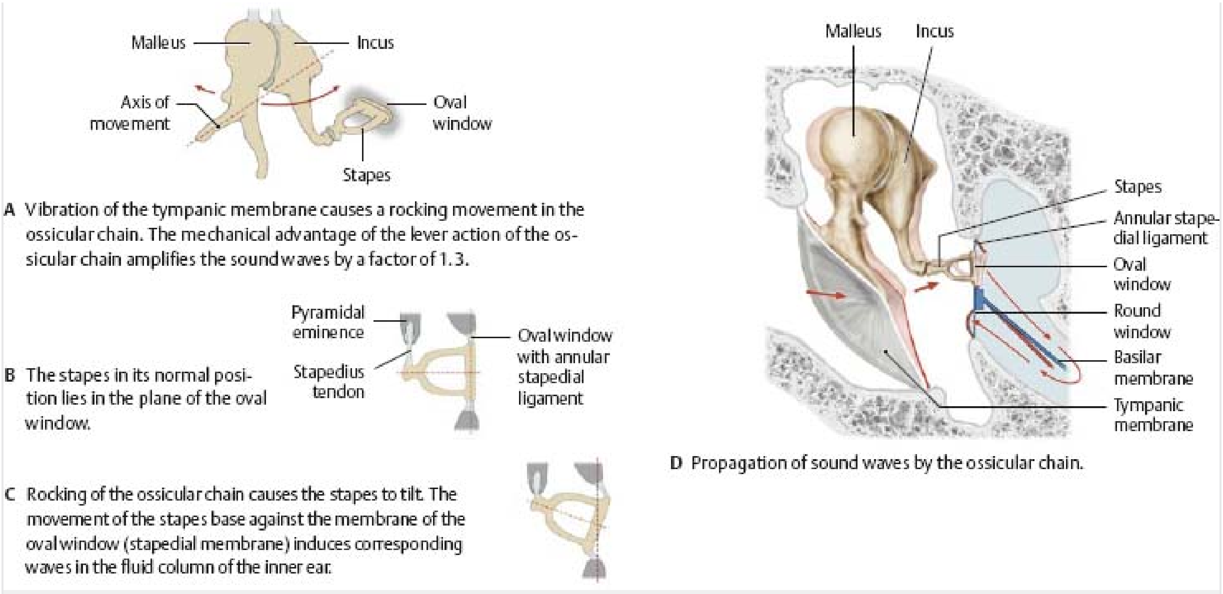
Lateral view of the right ear. *Revealed:* Ligaments of the ossicular chain and muscles of the middle ear (stapedius and tensor tympani).



Clinical

Ossicular chain in hearing

Sound waves funneled into the external auditory canal set the tympanic membrane into vibration. The ossicular chain transmits the vibrations to the oval window, which communicates them to the fluid column of the inner ear. Sound waves in fluid meet with higher impedance; they must therefore be amplified in the middle ear. The difference in surface area between the tympanic membrane and the oval window increases the sound pressure 17-fold. A total amplification factor of 22 is achieved through the lever action of the ossicular chain. If the ossicular chain fails to transform the sound pressure between the tympanic membrane and the footplate of the stapes, the patient will experience conductive hearing loss of magnitude 20 dB. See p. 619 for hearing.



A Vibration of the tympanic membrane causes a rocking movement in the ossicular chain. The mechanical advantage of the lever action of the ossicular chain amplifies the sound waves by a factor of 1.3.

B The stapes in its normal position lies in the plane of the oval window.

C Rocking of the ossicular chain causes the stapes to tilt. The movement of the stapes base against the membrane of the oval window (stapedial membrane) induces corresponding waves in the fluid column of the inner ear.

D Propagation of sound waves by the ossicular chain.

Arteries of the Middle Ear

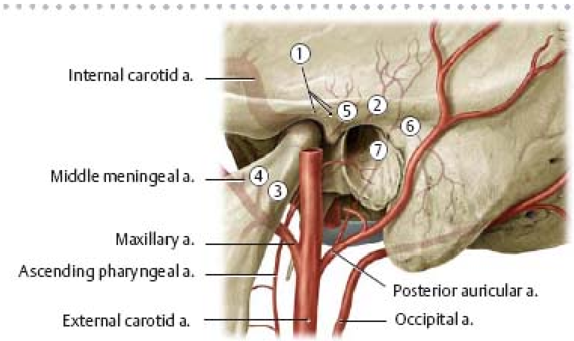


Table 35.2 Principal arteries of the middle ear

Origin	Artery			Distribution
Internal carotid a.	① Caroticotympanic aa.			Tympanic cavity (anterior wall), pharyngotympanic (auditory) tube
External carotid a.	Ascending pharyngeal a. (medial branch)	② Inferior tympanic a.		Tympanic cavity (floor), promontory
	Maxillary a. (terminal branch)	③ Deep auricular a.		Tympanic cavity (floor), tympanic membrane
		④ Anterior tympanic a.		Tympanic membrane, mastoid antrum, malleus, incus
		Middle meningeal a.	⑤ Superior tympanic a.	Tympanic cavity (roof), tensor tympani, stapes
	Posterior auricular a. (posterior branch)	Stylomastoid a.	⑥ Stylomastoid a.	Tympanic cavity (posterior wall), mastoid air cells, stapedius muscle, stapes
			⑦ Posterior tympanic a.	Chorda tympani, tympanic membrane, malleus

Fig. 35.17 Arteries of the middle ear: Ossicular chain and tympanic membrane

Medial view of the right tympanic membrane. With inflammation, the arteries of the tympanic membrane may become so dilated that their course can be observed (as shown here).

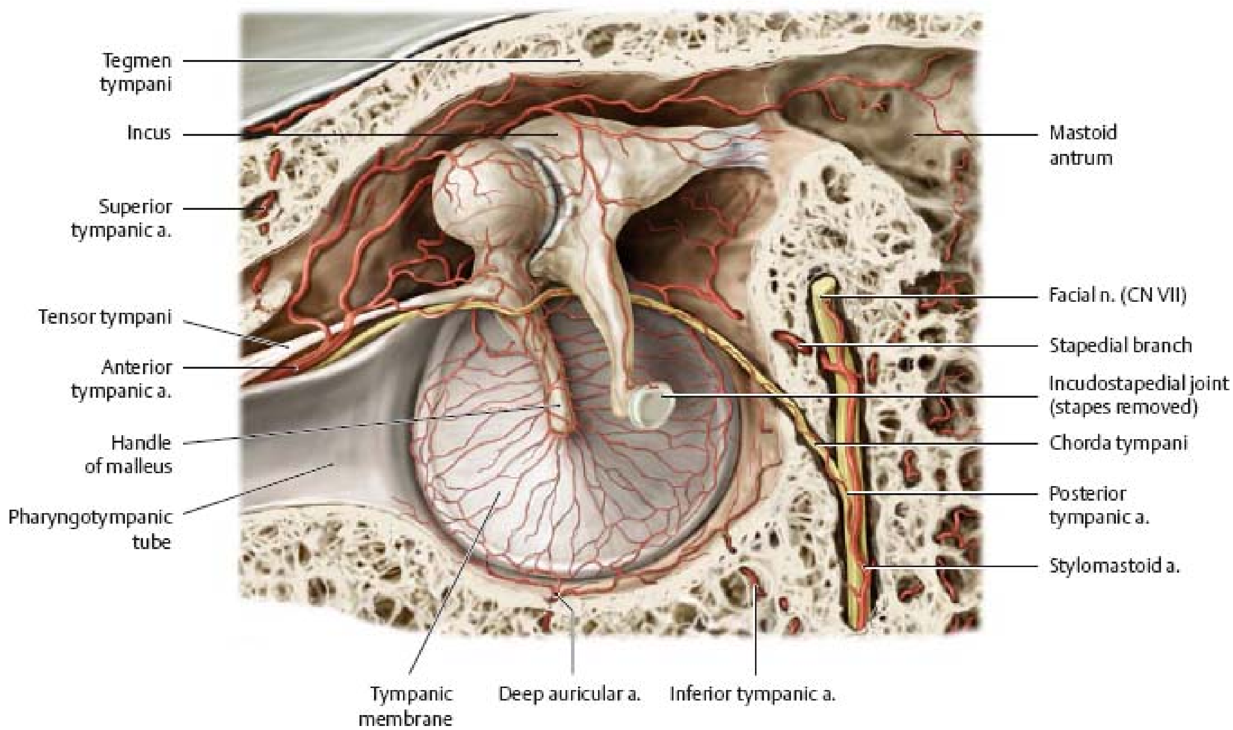
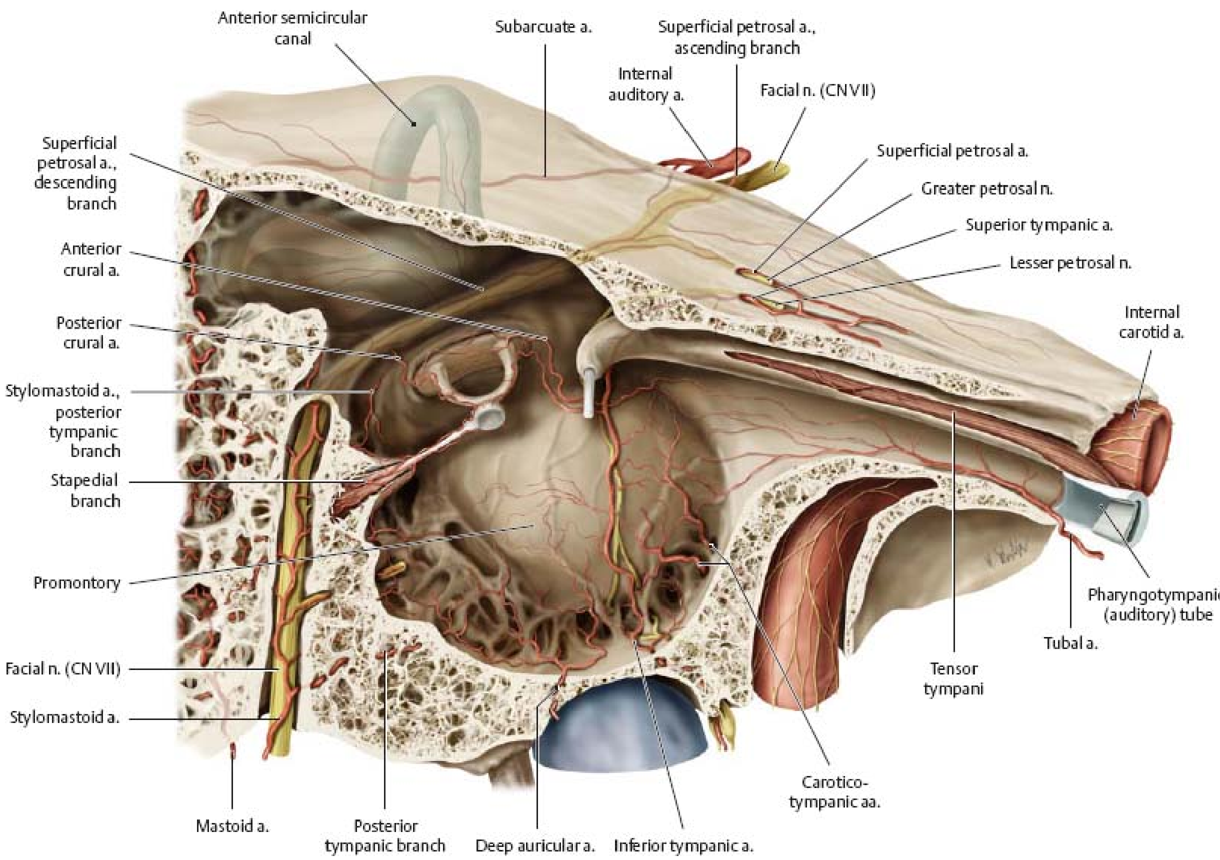


Fig. 35.18 **Arteries of the middle ear: Tympanic cavity**

Right petrous bone, anterior view. *Removed:* Malleus, incus, portions of chorda tympani, and anterior tympanic artery.

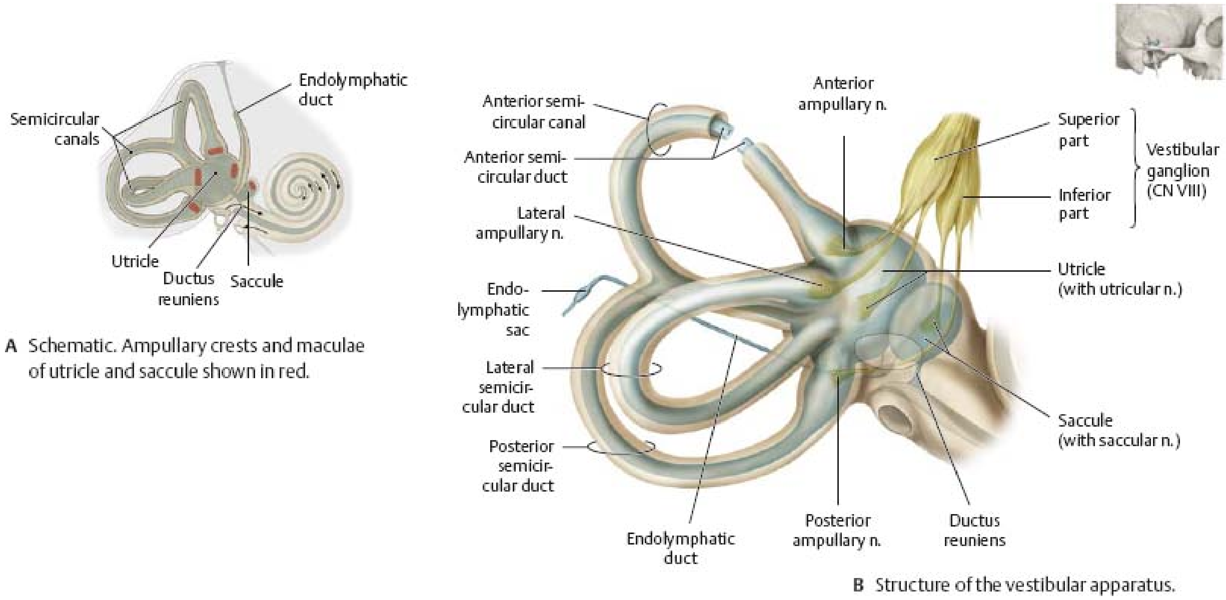


Inner Ear

The inner ear consists of the vestibular apparatus (for balance) and the auditory apparatus (for hearing). Both are formed by a membranous labyrinth filled with endolymph floating within bony labyrinth filled with perilymph and embedded in the petrous part of the temporal bone.

Fig. 35.19 **Vestibular apparatus**

Right lateral view.

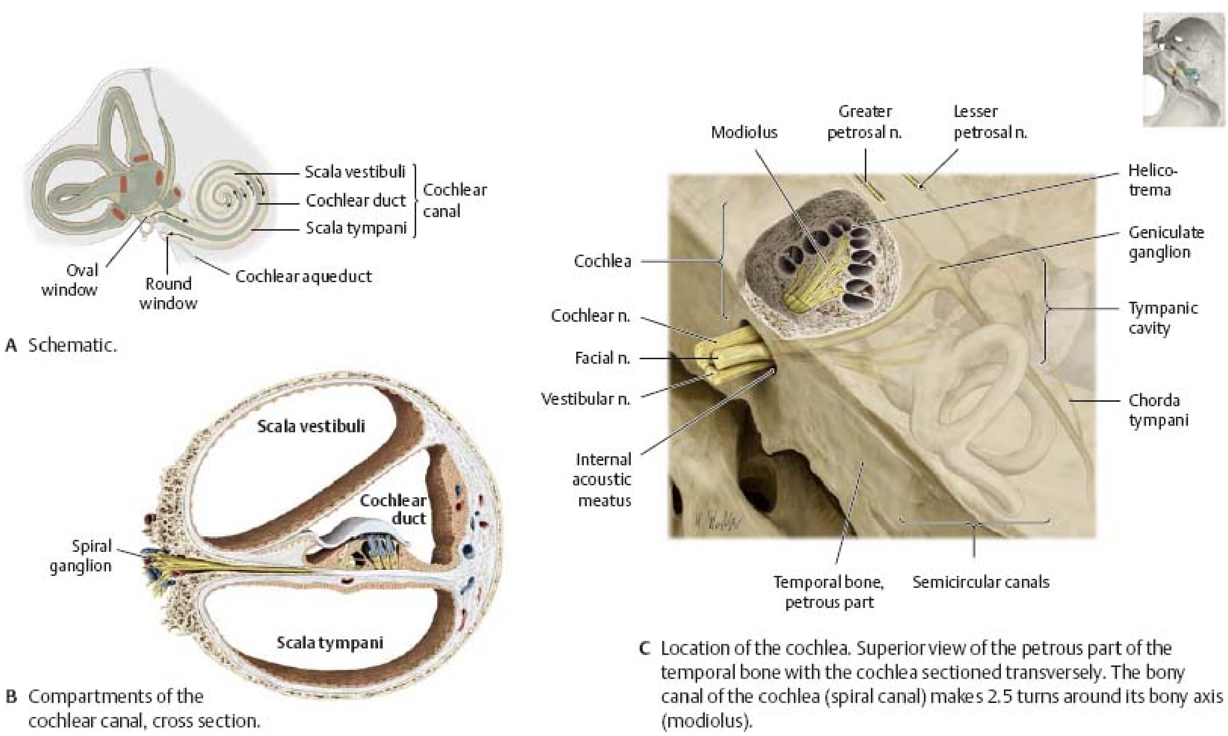


A Schematic. Ampullary crests and maculae of utricle and saccule shown in red.

B Structure of the vestibular apparatus.

Fig. 35.20 Auditory apparatus

The cochlear labyrinth and its bony shell form the cochlea, which contains the sensory epithelium of the auditory apparatus (organ of Corti).



A Schematic.

B Compartments of the cochlear canal, cross section.

C Location of the cochlea. Superior view of the petrous part of the temporal bone with the cochlea sectioned transversely. The bony canal of the cochlea (spiral canal) makes 2.5 turns around its bony axis (modiolus).

Fig. 35.21 Innervation of the membranous labyrinth

Right ear, anterior view. The vestibulocochlear nerve (CN VIII; see p. 480)

transmits afferent impulses from the inner ear to the brainstem through the internal acoustic meatus. The vestibulocochlear nerve is divided into the vestibular and cochlear nerves. *Note:* The sensory organs in the semicircular canals respond to angular acceleration, and the macular organs respond to horizontal and vertical linear acceleration.

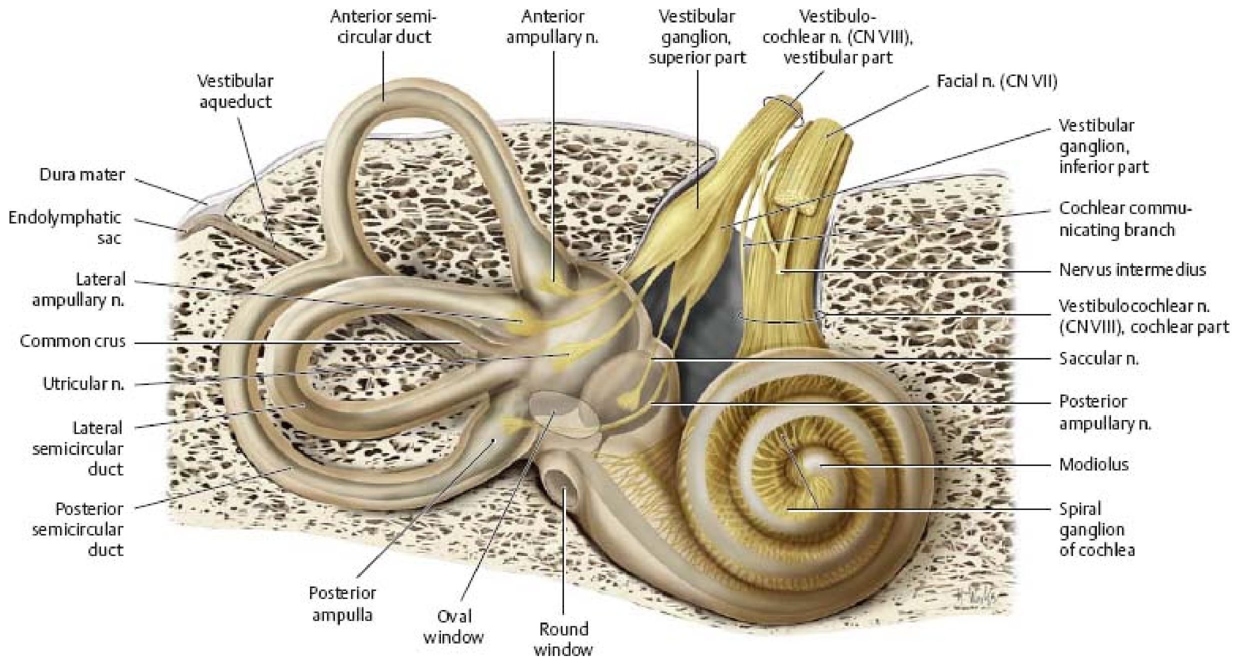
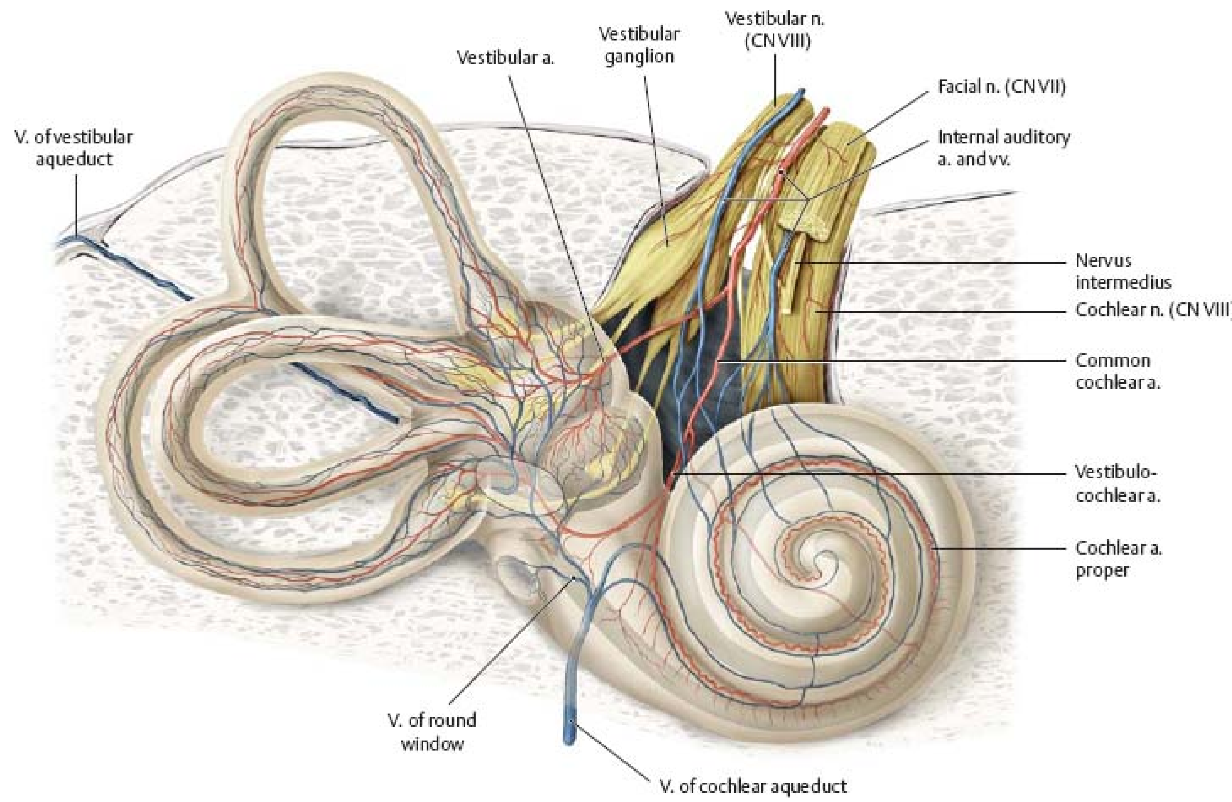


Fig. 35.22 Blood vessels of the inner ear

Right anterior view. The labyrinth receives its blood supply from the internal auditory artery, a branch of the anteroinferior cerebellar artery (see p. 608).


Vestibular a.
Vestibular ganglion
Vestibular n. (CN VIII)
Facial n. (CN VII)
Internal auditory a. and vv.
V. of vestibular aqueduct
Nervus intermedius
Cochlear n. (CN VIII)
Common cochlear a.
Vestibulo-cochlear a.
Cochlear a. proper
V. of round window
V. of cochlear aqueduct

36 Oral Cavity & Pharynx

Bones of the Oral Cavity

The floor of the nasal cavity (the maxilla and palatine bone) forms the roof of the oral cavity, the hard palate. The two horizontal processes of the maxilla (the palatine processes) grow together during development, eventually fusing at the median palatine suture. Failure to fuse results in a cleft palate.

Fig. 36.1 Hard palate: Inferior view

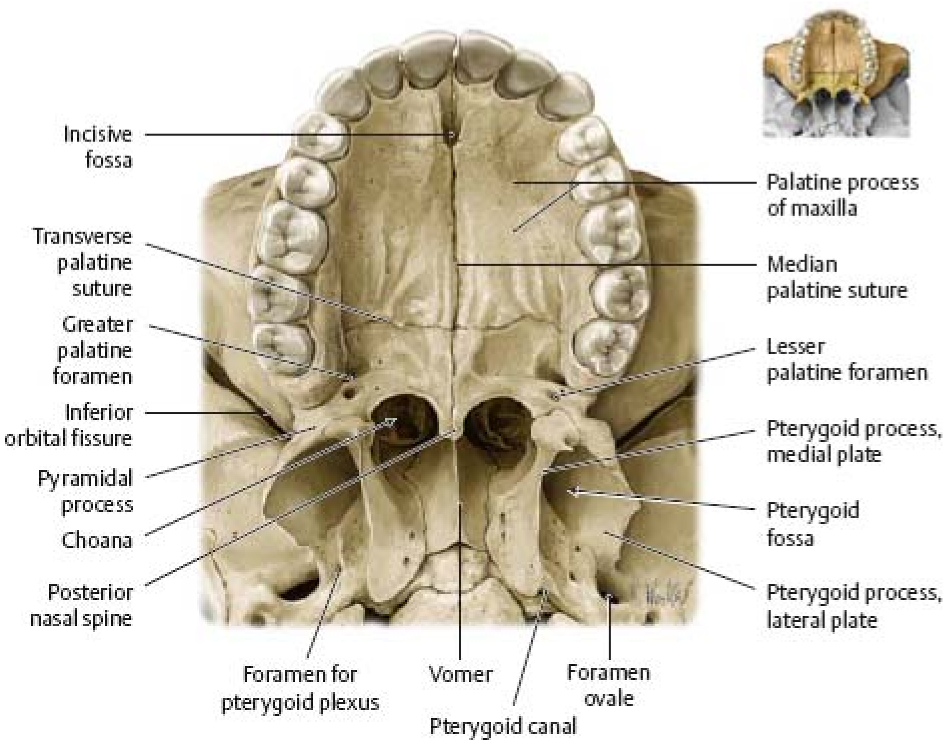


Fig. 36.2 Hard palate: Superior view

Removed: Maxilla (upper part).

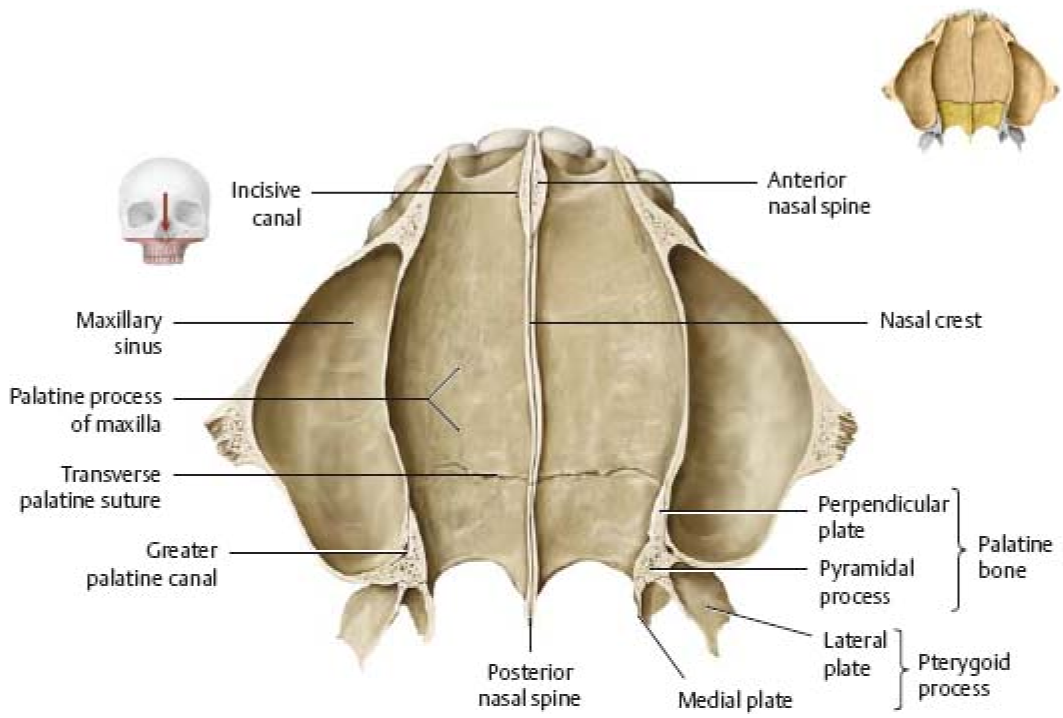


Fig. 36.3 Hard palate: Oblique posterior view

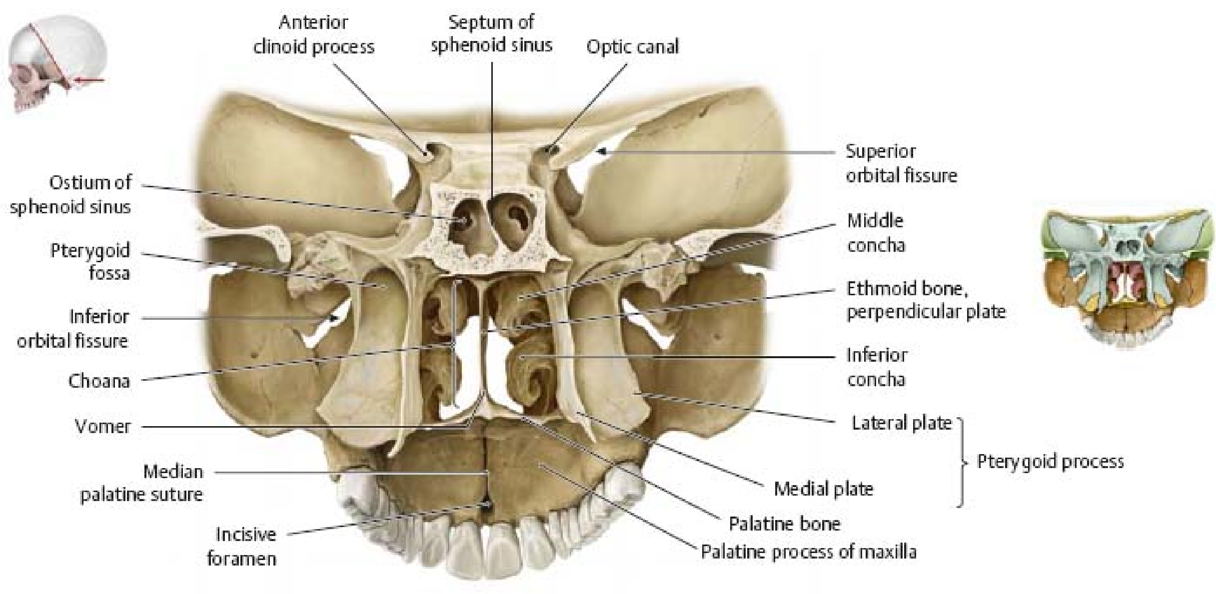


Fig. 36.4 Mandible

The mandible (jaw) is connected to the viscerocranium at the temporomandibular joint (p. 540).

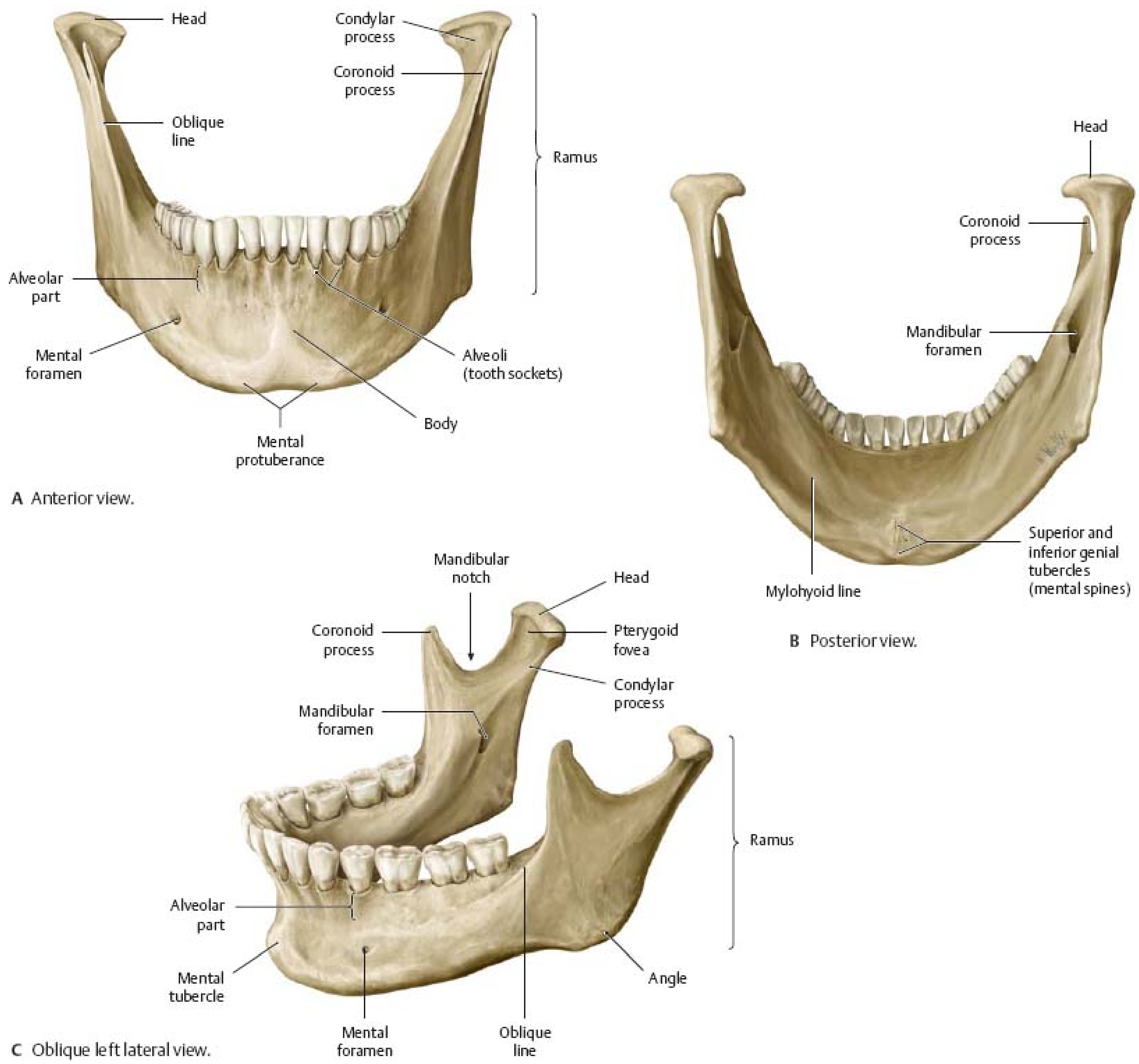
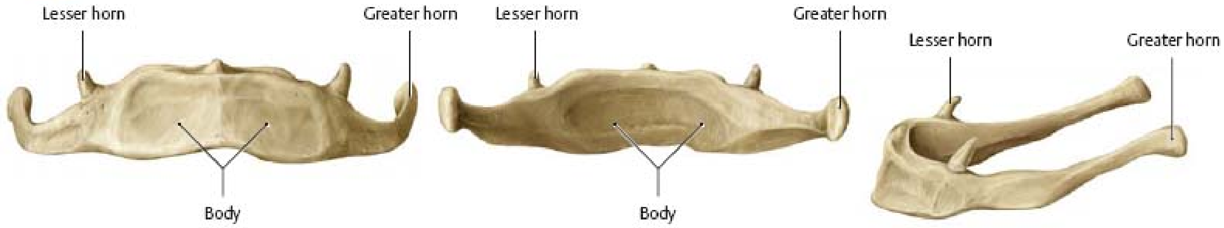


Fig. 36.5 Hyoid bone

The hyoid bone is suspended in the neck by muscles between the floor of the mouth and the larynx. Although not listed among the cranial bones, the hyoid bone gives attachment to the muscles of the oral floor. The greater horn and body of the hyoid are palpable in the neck.



A Anterior view.

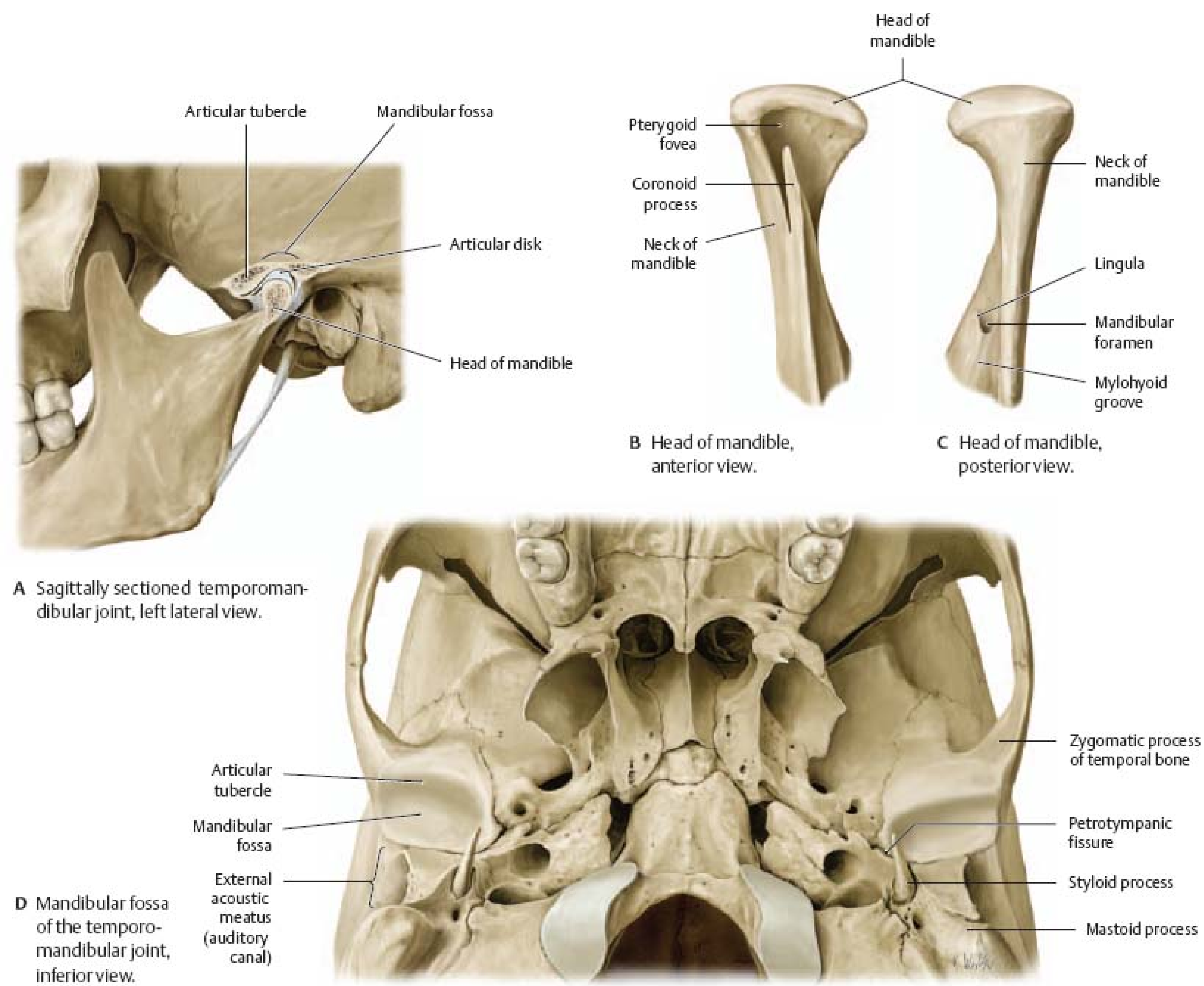
B Posterior view.

C Oblique left lateral view.

Temporomandibular Joint

Fig. 36.6 Temporomandibular joint

The head of the mandible articulates with the mandibular fossa in the temporomandibular joint.



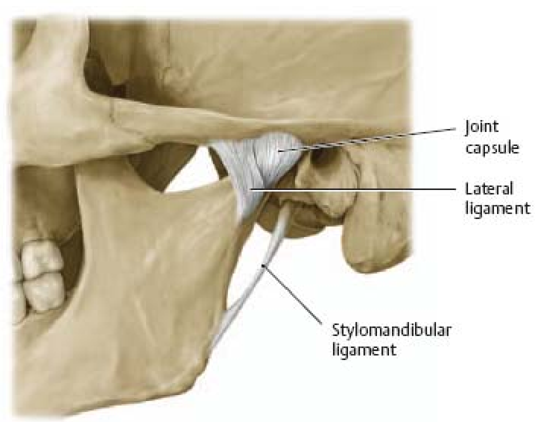
A Sagittally sectioned temporomandibular joint, left lateral view.

B Head of mandible, anterior view.

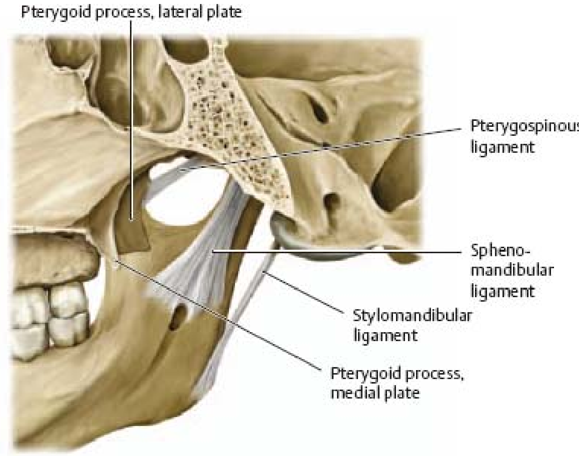
C Head of mandible, posterior view.

D Mandibular fossa of the temporomandibular joint, inferior view.

Fig. 36.7 Ligaments of the temporomandibular joint



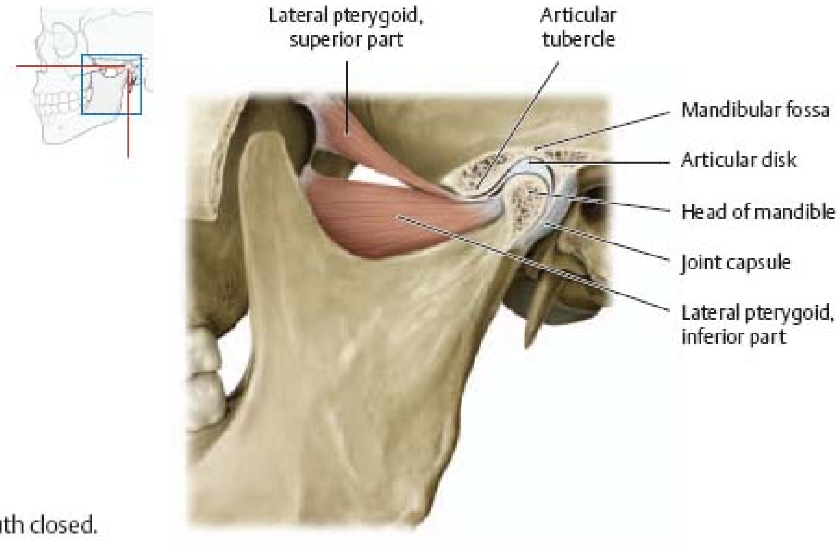
A Lateral view of the left temporomandibular joint.



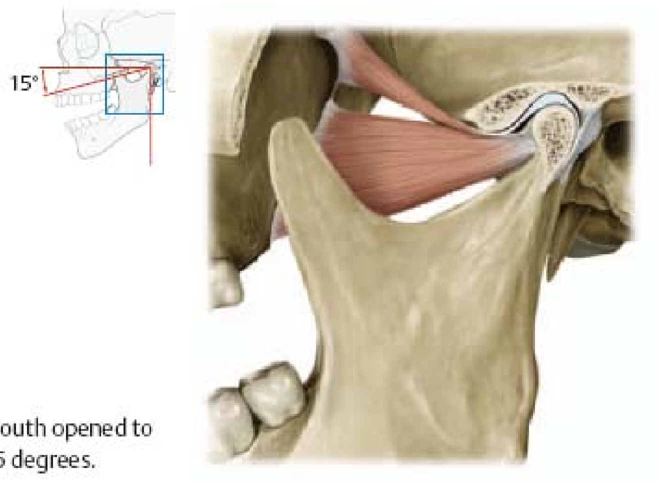
B Medial view of the right temporomandibular joint.

Fig. 36.8 Movement of the temporomandibular joint

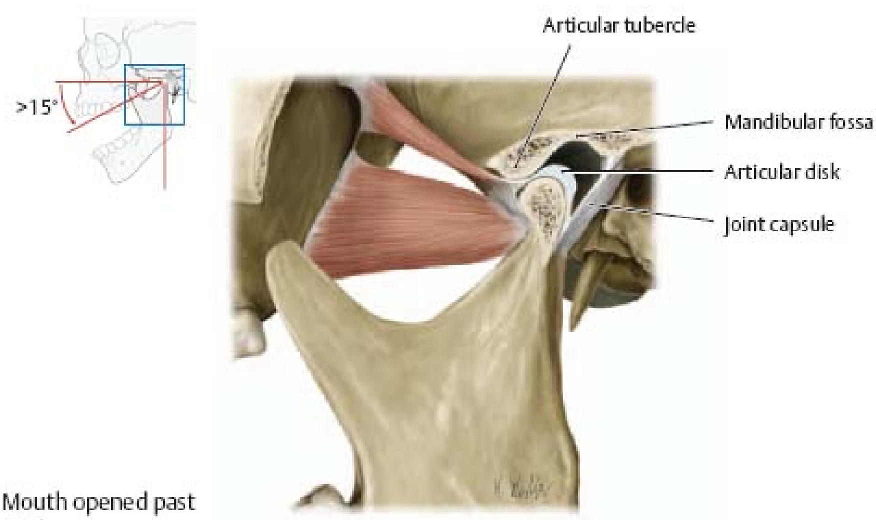
Left lateral view. Up to 15 degrees of abduction, the head of the mandible remains in the mandibular fossa. Past 15 degrees, the head of the mandible glides forward onto the articular tubercle.



A Mouth closed.



B Mouth opened to 15 degrees.



C Mouth opened past 15 degrees.

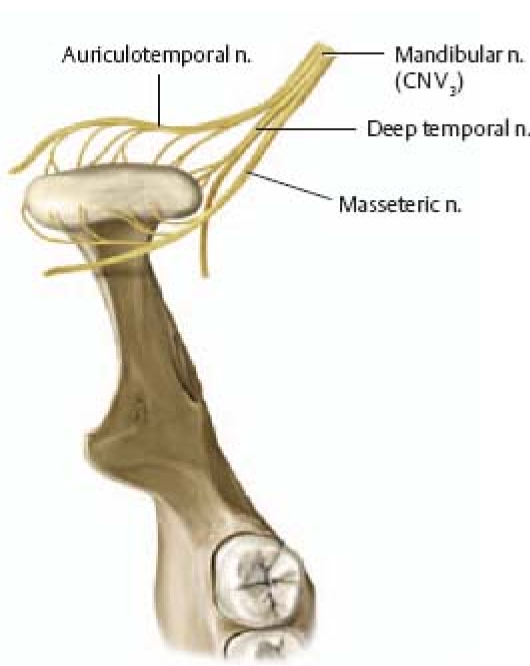
Clinical

Dislocation of the temporomandibular joint

Dislocation may occur if the head of the mandible slides past the articular tubercle. The mandible then becomes locked in a protruded position, a condition reduced by pressing on the mandibular row of teeth.

Fig. 36.9 **Innervation of the temporo mandibular joint capsule**

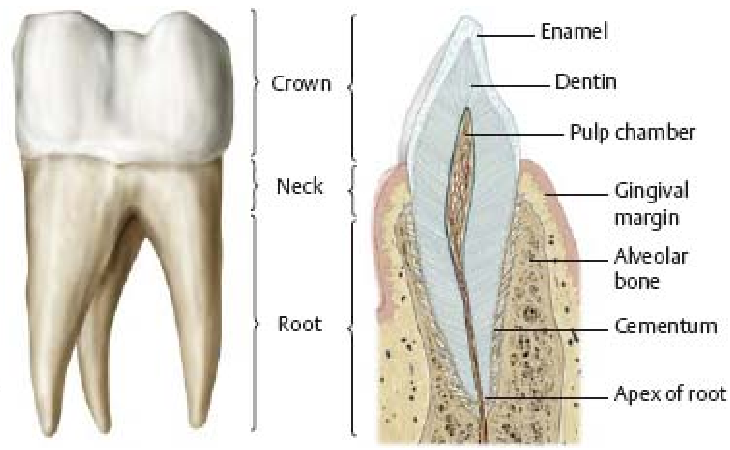
Superior view.



Teeth

Fig. 36.10 Structure of a tooth

Each tooth consists of hard tissue (enamel, dentin, cementum) and soft tissue (dental pulp) arranged into a crown, neck (cervix), and root.

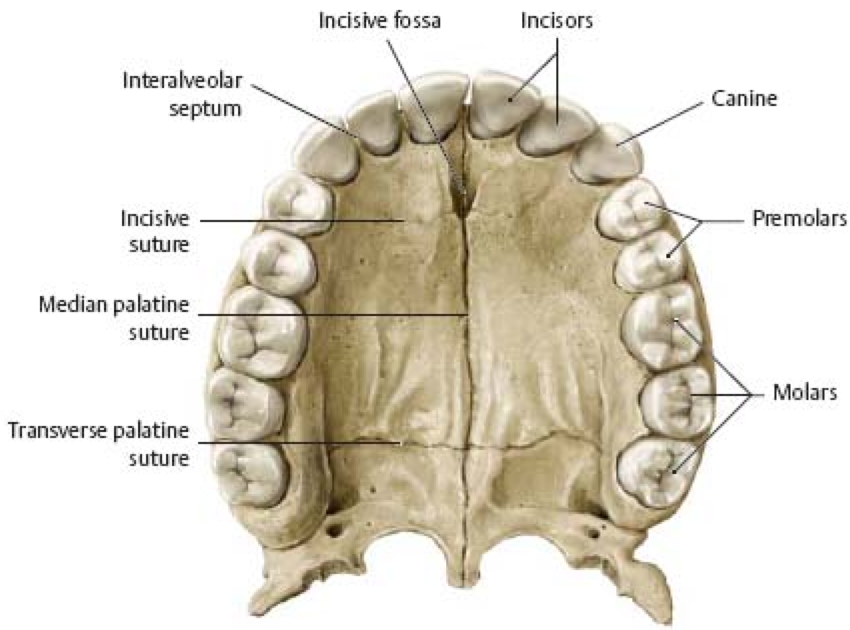


A Principal parts of a tooth (molar).

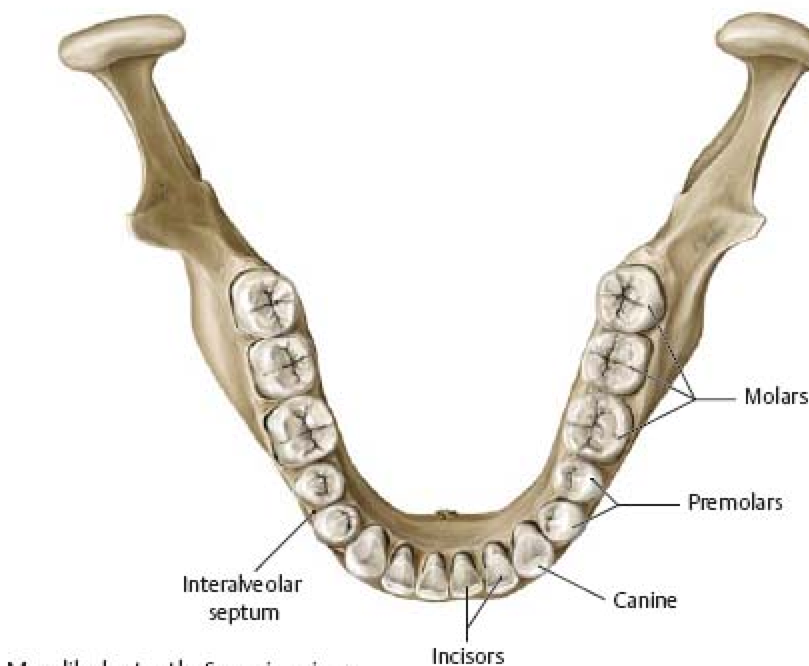
B Histology of a tooth (mandibular incisor).

Fig. 36.11 Permanent teeth

Each half of the maxilla and mandible contains a set of three anterior teeth (two incisors, one canine) and five posterior (postcanine) teeth (two premolars, three molars).



A Maxillary teeth. Inferior view of the maxilla.



B Mandibular teeth. Superior view of the mandible.

Fig. 36.12 Tooth surfaces

The top of the tooth is known as the occlusal surface.

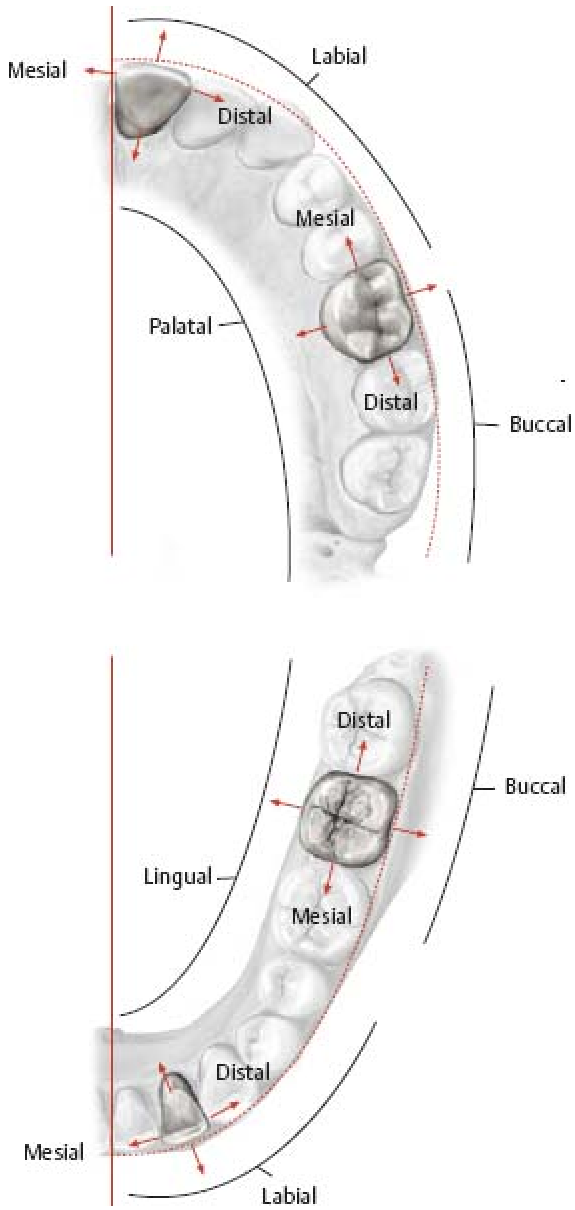


Fig. 36.13 Coding of the teeth

In the United States, the 32 permanent teeth are numbered sequentially (not assigned to quadrants). *Note:* The 20 deciduous (baby) teeth are coded A to J (upper arch), and K to T in a similar clockwise fashion. The third upper right molar is 1; the second upper right premolar is **A**.

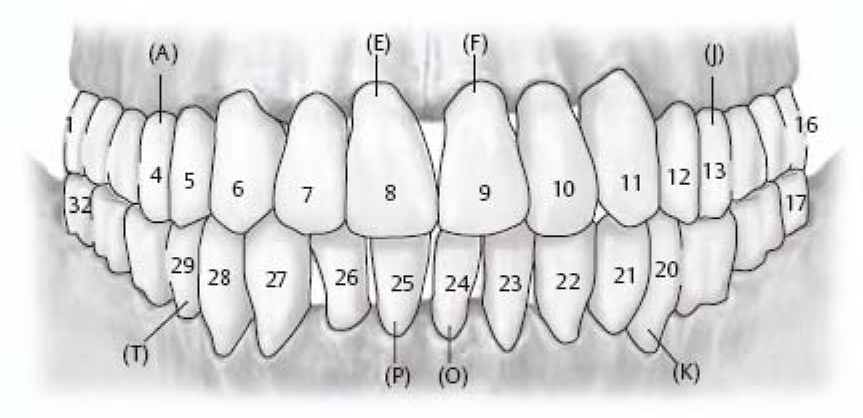
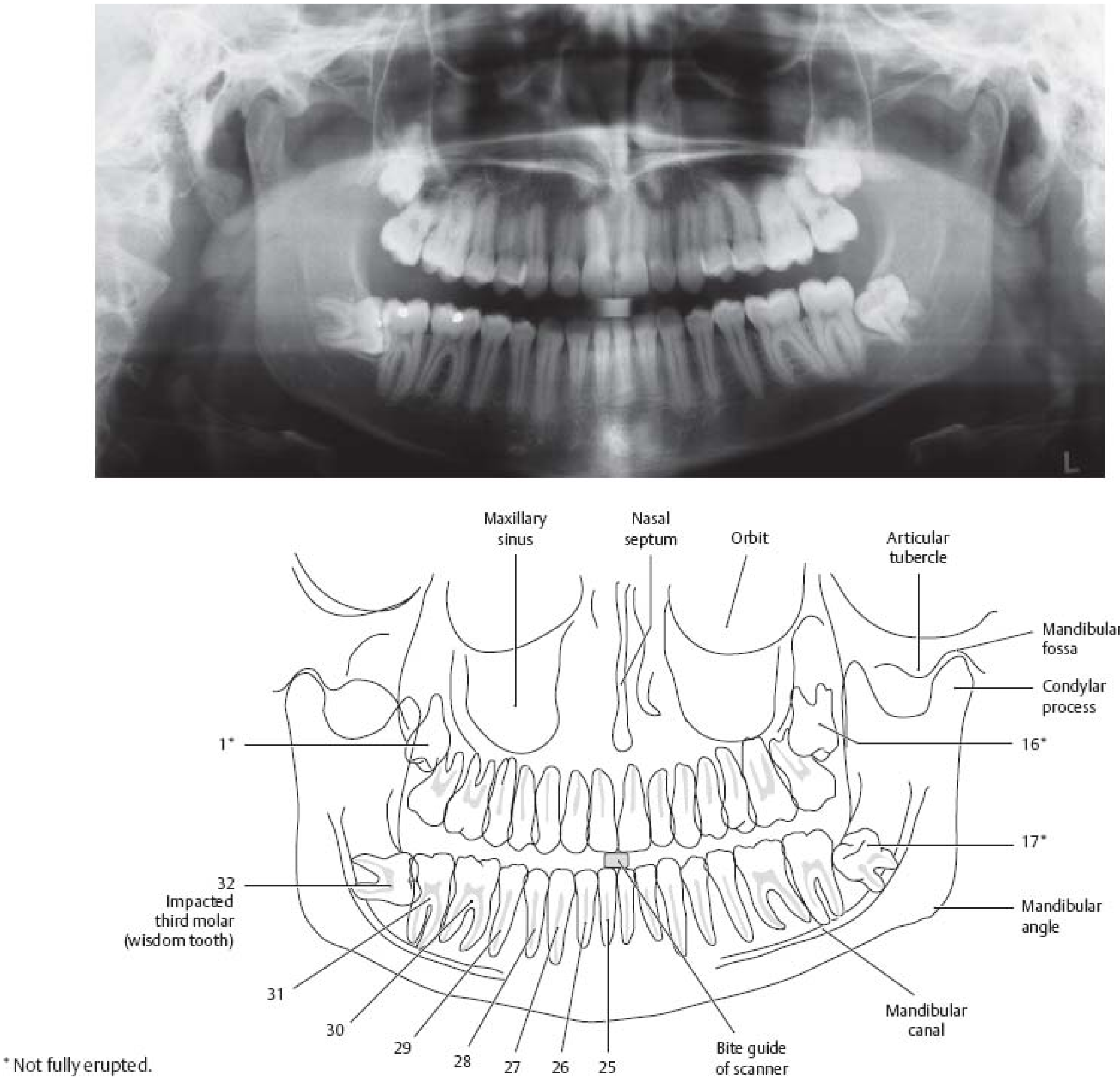


Fig. 36.14 **Dental panoramic tomogram**

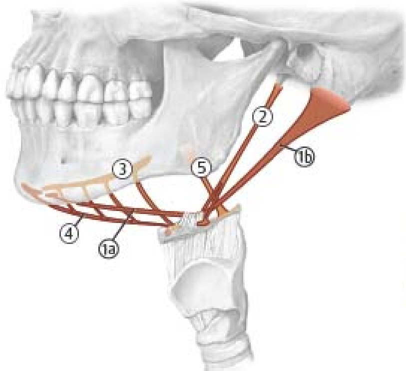
The dental panoramic tomogram (DPT) is a survey radiograph that allows preliminary assessment of the temporomandibular joints, maxillary sinuses, maxillomandibular bone, and dental status (carious lesions, location of wisdom teeth, etc.). *DPT courtesy of Dr. U. J. Rother, Director of the Department of Diagnostic Radiology, Center for Dentistry and Oromaxillofacial Surgery, Eppendorf University Medical Center, Hamburg, Germany.*



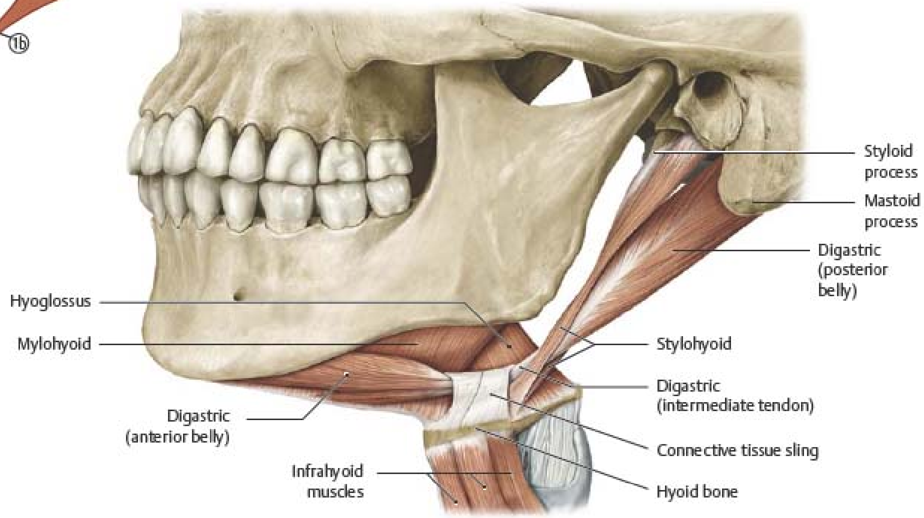
Oral Cavity Muscle Facts

Fig. 36.15 Muscles of the oral floor

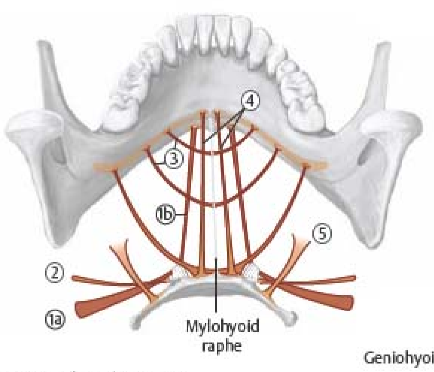
See pp. 562–563 for the infrahyoid muscles.



