
R G U H S · M O D E L A N S W E R B A N K

RGUHS MD/MS Anatomy — Paper I



M O D E L A N S W E R B A N K

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883 recurring topics · Textbook-grounded model answers · cited Recent Advances

G R O U N D E D I N :

Gray's Anatomy (Standring) 41e — spine text
BD Chaurasia · AK Datta · Moore's Clinically Oriented Anatomy — gross anatomy
Langman · Moore (Developing Human) · Larsen — embryology
Thompson & Thompson · Gangane — genetics
Junqueira · Ross · IB Singh — histology
Bancroft · Pranab Dey — microscopy & histotechniques
Halder · Govt Museum Handbook — organ donation & body preservation
Snell · Vishram Singh · IB Singh — neuroanatomy



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General anatomy



Classification of glands

Asked in: Paper I Nov 2017 · Paper I Apr 2006 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction

A gland is a single cell, or an aggregate of specialised epithelial cells, that synthesises and discharges a secretion whose composition differs from that of blood or interstitial fluid. Multicellular glands develop from the surface epithelium (ectoderm, endoderm, or lining mesothelium) by proliferation and evagination into the underlying connective tissue during early development. Glands are classified at several successive levels: first by the **number of cells** forming them, then by their **relationship to a duct** (exocrine, endocrine, or paracrine), and finally — for exocrine glands specifically — by the **branching pattern of the duct and shape of the secretory unit**, by the **mode of secretion**, and by the **nature of the secretory product**. Endocrine glands are classified separately by the arrangement of their secretory cells.

1. Based on the number of cells

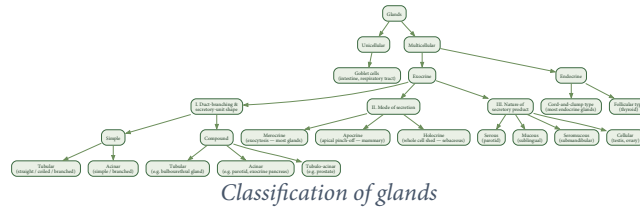
Type	Description	Example
Unicellular	Single secretory cells interspersed among non-secretory epithelial cells; pour secretion directly onto the epithelial surface	Goblet cells of the respiratory and intestinal columnar epithelium
Multicellular	Most glands; formed by proliferation and invagination of surface epithelium into the underlying connective tissue	Salivary glands, sweat glands, liver, pancreas

Unicellular glands, since they discharge onto a free surface, are conventionally grouped with exocrine glands.

2. Based on relationship to a duct / mode of release

Type	Duct	Route of secretion	Example
Exocrine	Present — retains connection with surface epithelium via a duct lined by epithelial cells	Onto a body surface or the lumen of a hollow viscus	Sweat, sebaceous, salivary, gastric, mammary glands
Endocrine	Absent (ductless) — loses connection with the surface epithelium	Directly into interstitial fluid and thence the bloodstream	Pituitary, thyroid, parathyroid, suprarenal glands

Type	Duct	Route of secretion	Example
Paracrine (neuroendocrine)	Absent	Secretion diffuses locally to nearby cellular targets rather than entering the general circulation; many share products with neurotransmitters	Gastrin-secreting G cells of the gut, diffuse neuroendocrine cells of the alimentary and respiratory tracts



3. Classification of exocrine glands

(a) According to the branching pattern of the duct and the shape of the secretory unit

Class	Sub-type	Example
Simple (duct does not branch)	Tubular — straight	Intestinal glands (crypts of Lieberkühn)
	Tubular — coiled	Sweat glands
	Tubular — branched	Gastric and uterine glands
	Acinar — simple	Urethral and para-urethral glands (male)
	Acinar — simple branched	Sebaceous glands
Compound (duct branches repeatedly)	Tubular	Bulbo-urethral glands
	Acinar	Salivary glands, exocrine pancreas
	Tubulo-acinar	Prostate gland

Fig 4.13 — Classification of exocrine glands according to the branching pattern of duct and types of secretory units (Vishram Singh — General Anatomy — 4e, p.153)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Reproduce the branching-pattern classification schematic with these exact labels:

- ▶ **Simple glands (unbranched duct):** Tubular — straight (crypts of Lieberkühn) / coiled (sweat gland) / branched (gastric gland); Acinar — simple (urethral gland) / branched (sebaceous gland).
- ▶ **Compound glands (branched duct):** Tubular (bulbo-urethral gland); Acinar (salivary gland/pancreas); Tubulo-acinar (prostate).
- ▶ Label the duct as unbranched vs branched, and the secretory end-piece as tubular, acinar (rounded/sac-like) or alveolar (flask-shaped) — acinus and alveolus are used synonymously.

(b) According to the mode of secretion

Type	Mechanism	Example
Merocrine	Secretory vesicles fuse with the apical plasma membrane and release contents by exocytosis; cell remains intact	Most glands of the body, e.g. salivary glands (eccrine sweat glands were formerly a separate category but are now known to be merocrine)
Apocrine	Secretion accumulates in the apical cytoplasm; that apical portion is pinched off with the secretion	Mammary glands
Holocrine	Entire secretory cell disintegrates and is discharged as part of the secretion; lost cells are replaced from deeper in the gland	Sebaceous glands

(c) According to the nature of the secretory product

Type	Example
Serous — watery, protein/enzyme-rich secretion; cells have central nuclei and eosinophilic granules	Parotid gland
Mucous — viscid, carbohydrate-rich secretion; cells have flattened basal nuclei and frothy (PAS-positive) cytoplasm	Sublingual salivary gland
Seromucous (mixed) — both serous and mucous acini, sometimes with serous demilunes capping mucous acini	Submandibular gland
Cellular — the "secretion" is the cell itself (gametes)	Testis, ovary

4. Classification of endocrine glands

Endocrine glands are structurally too variable to classify strictly, but two patterns of cell arrangement are recognised:

Type	Arrangement	Example
Cord-and-clump type	Cells form anastomosing cords/clumps separated by sinusoids; secretion is poured directly into the sinusoidal capillaries	Most endocrine glands (pituitary, parathyroid, suprarenal cortex, islets of Langerhans)
Follicular type	Cells enclose a cavity (follicle) in which secretion is stored extracellularly before release into capillaries as required	Thyroid gland

Except for the thyroid, every endocrine gland releases its hormone directly into the blood immediately after synthesis; the thyroid alone stores its secretion extracellularly in follicular colloid before release.

Isolated hormone-secreting cells also exist outside the classical ductless organs, forming the **diffuse (dispersed) neuroendocrine system** — e.g. pancreatic islet cells, thymic epithelial cells, renin- and erythropoietin-secreting renal cells, interstitial (Leydig) cells of the testis, and luteal cells of the ovary; these are described with their respective organ systems rather than as a separate "gland."

Applied / Clinical anatomy

- ▶ **Sebaceous gland pathology** follows directly from its holocrine mechanism — obstruction of the duct with retained holocrine debris and sebum produces acne vulgaris and epidermal (sebaceous) cysts.
- ▶ **Apocrine gland disease:** apocrine sweat glands (axilla, areola, perianal region) become active at puberty and their obstruction/infection underlies hidradenitis suppurativa; apocrine secretion, acted on by skin bacteria, is responsible for body odour.
- ▶ **Merocrine (eccrine) sweat glands** are the principal thermoregulatory glands of the body; their dysfunction produces anhidrosis (heat intolerance) or, conversely, hyperhidrosis.
- ▶ **Salivary gland disease** correlates with secretory type: the mucus-dominant, more viscid secretion of the submandibular (seromucous) gland predisposes it to sialolithiasis (salivary calculi), whereas the serous parotid is the classical site of mixed/pleomorphic adenoma and mumps.
- ▶ **Sjögren syndrome** is an autoimmune exocrinopathy targeting serous/seromucous glands (salivary and lacrimal), producing xerostomia and keratoconjunctivitis sicca.
- ▶ **Cystic fibrosis** is a disorder of exocrine gland secretion (defective CFTR chloride channel) producing abnormally viscid mucous secretions in the respiratory, pancreatic and other exocrine glands.
- ▶ **Mixed exocrine–endocrine organs:** the pancreas (acini = exocrine, digestive enzymes; islets of Langerhans = endocrine, insulin/glucagon) and the gonads (testis/ovary — gametes as a "cellular" exocrine-type product plus androgen/oestrogen secretion) illustrate a single organ combining both classes.
- ▶ **Follicular architecture** is clinically important because the thyroid is the one endocrine gland that stores its hormone extracellularly (as thyroglobulin in colloid) — the basis of radioiodine uptake studies and of colloid goitre.

- ▶ **Adenoma/adenocarcinoma nomenclature** in pathology follows this same structural classification — tubular adenoma, papillary/acinar adenocarcinoma, mucinous vs serous cystadenoma — so the classification of glands is directly examinable in histopathology correlation.

High-yield exam pointers

- ▶ Glands are first divided by **cellularity** — unicellular (goblet cell) vs multicellular.
- ▶ Multicellular glands are divided by duct relationship into **exocrine** (duct present), **endocrine** (ductless, into blood) and **paracrine/neuroendocrine** (local diffusion).
- ▶ Exocrine glands have **three independent classification axes**: (i) duct-branching pattern & secretory-unit shape (simple vs compound), (ii) mode of secretion (merocrine/apocrine/holocrine), (iii) nature of product (serous/mucous/seromucous/cellular).
- ▶ **Simple** glands: unbranched duct — tubular (straight/coiled/branched) or acinar (simple/branched).
- ▶ **Compound** glands: branched duct — tubular, acinar, or tubulo-acinar.
- ▶ **Merocrine** = exocytosis, cell survives (most glands); **Apocrine** = apical portion pinched off (mammary); **Holocrine** = whole cell shed (sebaceous).
- ▶ **Endocrine glands**: cord-and-clump type (most) vs follicular type (thyroid only — the sole gland that stores secretion extracellularly).
- ▶ Diffuse neuroendocrine/paracrine cells (e.g. gut G cells) secrete locally and share products with the nervous system.
- ▶ Pancreas and gonads are classic examples of glands combining exocrine and endocrine function in one organ.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e.



Dermatome

Asked in: Paper I Nov 2017 · Paper I May 2009 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction

A **dermatome** is the area of skin supplied by a single spinal nerve — through both its dorsal (posterior) and ventral (anterior) primary rami — and therefore by a single spinal cord segment. Of the 31 pairs of spinal nerves, all except the **first cervical nerve (C1)** are associated with a specific dermatome; C1 has no significant sensory (afferent) component and supplies no skin. Dermatomal maps are clinically indispensable — the pattern of cutaneous sensory loss following a lesion of a spinal nerve, posterior root, or spinal cord segment conforms to the dermatome and allows the segmental level of the lesion to be localised.

1. Dermatome, myotome and peripheral nerve field — the key distinction

Term	Defined by	Basis
Dermatome	Area of skin supplied by one spinal nerve/segment	Segmental (pre-plexus) distribution
Myotome	Muscle mass supplied by one spinal segment	Segmental motor distribution
Peripheral (cutaneous) nerve field	Area of skin supplied by one named peripheral nerve (e.g. median, radial)	Post-plexus distribution — each named nerve carries fibres from several spinal segments, so its cutaneous field differs from any single dermatome

This distinction is a favourite examiner trap: after plexus formation (brachial, lumbosacral), the territory of a *named* cutaneous nerve no longer coincides with the territory of a *single spinal segment*.

2. Embryological basis of the dermatomal pattern

- ▶ **Trunk** — simple (typical) arrangement: thoracic and upper lumbar spinal nerves reach the body wall directly without forming a plexus, so each dermatome extends as a band from the **posterior median line to the anterior median line**, encircling the trunk.
- ▶ **Limbs** — complicated arrangement, for two reasons:
- ▶ **Embryonic rotation of the limb buds.** Each paddle-shaped limb bud has a **preaxial** (cephalic) and **postaxial** (caudal) border; the thumb/great toe lie along the preaxial border. The **upper limb rotates laterally**, carrying its preaxial border and thumb to the lateral side; the **lower limb rotates medially**, carrying its preaxial border and great toe to the medial side.
- ▶ **Plexus formation** — spinal nerves supplying the limbs intermingle in the brachial/lumbosacral plexus before reaching the skin.
- ▶ Consequence: upper-limb dermatomes run **down the lateral border and up the medial border**; lower-limb dermatomes run **down the anterior/lateral (preaxial, L1–L4) border and up the posterior (postaxial, S1–S3) border**.
- ▶ As the limb elongates, the intervening (central) dermatomes (C6–C8 in the upper limb; L4, L5, S1 in the lower limb) are drawn out distally and "buried" proximally — the line along which non-consecutive dermatomes meet directly, with little or no overlap, is called the **axial line**; it is a more reliable clinical boundary than the heavily-overlapping interdermatomal borders elsewhere.
- ▶ Because the upper limb "borrows" C5–T1 from the trunk wall, the **C4 dermatome becomes directly contiguous with T2 at the sternal angle** anteriorly (C5–T1 have no significant trunk representation). Likewise, upward migration of upper cervical dermatomes during head/neck development brings the **C2 dermatome into direct continuity with the ophthalmic (trigeminal) territory at the interauricular line**.
- ▶ In the head and face, each of the three divisions of the **trigeminal nerve** supplies a precise territory with **little or no overlap** between divisions — unlike the generous overlap seen between spinal dermatomes.

3. Distribution — dermatomal map and clinically important landmarks

□ Fig 1.36 — *Dermatomes (segmental cutaneous innervation). Dermatom maps of the bo (Moore — Clinically Oriented Anatomy — 9e, p.170)*

Two composite maps are in clinical use — **Foerster's map (1933)**, derived from clinical observations (e.g. herpes zoster, cordotomy), preferred by clinicians for its correlation with disease patterns; and the **Keegan & Garrett map (1948)**, a more regular, symmetric, schematic map preferred by anatomists for its better correlation with limb development. The two differ somewhat, particularly over the limbs — a reminder that dermatome maps are **approximations/composites**, not fixed anatomical boundaries.

Landmark dermatomes (high-yield):

Dermatome	Cutaneous landmark
C2	Back of the scalp (occiput)
C4	Tip of the shoulder
C5	Lateral side of the arm
C6	Lateral forearm and thumb
C7	Hand and middle 3 digits
C8	Little finger and medial forearm
T1	Medial side of the arm
T2	Axilla
T4	Skin around the nipple
T7	Xiphoid process
T10	Skin around the umbilicus
L1	Groin / inguinal region
L1–L3	Anterior thigh (sequentially, above downward)
L4	Medial side of the leg
L5	Lateral thigh/leg, dorsum of foot, medial sole
S1	Lateral side of the foot and sole
S2	Middle of back of thigh and leg
S3, S4	Buttocks / perineum

(Note: the superomedial quadrant of the gluteal region is exceptionally supplied by the dorsal rami of L1–L3 and S1–S3, unlike the rest of the lower limb, which — being ventrolateral in origin — is innervated only by ventral rami.)

4. Overlap of dermatomes and sensory-modality differences

- Adjacent dermatomes **overlap considerably**; therefore, to produce a region of **complete anaesthesia**, at least **three contiguous spinal nerves** (or posterior roots) must be

sectioned/damaged — division of a single nerve produces little or no detectable sensory loss because neighbouring dermatomes cover the gap.

- ▶ The **area of tactile (touch) loss is always greater** than the area of loss of pain and temperature sensation after a nerve lesion. This is because the fibres carrying pain and temperature overlap **more extensively** between adjacent segments than fibres carrying touch — so touch loses more of its "back-up" cover when one nerve is cut.
- ▶ Overlap is least (and dermatome boundaries are sharpest and most clinically reliable) along the **axial lines** and over regions such as the upper anterior thoracic wall, where adjoining cutaneous territories are supplied by non-consecutive spinal nerves.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the anterior and posterior dermatome maps of the body (simple outline figure) and label:

- ▶ **Head/neck:** C2 (occiput), C3 (neck), trigeminal (V1/V2/V3) territory of the face with the C2–trigeminal junction at the interauricular line.
- ▶ **Trunk (anterior):** C4 (shoulder tip) → sternal-angle junction with T2 → T4 (nipple line) → T7 (xiphoid) → T10 (umbilicus) → L1 (groin).
- ▶ **Upper limb:** C5 (lateral arm) → C6 (lateral forearm/thumb) → C7 (middle digits) → C8 (little finger/medial forearm) → T1 (medial arm) → T2 (axilla), with the preaxial (lateral, C5–C7) and postaxial (medial, C8–T1) bands and the axial line between C4 (trunk) and T2 (medial arm).
- ▶ **Lower limb:** L1–L3 (anterior thigh, sequential) → L4 (medial leg) → L5 (lateral leg/dorsum of foot) → S1 (lateral foot/sole) → S2 (back of thigh/leg) → S3–S4 (buttock/perineum), with the axial line separating L3 from S3 on the posterior thigh.
- ▶ Mark **overlap zones** with hatching between adjacent bands to show the "smudged", not sharp-lined, real boundaries.

Applied / Clinical anatomy

- ▶ **Localising a spinal-cord/nerve-root lesion:** sensory examination for touch, pain and temperature over successive dermatomes lets the clinician map the **upper level of sensory loss**, which indicates the segmental level of a cord or root lesion (e.g., in paraplegia, disc prolapse, or spinal trauma).
- ▶ **Herpes zoster (shingles):** reactivation of latent varicella-zoster virus in a dorsal root (or trigeminal) ganglion produces a vesicular eruption strictly confined to that **single dermatome**; ophthalmic-division involvement is termed **herpes zoster ophthalmicus**, and geniculate ganglion involvement causes **Ramsay Hunt syndrome** (facial palsy ± vertigo/deafness).
- ▶ **Referred visceral pain** follows dermatomal rules, since the diseased viscus and the corresponding skin dermatome are supplied by afferents entering the **same spinal segment**: pain from the appendix, testis or ovary is referred to the **T10 (umbilical) dermatome**; cardiac pain is referred to the **T1–T4 dermatomes**, spreading to the medial arm and forearm.

- ▶ **Regional/spinal anaesthesia:** the sensory block level achieved is described in dermatomal terms — e.g., a block to the **T4 (nipple-line) dermatome** is the level targeted for Caesarean section, and **T10 (umbilicus)** for normal labour analgesia.
- ▶ **Because of dermatomal overlap**, an isolated single-root lesion (e.g., one prolapsed intervertebral disc) rarely causes complete anaesthesia — only reduced/altered sensation — which is why "at least three contiguous nerves" must be involved for frank numbness; this is tested clinically to distinguish a single-root from a multi-root or cord lesion.
- ▶ Dermatome charts are also used to assess **peripheral neuropathies** and to grade sensory levels in **spinal cord injury**.

High-yield exam pointers

- ▶ Dermatome = skin area of one spinal nerve/segment (both rami); **C1 has no dermatome**.
- ▶ Trunk dermatomes are simple bands (posterior → anterior median line); limb dermatomes are complex due to **limb-bud rotation + plexus formation**.
- ▶ Landmark dermatomes: **C6–thumb**, **T4–nipple**, **T10–umbilicus**, **L1–groin**, **L5/S1–sole/foot**.
- ▶ **Axial line** = line of minimal overlap where non-consecutive dermatomes meet (e.g., C4/T2 junction, L3/S3 junction).
- ▶ Two classical maps: **Foerster (1933)** and **Keegan & Garrett (1948)** — they differ, especially over the limbs.
- ▶ **≥3 contiguous nerves** must be cut for complete anaesthesia; tactile loss area > pain/temperature loss area (differential fibre overlap).
- ▶ Clinical uses: **localising cord/root lesions**, **herpes zoster**, **referred visceral pain** (**T10–appendix/testis/ovary**; **T1–T4–heart**), and **level of spinal/epidural anaesthesia**.
- ▶ Dermatome (segmental/spinal-nerve territory) ≠ peripheral/cutaneous nerve field (territory of a named post-plexus nerve) ≠ myotome (segmental muscle territory).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; Vishram Singh — Clinical Neuroanatomy 4e; Vishram Singh — Textbook of Anatomy Vol 1 (Thorax/Upper Limb) and Vol 2 (Lower Limb) 4e; Moore — Clinically Oriented Anatomy 9e; Snell — Clinical Neuroanatomy 7e; Moore — The Developing Human 9e; IB Singh — Textbook of Anatomy Vol 1 6e.



Fibrous joints

Asked in: Paper I 07-Jul-2023 · Paper I May 2019 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction — A joint (articulation) is the site of union between two or more bones or between bone and cartilage. Structurally, joints are classified into **fibrous**, **cartilaginous** and **synovial** varieties according to the type of connecting tissue and the presence or absence of a joint cavity. A **fibrous joint** is one in which the articulating bones are united directly by fibrous connective tissue, with no intervening joint cavity; such joints are functionally **immovable** (**synarthroses**) or permit only a **slight degree of movement** (**amphiarthroses**). Three subtypes are recognised — **sutures**, **syndesmoses** and **gomphoses** — distinguished by the amount and disposition of the connecting fibrous tissue.

1. Structural and functional classification of joints

Structural type	Connecting tissue	Joint cavity	Functional correlate	Example
Fibrous	Dense fibrous connective tissue	Absent	Synarthrosis / amphiarthrosis	Skull sutures, interosseous membranes
Cartilaginous	Hyaline cartilage (primary) or fibrocartilage (secondary)	Absent	Synarthrosis / amphiarthrosis	Epiphysial plate, pubic symphysis
Synovial	Articular (hyaline) cartilage + synovial membrane	Present	Diarthrosis	Knee, shoulder

Functionally, immovable joints (synarthroses) include cranial sutures in the adult; slightly movable joints (amphiarthroses) include syndesmoses and secondary cartilaginous joints; freely movable joints (diarthroses) are the synovial joints. Gray's Anatomy notes that no single classification of joints is fully satisfactory: movement-based schemes group all restricted joints (fibrous **and** cartilaginous) together as "synarthroses", whereas the conventional teaching scheme used above further separates immovable synarthroses from slightly-movable amphiarthroses — candidates should be prepared to use either terminology consistently.

2. General features of fibrous joints

- ▶ Bones are united by **fibrous connective tissue**; there is **no joint cavity** and no articular cartilage covering the bone ends.
- ▶ The **amount and arrangement of the fibrous tissue** determines both the subtype and the degree of mobility permitted.
- ▶ Movement, when present, is limited and depends on the length/pliability of the connecting fibres rather than on true articular gliding.
- ▶ In the growing skull, sutures additionally serve as **sites of ongoing intramembranous bone deposition**, allowing the cranial vault to expand in step with brain growth; this growth function is lost once the suture synostoses.
- ▶ The three subtypes — sutures, syndesmoses, gomphoses — are considered below.

3. Sutures

- ▶ Found **exclusively in the skull**; the two bones are separated by a thin layer of **membrane-derived connective tissue (sutural ligament)**, each sutural bone surface being covered by an osteogenic (cambial) layer.
- ▶ Essentially **immovable**, though a degree of mobility is retained in growing children (important for moulding of the head during birth).
- ▶ Classified by the shape of the articulating margins:

Subtype	Feature	Example
Plane suture	Smooth, flat apposed surfaces	Median palatine suture (maxilla–palatine)
Serrate (limbus) suture	Reciprocally serrated, interlocking like a jigsaw	Sagittal suture
Denticulate suture	Tooth-like interlocking projections	Lambdoid suture
Squamous suture	Bevelled, overlapping surfaces	Temporo-parietal suture
Schindylesis (wedge-and-groove)	A ridge of one bone fits a groove in the other	Rostrum of sphenoid into the cleft between the alae of the vomer

□ Fig 7.2 — A suture. (Vishram Singh — General Anatomy — 4e, p.285)

- ▶ With age, the loose fibrous tissue between the sutural surfaces diminishes and many sutures **synostose** (undergo bony fusion/obliteration) as the osteogenic surfaces become directly apposed; this normal ageing change can begin **in the early twenties** and continues into advanced age.

4. Syndesmoses

- ▶ Two adjacent bones are linked by a **considerably greater bulk of connective tissue** than at a suture, in the form of an **interosseous ligament/membrane**, a fibrous cord, or a fibrous membrane.
- ▶ Examples: the **interosseous membrane** between the shafts of the **radius and ulna**, the **interosseous** and **inferior tibiofibular** joints, the **ligamenta flava** connecting adjacent vertebral laminae, and the **tympano-stapedial syndesmosis** in the middle ear.
- ▶ A syndesmosis permits a **slight but functionally important degree of movement** — e.g., the interosseous membrane of the forearm allows rotation of the radius around the ulna during **pronation and supination** while simultaneously transmitting load between the two bones and giving attachment to forearm muscles.

5. Gomphoses

- ▶ A **peg-and-socket** joint restricted to the **dento-alveolar articulation** — the root (peg) of a tooth fitting into its alveolar socket (mandible or maxilla).
- ▶ The tooth is held in intimate contact with the bony socket by the collagen fibres of the **periodontal ligament**, which connects the dental cement to the alveolar bone.

- Strictly, since one component (the tooth) is not a skeletal element, a gomphosis is not a true articulation between two bones — but it is conventionally classified with the fibrous joints because of its fibrous connecting tissue and its virtually immobile nature.

6. Comparative summary of the three subtypes

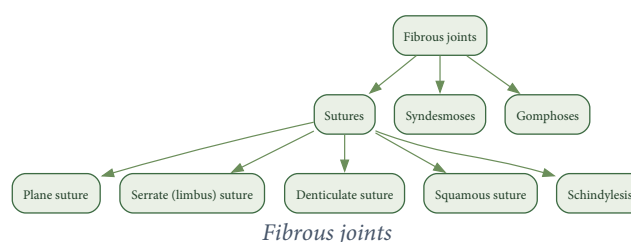
Feature	Suture	Syndesmosis	Gomphosis
Location	Skull only	Radio-ulnar, tibiofibular shafts; vertebral laminae; middle ear	Dento-alveolar joint (teeth)
Connecting tissue	Thin sutural (membrane-derived) ligament	Interosseous ligament/membrane, fibrous cord, or fibrous membrane	Periodontal ligament
Amount of fibrous tissue	Least	Intermediate to considerable	Specialised, confined to the socket
Mobility	Virtually none (some laxity in children)	Slight but functionally useful (e.g. pronation–supination)	Virtually none
Fate with age / disease	Synostosis (bony fusion)	Persists throughout life	Loosens in periodontitis
Example	Sagittal suture	Interosseous membrane of forearm	Tooth in its alveolar socket

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the three fibrous-joint subtypes side by side in cross-section, each clearly labelled:

- **Suture** — two skull bones, thin sutural ligament between apposed osteogenic (cambial) layers, periosteum continuous across the joint.
- **Syndesmosis** — radius and ulna (or tibia and fibula) united by a broad **interosseous membrane/ligament**.
- **Gomphosis** — tooth (peg) with **periodontal ligament** fibres anchoring it within the alveolar socket (bone).

Label: articulating bone(s), connecting fibrous tissue, absence of joint cavity, and one example under each.



Applied / Clinical anatomy

- ▶ **Craniosynostosis** — premature closure of a cranial suture causes characteristic skull deformity depending on which suture fuses early: premature **sagittal suture** closure (small/absent anterior fontanelle) gives a long, narrow, wedge-shaped skull (**scaphocephaly**); unilateral premature closure of the **coronal or lambdoid suture** gives an asymmetric, twisted skull (**plagiocephaly**); premature **coronal suture** closure produces a high, tower-like skull (**oxycephaly/turriccephaly**).
- ▶ **Age-related skull fracture pattern** — in children the unfused, resilient sutures allow the skull to withstand impact better; in adults, once sutures have synostosed, the skull behaves like a rigid eggshell and is more prone to splintering/fracture.
- ▶ **Sutural (Wormian) bones** — extra ossification centres appearing within a suture produce accessory sutural/Wormian bones, occasionally mistaken clinically for fracture fragments on skull radiographs.
- ▶ **Forearm interosseous membrane** — because the radial and ulnar shafts are firmly bound by this syndesmosis, an isolated fracture of one bone is commonly associated with dislocation of the nearby (proximal or distal) radioulnar joint.
- ▶ **Sacroiliac joint** — a compound joint with both a synovial and a syndesmotric (posterior interosseous ligament) component, reflecting its dual role in weight transfer/stability and, in females, parturition.
- ▶ **Periodontitis** — inflammation and degeneration of the periodontal ligament of the gomphosis loosens the tooth in its socket and may lead to tooth loss; this is the anatomical basis of periodontal disease in dentistry.
- ▶ **Ligamenta flava syndesmosis** — its marked elasticity permits flexion/extension of the vertebral column while restoring the column to the neutral position; degenerative thickening contributes to spinal canal/lateral recess stenosis.
- ▶ **Forensic/medico-legal relevance** — because sutural synostosis is a progressive, age-related change, the degree of obliteration of individual cranial sutures is used as one of several parameters for skeletal age estimation in forensic anatomy.

High-yield exam pointers

- ▶ Fibrous joints = bones united by **fibrous connective tissue**, **no joint cavity**; functionally synarthroses or amphiarthroses.
- ▶ Three subtypes: **sutures** (skull only), **syndesmoses** (interosseous ligament/membrane), **gomphoses** (peg-and-socket, teeth).
- ▶ Five suture subtypes by shape: **plane**, **serrate (limbus)**, **denticulate**, **squamous**, **schindylesis** — know one example of each.
- ▶ Sutures undergo age-related **synostosis**; premature synostosis = **craniosynostosis** (scaphocephaly/plagiocephaly/oxycephaly).
- ▶ Classic syndesmosis examples: **radio-ulnar and tibiofibular interosseous membranes**, **ligamenta flava**, **tympano-stapedial joint**.
- ▶ Gomphosis is technically not a bone-to-bone joint (tooth is not a skeletal element) but is grouped with fibrous joints by convention; held by the **periodontal ligament**.

- Sutural/Wormian bones arise from extra ossification centres within sutures.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; Moore's Clinically Oriented Anatomy 9e.



Anatomical terms of position, terms of movements

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction — Anatomy is an exact descriptive science, and to avoid ambiguity every description of the body is referred to a single, universally agreed reference posture — the **anatomical position** — and to a set of standard imaginary **planes** and **axes** passing through it. Movements at joints are likewise named according to the plane in which they occur and the axis around which they occur, so that "flexion of the elbow" or "abduction of the hip" means exactly the same thing to every examiner, surgeon and radiologist. This precise vocabulary is the foundation on which all regional, clinical and radiological anatomy is built.

1. Anatomical position and other reference positions

- **Anatomical position:** the body stands erect, eyes looking forward at the horizon, upper limbs hanging by the sides with **palms facing forwards**, lower limbs together with feet flat on the floor and **toes pointing forwards**. All anatomical descriptions are made as though the body were in this position, however it is actually placed on the table.
- **Fundamental position:** identical to the anatomical position except that the **palms face the sides of the body / forearms lie in the mid-prone position**; it is the position used when describing pronation and supination of the forearm.
- Other clinically used body positions:
 - **Supine (recumbent)** — lying on the back, face directed upwards.
 - **Prone** — lying on the abdomen, face directed downwards.
 - **Lithotomy** — supine with buttocks at the edge of the table, hips and knees semi-flexed and thighs abducted; used to expose the perineum.

2. Anatomical planes and axes

□ Fig 1.2 — Anatomical position and anatomical planes. The main planes of the body (Moore — Clinically Oriented Anatomy — 9e, p.95)

Plane	Orientation	Divides the body into
Median (mid-sagittal)	Vertical, longitudinal, passes through the midline	Equal right and left halves
Sagittal (para-sagittal)	Any vertical plane parallel to the median plane	Unequal right and left parts

Plane	Orientation	Divides the body into
Coronal (frontal)	Vertical, at right angles to the median plane	Anterior and posterior portions
Transverse (horizontal / axial)	Horizontal, at right angles to the long axis of the body; perpendicular to the median plane	Superior and inferior portions
Oblique	Any plane that is not median, sagittal, coronal or transverse	Irregular parts

- ▶ A plane passing through the centre of the body (sagittal, coronal or transverse) that divides it into **equal** parts is called a **cardinal plane**; the point at which the three cardinal planes intersect is the **centre of gravity** of the body.
- ▶ **Radiological convention:** transverse sections are called **(trans)axial**; by convention axial images are viewed as though looking from the feet towards the head — the same terminology and planes are used to describe CT/MRI cuts.

3. Descriptive (relational) terms of position

Term	Meaning
Anterior / ventral	Towards the front
Posterior / dorsal	Towards the back
Superior / cranial (cephalad)	Towards the head
Inferior / caudal	Towards the feet (caudal — tail end, chiefly embryology)
Medial	Closer to the median plane
Lateral	Farther from the median plane
Intermediate	Between a medial and a lateral structure
Median	Lying exactly in the median plane
Central	Towards the centre of the body mass
Peripheral	Away from the centre of the body mass
Superficial / external	Closer to the surface
Deep / internal	Closer to the centre or interior
Ipsilateral	Same side of the body
Contralateral	Opposite side of the body
Invagination / evagination	Inward / outward protrusion of a wall (e.g. of a hollow viscus)

Limb-specific terms:

Term	Meaning
Proximal	Nearer the root/trunk attachment of the limb
Distal	Farther from the root of the limb
Radial / ulnar	Lateral / medial border of the forearm
Tibial / fibular (peroneal)	Medial / lateral border of the leg
Pre-axial border	Thumb side of the upper limb; great-toe side of the lower limb (embryologically corresponding borders)
Post-axial border	Little-finger side of the upper limb; little-toe side of the lower limb
Flexor surface	Anterior surface of the upper limb; posterior surface of the lower limb
Extensor surface	Posterior surface of the upper limb; anterior surface of the lower limb
Palmar (volar) / plantar	Towards the palm of the hand / towards the sole of the foot

4. Terms of movement — the primary (uniaxial/biaxial) movements

Movement	Plane	Axis	Definition
Flexion	Sagittal	Transverse	Approximates the flexor surfaces, decreasing the joint angle (usually an anterior movement, but posterior at the knee)
Extension	Sagittal	Transverse	Approximates the extensor surfaces, increasing the joint angle; hyperextension = extension beyond the anatomical position so the joint angle exceeds 180° (e.g. bending the head backwards)
Abduction	Coronal	Antero-posterior	Movement of a part away from the midline (for digits, away from the axis of the middle finger in the hand / axis of the second toe in the foot)
Adduction	Coronal	Antero-posterior	Movement of a part towards the midline (towards the axis of the middle finger/second toe for digits)

Movement	Plane	Axis	Definition
Medial (internal) rotation	Horizontal	Longitudinal (vertical)	Anterior surface of the part turns to face medially
Lateral (external) rotation	Horizontal	Longitudinal (vertical)	Anterior surface of the part turns to face laterally
Circumduction	Sequential — a conical sweep	Combined	Flexion, abduction, extension and adduction performed in sequence, tracing a cone whose base is the distal end of the moving bone; possible only at biaxial/polyaxial joints — shoulder, hip, wrist and ankle

5. Terms of movement — special/regional movements

- **Supination:** lateral rotation of the forearm from the mid-prone position about its longitudinal axis so that the palm faces anteriorly.
- **Pronation:** medial rotation of the forearm from the mid-prone position so that the palm faces posteriorly.
- **Dorsiflexion:** at the ankle, the dorsum of the foot is elevated towards the leg. **Plantar flexion:** the foot is pressed downwards, as in rising on the toes.
- **Inversion:** the sole of the foot is turned to face medially/inwards. **Eversion:** the sole is turned to face laterally/outwards. (Functionally, supination/pronation of the forearm are equivalent to inversion/eversion of the foot.)
- **Protraction:** a part moves forward in a plane parallel to the ground (e.g. thrusting out the mandible, or the shoulder/scapula forwards). **Retraction:** the reverse movement, pulling the protracted part back.
- **Elevation:** a part is lifted upward (e.g. elevating the mandible to close the mouth, or shrugging/elevating the scapula). **Depression:** the opposite of elevation.
- **Lateral flexion:** side-bending of the trunk/neck occurring in the coronal plane.
- **Opposition of the thumb:** a combined movement of flexion, abduction and medial rotation at the first carpometacarpal joint that brings the pulp of the thumb into contact with the pulp of another finger; it is regarded as the movement unique to the human hand and is essential for precision grip.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A standing figure in anatomical position (anterior, posterior and lateral aspects), with the three cardinal planes (median/sagittal, coronal, transverse) sketched as intersecting sheets through the body, and movement arrows labelled at the major joints exactly as in the classic descriptive-anatomy composite figure:

- ▶ **SUP** (superior/cranial) ↔ **INF** (inferior/caudal) — vertical axis of the whole figure
- ▶ **MED** (medial) ↔ **LAT** (lateral) — at the wrist/forearm
- ▶ **ANT/ventral** ↔ **POST/dorsal** — on the trunk in lateral view
- ▶ **PROX** ↔ **DISTAL** — along the limb
- ▶ **FLEX** / **EXT** arrows at the hip (thigh) and knee (leg)
- ▶ **AB** (abduction) / **AD** (adduction) arrows at the shoulder and hip
- ▶ **Medial rotation** / **Lateral rotation** arrows at the shoulder
- ▶ **Pronation** / **Supination** arrows at the forearm
- ▶ **Inversion** / **Eversion** arrows at the foot

Applied / Clinical anatomy

- ▶ All clinical descriptions — of wounds, fracture displacement, tumour margins, or the level of a nerve/vessel injury — are conventionally recorded with reference to the anatomical position, irrespective of the patient's actual posture on the examination table or operating table.
- ▶ **Radiology:** CT and MRI sections are described and displayed using the same median/sagittal, coronal and transverse (axial) planes; by convention axial images are viewed as if looking from the feet towards the head, which is essential for correctly siding a lesion on a cross-sectional image.
- ▶ **Surgical positioning:** the lithotomy position (hip and knee semi-flexed, thighs abducted) is used for perineal, gynaecological and urological procedures and is described entirely in the vocabulary of flexion/abduction.
- ▶ **Localizing nerve lesions by loss of a named movement:** loss of dorsiflexion of the foot ("foot drop") points to a common fibular (peroneal) nerve palsy; loss of opposition of the thumb with an "ape-thumb" deformity points to a low median nerve lesion; loss of supination with preserved flexion suggests a posterior interosseous (deep radial) nerve lesion.
- ▶ **Range-of-motion (ROM) assessment** in orthopaedics and physiotherapy (goniometry) records flexion, extension, abduction, adduction and rotation in degrees at each joint, using exactly this terminology.
- ▶ The **pre-axial/post-axial border** concept underlies the description of congenital limb anomalies — pre-axial polydactyly (extra digit on the thumb/great-toe side) versus post-axial polydactyly (extra digit on the little-finger/little-toe side).
- ▶ **Directional terms** (proximal/distal, superficial/deep, medial/lateral) are the standard shorthand of operative notes for describing the exact site of an incision, a fracture, or the course of a structure relative to a landmark.

High-yield exam pointers

- ▶ Anatomical position: erect, eyes on the horizon, palms facing forwards, feet together, toes forwards; it is the universal reference for every anatomical description.
- ▶ Fundamental position = anatomical position except the palms face the sides of the body (forearms mid-prone) — used to describe pronation/supination.
- ▶ Four principal planes — median, sagittal, coronal, transverse — plus the oblique plane; a plane through the centre of the body is a "cardinal plane," and the three cardinal planes intersect at the centre of gravity.
- ▶ Flexion/extension occur in the **sagittal plane** around a **transverse axis**; abduction/adduction occur in the **coronal plane** around an **antero-posterior axis**; medial/lateral rotation occur around the **longitudinal (vertical) axis**.
- ▶ Circumduction = flexion + abduction + extension + adduction performed in sequence; possible only at biaxial/polyaxial joints (shoulder, hip, wrist, ankle).
- ▶ Hyperextension = extension carried beyond the anatomical position so the joint angle exceeds 180°.
- ▶ Supination/pronation of the forearm are functionally equivalent to inversion/eversion of the foot.
- ▶ The reference line for abduction/adduction of digits is the axis of the middle finger (hand) and the second toe (foot).
- ▶ Opposition of the thumb (flexion + abduction + medial rotation at the 1st carpometacarpal joint) is the movement unique to humans and the basis of precision grip.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; Moore's Clinically Oriented Anatomy 9e; IB Singh — Textbook of Anatomy Vol 1 6e.



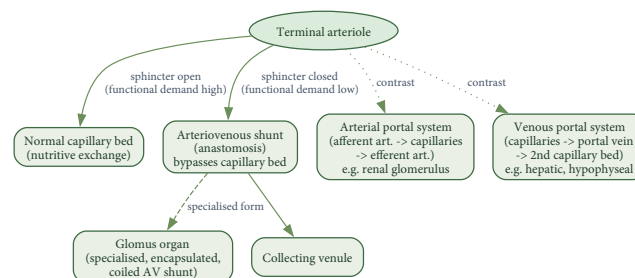
Arteriovenous shunts

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction Arteriovenous (AV) shunts, also called **arteriovenous anastomoses**, are direct vascular communications in which a terminal arteriole (or one of its side branches) joins a venule **without an intervening capillary bed**. They have a disproportionately thick muscular wall and are richly supplied by vasomotor (mainly sympathetic) nerves, so that the anastomotic channel itself can act as a **sphincter** — opening to short-circuit blood from artery to vein, or closing to force blood through the capillary plexus. They are best developed in the skin (fingertips, nose, lips, ears) and in erectile tissue, where they subserve thermoregulation and local haemodynamic control, and a specialised, encapsulated coiled form — the **glomus body/organ** — is of particular applied importance.

Definition and classification of vascular anastomoses

Type	Definition	Example / site
Arterial anastomosis	Two arteries communicate directly; capillary bed still intervenes distally	Palmar/plantar arches, circulus vasculosus around a joint
Venous anastomosis	Two veins communicate directly	Venous plexuses, dural sinuses
Arteriovenous anastomosis (shunt)	Arteriole joins venule directly, bypassing the capillary bed	Skin of nose/lips/ears, erectile tissue, tongue, thyroid, sympathetic ganglia
Glomus organ	A specialised, encapsulated, coiled AV anastomosis with a very thick wall of modified (epithelioid) smooth-muscle cells	Nail bed, pulps of fingers/toes, sole, palm
Arterial portal system	Afferent arteriole → capillary bed → efferent arteriole (capillaries interposed between two arterioles)	Renal glomerulus
Venous portal system	Capillary bed → portal vein → second capillary bed	Hepatic portal system; hypothalamo-hypophyseal portal system



Arteriovenous shunts

Sites / distribution

- **Skin:** nose, lips, external ear, digital pulps of fingers and toes, nail beds — richest concentration, sub-serving thermoregulation.

- ▶ **Mucous membranes:** nasal mucosa and alimentary canal mucosa.
- ▶ **Erectile tissue:** corpus cavernosum and corpus spongiosum of penis, and clitoris.
- ▶ **Glandular/endocrine tissue:** thyroid gland.
- ▶ **Neural tissue:** sympathetic ganglia; tongue.
- ▶ **Visceral (protective) shunts:** renal and intestinal microcirculation can open AV communications under stress (see Applied anatomy).
- ▶ **Developmental note:** few AV anastomoses are present at birth; they develop rapidly during early childhood, and in old age they atrophy, sclerose and diminish in number — contributing to the poorer thermoregulatory efficiency seen at both extremes of age.

Structure

- ▶ **Wall organisation** (from lumen outward): a continuous **endothelial** lining (intima); a markedly **thickened tunica media** composed of several layers of smooth-muscle cells, arranged either as a straight or (more often) a **coiled/tortuous** channel; and an **adventitia richly supplied by sympathetic (vasoconstrictor) and parasympathetic nerve fibres**, unlike an ordinary precapillary sphincter.
- ▶ Contraction of this medial smooth muscle **occludes the shunt**, diverting the entire flow into the capillary bed; relaxation opens the shunt and lets blood bypass the capillaries, partially or completely excluding them from the circulation.
- ▶ **Glomus organ (specialised AV anastomosis):** an afferent arteriole gives off fine periglomerular branches, then abruptly enlarges, follows a sinuous/coiled course, and narrows again into a short, funnel-shaped vein opening at right angles into a collecting vein. The smooth-muscle cells lining this coiled connecting segment are large, rounded and epithelium-like — termed **epithelioid cells** — and the whole unit is enclosed in a connective-tissue capsule.
- ▶ Glomus organs are concentrated in the digital pads and nail beds of the hands and feet.

□ Fig 10.5 — An arteriovenous anastomosis (glomus) (schematic representation). (IB Singh — *Textbook of Human Histology* — 9e, p.314)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled longitudinal schematic of a cutaneous AV anastomosis (glomus), showing:

- ▶ **Afferent arteriole** entering from a cutaneous artery
- ▶ **Periglomerular branches** given off before the shunt segment
- ▶ **Coiled anastomotic (shunt) channel** with its thick wall of layered smooth-muscle/epithelioid cells
- ▶ **Connective-tissue capsule** enclosing the coiled segment
- ▶ **Rich sympathetic (vasomotor) nerve supply** to the wall
- ▶ **Short funnel-shaped efferent vein** opening at right angles into the **collecting venule**
- ▶ An adjacent **capillary bed** shown bypassed when the shunt is open, and perfused when the shunt sphincter is closed

Functional / physiological role

- ▶ **Thermoregulation:** opening cutaneous shunts increases flow through the superficial (papillary) dermal plexus, promoting heat loss in warm conditions; closing them diverts blood to the deep plexus/capillary bed, conserving heat in the cold. This dermal thermoregulatory switching lies between the two major dermal vascular plexuses.
- ▶ **Regulation of regional blood flow and local blood pressure:** intermittent opening/closing of shunts and precapillary sphincters irrigates different microvascular units according to local metabolic demand.
- ▶ **Erectile function:** in the corpus cavernosum/spongiosum, AV shunts divert arterial blood directly into the cavernous vascular spaces, helping to initiate and maintain erection.
- ▶ **Protective/compensatory shunting in shock:** in organs such as kidney and intestine, AV anastomoses can open during severe haemorrhage, temporarily bypassing the capillary (e.g. glomerular) bed and redirecting blood to vital organs (heart, brain) at the expense of that organ's own perfusion.
- ▶ **Autonomic control:** sympathetic vasoconstrictor fibres are the dominant regulator, but parasympathetic fibres also contribute in some sites — distinguishing AV shunts from ordinary precapillary sphincters, which lack this rich dual innervation.

Applied / Clinical anatomy

- ▶ **Glomus tumour (glomangioma):** a rare, benign neoplasm arising from the modified (epithelioid) smooth-muscle cells of the glomus body, classically presenting as an exquisitely tender, pinpoint-painful subungual or digital-pulp nodule, often cold-sensitive — a direct clinical correlate of the glomus organ's structure and rich nerve supply.
- ▶ **Anuria following major trauma/haemorrhage:** opening of renal (and intestinal) AV shunts during hypovolaemic shock bypasses the glomerular capillary bed, reducing urine output; as circulating volume is restored, the shunts close, glomerular flow resumes, and improving urine output is a favourable clinical sign.

- ▶ **Bed sores (decubitus ulcers):** prolonged pressure over a body prominence reduces dermal AV-anastomosis-dependent blood flow, causing tissue necrosis and ulceration at pressure points.
- ▶ **Thermoregulatory failure at extremes of age:** the paucity of AV anastomoses in the neonate and their age-related atrophy in the elderly explain the poorer thermoregulation seen in both groups (risk of hypothermia).
- ▶ **Frostbite/chilblains:** excessive, prolonged closure of digital AV shunts in cold exposure predisposes acral skin to ischaemic cold injury.
- ▶ **Surgically created AV shunts:** a radiocephalic (Cimino-Brescia) arteriovenous fistula is deliberately fashioned between the radial artery and cephalic vein at the wrist to provide durable vascular access for chronic haemodialysis, exploiting the same artery-to-vein short-circuit principle.
- ▶ **Radiological/angiographic correlate:** pathological (congenital or post-traumatic) AV fistulae elsewhere in the body show early, abnormal venous opacification on angiography because the capillary bed is bypassed.

High-yield exam pointers

- ▶ AV shunt = terminal arteriole joins venule directly, **bypassing the capillary bed**; thick muscular wall, richly sympathetically innervated, acts as a sphincter.
- ▶ Sites: skin of nose/lips/ears/digits, GI and nasal mucosa, erectile tissue, tongue, thyroid, sympathetic ganglia.
- ▶ **Glomus organ** = specialised, encapsulated, coiled AV anastomosis with **epithelioid smooth-muscle cells**, found chiefly in nail beds/digital pulps — do not confuse with the chemoreceptor "glomus cells" of the carotid body, which are physiologically unrelated.
- ▶ Few at birth → develop in early childhood → atrophy/sclerose in old age → explains poor thermoregulation at both extremes of age.
- ▶ Functions: thermoregulation, regional blood-flow/BP regulation, erectile function, shock-related visceral shunting (anuria after trauma).
- ▶ Contrast with **arterial portal system** (afferent → capillaries → efferent arteriole, e.g. renal glomerulus) and **venous portal system** (two capillary beds in series joined by a portal vein, e.g. hepatic/hypophyseal) — a classic exam confusion point.
- ▶ Clinical correlates: glomus tumour (painful subungual nodule), bed sores, frostbite, surgically created AV fistula for dialysis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; Junqueira's Basic Histology 17e; Sontakke — Textbook of Human Histology 2e; IB Singh — Textbook of Human Histology 9e; Ross Histology — A Text and Atlas 7e.



Articular cartilage

Asked in: Paper I Nov 2017 — RGUHS MD/MS Anatomy

Definition / Introduction Articular cartilage is a specialized form of hyaline cartilage that caps the articulating ends of bones in synovial joints, providing a smooth, firm yet deformable, low-friction load-bearing surface. Unlike other hyaline cartilage, it lacks a perichondrium, and it is avascular, aneural and alymphatic, deriving all its nutrition by diffusion. Except at the temporomandibular, sternoclavicular and acromioclavicular joints — where the articular surface is fibrocartilage, making these "atypical" synovial joints — articular cartilage everywhere else is typical hyaline cartilage. It shows a distinctive four-zone microscopic architecture that underlies both its biomechanical function and its vulnerability to age-related degeneration (osteoarthritis).

Structural & gross features

- ▶ **Type:** specialized hyaline cartilage in almost all synovial joints; **fibrocartilage** at the temporomandibular, sternoclavicular and acromioclavicular joints (atypical synovial joints).
- ▶ **No perichondrium** — a feature unique to articular and fibrocartilage among cartilage types. At its periphery, the synovial membrane overlaps and merges into the cartilage circumferentially, forming a transitional zone over the peripheral few millimetres.
- ▶ **Thickness:** varies from 1–7 mm (typically ~2 mm) between different joints; the **patella bears the thickest articular cartilage in the body**. Central regions are thickest over convex osseous surfaces and thinnest over concave surfaces. Thickness does not increase with increased mechanical loading in adults, though matrix composition/stiffness can adapt.
- ▶ **Surface:** smooth but with microscopic undulations that trap synovial fluid, enabling fluid-film lubrication; a thin (0.03–0.1 μm), acellular, optically bright surface layer called the **lamina splendens** is seen at the free surface on phase-contrast microscopy.
- ▶ **Split-line pattern:** repeated needle puncture followed by Indian-ink staining produces elongated permanent splits whose orientation reveals the predominant direction of the tangential-zone collagen bundles — related to internal lines of tension generated during joint movement.

Microscopic zonation (histology)

Zone	Location	Cell morphology	Collagen fibril orientation
Tangential (superficial)	Immediately beneath articular surface	Small, elongated (flattened) chondrocytes oriented parallel to the surface	Fibrils run parallel to the surface, forming collagen "arcades"
Middle (intermediate/transitional)	Between superficial and deep zones	Larger, more rounded chondrocytes, randomly distributed	Fibrils obliquely/randomly arranged, transitional between the two adjoining zones

Zone	Location	Cell morphology	Collagen fibril orientation
Deep (radial)	Adjacent to the calcified zone	Chondrocytes arranged in columns (radial groups) perpendicular to the surface	Fibrils rise vertically , anchoring into the calcified zone
Calcified zone	Deepest, abutting subchondral bone	Few, small cells embedded in a calcified matrix	Continuous with deep-zone fibrils; matrix properties intermediate between cartilage and bone

- ▶ The **tidemark** is the basophilic line separating the (uncalcified) deep/radial zone from the calcified zone; it is keyed into subchondral bone by fine ridges/interdigitations that resist shearing.
- ▶ The calcified zone anchors cartilage firmly to subchondral bone and prevents gliding movement between the two.

□ Fig 8.23 — Articular cartilage. (*Junqueira's Basic Histology — Text & Atlas — 17e, p.397*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a vertical section through articular cartilage down to subchondral bone:

- ▶ Articular surface (top)
- ▶ Superficial/tangential zone — flattened chondrocytes, fibrils parallel to surface
- ▶ Middle/transitional zone — rounded chondrocytes, oblique fibrils
- ▶ Deep/radial zone — chondrocytes in vertical columns, fibrils vertical
- ▶ Tidemark (basophilic line)
- ▶ Calcified zone
- ▶ Subchondral bone (base)

Scale marker ~1 mm; annotate progressive change in chondrocyte size/shape and fibril direction from surface to base.

Biochemical composition

- ▶ **Water:** the largest single component; confers compressive "turgor" and enables adaptive swelling during growth/healing.
- ▶ **Collagen type II:** the principal fibrillar collagen of the interterritorial matrix, forming ~75% of its dry weight; provides tensile stiffness and the arcade architecture described above.
- ▶ **Proteoglycans** (~22% of dry weight): large aggrecan molecules bound non-covalently to hyaluronic acid, forming **proteoglycan–hyaluronic acid aggregates**. Their fixed negative charge retains water and resists compression, giving cartilage its load-bearing "turgor."
- ▶ **Mechanical properties** (comparative, from tensile testing): tensile strength ~5–20 MPa and elastic modulus ~4–10 MPa — far lower than cortical bone (strength 130 MPa, modulus 17,000

MPa) or tendon — but failure strain of 30–100%, i.e., articular cartilage is far more extensible/compliant than bone or tendon before failure.

Nutrition, blood and nerve supply

- ▶ **Avascular, aneural and alymphatic** — articular cartilage (like intra-articular menisci and discs) contains no blood vessels, lymphatics or nerve fibres; proteoglycans in the matrix are thought to inhibit vascular ingrowth, and high intra-tissue pressures would in any case collapse any vessels.
- ▶ **Nutrition is entirely by diffusion**, from two sources: (i) the synovial membrane and synovial fluid (the principal route), and (ii) hypochondral vessels of the adjacent medullary cavity, some of whose capillaries penetrate and occasionally traverse the calcified zone. The relative contribution of each source is uncertain and may change with age.
- ▶ Diffusion of small molecules through the matrix occurs at roughly half the rate seen in free aqueous solution; larger molecules diffuse more slowly, inversely related to molecular size, and matrix permeability is strongly influenced by glycosaminoglycan concentration.
- ▶ **No nerve endings** are present within the cartilage itself — clinically important, because articular surface damage per se is painless; pain in joint disease arises from richly innervated structures such as the synovial membrane, capsule, ligaments and subchondral bone (relevant to Hilton's law).

Functions and biomechanics

- ▶ Provides an extremely smooth, firm yet deformable load-bearing surface that **increases the contact area** between opposing bone ends and thereby **reduces contact stress**, an effect that depends on the congruence of the opposing joint surfaces.
- ▶ **Fluid-film lubrication**: microscopic surface undulations trap synovial fluid between articulating surfaces; **boundary lubrication** occurs at points of direct contact between cartilage asperities.
- ▶ **Creep behaviour**: under sustained load, cartilage undergoes progressive ("creep") deformation with exudation of water into the joint cavity (assisting lubrication), followed by elastic recovery once load is removed — a biphasic viscoelastic response.
- ▶ Generally too thin and stiff to act as a major shock absorber on its own, although where multiple cartilage-covered surfaces are stacked (e.g., carpus, tarsus), some shock-absorbing effect is achieved.
- ▶ Chondrocytes can sense hydrostatic pressure changes and matrix strain (mechanotransduction), allowing matrix turnover to be modulated by mechanical loading, though avascular tissue adapts only very slowly (matrix macromolecule turnover times can be as long as ~100 years).

Age changes

- ▶ Progressive **thinning** with age, due to upward advance of the tidemark and gradual replacement of calcified cartilage by subchondral bone.
- ▶ **Superficial-zone changes** predominate: age-related reduction in chondrocyte number/activity and biochemical alteration of the extracellular matrix, increasing the risk of mechanical failure and osteoarthritis.

- ▶ Surface undulations **deepen** and develop minute ragged projections with advancing age (wear-and-tear change), though this is normally an extremely slow process in healthy joints.
- ▶ Cells retain the capacity for division, but mitosis is rarely seen in adult articular cartilage, and cartilage damage is essentially **not repaired** in situ; superficial cells lost from the joint surface are normally replaced from deeper layers only.

Applied / Clinical anatomy

- ▶ **Osteoarthritis**: the commonest joint disease; weight-bearing joints (hip, knee) show progressive thinning, fibrillation and eventual full-thickness loss of articular cartilage, exposing subchondral bone to direct bone-on-bone attrition; the highly vascular, proliferative zone at the junction of articular cartilage, synovium and periosteum is the site of reactive **osteophyte** (pseudo-bone) formation.
- ▶ **Rheumatoid arthritis**: an autoimmune synovitis in which synovial hypertrophy/hyperplasia and inflammatory pannus (granulation tissue) erode articular cartilage, typically affecting small joints of the hands and feet.
- ▶ **Poor intrinsic repair**: because cartilage is avascular, a cartilage defect heals slowly and is typically filled by fibrocartilaginous scar rather than regenerated hyaline cartilage — the rationale behind clinical cartilage-repair strategies (e.g., microfracture, osteochondral grafting); homogeneity of cartilage matrix also permits allografting without the rejection seen with vascularised tissues.
- ▶ **Painless early damage**: because articular cartilage is aneural, early degenerative change is often clinically silent until adjacent innervated structures (synovium, capsule, subchondral bone) become involved.
- ▶ **Patellar cartilage**: being the thickest in the body, it is relevant to patellofemoral joint disorders and cartilage-softening (chondromalacia) of the patella.
- ▶ **Atypical (fibrocartilaginous) synovial joints** — TMJ, sternoclavicular and acromioclavicular — show a different pattern of wear because their articular surface is fibrocartilage rather than hyaline cartilage.

High-yield exam pointers

- ▶ Specialized **hyaline cartilage without a perichondrium** — exceptions (fibrocartilage): TMJ, sternoclavicular, acromioclavicular joints.
- ▶ **Four zones** (surface to depth): tangential/superficial → middle/transitional → deep/radial → calcified, separated from the deep zone by the **tidemark**.
- ▶ **Avascular + aneural + alymphatic**; nutrition purely by diffusion from synovial fluid (main) ± hypochondral vessels.
- ▶ Matrix = **type II collagen** (~75% dry wt) + **proteoglycan-hyaluronan aggregates** (~22%) + high water content (compressive turgor).
- ▶ Thickness 1–7 mm (typically 2 mm); **patella = thickest articular cartilage in the body**.
- ▶ Function: increases contact area/reduces contact stress; fluid-film + boundary lubrication; creep under sustained load.
- ▶ **No/minimal intrinsic repair** — defects fill with fibrocartilage scar, not hyaline cartilage.

- Age changes (thinning, tidemark advance, superficial-zone matrix loss) predispose to osteoarthritis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; Junqueira's Basic Histology — Text & Atlas 17e (figure).



Classification of bones

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction

Bone (osseous tissue) is a specialised, mineralised connective tissue that forms the rigid, living framework of the skeleton. Every bone can be described under three independent, complementary classification schemes — according to its **shape**, its **structure/architecture** (macroscopic and microscopic), and its **mode of development** (ossification) — because each scheme highlights a different clinically relevant property (fracture pattern, growth potential, blood supply, radiographic appearance). A single bone is classified simultaneously under all three: for example, the femur is a **typical long bone**, **compact-and-cancellous** in architecture, and **cartilaginous (endochondral)** in development.

1. Overview of the three classification schemes



2. Classification according to shape

Type	Salient features	Examples
Long bones	Length exceeds breadth/thickness; shaft (diaphysis) + 2 expanded ends (epiphyses); medullary cavity; ossify in cartilage; lie vertically; weight-bearing; act as levers	Humerus, radius, ulna, femur, tibia, fibula (typical); metacarpals, metatarsals, phalanges (miniature/short long bones — epiphysis at one end only)
Short bones	Small, cuboidal, present six surfaces	Carpal bones, tarsal bones
Flat bones	Flat, shallow, plate-like; form boundaries of a body cavity	Cranial vault (frontal, parietal, occipital); thoracic cage (scapula, ribs, sternum)
Irregular bones	Complex shape not fitting other groups	Hip bone, vertebrae, bones of the skull base

Type	Salient features	Examples
Pneumatic bones	A variety of irregular bones with air-filled cavities (paranasal air sinuses) — lighten the skull, add vocal resonance, air-condition inspired air	Maxilla, frontal, sphenoid, ethmoid
Sesamoid bones	Seed-like nodules developing within tendons where they rub over a convex bony surface; rubbing surface covered by articular cartilage	Patella (largest), pisiform, fabella, and others (see §4)
Accessory (sutural/Wormian) bones	Extra ossification centres in skull sutures, or non-union of an epiphysis	Sutural/Wormian bones; os trigonum (talus); os vesalianum (5th metatarsal styloid); patella cubiti (olecranon)
Heterotopic bones	Form in soft tissue not normally ossified	Rider's bone in the tendon of adductor longus

□ Fig 6.3 — Types of bones depending on their shapes. (Vishram Singh — General Anatomy — 4e, p.229)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Six labelled silhouettes side by side, one per shape category:

- ▶ **Long bone** — humerus/femur outline showing diaphysis, two epiphyses, medullary cavity.
- ▶ **Short bone** — a carpal bone as a cuboid with six surfaces.
- ▶ **Flat bone** — parietal bone in cross-section showing outer table, diploë, inner table.
- ▶ **Irregular bone** — a typical vertebra (body + neural arch + processes).
- ▶ **Pneumatic bone** — maxilla/frontal bone outline with the paranasal air sinus shaded.
- ▶ **Sesamoid bone** — patella lying within the quadriceps tendon anterior to the femoral condyles.

3. Long bones in detail — typical vs miniature

Feature	Typical long bone	Miniature/short long bone
Parts	Diaphysis + two epiphyses	Diaphysis + one epiphysis (distal end; proximal for the 1st metacarpal and 1st metatarsal)
Examples	Humerus, radius, ulna, femur, tibia, fibula	Metacarpals, metatarsals, phalanges
Orientation	Vertical, weight-bearing, act as levers for limb muscles	Same general plan on a smaller scale

- ▶ **N.B.** The clavicle is the only long bone that lies **horizontally**, ossifies mainly **in membrane** (not cartilage), and has **no medullary cavity** — it is therefore an important exception to the typical long-bone description.

4. Sesamoid bones — sites, functions, characteristics

- ▶ **Sites:** (1) Patella, in the quadriceps femoris tendon in front of the knee; (2) Fabella, in the lateral head of gastrocnemius behind the knee; (3) two sesamoids below the head of the 1st metatarsal, in the flexor hallucis brevis tendon; (4) one in the peroneus longus tendon where it binds around the cuboid; (5) Pisiform, in the flexor carpi ulnaris tendon; (6) one on the ulnar side of the 1st metacarpal head, in the adductor pollicis tendon; (7) occasionally one on the radial side of the 1st metacarpal head, in the flexor pollicis brevis tendon.
- ▶ **Functions:** act as pulleys for muscle contraction; alter the direction of pull of the muscle; minimise friction/attrition of the tendon against bone.
- ▶ **Characteristics:** develop within tendons; devoid of periosteum; ossify after birth, usually from multiple centres; lack the Haversian system; consequently **not classified as true bones**.
- ▶ **N.B.** The patella is the **largest sesamoid bone** in the body, and its articular cartilage is the **thickest articular cartilage** in the body.

5. Structural (architectural) classification

(a) Macroscopic — compact vs cancellous bone

Feature	Compact bone	Spongy (cancellous) bone
Density	Dense, ivory-like	Porous, sponge-like
Haversian systems	Present	Absent
Arrangement of lamellae	Regular	Irregular
Location in bone	Outer region	Inner region
Bone marrow	Absent within the tissue itself	Present, filling the spaces between trabeculae
Amount in body by weight	≈75%	≈25%

- ▶ **Distribution:** in a **long bone**, the shaft is a cylinder of compact bone around the medullary cavity, while the ends are cancellous covered by a thin compact shell; in **flat bones of the skull**, cancellous bone (**diploë**) is sandwiched between an outer and inner **table** of compact bone.
- ▶ **N.B.** All bones normally contain both compact and spongy bone **except the inferior nasal concha**, which is made of spongy bone alone.
- ▶ **Wolff's law** (trajectory theory, 1892): osteogenesis is proportional to stress/strain on the bone; trabeculae align along lines of maximal mechanical stress — pressure lamellae parallel to the line of weight transmission, tension lamellae at right angles to them (e.g. **calcar femorale** at the upper femur).

(b) Microscopic — woven vs lamellar bone

- ▶ **Woven bone:** collagen fascicles and mineral crystals arranged randomly (like woven fabric); seen in young fetal bone (most immature bone) and in fracture callus.
- ▶ **Lamellar bone:** matrix arranged in orderly thin layers, either as concentric cylindrical **Haversian systems (osteons)** in compact bone, or as branching, anastomosing curved plates in spongy bone.

- ▶ **N.B.** All adult human bone is lamellar bone.
- ▶ The **osteon** is the structural/functional unit of compact bone: a central **Haversian canal** (carrying vessels, nerves, loose connective tissue) surrounded by 4–20 concentric lamellae, with osteocytes in lacunae linked by canaliculi; Haversian canals communicate with the medullary cavity and periosteal surface via transversely running **Volkman's canals**.

6. Developmental (ossification) classification

Type	Mode of ossification	Examples
Membranous bones	Intramembranous ossification	Bones of the cranial vault; facial bones
Cartilaginous bones	Endochondral (intracartilaginous) ossification	Bones of the limbs; bones of the skull base; vertebrae; thoracic cage (ribs, sternum)
Membrano-cartilaginous bones	Both intramembranous and endochondral ossification	Mandible, clavicle, occipital bone, temporal bone, sphenoid bone

Applied / Clinical anatomy

- ▶ **Osteomyelitis:** in growing children, haematogenous infection characteristically lodges in the **metaphysis** of long bones, where nutrient-artery loops end in sluggish sinusoidal capillaries.
- ▶ **Fracture pattern by architecture:** long-bone shafts fail as tubes (transverse/oblique/spiral fractures), while cancellous-rich sites (vertebral bodies, calcaneus, distal radius) typically undergo **compression/crush fractures**, common in osteoporosis.
- ▶ **Wolff's law in practice:** after a mal-united fracture changes the weight-bearing axis, the trabecular pattern remodels along the new stress lines, and the patient may develop pain at the altered stress-bearing region.
- ▶ **Clavicle:** because it is membranous, subcutaneous, and lacks a medullary cavity, it is one of the most frequently fractured long bones (including at birth); its fracture pattern and healing differ from typical long bones.
- ▶ **Patella and the extensor mechanism:** being the largest sesamoid, a patellar fracture directly disrupts knee extension via the quadriceps tendon; accessory ossicles (bipartite patella) can mimic a fracture on X-ray.
- ▶ **Accessory/sutural bones on imaging:** os trigonum, os vesalianum and Wormian bones are frequently mistaken for avulsion fractures on radiographs — awareness of normal variants prevents misdiagnosis.
- ▶ **Pneumatic bones:** the paranasal sinuses within maxilla, frontal, sphenoid and ethmoid are clinically important in sinusitis, midface (Le Fort) fractures, and as surgical landmarks in functional endoscopic sinus surgery.
- ▶ **Inferior nasal concha:** being purely cancellous (no compact shell), it is comparatively fragile and prone to fracture during nasal instrumentation.

High-yield exam pointers

- ▶ Bones are classified three ways: by **shape**, by **structure (architecture)**, and by **development (ossification)** — state all three at the outset.
- ▶ Shape categories: long, short, flat, irregular, pneumatic, sesamoid, accessory (sutural)/heterotopic — long bones further split into **typical** and **miniature/short long**.
- ▶ **Clavicle** = only long bone that is horizontal, membranous, and without a medullary cavity.
- ▶ **Patella** = largest sesamoid bone; has the thickest articular cartilage in the body.
- ▶ Compact : cancellous bone ratio in the body by weight $\approx 75 : 25$.
- ▶ **Inferior nasal concha** = the only bone made entirely of spongy (cancellous) bone.
- ▶ Microscopically all adult bone is **lamellar**; woven bone is limited to fetal bone and fracture callus.
- ▶ **Wolff's law** — bone remodels along lines of mechanical stress (pressure and tension lamellae; calcar femorale).
- ▶ **Membrano-cartilaginous** (mixed-ossification) bones: mandible, clavicle, occipital, temporal, sphenoid.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (primary source — Skeleton: Bones and Cartilages); Gray's Anatomy (Standring) 41e; IB Singh — Textbook of Anatomy Vol 1 6e (cross-check); Moore — Clinically Oriented Anatomy 9e (cross-check).



Classification of muscles with examples

Asked in: Paper I Nov 2016 — RGUHS MD/MS Anatomy

Definition / Introduction Muscle is a contractile tissue, derived predominantly from mesenchyme, whose cells (fibres) contain the proteins actin and myosin and convert chemical energy into mechanical work; the study of muscle is **myology**. Muscle forms ~40% of body weight and there are roughly 400 named muscles in the human body. Muscles are classified on several independent bases — structure/development, fibre type, shape and fascicular architecture, nomenclature, functional (group) action, and vascular pattern — and a single muscle may be described under more than one scheme simultaneously.

1. Classification by structure, development and nervous control

Feature	Skeletal muscle	Cardiac muscle	Smooth muscle
Synonym	Voluntary/striated	Myocardium	Involuntary/non-striated
Location	Attached to skeleton	Wall of heart	Wall of hollow viscera (GIT, respiratory, urogenital tracts)
Control	Voluntary (somatic)	Involuntary (autonomic)	Involuntary (autonomic)

Feature	Skeletal muscle	Cardiac muscle	Smooth muscle
Fibre shape	Unbranched, cylindrical	Branched, cylindrical, intercalated discs	Unbranched, spindle-shaped
Nuclei	Multiple, peripheral	Single, central	Single, central
Cross-striations	Present	Faint	Absent
Rhythmicity	Absent	Present	Present
Nerve supply	Somatic	Autonomic	Autonomic
Neuromuscular junction	Present	Absent	Absent
Example	Biceps brachii	Myocardium	Muscularis of intestine

- All body muscle develops from mesenchyme **except**: arrectores pilorum, muscle of the iris, and myoepithelial cells of glands — these develop from ectoderm.
- Two additional single-cell contractile types are recognised: **myoepithelial cells** (basket cells around secretory acini of salivary/lacrimal/mammary/sweat glands — expel secretion) and **myofibroblasts** (involved in wound healing/contraction).

□ Fig 10.1 — Three types of muscle. (Junqueira's Basic Histology — Text & Atlas — 17e, p.487)

2. Classification by fibre type (physiological/biochemical)

Feature	Red fibre (Type I)	White fibre (Type II)
Speed of contraction	Slow (slow-twitch)	Fast (fast-twitch)
Fatigability	Fatigue-resistant	Fatigue-susceptible
Blood supply / myoglobin	Rich / high	Poor / low
ATP generation	Aerobic glycolysis (many mitochondria)	Anaerobic glycolysis (few mitochondria)
Fibre diameter	Smaller	Larger
Example	Postural (antigravity) muscles of the back	Extraocular muscles

- Red fibres suit **long-distance/endurance work**; white fibres suit **fast, brief, powerful movements**.
- In humans all muscles are physiologically mixed (fibres of both types intermingle); the classic red/white division is now largely superseded by myosin-isoform-based fibre typing, though it remains standard exam terminology.

3. Classification by shape and fascicular architecture

The arrangement of fibres/fasciculi relative to the line of pull determines the range of movement versus power of a muscle (parallel fibres → greater range; pennate fibres → greater force, since more fibres per unit cross-sectional area).

Type	Sub-type	Examples
Parallel fasciculi (fibres parallel to line of pull — good range, good endurance)	Quadrilateral	Thyrohyoid, pronator quadratus
	Strap-like	Infrahyoid muscles, sartorius
	Strap-like with tendinous intersections	Rectus abdominis
	Fusiform	Biceps brachii, digastric
Convergent fasciculi (fibres converge on insertion — powerful, reduced range)	Triangular	Adductor longus
	Fan-shaped	Temporalis
Spiral/twisted fasciculi	—	Trapezius, latissimus dorsi, pectoralis major, supinator
Cruciate muscles (fibres in superficial + deep planes crossing as 'X')	—	Sternocleidomastoid, masseter, adductor magnus
Sphincteric fasciculi (fibres encircle an orifice)	—	Orbicularis oculi, orbicularis oris
Pennate fasciculi (resemble a feather; many fibres/unit area → strong)	Unipennate	Extensor digitorum longus, flexor pollicis longus, peroneus tertius
	Bipennate	Flexor hallucis longus, dorsal interossei
	Multipennate	Deltoid
	Circumpennate	Tibialis anterior

□ Fig 3.5 — Muscle-shape and architecture (IB Singh — Textbook of Anatomy Vol 1 — 6e, p.37)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Outline of the human body (anterior view) with labelled arrows to representative muscles, one per architectural type:

- ▶ **Circular** → orbicularis oculi
- ▶ **Fusiform** → biceps brachii
- ▶ **Flat parallel with aponeurosis** → external oblique
- ▶ **Thin parallel** → sartorius
- ▶ **Bipennate** → rectus femoris
- ▶ **Unipennate** → extensor digitorum longus
- ▶ **Multipennate** → deltoid
- ▶ **Convergent** → pectoralis major
- ▶ **Quadrangle** → rectus abdominis

4. Classification by nomenclature (naming convention)

Muscles are named according to one or more of seven criteria:

Criterion	Example	Basis
Location	Tibialis anterior, temporalis, supraspinatus, infraspinatus, pectoralis, intercostals	Named for the bone/region/fossa they occupy
Shape	Trapezius, serratus anterior, quadratus, rhomboideus	Trapezoid, serrated edge, quadrangular, rhomboid
Action	Extensor carpi ulnaris, flexor carpi radialis	Movement produced
Number of heads	Biceps brachii (2), triceps brachii (3), quadriceps femoris (4)	Heads of origin
Attachments (origin + insertion)	Sternocleidomastoid, stylohyoid, cricothyroid	Named from both bony attachments
Direction of fibres	Rectus abdominis, transversus abdominis, rectus femoris, external oblique	Straight, transverse, oblique
Size	Gluteus maximus/medius/minimus; adductor magnus/longus/brevis	Largest, medium, smallest

5. Classification by functional (group) action

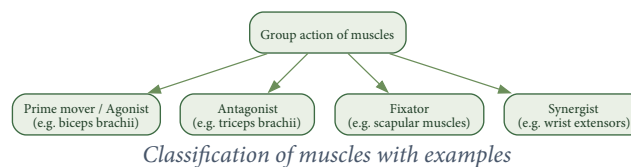
A single muscle rarely acts alone — whole movements, not individual muscles, are represented in the cerebral cortex, so a coordinated group acts together. The same muscle may play different roles in different movements.

- ▶ **Prime movers (agonists)** — chiefly responsible for the desired movement, e.g. biceps brachii for elbow flexion.

- **Antagonists** — produce the opposite movement and relax reciprocally (via the stretch reflex) as the agonist contracts, e.g. triceps brachii during elbow flexion (roles reverse in extension).
- **Fixators** — stabilise the origin of the prime mover so it can act efficiently, e.g. scapular muscles fixing the shoulder girdle so deltoid can abduct the shoulder.
- **Synergists** — prevent an undesired action at a joint crossed by a two-joint prime mover, e.g. wrist extensors contract as synergists to prevent wrist flexion when the long finger flexors clench the fist.

Shunt and spurt muscles (based on relation of attachments to the joint axis):

- **Shunt muscle** — proximal attachment near the joint, distal attachment away from it → produces a *greater range* of joint movement, e.g. brachioradialis.
- **Spurt muscle** — proximal attachment away from the joint, distal attachment near it → produces *less range* but stabilises the joint, e.g. brachialis.



6. Classification by vascular pedicle pattern (Mathes & Nahai, 1981)

Based on the number and relative dominance of vascular pedicles entering the muscle — of major surgical relevance for pedicled/free muscle flaps in plastic and reconstructive surgery:

Type	Pedicle pattern	Examples
I	Single vascular pedicle	Tensor fasciae latae, gastrocnemius
II	One dominant + minor pedicles	Gracilis
III	Two dominant pedicles from different source arteries	Rectus abdominis, gluteus maximus
IV	Multiple, segmental small pedicles (none alone sufficient)	Sartorius, tibialis anterior
V	One dominant pedicle + secondary segmental pedicles	Latissimus dorsi, pectoralis major

Applied / Clinical anatomy

- **Muscle flap surgery:** the Mathes–Nahai vascular type predicts which muscle will survive division of a given pedicle when raised as a pedicled or free flap.
- **Intramuscular injection sites:** deltoid (shoulder), gluteus medius (upper-outer quadrant of buttock), vastus lateralis (anterolateral mid-thigh) — chosen for their bulk and relatively safe neurovascular anatomy.
- **Reversal of muscle action:** origin/insertion can functionally swap if the "fixed" end becomes mobile, e.g. latissimus dorsi (normally an adductor/medial rotator of the arm) lifts the pelvis off a bed when the hands are fixed on the mattress.

- ▶ **Rigor mortis:** post-mortem ATP depletion prevents actin–myosin cross-bridge release, causing stiffening of both voluntary and involuntary muscle; begins 2–4 h after death, complete by 6–12 h, resolves in 2–4 days — used medicolegally to estimate time of death.
- ▶ **Tendon rupture:** biceps brachii and tendocalcaneus (Achilles) tendons are the most frequently ruptured; poor tendon blood supply means they do not heal spontaneously and usually need surgical repair.
- ▶ **Neuromuscular junction disorders:** myasthenia gravis (autoimmune destruction of ACh receptors → fatigable flaccid weakness) and organophosphorus poisoning (acetylcholinesterase inhibition → sustained depolarisation, spastic paralysis of respiratory muscles) both exploit knowledge of muscle/NMJ physiology.
- ▶ **Disuse atrophy:** a muscle deprived of periodic nerve stimulation atrophies — relevant to lower motor neuron lesions and post-immobilisation weakness.

High-yield exam pointers

- ▶ Three structural types — skeletal (voluntary, striated), cardiac (involuntary, striated), smooth (involuntary, non-striated); myoepithelial cells and myofibroblasts are exceptional single-cell contractile elements.
- ▶ Red (Type I, slow, fatigue-resistant, postural) vs White (Type II, fast, fatigable, extraocular) fibres — a physiological classification.
- ▶ Fascicular architecture: parallel (quadrilateral/strap/fusiform), convergent (triangular/fan), spiral, cruciate, sphincteric, and pennate (uni-/bi-/multi-/circumpennate) — pennate muscles are the strongest per unit area but have the least range.
- ▶ Seven naming criteria: location, shape, action, number of heads, attachments, direction of fibres, size.
- ▶ Group action: agonist, antagonist, fixator, synergist; shunt muscle (e.g. brachioradialis) increases range, spurt muscle (e.g. brachialis) increases stability.
- ▶ Mathes & Nahai vascular Types I–V determine flap viability in reconstructive surgery.
- ▶ Total muscles in the body ≈ 400; largest = gluteus maximus; longest = sartorius; smallest = stapedius; most variable = palmaris longus; largest tendon = tendocalcaneus (Achilles); most commonly used IM injection site = deltoid.
- ▶ All muscle develops from mesenchyme except arrectores pilorum, iris muscles and myoepithelial cells (ectodermal).

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (Chapter 9: Muscular system — types of muscle, fascicular architecture, nomenclature, group action, shunt/spurt muscles, vascular-pedicle classification); Gray's Anatomy (Standring) 41e (functional anatomy of the musculoskeletal system — fibre typing, Mathes & Nahai 1981 vascular classification); Junqueira's Basic Histology 17e (Fig. 10.1, three types of muscle); IB Singh — Textbook of Anatomy Vol 1, 6e (Fig. 3.5, muscle-shape and architecture); Moore's Clinically Oriented Anatomy 9e (corroborating architecture/shape terminology).



Collateral circulation

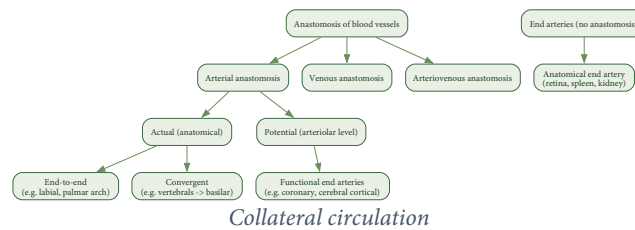
Asked in: Paper I Nov 2018 — RGUHS MD/MS Anatomy

Definition / Introduction — Collateral circulation is the alternative (anastomotic) route by which blood reaches the field of distribution of a main vessel when that vessel is narrowed, occluded or ligated. It is made possible by **anastomosis** — a natural communication between two blood vessels — which exists at multiple levels: between two arteries, between two veins, between an artery and a vein directly (arteriovenous anastomosis), and between the tributaries of two different venous systems (e.g. portal and systemic). The adequacy of collateral circulation depends on the calibre of the anastomotic channels, the suddenness of occlusion (slow occlusion allows time for channels to dilate), and the presence or absence of true "end arteries" at that site.

1. Anastomosis — definition and classification

- ▶ **Anastomosis:** a communication/connection between two blood vessels forming a collateral channel.
- ▶ **Arterial anastomosis** is of two types:
- ▶ **Actual (anatomical) anastomosis** — vessels are already joined by a continuous channel of adequate calibre, so collateral flow is available immediately on occlusion.
 - **End-to-end anastomosis:** two arteries join end to end, e.g. labial arteries, facial arteries, the arterial arches of the palm and sole.
 - **Convergent anastomosis:** two arteries converge and unite to form a larger vessel, e.g. the two vertebral arteries uniting to form the basilar artery.
- ▶ **Potential anastomosis** — communication exists only at the level of terminal arterioles; if the parent artery is **suddenly** blocked, collateral flow cannot take place immediately, but given sufficient time the arterioles dilate and establish collateral circulation, e.g. the coronary arteries.
- ▶ **End arteries** — arteries whose branches do not anastomose with branches of adjacent arteries. Examples: central artery of the retina; arteries of the spleen, liver and kidney; the metaphyseal arteries of long bones; central (medullary) branches of the cerebral arteries. Sudden occlusion of a true end artery causes ischaemia and infarction/necrosis of the field it supplies.

- **Functional end arteries** are not true anatomical end arteries — they do anastomose, but only at the arteriolar (potential-anastomosis) level, so a sudden block still produces ischaemia, e.g. coronary arteries and the cortical branches of the cerebral arteries.



2. Arteriovenous (AV) anastomoses

- Direct connections between an arteriole (or a side branch of a terminal arteriole) and a venule **without an intervening capillary bed** — true AV shunts.
- Thick muscular wall, richly supplied by vasomotor **sympathetic** nerve fibres, so the shunt itself can act as a sphincter.
- **Sites:** skin of the nose, lips and external ear; mucous membrane of the alimentary canal and nasal mucosa; erectile tissue of the sex organs; thyroid gland; tongue.
- **Functions:** regulation of body temperature (heat loss/conservation), regulation of regional blood flow, regulation of blood pressure — when the sphincter relaxes, blood bypasses the capillary bed (organ/tissue at rest); when it contracts, blood is directed through the capillaries (organ/tissue active).
- **Applied:** after severe haemorrhage (road accidents, war injuries) AV shunts in kidney and intestine open up, diverting blood away from the glomerular capillaries to protect the circulating volume to vital organs (heart, brain) — this is a mechanism of post-traumatic **anuria**; as blood volume is restored the shunts close and urine output recovers, a favourable clinical sign.

3. Periarticular (peri-joint) collateral circulation of the limbs

Around every major limb joint, a rich network of anastomoses links the vessel proximal to the joint with the vessels distal to it, so that ligation or gradual occlusion of the main trunk still permits perfusion of the distal limb.

Joint	Anastomosis	Vessels forming it
Shoulder/scapula	Scapular anastomosis	Suprascapular artery, dorsal scapular artery (deep branch of transverse cervical) and circumflex scapular artery (branch of subscapular artery, 3rd part of axillary) anastomose around the scapula

Joint	Anastomosis	Vessels forming it
Elbow	Anastomosis around the elbow joint (4 links)	<i>Anterior, lateral:</i> radial collateral (anterior descending br. of profunda brachii) ↔ radial recurrent br. of radial artery. <i>Posterior, lateral:</i> middle collateral (posterior descending br. of profunda brachii) ↔ interosseous recurrent br. of posterior interosseous artery. <i>Anterior, medial:</i> inferior ulnar collateral br. of brachial artery ↔ anterior ulnar recurrent br. of ulnar artery. <i>Posterior, medial:</i> superior ulnar collateral br. of brachial artery ↔ posterior ulnar recurrent br. of ulnar artery
Hip	Trochanteric anastomosis	Superior and inferior gluteal branches of internal iliac artery anastomose with the medial and lateral circumflex femoral branches of profunda femoris around the greater trochanter
Back of thigh	Cruciate anastomosis	Inferior gluteal artery (internal iliac) + medial and lateral circumflex femoral arteries + 1st perforating branch of profunda femoris — meet just below the trochanter, continuing down as a chain of anastomoses between successive perforating arteries to reach the popliteal artery
Knee	Genicular (peri-articular) anastomosis	Descending genicular (from femoral) and descending branch of lateral circumflex femoral above; superior medial/lateral, middle, inferior medial/lateral genicular branches of the popliteal artery; anterior tibial recurrent and circumflex fibular branches below

embed: ![Fig 21.17 — Sites of portosystemic anastomoses (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.362)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/c4594697d260e3cd.jpg)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the arterial anastomosis around the elbow joint (anterior view) and label:

- ▶ Brachial artery
- ▶ Profunda brachii artery
- ▶ Radial collateral artery (anterior descending branch)
- ▶ Middle collateral artery (posterior descending branch)
- ▶ Superior ulnar collateral artery
- ▶ Inferior ulnar collateral artery (supratrochlear)
- ▶ Radial artery
- ▶ Ulnar artery
- ▶ Radial recurrent artery
- ▶ Anterior and posterior ulnar recurrent arteries
- ▶ Common interosseous artery → anterior and posterior interosseous arteries
- ▶ Interosseous recurrent artery
- ▶ Lateral and medial epicondyles of humerus (landmarks)

Applied significance: because of this rich anastomosis, the brachial artery can be ligated below the origin of profunda brachii (e.g. in trauma) without endangering the forearm, as collateral flow reaches the radial and ulnar arteries through these four peri-elbow links.

4. Portosystemic (portocaval) collateral circulation

When the portal vein is obstructed (commonly **cirrhosis of the liver**, also portal vein thrombosis and Banti's disease), portal pressure rises from its normal 5–15 mmHg; the naturally-present but normally insignificant communications between the portal and systemic venous systems dilate and become clinically important collateral channels.

Site	Portal tributary	Systemic tributary	Clinical consequence
Lower end of oesophagus	Left gastric vein	Oesophageal (azygos) veins	Oesophageal varices → haematemesis
Lower end of rectum/anal canal	Superior rectal vein	Middle and inferior rectal veins	Ano-rectal venous anastomosis → haemorrhoids
Umbilicus/anterior abdominal wall	Paraumbilical veins (along ligamentum teres)	Superior epigastric, lateral thoracic (above); inferior/superficial epigastric (below)	Dilated subcutaneous veins radiating from the umbilicus — caput medusae
Bare area of liver	Portal radicles	Diaphragmatic (phrenic) veins	Minor collateral

Site	Portal tributary	Systemic tributary	Clinical consequence
Retroperitoneum (posterior abdominal wall)	Splenic vein tributaries	Left renal vein	Site used surgically for a spleno-renal shunt
Falciform ligament	Paraumbilical veins	Diaphragmatic veins	Minor collateral
Ligamentum venosum	Left branch of portal vein	Inferior vena cava	Minor collateral (obliterated ductus venosus remnant)

- Effects of portal hypertension: congestive splenomegaly, ascites, oesophageal varices (risk of fatal haematemesis), caput medusae, and haemorrhoids.
- The **marginal artery of Drummond** — formed by anastomoses between the ileocolic, right colic, middle colic, left colic and sigmoid arteries along the concave (mesenteric) border of the colon — is a key collateral arterial channel of the gut: it can maintain colonic perfusion even if one of the main feeding trunks (e.g. inferior mesenteric artery) is occluded, a fact exploited in colonic resections.

5. Other clinically important collateral pathways

- **Coronary collateral circulation:** arterial anastomoses (>100 µm calibre) occur throughout the myocardium; on gradual coronary occlusion (as in atherosclerosis) these enlarge and can maintain perfusion, but they cannot open fast enough to prevent infarction after a sudden acute occlusion. Extracardiac collateral routes also connect the coronary arteries with the vasa vasorum of the aorta/pulmonary trunk and with branches of the internal thoracic, bronchial and phrenic arteries.
- **Cerebral collateral circulation — Circle of Willis:** the two internal carotid arteries and the two vertebral (→ basilar) arteries anastomose on the inferior surface of the brain via the anterior communicating and posterior communicating arteries to form the arterial circle of Willis, providing potential collateral flow between the carotid and vertebrobasilar territories if one feeding vessel is slowly occluded.
- **Caval–caval collateral circulation:** gradual obstruction of the inferior vena cava (thrombosis, extrinsic compression) is compensated by an extensive collateral network draining into the superior vena cava — chiefly the **azygos–hemiazygos venous system**, the **vertebral venous plexuses**, and superficial body-wall veins; the lumbar veins contribute significantly to these channels.
- **Anastomoses around the wrist and hand:** the radial and ulnar arteries are linked at the wrist and by the superficial and deep palmar arches, ensuring hand perfusion even if one forearm artery is occluded (this is the anatomical basis of the Allen test).

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- **Vascular surgery/trauma:** knowledge of periarticular anastomoses (elbow, hip, knee, scapula) allows safe ligation of a major limb artery proximal to a joint, provided the ligation is distal to the origin of the principal collateral-feeding branch (e.g. profunda brachii/profunda femoris); if ligation is proximal to this origin, collateral supply is lost and gangrene may follow.

- ▶ **Cirrhosis of liver / portal hypertension:** recognising the sites of portosystemic anastomosis explains oesophageal varices, caput medusae and haemorrhoids, and underlies surgical **porto-systemic shunt** procedures (e.g. spleno-renal shunt using the splenic vein–left renal vein anastomotic site).
- ▶ **End arteries and infarction:** because arteries of the retina, spleen, kidney and brain (cortical) either lack anastomoses or anastomose only at arteriolar level, sudden embolic occlusion (e.g. central retinal artery occlusion, renal infarct, cerebral infarct) is not compensated in time and causes tissue necrosis.
- ▶ **Chronic ischaemia allows collateral development:** slowly progressive atherosclerotic narrowing (coronary or peripheral arterial disease) gives time for potential anastomoses to enlarge, which is why gradual occlusion is often better tolerated clinically than sudden occlusion of the same vessel.
- ▶ **Marginal artery of Drummond:** surgeons preserve or deliberately rely on this arcade during colonic resections and while raising a colonic conduit, since it can sustain the bowel supplied by a ligated main trunk.
- ▶ **AV anastomoses and shock:** opening of AV shunts in the gut and kidney after massive haemorrhage diverts blood from non-vital capillary beds to protect cardiac and cerebral perfusion, at the cost of transient renal shutdown (post-traumatic anuria).

High-yield exam pointers

- ▶ Define anastomosis and collateral circulation; classify arterial anastomosis into actual (end-to-end/convergent) and potential (arteriolar level).
- ▶ List true (anatomical) end arteries vs functional end arteries with examples (retina/spleen/kidney vs coronary/cerebral cortical).
- ▶ Name the four peri-elbow anastomotic links (radial collateral–radial recurrent; middle collateral–interosseous recurrent; inferior/superior ulnar collateral–ulnar recurrences) — a favourite diagram.
- ▶ Know trochanteric and cruciate anastomoses of the hip/thigh and their applied significance in femoral artery ligation.
- ▶ Reproduce the 7-site table of portosystemic anastomoses with the clinical correlate at each site (varices, piles, caput medusae).
- ▶ State normal portal pressure (5–15 mmHg) and the consequences of portal hypertension.
- ▶ Mention AV anastomoses — sites, sympathetic control, and role in thermoregulation and post-haemorrhagic anuria.
- ▶ Cite circle of Willis (cerebral) and azygos system (caval-caval) as further collateral examples beyond the limbs and portal system.
- ▶ Marginal artery of Drummond — the classic collateral of the large gut, relevant to colonic surgery.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e; BD Chaurasia — Human Anatomy Vol 1 (8e) and Vol 2 (8e); AK Datta — Human Anatomy Vol 2 (Head & Neck) and Vol 3 (Upper & Lower Limb); Gray's Anatomy (Standing) 41e; Snell — Clinical Neuroanatomy 7e; Moore — Clinically Oriented Anatomy 9e.



Deep fascia and its modifications

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction Deep fascia is a tough, inelastic sheet of dense regular (fibrous) connective tissue that lies immediately deep to the superficial fascia and invests the body like a tight sleeve, binding muscles, vessels and nerves into compact functional units. Histologically it is built of densely packed, sheet-aligned type I collagen fibres, which gives it high tensile strength with only modest extensibility (collagen fibres tolerate up to about 15% stretch before failure), and it is best developed over the limbs and neck. At many characteristic sites the deep fascia is locally thickened, condensed or specialised into named structures — retacula, aponeuroses, fibrous sheaths, capsules, septa and interosseous membranes — collectively called the **modifications of deep fascia**.

1. General structure and distribution

- ▶ Deep fascia is derived embryologically from **mesoderm**, the same source as bone; wherever it meets a bone it does not cross over it but fuses with the periosteum ("**Axiom**": deep fascia attaches to, never crosses, bone).
- ▶ It is **best marked in the limbs and neck**, where it forms a continuous investing sleeve.
- ▶ **Sites where deep fascia is deficient/absent** (per Vishram Singh's General Anatomy): face, breast, anterior abdominal wall, penis and scrotum, and the ischioanal fossa — in these regions only superficial fascia (sometimes itself specially named, e.g. Camper's/Scarpa's fascia of the abdominal wall, dartos of the scrotum) is present.
- ▶ **Nerve supply**: deep fascia is richly innervated and sensitive; its nerve supply is derived from (i) the cutaneous nerves supplying the overlying skin and (ii) the nerves supplying the muscles it encloses.
- ▶ **Composition**: dense regular connective tissue with collagen fibres arranged in adjacent sheets running in at least two directions, allowing it to resist tension from multiple planes (unlike a tendon, whose fibres run in one line of pull).

2. Functions of deep fascia

- ▶ Keeps underlying muscles, vessels and nerves in position and maintains the characteristic surface contour of the limbs and neck.
- ▶ Provides additional surface area for muscular origin/insertion (e.g. deep surface of fascia lata gives origin to vastus lateralis fibres).

- ▶ Facilitates venous and lymphatic return by acting as an unyielding sheath against which muscle contraction compresses veins (the "muscle pump").
- ▶ Binds adjacent bones together (interosseous membranes) and provides extra attachment area.
- ▶ Retains long tendons in position at joints, preventing **bowstringing**, and converts them into pulleys during muscle action.
- ▶ Compartmentalises muscle groups via intermuscular septa, allowing each group to contract independently and slide over its neighbours.
- ▶ Provides a plane of cleavage that surgeons use to reach deeper structures with minimal disturbance of surrounding tissue.

3. Modifications of deep fascia

The deep fascia becomes locally specialised into the following nine recognised forms:

Modification	Description	Classic examples
Retinacula	Localised thickened bands that retain long tendons in place across a joint and prevent bowstringing during muscle action	Flexor & extensor retinacula of the wrist; superior/inferior extensor and peroneal retinacula and flexor retinaculum of the ankle
Aponeuroses	Broad, flattened sheets of fibrous tissue giving attachment to muscles and protecting deeper structures; represent degenerated tendons	Palmar aponeurosis (degenerated tendon of palmaris longus); plantar aponeurosis (degenerated tendon of plantaris)
Fibrous (neurovascular) sheaths	Condensations of deep fascia that ensheath and protect neurovascular bundles	Carotid sheath (common carotid artery, internal jugular vein, vagus nerve); axillary sheath (axillary artery and vein — tighter around the artery, looser around the vein to permit venous distension); femoral sheath
Fibrous capsules of glands	Deep fascia splits to enclose a gland and support it	Capsules of the parotid, submandibular and thyroid glands
Interosseous membranes	Sheets of deep fascia joining two parallel long bones, also giving muscular origin	Between radius & ulna (forearm); between tibia & fibula (leg)
Intermuscular septa	Fibrous septa passing inward from the deep fascia to attach to the periosteum, separating muscle groups into osteofascial compartments	Medial, lateral and posterior intermuscular septa of the thigh, creating anterior, medial and posterior compartments; anterior & posterior septa of the leg
Fibrous flexor sheaths	Thickenings of deep fascia over the flexor aspect of digits forming an osteofibrous tunnel around the long flexor tendons	Fibrous flexor sheaths of the fingers and toes, preventing tendon bowstringing during grip

Modification	Description	Classic examples
Ligaments of joints	Localised, dense thickened bands of deep fascia that stabilise a joint	Most peripheral joint ligaments
Fascial sheath around individual muscles	Deep fascia condenses to form a discrete sheath around a single muscle for protection	Psoas sheath (fascia over psoas major)

4. Regional example — layering of deep cervical fascia

The neck illustrates how a single sheet of deep fascia can split into functionally distinct laminae:

- ▶ **Investing (superficial) layer** — encloses the whole neck like a collar and splits to enclose sternocleidomastoid and trapezius.
- ▶ **Pretracheal layer** — lies in front of the trachea and thyroid, enclosing the infrahyoid muscles and thyroid capsule.
- ▶ **Prevertebral layer** — covers the prevertebral muscles anterior to the cervical vertebral column.

Together these layers divide the neck into a **visceral compartment** and a **musculoskeletal compartment**, and the carotid sheath is formed by contributions from all three layers.

5. Other named regional deep fasciae (illustrative, not exhaustive)

- ▶ **Fascia lata** (thigh): a strong fibrous sleeve attached above to the inguinal ligament, iliac crest, sacrotuberous ligament and pubic arch, and below to the bony points around the knee; it is thickened laterally into the **iliotibial tract**, into which gluteus maximus and tensor fasciae latae insert, and it presents the **saphenous opening** medially (closed by the cribriform fascia) for passage of the long saphenous vein.
- ▶ **Clavipectoral fascia** (pectoral region): extends from the clavicle to the axillary fascia, splitting to enclose subclavius above and pectoralis minor below; pierced by the cephalic vein, thoracoacromial vessels and the lateral pectoral nerve.
- ▶ **Buck's fascia** (deep fascia of the penis): a strong fibrous envelope surrounding the corpus spongiosum and both corpora cavernosa, contributing to erection by limiting venous outflow.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Cross-section through the middle of the right thigh showing deep fascia and its modifications, labelling:

- ▶ Skin and superficial fascia (outer layer)
- ▶ **Deep fascia (fascia lata)** encircling the whole thigh like a sleeve
- ▶ **Medial, lateral and posterior intermuscular septa** running from the deep aspect of the fascia lata to the linea aspera/femur
- ▶ The three **osteofascial compartments** so formed — anterior (extensor), medial (adductor) and posterior (flexor) — with representative muscles, one artery and one nerve labelled in each compartment
- ▶ Femur at the centre with septa converging on it

□ Fig 5.10 — Transverse section through the middle of the right thigh to show the three intermuscular septa and three osteofascial compartments (Vishram Singh — General Anatomy — 4e, p.208)

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- ▶ **Compartment syndrome:** because deep fascia and its septa are inelastic, any increase in the volume of a closed osteofascial compartment (haemorrhage, oedema after fracture or ischaemia-reperfusion) raises intracompartmental pressure, compromising capillary perfusion and nerve function; emergency treatment is **fasciotomy** — surgical incision of the deep fascia to decompress the compartment.
- ▶ **Spread of infection along fascial planes:** because deep fascia defines potential planes between muscles, pus tracks along the line of least resistance — e.g. pus from a tuberculous focus in the thoracic vertebrae can track down the **psoas sheath** into the femoral triangle/upper thigh as a classic "cold abscess"; infection from the root of the neck can track into the arm through the **axillary sheath**.
- ▶ **Ganglion and tenosynovitis:** retinacula and fibrous flexor sheaths can be sites of tendon entrapment/ganglion formation because they form a rigid osteofibrous tunnel around the tendon.
- ▶ **Dupuytren's contracture:** pathological thickening/contracture of the palmar aponeurosis (a deep fascia modification) causes progressive flexion deformity, classically of the ring and little fingers.
- ▶ **Surgical planes:** surgeons deliberately dissect along deep fascial planes (e.g. raising fasciocutaneous flaps, or opening the carotid/axillary sheath) because this gives access with minimal disturbance to neurovascular structures.
- ▶ **Anterior abdominal wall:** deep fascia here is scanty/absent, so hernial sacs are covered only by superficial fascia (Camper's and Scarpa's) and peritoneum, not by a true deep fascial layer.
- ▶ **Femoral hernia:** exploits the saphenous opening in the fascia lata, protruding through the femoral canal and appearing below and lateral to the pubic tubercle.

High-yield exam pointers

- ▶ Deep fascia = dense regular (fibrous) connective tissue, mesodermal in origin; attaches to but never crosses a bone.

- ▶ Best developed in limbs and neck; deficient over face, breast, anterior abdominal wall, penis/scrotum and ischiorectal fossa.
- ▶ Nine modifications: retinacula, aponeuroses, fibrous (neurovascular) sheaths, fibrous capsules of glands, interosseous membranes, intermuscular septa, fibrous flexor sheaths, ligaments, and fascial sheaths around individual muscles — list all nine for full marks.
- ▶ Name at least one example of each modification (flexor/extensor retinacula; palmar/plantar aponeurosis; carotid/axillary sheath; parotid/thyroid capsule; radio-ulnar/tibiofibular interosseous membrane; thigh/leg intermuscular septa; digital fibrous flexor sheaths; joint ligaments; psoas sheath).
- ▶ Neck deep fascia has three named layers — investing, pretracheal, prevertebral — dividing the neck into visceral and musculoskeletal compartments.
- ▶ Fascia lata's two clinically important derivatives: iliotibial tract (knee stabiliser) and saphenous opening (site of femoral hernia, closed by cribriform fascia).
- ▶ Nerve supply of deep fascia: cutaneous nerves of overlying skin + nerves of enclosed muscles.
- ▶ Clinical relevance = compartment syndrome/fasciotomy, spread of pus along fascial planes (psoas/axillary sheath), Dupuytren's contracture of palmar aponeurosis.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e; BD Chaurasia — Human Anatomy Vol 1 & Vol 2 8e; Gray's Anatomy (Standring) 41e; IB Singh — Textbook of Anatomy Vol 1 6e.



Directional planes of human body

Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction — Anatomy is described using a precise, universally-accepted vocabulary so that the position of any structure can be stated without ambiguity. All such descriptions are referred to the body held in a fixed reference posture — the **anatomical position** — and are further specified using four imaginary **planes** (median, sagittal, coronal, transverse) and a set of paired **directional/relational terms** (superior–inferior, anterior–posterior, medial–lateral, and others). This terminology is codified in the **Terminologia Anatomica (TA, 1998)**, drawn up by the Federative Committee on Anatomical Terminology (FCAT), which Gray's Anatomy (41e) follows almost in entirety.

Anatomical position and fundamental position

- ▶ **Anatomical position:** the body stands erect, eyes looking directly forward at the horizon, upper limbs hanging by the sides with the **palms facing forwards**, lower limbs together, feet flat and parallel, and **toes pointing forwards**. Every anatomical description assumes this position, whether the subject is a living person, a cadaver lying supine/prone/on its side, or an imaging study.
- ▶ **Fundamental position:** identical to the anatomical position except that the **palms face the sides of the body** (forearm in mid-prone position). It is used when describing forearm rotation

(pronation/supination) so that "medial" and "lateral" retain their usual meaning irrespective of forearm rotation.

- The forearm and hand are the only parts whose anatomical-position posture (palms forward) is not the "natural" resting posture — adopted purely for descriptive consistency.

The four cardinal planes of the body

Descriptions are based on **four imaginary planes** applied to the body in the anatomical position — median, sagittal, coronal and horizontal (transverse). A plane that passes through the exact centre of the body (dividing it into two truly equal parts) is called a **cardinal plane**; the point where the three cardinal planes (one median, one coronal, one transverse) intersect is the **centre of gravity** of the body. Any plane that does not correspond to one of the four principal orientations is an **oblique plane**.

Plane	Orientation	Divides the body into	Notes / synonyms
Median (mid-sagittal) plane	Vertical, passes longitudinally through the midline (sagittal suture)	Right and left halves — equal	The one true "cardinal" sagittal plane; a structure lying in it is described as "median in position"
Sagittal (paramedian/parasagittal) plane	Any vertical plane parallel to the median plane	Right and left parts — unequal	Gray's 41e notes "parasagittal" is strictly redundant (any plane parallel to median is by definition sagittal) but the term remains in wide clinical use
Coronal (frontal) plane	Vertical, at right angles to the median plane; parallel to the coronal suture of the skull	Anterior (front) and posterior (back) parts	Orthogonal to the median plane
Transverse (horizontal) plane	Horizontal, at right angles to both the median and coronal planes	Superior (upper) and inferior (lower) parts	Orthogonal to both median and sagittal planes; radiologists call this the (trans)axial plane — by convention, axial images are viewed as though looking from the feet towards the head
Oblique plane	Any plane not matching the above four orientations	At an angle	Used, e.g., for many CT/MRI reformats that don't align with the cardinal axes

□ Fig 1.2 — Anatomical position and anatomical planes. The main planes of the body (Moore — *Clinically Oriented Anatomy* — 9e, p.95)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A standing figure in the anatomical position (facing forward, palms forward, toes forward) with three intersecting plane-lines drawn through it, each labelled:

- ▶ **Median (mid-sagittal) plane** — vertical line splitting the figure into equal right and left halves, passing through the vertex, nose, umbilicus and midline of perineum.
- ▶ **Coronal (frontal) plane** — vertical line at right angles to the median plane, separating anterior from posterior.
- ▶ **Transverse (horizontal) plane** — horizontal line at right angles to both, separating superior from inferior; mark it, e.g., at the level of the umbilicus.
- ▶ Mark the point of intersection of the three cardinal planes as the **centre of gravity**.
- ▶ Alongside the figure, draw arrows labelled with the paired directional terms: superior↔inferior, anterior↔posterior, medial↔lateral, proximal↔distal, superficial↔deep.

Directional and relational terms

These terms describe the position of one structure relative to another and are always used with the body assumed to be in the anatomical position.

Term pair	Meaning
Superior (cranial, cephalic/cephalad) — Inferior (caudal)	Nearer the head — nearer the feet. <i>Caudal</i> is used chiefly in embryology, for the hind end of the embryo.
Anterior (ventral) — Posterior (dorsal)	Towards the front of the body — towards the back. In the trunk and upper limb, anterior/ventral/flexor/palmar/volar are used as synonyms, likewise posterior/dorsal/extensor; <i>dorsal</i> and <i>ventral</i> are used particularly by embryologists and neuroanatomists.
Medial — Lateral	Closer to the median plane — farther from it. E.g., in the anatomical position the little finger is medial to the thumb, and the great toe is medial to the little toe.
Median	Lying in the median plane itself.
Intermediate	Lying between a medial and a lateral structure.
Proximal — Distal	Nearer to — farther from — the root/trunk attachment of a limb (also used for branching structures such as bronchi, vessels, nerves, taking the origin as the datum point).
Superficial — Deep	Nearer to — farther from — the surface of the body (relationship between two adjacent structures).
External — Internal	Farther from — nearer to — the centre of an organ or cavity (e.g., cortex vs medulla of kidney, layers of the body wall).

Term pair	Meaning
Central — Peripheral	Towards — away from — the centre of the body mass.
Ipsilateral — Contralateral — Bilateral	Same side of the body — opposite side — both sides.

Region-specific and limb directional terms

Certain structures have specialised direction-words that substitute for medial/lateral because "medial" and "lateral" alone are ambiguous once the limb is rotated:

Region	Term used for "medial"	Term used for "lateral"	Basis
Forearm/hand	Ulnar	Radial	Named after the medial (ulna) and lateral (radius) forearm bones
Leg/foot	Tibial	Fibular (peroneal)	Named after the medial (tibia) and lateral (fibula) leg bones
Upper limb border	Post-axial border	Pre-axial border (thumb side)	Embryological axis of limb rotation
Lower limb border	Pre-axial border (great-toe side)	Post-axial border	Embryological axis of limb rotation — note upper and lower limb pre-/post-axial borders are on opposite sides because the two limbs rotate in opposite directions during development

Additional paired surface terms: **palmar/volar** (towards the palm) vs **dorsal** (back of hand); **plantar** (sole) vs **dorsal** (dorsum of foot); **flexor surface** (anterior in the upper limb, posterior in the lower limb) vs **extensor surface** (the reverse) — compound oblique terms such as **postero-lateral** or **antero-medial** are used for structures lying between two cardinal directions.

Applied / Clinical anatomy

- **Radiological (cross-sectional/imaging) anatomy:** CT, MRI and ultrasound images are conventionally displayed and reported in the three cardinal planes — **axial (transverse)**, **coronal** and **sagittal** — and oblique reformats are used where a structure's long axis does not correspond to a cardinal plane (e.g., short-axis cardiac MRI). By radiological convention, an axial image is viewed as if the observer is standing at the patient's feet looking towards the head, so the patient's right side appears on the viewer's left — a rule every PG must apply correctly when reporting a scan.
- **Clinical body positions** used during examination and procedures are also referred to the anatomical position as baseline: **supine** (face up), **prone** (face down), and **lithotomy** (supine with

hips/knees flexed and thighs abducted, for perineal access) are standard positioning terms in surgery and obstetrics.

- ▶ **Surgical planning:** incisions are deliberately planned with respect to these planes — e.g., a **midline (median) laparotomy** follows the relatively avascular linea alba in the median plane, while a **Pfannenstiel incision** is a transverse (horizontal) incision; fracture description always specifies whether a fragment is displaced proximally/distally or medially/laterally.
- ▶ **Congenital anomalies of laterality:** the pre-axial/post-axial concept underlies anomalies such as **pre-axial polydactyly** (extra digit on the thumb/great-toe side); more generally, disturbance of the body's normal bilateral symmetry and organ "sidedness" produces **situs inversus** (mirror-image reversal of thoraco-abdominal viscera), a direct clinical application of medial–lateral/ipsilateral–contralateral concepts.
- ▶ **Clinical documentation:** precise use of superior/inferior, proximal/distal and medial/lateral (rather than vague terms like "above" or "behind") is mandatory in operative notes, radiology reports and case records to avoid ambiguity — the entire rationale for standardised anatomical nomenclature.

High-yield exam pointers

- ▶ All anatomical description is referred to the body in the **anatomical position**: erect, eyes forward, palms forward, toes forward.
- ▶ **Four planes:** median (equal right/left halves), sagittal/parasagittal (unequal right/left parts), coronal/frontal (anterior/posterior), transverse/horizontal (superior/inferior); anything else is an **oblique plane**.
- ▶ A plane through the exact centre of the body is a **cardinal plane**; the three cardinal planes intersect at the **centre of gravity**.
- ▶ Radiologists call the transverse plane the **axial plane** and view it from feet-to-head by convention.
- ▶ Key term pairs: superior/inferior (cranial/caudal), anterior/posterior (ventral/dorsal), medial/lateral, proximal/distal, superficial/deep, external/internal, ipsilateral/contralateral/bilateral.
- ▶ **Ulnar/radial** = medial/lateral in the forearm; **tibial/fibular** = medial/lateral in the leg.
- ▶ **Pre-axial border** = thumb side of upper limb = great-toe side of lower limb (opposite anatomical sides because of opposite limb rotation in development).
- ▶ Nomenclature is standardised by the **Terminologia Anatomica (TA, 1998)** of the FCAT/IFAA.
- ▶ Fundamental position differs from anatomical position only in forearm/palm orientation (palms face the sides, not forwards).

SOURCE & COVERAGE

Gray's Anatomy (Standing) 41e; Vishram Singh — General Anatomy 4e; Moore's Clinically Oriented Anatomy 9e; IB Singh — Textbook of Anatomy Vol 1, 6e.



Discuss the different types of fibrous joints with examples

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction. A joint (articulation) is a junction between two or more bones or cartilages. Joints are classified **structurally** (by the type of connecting tissue and presence/absence of a joint cavity) into **fibrous**, **cartilaginous** and **synovial** joints, and **functionally** (by degree of mobility) into **synarthroses** (immovable), **amphiarthroses** (slightly movable) and **diarthroses** (freely movable). A **fibrous joint** is one in which the articulating bones are united directly by **fibrous connective tissue**, with **no joint cavity**; movement is either absent or only slight. Fibrous joints are of **three types** — **sutures**, **syndesmoses** and **gomphoses** — each with characteristic sites, structure and examples, discussed below.

1. Structural classification of joints — where fibrous joints fit

Structural type	Connecting (uniting) tissue	Joint cavity	Usual functional class	Example
Fibrous	Dense fibrous connective tissue	Absent	Synarthrosis (sutures, gomphoses) or amphiarthrosis (syndesmoses)	Coronal suture, inferior tibiofibular joint
Cartilaginous	Hyaline cartilage (primary) or fibrocartilage (secondary)	Absent	Synarthrosis or amphiarthrosis	Costochondral joint, pubic symphysis
Synovial	Synovial membrane + cavity, articular cartilage	Present	Diarthrosis	Shoulder, knee, hip joints

- Fibrous joints therefore straddle two functional categories: **sutures and gomphoses are synarthroses** (essentially immobile), while **syndesmoses are amphiarthroses** (permit a slight, controlled movement).
- All fibrous joints share three defining features: (i) union by **fibrous connective tissue**, (ii) **absence of a joint cavity**, (iii) **little or no movement**, in keeping with their role of providing **strength and stability** rather than mobility.

2. Sutures

- **Definition:** Fibrous joints in which the articular surfaces of the bones are connected by a **thin layer of connective tissue (sutural ligament)**. Sutures are **peculiar to the skull** and are essentially **immobile**, though a degree of mobility is retained in growing children (important for accommodating brain growth and for moulding of the head during childbirth).
- **Microstructure:** on each bony surface a layer of osteogenic (cambial) cells is overlaid by a capsular lamella of fibrous tissue continuous with the periosteum; between the two capsular layers lies loose fibrous connective tissue, which diminishes with age until the osteogenic surfaces come into apposition.

- **Subtypes** (based on the shape of the articulating margins):

Subtype	Description	Example
Plane suture	Articular surfaces smooth and flat	Median palatine suture (between maxillae/palatine bones, forming hard palate)
Serrate (limbus) suture	Margins reciprocally serrated, interlocking jigsaw-fashion	Sagittal suture
Denticulate suture	Margins with tooth-like projections interlocking like a saw	Lambdoid suture
Squamous suture	Bevelled, overlapping articular surfaces	Suture between temporal and parietal bones
Schindylesis (wedge-and-groove)	A ridge of one bone fits into a groove of another	Rostrum of sphenoid into the cleft between the alae of vomer

- **Ageing change:** with advancing age most cranial sutures undergo **synostosis** (bony fusion, obliteration of the suture) — a process that normally begins in early adulthood and continues with age. This is why a child's skull is resilient to blows (mobile, unfused sutures absorb impact) while an adult skull is rigid and prone to splinter/fracture.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the five suture subtypes side by side in cross-section, labelling for each:

- **Plane suture** — two flat, smooth bony margins in apposition (e.g. median palatine suture)
- **Serrate suture** — interlocking saw-tooth margins (e.g. sagittal suture)
- **Denticulate suture** — coarse tooth-like projections interlocking (e.g. lambdoid suture)
- **Squamous suture** — bevelled overlapping margins (e.g. temporoparietal suture)
- **Schindylesis** — a ridge of one bone (sphenoidal rostrum) received into a groove/cleft of another (vomer)
- In each, label the **sutural ligament** (fibrous connective tissue) and the **periosteal (capsular) and osteogenic (cambial) layers** on the bony surfaces.

□ Fig 7.2 — A suture. (Vishram Singh — General Anatomy — 4e, p.285)

3. Syndesmoses

- **Definition:** Fibrous joints in which two adjacent bones are linked by a **considerably greater amount of connective tissue than in sutures**, in the form of an **interosseous ligament or membrane**, a slender fibrous cord, or a denser fibrous membrane.
- **Examples:**
- **Interosseous membrane of the forearm** — between the shafts of radius and ulna.
 - **Interosseous membrane of the leg** — between the shafts of tibia and fibula.
 - **Inferior (distal) tibiofibular joint** — a **compound fibrous joint** made up of the interosseous ligament together with the anterior and posterior tibiofibular ligaments, uniting the distal

- **Ligamenta flava** connecting adjacent vertebral laminae.
- **Tympanostapedial (tympano-stapedial) joint.**
- Posterior part of the **sacroiliac joint** (a denser fibrous membrane, as described by Gray's Anatomy).

- Fig 7.4 — Syndesmosis: (A) schematic diagram and (B) inferior tibiofibular joint representing syndesmosis. (Vishram Singh — General Anatomy — 4e, p.287)

□ Fig 7.5 — Gomphosis (peg and socket variety): (A) diagrammatic representation and (B) tooth in alveolar socket representing gomphosis. (Vishram Singh — General Anatomy — 4e, p.288)



- ▶ **Periodontitis:** inflammation and degeneration of the periodontal ligament of the gomphosis leads to loosening and eventual loss of teeth — the clinical basis of periodontal disease.
- ▶ **Tibiofibular syndesmosis injury:** the integrity of the inferior tibiofibular syndesmosis is essential for ankle-mortise stability; a **Pott fracture-dislocation** of the ankle (forced eversion) may fracture the fibula above the syndesmosis with disruption of the interosseous ligament, and severe eversion-external-rotation ankle injuries ("high ankle sprain") can diastase (widen) this joint, destabilising the ankle mortise.
- ▶ **Radiology/forensic relevance:** sutures appear as characteristic radiolucent lines on skull radiographs/CT in infants and young children and must be distinguished from fracture lines; the sequence and degree of suture closure is also used in **forensic age estimation** from the skull.

High-yield exam pointers

- ▶ Fibrous joint = bones united by **fibrous connective tissue**, **no joint cavity**, immovable or only slightly movable.
- ▶ **Three types: Sutures, Syndesmoses, Gomphoses** — remember as "the three S/G's of the skull, shaft and socket."
- ▶ **Sutures** — confined to the **skull**; five subtypes: **plane, serrate, denticulate, squamous, schindylesis**; undergo **synostosis** with age.
- ▶ **Syndesmoses** — greater bulk of connective tissue (**interosseous ligament/membrane**); classic examples: **interosseous radioulnar membrane, interosseous/inferior tibiofibular joint, ligamenta flava, tympanostapedial joint**; functionally **amphiarthroses**.
- ▶ **Gomphoses** — **peg-and-socket** union of tooth root to alveolar socket via the **periodontal ligament**; per Gray's Anatomy, strictly not a true bone-to-bone articulation.
- ▶ Functional counterpart: sutures & gomphoses = **synarthroses**; syndesmoses = **amphiarthroses**.
- ▶ Clinical hooks: **craniosynostosis** → **scaphocephaly/oxycephaly**; **periodontitis** (gomphosis); **Pott fracture-dislocation/high ankle sprain** (tibiofibular syndesmosis).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh's General Anatomy 4e; BD Chaurasia's Human Anatomy Vol 3-4 8e (abnormal crania); Moore's Clinically Oriented Anatomy 9e (tibiofibular syndesmosis, Pott fracture-dislocation).



Enumerate the diaphragms in the body. What are their attachments, relations, nerve supply, special features and functional importance?

Asked in: Paper I Oct 2006 — RGUHS MD/MS Anatomy

Definition / Introduction

In general anatomical usage, a "diaphragm" is any musculofascial or fibrous sheet that partitions one body space from another while transmitting specific structures through defined apertures. Besides the

principal thoraco-abdominal (thoracic) diaphragm, four other such partitioning sheets are recognised — the pelvic diaphragm, the urogenital diaphragm (now redescribed as the perineal membrane), the oral diaphragm (diaphragma oris, formed by mylohyoid), and the diaphragma sellae (a dural fold roofing the pituitary fossa). Each illustrates the same design principle — a supporting sheet that resists intracavitary pressure while allowing passage of viscera, vessels or nerves through its hiatus.

Enumeration and comparative overview

#	Diaphragm	Composed of	Separates
1	Thoracic (main) diaphragm	Skeletal muscle + central tendon	Thoracic cavity from abdominal cavity
2	Pelvic diaphragm	Levator ani + coccygeus (skeletal muscle)	Pelvic cavity from perineum
3	Urogenital diaphragm (perineal membrane)	Fibrous membrane ± deep transverse perinei	Urogenital triangle of the perineum
4	Oral diaphragm (diaphragma oris)	Mylohyoid muscle (paired)	Oral cavity from suprahyoid neck
5	Diaphragma sellae	Dura mater (fibrous)	Roofs the pituitary (hypophyseal) fossa

1. Thoracic (main) diaphragm

- **Attachments (origin → insertion):** sternal part — two fleshy slips from the posterior xiphoid; costal part — inner surfaces of the lower six costal cartilages/ribs, interdigitating with transversus abdominis; lumbar part — medial and lateral arcuate ligaments (lumbocostal arches) plus the crura (right crus from the upper three lumbar vertebrae/discs, left crus from the upper two), their medial margins uniting anterior to the aorta as the **median arcuate ligament**. All fibres converge on the trifoliate **central tendon** (anterior triangular folium + right/left tongue-shaped folia), partly fused above with the fibrous pericardium.

□ Fig 5.95 — Apertures of diaphragm. "8-10-12" is a convenient memory device, refer (Moore — Clinically Oriented Anatomy — 9e, p.903)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- ▶ Trifoliate central tendon (anterior triangular folium + right/left tongue-shaped folia)
- ▶ Three apertures in an oblique line: caval opening (T8/9, in central tendon), oesophageal hiatus (T10, in right crus), aortic hiatus (T12, behind median arcuate ligament)
- ▶ Sternal, costal and lumbar origins around the circumference; right and left crura from vertebral bodies; medial and lateral arcuate ligaments over psoas major and quadratus lumborum
- ▶ **Relations:** superior surface — parietal pleura and base of each lung on each side; fibrous pericardium over the central "cardiac plateau." Inferior (peritoneum-covered) surface — right side moulded over the right lobe of liver, right kidney and right suprarenal; left side over the left lobe of liver, gastric fundus, spleen, left kidney and left suprarenal.
- ▶ **Apertures:**

Opening	Level	Shape	Transmits
Caval opening	T8/T9 disc, in central tendon	Quadrilateral	IVC, branches of right phrenic nerve, hepatic lymphatics
Oesophageal hiatus	T10, in right crus muscle	Elliptical	Oesophagus, vagal trunks, oesophageal branches of left gastric vessels, lymphatics
Aortic hiatus	T12, behind median arcuate ligament	Rounded, osseo-aponeurotic	Aorta, thoracic duct, (occasionally azygos/hemiazygos veins)

Lesser openings: each crus pierced by the greater and lesser splanchnic nerves; sympathetic trunk behind the medial arcuate ligament; subcostal nerve/vessels behind the lateral arcuate ligament; superior epigastric vessels through the sternocostal hiatus (space of Larrey/foramen of Morgagni); musculophrenic vessels near the ninth costal cartilage.

- ▶ **Nerve supply:** motor — **phrenic nerve** (C3, C4, C5; chiefly C4), sole motor supply to each hemidiaphragm (right phrenic to right-crus fibres right of the oesophagus; left phrenic to the left crus plus right-crus fibres left of the oesophagus). Sensory — phrenic nerve to the central part; lower six/seven intercostal nerves to the peripheral part.
- ▶ **Blood supply:** inferior phrenic arteries (chief supply, aorta/coeliac trunk), superior phrenic arteries (thoracic aorta), musculophrenic and pericardiophrenic arteries (internal thoracic), lower five intercostal and subcostal arteries; venous return via phrenic veins to the IVC; lymphatics to parasternal, posterior mediastinal and brachiocephalic nodes.
- ▶ **Special features:** right dome higher than the left (liver); central tendon partly fused with the pericardium; **phreno-oesophageal ligament** anchors yet allows mobility of the cardio-oesophageal junction; crural fibres contract fractionally before costal fibres; acts as a "physiological sphincter" at the gastro-oesophageal junction on inspiration.

- **Functional importance:** chief muscle of quiet inspiration (~two-thirds of resting tidal volume); descends 1.5–2 cm in quiet breathing, 6–10 cm on deep inspiration; raises intra-abdominal pressure for expulsive acts (coughing, sneezing, straining, micturition, defaecation, parturition, vomiting) via a preceding deep inspiration and glottic closure; caval-opening dilation on inspiration augments venous return; braces the trunk during heavy lifting.

2. Pelvic diaphragm

- **Attachments:** formed by **levator ani** (pubococcygeus, puborectalis, iliococcygeus) and **coccygeus** (**ischiococcygeus**) of both sides, sharing a continuous linear origin from the pelvic surface of the body of the pubis, the tendinous arch (white line) of the obturator fascia, and the ischial spine; fibres slope down and back to insert into the perineal body, anococcygeal ligament/raphe, coccyx, and walls of the prostate/vagina and rectum.
 - Pubococcygeus — anterior fibres form levator prostatae (male)/sphincter vaginae (female), inserting into the perineal body; middle fibres form the **puborectalis** sling around the anorectal junction; posterior fibres pass to the anococcygeal ligament and coccyx tip.
 - Iliococcygeus — posterior white line + ischial spine → anococcygeal ligament and lower two coccygeal pieces.
 - Ischiococcygeus (coccygeus) — ischial spine + sacrospinous ligament → coccyx and fifth sacral segment.

□ Fig 31.16 — Superior view of the pelvic diaphragm (the levator ani and coccygeus) (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.484)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- ▶ Gutter/funnel shape viewed from above: pubococcygeus, iliococcygeus and ischiococcygeus arranged antero-posteriorly
- ▶ Continuous origin line: body of pubis → tendinous arch (white line of obturator fascia) → ischial spine
- ▶ Urogenital hiatus (urethra ± vagina) and anal hiatus; puborectalis sling around the anorectal junction; insertions into perineal body, anococcygeal raphe and coccyx
- ▶ **Relations:** superior (pelvic) surface — covered by parietal pelvic fascia, separating it from the bladder/prostate or uterus, rectum, and pelvic peritoneum. Inferior (perineal) surface — covered by anal fascia, forming the medial wall of the ischioanal fossa.
- ▶ **Nerve supply:** levator ani — branch of S4 and a branch of the inferior rectal nerve (pudendal, S2–4); coccygeus — branches from S4 and S5.
- ▶ **Special features:** the two levator ani muscles interlock like clasped fingers to close the posterior pelvic outlet, breached only by the urogenital and anal hiatuses; puborectalis maintains the anorectal angle, essential to faecal continence.
- ▶ **Functional importance:** chief active (muscular) support of the pelvic viscera; resists any rise in intra-abdominal pressure during coughing, sneezing and lifting, maintaining continence; relaxes selectively at the relevant hiatus during micturition, defaecation and parturition while the rest of the sling stays contracted to prevent prolapse; coccygeus draws the coccyx forward again after it is pushed back during defaecation/parturition.

3. Urogenital diaphragm (perineal membrane)

- ▶ **Classical concept and attachments:** a tough, triangular fibrous sheet stretched across the pubic arch between the two ischiopubic rami in the urogenital triangle; posterior border fused with the perineal body and the fascia of the superficial transverse perineal muscles; anteriorly thickened in the midline as the transverse perineal ligament, leaving a gap for the deep dorsal vein. Traditionally taught as urogenital sphincter muscles (deep transverse perineal muscle and sphincter urethrae) sandwiched between a superior and an inferior fascia (the perineal membrane), pierced by the urethra (and vagina in the female).
- ▶ **Relations/contents:** in the male, crossed by the membranous urethra (2–3 cm behind the pubic symphysis), vessels/nerves to the penile bulb, ducts of the bulbo-urethral glands, and, behind the pubic arch, the deep dorsal vessels/nerves of the penis. In the female, divided into two triangular halves by the urethra and vagina, the vaginal wall attaching at the hymenal-ring level, with levator ani on its cranial surface.
- ▶ **Nerve supply:** perineal branches of the pudendal nerve (S2–S4).
- ▶ **Special feature (modern view):** current anatomy (Oelrich 1983; Gray's 41e, BD Chaurasia 8e) holds that a discrete two-layered "urogenital diaphragm" enclosing a separate sphincter urethrae does **not** exist — sphincter urethrae lies within the urethral wall itself as the distal urethral sphincter, with the compressor urethrae and urethrovaginal sphincter in the female. The single sheet is now the **perineal membrane**; the deep perineal space above it is thin and open superiorly, not a closed compartment.

- **Functional importance:** firm base of support for the erectile bodies (crura of penis/clitoris, bulb) and the anterior pelvic floor; carries the urethral sphincter mechanism for voluntary control of micturition; supports the vaginal wall and, indirectly, the uterus.

4. Oral diaphragm (diaphragma oris) — mylohyoid

- **Attachments:** paired, flat, triangular muscle; origin along the whole length of the mylohyoid line of the mandible; posterior fibres insert on the body of the hyoid; middle/anterior fibres of the two sides decussate in a median fibrous raphe from the symphysis menti to the hyoid.
- **Relations:** inferior surface — platysma, anterior belly of digastric, superficial part of submandibular gland, facial/submental vessels, mylohyoid vessels/nerve. Superior surface — geniohyoid, hyoglossus, styloglossus, hypoglossal and lingual nerves, submandibular ganglion, sublingual gland, deep part of submandibular gland and its duct.
- **Nerve supply:** mylohyoid nerve, from the inferior alveolar nerve (mandibular division of trigeminal, V3).
- **Blood supply:** sublingual branch of lingual artery, mylohyoid branch of inferior alveolar artery, submental branch of facial artery.
- **Special features:** the muscular floor separating the oral cavity proper (above) from the submandibular/submental neck (below); a hiatus in about one-third of individuals allows a process of the sublingual gland to protrude; the median raphe may be absent, the muscles then forming a continuous sheet.
- **Functional importance:** elevates the floor of the mouth and tongue in the first (oral) stage of deglutition; also elevates the hyoid, or depresses the mandible when the hyoid is fixed.

5. Diaphragma sellae

- **Attachments:** a small, circular, horizontal fold of dura mater, attached anteriorly to the tuberculum sellae, posteriorly to the dorsum sellae, continuous laterally with the dura of the middle cranial fossa.
- **Relations:** roofs the hypophyseal fossa (sella turcica), covering the pituitary gland; related superiorly to the optic chiasma, tuber cinereum and the infundibular recess of the third ventricle.

□ Fig 12.3 — Tentorium cerebelli and diaphragma sellae seen from above (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.233)

- **Special features:** a central aperture of variable size transmits the infundibulum (pituitary stalk) to the floor of the third ventricle; the anterior and posterior intercavernous sinuses (joining the two cavernous sinuses) pass through it, in front of and behind the infundibulum respectively.
- **Nerve/blood supply:** as intracranial dura, sparse sensory supply mainly from the ophthalmic division of the trigeminal nerve; vascular supply via meningeal branches in the middle meningeal/internal carotid territory.
- **Functional importance:** roofs and protects the pituitary gland, limiting its unrestrained superior (suprasellar) extension.

Applied / Clinical anatomy

- ▶ **Hiatus hernia:** sliding (type I) from widening of the oesophageal hiatus with laxity of the phreno-oesophageal ligament; para-oesophageal (type II) when the stomach herniates alongside an intact cardio-oesophageal junction.
- ▶ **Congenital diaphragmatic hernia:** retrosternal, through the foramen of Morgagni/space of Larrey (commoner on the right, usually asymptomatic); posterolateral, through the pleuroperitoneal hiatus (foramen of Bochdalek) — the commonest type, more frequent on the left, potentially fatal in the neonate.
- ▶ **Phrenic nerve injury** causes hemidiaphragmatic paralysis with paradoxical movement on fluoroscopy/ultrasound "sniff test"; referred shoulder-tip pain reflects the shared C3–C5 root value with the supraclavicular nerves.
- ▶ Injury to pubococcygeus in difficult labour weakens vaginal/uterine support, predisposing to pelvic organ prolapse and stress incontinence; the puborectalis sling and anorectal angle are central to continence surgery.
- ▶ **Episiotomy** divides the perineal membrane and superficial perineal muscles; pelvic-fracture urethral injury classically disrupts the membranous urethra at the level of the perineal membrane.
- ▶ Deep floor-of-mouth infection (**Ludwig's angina**) spreads through the sublingual/submandibular spaces on either side of mylohyoid and threatens the airway.
- ▶ **Pituitary macroadenomas** may stretch or breach the aperture of the diaphragma sellae, producing suprasellar extension and chiasmal compression (bitemporal hemianopia); a wide/deficient diaphragma sellae underlies "empty sella syndrome."

High-yield exam pointers

- ▶ Five diaphragms: thoracic (main), pelvic, urogenital (perineal membrane), oral (mylohyoid), diaphragma sellae — muscular except #3 (perineal membrane, fibrous) and #5 (diaphragma sellae, dural).
- ▶ Mnemonic "8-10-12": caval opening at T8, oesophageal hiatus at T10, aortic hiatus at T12.
- ▶ Sole motor nerve to the thoracic diaphragm is the phrenic (C3, C4, C5); the crura around the oesophagus show crossed innervation.
- ▶ Pelvic diaphragm = levator ani (pubococcygeus + puborectalis + iliococcygeus) + coccygeus; nerve supply from S4 and the inferior rectal nerve.
- ▶ "Urogenital diaphragm" is now obsolete terminology — the current concept is the single **perineal membrane**; sphincter urethrae lies within the urethral wall (Oelrich 1983).
- ▶ Mylohyoid (diaphragma oris) is supplied by the mylohyoid nerve (from the inferior alveolar, V3), unlike most other floor-of-mouth muscles.
- ▶ Diaphragma sellae is pierced centrally by the infundibulum, and by the anterior and posterior intercavernous sinuses.
- ▶ Congenital diaphragmatic hernias: foramen of Morgagni (anterior, retrosternal, rare) versus foramen of Bochdalek (posterolateral, commonest, usually left-sided).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; BD Chaurasia's Human Anatomy Vol 3-4 8e; Moore's Clinically Oriented Anatomy 9e.



Joints of the body

Asked in: Paper I May 2007 — RGUHS MD/MS Anatomy

Definition / Introduction A joint (**articulation, arthrosis**) is a junction between two or more bones, or between bone and cartilage, that permits (or restricts) relative movement of the parts. Long bones articulate by their ends, flat bones by their margins, and irregular/short bones by their surfaces. The study of joints is **arthrology (syndesmology)**; **arthritis** is joint inflammation. There is no single satisfactory classification — joints are classified either by **structure** (the connecting tissue and presence/absence of a joint cavity) or by **function** (degree of mobility); the structural scheme — fibrous, cartilaginous, synovial — is the one used clinically and is described in detail below.

Classification of joints

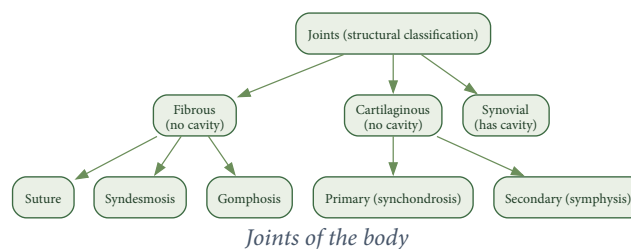
Functional classification (degree of mobility):

Type	Mobility	Examples
Synarthrosis	Immovable	Cranial sutures (adult); primary cartilaginous joints in growing children
Amphiarthrosis	Slightly movable	Secondary cartilaginous joints (symphyses); syndesmoses
Diarthrosis	Freely movable	Synovial joints

Structural classification (type of connecting tissue ± joint cavity) — the joints of the body fall into **three** structural types:

- **Fibrous joints** — united by fibrous connective tissue; no joint cavity.
- **Cartilaginous joints** — united by hyaline cartilage or fibrocartilage; no joint cavity.
- **Synovial joints** — possess a joint cavity lined by synovial membrane and filled with synovial fluid.

□ Fig 7.1 — Types of joints: (A) fibrous, (B) cartilaginous and (C) synovial (Vishram Singh — General Anatomy — 4e, p.283)



Fibrous joints

Bones are united by fibrous (collagenous) connective tissue; the joint is immovable or allows only slight movement, and there is **no joint cavity**. Three subtypes:

- ▶ **Sutures** — confined to the **skull**; articular surfaces joined by a thin sutural ligament.
 - **Plane suture** — smooth flat surfaces, e.g. median palatine suture.
 - **Serrate (limbus) suture** — reciprocally serrated, interlocking like a jigsaw, e.g. sagittal suture.
 - **Denticulate suture** — teeth-like projections interlock like a saw, e.g. lambdoid suture.
 - **Squamous suture** — flat, overlapping surfaces, e.g. temporo-parietal suture.
 - **Schindylesis (wedge-and-groove)** — a ridge of one bone fits into a groove of another, e.g. rostrum of sphenoid into the cleft of the vomer's alae.
 - Most sutures **synostose** (ossify) with age; hence a child's skull is resilient, an adult's brittle.
- ▶ **Syndesmoses** — bones linked by a greater amount of connective tissue (interosseous ligament/membrane) than in sutures, permitting slight movement, e.g. interosseous radio-ulnar and tibiofibular joints, inferior tibiofibular joint, ligamenta flava between vertebral laminae, tympanostapedial joint.
- ▶ **Gomphoses** (peg-and-socket) — fixation of a tooth in its alveolar socket by the periodontal ligament; strictly not a bone-to-bone joint. Clinically important — periodontitis loosens the tooth.

Cartilaginous joints

Bones are united by hyaline cartilage or fibrocartilage; **no joint cavity**. Two subtypes:

Feature	Primary cartilaginous joint (synchondrosis)	Secondary cartilaginous joint (symphysis)
Connecting tissue	Plate of hyaline cartilage	Bones capped by thin hyaline cartilage, united by a disc/pad of fibrocartilage
Mobility	Immovable	Slightly movable
Duration	Temporary — undergoes synostosis when growth ceases (except the 1st costosternal joint , which is permanent)	Permanent — persists throughout life
Location	Rarely in the midline	Typically in the midline
Examples	Epiphysis–diaphysis junction (growth plate); spheno-occipital joint; 1st costosternal joint	Pubic symphysis; intervertebral discs; manubriosternal joint; symphysis menti (a misnomer — present only in the fetal mandible)

- ▶ The **epiphyseal growth plate** is of great applied importance: it permits longitudinal bone growth, appears radiolucent on X-ray, and its injury in a child (growth-plate fracture) can cause limb shortening or deformity.

- All symphyses belong to the **axial skeleton** except the **pubic symphysis**, which belongs to the appendicular skeleton.

Synovial joints — structure and components

Synovial joints are the most common, most freely movable (**diarthrodial**) and clinically most important joints. A typical synovial joint has a **joint (articular) cavity** enclosed by an **articular capsule**, filled with **synovial fluid** (a viscous dialysate of plasma plus hyaluronic acid, resembling egg-white — hence the name).

□ Fig 5.3 — Synovial joint (IB Singh — *Textbook of Anatomy Vol 1* — 6e, p.56)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled diagram of a typical synovial joint showing:

- ▶ **Articular (hyaline) cartilage** capping the bone ends
- ▶ **Fibrous capsule** — outer sleeve of the articular capsule
- ▶ **Synovial membrane** — lining the capsule internally, reflected up to (but not covering) the articular cartilage
- ▶ **Joint (synovial) cavity** filled with **synovial fluid**
- ▶ An **intracapsular (true) ligament**, e.g. collateral ligament
- ▶ An **articular disc/meniscus**, if present
- ▶ A **fat pad** between synovial membrane and fibrous capsule/bone
- ▶ A nearby **bursa**

Components and their functional significance:

Component	Structure	Function
Fibrous capsule	Longitudinal/interlacing collagen bundles investing the joint like a sleeve	Stabilizes joint, permits movement, resists dislocation; rich sensory endings give reflex ("watch-dog") protection
True (intrinsic) ligaments	Local thickenings of the capsule, e.g. collateral ligaments of knee	Permit movement in one plane, prevent unwanted movement
Accessory ligaments	Separate from the capsule — extracapsular (e.g. stylomandibular) or intracapsular (e.g. cruciate ligaments of knee)	Reinforce joint, limit range of movement
Synovial membrane	Vascular connective tissue lining the capsule internally, absent over articular cartilage	Secretes synovial fluid for lubrication and cartilage nutrition
Articular cartilage	Hyaline cartilage (fibrocartilage at temporomandibular, sternoclavicular, acromioclavicular joints — "atypical" synovial joints)	Smooth, friction-free movement; resists compression; avascular
Articular disc/meniscus	Fibrocartilage pad, e.g. temporomandibular, sternoclavicular, acromioclavicular, radio-ulnar and knee joints	Improves congruity, may divide the cavity, cushions and modifies movement
Bursae	Synovial-fluid-filled sacs between tendon–bone, muscle–bone, skin–bone	Reduce friction
Fat pads (haversian pads)	Fat between synovial membrane and capsule/bone, e.g. infrapatellar fat pad	Cushion, accommodate to changing joint contours

Classification of synovial joints

A. According to the shape of the articular surfaces — commonly asked; a synovial joint's shape determines its movements:

Type	Shape	Movement	Examples
Plane (gliding)	Flat/near-flat surfaces	Gliding, slight rotation	Intercarpal, intertarsal, zygapophyseal joints
Hinge (ginglymus)	Pulley-shaped	Uniaxial — flexion/extension	Elbow (humero-ulnar), knee, ankle, interphalangeal joints — commonest type of joint in the body
Pivot (trochoid)	Rounded bone within a ligamentous ring	Uniaxial — rotation	Superior radio-ulnar joint; median atlanto-axial joint
Condylar	Round condyle in a socket	Biaxial	Knee, temporomandibular joints
Ellipsoidal	Elliptical convex-in-concave	Biaxial (+circumduction)	Radiocarpal (wrist), atlanto-occipital, metacarpophalangeal, metatarsophalangeal joints
Saddle (sellar)	Reciprocally concavo-convex	Biaxial, wide range	1st carpometacarpal, sternoclavicular, calcaneocuboid, incudomalleolar (smallest) joints
Ball and socket (spheroidal)	Convex head in a cup	Multiaxial — greatest range	Hip (largest), shoulder, incudostapedial (smallest) joints

B. According to axes/planes of movement: uniaxial (hinge, pivot) — biaxial (condylar, ellipsoid, saddle) — multiaxial/polyaxial (ball and socket).

C. According to number of articulating bones: simple (2 bones, e.g. interphalangeal) — compound (>2 bones, e.g. elbow — humerus/radius/ulna; ankle — tibia/fibula/talus; wrist — radius/scaphoid/lunate/triquetral) — complex (cavity divided by a disc/meniscus, e.g. knee, temporomandibular, sternoclavicular).

Movements at synovial joints

- **Gliding** — one flat surface slips over another (plane joints; e.g. intercarpal joints).
- **Angular** — flexion (↓ joint angle), extension (↑ joint angle, reverse of flexion), abduction (away from midline), adduction (towards midline); dorsiflexion/plantarflexion at the ankle are exceptions to the usual flexion/extension terminology.
- **Rotation** — around a longitudinal axis; supination/pronation of the forearm are special forms of rotation.

- ▶ **Circumduction** — sequential flexion–abduction–extension–adduction describing a cone (shoulder, hip).
- ▶ **Special movements** — inversion/eversion (subtalar, talocalcaneonavicular, midtarsal joints), protraction/retraction, elevation/depression.
- ▶ **Passive/accessory movements** — produced by an external force (examiner, gravity); accessory (small gliding/rotation) movements cannot be produced actively by the patient — clinically useful in assessing joint disorders.

Nerve supply, stability and biomechanics

- ▶ **Hilton's law**: the nerve supplying a joint also supplies the muscles moving that joint and the skin overlying it — explains referred pain and reflex muscle spasm protecting an injured joint.
- ▶ **Capsule** — Ruffini corpuscles (proprioception) + free nerve endings (pain); **ligaments** — pain-sensitive free endings; **synovial membrane** — vasomotor autonomic + pain fibres; **articular cartilage is aneural (and avascular)**.
- ▶ **Last's formulation**: four consecutive spinal segments regulate each limb joint's movements — upper two segments produce one movement, lower two the opposite; the next joint distally is supplied one segment lower in the cord (e.g. hip flexion L2,3 / extension L4,5; knee extension L3,4 / flexion L5,S1).
- ▶ **Stability** is maintained by (1) **bone shape** (e.g. deep acetabulum, tibiofibular mortice), (2) **ligaments** (intra-/extracapsular — cruciates for antero-posterior, collaterals for side-to-side stability at the knee), and (3) **muscle tone**, the single most important stabilising factor — weak/paralysed muscles predispose to dislocation.
- ▶ **Close-packed position** (maximum congruence, all ligaments taut, most stable, e.g. knee/elbow fully extended, hip extended + medially rotated, shoulder abducted + laterally rotated) vs **loose-packed position** (incongruent, joint space mobile, prone to dislocation, e.g. semiflexed knee/hip).
- ▶ **Levers**: the joint is the fulcrum, bone the lever arm, muscle the effort. **1st class** (fulcrum between effort and resistance) — atlanto-occipital joint balancing the head. **2nd class** (resistance between fulcrum and effort) — standing on toes at the metatarsophalangeal joints. **3rd class** (effort between fulcrum and resistance, the **commonest type in the body**) — elbow flexion by biceps brachii.

Applied / Clinical anatomy

- ▶ **Osteoarthritis** — degenerative/inflammatory disease of **articular cartilage**; affects weight-bearing joints (**hip, knee** commonest); cartilage attrition, bone-on-bone contact, osteophyte formation at the cartilage–synovium–periosteum junction; commonest joint disease overall.
- ▶ **Rheumatoid arthritis** — chronic autoimmune inflammation of the **synovial membrane**; synovial hypertrophy/hyperplasia, fibrinous effusion, cartilage erosion, joint deformity; affects small joints of hands and feet.
- ▶ **Dislocation** — loss of contact between articulating bones from failure of ligamentous/muscular/bony support; commonest dislocated joint overall is the **shoulder** (pulled elbow in children); hip is the joint most often congenitally dislocated.

- ▶ **Arthroplasty** — surgical repair/replacement of a diseased joint, now using artificial ligaments (carbon-fibre/polylactic-acid-coated).
- ▶ **Sprains** — tear of a ligament (e.g. anterior talofibular ligament, the commonest sprained ligament, at the commonly-sprained ankle joint).
- ▶ **Radiology** — growth plates appear radiolucent (primary cartilaginous joints); joint-space narrowing on X-ray is a hallmark of osteoarthritis.
- ▶ **Surgical/anaesthetic relevance** — knowledge of close-packed positions guides joint reduction and immobilisation; Hilton's law explains why hip disease can present as referred knee pain (obturator nerve territory).

High-yield exam pointers

- ▶ Three structural types: **fibrous (no cavity)** → sutures/syndesmoses/gomphoses; **cartilaginous (no cavity)** → synchondrosis/symphysis; **synovial (has cavity)**.
- ▶ Functional triad: **synarthrosis (immovable)** — **amphiarthrosis (slightly movable)** — **diarthrosis (freely movable)**.
- ▶ Synovial joint shapes (7): plane, hinge, pivot, condylar, ellipsoidal, saddle, ball-and-socket — hinge is commonest, ball-and-socket gives greatest range.
- ▶ Simple (2 bones) vs compound (>2 bones) vs complex (disc-divided cavity, e.g. knee).
- ▶ Articular cartilage is **hyaline** everywhere except TMJ, sternoclavicular, acromioclavicular joints (fibrocartilage — "atypical" synovial joints).
- ▶ **Hilton's law** — nerve to a joint also supplies the muscles moving it and overlying skin.
- ▶ Muscle tone is the **most important factor** for joint stability; close-packed = most stable, loose-packed = most prone to dislocation.
- ▶ OA affects **cartilage** of weight-bearing joints; RA affects **synovium** of small joints of hands/feet.
- ▶ All symphyses are axial except **pubic symphysis**; all primary cartilaginous joints are temporary except the **1st costosternal joint**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy, 4e; IB Singh — Textbook of Anatomy Vol 1, 6e; Moore's Clinically Oriented Anatomy, 9e.



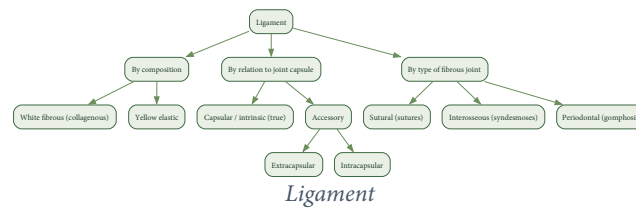
Ligament

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction — A ligament is a band or sheet of dense regular (fibrous) connective tissue that connects one bone to another bone, contributing to the stability of a joint while permitting a defined range of movement. Ligaments are derived embryologically and histologically from the same connective-tissue lineage as tendons, but unlike a tendon (which joins muscle to bone and transmits contractile force), a ligament joins bone to bone and resists excessive separation of the articulating bones. Ligaments form an integral structural component of every fibrous, cartilaginous and synovial joint and are therefore central to any description of joint anatomy.

1. Classification of ligaments

Basis of classification	Types	Examples
Composition (fibre content)	White fibrous (collagenous) ligaments — composed predominantly of type I collagen; majority of ligaments belong to this type	Collateral and cruciate ligaments of the knee, iliofemoral ligament
	Yellow elastic ligaments — contain a high proportion of elastic fibres in addition to collagen, permitting marked reversible stretch	Ligamenta flava (between vertebral laminae), ligamentum nuchae
Relation to the fibrous joint capsule (synovial joints)	Capsular (intrinsic/true) ligaments — local thickenings of the fibrous capsule itself; not separable from it	Tibial and fibular collateral ligaments of the knee
	Accessory ligaments — extracapsular — lie outside the fibrous capsule	Stylomandibular and sphenomandibular ligaments of the TMJ
	Accessory ligaments — intracapsular — lie within the capsule but outside the synovial cavity	Anterior and posterior cruciate ligaments of the knee
Type of fibrous joint they form	Sutural ligaments (sutures)	Skull sutures
	Interosseous ligaments/membranes (syndesmoses)	Interosseous membrane of forearm/leg, inferior tibiofibular ligament
	Periodontal ligament (gomphosis)	Tooth root within its alveolar socket



2. Gross structure and composition

- ▶ Ligaments of joints are derived from **dense regular connective tissue**, composed mainly of parallel/multidirectionally-oriented bundles of large, crimped **type I collagen fibres** with rows of elongated fibroblast nuclei between the bundles.
- ▶ The key structural difference from a tendon: collagen fibres of a **tendon** align strictly along the axis of muscle pull, whereas fibres of a **ligament** run in a range of directions because the ligament must resist separation of the two bones in more than one plane.
- ▶ Where the fibre content is predominantly elastic rather than collagenous, the ligament is termed an **elastic (yellow) ligament** — e.g. the **ligamentum flavum**, which can stretch by more than 80% during spinal flexion yet remains under constant tension so that it never buckles inward on the adjacent spinal cord; the **ligamentum nuchae** is a similar elastic ligament in the neck.
- ▶ Ligaments attach to bone by fibrocartilaginous or fibrous **entheses**; collagen fibres are anchored into the bone matrix as **Sharpey's fibres**, continuous with the periosteal collagen.
- ▶ Fibrous capsules of synovial joints, in contrast, are derived from **dense irregular** connective tissue.

3. Development

- ▶ In the mesenchymal (membranous) stage of the developing skeleton, the primordium of the future joint is continuous. As chondrification or ossification centres appear on either side of the future joint, the intervening residual mesenchyme condenses to form the ligaments of the joint.
- ▶ Cells in this residual zone elongate, multiply rapidly, align parallel to one another, and lay down large numbers of **collagenous fibres** (and, at a few sites such as between the vertebral laminae, predominantly **elastic fibres** — the ligamenta flava).

4. Blood supply and nerve supply

Structure	Supply
Articular cartilage	Avascular
Fibrous capsule and ligaments	Poor blood supply, from the peri-articular arterial network (circulus articularis vasculosus) around the joint
Synovial membrane	Rich vascular supply; also nourishes the periphery of the articular cartilage
Ligaments (nerve supply)	Pain-sensitive free nerve endings only

Structure	Supply
Fibrous capsule (nerve supply)	Encapsulated Ruffini corpuscles (proprioception — postural reflex, joint position sense) + free nerve endings (pain); myelinated articular nerve fibres also supply lamellated (Pacinian-type) corpuscles, which detect rapid movement/vibration, and endings resembling Golgi tendon organs , which mediate position sense
Articular cartilage / discs	No nerve supply (articular discs insensitive except at their attached margins)

- ▶ **Hilton's law:** the nerve that supplies a joint also supplies the muscles that move that joint and the skin overlying it.
- ▶ Because ligaments and capsule are poorly vascularised, ligament injuries heal slowly.

5. Functions

- ▶ **True (capsular) ligaments** permit movement in one plane while preventing unwanted movement in other planes, and thereby stabilise the joint.
- ▶ **Accessory ligaments** provide additional reinforcement to the joint capsule and further limit the range of movement (e.g. the cruciate ligaments prevent excessive antero-posterior glide of the tibia on the femur; the collateral ligaments resist side-to-side displacement).
- ▶ Ligaments are stiff in tension yet pliant in bending; they can rebound elastically from a stretch of up to 10–15% and are protected from over-stretch by reflex contraction of the muscles around the joint (a proprioceptive protective reflex mediated through the mechanoreceptors described above).
- ▶ Because most ligaments are essentially inextensible bundles of collagen, once markedly overstretched they tend to remain permanently elongated and do not restore the original joint stability — this is why a ligament, unlike a muscle, cannot compensate for continuous mechanical strain.

Vishram Singh — Textbook of Anatomy Vol 2 (4e), Fig 33.6, is a genuine dissection plate that illustrates true (capsular) collateral ligaments of a major synovial joint and their bony attachments:

□ Fig 33.6 — Attachments and relations of collateral ligaments of the knee joint (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.1259)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled schematic of a synovial joint (e.g. knee) showing the classification of ligaments discussed above. Labels to include:

- ▶ Articulating bone ends with articular cartilage
- ▶ Fibrous capsule
- ▶ **Capsular (true/intrinsic) ligament** — thickened part of the capsule, e.g. tibial collateral ligament
- ▶ **Extracapsular accessory ligament**, e.g. fibular collateral ligament
- ▶ **Intracapsular accessory ligaments** — anterior and posterior cruciate ligaments, lying within the capsule but outside the synovial cavity
- ▶ Synovial membrane lining the capsule
- ▶ Synovial cavity containing synovial fluid

6. Repair of an injured ligament

- ▶ The microstructure and biology of ligaments closely resembles that of tendons. Repair begins with an initial proliferation of fibroblasts, followed by interstitial deposition of new collagen fibres.
- ▶ As in tendon healing, complete remodelling/replacement of the tissue (as occurs in bone) does not take place; a healed ligament therefore does not fully regain its original tensile strength, which is why re-injury and residual joint laxity are common after a significant ligament tear.

Applied / Clinical anatomy

- ▶ **Sprain**: a tear (partial or complete) of a ligament, presenting clinically with pain, swelling and restricted joint movement; it must be distinguished from a strain, which is injury to a muscle-tendon unit. **The ankle is the most commonly sprained joint in the body, and the anterior talofibular ligament is the most commonly sprained ligament.**
- ▶ **Strongest ligament in the body**: the **iliofemoral ligament (Bigelow's ligament/Y-ligament of Bigelow)** of the hip joint, which checks hyperextension and helps maintain the erect posture.
- ▶ **Cruciate ligament injury**: rupture of the anterior or posterior cruciate ligament of the knee (classically from a twisting or hyperextension sports injury) produces anteroposterior instability of the knee, tested clinically by the anterior/posterior drawer and Lachman tests.
- ▶ **Periodontitis**: inflammation and degeneration of the periodontal ligament (the fibrous ligament of the gomphosis joint anchoring a tooth in its alveolar socket) leads to loosening and eventual loss of the tooth — a clinically important example of a ligament outside the limb skeleton.
- ▶ **Ligamentum flavum**: because of its very high elastin content it remains under tension in every posture of the spine and never buckles into the vertebral canal; degenerative thickening of the ligamenta flava is a recognised cause of lumbar canal stenosis.
- ▶ **Reconstructive surgery**: in ligament reconstruction and arthroplasty, artificial ligaments made of carbon fibres coated with a bio-absorbable polymer (polylactic acid) have been used as substitutes for irreparably torn ligaments.

- ▶ Because ligaments (and the fibrous capsule) are poorly vascularised while the synovial membrane is richly vascular, most nutrition to a healing ligament comes indirectly via the synovial and peri-articular circulation, explaining the characteristically slow and incomplete healing of ligament injuries.

High-yield exam pointers

- ▶ Ligament = bone-to-bone; tendon = muscle-to-bone — both are dense regular connective tissue rich in type I collagen, but ligament fibres run in multiple directions while tendon fibres are unidirectional.
- ▶ Two classifications to always state: (1) composition — white fibrous (collagenous) vs yellow elastic; (2) relation to joint capsule — capsular/true (intrinsic) vs accessory (extra-/intracapsular).
- ▶ Elastic ligaments (high elastin): ligamenta flava and ligamentum nuchae.
- ▶ Ligaments/capsule are poorly vascularised; synovial membrane is richly vascular.
- ▶ Ligaments carry only pain-sensitive free nerve endings; the fibrous capsule additionally carries proprioceptive Ruffini/lamellated-corporuscle-type endings — recall Hilton's law.
- ▶ Sprain = tear of a ligament (pain, swelling, loss of movement); ankle joint/anterior talofibular ligament = most commonly sprained joint/ligament.
- ▶ Iliofemoral (Bigelow's) ligament = strongest ligament in the body.
- ▶ Once a ligament is overstretched it does not regain its original length/strength — repair is by fibroblast proliferation and collagen deposition, without complete remodelling.
- ▶ Ligaments develop from condensed mesenchyme persisting between the chondrification/ossification centres of the embryonic skeleton.

SOURCE & COVERAGE

Vishram Singh — General Anatomy (4e); Vishram Singh — Textbook of Anatomy Vol 2 (4e); Gray's Anatomy (Standing) 41e; Hamilton, Boyd & Mossman — Human Embryology; Ross Histology — A Text and Atlas (7e); Junqueira's Basic Histology (17e); Sontakke — Textbook of Human Histology (2e); Moore — Clinically Oriented Anatomy (9e); BD Chaurasia — Human Anatomy Vol 1 (8e).



Methods of case study

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction

A **case study** (case report/case series) is a **descriptive, observational research method** that provides a detailed, systematic account of a single subject — a cadaver, patient, radiograph, or museum specimen (**case report**) — or a small consecutive group of similar subjects (**case series**), collected **without a comparison or control group**. In anatomical sciences it is the traditional, and still the commonest, route by which a **rare morphological variation, congenital anomaly, or unusual topographical relation**

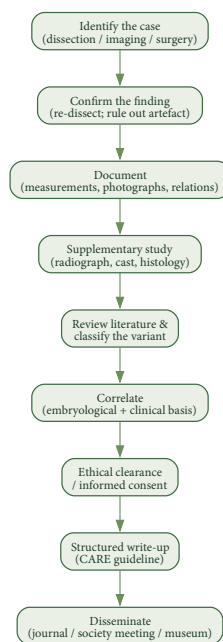
discovered during routine cadaveric dissection, radiological imaging, or surgery is identified, verified, measured, correlated with its embryological basis and clinical significance, and communicated to the scientific community. It occupies the entry, **hypothesis-generating** rung of the observational-study ladder and is the commonest format of MD/MS Anatomy dissertations and departmental publications in India.

1. Types of case study

- ▶ **Case report** — an in-depth description of a single case, e.g. "an accessory head of biceps brachii in a single cadaver."
- ▶ **Case series** — a consecutive collection of similar cases, without a control group, e.g. "variant origin of the renal artery noted in 15 cadavers dissected over three academic sessions."
- ▶ **Illustrative/teaching case study** — a well-documented variant used to demonstrate a principle to undergraduates or postgraduates.
- ▶ **Analytic (comparative) case study** — the finding is contrasted with the standard pattern in a reference text, with the contralateral side, or with previously reported cases, though still short of a formal case-control design.

2. Steps in conducting a case study

The workup follows a fixed, linear sequence from discovery to dissemination:



Methods of case study

- ▶ **Identification** — a deviation from standard descriptive anatomy is noticed during routine cadaveric dissection, radiography/CT/MR imaging, or an operative procedure.
- ▶ **Confirmation** — the finding is re-examined and, where possible, checked on the opposite side and in other cadavers of the same batch to exclude a dissection artefact, embalming damage, or a post-mortem change.

- ▶ **Documentation** — precise **measurements** (length, diameter, distance from fixed bony landmarks) are taken with calibrated instruments (vernier callipers, measuring tape/thread), and **gross photographs** are taken in situ and after careful clean dissection.
- ▶ **Supplementary investigation** — plain radiography, CT/MR angiography, corrosion casting, or histological confirmation is added where it strengthens the description.
- ▶ **Literature review** — a structured search for previously reported cases of the same variant, its reported incidence, and any existing **classification** scheme, so the present case can be placed in context.
- ▶ **Correlation** — the variant is explained on the basis of the aberrant **developmental** (embryological) **sequence** and its **clinical/surgical/radiological/forensic** relevance is discussed.
- ▶ **Ethical clearance and consent** — Institutional Ethics Committee clearance and, for a living patient or identifiable imaging, informed consent; for a cadaver, adherence to the Anatomy Act 1949 and the institutional body-donation consent already on record.
- ▶ **Structured reporting and dissemination** — write-up as a case report/series (see reporting standard below) followed by presentation at an anatomical/scientific society meeting, publication in an indexed journal, or cataloguing as a permanent museum specimen with an explanatory card.

3. Data-collection techniques used within a case study

Technique	Application in an anatomical case study
Observation	Direct gross observation of the variant during dissection or surgery
Measurement	Morphometric/anthropometric measurement referenced to fixed bony landmarks
History/interview	Taken when the case originates from a living patient (age, symptoms, relevant past history)
Documentary/record review	Hospital, radiology, or departmental dissection-register records
Photographic & imaging methods	Gross photography, plain radiograph, CT/MR angiography, 3-D reconstruction, corrosion cast
Comparative method	Comparison with the contralateral side, other cadavers of the batch, and the published literature
Genealogical/pedigree method	Used when the anomaly is suspected to be heritable

4. Documentation and reporting standard

- ▶ The internationally accepted format is the **CARE (CAse REport) guideline** (Gagnier et al., 2013), which specifies: title, keywords, introduction, patient/specimen information, clinical/anatomical findings, timeline, diagnostic assessment, therapeutic/surgical intervention (if any), discussion (comparison with existing literature, strengths and limitations), and patient perspective/informed-consent statement.

- For a **cadaveric** anatomical case, the write-up additionally records age, sex, side, probable cause of death, and the embalming method used, since these can affect tissue quality and the interpretation of the finding.

5. Uses of the case-study method in anatomy

- Records **rare anatomical variations** of surgical, radiological, obstetric, and forensic importance that a routine cross-sectional survey of a single department is too small to capture reliably.
- **Hypothesis-generating** — repeated case reports of the same variant from different centres may prompt a formal, adequately powered cross-sectional or cadaveric survey of its true incidence.
- Enriches **regional variation databases** and permanent **museum teaching collections**.
- High **educational value** — a single, well-documented and photographed case teaches embryological correlation and clinical relevance more vividly than a textbook description alone.
- **Low-cost and logistically simple** — requires no comparison group or external funding, making it the most feasible research design for a single anatomy department, and hence the standard format for a postgraduate dissertation/thesis.
- Historically, many now-standard "named" variants (e.g. persistent median artery, accessory soleus, an anomalous course of the recurrent laryngeal nerve) entered the surgical-anatomy literature first as isolated case reports.

6. Limitations

- **No control/comparison group** — cannot estimate the true incidence or prevalence of the variant, nor test a statistical association.
- **Selection and publication bias** — only unusual, striking, or clinically dramatic cases tend to get reported; minor or "boring" variants are under-reported.
- **Lowest position in the conventional hierarchy of evidence** among analytic designs — purely descriptive, so findings cannot be generalised to the population at large.
- **Risk of misclassification** without a large comparative series to validate the proposed type/grade of the variant.
- Recall/history bias when the case is patient-derived rather than a direct cadaveric finding.
- Cannot, by itself, prove the proposed embryological mechanism — this needs corroboration from developmental/comparative anatomical studies.

Applied / Clinical anatomy

- **Vascular variants** — an aberrant/accessory renal artery, a persistent sciatic artery, or a high division of the brachial artery with a persistent median artery are all first documented and still routinely reported through the case-study method, and are directly relevant to vascular and transplant surgery.
- **Neural variants** — an anomalous, non-recurrent course of the recurrent laryngeal nerve or a communicating branch between the median and ulnar nerves in the forearm (Martin–Gruber anastomosis) carries direct operative significance for thyroid and hand surgery respectively, and both entered the literature as case reports/series.

- ▶ **Muscular variants** — accessory muscles such as accessory soleus or palmaris profundus are frequently incidental MRI findings written up as case reports, important for correct radiological interpretation.
- ▶ Most **peer-reviewed anatomical journals** relevant to Indian postgraduates (e.g. the *Journal of the Anatomical Society of India*, *International Journal of Anatomical Variations*) now require submissions to follow the CARE checklist.
- ▶ A well-worked-up cadaveric case, once catalogued, becomes a **permanent museum teaching specimen** for undergraduate osteology and dissection-hall demonstrations.

High-yield exam pointers

- ▶ Case study = **case report** (single) or **case series** (multiple, no control) — descriptive, observational, hypothesis-generating.
- ▶ Sequence to remember: **identify** → **confirm** → **document** (measure + **photograph**) → **supplement** (imaging/histology) → **review literature/classify** → **correlate** (embryology + clinical) → **consent/ethics** → **write-up** (CARE) → **disseminate**.
- ▶ **CARE guideline (2013)** is the standard reporting checklist for case reports, analogous to STROBE for observational studies and CONSORT for trials.
- ▶ Chief strength: cheap, feasible with a single department's resources, ideal format for a PG dissertation; chief weakness: **no control group**, so incidence/causation cannot be established.
- ▶ Sits at the **base of the evidence hierarchy**, above only expert opinion.
- ▶ In anatomy it is the classical route by which named vascular, neural, and muscular variants (persistent median artery, Martin–Gruber anastomosis, accessory soleus, non-recurrent laryngeal nerve) first entered the surgical-anatomy literature.
- ▶ For cadaveric material, adherence to the **Anatomy Act 1949** and existing body-donation consent stands in for fresh patient consent; a living-patient case still needs explicit informed consent.

SOURCE & COVERAGE

This topic is **research-methodology content**, not gross/regional descriptive anatomy, so the RGUHS Anatomy textbook corpus (Gray's Anatomy, BD Chaurasia, AK Datta, Vishram Singh's *General Anatomy*, etc.) does not carry a dedicated treatment of the case-study research method — a targeted search of the corpus (including Vishram Singh's *General Anatomy* 4e, the specialty text assigned to this topic) returned only end-of-chapter clinical vignettes labelled "Case Study," not the methodology itself. The design description, steps, and reporting standard above are drawn from the standard research-methodology literature used across Indian PG medical curricula — **Park's Textbook of Preventive and Social Medicine** (K. Park) and **Mahajan's Methods in Biostatistics for Medical Students and Research Workers** for the case-report/case-series design and its place in the evidence hierarchy, and the **CARE (CAse REport) guideline** (Gagnier JJ et al., *J Med Case Rep* 2013;7:223) for the reporting checklist — consistent with the "Research methodology and biostatistics" component of the NMC competency-based PG Anatomy curriculum under Paper I (basic sciences of anatomy).

Coverage note: the anatomical examples cited under Applied/Clinical anatomy (persistent median artery, Martin–Gruber anastomosis, accessory soleus, non-recurrent laryngeal nerve) are well-established, universally-taught surgical-anatomy variants used here only to illustrate the case-study method in an anatomical setting; they are not independently re-verified against the corpus in this answer, since the question itself is a methodology question and not a request for their descriptive anatomy.



Retinacula

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction Retinacula are localized, band-shaped thickenings of the deep fascia that bridge over a group of tendons crossing a joint, converting an osteofascial groove into an osteofascial tunnel. Their principal function is to retain the underlying tendons in position and prevent their **bowstringing** during muscle contraction and joint movement; several also act as accessory ligaments stabilising the joint they cross. Retinacula are best described at the **wrist** (flexor and extensor retinacula) and at the **ankle** (superior and inferior extensor retinacula, superior and inferior peroneal/fibular retinacula, and the flexor retinaculum) — a total of two at the wrist and five around the ankle.

Classification — sites and named retinacula

Region	Aspect	Retinaculum
Wrist	Front (flexor aspect)	Flexor retinaculum
Wrist	Back (extensor aspect)	Extensor retinaculum
Ankle	Front	Superior extensor retinaculum, Inferior extensor retinaculum

Region	Aspect	Retinaculum
Ankle	Lateral side	Superior fibular (peroneal) retinaculum, Inferior fibular (peroneal) retinaculum
Ankle	Posteromedial side	Flexor retinaculum

1. Extensor retinaculum of the wrist

The extensor retinaculum is a strong fibrous band, about 2 cm broad, that runs obliquely downwards and medially across the back of the wrist.

- **Attachments** — Laterally: lower part of the sharp anterior border of the radius. Medially: (i) styloid process of the ulna, (ii) triquetral bone, (iii) pisiform bone.
- It sends deep septa to the longitudinal ridges on the posterior surface of the lower end of the radius, partitioning the space deep to it into **six osteofascial compartments**, each lined by its own synovial sheath.

Compartment	Tendon(s)/structures transmitted
I	Abductor pollicis longus, Extensor pollicis brevis
II	Extensor carpi radialis longus, Extensor carpi radialis brevis
III	Extensor pollicis longus
IV	Extensor digitorum, Extensor indicis, posterior interosseous nerve, anterior interosseous artery
V	Extensor digiti minimi
VI	Extensor carpi ulnaris

□ Fig 9.22 — Extensor retinaculum of wrist. (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.429)

2. Flexor retinaculum of the wrist

The flexor retinaculum is a strong fibrous band, about 2.5–3 cm both transversely and proximodistally, bridging the anterior concavity of the carpus and converting it into the **carpal tunnel**.

- **Attachments** — Medially: pisiform and hook of hamate. Laterally: tubercle of the scaphoid and crest of the trapezium.
- Laterally it splits into two laminae: the deep lamina attaches to the medial lip of the trapezial groove (forming a separate synovial tunnel for **flexor carpi radialis**); the superficial lamina attaches to the scaphoid tubercle.
- A slender medial superficial slip (the **volar carpal ligament**) bridges the ulnar neurovascular bundle to the pisiform, forming **Guyon's canal** — a fibro-osseous canal about 4 cm long, transmitting the ulnar nerve and artery (occasional site of ulnar nerve entrapment).
- Functionally the flexor retinaculum also acts as an accessory intercarpal ligament, and the thenar and hypothenar muscles take origin from it.

Structures superficial to the flexor retinaculum: palmaris longus tendon, palmar cutaneous branches of median and ulnar nerves, ulnar vessels, ulnar nerve.

Structures deep to the flexor retinaculum (contents of the carpal tunnel):

- ▶ Median nerve
- ▶ Four tendons of flexor digitorum superficialis
- ▶ Four tendons of flexor digitorum profundus (both enclosed in the common/ulnar bursa)
- ▶ Tendon of flexor pollicis longus (in the radial bursa)

(The tendon of flexor carpi radialis lies separately, between the retinaculum and its deep lamina, in the groove on the trapezium.)

□ Fig 11.8 — Flexor retinaculum (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.207)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Transverse section across the wrist at the level of the carpal tunnel — label: pisiform, hook of hamate, tubercle of scaphoid, crest of trapezium; flexor retinaculum (with its deep lamina); carpal tunnel contents — median nerve, 4 tendons of FDS, 4 tendons of FDP (ulnar bursa), tendon of FPL (radial bursa); tendon of flexor carpi radialis in its own tunnel; superficial to the retinaculum — palmaris longus tendon, ulnar nerve and vessels (Guyon's canal), palmar cutaneous branches of median and ulnar nerves.

3. Retinacula of the ankle

Superior extensor retinaculum — a band binding down tibialis anterior, extensor hallucis longus, extensor digitorum longus and fibularis (peroneus) tertius just proximal to the ankle joint. Attached laterally to the distal end of the anterior border of the fibula and medially to the anterior border of the tibia. The anterior tibial vessels and deep fibular nerve pass deep to it; the superficial fibular nerve passes superficial to it.

Inferior extensor retinaculum (also called the **cruciate crural ligament**) — a Y-shaped band anterior to the ankle joint. The stem of the Y is attached laterally to the upper surface of the calcaneus; medially it splits into a proximal limb (two laminae enclosing tibialis anterior and extensor hallucis longus tendons) and a distal limb continuing to the medial malleolar region and plantar fascia.

□ Fig 14.10 — Superior and inferior extensor retinacula of the ankle, surface view (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.230)

Superior fibular (peroneal) retinaculum — a short band from the back of the lateral malleolus to the deep fascia of the leg and the lateral surface of the calcaneus; binds the common synovial sheath of fibularis longus and brevis. Damage causes instability/subluxation of these tendons.

Inferior fibular (peroneal) retinaculum — continuous anteriorly with the inferior extensor retinaculum; attached posteriorly to the lateral surface of the calcaneus, blending with the periosteum over the fibular (peroneal) trochlea, which it uses to separate the sheaths of fibularis longus and brevis distally.

Flexor retinaculum of the ankle — attached anteriorly to the posterior border and tip of the medial malleolus, and posteriorly/laterally to the medial tubercle of the calcaneus. Septa from its deep surface

convert the space deep to it into **four osteofascial compartments** that together form the **tarsal tunnel**, transmitting, from medial to lateral (mnemonic **Tom, Dick, And Harry**):

Order (medial→lateral)	Structure
1	Tibialis posterior tendon
2	Flexor digitorum longus tendon
3	Posterior tibial vessels (Artery) and accompanying veins
4	Tibial Nerve
5	Flexor Hallucis longus tendon

Each tendon lies in its own synovial sheath; the neurovascular bundle shares one compartment. Near the calcaneus the retinaculum is pierced by the medial calcaneal vessels and nerve, and its deep surface gives origin to most of abductor hallucis.

Applied / Clinical anatomy

- **Carpal tunnel syndrome (CTS)** — the commonest entrapment neuropathy; compression of the median nerve within the unyielding carpal tunnel (idiopathic, pregnancy, hypothyroidism, rheumatoid arthritis, acromegaly, repetitive strain). Features: nocturnal pain/paraesthesiae over the lateral 3½ digits, thenar wasting ("ape hand"), positive **Phalen's test** and **Tinel's sign**; sensation over the thenar eminence is characteristically spared because the palmar cutaneous branch of the median nerve arises proximal to, and passes superficial to, the retinaculum.
- **Surgical carpal tunnel release** — the retinaculum is incised along the ulnar side of the tunnel (in line with the ring finger axis) to avoid the recurrent motor branch of the median nerve to the thenar muscles, which typically arises just distal to the retinaculum's distal border.
- **Guyon's canal (ulnar tunnel) syndrome** — compression of the ulnar nerve/artery in Guyon's canal from a ganglion, hook of hamate fracture, or repetitive pressure (e.g. cyclists) — causes hypothenar/interossei weakness with variable sensory loss depending on the level of compression.
- **De Quervain's tenosynovitis** — stenosing tenosynovitis of the first extensor compartment (abductor pollicis longus and extensor pollicis brevis) beneath the extensor retinaculum; pain over the radial styloid, positive **Finkelstein's test**.
- **Tarsal tunnel syndrome** — compression of the tibial nerve (or its medial/lateral plantar branches) deep to the flexor retinaculum of the ankle, from a space-occupying lesion (e.g. ganglion) or tenosynovitis; causes burning pain/paraesthesiae in the sole, with a positive Tinel's sign behind the medial malleolus. Much less common than CTS.
- **Peroneal (fibular) retinacular injury** — tearing of the superior fibular retinaculum (as in an inversion ankle sprain) predisposes to recurrent subluxation/dislocation of the peroneus longus and brevis tendons behind the lateral malleolus.
- **Surface marking** — the flexor retinaculum of the wrist is marked out by joining the pisiform, tubercle of the scaphoid, hook of the hamate and crest of the trapezium; this is the surgical landmark for carpal tunnel decompression.

High-yield exam pointers

- ▶ Retinacula = localized thickenings of deep fascia that prevent tendon bowstringing across a joint; wrist has 2 (flexor, extensor), ankle has 5 (superior/inferior extensor, superior/inferior fibular, flexor).
- ▶ Extensor retinaculum of wrist → **6 compartments** (I–VI); know the compartment table (esp. compartment I = APL + EPB → De Quervain's; compartment IV carries posterior interosseous nerve).
- ▶ Flexor retinaculum of wrist → forms **carpal tunnel**; contents = median nerve + 9 tendons (4 FDS + 4 FDP + 1 FPL); FCR tendon runs in its own separate tunnel.
- ▶ **Guyon's canal** is formed by the superficial slip (volar carpal ligament) of the flexor retinaculum; transmits ulnar nerve and artery.
- ▶ Inferior extensor retinaculum of the ankle is **Y-shaped** (cruciate crural ligament); superior extensor retinaculum binds tibialis anterior, EHL, EDL, peroneus tertius.
- ▶ Flexor retinaculum of ankle → **tarsal tunnel**, 4 compartments, 5 structures — mnemonic **Tom, Dick, ANd Harry** (Tibialis posterior, flexor Digitorum longus, posterior tibial Artery, tibial Nerve, flexor Hallucis longus).
- ▶ Clinical correlates to write in pairs: CTS (median n., wrist) ↔ tarsal tunnel syndrome (tibial n., ankle); De Quervain's (1st extensor compartment) ↔ peroneal tendon subluxation (fibular retinacula).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 & Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 1 & Vol 2, 4e.



Secondary osteon

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction A secondary osteon (mature **Haversian system**) is the structural and functional unit of adult compact (cortical) bone — a cylindrical package of **concentric lamellae** arranged around a central **Haversian canal**, oriented parallel to the long axis of the bone. It is called "secondary" because it is created by **remodelling** — an osteoclast-led resorption tunnel followed by osteoblastic infilling — rather than by the direct apposition that forms a primary osteon during initial ossification. Each secondary osteon is sharply demarcated from surrounding bone by a hypermineralized **cement (reversal) line**. Secondary osteons make up almost all of mature compact bone and are continuously created and replaced throughout life (roughly 10% of the adult skeleton is remodelled every year), making the topic central to bone physiology, forensic age estimation and metabolic bone disease.

1. Structure of the secondary osteon

Component	Description
Haversian (central) canal	Runs parallel to the long axis of the bone; mean diameter $\approx 50\ \mu\text{m}$ (larger nearer the marrow cavity); contains one or two capillaries (fenestrated endothelium, pericytes, basal lamina), unmyelinated and occasional myelinated axons, and loose connective tissue; lined by endosteum
Concentric lamellae	Usually 5–20 sheets of mineralized matrix wrapped around the canal; each lamella $\approx 3\text{--}7\ \mu\text{m}$ thick; collagen fibre orientation alternates between adjacent lamellae (differs by up to 90° , seen under polarised light), giving the osteon its resistance to crack propagation
Osteocytes	Lie in lacunae between successive lamellar rings; cell bodies are flattened/ellipsoid, connected to each other and to the canal by fine cytoplasmic processes
Canaliculi	Narrow ($0.25\text{--}0.5\ \mu\text{m}$) channels radiating from each lacuna, interconnecting osteocytes with each other and with the Haversian canal; provide the sole diffusion route for nutrients/waste since osteons (apart from their central canal) are otherwise avascular
Cement (reversal) line	Basophilic, collagen-poor, glycoprotein/proteoglycan-rich boundary marking the outer limit of the osteon — the point where osteoclastic erosion stopped and osteoblastic deposition began; canaliculi rarely cross it, so an osteon's osteocytes are functionally isolated from the interstitial bone outside

- **Dimensions:** osteon diameter 100–400 μm ; an adult skeleton contains an estimated ~21 million osteons.

- ▶ **Osteocyte-to-vessel distance:** the maximum osteon diameter ensures no osteocyte lies more than 200 μm from the central blood vessel — the diffusion limit that governs osteocyte survival.
- ▶ Osteons usually run parallel to each other and to the bone's long axis; they may spiral, branch or end blindly, and adjacent osteons often encroach on one another because they were laid down at different times during successive remodelling cycles.

□ Fig 6.7 — Haversian system in compact bone (schematic representation) (IB Singh — Textbook of Human Histology — 9e, p.183)

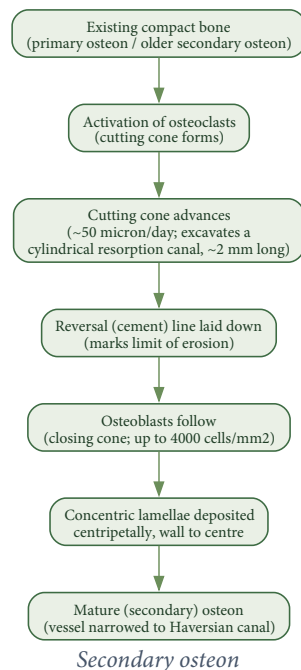
DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A transverse section through compact bone showing one complete secondary osteon and its neighbours, labelled with:

- ▶ **Haversian (central) canal** — with a blood vessel and nerve fibre inside
- ▶ **Concentric lamellae** (5–20, numbered around the canal)
- ▶ **Osteocyte lacunae** between lamellar rings
- ▶ **Canaliculi** radiating from lacunae, interconnecting and opening into the Haversian canal
- ▶ **Cement (reversal) line** — outer boundary of the osteon
- ▶ **Interstitial lamellae** — irregular fragments of older, resorbed osteons filling the gaps between complete osteons
- ▶ **Volkman's canal** — a transverse/oblique channel connecting adjacent Haversian canals and the periosteal/endosteal surfaces
- ▶ **Outer and inner circumferential lamellae** — running around the whole periosteal and endosteal circumference

2. Formation of a secondary osteon — the bone-remodelling unit (BMU)

A bone-remodelling unit (BMU) consists of an advancing cutting cone followed by a closing cone:



- ▶ **Cutting cone:** activated osteoclasts fuse into a multinucleate cutting front that tunnels through bone, advancing ahead of a central ingrowing blood vessel at roughly **50 $\mu\text{m}/\text{day}$** ; a typical cutting cone is about 2 mm long and takes **1–3 months** to traverse a given segment.
- ▶ **Reversal zone / cement line:** marks the transition from resorption to formation — the outer boundary of the new osteon.
- ▶ **Closing cone:** osteoblasts (up to $\sim 4000/\text{mm}^2$ in the closing cone) follow the osteoclasts and progressively line the walls of the resorption canal with new osteoid, laying down successive lamellae from the periphery inward until only a narrow central Haversian canal remains around the blood vessel; this, too, takes about **1–3 months**.
- ▶ The whole cycle (resorption + reversal + formation) replaces old, micro-damaged or primary bone with a new, fully mineralized secondary osteon, and repeats throughout adult life — remodelling roughly **10% of the skeleton per year**.
- ▶ The equivalent remodelling unit in cancellous (trabecular) bone is the **basic (bony) structural unit** (average thickness 40–70 μm , length $\sim 100 \mu\text{m}$) — the trabecular counterpart of the secondary osteon.

3. Primary vs secondary osteon

Feature	Primary osteon	Secondary osteon
Mode of origin	Formed directly during initial ossification, as thickening trabeculae of woven bone enclose narrowing vascular spaces	Formed by remodelling — resorption of existing bone (cutting cone) followed by deposition (closing cone)
Boundary	No cement line; blends with surrounding woven/primary bone	Sharply demarcated by a cement (reversal) line
Lamellae	Fewer, less regular concentric lamellae	Well-organised 5–20 concentric lamellae
Mineralization	Mineralizes rapidly but is less densely mineralized overall	Mineralizes from inside out; older osteons show the highest, most uniform mineral content
When seen	Predominates in fetal/young bone and early cortical drift	Predominates in and constitutes almost all mature adult compact bone
Fate	Eroded and replaced by generations of mature (secondary) osteons	Continuously renewed by further remodelling throughout life

4. Vascular connections and gaps between osteons

- ▶ **Volkman's canals** run obliquely/at right angles to the long axis of the bone, linking Haversian canals of neighbouring osteons to each other and to the periosteal and medullary (endosteal) vessels; unlike Haversian canals, they are not surrounded by concentric lamellae.

- ▶ **Interstitial lamellae** occupy the irregular gaps between complete osteons — they are the fragmentary remnants of older osteons or circumferential lamellae partially eroded during successive remodelling cycles.
- ▶ **Outer and inner circumferential lamellae** run around the whole periosteal and endosteal circumference of the shaft, uninterrupted by Haversian canals, and are distinct from the osteon-forming concentric lamellae of the interior.
- ▶ Cortical blood flow in the shaft is mainly **centrifugal** (medullary/nutrient artery → Haversian systems → periosteal plexus), with an additional centripetal periosteal contribution to the outer cortex.

Applied / Clinical anatomy

- ▶ **Wolff's law / mechanical adaptation:** the pattern and extent of osteonal remodelling are governed by mechanical loading rather than by cumulative use — bone hypertrophies under increased load (e.g. a **35% increase in cortical thickness** documented in the racket arm of elite tennis players) and is resorbed with disuse (bed rest, immobilisation, microgravity).
- ▶ **Forensic age estimation:** the rate of bone remodelling slows with age, so osteon density, the number of intact vs fragmented (interstitial) osteons, and Haversian canal size on a ground section of cortical bone are used to estimate age at death in forensic and archaeological material.
- ▶ **Osteoporosis and metabolic bone disease:** an imbalance of the BMU cycle — excess osteoclastic resorption relative to osteoblastic deposition — thins and porotic-ally weakens cortical bone, increasing fracture risk; Paget's disease shows the opposite problem of disorganised, accelerated remodelling producing structurally weak "mosaic" bone.
- ▶ **Fracture healing and callus remodelling:** the immature woven bone of a fracture callus is progressively replaced by organised secondary osteons during the remodelling phase of healing; malunion alters the trabecular stress lines, and patients may report pain at the old fracture site in later life as remodelling re-aligns to the new loading pattern.
- ▶ **Histomorphometry/bone biopsy:** iliac crest bone biopsies are examined for osteon number, Haversian canal diameter and mineral appositional rate to diagnose metabolic bone disease and monitor anti-resorptive therapy.
- ▶ **Radiological correlate:** cortical thickness and density on plain films/DEXA/CT reflect the net balance of osteonal remodelling, forming the basis for monitoring osteoporosis treatment.

High-yield exam pointers

- ▶ Secondary osteon = mature **Haversian system**: Haversian canal + concentric lamellae (5–20) + osteocytes in lacunae + canaliculi, bounded by a **cement (reversal) line**.
- ▶ Formed by a **bone-remodelling unit (BMU)** = osteoclastic **cutting cone** (advances ~50 µm/day) followed by osteoblastic **closing cone** (fills centripetally, up to 4000 osteoblasts/mm²); each phase takes 1–3 months.
- ▶ Distinguished from a **primary osteon**, which forms directly during ossification and has no cement line.
- ▶ Osteon diameter 100–400 µm; Haversian canal mean diameter ~50 µm; ~21 million osteons in the adult skeleton; no osteocyte lies >200 µm from a vessel.

- ▶ **Interstitial lamellae** = remnants of old osteons between complete osteons; **circumferential lamellae** ring the whole shaft; **Volkman's canals** interconnect Haversian canals transversely.
- ▶ Bone turns over via remodelling at ~10% of the skeleton per year in adults; remodelling responds to mechanical load (Wolff's law), not cumulative use.
- ▶ Clinically linked to forensic age estimation, osteoporosis/Paget's disease, fracture-callus remodelling and histomorphometric bone biopsy.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy, 4e; IB Singh — Textbook of Human Histology, 9e (figure).



Selection of statistical test for a case study

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction — Selecting the correct **statistical test** is the step in the research process that converts raw study data into a valid, interpretable answer to the research question. Every PG dissertation/case study — whether a cadaveric morphometric survey, a radio-anatomic measurement study, or a comparison of an anatomical variant across groups — must have its statistical method decided **before** data collection (a priori), not chosen retrospectively to fit a desired result ("data dredging"). The choice depends on four linked questions: (1) what is the scale of measurement of the outcome variable, (2) how many groups are being compared and whether they are paired or independent, (3) does the data follow a normal (Gaussian) distribution, and (4) what is the underlying study design/objective (comparison, association, or prediction). An incorrect test either fails to detect a true difference (Type II error) or wrongly claims one (Type I error), invalidating the study's conclusions.

Basic concepts underlying test selection

- ▶ **Null hypothesis (H_0)**: assumes no difference/association exists between groups/variables; the **alternative hypothesis (H_1)** assumes one does. Every statistical test is, formally, a test of H_0 .
- ▶ **p-value**: the probability of obtaining the observed (or a more extreme) result if H_0 were true; conventionally, $p < 0.05$ is taken as "statistically significant," meaning H_0 is rejected.
- ▶ **Type I error (α)**: falsely rejecting a true H_0 (a false-positive result); conventionally fixed at 5%.
- ▶ **Type II error (β)**: falsely accepting a false H_0 (a false-negative result); **power ($1 - \beta$)** is the probability of correctly detecting a true difference, conventionally set at 80–90%.
- ▶ **Confidence interval (CI)**: the range within which the true population value is expected to lie (usually 95% CI); increasingly preferred over a bare p-value because it also conveys the magnitude and precision of the effect.
- ▶ **Effect size**: a standardised measure of the magnitude of a difference/association (e.g., Cohen's d, odds ratio, correlation coefficient r) — should always accompany the p-value, since a large sample can make a trivially small difference "significant."

Step 1 — Identify the scale of measurement of the outcome variable

Scale	Definition	Anatomy-relevant example
Nominal	Unordered categories	Blood group, sex, presence/absence of a bony variant
Ordinal	Ordered categories, unequal intervals	Grade of a foramen/notch (mild/moderate/severe), Likert-scale response
Interval	Equal intervals, no true zero	Temperature in °C
Ratio	Equal intervals, true zero	Length, weight, angle, foramen diameter, vertebral height

- Interval and ratio data are together termed **continuous (quantitative)** data; nominal and ordinal data are termed **categorical (qualitative)** data. This first classification is the single most important branch-point in test selection.

Step 2 — Identify the design: number of groups, paired or independent

Comparison structure	Meaning	Example
Independent (unpaired) groups	Different, unrelated subjects in each group	Femur length in males vs females
Paired (matched/related) groups	Same subject measured twice, or matched pairs	Bone density before vs after an intervention; left vs right side in the same cadaver
2 groups vs >2 groups	Determines whether a simple two-group test or an ANOVA/Kruskal-Wallis-type test (with post-hoc correction) is required	Comparing a measurement across 2 age groups vs across 4 age groups

Step 3 — Test the assumption of normality before choosing parametric vs non-parametric

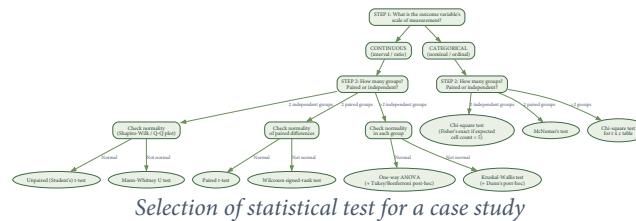
- A **parametric test** (t-test, ANOVA, Pearson correlation) assumes the data are drawn from a normally distributed population and requires roughly equal variances between groups; it is more powerful if these assumptions hold.
- A **non-parametric test** (Mann-Whitney, Wilcoxon, Kruskal-Wallis, Spearman correlation) makes no distributional assumption, works on ranks rather than actual values, and is the safer choice for skewed data or small samples.

Normality test	When used	Note
Shapiro-Wilk test	Small samples ($n < 50$)	Most powerful small-sample test
Kolmogorov-Smirnov test	Larger samples ($n > 50$)	Less powerful than Shapiro-Wilk for small n

Normality test	When used	Note
Q-Q plot / histogram (visual)	Always, alongside the formal test	More informative than a p-value alone

- **Practical rule:** for $n > 30$ the Central Limit Theorem makes most parametric tests reasonably robust to mild non-normality; for small, clearly skewed samples, the non-parametric alternative is preferred, or the data may be log-transformed (e.g., skewed enzyme/biomarker values) before applying a parametric test.

Decision algorithm for selecting the statistical test



Other common scenarios beyond the core algorithm

Objective	Parametric test	Non-parametric alternative
Association between two continuous variables	Pearson correlation coefficient (r)	Spearman's rank correlation (ρ)
Predicting a continuous outcome from one/more variables	Linear regression	—
Predicting a binary outcome (adjusting for confounders)	Logistic regression	—
Repeated measures (>2 time-points, same subjects)	Repeated-measures ANOVA	Friedman test
Time-to-event data (e.g., survival, time to fusion of an epiphysis)	Cox proportional-hazards regression	Kaplan-Meier estimate + log-rank test

- **Post-hoc tests after ANOVA** (which specific groups differ): **Tukey's HSD** (default, equal group sizes), **Bonferroni** (conservative, controls family-wise error), **Dunnnett's test** (each group vs one control group), **Scheffé's test** (complex/unequal contrasts).
- **Multiple testing caution:** performing many chi-square/t-tests on the same dataset instead of one global test with appropriate post-hoc correction inflates the Type I error rate.

Worked example (anatomy dissertation context)

- **Scenario A:** comparing the mean **vertebral body height** (continuous, ratio scale) between two independent groups of cadavers (young vs elderly) → check normality → if normal, **unpaired t-test**; if skewed, **Mann-Whitney U test**.
- **Scenario B:** comparing bone density in the **same limb before and after** a fixed intervention (continuous, paired) → check normality of the differences → **paired t-test** or **Wilcoxon signed-rank test**.

- ▶ **Scenario C:** comparing the **incidence of a bony variant** (e.g., a supracondylar process of the humerus — present/absent) between males and females (categorical, 2 independent groups) → **chi-square test** (or **Fisher's exact test** if any expected cell count is below 5).
- ▶ **Scenario D:** comparing a continuous morphometric measurement across **four age groups** → normality check → **one-way ANOVA** with Tukey post-hoc, or **Kruskal-Wallis** with Dunn's post-hoc if non-normal.

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- ▶ **Dissertation/thesis relevance:** every RGUHS PG anatomy dissertation's "Materials and Methods" chapter must state, and justify, the statistical test(s) used — incorrect test selection is one of the commonest reasons for adverse comments at synopsis/thesis evaluation and at journal peer review.
- ▶ **Morphometric and radio-anatomic research:** cadaveric osteometric studies, ultrasonographic/CT/MRI measurement studies, and studies of anatomical variants (accessory muscles, arterial/nerve variations, vertebral anomalies) are the commonest anatomy research designs requiring this decision framework.
- ▶ **Sample-size linkage:** the test chosen must match the test assumed during the a priori **sample-size calculation** — changing the test after data collection without adjusting for multiple comparisons is a recognised source of bias.
- ▶ **Reporting standards:** research reports/theses should state the test used, the software (e.g., SPSS, Epi Info, R, GraphPad Prism), the p-value/CI, and — increasingly required by journals — the effect size, in keeping with STROBE-type reporting guidance for observational studies.
- ▶ **Software-assisted decision:** statistical software can perform the normality check and suggest the corresponding test, but the underlying scale-of-measurement/design classification must still be made correctly by the investigator.

High-yield exam pointers

- ▶ Four questions decide the test: **scale of the outcome variable** → **number/pairing of groups** → **normality of the distribution** → **study objective (comparison/association/prediction)**.
- ▶ Continuous + 2 independent groups + normal → **unpaired t-test**; if not normal → **Mann-Whitney U**.
- ▶ Continuous + 2 paired groups + normal → **paired t-test**; if not normal → **Wilcoxon signed-rank test**.
- ▶ Continuous + >2 independent groups → **one-way ANOVA** (normal) or **Kruskal-Wallis** (not normal), each followed by an appropriate post-hoc test.
- ▶ Categorical + 2 independent groups → **chi-square test** (or **Fisher's exact** for small expected cell counts); categorical + paired → **McNemar's test**.
- ▶ Association between two continuous variables → **Pearson** (normal) or **Spearman** (not normal) correlation.
- ▶ Normality is checked with the **Shapiro-Wilk test** (small n) or **Kolmogorov-Smirnov test** (large n), plus a Q-Q plot/histogram.

- ▶ Report **effect size and confidence interval**, not just the p-value; the test must be fixed a priori, matching the sample-size calculation.
- ▶ Never run repeated unadjusted tests on the same data — use one global test with a proper post-hoc correction.

SOURCE & COVERAGE

Standard biostatistics/research-methodology texts used for this topic (not covered in Gray's Anatomy or the specialty anatomy texts): Mahajan BK — *Methods in Biostatistics*; Indrayan A — *Medical Biostatistics*; Bland JM & Altman DG — *Statistical Methods in Medical Research*; Bewick V, Cheek L, Ball J — statistics review series (accessible PubMed-indexed articles per test).

Coverage note: This is a biostatistics/research-methodology topic, and — as flagged in the topic spec — it is genuinely absent from Gray's Anatomy (Standing) and from the specialty anatomy texts in this library (confirmed by targeted grep of Vishram Singh's *General Anatomy* 4e, whose only overlapping chapter covers medical genetics, not biostatistics). The content above is therefore composed from standard, universally-taught biostatistics curriculum content (the "Research Methodology and Biostatistics" component common to RGUHS PG programmes across subjects) rather than from the anatomy corpus, per the spec's explicit allowance for genuinely thin/absent coverage.



Sesamoid bone

Asked in: Paper I May 2011 — RGUHS MD/MS Anatomy

Definition / Introduction A sesamoid bone (Arabic *sesam* = seed) is a seed-shaped nodule of bone that develops within the substance of a tendon, at a point where the tendon winds around a bony or cartilaginous surface near a joint and is subjected to friction and compression. Sesamoid bones form one of the eight categories in the shape-based classification of bones and are functionally distinct from "true" bones because they are devoid of periosteum. The **patella** is the largest sesamoid bone in the body; smaller, constant sesamoids occur at the wrist, the first metacarpophalangeal joint, and — most consistently — beneath the first metatarsophalangeal joint of the great toe.

Classification of bones by shape and general characteristics of sesamoid bones

Sesamoid bone is one of eight shape-based categories of bone:

Type	Defining feature	Example
Long	Length exceeds breadth/thickness	Femur, humerus
Short	Roughly cuboidal, cancellous core	Carpal, tarsal bones
Flat	Thin plate, two compact tables + diploë	Scapula, sternum, skull vault

Type	Defining feature	Example
Irregular	No consistent geometric shape	Vertebra, hip bone
Pneumatic	Contains an air-filled sinus	Maxilla, frontal bone
Sesamoid	Seed-like nodule within a tendon	Patella
Accessory	Extra bone from an independent centre that fails to fuse	Os trigonum
Heterotopic	Bone forming ectopically in soft tissue	Myositis ossificans

Characteristics that set sesamoid bones apart from true bones:

- ▶ Develop within the tendon of a muscle rather than in the primary cartilaginous/membranous skeletal model.
- ▶ Devoid of periosteum — together with the ear ossicles, they are the exception to the rule that every bone is periosteum-covered.
- ▶ Ossify **after birth**, usually from **multiple centres**; incomplete fusion of an extra centre gives a bipartite or tripartite bone (seen classically in the patella and the hallux sesamoids).
- ▶ Lack a Haversian (osteonal) system.
- ▶ Only the surface that rubs against the underlying bone is capped by articular hyaline cartilage; the tendon-facing surface is non-articular.
- ▶ Bone size is roughly proportional to the load transmitted through the tendon — hence the patella, bearing the entire quadriceps pull, is the largest sesamoid in the body, and its articular cartilage is the thickest in the body.

Sites of sesamoid bones in the body

Region	Sesamoid bone	Tendon in which it lies
Knee (anterior)	Patella — largest sesamoid	Quadriceps femoris
Knee (posterior)	Fabella	Lateral head of gastrocnemius
Wrist	Pisiform	Flexor carpi ulnaris
1st metacarpophalangeal joint	One sesamoid, ulnar side of metacarpal head	Adductor pollicis
1st metacarpophalangeal joint	One (inconstant) sesamoid, radial side	Flexor pollicis brevis
Elbow (rare, "true" sesamoid)	Ossiculum patellae cubiti	Triceps tendon
1st metatarsophalangeal joint	Two sesamoids — medial ("tibial") and lateral ("fibular")	Flexor hallucis brevis
Foot, lateral border	Os peroneum	Fibularis (peroneus) longus, at the cuboid

Region	Sesamoid bone	Tendon in which it lies
Foot (variable/inconstant)	Small sesamoids under the 2nd–5th metatarsal heads and toe interphalangeal joints	Long/short digital flexors

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Box titled "Sites of sesamoid bones in the human skeleton." Draw a simplified skeletal outline (or separate sketches of the knee, wrist/hand, and foot) and label:

- ▶ Patella — in quadriceps femoris tendon, front of knee.
- ▶ Fabella — lateral head of gastrocnemius, behind knee.
- ▶ Pisiform — in flexor carpi ulnaris tendon, wrist.
- ▶ Sesamoid in adductor pollicis tendon — ulnar side of 1st metacarpal head.
- ▶ Medial (tibial) and lateral (fibular) sesamoids — below 1st metatarsal head, in flexor hallucis brevis tendon; show the intersesamoid ligament and the flexor hallucis longus tendon grooved between them.
- ▶ Os peroneum — in peroneus longus tendon at the cuboid.

Add a side-note arrow: "no periosteum; ossifies postnatally from multiple centres."

Development, ossification and normal variants

- ▶ Sesamoid bones ossify by **metaplastic ossification within pre-existing dense tendon**, not by the classical intramembranous/endochondral sequence of the rest of the skeleton.
- ▶ Ossification is **postnatal** and typically **multicentric**. The patella ossifies from several centres appearing between **3 and 6 years of age**, with fusion complete by puberty. One or two extra centres persisting at the **superolateral angle** give a **bipartite** (or, if further subdivided, **tripartite**) patella; the anomaly is characteristically **bilateral and symmetrical**.
- ▶ The hallux sesamoids likewise ossify from single or multiple centres; roughly **30% of hallux sesamoids are bipartite**, the medial (tibial) sesamoid far more often than the lateral (fibular), which rarely shows more than two parts — this can be bilateral and must not be misread as a fracture.
- ▶ Some accessory ossicles of the foot are themselves sesamoid in nature rather than true accessory bones — e.g., the **Type I accessory navicular** is a genuine sesamoid within the tibialis posterior tendon (Type II, by contrast, is joined to the navicular body by a synchondrosis).

Vascular supply, innervation and ligamentous anchorage of the hallux sesamoids

- ▶ **Blood supply** follows one of three patterns: (i) from both the medial plantar artery and the deep plantar arch (~50% of individuals), (ii) predominantly from the deep plantar arch alone (~25%), or (iii) from the medial plantar artery alone (~25%). The major supply enters through the **proximal/plantar pole**, with only a minor contribution through the distal pole — a watershed arrangement that predisposes a fractured or avascular sesamoid fragment to non-union.

- ▶ **Innervation** is by the plantar digital nerves.
- ▶ Each sesamoid is held by a **sling** formed by the collateral and sesamoid ligaments of the 1st metatarsophalangeal joint, and the two sesamoids are joined to each other by the **intersesamoid ligament**, which floors the fibro-osseous tunnel for the flexor hallucis longus tendon. The medial sesamoid additionally receives fibres from **abductor hallucis** (medial stabiliser) and the lateral sesamoid from **adductor hallucis** (lateral stabiliser).

Functions of sesamoid bones

- ▶ Act as **frictionless pulleys**, redirecting the line of pull of the tendon around the joint.
- ▶ **Increase the mechanical (lever) advantage** of the muscle acting through them — e.g., the patella increases the moment arm of quadriceps femoris about the knee.
- ▶ **Protect the tendon** from attrition/compression against the underlying bone — the flexor hallucis longus tendon runs in the groove between the two hallux sesamoids, shielded from the head of the first metatarsal.
- ▶ **Share and transmit load** — the paired hallux sesamoids bear a large share of weight transmitted through the first ray during the push-off phase of gait.

True bone, sesamoid bone and accessory bone — the distinction

- ▶ **True bones** are covered by periosteum and belong to the primary skeletal pattern.
- ▶ **Sesamoid bones** are embedded within a tendon, lack periosteum, and ossify postnatally by multiple centres — hence excluded, along with the ear ossicles, from the rule that all bones are periosteum-covered.
- ▶ **Accessory bones** arise from an extra ossification centre of a *true* bone that fails to fuse with its parent (e.g., the **os trigonum**, an unfused posterolateral tubercle of the talus). Some accessory ossicles are, however, true sesamoids (Type I accessory navicular, above), so the two categories can overlap.

□ Fig 2.22 — Bipartite patella (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.52)

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- ▶ **Bipartite/tripartite patella** (above) must be differentiated radiologically from a fracture: the extra fragment at the superolateral angle has smooth, often sclerotic, rounded margins and is typically bilateral and symmetrical, unlike the sharp, usually unilateral fracture line.
- ▶ **Bipartite hallux sesamoid** (present in ~30% of medial sesamoids) can likewise mimic an acute sesamoid fracture; comparison with the opposite foot and the smooth cortical margins of each fragment resolve the diagnosis.
- ▶ **Patellar fracture**: transverse fractures disrupt the extensor mechanism of the knee, producing inability to actively extend the leg against gravity; comminuted/stellate fractures follow direct trauma to the subcutaneous anterior surface.
- ▶ **Hallux valgus**: lateral deviation of the great toe is commonly accompanied by lateral subluxation of the sesamoid complex relative to the medially drifting first metatarsal head, so that the sesamoids come to lie in the interval between the first and second metatarsal heads; the degree of sesamoid displacement on weight-bearing radiographs helps grade severity and plan corrective osteotomy.

- ▶ **Sesamoiditis and turf toe:** repetitive hyperextension-loading of the first metatarsophalangeal joint (running, dancing) can inflame the sesamoid–plantar plate complex; a forced hyperextension sprain of the same complex is the injury commonly called "turf toe."
- ▶ **Os peroneum** injury or an associated peroneus longus tendon tear near the cuboid can be mistaken for an avulsion fracture on plain radiographs of the lateral foot.
- ▶ **Sesamoidectomy** of the hallux, when required, is performed cautiously (usually one sesamoid at a time) because simultaneous excision of both destabilises the flexor hallucis brevis-mediated push-off of the first ray and predisposes to a cock-up/claw deformity of the great toe.
- ▶ The **patella**, being entirely subcutaneous, is a common site for direct-blow injury and for **prepatellar bursitis** ("housemaid's knee"); its posterior non-articular surface (related to the infrapatellar fat pad) is a landmark in knee-joint aspiration and arthroscopy portal planning.

High-yield exam pointers

- ▶ Sesamoid bone = seed-shaped bone ossifying **within a tendon**, at a site of friction against a bony/cartilaginous surface.
- ▶ **Largest sesamoid = patella**; constant sites = patella, fabella, pisiform, adductor pollicis sesamoid, two hallux sesamoids, os peroneum.
- ▶ **No periosteum, no Haversian system, postnatal, multicentric ossification** → normal bipartite/tripartite variant (patella, hallux sesamoid) that mimics fracture.
- ▶ Functions: pulley action, increase mechanical advantage, protect tendon from attrition, share load.
- ▶ Hallux sesamoids: medial (tibial) + lateral (fibular), linked by the intersesamoid ligament, floor the flexor hallucis longus tunnel; ~30% bipartite (usually medial).
- ▶ Displaced in **hallux valgus**; injured in **turf toe/sesamoiditis**.
- ▶ Distinguish from **accessory bones** (extra unfused centre of a true bone, e.g. os trigonum) and **heterotopic bone** (ectopic ossification in soft tissue) — though Type I accessory navicular is itself a true sesamoid.

SOURCE & COVERAGE

Vishram Singh — General Anatomy, 4e; BD Chaurasia — Human Anatomy Vol 2, 8e; Gray's Anatomy (Standring), 41e; Moore's Clinically Oriented Anatomy, 9e.



Shunt muscle

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction A **shunt muscle** is a skeletal muscle whose line of pull runs nearly **parallel to the long axis of the bone it moves**; most of its contractile force is therefore "shunted" into holding the two articular surfaces of the joint together (a stabilizing/compressive effect) rather than into producing rotation. It is the mechanical opposite of a **spurt muscle**, whose oblique line of pull produces rapid, effective joint rotation. The pair was defined electromyographically by **Basmajian (1959)** — "'Spurt' and 'shunt' muscles: an electromyographic confirmation" — and the terms are used to explain why some muscles crossing a joint are better suited to stabilising it while others are better suited to moving it.

1. Basis of the classification

Every muscle crossing a joint can be resolved, at any instant, into two force components relative to the bone it moves:

- ▶ A **rotatory component**, acting perpendicular to the bone, that produces angular movement (torque) about the joint axis.
- ▶ A **stabilizing (translatory) component**, acting parallel to the long axis of the bone, that presses the articular surfaces together (or, if directed away from the joint, tends to distract them).

Whichever component predominates through most of the range of movement determines whether the muscle behaves as a shunt or a spurt muscle for that action.

Feature	Shunt muscle	Spurt muscle
Line of pull relative to the moving bone	Nearly parallel to its long axis	Oblique/perpendicular to its long axis
Dominant force component	Stabilizing (compressive), holds articular surfaces apposed	Rotatory, produces angular movement
Site of proximal (fixed) attachment	Close to the joint axis	Away from the joint axis
Site of distal (moving) attachment	Away from the joint axis	Close to the joint axis
Lever arm at the moving segment	Long	Short
Mechanical effect	Resists dislocating/distracting forces; reduces effective rotational power	Produces fast, effective rotation; contributes little to joint stability
Classic example	Brachioradialis at the elbow; deltoid when the arm hangs at the side	Brachialis at the elbow; deltoid once abduction has been initiated beyond ~15°

2. Shunt muscle — structural and functional description

- ▶ **Structural criterion:** proximal attachment lies close to the joint it acts on, while the distal attachment lies well away from the joint along the moving bone, e.g. **brachioradialis** — arises from the upper two-thirds of the lateral supracondylar ridge of the humerus (just above the

elbow) and inserts into the lowest part of the lateral surface of the radius, just above the styloid process (near the wrist, i.e. far from the elbow).

- **Functional criterion:** because the muscle fibres run close to parallel with the forearm, most of the tension generated is directed along the shaft of the radius, compressing the radial head against the capitulum and helping to keep the elbow joint congruent; comparatively little of the force is converted into elbow flexion torque.
- **Deltoid as a shunt muscle:** with the arm hanging by the side, the deltoid's fibres run almost parallel to the shaft of the humerus. Contraction in this position is largely directed toward holding the humeral head in the glenoid cavity rather than abducting the arm — the deltoid is therefore acting as a shunt (stabilizing) muscle at this point in the range.

3. Spurt muscle — the functional counterpart

- **Structural criterion:** proximal attachment lies away from the joint (well up the shaft of the fixed bone), while the distal attachment lies close to the joint, e.g. **brachialis** — arises from the lower half of the anterior surface of the humeral shaft and inserts into the coronoid process/ulnar tuberosity, immediately below the elbow joint.
- **Functional criterion:** because the short distal lever arm keeps the muscle's pull oblique to the forearm through most of flexion, nearly all of its tension is converted into rotational (flexor) torque — brachialis is accordingly the principal "workhorse" flexor of the elbow, active through the full range and irrespective of forearm position.
- **Deltoid as a spurt muscle:** once abduction of the shoulder has been initiated (classically by supraspinatus, which "initiates and assists the deltoid in the first 15° of abduction"), the deltoid's line of pull becomes progressively more oblique to the humeral shaft; from this point on it acts as an efficient spurt muscle and becomes the principal abductor of the arm.

4. Biomechanical (lever-arm) basis

The shunt–spurt distinction is a specific application of the general lever principle of muscle action: **the perpendicular distance between a muscle's line of pull and the joint's centre of rotation (the lever/moment arm) — not the "class" of lever — determines whether the arrangement favours force/stability or speed/range.**

- A **short lever arm** (insertion close to the joint axis, as in a spurt muscle) — a given amount of muscle shortening produces a **large angular excursion**, so the arrangement is suited to **rapid, large-range movement**, but at reduced mechanical (torque) advantage.
- A **long lever arm** (insertion far from the joint axis, as in a shunt muscle) — the same shortening produces only a **small angular excursion**, but with **greater moment/force generation** and a pull directed more along the bone, favouring **stability over speed**.

This corresponds to the classical **first-, second- and third-class lever** systems described for skeletal muscle (fulcrum = joint; effort = muscle; resistance = the part moved/external load): a **third-class lever**, in which the effort (muscle insertion) lies between the fulcrum and the resistance — as with brachialis/biceps brachii acting on the elbow — is, by definition, "designed for a range of motion," which is exactly the spurt arrangement.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 9.20 — ■ *Shunt and spurt muscles.* (Vishram Singh — *General Anatomy* — 4e, p.413)

Labels for hand reproduction (elbow joint used as the model, per Fig. 9.20):

- ▶ Humerus (proximal/fixed bone)
- ▶ Radius/ulna (distal/moving bone)
- ▶ Elbow joint axis (fulcrum)
- ▶ **Shunt muscle** — origin close to the joint (on the humerus, near the elbow), insertion far along the forearm (e.g. brachioradialis); force arrow drawn nearly **parallel** to the forearm
- ▶ **Spurt muscle** — origin far from the joint (higher up the humeral shaft), insertion close to the joint (e.g. brachialis); force arrow drawn **oblique/perpendicular** to the forearm
- ▶ Resolved force components at the insertion: a small "stabilizing/compressive" arrow (along the bone) and a large "rotatory" arrow (perpendicular to the bone) for the spurt muscle, and the reverse proportion for the shunt muscle

5. Group action correlate — fixators and force couples

- ▶ Muscles rarely act alone; a movement is produced by coordinated **prime movers (agonists), antagonists, synergists and fixators**.
- ▶ When prime movers and antagonists co-contract, they act as **fixators**, stabilizing a joint by increased transarticular compression and creating a fixed base for other prime movers to act from (e.g. co-contraction of wrist flexors and extensors while gripping an object) — mechanically this is the same principle by which a shunt muscle contributes to joint stability.
- ▶ The **deltoid–rotator cuff** relationship at the shoulder is the classical illustration of the shunt/spurt concept operating within a coordinated group action: the rotator cuff (particularly supraspinatus, assisted by infraspinatus/subscapularis providing a medially-directed force couple) neutralises the shunting/subluxing tendency of an unopposed deltoid at low abduction angles, allowing the deltoid to convert to an effective spurt muscle once the humeral head is centred and abduction has progressed.

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- ▶ **Rotator cuff tear/attrition:** loss of the stabilizing (shunt-type) force couple normally provided by the cuff allows the deltoid's compressive pull to go unopposed, leading to superior migration of the humeral head against the acromion (a mechanism contributing to cuff-tear arthropathy and the classical "painful arc").
- ▶ **Tendon transfer surgery:** when re-routing a tendon (e.g. in radial or ulnar nerve palsy reconstructions), the surgeon must consider whether the new line of pull will make the transferred muscle act predominantly as a spurt muscle (to restore movement) or a shunt muscle (to restore joint stability), since the outcome depends on the geometry created at the new insertion.
- ▶ **Joint replacement biomechanics:** restoring an adequate lever arm (e.g. femoral "offset" for the hip abductors in hip arthroplasty) is essential — a shortened lever arm converts an efficient

abductor mechanism into a mechanically disadvantaged (shunt-like), unstable one, an application of the same lever-arm principle.

- ▶ **Surface/clinical correlate at the elbow:** brachioradialis, a shunt-type flexor, becomes maximally prominent and palpable along the lateral border of the forearm specifically when the elbow is flexed against resistance in the mid-prone position — a useful surface landmark and a bedside illustration of a shunt muscle contributing force at an intermediate (mechanically favourable-for-it) point in the range rather than through pure fast rotation.
- ▶ **Rehabilitation/exercise prescription:** distinguishing muscles that primarily stabilise a joint (shunt-type, e.g. rotator cuff, brachioradialis) from those that primarily move it (spurt-type, e.g. deltoid in mid-abduction, brachialis) underlies the rationale for "stability-first" strengthening protocols before power/range training in physiotherapy.

High-yield exam pointers

- ▶ Shunt–spurt is a **functional (kinesiological)**, not structural, classification of skeletal muscle, first described electromyographically by **Basmajian (1959)**.
- ▶ **Shunt muscle:** pull ~parallel to the bone's long axis → force diverted to resisting joint dislocation → stabilizes the joint; proximal attachment near the joint, distal attachment far, e.g. **brachioradialis**; deltoid with the arm at the side.
- ▶ **Spurt muscle:** pull oblique/perpendicular to the bone's long axis → force converted into effective rotation → produces rapid, large-range movement; proximal attachment far from the joint, distal attachment near, e.g. **brachialis**; deltoid once abduction is initiated (>15°, by supraspinatus).
- ▶ The same muscle can switch roles during a single movement (deltoid: shunt at 0°, spurt beyond ~15° of abduction) — this is a favourite viva point.
- ▶ Mechanistic basis = **lever-arm length**: short lever arm → speed/range (spurt, third-class-lever-like); long lever arm → force/stability (shunt).
- ▶ Clinically linked to the rotator-cuff/deltoid force-couple, tendon-transfer planning, and joint-replacement offset/lever-arm restoration.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (definitions, Fig. 9.20, lever classification); Moore's Clinically Oriented Anatomy 9e (line-of-pull mechanism, deltoid–supraspinatus example); IB Singh — Textbook of Anatomy Vol 1, 6e (corroborating definition); Gray's Anatomy (Standing) 41e (muscle lever-system/lever-arm principle, Ch. 5 "Muscles and Lever Systems"; Basmajian 1959 cited in the References); BD Chaurasia — Human Anatomy Vol 1, 8e (brachialis/brachioradialis/deltoid attachments and surface anatomy).



Synovial joints

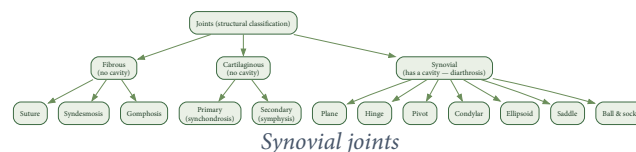
Asked in: Paper I Nov 2018 — RGUHS MD/MS Anatomy

Definition / Introduction A synovial joint (**diarthrosis**) is a freely movable joint in which the articulating ends of bones are capped by a thin plate of hyaline **articular cartilage**, separated by a **synovial (joint) cavity** filled with lubricating **synovial fluid**, and enclosed by an **articular capsule** made of an outer fibrous layer and an inner synovial membrane. Of the three structural types of joints — fibrous, cartilaginous and synovial — synovial joints are the most numerous, the most structurally evolved, and permit the greatest range of movement; they are also, clinically, the most important, being the principal site of degenerative (osteoarthritis) and inflammatory (rheumatoid) joint disease.

Classification of joints and the place of synovial joints

Joints are classified functionally (by mobility) and structurally (by connecting tissue and presence of a cavity); the two schemes correspond closely.

- ▶ **Functional classification:** (1) **synarthroses** — immovable, e.g. sutures; (2) **amphiarthroses** — slightly movable, e.g. symphyses; (3) **diarthroses** — freely movable, e.g. synovial joints.
- ▶ **Structural classification:** (1) **fibrous** (sutures, syndesmoses, gomphoses) — no joint cavity, united by fibrous tissue; (2) **cartilaginous** (primary/synchondroses, secondary/symphyses) — no joint cavity, united by hyaline cartilage or fibrocartilage; (3) **synovial** — possesses a joint cavity.



Characteristic features and structural components of a typical synovial joint

The defining features are: articular surfaces capped by hyaline cartilage; a capsule (fibrous capsule + synovial membrane) enclosing a joint cavity; synovial fluid filling the cavity; and, in some joints, an intra-articular disc/meniscus. The synovial membrane lines the joint everywhere **except over the articular cartilage**.

□ Fig 7.8 — Diagrammatic representation of a typical synovial joint (Vishram Singh — General Anatomy — 4e, p.293)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled schematic cross-section of a typical synovial joint, showing: **bone ends** of the two articulating bones (periosteum continuous with the fibrous capsule); **articular (hyaline) cartilage** capping each bone end; **fibrous capsule** (outer layer); **synovial membrane** (inner layer, reflected onto bone up to — but not over — the cartilage); **synovial (joint) cavity** with synovial fluid; and a **ligament** (capsular thickening).

Component	Structure	Functional significance
Fibrous capsule	Outer sleeve of interlacing white collagen fibres, attached near the articular margins	Stabilises the joint — permits movement, resists dislocation; richly supplied by pain/proprioceptive endings ("watch-dog" protective reflex)
Synovial membrane	Thin, highly vascular connective-tissue membrane lining the capsule; contains type A (macrophage-like) and type B (fibroblast-like) synoviocytes	Secretes synovial fluid (hyaluronan + lubricin); type A cells phagocytose debris, type B cells synthesise hyaluronan/lubricin
Synovial fluid	Clear/pale-yellow, viscous, slightly alkaline transudate of plasma plus hyaluronan; volume is small (< 0.5 ml can be aspirated from the knee)	Lubricates articular surfaces; nourishes avascular articular cartilage by diffusion
Articular cartilage	Thin plate of hyaline cartilage (fibrocartilage in temporomandibular, sterno-clavicular and acromio-clavicular joints — hence called atypical synovial joints)	Smooth, low-friction, load-bearing surface; resists compression
Articular disc/meniscus	Fibrocartilage pad, complete (knee-incomplete = meniscus proper; sterno-clavicular, inferior radio-ulnar = complete discs) or incomplete	Improves congruity, distributes load, absorbs shock, modifies movement
Bursae	Synovial-fluid-filled sacs between tendon/bone, muscle/bone, skin/bone	Reduce friction between moving structures
Fat pads (haversian pads)	Pads of fat between synovial membrane and capsule/bone, e.g. infrapatellar fat pad of knee, acetabular fat of hip	Fill irregular spaces; pliant cushioning that accommodates changing joint contours during movement

Classification of synovial joints

Synovial joints are further sub-classified by **shape of articular surface**, by **number of axes/planes of movement**, and by **number of bones/compartments** involved.

Type (by shape)	Articular surface	Axis/plane	Chief movements	Example
Plane (gliding)	Nearly flat	Multiaxial (limited gliding)	Side-to-side, back-and-forth slipping	Intercarpal, intertarsal, zygapophyseal joints
Hinge (ginglymus)	Pulley-shaped	Uniaxial (transverse)	Flexion, extension	Elbow (humero-ulnar), knee, ankle, interphalangeal joints — commonest type of synovial joint
Pivot (trochoid)	Rounded process within an osteo-ligamentous ring	Uniaxial (vertical/longitudinal)	Rotation only	Superior radio-ulnar joint, median atlanto-axial joint
Condylar	Convex condyle in a shallow socket	Biaxial	Flexion/extension + slight rotation	Knee, temporomandibular joint
Ellipsoid (condyloid)	Elliptical convex on elliptical concave	Biaxial	Flexion/extension, abduction/adduction, circumduction (no axial rotation)	Wrist (radiocarpal), metacarpophalangeal, atlanto-occipital joints
Saddle (sellar)	Reciprocally concavo-convex	Biaxial (+ conjunct rotation)	Flexion/extension, abduction/adduction	First carpometacarpal, sterno-clavicular, calcaneocuboid joints
Ball and socket (spheroidal)	Rounded head in a cup-shaped socket	Multiaxial	Flexion, extension, abduction, adduction, rotation, circumduction	Hip (largest), shoulder, incudostapedial (smallest)

- By number of bones: **simple** (two bones, e.g. interphalangeal joints), **compound** (more than two bones, e.g. elbow — humerus, radius, ulna), **complex** (a joint cavity divided by an intra-articular disc/meniscus, e.g. knee, temporomandibular, sterno-clavicular joints).

Movements at synovial joints

- **Gliding/slipping movements** — one flat surface slips over another (plane joints), e.g. small joints of hand, foot, vertebral column.
- **Angular movements** — change the joint angle: **flexion** (decreases the anteroposterior angle), **extension** (increases it, returning to anatomical position), **abduction** (away from the median plane), **adduction** (towards the median plane), **circumduction** (flexion + extension + abduction + adduction in sequence, describing a cone).

- ▶ **Rotary/circular movements** — occur only where a rounded surface articulates with a cup-shaped one: **rotation** (about a long axis), **supination/pronation** at the forearm.
- ▶ **Special movements** — **inversion/eversion** at the subtalar and midtarsal joints; **protraction/retraction** (movement parallel to the ground, e.g. of the mandible); **elevation/depression** (e.g. of the mandible or scapula).
- ▶ **Passive movements** are produced by an external force (gravity, an examiner) but reproduce the patient's own active range; **accessory movements** (a slight extra glide/rotation elicited only by an examiner's manipulation, e.g. at the wrist) cannot be produced actively by the patient and are used clinically to test joint and ligament integrity.

Blood and nerve supply; Hilton's law

- ▶ **Blood supply:** derived from a **periarticular anastomosis (circulus articularis vasculosus)** formed by articular branches of the arteries around the joint; it supplies the fibrous capsule, synovial membrane and adjoining epiphysis. The synovial membrane is richly vascular and, by diffusion, also nourishes the avascular articular cartilage. Articular cartilage itself, and the fibrous capsule/ligaments, are relatively poorly or non-vascularised.
- ▶ **Nerve supply** is rich and of three functional types:
 - **Sensory pain fibres** — free nerve endings in the capsule, ligaments and synovial membrane (articular cartilage and the central part of a disc/meniscus have no nerve supply and are effectively insensitive).
 - **Proprioceptive fibres** — encapsulated endings (**Ruffini corpuscles**) in the capsule, signalling joint position and movement.
 - **Autonomic (vasomotor) fibres** — sympathetic fibres supplying the vessels of the synovial membrane; the membrane itself is relatively insensitive to pain.
- ▶ **Hilton's law:** the nerve supplying a joint also supplies the muscles that move that joint and the skin overlying it. Clinically, when a joint is diseased, injured or over-distended, irritation of its nerve supply causes reflex spasm of the muscles acting on it — holding the joint in the position of maximum comfort (protective muscle spasm) — and pain may be referred to the skin over the joint or, importantly, to a distant joint sharing the same nerve trunk (e.g. hip joint disease presenting as knee pain, both being supplied by branches of the femoral and obturator nerves).
- ▶ **Gardner's observation:** the part of a joint capsule made taut by contraction of a muscle group is supplied by the nerve to the antagonist muscles — an arrangement that helps maintain joint stability during movement.

Stability of synovial joints

Three factors, in ascending order of importance, maintain synovial joint stability:

- ▶ **Bones** — congruity of articular surfaces, e.g. the deeply-fitting head of femur in the acetabulum (hip rarely dislocates); the talus gripped in the tibiofibular mortise at the ankle.
- ▶ **Ligaments** — intracapsular and extracapsular ligaments resist dislocation and guide movement (e.g. cruciate ligaments give anteroposterior, collateral ligaments give side-to-side stability at the knee) but, being largely collagenous, elongate permanently if chronically overstretched and so cannot resist sustained strain.

- **Muscles (most important)** — the tone and strength of muscles crossing the joint are the chief and most dynamic stabilisers; weakness, flaccidity or paralysis of these muscles predisposes to dislocation.

Joint	Close-packed position (maximum congruity, most stable, least likely — but if it occurs, most damaging — to dislocate)	Loose-packed position (least congruity, most mobile, most prone to dislocation)
Hip	Extended and medially rotated	Semiflexed
Knee	Fully extended	Semiflexed
Ankle	Fully extended (dorsiflexed)	Plantarflexed
Shoulder	Abducted and laterally rotated	Semiabducted
Elbow	Fully extended	—

Applied / Clinical anatomy

- **Osteoarthritis** — degenerative disease of articular cartilage; loss of cartilage/synovial fluid leads to bone-on-bone attrition, degeneration and osteophyte formation at the cartilage–synovium–periosteum junction; affects large weight-bearing joints (hip, knee, cervical/lumbar spine) — the commonest joint disease overall, with the knee the most frequently affected.
- **Rheumatoid arthritis** — chronic autoimmune inflammatory disease primarily of the synovial membrane, causing synovial hypertrophy/hyperplasia, fibrinous effusion, pannus formation and erosion of articular cartilage; typically affects the small joints of the hands and feet.
- **Dislocation** — loss of contact between articular surfaces due to inadequate ligamentous/muscular support or poor bony congruity; the shoulder is the most commonly (and recurrently) dislocated joint in adults because its shallow glenoid affords little bony stability; the hip is the joint most often involved in congenital dislocation.
- **Sprains** — a tear of a ligament (commonest at the ankle, involving the anterior talofibular ligament) causing pain and swelling without loss of bony apposition.
- **Referred pain (Hilton's law in practice)** — hip joint pathology classically presents as knee pain because the obturator and femoral nerves supply both joints; recognising this prevents missing the true (hip) lesion in a patient presenting with knee symptoms.
- **Joint aspiration (arthrocentesis)** and **arthroscopy** exploit the accessible synovial cavity for diagnosis (synovial fluid analysis in inflammatory/septic arthritis) and minimally invasive treatment (meniscal repair, ligament reconstruction).
- **Arthroplasty** — surgical repair/replacement of a joint (e.g. total hip/knee replacement), now the standard treatment for end-stage osteoarthritis of major weight-bearing joints.

High-yield exam pointers

- Synovial joint = diarthrosis; possesses a joint cavity, synovial fluid and articular cartilage — the only structural joint type with a cavity.

- ▶ Seven varieties by shape: plane, hinge, pivot, condylar, ellipsoid, saddle, ball-and-socket; **hinge is commonest, ball-and-socket (hip) gives the greatest range.**
- ▶ Atypical synovial joints (fibrocartilage-capped, not hyaline): **temporomandibular, sterno-clavicular, acromio-clavicular.**
- ▶ Blood supply = **circulus articularis vasculosus**; articular cartilage itself is avascular and aneural.
- ▶ **Hilton's law** — nerve to a joint also supplies the muscles moving it and the skin over it; explains protective muscle spasm and referred pain (classically, hip disease → knee pain).
- ▶ Stability order of importance: **muscles > ligaments > bones**; close-packed position = maximum congruity/stability; loose-packed = maximum mobility/instability.
- ▶ Golden facts: largest and most complex joint — **knee**; largest ball-and-socket — **hip**; smallest ball-and-socket — **incudo-stapedial**; most commonly dislocated — **shoulder**; strongest ligament — **iliofemoral (Bigelow's) ligament.**

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy, 4e.



Walking mechanism

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction Walking (gait) is the cyclical, alternating pattern of limb movements by which the body is propelled forward on level ground while a vertical, bipedal posture is maintained. Each limb passes repeatedly through a **stance phase** (foot in contact with the ground, ~60% of the cycle) and a **swing phase** (foot off the ground, ~40% of the cycle), the two limbs being out of phase so that the body is always supported. Normal, efficient walking depends on precisely timed, largely alternating (concentric/eccentric) contraction of the hip, knee and ankle-foot muscles acting as a single closed kinetic chain, so that the centre of gravity advances with minimal vertical and lateral excursion and minimal energy cost. Disturbance of any link in this hip-knee-ankle-foot chain — muscular, neural, or skeletal — produces a recognisable abnormal gait.

1. The gait cycle — terminology and phases

- ▶ **Gait cycle (stride):** interval between two successive occurrences of the same event in the same limb — classically heel strike to the next heel strike of the same foot. A *step* is the shorter interval between contacts of opposite feet.
- ▶ **Stance phase (~60% of cycle):** foot on the ground — **initial contact/heel strike, loading response, midstance, terminal stance (heel-off), preswing (toe-off).**
- ▶ **Swing phase (~40% of cycle):** foot off the ground — **initial swing, midswing, terminal swing.**
- ▶ **Double-support periods:** two short intervals (each ~10% of the cycle) at the start and end of stance, when both feet contact the ground as weight transfers between limbs; between them lies the longer **single-limb support**. Stance (60%) therefore exceeds swing (40%). Running abolishes double support entirely.

2. Muscle action through the gait cycle

Phase	Mechanical goal	Principal muscle groups (action)
Initial contact (heel strike)	Lower the forefoot gently to the ground; decelerate the swinging limb	Ankle dorsiflexors — tibialis anterior (eccentric); hip extensors — gluteus maximus
Loading response (foot flat)	Accept body weight; control knee flexion and ankle dorsiflexion	Knee extensors — quadriceps ; ankle plantarflexors — triceps surae (eccentric); hip abductors — gluteus medius/minimus , tensor fasciae latae
Midstance	Stabilise the knee; control forward momentum; stabilise the pelvis	Quadriceps ; triceps surae (eccentric); gluteus medius/minimus
Terminal stance (heel-off)	Accelerate the body mass forward	Triceps surae (concentric — propulsion); gluteus medius/minimus (pelvic stability); tibialis posterior and long toe flexors (maintain arches)
Preswing (toe-off)	Push off; decelerate the thigh in preparation for swing	Flexor hallucis longus , flexor digitorum longus (final propulsive thrust); iliopsoas , rectus femoris (eccentric)
Initial swing	Accelerate the thigh forward; clear the foot	Iliopsoas , rectus femoris (concentric hip flexion); tibialis anterior (dorsiflexion)
Midswing	Clear the foot off the ground	Tibialis anterior (dorsiflexion)
Terminal swing	Decelerate the thigh and leg; position the foot for the next heel strike	Gluteus maximus and hamstrings (eccentric hip deceleration); quadriceps (extends the knee, "presents" the heel)

Throughout stance, the **intrinsic muscles of the foot and the long tendons crossing it** (tibialis posterior, tibialis anterior, flexor digitorum brevis and longus tendons) continuously act to preserve the longitudinal arches under load.

□ Fig 7.23 — Gait cycle. The activity of one limb between two repeated events of walking. Eight phases are typically described (Moore — Clinically Oriented Anatomy — 9e, p.1155)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A horizontal timeline (0% → 100% of one gait cycle) with stick-figure foot positions labelled at each of the eight phases:

- ▶ **Initial contact (heel strike)** — 0%
- ▶ **Loading response** — 0–10%
- ▶ **Midstance** — 10–30%
- ▶ **Terminal stance (heel-off)** — 30–50%
- ▶ **Preswing (toe-off)** — 50–60%
- ▶ **Initial swing** — 60–73%
- ▶ **Midswing** — 73–87%
- ▶ **Terminal swing** — 87–100%

Bracket the whole line into **Stance (0–60%)** and **Swing (60–100%)**, and mark the two **double-support** intervals (0–10% and 50–60%) versus the intervening **single-limb support** (10–50%).

3. Hip joint mechanics in walking

- ▶ The hip alternates flexion (to advance the swinging thigh) and extension (to propel the trunk over the stance limb), driven reciprocally by the **iliopsoas/rectus femoris** (flexors) and **gluteus maximus/hamstrings** (extensors) as detailed in the table above.
- ▶ **Abductor mechanism of the hip:** normal single-limb stance requires the hip abductors of the stance side (**gluteus medius and minimus**) to hold the pelvis level so the swinging (unsupported) side can clear the ground. This mechanism has three components: (a) **power** — an intact gluteus medius/minimus; (b) **fulcrum** — a normal femoral head–acetabulum relationship; (c) **weight** — an intact femoral neck transmitting body weight.
- ▶ While standing on one limb, the body-weight moment about the stance hip is balanced by the abductors, whose lever arm is only about half that of body weight; the abductors must generate roughly **twice body weight**, giving a hip joint reaction force of about **2.5× body weight** in single-limb stance, rising to **≥4× body weight during walking** (ground-reaction forces plus pelvic-rotation deceleration).
- ▶ Failure of power, fulcrum, or weight (superior gluteal nerve palsy, congenital hip dislocation, ununited femoral neck fracture) drops the unsupported side of the pelvis — **positive Trendelenburg sign: uncompensated** (pelvis drops uncontrollably) or **compensated** (trunk lurches toward the stance limb, shortening the lever arm).
- ▶ The same abductors also rotate the contralateral (swinging) pelvis forward, contributing to stride length.

□ Fig 5.11 — Abductor mechanism at the hip joint (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.110)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A coronal diagram of the pelvis balanced on one femoral head, labelled:

- ▶ **Body weight (W)** acting through the centre of gravity, with its lever arm to the stance hip
- ▶ **Abductor force (Ab)** of gluteus medius/minimus, with its (shorter) lever arm
- ▶ **Fulcrum** — the femoral head in the acetabulum
- ▶ **Joint reaction force (JRF)** directed through the femoral neck
- ▶ Two panels: pelvis **level** (normal) vs pelvis **dropped on the unsupported side** (positive Trendelenburg sign)

4. Knee joint mechanics in walking

- ▶ The knee undergoes a small, essential flexion excursion during stance and a larger excursion during swing:
 - At **midstance**, the knee flexes to about **15°**; this allows the centre of gravity to travel forward at an almost constant height (avoiding the wasteful "up-and-down" arc that a rigid, fully extended knee would produce) and lets the impact energy of loading be absorbed by stretching (eccentric contraction of) the **quadriceps**.
 - During **swing**, the knee flexes to about **67°** so that the foot clears the ground without dragging the toes.
- ▶ **Screw-home (locking) mechanism**: at terminal extension, conjunct **lateral rotation of the tibia on the femur** produces the close-packed, "locked" extended position with maximal ligamentous tightening — stable with minimal muscular effort when the extended knee is loaded during stance. **Popliteus** "unlocks" the knee at the start of flexion by rotating the tibia medially (femur laterally on a fixed tibia).
- ▶ This rotation is one link in a hip-to-foot chain: hip lateral rotation for heel strike is transmitted, via the extending knee's tibial lateral rotation, to **invert the foot at the subtalar joint**, raising the arch into a **rigid lever for push-off**. The knee flexion that follows impact rotates the tibia medially instead, **everting** the foot into a mobile, shock-absorbing structure; toward toe-off, renewed extension and lateral rotation re-rigidify the foot for propulsion.

5. Ankle and foot mechanics in walking

- ▶ At **heel strike**, ankle dorsiflexors (**tibialis anterior**) contract eccentrically to lower the forefoot in a controlled manner, preventing foot-slap.
- ▶ **Through stance**, plantarflexors (**triceps surae**) control forward-tipping of the leg over the fixed foot (eccentric, midstance), then contract concentrically at **terminal stance/heel-off** for the major propulsive thrust; long toe flexors (**flexor hallucis/digitorum longus**) add a final thrust at **toe-off**.
- ▶ **During swing**, dorsiflexors (**tibialis anterior**) contract concentrically throughout to keep the forefoot clear of the ground.
- ▶ **Invertors and evertors** are the principal foot stabilisers during stance and, with the long plantar tendons, help support the **longitudinal arches** under load.

- ▶ **Windlass mechanism:** dorsiflexion of the toes (especially great toe) at toe-off draws the plantar aponeurosis taut, pulling calcaneus and metatarsal heads together and **heightening the medial longitudinal arch** — a rigid lever exactly when propulsive thrust is needed.
- ▶ Elastic strain energy stored in stretched tendons (notably **tendo calcaneus**) during loading is released later in the cycle, reducing the metabolic cost of walking.

Applied / Clinical anatomy

- ▶ **Trendelenburg (lurching) / waddling gait:** unilateral paralysis of gluteus medius/minimus (superior gluteal nerve injury, faulty gluteal intramuscular injection) makes the patient lurch toward the affected side to clear the opposite foot; bilateral weakness (e.g. bilateral hip dislocation, myopathy) gives a "waddling gait."
- ▶ **Foot drop / steppage gait:** common fibular (peroneal) nerve injury paralyses dorsiflexors/evertors; the foot cannot clear the ground in swing, so hip/knee flexion is exaggerated, and after heel strike the foot "slaps" down because eccentric braking by the dorsiflexors is lost.
- ▶ **High-heeled footwear** shifts the centre of gravity forward, increases lumbar lordosis and knee flexion, and predisposes to ankle-ligament sprains during walking.
- ▶ **Windlass (Jack's) test:** passive dorsiflexion of the great toe to tighten the plantar aponeurosis and assess arch integrity/plantar fascia pain — a direct clinical application of the windlass mechanism.
- ▶ **Screw-home mechanism** is clinically relevant to knee-replacement design (prostheses must permit conjunct rotation) and explains why the knee is most stable, and least fatiguing to hold, in full extension during prolonged standing.
- ▶ Other pathological gaits recognised on the same hip-knee-ankle framework include the **antalgic gait** (short stance phase on a painful limb) and the **scissoring gait** of spasticity (exaggerated hip adduction from spastic adductors).

High-yield exam pointers

- ▶ Gait cycle = stance (~60%) + swing (~40%); stance begins and ends with double support (2 × ~10%), separated by single-limb support.
- ▶ Eight phases: initial contact, loading response, midstance, terminal stance (heel-off), preswing (toe-off), initial swing, midswing, terminal swing.
- ▶ Abductor mechanism of hip = **Power** (gluteus medius/minimus) + **Fulcrum** (femoral head–acetabulum) + **Weight** (femoral neck); defect in any → **positive Trendelenburg sign**.
- ▶ Hip joint reaction force: ~2.5× body weight in single-limb standing, ≥4× body weight during walking.
- ▶ Knee flexes ~15° at midstance (shock absorption, smooth forward travel of the centre of gravity) and ~67° during swing (toe clearance).
- ▶ **Screw-home mechanism:** terminal knee extension → tibia rotates laterally → knee locks (close-packed) and, via the kinetic chain, the foot is inverted and rigidified for push-off; **popliteus** unlocks the knee to start flexion.

- ▶ **Windlass mechanism:** toe dorsiflexion at toe-off tightens the plantar aponeurosis and raises the medial longitudinal arch.
- ▶ Ankle dorsiflexors act eccentrically at heel strike (control foot-fall) and concentrically in swing (foot clearance); plantarflexors act eccentrically in midstance and concentrically at heel-off (propulsion).
- ▶ Common fibular nerve injury → foot drop → steppage gait; superior gluteal nerve injury/gluteal weakness → Trendelenburg/waddling gait.

SOURCE & COVERAGE

Moore's Clinically Oriented Anatomy, 9e; Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — General Anatomy, 4e. Coverage note: the general-anatomy specialty text carries only passing references to walking; the gait-cycle, muscle-action, and joint-biomechanics detail above is grounded chiefly in Moore's dedicated "Walking: Gait Cycle" section and Gray's hip/knee/ankle biomechanics subsections, cross-checked against BD Chaurasia's gait and abductor-mechanism sections.



Osteology



Epiphysis

Asked in: Paper I Oct 2009 · Paper I May 2009 · Paper I Oct 2006 (3×) — RGUHS MD/MS Anatomy

Definition / Introduction An **epiphysis** is the expanded end of a long bone that ossifies from a **secondary centre of ossification** and, throughout childhood and adolescence, remains separated from the shaft (**diaphysis**, which ossifies from the single primary centre) by a plate of hyaline cartilage — the **epiphyseal (growth) plate**. Together with the metaphysis, the epiphysis and epiphyseal plate are responsible for longitudinal growth of the bone; once the plate ossifies and epiphysio-diaphyseal fusion is complete, growth in length ceases. The epiphysis is therefore central to the biology of skeletal growth, to forensic age estimation, and to important clinical entities such as childhood osteomyelitis and growth-plate injury.

1. Parts of a Growing Long Bone

- ▶ **Diaphysis** — the elongated shaft, formed from the primary centre of ossification; consists of compact bone surrounding the medullary cavity.
- ▶ **Metaphysis** — the flared end of the diaphysis adjacent to the epiphyseal plate; the most actively growing and most vascular region of the bone.
- ▶ **Epiphyseal plate (growth plate)** — a disc of hyaline cartilage intervening between metaphysis and epiphysis; site of longitudinal growth.
- ▶ **Epiphysis** — the end of the bone, ossified from a secondary centre, usually capped by articular cartilage.

2. Types of Epiphysis

There are four types of epiphysis, classified by function and site:

Type	Covering / articulation	Function	Example
Pressure epiphysis	Covered by articular cartilage	Takes part in transmission of body weight through a joint	Head of femur, head of humerus, lower end of radius
Traction epiphysis	Non-articular	Produced by the pull of muscle(s); gives muscular attachment; always ossifies later than the pressure epiphysis	Greater & lesser trochanters of femur; greater & lesser tubercles of humerus
Aberrant epiphysis	Non-articular	Appears at the unusual end of a miniature/short long bone (normally these bones have an epiphysis at only one end)	Epiphysis at the head of the 1st metacarpal (normal epiphysis is at the base)
Atavistic epiphysis	Non-articular	An independent bone in lower mammals that, in humans, fuses "parasitically" to a neighbouring bone to receive its nutrition	Coracoid process of scapula; os trigonum (posterior tubercle of talus)

embed: ![Fig 6.9 — ■ Types of epiphyses: (A) pressure and traction epiphyses; (B) aberrant epiphysis; (C) and (D) atavistic epiphysis (Vishram Singh — General Anatomy — 4e, p.246)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/65f1d3b6d78caa22.jpg)

3. Development (Ossification) of the Epiphysis

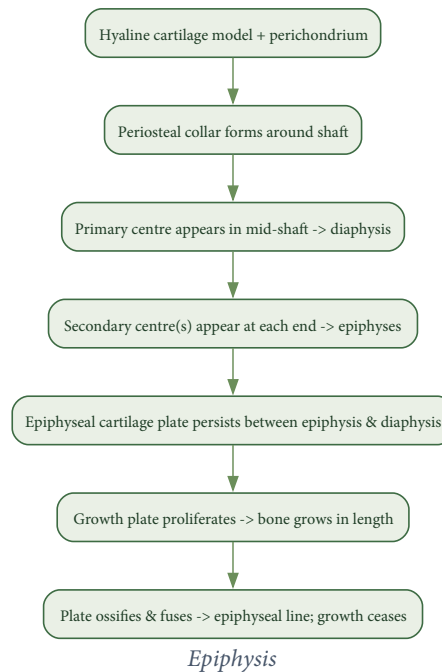
Long bones develop by **intracartilaginous (endochondral) ossification** of a hyaline cartilage model:

- ▶ A **primary centre of ossification** appears in the centre of the shaft and spreads toward the ends, forming the diaphysis; simultaneously, the periosteum lays down a **periosteal collar**.
- ▶ One or more **secondary centres of ossification** later develop at each end of the cartilage model, forming the epiphyses.
- ▶ The intervening **epiphyseal cartilage** (and the articular cartilage at each end) remains unossified, continuing to produce new cartilage and enabling growth in length — hence its name, the **growth plate**.
- ▶ Once growth is complete, the residual cartilage ossifies, leaving a scar — the **epiphyseal line**.

Laws of ossification:

- ▶ The primary centre is single and appears **before birth** (exception — carpal bones, which ossify after birth).

- ▶ Secondary centres appear **after birth** (exception — the lower end of the femur, which appears in the 9th intrauterine month; occasionally the upper ends of the tibia and humerus also appear before birth).
- ▶ The centre that **appears first, fuses last** (exception — the fibula, whose lower epiphysis appears first and, uniquely, also fuses first).



4. Epiphyseal (Growth) Plate — Structure and Growth Mechanism

Post-natal bone growth occurs by two distinct methods:

- ▶ **Appositional growth** — increase in *diameter*; periosteal osteoblasts lay down new bone on the outer surface of the shaft.
- ▶ **Endochondral growth** — increase in *length*; multiplication of cells in the epiphyseal plate pushes the epiphysis away from the diaphysis, while an equal amount of cartilage is replaced by bone on the metaphyseal side, so the plate's thickness stays constant.

The plate is organised into four zones, from the epiphyseal (superficial) to the diaphyseal (deep) surface:

Zone	Histological feature	Role in growth
Resting cartilage	Randomly arranged chondrocytes, nearest the epiphysis, dividing slowly	Reserve zone anchoring the plate
Proliferation	Chondrocytes divide, forming longitudinal columns ("stacks of coins")	Produces new cartilage — the engine of lengthening
Hypertrophy	Chondrocytes enlarge/mature and secrete alkaline phosphatase	Prepares matrix for mineralisation
Calcification	Thin zone; matrix calcified with calcium carbonate; chondrocytes die	Vascular invasion from the diaphysis; osteoblasts deposit bone on calcified cartilage bars

5. Blood Supply of the Epiphysis

A growing long bone is supplied by **four sets of arteries**:

- ▶ **Nutrient artery** — enters mid-shaft through the nutrient foramen, divides into ascending and descending medullary branches that supply the medullary cavity and inner two-thirds of the diaphyseal/metaphyseal cortex; its terminal branches form hairpin loops in the metaphysis.
- ▶ **Periosteal arteries** — numerous small vessels beneath the periosteum, entering through Volkmann's canals to supply the outer one-third of the cortex.
- ▶ **Metaphyseal (juxta-epiphyseal) arteries** — derived from neighbouring vessels, entering the metaphysis directly along with the joint capsule attachment.
- ▶ **Epiphyseal arteries** — derived from a peri-articular arterial anastomosis, the **circulus vasculosus**; they enter the epiphysis directly or after piercing the epiphyseal cartilage.

Before fusion, the epiphyseal plate keeps the epiphyseal and metaphyseal circulations functionally separate, and the metaphyseal vessels behave as **end arteries** with hairpin bends. After epiphyseal fusion, free anastomoses are established between epiphyseal and metaphyseal arteries, so the metaphysis no longer has end arteries.

embed: ![Fig 6.10 — ■ Blood supply to a growing long bone (Vishram Singh — General Anatomy — 4e, p.250)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/c6b132c034f072e0.jpg)

6. Fusion of the Epiphysis — Law of Union and the "Growing End"

- ▶ Epiphysio-diaphyseal fusion begins at **puberty** and is usually complete by **25 years** of age, after which no further growth in length is possible.
- ▶ **Law of union of epiphyses**: the epiphyseal centre that appears first unites last, and the one that appears later unites first — **the fibula alone violates this law**, its lower epiphysis appearing first and also fusing first, while its upper epiphysis appears late and fuses late.
- ▶ The **growing end** of a long bone is the end whose secondary centre appears first and fuses last; it always lies **opposite** to the direction of the nutrient foramen (mnemonic: "to the elbow I go, from the knee I flee" — upper-limb growing ends are at the shoulder/wrist, lower-limb growing ends are at the knee).
- ▶ Fusion of the secondary centres and epiphyses occurs **earlier in females** (oestrogen accelerates plate ossification, whereas testosterone is comparatively less potent in this respect) — this is why women, on average, attain a shorter final adult height than men.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- ▶ **Types of epiphysis** — a long bone end showing: (a) *pressure epiphysis* capped by articular cartilage (e.g. head of femur); (b) *traction epiphysis*, non-articular, with muscle attachment (e.g. greater trochanter); (c) *aberrant epiphysis* at the head of the 1st metacarpal; (d) *atavistic epiphysis* — os trigonum fused to the talus.
- ▶ **Blood supply of a growing long bone** — label: nutrient artery entering the nutrient foramen with ascending/descending medullary branches forming hairpin loops in the metaphysis; periosteal arteries entering via Volkmann's canals; metaphyseal (juxta-epiphyseal) arteries; epiphyseal arteries arising from the circulus vasculosus around the joint; and the epiphyseal plate separating epiphysis from metaphysis/diaphysis.

Applied / Clinical anatomy

- ▶ **Osteomyelitis in children:** the metaphysis is the commonest site because its end arteries form hairpin bends where circulating bacteria/emboli are easily trapped, causing infarction; after epiphyseal fusion establishes epiphyseal–metaphyseal anastomoses, this end-artery pattern disappears and osteomyelitis becomes rare in adults.
- ▶ **Growth-plate injury:** trauma or systemic illness interrupting epiphyseal growth produces dense transverse **growth-arrest (Harris's) lines** visible radiographically in the metaphysis; damage to the growing end in a child can cause permanent shortening of the limb because it disables further elongation at that plate.
- ▶ **Forensic/medico-legal significance:** the presence of the secondary ossification centre at the distal femoral epiphysis on a newborn's radiograph indicates a full-term pregnancy; sequential appearance/fusion of epiphyses is used for skeletal age estimation.
- ▶ **Radiographic appearance:** at birth the diaphysis is radiopaque (ossified) while the epiphyses are still radiolucent (cartilaginous); in a growing child, the diaphysis and epiphyses are both radiopaque while the intervening epiphyseal plate remains a radiolucent line.
- ▶ **Accessory bones from non-fusion of an epiphysis:** os trigonum (unfused posterior talar tubercle), os vesalianum (unfused 5th metatarsal styloid epiphysis), and patella cubiti (unfused olecranon epiphysis) — clinically important as they may be mistaken for fracture fragments.
- ▶ **Achondroplasia:** defective endochondral (epiphyseal-plate) ossification produces disproportionate short-limbed dwarfism, while the membranous skeleton (skull vault, face) is unaffected.

High-yield exam pointers

- ▶ Four parts of a growing long bone: **epiphysis, epiphyseal plate, metaphysis, diaphysis.**
- ▶ Four types of epiphysis: **pressure, traction, aberrant, atavistic.**
- ▶ Epiphysis = secondary ossification centre; diaphysis = primary ossification centre.
- ▶ Four zones of the epiphyseal plate (epiphysis to diaphysis): **resting → proliferation → hypertrophy → calcification.**
- ▶ Four arteries supply a growing bone: **nutrient, periosteal, metaphyseal (juxta-epiphyseal), epiphyseal** — the last two arise from/near the peri-articular **circulus vasculosus.**

- ▶ Metaphysis is the commonest site of **osteomyelitis in children** (end-artery hairpin loops); rare in adults after fusion.
- ▶ Fusion begins at puberty, complete by **~25 years**; earlier in females.
- ▶ The **law of union of epiphyses is violated only by the fibula**.
- ▶ **Growing end** = later-fusing epiphysis = end opposite the nutrient foramen.

SOURCE & COVERAGE

Vishram Singh — General Anatomy, 4th ed. (primary source for types of epiphysis, ossification, epiphyseal plate zones and blood supply — Ch. 6, Skeletal System); Gray's Anatomy (Standring), 41st ed. (Ch. 5, Functional anatomy of the musculoskeletal system — spine text, cross-checked for blood supply and growth-arrest lines); IB Singh — Human Embryology (CBME 2021, for ossification of a typical long bone).



Arterial supply of long bones

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction Bone is a living, richly vascular connective tissue whose osteocytes, osteoblasts and marrow elements require a continuous blood supply for nutrition, growth, remodelling and repair. A growing long bone (e.g. femur, tibia, humerus) receives blood from **four constant sets of arteries** — the nutrient artery, periosteal arteries, metaphyseal (juxta-epiphyseal) arteries and epiphyseal arteries — each dedicated to a distinct zone (diaphysis, metaphysis, epiphysis). Their pattern changes after epiphyseal fusion, and this developmental difference explains why osteomyelitis and avascular necrosis show age-specific sites of predilection.

SOURCE & COVERAGE

Source	Origin	Course	Region supplied
Nutrient artery	A large branch of the main regional artery of the limb (e.g. 2nd perforating branch of profunda femoris for the femur; posterior tibial artery for the tibia)	Runs obliquely through a cortical nutrient canal/foramen into the medullary cavity; divides into ascending and descending medullary branches	Bone marrow, spongy bone, and the inner two-thirds of the compact bone of diaphysis and metaphysis
Periosteal arteries	Numerous small twigs from adjacent muscular and regional vessels	Ramify beneath muscular and ligamentous attachments and enter the periosteum at multiple points along the shaft	Outer one-third of the compact bone of the diaphysis
Metaphyseal (juxta-epiphyseal) arteries	Derived from neighbouring (peri-articular) arteries	Enter the metaphysis directly, together with the attachment of the joint capsule	Metaphysis; anastomose with nutrient-artery loops
Epiphyseal arteries	Derived from the peri-articular anastomosis around the joint (circulus vasculosus)	Enter the epiphysis directly, or after piercing the epiphyseal (growth) cartilage	Epiphysis, and (via the growth plate) the germinal/proliferative zones of the physis

Nutrient artery — origin, course and direction

- Usually a **single** artery per long bone; it is the chief artery of the shaft.
- Enters at (or near) the middle of the diaphysis through the **nutrient foramen**, runs obliquely through the cortex (the **nutrient canal**), and divides in the medullary cavity into **ascending and descending branches** that run toward each end.
- These branches supply the **bone marrow**, the **spongy bone**, and the **inner two-thirds** of the compact bone; near the metaphysis they form fine hairpin loops that anastomose with the metaphyseal, epiphyseal and periosteal systems, making the **metaphysis the most vascular zone** of a growing long bone.

- ▶ **Direction of obliquity:** the canal is always directed away from the more actively growing (usually the "away-from-elbow, toward-the-knee") end — the classic dictum "to the elbow I go, from the knee I flee." Exception: the fibula, where the foramen points toward the growing (upper) end.
- ▶ **Named examples:** femur — usually the 2nd perforating branch of the profunda femoris artery; tibia — **nutrient artery of the tibia is the largest nutrient artery in the body**, arising from the posterior tibial artery.
- ▶ The nutrient artery is **tortuous just before entering the foramen**, a safety loop that protects it from stretching during bone movement.

Periosteal arteries

- ▶ Numerous small vessels arising from the overlying muscular/regional arteries; they ramify beneath the attachments of muscles, tendons and ligaments before penetrating the periosteum.
- ▶ Supply the **outer one-third of the compact bone** of the shaft by a fine network of cortical (Volkmann's canal) channels that connect with the Haversian systems.
- ▶ Because the periosteum also carries the osteogenic (cambium) layer, periosteal vessels are critical for **appositional growth, remodelling and fracture repair**, especially when the medullary supply is compromised.

Metaphyseal and epiphyseal arteries — the growing-end pattern

- ▶ **Metaphyseal (juxta-epiphyseal) arteries** arise from vessels adjacent to the joint capsule and enter the metaphysis directly; together with the terminal hairpin loops of the nutrient artery they make the metaphysis extremely vascular.
- ▶ **Epiphyseal arteries** arise from the peri-articular arterial ring (**circulus vasculosus**) and enter the epiphysis either directly or after piercing the epiphyseal cartilage; they nourish the ossific nucleus of the epiphysis and the germinal zone of the growth plate.
- ▶ **Before epiphyseal fusion:** the epiphyseal cartilage (growth plate) is an effective barrier, so metaphyseal and epiphyseal vessels remain functionally separate, terminal (**end arteries**) with sluggish, hairpin-bend flow in the metaphysis — the reason paediatric osteomyelitis characteristically begins in the **metaphysis**, where circulating bacteria/emboli are trapped in the loops.
- ▶ **After epiphyseal fusion:** free communications are established between the epiphyseal and metaphyseal arteries across the former growth-plate site, so the metaphysis is **no longer supplied by end arteries** in the adult — hence adult osteomyelitis of this region is comparatively rare.
- ▶ **Anastomotic reserve:** communication between the nutrient artery and periosteal vessels is normally meagre, but the **metaphyseal twigs of the peri-articular (epiphyseal) arteries anastomose freely with the metaphyseal branches of the nutrient artery**; consequently, if a fracture tears the nutrient artery, the distal fragment can still be nourished by these peri-articular/periosteal collaterals.

Variant pattern in "short" long bones

- ▶ In short long bones (metacarpals, metatarsals, phalanges) the nutrient artery enters near the middle of the shaft but **immediately divides into a plexus** rather than giving discrete long

ascending/descending branches — so infection here classically begins **in the middle of the shaft**, not at the metaphysis, and a diaphyseal sequestrum is less likely to be devascularised completely because collateral flow from this plexus persists.

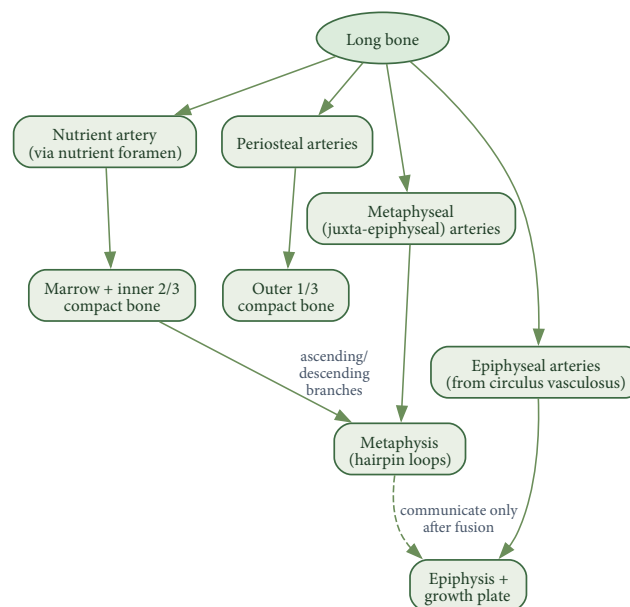
DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 6.10 — Blood supply to a growing long bone. (Vishram Singh — General Anatomy — 4e, p.250)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Longitudinal section of a growing long bone (e.g. upper end of femur/tibia) labelled with:

- ▶ Epiphysis with its ossific nucleus
- ▶ Epiphyseal (growth) cartilage/plate
- ▶ Metaphysis
- ▶ Diaphysis
- ▶ Nutrient foramen/canal with the **nutrient artery** entering obliquely and dividing into **ascending and descending medullary branches**
- ▶ Periosteal arteries entering the cortex along the shaft
- ▶ Metaphyseal (juxta-epiphyseal) arteries entering beside the capsular attachment
- ▶ Epiphyseal arteries arising from the peri-articular **circulus vasculosus** and entering the epiphysis
- ▶ Hairpin capillary loops at the metaphysis where nutrient, metaphyseal and epiphyseal systems anastomose



Arterial supply of long bones

Applied / Clinical anatomy

- ▶ **Direction of the nutrient foramen** is surgically important: osteotomies, plating and intramedullary nailing are planned to avoid transecting the nutrient artery near its oblique canal, since the artery is tortuous and easily injured close to the foramen.
- ▶ **Paediatric acute haematogenous osteomyelitis** localises to the **metaphysis** because of its slow, hairpin-loop, end-arterial circulation before growth-plate fusion; **short long bones** (metacarpals/phalanges) instead show mid-shaft onset because their nutrient artery divides immediately into a plexus.
- ▶ **Fracture and nutrient-artery injury**: when a fracture disrupts the nutrient artery, the bone is not necessarily devascularised — collateral flow through periosteal and metaphyseal/articular anastomoses can sustain viability and union.
- ▶ **Avascular necrosis (AVN)** occurs where the terminal blood supply is precarious:
 - **Neck/head of femur** — the intracapsular head and neck are largely dependent on **retinacular branches of the medial circumflex femoral artery** (running along the retinacula to enter as **lateral epiphyseal arteries**, supplying most of the adult head) together with a smaller **acetabular branch of the obturator artery** running with the **ligamentum teres** as the **medial epiphyseal (foveal) artery**. A displaced **subcapital (intracapsular) fracture of the femoral neck** tears the retinacular vessels, producing AVN and non-union of the femoral head in the elderly; the same vascular fragility underlies **Perthes disease** (idiopathic AVN of the femoral head in childhood).
 - **Scaphoid** — its own blood supply enters predominantly through the **distal** pole, so a fracture through the waist can devascularise the **proximal fragment**, causing AVN and non-union.
- ▶ **Radiological correlate**: in a growing child's radiograph, the metaphysis/diaphysis appears radio-opaque while the cartilaginous, avascular-appearing epiphyseal plate is radiolucent — trauma across this plate (growth-plate/Salter-Harris-type injury) can damage the epiphyseal vessels and cause limb shortening or angular deformity.
- ▶ **Venous drainage** runs parallel via periosteal and nutrient veins, with major outflow through large emissary veins near the bone ends into adjacent regional veins.

High-yield exam pointers

- ▶ Four arterial sources: **nutrient, periosteal, metaphyseal (juxta-epiphyseal), epiphyseal**.
- ▶ Nutrient artery → inner 2/3 of cortex + marrow; periosteal → outer 1/3 of cortex.
- ▶ Direction of nutrient foramen: away from the more actively growing end — "to the elbow I go, from the knee I flee"; exception — fibula (directed toward the growing end).
- ▶ Tibia has the **largest nutrient artery in the body**.
- ▶ Metaphysis = most vascular zone; before fusion its vessels are **end arteries** with hairpin loops → site of childhood osteomyelitis; after fusion, epiphyseal–metaphyseal communication is established → adult osteomyelitis here is rare.
- ▶ Short long bones (metacarpals/phalanges): nutrient artery divides immediately into a plexus at mid-shaft.

- ▶ Torn nutrient artery in a fracture → collateral supply via periosteal/articular (metaphyseal) anastomoses.
- ▶ Clinical AVN examples: subcapital femoral neck fracture / Perthes disease (retinacular + foveal arteries of femoral head); scaphoid waist fracture (proximal-pole AVN).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; IB Singh — Textbook of Anatomy Vol 1, 6e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb).



Blood supply of long bones

Asked in: Paper I May 2018 — RGUHS MD/MS Anatomy

Definition / Introduction A long bone (e.g. femur, tibia, humerus) consists of a tubular **diaphysis** (shaft) of compact bone enclosing a medullary cavity, and two expanded, cancellous **epiphyses** capped by articular cartilage, separated in the growing bone by the **epiphyseal (growth) plate** and its adjoining **metaphysis**. Bone is a living, richly vascular tissue, and its blood supply is organised regionally to match this structure. In the **growing (immature) long bone** four sets of vessels are described — the **nutrient artery**, **periosteal arteries**, **metaphyseal (juxta-epiphyseal) arteries**, and **epiphyseal arteries** — whose pattern of anastomosis changes fundamentally once the epiphysis fuses with the diaphysis. This vascular arrangement explains the clinical predilection of metaphyseal osteomyelitis for children, the rarity of the same in adults, and the vulnerability of certain bones to avascular necrosis and delayed union.

SOURCE & COVERAGE

Artery	Origin	Course / point of entry	Area supplied
Nutrient artery	A single named branch of a nearby systemic artery	Enters obliquely through the nutrient foramen near the middle of the shaft; divides into ascending and descending branches in the medullary cavity	Bone marrow of the medullary cavity + inner two-thirds of the compact bone of diaphysis and metaphysis
Periosteal arteries	Numerous small twigs from arteries of neighbouring muscles	Ramify beneath the periosteum; enter the cortex through Volkman's canals ; especially dense beneath muscular and ligamentous attachments	Outer one-third of the cortex
Metaphyseal (juxta-epiphyseal) arteries	Branches of neighbouring (peri-articular) systemic arteries	Enter the metaphysis directly, alongside the attachment of the joint capsule	Metaphysis
Epiphyseal arteries	Arterial anastomosis around the joint — the circulus vasculosus	Enter the epiphysis directly, or after piercing the epiphyseal cartilage	Epiphysis and the epiphyseal (growth) plate

- The terminal parallel branches of the nutrient artery subdivide repeatedly and, on reaching the metaphysis, turn back on themselves as **hairpin loops**; these loops anastomose with the metaphyseal, epiphyseal and periosteal arteries, making the **metaphysis the most vascular region of a long bone**.
- The epiphyseal plate/cartilage is nourished by **both** epiphyseal and metaphyseal arteries.

□ Fig 6.10 — Blood supply to a growing long bone (Vishram Singh — General Anatomy — 4e, p.250)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A longitudinal section of a growing long bone (e.g. upper end of tibia/femur), labelled with:

- ▶ **Epiphysis** (upper and lower) with articular cartilage
- ▶ **Epiphyseal artery** — looping around the epiphysis from the periarticular anastomosis (circulus vasculosus)
- ▶ **Epiphyseal plate** — between epiphysis and metaphysis
- ▶ **Metaphyseal artery** — entering the metaphysis directly from neighbouring vessels
- ▶ **Periosteal arteries** — multiple short vessels entering the shaft obliquely along its length
- ▶ **Nutrient artery** — entering through the **nutrient foramen** at mid-shaft, dividing into ascending and descending branches in the medullary cavity
- ▶ **Hairpin anastomotic loops** at the metaphysis where nutrient, metaphyseal, epiphyseal and periosteal branches meet

The nutrient artery

- ▶ Enters the shaft through the **nutrient foramen**, situated near the middle of the diaphysis, and runs **obliquely** through the cortex before opening into the medullary cavity.
- ▶ Divides into **ascending and descending branches**, each of which subdivides into several smaller parallel vessels running toward the two ends of the bone; near the metaphysis these form the hairpin loops described above.
- ▶ Supplies the **bone marrow** of the medullary cavity and the **inner two-thirds** of the compact bone of the diaphysis and metaphysis.
- ▶ **Direction/mnemonic:** the oblique direction of the nutrient foramen (and hence the nutrient artery) is **opposite the growing end** of the bone — remembered by the dictum "*to the elbow I go, from the knee I flee*" — so that in the upper limb the shoulder end of the humerus and the wrist ends of the radius/ulna are the growing ends, while in the lower limb the knee ends of the femur, tibia and fibula are the growing ends. The **fibula is the sole exception**, its nutrient foramen being directed *toward* its growing end.
- ▶ The nutrient artery is **tortuous** just before entering the foramen, a safeguard against traction injury during movements of the bone.
- ▶ The **nutrient artery of the tibia is the largest nutrient artery in the body**.

Periosteal arteries

- ▶ Numerous fine vessels arising from the arteries of overlying muscles; they ramify in a plexus beneath the periosteum and send branches into the cortex through **Volkman's canals**.
- ▶ Supply the **outer one-third** of the compact bone, complementing the inner two-thirds supplied by the nutrient artery.
- ▶ Are most abundant beneath sites of **muscular and ligamentous attachment**, where periosteal and muscular vascular plexuses become confluent.

- Provide the principal blood supply for **new bone formation during fracture repair and remodelling**, since the deep, osteogenic layer of periosteum (with its osteoprogenitor cells and osteoblasts) depends on this plexus.

Metaphyseal and epiphyseal arteries — the growth-plate circulation

- **Metaphyseal (juxta-epiphyseal) arteries** arise from neighbouring systemic vessels and enter the metaphysis directly, travelling with the attachment of the joint capsule.
- **Epiphyseal arteries** arise from the peri-articular anastomotic network around the joint (**circulus vasculosus**) and enter the epiphysis either directly or by piercing the epiphyseal cartilage.
- **Before epiphyseal fusion**, the epiphyseal and metaphyseal arteries enter the growth cartilage from opposite sides and **rarely anastomose with each other across it** — each therefore behaves as a functional **end artery** within its own zone, forming hairpin/blind-ended loops close to the advancing zone of ossification.
- **After epiphyseal fusion**, free communications are established between the epiphyseal and metaphyseal systems, so the metaphysis of the adult bone **no longer contains end arteries**.
- This single fact underlies the classic clinico-anatomical correlation of **osteomyelitis**: in children, bacteria and septic emboli become trapped in the sluggish hairpin loops of the richly vascular but end-arterial metaphysis, producing infarction and metaphyseal osteomyelitis; in adults, the same region is protected by free epiphyseal–metaphyseal anastomoses, so metaphyseal osteomyelitis is comparatively rare.

Blood supply of the mature (adult) long bone

- Once growth is complete, the epiphyseal and metaphyseal arterial supply remains **richer than the diaphyseal supply**.
- The large nutrient arteries of the epiphysis form numerous **intraosseous anastomoses**, their branches running through the trabecular spaces toward the articular surface; near the articular cartilage these vessels form **serial anastomotic arcades** (for example, three or four such arcades are described in the head of the femur), which give off **end-arterial loops**. These loops often pierce the thin subchondral compact bone to enter — and sometimes traverse — the calcified zone of the articular cartilage before draining back into the epiphyseal venous sinusoids.
- Within the diaphysis, **medullary (nutrient) arteries** give centripetal branches that feed a hexagonal mesh of medullary sinusoids draining into a wide central venous sinus, and cortical branches that pass through endosteal canals to feed the fenestrated capillaries of the Haversian systems; these cortical capillaries run longitudinally with oblique cross-links via **Volkman's canals**.
- There is also a **centripetal flow from periosteal vessels** into the outer cortical zones: cortical capillaries make capillary/venous connections at the bone surface with the **periosteal plexus**, which is formed by branches of neighbouring muscular arteries and permeates the deep osteogenic layer of periosteum.
- **Venous drainage** largely retraces the arteries — a large central venous sinus in the medullary cavity draining via veins that follow the path of the nutrient artery (occasionally piercing the shaft independently as emissary veins), together with venae comitantes of the periosteal vessels

running in Volkmann's canals. There are **no lymphatics within bone**; a few lymphatics accompany the periosteal vessels and drain to regional nodes.

Applied / Clinical anatomy

- ▶ **Metaphyseal osteomyelitis (children):** the end-arterial hairpin loops of the metaphysis trap circulating bacteria/emboli, producing infarction and the classical metaphyseal localisation of acute haematogenous osteomyelitis in growing bone; the same site is relatively immune in adults once epiphyseal–metaphyseal anastomoses are established.
- ▶ **Fracture repair and periosteum:** because the periosteal plexus provides the vessels of new bone (callus) formation, a fragment of bone stripped of its periosteum loses its capacity to survive and repair — the anatomical basis for careful periosteal preservation in fracture surgery and grafting.
- ▶ **Endosteal vessel vulnerability:** the endosteal (medullary) vessels are at particular risk during **intramedullary nailing**, since a metal implant passed into the medullary canal can damage them; the rich periosteal collateral supply, however, generally prevents this alone from causing bone death — a single metal pin does not interrupt the blood supply enough to kill the bone.
- ▶ **Regional vulnerability to delayed/non-union:** bones or regions relatively dependent on a single nutrient artery with sparse periosteal collaterals (classically the junction of the middle and lower thirds of the tibia, a subcutaneous surface with poor muscular/periosteal cover) are prone to delayed or non-union after fracture.
- ▶ **Avascular necrosis:** disruption of the retinacular/epiphyseal vessels supplying an epiphysis — the classic example being intracapsular fracture of the femoral neck compromising the retinacular branches to the femoral head — leads to avascular necrosis, directly illustrating the clinical importance of the epiphyseal (circulus vasculosus) supply described above.
- ▶ **Bone marrow biopsy/graft harvesting and vascularised grafts** exploit the same vascular anatomy — cancellous, richly vascular metaphyseal/epiphyseal bone is preferred for biopsy and incorporates faster as a graft than avascular cortical bone.

High-yield exam pointers

- ▶ **Four arteries** supply a growing long bone: nutrient, periosteal, metaphyseal (juxta-epiphyseal), and epiphyseal.
- ▶ Nutrient artery → inner $\frac{2}{3}$ of cortex + marrow; periosteal arteries → outer $\frac{1}{3}$ of cortex (via Volkmann's canals).
- ▶ **Metaphysis = most vascular zone** of a long bone (hairpin-loop anastomoses of all four sources).
- ▶ Before fusion: epiphyseal/metaphyseal vessels are **end arteries** (no cross-anastomosis) → after fusion, they freely communicate.
- ▶ **Osteomyelitis** is classically **metaphyseal in children**, rare in the metaphysis of adults — direct consequence of the end-artery-to-anastomosis switch at fusion.
- ▶ Mnemonic for nutrient-foramen direction: *"To the elbow I go, from the knee I flee"* — foramen/artery points away from the growing end; fibula is the exception.
- ▶ **Nutrient artery of the tibia = largest nutrient artery in the body.**
- ▶ Adult epiphysis: 3–4 **anastomotic arcades** near the articular surface (e.g. femoral head), giving end-arterial loops into subchondral bone.

- No lymphatics inside bone; periosteal lymphatics only. Venous drainage mirrors the arterial pattern (central sinus + Volkmann's venae comitantes).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy, 4e; IB Singh — Textbook of Anatomy Vol 1, 6e; Ross Histology — A Text and Atlas, 7e; Moore's Clinically Oriented Anatomy, 9e.



Blood supply of the long bones

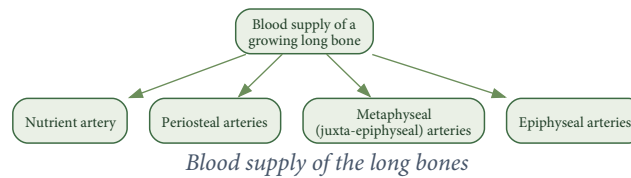
Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction

Bone is a highly vascular connective tissue, and its rich, redundant blood supply underlies its capacity for growth, remodelling and repair. A typical long bone (e.g. femur, tibia, humerus) receives blood from **four sets of arteries** — the nutrient artery, periosteal arteries, metaphyseal (juxta-epiphyseal) arteries and epiphyseal arteries — which anastomose extensively at the metaphysis, making it the most vascular zone of the bone. The pattern differs in the growing bone, where the epiphyseal cartilage keeps epiphyseal and metaphyseal systems functionally separate (end-arteries), and in the adult, where fusion establishes free communication between them. Understanding this supply explains the classic sites of childhood osteomyelitis and adult avascular necrosis.

1. Overview of the four arterial sources

Artery	Origin	Site / mode of entry	Area supplied
Nutrient artery	One or two branches from a neighbouring systemic artery	Nutrient foramen near mid-shaft, running obliquely through the cortex into the medullary cavity	Bone marrow (medullary cavity) + inner two-thirds of the cortex of diaphysis and metaphysis
Periosteal arteries	Numerous small twigs from vessels of overlying muscles and ligaments	Beneath the periosteum, entering cortex via Volkmann's canals	Outer one-third of the cortex
Metaphyseal (juxta-epiphyseal) arteries	Direct branches of neighbouring systemic vessels	Enter the metaphysis directly, along with the attachment of the joint capsule	Metaphysis
Epiphyseal arteries	Peri-articular vascular arcade (<i>circulus vasculosus</i>) formed by anastomoses around the joint	Enter the epiphysis directly, or after piercing the epiphyseal cartilage	Epiphysis; together with metaphyseal vessels, also nourish the epiphyseal (growth) plate



2. The nutrient artery

- ▶ Usually **one or two** nutrient arteries pierce the shaft; sites and angulation of entry are fairly constant for each bone.
- ▶ The nutrient foramen is directed **obliquely**, and is characteristically pointed **away from the growing (more actively growing) end** of the bone — the classic mnemonic is "*To the elbow I go, from the knee I flee*": in the upper limb the growing ends are at the shoulder (upper humerus) and wrist (lower radius/ulna), so nutrient foramina point towards the elbow; in the lower limb the growing ends are at the knee (lower femur, upper tibia/fibula), so foramina point away from the knee. The **fibula is the exception** — its nutrient foramen points *towards* its growing end.
- ▶ Within the medullary cavity the nutrient artery does **not** branch inside its own canal; instead it divides into **ascending and descending branches**, which subdivide further into small parallel vessels that run towards each metaphysis and end in **hairpin loops**. These loops anastomose with the epiphyseal, metaphyseal and periosteal arteries — hence the metaphysis is the most vascular part of the bone.
- ▶ The nutrient artery supplies the **medullary cavity (bone marrow)** and the **inner two-thirds** of the cortical (compact) bone of the diaphysis and metaphysis; blood flow through this cortical supply is essentially **centrifugal** (medulla → periphery).
- ▶ The **nutrient artery of the tibia is the largest nutrient artery in the body**.
- ▶ The vessel is tortuous just before it enters the foramen, which protects it from being stretched or torn during the movements and growth of the bone.

3. Periosteal arteries

- ▶ Numerous fine vessels arising from the arteries of neighbouring muscles and ligaments; they form vascular arcades with longitudinal links in the fibrous periosteum before penetrating the cortex through **Volkman's canals**.
- ▶ They are especially profuse **beneath sites of muscular and ligamentous attachment**.
- ▶ They supply the **outer one-third of the cortex**, providing a centripetal flow that supplements the centrifugal supply from the nutrient artery.
- ▶ The periosteum's osteogenic inner layer and its vascularity give it a key regenerative role — bone stripped of periosteum loses its capacity to survive/repair, which is why periosteal preservation matters in fracture surgery and bone grafting.

4. Metaphyseal and epiphyseal arteries

- ▶ **Metaphyseal (juxta-epiphyseal) arteries** are direct branches of nearby systemic arteries; they enter the metaphysis directly, travelling in with the attachment of the joint capsule.
- ▶ **Epiphyseal arteries** arise from the peri-articular anastomotic ring around the joint, the **circulus vasculosus**; they reach the epiphysis either directly or by piercing the epiphyseal (growth)

cartilage. Near the articular surface they form serial anastomotic arcades (three or four are described in the femoral head) that give off end-arterial loops, some of which pierce thin subchondral bone to enter the calcified zone of the articular cartilage before draining back into epiphyseal venous sinusoids.

- ▶ The **epiphyseal plate (growth cartilage)** itself is nourished by **both** epiphyseal and metaphyseal vessels; growth cartilage canals occasionally carry blood vessels directly into the plate.

5. Growing bone vs mature bone — the "end-artery" concept

- ▶ In the **growing long bone**, the epiphyseal cartilage physically separates the epiphyseal and metaphyseal vascular territories. Epiphyseal and metaphyseal arteries enter on either side of this cartilage and **rarely, if ever, anastomose directly across it** — i.e., before fusion they behave as **end arteries** forming characteristic hairpin bends at the metaphysis.
- ▶ This sluggish, end-arterial hairpin circulation is why the **metaphysis is the classic site of haematogenous osteomyelitis in children** — circulating bacteria and septic emboli are readily trapped in the hairpin loops, causing local infarction/necrosis of bone.
- ▶ After **epiphyseal fusion** (bony union of epiphysis with diaphysis), free communications are established between the erstwhile epiphyseal and metaphyseal arteries; the metaphysis therefore **no longer contains end arteries**, which is why metaphyseal osteomyelitis is rare in adults.
- ▶ Young periosteum is also more vascular than adult periosteum, communicating more freely with the shaft vessels and giving off more metaphyseal branches — another reason growing bone heals and remodels faster than mature bone.

6. Venous drainage and lymphatics

- ▶ Medullary (nutrient) arteries give centripetal branches feeding a hexagonal mesh of **medullary sinusoids**, which drain into a wide, thin-walled **central venous sinus**.
- ▶ The central sinus drains through veins that largely retrace the path of the nutrient artery (**nutrient veins**), sometimes leaving the shaft independently as **emissary veins**.
- ▶ In compact bone, veins accompany the arteries within **Volkman's canals**; at the surface, cortical capillaries make venous connections with the **periosteal venous plexus**.
- ▶ Veins are more numerous in cancellous (spongy) bone than in compact bone.
- ▶ **There are no lymphatic vessels within bone tissue itself**; a few lymphatics accompany the periosteal blood vessels and drain into regional lymph nodes.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 6.10 — Blood supply to a growing long bone. (Vishram Singh — General Anatomy — 4e, p.250)

Reproduce a longitudinal section of a growing long bone and label:

- ▶ **Epiphysis** with its articular cartilage
- ▶ **Epiphyseal (growth) plate/cartilage** between epiphysis and metaphysis
- ▶ **Metaphysis** — show the **hairpin-loop anastomoses** here (nutrient + periosteal + metaphyseal + epiphyseal vessels converging)
- ▶ **Diaphysis (shaft)** with the **medullary cavity**
- ▶ **Nutrient foramen** and **nutrient artery** entering obliquely, with its **ascending and descending branches** running in the medullary cavity
- ▶ **Periosteum** with **periosteal arteries** entering the cortex via **Volkman's canals**
- ▶ **Metaphyseal (juxta-epiphyseal) artery** entering directly with the joint capsule
- ▶ **Epiphyseal artery** arising from the peri-articular **circulus vasculosus**
- ▶ Arrows showing **centrifugal** flow from medulla through cortex (nutrient supply) and **centripetal** flow from periosteum inward (periosteal supply)

Applied / Clinical anatomy

- ▶ **Osteomyelitis in children** localises to the metaphysis because of its rich but end-arterial, hairpin-loop circulation, which traps circulating bacteria/emboli and predisposes to infarction; in adults, once epiphyseal–metaphyseal anastomoses are established, metaphyseal osteomyelitis is rare.
- ▶ **Avascular necrosis (AVN) of the femoral head** after an intracapsular fracture of the neck of femur: the head and most of the neck are supplied by **retinacular arteries** arising from an arterial circle formed by the **medial and lateral circumflex femoral arteries** at the capsular attachment on the neck; a displaced intracapsular fracture tears these retinacular vessels. Only a small area near the fovea capitis (supplied via acetabular branches of the obturator and medial circumflex femoral arteries, through the ligamentum teres) may escape, so the femoral head is highly prone to AVN.
- ▶ **Scaphoid (waist) fracture**: the proximal fragment depends on a retrograde blood supply, so union is slow (at least 3 months) and the proximal pole is prone to avascular necrosis, leading to degenerative wrist disease if unrecognised.
- ▶ **Fracture of the neck of the talus** similarly risks AVN of the head/body of the talus, again due to a precarious, largely retrograde vascular pattern.
- ▶ **Intramedullary nailing**: the endosteal (medullary) vessels are damaged by reaming and nail insertion; the periosteal supply becomes relatively more important for healing in such fractures.
- ▶ The rich collateral supply of bone means a metal pin passing through it does not interrupt flow enough to kill the bone — but stripping the periosteum during surgery (or in open/comminuted fractures) removes the outer one-third cortical supply and can cause bone necrosis and delayed/non-union.

- ▶ The **direction of the nutrient foramen** is used to identify the growing end of an isolated long bone (useful in forensic/age-estimation contexts) and helps predict the pattern of fracture healing/deformity relative to the growth plate.

High-yield exam pointers

- ▶ Four sources: **nutrient, periosteal, metaphyseal (juxta-epiphyseal), epiphyseal** arteries.
- ▶ Nutrient artery → inner two-thirds of cortex + marrow (centrifugal flow); periosteal arteries → outer one-third of cortex (via Volkmann's canals).
- ▶ Metaphysis = most vascular zone (site of anastomosis of all four sources).
- ▶ Before epiphyseal fusion: epiphyseal/metaphyseal vessels are **end arteries** (hairpin loops) → basis of childhood metaphyseal osteomyelitis. After fusion: anastomoses established → adults rarely get metaphyseal osteomyelitis.
- ▶ Epiphyseal arteries arise from the **circulus vasculosus** (peri-articular anastomosis); epiphyseal plate nourished by both epiphyseal and metaphyseal vessels.
- ▶ Mnemonic for nutrient foramen direction: *"To the elbow I go, from the knee I flee"* — foramen points away from the growing end (fibula is the exception).
- ▶ Nutrient artery of the **tibia** is the largest in the body.
- ▶ No lymphatics inside bone — only in periosteum.
- ▶ Clinical hooks: AVN of femoral head (retinacular arteries torn in intracapsular neck-of-femur fracture), scaphoid waist fracture, talar neck fracture — all due to retrograde/precarious terminal blood supply.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (primary account of the four arterial sources, nutrient-foramen direction rule, and the growing-bone end-artery concept); Gray's Anatomy (Standring) 41e (neurovascular supply of bone — centrifugal/centripetal cortical flow, medullary sinusoids and central venous sinus, peri-articular anastomotic arcades, absence of intraosseous lymphatics); Ross Histology — A Text and Atlas 7e (adult long-bone blood supply diagram, centrifugal flow, Volkmann's/Haversian routes); IB Singh — Textbook of Anatomy Vol 1 6e and BD Chaurasia — Human Anatomy Vol 2 8e (retinacular arteries and hip joint blood supply, scaphoid and talar avascular necrosis).



Blood supply to long bones

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

Definition / Introduction A long bone (e.g. femur, humerus, tibia) has a tubular **diaphysis** (shaft) of compact bone enclosing a medullary cavity, and two expanded, cancellous **epiphyses** covered by articular cartilage. In the growing bone the epiphysis is separated from the diaphysis by the **epiphyseal (growth) plate**, the adjoining part of the diaphysis being the **metaphysis**. Bone is a living, richly vascularised tissue, and this basic architecture dictates its vascular pattern: a **growing (immature) long bone** is supplied by four distinct sets of vessels — nutrient, periosteal, metaphyseal (juxta-epiphyseal) and epiphyseal arteries — whose interconnections change fundamentally once the epiphysis fuses with the diaphysis. This single vascular fact underlies several classic clinical correlations: the metaphyseal predilection of osteomyelitis in children, its rarity in the same site in adults, and the vulnerability of certain epiphyses to avascular necrosis after fracture.

Overview — the four vascular systems of a growing long bone

Artery	Origin	Point of entry / course	Region supplied
Nutrient artery	A single named branch of a neighbouring systemic artery	Enters obliquely through the nutrient foramen near the middle of the shaft; divides into ascending and descending branches in the medullary cavity	Bone marrow of the medullary cavity + inner two-thirds of the compact bone of diaphysis and metaphysis
Periosteal arteries	Numerous small twigs from arteries of overlying muscles	Ramify in a plexus beneath the periosteum; enter the cortex through Volkman's canals ; densest beneath muscular/ligamentous attachments	Outer one-third of the cortex
Metaphyseal (juxta-epiphyseal) arteries	Branches of neighbouring peri-articular systemic arteries	Enter the metaphysis directly, alongside the joint-capsule attachment	Metaphysis
Epiphyseal arteries	Peri-articular arterial anastomosis — the circulus vasculosus	Enter the epiphysis directly, or after piercing the epiphyseal cartilage	Epiphysis and epiphyseal plate

- Near the metaphysis the parallel branches of the nutrient artery turn back on themselves as **hairpin loops**, which anastomose with the metaphyseal, epiphyseal and periosteal systems — making the **metaphysis the most vascular zone of a long bone**.
- The epiphyseal (growth) plate/cartilage is nourished by **both** the epiphyseal and metaphyseal arteries.

The nutrient artery

- ▶ Enters near the **middle of the shaft** through the **nutrient foramen**, runs **obliquely** through the cortex, and then divides in the medullary cavity into an **ascending and a descending branch**.
- ▶ Each branch subdivides into several smaller parallel vessels that run toward the two ends of the bone; on approaching the metaphysis these form the hairpin loops described above.
- ▶ Supplies the **bone marrow** and the **inner two-thirds** of the compact bone of the diaphysis and metaphysis; the outer third is left to the periosteal system.
- ▶ **Direction rule:** the oblique course of the nutrient foramen (and therefore the nutrient artery) is always **directed away from the growing end** of the bone — summarised by the dictum "*to the elbow I go, from the knee I flee*". Thus the shoulder end of the humerus and the wrist ends of the radius and ulna are growing ends in the upper limb, while the knee ends of the femur, tibia and fibula are the growing ends in the lower limb. The **fibula alone is an exception** — its nutrient foramen points *toward* its growing (upper) end.
- ▶ The nutrient artery is **tortuous** just before it enters the foramen, which protects it from traction during movements of the bone.
- ▶ The **nutrient artery of the tibia is the largest nutrient artery in the body**.
- ▶ In **short long bones** (e.g. metacarpals, phalanges) the nutrient artery enters mid-shaft but divides immediately into a plexus, and the periosteal vessels take over as the dominant supply in adult life.

Periosteal, metaphyseal and epiphyseal arteries

□ Fig 6.10 — Blood supply to a growing long bone (Vishram Singh — General Anatomy — 4e, p.250)

- ▶ **Periosteal arteries** are numerous fine vessels derived from the arteries of overlying muscles; they form a plexus beneath the periosteum and send branches into the cortex through **Volkman's canals**, supplying the outer one-third of the compact bone. They are especially profuse where muscles and ligaments attach, and this same plexus is the principal source of new bone (callus) during **fracture repair**, since the deep osteogenic layer of periosteum depends on it.
- ▶ **Metaphyseal (juxta-epiphyseal) arteries** are direct branches of neighbouring systemic vessels; they enter the metaphysis together with the attachment of the joint capsule.
- ▶ **Epiphyseal arteries** arise from the peri-articular anastomotic network around the joint — the **circulus vasculosus** — and enter the epiphysis either directly or by piercing the epiphyseal cartilage.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A longitudinal section through the upper end of a growing long bone (femur/tibia), labelled with:

- ▶ **Epiphysis**, capped by articular cartilage
- ▶ **Epiphyseal artery** — looping into the epiphysis from the peri-articular circulus vasculosus
- ▶ **Epiphyseal (growth) plate** — between epiphysis and metaphysis
- ▶ **Metaphyseal (juxta-epiphyseal) artery** — entering the metaphysis directly with the joint-capsule attachment
- ▶ **Periosteal arteries** — multiple short oblique vessels entering the shaft along its length, via Volkmann's canals
- ▶ **Nutrient artery** — entering through the **nutrient foramen** at mid-shaft, then dividing into **ascending and descending branches** within the medullary cavity
- ▶ **Hairpin anastomotic loops** at the metaphysis, where nutrient, metaphyseal, epiphyseal and periosteal branches meet
- ▶ Label the **direction of the nutrient foramen** with an arrow pointing away from the growing (epiphyseal) end

End-arterial pattern at the metaphysis and its clinical basis

- ▶ **Before epiphyseal fusion**, the epiphyseal and metaphyseal arteries enter the growth cartilage from opposite sides and communicate with each other only through the terminal hairpin loops — they behave as **end arteries**, with sluggish, blind-ending anastomoses close to the zone of ossification.
- ▶ **After epiphyseal fusion**, free communications become established between the epiphyseal and metaphyseal systems, so the adult metaphysis **no longer contains end arteries**.
- ▶ This is the anatomical basis of **osteomyelitis**: in children, circulating bacteria and septic emboli are readily trapped in the sluggish end-arterial hairpin loops of the richly vascular metaphysis, producing infarction and the classical metaphyseal localisation of acute haematogenous osteomyelitis; in adults, the same region is protected once epiphyseal–metaphyseal anastomoses are freely established, so metaphyseal osteomyelitis there is comparatively rare.

Blood supply of the mature (adult) long bone

- ▶ Even after fusion, the **epiphyseal and metaphyseal supply remains richer than the diaphyseal supply**.
- ▶ The large nutrient arteries of the epiphysis form numerous **intraosseous anastomoses**; their branches run through the trabecular spaces toward the articular surface, where they form **serial anastomotic arcades** (three or four such arcades are described in the head of the femur) giving off **end-arterial loops**. These loops often pierce the thin subchondral compact bone and may traverse the calcified zone of articular cartilage before draining into the epiphyseal venous sinusoids.
- ▶ Within the diaphysis, **medullary (nutrient) arteries** give centripetal branches feeding a hexagonal mesh of **medullary sinusoids** that drain into a wide central venous sinus, plus cortical

branches passing through endosteal canals to feed the fenestrated capillaries of the Haversian systems; these cortical capillaries run longitudinally with oblique cross-connections via **Volkman's canals**.

- ▶ There is also a complementary **centripetal flow from periosteal vessels** into the outer cortex: at the bone surface, cortical capillaries connect with the periosteal plexus formed by branches of neighbouring muscular arteries.
- ▶ **Venous drainage** largely retraces the arterial pattern — the central medullary venous sinus drains through veins that follow the nutrient artery (sometimes piercing the shaft independently as emissary veins), together with venae comitantes of the periosteal vessels in the Volkman's canals.
- ▶ **There are no lymphatics within bone**; a few lymphatic vessels merely accompany the periosteal blood vessels and drain to regional nodes.

Applied / Clinical anatomy

- ▶ **Metaphyseal osteomyelitis in children**: end-arterial hairpin loops of the metaphysis trap circulating bacteria/emboli, producing infarction and the classical metaphyseal localisation of acute haematogenous osteomyelitis; the same site is relatively protected in adults once free epiphyseal–metaphyseal anastomoses form.
- ▶ **Periosteum and fracture healing**: since the periosteal plexus is the source of new bone (callus) at a fracture site, stripping the periosteum from a fragment compromises its capacity to heal. Where periosteum is normally absent — as within the joint capsule over the neck of the femur — fractures heal slowly for the same reason.
- ▶ **Avascular necrosis of the femoral head**: the intracapsular part of the neck of femur and most of the head are supplied by **retinacular arteries**, chiefly branches of the medial circumflex femoral artery via the trochanteric anastomosis; an intracapsular (subcapital/transcervical) fracture of the femoral neck tears these retinacular vessels, cutting off the epiphyseal supply and producing **avascular necrosis of the head of femur** — a direct clinical illustration of the epiphyseal (circulus vasculosus) blood supply described above.
- ▶ **Endosteal vessel vulnerability**: the endosteal (medullary) vessels are at risk during **intramedullary nailing**, where a metal implant passed into the medullary canal may damage them; however, the rich periosteal collateral supply is generally sufficient that a single metal pin does not interrupt the blood supply enough to kill the bone.
- ▶ **Bone grafting/biopsy**: the richly vascular, cancellous metaphyseal/epiphyseal bone is preferred for marrow biopsy and incorporates faster as a graft than relatively avascular compact cortical bone.

High-yield exam pointers

- ▶ Four arteries supply a growing long bone: **nutrient, periosteal, metaphyseal (juxta-epiphyseal), epiphyseal**.
- ▶ Nutrient artery → inner $\frac{2}{3}$ of cortex + medullary marrow; periosteal arteries → outer $\frac{1}{3}$ of cortex (via Volkman's canals).

- ▶ **Metaphysis = most vascular zone** of a long bone, owing to hairpin-loop anastomoses of all four sources.
- ▶ Before fusion: epiphyseal/metaphyseal vessels behave as **end arteries** → after fusion, they freely anastomose.
- ▶ **Osteomyelitis is classically metaphyseal in children**, rare in the same site in adults — a direct consequence of the end-artery-to-anastomosis switch at epiphyseal fusion.
- ▶ Direction mnemonic: *"To the elbow I go, from the knee I flee"* — the nutrient foramen/artery points away from the growing end; the fibula is the sole exception.
- ▶ **Nutrient artery of the tibia = largest nutrient artery in the body.**
- ▶ Adult epiphysis (e.g. femoral head): **3–4 anastomotic arcades** near the articular surface, giving subchondral end-arterial loops.
- ▶ **No lymphatics inside bone**; venous drainage mirrors the arterial pattern (central medullary sinus + Volkmann's venae comitantes).
- ▶ **Fracture neck of femur → retinacular artery injury → avascular necrosis of the femoral head** is the classic applied correlate of long-bone epiphyseal blood supply.

SOURCE & COVERAGE

Vishram Singh — General Anatomy, 4e; Gray's Anatomy (Standring) 41e; IB Singh — Textbook of Anatomy Vol 1, 6e; BD Chaurasia — Human Anatomy Vol 2, 8e; Ross Histology — A Text and Atlas, 7e; Moore's Clinically Oriented Anatomy, 9e.



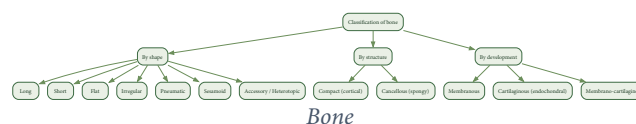
Bone

Asked in: Paper I Sep 2007 — RGUHS MD/MS Anatomy

Definition / Introduction Bone is a specialised, highly vascular connective tissue in which the intercellular matrix is mineralised, giving it rigidity combined with a degree of resilience. Structurally it consists of cells (osteoblasts, osteocytes, osteoclasts) embedded in an organic matrix (mainly type I collagen, one-third of dry weight) impregnated with inorganic salts (mainly hydroxyapatite, two-thirds of dry weight). Unlike the popular perception of bone as an inert scaffold, it is a living, richly innervated and vascularised tissue with the second-greatest regenerative capacity in the body after blood. The adult skeleton has approximately 206 bones (270 at birth, reduced by fusion), forming the rigid framework for support, protection of viscera, leverage for movement, hemopoiesis (marrow), and mineral homeostasis (95% of body phosphorus and the bulk of calcium reserves).

Classification of bones

Bones are classified in three complementary ways — by shape, by macroscopic structure, and by mode of development.



Shape	Features	Examples
Long	Length > breadth; diaphysis + 2 epiphyses; medullary cavity; ossify in cartilage	Humerus, femur, tibia (typical); metacarpals, phalanges (miniature — epiphysis at one end only)
Short	Cuboidal, six surfaces	Carpal, tarsal bones
Flat	Plate-like, form boundaries of a cavity	Cranial vault bones, scapula, sternum, ribs
Irregular	No definable shape	Vertebrae, hip bone, skull-base bones
Pneumatic	Irregular bones with air-filled paranasal sinuses (lighten skull, add vocal resonance)	Maxilla, frontal, sphenoid, ethmoid
Sesamoid	Seed-like nodules in tendons rubbing against convex bone; devoid of periosteum; lack Haversian system; ossify postnatally by multiple centres	Patella (largest), pisiform, fabella
Accessory / heterotopic	Extra centres in sutures (wormian bones) or failed epiphyseal fusion (os trigonum, os vesalianum); heterotopic bone forms in soft tissue (rider's bone)	—

Structural classification (macroscopic): every bone (except the inferior nasal concha, which is wholly spongy) has an outer shell of **compact bone** and an inner **cancellous (spongy) bone**; in the skull vault the spongy layer is sandwiched as the **diploë** between outer and inner tables.

Developmental classification: **membranous** bones ossify directly in a mesenchymal membrane (cranial vault, facial bones); **cartilaginous** bones ossify in a preformed hyaline-cartilage model (limb bones, vertebrae, base of skull, thoracic cage); **membrano-cartilaginous** bones ossify by both processes (mandible, clavicle, occipital, temporal, sphenoid).

Gross structure of a typical long bone

□ Fig 6.8 — Parts of a growing long bone. (Vishram Singh — General Anatomy — 4e, p.244)

A typical long bone has a shaft (**diaphysis**) and two expanded ends (**epiphyses**).

- **Diaphysis**: tubular shaft; outer thick cortex of compact bone enclosing the **medullary cavity** (yellow marrow in adults, red/hemopoietic at birth) — maximum strength with minimum weight.
- **Metaphysis**: flared end of diaphysis adjoining the epiphyseal plate; most actively growing and most vascular part of the bone.
- **Epiphysis**: knobby end, mainly cancellous bone with a thin compact shell, capped by **articular hyaline cartilage**. Four types are described: **pressure epiphysis** (weight-transmitting, e.g. head of femur), **traction epiphysis** (non-articular, muscle-pull, e.g. trochanters), **aberrant epiphysis** (appears at the unusual end of a miniature long bone, e.g. head of 1st metacarpal) and **atavistic**

epiphysis (an independent bone in lower mammals that fuses parasitically to the nearest bone in man, e.g. os trigonum).

- **Epiphyseal (growth) plate:** hyaline cartilage between epiphysis and diaphysis; its proliferation lengthens the bone; nourished by both epiphyseal and metaphyseal vessels; fusion (usually complete by ~25 years) ends longitudinal growth.
- **Periosteum:** outer fibrous covering (absent over articular cartilage), two layers — outer fibrous, inner osteogenic — anchored by **Sharpey's fibres**; nourishes outer cortex, gives attachment to muscles/ligaments, and is the principal source of regenerative osteoblasts.
- **Endosteum:** thin cellular membrane lining the medullary cavity, also osteogenic.

Diagram to draw

Longitudinal section of a typical long bone (e.g. upper end of femur/tibia) labelled: articular hyaline cartilage — epiphysis (pressure type) — epiphyseal (growth) plate — metaphysis — periosteum — compact bone (cortex) — cancellous bone with trabeculae — medullary cavity with marrow — endosteum — nutrient foramen and nutrient artery — diaphysis.

Microscopic structure of bone

Bone consists of **cells**, **fibres** and **ground substance** (the latter two forming the matrix).

Cells

Cell	Origin	Function
Osteoprogenitor cell	Mesenchyme, periosteum, endosteum	Pluripotent precursor
Osteoblast	Osteoprogenitor cell	Secretes osteoid (collagen I, proteoglycans); releases alkaline phosphatase and matrix vesicles for mineralisation; mitotic
Osteocyte	Osteoblast trapped in matrix	Maintains bone via canaliculi; non-mitotic
Osteoclast	Fusion of monocyte-lineage cells (haemopoietic)	Multinucleate; resorbs bone from Howship's lacunae; non-mitotic

Osteoclast differentiation is controlled by the **RANKL–RANK–osteoprotegerin (OPG)** axis: osteoblasts express RANKL, which binds RANK on osteoclast precursors to drive their differentiation; OPG is a soluble decoy receptor for RANKL that restricts osteoclastogenesis — the balance of this axis (modulated by PTH, vitamin D and mechanical load) governs the resorption–deposition balance of remodelling.

Matrix: organic (type I collagen ~90%, proteoglycans — chondroitin/keratan sulphate, glycoproteins — osteonectin, osteocalcin) and inorganic (hydroxyapatite crystals, $\text{Ca}_{10}[\text{PO}_4]_6[\text{OH}]_2$, plus citrate and bicarbonate); water contributes only ~7% (low hydration, unlike cartilage's 75%).

Compact vs cancellous bone

Feature	Compact bone	Cancellous (spongy) bone
Texture	Dense, ivory-like	Porous, meshwork of trabeculae
Haversian systems	Present	Absent
Location	Outer shell	Inner core, ends of long bones, diploë
Nutrition	Via Haversian/Volkmann's canals	Direct diffusion from marrow vessels
Proportion by weight	~75%	~25%

Haversian system (osteon) — the structural–functional unit of compact bone.

□ Fig 6.4 — Structure of compact bone: (A) Haversian systems and lamellae; (B) an osteon and (C) periosteum and outer circumferential lamellae. (Vishram Singh — General Anatomy — 4e, p.232)

Each osteon has a central **Haversian canal** (carries vessels/nerves, runs parallel to bone's long axis) surrounded by 4–20 **concentric lamellae**; osteocytes lie in **lacunae** between lamellae, linked by **canaliculi** for nutrient exchange. **Volkmann's canals**, running perpendicular to the shaft, connect Haversian canals to each other, the periosteum, and the medullary cavity. **Interstitial lamellae** (remnants of older, remodelled osteons) fill gaps between osteons; **circumferential lamellae** run around the whole bone circumference beneath the periosteum. Cancellous trabeculae are lamellar but lack Haversian systems, being nourished directly by marrow-space vessels.

Microscopically, bone is also classed as **woven** (randomly arranged collagen, immature — fetal bone, fracture callus) or **lamellar** (organised in layers — all adult bone).

Diagram to draw

Cross-section of compact bone labelled: Haversian (central) canal — concentric lamellae — lacunae with osteocytes — canaliculi — Volkmann's canal — interstitial lamellae — outer/inner circumferential lamellae — periosteum with Sharpey's fibres.

Blood and nerve supply of bone

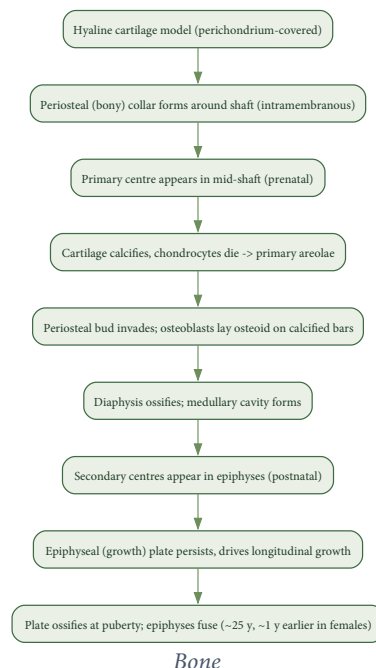
A growing long bone is supplied by **four sets of vessels**:

Vessel	Course	Territory
Nutrient artery	Enters via nutrient foramen (mid-shaft), runs obliquely, divides into ascending/descending medullary branches forming hairpin loops at the metaphysis	Marrow, inner two-thirds of cortex
Periosteal arteries	Ramify beneath periosteum, enter via Volkmann's canals	Outer one-third of cortex
Metaphyseal (juxta-epiphyseal) arteries	From neighbouring joint vessels, enter metaphysis directly	Metaphysis
Epiphyseal arteries	From peri-articular anastomosis (circulus vasculosus)	Epiphysis

The nutrient artery of the tibia is the largest in the body; its foramen points away from the growing end ("to the elbow I go, from the knee I flee"). Nerve fibres travel through the nutrient canal, Haversian and Volkmann's canals to the marrow; **periosteum is exquisitely pain-sensitive**, while cortical bone itself is relatively insensitive. Veins accompany arteries in Volkmann's canals; there are no lymphatics in bone (periosteal lymphatics only).

Ossification of bone

Laws of ossification: (1) a primary centre is single and appears prenatally (exception — carpal bones, postnatal); (2) secondary centres appear postnatally (exception — the lower femoral epiphysis, present at birth); (3) the centre that appears first fuses last (exception — the fibula, whose lower epiphysis both appears first and fuses first).



- **Intramembranous ossification:** mesenchyme condenses into a membrane → osteoprogenitor cells become osteoblasts at "ossification centres" → osteoid secreted → mineralised by alkaline phosphatase. Produces flat cranial-vault bones and clavicle.
- **Intracartilaginous (endochondral) ossification:** as sequenced above; produces all limb bones, vertebrae, base of skull, ribs, sternum.
- The **growing end** of a long bone is the end where the epiphysis fuses later and where the secondary centre appears first; it lies opposite the direction of the nutrient foramen (exception — fibula, where the foramen points toward the growing (upper) end).

Growth and remodelling of bone

Bone cannot grow interstitially (unlike cartilage); it grows only by **appositional deposition** on its surfaces, with simultaneous **osteoclastic removal (remodelling)** to preserve shape.

- **Appositional growth:** surface osteoblasts deposit new lamellae, increasing diameter.

- **Endochondral (longitudinal) growth:** proliferation in the epiphyseal plate, organised into four zones — resting cartilage → proliferation (columns of chondrocytes) → hypertrophy → calcification, followed by vascular invasion and ossification.
- **Remodelling:** surface remodelling converts the flared metaphyseal region into slender shaft as the bone lengthens; internal remodelling by coupled osteoclast "cutting cones" followed by osteoblast infill replaces roughly 10% of adult bone every year, renewing the skeleton and adapting its architecture to load (**Wolff's law**, 1892) — tensile and compressive forces both stimulate remodelling along lines of stress, producing pressure and tension trabecular lamellae (e.g. calcar femorale in the femoral neck).

Factors affecting bone growth

Factor	Effect
Vitamin A	Coordinates osteoblast/osteoclast balance; deficiency narrows skull/spinal foramina (nerve compression)
Vitamin C	Needed for collagen/ground-substance synthesis; deficiency → defective growing ends, subperiosteal haematoma (scurvy)
Vitamin D	Needed for intestinal Ca/PO ₄ absorption; deficiency → rickets (children), osteomalacia (adults)
Hormones	GH, thyroid, PTH and sex steroids regulate growth and epiphyseal fusion; oestrogen closes plates ~1 year earlier than testosterone (shorter female stature)
Genetic	e.g. chondrodystrophia foetalis — defective endochondral ossification
Mechanical	Tensile forces favour deposition, compressive forces favour resorption (Wolff's law)

Applied / Clinical anatomy

- **Fracture and repair:** haematoma (days 1–3) → granulation tissue → fibrocartilaginous (soft) callus → woven bony callus (osteoblasts from periosteum/endosteum) → remodelling to mature lamellar bone. Classified as simple/closed vs compound/open, and by fracture line (transverse, oblique, spiral, comminuted).
- **Osteomyelitis:** characteristically affects the **metaphysis** in children because metaphyseal vessels are richly vascular end-arteries forming hairpin loops where bacteria/emboli lodge; after epiphyseal fusion these anastomose, so metaphyseal osteomyelitis is rare in adults.
- **Paget's disease (osteitis deformans):** uncontrolled osteoclastic resorption followed by disorganised osteoblastic repair that halts at the woven-osteoid stage, producing thick, weak, bent bones (femur, tibia, skull, spine).
- **Achondroplasia:** defective endochondral ossification → disproportionate dwarfism with short limbs, normal trunk, dorsal kyphosis/lumbar lordosis.

- ▶ **Cleidocranial dysostosis:** defective intramembranous ossification → absent/hypoplastic clavicles, delayed fontanelle/suture closure.
- ▶ **Rickets/osteomalacia:** vitamin D deficiency → defective mineralisation of osteoid; bowed legs and knobby metaphyses in children, bone softening in adults.
- ▶ **Medicolegal/radiological anatomy:** presence of the distal femoral secondary ossification centre on a newborn's radiograph indicates a full-term fetus; in growing children, the radiolucent epiphyseal plate lies between radiopaque shaft and epiphysis.
- ▶ **Osteoarthritis:** progressive thinning of weight-bearing articular cartilage exposing subjacent bone.
- ▶ **Bone marrow aspiration sites:** sternum and lumbar spinous processes in adults; posterior iliac crest in children — clinically relevant extension of medullary-cavity anatomy.

High-yield exam pointers

- ▶ Adult skeleton = 206 bones (270 at birth); organic:inorganic matrix $\approx$ 1:2 by weight.
- ▶ Three classifications of bone: shape, structure (compact/cancellous), development (membranous/cartilaginous/membrano-cartilaginous).
- ▶ Osteon (Haversian system) = structural-functional unit of compact bone; Volkmann's canals run transversely, Haversian canals longitudinally.
- ▶ Laws of ossification and their sole exceptions: carpals (prenatal-primary-centre rule), lower femoral epiphysis (postnatal-secondary-centre rule), fibula (first-appears-fuses-last rule).
- ▶ Metaphysis = most vascular, fastest-growing region, and commonest site of childhood osteomyelitis (end-artery hairpin loops).
- ▶ Clavicle is the only long bone that is horizontal, ossifies mainly in membrane, and lacks a medullary cavity.
- ▶ Sesamoid bones lack periosteum and a Haversian system; patella is the largest.
- ▶ Wolff's law (1892): bone architecture remodels along lines of mechanical stress; RANKL–RANK–OPG signalling is the modern molecular basis of the resorption/deposition balance.
- ▶ Femur = longest/largest bone; stapes = smallest bone; malleus = smallest long bone; fibula = most slender long bone.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (primary specialty text for classification, gross/microscopic structure, blood supply, ossification, growth and applied anatomy); Gray's Anatomy (Standring) 41e (bone cell biology, RANKL–RANK–osteoprotegerin remodelling axis, Wolff's law/adaptive remodelling, annual bone turnover rate).



Epiphyseal cartilage

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The epiphyseal cartilage (epiphyseal plate, growth plate, or physis) is a disc of hyaline cartilage interposed between the epiphysis and the diaphysis of a growing long bone. It constitutes a primary cartilaginous joint (synchondrosis) between the two ossification centres, and through continued proliferation and endochondral ossification of its cells it is solely responsible for the longitudinal growth of the bone. It is nourished by both epiphyseal and metaphyseal arteries, and once growth is completed (around 18–25 years) the plate itself ossifies, fusing the epiphysis to the diaphysis and leaving behind only a faint bony scar, the epiphyseal line.

Structural context: parts of a growing long bone and types of epiphyses

Before ossification is complete, a growing long bone shows four definable parts (from a preformed hyaline-cartilage model surrounded by perichondrium):

Part	Feature
Diaphysis	Shaft; formed by the primary centre of ossification (appears before birth, usually 7th–12th intrauterine week, except carpal/most tarsal bones)
Epiphyses	Ends of the bone; formed by secondary centres of ossification (appear after birth, usually birth to 5 years, except the lower femoral epiphysis which appears in the 9th intrauterine month)
Epiphyseal (growth) plate/cartilage	Hyaline cartilage separating epiphysis from diaphysis; produces new cartilage, enabling growth in length
Metaphysis	End of the diaphysis adjoining the epiphyseal cartilage; the most vascular and most actively growing zone of the bone

The joint between epiphysis and diaphysis is a **synchondrosis (primary cartilaginous joint)** — immovable and temporary; it undergoes synostosis (complete replacement of cartilage by bone) once growth ceases.

Epiphyses themselves are of four types:

- ▶ **Pressure epiphysis** — covered by articular cartilage, transmits body weight (e.g. head of femur, humerus, lower end of radius).
- ▶ **Traction epiphysis** — produced by muscular pull, always non-articular, ossifies later than the pressure epiphysis (e.g. greater/lesser trochanters of femur, greater/lesser tubercles of humerus).
- ▶ **Aberrant epiphysis** — appears at an unusual end of a short long bone (e.g. head of the 1st metacarpal, instead of its base).
- ▶ **Atavistic epiphysis** — an independent bone in lower mammals that fuses parasitically to a neighbouring bone in man (e.g. os trigonum at the posterior tubercle of the talus; coracoid process of the scapula).

Histological zones of the epiphyseal (growth) plate

From the epiphyseal to the diaphyseal side, the plate is organised into four classical zones:

Zone	Location	Key activity
1. Zone of resting cartilage	Nearest the epiphysis	Randomly arranged chondrocytes; do not divide rapidly — a reserve of typical hyaline cartilage
2. Zone of proliferation	Next towards diaphysis	Chondrocytes divide repeatedly and organise into longitudinal columns ("stacks of coins/plates") parallel to the long axis of the bone
3. Zone of hypertrophy	Next towards diaphysis	Chondrocytes mature and hypertrophy, secreting alkaline phosphatase and type X collagen, which stiffens and compresses the matrix into aligned spicules
4. Zone of calcification	Nearest the diaphysis (thinnest zone)	Matrix mineralises with calcium salts; hypertrophied chondrocytes die; diaphyseal blood vessels invade, bringing osteoblasts that line the calcified cartilage bars and lay down bone

A maturation gradient runs along each column — cells near the resting zone are young and proliferating; cells nearer the diaphysis are older and hypertrophying. (Some histology texts, e.g. Junqueira, describe five overlapping zones by further splitting "zone of calcified cartilage," where chondrocytes about to undergo apoptosis release matrix vesicles that nucleate hydroxyapatite, from a distinct terminal "zone of ossification," where capillaries and osteoblasts actually invade the emptied lacunae to lay down woven bone — the underlying sequence of events is identical to the four-zone scheme above.)

□ Fig 6.18 — ■ Growth of bone—lengthwise: (A) four zones of epiphyseal cartilage and (B) conversion of calcified cartilage into bone. (Vishram Singh — General Anatomy — 4e, p.264)

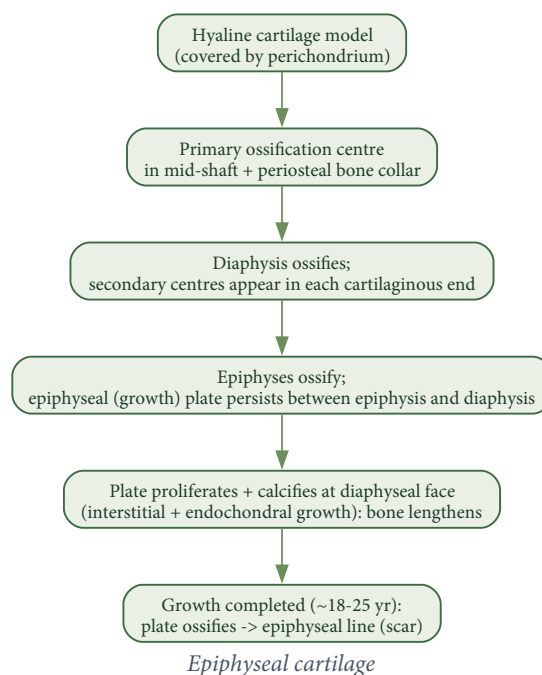
DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A longitudinal section through the epiphyseal plate and adjoining metaphysis, labelled with:

- ▶ Epiphysis (above)
- ▶ Zone of resting cartilage
- ▶ Zone of proliferation — columns of chondrocytes stacked like coins
- ▶ Zone of hypertrophy — enlarged chondrocytes
- ▶ Zone of calcification — thin band with dead/dying chondrocytes
- ▶ Metaphysis — osteoblasts depositing new bone on calcified cartilage bars
- ▶ An arrow marked "increase in length" directed away from the diaphysis
- ▶ A bracket noting "thickness of epiphyseal cartilage unchanged" (production of new cartilage = its replacement by bone)

Mechanism of longitudinal bone growth (endochondral growth)

Growth in length is an **endochondral growth** process — multiplication of the cells of the epiphyseal plate. The surface of the plate facing the epiphysis produces new cartilage, which pushes the epiphysis away from the diaphysis; this amount of new cartilage exactly equals the amount replaced by spongy bone at the metaphyseal surface, so the diaphysis lengthens while the plate's own thickness stays essentially constant.



Appositional growth (osteoblasts proliferating on the bone surface) separately increases bone diameter; bones cannot grow by interstitial growth the way cartilage, tendon or ligament can.

Growing ends and the law of union of epiphyses

The two epiphyses of a long bone do not fuse simultaneously; the end that fuses later is the **growing end**, and this is also the end at which the secondary centre of ossification appeared first. The growing end always lies opposite the direction of the nutrient foramen ("to the elbow I go, from the knee I flee").

Limb	Growing ends
Upper limb	Shoulder end of humerus; wrist ends of radius and ulna
Lower limb	Knee ends of femur, tibia and fibula

Law of union of epiphyses: the epiphyseal centre that appears *first* fuses *last*, and the one that appears later fuses first — **except the fibula**, which violates this law (its lower epiphyseal centre appears first and also unites first, while the upper centre appears and unites late). Fusion begins at puberty and is usually complete by about 25 years, after which no further growth in length occurs. Appearance of secondary centres and epiphyseal fusion occur somewhat earlier in females than males (variously cited as ~1–3 years), a major reason women average shorter adult stature than men; oestrogen produces earlier epiphyseal closure than testosterone does.

Factors regulating growth of the epiphyseal cartilage

Factor	Effect on the plate
Growth hormone (GH)/IGF-1	Required for normal interstitial proliferation in the growth cartilage; GH deficiency in the young causes quiescence and thinning of growth plates (pituitary dwarfism); hypersecretion before fusion causes gigantism , after fusion causes acromegaly
Thyroid hormone	Essential for proper development and growth of bone; imbalance produces skeletal growth defects
Sex hormones (oestrogen/androgen)	Stimulate ossification of the plate, driving epiphyseal fusion; oestrogen closes the plate earlier than testosterone
Parathyroid hormone (excess)	Stimulates unchecked osteoclastic bone erosion (osteitis fibrosa cystica)
Vitamin D (deficiency)	Defective mineralisation of osteoid; disorganised, thickened, irregular growth plates with failure of cartilage calcification despite continued chondrocyte proliferation — classic rickets in children
Vitamin C (deficiency)	Impaired collagen/matrix synthesis; growth plates become thin, ossification nearly stops, metaphyseal trabeculae are fragile
Vitamin A (deficiency/excess)	Deficiency slows osteoclastic remodelling, narrowing foramina; excess accelerates vascular erosion of growth cartilage, prematurely halting longitudinal growth

Factor	Effect on the plate
Genetic factors	Defective (autosomal dominant) endochondral ossification, e.g. chondrodystrophia foetalis
Mechanical factors	Tensile force favours bone formation; compressive force favours resorption

Applied / Clinical anatomy

- ▶ **Radiological appearance:** in a growing child, the ossified shaft and epiphyses appear radiopaque (white) while the unossified epiphyseal plate appears as a radiolucent gap between them — used routinely to assess "bone age."
- ▶ **Medicolegal significance:** in a newborn, presence of the secondary ossification centre at the lower end of the femur on radiograph indicates a full-term child — an important forensic marker.
- ▶ **Growth-plate injury:** because the plate is the weakest point of a growing long bone, trauma at the growing end is far more likely to injure the epiphyseal cartilage than the adjacent ligaments; damage here in a child can arrest local growth and cause permanent shortening or angular deformity of the limb. (Such injuries are conventionally graded on the well-known Salter–Harris scale, Types I–V, describing fracture lines through the physis alone, through physis and metaphysis, through physis and epiphysis, through all three, or a crush injury of the plate — the higher grades carrying the worst prognosis for growth arrest.)
- ▶ **Osteomyelitis:** the adjoining metaphysis is the commonest site of childhood osteomyelitis because its end-arteries (from nutrient, periosteal and metaphyseal vessels) form hairpin bends that readily trap bacteria/emboli, causing infarction; after epiphyseal fusion these vessels anastomose freely and the risk falls sharply in adults.
- ▶ **Achondroplasia:** defective endochondral ossification at the growth plate produces disproportionately short limbs with a relatively normal trunk, dorsal kyphosis and lumbar lordosis — the classical dwarfism of defective epiphyseal cartilage function.
- ▶ **Bone age/forensic estimation:** the sequence and timing of epiphyseal appearance and fusion is used extensively in radiological and forensic age estimation.

High-yield exam pointers

- ▶ Epiphyseal cartilage = growth plate = physis; a **primary cartilaginous joint (synchondrosis)** between epiphysis and diaphysis; temporary, ossifies once growth ceases.
- ▶ **Four zones** (epiphysis → diaphysis): resting cartilage → proliferation → hypertrophy → calcification; some texts split the last into calcified-cartilage and ossification zones (five-zone scheme) — same underlying sequence.
- ▶ Growth in **length** = endochondral growth (interstitial cartilage proliferation + replacement by bone); growth in **width/diameter** = appositional growth by periosteal osteoblasts.
- ▶ Plate thickness stays constant because new cartilage formation equals its replacement by bone at the metaphyseal surface.
- ▶ **Law of union of epiphyses:** centre appearing first fuses last — **except the fibula**, which breaks the rule.

- Fusion is complete by ~18–25 years; earlier in females (oestrogen > testosterone effect) — contributes to shorter average female stature.
- Nourished by epiphyseal and metaphyseal arteries; metaphysis is the most vascular part of the bone and the classic site of childhood osteomyelitis.
- Endocrine control: GH/IGF-1 drives proliferation (deficiency → pituitary dwarfism; excess → gigantism/acromegaly); sex hormones trigger closure; vitamin D deficiency → rickets; vitamin C deficiency → thin, fragile plates.
- Trauma to the plate in children can permanently arrest bone growth (graded by the Salter–Harris classification) — key applied-anatomy point.

SOURCE & COVERAGE

Vishram Singh — General Anatomy, 4e; Gray's Anatomy (Standring) 41e; Junqueira's Basic Histology — Text & Atlas, 17e (cross-referenced for the five-zone histological nomenclature).



Ossification of long bones

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction Ossification is the process of bone formation. Long bones develop chiefly by **endochondral (intracartilaginous) ossification**: within the mesenchymal condensation of the limb bud, a miniature hyaline-cartilage model of the future bone is laid down and progressively replaced by bone in an orderly, centre-driven sequence. The **clavicle** is the sole exception — it ossifies mainly by an intramembranous mechanism (except at its medial end) and is the first bone in the body to begin ossifying. This process determines the shape of the mature bone and, through the epiphyseal growth plate, the longitudinal growth of the skeleton until skeletal maturity.

1. Classification relevant to ossification

Basis	Types	Examples / notes
Shape	Typical long bones (diaphysis + 2 epiphyses, medullary cavity, ossify in cartilage)	Humerus, radius, ulna, femur, tibia, fibula
	Miniature/short long bones (epiphysis at one end only)	Metacarpals, metatarsals, phalanges (epiphysis distal, except 1st metacarpal/metatarsal — proximal)
Development	Cartilaginous (endochondral)	All typical long bones
	Membrano-cartilaginous	Clavicle (shaft membranous, sternal end cartilaginous)
Ossification centres	Primary centre → diaphysis	Appears in utero, usually 7th–12th week

Basis	Types	Examples / notes
	Secondary centre(s) → epiphyses	Usually birth–5 years; exception — lower femoral epiphysis at 9th intrauterine month (medicolegal full-term marker), occasionally upper tibia/humerus

2. Sequence of endochondral ossification

□ Fig 6.14 — Ossification of a long bone. (Vishram Singh — General Anatomy — 4e, p.258)

- ▶ **Step 1:** The bone is first laid down as a hyaline-cartilage model surrounded by perichondrium.
- ▶ **Step 2:** A **primary centre of ossification** appears in the centre of the shaft; chondrocytes here hypertrophy, accumulate glycogen, and the surrounding matrix calcifies. Ossification spreads towards both ends to form the **diaphysis**.
- ▶ **Step 3:** Simultaneously the deep (osteogenic) layer of the perichondrium lays down a thin **periosteal collar** of bone (intramembranous) around the shaft, which invades and supports the calcifying cartilage core.
- ▶ **Step 4:** Osteogenic vascular buds (capillaries + osteoprogenitor cells + osteoclasts) invade the calcified cartilage, eroding it and depositing the **primary spongiosa**; osteoclasts later excavate a medullary cavity.
- ▶ **Step 5:** After birth, one or more **secondary centres of ossification** appear at each cartilaginous end (epiphysis) and undergo the same hypertrophy–calcification–vascular invasion sequence, forming the **epiphyses**.
- ▶ **Step 6:** The **epiphyseal (growth) plate** of cartilage, intervening between epiphysis and diaphysis, keeps producing new cartilage on its epiphyseal face while it is replaced by bone on its metaphyseal face — this is the mechanism of growth in length ("growth plate"). Articular cartilage at each end remains permanently cartilaginous.
- ▶ **Step 7:** At puberty, the rate of cartilage proliferation slows; eventually the epiphyseal and metaphyseal ossification fronts meet, the plate is obliterated (bony fusion/epiphyseal line), and longitudinal growth ceases (usually complete by ~25 years).

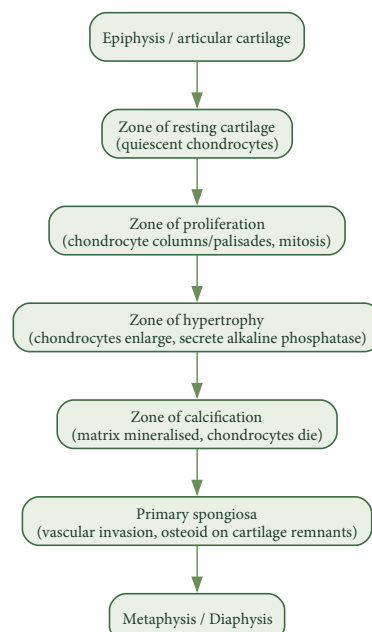
DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a longitudinal-section flow diagram (after Gray's Anatomy Fig. 5.25) through stages A–G: A cartilage template → B hypertrophy of central chondrocytes → C calcification of matrix + periosteal bony collar → D vascular osteogenic buds invade the primary centre → E primary bone laid on calcified-cartilage remnants; secondary centre appears and vascularises → F continued growth of the epiphyseal plate and epiphysis, red-marrow proliferation → G cessation of cartilage growth, complete ossification/fusion of the epiphyseal plate, replacement of red by yellow marrow. Label diaphysis, metaphysis, epiphysis, periosteal collar, medullary cavity, and articular cartilage on the final panel.

3. Structure of the growing long bone and the epiphyseal plate

A growing long bone has four regions: **epiphysis** (secondary-centre bone + overlying articular cartilage), **epiphyseal plate**, **metaphysis** (diaphyseal end abutting the plate — the most actively growing, most vascular region), and **diaphysis** (primary-centre bone).

The epiphyseal plate is organised into four zones, superficial (epiphyseal side) to deep (diaphyseal side):



Ossification of long bones

- ▶ **Zone of resting cartilage** — nearest the epiphysis; randomly arranged chondrocytes, low mitotic activity.
- ▶ **Zone of proliferation** — chondrocytes divide and form longitudinal columns ("stacks of coins"); interstitial expansion here is the basic mechanism of elongation.
- ▶ **Zone of hypertrophy** — chondrocytes mature, enlarge, and secrete alkaline phosphatase; a maturation gradient runs from young (resting side) to old (diaphyseal side) cells.
- ▶ **Zone of calcification** — thin; matrix mineralises, chondrocytes die, and diaphyseal blood vessels invade, bringing osteoblasts that deposit bone on the calcified cartilage bars (primary spongiosa).

4. Mechanisms of growth

Mechanism	Site	Effect
Endochondral (interstitial) growth	Epiphyseal plate cartilage	Increase in length of the bone
Appositional growth	Sub-periosteal osteoblasts	Increase in width/diameter
Internal remodelling	Endosteal osteoclastic resorption	Widens the medullary cavity while cortex thickness is regulated (osteoclasts remove bone internally as osteoblasts add it externally)
Surface remodelling	Periosteal deposition (shaft) + resorption (flared metaphyseal cone)	"Straightens" the diverging metaphyseal cone into the slender shaft as the bone lengthens; the junction of a resorbing and a depositing field is a surface reversal line

Bone cannot grow interstitially like cartilage/tendon/ligament — all post-natal shaft growth in width is appositional.

5. Blood supply of a growing long bone

Source	Course	Territory supplied
Nutrient artery	Enters obliquely through the nutrient foramen (mid-shaft), divides into ascending/descending medullary branches, ends in hairpin loops at the metaphysis anastomosing with metaphyseal/epiphyseal/periosteal vessels	Medullary cavity/marrow + inner two-thirds of diaphyseal & metaphyseal cortex
Periosteal arteries	Numerous, ramify beneath periosteum, enter via Volkmann's canals	Outer one-third of the cortex
Metaphyseal (juxta-epiphyseal) arteries	Direct branches of neighbouring vessels entering with the joint capsule	Metaphysis
Epiphyseal arteries	From a peri-articular anastomotic arcade ("circulus vasculosus"); enter the epiphysis directly or through the growth cartilage	Epiphysis; do not normally anastomose with metaphyseal vessels while the plate is open

The metaphysis is the most vascular region (convergence of all three loops) but these are functional end-arteries — the basis of paediatric osteomyelitis (below). The tibial nutrient artery is the largest in the body.

6. Types of epiphyses

Type	Feature	Example
Pressure epiphysis	Covered by articular cartilage; transmits body weight	Head of femur, head of humerus, lower end of radius
Traction epiphysis	Non-articular; provides muscular attachment; ossifies later than pressure epiphysis	Greater/lesser trochanter of femur, greater/lesser tubercle of humerus
Aberrant epiphysis	Appears at the unusual (normally non-epiphyseal) end of a miniature long bone	Head of the 1st metacarpal (normally the base has the epiphysis)
Atavistic epiphysis	An independent bone in lower mammals that fuses to the neighbouring human bone as a "parasitic" nutrient-dependent nodule	Coracoid process of scapula; os trigonum (posterior tubercle of talus)

7. Law of union of epiphyses and the "growing end"

- ▶ **General law:** the epiphysis that **appears first, fuses last**; the one that **appears later, fuses first**.
- ▶ **Exception — fibula:** violates this law entirely — its lower epiphysis both **appears first and fuses first**, while the upper epiphysis both appears late and fuses late.
- ▶ The end at which fusion occurs **later** is the **growing end**, and it is also the end where the secondary centre appears first; growing ends: shoulder end of humerus, wrist ends of radius/ulna (upper limb); knee ends of femur, tibia and fibula (lower limb).
- ▶ **Nutrient-foramen mnemonic:** the nutrient foramen always points **away from** the growing end — *"To the elbow I go, and from the knee I flee"* — except in the **fibula**, where the foramen is directed **towards** the growing end.
- ▶ Appearance of secondary centres and epiphyseal fusion occur **earlier in females than males** (commonly cited as ~1–3 years earlier depending on the bone/series), because oestrogen accelerates epiphyseal closure relative to testosterone — a contributor to the shorter average adult height of females.

8. Factors affecting bone growth/ossification

Category	Factor	Effect of deficiency/excess
Nutritional	Vitamin A	Coordinates osteoblast/osteoclast balance; deficiency slows osteoclastic resorption → narrowed skull/spinal foramina, nerve compression; excess → bone rarefaction

Category	Factor	Effect of deficiency/excess
	Vitamin C	Needed for collagen/ground-substance synthesis by osteoblasts; deficiency → defective growing ends, subperiosteal haemorrhage (scurvy)
	Vitamin D	Needed for intestinal $\text{Ca}^{2+}/\text{PO}_4^{3-}$ absorption; deficiency → defective mineralisation → rickets (children)/osteomalacia (adults)
Hormonal	Growth hormone, thyroid, parathyroid, sex hormones	GH drives interstitial proliferation of growth cartilage; deficiency → dwarfism, excess (before fusion) → gigantism, excess (after fusion) → acromegaly
Genetic	Autosomal-dominant defects (e.g. chondrodystrophia foetalis/achondroplasia)	Endochondral ossification fails to proceed normally → disproportionate short-limbed dwarfism
Mechanical	Tensile vs compressive load (Wolff's law)	Tension favours bone formation; compression favours resorption — basis of orthopaedic traction for fracture healing

Applied / Clinical anatomy

- **Forensic/medicolegal age estimation:** the secondary centre at the distal femoral epiphysis normally ossifies in the 9th intrauterine month; its presence on radiograph/autopsy of a dead newborn indicates a full-term fetus. Newborn radiographs show a radiopaque (ossified) shaft with radiolucent cartilaginous ends; in growing children, shaft and epiphysis are both radiopaque while the intervening plate remains a radiolucent line — the basis of paediatric **bone-age** assessment.
- **Osteomyelitis:** the hairpin-shaped, end-artery loops at the metaphysis trap bacterial emboli, making the metaphysis the classical site of haematogenous osteomyelitis in children; once the plate fuses, epiphyseal–metaphyseal vessels anastomose freely and end-arteries are lost, so metaphyseal osteomyelitis becomes rare in adults.
- **Growth-plate (epiphyseal) injury:** the plate is the mechanically weakest zone, so physeal fracture-separations in children (clinically graded as Salter–Harris injuries) risk premature growth arrest with limb shortening or angular deformity if poorly reduced.
- **Achondroplasia:** autosomal-dominant defect of endochondral ossification → disproportionately short limbs with a near-normal trunk, dorsal kyphosis/lumbar lordosis; membranous (skull vault) ossification is unaffected.

- ▶ **Rickets/osteomalacia and scurvy:** vitamin D and C deficiencies respectively produce widened, irregular plates with bowed, knobby-metaphysis legs (rickets), or thin plates with fragile metaphyseal bone and subperiosteal haemorrhage (scurvy).
- ▶ **Paget's disease (osteitis deformans):** uncontrolled osteoclastic resorption with disorganised osteoblastic repair produces thick, weak, bowed bone — a disorder of the remodelling that normally maintains adult bone shape.

High-yield exam pointers

- ▶ Long bones ossify by **endochondral** ossification from a cartilage model, except the **clavicle** (membrano-cartilaginous, first bone to ossify).
- ▶ **Primary centre** → **diaphysis** (in utero, 7th–12th week); **secondary centre(s)** → **epiphyses** (birth–5 years; exception — lower femoral epiphysis at 9th intrauterine month, medicolegal full-term marker).
- ▶ **Four zones of the epiphyseal plate:** resting → proliferative → hypertrophic → calcified (epiphysis to diaphysis).
- ▶ Growth in **length** = endochondral/interstitial (growth plate); growth in **width** = appositional (sub-periosteal) + endosteal resorption.
- ▶ **Four arterial sets:** nutrient, periosteal, metaphyseal, epiphyseal — metaphysis most vascular but end-arterial (→ osteomyelitis in children).
- ▶ **Law of union of epiphyses:** first-to-appear fuses last — except the **fibula**, which violates this at both ends.
- ▶ Nutrient foramen points away from the growing end (*"to the elbow I go, from the knee I flee"*), except the fibula.
- ▶ Epiphyses are **pressure, traction, aberrant or atavistic**; fusion complete by ~25 years, earlier in females (oestrogen effect).
- ▶ Applied: bone-age radiography, paediatric osteomyelitis, Salter–Harris growth-plate injury, achondroplasia, rickets/scurvy, Paget's disease.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; BD Chaurasia — Human Anatomy Vol 1 8e; Brijesh Kumar — Embryology Text & Atlas; Moore's Clinically Oriented Anatomy 9e.



Periosteum

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The periosteum is the specialised, richly vascular and innervated fibrous connective-tissue membrane that invests the outer (external) surface of every bone, except at areas covered by articular cartilage and at sesamoid bones and ear ossicles. At an articular margin it becomes continuous with the joint capsule; where a tendon or ligament attaches, its outer fibres blend with the fibrous connective tissue of that structure. It is the functional counterpart, on the inner (medullary) surface of bone, of the endosteum. Because it carries the osteoprogenitor-cell pool responsible for appositional bone growth and for fracture repair, and because it carries the sensory nerves that make bone painful when injured, the periosteum is of major applied importance in orthopaedics and surgery.

Structure (histology)

The periosteum is a two-layered dense connective-tissue membrane:

Layer	Composition	Cellularity	Main role
Outer fibrous layer	Dense irregular collagen (type I) bundles with fibroblasts and periosteal blood vessels	Relatively acellular	Mechanical strength; limits bone tissue from "spilling" into adjacent soft tissue; carries the vascular plexus
Inner cellular (osteogenic) layer	Loose connective tissue rich in osteoprogenitor cells	Highly cellular — numerous osteoblasts in young/growing bone; quiescent osteoprogenitor cells in the adult that reactivate on demand	Generates new osteoblasts for appositional growth, remodelling and fracture repair

- ▶ In the growing skeleton the inner layer is 2–3 cells deep and actively lays down new bone; in mature bone the osteoprogenitor cells are morphologically indistinguishable from fibroblasts but retain osteogenic potential.
- ▶ Osteoclasts are also found here, so the periosteum participates in surface resorption ("modelling") as well as deposition.

Attachment to bone

- ▶ The periosteum is bound to the underlying cortex by coarse, obliquely running collagen bundles called the **Sharpey's (perforating) fibres**, which arise from the outer fibrous layer, penetrate the outer circumferential lamellae, and become mineralised within the bone matrix — likened to "nails" bolting the membrane to the bone and keeping the lamellae in place.
- ▶ Where a tendon requires very firm anchorage, its own collagen fibres continue directly into the bone as Sharpey's fibres, bypassing a discrete periosteal interface.
- ▶ This periosteal attachment is the structural basis of all bone surface markings (crests, tubercles, lines) produced by muscle/tendon/ligament pull.

Blood supply

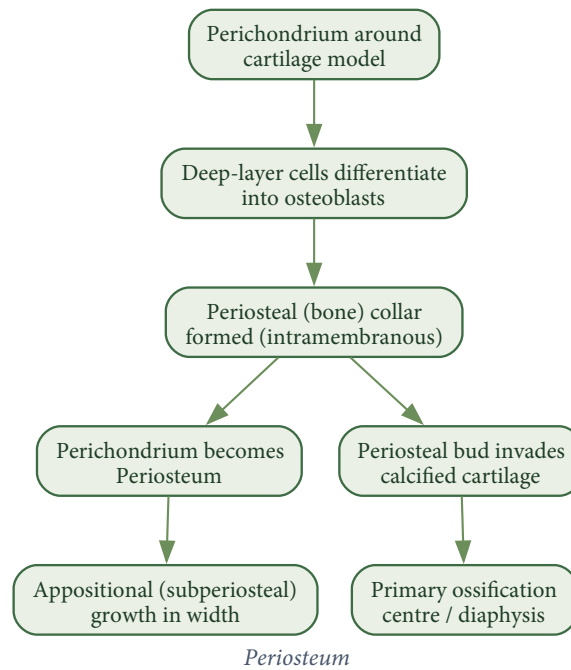
- ▶ The outer fibrous layer carries a dense **periosteal arterial plexus**, derived from numerous small independent branches of adjacent muscular/regional arteries (outside the periosteum), which enter the cortex via oblique **Volkman's canals** and communicate with the Haversian (osteonic) system.
- ▶ These periosteal vessels are responsible for nourishing most of the **outer (compact) cortex**; the medullary/nutrient artery supplies the marrow, spongy bone and deeper cortex. Consequently, a segment of bone stripped of its periosteum loses its main cortical blood supply and dies.
- ▶ In the growing bone, young periosteum is more vascular, and its vessels communicate more freely with shaft (medullary) vessels, giving off additional metaphyseal branches to support rapid growth.
- ▶ Abundant lymphatic vessels accompany the periosteal plexus, although true intraosseous lymphatics are not convincingly demonstrated.

Nerve supply

- ▶ The periosteum is one of the most richly innervated connective tissues in the body, carrying fine myelinated and unmyelinated **somatic sensory (nociceptive) periosteal nerve fibres** that accompany the periosteal blood vessels.
- ▶ These fibres make the periosteum exquisitely sensitive to **tearing and tension** rather than to cutting — the basis of the severe pain of fractures, of periosteal elevation during surgery, and of pain on needle penetration during an intramuscular injection.

Role in bone development and growth

- ▶ **Endochondral ossification:** cells in the deep (osteogenic) layer of the perichondrium around the cartilage model differentiate into osteoblasts and lay down a thin **periosteal (bone) collar** by intramembranous ossification, enclosing and supporting the primary ossification centre; this perichondrium becomes the periosteum once bone has formed beneath it.
- ▶ **Appositional growth:** during growth in width, the periosteum deposits new subperiosteal lamellar bone on the outer cortical surface while the endosteum resorbs bone on the inner (medullary) surface — the coordinated basis of both increase in shaft diameter and enlargement of the medullary cavity ("cortical drift"/modelling).
- ▶ **Fracture repair:** periosteal osteoprogenitor cells proliferate at the fracture site to form the external callus; where the periosteum is deficient or destroyed (e.g. intracapsular fracture of the femoral neck), healing is characteristically slow or fails.



□ Fig 6.4 — Longitudinal section of compact bone showing periosteum, Haversian canal, osteocytes, and perforating fibres of Sharpey anchoring a tendon (IB Singh — Textbook of Human Histology — 9e, p.178)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a longitudinal section through the shaft of a long bone at the site of a tendon insertion, and label:

- ▶ **Outer fibrous layer** of periosteum (dense collagen bundles)
- ▶ **Inner osteogenic (cellular) layer** — osteoprogenitor cells/osteoblasts
- ▶ **Sharpey's (perforating) fibres** penetrating into bone matrix
- ▶ **Periosteal blood vessels** entering via **Volkman's canal**
- ▶ **Haversian canal** with its osteon (concentric lamellae, osteocyte lacunae)
- ▶ **Tendon** merging with the outer fibrous layer
- ▶ **Underlying compact bone matrix**

Functions of the periosteum

- ▶ Protects the bone and maintains/moulds its external shape and surface markings.
- ▶ Nourishes the outer part of the cortex via the periosteal vascular plexus.
- ▶ Provides the interface of attachment for muscles (via tendons), ligaments and fascial (intermuscular) septa.
- ▶ Supplies osteoprogenitor cells for appositional bone growth in width.
- ▶ Provides the principal regenerative/reparative capability of bone after fracture.
- ▶ Carries the sensory (pain) innervation of bone.
- ▶ Acts as a "limiting membrane" that keeps osteogenic activity confined to the bone surface — when torn, ectopic bony spicules (exostoses) may form.

Structures/sites devoid of periosteum

- ▶ Articular (hyaline) cartilage-covered surfaces of bone.
- ▶ Enteses — the actual points of insertion of tendons and ligaments.
- ▶ Sesamoid bones (e.g. patella) — hence not classed as "true" bones.
- ▶ The ossicles of the middle ear.

Applied / Clinical anatomy

- ▶ **Fracture pain and repair:** because the periosteum is richly supplied by nociceptive fibres, fractures are extremely painful even before any movement of fragments; conversely, its osteoprogenitor cells make it the principal source of external callus in fracture healing — bone stripped of periosteum (surgically or by trauma) may fail to survive or unite.
- ▶ **Intramuscular injection/needle pain:** penetration of the periosteum by a needle produces sharp pain out of proportion to penetration of overlying soft tissue, because of its dense sensory supply.
- ▶ **Sub-periosteal haematoma:** tearing of the fine capillaries that bridge periosteum and bone produces a painful sub-periosteal collection of blood; this is seen physiologically in **cephalohaematoma** of the newborn skull, where bleeding is a sub-periosteal collection confined by the firm periosteal attachment at suture lines (giving it sharply-defined, bone-shaped margins that never cross a suture) — in contrast to caput succedaneum, which is not periosteum-limited. Vitamin C deficiency (scurvy) also causes painful sub-periosteal haemorrhage from defective collagen synthesis by osteoblasts.
- ▶ **Surgical importance:** surgeons deliberately preserve or elevate periosteum (subperiosteal dissection/resection) during bone and rib surgery specifically to protect the vascular supply and regenerative capacity of the underlying bone.
- ▶ **Periosteal elevation/reaction:** traction or inflammation lifting the periosteum off the cortex stimulates new subperiosteal bone formation, the basis of radiologically visible periosteal reaction in trauma, infection and tumours.
- ▶ **Absence at femoral neck:** the intracapsular part of the femoral neck is deficient in periosteum (it is covered instead by the reflected synovial membrane/capsule), which is why intracapsular femoral neck fractures characteristically show delayed union or non-union and a high risk of avascular necrosis.

High-yield exam pointers

- ▶ Periosteum = outer fibrous layer + inner cellular/osteogenic layer; absent over articular cartilage, enteses, sesamoid bones and ear ossicles.
- ▶ Attached to bone by **Sharpey's (perforating) fibres**.
- ▶ Nourishes the **outer cortex**; a bone stripped of periosteum dies.
- ▶ Richly supplied by **sensory (pain) nerves** — explains severe fracture pain and IM-injection pain.
- ▶ Source of **osteoprogenitor cells** for appositional (subperiosteal) growth in width and for **fracture callus**.
- ▶ Develops the **periosteal (bone) collar** in endochondral ossification (from the deep layer of the perichondrium).

- ▶ Continuous with joint capsule at articular margins; blends with tendon/ligament fibres at entheses.
- ▶ Clinically important in **cephalohaematoma**, femoral-neck fracture non-union, and surgical (subperiosteal) dissection technique.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; IB Singh — Textbook of Human Histology 9e; Junqueira's Basic Histology (Text & Atlas) 17e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh — Textbook of Anatomy Vol 3, 4e (cephalohaematoma).



Types of Epiphysis

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction

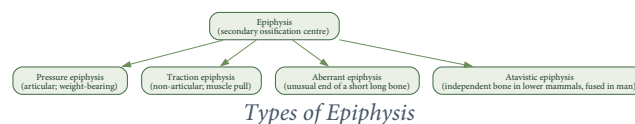
An **epiphysis** (plural *epiphyses*) is the part of a long bone that ossifies from a **secondary centre of ossification**, usually at its ends. It is separated from the diaphysis (shaft) by a plate of hyaline cartilage — the **epiphyseal (growth) plate** — until skeletal maturity, when the two fuse and longitudinal growth ceases. Epiphyses are classified, according to the **cause of their appearance**, into four types — **pressure, traction, aberrant and atavistic** — and this classification underlies the "law of union of epiphyses," several accessory-ossicle anomalies, and important clinical correlates such as growing-bone osteomyelitis and avascular necrosis.

1. Parts of a growing long bone

Part	Description
Diaphysis	Shaft; develops from the primary centre of ossification
Metaphysis	End of diaphysis adjoining the epiphyseal cartilage; most actively growing, most vascular part of the bone
Epiphyseal (growth) plate	Hyaline cartilage plate between epiphysis and diaphysis; proliferation here produces longitudinal growth; nourished by both epiphyseal and metaphyseal vessels
Epiphysis	End of the bone; develops from a secondary centre of ossification

2. Types of epiphysis (classified by cause of appearance)

Type	Basis / features	Examples
Pressure epiphysis	Occurs at an articular end; constant pressure/rubbing at the joint surface (weight transmission, movement) initiates ossification here	Head of femur, head of humerus, lower end of radius, lower end of fibula, upper end of tibia
Traction epiphysis	Produced by the traction/pull of an attached tendon or muscle ; always non-articular ; centre usually appears around puberty and ossifies later than a pressure epiphysis at the same bone	Greater and lesser trochanters of femur, greater and lesser tubercles of humerus
Aberrant epiphysis	An epiphysis appearing at the unusual end of a short long bone (i.e., at the end that normally has none)	Epiphysis at the head of the 1st metacarpal (normally the epiphysis of a metacarpal is at its distal/head end for the 2nd–5th, but the 1st metacarpal's epiphysis is normally at its base ; an epiphysis at its head is therefore "aberrant")
Atavistic epiphysis	An element that is a separate, independent bone in lower mammals but has become attached ("grows like a parasite") to a neighbouring bone in humans, ossifying from its own secondary centre	Coracoid process of the scapula ; posterior tubercle of the talus (os trigonum)



3. A special variant — annular (ring) epiphysis of the vertebra

- ▶ The vertebral body is regarded by some authorities as a **modified long bone**: the **centrum** corresponds to the diaphysis, and an **annular (ring) epiphysis** develops on its upper and lower surfaces, corresponding to the ends of a typical long bone.
- ▶ In a typical thoracic vertebra, **seven secondary (epiphyseal) centres** appear around puberty: an annular epiphysis each for the **upper and lower surfaces of the body**, one for the **tip of each transverse process**, one for **each mammillary process**, and one for the **tip of the spine**.
- ▶ These epiphyses fuse to the rest of the vertebra around the late teens to early twenties, and their persistence/fusion status is a useful **age-estimation marker** in the vertebral column.

4. Law of union of epiphyses ("law of ossification")

- ▶ **Rule:** the epiphyseal centre that **appears first, unites last**, and the centre that **appears later, unites first**.

- ▶ The end of the bone that unites last is called the **growing end** of that bone (e.g., upper end of humerus and lower ends of radius/ulna in the upper limb; lower end of femur and upper end of tibia in the lower limb).
- ▶ **The fibula is the sole exception** to this law:
- ▶ Its **lower epiphysis appears first** — because it is a **pressure epiphysis**, and the law of ossification states that a pressure epiphysis appears before a traction epiphysis at the same bone — and this lower epiphysis also **unites first** (rather than last).
- ▶ Its **upper epiphysis fuses last**, because the **upper end of the fibula is its true growing end** (as shown by the obliquity of its nutrient foramen), continuing to grow together with the upper end of the tibia, which is also a growing end.

5. Vascular and developmental correlates

- ▶ **Pressure epiphyses** are supplied via **epiphyseal arteries** derived from a peri-articular anastomosis (the *circulus vasculosus*), entering the epiphysis directly or through the epiphyseal cartilage.
- ▶ Before epiphyseal fusion, epiphyseal and metaphyseal vessels behave as **end arteries**, forming hairpin loops at the metaphysis — the vascular basis of childhood metaphyseal osteomyelitis; after fusion, free anastomoses are established.
- ▶ **Fusion of epiphysis with diaphysis occurs 2–3 years earlier in females than in males** (oestrogen accelerates epiphyseal closure) — a key reason women are, on average, shorter than men.
- ▶ Once epiphysis fuses with diaphysis, the bone can no longer grow in length.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 6.9 — Types of epiphyses: (A) pressure and traction epiphyses; (B) aberrant epiphysis; (C) and (D) atavistic epiphysis. (Vishram Singh — General Anatomy — 4e, p.246)

Reproduce a simple long-bone outline with four labelled insets and write the type beside each:

- ▶ (A) **Pressure epiphysis** — at an articular end, covered by articular cartilage, in line with the long axis of the shaft (e.g. head of femur)
- ▶ (A) **Traction epiphysis** — a bony outgrowth away from the articular end, at a tendon/muscle attachment (e.g. greater trochanter of femur)
- ▶ (B) **Aberrant epiphysis** — epiphyseal line at the *unusual* end of a short long bone (e.g. head of 1st metacarpal, contrasted with the normal *base* epiphysis)
- ▶ (C)/(D) **Atavistic epiphysis** — a small separate ossific nodule fused parasitically onto the parent bone (e.g. coracoid process of scapula / os trigonum of talus)

Applied / Clinical anatomy

- ▶ **Radiological/forensic age estimation:** the sequence of appearance and fusion of epiphyses is one of the most reliable indicators of skeletal (bone) age in children and young adults; an unfused epiphyseal line (radiolucent gap on X-ray) confirms an individual is below the known fusion age for that bone.
- ▶ **Non-union of a normal epiphysis produces named accessory ossicles**, which must not be mistaken for avulsion fractures on imaging: **os trigonum** (unfused posterior tubercle/talus —

itself also cited as an atavistic-type epiphysis), **os vesalianum** (unfused epiphysis at the styloid process of the 5th metatarsal), and **patella cubiti** (unfused olecranon epiphysis of the ulna).

- ▶ **Fibula's violation of the law of ossification** is a classic viva/theory point (see Section 4) and explains why its lower epiphysis fuses early (like a typical pressure epiphysis) while the true growing end lies proximally.
- ▶ **Traction epiphyses are avulsion-fracture-prone** in adolescent athletes because they are attached only by tendon pull and fuse later than pressure epiphyses (e.g., separation of the greater trochanter or tibial tuberosity apophysis).
- ▶ **Metaphyseal osteomyelitis in children** is explained by the end-arterial hairpin loops of the epiphyseal/metaphyseal circulation before fusion (Section 5); this is rare after fusion establishes epiphyseal–metaphyseal anastomoses.
- ▶ **Avascular necrosis of a pressure epiphysis** with a precarious terminal blood supply is clinically important — e.g. the femoral head after intracapsular neck-of-femur fracture (retinacular vessels torn), the proximal pole of the scaphoid, and the body of the talus.
- ▶ **Growth-plate (physeal) injuries** in children are a recognised cause of subsequent limb-length discrepancy or angular deformity if the epiphyseal plate is damaged, and are conventionally graded on the (widely used, non-anatomy-specific) Salter–Harris classification.
- ▶ **Sex difference in fusion timing** (females 2–3 years earlier) is used in forensic age and sex estimation from skeletal remains.

High-yield exam pointers

- ▶ Epiphysis = end of long bone ossifying from a **secondary centre**; four types by **cause of appearance**: **pressure, traction, aberrant, atavistic**.
- ▶ **Pressure** = articular, weight-transmitting (e.g. femoral head); **Traction** = non-articular, muscle-pull, ossifies later (e.g. trochanters, tubercles).
- ▶ **Aberrant** = epiphysis at the unusual end of a short long bone (1st metacarpal head); **Atavistic** = independent bone in lower mammals fused parasitically in man (coracoid process, os trigonum).
- ▶ **Law of ossification**: epiphysis appearing first fuses last, and vice versa; **fibula is the sole exception** — its lower (pressure) epiphysis appears first *and* fuses first; the upper end is the true growing end.
- ▶ **Annular (ring) epiphysis** of the vertebral body — vertebra as a "modified long bone" (centrum = diaphysis, ring epiphysis = ends); seven secondary centres in a typical thoracic vertebra.
- ▶ Fusion occurs **2–3 years earlier in females**.
- ▶ Non-union of a normal epiphysis → **os trigonum, os vesalianum, patella cubiti**.
- ▶ Clinical hooks: metaphyseal osteomyelitis (end-arterial epiphyseal/metaphyseal circulation before fusion), avascular necrosis of pressure epiphyses (femoral head, scaphoid, talus), forensic bone-age estimation.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (primary account — four types of epiphysis with definitions/examples, law of union of epiphyses and fibula exception, non-union accessory ossicles, sex difference in fusion); IB Singh — Textbook of Anatomy Vol 1 6e (corroborating definitions of pressure/traction/atavistic epiphysis and epiphyseal cartilage); BD Chaurasia — Human Anatomy Vol 1 8e and Vol 2 8e (law of ossification statement, detailed fibula-exception mechanism, annular epiphyses/secondary centres of the thoracic vertebra); Gray's Anatomy (Standring) 41e (ring epiphysis of the vertebral body and its relation to the vertebral growth plate).

♦ ♦ ♦

Upper limb

♦ ♦ ♦

Anastomoses around the Scapula

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction The scapula lies at the junction of the neck and the upper limb, a region where the two major arterial trunks of the limb — the **subclavian artery** (proximal to the first rib) and the **axillary artery** (distal to it) — are separated by the narrow, mobile, and trauma-prone axilla. To safeguard the blood supply of the upper limb across this vulnerable gap, an extensive network of arteries forms a rich anastomosis on and around the scapula, linking branches of the **first part of the subclavian artery** with branches of the **third part of the axillary artery**. This "scapular anastomosis" is a classic example of a pre-formed collateral circulation and is of high applied importance whenever the subclavian or axillary artery is diseased, injured, or surgically ligated.

1. The Two Sites of the Scapular Anastomosis

The anastomosis is described under two headings, both illustrated in the same regional network:

- ▶ **Anastomosis around the body of the scapula** — in the subscapular, supraspinous and infraspinous fossae.
- ▶ **Anastomosis over the acromion process** — on the point of the shoulder.

2. Anastomosis around the Body of the Scapula

This occurs between three arteries that meet in the subscapular, supraspinous and infraspinous fossae:

Artery	Origin	Course to reach the scapula
Suprascapular artery	Branch of the thyrocervical trunk , from the 1st part of the subclavian artery	Crosses the posterior triangle of the neck superficial to the trunks of the brachial plexus; passes above the superior transverse scapular ligament (the suprascapular <i>nerve</i> passes below it — "army over the bridge, navy under the bridge") to enter the supraspinous fossa; supplies supraspinatus, then curves round the scapular spine through the spinoglenoid notch (deep to the inferior transverse scapular ligament) into the infraspinous fossa
Dorsal scapular artery (or the deep branch of the transverse cervical artery)	Directly from the 2nd/3rd part of the subclavian artery in the majority of individuals; in the remainder it arises as the deep branch of the transverse cervical artery, itself from the thyrocervical trunk	Passes among the trunks of the brachial plexus, then descends along the medial border of the scapula , deep to levator scapulae and the rhomboids, accompanying the dorsal scapular nerve, to reach the subscapular and infraspinous fossae
Circumflex scapular artery	Larger of the two terminal branches of the subscapular artery , itself the largest branch of the 3rd part of the axillary artery	Curves backward around the lateral border of the scapula through the upper triangular (intermuscular) space ; enters the infraspinous fossa deep to teres minor, then divides into an infrascapular branch (running deep to subscapularis into the subscapular fossa) and a continuing branch along the scapular border to the inferior angle

At the inferior angle and within the three fossae these vessels freely inosculate, so that the **suprascapular** and **dorsal scapular arteries** (both ultimately from the subclavian) meet the **circumflex scapular artery** (from the axillary), completing the link between the two named systems. The subscapular artery's main trunk also anastomoses directly with the **lateral thoracic** and **posterior intercostal arteries** at the inferior angle, broadening the collateral field still further.

□ Fig 4.7 — ■ Anastomosis around the scapula (scapular) (Vishram Singh — *Textbook of Anatomy Vol 1 — 4e*, p.208)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A dorsal view of the right scapula and adjoining humerus/clavicle, labelled with:

- ▶ Outline of the **scapula** (spine, supraspinous fossa, infraspinous fossa, acromion, inferior angle) and proximal **humerus**.
- ▶ **Suprascapular artery** entering the supraspinous fossa over the superior transverse scapular ligament, continuing round the spine through the spinoglenoid notch into the infraspinous fossa (arrow from neck downward).
- ▶ **Dorsal scapular artery / deep branch of transverse cervical artery** descending along the medial border of the scapula (arrow from neck downward).
- ▶ **Circumflex scapular artery** emerging from the axilla through the upper triangular space into the infraspinous fossa (arrow from axilla laterally).
- ▶ An anastomotic loop/star drawn where the three arteries meet in the infraspinous fossa, with a second loop at the inferior angle (subscapular ↔ lateral thoracic ↔ intercostal).
- ▶ Over the acromion: three short converging arrows labelled **acromial branch of thoraco-acromial**, **acromial branch of suprascapular**, and **acromial branch of posterior circumflex humeral**, meeting at the acromion.
- ▶ Two-colour convention: vessels derived from the subclavian artery in one colour, vessels derived from the axillary artery in a second colour, to visually demonstrate the cross-link.

3. Anastomosis over the Acromion Process

A second, smaller anastomosis occurs on the point of the shoulder, formed by the acromial branches of three arteries:

Artery	Origin
Acromial branch of the thoraco-acromial artery	2nd part of the axillary artery
Acromial branch of the suprascapular artery	1st part of the subclavian artery (via the thyrocervical trunk)
Acromial branch of the posterior circumflex humeral artery	3rd part of the axillary artery

This acromial network again links the first part of the subclavian artery with the second and third parts of the axillary artery, and additionally anastomoses with the deltoid branch of the profunda brachii artery, extending the collateral field down into the arm.

4. The Circumflex Scapular Artery — the Key Axillary Contributor

Because it is the sole representative of the axillary system in the body-of-scapula anastomosis, its course deserves emphasis:

- ▶ It is the **larger terminal branch of the subscapular artery** (the other being the thoracodorsal artery, which supplies latissimus dorsi and serratus anterior).

- ▶ It reaches the back of the scapula by traversing the **upper triangular (intermuscular) space**, bounded by **subscapularis above (anteriorly)**, **teres minor posteriorly**, **teres major below**, and the **long head of triceps laterally** — the only structure that passes through this particular space.
- ▶ Small branches also supply the posterior fibres of deltoid and the long head of triceps, anastomosing with an ascending branch of the profunda brachii artery.
- ▶ Two cutaneous perforators arising as it emerges from the triangular space (a horizontal branch along the scapular spine, and a lower parascapular branch) form the vascular basis of the **scapular and parascapular skin flaps** used in reconstructive surgery.