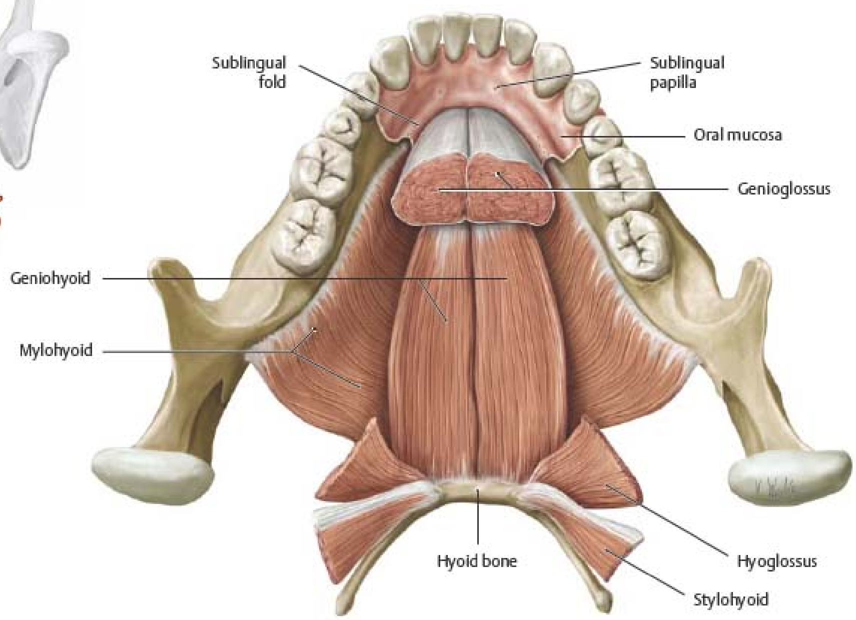
A Suprahyoid muscles, left lateral view.



B Left lateral view.



C Suprahyoid muscles, superior view.



D Superior view of the mandible and hyoid bone.

Table 36.1	Suprahyoid muscles					
Muscle		Origin	Insertion		Innervation	Action
① Digastric	ⓐ Anterior belly	Mandible (digastric fossa)	Hyoid bone (body)	Via an intermediate tendon with a fibrous loop	Mylohyoid n. (from CN V_3)	Elevates hyoid bone (during swallowing), assists in opening mandible
	ⓑ Posterior belly	Temporal bone (mastoid notch, medial to mastoid process)			Facial n. (CN VII)	
② Stylohyoid		Temporal bone (styloid process)		Via a split tendon		
③ Mylohyoid		Mandible (mylohyoid line)		Via median tendon of insertion (mylohyoid raphe)	Mylohyoid n. (from CN V_3)	Tightens and elevates oral floor, draws hyoid bone forward (during swallowing), assists in opening mandible and moving it side to side (mastication)
④ Geniohyoid		Mandible (inferior mental spine)		Body of hyoid bone	Ventral ramus of C1 via hypoglossal n. (CN XII)	Draws hyoid bone forward (during swallowing), assists in opening mandible
⑤ Hyoglossus		Hyoid bone (superior border of greater cornu)	Sides of tongue		Hypoglossal n. (CN XII)	Depresses the tongue

Fig. 36.16 Muscles of the soft palate

Inferior view. The soft palate forms the posterior boundary of the oral cavity, separating it from the oropharynx.

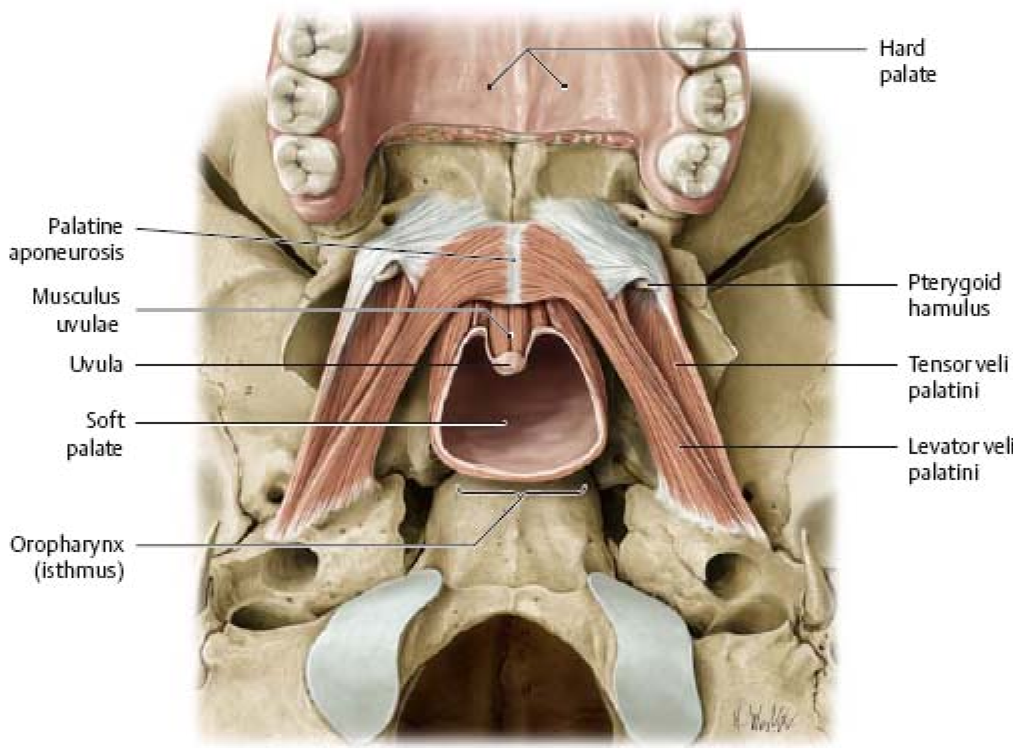


Table 36.2	Muscles of the soft palate			
Muscle	Origin	Insertion	Innervation	Action
Tensor veli palatini	Medial pterygoid plate (scaphoid fossa); sphenoid bone (spine); cartilage of pharyngotympanic tube	Palatine aponeurosis	Medial pterygoid n. (CN V_3 via otic ganglion)	Tightens soft palate; opens inlet to pharyngotympanic tube (during swallowing, yawning)
Levator veli palatini	Cartilage of pharyngotympanic tube; temporal bone (petrous part)	Palatine aponeurosis	Accessory n. (CN XI, cranial part) via pharyngeal plexus (vagus n., CN X)	Raises soft palate to horizontal position
Musculus uvulae	Uvula (mucosa)	Palatine aponeurosis; posterior nasal spine	Accessory n. (CN XI, cranial part) via pharyngeal plexus (vagus n., CN X)	Shortens and raises uvula
Palatoglossus*	Tongue (side)	Palatine aponeurosis	Accessory n. (CN XI, cranial part) via pharyngeal plexus (vagus n., CN X)	Elevates tongue (posterior portion); pulls soft palate onto tongue
Palatopharyngeus*	Tongue (side)	Palatine aponeurosis	Accessory n. (CN XI, cranial part) via pharyngeal plexus (vagus n., CN X)	Tightens soft palate; during swallowing pulls pharyngeal walls superiorly, anteriorly, and medially

*See pp. 548, 555.

Innervation of the Oral Cavity

Fig. 36.17 Trigeminal nerve in the oral cavity

Right lateral view.

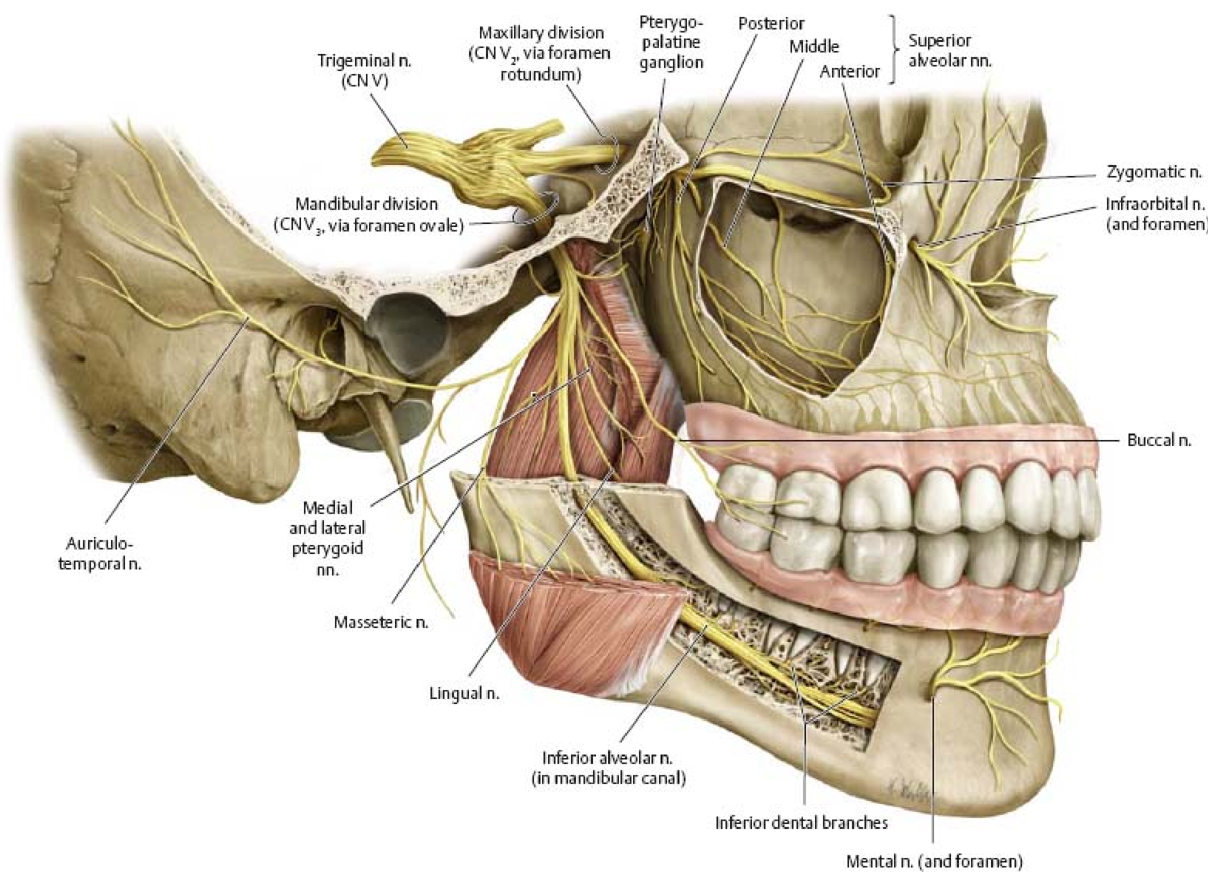
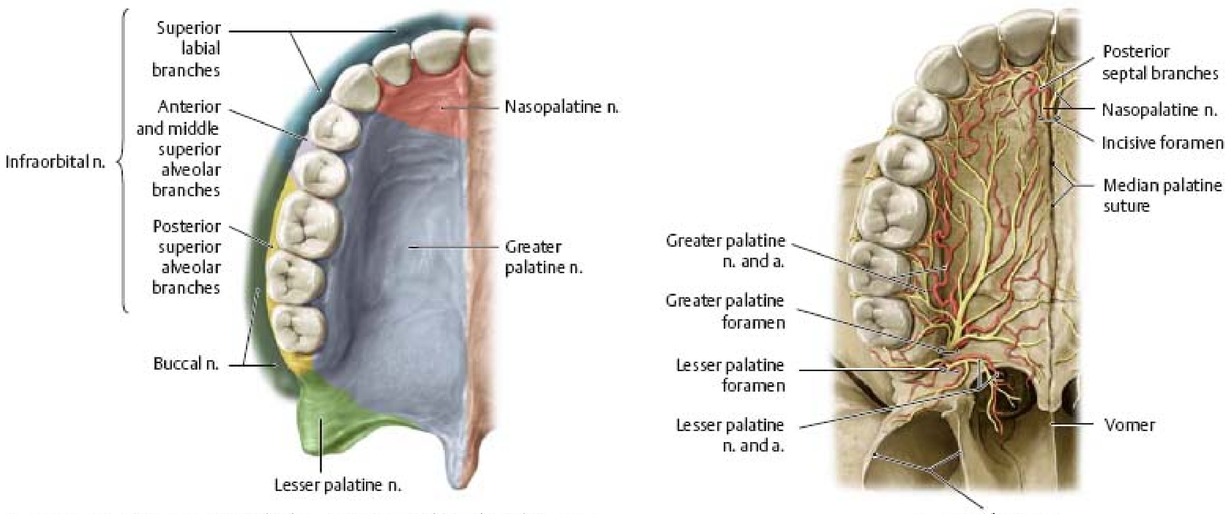


Fig. 36.18 Neurovasculature of the hard palate

Inferior view. The hard palate receives sensory innervation primarily from terminal branches of the maxillary division of the trigeminal nerve (CN V_2). The arteries of the hard palate arise from the maxillary artery.

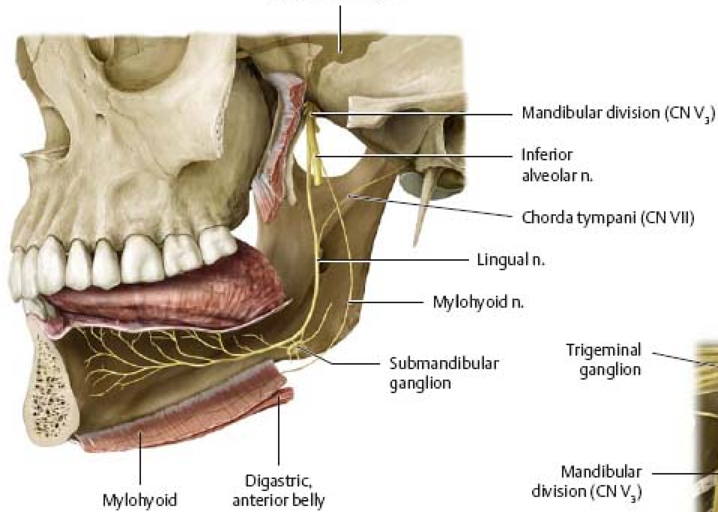


A Sensory innervation. *Note:* The buccal nerve is a branch of the mandibular division (CN V_3).

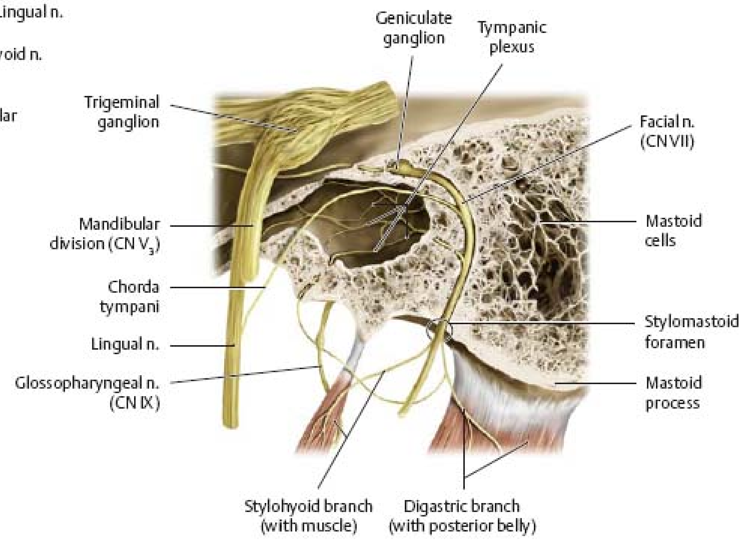
B Nerves and arteries.

The muscles of the oral floor have a complex nerve supply with contributions from the trigeminal nerve (CN V_3), facial nerve (CN VII), and C1 spinal nerve via the hypoglossal nerve (CN XII).

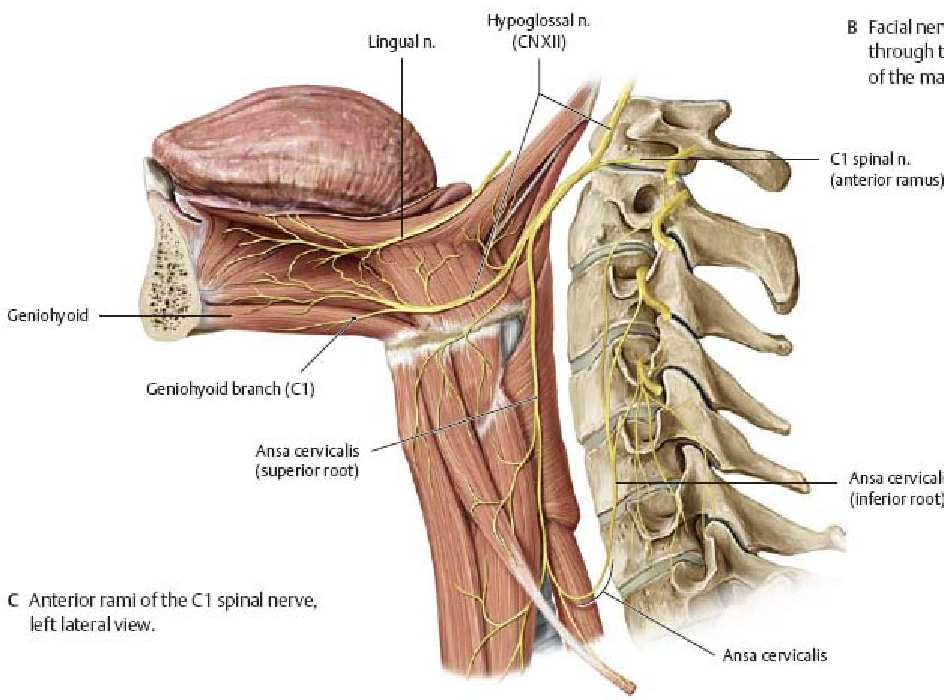
Fig. 36.19 Innervation of the oral floor muscles



A Mylohyoid nerve (CN V$_3$). Left lateral view with the left half of the mandible removed.



B Facial nerve (CN VII). Sagittal section through the right petrous bone at the level of the mastoid process, medial view.



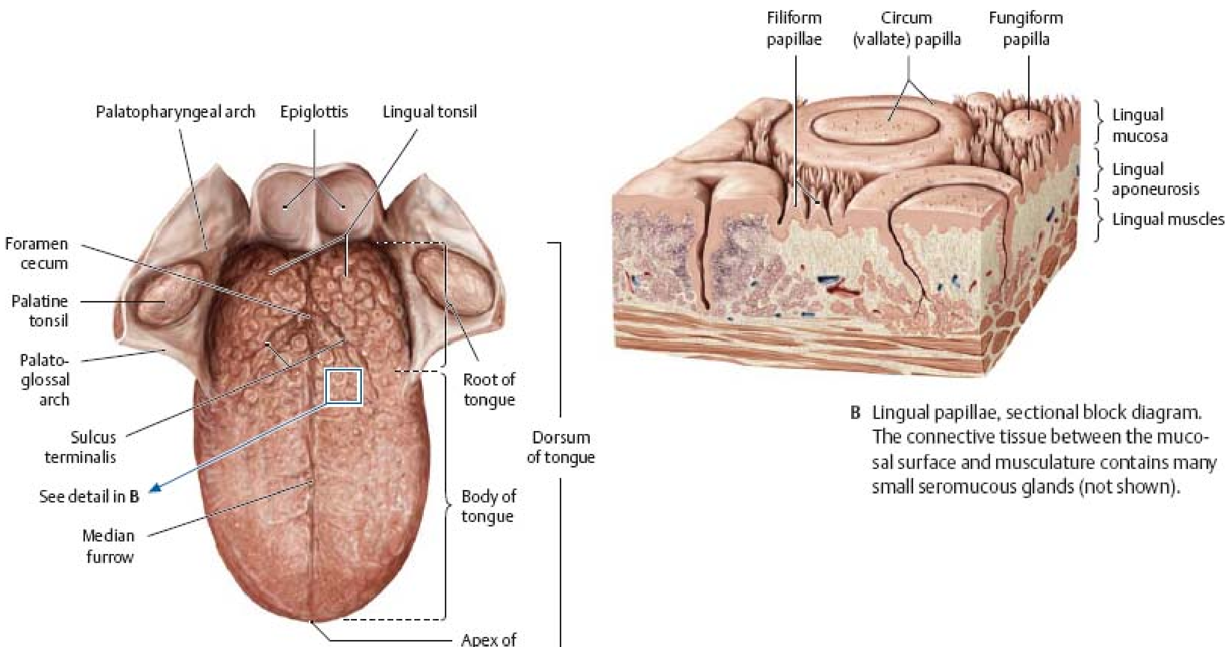
C Anterior rami of the C1 spinal nerve, left lateral view.

Tongue

The dorsum of the tongue is covered by a highly specialized mucosa that supports its sensory functions (taste and fine tactile discrimination; see p. 616). The tongue is endowed with a very powerful muscular body to support its motor properties during mastication, swallowing, and speaking.

Fig. 36.20 Structure of the tongue

The V-shaped sulcus terminalis divides the tongue into an anterior (oral, presulcal) and a posterior (pharyngeal, postsulcal) part.



A Superior view.

B Lingual papillae, sectional block diagram. The connective tissue between the mucosal surface and musculature contains many small seromucous glands (not shown).

Fig. 36.21 Muscles of the tongue

The extrinsic lingual muscles (genioglossus, hyoglossus, palatoglossus, and styloglossus) have bony attachments and move the tongue as a whole. The intrinsic lingual muscles (superior and inferior longitudinal muscles, transverse muscle, and vertical muscle) have no bony attachments and alter the shape of the tongue.

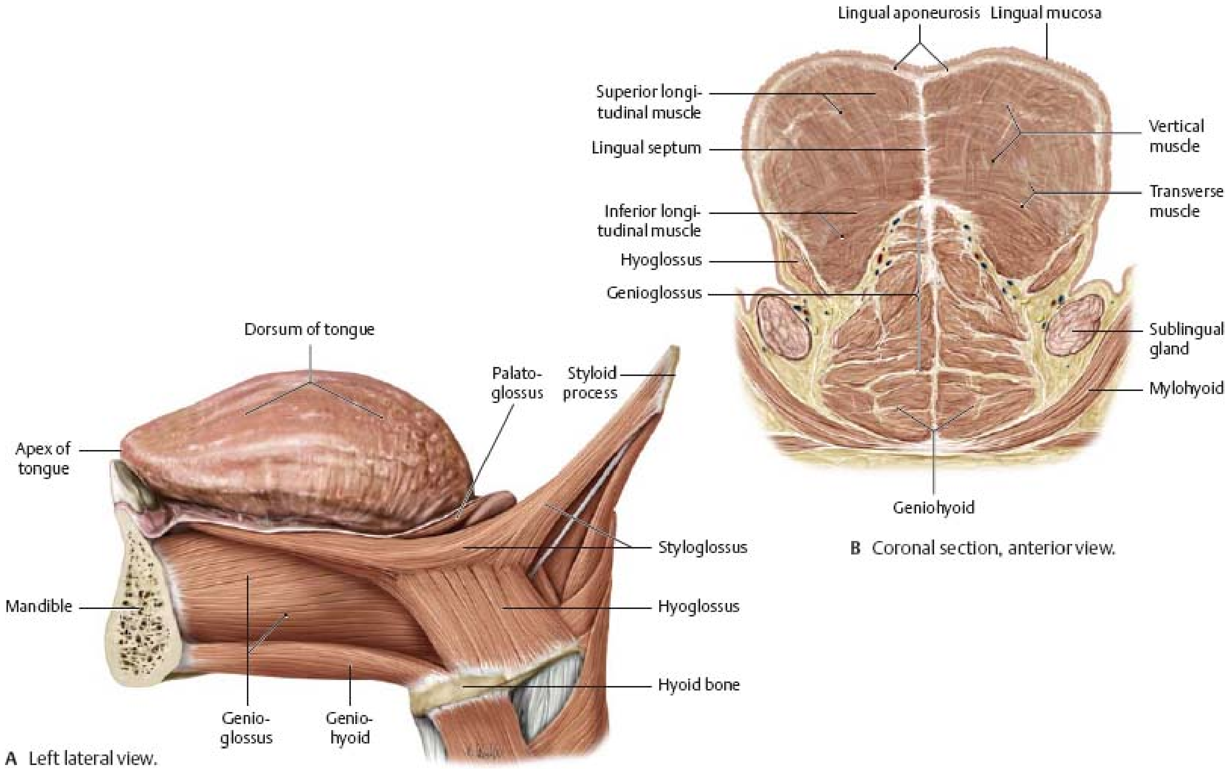


Fig. 36.22 **Somatosensory and taste innervation of the tongue**
Anterior view.

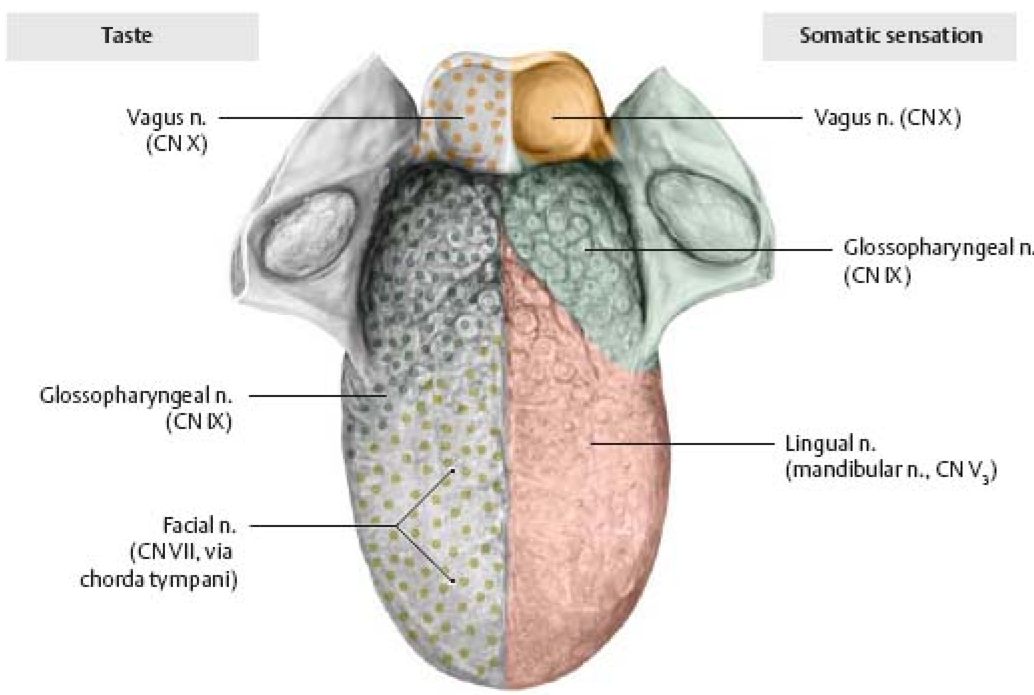
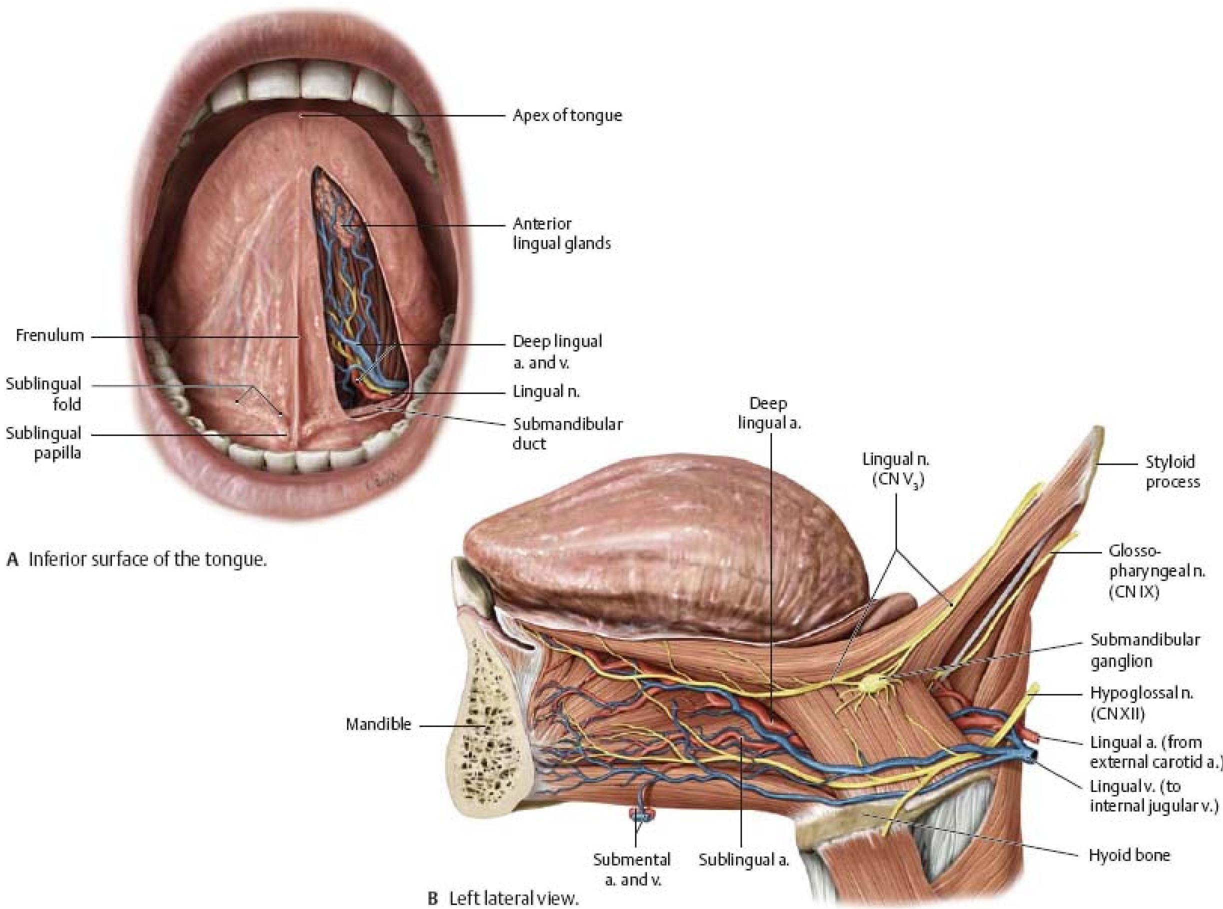


Fig. 36.23 Neurovasculature of the tongue

The lingual muscles receive somatomotor innervation from the hypoglossal nerve (CN XII), with the exception of the palatoglossus (supplied by the vagus nerve, CN X).



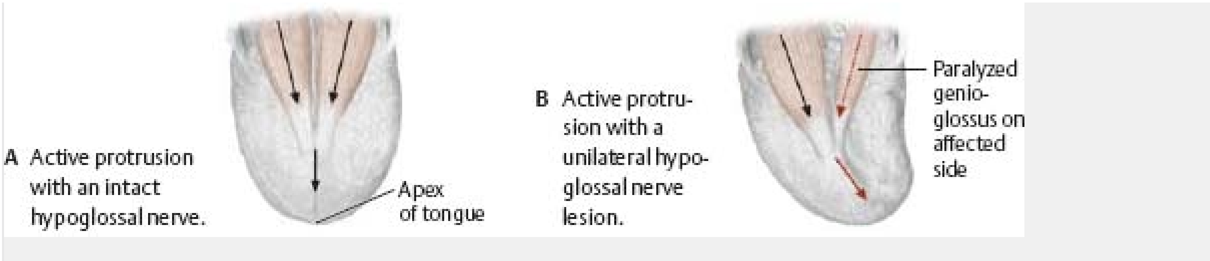
A Inferior surface of the tongue.

B Left lateral view.

Clinical

Unilateral hy pogiossal nerve palsy

Damage to the hypoglossal nerve causes paralysis of the genioglossus muscle on the affected side. The healthy (innervated) genioglossus on the unaffected side will therefore dominate. Upon protrusion, the tongue will deviate *toward* the paralyzed side.



Topography of the Oral Cavity & Salivary Glands

The oral cavity is located below the nasal cavity and anterior to the pharynx. It is bounded by the hard and soft palates, the tongue and muscles of the oral floor, and the uvula.

Fig. 36.24 Oral cavity

Midsagittal section, left lateral view.

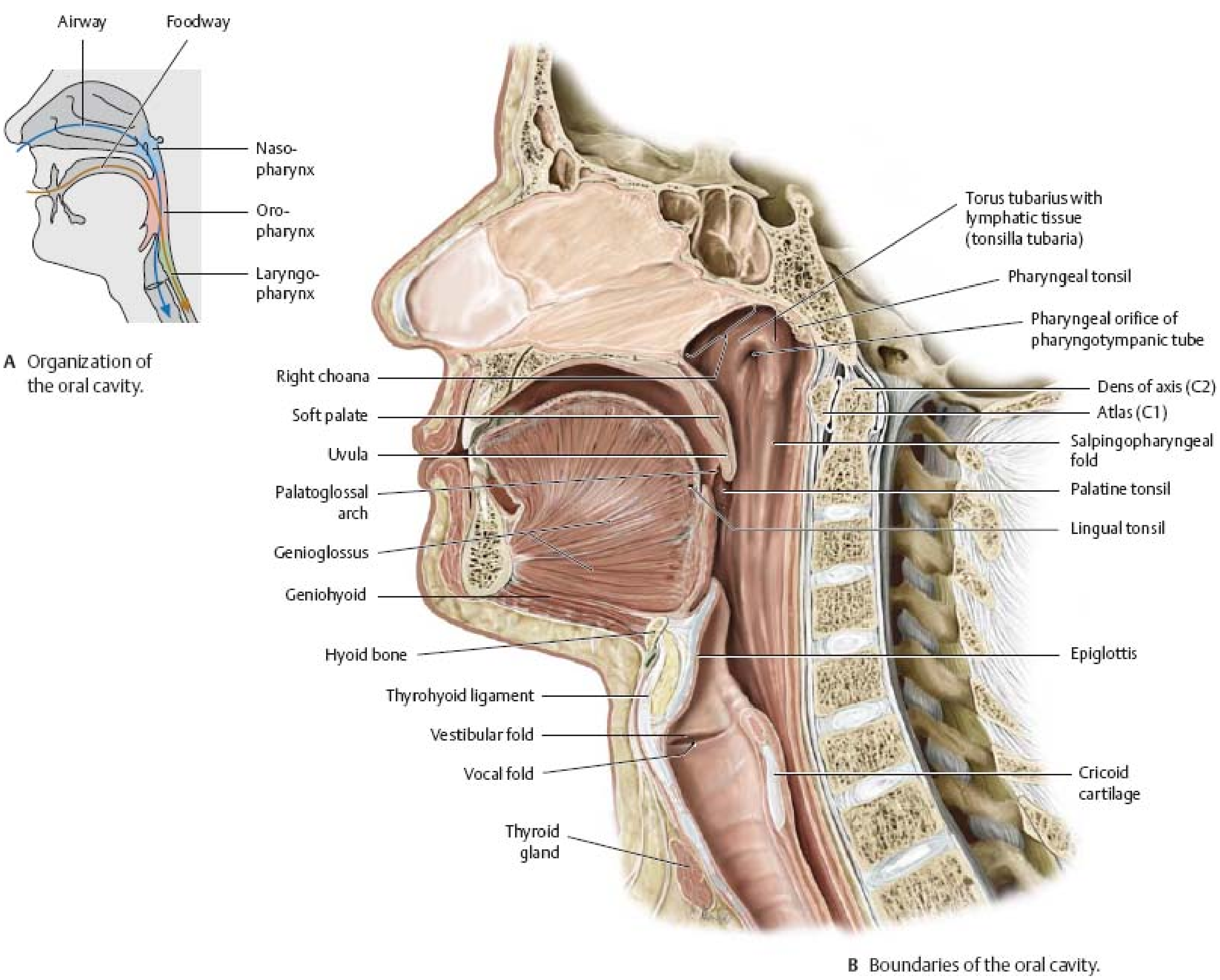


Fig. 36.25 Divisions of the oral cavity

Anterior view.

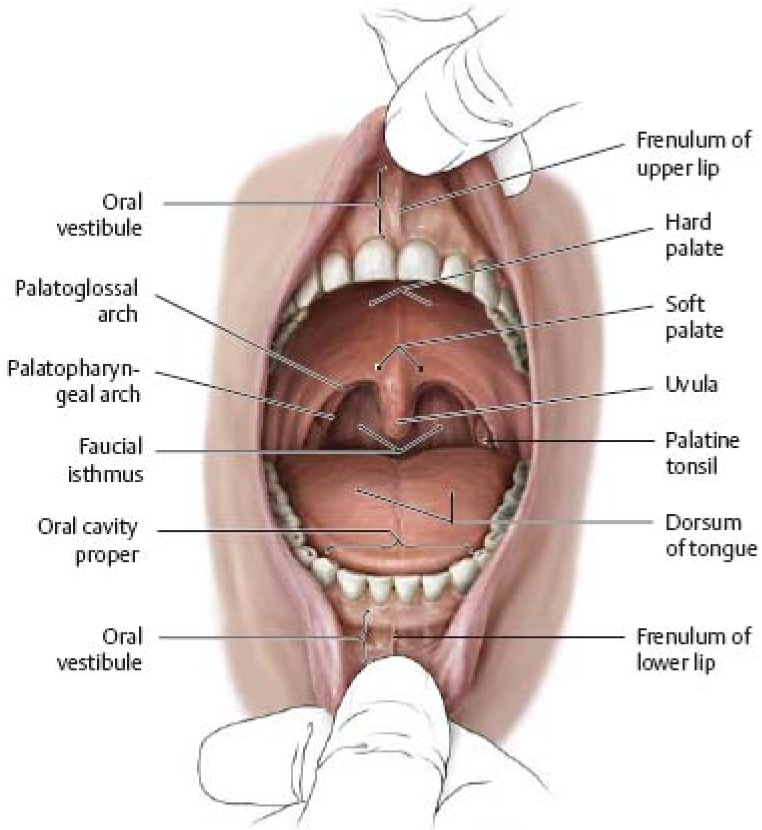
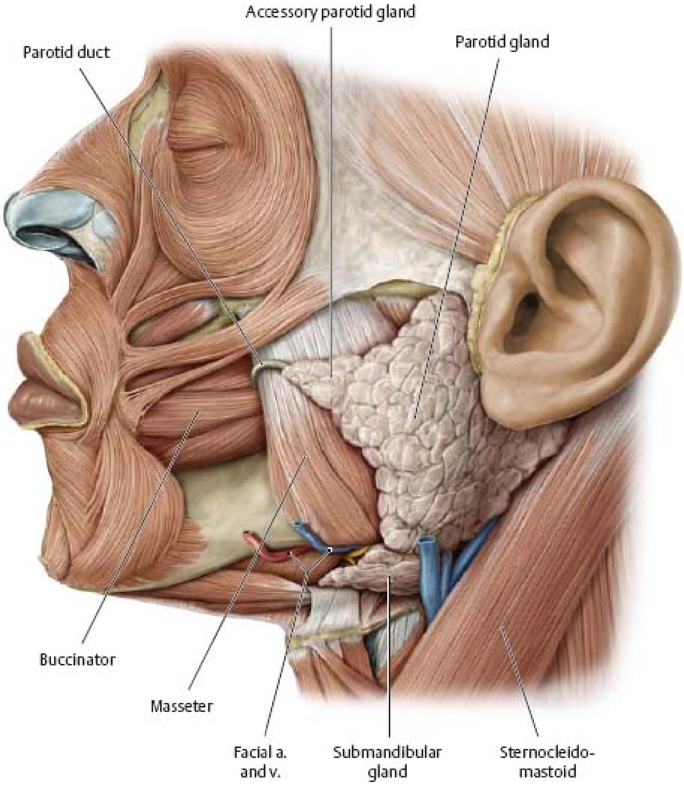


Table 36.3 **Divisions of the oral cavity**

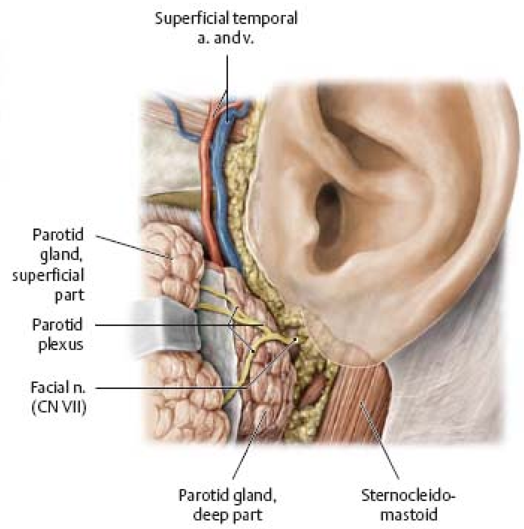
Part	**Anterior boundary**	**Posterior boundary**
Oral vestibule	Lips/cheek	Dental arches
Oral cavity proper	Dental arches	Palatoglossal arch
Fauces (throat)	Palatoglossal arch	Palatopharyngeal arch

The three large, paired salivary glands are the parotid, submandibular, and sublingual glands. The parotid gland is a purely serous (watery) salivary gland. The sublingual gland is predominantly mucous; the submandibular gland is a mixed seromucous gland.

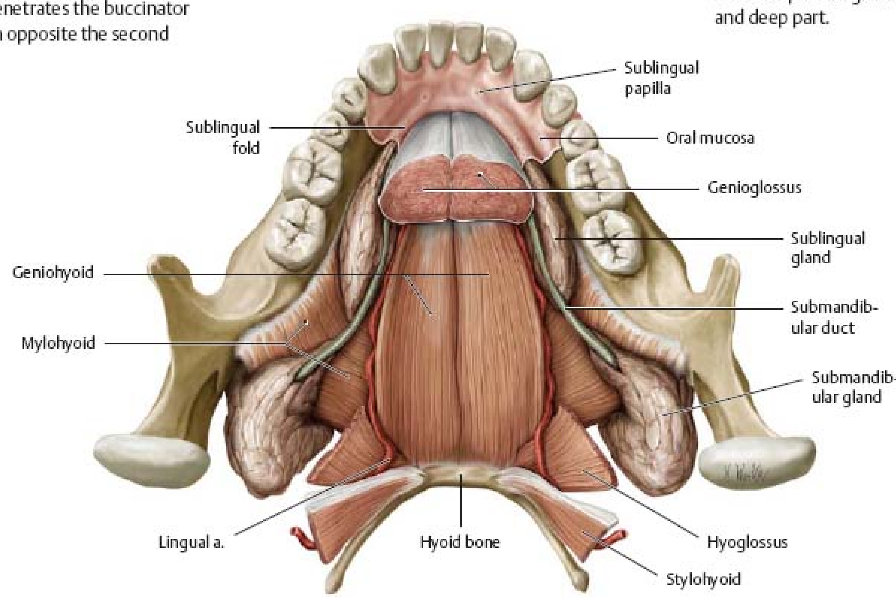
Fig. 36.26 Salivary glands



A Parotid gland, left lateral view. *Note*: The parotid duct penetrates the buccinator muscle to open opposite the second upper molar.



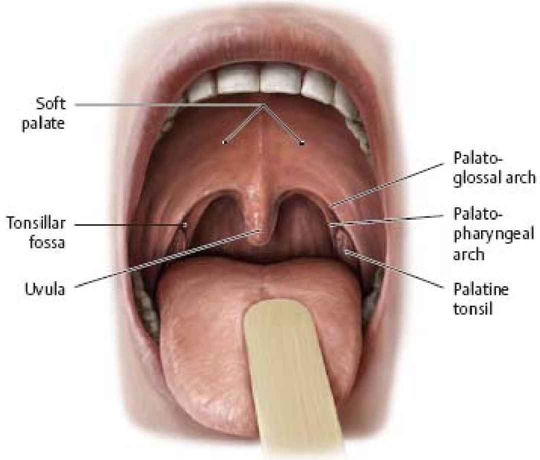
B Facial nerve in the parotid gland, left lateral view. The ramification of the facial nerve into the parotid plexus (see p. 478) separates the parotid gland into a superficial and deep part.



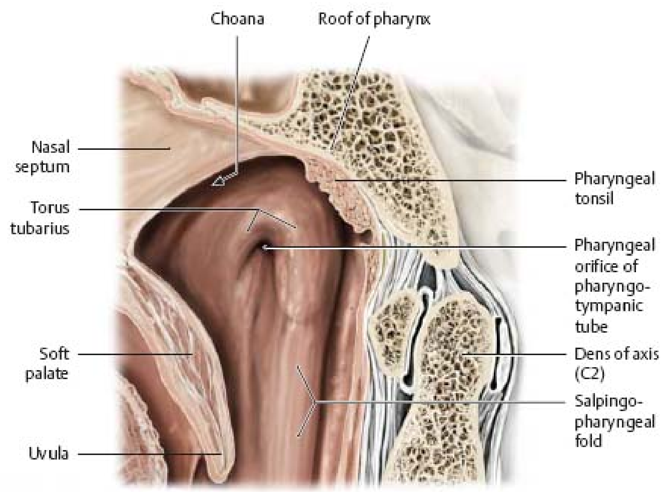
C Submandibular and sublingual glands, superior view with tongue removed.

Tonsils & Pharynx

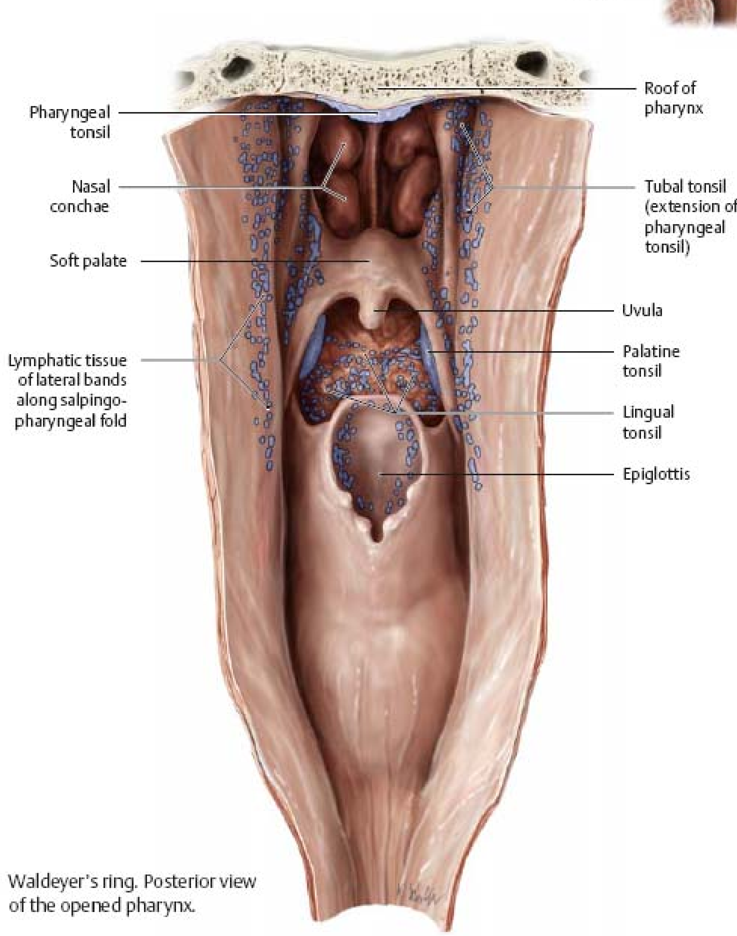
Fig. 36.27 Tonsils



A Palatine tonsils, anterior view.



B Pharyngeal tonsils. Sagittal section through the roof of the pharynx.



C Waldeyer's ring. Posterior view of the opened pharynx.

Table 36.4 **Structures in Waldeyer's ring**

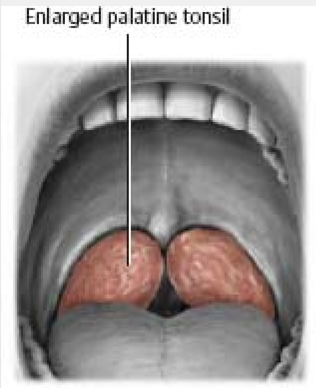
Tonsil	#

Tonsil	#
Pharyngeal tonsil	1
Tubal tonsils	2
Palatine tonsils	2
Lingual tonsil	1
Lateral bands	2

Clinical

Tonsil infections

Abnormal enlargement of the palatine tonsils due to severe viral or bacterial infection can result in obstruction of the oropharynx, causing difficulty swallowing.



Particularly well developed in young children, the pharyngeal tonsil begins to regress at 6 to 7 years of age. Abnormal enlargement is common, with the tonsil bulging into the nasopharynx and obstructing air passages, forcing the child to “mouth breathe.”

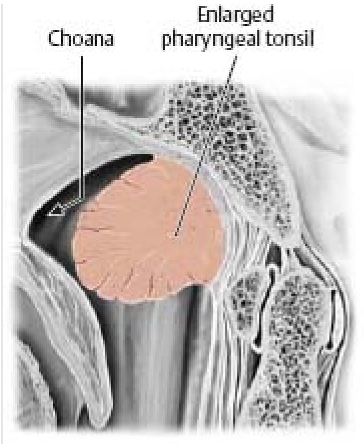
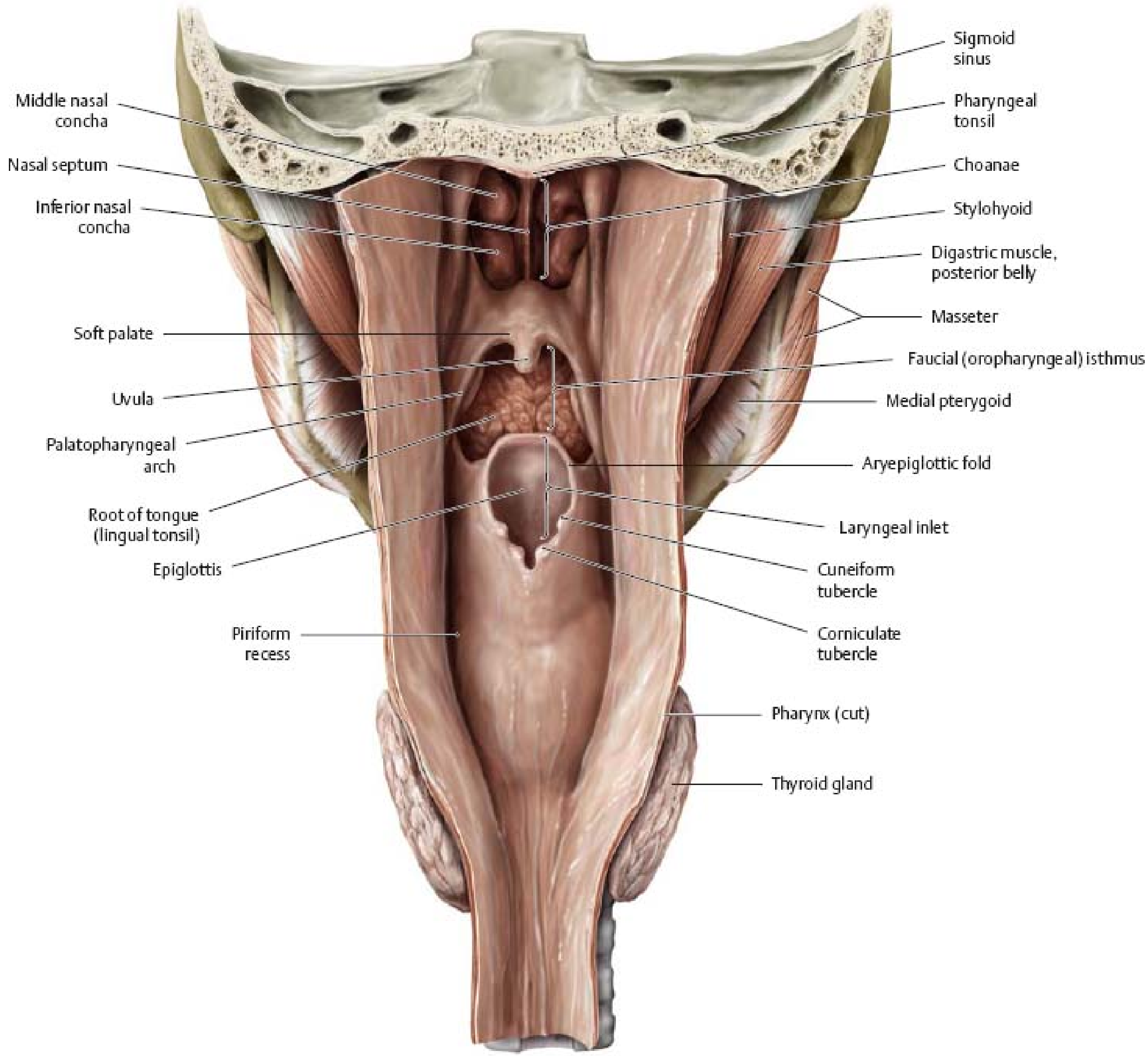


Fig. 36.28 Pharyngeal mucosa

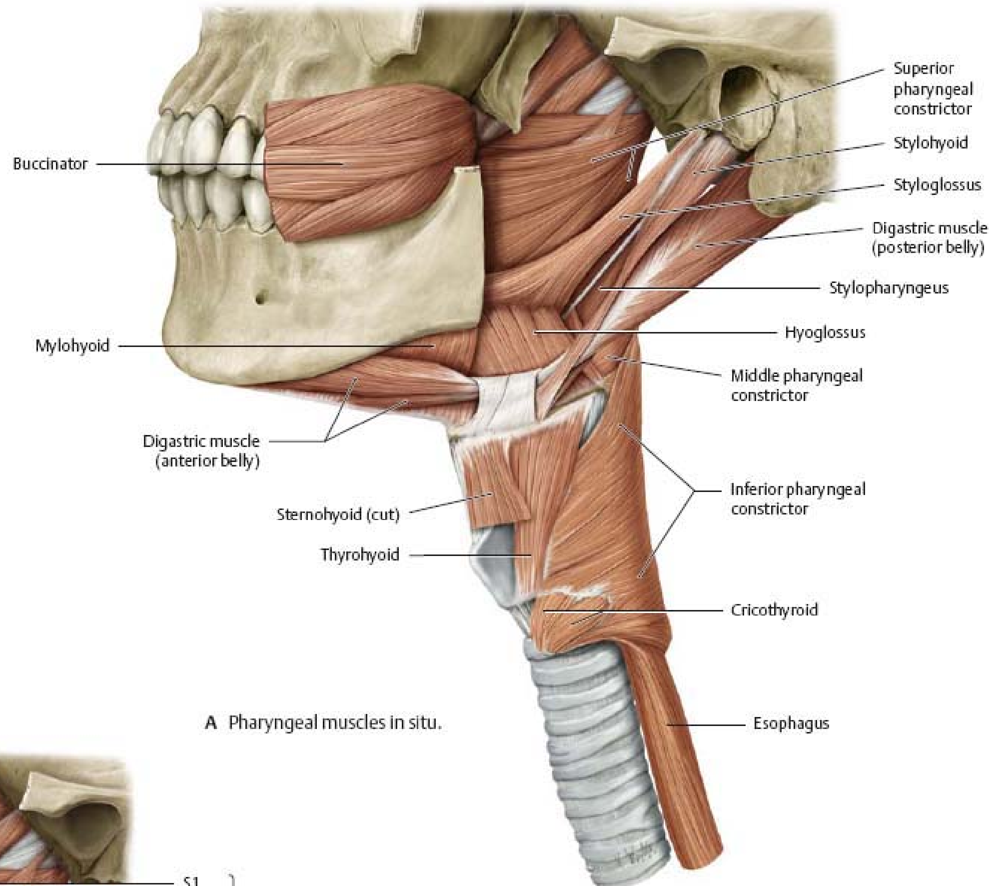
Posterior view of the opened pharynx. The anterior portion of the muscular tube contains three openings: choanae (to the nasal cavity), faucial isthmus (to the oral cavity), and aditus (to the laryngeal inlet).



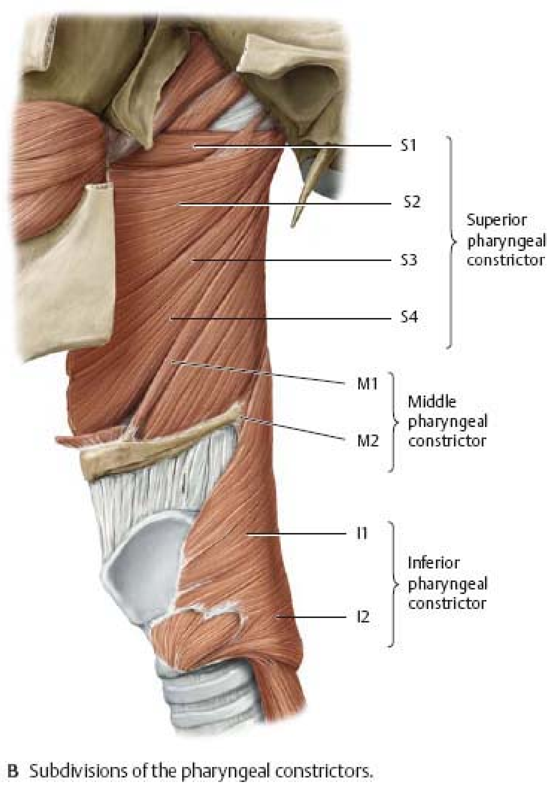
Pharyngeal Muscles

Fig. 36.29 Pharyngeal muscles: Left lateral view

The pharyngeal musculature consists of thepharyngeal constrictors and the relatively weak pharyngeal elevators.



A Pharyngeal muscles in situ.