5. Functional Basis of the Anastomosis

- ▶ The anastomosis effectively bridges the **first part of the subclavian artery** to the **third part of the axillary artery**, i.e. it spans the entire segment of vessel that lies within the mobile, poorly protected axilla and root of the neck — precisely the segment most exposed to stab wounds, fractures of the clavicle/proximal humerus, and thoracic-outlet compression.
- ▶ Under normal circumstances flow in the circumflex scapular and subscapular arteries runs from the axillary artery toward the scapula; when the proximal vessel is occluded, flow through the subscapular artery **reverses**, so that blood delivered via the subclavian-derived suprascapular and dorsal scapular arteries now flows retrogradely into the subscapular artery and onward into the third part of the axillary artery, re-establishing distal limb perfusion.

Applied / Clinical anatomy

- ▶ **Collateral circulation after arterial injury/ligation:** if the subclavian or axillary artery is torn (e.g. penetrating axillary trauma, clavicle fracture, first-rib fracture) or must be surgically ligated, the scapular anastomosis provides the principal alternative route by which blood reaches the third part of the axillary artery, sustaining the upper limb.
- ▶ **Safe vs unsafe level of ligation:** ligation of the axillary artery is well tolerated when performed **proximal to the origin of the subscapular artery** or **distal to the profunda brachii artery**, because the scapular (and peri-articular elbow) anastomoses can compensate. Ligation **between the origins of the subscapular artery and the profunda brachii artery**, however, isolates this segment from all collateral supply and produces ischaemia of the arm, forearm and hand.
- ▶ **Rate of occlusion matters:** slow, progressive occlusion (e.g. atherosclerotic stenosis, a slowly enlarging tumour) allows time for the collateral channels to dilate and become functionally adequate; sudden occlusion (acute trauma, embolism) does not, and typically results in acute limb ischaemia.
- ▶ **Compression for haemostasis:** the third part of the axillary artery can be compressed against the humerus in the lower part of the lateral axillary wall to control bleeding distal to the axilla; more proximal bleeding is controlled by compressing the subclavian artery against the first rib.
- ▶ **Aneurysm of the axillary artery:** may compress the adjacent trunks of the brachial plexus (classically described in athletes with repetitive forceful arm movements — e.g. baseball pitchers), producing pain and sensory loss in the corresponding dermatomes.

- ▶ **Basis of the scapular/parascapular flap:** the cutaneous perforators of the circumflex scapular artery supply a reliable, hairless skin paddle that can be raised as a free or pedicled flap for reconstruction elsewhere in the body — a direct surgical application of this anastomosis.
- ▶ **"Lifeline of the limb":** the branches of the thyrocervical trunk (suprascapular and transverse cervical/dorsal scapular arteries) are deliberately preserved during operations on a lacerated subclavian artery, since they alone can sustain the limb via the scapular anastomosis if the main vessel cannot be repaired.

High-yield exam pointers

- ▶ Scapular anastomosis links the **1st part of the subclavian artery** to the **3rd part of the axillary artery**, at two sites: **around the body of the scapula** and **over the acromion process**.
- ▶ Body-of-scapula anastomosis = **suprascapular + dorsal scapular (deep branch of transverse cervical) + circumflex scapular** arteries, meeting in the subscapular/supraspinous/infraspinous fossae.
- ▶ Acromial anastomosis = acromial branches of **thoraco-acromial, suprascapular, and posterior circumflex humeral** arteries.
- ▶ **Circumflex scapular artery** = larger terminal branch of the subscapular artery; the only content of the **upper triangular space** (subscapularis, teres minor, teres major, long head of triceps).
- ▶ Mnemonic at the suprascapular notch: **"Army (artery) over the bridge, Navy (nerve) under the bridge"** — suprascapular artery passes over, nerve passes under, the superior transverse scapular ligament.
- ▶ Subscapular artery also anastomoses with the **lateral thoracic** and **posterior intercostal** arteries at the inferior angle of the scapula.
- ▶ Clinical crux: ligation of the axillary artery **between the subscapular and profunda brachii origins** cuts off all collateral supply and is dangerous; ligation outside this segment is safe.
- ▶ Circumflex scapular artery's cutaneous perforators are the vascular pedicle of the **scapular/parascapular flap**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb); Vishram Singh — Textbook of Anatomy Vol 1, 4e; Moore's Clinically Oriented Anatomy, 9e.



Axillary lymph nodes

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction The axillary lymph nodes are a group of 20–30 lymph nodes scattered in the fibrofatty tissue of the axilla, arranged in a manner that reflects the pyramidal shape of the axillary space. Conventionally described in **five groups** — anterior (pectoral), posterior (subscapular), lateral (humeral), central and apical (infraclavicular) — they collectively drain the **entire upper limb, most of the breast** (>75% of its lymph), and the skin and superficial muscles of the **trunk wall above the level of the umbilicus**, both anteriorly and posteriorly. Of the five groups, four are purely intermediary stations; only the apical group is terminal, its efferents forming the subclavian lymphatic trunk. Their clinical importance is immense — they are the principal site of metastasis in carcinoma of the breast and the commonest palpable lymph node group in upper-limb and thoracic-wall sepsis.

1. Number and general arrangement

- ▶ 20–30 nodes (some texts, considering the full territory of breast drainage, describe up to 40) embedded in the axillary fat.
- ▶ Grouped **artificially** into five sets that correspond to the base and apex of the pyramidal axilla — three groups (anterior, posterior, lateral) lie near the triangular base, the central group lies centrally within the fat, and the apical group lies at the apex.
- ▶ Only the **apical group is terminal** (drains directly into the venous system); the anterior, posterior, lateral and central groups are all **intermediary**, passing their efferents onward to other axillary groups.

2. The five groups — situation, relations, afferents and efferents

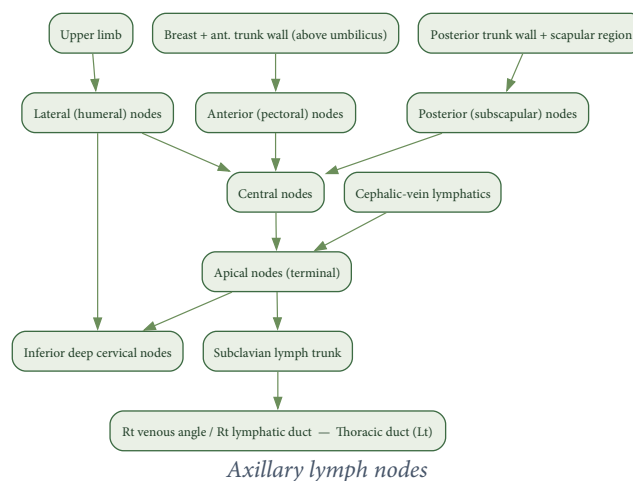
Group	Number	Situation / relations	Chief afferents (drains)	Efferents (drains into)
Anterior (pectoral)	4–5	Along the lateral thoracic vessels, at the lower border of pectoralis minor	Upper half of the anterior trunk wall (above umbilicus) and the major part of the breast (esp. superolateral quadrant, via the subareolar plexus of Sappey)	Partly to central, partly to apical group
Posterior (subscapular)	6–7	Along the subscapular vessels, on the posterior axillary fold	Posterior trunk wall (neck to iliac crest region) and the axillary tail of the breast	To central and apical groups
Lateral (humeral)	4–6	Along the upper humerus, posteromedial/medial to the axillary vein	Almost the whole upper limb, <i>except</i> vessels accompanying the cephalic vein	Partly to central and apical groups, partly directly to the inferior deep cervical nodes

Group	Number	Situation / relations	Chief afferents (drains)	Efferents (drains into)
Central	3–4 (large)	Embedded in fat in the upper axilla, near the 2nd part of the axillary artery	All three preceding groups; also some direct vessels from the floor of the axilla	To the apical group (the intercostobrachial nerve runs among these nodes)
Apical (infraclavicular)	6–12	Partly behind the upper part of pectoralis minor, partly above its upper border, extending to the apex of the axilla along the axillary vein and 1st part of the axillary artery	All other axillary groups; direct afferents from lymphatics accompanying the cephalic vein and from the upper/outer part of the breast	Unite as the subclavian lymphatic trunk (only terminal group)

- **Infraclavicular (deltopectoral) nodes** — 1–2 small nodes beside the cephalic vein in the groove between pectoralis major and deltoid, just below the clavicle; their efferents pierce the clavipectoral fascia to reach the apical group (occasionally passing in front of the clavicle to the inferior deep cervical/supraclavicular nodes instead).
- **Interpectoral (Rotter's) nodes** — one or two small nodes lying between pectoralis major and minor; a recognised route of contiguous spread in breast carcinoma.

3. Efferent pathway and termination

- Efferents of the apical nodes unite to form the **subclavian lymphatic trunk**, which may receive tributaries from the infraclavicular/supraclavicular nodes en route.
- **Right side:** the subclavian trunk may join the jugular and bronchomediastinal trunks to form a short **right lymphatic duct**, or enter the **right jugulo-subclavian venous angle** independently.
- **Left side:** the subclavian trunk usually joins the **thoracic duct**.
- A few efferents from the apical (and some from the lateral) group bypass the venous termination and pass instead to the **inferior deep cervical (supraclavicular) nodes**.



□ Fig 4.11 — The axillary lymph nodes (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.82)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the axilla as a **four-sided pyramid** (apex above, base at the skin) and mark:

- ▶ **Anterior wall** — pectoralis major/minor; **posterior wall** — subscapularis, latissimus dorsi, teres major; **medial wall** — serratus anterior/ribs; **lateral wall** — humerus (intertubercular sulcus).
- ▶ The **axillary vein**, running through the axilla, with the five node groups placed around it:
 - **Anterior (pectoral) nodes** — along lower border of pectoralis minor.
 - **Posterior (subscapular) nodes** — on the posterior axillary fold.
 - **Lateral (humeral) nodes** — medial to the axillary vein, along the humerus.
 - **Central nodes** — in the fat of the upper axilla (mark the intercostobrachial nerve passing among them).
 - **Apical nodes** — at the apex, medial to the axillary vein, partly behind pectoralis minor.
- ▶ Arrows showing lymph flow: anterior/posterior/lateral → central → apical → subclavian trunk → venous angle (right)/thoracic duct (left).
- ▶ Label pectoralis minor and mark the three surgical **Levels (I, II, III)** relative to its lower border, deep surface and upper border.

Applied / Clinical anatomy

- ▶ **Surgical levels (relative to pectoralis minor)** — used in breast-cancer staging and axillary clearance:
 - **Level I** — nodes lateral to (below) the lower border of pectoralis minor.
 - **Level II** — nodes deep to (behind) pectoralis minor.
 - **Level III** — nodes medial to (above) the upper border of pectoralis minor, up to the lower border of the clavicle (= the apical group).
- ▶ **Sentinel lymph node** — the first node(s) to receive lymph from the tumour-bearing area of the breast, usually a Level I node; localised by injecting a radioactive tracer/dye into the tumour site. Sentinel lymph node biopsy allows staging with far less morbidity than a full axillary clearance.
- ▶ **Vascular risk during axillary dissection** — the apical, central and lateral groups are very closely related to the axillary vein; block dissection/mastectomy can accidentally injure the vein, causing troublesome bleeding or postoperative thrombosis.
- ▶ **Nerve risk during block dissection** — the fibrofatty tissue must be removed carefully to avoid injuring the **long thoracic nerve** (winged scapula), the **thoracodorsal nerve**, and the **intercostobrachial nerve** (numbness/pain along the medial arm); an enlarged central-group node can itself compress the intercostobrachial nerve, producing pain along its distribution.
- ▶ **Axillary tail of Spence** lies in direct contact with the anterior (pectoral) group — a carcinoma arising in the tail may therefore be clinically mistaken for an enlarged lymph node.
- ▶ **Breast carcinoma spread** — because more than 60% of breast cancers arise in the lateral part of the gland, the axillary (chiefly anterior and central) groups are the most frequent site of

metastasis; when the normal pathway is blocked by tumour or destroyed by surgery/radiotherapy, lymph can be diverted across the midline to the opposite axilla or to the anterior abdominal wall.

- ▶ **Lymphangitis** — infection introduced through the hand/limb produces warm, red, tender streaks along the lymphatics, with resulting tender enlargement of the axillary nodes (the lateral/humeral group, receiving almost the entire limb, is typically first involved).
- ▶ **Lymphoedema** — surgical excision or irradiation of the axillary nodes can obstruct lymphatic return from the upper limb, producing chronic lymphoedema of the arm.
- ▶ **Bimanual palpation** — because the apical group lies deep, it is examined bimanually, pushing the fingers of one hand into the apex of the axilla from below while the fingers of the other hand palpate behind the clavicle from above; by convention, the left axillary nodes are palpated with the examiner's right hand and vice versa.

High-yield exam pointers

- ▶ **Five groups:** anterior (pectoral), posterior (subscapular), lateral (humeral), central, apical — only the apical group is terminal.
- ▶ Total **20–30 nodes**; approximate counts — anterior 4–5, posterior 6–7, lateral 4–6, central 3–4, apical 6–12.
- ▶ Collectively drain the **whole upper limb + most of the breast + trunk wall above the umbilicus**.
- ▶ Apical efferents form the **subclavian trunk** → right lymphatic duct/right venous angle; left side usually joins the **thoracic duct**.
- ▶ **Surgical Levels I/II/III** are defined relative to **pectoralis minor** — the anatomical basis of axillary clearance staging in breast carcinoma.
- ▶ **Rotter's (interpectoral) nodes** lie between pectoralis major and minor.
- ▶ **Sentinel node** = first draining node of a breast tumour, usually a Level I node.
- ▶ Apical, central and lateral groups are intimately related to the **axillary vein** — the chief structure at surgical risk during axillary clearance, alongside the long thoracic, thoracodorsal and intercostobrachial nerves.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; Vishram Singh — Textbook of Anatomy Vol 1 4e; IB Singh — Textbook of Anatomy Vol 1 6e; Moore's Clinically Oriented Anatomy 9e.



Brachial plexus

Asked in: Paper I May 2011 — RGUHS MD/MS Anatomy

Definition / Introduction The brachial plexus is the somatic nerve network formed by the ventral (anterior) primary rami of the fifth, sixth, seventh and eighth cervical and the first thoracic spinal nerves (C5–C8, T1), which supplies almost the entire motor and sensory innervation of the upper limb, together with the pectoral and scapular girdle muscles. It is built up in an orderly sequence — **roots** → **trunks** → **divisions** → **cords** → **branches** — and runs from the posterior triangle of the neck, deep to the clavicle, into the axilla, closely applied throughout its course to the subclavian and axillary vessels within a common axillary sheath. Its formation, relations and branches are among the most frequently asked long-answer questions in anatomy because of the clinical importance of its birth and traction injuries.

Formation — roots and their variations

- ▶ Formed by the ventral rami of C5, C6, C7, C8 and T1, which pass into the **posterior triangle of the neck between scalenus anterior and scalenus medius**.
- ▶ Occasional additional contributions from C4 or T2 give two named variants:
 - **Prefixed plexus:** large C4 contribution, C5 present, T1 small, T2 usually absent.
 - **Postfixed plexus:** large T1 contribution, T2 always present, C4 absent, C5 reduced.
- ▶ Rami of C7 and C8 are the thickest, C5 and T1 the thinnest; each terminal branch carries a fixed "root value" (e.g. suprascapular nerve C5,C6).
- ▶ **Sympathetic contribution:** postganglionic vasomotor/sudomotor/pilomotor fibres reach the plexus by grey rami communicantes from the **middle cervical ganglion (to C5,C6)**, **inferior cervical/stellate ganglion (to C7,C8)** and **first thoracic ganglion (to T1)** — the basis for Horner's syndrome in a proximal T1 lesion.

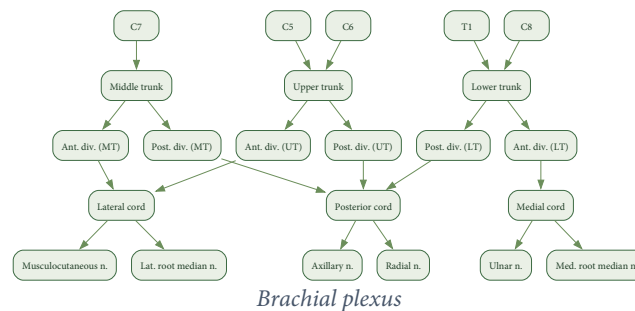
Trunks and Erb's point

- ▶ **Upper trunk** = union of C5 and C6, formed as they emerge deep to scalenus anterior.
- ▶ **Middle trunk** = direct continuation of C7.
- ▶ **Lower trunk** = union of C8 and T1, formed as these rami cross anterior to the neck of the first rib (T1 runs upward across the pleura and the vertebral/subclavian arteries).
- ▶ The three trunks lie one below the other in the lower posterior triangle, enclosed with the subclavian artery in the **axillary (prevertebral fascial) sheath**; the subclavian artery lies anteromedial to them.
- ▶ **Erb's point**, just above the clavicle, is where the C5,C6 roots unite into the upper trunk, which there gives off its two branches (suprascapular nerve and nerve to subclavius) — the site of the Erb–Duchenne traction injury and of the interscalene/supraclavicular nerve block.

Divisions and cords

- ▶ Behind the clavicle (**retroclavicular part**), each of the three trunks splits into an **anterior** and a **posterior division** — six in all. The upper trunk divides 2–3 cm above the clavicle; the middle/lower trunk divisions form deep to it.
- ▶ Posterior divisions of the upper and middle trunks are larger than their anterior divisions; the posterior division of the lower trunk is smaller and **absent in ~10% of subjects**.

- Functionally: anterior divisions/lateral & medial cords → **flexor (preaxial)** compartment; posterior divisions/posterior cord → **extensor (postaxial)** compartment.
- **Cords** (infraclavicular part, named from their relation to the second part of the axillary artery):
 - **Lateral cord** — anterior divisions of the upper and middle trunks.
 - **Medial cord** — anterior division of the lower trunk alone.
 - **Posterior cord** — all three posterior divisions; the **largest of the three cords**.
- Immediately below the clavicle the relations differ — posterior cord lateral, medial cord posterior, lateral cord anterior to the artery; the cords take up their name-giving position around the artery's second part only after passing deep to pectoralis minor.



Branches — supraclavicular (from roots and trunks)

Branch	Root value	Origin	Muscles / structures supplied
Nerve to longus colli and scaleni	C5–C8	Roots	Prevertebral neck muscles
Contribution to phrenic nerve	C5	Root	Joins C4 (main root) to form phrenic nerve — sole motor supply of the diaphragm
Dorsal scapular nerve	C5	Root	Rhomboid major and minor (contributes to levator scapulae)
Long thoracic nerve (nerve to serratus anterior / nerve of Bell)	C5–C7	Roots	Serratus anterior
Suprascapular nerve	C5, C6	Upper trunk	Supraspinatus, infraspinatus
Nerve to subclavius	C5, C6	Upper trunk	Subclavius (may carry an accessory root to the phrenic nerve)

Branches — infraclavicular (from the cords)

Cord	Branch	Root value	Supplies
Lateral	Lateral pectoral	C5–C7	Pectoralis major and minor
	Musculocutaneous	C5–C7	Coracobrachialis, biceps brachii, brachialis
	Lateral root of median nerve	C5–C7	Joins medial root → median nerve
Medial	Medial pectoral	C8, T1	Pectoralis major and minor
	Medial cutaneous nerve of arm	C8, T1	Sensory — medial arm
	Medial cutaneous nerve of forearm	C8, T1	Sensory — medial forearm
	Ulnar nerve	C7, C8, T1	1½ flexor muscles of forearm + intrinsic hand muscles
	Medial root of median nerve	C8, T1	Joins lateral root → median nerve
Posterior	Upper subscapular	C5, C6	Subscapularis
	Nerve to latissimus dorsi (thoracodorsal)	C6–C8	Latissimus dorsi
	Lower subscapular	C5, C6	Subscapularis, teres major
	Axillary (circumflex)	C5, C6	Deltoid, teres minor
	Radial nerve	C5–C8, T1	Triceps brachii (all heads) + all extensor muscles of the forearm — thickest branch of the plexus

- **Blood supply of the plexus:** derived from the subclavian and vertebral arteries — vertebral branches to C5/C6, the costocervical trunk to C8/T1, and the suprascapular and transverse cervical (superficial cervical) arteries (from the thyrocervical trunk) supplying the rest; these vessels are the surgical "lifeline" of the plexus and must be preserved during exploration.
- **Special feature ("M" of the axilla):** the lateral cord (giving the musculocutaneous nerve and lateral root of median) and the medial cord (giving the ulnar nerve and medial root of median) together with the median nerve trunk trace the outline of the letter "M" in the open axilla — a quick way to identify the nerves at operation.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 4.14 — *The right brachial plexus (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.83)*

A labelled schematic of the right brachial plexus in the standard "roots-to-branches" layout, with:

- ▶ **Roots** — C5, C6, C7, C8, T1 entering between scalenus anterior and medius
- ▶ **Trunks** — upper (C5,C6), middle (C7), lower (C8,T1)
- ▶ **Divisions** — anterior and posterior division of each trunk (label all six)
- ▶ **Cords** — lateral, medial and posterior, named around the axillary artery
- ▶ **Terminal branches** — musculocutaneous, axillary, radial, median (lateral + medial roots), ulnar
- ▶ Supraclavicular branches at their root of origin — dorsal scapular, long thoracic, suprascapular, nerve to subclavius
- ▶ Axillary artery sketched alongside the cords to show their name-giving relation, and the "M" shape of lateral cord–median nerve–medial cord–ulnar nerve

Applied / Clinical anatomy

- ▶ **Erb–Duchenne (Erb's) palsy** — traction injury of the **upper trunk (C5, C6)** at Erb's point from forceful separation of the head from the shoulder (difficult labour, fall on the shoulder, traction under anaesthesia). Produces the classic "**waiter's tip**" / "**policeman's tip**" / "**porter's tip**" hand — arm adducted and medially rotated, forearm extended and pronated; biceps and supinator jerks lost; small area of sensory loss over the lower/lateral deltoid.
- ▶ **Klumpke's palsy** — traction injury of the **lower trunk (C8, T1)** from sudden upward pulling of the arm (clutching at something while falling, or breech delivery). Produces a **complete claw hand** (metacarpophalangeal hyperextension with interphalangeal flexion) and ulnar-border sensory loss. If T1 is torn proximal to its white ramus communicans, an associated **Horner's syndrome** (ptosis, miosis, anhidrosis, enophthalmos) results from interruption of the sympathetic outflow to the head and neck.

Feature	Erb's palsy	Klumpke's palsy
Site of injury	Upper trunk (Erb's point)	Lower trunk
Roots	C5, C6	C8, T1
Mechanism	Head-shoulder separation (downward traction)	Upward traction on abducted arm
Muscles paralysed	Deltoid, biceps, brachialis, brachioradialis (± spinati, supinator)	Intrinsic hand muscles (T1) + ulnar flexors of wrist/fingers (C8)
Deformity	Waiter's/policeman's tip hand	Claw hand
Associated feature	—	Horner's syndrome (if pre-ganglionic T1 injury)

- ▶ **Long thoracic nerve (nerve of Bell) injury** — from shoulder pressure, heavy loads on the shoulder, or axillary/mastectomy surgery — paralyzes serratus anterior, causing **winging of the scapula** and loss of the pushing/punching action.
- ▶ **Pre- vs post-ganglionic injury**: a supraclavicular traction lesion may **avulse** a root proximal to the dorsal root ganglion (pre-ganglionic — more common at C8/T1, often with Horner's syndrome, poor prognosis, not repairable at the root) or **rupture** it distally (post-ganglionic — repairable by grafting/nerve transfer); this Bonney distinction guides surgical decision-making.
- ▶ **Nerve blocks** exploit the plexus's constant relations: **interscalene** (upper roots/trunks — reliably blocks the phrenic nerve, Horner's sign common), **supraclavicular** (2 cm above mid-clavicle, in the compact plane of the trunks over the first rib, posterior to the third part of the subclavian artery — risk of pneumothorax), and **axillary** (around the cords/terminal nerves at the axillary artery — avoids phrenic block/pneumothorax but often spares the musculocutaneous nerve).
- ▶ **Surface anatomy**: the upper trunk and suprascapular nerve are palpable in the supraclavicular fossa just posterolateral to the subclavian pulse.

High-yield exam pointers

- ▶ Roots C5–T1; **prefixed** (large C4, minimal T1) and **postfixed** (large T1, minimal C5) variants.
- ▶ Mnemonic for the plan — "Ramu Tailor Drinks Cold Beer": Roots → Trunks → Divisions → Cords → Branches.
- ▶ Formed between scalenus anterior and medius; enclosed with the subclavian/axillary artery in the axillary sheath.
- ▶ Only the **upper trunk** gives supraclavicular branches — suprascapular nerve and nerve to subclavius; **Erb's point** = union of C5,C6 into the upper trunk + these two branches.
- ▶ **Posterior cord** is the largest cord (all three posterior divisions); mnemonic for its five branches — "STAR": Subscapular (upper & lower), Thoracodorsal, Axillary, Radial.
- ▶ Terminal branches lateral→medial in the axilla — "My Aunt Ragged My Uncle": Musculocutaneous, Axillary, Radial, Median, Ulnar.
- ▶ **Radial nerve** (C5–T1) is the thickest branch; **axillary nerve** (C5,C6) the smallest terminal branch of the posterior cord.
- ▶ **Erb's palsy** (upper trunk, C5,C6) → waiter's tip hand; **Klumpke's palsy** (lower trunk, C8,T1) → claw hand ± Horner's syndrome.
- ▶ Pre-ganglionic root avulsion carries a poor prognosis (Horner's sign, no surgical repair of the root itself) versus a repairable post-ganglionic rupture.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb); Vishram Singh — Textbook of Anatomy Vol 1, 4e; Moore's Clinically Oriented Anatomy, 9e.



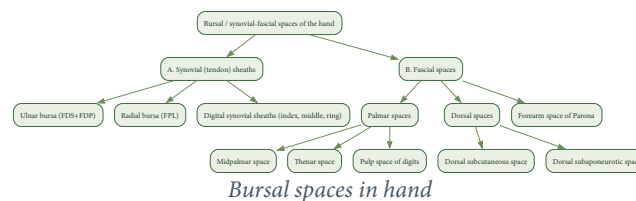
Bursal spaces in hand

Asked in: Paper I Nov 2017 — RGUHS MD/MS Anatomy

Definition / Introduction

A **bursa** is a synovium-lined sac that reduces friction between a moving tendon and an adjacent fibro-osseous or bony surface. In the hand the term "bursal spaces" is used, by long anatomical convention, for the two large **synovial sheaths** — the **ulnar bursa** (common flexor synovial sheath) and the **radial bursa** — that envelop the long flexor tendons within the carpal tunnel and continue variable distances into the palm and digits. These communicate, directly or through the potential **fascial (palmar, dorsal and forearm) spaces** of the hand, with the independent **digital synovial sheaths**. Together they form a single functional and surgical unit, because the pattern of continuity between bursae, digital sheaths and fascial spaces dictates how tenosynovial infections of the hand spread — the reason this is a recurrent gross/applied-anatomy question.

Classification



Synovial sheaths of the long flexor tendons

The eight long flexor tendons (4 flexor digitorum superficialis, FDS, and 4 flexor digitorum profundus, FDP) and the tendon of flexor pollicis longus (FPL), together with the digital tendons, are invested by synovial sheaths as they pass deep to the flexor retinaculum and into the digits.

Feature	Ulnar bursa	Radial bursa
Also called	Common flexor synovial sheath	—
Tendons enclosed	4 tendons of FDS + 4 tendons of FDP	Tendon of FPL
Proximal extent	~2.5 cm above the flexor retinaculum	~2.5 cm above the flexor retinaculum
Distal extent	To middle of the palm; prolonged along the little finger as its digital sheath	Along the whole length of the thumb to the insertion of FPL
Continuity with digital sheath	Continuous with the digital synovial sheath of the little finger only	Continuous with the digital synovial sheath of the thumb
Relation to index/middle/ring sheaths	Ends blindly at mid-metacarpal level; not continuous with these digital sheaths	Not related

Feature	Ulnar bursa	Radial bursa
Communication with each other	Usually separate; may communicate with the ulnar bursa deep to the flexor retinaculum in a minority of hands	Same
Tendon invagination	Tendons invaginate the sheath from its lateral side	Tendon invaginates from the lateral side

Digital synovial sheaths

- ▶ Each finger has its own digital synovial sheath, lining the osseo-fibrous flexor tunnel (formed by the annular and cruciate pulleys, A1–A5 and C0–C3) that runs from the metacarpal neck to the base of the distal phalanx.
- ▶ The sheaths of the **index, middle and ring fingers are independent**, terminating proximally at the level of the metacarpal heads/neck — they do **not** communicate with the ulnar bursa.
- ▶ The digital sheath of the **little finger is continuous proximally with the ulnar bursa**, and that of the **thumb is continuous with the radial bursa**.
- ▶ Vincula tendinum (vincula brevia and longa) are synovial folds within these sheaths that carry the blood supply to the otherwise avascular intra-sheath tendon segments.
- ▶ Functionally, all these sheaths provide a closed, synovial-fluid-lubricated system that lets the flexor tendons glide with minimal friction under the fibrous pulleys.

□ Fig 9.7 — The synovial sheaths of the flexor tendons, i.e. ulnar bursa, radial bursa and digital synovial sheaths (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.142)

Fascial spaces of the palm

Deep to the palmar aponeurosis, condensations of fascia (the medial, intermediate and lateral palmar septa) divide the palm into potential spaces of great surgical significance.

Feature	Midpalmar space	Thenar space
Shape	Triangular	Triangular
Situation	Under the medial half of the hollow of the palm	Under the lateral half of the hollow of the palm
Anterior boundary (superficial→deep)	Palmar aponeurosis; superficial palmar arch; digital vessels/nerves to medial 3½ fingers; ulnar bursa with flexor tendons of the medial 3 fingers; 2nd–4th lumbricals	Palmar aponeurosis (lateral part); digital vessels/nerves of the lateral 1½ digits; radial bursa with FPL tendon; flexor tendons of index finger; 1st lumbrical
Posterior boundary	Fascia covering the interossei and medial 3 metacarpals	Transverse head of adductor pollicis
Lateral boundary	Intermediate palmar septum	Lateral palmar septum
Medial boundary	Medial palmar septum (separates it from the hypothenar space)	Intermediate palmar septum

Feature	Midpalmar space	Thenar space
Proximal	Continuous with the forearm space of Parona through the carpal tunnel	Continuous with the forearm space of Parona through the carpal tunnel
Distal	Continuous with the medial 3 web spaces via the 3rd/4th lumbrical canals	Continuous with the first web space via the 1st lumbrical canal
Drainage incision	Vertical incision in the 3rd or 4th web space	Vertical incision in the first web space (dorsal approach preferred)

Other named spaces

- **Pulp space of the digits** — a subcutaneous compartment on the palmar aspect of each fingertip/thumb tip, superficial to the distal two-thirds of the distal phalanx, criss-crossed by numerous fibrous septa running from skin to periosteum that divide it into loculi packed with fat; the terminal branch of the digital artery supplying the phalangeal diaphysis traverses this space (the epiphysis is spared, as its supply does not pass through the septa).
- **Web space** — a subcutaneous space in each interdigital cleft, extending from the free margin of the web proximally to the level of the deep transverse metacarpal ligaments; contains the lumbrical tendon, an interosseous tendon, and digital vessels/nerve.
- **Dorsal subcutaneous space** — lies immediately deep to the loose skin of the dorsum of the hand.
- **Dorsal subaponeurotic space** — lies between the extensor tendons (bound together by a thin aponeurosis) and the metacarpal bones/interossei.
- **Forearm space of Parona** — a rectangular fascial interval in the lower forearm, anterior to pronator quadratus and deep to the long flexor tendons; extends proximally to the oblique origin of FDS and distally, through the carpal tunnel, into continuity with the midpalmar and thenar spaces; the proximal ends of the ulnar and radial bursae protrude into it.
- Gray's Anatomy (41e) additionally describes the deeper compartments in modern three-dimensional terms as a single "**deep palmar space**", bounded proximally by the carpal tunnel and subdivided by vertical septa into eight narrow compartments (4 for the digital flexor tendons, 4 for the lumbricals/neurovascular bundles) — conceptually the same territory as the classical midpalmar/thenar description used in Indian PG teaching and examinations.

□ Fig 11.21 — Midpalmar and thenar spaces of the hand and their surface projections (Vishram Singh — *Textbook of Anatomy Vol 1 — 4e, p.511*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a cross-section of the palm at the level of the metacarpals, and a separate longitudinal scheme of the flexor tendon sheaths, with these labels:

Cross-section of the hand (fascial spaces):

- ▶ Palmar aponeurosis
- ▶ Midpalmar space (medial)
- ▶ Thenar space (lateral)
- ▶ Hypothenar space
- ▶ Medial palmar septum
- ▶ Intermediate palmar septum
- ▶ Lateral palmar septum
- ▶ Flexor tendons of medial 3 digits (in ulnar bursa)
- ▶ Tendon of FPL (in radial bursa)
- ▶ 2nd–4th lumbricals / 1st lumbrical
- ▶ Dorsal subcutaneous space
- ▶ Dorsal subaponeurotic space
- ▶ Metacarpal bones / interossei

Synovial sheath scheme (longitudinal, palmar aspect):

- ▶ Flexor retinaculum
- ▶ Ulnar bursa (common flexor sheath) — FDS + FDP tendons
- ▶ Radial bursa — FPL tendon
- ▶ Digital synovial sheath of little finger (continuous with ulnar bursa)
- ▶ Digital synovial sheath of thumb (continuous with radial bursa)
- ▶ Independent digital sheaths of index, middle, ring fingers
- ▶ Forearm space of Parona (proximal to retinaculum)

Applied / Clinical anatomy

- ▶ **Tenosynovitis of the flexor sheaths** presents with fusiform swelling along the tendon, tenderness along the whole sheath, pain on passive extension of the finger, and a semiflexed resting posture of the digit — the classic combination described by Kanavel for pyogenic flexor tenosynovitis.
- ▶ **Infection of the little finger or thumb** is especially dangerous because their digital sheaths are continuous with the ulnar and radial bursae respectively; pus can track proximally up to ~2.5 cm above the wrist and into the forearm.
- ▶ **Infection of the index, middle or ring finger** sheaths, being independent, tends to remain localised distal to the palm — less dangerous than thumb/little-finger sheath infection.
- ▶ **Space of Parona's infection** — untreated ulnar (occasionally radial) bursal infection can burst proximally into the forearm space of Parona, collecting pus behind the long flexor tendons.

- ▶ **Compound palmar ganglion / "hour-glass" swelling** — chronic ulnar bursal distension (classically tuberculous) produces two swellings — one in the distal palm, one in the distal forearm — joined by a waist-like constriction at the flexor retinaculum, from which the name derives.
- ▶ **Midpalmar space infection**: the ulnar bursa is the classical inlet and the lumbrical canals the outlets; drained through incisions in the medial two web spaces (a dorsal, first-web-space approach is preferred surgically to protect the palmar cutaneous and motor branches of the median nerve when draining a thenar abscess).
- ▶ **Thenar space infection**: usually from an infected radial bursa or index-finger sheath; drained via an incision in the first web space.
- ▶ **Pulp space infection (whitlow/felon)**: rising pressure within the tightly septated pulp space causes severe throbbing pain and can occlude the digital artery supplying the diaphysis of the terminal phalanx, causing avascular necrosis of its distal four-fifths; the epiphysis is spared. Drained by a lateral (mid-axial) incision to avoid the pulp's tactile pad and the neurovascular bundle.
- ▶ **Surgical incisions** in the palm are planned parallel to skin creases and never at right angles across them, to avoid flexion contractures.

High-yield exam pointers

- ▶ Two flexor bursae: **ulnar bursa** (FDS + FDP, continuous with little-finger sheath) and **radial bursa** (FPL, continuous with thumb sheath); index/middle/ring digital sheaths are independent.
- ▶ Both bursae extend ~2.5 cm proximal to the flexor retinaculum and may communicate with each other deep to it.
- ▶ Palmar spaces: **midpalmar** (medial) and **thenar** (lateral), separated by the **intermediate palmar septum**; both continuous proximally with the **space of Parona** via the carpal tunnel.
- ▶ **Pulp space** = subcutaneous fat compartments over the distal phalanx, septated, diaphyseal artery at risk, epiphysis spared.
- ▶ **Dorsal subcutaneous** and **dorsal subaponeurotic** spaces on the back of the hand.
- ▶ **Space of Parona** = forearm space anterior to pronator quadratus, deep to flexor tendons.
- ▶ Clinical hooks: tenosynovitis (Kanavel), compound palmar ganglion (hourglass swelling), space-of-Parona infection, whitlow, and the web-space drainage incisions for midpalmar/thenar abscesses.
- ▶ Gray's 41e frames the deeper palmar territory as a single "deep palmar space" with 8 vertical-septum-defined compartments — useful as a modern cross-reference to the classical midpalmar/thenar scheme.

SOURCE & COVERAGE

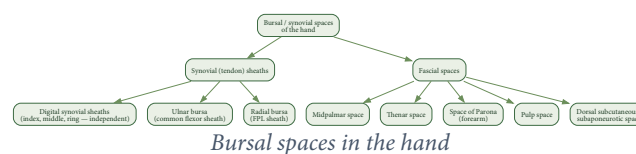
Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; Vishram Singh — Textbook of Anatomy Vol 1, 4e; IB Singh — Textbook of Anatomy Vol 1, 6e.



Bursal spaces in the hand

Asked in: Paper I May 2007 — RGUHS MD/MS Anatomy

Definition / Introduction A tendon-related synovial bursa forms an elongated **synovial sheath** — a double-layered, fluid-filled tube (parietal layer lining the fibrous tunnel, visceral layer applied to the tendon) that lets a tendon glide with minimal friction inside a rigid osseofibrous canal. In the hand, "bursal spaces" comprise two linked systems: (1) the **synovial sheaths of the long flexor tendons** — the digital synovial sheaths, the **ulnar bursa** and the **radial bursa** — enclosed within fibrous flexor sheaths reinforced by annular and cruciate pulleys; and (2) the **fascial (potential) spaces** of the palm and forearm — midpalmar space, thenar space, space of Parona, pulp space and the dorsal spaces — with which the sheaths freely communicate. Together they dictate the surgically important pattern of spread of hand infections.



1. Fibrous flexor sheaths and the pulley system

- ▶ Each finger has an osseofibrous tunnel running from the metacarpal head to the base of the distal phalanx; the thumb has a shorter tunnel carrying flexor pollicis longus (FPL) alone.
- ▶ The fibrous flexor sheath consists of thickened **annular pulleys (A1–A5)** over the phalanges (which resist bowstringing) alternating with thinner **cruciate pulleys (C0–C3)** over the joints (which fold to permit flexion).
 - **A1** — at the MCP joint; **A2** — mid-proximal phalanx (strongest, most important surgically); **A3** — at the PIP joint; **A4** — mid-middle phalanx; **A5** — at the DIP joint.
 - **C0** — palmar to the MCP joint; **C1, C2** — at the PIP joint; **C3** — at the DIP joint.
 - **A2 and A4** are the clinically critical pulleys preventing bowstringing of the flexor tendons.
 - The thumb has three constant pulleys: **A1** (MCP joint), an **oblique pulley** (mid-proximal phalanx — most important for FPL action) and **A2** (just proximal to the IP joint).
- ▶ Function: converts the long, gliding flexor tendons into a mechanically efficient system that keeps the tendon apposed to the joint axis throughout the range of flexion.

2. Digital synovial sheaths

- ▶ Each fibrous flexor sheath is lined internally by a synovial sheath — a closed, fluid-filled tube around each tendon, double layered (parietal + visceral), the two layers continuous at a **mesotendon** that carries the digital vessels as the **vincula**.
- ▶ The synovial sheaths of the **index, middle and ring fingers are independent**: they begin near the heads of the metacarpals and end at the base of the distal phalanx. The intervening length of these three tendons in the palm proper is **devoid of any synovial sheath**.
- ▶ The digital synovial sheath of the **little finger is continuous proximally with the ulnar bursa**; that of the **thumb is continuous proximally with the radial bursa** — the anatomical basis for the greater danger of infections of these two digits.

3. Ulnar bursa (common flexor synovial sheath)

□ Fig 9.7 — The synovial sheaths of the flexor tendons, i.e. ulnar bursa, radial bursa and digital synovial sheaths (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.142)

- ▶ The **ulnar bursa** is the common synovial sheath enclosing all eight long flexor tendons (4 of flexor digitorum superficialis + 4 of flexor digitorum profundus) as they cross the carpal tunnel deep to the flexor retinaculum; it is the **largest synovial sheath in the hand**.
- ▶ Extent: begins about **2.5 cm (a finger's breadth) proximal to the flexor retinaculum** in the forearm and extends distally in the palm to about the **middle of the shafts of the metacarpal bones**.
- ▶ The tendons invaginate the sheath from its lateral side: the parietal layer lines the carpal tunnel, the visceral layer is reflected over FDS ventrally and FDP dorsally.
- ▶ Its distal medial end is **continuous with the digital synovial sheath of the little finger** — the route by which infection of the little finger reaches the palm and forearm.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A palmar view of the wrist and hand, labelled with:

- ▶ **Flexor retinaculum**, with the **ulnar bursa** outlined from 2.5 cm proximal to it up to mid-metacarpal level, and the **radial bursa** outlined alongside it
- ▶ The three **independent digital synovial sheaths** of the index, middle and ring fingers as separate short tubes distal to the ulnar bursa
- ▶ Continuity of the **ulnar bursa** with the **little-finger digital sheath**, and of the **radial bursa** with the **thumb digital sheath**
- ▶ The **carpal tunnel** as the shared proximal landmark of both bursae

4. Radial bursa

Feature	Ulnar bursa	Radial bursa
Tendon(s) enclosed	FDS ×4 + FDP ×4 (one common sheath)	Flexor pollicis longus only
Proximal extent	~2.5 cm above flexor retinaculum	~2.5 cm above flexor retinaculum
Distal extent	Middle of the metacarpal shafts	Insertion of FPL, base of distal phalanx of thumb
Distal continuity	Digital sheath of little finger	Digital sheath of thumb
Mutual relation	Usually separate; may communicate with radial bursa deep to the retinaculum	Usually separate; occasional communication with ulnar bursa
Relative size	Largest synovial sheath of the hand	Narrower; coextensive with ulnar bursa proximally

- ▶ The radial bursa encloses the tendon of **FPL** alone as it crosses the carpal tunnel; proximally it is coextensive with the ulnar bursa, and distally it continues along the thumb to the FPL insertion.

- Because the two bursae may communicate deep to the flexor retinaculum, infection of the thumb can occasionally track across to the little finger (and vice versa) — the clinical basis of combined ulnar–radial bursal infection.

5. Vincula longa and vincula brevia

- These are folds of synovial membrane — the persisting parts of the mesotendon — that convey the digital blood vessels to the flexor tendons.
- Each digital sheath contains **five vincula**: **two vincula brevia** (short, triangular, attached near the tendon insertions — at the DIP joint for FDP and the PIP joint for FDS) and **three vincula longa** (long, filiform, two to FDS and one to FDP, more proximally placed).

6. Fascial (bursal) spaces of the palm and forearm

□ Fig 11.21 — Midpalmar and thenar spaces of the hand and their surface projections in the palm (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.511)

Feature	Midpalmar space	Thenar space
Shape / site	Triangular; under the medial half of the hollow of the palm	Triangular; under the lateral half of the hollow of the palm
Anterior (roof), superficial→deep	Palmar aponeurosis → superficial palmar arch → digital vessels/nerves of medial 3½ fingers → ulnar bursa → 2nd–4th lumbricals	Palmar aponeurosis (lateral part) → digital vessels/nerves of lateral 1½ digits → radial bursa → flexor tendons of index finger → 1st lumbrical
Posterior (floor)	Fascia over interossei and medial 3 metacarpals	Fascia over the transverse head of adductor pollicis
Lateral	Intermediate palmar septum (separates it from the thenar space)	Lateral palmar septum
Medial	Medial palmar septum (separates it from the hypothenar space)	Intermediate palmar septum
Proximal	Continuous with the space of Parona through the carpal tunnel	Continuous with the space of Parona through the carpal tunnel
Distal	Continuous with the medial 3 web spaces via the 3 lumbrical canals	Continuous with the 1st web space via the 1st lumbrical canal
Drainage incision	Medial two web spaces	First web space (posteriorly)

- **Space of Parona**: a rectangular fascial interval in the distal forearm, anterior to pronator quadratus and posterior to the long flexor tendons (with the ulnar and radial bursae protruding into it); continuous proximally with the intermuscular spaces of the forearm, and distally, through the carpal tunnel, with the midpalmar and thenar spaces.
- **Pulp space**: a subcutaneous fibrofatty space over the palmar aspect of each terminal phalanx, traversed by numerous fibrous septa (skin to periosteum) that divide it into loculi; it carries the terminal digital artery supplying the diaphysis of the distal phalanx.

- **Dorsal spaces:** the **dorsal subcutaneous space** lies deep to the loose skin of the dorsum of the hand; the **dorsal subaponeurotic space** lies between the metacarpals/extensor tendons and the thin dorsal aponeurosis uniting them.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A cross-section of the palm at the metacarpal level, labelled with:

- **Palmar aponeurosis, thenar and hypothenar eminences**
- **Medial, intermediate and lateral palmar septa** demarcating the hypothenar, midpalmar and thenar compartments
- **Midpalmar space** (medial) with the **ulnar bursa** and 2nd–4th lumbricals; **thenar space** (lateral) with the **radial bursa**/FPL tendon and 1st lumbrical
- **Interossei/adductor pollicis** as floor; **superficial palmar arch** and digital nerves in the roof

Applied / Clinical anatomy

- **Tenosynovitis and danger of little-finger/thumb wounds:** a penetrating wound (thorn, pin-prick) infects a digital sheath, which distends painfully with pus. Because the little-finger sheath communicates with the ulnar bursa, and the thumb sheath with the radial bursa (unlike the independent index/middle/ring sheaths), such infections track proximally into the palm and, if the bursa's proximal end is breached, into the **space of Parona**.
- **Compound palmar ganglion:** chronic distension of the ulnar bursa produces an **hour-glass swelling** — one swelling in the palm, another above the flexor retinaculum in the forearm, joined by a constricted waist at the retinaculum; pressure on one swelling transmits fluid to the other.
- **Combined bursal infection:** occasional communication between the ulnar and radial bursae deep to the flexor retinaculum lets infection spread from the thumb to the little finger, or vice versa.
- **Trigger finger (stenosing tenovaginitis):** localized thickening of the fibrous flexor sheath — usually at the **A1 pulley** — or of the tendon catches during gliding, locking the digit in flexion; forced extension gives a sudden painful click. Treated by surgical division of the A1 pulley.
- **Pulp-space infection (whitlow/felon):** rising tension within the pulp-space loculi causes severe throbbing pain; neglect may occlude the digital artery, causing avascular necrosis of the distal four-fifths of the terminal phalanx (the proximal epiphysis is spared, as its supply bypasses the pulp space).
- **Surgical incisions** (parallel to, never across, skin creases): thenar space and radial bursa — first web space / medial thenar margin; midpalmar space and ulnar bursa — medial web spaces / radial hypothenar margin; space of Parona — distal forearm; digital sheath — along phalangeal sides; pulp space — lateral, sparing the tactile pulp skin.

High-yield exam pointers

- **Ulnar bursa** = common synovial sheath for FDS + FDP (largest sheath in the hand); extends from 2.5 cm above the flexor retinaculum to mid-metacarpal level; continuous with the digital sheath of the little finger.

- ▶ **Radial bursa** = synovial sheath of FPL alone; extends to the insertion of FPL at the thumb tip; continuous with the digital sheath of the thumb.
- ▶ Index, middle and ring finger digital sheaths are **independent** of the common bursae — the key reason their infections usually stay localized.
- ▶ **A2 and A4** annular pulleys are surgically critical (prevent bowstringing); trigger finger classically involves the **A1** pulley.
- ▶ **Midpalmar space** — medial, related to the ulnar bursa and medial 3 lumbricals; **thenar space** — lateral, related to the radial bursa and 1st lumbrical; both drain proximally into the **space of Parona** through the carpal tunnel.
- ▶ **Space of Parona** = forearm space anterior to pronator quadratus, posterior to the long flexor tendons — site of the hour-glass swelling of compound palmar ganglion.
- ▶ **Vincula** (2 brevia + 3 longa per digit) are mesotendon remnants that carry the tendon's blood supply.
- ▶ Whitlow/felon = pulp-space infection; may cause avascular necrosis of the distal phalanx (epiphysis spared).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 1 8e; Vishram Singh Textbook of Anatomy Vol 1 4e; IB Singh Textbook of Anatomy Vol 1 6e.



Classify Joints. Describe the Shoulder Joint in Detail

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction A **joint (articulation/arthritis)** is a junction between two or more bones, cartilages, or a bone and a cartilage. Joints are classified **functionally** by the mobility they permit and **structurally** by the type of connecting tissue and presence/absence of a joint cavity. The **shoulder (glenohumeral) joint** is a synovial multiaxial ball-and-socket joint between the head of humerus and the glenoid cavity of the scapula — the most mobile but least stable joint in the body, sacrificing bony congruence for a huge range of motion.

Classification of Joints

A. Functional classification (degree of mobility)

Class	Mobility	Examples
Synarthrosis	Immovable	Cranial sutures (adult), primary cartilaginous joints in the growing child
Amphiarthrosis	Slightly movable	Secondary cartilaginous joints, syndesmoses
Diarthrosis	Freely movable	Synovial joints

B. Structural classification (connecting tissue ± joint cavity)

Type	Connecting tissue	Cavity	Subtypes	Examples
Fibrous	Dense fibrous tissue	Absent	Sutures (plane, serrate, denticulate, squamous, schindylesis), syndesmoses, gomphoses	Skull sutures; interosseous radio-ulnar/tibiofibular membranes; tooth-in-socket
Cartilaginous	Hyaline cartilage or fibrocartilage	Absent	Primary (synchondrosis), secondary (symphysis)	Epiphyseal plate, sphenoid-occipital joint (primary); pubic symphysis, intervertebral discs, manubriosternal joint (secondary)
Synovial	Fibrous capsule + synovial membrane	Present	Classified further by shape/axes (below)	Shoulder, hip, knee, elbow etc.

A typical **synovial joint** has: articular hyaline cartilage, a joint cavity with lubricating synovial fluid, a fibrous capsule lined by synovial membrane, and often accessory structures — ligaments (true/intrinsic and accessory), articular disc/meniscus, bursae, and fat pads (Haversian pads).

Classification of Synovial Joints

(a) By shape of articular surfaces

Type	Articular surface	Movement	Examples
Plane	Flat	Gliding	Intercarpal, intertarsal, zygapophyseal joints
Hinge (ginglymus)	Pulley-shaped	Flexion–extension (uniaxial)	Elbow (humero-ulnar), ankle, interphalangeal joints
Pivot (trochoid)	Rod within a ring	Rotation (uniaxial)	Superior radio-ulnar, median atlanto-axial joints
Condylar	Convex condyle on a socket	Biaxial	Knee, temporomandibular joints
Ellipsoid	Elliptical convex-on-concave	Biaxial	Wrist (radiocarpal), metacarpophalangeal joints
Saddle (sellar)	Reciprocally concavo-convex	Biaxial + conjunct rotation	First carpometacarpal, sternoclavicular joints
Ball-and-socket (spheroidal)	Sphere in a cup	Multiaxial	Shoulder, hip joints

(b) **By number of axes** — uniaxial (hinge, pivot), biaxial (condylar, ellipsoid, saddle), multiaxial (ball-and-socket, e.g. shoulder and hip). (c) **By complexity** — simple (two articular surfaces), compound (more than two surfaces, e.g. elbow complex), complex (contains an intra-articular disc, e.g. temporomandibular, sternoclavicular, knee joints).

Shoulder (Glenohumeral) Joint — Type and Articular Surfaces

- ▶ **Type:** Synovial, **multiaxial ball-and-socket (spheroidal)** joint — the **glenohumeral joint**, formed between the head of the humerus and the glenoid cavity of the scapula.
- ▶ **Articular surfaces:** Both surfaces are reciprocally curved **ovoids**, not true spheres, and are covered by hyaline cartilage (thickest centrally on the humerus, thinnest centrally on the glenoid — the reverse peripherally). The humeral head's surface area is ~**4 times** that of the glenoid fossa, so only a small part of the head contacts the glenoid in any one position.
- ▶ **Glenoid labrum:** A fibrocartilaginous rim around the glenoid margin that deepens the fossa and blends superiorly with the long head of biceps tendon; it is triangular anteriorly, ovoid posteriorly, and may be deficient inferiorly. Its anteroinferior attachment is relatively secure; deficiency here predisposes to the **anteroinferior labral (Bankart) tear** seen with anterior dislocation.
- ▶ **Loose- vs close-packing:** The joint is loose-packed in most positions; close-packing (maximal surface congruence) is reached only with the arm abducted and laterally rotated.
- ▶ **Stability factors (structural weakness compensated by soft tissue):**
- ▶ **Rotator (musculotendinous) cuff** — supraspinatus, infraspinatus, teres minor, subscapularis ("SITS") blend with the capsule and hold the head against the fossa by **concavity compression**.
- ▶ **Glenoid labrum** — deepens the socket.
- ▶ **Coracoacromial arch** (coracoid + coracoacromial ligament + acromion) — a secondary, superior "socket" that prevents upward displacement of the head.
- ▶ **Long head of biceps** (superiorly) and **long head of triceps** (inferiorly) — accessory dynamic ligaments.
- ▶ **Negative intra-articular (atmospheric) pressure** and capsular ligaments.

□ Fig 3.97 — Capsules and ligaments of glenohumeral and acromioclavicular joints. A (Moore — Clinically Oriented Anatomy — 9e, p.498)

Capsule, Synovial Membrane and Ligaments

- ▶ **Fibrous capsule:** Loose and lax, permitting the joint's wide range. Attached **medially** to the scapular neck beyond the glenoid labrum (including the supraglenoid tubercle, making the long head of biceps origin intracapsular) and **laterally** to the anatomical neck of the humerus — except **inferiorly**, where it descends onto the surgical neck, and **superiorly**, where it is deficient for passage of the biceps tendon. The capsule is **least supported inferiorly**, the common site of dislocation and where the axillary nerve is at risk.
- ▶ **Rotator interval:** A triangular gap in the capsule between the anterior edge of supraspinatus and the superior edge of subscapularis, reinforced by the coracohumeral and superior glenohumeral ligaments.

- **Synovial membrane:** Lines the capsule and is reflected onto the anatomical neck; it forms a tubular sheath around the intracapsular tendon of the long head of biceps as it traverses the joint into the intertubercular (bicipital) groove.

Ligaments

Ligament	Attachment / course	Function
Capsular ligament	Scapula (beyond labrum) → anatomical/surgical neck of humerus	Loose, permits free movement; weakest inferiorly
Glenohumeral ligaments (superior, middle, inferior)	Supraglenoid tubercle/glenoid rim → lesser tubercle region	Reinforce capsule anteriorly and inferiorly; the gap between superior and middle bands is the foramen of Weitbrecht , a site of anterior weakness/dislocation
Coracohumeral ligament	Root of coracoid process → greater tubercle	Strengthens capsule superiorly; reinforces rotator interval
Transverse humeral ligament	Greater ↔ lesser tubercle, bridging the bicipital groove	Retains the long head of biceps tendon in the groove
Coraco-acromial ligament (with acromion & coracoid)	Coracoid process → acromion	Forms the coracoacromial arch, a secondary socket

- **Bursae related to the joint:** Subacromial (subdeltoid) bursa (largest, between deltoid/acromion and the rotator cuff — does not normally communicate with the joint), **subscapularis bursa** (communicates with the joint cavity), **infraspinatus bursa** (may communicate).

Relations and Bursae

Direction	Structures
Superior	Coracoacromial arch, subacromial bursa, supraspinatus, deltoid
Inferior	Long head of triceps, axillary nerve, posterior circumflex humeral vessels
Anterior	Subscapularis, coracobrachialis, short head of biceps, deltoid
Posterior	Infraspinatus, teres minor, deltoid
Within the joint	Tendon of the long head of biceps brachii

Movements and Muscles Producing Them

Movement	Prime movers	Accessory
Flexion	Clavicular head of pectoralis major, anterior fibres of deltoid, coracobrachialis	Short head of biceps
Extension	Posterior fibres of deltoid, teres major, latissimus dorsi	Long head of triceps, sternocostal pectoralis major

Movement	Prime movers	Accessory
Abduction	Supraspinatus (0–90°) and deltoid throughout	Serratus anterior & trapezius rotate the scapula (90–180°)
Adduction	Pectoralis major, teres major, latissimus dorsi	Coracobrachialis, long head of triceps
Medial rotation	Pectoralis major, subscapularis, anterior deltoid	Latissimus dorsi, teres major
Lateral rotation	Posterior deltoid, infraspinatus, teres minor	—
Circumduction	Sequential combination of the above	—

- Movements are described relative to the **plane of the scapula**, not the coronal/sagittal planes.
- **Scapulohumeral rhythm**: full overhead elevation (170–180°) is a coordinated motion of the glenohumeral, sternoclavicular, acromioclavicular and scapulothoracic joints. The glenohumeral joint contributes ~100–120° of flexion/abduction while the scapula rotates upward by 50–60°; overall ratio **2° glenohumeral : 1° scapulothoracic** — for every 15° of arm elevation, ~10° occurs at the shoulder joint and ~5° by scapular rotation.
- The humeral head undergoes lateral rotation around 90° of abduction to clear the greater tubercle beneath the acromion.

Blood Supply and Nerve Supply

- **Arterial supply**: Anterior and posterior circumflex humeral arteries, suprascapular artery, and subscapular/circumflex scapular vessels — all branches of the axillary artery (directly or via the thyrocervical trunk for the suprascapular).
- **Nerve supply (Hilton's law — a joint is supplied by articular branches of the nerves supplying the muscles acting on it)**: axillary nerve (anteroinferior capsule), suprascapular nerve (postero-superior capsule), and lateral pectoral/musculocutaneous nerves (anterosuperior capsule/rotator interval).

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section through the shoulder joint — label: head of humerus; glenoid cavity of scapula; glenoid labrum; fibrous capsule; synovial membrane; articular (hyaline) cartilage; long head of biceps tendon (intracapsular, in intertubercular groove); coraco-acromial ligament; acromion; coracoid process; subacromial (subdeltoid) bursa; supraspinatus tendon (blending with capsule superiorly); subscapularis (anteriorly), infraspinatus/teres minor (posteriorly) tendons blending with capsule; axillary nerve and posterior circumflex humeral vessels (inferior to the capsule, in the quadrangular space); deltoid (overlying).

Applied / Clinical anatomy

- **Dislocation**: The shoulder is the **most commonly dislocated large joint**, due to capsular laxity and the gross disproportion between humeral head and glenoid fossa. Dislocation is almost

always **subglenoid/subcoracoid (anterior)**, occurring when the abducted arm forces the head against the unsupported inferior capsule; it endangers the closely related **axillary nerve** (test deltoid sensation/contraction) and posterior circumflex humeral vessels. An anteroinferior labral avulsion (**Bankart lesion**) and a posterolateral humeral head impaction (**Hill–Sachs lesion**) commonly accompany recurrent anterior dislocation.

- ▶ **Rotator cuff impingement/painful arc syndrome:** Repetitive overhead use (throwing/racquet sports, swimming) causes degenerative tendinitis and attrition of the supraspinatus tendon as it impinges under the coracoacromial arch; pain is characteristically felt during **50–130° of abduction** (painful arc). Calcific deposition in the tendon (calcific supraspinatus tendinitis) may irritate the overlying subacromial bursa (subacromial bursitis).
- ▶ **Frozen shoulder (adhesive capsulitis):** Adherence of the two synovial layers, typically age 40–60, causing progressive pain, stiffness and restricted movement (especially lateral rotation and abduction), with compensatory increase in scapulothoracic motion (altered scapulohumeral rhythm); usually self-limiting over ~2 years, hastened by physiotherapy.
- ▶ **Referred shoulder-tip pain:** Diaphragmatic/peritoneal irritation (e.g. subphrenic abscess, ruptured viscus, ectopic pregnancy) is referred to the shoulder because both the phrenic nerve (diaphragmatic peritoneum) and the supraclavicular nerves (skin over the shoulder) arise from C3, C4.
- ▶ **Optimum position of immobilisation:** the arm is splinted in ~45–90° abduction to avoid ankylosis in a disabling position.
- ▶ **Aspiration/injection:** Performed anteriorly through the deltopectoral triangle or laterally just below the acromion.

High-yield exam pointers

- ▶ Structural classes: **fibrous – cartilaginous – synovial**; functional classes: **synarthrosis – amphiarthrosis – diarthrosis**.
- ▶ Synovial joints subclassified by **shape** (plane, hinge, pivot, condylar, ellipsoid, saddle, ball-and-socket) and by **axes** (uni-, bi-, multiaxial).
- ▶ Shoulder joint = **synovial, multiaxial, ball-and-socket**; glenohumeral (head of humerus + glenoid cavity of scapula).
- ▶ Humeral head is ~4× the glenoid surface area → mobility at the cost of stability; capsule **weakest/least supported inferiorly**.
- ▶ Stability = **rotator cuff (SITS) + glenoid labrum + coracoacromial arch + long heads of biceps/triceps**, not bony congruence.
- ▶ **Foramen of Weitbrecht** = gap between superior and middle glenohumeral ligaments — site of anterior capsular weakness.
- ▶ Blood supply — **anterior & posterior circumflex humeral, suprascapular, subscapular/circumflex scapular** arteries.
- ▶ Nerve supply (Hilton's law) — **axillary, suprascapular, (lateral pectoral/musculocutaneous)**.
- ▶ **Scapulohumeral rhythm** = 2:1 glenohumeral-to-scapulothoracic contribution to overhead elevation.

- Applied: subglenoid anterior dislocation with axillary nerve risk; painful arc (50–130°) of supraspinatus impingement; frozen shoulder; shoulder-tip pain referred via C3–C4.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; Vishram Singh — General Anatomy 4e; Moore — Clinically Oriented Anatomy 9e.



Coracobrachialis

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction Coracobrachialis is the smallest and most medial of the three muscles of the anterior (flexor) compartment of the arm, the other two being biceps brachii and brachialis. It shares a common coracoid origin with the short head of biceps, and together the three anterior-compartment muscles form a single functional group that flexes the supinated hand towards the face. The muscle is of disproportionate examination importance because it is morphologically a tricipital (three-headed) muscle in lower mammals, and the rare persistence of its vestigial third head as the **ligament of Struthers** is a classic cause of neurovascular entrapment in the arm.

Attachments, Nerve Supply and Blood Supply

Feature	Description
Origin	Deep surface of the apex (tip) of the coracoid process of the scapula, deep to the tendon of the short head of biceps brachii, and by muscular fibres from the proximal 5–10 cm of that tendon
Insertion	A rough impression, 3–5 cm long, on the middle third of the medial border/surface of the shaft of the humerus, between the attachments of brachialis (in front) and the medial head of triceps (behind)
Nerve supply	Musculocutaneous nerve (C5, C6, C7) — the nerve pierces the muscle obliquely and supplies it both before and during its intramuscular course
Blood supply	Muscular branches from the axillary artery (via a twig passing deep to the median and musculocutaneous nerves), from the anterior circumflex humeral artery, from the artery accompanying the musculocutaneous nerve (which also gives a recurrent branch to the coracoid attachment), and accessory branches from the thoraco-acromial artery to its superficial part
Action	Weak flexor and adductor of the arm at the shoulder; acts as an antagonist to deltoid, particularly resisting departure from the plane of motion in abduction/extension

Feature	Description
Testing	Palpate the muscle belly during adduction and medial rotation of the flexed, elevated shoulder against resistance (or during forceful depression of the elbow against resistance)

Relations

- ▶ **Anteriorly** — related to pectoralis major above; at its humeral insertion it is crossed by the brachial vessels and the median nerve.
- ▶ **Posteriorly (deep surface)** — tendons of subscapularis, latissimus dorsi and teres major, the medial head of triceps, the shaft of the humerus, and the circumflex humeral vessels.
- ▶ **Medially** — the third part of the axillary artery and the proximal parts of the median and ulnar nerves lie medial to the muscle in the axilla; more distally the ulnar nerve and basilic vein lie medial to it in the upper arm.
- ▶ **Laterally** — fused proximally with the short head of biceps brachii; in the axilla the musculocutaneous nerve and the lateral root of the median nerve lie along its lateral border before the nerve pierces it.
- ▶ Together with the short head of biceps and the humerus, coracobrachialis helps form the **lateral wall of the axilla**, an important surgical landmark in axillary dissection.
- ▶ The muscle forms an inconspicuous rounded ridge on the upper medial side of the arm; the brachial artery's pulsation can be felt, and often seen, in the depression behind it.

Morphology and Variations

- ▶ Coracobrachialis represents the **medial compartment musculature of the limb bud**, well developed in quadrupeds but reduced in humans; the anterior compartment of the arm is homologous with the flexor/medial compartments of the thigh.
- ▶ In many mammals it is **tricipital** (three-headed). In humans, the upper two heads fuse (the musculocutaneous nerve passes between them, hence piercing the muscle), and the **lower third head normally disappears**.
- ▶ Persistence of the lower head is represented by a fibrous band, the **ligament of Struthers**, extending from an occasional bony spur on the antero-medial surface of the lower humerus (the **supratrochlear/supracondylar spur**) to the medial epicondyle; pronator teres may take a slip of origin from its lower part.
- ▶ The **median nerve and/or brachial artery pass deep to this ligament** and may be compressed beneath it, producing vascular spasm or median nerve palsy — a well-recognised "supracondylar process syndrome."
- ▶ Accessory slips of coracobrachialis may occasionally attach to the lesser tubercle, the medial epicondyle, or the medial intermuscular septum.

Landmark Value — Events at the Level of Its Insertion

The level of insertion of coracobrachialis (middle third of arm) is a key surface/dissection landmark because several anatomical changes occur here simultaneously:

Structure	Change at this level
Humeral shaft	Circular above, becomes triangular below
Intermuscular septa	Medial and lateral septa become well defined from this level downward
Brachial artery	Crosses from the medial side of the arm to lie anterior to the humerus
Median nerve	Crosses the brachial artery from lateral to medial side
Ulnar nerve	Pierces the medial intermuscular septum (with the superior ulnar collateral artery) to enter the posterior compartment
Radial nerve	Pierces the lateral intermuscular septum (with the anterior descending/radial collateral branch of profunda brachii) to re-enter the anterior compartment near the elbow
Basilic vein	Pierces the deep fascia to become subfascial
Nutrient artery of humerus	Enters the nutrient foramen close to this level

□ Fig 8.5 — Origin and insertion of the coracobrachialis muscle (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.334)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a **transverse (cross) section through the middle of the arm at the level of insertion of coracobrachialis**, showing the anterior and posterior compartments divided by the medial and lateral intermuscular septa, with the following labels:

- ▶ Humeral shaft (triangular in section)
- ▶ Anterior compartment — biceps brachii, brachialis, coracobrachialis (its insertion)
- ▶ Posterior compartment — triceps brachii (medial and lateral heads)
- ▶ Medial and lateral intermuscular septa
- ▶ Musculocutaneous nerve (between biceps and brachialis, having pierced coracobrachialis)
- ▶ Brachial artery with venae comitantes
- ▶ Median nerve crossing the brachial artery
- ▶ Basilic vein piercing the deep fascia (medial subcutaneous plane)
- ▶ Ulnar nerve with superior ulnar collateral artery, piercing the medial septum
- ▶ Radial nerve with profunda brachii artery, piercing the lateral septum
- ▶ Cephalic vein (lateral subcutaneous plane)
- ▶ Medial and lateral cutaneous nerves of the forearm

Applied / Clinical anatomy

- ▶ **Compression site for the brachial artery** — the artery can be effectively compressed against the humeral shaft at the level of insertion of coracobrachialis (mid-arm) to arrest haemorrhage from

distal wounds, e.g. a bleeding palmar arterial arch, and this is also the site used to auscultate/palpate brachial pulsation for blood pressure recording.

- ▶ **Surgical/dissection landmark** — because the musculocutaneous nerve invariably pierces coracobrachialis, the muscle is used as a guide to identify the nerve in the axilla and arm; the level of its humeral insertion also marks the nutrient foramen of the humerus, relevant during surgical exposure and internal fixation of shaft fractures.
- ▶ **Ligament of Struthers / supracondylar process syndrome** — a persistent third head presenting as a fibrous band from a supratrochlear spur to the medial epicondyle may entrap the median nerve and/or brachial artery beneath it, producing forearm pain, paraesthesiae in the median nerve distribution, and a diminished distal pulse; it must be distinguished clinically from pronator teres syndrome and may require surgical division of the band/spur.
- ▶ **"Shunt muscle" action** — together with deltoid and the long head of triceps, coracobrachialis helps resist inferior (downward) subluxation of the humeral head at the glenohumeral joint, e.g. when carrying a heavy suitcase or weight in the hand; this becomes clinically relevant when deltoid is paralysed (axillary nerve injury), as the remaining shunt muscles partly compensate.
- ▶ **Musculocutaneous nerve injury** — an uncommon injury (e.g. penetrating wound in the axilla) paralyses coracobrachialis, biceps brachii and brachialis together: flexion at the glenohumeral joint is weakened (loss of the coracobrachialis and long head of biceps contribution), and flexion at the elbow together with supination of the forearm are greatly weakened but not lost, since brachioradialis and supinator — both supplied by the radial nerve — still act weakly; sensation is lost over the lateral aspect of the forearm (territory of the lateral cutaneous nerve of forearm, the nerve's own continuation).
- ▶ **Axillary landmark** — coracobrachialis with the short head of biceps forms part of the lateral wall of the axilla, useful during axillary lymph node clearance and brachial plexus block to orient the neurovascular bundle, which lies medial to the muscle.

High-yield exam pointers

- ▶ Origin: tip of coracoid process (with short head of biceps); Insertion: middle third of medial border of humeral shaft.
- ▶ Sole nerve supply: musculocutaneous nerve (C5–C7), which characteristically **pierces** the muscle.
- ▶ Only muscle of the arm supplied purely by the musculocutaneous nerve that acts at the shoulder (not the elbow).
- ▶ Morphologically tricipital in lower mammals; persistent third head = **ligament of Struthers**, entrapping median nerve/brachial artery.
- ▶ Mid-arm level of its insertion is the single most important surface landmark of the arm (humeral shape change, artery/vein/nerve crossings, septal piercings, nutrient foramen).
- ▶ Best site to compress the brachial artery against the humerus is at the level of coracobrachialis insertion.
- ▶ Acts as antagonist to deltoid and, with deltoid and triceps (long head), as a "shunt muscle" preventing inferior glenohumeral subluxation.
- ▶ Musculocutaneous nerve palsy → weak elbow flexion and forearm supination + sensory loss over lateral forearm, with coracobrachialis, biceps and brachialis all paralysed.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 8e; AK Datta's Human Anatomy Vol 3 (Upper & Lower Limb); Vishram Singh's Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e.



Course and distribution of the median nerve

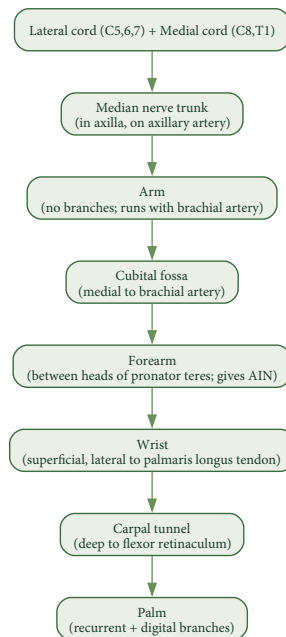
Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction The **median nerve** is the principal nerve of the flexor (front) compartment of the forearm and the chief motor and sensory nerve of the hand's "working" (radial) side. It is formed in the axilla by a **lateral root** (from the lateral cord, C5, C6, C7) and a **medial root** (from the medial cord, C8, T1), which together embrace the third part of the axillary artery. Because it supplies most of the long flexors of the forearm — producing coarse, power movements of the hand — it is popularly called the "**labourer's nerve**"; because it also carries sensation from most of the palmar hand, it is called the "**eye of the hand**." It has no branches in the arm, gives its major branches (including the anterior interosseous nerve) in the forearm, and terminates in the palm by supplying the thenar muscles, the first two lumbricals and the skin of the lateral three-and-a-half digits.

Origin and formation

Root	Cord of origin	Root value	Relation to axillary artery
Lateral root	Lateral cord	C5, C6, C7	Descends lateral to the third part of the axillary artery
Medial root	Medial cord	C8, T1	Crosses (usually anterior to) the artery to join the lateral root

- The two roots unite **anterior to (or lateral to)** the third part of the axillary artery to form the median nerve trunk.
- Some **C7 fibres** may leave the lateral root low in the axilla, pass medially behind the medial root and anterior to the axillary artery to join the **ulnar nerve** — these are believed to be motor fibres for flexor carpi ulnaris.
- If the lateral root is small, the **musculocutaneous nerve** (C5, 6, 7) may send a communicating connection to the median nerve in the arm (and vice versa) — a common variant.



Course and distribution of the median nerve

Course in the axilla and arm

- ▶ In the axilla, the median nerve lies at first **lateral to the axillary artery**, then crosses **anterior to it** (with the brachial artery in the arm) to lie **medial** to the vessel by the middle of the arm.
- ▶ It descends through the arm **in company with the brachial artery**, giving off **no muscular branches** here — only small vascular twigs to the brachial artery itself.
- ▶ At the elbow, it enters the **cubital fossa** as its most medial content, lying **medial to the brachial artery**, deep to the **bicipital aponeurosis** and anterior to **brachialis**.

Course in the forearm

- ▶ The nerve leaves the cubital fossa by passing **between the two heads of pronator teres** (humeral and ulnar heads); here it is separated from the ulnar artery by the deep (ulnar) head of the muscle.
- ▶ It then passes deep to a **fibrous arch (tendinous arch) of flexor digitorum superficialis** and runs down the forearm **adherent to the deep surface of flexor digitorum superficialis**, anterior to **flexor digitorum profundus**, accompanied by the (inconstant) **median artery**, a branch of the anterior interosseous artery.
- ▶ About **5 cm proximal to the flexor retinaculum**, the nerve emerges from behind the lateral border of flexor digitorum superficialis and becomes **superficial**, lying between the tendons of **flexor carpi radialis** (laterally) and **flexor digitorum superficialis** (medially), overlapped by the tendon of **palmaris longus**.
- ▶ **Surface marking:** at and above the wrist the median nerve is very superficial, running along the **lateral edge of the palmaris longus tendon** — a key landmark for locating it clinically.

Course at the wrist and in the hand

- ▶ The nerve passes **deep to the flexor retinaculum** through the osteofibrous **carpal tunnel**, lying superficial and lateral to the long flexor tendons (anterior to the "ulnar bursa").

- Just distal to the retinaculum it flattens and divides into a **lateral division** and a **medial division**.
- **Lateral division** → gives a **recurrent (muscular) branch** that curls around the distal border of the retinaculum to supply the thenar muscles, plus three digital branches (two to the thumb, one to the radial side of the index finger, the last also supplying the **first lumbrical**).
- **Medial division** → splits into two common palmar digital nerves for the second and third web spaces, supplying adjoining sides of index–middle and middle–ring fingers; the lateral common digital branch also supplies the **second lumbrical**.

Branches and muscles supplied (region-wise)

Region	Branch	Muscle(s) supplied	Root value
Arm	—	None (vascular twigs to brachial artery only)	—
Cubital fossa/upper forearm	Muscular branches	Pronator teres (first branch, arising 2–3 cm above the medial epicondyle, before the nerve passes between its heads)	C6, C7
Forearm	Muscular branches	Flexor carpi radialis , palmaris longus	C6/7 (FCR); C7/8 (PL)
Forearm	Muscular branch	Flexor digitorum superficialis	C7, C8, T1
Forearm	Anterior interosseous nerve	Flexor pollicis longus , lateral half of flexor digitorum profundus (index and middle), pronator quadratus ; articular twigs to distal radio-ulnar and wrist joints	C7, C8
Palm	Recurrent (muscular) branch	Abductor pollicis brevis , opponens pollicis , superficial head of flexor pollicis brevis	—
Palm	Digital branches	First and second lumbricals	—

- Mnemonic for the hand muscles: **LOAF** — **L**ateral two **l**umbricals, **O**pponens pollicis, **A**bductor pollicis brevis, **F**lexor pollicis brevis (superficial head).
- Of these, **abductor pollicis brevis** is the **only thenar muscle constantly supplied by the median nerve** alone; opponens pollicis commonly receives a dual supply (median + deep branch of ulnar), and the deep head of flexor pollicis brevis is usually ulnar-innervated — variation here is common and clinically relevant to how much thenar function survives a low median lesion.
- The **third lumbrical** frequently receives a supply from the median nerve as well as from the ulnar nerve.

Cutaneous (sensory) distribution

- ▶ **Palmar cutaneous branch:** arises about 3–7 cm proximal to the flexor retinaculum, runs superficial to it (NOT through the carpal tunnel), and supplies skin over the **thenar eminence** and the **central palm** — hence it is spared in carpal tunnel syndrome.
- ▶ **Palmar digital branches:** supply the palmar skin of the **thumb, index, middle and the radial (lateral) half of the ring finger** (the "lateral three-and-a-half digits"), including their nail beds.
- ▶ **Dorsal extension:** the median nerve also supplies the skin over the **dorsal aspect of the distal (and often middle) phalanges** of these same digits — the radial nerve supplies only the proximal dorsal skin of the thumb, index and lateral half of middle finger.
- ▶ A **communicating branch** passes from the median nerve (or its anterior interosseous branch) to the **ulnar nerve** in the forearm — the anatomical basis of the **Martin–Gruber anastomosis**, of practical importance in interpreting nerve conduction studies.

□ Fig 9.12 — Distribution of median nerve (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.145)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw an outline of the right upper limb (axilla to fingertips) and label, in sequence:

- ▶ **Lateral cord (C5,6,7)** and **medial cord (C8,T1)** giving lateral and medial roots that embrace the **axillary artery**.
- ▶ **Median nerve trunk** descending with the **brachial artery** in the arm (crossing it from lateral to medial in the mid-arm) — no branches shown here.
- ▶ Entry into the **cubital fossa** medial to the brachial artery, deep to the **bicipital aponeurosis**.
- ▶ Passage **between the two heads of pronator teres**; branch to **pronator teres** just above this point.
- ▶ **Anterior interosseous nerve** arising and descending on the interosseous membrane to **flexor pollicis longus**, lateral half of **flexor digitorum profundus**, and **pronator quadratus**.
- ▶ Nerve becoming superficial ~5 cm above the wrist, between **flexor carpi radialis** and **flexor digitorum superficialis/palmaris longus** tendons.
- ▶ Passage deep to the **flexor retinaculum** through the **carpal tunnel**.
- ▶ Division into **recurrent branch** (→ abductor pollicis brevis, opponens pollicis, flexor pollicis brevis) and **digital branches** (→ 1st and 2nd lumbricals; palmar skin of lateral 3½ digits).
- ▶ Separately labelled **palmar cutaneous branch** arising proximal to the retinaculum and running superficial to it.

Applied / Clinical anatomy

- ▶ **Sites of compression** (proximal to distal): the **ligament of Struthers** (over a supracondylar process, where the nerve may be accompanied by the brachial artery — combined vascular and neural symptoms), a thickened **bicipital aponeurosis**, between the **two heads of pronator teres** ("pronator teres syndrome"), and the **proximal fibrous arch of flexor digitorum superficialis**.
- ▶ **Anterior interosseous nerve (Kiloh–Nevin) syndrome:** a pure motor lesion causing weakness of flexor pollicis longus and the index/middle flexor digitorum profundus; the patient cannot form

a normal pincer ("OK sign") between thumb and index finger, instead making a **triangular/pinch deformity** because the terminal phalanges cannot flex.

- ▶ **High median nerve injury** (e.g., **supracondylar fracture of the humerus**): loss of pronation (forearm held supinated), weak wrist flexion with **radial deviation** (unopposed flexor carpi ulnaris), inability to flex the terminal phalanges of thumb and index ("**pointing index finger**" sign on attempted fisting), **ape/monkey-hand thumb deformity** from thenar wasting, sensory loss over the lateral 3½ digits, and vasomotor/trophic changes (warm, dry, scaly skin; cracked nails).
- ▶ **Low median nerve injury / carpal tunnel syndrome**: the most common entrapment mononeuropathy; caused by compression within the fibro-osseous carpal tunnel (rheumatoid disease, myxoedema, acromegaly, pregnancy, obesity, or idiopathic). Presents with nocturnal pain/paraesthesia in the median distribution, **thenar wasting** ("ape hand"), a positive **Phalen's test** (wrist flexion reproduces pain), and a positive **pen test** — the patient cannot hold a pen vertically off the table with the thumb pulp against resistance, revealing weak **abductor pollicis brevis**. Crucially, sensation over the **thenar eminence is spared**, since the palmar cutaneous branch arises proximal to, and runs superficial to, the retinaculum. Treatment is surgical division of the flexor retinaculum.
- ▶ **Complete claw hand**: results if both median and ulnar nerves are divided together (e.g., at the wrist), combining loss of the lumbricals of all four fingers with thenar and hypothenar wasting.
- ▶ Anatomical variation of the recurrent motor branch in relation to the flexor retinaculum (trans-, sub- or extra-ligamentous) is important during **carpal tunnel decompression** to avoid iatrogenic motor branch injury.

High-yield exam pointers

- ▶ Roots: **lateral root C5,6,7** (lateral cord) + **medial root C8,T1** (medial cord), uniting on the third part of the axillary artery.
- ▶ **No branches in the arm**; enters forearm between the **two heads of pronator teres**.
- ▶ Major forearm branch = **anterior interosseous nerve** → flexor pollicis longus, lateral half flexor digitorum profundus, pronator quadratus.
- ▶ In the hand supplies **LOAF**: Lateral 2 lumbricals, Opponens pollicis, Abductor pollicis brevis, Flexor pollicis brevis (superficial head) — **abductor pollicis brevis is the only constant median-supplied thenar muscle**.
- ▶ Sensory: palmar skin of **lateral 3½ digits** + dorsum of their distal phalanges; **palmar cutaneous branch** (to thenar skin) is spared in carpal tunnel syndrome because it runs superficial to the retinaculum.
- ▶ High lesion → "**pointing index**" sign + ape thumb deformity + wrist radial deviation; low lesion (carpal tunnel) → thenar wasting with sensation over thenar eminence preserved.
- ▶ Surface marking at the wrist: along the **lateral border of the palmaris longus tendon**.
- ▶ Communicating branch to ulnar nerve in the forearm = basis of the **Martin–Gruber anastomosis**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 (8e); Vishram Singh — Textbook of Anatomy Vol 1 (4e).



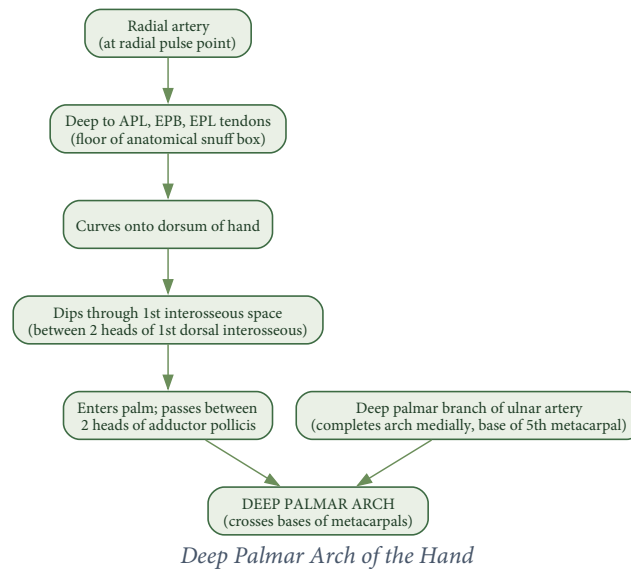
Deep Palmar Arch of the Hand

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction The deep palmar arch is the principal arterial anastomosis of the deep palm, formed mainly by the terminal part of the **radial artery** and completed medially by the small **deep palmar branch of the ulnar artery**. Together with the superficial palmar arch (formed mainly by the ulnar artery and completed by the superficial branch of the radial artery), it constitutes the two-arch arterial arcade system of the hand, providing rich collateral supply to the palm, fingers and intrinsic muscles even if either forearm artery is compromised. It lies deep to the long flexor tendons, about 1.2 cm proximal to the superficial arch, at the level of the bases of the metacarpal bones.

1. Formation

- ▶ Direct continuation of the terminal part of the **radial artery**.
- ▶ Course of the radial artery to reach the deep arch:
- ▶ From the site of the radial pulse, it runs obliquely downward and backward, deep to the tendons of abductor pollicis longus, extensor pollicis brevis and extensor pollicis longus, superficial to the radial collateral ligament of the wrist.
- ▶ It thus traverses the floor of the **anatomical snuff box** (crossing the scaphoid and trapezium).
- ▶ It curves around the lateral border of the carpus onto the dorsum of the hand, then dips forward through the proximal part of the **first (dorsal) interosseous space**, passing between the two heads of the **first dorsal interosseous muscle**, to re-enter the palm.
- ▶ In the palm it passes between the two heads (oblique and transverse) of **adductor pollicis** and crosses medially across the palm, deep to the long flexor tendons, as the deep palmar arch.
- ▶ Just before/as it enters the palm the radial artery gives off two named branches: **arteria princeps pollicis** (to the thumb) and **arteria radialis indicis** (to the lateral side of the index finger).
- ▶ **Completion:** medially, at the level of the base of the fifth metacarpal, the arch anastomoses with the **deep palmar branch of the ulnar artery** — a small (often double) branch given off as the ulnar artery crosses the hamate/Guyon's canal, which passes between abductor digiti minimi and flexor digiti minimi brevis, through or deep to opponens digiti minimi, to join the radial contribution.
- ▶ Rarely the arch may remain **incomplete**.



2. Level and relations

Aspect	Detail
Level	Crosses the bases of the metacarpal bones, ~1–1.2 cm proximal to the superficial palmar arch
Superficial (anterior) relations	Long flexor tendons of the fingers (flexor digitorum superficialis and profundus), lumbricals
Deep (posterior) relations	Proximal shafts/bases of the 2nd–5th metacarpals, palmar interossei
Covering muscle	Oblique head of adductor pollicis
Contents of concavity	Deep branch of the ulnar nerve , which accompanies the deep palmar branch of the ulnar artery throughout its course

3. Branches

- ▶ **Palmar metacarpal arteries (3)** — arise from the convexity (distal side) of the arch; run distally in the 2nd, 3rd and 4th intermetacarpal spaces along the palmar interossei; join the common palmar digital branches of the superficial palmar arch near the finger clefts, supplying the medial four metacarpals and contributing to digital supply.
- ▶ **(Proximal) perforating branches (3)** — pass dorsally through the 2nd, 3rd and 4th interosseous spaces to anastomose with the dorsal metacarpal arteries, linking palmar and dorsal circulations.
- ▶ **Recurrent branch(es)** — arise from the concavity, pass proximally anterior to the carpus, and end in the palmar carpal arch, supplying the carpal bones and joints.
- ▶ Muscular twigs to the interossei, adductor pollicis and hypothenar muscles.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Palmar view of the right hand — draw and label:

- ▶ Radial artery entering the palm between the two heads of adductor pollicis
- ▶ **Deep palmar arch** crossing the bases of the 2nd–5th metacarpals
- ▶ Arteria princeps pollicis and arteria radialis indicis (arising just proximal to the arch)
- ▶ Deep palmar branch of the ulnar artery completing the arch medially (base of 5th metacarpal)
- ▶ Deep branch of the ulnar nerve lying in the concavity of the arch
- ▶ Three palmar metacarpal arteries arising from the convexity, running in the 2nd–4th spaces
- ▶ Three perforating branches passing dorsally through the interosseous spaces
- ▶ Recurrent branch to the palmar carpal arch
- ▶ Superficial palmar arch shown ~1 cm distal, for orientation

□ Fig 9.32 — The superficial and deep palmar arches (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.157)

4. Superficial vs deep palmar arch — comparison

Feature	Superficial palmar arch	Deep palmar arch
Main contributor	Ulnar artery (direct continuation)	Radial artery (direct continuation)
Completed by	Superficial branch of radial artery	Deep palmar branch of ulnar artery
Plane	Superficial to long flexor tendons, deep to palmar aponeurosis	Deep to long flexor tendons, on the metacarpals/interossei
Level	At the level of the distal border of the fully extended thumb	~1–1.2 cm proximal to the superficial arch, at the bases of the metacarpals
Accompanying nerve	Superficial branch of ulnar nerve nearby	Deep branch of ulnar nerve in its concavity
Chief branches	3 common palmar digital arteries + 1 proper digital artery to little finger; cutaneous branches	3 palmar metacarpal arteries; 3 perforating branches; recurrent branches
Completeness	More often complete	Nearly always complete; rarely incomplete

Applied / Clinical anatomy

- ▶ **Laceration of the palmar arches** causes profuse, uncontrollable bleeding; because both arches freely anastomose with each other and with the palmar/dorsal carpal arches, proximal ligation of the radial or ulnar artery alone (or both) at the wrist fails to control the haemorrhage — direct pressure/packing, or compression of the brachial artery against the humerus, is the effective measure.

- ▶ **Deep branch of the ulnar nerve injury:** because this nerve runs in the concavity of the deep arch, penetrating palm injuries, deep palmar space infections, or an arch aneurysm can damage it together with the artery, producing weakness of adductor pollicis, the interossei and hypothenar muscles — clawing of the medial fingers and a positive Froment's sign (an "intrinsic-minus" pattern).
- ▶ **Deep palmar (mid-palmar) space infection** may track along the arch and its accompanying nerve, risking septic arterial thrombosis and spread of infection along the lumbrical canals to the fingers/dorsum.
- ▶ **Allen's test / Barbeau test:** performed before radial artery cannulation, harvesting (e.g., as a coronary artery bypass graft), or distal transradial "snuffbox" catheter access, to confirm the ulnar-supplied collateral flow (superficial arch, and the ulnar contribution completing the deep arch) is adequate to perfuse the hand once the radial artery's flow is interrupted.
- ▶ **Radial forearm free flap / thumb and index finger replantation surgery** requires preservation of arch continuity (princeps pollicis, radialis indicis and the deep arch itself) to avoid distal digital ischaemia.
- ▶ **Variability:** the arch is rarely incomplete; the radialis indicis and princeps pollicis may arise variably (from each other, from the superficial arch, or combine as a common first palmar metacarpal artery) — relevant to pre-operative vascular mapping in hand surgery.

High-yield exam pointers

- ▶ Deep arch = direct continuation of the **radial artery**; completed medially by the **deep palmar branch of the ulnar artery**.
- ▶ Lies **deep** to the long flexor tendons, on the bases of the metacarpals/interossei, under the oblique head of adductor pollicis — opposite plane to the superficial arch.
- ▶ **Deep branch of the ulnar nerve** lies in its concavity — always pair these two structures in answers.
- ▶ Level: ~1–1.2 cm **proximal** to the superficial palmar arch.
- ▶ Branches: **3 palmar metacarpal arteries**, **3 perforating branches**, **recurrent branch(es)** to the palmar carpal arch.
- ▶ Radial artery gives **princeps pollicis** and **radialis indicis** just before forming the arch.
- ▶ Radial artery reaches the palm via the **anatomical snuff box** → **first interosseous space (between heads of 1st dorsal interosseous)** → **between the two heads of adductor pollicis**.
- ▶ Clinically linked to Froment's sign/claw hand (via the deep ulnar nerve), and to Allen's test before radial artery harvesting.
- ▶ Rarely incomplete (unlike its near-constant completeness compared to the more variable superficial arch).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; Vishram Singh — Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e.



Describe in detail the course relations and branches of "Deep Branch of Ulnar Nerve". Add a note on its clinical anatomy

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction The ulnar nerve (C8, T1, from the medial cord of the brachial plexus) enters the palm superficial to the flexor retinaculum, lying between the pisiform bone and the ulnar artery, within the fibro-osseous **Guyon's (ulnar) canal**. At the level of the **hook of the hamate**, it divides into a **superficial terminal branch** (mainly cutaneous, plus a twig to palmaris brevis) and a **deep terminal branch** — the larger, purely motor division that is the subject of this question. The deep branch hooks around the hamulus, crosses the palm within the concavity of the deep palmar arch, and supplies almost all the intrinsic muscles of the hand; because it powers the fine, precise finger movements of grip and dexterity, the ulnar nerve is popularly called the "**musician's nerve**." Its isolated injury at the wrist produces the classic **ulnar claw hand**.

Origin — formation in Guyon's canal

- ▶ **Guyon's canal** is a fibro-osseous tunnel about 4 cm long on the anteromedial aspect of the wrist.
 - **Roof:** palmar carpal ligament and palmaris brevis.
 - **Floor:** flexor retinaculum and pisohamate ligament proximally; pisometacarpal ligament and the fibrous arcade at the origin of the hypothenar muscles distally.
 - **Medial (ulnar) wall:** flexor carpi ulnaris tendon, pisiform bone, abductor digiti minimi.
 - **Lateral (radial) wall:** the long flexor tendons, the flexor retinaculum, and the hook of the hamate.
- ▶ The canal transmits the **ulnar nerve and ulnar artery** (with occasional venae comitantes).
- ▶ **At the level of the hook of the hamate**, the ulnar nerve bifurcates:
 - **Superficial terminal branch** — supplies palmaris brevis, then continues as sensory digital nerves to the medial one-and-a-half fingers.
 - **Deep terminal branch** — a large motor nerve, accompanied throughout by the **deep (palmar) branch of the ulnar artery**.
- ▶ If the nerve is compressed **proximal** to this bifurcation, both branches (and hence both sensory and motor function) are affected; compression **distal** to the bifurcation involves only the motor or only the sensory branch selectively — the anatomical basis of the different clinical patterns of ulnar tunnel syndrome (see below).

Course and relations

1. In the hypothenar region (origin of the deep branch)

- ▶ The deep terminal branch turns dorsally and laterally, passing **between abductor digiti minimi** (superficial/ulnar) and **flexor digiti minimi brevis** (deep/radial) — separating the origins of these two hypothenar muscles.
- ▶ It then passes **between opponens digiti minimi and the base of the fifth metacarpal**, piercing (or passing deep to) opponens digiti minimi, which it often divides into two lamellae.

- ▶ Here it lies directly upon (in a shallow groove on) the **hook of the hamate**; the base of the hamate carries a notch for this "deep branch of ulnar nerve," and a bony groove for the terminal deep branch may be palpable on the hamular base.
- ▶ At this point of origin, the nerve gives off **muscular twigs to the three hypothenar muscles**: abductor digiti minimi, flexor digiti minimi brevis and opponens digiti minimi.

2. Across the palm

- ▶ The nerve curves around the hamulus and turns **laterally (radially)** across the palm, running **deep to the long flexor tendons and the lumbrical muscles**, on the interossei and the bases of the metacarpal bones.
- ▶ It lies **within the concavity of the deep palmar arch**, the artery of the same name (deep branch of ulnar artery, joining the radial artery) accompanying it throughout this stretch.
- ▶ Along this segment it supplies the **medial two lumbricals (3rd and 4th)** and **all the interossei** — four dorsal and three palmar by current descriptions (classically taught, e.g. in BD Chaurasia, as four dorsal and four palmar, i.e. eight interossei in total).

3. Termination (first web space)

- ▶ The nerve reaches the region of the first interosseous space, where it passes **between the two heads (transverse and oblique) of adductor pollicis**, alongside the deep palmar arch (here completed by anastomosis of the radial artery with the deep branch of the ulnar artery).
- ▶ It **terminates by supplying adductor pollicis** (both heads) and commonly gives a twig to the **deep head of flexor pollicis brevis** (variable; the superficial head is supplied by the median nerve).
- ▶ A communicating twig frequently passes to **opponens pollicis** as well, so that this thenar muscle receives a dual supply from the median nerve's recurrent branch and the deep branch of the ulnar nerve (this median–ulnar motor communication in the palm is described as the Riché–Cannieu anastomosis).
- ▶ **Articular branches** are given off throughout its course to the wrist, intercarpal, carpometacarpal (2nd–5th) and metacarpophalangeal joints.

The deep branch is thus a **purely motor nerve (with only articular twigs)** — it has no cutaneous distribution, in contrast to the superficial terminal branch.

Branches and structures supplied

Site along course	Branch	Structure(s) supplied
Origin, in hypothenar region	Muscular	Abductor digiti minimi, flexor digiti minimi brevis, opponens digiti minimi
Across the palm	Muscular	3rd and 4th lumbricals; all interossei (4 dorsal + 3 palmar; classically 4 + 4)

Site along course	Branch	Structure(s) supplied
Termination, 1st web space	Muscular	Adductor pollicis (both heads); usually deep head of flexor pollicis brevis; often a contribution to opponens pollicis (with median nerve)
Throughout	Articular	Wrist, intercarpal, carpometacarpal (2nd–5th) and metacarpophalangeal joints
Throughout	Vascular relation	Accompanied by, and lies in the concavity of the arch formed by, the deep branch of the ulnar artery / deep palmar arch

□ Fig 17.37 — Distribution of the deep terminal branch of the ulnar nerve (IB Singh — Textbook of Anatomy Vol 1 — 6e, p.218)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the palmar aspect of the right hand (flexor retinaculum removed) and label, in sequence along the nerve's course:

- ▶ Pisiform bone, flexor retinaculum, and Guyon's canal (ulnar artery and nerve entering superficial to the retinaculum).
- ▶ The bifurcation at the hook of the hamate into superficial (sensory) and deep (motor) terminal branches.
- ▶ The deep branch passing between abductor digiti minimi and flexor digiti minimi brevis, then through/deep to opponens digiti minimi, curving around the hamulus.
- ▶ The nerve running deep to the long flexor tendons and lumbricals, in the concavity of the deep palmar arch, accompanied by the deep branch of the ulnar artery.
- ▶ Termination between the two heads of adductor pollicis, with twigs to deep head of flexor pollicis brevis and opponens pollicis.
- ▶ Label the muscles supplied along the way: 3 hypothenar muscles, 3rd & 4th lumbricals, 4 dorsal + 3 palmar interossei, adductor pollicis.

Applied / Clinical anatomy

- ▶ **Guyon's canal (ulnar tunnel) syndrome:** compression within the canal. If compression is proximal to the bifurcation, both motor and sensory fibres are affected (mixed hypothenar/interossei weakness with sensory loss over the medial one-and-a-half fingers). If compression involves **only the deep branch** (e.g. around the hook of the hamate), the result is a **pure motor palsy** — hypothenar and interossei weakness with **sensation and palmaris brevis function preserved**; compression of the **superficial branch alone** gives isolated sensory loss. Common causes of isolated deep-branch compression include a **wrist ganglion**, a **fractured hook of hamate** (classically from a golf club or racquet handle, or a cyclist's handlebar — "handlebar palsy"), and repetitive occupational pressure on the hypothenar region.

- ▶ **Low ulnar nerve palsy (division at the wrist):** paralyses all the intrinsic muscles supplied by the deep branch — the three hypothenar muscles, all interossei, the medial two lumbricals and adductor pollicis ($\pm$ deep head of flexor pollicis brevis). Loss of the interossei and medial lumbricals, with the long flexors and extensors acting unopposed, produces **clawing (main en griffe)** of the ring and little fingers — hyperextension at the metacarpophalangeal joints with flexion at the interphalangeal joints; clawing is less marked in the index and middle fingers because their lumbricals are median-supplied.
- ▶ **"Ulnar paradox":** a lesion at the **wrist** produces a **more obvious** claw hand than a lesion at the **elbow**. A proximal (elbow) lesion also paralyses the ulnar half of flexor digitorum profundus, weakening interphalangeal flexion of the ring and little fingers and so lessening the clawing; a distal (wrist) lesion spares flexor digitorum profundus, so the intact long flexor tendons produce marked interphalangeal flexion while the interossei/lumbricals cannot check metacarpophalangeal hyperextension — hence more pronounced clawing distally.
- ▶ **Froment's sign:** with adductor pollicis paralysed, the patient compensates for weak thumb adduction (as in gripping a piece of paper between thumb and index finger) by flexing the thumb at the interphalangeal joint using flexor pollicis longus (median-innervated) — a positive sign of ulnar/deep-branch palsy.
- ▶ **Card (paper) test:** inability to hold a card firmly between the adducted fingers, from interossei weakness.
- ▶ **Wartenberg's sign:** persistent abduction of the little finger, from paralysis of the third palmar interosseous with unopposed pull of abductor digiti minimi and extensor digiti minimi.
- ▶ **Wasting:** hollowing/guttering of the interosseous spaces on the dorsum of the hand and flattening of the hypothenar eminence.
- ▶ Because the **dorsal cutaneous branch of the ulnar nerve arises about 5 cm proximal to the wrist**, sensation over the ulnar side of the dorsum of the hand is typically **preserved in a wrist-level lesion** but lost in an elbow-level lesion — a useful localising sign.
- ▶ **Combined median and ulnar nerve palsy** at the wrist gives a **complete/simian claw hand**, with thenar and hypothenar flattening and thumb adduction–flexion in addition to the ring/little finger clawing.
- ▶ Surgically, the deep branch must be carefully preserved — where it separates the origins of abductor and flexor digiti minimi, where it pierces opponens digiti minimi, and as it hooks around the hamulus — during **Guyon's canal decompression** or excision of a fractured/diseased hook of the hamate.

High-yield exam pointers

- ▶ Deep branch = the **motor** terminal division of the ulnar nerve, formed within **Guyon's canal** at the level of the **hook of the hamate**.
- ▶ Course: between abductor & flexor digiti minimi brevis $\rightarrow$ through/deep to opponens digiti minimi $\rightarrow$ hooks around the hamulus $\rightarrow$ crosses the palm in the **concavity of the deep palmar arch** (with the deep branch of the ulnar artery) $\rightarrow$ ends between the **two heads of adductor pollicis**.

- ▶ Supplies: 3 **hypothenar muscles** + **all interossei** + **3rd & 4th lumbricals** + **adductor pollicis** (± deep head flexor pollicis brevis, ± contribution to opponens pollicis) + articular twigs to wrist/carpometacarpal/metacarpophalangeal joints.
- ▶ **Purely motor** (with joint twigs only) — no cutaneous branch; contrast the sensory **superficial terminal branch**.
- ▶ Isolated deep-branch (pure motor) palsy classically follows a **wrist ganglion** or **hook of hamate fracture**.
- ▶ **Ulnar paradox** — a wrist lesion claws **more** than an elbow lesion, because flexor digitorum profundus is spared distally.
- ▶ **Froment's sign** and **Wartenberg's sign** are the classic bedside tests of deep-branch (adductor pollicis / interossei) function.
- ▶ Called the "**musician's nerve**" for its role in fine intrinsic hand movements.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 (8e); AK Datta's Human Anatomy Vol 3 (Upper & Lower Limb); IB Singh — Textbook of Anatomy Vol 1 (6e).



Describe the formation, course, relations and distribution of radial nerve. Explain the anatomical basis of wrist drop

Asked in: Paper I Sep 2007 — RGUHS MD/MS Anatomy

Definition / Introduction — The radial nerve is the largest branch of the brachial plexus and the direct continuation of the **posterior cord**, carrying fibres from **C5, C6, C7, C8 and (inconstantly) T1**. It is the nerve of the entire extensor (posterior) compartment of the arm and forearm, supplying triceps, anconeus, brachioradialis and every extensor of the wrist, fingers and thumb, together with a broad cutaneous territory over the back of the arm, forearm and radial half of the dorsum of the hand. Because it alone supplies the wrist extensors, its injury proximal to the elbow produces the classical disabling deformity of **wrist drop**.

Formation

- ▶ The posterior cord is formed by the union of the **posterior divisions of all three trunks** (upper, middle, lower) of the brachial plexus.
- ▶ The posterior cord ends by dividing, at the lower border of subscapularis (lower part of the axilla), into its two terminal branches:
 - **Axillary nerve** (smaller, C5–C6) and
 - **Radial nerve** (larger, C5–T1) — the direct continuation of the cord.
- ▶ **Root value:** C5, C6, C7, C8, T1 (the T1 contribution is inconstant/variable).
- ▶ It is the **largest nerve of the upper limb** and the largest branch of the brachial plexus.

Course and relations — in the axilla

Relation	Structure
Anterior	Third part of the axillary artery
Posterior	Subscapularis, tendons of latissimus dorsi and teres major
Lateral	Axillary nerve, coracobrachialis
Medial	Axillary vein

- ▶ The nerve descends behind the third part of the axillary artery and the upper part of the brachial artery, giving a branch to the **medial head of triceps** at this level.

Course and relations — in the arm (spiral/radial groove)

- ▶ The nerve leaves the axilla at the **lower border of teres major** and, with the **profunda brachii vessels**, passes through the **lower triangular space** (bounded above by teres major, medially by the long head of triceps, laterally by the shaft of the humerus).
- ▶ It then winds obliquely across the back of the humerus in the **spiral (radial) groove**, lying in direct contact with bone, sandwiched between the lateral and medial heads of triceps.
 - Boundaries of the groove: anteriorly the middle third of the humeral shaft; above, the origin of the lateral head of triceps; below, the origin of the medial head; posteriorly, fibres of the lateral and long heads of triceps.
- ▶ At the lower end of the groove (about 5 cm below the deltoid tuberosity), the nerve **pierces the lateral intermuscular septum** to enter the **anterior compartment** of the arm.
- ▶ In the anterior compartment it descends first between **brachialis and brachioradialis**, then between **brachialis and extensor carpi radialis longus (ECRL)**, to reach the lateral part of the **cubital fossa**, anterior to the lateral epicondyle.

Course, relations and termination — at the elbow and in the forearm

- ▶ At the level of the lateral epicondyle, in the cubital fossa (lying lateral to the biceps tendon; mnemonic for fossa contents medial→lateral — Median nerve, Brachial artery, tendon of Biceps, Radial nerve), the radial nerve **terminates by dividing into a superficial (sensory) and a deep (motor) branch**.
- ▶ **Deep branch (posterior interosseous nerve, PIN)**: motor; enters and supplies extensor carpi radialis brevis and supinator, then winds around the lateral aspect of the radius **between the two heads of supinator** (passing under the fibrous **arcade of Frohse**) to emerge on the back of the forearm and supply the remaining extensor muscles; ends by giving articular twigs to the wrist, distal radio-ulnar and carpal joints.
- ▶ **Superficial branch (superficial radial nerve)**: purely sensory; descends under cover of brachioradialis, lateral to the radial artery in the middle third of the forearm; about 7 cm **proximal to the wrist** it leaves the artery, winds backwards deep to the brachioradialis tendon, crosses the anatomical snuffbox, and divides into dorsal digital branches for the hand.

Branches and distribution

Region	Branches	Distribution
Axilla	Posterior cutaneous nerve of arm; nerve to long head of triceps; nerve to medial head of triceps	Skin of back of arm; long & medial heads of triceps
Spiral groove	Lower lateral cutaneous nerve of arm; posterior cutaneous nerve of forearm; nerves to lateral head of triceps, medial head of triceps, anconeus	Skin, lower lateral arm & posterior forearm; triceps (lateral/medial heads), anconeus
Anterior compartment (distal arm)	Nerve to brachialis (lateral part, proprioceptive); nerve to brachioradialis; nerve to ECRL	Brachialis (lateral part), brachioradialis, ECRL
Cubital fossa / deep branch	To extensor carpi radialis brevis, supinator	ECRB, supinator
Posterior interosseous nerve	Extensor digitorum, extensor digiti minimi, extensor carpi ulnaris; extensor pollicis longus, extensor indicis; abductor pollicis longus, extensor pollicis brevis	All remaining extrinsic extensors of wrist, digits and thumb
Superficial radial nerve	Dorsal digital branches	Skin over lateral two-thirds of dorsum of hand and dorsal aspect of lateral 3½ digits, proximal to the nail beds

Summary of overall distribution

- **Motor:** triceps brachii (all three heads), anconeus, brachioradialis, extensor carpi radialis longus and brevis, supinator, and (via the PIN) all extensors of the wrist, fingers and thumb — i.e., the entire posterior compartment of the arm and forearm.
- **Sensory:** skin of the posterior surface of the arm and forearm, and the lateral two-thirds of the dorsum of the hand together with the dorsal aspect of the lateral 3½ digits (excluding their distal phalanges, which are supplied palmarly by median/ulnar nerves).

□ Fig 17.39 — Scheme to show the course and distribution of the radial nerve and its terminal branches (IB Singh — Textbook of Anatomy Vol 1 — 6e, p.220)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Reproduce the figure above by hand; label sequentially from proximal to distal:

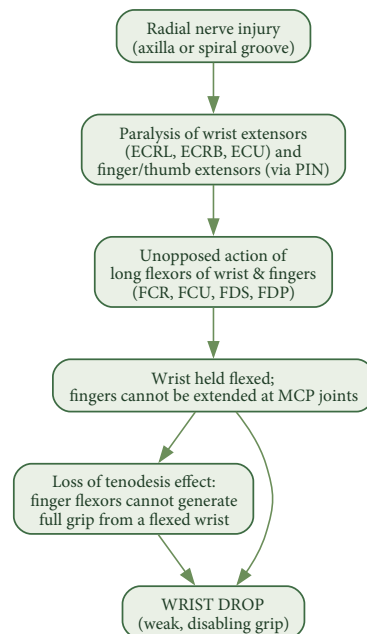
- ▶ **Posterior cord of brachial plexus** → origin of radial nerve
- ▶ **Axillary nerve** (sister terminal branch, for reference)
- ▶ **Posterior cutaneous nerve of arm** + nerve to long/medial heads of triceps (axillary branches)
- ▶ **Lower triangular space** (teres major / long head triceps / humerus)
- ▶ **Spiral (radial) groove** with **profunda brachii artery** alongside the nerve
- ▶ Branches in the groove: **lower lateral cutaneous nerve of arm**, **posterior cutaneous nerve of forearm**, nerves to lateral/medial heads of triceps and **anconeus**
- ▶ **Lateral intermuscular septum** (piercing point)
- ▶ Nerves to **brachialis**, **brachioradialis**, **ECRL** in the anterior compartment
- ▶ Division at lateral epicondyle into **superficial radial nerve** and **posterior interosseous nerve (deep branch)**
- ▶ PIN passing through **supinator** (arcade of Frohse) → branches to **ECRB**, **supinator**, **extensor digitorum**, **EDM**, **ECU**, **EPL**, **EI**, **APL**, **EPB**
- ▶ Superficial radial nerve winding round radius → **dorsal digital branches** to lateral 3½ digits

Applied / Clinical anatomy

Sites of injury and clinical picture

Site	Common cause	Motor loss	Sensory loss
Axilla	Pressure of crutch top ("crutch palsy"), dislocation of shoulder	Triceps (elbow extension) + all distal radial-supplied muscles → wrist drop	Back of arm, forearm, dorsum of hand/lateral 3½ digits
Radial (spiral) groove	Mid-shaft fracture of humerus; misplaced IM injection; sleeping with arm over chair back ("Saturday night palsy")	Wrist and finger extensors paralysed (triceps often spared/partly spared as its nerve arises above the lesion) → wrist drop	Narrow strip on back of forearm; small area on dorsum of hand
Elbow / proximal forearm (deep branch/PIN)	Entrapment at the arcade of Frohse, fibrous bands, radial recurrent vessels, fracture-dislocation of radial head, "radial tunnel syndrome"	Loss of finger and thumb extension; no wrist drop (ECRL, supplied proximal to the lesion, keeps the wrist extended)	None (PIN is purely motor)

Anatomical basis of wrist drop



Describe the formation, course, relations and distribution of radial nerve. Explain the anatomical basis of wrist drop

- The radial nerve is the **sole motor supply** to every extensor of the wrist (ECRL, ECRB, ECU), fingers (extensor digitorum, EI, EDM) and thumb (EPL, EPB, APL); a lesion proximal to the elbow abolishes all of these in one stroke.
- With the extensors paralysed, the unopposed **long flexor muscles of the forearm** (median/ulnar-supplied) pull the wrist into a position of flexion — the wrist cannot be actively extended against gravity, producing the characteristic **drooping** ("dropped") wrist.
- Because the wrist can no longer be fixed in slight extension, the long flexor tendons to the fingers start their excursion already near-shortened; the normal **tenodesis mechanism** (wrist extension lengthens finger flexors, allowing a powerful grip) is lost — this is why, as emphasised in gross anatomy texts, wrist drop is markedly **disabling** and the patient cannot grip an object firmly even though the flexor muscles themselves are intact.
- Extension at the **interphalangeal joints** may still be partly possible using the intact ulnar/median-supplied **lumbricals and interossei**, but extension at the **metacarpophalangeal joints** is lost, since only the radial-nerve-supplied long extensors act there — this dissociation is a useful bedside distinguishing sign.
- If the lesion is distal (PIN entrapped in supinator/arcade of Frohse), the branch to ECRL (given off proximal to the elbow) is spared, so the wrist can still be extended (though radially deviated) — **finger drop without wrist drop** — differentiating a distal PIN lesion from a proximal radial nerve injury.
- Elbow extension is preserved or only mildly weak in spiral-groove lesions because the nerve to the long head of triceps is given off in the axilla, proximal to the usual site of injury.

High-yield exam pointers

- Radial nerve = largest branch of brachial plexus; direct continuation of the **posterior cord**; root value C5–T1 (T1 inconstant).

- ▶ Passes through the **lower triangular space** with the **profunda brachii artery**, then lies in the **spiral (radial) groove** in direct contact with the humerus — hence vulnerable in midshaft humeral fractures.
- ▶ Terminates in the cubital fossa (anterior to lateral epicondyle) into **superficial radial nerve** (sensory) and **posterior interosseous nerve** (motor, deep branch).
- ▶ PIN passes through **supinator** (arcade of Frohse) — the classic entrapment site (radial tunnel syndrome / PIN syndrome).
- ▶ Supplies triceps, anconeus, brachioradialis, ECRL/ECRB, supinator, and **all** extensors of wrist, fingers and thumb; sensory to posterior arm/forearm and lateral dorsum of hand + lateral 3½ digits (proximal phalanges only).
- ▶ **Wrist drop** = unopposed flexor action after loss of wrist-extensor tone; grip is weak because the tenodesis effect is lost.
- ▶ Three classical injury sites: axilla (crutch palsy), spiral groove (Saturday night palsy/humeral shaft fracture), elbow (PIN/radial tunnel syndrome — finger drop only, no wrist drop, no sensory loss).
- ▶ Mnemonic for cubital fossa contents (medial→lateral): Median nerve, Brachial artery, Biceps tendon, Radial nerve (MBBR).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 8e; Vishram Singh — Textbook of Anatomy Vol 1 4e; IB Singh — Textbook of Anatomy Vol 1 6e.



Describe the radio ulnar joints

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The radius and ulna are united by **three radio-ulnar joints** — superior (proximal), middle, and inferior (distal) — that together permit **pronation and supination** of the forearm and hand while the elbow independently permits flexion-extension. The superior and inferior joints are synovial, uniaxial **pivot joints**; the middle joint is a fibrous **syndesmosis** formed by the interosseous membrane and oblique cord. Functionally the three joints act as a single mechanical unit: the radius spins on its own long axis proximally while its distal end sweeps in an arc around the relatively fixed ulna, carrying the hand with it.

Classification of the radio-ulnar joints

Joint	Type	Articulating surfaces	Principal connecting structure
Superior (proximal)	Synovial, uniaxial pivot	Circumference of head of radius ↔ osseofibrous ring (radial notch of ulna + annular ligament)	Annular ligament (+ quadrate ligament)
Middle	Fibrous syndesmosis	Interosseous borders of radial and ulnar shafts	Interosseous membrane + oblique cord
Inferior (distal)	Synovial, uniaxial pivot	Head of ulna (convex) ↔ ulnar notch of radius (concave)	Articular disc (triangular fibrocartilage)

Superior (proximal) radio-ulnar joint

- ▶ **Articulating surfaces** — the articular circumference of the head of radius rotates within an osseofibrous ring: the **radial notch of the ulna** (about one-fifth of the ring) and the **annular ligament** (remaining four-fifths).
- ▶ **Fibrous capsule** — continuous with the capsule of the elbow joint and attached to the annular ligament; the **synovial cavity is common with that of the elbow joint** (a single continuous synovial cavity for the humero-ulnar, humero-radial and superior radio-ulnar joints).
- ▶ **Ligaments**
 - **Annular ligament** — a strong, cup-shaped fibrous band (narrower below) that encircles the radial head; attached to the anterior and posterior margins of the radial notch of the ulna; blends above with the elbow capsule; its outer surface blends with the radial collateral ligament and gives partial origin to supinator; its inner surface is lined by cartilage where it contacts the radial head.
 - **Quadrate ligament** — a thin fibrous band from the distal border of the annular ligament to the neck of the radius; covers the synovial membrane reflected onto the radial neck and remains taut through most of pronation-supination.
- ▶ **Relations** — anconeus and the interosseous recurrent artery lie posterior to the annular ligament; supinator wraps around the joint laterally and posteriorly.

- ▶ **Blood supply** — rich peri-articular anastomotic plexus around the elbow (recurrent and collateral vessels).
- ▶ **Nerve supply** — branches of the musculocutaneous, median, radial and ulnar nerves.

Middle radio-ulnar joint (radio-ulnar syndesmosis)

- ▶ **Oblique cord** — a thin, inconstant fibrous band on the deep head of supinator, running from the lateral side of the ulnar tuberosity to the radius just distal to the radial tuberosity, its fibres at right angles to the interosseous membrane; possibly a remnant of the flexor pollicis longus origin; functional significance uncertain.
- ▶ **Interosseous membrane** — a broad, thin collagenous sheet joining the interosseous borders of radius and ulna; fibres slope **distomedially** (downward and medially, radius to ulna) except in its lowest part where the direction reverses.
 - Leaves a **triangular gap** proximally (between it and the oblique cord) for the posterior interosseous vessels, and an **oval gap** near its lower part for the anterior interosseous vessels passing to the back of the wrist.
 - Its most important part is the **central band** (Hotchkiss et al 1989), which stays taut throughout pronation-supination and, together with the radial head, resists proximal migration of the radius; four other subsidiary bands have also been described (Noda et al 2009).
 - Distally it is related anteriorly to pronator quadratus and blends with the capsule of the inferior radio-ulnar joint.
 - **Function** — binds radius to ulna, gives attachment to deep forearm muscles, and transmits load from the hand through the radius to the ulna and humerus; force from a pronated, closed fist can also be transmitted directly to the humerus through the radius alone.

Inferior (distal) radio-ulnar joint

- ▶ **Articulating surfaces** — the convex head of the ulna articulates with the concave ulnar notch of the radius; both bones are enclosed by a common articular capsule and connected below by the articular disc.
- ▶ **Fibrous capsule** — a loose envelope, thicker anteriorly and posteriorly, lax proximally; the synovial membrane projects proximally as a **recessus sacciformis (sacciform recess)** in front of the distal interosseous membrane, between it and pronator quadratus.
- ▶ **Articular disc / triangular fibrocartilage complex (TFCC)** — a biconcave triangular plate of chondroid fibrocartilage (2–5 mm thick) that separates the ulnar head from the wrist joint.
 - **Apex** attaches to a depression between the ulnar head and the base of the ulnar styloid process; **base** attaches to a ridge on the radius between the ulnar notch and the carpal articular surface.
 - Peripheral margins blend with the capsules of both the inferior radio-ulnar and the wrist joints.
 - Complete TFCC additionally comprises the meniscal homologue (ulnocarpal meniscus), the ulnar collateral ligament, dorsal and palmar radio-ulnar ligaments, the floor of the extensor carpi ulnaris subsheath, and the ulnolunate/ulnotriquetral ligaments.

- Only the outer 15–20% of the disc is vascularised (branches of the ulnar artery and the anterior interosseous artery); the central two-thirds is avascular, which explains its poor healing and its tendency to degenerate.
- **Function** — its upper surface permits the rotatory movement of the inferior radio-ulnar joint about a vertical axis, while its lower surface allows the angular (flexion-extension/deviation) movements of the wrist joint; it is a major stabiliser of the distal radio-ulnar joint and cushions the ulnar carpus against ulnar-sided load.
- ▶ **Blood supply** — palmar and dorsal branches of the anterior interosseous artery, reinforced by the posterior interosseous and ulnar arteries.
- ▶ **Nerve supply** — branches of the anterior and posterior interosseous nerves.

Diagram (real plate):

embed: ![\[Fig 3.106 — Radio-ulnar ligaments and interosseous arteries. The ligament of the p \(Moore — Clinically Oriented Anatomy — 9e, p.509\)\]](#)(C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/43f03ded613262d0.jpg)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw an anterior view of the forearm showing all three radio-ulnar joints in one schematic, with these labels:

- ▶ Head of radius seated in the annular ligament (osseo-fibrous ring)
- ▶ Radial notch of ulna
- ▶ Annular ligament (label ~4/5 fibrous : 1/5 bony ring)
- ▶ Quadratus ligament
- ▶ Interosseous membrane (mark the central oblique band)
- ▶ Oblique cord (proximal, at right angles to membrane fibres)
- ▶ Ulnar notch of radius
- ▶ Head of ulna and styloid process of ulna
- ▶ Articular disc (triangular fibrocartilage) — apex to ulnar styloid, base to radius
- ▶ Recessus sacciformis (synovial recess, in front of distal interosseous membrane)
- ▶ Axis of pronation-supination (dashed line from centre of radial head to ulnar attachment of the disc)

Movements of the radio-ulnar joints — pronation and supination

- ▶ The proximal and distal radio-ulnar joints work as a single functional unit: the **radius rotates**, the **ulna is relatively fixed** (though its distal end does show a small accessory excursion).
- ▶ **Pronation** — the head of radius spins within the annular ligament about a near-vertical axis and stays lateral to the ulna proximally, while the distal end of the radius (carrying the hand) rotates **anteriorly and medially**, crossing in front of the ulna; the ulnar head correspondingly shifts posterolaterally; the interosseous membrane becomes spiralised.

- ▶ **Supination** — the movement reverses: the distal radius uncrosses, moving laterally and posteriorly until radius and ulna lie parallel again; the ulnar head moves anteromedially; the interosseous membrane despiralises.
- ▶ **Axis** — passes obliquely from the centre of the head of radius proximally to the ulnar attachment of the articular disc (base of the ulnar styloid) distally; because the medial side of the radial head is longer than the lateral side, an eccentric "cam effect" occurs during proximal joint rotation.
- ▶ **Range** — with the elbow flexed (eliminating shoulder rotation), combined pronation-supination is about 140–150°; with the elbow extended, apparent hand rotation increases further as shoulder rotation and scapular movement are added.
- ▶ **Muscles**
 - *Pronators* — pronator teres (main mover, spinal segments C6, C7) and pronator quadratus (the deep, constant pronator, active in every pronation movement and against resistance); assisted by flexor carpi radialis and brachioradialis (from full supination toward mid-prone).
 - *Supinators* — supinator (C6) and biceps brachii (a powerful supinator, especially with the elbow flexed); assisted by extensor carpi radialis longus and brachioradialis (from full pronation toward mid-prone).
 - **Supination is more powerful than pronation** (biceps + supinator > pronator teres + pronator quadratus) — the biomechanical reason screw threads, taps and most right-handed tools are designed to tighten with a supinating action of the right hand.

Applied / Clinical anatomy

- ▶ **Pulled elbow (nursemaid's elbow)** — sudden longitudinal traction on the hand/wrist of a child under 6 years (forearm semi-pronated) partially slips the radial head out of the annular ligament, because the head and neck diameters of the immature radius are nearly equal; reduced by gentle supination (and flexion) of the forearm.
- ▶ **Monteggia fracture-dislocation** — fracture of the proximal ulna with dislocation of the radial head (type I, anterior dislocation, is commonest — hyperextension fall with forearm neutral/mid-pronated); the interosseous membrane and TFCC are usually intact, so reducing the ulnar fracture restores the radio-capitellar and superior radio-ulnar joints; the posterior interosseous/radial nerve is at particular risk.
- ▶ **Galeazzi fracture-dislocation** — fracture of the radius at the junction of its middle and distal thirds with disruption of the inferior radio-ulnar joint (axial load on a fully pronated, outstretched hand); the ulnar styloid may fracture too.
- ▶ **Essex-Lopresti injury** — radial head fracture + interosseous membrane disruption + distal radio-ulnar joint disruption, causing proximal radial migration ("radio-ulnar dissociation"); since the membrane's central band and radial head jointly resist this migration, excising the fractured radial head without addressing the membrane is hazardous.
- ▶ **TFCC tear/degenerative perforation** — a common cause of ulnar-sided wrist pain and distal radio-ulnar joint instability; degenerative perforation of the disc is a near-constant finding after age 50 because only its outer rim is vascularised.
- ▶ **Dislocation of the elbow** (usually posterior, in adults) can tear the annular ligament and disturb the proximal radio-ulnar relationship; may be associated with a coronoid process fracture.

- ▶ Because the annular ligament and quadrate ligament stay taut through nearly the whole range of rotation, surgical incisions/approaches to the proximal radius are planned to avoid stripping them and destabilising the joint.

High-yield exam pointers

- ▶ Three radio-ulnar joints: **superior and inferior are synovial pivot joints; the middle is a fibrous syndesmosis** (interosseous membrane + oblique cord).
- ▶ Superior joint's **synovial cavity is continuous with the elbow joint**; its capsule is attached to the annular ligament.
- ▶ Annular ligament forms four-fifths of the osseo-fibrous ring around the radial head; the ulnar radial notch supplies the remaining one-fifth (bony).
- ▶ Interosseous membrane fibres run **radius-proximal → ulna-distal**; its central band (Hotchkiss) resists proximal radial migration.
- ▶ Inferior joint's articular disc (TFCC) separates the ulnar head from the wrist joint; only the outer 15–20% is vascularised.
- ▶ Axis of pronation-supination runs from the centre of the radial head to the ulnar attachment of the articular disc.
- ▶ Radius rotates, ulna is (near) fixed; in pronation the distal radius crosses anteromedially over the ulna.
- ▶ Pronators: pronator teres + pronator quadratus. Supinators: supinator + biceps brachii; **supination is the stronger movement**.
- ▶ Key fracture-dislocations: **Monteggia** (proximal ulna fracture + radial head dislocation), **Galeazzi** (distal radius fracture + inferior radio-ulnar joint disruption), **Essex-Lopresti** (radial head fracture + interosseous membrane + distal radio-ulnar joint disruption).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb); Moore's Clinically Oriented Anatomy 9e.



Interossei muscles of the hand

Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction The interossei are eight small intrinsic muscles that occupy the intervals between the metacarpal bones and, together with the four lumbricals, form the deep intrinsic (interosseous-lumbrical) muscle group of the hand. They are arranged in two sets — **four palmar (unipennate)** and **four dorsal (bipennate)** — and are functionally the prime movers of finger abduction/adduction and of the coordinated **flexion at the metacarpophalangeal (MCP) joints with extension at the interphalangeal (IP) joints**. All eight are supplied by the **deep branch of the ulnar nerve (C8, T1)**, making them clinically important in ulnar nerve palsy (claw hand).

1. Palmar interossei — attachments

Muscle	Origin	Insertion
1st palmar interosseous	Ulnar side of palmar surface of base of 1st metacarpal	Ulnar side of base of proximal phalanx of thumb (often via a sesamoid, and into dorsal digital expansion); often rudimentary
2nd palmar interosseous	Ulnar side of shaft of 2nd metacarpal	Ulnar side of dorsal digital expansion of index finger
3rd palmar interosseous	Radial side of shaft of 4th metacarpal	Radial side of dorsal digital expansion of ring finger, with the 3rd lumbrical
4th palmar interosseous	Radial side of shaft of 5th metacarpal	Radial side of dorsal digital expansion of little finger, with the 4th lumbrical, and base of proximal phalanx

- Each is **unipennate**, smaller than its dorsal counterpart, and lies on the **palmar surface** of its metacarpal.
- The **middle (3rd) finger has no palmar interosseous** — it is the only digit without one, since it is the axis of reference for ab/adduction.
- The remaining digits have a palmar interosseous only on the side that faces the middle finger.

2. Dorsal interossei — attachments

Muscle	Origin (bipennate, two heads)	Insertion
1st dorsal interosseous (largest; also called <i>abductor indicis</i>)	Adjacent sides of shafts of 1st and 2nd metacarpals	Radial side of proximal phalanx of index finger + capsule of its MCP joint
2nd dorsal interosseous	Adjacent sides of shafts of 2nd and 3rd metacarpals	Radial side of middle finger — digital expansion and proximal phalanx
3rd dorsal interosseous	Adjacent sides of shafts of 3rd and 4th metacarpals	Ulnar side of middle finger — usually only the digital expansion

Muscle	Origin (bipennate, two heads)	Insertion
4th dorsal interosseous	Adjacent sides of shafts of 4th and 5th metacarpals	Ulnar side of ring finger — digital expansion, often with a slip to proximal phalanx

- Each dorsal interosseous is **bipennate**, arising more extensively from the metacarpal of the finger into which it inserts, and lies **between** (not on the surface of) two metacarpals.
- A narrow triangular interval exists between the two heads of each dorsal interosseous: the **radial artery** passes through the first interval (to reach the deep palmar arch), and a **perforating branch of the deep palmar arch** passes through each of the remaining three.
- Both index and little fingers have their **own independent abductors** (1st dorsal interosseous for index; abductor digiti minimi for little finger), so effectively only the middle and ring fingers depend solely on dorsal interossei for abduction.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Palmar aspect of the left hand showing (label each): metacarpals 1–5; **4 palmar interossei** (1st–4th, on the metacarpal shaft facing the axis digit); **4 dorsal interossei** (1st–4th, filling the intermetacarpal spaces, 1st being the largest/"abductor indicis"); the **axis line through the 3rd metacarpal/middle finger** (reference line for abduction–adduction); insertions into the **dorsal digital expansion** and **base of proximal phalanx** of each digit; deep branch of ulnar nerve and deep palmar arch running across the interossei.

□ Fig 9.23 — Palmar and dorsal interossei muscles (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.152)

3. Relations

- **1st palmar interosseous** lies anterior to the lateral head of the 1st dorsal interosseous and is overlapped anteriorly by the oblique head of adductor pollicis, which also crosses in front of the 2nd palmar interosseous.
- The **3rd and 4th palmar interossei** are overlapped by the long flexor tendons of the ring and little fingers within their flexor sheaths.
- The **1st dorsal interosseous** abuts anteriorly with adductor pollicis; it forms the floor of the "anatomical snuffbox"-adjacent first web space and can be palpated in the thumb web.
- The other dorsal interossei occupy the spaces between the 2nd and 5th metacarpals, deep to the long flexor tendons and lumbricals, and superficial (posterior relation) to the deep transverse metacarpal ligaments.

4. Insertion into the extensor (dorsal digital) expansion

Both sets of interossei, together with the lumbricals, contribute "wing tendons" to the **extensor expansion** of extensor digitorum on the dorsum of each digit — this is the anatomical basis of their action on the IP joints.

Digit	Interossei/lumbrical contributing to its expansion
Index	1st dorsal interosseous, 2nd palmar interosseous, 1st lumbrical, extensor digitorum slip, extensor indicis
Middle	2nd and 3rd dorsal interossei, 2nd lumbrical, extensor digitorum slip (no palmar interosseous)
Ring	4th dorsal interosseous, 3rd palmar interosseous, 3rd lumbrical, extensor digitorum slip
Little	4th palmar interosseous, 4th lumbrical, extensor digitorum slip, extensor digiti minimi

- The lumbrical and the phalangeal (distal) attachments of the dorsal interossei lie **anterior** to the transverse bands of the deep transverse metacarpal ligament; the remaining (proximal) attachments of both dorsal and palmar interossei lie **posterior** to it.

5. Nerve supply and vascular supply

	Nerve supply	Blood supply
All 8 interossei	Deep (terminal) branch of the ulnar nerve (C8, T1) — a branch derived from the deep branch of ulnar nerve after it supplies the hypothenar muscles; the 1st dorsal interosseous and adductor pollicis are supplied by its most distal portion	Palmar interossei: deep palmar arch, arteria princeps pollicis, arteria radialis indicis, palmar metacarpal arteries, proximal/distal perforating arteries, and common/proper digital arteries
		Dorsal interossei: dorsal metacarpal arteries (1st–4th), palmar metacarpal arteries (2nd–4th), radial artery (1st), arteria princeps pollicis, arteria radialis indicis, and proximal + distal perforating branches of the deep palmar arch

- Deep branch of the ulnar nerve, after leaving the hypothenar muscles, crosses the palm deep to the long flexor tendons, resting on the interossei, and supplies the medial two lumbricals and all eight interossei before ending in adductor pollicis.

6. Actions

Action	Muscle responsible	Mnemonic
Abduction of fingers away from the axis (longitudinal line through the middle finger)	Dorsal interossei (DAB)	Palmar ADduct, Dorsal ABduct = PAD–DAB
Adduction of fingers towards the axis	Palmar interossei (PAD)	as above

Action	Muscle responsible	Mnemonic
Flexion of MCP joints + extension of IP joints (acting with lumbricals) — the coordinated posture used in pinch/grip, sometimes termed the "Z-movement"	Both palmar and dorsal interossei, with lumbricals	—
Rotation of the digit at the MCP joint	Each interosseous has a rotational component, usually masked because interossei act in antagonist pairs	—

- **Axis of reference:** movements of the fingers (index, ring, little) are described relative to a line through the centre of the **middle finger** (not the middle finger itself, which itself abducts to either side — hence the middle finger alone has no palmar interosseous but has two dorsal interossei acting antagonistically on it).
- Because interossei have a large cross-sectional area relative to their small size, they contribute strongly to MCP flexion; when paralysed, grip strength falls and the arc of finger motion becomes abnormal.
- Interossei (with the long extensor) are also active during **hand opening**; the balance between long extensor pull at the base of the middle phalanx and interossei pull at the lateral slips determines whether the extensor force acts predominantly at the MCP joint ("intrinsic-minus"/claw posture when interossei are absent) or at the PIP joint ("intrinsic-plus" posture when interossei act strongly).
- Interossei and abductor digiti minimi also help maintain the **transverse and longitudinal arches of the hand**, since dorsal interossei contribute to arch stability along with palmar aponeurosis, thenar/hypothenar muscles and long flexor tendons.

Testing (clinical bedside tests)

- **Dorsal interossei:** patient spreads (abducts) fingers against resistance with hand flat on a table; the 1st dorsal interosseous belly can be felt/seen in the first web space (thumb web) as the index finger abducts.
- **Palmar interossei:** a piece of paper is held between adjacent fingers (2nd–3rd, 3rd–4th, 4th–5th) and the examiner tries to withdraw it — weak grip confirms palmar interosseous weakness.
- **Combined interossei + lumbricals:** patient flexes fingers at the MCP joints (with IP joints kept extended) against resistance — cannot be tested in isolation from lumbricals.

Applied / Clinical anatomy

- **Ulnar claw hand** (main clinical importance): a lesion of the ulnar nerve at the wrist (e.g. laceration, ganglion, Guyon's canal compression) paralyses all the interossei (plus medial two lumbricals, hypothenar muscles, adductor pollicis). Because the long flexors and extensors are spared, unopposed action produces **hyperextension at the MCP joints with flexion at the IP joints**, most marked in the ring and little fingers (less in index/middle, which retain the median-nerve-supplied 1st/2nd lumbricals). Wasting of the interossei produces visible **hollowing/guttering of the intermetacarpal (dorsal) spaces**. Claw deformity is paradoxically

more obvious in a wrist-level lesion than an elbow-level lesion, because flexor digitorum profundus is spared at the wrist and adds unopposed flexion of the terminal phalanges ("ulnar paradox").

- ▶ **Complete claw hand** results when both median and ulnar nerves are paralysed (loss of all lumbricals and interossei), producing clawing of all four fingers.
- ▶ **Froment's sign (book/paper test)**: tests adductor pollicis (ulnar-supplied); in ulnar palsy the patient substitutes flexor pollicis longus (median-supplied), producing thumb IP joint flexion when pinching a sheet of paper — tests the ulnar-innervated intrinsic group of which interossei are part of the same distal ulnar-nerve territory.
- ▶ **Compartment syndrome of the hand**: the hand has 10 recognised fascial compartments — four containing the dorsal interossei, three the palmar interossei, and three the thenar/hypothenar/adductor pollicis muscles. Crush injury, burns, or high-pressure injection injury can raise intracompartmental pressure in these interosseous compartments, producing an "intrinsic-minus" claw posture that mimics ulnar palsy and requires urgent fasciotomy (dorsal longitudinal incisions over the 2nd and 4th metacarpals).
- ▶ **Surgical/radial artery relation**: the radial artery, on entering the palm to form the deep palmar arch, passes through the **first dorsal interosseous space** between its two heads — relevant to radial-artery-based flaps and to injury patterns at the base of the thumb web.
- ▶ **Extensor tendon surgery**: because interossei insert into the extensor expansion, an isolated central-slip or lateral-band injury (e.g. boutonnière deformity) can alter the balance of interosseous pull on the PIP/DIP joints even with normal interossei.

High-yield exam pointers

- ▶ Interossei = **8 muscles** (4 palmar + 4 dorsal), all supplied by **deep branch of ulnar nerve (C8, T1)**.
- ▶ Mnemonic: **PAD–DAB** — Palmar ADduct, Dorsal ABduct.
- ▶ **Middle finger has no palmar interosseous**; it is the axis of reference for abduction/adduction and has 2nd + 3rd dorsal interossei acting on either side of it.
- ▶ **1st dorsal interosseous** = largest, aka *abductor indicis*; radial artery passes between its two heads to form the deep palmar arch.
- ▶ Interossei act with lumbricals to produce **MCP flexion + IP extension** ("Z-movement"/lumbrical action), and insert via "wing tendons" into the **dorsal digital (extensor) expansion**.
- ▶ Loss of interossei (ulnar nerve palsy) → **claw hand**, most marked in ring/little fingers, with **guttering of intermetacarpal spaces**; wrist-level lesion gives a more obvious claw than elbow-level lesion (ulnar paradox, since FDP is spared).
- ▶ Testing: paper/finger-spread test for palmar/dorsal interossei; Froment's sign for the associated ulnar-supplied adductor pollicis.
- ▶ Interossei lie within **10 fascial compartments of the hand** (4 dorsal + 3 palmar interosseous + 3 thenar/hypothenar) — clinically important in hand compartment syndrome.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh — Textbook of Anatomy Vol 1, 4e.



Lumbrical muscles of the hand

Asked in: Paper I Nov 2018 — RGUHS MD/MS Anatomy

Definition / Introduction — The lumbricals are four small, worm-like (*L. lumbricus* = earthworm) intrinsic muscles of the palm that arise from the tendons of flexor digitorum profundus (FDP) and insert into the dorsal digital (extensor) expansions of the medial four fingers. They are functionally and developmentally unique among skeletal muscles: both their origin and insertion are on mobile tendons rather than bone, so contraction can move either end, and they are the only muscle group of the hand supplied by two different nerves. Their coordinated action with the interossei (the "Z-movement") converts a clumsy hook-grip into a precise pulp-to-pulp pinch, making them clinically important in both median and ulnar nerve palsies.

Origin and insertion

Lumbrical	Type	Origin (from tendons of FDP)	Insertion
1st	Unipennate	Radial side and palmar surface of the tendon to the index (2nd) finger	Passes palmar to the deep transverse metacarpal ligament, winds round the radial side of the 2nd MCP joint, and joins the radial side of the dorsal digital expansion of the index finger
2nd	Unipennate	Radial side and palmar surface of the tendon to the middle (3rd) finger	Radial side of the dorsal expansion of the middle finger
3rd	Bipennate	Adjacent (facing) sides of the tendons to the middle and ring fingers	Radial side of the dorsal expansion of the ring finger
4th	Bipennate	Adjacent (facing) sides of the tendons to the ring and little fingers	Radial side of the dorsal expansion of the little finger

- Each tendon lies **anterior (palmar)** to the deep transverse metacarpal ligament and to the phalangeal slip of the corresponding dorsal interosseous — this is the reverse of the interossei, whose main bulk lies posterior to the ligament.

- ▶ At the extensor expansion, the lumbrical tendon joins the **lateral band**, more distally than the corresponding interosseous tendon, and contributes to the oblique fibres that produce interphalangeal extension.
- ▶ Variations are common: any lumbrical may be uni- or bipennate; a bipennate 1st lumbrical may take an additional head from flexor pollicis longus; accessory slips from flexor digitorum superficialis are occasionally seen.

□ Fig 11.15 — Lumbrical muscles. (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.495)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A simple palmar-view line diagram — label exactly:

- ▶ Four FDP tendons diverging in the distal palm (labelled "tendons of flexor digitorum profundus")
- ▶ Tendon of flexor pollicis longus (lateral to FDP tendons, for the accessory 1st lumbrical head)
- ▶ **1st lumbrical** — unipennate, arising from the radial side of the index FDP tendon
- ▶ **2nd lumbrical** — unipennate, arising from the radial side of the middle-finger FDP tendon
- ▶ **3rd lumbrical** — bipennate, from adjoining sides of middle + ring FDP tendons
- ▶ **4th lumbrical** — bipennate, from adjoining sides of ring + little FDP tendons
- ▶ Arrow labelled "Lateral side" and "Medial side" for orientation
- ▶ Each lumbrical tendon curving distally into the corresponding dorsal digital expansion

Nerve supply

Lumbrical	Nerve	Note
1st and 2nd	Median nerve (its digital branches to the index and middle fingers)	Part of the median-innervated " LOAF " muscles (Lumbricals 1–2, Opponens pollicis, Abductor pollicis brevis, Flexor pollicis brevis)
3rd and 4th	Deep (terminal) branch of the ulnar nerve	The 3rd lumbrical frequently receives an additional twig from the median nerve; occasionally the 1st/2nd receive a supply from the deep ulnar branch instead

- ▶ This dual (median + ulnar) supply is unique among the intrinsic muscles of the hand — every other short muscle of the hand is supplied by a single nerve (the interossei entirely by the deep ulnar branch).

Blood supply

- ▶ 1st and 2nd lumbricals — first and second **dorsal metacarpal** and **dorsal digital** arteries.
- ▶ 3rd and 4th lumbricals — second and third **common palmar digital** arteries, together with the third and fourth **dorsal digital** arteries and their anastomoses with the palmar digital vessels.

Relations — the lumbrical canal

- ▶ Each lumbrical, with its tendon, is enclosed in a thin fascial sheath called the **lumbrical canal**, which is a distal prolongation of the palmar fascial spaces into the web spaces.
- ▶ The **1st lumbrical canal** communicates proximally with the **thenar space**; the **2nd–4th lumbrical canals** communicate with the **midpalmar space**.
- ▶ Clinically, the lumbrical canals are regarded as the natural **outlets for pus** from the midpalmar/thenar spaces, so palmar space infection is drained by incisions over the appropriate web space(s) rather than directly over the palm.

Peculiar features (favourite viva/short-note points)

- ▶ The **only muscles in the body** whose both origin and insertion are on mobile soft tissue (tendon-to-tendon/aponeurosis) rather than bone — hence "no bony attachment."
- ▶ The **only hand-muscle group with a dual nerve supply** (median + ulnar).
- ▶ The 1st and 2nd are **unipennate**, the 3rd and 4th are **bipennate**.
- ▶ They contain a **high density of muscle spindles** relative to their small bulk and have a long fibre length, consistent with a strong **proprioceptive** (rather than purely motor) role in guiding finger posture during grip.

Actions and mechanism

- ▶ **Primary action:** flex the metacarpophalangeal (MCP) joints while simultaneously extending the proximal and distal interphalangeal (PIP/DIP) joints of the medial four digits — the so-called **Z-movement**, produced together with the interossei.
- ▶ **Mechanism:** because both attachments (FDP tendon proximally, extensor expansion distally) are mobile, contraction can act at either end. Pulling on the FDP tendon draws it distally (reducing profundus flexor pull on the distal phalanx), while pulling on the extensor expansion extends the IP joints — the combined effect re-postures the finger for **coordinated MCP flexion with IP extension**.
- ▶ **Functional significance:** without a lumbrical, pinching the index finger against the thumb produces a clumsy **nail-to-nail contact**; the lumbrical's IP-extending action converts this into an efficient **pulp-to-pulp pinch**.
- ▶ **Clinical test:** the examiner holds the MCP joint in hyperextension and asks the subject to extend the PIP joint against resistance — lumbricals cannot be isolated and are tested only as part of the lumbrical–interosseous complex.
- ▶ Acting with the interossei, they also stabilise the MCP joint and prevent "buckling" of the finger during power grip.

Applied / Clinical anatomy

- ▶ **Claw hand (main-en-griffe)** — **ulnar nerve palsy:** loss of the 3rd and 4th lumbricals (with the interossei) removes the flexor pull on the extensor expansion of the ring and little fingers. The unopposed long extensor now hyperextends the MCP joints, while the still-intact long flexors (FDS/FDP) flex the IP joints — producing the claw. The deformity is characteristically **more**

marked in a low (wrist-level) ulnar lesion than a high (elbow-level) one, because a high lesion also paralyses the ulnar half of FDP, weakening the very IP flexion that produces the "claw."

- ▶ **Hand of benediction (Pope's blessing) — median nerve palsy (proximal, e.g. supracondylar fracture/elbow injury):** paralysis of FDS/FDP to the index and middle fingers plus the 1st/2nd lumbricals means the index and middle fingers cannot flex at the MCP or IP joints; on attempted fist-making they **lag behind in extension** while the ulnar-supplied ring and little fingers flex normally.
- ▶ **Carpal tunnel syndrome:** the median nerve gives motor twigs to the 1st and 2nd lumbricals (and the thenar muscles) *after* passing through the carpal tunnel, so these muscles weaken in CTS along with thumb opposition; sensation over the central palm is characteristically **spared**, because the palmar cutaneous branch of the median nerve arises proximal to the flexor retinaculum and does not pass through the tunnel.
- ▶ **Lumbrical-plus finger:** after distal FDP tendon injury, repair under excess tension, or amputation of a fingertip, the lumbrical's proximal (FDP) attachment can be drawn further proximally on attempted flexion; because the same pull is transmitted distally through the extensor expansion, the finger paradoxically **extends at the IP joints instead of flexing** — a direct consequence of the lumbrical's unique double mobile attachment described above.
- ▶ **Testing/localising nerve lesions:** the lumbrical test (MCP hyperextension + resisted PIP extension) helps confirm intact median/ulnar innervation before surgery around the wrist and hand.

High-yield exam pointers

- ▶ 4 lumbricals; 1st and 2nd **unipennate**, 3rd and 4th **bipennate**; all arise from FDP tendons.
- ▶ Insert into the **radial side of the dorsal digital expansion** of the corresponding finger (2nd–5th), passing **palmar** to the deep transverse metacarpal ligament.
- ▶ **Nerve supply:** 1st & 2nd — median nerve (LOAF muscles); 3rd & 4th — deep branch of ulnar nerve.
- ▶ **Action:** flex MCP + extend IP joints together = **Z-movement**; converts nail-to-nail pinch to **pulp-to-pulp pinch**.
- ▶ Only muscles with **no bony attachment** and the only hand-muscle group with **dual nerve supply**.
- ▶ Rich in **muscle spindles** — proprioceptive as well as motor function.
- ▶ **Claw hand** = loss of 3rd/4th lumbricals + interossei (ulnar palsy); **Hand of benediction** = loss of 1st/2nd lumbricals + long flexors (median palsy, proximal lesion).
- ▶ **Lumbrical canal** connects thenar (1st)/midpalmar (2nd–4th) spaces to the web spaces — route for spread of palmar space infection.
- ▶ Mnemonic: lumbricals make the hand form an "L" shape (as in holding a pea) — "L is for Lumbrical."

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb); Vishram Singh — Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e; IB Singh — Textbook of Anatomy Vol 1 6e.

**Lumbricals of hand**

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The lumbricals are four small, slender, worm-like muscles (*L. lumbricus*, earthworm) in the palm, one related to each of the four fingers. They are unique among the skeletal muscles of the body in having **no bony attachment at either end**: each arises from a tendon of flexor digitorum profundus (FDP) and inserts into the extensor (dorsal digital) expansion. Because both the origin and the insertion are themselves mobile tendinous structures, contraction of a lumbrical can move both the metacarpophalangeal (MCP) and the interphalangeal (IP) joints simultaneously, converting the hook-like grip of the long flexors into the fine pulp-to-pulp pinch used in writing, threading a needle or holding a pen. Their split nerve supply — the first and second from the median nerve, the third and fourth from the ulnar nerve — makes them central to the classical description of claw-hand deformity.

Origin (proximal attachment)

Lumbrical	Arises from tendon(s) of flexor digitorum profundus to	Pennation
First	Radial side and palmar surface of the tendon to the index (2nd) finger	Unipennate (occasionally bipennate, second head from flexor pollicis longus tendon)
Second	Radial side and palmar surface of the tendon to the middle (3rd) finger	Unipennate
Third	Adjacent (facing) sides of the tendons to the middle and ring fingers	Bipennate
Fourth	Adjoining sides of the tendons to the ring and little fingers	Bipennate

- The first and second lumbricals, arising from a single tendon, are unipennate; the third and fourth, sandwiched between two adjoining profundus tendons, are bipennate.
- Accessory lumbrical slips may be attached to an adjacent tendon of flexor digitorum superficialis; variations in the attachments of the lumbricals are common.

Insertion (distal attachment)

- ▶ Each lumbrical passes to the **radial side** of the corresponding finger, palmar (anterior) to the deep transverse metacarpal ligament, and is attached to the **lateral margin of the dorsal digital expansion** of extensor digitorum on the dorsum of the proximal phalanx.
- ▶ There is, therefore, **no attachment to bone** — the lumbrical runs from one tendon (flexor) to another (extensor), which is the anatomical basis of its unusual double action described below.

Nerve supply

Lumbrical	Nerve	Root value
First and second	Median nerve — the digital branch to the index finger supplies the 1st, the common digital branch to the 2nd cleft supplies the 2nd	C8, T1
Third and fourth	Deep terminal (motor) branch of the ulnar nerve	C8, T1

- ▶ The third lumbrical frequently receives a dual supply from both median and ulnar nerves; occasionally the first and second are also supplied, in part, by the deep branch of the ulnar nerve.
- ▶ This split innervation (unlike the rest of the intrinsic hand muscles, which are almost entirely ulnar) is the single most examined fact about the lumbricals.

Blood supply

- ▶ **First and second lumbricals:** first and second dorsal metacarpal and dorsal digital arteries.
- ▶ **Third and fourth lumbricals:** second and third common palmar digital arteries, together with the third and fourth dorsal digital arteries and their anastomoses with the palmar digital arteries.

Actions and the mechanism of the "double action"

- ▶ The lumbrical lies **palmar (anterior) to the axis of the MCP joint** (it passes anterior to the deep transverse metacarpal ligament, whereas most attachments of the interossei lie posterior to it) but inserts **dorsal to the axis of both IP joints** (into the extensor expansion).
- ▶ This geometry allows a single muscle to **flex the MCP joint** (a weak and disputed action on the flexor side) while **extending both the proximal and distal interphalangeal joints in a coordinated manner** on the extensor side — the classic "L" posture of the finger (L for lumbrical: MCP flexed, IP joints straight).
- ▶ Because the origin (the FDP tendon) is also mobile, the lumbrical's pull has a reciprocal effect there too: it draws the profundus tendon **distally**, relaxing the long flexor slightly as the finger straightens at the IP joints — a built-in mechanism that fine-tunes the balance between the long flexor and the extensor hood.
- ▶ **Functional significance — the pulp-to-pulp pinch:** pinching the index finger against the thumb *without* a functioning lumbrical produces a nail-to-nail contact (both digits maximally flexed at the IP joints by the profundus and flexor pollicis longus). Lumbrical action extends the IP joints just enough to convert this into the more useful **pulp-to-pulp pinch** used for holding a pen or picking up a small object.

- ▶ Lumbricals contain an unusually large number of **muscle spindles** and have a long fibre length for their size, features that support a significant **proprioceptive role** in monitoring digital posture during fine manipulative tasks.
- ▶ **Clinical/viva testing:** lumbricals cannot be tested in isolation, only as part of the lumbrical–interosseous complex. The examiner holds the patient's MCP joint hyperextended and asks the patient to extend the PIP joint against resistance; this is repeated for each finger.

Peculiarities of the lumbricals

- ▶ Only muscles in the body attached at **both ends to tendons**, with **no bony origin or insertion**.
- ▶ Named purely for their worm-like shape, not their action or position.
- ▶ Lie **palmar to the deep transverse metacarpal ligament**, together with the phalangeal attachments of the dorsal interossei — the remaining (proximal) attachments of the interossei lie dorsal to this ligament.
- ▶ Uniquely among the short muscles of the hand, receive a **dual nerve supply** (median for the radial two, ulnar for the ulnar two) rather than a single nerve.
- ▶ Capable of simultaneous, opposite-direction action at two different joints (MCP flexion, IP extension) because both attachments are mobile.

□ Fig 50.33 — Lumbricals of the left hand: palmar aspect. (Gray's Anatomy — Standring — 41e, p.1213)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A palmar view of the left hand after removal of the flexor tendons' sheaths, showing the four lumbricals arising from the FDP tendons, labelled with:

- ▶ **Tendons of flexor digitorum profundus (four)** — running to the index, middle, ring and little fingers
- ▶ **First lumbrical** — from the radial side of the tendon to the index finger
- ▶ **Second lumbrical** — from the radial side of the tendon to the middle finger
- ▶ **Third lumbrical** — from adjacent sides of the middle and ring finger tendons (bipennate)
- ▶ **Fourth lumbrical** — from adjacent sides of the ring and little finger tendons (bipennate)
- ▶ **Deep transverse metacarpal ligament** — deep to the lumbricals
- ▶ **Dorsal digital expansion of extensor digitorum** — the insertion of each lumbrical on the radial side of each finger

Applied / Clinical anatomy

- ▶ **Ulnar claw hand:** a lesion of the ulnar nerve at the wrist paralyses all the interossei and the **third and fourth lumbricals**, along with hypothenar muscles and adductor pollicis. The unopposed long extensor and long flexor tendons produce **hyperextension at the MCP joints and flexion at the IP joints**, i.e. clawing — but this is markedly **more intense in the ring and little fingers**, because the **first and second lumbricals (median-supplied)** are spared and continue to extend the IP joints of the index and middle fingers. The claw is more obvious in wrist-level lesions than elbow-level lesions because flexor digitorum profundus (which flexes the terminal phalanges) is unaffected — the "paradox" of ulnar claw hand.

- ▶ **Median nerve lesion at the wrist:** paralyses the **first and second lumbricals** together with the thenar (LOAF) muscles. Clinically, the index and (to a lesser degree) middle fingers **lag behind** the ring and little fingers when the patient tries to make a fist, because their IP joints are no longer actively extended by a lumbrical once the profundus/superficialis flex the MCP joints; this is best seen alongside the ape-thumb deformity of thenar wasting.
- ▶ **Complete claw hand:** combined median and ulnar nerve injury paralyses all four lumbricals (and both interossei and thenar/hypothenar groups), producing clawing of all four fingers.
- ▶ **Loss of pulp pinch:** paralysis of the lumbricals of the index and thumb-side fingers converts precision pinch towards a nail-to-nail contact, impairing fine tasks such as writing and buttoning — a functional correlate frequently tested clinically alongside sensory examination in ulnar/median nerve injury.
- ▶ **Surgical relevance:** because the lumbricals arise from and insert into mobile tendinous structures rather than bone, laceration or excessive tension on the flexor digitorum profundus distal to a lumbrical origin can alter lumbrical length and produce paradoxical IP-joint extension on attempted grip — an anatomical basis frequently invoked in tendon-injury and hand-surgery discussions of lumbrical mechanics.
- ▶ **LOAF/interossei mnemonics:** the median-supplied intrinsic muscles of the hand are remembered as **LOAF** — Lumbricals (1st, 2nd), Opponens pollicis, Abductor pollicis brevis, Flexor pollicis brevis — all the rest of the 20 intrinsic hand muscles, including the remaining two lumbricals, are ulnar-supplied.

High-yield exam pointers

- ▶ **4 lumbricals**, one for each finger; arise from the four tendons of **flexor digitorum profundus** — 1st and 2nd unipennate (index, middle finger tendons), 3rd and 4th bipennate (from adjacent tendons).
- ▶ Insert into the **radial side of the dorsal digital expansion**, palmar to the deep transverse metacarpal ligament — **no bony attachment at either end**, unique in the body.
- ▶ Nerve supply: **1st and 2nd — median nerve; 3rd and 4th — deep branch of the ulnar nerve** (root value C8, T1); the 3rd is often dually supplied.
- ▶ Action: **flex the MCP joint (weak) and extend both IP joints together** — converts nail-to-nail pinch into pulp-to-pulp pinch; rich in muscle spindles (proprioception).
- ▶ Cannot be tested in isolation — tested as the lumbrical-interosseous complex (MCP held hyperextended, patient extends PIP against resistance).
- ▶ **Ulnar nerve lesion at wrist:** clawing of ring and little fingers is worse than index and middle (whose lumbricals are median-supplied) — classical asymmetric ulnar claw hand.
- ▶ **Median nerve lesion at wrist:** index and middle fingers lag behind in making a fist (1st/2nd lumbrical paralysis), with associated thenar (ape-thumb) wasting.
- ▶ **Combined median + ulnar lesion** → complete claw hand of all four fingers.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; Moore's Clinically Oriented Anatomy, 9e; IB Singh — Textbook of Anatomy Vol 1, 6e; Vishram Singh — Textbook of Anatomy Vol 1, 4e.

**Median nerve**

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction. The median nerve is the principal nerve of the flexor (anterior) compartment of the forearm and of the thenar musculature, formed by the union of a lateral and a medial root from the lateral and medial cords of the brachial plexus. It has no branches in the arm except vascular and articular twigs, but supplies almost all the flexor-pronator muscles of the forearm and five intrinsic muscles of the hand, together with cutaneous sensation to the palmar aspect of the lateral three-and-a-half digits. Because it drives the coarse, power-grip long flexors it is called the "**labourer's nerve**", and because it is sensory to most of the working surface of the hand it is also called the "**eye of the hand**."

Origin and Root Value

- ▶ The median nerve arises in the **axilla** by **two roots** that embrace the third part of the axillary artery and unite anterior (or lateral) to it:
 - **Lateral root** — from the **lateral cord** (C5, C6, C7).
 - **Medial root** — from the **medial cord** (C8, T1).
- ▶ Composite root value: **C5–T1** (C6–T1 is the constant core; the C5 contribution is variable).
- ▶ Occasionally, C7 fibres leave the lateral root in the lower axilla and pass posterior to the medial root to join the ulnar nerve; if the lateral root is small, the musculocutaneous nerve (C5,6,7) sends a communicating branch to the median nerve in the arm — the anatomical basis of variant "Martin-Gruber-type" communications.
- ▶ The nerve gives **no branches in the axilla**.

Course and Relations — Arm and Cubital Fossa

- ▶ **Arm:** The median nerve runs down with the brachial artery, related to it throughout — **lateral** to the artery in the upper arm, crossing **anterior to it in the middle of the arm** (lateral to medial), and lying **medial** to it from mid-arm to the elbow. It gives off vascular twigs to the brachial artery, an inconstant twig to pronator teres just above the elbow, and an articular branch to the elbow joint.
- ▶ **Cubital fossa:** The nerve is the **most medial content** of the fossa, lying medial to the brachial artery, deep to the bicipital aponeurosis and anterior to brachialis. The classical order of structures from medial to lateral at the elbow (mnemonic **MBBR**) is: **Median nerve** — **Brachial artery** — tendon of **Biceps brachii** — **Radial nerve** (deepest, on the lateral side).
- ▶ Here it gives muscular branches to **flexor carpi radialis**, **palmaris longus** and **flexor digitorum superficialis**.

□ Fig 9.12 — Distribution of median nerve (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.145)

Course and Relations — Forearm, Wrist and Palm

- ▶ The nerve enters the forearm between the two heads of pronator teres; here it crosses anterior to the ulnar artery, being separated from it by the deep head of pronator teres.
- ▶ It then passes deep to the fibrous (tendinous) arch of flexor digitorum superficialis and descends through the forearm applied to the deep surface of FDS and superficial to flexor digitorum profundus, accompanied by the median branch of the anterior interosseous artery.
- ▶ About 5 cm proximal to the flexor retinaculum, it emerges from behind the lateral edge of FDS and becomes superficial, lying between the tendons of flexor carpi radialis (laterally) and palmaris longus/FDS (medially), overlapped by the palmaris longus tendon.
- ▶ **Wrist and palm:** The nerve passes deep to the flexor retinaculum through the carpal tunnel (anterior to the long flexor tendons and the ulnar bursa) to enter the palm, where it flattens and divides into a lateral and a medial terminal division.

Branches

Region	Branch	Structures supplied
Arm	Vascular twigs; inconstant twig to pronator teres; articular branch	Brachial artery; pronator teres (variable); elbow joint
Cubital fossa / upper forearm	Muscular branches	Flexor carpi radialis, palmaris longus, flexor digitorum superficialis
Upper forearm	Anterior interosseous nerve (arises just distal to the muscular branches, runs with the anterior interosseous artery)	Flexor pollicis longus; lateral half of flexor digitorum profundus (index & middle finger tendons); pronator quadratus (via its deep surface); articular twigs to distal radio-ulnar, radiocarpal and carpal joints
Lower forearm (~3–5 cm above retinaculum)	Palmar cutaneous branch (runs superficial to the flexor retinaculum, in its own tunnel in the FCR sheath)	Skin of the thenar eminence and central palm
Forearm	Communicating branch	To the ulnar nerve
Palm, just distal to retinaculum	Recurrent (muscular) branch — curls around the distal border of the retinaculum	Abductor pollicis brevis, flexor pollicis brevis, opponens pollicis
Palm	Digital branches (lateral and medial divisions)	Palmar (and dorsal, distal phalanx) skin of the lateral 3½ digits (thumb, index, middle, lateral half of ring); 1st and 2nd lumbricals

Mnemonic for the five muscles supplied in the hand — LOAF: Lateral 2 Lumbricals, Opponens pollicis, Abductor pollicis brevis, Flexor pollicis brevis.

Applied / Clinical anatomy

- ▶ **High median nerve palsy** (lesion at or above the elbow, e.g., **supracondylar fracture of the humerus**):
 - Forearm kept **supinated** (pronators paralysed); wrist flexion is weak and the hand is adducted (ulnar-deviated) due to paralysis of flexor carpi radialis.
 - Flexion at the interphalangeal joints of the index and (to a lesser extent) middle finger is lost — the fingers remain extended on attempted fist-making, the "**pointing index**" sign / "**hand of benediction**" on making a fist.
 - **Ape (monkey) thumb deformity** — thenar wasting and loss of opposition/abduction of the thumb.
 - Sensory loss over the palmar aspect of the lateral 3½ digits; **pen test** (weakness of abductor pollicis brevis) is positive.
- ▶ **Anterior interosseous nerve syndrome** — a pure motor lesion (no cutaneous loss): paralysis of flexor pollicis longus, the lateral half of flexor digitorum profundus and pronator quadratus. The patient cannot make the "OK sign" (pinch tip-to-tip of thumb and index) and instead makes a flat "pinch" posture.
- ▶ **Pronator syndrome** — entrapment of the median nerve between the two heads of pronator teres (trauma, muscular hypertrophy, fibrous bands); presents with pain/tenderness in the proximal forearm and sensory disturbance over the lateral 3½ digits, aggravated by repetitive pronation.
- ▶ **Carpal tunnel syndrome (low/distal lesion)** — the commonest entrapment mononeuropathy; any lesion narrowing the tunnel or enlarging its contents (tenosynovitis, fluid retention/pregnancy, rheumatoid arthritis, distal radius/Colles' fracture, acromegaly) compresses the nerve deep to the flexor retinaculum.
 - Nocturnal paraesthesia/pain over the lateral 3½ digits; **thenar skin sensation is spared** because the palmar cutaneous branch arises proximal to, and runs superficial to, the retinaculum.
 - Progressive thenar wasting (ape-hand), weak thumb opposition/abduction — difficulty buttoning a shirt or gripping objects.
 - **Phalen's test** (acute wrist flexion reproduces symptoms) and direct compression/percussion (Tinel-type sign) at the wrist are used to elicit symptoms; treatment is surgical division of the flexor retinaculum (**carpal tunnel release**), the incision kept toward the ulnar side of the retinaculum to protect the recurrent motor branch.
- ▶ **Communications with the ulnar nerve** in the forearm are clinically important — with a complete median nerve lesion, some "median-innervated" muscles may escape paralysis, leading to under-estimation of the injury.
- ▶ If **both** median and ulnar nerves are injured, the result is a **complete claw hand**.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled schematic of the median nerve (as commonly drawn for this question) should show:

- ▶ Roots: lateral root (C5,6,7) + medial root (C8,T1) embracing the axillary artery.
- ▶ Course line through axilla → arm (relation to brachial artery) → cubital fossa (MBBR order) → between the two heads of pronator teres → deep to FDS arch → carpal tunnel.
- ▶ Branch points labelled along the course: articular twig (elbow), muscular twigs (FCR, PL, FDS), **anterior interosseous nerve** (FPL, lateral half FDP, pronator quadratus), palmar cutaneous branch (thenar/central palmar skin), recurrent muscular branch (APB, FPB, opponens pollicis), digital branches to lateral 3½ digits with 1st/2nd lumbrical twigs.
- ▶ Shade/annotate the area of cutaneous distribution on a palm outline (lateral 3½ digits, sparing the thenar eminence which is served by the palmar cutaneous branch arising proximal to the retinaculum).

High-yield exam pointers

- ▶ Root value C5–T1; lateral root (C5,6,7) + medial root (C8,T1); no branches in the axilla.
- ▶ Order at the elbow (medial → lateral): **MBBR** — Median nerve, Brachial artery, Biceps tendon, Radial nerve.
- ▶ Enters forearm **between the two heads of pronator teres**; gives off the **anterior interosseous nerve** here.
- ▶ Supplies **all** flexor-pronator forearm muscles **except** flexor carpi ulnaris and the medial half of flexor digitorum profundus (both ulnar).
- ▶ In the hand supplies **5 muscles** — **LOAF** — and cutaneous sensation to the lateral 3½ digits.
- ▶ **Palmar cutaneous branch** arises proximal to the flexor retinaculum and is spared in carpal tunnel syndrome (thenar skin sensation preserved) — key distinguishing point.
- ▶ High lesion (supracondylar fracture): pointing index/hand of benediction on fist-making + ape thumb + supinated forearm.
- ▶ Low lesion (carpal tunnel syndrome): thenar wasting/ape hand with **spared** thenar skin sensation; Phalen's test.
- ▶ Called the "**labourer's nerve**" (coarse power movements) and "**eye of the hand**" (chief sensory nerve of the palm).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; Vishram Singh — Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e.



Movements and relations of shoulder joints

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction — The term "shoulder joint" clinically denotes the **glenohumeral (GH) joint**, a synovial ball-and-socket articulation between the head of humerus and the glenoid cavity of scapula, but functional shoulder movement is produced by the coordinated **shoulder joint complex** of four joints — sternoclavicular (SC), acromioclavicular (AC), glenohumeral, and the physiological scapulothoracic gliding plane. The glenohumeral joint is the most mobile joint in the body; this mobility is achieved by sacrificing bony stability, which is instead maintained dynamically by the rotator cuff, capsule, ligaments and long head of biceps.

The Shoulder Joint Complex — Overview

- ▶ **Sternoclavicular joint** — saddle-type synovial joint, sternal end of clavicle with the clavicular notch of manubrium + first costal cartilage; the only joint linking the upper limb to the axial skeleton.
- ▶ **Acromioclavicular joint** — plane synovial joint between the lateral end of clavicle and the acromion.
- ▶ **Glenohumeral joint** — multiaxial ball-and-socket synovial joint; the "true" shoulder joint, with three degrees of freedom.
- ▶ **Scapulothoracic joint** — not a true synovial joint; a muscle-mediated (serratus anterior, subscapularis) gliding plane letting the scapula rotate, elevate, depress, protract and retract.
- ▶ All four act together in every overhead arm movement (scapulohumeral rhythm, below); disrupting any one (clavicle fracture, AC dislocation) impairs total shoulder mobility.

Glenohumeral Joint: Articular Surfaces & Stability

- ▶ **Type:** synovial, ball-and-socket (spheroidal) variety.
- ▶ **Articular surfaces:** the hemispherical **head of humerus** (directed medially, upward and backward) articulates with the small, shallow, pear-shaped **glenoid cavity of scapula** (faces laterally, upward and forward). The humeral head's surface area is roughly **3–4 times** that of the glenoid — only a small part of the head contacts the glenoid in any one position, hence the joint is structurally weak but highly mobile.
- ▶ Both surfaces are covered by hyaline cartilage (thick centrally, thin peripherally on the humerus; the reverse on the glenoid).
- ▶ **Glenoidal labrum:** a fibrocartilaginous rim attached to the margin of the glenoid cavity, deepening the socket and providing a pliable cushion; the superior part is continuous with the long head of biceps tendon.
- ▶ **Factors maintaining stability** (compensating for the shallow socket):
- ▶ **Rotator cuff** (SITS — subscapularis, infraspinatus, teres minor, supraspinatus) — dynamic "concavity-compression" holding the head against the glenoid.
- ▶ **Coracoacromial arch** (coracoid + acromion + coracoacromial ligament) — a secondary bony-ligamentous socket above the joint preventing superior displacement.
- ▶ **Glenoidal labrum** — deepens the fossa.

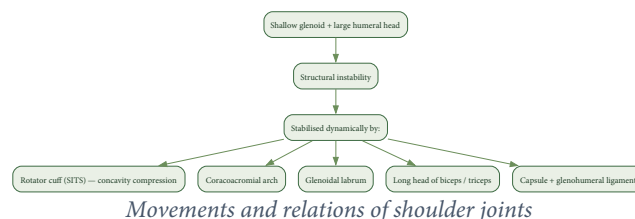
- ▶ **Long head of biceps** and long head of triceps — check upward/downward displacement.
- ▶ Negative intra-articular (atmospheric) pressure.
 - The joint becomes **close-packed** (fully congruent) only in abduction with lateral rotation; otherwise it is loose-packed.

Capsule, Ligaments & Bursae

- ▶ **Fibrous capsule:** a loose envelope permitting free movement. Medially attached to the glenoid neck outside the labrum (including the supraglenoid tubercle, making the long head of biceps origin intracapsular); laterally to the anatomical neck of humerus, except (a) superiorly, where it is deficient for passage of the long head of biceps tendon, and (b) inferomedially, where it descends about 1 cm onto the surgical neck. The capsule is **weakest and least supported inferiorly** — the common site of dislocation and where it lies close to the axillary nerve.
- ▶ **Rotator interval:** a triangular gap of unreinforced capsule between the anterior edge of supraspinatus and the superior edge of subscapularis, reinforced by the coracohumeral and superior glenohumeral ligaments.
- ▶ **Foramen of Weitbrecht:** the gap between the superior and middle glenohumeral ligaments through which the subscapular bursa communicates with the joint — a recognised point of capsular weakness and common site of anterior dislocation.
- ▶ **Ligaments:**

Ligament	Attachment / Course	Function
Glenohumeral (superior, middle, inferior)	Glenoid margin → lesser tubercle / anatomical neck; visible only from within the joint	Reinforce capsule anteriorly and inferiorly; inferior band is the primary anterior stabiliser in abduction
Coracohumeral	Root of coracoid process → greater and lesser tubercles	Strengthens the rotator interval; taut in external rotation; prevents inferior subluxation
Transverse humeral	Bridges greater and lesser tubercles	Converts intertubercular sulcus into a canal; retains the biceps tendon
Coracoacromial	Coracoid process → tip of acromion	Forms the coracoacromial arch (secondary socket)

- ▶ **Synovial membrane** lines the capsule and is reflected as a tubular sheath around the intracapsular part of the long head of biceps tendon, continuing into the intertubercular sulcus.
- ▶ **Bursae:** subacromial (subdeltoid) bursa — between deltoid/acromion and supraspinatus, does not communicate with the joint; subscapularis bursa — communicates with the joint cavity through the foramen of Weitbrecht; infraspinatus bursa — may communicate with the joint.



Relations of the Glenohumeral Joint

Aspect	Structures
Superior	Supraspinatus, subacromial bursa, coracoacromial arch, deltoid
Inferior	Long head of triceps; the quadrangular space transmitting the axillary nerve and posterior circumflex humeral vessels
Anterior	Subscapularis, coracobrachialis, short head of biceps, deltoid
Posterior	Infraspinatus, teres minor, deltoid
Within the joint	Tendon of the long head of biceps brachii, traversing from the supraglenoid tubercle through the rotator interval into the intertubercular sulcus

- Deltoid covers the joint in front, behind and laterally. **Quadrangular space** (boundaries: subscapularis + capsule above, teres major below, long head of triceps medially, surgical neck of humerus laterally) explains why subglenoid dislocation risks the axillary nerve.

Vascular Supply, Nerve Supply & Movements

- **Arterial supply:** anterior and posterior circumflex humeral, suprascapular, and subscapular/circumflex scapular arteries — all branches of the axillary artery/subclavian system, forming an anastomotic network around the joint.
- **Nerve supply** (mainly from the posterior cord territory, following **Hilton's law** — nerves crossing a joint also supply it): **axillary nerve** (anteroinferior capsule), **suprascapular nerve** (postero-superior capsule), and articular twigs from the **lateral pectoral** and **musculocutaneous** nerves anteriorly (including the rotator-interval capsule).
- **Movements:** flexion–extension, abduction–adduction, medial (internal)–lateral (external) rotation, and circumduction (a combination of the above). Movements are conventionally described relative to the scapula, not the trunk, since the glenoid faces anterolaterally at rest.

Movement	Prime movers	Accessory / synergists
Flexion	Clavicular head of pectoralis major, anterior fibres of deltoid, coracobrachialis	Short head of biceps
Extension	Posterior fibres of deltoid, teres major	Latissimus dorsi, long head of triceps, sternocostal pectoralis major
Abduction	Supraspinatus (initiates 0–15°) and deltoid (middle fibres) — form a force-couple	Serratus anterior and trapezius (90–180°, via scapular rotation)
Adduction	Pectoralis major, teres major, latissimus dorsi	Coracobrachialis, short head of biceps, long head of triceps
Medial rotation	Pectoralis major, subscapularis, anterior deltoid	Latissimus dorsi, teres major

Movement	Prime movers	Accessory / synergists
Lateral rotation	Infraspinatus, teres minor, posterior deltoid	—

- ▶ The rotator cuff (subscapularis, supraspinatus, infraspinatus, teres minor) acts throughout the range as a "centralising" force-couple against deltoid's translating pull, keeping the humeral head seated on the glenoid — deltoid alone, unopposed, would ride the head upward against the acromion.
- ▶ Lateral rotation of the humerus at $\sim 90^\circ$ of abduction is essential to clear the greater tubercle beneath the coracoacromial arch (impingement mechanism).

Sternoclavicular & Acromioclavicular Joints — Movements and the Scapulohumeral Rhythm

- ▶ **Sternoclavicular joint:** an articular disc divides the cavity into meniscoclavicular and meniscosternal compartments; ligaments are the capsular (anterior/posterior sternoclavicular), interclavicular, and costoclavicular ligaments. Permits elevation/depression, protraction/retraction and axial rotation of the clavicle.
- ▶ **Acromioclavicular joint:** fibrous capsule (thickened as the AC ligament) plus the strong **coracoclavicular ligament** (conoid + trapezoid parts), which suspends the scapula from the clavicle and transmits the weight of the limb; the joint permits gliding and rotation of the scapula on the clavicle.
- ▶ **Overhead elevation (0° – 180°)** is a combined glenohumeral + scapulothoracic movement — the **scapulohumeral rhythm**: for every 15° of arm elevation, **10° occurs at the glenohumeral joint and 5° by scapular rotation** (an overall 2:1 ratio; Inman et al 1944). Scapular rotation (about 60° total) occurs at both the AC joint ($\sim 20^\circ$) and the SC joint ($\sim 40^\circ$), produced by trapezius (upper and lower fibres) and the lower digitations of serratus anterior, which rotate the glenoid cavity upward.
- ▶ In the first 25 – 30° of abduction, movement is almost purely glenohumeral before girdle rotation begins; a further $\sim 60^\circ$ beyond 120° of true glenohumeral abduction is contributed by the sterno- and acromioclavicular joints (and contralateral trunk flexion) to reach full 180° elevation.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sagittal section through the shoulder joint (as in the classical exam figure) with these labels: acromion; coracoacromial ligament; subacromial bursa; supraspinatus tendon fused with capsule superiorly; glenoid cavity and glenoid labrum; head of humerus; fibrous capsule; synovial membrane; long head of biceps tendon (intracapsular, in intertubercular sulcus); coracohumeral ligament; subscapularis anteriorly; infraspinatus and teres minor posteriorly; axillary nerve and posterior circumflex humeral vessels inferiorly (quadrangular space); long head of triceps inferiorly. A second panel (anterior view) should label the three glenohumeral ligaments (superior, middle, inferior), the coracoclavicular ligament (conoid + trapezoid parts), and the acromioclavicular joint.

□ Fig 3.97 — Capsules and ligaments of glenohumeral and acromioclavicular joints. A (Moore — Clinically Oriented Anatomy — 9e, p.498)

□ Fig 3.98 — Movements of glenohumeral joint. (Moore — Clinically Oriented Anatomy — 9e, p.500)

Applied / Clinical anatomy

- ▶ **Glenohumeral dislocation** is the commonest joint dislocation in the body, owing to capsular laxity and the disproportion between head and glenoid size. Over 95% are **anterior** dislocations, occurring when the abducted, extended, laterally rotated arm is forced further — the head slips through the capsular weak points (foramen of Weitbrecht / rotator interval) to lie subglenoid, then sub-coracoid or sub-clavicular. The closely related **axillary nerve** is vulnerable in inferior/subglenoid dislocation.
- ▶ **Bankart lesion**: a tear of the antero-inferior glenoid labrum (from the pull of the inferior glenohumeral ligament during dislocation), predisposing to **recurrent anterior dislocation**.
- ▶ **Painful arc syndrome**: pain on abduction between 60° and 120°, from impingement of an inflamed/degenerate supraspinatus tendon against the coracoacromial arch.
- ▶ **Frozen shoulder (adhesive capsulitis)**: adhesions between the two layers of synovial membrane, causing progressive pain and global restriction of movement (especially lateral rotation, abduction, medial rotation), typically age 40–60; the scapulohumeral rhythm is altered as scapular motion compensates for reduced glenohumeral contribution.
- ▶ **Referred "shoulder tip" pain**: diaphragmatic/peritoneal irritation is referred to the shoulder because both the phrenic nerve (supplying diaphragmatic peritoneum) and the supraclavicular nerves (supplying shoulder skin) arise from the C3, C4 segments.
- ▶ **Joint aspiration**: performed anteriorly through the deltopectoral triangle, or laterally just below the acromion.
- ▶ Shoulder joint disease can be clinically excluded if the patient can raise both arms overhead and appose the palms — this confirms an intact deltoid and axillary nerve.

High-yield exam pointers

- ▶ Glenohumeral joint = synovial ball-and-socket; humeral head is ~3–4× the glenoid surface area — mobility traded for stability.

- ▶ Capsule is weakest inferiorly (subglenoid dislocation site) and reinforced anteriorly by three glenohumeral ligaments and the coracohumeral ligament; rotator interval and foramen of Weitbrecht are named capsular weak zones.
- ▶ Relations: superior = supraspinatus/subacromial bursa; inferior = quadrangular space (axillary nerve + posterior circumflex humeral vessels); anterior = subscapularis; posterior = infraspinatus/teres minor; within joint = long head of biceps.
- ▶ Stability factors: rotator cuff (SITS), coracoacromial arch, glenoidal labrum, long head of biceps.
- ▶ Scapulohumeral rhythm = 2:1 (10° glenohumeral : 5° scapular per 15° elevation; Inman et al 1944).
- ▶ Muscle pairs: abduction — supraspinatus + deltoid couple; medial rotation — subscapularis, pectoralis major, latissimus dorsi, teres major; lateral rotation — infraspinatus, teres minor, posterior deltoid.
- ▶ Bankart lesion (antero-inferior labral tear) → recurrent anterior dislocation; painful arc (60–120°) → supraspinatus impingement; frozen shoulder → capsular adhesions.
- ▶ Nerve supply follows Hilton's law: axillary, suprascapular, lateral pectoral and musculocutaneous nerves.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 (8e); AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb); Moore's Clinically Oriented Anatomy 9e; Vishram Singh — Textbook of Anatomy Vol 1 (4e); IB Singh — Textbook of Anatomy Vol 1 (6e).



Ulnar nerve in the hand

Asked in: Paper I Oct 2006 — RGUHS MD/MS Anatomy

Definition / Introduction The ulnar nerve (root value C8, T1) is the larger terminal branch of the medial cord of the brachial plexus. In the hand it is the chief motor nerve of the intrinsic muscles and is therefore nicknamed the "nerve of fine movements" / "musician's nerve." It enters the palm superficial to the flexor retinaculum, alongside the ulnar artery, through the **ulnar tunnel (Guyon's canal)**, and terminates just distal to the pisiform by dividing into a **superficial (mainly sensory)** and a **deep (purely motor)** terminal branch, which together supply almost all the intrinsic muscles of the hand and the skin of the medial one-third of the hand.

1. Entry into the hand — the ulnar tunnel (Guyon's canal)

- ▶ The nerve crosses **superficial to the flexor retinaculum**, immediately radial (lateral) to the pisiform bone, lying medial to the ulnar artery.
- ▶ Here it is roofed by a slender fascial band, the **superficial part of the flexor retinaculum (volar carpal ligament)**, which bridges the ulnar neurovascular bundle to form the **ulnar tunnel / Guyon's canal** — an occasional site of nerve entrapment.
- ▶ Boundaries of Guyon's canal: **roof** — palmar carpal ligament and palmaris brevis; **floor** — transverse carpal and pisohamate ligaments (distally, pisometacarpal ligament and flexor digiti

minimi); **ulnar wall** — flexor carpi ulnaris, pisiform, abductor digiti minimi; **radial wall** — extrinsic flexor tendons, transverse carpal ligament and the hook of hamate.

- ▶ **Just distal to the pisiform**, the nerve divides into its **superficial terminal branch** and **deep terminal branch**.