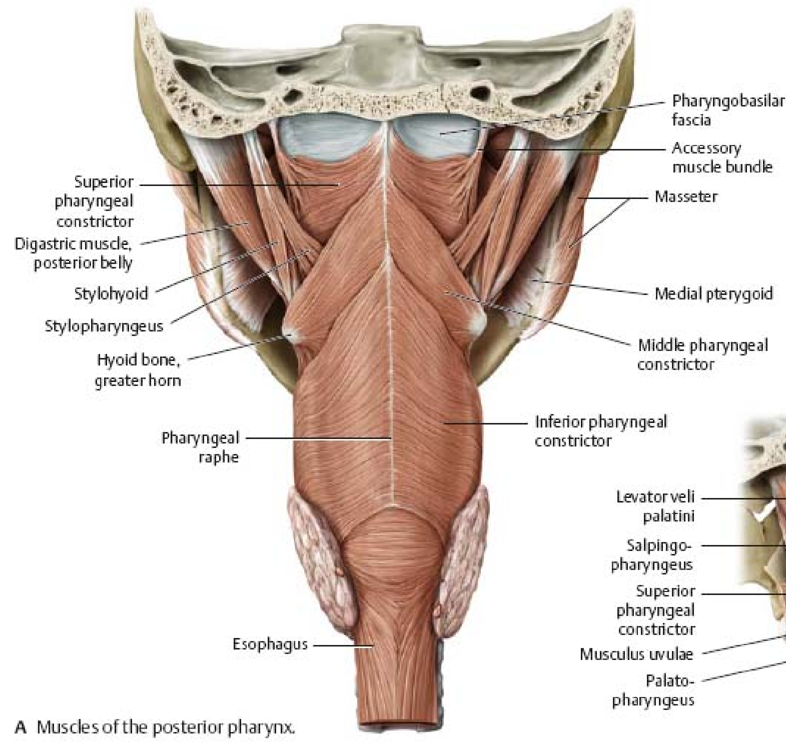
B Subdivisions of the pharyngeal constrictors.

Table 36.5 **Pharyngeal constrictors**

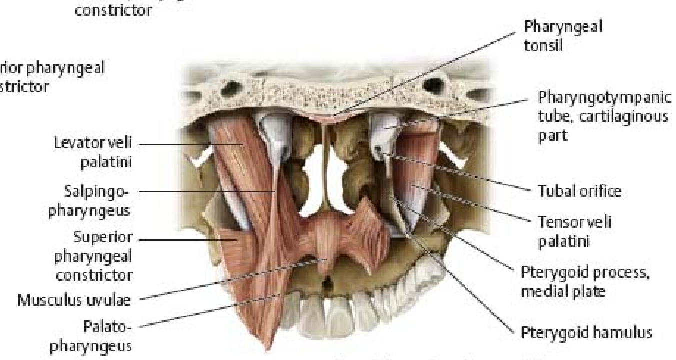
Superior pharyngeal constrictor	
S1	Pterygopharyngeal part

S2	Buccopharyngeal part
S3	Mylopharyngeal part
S4	Glossopharyngeal part
Middle pharyngeal constrictor	
M1	Chondropharyngeal part
M2	Ceratopharyngeal part
Inferior pharyngeal constrictor	
I1	Thyropharyngeal part
I2	Cricopharyngeal part

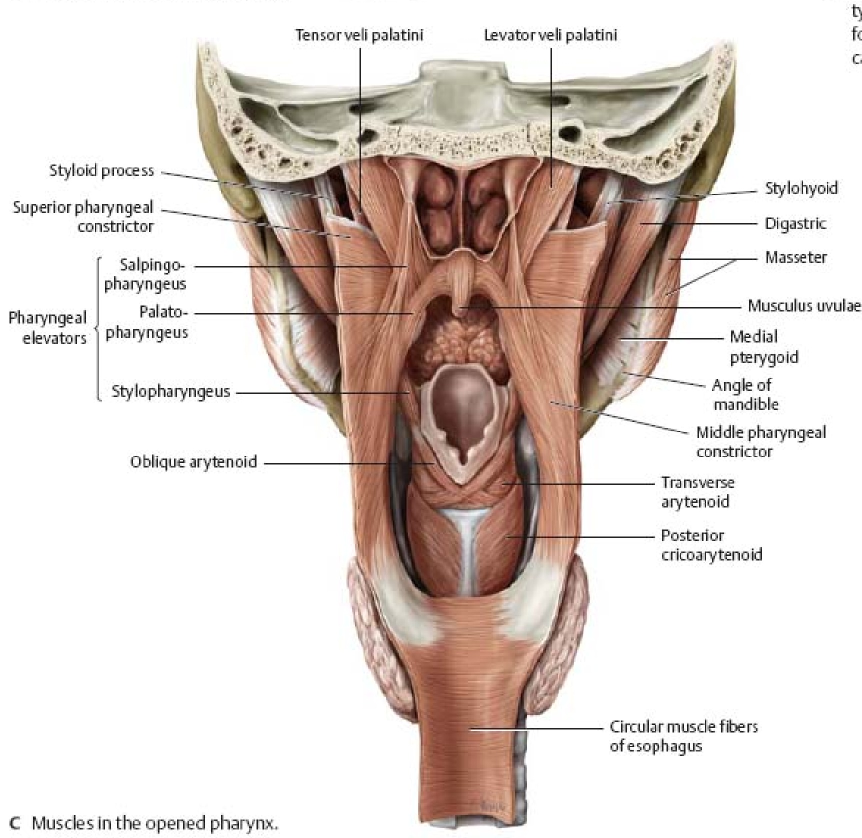
Fig. 36.30 **Pharyngeal muscles: Posterior view**



A Muscles of the posterior pharynx.



B Muscles of the soft palate and pharyngotympanic tube. The muscles of the fauces form the posterior boundary of the oral cavity.



C Muscles in the opened pharynx.

Neurovasculature of the Pharynx

Fig. 36.31 Neurovasculature in the parapharyngeal space

Posterior view. *Removed:* Vertebral column and posterior structures.

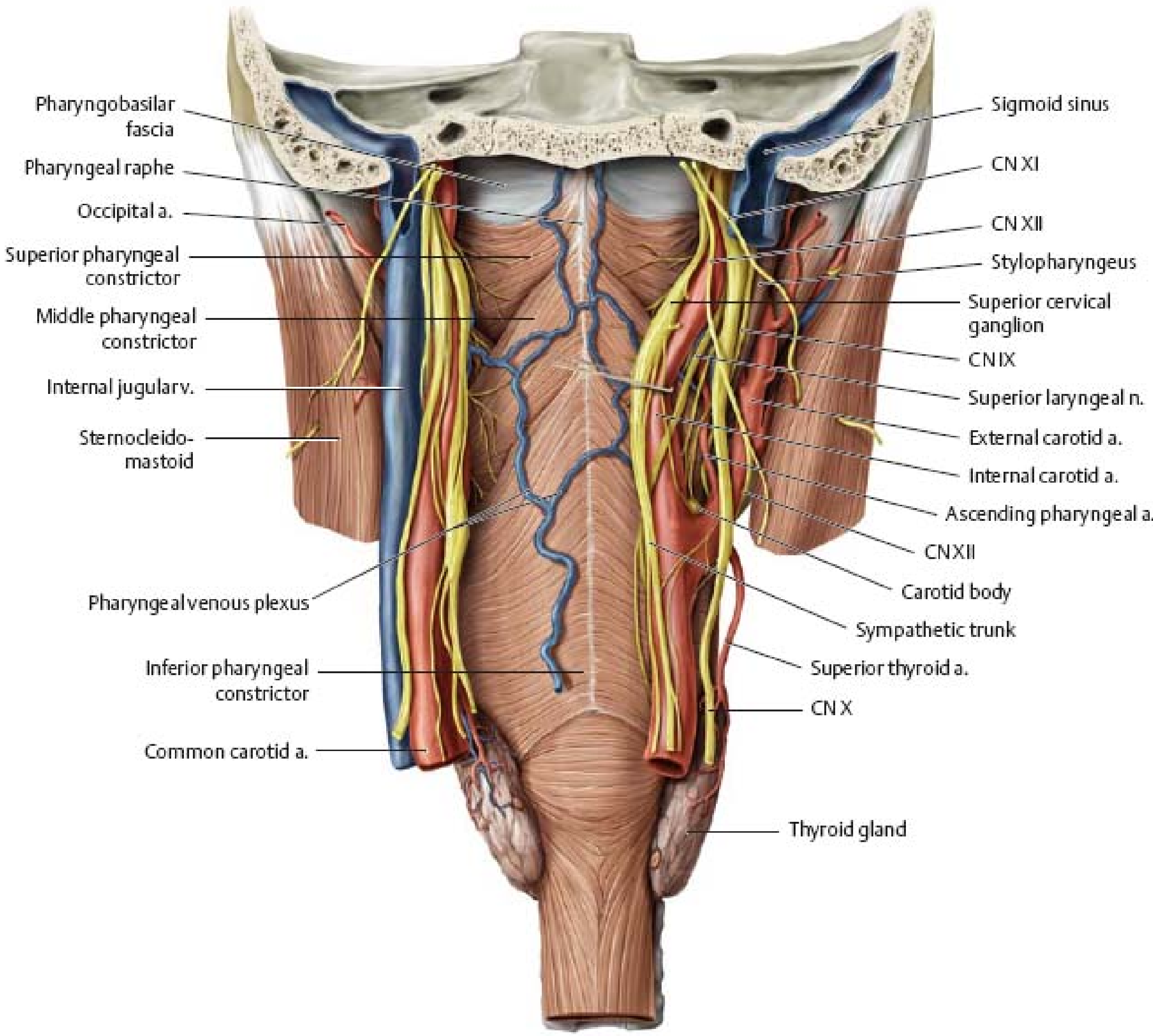
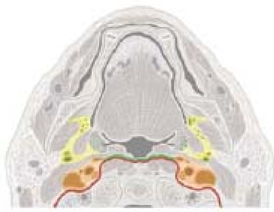
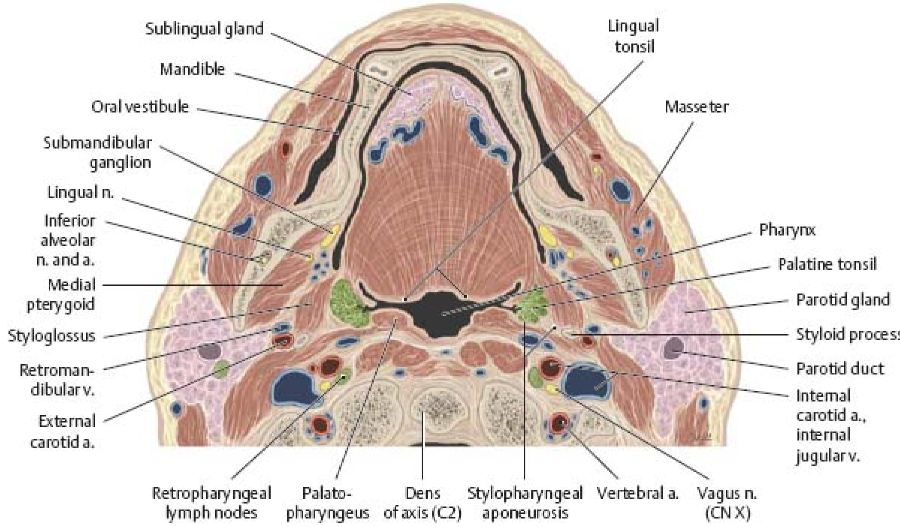


Fig. 36.32 Parapharyngeal space

Transverse section, superior view.



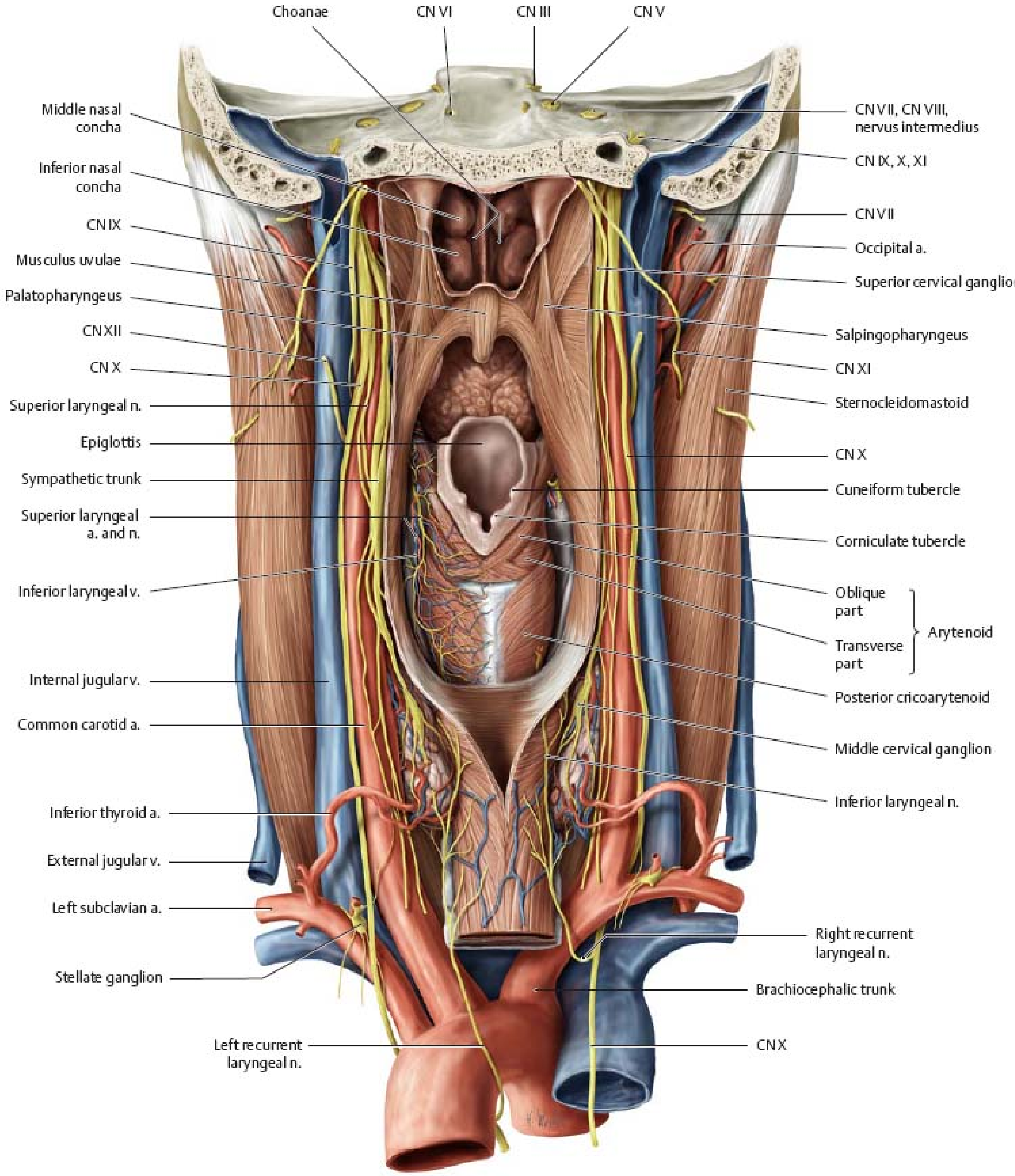
A Parapharyngeal space. The parapharyngeal space consists of a retropharyngeal (green) and a lateropharyngeal space. The lateropharyngeal space is further subdivided into an anterior (yellow) and a posterior (orange) part. Note the deep layer of cervical fascia (prevertebral lamina, red).



B Superior view of the transverse section at the level of the tonsillar fossa.

Fig. 36.33 **Neurovasculature of the opened pharynx**

Posterior view.



CN III = Oculomotor n., CN V = Trigeminal n., CN VI = Abducent n.,
CN VII = Facial n., CN VIII = Vestibulocochlear n., CN IX = Glossopharyngeal n.,
CN X = Vagus n., CN XI = Accessory n., CN XII = Hypoglossal n.
See Chapter 31 for the cranial nerves.

37 Neck

Bones & Ligaments of the Neck

Fig. 37.1 Boundaries of the neck

Left lateral view.

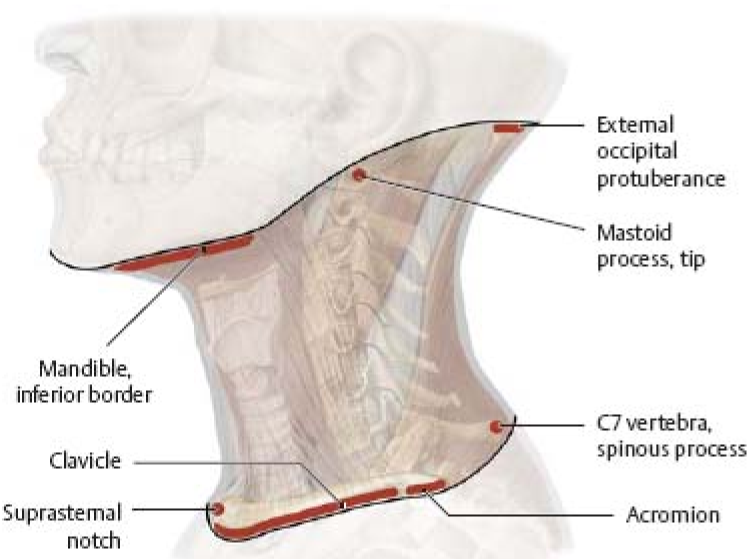
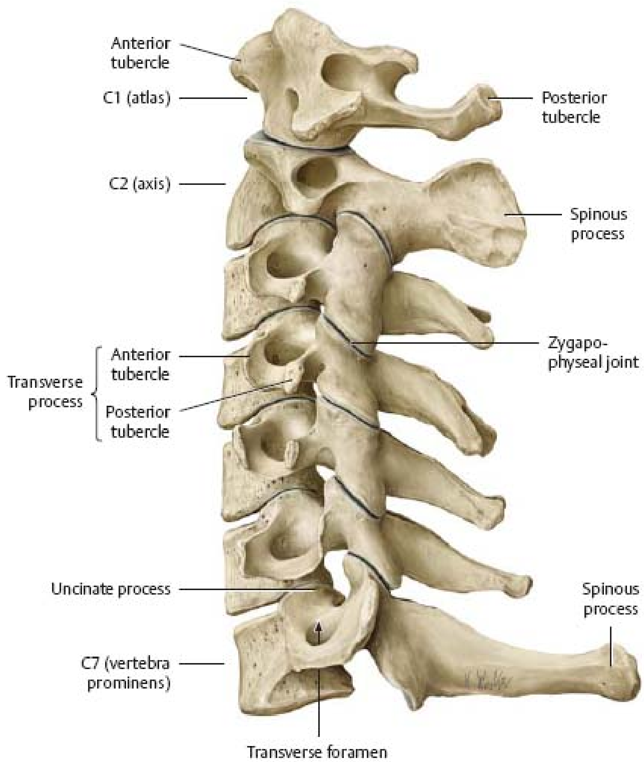


Table 37.1 **Bones and joints of the neck**

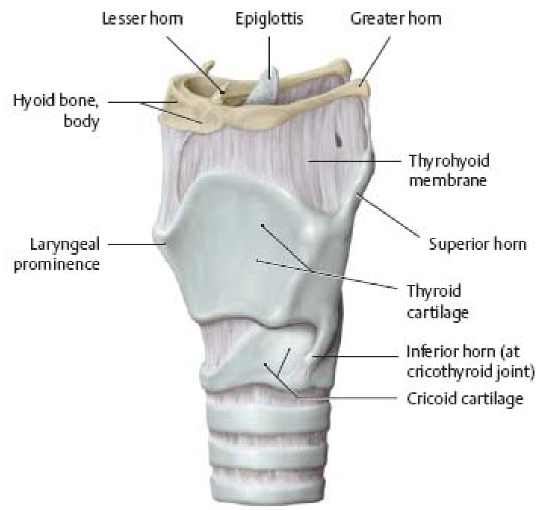
Cervical spinep.		p.6
Hyoid bone		p. 539
Craniovertebral joints	Atlanto-occipital jointsp.	p. 16
	Atlantoaxial joints	
Uncovertebral joints		p.15
Zygapophyseal (intervertebral facet) joints		p. 14
Larynxp.		p. 571

Fig. 37.2 Bony structures of the neck

Left lateral view.



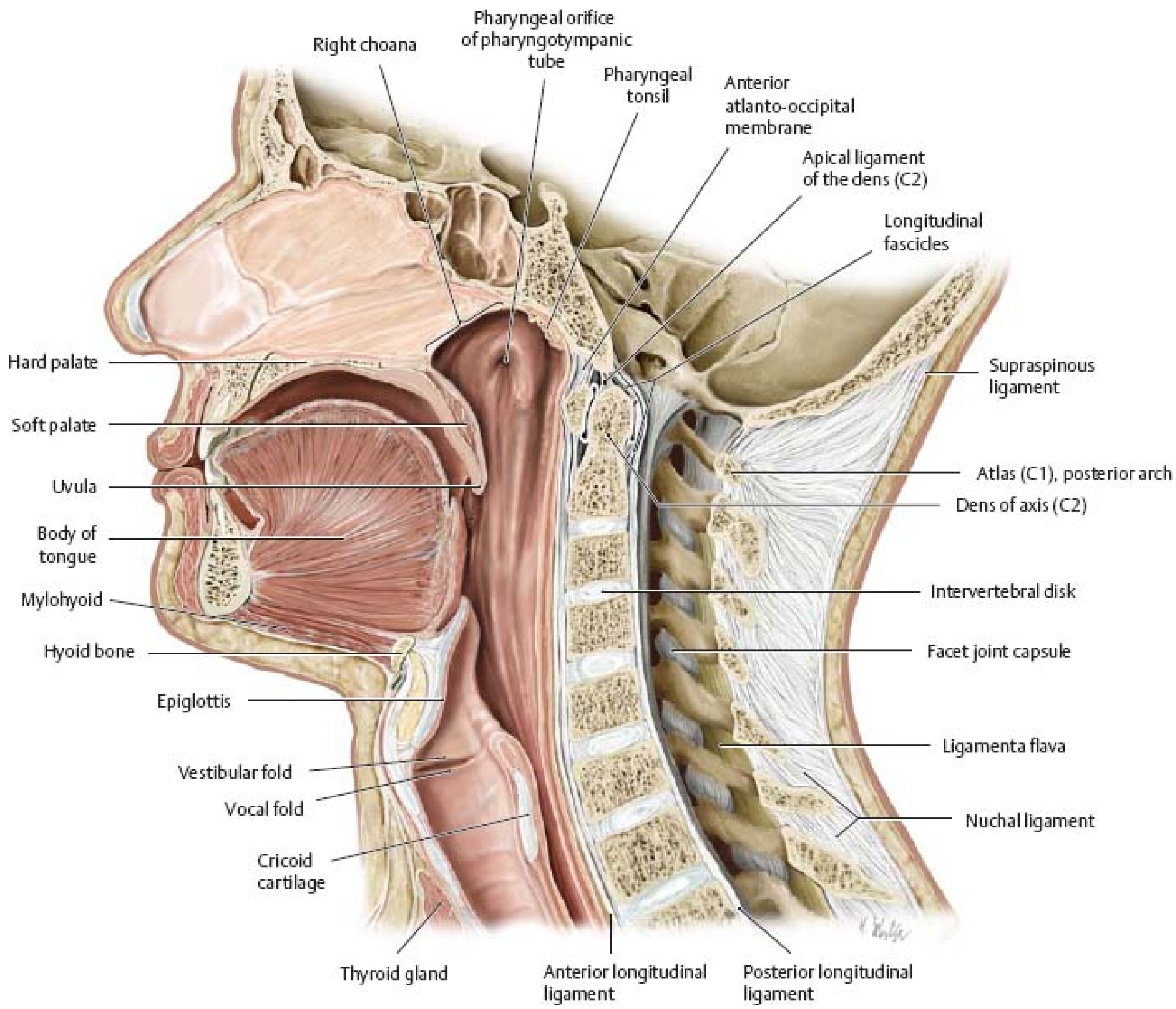
A Cervical spine. The seven vertebrae of the cervical spine are specialized for bearing the weight of the head.

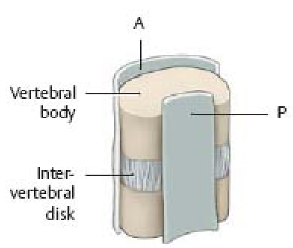


B Hyoid bone and larynx. The hyoid bone provides a site for bony attachment for the supra- and infrahyoid muscles. *Note:* The larynx is suspended from the hyoid bone, primarily by the thyrohyoid membrane.

Fig. 37.3 Ligaments of the cervical spine

Midsagittal section, viewed from the left side. For the ligaments of the craniovertebral joints, see p. 16.



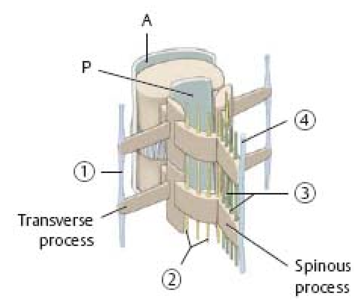


A Vertebral body ligaments.

Table 37.2 Ligaments of the vertebral column

Vertebral body ligaments	Vertebral arch ligaments
A Anterior longitudinal ligament	① Intertransverse ligament
P Posterior longitudinal ligament	② Ligamenta flava
	③ Interspinous ligament
	④ Supraspinous ligament*

* In the cervical spine, the supraspinous ligament broadens into the nuchal ligament.



B Vertebral arch ligaments.

Muscle Facts (I)

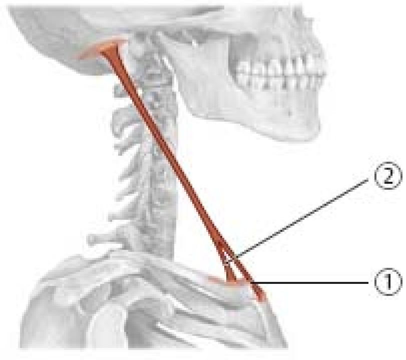
From a topographical standpoint, there are six major muscle groups in the neck. Functionally, however, the platysma belongs to the muscles of facial expression, the trapezius belongs to the muscles of the shoulder girdle, and the nuchal muscles belong to the intrinsic back muscles. The suboccipital muscles (short nuchal and craniovertebral joint muscles) are included in this chapter with the deep muscles of the neck.

Table 37.3 **Classification of neck muscles**

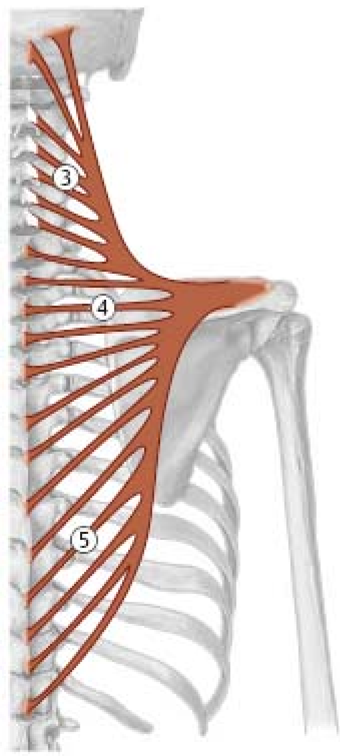
I	**Superficial neck muscles**			III	**Suprahyoid muscles**	
	Platysma, sternocleidomastoid, trapezius		Fig. 37.4		Digastric, geniohyoid, mylohyoid, stylohyoid	Fig. 37.7A
II	**Nuchal muscles (intrinsic back muscles)**			IV	**Infrahyoid muscles**	
	⑥ Semispinalis capitis	⑦ Semispinalis cervicis	See p. 32		Sternohyoid, sternothyroid, thyrohyoid, omohyoid	Fig. 37.7B
	⑧ Splenius capitis	⑨ Splenius cervicis		V	**Prevertebral muscles**	
	⑩ Longissimus capitis	⑪ Longissimus cervicis	See p. 30		Longus capitis, longus coli, rectus capitis anterior and lateralis	Fig. 37.9A
	⑫ Iliocostalis cervicis			VI	**Lateral (deep) neck muscles**	
	Suboccipital muscles (short nuchal and craniovertebral joint muscles)		Fig. 37.9C		Anterior, middle, and posterior scalenes	Fig. 37.9B

Fig. 37.4 Superficial neck muscles

See Table 37.4 for details.



A Sternocleidomastoid.



B Trapezius.

Fig. 37.5 **Nuchal muscles**

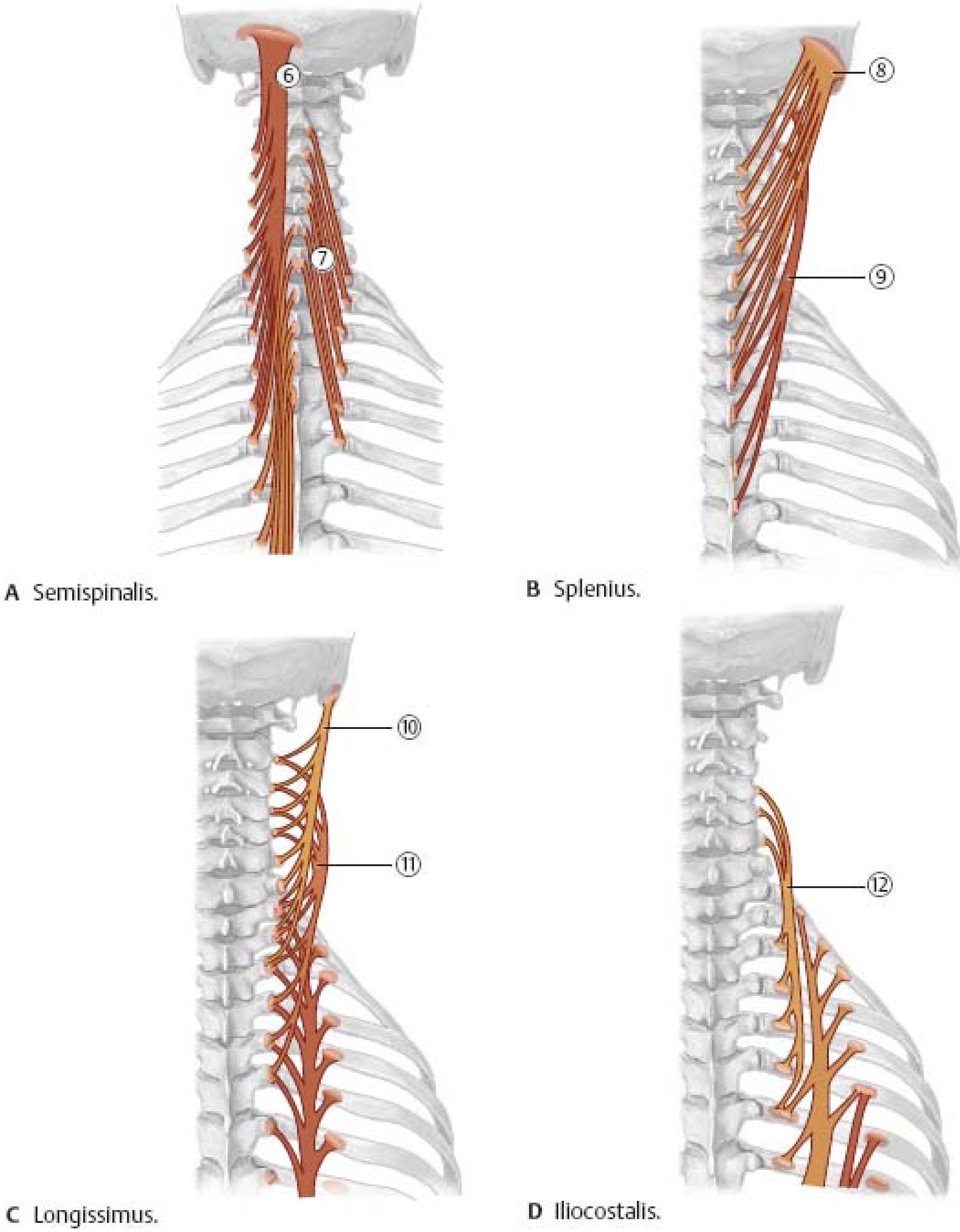
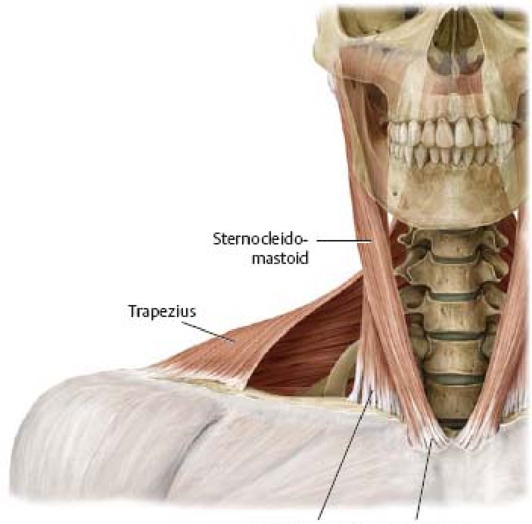
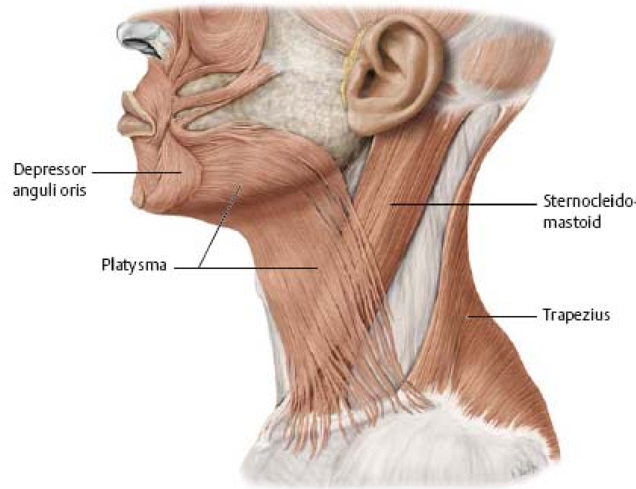


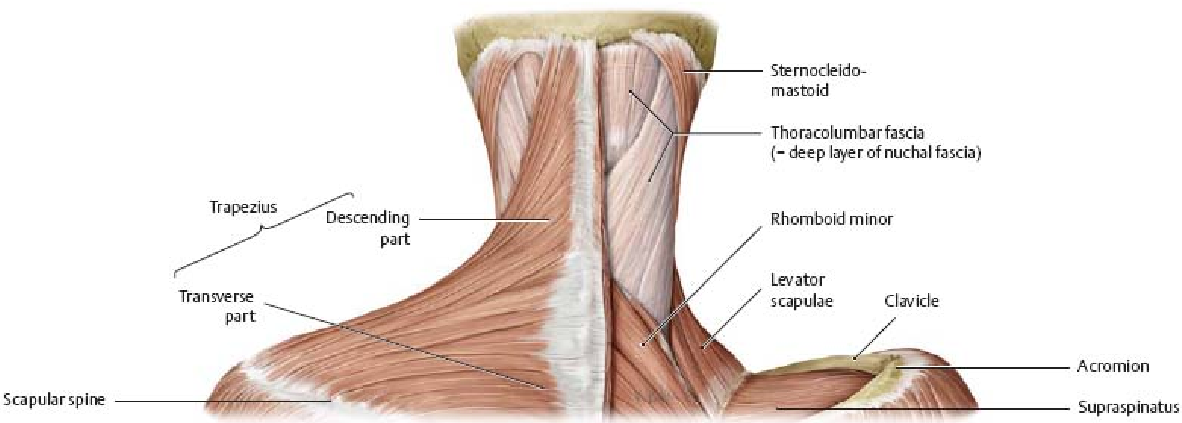
Fig. 37.6 **Superficial musculature of the neck**



A Anterior view.



B Left lateral view.



C Posterior view. *Removed:* Trapezius (right side).

Table 37.4 Superficial neck muscles

Muscle		Origin	Insertion	Innervation	Action
Platysma		Skin over lower neck and upper lateral thorax	Mandible (inferior border), skin over lower face and angle of mouth	Cervical branch of facial n. (CN VII)	Depresses and wrinkles skin of lower face and mouth, tenses skin of neck, aids forced depression of mandible
Sternocleido-mastoid	① Sternal head	Sternum (manubrium)	Temporal bone (mastoid process), occipital bone (superior nuchal line)	*Motor:* Accessory n. (CN XI) *Pain and proprioception:* Cervical plexus (C2, C3)	*Unilateral:* Tilts head to same side, rotates head to opposite side *Bilateral:* Extends head, aids in respiration when head is fixed
	② Clavicular head	Clavicle (medial one third)			
Trapezius	③ Descending part*	Occipital bone, spinous processes of C1–C7	Clavicle (lateral one third)		Draws scapula obliquely upward, rotates glenoid cavity superiorly

* The transverse ④ and ascending ⑤ parts are described on p. 276.

Muscle Facts (II)

Table 37.5	Suprahyoid muscles					
The suprahyoid muscles are also considered accessory muscles of mastication.						
Muscle		**Origin**	**Insertion**		**Innervation**	**Action**
Digastric	(1a) Anterior belly	Mandible (digastric fossa)	Hyoid bone (body)	Via an intermediate tendon with a fibrous loop	Mylohyoid n. (from CN V_3)	Elevates hyoid bone (during swallowing), assists in opening mandible
	(1b) Posterior belly	Temporal bone (mastoid notch, medial to mastoid process)			Facial n. (CN VII)	
(2) Stylohyoid		Temporal bone (styloid process)		Via a split tendon		
(3) Mylohyoid		Mandible (mylohyoid line)		Via median tendon of insertion (mylohyoid raphe)	Mylohyoid n. (from CN V_3)	Tightens and elevates oral floor, draws hyoid bone forward (swallowing), assists in opening mandible and moving it side to side (mastication)
(4) Geniohyoid		Mandible (inferior mental spine)		Directly	Anterior ramus of C1 (via CN XII)	Draws hyoid bone forward (swallowing), assists in opening mandible

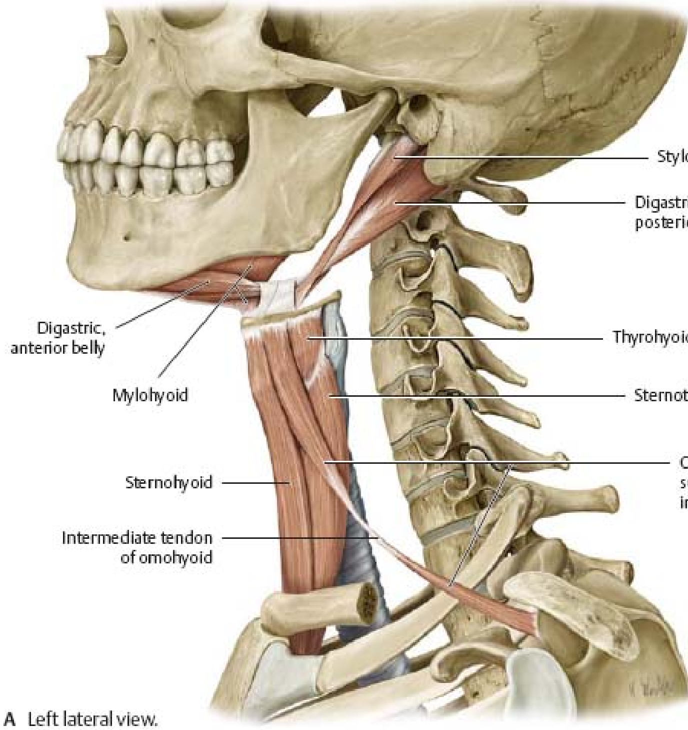
Fig. 37.7 Supra- and infrahyoid muscles

A Suprahyoid muscles, left lateral view.

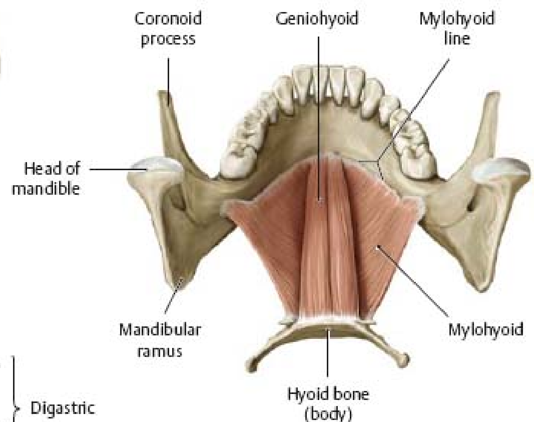
B Infrahyoid muscles, anterior view.

Table 37.6	Infrahyoid muscles			
Muscle	**Origin**	**Insertion**	**Innervation**	**Action**
(5) Omohyoid	Scapula (superior border)	Hyoid bone (body)	Ansa cervicalis of cervical plexus (C1–C3)	Depresses (fixes) hyoid, draws larynx and hyoid down for phonation and terminal phases of swallowing*
(6) Sternohyoid	Manubrium and sternoclavicular joint (posterior surface)			
(7) Sternothyroid	Manubrium (posterior surface)	Thyroid cartilage (oblique line)	Ansa cervicalis (C2–C3)	
(8) Thyrohyoid	Thyroid cartilage (oblique line)	Hyoid bone (body)	C1 via hypoglossal n. (CN XII)	Depresses and fixes hyoid, raises the larynx during swallowing
* The omohyoid also tenses the cervical fascia (with an intermediate tendon).				

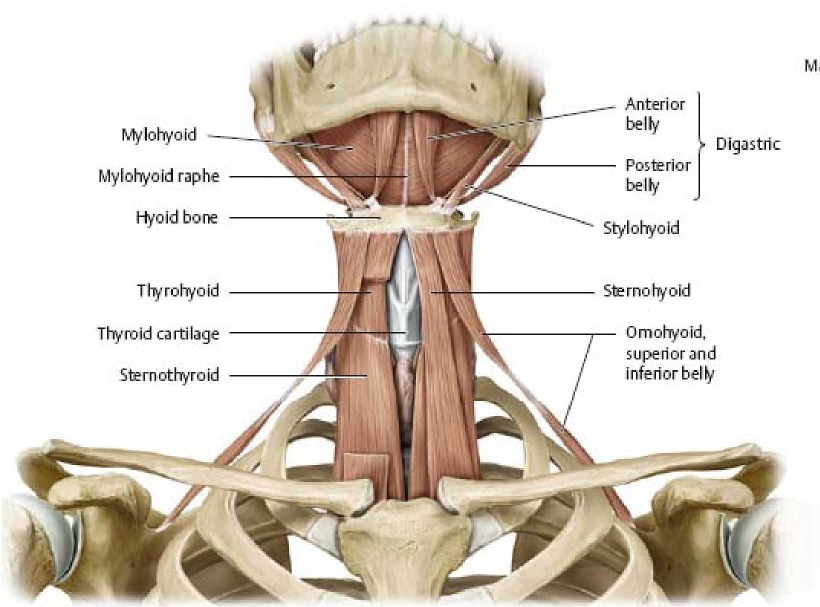
Fig. 37.8 Supra- and infrahyoid muscles



A Left lateral view.



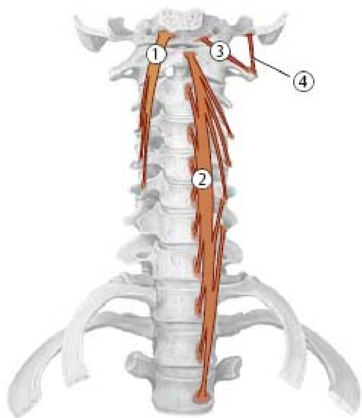
B Mylohyoid and geniohyoid (oral floor), posterosuperior view.



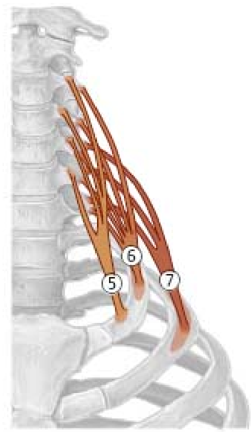
C Anterior view. The sternohyoid has been cut (right).

Muscle Facts (III)

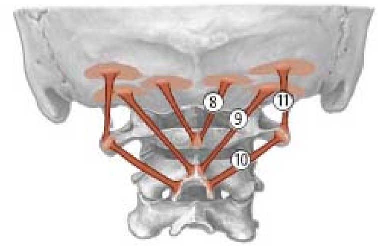
Fig. 37.9 Deep muscles of the neck



A Prevertebral muscles, anterior view.



B Scalene muscles, anterior view.

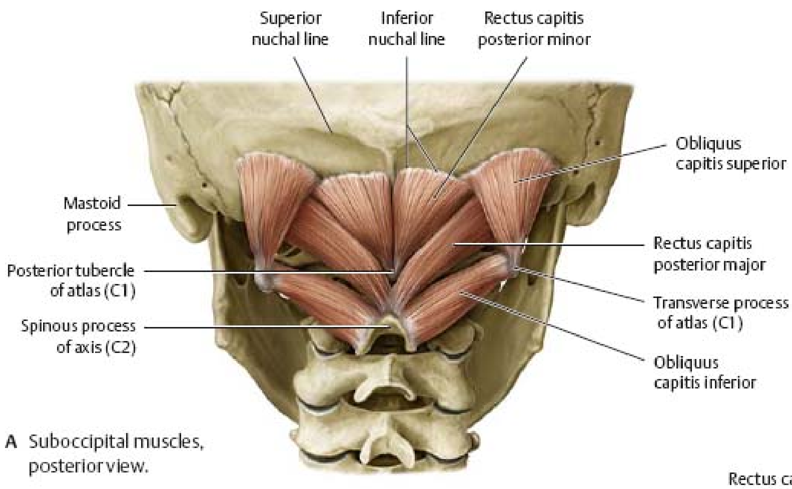


C Suboccipital muscles, posterior view.

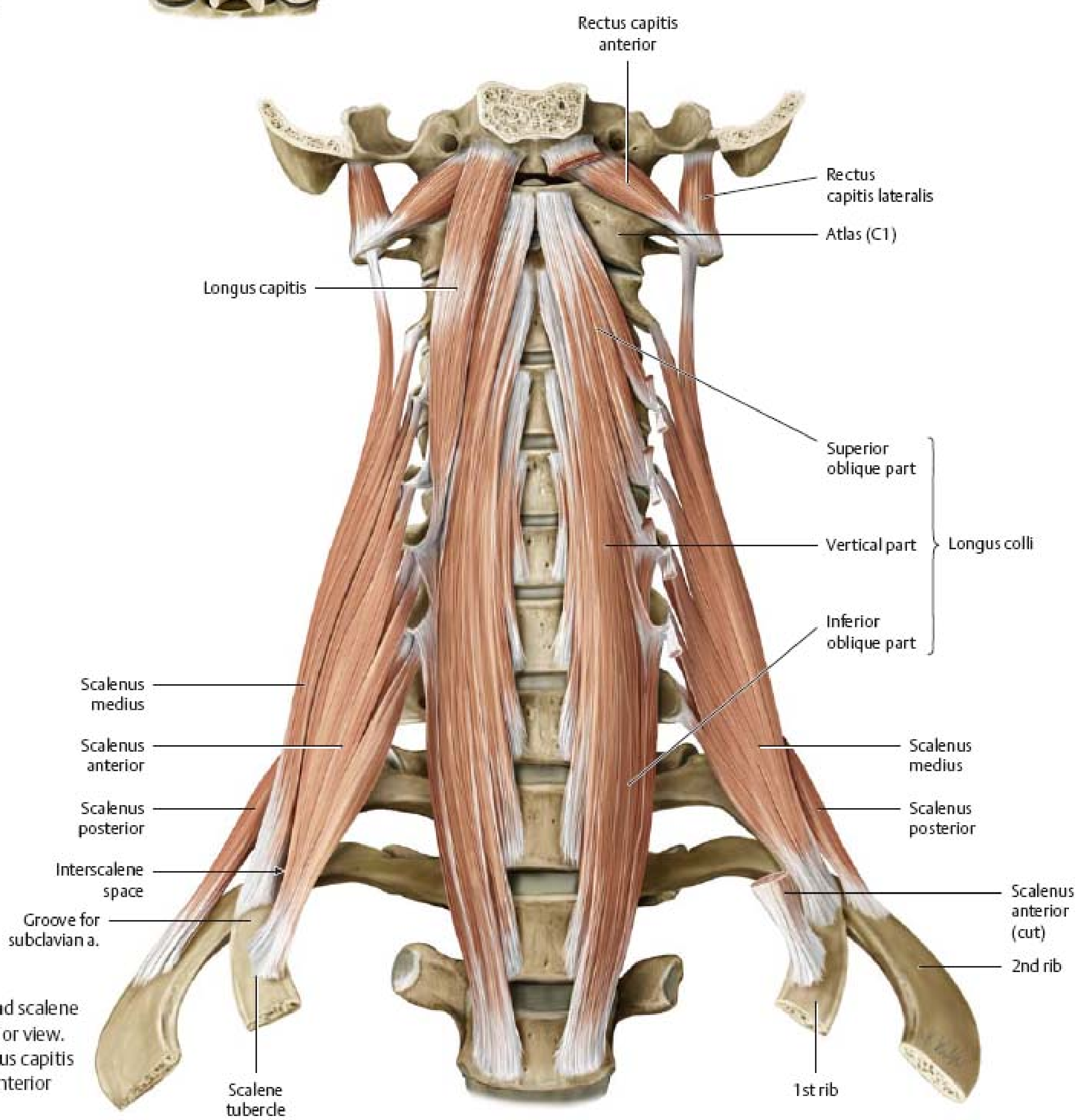
Table 37.7 **Deep muscles of the neck**

Muscle		Origin	Insertion	Innervation	Action
Prevertebral muscles					
① Longus capitis		C3–C6 (anterior tubercles of transverse processes)	Occipital bone (basilar part)	Direct branches from cervical plexus (C1–C3)	Flexion of head at atlanto-occipital joints
② Longus colli	Vertical (intermediate) part	C5–T3 (anterior surfaces of vertebral bodies)	C2–C4 (anterior surfaces)	Direct branches from cervical plexus (C2–C6)	*Unilateral:* Tilts and rotates cervical spine to opposite side *Bilateral:* Forward flexion of cervical spine
	Superior oblique part	C3–C5 (anterior tubercles of transverse processes)	Atlas (anterior tubercle)		
	Inferior oblique part	T1–T3 (anterior surfaces of vertebral bodies)	C5–C6 (anterior tubercles of transverse processes)		
③ Rectus capitis anterior		C1 (lateral mass)	Occipital bone (basilar part)	Anterior rami of C1 and C2	*Unilateral:* Lateral flexion at the atlanto-occipital joint *Bilateral:* Flexion at the atlanto-occipital joint
④ Rectus capitis lateralis		C1 (transverse process)	Occipital bone (basilar part, lateral to occipital condyles)		
Scalene muscles					
⑤ Scalenus anterior		C3–C6 (anterior tubercles of transverse processes)	1st rib (anterior scalene tubercle)	Direct branches from cervical and brachial plexuses (C3–C8)	*With ribs mobile:* Elevates upper ribs (during forced inspiration) *With ribs fixed:* Bends cervical spine to same side (unilateral), flexes neck (bilateral)
⑥ Scalenus medius		C1–C2 (transverse processes), C3–C7 (posterior tubercles of transverse processes)	1st rib (posterior to groove for subclavian artery)		
⑦ Scalenus posterior		C5–C7 (posterior tubercles of transverse processes)	2nd rib (outer surface)		
Suboccipital muscles (short nuchal and craniovertebral joint muscles)					
⑧ Rectus capitis posterior minor		C1 (posterior tubercle)	Occipital bone (inner third of inferior nuchal line)	Posterior ramus of C1 (suboccipital n.)	*Unilateral:* Rotates head to same side *Bilateral:* Extends head
⑨ Rectus capitis posterior major		C2 (spinous process)	Occipital bone (middle third of inferior nuchal line)		
⑩ Obliquus capitis inferior			C1 (transverse process)		
⑪ Obliquus capitis superior		C1 (transverse process)	Occipital bone (above insertion of rectus capitis posterior major)		*Unilateral:* Tilts head to same side, rotates it to opposite side *Bilateral:* Extends head

Fig. 37.10 Deep muscles of the neck



A Suboccipital muscles, posterior view.



B Prevertebral and scalene muscles, anterior view. *Removed:* Longus capitis and scalenus anterior (left).

Arteries & Veins of the Neck

***Fig. 37.11* Arteries of the neck**

Left lateral view. The structures of the neck are primarily supplied by the external carotid artery (anterior branches) and the subclavian artery (vertebral artery, thyrocervical trunk, and costocervical trunk).

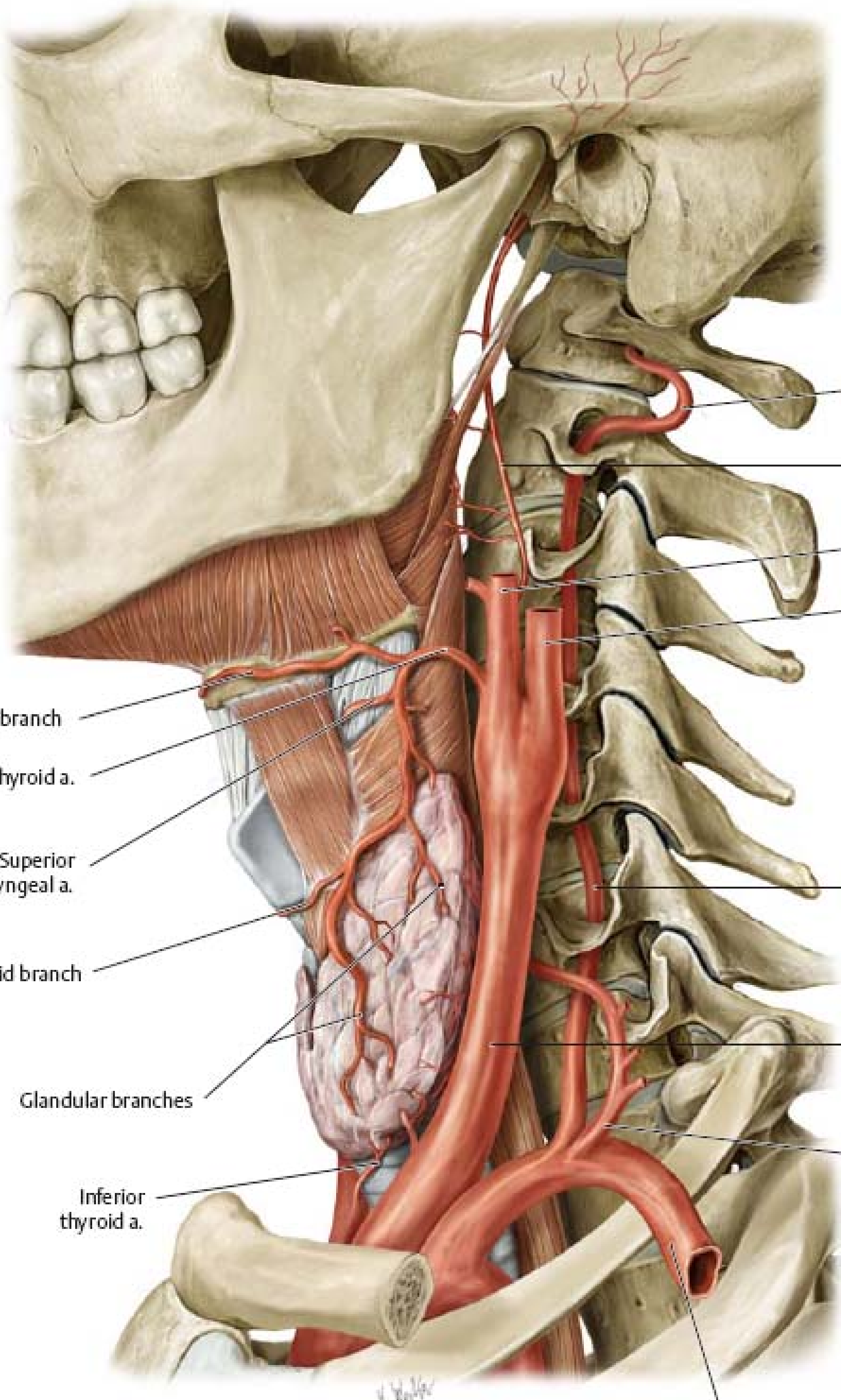
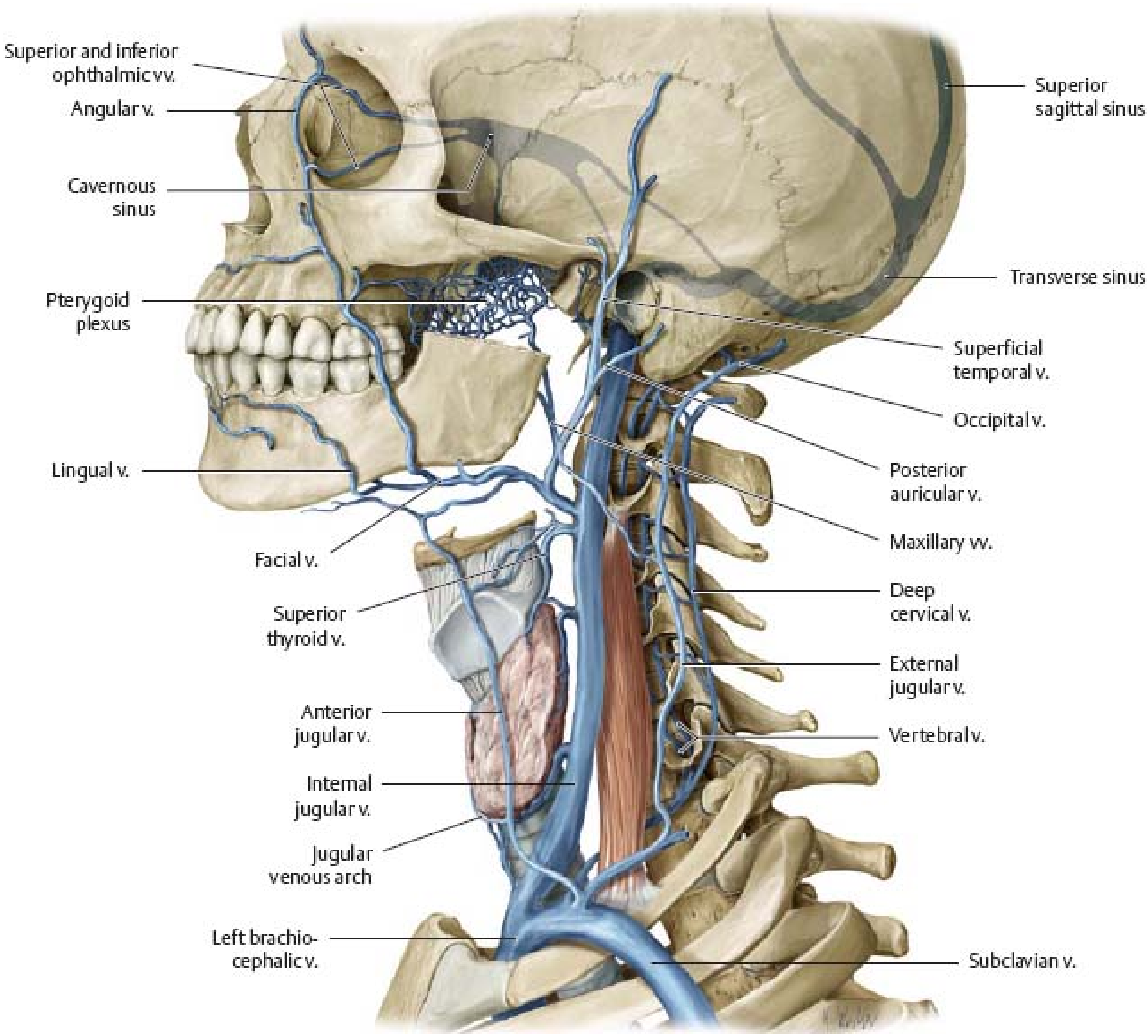


Fig. 37.12 **Veins of the neck**

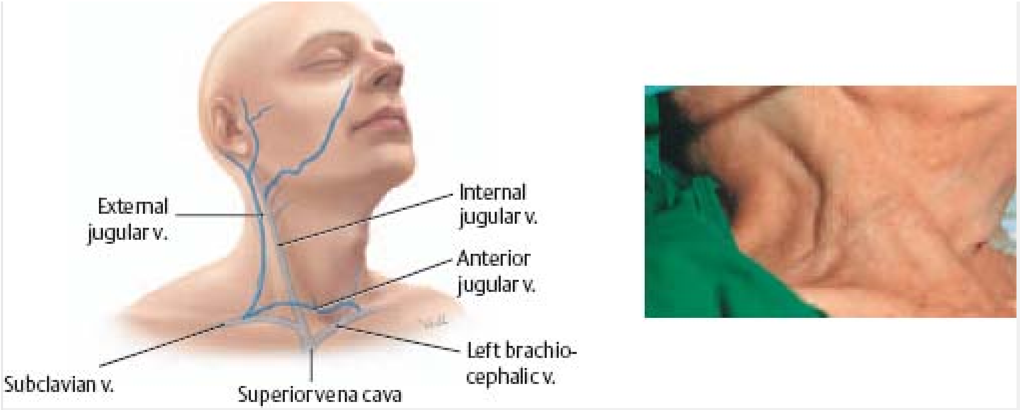
Left lateral view. The principal veins of the neck are the internal, external, and anterior jugularveins.