2. Superficial terminal branch

- ▶ **Muscular twig**: to **palmaris brevis** (wrinkles the skin of the hypothenar eminence, deepening the palmar hollow to improve grip).
- ▶ **Cutaneous continuation**: divides into **two palmar digital nerves**:
 - the medial branch supplies the **medial side of the little finger**;
 - the lateral branch is a **common palmar digital nerve** that splits into two proper digital nerves for the **adjoining sides of the ring and little fingers**, supplying the skin and nail beds up to the tips.
- ▶ The common palmar digital nerve sends a **communicating twig to the median nerve** in the palm (an important variant to remember when interpreting mixed sensory loss).

3. Deep terminal branch

- ▶ Purely motor; accompanies the **deep branch of the ulnar artery**.
- ▶ **Course**: passes backward **between abductor digiti minimi and flexor digiti minimi brevis**, then **between opponens digiti minimi and the base of the 5th metacarpal**, lying on the **hook of the hamate**; it then curves laterally within the **concavity of the deep palmar arch** (deep to the long flexor tendons) and terminates by supplying **adductor pollicis**.
- ▶ **At its origin** it supplies the three hypothenar muscles; **as it crosses the palm** it supplies the interossei and the medial two (3rd & 4th) lumbricals; **at its termination** it supplies adductor pollicis and, variably, the deep head of flexor pollicis brevis.

4. Motor distribution in the hand

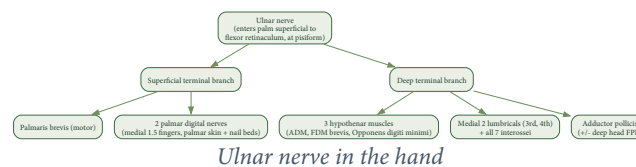
Terminal branch	Muscles supplied
Superficial terminal branch	Palmaris brevis
Deep terminal branch — origin	Abductor digiti minimi, Flexor digiti minimi brevis, Opponens digiti minimi (the 3 hypothenar muscles)
Deep terminal branch — across palm	3rd and 4th (medial two) lumbricals; all 7 interossei — 4 dorsal (abductors) + 3 palmar (adductors) of the fingers
Deep terminal branch — termination	Adductor pollicis; variably, the deep head of flexor pollicis brevis and a twig to opponens pollicis

- ▶ High-yield mnemonic: the **median nerve supplies only the "LOAF" muscles** in the hand — Lumbricals 1 & 2, Opponens pollicis, Abductor pollicis brevis, Flexor pollicis brevis (superficial head). **Every other intrinsic muscle of the hand is ulnar-supplied.**
- ▶ Interossei action mnemonic: "**PAD and DAB**" — Palmar interossei **AD**duct, Dorsal interossei **AB**duct the fingers relative to the axis of the middle finger.

5. Cutaneous (sensory) distribution in the hand

Branch	Level of origin	Area supplied
Palmar cutaneous branch	Mid-forearm, crosses superficial to flexor retinaculum	Skin over the hypothenar eminence
Dorsal cutaneous branch	~5 cm proximal to the wrist, deep to flexor carpi ulnaris	Medial third of the dorsum of the hand; dorsum of the little finger and medial half of the ring finger (up to the base of the middle/distal phalanx)
Superficial terminal branch → 2 palmar digital nerves	At the pisiform, after main division	Palmar skin and nail beds of the little finger and medial half of the ring finger

- Overall cutaneous territory: **medial one-third of the palm and dorsum of the hand, and the medial one-and-a-half fingers.**



DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the palmar view of the right hand at the wrist/palm level and label:

- **Flexor retinaculum** and **pisiform** (nerve crosses superficial, just radial to pisiform).
- **Ulnar artery** running lateral to the nerve.
- Point of division into **superficial** and **deep terminal branches**.
- **Superficial terminal branch** → palmaris brevis + 2 palmar digital nerves to medial 1½ fingers.
- **Deep terminal branch** path: between abductor digiti minimi & flexor digiti minimi brevis → deep to opponens digiti minimi → over the **hook of hamate** → curving with the **deep palmar arch** → ending in **adductor pollicis**.
- Label the **3 hypothenar muscles**, **medial 2 lumbricals**, **7 interossei**, and **adductor pollicis** at the points supplied.
- Shade the cutaneous field: medial 1/3 palm + dorsum, medial 1½ fingers.

□ Fig 11.18 — ■ *Course and distribution of the ulnar nerve in* (Vishram Singh — *Textbook of Anatomy Vol 1 — 4e, p.504*)

Applied / Clinical anatomy

- **Sites of injury:** (a) at the **elbow** — behind the medial epicondyle ("funny bone"), or in the cubital tunnel between the two heads of flexor carpi ulnaris; (b) at the **wrist** — from its superficial position (vulnerable to lacerations) or from compression in **Guyon's canal** / **the pisohamate tunnel** (ulnar tunnel syndrome).

- ▶ **Ulnar claw hand (main en griffe):** loss of the intrinsic action of flexing the metacarpophalangeal joints and extending the interphalangeal joints leaves the unopposed long extensors and flexors to produce **MP joint hyperextension with IP joint flexion**, most marked in the **ring and little fingers** (clawing is milder in the index/middle fingers because their lumbricals are median-supplied).
- ▶ **The "ulnar paradox":** clawing is **more pronounced with a wrist-level lesion** than an elbow-level lesion, because at the wrist the flexor digitorum profundus (supplied more proximally) is spared and produces marked DIP-joint flexion; a high (elbow) lesion also paralyses FDP, which paradoxically reduces the clawing.
- ▶ **Sensory loss:** medial one-third of the palm and dorsum, and the medial one-and-a-half fingers including their nail beds; the **dorsum of the hand is spared in a low wrist lesion distal to the origin of the dorsal cutaneous branch** (given off ~5 cm proximal to the wrist) — a key point differentiating a wrist-level from an elbow-level lesion.
- ▶ **Vasomotor/trophic changes:** the anaesthetic skin is warmer (arteriolar dilatation) and drier (loss of sweating); long-standing palsy causes dry, scaly skin, cracked nails and pulp atrophy.
- ▶ **Clinical tests:** **Froment's sign** (paralysis of adductor pollicis — patient substitutes flexor pollicis longus (median) to grip a card, producing thumb IP-joint flexion); **card/paper test** (weak interossei fail to hold a card between the fingers).
- ▶ **Combined median + ulnar nerve section at the wrist** produces a full claw hand with thenar and hypothenar flattening plus thumb adduction/flexion — the **"simian hand."**
- ▶ Loss of ability to **abduct/adduct the fingers** (interossei) and to **spread the fingers**; loss of **thumb adduction** (adductor pollicis).

High-yield exam pointers

- ▶ Ulnar nerve enters the hand superficial to the flexor retinaculum (unlike the median nerve, which is deep to it in the carpal tunnel) via the **ulnar tunnel/Guyon's canal**.
- ▶ Divides **just distal to the pisiform** into a **superficial (sensory + palmaris brevis)** and a **deep (purely motor)** terminal branch.
- ▶ Deep branch path: between **abductor digiti minimi & flexor digiti minimi brevis** → deep to **opponens digiti minimi** → over the **hook of hamate** → **deep palmar arch** → ends in **adductor pollicis**.
- ▶ Motor supply = all intrinsic hand muscles **EXCEPT the "LOAF" muscles** (median-supplied).
- ▶ Sensory supply = medial 1/3 of palm & dorsum + medial 1½ fingers.
- ▶ Clinical hallmark = **ulnar claw hand**, worse at the wrist than the elbow (**ulnar paradox**); test with **Froment's sign** and the **card test**.
- ▶ Combined median + ulnar wrist injury → **simian hand**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; Vishram Singh — Textbook of Anatomy Vol 1, 4e; Moore's Clinically Oriented Anatomy, 9e.



Lower limb



Describe the knee joint in detail

Asked in: Paper I 06-Apr-2026 · Paper I 07-Jul-2023 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction — The knee (tibiofemoral + patellofemoral) joint is the **largest and most complex synovial joint** in the body. It results from the fusion of three articulations sharing one joint cavity — the **medial femorotibial**, **lateral femorotibial**, and **femoropatellar** joints — and functions as a modified hinge that combines great mobility (needed for locomotion) with the stability required to bear multiples of body weight. Its inherent bony incongruity is compensated by a dense system of intra- and extra-capsular ligaments, menisci, and dynamic muscular support (chiefly quadriceps femoris).

Type, classification & articular surfaces

- ▶ **Type:** synovial joint — a **condylar (bicondylar)** joint between the femoral and tibial condyles, combined with a **saddle (sellar)** joint between the patella and the femur; the cavity is further subdivided by the menisci, making it a **compound, complex synovial joint**.
- ▶ **Articular surfaces:**
 - **Femoral condyles** — medial and lateral, almost wholly convex, continuous anteriorly over the intercondylar (patellar) groove; the lateral condyle's articular arc has a single radius of curvature, the medial condyle describes two arcs (a "closing helix").
 - **Tibial condyles (tibial plateau)** — medial facet oval and longer (mainly flat posteriorly), lateral facet more circular and relatively convex; separated by the **intercondylar eminence** with medial and lateral intercondylar tubercles which act as a stabilising pivot.
 - **Patella** — the largest sesamoid bone in the body, embedded in the quadriceps tendon; its posterior articular surface has medial and lateral facets (each subdivided into thirds) plus a narrow "**odd**" facet medially that contacts the femur only in extreme flexion. Patellar articular cartilage is the **thickest in the body**.
 - All surfaces are covered by hyaline cartilage; congruity is improved by the menisci.

Diagram (real plate):

embed: ![Fig 7.93 — Articular surfaces, cruciate ligaments, and synovial cavity of knee joint (Moore — Clinically Oriented Anatomy — 9e, p.1298)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/d424f2b8a423987a.jpg)

Capsule and ligaments

The **fibrous capsule** is thin and deficient anteriorly (replaced by the quadriceps tendon, patella and patellar ligament); posteriorly it is thickened and reinforced by the **oblique popliteal ligament** (an expansion of semimembranosus). It is strengthened anteriorly by the medial and lateral **patellar retinacula** (expansions of vasti), laterally by the **iliotibial tract**, and medially by expansions of sartorius and semimembranosus.

Ligament	Attachments	Chief function / note
Patellar ligament ("patellar tendon")	Patellar apex → tibial tuberosity; ~6–8 cm long, 2.5 cm broad	Continuation of quadriceps femoris tendon; separated from tibia by deep infrapatellar bursa and infrapatellar fat pad
Tibial (medial) collateral ligament	Medial epicondyle of femur → medial tibial shaft (~5 cm below joint line)	Flat band; blends with capsule and medial meniscus; resists valgus (abduction) strain; morphologically the degenerated tendon of adductor magnus
Fibular (lateral) collateral ligament	Lateral epicondyle of femur → head of fibula	Cord-like, free from capsule (separated by popliteus tendon and inferior lateral genicular vessels); resists varus (adduction) strain; represents the femoral attachment of peroneus longus
Oblique popliteal ligament	Expansion of semimembranosus tendon, crossing postero-medial capsule to lateral condyle	Reinforces posterior capsule; pierced by middle genicular vessels and the obturator nerve's articular branch
Arcuate popliteal ligament	Head of fibula, arching over popliteus tendon, to posterior intercondylar area of tibia	Reinforces postero-lateral capsule; part of the "posterolateral corner"
Anterior cruciate ligament (ACL)	Anterior intercondylar area of tibia → postero-medial aspect of lateral femoral condyle	~38 mm long, 11 mm wide; taut in extension; primary restraint to anterior tibial translation; injured more often than PCL
Posterior cruciate ligament (PCL)	Posterior intercondylar area of tibia → lateral surface of medial femoral condyle	~38 mm long, 13 mm wide; thicker/stronger than ACL; taut in flexion; primary restraint to posterior tibial translation

- The cruciates are **intracapsular but extrasynovial** — the synovium is reflected forward around them so they lie outside the true synovial cavity.
- **Popliteus tendon** is intracapsular, grooving the lateral meniscus, and the "**popliteus hiatus**" (where the lateral meniscus lacks a peripheral bony attachment) makes the lateral meniscus relatively mobile.

Menisci (semilunar cartilages)

Crescentic, wedge-shaped fibrocartilaginous laminae that deepen the tibial articular surfaces, improve congruity, act as shock absorbers, aid lubrication, and carry proprioceptive (sensory) fibres; only the peripheral 25–33% is vascular (from capsule/synovium) — the inner two-thirds is avascular and nourished by synovial fluid.

Feature	Medial meniscus	Lateral meniscus
Shape	Semicircular (C-shaped), broader posteriorly	Almost circular (~4/5th of a circle), more uniform

Feature	Medial meniscus	Lateral meniscus
Anterior horn	Attached to anterior intercondylar area, in front of ACL; continuous with transverse ligament	Attached in front of intercondylar eminence, posterolateral to ACL
Posterior horn	Attached to posterior intercondylar area, between lateral meniscus and PCL attachments	Attached behind the eminence; gives rise to meniscomfemoral ligaments (of Humphrey — anterior to PCL; of Wrisberg — posterior to PCL) to medial femoral condyle
Peripheral fixity	Firmly adherent to deep part of tibial collateral ligament (coronary ligament)	Separated from fibular collateral ligament by popliteus tendon; less fixed, more mobile
Clinical	More frequently torn (fixed + greater rotational strain)	Protected — popliteus retracts it during flexion; site of discoid lateral meniscus anomaly

- **Transverse ligament** connects the anterior horns of the two menisci.
- Load-bearing: the wedge-shaped cross-section converts axial load into circumferential "**hoop tension**" in the peripheral fibres, transmitted to the tibial plateau via the meniscal horn attachments; this increases the contact area between femur and tibia and lowers contact stress on the articular cartilage — meniscectomy removes this effect, raising contact stress and predisposing to osteoarthritis.

Synovial membrane, bursae & relations

- The **synovial membrane** is the most extensive/complex in the body. It lines the capsule, is reflected around the cruciate ligaments (excluding them from the true cavity), and extends proximally as the **suprapatellar bursa** (a "hand's breadth" above the patella) — an upward prolongation of the joint cavity held open by articularis genus.
- Distally it is separated from the patellar ligament by the **infrapatellar fat pad**; two **alar folds** converge into a single **infrapatellar (synovial) fold / ligamentum mucosum**.
- **Bursae (~12 described)** —
 - *Anterior*: suprapatellar, subcutaneous prepatellar ("housemaid's knee"), subcutaneous infrapatellar ("clergyman's knee"), deep infrapatellar.
 - *Medial*: anserine bursa (deep to sartorius/gracilis/semitendinosus), semimembranosus bursa, bursa deep to medial head of gastrocnemius, bursa deep to tibial collateral ligament.
 - *Lateral*: bursa deep to lateral head of gastrocnemius, between fibular collateral ligament and biceps femoris, between fibular collateral ligament and popliteus, between popliteus and lateral tibial condyle.
- **Relations**:
 - *Anteriorly*: quadriceps tendon, patella, patellar ligament, patellar retinacula, anterior bursae.

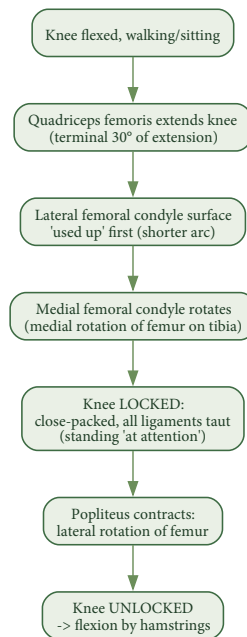
- *Posteriorly (centrally)*: popliteal vessels and tibial nerve; *postero-laterally*: lateral head of gastrocnemius, plantaris, common fibular (peroneal) nerve; *postero-medially*: medial head of gastrocnemius, semimembranosus, semitendinosus, gracilis, popliteus.
- *Medially*: sartorius, gracilis, semitendinosus, great saphenous vein with saphenous nerve.
- *Laterally*: biceps femoris and the origin of popliteus.

Blood supply, nerve supply & lymphatic drainage

- ▶ **Arterial supply** — a dense **genicular anastomosis** around the patella and femoral/tibial condyles, formed by: (i) five genicular branches (superior medial, superior lateral, middle, inferior medial, inferior lateral) of the **popliteal artery**; (ii) the **descending genicular** branch of the femoral artery; (iii) the **descending branch of the lateral circumflex femoral** artery; (iv) **anterior and posterior tibial recurrent** branches of the anterior tibial artery; (v) the **circumflex fibular** branch of the posterior tibial artery. The middle genicular artery pierces the oblique popliteal ligament to supply the cruciates and synovium.
- ▶ **Venous drainage** follows the arteries into the popliteal vein.
- ▶ **Nerve supply** (obeys **Hilton's law**) — via the **femoral nerve** (branches to vasti, especially vastus medialis), the **sciatic nerve** (genicular branches of the tibial and common fibular nerves), and the **obturator nerve** (terminal branch of its posterior division). Four articular nerve-ending types have been described (Freeman & Wyke).
- ▶ **Lymphatic drainage** — to the **popliteal nodes**, then along the femoral vessels to the **deep inguinal nodes** (some via the long saphenous vein to superficial inguinal nodes).

Movements, locking–unlocking mechanism & biomechanics

- ▶ **Movements**: flexion, extension, and a small range of medial/lateral (axial) rotation.
 - **Extension** — quadriceps femoris (assisted by tensor fasciae latae).
 - **Flexion** — biceps femoris, semitendinosus, semimembranosus (assisted by gracilis, sartorius, popliteus; gastrocnemius/plantar when foot fixed).
 - **Medial rotation of flexed leg** — popliteus, semimembranosus, semitendinosus (assisted by sartorius, gracilis).
 - **Lateral rotation of flexed leg** — biceps femoris.
- ▶ **Range**: active flexion ~120–130° (up to 160° passively); extension 5–10° beyond neutral; axial (voluntary) rotation 60–70°, conjunct rotation only ~20°.
- ▶ **Conjunct (obligatory) rotation / "screw-home" mechanism**: because the medial femoral condyle's articular arc is longer than the lateral, the lateral condyle "runs out" of surface first during terminal extension; the femur then rotates medially on the tibia (with the foot planted) to use up the remaining medial condylar surface — this **locks** the knee into the close-packed, fully extended position with all major ligaments taut, allowing standing with minimal quadriceps effort. **Popliteus** initiates lateral rotation of the femur to **unlock** the joint before flexion can begin.



Describe the knee joint in detail

- **Stability:** cruciate ligaments give antero-posterior stability; collateral ligaments give side-to-side (valgus/varus) stability; the posterolateral corner (popliteofibular, fabellofibular and arcuate ligaments + iliotibial tract + popliteus) resists tibial lateral rotation. Q angle (line of quadriceps pull vs patellar ligament) is 12–15° in males and 15–18° in females, producing a lateralising force on the patella countered by vastus medialis obliquus.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Superior view of the right tibial plateau (as seen after removing the femur), showing:

- Medial tibial condyle and lateral tibial condyle (articular facets)
- Intercondylar eminence with medial and lateral intercondylar tubercles
- Medial meniscus (anterior horn and posterior horn) and Lateral meniscus (anterior horn and posterior horn)
- Transverse ligament (joining the two anterior horns)
- Attachment sites: anterior cruciate ligament (anteromedial to eminence) and posterior cruciate ligament (posterior intercondylar area)
- Tibial tuberosity (anterior) and groove for popliteus (postero-lateral, "popliteus hiatus")

Applied / Clinical anatomy

- **Meniscal tears:** a twisting strain on a semi-flexed, weight-bearing knee (e.g. kicking, squatting) tears the meniscus — longitudinally ("**bucket-handle tear**") or transversely. The **medial meniscus is torn far more often** than the lateral because of its firm capsular/collateral-ligament fixity and greater excursion; the lateral meniscus is protected by popliteus retracting it during flexion. Peripheral (vascular-zone) tears can heal; central (avascular-zone) tears usually need resection.
- **Cruciate ligament injury:** the ACL is injured more often than the PCL — classically in violent hyperextension or a sudden anterior-directed force with the tibia fixed (e.g. sporting pivot

injury), producing a positive **anterior drawer sign** (excess forward tibial translation). PCL injury (posterior dislocation force, "dashboard injury") gives a positive **posterior drawer sign**.

- ▶ **"Unhappy triad" (O'Donoghue's triad):** combined injury of the tibial collateral ligament + medial meniscus + anterior cruciate ligament, from a lateral blow to a flexed, weight-bearing knee (classically in contact sports) — explained by the medial meniscus's fixed attachment to the tibial collateral ligament.
- ▶ **Collateral ligament sprain/rupture:** from severe abduction (valgus) or adduction (varus) strains; tested clinically by side-to-side stress at 20–30° flexion.
- ▶ **Genu valgum (knock-knee)** and **genu varum (bow-leg):** abnormal frontal-plane angulation of the femoral/tibial shafts, seen in rickets, constitutional/postural causes, or as a sequel of trauma near the growth plate.
- ▶ **Osteoarthritis:** the commonest disease of the knee — degeneration of articular cartilage with osteophyte formation, joint-space narrowing on X-ray, and painful, limited, crepitant movement; often an indication for **total knee replacement (TKR)**.
- ▶ **Housemaid's knee** (prepatellar bursitis) and **clergyman's knee** (infrapatellar bursitis) — occupational bursal inflammation from repeated kneeling; **anserine bursitis** in athletes.
- ▶ **Baker's (popliteal) cyst:** herniation/distension of the semimembranosus bursa (which usually communicates with the joint) into the popliteal fossa, typically secondary to intra-articular disease such as osteoarthritis.
- ▶ **Joint effusion / haemarthrosis:** fluid collects readily in the capacious suprapatellar bursa, producing a swelling above and to the sides of the patella with a "floating patella" (patellar tap); aspirated from either side of the patellar ligament.
- ▶ **Arthroscopy:** portals placed lateral or medial to the patellar ligament; the infrapatellar branch of the saphenous nerve is vulnerable in medial approaches (post-arthroscopy numbness/neuroma).
- ▶ **Popliteal artery injury:** the artery is tethered at the adductor hiatus and by the fascia over soleus, making it vulnerable to stretch/occlusion in posterior knee dislocation or supracondylar femoral fracture.

High-yield exam pointers

- ▶ Knee = largest, most complex synovial joint; a **compound joint** (2 condylar + 1 saddle articulation) with the cavity subdivided by menisci.
- ▶ Fibrous capsule deficient anteriorly (replaced by extensor mechanism); cruciates are **intracapsular but extrasynovial**.
- ▶ Medial meniscus (semicircular, firmly fixed) tears more often than lateral (circular, mobile, protected by popliteus).
- ▶ Locking = terminal medial rotation of femur (screw-home); unlocking = popliteus produces lateral rotation of femur.
- ▶ Blood supply: genicular anastomosis (5 genicular + descending genicular + descending branch of lateral circumflex femoral + tibial recurrents + circumflex fibular).
- ▶ Nerve supply follows **Hilton's law:** femoral, obturator, tibial and common fibular nerves.

- ▶ ACL taut in extension, resists anterior tibial translation (anterior drawer +ve); PCL taut in flexion, resists posterior translation (posterior drawer +ve); ACL injured more often.
- ▶ Unhappy triad = ACL + medial meniscus + tibial collateral ligament.
- ▶ Suprapatellar bursa = upward extension of joint cavity ("hand's breadth" above patella) — key to effusions and floating patella.
- ▶ Q angle 12–15° (male), 15–18° (female) — greater lateralising force on patella in females.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e — Chapter 82 "Knee"; BD Chaurasia Human Anatomy Vol 2 (8e) — Chapter 12 "Joints of Lower Limb" and Chapter 6 "Popliteal Fossa"; Vishram Singh Textbook of Anatomy Vol 2 (4e) — Chapter 33 "Joints of the Lower Limb"; Moore's Clinically Oriented Anatomy 9e; IB Singh Textbook of Anatomy Vol 1 (6e) — Chapter 29 "Joints of Lower Limb".



Femoral sheath

Asked in: Paper I May 2018 · Paper I May 2010 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction

The femoral sheath is a funnel-shaped fascial tube, about 3–4 cm long, that encloses the proximal parts of the femoral vessels as they pass from the abdomen into the anterior thigh, deep to the inguinal ligament. It is formed by a downward prolongation of the two extraperitoneal fasciae of the abdominal wall — the fascia transversalis in front and the fascia iliaca behind — and occupies the vascular compartment (lacuna vasculorum) of the retro-inguinal space. Functionally it allows the femoral vessels to glide freely beneath the fixed inguinal ligament during flexion–extension of the hip, and its medial, lymphatic compartment (the femoral canal) provides the anatomical basis for femoral hernia. The femoral nerve, though it enters the thigh alongside the vessels, lies outside the sheath.

Formation and extent

- ▶ The sheath is a distal prolongation of the extraperitoneal fascia lining the abdominal wall, not a new fascial layer created in the thigh.
- ▶ **Anterior wall** — formed by the **fascia transversalis**, which lines the deep surface of transversus abdominis.
- ▶ **Posterior wall** — formed by the **fascia iliaca** (iliopsoas fascia), which covers iliacus and psoas major.
- ▶ The sheath is **wider proximally** and tapers distally, fusing with the tunica adventitia of the femoral vessels **3–4 cm below the inguinal ligament**.
- ▶ It is **asymmetrical**: the lateral wall is vertical, while the medial wall slopes downward and laterally.
- ▶ At birth the sheath is short; it **elongates with habitual extension at the hip** (i.e., with walking).

- ▶ The **femoral branch of the genitofemoral nerve** (L1, L2) pierces its **lateral wall** about 2 cm below the mid-inguinal point to supply skin over the femoral triangle.
- ▶ Its **medial wall** is pierced by the **great (long) saphenous vein** and lymphatic vessels as they join the femoral vein/femoral canal.
- ▶ Comparable in principle to the carotid sheath of the neck — a fascial tube conducting a major neurovascular bundle across a mobile joint.
- ▶ **Why the femoral nerve is excluded:** in the posterior abdominal wall, the fascia transversalis/iliaca lies deep to the main arteries but superficial to the main nerves; since the femoral nerve forms behind the fascia iliaca, it is carried into the thigh **lateral to, and outside, the sheath**, in the groove between iliacus and psoas major.
- ▶ **Iliopectineal arch** — a thickened band of iliopsoas fascia running from the deep surface of the inguinal ligament to the iliopubic eminence — divides the retro-inguinal space into a lateral **lacuna musculorum** (iliopsoas + femoral nerve) and a medial **lacuna vasculorum** (femoral vessels, within the femoral sheath).

Compartments of the femoral sheath

Two anteroposterior (vertical) septa of extraperitoneal connective tissue subdivide the sheath into three compartments.

Compartment	Position	Contents
Lateral (arterial)	Widest, most lateral	Femoral artery; femoral branch of genitofemoral nerve
Intermediate (venous)	Middle	Femoral vein
Medial (lymphatic)	Smallest	Femoral canal — lymphatics ± a lymph node, in areolar/fatty tissue

□ Fig 23.17 — Compartments of the femoral sheath (Vishram Singh — *Textbook of Anatomy Vol 2 — 4e, p.968*)

Femoral canal

- ▶ The **medial compartment** of the femoral sheath; conical, wide above and narrowing below.
- ▶ Length approximately **1.25–1.5 cm**; closed inferiorly by fusion of its walls at the level of the proximal margin of the saphenous opening.
- ▶ Contains loose areolar/fatty tissue, lymphatic vessels, and sometimes a lymph node — the **node of Cloquet (or Rosenmüller)**.
- ▶ **Function:** provides a **dead space/reservoir** that allows the femoral vein to distend when venous return increases or during a rise in intra-abdominal pressure (e.g. Valsalva manoeuvre).
- ▶ Its upper, open (abdominal) end is the **femoral ring**.

Femoral ring

The femoral ring is the base (proximal opening) of the femoral canal, opening into the abdominal cavity.

Boundary	Structure
Anterior	Inguinal ligament
Posterior	Superior ramus of pubis (pecten pubis), covered by pectineus and its fascia, reinforced by the pectineal ligament (of Cooper)
Medial	Sharp, crescentic (concave) lateral edge of the lacunar ligament
Lateral	Femoral vein (the septum separating the canal from the vein)

- ▶ The **spermatic cord** (or round ligament of the uterus) lies just above its anterior margin; the **inferior epigastric vessels** are closely related to the junction of the anterior and lateral walls of the ring.
- ▶ Normally admits only the tip of the little finger; it is **wider in women** — due to the greater width of the female pelvis and the smaller size of the female femoral vessels — which is why femoral hernia is more common in females.
- ▶ The ring is normally plugged by a condensation of extraperitoneal fatty tissue, the **femoral septum**, covered on its abdominal aspect by parietal peritoneum (the shallow depression here is the **femoral fossa**). The septum is pierced by lymphatics connecting the deep inguinal to the external iliac nodes.
- ▶ **Deep inguinal lymph nodes** (1–3, medial to the femoral vein): the lowest lies just below the saphenofemoral junction, the middle one lies **in the femoral canal (node of Cloquet/Rosenmüller)**, and the most proximal lies **in the femoral ring** (often absent). These drain the glans penis/clitoris and receive efferents from the superficial inguinal nodes; their own efferents traverse the femoral canal to reach the external iliac nodes.

Relations within the femoral triangle

- ▶ **Anterior** to the vessels: skin, superficial fascia, fascia lata, and the anterior wall of the femoral sheath.
- ▶ **Posterior**: psoas major, pectineus and adductor longus, separated from the vessels by the posterior wall of the sheath.
- ▶ **Femoral nerve**: lateral to the femoral artery, lying **outside** the sheath, in the groove between iliacus and psoas major; it divides into anterior and posterior divisions about 2.5 cm below the inguinal ligament. Its branch, the **nerve to pectineus**, passes obliquely behind the sheath to reach that muscle.
- ▶ **Femoral vein**: lies medial to the artery at the base of the femoral triangle, and posterior to it at the apex, occupying the intermediate compartment throughout.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a cross-section through the right femoral sheath just below the inguinal ligament:

- ▶ Inguinal ligament (anterior wall/boundary)
- ▶ Fascia transversalis (contributes anterior wall) and fascia iliaca (contributes posterior wall)
- ▶ Three compartments side by side — lateral (femoral artery + femoral branch of genitofemoral nerve), intermediate (femoral vein), medial (femoral canal)
- ▶ Femoral canal contents — lymphatic, node of Cloquet/Rosenmüller
- ▶ Femoral nerve — shown lateral to, and outside, the sheath
- ▶ Femoral ring boundaries in a second inset — anterior: inguinal ligament; posterior: pecten pubis/pectineus + pectineal ligament; medial: lacunar ligament; lateral: femoral vein
- ▶ Femoral septum closing the ring, with inferior epigastric vessels at its anterolateral rim

Applied / Clinical anatomy

- ▶ **Femoral hernia:** protrusion of abdominal contents (commonly a loop of small intestine, occasionally omentum) through the femoral ring into the femoral canal. It is never congenital. Typical course: downward through the femoral canal, then forward through the saphenous opening (piercing the cribriform fascia), and finally upward in the superficial fascia of the thigh — producing a globular swelling **inferolateral to the pubic tubercle** (in contrast to an inguinal hernia, which lies superomedial to it).
- ▶ **Coverings of the sac** (superficial to deep): skin → superficial fascia → cribriform fascia → femoral sheath → femoral septum.
- ▶ **Sex predilection:** more common in females because of the wider pelvis and correspondingly wider femoral ring/canal, and the smaller calibre of the female femoral vessels.
- ▶ **Strangulation:** the rigid, unyielding boundaries of the ring — particularly the sharp concave margin of the lacunar ligament — readily compress the neck of the hernial sac, compromising the blood supply of the contained bowel and precipitating strangulation (pain, obstruction, vascular compromise).
- ▶ **Surgical relief of strangulation:** the surgeon enlarges the ring by incising the lacunar ligament (its medial boundary). This is usually safe, but occasionally an **abnormal (accessory) obturator artery**, arising from the inferior epigastric artery, runs along the free margin of the lacunar ligament and may be inadvertently cut, causing severe haemorrhage.
- ▶ **Psoas abscess:** the fascia iliaca forming the posterior wall of the femoral sheath is continuous, proximally, with the psoas sheath. Tuberculous caries of thoracolumbar vertebrae produces pus that (being unable to spread anteriorly, held back by the anterior longitudinal ligament) tracks laterally into the psoas sheath, descends under the inguinal ligament along psoas major, and points as a soft, often fluctuant swelling in the femoral triangle — a differential for femoral hernia and inguinal lymphadenopathy.
- ▶ **Cloquet's/Rosenmüller node:** the deep inguinal node lying within the femoral canal is the classic sentinel node en route to the external iliac group and is relevant in lymphatic staging/spread of carcinoma of the glans penis or clitoris.

- **Vascular access landmark:** the femoral artery is palpated/cannulated at the mid-inguinal point (mid-way between the anterior superior iliac spine and the pubic symphysis), within the lateral compartment of the sheath; the femoral vein, medial to it in the intermediate compartment, is the classical site for femoral venous cannulation. The femoral nerve, being outside the sheath, is blocked lateral to the arterial pulse.

High-yield exam pointers

- Femoral sheath = downward prolongation of **fascia transversalis (anterior wall) + fascia iliaca (posterior wall)**; encloses upper 3–4 cm of femoral vessels.
- Three compartments: **lateral (artery) — intermediate (vein) — medial (femoral canal, lymphatics)**.
- **Femoral nerve lies outside the sheath** (lateral to the artery, between iliacus and psoas major) — a classic viva/MCQ trap.
- Femoral canal ≈ 1.25–1.5 cm long; conical; allows venous distension; upper open end = **femoral ring**.
- Femoral ring boundaries: **anterior — inguinal ligament; posterior — pecten pubis/pectineus + pectineal ligament; medial — lacunar ligament; lateral — femoral vein**.
- Ring is closed by the **femoral septum**; contains the **node of Cloquet/Rosenmüller**.
- **Femoral hernia** is more common in **females** (wider pelvis, smaller vessels, wider ring); presents **inferolateral to the pubic tubercle**; strangulates because of the sharp lacunar ligament margin.
- Enlarging the ring at surgery risks cutting an **abnormal obturator artery** running along the lacunar ligament's free edge.
- Continuity of the **fascia iliaca/psoas sheath** with the posterior wall of the femoral sheath explains the descent of a **psoas abscess** into the femoral triangle.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e; Moore's Clinically Oriented Anatomy 9e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb).



Discuss the venous drainage of lower limb

Asked in: Paper I May 2011 · Paper I Apr 2006 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction

The lower limb is drained by three functionally interconnected sets of veins — **superficial, deep and perforating (communicating)** — that ultimately empty into the **external iliac vein**. Because venous blood must ascend against gravity in the erect posture, the system is heavily valved and depends on an active "calf pump" for efficient return. The topic carries immense clinical importance — varicose veins, deep vein thrombosis, venesection, and the great saphenous vein graft used in coronary artery bypass surgery are all direct applications of this anatomy.

Classification and general plan

Feature	Superficial veins	Deep veins	Perforating veins
Location	Superficial fascia, superficial to deep fascia	Beneath deep fascia, between/along muscles, accompany arteries	Pierce the deep fascia to connect the other two
Members	Great (long) and small (short) saphenous veins + tributaries	Venae comitantes of tibial/peroneal arteries, popliteal vein, femoral vein	Direct (e.g. saphenous veins themselves) and indirect perforators
Wall	Thick-walled, more smooth muscle	Thin-walled but supported by surrounding muscle	Valved, unidirectional
Valves	Numerous, more distally	More numerous than superficial veins	Permit flow only superficial → deep
Share of drainage	Minor	>90% of venous return	Connecting channels

Direction of flow — in the thigh and leg, blood flows from superficial to deep veins through the perforators (directed by their valves); in the foot, uniquely, flow is from deep veins (of the sole) to superficial veins (on the dorsum), because the sole must withstand the compressive load of weight-bearing.

□ Fig 11.1 — Scheme to show the arrangement of the veins of lower limb. Popliteal, short saphenous an (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.178)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A schematic of the lower-limb venous system (as above) reproduced by hand should carry these labels:

- ▶ **Dorsal venous arch of foot**, with medial and lateral marginal veins.
- ▶ **Great (long) saphenous vein** — anterior to medial malleolus → medial border of tibia → hand's-breadth posterior to patella → saphenous opening → **femoral vein**.
- ▶ **Small (short) saphenous vein** — posterior to lateral malleolus → midline of calf → **popliteal vein**.
- ▶ **Posterior arch vein** joining the three medial ankle perforators to the great saphenous vein.
- ▶ **Perforators** (labelled and colour-coded, e.g. violet): adductor canal (Hunterian), Boyd's (below knee), three of Cockett (medial ankle), lateral ankle perforator.
- ▶ **Deep veins**: venae comitantes of anterior tibial, posterior tibial and peroneal arteries → **popliteal vein** → **femoral vein** (joined by **profunda femoris vein**) → **external iliac vein**.
- ▶ Arrowheads on perforators showing unidirectional **superficial → deep** flow (valves).

Great (long) saphenous vein

The **great saphenous vein (GSV)** is the longest vein in the body and represents the preaxial vein of the developing lower limb.

- ▶ **Origin:** union of the medial end of the dorsal venous arch of the foot with the medial marginal vein of the great toe.
- ▶ **Course:** ascends about 2.5 cm anterior to the medial malleolus; crosses the distal third of the medial surface of the tibia obliquely; runs a little behind the medial border of the tibia to the knee, where it lies about a hand's breadth posterior to the medial margin of the patella; ascends the medial side of the thigh to the **saphenous opening (fossa ovalis)**.
- ▶ **Termination:** pierces the cribriform fascia and drains into the **femoral vein** a short distance below the inguinal ligament (saphenofemoral junction).
- ▶ **Relations:** the **saphenous nerve** lies anterior to it at the ankle and in the leg — clinically important during venesection.
- ▶ **Tributaries:** (1) at its commencement — medial marginal vein; (2) in the leg — the **posterior arch vein** (vein of Leonardo da Vinci), which links the three medial ankle perforators, and anterior leg veins; (3) in the thigh — the **anterolateral (anterior femoral cutaneous) vein** and the **posteromedial vein** (accessory saphenous vein); (4) just before piercing the cribriform fascia — superficial epigastric, superficial circumflex iliac and superficial external pudendal veins; (5) at termination — deep external pudendal vein.
- ▶ **Valves:** about 10–20, more numerous in the leg than the thigh; two are constant — one just before it pierces the cribriform fascia and one at the saphenofemoral junction (the **saphenofemoral valve**). In roughly 80% of individuals the external iliac vein also has a valve that protects the saphenofemoral valve from high venous pressure; its absence predisposes to varicose veins beginning at the saphenofemoral junction.
- ▶ **Surface marking:** 2.5 cm anterior to the medial malleolus → medial border of tibia → a hand's breadth posterior to the patella at the knee → point ~3–4 cm inferolateral to the pubic tubercle (saphenofemoral junction).

Small (short) saphenous vein

Represents the postaxial vein of the developing limb.

- ▶ **Origin:** union of the lateral end of the dorsal venous arch with the lateral marginal vein of the little toe, formed just behind and below the lateral malleolus.
- ▶ **Course:** ascends along the lateral border of the tendocalcaneus, accompanied by the **sural nerve**; runs in the midline of the back of the leg, pierces the deep fascia, and ascends between the two heads of gastrocnemius.
- ▶ **Termination:** turns forward to drain into the **popliteal vein**, 3–7.5 cm above the knee joint (variable — may join the great saphenous vein, or bifurcate between the two).
- ▶ **Valves:** about 7–13, with one near its termination.

	Great saphenous vein	Small saphenous vein
Begins	Medial end of dorsal venous arch	Lateral end of dorsal venous arch
Malleolar relation	Anterior to medial malleolus	Posterior to lateral malleolus
Accompanying nerve	Saphenous nerve	Sural nerve

	Great saphenous vein	Small saphenous vein
Termination	Femoral vein (saphenous opening)	Popliteal vein
Valves	~10–20	~7–13

Perforating (communicating) veins

Perforators pierce the deep fascia and connect superficial to deep veins; their valves permit flow in **one direction only** — **superficial to deep**. They are classified as **direct** (superficial vein connects straight into a deep vein — the saphenous veins themselves are the largest direct perforators) and **indirect** (connect via intervening muscular veins). About five perforators accompany the great saphenous vein and one the small saphenous vein, though named constant sites are described:

Named perforator	Connects	Location
Adductor canal (Hunterian) perforator	Great saphenous vein ↔ femoral vein	Lower part of adductor (Hunter's) canal, thigh
Knee (Boyd's) perforator	Great saphenous vein ↔ posterior tibial vein	Just below knee, near medial border of tibia
Three medial ankle perforators (of Cockett)	Posterior arch vein ↔ posterior tibial vein	Upper (junction of middle/lower leg), middle (~4 cm above medial malleolus), lower (postero-inferior to medial malleolus)
Lateral ankle perforator	Small saphenous vein ↔ peroneal vein	Junction of middle and lower third of leg

Deep veins

- **Sole:** medial and lateral plantar veins, forming *venae comitantes* of the corresponding arteries.
- **Leg:** below the knee the deep veins are **paired venae comitantes** accompanying the anterior tibial, posterior tibial and peroneal arteries. Within **soleus**, they expand into **venous sinuses (soleal sinuses)** — an important reservoir and a common site of thrombosis.
- **Popliteal vein:** formed at the lower border of popliteus by union of the *venae comitantes*; its relation to the popliteal artery changes as it ascends — medial to the artery distally, superficial (posterior) to it between the heads of gastrocnemius, and posterolateral to it proximal to the knee. It receives the small saphenous vein, genicular veins and muscular veins (including a large tributary from each head of gastrocnemius), and has **4–5 valves**.
- **Femoral vein:** the direct continuation of the popliteal vein above the adductor hiatus; ascends in the adductor canal and then the femoral triangle, lying posterior to the femoral artery in the canal, medial to it in the lower triangle, and posterior/lateral to it within the femoral sheath at the inguinal ligament. It receives the **profunda femoris (deep femoral) vein** posteriorly, 4–12 cm below the inguinal ligament, and the **great saphenous vein** anteriorly shortly after. It has **4–5 valves**, the two most constant being just distal to the entry of the profunda femoris vein and near the inguinal ligament. Above the inguinal ligament it continues as the **external iliac vein**.

Mechanism of venous return — the "calf pump"

Venous return from the erect lower limb against gravity is aided by:

- ▶ **Calf muscle pump (peripheral heart)** — the chief factor. Contraction of the calf muscles, especially soleus with its venous sinuses, squeezes blood upward in the deep veins; relaxation allows refilling from the superficial veins via perforators. Hence soleus is called the **peripheral heart**.
- ▶ **Valves** in the deep veins and perforating veins — support the long column of blood, divide it into shorter segments, and enforce unidirectional (superficial→deep, distal→proximal) flow.
- ▶ **Transmitted arterial pulsations** from adjacent arteries compressing the venae comitantes.
- ▶ **Negative intrathoracic pressure**, more negative on inspiration, aiding the suction of blood centrally.
- ▶ **Vis-a-tergo** — the residual force of cardiac contraction, assisted by diaphragmatic suction in the recumbent position.

Applied / Clinical anatomy

- ▶ **Venesection (cut-down)**: the great saphenous vein in front of the medial malleolus is the preferred site for emergency venous access when peripheral veins elsewhere have collapsed; the saphenous nerve (lying anterior to the vein here) must be identified and preserved.
- ▶ **Coronary artery bypass graft**: a segment of great saphenous vein is harvested and reversed before use, because its valves would otherwise obstruct graft flow.
- ▶ **Varicose veins**: incompetence of the saphenofemoral valve (commonest, especially if the protective external iliac valve is absent) or of perforator valves converts perforators into "high-pressure leaks," transmitting deep venous pressure to superficial veins during muscle contraction and producing dilated, tortuous superficial veins, most often of the great saphenous system; chronic venous stasis can progress to varicose ulcers. Predisposed by prolonged standing (bus conductors, nurses) and pregnancy (pelvic vein compression by the gravid uterus).
- ▶ **Deep vein thrombosis (DVT)**: the soleal venous sinuses, with sluggish flow especially during bed rest/immobility, are a classic site of thrombus formation; embolisation can cause life-threatening pulmonary embolism.
- ▶ **Trendelenburg test**: distinguishes saphenofemoral (superficial) valve incompetence from perforator incompetence by controlled release/retention of pressure at the saphenofemoral junction after emptying the veins.
- ▶ **Perthes' (tourniquet) test**: assesses patency of deep and perforating veins during exercise with a thigh tourniquet occluding only the superficial system.
- ▶ Because of these clinical stakes, the entire great saphenous vein may be removed by **stripping** when multiple perforators are incompetent, and defective perforators are individually ligated ("perforator ligation").

High-yield exam pointers

- ▶ Three sets of veins: superficial, deep, perforating; deep veins carry >90% of venous return.
- ▶ Direction of flow: superficial→deep in thigh/leg; deep→superficial in the foot.

- ▶ Great saphenous vein: longest vein in the body; ~10–20 valves; drains into femoral vein at the saphenous opening.
- ▶ Small saphenous vein: ~7–13 valves; drains into popliteal vein 3–7.5 cm above the knee; accompanied by sural nerve.
- ▶ Perforator valves permit flow only superficial→deep; named perforators — Hunterian (adductor canal), Boyd's (below knee), three of Cockett (medial ankle), one lateral ankle.
- ▶ Soleus = "peripheral heart"; soleal sinuses = common DVT site.
- ▶ Femoral and popliteal veins each carry 4–5 valves; profunda femoris vein joins femoral vein 4–12 cm below the inguinal ligament.
- ▶ Great saphenous vein = site of venesection (in front of medial malleolus) and of the reversed CABG graft.
- ▶ Posterior arch vein = "vein of Leonardo da Vinci."

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e.



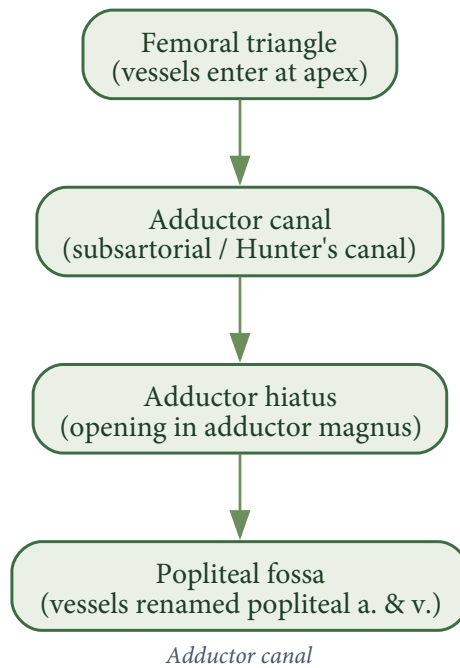
Adductor canal

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction The adductor canal (subsartorial canal; **Hunter's canal**) is a triangular, trough-shaped intermuscular tunnel on the medial side of the middle one-third of the thigh. It carries the femoral vessels and their accompanying nerves from the apex of the femoral triangle to the popliteal fossa, and is one of the most frequently examined "conduit" spaces of the lower limb because of its surgical importance in vascular access and varicose-vein surgery. It is named after **John Hunter**, the 18th-century London surgeon-anatomist who first ligated the femoral artery within it for popliteal aneurysm.

Location, extent and shape

- ▶ **Site:** medial aspect of the thigh, middle one-third, deep to sartorius.
- ▶ **Extent:** from the **apex of the femoral triangle** (junction of upper and middle thirds of the thigh) above, to the **tendinous (adductor) opening in adductor magnus** — the adductor hiatus — below, at the junction of the middle and lower thirds of the thigh.
- ▶ **Shape:** triangular on cross-section.
- ▶ **Continuity:** the canal is the middle link in the passage of the femoral vessels — femoral triangle → adductor canal → adductor hiatus → popliteal fossa, where the vessels continue as the popliteal artery and vein.



□ Fig 3.34 — Transverse section through the middle of the right adductor canal, seen from above. Note the boundaries and contents of the canal (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.92)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A cross-section through the middle one-third of the right thigh at the level of the adductor canal, labelled with:

- ▶ **Vastus medialis** — anterolateral wall
- ▶ **Adductor longus / adductor magnus** — posterior wall (floor)
- ▶ **Subsartorial (vasoadductor) fascia** — medial wall (roof)
- ▶ **Sartorius** — overlying the roof
- ▶ **Femoral artery and femoral vein** — centre of the canal, vein posterior/posterolateral to artery
- ▶ **Saphenous nerve** — crossing the artery anteriorly
- ▶ **Nerve to vastus medialis** — lateral to the artery
- ▶ **Subsartorial plexus** — on the deep surface of sartorius

Boundaries

Wall	Formed by
Anterolateral wall	Vastus medialis
Posterior wall (floor)	Adductor longus (upper part), continued by adductor magnus (lower part)
Medial wall (roof)	A strong fibrous membrane (the subsartorial / vasoadductor fascia) stretching from vastus medialis to the adductors; overlapped superficially by sartorius

- ▶ The vastus medialis curves anteriorly and the adductors curve posteriorly, creating a muscular gutter; the vasoadductor fascia converts this gutter into a closed canal.
- ▶ The **subsartorial nerve plexus** lies on the fibrous roof, deep to sartorius, formed by contributions from the medial cutaneous nerve of the thigh, the saphenous nerve, and the anterior division of the obturator nerve; it supplies the overlying fascia lata and adjacent skin.

Contents

Content	Course / key point
Femoral artery	Enters at the apex of the femoral triangle; gives muscular branches and the descending genicular artery (its last branch, arising just above the hiatus); leaves via the adductor hiatus to become the popliteal artery
Femoral vein	Upward continuation of the popliteal vein; changes relation to the artery along the canal (see below)
Saphenous nerve	Longest cutaneous nerve in the body; crosses the femoral artery anteriorly from lateral to medial side; leaves the canal (with the saphenous branch of the descending genicular artery) by piercing the fibrous roof; gives an infrapatellar branch near its exit
Nerve to vastus medialis	Thickest muscular branch of the femoral nerve; lies lateral to the femoral artery in the upper part of the canal and enters vastus medialis
Anterior & posterior divisions of the obturator nerve (inconstant)	Anterior division contributes to the subsartorial plexus and ends by supplying the femoral artery; posterior division runs on the anterior surface of adductor magnus and supplies the knee joint
Descending genicular artery	Last branch of the femoral artery within the canal; divides into a superficial saphenous branch (accompanies the saphenous nerve) and a deep muscular branch to vastus medialis and the knee anastomosis

Relations of the femoral vessels within the canal

	Upper (proximal) part	Lower (distal) part
Femoral artery — anterior relations	Skin, superficial fascia, deep fascia, sartorius, and the fibrous roof (vasoadductor fascia)	Same
Femoral artery — posterior relations	Adductor longus	Adductor magnus
Femoral vein	Posterior to the artery	Posterolateral (lateral) to the artery
Saphenous nerve	Crosses the artery anteriorly from lateral to medial throughout the canal	

	Upper (proximal) part	Lower (distal) part
Nerve to vastus medialis	Lateral to the artery	

Developmental basis of the spiral relations

- ▶ The lower limb bud rotates **medially** in utero (unlike the upper limb, which rotates laterally), bringing the original extensor (quadriceps) compartment to lie anteriorly and the adductor/flexor-derived compartment to lie posteriorly.
- ▶ This medial rotation is why the femoral vein — posterior to the artery proximally — spirals to lie posterolateral to it distally, and why the saphenous nerve, originally lateral to the artery, crosses anterior to it to reach the medial side of the knee.
- ▶ The same rotation explains why vastus medialis (an extensor-compartment muscle) forms the anterolateral wall of the canal while the adductor muscles (flexor-compartment derivatives) form its floor.

Applied / Clinical anatomy

- ▶ **Hunter's operation:** the femoral artery is exposed and ligated within the adductor canal for surgical treatment of popliteal aneurysm — the artery here is healthy and unlikely to tear when tied, unlike the diseased segment in the popliteal fossa itself. This is a landmark event in the history of vascular surgery.
- ▶ **Collateral circulation:** after ligation of the femoral artery in the canal, limb perfusion distal to the tie is maintained through the **genicular anastomosis** around the knee joint (branches of the descending genicular, circumflex femoral and popliteal arteries).
- ▶ **Surgical accessibility:** only the sartorius needs to be retracted, and the vasoadductor fascia opened, to expose the femoral vessels, saphenous nerve and nerve to vastus medialis — making the canal a convenient, safe surgical field.
- ▶ **Mid-thigh (Hunter's) perforator:** a perforating vein within the adductor canal connects the great saphenous vein to the femoral vein by piercing the fibrous roof; it is a recognised site of incompetent-perforator ligation in varicose-vein surgery.
- ▶ **Saphenous nerve vulnerability:** because the nerve lies applied to the artery and pierces the roof to become superficial, it is at risk during femoral vessel exposure or vein-harvest procedures in the canal, producing numbness over the medial leg, ankle and foot if injured.
- ▶ **Regional anaesthesia:** the saphenous nerve within the canal is the target of the "adductor canal block," a motor-sparing regional block used for post-operative analgesia after knee surgery — a direct clinical application of the canal's contents.
- ▶ **Surface marking:** the middle third of the line joining the mid-inguinal point to the adductor tubercle (with the thigh flexed, abducted and laterally rotated) represents the femoral artery's course through the adductor canal.

High-yield exam pointers

- ▶ Adductor canal = subsartorial canal = **Hunter's canal**; named for John Hunter's ligation of the femoral artery here for popliteal aneurysm.

- ▶ Extends from the **apex of the femoral triangle** to the **adductor hiatus** in adductor magnus; triangular in cross-section; middle one-third of the thigh.
- ▶ Three walls: **anterolateral** — **vastus medialis**; **posterior/floor** — **adductor longus then adductor magnus**; **medial/roof** — **vasoadductor (subsartorial) fascia overlapped by sartorius**.
- ▶ **Contents (6)**: femoral artery, femoral vein, saphenous nerve, nerve to vastus medialis, descending genicular artery, and (inconstant) branches of the obturator nerve.
- ▶ Femoral vein: **posterior** to the artery proximally, **posterolateral** distally; saphenous nerve crosses the artery **lateral** → **medial**.
- ▶ Subsartorial plexus lies on the roof (medial cutaneous nerve of thigh + saphenous nerve + obturator nerve anterior division).
- ▶ Applied anatomy triad to remember: Hunter's ligation for popliteal aneurysm, mid-thigh perforator in varicose-vein surgery, and the adductor canal (saphenous) block for knee analgesia.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Textbook of Anatomy Vol 1, 6e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb); Moore's Clinically Oriented Anatomy, 9e.



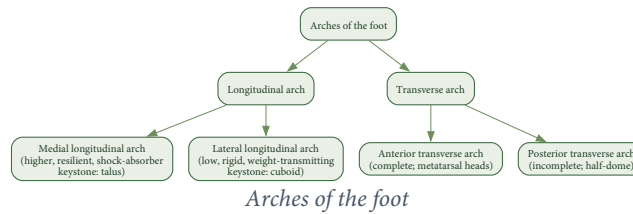
Arches of the foot

Asked in: Paper I Sep 2007 — RGUHS MD/MS Anatomy

Definition / Introduction The human foot is built as a series of elastic, segmented **arches** — a bipedal adaptation not seen in other primates — rather than as a flat platform. The arches let the foot act both as a **pliable platform** that supports body weight in the upright posture and as a **lever** that propels the body forward in walking, running and jumping. They are present from birth (though masked by infantile plantar fat) and are maintained by the shape of the bones, by ligaments and the plantar aponeurosis, and by muscles acting as dynamic slings. Three arches are recognised — the **medial longitudinal**, **lateral longitudinal** and **transverse** arches — and their integrity underlies the clinical conditions of flat foot, high-arched foot and clawfoot.

Classification of the arches

- ▶ **Longitudinal arches** (run from front to back of the foot)
 - Medial longitudinal arch
 - Lateral longitudinal arch
- ▶ **Transverse arch** (runs across the foot; conventionally described as two components)
 - Anterior transverse arch (at the metatarsal heads)
 - Posterior transverse arch (at the tarsus and metatarsal bases)



Medial longitudinal arch

- **Bones:** part of the calcaneus, the talus, the navicular, all three cuneiforms, and the 1st–3rd metatarsals (phalanges take no part in any arch).
- **Keystone:** the head of the **talus**; **main joint:** the talocalcaneonavicular joint (ends/pillars in the comparison table below).
- Considered "a big arc of a small circle" — higher, more mobile and more resilient than the lateral arch, and it acts chiefly as the body's shock absorber.

Lateral longitudinal arch

- **Bones:** part of the calcaneus, the cuboid, and the 4th and 5th metatarsals.
- **Keystone:** the **cuboid**; **main joint:** the calcaneocuboid joint (ends/pillars in the comparison table below).
- Considered "a small arc of a big circle" — low, with limited mobility, contributing little to stability by itself; built mainly to transmit weight and thrust, and it rests almost on the ground during standing.

Transverse arch

- **Bones:** the cuboid, the three cuneiforms, and the bases of the metatarsals; the medial and lateral parts of the longitudinal arches act as its pillars.
- **Anterior transverse arch** — formed by the heads of all five metatarsals; it is **complete**, since the heads of the 1st and 5th metatarsals both reach the ground and form the two ends of the arch. During weight-bearing the metatarsal heads flatten out.
- **Posterior transverse arch** — formed by the greater part of the tarsus (three cuneiforms and cuboid) and the metatarsal bases; it is **incomplete**, only the lateral end touching the ground, so it forms a "half-dome" that is completed by the corresponding half-dome of the opposite foot when the feet are held together.

Comparison of the arches

Feature	Medial longitudinal	Lateral longitudinal
Character	Higher, more mobile, resilient, shock-absorber	Lower, limited mobility, rigid, weight-transmitting
Anterior end	Heads of 1st–3rd metatarsals	Heads of 4th, 5th metatarsals
Posterior end	Medial tubercle of calcaneum	Lateral tubercle of calcaneum
Summit / keystone	Superior surface of talus / talus	Articular facet on calcaneum at subtalar joint / cuboid

Feature	Medial longitudinal	Lateral longitudinal
Anterior pillar	Talus, navicular, 3 cuneiforms, 1st–3rd metatarsals	Cuboid, 4th–5th metatarsals
Posterior pillar	Medial half of calcaneum	Lateral half of calcaneum
Main joint	Talocalcaneonavicular joint	Calcaneocuboid joint

Feature	Anterior transverse arch	Posterior transverse arch
Formation	Heads of 1st–5th metatarsals	Navicular, 3 cuneiforms, bases/shafts of metatarsals
Completeness	Complete (1st and 5th metatarsal heads touch ground)	Incomplete — half-dome, completed by opposite foot
Bony factor	Rounded metatarsal heads	Wedge-shaped cuneiforms/metatarsal bases

Factors maintaining the arches

Four groups of factors, acting together, maintain every arch of the foot:

Factor	Medial longitudinal arch	Lateral longitudinal arch	Transverse arch
Bony factor (shape of bones)	Minor role	Minor role	Major role — wedge-shaped cuneiforms and metatarsal bases (apex down)
Intersegmental ties (ligaments uniting the segments)	Spring ligament (plantar calcaneonavicular lig.), talocalcaneal ligaments, anterior fibres of deltoid ligament	Long plantar and short (plantar calcaneocuboid) ligaments	Ligaments binding tarsal/metatarsal bones + interosseous muscles
Tie beams (bowstrings connecting the two ends)	Plantar aponeurosis (medial part); abductor hallucis; medial part of flexor digitorum brevis	Plantar aponeurosis (lateral part); abductor digiti minimi; lateral part of flexor digitorum brevis	Adductor hallucis (transverse head); deep transverse metatarsal ligaments
Slings (muscles pulling the summit up)	Tibialis posterior, tibialis anterior, flexor hallucis longus, flexor digitorum longus	Fibularis (peroneus) longus and brevis, fibularis tertius	Fibularis longus (stirrup with tibialis posterior/anterior)

- The **tibialis anterior + fibularis longus** together form a **stirrup (sling)** across the sole that pulls the middle of the foot upward, supporting the longitudinal arches; fibularis longus, running transversely, also draws the medial and lateral borders of the sole together, supporting the transverse arch.

- ▶ Tibialis posterior grips numerous tarsal bones (all except the talus) and the middle three metatarsals through its multiple slips, reinforcing both the medial longitudinal and the transverse arch.
- ▶ Of all these supports, the **plantar ligaments and the plantar aponeurosis bear the greatest mechanical stress** and are the single most important passive supports of the arches.

Windlass mechanism and weight transmission

- ▶ Body weight passes from the tibia to the **talus**, then splits **posteriorly to the calcaneus (heel)** and **anteriorly to the "ball of the foot"** — the sesamoids under the 1st metatarsal head and the head of the 2nd metatarsal — with the remaining load shared across the heads of the 3rd–5th metatarsals; weight is divided roughly equally between the hindfoot and the forefoot, and the 1st metatarsal carries the largest single share of the forefoot load.
- ▶ **Passive support** of the longitudinal arch is provided by four successive layers of fibrous tissue (superficial to deep): **plantar aponeurosis → long plantar ligament → plantar calcaneocuboid (short plantar) ligament → plantar calcaneonavicular (spring) ligament**.
- ▶ **Windlass mechanism:** passive dorsiflexion of the toes — especially the great toe at the metatarsophalangeal joint — winds the plantar aponeurosis around the metatarsal head like a windlass drum, drawing the two pillars of the arch together and thereby **heightening (accentuating) the medial longitudinal arch**. This is the basis of the clinical windlass ("Jack's great toe") test: in a flexible (physiological) flat foot the arch reappears on toe dorsiflexion, whereas in a fixed/pathological flat foot it does not.
- ▶ Failure of the **spring ligament** allows the navicular and calcaneus to separate, letting the talar head — the highest point of the arch — descend, producing a flat-foot deformity; loss of the **tibialis posterior** tendon similarly collapses the medial longitudinal arch.

□ Fig 7.107 — Arches of foot. A. Medial longitudinal arch. B. Lateral longitudinal arch. C. Transverse arch shown at the level of the cuneiforms, receiving stirrup-like support from tibialis posterior and fibularis longus. D. Components of medial and lateral longitudinal arches. E. Structures providing active and passive support of the arches (Moore — Clinically Oriented Anatomy — 9e, p.1317)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A composite scheme of the foot (medial view + plantar view) labelled with:

- ▶ **Bones:** calcaneus, talus, navicular, 3 cuneiforms, cuboid, 1st–5th metatarsals
- ▶ **Keystones:** head of talus (medial longitudinal arch); cuboid (lateral longitudinal arch)
- ▶ **Ligaments:** spring (plantar calcaneonavicular) ligament, long plantar ligament, short plantar (plantar calcaneocuboid) ligament
- ▶ **Tie beam:** plantar aponeurosis, running from calcaneal tuberosity to the digits
- ▶ **Slings/tendons:** tibialis posterior, tibialis anterior, fibularis (peroneus) longus, fibularis brevis, flexor hallucis longus, flexor digitorum longus — arrows showing the stirrup formed by tibialis anterior + fibularis longus

Functions of the arches

- ▶ Distribute body weight to the weight-bearing areas of the sole — mainly the heel and the 1st and 5th toes; the lateral border bears reduced weight because of the lateral longitudinal arch.

- ▶ Act as **springs** (chiefly the medial longitudinal arch), aiding propulsion in walking and running.
- ▶ Act as **shock absorbers** during stepping and, especially, jumping.
- ▶ The concavity of the arches protects the soft tissues (vessels, nerves) of the sole from compression.
- ▶ The medial longitudinal arch is characteristically **resilient**; the lateral longitudinal arch is characteristically **rigid**.

Applied / Clinical anatomy

- ▶ **Pes planus (flat foot)**: loss/collapse of the medial longitudinal arch, congenital or acquired. Causes include rupture of the spring ligament, tibialis posterior tendon dysfunction, tarsal coalition, and tarsometatarsal or hindfoot (subtalar) arthritis. Consequences: loss of spring → clumsy, shuffling gait; loss of shock absorption → arthritis and trauma; loss of sole concavity → compression of the neurovascular bundle in the sole, producing **metatarsalgia** (compression at the communication between the medial and lateral plantar nerves) and vascular disturbance in the toes.
- ▶ **Windlass/Jack's test**: distinguishes flexible from fixed flat foot, as above; an alternative bedside method has the patient stand with both feet plantarflexed, viewed from behind — in flexible flat foot the calcaneus swings into a **varus** position, whereas in pathological pes planus it does not.
- ▶ **Pes cavus**: an abnormally high medial longitudinal arch, usually neurogenic (e.g. Charcot–Marie–Tooth disease, poliomyelitis, spina bifida, tethered cord); classified by site into hindfoot, midfoot, forefoot or "global" cavus. When dorsiflexion at the metatarsophalangeal joints combines with plantar flexion at the interphalangeal joints (from intrinsic muscle — lumbrical/interosseous — wasting), the deformity is termed **clawfoot**.
- ▶ **Talipes deformities**: talipes equinus (walks on toes, heel raised), talipes calcaneus (walks on heel, forefoot raised), talipes varus (walks on the inverted/adducted outer border), talipes valgus (walks on the everted/abducted inner border). The commonest combination is **talipes equinovarus (club foot)** — inverted, adducted and plantar-flexed — occasionally associated with spina bifida; the reverse pattern, **talipes calcaneovalgus**, is dorsiflexed and everted.
- ▶ **Hallux valgus**: lateral deviation of the great toe at the 1st metatarsophalangeal joint, commonly associated with metatarsus primus varus; footwear and genetic predisposition are implicated, explaining its higher prevalence in women. A spheroidal (rather than flat) 1st metatarsal head predisposes to instability; progressive lateral drift of the proximal phalanx displaces the sesamoid sling medially relative to the metatarsal head, and unopposed abductor hallucis pull produces the characteristic varus rotation deformity.
- ▶ **March fracture**: a stress fracture of the shaft of the 2nd, 3rd or 4th metatarsal from repeated marching load on the anterior transverse arch, classically seen in army recruits and policemen, attributed to decalcification and localised vascular compromise of the bone.

High-yield exam pointers

- ▶ Three arches: **medial longitudinal, lateral longitudinal, transverse** (anterior + posterior components).

- ▶ Medial longitudinal arch: talus (keystone), talocalcaneonavicular joint, high/mobile/resilient; supported chiefly by the **spring ligament** and **tibialis posterior**.
- ▶ Lateral longitudinal arch: cuboid (keystone), calcaneocuboid joint, low/rigid; supported by **long and short plantar ligaments** and **fibularis longus**.
- ▶ Four maintaining factors for every arch: **bony shape**, **intersegmental ties (ligaments)**, **tie beams (plantar aponeurosis/muscles)**, **slings (long tendons)**.
- ▶ Plantar aponeurosis + plantar ligaments bear the greatest stress of all supporting structures.
- ▶ **Windlass mechanism** — great-toe dorsiflexion tightens the plantar aponeurosis and heightens the medial longitudinal arch; basis of the windlass/Jack's test for flexible vs fixed flat foot.
- ▶ Weight is shared roughly equally between hindfoot (calcaneus) and forefoot (metatarsal heads); the 1st metatarsal/sesamoid complex carries the greatest forefoot load.
- ▶ Applied triad: **pes planus** (spring ligament/tibialis posterior failure), **pes cavus/clawfoot** (neurogenic), **talipes equinovarus (club foot)** — commonest congenital foot deformity.
- ▶ **March fracture** = 2nd–4th metatarsal shaft stress fracture from repetitive marching, reflecting transverse-arch overload.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Moore's Clinically Oriented Anatomy, 9e.



Deep peroneal nerve

Asked in: Paper I Nov 2016 — RGUHS MD/MS Anatomy

Definition / Introduction The **deep peroneal (fibular) nerve** is one of the two terminal branches of the **common peroneal (fibular) nerve**, the other being the superficial peroneal nerve. It is the **nerve of the anterior compartment of the leg and of the dorsum of the foot**, supplying every muscle of that compartment plus extensor digitorum brevis, and carrying a small but clinically vital patch of skin over the first (great toe–second toe) web space. Because it runs the same "one compartment–one nerve" course between an interosseous membrane and extensor tendons that the posterior interosseous nerve follows in the forearm, it is classically described as **corresponding to the posterior interosseous nerve of the upper limb**. Its clinical importance is out of proportion to its size: injury to it (or to the parent common peroneal nerve) produces the classical **foot-drop**.

Origin, formation and root value

- ▶ Terminal branch of the **common peroneal nerve**, which is itself the smaller of the two terminal divisions of the **sciatic nerve**, derived from the **dorsal divisions of the ventral rami of L4, L5, S1 and S2**.
- ▶ The deep peroneal nerve **begins at the bifurcation of the common peroneal nerve**, on the **lateral side of the neck of the fibula**, deep to the fibres of **fibularis (peroneus) longus**.

- ▶ **Root value:** L4, L5, S1, S2 ventral rami — the root value quoted for the deep peroneal nerve in BD Chaurasia, matching the dorsal-division root value (L4–S2) of the parent common peroneal nerve in Gray's Anatomy.
- ▶ It is accompanied at its origin by an **articular trunk** that gives a recurrent articular branch (travelling with the anterior tibial recurrent artery) and a proximal twig to tibialis anterior.

Course and relations

- ▶ From its origin it **pierces the anterior intermuscular septum** to enter the **anterior (extensor) compartment of the leg**, then pierces **extensor digitorum longus** to lie against the front of the **interosseous membrane**.
- ▶ It reaches the **anterior tibial artery** in the **proximal third of the leg** and descends with it to the ankle, where both structures lie deep to the extensor retinacula alongside tibialis anterior, extensor hallucis longus and extensor digitorum longus tendons.
- ▶ Its relation to the anterior tibial artery changes classically along the three thirds of the leg:

Level	Relation of nerve to anterior tibial artery
Upper third of leg	Lateral to the artery
Middle third of leg	Anterior to the artery (crossed by the tendon of extensor hallucis longus)
Lower third of leg / ankle	Lateral to the artery again

- ▶ At the ankle the artery becomes the **dorsalis pedis artery**; the nerve continues in company, lying just lateral to it, before ending near the ankle joint by dividing into **lateral and medial terminal branches**. A rare variant, the **accessory deep fibular nerve**, has been described.

Branches

Muscular branches — supply all four muscles of the anterior compartment (the "one compartment-one nerve" principle):

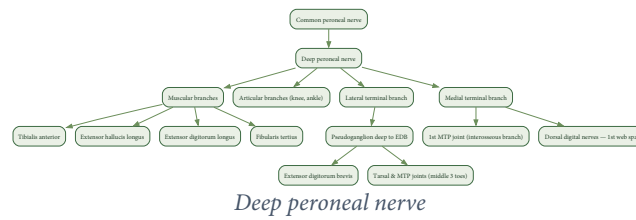
- ▶ Tibialis anterior
- ▶ Extensor hallucis longus
- ▶ Extensor digitorum longus
- ▶ Fibularis (peroneus) tertius

Articular branches — to the knee joint (recurrent articular branch, running with the anterior tibial recurrent artery, to the anterolateral knee capsule and proximal tibiofibular joint) and to the ankle joint.

Terminal branches (given off near the ankle):

- ▶ **Lateral terminal branch** — passes deep to extensor digitorum brevis, **enlarges into a pseudoganglion**, and from it supplies extensor digitorum brevis and, via three minute interosseous branches, the tarsal and metatarsophalangeal joints of the middle three toes.
- ▶ **Medial terminal branch** — runs on the dorsum of the foot lateral to the dorsalis pedis artery, communicates with the medial branch of the superficial peroneal nerve in the first intermetatarsal space, gives an interosseous branch to the first metatarsophalangeal joint, and

ends as **two dorsal digital nerves** supplying the adjoining (contiguous) sides of the great and second toes.



Sensory territory

- The entire cutaneous supply of the deep peroneal nerve is confined to the **skin of the first interdigital (web) space** — the adjoining/contiguous sides of the great and second toes — via the terminal digital branches of the medial terminal branch.
- The rest of the dorsum of the foot is supplied by the **superficial peroneal nerve** (medial and intermediate dorsal cutaneous nerves), with the lateral border by the **sural nerve** and the medial border by the **saphenous nerve**. This small, sharply demarcated territory is a key localising sign in deep peroneal nerve lesions.

□ Fig 8.9 — Common peroneal nerve and its terminal branches; the peroneal retinacula also seen (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.143)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the front of the leg (knee to ankle) and dorsum of the foot in outline and label:

- ▶ **Neck of fibula** — site of origin of the deep peroneal nerve at the bifurcation of the **common peroneal nerve**, deep to **fibularis longus**.
- ▶ **Anterior intermuscular septum** pierced by the nerve to enter the **anterior compartment**; nerve then piercing **extensor digitorum longus**.
- ▶ **Interosseous membrane** and **anterior tibial artery**, with the nerve drawn **lateral** to it in the upper third, **anterior** (crossed by extensor hallucis longus tendon) in the middle third, and **lateral** again in the lower third.
- ▶ Muscles labelled in sequence from medial to lateral: **tibialis anterior**, **extensor hallucis longus**, **extensor digitorum longus**, **fibularis tertius** — all bracketed as "supplied by deep peroneal nerve."
- ▶ **Superior and inferior extensor retinacula** at the ankle, with tibialis anterior, EHL, anterior tibial vessels, EDL and fibularis tertius tendons passing deep to them.
- ▶ **Dorsalis pedis artery** at the ankle (continuation of anterior tibial artery), with the nerve lying just lateral to it.
- ▶ Termination near the ankle into **lateral terminal branch** → **pseudoganglion** deep to **extensor digitorum brevis** → EDB + tarsal/MTP joints of middle 3 toes; and **medial terminal branch** → **1st intermetatarsal space** → two **dorsal digital nerves** to the **first web space** (adjoining sides of great and second toes).

Applied / Clinical anatomy

- ▶ **Foot drop**: injury to the common peroneal nerve (most common site — where it winds round the fibular neck, e.g. plaster casts, prolonged squatting/cross-legged sitting, fibular head fracture, or leprosy/peripheral neuritis) paralyses the anterior compartment muscles supplied by the deep peroneal nerve. Loss of dorsiflexion and toe extension leaves the foot **unopposed by plantarflexors**, producing plantar-flexed "drop foot" and a compensatory **high-stepping (steppage) gait**, with the classic "foot slap" at heel strike. Sensory loss is confined to the **first web space**.
- ▶ **Isolated deep peroneal nerve injury**: results from **anterior compartment syndrome**, or from an **intra-neural (mucinous) ganglion cyst** arising from the superior tibiofibular joint that tracks along the articular branch. It produces weakness of dorsiflexion and toe extension with **normal foot eversion** (superficial peroneal nerve intact), and sensory loss again limited to the first web space.
- ▶ **Anterior (tibial) compartment syndrome / "fresher's syndrome"**: sudden unaccustomed exercise causes swelling within the tight, non-expansile anterior osteofascial compartment, compressing the deep peroneal nerve and anterior tibial vessels — presents with pain and tenderness over the anterior compartment muscles.
- ▶ **Distal entrapment** — "**ski-boot syndrome**": compression of the deep peroneal nerve deep to the **inferior extensor retinaculum** and extensor hallucis brevis (from tight ski boots, footwear, or repetitive dorsiflexion in skiing/running/dancing) causes dorsal foot pain radiating to the **first**

web space, without weakness of the proximal anterior compartment muscles (already innervated proximal to the compression).

- ▶ **Surface marking:** a line from a point on the **lateral side of the neck of the fibula** to a point in **front of the ankle, midway between the two malleoli** — useful for localising the nerve clinically and in surgical approaches to the front of the leg/ankle.
- ▶ **Clinical testing:** dorsiflexion of the ankle and extension of the toes against resistance tests the muscles supplied by the deep peroneal nerve; sensory testing of the first web space localises the lesion to this nerve rather than the common peroneal trunk.
- ▶ **Vascular landmark:** the nerve accompanies the anterior tibial/dorsalis pedis artery throughout, so palpation of the dorsalis pedis pulse (lateral to extensor hallucis longus tendon) also localises the nerve for nerve blocks at the ankle.
- ▶ **Homology:** corresponds functionally and topographically to the **posterior interosseous nerve of the forearm** (deep terminal branch of a nerve winding around a proximal bone, running with the interosseous membrane, supplying an extensor compartment) — a favourite comparative viva point.

High-yield exam pointers

- ▶ Deep peroneal nerve = terminal branch of common peroneal nerve; begins at the **neck of the fibula**; root value L4, L5, S1.
- ▶ Nerve of the **anterior compartment of the leg + dorsum of foot**; corresponds to the **posterior interosseous nerve** of the forearm.
- ▶ Relation to anterior tibial artery: **lateral (upper 1/3) → anterior (middle 1/3) → lateral (lower 1/3)**.
- ▶ Muscular branches: **tibialis anterior, extensor hallucis longus, extensor digitorum longus, fibularis tertius** — the "one compartment–one nerve" muscles.
- ▶ Terminal branches at the ankle: **lateral** (→ pseudoganglion → extensor digitorum brevis + tarsal/MTP joints of middle 3 toes) and **medial** (→ dorsal digital nerves to the **first web space**).
- ▶ Entire cutaneous territory = **first interdigital (web) space** only.
- ▶ Lesion → **foot drop** with steppage gait, sensory loss confined to first web space, **eversion preserved** (distinguishes isolated deep peroneal lesion from common peroneal nerve lesion, where eversion is also lost).
- ▶ Causes: fibular neck compression, anterior compartment syndrome, intraneural ganglion (via articular branch from superior tibiofibular joint), tight footwear ("ski-boot syndrome"), leprosy.
- ▶ Surface marking: neck of fibula → midpoint between the malleoli in front of the ankle.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 (8e); Vishram Singh — Textbook of Anatomy Vol 2 (4e); IB Singh — Textbook of Anatomy Vol 1 (6e); Moore's Clinically Oriented Anatomy (9e).



Describe the ankle joint in detail

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The ankle (talocrural) joint is a synovial joint of the hinge (ginglymus) variety, essentially uniaxial, formed between the distal ends of the **tibia and fibula above** and the **body (trochlea) of the talus below**. The malleoli of the tibia and fibula, bridged posteriorly by the **inferior transverse tibiofibular ligament**, form a deep socket or "**mortise**" into which the pulley-shaped trochlea of the talus fits snugly. The joint is structurally very strong — stability is provided by close interlocking of the articular surfaces, strong medial and lateral collateral ligaments, and the tendons crossing the joint — yet it is also the **most frequently injured major joint of the body**, being clinically important for sprains, fracture-dislocations, and nerve entrapment around the malleoli.

Type and articular surfaces

- ▶ **Type:** synovial, hinge (ginglymus) joint; movement essentially uniaxial (dorsiflexion–plantarflexion), though minor wobble (inversion/eversion) occurs when the joint is unlocked in plantarflexion.
- ▶ **Proximal (upper) articular surface — the "mortise"**, formed by three components uniting into a deep socket:
 - ▶ The **inferior articular surface of the lower end of the tibia**, which transmits body weight onto the talus.
 - ▶ The **medial malleolus** of the tibia, articulating with the medial facet of the talus.
 - ▶ The **lateral malleolus** of the fibula, articulating with the lateral facet of the talus.
 - ▶ The **inferior transverse tibiofibular ligament**, which bridges the gap between tibia and fibula posteriorly and itself contacts the talus, deepening the socket.
- ▶ **Distal (lower) articular surface — the trochlea (body) of the talus:** convex sagittally and gently concave transversely, and distinctly **wider anteriorly than posteriorly** (wedge-shaped). It presents:
 - A **comma-shaped, flat, medial facet** (deeper anteriorly) for the medial malleolus.
 - A larger, **triangular, vertically-concave lateral facet** for the lateral malleolus.
 - A narrow posterior triangular area contacting the inferior transverse tibiofibular ligament.
- ▶ All the above surfaces are covered by hyaline cartilage and are contiguous with one another.
- ▶ Because the talar trochlea is wider in front, **dorsiflexion wedges the wide part between the malleoli**, forcing them slightly apart (with a little lateral rotation/give at the inferior tibiofibular syndesmosis) — this is the **close-packed position** with maximum congruence; **plantarflexion** brings the narrow posterior part into the mortise, so the joint is comparatively loose and **most vulnerable to injury** in this position.

Capsule and synovial membrane

- ▶ The **fibrous capsule** surrounds the joint but is thin and weak anteriorly and posteriorly, and is reinforced on each side by the strong collateral ligaments.
- ▶ Proximal attachment: borders of the tibial and malleolar articular surfaces.

- Distal attachment: to the talus close to the margins of the trochlear surface, **except anteriorly**, where it is attached to the dorsum of the neck of the talus, some distance away from the trochlear margin (allowing free hinge movement).
- Posteromedially the capsule blends with the **inferior transverse tibiofibular ligament**.
- The **synovial membrane** lines the fibrous capsule and characteristically projects proximally for a short distance (~4 mm) between the tibia and fibula into the **inferior tibiofibular joint**.

Ligaments

The capsule is reinforced medially by one strong ligament and laterally by three separate bands.

Ligament	Parts	Attachments
Medial (deltoid) ligament — strong, triangular, resists eversion	Superficial layer: tibionavicular, tibiocalcaneal, superficial posterior tibiotalar fibres	From apex/margins of medial malleolus to: tuberosity of navicular (blending with spring ligament); whole length of sustentaculum tali; medial tubercle of the talus
	Deep layer: anterior tibiotalar, deep posterior tibiotalar fibres	From medial malleolus to non-articular part of medial talar surface and medial tubercle of talus
Lateral ligament — three discrete cords, resists inversion	Anterior talofibular ligament (ATFL)	Anterior margin of lateral malleolus → neck/lateral surface of talus (weakest part; crossed by peroneal tendons)
	Posterior talofibular ligament (PTFL)	Malleolar fossa of fibula (posteriorly) → lateral tubercle of posterior process of talus (strongest part)
	Calcaneofibular ligament (CFL)	Notch near tip of lateral malleolus → tubercle on lateral surface of calcaneus; crossed superficially by tendons of peroneus (fibularis) longus and brevis

- Tendons of **tibialis posterior** and **flexor digitorum longus** cross the deltoid ligament superficially.
- The deltoid ligament is so strong that excessive tensile force tends to avulse the medial malleolus rather than tear the ligament itself.

□ Fig 33.15 — Collateral ligaments of the ankle joint: (A) medial (deltoid) ligament; (B) lateral ligament (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.1281)

Relations

Region	Structures (medial → lateral)
Anteriorly	Tibialis anterior, extensor hallucis longus, anterior tibial vessels, deep peroneal (fibular) nerve, extensor digitorum longus, peroneus (fibularis) tertius
Posteromedially	Tibialis posterior, flexor digitorum longus, posterior tibial vessels, tibial nerve, flexor hallucis longus — mnemonic "Tom, Dick ANd Harry"
Posterolaterally	Peroneus (fibularis) longus and brevis, in the groove behind the lateral malleolus (brevis lying anterior to longus)
Medial, superficial	Great (long) saphenous vein and saphenous nerve cross the joint just anterior to the medial malleolus, medial to tibialis anterior tendon

These structures — especially the anterior and posteromedial neurovascular bundles, and the superficial peroneal nerve branches anterolaterally — are at particular risk during ankle surgery and arthroscopy.

Movements and muscles producing them

The only substantial active movements are **dorsiflexion** and **plantarflexion** about a transverse axis through the talus.

Movement	Range (approx.)	Principal muscles	Accessory muscles
Dorsiflexion (angle between leg and dorsum of foot diminishes)	~10° with knee extended; up to ~30° with knee flexed (calcaneal tendon relaxed)	Tibialis anterior	Extensor digitorum longus, extensor hallucis longus, peroneus tertius
Plantarflexion (angle between leg and foot increases)	~30°	Gastrocnemius, soleus (via tendocalcaneus)	Plantaris, tibialis posterior, flexor hallucis longus, flexor digitorum longus

- ▶ **Dorsiflexion = close-packed position** — maximal congruence and ligamentous tension; all major thrusting movements of walking/running/jumping are exerted from here, and dislocation risk is minimal.
- ▶ **Plantarflexion** loosens the mortise (narrow posterior talar trochlea lies loosely between the malleoli), producing slight accessory "wobble" (inversion/eversion) and making this the position of **maximum instability and injury risk**.
- ▶ Dorsiflexion is limited passively by tension in the triceps surae and posterior ligaments.

Blood and nerve supply

- ▶ **Blood supply:** malleolar branches of the **anterior tibial, posterior tibial, and fibular (peroneal) arteries**.

- **Nerve supply:** branches of the **deep peroneal (fibular), tibial, sural, and saphenous nerves** (occasionally also the superficial peroneal nerve).

Factors maintaining stability

- **Bony factors** — the talar trochlea is wedge-shaped (wider in front), and the malleoli are shaped to grip it; the posterior border of the lower tibia is prolonged downward.
- **Ligamentous factors** — the inferior transverse tibiofibular ligament deepens the socket; the posteriorly-directed tibiocalcaneal, posterior tibiotalar, calcaneofibular and posterior talofibular fibres resist forward slipping of the leg bones on the talus.
- **Muscular/dynamic factors** — tonic contraction of triceps surae (through the tendocalcaneus) resists the natural tendency of the leg to slide forward off the talus (the body's line of gravity falls slightly anterior to the joint axis); gravity, ground-reaction forces and continuous soleus–gastrocnemius activity provide ongoing dynamic stability during standing and gait.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a **coronal section through the right ankle joint** with these exact labels:

- **Tibia** (with **medial malleolus**) medially, **fibula** (with **lateral malleolus**) laterally, articulating with the **body (trochlea) of talus** below, forming the **mortise**.
- **Deltoid (medial) ligament** — label superficial (tibionavicular, tibiocalcaneal, superficial posterior tibiotalar) and deep (anterior tibiotalar) fibres, running to **navicular, sustentaculum tali, talus**.
- **Lateral ligament** — three cords: **anterior talofibular, posterior talofibular, calcaneofibular**, running to **talus** (neck and posterior tubercle) and **calcaneus**.
- **Inferior transverse tibiofibular ligament** bridging tibia–fibula posteriorly.
- Tendon relations on each side: anteriorly **tibialis anterior, EHL, anterior tibial vessels, deep peroneal nerve, EDL, peroneus tertius**; posteromedially **tibialis posterior, FDL, posterior tibial vessels, tibial nerve, FHL**; posterolaterally **peroneus longus and brevis**.

Applied / Clinical anatomy

- **Ankle is the most frequently injured major joint in the body**; most injuries occur in **plantarflexion**, when the mortise is loose.
- **Ankle sprain (inversion injury)** — commonest ankle injury; a plantarflexed, inverted foot tears the (weaker) lateral ligament — the **anterior talofibular ligament is torn first and most often**, followed by the calcaneofibular ligament; the posterior talofibular ligament is almost always spared.
- **Medial (eversion) sprains** are less common because the deltoid ligament is very strong; excessive tensile force here more often **avulses the medial malleolus** than tears the ligament.
- **Pott's fracture-dislocation** — classically from forced **abduction/eversion and external rotation** of the foot: **1st degree** = spiral fracture of the lateral malleolus; **2nd degree** = additional fracture of the medial malleolus (bimalleolar); **3rd degree** = additional shearing of the posterior margin of the tibia (**trimalleolar fracture**), as the talus is driven laterally and (if the tibia is carried anteriorly) posteriorly against the tibia.

- ▶ **Optimal position for ankle immobilisation/ankylosis:** slight plantarflexion.
- ▶ **Joint aspiration/injection:** needle inserted between the tendons of extensor hallucis longus and tibialis anterior, with the ankle held in slight plantarflexion.
- ▶ **Tarsal tunnel syndrome:** entrapment of the **tibial nerve** deep to the flexor retinaculum between the medial malleolus and the calcaneus, producing heel/sole pain.
- ▶ **Posterior tibial tendon dysfunction:** chronic failure of tibialis posterior can produce progressive **valgus instability and adult-acquired flatfoot (planovalgus) deformity**.
- ▶ Because of the deep, strong tibiofibular mortise, **frank dislocation of the ankle without associated malleolar fracture is rare**.

High-yield exam pointers

- ▶ Synovial **hinge** joint between tibia + fibula (mortise) above and the **trochlea of the talus** below; the inferior transverse tibiofibular ligament completes the socket posteriorly.
- ▶ Talar trochlea is **wider anteriorly** → **dorsiflexion = close-packed, most stable; plantarflexion = loose, most injury-prone**.
- ▶ **Medial ligament = deltoid** (superficial + deep parts; resists eversion); **lateral ligament = ATFL + PTFL + CFL** (resists inversion); ATFL is the weakest and most commonly torn.
- ▶ Relations: anterior — Tibialis anterior, EHL, vessels, deep peroneal nerve, EDL, peroneus tertius; posteromedial — "**Tom, Dick AND Harry**" (Tibialis posterior, FDL, vessels, tibial Nerve, FHL); posterolateral — peroneus longus and brevis.
- ▶ Movements: dorsiflexion (~10–30°, tibialis anterior) and plantarflexion (~30°, gastrocnemius + soleus) only.
- ▶ Blood supply: malleolar branches of anterior tibial, posterior tibial and fibular arteries. Nerve supply: deep peroneal, tibial, sural, saphenous.
- ▶ Ankle sprain = inversion injury, ATFL torn first; Pott's fracture-dislocation = eversion injury, graded 1st (lateral malleolus) → 2nd (+ medial malleolus) → 3rd/trimalleolar (+ posterior tibial margin).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 (8e); AK Datta's Human Anatomy Vol 3 (Upper & Lower Limb); Moore's Clinically Oriented Anatomy (9e); Vishram Singh — Textbook of Anatomy Vol 2 (4e).



Describe the hip joint in detail

Asked in: Paper I Nov 2018 — RGUHS MD/MS Anatomy

Definition / Introduction The hip joint is a multiaxial **ball-and-socket (spheroidal)** synovial joint between the head of the femur and the cup-shaped acetabulum of the hip bone, forming the sole bony link between the pelvic girdle and the lower limb. Its centre lies a little inferior to the mid-point of the inguinal ligament. Uniquely among the major limb joints it combines a **high degree of both mobility and stability**, the latter being sacrificed in the otherwise-analogous shoulder joint — a trade-off dictated by its weight-bearing role in bipedal stance and gait.

1. Type and articular surfaces

- ▶ **Type:** synovial joint, ball-and-socket (multiaxial spheroidal) variety.
- ▶ **Femoral head:** forms more than half a sphere; covered by hyaline cartilage except at the **fovea capitis**, the rough pit for attachment of the ligament of the head of femur; cartilage is thickest anterolaterally (the principal load-bearing zone).
- ▶ **Acetabulum:** formed by confluence of ilium, ischium and pubis at the **triradiate cartilage**; presents a horseshoe-shaped **lunate (articular) surface** — broadest antero-superiorly where body-weight stress is greatest and narrowest at the pubic region — a non-articular **acetabular fossa** containing fibroelastic fat, and the **acetabular notch** inferiorly.
- ▶ The two surfaces are reciprocally curved but **not co-extensive**; the **acetabular labrum**, a triangular fibrocartilaginous rim, deepens the socket, bridges the notch (as the **transverse acetabular ligament**), and creates a suction/vacuum seal that aids stability, nutrition of cartilage and proprioception.
- ▶ Acetabular anteversion is about 17° (inclined ~45° inferiorly from the horizontal in the coronal plane).

2. Fibrous capsule and synovial membrane

- ▶ A strong, dense fibrous sac. **Proximal (acetabular) attachment:** 5–6 mm beyond the acetabular margin, to the outer aspect of the labrum and the transverse acetabular ligament.
- ▶ **Distal (femoral) attachment:** anteriorly to the **intertrochanteric line** (so the upper femoral epiphysis is entirely intracapsular anteriorly); posteriorly about **1 cm medial to the intertrochanteric crest** (leaving part of the neck extracapsular posteriorly); superiorly to the base of the neck; inferiorly near the lesser trochanter.
- ▶ Thickest and firmly attached **antero-superiorly** (maximal stress in standing); thin and loose **postero-inferiorly**.
- ▶ Two fibre sets: outer **longitudinal fibres** (reflected along the neck as retinacula carrying vessels to the head/neck) and inner circular fibres, the **zona orbicularis**, forming a collar around the neck not directly attached to bone.
- ▶ **Synovial membrane** lines the capsule, the intracapsular neck, both surfaces of the labrum, the transverse ligament, the ligamentum teres, and the fat in the acetabular fossa.

3. Ligaments

Ligament	Attachments	Key feature
Iliofemoral (of Bigelow)	Apex: lower AIIS/acetabular margin → Base: intertrochanteric line	Inverted-Y shape; strongest ligament in the body ; oblique + vertical thick bands with a thin middle part; checks hyperextension and prevents the trunk falling backward in standing
Pubofemoral	Iliopubic eminence, superior pubic ramus, obturator crest/membrane → blends with capsule and medial band of iliofemoral	Triangular; supports joint infero-medially; checks over-abduction and lateral rotation
Ischiofemoral	Ischium postero-inferior to acetabulum → spirals behind the neck to greater trochanter, deep to iliofemoral	Weakest of the three capsular ligaments; its fibres help form the zona orbicularis; checks medial rotation and adduction in extension
Transverse acetabular ligament	Bridges the acetabular notch, continuous with the labrum	Converts the notch into a foramen for acetabular vessels/nerves; devoid of cartilage cells
Ligament of the head of femur (ligamentum teres)	Apex: fovea capitis → Base: margins of acetabular notch, blending with the transverse ligament	Flat, triangular, intracapsular but extrasynovial (ensheathed by synovium); carries the (minor) acetabular vessels to the head; taut in the semi-flexed, adducted, laterally rotated position
Acetabular labrum	Acetabular margin	Fibrocartilaginous, triangular in cross-section; deepens socket, produces a fluid seal (vacuum effect)

4. Relations

Aspect	Structures
Anterior	Femoral vein (medial), femoral artery, and femoral nerve (in the groove between iliacus and psoas major tendon), the tendon of iliopsoas separated from the capsule by the ilipectineal bursa; more laterally, the straight head of rectus femoris and a deep layer of iliotibial tract
Posterior (below upward)	Tendon of obturator externus (covered by quadratus femoris), obturator internus with the gemelli, the sciatic nerve, piriformis, and gluteus maximus

Aspect	Structures
Superior	Reflected head of rectus femoris medially; gluteus minimus (closely adherent) and partly gluteus medius/maximus laterally
Inferior	Medial fibres of pectineus and obturator externus

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Ligaments of the hip joint (anterior and posterior aspect) — label: acetabular margin, iliofemoral ligament (oblique band, vertical band), anterior inferior iliac spine, intertrochanteric line, pubofemoral ligament, obturator membrane/crest, greater trochanter, lesser trochanter, ischiofemoral ligament (posterior view), zona orbicularis, neck of femur, head of femur.

□ Fig 81.5 — Schematic dissection to display the structures surrounding the hip joint (Gray's Anatomy — Standring — 41e, p.1891)

5. Bursae around the hip joint

Seven bursae are described: four related to gluteus maximus — (i) between it and the smooth gluteal surface of ilium, (ii) the **trochanteric bursa** over the greater trochanter, (iii) the ischial bursa over the ischial tuberosity (site of "Weaver's bottom"), (iv) the gluteofemoral bursa between its tendon and vastus lateralis; one deep to gluteus medius over the greater trochanter; one deep to gluteus minimus over the greater trochanter; and the **subsoas (iliopectineal) bursa**, which in about 10% of individuals communicates with the joint cavity through a gap in the capsule between the pubofemoral and iliofemoral ligaments.

6. Blood supply and nerve supply

- ▶ **Arteries:** obturator, medial and lateral circumflex femoral, and the superior and inferior gluteal arteries, which together form the **cruciate and trochanteric anastomoses** around the joint.
- ▶ The **medial circumflex femoral artery** gives the **retinacular arteries** — the chief and most important source of blood to the head and neck of femur — which ascend along the neck within the capsular retinacula.
- ▶ A minor contribution reaches the head near the fovea capitis via the **acetabular branches of the obturator and medial circumflex femoral arteries**, running in the ligament of the head of femur; this route is proportionately more important in children, before the retinacular vessels are fully established across the growth plate.
- ▶ **Lymphatics:** anterior aspect → deep inguinal nodes; medial and posterior aspects → internal iliac nodes (along obturator and gluteal vessels respectively).
- ▶ **Nerve supply** (Hilton's law — nerves crossing a joint also supply it): anterior capsule — femoral nerve (via nerve to rectus femoris), obturator nerve (anterior division), and the accessory obturator nerve when present; posterior capsule — sciatic nerve, superior gluteal nerve, and the nerve to quadratus femoris. Segmentally, L2–L3 mediate flexion/adduction/medial rotation and L4–L5 mediate extension/abduction/lateral rotation.

7. Movements, muscles, and stability

Movement	Chief muscles	Accessory muscles	Approx. range
Flexion	Psoas major, iliacus	Pectineus, rectus femoris, sartorius; adductors (early stage)	110–120°
Extension	Gluteus maximus, hamstrings	Posterior fibres of gluteus medius	~15°
Abduction	Gluteus medius, gluteus minimus	Tensor fasciae latae, sartorius	~50°
Adduction	Adductor longus, brevis, magnus	Pectineus, gracilis	limited by opposite limb
Medial rotation	Anterior fibres of glutei medius and minimus	Tensor fasciae latae	~25°
Lateral rotation	Piriformis, obturator internus/externus, gemelli, quadratus femoris	Gluteus maximus, sartorius	~60°

Circumduction is a composite of these movements. Flexion is checked by contact of the thigh with the anterior abdominal wall; adduction, by contact with the opposite limb. The **close-packed position** (maximal ligamentous tautness/congruence) is full extension with slight abduction and medial rotation; joint capacity for synovial fluid is instead maximal in the semi-flexed, abducted position, which is why a hip effusion is held most comfortably there.

Stability depends on: (i) depth of the acetabulum, narrowed further by the labrum; (ii) the three strong capsular ligaments (iliofemoral, pubofemoral, ischiofemoral); (iii) strength of surrounding muscles, chiefly glutei medius and minimus; (iv) length and obliquity of the femoral neck; and (v) an intra-articular vacuum/suction effect maintained by the labral seal.

Biomechanics: the **neck–shaft (collo-diaphyseal/Mikulicz) angle** averages ~125–135° in the adult (wider, ~150–160°, in infancy, remodelling with weight-bearing) — reduced angles give **coxa vara**, increased angles **coxa valga**. The femoral neck is **anteverted** ~10–15° in the adult relative to the transcondylar axis (as much as 35–40° at birth). Each femoral head normally bears about one-third of body weight in quiet bipedal stance; during the single-limb stance phase of walking, the pull of the abductor muscles (chiefly gluteus medius/minimus) needed to level the pelvis raises the joint reaction force to roughly 2.5–4 times body weight — the basis of the **Trendelenburg mechanism**.

Applied / Clinical anatomy

- **Congenital dislocation of the hip (CDH/DDH):** commonest congenital dislocation of any joint; occurs because the acetabular roof is developmentally shallow/hypoplastic and the capsule is lax at birth, so the femoral head rides up onto the gluteal surface of the ilium. Presents with limited abduction, limb shortening with lateral rotation, asymmetric thigh skin folds, a lurching gait, and a **positive Trendelenburg's sign**.

- ▶ **Trendelenburg's sign:** normally the abductors (glutei medius/minimus, superior gluteal nerve) of the stance limb raise the opposite (swing) side of the pelvis; the sign is positive (pelvis drops on the unsupported side) with a defect of **power** (glutei medius/minimus paralysis), **fulcrum** (CDH or pathological dislocation), or **weight-bearing lever** (ununited fracture neck of femur).
- ▶ **Perthes' disease (pseudocoxalgia):** avascular necrosis/flattening of the femoral head epiphysis in children, with a radiographically widened joint space.
- ▶ **Coxa vara / coxa valga:** decreased or increased neck–shaft angle respectively; coxa vara limits abduction (seen after fracture neck of femur or rickets); coxa valga limits adduction (seen in CDH).
- ▶ **Hip disease by age:** below 5 years — CDH, tuberculosis; 5–10 years — Perthes' disease; 10–20 years — coxa vara; above 40 years — osteoarthritis.
- ▶ **Dislocation of the hip:** posterior (commonest, ~90%; the flexed-adducted-medially-rotated hip is unstable and the femoral head is driven backward through the thin postero-inferior capsule, e.g. in the "dashboard injury" — risks the sciatic nerve), anterior (less common), and central (rare, through a fractured acetabular floor).
- ▶ **Fracture neck of femur:** commonest in elderly, osteoporotic females after trivial trauma; classified as **intracapsular** (subcapital, transcervical) or **extracapsular** (basal, intertrochanteric, subtrochanteric). Intracapsular fractures tear the retinacular vessels, risking **avascular necrosis, delayed/non-union**; the limb is classically shortened and laterally rotated (psoas major becomes an unopposed lateral rotator once the shaft loses continuity with the head).
- ▶ **Radiological landmarks:** **Shenton's line** — the continuous curve formed by the upper border of the obturator foramen and the lower border of the femoral neck, disrupted in fracture or dislocation; **Schoemaker's line** (greater trochanter to ASIS, extended to the umbilicus) and **Nelaton's line/Bryant's triangle** detect supratrochanteric shortening. **Ward's triangle** (cancellous bone in the head) and the **calcar femorale** are surface-anatomy correlates of load transmission seen on radiographs.
- ▶ **Weaver's bottom:** chronic inflammation/enlargement of the ischial (subgluteal) bursa from prolonged sitting.
- ▶ **Referred pain:** hip disease (e.g. tuberculosis, osteoarthritis) commonly refers pain to the knee via the shared obturator/femoral nerve supply of both joints; true hip pain is felt deep in the groin.
- ▶ **Aspiration of the hip joint:** anteriorly, a needle is passed 5 cm below the mid-inguinal point/ASIS, upward, backward and medially; or laterally, from the posterior edge of the greater trochanter parallel to the femoral neck.
- ▶ **Osteoarthritis:** degenerative joint disease of old age with osteophyte formation, joint-space narrowing and painful, grating restricted movement; may also follow femoro-acetabular impingement from labral/chondrolabral injury.
- ▶ **Surgical hip replacement (arthroplasty):** the diseased acetabulum and femoral head/neck are replaced by prosthetic components — the definitive treatment for advanced osteoarthritis, femoral neck fracture with avascular necrosis, and failed conservative management.

High-yield exam pointers

- ▶ Ball-and-socket synovial (multiaxial spheroidal) joint; its centre lies just below the mid-inguinal point.
- ▶ **Iliofemoral ligament (Bigelow's)** = strongest ligament in the body; prevents backward fall of the trunk in standing.
- ▶ Chief blood supply to the femoral head/neck = **retinacular arteries** from the medial circumflex femoral artery; the ligamentum teres route is minor but clinically important in children.
- ▶ Close-packed position = full extension + slight abduction + medial rotation; maximum joint capacity (best position for an effusion) = flexion + abduction.
- ▶ **Posterior dislocation** is commonest (~90%) and endangers the sciatic nerve; the limb lies shortened, adducted, flexed and medially rotated.
- ▶ **Intracapsular** fracture neck of femur risks avascular necrosis (retinacular vessel damage); the limb is shortened and laterally rotated.
- ▶ **Trendelenburg's sign** — positive with defects of power (glutei medius/minimus), fulcrum (CDH), or lever/weight (united fracture neck of femur).
- ▶ **Shenton's line** is disrupted in fracture neck of femur or hip dislocation.
- ▶ Neck-shaft angle ~125–135° (adult); femoral neck anteversion ~10–15° (adult), up to 35–40° at birth.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 (Lower Limb) 8e; Vishram Singh Textbook of Anatomy Vol 2 4e.



Describe the knee joint and discuss the role of the ligaments of the knee joint. Add a note on the recent advances in the visualization of the Knee joint

Asked in: Paper I May 2007 — RGUHS MD/MS Anatomy

Definition / Introduction The knee is the largest and most complex synovial joint in the body, formed by fusion of three articulations — the medial and lateral **femorotibial (condylar) joints** and the intervening **femoropatellar (sellar) joint** — within one capsule. Functionally a modified hinge (condylar) joint, it combines a large flexion-extension range with the ability to bear two to four times body weight, a conflict resolved chiefly by its ligaments, menisci and crossing muscles rather than by bony congruity. Because the femoral and tibial surfaces are relatively incongruent, the knee sacrifices bony stability for mobility and is correspondingly ligament-dependent.

Type and articular surfaces

Component	Articulating surfaces	Type
Medial femorotibial	Medial femoral condyle — medial tibial condyle (+ medial meniscus)	Condylar (synovial)
Lateral femorotibial	Lateral femoral condyle — lateral tibial condyle (+ lateral meniscus)	Condylar (synovial)
Femoropatellar	Patellar articular surface — femoral (trochlear) surface	Sellar (saddle) synovial

- ▶ The joint cavity is partially divided by the menisci into an **upper compartment** (flexion–extension) and a **lower compartment** (rotation).
- ▶ Articular cartilage is thickest on the patella, reflecting the large compressive loads generated during activities such as running.

Fibrous capsule, synovial membrane and bursae

- ▶ The **fibrous capsule** is thin and deficient anteriorly (replaced by the quadriceps tendon, patella and patellar ligament); reinforced by the patellar retinacula, the iliotibial tract laterally, sartorius/semimembranosus expansions medially, and the **oblique popliteal ligament** posteriorly.
- ▶ The **synovial membrane**, the most extensive in the body, forms the **suprapatellar bursa** and is reflected forward off the posterior capsule by the cruciate ligaments (so the intercondylar posterior capsule has no synovial covering); the **infrapatellar fat pad** and alar/infrapatellar folds lie deep to the patellar ligament.
- ▶ **Bursae (~12)**: 4 anterior (suprapatellar, prepatellar, subcutaneous & deep infrapatellar), 4 lateral (deep to lateral gastrocnemius; between fibular collateral ligament and biceps femoris; between it and popliteus; between popliteus and lateral tibial condyle) and 4 medial (deep to medial gastrocnemius; anserine bursa; deep to tibial collateral ligament; deep to semimembranosus).
- ▶ Clinically important: prepatellar bursitis ("**housemaid's knee**"), infrapatellar bursitis ("**clergyman's knee**"), anserine and semimembranosus bursitis.

Ligaments of the knee joint and their role

The ligaments are the principal restraints of the knee; testing joint laxity shows some ligaments are better aligned to resist a given displacement (**primary restraints**) while others contribute a lesser, backup effect (**secondary restraints**).

Ligament	Attachments	Role / stabilizing function
Patellar ligament	Apex of patella → tibial tuberosity	Transmits quadriceps pull; extensor mechanism
Tibial (medial) collateral ligament	Medial epicondyle of femur → medial tibial shaft, blending with medial meniscus	Primary restraint vs valgus strain; its tears often co-injure the meniscus
Fibular (lateral) collateral ligament	Lateral epicondyle of femur → fibular head (cord-like)	Primary restraint vs varus strain
Oblique popliteal ligament	Semimembranosus expansion across posterior capsule	Reinforces posterior capsule; checks hyperextension
Arcuate popliteal ligament	Fibular head, over popliteus, to posterior intercondylar area	Reinforces posterolateral capsule
Popliteofibular ligament	Popliteus tendon → fibular head	Chief stabilizer of the posterolateral corner ; resists tibial lateral rotation
Anterior cruciate ligament (ACL)	Anterior intercondylar area of tibia → posteromedial lateral femoral condyle ($\approx 38 \times 11$ mm)	Primary restraint vs anterior tibial translation; taut in extension; pivot for rotation
Posterior cruciate ligament (PCL)	Posterior intercondylar area of tibia → lateral surface of medial femoral condyle ($\approx 38 \times 13$ mm; thicker/stronger than ACL)	Primary restraint vs posterior tibial translation; taut in flexion
Transverse ligament	Anterior horn, lateral meniscus → anterior horn, medial meniscus	Links the anterior meniscal horns
Meniscomfemoral ligaments (Humphrey/Wrisberg)	Posterior horn, lateral meniscus → medial femoral condyle	Secondary restraints supporting the PCL; control lateral-meniscus posterior-horn mobility

- In sum: cruciates → **anteroposterior stability**, collaterals → **mediolateral stability**, capsular thickenings (oblique popliteal, arcuate, popliteofibular) reinforce the posterior/posterolateral corners, and the iliotibial tract adds a lateral dynamic stabilizer.
- In terminal extension the collaterals and parts of both cruciates tauten, contributing to the **screw-home locking mechanism** (below); in flexion the cruciates stay taut while the collaterals relax, allowing a small range of adjunct rotation.



Describe the knee joint and discuss the role of the ligaments of the knee joint. Add a note on the recent advances in the visualization of the Knee joint

- Fig 7.93 — Articular surfaces, cruciate ligaments, and synovial cavity of knee joint (Moore — Clinically Oriented Anatomy — 9e, p.1298)

Menisci (semilunar cartilages)

- ▶ Two crescentic fibrocartilaginous discs deepening the tibial surfaces for the femoral condyles.
- ▶ **Medial meniscus:** nearly semicircular, wider posteriorly, firmly bound to the deep tibial collateral ligament and capsule — relatively fixed and **more commonly torn**.
- ▶ **Lateral meniscus:** nearly circular, separated from the fibular collateral ligament by popliteus; more mobile via its menisiofemoral-ligament/popliteus attachments — popliteus retracts it in flexion, **protecting it from injury**.
- ▶ Peripheral one-third is vascular ("red zone") and heals after tears; the avascular inner two-thirds, nourished only by synovial fluid, rarely heals and is usually resected.
- ▶ Functions: improve congruence, shock absorption, lubrication, proprioception, and convert axial load into hoop stress — hence osteoarthritis is common after meniscectomy.

Movements and the locking–unlocking (screw-home) mechanism

Movement	Principal muscles
Flexion	Biceps femoris, semitendinosus, semimembranosus (assisted by gracilis, sartorius, popliteus; gastrocnemius/plantar when foot fixed)
Extension	Quadriceps femoris (assisted by tensor fasciae latae)
Locking (terminal extension)	Vastus medialis
Unlocking (initial flexion)	Popliteus
Medial rotation of flexed leg	Popliteus, semimembranosus, semitendinosus
Lateral rotation of flexed leg	Biceps femoris

- ▶ Range: extension 5–10° beyond neutral; active flexion ≈120° (hip extended), 140° (hip flexed), up to 160° passively.
- ▶ **Screw-home mechanism:** the lateral femoral condyle's smaller articular arc is "used up" before the medial during extension, so the femur rotates medially on the remaining medial condylar surface (equivalently, with the foot fixed, the tibia rotates laterally on the femur) in the last ~20–30° of extension. This **conjunct rotation locks the fully extended knee**, tautening collaterals and cruciates so standing needs minimal quadriceps effort; popliteus unlocks the joint by reversing the rotation at the onset of flexion.

Blood and nerve supply

- ▶ **Arterial supply** — the genicular anastomosis around the knee: five genicular branches of the popliteal artery (superior medial, superior lateral, inferior medial, inferior lateral, middle), the descending genicular branch of the femoral artery, the descending branch of the lateral circumflex femoral artery, two recurrent branches of the anterior tibial artery, and the circumflex fibular branch of the posterior tibial artery.
- ▶ **Nerve supply** (Hilton's law) — femoral nerve (chiefly via its branch to vastus medialis), sciatic nerve (via genicular branches of the tibial and common fibular nerves), and the posterior division of the obturator nerve.

- Lymphatics drain to the **popliteal nodes**.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Superior view of the right tibial plateau, showing the menisci and the tibial attachments of the cruciate ligaments (quick to draw, carries the highest label-density for marks):

- Tibial tuberosity
- Medial tibial condyle (articular facet)
- Lateral tibial condyle (articular facet)
- Intercondylar eminence (medial + lateral tubercles)
- Attachment of anterior horn, medial meniscus
- Attachment of posterior horn, medial meniscus
- Attachment of anterior horn, lateral meniscus
- Attachment of posterior horn, lateral meniscus
- Attachment of anterior cruciate ligament
- Attachment of posterior cruciate ligament
- Transverse ligament (joining the anterior horns)
- Facet for the head of the fibula (posterolateral)

Imaging and visualization of the knee joint

- **Plain radiographs** — AP/lateral views for the tibiofemoral joint and growth plates; **skyline (sunrise)** view for the patellofemoral joint; **tunnel (notch)** view for the intercondylar area.
- **Ultrasonography** — quick, dynamic, radiation-free look at superficial structures: patellar ligament, collateral ligaments, quadriceps tendon, effusions and bursae (e.g. a Baker's/popliteal cyst).
- **Magnetic resonance imaging (MRI)** — now the modality of choice for the soft-tissue knee: T1-, T2- and proton-density-weighted sequences directly visualize the menisci and the cruciate/collateral ligaments, and grade meniscal tears and ligament ruptures pre-operatively.
- **Arthroscopy** — an endoscopic technique giving direct visualization of the joint interior through small portal incisions; diagnostic (meniscal tear, ligament rupture, discoid meniscus) and therapeutic (meniscectomy/repair, ACL/PCL reconstruction, debridement, loose-body removal) in one sitting.
- **CT/CT-arthrography** — reserved for detailed bony assessment (fracture, tunnel placement after ligament reconstruction) when MRI is unsuitable.
- Because the synovial fold around the cruciate ligaments effectively separates the medial and lateral femorotibial compartments, arthroscopic and MRI reporting now visualizes and grades each compartment individually rather than the joint as a single unit — refining conservative versus arthroscopic/reconstructive decision-making.

□ Fig 82.9 — Left knee joint, T1-weighted coronal MRI: 1 posterior cruciate ligament, 2 tibial collateral ligament, 3 medial meniscus, 4 lateral meniscus, 5 fibular collateral ligament, 6 anterior cruciate ligament (Gray's Anatomy — Standring — 41e, p.1906)

Applied / Clinical anatomy

- ▶ **"Unhappy triad"** — a valgus strain on the flexed, planted knee tears the tibial collateral ligament, the medial meniscus (firmly attached to it) and the ACL together.
- ▶ **ACL rupture** — from hyperextension or anterior force on a semiflexed knee (skiing, sudden deceleration); gives the **anterior drawer sign**, tested clinically by the **Lachman test**.
- ▶ **PCL rupture** — from a posteriorly directed blow on the flexed knee/tibial tuberosity ("dashboard injury"); gives the **posterior drawer sign**.
- ▶ **Collateral ligament tears** — from severe abduction (tibial collateral ligament) or adduction (fibular collateral ligament) strain; the medial meniscus often tears along with the tibial collateral ligament.
- ▶ **Meniscal tears** — bucket-handle (longitudinal) or transverse, commoner medially; pain on medial tibial rotation suggests a medial tear, on lateral rotation a lateral tear; peripheral (vascular) tears may be repaired arthroscopically, central tears are usually resected.
- ▶ **Genu valgum (knock-knee) / genu varum (bow-knee)** — abnormal thigh-leg axis from rickets, posture or congenital causes.
- ▶ **Osteoarthritis** — cartilage degeneration with osteophytes; may follow meniscectomy owing to increased peak contact stress.
- ▶ **Baker's (popliteal) cyst** — synovial herniation through the posterior capsule, usually secondary to osteoarthritis/effusion.
- ▶ **Knee aspiration** — via the suprapatellar bursa or either side of the patella; in knee-joint disease, **vastus medialis is the first muscle to atrophy and the last to recover**.
- ▶ **Patellofemoral instability** — related to the Q angle (12–15° males, 15–18° females) and weakness of vastus medialis obliquus, the dynamic medial stabilizer of the patella.

High-yield exam pointers

- ▶ Knee = largest, most complex synovial joint; three articulations (2 femorotibial + 1 femoropatellar) in one capsule.
- ▶ Cruciates → anteroposterior stability; collaterals → mediolateral stability; popliteofibular ligament → chief posterolateral stabilizer.
- ▶ ACL taut in extension (resists anterior translation); PCL taut in flexion (resists posterior translation); PCL thicker/stronger, ruptures less often.
- ▶ Medial meniscus fixed and more often torn; lateral meniscus mobile (protected by popliteus) and rarely torn.
- ▶ Screw-home mechanism: terminal-extension conjunct rotation locks the knee (vastus medialis); popliteus unlocks it.
- ▶ "Unhappy triad" = tibial collateral ligament + medial meniscus + ACL injured together.
- ▶ MRI is now the imaging modality of choice for menisci/ligaments; arthroscopy gives direct diagnostic-cum-therapeutic visualization.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Moore's Clinically Oriented Anatomy 9e; IB Singh's Textbook of Anatomy Vol 1 6e; Vishram Singh's Textbook of Anatomy Vol 2 4e (figure reference).



Femoral artery

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction

The femoral artery is the principal arterial channel of the lower limb, a direct continuation of the external iliac artery. It begins behind the inguinal ligament at the mid-inguinal point (midway between the anterior superior iliac spine and the pubic symphysis), traverses the femoral triangle and the adductor (subsartorial) canal, and ends at the adductor hiatus by becoming the popliteal artery. Because its proximal 3–4 cm lie superficially within the femoral sheath, it is the most commonly accessed peripheral artery for palpation, compression, cannulation and angiography, and it is developmentally distinct from the primitive axial artery of the limb (which is represented by the inferior gluteal artery).

Origin, extent and termination

- ▶ **Origin:** Continuation of the **external iliac artery**, beginning behind the inguinal ligament at the **mid-inguinal point**.
- ▶ **Course:** Descends downward and medially, first through the **femoral triangle**, then through the **adductor (subsartorial) canal**.
- ▶ **Termination:** At the junction of the middle and distal thirds of the thigh it passes through the **adductor hiatus** (an opening in adductor magnus) to become the **popliteal artery** in the popliteal fossa.
- ▶ Its first 3–4 cm are enclosed, together with the femoral vein, within the **femoral sheath**.
- ▶ Rarely, the artery divides distal to the origin of profunda femoris into two trunks that reunite near the adductor opening; very rarely the inferior gluteal artery (persistent axial artery) replaces a hypoplastic distal external iliac/femoral artery.

Femoral triangle — relations of the artery

Boundary/plane	Structure
Base	Inguinal ligament
Lateral boundary	Medial border of sartorius
Medial boundary	Medial border of adductor longus
Apex	Where sartorius crosses over adductor longus
Roof	Fascia lata (pierced by saphenous opening structures)

Boundary/plane	Structure
Floor	Iliopsoas laterally, pectineus and adductor longus medially

Relations of the femoral artery within the triangle:

Relation	Structures
Anterior	Skin, superficial fascia, deep fascia, anterior wall of the femoral sheath; superficial circumflex iliac vein and femoral branch of genitofemoral nerve cross here; medial femoral cutaneous nerve crosses in front near the apex
Posterior	Psoas major, pectineus, adductor longus — separated from the artery by the posterior wall of the femoral sheath
Medial	Femoral vein at the base of the triangle (crosses to lie posterior at the apex)
Lateral	Femoral nerve (outside the femoral sheath) proximally; its branches more distally

The **femoral sheath** is a funnel-shaped downward prolongation of the transversalis fascia (anteriorly) and iliac fascia (posteriorly), divided into three compartments: **lateral** (femoral artery), **intermediate** (femoral vein) and **medial** (femoral canal, containing lymphatics ± a lymph node — the potential site of femoral hernia).

Course through the adductor canal

- ▶ The artery enters the canal at the apex of the femoral triangle, deep to sartorius.
- ▶ **Relations:** the saphenous nerve lies at first lateral, then crosses anteriorly, and finally lies medial to the artery; the nerve to vastus medialis is anterolateral; the femoral vein lies posterior proximally and becomes posterolateral/lateral distally; adductor longus and adductor magnus lie posteriorly.
- ▶ The artery gives off the **descending genicular artery** (its last branch) just proximal to the adductor hiatus, then leaves the canal through the hiatus to become the popliteal artery.

Branches

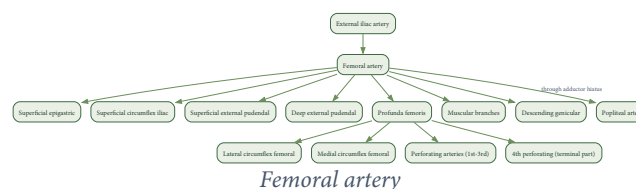
The femoral artery gives off **three superficial and three deep branches** in the femoral triangle, plus the descending genicular artery in the adductor canal.

Branch	Origin/course	Distribution
Superficial epigastric	Arises ~1 cm distal to the inguinal ligament, pierces cribriform fascia, ascends toward the umbilicus	Superficial inguinal nodes, subcutaneous tissue, skin of lower abdominal wall
Superficial circumflex iliac	Smallest superficial branch; runs laterally toward the ASIS	Skin/subcutaneous tissue over the iliac crest; basis of the groin flap

Branch	Origin/course	Distribution
Superficial external pudendal	Passes medially, deep to the long saphenous vein	Skin of scrotum/labium majus, lower abdominal wall
Deep external pudendal	Passes medially across pectineus, deep to fascia lata	Skin of perineum, scrotum/labium majus
Profunda femoris (deep artery of thigh)	Largest branch; arises posterolaterally ~3.5–4 cm distal to the inguinal ligament	Chief arterial supply to all three compartments of the thigh (see below)
Muscular branches	Direct branches to the medial thigh muscles	Sartorius, vastus medialis, adductors
Descending genicular	Last branch, arises just proximal to the adductor hiatus, gives a saphenous branch	Vastus medialis, adductor magnus, articular contribution to the peri-patellar/genicular anastomosis

Profunda femoris artery and its branches

- Arises from the posterolateral aspect of the femoral artery, spirals posteriorly to reach the medial side of the femur, passing between pectineus/adductor longus and then adductor longus/adductor brevis, finally piercing adductor magnus to anastomose with muscular branches of the popliteal artery (its terminal part is sometimes termed the **fourth perforating artery**).
- **Lateral circumflex femoral artery:** passes between the anterior and posterior divisions of the femoral nerve, deep to sartorius and rectus femoris; divides into **ascending** (to the greater trochanter, anastomoses with superior gluteal and deep circumflex iliac), **transverse** (joins the cruciate anastomosis) and **descending** (supplies vastus lateralis, anastomoses with the superior lateral genicular artery) branches.
- **Medial circumflex femoral artery:** usually the larger of the two; passes between pectineus/psoas major and then obturator externus/adductor brevis; gives an acetabular branch and ascending/transverse branches; is the chief supply to the **head and neck of femur** via the retinacular vessels of the trochanteric anastomosis.
- **Three (occasionally four) perforating arteries:** pierce adductor magnus close to the linea aspera to supply the adductors, hamstrings and vasti, forming a chain of anastomoses down the back of the thigh.



DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Because a genuine matching plate is available in the library, embed it directly:

embed: ![Fig 23.19 — Femoral artery in femoral triangle (IB Singh — Textbook of Anatomy Vol 1 — 6e, p.329)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/1b87db80acc6c130.jpg)

For hand reproduction in the exam, draw the **femoral triangle** (inverted triangle: base = inguinal ligament, lateral side = sartorius, medial side = adductor longus, apex = crossing point of sartorius over adductor longus) and label, from lateral to medial:

- ▶ **Femoral nerve** (outside the femoral sheath)
- ▶ **Femoral artery** (lateral compartment of the sheath), with its three superficial branches (superficial epigastric, superficial circumflex iliac, superficial external pudendal) arising anteriorly, and the **profunda femoris artery** arising posterolaterally
- ▶ **Femoral vein** (intermediate compartment)
- ▶ **Femoral canal** (medial compartment, with a lymph node)
- ▶ Floor muscles: iliopsoas (lateral), pectineus and adductor longus (medial)
- ▶ Mark the **mid-inguinal point** (surface marking of the artery's origin) at the base

Applied / Clinical anatomy

- ▶ **Surface marking:** The femoral artery is represented by the upper two-thirds of a line from the **mid-inguinal point** to the **adductor tubercle**, with the thigh slightly flexed, abducted and laterally rotated.
- ▶ **Palpation and compression:** Pulsation is felt at the mid-inguinal point, where the artery lies directly over the femoral head and the psoas tendon; this is also the site for compressing the artery (against the superior pubic ramus/femoral head) to control haemorrhage from the thigh or leg.
- ▶ **Cannulation and angiography:** Because the proximal artery is superficial and fixed over bone, it is the standard site for arterial puncture/catheterisation — retrograde catheters passed via the external iliac artery, aorta and into the left ventricle for cardiac and coronary angiography, and for arterial blood gas sampling.
- ▶ **"Superficial femoral artery" — a discouraged misnomer:** some clinicians still call the segment distal to profunda femoris the "superficial femoral artery"; this term is rejected by Terminologia Anatomica because the vessel is in fact deep, and its use has led to dangerous under-recognition of deep venous thrombosis in the corresponding "superficial femoral vein."
- ▶ **Ligation and collateral circulation:** The femoral artery is superficial in the triangle and can be easily exposed for ligation. If ligated proximal to the origin of profunda femoris, the limb is still perfused through five collateral pathways: (i) superior/inferior gluteal ↔ medial/lateral circumflex femoral ↔ first perforating artery (the **trochanteric** and **cruciate anastomoses**); (ii) obturator ↔ medial circumflex femoral; (iii) internal pudendal ↔ superficial/deep external pudendal; (iv) deep circumflex iliac ↔ lateral circumflex femoral ↔ superficial circumflex iliac; (v) inferior gluteal ↔ perforating arteries of profunda femoris.

- ▶ **Trauma:** The artery's superficial position in the triangle makes it vulnerable to laceration; the femoral artery, vein and profunda vessels lie almost in one anteroposterior line at the apex of the triangle, so a stab wound there may transect all the major vessels of the limb, causing fatal haemorrhage.
- ▶ **Absent/feeble femoral pulse:** Suggests proximal occlusion — coarctation of the aorta (classically radiofemoral delay) or iliofemoral thrombosis/atherosclerosis; loss of the more distal popliteal/posterior tibial pulses with intermittent claudication indicates peripheral arterial occlusive disease, in which the profunda femoris–perforating chain and the genicular anastomosis act as vital collaterals.
- ▶ **Femoral hernia:** Passes through the femoral canal (the medial, most compressible compartment of the femoral sheath), presenting inferolateral to the pubic tubercle — distinguishing it from an inguinal hernia; the femoral artery forms the lateral relation/limit of the femoral ring.
- ▶ **Embalming:** The femoral artery is a standard cannulation site for injecting embalming fluid into the lower limb.
- ▶ **Vascular anatomy of the femoral head:** The retinacular branches of the medial circumflex femoral artery (via the trochanteric anastomosis) are the dominant supply to the femoral head/neck; disruption in intracapsular femoral neck fractures or dislocation predisposes to avascular necrosis.

High-yield exam pointers

- ▶ Continuation of the **external iliac artery**; begins at the **mid-inguinal point**; ends at the **adductor hiatus** as the popliteal artery.
- ▶ Passes through the **femoral triangle** then the **adductor canal**; surface marking = upper 2/3 of a line from mid-inguinal point to adductor tubercle.
- ▶ **3 superficial + 3 deep branches** in the triangle; **profunda femoris** is the largest branch and chief supplier of the thigh.
- ▶ Profunda femoris gives **medial and lateral circumflex femoral arteries + 3 perforating arteries** ($\pm$ terminal 4th).
- ▶ **Medial circumflex femoral** dominates supply to the femoral head/neck (retinacular vessels) — clinically vital in femoral neck fracture/AVN.
- ▶ **Trochanteric anastomosis** (near trochanteric fossa) and **cruciate anastomosis** (at level of lesser trochanter) are the key collateral pathways after proximal occlusion/ligation.
- ▶ Femoral vein relation changes: medial at the base of the triangle $\rightarrow$ posterior at the apex $\rightarrow$ posterolateral/lateral in the adductor canal.
- ▶ Clinically important site for **palpation, compression, and cannulation/angiography**; "superficial femoral artery" is an anatomically incorrect but persisting clinical term.
- ▶ Related to **femoral hernia** (through the femoral canal, medial compartment of the femoral sheath).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 8e; Moore's Clinically Oriented Anatomy 9e; AK Datta Human Anatomy Vol 3 (Upper & Lower Limb); IB Singh Textbook of Anatomy Vol 1 6e; Vishram Singh Textbook of Anatomy Vol 2 4e.



Intra capsular ligaments of knee joint

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction The knee (tibiofemoral + patellofemoral) is the largest and most complex synovial joint in the body — a condylar variety of synovial joint that also permits a small arc of axial rotation. Its ligaments are conventionally divided into an **extracapsular** group (lying outside the fibrous capsule — ligamentum patellae, tibial and fibular collateral ligaments, oblique and arcuate popliteal ligaments) and an **intracapsular** group, which lies within the fibrous capsule but, because the synovial membrane reflects around them, is itself **extrasynovial** (i.e. excluded from the true joint cavity). The intracapsular ligaments are the **anterior and posterior cruciate ligaments, the transverse ligament of the knee, the two meniscomfemoral ligaments and the coronary (meniscotibial) ligaments**, together with the two intracapsular fibrocartilages — the **medial and lateral menisci** — to which most of them attach.

Classification of the ligaments of the knee joint

Group	Ligaments	Relation to synovium
Extracapsular	Ligamentum patellae; tibial (medial) collateral ligament; fibular (lateral) collateral ligament; oblique popliteal ligament; arcuate popliteal ligament	Outside the capsule
Intracapsular (extrasynovial)	Anterior cruciate ligament (ACL); posterior cruciate ligament (PCL); transverse ligament of the knee; anterior & posterior meniscomfemoral ligaments; coronary (meniscotibial) ligaments	Inside the fibrous capsule, but excluded from the synovial cavity
Intracapsular fibrocartilages	Medial and lateral menisci	Deep (articular) surfaces bare of synovium; peripheral rim covered

Synovial relations — why the cruciates are "intracapsular but extrasynovial"

The synovial membrane lines the fibrous capsule but, posteriorly, is reflected forward from the roof and sides of the intercondylar fossa to invest the two cruciate ligaments almost completely, carrying a common fold anteriorly to the menisci. As a result, the intercondylar part of the posterior fibrous

capsule has no synovial covering, and the cruciate ligaments — although they lie deep within the capsule — remain outside the true synovial cavity, exactly as an intraperitoneal organ is covered by, but not open into, peritoneum. The **ligamentum mucosum (infrapatellar synovial fold/plica)** is the synovial counterpart of this arrangement anteriorly: the alar folds flanking the infrapatellar fat pad converge into a single median fold that curves back to the intercondylar fossa immediately anterior to the ACL, and — when well developed — can be mistaken arthroscopically for the ACL itself.

Anterior cruciate ligament (ACL)

- ▶ **Tibial attachment:** anterior intercondylar area of the tibia, just anterior and slightly lateral to the medial intercondylar tubercle, blending partly with the anterior horn of the lateral meniscus.
- ▶ **Course:** ascends posterolaterally, twisting on itself and fanning out as it rises.
- ▶ **Femoral attachment:** high on the posteromedial aspect of the lateral femoral condyle.
- ▶ **Dimensions:** average length 38 mm, width 11 mm.
- ▶ **Bundles:** two (possibly three) functional bundles — anteromedial, intermediate and posterolateral — named from their tibial attachments; not separable to the naked eye.
- ▶ **Function:** taut in extension; the principal (primary) restraint against anterior displacement of the tibia on the femur and against hyperextension/rotational stress.

Posterior cruciate ligament (PCL)

- ▶ **Tibial attachment:** posterior intercondylar area of the tibia.
- ▶ **Course:** ascends anteromedially (upward, forward and medially).
- ▶ **Femoral attachment:** lateral surface of the medial femoral condyle, extending on to the anterior part of the roof of the intercondylar fossa (an anteroposteriorly extensive attachment).
- ▶ **Dimensions:** average length 38 mm, width 13 mm — **thicker and stronger** than the ACL.
- ▶ **Bundles:** anterolateral bundle (tight in flexion) and posteromedial bundle (tight in extension), named — unlike the ACL — from their **femoral** attachments; each slackens as the other tightens, so the PCL, unlike the ACL, is not isometric through knee motion.
- ▶ **Function:** taut in flexion; the primary restraint against posterior displacement of the tibia. Ruptures less often than the ACL and is generally better tolerated clinically.

Menisci — the intracapsular fibrocartilages

The menisci are crescentic, wedge-shaped fibrocartilaginous laminae that deepen the tibial articular surfaces for the femoral condyles, each with an anterior and a posterior "horn," a thick convex peripheral border (attached to the capsule) and a thin concave free inner border.

Feature	Medial meniscus	Lateral meniscus
Shape	Nearly semicircular (C-shaped), broader posteriorly	Forms about four-fifths of a circle, more uniform breadth
Anterior horn	Tibial intercondylar area in front of the ACL; posterior fibres continuous with the transverse ligament	In front of the intercondylar eminence, posterolateral to the ACL, partly blending with it

Feature	Medial meniscus	Lateral meniscus
Posterior horn	Posterior intercondylar area, between the lateral meniscus and PCL attachments	Behind the intercondylar eminence; commonly attached only via the meniscomfemoral ligament(s) — no peripheral bony attachment here (the "popliteus hiatus")
Peripheral/tibial attachment	Firmly bound to the capsule and the deep part of the tibial collateral ligament (coronary ligament)	Grooved posterolaterally by popliteus, which separates it from the fibular collateral ligament; loose coronary attachment
Mobility	Relatively fixed — moves much less	More mobile — moved by popliteus and the meniscomfemoral ligaments
Vascularity	Peripheral one-third vascularized by capillary loops from the capsule/synovium; inner two-thirds avascular, nourished by synovial fluid	Same pattern

Coronary (meniscotibial) ligaments

The weak, lax anterior part of the fibrous capsule between the inferior border of each meniscus and the tibial condylar margin is termed the coronary ligament — the tibial attachment of both menisci.

Transverse ligament of the knee

Connects the anterior convex margin of the lateral meniscus to the anterior horn of the medial meniscus. It varies considerably in thickness and is often absent; when present it is slightly taut in extension and is thought to reduce tension generated in the circumferential fibres of the menisci under load.

Meniscomfemoral ligaments

Two small but strong bands connect the **posterior horn of the lateral meniscus to the lateral aspect of the medial femoral condyle**, running alongside the PCL:

- ▶ **Anterior meniscomfemoral ligament (ligament of Humphrey)** — passes anterior to the PCL.
- ▶ **Posterior meniscomfemoral ligament (ligament of Wrisberg)** — passes posterior to the PCL, attaching just proximal to the PCL's femoral attachment.

At least one is almost always present (occasionally both coexist); their cross-sectional area and strength are comparable to the posterior fibre bundle of the PCL. Functionally they act as **secondary restraints**, supporting the PCL against posterior tibial displacement, and — together with popliteus — control the mobility of the posterior horn of the lateral meniscus.

□ Fig 7.93 — Articular surfaces, cruciate ligaments, and synovial cavity of knee joint (Moore — Clinically Oriented Anatomy — 9e, p.1298)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Superior view of the right tibial plateau (intercondylar area), labelling:

- ▶ Medial tibial condyle / articular facet
- ▶ Lateral tibial condyle / articular facet
- ▶ Intercondylar eminence with medial and lateral tubercles
- ▶ Anterior horn, medial meniscus
- ▶ Anterior horn, lateral meniscus
- ▶ Posterior horn, medial meniscus
- ▶ Posterior horn, lateral meniscus
- ▶ Tibial attachment of ACL (anterior intercondylar area)
- ▶ Tibial attachment of PCL (posterior intercondylar area)
- ▶ Transverse ligament (joining the two anterior horns)
- ▶ Anterior meniscomfemoral ligament (of Humphrey) and posterior meniscomfemoral ligament (of Wrisberg) — drawn running from the posterior horn of the lateral meniscus toward the medial femoral condyle, anterior and posterior to the PCL respectively

Applied / Clinical anatomy

- ▶ **ACL injury:** typically a non-contact pivoting/deceleration sports injury. Laxity is tested by the **anterior drawer test** — patient supine, knee flexed to 80–90°, passive anterior traction applied to the tibia (a modification, the Lachman test, uses 20–30° flexion, standard bedside practice). Because the ACL is the primary restraint to anterior tibial translation, its rupture forces the tibial collateral ligament to act as an overloaded secondary restraint, predisposing it to secondary failure.
- ▶ **ACL/PCL reconstruction grafts:** the **middle third of the patellar ligament** (bone–patellar tendon–bone graft) or the **hamstring tendons (gracilis and semitendinosus)**, both harvested during cruciate reconstruction, are the standard autograft sources — both structures lie immediately superficial to the cruciate ligaments in the medial soft-tissue layers of the knee.
- ▶ **PCL injury:** classically a "dashboard injury" — a posteriorly directed blow on the proximal tibia with the knee flexed (e.g. in a road-traffic accident); assessed by the posterior drawer test. PCL rupture is less common and better tolerated than ACL rupture because the meniscomfemoral ligaments act as effective secondary restraints.
- ▶ **Meniscal tears:** peripheral (vascularized) tears can heal, especially with surgical repair; tears in the avascular inner two-thirds seldom heal spontaneously and often require (partial) meniscectomy. Because the menisci spread load and reduce contact pressure, meniscectomy concentrates load onto a smaller area of articular cartilage and predisposes to premature osteoarthritis.
- ▶ **Discoid lateral meniscus:** a congenital variant in which the lateral meniscus is abnormally broad/disc-shaped; the Wrisberg-type variant lacks the normal tibial attachment of the posterior horn and relies solely on the posterior meniscomfemoral ligament, rendering the posterior horn unstable and producing the "clunking knee" (may catch between femur and tibia).

- ▶ **Arthroscopic pitfall:** a prominent ligamentum mucosum (infrapatellar plica), lying directly anterior to the ACL, may be mistaken for the ACL itself.

High-yield exam pointers

- ▶ Knee ligaments = **extracapsular** (patellar, tibial/fibular collateral, oblique & arcuate popliteal) vs **intracapsular** (ACL, PCL, transverse ligament, meniscomfemoral ligaments, coronary ligaments) — the intracapsular ones are extrasynovial, not intra-articular in the synovial sense.
- ▶ ACL: tibia (anterior intercondylar area) → femur (high, posteromedial aspect of lateral condyle); 38 × 11 mm; **taut in extension**; primary restraint to anterior tibial displacement.
- ▶ PCL: tibia (posterior intercondylar area) → femur (lateral surface of medial condyle); 38 × 13 mm; thicker/stronger than ACL; **taut in flexion**; primary restraint to posterior tibial displacement.
- ▶ Medial meniscus = semicircular, firmly fixed (via coronary + deep tibial collateral ligament) → less mobile; lateral meniscus = near-circular, popliteus hiatus + meniscomfemoral ligaments → more mobile.
- ▶ Meniscomfemoral ligaments: **anterior = Humphrey (anterior to PCL)**; **posterior = Wrisberg (posterior to PCL)** — both run from posterior horn of lateral meniscus to medial femoral condyle; secondary restraints to the PCL.
- ▶ Transverse ligament joins the two anterior horns; frequently absent.
- ▶ Peripheral one-third of each meniscus is vascular (heals); inner two-thirds is avascular (does not heal) — the anatomical basis of meniscal repair vs meniscectomy.
- ▶ Cruciate ligaments + collateral ligaments = **primary restraints**; menisci + meniscomfemoral ligaments = **secondary restraints** to anteroposterior knee laxity.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 (8e); Vishram Singh's Textbook of Anatomy Vol 2 (4e); Moore's Clinically Oriented Anatomy (9e).



Inversion and Eversion

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction — Inversion and eversion are the two "special" movements of the foot: **inversion** raises the medial border of the foot so that the sole faces medially (inward), while **eversion** raises the lateral border so that the sole faces laterally (outward). Neither occurs at the ankle (talocrural) joint itself; both take place principally at the subtalar and talocalcaneonavicular joints of the hindfoot, with a smaller contribution from the transverse tarsal joint. Functionally they are the lower-limb equivalents of supination and pronation of the forearm, and together with dorsiflexion/plantar flexion at the ankle they let the plantigrade foot adapt to uneven, sloping ground while the leg above stays vertical.

1. Definition and joints taking part

- **Inversion:** medial border of the foot raised, sole faces medially; accompanied by adduction and plantar flexion of the forefoot.
- **Eversion:** lateral border of the foot raised, sole faces laterally; accompanied by abduction and dorsiflexion of the forefoot.
- In both movements the whole of the foot **distal to the talus** — calcaneus, navicular, cuboid and the forefoot carried with them — rotates as a single unit around the talus, which itself stays gripped in the tibiofibular mortise and does not invert or evert.

Joints taking part	Constituent joints
Main	Subtalar (talocalcanean) joint; Talocalcaneonavicular joint
Accessory	Transverse tarsal (midtarsal) joint = calcaneocuboid joint + talonavicular joint (the talonavicular component is itself part of the talocalcaneonavicular joint)

□ Fig 2.15 — ■ Inversion and eversion of the foot. (Vishram Singh — General Anatomy — 4e, p.96)

2. Axis of movement and range

- **Axis:** an oblique axis running forward, upward and medially — starting at the posterior aspect of the calcaneus, passing through the **sinus tarsi** (tarsal canal/sulcus tali–sulcus calcanei), and emerging at the **superomedial aspect of the neck of the talus**. Because the axis is oblique rather than a pure sagittal, coronal or vertical axis, the movements it produces are inevitably compound — accompanied by adduction/abduction and plantar-/dorsiflexion.
- **Range:** inversion ($\approx 30^\circ$) is always considerably freer than eversion ($\approx 20^\circ$).
- The range of both movements is **appreciably increased when the foot is plantar-flexed**: in this position the narrower posterior part of the trochlear surface of the talus occupies the wider anterior part of the tibiofibular mortise (socket), loosening the normally tight grip on the talus and permitting a little extra side-to-side rocking at the subtalar joint. This is precisely why the ankle is most vulnerable to an inversion injury when the foot is plantar-flexed — e.g. missing a step or landing awkwardly from a jump.

3. Movement on the ground versus off the ground

- ▶ **Foot off the ground** (non-weight-bearing) — range of motion is greatest:
 - Inversion = adduction of the forefoot + lateral rotation (supination) of the forefoot + plantar flexion of the ankle.
 - Eversion = abduction of the forefoot + medial rotation (pronation) of the forefoot + dorsiflexion of the ankle.
- ▶ **Foot on the ground** (weight-bearing) — the calcaneus is fixed by body weight, so range of motion is reduced and only the forefoot can rotate on it:
 - Inversion is reduced to pure lateral rotation (supination) of the forefoot; the heads of the medial two metatarsals are raised.
 - Eversion is reduced to pure medial rotation (pronation) of the forefoot; the heads of the lateral three metatarsals are raised.
- ▶ **Mechanism:** during inversion, the forepart of the foot is first adducted at the midtarsal joint, followed by lateral rotation of the whole foot at the subtalar joint; eversion is the exact reverse sequence.

4. Muscles producing the movements

Movement	Principal muscles	Accessory muscles
Inversion ($\approx 30^\circ$)	Tibialis anterior, Tibialis posterior	Flexor hallucis longus, Flexor digitorum longus
Eversion ($\approx 20^\circ$)	Peroneus (fibularis) longus, Peroneus (fibularis) brevis	Peroneus (fibularis) tertius

- ▶ Tibialis anterior and tibialis posterior are supplied by the deep fibular and tibial nerves respectively; peroneus longus and brevis by the superficial fibular nerve, and peroneus tertius by the deep fibular nerve — so an inversion or eversion deficit can help localise a lesion of these nerves.

5. Ligaments and limiting factors

- ▶ **Cervical ligament** — lies just lateral to the sinus tarsi, running from the superior surface of the calcaneus to a tubercle on the inferolateral neck of the talus; it becomes **taut in inversion** and is one of the principal checks on further inversion.
- ▶ **Interosseous talocalcaneal ligament** — the thick, strong bilaminar band occupying the sinus tarsi that forms the chief bond between talus and calcaneus; its **medial fibres become taut in eversion**.
- ▶ **Deltoid (medial collateral) ligament** of the ankle — becomes taut in eversion.

Movement limited by	Structures
Inversion	Tension of the peronei (antagonist muscles); tension of the cervical ligament
Eversion	Tension of tibialis anterior and tibialis posterior (antagonist muscles); tension of the deltoid ligament

6. Functional significance and relation to pronation/supination

- ▶ Inversion and eversion allow the foot to adjust itself to uneven, sloping and slippery ground, so that the sole maintains maximal contact with the ground while the leg above remains vertical — essential for standing, walking and running on irregular terrain.
- ▶ When the foot is bearing the body's weight, inversion and eversion occur only in this constrained, on-ground form, which is then termed **supination** and **pronation** of the foot respectively — movements imposed on the forefoot by ground reaction and body weight rather than produced by free active contraction. Supination is thus the weight-bearing component of inversion; pronation is the weight-bearing component of eversion.
- ▶ These movements are functionally analogous to supination and pronation of the forearm at the radio-ulnar joints.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A plantar/posterior schematic of the hindfoot showing:

- ▶ **Talus** (shaded, shown as the fixed pivot, gripped in the tibiofibular mortise), **calcaneus**, **navicular**, **cuboid**.
- ▶ The **oblique axis of inversion-eversion**, drawn as a line through the sinus tarsi from the back of the calcaneus to the superomedial neck of the talus, clearly labelled.
- ▶ Two curved arrows: one raising the medial border labelled **INVERSION**, one raising the lateral border labelled **EVERSION**.
- ▶ The three joints labelled in small print: **subtalar joint**, **talocalcaneonavicular joint**, **transverse tarsal joint** (calcaneocuboid + talonavicular).
- ▶ Muscle-pull arrows: **tibialis anterior** + **tibialis posterior** on the medial/dorsal side (inversion); **peroneus longus** + **peroneus brevis** on the lateral side (eversion), tendons shown curving behind/below the malleoli.
- ▶ Inset in the sinus tarsi: the **cervical ligament** (taut in inversion) and the **interosseous talocalcaneal ligament** (medial fibres taut in eversion).

Applied / Clinical anatomy

- ▶ **Ankle (inversion) sprain** — the commonest ligamentous injury of the lower limb. An excessively inverted, plantar-flexed foot (classically, missing a step) stretches and tears the lateral ligament complex of the ankle: the **anterior talofibular ligament is torn first and most commonly**, followed, with greater force, by the calcaneofibular ligament; the posterior talofibular ligament is almost always spared. Inversion sprains are far more frequent than eversion sprains because inversion has the greater range and its restraints are comparatively weaker.
- ▶ **Eversion sprain** — an excessively everted, dorsiflexed foot stresses the strong deltoid (medial collateral) ligament of the ankle. Because the deltoid ligament is stronger than the lateral ligament complex, it typically resists tearing; instead, the pull is transmitted to bone and produces an **avulsion fracture of the medial malleolus**.

□ Fig 33.18 — ■ *Inversion and eversion injuries of the foot* (Vishram Singh — *Textbook of Anatomy Vol 2* — 4e, p.1287)

- ▶ **Pott's fracture-dislocation** — forced eversion of a foot that is fixed (e.g. caught in a hole) produces, in sequence: (1) oblique fracture of the lateral malleolus from internal rotation of the tibia; (2) transverse fracture of the medial malleolus from the pull of the taut deltoid ligament; (3) fracture of the posterior margin of the lower end of the tibia (the "third malleolus"). All three together constitute the third-degree (trimalleolar) Pott's fracture.
- ▶ **Talipes (clubfoot) deformities** are described directly in terms of fixed inversion/eversion: **talipes varus** — the foot is fixed in inversion and adduction, so the patient walks on the outer (lateral) border of the foot; **talipes valgus** — the foot is fixed in eversion and abduction, so the patient walks on the inner (medial) border. The commonest congenital foot deformity, **talipes equinovarus (club foot)**, combines inversion, adduction and plantar flexion (equinus), and may be associated with spina bifida.
- ▶ The **superficial fibular nerve** can be damaged in severe inversion injuries of the ankle; the peronei it supplies are the principal dynamic restraint against recurrent inversion, which is why peroneal-strengthening exercises form the core of ankle-sprain rehabilitation.

High-yield exam pointers

- ▶ Inversion = sole faces medially (medial border raised); eversion = sole faces laterally (lateral border raised) — never occurs at the ankle joint proper.
- ▶ Main joints: subtalar + talocalcaneonavicular; accessory: transverse tarsal (calcaneocuboid + talonavicular).
- ▶ Oblique axis: posterior calcaneus → sinus tarsi → superomedial neck of talus.
- ▶ Range: inversion (30°) is much freer than eversion (20°); range increases in plantar flexion because the narrow posterior talar trochlea sits loosely in the wider mortise.
- ▶ Principal muscles: inversion — tibialis anterior + tibialis posterior; eversion — peroneus longus + peroneus brevis.
- ▶ Cervical ligament taut in inversion; medial fibres of the interosseous talocalcaneal ligament and the deltoid ligament taut in eversion.
- ▶ Weight-bearing (on-ground) inversion/eversion is termed supination/pronation of the forefoot on a fixed calcaneus.
- ▶ Clinical: inversion sprain tears the anterior talofibular ligament first (commonest ankle injury); eversion stresses the deltoid ligament, producing medial malleolar avulsion or, if the foot is fixed, a Pott's trimalleolar fracture.
- ▶ Talipes varus (fixed inversion + adduction) versus talipes valgus (fixed eversion + abduction); talipes equinovarus (club foot) is the commonest congenital foot deformity.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; Vishram Singh — Textbook of Anatomy Vol 2 4e; BD Chaurasia — Human Anatomy Vol 2 8e.



Knee joint

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction

The knee is the largest and structurally most complex synovial joint in the body, formed by the fusion of three separate joints into a single compound cavity — the medial femorotibial, the lateral femorotibial (both condylar/hinge joints), and the femoropatellar (a saddle joint). It is a modified hinge (condylar) synovial joint whose cavity is incompletely subdivided by the menisci into upper (flexion–extension) and lower (rotation) compartments. Structurally the articular surfaces are markedly incongruent, so stability is sacrificed for mobility and is instead provided by a strong system of intra- and extra-capsular ligaments, the menisci, and the surrounding muscles — making the joint biomechanically efficient for bipedal locomotion but highly vulnerable to sports injury.

Type and articular surfaces

- **Type:** Synovial joint of the **condylar variety** — two condylar (femorotibial) joints plus one saddle (femoropatellar) joint combined in one capsule; the cavity is a **complex joint** because of the interposed menisci.
- **Articular surfaces** are formed by three bones:

Component	Surfaces in articulation
Femorotibial (medial & lateral)	Condyles of the femur (below & behind) with condyles of the tibia
Femoropatellar	Patellar (articular) surface of the femur with the posterior surface of the patella

- The femoral condyles are asymmetric — the medial condyle projects further forward and has a longer articular surface (curved) than the lateral condyle, a fact central to the locking mechanism (below).
- During movement, different facets of the patella engage the femur: the **lower pair** of facets in extension, the **middle pair** at the start of flexion, the **upper pair** in mid-flexion, and the **medial (odd) facet** only in full flexion.

Capsule, synovial membrane and bursae

- The **fibrous capsule** is thin, deficient anteriorly (replaced by the quadriceps expansion, patella and ligamentum patellae), and attached ~0.5–1 cm beyond the articular margins. On the femur it is deficient anteriorly, attached posteriorly to the intercondylar line, and encloses the popliteus origin laterally; on the tibia it descends to the tibial tuberosity anteriorly, attaches to the intercondylar ridge posteriorly, and gaps posterolaterally for the popliteus tendon.
- The capsule between menisci and tibia is the **coronary ligament**; a deep thickening beneath the fibular collateral ligament is the **short lateral ligament**. It is reinforced anteriorly by the **patellar retinacula**, laterally by the **iliotibial tract**, medially by sartorius/semimembranosus expansions, and posteriorly by the **oblique popliteal ligament**.
- **Synovial membrane** lines the capsule but is reflected forward off the posterior wall by the cruciate ligaments, so the cruciates are intracapsular but extrasynovial. Anteriorly it extends 5 cm

above the patella as the **suprapatellar bursa**, and is separated from the ligamentum patellae by the **infrapatellar pad of fat**, from which the **infrapatellar synovial fold** (with alar folds) runs back to the intercondylar fossa.

- **Bursae around the knee** (~12 described): anteriorly — suprapatellar, prepatellar (subcutaneous), infrapatellar (subcutaneous & deep); medially — deep to medial gastrocnemius, anserine (deep to sartorius/gracilis/semitendinosus), deep to tibial collateral ligament, deep to semimembranosus; laterally — deep to lateral gastrocnemius, and three between the fibular collateral ligament/popliteus/lateral tibial condyle.

Ligaments and menisci

□ Fig 7.93 — Articular surfaces, cruciate ligaments, and synovial cavity of knee joint (Moore — Clinically Oriented Anatomy — 9e, p.1298)

Ligament	Attachment / course	Function
Ligamentum patellae	Apex/margins of patella → tibial tuberosity (central part of quadriceps tendon)	Extensor mechanism
Tibial (medial) collateral	Medial epicondyle of femur → medial tibial shaft (anterior part) and medial meniscus (deep part); degenerated adductor magnus tendon	Resists valgus stress; blends with capsule and medial meniscus
Fibular (lateral) collateral	Lateral epicondyle of femur → head of fibula; separate from capsule; degenerated peroneus longus attachment	Resists varus stress
Oblique popliteal ligament	Expansion of semimembranosus → intercondylar line/lateral femoral condyle	Reinforces posterior capsule
Arcuate popliteal ligament	Posterior expansion of short lateral ligament, arches over popliteus	Reinforces posterolateral capsule
Anterior cruciate (ACL)	Anterior intercondylar area of tibia → posteromedial part of lateral femoral condyle	Taut in extension; prevents anterior tibial translation
Posterior cruciate (PCL)	Posterior intercondylar area of tibia → anterolateral part of medial femoral condyle	Taut in flexion; prevents posterior tibial translation
Transverse ligament	Connects anterior horns of the two menisci	Stabilises anterior menisci
Meniscomfemoral ligaments (of Humphry, anterior; of Wrisberg, posterior)	Posterior horn of lateral meniscus → medial femoral condyle, passing anterior/posterior to the PCL respectively	Control mobility of lateral meniscus posterior horn

- **Menisci** are crescentic fibrocartilages deepening the shallow tibial condyles and partly dividing the joint cavity (flexion–extension above, rotation below). Each has anterior/posterior horns

(attached to tibia), a thick convex peripheral border fused to the capsule, a thin free concave inner border, and a concave superior surface (for the femur)/flat inferior surface (on tibia).

- **Medial meniscus** — semicircular, wider behind, firmly bound to the deep tibial collateral ligament and capsule → relatively fixed, more prone to tearing. **Lateral meniscus** — circular, separated from the fibular collateral ligament by popliteus tendon, its posterior horn controlled by popliteus and the menisiofemoral ligaments → more mobile, better protected from injury.
- Only the peripheral 25–33% is vascularised (capsular/synovial capillaries); the inner two-thirds is avascular, nourished by synovial fluid ("red zone/white zone" concept in repair).
- Functions: improve articular congruity, act as shock absorbers, aid lubrication, and (via free nerve endings) give proprioceptive feedback.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Superior view of the right tibial plateau with menisci and cruciate attachments (simplified from BD Chaurasia Fig. 12.11b) — label: medial and lateral condyles of tibia; intercondylar eminence; anterior intercondylar area (ACL + anterior horns of both menisci); posterior intercondylar area (PCL + posterior horns of both menisci); medial meniscus (C-shaped) and lateral meniscus (O-shaped); transverse ligament joining anterior horns; groove for popliteus tendon (posterolateral); attachment of deep tibial collateral ligament to medial meniscus.

Relations

Aspect	Structures
Anterior	Quadriceps expansion, patella, ligamentum patellae, anterior bursae, peripatellar plexus of nerves
Posterior (middle)	Popliteal vessels, tibial nerve
Posterolateral	Lateral head of gastrocnemius, plantaris, common fibular (peroneal) nerve
Posteromedial	Medial head of gastrocnemius, semitendinosus, semimembranosus, gracilis, popliteus insertion
Medial	Sartorius, gracilis, semitendinosus; great saphenous vein with saphenous nerve
Lateral	Biceps femoris; popliteus tendon of origin

Blood and nerve supply

- **Blood supply** — from the peri-articular genicular anastomosis: five genicular branches of the popliteal artery (superior medial, superior lateral, inferior medial, inferior lateral, middle genicular), the descending genicular branch of the femoral artery, the descending branch of the lateral circumflex femoral artery, two recurrent branches of the anterior tibial artery, and the circumflex fibular branch of the posterior tibial artery.
- **Nerve supply** (obeys Hilton's law — a nerve crossing a joint supplies the muscles moving it and the skin over it): femoral nerve (via nerves to the vasti, especially vastus medialis), sciatic nerve

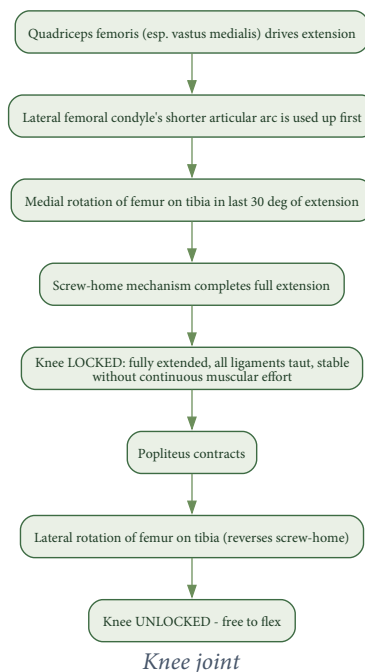
(via genicular branches of the tibial and common fibular nerves), and the posterior division of the obturator nerve.

Movements, muscles and the locking–unlocking mechanism

- **Movements:** flexion, extension, and (in the flexed knee only) medial and lateral rotation.

Movement	Principal muscle(s)
Extension	Quadriceps femoris (four heads)
Locking (final extension, "attention")	Vastus medialis
Unlocking	Popliteus
Flexion	Biceps femoris, semitendinosus, semimembranosus
Medial rotation of flexed leg	Popliteus, semimembranosus, semitendinosus
Lateral rotation of flexed leg	Biceps femoris

- Flexion–extension is not a pure hinge movement — the transverse axis shifts forward-and-up in extension (reverses in flexion), accompanied by an obligatory **conjunct rotation**. Because the medial femoral condyle has a longer articular arc than the lateral, the lateral surface is "used up" first — so in the last ~30° of extension the femur rotates medially on the fixed tibia (or, foot free, the tibia rotates laterally on the femur) to bring the rest of the medial condyle into contact. This is the **screw-home mechanism**.



- Rotation occurs about a vertical axis in the lower (inframeniscal) compartment and is of small range; accessory/passive movements possible only in a partially flexed knee include wider rotation, anteroposterior gliding of tibia on femur, some abduction/adduction, and slight surface separation.

Applied / Clinical anatomy

- ▶ **Meniscal tears:** typical in a slightly flexed, loaded, rotating knee (e.g. twisting on a planted foot, as in football); longitudinal ("bucket-handle") or transverse. **Medial meniscus is injured far more often** — firm attachment to the deep tibial collateral ligament and greater excursion; the lateral meniscus is comparatively protected by popliteus, which retracts it in flexion.
- ▶ **Cruciate injuries:** ACL torn more often than PCL, classically in violent hyperextension or anterior tibial dislocation — a positive **anterior drawer sign**. PCL tears (posterior tibial dislocation force, e.g. dashboard injury) give a positive **posterior drawer sign**.
- ▶ **"Unhappy triad":** combined tibial collateral ligament + medial meniscus + ACL injury from a lateral blow to a fixed, slightly flexed knee (classic contact-sport injury), explained by the firm medial-side interconnection of these three structures.
- ▶ **Collateral ligament injuries:** less common — severe abduction (valgus) tears the MCL, adduction (varus) tears the LCL.
- ▶ **Osteoarthritis:** age-related cartilage degeneration with marginal osteophytes, limiting movement painfully; the knee is predisposed by inherently incongruent articular surfaces (shallow tibial condyles under large convex femoral condyles) and the oblique thigh–leg angulation at the femoropatellar joint.
- ▶ **Joint effusion/haemarthrosis:** fluid collects above and beside the patella, giving a **floating/tapping patella**; aspirated on either side of the patella. Bursal effusions similarly swell the corresponding bursa.
- ▶ **Baker's (popliteal) cyst:** synovial herniation through a posterior capsular defect, associated with osteoarthritis or a gastrocnemius/semimembranosus bursal communication.
- ▶ **Genu valgum (knock-knee)/genu varum (bow-leg):** abnormal femorotibial shaft angulation from rickets, posture or congenital deformity.
- ▶ In knee-joint disease, **vastus medialis atrophies first and recovers last** — a useful rehabilitation pointer. Functional stability comes from the cruciates (anteroposterior), collaterals (side-to-side), capsular ligaments and the iliotibial tract.

High-yield exam pointers

- ▶ Largest and most complex synovial joint; a condylar joint that is functionally a fusion of 2 femorotibial + 1 femoropatellar joint.
- ▶ Cruciate ligaments are intracapsular but extrasynovial (synovium is reflected off them from behind).
- ▶ ACL taut in extension; PCL taut in flexion — mnemonic basis for drawer-sign direction.
- ▶ Medial meniscus (semicircular, fixed) tears more often than lateral meniscus (circular, mobile, protected by popliteus).
- ▶ Locking = medial rotation of femur (vastus medialis) in terminal extension (screw-home mechanism); unlocking = lateral rotation of femur by popliteus.
- ▶ Blood supply is entirely via the genicular anastomosis (5 genicular branches of popliteal + descending genicular + descending branch of lateral circumflex femoral + 2 anterior tibial recurrent + circumflex fibular of posterior tibial).

- ▶ Nerve supply follows Hilton's law: femoral, sciatic (tibial + common fibular genicular branches) and obturator (posterior division) nerves.
- ▶ "Unhappy triad" = MCL + medial meniscus + ACL injury.
- ▶ Vastus medialis atrophies first and recovers last in knee-joint disease.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore — Clinically Oriented Anatomy, 9e.



Locking and unlocking of knee joint

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction Locking of the knee is the automatic mechanical event, occurring in the terminal 20–30° of extension, by which the knee joint is converted from a mobile hinge into a completely rigid, close-packed weight-bearing column with minimal muscular effort. It results from an obligatory **conjunct medial rotation of the femur on the tibia** (the "**screw-home movement**"), driven by the asymmetric shape of the femoral condyles and completed by the quadriceps, especially **vastus medialis**. The locked knee can be flexed again only after it is **unlocked** by the **popliteus** muscle, which reverses the rotation. This locking–unlocking cycle recurs rhythmically with every step of gait, and is one of the most clinically important mechanical adaptations of the human knee for erect bipedal posture.

Conjunct and adjunct rotation — the setting for locking/unlocking

- ▶ Flexion–extension occurs in the **upper (menisofemoral) compartment**; medial–lateral rotation occurs in the **lower (meniscotibial) compartment**, around a vertical axis.
- ▶ Rotation that occurs *automatically and inseparably* with flexion/extension is called **conjunct rotation** — it is this conjunct rotation that produces locking (with terminal extension) and unlocking (with initial flexion).
- ▶ Rotation occurring independently, best demonstrated in the semi-flexed knee, is **adjunct (voluntary) rotation** — total voluntary axial rotation is about 60–70°, but the obligatory conjunct component is only about 20°.
- ▶ When the **foot is planted** (closed kinetic chain, e.g. standing), the **femur** rotates on the fixed tibia. When the **foot is off the ground** (open kinetic chain, e.g. sitting with the leg swinging), the relative motion is achieved instead by rotation of the **tibia** on the fixed femur — the same locking/unlocking events, viewed from the opposite bone.

Mechanism of locking (the screw-home movement)

- ▶ **Cause — asymmetry of the femoral condyles:** the lateral femoral condyle and its meniscotibial "receiving surface" are smaller, more circular and reach full articular congruence about 30° *before* the medial condyle during extension. Ordinary hinge extension therefore cannot proceed further once the lateral condylar surface is fully used up.

- ▶ **Medial rotation of the femur:** to allow the remaining, larger medial condylar surface to also become congruent, the femur (with the lateral condyle acting as a relatively fixed pivot) rotates medially on the tibia through roughly 20° during the last 30° of extension. If the foot is off the ground, the complementary movement — lateral rotation of the tibia on the fixed femur — achieves the same locking.
- ▶ **Ligamentous tightening:** this terminal rotation winds up and tightens the collateral and cruciate ligaments; the **anterior cruciate ligament**, maximally taut in full extension, acts as a pivotal axis for the screw-home rotation.
- ▶ **Muscular drive:** locking is produced by the *same* muscle that produces extension — the **quadriceps femoris**, particularly its **vastus medialis** component, whose oblique fibres are essential for completing and stabilising the last few degrees of rotation-extension.
- ▶ **End-result — the locked position:** the knee becomes completely rigid; both femoral condyles are in maximal congruence with the tibial plateau; all major ligaments (collaterals and cruciates) are taut; the articular surfaces are close-packed. The body's line of gravity now passes anterior to the knee axis, so the quadriceps can relax and a person can stand upright for long periods without muscular fatigue.

Mechanism of unlocking

- ▶ The locked, fully extended knee can be flexed only after the medial rotation of the femur is undone — this is **unlocking**, brought about by the **popliteus** muscle, often called the "key to the knee."
- ▶ Popliteus arises from a groove on the **lateral femoral condyle** and passes infero-medially to the posterior tibia above the soleal line; contracting, it rotates the **femur laterally** on the tibia by roughly 5°, reversing the screw-home rotation before flexion by the hamstrings proceeds.
- ▶ Popliteus can act from **either attachment**: with the foot planted (closed chain — e.g. sitting down from standing), it acts from its femoral attachment and laterally rotates the femur on the fixed tibia; with the foot free (open chain — e.g. the swing phase of walking), it acts from its tibial attachment and medially rotates the tibia on the fixed femur. Either way, the *conjunct* effect — unlocking — is achieved.
- ▶ Popliteus additionally retracts the posterior horn of the **lateral meniscus** during this lateral rotation (via its meniscal slip), protecting the meniscus from being crushed between the condyles as flexion begins.
- ▶ Once unlocking is complete, further flexion is carried out by the hamstrings (biceps femoris, semitendinosus, semimembranosus), assisted by gracilis and sartorius.

Locking vs unlocking — summary

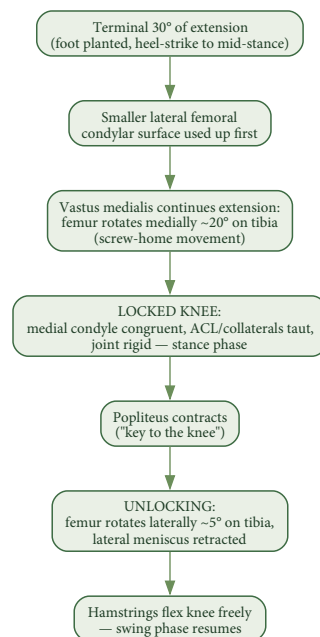
Feature	Locking	Unlocking
Phase of movement	Terminal 20–30° of extension	Initial phase of flexion
Rotation (foot on ground)	Medial rotation of femur on tibia	Lateral rotation of femur on tibia
Rotation (foot off ground)	Lateral rotation of tibia on femur	Medial rotation of tibia on femur

Feature	Locking	Unlocking
Prime mover	Quadriceps femoris (vastus medialis)	Popliteus
State of ligaments	All ligaments taut, joint rigid	Ligaments relaxed, joint mobile
Functional role	Weight-bearing without muscular effort	Permits flexion for locomotion

Mnemonic (BD Chaurasia):

- ▶ **L M F T T E** — Locking: Medial rotation of Femur on Tibia at Terminal stage of Extension (foot on ground).
- ▶ **U L F T I F** — Unlocking: Lateral rotation of Femur on Tibia at Initial stage of Flexion (foot on ground).
- ▶ **L L T F T E** — Locking: Lateral rotation of Tibia on Femur at Terminal stage of Extension (foot off ground).
- ▶ **U M T F I F** — Unlocking: Medial rotation of Tibia on Femur at Initial stage of Flexion (foot off ground).

(An equivalent mnemonic used in other texts: for locking — "More Fun, Less Time" = Medial rotation of Femur or Lateral rotation of Tibia; for unlocking — "Less Fun, More Time" = Lateral rotation of Femur or Medial rotation of Tibia.)



Locking and unlocking of knee joint

□ Fig 7.95 — Movements of knee joint. (Moore — Clinically Oriented Anatomy — 9e, p.1301)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A superior (axial) view of the right tibial plateau with the femoral condyles superimposed, labelled with:

- ▶ **Medial femoral condyle** — larger, longer anteroposterior curvature; its meniscotibial surface is the *last* to become congruent.
- ▶ **Lateral femoral condyle** — smaller, more circular articular surface; congruent *first* (about 30° before full extension), acting as the relative pivot for medial rotation.
- ▶ **Vertical axis of rotation** through the femur, with a curved arrow showing **medial rotation of femur (locking)** and an opposing arrow for **lateral rotation of femur (unlocking)**.
- ▶ **Anterior cruciate ligament** — labelled taut in extension, pivotal axis of the screw-home rotation.
- ▶ **Popliteus tendon** — origin in the groove on the lateral femoral condyle, coursing to the posterior tibia above the soleal line; arrow showing its pull rotating the femur laterally and retracting the lateral meniscus.
- ▶ **Vastus medialis (oblique fibres)** on the medial patella/quadriceps expansion — labelled as the locking muscle.
- ▶ Two small inset panels: "foot on ground — femur rotates" and "foot off ground — tibia rotates," to depict the closed- vs open-chain versions of the same mechanism.

Applied / Clinical anatomy

- ▶ **Vastus medialis weakness:** in knee-joint disease or after injury, vastus medialis (the terminal locking muscle) is characteristically the **first to atrophy and the last to recover**; its weakness impairs terminal extension/locking, producing an unstable, "give-way" knee during stance and contributing to patellar mal-tracking.
- ▶ **Popliteus tendinopathy/instability:** because popliteus is the sole unlocking muscle and a key posterolateral corner stabiliser (with the popliteofibular ligament), injury here (e.g. in twisting sports) causes difficulty initiating flexion from full extension and posterolateral rotatory instability of the tibia.
- ▶ **ACL injury and screw-home loss:** since the ACL acts as the pivotal axis for the screw-home rotation, its rupture (classically in the "unhappy triad" with the tibial collateral ligament and medial meniscus) disrupts the normal conjunct rotation, producing rotatory instability and a positive anterior drawer/Lachman sign.
- ▶ **"True" locked knee (pathological) vs physiological locking:** a displaced bucket-handle tear of a meniscus (commonly the medial meniscus, which is more vulnerable owing to its firm capsular/collateral-ligament attachment) can mechanically jam between the condyles, producing a **painful, pathologically "locked knee"** that cannot be *fully extended* — the opposite functional problem from, but often confused in exams with, the normal screw-home locking mechanism.
- ▶ **Genu recurvatum:** habitual passive hyperextension/locking of a quadriceps-weak knee (e.g. in poliomyelitis or other quadriceps paresis) to substitute for active muscular stability during stance.

- ▶ **Surgical/functional relevance:** the screw-home mechanism converts the limb into a rigid column for efficient weight transmission and is exploited/considered in total knee arthroplasty design (femoral component asymmetry) so that prosthetic knees retain some rotatory "locking" stability.

High-yield exam pointers

- ▶ Locking = **medial rotation of femur on tibia** (foot planted) in the terminal 20–30° of extension = the "**screw-home movement**"; converts the knee into a rigid, close-packed column.
- ▶ Cause: the **lateral femoral condyle's smaller articular surface is used up first**, forcing medial femoral rotation so the larger medial condylar surface also becomes congruent.
- ▶ **Locking muscle:** vastus medialis (part of quadriceps femoris); **Unlocking muscle:** popliteus, the "key to the knee."
- ▶ Popliteus can act from its **femoral attachment** (foot on ground, rotates femur laterally) or its **tibial attachment** (foot off ground, rotates tibia medially) — either way the conjunct effect is unlocking.
- ▶ Conjunct (obligatory) rotation $\approx 20^\circ$ total, versus $\approx 60\text{--}70^\circ$ of voluntary (adjunct) axial rotation possible in a semi-flexed knee.
- ▶ ACL is maximally taut in extension and serves as the pivotal axis of the screw-home rotation.
- ▶ When the knee is locked, all major ligaments are taut and quadriceps activity can relax — the basis of fatigue-free standing.
- ▶ Distinguish physiological screw-home "locking" from a pathological "locked knee" due to a displaced meniscal tear (mechanical block to extension).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; IB Singh — Textbook of Anatomy Vol 1, 6e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore's Clinically Oriented Anatomy, 9e.



Longitudinal Arches of the Foot

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction

The foot possesses three arches — two **longitudinal** (medial and lateral) and one **transverse** — built from the tarsal and metatarsal bones and held together by ligaments, tie-beams (plantar aponeurosis, short muscles) and slings (long tendons). This architecture converts the foot into an elastic, segmented spring that supports body weight in the upright posture and simultaneously acts as a rigid lever that propels the body forward in walking, running and jumping. The arches are present from birth, though masked in infancy by plantar fat pads, and the arched sole (best seen on a footprint) is a distinctive feature of the human foot compared with other primates.

General architecture of a longitudinal arch

Each longitudinal arch is conceived, like the arch of a stone bridge, as having two **pillars** (a short strong posterior pillar and a long weak anterior pillar), a **summit** (the keystone, the highest and least stable point), and is maintained by four factors:

- ▶ **Shape of the bones** — of minor importance for the longitudinal arches (it is the principal factor for the transverse arch, where the cuneiforms and metatarsal bases are wedge-shaped).
- ▶ **Intersegmental ties (ligaments)** — bind adjoining bones of the arch to each other.
- ▶ **Tie beams (bowstrings)** — connect the two ends of the arch, preventing it from flattening.
- ▶ **Slings** — long tendons passing beneath the sole that pull the summit of the arch upward.

Both longitudinal arches share the **calcaneus** as their common posterior element, though the calcaneus contributes primarily to the medial arch.

Medial longitudinal arch

- ▶ **Bones** (posterior to anterior): medial part of **calcaneus** → head of **talus** → **navicular** → three **cuneiforms** → medial three **metatarsals** (1st–3rd). The phalanges take no part in either arch.
- ▶ **Posterior pillar**: medial tubercle of the calcaneal tuberosity — short and strong.
- ▶ **Anterior pillar**: talus, navicular, the three cuneiforms and the 1st–3rd metatarsals — long and weak; formed anteriorly by the heads of the first three metatarsals.
- ▶ **Summit/keystone**: superior articular surface of the **head of talus** — the highest point of the arch and the point most liable to descend in flat foot.
- ▶ **Main joint**: **talocalcaneonavicular joint**.
- ▶ **Character**: higher, more mobile and more resilient than the lateral arch; behaves chiefly as a shock absorber.

Lateral longitudinal arch

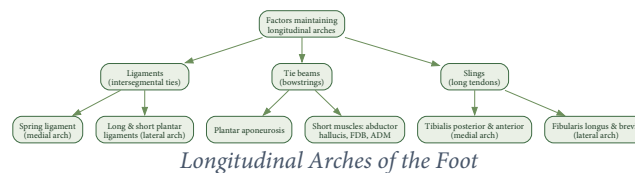
- ▶ **Bones**: lateral part of **calcaneus** → **cuboid** → 4th and 5th **metatarsals**.
- ▶ **Posterior pillar**: lateral tubercle of the calcaneal tuberosity — short and strong.
- ▶ **Anterior pillar**: cuboid and the 4th–5th metatarsals — long and weak; formed anteriorly by the heads of the 4th and 5th metatarsals.
- ▶ **Summit/keystone**: the articular facet on the superior surface of the calcaneus at the level of the **subtalar joint**; the **cuboid** is regarded as the bony keystone of the anterior pillar.
- ▶ **Main joint**: **calcaneocuboid joint**.
- ▶ **Character**: low, with limited mobility; the bones contribute little to stability, and it is built mainly to **transmit weight and thrust to the ground** rather than to absorb shock.

Comparison of the two longitudinal arches

Feature	Medial longitudinal arch	Lateral longitudinal arch
Bones	Calcaneus, talus, navicular, 3 cuneiforms, 1st–3rd metatarsals	Calcaneus, cuboid, 4th–5th metatarsals

Feature	Medial longitudinal arch	Lateral longitudinal arch
Posterior pillar	Medial part of calcaneal tuberosity (short, strong)	Lateral part of calcaneal tuberosity (short, strong)
Anterior pillar	Talus–navicular–cuneiforms–metatarsal heads (long, weak)	Cuboid–metatarsal heads (long, weak)
Summit / keystone	Head of talus	Calcaneal facet at subtalar level / cuboid
Main joint	Talocalcaneonavicular joint	Calcaneocuboid joint
Principal ligament (intersegmental tie)	Spring (plantar calcaneonavicular) ligament, talocalcaneal & deltoid ligament fibres	Long plantar ligament and short (plantar calcaneocuboid) ligament
Principal tie beam	Plantar aponeurosis (medial part); abductor hallucis, flexor digitorum brevis	Plantar aponeurosis (lateral part); abductor digiti minimi, flexor digitorum brevis
Principal slings	Tibialis posterior and anterior, flexor hallucis longus, flexor digitorum longus	Fibularis (peroneus) longus and brevis, fibularis tertius
Character	Higher, mobile, resilient — shock absorber	Lower, rigid, limited mobility — weight/thrust transmitter

Factors maintaining the arches — mechanism



- The **plantar aponeurosis** is the single most important tie beam: it stretches between the posterior and anterior pillars of both arches and, on dorsiflexion of the toes (especially the great toe), is drawn taut around the metatarsal heads, shortening its effective span and raising the arch — the **windlass mechanism** (Hicks).
- Next in importance for the medial arch is the **spring (plantar calcaneonavicular) ligament**, which slings the head of the talus; if it fails, the talus head descends and the navicular and calcaneus separate, producing flat foot.
- Flexor hallucis longus acts as a bowstring for the medial arch; flexor digitorum longus, abductor hallucis and the medial half of flexor digitorum brevis contribute to a lesser degree.
- **Tibialis posterior** and tibialis anterior invert and adduct the foot, raising its medial border; together with fibularis longus they also form a **stirrup (sling)** that cradles the midfoot. Failure of the tibialis posterior tendon is a well-recognised cause of progressive collapse of the medial longitudinal arch.
- For the lateral arch, the **long and short plantar ligaments** and the lateral part of the plantar aponeurosis are the chief ligamentous supports, but the tendon of **fibularis (peroneus) longus**, grooving the cuboid, makes the single most important contribution to maintaining this arch.

Functions of the longitudinal arches

- ▶ **Weight distribution:** body weight is transmitted mainly to the heel and to the heads of the first and fifth metatarsals; the great toe, through its two sesamoids, bears roughly double the load of the other toes.
- ▶ **Resilience/spring action:** chiefly the medial arch, aiding propulsion in walking and running.
- ▶ **Shock absorption:** particularly important on jumping and landing.
- ▶ **Protection:** the concavity of the sole shields the plantar neurovascular bundle and intrinsic muscles from pressure.
- ▶ **Lever for propulsion:** the windlass mechanism stiffens the foot into a rigid lever at toe-off.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 7.107 — Arches of foot. A. Medial longitudinal arch. B. Lateral longitudinal arch (Moore — Clinically Oriented Anatomy, 9e, p.1317)

Reproduce a medial-view and a lateral-view outline of the foot skeleton and label:

- ▶ Medial view (medial longitudinal arch): calcaneus (posterior pillar), talus (keystone/summit), navicular, 3 cuneiforms, 1st–3rd metatarsals (anterior pillar); mark spring ligament under the talonavicular joint and plantar aponeurosis as the tie beam.
- ▶ Lateral view (lateral longitudinal arch): calcaneus (posterior pillar), cuboid (keystone), 4th–5th metatarsals (anterior pillar); mark the long and short plantar ligaments and the groove for fibularis longus tendon under the cuboid.
- ▶ Indicate the talocalcaneonavicular joint (medial arch) and calcaneocuboid joint (lateral arch) as the main joints of each arch.

Applied / Clinical anatomy

- ▶ **Pes planus (flat foot):** absence/collapse of the medial longitudinal arch. May be **physiological** (common in pre-school children, feet flexible, asymptomatic) or **pathological** (stiff, painful). The **windlass (Jack's toe) test** — passive dorsiflexion of the great toe — tightens the plantar aponeurosis and re-accentuates the arch in flexible flat foot but not in the pathological/rigid variety. Causes of pathological pes planus include disruption of the tibialis posterior tendon (progressive collapse staged by the Johnson & Strom / Myerson classification), rupture of the spring ligament, tarsal coalition, and tarsometatarsal or subtalar joint arthritis.
- ▶ **Clinical effects of flat foot:** loss of spring gives a clumsy, shuffling gait; loss of shock absorption predisposes to trauma and osteoarthritis; loss of the concavity compresses the neurovascular bundle in the sole, causing **metatarsalgia** (compression of the communication between medial and lateral plantar nerves) and vascular disturbance in the toes.
- ▶ **Pes cavus:** exaggeration of the longitudinal arches, usually of neurological origin (Charcot-Marie-Tooth disease, spina bifida, poliomyelitis, tethered cord); classified by site as hindfoot, midfoot, forefoot or "global" cavus. When accompanied by dorsiflexion at the metatarsophalangeal and flexion at the interphalangeal joints (from wasting of lumbricals and interossei), the deformity is termed **clawfoot**.
- ▶ **Plantar fasciitis:** repetitive strain at the calcaneal attachment of the plantar aponeurosis (the principal tie beam) causes plantar heel pain and, chronically, a calcaneal (heel) spur.

- ▶ **Footprint test:** because the arches lift the midfoot off the ground, a normal wet footprint is incomplete along the medial border; a complete footprint indicates a flattened medial longitudinal arch.

High-yield exam pointers

- ▶ Two longitudinal arches (medial, lateral) share the calcaneus as posterior pillar; medial arch is higher/mobile/resilient, lateral is low/rigid.
- ▶ Medial arch: calcaneus–talus–navicular–3 cuneiforms–1st–3rd metatarsals; keystone = head of talus; main joint = talocalcaneonavicular joint.
- ▶ Lateral arch: calcaneus–cuboid–4th/5th metatarsals; keystone = cuboid; main joint = calcaneocuboid joint.
- ▶ Spring ligament is the single most important ligament for the medial arch; long/short plantar ligaments for the lateral arch.
- ▶ Plantar aponeurosis is the chief tie beam for both arches and the basis of the windlass mechanism.
- ▶ Tibialis posterior/anterior sling the medial arch; fibularis longus/brevis sling the lateral arch.
- ▶ Functions: weight distribution, resilience/spring, shock absorption, protection of sole, propulsive lever.
- ▶ Pes planus (flat, windlass test negative if pathological) vs pes cavus (exaggerated, usually neurogenic) are the key applied correlates.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh Textbook of Anatomy Vol 2 4e; Moore's Clinically Oriented Anatomy 9e.



Menisci and cruciate ligaments of knee joint

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction The knee (tibiofemoral) joint is a synovial hinge joint whose intracapsular fibrocartilaginous **menisci** and intracapsular ligamentous **cruciates** are together the principal determinants of its stability and load transmission. The menisci (medial and lateral semilunar cartilages) deepen the tibial plateau and convert axial load into circumferential hoop stress, while the anterior and posterior cruciate ligaments (ACL, PCL) are the primary restraints against anteroposterior tibiofemoral translation and are central to the "screw-home" locking mechanism of the joint. Both structures are frequently injured together and are classic viva/theory subjects because of their surgical and arthroscopic importance.

1. Menisci — general structure and functions

- ▶ **Nature:** crescentic, intracapsular, fibrocartilaginous laminae; peripheral border thick and convex (attached), inner free border thin and concave (unattached).

- ▶ Each meniscus covers approximately **two-thirds** of its corresponding tibial articular surface; proximal surface smooth/concave (contacts femoral condyle), distal surface smooth/flat (rests on tibial cartilage).
- ▶ **Microstructure** (two functionally distinct zones): the inner two-thirds consists of radially organised collagen bundles suited to resisting **compressive** forces; the peripheral one-third consists of thicker circumferentially arranged collagen bundles suited to resisting **tensile (hoop-stress)** forces.
- ▶ **Vascularity**: the peripheral third is vascularised by capillary loops from the fibrous capsule and synovium; the inner two-thirds is relatively avascular. This determines healing capacity (see Applied anatomy).
- ▶ **Innervation**: the meniscal horns are richly innervated; the central one-third is devoid of innervation.
- ▶ **Functions**: improve tibiofemoral **congruence**; transmit/spread axial load by converting it into meniscal hoop tension (removal raises contact stress on cartilage — see Applied anatomy); provide **secondary restraint** to anteroposterior/rotatory displacement (cruciates are primary restraints); give proprioceptive feedback and cushion bone at extremes of flexion/extension. Outward displacement under load is resisted by firm anchorage of the peripheral circumferential fibres at the meniscal horns.

2. Medial versus lateral meniscus

Feature	Medial meniscus	Lateral meniscus
Shape	Almost a semicircle (C-shaped); broader posteriorly	Forms about four-fifths of a circle (more nearly O-shaped); breadth fairly uniform
Area covered	Smaller	Larger — covers more of the tibial plateau
Anterior horn attachment	Anterior tibial intercondylar area, in front of the ACL; posterior fibres continuous with the transverse ligament	In front of the intercondylar eminence, posterolateral to the ACL, partly blending with it
Posterior horn attachment	Posterior tibial intercondylar area, between attachments of the lateral meniscus and the PCL	Behind the intercondylar eminence, in front of the posterior horn of the medial meniscus; often via menisiofemoral ligament(s)
Peripheral fixation	Firmly attached to the fibrous capsule and the deep surface of the tibial collateral ligament via the coronary (meniscotibial) ligament	Tibial attachment via its own coronary ligament, but no peripheral bony attachment opposite popliteus (the "popliteus hiatus"); grooved by the popliteus tendon, which separates it from the fibular collateral ligament

Feature	Medial meniscus	Lateral meniscus
Mobility	Relatively fixed , moves little	Considerably more mobile — controlled by menisiofemoral ligaments and the popliteus tendon (part of which attaches to it)
Clinical relevance	Torn more often (see Applied anatomy)	Torn less often; site of the discoid meniscus anomaly

3. Accessory ligaments connecting the menisci

- ▶ **Transverse (genual) ligament:** connects the anterior convex margin of the lateral meniscus to the anterior horn of the medial meniscus; variable in thickness and often absent; found slightly taut in extension.
- ▶ **Menisiofemoral ligaments (two):** connect the posterior horn of the lateral meniscus to the lateral aspect of the medial femoral condyle —
 - **Anterior menisiofemoral ligament (ligament of Humphrey)** — passes anterior to the PCL.
 - **Posterior menisiofemoral ligament (ligament of Wrisberg)** — passes posterior to the PCL, attaching proximal to the PCL's margin of attachment.
 - These are often the **sole** posterior attachment of the lateral meniscus's posterior horn.
- ▶ **Coronary (menisiotibial) ligaments:** the thin, lax peripheral tibial attachments of each meniscus to the tibial condyles, permitting some gliding.
- ▶ **Menisiofibular ligament:** present in most knees, adding to lateral meniscus stability.
- ▶ **Discoid lateral meniscus:** a disc-shaped rather than crescentic lateral meniscus (see Applied anatomy); a discoid medial meniscus is extremely rare.

4. Cruciate ligaments — attachments and structure

The cruciate ligaments are strong, richly innervated **intracapsular but extrasynovial** structures, named "cruciate" because they cross each other, and named anterior/posterior according to their **tibial** attachment. A synovial fold almost surrounds them but is reflected posteriorly from the PCL to the capsule, so the intercondylar part of the posterior fibrous capsule has no synovial covering.

Feature	Anterior cruciate ligament (ACL)	Posterior cruciate ligament (PCL)
Tibial attachment	Anterior intercondylar area, just anterior and slightly lateral to the medial intercondylar tubercle, partly blending with the anterior horn of the lateral meniscus	Posterior intercondylar area, in a depression on the posterior tibia
Femoral attachment	Ascends posterolaterally, twisting on itself, fanning out onto the posteromedial aspect of the lateral femoral condyle	Attached to the lateral surface of the medial femoral condyle, extending onto the anterior roof of the intercondylar fossa
Average dimensions (adult)	~38 mm long, ~11 mm wide	~38 mm long, ~13 mm wide (thicker and stronger than ACL)

Feature	Anterior cruciate ligament (ACL)	Posterior cruciate ligament (PCL)
Functional bundles	Anteromedial, intermediate and posterolateral bundles (named by tibial attachment)	Anterolateral bundle (taut in flexion) and posteromedial bundle (taut in extension), named by femoral attachment; each slackens as the other tightens
Isometry	Relatively isometric through knee motion	Not isometric — inter-attachment distance varies with knee position
Rupture frequency	Ruptures more commonly	Ruptures less commonly, and is generally better tolerated clinically

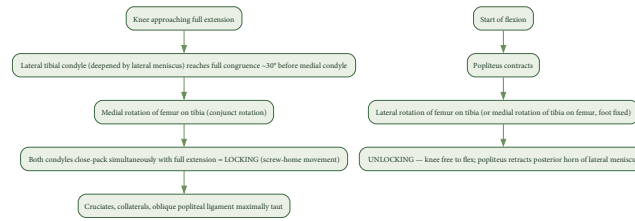
□ Fig 7.93 — Articular surfaces, cruciate ligaments, and synovial cavity of knee joint (Moore — Clinically Oriented Anatomy — 9e, p.1298)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Superior view of the left tibial plateau (as in Gray's Fig. 82.7/82.8), labelling: (1) tibial tuberosity; (2) anterior horn, lateral meniscus; (3) lateral condyle articular surface; (4) posterior horn, lateral meniscus; (5) anterior horn, medial meniscus; (6) attachment of ACL; (7) medial condyle articular surface; (8) intercondylar eminence (medial and lateral tubercles); (9) posterior horn, medial meniscus; (10) attachment of PCL; plus the transverse ligament joining the two anterior horns.

5. Functions of the cruciate ligaments and the locking–unlocking mechanism

- The cruciates are the **primary restraints** to anteroposterior tibiofemoral displacement — ACL resists anterior tibial translation (and checks hyperextension); PCL resists posterior translation (taut in flexion, checking excess flexion with soft-tissue compression) — and act as the pivot for conjunct rotation during terminal extension/initial flexion.
- **Screw-home movement**: in the last ~30° of extension, the smaller, more deeply concave lateral tibial condyle (deepened by the lateral meniscus) reaches full congruence before the medial condyle, so **medial rotation of the femur on the tibia** (conjunct rotation) completes extension — this is "locking," with maximal tautness of the cruciates, collaterals, oblique popliteal ligament and posterior capsule.
- **Unlocking**: at the start of flexion, **popliteus** contracts to produce lateral rotation of the femur on the tibia (or medial rotation of the tibia on the femur, foot fixed), and also retracts the posterior horn of the lateral meniscus via its attachment, protecting it from compression.
- **Primary vs secondary restraints**: on a laxity test (e.g. anterior drawer), ligaments best aligned to resist the load are *primary restraints* (cruciates, collaterals); less well aligned but still contributory ones are *secondary restraints* (menisci, meniscofemoral ligaments) — loss of a primary restraint overloads the secondary ones.



Menisci and cruciate ligaments of knee joint

6. Blood supply, innervation and synovial relations

- ▶ **Genicular anastomosis:** an intricate periarticular arterial network supplying the menisci, cruciates, capsule and synovium, formed by: superior medial and superior lateral genicular, inferior medial and inferior lateral genicular, and middle genicular arteries (all from the popliteal artery); the descending genicular artery and descending branch of the lateral circumflex femoral artery (from the femoral system); and the circumflex fibular and anterior/posterior tibial recurrent arteries (from the tibial system).
- ▶ The **middle genicular artery** arises from the popliteal artery, pierces the oblique popliteal ligament, and supplies the **cruciate ligaments and the synovial membrane directly** — the single most important named vessel for this answer.
- ▶ The **peripheral (outer) one-third** of each meniscus is vascularised via capillary loops from the capsule/synovium; the **inner two-thirds** is avascular and nutritionally dependent on synovial fluid diffusion (with canal-like nutrient structures noted in infants/children).
- ▶ **Innervation:** genicular branches of the tibial and common fibular nerves (tibial nerve branches accompany the medial and middle genicular arteries; common fibular nerve branches accompany the lateral genicular and anterior tibial recurrent arteries), plus articular branches from the femoral nerve (via vastus medialis) and the posterior division of the obturator nerve.
- ▶ **Synovial relations:** the synovial membrane lines the capsule as far as the menisci (whose surfaces have no synovial covering) and is reflected around the cruciates, so they lie *intracapsular but extrasynovial* — hence at arthroscopy the joint behaves as two separate (medial/lateral) compartments divided by this synovial fold.

Applied / Clinical anatomy

- ▶ **Meniscal tears:** the **medial meniscus tears far more often** than the lateral, because it is firmly fixed to the capsule and the deep tibial collateral ligament and is far less mobile; the mobile lateral meniscus rarely tears alone. Typical mechanism: a valgus/rotational force on a flexed, weight-bearing knee with the foot fixed (e.g. twisting sports). Peripheral (vascular-zone) tears can heal, especially with surgical repair; central (avascular-zone) tears do not heal spontaneously and usually require arthroscopic partial meniscectomy.
- ▶ **"Unhappy triad" (O'Donoghue's triad):** combined injury of the **tibial (medial) collateral ligament, the medial meniscus (which is attached to it), and the anterior cruciate ligament**, from a lateral blow to an extended knee or forced lateral rotation of a flexed knee — classic in football/basketball players.
- ▶ **ACL rupture:** caused by hyperextension, a severe anteriorly-directed force on a semiflexed knee, or non-contact pivoting/deceleration injuries (e.g. skiing); produces the **anterior drawer sign**

(excess anterior tibial glide on the fixed femur), clinically elicited by the **anterior drawer test** and, more sensitively, the **Lachman test**.

- ▶ **PCL rupture:** less common; classically from a blow to the tibial tuberosity with the knee flexed ("dashboard injury"), producing the **posterior drawer sign**; often accompanies collateral ligament tears.
- ▶ **Discoïd lateral meniscus:** congenital anomaly; the *Wrisberg type* lacks a normal tibial attachment of its posterior horn (held only by the posterior meniscomfemoral ligament), so it is unstable and becomes trapped between femur and tibia, producing the classic "clunking knee"; usually an incidental arthroscopic finding.
- ▶ **Meniscectomy:** range of motion is preserved after meniscal removal, but joint stability falls and contact stresses rise, predisposing to secondary osteoarthritis — favouring repair over excision wherever possible.
- ▶ **Aspiration/haemarthrosis:** effusions (e.g. haemarthrosis after ACL tear) are aspirated from the sides of the patellar ligament, using the suprapatellar bursa's free communication with the joint cavity.

□ Fig 33.11 — Injury of cruciate ligaments of the knee joint: (A) rupture of anterior cruciate ligament (positive anterior drawer sign) and (B) rupture of the posterior cruciate ligament (positive posterior drawer sign) (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.1273)

High-yield exam pointers

- ▶ Medial meniscus = semicircle, fixed to deep MCL, tears often; lateral meniscus = 4/5 circle, more mobile (popliteus + meniscomfemoral ligaments), tears rarely.
- ▶ Transverse ligament joins the two anterior horns; meniscomfemoral ligaments (Humphrey — anterior to PCL; Wrisberg — posterior to PCL) join the lateral meniscus's posterior horn to the medial femoral condyle.
- ▶ ACL: tibial-eminence anterior → lateral femoral condyle posteromedial surface, ~38×11 mm; resists anterior tibial translation; ruptures more often.
- ▶ PCL: tibial posterior intercondylar area → medial femoral condyle, ~38×13 mm, thicker/stronger than ACL; resists posterior tibial translation; ruptures less often.
- ▶ Cruciates are intracapsular but extrasynovial (synovium reflected posterior to PCL).
- ▶ Screw-home movement = terminal medial rotation of femur on tibia in extension = "locking"; popliteus laterally rotates the femur to "unlock" and protects the lateral meniscus's posterior horn.
- ▶ Middle genicular artery (from popliteal artery, pierces oblique popliteal ligament) is the specific vessel supplying the cruciates and synovium; peripheral 1/3 of menisci is vascular, inner 2/3 avascular — governs healing/repair vs excision.
- ▶ Unhappy triad = ACL + medial (tibial) collateral ligament + medial meniscus.
- ▶ Anterior/posterior drawer signs and the Lachman test clinically localise ACL/PCL rupture.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh — Textbook of Anatomy Vol 2 (4e); IB Singh — Textbook of Anatomy Vol 1 (6e); BD Chaurasia — Human Anatomy Vol 3-4 (8e, exam Q&A on unhappy triad).



Popliteal fossa

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction The popliteal fossa is a shallow, fat-filled, diamond (rhomboid)-shaped depression on the posterior aspect of the knee, corresponding functionally to the cubital fossa of the upper limb. It is roughly 2.5 cm wide, bounded by the hamstrings above and the two heads of gastrocnemius below, with a floor and a roof. It is the passage through which the popliteal vessels, tibial and common peroneal nerves, and popliteal lymph nodes travel from thigh to leg — making it a frequent clinical site of aneurysm, nerve injury, abscess and swellings requiring differentiation.

Extent and boundaries

Boundary	Formed by
Superomedial	Semitendinosus and semimembranosus, supplemented by gracilis, sartorius and adductor magnus
Superolateral	Biceps femoris
Inferomedial	Medial head of gastrocnemius
Inferolateral	Lateral head of gastrocnemius, supplemented by plantaris

- Deep aspect: superior boundaries correspond to the medial/lateral supracondylar lines of the femur; inferior limit to the soleal line of the tibia.

Roof and floor

- **Roof** (posterior wall): skin, superficial fascia and the strong **popliteal (deep) fascia**, continuous with the fascia lata above and deep fascia of the leg below, reinforced by transverse fibres. Superficial fascia carries the terminating **small saphenous vein** and three cutaneous nerves — posterior cutaneous nerve of the thigh, posterior division of the medial cutaneous nerve of thigh, and the peroneal (sural) communicating nerve — piercing the roof to reach skin.
- **Floor** (anterior wall), from above downwards: (1) **popliteal surface of the femur**, (2) **capsule of the knee joint** reinforced by the **oblique popliteal ligament**, (3) **fascia covering popliteus**, with popliteus lying deep to it.
- Taut on extension, the popliteal fascia compresses the fat and pushes semimembranosus medially, protecting the contents; being dense and non-yielding it does **not** permit expansion of the fossa (relevant to abscess behaviour, see Applied anatomy).

Contents of the fossa

□ Fig 25.1 — Popliteal fossa—boundaries and contents (IB Singh — Textbook of Anatomy Vol 1 — 6e, p.355)

- ▶ Popliteal artery and its branches
- ▶ Popliteal vein and its tributaries
- ▶ Tibial nerve and its branches
- ▶ Common peroneal nerve and its branches
- ▶ Posterior cutaneous nerve of the thigh
- ▶ Genicular branch of the obturator nerve
- ▶ Popliteal lymph nodes
- ▶ Fat, surrounding and supporting all the above

The popliteal vessels and tibial nerve cross the fossa vertically, one over the other; the arrangement changes as they descend:

Level	Arrangement (superficial → deep, or side to side)
Upper part	Medial to lateral: artery, vein, nerve (A, V, N)
Middle part	Behind forwards: nerve, vein, artery (N, V, A)
Lower part	Medial to lateral: nerve, vein, artery (N, V, A)

- ▶ Overall the **tibial nerve** is most superficial, the **popliteal vein** intermediate, and the **popliteal artery** deepest, lying on the floor — hence the artery is most at risk in trauma/fractures around the knee, while the nerve is comparatively protected.
- ▶ The **common peroneal nerve** crosses obliquely from the superior to the lateral angle along the medial border of biceps femoris, in the same superficial plane as the tibial nerve.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A posterior view of the right knee showing the diamond-shaped popliteal fossa, labelled with:

- ▶ Biceps femoris (superolateral boundary) and semitendinosus/semimembranosus (superomedial boundary)
- ▶ Medial and lateral heads of gastrocnemius (inferomedial/inferolateral boundaries), with plantaris
- ▶ Popliteal artery, popliteal vein, tibial nerve — centre of the fossa, one above the other
- ▶ Common peroneal nerve — running along the medial border of biceps femoris
- ▶ Small saphenous vein piercing the roof, with the popliteal lymph nodes alongside it
- ▶ Popliteus muscle on the floor, below the joint capsule

Popliteal artery — course, relations and branches

- ▶ Continuation of the femoral artery, beginning at the **adductor hiatus** (opening in adductor magnus) at the junction of the middle and lower one-thirds of the thigh.

- **Course:** runs downwards and slightly laterally, lying successively on the popliteal surface of the femur, the capsule of the knee joint, and the fascia over popliteus; it **terminates at the lower border of popliteus** by dividing into the **anterior and posterior tibial arteries**.
- **Relations:** anterior (deep) — popliteal surface of femur, knee joint capsule, popliteus fascia; posterior (superficial) — popliteal vein and tibial nerve; lateral — biceps femoris/lateral condyle above, plantaris/lateral gastrocnemius below; medial — semimembranosus/medial condyle above, medial head of gastrocnemius below.
- **Surface marking:** a line from 2.5 cm medial to the midline at the junction of middle/lower thigh, to the midline behind the knee, to the midline at the tibial tuberosity — concave medially above, then vertical.

Branch group	Details
Muscular (superior)	2–3 branches to adductor magnus and hamstrings; anastomose with the fourth perforating artery
Muscular (sural arteries)	Supply gastrocnemius, soleus and plantaris
Genicular (5)	Superior medial, superior lateral, inferior medial, inferior lateral, and middle genicular arteries; the middle genicular pierces the oblique popliteal ligament to supply the cruciate ligaments and synovial membrane
Cutaneous	Arise directly, or indirectly via muscular branches; one usually accompanies the small saphenous vein

Tibial nerve and common peroneal nerve in the fossa

Feature	Tibial nerve	Common peroneal nerve
Root value	Ventral divisions of ventral rami, L4, 5, S1, 2, 3	Dorsal divisions of ventral rami, L4, 5, S1, 2
Origin	Larger terminal branch of the sciatic nerve, at the superior angle of the fossa	Smaller terminal branch of the sciatic nerve
Course in fossa	Descends centrally/vertically, superficial to the popliteal vessels, crossing them from lateral to medial as it descends, to the inferior angle	Runs along the medial border of biceps femoris (superolateral boundary) to the lateral angle, then winds round the neck of the fibula
Termination	Continues into the leg (posterior compartment)	Pierces peroneus longus and divides into superficial and deep peroneal nerves

Feature	Tibial nerve	Common peroneal nerve
Branches in fossa	3 genicular (superior medial, middle — pierces capsule, inferior medial); cutaneous (sural nerve); muscular to both heads of gastrocnemius, soleus, plantaris and popliteus (nerve to popliteus also supplies tibialis posterior, tibia, interosseous membrane and inferior tibiofibular joint)	2 cutaneous (lateral cutaneous nerve of calf; sural/peroneal communicating nerve, joining the sural nerve); articular (superior & inferior lateral genicular, and a recurrent genicular nerve to the knee joint and tibialis anterior); no true muscular branch (occasional twig to short head of biceps femoris)

Popliteal lymph nodes and genicular anastomosis

□ Fig 7.55 — Genicular anastomosis around the knee joint (Moore — Clinically Oriented Anatomy — 9e, p.1222)

- ▶ **Popliteal lymph nodes** (6–7, embedded in the fat) form **superficial** and **deep** groups:
 - *Superficial* nodes lie in the superficial fascia; the largest is at the point where the small saphenous vein pierces the deep fascia and drains lymphatics accompanying it.
 - *Deep* nodes lie within the fossa fat, surrounding the popliteal vessels, and receive afferents from the deep veins and the knee joint.
 - Overall afferents: lateral part of the sole, superficial and deep back of the leg, and the knee joint. Efferents follow the femoral vessels to the **deep inguinal lymph nodes**.
- ▶ **Genicular (peri-articular) anastomosis**: the five genicular branches of the popliteal artery anastomose with the **descending genicular artery** (from the femoral, superomedially), the **descending branch of the lateral circumflex femoral artery** (superolaterally), and the **anterior/posterior tibial recurrent** and **circumflex fibular** arteries (inferiorly) to form a quadrilateral network around the patella and the adjoining femoral/tibial condyles.
- ▶ This anastomosis provides collateral circulation that keeps the leg perfused when the popliteal artery is kinked during full knee flexion, and is the route by which blood reaches the leg after ligation of the femoral or popliteal artery (e.g., Hunter's operation).

Applied / Clinical anatomy

- ▶ **Popliteal aneurysm**: the popliteal artery is the artery most prone to aneurysm in the body, from constant pulsation against the unyielding adductor magnus opening. Presents as a **pulsatile, midline** swelling; may stretch/compress the tibial nerve, causing referred pain on the medial leg and foot.
- ▶ **Baker's cyst vs aneurysm**: a Baker's cyst (semimembranosus bursa herniation or synovial protrusion of the knee) is **cystic, non-pulsatile** and **medial**, unlike the pulsatile midline aneurysm.
- ▶ **Trauma**: fixation at the adductor hiatus and proximity to the femur/joint capsule means **distal femoral fractures and knee dislocation** can lacerate or thrombose the artery, causing an **arteriovenous shunt**, haemorrhage, or (if collaterals fail) gangrene up to the knee.
- ▶ **Popliteal artery entrapment syndrome**: abnormal relation of the artery to the medial head of gastrocnemius compresses it on muscle contraction, causing claudication in young athletes.

- ▶ **Blood pressure in the lower limb:** recorded by auscultating the popliteal artery (prone, knee slightly flexed, thigh cuff); it is characteristically **lower than brachial pressure in coarctation of the aorta**. The popliteal pulse is the **most difficult peripheral pulse to palpate**.
- ▶ **Nerve injuries:** tibial nerve injury (rare, protected) causes paralysis of posterior leg/intrinsic foot muscles with the foot **everted and dorsiflexed** (walks on the heel). The **common peroneal nerve** — the **commonest injured nerve of the lower limb** at the fibular neck — gives painless **foot drop** with intact inversion, plantarflexion and ankle jerk.
- ▶ **Abscess/swellings:** the tough, non-yielding popliteal fascia causes disproportionate pain and makes pus track supero-inferiorly along fascial planes rather than expand locally; short saphenous varicosity and inflamed knee bursae also present as popliteal swellings needing differentiation from aneurysm/Baker's cyst.
- ▶ **Surgical landmark:** the small saphenous vein and sural cutaneous nerves piercing the roof mark the direct posterior approach to the knee joint.

High-yield exam pointers

- ▶ Diamond-shaped fossa; boundaries — **ST/SM** (superomedial), **biceps femoris** (superolateral), **medial head gastrocnemius** (inferomedial), **lateral head gastrocnemius + plantaris** (inferolateral).
- ▶ Floor, above downwards: **popliteal surface of femur** → **knee joint capsule/oblique popliteal ligament** → **popliteus fascia**.
- ▶ Contents (8): popliteal artery & vein, tibial & common peroneal nerves, posterior cutaneous nerve of thigh, genicular branch of obturator nerve, popliteal lymph nodes, fat.
- ▶ Arrangement by level: upper — A,V,N (medial to lateral); middle — N,V,A (behind forwards); lower — N,V,A (medial to lateral). **Nerve most superficial, artery deepest overall**.
- ▶ Tibial nerve root value **L4–S3**; common peroneal **L4–S2**; common peroneal is the commonest nerve injured in the lower limb (neck of fibula → foot drop).
- ▶ Genicular branches of the popliteal artery are **five** (2 superior, 2 inferior, 1 middle); they form the peri-articular anastomosis that maintains leg perfusion during full knee flexion and after femoral/popliteal ligation.
- ▶ Popliteal lymph nodes (6–7) — superficial (along short saphenous vein) and deep (around vessels) groups; drain to deep inguinal nodes.
- ▶ Popliteal artery is the commonest site of a peripheral arterial aneurysm; differentiate a pulsatile midline aneurysm from a non-pulsatile medial Baker's cyst.
- ▶ Popliteal artery is used to record lower-limb blood pressure; lower than brachial pressure suggests coarctation of the aorta.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; IB Singh — Textbook of Anatomy Vol 1, 6e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore's Clinically Oriented Anatomy, 9e.



Sciatic nerve

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction The sciatic nerve is the thickest and longest nerve in the human body (about 2 cm wide at its origin) and is the principal nerve of the lower limb. It is the largest branch of the sacral plexus, formed in front of piriformis from the ventral rami of L4 to S3, and consists of two functionally distinct components — the tibial and common peroneal parts — bound together in a common connective-tissue sheath from their very origin. It supplies the hamstring muscles directly and, through its two terminal branches, virtually the whole of the leg and foot; its course through the gluteal region and thigh, and its close relation to piriformis, underlie most of its surgical and clinical importance.

Root value, formation and composition

- ▶ **Root value:** ventral rami of L4, L5, S1, S2, S3.
- ▶ It is made up of two cords bound in one sheath:
 - **Tibial part** — formed by the **ventral divisions** of the ventral rami of L4, L5, S1, S2, S3.
 - **Common peroneal (fibular) part** — formed by the **dorsal divisions** of the ventral rami of L4, L5, S1, S2.
- ▶ It is the **largest branch of the sacral plexus** and is formed **in front of piriformis**, under cover of its fascia, within the pelvis.

Course and extent

Region	Course
Pelvis	Lies in front of piriformis, under cover of its fascia.
Gluteal region	Leaves the pelvis through the greater sciatic foramen below piriformis ; runs downward with a slight lateral convexity, passing between the ischial tuberosity and the greater trochanter . Gives no branches here.
Back of thigh	Enters the thigh at the lower border of gluteus maximus; descends vertically downward in the angle between gluteus maximus and the long head of biceps femoris (its only superficial exposure), giving articular and hamstring muscular branches.
Termination	Divides into the tibial and common peroneal nerves at, or just above, the apex of the popliteal fossa — usually at the junction of the middle and lower thirds of the thigh ; the level of division is variable and can occur anywhere above this point, or rarely below it.

Variations in relation to piriformis (Beason & Anson classification): normally the whole nerve passes below piriformis; in about 12% the common peroneal part pierces piriformis while the tibial part passes below it; in about 0.5% the common peroneal part passes above piriformis while the tibial part passes below — an anatomical basis for piriformis syndrome.

Relations

Region	Superficial (posterior)	Deep (anterior) / medial
Gluteal region	Gluteus maximus	Deep — body of ischium, tendon of obturator internus with the two gemelli, quadratus femoris (separating the nerve from obturator externus and the hip joint), and the upper transverse fibres of adductor magnus. Medial — inferior gluteal nerve/vessels and the posterior femoral (cutaneous) nerve of the thigh.
Back of thigh	Long head of biceps femoris	Deep — adductor magnus. Medial — semimembranosus and semitendinosus. Lateral — biceps femoris.

The deep (anterior) relations from above downward — **ischium** → **obturator internus with gemelli** → **quadratus femoris** → **adductor magnus** — constitute the "sciatic bed".

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Real labelled plate embedded below — reproduce with these exact labels: Piriformis; Ischial spine; Obturator internus with two gemelli; Ischial tuberosity; Greater trochanter; Quadratus femoris; Sciatic nerve; Gluteal tuberosity; Semitendinosus; Adductor magnus; Short head of biceps femoris; Semimembranosus; Long head of biceps femoris; Tibial nerve; Common peroneal nerve.

□ Fig 7.7 — Relations of sciatic nerve in the gluteal region and back of thigh (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.129)

Branches / distribution

Branch	Site of origin	Distributed to
Articular branches	Gluteal region (occasionally direct from sacral plexus)	Hip joint (posterior capsule)
Muscular branches (from medial side of tibial part)	Lower gluteal region / upper thigh	Semitendinosus, semimembranosus, long head of biceps femoris, ischial (hamstring) part of adductor magnus
Muscular branch (from lateral side of common peroneal part)	Lower thigh	Short head of biceps femoris
Terminal branches	At/near apex of popliteal fossa	Tibial nerve (larger) and common peroneal nerve (smaller)

- ▶ **Motor:** directly supplies all muscles of the back of the thigh (hamstrings and the hamstring part of adductor magnus); indirectly, via its terminal branches, supplies all muscles of the leg and foot.
- ▶ **Sensory:** the sciatic nerve itself gives **no direct cutaneous branch**; indirectly, through the tibial and common peroneal nerves, it supplies the skin of the whole leg (except the saphenous nerve's area) and both dorsal and plantar surfaces of the foot.
- ▶ N.B.: **all** muscular branches arise from the **medial side** of the nerve **except** the nerve to the short head of biceps femoris, which arises from the **lateral side** — the anatomical basis of the "safe side" (see below).

Blood supply

- ▶ Accompanied by a slender **companion artery** — **arteria comitans nervi ischiadici** (artery of the **sciatic nerve**) — a branch of the inferior gluteal artery that sinks into the substance of the nerve; it represents the remnant of the **embryonic axial artery** of the lower limb.
- ▶ **Gluteal region:** inferior gluteal artery and the **cruciate anastomosis** (medial and lateral circumflex femoral arteries, inferior gluteal artery, and the first perforating branch of profunda femoris).
- ▶ **Thigh:** perforating branches of the **profunda femoris artery**, which anastomose with the companion artery of the sciatic nerve to form an intraneural/extraneural arterial chain.

Surface marking

The sciatic nerve is marked by a line drawn from a point **just medial to the midpoint between the ischial tuberosity and the greater trochanter**, running down to the **apex of the popliteal fossa**. For a sciatic nerve block, the anaesthetic agent is injected **1.5 cm below the midpoint of the line joining the posterior superior iliac spine and the upper border of the greater trochanter**.

Applied / Clinical anatomy

- ▶ **Safe vs unsafe side:** since all hamstring muscular branches (except the one to the short head of biceps femoris) leave the medial side of the nerve, the **lateral side of the back of the thigh is the "safe side"** for surgical approach and the medial side is the "unsafe/dangerous side".
- ▶ **Intramuscular injections:** given into the **upper-and-outer (anterosuperior) quadrant** of the gluteal region (into gluteus medius/minimus), because the sciatic nerve and the major gluteal vessels lie in the lower and medial part of the region; a misplaced gluteal injection is the **most common cause** of iatrogenic sciatic nerve injury.
- ▶ **Sleeping foot:** the nerve is superficial and unprotected only in the angle between the lower border of gluteus maximus and the long head of biceps femoris, where it lies briefly on the femur between quadratus femoris and adductor magnus; transient compression here (e.g. sitting on a hard chair edge or a bicycle bar) produces temporary paraesthesia of the limb, relieved once weight is shifted or the foot is tapped on the ground.
- ▶ **Piriformis syndrome:** an anomalous relationship between the nerve and piriformis (including the variant courses in which the common peroneal part pierces or passes above piriformis) may entrap or tether the nerve, producing buttock pain radiating along its course; a controversial and rare entrapment neuropathy.

- ▶ **Sciatica**: shooting pain beginning in the low back, radiating through the buttock and back of the thigh to the lateral side of the leg and often into the foot, due to compression/irritation of the L4–S3 nerve roots, classically by a **prolapsed lumbar intervertebral disc**. The **straight-leg-raising test** (passive hip flexion with the knee extended) reproduces the pain by stretching the nerve and its roots and is used to confirm root/nerve irritation.
- ▶ **Sciatic nerve injury**: caused by penetrating wounds, **posterior dislocation of the hip**, pelvic fracture, misplaced gluteal intramuscular injection, or **total hip replacement surgery** (occurs in about 1% of cases, from sharp injury, thermal injury from bone cement, traction on instruments, hip manipulation, inadvertent limb lengthening, or a peri-nerve haematoma). Complete section causes a **flail/drop foot** with loss of all movements below the knee, a **high-stepping gait**, and sensory loss over the back of the thigh and the whole of the leg and foot except the area supplied by the saphenous nerve. The **common peroneal component is more frequently and more severely affected** than the tibial component.
- ▶ Loss of the **ankle jerk** (S1–S2, mediated via the tibial nerve) is an important clinical sign of sciatic nerve or root involvement.

High-yield exam pointers

- ▶ Thickest nerve in the body (~2 cm wide at origin); largest branch of the sacral plexus; root value L4–S3.
- ▶ Two components — **tibial** (ventral divisions) and **common peroneal** (dorsal divisions) — bound in one sheath from origin; divide near the **apex of the popliteal fossa**.
- ▶ Leaves the pelvis via the **greater sciatic foramen below piriformis**; piriformis is the "key" and "gateway" muscle of the region.
- ▶ **Sciatic bed** (deep relations, above downward): ischium → obturator internus with gemelli → quadratus femoris → adductor magnus.
- ▶ Gives **no branches and no cutaneous supply in the gluteal region**; only articular and hamstring muscular branches arise in the thigh, all from its medial side except the branch to short head of biceps femoris.
- ▶ Companion vessel = **arteria comitans nervi ischiadici**, an embryonic axial-artery remnant.
- ▶ **Safe side** = **lateral** side of the back of the thigh.
- ▶ IM injections must go into the **upper-outer quadrant** of the buttock to avoid the nerve.
- ▶ Piriformis relation variants (~12% pierces piriformis; ~0.5% passes above it) explain piriformis syndrome.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e.



Sub talar joints

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

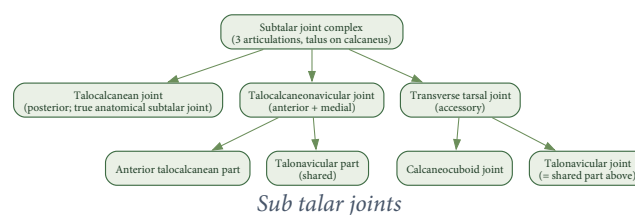
Definition / Introduction The term "subtalar joints" is used in two senses. Anatomically, the **talocalcaneal (posterior subtalar) joint** is a single, discrete synovial joint between talus and calcaneus, separate from the **talocalcaneonavicular joint** in front of it. Functionally, the talus rests on the calcaneus at three articulations — posterior, anterior and medial — acting together as one **modified multiaxial synovial complex**, loosely termed "the subtalar joint(s)" as asked here. Together with the accessory transverse tarsal joint, this complex is the principal site of **inversion and eversion** of the foot, movements that adapt the sole to uneven or sloping ground during locomotion.

Classification and joints taking part

The joints that together bring about inversion and eversion are grouped as follows.

Category	Joint	Articulation
Main	Talocalcaneal (subtalar) joint	Posterior facet of talus on posterior facet of calcaneus
Main	Talocalcaneonavicular joint	Anterior/middle facets of talus on calcaneus + navicular + spring ligament
Accessory	Transverse tarsal (midtarsal) joint	Calcaneocuboid joint + talonavicular joint (the talonavicular component is shared with the talocalcaneonavicular joint)

Because the talonavicular articulation is shared with the talocalcaneonavicular joint, the transverse tarsal joint is sometimes said to comprise "only one-and-a-half joints." Its two components lie in nearly the same coronal plane but have different axes of movement and, unlike the talocalcaneal–talocalcaneonavicular pair, do not form a true functional unit.



Talocalcaneal (subtalar) joint proper

- **Type:** a plane synovial joint, functionally described as a modified multiaxial joint since it moves in concert with the talocalcaneonavicular joint.
- **Articular surfaces:** the concave facet on the posterior part of the inferior surface of the body of the talus articulates with the convex facet on the middle one-third of the superior surface of the calcaneus.
- **Fibrous capsule:** thin, with short fibres attached close to the articular margins; envelops the joint.
- **Ligaments:**

- **Lateral talocalcaneal ligament** — short, flat band from the lateral talar process to the lateral calcaneal surface, anterosuperior to the calcaneofibular ligament.
- **Medial talocalcaneal ligament** — connects the medial tubercle of the talus to the sustentaculum tali and adjoining calcaneal surface; blends with the deltoid ligament of the ankle.
- **Interosseous talocalcaneal ligament** — thick, very strong bilaminar band occupying the sinus tarsi; the chief bond of union between talus and calcaneus; its posterior lamina belongs to this joint (the anterior lamina belongs to the talocalcaneonavicular joint); it separates the two joint cavities and becomes **taut in eversion**, limiting that movement.
- **Cervical ligament** — lateral to the sinus tarsi, passing from the superior calcaneal surface to a tubercle on the inferolateral talar neck; becomes **taut in inversion**, limiting that movement.
- The collateral (medial and lateral) ligaments of the ankle joint additionally stabilise this joint.
- ▶ **Synovial cavity:** usually separate from the ankle joint and from the talocalcaneonavicular joint cavity, though rare direct communications are described.
- ▶ **Innervation:** branches of the tibial, medial plantar and sural nerves.

Talocalcaneonavicular joint

- ▶ **Type:** a compound, multiaxial joint with the functional features of a **ball-and-socket joint**.
- ▶ **Articular surfaces:** the ovoid head of the talus is the "ball"; the "socket" is formed collectively by the posterior surface of the navicular, the middle and anterior calcaneal facets, and the fibrocartilaginous upper surface of the plantar calcaneonavicular (spring) ligament.
- ▶ **Fibrous capsule:** poorly developed except posteriorly, where it is thick and blends with the anterior lamina of the interosseous talocalcaneal ligament filling the sinus tarsi.
- ▶ **Ligaments:**
 - **Talonavicular ligament** — a broad, thin dorsal band connecting the talar neck to the navicular, covered by extensor tendons.
 - **Plantar calcaneonavicular (spring) ligament** — a broad, thick, fibrocartilaginous band from the sustentaculum tali to the plantar surface of the navicular; supports the talar head as part of the joint socket and is the single most important ligament maintaining the **medial longitudinal arch**; per Davis et al, it has a larger superomedial calcaneonavicular part and a smaller inferior calcaneonavicular part; its plantar surface is buttressed by the tendon of tibialis posterior medially and by flexor hallucis longus/flexor digitorum longus tendons laterally.
 - **Calcaneonavicular (medial) limb of the bifurcate ligament** — the lateral support of the socket.
- ▶ **Stability:** from bony contours, the spring ligament, and the calcaneonavicular part of the bifurcate ligament.
- ▶ **Innervation:** deep fibular and medial plantar nerves.
- ▶ **Synovial cavity:** sometimes communicates with the talocalcaneal joint cavity.

Relations of the joint complex

Aspect	Structures (dorsal → plantar / medial → lateral)
Medial (talocalcaneal joint)	Posterior tibial vessels and tibial nerve, tendon of flexor hallucis longus — all at risk in posteromedial surgical approaches
Medial (talocalcaneonavicular joint, above sustentaculum tali)	Tendon of tibialis posterior, then flexor digitorum longus (dorsal to plantar), with flexor hallucis longus below; the medial/lateral plantar vessels and tibial nerve lie deep to flexor hallucis longus here
Lateral	Tendons of fibularis brevis (anterior) and fibularis longus, both behind the lateral malleolus; sural nerve just posterior to these tendons
Dorsal (talonavicular joint)	Tendons of tibialis anterior and extensor hallucis longus (medial to lateral), deep fibular nerve, dorsalis pedis artery, and extensor hallucis brevis muscle belly passing deep to extensor digitorum longus/fibularis tertius tendons

Movements — inversion and eversion

- **Inversion:** the medial border of the foot is raised so that the sole faces medially.
- **Eversion:** the lateral border of the foot is raised so that the sole faces laterally.
- Both movements occur mainly at the **subtalar and talocalcaneonavicular joints**, with a smaller contribution from the **transverse tarsal joint**; the calcaneus and navicular rotate medially or laterally around the head of the talus, carrying the forefoot with them.
- **Axis of movement:** a single oblique axis running upward, forward and medially from the back of the calcaneus, through the sinus tarsi, to the superomedial talar neck; its obliquity accounts for the added components of adduction/abduction and plantar-/dorsiflexion noted below.

	Foot off the ground	Foot on the ground (weight-bearing)
Inversion	Greater range; forefoot adduction + lateral rotation (supination) of forefoot + plantar flexion of the foot	Range much reduced; only lateral rotation (supination) of the forefoot occurs; heads of the medial two metatarsals are raised
Eversion	Greater range; forefoot abduction + medial rotation (pronation) of forefoot + dorsiflexion of the foot	Range much reduced; only medial rotation (pronation) of the forefoot occurs; heads of the lateral three metatarsals are raised

- **Range of movement:** inversion (~30°) is considerably freer than eversion (~20°); movement at both joints increases in plantar flexion, because the narrow posterior part of the talar trochlea then occupies the wider anterior part of the tibiofibular mortise, permitting slight side-to-side play of the talus.
- **Muscles producing movement**

Movement	Principal muscles	Accessory muscles
Inversion	Tibialis anterior, tibialis posterior	Flexor hallucis longus, flexor digitorum longus
Eversion	Fibularis (peroneus) longus, fibularis brevis	Fibularis (peroneus) tertius

- **Limiting factors:** inversion is checked by tension of the fibulares (peronei) and the cervical ligament; eversion is checked by tension of tibialis anterior, tibialis posterior and the deltoid ligament (plus the interosseous talocalcaneal ligament).
- **Functional significance:** these movements let the plantigrade foot adapt to uneven ground. In weight-bearing they occur as **supination** (inversion component) and **pronation** (eversion component) of the forefoot, chiefly at the transverse tarsal and smaller intertarsal joints, with compensatory talar movement completing the arc.

□ Fig 33.20 — Subtalar and talocalcaneonavicular joints (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.1289)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A disarticulated talus (inferior surface) and calcaneus (superior surface), or a coronal/sagittal section through the hindfoot, labelled with:

- **Posterior talar articular facet** and its calcaneal counterpart — the talocalcaneal (subtalar) joint
- **Middle and anterior talar facets** on the calcaneus, and the **head of talus** — the talocalcaneonavicular joint
- **Sinus tarsi** with the **interosseous talocalcaneal ligament** running through it
- **Cervical ligament** (lateral to sinus tarsi)
- **Sustentaculum tali** and the **plantar calcaneonavicular (spring) ligament** arising from it
- **Navicular** and its articulation with the talar head
- **Bifurcate ligament** (Y-shaped: calcaneonavicular and calcaneocuboid limbs)
- **Cuboid** and the calcaneocuboid joint
- The **oblique axis of inversion–eversion**, drawn as a line from the posterior calcaneus through the sinus tarsi to the superomedial talar neck

Applied / Clinical anatomy

- **Ankle/subtalar sprains:** sprains at the ankle are almost always **abduction (eversion) sprains involving the subtalar joint**, with a few fibres of the deltoid ligament also torn; forced plantar flexion with excessive **inversion** tears the lateral ligament complex (anterior talofibular fibres first), the commonest sports ankle injury, since inversion has the greater range of the two movements.
- **Pott's fracture-dislocation:** forced eversion produces, in sequence, an oblique lateral malleolar fracture, then medial-side tearing (deltoid ligament/medial malleolus), and finally a posterior tibial-margin (third malleolus) fracture — the first, second and third degrees, the last being trimalleolar.

- ▶ **Spring ligament failure:** attenuation of the inferior calcaneonavicular part of the spring ligament leads to plantar flexion and adduction of the talar head, producing **adult acquired flatfoot (pes planovalgus)**; surgical reconstruction of the ligament may be required.
- ▶ **Talocalcaneal (subtalar) coalition:** an abnormal fibrous, cartilaginous or bony bridge across the sinus tarsi restricts inversion/eversion and presents as a rigid, painful flatfoot in adolescents; surgical resection is via the same medial approach noted above, so carries the same neurovascular risk.
- ▶ Hindfoot alignment and subtalar range are routinely assessed clinically in flatfoot, clubfoot and post-traumatic stiffness, since this complex is the chief terrain-adapting mechanism of the foot in gait.

High-yield exam pointers

- ▶ "Subtalar joints" = talocalcaneal (posterior, true anatomical subtalar) + talocalcaneonavicular (anterior + medial) joints, acting as one functional multiaxial complex; transverse tarsal (calcaneocuboid + talonavicular) is the accessory joint.
- ▶ Talocalcaneal joint: plane synovial joint; interosseous talocalcaneal ligament (taut in eversion) and cervical ligament (taut in inversion) are the key stabilising/limiting ligaments in the sinus tarsi.
- ▶ Talocalcaneonavicular joint: functions as a ball-and-socket joint; the socket is calcaneus + navicular + **spring ligament**, which is the chief support of the medial longitudinal arch.
- ▶ Both joints together (with a small transverse tarsal contribution) produce **inversion** (sole faces medially) and **eversion** (sole faces laterally) around a single oblique axis running from the calcaneus through the sinus tarsi to the talar neck.
- ▶ Range of motion: inversion ($\sim 30^\circ$) > eversion ($\sim 20^\circ$); both increase in plantar flexion.
- ▶ Muscles: inversion — tibialis anterior + tibialis posterior; eversion — fibularis longus + brevis (+ fibularis tertius).
- ▶ Weight-bearing equivalents: supination (inversion component) and pronation (eversion component) of the forefoot.
- ▶ Clinical triad to remember: inversion ankle sprain (commonest), Pott's fracture (eversion mechanism), and spring-ligament failure causing acquired flatfoot; talocalcaneal coalition as a cause of rigid painful flatfoot.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; AK Datta — Human Anatomy Vol 3 (Upper & Lower Limb); Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore's Clinically Oriented Anatomy, 9e.



Superficial peroneal nerve

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The **superficial peroneal (fibular) nerve** is the smaller of the two terminal branches of the **common peroneal (fibular) nerve**, the other being the deep peroneal nerve. Also called the **musculocutaneous nerve of the leg**, it is the **nerve of the lateral compartment of the leg**, supplying peroneus longus and peroneus brevis, and then continuing as the principal cutaneous nerve of the **distal lateral leg and dorsum of the foot**. Its superficial course as it pierces the deep fascia and its constant relation to the fibular neck make it clinically important both for isolated entrapment neuropathy and as a landmark in common peroneal nerve injury.

Origin and root value

- ▶ Terminal branch (with the deep peroneal nerve) of the **common peroneal nerve**, itself the smaller terminal division of the **sciatic nerve**, derived from the dorsal divisions of the ventral rami of **L4, L5, S1, S2**.
- ▶ Begins on the **lateral side of the neck of the fibula**, arising **in the substance of peroneus longus**, under cover of its upper fibres.
- ▶ **Root value: L5, S1** ventral primary rami (as distinct from the L4–S2 root value quoted for the parent common peroneal trunk).

Course and relations

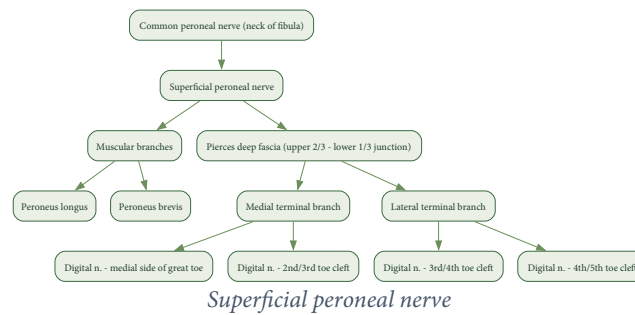
- ▶ **Upper third of leg:** descends **within the substance of peroneus longus**.
- ▶ **Middle third of leg:** descends for a short distance **between peroneus longus and peroneus brevis**, reaches the anterior border of peroneus brevis, and then lies in the **groove between peroneus brevis and extensor digitorum longus**, deep to the deep fascia.
- ▶ At the **junction of the upper two-thirds and lower one-third of the leg**, it **pierces the deep fascia** to become subcutaneous (a fixed, exam-favourite level).
- ▶ Immediately after piercing the fascia (occasionally while still deep to it), it divides into a **medial** and a **lateral terminal (cutaneous) branch**, which descend onto the dorsum of the foot. In Gray's Anatomy terminology these are the **medial dorsal cutaneous nerve** and the (smaller, more lateral) **intermediate dorsal cutaneous nerve**.
- ▶ The deep, compartmental course and the peripheral digital distribution of the nerve are noted to be **anatomically variable** (Kosinski's classification).

Branches and distribution

Branch	Supplies
Muscular branches	Peroneus (fibularis) longus and peroneus (fibularis) brevis — the two evertors of the foot
Cutaneous trunk	Skin of the lower one-third of the lateral side of the leg, and the greater part of the dorsum of the foot, except territories of the saphenous, sural, deep peroneal and plantar nerves

Branch	Supplies
Medial terminal branch (medial dorsal cutaneous n.)	Crosses the ankle → 2 dorsal digital nerves: medial side of the great toe , and adjoining sides of the 2nd and 3rd toes (communicates with the saphenous and deep peroneal nerves)
Lateral terminal branch (intermediate dorsal cutaneous n.)	2 dorsal digital nerves for adjoining sides of the 3rd/4th and 4th/5th toes (communicates with the sural nerve)

- **Exclusions from its cutaneous field:** the first (1st–2nd toe) web space is supplied by the deep peroneal nerve; the lateral side of the little toe by the sural nerve; the medial border of the foot up to the great toe by the saphenous nerve.
- **Variability:** the lateral (intermediate) branch is frequently absent and replaced by branches of the sural nerve; conversely, **accessory superficial and deep peroneal nerves** are recognised variants, probably from atypical branching of the parent trunk deep to the fascia.



□ Fig 30.10 — Distribution of superficial peroneal nerve (IB Singh — Textbook of Anatomy Vol 1 — 6e, p.441)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the lateral compartment of the leg and dorsum of the foot in outline and label:

- **Neck of fibula** — site of origin of the superficial peroneal nerve at the bifurcation of the **common peroneal nerve**, arising within the substance of **peroneus longus**.
- Course through the **upper third** (within peroneus longus) → **middle third** (groove between peroneus brevis and extensor digitorum longus).
- The point at the **junction of upper 2/3 and lower 1/3 of the leg** where the nerve **pierces the deep fascia** — mark this as the classic **entrapment site**.
- **Medial terminal branch** running to the great toe and 2nd/3rd cleft, and **lateral terminal branch** to the 3rd/4th and 4th/5th clefts.
- Adjoining territories to exclude and label separately: 1st web space (**deep peroneal nerve**), lateral border of little toe (**sural nerve**), medial border of foot (**saphenous nerve**).
- Muscles labelled **peroneus longus** and **peroneus brevis**, bracketed "supplied by superficial peroneal nerve."

Applied / Clinical anatomy

- **Common peroneal nerve injury at the fibular neck** (plaster casts, prolonged squatting/cross-legged sitting, fibular head fracture, ganglia, leprosy) damages both terminal branches, producing

foot drop — loss of dorsiflexion, toe extension **and** eversion, with sensory loss over the dorsum of the foot; ankle jerk is preserved.

- ▶ **Isolated superficial peroneal nerve injury:** paralysis of peroneus longus and brevis causes **loss of eversion of the foot**, with **dorsiflexion, inversion and plantar flexion preserved** (deep peroneal and tibial nerves intact) — this distinguishes an isolated superficial peroneal lesion from a common peroneal trunk lesion. Sensory loss occurs on the **lateral aspect of the leg** and the **dorsum of the foot**, sparing the first web space, the lateral border of the little toe, and the medial border of the foot.
- ▶ **Deformity:** unopposed action of the invertors of the foot (tibialis anterior/posterior) after superficial peroneal nerve paralysis produces **talipes varus** (contrast: unopposed evertor action after an isolated deep peroneal/anterior tibial-muscle paralysis produces talipes valgus).
- ▶ **Superficial peroneal nerve entrapment:** the nerve can be compressed as it **pierces the deep fascia** at the junction of the upper two-thirds and lower one-third of the leg (a fixed, narrow fascial tunnel); it may also be stretched by **chronic/recurrent ankle sprains**, or compressed in **lateral compartment syndrome**. Presents with pain and paraesthesia along the lateral leg and dorsum of the foot/ankle that worsens with activity and with passive inversion–plantarflexion of the ankle (positive nerve-stretch/Tinel sign at the exit point).
- ▶ **Regional anaesthesia:** because its medial and intermediate cutaneous terminal branches become subcutaneous well above the ankle (visible as skin ridges in thin patients on plantarflexion), a subcutaneous "ring" block anterior to the palpable fibula, above the malleoli, anaesthetises most of the dorsum of the foot except the first web space — useful for foot surgery under ankle block.
- ▶ **Surgical risk:** the terminal cutaneous branches (especially the intermediate branch) are vulnerable during **ankle arthroscopy portal placement** and open approaches to the ankle/distal fibula.
- ▶ **Reconstructive use:** an anterior tibial artery perforator that accompanies the superficial peroneal nerve permits a **neurocutaneous flap** incorporating the nerve, used to resurface anterolateral leg/foot skin defects.
- ▶ **Surface marking:** traced along a line from the neck of the fibula to the point where it pierces the deep fascia at the junction of the upper two-thirds and lower one-third of the leg, continuing as its two terminal branches onto the dorsum of the foot.

High-yield exam pointers

- ▶ Smaller terminal branch of the **common peroneal nerve**; begins at the **neck of the fibula**, arising in the substance of **peroneus longus**; root value L5, S1.
- ▶ Nerve of the **lateral compartment of the leg**; muscular supply — **peroneus longus and peroneus brevis** only.
- ▶ Pierces the **deep fascia at the junction of upper 2/3–lower 1/3 of the leg** — the classic entrapment level.
- ▶ Divides into **medial** (great toe + 2nd/3rd cleft) and **lateral** (3rd/4th + 4th/5th cleft) terminal branches = Gray's "**medial/intermediate dorsal cutaneous nerves**."

- ▶ Cutaneous supply = **most of the dorsum of the foot and distal lateral leg**, EXCLUDING the 1st web space (deep peroneal), lateral border of little toe (sural), and medial foot border (saphenous).
- ▶ Isolated lesion → **loss of eversion only**, sensory loss over dorsum of foot; dorsiflexion/inversion preserved — distinguishes it from a common peroneal trunk lesion (which also causes foot drop).
- ▶ Unopposed invertors after superficial peroneal palsy → **talipes varus**.
- ▶ Lateral terminal branch frequently replaced by **sural nerve** branches (clinically relevant variant); "accessory" superficial/deep peroneal nerves also described.
- ▶ Entrapment neuropathy presents with lateral leg/dorsal foot pain worsened by ankle inversion-plantarflexion; also at risk in ankle arthroscopy and chronic ankle sprain.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 (8e); Vishram Singh — Textbook of Anatomy Vol 2 (4e); IB Singh — Textbook of Anatomy Vol 1 (6e); Moore's Clinically Oriented Anatomy (9e).



Thorax



Arch of Aorta

Asked in: Paper I May 2018 · Paper I May 2009 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction The arch of the aorta is the second, curved part of the aorta lying in the **superior mediastinum**, connecting the ascending aorta to the descending thoracic aorta. It arches over the root of the left lung and gives origin to the three great arteries that supply the head, neck and upper limbs. Being an elastic artery close to the heart, it also plays a key haemodynamic (Windkessel) role, and its relations to the trachea, oesophagus, recurrent laryngeal nerve and ligamentum arteriosum make it one of the most clinically important segments of the thoracic aorta.

Extent, course and dimensions

- ▶ **Begins** behind the upper border of the **right 2nd sternocostal (sternochondral) joint**, as a direct continuation of the ascending aorta at the level of the sternal angle.
- ▶ **Courses** upwards, backwards and to the left, crossing the left side of the tracheal bifurcation; it then passes downwards behind the left principal bronchus and along the left side of the body of the **4th thoracic vertebra**, arching over the root of the left lung.
- ▶ **Ends** at the lower border of the body of T4 by becoming continuous with the descending thoracic aorta — so the beginning and end lie at the same vertebral/costal level, although the arch begins anteriorly and ends posteriorly.
- ▶ The **highest point (summit)** of the arch lies about 2.5 cm below the jugular (suprasternal) notch, roughly at the level of the middle of the manubrium sterni.

- **Diameter:** about 3 cm at its origin (same as the ascending aorta), tapering to about 2 cm just before its termination, where a slight constriction — the **aortic isthmus** — is seen; the isthmus is immediately followed by a small post-isthmic dilatation. The isthmus is the classical site of coarctation.

Relations

The arch has five structures related to each of its aspects — anterior/left, posterior/right, superior and inferior.

Aspect	Structures related
Anteriorly and to the left	Left lung and pleura; remains of the thymus; left superior intercostal vein; and, from before backwards, four nerves — left phrenic nerve, lower cervical cardiac branch of left vagus, superior cervical cardiac branch of left sympathetic trunk, and the left vagus nerve itself
Posteriorly and to the right	Trachea (with the deep cardiac plexus and tracheobronchial lymph nodes); oesophagus; left recurrent laryngeal nerve; thoracic duct; body of the vertebral column
Superiorly	The three branches of the arch — brachiocephalic, left common carotid and left subclavian arteries — all crossed anteriorly, close to their origin, by the left brachiocephalic vein
Inferiorly	Bifurcation of the pulmonary trunk; left principal bronchus; ligamentum arteriosum (with the superficial cardiac plexus on it); left recurrent laryngeal nerve hooking below the arch and around the ligamentum

□ Fig 22.6 — Relations of the arch of the aorta (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.876)

Branches

The arch gives off its branches from its **convexity** (superior border), in order, from right to left:

- **Brachiocephalic (innominate) trunk** — the largest branch; arises first, from the beginning of the arch, and divides behind the right sternoclavicular joint into the right common carotid and right subclavian arteries.
- **Left common carotid artery** — the second branch, arising just to the left of the brachiocephalic trunk.
- **Left subclavian artery** — the third and most posterior branch, arising about 1 cm distal to the left common carotid.
- An inconstant small **arteria thyroidea ima** may arise from the arch (or from the brachiocephalic trunk) to supply the thyroid isthmus — of surgical importance in tracheostomy.

□ Fig 8.14 — Diagram to show the branches of the arch of the aorta (IB Singh — Textbook of Anatomy Vol 2 — 6e, p.119)

Variations in branching (of applied importance in vascular/CT imaging):

Pattern	Approximate frequency
Usual pattern (3 separate branches as above)	~65%
Left common carotid arises from the brachiocephalic trunk (common "bovine" pattern)	~27%
Brachiocephalic trunk absent — all four arteries (right/left common carotid, right/left subclavian) arise independently from the arch	~2.5%
Left vertebral artery arises directly from the arch	~5%
Both a right and a left brachiocephalic trunk present	~1.2%

Development

The arch of the aorta develops from three components on the **left side** only: (i) the **left horn of the aortic sac**, (ii) the **left 4th pharyngeal (aortic) arch artery**, and (iii) the **left dorsal aorta** cranial to the 7th intersegmental artery. The brachiocephalic trunk forms from the **right horn of the aortic sac**. The right subclavian artery is composite — its proximal part from the right 4th arch artery and its distal part from the right 7th cervical intersegmental artery — whereas the left subclavian artery is formed entirely from the left 7th cervical intersegmental artery.



Arch of Aorta

This asymmetric development explains the **course of the recurrent laryngeal nerves**: the distal part of the 6th aortic arch artery persists only on the left as the **ligamentum arteriosum**, so the left recurrent laryngeal nerve is dragged down into the thorax and hooks around the ligamentum arteriosum; on the right, the corresponding distal 6th arch artery disappears, so the right recurrent laryngeal nerve remains in the neck and hooks around the right subclavian artery instead.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the arch of aorta arching over the left bronchus with its three branches, and label:

- ▶ **Ascending aorta** (below) and **descending thoracic aorta** (continuing behind) with the **aortic isthmus** at the junction.
- ▶ The three branches from the convexity: **brachiocephalic trunk**, **left common carotid artery**, **left subclavian artery**, each crossed by the **left brachiocephalic vein**.
- ▶ Structures below the arch: **bifurcation of pulmonary trunk**, **left principal bronchus**, **ligamentum arteriosum**, and the **left recurrent laryngeal nerve** hooking around it.
- ▶ Structures behind/right: **trachea**, **oesophagus**, **thoracic duct**, **vertebral column**.
- ▶ Structures in front/left: **left phrenic nerve**, **left vagus nerve**, **left superior intercostal vein**, **remains of thymus**.

Applied / Clinical anatomy

- ▶ **Aortic knuckle**: on a PA chest radiograph the arch projects as a rounded opacity just above the left border of the cardiac shadow; it becomes more prominent with age and in hypertension.
- ▶ **Aortic window**: on a left anterior oblique radiograph, a radiolucent space is seen below the arch in which the pulmonary trunk and left pulmonary artery can be visualised; widening/obliteration suggests mediastinal lymphadenopathy or aortic pathology.
- ▶ **Coarctation of the aorta**: a localised narrowing typically at or near the aortic isthmus/site of the ligamentum arteriosum. **Pre-ductal** (infantile) type — narrowing proximal to a patent ductus arteriosus, causing lower-body cyanosis from unoxygenated ductal blood. **Post-ductal** (adult) type — ductus usually closed; collateral circulation develops via the internal thoracic → anterior intercostal → posterior intercostal arteries to the aorta distal to the coarctation, producing **notching of the ribs** (visible radiographically) and **radiofemoral delay**, with upper-limb hypertension and lower-limb hypotension.
- ▶ **Patent ductus arteriosus (PDA)**: failure of closure of the ductus arteriosus connecting the beginning of the left pulmonary artery to the arch just distal to the left subclavian origin; the left recurrent laryngeal nerve hooks around its remnant, the ligamentum arteriosum.
- ▶ **Aneurysm of the arch**: a dilatation that may compress the trachea, oesophagus or the left recurrent laryngeal nerve (causing hoarseness from left vocal cord palsy) and produce the mediastinal syndrome (dyspnoea, dysphagia, dysphonia); may also dissect.
- ▶ **Retro-oesophageal right subclavian artery ("arteria lusoria")**: an anomalous right subclavian artery arising as the last, most left-sided branch of the arch and crossing behind the oesophagus to reach the right upper limb, producing dysphagia (dysphagia lusoria).
- ▶ **Double aortic arch / right aortic arch**: rare developmental anomalies of the aortic arch system that may form a vascular ring around the trachea and oesophagus, occasionally requiring surgical division.
- ▶ **Surgical/anaesthetic relevance**: the arch and its branches are landmarks in cardiothoracic and vascular surgery (arch replacement, TEVAR), and knowledge of the recurrent laryngeal nerve's

relation to the ligamentum arteriosum is essential during PDA ligation and mediastinal dissection to avoid iatrogenic nerve injury.

High-yield exam pointers

- ▶ Begins at the upper border of the right 2nd sternocostal joint; ends at the lower border of T4 (sternal angle level both ends).
- ▶ Five relations on each of four aspects: anterior-left, posterior-right, superior, inferior — learn as a table.
- ▶ Three branches from the convexity: brachiocephalic trunk, left common carotid, left subclavian — usual pattern in ~65%; "bovine arch" variant (left CC from brachiocephalic trunk) in ~27%.
- ▶ Aortic isthmus = site of physiological narrowing and the classical site of coarctation.
- ▶ Develops from left aortic sac horn + left 4th arch artery + left dorsal aorta; explains why only the left recurrent laryngeal nerve hooks around the ligamentum arteriosum.
- ▶ Clinical triad to remember: aortic knuckle (PA film), aortic window (LAO film), radiofemoral delay (coarctation).
- ▶ Ligamentum arteriosum = remnant of ductus arteriosus; left recurrent laryngeal nerve hooks around it below the arch.

SOURCE & COVERAGE

BD Chaurasia's Human Anatomy Vol 1 (8e); IB Singh — Textbook of Anatomy Vol 2 (6e); Vishram Singh — Textbook of Anatomy Vol 1 (4e); Vishram Singh — Textbook of Clinical Embryology; Moore's Clinically Oriented Anatomy (9e); Gray's Anatomy (Standing) 41e.



Lymphatic drainage of breast

Asked in: Paper I May 2009 · Paper I Apr 2006 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction The lymphatic drainage of the breast is of outstanding clinical importance because carcinoma of the breast spreads chiefly along lymphatic channels to regional lymph nodes, and the pattern of nodal involvement dictates staging and surgical management. The dominant drainage arises from an extensive **dermal (subepithelial) lymphatic network** and a **periductal/perilobular plexus** within the parenchyma; breast lymphatics are valveless, so tumour occlusion can cause reversed (retrograde) flow. More than **75% of breast lymph drains to the axillary nodes**, the remainder chiefly to the **parasternal (internal thoracic) nodes**, with small contributions to posterior intercostal, supraclavicular and other groups. The subject is best studied under two heads — the **regional lymph node groups** and the **lymphatic vessels/pathways** that connect the breast to them.

Regional lymph node groups receiving breast lymph

Node group	Location	Share received from breast
Axillary nodes (chiefly anterior/pectoral group; also posterior, lateral, central, apical)	Fibrofatty tissue of the axilla	~75% of total lymph — the major pathway
Anterior thoracic (parasternal/internal mammary) nodes	Along the internal thoracic vessels, in the first 3–4 intercostal spaces close to the sternal border	~20% — drain both medial <i>and</i> lateral parts of the breast via perforating branches of the internal thoracic artery
Posterior intercostal nodes	Near the heads/necks of the ribs, posteriorly	~5% — reached via lateral cutaneous branches of posterior intercostal vessels
Supraclavicular nodes	Root of the neck, above the clavicle	Secondary drainage, mainly after the apical axillary group
Cephalic (deltopectoral) node	Deltopectoral groove, along the cephalic vein — a displaced member of the infraclavicular set	Drains chiefly the upper part of the breast
Subdiaphragmatic & subperitoneal lymph plexuses	Below the costal margin	From the lower and inner quadrants, after vessels cross the costal margin and pierce the abdominal wall near the linea alba

- Anterior (pectoral) and central groups of axillary nodes are the ones **most commonly involved in carcinoma of the breast**.
- Lymphatics of the two breasts communicate across the midline, so cancer may spread from one breast to the other; connections with subdiaphragmatic/subperitoneal plexuses similarly allow spread toward the abdomen.

Axillary lymph nodes — five groups and surgical levels

The axillary nodes (20–40 in number) are described both by *anatomical group* and by *surgical level* (in relation to pectoralis minor) — the latter is what determines the extent of axillary clearance in breast cancer surgery.

Anatomical group	Position	Drainage received
Anterior (pectoral)	Along the lateral thoracic vessels, lower border of pectoralis minor	Major part of the breast; upper half of the anterior trunk wall
Posterior (subscapular)	Along subscapular vessels, posterior axillary fold	Axillary tail of the breast; posterior trunk wall (upper half)
Lateral	Along the upper humerus, medial to the axillary vein	Upper limb
Central	Fat of the upper axilla (related to the intercostobrachial nerve)	Receives from anterior, posterior and lateral groups; some direct vessels from axillary floor
Apical (infraclavicular)	Deep to clavipectoral fascia, along axillary vessels	Central group; upper part of the breast; thumb and its web

Surgical level (relative to pectoralis minor)	Nodes included
Level I (low)	Nodes lateral to / below the lower border of pectoralis minor
Level II (middle)	Nodes deep to (behind) pectoralis minor, including the interpectoral (Rotter's) nodes between pectoralis major and minor
Level III (high/apical)	Nodes medial to / above the upper border of pectoralis minor, up to the lower border of the clavicle

- ▶ **Rotter's nodes** — one or two small, inconstant interpectoral nodes lying between pectoralis major and pectoralis minor; classified as Level II.
- ▶ Lymph normally flows anterior → central/lateral → apical → supraclavicular, i.e., low-level nodes are affected before high-level (apical) nodes, which is the anatomical basis of level-wise axillary clearance in surgical oncology.

□ Fig 4.24 — Lymphatic drainage of breast. A. Location of lymph nodes receiving drainage from breast. (Moore — Clinically Oriented Anatomy — 9e, p.578)

Lymphatic vessels and the subareolar plexus

- ▶ **Superficial lymphatics** drain the skin over the breast (except the nipple and areola) and pass radially to surrounding nodes — axillary, anterior thoracic (parasternal), supraclavicular and cephalic.
- ▶ **Deep lymphatics** drain the parenchyma (glandular tissue) of the breast, and also drain the nipple and areola.

- ▶ A rich plexus of lymph vessels lies deep to the areola — the **subareolar plexus of Sappey** (also called the retro-areolar plexus). This plexus, together with most of the lymph of the gland, drains chiefly into the anterior (pectoral) group of axillary nodes.
- ▶ Direction of lymph flow within the breast parallels the major venous tributaries; lymph enters the regional nodes via an extensive **periductal and perilobular network**.
- ▶ Deep lymphatics from the deep (posterior) surface of the gland pierce **pectoralis major** and the **clavipectoral fascia** to reach the apical axillary nodes, sometimes interrupted en route by infraclavicular nodes or the interpectoral (Rotter's) nodes; some instead reach the anterior thoracic (parasternal) nodes.
- ▶ Efferents leaving the breast directly pass round the anterior axillary border, through the axillary fascia, to the pectoral (anterior) nodes; a few pass directly to the subscapular (posterior) nodes.
- ▶ Because breast lymphatics are **valveless**, blockage by tumour can reverse the normal direction of flow — producing cutaneous lymphatic spread (dermal lymphatic permeation), seen clinically as *peau d'orange* and satellite skin nodules.

Terminal drainage and cross-communications

- ▶ **Left breast:** lymph ultimately reaches the **thoracic duct**, then the **left subclavian vein**.
- ▶ **Right breast:** lymph ultimately reaches the **right lymphatic duct**, draining into the **right subclavian vein** near its junction with the right internal jugular vein.
- ▶ Part of the medial side of the **right breast** drains toward the **internal thoracic (parasternal) chain**, which may in turn drain inferiorly via the superior and inferior epigastric lymphatic routes toward the groin.
- ▶ **Connecting lymphatics across the midline** allow drainage to reach the *opposite* axilla — the anatomical basis for contralateral axillary and breast spread in advanced disease.
- ▶ Lower and inner-quadrant lymphatics may communicate with the **subdiaphragmatic and subperitoneal lymph plexuses** after crossing the costal margin and piercing the anterior abdominal wall through the upper linea alba — a route for intra-abdominal metastatic spread.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw an oval outline of the breast on the chest wall with the axilla laterally, and label:

- ▶ Nipple and areola with the subareolar (Sappey's) plexus deep to it.
- ▶ Radiating superficial lymphatics from the skin converging on the axilla.
- ▶ Deep lymphatics from the gland parenchyma piercing pectoralis major and clavipectoral fascia.
- ▶ The five axillary groups: anterior (pectoral), posterior (subscapular), lateral, central, apical (infraclavicular) — with arrows showing flow anterior/posterior/lateral → central → apical → supraclavicular.
- ▶ Interpectoral (Rotter's) nodes between pectoralis major and minor, labelled as Level II.
- ▶ Pectoralis minor drawn in outline with Level I (below), Level II (behind), Level III (above) marked.
- ▶ Internal thoracic (parasternal) nodes along the internal thoracic vessels, receiving perforators from medial and lateral parts of the breast.
- ▶ Posterior intercostal nodes, supraclavicular nodes, and the downward route via subdiaphragmatic/subperitoneal plexuses.
- ▶ Arrows crossing the midline to the opposite breast/axilla.

Applied / Clinical anatomy

- ▶ **Sentinel lymph node biopsy (SLNB):** a radiolabelled colloid (injected into the subareolar tissue of the index quadrant or peritumoral/intradermal tissue) combined with a vital blue dye identifies the **sentinel node** — the first axillary node draining the tumour-bearing area. The sentinel node is removed and examined histopathologically; a negative result can spare the patient a full axillary dissection. Most sentinel nodes lie at **Level I**; "skip" metastases to higher levels occur in 5–10% of cases, and the sentinel node is occasionally found outside the axilla — as an intramammary node, an internal thoracic (parasternal) node, or in the supraclavicular fossa.
- ▶ **Axillary lymph node dissection:** performed because axillary nodal status has strong prognostic significance and guides adjuvant therapy; it may be complicated by pain, seroma, restricted shoulder mobility, sensory loss (from the **intercostobrachial nerve**, closely related to the central group and often sacrificed) and **lymphoedema** of the upper limb.
- ▶ **Modified radical mastectomy with axillary clearance:** during dissection, the nerve to serratus anterior (long thoracic nerve), thoracodorsal vessels and nerve, and the medial/lateral pectoral nerves must be identified and preserved; injury to the nerve to serratus anterior causes winging of the scapula.
- ▶ **Anterior (pectoral) and central axillary groups are the nodes most commonly involved** in carcinoma of the breast, correlating with the upper-and-outer quadrant of the breast being the commonest site of malignancy (this quadrant drains predominantly to the anterior/pectoral nodes).
- ▶ **Interpectoral (Rotter's) nodes** are a recognised, though inconstant, site of metastasis and must be sought during Level II clearance.

- ▶ **Cross-drainage** across the midline and via the subdiaphragmatic/subperitoneal plexuses explains rarer patterns of spread to the opposite breast/axilla and into the abdomen.
- ▶ **Peau d'orange** and dermal nodularity in inflammatory/locally advanced carcinoma result from valveless dermal lymphatic blockage causing cutaneous lymphoedema.
- ▶ **Radical incisions for breast surgery/abscess drainage are made radially**, respecting the direction of the lactiferous ducts and superficial lymphatics, to minimise duct/lymphatic injury.

High-yield exam pointers

- ▶ ~75% axillary, ~20% parasternal (internal thoracic), ~5% posterior intercostal — the classic percentage split of breast lymph drainage.
- ▶ Five axillary groups: **anterior (pectoral)**, **posterior (subscapular)**, **lateral**, **central**, **apical (infraclavicular)**; anterior and central groups are most often involved in carcinoma.
- ▶ Surgical Levels I/II/III are defined relative to **pectoralis minor** (below/behind/above); **Rotter's (interpectoral) nodes** lie at Level II, between pectoralis major and minor.
- ▶ **Subareolar plexus of Sappey** — the key deep lymphatic confluence beneath the nipple-areola complex, draining chiefly to the anterior (pectoral) axillary nodes.
- ▶ Superficial lymphatics drain the skin (except nipple/areola); deep lymphatics drain the parenchyma, nipple and areola.
- ▶ **Left breast → thoracic duct → left subclavian vein; right breast → right lymphatic duct → right subclavian vein.**
- ▶ Breast lymphatics are **valveless** — tumour blockage causes retrograde/dermal flow (peau d'orange).
- ▶ **Sentinel lymph node** = first draining axillary node, mapped with radiocolloid + blue dye; usually at Level I; "skip" nodes in 5–10%.
- ▶ Cross-midline and subdiaphragmatic/subperitoneal communications explain contralateral and abdominal spread.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 (8e); Moore's Clinically Oriented Anatomy (9e).



Thoracic duct

Asked in: Paper I 12-Nov-2019 · Paper I May 2018 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction The thoracic duct is the largest lymphatic channel (great lymph trunk) in the body, conveying chyle and lymph from almost the whole body back into the venous circulation. It is a direct continuation of the **cisterna chyli**, begins in the abdomen at the lower border of the T12 vertebra, ascends through the posterior and superior mediastinum crossing the midline at T5, and terminates in the root of the neck at the left venous angle. Its beaded appearance (due to numerous valves) and its vulnerability during thoracic/oesophageal/neck surgery make it a recurrently asked, high-yield gross anatomy topic.

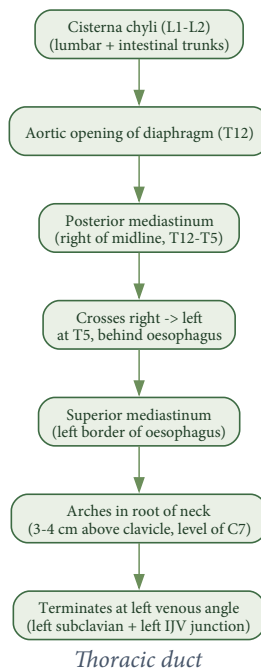
Formation, extent and measurements

- ▶ **Formation:** the upper end of the **cisterna chyli** — a lymphatic sac formed by confluence of the **right and left lumbar lymph trunks** (draining both lower limbs, pelvis, and posterior abdominal wall) and the **intestinal lymph trunk** (draining the gut via coeliac/superior mesenteric nodes) — lying anterior to the L1–L2 vertebral bodies, to the right of the abdominal aorta and behind the right crus of the diaphragm.
- ▶ **Extent:** from the lower border of the T12 vertebra to the junction of the left subclavian and left internal jugular veins at the root of the neck.
- ▶ **Length:** ~40–45 cm (about 18 inches).
- ▶ **Calibre:** widest at its two ends (~5 mm), narrowing to 2–3 mm at mid-thoracic level.
- ▶ **Total lymph flow:** 1500–2400 mL/day, varying with dietary long-chain triglyceride intake.
- ▶ **Drainage territory:** the entire body **except** the right side of the head and neck, right upper limb, right half of the thorax (right lung, right side of heart), and the right side of the convex surface of the liver — these instead drain via the **right lymphatic duct** into the right venous angle.

Course

- ▶ **Abdomen:** begins as the continuation of the cisterna chyli at the lower border of T12; passes through the **aortic opening of the diaphragm**, lying to the right of the aorta and to the left of the azygos vein.
- ▶ **Posterior mediastinum:** ascends on the front of the vertebral bodies between the azygos vein (right) and the descending thoracic aorta (left), up to the level of the **T5 vertebra**.
- ▶ **Crossover:** at T5 it inclines/crosses obliquely from right to left, passing posterior to the oesophagus, and enters the superior mediastinum.
- ▶ **Superior mediastinum:** ascends along the left border of the oesophagus, posterior to the arch of the aorta and then posterior to the first part of the left subclavian artery, to reach the root of the neck.
- ▶ **Root of neck:** arches laterally about 3–4 cm above the clavicle (at the level of the transverse process of C7), over the dome of the pleura, between the carotid sheath in front and the vertebral vessels/sympathetic trunk behind; then descends anterior to the first part of the left subclavian artery.

- **Termination:** opens into the angle of union of the left subclavian and left internal jugular veins (occasionally into the left brachiocephalic vein), the orifice guarded by a pair of valves that prevent reflux of blood into the duct.



Relations

Level	Anterior	Posterior	Right	Left
At aortic opening of diaphragm	Median arcuate ligament of diaphragm	T12 vertebra	Azygos vein	Aorta
In posterior mediastinum (T12-T5)	Diaphragm; oesophagus (lower part); right pleural recess	Vertebral column; anterior longitudinal ligament; terminal parts of hemiazygos/accessory hemiazygos veins; right posterior intercostal arteries	Azygos vein	Descending thoracic aorta
In superior mediastinum (above T5)	Arch of aorta; origin of left subclavian artery	Vertebral column	Oesophagus	Left pleura and lung

Level	Anterior	Posterior	Right	Left
In root of neck (cervical arch)	Carotid sheath — left common carotid artery, left internal jugular vein, left vagus nerve	Vertebral artery/vein; left sympathetic trunk; thyrocervical trunk and branches; left phrenic nerve; medial border of scalenus anterior; prevertebral fascia	—	First part of left subclavian artery (duct descends in front of it before terminating)

Tributaries

- ▶ **In the abdomen (forming the cisterna chyli):** right and left lumbar lymph trunks; intestinal lymph trunk.
- ▶ **In the thorax:**
 - A pair of descending lymph trunks from the posterior intercostal nodes of the lower six intercostal spaces (both sides).
 - Paired ascending lumbar lymph trunks from the upper lateral aortic nodes, which pierce the corresponding crus of the diaphragm and join the duct in the posterior mediastinum.
 - Efferents of the posterior mediastinal nodes (draining oesophagus, pericardium, diaphragm, and the bare/convex area of the liver).
- ▶ **In the neck, near its termination:**
 - **Left jugular lymph trunk** — left half of head and neck.
 - **Left subclavian lymph trunk** — left upper limb.
 - **Left bronchomediastinal trunk** — left half of thorax; frequently opens independently into the subclavian vein instead of the duct.

Development

Described in three stages from paired embryonic lymphatic plexuses:

- ▶ **Stage I:** a network of lymph channels forms in front of the thoracic part of the vertebral column.
- ▶ **Stage II:** within this network, two longitudinal channels appear — one right, one left — joined by numerous cross-communications.
- ▶ **Stage III:** a persistent cross-communication at the level of T5 links the **right longitudinal channel below T5** with the **left longitudinal channel above T5**; these two segments persist and fuse to form the adult thoracic duct, while the rest of the plexus regresses.

This developmental crossover explains both the normal right-to-left transition of the duct at T5 and the anomalies seen clinically — a persisting double (bifid) duct, or a duct that remains entirely right-sided (especially associated with an aberrant right subclavian artery).

□ Fig 9.1 — Course and relations of thoracic duct (IB Singh — Textbook of Anatomy Vol 2 — 6e, p.126)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sagittal/coronal schematic of posterior mediastinum showing:

- ▶ Vertebral column (T12 to C7) as the posterior landmark.
- ▶ Cisterna chyli (L1–L2) with right lumbar, left lumbar, and intestinal trunks joining it.
- ▶ Duct ascending to the right of vertebral bodies, between azygos vein (right) and descending aorta (left), up to T5.
- ▶ Oblique crossing line at T5, duct now left of oesophagus.
- ▶ Arch of aorta and left subclavian artery labelled as anterior relations in the superior mediastinum.
- ▶ Cervical arch 3–4 cm above the clavicle at the level of C7 transverse process, with carotid sheath (anterior) and vertebral vessels/sympathetic trunk (posterior) labelled.
- ▶ Termination arrow into the angle of left subclavian vein + left internal jugular vein, with the guarding valve marked.
- ▶ Tributaries labelled at their point of entry: descending/ascending lymph trunks (thorax); left jugular, left subclavian and left bronchomediastinal trunks (neck).

Applied / Clinical anatomy

- ▶ **Chylothorax:** the commonest applied fact. The duct is thin-walled and colourless in life, so it is easily injured unnoticed during thoracic/oesophageal surgery (0.2–3% incidence with transhiatal and thoroscopic oesophagectomy); laceration causes leakage of chyle (rich in lipid, protein, T-lymphocytes 400–6800 cells/ μ L, fat-soluble vitamins) into the pleural cavity, producing a progressive nutritional and immune deficit if untreated.
- ▶ **Laterality rule:** because the duct crosses the midline at T5, injury/obstruction **above** T5 gives a **left-sided** pleural effusion, while injury **below** T5 gives a **right-sided** effusion.
- ▶ **Cervical (neck) injury:** the terminal arch may be damaged during radical/block dissection of the neck, or during exposure of the vertebral/subclavian vessels or the cervicothoracic (stellate) ganglion. If recognised, it should be **ligated immediately** — collateral lymphaticovenous anastomoses re-establish drainage; if missed, it leads to a troublesome **chylous fistula**.
- ▶ **Filarial obstruction:** infestation by *Wuchereria bancrofti* microfilariae can obstruct the duct, producing chylothorax, chyloperitoneum, chyluria, and chylocele (chyle in the tunica vaginalis).
- ▶ **Diagnosis/localisation:** milky pleural fluid rich in chylomicrons/triglycerides on electrophoresis confirms chylothorax; the site of leakage or anatomical anomaly is localised by **lymphangiography** (pedal lymphatic cannulation with Lipiodol contrast), with or without post-procedure CT, or by lymphoscintigraphy.
- ▶ **Anatomical variation:** a double thoracic duct, or a single duct that remains entirely right-sided (more frequent with an aberrant right subclavian artery), occurs due to persistence of both embryonic longitudinal channels — surgically relevant during mediastinal/oesophageal dissection.

- ▶ **Surface/clinical marking:** the cervical arch lies 3–4 cm above the clavicle, deep to the angle between the internal jugular and subclavian veins — a landmark to be respected during left supraclavicular lymph node biopsy or central line placement on the left side.

High-yield exam pointers

- ▶ Continuation of the **cisterna chyli** (union of right + left lumbar trunks + intestinal trunk) at L1–L2; enters thorax through the **aortic opening of the diaphragm** at T12.
- ▶ Crosses from **right to left at T5** — the single most repeatedly tested fact.
- ▶ Terminates at the **left venous angle** (junction of left subclavian and left internal jugular veins), guarded by a pair of valves preventing reflux.
- ▶ Largest lymphatic vessel in the body; ~40–45 cm long, beaded due to numerous valves; drains lymph from the whole body except the right upper quadrant (right head/neck, right upper limb, right thorax).
- ▶ **Chylothorax** is the key clinical correlate; laterality of the effusion depends on whether the injury is above (left) or below (right) T5.
- ▶ Thin-walled and colourless in life — easily missed at surgery; must be ligated immediately if injured to prevent a chylous fistula.
- ▶ The **right lymphatic duct** is its mirror-image counterpart, draining the right upper quadrant into the right venous angle.
- ▶ Developmental persistence of the right channel below T5 and left channel above T5 (from paired embryonic plexuses) explains both the normal crossover and anomalies (double or right-sided duct).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; Vishram Singh — Textbook of Anatomy Vol 1 4e; IB Singh — Textbook of Anatomy Vol 2 6e.



Azygos vein

Asked in: Paper I Sep 2007 — RGUHS MD/MS Anatomy

Definition / Introduction The azygos ("unpaired") vein is the principal vein of the posterior thoracic wall and posterior mediastinum. It lies anterior to the bodies of the lower eight thoracic vertebrae on the right side and, together with the hemiazygos and accessory hemiazygos veins, constitutes the **azygos venous system**. Its chief importance lies in forming a major collateral channel connecting the superior vena cava (SVC) with the inferior vena cava (IVC), while simultaneously linking the caval, vertebral and (via oesophageal tributaries) portal venous systems — a triple anastomotic role that gives the vein great applied significance whenever the great veins are obstructed.

Formation

- ▶ Most commonly (and on developmental grounds), the azygos vein is formed at the level of the **12th thoracic vertebra** by the union of:

- ▶ The **right subcostal vein**, and
- ▶ The **right ascending lumbar vein** (itself formed by vertical anastomoses connecting the lumbar veins).
- ▶ Variable alternative modes of origin:
 - As a direct continuation of the **lumbar azygos vein**, which arises from the posterior aspect of the IVC at or below the level of the renal veins, ascends anterior to the upper lumbar vertebrae, and enters the thorax by piercing (or passing behind) the right crus of the diaphragm or through the aortic hiatus; opposite T12 it is joined by the right subcostal + ascending lumbar trunk to complete the azygos vein.
 - Occasionally from the right renal vein or the right first lumbar vein.
- ▶ **Functions:** (i) drains the posterior thoracic wall and the upper part of the posterior abdominal wall; (ii) forms the principal collateral pathway connecting the SVC and IVC.

Course and termination

- ▶ Enters the thorax through the **aortic opening of the diaphragm** (alongside the aorta and thoracic duct).
- ▶ Ascends vertically through the **posterior mediastinum**, lying anterior to the vertebral column, up to the level of the **4th thoracic vertebra**.
- ▶ At T4 it arches forward above the **root/hilum of the right lung** — the "arch of the azygos vein" — and terminates by joining the **posterior aspect of the SVC**, just before the SVC pierces the fibrous pericardium. The arch of the azygos vein is thus a content of the **middle mediastinum**, while its vertical part lies in the **posterior mediastinum**.
- ▶ Surgically/clinically this termination corresponds to the level of the **sternal angle (angle of Louis)**; CT-based surface studies place the point of entry into the SVC a little lower, at the level of the **lower part of T5**, roughly 2 cm inferior to the sternal-angle plane.
- ▶ A pair of valves lies midway along the arch (between its vertical part and its entry into the SVC); this segment may appear slightly tortuous even in the absence of disease.
- ▶ **Variation:** before opening into the SVC, the arch occasionally splits the apex of the right lung, lodging in a fold of pleura suspended by a mesentery (the **azygos lobe**, enclosed within an "azygos fissure" of four pleural layers).

Relations

Direction	Structures
Anterior	Right edge of the oesophagus, separated from it by the azygo-oesophageal recess of the right pleura
Posterior	Bodies of the lower eight thoracic vertebrae, anterior longitudinal ligament, right posterior intercostal arteries
Right	Right lung and pleura; right greater splanchnic nerve (in its lower part)

Direction	Structures
Left	Descending thoracic aorta and thoracic duct (lower part); oesophagus, trachea and right vagus nerve (upper part, near the arch)
Arch (at T4, over right lung root)	Below — root/hilum of right lung; crosses the right pulmonary artery and right main bronchus, separating the right vagus nerve from the right lung and pleura

Tributaries

- ▶ Right superior intercostal vein — union of the 2nd, 3rd and 4th right posterior intercostal veins.
- ▶ 5th–11th right posterior intercostal veins.
- ▶ Hemiazygos vein — joins at the level of the lower border of T8.
- ▶ Accessory hemiazygos vein — joins at the level of the upper border of T8.
- ▶ Right subcostal vein and right ascending lumbar vein (when not already incorporated in its formation).
- ▶ Right bronchial vein — near its termination.
- ▶ Oesophageal, mediastinal and pericardial veins.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

embed: ![Fig 24.6 — Azygos, hemiazygos, and accessory hemiazygos veins. Numbers 1 to 11 represent posterior intercostal veins (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.929)]
(C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/f1d5646003059ebd.jpg)

Reproduce the azygos venous system diagram by hand with these labels:

- ▶ Right and left brachiocephalic veins; superior vena cava
- ▶ Right superior intercostal vein (2nd–4th right posterior intercostal veins) and left superior intercostal vein
- ▶ **Azygos vein** — vertical part (anterior to T5–T12 vertebral bodies) and its arch at T4 over the root of the right lung, entering the SVC
- ▶ Numbered posterior intercostal veins 1–11 on both sides
- ▶ **Accessory hemiazygos vein** (draining left 5th–8th spaces) joining the azygos at T8 (upper border)
- ▶ **Hemiazygos vein** (draining left 9th–11th spaces) joining the azygos at T8 (lower border)
- ▶ Right and left subcostal veins and ascending lumbar veins
- ▶ Diaphragm with the aortic opening (transmitting azygos vein/lumbar azygos vein, aorta, thoracic duct)
- ▶ Inferior vena cava

Hemiazygos and accessory hemiazygos veins

Feature	Hemiazygos vein (inferior hemiazygos)	Accessory hemiazygos vein (superior hemiazygos)
Position	Mirror image of the lower part of the azygos vein, on the left	Mirror image of the upper part of the azygos vein, on the left
Formation	Union of the left ascending lumbar vein and the left subcostal vein	Begins at the medial end of the left 4th/5th intercostal space
Course	Pierces the left crus of the diaphragm; ascends on the left side of the vertebral column overlapped by the aorta	Descends on the left side of the vertebral column
Termination	At T8 (lower border), crosses right behind the oesophagus and thoracic duct to join the azygos vein	At T8 (upper border), crosses right behind the aorta and thoracic duct to join the azygos vein
Tributaries	9th–11th left posterior intercostal veins; oesophageal and mediastinal veins	5th–8th left posterior intercostal veins; occasionally left bronchial veins

Feature	Hemiazygos vein (inferior hemiazygos)	Accessory hemiazygos vein (superior hemiazygos)
Note	The terminal parts of the two veins sometimes unite to form a common trunk before crossing to join the azygos vein	May also communicate with the left superior intercostal vein above and the hemiazygos vein below

Applied / Clinical anatomy

- **SVC obstruction:** the azygos system is the principal collateral pathway. If the block lies **above (proximal to)** the azygos entry point, the azygos vein itself becomes the main channel shunting blood from the upper half of the body down into the distal (retro-obstructive) part of the SVC and thence to the right atrium — collateral flow is comparatively mild. If the block lies **at or below the azygos entry**, blood must bypass the SVC entirely via the superficial thoraco-abdominal anastomoses — internal thoracic → superior epigastric → inferior epigastric → external iliac vein, and lateral thoracic → thoraco-epigastric → femoral vein — reaching the IVC and right atrium; this produces the classical dilated, tortuous subcutaneous veins of the chest and abdominal wall seen clinically in SVC obstruction syndrome (mediastinal tumours, bronchogenic carcinoma, fibrosing mediastinitis).
- **Congenital IVC interruption / azygos continuation:** when the hepatic segment of the IVC fails to develop, venous return from the lower body is diverted through the persisting azygos (right-sided) or hemiazygos (left-sided) vein, producing a markedly dilated azygos arch — an entity of particular relevance to paediatric surgeons operating on oesophageal atresia/tracheo-oesophageal fistula (where an enlarged azygos arch may be mistaken for other structures), and one that is associated with **situs ambiguus/heterotaxy and polysplenia syndromes**.
- **Azygos lobe/fissure:** an anomalous azygos arch enclosed in a mesentery of four pleural layers isolates a small medial part of the right upper lobe as an "azygos lobe" — a normal anatomical variant, not a true accessory lobe, that is occasionally visible on a chest radiograph as a comma-shaped opacity and must not be mistaken for a lung nodule, tumour or metastasis.
- **Portal-systemic anastomosis:** the azygos system receives lower oesophageal veins that also drain into the left gastric (portal) vein; in **portal hypertension** this communication contributes to oesophageal varices, and the azygos vein carries the collateral flow away from the varices toward the SVC.
- **Vertebral venous plexus (Batson's plexus):** posteriorly, the azygos system communicates freely with the valveless vertebral venous plexus, which in turn links the intracranial venous sinuses above with the pelvic and portal veins below. This valveless network allows retrograde, pressure-dependent flow and is the classical route for spread of vertebral tuberculosis (cold abscess tracking along the neurovascular bundle), pyogenic vertebral osteomyelitis/epidural abscess, and skeletal metastasis (e.g., from prostatic carcinoma) independent of the caval circulation, particularly during raised intra-abdominal or intrathoracic pressure (coughing, straining).
- **Surface anatomy/imaging:** on a lateral chest radiograph or CT, the azygos arch produces the small oval "azygos node/vein shadow" at the junction of the right paratracheal stripe and the SVC, at (or just below) the sternal angle plane; it enlarges conspicuously in right heart failure,

tricuspid regurgitation, portal hypertension and IVC obstruction, making it a useful imaging sign.

- ▶ **Surgical:** the azygos arch, arching over the root of the right lung to the posterior aspect of the SVC, is an important operative landmark during right thoracotomy and mediastinoscopy, and corresponds surgically/radiologically to the transverse thoracic (sternal-angle) plane along with the tracheal bifurcation and the concavity of the aortic arch.

High-yield exam pointers

- ▶ "Azygos" = unpaired; lies right side, anterior to lower 8 thoracic vertebrae; connects SVC and IVC.
- ▶ Formed (T12) by union of right subcostal vein + right ascending lumbar vein, or from the lumbar azygos vein continuing from the IVC.
- ▶ Arches forward at T4, over the root of the right lung, to end in the SVC just before it enters the pericardium.
- ▶ Relations: anterior — oesophagus; posterior — vertebral bodies/intercostal arteries; right — lung/pleura, splanchnic nerve; left — thoracic duct/aorta (below), oesophagus/trachea/vagus (above, at the arch).
- ▶ Chief tributaries: right superior intercostal vein, 5th–11th right posterior intercostal veins, hemiazygos (at T8 lower border), accessory hemiazygos (at T8 upper border), bronchial and oesophageal veins.
- ▶ Hemiazygos = mirror of lower azygos (drains left 9th–11th spaces); accessory hemiazygos = mirror of upper azygos (drains left 5th–8th spaces); both cross at T8 to join the azygos, passing behind the aorta/oesophagus/thoracic duct.
- ▶ Provides the main collateral in SVC obstruction and IVC interruption (azygos continuation of IVC).
- ▶ Azygos lobe/fissure — a comma-shaped pseudo-nodule on chest X-ray, not a true tumour.
- ▶ Communicates with the vertebral venous plexus (Batson's) — route for spread of infection/metastasis, and with the portal system via oesophageal veins — relevant in portal hypertension.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 & Vol 2 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 1 4e.



Azygous vein

Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction The azygos vein ("azygos" = unpaired) is the principal channel of the **azygos venous system**, an unpaired, longitudinally-running valveless (or sparsely-valved) venous complex occupying the posterior mediastinum and upper posterior abdominal wall. Together with its left-sided partners — the **hemiazygos** and **accessory hemiazygos** veins — it drains the posterior thoracic and abdominal walls and forms the single most important collateral channel connecting the **superior vena cava (SVC)** and **inferior vena cava (IVC)**. It also links the caval, portal and internal vertebral venous plexus systems, which underlies most of its applied importance.

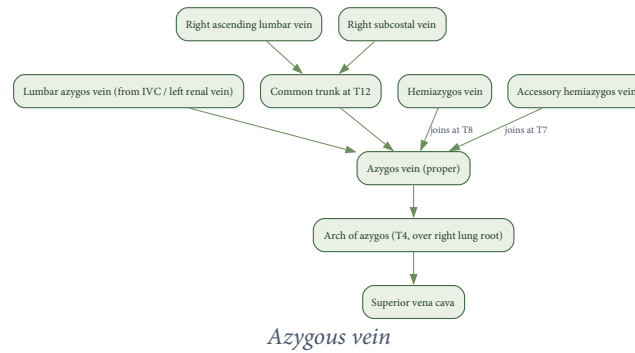
Development

- ▶ The azygos vein develops from **two sources**: (a) its lower vertical (abdominal-to-mid-thoracic) part forms from the persistent **right azygos venous line**, i.e. the **right supracardinal vein**; (b) its **arch** develops from the persistent cephalic part of the **right posterior cardinal vein**.
- ▶ The **hemiazygos** and **accessory hemiazygos** veins are the corresponding left-sided derivatives of the **cranial supracardinal veins**.
- ▶ Embryologically, the hepatic segment of the IVC forms when the right subcardinal vein anastomoses with the hepatic sinusoids; if this anastomosis fails, the hepatic segment of the IVC does not develop, and venous return from below is instead carried entirely by the hemiazygos/azygos veins — the basis of **azygos continuation of the IVC** (discussed under Applied anatomy).

Origin, course and termination

- ▶ **Origin** is variable. It classically begins as the **azygos lumbar vein**, arising from the back of the IVC (or from a common trunk with the left renal vein) at or below the level of the renal veins; this ascends anterior to the upper lumbar vertebral bodies and enters the thorax by passing posterior to (or piercing) the **right crus of the diaphragm**, or through the **aortic opening** of the diaphragm.
- ▶ Opposite the **12th thoracic vertebra**, it is joined by a common trunk formed by the union of the **right ascending lumbar vein** and the **right subcostal vein**, to constitute the azygos vein proper. (When no lumbar azygos vein is present, this right ascending-lumbar/subcostal trunk itself continues as the azygos vein.)
- ▶ It then **ascends** in the posterior mediastinum, along the right side of the bodies of the lower eight thoracic vertebrae, up to the level of the **4th thoracic vertebra**.
- ▶ Here it **arches forward**, above the root of the right lung, and ends by joining the **posterior aspect of the superior vena cava**, just before the SVC pierces the fibrous pericardium. The arch of the azygos vein is described as a content of the **middle mediastinum**.

□ Fig 56.2 — A common course followed by the intrathoracic azygos, hemiazygos and accessory azygos veins (Gray's Anatomy — Standring — 41e, p.1353)



Relations

Aspect	Structures related
Anterior	Oesophagus (lower part), separated by the pleural azygo-oesophageal recess ; at the arch (T4) it crosses anterior to the right pulmonary hilum and is related to the trachea, oesophagus and right vagus nerve, which it crosses
Posterior	Bodies of the lower eight thoracic vertebrae, intervertebral discs, anterior longitudinal ligament, and the right posterior intercostal arteries
Right (lateral)	Right lung and pleura; right greater splanchnic nerve (lower part)
Left (lateral)	Thoracic duct and descending thoracic aorta (lower part); oesophagus, trachea and right vagus nerve (upper part / at the arch)

Tributaries

Tributary	Level / detail
Right superior intercostal vein	formed by union of 2nd–4th right posterior intercostal veins
5th–11th right posterior intercostal veins	drain directly into the azygos vein
Hemiazygos vein	joins at the level of T8
Accessory hemiazygos vein	joins after crossing T7
Right bronchial vein	usually the last tributary, near the termination
Oesophageal, mediastinal and pericardial veins	small direct tributaries
Right ascending lumbar + right subcostal veins	form the vein at its origin (T12), or constitute its first tributary if a separate lumbar azygos vein is present

Hemiazygos and accessory hemiazygos veins

Feature	Azygos vein	Hemiazygos vein	Accessory hemiazygos vein
Side	Right	Left	Left
Formation	Lumbar azygos vein $\pm$ union of right ascending lumbar and right subcostal veins	Union of left ascending lumbar and left subcostal veins; communicates with left renal vein below	Continuation of the left 4th posterior intercostal vein
Entry into thorax	Posterior to/through right crus, or aortic opening, of diaphragm	Pierces the left crus of the diaphragm	Arises within the thorax (does not traverse the diaphragm)
Course	Ascends right of vertebral bodies to T4; arches forward over right lung root	Ascends left of vertebral column (overlapped by aorta) to T8, then crosses right behind oesophagus and thoracic duct	Descends left of vertebral column from T4/5 to T7, then crosses right behind aorta and thoracic duct
Tributaries	Right posterior intercostal veins 5–11, right superior intercostal vein, hemiazygos and accessory hemiazygos veins, right bronchial vein	9th–11th left posterior intercostal veins, oesophageal veins	5th–8th left posterior intercostal veins, occasionally left bronchial veins
Termination	Superior vena cava (at T4)	Azygos vein (at T8)	Azygos vein (at T7), or joins the hemiazygos vein

Variations of the azygos venous system

- The origin, course, tributaries, anastomoses and termination of the whole azygos system are highly variable; the pattern above is simply the commonest.
- The left-sided channel (hemiazygos/accessory hemiazygos) may be underdeveloped or absent, in which case the left intercostal veins drain directly across into the azygos vein and/or the accessory hemiazygos terminates in the left brachiocephalic vein instead; the azygos vein may then lie in a **median position**.
- Numerous anastomoses exist between the azygos/hemiazygos/accessory hemiazygos trunks, the IVC and the vertebral venous plexuses, providing alternative drainage pathways whenever there is segmental agenesis ("interruption") or thrombosis of the IVC.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a vertical schematic of the azygos venous system (as in the plate above) and label:

- ▶ **Superior vena cava** (top) and **inferior vena cava** (bottom), with the **azygos vein** on the right and **hemiazygos/accessory hemiazygos veins** on the left connecting the two.
- ▶ **Right and left subclavian, brachiocephalic and internal jugular veins** at the top; **right and left superior intercostal veins**.
- ▶ **Lumbar azygos veins, ascending lumbar veins, subcostal veins, common/external/internal iliac veins and median sacral vein** at the base.
- ▶ Mark the vertebral levels: **T12** (formation of azygos vein), **T8** (hemiazygos joins azygos), **T7** (accessory hemiazygos joins azygos), **T4** (arch of azygos over right lung root, ending in SVC).
- ▶ Show the **thoracic duct** and **descending aorta** running between the two limbs of the system, crossed by the hemiazygos and accessory hemiazygos veins.

Applied / Clinical anatomy

- ▶ **Collateral in SVC obstruction:** SVC obstruction (commonly a mediastinally-invasive right upper-lobe bronchogenic carcinoma, or metastatic right paratracheal nodes) produces headache, facial/neck venous congestion and oedema, and chest-wall telangiectasia from a dilated collateral circulation; symptoms are eased by recumbency and aggravated by standing. The azygos vein, as the chief tributary of the SVC, becomes a major collateral pathway.
- ▶ **Collateral in IVC obstruction/interruption:** In congenital interruption or acquired thrombosis of the IVC, the azygos and hemiazygos veins together with the internal vertebral venous plexuses are the main collateral channels linking the two venae cavae; collateral flow may also reach the IVC/right atrium via the superior and inferior epigastric and lateral thoracic/thoraco-epigastric veins.
- ▶ **Azygos continuation of the IVC:** when the hepatic segment of the IVC fails to develop, the prominent azygos (or hemiazygos) vein carries all infra-diaphragmatic venous return to the SVC. This is of critical surgical importance in neonatal repair of **oesophageal atresia with tracheo-oesophageal fistula**: the azygos vein, which is routinely ligated and divided during this operation, must be recognised and spared in a child with azygos continuation of the IVC, since its ligation causes intraoperative circulatory collapse and death. The anomaly is also associated with **situs ambiguus/heterotaxy** (polysplenia and asplenia syndromes).
- ▶ **Portosystemic anastomosis (oesophageal varices):** the venous plexus of the lower oesophagus drains partly into the azygos/hemiazygos veins (systemic) and partly into the left gastric vein (portal). In **portal hypertension**, this anastomosis becomes distended into oesophageal varices, which may rupture and cause severe haematemesis.
- ▶ **Vertebral venous plexus communication:** the valveless (or poorly-valved) azygos system freely communicates with the internal vertebral venous plexus. This is the classical route by which **carcinoma of the breast** can metastasise via veins (rather than lymphatics) to the vertebrae and, from there, to the cranium and brain.

- **Radiological anatomy:** the azygos arch forms a rounded shadow above the right pulmonary hilum on a PA chest radiograph; normal arch width is up to 5 mm, but may reach 10 mm in the third trimester of pregnancy owing to compensatory drainage through the azygos system when IVC flow is reduced by uterine compression. The arch also enlarges in congenital IVC interruption or acquired IVC thrombosis. On CT, the azygo-oesophageal recess contour is dextroconvex in children under 6 years, becomes non-concave between 6–12 years, and is concave (as in adults) thereafter — a useful paediatric mediastinal-imaging landmark. A high azygos arch running within an accessory pleural (azygos) fissure may isolate a medial "azygos lobe" of the right upper lobe and typically produces a comma-shaped **pseudo-nodule** on chest radiograph that must not be mistaken for a rounded early lung carcinoma or metastasis.

High-yield exam pointers

- "Azygos" = unpaired; connects the SVC and IVC and forms the azygos venous system with the hemiazygos and accessory hemiazygos veins.
- Right-sided vein; arches over the root of the right lung at T4 to end in the SVC; the arch is a content of the middle mediastinum.
- Enters the thorax through the aortic opening of the diaphragm (or posterior to/through the right crus); formed opposite T12 by the union of the right ascending lumbar and right subcostal veins ($\pm$ a lumbar azygos vein).
- Hemiazygos joins the azygos vein at T8; accessory hemiazygos joins at T7 — both cross the midline behind the aorta and thoracic duct.
- Develops from the right supracardinal vein (body) and right posterior cardinal vein (arch); failure of the right subcardinal–hepatic sinusoidal anastomosis produces **azygos continuation of the IVC**.
- Chief collateral pathway in both SVC and IVC obstruction; communicates with the vertebral venous plexus and, via oesophageal veins, with the portal system (site of oesophageal varices).
- Normal azygos arch width on chest radiograph ≤ 5 mm; widens in caval obstruction, portal hypertension and late pregnancy.
- Surgical pitfall: never ligate an unexpectedly prominent azygos vein during neonatal tracheo-oesophageal fistula repair without excluding azygos continuation of the IVC.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 (8e); AK Datta's Essentials of Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 1 (4e); Moore's Clinically Oriented Anatomy (9e).



Blood supply of heart

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The heart is supplied by two **coronary arteries** — right and left — the first branches of the ascending aorta, arising from the anterior and left-posterior aortic sinuses respectively and running in the coronary (atrioventricular) sulcus. They are **functional end arteries**: intramyocardial anastomoses exist but cannot substitute for a blocked branch, so sudden occlusion produces myocardial infarction. Venous return is chiefly through the **coronary sinus** into the right atrium, supplemented by anterior cardiac veins and the venae cordis minimae (Thebesian veins), which open directly into the cardiac chambers. This dual arterial/venous scheme is the anatomical basis of ischaemic heart disease, coronary angiography and revascularisation.

General features of the coronary arteries

Feature	Detail
Origin	Right coronary artery (RCA) — anterior aortic sinus; Left coronary artery (LCA) — left posterior aortic sinus, both of the ascending aorta
Course	Both run initially in the coronary (atrioventricular) sulcus
Filling	Coronary flow is maximal during ventricular diastole
Calibre	External diameter ~1.5–5.5 mm; LCA usually larger and supplies the greater bulk of myocardium
Functional status	Functional end arteries — anastomoses are present but of little value as an alternative supply
Autonomic effect	Sympathetic stimulation dilates the intramuscular arteries but constricts the epicardial arteries

Right coronary artery (RCA)

- ▶ **Origin:** anterior ('right coronary') aortic sinus; ostium usually below the sinutubular junction.
- ▶ **Course:**
 - ▶ Passes forward and to the right, emerging between the right auricle and the root of the pulmonary trunk.
 - ▶ Descends in the right anterior coronary sulcus to the right (acute) border of the heart.
 - ▶ Winds around the inferior border onto the diaphragmatic surface and runs in the right posterior coronary sulcus towards the **crux** (junction of the interatrial, interventricular and atrioventricular grooves).
 - ▶ Ends near the crux by anastomosing with the circumflex branch of the LCA.
- ▶ **Branches:**
 - **Right conal (infundibular) artery** — ramifies over the pulmonary conus; anastomoses with a similar left conal branch to form the **anulus of Vieussens** around the right ventricular outflow tract.

- **SA nodal artery** — one of the anterior atrial branches; arises from the RCA in ~60% of hearts (from the circumflex/LCA in the remaining ~40%).
 - Anterior ventricular branches (2–3), the largest being the **right marginal artery**, which usually reaches the apex.
 - Posterior (inferior) ventricular branches to the diaphragmatic right ventricle.
 - **Posterior interventricular (descending) artery** — in most hearts arises near the crux, runs in the posterior interventricular groove, and gives septal perforators to the posterior one-third of the interventricular septum; its largest septal branch almost always supplies the **AV node**.
 - Atrial branches — anterior, lateral and posterior groups.
- **Area of distribution:** right atrium; most of the right ventricle (except a strip flanking the anterior interventricular groove); a small part of the diaphragmatic left ventricle; posterior one-third of the interventricular septum; and (see conducting-system table below) almost the whole conducting system.

Left coronary artery (LCA)

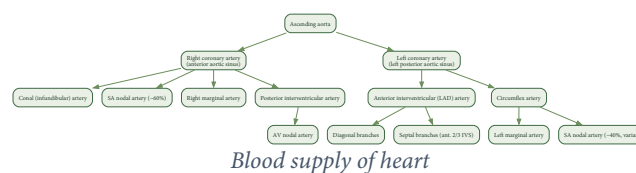
- **Origin:** left posterior ('left coronary') aortic sinus.
- **Course:** passes to the left between the pulmonary trunk and left auricle, then divides (in the left anterior coronary sulcus) into two roughly equal terminal branches:
 - **Anterior interventricular artery** (left anterior descending, LAD) — descends in the anterior interventricular groove; gives anterior ventricular branches (the largest called the **left diagonal artery**), septal branches to the anterior two-thirds of the interventricular septum, and a left conal branch completing the anulus of Vieussens.
 - **Circumflex artery** — the continuation of the LCA stem; runs in the left anterior coronary sulcus, curves around the left (obtuse) border, and continues in the left posterior coronary sulcus to end near the crux by anastomosing with the RCA; gives the **left marginal artery**, anterior/posterior ventricular branches, and atrial branches. In left-dominant hearts, the circumflex itself gives the posterior interventricular artery and supplies the AV node.
- **Area of distribution:** left atrium; most of the left ventricle (except a strip flanking the posterior interventricular groove); a small part of the right ventricle flanking the anterior interventricular groove; anterior two-thirds of the interventricular septum; and part of the conducting system (see below).

Arterial supply of the conducting system

Component	Usual arterial supply
SA node	RCA in ~60%; circumflex/LCA in ~40%
AV node	Septal branch of the posterior interventricular artery — usually from RCA (right-dominant hearts); from circumflex in left-dominant hearts
AV bundle (of His) and right bundle branch	RCA
Left bundle branch	Dual supply — chiefly LCA (septal branches of the anterior interventricular artery), partly RCA

Coronary dominance and collateral circulation

- **Dominance** is defined purely by which artery gives the **posterior interventricular artery** — not by which supplies more muscle (the LCA nearly always supplies the greater volume of myocardium regardless of dominance).
 - **Right dominance** (majority — the right artery is dominant in ~60% of hearts): posterior interventricular artery from the RCA.
 - **Left dominance** (~10% of hearts): the RCA is too small to reach the crux, so the circumflex continues as the posterior interventricular artery and also supplies the AV node.
 - **Balanced/co-dominant pattern**: parallel posterior interventricular branches arise from both arteries.
- **Collateral circulation**:
 - *Intracardiac (cardiac) anastomoses* between RCA and LCA branches within the myocardium and around the apex — of little functional value acutely, but may enlarge in chronic hypoxia/coronary artery disease.
 - *Extracardiac anastomoses* — with the vasa vasorum of the aorta and pulmonary trunk, and with the internal thoracic, bronchial and pericardiophrenic arteries (via the pericardium); these may open up in emergencies but are usually too slow to prevent infarction after sudden complete occlusion.
 - Because the coronary arteries are **functional end arteries**, thrombosis of a branch typically produces infarction of its territory.



□ Fig 8.10 — Schematic diagram to show the coronary arteries (IB Singh — Textbook of Anatomy Vol 2 — 6e, p.116)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the heart in two views and label:

- ▶ **Sternocostal (anterior) surface:** ascending aorta; pulmonary trunk; right auricle; left auricle; right coronary artery in the right atrioventricular groove; its conal branch and SA nodal artery; right marginal artery; anterior interventricular (LAD) artery in the anterior interventricular groove with diagonal and septal branches; left coronary artery stem; circumflex artery in the left atrioventricular groove; left marginal artery; the great cardiac vein running alongside the LAD then the circumflex artery.
- ▶ **Diaphragmatic (inferior) surface:** inferior vena cava opening; coronary sinus in the left posterior atrioventricular groove; posterior interventricular artery in the posterior interventricular groove with its septal perforators; middle cardiac vein; small cardiac vein; posterior vein of the left ventricle; the **crux of the heart** (junction of both interventricular grooves with the atrioventricular groove) — mark the origin of the AV nodal artery here.

Venous drainage of the heart

Cardiac venous return has two systems: a **greater system** of named subepicardial veins draining via the coronary sinus, and a **lesser system** of small veins opening directly into the cardiac chambers.

- ▶ **Coronary sinus** — the largest cardiac vein, ~2–3 cm long, lies in the left posterior atrioventricular groove between the left atrium and left ventricle; opens into the right atrium between the openings of the inferior vena cava and the tricuspid orifice, guarded by a rudimentary valve.

Tributary	Course	Enters sinus at
Great cardiac vein	Accompanies the anterior interventricular artery, then the circumflex artery; receives the left marginal vein	Left end
Oblique vein of the left atrium (of Marshall)	Small vein on the posterior left atrial wall; a vestige of the left common cardinal vein/duct of Cuvier	Left end
Middle cardiac vein	Accompanies the posterior interventricular artery	Right/middle part
Small cardiac vein	Accompanies the RCA in the right posterior coronary sulcus; may receive the right marginal vein	Right end
Posterior vein of the left ventricle	Diaphragmatic surface of the left ventricle	Sinus

- ▶ **Anterior cardiac veins (3–4)** — run on the anterior right ventricular wall and open **directly into the right atrium**, bypassing the coronary sinus; the right marginal vein may join this group instead.

- ▶ **Venae cordis minimae (Thebesian veins)** — numerous minute valveless veins present in all four chambers, opening directly into the chamber lumen; more numerous on the right side of the heart.

Applied / Clinical anatomy

- ▶ **Angina pectoris** — transient myocardial ischaemia from incomplete occlusion or spasm; produces agonising precordial pain radiating along the medial side of the left arm and forearm, relieved by sublingual nitrates. The referred pattern reflects convergence of visceral cardiac afferents with somatic afferents from the same (upper thoracic) spinal segments — pain from the low-sensory-output viscus is projected to the higher-sensory-output somatic dermatome.
- ▶ **Myocardial infarction** — complete thrombotic occlusion of a coronary branch causes irreversible ischaemic necrosis of its territory (functional end arteries). LAD occlusion gives the most extensive infarct (anteroseptal wall + both bundle branches); RCA occlusion gives inferior/posterior wall infarction with a high risk of SA/AV nodal ischaemia and heart block — the left bundle branch's dual supply makes isolated left-bundle-branch ischaemia less common.
- ▶ **Coronary/CT coronary angiography, PTCA with stenting** — catheter via the femoral or radial artery localises and treats focal stenoses.
- ▶ **Coronary artery bypass grafting (CABG)** — great saphenous vein or internal thoracic (mammary) artery grafted beyond the block; used for multiple or long-segment disease.
- ▶ **Coronary sinus catheterisation** — used for electrophysiological study of AV-junctional arrhythmias/accessory pathways, retrograde cardioplegia during surgery, and as the access route for a biventricular pacemaker's left-ventricular lead.

High-yield exam pointers

- ▶ RCA arises from the anterior aortic sinus; gives conal, SA nodal (~60%), marginal and (usually) the posterior interventricular artery; supplies RA, most of RV, posterior 1/3 IVS and almost the whole conducting system.
- ▶ LCA arises from the left posterior aortic sinus and divides into the anterior interventricular (LAD) and circumflex arteries; supplies LA, most of LV and anterior 2/3 IVS.
- ▶ **Dominance** = the artery giving the posterior interventricular artery (right in ~60%, left in ~10%, balanced in the rest) — NOT the artery supplying more muscle (LCA always supplies more).
- ▶ Coronary arteries are **functional end arteries**; extracardiac anastomoses (vasa vasorum, internal thoracic, bronchial, pericardiophrenic) are of little acute value.
- ▶ Coronary blood flow occurs predominantly during ventricular diastole.
- ▶ Venous drainage: coronary sinus (great, middle, small cardiac veins + oblique vein of left atrium + posterior vein of left ventricle) → right atrium; anterior cardiac veins and venae cordis minimae bypass the sinus and open directly into the chambers.
- ▶ **Anulus of Vieussens** = anastomotic ring formed by the right and left conal arteries around the pulmonary conus/RV outflow tract.
- ▶ AV node supply is the key applied point: usually RCA (right dominance) — hence heart block after inferior MI.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 1 8e; IB Singh Textbook of Anatomy Vol 2 6e; Vishram Singh Textbook of Anatomy Vol 1 4e; Vishram Singh General Anatomy 4e; Moore's Clinically Oriented Anatomy 9e.



Boundaries of superior mediastinum

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction The mediastinum is the median partition of the thoracic cavity lying between the two pleural sacs, extending from the thoracic inlet above to the diaphragm below, and from the sternum in front to the thoracic vertebral column behind, limited laterally by the mediastinal (parietal) pleura on each side. An imaginary transverse plane — the **plane of Ludwig** (transverse thoracic plane) — passing through the sternal angle anteriorly and the lower border of the body of the 4th thoracic vertebra posteriorly divides it into a **superior mediastinum** above and an **inferior mediastinum** below, the latter further subdivided into anterior, middle and posterior parts by the pericardium. The superior mediastinum is the wedge-shaped compartment that forms the thoroughfare between the root of the neck and the thorax for the great vessels, trachea, oesophagus and associated nerves, and its boundaries and contents are a classic short/long-answer topic.

Boundaries of the superior mediastinum

Boundary	Structure
Anterior	Manubrium sterni
Posterior	Bodies of the upper four thoracic vertebrae (T1–T4) with their intervening intervertebral discs and the anterior longitudinal ligament
Superior	Plane of the superior thoracic aperture (thoracic inlet) — bounded by the upper border of the manubrium in front, the first pair of ribs and costal cartilages on each side, and the body of T1 behind
Inferior	Transverse thoracic plane (plane of Ludwig) — an imaginary plane passing through the sternal angle in front and the lower border of the body of T4 (T4–T5 intervertebral disc) behind
Lateral (each side)	Mediastinal (parietal) pleura

- ▶ The costomediastinal pleural reflection runs from the sternoclavicular joint inferomedially to the midline behind the sternal angle, enclosing a **triangular retrosternal space** that is occupied by the thymus or its fatty/fibrous remnant.
- ▶ Because the posterior wall (T1–T4) extends higher than the anterior wall and the inferior plane runs obliquely downward and backward, the superior mediastinum is a wedge, narrower in front and broader behind.

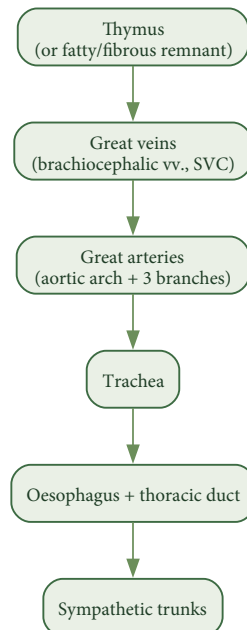
- The transverse thoracic plane at its inferior limit is an important level of reference: it corresponds to the sternal angle, the 2nd costal cartilage, the beginning and end of the arch of the aorta, the bifurcation of the trachea, the termination of the arch of the azygos vein, and the point at which the thoracic duct crosses from right to left of the midline.

Contents of the superior mediastinum

Category	Structures
Arteries	Arch of aorta; and its three branches — brachiocephalic (innominate) artery, left common carotid artery, left subclavian artery
Veins	Right and left brachiocephalic veins; upper (extrapericardial) half of the superior vena cava; left superior intercostal vein; arch of the azygos vein
Nerves	Phrenic nerves (right and left); vagus nerves (right and left); sympathetic trunks and cardiac nerves; left recurrent laryngeal nerve
Lymphoid organs/lymphatics	Thymus (or its remnant); terminal/upper part of the thoracic duct; tracheobronchial, paratracheal and brachiocephalic lymph nodes
Tubular viscera	Trachea; oesophagus
Muscles	Origins of sternohyoid and sternothyroid (retrosternally); longus colli (prevertebrally — its deepest element, extending up to the 3rd thoracic vertebra)

Arrangement of contents (anterior → posterior)

For descriptive and surgical orientation, the structures of the superior mediastinum are arranged from anterior to posterior in a fixed order:



Boundaries of superior mediastinum

- This order — **thymus, veins, arteries, airway, alimentary tract, lymphatic duct, sympathetic trunk** — is identical in a median sagittal section and in a transverse (cross-sectional/CT) view, and is the basis for locating structures at mediastinoscopy.
- **Potential dead space:** all the large veins (SVC, right and left brachiocephalic veins) lie on the right side while all the large arteries (arch of aorta and its three branches) lie on the left side. Because veins distend far more readily than arteries under increased flow or a mass effect, there is more "spare" space on the right; mediastinal tumours and enlarging masses therefore tend to bulge preferentially to the right.

□ Fig 4.64 — *Boundaries of superior mediastinum. The superior mediastinum extends inferiorly from the superior thoracic aperture to the transverse thoracic plane (Moore — Clinically Oriented Anatomy — 9e, p.677)*

□ Fig 20.7 — *Transverse section of the superior mediastinum showing the arrangement of its contents (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.799)*

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a sagittal outline of the upper thoracic cage (manubrium in front, bodies of T1–T4 behind) and label:

- ▶ The **superior boundary line** (plane of the thoracic inlet) and the **inferior boundary line** (transverse thoracic plane, sternal angle to lower border of T4)
- ▶ **Anterior wall** — manubrium sterni; **posterior wall** — T1–T4 vertebral bodies + discs; **lateral walls** — mediastinal pleura (mark the costomediastinal reflection and the triangular retrosternal space for the thymus)
- ▶ Contents in anteroposterior sequence — thymus → brachiocephalic veins/SVC → aortic arch with its three branches (brachiocephalic, left common carotid, left subclavian arteries) → trachea → oesophagus + thoracic duct → sympathetic trunks
- ▶ Nerves crossing the field — phrenic nerves (most lateral), vagus nerves (medial to phrenic), left recurrent laryngeal nerve hooking under the aortic arch
- ▶ Arch of azygos vein arching over the right main bronchus to join the SVC

Applied / Clinical anatomy

- ▶ **Mediastinal (compression) syndrome:** expanding lesions confined to the superior mediastinum (bronchogenic carcinoma, aortic aneurysm, enlarged lymph nodes in Hodgkin lymphoma) compress its contents to produce a characteristic symptom complex — engorgement of veins of the head, neck and upper limb (SVC obstruction), dyspnoea (tracheal compression), dysphagia (oesophageal compression), dysphonia/hoarseness (compression of the left recurrent laryngeal nerve), and, with long-standing pressure, erosion of vertebral bodies.
- ▶ **Hoarseness of voice:** because the left recurrent laryngeal nerve loops under the arch of the aorta within the superior mediastinum, an aortic arch aneurysm or malignant paratracheal/subaortic lymphadenopathy here characteristically produces vocal cord palsy and hoarseness before a corresponding right-sided lesion would (the right recurrent laryngeal nerve loops around the right subclavian artery in the root of the neck, outside the superior mediastinum).
- ▶ **Retrosternal (plunging) goitre:** an enlarging thyroid gland may extend inferiorly into the superior mediastinum between the sternum and the brachiocephalic veins; because the veins may become adherent to the gland, thyroidectomy for a retrosternal goitre demands careful dissection to avoid venous injury.
- ▶ **Thymic masses:** the triangular retrosternal space bounded by the costomediastinal pleural reflection, normally occupied by the thymus, is the typical site of thymomas and other anterior superior mediastinal masses; combined with the "dead space" on the right, this explains the characteristic right-sided bulge seen with many superior mediastinal masses on plain radiographs.
- ▶ **Widening of the mediastinum on chest radiograph** may result from haemorrhage into the mediastinum from lacerated great vessels (e.g. traumatic aortic injury after a deceleration injury) or from massive enlargement of mediastinal lymph nodes in lymphoma; both are classic causes referable to the superior mediastinal contents.

- ▶ **Surgical access to superior mediastinal/paratracheal nodes:** cervical mediastinoscopy can sample most paratracheal and subcarinal nodal stations for lung cancer staging, but the anterior part of the superior mediastinum (and the left paratracheal/subaortic/para-aortic stations) is difficult to reach this way and usually requires an **anterior mediastinotomy (Chamberlain procedure)**.
- ▶ **Great-vessel and thymic surgery:** the superior mediastinum is approached surgically via median sternotomy for procedures on the great vessels, thymus and retrosternal thyroid.
- ▶ **Subcutaneous emphysema/mediastinitis:** because the fascial planes of the superior mediastinum are continuous with the pretracheal and retropharyngeal fascial spaces of the neck, deep neck infections may spread down into the mediastinum (descending mediastinitis), and, conversely, air from an oesophageal or tracheal perforation in the superior mediastinum can track upward into the neck producing surgical emphysema.

High-yield exam pointers

- ▶ **Boundaries:** Anterior — manubrium sterni; Posterior — upper four thoracic vertebrae; Superior — plane of thoracic inlet; Inferior — transverse thoracic plane (sternal angle to lower border of T4); Lateral — mediastinal pleura on each side.
- ▶ The transverse thoracic plane (plane of Ludwig) = sternal angle level = 2nd costal cartilage = beginning/end of the aortic arch = tracheal bifurcation = termination of arch of azygos vein.
- ▶ Only three branches arise from the arch of aorta within the superior mediastinum, in order: **brachiocephalic, left common carotid, left subclavian arteries**.
- ▶ Anteroposterior order of contents: **Thymus → great veins → great arteries → trachea → oesophagus/thoracic duct → sympathetic trunks**.
- ▶ The **left recurrent laryngeal nerve** (not the right) lies within the superior mediastinum, hooking under the aortic arch.
- ▶ The thymus occupies a triangular retrosternal space formed by the costomediastinal pleural reflection.
- ▶ All great veins lie on the right, all great arteries on the left — creating a "potential dead space" on the right that masses tend to occupy/bulge into.
- ▶ Clinically remember mediastinal syndrome as SVC obstruction + dyspnoea + dysphagia + dysphonia (± vertebral erosion), and that anterior superior mediastinal nodes need a Chamberlain mediastinotomy rather than routine cervical mediastinoscopy.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e.



Broncho-pulmonary segments

Asked in: Paper I Oct 2006 — RGUHS MD/MS Anatomy

Definition / Introduction A bronchopulmonary segment is the largest subdivision of a pulmonary lobe — a well-defined, pyramidal-shaped anatomical, functional and surgical unit of lung tissue that is aerated by its own tertiary (segmental) bronchus and supplied by its own segmental branch of the pulmonary artery. Each lung contains **10 bronchopulmonary segments**, a numbering standardised by the **International Congress of Anatomists (1960)**. Because every segment has its own bronchovascular pedicle and is separated from its neighbours by definite connective-tissue planes, it is the smallest unit of lung that can be independently imaged, localised for disease, or surgically resected (segmentectomy) without disturbing the rest of the lobe — making this concept the anatomical basis of conservative lung surgery.

Definition and salient features

- ▶ Each segment is **pyramidal in shape**, with its **apex directed towards the hilum/root of the lung** and its **base directed towards the lung surface (periphery/pleura)**.
- ▶ Each segment is aerated by its own **segmental (tertiary) bronchus**, given off by the lobar (secondary) bronchus; the tertiary bronchus, its accompanying **segmental artery** (a branch of the pulmonary artery), **autonomic nerves** and **lymph vessels** all occupy a central position within the segment.
- ▶ The **segmental artery lies dorsolateral (posterior) to its bronchus** and supplies only that segment — each segment therefore has its own separate arterial supply.
- ▶ **Venous drainage is NOT segmental**: intersegmental (segmental) veins run in the loose connective-tissue septa **between** adjacent segments, so each vein drains parts of **two neighbouring segments**, and each segment is drained by **more than one vein**. Near the hilum the veins lie ventromedial to the bronchus. For this reason a bronchopulmonary segment is a true **broncho-arterial** unit but not a complete "broncho-vascular" unit.
- ▶ Each segment is enveloped by connective tissue continuous with the **visceral pleura**, which — together with the intersegmental veins — forms the plane along which the surgeon dissects during segmental resection.
- ▶ Because segments are independent functional units, localised disease remains confined to one segment for long periods, and adjoining healthy segments are spared during resection.

Enumeration of the bronchopulmonary segments

Lobe	Right lung (10 segments)	Left lung (10 segments)
Superior/upper lobe	I Apical · II Posterior · III Anterior	I Apical · II Posterior · III Anterior (upper division); IV Superior lingular · V Inferior lingular (lower/lingular division)
Middle lobe (right only)	IV Lateral · V Medial	— (represented by the lingula, a tongue-like part of the left upper lobe)

Lobe	Right lung (10 segments)	Left lung (10 segments)
Inferior/lower lobe	VI Superior (apical) · VII Medial basal · VIII Anterior basal · IX Lateral basal · X Posterior basal	VI Superior (apical) · VII Medial basal · VIII Anterior basal · IX Lateral basal · X Posterior basal

Common fusions (important variant): in the left lung, the **apical (I)** and **posterior (II)** segments of the upper lobe usually arise from a single common stem bronchus and fuse to form the **apico-posterior segment**; similarly the **medial basal (VII)** and **anterior basal (VIII)** segments of the left lower lobe often fuse to form an **antero-medial basal segment**. This is why the left lung is frequently described clinically as having only 8–9 grossly separable segments even though 10 are named.

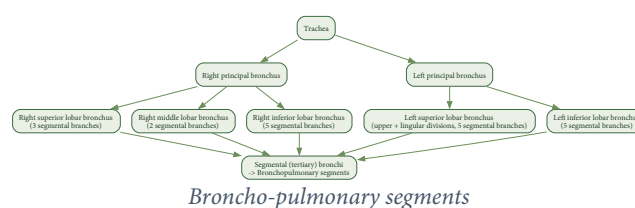
□ Fig 19.20 — Bronchopulmonary segments of the right lung seen on (A) lateral aspect, (B) medial aspect, (C) lobar and segmental bronchi (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.783)

□ Fig 19.21 — Bronchopulmonary segments of the left lung seen on (A) lateral aspect, (B) medial aspect, (C) lobar and segmental bronchi (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.784)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sketch each lung in lateral and medial views (as above) and label:

- ▶ Lobes: **superior, middle (right only), inferior**, separated by the **oblique fissure** (both lungs) and **horizontal fissure** (right lung only).
- ▶ Number every segment **I–X** using the scheme in the table above; shade the upper-lobe group, middle-lobe/lingular group, and lower-lobe group in three different colours.
- ▶ Alongside, draw the **bronchial tree**: trachea → right/left principal bronchus → lobar (secondary) bronchus → segmental (tertiary) bronchus, labelling each segmental bronchus **B1–B10** to match its Roman-numeral segment (e.g., apical = B1, posterior = B2 ... posterior basal = B10). On the left, show **B1+B2** arising from one common stem (apico-posterior).



Right vs left principal bronchus — why it matters for the segments

Feature	Right principal bronchus	Left principal bronchus
Length	~2.5 cm	~5 cm (twice as long)
Width/course	Wider, more vertical, in line with the tracheal axis	Narrower, more horizontal, deviates from the tracheal axis
Angle with trachea	~25°	~45°
Relation	Eparterial (upper-lobe branch given off above the pulmonary artery)	Hyparterial (passes below the arch of aorta, in front of the oesophagus)

Feature	Right principal bronchus	Left principal bronchus
Number of lobar branches	3 (superior, middle, inferior)	2 (superior — with upper + lingular divisions, and inferior)

Broncho-vascular relations within a segment

- **Bronchus + artery** occupy the **centre (axis)** of the segment; the artery runs dorsolateral to the bronchus.
- **Veins** run in the **intersegmental septa** (periphery of the segment), each vein draining two adjacent segments.
- The pleural covering and the loose connective tissue framework around each segment continues the visceral pleura inward, providing a plane of separation without a true avascular cleavage plane — a few intersegmental veins and small arterial branches cross the plane and must be deliberately preserved (veins) or ligated (segmental artery/bronchus) during **segmental resection**.

Applied / Clinical anatomy

- **Aspiration and foreign bodies:** because the right principal bronchus is shorter, wider and more vertical (in line with the trachea), inhaled foreign bodies and aspirated material preferentially enter the **right lung**, so foreign-body impaction, aspiration pneumonia and lung abscess are all commoner on the right side.
- **Postural (gravity-dependent) aspiration:** the **superior (apical) segment of the lower lobe (segment VI)** arises from the highest point on the posterior aspect of the lower-lobe bronchus and is the most dependent segment in the **supine position**; aspirated material in a comatose/supine patient therefore gravitates preferentially into this segment (more often on the right).
- **Bronchiectasis:** chronic necrotising infection with permanent bronchial/bronchiolar dilatation and pus retention classically affects the **basal segments of the lower lobe**.
- **Segmental (conservative) resection:** because each segment is a self-contained broncho-arterial unit with definable intersegmental planes, localised disease (tuberculosis, bronchiectasis, lung abscess, a solitary benign nodule, or an early bronchogenic carcinoma) confined to one or two segments can be excised as a **segmentectomy**, sparing the rest of the lobe — an advance over the more radical **lobectomy** or **pneumonectomy**. During dissection, intersegmental veins must be carefully preserved, as they also drain the adjacent healthy segment.
- **Segmental (lobar) atelectasis:** obstruction of a segmental bronchus (mucus plug, aspirated foreign body, tumour) causes gradual absorption of trapped air and collapse restricted to that segment's territory — visible as a wedge-shaped opacity on a chest radiograph, distinct from lobar or whole-lung collapse.
- **Radiological and surgical localisation:** bronchograms, CT and bronchoscopy are all interpreted segment-by-segment; precise knowledge of segmental anatomy is essential for image-guided biopsy, for planning a thoracic surgeon's approach to an abscess or tumour, and for correlating auscultatory/radiographic findings with the underlying segment.

- ▶ **Auscultation correlate:** the upper lobes are best auscultated above the 4th rib anteriorly, the middle lobe between the 4th and 6th ribs on the right, and the lower lobes on the back — a simple bedside application of lobar (and hence segmental-group) topography.

High-yield exam pointers

- ▶ Bronchopulmonary segment = pyramidal unit of lung aerated by one **tertiary (segmental) bronchus**; apex to hilum, base to periphery.
- ▶ **10 segments per lung** (ICA, 1960); right lung has segments in 3 lobes (3+2+5), left lung in 2 lobes (5+5) because of the lingula replacing the middle lobe.
- ▶ Segment has its **own bronchus + artery** (centrally placed) but **shares its veins** with neighbouring segments (intersegmental veins) — hence "broncho-arterial," not "broncho-vascular," unit.
- ▶ Left-lung fusions to remember: **apex + posterior** → **apico-posterior (I+II)**; **medial + anterior basal** → **antero-medial basal (VII+VIII)**.
- ▶ Mnemonic for right-lung segments (superior→inferior): "**A PALM Seed Makes Another Little Palm**" — Apical, Posterior, Anterior, Lateral, Medial, Superior, Medial basal, Anterior basal, Lateral basal, Posterior basal.
- ▶ Right principal bronchus: shorter (2.5 cm), wider, more vertical, 25° from tracheal axis — foreign bodies go here preferentially.
- ▶ Superior segment of the lower lobe (VI) = most dependent segment in supine position → classic site for aspirated material.
- ▶ Segmentectomy is possible because each segment is an independent bronchovascular/surgical unit — the anatomical basis of conservative lung resection for TB, bronchiectasis, abscess or localised tumour.
- ▶ Basal segments of the lower lobe are the classic site for **bronchiectasis**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 8e; Vishram Singh's Textbook of Anatomy Vol 1 4e (text and figures); Moore's Clinically Oriented Anatomy 9e.



Conducting system of the heart

Asked in: Paper I May 2007 — RGUHS MD/MS Anatomy

Definition / Introduction — The conducting system of the heart is a network of specialised, modified cardiac myocytes (not nervous tissue) that initiates the cardiac impulse and conducts it in an orderly sequence through the atria and ventricles, producing a coordinated, rhythmic heartbeat. Its fibres are finer than ordinary myocardial fibres and are the only site of muscular continuity between the atrial and ventricular musculature, the two being otherwise electrically insulated from each other by the fibrous cardiac skeleton. It comprises the sinu-atrial (SA) node, the atrioventricular (AV) node, the atrioventricular bundle (bundle of His) with its right and left branches, and the subendocardial Purkinje plexus.

Components of the conducting system

Component	Location	Approx. intrinsic rate	Role
Sinu-atrial (SA) node	Upper part of the terminal groove/crista terminalis, inferolateral to the opening of the superior vena cava	70–100 impulses/min	Pacemaker — initiates the cardiac impulse
Atrioventricular (AV) node	Triangle of Koch, in the atrial septum just above the opening of the coronary sinus	40–60 impulses/min	Receives the impulse from the atria; delays it before passing to the ventricles
Atrioventricular (AV) bundle (bundle of His)	Penetrates the central fibrous body; branches on the crest of the muscular interventricular septum	Rapid conduction (2–3 m/sec)	Sole muscular bridge between atrial and ventricular myocardium
Right and left bundle branches	Subendocardial, on either side of the interventricular septum	Rapid conduction	Carry the impulse to the respective ventricles
Purkinje fibres	Subendocardial plexus over papillary muscles and ventricular walls	20–35 impulses/min (subsidiary pacemaker)	Rapid, near-simultaneous activation of ventricular myocardium

□ Fig 18.14 — The conducting system of the heart (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.315)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the right atrium and right ventricle opened up (a right-heart "clock-face" schematic) and label:

- ▶ Superior vena cava opening; crista terminalis (terminal groove)
- ▶ **SA node** — subepicardial, in the terminal groove, inferolateral to the SVC opening
- ▶ Inferior vena cava opening; fossa ovalis; tendon of Todaro
- ▶ Opening of the coronary sinus; septal leaflet of the tricuspid valve
- ▶ **Triangle of Koch** (bounded by tendon of Todaro, coronary sinus orifice, septal tricuspid leaflet)
- ▶ **AV node** at the apex of the triangle of Koch
- ▶ Central fibrous body; **penetrating AV bundle (bundle of His)**
- ▶ Membranous interventricular septum
- ▶ **Right bundle branch** → septomarginal trabecula (moderator band) → anterior papillary muscle
- ▶ **Left bundle branch** → radiating subendocardially on the left septal surface
- ▶ **Purkinje fibre plexus** spreading subendocardially over both ventricles

Sinu-atrial (SA) node

- ▶ A crescent-shaped structure, 8–25 mm long, situated subepicardially in the terminal groove, inferolateral to the opening of the superior vena cava; described as having a **head, body and tail**, with short digitations radiating toward the SVC, subepicardium and crista terminalis.
- ▶ Known as the **pacemaker of the heart** — its myocytes depolarise fastest of all cardiac cells and override slower subsidiary rhythms; generates ~70–100 impulses/minute.
- ▶ Histology: small, pale-staining cells (5–10 µm diameter) with sparse myofibrils, little glycogen, and a large central nucleus; surrounded by a dense fibrous matrix and grouped around a central **SA nodal artery**; there are no autonomic ganglion cells within the node itself, though many border it.
- ▶ The impulse spreads from the SA node through the **ordinary working atrial myocardium**, not through discrete insulated tracts; conduction is only marginally faster along well-organised muscle bundles — the crista terminalis, the rim of the fossa ovalis, and **Bachmann's bundle** (the principal pathway to the left atrium). Current teaching (Gray's Anatomy 41e) holds that no specialised internodal or interatrial tracts, insulated from working myocardium, actually exist.

Atrioventricular (AV) node

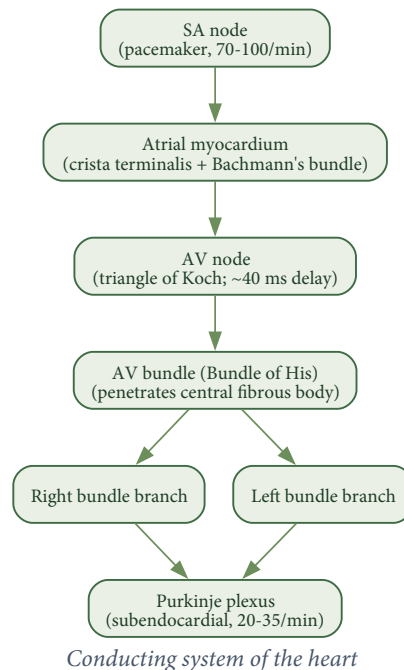
- ▶ An oblique, half-oval structure lying within the atrial component of the muscular atrioventricular septum, separated from the ventricular myocardium by the insulating fibrofatty tissue of the AV groove.
- ▶ Its surgical landmark is the **triangle of Koch**, bounded by: the septal leaflet of the tricuspid valve (inferiorly), the orifice of the coronary sinus (basally), and the tendon of Todaro (superiorly); the AV node lies at the apex of this triangle.

- ▶ Consists of a **compact zone** (interlocking nodal cells) surrounded by a **transitional zone** of elongated cells intermediate between nodal and working atrial myocytes; conduction through these poorly-coupled cells is slow, producing an atrioventricular delay of about 40 ms — the anatomical basis of the PR interval — which allows atrial systole to complete before ventricular contraction begins.
- ▶ Its anteroinferior end enters the central fibrous body to continue as the penetrating AV bundle; there is no distinct transition zone between the node and the bundle in humans.

Atrioventricular bundle (bundle of His) and bundle branches

- ▶ The **AV bundle** is the direct, and only, continuation of the AV node; it becomes oval/triangular in cross-section as it traverses the central fibrous body, then runs along the crest of the muscular interventricular septum, sandwiched between the muscular and membranous septal components.
- ▶ **Right bundle branch (crus dextrum)**: a narrow, discrete group of fascicles running first intramyocardially, then subendocardially, toward the apex; it enters the **septomarginal trabecula (moderator band)** to reach the anterior papillary muscle, then divides profusely into subendocardial fascicles for the rest of the right ventricular wall.
- ▶ **Left bundle branch (crus sinistrum)**: arises as numerous fine fascicles that leave the left margin of the branching bundle beneath the membranous septum, fan out as a flattened subendocardial sheet over the smooth left septal surface, and trifurcate into anterior, septal and posterior divisions, again first surrounding the papillary muscles before curving back to the rest of the ventricle.
- ▶ **Purkinje fibres** are the terminal ramifications of both bundle branches, forming a subendocardial plexus; they are large, pale, barrel-shaped cells with sparse myofibrils, insulated from ordinary myocardium by connective-tissue sheaths, and make functional (working) contact with ordinary myocytes only at their subendocardial terminations — hence ventricular activation spreads from endocardium to epicardium, with the papillary muscles contracting first.

Sequence and physiology of impulse conduction



- ▶ The SA node fires first (fastest intrinsic rhythm), and excitation spreads through ordinary atrial myocardium to depolarise both atria and to reach the AV node.
- ▶ Conduction velocity is slowest in nodal tissue and fastest in the His–Purkinje system (about 2–3 m/sec, versus ~0.6 m/sec in normal working myocardium) — this ensures the impulse reaches the ventricular apex before spreading through the ventricular walls, giving a properly coordinated, apex-to-base ejection.
- ▶ The AV nodal delay is essential: it lets the atria finish contracting (topping up ventricular filling) before ventricular systole begins, and it also imposes an upper limit on the ventricular response rate to rapid atrial rates.
- ▶ Each level of the system can act as a subsidiary ("escape") pacemaker if a higher level fails — AV node/junctional tissue at ~40–60/min, Purkinje fibres at ~20–35/min — explaining the slow idioventricular rhythm of complete heart block.

Arterial supply of the conducting system

Structure	Usual arterial supply	Notes
SA node	SA nodal artery — from the right coronary artery in the majority, but from the circumflex branch of the left coronary artery in about 40% of hearts	Runs directly through the node
AV node	AV nodal artery, a branch of the artery that reaches the crux of the heart (the "dominant" coronary artery — right coronary in ~60% of hearts)	Small, characteristic vessel arising near the cardiac crux

Structure	Usual arterial supply	Notes
AV bundle and right bundle branch	Predominantly right coronary artery (via posterior/inferior interventricular septal branches), with a variable contribution from septal perforators of the left anterior descending artery	—
Left bundle branch	Dual supply — septal perforators of the left anterior descending artery (anterior division) and the posterior/inferior interventricular artery (posterior division)	Relatively protected from single-vessel occlusion, unlike the right bundle branch

Practically, therefore, the right coronary artery supplies the whole conducting system except part of the left bundle branch — an important basis for the arrhythmias seen with right coronary versus left anterior descending occlusion.

Applied / Clinical anatomy

- ▶ **Heart block:** Ischaemia or fibrosis involving the AV node, AV bundle, or its branches produces partial or complete heart block. In **complete heart block**, the ventricles no longer receive atrial impulses and beat independently on a slow idioventricular rhythm (~30–40/min, from the Purkinje system) while the atria continue at their own faster rate (~70/min) — a dissociation exploited diagnostically on ECG and by auscultation/pulse examination.
- ▶ **Sinus node disease ("sick sinus syndrome"):** SA nodal dysfunction causes bradycardia or syncopal attacks (Stokes–Adams attacks) from cerebral ischaemia; treated with a permanent artificial pacemaker.
- ▶ **Wolff–Parkinson–White syndrome:** an accessory, non-insulated strand of ventricular myocardium crosses the fibrofatty AV groove, short-circuiting the normal AV nodal delay and pre-exciting the ventricle.
- ▶ **Triangle of Koch** is a key surgical/electrophysiological landmark: it localises the AV node for identifying re-entrant circuits (e.g., AV nodal re-entrant tachycardia) and guiding radiofrequency catheter ablation, and must be avoided during tricuspid valve or ASD surgery to prevent iatrogenic heart block.
- ▶ **Artificial cardiac pacing:** Temporary or permanent pacing leads are introduced via the subclavian, internal jugular, or cephalic vein into the right atrium/ventricle; the generator is usually implanted subcutaneously on the anterior chest wall (commonly beneath pectoralis major).
- ▶ **ECG correlation:** SA nodal discharge and atrial depolarisation generate the P wave; the AV nodal delay corresponds to the PR interval; depolarisation via the His–Purkinje system produces the QRS complex.
- ▶ **Congenital conduction defects:** may arise from accessory pathways or dysgenesis of conduction tissue anywhere from the AV node to the AV bundle, and are increasingly seen as long-term sequelae of surgery for congenital heart disease.

High-yield exam pointers

- ▶ Conducting system = specialised cardiac myocytes (not nerve tissue); the AV bundle is the **only** muscular continuity between atrial and ventricular myocardium.
- ▶ SA node = pacemaker; located in the terminal groove/crista terminalis, inferolateral to the SVC opening; fastest intrinsic rate (~70–100/min).
- ▶ AV node lies at the apex of the **triangle of Koch** (tendon of Todaro, coronary sinus orifice, septal leaflet of tricuspid valve); imposes a ~40 ms conduction delay (basis of the PR interval).
- ▶ AV bundle penetrates the central fibrous body, then divides into right and left bundle branches on the interventricular septum; the right bundle branch runs in the septomarginal trabecula (moderator band).
- ▶ Purkinje fibres are large, pale, subendocardial cells with the fastest conduction velocity (2–3 m/sec) in the heart.
- ▶ No genuine specialised internodal tracts exist; atrial conduction is via ordinary myocardium, marginally faster along the crista terminalis, fossa ovalis rim, and Bachmann's bundle.
- ▶ Right coronary artery supplies the whole conducting system except part of the left bundle branch, which has dual (LAD + posterior descending) supply.
- ▶ Clinical correlates: complete heart block → idioventricular rhythm; sick sinus syndrome → pacemaker; WPW syndrome → accessory pathway; triangle of Koch is the landmark for AV node-related ablation/surgery.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 8e; AK Datta's Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh's Textbook of Anatomy Vol 1 4e; IB Singh's Textbook of Anatomy Vol 2 6e.



Describe in detail about the anatomy of mammary gland along with its lymphatic drainage

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction — The breast (mammary gland) is a modified, compound tubulo-alveolar apocrine sweat gland lying in the superficial fascia of the pectoral region. It is rudimentary in the male and undergoes full functional development in the female after puberty, forming a secondary sexual organ whose purpose is lactation. Its clinical importance is disproportionate to its anatomical simplicity because carcinoma of the breast is common and spreads chiefly along the lymphatics described below.

Location, Extent & Relations

- ▶ **Situation:** lies in the superficial fascia over the pectoral region, extending from the **2nd to the 6th** rib vertically and from the **lateral border of the sternum to the mid-axillary line** horizontally.

- **Quadrants:** divided by a vertical and a horizontal line through the nipple into **upper medial, upper lateral, lower medial and lower lateral quadrants**; the upper lateral quadrant is the largest and the commonest site of carcinoma.
- **Axillary tail (of Spence):** a prolongation of the upper-lateral quadrant that pierces the deep fascia through an opening called the **foramen of Langer** and lies in the axilla.
- **Deep relations** (superficial to deep): skin → breast (in superficial fascia) → **retromammary (submammary) space** (loose areolar tissue permitting free mobility over the underlying muscle) → **deep pectoral fascia** covering pectoralis major → pectoralis major, serratus anterior and external oblique aponeurosis.
- **Nipple:** a conical projection at the level of the **4th intercostal space**, about **10 cm from the midline**, pierced by 15–20 lactiferous ducts; contains circular and longitudinal smooth muscle that can erect or flatten it.
- **Areola:** pigmented skin around the nipple base, containing sebaceous glands that enlarge in pregnancy/lactation as **Montgomery's tubercles**, plus sweat and accessory mammary glands; hairless and without subcutaneous fat.

Structure of the Breast

The breast is conventionally described under skin, parenchyma and stroma.

Component	Description
Skin	Covers the gland; nipple and areola as above.
Parenchyma (mammary gland proper)	Compound tubulo-alveolar gland of 15–20 lobes , arranged radially like spokes of a wheel; each lobe is a cluster of lobules/alveoli drained by one lactiferous duct ; ducts converge and open as separate orifices on the nipple tip; near its termination each duct dilates into a lactiferous sinus that stores milk. No capsule is present since the gland lies in superficial fascia.
Stroma	Partly fibrous, partly fatty. Fibrous septa form the suspensory ligaments of Cooper , anchoring skin and gland to the deep pectoral fascia and supporting the breast; fat forms the bulk of the gland everywhere except beneath the nipple and areola, and is responsible for most of the increase in breast size at puberty.

□ Fig 3.16 — Structure of the breast: (A) parenchyma (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.178)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sagittal section of the breast — label: skin; nipple with lactiferous duct orifices; areola with tubercle of Montgomery; lactiferous sinus; lactiferous duct; secretory lobule (alveoli); suspensory ligament of Cooper; fat (stroma); retromammary/submammary space; deep (pectoral) fascia; pectoralis major and pectoralis minor; rib; axillary tail extending toward axilla.

Blood Supply

- **Arteries** — the breast is highly vascular and is supplied from three sources, all converging on and supplying it from its **anterior surface** (the posterior surface is relatively avascular):

Source artery	Branch reaching breast	Area supplied
Internal thoracic artery (subclavian)	Perforating branches (2nd–4th spaces)	Anteromedial breast; the 2nd perforator is usually the largest, supplying nipple, areola and adjacent tissue
Axillary artery	Superior thoracic, pectoral branch of thoraco-acromial, and lateral thoracic arteries	Lateral aspect of the breast
Posterior intercostal arteries	Lateral cutaneous branches	Lateral/deep breast tissue

- **Veins** — converge toward the base of the nipple to form a **circular anastomotic venous plexus**, then drain by superficial and deep sets: superficial veins into the **internal thoracic vein** and superficial veins of the lower neck; deep veins into the **axillary, internal thoracic and posterior intercostal veins**.

Nerve Supply

- Anterior and lateral cutaneous branches of the **4th to 6th intercostal nerves** supply sensory fibres to the skin and sympathetic (autonomic) fibres to the smooth muscle and blood vessels of the breast.
- The **nipple** is predominantly supplied by the anterior division of the lateral cutaneous branch of T4, which forms a rich subareolar plexus terminating as free nerve endings, Meissner's corpuscles and Merkel discs — essential for the suckling (milk-ejection) reflex; the areola is less richly innervated.
- Secretion of milk is **not** under neural control; it is governed by the hormone **prolactin** (anterior pituitary), with oestrogen and progesterone driving ductal/lobular growth.

Lymphatic Drainage

Lymphatic drainage is of paramount surgical importance since breast carcinoma disseminates chiefly by this route.

Lymphatic vessels

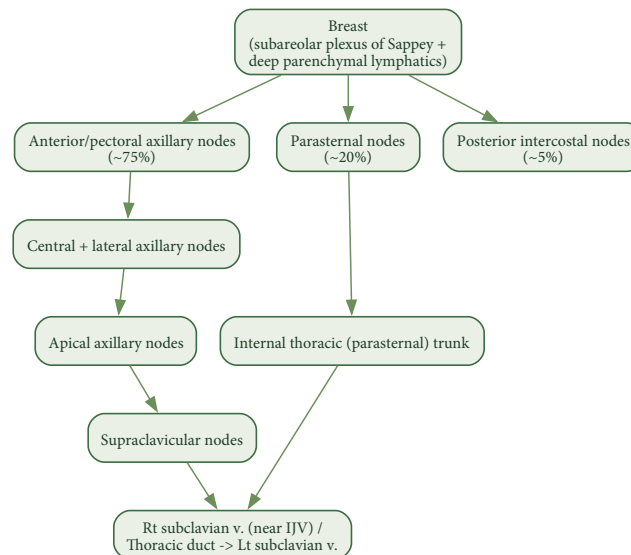
- **Superficial lymphatics** drain the skin of the breast (except nipple and areola) radially to the surrounding nodes.

- ▶ **Deep lymphatics** drain the parenchyma, nipple and areola via a rich **subareolar (Sappey's) plexus**, which channels most of the gland's lymph to the anterior (pectoral) axillary nodes.
- ▶ Deep lymphatics from the posterior surface of the gland pierce pectoralis major and the clavipectoral fascia to reach the apical nodes directly.

Lymph node groups and proportional drainage

Destination	Approx. share	Notes
Axillary nodes	~75%	Chiefly the anterior/pectoral group (close to the axillary tail); also posterior (subscapular), lateral, central and apical groups
Parasternal (internal thoracic/anterior thoracic) nodes	~20%	Along the internal thoracic vessels; drain both medial and lateral halves of the breast
Posterior intercostal nodes	~5%	Lying in front of the rib heads

- ▶ **Axillary nodes (20–40 in number)** are grouped anatomically as **anterior/pectoral**, **posterior/subscapular**, **lateral (brachial)**, **central** and **apical**, and surgically (Berg's levels, relative to pectoralis minor) as **Level I** (below/lateral to pec. minor), **Level II** (behind pec. minor, including the inconstant **interpectoral/Rotter's nodes**) and **Level III/apical** (above pec. minor, below the clavicle).
- ▶ **Sequence of flow:** anterior and posterior groups → central and lateral groups → **apical group** → **supraclavicular nodes** → right lymphatic duct/subclavian vein (right side) or **thoracic duct** → left subclavian vein (left side).
- ▶ Some lymphatics from the lower and inner quadrants cross the costal margin, pierce the linea alba, and communicate with the **subdiaphragmatic and subperitoneal lymph plexuses** — a route of intra-abdominal/hepatic metastasis.
- ▶ Free communication across the midline can carry spread to the **opposite breast/axilla**.
- ▶ Clinically, the first-echelon (**sentinel**) node — usually a low axillary (Level I) node — is biopsied using radiocolloid + blue dye to stage early breast cancer without full axillary clearance.



Describe in detail about the anatomy of mammary gland along with its lymphatic drainage

□ Fig 53.24 — Lymph vessels of the breast and the draining axillary and supraclavicular nodal groups. (Gray's Anatomy — Standing — 41e, p.1307)

Applied / Clinical anatomy

- ▶ **Carcinoma breast** most commonly arises in the **upper-outer quadrant**; spreads mainly by lymphatics (as above) and also by blood (vertebral venous plexus of Batson, to spine/skull/pelvis) and direct local infiltration.
- ▶ **Nipple retraction** results from infiltration and fibrosis of lactiferous ducts or the suspensory ligaments of Cooper by tumour, pulling the nipple inward.
- ▶ **Peau d'orange** (orange-peel skin) occurs when tumour blocks the superficial (cutaneous) lymphatics, producing dermal oedema that is tethered at hair-follicle/sweat-gland pits by Cooper's ligaments.
- ▶ **Fixation of the breast** to the chest wall in advanced disease is due to tumour infiltration of the retromammary space/Cooper's ligaments and pectoral fascia.
- ▶ **Axillary lymph node dissection/sentinel node biopsy** is central to breast-cancer staging; over-radical dissection risks lymphoedema of the arm, winged scapula (long thoracic nerve injury) or loss of shoulder adduction (thoracodorsal nerve injury) because these nerves cross the axilla close to the nodal groups.
- ▶ **Surgical incisions** for breast abscess drainage are made **radially** to avoid cutting the radially-arranged lactiferous ducts; incisions for tumour excision are usually **circumareolar or elliptical** along Langer's lines.
- ▶ **Mastectomy variants**: radical mastectomy (breast + pectoralis major & minor + axillary nodes), modified radical mastectomy (pectoralis major preserved), and breast-conservation surgery/lumpectomy for smaller lesions, sometimes with immediate reconstruction (e.g. latissimus dorsi or TRAM/DIEP flap).
- ▶ **Self-examination** and mammography/ultrasonography exploit the quadrant anatomy and axillary tail to detect lumps and nodal masses early.

High-yield exam pointers

- ▶ Extent: 2nd–6th rib vertically, sternal edge to mid-axillary line horizontally; axillary tail through the **foramen of Langer**.
- ▶ 15–20 lobes → each drained by one lactiferous duct → **lactiferous sinus** just deep to the nipple.
- ▶ Suspensory ligaments of **Cooper** anchor gland to skin and deep fascia; retromammary space allows mobility over pectoralis major.
- ▶ Arterial triad: **internal thoracic** (perforators, largest = 2nd), **lateral thoracic/thoraco-acromial** (axillary artery), **posterior intercostal** arteries.
- ▶ Nerve supply: **T4–T6** intercostal nerves (sensory + sympathetic); nipple mainly by T4; secretion is hormonal (prolactin), not neural.
- ▶ Lymph split: **75% axillary : 20% parasternal : 5% posterior intercostal**; subareolar plexus of **Sappey**.
- ▶ Axillary nodes: anterior/pectoral, posterior/subscapular, lateral, central, apical (20–40 nodes); surgical Levels I/II/III relative to pectoralis minor; **Rotter's (interpectoral)** nodes between pec. major and minor.
- ▶ Drainage sequence: anterior+posterior → central/lateral → apical → supraclavicular → subclavian vein (right) / thoracic duct (left).
- ▶ Upper-outer quadrant = commonest site of breast carcinoma; nipple retraction and peau d'orange are classic signs of ductal/lymphatic infiltration.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1, 8e; Vishram Singh — Textbook of Anatomy Vol 1, 4e.



Describe the anatomy of thoracic diaphragm. Add a note on its role in respiration

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The diaphragm is a dome-shaped, musculotendinous septum that separates the thoracic and abdominal cavities and forms the floor of the thorax. It is the chief muscle of respiration, contributing the largest single share of quiet tidal breathing. Peripherally it is muscular, arising in a continuous ring from the circumference of the thoracic outlet; centrally the fibres converge into an aponeurotic **central tendon**. Although it separates the two cavities, it is not a complete partition — it is pierced by numerous structures passing between thorax and abdomen. It develops in the cervical region (from the septum transversum and cervical myotomes), and despite its descent to the thoraco-abdominal junction it is loyally followed and supplied by the **phrenic nerve** (C3, C4, C5).

Origin (peripheral attachments)

Part	Origin
Sternal part	Two fleshy slips from the posterior aspect of the xiphoid process
Costal part	Inner surfaces of the cartilages and adjoining ends of the lower six ribs on each side, interdigitating with the slips of origin of transversus abdominis
Lumbar part	Medial and lateral lumbocostal (arcuate) arches, and the right and left crura from the upper lumbar vertebrae

- **Medial arcuate ligament** (over psoas major): from the side of the body of L1 (continuous with the crus) to the transverse process of L1. **Lateral arcuate ligament** (over quadratus lumborum): from the transverse process of L1 to the lower border of the **12th rib**.
- **Right crus**: broader, longer, stronger — arises from the anterolateral surfaces of the bodies/discs of the **upper three lumbar vertebrae**; it pulls the liver down each inspiration and its medial fibres split to encircle the oesophagus.
- **Left crus**: from the corresponding **upper two lumbar vertebrae** only.
- **Median arcuate ligament**: medial tendinous margins of the two crura, arching across the front of the aorta at the T12/L1 disc level.

From this oblique circumferential origin the fibres arch upward and inward to form the **right and left domes (cupulae)** before converging on the central tendon. The right dome (over the liver) is higher than the left (over the fundus of stomach and spleen); on full expiration the right dome reaches the **4th intercostal space/rib** and the left the **5th rib**. On an erect chest radiograph the right hemidiaphragm lies at the anterior end of the 6th rib, the left 1.5–2.5 cm lower.

Insertion — the central tendon

- All muscle fibres converge and insert into the margins of a thin but strong aponeurosis, the **central tendon**, which lies nearer the sternum than the vertebral column (so the posterior muscular fibres are the longest).

- ▶ It is **trifoliate**: a triangular middle (anterior) leaflet with its apex toward the xiphoid, and tongue-shaped right and left leaflets curving posterolaterally — the left leaflet a little narrower than the right.
- ▶ Centrally it is fused with the **fibrous pericardium** above; four diagonal tendinous bands fan out from a central point of decussation that lies anterior to the oesophagus and to the left of the inferior vena cava.

Openings in the diaphragm

Major (large) openings

Opening	Vertebral level	Site/shape	Structures transmitted	Effect of contraction
Vena caval opening	T8	Central tendon, at junction of right and middle leaflets; quadrilateral	Inferior vena cava, branches of right phrenic nerve , lymphatics of liver	Dilates — aids venous return
Oesophageal opening	T10	Muscular part, formed by splitting fibres of the right crus; oval	Oesophagus, right & left vagal trunks , oesophageal branches of left gastric vessels	Constricts — physiological "pinch-cock" sphincter
Aortic opening	T12 (lower border)	Behind the median arcuate ligament; osseo-aponeurotic, retro-muscular; rounded	Aorta, thoracic duct, azygos vein	No change — aorta lies posterior to the diaphragm proper

Mnemonic: "I 8, oesophagus 10, aorta at 12" — the openings ascend numerically as one moves caudally through the crus into the central tendon.

Minor openings

- ▶ Each crus is pierced by the **greater and lesser splanchnic nerves**; the **left crus** is additionally pierced by the **hemiazygos vein**.
- ▶ The **sympathetic trunk** passes behind the medial arcuate ligament.
- ▶ The **subcostal nerve and vessels** pass behind the lateral arcuate ligament.
- ▶ The **superior epigastric vessels** and some lymphatics pass through the gap between the sternal and costal origins — the **space of Larrey / foramen of Morgagni**.
- ▶ The **musculophrenic vessels** pierce the diaphragm near the costal origin.
- ▶ **Intercostal nerves and vessels** pass through the interdigitating slips of diaphragm and transversus abdominis.
- ▶ The **left phrenic nerve** pierces the muscular part anterior to the central tendon; the **right phrenic nerve** pierces the central tendon at/near the caval opening.

Relations

Surface	Related structures
Superior	Pleura and bases of both lungs; fibrous pericardium (fused to central tendon)
Inferior — right side	Right lobe of liver, right kidney, right suprarenal gland
Inferior — left side	Left lobe of liver, fundus of stomach, spleen, left kidney, left suprarenal gland

Nerve supply

- ▶ **Motor** — the **phrenic nerves alone** (ventral rami C3, C4, C5); no other nerve produces useful diaphragmatic contraction. The diaphragm develops in the neck, so the nerve is "dragged" down with it during descent, giving the phrenic nerve its long thoracic course.
- ▶ The **right phrenic nerve** descends more vertically, lateral to the brachiocephalic vein, SVC and the fibrous pericardium over the right atrium/IVC, and pierces the central tendon; it supplies the **right half of the diaphragm** and the part of the right crus to the right of the oesophagus.
- ▶ The **left phrenic nerve** crosses the left subclavian artery, the aortic arch and the left pulmonary hilum, and pierces the muscular part anterior to the central tendon; it supplies the **left half** and the left crus, plus the part of the right crus to the left of the oesophagus.
- ▶ Each nerve divides near the diaphragm into anterior (sternal), anterolateral, and posterior (crural) branches.
- ▶ **Sensory** — the phrenic nerves supply the **central part** (central tendon, mediastinal and diaphragmatic pleura, fibrous pericardium, and central parietal peritoneum); the **lower six intercostal/subcostal nerves** (T7–T12) supply the **peripheral muscular part**.

Blood supply and lymphatic drainage

Arterial

- ▶ **Inferior phrenic arteries** (from abdominal aorta/coeliac trunk) — the major supply to the inferior surface.
- ▶ **Superior phrenic arteries** (from thoracic aorta) — supply the posterosuperior part.
- ▶ **Pericardiophrenic arteries** (from the internal thoracic artery).
- ▶ **Musculophrenic arteries** (terminal branch of internal thoracic artery).
- ▶ **Superior epigastric arteries** (terminal branch of internal thoracic artery).
- ▶ **Lower five intercostal and subcostal arteries** — supply the costal margins.

Venous drainage — superior surface via musculophrenic and pericardiophrenic veins; inferior surface via right and left **inferior phrenic veins**, draining into the IVC (right side), and into the IVC, left suprarenal or left renal vein (left side).

Lymphatic drainage — **anterior** diaphragmatic nodes (behind the xiphoid), **posterior** diaphragmatic nodes (near the aortic opening), and **right lateral** diaphragmatic nodes (near the caval opening); these also drain the bare area of the liver and gastro-oesophageal region.

□ Fig 26.1 — The diaphragm as seen from below (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.418)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the diaphragm as seen from below and label: **xiphoid process** (sternal slips); **costal slips** from the lower six costal cartilages; **right crus** and **left crus**; **medial arcuate ligament** and **lateral arcuate ligament**; **median arcuate ligament**; **central tendon** (middle, right and left leaflets); the three major openings — **vena caval opening** (T8) with IVC, **oesophageal opening** (T10) with oesophagus and vagal trunks, **aortic opening** (T12) with aorta, thoracic duct and azygos vein; **sympathetic trunk** and **greater/lesser splanchnic nerves** piercing the crura; **psoas major** and **quadratus lumborum** deep to the arcuate ligaments.

Role in respiration

- ▶ The diaphragm is the **principal muscle of quiet inspiration**. On contraction its fibres shorten, the **central tendon descends** and the domes flatten, increasing the **vertical diameter** of the thoracic cavity.
- ▶ The bony/membranous roof of the thorax (suprapleural membrane) is fixed and cannot move; only the diaphragmatic floor is mobile, so the vertical diameter increases *solely* through diaphragmatic descent.
- ▶ This enlargement lowers intrathoracic pressure below atmospheric pressure, so air is drawn into the lungs (inspiration). Anteroposterior and transverse diameters are increased separately by the **pump-handle** (vertebrosternal ribs, via external intercostals) and **bucket-handle** (vertebrochondral ribs) movements respectively, but the vertical component from the diaphragm is the dominant contributor at rest.
- ▶ **Excursion**: about **1.5 cm** during quiet breathing, increasing to **6–10 cm** in deep/forced inspiration.
- ▶ **Expiration** in quiet breathing is passive — brought about by elastic recoil of the lungs, relaxation of the diaphragm and intercostals, and rising tone of the anterior abdominal wall muscles that push the relaxing diaphragm back up.

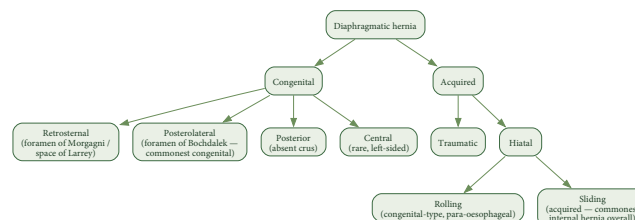
Type of respiration	Inspiratory muscles	Expiratory muscles
Quiet	External intercostals, diaphragm	Passive (none)
Deep	Above + scalenes, sternocleidomastoid, levatores costarum, serratus posterior superior	Passive (none)
Forced	Above + trapezius, levator scapulae, rhomboids, pectorals, serratus anterior (scapula fixed)	Internal intercostals, transversus thoracis, serratus posterior inferior, quadratus lumborum, abdominal muscles

- ▶ **Ancillary respiratory actions of the diaphragm**:
 - Descent of the central tendon **dilates the caval opening**, increasing venous return to the right atrium with each inspiration (the "thoraco-abdominal pump").

- The right crus **constricts the oesophageal opening** on inspiration, acting as a physiological "pinch-cock" sphincter that reinforces the lower oesophageal sphincter and helps prevent gastro-oesophageal reflux.
- The diaphragm powers all **expulsive acts** — sneezing, coughing, straining, defaecation, micturition and parturition — each preceded by a deep inspiration, glottic closure, and forceful contraction of the diaphragm with the trunk muscles (Valsalva-type mechanism).
- **Postural factors** governing diaphragmatic level — elastic lung recoil (pulls up), pressure of abdominal viscera (up on lying down, down on standing), and abdominal-wall tone (up on standing) — make the diaphragm **highest when supine, lowest when sitting**, so orthopnoeic patients prefer sitting up for a greater excursion.

Applied / Clinical anatomy

- **Diaphragmatic hernia** — a defect allowing abdominal viscera into the thorax:



Describe the anatomy of thoracic diaphragm. Add a note on its role in respiration

- **Sliding hiatus hernia** — the commonest internal hernia; due to laxity of the **phreno-oesophageal ligament**, letting the cardio-oesophageal junction slide up, disturbing the valvular mechanism and causing reflux (classically the "busy obese businessman with acidity").
- **Eventration** — congenital thinning/absence of muscle (usually the left anteromedial segment), producing a focal upward bulge that can mimic a hernia radiologically.
- **Phrenic nerve palsy** — unilateral lesion causes **paradoxical** (upward) movement of the paralysed dome on sniffing (fluoroscopy/USG); bilateral palsy causes severe respiratory embarrassment.
- **Referred shoulder-tip pain** — diaphragmatic irritation (subphrenic abscess, splenic/hepatic injury, haemoperitoneum) refers to the shoulder as the phrenic and supraclavicular nerves share root value C3, C4, C5.
- **Hiccough** — spasmodic diaphragmatic contraction; peripheral (local diaphragm/phrenic irritation) or central (medullary hiccough centre, e.g. uraemia).

High-yield exam pointers

- Sole motor supply is the **phrenic nerve (C3, C4, C5)** — "C3, 4, 5 keeps the diaphragm alive"; sensory — phrenic to the central part, lower six intercostal/subcostal nerves to the periphery.
- **Right crus** is longer/stronger (pulls the liver down each inspiration), encircles the oesophagus and gives it a sphincteric, antireflux action.
- Opening levels ascend with the vertebra: **IVC at T8** (central tendon, dilates), **oesophagus at T10** (right crus, constricts), **aorta at T12** (behind median arcuate ligament, unaffected).
- **Foramen of Morgagni/space of Larrey** (sternocostal) → retrosternal congenital hernia; **foramen of Bochdalek** (posterolateral, left-sided) → commonest congenital diaphragmatic hernia; **sliding hiatus hernia** → commonest acquired/internal hernia overall.

- ▶ Central tendon is **trifoliate** and fused to the fibrous pericardium; right dome is higher than the left (liver).
- ▶ Diaphragmatic descent is the sole mechanism increasing the thorax's **vertical diameter**; excursion ~1.5 cm quiet, 6–10 cm deep breathing.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e (Chapter: Diaphragm); Vishram Singh — Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e (figure reference).



Describe the conducting system of heart with functional significance

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction The conducting system of the heart is a network of specialized, modified cardiac muscle fibres — not nervous tissue — that initiates and conducts the cardiac impulse, thereby coordinating rhythmic contraction of the four chambers. It comprises the sinoatrial (SA) node, the atrioventricular (AV) node, the atrioventricular bundle (bundle of His) with its right and left bundle branches, and the subendocardial Purkinje fibre network. Functionally, it confers **autorhythmicity** on the heart (myogenic, not neurogenic, origin of the heartbeat), imposes a physiological **delay** at the AV node so that atrial systole is completed before ventricular systole begins, and produces a rapid, coordinated **apex-to-base wave of ventricular activation** essential for efficient ejection.

1. Components and general architecture

Component	Location	Nature of tissue	Approx. intrinsic rate
SA node (pacemaker)	Upper end of sulcus/crista terminalis, at junction of SVC and right atrium	Small, pale, spindle-shaped cells; sparse myofibrils, no proper sarcotubular system	70–100/min
AV node	Triangle of Koch, in the atrial part of the muscular AV septum	Compact zone + transitional zone; collagen-enmeshed nodal cells	40–60/min
AV bundle (of His) + bundle branches	Penetrates central fibrous body; runs along crest of muscular interventricular septum	Larger, rapidly conducting fibres, insulated by connective-tissue sheaths	—
Purkinje fibres	Subendocardial plexus of both ventricles	Large, pale, barrel-shaped fibres, peripherally striated, glycogen-rich	20–35/min

All components are made of specialized cardiomyocytes, finer and more richly cross-striated than working myocardium, and are electrically coupled by gap junctions; nodal tissue itself is not directly innervated by autonomic nerve terminals, though ganglia lie close to both nodes.

2. Sinuatrial (SA) node

- ▶ The **pacemaker** of the heart; a crescent-shaped structure about 8–25 mm long.
- ▶ Lies subepicardially within the terminal groove (sulcus terminalis), at the junction of the superior vena cava and the right atrial appendage, extending into the upper crista terminalis.
- ▶ Consists of a head, body and tail, from which digitations of nodal tissue radiate into the surrounding working atrial myocardium.
- ▶ Marked consistently by a large central **SA nodal artery**.
- ▶ Discharges spontaneously at the fastest intrinsic rate of any cardiac tissue and therefore overrides all subsidiary pacemakers, setting **sinus rhythm**.

3. Spread of the impulse through the atria

- ▶ The impulse from the SA node spreads to the rest of the atrial musculature through **ordinary working atrial myocardium**, not through histologically distinct insulated tracts — current anatomical teaching (Gray's 41e) finds **no evidence of specialized internodal or interatrial conduction pathways** of the kind classically named (His, Wenckebach, Thorel tracts).
- ▶ Conduction is, however, preferentially more rapid along well-organized atrial muscle bundles: the **terminal crest (crista terminalis)**, the **margins of the fossa ovalis**, and **Bachmann's bundle**, which carries the impulse to the left atrium.
- ▶ Additional pathways to the left atrium exist through muscular connections between the coronary sinus wall and the left atrium.

4. Atrioventricular (AV) node

- ▶ Oblique, half-oval nodal structure lying within the atrial component of the muscular AV septum, separated from the ventricular myocardium by the fibro-fatty AV groove.
- ▶ Bounded by the landmarks of the **triangle of Koch**: the septal leaflet of the tricuspid valve inferiorly, the ostium of the coronary sinus basally, and the tendon of Todaro superiorly.
- ▶ Has a **compact zone** (interlocking nodal cells fed directly by right and left atrial and septal myocardium) and a **transitional zone** (elongated cells intermediate between nodal and working atrial cells).
- ▶ **Functional significance — AV delay**: conduction through the node is deliberately slow (transitional cells have sparse gap junctions/connexin-43), delaying the impulse by about **40 ms**. This (a) allows the atria to complete ejection of blood into the ventricles before ventricular systole begins, and (b) imposes an upper limit ("filter") on the rate at which atrial impulses can be transmitted to the ventricles, protecting them from very rapid atrial rates.
- ▶ Acts as a **subsidiary (escape) pacemaker** (40–60/min) if the SA node fails.

5. Atrioventricular bundle (bundle of His) and bundle branches

- ▶ The **only muscular continuity** between atrial and ventricular myocardium; the node's cells become continuous, without histological transition, with the penetrating AV bundle.
- ▶ Traverses the central fibrous body and branches at the crest of the muscular interventricular septum, sandwiched between the muscular and membranous septal components.
- ▶ **Right bundle branch**: a narrow, discrete fascicle that runs subendocardially down the right septal surface, enters the **septomarginal trabecula (moderator band)** to reach the anterior papillary muscle, then divides into fine subendocardial fascicles for the rest of the right ventricular wall.
- ▶ **Left bundle branch**: fans out early into multiple fine fascicles beneath the endocardium of the left septal surface, spreading apically and trifurcating into **anterior, septal and posterior divisions**, forming a subendocardial network around the papillary muscles and the rest of the left ventricle.
- ▶ Conduction velocity in the bundle and its branches is **rapid (2–3 m/sec)** compared with **0.6 m/sec** in ordinary ventricular myocardium — the anatomical basis for near-simultaneous activation of both ventricles.

6. Purkinje fibres

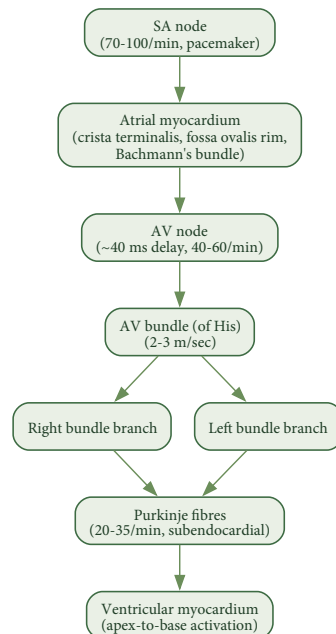
- ▶ The terminal, subendocardial ramifications of the right and left bundle branches, forming a dense plexus deep to the endocardium of both ventricles.
- ▶ Large, pale fibres, striated only at their margins, glycogen-rich, with functional (not morphological) contact to working myocytes occurring only at their terminal ramifications.
- ▶ Because the Purkinje network is subendocardial, ventricular **excitation spreads from endocardium to epicardium**, and the papillary muscles are activated first — contracting fractionally ahead of the ventricular wall so that the chordae tendineae are already taut when systolic pressure rises, preventing atrioventricular valve prolapse.
- ▶ The impulse reaches the cardiac apex before spreading to the outflow tracts, producing a properly coordinated, apex-to-base ventricular ejection.
- ▶ Capable of independent, slow **idioventricular pacemaker activity (20–35/min)** if all proximal conduction fails.

7. Blood supply and nerve supply of the conducting system

Structure	Arterial supply
SA node	Right coronary artery (~60%) or circumflex branch of left coronary artery (~40%)
AV node, AV bundle, right bundle branch	Right coronary artery (AV-nodal branch arising near the crux, from whichever artery is dominant)
Left bundle branch	Largely spared by isolated right coronary occlusion — receives supply distinct from the right branch, making it more resistant to single-vessel ischaemia

- ▶ **Nerve supply**: both divisions of the autonomic system reach the heart via the superficial and deep cardiac plexuses and travel along the coronary arteries to the nodes.

- **Parasympathetic (vagus)** — cardio-inhibitory; slows SA discharge and prolongs AV conduction.
- **Sympathetic (upper 4–5 thoracic segments)** — cardio-acceleratory; increases SA rate and speeds AV conduction.
- Autonomic ganglion cells lie adjacent to, but not within, the nodes themselves; the nodal cells are only modulated, not driven, by these nerves — automaticity itself is myogenic.