Clinical

Impeded blood flow and veins of the neck

When clinical factors (e.g., chronic lung disease, mediastinal tumors, or infections) impede the flow of blood to the right heart, blood darns up in the superior vena cava and, consequently, the jugular veins. This causes conspicuous swelling in the jugular (and sometimes more minor) veins.



Innervation of the Neck

Table 37.8 Branches of the spinal nerves in the neck

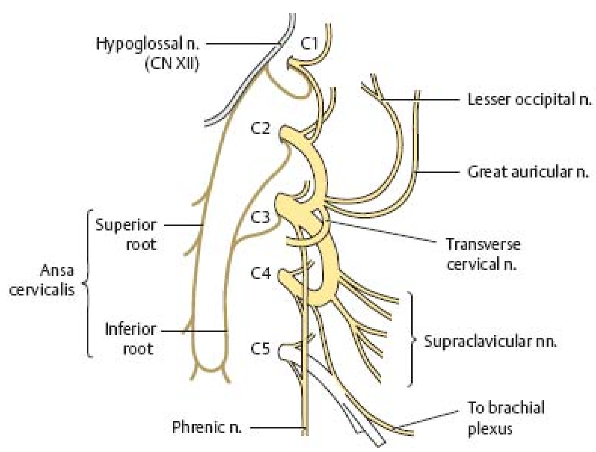
Posterior (dorsal) ramus

	Nerve	Sensory function	Motor function
C1	Suboccipital n.	No C1 dermatome	Innervate intrinsic nuchal muscles
C2	Greater occipital n.	Innervate C2 dermatome	
C3	3rd occipital n.	Innervate C3 dermatome	

Anterior (ventral) ramus

	Sensory branches	Sensory function	Motor branches	Motor function
C1	–	–	Form ansa cervicalis (motor part of cervical plexus)	Innervate infrahyoid muscles (except thyrohyoid)
C2	Lesser occipital n.	Form sensory part of cervical plexus, innervate anterior and lateral neck		
C2–C3	Great auricular n.			
	Transverse cervical n.			
C3–C4	Supraclavicular nn.			
			Contribute to phrenic n.*	Innervate diaphragm and pericardium*

* The anterior roots of C3–C5 combine to form the phrenic nerve (see p. 54).



Branching of the cervical plexus.

Fig. 37.13 Innervation of the nuchal region

Posterior view.

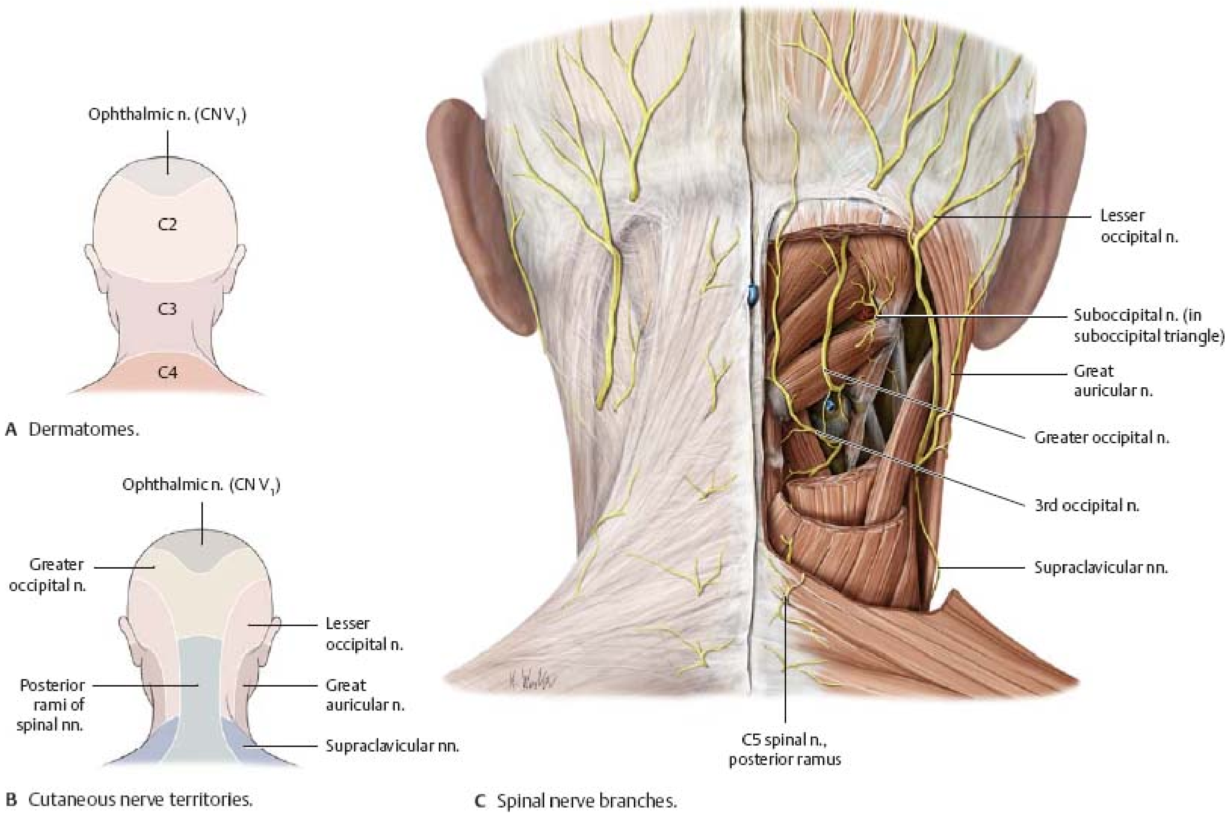


Fig. 37.14 Sensory innervation of the anterolateral neck

Left lateral view.

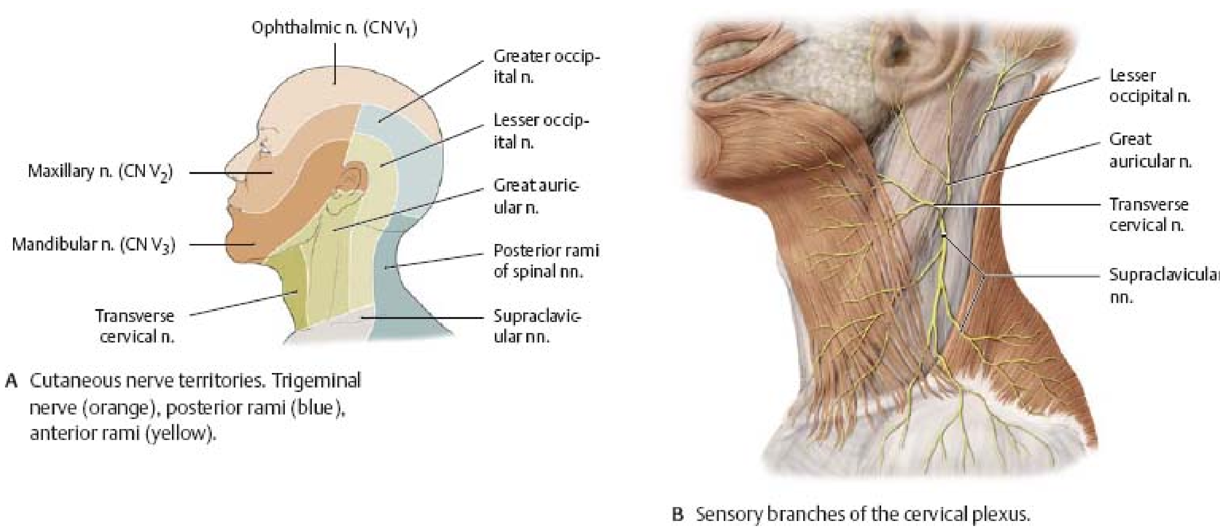
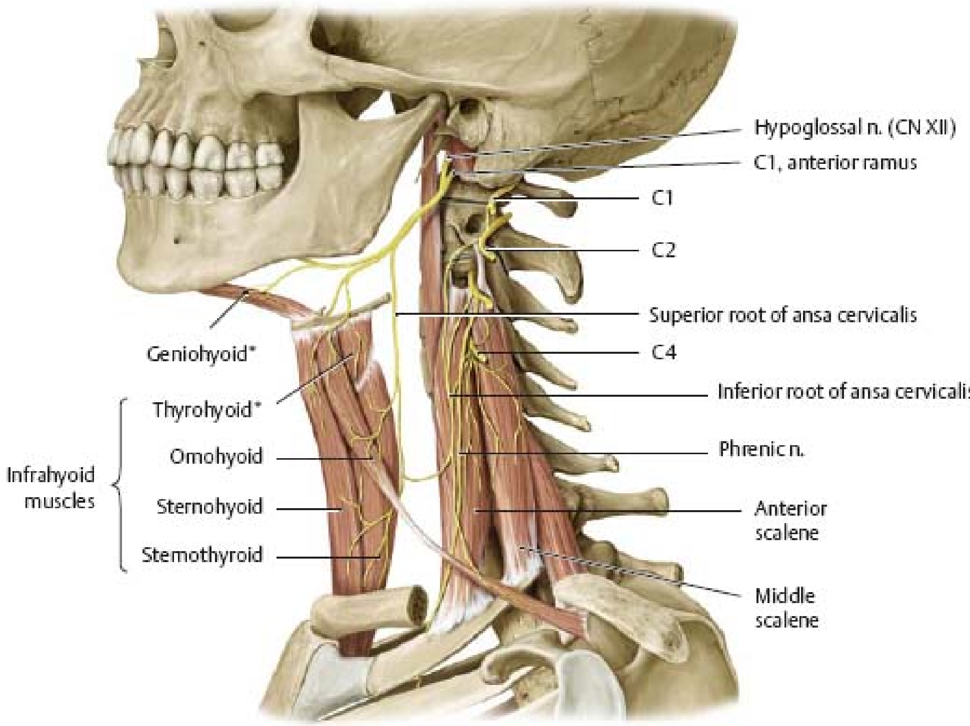


Fig. 37.15 Motor innervation of the anterolateral neck

Left lateral view.



* Innervated by the anterior ramus of C1 (distributed by the hypoglossal n.).

Larynx: Cartilage & Structure

Fig. 37.16 Laryngeal cartilages

Left lateral view. The larynx consists of five laryngeal cartilages: epiglottic, thyroid, cricoid, and the paired arytenoid and corniculate cartilages. They are connected to each other, the trachea, and the hyoid bone by elastic ligaments.

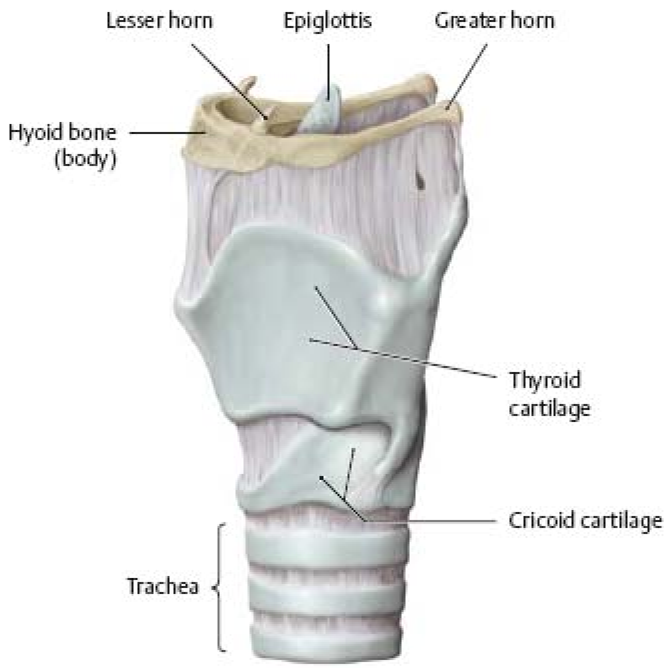


Fig. 37.17 **Epiglottic cartilage**

The elastic epiglottic cartilage comprises the internal skeleton of the epiglottis, providing resilience to return it to its initial position after swallowing.

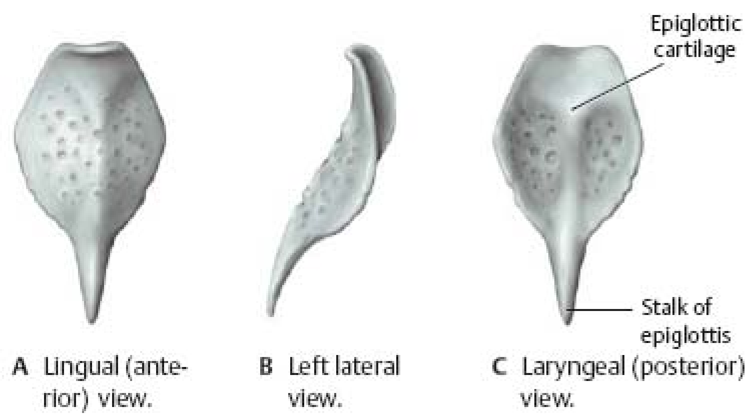


Fig. 37.18 **Thyroid cartilage**

Left oblique view.

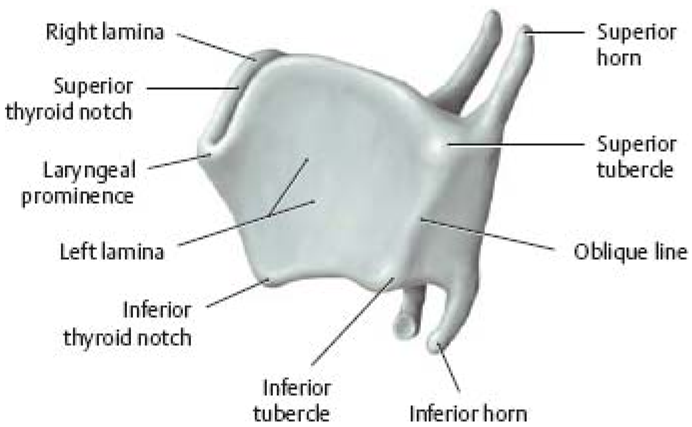


Fig. 37.19 **Cricoid cartilage**

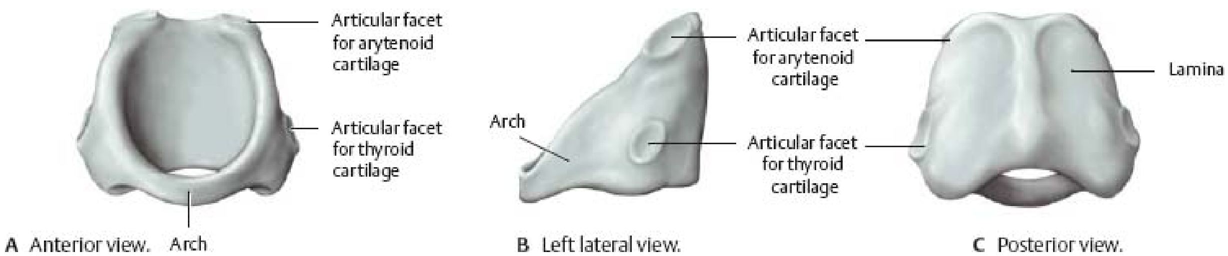


Fig. 37.20 **Arytenoid and corniculate cartilages**

Right cartilages.

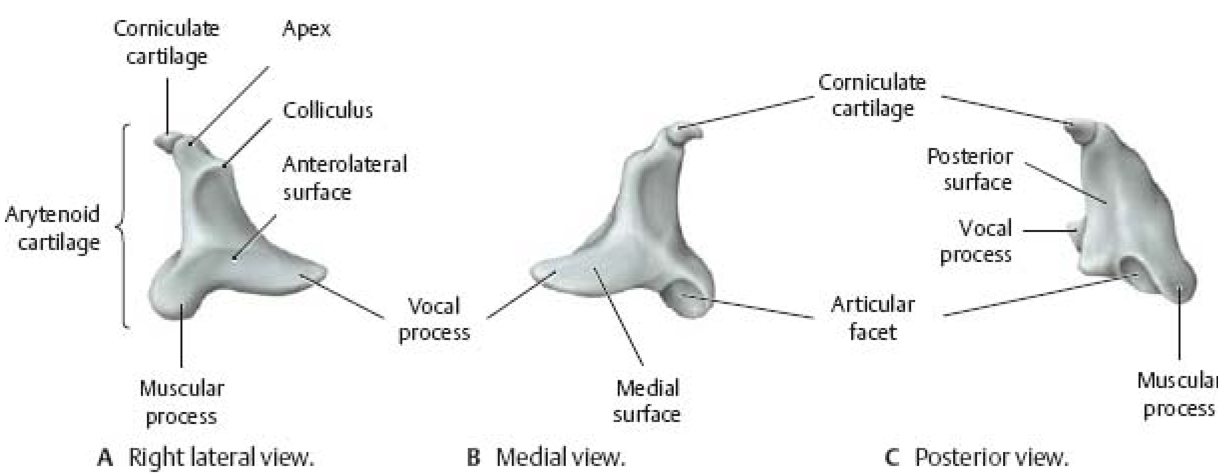
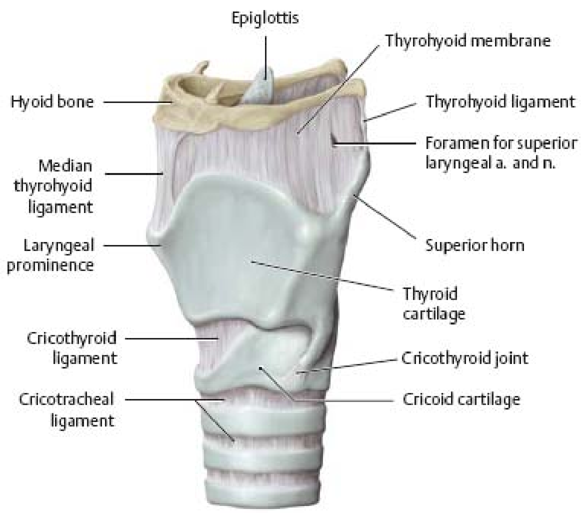
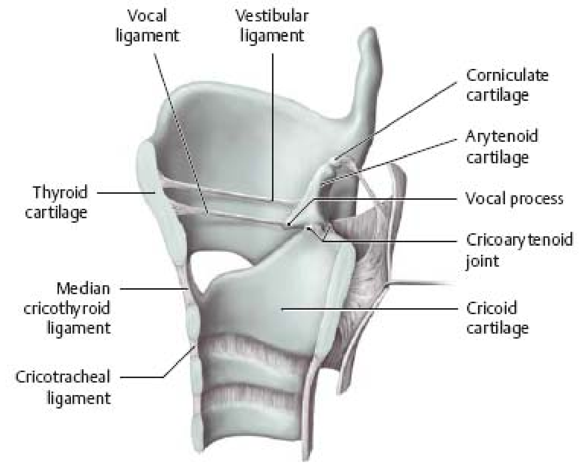


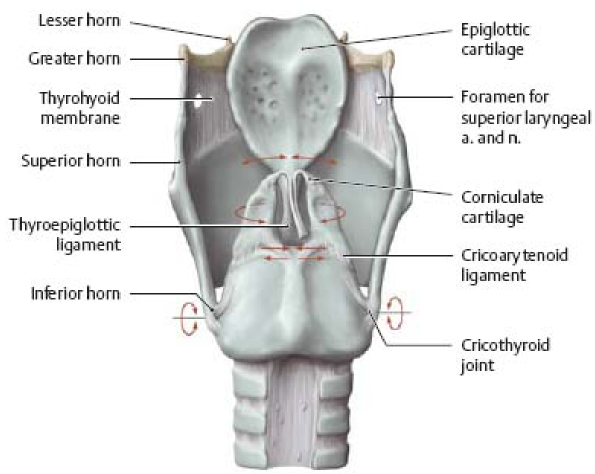
Fig. 37.21 **Structure of the larynx**



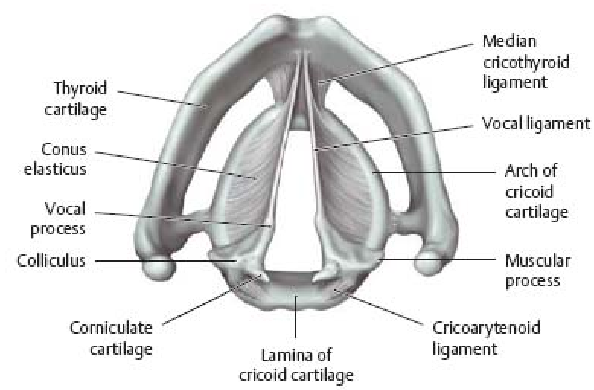
A Left anterior oblique view.



B Sagittal section, viewed from the left medial aspect. The arytenoid cartilage alters the position of the vocal folds during phonation.



C Posterior view. Arrows indicate the directions of movement in the various joints.

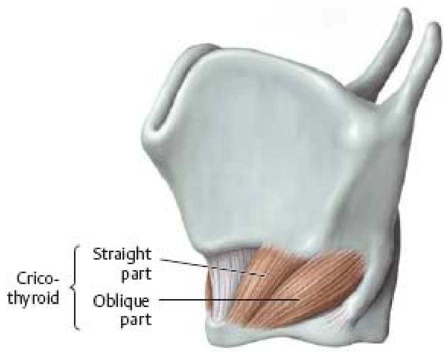


D Superior view.

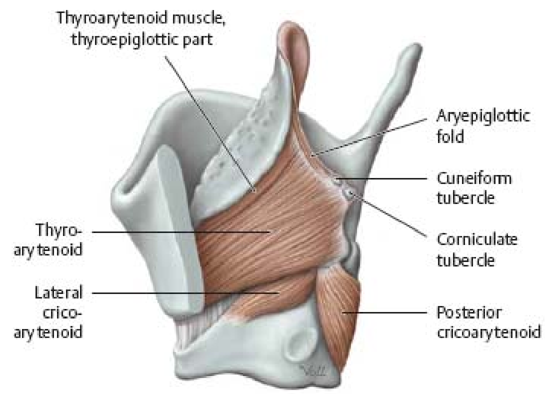
Larynx: Muscles & Levels

Fig. 37.22 Laryngeal muscles

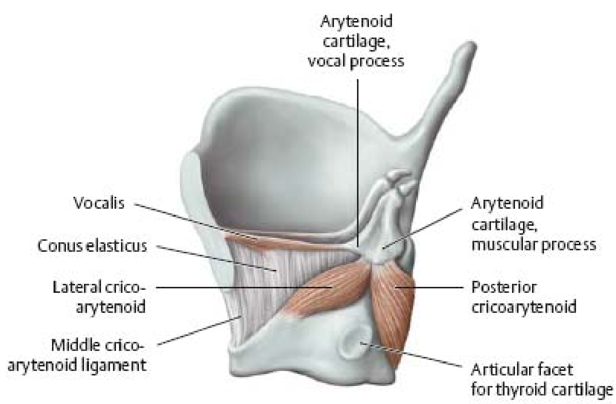
The laryngeal muscles move the laryngeal cartilages relative to one another, affecting the tension and/or position of the vocal folds. Muscles that move the larynx as a whole (infra- and suprahyoid muscles) are described on p. 562.



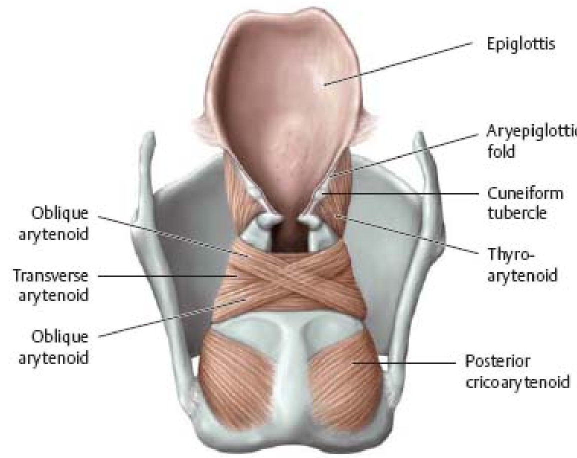
A Extrinsic laryngeal muscles, left lateral oblique view.



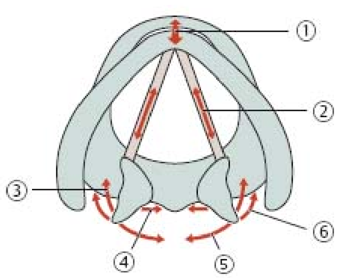
B Intrinsic laryngeal muscles, left lateral view. *Removed:* Thyroid cartilage (left half). *Revealed:* Epiglottis and external thyroarytenoid muscle.



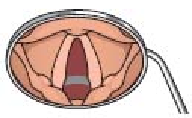
C Left lateral view with the epiglottis removed.



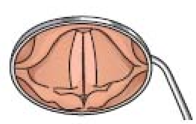
D Posterior view.



A Laryngeal muscles, superior view.



B Open rima glottidis.



C Closed rima glottidis.

Table 37.9 Actions of the laryngeal muscles

Muscle	Action	Effect on rima glottidis
① Cricothyroid m.*	Tightens the vocal folds	None
② Vocalis m.		
③ Thyroarytenoid m.	Adducts the vocal folds	Closes
④ Transverse arytenoid m.		
⑤ Posterior cricoarytenoid m.	Abducts the vocal folds	Opens
⑥ Lateral cricoarytenoid m.	Adducts the vocal folds	Closes

* The cricothyroid is the only extrinsic laryngeal muscle.

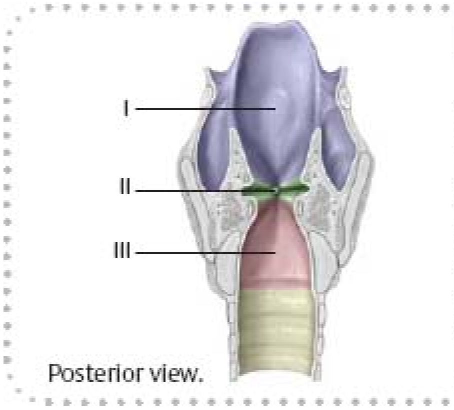
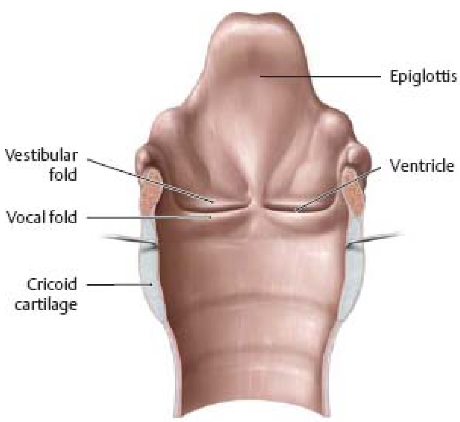
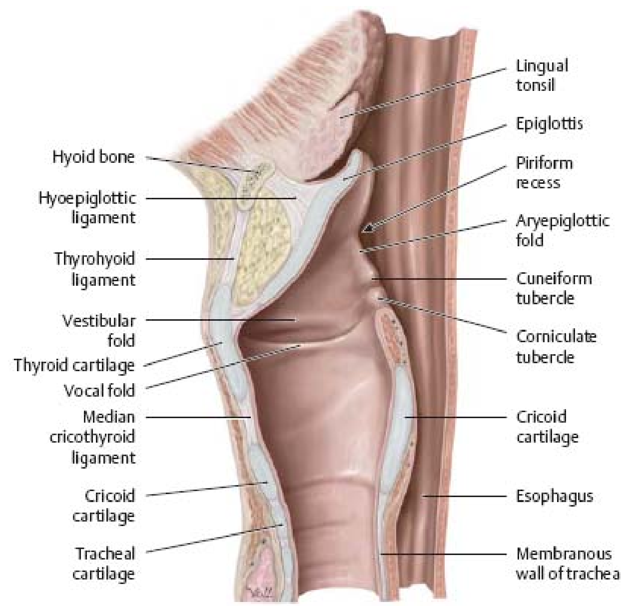


Table 37.10	Levels of the larynx	
Level	Space	Extent
I	Supraglottic space (laryngeal vestibule)	Laryngeal inlet (aditus laryngis) to vestibular folds
II	Transglottic space (intermediate laryngeal cavity)	Vestibular folds across laryngeal ventricle (lateral evagination of mucosa) to vocal folds
III	Subglottic space (infraglottic cavity)	Vocal folds to inferior border of cricoid cartilage

***Fig. 37.23* Cavity of the larynx**



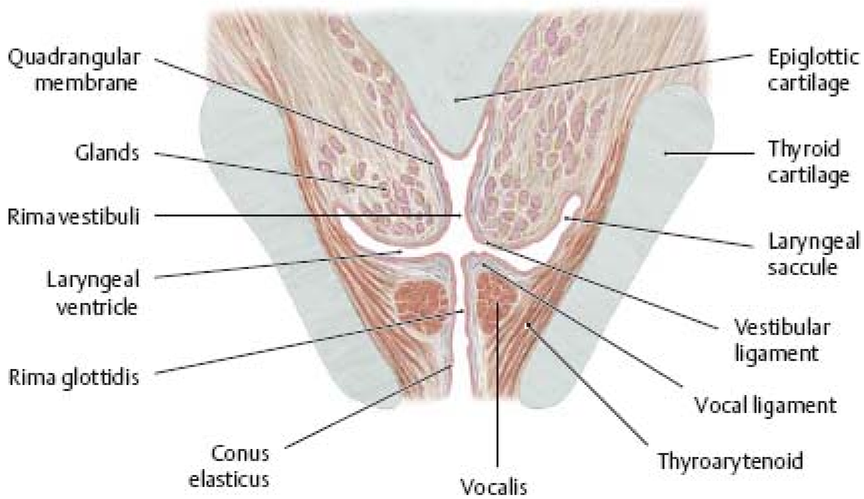
A Posterior view with the larynx splayed open.



B Midsagittal section viewed from the left side.

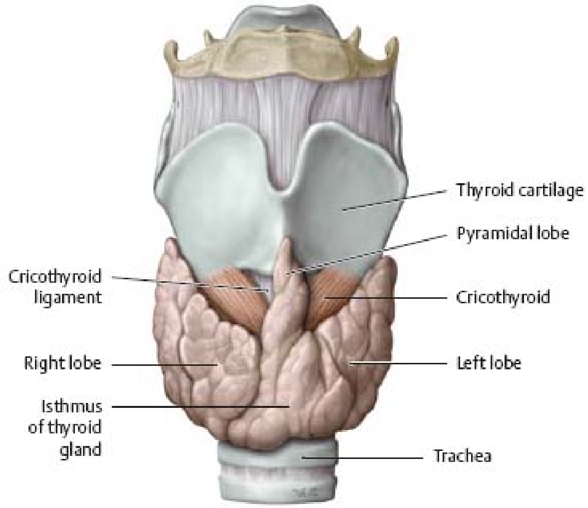
***Fig. 37.24* Vestibular and vocal folds**

Coronal section, superior view.

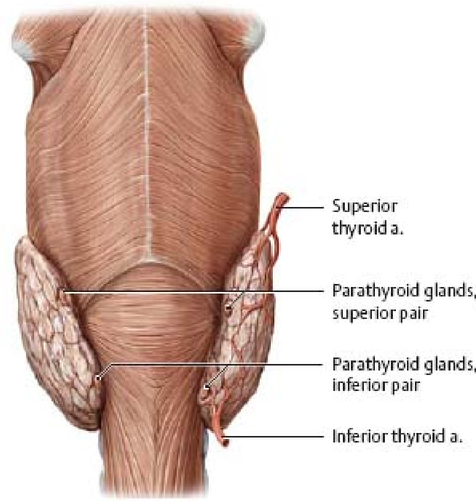


Neurovasculature of the Larynx, Thyroid & Parathyroids

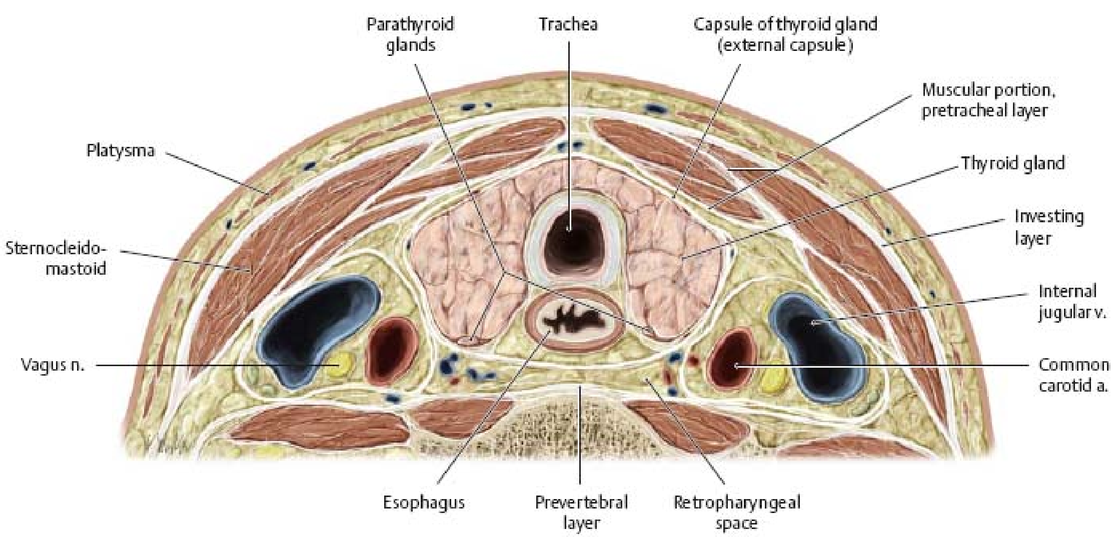
Fig. 37.25 Thyroid and parathyroid glands



A Thyroid gland, anterior view.



B Thyroid and parathyroid glands, posterior view.



C Topographical relations of the thyroid and parathyroid glands. See p. 577 for the layers of cervical fascia.

Fig. 37.26 Arteries and nerves

Anterior view.

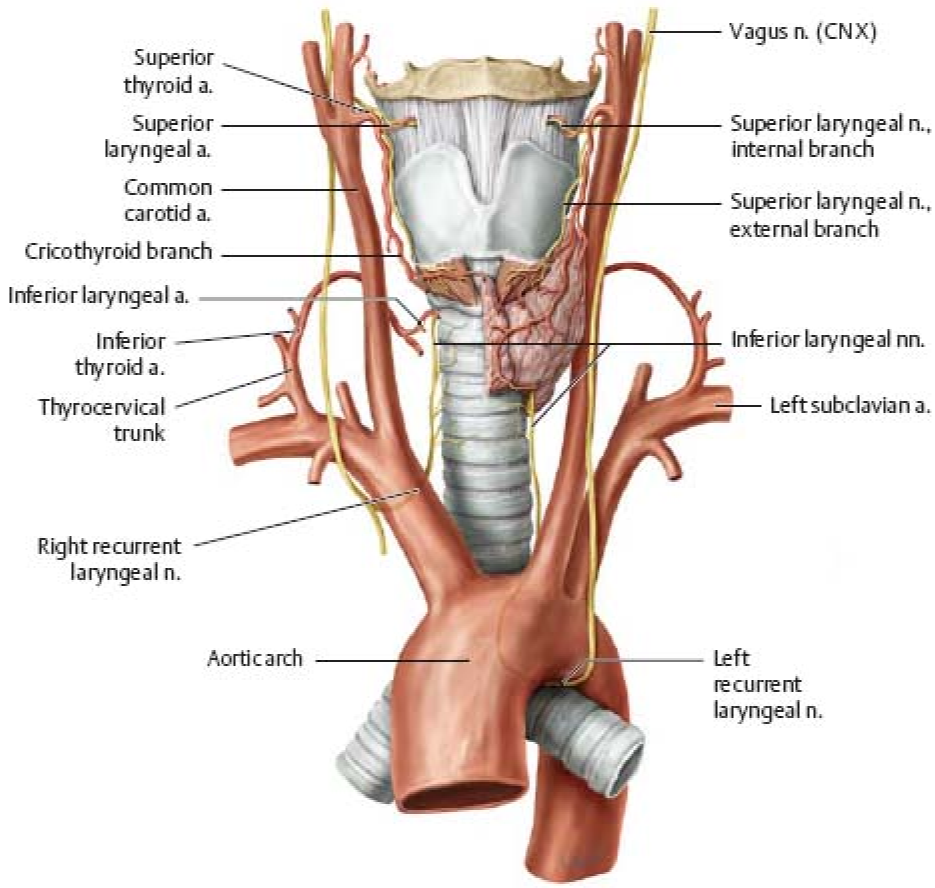


Fig. 37.27 Veins

Left lateral view. *Note*: The inferior thyroid vein generally drains into the left brachiocephalic vein.

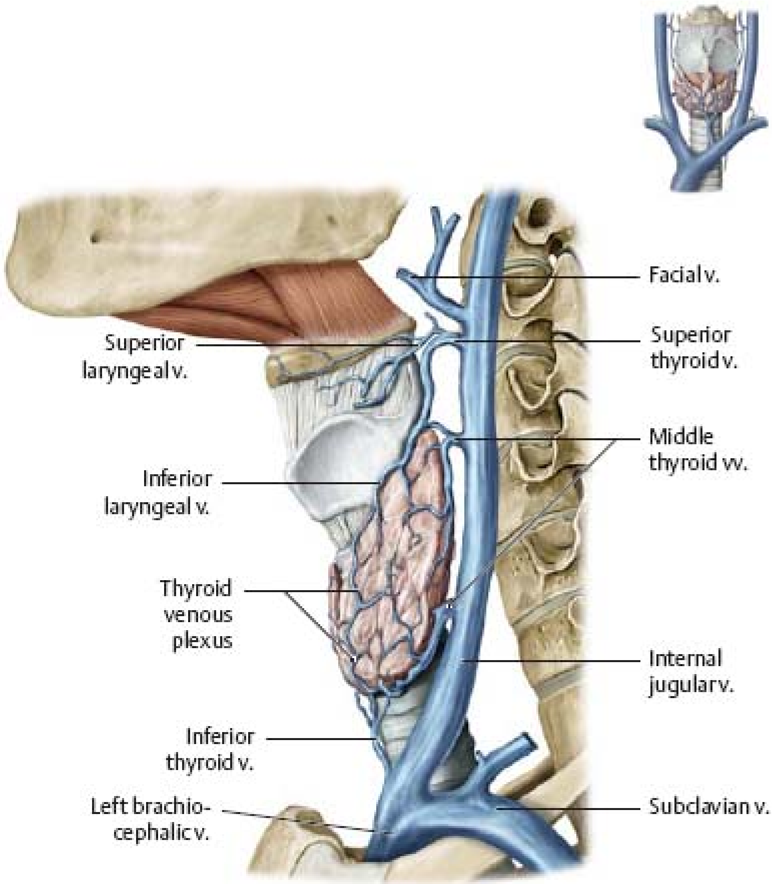
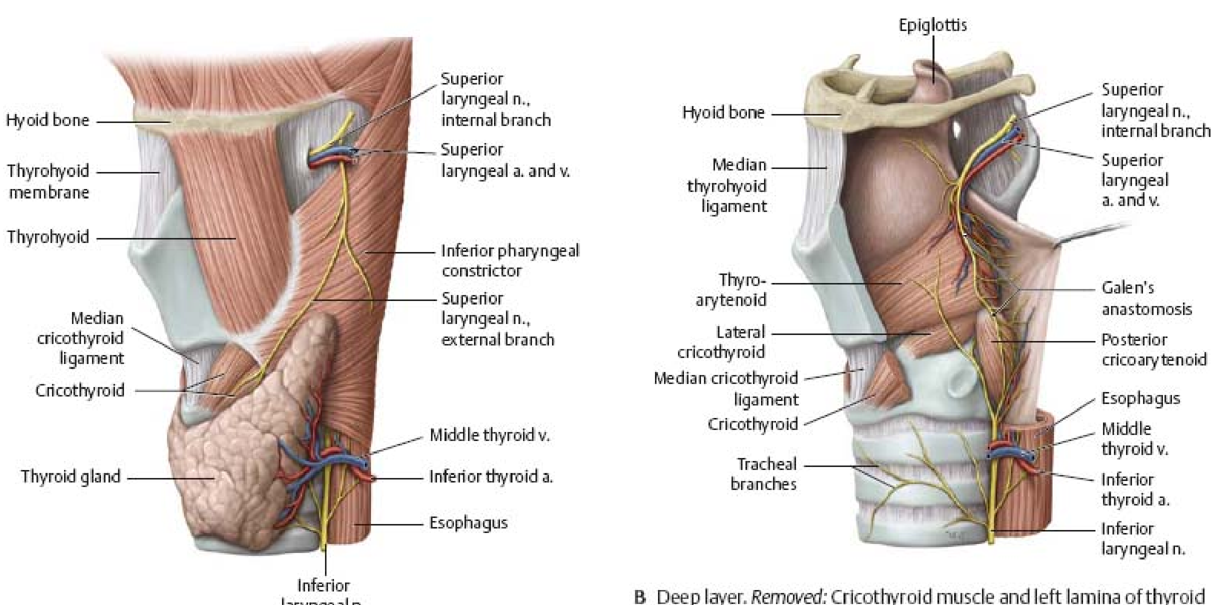


Fig. 37.28 Neurovasculature

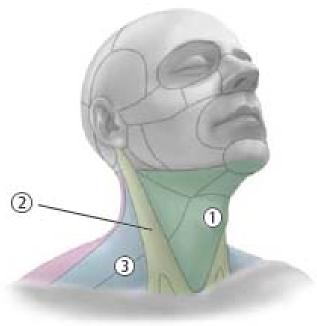
Left lateral view.



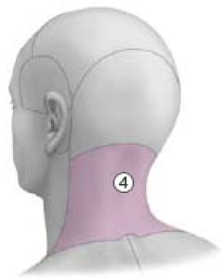
A Superficial layer.

B Deep layer. *Removed:* Cricothyroid muscle and left lamina of thyroid cartilage. *Retracted:* Pharyngeal mucosa.

Topography of the Neck: Regions & Fascia



A Right anterior oblique view.



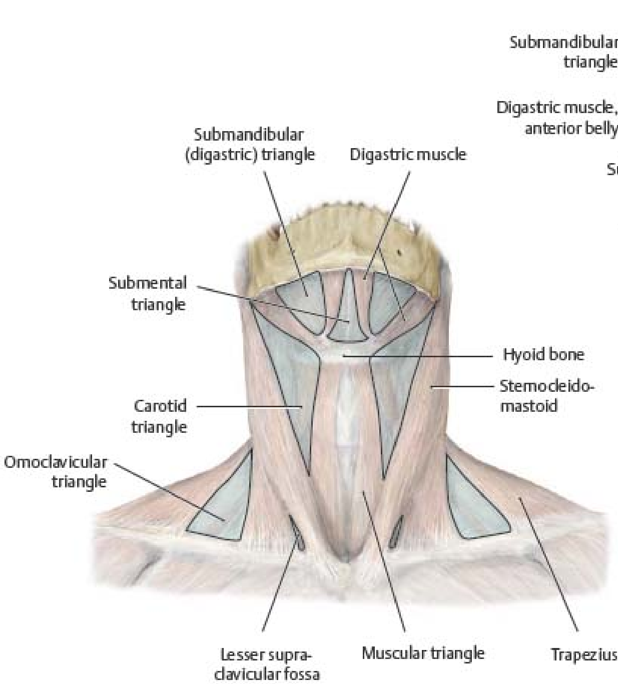
B Left posterior oblique view.

Table 37.11 Regions of the neck

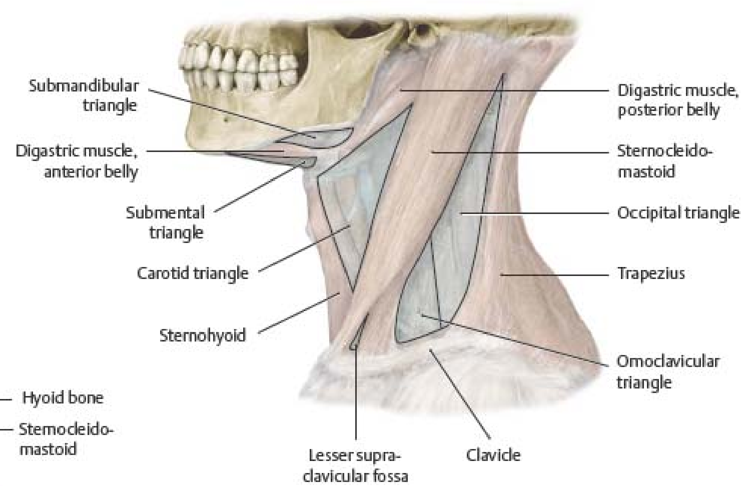
Region	Divisions	Contents
① Anterior cervical region (triangle)	Submandibular (digastric) triangle	Submandibular gland and lymph nodes, hypoglossal n. (CN XII), facial a. and v.
	Submental triangle	Submental lymph nodes
	Muscular triangle	Sternothyroid and sternohyoid muscles, thyroid and parathyroid glands
	Carotid triangle	Carotid bifurcation, carotid body, hypoglossal (CN XII) and vagus (CN X) nn.
② Sternocleidomastoid region*		Sternocleidomastoid, carotid a., internal jugular v., vagus n. (CN X), jugular lymph nodes
③ Lateral cervical region (posterior triangle)	Omoclavicular (subclavian) triangle	Subclavian a., subscapular a., supraclavicular l.n.
	Occipital triangle	Accessory n. (CN XI), trunks of brachial plexus, transverse cervical a., cervical plexus (posterior branches)
④ Posterior cervical region		Nuchal muscles, vertebral a., cervical plexus

* The sternocleidomastoid region also contains the lesser supraclavicular fossa.

Fig. 37.29 Cervical regions

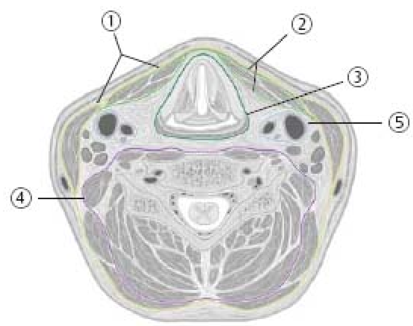


A Anterior view.

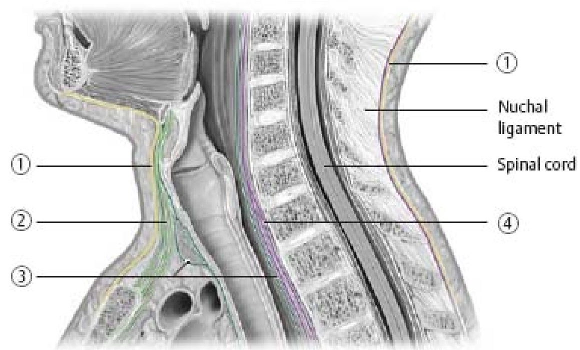


B Left lateral view.

Table 37.12	Deep cervical fascia		
The deep cervical fascia is divided into four layers that enclose the structures of the neck.			
Layer	**Lamina**	**Type of fascia**	**Description**
① Investing layer	Superficial lamina	Muscular	Envelopes entire neck; splits to enclose sternocleidomastoid and trapezius muscles
Pretracheal layer	② Pretracheal lamina		Encloses infrahyoid muscles
	③ Visceral fascia	Visceral	Surrounds thyroid gland, larynx, trachea, pharynx, and esophagus
④ Prevertebral layer	Prevertebral lamina	Muscular	Surrounds cervical vertebral column and associated muscles
⑤ Carotid sheath		Neurovascular	Encloses common carotid artery, internal jugular vein, and vagus nerve



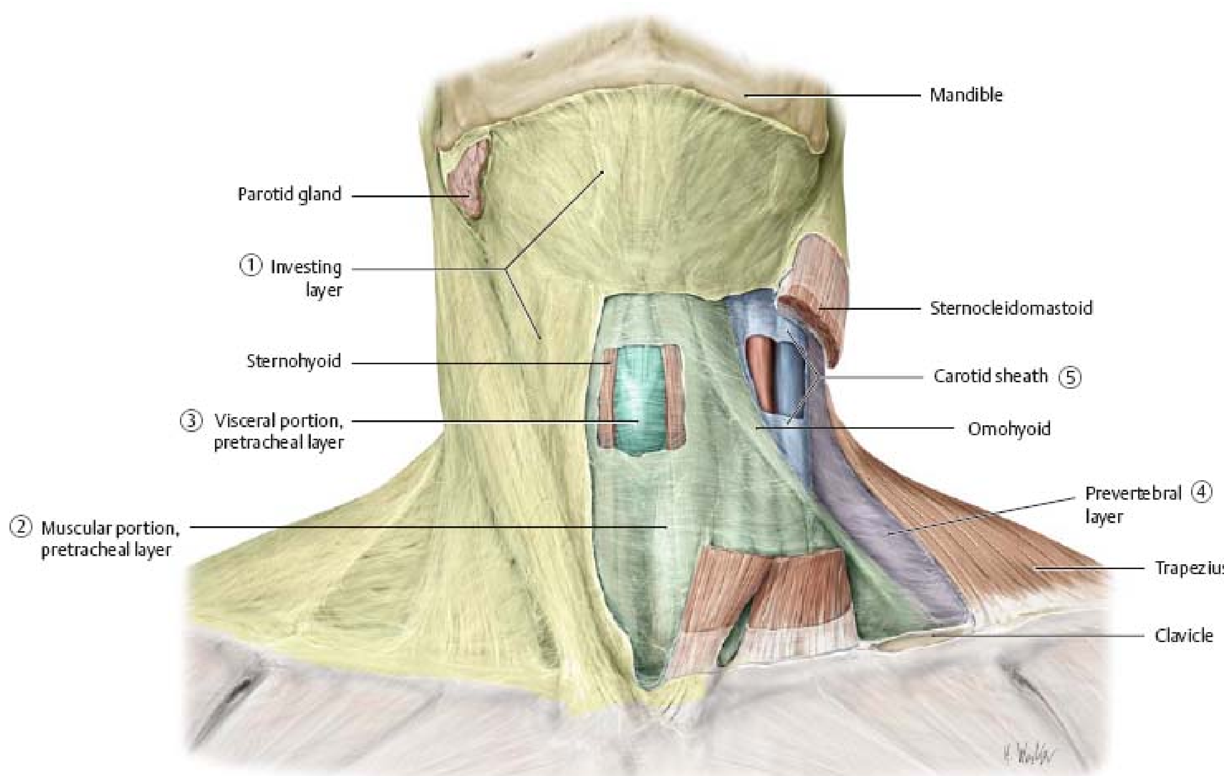
A Transverse section at level of C5 vertebra.



B Midsagittal section, left lateral view.

Fig. 37.30 Deep cervical fascial layers

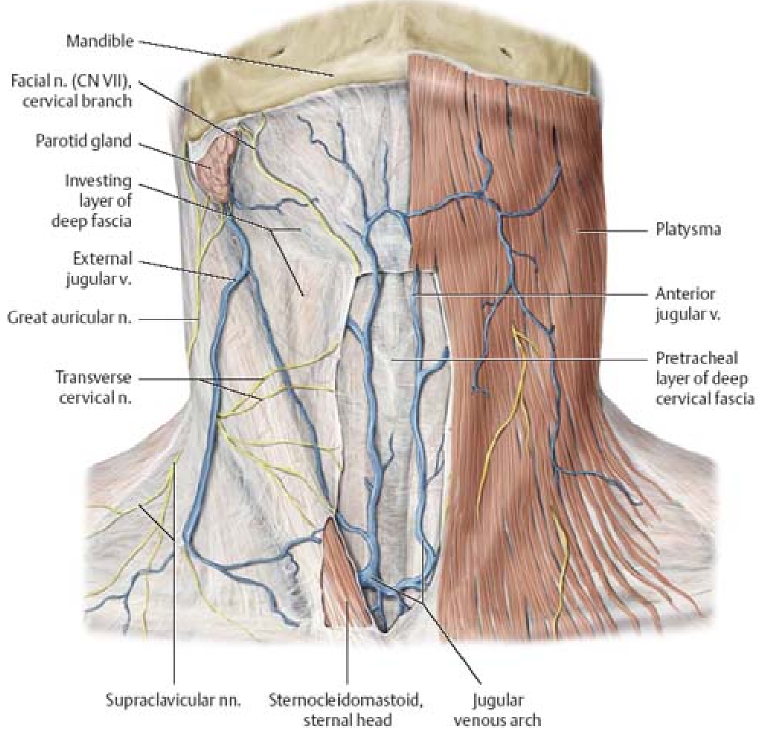
Anterior view.



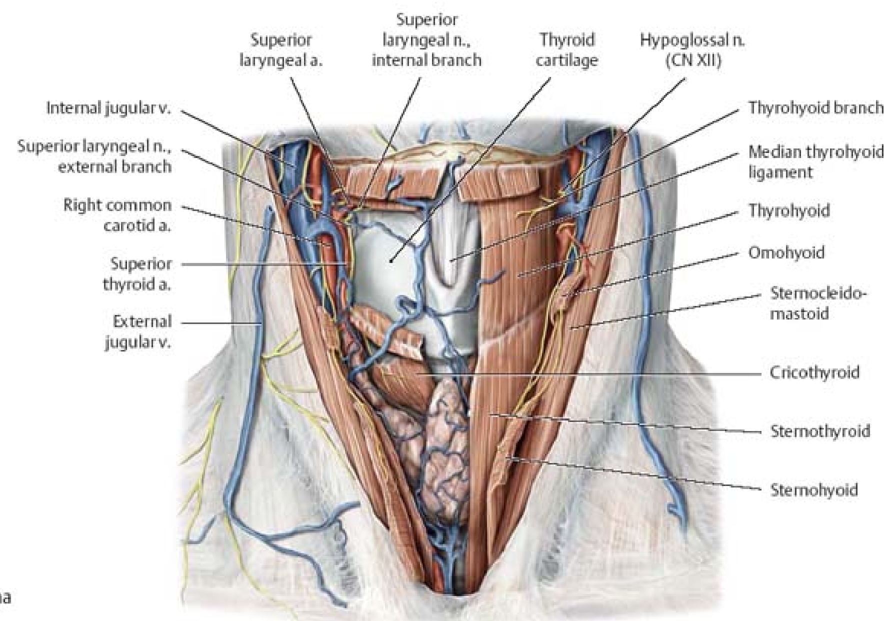
Topography of the Anterior Cervical Region

Fig. 37.31 Anterior cervical triangle

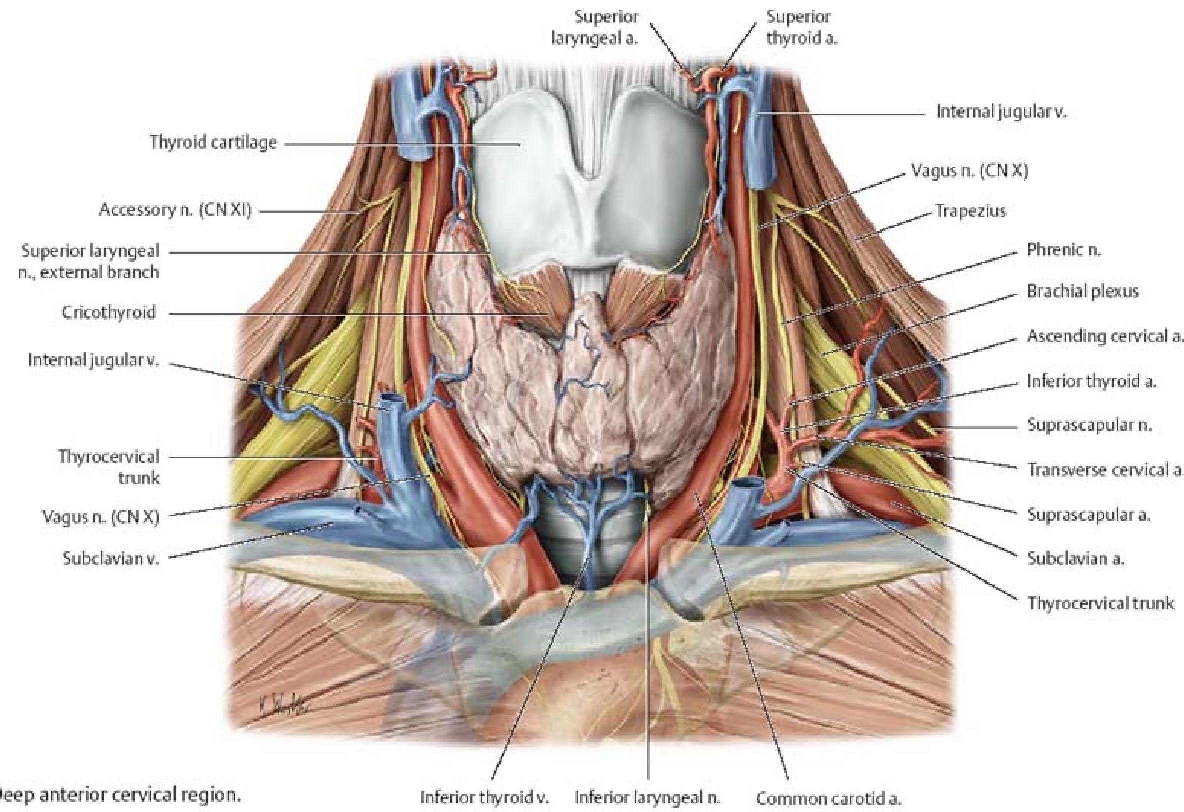
Anterior view.



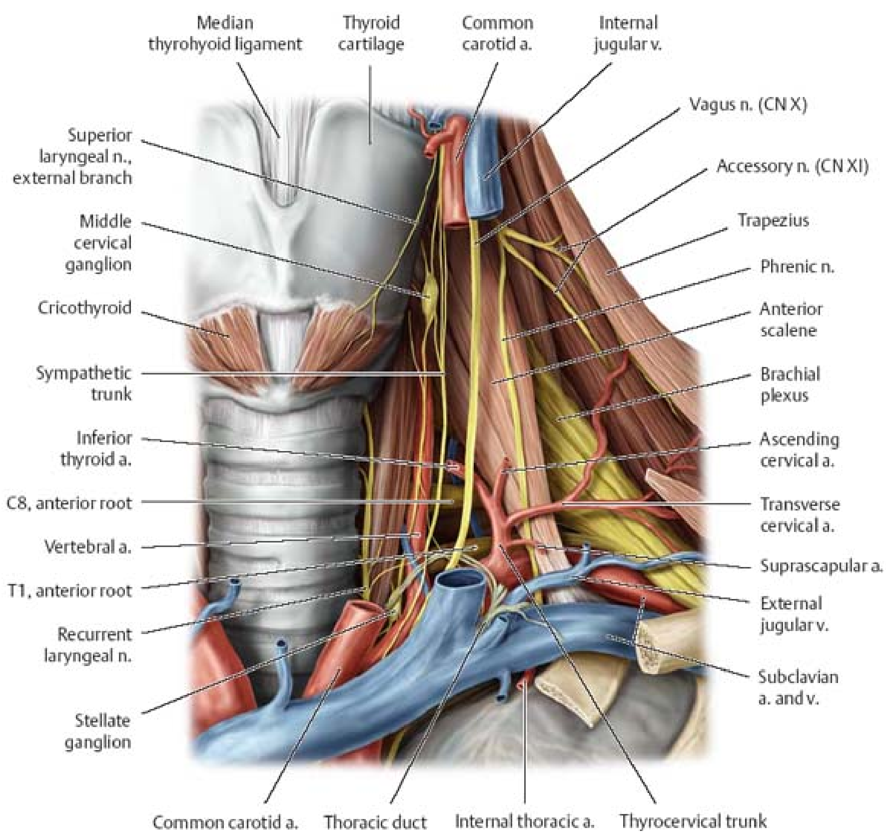
A Superficial layer. *Removed:* Subcutaneous platysma (right side) and investing layer of deep cervical fascia (center).



B Deep layer. *Removed:* Pretracheal lamina (middle layer of cervical fascia).



C Deep anterior cervical region.



D Root of the neck.

Topography of the Anterior & Lateral Cervical Regions

Fig. 37.32 Carotid triangle

Right lateral view.

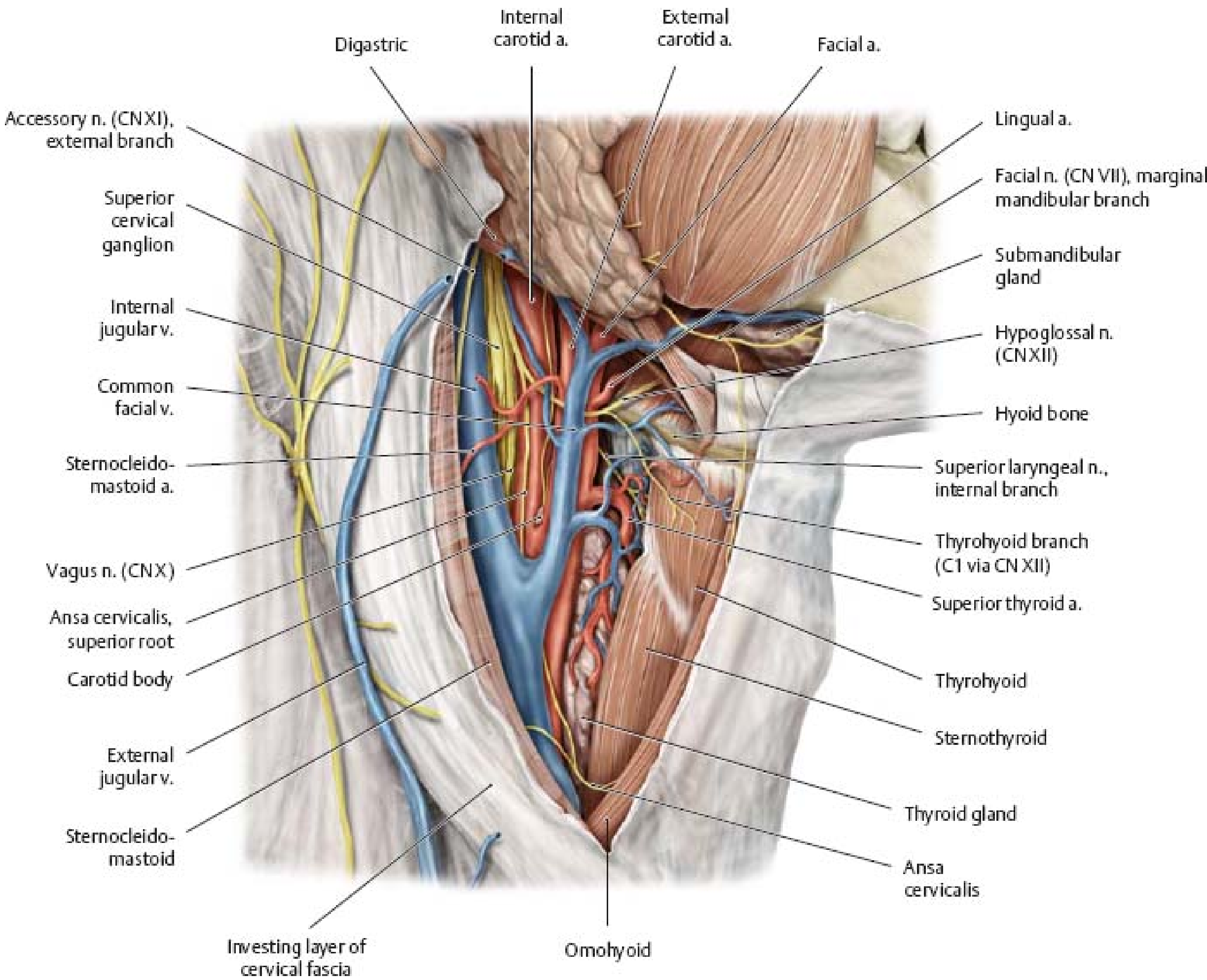
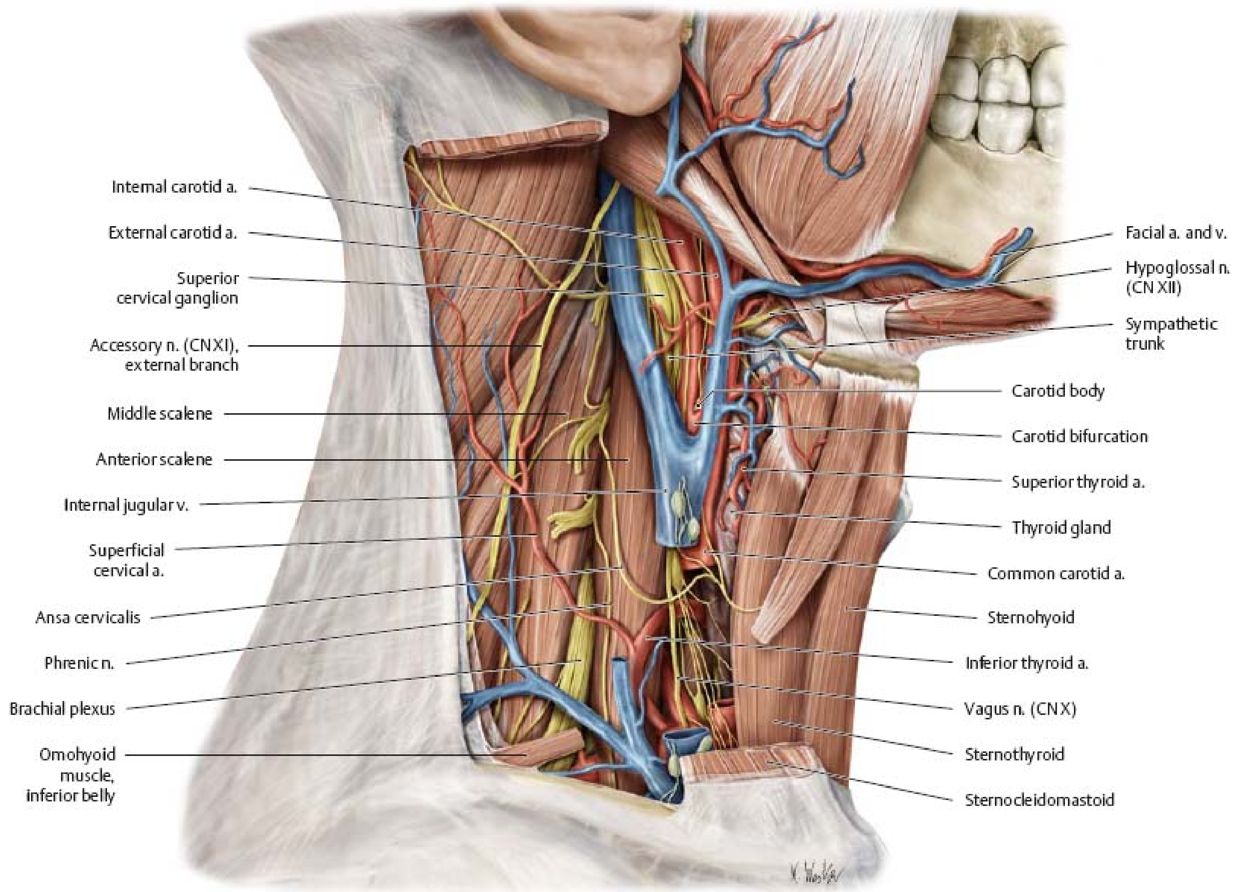


Fig. 37.33 Deep lateral cervical region

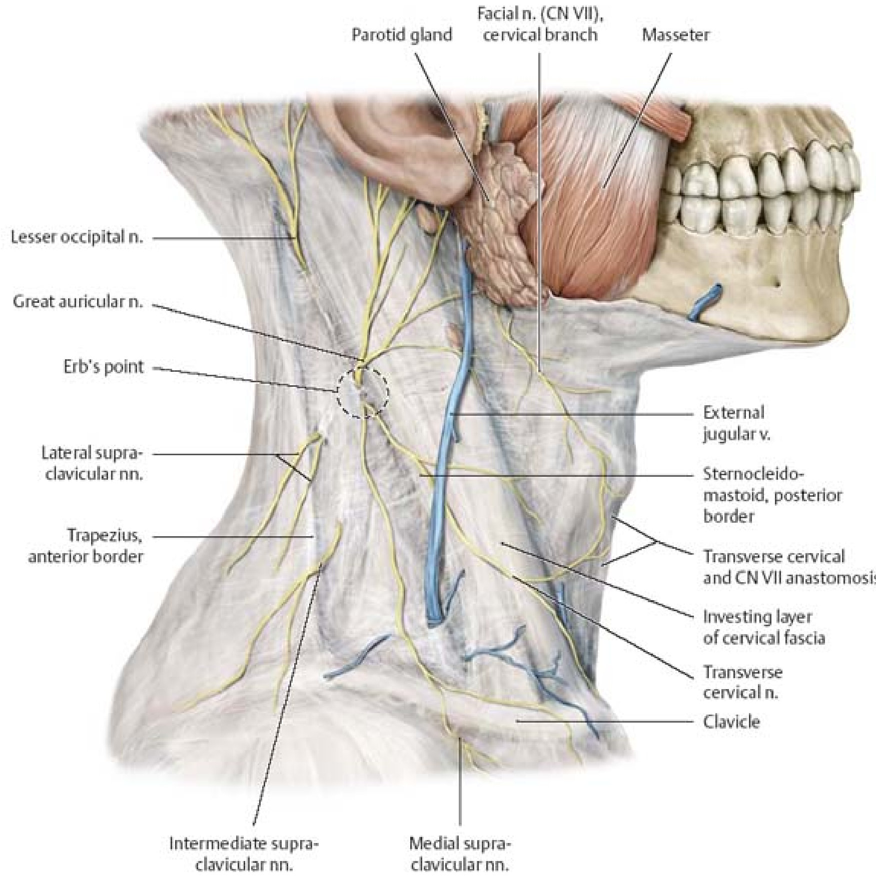
Right lateral view with sternocleidomastoid windowed.



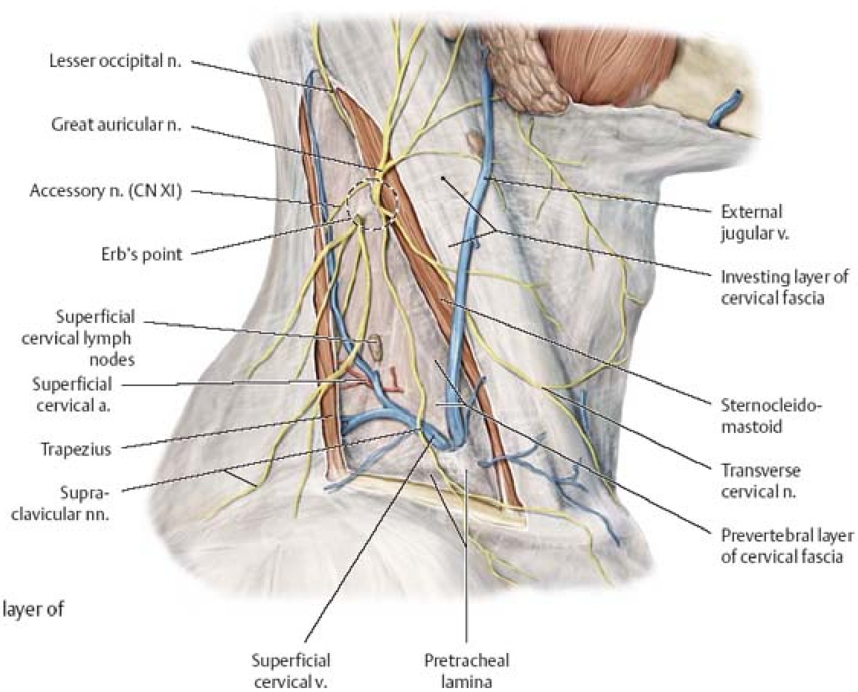
Topography of the Lateral Cervical Region

Fig. 37.34 Lateral cervical region

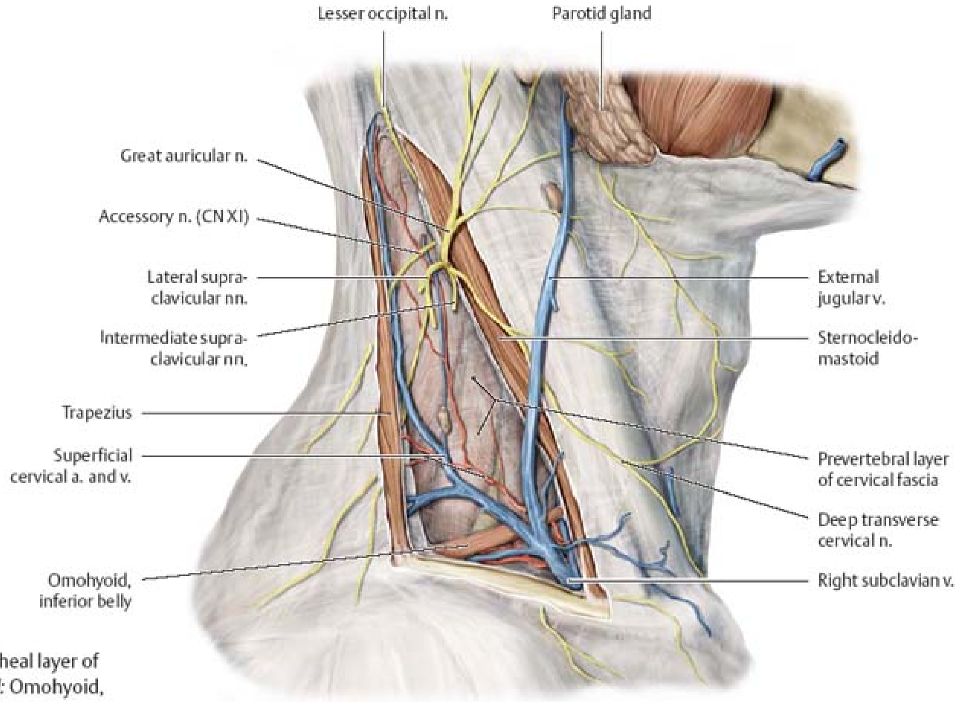
Right lateral view. The contents of the deep lateral cervical region are found in Fig. 37.33.



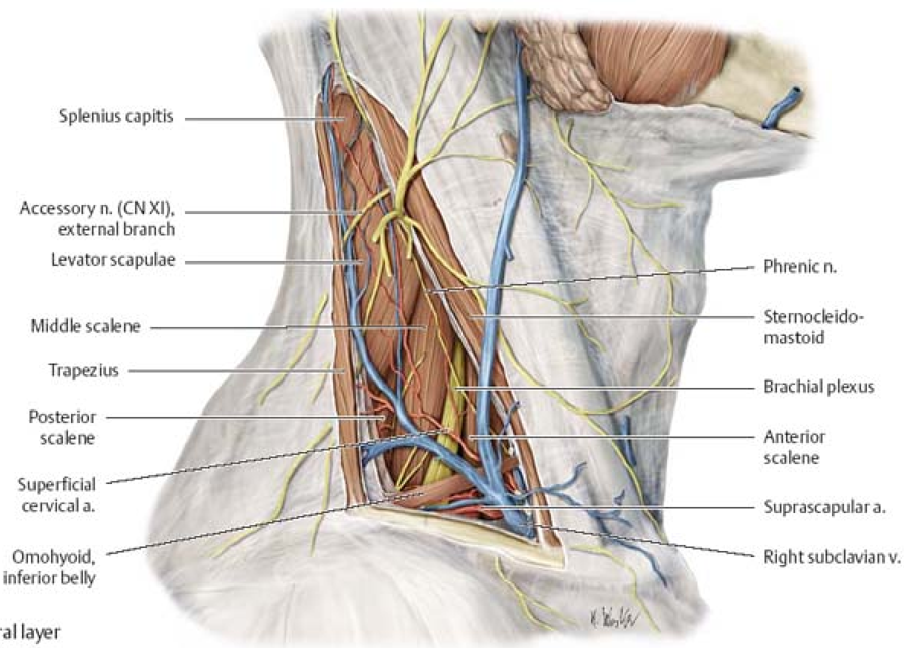
A Subcutaneous layer.



B Subfascial layer. *Removed:* Investing layer of deep cervical fascia.



C Deep layer. *Removed:* Pretracheal layer of deep cervical fascia. *Revealed:* Omohyoid, omoclavicular (subclavian) triangle.



D Deepest layer. *Removed:* Prevertebral layer of deep cervical fascia. *Revealed:* Muscular floor of posterior triangle, brachial plexus and phrenic nerve.

Topography of the Posterior Cervical Region

Fig. 37.35 Occipital and posterior cervical regions

Posterior view. Subcutaneous layer (left), subfascial layer (right). The occiput is technically a region of the head, but it is included here due to the continuity of the vessels and nerves from the neck.

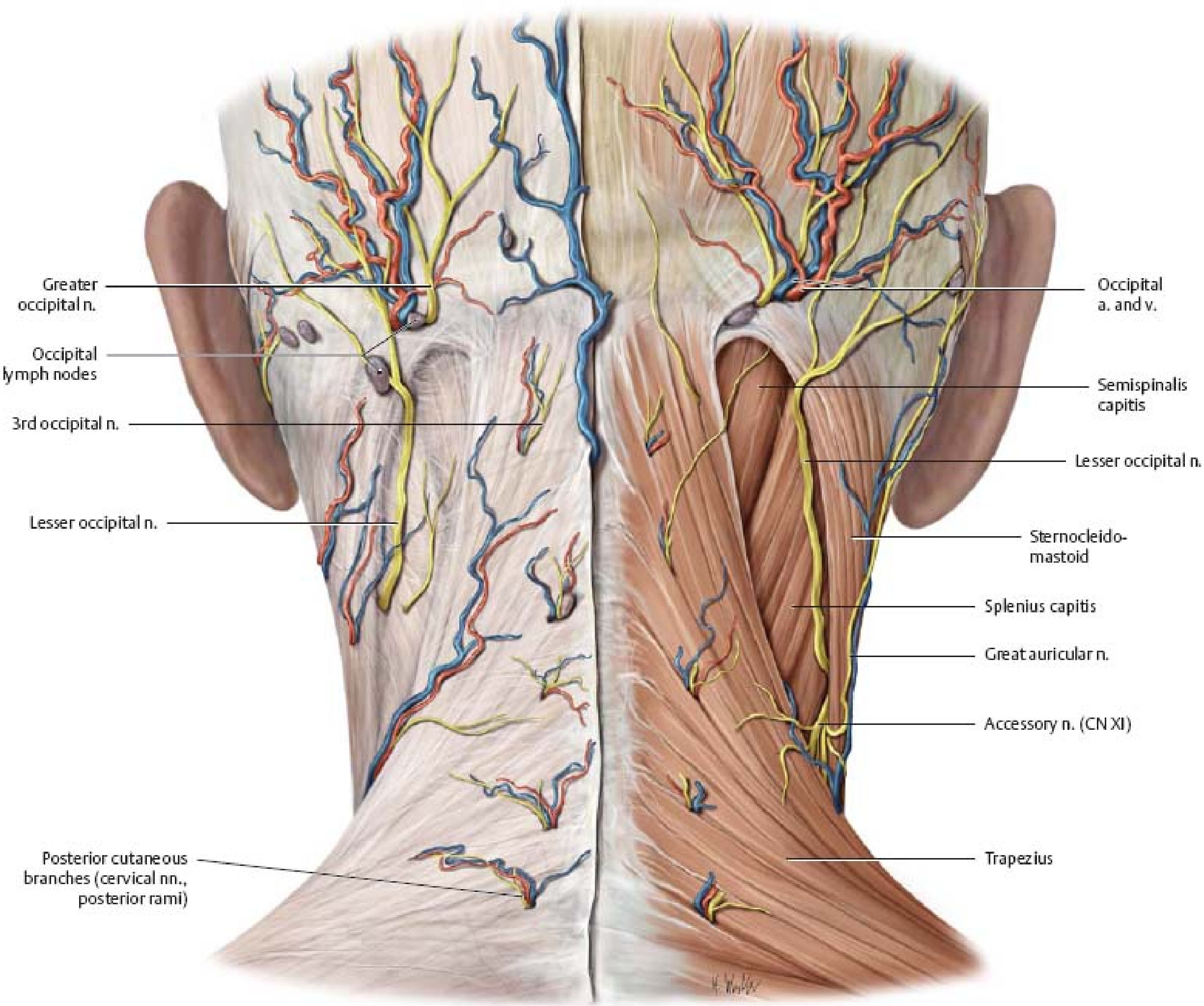
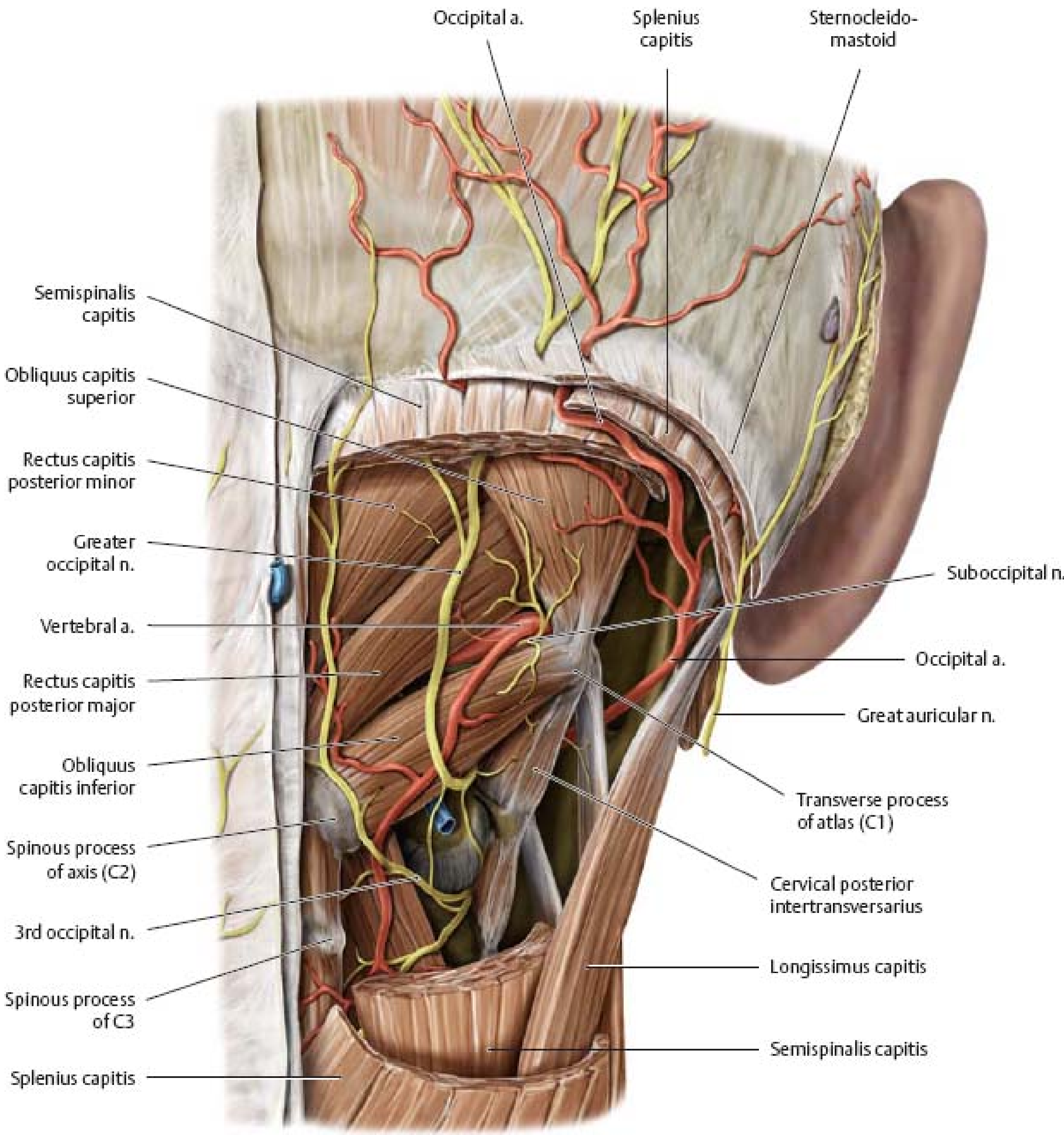


Fig. 37.36 Suboccipital triangle

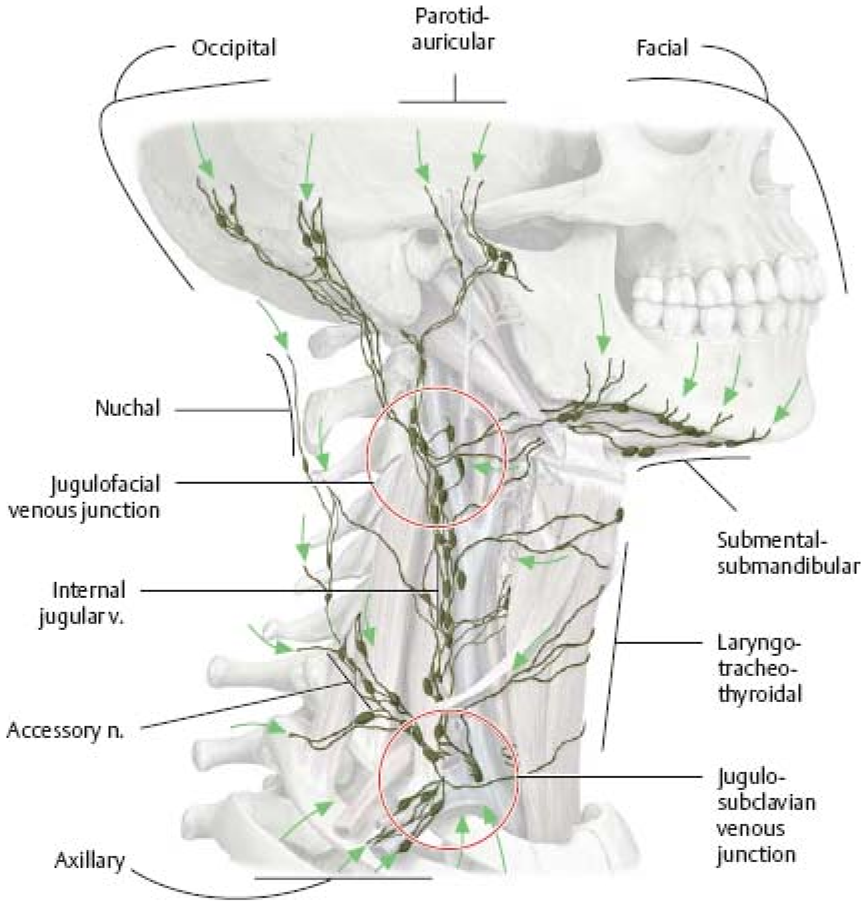
Right side, posterior view. The suboccipital triangle is bounded by the suboccipital muscles (rectus capitis posterior major and obliquus capitis superior and inferior) and contains the vertebral artery. The left and right vertebral arteries pass through the atlanto-occipital membrane and combine to form the basilar artery.



Lymphatics of the Neck

Fig. 37.37 Lymphatic drainage regions

Right lateral view.



Clinical

Tumor metastasis

Lymph from the entire body is channeled to the left and right jugulosubclavian junctions (red circles). Gastric carcinoma may metastasize to the left supraclavicular group of lymph nodes, producing an enlarged *sentinel node* (see pp. 73, 231). Systemic lymphomas may also spread to the cervical lymph nodes by this pathway.

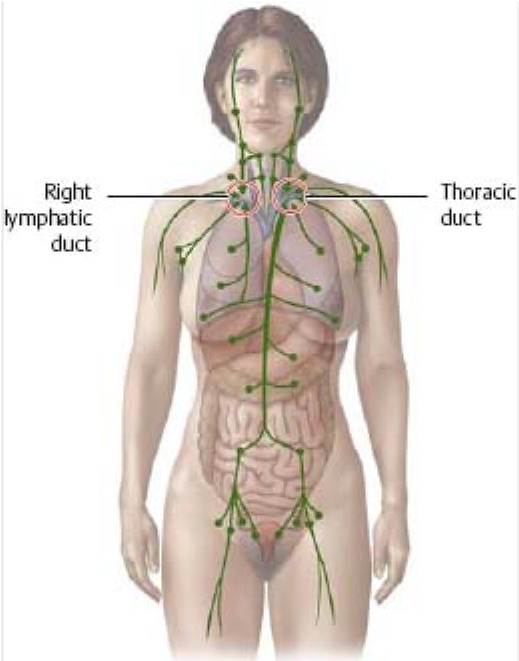


Fig. 37.38 Superficial cervical lymph nodes

Right lateral view.

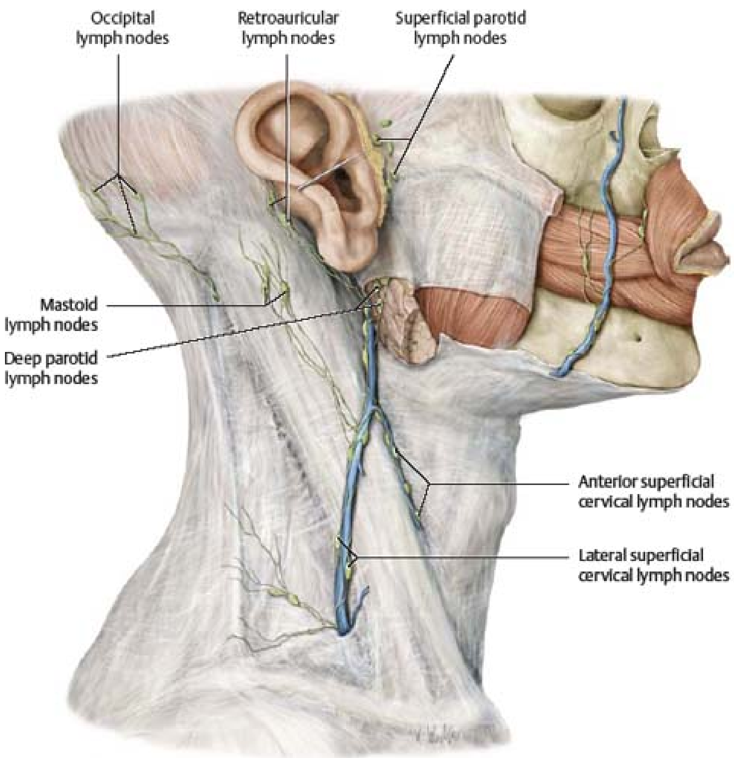


Table 37.13 Superficial cervical lymph nodes

Lymph nodes (l.n.)	Drainage region
Retroauricular l.n.	Occiput
Occipital l.n.	
Mastoid l.n.	
Superficial parotid l.n.	Parotid-auricular region
Deep parotid l.n.	
Anterior superficial cervical l.n.	Sternocleidomastoid region
Lateral superficial cervical l.n.	

Fig. 37.39 Deep cervical lymph nodes

Right lateral view.

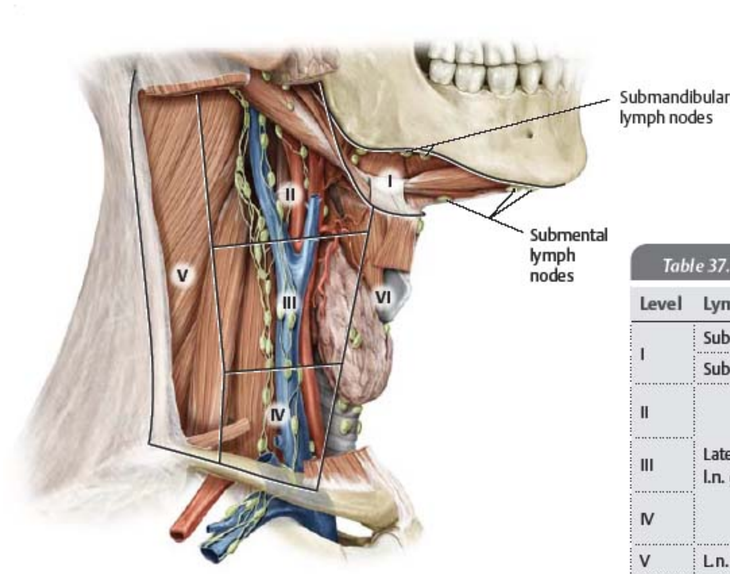


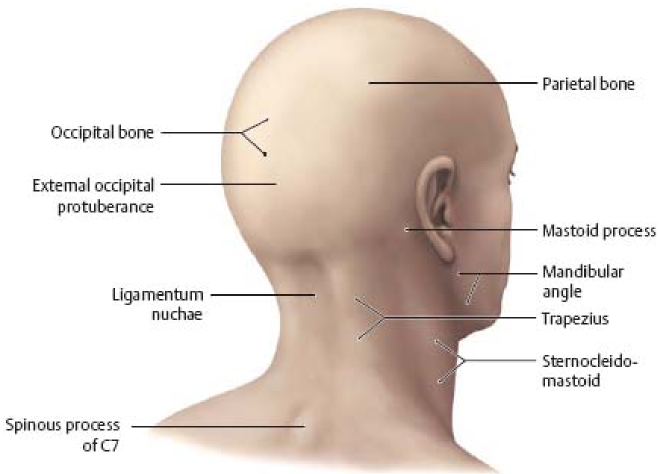
Table 37.14 Deep cervical lymph nodes

Level	Lymph nodes (l.n.)		Drainage region
I	Submental l.n.		Face
	Submandibular l.n.		
II	Lateral jugular l.n. group	Upper lateral group	Nuchal region, laryngo-tracheo-thyroidal region
III		Middle lateral group	
IV		Lower lateral group	
V	L.n. in posterior cervical triangle		Nuchal region
VI	Anterior cervical l.n.		Laryngo-tracheo-thyroidal region

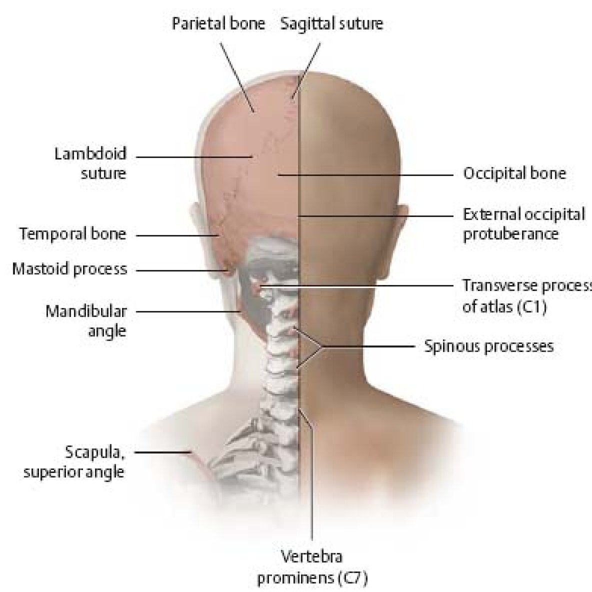
38 Surface Anatomy

Surface Anatomy

Fig. 38.1 Surface anatomy of the skull and nuchal region



A Surface anatomy. Right posterolateral view.

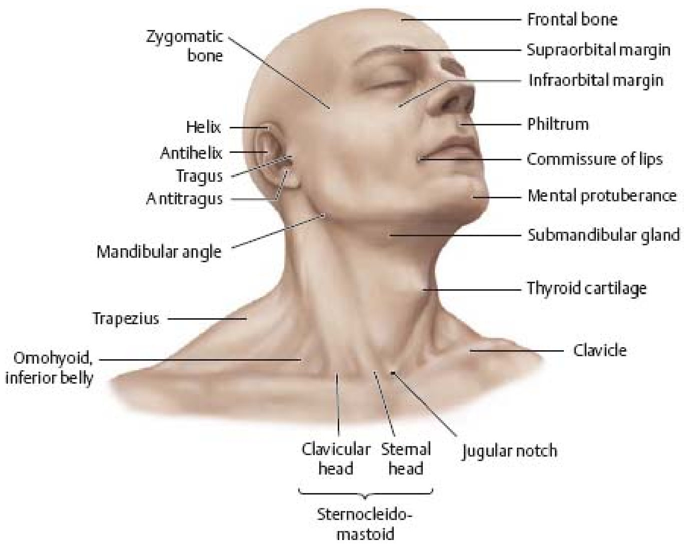


B Palpable bony prominences. Posterior view.

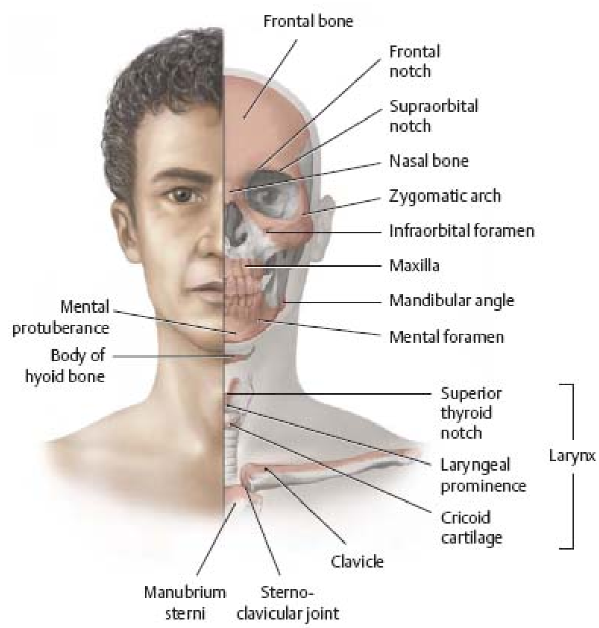
Q1: Injecting a bolus of anesthetic two thirds of the way up the posterior border of the sternocleidomastoid would accomplish what task?

Q2: What palpable bony landmark would you use to auscultate the venous blood in the confluence of the sinuses?

Fig. 38.2 Surface anatomy of the face and neck



A Surface anatomy. Right anterolateral view.



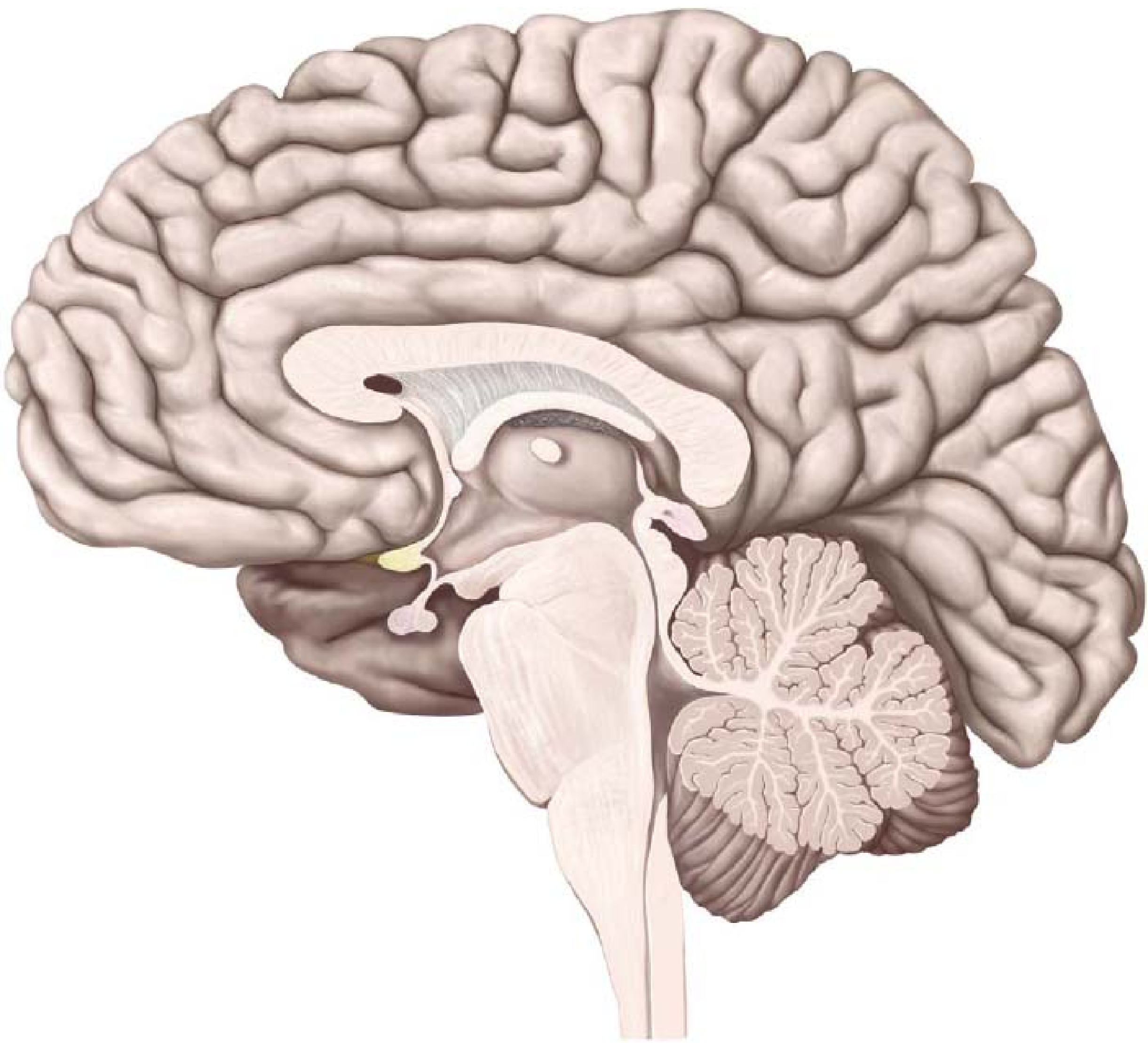
B Palpable bony prominences. Anterior view.

See answers beginning on p. 626.

Q3: What are the boundaries of the lateral cervical triangle (posterior triangle)? Name two structures within this region that supply motor innervation to the muscles of the upper limb.

Q4: What are the boundaries of the carotid triangle? Name one non-vascular component of the vertical neurovascular bundle within the carotid sheath located in the carotid triangle.

Q5: What is the anatomical structure referred to as the “Adam's apple”?



Neuroanatomy

39 Brain & Spinal Cord

Nervous System: Overview

Fig. 39.1 Central and peripheral nervous systems

The nervous system is divided into the central (CNS) and peripheral (PNS) nervous systems. The CNS consists of the brain and spinal cord, which comprise a functional unit. The PNS consists of the nerves emerging from the brain and spinal cord (cranial and spinal nerves, respectively).

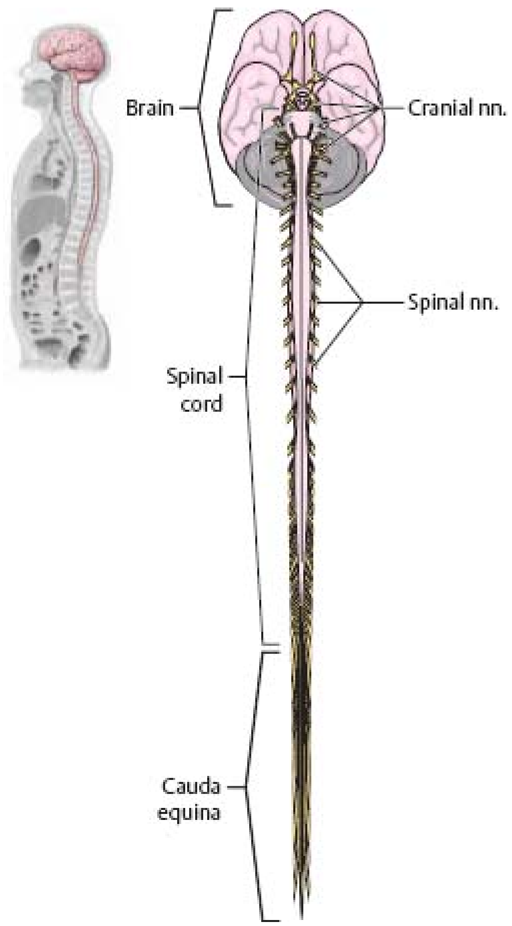


Fig. 39.2 Neurons (nerve cells)

The nervous system is composed of neurons (nerve cells) and supporting neuroglial cells, which vastly outnumber them (10 to 1). Each neuron contains a cell body (soma) with one axon (projecting segment) and one or more dendrites (receptor segments). The release of neurotransmitters at synapses creates an excitatory or inhibitory postsynaptic potential at the target neuron. If this exceeds the depolarization threshold of the neuron, the axon “fires,” initiating the release of a transmitter from its presynaptic knob (bouton).

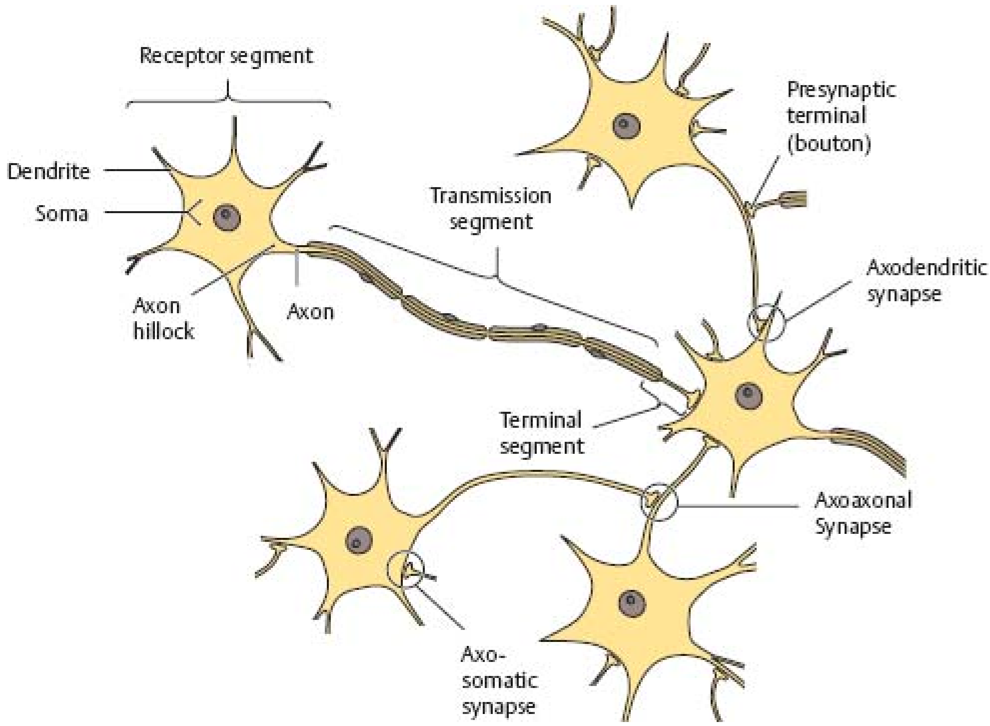


Fig. 39.3 **Myelination**

Certain glial cells with lipid-rich membranes may myelinate axons (nerve fibers). Myelination electrically insulates axons, thereby increasing impulse conduction speed. In the CNS, one oligodendrocyte myelinates multiple axons; in the PNS, one Schwann cell myelinates one axon.

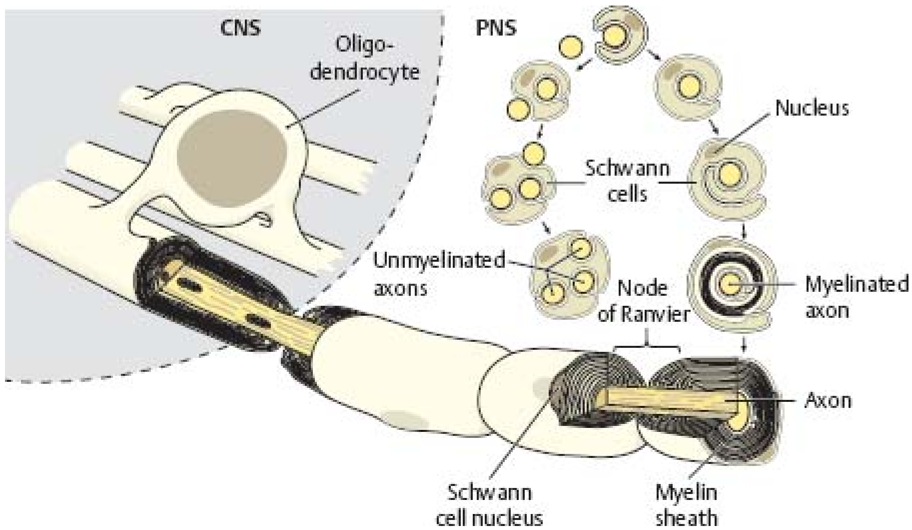
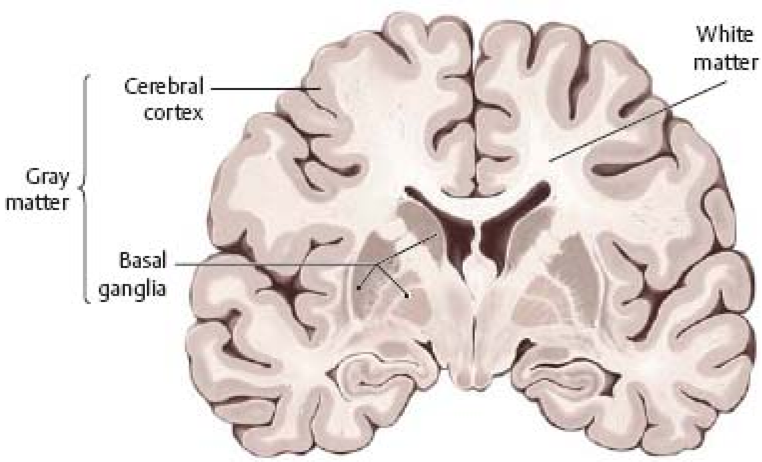
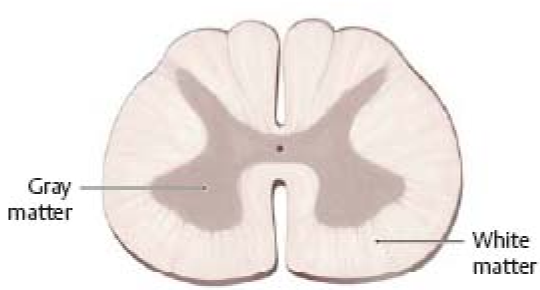


Fig. 39.4 **Gray and white matter in the CNS**

Nerve cell bodies appear gray in gross inspection, whereas nerve cell processes (axons) and their insulating myelin sheaths appear white.



A Coronal section through the brain.



B Transverse section through the spinal cord.

Table 39.1 Development of the brain

	Primary vesicle	Region			Structure
Neural tube	Pros-encephalon (forebrain)	Telencephalon (cerebrum)			Cerebral cortex, white matter, and basal ganglia
		Diencephalon			Epithalamus (pineal), dorsal thalamus, subthalamus, and hypothalamus
	Mesencephalon (midbrain)*				Tectum, tegmentum, and cerebral peduncles
	Rhombencephalon (hindbrain)	Metencephalon	Cerebellum		Cerebellar cortex, nuclei, and peduncles
			Pons*		Nuclei and fiber tracts
		Myelencephalon	Medulla oblongata*		

* The mesencephalon, pons, and medulla oblongata are collectively known as the brainstem.

Fig. 39.5 Embryonic development of the brain

Left lateral view.

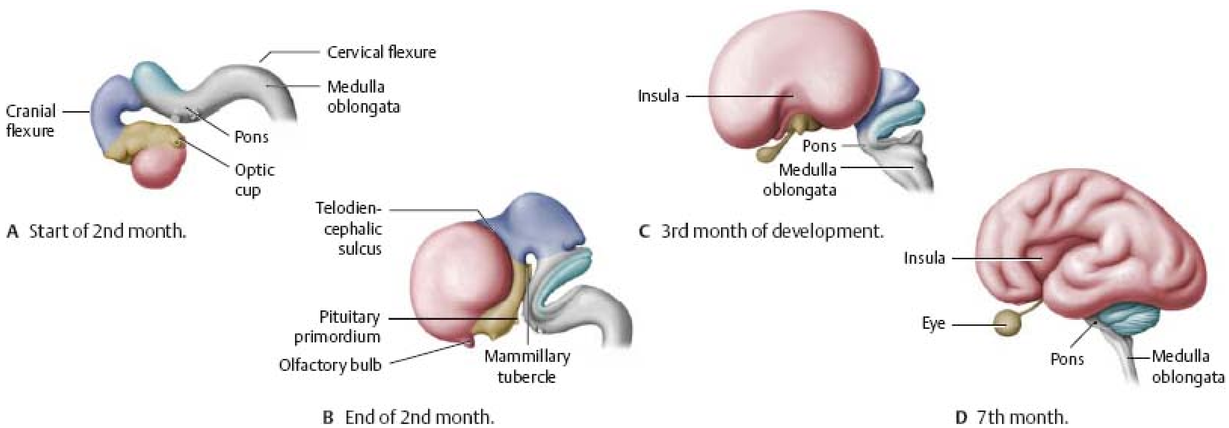
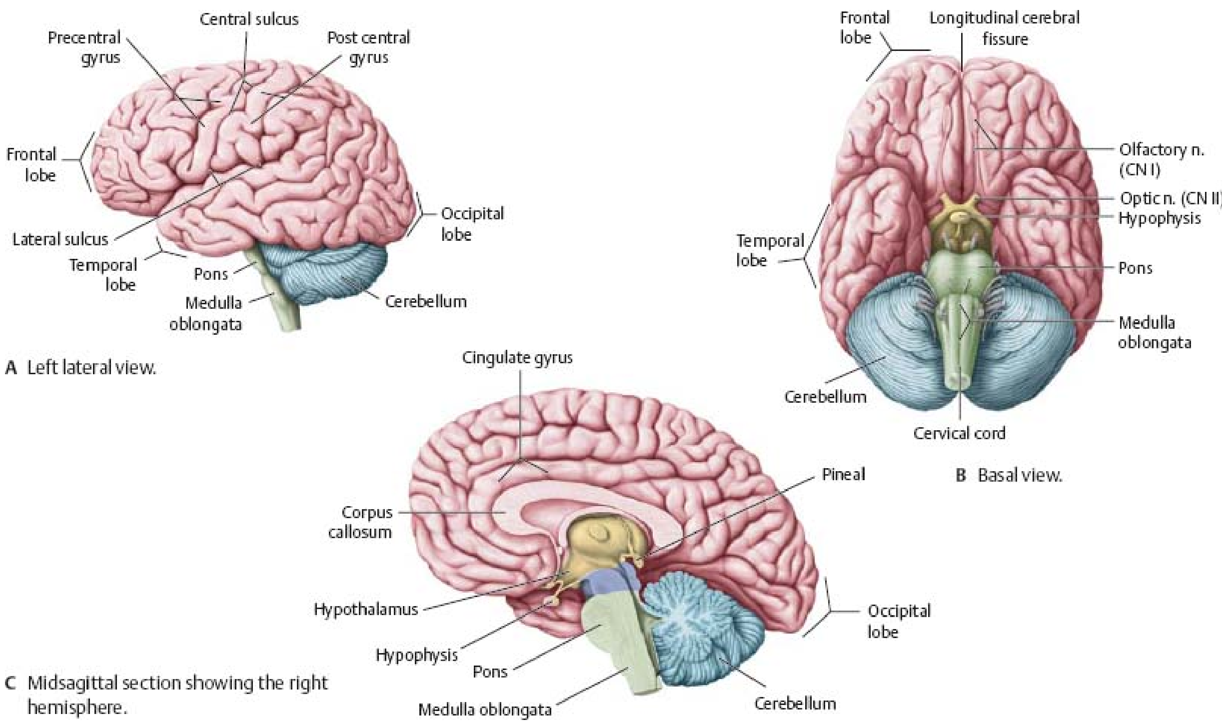


Fig. 39.6 Adult brain

See Fig. 39.12 for lobes of the cerebrum. CN = cranial nerve.



Telencephalon

Fig. 39.7 Divisions of the telencephalon

Coronal section, anterior view. The telencephalon is divided into the cerebral cortex, white matter, and basal ganglia. The cerebral cortex is further divided into the allocortex and isocortex (neocortex).

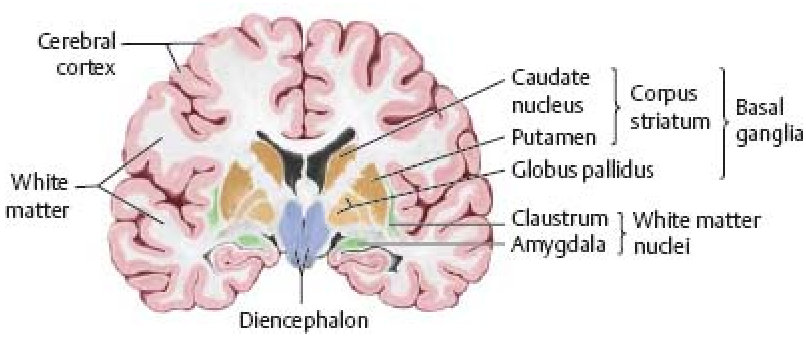
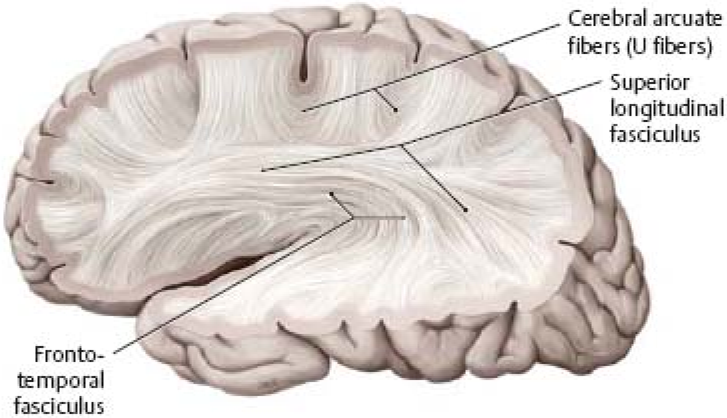
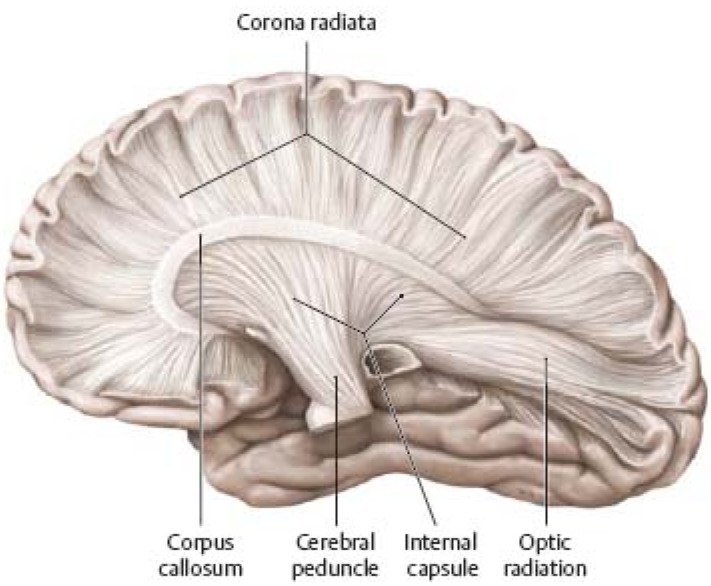


Fig. 39.8 White matter

A special preparation technique was used to show the fiber structure of the superficial layer of white matter.



A Lateral view of left hemisphere.



B Medial view of right hemisphere.

Fig. 39.9 **Basal ganglia**

Transverse section, superior view. The basal ganglia are an essential component of the motor system (see p. 615).

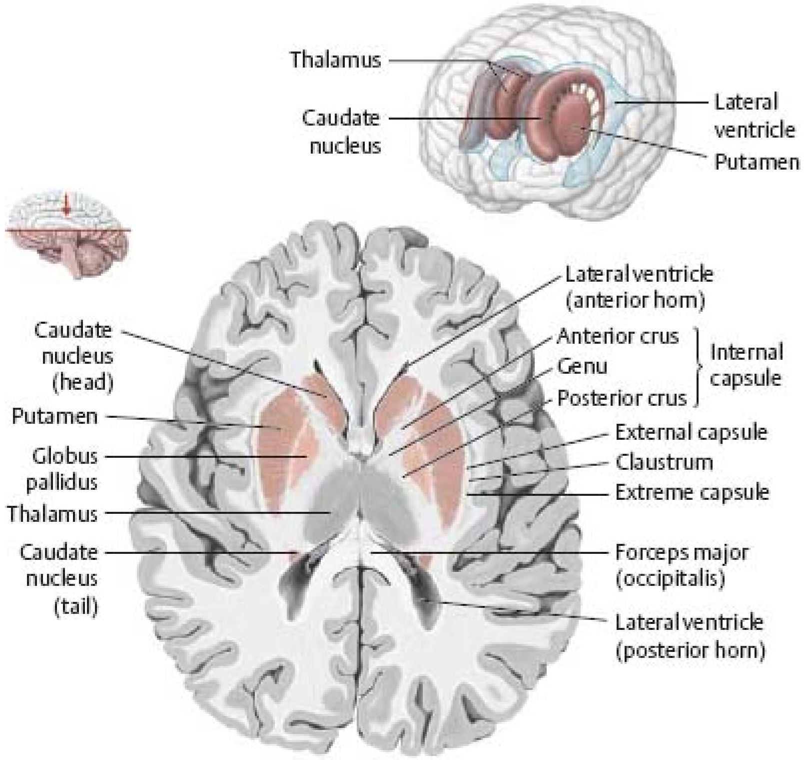


Fig. 39.10 Allocortex

The three-layered allocortex consists of the olfactory cortex (blue) and the hippocampus (pink).