Describe the conducting system of heart with functional significance

□ Fig 18.14 — The conducting system of the heart (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.315)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw an opened right atrium and right ventricle (coronal section) and label:

- ▶ Superior vena cava and inferior vena cava openings
- ▶ Crista terminalis (sulcus/terminal groove) with **SA node** at its upper end
- ▶ Fossa ovalis (its margins as an atrial conduction pathway)
- ▶ Bachmann's bundle (interatrial conduction to left atrium)
- ▶ Triangle of Koch — bounded by septal leaflet of tricuspid valve, tendon of Todaro, and orifice of coronary sinus
- ▶ **AV node** within the triangle of Koch
- ▶ **AV bundle (of His)** penetrating the central fibrous body/membranous septum
- ▶ Right bundle branch running to the septomarginal trabecula (moderator band) and anterior papillary muscle
- ▶ Left bundle branch fanning out on the left septal surface (anterior, septal, posterior divisions)
- ▶ Subendocardial **Purkinje fibre** network over both ventricles
- ▶ Central fibrous body and membranous interventricular septum

Applied / Clinical anatomy

- ▶ **Sick sinus syndrome:** SA nodal dysfunction causing bradycardia, sinus arrest or tachy-brady syndrome; may need permanent pacemaker.
- ▶ **Heart block:** interruption of conduction may occur at the AV node (1st/2nd/3rd-degree AV block) or lower in the bundle; **complete heart block** dissociates atrial and ventricular rhythms, the ventricle then beating at the slow idioventricular (Purkinje) rate — an indication for pacing. Iatrogenic complete heart block can follow surgical closure of a perimembranous VSD or valve surgery near the triangle of Koch/membranous septum, where the AV bundle is at risk.
- ▶ **Bundle branch block:** right or left bundle branch block delays activation of the corresponding ventricle, altering the QRS morphology on ECG; the right bundle branch, being a single discrete fascicle, is more vulnerable to focal injury than the early-fanning left branch.
- ▶ **Wolff-Parkinson-White syndrome:** an accessory myocardial strand crosses the fibro-fatty AV groove, short-circuiting the AV node and producing pre-excitation (short PR interval, delta wave) and a substrate for re-entrant tachycardia; treated by radiofrequency catheter ablation.
- ▶ **Electrophysiology/ablation landmarks:** the coronary sinus is cannulated to map AV-junctional arrhythmias and accessory pathways; the triangle of Koch is the key surgical/ablation landmark for locating the AV node while avoiding injury to it.
- ▶ **Pacemaker implantation:** temporary pacing wires via internal jugular or subclavian vein (subclavian route risks pneumothorax and, on the left, thoracic duct injury); permanent devices are sited subcutaneously on the anterior chest wall with the lead passed via the cephalic vein to the right heart chambers.

- ▶ **ECG correlation:** P wave = atrial depolarization spreading from the SA node; PR interval = AV nodal delay; QRS complex = ventricular depolarization via the bundle branches and Purkinje network; the entire system's electrical events are what the surface ECG records.

High-yield exam pointers

- ▶ The conducting system is made of **specialized cardiac muscle**, never nervous tissue.
- ▶ **SA node** = pacemaker; upper crista terminalis at the SVC–right atrial junction; fastest intrinsic rate (70–100/min).
- ▶ Modern teaching (Gray's 41e): **no discrete internodal tracts** in humans — conduction to the AV node is via ordinary atrial myocardium, preferentially along the crista terminalis, fossa ovalis rim and Bachmann's bundle.
- ▶ **AV node** lies in the **triangle of Koch**; produces a ~40 ms delay that lets atrial systole finish before ventricular systole and protects the ventricle from over-rapid atrial rates.
- ▶ **AV bundle** is the sole muscular bridge across the fibrous skeleton; conducts at 2–3 m/sec versus 0.6 m/sec in ordinary myocardium.
- ▶ Right bundle branch traverses the **moderator band**; left bundle branch fans out early and trifurcates.
- ▶ **Right coronary artery** supplies almost the whole conducting system (SA node in ~60%, AV node/bundle/right bundle branch always); SA node is supplied by the **circumflex artery** in ~40% of hearts.
- ▶ **Vagus slows, sympathetics accelerate** SA/AV activity — automaticity itself remains myogenic.
- ▶ Clinically linked to heart block, bundle branch block, WPW syndrome and pacemaker/ablation practice.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; Vishram Singh — Textbook of Anatomy Vol 1, 4e; IB Singh — Textbook of Anatomy Vol 2, 6e.



Describe the pleura in detail & add a note on areas of clinical interest

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The pleura is a thin serous membrane lined by mesothelium that forms two separate, closed, invaginated sacs, one on either side of the mediastinum. Each sac is invaginated from its medial side by the corresponding lung so that it presents an outer **parietal layer** (lining the thoracic wall, mediastinum, and diaphragm) and an inner **visceral (pulmonary) layer** (closely applied to the lung surface). The two layers are continuous with each other around the hilum and pulmonary ligament and enclose between them a potential space, the **pleural cavity**, containing a thin film of serous fluid that keeps the cavity at a slight negative pressure and permits frictionless sliding of the lung during respiration. The right and left pleural cavities are separate compartments; the right is normally the larger, while the left is reduced by the cardiac bulge.

1. Development

- ▶ **Parietal pleura** develops from the **somatopleuric layer** of lateral plate mesoderm — hence its **somatic** nerve supply and pain sensitivity.
- ▶ **Visceral pleura** develops from the **splanchnopleuric layer** of lateral plate mesoderm — hence its **autonomic** nerve supply and insensitivity to pain.

2. Visceral (pulmonary) pleura

- ▶ Covers the surfaces and fissures of the lung; **firmly adherent** to the lung substance and cannot be stripped off it.
- ▶ Continuous with the parietal pleura only at the **hilum** and along the line of attachment of the **pulmonary ligament**.
- ▶ Surface marking of visceral pleura (= surface marking of the lung): the apex coincides with the cervical pleura; the anterior border follows the costomediastinal line down to the level of the 4th costal cartilage, where the **left** lung recedes to form the **cardiac notch** before rejoining the sternal margin at the 6th costal cartilage (4 cm from the midline); the lower border of the lung lies **two ribs higher** than the parietal pleural reflection — crossing the 6th rib in the mid-clavicular line, the 8th rib in the mid-axillary line, and the 10th rib at the lateral border of erector spinae, ending 2 cm lateral to the T10 spine.
- ▶ The cardiac notch leaves the pericardium covered only by a **double layer of parietal (costal + mediastinal) pleura with no intervening lung** — the anatomical basis of the **area of superficial cardiac dullness** on percussion and of the preferred left parasternal (5th intercostal space) approach for pericardiocentesis, where the risk of traversing lung is minimised.

3. Parietal pleura — four parts

The parietal pleura, though continuous, is described in four named parts:

Part	Location	Key relations
Costal (costovertebral)	Lines the ribs, costal cartilages, sternum, transversus thoracis, intercostal muscles and sides of vertebral bodies	Separated from the chest wall by loose areolar endothoracic fascia ; posteriorly crosses the sympathetic trunk
Diaphragmatic	Thin, tightly adherent layer covering the thoracic (superior) surface of the diaphragm	Continuous laterally with costal and medially with mediastinal pleura along the line of pericardial attachment
Mediastinal	Lines the lateral surface of the mediastinum from sternum to vertebral column	On the right — covers SVC, right brachiocephalic vein, azygos vein, right phrenic and vagus nerves, trachea, oesophagus; on the left — covers aortic arch, left phrenic and vagus nerves, left brachiocephalic and superior intercostal veins, left common carotid and subclavian arteries, thoracic duct, oesophagus. At the hilum it reflects laterally to enclose the root and becomes continuous with the visceral pleura
Cervical (pleural dome)	Extends into the root of the neck, about 5 cm above the 1st costal cartilage and 2.5 cm above the medial third of the clavicle, capping the apex of the lung	Strengthened by the suprapleural membrane (Sibson's fascia) , attached to the inner border of the 1st rib and the transverse process of C7; related anteriorly to subclavian artery and scalenus anterior, posteriorly to the neck of the 1st rib, laterally to scalenus medius, medially to the great vessels of the neck

4. Pulmonary ligament

- A fold of mediastinal (parietal) pleura that extends below the hilum, from the lung's mediastinal surface to the oesophagus/pericardium, ending inferiorly in a free sickle-shaped border, and continuous superiorly with pleura around the hilar structures.
- Function: provides a **reserve pocket** into which the pulmonary veins can distend during increased venous return (e.g. exercise), and allows the lung root to descend with the diaphragm during inspiration.

5. Lines of pleural reflection (surface marking of parietal pleura)

Line	Course
Cervical	Curved line from the sternoclavicular joint to the junction of medial and middle thirds of the clavicle; summit 2.5 cm above the clavicle ($\approx$ 5 cm above 1st costal cartilage)

Line	Course
Anterior (costomediastinal)	Both sides in contact behind the sternum from the sternal angle to the 4th costal cartilage, then diverge: right descends vertically to the xiphisternal joint; left deviates laterally ~3.5 cm from the sternal margin (cardiac notch) and descends to the 6th costal cartilage, 4 cm from the midline
Inferior (costodiaphragmatic)	Crosses the 8th rib in the mid-clavicular line, the 10th rib in the mid-axillary line, and the 12th rib (or just below it) at the lateral border of erector spinae, then passes medially to the lower border of the T12 spine, 2 cm lateral to it
Posterior	A line joining a point 2 cm lateral to the C7 spine to a point 2 cm lateral to the T12 spine

A simple recall device is the **even-rib rule** — 2, 4, 6, 8, 10, 12: the two pleurae meet in the midline down to rib 2; the left diverges laterally at rib 4 (cardiac notch); both diverge widely by rib 6; the reflection crosses rib 8 in the mid-clavicular line, rib 10 in the mid-axillary line, and reaches the back near rib 12.

Clinically important: the parietal pleura descends *below* the costal margin at **three sites** — the right xiphocostal angle, and the right and left costovertebral angles (behind the 12th rib, over the upper poles of the kidneys) — making these areas vulnerable to inadvertent puncture.

6. Pleural recesses

Two "reserve spaces" of the parietal pleura allow the lung to expand fully on deep inspiration; they are obliterated in deep inspiration and re-appear in expiration:

- **Costodiaphragmatic recess** — between costal and diaphragmatic pleura; vertical extent ≈5 cm, from the 8th to the 10th rib in the mid-axillary line. The lower border of the lung is normally 5 cm above the lowest limit of the pleura here. This is the most dependent part of the pleural cavity and the site where fluid collects first in a pleural effusion.
- **Costomediastinal recess** — between costal and mediastinal pleura anteriorly, behind the sternum and costal cartilages, most marked in relation to the cardiac notch of the left lung; largely filled by the anterior lung margin even in quiet breathing.

7. Nerve supply, blood supply and lymphatic drainage

Feature	Visceral (pulmonary) pleura	Parietal pleura
Development	Splanchnopleuric mesoderm	Somatopleuric mesoderm
Nerve supply	Autonomic — sympathetic (T2–T5 ganglia) + parasympathetic (vagus), travelling with bronchial vessels	Somatic — intercostal nerves (costal + peripheral diaphragmatic parts) and phrenic nerve, C4 (mediastinal + central diaphragmatic parts)
Pain sensitivity	Insensitive to pain	Pain-sensitive; pain may be referred

Feature	Visceral (pulmonary) pleura	Parietal pleura
Blood supply	Bronchial vessels	Intercostal, internal thoracic and musculophrenic arteries; cervical pleura by branches of the subclavian artery
Venous drainage	Pulmonary veins (hilar region drains via bronchial veins)	Azygos and internal thoracic veins
Lymph drainage	Tracheobronchial (bronchopulmonary) nodes	Intercostal, internal thoracic (parasternal), posterior mediastinal and diaphragmatic nodes

- Irritation of the **costal/peripheral diaphragmatic** parietal pleura (intercostal nerves) refers pain to the corresponding thoracic or abdominal wall dermatome.
- Irritation of the **mediastinal/central diaphragmatic** parietal pleura (phrenic nerve, C4) refers pain to the **tip of the shoulder** (C3, C4 dermatome), because the supraclavicular nerves share this root value.

8. Physiology of the pleural fluid

- A thin liquid pellicle is maintained between the two layers at a steady-state volume of about **0.1–0.2 mL/kg**, produced continuously at **0.01–0.02 mL/kg/h** and constantly reabsorbed via the pleural lymphatics; the balance depends on hydrostatic/oncotic pressure gradients between the pleural capillaries and the pleural space.
- The resulting **negative intrapleural pressure** is the net effect of the outward elastic recoil of the chest wall opposing the inward elastic recoil of the lung; it becomes more negative on inspiration, drawing air into the lungs. Loss of this negative pressure (air or fluid entry) causes lung collapse.

Diagram (real plate):

embed: ![Fig 15.4 — Surface projection of the parietal pleura (black); visceral pleura and lung (pink) on th (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.281)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/d45df40af10f60dc.jpg)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the anterior thoracic cage outline and mark, with two different line-styles (parietal pleura = solid black; visceral pleura/lung = dashed/pink), the following labelled points:

- ▶ Apex/dome of cervical pleura, 2.5 cm above the medial third of the clavicle
- ▶ Sternoclavicular joint → sternal angle (midpoint) → xiphisternal joint (right costomediastinal line)
- ▶ Left costomediastinal line diverging at the 4th costal cartilage to the **cardiac notch**, rejoining at the 6th costal cartilage
- ▶ Costodiaphragmatic (inferior) line crossing rib 8 (mid-clavicular line), rib 10 (mid-axillary line), rib 12 (lateral border of erector spinae)
- ▶ **Costodiaphragmatic recess** and **costomediastinal recess** shaded as the gap between the pleural line and the lung-margin line
- ▶ Mid-clavicular line and mid-axillary line as vertical reference lines
- ▶ Lower border of the lung two ribs above the corresponding pleural line (ribs 6/8/10 vs 8/10/12)

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- ▶ **Paracentesis (thoracocentesis) thoracis** — pleural fluid is aspirated through the **8th intercostal space in the mid-axillary line**; the needle is passed through the *lower* part of the space, close to the upper border of the rib below, to avoid the intercostal vein–artery–nerve (VAN) bundle running along the lower border of the rib above.
- ▶ **Sites vulnerable to accidental pleural puncture** — the right xiphicostal angle and the right and left costovertebral angles, where parietal pleura descends below the costal margin over the upper poles of the kidneys; the 12th rib may be mistaken for the 11th during the posterior surgical approach to the kidney, and an incision carried too high can breach the pleura and cause pneumothorax. The **cervical dome** is similarly at risk during supraclavicular procedures — subclavian vein catheterisation, brachial plexus block, or cervical sympathectomy — again risking an apical pneumothorax.
- ▶ **Pleurisy** — inflammation of the pleura; may be dry (painful, due to visceral–parietal friction on inspiration) or exudative, producing a **pleural effusion**.
- ▶ **Pneumothorax** — air in the pleural cavity; may be spontaneous (rupture of sub-pleural emphysematous bullae, classically in tall, asthenic young males) or traumatic/iatrogenic.
- ▶ **Haemothorax, chylothorax, hydropneumothorax, empyema** — blood, lymph, air-plus-fluid, and pus respectively accumulating in the pleural cavity.
- ▶ **Referred pain patterns** — costal/peripheral diaphragmatic pleural disease (e.g. pleurisy from pneumonia) refers pain to the chest or abdominal wall via intercostal nerves (may mimic an acute abdomen when the lower costal pleura is involved); mediastinal/central diaphragmatic pleural irritation refers pain to the shoulder tip via the phrenic nerve (C4) — the classical basis of shoulder-tip pain in diaphragmatic pleurisy, subphrenic abscess or splenic/gallbladder pathology.

- ▶ **Costodiaphragmatic recess obliteration** (blunting of the costophrenic angle on a chest radiograph) is the earliest radiological sign of a pleural effusion, since fluid gravitates here first.
- ▶ Only the folded reflections of pleura (retrosternal, interlobar fissures, azygo-oesophageal recess) are normally visible on a chest radiograph; shadowing elsewhere usually signals pathology.
- ▶ At thoracoscopy/VATS, both layers of normal pleura appear translucent, with the thoracic wall vessels visible beneath the parietal layer and the sub-pleural pulmonary vasculature beneath the visceral layer.

High-yield exam pointers

- ▶ Two layers — **visceral** (splanchnopleuric, autonomic supply, pain-insensitive) and **parietal** (somatopleuric, somatic supply, pain-sensitive) — continuous at the hilum and along the pulmonary ligament.
- ▶ Parietal pleura has **four parts**: costal, diaphragmatic, mediastinal, cervical.
- ▶ Cervical pleura reinforced by the **suprapleural membrane (Sibson's fascia)**; extends 2.5 cm above the clavicle / 5 cm above the 1st costal cartilage.
- ▶ **Two recesses**: costodiaphragmatic (≈ 5 cm, ribs 8–10, mid-axillary line — largest, site of effusion pooling) and costomediastinal (at the cardiac notch).
- ▶ Surface marking mnemonic — pleural reflection crosses ribs **2, 4, 6, 8, 10, 12**.
- ▶ Pleura descends below the costal margin at **3 sites**: right xiphicostal angle and both costovertebral angles — vulnerable in renal surgery.
- ▶ **Nerve supply determines referred pain**: costal/peripheral diaphragmatic pleura → intercostal nerves → chest/abdominal wall; mediastinal/central diaphragmatic pleura → phrenic nerve (C4) → shoulder tip.
- ▶ **Paracentesis thoracis**: 8th intercostal space, mid-axillary line, lower part of the space (avoid the VAN bundle).
- ▶ Key clinical conditions: pleurisy, pleural effusion, pneumothorax, haemothorax, chylothorax, hydropneumothorax, empyema.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen).



Describe the venous drainage of the thoracic wall

Asked in: Paper I Nov 2016 — RGUHS MD/MS Anatomy

Definition / Introduction

The thoracic wall (skin, muscles, ribs, costal cartilages and parietal pleura) is drained by two parallel venous channels in every intercostal space — an **anterior intercostal vein** and a **posterior intercostal vein** — each running with the artery of the same name. Anteriorly these veins end in the **internal thoracic** (and musculophrenic) **veins**, which drain into the brachiocephalic veins; posteriorly they end

in the **azygos venous system** (azygos, hemiazygos and accessory hemiazygos veins), which empties into the **superior vena cava (SVC)**. A superficial subcutaneous network (**lateral thoracic** and **thoraco-epigastric veins**) supplements this deep drainage and forms a clinically important SVC–IVC collateral pathway.

1. General plan of intercostal veins

- ▶ Each of the upper 11 intercostal spaces has **two anterior** and **one posterior** intercostal vein; the subcostal vein lies below the twelfth rib.
- ▶ In the neurovascular bundle of the costal groove the order from above down is **Vein–Artery–Nerve (VAN)**; the vein therefore lies superior to its artery.
- ▶ Tributaries of the posterior intercostal veins include a **posterior tributary** that drains the back muscles/skin and the **vertebral venous plexus** — this communication is essentially **valveless** and is a recognised route for spread of infection or malignant emboli to the vertebral column (Batson's concept), even though a few imperfect valves exist in the main azygos/hemiazygos trunks themselves.

2. Anterior intercostal veins and the internal thoracic venous system

- ▶ **Anterior intercostal veins** — two in each of the upper nine spaces, accompanying the anterior intercostal arteries.
 - Upper 3 spaces → end directly in the **internal thoracic vein**.
 - 4th–6th spaces → end in the venae comitantes of the internal thoracic artery.
 - 7th–9th spaces → end in the venae comitantes of the **musculophrenic artery**.
- ▶ **Internal thoracic veins** are venae comitantes of the inferior half of the internal thoracic artery; near the third costal cartilage the paired veins unite into a single trunk on each side, ascend medial to the artery, and end in the corresponding **brachiocephalic vein**. Tributaries mirror the arterial branches and include the musculophrenic vein, superior epigastric vein, pericardiacophrenic vein and medial perforating veins (which also drain the breast). The internal thoracic veins possess valves.

3. Posterior intercostal veins

There are 11 pairs (plus the subcostal vein), running with the posterior intercostal arteries. Their mode of termination differs from side to side and from space to space:

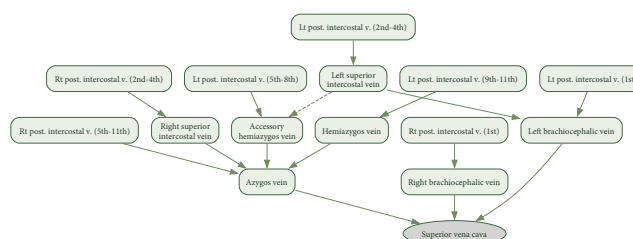
Posterior intercostal vein(s)	Right side	Left side
1st space	Right brachiocephalic (occasionally vertebral) vein	Left brachiocephalic (occasionally vertebral) vein
2nd–4th spaces	Unite to form the right superior intercostal vein → arch of azygos vein	Unite to form the left superior intercostal vein → left brachiocephalic vein (also connects inferiorly with the accessory hemiazygos vein)

Posterior intercostal vein(s)	Right side	Left side
5th–8th spaces	Drain directly into the azygos vein	Drain into the accessory hemiazygos vein
9th–11th spaces + subcostal	Drain directly into the azygos vein	Drain into the hemiazygos vein

(The left superior intercostal vein crossing the aortic arch produces the "aortic nipple" shadow on a chest radiograph.)

4. The azygos venous system

- **Azygos vein** — lies on the right side of the vertebral bodies in the posterior mediastinum; connects the IVC to the SVC.
 - *Formation* (variable): commonly by union of the right subcostal vein and right ascending lumbar vein at the level of T12; alternatively as a direct continuation of the IVC near the renal veins, or of the right subcostal vein alone.
 - *Course*: enters the thorax through the aortic opening of the diaphragm (occasionally through a separate opening in the right crus), ascends anterior to the vertebral bodies to the level of T4, then arches forward above the root of the right lung to join the posterior aspect of the SVC just before its pericardial covering.
 - *Relations*: anteriorly the oesophagus; posteriorly the vertebral bodies and right posterior intercostal arteries; to the left the thoracic duct and descending aorta; to the right the right lung and pleura.
 - *Tributaries*: right superior intercostal vein; 5th–11th right posterior intercostal veins; hemiazygos vein (at the lower border of T8); accessory hemiazygos vein (at the upper border of T8); right subcostal and ascending lumbar veins; right bronchial, oesophageal, mediastinal and pericardial veins.
- **Hemiazygos vein** — the left-sided mirror image of the lower part of the azygos vein; formed by union of the left ascending lumbar and left subcostal veins; pierces the left crus of the diaphragm, ascends behind the aorta, oesophagus and thoracic duct, and crosses the midline at T8 to join the azygos vein. It drains the lower three (9th–11th) left posterior intercostal veins plus mediastinal and oesophageal veins.
- **Accessory hemiazygos vein** — the mirror image of the upper part of the azygos vein; drains the 5th–8th (occasionally from the 4th) left posterior intercostal veins and sometimes the left bronchial veins; crosses the vertebral column at T7 to end in the azygos vein (or, less commonly, joins the hemiazygos vein).



Describe the venous drainage of the thoracic wall

5. Superficial (subcutaneous) venous drainage

- ▶ The **lateral thoracic vein** drains the lateral chest wall and lateral part of the breast, ending in the **axillary vein**.
- ▶ The **thoraco-epigastric vein** links the lateral thoracic vein (an SVC tributary via the axillary–subclavian route) with the **superficial epigastric vein** (an IVC tributary via the great saphenous–femoral route), running subcutaneously across the flank. It constitutes a natural **superficial cavo-caval collateral channel**.
- ▶ Medial perforating veins accompanying the internal thoracic vessels drain the anterior chest wall skin and the medial breast into the internal thoracic vein.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 4.20 — *Veins of thoracic wall* (Moore — *Clinically Oriented Anatomy* — 9e, p.571)

Label: right & left brachiocephalic veins; superior vena cava; internal thoracic vein (each side) with anterior intercostal veins entering it; musculophrenic vein; right superior intercostal vein → azygos arch; left superior intercostal vein → left brachiocephalic vein; azygos vein (vertical + arch); hemiazygos vein; accessory hemiazygos vein; posterior intercostal veins (numbered 1–11) on each side; subcostal vein; inferior vena cava (for orientation); oesophagus and thoracic duct (landmarks, unlabelled outline).

Applied / Clinical anatomy

- ▶ **SVC obstruction above the azygos entry:** blood from the upper body is shunted through the azygos vein into the SVC below the block; superficial chest veins dilate down to the costal margin, and upper-limb blood returns via peri-scapular anastomotic veins joining the intercostal veins, which drain into the azygos system.
- ▶ **SVC obstruction below the azygos entry:** collateral flow is instead diverted through the IVC via the femoral vein, using the **thoraco-epigastric vein** (lateral thoracic vein ↔ superficial epigastric vein); superficial veins over both chest and abdomen dilate down to the saphenous opening.
- ▶ **IVC interruption/agenesis or thrombosis:** the rich anastomoses of the azygos, hemiazygos and accessory hemiazygos veins with the IVC and vertebral venous plexuses allow the azygos system to act as a ready-made collateral, returning lower-body blood to the heart (congenital "azygos continuation of the IVC").
- ▶ **Radiology:** the left superior intercostal vein crossing the aortic arch produces the classic "**aortic nipple**" on a frontal chest X-ray, not to be mistaken for a lung nodule; a redundant azygos vein invaginating the right upper lobe produces the **azygos fissure/lobe**, seen as a comma-shaped opacity that can likewise mimic a pseudo-nodule.
- ▶ **Central venous catheters:** a catheter tip that curves posteriorly instead of lying in the SVC may have entered the azygos arch — a recognised malposition on chest radiographs.
- ▶ **Portosystemic link:** oesophageal veins draining into the azygos system connect it, via the left gastric vein, to the portal venous system; in portal hypertension this contributes to oesophageal varices.

High-yield exam pointers

- ▶ Two vein sets per intercostal space: **anterior** (→ internal thoracic/musculophrenic → brachiocephalic vein) and **posterior** (→ azygos system → SVC).
- ▶ Order in costal groove: **Vein above, Artery, Nerve below** (VAN).
- ▶ 1st posterior intercostal vein (both sides) bypasses the azygos system entirely, draining straight into the brachiocephalic (or vertebral) vein.
- ▶ 2nd–4th posterior intercostal veins on each side unite to form the **superior intercostal vein** (right → azygos arch; left → left brachiocephalic vein, producing the "aortic nipple").
- ▶ **Accessory hemiazygos** drains left spaces 5–8; **hemiazygos** drains left spaces 9–11 + subcostal; both usually cross to join the azygos vein around T7–T8.
- ▶ Azygos vein connects **IVC to SVC** — the single most important collateral in caval obstruction.
- ▶ Communication with the **valveless vertebral venous plexus** is a classical route for metastatic/infective spread to the vertebral column.
- ▶ **Thoraco-epigastric vein** = superficial cavo-caval link (lateral thoracic vein ↔ superficial epigastric vein).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; Vishram Singh — Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e.



Esophagus

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction — The **oesophagus** is a narrow, flattened, muscular tube, about **25 cm long**, that forms the food passage between the pharynx and the stomach. It begins in the neck at the lower border of the cricoid cartilage (level of **C6 vertebra**) and ends at the cardiac orifice of the stomach (level of **T11 vertebra**), traversing the neck, superior and posterior mediastina, and the diaphragm on the way. It is the **second narrowest part of the alimentary canal** after the vermiform appendix, and its lumen is normally collapsed (flattened antero-posteriorly), dilating only during passage of a food bolus.

Extent, parts and dimensions

Part	Extent	Length
Cervical part	Lower border of cricoid cartilage (C6) → upper border of manubrium sterni / thoracic inlet	~4 cm (1½ in)
Thoracic part	Thoracic inlet → oesophageal opening of diaphragm (T10)	~20 cm (8 in)
Abdominal part	Oesophageal hiatus (T10) → cardiac orifice of stomach (T11)	~1–2 cm — shortest part; the only part covered by peritoneum
Total	C6 → T11	25 cm (10 in); breadth ~2 cm

Course and curvatures

- Descends almost vertically in front of the vertebral column, through the **superior mediastinum** (behind trachea and arch of aorta), then the **posterior mediastinum**, pierces the **diaphragm at T10** (~2.5 cm left of the midline, through a sling formed by the right crus), and ends at the cardiac orifice at T11.
- **Antero-posterior curves** — correspond to the cervical and thoracic curvatures of the vertebral column.
- **Side-to-side curves** — the oesophagus deviates **twice to the left**: (1) at the root of the neck before entering the thoracic inlet, and (2) at the level of T7, before passing in front of the descending thoracic aorta to reach the hiatus; it returns towards the midline near T5.

Constrictions

The oesophagus shows **four anatomical constrictions** (indentations), important because swallowed foreign bodies lodge here, corrosive strictures and carcinoma have a predilection for these sites, and they impede passage of an oesophagoscope/nasogastric tube.

No.	Site	Vertebral level	Distance from incisor teeth	Cause
1	Cricopharyngeal (pharyngo-oesophageal) constriction — narrowest of all	C6	15 cm (6 in)	Cricopharyngeus part of the inferior pharyngeal constrictor
2	Aortic constriction	T4	22.5 cm (9 in)	Crossed by the arch of the aorta
3	Bronchial constriction	T6	27.5 cm (11 in)	Crossed by the left principal bronchus
4	Diaphragmatic constriction	T10	37.5–40 cm (15–16 in)	Traverses the oesophageal hiatus of the diaphragm

□ Fig 9.4 — Natural constrictions of the oesophagus (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.203)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a longitudinal (anterior-view) outline of the oesophagus in situ, C6 to T11, and label:

- ▶ **Cricopharyngeus / lower border of cricoid cartilage (C6)** — start, 1st constriction (15 cm)
- ▶ **Trachea** (posterior relation in the neck and superior mediastinum) with **recurrent laryngeal nerves** in the tracheo-oesophageal groove
- ▶ **Arch of aorta** crossing anteriorly — 2nd constriction (22.5 cm, T4)
- ▶ **Left principal bronchus** crossing anteriorly — 3rd constriction (27.5 cm, T6)
- ▶ **Pericardium / left atrium** — anterior relation below the bronchus
- ▶ **Descending thoracic aorta, azygos vein, thoracic duct** — posterior/right relations in the posterior mediastinum
- ▶ **Diaphragm / oesophageal hiatus** — 4th constriction (37.5–40 cm, T10)
- ▶ **Abdominal part and cardiac orifice of stomach (T11)** — end point
- ▶ Mark the two left-sided curves (root of neck; T7) and the peritoneal covering confined to the abdominal part.

Relations**Cervical part**

Aspect	Relations
Anterior	Trachea (both recurrent laryngeal nerves in the tracheo-oesophageal groove)
Posterior	Cervical vertebrae, longus colli, prevertebral fascia
Each side	Common carotid artery, lateral lobe of thyroid gland; thoracic duct on the left side only

Thoracic part

Aspect	Relations
Anterior	Trachea → arch of aorta → left principal bronchus → pericardium (separating it from the left atrium) → posterior sloping surface of diaphragm
Posterior	Vertebral column, right posterior intercostal arteries, azygos vein and hemiazygos terminations, thoracic duct, descending thoracic aorta
Right	Right lung and pleura, azygos vein (arches over the root of right lung), right vagus nerve
Left	Arch of aorta, left subclavian artery, thoracic duct, left lung and pleura, left recurrent laryngeal nerve

Abdominal part

Aspect	Relations
Anterior	Posterior surface of left lobe of liver, anterior gastric (vagal) nerve
Posterior	Left crus of diaphragm, posterior gastric (vagal) nerve

N.B. — At the oesophageal hiatus, the **anterior vagal trunk** (formed mainly from the left vagus) lies anteriorly and the **posterior vagal trunk** (from the right vagus) lies posteriorly.

Blood supply, venous drainage and lymphatic drainage

The oesophagus has a **segmental arterial supply**, matching its three parts:

Part	Artery	Vein	Lymph nodes
Cervical	Inferior thyroid artery	Inferior thyroid vein	Deep cervical (jugulo-omohyoid) nodes
Thoracic	Oesophageal branches of the descending thoracic aorta + bronchial arteries	Azygos and hemiazygos veins	Posterior mediastinal (upper thoracic part also to paratracheal/tracheobronchial) nodes
Abdominal	Oesophageal branches of the left gastric artery + left inferior phrenic artery	Left gastric vein (→ portal vein) and hemiazygos vein (→ SVC)	Left gastric and coeliac (pre-aortic) nodes

- ▶ These arterial and venous channels **anastomose longitudinally**, forming a continuous chain along the tube.
- ▶ The **lower end of the oesophagus is a site of porto-systemic (porto-caval) anastomosis** — the left gastric vein (portal system) communicates with the hemiazygos/oesophageal veins (systemic system); in portal hypertension these dilate to form **oesophageal varices**, which may rupture causing severe haematemesis.
- ▶ Lymphatics of the lower third pass through the oesophageal hiatus to coeliac nodes — the anatomical basis for including coeliac-axis clearance in oesophagectomy for lower-third carcinoma.

Nerve supply

- ▶ **Parasympathetic** (sensory, motor and secretomotor):
 - **Upper half** — recurrent laryngeal nerves (supply the striated muscle).
 - **Lower half** — **oesophageal plexus**, formed mainly by the anterior and posterior vagal trunks (continuations of the left and right vagi respectively) around the lower oesophagus; these continue into the abdomen through the oesophageal hiatus as the anterior and posterior gastric nerves.
- ▶ **Sympathetic** (vasomotor, and carries pain):
 - **Upper half** — postganglionic fibres from the **middle cervical ganglion**, running with the inferior thyroid artery.

- **Lower half** — fibres from the **thoracic sympathetic ganglia (T5–T9)**, contributing to the oesophageal plexus. This is the basis for oesophageal pain being referred to the lower thoracic/epigastric region and, at times, being mistaken for anginal (cardiac) pain.
- ▶ Ganglion cells of the **myenteric (Auerbach's) plexus** act as postganglionic neurons for the parasympathetic supply; their **congenital absence** causes failure of the lower oesophagus to relax — **achalasia cardia (cardiospasm)**.

Structure (brief)

- ▶ Four coats, from without in: **fibrous (adventitia)** → **muscular** (outer longitudinal, inner circular) → **submucous** (oesophageal mucous glands) → **mucous membrane** (non-keratinised stratified squamous epithelium).
- ▶ Muscularis externa: **upper third** — **striated (voluntary)**, **middle third** — **mixed**, **lower third** — **smooth (involuntary)**.
- ▶ There is **no true anatomical sphincter** at the cardiac orifice — the circular muscle is not thickened there — but a **physiological lower oesophageal sphincter (LOS)** exists as a high-pressure zone.
- ▶ Bolus transit (approx.): 1 s through the pharynx, 1 s through the upper third, 2 s through the middle third, 3 s through the lower third of the oesophagus.

Applied / Clinical anatomy

- ▶ **Gastro-oesophageal anti-reflux mechanisms** — the intra-abdominal segment of oesophagus compressed by positive intra-abdominal pressure; the **right crus of the diaphragm** forming a sling/pinchcock at the hiatus; the **phrenico-oesophageal ligament** anchoring the oesophagus to the diaphragm while permitting movement during swallowing and respiration; the acute **cardio-oesophageal angle (angle of His)** maintained by the oblique/sling fibres of the stomach; and tonic contraction of the physiological LOS. Disturbance of this valvular mechanism (e.g., **sliding hiatus hernia**, where the cardiac end slides up through the hiatus) allows **gastro-oesophageal reflux**.
- ▶ **Achalasia cardia** — failure of the lower oesophageal sphincter to relax due to congenital absence of ganglion cells in the myenteric plexus; food accumulates above, and barium swallow shows a characteristic **bird's-beak/rat-tail** appearance.
- ▶ **Tracheo-oesophageal fistula** — the commonest congenital anomaly of the oesophagus, from faulty partitioning of the laryngotracheal septum during development (oesophagus develops from the foregut, closely related to the laryngotracheal diverticulum); commonly presents with polyhydramnios and choking/regurgitation on feeding.
- ▶ **Oesophageal atresia** — failure of recanalisation of the solid epithelial-plug stage of the developing oesophageal lumen.
- ▶ **Oesophageal varices** — dilated porto-systemic anastomotic channels at the lower end of the oesophagus in portal hypertension (e.g., cirrhosis); a leading cause of haematemesis.
- ▶ **Barrett's oesophagus** — metaplastic replacement of the normal stratified squamous epithelium by columnar (gastric-type) epithelium at the lower end, secondary to chronic reflux; a premalignant condition.

- ▶ **Carcinoma of the oesophagus** — most common in the **lower third**; spreads along the peri-oesophageal lymphatics to coeliac nodes below the diaphragm — hence coeliac-node clearance accompanies resection.
- ▶ **Dysphagia** — from external compression (aortic aneurysm, enlarged mediastinal/tracheobronchial nodes, an aberrant right subclavian artery passing behind the oesophagus — dysphagia lusoria) or intrinsic narrowing (stricture, carcinoma, achalasia).
- ▶ **Radiology** — barium swallow of the normal oesophagus shows three indentations corresponding to the aortic arch, the left principal bronchus, and (in mitral stenosis) an enlarged left atrium; also used to detect strictures, achalasia and carcinoma.
- ▶ **Mediastinal syndrome** — compression of the oesophagus (with trachea, great veins) by mediastinal masses (thymus, thyroid, lymph nodes, aortic aneurysm) causes dysphagia along with dyspnoea and a husky voice.

High-yield exam pointers

- ▶ Extent: C6 (cricoid cartilage) → T11 (cardiac orifice); total length 25 cm; parts — cervical 4 cm, thoracic 20 cm, abdominal 1–2.5 cm (shortest, only peritonised part).
- ▶ **Four constrictions**: cricopharyngeal (15 cm, narrowest of all), aortic (22.5 cm), bronchial (27.5 cm), diaphragmatic (37.5–40 cm) — measured from the incisor teeth.
- ▶ Arterial supply is **segmental**: inferior thyroid (cervical) → aortic/bronchial branches (thoracic) → left gastric/left inferior phrenic (abdominal).
- ▶ Lower end is a classic site of **porto-systemic anastomosis** → oesophageal varices in portal hypertension.
- ▶ Nerve supply: parasympathetic (recurrent laryngeal nerves upper half; vagal oesophageal plexus/gastric nerves lower half) and sympathetic (middle cervical ganglion upper half; T5–T9 ganglia lower half — explains referred pain mimicking angina).
- ▶ No true anatomical sphincter at the cardio-oesophageal junction; reflux is prevented by a composite mechanism (intra-abdominal segment, right crus sling, phrenico-oesophageal ligament, angle of His).
- ▶ Achalasia cardia = congenital absence of myenteric ganglion cells; tracheo-oesophageal fistula = commonest congenital anomaly; carcinoma is commonest in the lower third and spreads to coeliac nodes.

SOURCE & COVERAGE

BD Chaurasia's Human Anatomy, Vol. 1 (8e); AK Datta's Essentials of Human Anatomy — Thorax & Abdomen; Vishram Singh's Textbook of Anatomy, Vol. 1 (4e); Gray's Anatomy (Standring) 41e; Moore's Clinically Oriented Anatomy 9e.



Interatrial septum

Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction — The interatrial (atrial) septum is the thin, obliquely-placed musculo-membranous partition that separates the right atrium from the left atrium, preventing admixture of deoxygenated and oxygenated blood after birth. It develops from two overlapping folds, the **septum primum** and **septum secundum**, whose imperfect fusion leaves the **fossa ovalis** — the anatomical scar of the fetal shunt (foramen ovale) that allowed placental blood to bypass the lungs in utero. Its developmental complexity makes it the commonest site of congenital cardiac septal defects.

Position, extent and orientation

- Lies obliquely in the coronal plane, facing anteriorly and to the right (into the right atrium) and posteriorly and to the left (into the left atrium); it is **not truly sagittal**, so the right atrium lies anterior/right and the left atrium posterior/left to it.
- Forms part of the medial (septal) wall of both atria; extends from the roof of the atria down to the atrioventricular junction.
- **Anterosuperior relation:** the aortic mound (torus aorticus), a bulge produced by the non-coronary sinus of the aortic valve, overlies the atrioventricular part of the membranous septum where it separates the right atrium from the subaortic outlet of the left ventricle.
- **Posteroinferior relation:** orifice of the coronary sinus and the inferior vena caval orifice open close to its lower margin; the septal cusp of the tricuspid valve is attached along its right-sided (right atrial) margin.

Right atrial (septal) surface — gross features

Feature	Description
Fossa ovalis	Oval, shallow, saucer-shaped depression in the lower part of the septum; its floor is the remnant of the septum primum ; represents the site of the fetal foramen ovale
Annulus ovalis (limbus fossae ovalis)	Thickened, crescentic margin surrounding the fossa, classically taught as the free edge of the septum secundum ; distinct antero-superiorly and at the sides, deficient inferiorly; its anterior end continues with the left end of the valve of the inferior vena cava
Probe-patent slit	A small oblique slit sometimes present at the upper margin of the fossa, ascending beneath the limbus into the left atrium — represents incomplete obliteration of the foramen ovale; found in up to one-third of normal adult hearts
Sinus septum	The part of the septal wall between the coronary sinus orifice and the fossa ovalis; continuous with the tendon of Todaro

Feature	Description
Triangle of Koch	Landmark bounded by the tendon of Todaro , the septal leaflet of the tricuspid valve , and the orifice of the coronary sinus ; floor overlies the atrioventricular (AV) node — of major surgical importance
Membranous septum (AV part)	Anterosuperior to the tendon of Todaro, intervenes between right atrium and the subaortic outlet of the left ventricle

Note (Gray's Anatomy 41e): although classically the limbus is described as the free margin of the septum secundum, careful anatomical study shows the muscular rim is largely an **infolding of the atrial walls incorporating extracardiac adipose tissue** rather than a discrete embryological septum — occasionally exaggerated as the intervenous tubercle of Lower.

Left atrial (septal) surface — gross features

- ▶ Rough, in contrast to the smooth venous part of the left atrium; bounded by a **crescentic, superiorly-concave ridge** that marks the site of the foramen ovale (the flap valve, derived from septum primum).
- ▶ Below and around it, the smooth **vestibule** surrounds the mitral orifice.
- ▶ The valve of the foramen ovale lies applied against the septum secundum from the left side, forming a one-way flap in fetal life.

□ Fig 21.10 — Interior of the right atrium, showing the interatrial septum with fossa ovalis, annulus ovalis, and triangle of Koch (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.829)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Right atrium opened along the sulcus terminalis; label — **Superior vena cava, Crista terminalis, Musculi pectinati, Auricle, Openings of venae cordis minimae, Annulus ovalis (limbus fossae ovalis), Fossa ovalis, Triangle of Koch, Tendon of Todaro, Opening of coronary sinus, Valve of coronary sinus, Right atrioventricular (tricuspid) orifice, Septal leaflet of tricuspid valve, Valve of inferior vena cava (Eustachian valve), Inferior vena cava.**

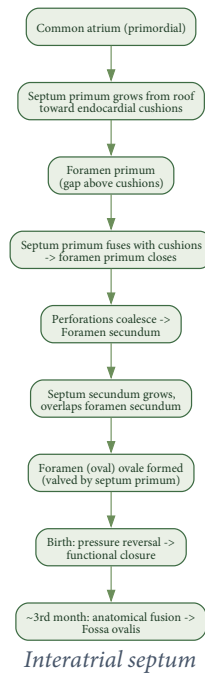
Development of the interatrial septum

The septum is formed in the 4th–6th weeks by two overlapping crescentic folds growing into the common atrium:

Fold	Sequence of events
Septum primum	A thin, crescent-shaped membrane grows from the roof of the primordial atrium toward the fused endocardial (AV) cushions. The gap between its free edge and the cushions is the foramen (ostium) primum — the first interatrial communication, allowing right-to-left shunt. As the septum primum fuses with the cushions, the foramen primum closes, but before closure is complete, apoptotic perforations appear in the upper part of the septum primum and coalesce to form the foramen (ostium) secundum , maintaining the shunt
Septum secundum	A thick, muscular crescentic fold grows from the ventrocranial (right atrial) wall immediately to the right of the septum primum during the 5th–6th weeks. It grows down but remains incomplete, leaving an oval gap — the foramen (oval) ovale — overlapped from the left by the residual septum primum, which now acts as a flap valve of the oval foramen

- The cranial part of septum primum degenerates; its remaining part (attached to the fused endocardial cushions) forms the flexible **valve of the oval foramen**.
- Before birth, right atrial pressure exceeds left atrial pressure (placental venous return via IVC), so the valve of the oval foramen is pushed open and oxygenated blood passes right-to-left through the foramen ovale; the rigid septum secundum prevents left-to-right flow.
- At birth, aeration of the lungs raises pulmonary venous return and left atrial pressure above right atrial pressure; the flap valve (septum primum) is pressed against the septum secundum, producing **functional closure** of the foramen ovale within hours to days.
- **Anatomical fusion** of the septum primum to the septum secundum follows by about the 3rd postnatal month, permanently obliterating the foramen ovale and converting it into the **fossa ovalis**, whose floor is septum primum and whose margin (limbus/annulus ovalis) is the free edge of septum secundum.
- Failure of complete fusion leaves a **probe-patent foramen ovale**, present in roughly 15–30% of adult hearts, usually of no haemodynamic significance.
- Molecular note: cardiac septation (including atrial septation) is regulated by transcription factors such as TBX5 (also implicated in Holt–Oram syndrome), acting with NKX2-5 and GATA4 on cardiac progenitor gene programmes.

□ Fig 18.8 — Development of the interatrial septum: sagittal sections showing (A) septum primum with foramen primum, (B) foramen primum closing, (C) septum secundum with foramen secundum, (D) foramen ovale formed (Sontakke — *Textbook of Human Embryology*, p.182)



Applied / Clinical anatomy

Congenital atrial septal defects (ASD) — result from the septum's complex, two-fold developmental history:

Type	Site / mechanism
Ostium (septum) secundum ASD	Commonest type (~most frequent ASD); defect in the region of the oval fossa from abnormal resorption of septum primum (fenestrated/net-like, or excessively short flap) and/or defective, deficient septum secundum; may be well tolerated till adulthood; female : male $\approx$ 3 : 1
Ostium (septum) primum ASD / endocardial cushion defect	Lower part of the septum; septum primum fails to fuse with the fused endocardial cushions, leaving a patent foramen primum; often combined with a cleft in the anterior (mitral) leaflet; the complete form (common AV septal/canal defect) is strongly associated with Down syndrome
Sinus venosus ASD	High defect near the entry of the superior vena cava, from defective incorporation of the sinus venosus into the atrium; often linked to anomalous pulmonary venous drainage
Common atrium	Rare — combined failure of both septum primum and septum secundum to develop, leaving the interatrial septum essentially absent

- **Patent foramen ovale (PFO)**: septum primum and septum secundum form normally but fail to fuse — usually a benign, linear, probe-patent gap in the upper fossa, present in a significant minority of normal adults; clinically relevant as a route for paradoxical embolism.

- ▶ **Triangle of Koch** demarcates the site of the AV node — a vital landmark to avoid injury (heart block) during surgical/catheter closure of ASDs near the fossa ovalis, or during ablation procedures.
- ▶ The thin, membranous floor of the fossa ovalis (septum primum only) is the conventional, safest site for **transseptal puncture** in interventional cardiology (e.g., mitral balloon valvuloplasty, left atrial ablation) and the natural site for percutaneous device closure of ASD/PFO.
- ▶ Persisting probe-patency of the foramen ovale in the fetus/neonate before functional closure explains transient right-to-left shunting seen in conditions raising right atrial pressure (e.g., persistent pulmonary hypertension of the newborn).
- ▶ Chiari's network — a reticulated remnant of the right venous valve of the sinus venosus attached near the Eustachian valve — is an embryological relative of interatrial septal development and may be mistaken for pathology on echocardiography.

High-yield exam pointers

- ▶ Interatrial septum is obliquely placed — right atrium lies anterior/right, left atrium posterior/left to it.
- ▶ Fossa ovalis = floor from **septum primum**; annulus/limbus ovalis (classic teaching) = free edge of **septum secundum**.
- ▶ Developmental sequence: foramen primum → (septum primum fuses with cushions) → foramen secundum → septum secundum grows → foramen (oval) ovale → functional closure at birth → anatomical fusion by ~3 months → fossa ovalis.
- ▶ Triangle of Koch = tendon of Todaro + septal cusp of tricuspid valve + orifice of coronary sinus; overlies the AV node.
- ▶ Probe-patent foramen ovale found in up to one-third of normal adult hearts; usually of no haemodynamic significance.
- ▶ ASD types: ostium secundum (commonest), ostium primum/endocardial cushion (Down syndrome association), sinus venosus (near SVC), common atrium (rarest, both septa absent).
- ▶ Fetal shunt direction: IVC → right atrium → (directed by Eustachian valve) → foramen ovale → left atrium, bypassing the pulmonary circuit.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1, 8e; AK Datta's Human Anatomy Vol 1 (Thorax & Abdomen); IB Singh's Textbook of Anatomy Vol 2, 6e; Vishram Singh's Textbook of Anatomy Vol 1, 4e; Moore — The Developing Human, 9e; Sontakke — Textbook of Human Embryology; IB Singh — Human Embryology (CBME 2021).



Lymphatic drainage of mammary gland

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

Definition / Introduction The mammary gland is a modified, cutaneous apocrine sweat gland lying in the superficial fascia of the pectoral region, and its lymphatic drainage is one of the most clinically important facts in the whole of gross anatomy because carcinoma of the breast spreads chiefly along lymphatic channels. The drainage is organised into two interconnected plexuses (a deep perilobular/parenchymal plexus and a superficial subareolar plexus of Sappey) that empty predominantly into the axillary lymph nodes, with lesser but important routes to the parasternal (internal mammary), posterior intercostal, supraclavicular and sub-diaphragmatic/subperitoneal groups. Because the breast lymphatics are valveless and communicate freely across the midline and with the anterior abdominal wall, tumour emboli can travel by unexpected as well as expected routes — the basis of the surgical staging of breast cancer.

Lymphatic plexuses of the breast

- ▶ **Perilobular (parenchymal) plexus** — a dense network of valveless lymphatic capillaries around the lobules and ducts, draining the glandular parenchyma itself; also called the *deep* lymphatics.
- ▶ **Subareolar plexus of Sappey** — a dense plexus of lymph vessels lying deep to the skin of the areola and nipple; it receives tributaries from the perilobular plexus and also drains the skin over the nipple/areola.
- ▶ The two plexuses communicate freely; efferents from the subareolar plexus pass mainly to the **anterior (pectoral) group of axillary nodes**, which therefore receives the bulk of breast lymph.
- ▶ **Superficial lymphatics** drain the skin of the breast (excluding nipple/areola) and run radially outward to the same node groups (axillary, parasternal, supraclavicular, cephalic/deltopectoral).
- ▶ Superficial lymphatics of one breast **communicate freely across the midline** with those of the opposite breast — the anatomical basis for a unilateral carcinoma later presenting with contralateral axillary or breast involvement.

Lymph node groups draining the breast

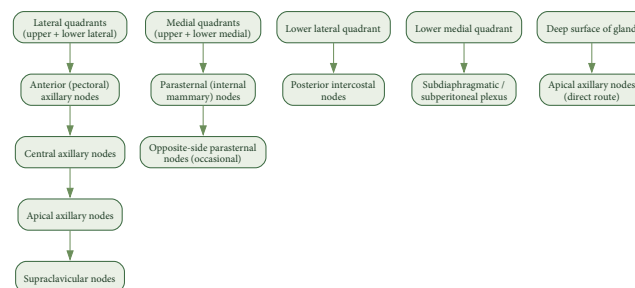
Node group	Location	Share of drainage received
Axillary nodes (anterior/pectoral, posterior/subscapular, central, lateral, apical)	Axilla; anterior/pectoral group lies along the lower border of pectoralis minor	~75% of total lymph — the dominant route
Parasternal (internal mammary/internal thoracic) nodes	Along the internal thoracic vessels, within the thorax close to the sternal margins	~20%
Posterior intercostal nodes	Posterior ends of intercostal spaces, in front of the rib heads	~5% (from the lower and lateral part of the gland)
Supraclavicular nodes	Lowest deep cervical chain, just above the clavicle	Small but important secondary route (from upper part of skin, crossing the clavicle)

Node group	Location	Share of drainage received
Cephalic (deltopectoral) nodes	Deltopectoral groove	Minor route, from skin of upper outer part
Subdiaphragmatic and subperitoneal lymph plexuses / hepatic nodes	Below the costal margin, reached by piercing the linea alba	Minor route, from the lower medial quadrant
Interpectoral (Rotter's) nodes	Between pectoralis major and pectoralis minor	Occasional (1–2 nodes) — an important surgical station

Quadrant-wise pathways of drainage

The gland is conventionally divided into four quadrants (upper/lower × medial/lateral) for clinical description, and each has a fairly consistent lymphatic pathway:

- ▶ **Lateral quadrants (upper and lower lateral)** — drain into the **anterior (pectoral) group of axillary nodes**, lying deep to the lower border of pectoralis minor; this is the single largest route, accounting for the great majority of drainage.
- ▶ **Medial quadrants** — drain along the perforating branches of the internal thoracic artery into the **parasternal (internal mammary) nodes**; some vessels cross to the parasternal nodes of the opposite side.
- ▶ **Lower lateral quadrant** — a few vessels follow the lateral cutaneous branches of the posterior intercostal arteries backward to the **posterior intercostal nodes**.
- ▶ **Lower medial quadrant** — a few vessels cross the costal margin, pierce the **linea alba**, and communicate with the **subdiaphragmatic and subperitoneal lymph plexuses**.
- ▶ **Deep surface of the gland** — lymphatics pierce pectoralis major and the clavipectoral fascia to drain **directly into the apical group of axillary nodes**, bypassing the lower axillary groups.



Lymphatic drainage of mammary gland

Onward course to the venous system

- ▶ Efferents from the **anterior and posterior (subscapular) axillary groups** converge on the **central group**, then the **apical group**, and finally the lowest deep cervical (**supraclavicular**) nodes.
- ▶ On the **left side**, breast lymph ultimately reaches the **thoracic duct**, which drains into the **left subclavian vein** (at its junction with the left internal jugular vein).
- ▶ On the **right side**, lymph drains via the **right lymphatic duct** into the **right subclavian vein** near its junction with the right internal jugular vein.

- ▶ The parasternal chain may also communicate inferiorly with the superior and inferior epigastric lymphatics, providing a route to the groin.

Axillary lymph node groups and surgical levels

Anatomical group	Surgical level (relation to pectoralis minor)
Anterior (pectoral), posterior (subscapular), central, lateral	Level I — below/lateral to the lower border of pectoralis minor
Interpectoral (Rotter's) nodes, and nodes behind pectoralis minor	Level II — deep to pectoralis minor
Apical (infraclavicular) nodes	Level III — between the upper border of pectoralis minor and the lower border of the clavicle

- ▶ There are typically **20–40 axillary nodes**; free communication exists between all groups, so disease can spread between them in either direction.
- ▶ The apical nodes are the final common axillary station before lymph passes to the supraclavicular nodes.

□ Fig 4.24 — Lymphatic drainage of breast. A. Location of lymph nodes receiving drainage (Moore — Clinically Oriented Anatomy — 9e, p.578)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A schematic coronal view of the right breast and axilla, labelled with:

- ▶ **Perilobular lymphatic plexus** (within the gland) and **subareolar plexus of Sappey** (deep to areola/nipple)
- ▶ **Anterior (pectoral) axillary nodes** — along the lower border of pectoralis minor, receiving the main efferents
- ▶ **Posterior (subscapular), central, lateral and apical axillary nodes** — with arrows showing the sequence anterior/posterior → central → apical
- ▶ **Interpectoral (Rotter's) nodes** — between pectoralis major and minor
- ▶ **Parasternal (internal mammary) nodes** — along the internal thoracic vessels, medial to the sternum
- ▶ **Posterior intercostal nodes** — near the rib heads
- ▶ **Supraclavicular nodes** — above the clavicle
- ▶ Arrows crossing the costal margin/linea alba to the **subdiaphragmatic and subperitoneal plexuses**, and arrows crossing the midline to the **opposite breast/axilla**

Applied / Clinical anatomy

- ▶ **Basis of breast cancer staging:** because ~75% of lymph drains to the axilla, axillary nodal status is the single most important prognostic factor in breast carcinoma and directly determines adjuvant therapy decisions.
- ▶ **Sentinel lymph node biopsy:** a radiolabelled colloid (injected into the subareolar tissue or peritumoral/intradermal tissue) combined with a vital blue dye identifies the **first draining**

(sentinel) node — usually a Level I anterior/pectoral node — which is removed and examined histologically; if negative, the morbidity of a full axillary dissection (lymphoedema, restricted shoulder movement, sensory loss) can be avoided. "Skip" metastases to higher levels occur in only 5–10% of cases; occasionally the sentinel node is extra-axillary (an intramammary node, an internal thoracic/parasternal node, or in the supraclavicular fossa).

- ▶ **Axillary clearance:** removal of Level I–III nodes for node-positive disease; because efferents communicate freely between groups, systematic clearance (not just Level I) is often needed for adequate staging/control.
- ▶ **Cross-communication and bilateral spread:** the free communication of superficial lymphatics across the midline explains why a carcinoma of one breast can, rarely, metastasise to the opposite breast or axilla.
- ▶ **Route to the peritoneum:** lymph from the lower medial quadrant reaching the subdiaphragmatic/subperitoneal plexus explains transcoelomic/peritoneal spread of advanced breast carcinoma, occasionally producing an ovarian secondary (Krukenberg-type) deposit.
- ▶ **Valveless, bidirectional flow:** breast lymphatics lack valves, so tumour occlusion of the dermal lymphatics can reverse flow direction — the mechanism underlying **peau d'orange** skin changes and inflammatory carcinoma.
- ▶ **Mammary/parasternal imaging:** internal mammary (parasternal) node involvement, though less accessible clinically than axillary nodes, is assessed by imaging (mammography/CT/PET) and influences radiotherapy planning.

High-yield exam pointers

- ▶ Two lymphatic plexuses: **perilobular (deep)** and **subareolar plexus of Sappey**; they communicate and drain mainly to the **anterior (pectoral) axillary nodes**.
- ▶ Distribution: **axillary ~75%**, **parasternal (internal mammary) ~20%**, **posterior intercostal ~5%**; a small amount also to supraclavicular, cephalic and subdiaphragmatic/subperitoneal routes.
- ▶ Quadrant rule: **lateral quadrants → pectoral axillary nodes**; **medial quadrants → parasternal nodes**; **lower medial quadrant → subdiaphragmatic/subperitoneal plexus (via linea alba)**; **deep surface → apical nodes directly**.
- ▶ Axillary node sequence: anterior/posterior (Level I) → central → apical (Level III), finally to **supraclavicular nodes**; interpectoral **Rotter's nodes** = Level II.
- ▶ Left breast lymph → thoracic duct → left subclavian vein; right breast lymph → right lymphatic duct → right subclavian vein.
- ▶ **20–40 axillary nodes**, freely intercommunicating — basis for unpredictable, multi-directional nodal spread in carcinoma.
- ▶ **Sentinel node biopsy** = radiocolloid + blue dye to identify the first draining (usually Level I) node; skip nodes in 5–10%.
- ▶ Superficial lymphatics communicate across the midline — basis for bilateral/contralateral spread.
- ▶ Valveless lymphatics + dermal blockage by tumour → reversed flow → **peau d'orange**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; IB Singh — Textbook of Anatomy Vol 1, 6e; Vishram Singh — Textbook of Anatomy Vol 1, 4e; Moore's Clinically Oriented Anatomy, 9e.



Lymphatic drainage of thorax

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The lymphatic drainage of the thorax has three components: (1) lymph nodes draining the **thoracic wall**, (2) lymph nodes draining the **thoracic viscera** (mediastinal group), and (3) the two great terminal channels — the **thoracic duct** (left side) and the **right lymphatic duct** (right side) — which return this lymph, together with chyle from below the diaphragm, into the venous system at the respective jugulo-subclavian confluences. As a rule, the right side of the thorax drains to the right, and the left side (plus everything from below the diaphragm) drains via the thoracic duct on the left.

1. Lymph nodes of the thoracic wall

Group	Location	Drains
Parasternal (internal mammary) nodes	Along the internal thoracic vessels, lateral to the sternum	Anterior chest wall, medial breast, upper anterior abdominal wall, diaphragm (anterior part), liver (via subdiaphragmatic vessels)
Intercostal nodes	Posterior ends of intercostal spaces, near heads/necks of ribs	Posterolateral chest wall, parietal pleura
Diaphragmatic nodes	On the thoracic surface of the diaphragm — anterior (behind xiphoid), lateral (at phrenic nerve exit), posterior (behind the crura)	Diaphragm; anterior group → parasternal nodes; lateral group → parasternal + posterior mediastinal nodes; posterior group → nodes at the lower thoracic aorta

The skin over the thorax drains mainly to the **axillary nodes** (posterior skin → posterior axillary group, anterior skin → anterior axillary group), while skin near the sternum drains to the parasternal nodes. Deeper chest-wall tissue (muscle, costal pleura) drains anteriorly to parasternal nodes and posteriorly to intercostal nodes.

2. Lymph nodes of the thoracic viscera (mediastinal group)

- ▶ **Brachiocephalic nodes** — in the superior mediastinum, in front of the brachiocephalic veins.
- ▶ **Posterior mediastinal nodes** — around the oesophagus and descending thoracic aorta.
- ▶ **Tracheobronchial nodes** — the largest and clinically most important group, with four sub-sets:
 - **Paratracheal nodes** — on either side of the trachea.

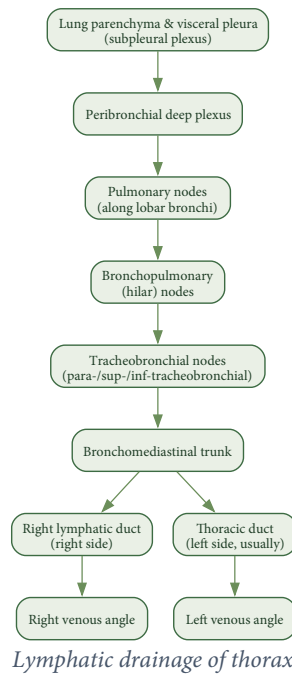
- **Superior tracheobronchial nodes** — in the angle between trachea and each principal bronchus.
- **Inferior (subcarinal) tracheobronchial nodes** — below the tracheal bifurcation.
- **Bronchopulmonary (hilar) nodes** — at the hilum of each lung; continuous distally with the **pulmonary nodes** that lie along the lobar bronchi within the lung substance.

Efferents of the parasternal, tracheobronchial and brachiocephalic nodes unite to form the **bronchomediastinal trunk** on each side — this drains into the right lymphatic duct on the right and usually opens independently near the left venous angle on the left (occasionally joining the thoracic duct).

□ Fig 9.4 — Scheme to show the lymph nodes of thorax (IB Singh — Textbook of Anatomy Vol 2 — 6e, p.127)

3. Lymphatic drainage of individual thoracic viscera

- ▶ **Lungs and pleura** — two freely-communicating plexuses: a **superficial (subpleural) plexus** deep to the visceral pleura, draining lung parenchyma and visceral pleura; and a **deep (peribronchial) plexus** in the bronchial submucosa and peribronchial tissue, draining the root structures. Both drain via **pulmonary nodes** → **bronchopulmonary (hilar) nodes** → **superior/inferior tracheobronchial nodes** → **bronchomediastinal trunks**. Lymphatics are conspicuously **absent around the alveolar walls**.
- ▶ **Trachea** — cervical part drains directly to the deep cervical nodes and also via pretracheal/paratracheal nodes; thoracic part drains to the superior and inferior tracheobronchial nodes.
- ▶ **Heart** — drained mainly along the interventricular and atrioventricular grooves: one set in the anterior AV groove crosses the aorta to end in the brachiocephalic nodes; another along the anterior interventricular groove ends in the inferior tracheobronchial (subcarinal) nodes.
- ▶ **Oesophagus** — cervical part → deep cervical nodes; thoracic part → posterior mediastinal nodes; abdominal part → left gastric nodes (this longitudinal, multidirectional drainage explains the wide skip-metastasis pattern of oesophageal carcinoma).
- ▶ **Thymus** — has no afferent lymphatics; efferents arise from the medulla/corticomedullary junction and end in the brachiocephalic, tracheobronchial and parasternal nodes.
- ▶ **Diaphragm** — thoracic surface drains separately from the abdominal surface (anterior/lateral/posterior groups as above); the abdominal surface drains to nodes along the inferior phrenic artery and the lateral aortic/pre-aortic nodes.



4. Thoracic duct

The thoracic duct is the **largest lymphatic channel in the body**, usually quoted as ~45 cm long (BD Chaurasia; ~40 cm per IB Singh), beaded from numerous valves, and carrying lymph from the entire body **except** the right side of the head and neck, right upper limb, right lung, right side of the heart, and part of the convex (diaphragmatic) surface of the liver.

Origin. It begins as the upward continuation of the **cisterna chyli**, a saccular/plexiform confluence of the paired lumbar lymph trunks and the intestinal lymph trunk lying anterior to the L1–L2 vertebral bodies. It enters the thorax through the **aortic opening of the diaphragm** at the level of T12, lying to the right of the aorta and left of the azygos vein.

Course and relations

Region	Course/relations
Posterior mediastinum (T12 → T5)	Ascends between the descending thoracic aorta (left) and azygos vein (right), anterior to the vertebral column and hemiazygos vein terminations, posterior to the diaphragm and oesophagus
At T5	Crosses obliquely from right to left , posterior to the oesophagus
Superior mediastinum	Ascends along the left border of the oesophagus , posterior to the aortic arch and then the left subclavian artery
Root of neck	Arches laterally at the level of the transverse process of C7 , anterior to the vertebral vessels, left sympathetic trunk, thyrocervical trunk and left phrenic nerve

Region	Course/relations
Termination	Descends in front of the first part of the left subclavian artery and opens at the junction of the left subclavian and left internal jugular veins (left venous angle), guarded by a pair of valves preventing venous reflux

Calibre: about **5 mm** at its origin, narrowing to **2–3 mm** in the **mid-thorax**, and widening again near its termination.

Tributaries — cisterna chyli and its roots; paired ascending lumbar trunks; descending trunks from the posterior intercostal nodes of the lower six intercostal spaces (both sides); lymphatics from posterior mediastinal nodes and upper left intercostal spaces; the **left jugular trunk** and **left subclavian trunk** near its termination; occasionally the **left bronchomediastinal trunk** (which more often opens independently into the subclavian vein).

Total lymph/chyle flow through the duct is about **1500–2400 mL/day**, varying with dietary long-chain-triglyceride intake.

□ Fig 20.11 — The course of the thoracic duct (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.350)

5. Right lymphatic duct

A short trunk formed near the root of the neck by the union of the **right jugular, right subclavian and right bronchomediastinal trunks** (its anatomy is inconstant — the tributaries often open separately). It drains the right side of the head and neck, right upper limb, right half of the thorax (right lung, right side of heart) and part of the convex surface of the liver, and terminates at the **right venous angle** — the junction of the right subclavian and right internal jugular veins — with a course and relations mirroring the cervical part of the thoracic duct.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A composite scheme of thoracic lymphatics, labelling:

- ▶ Chest-wall groups: **parasternal nodes, intercostal nodes, diaphragmatic nodes** (anterior/lateral/posterior)
- ▶ Visceral (mediastinal) groups: **brachiocephalic nodes, posterior mediastinal nodes, tracheobronchial nodes** with its four sub-groups (paratracheal, superior tracheobronchial, inferior tracheobronchial, bronchopulmonary/hilar)
- ▶ **Thoracic duct**: cisterna chyli → aortic opening of diaphragm (T12) → posterior mediastinum → crossover at T5 → superior mediastinum along left border of oesophagus → arch at C7 → termination at left venous angle
- ▶ **Right lymphatic duct** and its three tributaries, terminating at the right venous angle
- ▶ Arrows showing bronchomediastinal trunks draining into the two ducts

Applied / Clinical anatomy

- ▶ **Chylothorax** — laceration of the thoracic duct (blunt/penetrating trauma, or iatrogenic injury during oesophageal, thoracic or neck surgery) allows chyle to leak into the pleural cavity at rates

of 75–200 mL/hour, producing a milky effusion confirmed by demonstrating chylomicrons in the aspirate.

- ▶ **Thoracic duct injury during oesophagectomy** — reported in ~0.2–3% of trans-hiatal/thoracoscopic oesophageal resections because of the duct's variable course and often colourless, hard-to-identify wall; may require ligation, after which lymph returns via collateral channels joining the duct above the ligature.
- ▶ **Filarial obstruction** of the thoracic duct can cause chylous ascites, chylous hydrocoele and chyluria.
- ▶ **Virchow's node** — enlargement of the left supraclavicular (terminal jugular/subclavian) lymph node from retrograde spread along the thoracic duct is a classic sign of intra-abdominal or intrathoracic malignancy (e.g., gastric or bronchogenic carcinoma).
- ▶ **Lung cancer nodal staging** — thoracic surgeons group mediastinal nodes into numbered regional stations (paratracheal, subcarinal, hilar, etc.); involvement is staged as **N1** (ipsilateral hilar/peribronchial), **N2** (ipsilateral mediastinal/subcarinal) or **N3** (contralateral mediastinal/hilar or supraclavicular), directly influencing resectability and prognosis.
- ▶ **Sentinel/parasternal node spread** — because the parasternal chain lies along the internal thoracic vessels, medial breast tumours may metastasise here rather than to the axilla, altering staging and radiotherapy fields.
- ▶ **Mediastinoscopy** — allows biopsy of the paratracheal/subcarinal nodal stations for staging, guided by their consistent relation to the trachea and its bifurcation.

High-yield exam pointers

- ▶ Thoracic duct = largest lymphatic channel in the body (~45 cm); begins at the cisterna chyli (L1–L2), enters thorax through the aortic opening of diaphragm at T12.
- ▶ Crosses from right to left at the **T5 vertebral level**; terminates at the **left venous angle** (junction of left subclavian and left internal jugular veins), guarded by valves.
- ▶ Right lymphatic duct is formed by right jugular + right subclavian + right bronchomediastinal trunks; opens at the **right venous angle**.
- ▶ Tracheobronchial nodes have four sub-groups: paratracheal, superior tracheobronchial, inferior (subcarinal) tracheobronchial, bronchopulmonary (hilar).
- ▶ Lungs drain via two plexuses (subpleural + peribronchial); **no lymphatics in the alveolar walls**.
- ▶ Diaphragmatic nodes: anterior, lateral, posterior groups on the thoracic surface; drain separately from the abdominal surface.
- ▶ Right side of thorax + right limb/head-neck → right lymphatic duct; left side of thorax + everything below the diaphragm → thoracic duct.
- ▶ Chylothorax and Virchow's node are the two classic clinical correlates of thoracic-duct anatomy.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 1 8e; IB Singh Textbook of Anatomy Vol 2 6e; Moore's Clinically Oriented Anatomy 9e.



Medial Surface of the Lungs

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction The medial surface (the question paper's "medical surface" is a copyist's slip for **medial surface**) is one of the two surfaces of each conical lung, the other being the costal surface. It is divided into a posterior **vertebral part** and an anterior **mediastinal part**, the latter moulded deeply against the heart and great vessels. Set posterosuperior to its central cardiac impression is the triangular **hilum**, where the **root of the lung** — bronchus, pulmonary vessels, bronchial vessels, nerve plexuses and lymphatics — enters or leaves, all invested by a sleeve of pleura that continues below as the **pulmonary ligament**. Because the mediastinal part abuts almost every major thoracic organ, it carries a mirror-image set of impressions that are classic viva and radiology material and are of direct surgical importance during hilar dissection.

Parts and boundaries of the medial surface

- ▶ **Vertebral part** — narrow, lies against the sides of the thoracic vertebral bodies and intervertebral discs, the posterior intercostal vessels and the splanchnic nerves; featureless and unmarked.
- ▶ **Mediastinal part** — broad and deeply concave, related to the mediastinal septum; bears the **cardiac impression**, the **hilum**, and a set of vascular/visceral grooves that differ on the two sides.
- ▶ Bounded by the **anterior border** (thin; shows the cardiac notch on the left), the **posterior border** (thick, corresponds to the heads of the ribs, forms the featureless junction of costal and vertebral parts), and the **base** below.
- ▶ The hilum itself lies opposite the bodies of the **5th–7th thoracic vertebrae**; the root of the lung is the short, broad pedicle connecting this hilum to the mediastinum.

Impressions on the mediastinal part

Right lung	Left lung
Cardiac impression — shallow/absent; related to right atrium and auricle, and partly to the right ventricle	Cardiac impression — deep and large (heart projects further left); related to left ventricle and auricle, the anterior infundibulum, and the adjoining part of the right ventricle
Groove for the superior vena cava and terminal right brachiocephalic vein, ascending anterior to the hilum	Groove for the pulmonary trunk , ascending anterior to the hilum
Groove for the azygos vein , arching forward above the hilum and joining the SVC groove	Groove for the arch of the aorta , arching over the hilum, continuing down behind it as the groove for the descending thoracic aorta

Right lung	Left lung
Shallow vertical groove for the oesophagus behind the hilum and pulmonary ligament; right vagus nerve nearby	Groove for the left subclavian artery , ascending from the summit of the aortic groove to the apex
Groove for the inferior vena cava , posteroinferior, confluent with the cardiac impression	Faint groove for the left brachiocephalic vein , anterior to the subclavian groove
Trachea and right vagus lie close to the apex but leave no true mark	Oesophagus and thoracic duct , posterosuperior to the aortic groove; oesophagus may also mould the surface anterior to the lower end of the pulmonary ligament
Right phrenic nerve — anterior relation	Left phrenic nerve — anterior relation; left recurrent laryngeal nerve near the arch

- ▶ These impressions are best seen on **embalmed/fixed museum lungs**; in fresh cadaveric, surgical or post-mortem specimens, only the **cardiac impression** is consistently evident.
- ▶ The cardiac impression is confluent below with the IVC groove (right) or the aortic groove (left), and its size directly reflects the corresponding chamber's bulk — clinically relevant in cardiomegaly.

The hilum and root of the lung

- ▶ The **hilum** is a roughly triangular depression on the mediastinal part, posterosuperior to the cardiac impression, opposite the bodies of T5–T7.
- ▶ The **root of the lung** is the short, broad pedicle traversing the hilum that connects the lung's medial surface to the mediastinum; it is invested by a pleural sleeve that continues below and behind the cardiac impression as the **pulmonary ligament**.
- ▶ **Contents of the root**: principal bronchus (eparterial + hyparterial on the right; a single hyparterial bronchus on the left), one pulmonary artery, two pulmonary veins (superior and inferior), bronchial arteries (one right, two left) and bronchial veins, anterior and posterior pulmonary nerve plexuses, lymphatics of the lung, bronchopulmonary lymph nodes, and areolar tissue.
- ▶ **Antero-posterior arrangement** (both sides): bronchus/bronchi posteriorly (with bronchial vessels and the posterior pulmonary plexus along the posterior wall) → pulmonary artery in the middle plane → superior and inferior pulmonary veins anteriorly → anterior pulmonary plexus, lymph nodes and lymph vessels in the antero-inferior part.
- ▶ **Vertical (superior-to-inferior) order at the hilum**: on the **right**, superior lobar (eparterial) bronchus, then pulmonary artery, then principal bronchus, then inferior pulmonary vein; on the **left**, pulmonary artery (uppermost), then the principal (hyparterial) bronchus, then the inferior pulmonary vein.

Relation of the root	Right lung	Left lung
Anterior (common)	Phrenic nerve, pericardiophrenic vessels, anterior pulmonary plexus	same

Relation of the root	Right lung	Left lung
Anterior (side-specific)	Superior vena cava; part of right atrium	—
Posterior (common)	Vagus nerve, posterior pulmonary plexus	same
Posterior (side-specific)	—	Descending thoracic aorta
Superior	Terminal part of azygos vein	Arch of the aorta
Inferior (common)	Pulmonary ligament	same

Left lung — cardiac notch and lingula

- ▶ The thin anterior border of the left lung shows a wide, variable **cardiac notch** below the 4th costal cartilage: its edge runs laterally about 3.5 cm before curving inferomedially to the 6th costal cartilage, roughly 4 cm from the midline.
- ▶ Within this notch the pericardium is covered only by a double layer of pleura and not by lung — the **area of superficial cardiac dullness**.
- ▶ A tongue-like process at the lower end of the notch, the **lingula**, is the left-sided homologue of the right middle lobe.

☐ Fig 16.2 — Impressions on the mediastinal surface of the right lung (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.289)

☐ Fig 16.3 — Impressions on the mediastinal surface of the left lung (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.289)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the medial (mediastinal) surface of the right and left lung side by side, each showing the hilum, and label:

- ▶ **Cardiac impression** (shallow on right, deep on left) with the chamber it corresponds to (right atrium/auricle vs left ventricle/auricle).
- ▶ **Hilum**, with the bronchus, pulmonary artery and pulmonary veins passing through it; mark the **pulmonary ligament** below.
- ▶ Right lung grooves: **SVC**, **azygos vein** (arching over the hilum), **oesophagus**, **IVC**.
- ▶ Left lung grooves: **arch of aorta** (arching over the hilum), **descending thoracic aorta**, **left subclavian artery**, **left brachiocephalic vein**, **oesophagus**, **thoracic duct**.
- ▶ **Cardiac notch** and **lingula** on the anterior border of the left lung only.
- ▶ Vertebral part posteriorly (plain, unlabelled) versus mediastinal part anteriorly (all the above impressions).

Differences between the right and left lung

Feature	Right lung	Left lung
Size/weight	Shorter, broader; ~700 g	Longer, narrower; ~600 g
Anterior border	Straight	Interrupted by the cardiac notch

Feature	Right lung	Left lung
Cardiac impression	Shallow/absent	Deep
Lingula	Absent	Present
Fissures/lobes	2 fissures, 3 lobes	1 fissure, 2 lobes
Bronchus at hilum	Eparterial + hyparterial	Single hyparterial bronchus
Superior relation of root	Azygos vein	Arch of aorta

Applied / Clinical anatomy

- ▶ Only the **cardiac impression** is seen intra-operatively or in fresh/post-mortem lungs; the vascular grooves (SVC, azygos, aortic arch, IVC) are chiefly a feature of fixed **museum specimens** — a frequent source of viva confusion.
- ▶ The **depth/size of the cardiac impression** reflects the corresponding cardiac chamber's bulk; marked deepening is seen with cardiomegaly (e.g. left atrial/ventricular enlargement in mitral valve disease deepens the left cardiac impression).
- ▶ The **area of superficial cardiac dullness**, corresponding to the cardiac notch, is where true cardiac (not resonant lung) dullness is percussed even though the region lies within the "lung territory" of the chest wall — a key point for cardiac percussion and auscultation.
- ▶ During **hilar dissection for lobectomy/pneumonectomy**, structures are divided in the antero-posterior order in which they lie in the root — pulmonary vein(s) first, then the pulmonary artery, then the bronchus last; the very short right eparterial (upper lobe) bronchial stump must be recognised to avoid a long residual stump (risk of bronchopleural fistula/"sump" complications).
- ▶ The **phrenic nerve**, the constant anterior relation of both hila, is vulnerable during hilar lymph-node clearance in lung cancer surgery; injury causes ipsilateral diaphragmatic paralysis.
- ▶ **Bronchopulmonary and hilar lymph nodes**, lying along the root, are the first-echelon nodes for spread of **bronchogenic carcinoma** arising near the hilum; their enlargement widens the hilar shadow on chest radiography and is sampled by EBUS-guided or mediastinoscopic biopsy for staging.
- ▶ A tumour or enlarged node encroaching on the right mediastinal surface near the SVC groove can produce **superior vena cava obstruction syndrome** (facial/neck venous congestion and oedema); left-sided hilar disease can involve the **left recurrent laryngeal nerve**, producing hoarseness.
- ▶ The **pulmonary ligament**, the constant inferior relation of the root, is divided surgically to mobilise the inferior lobe during lobectomy/pneumonectomy and to allow the remaining lung and mediastinum to shift and fill the pleural cavity.

High-yield exam pointers

- ▶ Medial surface = **vertebral part** (posterior, plain) + **mediastinal part** (anterior, bears the impressions and hilum).
- ▶ Hilum lies posterosuperior to the cardiac impression, opposite the bodies of T5–T7.

- ▶ Cardiac impression is **shallow on the right, deep on the left** (heart projects more to the left).
- ▶ Root contents, antero-posterior: **veins anterior** → **artery middle** → **bronchus/bronchi posterior**, on both sides.
- ▶ Vertical order at hilum: **right** — eparterial bronchus, pulmonary artery, principal bronchus, inferior pulmonary vein (top to bottom); **left** — pulmonary artery, hyparterial bronchus, inferior pulmonary vein.
- ▶ Common relations of the root: **anterior** = phrenic nerve + pericardiophrenic vessels + anterior plexus; **posterior** = vagus + posterior plexus; **inferior** = pulmonary ligament (all common to both sides).
- ▶ Side-specific superior relation: **azygos vein** (right) vs **arch of aorta** (left).
- ▶ Right lung: straight border, no lingula, 3 lobes/2 fissures, ~700 g. Left lung: cardiac notch + lingula, 2 lobes/1 fissure, ~600 g.
- ▶ Pulmonary ligament = double pleural fold below the hilum; surgical handle for lobe mobilisation.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 (8e); Moore's Clinically Oriented Anatomy (9e); Vishram Singh — Textbook of Anatomy Vol 1 (4e).



Nerve supply of heart

Asked in: Paper I Apr 2006 — RGUHS MD/MS Anatomy

Definition / Introduction Initiation of the cardiac cycle is **myogenic** — it originates in the sinu-atrial (SA) node and is conducted through the intrinsic conducting system. Autonomic nerves do not initiate the beat; they **modulate** its rate, force and coronary flow, acting on the nodal tissue, the working myocardium and the coronary vessels. This autonomic supply reaches the heart as a mixed **cardiac plexus**, built from sympathetic and parasympathetic (vagal) contributions, each carrying both efferent (motor) and afferent (sensory) fibres.

Formation and parts of the cardiac plexus

Nearing the base of the heart, the cardiac branches of the vagi, the recurrent laryngeal nerves, and the cervical and upper thoracic sympathetic ganglia interlace to form the cardiac plexus. It is conventionally described as a **superficial (ventral)** and a **deep (dorsal)** part, continuous with each other and prolonged onward as the coronary, atrial and pulmonary plexuses.

Feature	Superficial cardiac plexus	Deep cardiac plexus
Situation	Below the arch of the aorta, in front of the right pulmonary artery / bifurcation of the pulmonary trunk, just to the right of the ligamentum arteriosum	In front of the bifurcation of the trachea, above the division of the pulmonary trunk, behind the arch of the aorta

Feature	Superficial cardiac plexus	Deep cardiac plexus
Formed by	(a) Superior cervical cardiac branch of the left sympathetic trunk, and (b) the lower (inferior) cervical cardiac branch of the left vagus	All cardiac branches of the cervical + upper 4–5 thoracic sympathetic ganglia (both sides) and all cardiac branches of the vagus + recurrent laryngeal nerves (both sides) — i.e., every cardiac nerve except the two that form the superficial plexus
Special feature	A small cardiac ganglion (of Wrisberg) lies close to the ligamentum arteriosum — a relay/cell station chiefly for vagal fibres	Consists of separate right and left halves ; right surrounds the brachiocephalic trunk, left surrounds the aortic arch; the dorsal aspect is larger than the ventral on each side
Distribution	Continues into the deep plexus, the right coronary plexus, and the left anterior pulmonary plexus	Right half → branches pass in front of and behind the right pulmonary artery to the right anterior pulmonary plexus and right atrium, and continue into the right and left coronary plexuses; left half → connects with the superficial plexus and supplies the left atrium, left anterior pulmonary plexus, and forms most of the left coronary plexus

From the deep plexus arise the **right and left coronary plexuses** (accompanying the respective coronary arteries to the atrium and ventricle of that side — the left is the larger) and the **atrial plexuses**, which are simply prolongations of the coronary plexuses distributed to the corresponding atrium.

Sympathetic (cardio-accelerator) supply

- ▶ Preganglionic cell bodies lie in the **intermediolateral column of the upper four or five thoracic spinal segments (T1–T5)**.
- ▶ Their axons leave via white rami communicantes to the corresponding thoracic sympathetic ganglia; some synapse there, others ascend the sympathetic trunk to synapse in the **superior, middle and inferior cervical ganglia**.
- ▶ Postganglionic fibres from the cervical ganglia (superior, middle, inferior cervical cardiac nerves) and from the upper 4–5 thoracic ganglia (thoracic cardiac branches) constitute the **sympathetic cardiac nerves**, which join the cardiac plexus.
- ▶ **Exception:** the cardiac branch of the **superior cervical sympathetic ganglion is purely efferent** — it alone, of all the cardiac nerves, carries no afferent (pain) fibres.
- ▶ **Action:** increases heart rate and cardiac output (cardio-acceleration); overall, sympathetic stimulation dilates the coronary arteries (Gray's/Vishram Singh) — with the added classical nuance that it produces vasodilatation of the smaller intramuscular coronary branches together with vasoconstriction of the larger epicardial branches (AK Datta).

Parasympathetic (vagal, cardio-inhibitory) supply

- ▶ Preganglionic cell bodies lie in the **dorsal nucleus of the vagus** (and some near the nucleus ambiguus) in the medulla oblongata.
- ▶ Axons descend in the vagus nerve as its cervical and thoracic cardiac branches (and via the recurrent laryngeal nerve) to reach the cardiac plexus.
- ▶ **Postganglionic** neurons are intrinsic to the heart — situated within the superficial and deep cardiac plexuses and, more importantly, as small ganglia in the atrial walls and interatrial septum, most numerous in the subepicardial tissue near the SA and AV nodes.
- ▶ **Action:** slows the heart rate and diminishes force (cardio-inhibition); causes coronary arterial constriction, and secondarily reduces coronary blood flow.
- ▶ Cholinergic (and co-existing adrenergic) fibres arising in or traversing the cardiac plexus are distributed most profusely to the **SA and AV nodes**; supply to the working atrial and ventricular myocardium is comparatively sparse.

Distribution to individual cardiac structures

Structure	Nerve supply
SA node & AV node (conducting system)	Richly supplied by both sympathetic and parasympathetic fibres — the densest autonomic innervation in the heart; intrinsic ganglion cells are most numerous here
Atrial myocardium	Both sympathetic and parasympathetic
Ventricular myocardium	Sympathetic only — no functional vagal supply to ventricular muscle
Coronary arteries	Larger (epicardial) branches predominantly sympathetic (adrenergic); smaller (intramuscular) branches also receive parasympathetic (vagal) fibres
Cardiac veins	Adrenergic (sympathetic) fibres

Afferent (sensory) pathways and cardiac reflexes

Two separate afferent streams travel back from the heart, and they subserve different jobs:

- ▶ **Vagal afferents** — accompany the parasympathetic efferents and carry subconscious cardiovascular reflex information (from baroreceptor- and chemoreceptor-type endings) centrally to the reticular formation/dorsal vagal complex in the medulla; these do **not** carry pain.
- ▶ **Sympathetic afferents** — carry **pain (nociceptive)** impulses from an ischaemic myocardium. Their cell bodies lie in the **dorsal root ganglia of the upper 4–5 thoracic spinal nerves (T1–T5)**; the peripheral processes travel centrally with the sympathetic cardiac nerves, through the cervical and thoracic sympathetic ganglia, and reach the cord via white rami communicantes to enter the posterior (dorsal) horn at T1–T5. As already noted, the cardiac branch of the superior cervical ganglion carries **no** afferent (pain) fibres.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- Fig 21.25 — *Superficial cardiac plexus* (Vishram Singh — *Textbook of Anatomy Vol 1 — 4e, p.860*)
- Fig 21.26 — *Deep cardiac plexus (A) Parasympathetic contribution* (Vishram Singh — *Textbook of Anatomy Vol 1 — 4e, p.861*)

For hand reproduction, label on a base-of-heart diagram: **arch of aorta, pulmonary trunk & its bifurcation, trachea & its bifurcation, ligamentum arteriosum**; the **left/right vagus nerves** with their cervical and thoracic cardiac branches; the **left/right recurrent laryngeal nerves**; the **cervical sympathetic ganglia (superior, middle, inferior)** with their cardiac branches and the **thoracic sympathetic ganglia (T1–T5)**; the **superficial cardiac plexus** (right of the ligamentum arteriosum) with the **cardiac ganglion of Wrisberg**; the **deep cardiac plexus** (right and left halves, behind the aortic arch); and its onward continuations — **right/left coronary plexus, right/left anterior pulmonary plexus**, and the **atrial plexuses** — converging on the **SA node and AV node**.

The functional wiring (afferent/efferent components) is better shown as a flow scheme:

(*diagram failed: graphviz*)

Applied / Clinical anatomy

- ▶ **Referred pain of angina/myocardial infarction:** because cardiac pain afferents enter the cord at T1–T5 — the same segments that receive somatic afferents from the chest wall and the medial (ulnar) side of the arm and forearm — ischaemic cardiac pain is typically felt in the **retrosternal/precordial region**, radiating along the **medial side of the left arm**; it may occasionally be referred to the right arm, both arms, the neck/mandible (via sympathetic connections to the cervical nerves), or the epigastrium.
- ▶ **No pain from the superior cervical ganglion route:** since this branch is purely efferent, cardiac afferents never travel this path — a useful discriminator when tracing referred-pain anatomy.
- ▶ **Vagal cardiovascular reflexes:** carotid sinus massage/Valsalva manoeuvre increase vagal tone, slowing the heart via the dense vagal supply to the SA/AV nodes — the physiological basis for terminating supraventricular tachycardia at the bedside.
- ▶ **Denervated (transplanted) heart:** because the SA node is intrinsically myogenic, a transplanted heart continues to beat despite loss of its extrinsic autonomic supply, but it loses vagal tone/reflex bradycardia and does not respond to atropine or carotid sinus pressure.
- ▶ **Surgical/anatomical landmark:** the superficial cardiac plexus and its cardiac ganglion lie immediately to the right of the ligamentum arteriosum — close to the site of the left recurrent laryngeal nerve, relevant during mediastinal and cardiac surgical dissection.

High-yield exam pointers

- ▶ Cardiac cycle is myogenic (SA node); autonomic nerves only modulate rate, force and coronary flow.
- ▶ Cardiac plexus = superficial (below aortic arch, right of ligamentum arteriosum, contains cardiac ganglion of Wrisberg) + deep (in front of tracheal bifurcation, behind aortic arch, right & left halves).

- ▶ Sympathetic: preganglionic T1–T5 → cervical/upper thoracic ganglia → postganglionic sympathetic cardiac nerves; cardio-accelerator; superior cervical ganglion branch is purely efferent (no pain fibres).
- ▶ Parasympathetic: preganglionic in dorsal nucleus of vagus → vagal cardiac branches → postganglionic neurons intrinsic to atrial walls, dense near SA/AV nodes; cardio-inhibitor.
- ▶ Ventricular myocardium receives sympathetic supply only; SA/AV nodes and atria get both.
- ▶ Pain afferents run with sympathetics to T1–T5 dorsal root ganglia; reflex (non-painful) afferents run with the vagus.
- ▶ Larger coronary vessels predominantly sympathetic; smaller intramuscular branches also vagal.
- ▶ Recurrent laryngeal nerves contribute cardiac branches to the deep cardiac plexus.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); BD Chaurasia — Human Anatomy Vol 1 8e; IB Singh — Textbook of Anatomy Vol 2 6e; Vishram Singh — Textbook of Anatomy Vol 1 4e (text and figures 21.25, 21.26); Vishram Singh — Clinical Neuroanatomy 4e.



Oesophagus

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction — The oesophagus is a collapsible, muscular food-conducting tube, about 25 cm long, connecting the pharynx to the stomach. It extends from the lower border of the cricoid cartilage (opposite the 6th cervical vertebra, C6) in the neck to the cardiac orifice of the stomach (opposite the 11th thoracic vertebra, T11) in the abdomen, traversing the neck, the superior and posterior mediastina of the thorax, and piercing the diaphragm at T10. Apart from the vermiform appendix, the pharyngo-oesophageal junction is the narrowest part of the entire alimentary canal.

Extent, Parts and Measurements

- ▶ **Extent:** begins at the lower border of the cricoid cartilage (C6) as a continuation of the pharynx; ends at the cardiac orifice of the stomach (T11), about 2.5 cm to the left of the median plane.
- ▶ **Three parts** with approximate lengths (total ≈ 25 cm):

Part	Extent	Length
Cervical	C6 (cricoid) → superior border of manubrium sterni (T1)	≈ 4 cm
Thoracic	T1 → oesophageal hiatus of diaphragm (T10)	≈ 20 cm
Abdominal	T10 (hiatus) → cardiac orifice (T11)	≈ 1–1.25 cm

- ▶ External breadth ≈ 2 cm; the tube is flattened antero-posteriorly and its lumen stays collapsed except while a food bolus is passing.

- **Curvatures:** two gentle **lateral (side-to-side)** curves, both convex to the left — one at the root of the neck (commencement) and the other as it approaches the diaphragm, returning briefly to the median plane near the mid-thoracic level in between; and **antero-posterior** curves that follow the cervical and thoracic curvatures of the vertebral column.

Curvatures and Constrictions

The oesophagus shows **four constant constrictions** (indentations), important as sites of impaction of foreign bodies/food boluses, stricture and carcinoma, and as landmarks for passing an oesophagoscope or nasogastric tube (distances measured from the incisor teeth):

No.	Constriction	Cause	Vertebral level	Distance from incisor teeth
1	Commencement (pharyngo-oesophageal)	Cricopharyngeus part of inferior constrictor of pharynx	C6	15 cm
2	Aortic arch	Crossed anteriorly by the arch of aorta	T4	22.5 cm
3	Left bronchus	Crossed anteriorly by the left principal bronchus	T6	27.5 cm
4	Diaphragmatic	Oesophageal opening (hiatus) of the diaphragm	T10	37.5 cm

(Endoscopic measurement with a flexible scope gives marginally longer figures — about 15, 23, 28 and 40 cm respectively — the discrepancy being one of instrument/technique, not of anatomy.)

□ Fig 9.4 — Natural constrictions of the oesophagus (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.203)

Relations

Cervical part (posterior to the trachea, inclining slightly left):

Aspect	Relations
Anterior	Trachea; recurrent laryngeal nerve (in the tracheo-oesophageal groove)
Posterior	Prevertebral fascia; longus colli muscles; cervical vertebral column
Each side	Lobe of thyroid gland; common carotid artery; thoracic duct (left side only)

Thoracic part (superior mediastinum, then posterior mediastinum):

Aspect	Relations (above downwards where relevant)
Anterior	Trachea → arch of aorta → left principal bronchus → pericardium (separating it from the left atrium) → posterior sloping surface of the diaphragm
Posterior	Thoracic vertebral column (covered by anterior longitudinal ligament); right posterior intercostal arteries; thoracic duct; azygos vein with terminations of the hemiazygos veins; descending thoracic aorta; diaphragm
Right	Right lung and pleura (azygo-oesophageal recess); azygos vein arching over the right lung root; right vagus nerve
Left	Arch of aorta; left subclavian artery; thoracic duct; left lung and pleura; left recurrent laryngeal nerve

Abdominal part ($\approx 1-1.25$ cm, covered by peritoneum anteriorly and on the left only):

Aspect	Relations
Anterior	Left lobe of liver; anterior vagal trunk; peritoneum
Posterior	Left crus of diaphragm; posterior vagal trunk
Right border	Continuous with the lesser curvature of the stomach
Left border	Separated from the fundus of the stomach by the cardiac notch (angle of His)

□ Fig 23.10 — Cross section of the posterior mediastinum at the level of the T8 vertebra (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.909)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Reproduce a simple outline of the oesophagus (pharynx above, cardiac orifice of stomach below) and mark, with distance-from-incisors and vertebral level:

- ▶ **Cricopharyngeus constriction** — 15 cm, C6
- ▶ **Aortic-arch constriction** — 22.5 cm, T4
- ▶ **Left-bronchial constriction** — 27.5 cm, T6
- ▶ **Diaphragmatic constriction** — 37.5 cm, T10
- ▶ Label the **cardiac orifice** at T11, 2.5 cm left of the midline.

For the thoracic cross-section, additionally label around the oesophagus: **trachea** (anterior), **vertebral column** (posterior), **azygos vein** and **right pleura** (right), **arch of aorta/descending aorta**, **thoracic duct** and **left pleura** (left).

Blood Supply, Venous Drainage and Lymphatic Drainage

Arterial supply and venous drainage are segmental, matching the three parts, and anastomose in a continuous longitudinal chain (surgically important — this collateral chain must be respected during mobilisation to avoid ischaemic necrosis):

Part	Arterial supply	Venous drainage
Cervical	Inferior thyroid artery	Inferior thyroid veins → left brachiocephalic vein
Thoracic	Oesophageal and bronchial branches of the descending thoracic aorta	Azygos vein, and terminally the hemiazygos veins
Abdominal	Oesophageal branches of the left gastric artery (reinforced by left inferior phrenic artery)	Oesophageal veins → partly left gastric vein (portal), partly hemiazygos/azygos (systemic)

- ▶ The abdominal-part veins constitute one of the classical **porto-systemic anastomoses**; in portal hypertension they dilate into **oesophageal varices**, which can rupture and cause severe haematemesis.
- ▶ **Lymphatic drainage** follows the same three-part plan: cervical part → deep cervical nodes (directly, or via paratracheal nodes); thoracic part → posterior mediastinal nodes; abdominal part → left gastric nodes. The oesophagus additionally has an extensive, **longitudinally continuous submucosal lymphatic plexus**, which explains why carcinoma oesophagus can produce lymph node metastases remote from the primary tumour (skip metastases) — the anatomical basis for wide longitudinal surgical clearance in oesophagectomy.

Nerve Supply

- ▶ **Parasympathetic**: the **upper half** is supplied by the **recurrent laryngeal nerves**; the **lower half** by the **oesophageal plexus**, formed mainly by the two vagus nerves below the level of the pulmonary hila (right vagus predominantly posterior, left predominantly anterior), which re-condense into the **posterior and anterior vagal trunks** that pass with the oesophagus through the oesophageal

hiatus of the diaphragm. Parasympathetic fibres are motor, secretomotor and sensory (mediate peristalsis and the swallowing/vomiting reflexes).

- ▶ **Sympathetic:** for the upper half, fibres arise from the **middle cervical ganglion** and travel with the inferior thyroid artery; for the lower half, fibres come directly from the **upper four thoracic sympathetic ganglia** (T1–T4) to join the oesophageal plexus. Sympathetic fibres are chiefly vasomotor.
- ▶ No true anatomical sphincter guards the cardia, but a **physiological (functional) lower oesophageal "sphincter"** exists, producing a brief closure that resists reflux of gastric contents; disordered relaxation of this zone (with loss of myenteric ganglion cells) is the basis of **achalasia cardia**.

Development (brief)

- ▶ The oesophagus is a **foregut** derivative. In the 4th week, the respiratory (laryngotracheal) diverticulum buds from the ventral wall of the foregut; fusion of the tracheo-oesophageal ridges forms the **tracheo-oesophageal septum**, dividing the foregut into a ventral trachea/lung bud and a dorsal oesophagus, the two remaining connected only through the laryngeal orifice.
- ▶ At first the oesophagus is short; with descent of the heart and lungs it **lengthens rapidly** during the 4th–5th weeks.
- ▶ Its muscular coat differentiates from the surrounding splanchnic mesenchyme: the cranial part becomes **striated muscle** (innervated by the vagus), the caudal part remains **smooth muscle** (innervated via the splanchnic/sympathetic plexus) — the developmental basis of the mixed muscle coat along its length.
- ▶ **Anomaly:** incomplete/faulty fusion of the tracheo-oesophageal septum produces the spectrum of **tracheo-oesophageal fistula (TOF)** and **oesophageal atresia** — commonest (~90% of cases) is a blind-ending proximal pouch with the distal segment communicating with the trachea near the carina; isolated oesophageal atresia without fistula, and the H-type fistula without atresia, each account for about 4% of cases.

Applied / Clinical anatomy

- ▶ The four constrictions are the classical sites for **impaction of swallowed foreign bodies and food boluses**, for **strictures and carcinoma**, and their fixed distances from the incisor teeth guide safe passage of an oesophagoscope or nasogastric/Ryle's tube.
- ▶ **Achalasia cardia:** failure of the physiological sphincter/lower segment to relax (congenital deficiency of myenteric ganglion cells) causes progressive dysphagia with proximal dilatation, demonstrable on barium swallow.
- ▶ **Oesophageal varices:** porto-systemic anastomosis at the lower end dilates in portal hypertension, producing "worm-like" filling defects on barium swallow; rupture causes life-threatening haematemesis.
- ▶ **Left atrial enlargement** (e.g. mitral stenosis) indents the anterior wall of the thoracic oesophagus at the level of the left atrium — a sign historically sought on barium swallow.

- ▶ **Dysphagia lusoria:** an aberrant right subclavian artery, arising distal to the left subclavian artery and coursing posterior to the oesophagus to reach the right upper limb, can compress it and cause dysphagia.
- ▶ **Tracheo-oesophageal fistula/oesophageal atresia:** presents with polyhydramnios antenatally (impaired fetal swallowing) and choking/aspiration on feeding after birth; the abnormal communication is a direct consequence of failed tracheo-oesophageal septation.
- ▶ **Mediastinal syndrome:** extrinsic compression of the oesophagus by mediastinal masses/lymphadenopathy produces dysphagia.
- ▶ The **extensive longitudinal submucosal lymphatic plexus** underlies the tendency of oesophageal carcinoma to spread submucosally well beyond the visible tumour margin, mandating wide resection margins.

High-yield exam pointers

- ▶ Total length $\approx$ 25 cm; extends from C6 (cricoid) to T11 (cardiac orifice); pierces the diaphragm at T10.
- ▶ Narrowest part of the alimentary canal after the vermiform appendix.
- ▶ **Four constrictions:** commencement/cricopharyngeus (C6, 15 cm), aortic arch (T4, 22.5 cm), left bronchus (T6, 27.5 cm), diaphragm (T10, 37.5 cm) — all measured from the incisor teeth.
- ▶ Arterial supply mirrors the three parts: **inferior thyroid** $\rightarrow$ **aortic/bronchial** $\rightarrow$ **left gastric**, forming one continuous longitudinal anastomotic chain.
- ▶ Venous drainage of the abdominal part is a classical **porto-systemic anastomosis** — clinical basis of oesophageal varices.
- ▶ Lymphatic drainage: cervical $\rightarrow$ deep cervical nodes; thoracic $\rightarrow$ posterior mediastinal nodes; abdominal $\rightarrow$ left gastric nodes.
- ▶ Nerve supply: parasympathetic upper half via **recurrent laryngeal nerve**, lower half via the **oesophageal (vagal) plexus**; sympathetic upper half from the middle cervical ganglion, lower half from T1–T4 ganglia.
- ▶ No anatomical sphincter at the cardia — only a physiological one; its dysfunction underlies achalasia.
- ▶ Developmentally a foregut derivative separated from the trachea by the tracheo-oesophageal septum; failure of this septation causes TOF/oesophageal atresia.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 (Trachea, Oesophagus and Thoracic Duct) and Vol 2 (Abdominal Part of Oesophagus and Stomach); AK Datta's Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh's Textbook of Anatomy Vol 3 (cervical oesophagus) and Vol 1 (figures); Langman's Medical Embryology (Sadler) 14e (development and tracheo-oesophageal fistula).



Pericardium

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction

The pericardium (Greek, "around the heart") is a conical fibroserous sac that encloses the heart and the roots of the great vessels. It lies in the **middle mediastinum**, behind the body of the sternum and the 2nd–6th costal cartilages, and in front of the bodies of the 5th–8th thoracic vertebrae. It is made up of an outer **fibrous pericardium** and an inner **serous pericardium** (parietal and visceral layers), the two together protecting the heart, restraining over-distension, and permitting frictionless cardiac pulsation. Because the developing heart invaginates the serous sac from behind without breaching it, the heart lies **inside the fibrous pericardium but outside the serous pericardial cavity** — it is intra-fibrous but extra-serous.

1. Fibrous pericardium

- ▶ A tough, conical, collagenous sac; its **apex** is blunt, lies at the level of the **sternal angle**, and fuses with the adventitia of the great vessels and with the pretracheal fascia.
- ▶ Its **base** is broad and inseparably blended with the **central tendon of the diaphragm** — both structures share a common developmental origin from the septum transversum.
- ▶ Anteriorly it is tethered to the upper and lower ends of the body of the sternum by weak **superior and inferior sternopericardial ligaments** (a three-point "cardiac seat belt" — apex, base, sternum — that anchors the heart in the thorax).
- ▶ Functionally it prevents sudden overfilling/over-distension of the heart.

Relation	Structures
Anterior	Anterior margins of both pleurae and lungs (except a bare area below the left 4th costal cartilage, where pericardium contacts the sternum directly because the pleura/lung deviate laterally)
Posterior	Both principal bronchi, oesophagus with its nerve plexus, descending thoracic aorta, azygos and hemi-azygos veins, thoracic duct
Each side	Mediastinal pleura, mediastinal surface of lung, phrenic nerve and pericardiophrenic vessels (between pleura and pericardium)
Superior	Apex fused to roots of great vessels and pretracheal fascia
Inferior	Central tendon of diaphragm; left lobe of liver and fundus of stomach lie below the diaphragm

2. Serous pericardium and the pericardial cavity

- ▶ A closed, double-layered mesothelial sac lying within the fibrous pericardium.
- ▶ **Parietal layer** lines the inner surface of, and is fused with, the fibrous pericardium.
- ▶ **Visceral layer (epicardium)** invests the heart and is adherent to the myocardium except along the cardiac grooves, where vessels intervene.

- ▶ The two layers are continuous with each other at the roots of the great vessels — an **arterial tube** enclosing the ascending aorta and pulmonary trunk, and a **venous tube** enclosing the superior and inferior venae cavae and the four pulmonary veins.
- ▶ The **pericardial cavity** is the potential space between parietal and visceral layers, containing only a thin, capillary film of serous fluid that lubricates the surfaces and allows smooth cardiac movement.
- ▶ Embryological basis: the heart tube invaginates the pericardial coelom from behind, suspended initially by the **dorsal mesocardium**; degeneration of the central part of this mesocardium, and later crowding/separation of the systemic and pulmonary veins as the heart enlarges, together generate the two pericardial sinuses described below.

3. Sinuses of the pericardium

Feature	Transverse sinus	Oblique sinus
Nature	Inter-visceral space (lined by visceral layer only)	Parieto-visceral space (parietal layer behind, visceral layer in front)
Position	Horizontal passage above and in front of the left atrium, between the arterial and venous tubes	Cul-de-sac behind the left atrium
Anterior boundary	Ascending aorta and pulmonary trunk	Left atrium
Posterior boundary	Superior vena cava (and upper margin of left atrium)	Parietal pericardium overlying oesophagus/posterior mediastinum
Right/left boundary	Opens into general pericardial cavity on each side	Right pulmonary veins + IVC (right); left pulmonary veins (left)
Development	Degeneration of the central part of the dorsal mesocardium	Pericardial reflection enclosing the pulmonary veins as they separate during cardiac growth
Function/note	Allows a surgical ligature/clamp around the aorta and pulmonary trunk	Permits free pulsation of the left atrium

□ Fig 18.4 — The pericardial cavity seen after removal of the heart. Note the reflections of pericard (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.308)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sagittal/posterior view of the pericardial sac after removal of the heart (as in dissection), labelled: Ascending aorta · Pulmonary trunk · Superior vena cava · Inferior vena cava · Right pulmonary veins (2) · Left pulmonary veins (2) · Transverse sinus (between arterial and venous tubes) · Oblique sinus (cul-de-sac behind left atrium) · Fold/ligament of the left vena cava · Cut edge of fibrous pericardium.

4. Contents of the pericardium and structures piercing it

- ▶ **Contents:** heart with its vessels and nerves; ascending aorta; pulmonary trunk; lower half of the superior vena cava; terminal part of the inferior vena cava; terminal parts of the four pulmonary veins.
- ▶ **Structures piercing the fibrous pericardium:** ascending aorta, superior and inferior venae cavae, right and left pulmonary arteries, and four pulmonary veins. All of these receive a sleeve/prolongation from the fibrous pericardium **except the inferior vena cava**, which enters without one.
- ▶ A vestigial fold, the **ligament (fold) of the left vena cava** (fold of Marshall), runs from the left pulmonary artery to the upper left pulmonary vein within the oblique sinus; it contains the fibrous remnant of the left duct of Cuvier.

5. Blood supply, nerve supply and lymphatic drainage

- ▶ **Arterial supply:** fibrous and parietal layers — chiefly the **pericardiophrenic branches of the internal thoracic arteries** ($\approx 80\%$ of pericardial blood supply), with contributions from the musculophrenic arteries and small branches of the descending thoracic aorta; visceral layer (epicardium) — by the coronary arteries.
- ▶ **Venous drainage:** fibrous/parietal layers drain into the internal thoracic and azygos veins; visceral layer drains via the coronary sinus.
- ▶ **Nerve supply:** fibrous pericardium and parietal serous layer are supplied by the **phrenic nerves** (somatic afferents) and are therefore pain-sensitive; the visceral layer (epicardium) is supplied by autonomic fibres of the vagus and sympathetic trunk via the cardiac/coronary plexus and is insensitive to pain.
- ▶ **Lymphatic drainage:** chiefly to the anterior mediastinal and tracheobronchial nodes.

6. Development

- ▶ **Fibrous pericardium** and the **parietal layer of serous pericardium** develop from the **septum transversum** (somatopleuric mesoderm).
- ▶ **Visceral layer (epicardium)** develops from the splanchnopleuric layer investing the primitive heart tube (the "myo-epicardial mantle"/pro-epicardial migration).
- ▶ The primitive heart forms a U-shaped bulboventricular loop suspended by the dorsal mesocardium; the pulmonary ridge of Mall (containing the anterior cardinal vein) separates the pericardial coelom from the pleural coeloms on either side.

Applied / Clinical anatomy

- ▶ **Pericardial effusion / cardiac tamponade:** accumulation of fluid (serous, blood, or pus) in the pericardial cavity compresses the heart, restricts venous filling and diastolic capacity, and reduces cardiac output, with a reflex rise in pulse and venous pressure.
- ▶ **Pericardiocentesis routes:**
 - *Subxiphoid (subcostal) approach* — needle inserted in the angle between the xiphoid process and left costal margin, directed upward, backward and to the left at about 45° (avoids pleura and lung); the classic route for draining tamponade.
 - *Parasternal (left 4th–5th intercostal space) approach* — needle close to the lateral sternal margin, avoiding the left lung, pleura and internal thoracic artery; traditionally the preferred route for intracardiac injection, and now the preferred ultrasound-guided elective approach.
- ▶ **Clinical importance of the transverse sinus:** during cardiac and great-vessel surgery (e.g. coronary bypass, aortic surgery) a ligature or clamp is passed through the transverse sinus around the aorta and pulmonary trunk together to control haemorrhage.
- ▶ **Pain referral:** pericarditis pain arises from the parietal (somatically-innervated) pericardium and is typically sharp and referred via the phrenic nerve distribution (C3–C5), often to the shoulder tip; true cardiac/anginal pain arises instead from the myocardium/coronary vessels via visceral afferents.
- ▶ **Left atrial enlargement** (e.g. in mitral stenosis) bulges into the oblique sinus and can compress the oesophagus lying immediately behind, producing dysphagia.
- ▶ **Congenital anomalies:** pericardial cysts (springwater cysts, classically at the right cardiophrenic angle, formed when a portion of pericardium is pinched off in development) and pericardial diverticula; congenital absence of the pericardium (usually partial and left-sided, related to premature atrophy of the left common cardinal vein/pleuropericardial membrane) may allow abnormal cardiac displacement/rotation.
- ▶ **Imaging:** on CT/MRI the normal pericardium (fused fibrous + serous layers) appears as a thin curvilinear structure of combined thickness about 1–2 mm, best seen along the right heart border; pericardial effusion appears as an expanded fluid-attenuation/signal space around the heart.

High-yield exam pointers

- ▶ Pericardium = **fibrous** (outer, tough, protective) + **serous** (inner, parietal + visceral/epicardium) layers; heart is intra-fibrous but extra-serous.
- ▶ Apex of fibrous pericardium fuses with pretracheal fascia at the sternal angle; base fuses with the central tendon of the diaphragm (both from septum transversum).
- ▶ Two sinuses: **transverse** (inter-visceral, between arterial and venous tubes, allows surgical clamping of aorta + pulmonary trunk) and **oblique** (parieto-visceral cul-de-sac behind the left atrium, permits free atrial pulsation).
- ▶ **Inferior vena cava** is the one great vessel that pierces the pericardium without receiving a fibrous/serous sleeve.
- ▶ Nerve supply: **phrenic** (fibrous + parietal — pain-sensitive) vs **vagus/sympathetic** (visceral/epicardium — pain-insensitive).

- ▶ ~80% of pericardial arterial supply is via **pericardiophrenic branches of the internal thoracic arteries**.
- ▶ Pericardiocentesis: subxiphoid (commonest, safest) or left parasternal 4th/5th intercostal space route.
- ▶ Fold of left vena cava (fold of Marshall) is a vestige of the left duct of Cuvier, lying within the oblique sinus.
- ▶ Cardiac tamponade classically reduces cardiac output while raising venous pressure and heart rate (Beck's triad in acute tamponade).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen).

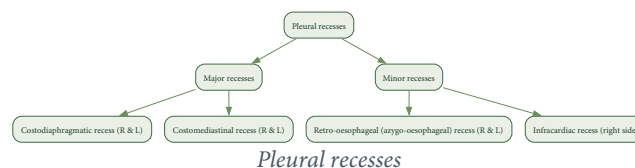


Pleural recesses

Asked in: Paper I Nov 2017 — RGUHS MD/MS Anatomy

Definition / Introduction The parietal pleura is reflected from one wall of the thoracic cavity onto another (costal → diaphragmatic, costal → mediastinal) without the lung following it into the angle so formed. These "blind" angular extensions of the pleural cavity, where parietal (costal) pleura lies directly against parietal (diaphragmatic or mediastinal) pleura with only a thin film of serous fluid between them and no lung tissue intervening, are called **pleural recesses**. Since the lung does not fully occupy them even in deep inspiration, they act as **reserve spaces** into which the lung expands during forced inspiration, and they are of major radiological and clinical importance because fluid, air or pus collecting in the pleural cavity accumulates here first.

Classification of pleural recesses



- ▶ **Major recesses** (large, constant, of chief clinical importance): costodiaphragmatic and costomediastinal recesses, each present bilaterally.
- ▶ **Minor recesses** (small, inconstant, of mainly radiological interest): the right and left retro-oesophageal (vertebro-mediastinal) recesses, and a solitary infracardiac recess of the right pleural sac.

□ Fig 15.8 — Reflections of the pleura to show costodiaphragmatic and costomediastinal (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.283)

Costodiaphragmatic recess

- ▶ Situated **inferiorly**, between the **costal pleura** and the **diaphragmatic pleura**.

- ▶ Vertical depth about 5 cm; deepest along the **mid-axillary line**, extending between the **8th and 10th ribs**.
- ▶ The lower border of the lung lies **two ribs higher** than the pleural reflection in quiet breathing:

Line	Lower margin of lung	Lower margin of pleura
Mid-clavicular line	6th rib	8th rib
Mid-axillary line	8th rib	10th rib
Paravertebral (lateral border of erector spinae)	10th rib	12th rib

- ▶ It is the **most dependent part of the pleural cavity**, so fluid, blood, pus or air collecting in the pleural cavity gravitates here first.
- ▶ On quiet respiration the recess is obvious as a genuine slit between costal and diaphragmatic pleura; on **deep inspiration** the descending, expanding lung occupies almost the whole recess, all but obliterating it — the recess is best seen during **expiration**.

Costomediastinal recess

- ▶ Situated **anteriorly**, behind the sternum and costal cartilages, between the **costal pleura** and the **mediastinal pleura**.
- ▶ **Right costomediastinal recess** — narrow and shallow; it is filled by the thin anterior margin of the right lung even during quiet breathing, so it is barely demonstrable.
- ▶ **Left costomediastinal recess** — much larger because of the **cardiac notch** of the left lung: the anterior border of the left lung follows the pleural reflection down to the 4th costal cartilage, then diverges 3.5 cm lateral to the sternal margin before curving back to the 6th costal cartilage, 4 cm from the midline. In this triangular zone the pericardium is covered only by a double layer of pleura with no intervening lung — the **area of superficial cardiac dullness**, demonstrable clinically by a change from resonant to dull note on percussion.

Lines of pleural reflection that create the recesses (surface anatomy)

Line	Course
Apex (cervical pleura)	Domes 2.5 cm above the medial one-third of the clavicle
Anterior/costomediastinal line	Right: sternoclavicular joint → midline at the sternal angle → midline just above the xiphisternal joint. Left: same course to the 4th costal cartilage, then laterally 3.5 cm (cardiac notch) and back to the 6th costal cartilage, 4 cm from midline
Inferior/costodiaphragmatic line	Crosses the 8th rib in the mid-clavicular line, the 10th rib in the mid-axillary line, and the 12th rib at the lateral border of erector spinae, then passes medially to reach 2 cm lateral to the spine of T12
Posterior line	From 2 cm lateral to the C7 spine to 2 cm lateral to the T12 spine

The pleura therefore projects below the costal margin at **three sites** — the right xiphicostal angle, and the right and left costovertebral angles below the 12th rib, behind the upper poles of the kidneys.

Minor recesses

- ▶ **Retro-oesophageal (azygo-oesophageal) recess** — right and left, formed where the mediastinal pleura reflects behind the oesophagus; each is occupied by a small tongue of lung and contributes to the retrocardiac space seen on chest radiographs.
- ▶ **Infracardiac recess** — a small recess of the **right** pleural sac only, which may extend beneath the inferior vena cava.

Nerve supply relevant to the recesses

Part of parietal pleura forming the recess	Nerve supply	Referred pain
Costal pleura + peripheral diaphragmatic pleura (walls of costodiaphragmatic and costomediastinal recesses)	Intercostal nerves	Chest/abdominal wall (dermatomal)
Mediastinal pleura + central diaphragmatic pleura	Phrenic nerve (C3, C4, C5)	Tip of the shoulder

Visceral pleura is insensitive to pain (autonomic supply only — sympathetics from T2–T5 ganglia, parasympathetics from the vagus).

Applied / Clinical anatomy

- ▶ **Pleural effusion / haemothorax / empyema** collect first in the costodiaphragmatic recess because it is the most dependent part of the pleural cavity; on an erect chest radiograph this is seen as **blunting/obliteration of the costophrenic angle**, often the earliest radiological sign of pleural fluid.
- ▶ **Paracentesis thoracis (thoracocentesis)** is performed through the costodiaphragmatic recess, classically in the **8th intercostal space in the mid-axillary line**, with the needle passed close to the **lower border of the rib/space** to avoid the intercostal vein, artery and nerve (VAN) running in the costal groove above.
- ▶ **Renal/posterior approach surgery**: the pleura descends to cross the **12th rib at the lateral border of erector spinae**, close to the upper pole of the kidney; an incision or dissection placed too high or medial risks opening the costodiaphragmatic recess and causing a pneumothorax.
- ▶ **Area of superficial cardiac dullness**: clinically demonstrated by percussion over the large left costomediastinal recess (cardiac notch region), where only a double layer of pleura, and no lung, overlies the pericardium.
- ▶ **Retrocardiac/retro-oesophageal shadow** on lateral chest radiographs corresponds to the retro-oesophageal recesses; the infracardiac recess may occasionally be mistaken for pathology on imaging.
- ▶ Loss of the normal costophrenic angle also occurs in pulmonary fibrosis/adhesions, which limit the reserve expansion function of the recesses.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Lateral (or postero-lateral) view of the right hemithorax outlining the ribcage, showing the lung margin (dotted) separate from the parietal pleural line (solid), labelled:

- ▶ Apex of pleura, 2.5 cm above medial 1/3 clavicle
- ▶ Costal pleura
- ▶ Anterior (costomediastinal) line of reflection
- ▶ Inferior (costodiaphragmatic) line of reflection
- ▶ **Costodiaphragmatic recess** shaded between the two lines, 8th–10th rib, mid-axillary line, depth ~5 cm
- ▶ **Costomediastinal recess** shaded anteriorly at the cardiac notch (left) / behind xiphisternum (right)
- ▶ Diaphragmatic pleura and mediastinal pleura, correctly named at their junctions
- ▶ Lower border of lung (6th rib MCL / 8th rib MAL / 10th rib paravertebral) drawn two ribs above the pleural reflection line

High-yield exam pointers

- ▶ Pleural recesses = angular parts of the pleural cavity where costal pleura meets diaphragmatic or mediastinal pleura with no lung between them; **reserve spaces** for deep inspiration.
- ▶ Two **major** recesses (each bilateral): **costodiaphragmatic** and **costomediastinal**; three **minor** recesses: right + left **retro-oesophageal** and one right-sided **infracardiac**.
- ▶ Costodiaphragmatic recess: depth ~5 cm, deepest at 8th–10th rib mid-axillary line; the **most dependent part of the pleural cavity** — first site of fluid collection.
- ▶ Lung's inferior border lies **two ribs above** the pleural reflection (6th/8th/10th rib for lung vs 8th/10th/12th rib for pleura, at mid-clavicular/mid-axillary/paravertebral lines respectively).
- ▶ **Left** costomediastinal recess is large (cardiac notch) → area of superficial cardiac dullness; **right** is small and nearly filled by lung.
- ▶ Thoracocentesis site: **8th intercostal space, mid-axillary line**, along the lower rib border.
- ▶ Pleura crosses the **12th rib at the lateral border of erector spinae**, close to the kidney — key in renal surgery.
- ▶ Costal/peripheral-diaphragmatic pleura → intercostal nerve pain; mediastinal/central-diaphragmatic pleura → phrenic nerve → shoulder-tip pain.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 8e; Vishram Singh's Textbook of Anatomy Vol 1 4e; Moore's Clinically Oriented Anatomy 9e; IB Singh's Textbook of Anatomy Vol 2 6e.



Pleural reflection

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction The **pleura** is a serous membrane, lined by mesothelium, that invests each lung (**visceral pleura**) and lines the corresponding half of the thoracic cavity (**parietal pleura**). The parietal pleura is shaped like a half-cone and is described in four continuous parts — **cervical, costal, mediastinal and diaphragmatic** — which pass into one another along lines of change of direction. These turning points, projected on to the surface of the chest and back, constitute the **lines of pleural reflection**; their knowledge is essential for percussion, auscultation, thoracocentesis, chest-tube insertion, and for avoiding inadvertent pleural injury during neck, renal and upper-abdominal surgery.

Parts of the parietal pleura

Part	Extent / description
Cervical pleura (cupola/dome)	Covers the apex of the lung; extends into the root of the neck; reinforced above by the suprapleural membrane (Sibson's fascia)
Costal pleura	Lines the inner aspect of the ribs, costal cartilages and intercostal spaces; separated from the thoracic wall by loose areolar endothoracic fascia
Mediastinal pleura	Lines the lateral surface of the mediastinum; reflected as a sleeve around the root of the lung (cuff), where it becomes continuous with the visceral pleura, and continues below the hilum as the pulmonary ligament
Diaphragmatic pleura	Covers the thoracic (superior) surface of the diaphragm; in quiet respiration it lies applied against the costal pleura below the lower border of the lung

Lines of pleural reflection (surface marking)

The reflection of parietal on to parietal pleura (costal↔mediastinal↔diaphragmatic↔cervical) is marked by four lines. The **cervical and costodiaphragmatic** lines are essentially the same on both sides; the **anterior (costomediastinal)** line differs because of the cardiac notch on the left.

Line	Right side	Left side
Cervical	Curved line, convexity upward, from the sternoclavicular joint to the junction of the medial and middle thirds of the clavicle; summit of the dome 2.5 cm (1 in) above the medial third of the clavicle	Same

Line	Right side	Left side
Anterior (costomediastinal)	From the sternoclavicular joint downward/medially to the midpoint of the sternal angle , then vertically down to the midpoint of the xiphisternal joint , crossing just to the right of the xiphicostal angle	Same course to the level of the 4th costal cartilage , then arches laterally and descends along the sternal margin to the 6th costal cartilage (~3 cm from the midline) — leaving the bare area of the heart in contact with the chest wall
Inferior (costodiaphragmatic)	From the xiphisternal joint, crosses the 8th rib in the midclavicular line, the 10th rib in the midaxillary line, and the 12th rib at the lateral border of erector spinae (2 cm lateral to the T12 spine)	Starts at the level of the 6th costal cartilage (~2 cm lateral to the midline), then follows the same course as the right
Posterior (costovertebral)	Ascends from 2 cm lateral to the T12 spine, along the vertebral column, to 2 cm lateral to the C7 spine (costal pleura becomes mediastinal pleura along this line)	Same

Sites where the pleura extends beyond the thoracic cage / descends below the costal margin — of applied importance:

- ▶ In the **root of the neck** on either side (cervical dome).
- ▶ At the **right xiphicostal (costoxiphoid) angle** anteriorly.
- ▶ At the **right and left costovertebral angles**, below the 12th rib, behind the upper poles of the kidneys.

□ Fig 18.6 — Schematic diagram showing the lines of pleural reflection (C4 = 4th costal cartilage, R12 = 12th rib, T12 = 12th thoracic vertebra, BA = bare area of heart) (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.735)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw an anterior view of the chest wall (sternum, costal cartilages, ribs 1–12, clavicles) and mark:

- ▶ Cervical dome: curved line, apex 2.5 cm above medial 1/3 of clavicle (both sides).
- ▶ Right anterior line: sternoclavicular joint → mid-sternal angle → mid-xiphisternal joint.
- ▶ Left anterior line: sternoclavicular joint → mid-sternal angle → **4th costal cartilage** → arch laterally → **6th costal cartilage** (label the gap as **bare area of heart**).
- ▶ Inferior line (both sides, label right start at xiphisternal joint, left start at 6th costal cartilage): crossing **8th rib (midclavicular line)** → **10th rib (midaxillary line)** → **12th rib (lateral border of erector spinae)**.
- ▶ Posterior line: from 2 cm lateral to T12 spine up to 2 cm lateral to C7 spine.
- ▶ Shade and label the **costodiaphragmatic recess** (between costal and diaphragmatic pleura) and the **costomediastinal recess** (between costal and mediastinal pleura, prominent on the left around the cardiac notch).
- ▶ Mark the three sites of pleural extension beyond the thoracic cage (neck domes, right xiphicostal angle, both costovertebral angles) with asterisks.

Pleural recesses

The lung does not fully occupy the pleural cavity during quiet breathing; the potential spaces left over, where costal pleura lies directly against diaphragmatic or mediastinal pleura, are the **pleural recesses** — reserve spaces that allow the lung to expand fully on deep inspiration.

Recess	Location	Dimensions / notes	Clinical significance
Costodiaphragmatic recess (right & left)	Between costal and diaphragmatic pleura, around the periphery of the diaphragm	About 4–5 cm deep; lies opposite the 8th–10th ribs in the midaxillary line	Most dependent part of the pleural cavity — first site of collection of pleural effusion; obliteration of the costophrenic angle is the earliest radiographic sign of effusion
Costomediastinal recess	Between costal and mediastinal pleura, behind the sternum and costal cartilages	Small on the right; large on the left because of the cardiac notch, lying between the 4th and 6th costal cartilages	Percussion here shifts from resonant (over aerated lung) to dull (over the recess/heart) — the area of superficial cardiac dullness
Retro-oesophageal recesses (minor)	Behind the oesophagus, formed by reflection of mediastinal pleura	Occupied by a tongue of lung	Contribute to the retrocardiac space on chest radiographs
Infracardiac recess (minor)	Right pleural sac, occasionally beneath the IVC	—	—

Pleural reflection versus lower border of lung

The lower border of the lung lies **two ribs higher** than the corresponding line of **pleural reflection** at each vertical reference line — the gap between the two constitutes the costodiaphragmatic recess.

Reference line	Lower border of lung	Costodiaphragmatic line of pleura
Midclavicular line	6th rib	8th rib
Midaxillary line	8th rib	10th rib
Lateral to erector spinae	10th rib	12th rib

Nerve supply and referred pain

- ▶ The **parietal pleura** develops from **somatopleuric** mesoderm and is somatically innervated, hence pain-sensitive:
- ▶ **Costal pleura and the peripheral part of diaphragmatic pleura** → **intercostal nerves** → pain localised to, and referred along, the thoracic/abdominal wall.
- ▶ **Mediastinal pleura and the central part of diaphragmatic pleura** → **phrenic nerve (C3–C5)** → pain referred to the **shoulder tip/root of the neck**, because the skin there shares the same (C3–C5, supraclavicular nerve) segmental supply.
- ▶ The **visceral pleura** develops from **splanchnopleuric** mesoderm, is supplied by autonomic (sympathetic, T2–T5) fibres, and is **insensitive to pain**.

Applied / Clinical anatomy

- ▶ **Thoracocentesis (pleural tap)**: performed with the patient sitting, needle inserted in the **9th intercostal space in the midaxillary line**, along the **upper border of the rib below** to avoid the neurovascular bundle; traverses skin, superficial fascia, serratus anterior/intercostal muscles, endothoracic fascia and parietal pleura to reach the costodiaphragmatic recess.
- ▶ **Pleural effusion**: excess serous fluid collects first in the costodiaphragmatic recess (most dependent site); clinically produces decreased breath sounds, stony dullness, and radiographically an **obliterated costophrenic angle** with a fluid level.
- ▶ **Pneumothorax**: air in the pleural cavity — spontaneous (ruptured emphysematous bulla), open (penetrating chest wound) or tension (one-way valve effect causing mediastinal shift to the opposite side).
- ▶ **Cervical pleura vulnerability**: the dome rises above the clavicle and first rib, so it is at risk during **supraclavicular brachial-plexus block, subclavian vein catheterisation, and excision of a cervical rib**, any of which may cause an iatrogenic apical pneumothorax; Sibson's fascia offers only partial protection.
- ▶ **Renal/retroperitoneal surgery**: the pleura descends behind the upper pole of each kidney at the costovertebral angle (below the 12th rib), so posterior/flank incisions (e.g. lumbotomy for pyelolithotomy/nephrectomy) risk pleural injury and pneumothorax.
- ▶ **Right xiphicostal angle**: the low anterior reflection here places the pleura at risk during upper abdominal procedures (e.g. liver/gallbladder surgery through a right subcostal approach).

- ▶ **Cardiac notch/bare area:** because the left costomediastinal recess overlies the cardiac notch, the pericardium here is separated from the anterior chest wall by only a double layer of pleura (**bare area of the heart**) — this is the region of superficial cardiac dullness used in cardiac percussion.
- ▶ **Pleurisy/pleural rub:** inflammation (classically pulmonary tuberculosis) roughens apposed parietal and visceral pleura, producing an audible/palpable friction rub synchronous with respiration, and pain referred per the nerve-supply pattern above.

High-yield exam pointers

- ▶ Parietal pleura has **4 parts**: cervical, costal, mediastinal, diaphragmatic; lines of pleural reflection mark the turning points between them.
- ▶ Cervical dome: **2.5 cm above the medial 1/3 of the clavicle** — vulnerable in supraclavicular procedures.
- ▶ Anterior line differs left vs right only below the **4th costal cartilage** because of the **cardiac notch**; left reaches the **6th costal cartilage**, right continues to the **xiphisternal joint**.
- ▶ Inferior (costodiaphragmatic) line: **8th rib (midclavicular) → 10th rib (midaxillary) → 12th rib (erector spinae)**.
- ▶ Lung border lies **two ribs higher** than pleura at each line (6-8-10 vs 8-10-12) — this gap is the costodiaphragmatic recess.
- ▶ Costodiaphragmatic recess: **~4–5 cm deep**, most dependent — first site of pleural effusion; costomediastinal recess large on the **left** (cardiac notch).
- ▶ Pleura descends below the costal margin at **three sites**: neck domes, right xiphicostal angle, both costovertebral angles (behind kidney upper poles).
- ▶ Nerve supply splits by embryological origin: intercostal nerves (costal/peripheral diaphragmatic, localised pain) vs phrenic nerve C3–C5 (mediastinal/central diaphragmatic, referred shoulder-tip pain); visceral pleura is pain-insensitive.
- ▶ Thoracocentesis: **9th ICS, midaxillary line**, needle along the upper border of the lower rib.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1 8e; Vishram Singh — Textbook of Anatomy Vol 1 4e.



Right Atrium of the Heart

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction. The right atrium is the right-sided, upper receiving chamber of the heart that collects deoxygenated venous blood from the entire body — via the superior and inferior venae cavae and the coronary sinus — and pumps it through the right atrioventricular (tricuspid) orifice into the right ventricle. It forms the **right border of the heart**, part of the **upper border**, most of the **sternocostal (anterior) surface** on that side, and a small part of the **base**. Developmentally it is a composite chamber — a smooth posterior part (sinus venarum) derived from the absorbed right horn of the sinus venosus, and a rough anterior part (atrium proper, including the auricle) derived from the primitive atrium — and this dual origin explains almost every internal landmark described below, including the crista terminalis, the fossa ovalis, and the sinu-atrial node.

1. Situation, extent and external features

- ▶ **Situation:** right and anterior to the left atrium; extends inferior to it.
- ▶ **Extent:** from the orifice of the **superior vena cava (SVC)**, behind the right 3rd costal cartilage, to the orifice of the **inferior vena cava (IVC)**, behind the right 6th costal cartilage — the chamber is thus elongated vertically.
- ▶ **Right auricle:** the upper end of the atrium is prolonged to the left as a hollow, conical, muscular pouch, the right auricle, which covers the root of the ascending aorta and partly overlaps the infundibulum of the right ventricle. Its margins are notched and its interior is trabeculated (sponge-like), which retards free flow of blood — clinically an important site of thrombus formation in atrial fibrillation.
- ▶ **Sulcus terminalis:** a shallow vertical groove along the right border, running from the SVC to the IVC opening; it is produced internally by the muscular **crista terminalis** and marks the junction between the smooth (sinus venosus-derived) and rough (atrium-proper-derived) parts. The **upper part of this groove houses the sinu-atrial (SA) node**, the pacemaker of the heart.
- ▶ **Right atrioventricular groove (coronary sulcus):** separates the right atrium from the right ventricle; it is near-vertical and lodges the right coronary artery and the small cardiac vein.
- ▶ **Crux of the heart:** the point where the interatrial, atrioventricular and posterior interventricular grooves meet — a key surgical landmark for the AV node region.

2. Relations

Aspect	Related structures
Anterior (sternocostal)	Pericardium; right auricle overlapping the root of the ascending aorta and the infundibulum of the right ventricle
Posterior	Left atrium and right pulmonary veins, separated by the interatrial groove
Lateral	Right phrenic nerve and pericardiophrenic vessels; mediastinal pleura; cardiac impression of the right lung

Aspect	Related structures
Medial	Roots of the ascending aorta and pulmonary trunk
Inferior	Diaphragm (through the pericardium), close to the entry of the IVC

3. Interior of the right atrium

The interior is conventionally described in **three parts**, each with a distinct developmental origin.

Part	Origin	Chief features
Sinus venarum (smooth posterior part)	Absorbed right horn of the sinus venosus	Receives SVC (upper end, valveless, faces anteroinferiorly), IVC (lower end, guarded by the Eustachian valve), coronary sinus (guarded by the Thebesian valve), and numerous venae cordis minimae (Thebesian veins) through small foramina, mostly on the septal wall; the intervenous tubercle of Lower , a small projection just below the SVC opening, directs SVC flow towards the tricuspid orifice
Atrium proper / pectinate part , including the auricle	Primitive (common) atrium	Bears parallel ridges, the musculi pectinati , arising from the crista terminalis and running forward and down towards the AV orifice like the teeth of a comb; the largest ridge, the taenia sagittalis (septum spurium), forms the internal bridge of the sulcus terminalis; in the auricle the ridges interlace into a reticular network
Interatrial septum	Septum primum + septum secundum	Presents the fossa ovalis , a shallow, oval depression (its floor is the remnant of septum primum), superior and to the left of the IVC orifice; its margin, the annulus ovalis (limbus fossa ovalis) — the free edge of septum secundum — is distinct superiorly and laterally but deficient inferiorly; a probe-patent slit at its upper margin (persistent foramen ovale) is found in up to a third of normal adult hearts

Anteroinferior to the fossa is a smooth, funnel-shaped zone, the **vestibule**, leading to the **right atrioventricular (tricuspid) orifice**, guarded by the tricuspid valve (anterosuperior, septal and inferior/posterior cusps). Between the septal cusp of the tricuspid valve, the orifice of the coronary sinus,

and the tendon of Todaro lies the **triangle of Koch** — its apex is the surgical landmark for the AV node (see below).

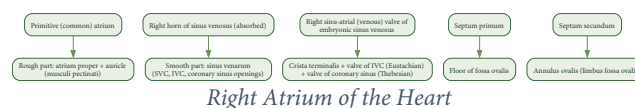
DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 21.10 — Interior of the right atrium (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.829)

Reproduce a coronal section through an opened right atrium, labelling in sequence:

- ▶ **Superior vena cava** (entering above) and **inferior vena cava** (entering below), each with its valve (Eustachian valve on the IVC)
- ▶ **Auricle** with **crista terminalis** and **musculi pectinati** radiating from it
- ▶ **Openings of the venae cordis minimae** scattered on the septal wall
- ▶ **Fossa ovalis** with its margin, the **annulus ovalis (limbus fossa ovalis)**
- ▶ **Opening of the coronary sinus** with its valve
- ▶ **Triangle of Koch**, bounded by the **septal leaflet of the tricuspid valve**, the **tendon of Todaro**, and the **coronary sinus ostium** — mark the **AV node** at its apex
- ▶ **Right atrioventricular orifice** with the **septal leaflet of the tricuspid valve**

4. Development of the right atrium



- ▶ The **crista terminalis** externally corresponds to the **sulcus terminalis** and internally marks the line of the embryonic **right sinu-atrial valve**; its persistence explains why the SA node — which develops at the sinu-atrial junction — comes to lie at the upper end of this crest.
- ▶ Failure of apposition/fusion of septum primum and septum secundum leaves a probe-patent foramen ovale (physiological in utero, where it — together with the Eustachian valve — directs oxygenated IVC blood preferentially towards the left atrium, bypassing the non-aerated lungs); persistence beyond infancy underlies **patent foramen ovale** and **ostium secundum atrial septal defect**.

5. Conducting system related to the right atrium

- ▶ **Sinu-atrial (SA) node**: a horseshoe/crescent-shaped mass of specialised cardiac muscle, situated at the **atriocaval junction in the upper part of the sulcus (crista) terminalis**, inferolateral to the SVC orifice. It is the **pacemaker of the heart**, generating impulses at **70–100/min**. Conduction spreads through ordinary atrial myocardium, preferentially along the terminal crest and the margins of the fossa ovalis towards the AV node, and via **Bachmann's bundle** to the left atrium.
- ▶ **Atrioventricular (AV) node**: smaller than the SA node, sited in the lower, dorsal part of the interatrial septum, just above the coronary sinus opening — at the **apex of the triangle of Koch**; it generates impulses at **40–60/min** and introduces the physiological AV delay.
- ▶ **AV bundle (bundle of His)**: the sole muscular bridge between atrial and ventricular myocardium; it traverses the central fibrous body and descends along the membranous

interventricular septum before dividing into right and left bundle branches (the right branch reaching the anterior papillary muscle via the moderator band).

- ▶ **Blood supply of the conducting system:** the whole conducting system (except part of the left bundle branch) is supplied by the **right coronary artery**; in about **40% of hearts the SA node is instead supplied by the left coronary artery** (circumflex branch) — a fact of direct relevance to arrhythmias following coronary occlusion.

Applied / Clinical anatomy

- ▶ **Atrial septal defects (ASDs):** the **ostium secundum type** (commonest) occurs in the region of the fossa ovalis from deficient septum primum/secundum; the **sinus venosus type** occurs near the SVC or IVC opening from faulty absorption of the sinus venosus and is often associated with anomalous pulmonary venous drainage; the **ostium primum type** is an endocardial-cushion defect near the AV valves. A probe-patent foramen ovale (present in roughly a third of adults) is usually asymptomatic but is a recognised route for **paradoxical embolism**.
- ▶ **Cavotricuspid isthmus:** the zone of atrial wall between the Eustachian valve/ridge and the tricuspid annulus, inferior to the coronary sinus ostium, is the anatomical substrate and the target of catheter ablation for **typical (isthmus-dependent) atrial flutter**.
- ▶ **Triangle of Koch:** an essential surgical/electrophysiological landmark — surgery or ablation within this triangle risks damaging the AV node and producing **heart block**.
- ▶ **Chiari's network:** a reticulated remnant of the right valve of the sinus venosus, extending from the Eustachian valve towards the coronary sinus and other parts of the atrial wall; usually an incidental finding but implicated in thromboembolism, arrhythmias and catheter entrapment.
- ▶ **Pericardial tamponade / pericardiocentesis:** because the venae cavae drain directly into the thin-walled right atrium, a rise in intrapericardial pressure (haemopericardium, effusion) first impedes atrial filling, producing engorged neck veins (raised jugular venous pressure) and requiring emergency pericardiocentesis.
- ▶ **Right atrial enlargement:** seen in tricuspid stenosis/regurgitation, pulmonary hypertension and cor pulmonale, and recognised radiologically as prominence of the right heart border.
- ▶ **Central venous access and pressure monitoring:** the SA-node-bearing atriocaval junction is the standard landmark for positioning central venous catheter tips (cavoatrial junction), and right atrial pressure is the reference for central venous pressure and the jugular venous pulse waveform.
- ▶ **Cardiac myxoma:** the most common primary cardiac tumour typically arises from the region of the fossa ovalis on the interatrial septum — most often in the left atrium, less commonly projecting from the right atrial septal surface.

High-yield exam pointers

- ▶ Right atrium = right border of heart + part of upper border + part of base; extends from SVC opening (behind right 3rd costal cartilage) to IVC opening (behind right 6th costal cartilage).
- ▶ Interior has **three parts:** sinus venarum (smooth, sinus-venosus-derived), atrium proper/auricle (rough, pectinate-muscle-bearing, primitive-atrium-derived), and interatrial septum (fossa ovalis + limbus).

- ▶ **Crista terminalis** demarcates smooth from rough parts; its **upper end houses the SA node**.
- ▶ **Fossa ovalis** = remnant of septum primum; **annulus ovalis (limbus)** = free edge of septum secundum; probe-patent in up to one-third of adults.
- ▶ **Triangle of Koch** (septal tricuspid leaflet + tendon of Todaro + coronary sinus ostium) marks the **AV node** at its apex — key surgical landmark.
- ▶ Valves: **Eustachian valve** guards the IVC opening; **Thebesian valve** guards the coronary sinus opening.
- ▶ SA node: pacemaker, 70–100/min, supplied by right coronary artery (60%) or left circumflex (40%); AV node: 40–60/min, apex of Koch's triangle.
- ▶ Clinical correlates to remember: ostium secundum/primum/sinus venosus ASD, patent foramen ovale (paradoxical embolism), cavotricuspid isthmus (atrial flutter ablation), Chiari's network, pericardial tamponade.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 1 8e; AK Datta's Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh's Textbook of Anatomy Vol 1 4e (figure); Moore's Clinically Oriented Anatomy 9e.



Root of the Right Lung

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The root of the lung is a short, broad pleura-invested pedicle that connects the mediastinal (medial) surface of the lung to the mediastinum, at the **hilum** (Latin *depression*) — the triangular area on the medial surface through which structures enter or leave the lung. The roots of both lungs lie opposite the bodies of the **5th, 6th and 7th thoracic vertebrae**. The root of the right lung is distinctive because, unlike the left, it already contains **two** bronchi (not one) by the time it reaches the hilum — a direct consequence of the right upper-lobe (eparterial) bronchus branching off before the principal bronchus enters the lung.

1. Formation and extent

- ▶ The parietal (mediastinal) pleura is reflected from the mediastinum on to the lung as the visceral pleura, forming a **pleural sleeve** that invests the entire root.
- ▶ Below the root, the two pleural layers fall together and hang down as a two-layered fold — the **pulmonary ligament** — which reaches down to near the diaphragm.
- ▶ The pulmonary ligament provides a "dead space" that allows the inferior pulmonary vein to distend during increased venous return (e.g., exercise) and permits the root to descend as the diaphragm descends.
- ▶ The root is otherwise the only point of fixity of the lung within its pleural cavity.

2. Contents of the root

No.	Structure
1	Eparterial (superior lobar) and hyparterial bronchi, in the posterior part
2	One pulmonary artery, in the middle part
3	Two pulmonary veins — superior and inferior — in the anterior part
4	One bronchial artery (from the 3rd right posterior intercostal artery)
5	Bronchial veins (drain to the azygos vein)
6	Anterior and posterior pulmonary (autonomic) plexuses of nerves
7	Lymphatics of the lung
8	Bronchopulmonary (hilar) lymph nodes
9	Loose areolar tissue, all enclosed within the pleural sleeve

3. Arrangement of structures at the right hilum

Two complementary orientations are described and are both examiner-favourites.

(a) **Antero-posterior order** (from behind forwards):

- ▶ Eparterial and hyparterial bronchi, with the bronchial vessels and the **posterior pulmonary plexus** running along their posterior walls — most posterior.
- ▶ **Pulmonary artery**, in the mid-plane, lying between the two bronchi.
- ▶ Superior and inferior **pulmonary veins**, in the anterior part.
- ▶ **Anterior pulmonary plexus**, lymph nodes and lymph vessels, in the anterior and inferior parts.

(b) **Vertical (superior-to-inferior) order at the right hilum** (Gray's): Superior lobar (**eparterial**) bronchus → **pulmonary artery** → **principal bronchus** → **inferior pulmonary vein**.

This vertical sequence exists only on the right, because the right principal bronchus gives off its superior lobar branch just before/as it reaches the hilum — the branch runs postero-superior to the pulmonary artery, while the parent bronchus crosses behind the artery and enters the hilum postero-inferiorly, dividing there into middle and inferior lobar bronchi. This is why *two* bronchi (an eparterial one above, and a hyparterial one below/behind the artery) are seen in the root of the right lung, whereas the left root contains only a single (hyparterial) principal bronchus that has not yet divided.

□ Fig 18.5B — Root of the lung and pulmonary ligament (Vishram Singh — *Textbook of Anatomy Vol 1 — 4e*, p.734)

4. Relations of the root of the right lung

Direction	Structures related
Anterior	Phrenic nerve, pericardiophrenic vessels and anterior pulmonary plexus (common to both lungs); on the right side additionally the superior vena cava and a part of the right atrium
Posterior	Vagus nerve and posterior pulmonary plexus (common); on the mediastinal surface immediately behind/above the hilum lie the impressions of the azygos vein and the oesophagus
Superior	The terminal, arching part of the azygos vein , as it passes forward over the root to open into the superior vena cava
Inferior	The pulmonary ligament

5. Distinguishing features — right root vs left root

Feature	Right root	Left root
Bronchus/bronchi	Two — eparterial + hyparterial	One — single (hyparterial) principal bronchus
Position of pulmonary artery	In the mid-plane, between the two bronchi	Lies above the single bronchus
Bronchial arteries	One, from the 3rd right posterior intercostal artery	Two, both from the descending thoracic aorta
Superior relation	Terminal part of the azygos vein	Arch of the aorta
Additional posterior relation	None (only vagus/posterior plexus)	Descending thoracic aorta
Principal bronchus	Shorter (2.5 cm), wider, more vertical (25° from the trachea)	Longer (5 cm), narrower, more oblique (45° from the trachea)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the right hilum in coronal section (coat-sleeve analogy) and label, from posterior to anterior: **eparterial bronchus**, **hyparterial bronchus (bronchus intermedius)** with **bronchial vessels** and **posterior pulmonary plexus** along their posterior walls; **pulmonary artery** in the mid-plane; **superior pulmonary vein** and **inferior pulmonary vein** anteriorly; **anterior pulmonary plexus** and **bronchopulmonary lymph nodes** anteroinferiorly. Around the pedicle, label the **pleural sleeve** continuing below as the **pulmonary ligament**, and the surrounding relations — **superior vena cava** and **right atrium** (anterior), **azygos vein** arching over (superior), **vagus nerve** (posterior), and **phrenic nerve with pericardiophrenic vessels** running vertically in front of the root.

Applied / Clinical anatomy

- ▶ **Foreign-body aspiration:** the right principal bronchus is shorter, wider and more in line with the trachea (25° angle vs 45° on the left), so inhaled foreign bodies and aspirated material pass preferentially into the right lung — a key reason right-sided aspiration pneumonia and lower-lobe collapse are more common; managed by bronchoscopic removal.
- ▶ **Carina:** the keel-like carina at the tracheal bifurcation may be widened, flattened or distorted by enlarged **subcarinal (bronchopulmonary) lymph nodes** in tuberculosis or bronchogenic carcinoma — an important bronchoscopic sign of hilar lymphadenopathy.
- ▶ **Bronchogenic carcinoma / hilar mass:** a right hilar mass or enlarged lymph nodes can compress the closely related **superior vena cava**, producing SVC obstruction (facial/neck venous engorgement), or compress the **right phrenic nerve** (raised right hemidiaphragm) as both structures lie directly anterior to the root.
- ▶ **Surgical anatomy:** precise knowledge of the arrangement of bronchus, artery and veins at the hilum is essential before **pneumonectomy, lobectomy or segmentectomy** for lung cancer, tuberculosis or bronchiectasis, and for correct interpretation of hilar shadows on chest radiographs/CT.
- ▶ **Right pulmonary artery and the Glenn shunt:** the right pulmonary artery emerges from behind the superior vena cava — this intimate relationship is exploited in the surgical cavopulmonary (Glenn) anastomosis used to palliate certain congenital cyanotic heart defects.
- ▶ **Haemoptysis:** the bronchial arteries anastomose with branches of the pulmonary artery at the hilum; these anastomoses enlarge in chronic bronchial disease (e.g., bronchiectasis) and are the source of bleeding in roughly 95% of cases of haemoptysis.
- ▶ **Postural drainage:** because secretions from the right bronchial tree gravitate towards the carina when the patient lies on the left side, this position is used clinically to stimulate the cough reflex and clear right-sided bronchial secretions.

High-yield exam pointers

- ▶ Root of the right lung lies opposite the bodies of T5–T7 vertebrae; it is a pleura-invested pedicle continued below by the **pulmonary ligament**.

- ▶ Nine contents: (eparterial + hyparterial) bronchi, 1 pulmonary artery, 2 pulmonary veins, 1 bronchial artery, bronchial veins, anterior/posterior pulmonary plexuses, lymphatics, bronchopulmonary lymph nodes, areolar tissue.
- ▶ Antero-posterior order: **bronchi (posterior)** → **pulmonary artery (middle)** → **pulmonary veins (anterior)**.
- ▶ Vertical order unique to the right hilum: **eparterial bronchus** → **pulmonary artery** → **principal bronchus** → **inferior pulmonary vein**.
- ▶ Right root has **two** bronchi (because the superior lobar bronchus is given off before the hilum) — the left root has only one.
- ▶ Anterior relations: phrenic nerve, pericardiophrenic vessels, anterior pulmonary plexus, **plus SVC and right atrium** (right-specific).
- ▶ Superior relation: terminal/arching part of the **azygos vein**; Posterior: vagus nerve and posterior pulmonary plexus; Inferior: pulmonary ligament.
- ▶ Right bronchial artery — single, from the 3rd right posterior intercostal artery (left has two, from the descending thoracic aorta).
- ▶ Clinical pearls: right bronchus favours foreign-body aspiration; hilar lymphadenopathy widens the carina and can obstruct the SVC; right pulmonary artery–SVC relation underlies the Glenn shunt.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh — Textbook of Anatomy Vol 1, 4e (figure).



Sympathetic chain

Asked in: Paper I May 2011 — RGUHS MD/MS Anatomy

Definition / Introduction The sympathetic chain (sympathetic trunk) is a paired, segmented, ganglionated cord of nerve fibres that runs on either side of the vertebral column from the base of the skull to the coccyx, where the two trunks unite in the median **ganglion impar**. It is the principal relay station of the **thoracolumbar (sympathetic) outflow**, receiving preganglionic fibres only from spinal segments T1–L2 and distributing postganglionic fibres to every somatic and visceral structure of the body except the sweat glands, arrector pili muscles and blood vessels of the skeletal muscles which are supplied segmentally by cervical/lumbar/sacral ganglia via ascending/descending relay. Each side classically bears about 22 ganglia — 3 cervical, 11 thoracic, 4 lumbar and 4 sacral — joined end to end by interganglionic nerve fibres.

Development

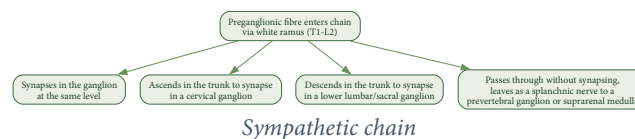
- ▶ The sympathetic chain, the prevertebral (preaortic) ganglia and the adrenal medulla are all **neural-crest derivatives**.
- ▶ Neural crest cells destined for the sympathetic chain migrate ventrally from the thoracic (and adjacent) neural tube during the **5th week** of intrauterine life and aggregate as segmental masses

on either side of the developing vertebral bodies/aorta; these masses become linked craniocaudally by fibre tracts to form the paravertebral (chain) ganglia.

- Cell bodies of preganglionic neurons remain in the intermediolateral (lateral grey) column of the spinal cord (T1–L2); cell bodies of postganglionic neurons differentiate within the migrated neural-crest masses — i.e., the paravertebral ganglia of the chain and the prevertebral ganglia around the coeliac, superior mesenteric and inferior mesenteric arteries.
- Cranial and caudal ends of the segmental masses fuse with neighbouring ones, which is why the adult cervical and sacral ganglia are fewer than the number of segments they represent (a fusion phenomenon repeated at every level of the trunk — see below).

Extent, general plan & fate of preganglionic fibres

- **Extent:** from the base of the skull (continuing intracranially as the internal carotid nerve/plexus) to the front of the coccyx (ganglion impar).
- **Position:** lies in the prevertebral fascial plane — behind the carotid sheath in the neck, in front of the rib heads in the thorax, along the medial border of psoas major in the abdomen, and medial to the anterior sacral foramina in the pelvis.
- **White rami communicantes** (preganglionic, myelinated) connect the trunk to spinal nerves **only** at T1–L2 — this is the sole site of afferent input into the whole chain.
- **Grey rami communicantes** (postganglionic, non-myelinated) pass from every ganglion of the chain (cervical to sacral) to the corresponding spinal nerve for distribution to skin (vasomotor, sudomotor, pilomotor fibres).
- A preganglionic fibre entering a ganglion via a white ramus has one of four fates:



- Postganglionic fibres from (B), (C) and (D) rejoin the corresponding spinal nerve as a grey ramus; the outflow described in (E) bypasses the chain to relay peripherally.

Regional organisation of the chain

Region	Ganglia (each side)	Formed by fusion of	Typical position
Cervical	3 — superior, middle, inferior	8 primitive cervical ganglia	Superior: front of C2/C3; middle: front of C6 (near inferior thyroid artery); inferior: C7/neck of 1st rib
Thoracic	11 (T1 fuses with inferior cervical ganglion)	12 segmental ganglia	Heads of ribs 2–10; bodies of T11–T12 vertebrae
Lumbar	4 (1st and 2nd often fused)	—	Medial margin of psoas major

Region	Ganglia (each side)	Formed by fusion of	Typical position
Sacral	4 (or 5)	—	Medial to the anterior (pelvic) sacral foramina
Ganglion impar	1, median, unpaired	Union of both chains	In front of the coccyx

Cervical part

- ▶ Extends from the base of the skull to the neck of the 1st rib, lying in front of the transverse processes of the cervical vertebrae, behind the carotid sheath and in front of the prevertebral fascia. It does **not** receive white rami from the cervical cord — its three ganglia receive preganglionic fibres only from **T1 and T2** segments via the trunk.
- ▶ **Superior cervical ganglion** — the largest (~2.5 cm, spindle-shaped), formed by fusion of the upper 4 primitive ganglia, lying opposite C2–C3. Branches: grey rami to upper four cervical nerves; internal carotid nerve (plexus on internal carotid artery, supplying dilator pupillae and Müller's muscle — smooth part of levator palpebrae superioris); external carotid branches (plexus on external carotid artery); superior cervical cardiac branch; pharyngeal branch.
- ▶ **Middle cervical ganglion** — smallest, often absent, formed by fusion of the 5th–6th ganglia; lies at the level of C6 close to the inferior thyroid artery. Gives grey rami to C5–C6, a plexus on the inferior thyroid artery, tracheal/oesophageal branches, and the middle cervical cardiac nerve.
- ▶ **Inferior cervical ganglion** — formed by fusion of the 7th–8th cervical ganglia; almost always fuses with the 1st thoracic ganglion to form the **cervicothoracic (stellate) ganglion**. Gives grey rami to C7, C8 (and often T1); plexuses on the subclavian and vertebral arteries; inferior cervical cardiac branch.
- ▶ **Ansa subclavia** — a nerve loop looping around the subclavian artery, connecting the middle and inferior cervical ganglia.

□ Fig 12.13 — Cervical sympathetic trunk and its branches (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.536)

Thoracic part

- ▶ Continuous above with the cervical part (at the neck of the 1st rib) and below with the lumbar part (deep to the medial arcuate ligament of the diaphragm).
- ▶ Usually **11 ganglia** per side (the 1st fuses with the inferior cervical ganglion). The chain crosses the neck of the 1st rib, the heads of ribs 2–10, and the bodies of T11–T12 vertebrae, descending in front of the posterior intercostal vessels and intercostal nerves.
- ▶ Each ganglion is connected to the corresponding intercostal (spinal) nerve by white and grey rami communicantes.
- ▶ **Medial branches from the upper 5 ganglia** (postganglionic) join the cardiac, pulmonary, aortic and oesophageal plexuses.
- ▶ **Medial branches from the lower 7 ganglia** (preganglionic) form the three **splanchnic nerves**:
 - **Greater splanchnic nerve** — roots from the 5th–9th ganglia; pierces the crus of the diaphragm; ends mainly in the coeliac ganglion.
 - **Lesser splanchnic nerve** — roots from the 10th–11th ganglia; ends in the aorticorenal ganglion.

- **Least splanchnic nerve** — from the 12th (last) ganglion; ends in the renal plexus.

Lumbar part

- ▶ A ganglionated chain along the sides of the lumbar vertebral bodies and intervertebral discs, commencing deep to the medial arcuate ligament as a continuation of the thoracic part and ending, in front of the ala of the sacrum beneath the common iliac vessels, by continuing as the sacral part.
- ▶ Overlapped by the **inferior vena cava on the right** and the **abdominal aorta on the left**; lumbar arteries lie deep to the chain, but lumbar veins may cross superficial to it.
- ▶ **4 ganglia** (1st and 2nd often fused) lying along the medial margin of psoas major.
- ▶ Only the upper two ganglia receive white rami (from L1, L2); all four give grey rami to the corresponding lumbar nerves.
- ▶ **Lumbar splanchnic nerves** (usually 4): the upper two join the coeliac/aortic plexuses, the lower two join the superior hypogastric plexus.

Sacral part, ganglion impar & prevertebral ganglia

- ▶ The two sacral trunks descend in the pelvis between the bodies of the sacral vertebrae and the anterior (pelvic) sacral foramina, medial to the anterior sacral foramina, and converge in front of the coccyx to form the **ganglion impar**.
- ▶ **4 (or 5) ganglia** per side. Branches: grey rami to all sacral and coccygeal nerves; small branches to the median sacral artery; **sacral splanchnic nerves** from the upper ganglia to the inferior hypogastric plexus, and from the lower ganglia to the rectum; a small branch from the ganglion impar to the coccygeal body (glomus coccygeum).
- ▶ **Prevertebral (preaortic) ganglia** — situated in front of the aorta at the origins of its unpaired branches, receiving splanchnic nerve input and supplying postganglionic fibres to the abdominal/pelvic viscera:
 - **Coeliac ganglia** (two, each divisible into an upper part and a lower **aorticorenal ganglion**) — around the coeliac trunk/SMA origin; the largest autonomic plexus (solar plexus); receives the greater splanchnic nerve (upper part) and lesser splanchnic nerve (aorticorenal part).
 - **Superior mesenteric ganglion** — at the origin of the superior mesenteric artery.
 - **Inferior mesenteric ganglion** — at the origin of the inferior mesenteric artery; contributes to the superior hypogastric plexus.

Applied / Clinical anatomy

- ▶ **Horner syndrome** — injury/interruption of the cervical sympathetic trunk (apical lung tumour, neck trauma/surgery, carotid dissection) abolishes sympathetic supply to the head and neck via the superior cervical ganglion, producing: partial ptosis (paralysis of Müller's muscle), miosis (unopposed constrictor pupillae), anhidrosis and vasodilatation/flushing of the face, enophthalmos, and loss of the ciliospinal reflex.
- ▶ **Stellate ganglion block/excision** — used for upper-limb vasospastic disease and complex regional pain; because the arteries of the upper limb receive sympathetic fibres (T2–T8) that

ascend to synapse in the stellate and middle cervical ganglia, block/removal here produces upper-limb vasodilatation.

- ▶ **Raynaud's disease** — vasospasm of digital arteries of the hand on cold exposure/emotion; treated medically or, in severe cases, by cervicothoracic (preganglionic) sympathectomy/stellate ganglion excision.
- ▶ **Buerger's disease and lower-limb ischaemia** — arteries of the lower limb are supplied by preganglionic fibres from T10–L2 relaying in lumbar/sacral ganglia; **lumbar sympathectomy** (removal of the upper 2–3 lumbar ganglia and intervening chain) produces vasodilatation and improved collateral flow; the chain's close relation to the psoas major, IVC (right) and aorta (left) is the key operative landmark.
- ▶ **Palmar/axillary/plantar hyperhidrosis** — treated by thoracic (T2/T3) or lumbar sympathectomy respectively.
- ▶ **Ganglion impar block** — used for chronic perineal/pelvic pain (visceral afferents from pelvic organs travel with the sympathetic chain).
- ▶ **Referred visceral pain** — sympathetic afferents accompanying cardiac/oesophageal/gastric branches enter the cord at T1–T5 (or T6–T9 for upper GI), explaining referral of cardiac and epigastric visceral pain to the corresponding dermatomes.
- ▶ **Excision of the first lumbar ganglion** interrupts the sympathetic supply to the vas deferens/seminal vesicles and can result in failure of emission ("dry coitus"), a recognised complication of extensive lumbar/aortic surgery.
- ▶ **Surgical landmarks:** the chain's course over the rib heads (thorax), medial border of psoas (abdomen) and in front of the sacral foramina (pelvis) is used to identify/preserve or deliberately divide it during thoracotomy, retroperitoneal and pelvic surgery.

High-yield exam pointers

- ▶ Sympathetic outflow is **thoracolumbar (T1–L2)** — white rami exist only here; grey rami exist at every level, cervical to sacral.
- ▶ Classic ganglion count per side: **3 cervical + 11 thoracic + 4 lumbar + 4 sacral = 22**, plus the unpaired ganglion impar.
- ▶ **Stellate ganglion** = fused inferior cervical + 1st thoracic ganglion; **ansa subclavia** links middle and inferior cervical ganglia around the subclavian artery.
- ▶ Three thoracic splanchnic nerves: **greater (T5–9) → coeliac ganglion**; **lesser (T10–11) → aorticorenal ganglion**; **least (T12) → renal plexus**.
- ▶ Lumbar chain relations: **IVC on the right, aorta on the left**, along the medial border of psoas major — vital operative landmark for lumbar sympathectomy.
- ▶ Ganglion impar = median unpaired terminal ganglion in front of the coccyx, formed by union of the two chains.
- ▶ Horner syndrome = ptosis + miosis + anhidrosis (± enophthalmos) from cervical sympathetic interruption.
- ▶ Prevertebral ganglia (coeliac, superior mesenteric, inferior mesenteric) receive splanchnic nerves directly, bypassing the paravertebral chain.

- All ganglia of the chain are neural-crest derivatives, migrating and fusing segmentally during the 5th week.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 1, Vol 2 and Vol 3–4 8e; AK Datta Human Anatomy Vol 1 and Vol 2; Vishram Singh Textbook of Anatomy Vol 2 and Vol 3 4e; Vishram Singh Clinical Neuroanatomy 4e; Langman's Medical Embryology (Sadler) 14e.



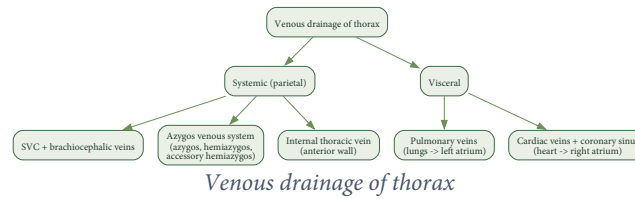
Venous drainage of thorax

Asked in: Paper I Nov 2018 — RGUHS MD/MS Anatomy

Definition / Introduction The thorax is drained by two functionally distinct venous systems. The **systemic (parietal) system** collects blood from the thoracic wall, posterior mediastinal structures, and the upper limb/head-and-neck region, channelling it via the **azygos venous system** and **brachiocephalic veins/superior vena cava (SVC)** into the right atrium. The **visceral system** drains the thoracic organs — lungs via **pulmonary veins** into the left atrium, heart via **cardiac veins** and **coronary sinus** into the right atrium. The azygos system is especially important as a collateral pathway connecting the SVC and inferior vena cava (IVC).

1. Classification of venous drainage of the thorax

Region drained	Principal vein(s)	Terminates in
Anterior thoracic wall (upper 9 spaces)	Anterior intercostal veins → internal thoracic vein & musculophrenic vein	Brachiocephalic vein
Posterior thoracic wall (posterior intercostal veins)	Azygos, hemiazygos, accessory hemiazygos veins	Azygos vein → SVC
Head, neck, upper limb	Internal jugular + subclavian veins → brachiocephalic veins	Superior vena cava
Lungs (alveolar/parenchymal blood)	Pulmonary veins (2 each side)	Left atrium
Lungs (bronchial/hilar blood)	Bronchial veins	Azygos (right)/accessory hemiazygos or left superior intercostal (left)
Heart	Cardiac veins → coronary sinus ; anterior cardiac veins; venae cordis minimae	Right atrium (via coronary sinus, directly, or into any chamber)
Oesophagus, thymus, pericardium	Oesophageal, thymic, pericardial veins	Azygos system / brachiocephalic veins



2. Superior vena cava and brachiocephalic veins

- ▶ **Brachiocephalic veins** are formed behind each sternoclavicular joint by the union of the **internal jugular vein** and the **subclavian vein**.
 - **Right brachiocephalic vein** — about **2.5 cm** long, descends almost vertically; tributaries: right vertebral, internal thoracic, inferior thyroid veins, and sometimes the 1st right posterior intercostal vein.
 - **Left brachiocephalic vein** — about **6 cm** long (over twice the right), crosses obliquely behind the manubrium in front of the great arterial branches of the aortic arch; tributaries: left vertebral, internal thoracic, inferior thyroid and left superior intercostal veins, and sometimes the 1st left posterior intercostal, thymic and pericardial veins.
- ▶ The two brachiocephalic veins unite **posterior to the lower border of the right 1st costal cartilage** to form the **superior vena cava (SVC)**.
- ▶ **SVC**: ~**7 cm** long, valveless; descends vertically and drains into the upper right atrium posterior to the 3rd right costal cartilage; its lower half lies within the fibrous pericardium. Its only large tributary is the **azygos vein** (joining its posterior aspect just above the pericardial reflection), plus small pericardial/mediastinal veins.

□ Fig 19.1 — Formation of superior vena cava (BD Chaurasia — Human Anatomy Vol 1 — 8e, p.334)

3. Azygos venous system — azygos vein

- ▶ **Formation**: most commonly by union of the **right subcostal vein** and the **right ascending lumbar vein** at the level of the **T12 vertebra** (this combined trunk may also be regarded as continuing the **azygos lumbar vein**); alternatively it may arise from the posterior aspect of the IVC near the renal veins.
- ▶ **Course**: enters the thorax through the **aortic opening of the diaphragm**, ascends in the posterior mediastinum in front of the vertebral column to the level of T4, where it **arches forward above the root of the right lung** to join the posterior aspect of the SVC, just before the SVC enters the pericardium.
- ▶ **Relations**: anteriorly, the oesophagus (right edge); posteriorly, the lower eight thoracic vertebral bodies and right posterior intercostal arteries; to the right, the right lung/pleura, right sympathetic chain and right greater splanchnic nerve; to the left, the thoracic duct and descending thoracic aorta (and, where it arches forward, the oesophagus, trachea and right vagus).
- ▶ **Tributaries**: right superior intercostal vein (union of 2nd–4th right posterior intercostal veins), 5th–11th right posterior intercostal veins, right subcostal and right ascending lumbar veins, hemiazygos vein, accessory hemiazygos vein, right bronchial vein, and oesophageal, mediastinal and pericardial veins.

- **Function:** drains the posterior thoracic and upper posterior abdominal wall, and forms a major collateral channel linking the SVC and IVC.

□ Fig 24.6 — Azygos, hemiazygos, and accessory hemiazygos veins. Numbers 1 to 11 represent posterior intercostal veins (Vishram Singh — Textbook of Anatomy Vol 1 — 4e, p.929)

4. Hemiazygos and accessory hemiazygos veins

Feature	Hemiazygos vein	Accessory hemiazygos vein
Equivalent to	Lower (inferior) part of azygos vein — mirror image	Upper (superior) part of azygos vein — mirror image
Formation	Union of left ascending lumbar vein + left subcostal vein (may arise from left renal vein)	Begins at medial end of left 4th/5th intercostal space
Course	Pierces left crus of diaphragm, ascends left of vertebral column; at T8 crosses right behind aorta, oesophagus and thoracic duct	Descends on left of vertebral column; crosses right at T7–T8, behind aorta, oesophagus and thoracic duct
Tributaries	9th–11th left posterior intercostal veins, left subcostal, left ascending lumbar, small oesophageal/mediastinal veins	5th–8th left posterior intercostal veins; occasionally left bronchial veins
Termination	Azygos vein, at lower border of T8	Azygos vein, at upper border of T8 (may also join hemiazygos vein directly)

5. Venous drainage of the thoracic wall — intercostal veins

Anterior intercostal veins (present in the upper nine spaces) are small and drain into the **internal thoracic** and **musculophrenic veins**, which in turn drain into the brachiocephalic veins. Posterior intercostal veins show an asymmetric termination pattern that is high-yield for the exam:

Posterior intercostal vein	Right side drains into	Left side drains into
1st	Right brachiocephalic vein	Left brachiocephalic vein
2nd, 3rd, 4th	Unite to form right superior intercostal vein → azygos vein	Unite to form left superior intercostal vein → left brachiocephalic vein
5th–8th	Azygos vein	Accessory hemiazygos vein
9th–11th and subcostal	Azygos vein	Hemiazygos vein

6. Venous drainage of thoracic viscera

- **Lungs:** oxygenated blood returns via **two pulmonary veins on each side** (superior and inferior) directly into the **left atrium** — the only veins in the body carrying oxygenated blood. Bronchial/hilar blood is drained partly by **bronchial veins**: the deep set joins a pulmonary vein or the left atrium, the superficial set drains into the **azygos vein (right)** and the **left superior intercostal/accessory hemiazygos vein (left)**.

- ▶ **Heart:** most cardiac venous blood collects in the **coronary sinus** (2–3 cm, in the posterior atrioventricular groove), opening into the right atrium between the IVC orifice and tricuspid valve, guarded by the **Thebesian valve**. Tributaries: **great, middle and small cardiac veins**, **oblique vein of the left atrium**, **left marginal vein**, **inferior vein of the left ventricle**. **Anterior cardiac veins** bypass the sinus, opening directly into the right atrium; minute **venae cordis minimae** (**Thebesian veins**) drain the subendocardium directly into any chamber.
- ▶ **Oesophagus, thymus, pericardium:** thoracic oesophageal veins drain mainly to the azygos/hemiazygos system, but the lowest part also drains toward the **left gastric vein** — a clinically vital **porto-systemic anastomosis**. Thymic and pericardial veins drain chiefly into the internal thoracic and left brachiocephalic veins.

□ Fig 4.61 — Cardiac veins. The great, middle, and small cardiac veins; the oblique vein of the left atrium and the left posterior ventricular vein drain into the coronary sinus (Moore — Clinically Oriented Anatomy — 9e, p.653)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A composite schematic of the systemic thoracic venous system, labelling:

- ▶ Right and left brachiocephalic veins (formed behind each sternoclavicular joint) uniting to form the SVC, which descends to open into the right atrium
- ▶ **Azygos vein** — entering through the aortic opening of the diaphragm, ascending anterior to the vertebral bodies, arching forward over the root of the right lung at T4, and joining the posterior aspect of the SVC
- ▶ **Hemiazygos** and **accessory hemiazygos veins** on the left of the vertebral column, both crossing at T8 to join the azygos vein
- ▶ Posterior intercostal veins (numbered 1–11) on both sides, with arrows showing the termination pattern (1st → brachiocephalic; 2nd–4th → superior intercostal vein; 5th–8th → azygos/accessory hemiazygos; 9th–11th → azygos/hemiazygos)
- ▶ IVC, thoracic duct, oesophagus and descending thoracic aorta as adjacent posterior-mediastinal landmarks

Applied / Clinical anatomy

- ▶ **SVC obstruction (SVC syndrome):** usually from a mediastinally invasive right upper-lobe bronchogenic carcinoma or paratracheal lymphadenopathy; causes headache, facial/neck venous congestion and oedema, with collateral flow diverted chiefly through the **azygos system** (caval–caval anastomosis).
- ▶ **IVC interruption/agenesis:** since azygos/hemiazygos veins are continuous with the ascending lumbar veins, congenital absence or thrombosis of the IVC is compensated by **azygos continuation** — often an incidental radiological finding.
- ▶ **Porto-systemic anastomosis at the lower oesophagus:** in **portal hypertension**, retrograde flow from the left gastric vein into the oesophageal (azygos-system) veins dilates the submucosal plexus, producing **oesophageal varices** — a leading cause of haematemesis.
- ▶ **Azygos lobe:** a rare anomaly in which a high azygos arch invaginates the medial right upper lobe within an accessory "azygos fissure", seen as an oval "nodule" on a chest radiograph.

- ▶ **Central venous access/pacemaker leads:** the SVC's constant relations make it the standard route for central lines and pacemaker/ICD leads; the coronary sinus ostium is used for retrograde cardioplegia and CRT lead placement.
- ▶ **Persistent left SVC** (failed obliteration of the left common cardinal vein) drains via an enlarged coronary sinus — an incidental finding at central-line placement or cardiac surgery.

High-yield exam pointers

- ▶ Two systems: **systemic** (azygos + SVC/brachiocephalic veins, → right atrium) and **visceral** (pulmonary veins → left atrium; cardiac veins/coronary sinus → right atrium).
- ▶ **Azygos vein:** forms at T12 (right subcostal + right ascending lumbar veins); arches over right lung root at T4; joins SVC posteriorly — the key SVC–IVC collateral channel.
- ▶ **Hemiazygos** joins azygos at **lower border of T8**; **accessory hemiazygos** joins at **upper border of T8**.
- ▶ **Brachiocephalic veins:** right ≈ 2.5 cm, left ≈ 6 cm; unite behind right 1st costal cartilage to form SVC (≈ 7 cm, valveless).
- ▶ Posterior intercostal vein termination: 1st → brachiocephalic vein; 2nd–4th → superior intercostal vein; 5th–8th → azygos (R)/accessory hemiazygos (L); 9th–11th → azygos (R)/hemiazygos (L).
- ▶ **Coronary sinus** opens into the right atrium between the IVC orifice and tricuspid valve, guarded by the Thebesian valve; receives great, middle and small cardiac veins, oblique vein of left atrium, and left marginal/inferior left-ventricular veins.
- ▶ **Anterior cardiac veins** and **venae cordis minimae** bypass the coronary sinus, draining directly into cardiac chambers.
- ▶ Pulmonary veins (4 total, 2 each side) are the only veins carrying oxygenated blood — into the left atrium.
- ▶ Clinically vital: SVC obstruction, azygos continuation of IVC, and oesophageal varices from porto-systemic anastomosis at the lower oesophagus.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; Vishram Singh — Textbook of Anatomy Vol 1, 4e; Moore's Clinically Oriented Anatomy 9e.

♦ ♦ ♦

Abdomen

♦ ♦ ♦

Lesser sac

Asked in: Paper I May 2009 · Paper I Sep 2007 (3×) — RGUHS MD/MS Anatomy

Definition / Introduction The lesser sac (omental bursa) is the smaller of the two compartments of the peritoneal cavity — a large diverticulum of the greater (main) peritoneal cavity that lies behind the stomach, the lesser omentum and the caudate lobe of the liver, and in front of the pancreas, left kidney/suprarenal, splenic vessels and diaphragm. It develops from the right side of the dorsal mesogastrium and is therefore classed as part of the right supramesocolic compartment. It is closed on all sides except at its upper right border, where a single narrow opening — the epiploic foramen (of Winslow) — connects it to the greater sac. Functionally, the fluid film within the lesser sac allows the stomach to distend and glide freely against the structures of its "bed" without compressing them.

1. Boundaries of the Lesser Sac

Wall/border	Composition
Anterior wall	Posterior (peritoneal) layer of the lesser omentum; peritoneum over the posterior surface of the stomach and first part of duodenum; the posterior, upper part of the anterior (two-layered) sheet of the greater omentum; peritoneum over the caudate lobe/process of the liver on the right
Posterior wall	From below upward: the anterior peritoneal layer of the posterior sheet of the greater omentum overlying the transverse mesocolon; then peritoneum covering part of the head and the whole neck and body of pancreas, the medial part of the upper pole of the left kidney, most of the left suprarenal gland, the start of the abdominal aorta, the coeliac trunk and part of the diaphragm. The inferior phrenic, splenic, left gastric and common hepatic arteries lie partly behind the bursa — these structures together form the "stomach bed"
Superior border	Narrow; lies between the right side of the oesophagus and the upper end of the fissure for the ligamentum venosum (the superior recess); here the posterior-wall peritoneum reflects anteriorly from the diaphragm to join the posterior layer of the lesser omentum
Inferior border	Runs along the line of fusion of the two layers of the greater omentum, from the gastrosplenic ligament (left) to the peritoneal fold behind the first part of the duodenum (right)

Wall/border	Composition
Right border	Peritoneum over the head/neck of pancreas reflected onto the inferior aspect of the first part of the duodenum, ascending along the medial side of the gastroduodenal artery to join the floor of the epiploic foramen around the hepatic artery proper — the epiploic foramen interrupts this border; above the foramen, the border is the peritoneal reflection from the diaphragm to the right margin of the caudate lobe, crossing the inferior vena cava
Left border	From the left end of the root of the transverse mesocolon, formed by the inner peritoneal layers of the splenorenal and gastrosplenic ligaments (the sac between these two ligaments = splenic recess); above the spleen the two ligaments merge to form the gastrophrenic ligament

2. Recesses (Subdivisions) of the Lesser Sac

A crescentic **gastropancreatic fold** — raised below by the common/proper hepatic artery and above by the left gastric artery as they run from the posterior abdominal wall towards the lesser curvature — indents the sac and, when prominent, divides it into:

- **Superior recess** — lies behind the lesser omentum and liver, encloses the caudate lobe, extends up into the fissure for the ligamentum venosum, and lies against the right crus of the diaphragm posteriorly. The part of this recess directly behind the lesser omentum is called the **vestibule of the lesser sac**.
- **Inferior recess** — lies between the stomach and pancreas, contained within the double sheet (fused layers) of the greater omentum. Its right part is the clinically important **subpyloric space**.
- **Splenic recess** — the portion of the sac between the gastrosplenic and splenorenal (lienorenal) ligaments, extending to the hilum of the spleen.

3. Epiploic Foramen (Foramen of Winslow)

This is the sole communication between the lesser and greater sacs — a short, vertical slit about **3 cm** in height in the adult, lying behind the free right border of the lesser omentum, roughly at the level of the **T12 vertebra**.

Boundary	Structure
Anterior	Hepatoduodenal ligament (free right margin of the lesser omentum), carrying the portal triad — bile duct (anteriorly, right), hepatic artery proper (anteriorly, left), portal vein (posteriorly) — plus autonomic nerves and lymphatics
Posterior	Peritoneum over the inferior vena cava
Superior (roof)	Peritoneum over the caudate process of the liver

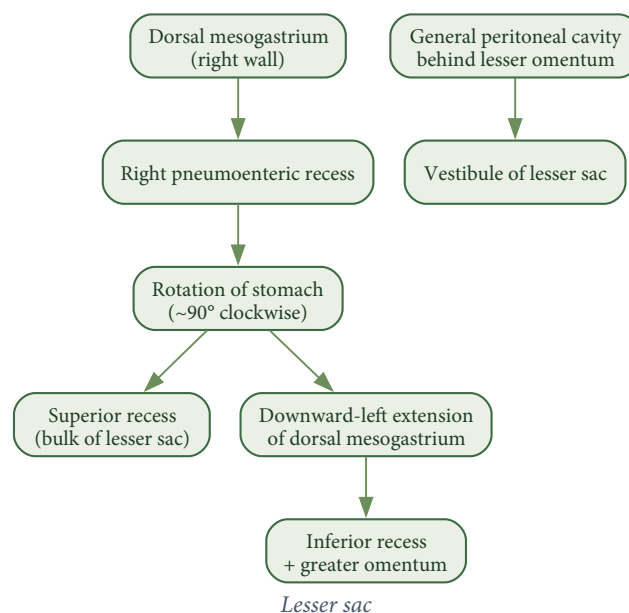
Boundary	Structure
Inferior (floor)	Peritoneal reflection over the upper border of the first part of the duodenum as it passes above the head of pancreas

To the right, the foramen is continuous with the **hepatorenal pouch (of Morison)** of the greater sac; to the left it opens into the lesser sac proper through a short passage, the **vestibule**, between the caudate process above and the first part of duodenum below. The anterior and posterior walls of the foramen are normally apposed, which is why fluid collections can remain confined to either the greater or the lesser sac.

□ Fig 5.29 — Omental (epiploic) foramen and omental bursa. The index finger is passing from the great (Moore — Clinically Oriented Anatomy — 9e, p.768)

4. Development

- ▶ The lesser sac develops from the **right pneumoenteric recess** in the right wall of the dorsal mesogastrium; with rotation of the stomach (approximately 90° clockwise about its longitudinal axis), this recess enlarges to form the greater part of the lesser sac, except for the vestibule.
- ▶ The **vestibule** develops separately from the general peritoneal cavity lying behind the lesser omentum, established after the rotation of the stomach.
- ▶ The **inferior recess** forms by a downward-and-leftward extension (invagination) of the dorsal mesogastrium — the same process that forms the greater omentum — during rotation of the stomach.
- ▶ Because the sac originates on the right side of the dorsal mesogastrium, it is grouped with the right supramesocolic compartment of the peritoneal cavity.



DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a sagittal/oblique section through the upper abdomen showing the lesser sac opened from the right, with these labels: **stomach** (retracted anteriorly), **lesser omentum** (cut edge, showing posterior layer), **caudate lobe of liver**, **epiploic foramen** with its four boundaries labelled (hepatoduodenal ligament with bile duct/hepatic artery/portal vein anteriorly, inferior vena cava posteriorly, caudate process superiorly, first part of duodenum inferiorly), **hepatorenal pouch** (of Morison), **vestibule**, **superior recess**, **inferior recess**, **splenic recess**, **gastropancreatic fold**, **pancreas** (neck and body), **splenorenal ligament**, **gastrosplenic ligament**, **spleen**, **transverse mesocolon**, and **greater omentum**.