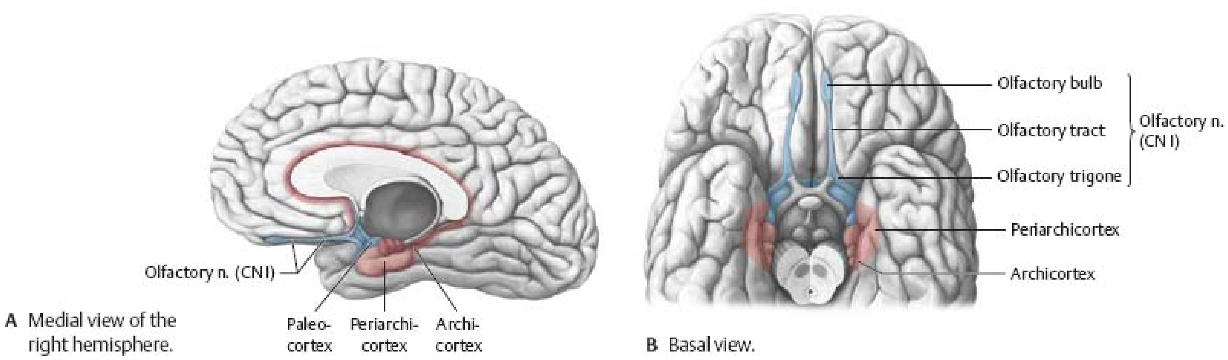
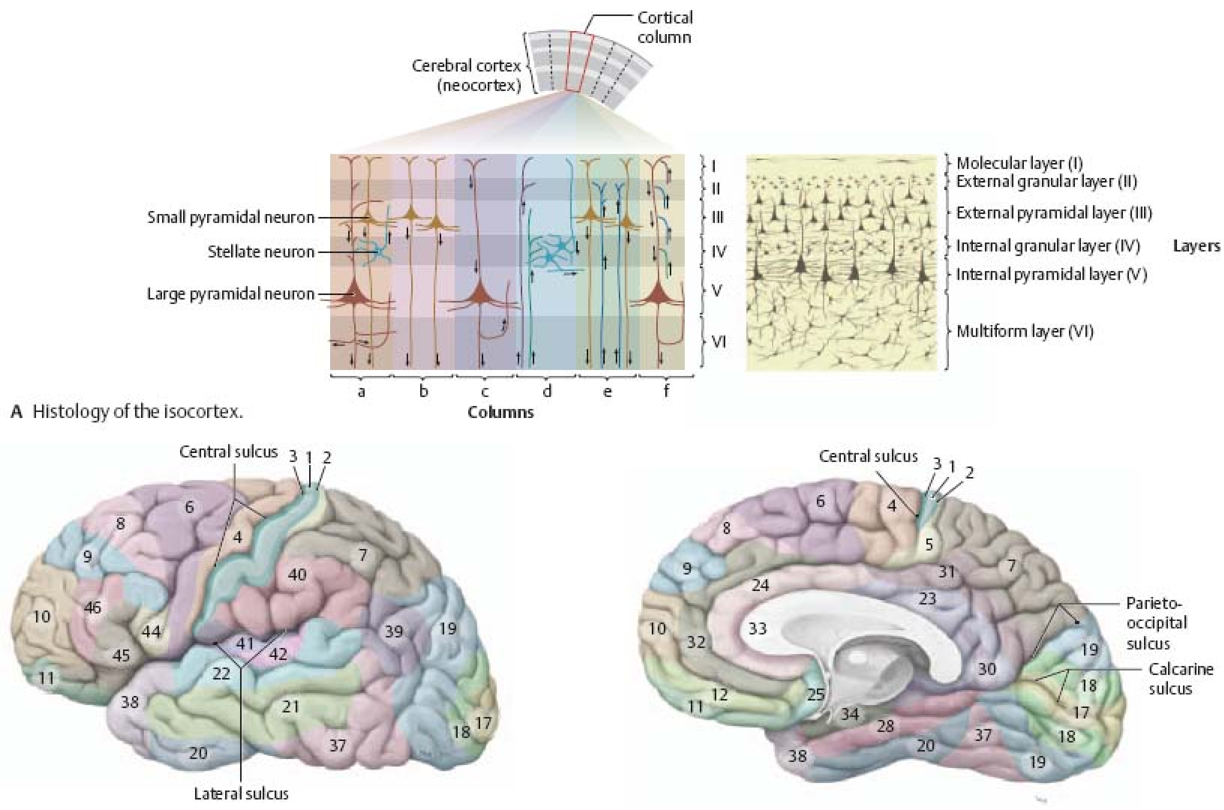


Fig. 39.11 Isocortex: Columnar organization

Morphological considerations divide the isocortex into six horizontal layers; functional considerations divide it into cortical columns.



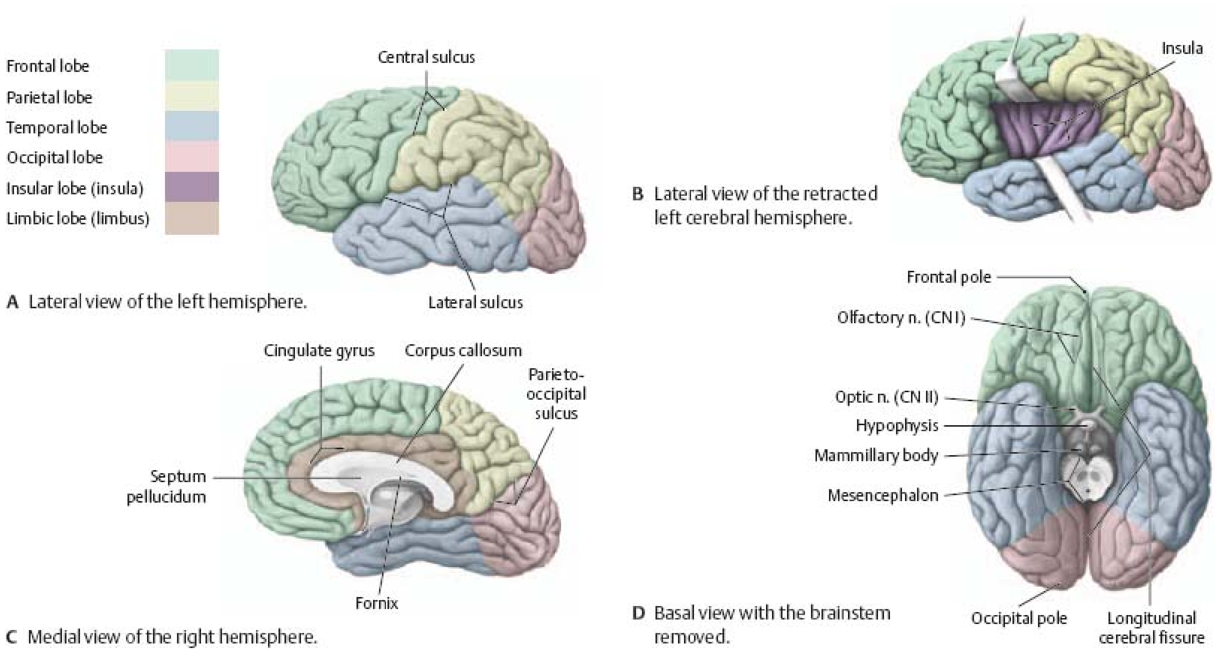
A Histology of the isocortex.

B Brodmann (cortical) areas, lateral view of the left cerebral hemisphere.

C Brodmann (cortical) areas, medial view of the right cerebral hemisphere.

Fig. 39.12 Lobes in the cerebral hemispheres

The isocortex also may be functionally divided into association areas (lobes).



A Lateral view of the left hemisphere.

B Lateral view of the retracted left cerebral hemisphere.

C Medial view of the right hemisphere.

D Basal view with the brainstem removed.

Telencephalon & Diencephalon

Fig. 39.13 Hippocampal formation

The hippocampus, fornix, and amygdala are the major components of the limbic system (see p. 621).

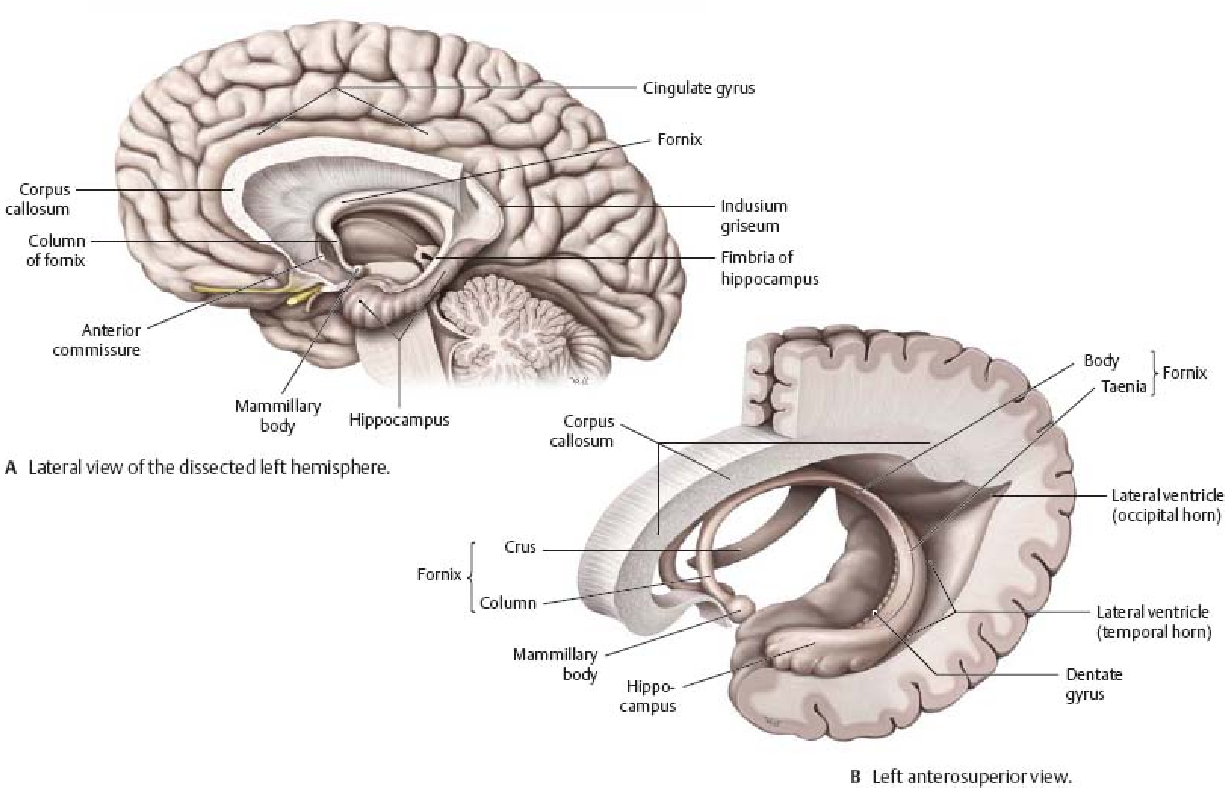
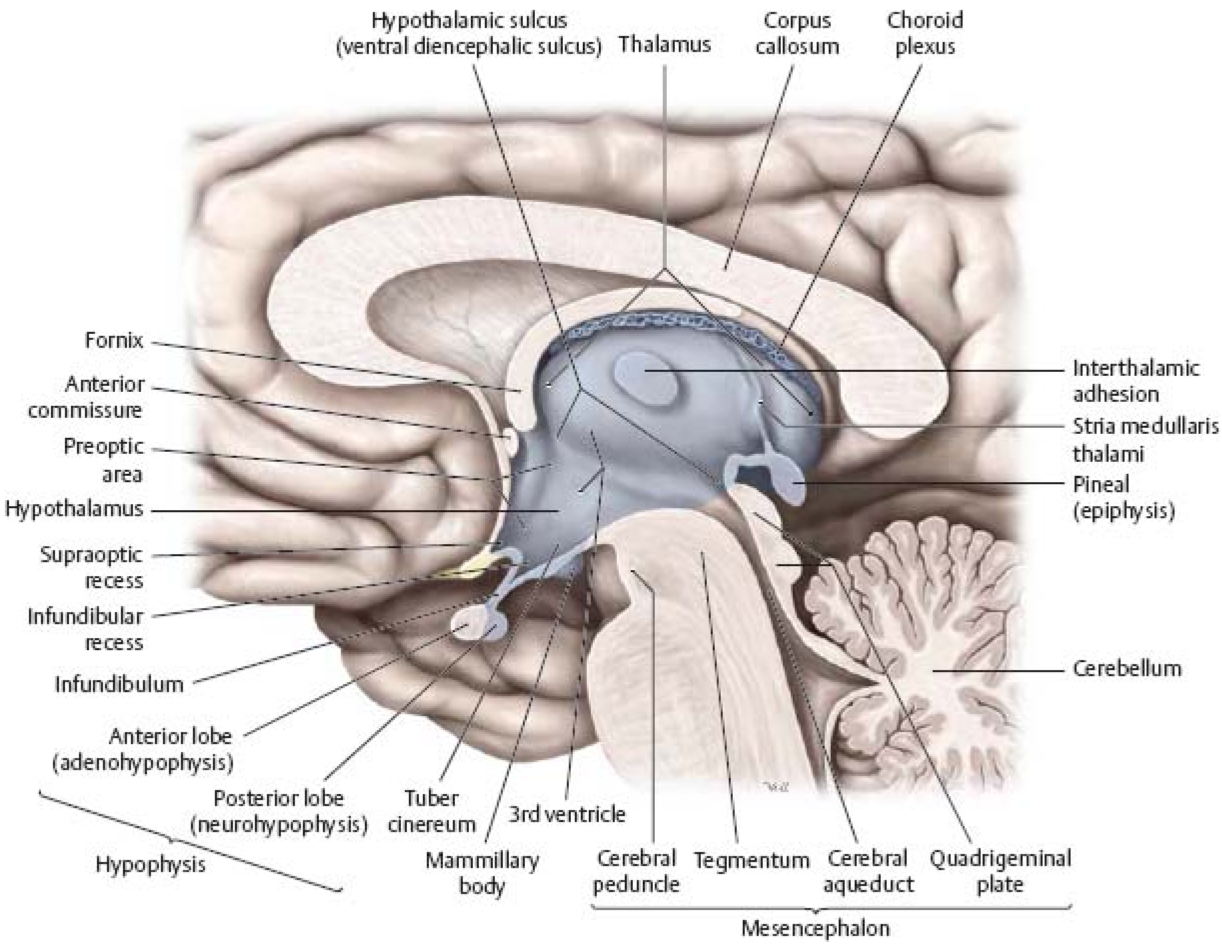


Fig. 39.14 Diencephalon

Midsagittal section, medial view of the right hemisphere. The major components of the diencephalons are the thalamus, hypothalamus, and hypophysis (anterior lobe). See p. 598 for the extracted diencephalon.



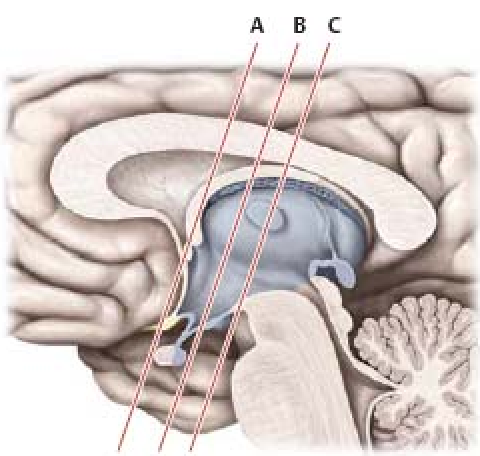
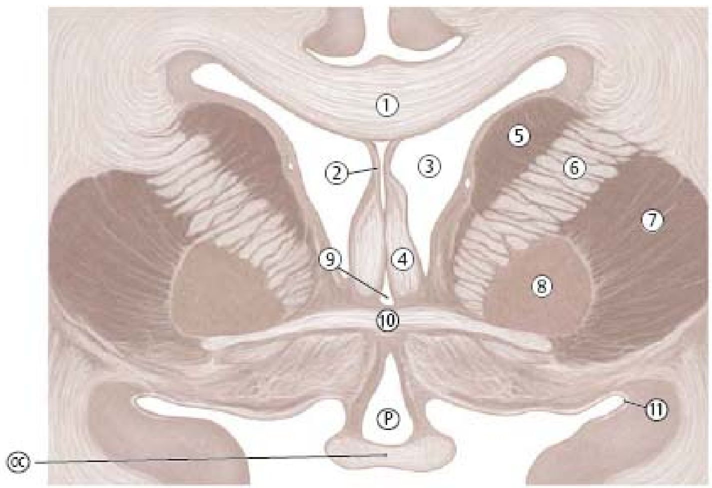
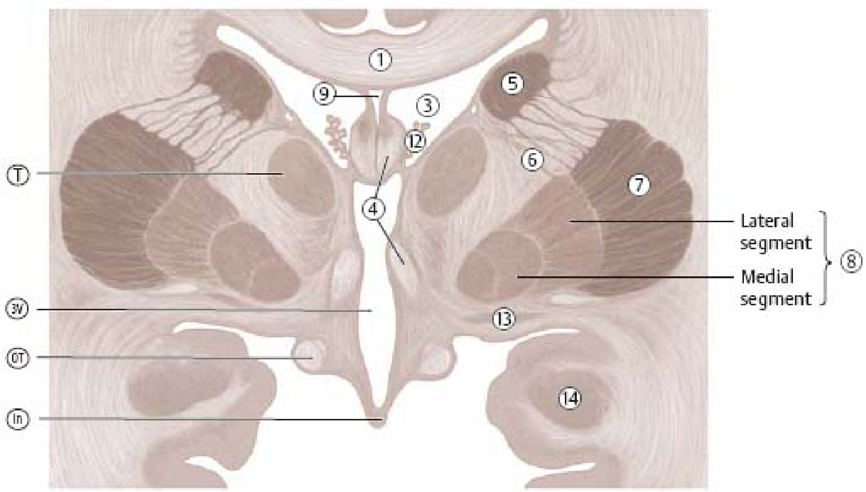


Fig. 39.15 **Telencephalon and diencephalon: Internal structure**

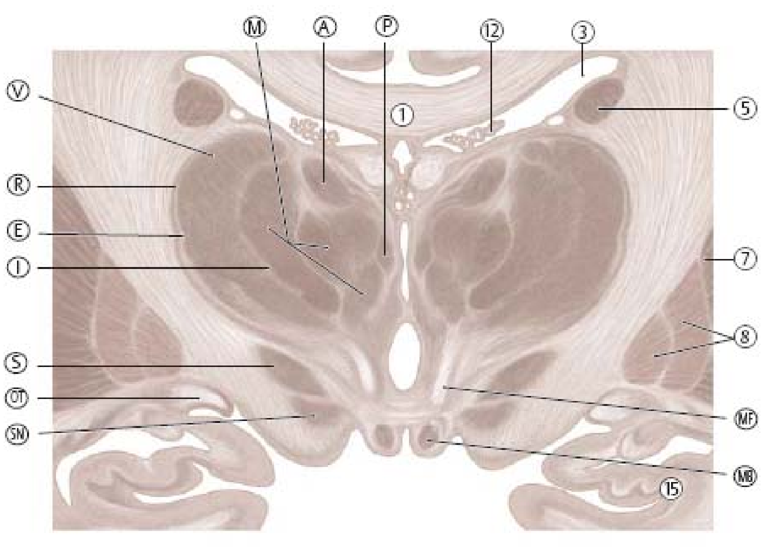
Coronal section.



A Level of the optic chiasm.



B Level of the tuber cinereum.



C Level of the mammillary bodies.

Table 39.2	Structures of the diencephalon		
Ⓟ	Preoptic recess		
Ⓞⓒ	Optic chiasm		
③Ⓥ	3rd ventricle		
ⓄⓉ	Optic tract		
Ⓘⓝ	Infundibulum		
Ⓣ	Thalamus (with thalamic nuclei):		
		Ⓡ	Reticular nucleus of thalamus
		Ⓔ	External medullary lamina
		Ⓥ	Ventrolateral thalamic nuclei
		Ⓘ	Internal medullary lamina
		Ⓜ	Medial thalamic nuclei
		Ⓐ	Anterior thalamic nuclei
		Ⓟ	Paraventricular nuclei
Ⓢ	Subthalamic nucleus		
ⓈⓃ*	Substantia nigra		
ⓂⒻ	Mammillothalamic fasciculus		
ⓂⒷ	Mammillary body		

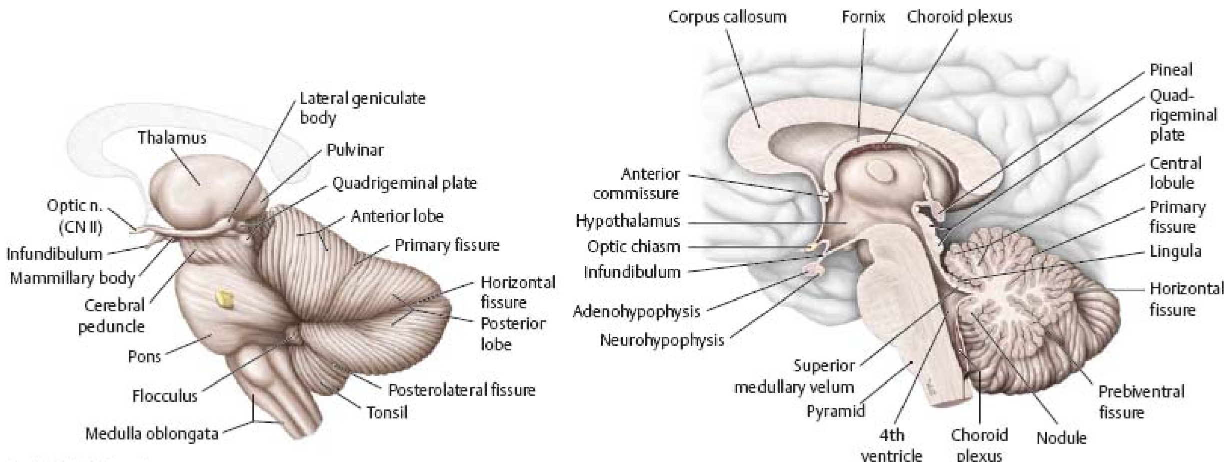
*Actually a structure of the mesencephalon.

Table 39.3	Structures of the telencephalon
①	Corpus callosum
②	Septum pellucidum
③	Lateral ventricle
④	Fornix
⑤	Caudate nucleus
⑥	Internal capsule
⑦	Putamen
⑧	Globus pallidus
⑨	Cavum septi pellucidi
⑩	Anterior commissure
⑪	Lateral olfactory stria
⑫	Choroid plexus
⑬	Basal ganglia
⑭	Amygdala
⑮	Hippocampus

Diencephalon, Brainstem & Cerebellum

Fig. 39.16 Diencephalon, brainstem, and cerebellum

Left lateral view.



A Isolated structures.

B Midsagittal section.

Fig. 39.17 Cerebellum

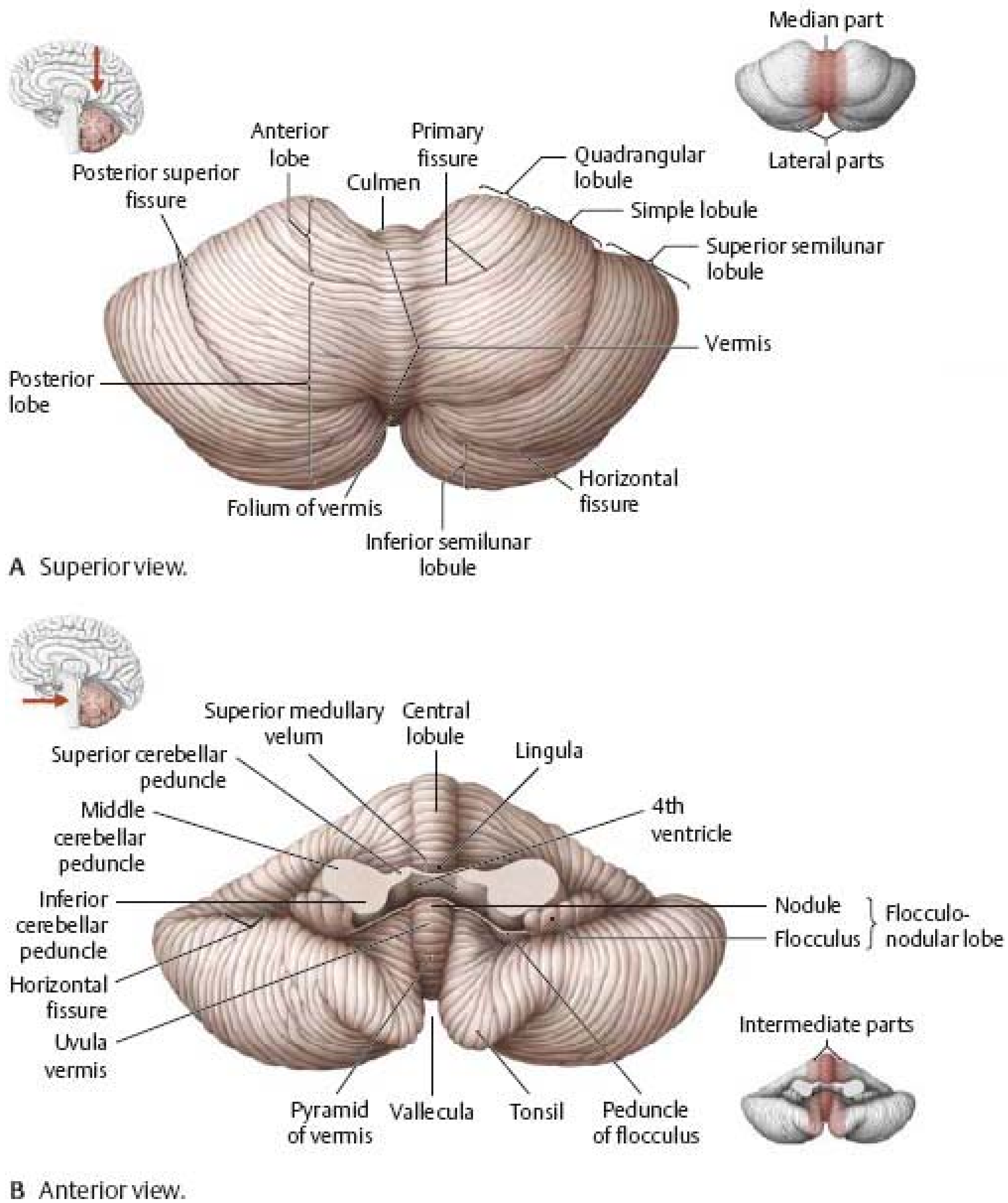


Fig. 39.18 Cerebellar peduncles

Tracts of afferent (sensory) or efferent (motor) axons enter or leave the cerebellum through cerebellar peduncles. Afferent axons originate in the spinal cord, vestibular organs, inferior olive, and pons. Efferent axons originate in the cerebellar nuclei.

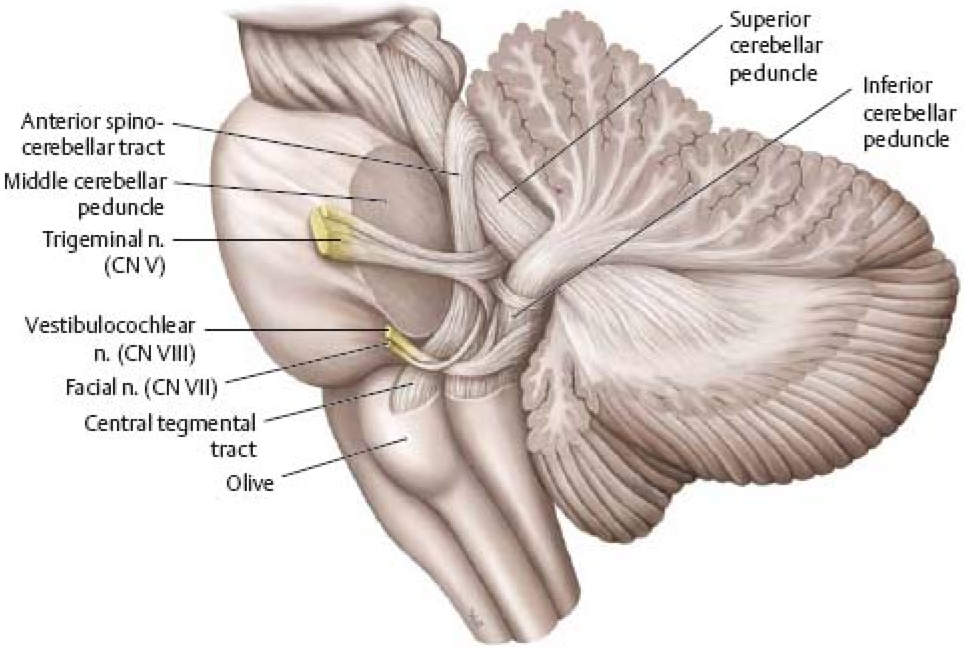
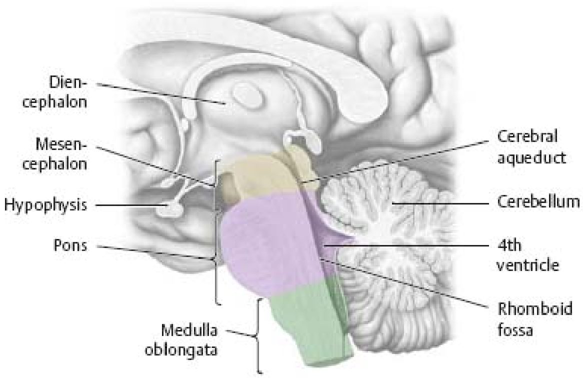
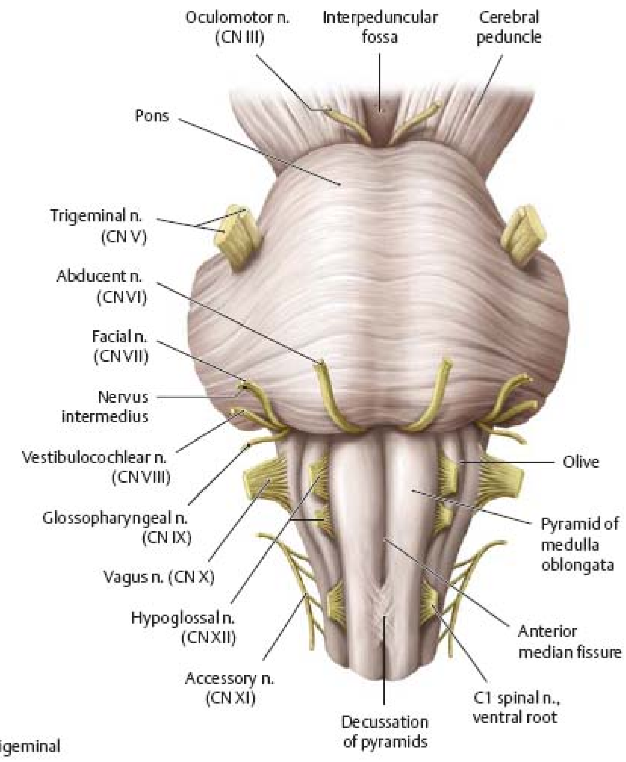


Fig. 39.19 **Brainstem**

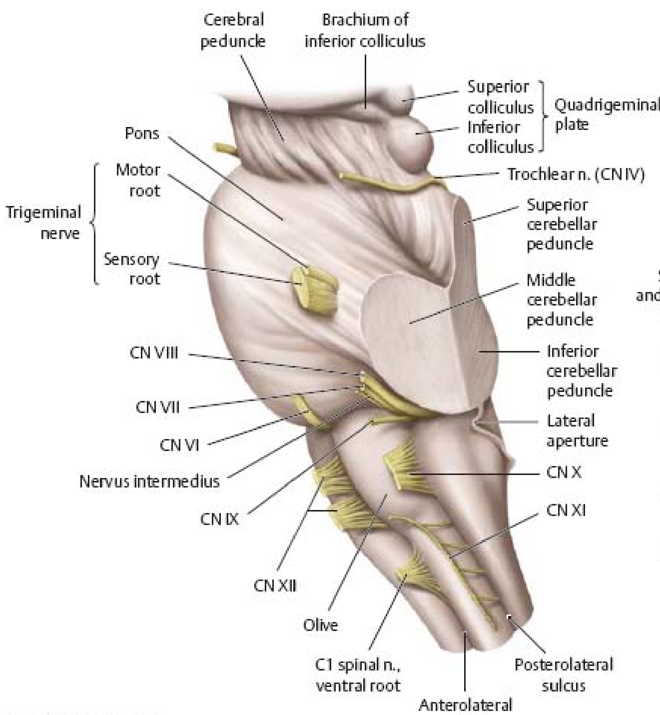
The brainstem is the site of emergence and entry of the 10 pairs of true cranial nerves (CN III-XII). See p. 470 for an overview of the cranial nerves and their nuclei.



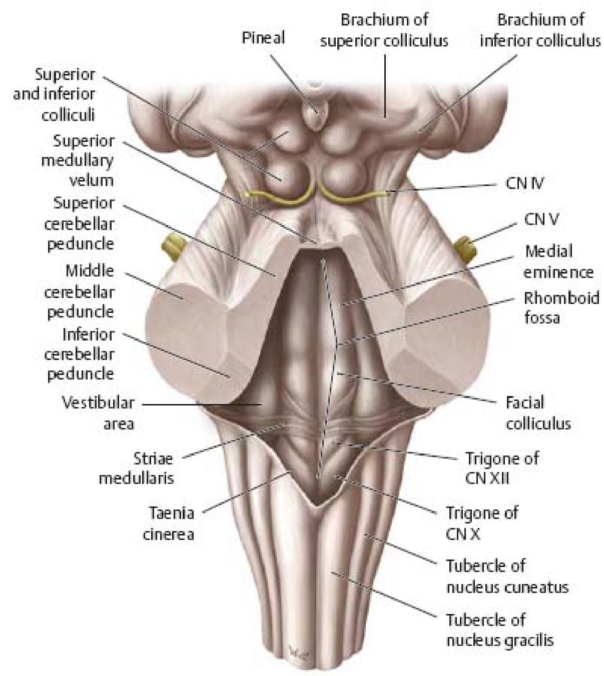
A Levels of the brainstem.



B Anterior view.



C Left lateral view.

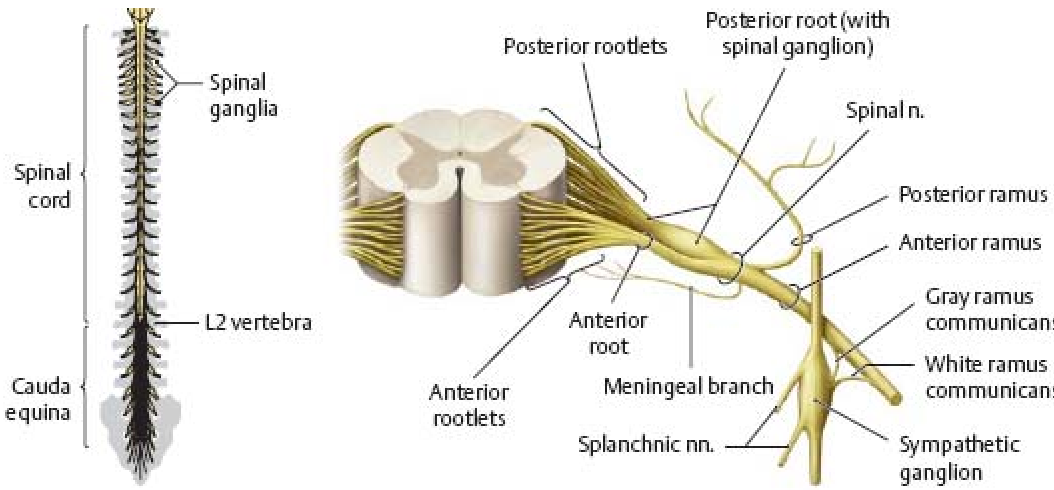


D Posterior view.

Spinal Cord

Fig. 39.20 Spinal cord and segments

The spinal cord consists of 31 segments innervating a specific area in the trunk or limbs (see Fig. 39.22). Afferent (sensory) posterior rootlets and efferent (motor) anterior rootlets form the posterior and anterior roots, respectively. The two roots fuse to form a mixed spinal nerve, which then divides into various branches.



A Spinal cord, posterior view. **B** Spinal cord segment, anterior view.

Fig. 39.21 Spinal cord in situ

Posterior view with vertebral canal windowed.

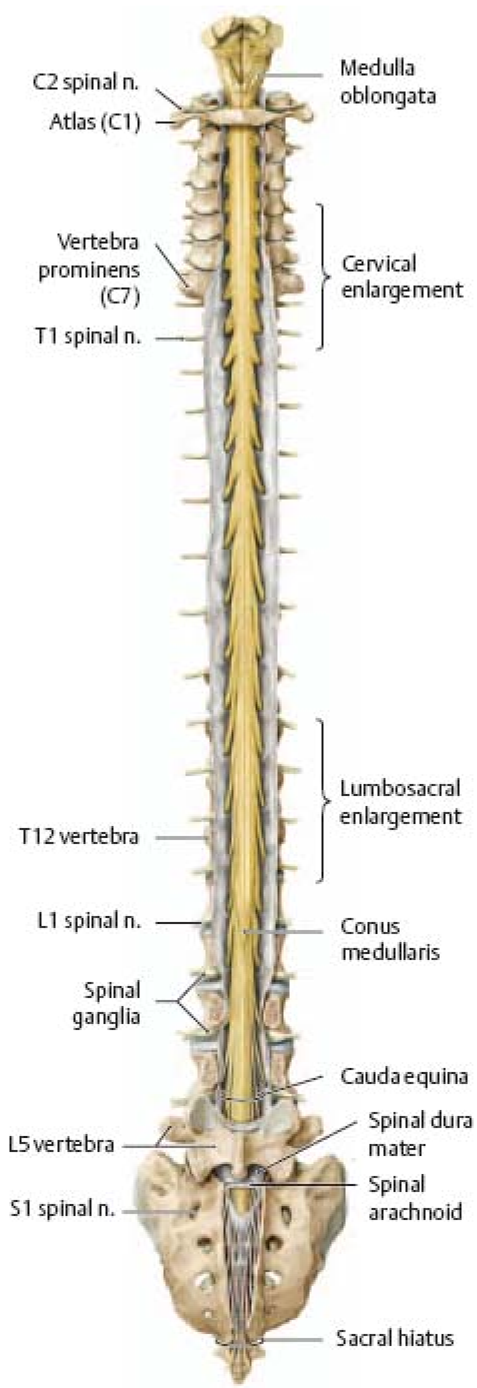
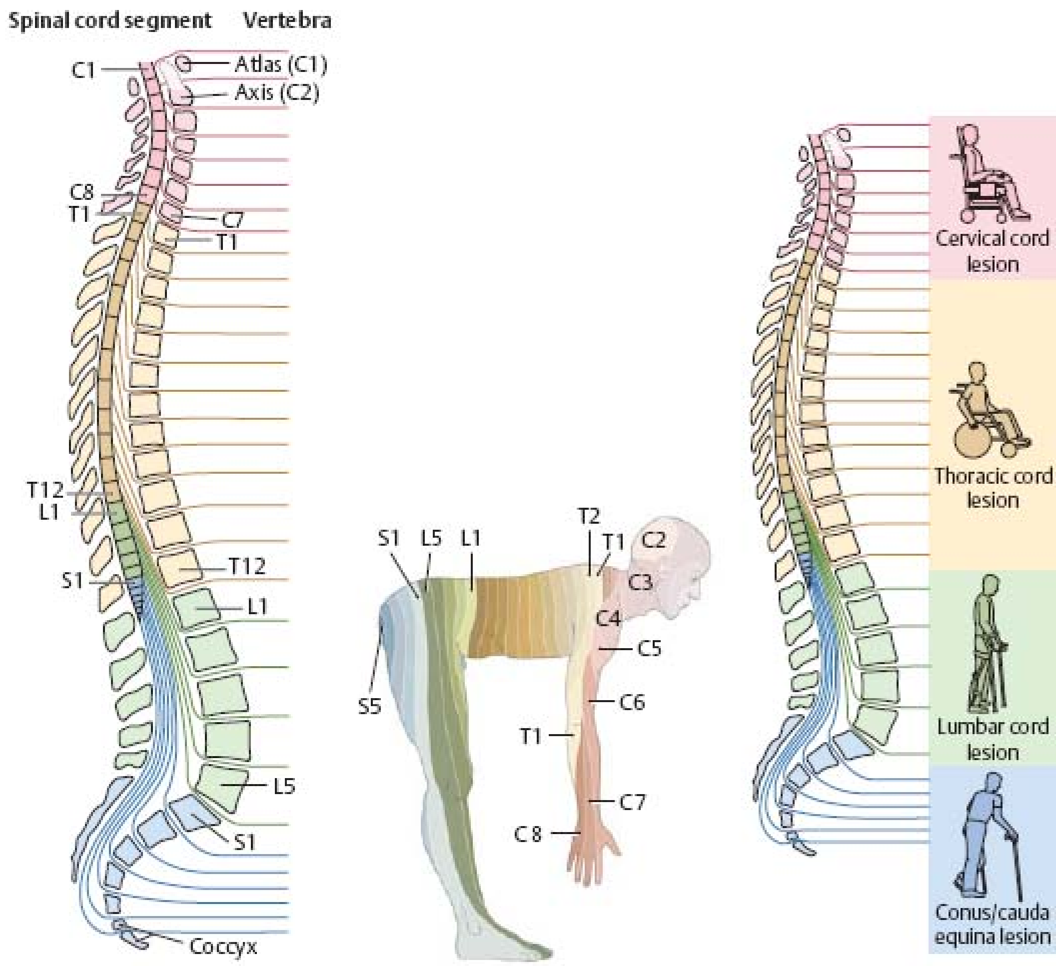


Fig. 39.22 **Segmental innervation and spinal cord lesions**

The spinal cord is divided into four major regions: cervical, thoracic, lumbar, and sacral. Spinal cord segments are numbered by the exit points of their associated spinal nerves. (*Note:* This does not necessarily correlate numerically with the nearest skeletal element.)



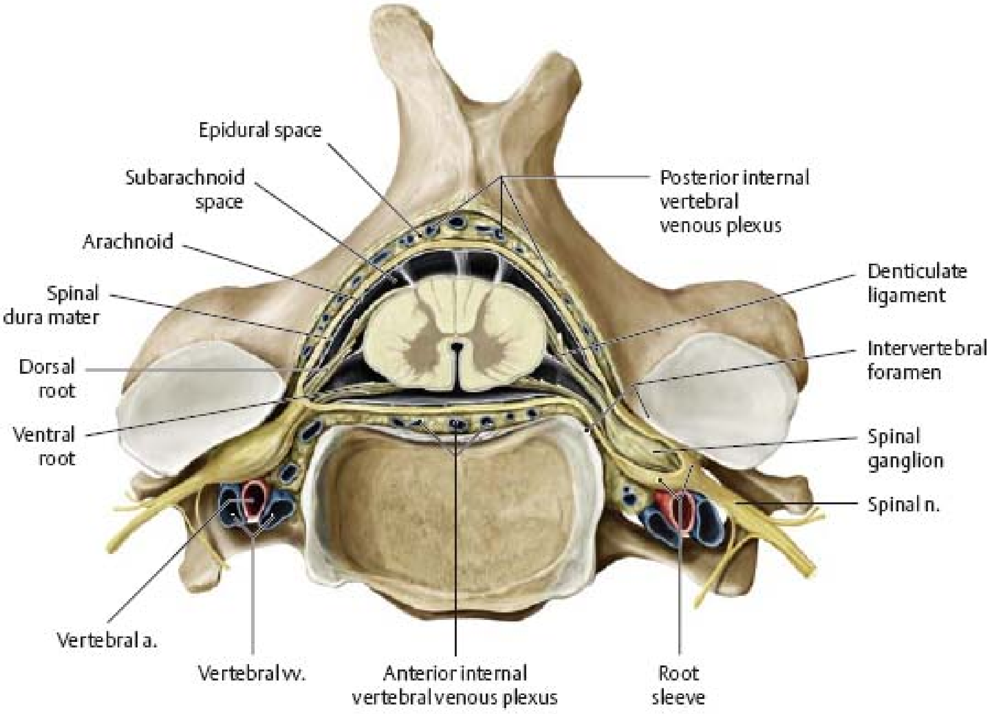
A Spinal cord segments.

B Dermatomes. Each spinal cord segment innervates a particular skin area (dermatome).

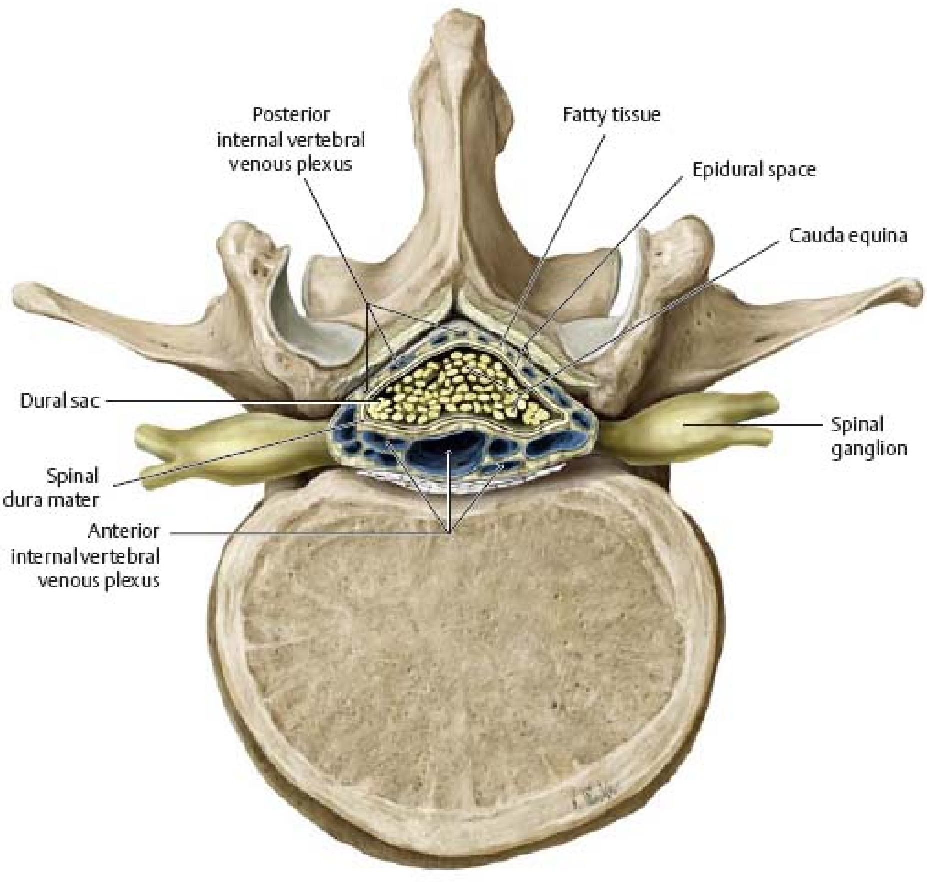
C Spinal cord lesions.

Fig. 39.23 **Spinal cord in situ: Transverse section**

Superior view.



A Spinal cord at level of C4 vertebra.

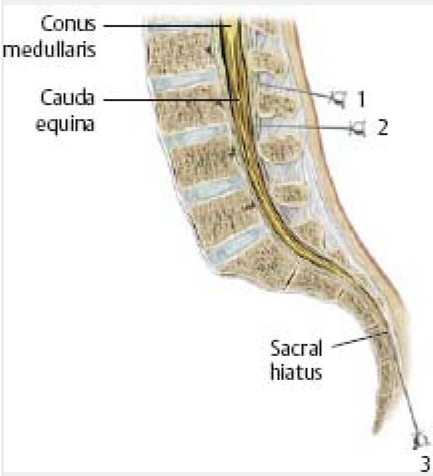


B Cauda equina at level of L2 vertebra.

Clinical

Lumbar puncture

A needle introduced into the dural sac (lumbar cistern) generally slips past the spinal nerve roots without injuring the spinal cord. Cerebro-spinal fluid (CSF) samples are therefore taken between the L3 and L4 vertebrae (2), once the patient has leaned forward to separate the spinous processes of the lumbar spine.

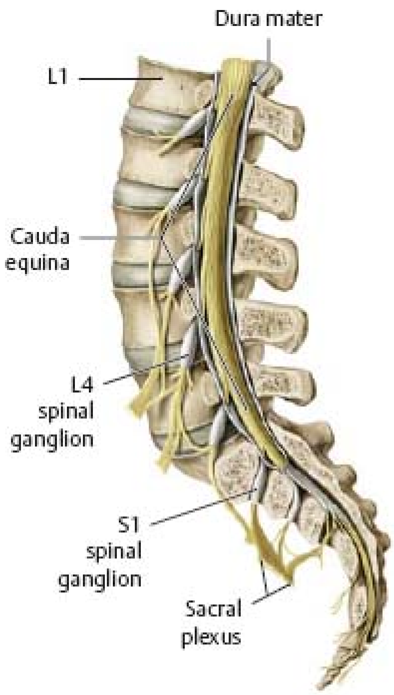


Anesthesia

Lumbar anesthesia may be administered in a similarfashion (2). Epidural anesthesia is administered by placing a catheter in the epidural space without penetrating the dural sac (1). This may also be done by passing a needle through the sacral hiatus (3).

Fig. 39.24 Cauda equina

In adults, the spinal cord ends at approximately the level of L1. Below this, ventral and dorsal roots course through the vertebral canal, uniting in the intervertebral foramen to form the spinal nerve (see p. 36).



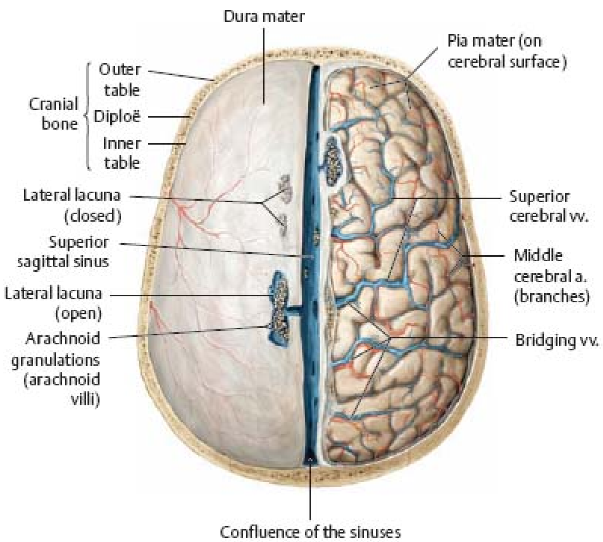
Meninges

The brain and spinal cord are covered by membranes called meninges. The meninges are composed of three layers: dura mater (dura), arachnoid (arachnoid membrane), and pia mater.

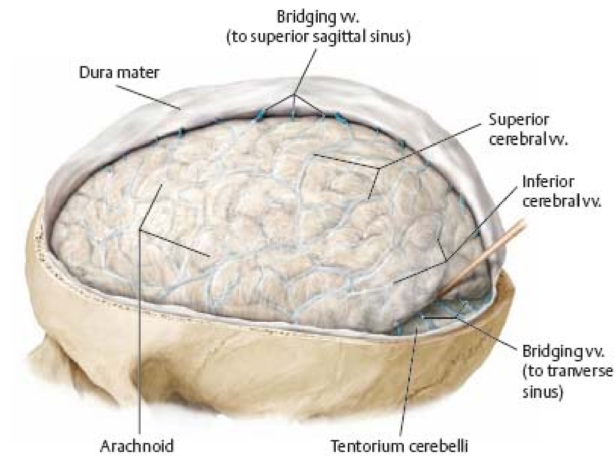
The subarachnoid space, located between the arachnoid and pia, contains cerebrospinal fluid (CSF, see p. 604). See p. 601 for the coverings of the spinal cord.

Fig. 39.25 Meninges

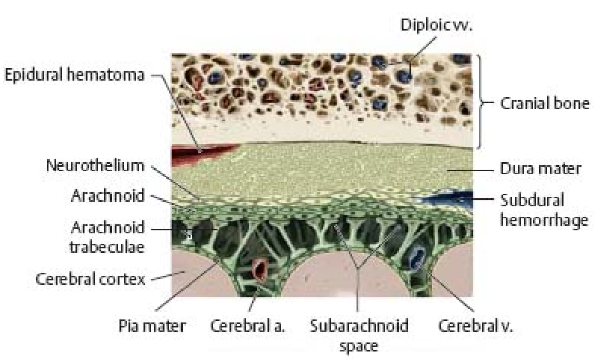
See p. 606 for the veins of the brain.



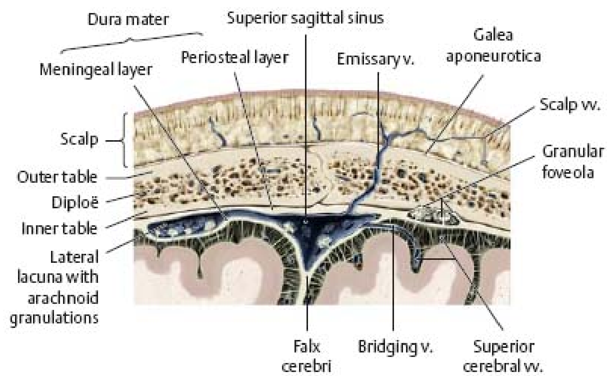
A Superior view. Left side: Dura mater (outer layer). Right side: Pia mater (inner layer). Arachnoid granulations (protrusions of the arachnoid) are sites for reabsorption of CSF.



B Arachnoid (middle layer), left anterior oblique view.



C Layers of the meninges, coronal section, anterior view.

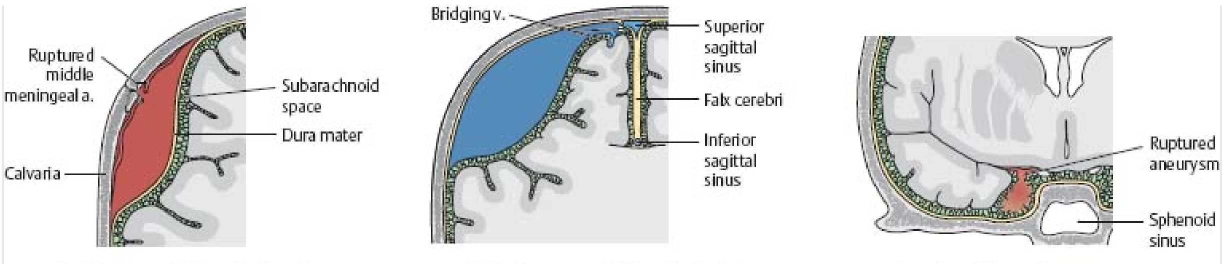


D Dura mater and calvarium, coronal section, anterior view.

Clinical

Extracerebral hemorrhages

Bleeding between the bony calvarium and the soft tissue of the brain (extracerebral hemorrhage) exerts pressure on the brain. A rise of intracranial pressure may damage brain tissue both at the bleeding site and in more remote brain areas. Three types of intracranial hemorrhage are distinguished based on the relationship to the dura mater. See p. 608 for the arteries of the brain.



A Epidural hematoma (above the dura).

B Subdural hematoma (below the dura).

C Subarachnoid hemorrhage.

Fig. 39.26 Dural septa

Left anterior oblique view. The major dural reflections are the falx cerebri, tentorium cerebelli, and falx cerebelli (not shown). The dural septa separate the regions of the brain from each other.

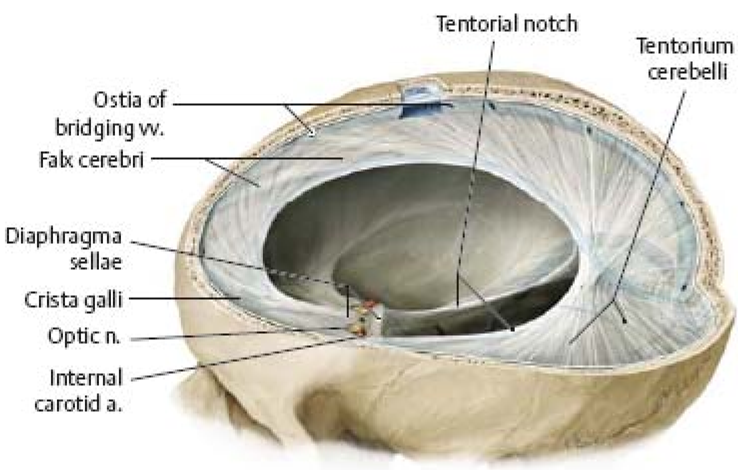


Fig. 39.27 Innervation of the dura mater

Superior view. *Removed:* Tentorium cerebelli (right side).

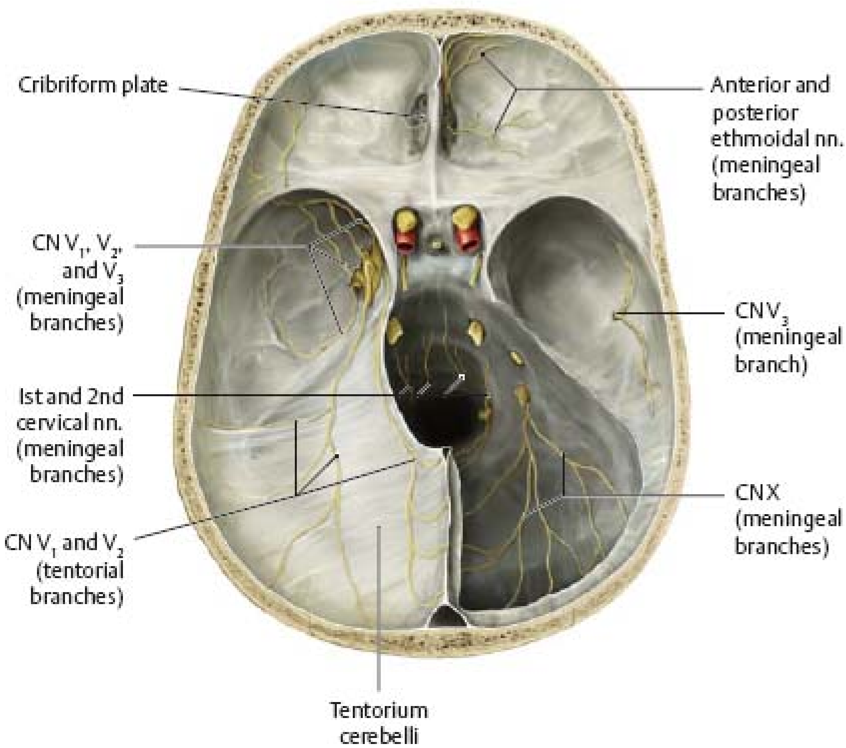
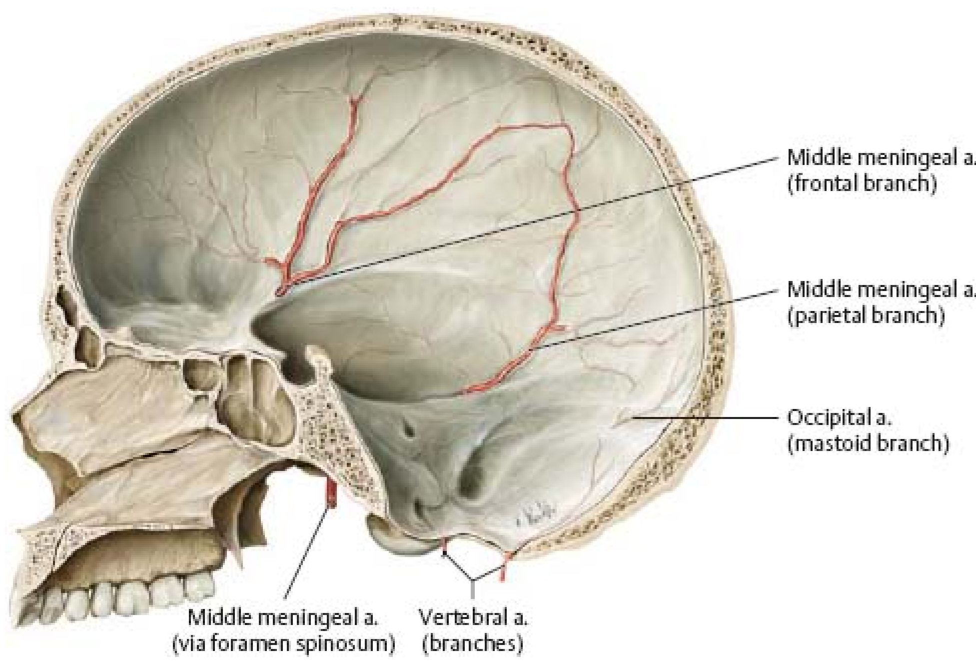


Fig. 39.28 Arteries of the dura mater

Midsagittal section, left lateral view. See p. 608 for the arteries of the brain.



Ventricles & CSF Spaces

Fig. 39.29 Circulation of cerebrospinal fluid (CSF)

The brain and spinal cord are suspended in CSF. Produced in the choroids plexus, CSF occupies the subarachnoid space and ventricles of the brain.