Applied / Clinical anatomy

- ▶ **Pancreatitis** is the commonest cause of a fluid collection within the lesser sac — a pseudocyst typically forms in the inferior recess, separated from the pancreas only by the peritoneal lining.
- ▶ Other causes of lesser-sac collections: bleeding from trauma or a ruptured splenic artery aneurysm, and **perforation of a posterior gastric ulcer** — the leaking fluid may seal the epiploic foramen by adhesions, so the bursa becomes progressively distended and needs tube drainage; if the foramen remains patent, fluid tracks through it into the hepatorenal pouch.
- ▶ **Internal herniation**: small intestine, caecum, transverse colon or even the gallbladder can herniate through the epiploic foramen into the lesser sac, causing obstruction or strangulation. Because vital structures (portal triad, IVC) surround the foramen, it cannot be safely enlarged at operation — a strangulated internal hernia here is therefore approached and released through the greater omentum, not by incising the foramen itself.
- ▶ **Subpyloric space** (the right part of the inferior recess) is a dependent site where free tumour cells from mucinous malignancies may settle by gravity, occasionally producing gastric outlet obstruction.
- ▶ **Pringle manoeuvre**: temporary compression of the contents of the free edge of the lesser omentum (hepatoduodenal ligament — hepatic artery and portal vein) controls haemorrhage during liver trauma or hepatic resection.
- ▶ Surgical access to the lesser sac (e.g. to drain a pancreatic pseudocyst or débride pancreatic necrosis) is through the greater omentum anteriorly, not via the epiploic foramen.
- ▶ The lesser sac's fluid film prevents the full stomach from compressing the pancreas, kidneys, suprarenal glands and great vessels that lie behind it.
- ▶ On contrast CT, lesser-sac collections appear as a fluid collection wedged between the stomach and pancreas, distinguishable from free (greater-sac) ascites.

High-yield exam pointers

- ▶ Lesser sac = omental bursa; the smaller peritoneal compartment, connected to the greater sac **only** through the epiploic foramen (of Winslow).
- ▶ Develops from the **right pneumoenteric recess** of the dorsal mesogastrium — hence classified with the right supramesocolic compartment.

- ▶ Epiploic foramen: vertical slit, ~3 cm, at the level of T12; boundaries — hepatoduodenal ligament (portal triad) anteriorly, IVC posteriorly, caudate process superiorly, first part of duodenum inferiorly.
- ▶ Portal triad in the free edge of the lesser omentum: bile duct (right), hepatic artery (left), portal vein (posterior) — basis of the Pringle manoeuvre.
- ▶ Three recesses — superior (encloses caudate lobe; contains the vestibule), inferior (between stomach and pancreas; contains the subpyloric space), and splenic (between gastrosplenic and splenorenal ligaments) — separated by the gastropancreatic fold.
- ▶ Continuous on the right with the **hepatorenal pouch (of Morison)** of the greater sac.
- ▶ Clinical favourites: pancreatitis-related pseudocyst, posterior gastric ulcer perforation, and internal herniation through the epiploic foramen.
- ▶ Surgical rule: the epiploic foramen must never be forcibly enlarged (vital structures around it) — approach the lesser sac through the greater omentum instead.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Moore's Clinically Oriented Anatomy 9e (figure).



Give an account of Peritoneal recesses

Asked in: Paper I Oct 2010 · Paper I Oct 2009 (3×) — RGUHS MD/MS Anatomy

Definition / Introduction — Peritoneal recesses (peritoneal fossae) are small pockets or pouches of the peritoneal cavity, enclosed by small, inconstant folds of peritoneum that are usually raised over a blood vessel, duct or developmental remnant. They characteristically occur at transitional zones between the mobile (intraperitoneal) and the fixed, secondarily retroperitoneal parts of the gut — hence they cluster around the duodenojejunal flexure, the ileocaecal junction, and the apex of the sigmoid mesocolon. They are best marked in the fetus and infant, and many are obliterated by adulthood. Apart from the lesser sac, which is always present, all are inconstant; their sole clinical importance is as a potential orifice for internal (peritoneal) herniation and strangulation.

Classification of peritoneal recesses



Give an account of Peritoneal recesses

- ▶ **Lesser sac (omental bursa)** — the largest recess; always present.
- ▶ **Duodenal fossae** — up to six named recesses around the duodenojejunal junction.
- ▶ **Caecal fossae** — three named recesses around the ileocaecal junction, plus inconstant shallow paracaecal/paracolic depressions.
- ▶ **Intersigmoid recess** — a single recess behind the apex of the sigmoid mesocolon.

Recesses of the lesser sac (omental bursa)

□ Fig 18.24 — The lesser sac with its opening and recesses (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.312)

- ▶ The lesser sac lies behind the stomach, lesser omentum and caudate lobe of the liver; it is closed all around except at the **epiploic (omental) foramen of Winslow**, through which it communicates with the greater sac.
- ▶ Two peritoneal folds subdivide it further:
 - The **right gastropancreatic fold**, raised by the common hepatic artery.
 - The **left gastropancreatic fold**, raised by the left gastric artery.
 - Together these folds demarcate a **superior recess** (behind the lesser omentum and liver; its part behind the lesser omentum is the "vestibule") and an **inferior recess** (behind the stomach, within the layers of the greater omentum).
- ▶ The **splenic recess** lies between the two layers of the gastrosplenic ligament and the lienorenal (splenorenal) ligament, extending the lesser sac up to the splenic hilum.
- ▶ Though large, the lesser sac is **not classified as a "peritoneal recess" in the strict sense** used for the duodenal/caecal fossae — it is a constant, named subdivision of the peritoneal cavity, but is conventionally described alongside the recesses because it too can be a site of internal herniation (small intestine, caecum, transverse colon or gallbladder migrating through the epiploic foramen).

Duodenal recesses

Several inconstant peritoneal folds around the third/fourth parts of the duodenum and the duodenojejunal flexure enclose up to six named recesses, thought to arise from minor variations of gut rotation and fixation.

□ Fig 18.32 — Duodenal recesses of peritoneum (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.316)

Recess	Incidence	Position	Depth	Orifice faces	Bounding fold / contents
Superior duodenal	~50%	Left of 4th part of duodenum, level of L2	~2 cm	Downwards	Crescentic superior duodenal fold; inferior mesenteric vein lies behind its lateral end
Inferior duodenal	~75%	Left of 4th part, level of L3	~3 cm	Upwards	Sharp-edged, avascular inferior duodenal fold; often shares an orifice with the superior recess

Recess	Incidence	Position	Depth	Orifice faces	Bounding fold / contents
Paraduodenal	~20%	Left and slightly behind 4th part of duodenum	Variable	To the right	Falciform fold whose free right edge carries the inferior mesenteric vein and ascending branch of left colic artery — site of the left paraduodenal hernia
Retroduodenal	Occasional	Behind 3rd/4th parts, in front of aorta	8–10 cm (largest)	To the left	Wide orifice flanked by duodenoparietal folds
Duodenojejunal (mesocolic)	~20%	Left of aorta, between duodenojejunal junction and root of transverse mesocolon	~3 cm	Down and to the right	Bounded above by pancreas, left by kidney, below by left renal vein
Mesentericoparietal (of Waldeyer)	~1%	Below 3rd part of duodenum, invaginating upper mesentery	—	To the left	Fold raised by the superior mesenteric vessels — site of the rare right paraduodenal hernia

Caecal recesses

Peritoneal folds around the caecum and terminal ileum enclose three named recesses.

 Fig 18.33 — *Caecal recesses of peritoneum* (BD Chaurasia — *Human Anatomy Vol 2* — 8e, p.316)

Recess	Boundaries	Orifice faces	Note
Superior ileocaecal recess	In front — vascular fold carrying the anterior caecal vessels; behind — ileal mesentery; below — terminal ileum; right — ileocaecal junction	Left	Best developed in children; may be absent in the aged/obese

Recess	Boundaries	Orifice faces	Note
Inferior ileocaecal recess	Bounded by the ileocaecal fold ("bloodless fold of Treves") running from the ileum to the mesoappendix	Down and to the left	Fold sometimes carries small vessels despite its name; can be mistaken for the mesoappendix when the appendix is retrocaecal
Retrocaecal recess	In front — caecum (and sometimes proximal ascending colon); behind — parietal peritoneum; sides — caecal (parietocolic) folds	Downwards	Large enough to admit a finger; frequently lodges the vermiform appendix (retrocaecal appendix)

- In addition, one or more shallow **paracaecal/paracolic recesses** may be present as simple depressions within the right paracolic gutter; these are not sites of herniation but are common locations for **abscess formation after acute appendicitis**.

Intersigmoid recess

- Lies behind and below the apex of the V-shaped attachment of the sigmoid mesocolon; its orifice opens downwards.
- Its posterior wall is the parietal peritoneum of the posterior abdominal wall covering the **left ureter** as it crosses the bifurcation of the left common iliac artery — making it a useful surgical landmark to locate the ureter.
- Constantly present in the fetus and early infancy; frequently disappears with age. A rare site of internal hernia.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- **Lesser sac** (Fig. 18.24 style): label epiploic foramen, superior recess, inferior recess, splenic recess, outline of omental bursa relative to stomach/liver.
- **Duodenal recesses** (Fig. 18.32 style): duodenum (3rd–4th part), duodenojejunal recess, superior duodenal recess + superior duodenal fold, inferior duodenal recess, paraduodenal recess + inferior mesenteric vein, retroduodenal recess, mesentericoparietal recess + superior mesenteric vessels.
- **Caecal recesses** (Fig. 18.33 style): ascending colon, ileum, branch of ileocolic artery, superior ileocaecal recess, inferior ileocaecal recess (fold of Treves), vermiform appendix, retrocaecal recess, caecum.
- **Intersigmoid recess**: sigmoid colon, apex of sigmoid mesocolon, intersigmoid recess (orifice facing down), left ureter and left common iliac artery bifurcation posterior to it.

Applied / Clinical anatomy

- **Internal hernia** is protrusion of a viscus through a peritoneal recess, foramen or cul-de-sac within the confines of the peritoneal cavity; the recess is typically enlarged and its aperture

narrowed compared to normal. The commonest sites, in descending order, are **paraduodenal**, then **pericaecal**, then through the **epiploic foramen**.

- ▶ A loop of bowel trapped in a recess may obstruct or **strangulate** at the constricted orifice; the peritoneal fold forming the recess must be considered (and often divided) during surgical repair.
- ▶ The **retrocaecal appendix** lies in the retrocaecal recess — the commonest site of anomalous appendix position and a cause of atypical (loin/flank) pain in appendicitis.
- ▶ The **bloodless fold of Treves** bounding the inferior ileocaecal recess is a key operative landmark during appendicectomy, though it occasionally does carry small vessels that bleed if divided carelessly.
- ▶ **Paracaecal recesses** are frequent sites of localized abscess formation following acute appendicitis.
- ▶ The **superior and inferior duodenal recesses** are recognized sites of occult peritoneal metastatic deposits and must be specifically examined during cytoreductive surgery for peritoneal malignancy.
- ▶ The **intersigmoid recess** overlies the left ureter crossing the common iliac bifurcation — a landmark used to identify and protect the ureter during sigmoid colectomy.
- ▶ A posterior gastric ulcer may perforate into the **lesser sac**; leaking fluid may track through the epiploic foramen to the hepatorenal (Morison's) pouch, or, if the foramen is sealed by adhesions, distend the lesser sac as a localized collection drainable via the lesser omentum.
- ▶ Cross-sectional imaging (CT/MRI) now identifies internal hernias by clustered, displaced small-bowel loops with crowded, engorged mesenteric vessels at the neck of the affected recess.

High-yield exam pointers

- ▶ Peritoneal recesses occur at **transitional zones** between mobile and fixed gut segments; best seen in the fetus, mostly obliterated in adults.
- ▶ **Lesser sac** = largest recess, constant; communicates with the greater sac via the **epiploic foramen of Winslow**; subdivided by gastropancreatic folds into superior, inferior and splenic recesses.
- ▶ **Duodenal recesses (6)**: superior duodenal (~50%), inferior duodenal (~75%), paraduodenal (~20%, left paraduodenal hernia), retroduodenal (largest, 8–10 cm), duodenojejunal/mesocolic (~20%), mesentericoparietal of Waldeyer (~1%, right paraduodenal hernia).
- ▶ **Caecal recesses (3)**: superior ileocaecal, inferior ileocaecal (fold of Treves), retrocaecal (houses appendix) ± paracaecal depressions.
- ▶ **Intersigmoid recess** — behind apex of sigmoid mesocolon; overlies left ureter at the common iliac bifurcation.
- ▶ Commonest sites of internal hernia, in order: **paraduodenal > pericaecal > epiploic foramen**.
- ▶ Clinical relevance: internal hernia/strangulation, retrocaecal appendicitis, post-appendicectomy paracaecal abscess, occult peritoneal metastases in duodenal recesses, ureteric landmark at the intersigmoid recess.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e.



Inguinal canal

Asked in: Paper I Nov 2018 · Paper I Oct 2009 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction The inguinal canal is an oblique intermuscular passage, about 4 cm long, situated in the lower part of the anterior abdominal wall just above the medial half of the inguinal ligament. It extends from the deep (internal) inguinal ring laterally to the superficial (external) inguinal ring medially, and transmits the spermatic cord in the male (round ligament of the uterus in the female) together with the ilioinguinal nerve. The canal marks the pathway traversed by the gubernaculum and the processus vaginalis during testicular descent, and its four walls and two obliquely-placed rings constitute a mechanically reinforced yet inherently weak zone — the commonest site of external abdominal herniation.

Location, extent and dimensions

Feature	Description
Location	Lower part of anterior abdominal wall, just above the medial half of the inguinal ligament
Extent	From the deep inguinal ring (lateral) to the superficial inguinal ring (medial)
Length	About 4 cm (1.5 in); Gray's Anatomy gives an adult range of 3–6 cm, size varying with age
Direction	Downwards, forwards and medially
Sex difference	Larger and more prominent in males (transmits the bulkier spermatic cord) than in females

Boundaries of the inguinal canal

Wall	Composition
Anterior wall	Throughout its whole extent: skin, superficial fascia, aponeurosis of external oblique. Reinforced in its lateral one-third by the fleshy fibres of internal oblique.
Posterior wall	Throughout its whole extent: fascia transversalis, extraperitoneal tissue, parietal peritoneum. Reinforced in its medial two-thirds by the conjoint tendon, and at its extreme medial end by the reflected part of the inguinal ligament.

Wall	Composition
Roof	Arched fibres of internal oblique and transversus abdominis, which fuse medially to form the conjoint tendon.
Floor	Grooved (gutter-like) upper surface of the inguinal ligament; reinforced at the medial end by the lacunar ligament.

Because the anterior wall is strongest where the posterior wall is weakest (and vice versa), the canal has separate, alternating anterior and posterior walls that create a protective "shutter" arrangement rather than one continuous weak tube.

The two inguinal rings

- **Deep (internal) inguinal ring** — an oval opening in the fascia transversalis, situated about 1.2 cm above the mid-inguinal point (the midpoint of a line joining the anterior superior iliac spine and the pubic symphysis), immediately lateral to the inferior epigastric artery. It is guarded anteriorly by the fleshy fibres of internal oblique and gives origin to the internal spermatic fascia. (Classically distinguished from the midpoint of the inguinal ligament — ASIS to pubic tubercle — which marks the femoral artery entering the thigh; the two points lie close together and are occasionally used loosely for each other.)
- **Superficial (external) inguinal ring** — a triangular hiatus in the aponeurosis of external oblique, just above and lateral to the pubic crest; about 2.5 cm long and 1.2 cm broad at its base. The base is formed by the pubic crest; the two margins (crura) — a lateral/inferior crus attached to the pubic tubercle and a medial/superior crus attached to the front of the pubic symphysis — are united at the lateral apex by **intercrural fibres**. It gives origin to the external spermatic fascia.

Contents of the inguinal canal

- **Spermatic cord** in the male, or the **round ligament of the uterus** in the female — enters the canal through the deep ring and leaves through the superficial ring.
- **Ilioinguinal nerve** — enters the canal through the interval between external and internal oblique (not through the deep ring), runs on the outer surface of the cord, and leaves through the superficial ring.
- *Golden fact:* of all the contents of the inguinal canal, the ilioinguinal nerve is the only one that does **not** lie within the spermatic cord proper.

Constituents of the spermatic cord ("3-3-3" mnemonic):

Group	Structures
3 arteries	Testicular artery, artery to the ductus (vas) deferens, cremasteric artery
3 nerves	Genital branch of the genitofemoral nerve, sympathetic (autonomic) plexus around the artery to the vas, visceral afferent fibres

Group	Structures
3 others	Ductus deferens, pampiniform plexus of veins, remains of the processus vaginalis
+	Lymphatics draining the testis

Coverings of the spermatic cord (from within outwards):

Layer	Derived from
Internal spermatic fascia	Fascia transversalis — covers the cord throughout its length
Cremasteric fascia (with cremaster muscle)	Internal oblique and transversus abdominis — covers the cord below the level of these muscles
External spermatic fascia	Aponeurosis of external oblique — covers the cord below the superficial inguinal ring

□ Fig 4.5 — Boundaries of the inguinal canal: (A) anterior view (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.202)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a coronal/oblique schematic of the right inguinal region with:

- ▶ Anterior superior iliac spine and pubic tubercle (bony landmarks)
- ▶ Inguinal ligament (grooved floor)
- ▶ Deep inguinal ring (in fascia transversalis, above mid-inguinal point, lateral to inferior epigastric artery)
- ▶ Superficial inguinal ring (in external oblique aponeurosis, with medial and lateral crura + intercrural fibres)
- ▶ Conjoint tendon (medial part of posterior wall/roof)
- ▶ Internal oblique and transversus abdominis arching fibres (roof)
- ▶ Inferior epigastric vessels (medial to deep ring)
- ▶ Spermatic cord/round ligament traversing the canal, with ilioinguinal nerve running outside it
- ▶ Lacunar ligament (medial end of floor)
- ▶ Hesselbach's triangle outlined on the posterior wall

Mechanism preventing herniation

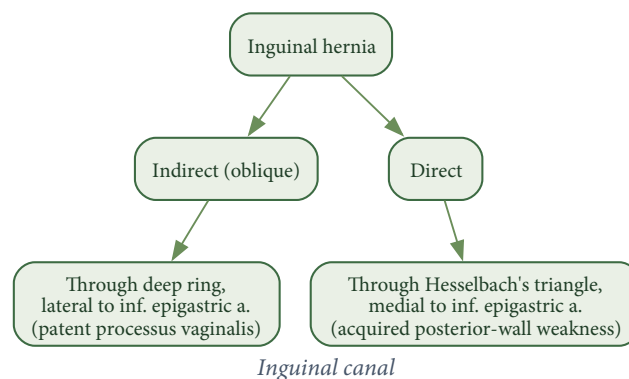
- ▶ **Obliquity of the canal / flap-valve mechanism** — the deep and superficial rings do not lie directly opposite each other; a rise in intra-abdominal pressure approximates the anterior and posterior walls, obliterating the passage.
- ▶ **Guarding of the superficial ring** from behind by the conjoint tendon and the reflected part of the inguinal ligament.
- ▶ **Guarding of the deep ring** from the front by the fleshy fibres of internal oblique.

- **Shutter mechanism of internal oblique** — it forms the anterior wall, roof and part of the posterior wall; on contraction, roof approximates floor like a shutter (transversus abdominis assists).
- **Ball-valve mechanism of cremaster** — contraction helps the spermatic cord plug the superficial ring.
- **Slit-valve mechanism of external oblique** — contraction approximates the two crura of the superficial ring; integrity is reinforced by the intercrural fibres.
- **Hormonal tone** of the inguinal musculature may also contribute.

These mechanisms act together during coughing, sneezing and lifting so that the canal is obliterated and herniation is normally prevented.

Development (brief)

The inguinal canal represents the pathway of the **gubernaculum**, extending from the caudal pole of the developing gonad to the labioscrotal swelling. The **processus vaginalis**, a tubular peritoneal diverticulum, precedes the descending testis through the canal and normally obliterates after birth except for the part forming the tunica vaginalis. The canal is very short in early life; as the pelvis widens, the deep ring shifts laterally and the canal attains its adult length and obliquity.



Applied / Clinical anatomy

- **Hesselbach's (inguinal) triangle** — bounded laterally by the inferior epigastric artery, medially by the lateral border of rectus abdominis, and inferiorly by the inguinal ligament; the site through which a direct inguinal hernia protrudes.
- **Indirect vs direct inguinal hernia:**

Feature	Indirect (oblique) hernia	Direct hernia
Cause	Congenital — persistence of processus vaginalis, or acquired weakening of deep ring	Acquired weakness of posterior wall (Hesselbach's triangle)
Relation to inferior epigastric vessels	Lateral	Medial
Path	Through deep ring → canal → superficial ring (may descend into scrotum)	Bulges directly forward through/near the superficial ring

Feature	Indirect (oblique) hernia	Direct hernia
Age group	Infants, children, young adults	Older men
Neck of sac	Narrow	Wide
Obstruction/strangulation	Common (narrow neck)	Uncommon (wide neck)
On standing	Comes out from lateral to medial	Comes out directly forward
Internal ring occlusion test	Controlled — swelling does not reappear	Not controlled — swelling still appears

- ▶ **Coverings of hernial sac:** indirect hernia — extraperitoneal tissue, internal spermatic fascia, cremasteric fascia, external spermatic fascia, skin (i.e., the same layers as the spermatic cord); direct hernia — extraperitoneal tissue, fascia transversalis ($\pm$ conjoint tendon medially), external spermatic fascia, skin.
- ▶ **Surface marking** — deep ring at ~1.2 cm above the mid-inguinal point; superficial ring just above and lateral to the pubic tubercle. Used clinically for the internal (deep) ring occlusion test to differentiate indirect from direct hernia.
- ▶ **Iliopubic tract**, a thickening of the fascia transversalis parallel to the inguinal ligament, is an important landmark in open and laparoscopic (TEP/TAPP) inguinal hernia repair.
- ▶ **Congenital/infantile hydrocele and encysted hydrocele of the cord** result from incomplete obliteration of the processus vaginalis along the canal; an **undescended testis (cryptorchidism)** may become arrested within the canal.
- ▶ **Varicocele** is a dilatation of the pampiniform plexus, palpable through/below the superficial ring.
- ▶ Femoral hernia is comparatively more frequent in women owing to a wider pelvis and femoral canal, while inguinal hernia predominates in men because of the larger canal transmitting the spermatic cord.
- ▶ The upright posture of humans (forward growth of the iliac crest into external oblique, altered origin of internal oblique/transversus, widened crural interval) is held responsible for inguinal and femoral herniation being essentially unique to man among mammals.

High-yield exam pointers

- ▶ Canal $\approx$ 4 cm long (Gray's range 3–6 cm); runs from deep ring to superficial ring, downwards-forwards-medially, just above the medial half of the inguinal ligament.
- ▶ Anterior wall = EO aponeurosis (+ IO laterally); posterior wall = fascia transversalis (+ conjoint tendon medially); roof = arching IO + transversus fibres; floor = grooved inguinal ligament (+ lacunar ligament medially).
- ▶ Deep ring: oval opening in fascia transversalis, 1.2 cm above mid-inguinal point, lateral to inferior epigastric artery.
- ▶ Superficial ring: triangular gap in EO aponeurosis above the pubic crest, with medial and lateral crura joined by intercrural fibres.
- ▶ Only the ilioinguinal nerve, among the canal's contents, lies outside the spermatic cord.

- ▶ Three coverings of the cord = internal spermatic fascia (from fascia transversalis), cremasteric fascia (from IO + transversus), external spermatic fascia (from EO) — corresponding exactly to the three layers of an indirect hernial sac.
- ▶ Hesselbach's triangle = inferior epigastric artery (lateral) + lateral border of rectus abdominis (medial) + inguinal ligament (inferior) — site of direct hernia.
- ▶ Indirect hernia is lateral to the inferior epigastric vessels and follows a patent processus vaginalis (young patients, narrow neck); direct hernia is medial to these vessels through an acquired posterior-wall defect (older patients, wide neck).
- ▶ Protective mechanisms: obliquity/flap valve, shutter mechanism of internal oblique, ball-valve of cremaster, slit-valve of intercrural fibres.
- ▶ Iliopubic tract is the key surgical landmark in laparoscopic hernia repair.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e (figure); IB Singh — Textbook of Anatomy Vol 2 6e.



Mesentery

Asked in: Paper I Nov 2018 · Paper I May 2007 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction The mesentery (mesentery proper, or mesentery of the small intestine) is a broad, fan-shaped, double-layered fold of peritoneum that suspends the coils of the jejunum and ileum from the posterior abdominal wall. Each layer is lined by mesothelium and separated from its fellow by fatty connective tissue carrying the vessels, nerves and lymphatics of the small bowel. It is the largest and most mobile mesenteric fold in the abdomen, derived embryologically from the persisting dorsal mesentery of the midgut, and is distinct from a mesocolon (suspends the colon) and from an omentum (connects the stomach to other viscera).

1. Definition and General Features

- ▶ A **mesentery** is a peritoneal fold that suspends a part of the gut tube from the posterior abdominal wall, conducting neurovascular structures to it; a fold suspending the colon is a **mesocolon**, and one connecting the stomach to adjacent viscera is an **omentum**.
- ▶ It presents **two surfaces** (anterosuperior and posteroinferior layers of peritoneum) and **two borders**: the **attached border (root)** and the **free (intestinal) border**.
- ▶ Organs that possess a mesentery are mobile (intraperitoneal); organs that lose their mesentery during development by fusion with the parietal peritoneum (**zygosis**) become **secondarily retroperitoneal** — the duodenum (distal to its first 2 cm), ascending colon, descending colon, pancreas (except tail) and upper two-thirds of rectum. The kidneys, suprarenal glands and ureters are **primarily retroperitoneal** and never possessed a mesentery.

2. Extent, Attachment and Dimensions

Feature	Root (attached border)	Free (intestinal) border
Length	15 cm	~6 m (BD Chaurasia, Vishram Singh); Gray's Anatomy equates it with the length of the small intestine (~5 m)
Course	Oblique, directed downward and to the right	Thrown into multiple pleats/folds because it is far longer than the root — a "frill" or "full-skirt" arrangement
Extent	From the duodenojejunal flexure (left side of the L2 vertebral body) to the right sacro-iliac joint (ileocaecal junction)	Encloses the entire jejunum and ileum, forming their visceral peritoneal coat

- ▶ **Breadth (depth)** of the mesentery from root to intestinal border averages 15–20 cm; it is **maximal (~20 cm) in the central part** and tapers towards both ends — shortest at the duodenojejunal end and at the terminal ileum, deepest in the mid-ileal region.
- ▶ **Surface marking of the root:** the duodenojejunal-flexure point lies **1 cm below the transpyloric plane** and **2.5 cm left of the median plane**; the ileocaecal-junction point lies at the **intersection of the right lateral and transtubercular planes**.

3. Relations — Structures Crossed by the Root

From above downward, the oblique root of the mesentery crosses, in order:

- ▶ The **horizontal (third) part of the duodenum** — where the superior mesenteric vessels enter the root
- ▶ The **abdominal aorta**
- ▶ The **inferior vena cava**
- ▶ The **right gonadal (testicular/ovarian) vessels**
- ▶ The **right ureter**
- ▶ The **right psoas major**
- ▶ The root divides the **infracolic compartment** into a small **right infracolic space** (triangular, apex below, terminates in the right iliac fossa) and a larger **left infracolic space**, which is continuous below without interruption into the true pelvis.

□ Fig 18.11 — Structures crossed by the root of mesentery (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.306)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the posterior abdominal wall in outline with the oblique root-line running from upper left to lower right, and label along it, from above down: **duodenojejunal flexure (left of L2) → third part of duodenum → abdominal aorta → inferior vena cava → right gonadal vessels → right ureter → right psoas major → ileocaecal junction (right sacro-iliac joint)**. On either side of the line, label the **right infracolic space** and **left infracolic space**. In a second small inset, draw the fan-shaped mesentery itself with its **root (15 cm)**, its pleated **free border (~6 m)** enclosing jejunal/ileal loops, the **superior mesenteric artery and vein** running in the root, and radiating **jejunal/ileal arterial arcades**.

4. Contents of the Mesentery

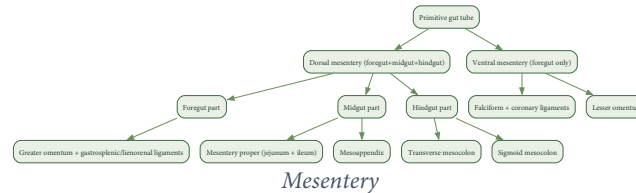
- ▶ **Superior mesenteric artery and vein** in the root (the vein lies to the right of the artery); the SMA descends in front of the uncinate process of the pancreas and the third part of the duodenum to enter the root, running between its two peritoneal layers
- ▶ **Jejunal and ileal branches** (12–15 in number) of the SMA, arising from its convex left side, with their accompanying veins
- ▶ **Arterial arcades and vasa recta** formed by anastomoses of these branches
- ▶ **Autonomic nerve plexuses** (sympathetic and vagal parasympathetic fibres of the superior mesenteric plexus)
- ▶ **Lymphatics (lacteals) and 100–200 mesenteric lymph nodes**
- ▶ **Fat and areolar connective tissue** — most abundant near the root and in the lower (distal, ileal) part; scanty near the intestinal border, which shows oval/circular fat-free translucent "windows"
- ▶ **The jejunum and ileum** themselves, enclosed within the free border

Feature	Jejunum	Ileum
Arterial arcades	Fewer (as few as one tier)	More numerous (up to five tiers)
Vasa recta	Longer, fewer, straighter	Shorter, more numerous, closer together
Mesenteric fat / windows	Fat-free translucent windows more evident	More fat, windows less obvious

5. Development (Embryological Basis)

- ▶ The primitive gut tube is suspended by a **dorsal mesentery** along its entire length and, in the **foregut only**, an additional **ventral mesentery**.
- ▶ The **ventral mesentery is largely resorbed**; its persisting derivatives (falciform and coronary ligaments, lesser omentum) belong to the foregut alone. The mesenteries of the intestines in the adult are all **remnants of the dorsal mesentery**.
- ▶ The **midgut and hindgut possess only a dorsal mesentery**, which gives rise to the **mesentery proper** of the jejunum and ileum, the **mesoappendix**, the **transverse mesocolon** and the **sigmoid mesocolon**.

- The dorsal mesentery of the duodenum (distal part), ascending colon, descending colon and rectum is subsequently lost by **zygosis** (fusion with, then absorption into, the parietal peritoneum), rendering these segments secondarily retroperitoneal — whereas the mesentery of the jejunum-ileum persists throughout life, accounting for its mobility.



6. Related Peritoneal Folds and Recesses

- **Mesoappendix:** a small, triangular fold derived from the posterior/left layer of the lower end of the mesentery, close to the ileocaecal junction; it suspends the vermiform appendix and carries the appendicular vessels, nerves and lymphatics. It usually extends to the tip of the appendix but sometimes falls short of the distal one-third.
- **Mesentericoparietal fossa (of Waldeyer):** present in about 1% of subjects, behind the upper part of the mesentery, with its orifice facing left; the superior mesenteric vessels lie in the peritoneal fold overlying it.
- **Paraduodenal recesses:** left and right paraduodenal peritoneal recesses near the duodenojejunal flexure and root of the mesentery are the commonest sites of internal (paraduodenal) herniation.

Applied / Clinical anatomy

- **Length and mobility:** the short (15 cm), fixed root combined with the long (~6 m), freely mobile intestinal border allows loops of jejunum/ileum to migrate widely in the peritoneal cavity; this same mobility can make it difficult to identify the site and orientation of a loop of bowel through a small surgical incision, and predisposes to **volvulus** of the small intestine around the axis of the mesentery.
- **Herniation:** the great length of the mesentery permits descent of small-bowel loops into the sac of an **inguinal or femoral hernia**. Failure of the root to fuse completely with the posterior parietal peritoneum leaves a peritoneal pocket that can form the sac of an internal (retroperitoneal) hernia — the **mesenteric-parietal (Waldeyer's) hernia**; **left and right paraduodenal hernias** are similarly explained by persistent paraduodenal recesses near the root.
- **Mesenteric lymphadenitis:** infection of the 100–200 mesenteric lymph nodes may cause acute **mesenteric lymphadenitis**, which can be clinically indistinguishable from acute appendicitis, and infected nodes adherent to a bowel loop may cause mechanical intestinal obstruction.
- **Mesenteric cyst:** a cystic swelling arising from mesenteric lymphatics/lymph nodes presents as a painless, fluctuant umbilical swelling that is characteristically **more mobile at right angles to the line of the root and less mobile along the line of the root** — a bedside sign that distinguishes it from other abdominal masses.
- **Vascular relations of the root:** the root crosses the third part of the duodenum at the point where the superior mesenteric vessels emerge — the anatomical basis of duodenal compression between the SMA and the aorta in the **superior mesenteric artery (Wilkie's) syndrome**.

- ▶ **Surgical/radiological orientation:** the root of the mesentery is a key landmark for orientating small-bowel loops at laparotomy and for interpreting the **infracolic compartments** (right and left) on cross-sectional imaging; abnormal twisting of the mesenteric vessels around the root produces the "whirl sign" seen in volvulus or internal herniation on CT.
- ▶ **Vascular arcades:** the jejunum's long vasa recta and sparse arcades versus the ileum's short vasa recta and multiple (up to five) arcades explain why segmental resection and end-to-end anastomosis is technically easier and better vascularised in the jejunum.

High-yield exam pointers

- ▶ Root: **15 cm**, oblique, duodenojejunal flexure (left of L2) → right sacro-iliac joint; free border: **~6 m** (pleated).
- ▶ Structures crossed by the root (mnemonic — **D**uodenum, **A**orta, **C**ava, **G**onadal vessels, **U**reter, **P**soas): 3rd part duodenum, abdominal aorta, IVC, right gonadal vessels, right ureter, right psoas major.
- ▶ Root divides infracolic compartment into right (small) and left (large, continuous with pelvis) infracolic spaces.
- ▶ Contents: SMA + SMV, 12–15 jejunal/ileal branches with arcades and vasa recta, autonomic nerves, lacteals, **100–200 lymph nodes**, fat.
- ▶ Develops from the persisting **dorsal mesentery of the midgut** (ventral mesentery belongs only to the foregut and is mostly resorbed); midgut dorsal mesentery also gives mesoappendix, transverse and sigmoid mesocolon.
- ▶ Clinical triad to remember: **mesenteric lymphadenitis** (mimics appendicitis), **mesenteric cyst** (mobile at right angles to root), **Walden's/paraduodenal internal hernia**.
- ▶ Breadth maximal (~20 cm) centrally, tapering at both ends; fat greatest near the root and distally, leaving translucent "windows" near the gut border.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 8e; Vishram Singh Textbook of Anatomy Vol 2 4e; Moore's Clinically Oriented Anatomy 9e (corroboration of structures crossed by the root).



Appendix

Asked in: Paper I Sep 2007 — RGUHS MD/MS Anatomy

Definition / Introduction

The vermiform ("worm-like") appendix is a narrow, blind, muscular diverticulum that arises from the postero-medial wall of the caecum about 2 cm below the ileocaecal orifice. Though embryologically and histologically continuous with the large intestine, it lacks taenia coli, sacculations (haustriations) and appendices epiploicae, and its submucosa is packed with lymphoid follicles — earning it the label "abdominal tonsil." It lies in the right iliac fossa with a fixed base but a highly mobile, variably positioned

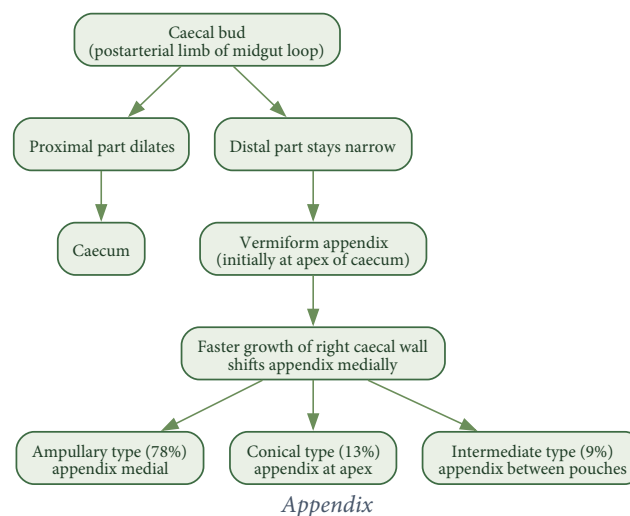
tip, a fact that underlies both its clinical unpredictability and its importance as an exam topic linking gross anatomy, embryology and applied surgery.

Development

- ▶ The caecum and appendix develop from the **caecal bud**, a diverticulum arising from the **postarterial (caudal) limb of the midgut loop**, distal to the origin of the future ileocolic pedicle.
- ▶ The **proximal (wider) part** of this bud dilates to form the **caecum**; the **distal (narrow) part** remains slender and becomes the **vermiform appendix** — so the appendix initially arises from the apex of the caecum.
- ▶ With continued growth, the **right (lateral) wall of the caecum grows disproportionately faster** than the medial wall, so the point of attachment of the appendix is progressively displaced medially, from the apex towards the postero-medial aspect of the caecum.
- ▶ **Arrest of this medial shift at different stages** gives rise to the three developmental/anatomical types of caecum, each defined by where the appendix arises:

Type of caecum	Frequency	Site of origin of appendix
Ampullary	~78% (commonest)	Right caecal pouch much larger than left; appendix arises from the medial side
Conical	~13%	Caecum tapers to a point; appendix arises from the apex
Intermediate	~9%	Right and left caecal pouches roughly equal; appendix arises from a depression between them

- ▶ The caecum and appendix, carried on the postarterial midgut limb, undergo the same **270° anticlockwise rotation around the axis of the superior mesenteric artery** as the rest of the midgut before finally descending from a sub-hepatic position into the right iliac fossa in the perinatal period.
- ▶ **Error of descent/rotation** can leave the caecum (and appendix) in a **sub-hepatic, left iliac fossa**, or midline position — the anatomical basis of atypical presentations of appendicitis.



Gross anatomy — dimensions and parts

- ▶ **Length:** 2–20 cm, average 9 cm; longer in children and young adults, tends to shorten/atrophy after mid-adult life.
- ▶ **Diameter:** about 5 mm; the **lumen is narrow** and is frequently partially or completely obliterated after mid-adult life.
- ▶ **Parts:** **base** (fixed, attached to the postero-medial wall of the caecum, about 2 cm below the ileocaecal orifice), **body** (narrow, tubular, kinked where the free border of the mesoappendix ends short of the appendix's full length), and **tip** (free, mobile, and the least vascular part).
- ▶ All three **taeniae coli of the caecum converge on the base of the appendix** — a key intra-operative landmark for locating the appendix when the tip is buried in adhesions or an abnormal position.
- ▶ **Appendicular (caecal) orifice:** a small opening on the postero-medial wall of the caecum, about 2 cm below the ileocaecal orifice, guarded by an indistinct semilunar mucosal fold, the **valve of Gerlach**.
- ▶ Unlike the rest of the large intestine, the appendix wall is **devoid of taeniae coli, sacculations and appendices epiploicae**, and its longitudinal muscle forms a complete (not banded) coat.

Position of the appendix

The base is fixed, but the tip may point in almost any direction; positions are conventionally described by comparison with the hour positions on a clock face.

□ Fig 20.26 — Positions of the appendix (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.345)

Position (clock analogy)	Approximate frequency	Description
Retrocaecal/retrocolic (12 o'clock)	~65% (commonest)	Lies behind the caecum/ascending colon, extraperitoneally; if long may reach the right kidney or liver
Pelvic (4 o'clock)	~30% (2nd commonest)	Descends over the pelvic brim; may relate to right ureter, uterine tube, ovary or broad ligament in females
Splenic (2 o'clock)	~1–2%	Passes upward and to the left towards the spleen; may be pre-ileal (in front of ileum — most dangerous, as pain is masked) or post-ileal
Sub-caecal/paracolic (11 o'clock)	~2%	Lies below the caecum, ascends alongside the ascending colon
Promontoric (3 o'clock)	Rare	Points horizontally towards the sacral promontory
Mid-inguinal (6 o'clock)	Rare	Points vertically downward towards the inguinal ligament

- ▶ **Surface marking of the base:** a point about 2 cm below the intersection of the transtuberular and right lateral (mid-clavicular) planes.

- **McBurney's point:** the junction of the lateral one-third and medial two-thirds of the line joining the right anterior superior iliac spine to the umbilicus — classically the site of maximum tenderness in appendicitis and the point roughly corresponding to the base of the appendix; **McBurney's incision** for open appendicectomy is made at right angles to this line through this point. (Note — imaging studies, e.g. Ramsden et al 1993, have shown that the actual radiographic position of the appendix base is variable and only rarely lies precisely at McBurney's point, though it remains the standard clinical/surface landmark taught and examined.)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a right iliac fossa/caecum schematic with a clock face superimposed on the caecal base, showing:

- Caecum and terminal ileum with ileocaecal (Bauhin's) valve
- Base of appendix — point of convergence of the three taeniae coli
- 12 o'clock — **retrocaecal/retrocolic** (commonest, ~65%)
- 4 o'clock — **pelvic** (2nd commonest, ~30%)
- 2 o'clock — **splenic** (pre-ileal/post-ileal)
- 11 o'clock — **sub-caecal/paracolic**
- 3 o'clock — **promontoric**
- 6 o'clock — **mid-inguinal**
- Right ASIS, umbilicus, and **McBurney's point** marked on the surface line joining them
- Mesoappendix and appendicular artery running along its free margin

Peritoneal relations, blood supply, nerve supply and lymphatics

- **Mesoappendix:** a small, triangular fold of peritoneum suspending the appendix, passing upward behind the terminal ileum to attach to the left (posterior) layer of the mesentery of the small intestine; its free edge falls short of the tip of the appendix, so the body is characteristically **kinked** at this point.
- **Arterial supply:** the **appendicular artery**, a branch of the **lower division of the ileocolic artery** (itself the terminal branch of the superior mesenteric artery), runs behind the terminal ileum, enters the mesoappendix a short distance from the base, gives a **recurrent branch** that anastomoses with the posterior caecal artery near the base, then runs in the free margin of the mesoappendix to supply the whole organ down to its tip. It behaves functionally as an **end artery** — its thrombosis (as in acute appendicitis) rapidly causes ischaemia, gangrene and perforation of the appendix, particularly at the poorly-vascularised tip.
- **Venous drainage:** appendicular vein → ileocolic vein → superior mesenteric vein → **portal vein**.
- **Nerve supply:** sympathetic fibres from **T9–T10 spinal segments** via the coeliac plexus; parasympathetic supply from the **vagus**. Because the appendix and the umbilical skin share the same (T10) segmental innervation, early visceral pain of appendicitis is referred to the peri-umbilical region.
- **Lymphatic drainage:** mostly directly to the **ileocolic lymph nodes**, with some vessels passing indirectly through small **appendicular nodes** situated within the mesoappendix.

Microscopic structure (brief)

- ▶ **Mucosa:** lined by simple columnar epithelium with goblet cells; forms **crypts of Lieberkühn** but no villi.
- ▶ **Lamina propria/submucosa:** dominated by **abundant, confluent lymphoid follicles** encroaching on the muscularis mucosae (which is consequently ill-defined) — the histological basis of the term "**abdominal tonsil**."
- ▶ **Muscularis externa:** inner circular and outer longitudinal smooth-muscle layers, complete (unlike the taeniae of the colon).
- ▶ **Serosa:** outermost layer, continuous with the mesoappendix.

Applied / Clinical anatomy

- ▶ **Referred pain sequence:** appendicitis begins as poorly-localised, colicky **peri-umbilical pain** (visceral, via T10 sympathetic afferents shared with the umbilical dermatome); as inflammation spreads to involve the pain-sensitive **parietal peritoneum** of the right iliac fossa, pain becomes sharp and **localises to McBurney's point** — a classic history-taking pearl.
- ▶ **Why appendicitis is common and dangerous:** (i) abundant submucosal lymphoid tissue can hypertrophy and obstruct the narrow lumen (common in adolescents); (ii) the lumen is narrow and easily occluded by a **faecolith**, seed, or worm; (iii) the appendicular artery is an **end artery**, so obstruction/venous congestion rapidly progresses to ischaemia, gangrene and perforation; (iv) gaps/thinness in the muscularis externa allow rapid transmural spread of infection.
- ▶ **Positional variants and signs:** a **retrocaecal** appendix, in contact with psoas major, produces pain on hip extension (**psoas sign**); a **pelvic** appendix, related to obturator internus, produces pain on flexion and medial rotation of the thigh (**obturator sign**), and may mimic gynaecological or urinary pathology; a **pre-ileal splenic** appendix is regarded as the most dangerous variant because its inflammation can be masked by the overlying ileum.
- ▶ **Examination signs:** hyperaesthesia in the right iliac fossa, tenderness at McBurney's point, muscle guarding, and rebound tenderness are the classical physical findings of acute appendicitis.
- ▶ **Appendicular dyspepsia:** chronic/recurrent appendicitis can produce dyspeptic symptoms resembling gastric, duodenal or gallbladder disease, attributed to spread of infected lymph to sub-pyloric lymph nodes causing pyloric irritation.
- ▶ **Carcinoid tumour:** excessive proliferation of the argentaffin (enterochromaffin) cells of the gut, which secrete serotonin, is most frequently encountered in the vermiform appendix, making the appendix the commonest site of carcinoid tumours of the gastrointestinal tract.
- ▶ **Congenital/positional anomalies:** due to errors of midgut rotation, the caecum and appendix may lie in the sub-hepatic region, the left iliac fossa, or the umbilical region — a cause of atypical, diagnostically confusing presentations of appendicitis.
- ▶ **Surgical correlates:** the operation of removal is **appendicectomy** (open, via McBurney's/gridiron incision at right angles to the ASIS–umbilicus line, or laparoscopic); the taeniae coli of the caecum are followed to their point of convergence to locate a difficult (e.g., retrocaecal) appendix intra-operatively; care is taken with the mesoappendix and its end-artery during ligation to avoid stump ischaemia.

High-yield exam pointers

- ▶ Appendix develops from the **narrow distal part of the caecal bud** (postarterial midgut); differential caecal-wall growth explains the **ampullary (78%) / conical (13%) / intermediate (9%)** caecal types.
- ▶ Average length **9 cm** (range 2–20 cm); lumen narrow, often obliterated in later adult life.
- ▶ **Retrocaecal (65%)** is the commonest position; **pelvic (30%)** is the second commonest.
- ▶ All three **taeniae coli converge at the base** of the appendix — the operative landmark for finding it.
- ▶ Appendicular artery = branch of the **lower division of the ileocolic artery**; it is an **end artery** → rapid gangrene in appendicitis.
- ▶ Nerve supply **T9–T10 sympathetic** (shared with umbilicus) explains the classic **peri-umbilical** → **right iliac fossa** shift of pain.
- ▶ **McBurney's point** = lateral 1/3–medial 2/3 junction of the ASIS–umbilicus line = site of maximum tenderness and of the McBurney's/gridiron incision.
- ▶ Submucosal lymphoid abundance earns it the name "**abdominal tonsil**"; also makes the appendix the **commonest site of GI carcinoid tumour**.
- ▶ Psoas sign (retrocaecal appendix) and obturator sign (pelvic appendix) localise atypically-placed appendicitis clinically.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore's Clinically Oriented Anatomy, 9e.



Biliary apparatus

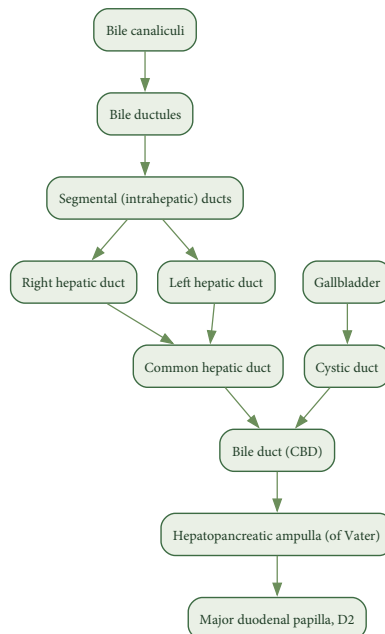
Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction The biliary apparatus is the system of ducts, together with the gallbladder, that collects bile secreted by hepatocytes and delivers it to the second part of the duodenum. It is conventionally divided into an **intrahepatic** component (bile canaliculi, ductules and segmental ducts within the liver substance) and an **extrahepatic** component — the right and left hepatic ducts, the common hepatic duct, the gallbladder, the cystic duct and the bile (common bile) duct. The extrahepatic apparatus also stores and concentrates bile between meals and releases it on a hormonal (cholecystokinin) cue when chyme enters the duodenum. Its surgical importance (cholecystectomy, biliary anomalies, Calot's triangle) makes it a favourite gross-anatomy exam topic.

1. Components and the ductal confluence

- ▶ **Intrahepatic:** bile canaliculi → bile ductules → segmental ducts, which unite to form the right and left hepatic ducts near the porta hepatis.

- **Extrahepatic:** right and left hepatic ducts → **common hepatic duct** → joined by the **cystic duct** (draining the gallbladder) → **bile duct** → **hepatopancreatic ampulla (of Vater)** → major duodenal papilla, second part of duodenum.
- At the **porta hepatis**, the three structures are arranged from behind forwards: portal vein branches (posterior) → proper hepatic artery (middle) → hepatic ducts (anterior, and to the right of the artery).



Biliary apparatus

2. Gallbladder — position, parts and relations

The gallbladder is a pear-/flask-shaped reservoir lying in a fossa on the visceral surface of the right lobe of the liver, between hepatic segments IV and V, extending from the right end of the porta hepatis to the inferior liver border.

Part	Position / relations
Fundus	Projects beyond the liver's inferior border in the angle between the lateral border of right rectus abdominis and the 9th costal cartilage (Murphy's point); wholly peritonealised; related to the anterior abdominal wall anteriorly and the transverse colon posteriorly
Body	Lies in the gallbladder fossa; superior surface bare, adherent to liver; inferior (peritonealised) surface related to transverse colon and the 1st/2nd parts of duodenum
Neck	Narrow upper end near the porta hepatis; curves anterosuperiorly then posteroinferiorly; its posteromedial wall bulges to form Hartmann's pouch , a common site for impacted gallstones; mucosa thrown into spiral folds

- **Dimensions/capacity:** 7–10 cm long, up to 3 cm broad at its widest part, capacity ~30–50 mL (resting volume ~25 mL, per Gray's 41e).
- **Functions:** (1) storage and timed release of bile; (2) absorption of water and electrolytes, concentrating bile up to ten-fold; (3) selective absorption of bile salts (leaving cholesterol behind when inflamed — a mechanism in gallstone formation); (4) regulates biliary pressure, maintaining the choledochoduodenal mechanism.
- **Peritoneal variants:** may be largely intrahepatic, suspended on a mesentery (predisposing to torsion), or connected to the duodenum by a cystoduodenal fold.

□ Fig 8.12 — Components of the extrahepatic biliary apparatus. Note the sphincters around hepatopancreatic ampulla (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.380)

3. Extrahepatic ducts — hepatic ducts, cystic duct and bile duct

- **Right and left hepatic ducts:** the extrahepatic right duct is short (0.5–2 cm) and near-vertical; the left is longer (1.5–3.5 cm), more horizontal, and surgically more accessible for hilar biliary bypass. **Accessory hepatic ducts** ("Luschka's duct," usually from the right lobe) occur in up to 15% of subjects, opening into the gallbladder, CHD or bile duct — a recognised cause of post-cholecystectomy bile leak.
- **Common hepatic duct (CHD):** formed by union of the right and left hepatic ducts near the porta hepatis; descends ~3 cm, joined on its right at an acute angle by the cystic duct.
- **Cystic duct:** 2–4 cm long, ~2–3 mm diameter; runs from the neck of the gallbladder backwards and to the left to join the CHD; its mucosa forms 5–12 crescentic folds arranged spirally — the **spiral valve of Heister** (not a true valve; helps keep the narrow duct patent).
- **Bile duct (common bile duct, CBD):** formed by union of the cystic and common hepatic ducts; ~6–8 cm long, ~6 mm diameter (upper limit ~7–8 mm on imaging).

Part of bile duct	Course / key relations
Supraduodenal	In the free right margin of the lesser omentum; anterior to portal vein, right of the hepatic artery, anterior to the epiploic foramen — the most surgically accessible part
Retroduodenal	Behind the first part of duodenum; gastroduodenal artery to its left, IVC posteriorly
Infraduodenal (pancreatic)	In a groove on (or embedded in) the posterior surface of the head of pancreas, anterior to the IVC
Intraduodenal (intramural)	Runs obliquely in the duodenal wall, joins the pancreatic duct to form the hepatopancreatic ampulla, opening at the major duodenal papilla 8–10 cm distal to the pylorus

4. Sphincters of the bile and pancreatic ducts

Sphincter	Location	Function
Sphincter choledochus (of Boyden)	Terminal bile duct, just above its union with the pancreatic duct	Always present; keeps the CBD closed between meals so bile accumulates and concentrates in the gallbladder
Sphincter pancreaticus	Terminal main pancreatic duct	Usually, but not always, present
Sphincter ampullae (of Oddi)	Around the hepatopancreatic ampulla	Regulates combined outflow of bile and pancreatic juice into the duodenum

The whole sphincter complex lies within the duodenal wall and is developmentally distinct from duodenal muscle. **Cholecystokinin (CCK)**, released from duodenal mucosa on contact with fatty chyme, both relaxes the sphincters and contracts the gallbladder.

5. Vascular supply, lymphatic drainage and innervation

- **Cystic artery** — chief supply to the gallbladder, cystic duct, hepatic ducts and upper bile duct. Usually from the **right hepatic artery**, passing posterior to the CHD within the hepatobiliary triangle, dividing at the gallbladder neck into superficial and deep branches. Variant origins: hepatic artery proper (commonest), left hepatic, gastroduodenal, superior pancreaticoduodenal, coeliac, right gastric or superior mesenteric arteries; may be double, or the right hepatic artery may loop through the triangle — **Moynihan's hump** — at risk of inadvertent ligation in cholecystectomy.
- **Ductal arteries**: upper bile duct via cystic artery twigs; middle part via the right hepatic artery; lower part via posterior superior pancreaticoduodenal and retroduodenal arteries.
- **Venous drainage**: multiple small cystic veins (no single dominant vein) draining directly into the liver or into portal vein tributaries; lower CBD drains into the portal vein.
- **Lymphatic drainage**: **cystic lymph node (of Lund)** in the hepatobiliary/Calot's triangle (constantly enlarged in cholecystitis) → hepatic nodes at the porta hepatis → coeliac nodes; lower bile duct also to retropancreaticoduodenal and superior mesenteric nodes.
- **Innervation**: hepatic plexus (coeliac plexus, vagi, right phrenic nerve). Parasympathetic fibres are motor to the musculature but inhibitory to the sphincters; sympathetic fibres (T7–T9) are motor to the sphincters and carry pain afferents.

6. Hepatobiliary (Calot's) triangle

As taught in Indian curricula, the **cystohepatic triangle of Calot** is bounded by the **cystic duct** (right), the **common hepatic duct** (left) and the **inferior surface of the liver/segment V** (above); it contains the **cystic artery**, an often-aberrant **right hepatic artery**, and the **cystic lymph node of Lund**. (Gray's 41e notes Calot's original 1891 triangle used the **cystic artery**, not the liver, as its third side — strictly the "hepatobiliary triangle"; either definition is exam-acceptable if contents are stated correctly.)

- **Surgical significance**: dissecting this triangle to obtain the "critical view of safety" (clear identification of cystic duct and cystic artery entering the gallbladder) prevents bile duct/right hepatic artery injury at cholecystectomy.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A right-side sagittal/oblique view after removal of the liver, labelled with:

- ▶ Cystic duct (right boundary) and **common hepatic duct** (left boundary)
- ▶ **Inferior/visceral surface of the liver (segment V)** as the upper boundary
- ▶ Cystic artery running within the triangle to the neck of the gallbladder
- ▶ **Right hepatic artery** (aberrant course/Moynihan's hump)
- ▶ Cystic lymph node (of Lund)
- ▶ Gallbladder with **Hartmann's pouch** at its neck

7. Development of the extrahepatic biliary apparatus

- ▶ The **hepatic diverticulum (liver bud)** arises in the 4th week from the endoderm of the caudal foregut and penetrates the septum transversum.
- ▶ Its cranial part, the **pars hepatica**, proliferates to form liver parenchyma and the (right and left) hepatic ducts and common hepatic duct.
- ▶ A small ventral outgrowth, the **pars cystica**, gives rise to the **gallbladder and cystic duct**.
- ▶ The narrowing stalk connecting the diverticulum to the foregut becomes the **bile duct**.
- ▶ The lumen of the extrahepatic biliary tree is transiently occluded by proliferating epithelium and is **recanalized by vacuolation**; bile secretion begins around the 12th week, giving meconium its characteristic colour.
- ▶ **Congenital anomalies**: biliary atresia (failure of recanalization), gallbladder agenesis or duplication, phrygian cap, floating (mesenteric) gallbladder, and accessory/aberrant hepatic ducts.

Applied / Clinical anatomy

- ▶ **Cholelithiasis**: classic "fat, fertile, female of forty"; inflamed gallbladder selectively reabsorbs bile salts, precipitating cholesterol. Stones lodge in Hartmann's pouch/cystic duct (biliary colic, acute cholecystitis) or pass into the CBD (obstructive jaundice).
- ▶ **Acute cholecystitis**: pain referred to the epigastrium, inferior angle of right scapula (T7–T9) or right shoulder tip (phrenic, C3–C4); **Murphy's sign** (inspiratory arrest on palpation at the 9th costal cartilage tip) is diagnostic.
- ▶ **Mirizzi syndrome**: a stone impacted in the cystic duct/Hartmann's pouch compresses and obstructs the adjacent CHD.
- ▶ **Courvoisier's law**: a palpably distended, non-tender gallbladder with jaundice favours malignant (extrinsic) CBD obstruction over stones, since stone disease renders the gallbladder fibrotic/non-distensible.
- ▶ **Cholecystectomy**: Moynihan's hump and cystic artery/duct variants make hepatobiliary triangle dissection ("critical view of safety") essential; an unrecognised accessory hepatic duct causes post-operative bile leak.
- ▶ **Imaging**: ultrasonography is the primary modality; ERCP/MRCP allow ductal visualisation plus therapeutic stenting/sphincterotomy.

- ▶ Gallbladder is a recognised carrier site for *Salmonella typhi*.

High-yield exam pointers

- ▶ Extrahepatic biliary apparatus = right + left hepatic ducts → common hepatic duct → (+ cystic duct from gallbladder) → bile duct → hepatopancreatic ampulla → major duodenal papilla.
- ▶ Gallbladder: 7–10 cm long, capacity ~30–50 mL; parts = fundus, body, neck (with Hartmann's pouch).
- ▶ Cystic duct has the **spiral valve of Heister**; bile duct has 4 parts — supraduodenal, retroduodenal, infraduodenal (pancreatic), intraduodenal.
- ▶ Three sphincters: choledochus (Boyden), pancreaticus, ampullae (Oddi) — all relaxed by CCK along with gallbladder contraction.
- ▶ Cystic artery usually from the right hepatic artery; watch for **Moynihan's hump** (looped right hepatic artery) during cholecystectomy.
- ▶ Calot's/hepatobiliary triangle = cystic duct + common hepatic duct + liver (segment V); contains cystic artery, aberrant right hepatic artery, cystic node of Lund — key to the "critical view of safety."
- ▶ Develops from the hepatic diverticulum: pars hepatica → liver + hepatic ducts; pars cystica → gallbladder + cystic duct; lumen recanalizes by vacuolation.
- ▶ Referred pain triad: epigastrium (vagal), inferior angle of right scapula (T7–T9 sympathetic), right shoulder tip (phrenic, C3–C4); Murphy's sign for cholecystitis; Courvoisier's law for painless jaundice with a distended gallbladder.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Textbook of Anatomy Vol 2, 6e; Langman's Medical Embryology (Sadler), 14e; Moore's Clinically Oriented Anatomy, 9e.



Caput medusae

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction — Caput medusae is the clinical sign of grossly dilated, tortuous subcutaneous veins radiating outward from the umbilicus, seen when portal venous blood is diverted into the systemic circulation through the **paraumbilical veins**. The name comes from its resemblance to the snake-covered head of Medusa of Greek mythology. It is one of the three classic external stigmata of **portal hypertension** (with oesophageal varices and haemorrhoids) and the only one of the three that is directly visible/palpable on inspection of the abdominal wall, making it of high diagnostic and examination value.

1. Normal venous drainage of the umbilical region

- ▶ The subcutaneous venous plexus of the anterior abdominal wall normally drains in two directions from a watershed line at the level of the umbilicus:

- **Above the umbilicus** — via superficial thoraco-epigastric tributaries into the **lateral thoracic vein** → **axillary vein** → **superior vena cava (SVC)**.
- **Below the umbilicus** — via **superficial epigastric and superficial circumflex iliac veins** → **great saphenous vein** → **femoral vein** → **inferior vena cava (IVC)**.
- ▶ A separate, normally insignificant set of **paraumbilical veins (of Sappey)** run in the free edge of the **falciform ligament**, alongside the **ligamentum teres hepatis** (the fibrous remnant of the obliterated left umbilical vein), and join the **left branch of the portal vein** at the porta hepatis.
- ▶ These paraumbilical veins are the embryological remnant of the fetal umbilical venous channel and constitute a **potential communication between the portal and systemic (caval) venous systems** at the umbilicus. In health this channel carries negligible flow.
- ▶ **Embryological basis:** in the fetus, paired umbilical veins carry oxygenated blood from the placenta; the **right umbilical vein and the proximal part of the left disappear**, while the distal left umbilical vein persists and (via the ductus venosus) bypasses the hepatic sinusoids to reach the IVC. After birth the intra-abdominal part of the left umbilical vein obliterates to form the **ligamentum teres hepatis**, and the ductus venosus obliterates to form the **ligamentum venosum** — but the lumen is not always completely lost, which is why it can reopen (recanalise) under raised portal pressure to again carry blood, now in the reverse direction, toward the umbilicus.

2. Anatomical basis — how portal hypertension produces caput medusae

- ▶ In **portal hypertension** (commonly from cirrhosis of the liver, less often portal vein thrombosis or Banti's disease), resistance to flow through the hepatic sinusoids rises and portal venous pressure exceeds systemic venous pressure.
- ▶ Blood in the left branch of the portal vein is diverted **retrograde down the paraumbilical veins** (which run with the ligamentum teres in the falciform ligament) to reach the subcutaneous venous plexus around the umbilicus.
- ▶ From there it decompresses into the **systemic** superior and inferior epigastric veins, which become engorged and are seen and felt as **tortuous, dilated veins radiating from the umbilicus** — caput medusae.
- ▶ Because flow is now away from the umbilicus in both directions, it still respects the **normal watershed line**: flow continues **upward above the umbilicus** (into the SVC via the thoraco-epigastric/lateral thoracic/axillary route) and **downward below the umbilicus** (into the IVC via the superficial epigastric/great saphenous route) — it does **not** cross the watershed line. This distinguishes it from the collateral pattern of **SVC or IVC obstruction**, where the thoraco-epigastric vein itself opens up and flow crosses the watershed line (upward throughout in IVC obstruction, downward throughout in SVC obstruction).

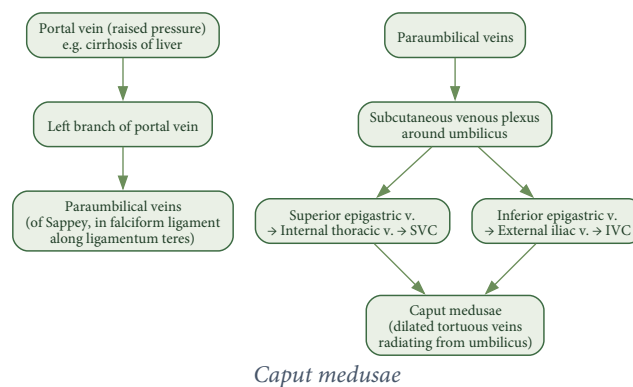
3. Sites of portosystemic (portocaval) anastomoses

Site	Portal tributary	Systemic tributary	Clinical sign
Umbilicus	Paraumbilical veins (left branch of portal vein)	Superior & inferior epigastric veins → SVC / IVC	Caput medusae

Site	Portal tributary	Systemic tributary	Clinical sign
Lower 1/3 oesophagus	Left gastric vein	Oesophageal tributaries of azygos/hemiazygos vein	Oesophageal varices → haematemesis
Anal canal (mid-anal canal)	Superior rectal vein (→ inferior mesenteric vein)	Middle & inferior rectal veins → internal iliac vein	Internal haemorrhoids
Bare area of liver	Portal radicles in liver substance	Phrenic & intercostal veins (retroperitoneal, of Retzius)	Usually silent

- The **umbilicus, lower oesophagus and anal canal** are the three sites of major clinical importance; caput medusae is the visible sign at the umbilical site.
- All three arise because the fetal portal venous system develops in continuity with systemic veins at these transitional sites, and the connections persist as small-calibre channels that only enlarge under raised portal pressure.

4. Diagrams



□ Fig 23.30 — *Caput medusae* (BD Chaurasia — *Human Anatomy Vol 2 — 8e, p.390*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled outline of the trunk showing the three classic sites of portocaval anastomosis, for hand reproduction:

- ▶ Outline of trunk with **umbilicus** marked centrally; draw radiating tortuous veins from it labelled "**paraumbilical veins → caput medusae**".
- ▶ Label the **falciform ligament / ligamentum teres** running from umbilicus to liver, carrying the paraumbilical veins to the **left branch of portal vein**.
- ▶ Mark **superior epigastric vein → internal thoracic vein → SVC** (arrow pointing up, above umbilicus).
- ▶ Mark **inferior epigastric vein → external iliac vein → IVC** (arrow pointing down, below umbilicus).
- ▶ Show the **lower oesophagus** (left gastric vein ↔ azygos system → oesophageal varices) and the **anal canal** (superior rectal vein ↔ middle/inferior rectal veins → haemorrhoids) as the two other classic sites, for completeness of the portocaval-anastomosis diagram.

Applied / Clinical anatomy

- ▶ **Commonest cause:** cirrhosis of the liver (alcoholic, viral, biliary); other causes include extrahepatic portal vein thrombosis and Banti's disease.
- ▶ **Cruveilhier–Baumgarten syndrome:** a rare variant in which the paraumbilical/umbilical vein remains widely patent from birth (rather than merely reopening), producing a prominent caput medusae together with an audible **venous hum/bruit on auscultation over the umbilicus** — a classic bedside sign of a large-calibre portosystemic shunt.
- ▶ **Bedside differentiation from caval obstruction:** emptying a segment of a dilated vein and releasing one end shows flow returning **away from the umbilicus in both directions** in portal obstruction, versus flow crossing the umbilical watershed line in SVC/IVC obstruction (via the thoraco-epigastric vein).
- ▶ **Surgical/interventional relevance:** knowledge of this collateral pathway underlies **portosystemic shunt surgery** (e.g., splenorenal, portocaval shunt) and the modern **transjugular intrahepatic portosystemic shunt (TIPS)**, both aimed at decompressing the portal system and pre-empting variceal bleeding.
- ▶ **Diagnostic value:** caput medusae, being visible/palpable, is a reliable external clinical pointer to portal hypertension even before oesophageal varices are demonstrated endoscopically or radiologically.
- ▶ **Danger of the sign:** while caput medusae itself is usually asymptomatic, it signals the presence of oesophageal varices and haemorrhoids elsewhere in the same patient, which carry the real risk of fatal haematemesis and bleeding per rectum.

High-yield exam pointers

- ▶ Caput medusae = dilated, tortuous **paraumbilical veins** radiating from the umbilicus, seen in **portal hypertension**.

- ▶ Anatomical basis: **paraumbilical veins (of Sappey)** run in the **falciform ligament** with the **ligamentum teres hepatis** (obliterated left umbilical vein) and join the **left branch of the portal vein**.
- ▶ One of the **three classic sites of portocaval anastomosis**: umbilicus (caput medusae), lower oesophagus (varices), anal canal (haemorrhoids).
- ▶ Direction of flow **does not cross the watershed line at the umbilicus** — distinguishes it from SVC/IVC obstruction, where the **thoraco-epigastric vein** opens up and flow does cross the watershed line.
- ▶ Most common cause: **cirrhosis of the liver**.
- ▶ **Cruveilhier–Baumgarten syndrome** = caput medusae + venous hum over the umbilicus from a persistently patent umbilical/paraumbilical vein.
- ▶ Clinically significant because it coexists with oesophageal varices and haemorrhoids — all three arise from the same rise in portal pressure.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Textbook of Anatomy Vol 2, 6e; Moore's Clinically Oriented Anatomy, 9e.



Describe in detail anatomy of inguinal canal. Add a note on inguinal hernias

Asked in: Paper I Nov 2017 — RGUHS MD/MS Anatomy

Definition / Introduction — The inguinal canal is an oblique intermuscular passage, about 4 cm long, situated in the lower part of the anterior abdominal wall just above the medial half of the inguinal ligament. It runs from the deep (internal) inguinal ring to the superficial (external) inguinal ring and transmits the spermatic cord in the male, the round ligament of the uterus in the female, and the ilioinguinal nerve in both sexes. It is best developed in the male and is a site of surgical importance because its two openings do not lie opposite each other, converting a potential weak spot into a self-closing valve — failure of this mechanism produces an inguinal hernia.

Location, extent and the two inguinal rings

- ▶ **Location/direction**: an oblique passage lying parallel to, and just above, the medial part of the inguinal ligament; directed downwards, forwards and medially from the deep to the superficial ring.
- ▶ **Length**: about 4 cm (1.5 inches) in the adult (BD Chaurasia); Gray's Anatomy gives an adult range of 3–6 cm. The canal is almost absent at birth (deep and superficial rings nearly superimposed) and lengthens as the pelvis widens with growth — in infants undergoing hernia repair it may be only ~1 cm long.
- ▶ **Deep inguinal ring**: an oval opening in the fascia transversalis, midway between the anterior superior iliac spine and the pubic symphysis (the **mid-inguinal point**), about 1–1.2 cm above the

inguinal ligament, and immediately lateral to the inferior epigastric vessels. It is 1–2 cm wide in the adult and larger in the male; guarded in front by the fleshy fibres of internal oblique.

- **Superficial inguinal ring:** a triangular (obtuse-angled) gap in the aponeurosis of external oblique, just above and lateral to the pubic crest, with its apex directed laterally towards the anterior superior iliac spine; about 2.5 cm long and 1.2 cm broad at the base. Its base is the pubic crest; its sides are the **lateral crus** (stronger, attached to the pubic tubercle) and **medial crus** (thinner, attached to the pubic symphysis, interlacing with fibres from the opposite side); **intercrural fibres** arch across the apex, reinforcing the ring. It is smaller in the female.

Boundaries of the inguinal canal

Wall	Extent	Structures
Anterior	Whole extent	Skin, superficial fascia, aponeurosis of external oblique
Anterior (reinforced)	Lateral one-third	Fleshy fibres of internal oblique
Posterior	Whole extent	Fascia transversalis, extraperitoneal tissue, parietal peritoneum
Posterior (reinforced)	Medial two-thirds	Conjoint tendon (falx inguinalis); reflected part of the inguinal ligament at the medial end
Roof	—	Arched fibres of internal oblique and transversus abdominis
Floor	—	Grooved upper surface of the inguinal ligament; lacunar ligament at the medial end

Contents of the canal and the spermatic cord

- **Spermatic cord (male) or round ligament of the uterus (female)** — enters through the deep ring and leaves through the superficial ring.
- **Ilioinguinal nerve** — enters the canal through the interval between external and internal oblique (not through the deep ring), traverses the canal, and leaves through the superficial ring lying **outside** the fascial coverings of the spermatic cord — the one content of the canal that is not enclosed within the cord.
- **Constituents of the spermatic cord ("3-3-3"):** 3 arteries — testicular, artery to the ductus (vas) deferens, cremasteric; 3 "other" structures — ductus deferens, pampiniform plexus of veins, remains of the processus vaginalis; and the genital branch of the genitofemoral nerve with the autonomic (sympathetic) plexus around the artery to the vas, together with testicular lymphatics.
- **Coverings of the spermatic cord**, from within outwards: (1) **internal spermatic fascia** — from the fascia transversalis, covering the cord throughout; (2) **cremasteric fascia** — loops of cremaster muscle with intervening areolar tissue, derived from internal oblique and transversus abdominis, covering the cord below the level of these muscles; (3) **external spermatic fascia** — from the external oblique aponeurosis, covering the cord below the superficial inguinal ring.

Mechanisms maintaining the integrity of the canal

- ▶ **Obliquity/flap-valve mechanism** — the deep and superficial rings do not lie opposite each other, so raised intra-abdominal pressure approximates the anterior and posterior walls, obliterating the passage.
- ▶ Superficial ring is guarded from behind by the **conjoint tendon** and the **reflected part of the inguinal ligament**.
- ▶ Deep ring is guarded in front by the fleshy fibres of **internal oblique**.
- ▶ **Shutter mechanism** — internal oblique forms the anterior wall, roof and posterior wall of the canal; its contraction approximates roof to floor (transversus abdominis fibres assist).
- ▶ **Ball-valve mechanism** — contraction of **cremaster** helps the cord plug the superficial ring.
- ▶ **Slit-valve mechanism** — contraction of external oblique approximates the two crura of the superficial ring, aided by the intercrural fibres.
- ▶ Hormonal tone of the inguinal musculature may also contribute.

Developmentally the canal marks the path of the **gubernaculum** from the caudal pole of the developing gonad to the labioscrotal (or labial) swelling; the canal is very short in early life and attains adult proportions as the pelvis widens and the deep ring shifts laterally. A tubular peritoneal diverticulum, the **processus vaginalis**, accompanies testicular descent through the canal and normally obliterates after birth — its persistence, complete or partial, underlies most **indirect** inguinal hernias (and, in the female, a persistent processus is the **canal of Nuck**).

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 4.5 — Boundaries of the inguinal canal (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.202)

Reproduce by hand with these exact labels —

- ▶ **Panel A (coverings, en route to the scrotum)**: Parietal peritoneum, Deep inguinal ring, Inferior epigastric artery, Obliterated umbilical artery, Transversus abdominis, Internal oblique, External oblique, Fascia transversalis, Conjoint tendon, External oblique aponeurosis, Superficial inguinal ring, External spermatic fascia, Cremasteric fascia, Internal spermatic fascia, Dartos, Skin, Testis.
- ▶ **Panel B (walls in cross-section)**: Roof — Internal oblique, Transversus abdominis; anterior wall — External oblique; posterior wall — Fascia transversalis; Floor — Inguinal ligament; contents — Spermatic cord.

Applied / Clinical anatomy — note on inguinal hernias

An **inguinal hernia** is the protrusion of an abdominal viscus (usually a loop of small bowel or omentum) through the inguinal canal or its wall. Like any hernia, it has a **sac** (neck + body, formed of peritoneum), **contents**, and **coverings** (the layers of the abdominal wall traversed). Two varieties are described, distinguished by their relation to the inferior epigastric vessels.

Indirect (oblique) inguinal hernia

- ▶ Enters the deep inguinal ring **lateral** to the inferior epigastric vessels, traverses the whole canal, and emerges through the superficial ring — may descend into the scrotum or labium majus.

- Usually related to a partially or fully **patent processus vaginalis** (a "preformed sac"); some are acquired through progressive dilatation of the deep ring.
- The commonest groin hernia; typically presents in infants, children and young adults.
- Sac is elongated/pear-shaped; neck is **narrow** (at the deep ring) → more liable to obstruction and strangulation.
- Coverings, from within outwards: extraperitoneal tissue, internal spermatic fascia, cremasteric fascia, external spermatic fascia, skin.

Direct inguinal hernia

- Protrudes **medial** to the inferior epigastric vessels, straight forwards through the weak posterior wall of the canal — i.e. through **Hesselbach's triangle**, bounded by the inguinal ligament (inferiorly), the lateral border of rectus abdominis (medially) and the inferior epigastric vessels (laterally).
- Always **acquired**, due to weakness of the fascia transversalis/posterior wall, precipitated by raised intra-abdominal pressure — chronic cough/bronchitis, constipation, prostatic enlargement, heavy lifting; occurs in older men.
- Sac is globular with a **wide** neck → rarely strangulates, rarely scrotal.
- Coverings: extraperitoneal tissue, fascia transversalis, then (medial to the obliterated umbilical artery) **conjoint tendon**, or (lateral to it) **cremasteric fascia**; external spermatic fascia; skin.

Feature	Indirect inguinal hernia	Direct inguinal hernia
Aetiology	Preformed sac (patent processus vaginalis)	Acquired weakness of posterior wall
Relation to inferior epigastric vessels	Lateral	Medial
Course/shape	Oblique; pear-shaped; often scrotal	Straight forward; globular; rarely scrotal
Neck of sac	Narrow	Wide
Age group	Children, young adults	Older men
Precipitating factor	—	Chronic bronchitis, straining, enlarged prostate
Internal ring occlusion test	Positive (hernia does not reappear when the reduced sac is held back by pressure over the deep ring, and the patient coughs)	Negative (hernia still reappears)
Liability to obstruction/strangulation	Common (narrow neck)	Uncommon (wide neck)

Related clinical points

- The **mid-inguinal point** (midway between the anterior superior iliac spine and the pubic symphysis) overlies the femoral artery and marks the deep inguinal ring; the **midpoint of the inguinal ligament** (slightly lateral to it) overlies the femoral nerve.

- ▶ **Inguinal hernia lies above and medial to the pubic tubercle; femoral hernia lies below and lateral to it** — the key bedside discriminator between the two.
- ▶ The **canal of Nuck** is a persistent processus vaginalis in the female inguinal canal, which may present as a hydrocele or a hernial sac.
- ▶ Femoral hernia is commoner in women (wider pelvis, larger femoral canal) and, unlike inguinal hernia, is never congenital; it strangulates more readily than an inguinal hernia because of the rigid boundaries of the femoral ring.

High-yield exam pointers

- ▶ Deep ring: oval defect in fascia transversalis, ~1–1.2 cm above the mid-inguinal point, lateral to the inferior epigastric vessels; superficial ring: triangular defect in the external oblique aponeurosis above the pubic crest.
- ▶ Canal length ≈ 4 cm in the adult (BD Chaurasia)/3–6 cm (Gray's); nearly obliterated at birth.
- ▶ Posterior wall = fascia transversalis + conjoint tendon (medial two-thirds); anterior wall = external oblique aponeurosis + internal oblique (lateral one-third).
- ▶ The only content of the canal lying **outside** the fascial coverings of the cord is the **ilioinguinal nerve**.
- ▶ Continence is maintained by the flap-valve (obliquity), shutter (internal oblique), ball-valve (cremaster) and slit-valve (external oblique) mechanisms.
- ▶ Indirect hernia = lateral to inferior epigastric vessels, through the deep ring, congenital sac (patent processus vaginalis), narrow neck, positive occlusion test.
- ▶ Direct hernia = medial to inferior epigastric vessels, through Hesselbach's triangle, acquired, wide neck, negative occlusion test.
- ▶ Hesselbach's triangle: inguinal ligament (inferior), lateral border of rectus abdominis (medial), inferior epigastric vessels (lateral).
- ▶ Pubic tubercle is the landmark separating inguinal hernia (above/medial) from femoral hernia (below/lateral).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e.



Describe in detail Boundaries and contents of “Inguinal Canal”. Add a note on its surgical importance

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction — The inguinal canal (syn. Velpeau's canal, abdominal canal) is an oblique musculo-aponeurotic passage in the lower part of the anterior abdominal wall, situated just above the medial half of the inguinal ligament. It extends from the **deep (internal) inguinal ring** to the **superficial (external) inguinal ring** and transmits the spermatic cord in males (round ligament of uterus in females) and the ilioinguinal nerve in both sexes. It represents the pathway of descent of the gonad and is a common site of herniation — it is present in every human being but is clinically important chiefly because it is a locus of anatomical weakness.

Location, extent and direction

- Lies in the inguinal region (groin), above the medial half of the inguinal ligament, extending between the anterior superior iliac spine (ASIS) and the pubic tubercle.
- **Length:** about 4 cm (1.5 inches) in the adult (range 3–6 cm depending on age and build).
- **Direction:** downwards, forwards and medially — parallel to the medial part of the inguinal ligament.
- **Sex difference:** larger and better developed in the male; narrow in the female (hence inguinal hernia is comparatively less common in women).
- In the **newborn** the deep and superficial rings lie almost superimposed and the canal is very short and nearly straight; as the pelvis widens with growth, the deep ring shifts laterally and the canal elongates and becomes progressively more oblique.

The two inguinal rings

Feature	Deep (internal) inguinal ring	Superficial (external) inguinal ring
Situation	Oval opening in the fascia transversalis	Triangular gap in the external oblique aponeurosis
Position	~1.2–1.25 cm above the mid-inguinal point, immediately lateral to the inferior epigastric vessels	Just above and lateral to the pubic crest
Shape/size	Oval (functionally V-shaped, open end upward-lateral); 1–2 cm wide	Triangular (obtuse-angled); ~2.5 cm (base to apex) x ~1.2 cm at the base
Boundaries	Superior and inferior crura of fascia transversalis	Base = pubic crest; lateral (inferior) crus → pubic tubercle; medial (superior) crus → pubic symphysis; apex bridged by intercrural fibres
Guarded by	Fleshy fibres of internal oblique in front	Conjoint tendon and reflected part of inguinal ligament behind

Feature	Deep (internal) inguinal ring	Superficial (external) inguinal ring
Transmits	Spermatic cord / round ligament of uterus (entire structure enters here)	Spermatic cord / round ligament + ilioinguinal nerve (exit)

Boundaries of the inguinal canal

Wall	Whole extent	Reinforced/added part
Anterior wall	Skin, superficial fascia, aponeurosis of external oblique	Lateral one-third reinforced by fleshy fibres of internal oblique
Posterior wall	Fascia transversalis, extraperitoneal tissue, parietal peritoneum	Medial two-thirds reinforced by the conjoint tendon ; medial end further strengthened by the reflected part of the inguinal ligament
Roof	Arched fibres of internal oblique and transversus abdominis	—
Floor	Grooved upper surface of the inguinal ligament	Medial end reinforced by the lacunar ligament

The **inguinal (Hesselbach's) triangle**, a clinically vital landmark on the posterior wall, is bounded laterally by the inferior epigastric vessels, medially by the lateral border of rectus abdominis, and inferiorly by the medial third of the inguinal ligament.

Real dissection plate

□ Fig 4.5 — Boundaries of the inguinal canal (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.202)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label, in a horizontal (transverse) section through the canal:

- ▶ Superficial inguinal ring and deep inguinal ring (with intervening 4 cm oblique course)
- ▶ Anterior wall: external oblique aponeurosis (+ internal oblique fibres laterally)
- ▶ Posterior wall: fascia transversalis (+ conjoint tendon medially, reflected inguinal ligament at the medial end)
- ▶ Roof: arched internal oblique + transversus abdominis fibres
- ▶ Floor: inguinal ligament (+ lacunar ligament medially)
- ▶ Inferior epigastric vessels at the medial margin of the deep ring
- ▶ Hesselbach's triangle (inferior epigastric vessels / rectus abdominis / inguinal ligament)
- ▶ Spermatic cord traversing the canal; ilioinguinal nerve lying anterior to it
- ▶ ASIS, pubic tubercle and the mid-inguinal point

Contents of the inguinal canal

- ▶ **Spermatic cord** in the male, or the **round ligament of the uterus** in the female — the entire content, entering through the deep ring and leaving through the superficial ring.
- ▶ **Ilioinguinal nerve** — a *partial* content only: it does **not** pass through the deep ring but enters the canal by piercing the internal oblique (through the interval between external and internal oblique, about 2.5 cm below/medial to the ASIS); it lies anterior to the cord and leaves through the superficial ring.

Constituents of the spermatic cord ("3 arteries – 3 others" scheme):

- ▶ 3 arteries: testicular artery, artery to the ductus (vas) deferens, cremasteric artery.
- ▶ 3 others: ductus deferens; pampiniform plexus of veins; lymphatics from the testis.
- ▶ Plus: genital branch of the genitofemoral nerve, a sympathetic plexus around the artery to the vas with visceral afferents, and remnants of the processus vaginalis.

Coverings of the spermatic cord (deep to superficial):

- ▶ **Internal spermatic fascia** — from the fascia transversalis (covers the cord in its whole extent).
- ▶ **Cremasteric fascia** — the cremaster muscle (looped fibres) and areolar tissue, derived from internal oblique and transversus abdominis; covers the cord only below the level of these muscles.
- ▶ **External spermatic fascia** — from the external oblique aponeurosis; covers the cord below the superficial ring.

Note: the ilioinguinal nerve, though it travels with the cord, is **not** one of its coverings or constituents — it lies free, outside the fascial sheaths, on the anterior aspect of the cord.

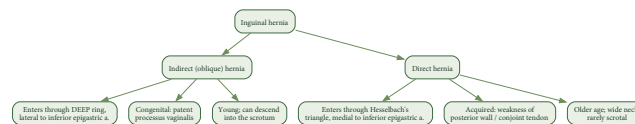
Mechanisms maintaining the integrity of the canal ("shutter" defence)

Despite creating an apparent weak point in the abdominal wall, herniation is prevented in health by several built-in mechanisms:

- **Obliquity of the canal / flap-valve mechanism** — the two rings do not lie opposite each other; a rise in intra-abdominal pressure pushes the posterior wall against the anterior wall, obliterating the canal.
- **Shutter mechanism of internal oblique** — internal oblique contributes to the anterior wall, roof and posterior wall; its contraction approximates roof to floor like a shutter (transversus abdominis assists).
- Deep ring guarded anteriorly by the fleshy fibres of internal oblique; superficial ring guarded posteriorly by the conjoint tendon and reflected part of the inguinal ligament.
- **Ball-valve (cremasteric plug) mechanism** — cremaster contraction pulls the testis/cord up to plug the superficial ring.
- **Slit-valve mechanism** — contraction of external oblique approximates the two crura of the superficial ring; integrity is reinforced by the intercrural fibres.
- Contraction of transversus abdominis draws the deep ring upward and laterally, increasing the obliquity of the canal.

Development (brief)

The inguinal canal develops as the anterior abdominal wall musculature differentiates around an inguinal fold of peritoneum that encloses the **gubernaculum**, extending from the caudal pole of the developing gonad (lumbar region) to the labioscrotal swelling. The canal is established before descent of the testis occurs, and is initially very short; it lengthens and becomes more oblique only as the pelvis widens with growth — explaining why hernia repair in infants deals with a canal only ~1 cm long.



Describe in detail Boundaries and contents of "Inguinal Canal". Add a note on its surgical importance

Applied / Clinical anatomy — surgical importance

- **Anatomical basis of hernia:** the canal is the classic site of the **inguinal hernia**, a protrusion of a peritoneal sac (with or without viscus) through the inguinal region. As Bassini stated, "*in order to achieve a radical cure of inguinal hernia, it is absolutely essential to restore those conditions in the area of hernial orifice which exist under normal circumstances*" — i.e., every repair aims to re-create the normal shutter/valve mechanisms described above.
- **Indirect (oblique) hernia** — sac passes through the deep ring (lateral to the inferior epigastric vessels), congenital, due to a persistent processus vaginalis; commoner in the young; can traverse the whole canal to reach the scrotum (complete/vaginal variety), or remain funicular, infantile, or interstitial depending on the extent of patency. When a Meckel's diverticulum is the content of the sac, it is called a **Littre's hernia**.
- **Direct hernia** — sac bulges straight forward through **Hesselbach's triangle** (medial to the inferior epigastric vessels), acquired, due to weakness of the posterior wall/conjoint tendon; commoner in elderly men; wide neck, rarely enters the scrotum.

Feature	Indirect (oblique) hernia	Direct hernia
Site of entry	Deep inguinal ring	Hesselbach's triangle
Relation to inferior epigastric a.	Lateral to it	Medial to it
Cause	Congenital (patent processus vaginalis)	Acquired (weak posterior wall)
Age	Younger patients	Older patients
Course	Oblique, may reach scrotum	Straight forward, rarely scrotal
Neck of sac	Narrow — more prone to obstruction/strangulation	Wide — obstruction less common
Reduction on lying down / control by deep-ring pressure	Controlled by pressure over deep ring	Not controlled by deep-ring pressure

- **Surface landmark for the surgeon** — the **mid-inguinal point** (midpoint of a line joining the ASIS and the pubic symphysis) marks the **femoral artery** just below the ligament and the **deep inguinal ring** just above it; this must not be confused with the **midpoint of the inguinal ligament** (midpoint of a line joining the ASIS to the pubic tubercle, lying slightly lateral to the mid-inguinal point), which overlies the **femoral nerve**. Confusing the two landmarks is a classic examination pitfall.
- **Coverings of hernial sac** mirror the coverings of the spermatic cord and are used clinically to stage the extent of an indirect hernia (peritoneum → extraperitoneal tissue → internal spermatic fascia → cremasteric fascia → external spermatic fascia → skin); a direct hernia additionally passes deep to the conjoint tendon medially or fascia transversalis laterally, rather than through the deep ring.
- **Principle of surgical repair** — every technique (Bassini's reconstruction of the posterior wall by suturing conjoint tendon to the inguinal ligament, Shouldice multilayer imbrication, Lichtenstein tension-free mesh hernioplasty, or laparoscopic TAPP/TEP mesh placement) works by reinforcing or bypassing the weak **posterior wall** of the canal — the common denominator of both indirect and direct hernia.
- **Nerves at surgical risk**: the **ilioinguinal nerve** (superficial to the cord) and the **iliohypogastric nerve** are vulnerable during open herniorrhaphy/hernioplasty incisions, and their entrapment in sutures or mesh is a recognised cause of chronic post-herniorrhaphy groin pain (ilioinguinal neuralgia); the **genital branch of the genitofemoral nerve**, running with the cord, may also be injured.
- **Other surgical relevance of the canal**: the deep ring and cord are the operative route for **high ligation of the sac** in herniotomy (infants), for **orchidopexy** of an undescended testis (which follows the gubernacular path through the canal), for **ligation of the testicular veins** at/above the deep ring in **varicocele** surgery, and for the **spermatic cord (ilioinguinal) block** used for anaesthesia in inguinoscrotal surgery.
- **Femoral hernia comparison** — a useful differential: it lies below and lateral to the pubic tubercle (through the femoral ring/canal, medial to the femoral vein), unlike an inguinal hernia which lies

above and medial to the tubercle; femoral hernias are more prone to strangulation because of the rigid boundaries of the femoral ring.

High-yield exam pointers

- ▶ Inguinal canal: ~4 cm long, from deep to superficial ring, directed downward-forward-medial, above the medial half of the inguinal ligament.
- ▶ Anterior wall = external oblique aponeurosis (+ internal oblique laterally); Posterior wall = fascia transversalis (+ conjoint tendon medially); Roof = arching internal oblique/transversus; Floor = inguinal ligament (+ lacunar ligament medially).
- ▶ Deep ring: fascia transversalis, ~1.2 cm above mid-inguinal point, lateral to inferior epigastric artery. Superficial ring: external oblique aponeurosis, above pubic crest.
- ▶ Only true contents: spermatic cord/round ligament (entire) + ilioinguinal nerve (partial, not through deep ring).
- ▶ Spermatic cord coverings (3): internal spermatic fascia, cremasteric fascia, external spermatic fascia — mirror the three flat muscles.
- ▶ Hesselbach's triangle = inferior epigastric vessels + rectus abdominis (lateral border) + inguinal ligament → site of direct hernia.
- ▶ Mid-inguinal point (femoral artery/deep ring) ≠ midpoint of inguinal ligament (femoral nerve) — frequently confused.
- ▶ Defence mechanisms: obliquity/flap valve, shutter mechanism, ball-valve (cremaster), slit-valve (intercrural fibres).
- ▶ Every hernia repair technique shares one principle: reinforce the posterior wall.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 2 4e; IB Singh — Textbook of Anatomy Vol 2 6e.



Describe rectus sheath

Asked in: Paper I May 2018 — RGUHS MD/MS Anatomy

Definition / Introduction The rectus sheath is the strong aponeurotic sheath that encloses **rectus abdominis** (and, when present, **pyramidalis**) on each side of the anterior abdominal wall. It is formed by the splitting and reunion of the aponeuroses of the three flat muscles of the abdomen — **external oblique, internal oblique and transversus abdominis** — and is a classic RGUHS long-answer topic because its formation changes at three distinct levels and it carries important surgical and applied implications (paramedian incision, rectus sheath haematoma, Spigelian hernia, divarication of recti). This answer covers its formation at different levels, contents, and clinical anatomy.

Location, extent and boundaries

- ▶ Lies on either side of the midline, extending from the **costal margin/xiphoid process** above to the **pubic crest/symphysis** below, enclosing rectus abdominis (and pyramidalis, if present) throughout its length.
- ▶ **Anterior wall** — complete from end to end; firmly adherent to the tendinous intersections of rectus abdominis.
- ▶ **Posterior wall** — incomplete; deficient above the costal margin and again below the **arcuate line**; free from the underlying muscle (not adherent to the tendinous intersections).
- ▶ **Medially**, the anterior and posterior walls of the two sides fuse in the midline to form the **linea alba**.
- ▶ **Laterally**, the two walls fuse along the **linea semilunaris**, a curved line extending from the tip of the **9th costal cartilage** to the **pubic tubercle** — this is the lateral limit of the sheath and the site of Spigelian hernia.

Formation of the sheath at different levels

The contribution of each muscle's aponeurosis to the anterior and posterior walls changes at three levels along the length of rectus abdominis:

Level	Anterior wall	Posterior wall
Above the costal margin	External oblique aponeurosis only	Deficient — rectus abdominis rests directly on the 5th, 6th and 7th costal cartilages
Between the costal margin and the arcuate line	External oblique aponeurosis + anterior lamina of internal oblique aponeurosis	Posterior lamina of internal oblique aponeurosis + aponeurosis of transversus abdominis
Below the arcuate line	Aponeuroses of all three flat muscles (transversus and internal oblique fused; external oblique separate)	Deficient — rectus abdominis rests on the fascia transversalis and extraperitoneal tissue

□ Fig 3.25 — Formation of the rectus sheath as seen in transverse sections through rectus abdominis and its sheaths at three different levels (Vishram Singh — *Textbook of Anatomy Vol 2 — 4e, p.179*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Three labelled transverse (cross-sectional) mini-diagrams through rectus abdominis, one at each level above, each showing:

- ▶ **Rectus abdominis** — centred, with the sheath around it
- ▶ **External oblique aponeurosis, internal oblique aponeurosis** (split into anterior/posterior laminae where applicable), **transversus abdominis aponeurosis**
- ▶ **Linea alba** — medial fusion point
- ▶ **Linea semilunaris** — lateral fusion point
- ▶ At the highest level: costal cartilage deep to muscle (no posterior wall)
- ▶ At the lowest level: fascia transversalis + parietal peritoneum deep to muscle (no posterior wall)
- ▶ Label the **arcuate line** on the middle-to-lower transition diagram

The bilaminar concept, linea alba and the arcuate line

- ▶ Each of the three flat-muscle aponeuroses is **bilaminar**: fibres of the anterior lamina run obliquely **upward and medially**, while the posterior lamina runs obliquely **downward and medially**, at right angles to the anterior lamina.
- ▶ Above the arcuate line, the **anterior sheath** = both laminae of external oblique + anterior lamina of internal oblique; the **posterior sheath** = posterior lamina of internal oblique + both laminae of transversus abdominis. Thus each wall of the sheath itself contains three layers of fibres, the middle layer running at right angles to the outer two.
- ▶ At the midline, fibres from each layer **decussate** to the opposite side and also decussate anteroposteriorly (anterior sheath ↔ posterior sheath), producing the dense fibrous **linea alba** — for this reason the three lateral abdominal muscles are sometimes described as "**digastric**" **muscles with a central tendon**, the linea alba.
- ▶ **Linea alba**: a tendinous raphe from the xiphoid process to the pubic symphysis/pubis crest. Superficial fibres attach to the pubic symphysis; deeper fibres form a triangular lamella (**adminiculum lineae albae**) attached behind rectus abdominis to the posterior surface of the pubic crest. The fundiform ligament of the penis and pyramidalis attach to its suprapubic part.
- ▶ **Arcuate line** (linea semicircularis; fold/line of Douglas) — the curved, concave-downward line at which the posterior wall of the sheath abruptly ends, classically described as lying **midway between the umbilicus and the pubic symphysis**; below it, the posterior wall is absent and rectus abdominis lies directly on the fascia transversalis. *Note*: the termination of the posterior wall is not always a sharp line — it is frequently a **gradual transition** rather than an abrupt edge, and morphometric studies (Loukas et al., cited in Gray's 41e) show its level is variable, sometimes corresponding to only about one-third of the umbilicus-to-pubis distance rather than the midpoint — a useful discriminating point for viva.

Contents of the rectus sheath

Content	Key points
Rectus abdominis	The chief and largest content, running the full length of the sheath
Pyramidalis (if present; may be absent on one or both sides, or rarely doubled)	Small triangular muscle in front of the lower part of rectus abdominis; attaches to the pubis below and the linea alba above
Superior epigastric artery	Terminal branch of the internal thoracic artery; enters the sheath at its upper end by passing between the costal and xiphoid origins of the diaphragm, crossing the upper border of transversus abdominis behind the 7th costal cartilage; supplies rectus abdominis and anastomoses with the inferior epigastric artery
Inferior epigastric artery	Branch of the external iliac artery; pierces the transversalis fascia and enters the sheath by passing anterior to the arcuate line ; ascends to anastomose with the superior epigastric artery, forming an important anastomotic channel between the internal thoracic and external iliac systems
Superior and inferior epigastric veins	Venae comitantes of the corresponding arteries; superior epigastric veins drain to the internal thoracic vein, inferior epigastric veins to the external iliac vein
Nerves	Terminal parts of the ventral rami of the lower five intercostal nerves (T7–T11) and the subcostal nerve (T12) — the segmental nerves of the anterior abdominal wall. They run in the neurovascular plane between internal oblique and transversus abdominis, pierce the posterior lamina of internal oblique aponeurosis to enter the sheath at its lateral margin , pass posterior to rectus abdominis, then pierce the muscle from behind and finally the anterior wall of the sheath close to the midline as anterior cutaneous branches. The subcostal nerve also supplies pyramidalis. (Iliohypogastric and ilioinguinal nerves supply the abdominal wall lower down but do not enter the rectus sheath.)

□ Fig 14.18 — Diagram showing contents of the rectus sheath (IB Singh — Textbook of Anatomy Vol 2 — 6e, p.179)

Functions of the rectus sheath

- Checks the **bowing** (bulging forward) of rectus abdominis during its contraction, thereby increasing the muscle's mechanical efficiency.
- Maintains the strength and integrity of the anterior abdominal wall, helping to contain the abdominal viscera.
- Provides an aponeurotic conduit for the epigastric vessels and the segmental thoraco-abdominal nerves as they cross the wall to reach rectus abdominis and the overlying skin.

Applied / Clinical anatomy

- ▶ **Paramedian incision:** preferred over a median incision for laparotomy because, although the median incision is relatively bloodless, it can leave a weak postoperative scar prone to incisional (ventral) hernia; a paramedian incision through the rectus sheath heals more soundly. Rectus abdominis is retracted **laterally** (not medially) during this incision to protect the segmental nerves, which enter the muscle from its lateral side.
- ▶ **Rectus sheath haematoma:** the inferior epigastric artery, on entering the sheath in front of the arcuate line, is visible through the peritoneum as the lateral umbilical fold and is vulnerable to injury during laparoscopic port insertion or abdominal drain placement; because there is no surrounding tissue against which bleeding can be tamponaded within the sheath, disruption can produce a rapidly expanding haematoma.
- ▶ **Spigelian hernia:** an interstitial hernia occurring near the junction of the linea semilunaris with the arcuate line — bowel or preperitoneal fat protrudes through a defect in the transversus abdominis and internal oblique aponeuroses but remains deep to the intact external oblique aponeurosis, so the swelling is often impalpable and its diagnosis may be delayed.
- ▶ **Divarication (diastasis) of recti:** thinning and widening of the linea alba in the upper abdomen, typically from pregnancy, obesity or chronic straining, causes the recti to separate widely with a midline bulge on raised intra-abdominal pressure; because all layers remain intact, this is **not** a true hernia.
- ▶ **Myocutaneous flaps:** rectus abdominis, together with its reliable epigastric blood supply and the ease with which the muscle belly separates from its sheath, is used as a pedicled or free flap — the upper half for breast reconstruction and the lower half (rotated on its lower attachment or as a free flap) for reconstruction after radical pelvic/perineal resection.
- ▶ **Surgical landmark:** the arcuate line is a key intraoperative landmark distinguishing sheath anatomy above (posterior wall present) from below (posterior wall absent, rectus on transversalis fascia), relevant to component-separation and mesh-repair techniques for large ventral hernias.

High-yield exam pointers

- ▶ Rectus sheath = aponeurotic sheath of external oblique + internal oblique + transversus abdominis around rectus abdominis ($\pm$ pyramidalis); anterior wall complete and adherent to tendinous intersections, posterior wall incomplete and free.
- ▶ **Three levels of formation:** above costal margin (anterior = EO only, posterior absent); costal margin to arcuate line (anterior = EO + anterior lamina IO, posterior = posterior lamina IO + TA); below arcuate line (anterior = all three fused, posterior absent).
- ▶ **Arcuate line** (linea semicircularis/of Douglas) = classic teaching "midway between umbilicus and pubic symphysis"; transition is often gradual, not always sharp.
- ▶ Medial fusion = **linea alba** (xiphoid to pubic symphysis/crest); lateral fusion = **linea semilunaris** (9th costal cartilage to pubic tubercle).
- ▶ **Contents:** rectus abdominis + pyramidalis; superior & inferior epigastric arteries/veins; lower 5 intercostal nerves + subcostal nerve (T7–T12).
- ▶ Superior epigastric artery enters at the top (piercing between costal/xiphoid diaphragmatic origins); inferior epigastric artery enters **in front of the arcuate line**; the two anastomose.

- ▶ Nerves enter the sheath at its **lateral margin**, run behind rectus abdominis, then pierce it and the anterior wall near the midline.
- ▶ Applied triad: paramedian incision with lateral retraction; rectus sheath haematoma (inferior epigastric artery, no tamponade below arcuate line); Spigelian hernia at the semilunaris–arcuate line junction; divarication of recti (linea alba stretching, not a true hernia).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Textbook of Anatomy Vol 2, 6e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen).



Describe the peritoneal reflection and discuss the subphrenic spaces

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

Definition / Introduction The **peritoneum** is the largest serous membrane of the body, lining the abdominal/pelvic walls (**parietal layer**) and investing the viscera (**visceral layer**); the two layers are continuous by **reflection** at the root of each viscus, and this folding-back creates the mesenteries, omenta and ligaments that partition the peritoneal cavity. Tracing this reflection explains how the **greater sac** is divided by the transverse mesocolon into **supracolic** and **infracolic compartments**, the supracolic compartment being further subdivided by the liver's ligaments into the **subphrenic (perihepatic) spaces** — the commonest sites of intraperitoneal abscess.

1. General plan of the peritoneum

- ▶ **Parietal peritoneum** — lines abdominal/pelvic walls and the inferior diaphragmatic surface; derived from **somatopleuric** lateral plate mesoderm; supplied by somatic nerves of the body wall → pain is **well-localized** (produces guarding/rigidity).
- ▶ **Visceral peritoneum** — firmly adherent to viscera; derived from **splanchnopleuric** mesoderm; supplied by autonomic afferents → pain from stretch/ischaemia is **poorly localized**.
- ▶ **Peritoneal cavity** — a potential space between the two layers containing a thin film of lubricating serous fluid; divided into the **greater sac** (main cavity) and the **lesser sac/omental bursa** (behind stomach, lesser omentum and liver), which communicate through the **epiploic foramen (of Winslow)**.
- ▶ Peritoneal folds are named by convention: **meso-** + organ (mesentery, mesocolon), **omenta** (folds attached to stomach), and **ligaments** (folds connecting two viscera, or a viscus to the wall).

2. Sagittal (vertical) tracing of the peritoneal reflection

Following the reflection from the anterior abdominal wall, over the viscera, to the pelvis and back:

- ▶ Peritoneum lines the **anterior abdominal wall and diaphragm** (1st layer).
- ▶ It reaches the **liver**, is reflected onto its surfaces (2nd layer), then reflected again at the **porta hepatis** to form the two layers of the **lesser omentum**.

- ▶ The lesser omentum encloses the **stomach**; its two layers continue down as the **greater omentum**, which folds upon itself — the 1st layer becomes the 4th, the 2nd becomes the 3rd.
- ▶ The 3rd and 4th layers enclose the **transverse colon**, continuing as the **transverse mesocolon**.
- ▶ The 3rd layer lines the **upper posterior abdominal wall**; the 4th layer passes around the small bowel to form the **mesentery**.
- ▶ Peritoneum continues over the **posterior abdominal wall**, descends into the **true pelvis**, and passes in front of the **rectum**.
- ▶ **In the male** — from the rectum it passes onto the **urinary bladder**, forming the **rectovesical pouch**.
- ▶ **In the female** — from the rectum it passes onto the **uterus** (forming the **rectouterine pouch of Douglas**) and from the uterus onto the bladder (forming the **vesicouterine pouch**).
- ▶ In both sexes it then passes from the bladder back onto the **anterior abdominal wall**, completing the sagittal circuit.

3. Horizontal tracing of the peritoneal reflection

Level	Course of reflection
Above transverse colon	Falciform ligament → over liver → lesser omentum → stomach → gastrosplenic ligament → spleen → lienorenal (splenorenal) ligament → posterior abdominal wall → back as the deep layer, re-forming the falciform ligament on the liver
Below transverse colon	Posterior abdominal wall → medially becomes continuous with the two layers of the mesentery → reaches the small intestine; on the back of the anterior wall it raises the median, medial and lateral umbilical folds and the inguinal/femoral fossae
Pelvis (male)	Rectovesical pouch, sacrogenital folds, pararectal and paravesical fossae
Pelvis (female)	Broad ligament (a transverse septum), rectouterine and vesicouterine pouches, pararectal/paravesical fossae, mesovarium

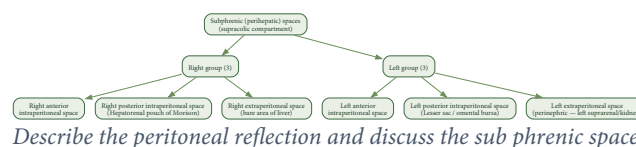
4. Major peritoneal folds produced by the reflection

Fold/ligament	Connects	Note
Falciform ligament	Liver ↔ anterior abdominal wall/diaphragm	Free margin carries ligamentum teres (obliterated left umbilical vein); separates right and left anterior subphrenic spaces
Lesser omentum (hepatogastric + hepatoduodenal parts)	Liver ↔ stomach/1st part of duodenum	Free right margin (hepatoduodenal ligament) carries the portal triad
Greater omentum	Stomach/duodenum → transverse colon	Four-layered "abdominal policeman"; rich in fat and milky spots

Fold/ligament	Connects	Note
Coronary & triangular ligaments	Liver ↔ diaphragm	Enclose the bare area of the liver between their two layers
Gastrosplenic ligament	Stomach ↔ spleen	Carries short gastric & left gastro-epiploic vessels
Lienorenal (splenorenal) ligament	Spleen ↔ posterior abdominal wall	Carries splenic vessels and tail of pancreas
Phrenicocolic ligament	Splenic flexure ↔ diaphragm	Slings the spleen; partially blocks the left paracolic gutter
Mesentery proper	Jejunum/ileum ↔ posterior abdominal wall	Carries superior mesenteric vessels, nerves, nodes
Transverse mesocolon	Transverse colon ↔ pancreas	Divides greater sac into supracolic/infracolic compartments
Sigmoid mesocolon	Sigmoid colon ↔ pelvic wall	Inverted-V root; apex over left ureter

5. Compartmentalisation of the greater sac and classification of the sub-phrenic spaces

- ▶ The transverse mesocolon divides the greater sac into a **supracolic compartment** (above) and an **infracolic compartment** (below); the infracolic compartment is further divided by the **root of the mesentery** into a triangular **right infracolic space** (apex at the ileocaecal junction) and a quadrangular **left infracolic space** (opens freely into the pelvis).
- ▶ **Paracolic gutters** lie lateral to the ascending/descending colon, connecting the supracolic and infracolic/pelvic compartments — the principal pathways for spread of infected peritoneal fluid.
- ▶ The **supracolic compartment** is itself subdivided by the liver's peritoneal ligaments into **six subphrenic (perihepatic) spaces** — three on the right and three on the left; in each triad, two are **intraperitoneal** and one is **extraperitoneal**.



□ Fig 6.22 — Schematic diagram showing subphrenic spaces and paracolic gutters (GB = gall bladder; RIS = right infracolic space; LIS = left infracolic space) (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.299)

Note (BD Chaurasia): some texts additionally name a small midline extraperitoneal space corresponding to the bare area itself, bounded above and below by the superior and inferior layers of the coronary ligament — a direct route for spread of a liver abscess.

6. Boundaries of the individual sub-phrenic spaces

Space	Anterior	Posterior	Superior	Communications
Right anterior intraperitoneal space	Diaphragm/ anterior abdominal wall	Anterior surface of liver	Superior layer of coronary ligament	Left: falciform ligament (separates from left anterior space); communicates with right posterior space around the liver's sharp inferior border
Right posterior intraperitoneal space (Hepatorenal pouch of Morison)	Visceral surface of right lobe of liver + gallbladder	Right suprarenal, upper pole right kidney, 2nd part duodenum, hepatic flexure, transverse mesocolon, head of pancreas	Inferior layer of coronary ligament	Epiploic foramen → lesser sac; opens into right paracolic gutter
Right extraperitoneal space (bare area)	Superior layer of coronary ligament	Inferior layer of coronary ligament	Diaphragm	Closed off — around the upper pole of the right kidney/IVC
Left anterior intraperitoneal space	Anterior abdominal wall	Left lobe of liver	Left triangular ligament	Continuous below in front of the lesser omentum/stomach, and around the spleen
Left posterior intraperitoneal space (Lesser sac/omental bursa)	Caudate lobe, lesser omentum, posterior wall of stomach, anterior 2 layers of greater omentum	Posterior 2 layers of greater omentum + stomach bed (pancreas, upper pole left kidney/suprarenal, transverse mesocolon)	—	Epiploic foramen (Winslow) → greater sac
Left extraperitoneal space	—	—	—	Loose tissue around left suprarenal gland/upper pole of left kidney — site of left perinephric abscess

The **epiploic foramen** (bounded in front by the free right margin of the lesser omentum containing the bile duct, hepatic artery and portal vein; behind by the IVC; above by the caudate process; below by the

1st part of duodenum) is the sole communication of the lesser sac with the greater sac, and hence with the right posterior (hepatorenal) space.

7. Paracolic gutters and spread of infection

- ▶ **Right paracolic gutter** — lateral to ascending colon; freely continuous above with the **hepatorenal pouch** and below with the pelvis; the principal channel by which infection ascends from the appendix/right iliac fossa or descends from the hepatorenal pouch/lesser sac.
- ▶ **Left paracolic gutter** — lateral to descending colon; continuous below with the pelvis, but **partially obstructed above by the phrenicocolic ligament** — this is why left subphrenic collections are distinctly less common than right-sided ones.
- ▶ Peritoneal fluid circulates in a predominantly **clockwise** direction around the cavity (ascending the right paracolic gutter into the right subphrenic space, and pooling in the pelvis), which explains characteristic patterns of spread of intraperitoneal infection and metastasis.

Applied / Clinical anatomy

- ▶ **Subphrenic abscess** — localized pus collection below the diaphragm, above the transverse colon/mesocolon; usual causes are perforated appendicitis or peptic ulcer, cholecystitis, pancreatitis, or postoperative leaks (cholecystectomy, gastrectomy, splenectomy). The **hepatorenal pouch of Morison** is the commonest site because it is the most dependent part of the peritoneal cavity above the pelvic brim in the supine position — summarized by the classic teaching aphorism, "**pus somewhere, pus nowhere else, pus under the diaphragm**," reflecting the notorious difficulty of clinical diagnosis.
- ▶ **Referred pain** — the central diaphragmatic peritoneum is supplied by the **phrenic nerve** (C3–C5), so central irritation (e.g., subphrenic abscess) refers pain to the **shoulder tip**; the peripheral diaphragmatic peritoneum is supplied by the lower intercostal/subcostal nerves, giving well-localized costal margin pain instead.
- ▶ **Fitz-Hugh–Curtis syndrome** — gonococcal or chlamydial organisms ascend from the uterine tubes and are carried by the clockwise flow of peritoneal fluid to the right upper quadrant, producing perihepatic ("violin-string") adhesions in the right subphrenic/subhepatic spaces.
- ▶ **Lesser sac collections** — acute pancreatitis or a perforated posterior gastric ulcer are the commonest causes; may result in a **pancreatic pseudocyst** bulging forward between stomach and liver, or stomach and transverse colon.
- ▶ **Imaging/intervention** — erect radiograph shows free gas under the diaphragm in visceral perforation; **ultrasound/CT-guided percutaneous drainage** has largely replaced open surgical drainage (classically an extraperitoneal posterior approach through the bed of the 12th rib, avoiding soiling of the pleura/general peritoneal cavity).
- ▶ Rare **pleuroperitoneal fenestrae** allow a subphrenic abscess to burst into the pleural cavity, producing an empyema.

High-yield exam pointers

- ▶ Six subphrenic spaces: **three right + three left**; each triad = **2 intraperitoneal + 1 extraperitoneal**.
- ▶ Right posterior intraperitoneal space = **hepatorenal pouch of Morison** — commonest site of subphrenic abscess (most dependent space, supine).

- ▶ Left posterior intraperitoneal space = the **lesser sac (omental bursa)**.
- ▶ **Falciform ligament** separates the right and left anterior spaces and blocks leftward spread of peritoneal fluid.
- ▶ **Phrenicocolic ligament** partially blocks the left paracolic gutter → fewer left-sided subphrenic abscesses.
- ▶ **Right paracolic gutter** freely connects Morison's pouch to the pelvis — main route of ascending/descending spread of infection.
- ▶ **Epiploic foramen of Winslow** is the only communication of the lesser sac with the greater sac; bounded by the portal triad in front, IVC behind.
- ▶ Central diaphragmatic peritoneum (phrenic nerve, C3–C5) → referred **shoulder-tip pain** in subphrenic pathology.
- ▶ USG/CT-guided percutaneous drainage is now first-line management of a subphrenic abscess.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- ▶ **Sagittal section of the abdomen** showing the peritoneal reflection and 4 layers of greater omentum — label: Diaphragm; Liver; Falciform ligament; Lesser omentum; Stomach; Greater omentum (layers 1–4); Transverse colon/mesocolon; Duodenum; Pancreas; Mesentery; Rectum; Rectovesical pouch (male) or Pouch of Douglas + Vesicouterine pouch (female); Urinary bladder.
- ▶ **Subphrenic spaces with paracolic gutters** (as embedded above) — label: Diaphragm; Falciform ligament; Liver; Gallbladder; Stomach; Right/Left anterior subphrenic space; Morison's pouch; Phrenicocolic ligament; Right/Left paracolic gutter; RIS; LIS; Rectum.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh's Textbook of Anatomy Vol 2 4e.



Give the formation of rectus sheath, its contents and applied aspects

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction The rectus sheath is a strong, bilaminar aponeurotic sheath that encloses rectus abdominis (and pyramidalis, when present) on each side of the anterior abdominal wall. It is formed by the splitting and fusion of the aponeuroses of the three flat anterolateral abdominal muscles — external oblique, internal oblique and transversus abdominis — as they pass medially towards the linea alba. The sheath confers mechanical advantage on rectus abdominis by preventing it from "bow-stringing" during contraction, maintains the tensile strength of the anterior abdominal wall, and transmits the epigastric vessels and the thoraco-abdominal nerves. Its composition changes at three distinct levels, and its lower limit — the **arcuate line** — is of major surgical importance.

Formation of the rectus sheath

Each of the three lateral abdominal muscles becomes aponeurotic before it reaches rectus abdominis. At the lateral border of rectus (the **linea semilunaris**, extending from the tip of the 9th costal cartilage to the pubic tubercle), the aponeurosis of internal oblique splits into an anterior and a posterior lamina — the anterior lamina fusing with the aponeurosis of external oblique, and the posterior lamina fusing with the aponeurosis of transversus abdominis. Each aponeurosis is itself bilaminar, with fibres of the anterior leaves running obliquely upward and the posterior leaves running obliquely downward, at right angles to each other; the three muscles thus behave as **digastric muscles with a common central tendon**, the linea alba, at which fibres decussate both from side to side and from front to back (Rizk's concept). This gives three distinct patterns of formation:

Level	Anterior wall of sheath	Posterior wall of sheath
Above the costal margin (opposite 5th–7th costal cartilages)	External oblique aponeurosis only	Absent — rectus abdominis lies directly on the costal cartilages
Costal margin to arcuate line	External oblique aponeurosis + anterior lamina of internal oblique aponeurosis	Posterior lamina of internal oblique aponeurosis + aponeurosis of transversus abdominis
Below the arcuate line	Aponeuroses of all three muscles (external oblique separate; internal oblique and transversus abdominis fused)	Absent — rectus abdominis rests directly on the transversalis fascia and extraperitoneal fat

The anterior wall is complete along the whole length of the muscle and is firmly adherent to its tendinous intersections; the posterior wall is free from the muscle and is deficient both above the costal margin and below the arcuate line.

Arcuate line (linea semicircularis / fold of Douglas)

- A curved, concave-downward line marking the lower limit of the posterior rectus sheath, classically described as lying **midway between the umbilicus and the pubic symphysis**.

- ▶ Below this line all three aponeuroses pass **anterior** to rectus abdominis, so the muscle is separated from the peritoneum only by transversalis fascia and extraperitoneal connective tissue — this is the plane through which the **inferior epigastric vessels** enter the sheath.
- ▶ The transition is usually gradual but can be abrupt; this level corresponds to roughly the junction of the upper two-thirds and lower one-third of the muscle's posterior covering.
- ▶ Surgically it is the intersection point exploited in **Spigelian hernia** and in retromuscular (Rives–Stoppa) hernia repairs (see Applied anatomy).

Contents of the rectus sheath

Category	Structures	Course/notes
Muscles	Rectus abdominis (chief content); pyramidalis (if present)	Pyramidalis lies anterior to the lowest part of rectus abdominis and inserts into the linea alba
Arteries	Superior epigastric artery (terminal branch of internal thoracic artery)	Enters the sheath behind the 7th costal cartilage, between the costal and xiphoid origins of the diaphragm; runs down behind rectus abdominis and anastomoses with the inferior epigastric artery
	Inferior epigastric artery (branch of external iliac artery)	Runs medially in extraperitoneal tissue, pierces transversalis fascia at the lateral border of rectus abdominis, and enters the sheath in front of the arcuate line
Veins	Superior epigastric venae comitantes → internal thoracic vein; inferior epigastric venae comitantes → external iliac vein	Provide a porto-systemic/caval collateral pathway across the sheath
Nerves	Terminal (anterior cutaneous) branches of the lower six thoracic ventral rami — the 7th–11th intercostal and the subcostal (T12) nerves	Enter the neurovascular plane between internal oblique and transversus abdominis, pierce the posterior lamina of internal oblique aponeurosis to enter the sheath, run behind rectus abdominis, then pierce the muscle and the anterior wall near the midline to supply overlying skin (T10 at the umbilicus)

The subcostal nerve additionally supplies pyramidalis; the ilioinguinal and iliohypogastric nerves (L1) do **not**, as a rule, enter the rectus sheath — they remain extraperitoneal/subaponeurotic and become cutaneous near the superficial inguinal ring (occasional aberrant contribution of the ilioinguinal nerve to rectus abdominis is described).

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a transverse (cross-sectional) diagram of the anterior abdominal wall at two levels — above the umbilicus and below the arcuate line — and label:

- ▶ Rectus abdominis (and pyramidalis, if drawn below the umbilicus)
- ▶ Linea alba (midline) and linea semilunaris (lateral border of rectus)
- ▶ External oblique muscle/aponeurosis
- ▶ Internal oblique muscle, with its anterior and posterior laminae shown splitting around rectus abdominis (above arcuate line only)
- ▶ Transversus abdominis muscle/aponeurosis
- ▶ Anterior wall of rectus sheath and posterior wall of rectus sheath (mark posterior wall "absent" in the below-arcuate-line diagram)
- ▶ Transversalis fascia and extraperitoneal fat (shown directly against rectus abdominis in the below-arcuate-line diagram)
- ▶ Peritoneum

 Fig 61.8 — The rectus sheath. Computed tomography scan (A) and diagram (B) of the anterior abdominal wall, demonstrating the formation of the rectus sheath above the umbilicus (Gray's Anatomy — Standring — 41e, p.1496)

Applied / Clinical anatomy

- ▶ **Paramedian incision:** preferred over a median incision for laparotomy because it is more sound mechanically. It is made through the anterior wall of the rectus sheath about 2–3 cm lateral to the midline; rectus abdominis is retracted **laterally** (not incised) to protect its segmental nerve supply, which enters the muscle from the lateral side. The risk of subsequent incisional/ventral hernia is minimal compared with a midline incision.
- ▶ **Median (midline) incision:** bloodless and rapid as it passes through the avascular linea alba, but a supra-umbilical median incision can leave postoperative weakness with risk of a **ventral (incisional) hernia**; an infra-umbilical median incision is safer because the closely apposed recti below the umbilicus resist gaping.
- ▶ **Epigastric hernia:** protrusion of extraperitoneal fat (occasionally with a peritoneal sac) through a defect in the wide upper part of the linea alba, above the umbilicus.
- ▶ **Divarication (diastasis) of recti:** thinning and widening of the linea alba, typically in multiparous or obese patients, causing the two recti to separate; a broad midline bulge appears on straining/coughing but reduces spontaneously — this is **not** a true hernia because all layers of the abdominal wall remain intact.
- ▶ **Spigelian hernia:** an interstitial hernia occurring at (or near) the point where the linea semilunaris crosses the arcuate line; it passes through a defect in the aponeuroses of transversus abdominis and internal oblique but remains covered by the intact external oblique aponeurosis, making it easy to miss clinically.
- ▶ **Arcuate line as a plane of surgical access:** because the posterior rectus sheath is absent below this line, surgeons exploit the retromuscular (Rives–Stoppa–Wantz) plane above it — incising the

posterior sheath just lateral to the linea alba — for mesh placement during large ventral/incisional hernia repair (component separation techniques).

- ▶ **Rectus sheath haematoma:** bleeding into the sheath from rupture of the epigastric vessels or a tear of rectus abdominis itself (anticoagulation, forceful coughing/straining, trauma, or injections); it presents as a tender abdominal wall mass that does **not** cross the midline above the arcuate line (because the sheath is adherent to the linea alba) but may spread more diffusely below it (where the posterior wall is deficient) — a well-recognised mimic of an acute intra-abdominal emergency, distinguished clinically by a positive Carnett's sign (pain persists/worsens on tensing the recti).
- ▶ **Rectus sheath block:** local anaesthetic deposited in the plane between rectus abdominis and its posterior sheath, exploiting the course of the thoraco-abdominal nerves within the sheath, to provide analgesia for umbilical hernia repair and midline laparotomy incisions.
- ▶ **Myocutaneous flap:** the excellent vascularity of rectus abdominis from the superior and inferior epigastric vessels, together with the ease of separating the muscle from its sheath, makes it a reliable flap (e.g., TRAM flap) for breast and pelvic/perineal reconstruction.

High-yield exam pointers

- ▶ Three flat muscles → bilaminar aponeuroses → rectus sheath; "digastric muscle, common tendon = linea alba" concept.
- ▶ Three zones of formation: above costal margin (anterior wall only, from external oblique); costal margin to arcuate line (both walls); below arcuate line (all three aponeuroses anterior, posterior wall absent).
- ▶ Arcuate line = midway between umbilicus and pubic symphysis; marks the point of entry of the inferior epigastric artery into the sheath.
- ▶ Contents: rectus abdominis + pyramidalis; superior and inferior epigastric arteries with venae comitantes; terminal branches of the lower six thoracic nerves (T7–T12).
- ▶ Linea semilunaris = lateral border of rectus/lateral limit of the sheath, from 9th costal cartilage to pubic tubercle.
- ▶ Paramedian incision — retract rectus laterally to save its nerve supply; safer than median incision for avoiding incisional hernia.
- ▶ Applied triad to remember: epigastric hernia (linea alba), divarication of recti (not a true hernia), Spigelian hernia (linea semilunaris × arcuate line).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2, 8e; AK Datta Human Anatomy Vol 1 (Thorax & Abdomen).



Gross anatomy of pancreas

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction. The pancreas (Gk. *pan* = all, *kreas* = flesh) is a soft, lobulated, mixed exocrine-endocrine digestive gland that develops at the junction of the foregut and midgut from a dorsal and a ventral pancreatic bud. It lies transversely (with a slight upward and backward slant) across the posterior abdominal wall, behind the stomach, at the level of the L1-L2 vertebrae, extending from the C-loop of the duodenum on the right to the hilum of the spleen on the left. It is **secondarily retroperitoneal** throughout most of its length (the tail alone is enclosed in the lienorenal/splenorenal ligament) and is separated from the stomach anteriorly by the cavity of the lesser sac.

Location, dimensions and shape

Feature	Description
Situation	Posterior part of epigastrium and left hypochondrium; transversely placed at level of L1-L2 vertebrae
Peritoneal relation	Secondarily retroperitoneal (except tail, which lies between the two layers of the lienorenal ligament)
Shape	J-shaped / retort-shaped , set obliquely; bowl of the retort = head, stem = neck, body and tail
Length	About 15-20 cm (BD Chaurasia); 12-15 cm (Gray's, AK Datta)
Breadth	2.5-3.8 cm
Thickness	1.2-1.8 cm
Weight	About 80-90 g
Colour/consistency	Creamy-pink, soft, lobulated surface

Parts and external features

- ▶ **Head** — the enlarged right end, flattened antero-posteriorly, lodged within the concavity of the C-shaped duodenum. Has three borders (superior, inferior, right lateral), two surfaces (anterior, posterior) and one process:
 - **Uncinate process** — a hook-like prolongation from the lower and left part of the head, projecting behind the superior mesenteric vessels towards the left; embryologically it is a separate (ventral bud) element.
- ▶ **Neck** — a short, constricted part (~2 cm wide) connecting head to body; directed forwards, upwards and to the left; lies anterior to the site of formation of the portal vein (union of splenic and superior mesenteric veins).
- ▶ **Body** — the longest part, extends from neck to tail; triangular on cross-section with three borders (anterior, superior, inferior) and three surfaces (anterior, posterior, inferior). A projection on the superior border just left of the neck is the **tuber omentale**.

- **Tail** — the narrowest, most lateral part; lies within the lienorenal (splenorenal) ligament together with the splenic vessels and reaches the hilum of the spleen; the only intraperitoneal part of the gland and therefore the most mobile.

Relations

Part	Anterior	Posterior
Head	First part of duodenum; transverse mesocolon	Inferior vena cava, terminal parts of renal veins, right crus of diaphragm, bile duct (often embedded in the gland substance)
Uncinate process	Superior mesenteric vessels	Aorta
Neck	Peritoneum of lesser sac; pylorus	Beginning of portal vein (union of splenic + superior mesenteric veins)
Body	Lesser sac and stomach (root of transverse mesocolon attaches to anterior border)	Aorta with origin of SMA, left crus of diaphragm, left suprarenal gland, left kidney, left renal vessels, splenic vein
Tail	—	Splenic vessels (within lienorenal ligament); touches the gastric surface (lower part) of the spleen

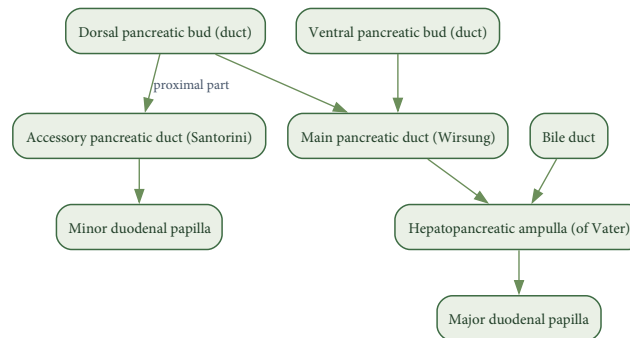
- **Three borders of the head:** superior (overlapped by 1st part of duodenum; related to superior pancreaticoduodenal artery), inferior (related to 3rd part of duodenum and inferior pancreaticoduodenal artery), right lateral (related to 2nd part of duodenum, terminal bile duct, and the pancreaticoduodenal arterial anastomosis).
- **Three borders of the body:** superior (related to coeliac trunk over the tuber omentale, hepatic artery to the right, splenic artery to the left), inferior (related to superior mesenteric vessels at its right end), anterior (gives attachment to the root of the transverse mesocolon).
- **Inferior surface of body:** covered by peritoneum, related to duodenojejunal flexure, coils of jejunum and the left colic (splenic) flexure.

Pancreatic ducts

- **Main pancreatic duct (of Wirsung)** — begins at the tail, runs to the right through the body lying nearer the posterior surface, receiving small tributaries at acute angles ("**herring-bone**" pattern); bends downward, backward and to the right within the head; ultrasound calibre is roughly 3 mm in the head, 2 mm in the body, 1 mm in the tail.
- Within the head, the main duct lies to the left of, and joins, the **bile duct**, which lies on its right side; together they form the short **hepatopancreatic ampulla (of Vater)**, guarded by the **sphincter of Oddi**, opening on the summit of the **major duodenal papilla** (about 8-10 cm distal to the pylorus).
- **Accessory pancreatic duct (of Santorini)** — drains the upper anterior part of the head, crosses in front of the main duct with which it usually communicates, and opens independently on the

minor duodenal papilla (about 6-8 cm distal to the pylorus, roughly 2 cm proximal to the major papilla).

- The two ducts recapitulate the **double (dorsal + ventral bud) embryological origin** of the gland — the main duct is formed by fusion of the ventral duct with the distal part of the dorsal duct, while the accessory duct represents the proximal (unfused) part of the dorsal duct.



Gross anatomy of pancreas

Blood supply, lymphatics and nerve supply

- **Arterial supply** (reflects the foregut/midgut origin — coeliac axis + SMA):
 - Head and uncinate process: **superior pancreaticoduodenal artery** (anterior + posterior, from the gastroduodenal branch of the coeliac trunk) and **inferior pancreaticoduodenal artery** (anterior + posterior, from the SMA); the anterior and posterior pairs anastomose to form **pancreaticoduodenal arcades**.
 - Body and tail: multiple pancreatic branches of the **splenic artery**, including the dorsal pancreatic, great pancreatic (pancreatica magna) and caudal (arteria caudae pancreatis) arteries.
- **Venous drainage** — corresponding veins drain into the **splenic, superior mesenteric and portal veins**; the portal vein itself is formed behind the neck of the pancreas.
- **Lymphatic drainage** — follows the arteries: tail/body → nodes along the splenic artery → pre-aortic (coeliac) nodes; neck/head → pancreaticoduodenal, superior mesenteric and hepatic node groups → pre-aortic nodes. Collectively described as the **pancreaticosplenic, coeliac and superior mesenteric groups**.
- **Nerve supply** — sympathetic fibres (thoracic splanchnic nerves, vasomotor) and parasympathetic fibres (vagus, secretomotor to acini) reach the gland via the periarterial (coeliac and splenic) plexuses; pancreatic ganglia are most abundant in the head and neck. Secretion is additionally driven by the hormones **secretin** and **cholecystokinin** released from duodenal mucosal cells.

□ Fig 27.12 — Duodenum with pancreas (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.435)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the "retort/J-shaped" pancreas lying transversely with the duodenal C-loop on the right and the splenic hilum on the left. Label:

- ▶ Head (within concavity of duodenum), **uncinate process**, neck, body, tail (reaching hilum of spleen)
- ▶ Duodenum — 1st, 2nd, 3rd, 4th parts encircling the head
- ▶ Bile duct grooving/embedded in the posterior part of the head
- ▶ Superior mesenteric artery and vein crossing anterior to the uncinate process / posterior to the neck
- ▶ Portal vein formation behind the neck (union of splenic + SMV)
- ▶ Main pancreatic duct (Wirsung) running through body/tail into the head, joining the bile duct
- ▶ Accessory pancreatic duct (Santorini) opening at the minor duodenal papilla, proximal to the major papilla
- ▶ Splenic artery and vein along the superior border of body/tail
- ▶ Tuber omentale on the superior border of the body

Applied / Clinical anatomy

- ▶ **Carcinoma of the head of pancreas** is the commonest site of pancreatic cancer; by compressing the bile duct embedded in the head it produces painless, progressive **obstructive jaundice**; it may also compress the portal vein (ascites) or the stomach/duodenum (pyloric/duodenal obstruction).
- ▶ Because the neck lies directly anterior to the **portal vein confluence**, tumour involvement of this plane is a key determinant of resectability on imaging.
- ▶ **Acute pancreatitis** — pain is poorly localized, felt in the epigastrium and referred to the back/paravertebral region (lower thoracic segments) owing to the retroperitoneal position; fluid may collect in the lesser sac as a **pseudocyst**. It may follow gallstones impacted at the common channel/ampulla, or mumps.
- ▶ **Annular pancreas** — persistence of a ring of ventral pancreatic tissue encircling the 2nd part of the duodenum, a cause of duodenal obstruction (bilious or non-bilious vomiting in the neonate).
- ▶ **Pancreas divisum** — failure of fusion of dorsal and ventral duct systems, so the bulk of the gland drains via the (dominant) accessory duct through the minor papilla — a risk factor for recurrent pancreatitis.
- ▶ The **tail** lies close to the splenic hilum and is at risk of injury during splenectomy while ligating the splenic vessels.
- ▶ The pancreas is richly vascular and prone to profuse haemorrhage in trauma/pancreatitis; blood may track into the flanks, groins or (via the bare area of the liver) into the falciform ligament.
- ▶ **Ectopic/accessory pancreatic tissue** may occur in the stomach, duodenum, jejunum, ileum or a Meckel's diverticulum.

- ▶ Only the head and neck are amenable to partial (Whipple-type) resection because of the vascular relations of the body and tail to the splenic vessels and left kidney.

High-yield exam pointers

- ▶ J-/retort-shaped, secondarily retroperitoneal gland (except tail) at the level of L1-L2 vertebrae; ~15 cm long, ~90 g.
- ▶ Four parts: head (with uncinate process), neck, body (tuber omentale), tail (in lienorenal ligament, at spleen hilum).
- ▶ Neck lies anterior to the formation of the portal vein — surgically critical for resectability.
- ▶ Bile duct is embedded in the posterior part of the head; carcinoma of the head → obstructive jaundice.
- ▶ Main duct (Wirsung) → hepatopancreatic ampulla of Vater → major duodenal papilla; accessory duct (Santorini) → minor duodenal papilla.
- ▶ Dual arterial supply: pancreaticoduodenal arcades (coeliac + SMA) for head/uncinate process; splenic artery branches for body/tail — reflects foregut-midgut junctional development.
- ▶ Dorsal + ventral pancreatic buds explain both the uncinate process and the double-duct system; failure of fusion → pancreas divisum; persistent ventral ring → annular pancreas.
- ▶ Lymphatics drain via pancreaticosplenic, coeliac and superior mesenteric node groups to pre-aortic nodes.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e (Spleen, Pancreas and Liver); AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 2, 4e.



Gross anatomy of second part of Duodenum

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction The duodenum is the first and shortest part of the small intestine, extending from the pylorus to the duodenojejunal flexure, and is C-shaped, cradling the head of the pancreas. It is divided into four parts — superior, descending (second), horizontal (third) and ascending (fourth). The **second (descending) part** is the longest-fixed segment and the most clinically important, because the bile duct and main pancreatic duct open into it at the major duodenal papilla — the site marking the embryological junction of the foregut and midgut. It is almost entirely retroperitoneal and is a key relation of the head of pancreas, right kidney and biliary tree.

Extent, Course and Peritoneal Relations

Part	Length	Course
First (superior)	5 cm (2 in)	Pylorus → superior duodenal flexure

Part	Length	Course
Second (descending)	7.5 cm (3 in)	Superior duodenal flexure → inferior duodenal flexure
Third (horizontal)	10 cm (4 in)	Inferior duodenal flexure → in front of aorta
Fourth (ascending)	2.5 cm (1 in)	Left of aorta → duodenojejunal flexure

- Begins at the **superior duodenal flexure** (right of L1 vertebra), descends **vertically along the right side of the bodies of L1–L3 vertebrae**, and turns medially at the **inferior duodenal flexure** (lower border of L3) to become the third part.
- **Retroperitoneal and fixed** throughout its length.
- Its **anterior surface is covered by peritoneum**, except near its middle, where it is directly crossed by (related to) the **transverse colon and the root of the transverse mesocolon**, which divide it into a supracolic and an infracolic segment.
- Lies embedded in a groove along the concave (duodenal) border of the **head of the pancreas**, to which it is adherent, particularly around the duodenal papillae.

Visceral Relations

Direction	Structures related
Anteriorly	Right lobe of liver; transverse colon; root of transverse mesocolon; coils of small intestine
Posteriorly	Anterior surface of right kidney (near medial border); right renal vessels; right edge of inferior vena cava; right psoas major
Medially	Head of pancreas (with which it is applied and adherent); bile duct (running in a groove/tunnel in the pancreatic head before piercing the duodenal wall)
Laterally	Right colic (hepatic) flexure of colon

- The **bile duct** descends behind the head of the pancreas, lying up to about 2 cm from the medial wall of the second part, before it pierces the postero-medial wall obliquely along with the main pancreatic duct.

Interior of the Second Part

- Mucosa bears **circular folds (plicae circulares / valvulae conniventes)**, which begin to appear in the second part (absent in the first part) and become tall and closely set more distally.
- **Major duodenal papilla** — a rounded elevation on the postero-medial wall, about 8–10 cm distal to the pylorus; at its summit opens the **hepatopancreatic ampulla (of Vater)**, formed by the union of the bile duct and the main pancreatic duct (of Wirsung), guarded by the **sphincter of Oddi**.

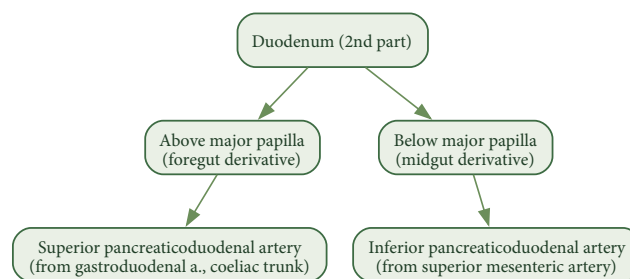
- ▶ **Minor duodenal papilla** — a smaller elevation about 6–8 cm distal to the pylorus, slightly proximal and anterior to the major papilla; gives passage to the **accessory pancreatic duct** (of Santorini).
- ▶ A **longitudinal fold (plica longitudinalis)** runs upward from the major papilla, formed by the terminal intramural course of the bile duct.

Diagram to draw — label a longitudinal (opened) view of the second part of the duodenum showing: pylorus, superior duodenal flexure, circular (mucosal) folds, minor duodenal papilla (accessory pancreatic duct), plica longitudinalis, major duodenal papilla (hepatopancreatic ampulla of Vater, bile duct + main pancreatic duct union), inferior duodenal flexure, and the head of pancreas applied along its medial/postero-medial wall.

□ Fig 9.4 — Relations of the second part of the duodenum (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.404)

Vascular Supply, Lymphatic Drainage and Nerve Supply

- ▶ The duodenum develops partly from the **foregut** and partly from the **midgut**; the site of entry of the bile duct into the second part marks this **foregut–midgut junction**, which governs its arterial supply.



Gross anatomy of second part of Duodenum

- ▶ Additional minor supply to the first part: right gastric artery, supraduodenal artery of Wilkie, retroduodenal branches of gastroduodenal artery, and right gastro-epiploic branches.
- ▶ **Venous drainage:** corresponding veins drain into the splenic, superior mesenteric and portal veins.
- ▶ **Lymphatic drainage:** to pancreaticoduodenal nodes along the duodeno-pancreatic groove → partly to hepatic nodes → coeliac nodes; partly to superior mesenteric nodes → intestinal lymph trunk → cisterna chyli.
- ▶ **Nerve supply:** sympathetic fibres from T9–T10 spinal segments and parasympathetic fibres from the vagus, reaching the gut wall via the coeliac plexus along the arteries.

Developmental Basis

- ▶ The duodenum forms from the caudal foregut and cranial midgut; the junction lies at the opening of the bile duct into the second part (major duodenal papilla).
- ▶ The **ventral pancreatic bud** rotates with the bile duct to lie below and behind the dorsal bud; the two buds **fuse**, so the ventral bud (and its duct) forms the lower part of the head/uncinate process and opens, with the bile duct, at the **major duodenal papilla**; the dorsal bud forms the rest of the head, neck, body and tail, and its proximal duct may persist as the **accessory pancreatic duct opening at the minor papilla**.

- ▶ This dual origin explains why the duodenal lumen is **temporarily obliterated by proliferation of its epithelial cells during the 5th–6th week**, normally becoming **recanalized by the end of the embryonic period (~8th week)** — failure/defective recanalization near the ampulla produces duodenal atresia/stenosis at this exact site.

Applied / Clinical anatomy

- ▶ **Duodenal (peptic) ulcer and its extension:** though classically a first-part lesion, ulcers can erode posteriorly toward the pancreatic head and gastroduodenal artery.
- ▶ **Congenital duodenal atresia/stenosis** characteristically occurs just distal to the ampulla, in the second part; presents with bilious vomiting soon after birth and the **"double bubble" sign** (distended stomach + proximal duodenum) on X-ray/USG. **Annular pancreas** — pancreatic tissue encircling the second part from failure of ventral bud rotation — is another cause of neonatal duodenal obstruction here.
- ▶ **Endoscopic retrograde cholangiopancreatography (ERCP):** the major duodenal papilla is the key surgical/endoscopic landmark for cannulating the bile and pancreatic ducts; the sphincter of Oddi can be incised (sphincterotomy) here to relieve obstruction or extract stones.
- ▶ **Periampullary/pancreatic head carcinoma:** because the second part is adherent to and shares blood supply with the head of pancreas, a growth here compresses the intramural bile duct, producing early **painless obstructive jaundice** with pale stools and dark urine — a classic surgical anatomy correlation.
- ▶ **Duodenal diverticula** occur along its concave (medial) border, typically at sites where the pancreaticoduodenal vessels perforate the wall (a locus minoris resistentiae).
- ▶ **Radiology:** the retroperitoneal, fixed second part is well shown on contrast studies and CT/MRCP as it curves around the pancreatic head; the CBD and pancreatic duct can be traced converging on the ampulla.

High-yield exam pointers

- ▶ Length **7.5 cm**; extends from superior duodenal flexure to inferior duodenal flexure, along right side of L1–L3 vertebral bodies.
- ▶ Retroperitoneal and fixed; peritoneum covers only its anterior surface, interrupted where the transverse mesocolon crosses it.
- ▶ Medially related to head of pancreas and the intramural bile duct; posteriorly to right kidney, right renal vessels, IVC and psoas major.
- ▶ **Major duodenal papilla** (8–10 cm from pylorus) = opening of hepatopancreatic ampulla (bile duct + main pancreatic duct), guarded by sphincter of Oddi; **minor papilla** (6–8 cm from pylorus) = accessory pancreatic duct.
- ▶ Marks the **foregut–midgut junction**: supply above the papilla via superior pancreaticoduodenal artery, below via inferior pancreaticoduodenal artery.
- ▶ Congenital atresia/annular pancreas classically affects this segment just distal to the ampulla → double-bubble sign.
- ▶ Clinical gateway for ERCP/sphincterotomy; site of earliest obstructive jaundice in periampullary carcinoma.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e; IB Singh — Textbook of Anatomy Vol 2 6e; Moore — Clinically Oriented Anatomy 9e; Vishram Singh — Textbook of Clinical Embryology.



Hepatic portal system

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction The hepatic portal system is a unique venous arrangement in which blood begins in one set of capillaries — in the wall of the abdominal gut, spleen, pancreas and gallbladder — and, instead of returning directly to the heart, is collected by the **portal vein** and ends in a *second* capillary bed, the hepatic sinusoids, before finally reaching the systemic (caval) circulation via the hepatic veins. It thus behaves like a vein at its origin and like an artery at its termination. The portal vein supplies about **75–80% of the blood flowing through the liver** (the remaining 20–25% is oxygen-rich blood from the hepatic artery), and its tributaries and branches together contain nearly one-third of the total blood volume of the body.

1. Formation, level and dimensions

- ▶ The portal vein is formed **behind the neck of the pancreas**, anterior to the inferior vena cava, by the union of the **superior mesenteric vein (SMV)** and the **splenic vein**.
- ▶ Level: in the **transpyloric plane**, between the lower border of the body of the first lumbar vertebra (L1) and the upper border of L2 (commonly rounded off to "L2" in Indian texts).
- ▶ The **inferior mesenteric vein (IMV)** usually joins the splenic vein (~60%) or the SMV (~40%); in roughly a third of individuals it joins exactly at the SMV–splenic confluence, so that all three veins together form the portal vein.
- ▶ Length: about **7–8 cm** (quoted as 8 cm by BD Chaurasia/Gray's, ~7.5 cm/3 inches by Vishram Singh) — a short but wide vein.
- ▶ It contains smooth muscle in its wall and, importantly, **it and its tributaries are devoid of valves** — the basis for reversal of flow in portal hypertension.

□ Fig 21.13 — Formation of portal vein (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.359)

2. Course, parts and relations

The portal vein runs upward and a little to the right — first behind the neck of the pancreas, then behind the first part of the duodenum, and finally within the right free margin of the lesser omentum (hepatoduodenal ligament) — where, together with the bile duct and hepatic artery, it forms the **portal triad**.

Part	Extent	Anterior relation(s)	Posterior relation
Infraduodenal	Below the 1st part of duodenum	Neck of pancreas	Inferior vena cava

Part	Extent	Anterior relation(s)	Posterior relation
Retroduodenal	Behind the 1st part of duodenum	1st part of duodenum, bile duct, gastroduodenal artery	Inferior vena cava
Supraduodenal	In the right free margin of the lesser omentum	Hepatic artery (left) and bile duct (right)	Inferior vena cava, separated by the epiploic (omental) foramen

The **epiploic foramen (of Winslow)** lies immediately posterior to this supraduodenal part: bounded anteriorly by the hepatoduodenal ligament (portal triad), posteriorly by the IVC and right crus of diaphragm, superiorly by the liver and inferiorly by the first part of duodenum. Compressing the hepatoduodenal ligament between finger and thumb here (the **Pringle manoeuvre**) temporarily occludes both portal and arterial inflow to control haemorrhage during liver surgery.

3. Tributaries

- ▶ **Splenic vein** — the larger formative tributary; drains the spleen, short gastric and left gastro-omental veins, pancreatic veins, and usually the IMV.
- ▶ **Superior mesenteric vein** — the smaller formative tributary; drains the small intestine, caecum, ascending and transverse colon (jejunal/ileal, ileocolic, right colic, middle colic and right gastro-omental veins), and pancreaticoduodenal veins.
- ▶ **Left gastric (coronary) vein** — joins the portal vein directly near its left margin; receives oesophageal tributaries at the cardiac end of the stomach.
- ▶ **Right gastric vein** — joins near the right margin; receives the prepyloric vein (of Mayo), a useful surgical landmark for the pylorus.
- ▶ **Superior pancreaticoduodenal vein** — joins behind the first part of the duodenum.
- ▶ **Cystic vein** — joins the **right branch** of the portal vein just before it enters the right lobe.
- ▶ **Paraumbilical veins (of Sappey)** — small veins running in the falciform ligament along the ligamentum teres, joining the **left branch**.

□ Fig 9.25 — Tributaries of the portal vein (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.430)

4. Termination and intrahepatic distribution

- ▶ The portal vein ends at the right end of the **porta hepatis** by dividing into **right and left branches**.
- ▶ **Right branch**: shorter and wider; receives the cystic vein; supplies the right lobe.
- ▶ **Left branch**: longer and narrower; crosses the porta hepatis to its left end, giving branches to the caudate and quadrate lobes before entering the left lobe. In fetal life it receives the **paraumbilical veins** (via the ligamentum teres) and the **ductus venosus** (via the ligamentum venosum).
- ▶ Within the liver, each branch divides and redivides alongside the hepatic artery to end in the **hepatic sinusoids**, where portal venous blood mixes with hepatic arterial blood; the mixed blood, separated from hepatocytes only by a fenestrated sinusoidal endothelium, is finally drained by the hepatic veins into the IVC.

- ▶ **Streamline flow:** blood from the SMV (nutrient-rich, from the gut) preferentially perfuses the right lobe, while blood from the splenic and inferior mesenteric veins (carrying products of red-cell breakdown from the spleen) preferentially perfuses the left lobe.
- ▶ The segmental branching pattern of the portal vein (Couinaud's 8 hepatic segments) forms the basis of modern liver-resection surgery.

5. Development (in brief)

The portal vein develops from the **vitelline (vitello-umbilical) veins** and the anastomoses that form around the developing duodenum:

- ▶ **Infraduodenal part** — from the left vitelline vein distal to the dorsal (subduodenal) anastomosis.
- ▶ **Retroduodenal part** — from the dorsal anastomosis between the two vitelline veins.
- ▶ **Supraduodenal part** — from the cranial part of the right vitelline vein.

6. Portosystemic (portocaval) anastomoses

Because the portal system is valveless, these sites act as pressure-relief collateral channels when portal flow is obstructed.

Site	Portal tributary	Systemic tributary	Clinical result when dilated
Lower end of oesophagus	Oesophageal tributaries of left gastric vein	Oesophageal tributaries draining into azygos/hemiazygos veins	Oesophageal varices → haematemesis
Umbilicus	Paraumbilical veins (of Sappey) along ligamentum teres	Superficial/superior & inferior epigastric veins of anterior abdominal wall	Caput medusae
Anal canal	Superior rectal vein → inferior mesenteric vein → splenic vein → portal vein	Middle and inferior rectal veins → internal iliac vein → IVC	Haemorrhoids (piles)
Bare area of liver	Portal venules of the liver	Phrenic and intercostal veins	Minor collateral, little clinical effect
Retroperitoneal (paracolic) surfaces of duodenum, ascending & descending colon	Colic veins	Veins of the posterior abdominal wall and renal capsule (veins of Retzius)	Minor collateral

□ Fig 9.26 — Sites of portocaval anastomosis (Vishram Singh — *Textbook of Anatomy Vol 2 — 4e*, p.432)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Two simple line diagrams score full marks:

- ▶ **Formation of the portal vein** — draw the confluence of splenic vein + SMV behind the neck of pancreas, with the IMV joining the splenic vein; label the transpyloric plane/L1–L2 level, the epiploic foramen, and the right/left terminal branches at the porta hepatis (receiving cystic vein and paraumbilical veins respectively).
- ▶ **Sites of portosystemic anastomosis** — a schematic figure of the trunk showing four labelled points: (1) lower end of oesophagus (left gastric vein ↔ azygos system), (2) umbilicus (paraumbilical veins ↔ superficial epigastric veins), (3) anal canal (superior rectal vein ↔ middle/inferior rectal veins), (4) bare area of liver (portal venules ↔ phrenic/intercostal veins). Label each with the resulting clinical condition (varices / caput medusae / haemorrhoids).

Applied / Clinical anatomy

- ▶ **Portal pressure:** normal is 5–15 mmHg, measured by splenic puncture and recording intrasplenic pressure; **portal hypertension** is a pressure **above 40 mmHg**.
- ▶ **Causes of portal hypertension:** cirrhosis of the liver (commonest — usually alcoholic, in which the hepatic vascular bed is obliterated), Banti's disease, and portal vein thrombosis.
- ▶ **Effects of portal hypertension:** splenomegaly, ascites, oesophageal varices, haemorrhoids and caput medusae — all consequences of dilated portosystemic collaterals described above.
- ▶ **Splenoportography:** radiopaque contrast injected into the spleen outlines the portal vein and its tributaries; care is needed as the needle traverses the costodiaphragmatic recess.
- ▶ **Portosystemic shunt surgery:** a surgical communication between the portal vein and IVC, or a **splenorenal (Linton/Warren) shunt** joining the splenic vein to the left renal vein after splenectomy, diverts portal blood into the systemic circuit and lowers portal pressure.
- ▶ **TIPS (transjugular intrahepatic portosystemic shunt):** an interventional-radiology alternative — a catheter is passed via the right internal jugular vein, right brachiocephalic vein, SVC, right atrium and IVC into a hepatic vein, then advanced through the hepatic parenchyma into a portal vein branch, where an expandable stent creates the shunt.
- ▶ **Pringle manoeuvre:** temporary digital/clamp compression of the hepatoduodenal ligament (portal triad) at the epiploic foramen controls bleeding during hepatic surgery, exploiting the fact that the portal vein and hepatic artery together supply virtually all afferent blood to the liver.
- ▶ **Portal vein thrombosis/tumour invasion** (e.g., pancreatic head carcinoma, hepatocellular carcinoma) is assessed pre-operatively by its close relations to the pancreas, duodenum and porta hepatis described above.
- ▶ The **cystic vein** draining directly into the right branch of the portal vein explains early hepatic metastasis from gallbladder carcinoma.

High-yield exam pointers

- ▶ Portal vein = union of SMV + splenic vein, behind neck of pancreas, transpyloric plane (L1–L2), ~8 cm long, no valves.

- ▶ Three parts by relation to duodenum: infra-, retro-, and supraduodenal — each with IVC posteriorly.
- ▶ Six tributaries besides the two formative veins: left & right gastric, superior pancreaticoduodenal, cystic (into right branch), paraumbilical (into left branch).
- ▶ Ends at porta hepatis → right (wider, + cystic vein) and left (longer, fetal ligamentum teres/venosum) branches.
- ▶ Carries 75–80% of hepatic blood flow; streamline flow — SMV blood to right lobe, splenic/IMV blood to left lobe.
- ▶ Four classical sites of portosystemic anastomosis: lower oesophagus, umbilicus, anal canal, bare area of liver — remember with the resulting clinical sign (varices/caput medusae/piles).
- ▶ Normal portal pressure 5–15 mmHg; portal hypertension >40 mmHg — commonest cause is cirrhosis.
- ▶ Surgical relief: splenorenal shunt, portocaval shunt, TIPS; Pringle manoeuvre controls inflow bleeding via the epiploic foramen.
- ▶ Develops from vitelline veins and their dorsal/subduodenal anastomoses.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 8e; Vishram Singh Textbook of Anatomy Vol 2 4e; IB Singh Textbook of Anatomy Vol 2 6e; Moore's Clinically Oriented Anatomy 9e.



Inferior vena cava

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction The inferior vena cava (IVC) is the largest vein in the body. It is a retroperitoneal structure formed by the union of the two common iliac veins and returns venous blood from the lower limbs, pelvis and abdominal parietes/viscera (apart from the portal-drained gut, spleen and pancreas, which pass through the liver first) to the right atrium. Its asymmetric origin from four paired embryonic venous systems — postcardinal, subcardinal, supracardinal and vitelline — explains both its segmental relations and its numerous clinically important congenital variants.

1. Formation, course and termination

- ▶ Formed anterior to the body of the **5th lumbar vertebra**, about 1 cm to the right of the median plane, by the union of the right and left common iliac veins.
- ▶ Ascends anterior to the vertebral column, to the **right of the abdominal aorta**.
- ▶ Grooves the posterior (bare) surface of the liver and may be partly embedded within liver tissue.
- ▶ Pierces the **central tendon of the diaphragm**, between its median and right leaves, at the level of the **8th thoracic vertebra** (the caval opening).
- ▶ Traverses a short intrapericardial course and opens into the **postero-inferior part of the right atrium**.

- The abdominal part of the IVC is **devoid of valves**; at its atrial orifice it is guarded by a crescentic vestigial fold, the **valve of the IVC (Eustachian valve)**, which in fetal life directs oxygenated blood across the foramen ovale into the left atrium.
- **Surface marking**: two vertical parallel lines 2.5 cm apart, a little to the right of the median plane, extending from just below the trans-tubercular plane to the sternal end of the right 6th costal cartilage.

2. Relations of the abdominal course

Aspect	Structures (below → above)
Anterior	Right common iliac artery at its origin → root of the small-bowel mesentery with its vessels/nerves, right gonadal artery, third part of duodenum → head of pancreas and first part of duodenum (separated by the common bile duct and portal vein) → peritoneum of the posterior abdominal wall forming the posterior wall of the epiploic foramen (separating the IVC from the right free border of the lesser omentum) → bare area of the liver
Posterior	Lower 3 lumbar vertebral bodies and intervertebral discs, anterior longitudinal ligament, right sympathetic trunk, right 3rd & 4th lumbar arteries, right psoas major; higher up — right renal artery, right middle suprarenal artery, medial part of the right suprarenal gland, right coeliac ganglion, right inferior phrenic artery
Right side	Right ureter, medial border of right kidney, second part of duodenum, right lobe of liver
Left side	Abdominal aorta, right crus of diaphragm, caudate lobe of liver

3. Tributaries

Mnemonic — "I Like To Rise So High": Iliac, Lumbar, Testicular/ovarian (gonadal), Renal, Suprarenal, Hepatic.

Tributary	Notable feature
Common iliac veins (R & L)	Unite anterior to L5 to form the IVC; each preceded by an iliolumbar vein; median sacral vein usually joins the left common iliac vein
Lumbar veins (4 pairs)	3rd & 4th pairs open directly into the posterior aspect of the IVC (left-sided ones cross behind the aorta, hence longer); 1st & 2nd pairs are variable, usually draining via the ascending lumbar vein
Right gonadal (testicular/ovarian) vein	Opens directly into the IVC ~2 cm below the left renal vein, at an acute angle; left gonadal vein drains into the left renal vein instead

Tributary	Notable feature
Renal veins	Enter almost at right angles, just below the transpyloric plane; right vein ~2.5 cm, short (behind 2nd part of duodenum); left vein ~7.5 cm — three times longer, crosses anterior to the aorta below the origin of the superior mesenteric artery, behind the pancreas and splenic vein; receives the left suprarenal and left gonadal veins
Suprarenal veins	Right: very short, drains directly into the IVC at the level of T12; Left: drains into the left renal vein
Inferior phrenic veins	Drain into the postero-lateral IVC just below the diaphragm, sometimes as a short common trunk
Hepatic veins (3 large + several small)	Open directly into the IVC just before it pierces the diaphragm; act as an important structural support ("guy ropes") of the liver

□ Fig 21.8 — Scheme to show the inferior vena cava and its tributaries (IB Singh — Textbook of Anatomy Vol 2 — 6e, p.289)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the IVC ascending on the right of the aorta from L5 to the right atrium, and label:

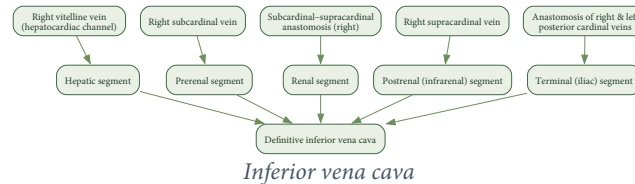
- ▶ Right and left common iliac veins (confluence)
- ▶ Four pairs of lumbar veins + ascending lumbar vein
- ▶ Right gonadal vein (direct) and left gonadal vein (→ left renal vein)
- ▶ Right and left renal veins (with the left crossing anterior to the aorta)
- ▶ Right suprarenal vein (direct) and left suprarenal vein (→ left renal vein)
- ▶ Inferior phrenic veins
- ▶ Three hepatic veins entering just below the diaphragm
- ▶ Abdominal aorta (for reference), right atrium (termination)

4. Development of the inferior vena cava

The IVC develops between the 5th and 7th weeks from an asymmetric fusion of four paired embryonic venous channels — the **postcardinal** (posterior cardinal), **subcardinal**, **supracardinal**, and **vitelline** veins — almost entirely on the right side.

Component of definitive IVC	Embryonic origin
Hepatic segment	New channel (hepatocardiac channel) between the right subcardinal vein and the cranial part of the right vitelline vein
Prerenal (suprarenal) segment	Right subcardinal vein
Renal segment	Right subcardinal–supracardinal anastomosis
Postrenal (infrarenal) segment	Right supracardinal vein

Component of definitive IVC	Embryonic origin
Terminal segment (iliac confluence)	Anastomosis of the right and left posterior cardinal veins



5. Congenital anomalies of the IVC

Anomaly	Embryological basis
Double (duplicated) infrarenal IVC	The anastomosis between the two posterior cardinal veins fails to develop; the left posterior cardinal vein below the level of the renal vein persists as an accessory IVC that opens into the left renal vein , while the normal IVC develops on the right — duplication is therefore only infrarenal
Absence of the IVC / azygos continuation	The anastomosing channel between the right subcardinal vein and the right hepatocardiac channel fails to develop; the cranial part of the right subcardinal vein persists and carries infrarenal blood to the superior vena cava via a markedly dilated azygos vein; the hepatic veins then open directly into the right atrium at the usual caval site
Left-sided (infrarenal) IVC	The infrarenal segment develops from the left instead of the right supracardinal vein, existing in isolation or as part of situs inversus
Preureteric (retrocaval/"circumcaval") ureter	The infrarenal IVC develops from the subcardinal vein (which lies anterior to the ureter) instead of the supracardinal vein (posterior to the ureter), so the right ureter comes to lie anterior to, and hooks around, the IVC

Applied / Clinical anatomy

- **IVC thrombosis/obstruction** produces bilateral lower-limb and back oedema; collateral circulation opens via superficial channels (superficial epigastric, thoraco-epigastric, lateral thoracic, external pudendal veins) and deep channels (azygos–hemiazygos system, lumbar veins, internal/external vertebral venous plexus), all ultimately draining into the superior vena cava.
- **Abdominal aortic aneurysm** most commonly occurs between the renal arteries and the aortic bifurcation, immediately anterior/left to the IVC, and can compress or erode into it.
- **Renal cell carcinoma** characteristically extends along the renal vein into the IVC as a tumour thrombus (occasionally reaching the right atrium); the IVC can be surgically encircled and controlled between the renal veins below and the hepatic veins above during resection.

- ▶ **Nutcracker syndrome:** the long left renal vein is compressed between the aorta and the superior mesenteric artery as it crosses anteriorly, causing left renal vein hypertension with haematuria and varicocele; the left kidney (longer vein) is therefore the preferred side for live-donor nephrectomy.
- ▶ **Retrocaval (preureteric) ureter** presents as right hydroureteronephrosis due to extrinsic compression at the point where the ureter passes behind the IVC.
- ▶ **Azygos continuation of the IVC** is a clinically important incidental cross-sectional imaging finding (absent hepatic segment, markedly dilated azygos vein, hepatic veins draining directly into the right atrium).
- ▶ **IVC filter placement** (for recurrent pulmonary embolism despite anticoagulation) is sited infrarenally, below the renal veins, to preserve renal venous drainage.
- ▶ Normal adult calibre is up to ~30 mm; its cross-sectional shape/diameter varies with respiration and venous filling and is used as a bedside ultrasound index of intravascular volume/right atrial pressure. On cross-sectional imaging the IVC is conventionally described in **hepatic, peritonealized, renal and infrarenal segments**.

High-yield exam pointers

- ▶ Largest vein in the body; formed anterior to L5 (1 cm right of midline); ascends right of the aorta; pierces the diaphragm at T8; opens into the right atrium.
- ▶ Devoid of valves in its abdominal course; guarded at its atrial opening by the vestigial Eustachian valve (developmentally directed fetal blood through the foramen ovale).
- ▶ Tributary mnemonic: **"I Like To Rise So High"** — Iliac, Lumbar, Testicular/ovarian, Renal, Suprarenal, Hepatic.
- ▶ Right gonadal and suprarenal veins drain **directly** into the IVC; the corresponding **left** veins drain into the left renal vein first.
- ▶ Left renal vein (~7.5 cm) is three times longer than the right (~2.5 cm) — crosses anterior to the aorta below the SMA origin (site of nutcracker syndrome).
- ▶ Develops from four right-sided segments — hepatic (vitelline), prerenal (subcardinal), renal (subcardinal–supracardinal anastomosis), postrenal (supracardinal) — plus a terminal segment from the posterior cardinal vein anastomosis.
- ▶ Key anomalies: double IVC, absence-with-azygos-continuation, left-sided IVC, and preureteric (retrocaval) ureter — all explained by persistence/regression of the paired embryonic channels.
- ▶ Surgical control of a tumour-bearing IVC (e.g. renal cell carcinoma) is obtained between the renal veins and the hepatic veins.
- ▶ Surface marking: two vertical lines 2.5 cm apart, just right of the median plane, from the trans-tubercular plane to the right 6th costal cartilage.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2, 8e; IB Singh's Textbook of Anatomy Vol 2, 6e (figure); Vishram Singh's Textbook of Anatomy Vol 2, 4e; Vishram Singh's Textbook of Clinical Embryology; Langman's Medical Embryology (Sadler) 14e; IB Singh's Human Embryology (CBME 2021); Moore's Clinically Oriented Anatomy 9e.



Ligaments of Liver and relations of visceral surface of liver

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction The liver is almost completely invested by visceral peritoneum, which is thrown into folds that pass to the diaphragm and neighbouring viscera; these folds constitute the **peritoneal ligaments of the liver** (falciform, ligamentum teres, coronary, right and left triangular, lesser omentum, ligamentum venosum) and are largely remnants of the embryonic ventral mesogastrium and fetal umbilical/ductus-venosus circulation. The only part of the liver devoid of peritoneum is the **bare area**, lying between the two layers of the coronary ligament. The **visceral surface** is the postero-inferior surface of the liver, directed downwards, backwards and to the left; it carries an H-like arrangement of two sagittal fossae joined by a transverse fissure (the porta hepatis) and is applied to the stomach, duodenum, colon, right kidney, suprarenal gland, gallbladder and oesophagus.

1. Peritoneal ligaments of the liver

Ligament	Composition / layers	Attachment	Contents / continuity	Developmental basis
Falciform ligament	Two layers (right & left), sickle-shaped	Anterior abdominal wall and diaphragm to the anterosuperior (diaphragmatic) surface, a little right of the median plane	Free postero-inferior margin runs from umbilicus to the notch on the inferior border; encloses the ligamentum teres and para-umbilical veins near this margin	Ventral mesogastrium
Ligamentum teres (round ligament)	Single fibrous cord within the free edge of the falciform ligament	Umbilicus → fissure for the ligamentum teres on the visceral surface → left branch of the portal vein at the porta hepatis	Carries para-umbilical veins (portosystemic collaterals)	Obliterated left umbilical vein

Ligament	Composition / layers	Attachment	Contents / continuity	Developmental basis
Coronary ligament	Two layers — superior and inferior	Diaphragm to the posterior part of the diaphragmatic surface of the right lobe	The two layers enclose the bare area between them; the inferior layer (hepatorenal ligament) is reflected onto the right kidney; superior layer continuous with the right layer of the falciform ligament	Peritoneal reflection, right lobe
Right triangular ligament	Short, single fold	Formed where the superior and inferior layers of the coronary ligament converge and fuse on the right	Forms the apex of the bare area	Convergence of coronary ligament
Left triangular ligament	Two layers — anterior and posterior	Upper surface of the left lobe to the diaphragm	Anterior layer continuous with left layer of falciform ligament; posterior layer continuous with the anterior layer of the lesser omentum at the upper end of the fissure for the ligamentum venosum; lies in front of the abdominal oesophagus and gastric fundus	Peritoneal reflection, left lobe
Lesser omentum (hepatogastric + hepatoduodenal parts)	Two layers, L-shaped line of attachment	Fissure for the ligamentum venosum + both lips of the porta hepatis → lesser curvature of stomach and first 2 cm of duodenum	Hepatoduodenal part forms the free right margin, enclosing the portal triad (bile duct, hepatic artery, portal vein) and forming the anterior boundary of the epiploic foramen (of Winslow)	Ventral mesogastrium

Ligament	Composition / layers	Attachment	Contents / continuity	Developmental basis
Ligamentum venosum	Fibrous cord in the floor of its fissure	Left branch of portal vein (below) to the inferior vena cava (above)	Lies in the fissure separating the caudate lobe from the left lobe; roofed by the two layers of the lesser omentum	Obliterated ductus venosus

Note: falciform → coronary → right triangular ligament forms one continuous peritoneal sheet on the right; falciform → left triangular ligament → lesser omentum forms the continuous sheet on the left.

2. Visceral surface — boundaries, fissures and lobes

- ▶ The visceral surface is bounded **anteriorly** by the sharp inferior border (which bears the *cystic notch* for the gallbladder fundus and the *umbilical/interlobar notch* for the ligamentum teres) and merges posteriorly with the posterior (diaphragmatic) surface.
- ▶ It is marked by **two sagittal fossae** joined by a **transverse fissure**, giving an H/cruciform pattern:
 - **Right sagittal plane** — fossa for the gallbladder (in front) continuous with the groove for the inferior vena cava (behind).
 - **Left sagittal plane** — fissure for the ligamentum teres (in front) continuous with the fissure for the ligamentum venosum (behind).
 - **Transverse bar** — the **porta hepatis**, connecting the two sagittal planes.
- ▶ These fissures demarcate two accessory lobes on the visceral surface:
 - **Quadrato lobe** — anterior, between the fissure for the ligamentum teres (left), gallbladder fossa (right), porta hepatis (behind) and inferior border (in front); related functionally to the left hemi-liver though classically described with the right lobe.
 - **Caudate lobe** — posterior, between the fissure for the ligamentum venosum (left), groove for the inferior vena cava (right) and porta hepatis (below); connected to the right lobe by the **caudate process** and bears the small **papillary process**; lies in the superior recess of the lesser sac.
- ▶ **Areas devoid of peritoneum** on/near the visceral aspect: the bare area (posterior surface, between the two coronary-ligament layers), the groove for the inferior vena cava, the fossa for the gallbladder, and the line of attachment of the lesser omentum/fissure for the ligamentum venosum.

3. Porta hepatis

- ▶ A deep transverse fissure (~5 cm) on the visceral surface between the caudate lobe (above) and quadrato lobe (below/in front); the hilum of the liver.
- ▶ **Entering:** portal vein, hepatic artery proper, hepatic nerve plexus. **Leaving:** right and left hepatic ducts, hepatic lymphatics.
- ▶ Order within the porta hepatis from **behind forward**: portal vein → hepatic artery → hepatic ducts (i.e., the duct lies most anterior, the vein most posterior).

- Both lips give attachment to the two layers of the lesser omentum, which diverge at the porta hepatis to enclose these structures and continue as the free right margin (anterior boundary of the epiploic foramen).

4. Relations of the visceral surface

Area / impression	Location	Related structure
Gastric (and omental) area	Left lobe, and part of quadrate lobe near the fissure for the ligamentum venosum	Body/fundus of stomach; tuber omentale (raised area) contacts the lesser omentum
Oesophageal area	Postero-superior part of the visceral surface, near the upper end of the fissure for the ligamentum venosum	Abdominal oesophagus (shallow impression)
Pyloric area	Postero-superior part of the quadrate lobe	Pylorus of stomach
Duodenal area	Right of the gallbladder fossa/quadrate lobe; first part of duodenum also crosses the upper part of the gallbladder	First and second parts of duodenum
Colic (hepatic flexure) area	Lower part of quadrate lobe, lower gallbladder, and strip to the right of the gallbladder, extending to the inferior border	Transverse colon / right colic (hepatic) flexure
Renal area	Posteroinferior part of the right lobe's visceral surface, right of the gallbladder region	Upper pole/anterior surface of right kidney
Suprarenal area	On the bare area, medial to the renal impression, right of the lower IVC groove	Right suprarenal gland (direct contact, no peritoneum)
Gallbladder fossa	Between the quadrate lobe and right lobe proper	Fundus and body of gallbladder
Porta hepatis	Transverse fissure, right lobe's visceral surface	Portal triad (see above)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sketch the visceral (postero-inferior) surface of the liver and label: Right lobe · Left lobe · Quadrate lobe · Caudate lobe (with caudate process and papillary process) · Fossa for gallbladder · Groove for inferior vena cava · Fissure for ligamentum teres · Fissure for ligamentum venosum · Porta hepatis (label portal vein, hepatic artery, hepatic ducts within it) · Bare area (posterior margin) · Inferior border with cystic notch and umbilical notch · Attachment line of the lesser omentum · Impressions — gastric, oesophageal, pyloric, duodenal, colic, renal, suprarenal · Tuber omentale.

- ☐ Fig 5.65 — Visceral surface of liver. A. Anatomical lobes. The four anatomical lobes of the liver (Moore — Clinically Oriented Anatomy — 9e, p.838)
- ☐ Fig 5.64 — Peritoneal and visceral relationships of liver. A. Diaphragmatic surface (Moore — Clinically Oriented Anatomy — 9e, p.837)
- ☐ Fig 23.25 — Relations of the inferior surface of the liver (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.387)

Applied / Clinical anatomy

- ▶ **Portal hypertension:** para-umbilical veins running with the ligamentum teres in the free margin of the falciform ligament recanalise and dilate, producing periumbilical varicosities — **caput medusae** — an important porto-systemic anastomosis in cirrhosis.
- ▶ **Liver mobilisation:** the ligamentum teres is divided/ligated during upper abdominal surgery for exposure; it is a surgical guide to the segment III hepatic duct and to the left portal vein in the umbilical fissure. Division of the right triangular and coronary ligaments mobilises the right lobe forward and exposes the retrohepatic inferior vena cava; division of the left triangular ligament mobilises the left lobe for exposure of the abdominal oesophagus and diaphragmatic crura, but this ligament is an important stabiliser of the left lobe after right hepatectomy — if divided, the falciform ligament should be re-fixed to the abdominal wall to prevent torsion/venous congestion.
- ▶ **Bare area:** being devoid of peritoneum, it is a direct pathway of spread for infection or malignancy between the liver and the diaphragm/retroperitoneum, and is the plane surgeons use to approach the retrohepatic IVC.
- ▶ **Porta hepatis / hepatoduodenal ligament:** the free right margin of the lesser omentum (anterior boundary of the epiploic foramen of Winslow) can be compressed to control haemorrhage from the hepatic pedicle — the **Pringle manoeuvre**.
- ▶ **Peritoneal recesses around the liver:** the right and left **subphrenic spaces** (bounded by the falciform ligament and, respectively, the coronary and left triangular ligaments) and the right **subhepatic space (hepatorenal pouch of Morison)**, the most dependent part of the peritoneal cavity in supine position, are important sites for collection of pus/blood/fluid (e.g., after perforated ulcer, ruptured appendix or gallbladder) and are screened in the FAST ultrasound protocol.
- ▶ The **caudate lobe** lies in the superior recess of the lesser sac; fluid from the omental bursa preferentially collects here and in Morison's pouch.

- ▶ **Chilaiditi's syndrome:** rarely the hepatic flexure/transverse colon interposes between liver and diaphragm, mimicking pneumoperitoneum on imaging.

High-yield exam pointers

- ▶ Six ligaments: falciform, coronary, right triangular, left triangular, lesser omentum, and (functionally) ligamentum teres + ligamentum venosum within them.
- ▶ Falciform ligament = remnant of ventral mesogastrium; encloses ligamentum teres (obliterated left umbilical vein) in its free margin.
- ▶ Ligamentum venosum = obliterated ductus venosus, connecting left portal vein to IVC.
- ▶ Bare area lies between the two layers of the coronary ligament — the only peritoneum-free part of the liver.
- ▶ Visceral surface = H-shaped fissure pattern (GB fossa + IVC groove on the right; ligamentum teres + venosum fissures on the left) joined by porta hepatis.
- ▶ Quadrate lobe (anterior, related to stomach/duodenum) and caudate lobe (posterior, in the superior recess of lesser sac) both drain via the left hepatic duct despite classical "right lobe" description.
- ▶ Porta hepatis contents front-to-back: hepatic ducts → hepatic artery → portal vein.
- ▶ Visceral-surface impressions to recall: gastric, oesophageal, pyloric, duodenal, colic (hepatic flexure), renal, suprarenal.
- ▶ Clinical hooks: caput medusae (ligamentum teres/para-umbilical veins), Pringle manoeuvre (hepatoduodenal ligament), Morison's pouch (subhepatic space).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; IB Singh — Textbook of Anatomy Vol 2 6e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Moore's Clinically Oriented Anatomy 9e.



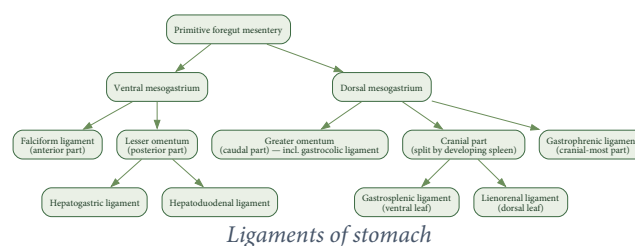
Ligaments of stomach

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction The stomach is an intraperitoneal organ, invested by peritoneum on both its anterior and posterior surfaces except along a small posterior **bare area** near the cardia. Where the two peritoneal layers covering the stomach meet neighbouring viscera or the abdominal wall, they form double-layered peritoneal folds called the **ligaments (mesenteries) of the stomach** — these tether the stomach at the cardio-oesophageal junction and pylorus while allowing the body and greater curvature to move and distend freely. All are derivatives of the embryonic **ventral and dorsal mesogastria**, and each carries the named vessels, nerves and lymphatics that supply the stomach and spleen.

Embryological basis

- ▶ The **foregut** (stomach) is suspended by a **ventral mesogastrium** (between stomach/duodenum and the septum transversum/liver) and a **dorsal mesogastrium** (between stomach and posterior abdominal wall).
- ▶ The developing **liver** grows into the ventral mesogastrium, splitting it into: (i) an anterior part → **falciform ligament** (to the anterior abdominal wall) and (ii) a posterior part → **lesser omentum** (to the stomach and duodenum).
- ▶ The **dorsal mesogastrium** undergoes differential growth and rotation of the stomach to give rise to:
 - its caudal, greatly elongated part → the **greater omentum** (including the **gastrocolic ligament**);
 - its cranial part, which is invaded and split by the developing **spleen** into a ventral leaf → **gastrosplenic (gastrolial) ligament**, and a dorsal leaf → **lienorenal (splenorenal) ligament**;
 - its cranial-most part (above the developing spleen) → **gastrophrenic ligament**.
- ▶ Because they are all continuous derivatives of one embryonic sheet, the gastrosplenic ligament, greater omentum, gastrophrenic ligament and lienorenal ligament remain in continuity in the adult — their different names simply mark different regions of the same fold.



Classification — the named ligaments of the stomach

Ligament	Attachment (extent)	Peritoneal derivative
Hepatogastric ligament (part of lesser omentum)	Lesser curvature of stomach ↔ liver (fissure for ligamentum venosum above, porta hepatis)	Posterior (dorsal) part of ventral mesogastrium
Hepatoduodenal ligament (part of lesser omentum)	First 2 cm of duodenum ↔ liver (porta hepatis); free right margin	Posterior (dorsal) part of ventral mesogastrium

Ligament	Attachment (extent)	Peritoneal derivative
Gastrocolic ligament (part of greater omentum)	Greater curvature of stomach ↔ transverse colon	Caudal part of dorsal mesogastrium
Gastrosplenic (gastrolial) ligament	Greater curvature/fundus of stomach ↔ hilum of spleen	Ventral leaf of cranial dorsal mesogastrium
Gastrophrenic ligament	Posterior bare area near cardia/fundus ↔ inferior surface of left crus of diaphragm	Cranial-most part of dorsal mesogastrium
Lienorenal (splenorenal) ligament (<i>continuous with the gastrosplenic ligament — completes the splenic "sling"</i>)	Hilum of spleen ↔ anterior surface of left kidney/renal fascia	Dorsal leaf of cranial dorsal mesogastrium

□ Fig 7.5 — Peritoneal relations of the stomach (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.325)

□ Fig 23.4 — Peritoneal ligaments attached to the spleen, and common sites of accessory spleen (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.374)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A cross-diagram of the upper abdomen (transverse/coronal schematic) showing the stomach in the centre with each ligament labelled radiating outward:

- ▶ **Stomach** — outline with fundus, body, pyloric antrum; lesser curvature (right) and greater curvature (left) marked
- ▶ **Liver** (above/right) — connected to lesser curvature by the **hepatogastric ligament**; to first part of duodenum by the **hepatoduodenal ligament** (both together = **lesser omentum**, with the free right margin and **epiploic foramen of Winslow** behind it)
- ▶ **Transverse colon** (below) — connected to greater curvature by the **gastrocolic ligament** (upper part of greater omentum)
- ▶ **Spleen** (left) — connected to greater curvature/fundus by the **gastrosplenic ligament**, and to the left kidney by the **lienorenal ligament**
- ▶ **Diaphragm/left crus** (posterosuperior) — connected to the posterior bare area near the cardia by the **gastrophrenic ligament**
- ▶ Mark the **bare area** of the stomach (uncovered by peritoneum, in contact with left crus)
- ▶ Mark the **lesser sac (omental bursa)** lying behind the stomach and lesser omentum

Contents and clinical/surgical significance of each ligament

Ligament	Contents	Key point
Hepatogastric + hepatoduodenal ligament (lesser omentum)	Right & left gastric vessels, gastric lymph nodes and nerves (along lesser curvature); in the free right margin — portal vein, hepatic artery proper, bile duct (portal triad), lymphatics, hepatic nerve plexus	Free margin forms the anterior boundary of the epiploic foramen (IVC posterior, caudate process superior, 1st part of duodenum inferior); site of the Pringle manoeuvre (temporary occlusion of the triad to control hepatic haemorrhage)

Ligament	Contents	Key point
Gastrocolic ligament	Right and left gastro-epiploic (gastro-omental) vessels and their gastro-epiploic lymph nodes, running near the greater curvature	The most mobile stomach attachment; surgical entry point into the lesser sac (dividing it opens the omental bursa)
Gastrosplenic ligament	Short gastric vessels (5–7, from the terminal splenic artery) and the left gastro-epiploic vessels (origin), with accompanying lymphatics and sympathetic fibres	Must be divided and its vessels ligated first during splenectomy ; along with the lesser omentum and gastrocolic omentum, chronic laxity of this ligament predisposes to organoaxial gastric volvulus
Gastrophrenic ligament	Relatively avascular (occasional twigs of the left inferior phrenic vessels)	Marks the extent of the posterior bare area of the stomach; divided to mobilise the fundus in fundoplication/sleeve gastrectomy
Lienorenal ligament	Splenic vessels and the tail of the pancreas between its two layers	Tail of pancreas is vulnerable during splenectomy while this ligament is incised
Right & left gastropancreatic folds (<i>peritoneal folds bounding recesses of the lesser sac, related to the lesser omentum</i>)	Right (inferior) fold carries the hepatic artery to the free margin of the lesser omentum; left (superior) fold carries the left gastric artery to the lesser curvature	Landmarks during dissection of the coeliac trunk and lesser-sac recesses (AK Datta)

Applied / Clinical anatomy

- ▶ **Traube's semilunar space** — the resonant area bounded by the left costal margin, lower border of the left lung and the lateral border of the spleen overlies the fundus (gastric air bubble); dullness here suggests splenomegaly or left pleural effusion.
- ▶ **Organoaxial gastric volvulus** — occurs when the four principal ligamentous attachments (lesser omentum, gastrosplenic ligament, gastrocolic omentum, gastrophrenic ligament) become abnormally lax, allowing the stomach to rotate along its long (cardiopyloric) axis; a surgical emergency.
- ▶ **Splenectomy** — the gastrosplenic ligament (short gastric and left gastro-epiploic vessels) and lienorenal ligament (splenic vessels, tail of pancreas) are the two pedicles that must be individually ligated; injury to the short gastric vessels or gastric wall during this step is a recognised complication.
- ▶ **Total/proximal gastrectomy for carcinoma** — the gastrosplenic and gastrocolic ligaments carry the lymphatic routes of spread from the greater curvature to the splenic hilar and omental nodes, so splenectomy or omentectomy may be added *en bloc* depending on the primary site.
- ▶ **Epiploic foramen (of Winslow)** — bounded anteriorly by the free margin of the hepatoduodenal ligament (portal triad); a loop of bowel herniating through it constitutes an internal hernia.