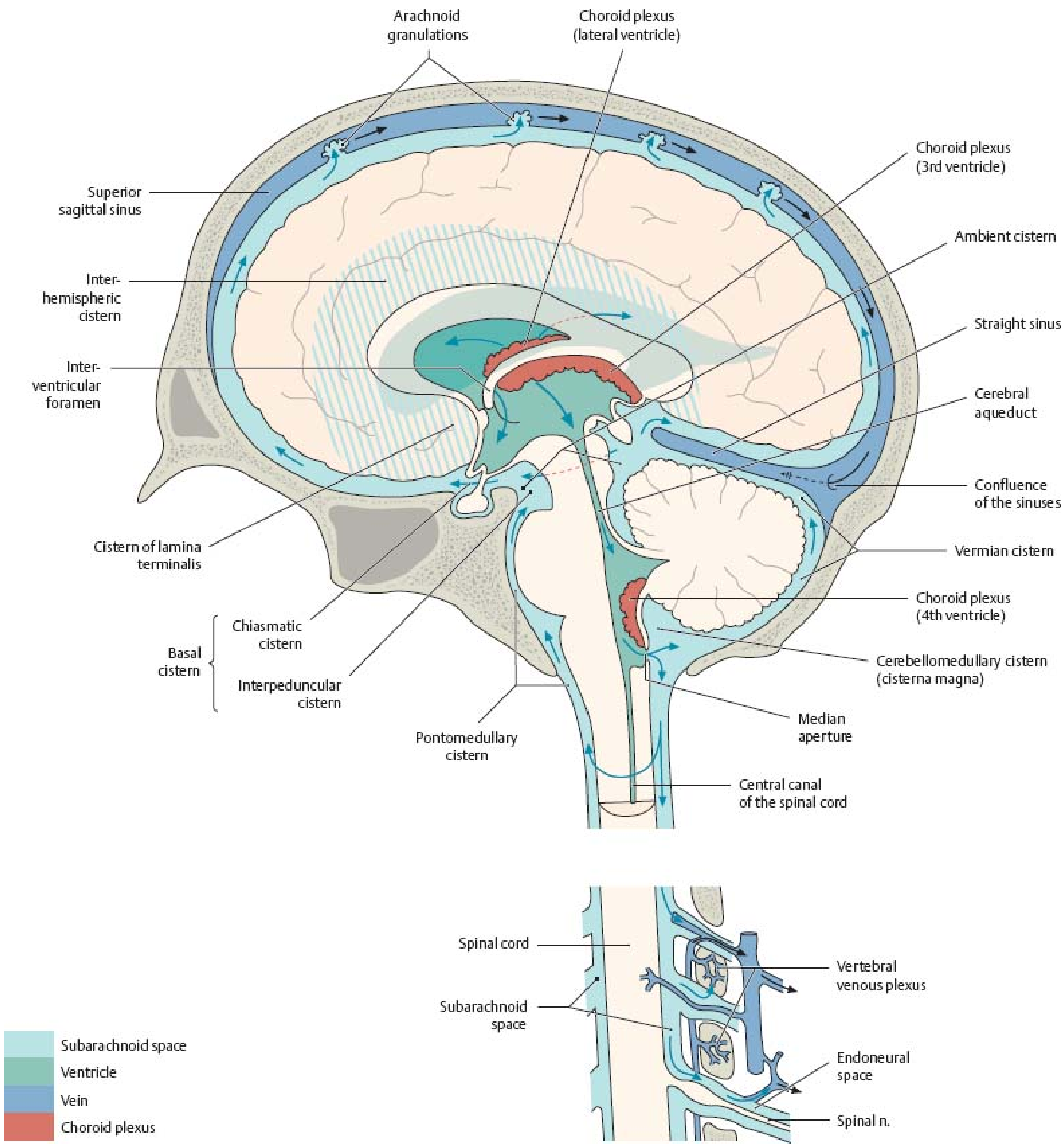


Fig. 39.30 Ventricular system

The ventricular system is a continuation of the central spinal canal into the brain. Cast specimens are used to demonstrate the connections between the four ventricular cavities.

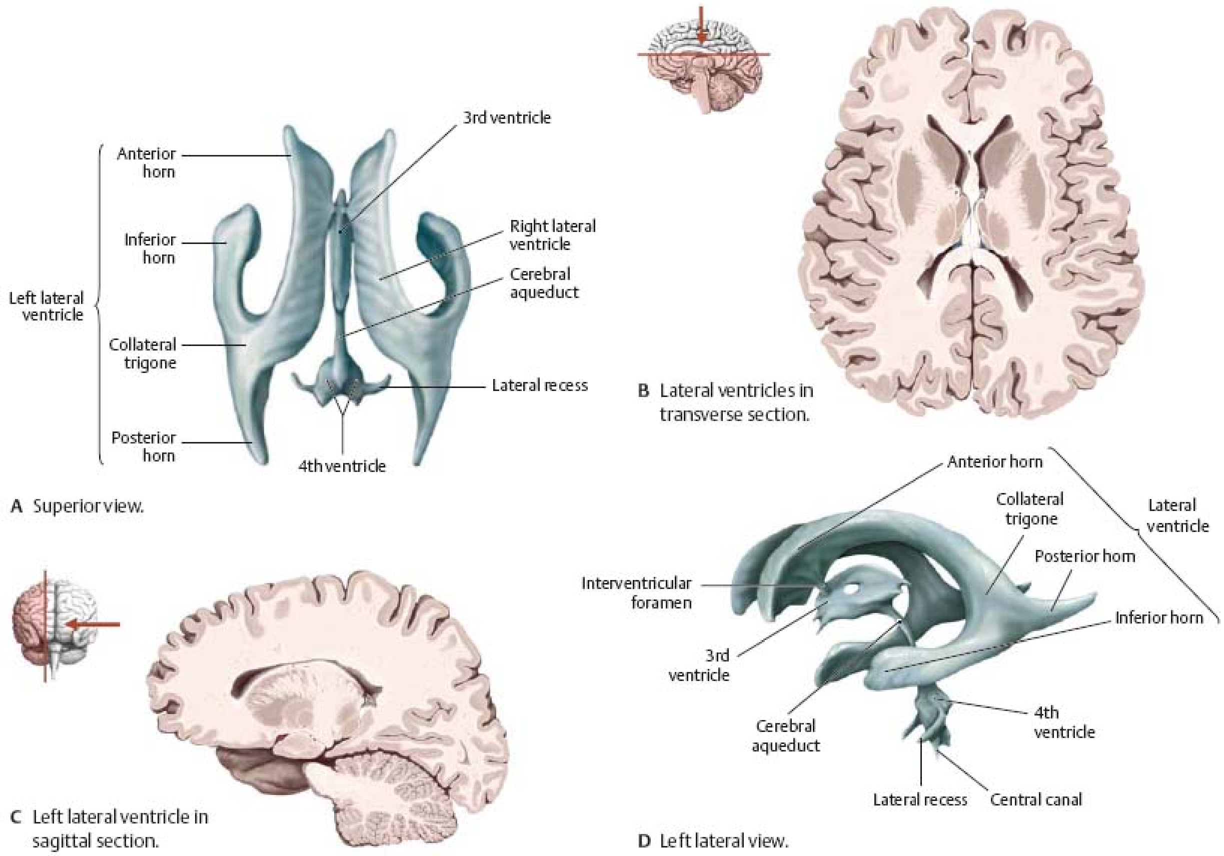
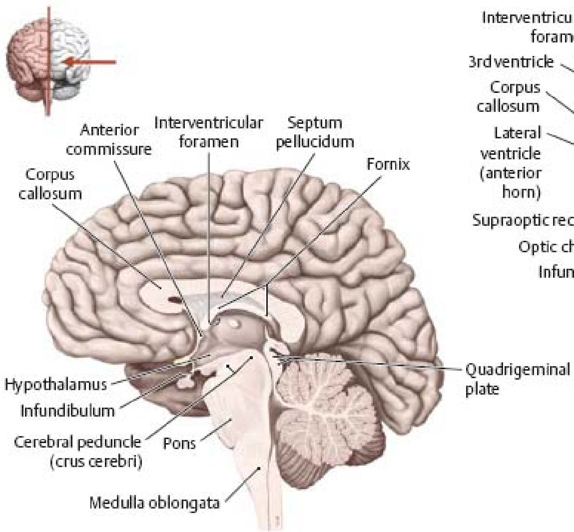
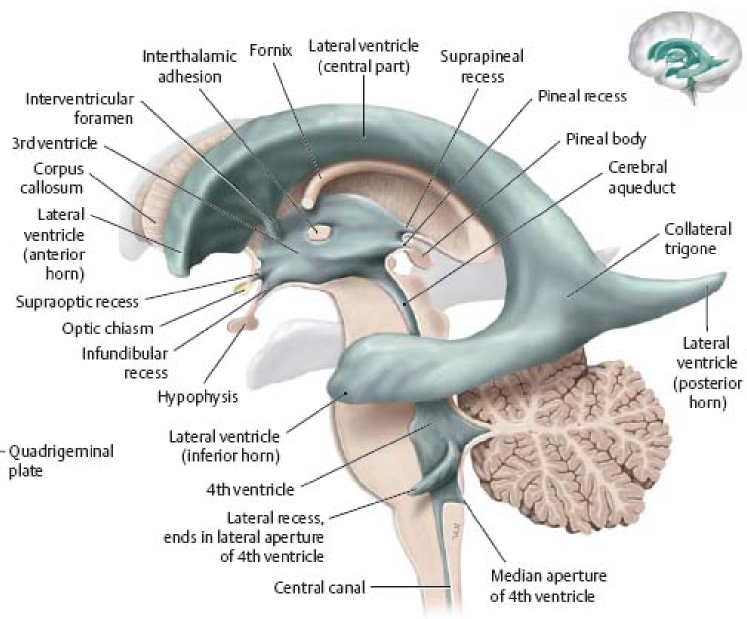


Fig. 39.31 **Ventricular system in situ**

Left lateral view.



A 3rd and 4th ventricles in the midsagittal section.



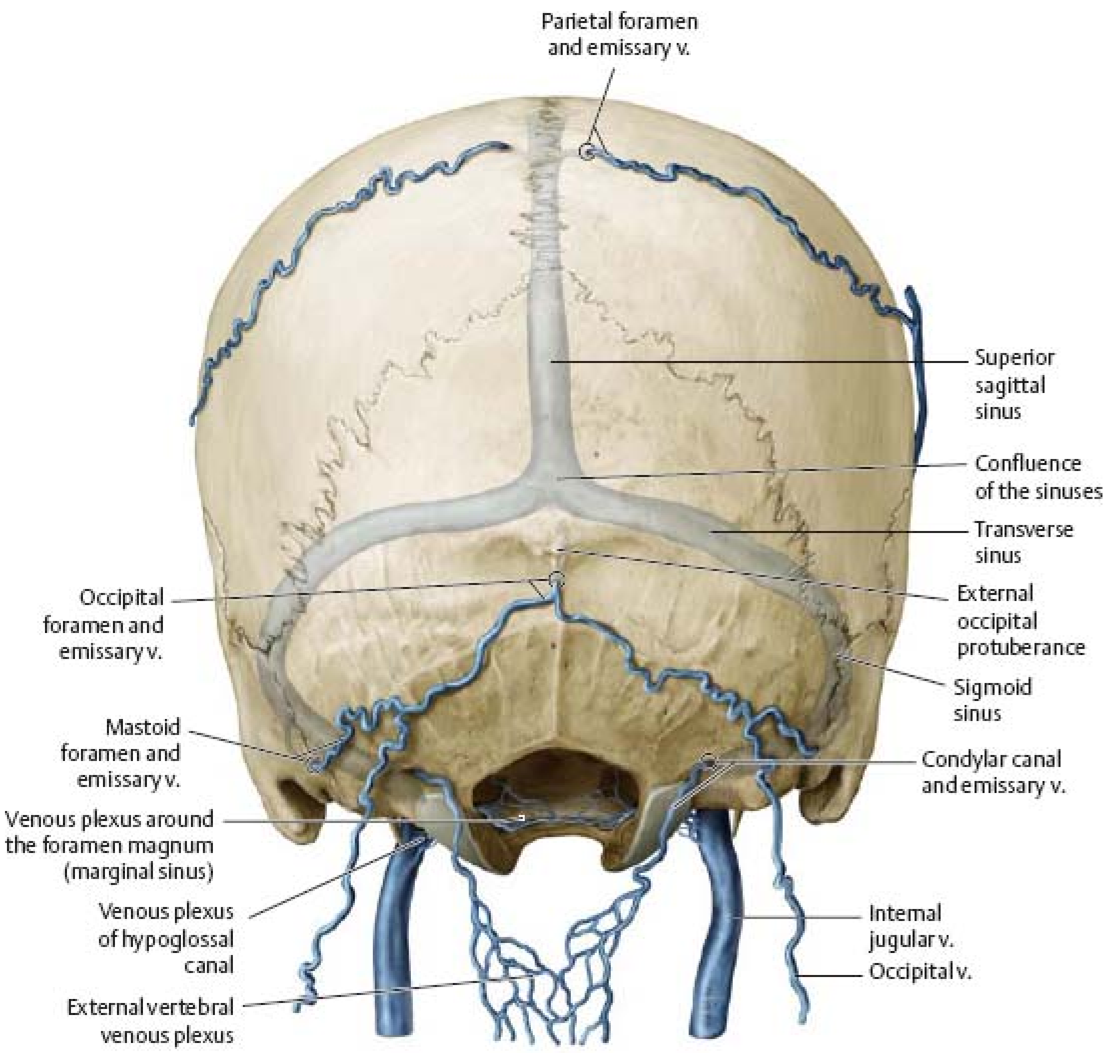
B Ventricular system with neighboring structures.

40 Blood Vessels of the Brain & Spinal Cord

Dural Sinuses & Veins of the Brain

Fig. 40.1 **Confluence of the sinuses**

Posterior view.



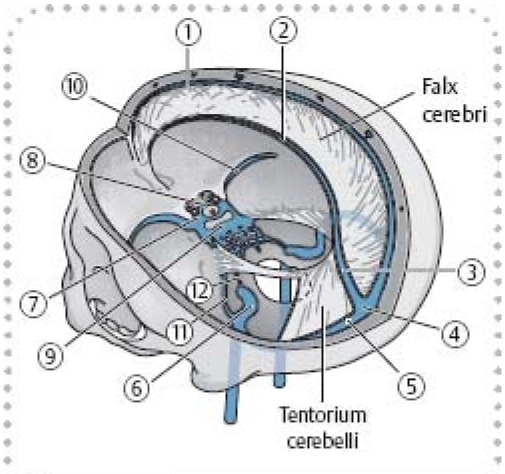
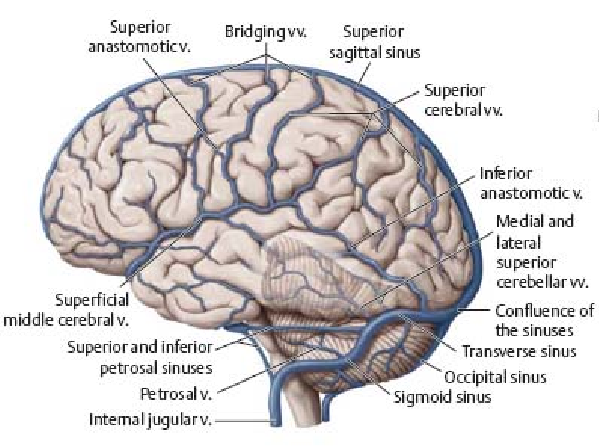


Table 40.1 Principal dural sinuses

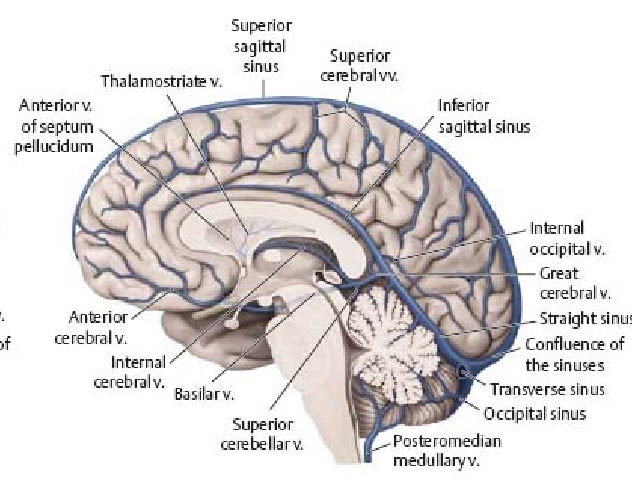
Upper group		Lower group	
①	Superior sagittal sinus	⑦	Cavernous sinus
②	Inferior sagittal sinus	⑧	Anterior intercavernous sinus
③	Straight sinus	⑨	Posterior intercavernous sinus
④	Confluence of the sinuses	⑩	Sphenoparietal sinus
⑤	Transverse sinus	⑪	Superior petrosal sinus
⑥	Sigmoid sinus	⑫	Inferior petrosal sinus

The occipital sinus is also included in the upper group (see Fig. 40.2).

Fig. 40.2 Superficial cerebral veins



A Lateral view of the left hemisphere.



B Medial view of the right hemisphere.

Fig. 40.3 Basal cerebral venous system

Basal view.

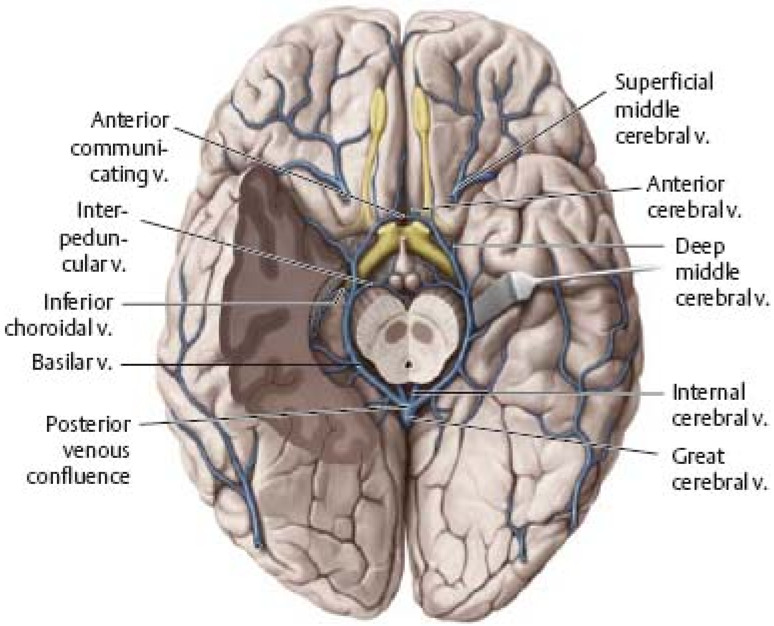


Fig. 40.4 Veins of the brainstem

Basal view.

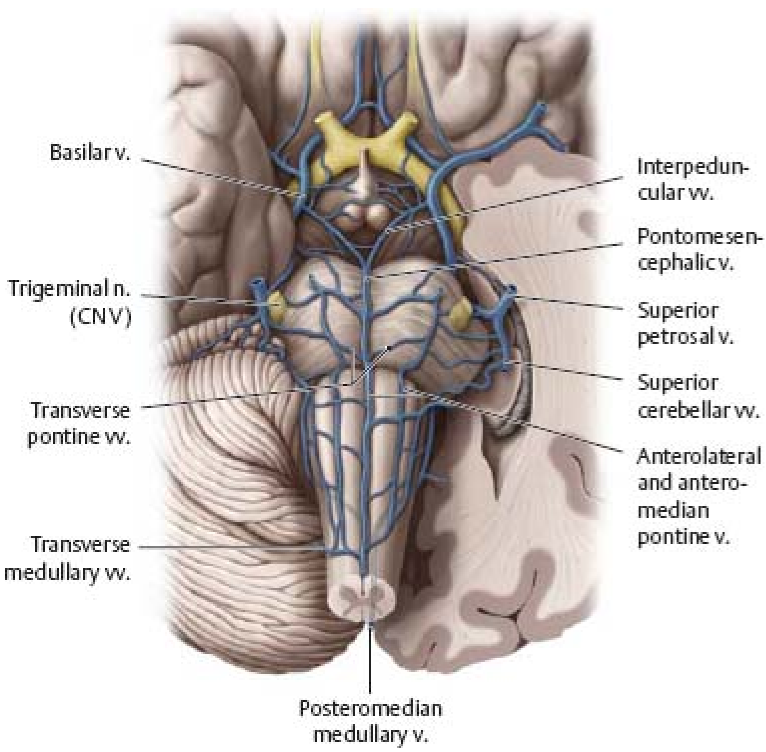
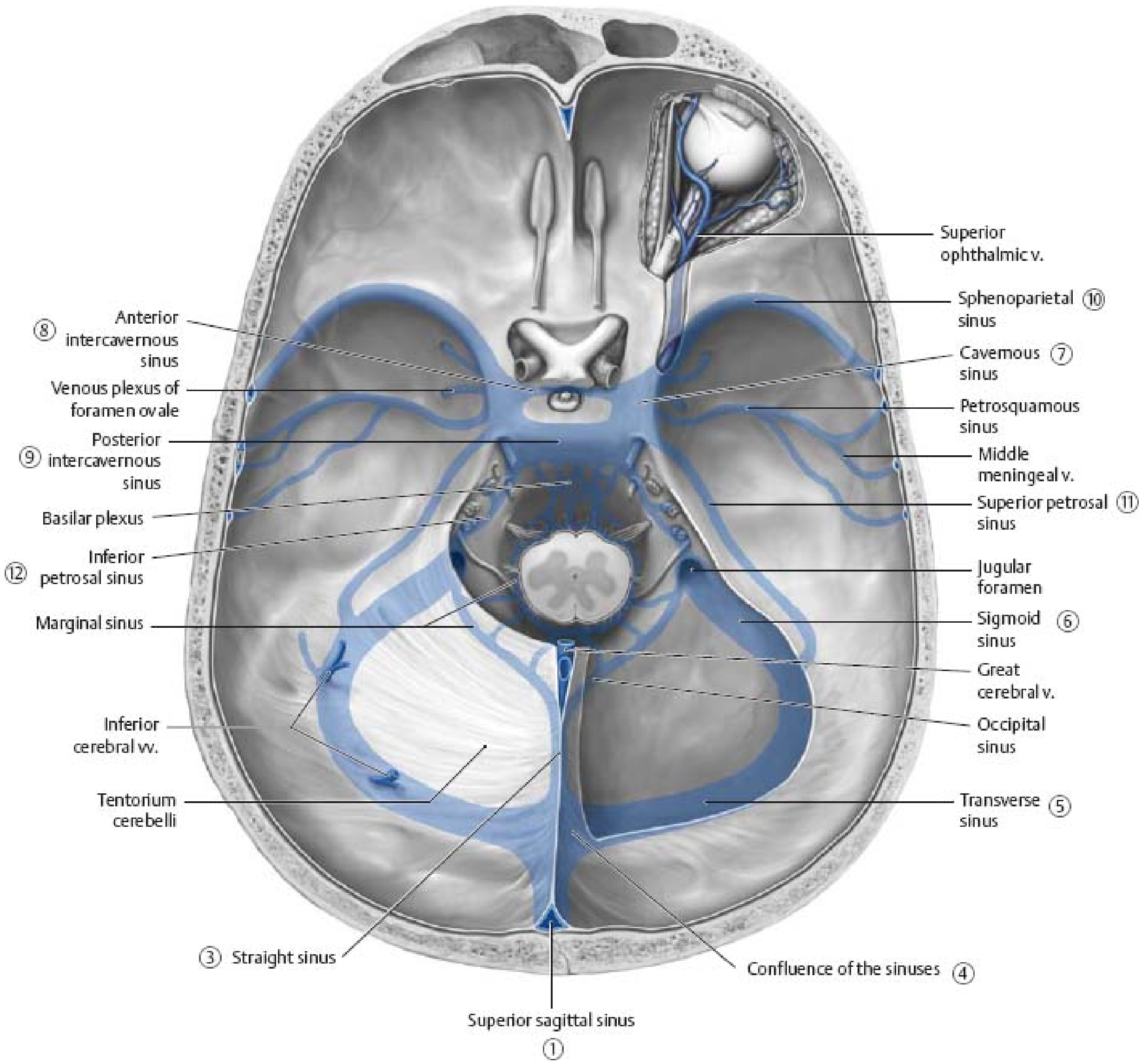


Fig. 40.5 Dural sinuses in the skull base

Superior view of the opened cranial cavity. *Removed:* Tentorium cerebelli (right side).



Arteries of the Brain

Fig. 40.6 Internal carotid artery

Left lateral view. See p. 490 for details of the internal carotid artery.

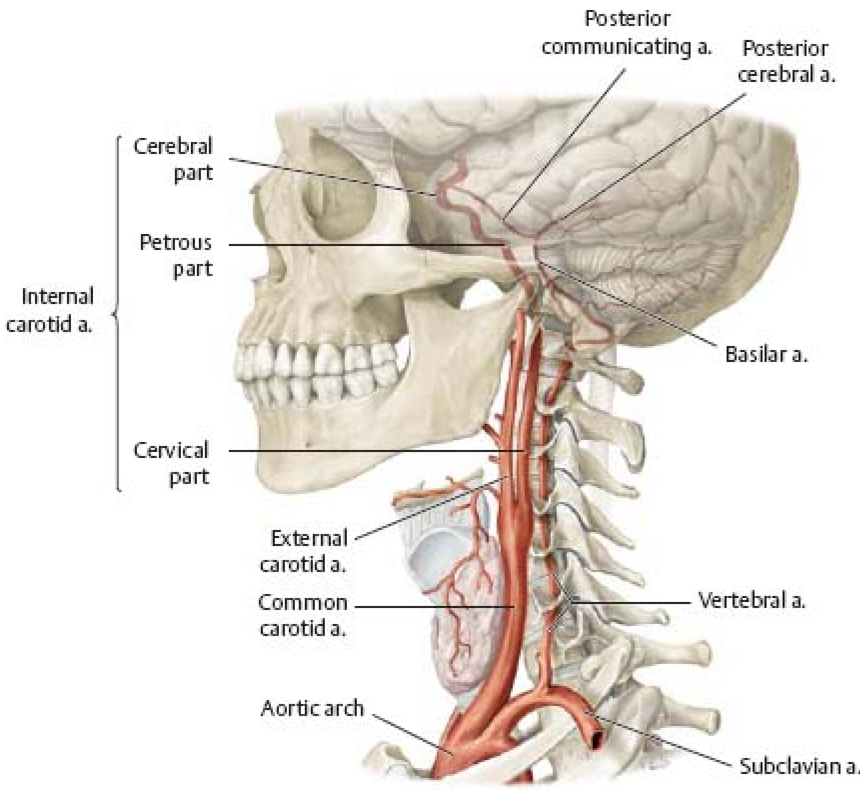


Fig. 40.7 **Arteries of the brainstem and cerebellum**

Left lateral view.

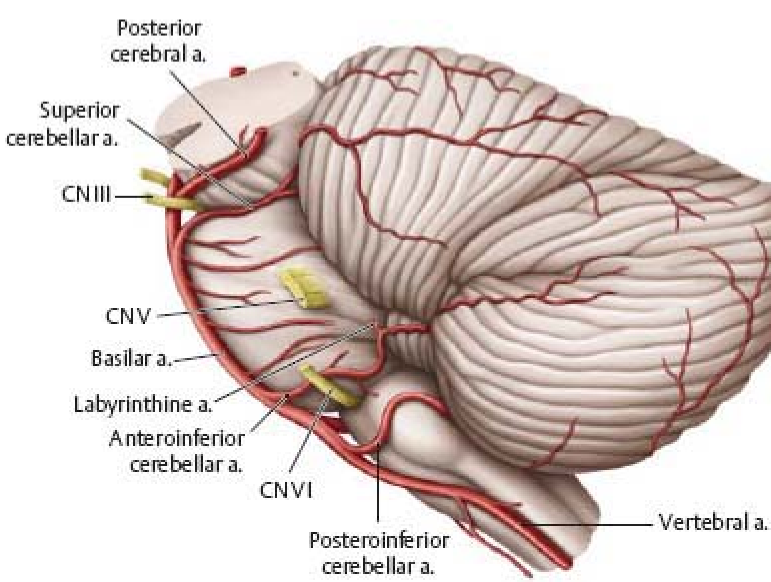


Fig. 40.8 **Arteries of the brain**

Basal (inferior) view.

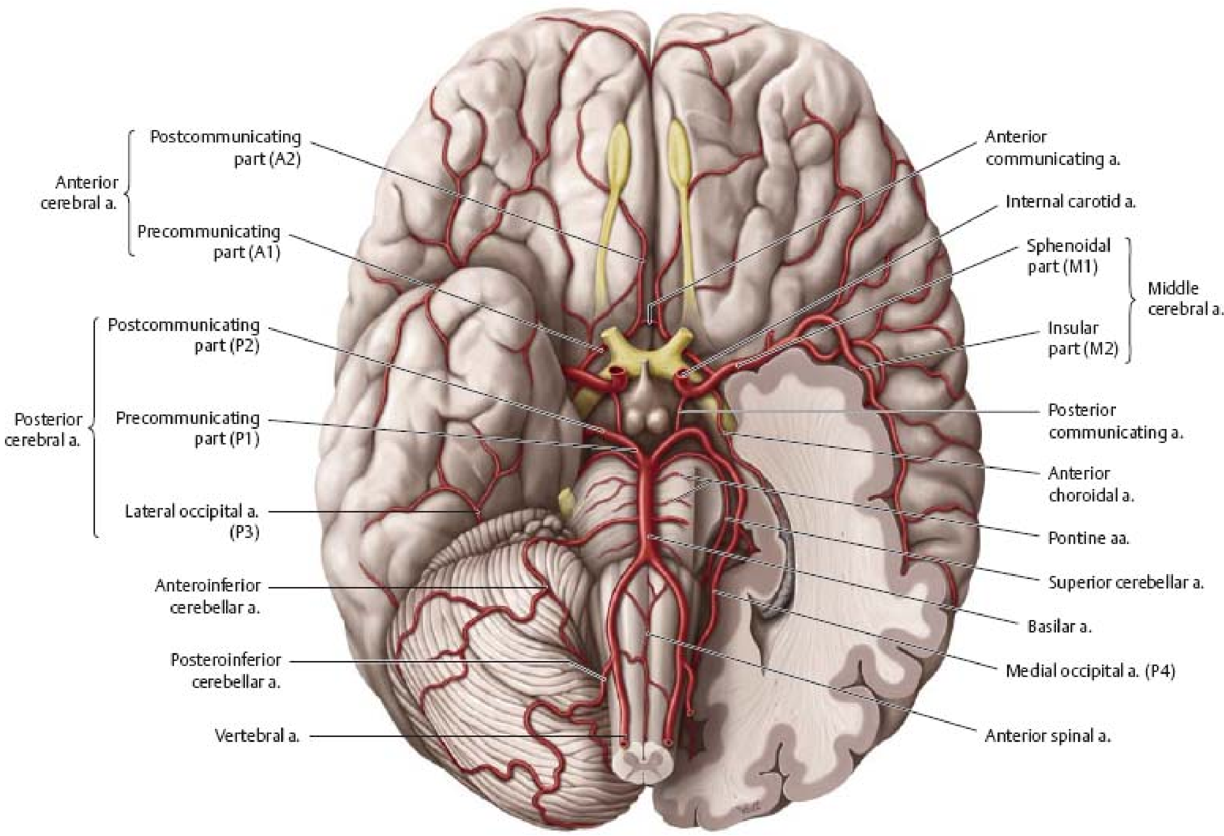
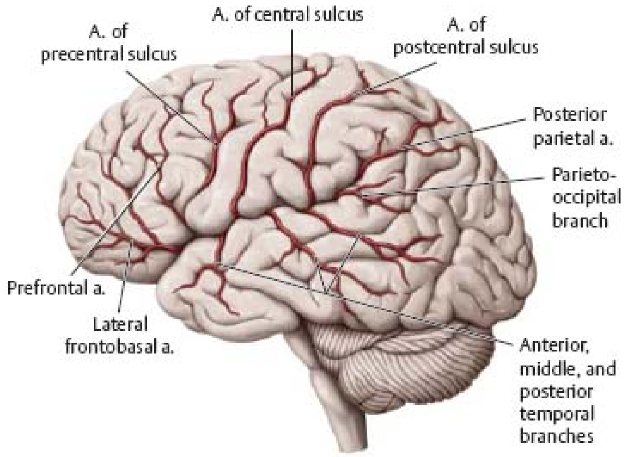
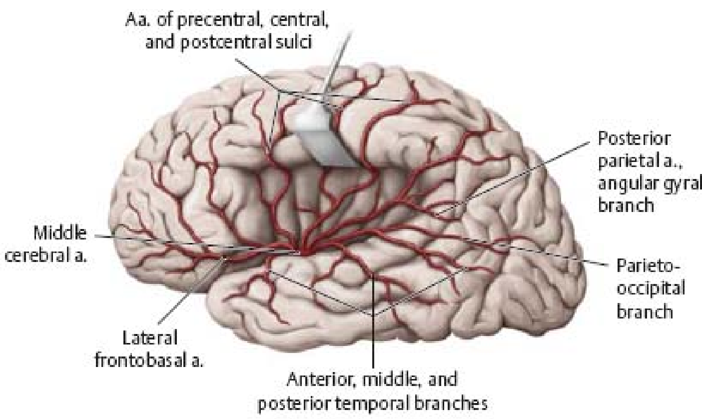


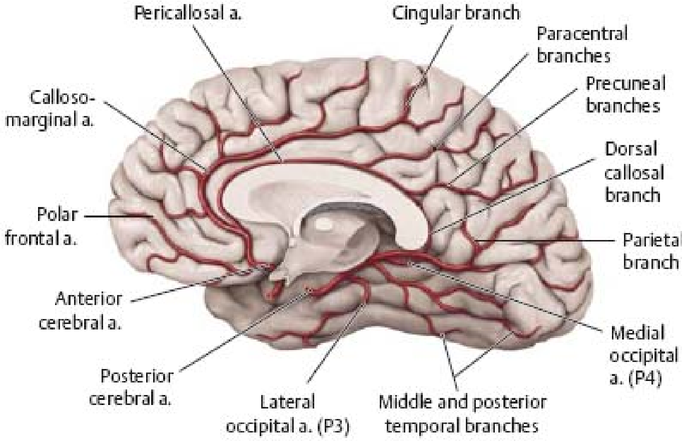
Fig. 40.9 **Cerebral arteries**



A Middle cerebral artery. Lateral view of the left hemisphere.



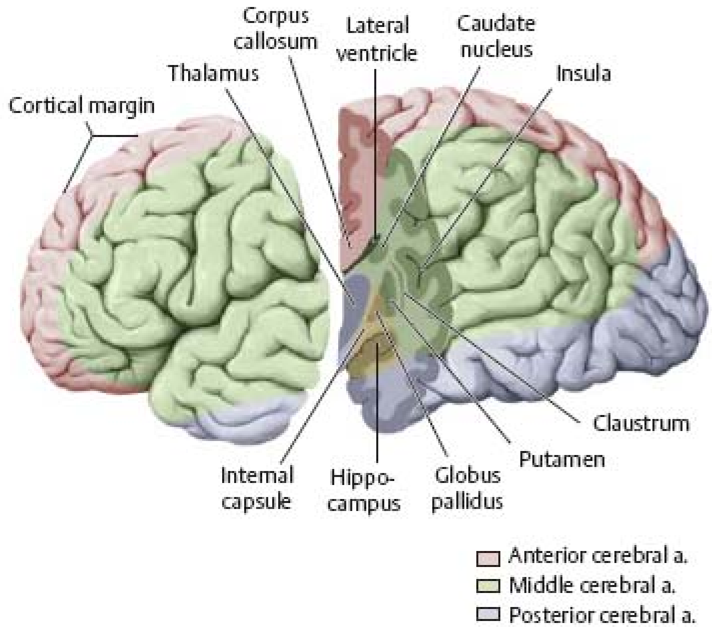
B Middle cerebral artery. Left lateral view with the lateral sulcus retracted.



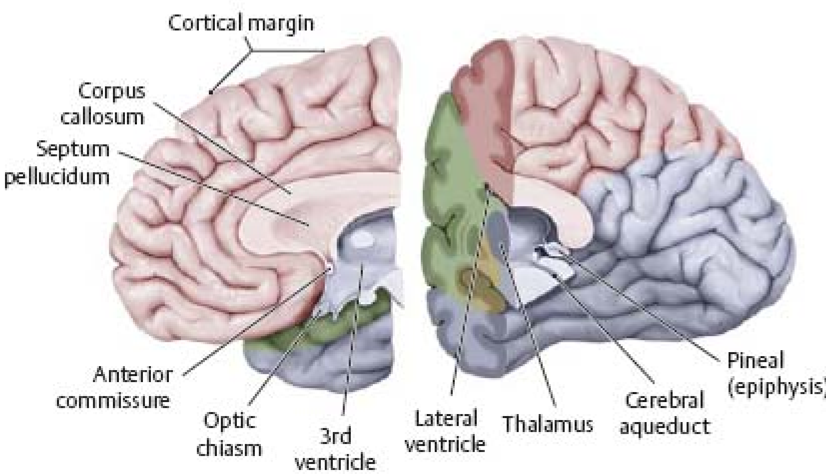
C Anterior and posterior cerebral arteries. Medial view of the right hemisphere.

Fig. 40.10 **Cerebral arteries: Distribution areas**

The central gray and white matter have a complex blood supply (yellow) that includes the anterior choroidal artery.



A Lateral view of the left hemisphere.



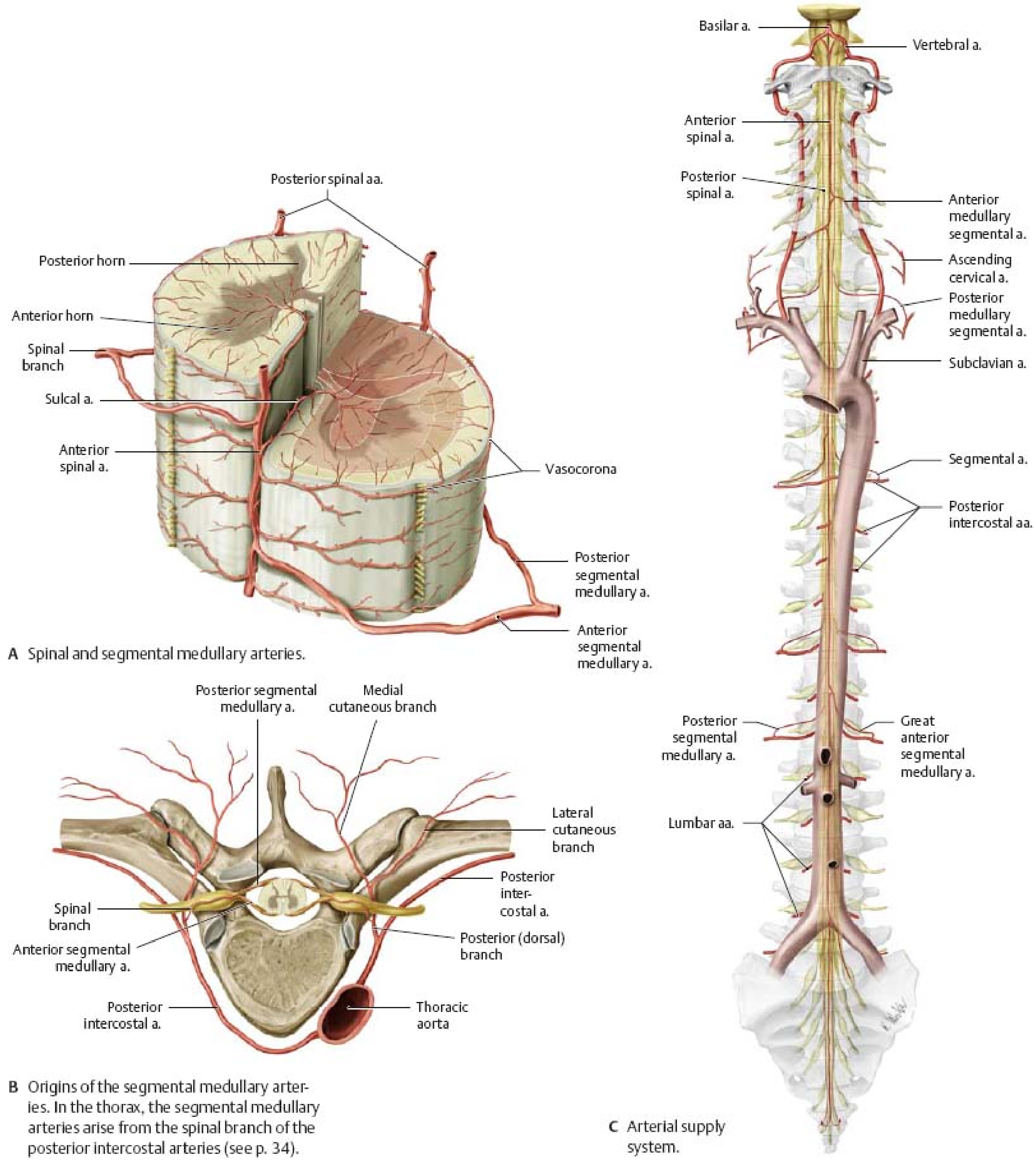
B Medial view of the right hemisphere.

Arteries & Veins of the Spinal Cord

Like the spinal cord itself, the arteries and veins of the spinal cord consist of multiple horizontal systems (blood vessels of the spinal cord segments) that are integrated into a vertical system.

Fig. 40.11 Arteries of the spinal cord

The unpaired anterior and paired posterior spinal arteries typically arise from the vertebral arteries. As they descend within the vertebral canal, the spinal arteries are reinforced by anterior and posterior segmental medullary arteries. Depending on the spinal level, these reinforcing branches may arise from the vertebral, ascending or deep cervical, posterior intercostal, lumbar, or lateral sacral arteries.



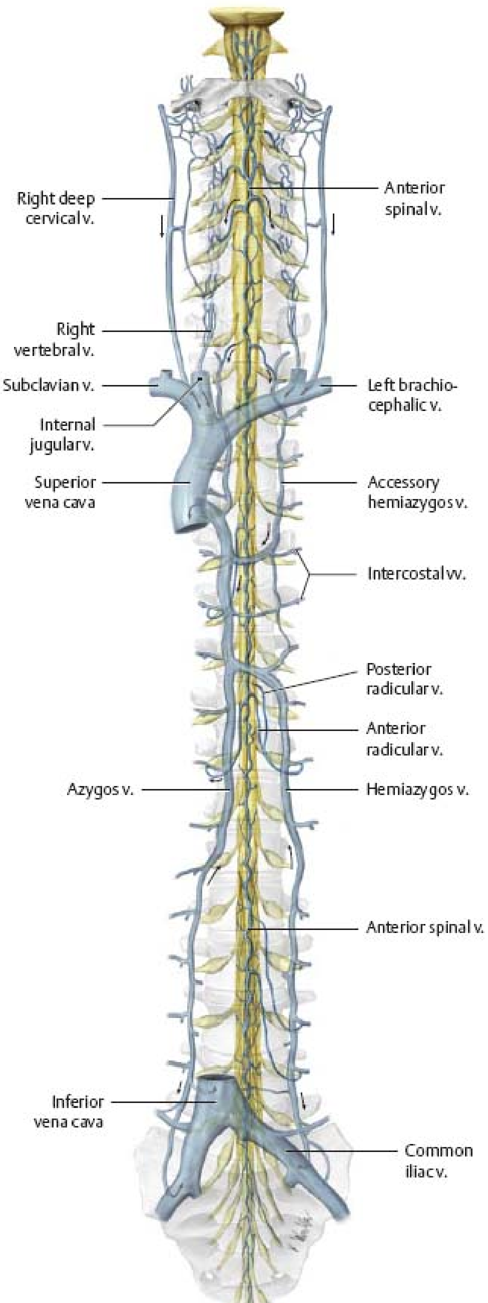
A Spinal and segmental medullary arteries.

B Origins of the segmental medullary arteries. In the thorax, the segmental medullary arteries arise from the spinal branch of the posterior intercostal arteries (see p. 34).

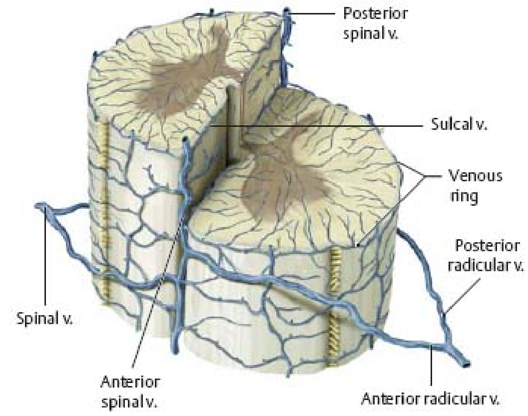
C Arterial supply system.

Fig. 40.12 Veins of the spinal cord

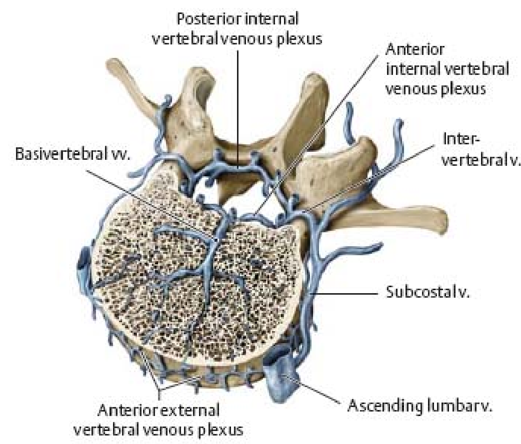
The interior of the spinal cord drains via venous plexuses into an anterior and a posterior spinal vein. The radicular and spinal veins connect the veins of the spinal cord with the internal vertebral venous plexus. The intervertebral and basivertebral veins connect the internal and external venous plexuses, which drain into the azygos system.



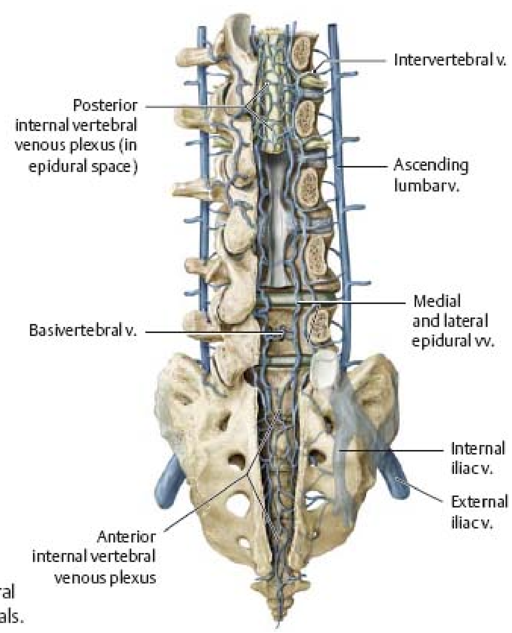
A Venous drainage system.



B Spinal and radicular veins.



C Vertebral venous plexuses.



D Veins in the sacral and lumbar canals.

41 Functional Systems

Circuitry

Fig. 41.1 Divisions of the nervous system

Direction of information flow divides nerve fibers into two types: afferent (sensory) fibers, which transmit impulses toward the central nervous system (CNS), and efferent (motor) fibers, which transmit impulses away. The nervous system may also be divided into a somatic and an autonomic part. The somatic nervous system mediates interaction with the environment, whereas the autonomic (visceral) nervous system coordinates the function of the internal organs.

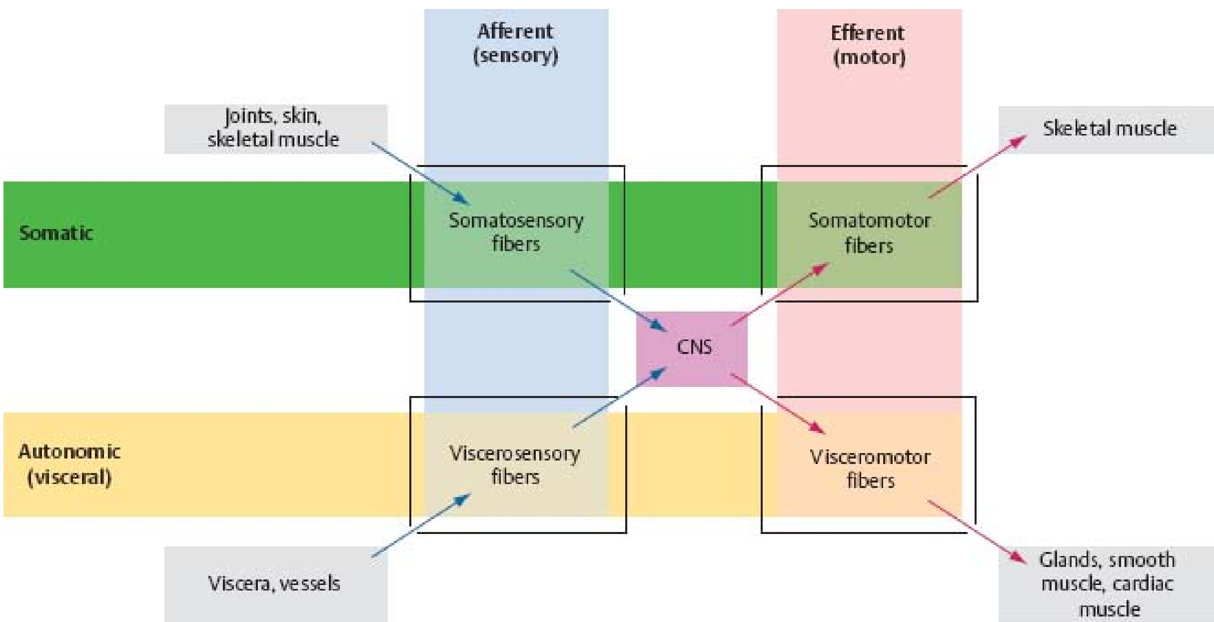


Fig. 41.2 Organization of the gray matter

Left oblique anterosuperior view. The gray matter of the spinal cord is divided into three columns (horns). Afferent (blue) and efferent (red) neurons within these columns are clustered according to function.

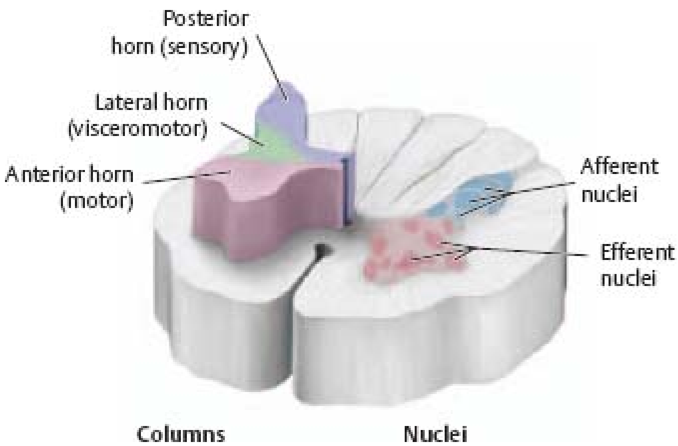


Fig. 41.3 Muscle innervation

Indicator muscles are innervated by motor neurons in the anterior horn of one spinal cord segment. Most muscles (multisegmental muscles) receive innervation from a motor column, a vertical arrangement of motor nuclei spanning several segments.

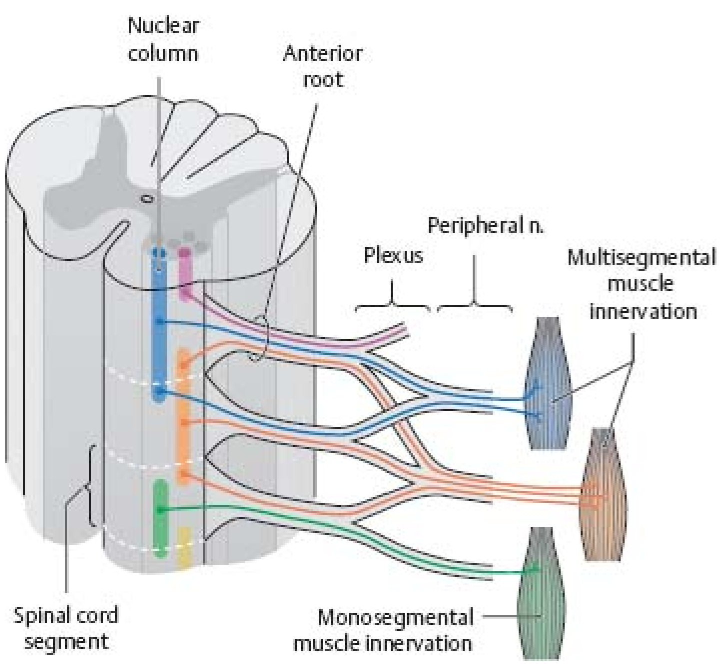
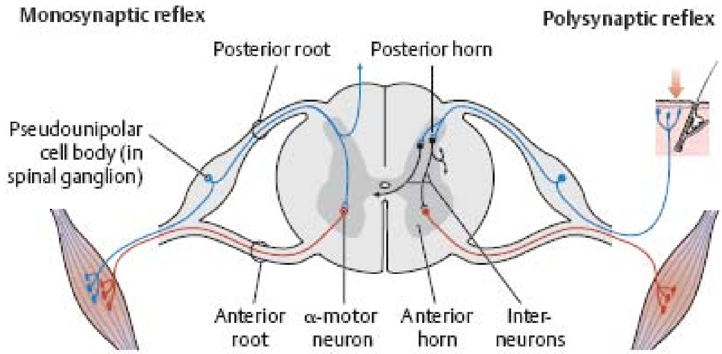
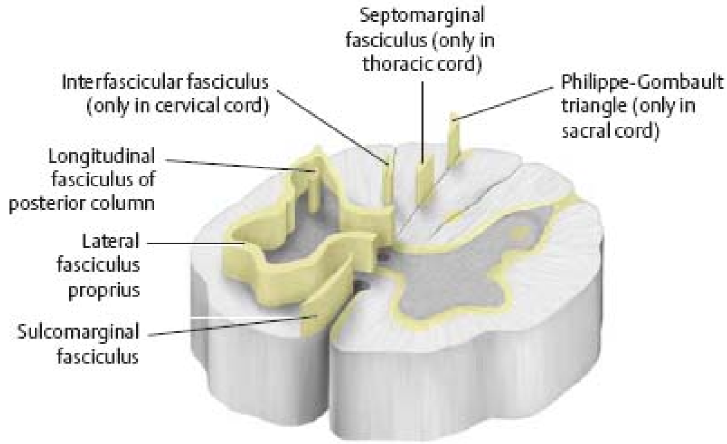


Fig. 41.4 Reflexes

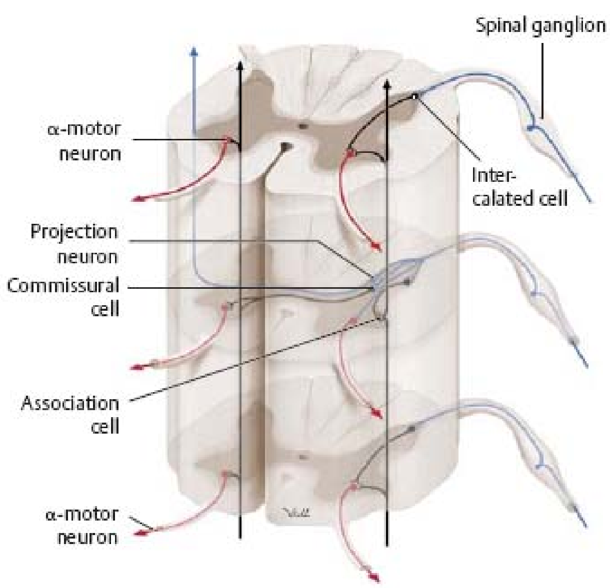
Muscular function at the unconscious (reflex) level is controlled by the gray matter of the spinal cord.



A Polysynaptic reflexes may be mediated by receptors inside of or remote from the muscle (i.e., skin); these receptors act via interneurons to stimulate muscle contraction.



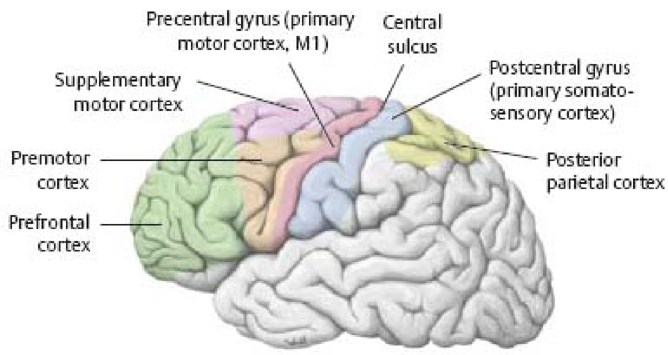
B Principal intrinsic fascicles of the spinal cord. The intrinsic fascicles are the conduction apparatus of the intrinsic circuits, allowing axons to ascend and descend to coordinate spinal reflexes for multisegmental muscles.



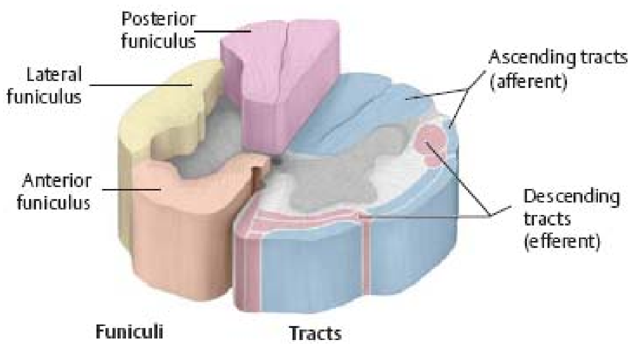
C Intrinsic circuits of the spinal cord.

Fig. 41.5 Sensory and motor systems

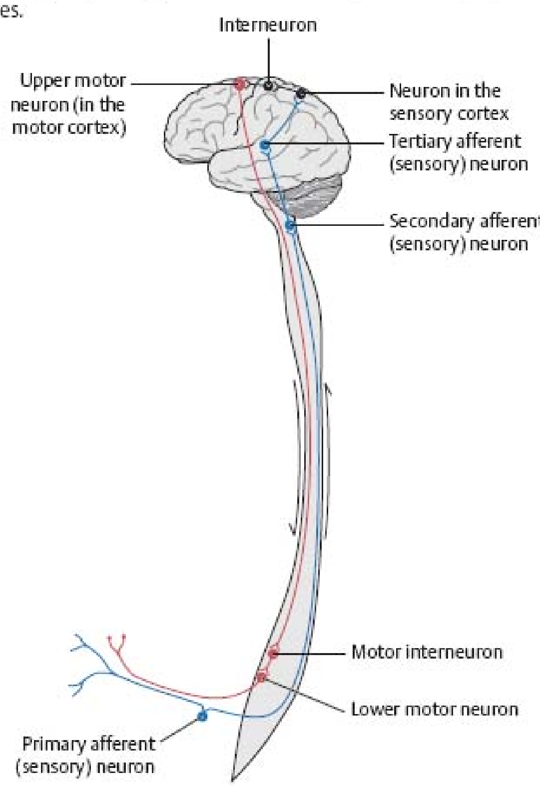
The sensory system (see p. 614) and motor system (see p. 615) are so functionally interrelated they may be described as one (sensorimotor system).



A Cortical areas of the sensorimotor system. Lateral view of the left hemisphere.



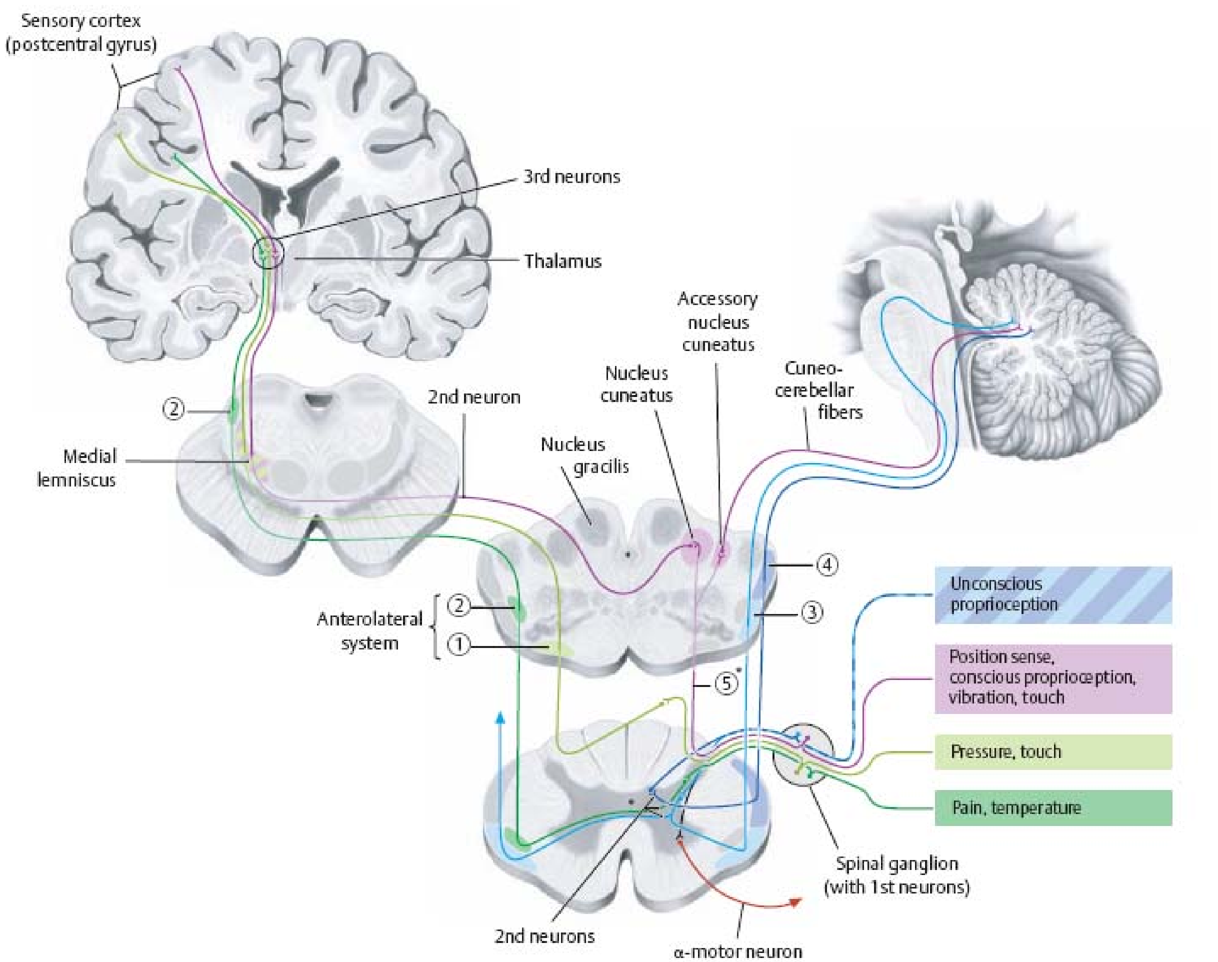
B White matter of the spinal cord. The white matter of the spinal cord contains ascending tracts (afferent, see p. 614) and descending tracts (efferent, see p. 615), which are the CNS equivalent of peripheral nerves.



C Overview of sensorimotor integration.

Sensory & Motor Pathways

Fig. 41.6 Sensory pathways (ascending tracts)



*The fasciculi cuneatus and gracilus convey information from the upper and lower limbs, respectively. At this spinal cord level, only the fasciculus cuneatus is present.

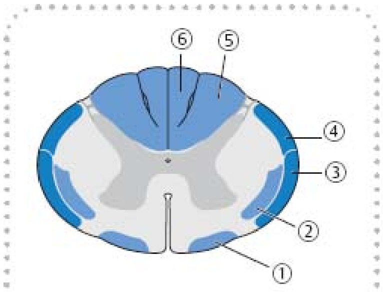


Table 41.1	Ascending tracts of the spinal cord				
Tract		Location	Function		Neurons
①	Anterior spino-thalamic tract	Anterior funiculus	Pathway for crude touch and pressure sensation		1st afferent neurons located in spinal ganglia; contain 2nd neurons and cross in the anterior commissure
②	Lateral spino-thalamic tract	Anterior and lateral funiculi	Pathway for pain, temperature, tickle, itch, and sexual sensation		
③	Anterior spino-cerebellar tract	Lateral funiculus	Pathway for unconscious coordination of motor activities (unconscious proprioception, automatic processes, e.g., jogging, riding a bike) to the cerebellum		Projection (2nd) neurons receive proprioceptive signals from 1st afferent fibers originating at the 1st neurons of spinal ganglia
④	Posterior spino-cerebellar tract				
⑤	Fasciculus cuneatus	Posterior funiculus	Pathway for position sense (conscious proprioception) and fine cutaneous sensation (touch, vibration, fine pressure sense, two-point discrimination)	Conveys information from *upper* limb (not present below T3)	Cell bodies of 1st neuron located in spinal ganglion; pass uncrossed to the dorsal column nuclei
⑥	Fasciculus gracilis*			Conveys information from *lower* limb	

Fig. 41.7 Motor pathways (descending tracts)

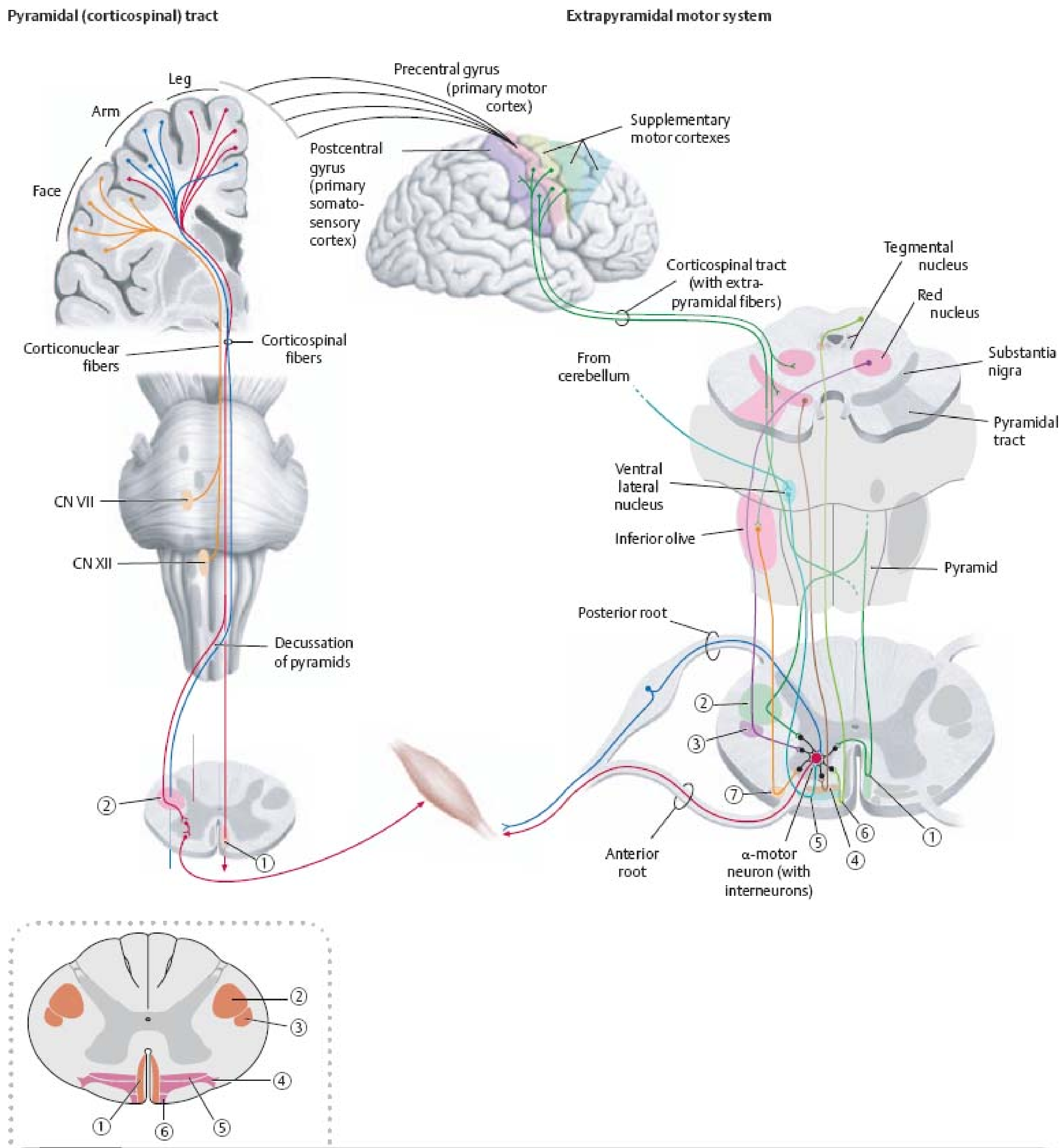


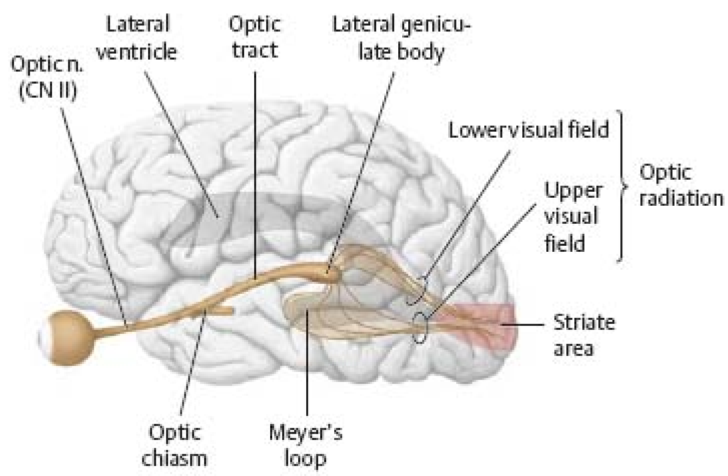
Table 41.2 Descending tracts of the spinal cord

Tract			Function	
Pyramidal tract	①	Anterior corticospinal tract	Most important pathway for voluntary motor function	Originates in the motor cortex *Corticonuclear* fibers to motor nuclei of cranial nerves *Corticospinal* fibers to motor cells in anterior horn of the spinal cord *Corticoreticular* fibers to nuclei of the reticular formation
	②	Lateral corticospinal tract		
Extrapyramidal motor system	③	Rubrospinal tract	Pathway for automatic and learned motor processes (e.g., walking, running, cycling)	
	④	Reticulospinal tract		
	⑤	Vestibulospinal tract		
	⑥	Tectospinal tract		
	⑦	Olivospinal tract		

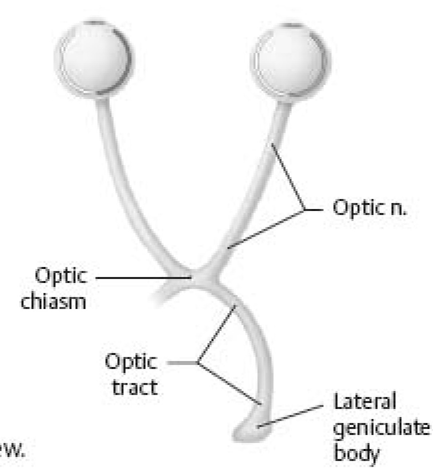
Sensory Systems (I)

Table 41.3	Special sensory qualities (senses)		
Sense	Cranial nerve		Ref.
Vision	Optic n. (CN II)		See p. 473
Balance	Vestibulocochlear n. (CN VIII)	Vestibular branch	See p. 480
Hearing		Cochlear branch	See p. 481
Taste	Facial n. (CN VII)		See p. 478
	Glossopharyngeal n. (CN IX)		See p. 482
	Vagus n. (CN X)		See p. 484
Smell	Olfactory n. (CN I)		See p. 472

Fig. 41.8 Visual system: Overview



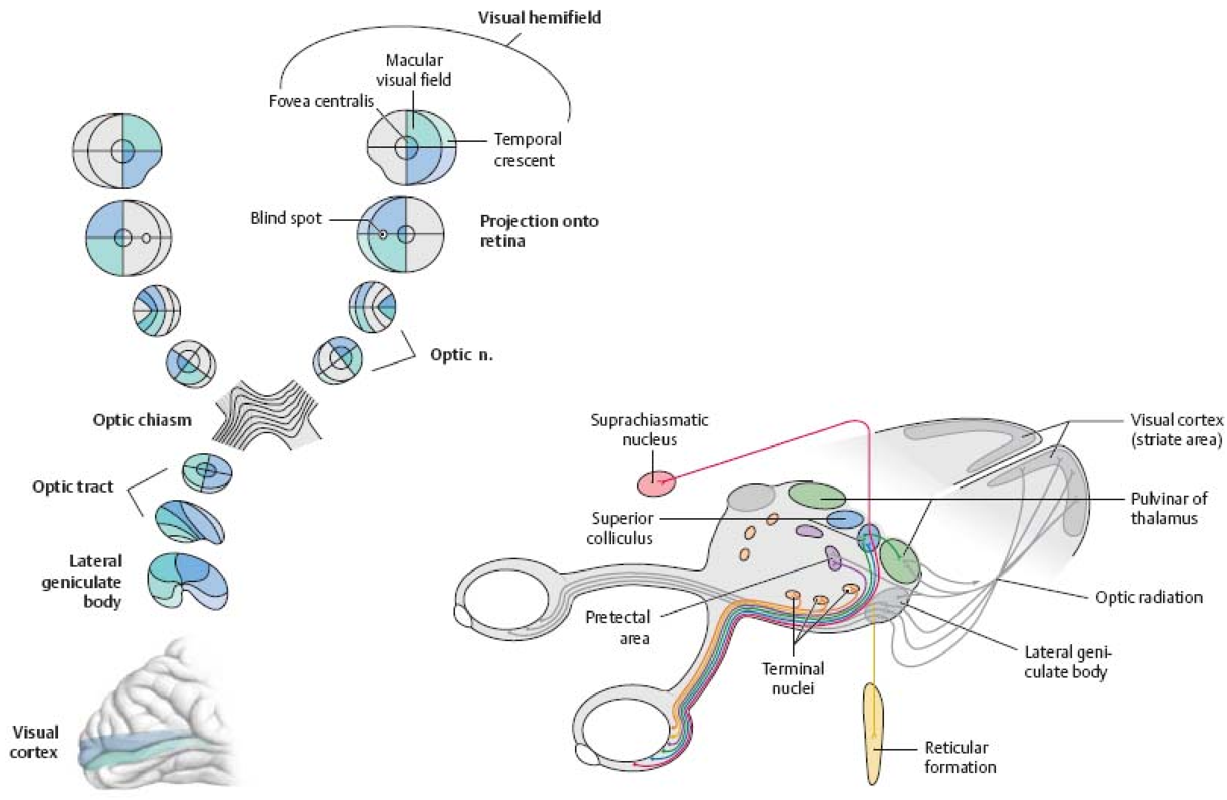
A Left lateral view.



B Inferior view.

Fig. 41.9 Visual pathways

90% of optic nerve fibers terminate in the lateral geniculate body on neurons that project to the striate area (visual cortex). This forms the geniculate pathway, responsible for conscious visual perception. The remaining 10% travel along the medial root of the optic tract, forming the non-geniculate pathway. This pathway plays an important role in the unconscious regulation of vision-related processes and reflexes.



A Geniculate pathway. Left visual hemifield.

B Non-geniculate pathway.

Clinical

Lesions of the visual pathway
Visual field defects and lesion sites are here illustrated for the left visual pathway.

1	Unilateral lesion of optic n.	
	Blindness in affected eye	●○
2	Lesion of optic chiasm	
	Bitemporal hemianopia ("blinders")	◐◑
3	Unilateral lesion of optic tract	
	Contralateral homonymous hemianopia	◑◑
4	Unilateral lesion of optic radiation in Meyer's loop (anterior temporal lobe)	
	Contralateral upper quadrantanopia ("pie-in-the-sky")	
5	Unilateral lesion of optic radiation, medial part	
	Contralateral lower quadrantanopia	
6	Lesion of occipital lobe	
	Homonymous hemianopia	◑◑
7	Lesion of occipital pole (cortical areas)	
	Homonymous hemianopic central scotoma	

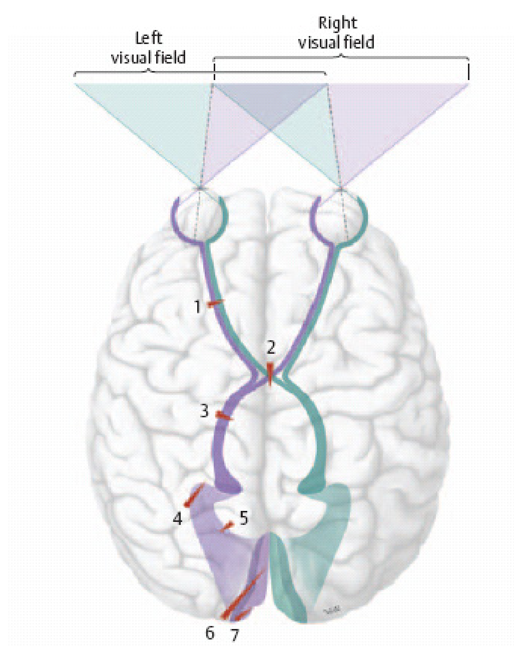
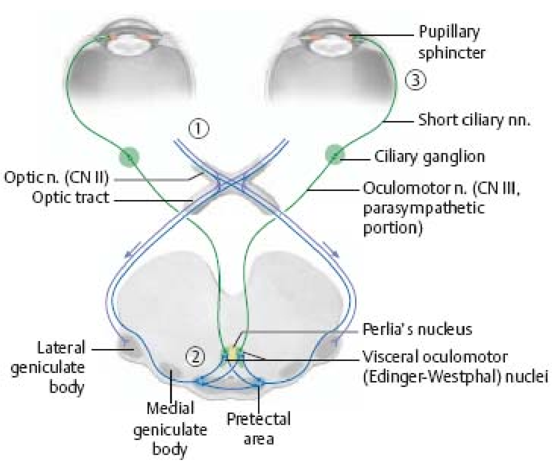
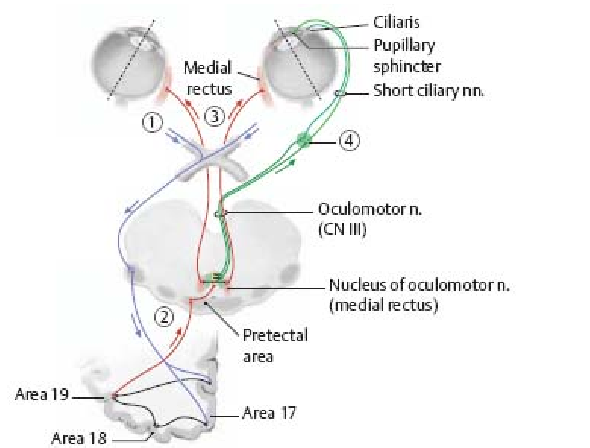


Fig. 41.10 Reflexes of the visual system

The reflexes of the visual system are mediated by the optic (afferent) and oculomotor (efferent) nerves.



A Pupillary light reflex.
① Incoming light is transmitted via the optic nerve.
② Large amounts of light are transmitted to the pretectal area, bypassing the geniculate pathway.
③ The neurons of the visceral oculomotor nucleus synapse on the ciliary ganglion, which induces contraction of the pupillary sphincter.



B Pathways for convergence and accommodation.
① Light is received from an approaching object.
② Information is relayed via the primary (17) and secondary (19) visual cortexes to the nuclei of the oculomotor nerve.
③ Convergence: Constriction of the medial rectus muscles converges the visual axes of the eyes, keeping the approaching image on the fovea centralis, the point of maximum visual acuity.
④ Accommodation: The curvature of the lens is increased via contraction of the ciliary muscles. The sphincter pupillae also contracts.

Sensory Systems (II)

Fig. 41.11 Balance

Human balance is regulated by the visual, proprioceptive, and vestibular systems. All three systems send afferent fibers to the vestibular nuclei, which then distribute them to the spinal cord (motor support), cerebellum (fine motor function), and brainstem (oculomotor function). Proprioception ("position sense") is the perception of limb position in space. *Note:* Efferents to the thalamus and cortex control spatial sense; efferents to the hypothalamus regulate vomiting in response to vertigo.

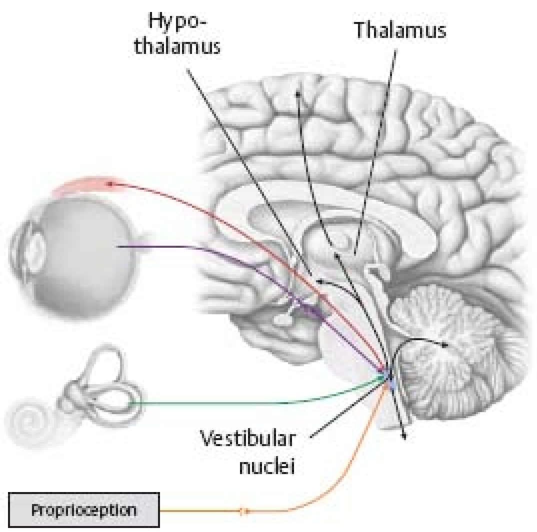


Fig. 41.12 Oculomotor nuclei

The oculomotor nuclei receive efferent fibers from both the vestibular and visual systems. Conjugate eye movement requires the activity of multiple extraocular muscles and their corresponding nerves. The oculomotor nuclei are therefore coordinated at a supranuclear level by premotor nuclei (purple).

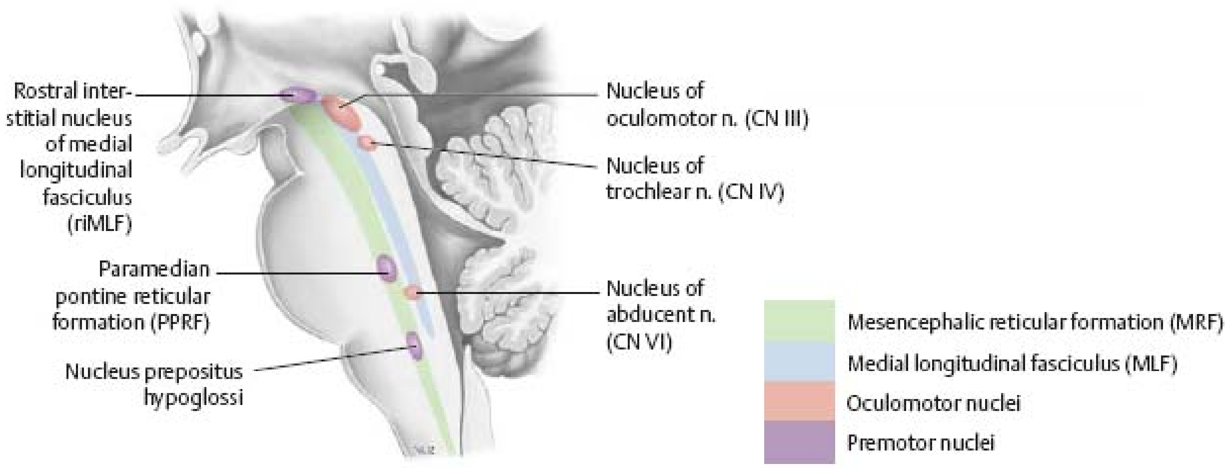


Fig. 41.13 **Vestibular system and nuclei**

The receptors of the vestibular system are located in the membranous labyrinth. The maculae of the utricle and saccule respond to linear acceleration, whereas the semicircular duct organs in the ampullary crests respond to angular (rotational) acceleration.

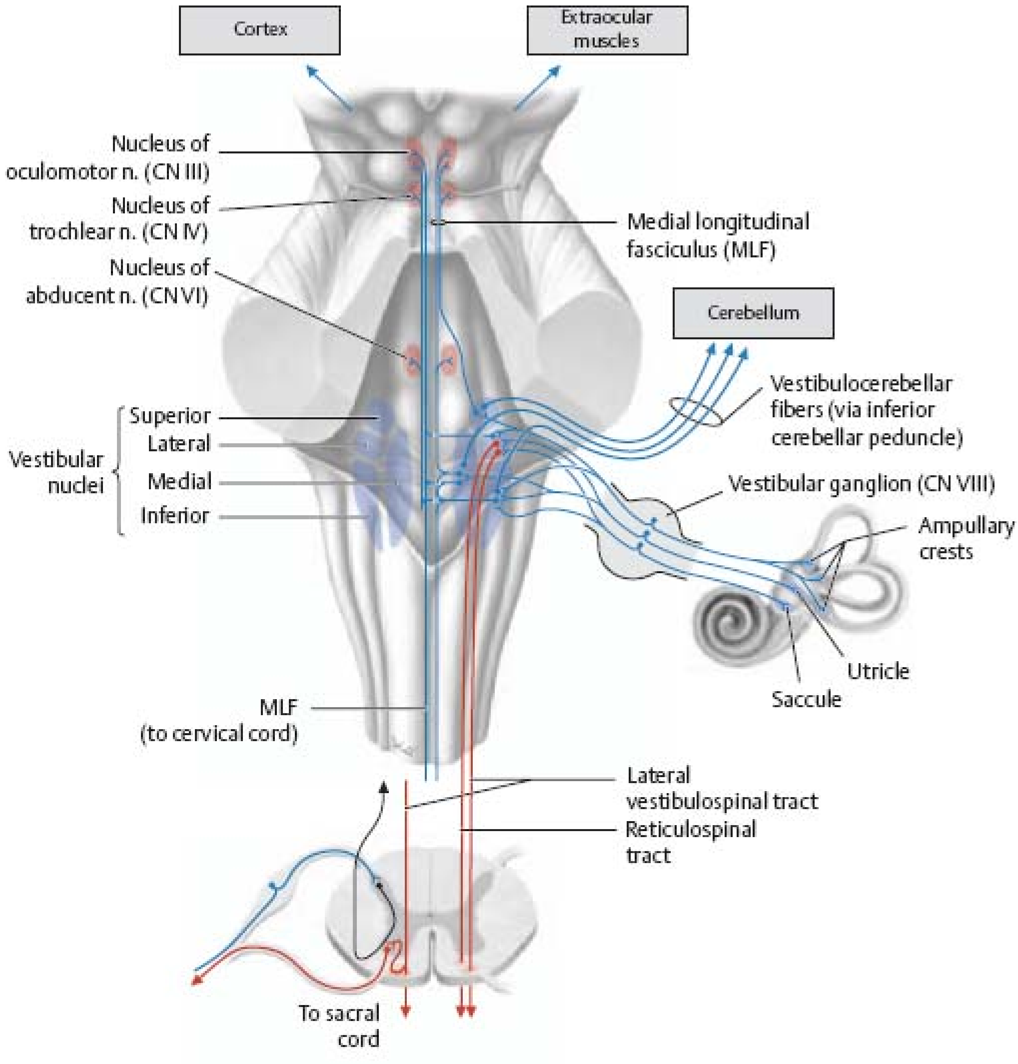


Fig. 41.14 **Auditory system (hearing)**

See p. 480 for the vestibulocochlear nerve (CN VIII).

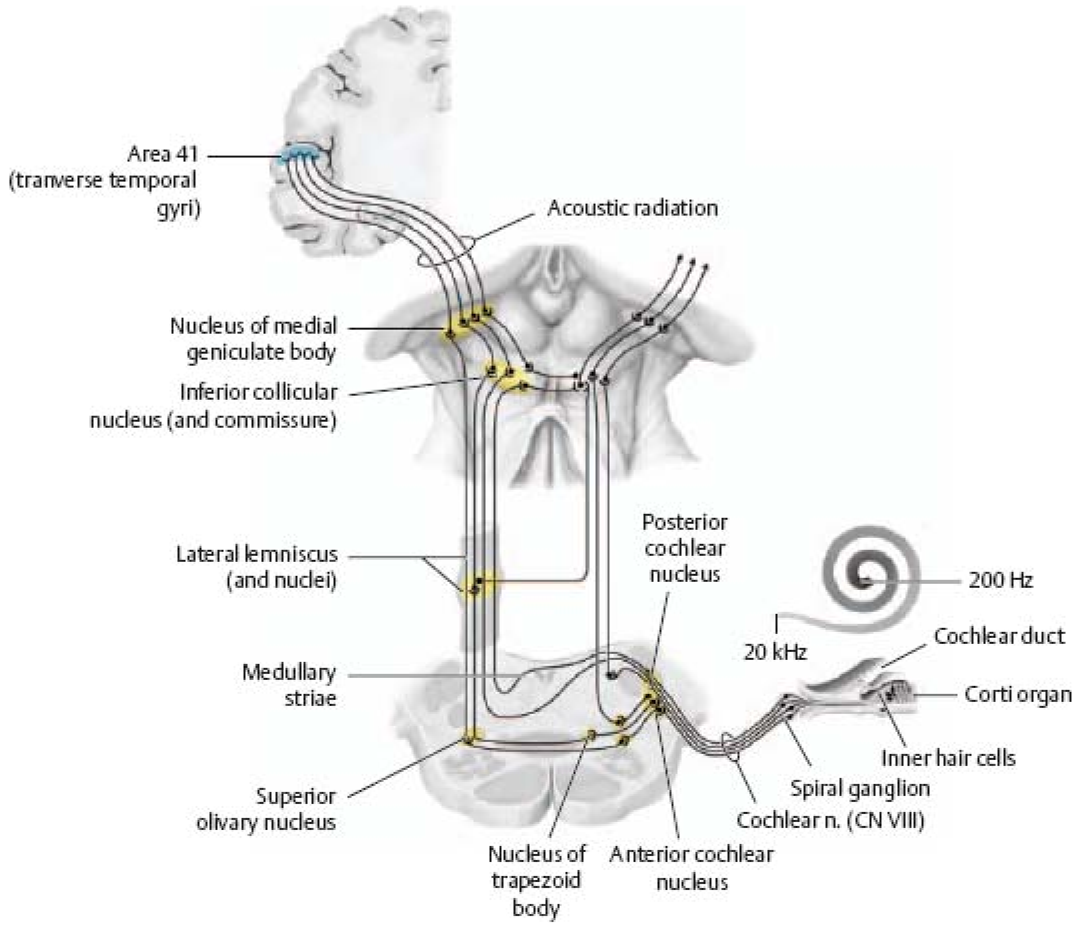
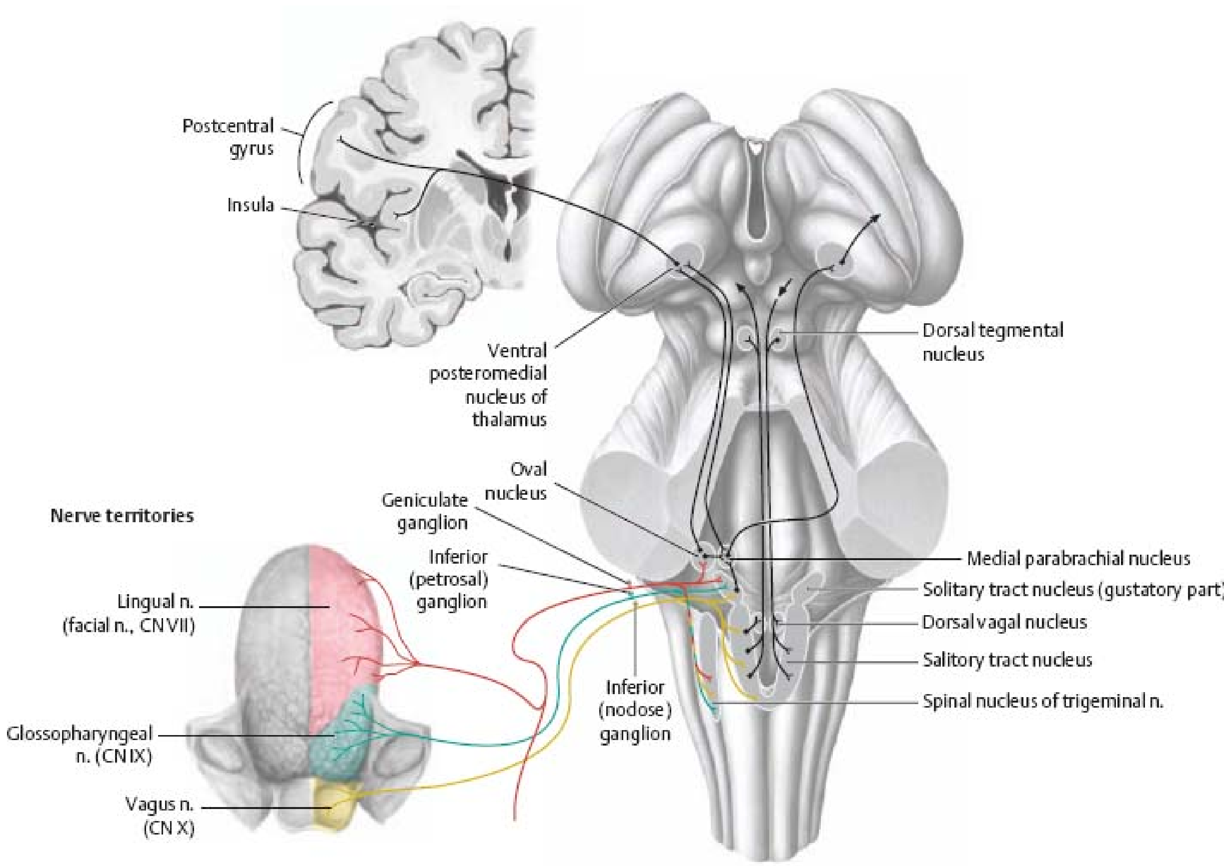


Fig. 41.15 **Gustatory system (taste)**

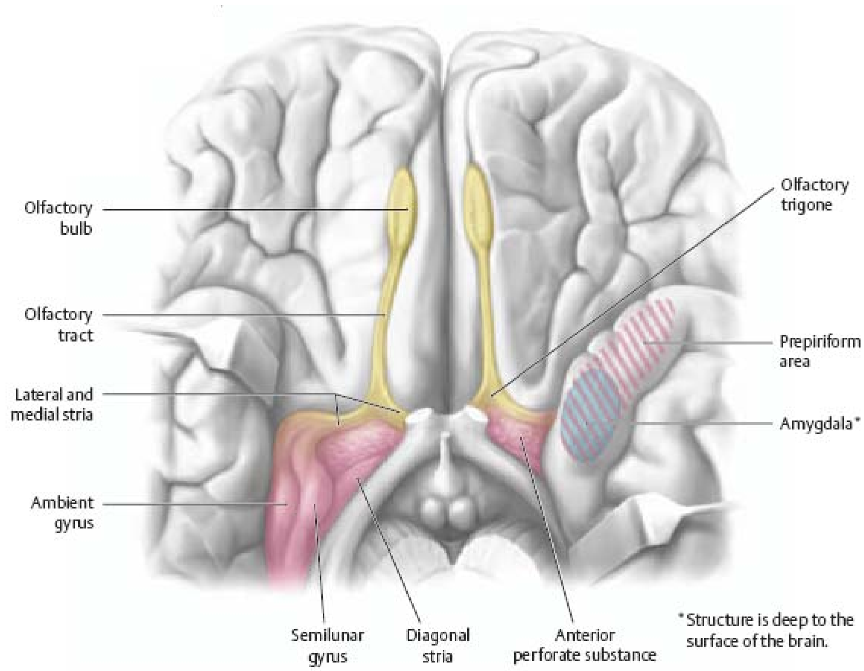
When specialized epithelial cells (secondary sensory cells with no axon) in the tongue are chemically stimulated, the cell bases release glutamate, stimulating the peripheral processes of afferent cranial nerves VII, IX, and X. *Note:* Spicy foods may also stimulate trigeminal fibers (not shown).



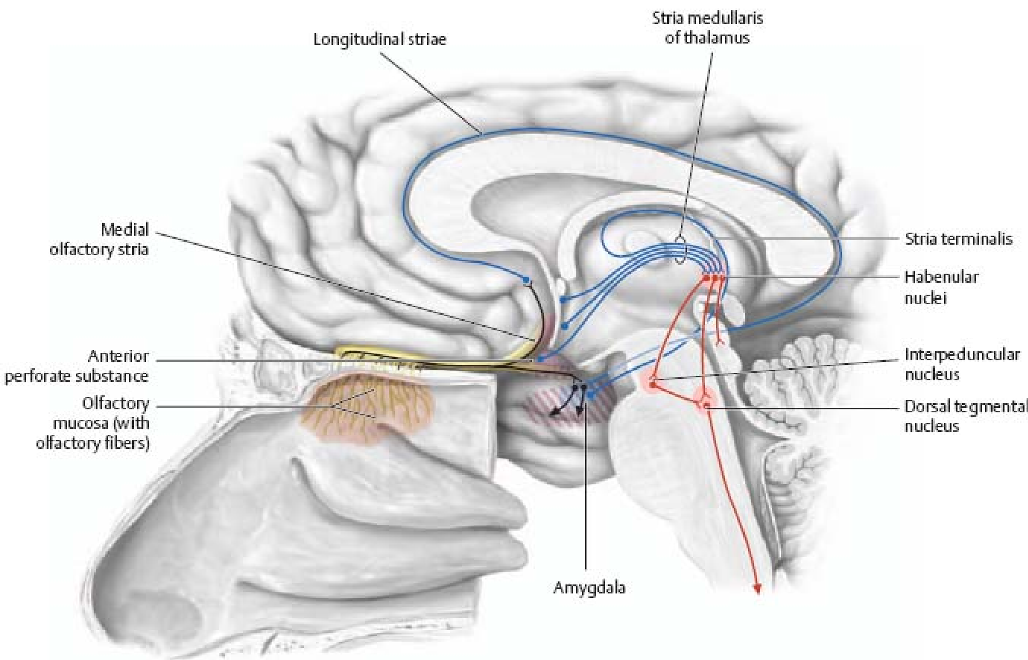
Sensory Systems (III)

Fig. 41.16 Olfactory system (smell)

The olfactory system is the only sensory system not relayed in the thalamus before reaching the cortex (the prepiriform area is considered the primary olfactory cortex). The olfactory system is linked to other brain areas and can therefore evoke complex emotional and behavioral responses (mediated by the hypothalamus, thalamus, and limbic system): noxious smells induce nausea; appetizing smells evoke salivation.

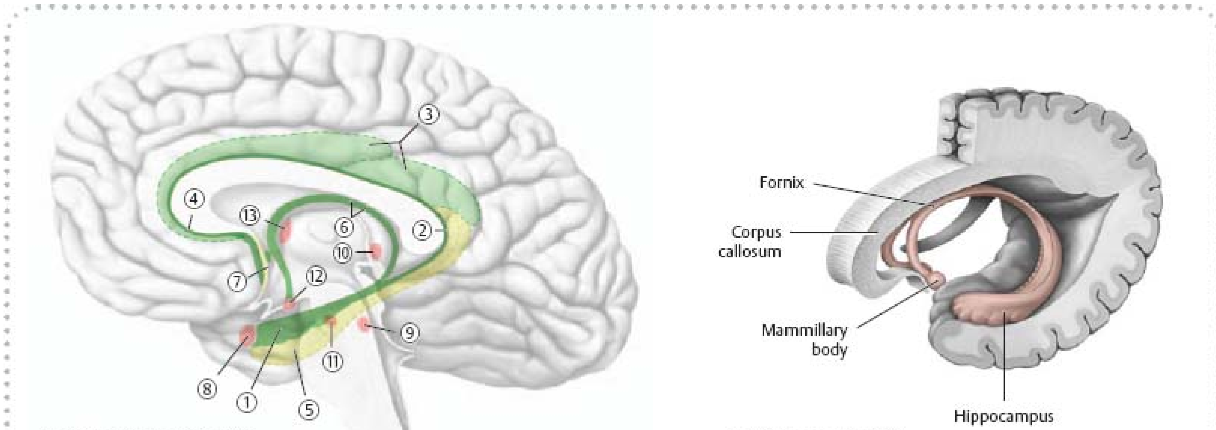


A Olfactory system, inferior view.



B Olfactory system with nuclei, left lateral view of midsagittal section.

The limbic system, which exchanges and integrates information between the telencephalon, diencephalon, and mesencephalon, regulates drive and affective behavior. It plays a crucial role in memory and learning.



A Midsagittal section, left lateral view.

B Hippocampus, left anterior oblique view.

Table 41.4 **Structures of the limbic system**

Outer arc		Inner arc*		Subcortical nuclei	
①	Parahippocampal gyrus	⑤	Hippocampal formation (hippocampus, entorhinal area of parahippocampal gyrus)	⑧	Amygdala
②	Indusium griseum	⑥	Fornix	⑨	Dorsal tegmental nuclei
③	Subcallosal (paraolfactory) area	⑦	Septal area (septum)	⑩	Habenular nuclei
				⑪	Interpeduncular nuclei
④	Cingulate (limbic) gyrus		Paraterminal gyrus	⑫	Mammillary bodies
				⑬	Anterior thalamic nuclei

* The inner arc also contains the diagonal band of Broca (not shown).

Fig. 41.17 Limbic system nuclei

This neuronal circuit (Papez circuit) establishes a connection between information stored at the conscious and unconscious level.

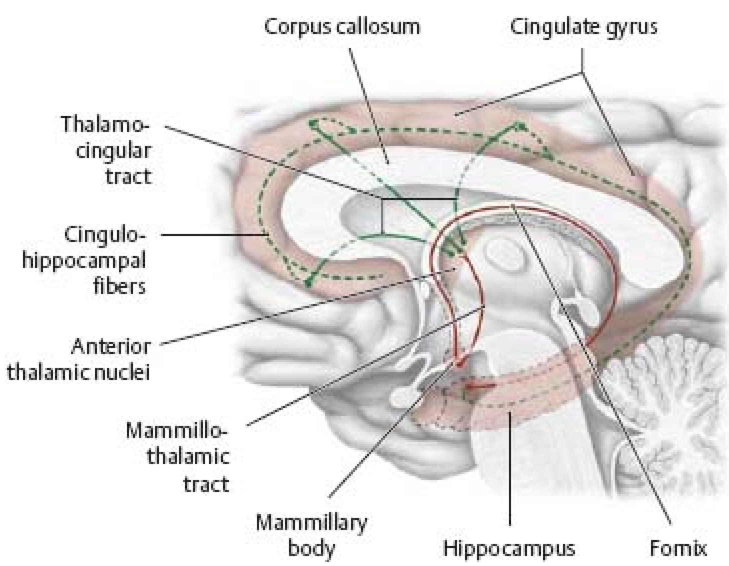
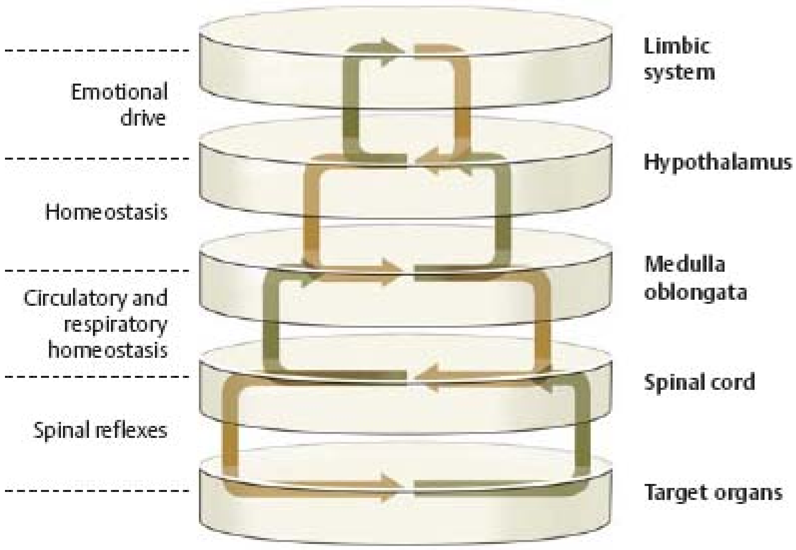


Fig. 41.18 **Limbic regulation of the peripheral autonomic nervous system**

The limbic system receives afferent feedback signals from its target organs. See p. 623 for the autonomic nervous system.



42 Autonomic Nervous System

Autonomic Nervous System

Fig. 42.1 Autonomic nervous system circuitry

The autonomic nervous system innervates smooth muscle, cardiac muscle, and glands. It is divided into the sympathetic (red) and parasympathetic (blue) nervous systems, which often act in antagonistic ways to regulate blood flow, secretions, and organ function. Green: Afferent. Purple: Efferent.

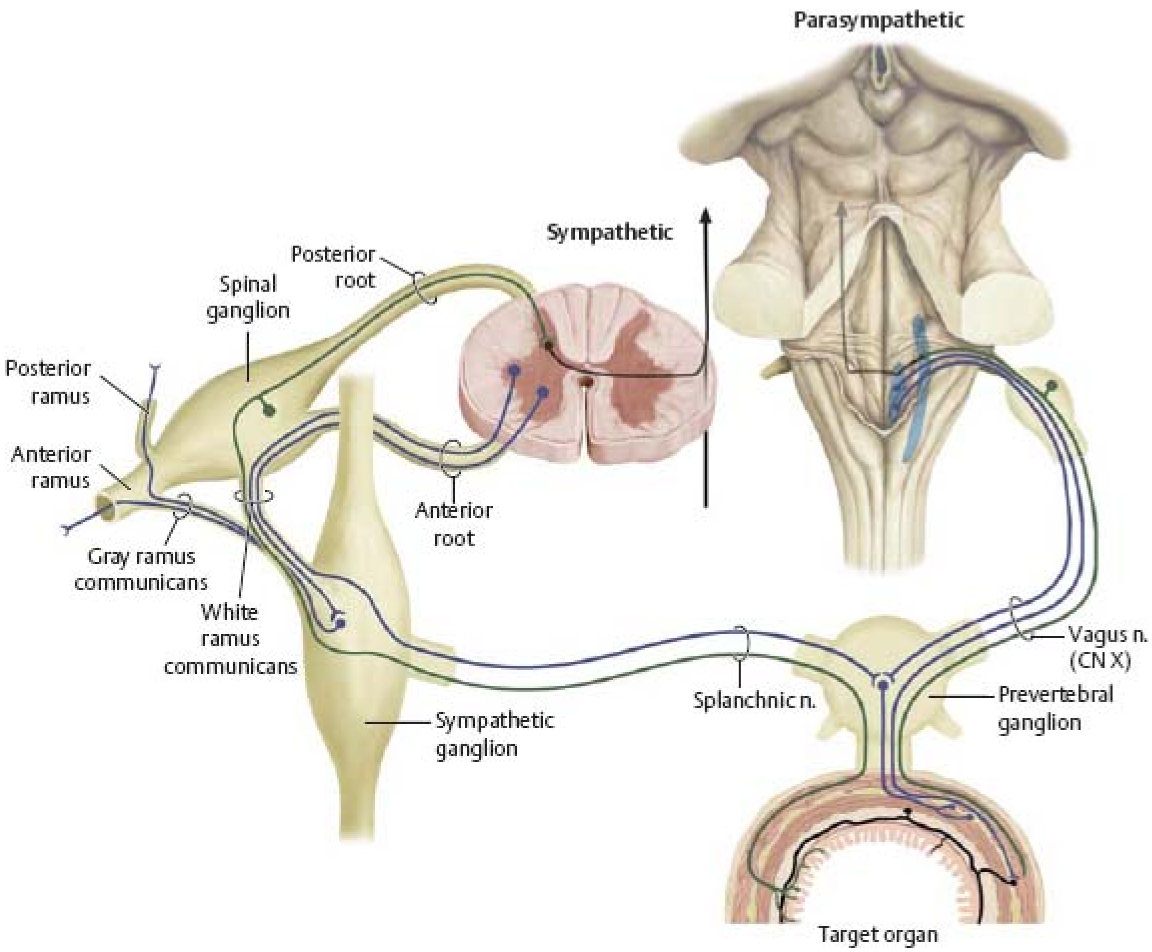


Fig. 42.2 Autonomic tracts in the spinal cord

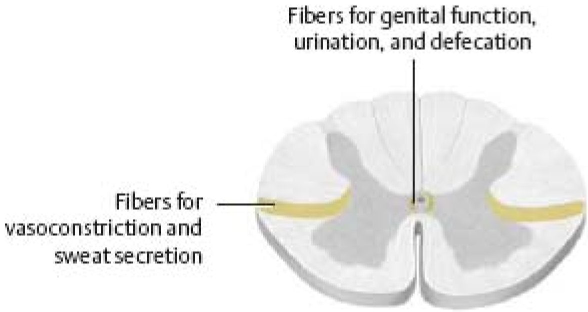


Fig. 42.3 **Regulatory effects of the autonomic neurotransmitters**

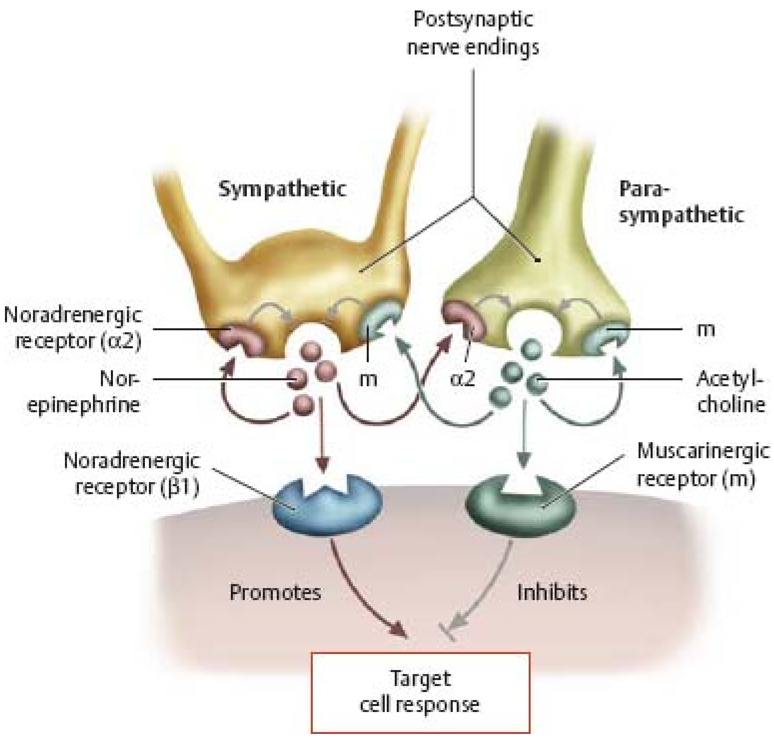


Fig. 42.4 **Blood pressure regulation**

Sympathetic fibers may release norepinephrine, inducing the α1 receptor to mediate contraction of the vascular smooth muscle (thus increasing blood pressure). Circulating epinephrine acts on the β2 receptors to induce vasodilation (decreasing blood pressure). *Note:* Parasympathetic fibers do not terminate on blood vessels.

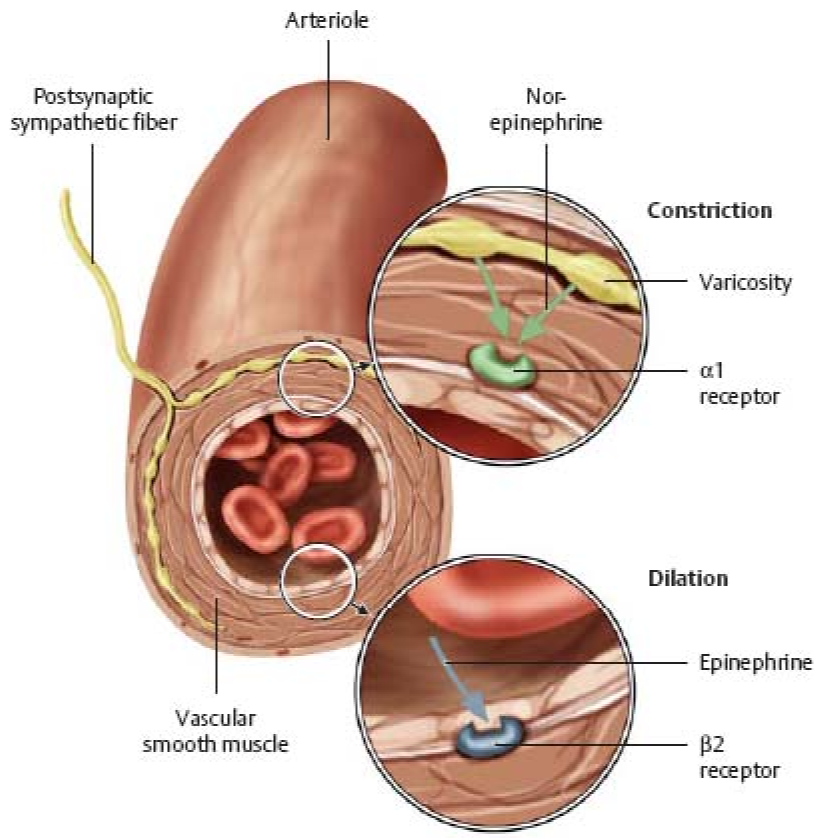
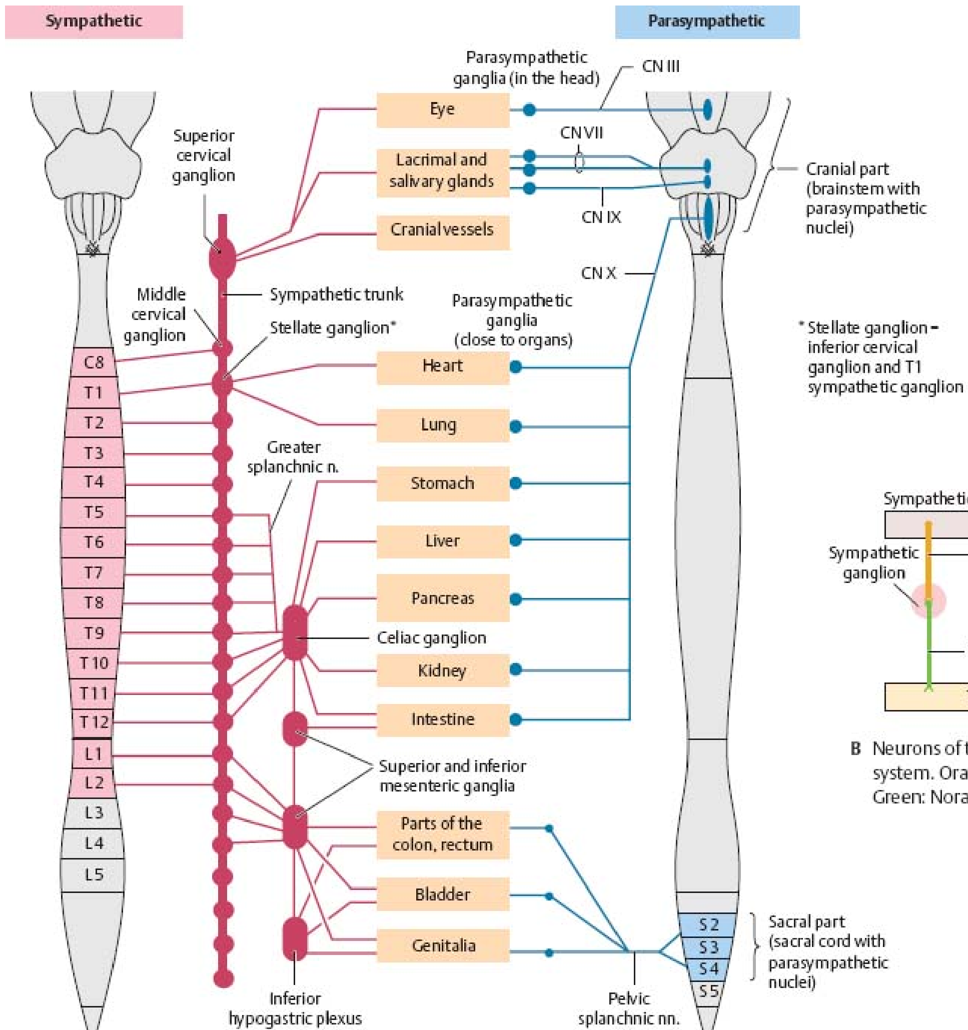


Fig. 42.5 **Autonomic nervous syste**



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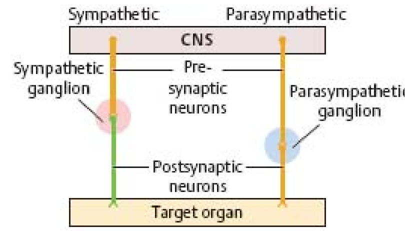

B Neurons of the autonomic nervous system. Orange: Cholinergic neuron. Green: Noradrenergic neuron.

Table 42.1 Effects of the sympathetic and parasympathetic nervous systems

Organ (organ system)		Sympathetic NS effect	Parasympathetic NS effect
Gastro-intestinal tract	Longitudinal and circular muscle fibers	↓ motility	↑ motility
	Sphincter muscles	Contraction	Relaxation
	Glands	↓ secretions	↑ secretions
Splenic capsule		Contraction	No effect
Liver		↑ glycogenolysis/gluconeogenesis	
Pancreas	Endocrine pancreas	↓ insulin secretion	
	Exocrine pancreas	↓ secretion	↑ secretion
Bladder	Detrusor vesicae	Relaxation	Contraction
	Functional bladder sphincter	Contraction	No effect
Seminal vesicle		Contraction (ejaculation)	
Vas deferens			
Uterus		Contraction or relaxation, depending on hormonal status	
Arteries		Vasoconstriction	Vasodilation of the arteries of the penis and clitoris (erection)

NS = nervous system. See also p. 244.

Appendix

Answers to Surface Anatomy Questions

Back (pp. 40–41)

Q1: The superior boundaries of Michaelis' rhomboid run from the spinous process of L4 to the posterior superior iliac spines. The rhomboid then follows the curve of the iliac crest to the anal cleft.

Q2: The inferior angle of the scapula is at the level of the T7 spinous process. The iliac crest is at the level of the L4 spinous process. See p. 40 for palpable bony landmarks.

Thorax (pp. 120–121)

Q1: After careful inspection, undertake a systematic palpation of each breast. Palpate the tissue of each breast by quadrant in the following sequence: inferior lateral, inferior medial, superior medial, and superior lateral. Palpate the axilla to examine the axillary tail of breast tissue. The majority of lymph drainage from the breast is to the axillary lymph nodes. The parasternal lymph nodes, which run along the internal thoracic vessels, drain the medial portions of the breast. See p. 64 for the axillary lymph nodes.

Q2: The aortic and pulmonary valves are best auscultated at the 2nd right and left intercostal spaces, respectively. Locate the 2nd intercostal spaces by finding the usually palpable sternal angle (the junction between the manubrium and body of the sternum). The 2nd ribs attach to the sternum at the sternal angle. The tricuspid (right atrioventricular) and bicuspid (left atrioventricular) valves are best auscultated at the left 5th intercostal space. If the ribs are visible/palpable, the 5th rib can be found by counting up from below (the lowest rib at the midclavicular line is the 10th rib). See p. 87 for auscultation sites; see p. 120 for reference lines in the thorax.

Abdomen & Pelvis (pp. 248–249)

Q1: Use a vertical and a horizontal line through the umbilicus (at approximately the level of L4) to divide the abdomen and pelvis into right and left upper and lower quadrants (see p. 142).

LUQ Liver, stomach, transverse colon, small intestine, spleen, pancreas, duodenum, descending colon, left kidney and suprarenal gland, left ureter.

RUQ Liver, stomach, transverse colon, small intestine, gallbladder, pancreas, duodenum, ascending colon, right kidney and suprarenal gland, right ureter.

LLQ Small intestine, descending colon, left ureter, urinary bladder, reproductive organs.

RLQ Small intestine, ascending colon (with cecum and vermiform appendix), right ureter, urinary bladder, reproductive organs.

Q2: *Direct* inguinal hernias are most common in middle-aged or older males and are believed to be caused by “wear and tear.” They typically occupy the medial portion of the inguinal canal (having exited the abdomen through the inguinal triangle). They may also exit via the superficial inguinal ring. Rarely, they enter the scrotum. *Indirect* hernias are seen in male children and young adults and are believed to have a congenital basis. They generally exit via the deep inguinal ring and thus may occupy the entire length of the inguinal canal. They may also exit via the superficial inguinal ring, and occasionally enter the scrotum. See p. 135 for inguinal hernias.

Upper Limb (pp. 350–353)

Q1: The medial and lateral antebrachial cutaneous nerves are both vulnerable during intravenous punctures in the cubital fossa. The medial nerve is a direct branch from the medial cord of the brachial plexus; the lateral nerve is the cutaneous component of the musculatocutaneous nerve (lateral cord). See p. 339 for the cubital region.

Q2: With the elbow joint in flexion, the ulnar collateral ligament can be palpated using the olecranon, the medial and lateral epicondyles, and the coronoid process. The radial collateral ligament can be palpated using the lateral epicondyle. See p. 284 for the collateral ligaments of the elbow.

Q3: In the wrist, the flexor carpi ulnaris tendon runs laterally to the ulnar artery and nerve until the ulnar tunnel. The median nerve is located between the palpable tendons of palmaris longus and flexor carpi radialis. The radial artery is slightly lateral to the flexor carpi radialis tendon. See p. 342 for the topography of the carpal region.

Q4: Tenderness at the base of the anatomic snuffbox suggests a fracture of the scaphoid. See p. 347 for the anatomic snuffbox; see p. 299 for scaphoid fractures.

Lower Limb (pp. 450–451)

Q1: The head of the femur is located directly behind the femoral artery. The femoral artery emerges below the midpoint of the inguinal ligament. See p. 436 for the inguinal region.

Q2: The sciatic nerve can be located as it exits the greater sciatic foramen by identifying the midpoint between the posterior superior iliac spine and the ischial tuberosity. In the gluteal region (see pp. 438–439), the sciatic nerve passes just medial to the midpoint of a line connecting the greater trochanter of the femur and the ischial tuberosity. The common fibular nerve can be palpated on the lateral border of the popliteal fossa as it courses along the medial border of the biceps femoris tendon (see p. 442). At the ankle, the tibial nerve is located midway between the palpable medial malleolus and the calcaneal (Achilles') tendons (see p. 442).

Head & Neck (pp. 588–589)

Q1: A bolus of anesthetic injected approximately two thirds of the way up the posterior border of the sternocleidomastoid would serve as a nerve block for the cervical plexus.

Q2: The confluence of the sinuses is found deep to the external occipital protuberance. See p. 608 for the dural sinuses.

Q3: The lateral cervical (posterior) triangle is bounded by the sternocleidomastoid and trapezius muscles and the clavicle. It contains the (spinal) accessory nerve (CN XI) and the brachial plexus. See p. 576 for the triangles of the neck. See p. 582 for the contents of the lateral cervical triangle.

Q4: The carotid triangle is bounded by the sternohyoid, posterior belly of the digastric, and sternocleidomastoid. It contains the vagus nerve (CN X). See p. 576 for the triangles of the neck. See p. 580 for the contents of the carotid triangle.

Q5: The thyroid cartilage (see p. 570) is commonly referred to as the “Adam's apple.”

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Note: *Italicized* page numbers represent clinical applications. Tabular material is indicated by a "t" following the page number.

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