- ▶ **Bare area of the stomach** — the small posterior area between the gastrophrenic ligament and the peritoneal reflections is directly related to the left crus of the diaphragm; relevant during proximal gastric/oesophago-gastric junction surgery and hiatal dissection.
- ▶ **Lesser sac (omental bursa)** — lies behind the stomach and lesser omentum; free fluid, pseudocysts of the pancreas or abscesses may collect here, bounded in front by the stomach/lesser omentum and its named ligaments.

High-yield exam pointers

- ▶ Ligaments of the stomach are peritoneal folds derived from the **ventral mesogastrium** (→ lesser omentum: hepatogastric + hepatoduodenal ligaments) and the **dorsal mesogastrium** (→ greater omentum/gastrocolic ligament, gastrosplenic ligament, gastrophrenic ligament, lienorenal ligament).
- ▶ **Six named ligaments** to write in a 10-mark answer: hepatogastric, hepatoduodenal, gastrocolic, gastrosplenic, gastrophrenic, and (completing the splenic sling) lienorenal.
- ▶ Gastrosplenic, gastrophrenic, lienorenal ligaments and the greater omentum are **continuous derivatives of one sheet** (the dorsal mesogastrium) — same fold, different regional names.
- ▶ **Contents to remember:** hepatogastric/hepatoduodenal → right & left gastric vessels + portal triad (in free margin); gastrocolic → gastro-epiploic vessels; gastrosplenic → short gastric + left gastro-epiploic vessels; lienorenal → splenic vessels + tail of pancreas.
- ▶ **Free margin of the lesser omentum** = anterior boundary of the epiploic foramen (Winslow); contains the portal vein, hepatic artery proper and bile duct.
- ▶ Laxity of the gastrosplenic, gastrocolic and lesser omentum attachments predisposes to **organoaxial volvulus**.
- ▶ Gastrosplenic and lienorenal ligaments are the two vascular pedicles divided during **splenectomy**.
- ▶ **Bare area** of the stomach lies cranial to the gastrophrenic ligament, against the left crus of the diaphragm.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Human Embryology (CBME 2021); Moore's Clinically Oriented Anatomy, 9e.



Lobes of liver

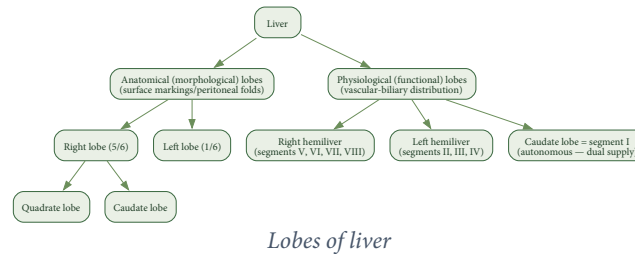
Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction

The liver, the largest gland in the body, is described in two independent classification systems that examiners frequently test together. Externally, peritoneal reflections and surface fissures divide it into four **anatomical (morphological) lobes** — right, left, quadrate and caudate. Internally, the branching

pattern of the portal triad (portal vein, hepatic artery, bile duct) divides it into **physiological (functional) lobes** — right and left hemilivers — which are further subdivided into **Couinaud's eight surgical segments (I–VIII)**. The two schemes do not coincide, and this discrepancy is itself a favourite examiner point.

1. Classification overview



2. Surface fissures that demarcate the anatomical lobes ("H"-shaped fissure)

On the visceral (inferior) surface, a non-peritoneal fissure shaped like the letter **H** outlines the quadrate and caudate lobes:

Limb of the "H"	Formed by
Left limb	Fissure for the ligamentum teres (anteriorly) continuous with the fissure for the ligamentum venosum (posteriorly)
Right limb	Fossa for the gallbladder (anteriorly) continuous with the groove for the inferior vena cava (posteriorly)
Cross-bar	The porta hepatis — a deep transverse fissure, about 5 cm long, lying between the quadrate lobe in front and the caudate lobe behind

- ▶ On the anterior and superior (diaphragmatic) surfaces, the right and left anatomical lobes are separated by the attachment of the **falciform ligament**.
- ▶ Through the porta hepatis pass (behind forwards): **portal vein** → **hepatic artery** → **hepatic ducts**, with the ducts usually anterior-most; it transmits the hepatic nerve plexus and lymphatics, and gives attachment to the lesser omentum.

3. Anatomical (morphological) lobes

Lobe	Location / boundaries	Size	Distinguishing features
Right lobe	Larger of the two; contributes to all five surfaces of the liver	~5/6 of liver substance	Bears the quadrate and caudate lobes; related below to hepatic flexure of colon, right kidney/suprarenal gland, 2nd part of duodenum

Lobe	Location / boundaries	Size	Distinguishing features
Left lobe	Left of the falciform ligament/fissure for ligamentum teres/ligamentum venosum	~1/6 of liver substance	Flattened, thinner than right lobe; bears the omental tuberosity (tuber omentale) near the fissure for ligamentum venosum; related to fundus of stomach and abdominal oesophagus
Quadrate lobe	Inferior surface; between the fissure for ligamentum teres (left), gallbladder fossa (right), inferior border (front) and porta hepatis (behind)	Small, rectangular	Anatomically "of" the right lobe but functionally part of the left hemiliver (= segment IV); related to pylorus and 1st part of duodenum
Caudate lobe	Posterior surface; between the groove for IVC (right), fissure for ligamentum venosum (left) and porta hepatis (below)	Small	Gives off the caudate process (right, joining the right lobe) and the papillary process (left, a small rounded elevation); lies in the superior recess of the lesser sac; functionally autonomous (= segment I)

- Quadrate and caudate lobes are together termed the "**accessory lobes**" by some texts, since neither belongs functionally to the anatomical lobe (right) that contains it.
- A normal variant, **Riedel's lobe**, is a tongue-like downward projection from the right lobe extending below the right costal margin; it may be mistaken clinically for hepatomegaly or an abdominal mass.

4. Physiological (functional) lobes — right and left hemilivers

- Based on the primary division of the portal triad, NOT on surface markings.
- The plane separating right and left hemilivers is the **main portal fissure**, containing the **middle hepatic vein**; on the surface it is marked by an imaginary line — the **cholecysto-caval line** / **Cantlie's line** — running from the midpoint of the gallbladder fossa to the middle of the groove for the inferior vena cava (on the diaphragmatic surface it runs a little to the right of the falciform ligament).
- Each hemiliver receives its own principal branch of the hepatic artery and portal vein and is drained by its own hepatic duct; the two territories do **not** communicate (each branch behaves as an end-artery).
- Consequence: the **quadrate lobe (anatomically right)** is **functionally part of the left hemiliver**, and the **caudate lobe** is **functionally autonomous**, receiving branches from both right and left

divisions and draining directly into the IVC by small independent hepatic veins — hence sometimes called a "third liver."

Feature	Anatomical lobes	Physiological (functional) lobes
Basis	External surface markings/peritoneal folds	Internal distribution of portal triad
Dividing plane	Falciform ligament + fissures for ligamentum teres/venosum	Main portal fissure (Cantlie's/cholecysto-caval line)
Relative size	Right 5/6, left 1/6	Right and left hemilivers are much more nearly equal
Quadrangle lobe	Part of right lobe	Part of left hemiliver (segment IV)
Caudate lobe	Part of right lobe	Autonomous (segment I; dual supply)

5. Couinaud's segmental (surgical) anatomy

Within each hemiliver, secondary and tertiary branches of the portal triad create four sectors and then eight independently resectable segments (numbered I–VIII, clockwise, beginning at the caudate lobe):

Sector	Segments	Draining hepatic vein	Anatomical correlate
Left lateral sector	II	Left hepatic vein	—
Left medial sector	III, IV	Left hepatic vein (III); middle hepatic vein (IV)	Segment IV = quadrangle lobe
Right medial (anterior) sector	V, VIII	Right + middle hepatic veins	—
Right lateral (posterior) sector	VI, VII	Right hepatic vein	—
—	I (caudate)	Direct small veins → IVC	Segment I = caudate lobe; supplied by branches of both right and left divisions

- Each segment has its own independent portal-triad supply and biliary drainage; the three main hepatic veins run *between* sectors (intersegmental), not within them, which is why segmentectomy is planned along vein-free planes.
- Segment IV is often further split into IVa (superior) and IVb (inferior) for planning transverse resections.
- This scheme (Couinaud 1957) underlies all modern hepatic resection nomenclature and cross-sectional (CT/MRI) reporting.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 5.65 — Visceral surface of liver. A. Anatomical lobes. The four anatomical lobes (Moore — Clinically Oriented Anatomy — 9e, p.838)

Real plate above shows the visceral surface with all four anatomical lobes labelled — use it as the reference; reproduce the following labelled sketch by hand in the exam:

- ▶ Outline of liver, visceral (inferior) surface, oriented postero-anterior
- ▶ **Right lobe** and **left lobe** (separated by the fissure for ligamentum teres/venosum)
- ▶ **Quadrato lobe** (anterior, between gallbladder fossa and fissure for ligamentum teres)
- ▶ **Caudate lobe** (posterior, between IVC groove and fissure for ligamentum venosum), with its **caudate process** and **papillary process**
- ▶ **Porta hepatis** (the H cross-bar) — label portal vein, hepatic artery, hepatic ducts
- ▶ **Gallbladder fossa, groove for IVC, fissure for ligamentum teres, fissure for ligamentum venosum** — the four limbs of the "H"
- ▶ Dotted line for **Cantlie's/cholecysto-caval line** demarcating right and left functional hemilivers
- ▶ Inset: Couinaud's segments I–VIII arranged clockwise around the caudate (I)

Applied / Clinical anatomy

- ▶ **Hepatectomy and segmentectomy**: because the three hepatic veins run in avascular intersegmental planes, individual segments (or combinations, e.g. segments IVb + V + VI in central/transverse hepatectomy) can be resected with minimal blood loss; the liver regenerates to near-original volume within weeks to months.
- ▶ **Cantlie's line** is the surgical landmark for right vs left hepatectomy on the diaphragmatic surface.
- ▶ **Segment I (caudate lobe) resection** is often required in hilar cholangiocarcinoma (Klatskin tumour) surgery because its ducts drain near the confluence of the right and left hepatic ducts.
- ▶ **Split-liver and living-donor transplantation** exploit the segmental (Couinaud) plan — e.g. a left lateral segment (II + III) graft for a paediatric recipient, or a right hemiliver (V–VIII) graft for an adult, based on the umbilical and main portal fissures.
- ▶ **Riedel's lobe** — a normal variant tongue of the right lobe below the costal margin — must be distinguished on examination/imaging from true hepatomegaly, gallbladder, or a right renal/colonic mass.
- ▶ **Radiology**: axial CT/MRI readily identifies segment I lying between the IVC and portal vein, with segments II–IV arranged clockwise above the portal vein and V–VIII below it — the basis of standardised cross-sectional segmental reporting.
- ▶ **Surface marking**: the liver extends upward under the rib cage as far as the right 5th rib (below the right nipple) and the left 5th intercostal space (below and medial to the left nipple); the sharp inferior border crosses the midline at the transpyloric plane — clinically, a palpable liver edge below the costal margin signals hepatomegaly (or, rarely, Riedel's lobe/a mobile right lobe).

- ▶ The **anatomical** lobar division has no relation to the microscopic (histological) **hepatic lobule**, which is an independent classification based on the classic hexagonal parenchymal unit around a central vein — the two terms ("lobe" vs "lobule") should never be conflated in the exam.

High-yield exam pointers

- ▶ Four **anatomical** lobes: right, left, quadrate, caudate — demarcated by falciform ligament + the "H"-shaped fissure (limbs: ligamentum teres/venosum fissures; gallbladder fossa/IVC groove; cross-bar = porta hepatis).
- ▶ Right lobe = 5/6, left lobe = 1/6 of liver bulk.
- ▶ Quadrate lobe is anatomically right but **functionally left** (= Couinaud segment IV); caudate lobe is **functionally autonomous** (= segment I, dual blood supply, drains directly into IVC).
- ▶ **Physiological** division = right/left hemiliver, separated by the main portal fissure (Cantlie's/cholecysto-caval line), each with its own hepatic artery, portal vein branch and hepatic duct — end-arterial, non-communicating territories.
- ▶ **Couinaud's 8 segments** (1957) numbered clockwise from the caudate: II, III (left lateral/medial), IV (left medial = quadrate lobe), V, VIII (right anterior), VI, VII (right posterior), I (caudate) — the basis of modern liver surgery and radiology.
- ▶ Porta hepatis: ~5 cm transverse fissure; contents behind-forwards = portal vein, hepatic artery, bile ducts.
- ▶ Applied variant: **Riedel's lobe** — downward tongue from right lobe, may mimic hepatomegaly.
- ▶ Do not confuse gross anatomical/functional "lobes" with the microscopic hepatic "lobule."

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Moore's Clinically Oriented Anatomy 9e; BD Chaurasia Human Anatomy Vol 2 8e; AK Datta Human Anatomy Vol 1 (Thorax & Abdomen).



Lumbar plexus

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction The lumbar plexus is a somatic nerve plexus formed within the substance of psoas major, on the posterior abdominal wall, by the ventral rami of the upper four lumbar nerves (L1–L4) together with a contribution from the twelfth thoracic (subcostal) ventral ramus. It supplies the anterolateral abdominal wall, the external genitalia, and the anterior and medial compartments of the thigh, and its L4 fibres also help form the lumbosacral trunk that joins the sacral plexus. Clinically it is important in retroperitoneal disease, inguinal/pelvic surgery, and as the target of psoas-compartment regional anaesthesia blocks.

1. Formation and root value

- ▶ Formed by the ventral rami of **L1, L2, L3 and most of L4**, joined by a descending branch of the **subcostal (T12) ventral ramus** — the so-called dorsolumbar nerve.

- ▶ L1 unites with the T12 contribution to form the **iliohypogastric** and **ilioinguinal** nerves; a branch of L1 joins L2 to form the **genitofemoral** nerve.
- ▶ L2, L3 and most of L4 each split into a **ventral division** and a **dorsal division**:
 - Ventral divisions of L2–L4 unite to form the **obturator nerve**.
 - Dorsal divisions of L2–L4 unite to form the **femoral nerve**.
 - Dorsal divisions of L2, L3 unite to form the **lateral cutaneous nerve of the thigh**.
- ▶ The remaining fibres of L4 join L5 to form the **lumbosacral trunk**, which descends into the pelvis to join the sacral plexus.
- ▶ An **accessory obturator nerve** is an inconstant branch, when present arising from L3, L4 ventral divisions.
- ▶ A **furcal nerve** (an independent nerve with its own dorsal and ventral rootlets, usually alongside L4) may link the lumbar and sacral plexuses; its level of origin determines whether the sacral plexus is "pre-fixed" (from L3) or "post-fixed" (from L5).
- ▶ The plexus receives its own arterial supply from lumbar vessels that supply *psoas major*.

2. Site and relations

The plexus lies in the **posterior part of the substance of *psoas major***, anterior to the transverse processes of the lumbar vertebrae; it lies roughly in the coronal plane of the posterior part of the L1 vertebral body but becomes progressively more anterior in the lower lumbar spine.

Relation	Structure
Posterior	Lumbar transverse processes, <i>psoas major</i> fibres
Anterior (separated by <i>psoas fascia</i>)	Kidney (upper part), ureter, colon, common/external iliac vessels, sigmoid mesocolon (left)
Medial	Vertebral bodies, lumbar sympathetic trunk
Lateral	<i>Quadratus lumborum</i> (branches cross it — iliohypogastric, ilioinguinal)

3. Branches of the lumbar plexus

Branch	Root value	Division	Exit from <i>psoas major</i>
Muscular branches	T12–L4	—	Direct, to <i>psoas major</i> , <i>psoas minor</i> , <i>quadratus lumborum</i>
Iliohypogastric	L1 (± T12)	—	Upper lateral border
Ilioinguinal	L1	—	Lateral border, just below iliohypogastric
Genitofemoral	L1, L2	ventral divisions	Formed within <i>psoas</i> , emerges on its anterior surface (opposite L3/L4)

Branch	Root value	Division	Exit from psoas major
Lateral cutaneous nerve of thigh	L2, L3	dorsal divisions	Lateral (posterolateral) border
Femoral	L2, L3, L4 (largest branch)	dorsal divisions	Low on the lateral border
Obturator	L2, L3, L4	ventral divisions	Medial border, near pelvic brim
Accessory obturator (inconstant)	L3, L4	ventral divisions	Medial border
Lumbosacral trunk	L4 (part) + L5	—	Medial border, grooves ala of sacrum, joins sacral plexus

□ Fig 3.3 — The lumbar plexus and its branches (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.76)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw psoas major "windowed" (partly cut away) on the posterior abdominal wall to expose the plexus, and label:

- ▶ Vertebral levels T12, L1, L2, L3, L4, L5 on the medial side
- ▶ Psoas major (cut edge) and quadratus lumborum
- ▶ Muscular branches to psoas major/quadratus lumborum
- ▶ Iliohypogastric nerve and ilioinguinal nerve (crossing quadratus lumborum, exiting near iliac crest/inguinal region)
- ▶ Genitofemoral nerve, dividing into genital and femoral branches near the deep inguinal ring
- ▶ Lateral cutaneous nerve of thigh, crossing iliacus toward the anterior superior iliac spine
- ▶ Femoral nerve, in the groove between psoas major and iliacus
- ▶ Obturator nerve, emerging from the medial border, crossing the pelvic brim toward the obturator canal
- ▶ Accessory obturator nerve (dashed, "when present")
- ▶ Lumbosacral trunk, descending over the sacral ala to the sacral plexus

4. Course and distribution of individual branches

- ▶ **Iliohypogastric nerve (L1)**: emerges at the upper lateral border of psoas, crosses obliquely behind the lower renal pole on quadratus lumborum, pierces transversus abdominis above the iliac crest, and runs between transversus abdominis and internal oblique. Gives a **lateral cutaneous branch** (posterolateral gluteal skin) and an **anterior cutaneous branch** (suprapubic skin) after piercing external oblique aponeurosis. Motor to transversus abdominis and internal oblique.
- ▶ **Ilioinguinal nerve (L1)**: similar course, slightly inferior to the iliohypogastric; crosses quadratus lumborum and iliacus, pierces transversus abdominis and internal oblique, traverses the inguinal canal superficial to the spermatic cord/round ligament, and exits the superficial inguinal ring.

Motor to transversus abdominis/internal oblique (conjoint tendon); sensory to upper medial thigh and root of penis/scrotum (or mons pubis/labium majus).

- ▶ **Genitofemoral nerve (L1, L2):** formed within psoas major, emerges on its anterior surface near the medial border, descends under the peritoneum crossing obliquely behind the ureter, and divides into a **genital branch** (through the deep inguinal ring, supplies cremaster and scrotal/labial skin) and a **femoral branch** (enters the femoral sheath lateral to the femoral artery, supplies skin over the femoral triangle).
- ▶ **Lateral cutaneous nerve of the thigh (L2, L3):** emerges at the lateral border of psoas, crosses iliacus obliquely toward the anterior superior iliac spine, and enters the thigh behind the lateral end of the inguinal ligament to supply the anterolateral thigh skin down to the knee.
- ▶ **Femoral nerve (L2–L4):** the largest branch; emerges low on the lateral border of psoas, runs in the groove between psoas and iliacus deep to the iliac fascia, and passes behind the inguinal ligament into the thigh lateral to the femoral sheath. Supplies iliacus and pectineus in the abdomen; in the thigh, supplies quadriceps femoris and sartorius, and continues as the saphenous nerve to the medial leg and foot.
- ▶ **Obturator nerve (L2–L4):** emerges at the medial border of psoas near the pelvic brim, crosses posterior to the common iliac vessels, descends on the lateral pelvic wall (on obturator internus, anterosuperior to the obturator vessels), and enters the thigh through the obturator canal, dividing into anterior and posterior branches supplying the adductor group (adductor longus, adductor brevis, gracilis, obturator externus, and often pectineus).
- ▶ **Accessory obturator nerve (L3, L4, when present):** emerges at the medial border of psoas, runs on the superior pubic ramus behind pectineus, supplying pectineus and the hip joint.
- ▶ **Lumbosacral trunk (L4 + L5):** descends grooving the sacral ala, posterior to the common iliac vessels, to join the sacral plexus.

Applied / Clinical anatomy

- ▶ **Psoas abscess:** tuberculous (Pott's) disease of the lumbar vertebrae discharges pus into the psoas sheath, which tracks down deep to the inguinal ligament to present as a soft swelling in the femoral triangle — classically with a history of low backache and vertebral changes on X-ray; may irritate branches of the plexus en route.
- ▶ **Retroperitoneal disease irritating the plexus:** retrocaecal appendicitis (right side) or a diverticular abscess (left side), lying anterior to psoas major, may irritate one or more branches, causing pain/sensory disturbance referred to the thigh, hip or buttock.
- ▶ **Meralgia paraesthetica:** entrapment of the **lateral cutaneous nerve of the thigh** as it crosses under (or through) the inguinal ligament near the anterior superior iliac spine, producing burning pain/paraesthesia over the anterolateral thigh.
- ▶ **Femoral neuropathy:** the main trunk is not usually entrapped but may be compressed by a retroperitoneal tumour or haemorrhage (e.g. in anticoagulated patients), or damaged in diabetic amyotrophy; presents with quadriceps wasting/weakness, difficulty rising from a chair or climbing stairs, a diminished/absent knee jerk, and saphenous-distribution paraesthesia down the medial leg.

- ▶ **Iliohypogastric/ilioinguinal nerve injury:** may be damaged by incisions in the iliac fossa (appendicectomy, inguinal hernia repair, trocar placement), causing chronic groin pain or, if divided above the ASIS, weakening of the inguinal canal's posterior wall and predisposing to a direct inguinal hernia.
- ▶ **Genitofemoral nerve injury:** the genital branch may be injured during open or laparoscopic inguinal hernia repair, producing groin neuralgia and loss of the cremasteric reflex.
- ▶ **Obturator hernia and nerve compression:** herniation of bowel through the obturator canal can compress the obturator nerve, producing pain referred to the hip, medial thigh and knee — the **Howship–Romberg sign**; the nerve may also be injured during parturition, anterior hip dislocation, or pelvic (obturator lymph node) surgery.
- ▶ **Psoas-compartment (lumbar plexus) block:** because the plexus is embedded within psoas major, a single injection in the psoas compartment can anaesthetise the femoral, obturator and lateral cutaneous nerves of the thigh together — used for hip and knee surgery.
- ▶ **Clinical root testing:** the L2–L4 segments (mainly via the femoral nerve) mediate the knee jerk (patellar reflex) and hip flexion/knee extension power, tested in localising lumbar radiculopathy or plexopathy.

High-yield exam pointers

- ▶ Lumbar plexus = ventral rami of L1–L4 + T12 (subcostal) contribution, formed within psoas major.
- ▶ Remember by root value: Iliohypogastric & ilioinguinal — L1; genitofemoral — L1, L2; lateral cutaneous nerve of thigh — L2, L3 (dorsal divisions); femoral — L2–L4 dorsal divisions; obturator — L2–L4 ventral divisions; accessory obturator (inconstant) — L3, L4.
- ▶ **Femoral nerve** is the largest branch; **obturator nerve** emerges from the medial border, **femoral** and **lateral cutaneous nerve of thigh** from the lateral border, **genitofemoral** through the substance of the muscle.
- ▶ **L4** is the "shared" root — contributes to both lumbar plexus (femoral/obturator) and, via the lumbosacral trunk with L5, to the sacral plexus.
- ▶ Clinical triad to recall: **meralgia paraesthetica** (LFCN), **Howship–Romberg sign** (obturator hernia), **psoas abscess tracking to the femoral triangle**.
- ▶ Psoas-compartment block anaesthetises femoral + obturator + lateral cutaneous nerve of thigh in one injection.
- ▶ Knee jerk tests L3, L4 (femoral nerve) — used to localise lumbar plexus/root lesions.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh's Textbook of Anatomy Vol 2 4e.



Mesocolon

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction

The mesocolon is a fold (mesentery) of visceral peritoneum that suspends part of the large intestine from the posterior abdominal or pelvic wall, carrying its blood vessels, lymphatics, lymph nodes and autonomic nerves between two layers of mesothelium enclosing extraperitoneal fat. In the adult only two true, free mesocolons persist — the **transverse mesocolon** and the **sigmoid mesocolon** — because the embryonic mesenteries of the ascending and descending colon fuse with the parietal peritoneum and are lost. The mesocolon is continuous proximally with the mesentery of the small intestine and distally with the mesorectum, and its root divides the peritoneal cavity into supracolic and infracolic (inframesocolic) compartments.

Development of the mesocolon

- ▶ The midgut and hindgut possess **only a dorsal mesentery** (no ventral mesentery, which is a foregut-only structure derived from the septum transversum).
- ▶ This dorsal mesentery gives rise to: the mesentery proper (jejunum and ileum), the **mesoappendix**, the **transverse mesocolon**, and the **pelvic (sigmoid) mesocolon**.
- ▶ The mesenteries of the **duodenum, ascending colon, descending colon and rectum are lost during development** — as the colon is pressed against the posterior abdominal wall during gut rotation, its posterior mesothelial layer fuses with the parietal peritoneum (**zygosis**), rendering these segments **secondarily retroperitoneal**.
- ▶ The fused plane of areolar tissue left behind this fusion is **Toldt's fascia** — an avascular surgical plane, not a true mesentery.
- ▶ Only the transverse colon and the sigmoid colon retain a fully free, mobile mesocolon into adult life.

Regional mesocolons — comparative summary

Colonic segment	Peritoneal status in the adult	True free mesocolon?	Key point
Caecum	Intraperitoneal; usually has no true mesentery	Absent	Occasionally retains a short mesentery → "mobile caecum," predisposing to caecal volvulus
Ascending colon	Secondarily retroperitoneal	Absent (fused)	The "ascending mesocolon" is adherent to the retroperitoneum via Toldt's fascia ; this is the plane of dissection in right hemicolectomy
Transverse colon	Fully intraperitoneal, highly mobile	Present — transverse mesocolon	Longest, most mobile segment of colon

Colonic segment	Peritoneal status in the adult	True free mesocolon?	Key point
Descending colon	Secondarily retroperitoneal	Absent (fused)	Fused via Toldt's fascia; plane of dissection in left-sided colon mobilisation
Sigmoid colon	Fully intraperitoneal, mobile	Present — sigmoid mesocolon	Length highly variable → predisposes to sigmoid volvulus
Rectum (upper 1/3)	Peritoneum on anterior and lateral aspects only	Absent; continuous with mesorectum	Mesorectum is the surgical plane for total mesorectal excision (TME)

Transverse mesocolon

- ▶ A **broad fold of peritoneum** that suspends the transverse colon in the peritoneal cavity, reflected anteriorly from the posterior abdominal wall.
- ▶ **Root/attachment**: passes obliquely and almost horizontally (with a slight upward inclination to the left) from the anterior surface of the second part of the duodenum, across the anterior border of the head and body of the pancreas, superior to the duodenojejunal flexure, over the upper pole of the left kidney, to the **splenic flexure**.
- ▶ **Two peritoneal layers** separate at the transverse colon to invest it: the **upper layer** is continuous with, and adherent to, the posterior layer of the greater omentum; the **lower layer** is continuous with the parietal peritoneum of the posterior abdominal wall.
- ▶ **Contents**: the middle colic vessels and their branches (the ascending branch of the left colic artery terminates within the mesocolon near the splenic flexure), together with autonomic nerves from the aortic/superior mesenteric plexus, lymphatics and lymph nodes.
- ▶ **Lateral extensions** form two named peritoneal folds:
 - the **duodenocolic ligament** (right) — from the transverse mesocolon at the hepatic flexure to the second part of the duodenum;
 - the **phrenicocolic ligament** (left, = **sustentaculum lienis**) — a horizontal fold from the splenic flexure to the diaphragm opposite the eleventh rib in the midaxillary line; it supports the anterior end of the spleen and limits the upper end of the left paracolic gutter.
- ▶ The root of the transverse mesocolon lies close to the upper limit of the root of the small-bowel mesentery, near the uncinate process of the pancreas, and its posterior peritoneal layer contributes to the lower boundary of the **lesser sac**.

□ Fig 18.13 — Attachment of the root of the transverse mesocolon (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.307)

Sigmoid mesocolon

- ▶ A **fan-shaped/triangular fold** of peritoneum suspending the sigmoid colon from the pelvic wall; its length and depth vary considerably between individuals.
- ▶ **Root/attachment**: shallow, **inverted-V-shaped** (occasionally a gentle curve). The **apex** overlies the division of the left common iliac artery and lies anterior to the left ureter. The **left limb** runs

upward over left psoas major and along the left external iliac vessels; the **right limb** passes medially over the pelvic brim to the median plane at the level of the third sacral vertebra.

- ▶ Peritoneal layers: the **anteromedial layer** is continuous with the peritoneum of the lower left posterior abdominal wall; the **posterolateral layer** is continuous with the peritoneum of the lateral abdominal wall.
- ▶ **Contents:** the sigmoid vessels (in the left limb) and the superior rectal vessels (in the right limb), with accompanying nerves, lymphatics and lymph nodes.
- ▶ The **left ureter** descends into the pelvis behind the apex of the sigmoid mesocolon and anterior to the bifurcation of the left common iliac artery; the ureter and gonadal vessels actually lie in a **separate fascial plane** (the inferior extension of the retroperitoneal perirenal fascia), distinct from the sigmoid mesocolon proper — a plane the surgeon must identify and preserve during sigmoid resection.
- ▶ The **intersigmoid recess** lies behind and inferior to the apex of the V; it is constant in fetal life/infancy and often disappears later, but occasionally persists.

□ Fig 18.14 — Attachment of the root of the sigmoid mesocolon (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.307)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Reproduce a simple schematic of the posterior abdominal wall with the two mesocolic roots labelled:

- ▶ Duodenum (2nd part) — start of transverse mesocolon root
- ▶ Head and body of pancreas (anterior border) — root crosses here
- ▶ Duodenojejunal flexure (superior to it)
- ▶ Upper pole of left kidney
- ▶ Splenic flexure of colon — end of transverse mesocolon root; origin of phrenicocolic ligament
- ▶ Hepatic flexure of colon — origin of duodenocolic ligament
- ▶ Middle colic vessels (within the mesocolon)
- ▶ Left common iliac artery bifurcation — apex of sigmoid mesocolon root
- ▶ Left ureter — behind apex of sigmoid mesocolon
- ▶ Third sacral vertebra — termination of right limb of sigmoid mesocolon root
- ▶ Sigmoid vessels / superior rectal vessels (within the mesocolon)

Microscopic structure and continuity

- ▶ The mesocolon consists of **fat embedded in a connective-tissue lattice**, sandwiched between **two layers of mesothelium**; it also carries nerves, blood and lymphatic vessels, and lymph nodes.
- ▶ **Toldt's fascia** is a layer of loose connective tissue lying immediately posterior to the mesocolon, representing the fused embryological plane where the mesocolon of the ascending/descending colon adhered to the retroperitoneum; it is the natural avascular surgical plane.

- ▶ The mesocolon is **structurally continuous**: proximally with the mesentery of the small intestine, distally with the **mesorectum** — i.e., functionally one continuous mesenteric organ running from the duodenojejunal flexure to the pelvic floor.
- ▶ Occasionally the ascending (or descending) mesocolon fails to fuse fully and remains partly mobile/reflected forward from the posterior abdominal wall, conferring extra mobility on an otherwise retroperitoneal segment.

Applied / Clinical anatomy

- ▶ **Complete mesocolic excision (CME)**: dissecting within or behind the plane of Toldt's fascia to remove the tumour-bearing segment of colon together with its intact mesocolon and lymphovascular pedicle has been shown to improve survival in colon cancer surgery.
- ▶ **Sigmoid volvulus**: a long sigmoid colon suspended by a long, narrow-based sigmoid mesocolon predisposes to axial rotation of the loop around its mesenteric pedicle, causing closed-loop obstruction; it is especially common where the sigmoid colon and its mesocolon are unusually long (e.g., in sub-Saharan Africans and chronically institutionalised patients). Volvulus does not occur when the sigmoid colon and its mesocolon are short.
- ▶ **Caecal volvulus**: when the caecum/ascending colon is attached by an abnormally narrow, mobile mesentery instead of being fixed retroperitoneally, the ileocolic region can twist about its mesenteric pedicle, producing a strangulating closed-loop obstruction with marked caecal distension.
- ▶ **Phrenicocolic ligament (sustentaculum lienis)**: supports the anterior end of the spleen and limits the upper end of the left paracolic gutter; it must be divided to mobilise the splenic flexure (left hemicolectomy) or to deliver the spleen during splenectomy.
- ▶ **Duodenocolic ligament**: encountered and divided while mobilising the hepatic flexure in right hemicolectomy.
- ▶ **Compartmentalisation**: the root of the transverse mesocolon (with the transverse colon) divides the peritoneal cavity into supracolic and infracolic compartments, governing the spread and localisation of intraperitoneal fluid, pus and malignant deposits.
- ▶ **Duodenal vulnerability**: the origin of the transverse mesocolon and the gastrocolic omentum are loosely attached over the anterior surface of the second part of the duodenum, an area at risk during blunt trauma and right-sided colonic mobilisation.
- ▶ **Ureteric safety**: the left ureter runs deep to the apex of the sigmoid mesocolon in its own fascial plane; failure to identify this plane during sigmoid colectomy risks ureteric injury.
- ▶ **Continuity with mesentery/mesorectum**: because the mesocolon is one continuous mesenteric sheet with the small-bowel mesentery and mesorectum, disease (inflammatory or neoplastic) can spread along these contiguous planes.

High-yield exam pointers

- ▶ Only the **transverse** and **sigmoid** mesocolons persist as true, free mesenteries in the adult; ascending/descending colon mesenteries are lost by fusion (zygosis) with the parietal peritoneum.

- ▶ Root of transverse mesocolon: duodenum (2nd part) → pancreas (head, anterior border of body) → above duodenojejunal flexure → upper pole of left kidney → splenic flexure.
- ▶ Contents of transverse mesocolon: middle colic vessels, autonomic nerves, lymphatics/lymph nodes.
- ▶ Duodenocolic ligament (right) and phrenicocolic ligament/sustentaculum lienis (left) are lateral extensions of the transverse mesocolon.
- ▶ Root of sigmoid mesocolon: inverted-V, apex at the left common iliac artery bifurcation (anterior to left ureter), right limb to S3 vertebra, left limb along external iliac vessels.
- ▶ Toldt's fascia = fused embryological plane behind the mesocolon; basis of complete mesocolic excision (CME) and colonic mobilisation.
- ▶ Mesocolon is continuous with small-bowel mesentery proximally and mesorectum distally.
- ▶ Clinical correlates: sigmoid volvulus (long mesocolon), caecal volvulus (mobile caecal mesentery), ureteric injury risk during sigmoid mesocolon dissection.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Textbook of Anatomy Vol 2, 6e; Moore's Clinically Oriented Anatomy, 9e; Langman's Medical Embryology (Sadler), 14e (embryological origin of dorsal mesentery/mesocolon).



Name the parts, its borders, surfaces and peritoneal reflections, relations, blood supply of the pancreas

Asked in: Paper I May 2007 — RGUHS MD/MS Anatomy

Definition / Introduction The pancreas is a soft, finely lobulated, retort- (J-) shaped gland, both exocrine (pancreatic juice — trypsin, amylase, lipase) and endocrine (insulin, glucagon from the islets of Langerhans). It lies almost entirely retroperitoneally, transversely across the posterior abdominal wall, extending obliquely from the concavity of the C-shaped duodenal loop (head) to the hilum of the spleen (tail), largely in the floor of the lesser sac. It measures about 12–15 cm in length and weighs approximately 80–90 g. Its parts, borders, surfaces, peritoneal reflections and relations are of prime applied importance in obstructive jaundice, pancreatitis and pancreatic/periampullary carcinoma.

General Features and Location

- ▶ Set obliquely — the **head** (the "bowl" of the retort) lies within the C-concavity of the duodenum, opposite the **L2 vertebra**; the **neck, body and tail** (the "stem") run upward and to the left, crossing the **transpyloric plane** (L1) and reaching as high as **T12** at the splenic hilum.
- ▶ **Retroperitoneal (secondarily)** on the posterior abdominal wall, applied to the great vessels and left kidney, EXCEPT the **tail**, which lies between the two layers of the **lienorenal (splenorenal) ligament** and is therefore the only mobile part.

- ▶ The posterior edge of the greater omentum and the upper leaf of the transverse mesocolon both attach along the anterior border of the body, dividing its anterior surface into a supracolic part (lesser-sac floor) and an infracolic part (greater sac).

Parts of the Pancreas

- ▶ **Head** — the enlarged, disc-shaped right end, lying in the concavity of the "C" of the duodenum; gives off the **uncinate process**, a hook-like projection from its lower and left part passing behind the superior mesenteric vessels.
- ▶ **Neck** — a short (~2–2.5 cm), constricted part connecting head to body, directed forward, upward and to the left; lies immediately in front of the point of union of the superior mesenteric and splenic veins (i.e., in front of the origin of the portal vein) and overlies the pylorus.
- ▶ **Body** — the longest part, triangular in cross-section, running from the neck to the tail with a slight upward and backward inclination; bears the **tuber omentale**, a projection of its upper part beyond the lesser curvature of the stomach that contacts the lesser omentum.
- ▶ **Tail** — the narrow, mobile, leftmost extremity, lying within the lienorenal ligament with the splenic vessels; its tip touches the visceral (gastric) surface of the spleen between the gastric and colic impressions. It contains the highest density of islets of Langerhans of any part of the gland.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a longitudinal external view of the pancreas showing: **Head** (in the duodenal C-loop) with its **uncinate process**; **Neck**; **tuber omentale** at the upper part of the **Body**; **Tail** reaching the splenic hilum; and, in a companion cross-section, the three borders and three surfaces of the body.

□ Fig 9.13 — *Parts of the pancreas* (Vishram Singh — *Textbook of Anatomy Vol 2 — 4e, p.416*)

Borders and Surfaces

Part	Borders	Surfaces
Head	Superior, Inferior, Right lateral	Anterior, Posterior
Uncinate process	—	Anterior, Posterior
Neck	Upper, Lower	Anterior, Posterior
Body	Anterior, Superior, Inferior (triangular on cross-section)	Anterior, Posterior, Inferior
Tail	No distinct borders (rounded, mobile tip)	Contacts visceral surface of spleen

Peritoneal Reflections

- ▶ The pancreas contributes much of the **floor (posterior wall) of the lesser sac (omental bursa)**.
- ▶ **Body** — **anterior surface**: covered by peritoneum continuous with the anterior of the two layers forming the **greater omentum**, lying in the posterior wall of the lesser sac; separated from the **stomach** by the lesser sac.
- ▶ **Body** — **inferior surface**: covered by peritoneum continuous with the **posterior layer of the transverse mesocolon**; related to the **greater (infracolic) sac**.

- **Head — anterior surface:** covered by peritoneum related to the **root/origin of the transverse mesocolon**.
- **Neck — anterior surface:** the peritoneum lining the posterior aspect of the **pylorus** is reflected onto the front of the neck of the pancreas — this reflection forms the **right boundary of the lesser sac** at this level.
- **Posterior surfaces** of the head, body and (medial) tail are **devoid of peritoneum** — true retroperitoneal surface, applied to the fascia of Treitz (behind the head) and fascia of Toldt (behind body/tail), through which the supplying vessels reach the gland.
- **Tail:** uniquely covered by peritoneum on both aspects, lying between the two layers of the lienorenal ligament; it may extend up to, or into, the splenic hilum.

Relations

Head

Border/Surface	Related to
Superior border	First part of duodenum; superior pancreaticoduodenal artery
Inferior border	Third part of duodenum; inferior pancreaticoduodenal artery
Right lateral border	Second part of duodenum; anastomosis of the pancreaticoduodenal arterial arcades; terminal bile duct
Anterior surface (above down)	Transverse colon; root of transverse mesocolon; jejunum
Posterior surface	Inferior vena cava; termination of the right renal vein; right crus of diaphragm; bile duct (often embedded in the gland substance)
Uncinate process	Anteriorly — superior mesenteric vessels; Posteriorly — abdominal aorta

Neck

Surface/Border	Related to
Anterior surface	Peritoneum of lesser sac; pylorus
Posterior surface	Termination of superior mesenteric vein and commencement of the portal vein
Upper border	First part of duodenum
Lower border	Root of the transverse mesocolon

Body

Border/Surface	Related to
Anterior border	Attachment of the root of the transverse mesocolon

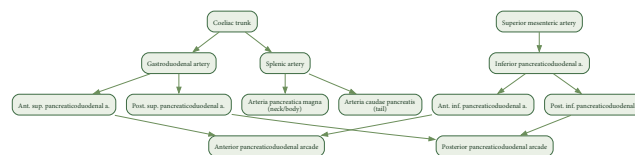
Border/Surface	Related to
Superior border	Coeliac trunk (over the tuber omentale); hepatic artery (to the right); splenic artery (to the left)
Inferior border	Superior mesenteric vessels, at its right end
Anterior surface	Lesser sac; stomach
Posterior surface	Aorta and origin of the superior mesenteric artery; left crus of diaphragm; left suprarenal gland; left kidney; left renal vessels; splenic vein (grooving/indenting it)
Inferior surface	Duodenojejunal flexure; coils of jejunum; left (splenic) colic flexure

Tail — lies in the lienorenal ligament with the splenic vessels; contacts the visceral surface of the spleen between the gastric and colic impressions.

Blood Supply

The pancreas develops at the junction of the **foregut and midgut**, and this is reflected in a dual arterial supply:

- **Head and adjoining duodenum** — four arteries: the **anterior and posterior superior pancreaticoduodenal arteries** (branches of the **gastrooduodenal artery**, from the coeliac trunk — foregut supply) and the **anterior and posterior inferior pancreaticoduodenal arteries** (branches of the **superior mesenteric artery** — midgut supply). The anterior pair unite to form the **anterior pancreaticoduodenal arcade**; the posterior pair unite to form the **posterior pancreaticoduodenal arcade** around the head and uncinate process.
- **Body and tail** — multiple branches of the **splenic artery**, chiefly the **arteria pancreatica magna** (greater pancreatic artery, to the neck/body) and the **arteria caudae pancreatis** (artery to the tail), with a variable contribution from the **dorsal pancreatic artery**. Small arteries run along the superior and inferior borders of the body, fed by the pancreaticoduodenal and splenic arteries.



Name the parts, its borders, surfaces and peritoneal reflections, relations, blood supply of the pancreas

- **Venous drainage:** corresponding veins from the head/neck and body/tail run largely on the posterior surface and empty into the **splenic vein**, **superior mesenteric vein** and **portal vein**. The **portal vein** itself is formed behind the neck of the pancreas, by union of the superior mesenteric and splenic veins (in the transpyloric plane) — a key surgical landmark, since the neck is defined as the part of the gland anterior to this venous confluence.

Applied / Clinical anatomy

- **Carcinoma of the head of the pancreas** is the commonest site of pancreatic cancer (~75%). Since the **bile duct** is embedded in the **posterior surface of the head** just before joining the pancreatic duct, a growth here compresses it, producing **painless obstructive jaundice** with a **palpable**,

distended gall bladder — **Courvoisier's law**: a palpable gall bladder in a jaundiced patient is unlikely due to gallstones (which fibrose the gall bladder), and instead suggests malignant obstruction (head of pancreas/periampullary growth).

- ▶ The neck's relation to the **origin of the portal vein**, and the head's relation to the **inferior vena cava**, mean head-of-pancreas tumours can cause portal hypertension/ascites or IVC compromise; SMV–portal confluence involvement determines **resectability at Whipple's pancreaticoduodenectomy**.
- ▶ The **anterior surface of the body forming the floor of the lesser sac** explains why inflammatory fluid of **acute pancreatitis** collects there as a **pseudocyst**; the retroperitoneal fascial planes behind the head (fascia of Treitz) and body/tail (fascia of Toldt) let exudate track to the paracolic gutters or left perirenal space — the anatomical basis of the back pain of pancreatitis.
- ▶ The **tail's proximity to the splenic hilum** (within the lienorenal ligament) risks injury during **splenectomy** and, conversely, the spleen is at risk during **distal pancreatectomy**.
- ▶ The **uncinate process**, sandwiched between the superior mesenteric vessels anteriorly and the aorta posteriorly, may be compressed by, or itself compress, the third part of the duodenum in pancreatic head masses.
- ▶ The **transpyloric plane** crossing the neck/body junction is a useful surface/radiological landmark for locating the gland on CT/ultrasound.

High-yield exam pointers

- ▶ Four named parts — **Head, Neck, Body, Tail** — plus the **uncinate process** (head) and **tuber omentale** (body); ~12–15 cm long, ~80–90 g.
- ▶ Head: 3 borders (superior, inferior, right lateral) + 2 surfaces (anterior, posterior); Neck: 2 surfaces (anterior, posterior) + upper/lower borders; Body: 3 borders + 3 surfaces (triangular cross-section); Tail: no distinct borders, mobile.
- ▶ Whole gland retroperitoneal EXCEPT the tail, which lies between the two peritoneal layers of the lienorenal ligament.
- ▶ Anterior surface of body = floor of the lesser sac (above transverse mesocolon attachment); its inferior surface relates to the greater sac.
- ▶ Peritoneal reflection from the back of the pylorus onto the front of the neck forms the right boundary of the lesser sac.
- ▶ **Portal vein formed behind the neck** by union of the superior mesenteric and splenic veins.
- ▶ Arterial supply straddles the **foregut (coeliac trunk → gastroduodenal → superior pancreaticoduodenal aa.)** and **midgut (superior mesenteric a. → inferior pancreaticoduodenal a.)** territories — reflecting its dual embryological origin; body/tail chiefly via splenic artery (arteria pancreatica magna, arteria caudae pancreatis).
- ▶ Anterior and posterior pancreaticoduodenal arcades encircle the head/uncinate process.
- ▶ **Courvoisier's law** and painless obstructive jaundice — classic applied correlate of head-of-pancreas carcinoma (bile duct embedded in its posterior surface).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e; IB Singh — Textbook of Anatomy Vol 2 6e.



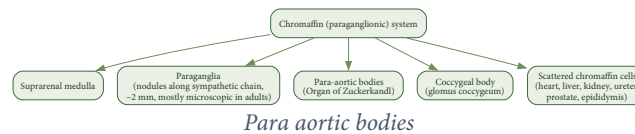
Para aortic bodies

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction The para-aortic bodies — collectively also called the **organ of Zuckerlandl** — are paired collections of neural-crest-derived **chromaffin tissue** lying anterolateral to the abdominal aorta, close to the origin of the inferior mesenteric artery (IMA). They form the largest extra-adrenal component of the **chromaffin (paraganglionic) system**, are prominent in fetal and early postnatal life, and normally involute with age. They are of major applied importance as a recognised site of **extra-adrenal phaeochromocytoma (paraganglioma)**.

1. The chromaffin (paraganglionic) system — where the para-aortic bodies fit

Chromaffin cells are neuroendocrine cells with an affinity for chromic-acid salts (the **chromaffin reaction**), all derived from the **neural crest**. BD Chaurasia groups them into five sites:



2. Development

- ▶ Chromaffin cells and sympathetic ganglion cells share a common origin: **neural crest cells** migrating ventro-laterally alongside the developing spinal ganglia form a syncytial mass, the **sympatho-chromaffin condensation**.
- ▶ This mass differentiates into two cell lines: small **sympathoblasts**, which form the ganglia of the sympathetic trunk and prevertebral plexuses, and large **chromaffin cells** (**sympathogonia** → **pheochromocytes**).
- ▶ The chromaffin cells then migrate to colonise: (a) the medulla of the suprarenal gland, (b) the sympathetic ganglia as paraganglia, and (c) the front of the aorta around the origin of the inferior mesenteric artery, forming the **para-aortic bodies**.
- ▶ They are relatively large in the fetus — where catecholamine secretion from this extra-adrenal tissue may help maintain fetal blood pressure — reach **maximum size at about 3 years of age**, and thereafter regress; BD Chaurasia further notes they atrophy and largely disappear by about **14 years**.

3. Gross anatomy — location, shape, size, relations

Feature	Description
Number	Two (paired), one on each side
Size	About 1 cm long each
Location	Anterolateral to the abdominal aorta, at the origin of the inferior mesenteric artery (IMA arises from the front of the aorta at the L3 vertebral level, behind the third part of the duodenum, 3–4 cm above the aortic bifurcation)
Shape/arrangement	The two bodies are joined together above the IMA origin, producing an inverted horseshoe (H-shaped) mass draped across the front of the aorta
Range	May occasionally be found as high as the coeliac plexus or as low as the inferior hypogastric plexus in the pelvis; may also lie closely applied to the lumbar sympathetic chain ganglia
Related plexuses	Lie in relation to the intermesenteric (aortic) plexus , the inferior mesenteric plexus and the superior hypogastric plexus

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a simple anterior-view line diagram of the lower abdominal aorta:

- ▶ Abdominal aorta (descending) and its **bifurcation into the two common iliac arteries** (at L4)
- ▶ Origin of the **inferior mesenteric artery** from the front of the aorta at L3, 3–4 cm above the bifurcation
- ▶ **Two para-aortic bodies**, one on either side of the IMA origin, lying anterolateral to the aorta
- ▶ A connecting band **above** the IMA origin joining the two bodies — the classic "**inverted horseshoe/H-shaped**" outline
- ▶ Continuation inferiorly as the **superior hypogastric plexus** (presacral nerve)
- ▶ Lumbar **sympathetic chain** and ganglia shown lateral to the aorta, for relational reference
- ▶ **Suprarenal gland** at the upper pole of the kidney, shown for comparison as the principal chromaffin organ
- ▶ Third part of **duodenum** crossing anterior to the aorta near the IMA origin

4. Microscopic structure

- ▶ Composed of clumps/strands of large polyhedral **chromaffin cells (pheochromocytes)** with granular cytoplasm, arranged around **sinusoidal capillaries**, similar in appearance to suprarenal medullary tissue.

- ▶ Chromaffin cells show the characteristic brown staining reaction with potassium-bichromate/chromic-acid salts (chromaffin reaction), the basis of their name.
- ▶ Unlike the coccygeal body (glomus coccygeum), which is made of epithelioid cells around a single sinusoidal capillary and does not truly belong to the chromaffin system, the para-aortic bodies are genuine chromaffin (catecholamine-secreting) tissue.

5. Function and age changes

- ▶ The chromaffin cells of the para-aortic bodies secrete predominantly **noradrenaline**, contributing to catecholamine output additional to the suprarenal medulla.
- ▶ In fetal life they are believed to help sustain blood pressure by catecholamine release; other small chromaffin collections in the fetal prevertebral plexuses reach their peak between the **5th and 8th months** of intra-uterine life.
- ▶ Postnatally the organ of Zuckerkandl involutes — largest around 3 years of age, essentially regressed/atrophied by adulthood (BD Chaurasia: disappearing by ~14 years) — though scattered chromaffin cells may persist as adult remnants, particularly around the coeliac and superior mesenteric arteries.

6. Para-aortic bodies vs the true chemoreceptor "aortic bodies" — a common confusion

A frequent point of confusion (and a favourite viva trap) is that the para-aortic bodies are sometimes loosely called "aortic bodies," but they must **not** be confused with the true **aortic bodies of the arch of the aorta** (aorticopulmonary paraganglia), which are genuine **chemoreceptors**:

Feature	Para-aortic bodies (Organ of Zuckerkandl)	Aortic bodies (of the aortic arch)
Location	Anterolateral to aorta at IMA origin (posterior abdominal wall)	Between the arch of the aorta and pulmonary artery
Cell type	Chromaffin cells (endocrine, catecholamine-secreting)	Glomus cells resembling carotid-body chemoreceptors
Function	Endocrine — secrete noradrenaline into blood	Sensory chemoreceptor — monitor blood O ₂ /CO ₂ /pH, reflex respiratory & cardiovascular response
Innervation	Autonomic (sympathetic) plexus fibres	Afferent fibres of the vagus nerve
Fate with age	Involutes after early childhood	Persists functionally throughout life

Applied / Clinical anatomy

- ▶ **Extra-adrenal pheochromocytoma (paraganglioma)**: scattered chromaffin cells that persist into adulthood may rarely be the site of a paraganglioma; the para-aortic region (organ of Zuckerkandl) is the classic **extra-adrenal site**, presenting with paroxysmal hypertension, headache, palpitation and sweating from catecholamine excess, exactly as in adrenal pheochromocytoma.

- ▶ **"Rule of 10s"** for pheochromocytoma: about 10% are extra-adrenal (paragangliomas), and of those about 10% lie outside the abdomen — the organ of Zuckerkandl accounts for the great majority of intra-abdominal extra-adrenal cases.
- ▶ **Hereditary paraganglioma syndromes:** familial paragangliomas are autosomal-dominant conditions associated with succinate dehydrogenase (SDHx, e.g. SDHD) gene mutations, underlining the need to consider multifocal/extra-adrenal paraganglia including the para-aortic bodies when a chromaffin tumour is diagnosed.
- ▶ **Neuroblastoma:** as a pediatric tumour of primitive neural-crest-derived sympathetic tissue, neuroblastoma classically arises in the adrenal medulla or paravertebral sympathetic ganglia; residual extra-adrenal chromaffin tissue such as the para-aortic bodies is one of the recognised alternative sites along the sympathetic axis.
- ▶ **Surgical/radiological relevance:** because the para-aortic bodies straddle the IMA origin, they lie in the operative field of aortic/retroperitoneal surgery (aneurysm repair, para-aortic lymphadenectomy) and anterior resection with IMA ligation; a persistent or enlarged organ of Zuckerkandl can mimic a para-aortic lymph node or retroperitoneal mass on CT/MRI, and functional imaging exploiting catecholamine uptake helps localise a suspected extra-adrenal paraganglioma.
- ▶ **Diagnostic work-up** of suspected pheochromocytoma/paraganglioma combines clinical history, biochemical assay (urinary/plasma catecholamines and metanephrines) and cross-sectional imaging (CT/MRI), as for suprarenal pheochromocytoma.

High-yield exam pointers

- ▶ Para-aortic bodies = **Organ of Zuckerkandl**; paired, ~1 cm each, joined above the IMA origin as an **inverted horseshoe/H-shape**.
- ▶ Located anterolateral to the aorta at the origin of the IMA (L3, 3–4 cm above the aortic bifurcation).
- ▶ Derived from **neural crest** via the sympatho-chromaffin condensation; chromaffin cells (not sympathoblasts) populate them.
- ▶ Largest component of the **extra-adrenal chromaffin system**; largest at **3 years**, regress with age (BD Chaurasia: gone by ~14 years).
- ▶ Secrete mainly **noradrenaline**; important for fetal BP homeostasis.
- ▶ Classic site of **extra-adrenal pheochromocytoma (paraganglioma)** — "rule of 10s."
- ▶ Do **not** confuse with the true chemoreceptor **aortic bodies of the aortic arch** (vagal innervation, sensory function) — para-aortic bodies are purely endocrine.
- ▶ Other chromaffin-system members for comparison: suprarenal medulla, paraganglia (sympathetic chain), coccygeal body (glomus coccygeum — epithelioid, not true chromaffin tissue).

SOURCE & COVERAGE

Gray's Anatomy (Standing) 41e; BD Chaurasia Human Anatomy Vol 2 8e (Suprarenal Gland and Chromaffin System); AK Datta Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh Textbook of Anatomy Vol 2 4e; Vishram Singh Textbook of Clinical Embryology; Sontakke Textbook of Human Embryology; Ross Histology — A Text and Atlas 7e; Larsen Human Embryology 6e; Thompson & Thompson Genetics in Medicine 8e.



Portal circulation

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

Definition / Introduction Portal circulation is a venous arrangement in which blood from one capillary bed is carried by a vein to a second capillary bed before it returns to the systemic circulation, instead of draining directly into a systemic vein. The **hepatic portal system** collects venous blood from the abdominal part of the gut tube (lower oesophagus to upper anal canal), the spleen, the pancreas and the gallbladder, and conveys it through the **portal vein** to the hepatic sinusoids, so that absorbed nutrients, bacteria and toxins are filtered and metabolised by hepatocytes before the blood reaches the inferior vena cava via the hepatic veins. The portal vein is therefore unique in that it "begins like a vein" in the capillary bed of the gut and "ends like an artery" in the hepatic sinusoids. Its formation, tributaries and sites of portosystemic anastomosis form the anatomical basis of portal hypertension and are high-yield.

1. Formation, course and parts of the portal vein

- ▶ The portal vein is formed **behind the neck of the pancreas** by the union of the **splenic vein** (the larger formative tributary) and the **superior mesenteric vein** (the smaller formative tributary), at the level of the **L2 vertebra** — Gray's Anatomy places its origin in the transpyloric plane, between the lower border of L1 and the upper border of L2.
- ▶ It is about **8 cm long**, is **valveless**, and its wall contains smooth muscle that produces slow, spontaneous contractions.
- ▶ It runs upward and slightly to the right, first behind the neck of the pancreas, then behind the first part of the duodenum, and finally within the right free margin of the lesser omentum, lying posterior to both the bile duct and the hepatic artery throughout.
- ▶ For description it is divided into three parts:

Part	Extent	Anterior relation	Posterior relation
Infraduodenal	Below the first part of the duodenum	Neck of pancreas	Inferior vena cava
Retroduodenal	Behind the first part of the duodenum	First part of duodenum, bile duct, gastroduodenal artery	Inferior vena cava
Supraduodenal	In the right free margin of the lesser omentum	Hepatic artery (to the left), bile duct (to the right)	Inferior vena cava, separated by the epiploic foramen

- It terminates at the right end of the **porta hepatis** by dividing into a **right branch** (shorter, wider; receives the cystic vein before entering the right lobe) and a **left branch** (longer, narrower; supplies the caudate and quadrate lobes, and receives the paraumbilical veins along the ligamentum teres and, in fetal life, the ductus venosus along the ligamentum venosum).

□ Fig 9.24 — ■ *Course and parts of the portal vein.* (Vishram Singh — *Textbook of Anatomy Vol 2 — 4e, p.429*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label: neck of pancreas; splenic vein and superior mesenteric vein uniting behind it; the three parts (infraduodenal, retroduodenal, supraduodenal) with the duodenum drawn alongside; inferior vena cava behind the vein throughout; termination at the porta hepatis into right and left branches; bile duct and hepatic artery in front, within the free margin of the lesser omentum.

2. Tributaries of the portal vein

Tributary	Note
Splenic vein	Larger formative tributary; usually also receives the inferior mesenteric vein
Superior mesenteric vein	Smaller formative tributary; lies to the right of the artery
Left gastric (coronary) vein	Joins near the cardiac end of the stomach; receives lower oesophageal veins
Right gastric vein	Receives the prepyloric vein of Mayo, which runs vertically in front of the pylorus
Superior pancreaticoduodenal vein	Joins behind the first part of the duodenum
Cystic vein	Joins the right branch just before it enters the right lobe
Paraumbilical veins (of Sappey)	Run with the ligamentum teres in the falciform ligament; join the left branch

- The inferior mesenteric vein is **not** a direct tributary of the main portal trunk — it drains into the splenic vein in about 60% of individuals and into the superior mesenteric vein in about 40% (Moore), before the two unite to form the portal vein.

□ Fig 9.25 — ■ *Tributaries of the portal vein.* (Vishram Singh — *Textbook of Anatomy Vol 2 — 4e, p.430*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label: portal vein trunk with splenic vein and superior mesenteric vein as roots; inferior mesenteric vein joining the splenic vein; left and right gastric veins entering the portal vein near the lesser omentum; superior pancreaticoduodenal vein; cystic vein joining the right branch; paraumbilical veins joining the left branch.

3. Intrahepatic distribution and streamline flow

- ▶ After entering the liver, the right and left branches divide and redivide alongside the hepatic artery branches to end in the **hepatic sinusoids**, where portal venous blood mixes with hepatic arterial blood before drainage by the hepatic veins into the inferior vena cava.
- ▶ Flow within the portal vein is **slow and streamlined**: blood from the superior mesenteric vein preferentially enters the **right lobe**, while blood from the splenic and inferior mesenteric veins preferentially enters the **left lobe**.
- ▶ The portal vein supplies roughly **70–80% of the blood reaching the liver** (about two-thirds to three-quarters by volume), the hepatic artery supplying the remainder; because arterial blood is fully oxygen-saturated, the hepatic artery nevertheless contributes close to half the liver's oxygen.
- ▶ Clinically, this streamline pattern is invoked to explain why pyogenic/amoebic liver abscesses (carried by superior-mesenteric-vein blood from an infected ileocaecal region) are commoner in the right lobe, while blood poor in amino acids from the inferior mesenteric vein has been linked to left-lobe changes.

4. Portosystemic (portocaval) anastomoses

Because the portal system is otherwise a closed circuit with no direct communication with the systemic veins except through the liver, several sites of naturally-occurring anastomosis assume great clinical importance when portal flow is obstructed.

Site	Portal tributary	Systemic tributary	Clinical result
Lower end of oesophagus	Left gastric (coronary) vein	Oesophageal veins draining into the azygos/hemiazygos system	Oesophageal varices → may rupture causing haematemesis
Umbilicus	Paraumbilical veins (along the ligamentum teres)	Superior epigastric and lateral thoracic veins (above); superficial and inferior epigastric veins (below)	Caput medusae — a diagnostically useful sign
Anal canal (mid-anal canal)	Superior rectal vein	Middle and inferior rectal veins (draining to the internal iliac vein)	Internal haemorrhoids
Bare area of liver	Portal radicles (hepatic venules)	Phrenic and intercostal (diaphragmatic) veins	Usually of little significance; opens up in cirrhosis

Site	Portal tributary	Systemic tributary	Clinical result
Retroperitoneal surfaces (veins of Retzius)	Colic veins of the ascending and descending colon, duodenal and pancreatic veins	Renal, lumbar and phrenic veins of the posterior abdominal wall	May bleed during mobilisation of colon/duodenum in surgery

- Of these, the **oesophageal, umbilical and anal** sites are the three classically tested "important sites."
- A therapeutic application of the same principle: in portal hypertension a surgical **portosystemic shunt** may be fashioned by anastomosing a main portal channel (portal, splenic or superior mesenteric vein) directly to the inferior vena cava or the left renal vein (spleno-renal shunt); the modern radiological equivalent is the **transjugular intrahepatic portosystemic shunt (TIPS)**.

□ Fig 9.26 — ■ Sites of portocaval anastomosis: 1, lower end (Vishram Singh — *Textbook of Anatomy Vol 2 — 4e, p.432*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label: outline of the trunk with the liver, stomach, and rectum indicated; site 1 — lower end of oesophagus (left gastric vein ↔ azygos/hemiazygos); site 2 — umbilicus (paraumbilical veins ↔ epigastric veins, radiating "caput medusae" pattern); site 3 — anal canal (superior rectal vein ↔ middle/inferior rectal veins); site 4 — bare area of liver (portal radicles ↔ phrenic/intercostal veins); site 5 — retroperitoneal surface of ascending/descending colon (colic veins ↔ renal/lumbar veins).

5. Development (brief)

- The portal vein develops from the **anastomotic venous plexus** that forms around the duodenum between the paired vitelline veins of the early embryo.
- The **infraduodenal part** arises from the left vitelline vein distal to this plexus, the **retroduodenal part** from the dorsal anastomosis between the two vitelline veins, and the **supraduodenal part** from the cranial part of the right vitelline vein.
- The **superior mesenteric vein** is derived from the right vitelline vein, which drains the primary intestinal loop.

Applied / Clinical anatomy

- **Portal hypertension:** normal portal venous pressure is about 5–15 mm Hg (measured by splenic puncture/intrasplenic manometry); sustained elevation is termed portal hypertension. Commonest cause is **cirrhosis of the liver** (usually alcoholic), others being Banti's disease and portal/splenic vein thrombosis.
- Effects of portal hypertension: **congestive splenomegaly, ascites**, and dilatation of the portosystemic collateral channels producing oesophageal varices, caput medusae and haemorrhoids as above.
- **Oesophageal varices** are the most dangerous consequence, as their rupture causes life-threatening haematemesis; they are managed endoscopically (sclerotherapy/band ligation) or by TIPS/surgical shunt when refractory.

- ▶ **Caput medusae** — a whorl of dilated, tortuous paraumbilical veins radiating from the umbilicus — is of diagnostic value at the bedside and points to chronic portal hypertension (occasionally with a patent ligamentum teres/paraumbilical channel).
- ▶ The **hepatoduodenal ligament** (free edge of the lesser omentum) carries the portal triad — portal vein posteriorly, bile duct anteriorly to the right, and the hepatic artery anteriorly to the left — and can be compressed manually at the epiploic foramen (**Pringle's manoeuvre**) to control haemorrhage from the liver, since it contains both afferent vessels to the liver.
- ▶ Portal vein occlusion/thrombosis leads to cavernous transformation (a tangle of collateral veins at the porta hepatis) and is a recognised cause of extrahepatic portal venous obstruction, particularly in children.

High-yield exam pointers

- ▶ Portal vein = union of **splenic vein** + **superior mesenteric vein** behind the neck of the pancreas, at L2 (transpyloric plane per Gray's).
- ▶ About **8 cm long, valveless**; three parts — infraduodenal, retroduodenal, supraduodenal — each related posteriorly to the IVC.
- ▶ Ends at the porta hepatis by dividing into a **short, wide right branch** and a **long, narrow left branch**.
- ▶ Tributaries: splenic, superior mesenteric, left and right gastric, superior pancreaticoduodenal, cystic (right branch), paraumbilical (left branch); the **inferior mesenteric vein drains into the splenic vein**, not directly into the portal vein.
- ▶ Carries **~70–80% of hepatic blood flow** (hepatic artery ~20–30%, but nearly half the oxygen).
- ▶ **Streamline flow**: superior-mesenteric-vein blood → right lobe; splenic/inferior-mesenteric-vein blood → left lobe.
- ▶ **Three classic sites of portocaval anastomosis**: lower oesophagus (→ varices), umbilicus (→ caput medusae), anal canal (→ haemorrhoids); plus bare area of liver and retroperitoneal (colic) veins.
- ▶ Portal HTN defined by sustained pressure rise above normal (5–15 mm Hg); commonest cause = cirrhosis; effects = varices, caput medusae, haemorrhoids, splenomegaly, ascites.
- ▶ Develops from the vitelline-vein anastomotic plexus around the duodenum; SMV derives from the right vitelline vein.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Langman's Medical Embryology (Sadler) 14e.



Portal vein

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The **hepatic portal vein** is the valveless venous trunk that drains blood from the abdominal part of the alimentary tract (excluding the lower anal canal), the gallbladder, the pancreas and the spleen, and conveys it to the liver. It is called a "portal" vein because it begins in one capillary bed (the gut wall) and ends in another (the hepatic sinusoids) — behaving like a vein at its origin and like an artery at its termination. It supplies about **80% of the blood flowing through the liver** (the hepatic artery supplies the remaining ~20%, but a disproportionate share of the oxygen), and its tributaries together hold up to one-third of the body's total blood volume at any time.

Formation

- ▶ Formed by the union of the **splenic vein** and the **superior mesenteric vein (SMV)** behind the neck of the pancreas, at the level of the **L2 vertebra** (transpyloric plane — Gray's places the origin between the lower border of L1 and the upper border of L2).
- ▶ The **inferior mesenteric vein (IMV)** usually joins the **splenic vein** (~60% of individuals) or the SMV (~40%) before the confluence, rather than joining the portal trunk directly.
- ▶ Length: $\approx 7.5\text{--}8\text{ cm}$ (Gray's/Chaurasia state 8 cm; Vishram Singh gives "3 inches").
- ▶ The portal vein and its tributaries are **devoid of valves** and show smooth muscle in their wall with slow, weak spontaneous contractions.

Course, parts and termination

The vein passes upward and slightly to the right and is described in **three parts**:

- ▶ **Infraduodenal part** — below the first part of the duodenum, behind the neck of the pancreas.
- ▶ **Retroduodenal part** — behind the first part of the duodenum.
- ▶ **Supraduodenal part** — above the first part of the duodenum, in the **right free margin of the lesser omentum**, anterior to the epiploic (omental) foramen.

It terminates at the **right end of the porta hepatis** by dividing into **right and left branches**, which carry blood into the liver substance. Because streamline (non-mixing) flow occurs, SMV blood preferentially perfuses the **right lobe** and splenic/IMV blood the **left lobe** — of applied importance in the lateralisation of amoebic liver abscess (right lobe) versus cirrhotic change from malabsorbed blood (left lobe).

Relations

Part	Anterior relations	Posterior relations
Infraduodenal	Neck of pancreas	Inferior vena cava (IVC)
Retroduodenal	First part of duodenum, bile duct, gastroduodenal artery	IVC
Supraduodenal (in lesser omentum)	Bile duct (right) and hepatic artery (left) — the portal triad	IVC, separated by the epiploic foramen

- ▶ Throughout the free edge of the lesser omentum the portal vein lies **posterior to both the bile duct and hepatic artery**, invested by the hepatic nerve plexus and accompanied by lymphatics/lymph nodes.

- **Intrahepatic course:** on entering the porta hepatis, each branch divides and redivides alongside branches of the hepatic artery to terminate in the **hepatic sinusoids**, where portal and arterial blood mix before draining via the hepatic veins into the IVC.

Branches and intrahepatic division

- **Right branch** — shorter and wider; receives the **cystic vein** before entering the right lobe; usually divides into a **right medial (anterior) sectoral branch** (segments V, VIII) and a **right lateral (posterior) sectoral branch** (segments VI, VII). In 10–15% of individuals the right branch is absent and the portal vein **trifurcates** into left, right-medial and right-lateral sectoral veins (relevant to split-liver/live-donor hepatectomy).
- **Left branch** — longer and narrower; runs horizontally along the inferior surface of segment IV, then turns anteriorly/vertically in the **umbilical fissure**; supplies segments II, III and (mainly) IV, and gives branches to the caudate lobe (segment I). In fetal life it receives the **ligamentum teres** (obliterated left umbilical vein) and is continuous with the **ligamentum venosum** (obliterated ductus venosus).

Tributaries

- **Splenic vein** — major formative tributary (also receives the IMV in most people).
- **Superior mesenteric vein** — major formative tributary.
- **Left gastric (coronary) vein** — joins near the origin/left margin of the portal vein; receives a few **oesophageal veins** at the cardiac end of the stomach.
- **Right gastric vein** — receives the **prepyloric vein (of Mayo)**, a useful surgical landmark for the pylorus.
- **Superior pancreaticoduodenal vein** — joins behind the first part of the duodenum.
- **Cystic vein** — usually drains into the right branch.
- **Paraumbilical veins (of Sappey)** — small veins running in the falciform ligament along the ligamentum teres, joining the left branch.

□ Fig 9.25 — Tributaries of the portal vein (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.430)

Portosystemic (portocaval) anastomoses

Because the portal vein is valveless, obstruction to portal flow (classically hepatic cirrhosis) raises portal pressure and reverses flow at sites where portal tributaries communicate with systemic (caval) veins, opening collateral channels.

Site	Portal tributary	Systemic tributary	Clinical result
Lower end of oesophagus	Left gastric vein (oesophageal tributaries)	Oesophageal veins → hemiazygos/azygos → SVC	Oesophageal varices → haematemesis

Site	Portal tributary	Systemic tributary	Clinical result
Umbilicus	Paraumbilical veins (of Sappey)	Superior epigastric (above), inferior/superficial epigastric (below), lateral thoracic, posterior intercostal & lumbar (sides)	Caput medusae
Anal canal (mid-anal)	Superior rectal (haemorrhoidal) vein	Middle and inferior rectal veins → internal iliac vein	Hemorrhoids / piles; bleeding per rectum
Bare area of liver	Portal radicles	Diaphragmatic veins	Usually asymptomatic
Retroperitoneal surfaces (ascending/descending colon, duodenum, pancreas)	Colic/pancreatic veins (veins of Retzius)	Renal-capsule and posterior abdominal wall (lumbar) veins	Usually silent; may bleed in retroperitoneal surgery
Ligamentum venosum	Left branch of portal vein	IVC (via obliterated ductus venosus)	Minor, usually of no clinical significance

□ Fig 9.26 — Sites of portocaval anastomosis (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.432)

Development

- ▶ The portal vein develops from the **paired vitelline (omphalomesenteric) veins**, which run on either side of the primitive gut tube and are joined by **three transverse anastomoses** — cranial (cephalic) ventral, middle dorsal and caudal ventral — around the developing duodenum, forming a "figure of 8" pattern.
- ▶ Selective persistence/disappearance of segments of this plexus gives:
 - **Superior mesenteric vein** and the **trunk, right branch and left branch of the portal vein**, from the infrahepatic vitelline segments (BD Chaurasia maps: infraduodenal part from the left vitelline vein distal to the dorsal anastomosis; retroduodenal part from the dorsal anastomosis itself; supraduodenal part from the cranial part of the right vitelline vein).
 - **Splenic vein**, which drains into the middle dorsal anastomosis.
 - Intrahepatic vitelline plexus → afferent *venae advehentes* (become the intrahepatic portal branches) and efferent *venae revehentes* (become hepatic vein tributaries).
 - Suprahepatic vitelline remnants → common hepatic vein (→ terminal IVC), ductus venosus and left hepatic vein; the left vitelline vein itself regresses.

Applied / Clinical anatomy

- ▶ **Portal pressure**: normal is **5–15 mm Hg** (measured indirectly by splenic puncture); **portal hypertension** is diagnosed above **~40 mm Hg** wedge/intrasplenic pressure gradient.
- ▶ **Causes of portal hypertension**: cirrhosis of the liver (commonly alcoholic — the most frequent cause), Banti's disease, and portal vein thrombosis.
- ▶ **Effects of portal hypertension**: congestive splenomegaly, ascites, and dilatation of the three classic portosystemic collaterals — **oesophageal varices** (risk of fatal haematemesis), **caput medusae** at the umbilicus, and **haemorrhoids** in the anal canal.

- ▶ **Streamline (laminar) flow:** unmixed SMV blood (carrying absorbed toxins/infective material from the small gut) preferentially perfuses the **right lobe**, predisposing it to toxic change/amoebic liver abscess; IMV-derived blood (nutrient-poor) preferentially perfuses the **left lobe**, predisposing it to fibrotic/cirrhotic change.
- ▶ **Surgical decompression:** in cirrhotic portal hypertension a **shunt operation** may anastomose one of the major portal channels (splenic vein, SMV or the portal vein trunk) directly to the IVC or to the **left renal vein** (spleno-renal shunt), bypassing the obstructed liver.
- ▶ **Porta hepatis / portal triad:** the portal vein lies posterior to the bile duct and hepatic artery within the free edge of the lesser omentum — surgically important during cholecystectomy, Pringle's manoeuvre (temporary occlusion of the triad to control hepatic haemorrhage), and liver transplantation dissection.
- ▶ **Portal vein imaging:** it is readily identified on ultrasound/CT at the porta hepatis anterior to the IVC, and is a key structure assessed for **portal vein thrombosis**, tumour invasion (e.g. hepatocellular carcinoma), and pre-operative planning in split-liver/live-donor hepatectomy (where an absent right branch/trifurcation pattern is a relative contraindication).

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a simplified coronal scheme of the porta hepatis region and label:

- ▶ Splenic vein, superior mesenteric vein, inferior mesenteric vein → **confluence forming the portal vein trunk**
- ▶ Neck of pancreas (anterior to infraduodenal part)
- ▶ First part of duodenum, common bile duct, gastroduodenal artery (retroduodenal relations)
- ▶ Inferior vena cava (posterior relation throughout) and epiploic (omental) foramen
- ▶ Free margin of lesser omentum showing the **portal triad**: bile duct (right), hepatic artery (left), portal vein (posterior)
- ▶ Porta hepatis with right branch (→ cystic vein) and left branch (→ ligamentum teres, ligamentum venosum) of the portal vein
- ▶ Left gastric, right gastric, superior pancreaticoduodenal, cystic and paraumbilical veins as labelled tributaries

In a second small schematic, mark the three classic portocaval anastomotic sites — lower oesophagus, umbilicus and anal canal — with arrows showing portal-to-systemic communication.

High-yield exam pointers

- ▶ Formed behind the **neck of pancreas** at L2, by union of **splenic + superior mesenteric veins**; ~8 cm long, valveless.
- ▶ Three descriptive parts: **infraduodenal, retroduodenal, supraduodenal**; always posterior to the IVC.
- ▶ Ends at the **porta hepatis**, dividing into **right (shorter, wider)** and **left (longer, narrower)** branches.

- ▶ Five formative/named tributaries besides splenic & SMV: **left gastric, right gastric, superior pancreaticoduodenal, cystic, paraumbilical**.
- ▶ **Three classic portocaval anastomoses** (esophagus, umbilicus, anal canal) — clinically produce varices, caput medusae, haemorrhoids respectively.
- ▶ Normal portal pressure 5–15 mmHg; portal hypertension >40 mmHg, usually from cirrhosis.
- ▶ Develops from the paired **vitelline veins** and their three transverse anastomoses.
- ▶ Right branch absent/trifurcation in 10–15% — surgically relevant to live-donor liver transplantation.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore — Clinically Oriented Anatomy, 9e; Sontakke — Textbook of Human Embryology (for developmental origin from the vitelline veins).



Portocaval anastomosis

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction A **portocaval (portosystemic) anastomosis** is a site where a tributary of the **portal venous system** (which drains the gut, spleen, pancreas and gallbladder into the liver) communicates directly with a tributary of the **systemic venous system** (draining into the superior or inferior vena cava). Normally these communications are of little functional consequence because portal pressure is low and portal blood drains preferentially through the liver. When portal flow is obstructed — most commonly in **cirrhosis of the liver** — these small anastomotic channels dilate enormously and become important collateral pathways of portal decompression, producing the classical clinical triad of oesophageal varices, haemorrhoids and caput medusae. Knowledge of their precise sites is therefore both an anatomical and a clinical necessity.

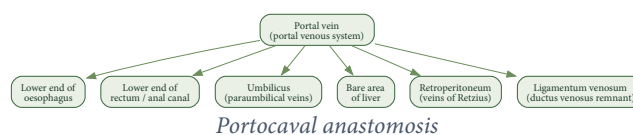
The portal venous system: formation and tributaries

- ▶ The **portal vein** is about 8 cm long; it is formed **behind the neck of the pancreas**, at the level of the **second lumbar vertebra**, by the union of the **superior mesenteric vein** and the **splenic vein**; the **inferior mesenteric vein** usually drains into the splenic vein (occasionally into the superior mesenteric vein or the splenomesenteric confluence).
- ▶ It ascends behind the neck of pancreas, the first part of the duodenum, and then lies in the right free margin of the lesser omentum (within the epiploic foramen boundaries), posterior to the bile duct and hepatic artery, before dividing at the **porta hepatis** into **right and left branches**.
- ▶ It is a **valveless** vein; blood flow is slow and "streamlined" — superior mesenteric venous blood preferentially enters the right lobe, while splenic/inferior mesenteric blood preferentially enters the left lobe.
- ▶ **Direct tributaries:** left and right gastric veins, superior pancreaticoduodenal vein, cystic vein (into the right branch), and the **paraumbilical veins** (into the left branch, running in the falciform ligament along the ligamentum teres).

- The portal vein carries **no oxygenated blood of its own** — it supplies the **majority of hepatic blood flow** (nutrient-rich blood from the gut, spleen and pancreas), while the hepatic artery contributes proportionately less volume but a larger share of oxygen — this physiological point underlines why portal tributaries are numerous and why portal obstruction has such widespread venous consequences.

Sites of portocaval (portosystemic) anastomoses

Site	Portal tributary	Systemic tributary	Clinical consequence in portal hypertension
Lower end of oesophagus	Left (coronary) gastric vein	Oesophageal veins → azygos/hemiazygos → SVC	Oesophageal varices — may rupture, causing fatal haematemesis
Lower end of rectum / anal canal	Superior rectal vein → inferior mesenteric vein	Middle and inferior rectal veins → internal iliac/internal pudendal veins → IVC	Rectal varices / internal haemorrhoids — recurrent bleeding per rectum
Umbilicus (anterior abdominal wall)	Paraumbilical veins (along ligamentum teres, to left branch of portal vein)	Superior epigastric (→ internal thoracic → SVC) and inferior/superficial epigastric, lateral thoracic (→ femoral/external iliac → IVC) veins	Caput medusae — radiating dilated subcutaneous veins around the umbilicus
Bare area of the liver	Portal radicles	Diaphragmatic (phrenic) and intercostal veins	Minor retroperitoneal anastomosis; usually of little clinical significance
Retroperitoneum (veins of Retzius) — colon (near hepatic and splenic flexures), duodenum, pancreas	Colic, pancreatic and duodenal veins draining to portal tributaries	Renal, lumbar, phrenic, azygos/hemiazygos veins	Retroperitoneal varices — at surgical risk during mobilisation of colon/duodenum
Ligamentum venosum (fetal ductus venosus remnant)	Left branch of portal vein	Inferior vena cava	If the ductus venosus fails to close (patent ductus venosus), a direct portocaval shunt persists



□ Fig 9.26 — Sites of portocaval anastomosis: 1, umbilicus; 2, lower end of oesophagus; 3, anal canal; 4, bare area of liver; 5, anterior aspect of kidney (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.432)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A schematic outline of the trunk showing the portal vein centrally, with arrows to each anastomotic site, labelled:

- ▶ **Lower end of oesophagus** — left gastric vein ↔ oesophageal veins (azygos system)
- ▶ **Umbilicus** — paraumbilical veins ↔ superior/inferior epigastric veins
- ▶ **Lower end of rectum** — superior rectal vein ↔ middle/inferior rectal veins
- ▶ **Bare area of liver** — portal radicles ↔ diaphragmatic veins
- ▶ **Posterior abdominal wall / retroperitoneum** — colic/pancreatic veins ↔ renal, lumbar, phrenic veins
- ▶ **Ligamentum venosum** — left portal branch ↔ inferior vena cava
- ▶ Arrowheads at each site indicating direction of collateral flow when portal pathway is obstructed

Developmental basis of the anastomotic sites

- ▶ The portal vein develops from the paired **vitelline veins** and their anastomoses around the developing duodenum and liver: the **infraduodenal part** from the left vitelline vein distal to the dorsal anastomosis, the **retroduodenal part** from the dorsal anastomosis between the two vitelline veins, and the **supraduodenal part** from the cranial part of the right vitelline vein.
- ▶ The **paraumbilical veins** are remnants of the embryonic communication between the intra-abdominal portal system and the extra-embryonic umbilical/vitelline circulation; the **ligamentum teres** is the obliterated left umbilical vein and the **ligamentum venosum** the obliterated **ductus venosus** — both fetal shunts that once carried oxygenated placental blood around the developing liver, and both remain potential portocaval pathways in the adult.
- ▶ Because the gut, its mesenteries and the developing kidney/posterior body wall share a common venous plexus in early development, small residual communications persist between splanchnic (portal) and somatic (caval) drainage at the bare area of the liver and in the retroperitoneum — these are the anatomical basis of the "veins of Retzius."

Portal hypertension — pressure and haemodynamic basis

- ▶ **Normal portal venous pressure** is about 5–15 mm Hg, conventionally measured by splenic puncture and recording the intrasplenic pressure.
- ▶ **Portal hypertension** (markedly raised portal pressure) is produced by:
 - **Cirrhosis of the liver** — the commonest cause; the intrahepatic vascular bed is obliterated by fibrosis, raising resistance to portal flow.
 - **Banti's disease** (idiopathic non-cirrhotic portal hypertension with splenomegaly).
 - **Thrombosis of the portal vein.**
- ▶ Raised portal pressure diverts blood along the portocaval anastomotic channels described above, which dilate and become tortuous — the anatomical basis of the clinical picture of portal hypertension.

- **Effects of portal hypertension:** congestive splenomegaly, ascites, and collateral circulation through the portosystemic communications (caput medusae, oesophageal varices, haemorrhoids).

Applied / Clinical anatomy

- **Oesophageal varices:** dilatation of the submucosal venous plexus at the lower oesophagus; rupture causes life-threatening **haematemesis** — the single most important clinical consequence of portal hypertension.
- **Caput medusae:** dilated, radiating paraumbilical veins visible/palpable around the umbilicus in advanced cirrhosis; a classical sign on abdominal examination with direct diagnostic value.
- **Haemorrhoids (piles):** anastomosis of the superior rectal vein with the middle and inferior rectal veins at the anal canal can enlarge in portal hypertension, though most haemorrhoids in practice are unrelated to portal disease.
- **Retroperitoneal varices (veins of Retzius):** dilated collateral veins near the hepatic and splenic flexures of the colon and around the duodenum/pancreas are a recognised hazard during colonic mobilisation or retroperitoneal surgery in a cirrhotic patient.
- **Streamline flow and lobar disease:** because superior mesenteric venous blood (carrying absorbed toxins/infective material from the small intestine) preferentially streams into the right lobe while inferior mesenteric/splenic blood (relatively amino-acid-poor) streams into the left lobe, this has been invoked to explain the tendency for amoebic liver abscess to affect the right lobe more often, and for certain hepatic fibrotic changes to be left-lobe predominant.
- **Surgical portosystemic shunts:** in refractory portal hypertension, one of the main portal channels (splenic vein, superior mesenteric vein, or the portal vein itself) may be surgically anastomosed directly to the inferior vena cava or to the left renal vein (spleno-renal / "Warren-type" shunt) to decompress the portal system.
- **TIPS (Transjugular Intrahepatic Portosystemic Shunt):** a modern interventional-radiological alternative — a catheter is passed from the **internal jugular vein** → **superior vena cava** → **inferior vena cava** → **hepatic vein**, through the liver parenchyma, into a **portal vein branch**, and a stent is placed to create an artificial low-resistance portosystemic channel, directly exploiting the anatomical proximity of hepatic veins and portal vein branches within the liver.
- **Patent ductus venosus:** failure of closure of the fetal ductus venosus leaves a persistent direct communication between the left branch of the portal vein and the inferior vena cava, a rare congenital portocaval shunt.

High-yield exam pointers

- Portocaval (portosystemic) anastomosis = communication between a **portal** vein tributary and a **systemic (caval)** vein tributary; clinically significant only when portal flow is obstructed.
- **Five classical sites:** lower oesophagus, anal canal/lower rectum, umbilicus (paraumbilical veins), bare area of liver, and the retroperitoneum (veins of Retzius); plus the fetal remnant site at the **ligamentum venosum**.

- ▶ Site–clinical sign pairing: oesophagus → **varices/haematemesis**; anal canal → **haemorrhoids**; umbilicus → **caput medusae**; retroperitoneum → **retroperitoneal varices** (surgical hazard); bare area → usually silent.
- ▶ Normal portal pressure **5–15 mm Hg** (splenic puncture); portal hypertension defined by markedly raised pressure, classically from **cirrhosis**, **Banti's disease**, or **portal vein thrombosis**.
- ▶ Portal vein: formed behind the **neck of pancreas** (L2) by union of **splenic + superior mesenteric veins**; ~8 cm long; **valveless**.
- ▶ Effects of portal hypertension: **congestive splenomegaly, ascites, and portosystemic collaterals**.
- ▶ Surgical decompression: **splenorenal/portocaval shunt surgery**, or the modern **TIPS** procedure via the internal jugular–hepatic vein route.
- ▶ Developmental basis: portal vein from paired **vitelline veins**; ligamentum teres (obliterated left umbilical vein) and ligamentum venosum (obliterated ductus venosus) are persistent potential shunt pathways.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Textbook of Anatomy Vol 2, 6e.



Second part of duodenum

Asked in: Paper I Apr 2006 — RGUHS MD/MS Anatomy

Definition / Introduction The duodenum is the shortest, widest and most fixed part of the small intestine (25 cm total), C-shaped around the head of the pancreas, extending from the pylorus to the duodenojejunal flexure. The **second (descending) part** is 7.5 cm (3 inches) long and is the clinically most important segment — it houses the openings of the bile and main pancreatic ducts, marks the embryological **foregut–midgut junction**, and is entirely retroperitoneal. It is a favourite gross-anatomy and applied-anatomy exam topic because of its relations, its ductal openings, and its dual blood supply.

Extent, course & peritoneal relations

- ▶ **Extent:** begins at the **superior duodenal flexure** (continuation of the first part, opposite the neck of the gallbladder/L1) and ends at the **inferior duodenal flexure** (lower border of L3), where it turns left to become the third part.
- ▶ **Course:** descends almost vertically along the right side of the bodies of L1–L3, curving around the right/lateral aspect of the head of the pancreas; lies initially to the right of, and parallel to, the inferior vena cava (IVC).
- ▶ **Peritoneal relations:** entirely **retroperitoneal and fixed**. Its anterior surface is covered by peritoneum except near the middle third, where the peritoneum reflects off to form the **root of the transverse mesocolon** — here the wall is directly related to (and fused with) the transverse colon.

Visceral relations

Aspect	Structures related
Anteriorly	Right lobe of liver; transverse colon; root of transverse mesocolon; coils of small intestine (jejunum)
Posteriorly	Anterior surface of right kidney (near its medial border/hilum); right renal vessels; right edge of the IVC; right psoas major
Medially	Head of pancreas; bile duct (descending in a groove on the postero-medial aspect of the pancreatic head before entering the duodenal wall)
Laterally	Right colic (hepatic) flexure of the colon

□ Fig 9.4 — Relations of the second part of the duodenum (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.404)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a horizontal (axial) schematic through L2, with the C-loop of the duodenum around the pancreatic head, and label:

- ▶ Superior duodenal flexure, second (descending) part, inferior duodenal flexure
- ▶ Head of pancreas (with bile duct in its posteromedial groove)
- ▶ Major duodenal papilla and minor duodenal papilla (postero-medial wall)
- ▶ Anteriorly: transverse colon / root of transverse mesocolon
- ▶ Posteriorly: right kidney, right renal vessels, IVC, right psoas major
- ▶ Laterally: right colic (hepatic) flexure

Interior features — major and minor duodenal papillae

Feature	Position	Opens
Minor duodenal papilla	~6–8 cm distal to the pylorus (proximal/above the major papilla)	Accessory pancreatic duct (of Santorini)
Major duodenal papilla	~8–10 cm distal to the pylorus, an elevation on the postero-medial wall a little below the middle of the second part	Hepatopancreatic ampulla (of Vater) — the union of the bile duct and the main pancreatic duct
Plica longitudinalis duodeni	A longitudinal mucosal fold running upward from the major papilla	Produced by the oblique intramural course of the terminal bile duct/ampulla; used to locate the papilla endoscopically

- ▶ The two ducts run very obliquely through the duodenal wall and usually unite to form the **hepatopancreatic ampulla**, guarded by the **sphincter of Oddi** (a smooth-muscle complex with separate choledochal, pancreatic-duct and ampullary components — the "Boyden sphincter complex").

- ▶ **Plicae circulares (valves of Kerckring)** begin in the second part and become large and closely set just below the level of the major papilla — a mucosal feature that distinguishes D2 from D1 radiologically.
- ▶ **Brunner's glands** (mucus-secreting, alkaline, submucosal) are most numerous in the first part but extend into the second part, diminishing distally; they neutralise acidic chyme entering the duodenum.

Blood supply, venous & lymphatic drainage

- ▶ The opening of the bile duct into the second part marks the **junction of the foregut and the midgut**; this level divides the arterial supply of the whole duodenum:
 - **Proximal to the bile-duct opening** (foregut derivative) → **superior pancreaticoduodenal artery** (anterior and posterior divisions), a branch of the **gastroduodenal artery** (from the common hepatic artery, coeliac trunk).
 - **Distal to the bile-duct opening** (midgut derivative) → **inferior pancreaticoduodenal artery** (anterior and posterior divisions), from the **superior mesenteric artery (SMA)**.
 - The anterior and posterior branches anastomose to form the **anterior and posterior pancreaticoduodenal arcades** in the groove between the duodenum and pancreatic head — the site of anastomosis between coeliac-trunk and SMA territory (a true "watershed" of the gut, embryologically the foregut–midgut junction).
- ▶ **Venous drainage:** corresponding pancreaticoduodenal veins → superior mesenteric and splenic veins → **portal vein** (the posterior superior pancreaticoduodenal vein drains directly into the portal vein near the neck of the pancreas).
- ▶ **Lymphatic drainage:** vessels end in the **pancreaticoduodenal nodes** lying along the duodeno-pancreatic groove → partly to **hepatic nodes** → **coeliac nodes**; and partly to **superior mesenteric nodes** → intestinal lymph trunk → cisterna chyli.

Nerve supply & embryological basis

- ▶ **Sympathetic:** T9–T10 spinal segments, reaching the gut via the coeliac plexus and running along the arteries; motor to sphincters, inhibitory to peristalsis.
- ▶ **Parasympathetic:** vagus, via the coeliac plexus; stimulates peristalsis, inhibits sphincters.
- ▶ **Development:** the duodenum develops partly from the **foregut** and partly from the **midgut**. Up to the origin of the hepatic bud (and hence up to the level of the bile-duct opening) it is foregut-derived — i.e. the first part and the **upper half of the second part**; the remaining two-and-a-half parts (lower half of D2 onward) are midgut-derived. This explains the dual (coeliac + SMA) arterial supply and dual lymphatic/venous drainage described above.

Applied / Clinical anatomy

- ▶ **ERCP / endoscopic sphincterotomy:** the major duodenal papilla on the postero-medial wall of D2 is the site cannulated for cholangiopancreatography and for sphincterotomy in choledocholithiasis; the plica longitudinalis is the endoscopic landmark leading to the papilla.

- ▶ **Annular pancreas:** an abnormally persistent/malrotated ventral pancreatic bud may encircle the second part of the duodenum, causing duodenal obstruction (may present as neonatal double-bubble obstruction or later recurrent adult obstruction).
- ▶ **Periampullary/pancreatic head carcinoma:** because the bile duct descends in a groove on the postero-medial aspect of the pancreatic head before piercing D2, a tumour here compresses the duct early, producing painless obstructive jaundice with a palpable, non-tender gallbladder (**Courvoisier's sign**); on barium studies the medial wall of D2 may show tethering/infiltration ("reversed-3 sign of Frostberg").
- ▶ **Retroperitoneal perforation:** because D2 (like D3–D4) is retroperitoneal, perforation here (blunt trauma, ERCP injury, penetrating ulcer) tracks retroperitoneally rather than into the general peritoneal cavity, giving subtle signs and gas outlining the right psoas/perinephric plane on imaging rather than free intraperitoneal air.
- ▶ **Pancreaticoduodenectomy (Whipple's procedure):** the head of pancreas and the second part of the duodenum share the pancreaticoduodenal arcades and lymphatic drainage, so both are resected en bloc for periampullary/pancreatic-head malignancy; the arcade (foregut–midgut anastomosis) may be markedly hypertrophied in coeliac-axis stenosis and must be deliberately preserved during resection to avoid hepatic/foregut ischaemia.
- ▶ **Radiology:** the "duodenal cap" (triangular shadow on barium meal) belongs to the mobile first part only; the second part shows a characteristic feathery mucosal (plicae circulares) pattern and is the segment imaged by hypotonic duodenography to profile the pancreatic head and ampullary region.

High-yield exam pointers

- ▶ Second part = 7.5 cm, retroperitoneal and fixed throughout; extends from superior to inferior duodenal flexure (opposite L1 to L3).
- ▶ Major duodenal papilla ≈ 8–10 cm from pylorus → opens the hepatopancreatic ampulla (bile duct + main pancreatic duct); minor papilla ≈ 6–8 cm from pylorus → accessory pancreatic duct.
- ▶ Medially: head of pancreas and bile duct. Posteriorly: right kidney/renal vessels/IVC/right psoas. Anteriorly (middle third): root of transverse mesocolon.
- ▶ Bile-duct opening = anatomical/embryological **foregut–midgut junction**: proximal supply from coeliac trunk (superior pancreaticoduodenal a.), distal from SMA (inferior pancreaticoduodenal a.); the two arcades anastomose here.
- ▶ Foregut portion = first part + upper half of second part (up to hepatic-bud origin); remainder is midgut.
- ▶ Venous drainage → portal vein (via superior mesenteric/splenic veins); lymphatics → pancreaticoduodenal nodes → hepatic/coeliac nodes and superior mesenteric nodes.
- ▶ Sphincter of Oddi guards the ampulla; plica longitudinalis duodeni is the endoscopic guide to the major papilla.
- ▶ Applied: site of ERCP cannulation, annular pancreas obstruction, Courvoisier's sign in periampullary carcinoma, and en-bloc resection with pancreatic head in Whipple's procedure.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh — Textbook of Anatomy Vol 2, 4e (figure).



Spleen

Asked in: Paper I Oct 2006 — RGUHS MD/MS Anatomy

Definition / Introduction The spleen is the largest single mass of lymphoid tissue in the body and the largest organ of the reticuloendothelial (mononuclear phagocytic) system. It is a wedge-shaped, soft, highly vascular, dark purple organ lying in the left hypochondrium and epigastrium, wedged between the fundus of the stomach and the diaphragm, developing in the dorsal mesogastrium. Functionally it filters blood, removes effete cells and blood-borne particulate matter, stores blood elements, and mounts humoral and cellular immune responses; it is not essential for life, its functions being largely assumed by the liver and bone marrow after splenectomy.

1. Situation, Shape & Surface Marking

Parameter	Detail
Situation	Left hypochondrium, extending into the epigastrium; intraperitoneal viscus
Shape	Wedge-shaped/tetrahedral (BD Chaurasia); a slightly curved wedge (Gray's)
Length	9–14 cm ($\approx$ 5 inches)
Breadth	6–8 cm ($\approx$ 3 inches)
Thickness	3–5 cm ($\approx$ 1 inch)
Weight	150–350 g in vivo; 70–120 g when emptied of blood ($\approx$ 7 ounces average)
Surface marking	Deep to the left 9th–11th ribs; long axis corresponds to the long axis of the 10th rib, sloping $\sim 45^\circ$ to the horizontal
Palpability	Not palpable normally; a normal spleen must enlarge to roughly 2–3 times its size before its edge becomes palpable below the left costal margin

Mnemonic (BD Chaurasia): "1, 3, 5, 7, 9, 11" — 1 inch thick, 3 inches broad, 5 inches long, 7 ounces in weight, related to the 9th–11th ribs.

2. External Features

Feature	Description
Ends	Anterior (lateral) end — expanded, more like a border; directed down and forward to the mid-axillary line. Posterior (medial) end — rounded; directed up, back and medially, resting on the upper pole of the left kidney
Borders	Superior border — notched near the anterior end (vestige of fetal lobulation). Inferior border — rounded. Intermediate border — rounded, directed to the right
Surfaces	Diaphragmatic surface — convex, smooth. Visceral surface — concave, irregular
Angles	Anterobasal angle — junction of superior border with the anterior end; most forward-projecting part, felt first in splenomegaly, hence the "clinical angle of the spleen". Posterobasal angle — junction of inferior border with the anterior end
Hilum	Lies between the superior and intermediate borders on the visceral surface; a long fissure transmitting the splenic vessels, nerves and lymphatics; gives attachment to the gastrosplenic and lienorenal ligaments

3. Peritoneal Relations (Ligaments)

Ligament	Extent	Contents / Note
Gastrosplenic ligament	Hilum of spleen → greater curvature of stomach	Short gastric vessels, left gastro-epiploic vessels, lymphatics, sympathetic nerves; forms the anterior pedicle at splenectomy
Lienorenal (splenorenal) ligament	Hilum of spleen → anterior surface of left kidney	Tail of pancreas, splenic vessels, pancreaticosplenic nodes/lymphatics/nerves; forms the posterior pedicle at splenectomy
Phrenicosplenic ligament	Superior pole of spleen → peritoneum on the under-surface of the diaphragm	Variably developed
Phrenicocolic ligament (sustentaculum lienis)	Splenic flexure of colon → diaphragm opposite the 11th rib in the mid-axillary line	Not attached to the spleen itself; supports the anterior end/inferior pole and limits the upper end of the left paracolic gutter

Longer ligaments give the spleen greater mobility (predisposing to a "wandering/floating spleen" and pedicle torsion) but render it more prone to traction injury.

4. Visceral & Diaphragmatic Relations

□ Fig 7.20 — ■ Visceral surface of the spleen showing (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.346)

Impression	Site on spleen	Structure related
Gastric impression	Between superior and intermediate borders; largest, most concave impression	Fundus, upper body and upper greater curvature of stomach
Renal impression	Between inferior and intermediate borders	Anterior surface (upper lateral area) of left kidney; occasionally the superior pole of the left suprarenal gland
Colic impression	Triangular area adjoining the anterior end	Splenic (left colic) flexure of colon; related below to the phrenicocolic ligament
Pancreatic impression	Between the hilum and the colic impression	Tail of pancreas

The **diaphragmatic surface** is separated by the left dome of the diaphragm from the left costodiaphragmatic pleural recess, the base of the left lung, and the 9th–11th ribs of the left side — hence splenic disease/surgery can produce a left basal pleural effusion or lower-lobe atelectasis.

5. Blood Supply, Lymphatic Drainage & Nerve Supply

- ▶ **Splenic artery** — largest branch of the coeliac trunk, one of the most tortuous arteries in the body (length 8–32 cm, calibre 3–12 mm); carries ~7% of cardiac output. It runs behind the upper border of the body and tail of the pancreas, within the lienorenal ligament, to the hilum. Branches: numerous **pancreatic branches**, 5–7 **short gastric arteries**, the **left gastro-epiploic artery**, and (in ~40%) a posterior gastric artery.
- ▶ **Terminal division** — into two (occasionally three) branches (superior and inferior "polar"/lobar arteries) which divide, near the hilum, into 4–5 **segmental arteries** supplying superior and inferior vascular segments separated by a relatively avascular plane; each segment further subdivides into disc-like and cap-like (polar) subsegments. Segmental arteries are functional **end arteries with little collateral anastomosis** — the anatomical basis of both **segmental splenic infarction** on occlusion and **partial (segment-preserving) splenectomy**.
- ▶ **Venous drainage** — trabecular veins → segmental veins → superior/inferior (occasionally middle) lobar veins uniting at the hilum to form the **splenic vein**, which runs a straight course behind the body and tail of the pancreas, crosses anterior to the left kidney/renal hilum/aorta, and joins the superior mesenteric vein behind the neck of the pancreas to form the **portal vein**. Tributaries: short gastric, left gastro-epiploic, pancreatic, and inferior mesenteric veins.
- ▶ **Lymphatic drainage** — splenic parenchyma itself has no true lymphatics; the few lymphatics present arise from the capsule/trabeculae and white pulp, forming a subcapsular plexus that drains via the hilum to the **pancreaticosplenic (splenic hilar) nodes** and nodes around the tail of the pancreas, then to suprapancreatic/infrapancreatic and coeliac nodes, and ultimately the cisterna chyli.

- **Nerve supply** — autonomic, sympathetic-dominant, from the **coeliac plexus** (vasomotor, and supplying the sparse smooth muscle of the capsule/trabeculae — largely vestigial in humans, so the spleen does not actively contract); parasympathetic fibres from the **vagal trunks** travel with the splenic vessels. Sensory (pain) fibres accompany the sympathetic supply; splenic pain is poorly localized and referred to the **epigastrium**, while acute capsular stretch (haematoma, infarction) causes localized left-hypochondrial pain that may radiate to the **left shoulder tip** (**Kehr's sign**) via diaphragmatic/phrenic irritation.

6. Development & Accessory Spleen

- The spleen is **mesodermal** in origin (unlike the gut-derived viscera around it), developing from mesenchymal condensations in the cephalic part of the **left layer of the dorsal mesogastrium** during the sixth week of intra-uterine life.
- Multiple splenic nodules develop and coalesce to form a single, lobulated organ; the **notch on the adult superior border** is a vestige of this fetal lobulation.
- Nodules that fail to fuse with the main mass persist as **accessory spleens** (**spleniculi/splenunculi**) — fully functional splenic tissue found in roughly 10% of individuals, usually solitary, most often near the splenic hilum in the gastrosplenic or lienorenal ligament or the greater omentum, and less commonly in the tail of the pancreas, mesentery, broad ligament of the uterus, or spermatic cord.
- **Clinical importance** — an accessory spleen left behind during splenectomy for a haematological indication (e.g. hereditary spherocytosis, ITP) can hypertrophy and cause recurrence of the disease being treated; it must be actively sought.

7. Microstructure & Functions

- **Fibrous framework** — a peritoneal serosa covers the whole organ except at the hilum; deep to it, a ~1.5 mm collagen (type I) and elastin **capsule** sends **trabeculae** into the substance, continuous with a fine reticular (type III collagen) framework pervading the pulp.
- **White pulp** (5–20% of splenic volume) — a peri-arteriolar lymphatic sheath (PALS) of T lymphocytes around central (follicular) arterioles, expanded focally by B-lymphocyte follicles (0.25–1 mm, with germinal centres after antigenic stimulation) — together forming the **Malpighian corpuscles**.
- **Red pulp** (up to 90% of volume) — splenic cords (reticular cells, macrophages) alternating with venous sinusoids (~50 µm) lined by a discontinuous, specialized "stave-cell" endothelium that allows blood cells to squeeze through — the structural basis of splenic blood filtration ("open" vs "closed" circulation theories).
- **Functions** (summarised):

Category	Functions
Haemopoietic/immunological	Fetal haemopoiesis (can resume postnatally in myelofibrosis, CML); maturation and recirculation of T/B lymphocytes; immunoglobulin (mainly IgM) production; humoral and cellular immune responses

Category	Functions
Production	Leukocytes; opsonins (tuftsin, properdin); complement factors
Storage	Leukocytes, platelets, red cells, metals
Clearance/phagocytosis	Micro-organisms, parasites, circulating antigens, effete/aged red cells and other blood cells, foreign particulate matter
Metabolic	Lipid, cholesterol, bilirubin and amino acid metabolism
Regulatory	Modulation of bone marrow activity and the mononuclear phagocytic system

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Visceral surface of the spleen (label): **Superior border** (with notch), **Inferior border**, **Intermediate border**, **Anterior (lateral) end**, **Posterior (medial) end**, **Anterobasal angle**, **Posterobasal angle**, **Hilum** with entering **splenic artery segmental branches** and **vein leaving hilum**, **Gastric impression**, **Renal impression**, **Colic impression**, **Pancreatic impression**. Show the **gastrosplenic ligament** and **lienorenal ligament** attached at the hilum.

Applied / Clinical anatomy

- ▶ **Traube's (semilunar) space** — the area of gastric tympany overlying the fundus of the stomach, bounded superiorly by the lower border of the left lung, inferiorly by the left costal margin, on the left by the lateral end of the spleen, and on the right by the lower border of the left lobe of liver; it is obliterated by splenomegaly, hepatomegaly, or a left pleural effusion — used clinically to detect early splenic enlargement.
- ▶ **Splenomegaly** — an enlarged spleen descends obliquely towards the **right iliac fossa** along the axis of the 10th rib (not to the left flank, being checked laterally by the phrenicocolic ligament/sustentaculum lienis); the persistent anterosuperior notch on the enlarging spleen helps distinguish it from an enlarged left kidney, which lacks a notch and is bimanually ballotable.
- ▶ **Splenectomy** — the spleen is mobilised by dividing its two peritoneal pedicles: the **anterior (gastrosplenic)** pedicle carrying the short gastric vessels, and the **posterior (lienorenal)** pedicle carrying the splenic vessels and tail of pancreas. The **tail of the pancreas** (rich in islets of Langerhans) must be safeguarded to avoid pancreatitis/fistula, and the short gastric vessels must not be ligated too close to the stomach to avoid gastric fundal necrosis. Because of the segmental arterial supply, **partial (segment-sparing) splenectomy** is possible; small capsular tears may instead be sutured or wrapped in omentum.
- ▶ **Splenic trauma** — the spleen is among the most frequently injured abdominal organs in blunt trauma, particularly with fractures of the left 9th–11th ribs; its rich vascularity can produce severe, rapid haemorrhage.
- ▶ **Overwhelming post-splenectomy infection (OPSI)** — the most serious long-term consequence of splenectomy; carries about a 2% mortality even in previously healthy adults, and a greater risk

in children, the elderly, and the chronically ill, reflecting loss of the spleen's phagocytic/immune-clearance functions against encapsulated organisms.

- ▶ **Splenic puncture/biopsy** — performed through the left 9th or 10th intercostal space in the mid-axillary line, with the patient holding their breath, because the costodiaphragmatic pleural recess descends to the level of the 10th rib here and may otherwise be transgressed.
- ▶ **Wandering (floating) spleen** — results from unusually long/lax peritoneal ligaments permitting excessive mobility; the pedicle may undergo torsion, producing acute pain and infarction.
- ▶ **Splenic infarction** — because segmental splenic arteries are end arteries, embolic or thrombotic occlusion causes wedge-shaped infarcts, presenting with pain referred to the left shoulder tip (**Kehr's sign**).
- ▶ **Banti's disease** — chronic congestive splenomegaly (classically from portal hypertension) causing premature destruction of red cells (haemolytic anaemia); splenic/portal venous obstruction also produces reversed venous flow and gastro-oesophageal/short-gastric varices.

High-yield exam pointers

- ▶ Mnemonic "1, 3, 5, 7, 9, 11" — thickness (1 in), breadth (3 in), length (5 in), weight (7 oz), related ribs (9th–11th).
- ▶ Long axis of the spleen corresponds to the long axis of the **10th rib**; not palpable normally, palpable only after 2–3× enlargement.
- ▶ Two peritoneal pedicles at splenectomy: **gastrosplenic** (anterior, short gastric vessels) and **lienorenal** (posterior, splenic vessels + tail of pancreas).
- ▶ Splenic tissue proper has **no true lymphatics**; only capsular/trabecular lymphatics drain to pancreaticosplenic nodes.
- ▶ Splenic artery segmental branches are **end arteries** → basis of segmental infarction and partial splenectomy.
- ▶ Accessory spleens (spleniculi) occur in ~10%, most often near the hilum — must be sought at splenectomy.
- ▶ Spleen is **mesodermal**, from the dorsal mesogastrium; the adult notch marks fetal lobulation.
- ▶ **Traube's space** obliteration signals splenomegaly; **Kehr's sign** signals splenic irritation/rupture; **OPSI** is the key post-splenectomy complication.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; AK Datta's Essentials of Human Anatomy (Thorax & Abdomen); Moore's Clinically Oriented Anatomy 9e; Vishram Singh's Textbook of Anatomy Vol 2 4e.



Superior mesenteric artery

Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction The superior mesenteric artery (SMA) is the artery of the **midgut** — the second, and largest, of the three unpaired ventral (splanchnic) branches of the abdominal aorta, the other two being the coeliac trunk (foregut) and the inferior mesenteric artery (hindgut). It supplies every midgut derivative, from the post-ampullary (lower) duodenum to the distal one-third of the transverse colon. Embryologically it forms the fixed axis around which the primary intestinal loop undergoes its 270° counter-clockwise rotation, and clinically its acute angle of origin and close relation to the pancreas, duodenum and left renal vein underlie several important compressive and ischaemic syndromes.

Origin

- ▶ Arises from the **anterior surface of the abdominal aorta**, about **1 cm below the coeliac trunk**, at the level of the **lower border of the L1 vertebral body** (the transpyloric plane), behind the body of the pancreas.
- ▶ The angle it makes with the aorta is **acute** (mean $\approx 45^\circ$, range 38–60°, wider in individuals with higher body mass index); it is normally kept open by a cushion of fat, lymphatics and neural tissue that prevents the vessel from compressing the duodenum crossing beneath it.
- ▶ This acute angle of origin and its constant relation to L1 make the SMA a key landmark for **transfemoral catheter angiography/embolectomy** and for locating the **transpyloric plane** clinically.

Course and relations

- ▶ From its origin the artery descends steeply and then curves downward and to the right, describing a curve **convex to the left**.

Segment	Anterior relation	Posterior relation
Above the root of the mesentery	Body of pancreas, splenic vein	Aorta, left renal vein , uncinate process of pancreas, third part of duodenum
Within the root of the mesentery of the small intestine	—	Crosses inferior vena cava, right ureter, right psoas major

- ▶ Throughout its course it is accompanied by the **superior mesenteric vein (SMV)**, which lies on its **right side** and, behind the neck of the pancreas, joins the splenic vein to form the portal vein.
- ▶ The artery is surrounded by the **superior mesenteric (autonomic) plexus** — sympathetic fibres reach it chiefly via the **lesser splanchnic nerve (T10, T11)** relayed in the aortico-renal ganglion, and parasympathetic fibres via the vagus.
- ▶ It **terminates in the right iliac fossa** by anastomosing with the terminal (ileal) branch of the ileocolic artery.

Branches

The SMA gives off **five sets of branches** — four named branches from its right/convex side and one unnamed group from its left/concave side.

Side	Branch	Origin / course	Distribution
Right	Inferior pancreaticoduodenal	Arises opposite the upper border of the 3rd part of duodenum; divides into anterior and posterior branches in the pancreaticoduodenal groove	Head of pancreas and duodenum; anastomoses with the superior pancreaticoduodenal artery (from coeliac trunk via gastroduodenal)
Right	Middle colic	Arises just below the neck of the pancreas; runs in the transverse mesocolon; divides into right and left branches	Transverse colon; left branch anastomoses with left colic near the splenic flexure
Right	Right colic	Arises near the middle of the concavity of the SMA; divides into ascending and descending branches	Ascending colon; ascending branch → middle colic, descending branch → ileocolic
Right	Ileocolic	Terminal-most right-side branch; divides into superior and inferior divisions	Inferior division → anterior/posterior caecal, appendicular and ileal branches; supplies caecum, appendix, terminal ileum
Left	Jejunal and ileal branches (12–15 in number)	Run between the two mesenteric layers, uniting to form arcades	Jejunum and most of ileum; terminal ileum is supplied by the ileocolic artery

Jejunal vs ileal vascular pattern (surgically important for identifying bowel at operation):

Feature	Jejunum	Ileum
Arcade tiers	1–3	2–6
Vasa recta	Fewer, longer	More numerous, shorter and narrower
Mesenteric length (SMA to bowel)	Shorter	Longer
Marginal artery	Last (most distal) arcade, incomplete	Same

□ Fig 21.7 — Branches of the superior mesenteric artery (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.356)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label on a diagram of the SMA and its territory:

- ▶ Abdominal aorta and coeliac trunk (for reference)
- ▶ Origin of SMA — L1 level, 1 cm below coeliac trunk
- ▶ Body of pancreas and splenic vein (anterior relation, above root of mesentery)
- ▶ Left renal vein, uncinate process, third part of duodenum (posterior relation)
- ▶ Superior mesenteric vein — on the right of the artery throughout
- ▶ Inferior pancreaticoduodenal artery
- ▶ Middle colic artery (→ right and left divisions)
- ▶ Right colic artery (→ ascending and descending divisions)
- ▶ Ileocolic artery (→ superior and inferior divisions; anterior/posterior caecal, appendicular, ileal branches)
- ▶ Jejunal and ileal branches with arcades and vasa recta
- ▶ Marginal artery of the small intestine (incomplete distal arcade)
- ▶ Termination — anastomosis with ileocolic branch in the right iliac fossa

Territory of distribution

The SMA supplies all derivatives of the midgut:

- ▶ Duodenum distal to the opening of the bile duct (post-ampullary part)
- ▶ Jejunum and ileum
- ▶ Caecum and vermiform appendix
- ▶ Ascending colon
- ▶ Right two-thirds of the transverse colon
- ▶ Lower part (uncinate process) of the head of the pancreas

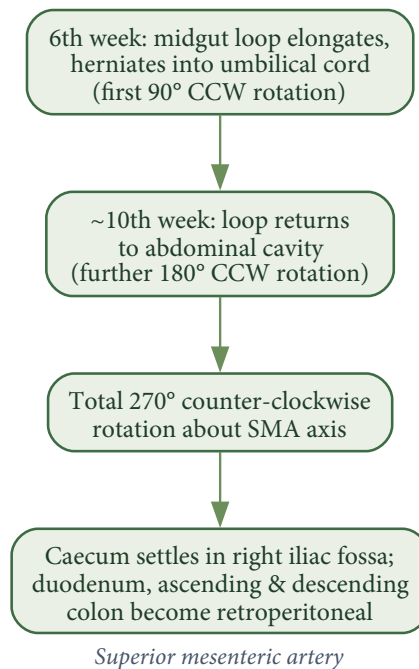
Anastomoses and collateral circulation

- ▶ **Coeliac ↔ SMA:** anterior and posterior pancreaticoduodenal arcades link the inferior pancreaticoduodenal (SMA) with the superior pancreaticoduodenal (gastrooduodenal, from coeliac trunk) around the head of the pancreas.
- ▶ **Within SMA territory:** the ileal branch of the ileocolic artery anastomoses with the terminal branch of the SMA around the caecum, providing collateral supply to the caecum.
- ▶ **SMA ↔ IMA:** the **marginal artery of Drummond** — formed by the chain of arcades from ileocolic, right colic, middle colic and left colic (and continuing via sigmoid and superior rectal) arteries — runs along the mesenteric border of the whole colon. It is reinforced by the **arc of Riolan**, a variable, meandering inner anastomosis directly linking the trunk of the middle colic artery with the ascending branch of the left colic artery; it becomes prominent only when a main mesenteric trunk is occluded.

- **Watershed zone:** the marginal artery is often deficient near the **splenic flexure**, the embryological junction of midgut and hindgut territories — making this the most ischaemia-prone segment of the colon.

Embryological basis

- The SMA is the artery of the midgut and forms the **fixed axis of the primary intestinal loop**.
- During the 6th week the elongating midgut loop herniates physiologically into the umbilical cord, undergoing the first 90° of a counter-clockwise rotation; during its return to the abdominal cavity (~10th week) it completes a further 180°, giving a **total of 270° counter-clockwise rotation** about the SMA axis.
- Failure or reversal of this rotation produces midgut malrotation/volvulus; in reversed rotation the transverse colon comes to lie **behind** the SMA instead of in front of it.
- The proximal SMA develops from the fused paired **vitelline (omphalomesenteric) arteries** of the yolk sac; a persisting distal remnant of a vitelline artery supplies a **Meckel's diverticulum**, when present.



Applied / Clinical anatomy

- **Acute mesenteric ischaemia:** sudden occlusion of the SMA, its vein, or both (embolism or thrombosis) is followed by a rapidly spreading intestinal obstruction due to haemorrhagic infarction of the affected midgut — a surgical emergency.
- **SMA (aortomesenteric) syndrome** — narrowing of the acute aortomesenteric angle (loss of mesenteric fat, prolonged supine immobilisation, rapid weight loss, lumbar lordosis) traps the third part of the duodenum between the SMA anteriorly and the aorta/vertebral column posteriorly, causing bilious vomiting and post-prandial pain.
- **Nutcracker (renal vein entrapment) syndrome:** the left renal vein, crossing in the same acute angle between the SMA and the aorta, may be compressed — producing haematuria/proteinuria,

left flank pain and, in men, a left-sided varicocele (via the left testicular vein draining into the compressed renal vein).

- ▶ **Referred pain:** visceral afferents from midgut structures (e.g. an inflamed appendix) travel with sympathetic fibres of the superior mesenteric plexus back to T10 spinal segments, so early appendicitis pain is felt in the **peri-umbilical region** before localising to the right iliac fossa as parietal peritoneum is involved.
- ▶ **Surgical anatomy:** traction on the caecum towards the anterior superior iliac spine tents up the ileocolic artery, aiding its identification at operation; ligation of SMA branches close to the bowel wall (rather than the main arcades) preserves collateral flow. Jejunal diverticula characteristically occur at the mesenteric border, at the site of vasa recta entry, a point of relative wall weakness.
- ▶ **Radiological anatomy:** the constant L1/transpyloric-plane origin and acute take-off angle are used for catheter positioning in mesenteric angiography and embolectomy for acute mesenteric ischaemia.

High-yield exam pointers

- ▶ Artery of the midgut; arises 1 cm below the coeliac trunk, at L1 (transpyloric plane), acute angle ($\sim 45^\circ$).
- ▶ Passes anterior to the left renal vein, uncinate process and third part of duodenum; posterior to the pancreas and splenic vein.
- ▶ SMV always lies on its right side; joins splenic vein behind pancreatic neck to form the portal vein.
- ▶ Five sets of branches: 4 named right-side (inferior pancreaticoduodenal, middle colic, right colic, ileocolic) + 12–15 unnamed left-side jejunal/ileal branches.
- ▶ Jejunum: fewer arcade tiers (1–3), longer vasa recta; ileum: more tiers (2–6), shorter vasa recta.
- ▶ Terminates by anastomosing with the ileocolic artery in the right iliac fossa.
- ▶ Collateral links: pancreaticoduodenal arcade (with coeliac trunk); marginal artery of Drummond + arc of Riolan (with inferior mesenteric artery); splenic flexure = watershed zone.
- ▶ Embryological axis of the 270° counter-clockwise midgut rotation; derived from the fused vitelline arteries.
- ▶ Clinically: acute mesenteric ischaemia, SMA (aortomesenteric) syndrome, nutcracker syndrome, peri-umbilical referred pain of appendicitis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Moore's Clinically Oriented Anatomy, 9e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; Langman's Medical Embryology (Sadler), 14e.



Superior mesenteric vessels

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction The **superior mesenteric artery (SMA)** is the artery of the **midgut**, the second of the three unpaired ventral (visceral) branches of the abdominal aorta (coeliac trunk, SMA, inferior mesenteric artery), supplying the gut from the lower half of the duodenum to the right two-thirds of the transverse colon. It is accompanied throughout its course by the **superior mesenteric vein (SMV)**, which lies on its right side and is the principal tributary of the **portal vein**. Together the SMA and SMV are of major surgical and radiological importance — as the vascular pedicle of the small bowel and right colon, as landmarks in pancreatic/mesenteric imaging, and as the site of two classical compression syndromes.

Origin, course and termination of the SMA

- ▶ **Origin:** from the front of the abdominal aorta, 1 cm below the coeliac trunk, at the level of the lower border of the L1 vertebra, in the transpyloric plane, behind the neck/body of the pancreas.
- ▶ The angle it makes with the aorta (the **aortomesenteric angle**) is acute — mean about **45° (range 38–60°)** — narrower individuals and greater weight loss reduce this angle and the periaortic fat pad, which is of clinical importance (see below).
- ▶ **Course:** runs downwards and to the right, describing a curve with its **convexity to the left**. At its origin it lies behind the body of the pancreas, then passes **anterior to the uncinate process** of the pancreas, then **crosses anterior to the third (horizontal) part of the duodenum**, enters the **root of the mesentery**, and runs between its two layers.
- ▶ **Termination:** in the **right iliac fossa**, by anastomosing with the ascending (superior) branch of its own ileocolic artery.
- ▶ Throughout its course it is accompanied by the **SMV on its right side** and is surrounded by the **superior mesenteric plexus** of autonomic nerves.

Relations

Region	Anteriorly	Posteriorly
Above the root of the mesentery	Body/neck of pancreas; splenic vein	Aorta; left renal vein; uncinate process of pancreas; third part of duodenum
Within the root of the mesentery	— (lies between the two mesenteric layers)	Inferior vena cava; right ureter; right psoas major

- ▶ On its **right side**, throughout its course, lies the **SMV**.
- ▶ The relation to the **left renal vein** and the **third part of duodenum** posteriorly, and the pancreas/uncinate process anteriorly, explains the two "nutcracker" compression syndromes discussed under Applied anatomy.

Branches of the SMA

The SMA gives off **five sets of branches** — four from its **right (convex) side** and one large set from its **left (concave) side**.

Side	Branch	Course / anastomosis	Territory
Right	Inferior pancreaticoduodenal (first branch)	Arises at the upper border of the 3rd part of duodenum; divides into anterior + posterior branches in the pancreaticoduodenal groove; anastomoses with the superior pancreaticoduodenal artery (from the gastroduodenal, a coeliac-trunk branch)	Head of pancreas, lower duodenum
Right	Middle colic	Arises just below the pancreas; runs in the transverse mesocolon; right branch → anastomoses with right colic; left branch → anastomoses with left colic (from inferior mesenteric artery)	Transverse colon
Right	Right colic	Arises near the middle of the concavity; divides into ascending branch (→ middle colic) and descending branch (→ ileocolic)	Ascending colon, right (hepatic) flexure
Right	Ileocolic (lowest/terminal branch)	Divides into an ascending branch (→ right colic) and a descending branch (→ termination of SMA); the descending branch gives ascending colic, anterior/posterior caecal, appendicular and ileal branches	Terminal ileum, caecum, appendix, lower ascending colon
Left	Jejunal and ileal branches (~12–15 in number; Gray's: 4–6 jejunal + 8–12 ileal)	Run between the two mesenteric layers, dividing and re-anastomosing to form arterial arcades , the most distal of which gives off vasa recta to the gut wall	Jejunum and ileum (except terminal ileum, supplied by the ileocolic)

□ Fig 21.7 — Branches of the superior mesenteric artery (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.356)

Jejunal vs ileal branches (classic comparison):

Feature	Jejunum	Ileum
Number of arcade tiers	1–3	2–6
Vasa recta	Longer, fewer	Shorter, more numerous
Branch calibre	Slightly larger	Slightly smaller
Mesenteric length (artery to gut wall)	Shorter	Longer
Vascular arcade "leaves"	Distinct, with an avascular plane between	Less distinct

- ▶ The last arcade of the jejunal/ileal branches forms an irregular, incomplete **marginal artery** of the small intestine, from which the vasa recta arise.
- ▶ Successive vasa recta are distributed **alternately to opposite sides** of the gut, and neighbouring vessels do not anastomose — hence division of several consecutive vasa recta can cause segmental ischaemia even though the arcades themselves anastomose freely.
- ▶ The **ileocolic, right colic and middle colic** branches anastomose in sequence with the left colic and sigmoid branches of the inferior mesenteric artery to complete the **marginal artery of Drummond**, the continuous anastomotic arcade along the concave (mesenteric) border of the colon.

Superior mesenteric vein

- ▶ **Formation:** begins in the **right iliac fossa** by the union of tributaries draining the **ileocaecal region**.
- ▶ **Course:** ascends in the small-bowel mesentery **on the right side of the SMA**, within the root of the mesentery crossing anterior to the **inferior vena cava, right ureter, third part of duodenum and uncinate process of the pancreas**; it then passes **behind the neck of the pancreas**, at the level of the transpyloric plane (lower border of L1), where it joins the **splenic vein** to form the **portal vein**.
- ▶ **Tributaries:** jejunal, ileal, ileocolic, right colic and middle colic veins (corresponding to the arterial branches), the **right gastroepiploic vein**, and the **inferior pancreaticoduodenal vein**. The right colic vein is variable — it may drain directly into the SMV or first join the right gastroepiploic/inferior pancreaticoduodenal veins to form a common **gastrocolic trunk**.
- ▶ **Drainage territory:** small intestine, caecum, appendix, ascending colon and (proximal two-thirds of the) transverse colon, plus part of the stomach (via the right gastroepiploic vein) and the pancreas and greater omentum.
- ▶ The **inferior mesenteric vein** usually drains into the splenic vein but occasionally joins the SMV directly or at its confluence with the splenic vein.

Anastomoses and embryological correlate

- ▶ **Foregut–midgut link:** the inferior pancreaticoduodenal artery (SMA) anastomoses with the superior pancreaticoduodenal artery (coeliac trunk via the gastroduodenal artery), providing collateral flow between the coeliac and superior mesenteric territories around the head of pancreas/duodenum.

- ▶ **Vitellointestinal artery:** the SMA is the adult derivative of the embryonic artery that supplied the midgut loop during physiological herniation; its distal remnant (from the termination of the SMA to the ileum) usually obliterates, but when it persists it forms the artery of a **Meckel's diverticulum**.
- ▶ **Portal formation:** because its principal tributary, the SMV, begins in one capillary bed (the gut) and the portal vein ends in another (hepatic sinusoids), the SMV–splenic vein confluence is the classical description of why the portal vein is a true "portal" system.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the abdominal aorta with the SMA arising 1 cm below the coeliac trunk at L1, curving downwards/right with its convexity to the left, and label:

- ▶ **Relations:** pancreas + splenic vein anteriorly; aorta, left renal vein, uncinate process and 3rd part of duodenum posteriorly (above the mesenteric root); IVC, right ureter and right psoas major (within the mesenteric root).
- ▶ SMV running parallel, on the right of the SMA, throughout.
- ▶ **Right-side branches** in order: inferior pancreaticoduodenal, middle colic, right colic, ileocolic (with its ascending colic, caecal, appendicular and terminal ileal twigs).
- ▶ **Left-side branches:** 12–15 jejunal and ileal branches forming arterial arcades and vasa recta.
- ▶ **Termination:** SMA anastomosing with the ileocolic artery in the right iliac fossa; SMV joining the splenic vein behind the pancreas to form the portal vein.

Applied / Clinical anatomy

- ▶ **Acute mesenteric ischaemia:** sudden occlusion of the SMA, SMV or both (embolism or thrombosis) is followed by rapidly spreading intestinal obstruction due to **haemorrhagic infarction** of the midgut-derived bowel — a surgical emergency, since the poor terminal anastomoses between vasa recta give little collateral protection distally.
- ▶ **SMA (Wilkie's) syndrome:** the third part of the duodenum crosses between the SMA anteriorly and the aorta/vertebral column posteriorly, behaving like "a nut between two tongs"; a reduced aortomesenteric angle/distance (e.g. after rapid weight loss, prolonged supine bed rest, or in a thin build) compresses the duodenum, producing intermittent duodenal (mesenteric root) obstruction.
- ▶ **Nutcracker (renal vein entrapment) syndrome:** the left renal vein crosses the midline in the acute angle between the SMA (anteriorly) and the aorta (posteriorly); compression here causes left renal vein hypertension, presenting with haematuria, proteinuria, left flank pain and, in men, a left-sided varicocele (via the left testicular vein draining into the compressed left renal vein).
- ▶ **Meckel's diverticulitis:** inflammation of a persistent vitellointestinal (Meckel's) diverticulum, supplied by a remnant vitellointestinal artery from the SMA, can mimic acute appendicitis because both structures are midgut derivatives with periumbilical referred pain.
- ▶ **Surgical relevance:** the ileocolic artery has few collateral connections to the rest of the SMA territory, making it easy to dissect to its origin during right hemicolectomy; the parallel-arcade

arrangement of jejunal vessels is exploited in bowel-lengthening procedures for short-bowel syndrome.

- ▶ **Imaging:** the SMA/SMV relationship to the uncinate process and pancreatic neck is a key landmark on CT for staging pancreatic head carcinoma (vessel contact/encasement determines resectability); Doppler ultrasound and CT/MR angiography assess the aortomesenteric angle and distance in suspected SMA syndrome, and detect SMA embolism/thrombosis in acute mesenteric ischaemia.
- ▶ **Marginal artery significance:** because the marginal artery of Drummond can maintain colonic viability even if one main feeding trunk is ligated, surgeons rely on it during colonic resections — but anastomotic weak points exist at the junctions between main vessels.

High-yield exam pointers

- ▶ SMA = artery of midgut; arises **1 cm below coeliac trunk**, at L1 (**transpyloric plane**), angle $\sim 45^\circ$ ($38\text{--}60^\circ$) with the aorta.
- ▶ Course: behind pancreas → in front of uncinate process → in front of 3rd part duodenum → root of mesentery → terminates in right iliac fossa by anastomosing with ileocolic artery.
- ▶ **SMV lies to the right of the SMA** throughout; joins the splenic vein behind the pancreatic neck to form the **portal vein**.
- ▶ Five branch sets: inferior pancreaticoduodenal, middle colic, right colic, ileocolic (right side) + 12–15 jejunal/ileal branches (left side).
- ▶ Jejunum: fewer arcades (1–3), longer/fewer vasa recta. Ileum: more arcades (2–6), shorter/more numerous vasa recta.
- ▶ Two classic compression syndromes at the aortomesenteric angle: **SMA (Wilkie's) syndrome** (duodenum) and **nutcracker syndrome** (left renal vein).
- ▶ Vitellointestinal artery remnant (from SMA termination) supplies a **Meckel's diverticulum**.
- ▶ Marginal artery of Drummond = anastomotic chain of ileocolic–right colic–middle colic (SMA) with left colic–sigmoidal (IMA branches).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 (8e); Vishram Singh — Textbook of Anatomy Vol 2 (4e); Moore's Clinically Oriented Anatomy 9e.



Supports and posterior relations of Kidneys

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction — The kidneys are a pair of bean-shaped, retroperitoneal excretory organs lying against the posterior abdominal wall, extending vertically from the upper border of T12 to the body of L3, the right lying slightly lower than the left. Unlike most abdominal viscera, the kidney has no true peritoneal covering or mesentery holding it in place; instead it is held in its normal position by a combination of fascial, fatty and vascular **supports**, and rests posteriorly on a firm muscular bed with which it forms its **posterior relations**. Both aspects are surgically important — for the posterior (loin) approach to the kidney and for understanding nephroptosis ("floating kidney").

Coverings (capsules) of the kidney — the anatomical basis of its supports

From within outward, the kidney is invested by four coverings (Fig. shown below):

Layer	Description
1. Fibrous (true) capsule	Thin membrane of condensed fibrous stroma closely investing the kidney; lines the renal sinus at the hilum; strips easily off a healthy kidney but becomes adherent in disease
2. Perirenal (perinephric) fat	Adipose tissue between the fibrous capsule and the renal fascia; thickest at the borders/poles; fills the renal sinus
3. Renal fascia (false capsule, fascia of Gerota)	Fibroareolar sheath enclosing the kidney and perirenal fat; has an anterior layer (fascia of Toldt) and a thicker posterior layer (fascia of Zuckerkandl)
4. Paranephric (pararenal) fat	Fat lying outside the renal fascia, more abundant posteriorly and toward the lower pole; fills the paravertebral gutter

□ Fig 24.6 — Transverse section through the lumbar region showing the capsules of the kidney (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.397)

Extensions of the renal fascia (the key to its supportive role):

- **Superiorly** — the two layers first enclose the suprarenal gland in a separate compartment, then blend with the inferior phrenic (diaphragmatic) fascia, forming the *suspensory ligament of the suprarenal gland*; this is why downward displacement of the kidney is not accompanied by displacement of the suprarenal gland.
- **Inferiorly** — the two layers remain separate, extend along the ureter, and are gradually lost in the extraperitoneal tissue of the iliac fossa (the posterior layer blends with the fascia iliaca).
- **Medially** — the anterior layer passes in front of the kidney/renal vessels and is continuous with its fellow around the aorta and IVC; the posterior layer is attached to the fascia over psoas major and quadratus lumborum, and to the sides of the vertebral bodies. A connective-tissue septum at the medial border, pierced by the renal vessels, closes off the perinephric space and prevents fluid tracking to the opposite side.
- **Laterally** — both layers fuse and blend with the fascia transversalis (as the *lateral conal fascia*).

Supports of the kidney (factors maintaining its normal position)

Although classically taught as a fixed organ, each kidney normally moves about 2–3 cm during respiration and with change of posture. It is held in this "mobile-but-fixed" state by:

- ▶ **Renal fascia and its fibrous septa** — the fascia of Gerota, firmly anchored posteriorly to the fasciae of psoas major and quadratus lumborum and superiorly continuous with the diaphragmatic fascia, forms the principal sling suspending the kidney from the posterior abdominal wall.
- ▶ **Perirenal fat** — acts as an elastic cushion within the renal fascia, permitting respiratory excursion while resisting displacement; wasting of this fat (severe emaciation, rapid weight loss) is the chief cause of pathological hypermobility.
- ▶ **Paranephric fat** — a further cushion external to the renal fascia, binding it to the posterior abdominal wall.
- ▶ **Renal vessels and the ureter** — the short renal pedicle (artery and vein passing almost directly to the aorta/IVC) and the ureter tether the kidney medially and inferiorly and limit its range of movement.
- ▶ **Peritoneal/ligamentous attachments of adjoining viscera** — the hepatorenal fold on the right and the lienorenal ligament on the left buttress the kidney anteriorly.
- ▶ **Intra-abdominal pressure and the muscular bed** — the firm posterior support of psoas major, quadratus lumborum and the diaphragm, combined with the tone of the anterior abdominal wall maintaining normal intra-abdominal pressure, wedges the kidney in place; loss of abdominal wall tone (multiparity, thin asthenic build) predisposes to descent.

Clinical correlate: when perirenal fat is depleted or the renal fascia is lax, mobility increases beyond the normal range, producing a **floating kidney (nephroptosis)** — commoner on the right and in thin, multiparous women. A floating kidney can move up and down but not from side to side within its fascial sheath (the fascial septum prevents lateral displacement). Downward tug on the ureter may cause kinking and intermittent hydronephrosis with colicky pain (Dietl's crisis). Treatment, when required, is **nephropexy** — suturing the posterior layer of renal fascia (or the fibrous capsule) to the psoas fascia, quadratus lumborum, or twelfth rib.

Posterior relations of the kidney

The posterior surface is flat, entirely non-peritoneal, and embedded in fat. The posterior relations are the **same for both kidneys**, except for the rib related to each. From medial to lateral, they fall into an upper and a lower part:

Region	Structures related (medial → lateral)
Upper part	Diaphragm, arising here from the medial and lateral arcuate (lumbocostal) ligaments ; the costodiaphragmatic recess of pleura intervenes between the diaphragm and the kidney
Ribs	Right kidney — related to the 12th rib only; Left kidney — related to the 11th and 12th ribs (it lies slightly higher than the right)

Region	Structures related (medial → lateral)
Lower part	Psoas major (covered by psoas fascia) → quadratus lumborum (covered by the anterior layer of thoracolumbar fascia) → transversus abdominis (covered by fascia transversalis, via its aponeurotic origin)
Nerves & vessels (crossing obliquely, superficial to quadratus lumborum, deep to thoracolumbar fascia)	Subcostal vessels and nerve (T12), iliohypogastric nerve (L1), ilioinguinal nerve (L1) — running downward and laterally in that order

□ Fig 24.4 — Posterior relations of the right kidney (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.396)

Key points on the posterior relations:

- ▶ The costodiaphragmatic recess extends posterior to the kidney; because of this, a **posterior surgical incision** for the kidney risks opening the pleural cavity, especially if the 12th rib is short/absent and the 11th rib is mistaken for it.
- ▶ The diaphragmatic muscle is occasionally deficient in a small triangle immediately above the lateral arcuate ligament, allowing perirenal fat to abut directly on the diaphragmatic pleura.
- ▶ The **renal angle** — between the lower border of the 12th rib and the lateral border of erector spinae — overlies the lower part of the kidney and is the site elicited for renal tenderness (Murphy's punch sign, positive in pyelonephritis/renal calculus).
- ▶ **Surface marking (parallelogram of Morris)**: two horizontal lines at the spine of T11 and spine of L3, and two vertical lines 2.5 cm and 9 cm from the posterior median plane; the hilum lies at the lower border of L1. The classic **oblique loin incision** runs from the renal angle downward and forwards toward the anterior superior iliac spine.
- ▶ Layers reflected during the posterior approach to the kidney: skin → superficial fascia → posterior layer of thoracolumbar fascia (with latissimus dorsi/serratus posterior inferior) → erector spinae → middle layer of thoracolumbar fascia → quadratus lumborum → anterior layer of thoracolumbar fascia → renal fascia → kidney.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- ▶ **Transverse (cross) section through the lumbar region** showing, from the vertebral body outward: aorta/IVC → kidney with fibrous capsule → perirenal fat → renal fascia (anterior + posterior layers) → paranephric fat → psoas major (medially) and quadratus lumborum with transversus abdominis (posteriorly) → erector spinae. Label all four capsules and the two renal-fascia layers.
- ▶ **Posterior view of both kidneys in situ** — label (medial to lateral, upper part) diaphragm with medial and lateral arcuate ligaments and costodiaphragmatic recess; (rib relations) 12th rib on the right, 11th + 12th ribs on the left; (lower part) psoas major → quadratus lumborum → transversus abdominis; and the subcostal vessels/nerve, iliohypogastric and ilioinguinal nerves crossing obliquely. Mark the renal angle.

Applied / Clinical anatomy

- ▶ **Nephroptosis (floating kidney):** loss of perirenal fat/fascial support → excess mobility → ureteric kinking → intermittent hydronephrosis and colic (Dietl's crisis); treated by nephropexy.
- ▶ **Perinephric abscess/haematoma:** blood or pus first distends the renal fascia, then tracks downward within it toward the pelvis (never crossing the midline, owing to the medial fascial septum) — explains the clinical spread pattern of perinephric collections.
- ▶ **Renal trauma:** the muscular posterior bed (ribs, psoas, quadratus lumborum, vertebral column) protects the kidney, but severe blunt trauma can crush it against the 11th/12th ribs and vertebrae; penetrating injury risks the pleura owing to the overlying costodiaphragmatic recess.
- ▶ **Percutaneous nephrolithotomy / renal biopsy:** performed via the posterior loin approach along the renal angle, staying below the costodiaphragmatic recess and lateral to erector spinae to avoid the pleura.
- ▶ **Renal angle tenderness (Murphy's punch sign):** clinical bedside test for pyelonephritis and renal calculus.
- ▶ **Radiological correlation:** on a plain X-ray/CT, the psoas shadow and the 12th-rib relation help localise renal calculi and assess perinephric spread of disease/blood.

High-yield exam pointers

- ▶ Four coverings from within out: fibrous capsule → perirenal fat → renal fascia (Gerota) → paranephric fat.
- ▶ Renal fascia = anterior layer (fascia of Toldt) + posterior layer (fascia of Zuckerkandl); fuses above around the suprarenal gland (suspensory ligament of suprarenal), stays open below along the ureter.
- ▶ Supports of kidney = renal fascia + perirenal/paranephric fat + renal vessels/ureter + peritoneal ligaments of neighbouring viscera + tone of abdominal wall/intra-abdominal pressure.
- ▶ Normal renal mobility ≈ 2–3 cm (respiration/posture); floating kidney moves up-down, never side-to-side (fascial septum).

- ▶ Posterior relations common to both kidneys: diaphragm (medial + lateral arcuate ligaments), psoas major, quadratus lumborum, transversus abdominis, subcostal vessels/nerve, iliohypogastric and ilioinguinal nerves.
- ▶ Right kidney → related to 12th rib only; Left kidney → related to 11th and 12th ribs (asymmetry is a favourite MCQ/short-note point).
- ▶ Renal angle = between lower border of 12th rib and lateral border of erector spinae; site of tenderness; overlies lower pole.
- ▶ Costodiaphragmatic recess of pleura lies posterior to the upper part of the kidney — key hazard in posterior surgical approaches.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol. 2 (8e); AK Datta's Essentials of Human Anatomy, Vol. 1 — Thorax & Abdomen; Vishram Singh's Textbook of Anatomy Vol. 2 (4e); IB Singh's Textbook of Anatomy Vol. 2 (6e).



Ureter

Asked in: Paper I May 2011 — RGUHS MD/MS Anatomy

Definition / Introduction The ureter is a paired, thick-walled, muscular retroperitoneal tube, about 25 cm long, that conveys urine from the renal pelvis to the urinary bladder by peristalsis. It begins as a direct continuation of the funnel-shaped renal pelvis and descends through the posterior abdominal wall, crosses the pelvic brim, and traverses the pelvis to pass obliquely through the bladder wall before opening at the trigone. Developing from the **ureteric bud**, an outgrowth of the mesonephric duct, it is exam-important both for its anatomical relations (right vs left, male vs female pelvis) and for its applied anatomy — the commonest sites of calculus impaction, and the classic sites of iatrogenic surgical injury.

Gross anatomy and dimensions

- ▶ A paired muscular tube connecting the renal pelvis to the urinary bladder; **retroperitoneal** throughout its course.
- ▶ **Length:** about 25 cm (10 inches) — abdominal part ~12.5 cm (upper half), pelvic part ~12.5 cm (lower half).
- ▶ **Diameter:** about 3 mm on average; slightly narrower at the sites of normal constriction described below.
- ▶ **Wall, outside in:** fibrous adventitia → smooth muscle coat → mucosa lined by transitional epithelium (urothelium).
- ▶ **Parts:** (1) **abdominal part** — from the pelviureteric junction (PUJ) to the pelvic brim; (2) **pelvic part** — from the pelvic brim to the bladder wall, including a short **intramural (intravesical)** segment.

Course and relations

Abdominal part — descends on the medial part of psoas major, anterior to the tips of the lumbar transverse processes (separated from them by psoas), and enters the lesser pelvis anterior to the bifurcation of the common iliac artery (or the origin of the external iliac vessels).

Relation	Right ureter	Left ureter
Anterior	peritoneum; third part of the duodenum overlaps its origin; right colic and ileocolic vessels; gonadal vessels; root of the mesentery and terminal ileum	peritoneum; gonadal (testicular/ovarian) artery; left colic vessels; sigmoid colon and its mesocolon (behind the intersigmoid recess)
Posterior	psoas major, tips of lumbar transverse processes, genitofemoral nerve	same
Medial	inferior vena cava	gonadal vein, and further medially the inferior mesenteric vein; lies lateral to the aorta

Pelvic part — at the pelvic brim it runs downward, backward and laterally along the anterior margin of the greater sciatic notch on the lateral pelvic wall; opposite the ischial spine it turns anteromedially in fibro-fatty tissue above levator ani to reach the base of the bladder.

	Posterior relations	Lateral relations
Pelvic ureter	internal iliac artery and vein, lumbosacral trunk, sacroiliac joint	fascia over obturator internus; obturator vessels/nerve; superior and inferior vesical vessels; middle rectal artery

Sex-specific relations near the bladder:

- **Male:** the vas deferens crosses the ureter superiorly from lateral to medial side; the ureter then passes anterior and slightly superior to the seminal vesicle to reach the bladder; vesical veins surround its terminal part.
- **Female:** the ureter forms the posterior boundary of the ovarian fossa; it runs in extraperitoneal tissue in the base of the broad ligament, where the **uterine artery lies above and anterior to it for about 2.5 cm and then crosses it superiorly from lateral to medial** ("water under the bridge"); it lies about 2 cm lateral to the supravaginal cervix, just above the lateral vaginal fornix, and its terminal part is anterior to the vagina.

Intramural (intravesical) part — the distal 1–2 cm is surrounded by an incomplete muscular collar (sheath of Waldeyer); the ureter pierces the bladder wall and runs obliquely within it for 1.5–2.0 cm before opening at the ureteric orifice. This oblique intramural course gives a valvular action that resists reflux of urine from the bladder (there is no discrete anatomical sphincter). The two ureteric orifices are about 5 cm apart in the distended bladder and only 2.5 cm apart when it is empty.

Normal constrictions

The ureter is slightly narrowed at **five sites** — all classic locations for a calculus to lodge:

□ Fig 24.23 — Constrictions in the course of ureter (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.404)

No.	Site	Note
1	Pelviureteric junction (PUJ)	continuation from renal pelvis
2	Brim of the lesser pelvis	crosses common iliac vessel bifurcation
3	Crossing by the vas deferens (male) / broad ligament–uterine artery (female)	near the ischial spine
4	Oblique intramural passage through the bladder wall	—
5	Ureteric orifice at the trigone	narrowest of all — can arrest a stone as small as 2–3 mm

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Reproduce the labelled scheme of ureteric course and constrictions with these exact labels: **Kidney (lower pole) → Renal pelvis → Pelviureteric junction → Abdominal ureter → Crossing the pelvic brim (common iliac vessels) → Pelvic ureter → Crossing by ductus deferens/broad ligament → Oblique intramural (bladder-wall) segment → Ureteric orifice at the trigone → Urinary bladder.** Mark psoas major and the ischial spine as bony/muscular landmarks along the course.

Blood supply, venous and lymphatic drainage

- Supplied segmentally by twigs from **all adjacent vessels**, forming a longitudinal anastomotic plexus on the ureteric wall: renal artery (constant, upper part), gonadal (testicular/ovarian), direct branches from the aorta, common and internal iliac arteries, and — constantly — the inferior vesical/uterine artery for the lower part.
- **Rule of sidedness:** the abdominal (upper and middle) ureter is supplied from its **medial** side; the pelvic ureter is supplied from its **lateral** side.
- The good longitudinal anastomosis means the ureter can be safely transected at any level intra-operatively and repaired by uretero-ureterostomy without compromising viability; however, stripping the periureteric fascia while mobilising the ureter (e.g. for transplantation) damages this anastomosis and risks ischaemic necrosis/stricture — the renal-artery branch is deliberately preserved during renal transplantation.
- **Veins** generally follow the corresponding arteries.
- **Lymphatics** begin in submucosal, intramuscular and adventitial plexuses: from the upper abdominal ureter drain to renal hilar/lateral aortic nodes; from the lower abdominal ureter to common iliac nodes; from the pelvic ureter to common, external or internal iliac nodes.

Nerve supply and referred pain

- ▶ **Sympathetic:** T10–L1 segments, reaching the ureter via the renal and aortic plexuses (upper part), the superior hypogastric plexus (middle part), and the hypogastric nerve/inferior hypogastric plexus (lower part).
- ▶ **Parasympathetic:** S2–S4 segments via the same plexuses.
- ▶ These autonomic fibres are chiefly **sensory (afferent)**; peristalsis itself is myogenic — from pacemaker cells in the minor calyces, propagated by gap junctions towards the bladder (about six coordinated waves/minute; 20–80 cm H₂O pressure) — nerves only modulate, not initiate, this activity.
- ▶ **Ureteric colic:** sudden distension or spasm of the ureter (typically due to an obstructing calculus) produces severe colicky pain referred to the cutaneous areas supplied by the same segments as the ureter, **mainly T11–L2** — beginning in the loin and shooting down and forward to the groin and into the scrotum or labium majus, sometimes into the proximal anterior thigh (genitofemoral nerve, L1–L2); the cremaster muscle, sharing this innervation, may reflexly retract the testis.

Microscopic structure and development

- ▶ **Mucosa:** transitional epithelium (urothelium), extensively folded, giving the lumen a stellate outline, on a fibroelastic lamina propria.
- ▶ **Muscularis:** inner longitudinal + outer circular layer in the upper two-thirds; an additional outermost longitudinal layer appears in the lower one-third.
- ▶ **Adventitia:** fibroareolar tissue carrying the segmental vessels and nerve plexus described above.
- ▶ **Development:** the metanephric collecting system (ureter, renal pelvis, major/minor calyces, and 1–3 million collecting tubules) arises from the **ureteric bud**, an outgrowth of the caudal mesonephric duct; its stalk becomes the ureter, while its dilating, dichotomously-branching tip (capped by the metanephric blastema) forms the pelvicalyceal system. The excretory nephron (Bowman's capsule to distal convoluted tubule) differentiates separately from the metanephric mesenchyme and joins the collecting ducts. The developing kidney and ureter ascend from an initially sacral position to the definitive lumbar level.

Applied / Clinical anatomy

- ▶ **Calculus impaction:** stones most often arrest at the PUJ, the pelvic brim, or the intramural (vesico-ureteric) segment — the last being the narrowest site, capable of arresting a stone as small as 2–3 mm.
- ▶ **Radiological localisation:** on a plain abdominal film or intravenous urogram, the ureteric shadow is traced near the tips of the lumbar transverse processes, across the sacroiliac joint, and just medial to the ischial spine, down to the bladder base; most renal/ureteric calculi are radio-opaque (unlike most gallstones).
- ▶ **Dangerous sites of surgical injury** (per Kenson and Hinman): (i) where it crosses the common/external iliac vessels at the pelvic brim, (ii) within the ovarian fossa, (iii) where crossed by the uterine artery — the single most dangerous site, injured during hysterectomy, and (iv) at the base of the bladder.

- ▶ **Intra-operative identification:** its glistening, thick muscular wall shows characteristic worm-like (vermicular) writhing when gently touched, distinguishing it from vessels or fibrous bands; an extraperitoneal approach is preferred since the ureter adheres to, and moves with, the peritoneum.
- ▶ **Congenital anomalies:** duplex ureter/pelvis (two ureteric buds; about 1 in 125, bilateral in about 1 in 800) — by the **Weigert–Meyer rule** the upper-pole ureter inserts more caudally and medially than the lower-pole ureter, and the lower-pole ureter, having a shorter intramural course, is prone to vesico-ureteric reflux; ectopic ureteric opening (in the male always cranial to the external urethral sphincter; in the female may open distal to the sphincter or into the vagina, causing continuous incontinence); ureterocele (cystic dilatation of the intramural ureter, giving the "cobra-head" sign on urography); retrocaval (circumcaval) ureter (about 1 in 1500, from persistence of the posterior cardinal vein — the ureter passes behind the IVC before emerging medial to lateral, occasionally causing upper ureteric obstruction).
- ▶ **Reflux prevention:** the oblique intramural course together with the sheath of Waldeyer produces a valvular action rather than a true anatomical sphincter; its inadequacy (e.g. a short intramural tunnel in a duplex lower-pole ureter) predisposes to vesico-ureteric reflux.

High-yield exam pointers

- ▶ 25 cm long, ~3 mm wide, retroperitoneal muscular tube; abdominal and pelvic parts, each about 12.5 cm.
- ▶ **Five constrictions** — PUJ, pelvic brim, vas deferens/broad-ligament crossing, oblique intramural passage, and ureteric orifice; the vesico-ureteric junction is the narrowest and the commonest site of stone arrest.
- ▶ Right ureter: related anteriorly to the duodenum and medially to the IVC. Left ureter: related to the left colic vessels/sigmoid mesocolon and lies lateral to the aorta.
- ▶ Blood supply is segmental with a longitudinal anastomosis — abdominal part fed from the medial side (renal, gonadal, aortic), pelvic part fed from the lateral side (vesical/uterine, middle rectal) — hence safe to transect anywhere for repair.
- ▶ Nerve supply T10–L1 sympathetic, S2–S4 parasympathetic, mainly afferent; peristalsis is myogenic, from calyceal pacemakers. Referred pain of ureteric colic is T11–L2 (loin to groin/scrotum/labium majus).
- ▶ Muscle coat: inner longitudinal + outer circular in the upper two-thirds; an additional outer longitudinal layer appears in the lower one-third.
- ▶ The uterine artery crossing the ureter ("water under the bridge") is the classic site of ureteric injury at hysterectomy.
- ▶ Develops from the ureteric bud (an outgrowth of the mesonephric duct); the Weigert–Meyer rule governs duplex-ureter insertion.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy, Vol 2, 8e; Vishram Singh's Textbook of Anatomy, Vol 2, 4e; IB Singh's Textbook of Anatomy, Vol 2, 6e.



Pelvis & perineum



Perineal pouches

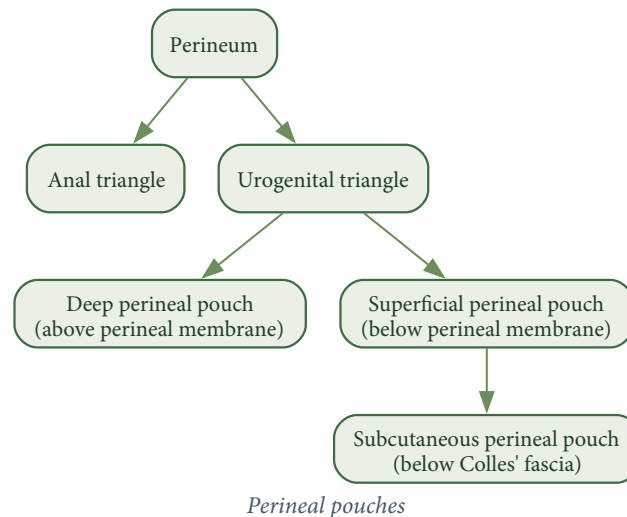
Asked in: Paper I 26-May-2025 · Paper I 14-Jul-2020 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction

The perineum is the diamond-shaped region below the pelvic floor, split by an imaginary transverse (interischial) line joining the two ischial tuberosities into a posterior **anal triangle** and an anterior **urogenital (UG) triangle**. Within the UG triangle, a tough triangular fibrous sheet — the **perineal membrane** — is stretched between the two ischiopubic rami and divides the triangle into two principal fascial compartments: the **deep perineal pouch** above it and the **superficial perineal pouch** below it. A third, more superficial potential space, the **subcutaneous perineal pouch**, lies between the deep perineal (investing) fascia of the superficial muscles and the membranous layer of superficial fascia (**Colles' fascia**). Each pouch has defined boundaries and characteristic muscular, glandular, vascular, neural and visceral contents that differ between the sexes, and each is of major applied importance in urethral trauma and obstetric/perineal surgery.

Scheme of the perineal pouches

- ▶ The UG triangle is bounded posteriorly by the interischial line, anteriorly/laterally by the pubic symphysis and ischiopubic rami; in the male it extends superficially to the scrotum and root of penis, in the female to the labia majora and mons pubis.
- ▶ **Subcutaneous perineal pouch** — lies between the deep perineal fascia (investing fascia of the superficial perineal muscles) and Colles' fascia; contains only thin loose connective tissue but expands considerably when blood/urine collects in it.
- ▶ **Superficial perineal pouch** — lies between Colles' fascia (below) and the perineal membrane (above).
- ▶ **Deep perineal pouch** — lies between the perineal membrane (below) and the inferior fascia of the pelvic diaphragm/thin endopelvic fascia (above); it contributes to the pelvic floor.



□ Fig 15.7 — Coronal section of the urogenital region of male perineum showing superficial and deep perineal pouches
(Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.657)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section through the male urogenital region — label, from superficial to deep:

- ▶ Skin
- ▶ Superficial (fatty) fascia
- ▶ Colles' fascia (membranous layer of superficial fascia) — floor of superficial pouch
- ▶ **Superficial perineal pouch:** bulbospongiosus (covering bulb of penis), ischiocavernosus (covering crus of penis), superficial transverse perineal muscle, branches of internal pudendal vessels/pudendal nerve
- ▶ **Perineal membrane** (roof of superficial pouch / floor of deep pouch)
- ▶ **Deep perineal pouch:** sphincter urethrae, deep transverse perineal muscle, bulbourethral gland and duct, membranous urethra
- ▶ Inferior (endopelvic) fascia of the pelvic diaphragm — roof of deep pouch
- ▶ Levator ani, ischiopubic ramus, obturator internus and its fascia (lateral wall)

Perineal membrane

- ▶ A strong, triangular fibrous sheet stretched across the UG triangle, attached laterally to the ischiopubic rami on each side.
- ▶ Anteriorly it thickens into the **transverse perineal ligament**; a small gap between this ligament and the arcuate pubic ligament transmits the deep dorsal vein of the penis/clitoris.
- ▶ Posteriorly it is fused centrally to the **perineal body**, and its fascia is continuous with the fascia over the superficial transverse perineal muscles.
- ▶ It is pierced (in the male) by the urethra, and (in the female) by both the urethra and the vagina.

Structures piercing the perineal membrane	Male	Female
Tube(s)	Urethra (2–3 cm behind the pubic symphysis)	Urethra and vagina
Duct	Ducts of bulbourethral (Cowper's) glands	—
Artery to bulb	Artery to bulb of penis	Artery to bulb of vestibule
Deep artery	Deep artery of penis	Deep artery of clitoris
Dorsal vessels/nerve	Dorsal artery and dorsal nerve of penis	Dorsal artery and dorsal nerve of clitoris
Cutaneous branches	Posterior scrotal vessels and nerves	Posterior labial vessels and nerves

Above the perineal membrane the urethra (and, classically, the sphincter urethrae) lies in the deep pouch; below it lie the erectile roots and superficial muscles.

Deep perineal pouch

Boundaries — inferiorly/superficially: perineal membrane; superiorly/deeply: inferior (endopelvic) fascia of the pelvic diaphragm (continuous with the fascia over levator ani) — classically called the "superior fascia of the urogenital diaphragm"; on each side: ischiopubic rami and inferior part of obturator fascia; the space is pierced through and through by the urethra (male) or urethra and vagina (female).

Contents	Male	Female
Tubular structure	Membranous (intermediate) part of urethra	Urethra and vagina
Muscles	Sphincter urethrae; deep transverse perineal muscle	Sphincter urethrae, deep transverse perineal muscle, compressor urethrae, sphincter urethrovaginalis
Glands	Bulbourethral (Cowper's) glands, one on each side of the urethra	None
Vessels	Artery to the penis and its branches (artery to the bulb, urethral artery, deep and dorsal arteries of penis)	Artery to the clitoris and its branches (artery to bulb of vestibule, urethral artery, deep and dorsal arteries of clitoris)
Nerves	Dorsal nerve of the penis; muscular branches of the perineal nerve	Dorsal nerve of the clitoris; muscular branches of the perineal nerve

- The membranous urethra is only 1.5–2 cm long, running downward and forward through the deep pouch; it is the **narrowest and least dilatable part of the urethra**.
- The bulbourethral glands are pea-sized; their ~2.5 cm ducts pierce the perineal membrane to open into the bulbar (spongy) urethra.

- The deep transverse perineal muscle runs from the ischiopubic ramus to the perineal body, where its fibres decussate with the opposite side; together with the superficial transverse perineal muscle it tethers the perineal body in the median plane.

Superficial perineal pouch

Boundaries — superiorly/deeply: perineal membrane; inferiorly/superficially: Colles' fascia; on each side: ischiopubic rami; posteriorly it is closed by fusion of the perineal membrane with Colles' fascia; anteriorly it is open and continuous with the tissue spaces of the scrotum/penis (or clitoris/labia) and, through the continuity of Colles' fascia with Scarpa's fascia, with the subcutaneous tissue of the anterior abdominal wall.

Contents	Male	Female
Erectile tissue	Root of penis — bulb of penis (covered by bulbospongiosus), crura of penis (covered by ischiocavernosus)	Root of clitoris — bulbs of the vestibule (covered by bulbospongiosus), crura of clitoris (covered by ischiocavernosus)
Muscles	Bulbospongiosus, ischiocavernosus, superficial transverse perineal muscle	Same three muscles
Glands	Ducts of the bulbourethral glands	Greater vestibular (Bartholin's) glands and their ducts
Tube	Urethra, within the bulb of the penis	Urethra
Vessels	Branches of internal pudendal artery — perineal artery, dorsal and deep arteries of penis	Branches of internal pudendal artery — perineal artery, dorsal and deep arteries of clitoris
Nerves	Branches of pudendal nerve — perineal nerve, dorsal nerve of penis	Branches of pudendal nerve — perineal nerve, dorsal nerve of clitoris

- The greater vestibular (Bartholin's) glands are homologous to the male bulbourethral glands but, unlike them, lie in the **superficial** pouch; each opens by a duct into the groove between the hymen and labium minus.
- The superficial transverse perineal muscles run from the ischial ramus to the perineal body on each side, steadying it.

The "urogenital diaphragm" — classical concept vs current view

- **Classical description** (still widely used for exam purposes): the sphincter urethrae and deep transverse perineal muscles together form a triangular musculofascial sheet, the **urogenital diaphragm**, covered on its pelvic (superior) surface by the *superior fascia of the urogenital diaphragm* and on its perineal (inferior) surface by the perineal membrane (*inferior fascia of the urogenital diaphragm*), pierced by the urethra (and vagina in the female).
- **Current (revised) view**: detailed histological study shows that sphincter urethrae fibres lie intrinsically within the wall of the urethra itself (the "distal urethral sphincter mechanism,"

continuous with pubourethralis fibres of levator ani) rather than forming a separate sheet between two fasciae; consequently a discrete "superior fascia of the urogenital diaphragm" and a true urogenital diaphragm are no longer considered to exist. The deep perineal pouch is now regarded as a thin space, closed below by the perineal membrane but **open superiorly**, continuous with the extraperitoneal tissue of the pelvic floor.

- ▶ Both descriptions are worth stating: RGUHS answer keys expect the classical boundaries/contents tables above, while the revised concept is a mark-scoring "recent understanding" addition.

Applied / Clinical anatomy

- ▶ **Extravasation of urine** — rupture of the **bulbar (penile) urethra** distal to the perineal membrane (classic straddle injury) causes *superficial* extravasation: urine/blood is confined by the firm attachment of Colles' fascia to the ischiopubic rami and its posterior fusion to the perineal membrane, so it cannot spread into the thigh or ischio-anal fossa; instead it tracks forward into the superficial perineal pouch and then, via the continuity of Colles' with Scarpa's fascia, into the scrotum, penis and lower anterior abdominal wall.
- ▶ Rupture of the **membranous urethra** within the deep perineal pouch (e.g. pelvic fracture, difficult catheterisation) causes *deep* extravasation: urine tracks upward into the extraperitoneal space around the bladder and prostate and into the anterior abdominal wall, and only enters the superficial pouch if the perineal membrane itself is also torn.
- ▶ Because the membranous urethra is the narrowest, least dilatable segment and lies fixed within the deep pouch, it is the **commonest site of iatrogenic urethral injury/false passage** during catheterisation or instrumentation.
- ▶ **Bulbourethral (Cowper's) gland** disease/duct obstruction in the deep pouch, and **Bartholin's gland** cyst/abscess in the superficial pouch (presenting posterolateral to the vaginal orifice), are the respective sex-specific gland pathologies of the two pouches.
- ▶ **Episiotomy** — a deliberate incision through the superficial perineal pouch (and perineal body) to enlarge the vaginal orifice during delivery: a *median* episiotomy cuts skin, vaginal wall, perineal body and superficial transverse perineal (risking inadvertent anal sphincter injury); a *mediolateral* episiotomy angles away from the anal sphincter, cutting skin, vaginal wall and bulbospongiosus.
- ▶ **Perineal body** damage during childbirth or episiotomy can lead to prolapse of the uterus, bladder or rectum, since it anchors the perineal membrane, superficial and deep transverse perineal, bulbospongiosus, external anal sphincter and levator ani.
- ▶ **Pudendal nerve block**, given at the ischial spine, anaesthetises the structures of both perineal pouches for episiotomy or instrumental/forceps delivery.
- ▶ Surgical awareness of the deep pouch's contained "distal urethral sphincter mechanism" is essential in radical perineal prostatectomy and urethroplasty to preserve continence.

High-yield exam pointers

- ▶ UG triangle is divided by the **perineal membrane** into a deep pouch (above) and a superficial pouch (below); a subcutaneous pouch lies below Colles' fascia, still more superficial.

- ▶ Deep pouch contents (mnemonic — "SDB-N-V"): Sphincter urethrae, Deep transverse perinei, Bulbourethral glands (male only), pudendal Nerve and Vessel branches; pierced by membranous urethra ($\pm$ vagina).
- ▶ Superficial pouch contents: root of penis/clitoris + ischiocavernosus + bulbospongiosus + superficial transverse perinei + Bartholin's glands (female only).
- ▶ Perineal membrane is pierced by the urethra, Cowper's gland ducts, and the deep/dorsal vessels and nerves of the penis or clitoris.
- ▶ Membranous urethra = narrowest, least dilatable part of the urethra, lying entirely within the deep perineal pouch.
- ▶ Superficial extravasation of urine spreads to scrotum/penis/labia and anterior abdominal wall, but never into the thigh or ischio-anal fossa.
- ▶ Bartholin's gland (superficial pouch) is the female homologue of Cowper's gland (deep pouch).
- ▶ Current concept: no discrete "urogenital diaphragm" exists — sphincter urethrae is intrinsic to the urethral wall, and the deep pouch is a thin space open superiorly.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 8e; Vishram Singh Textbook of Anatomy Vol 2 4e; Moore's Clinically Oriented Anatomy 9e.



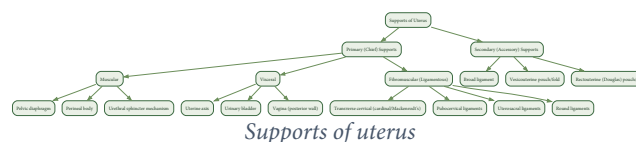
Supports of uterus

Asked in: Paper I 24-Sep-2025 · Paper I 29-Jul-2021 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction

The uterus is a mobile, pyriform pelvic organ (≈ 7.5 cm long, 5 cm broad, 2.5 cm thick) that undergoes marked cyclical and gestational changes in size, weight and vascularity, yet must be retained in its normal **anteverted** ($\approx 90^\circ$ to vaginal axis) and **anteflexed** ($\approx 125^\circ$ at the internal os) position above the pelvic floor. It is prevented from sagging or prolapsing through the vagina by a combination of muscular, visceral and fibromuscular (ligamentous) mechanisms — together the **Primary (chief) supports** — reinforced by a peritoneal layer of doubtful mechanical value, the **Secondary (accessory) supports**. Weakness of any of these, particularly during parturition, is the basis of uterovaginal prolapse.

Classification of supports



Primary supports — Muscular

- ▶ **Pelvic diaphragm** (levator ani + coccygeus, with covering pelvic fascia) — the principal muscular floor that resists any rise in intra-abdominal pressure. The **pubovaginalis** part of pubococcygeus constricts the hiatus urogenitalis and directly braces the vagina (hence the uterus and bladder indirectly); the **puborectalis** part maintains the anorectal flexure, on which the obliquely-sloping

posterior vaginal wall rests, which in turn props up the cervix of the anteverted uterus. If the pubococcygeus/puborectalis is torn in labour, this indirect support to the cervix is lost and uterine prolapse follows.

- ▶ **Perineal body** — a fibromuscular node between the vaginal and anal orifices that anchors ten muscles (2 superficial transversus perinei, 2 deep transversus perinei, 2 pubococcygeus slips, 2 bulbospongiosus, sphincter ani externus, and the longitudinal muscle coat of the anal canal). It fixes the perineal muscles and thereby maintains the integrity of the whole pelvic floor; damage to it (unrepaired obstetric tear/episiotomy) is a classical cause of prolapse of the uterus and other pelvic organs.
- ▶ **Urethral sphincter mechanism** — sphincter urethrae, compressor urethrae and sphincter urethrae vaginalis are inserted into the vaginal wall and so contribute indirectly to uterine support.

Primary supports — Visceral

- ▶ **Uterine axis** — the anteverted posture of the uterus is itself a support: a rise in intra-abdominal pressure pushes the fundus against the bladder and pubic symphysis, which *accentuates* anteversion rather than forcing the uterus down the vaginal canal. The angle of anteversion is actively maintained by the antagonistic pull of the round and uterosacral ligaments (see below).
- ▶ **Urinary bladder** — its distended upper (superior) surface acts as a shelf on which the body of the anteverted uterus rests.
- ▶ **Vagina** — the obliquely-slanting posterior vaginal wall supports the uterine load; it is itself propped up by the anorectal flexure maintained by puborectalis.
- ▶ Pressure of the **sigmoid colon and small intestine** on the posterior/superior aspect of the uterus reinforces the anteverted posture.

Primary supports — Fibromuscular (ligamentous)

These are condensations of pelvic (endopelvic) visceral fascia around the uterine vessels, not true discrete cords, and radiate from the cervix "like the spokes of a wheel" to the pelvic side wall.

Ligament	Extent / attachment	Composition	Principal role
Transverse cervical (cardinal, of Mackenrodt; also lateral cervical/paracervical ligament, retinaculum uteri of Bonney)	Fan-shaped condensation from the cervix and lateral vaginal fornix to the lateral pelvic wall, ~2.5 cm ventral to the ischial spine, above levator ani, around the uterine vessels	Endopelvic fascia + smooth muscle; ureter and uterine vessels traverse it	Forms a fibrous "hammock" that is the single most important support , resisting downward descent of the cervix/uterus

Ligament	Extent / attachment	Composition	Principal role
Uterosacral ligaments	Cervix and uterine body → periosteum of sacrum (S2, S3), passing on either side of the rectum within the recto-uterine folds	Fibrous tissue + smooth muscle	Braces the cervix backward , palpable per rectum/per vaginam (posterior fornix); with the round ligament forms the couple of forces maintaining anteversion
Pubocervical ligaments	Cervix and upper vagina → posterior surface of pubic bones, diverging around the urethra	Endopelvic fascia (correspond to puboprostatic ligaments in the male)	Anterior anchor of the cervix
Round ligaments of the uterus (ligamentum teres uteri)	Uterine cornu → between the layers of the broad ligament → deep inguinal ring → inguinal canal → superficial ring → breaks up in labium majus (remnant of gubernaculum; 10–12 cm long, contains smooth + some striated muscle)	Fibromuscular band	Pulls the fundus forward , maintaining anteversion/anteflexion against the backward pull of the uterosacral ligaments

Mechanism (couple of forces): the transverse cervical and uterosacral ligaments run almost vertically in the erect posture and hold the cervix fixed and braced backward, while the round ligament pulls the fundus forward — the two opposing pulls form a **couple** that keeps the uterus anteverted rather than allowed to prolapse along the vaginal axis.

□ Fig 31.19 — Cervical ligaments supporting the uterus (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.485)

□ Fig 31.20 — Uterosacral and round ligaments supporting the uterus (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.485)

Secondary (accessory) supports

Of doubtful mechanical value — they are peritoneal folds rather than fibrous condensations:

- ▶ **Broad ligaments** — paired peritoneal folds passing from the uterine sides to the lateral pelvic wall, subdivided into mesometrium, mesosalpinx and mesovarium; enclose the uterine tube, round ligament, ligament of ovary, uterine/ovarian vessels, ureter (lower part), lymphatics, nerves and vestigial epoophoron/paroophoron/Gartner's duct.
- ▶ **Vesicouterine pouch and fold of peritoneum** (anterior reflection onto the bladder).
- ▶ **Rectouterine (recto-vaginal/Douglas) pouch and fold of peritoneum** (posterior reflection onto the rectum), whose lateral boundaries are formed by the rectouterine folds overlying the uterosacral ligaments.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Superior view of the female pelvis with the uterus retracted forward (as in BD Chaurasia Fig 31.18a) — label:

- ▶ Symphysis pubis and **pubocervical ligament**
- ▶ Cervix uteri
- ▶ **Transverse cervical (cardinal) ligament** with the uterine artery/vein and ureter running within it
- ▶ Ischial spine (~2.5 cm from ligament attachment)
- ▶ **Uterosacral ligament** running back to the sacrum (S2–S3), flanking the rectouterine pouch
- ▶ Rectum and sacrum
- ▶ Bladder and vesicouterine pouch anteriorly

Companion lateral schematic (as in Fig 31.17) showing the **couple of forces**: round ligament pulling the fundus forward (arrow) vs uterosacral ligament pulling the cervix backward (arrow), pivoting at the internal os to maintain anteversion/anteflexion.

Applied / Clinical anatomy

- ▶ **Uterine/uterovaginal prolapse** results from combined failure of the muscular (levator ani, perineal body) and fibromuscular supports, classically after unrepaired childbirth trauma; the cardinal and uterosacral ligaments stretch, allowing the cervix and then the body of the uterus to descend through the vagina.
- ▶ **Fascial (Manchester-type) repair** for prolapse surgically shortens/plicates the stretched transverse cervical (Mackenrodt's) and uterosacral ligaments to restore support.
- ▶ **Cystocele, urethrocele and rectocele** are herniations of the bladder/urethra and rectum respectively when the anterior or posterior vaginal wall supports (which share the same fascial and muscular framework) fail; **culdocentesis** (needle through the posterior fornix into the pouch of Douglas) exploits the same rectouterine pouch anatomy to drain blood/pus.
- ▶ **Hysterectomy** — the ureter runs within/just deep to the base of the transverse cervical ligament, crossing below the uterine artery ("water under the bridge"); both vessel and ureter must be identified and safeguarded while clamping the cardinal ligament, or the ureter may be inadvertently ligated.
- ▶ **Retroversion/retroflexion** of the uterus is usually a harmless positional variant (uterosacral/round ligament pull unopposed by the normal anteverting couple), but a fixed retroverted uterus may indicate endometriosis or pelvic inflammatory adhesions tethering the uterosacral ligaments.
- ▶ **Episiotomy** protects the perineal body (and thus the pelvic floor support mechanism) from an uncontrolled tear during the second stage of labour.

High-yield exam pointers

- ▶ Supports = **Primary** (Muscular + Visceral + Fibromuscular) + **Secondary** (peritoneal folds) — always state this classification first.

- ▶ The **transverse cervical (cardinal) ligament of Mackenrodt** is the single most important individual support; ureter and uterine vessels run within it.
- ▶ Anteversion is maintained by a **couple of forces**: round ligament (pulls fundus forward) vs uterosacral ligament (pulls cervix backward).
- ▶ Pelvic diaphragm + perineal body are the chief **muscular** supports; damage to either is the anatomical basis of uterine prolapse.
- ▶ Broad ligament and the vesico-/rectouterine peritoneal folds are **secondary supports of doubtful value** — do not confuse them with the true fibromuscular ligaments.
- ▶ Angle of anteversion $\approx 90^\circ$, angle of anteflexion $\approx 125^\circ$ (long axis of uterus vs vagina, and at the internal os respectively).
- ▶ Round ligament (10–12 cm) traverses the inguinal canal exactly like the male processus vaginalis/spermatic cord path — a persistent peritoneal diverticulum along it is the **canal of Nuck**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 8e; Vishram Singh Textbook of Anatomy Vol 2 4e; IB Singh Textbook of Anatomy Vol 2 6e.



Blood vessels of pelvic cavity

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction — The pelvic cavity is supplied chiefly by the **internal iliac artery**, the principal artery of the pelvic walls, viscera, perineum and gluteal region, with additional supply to specific viscera from the **ovarian/testicular**, **superior rectal** and **median sacral** arteries that reach the pelvis independently of the iliac system. Venous return is mainly through the **internal iliac vein** and a set of interconnecting **visceral venous plexuses** (vesical, prostatic/uterine, vaginal, rectal) that also communicate with the vertebral venous plexus and, at the anal canal, with the portal venous system. The **external iliac vessels**, though primarily vessels of the lower limb, traverse the pelvic brim and are conventionally described with the pelvic vasculature.

1. Common iliac arteries and vessels crossing the pelvic brim

- ▶ The **abdominal aorta** bifurcates anterolateral to the body of the **4th lumbar vertebra** into right and left **common iliac arteries**; each divides at the **sacroiliac joint** into an **external iliac artery** (principal artery of the lower limb) and an **internal iliac artery** (principal artery of the pelvis).
- ▶ **Right common iliac artery** ≈ 5 cm long; crossed anteriorly by the ureter at its bifurcation and by sympathetic rami to the pelvic plexus.
- ▶ **Left common iliac artery** ≈ 4 cm long; crossed anteriorly by the superior rectal vessels and the ureter.
- ▶ Each common iliac artery gives small branches to peritoneum, psoas major, ureter and surrounding tissue.

- **Vessels crossing the pelvic brim/inlet:** median sacral vessels, iliolumbar artery, internal iliac vessels, superior rectal vessels (left side, in the sigmoid mesocolon), ureter, and the ovarian vessels (female).

2. Internal iliac artery — origin, course and relations

Feature	Description
Origin	Terminal (medial/posterior) division of the common iliac artery, opposite the lumbosacral intervertebral disc , anterior to the sacroiliac joint
Length	≈ 3.5–4 cm
Course	Runs postero-inferiorly to the upper margin of the greater sciatic foramen , where it divides into an anterior and a posterior division (trunk)
Anterior relation	Ureter; in the female, the ovary and fimbriated end of the uterine tube
Posterior relation	Internal iliac vein, lumbosacral trunk, sacroiliac joint
Lateral relation	External iliac vein and vessels, obturator nerve
Medial relation	Parietal peritoneum, tributaries of the internal iliac vein
Fetal note	Internal iliac artery is twice the calibre of the external iliac artery in the fetus, continuing as the umbilical artery to the placenta; postnatally the proximal 2–2.5 cm persists as the superior vesical artery and the rest fibroses into the medial umbilical ligament

3. Branches of the internal iliac artery

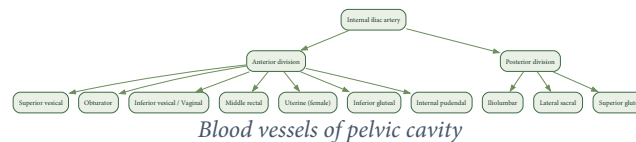
The internal iliac artery divides into an anterior trunk (mainly to pelvic viscera) and a posterior trunk (mainly to hip/back muscles).

Division	Branches	Chief distribution
Anterior (6 in male, 7 in female)	Superior vesical, obturator, inferior vesical (male)/ vaginal (female, often replaces inferior vesical), middle rectal, uterine (female only), inferior gluteal, internal pudendal	Bladder, prostate/vagina, rectum (muscular coats), uterus/cervix, perineum, gluteal region and posterior thigh
Posterior (3)	Iliolumbar, lateral sacral (×2), superior gluteal	Psoas/iliacus, sacral canal contents, gluteus medius/minimus/maximus

- **Superior vesical artery:** persistent proximal umbilical artery; supplies the upper bladder and gives the artery to the **ductus deferens**.

- **Obturator artery:** runs below the obturator nerve to leave via the obturator canal; a **pubic branch** anastomoses with the inferior epigastric artery — when unusually large (~30% of cases) and lying along the free margin of the lacunar ligament, this loop is the **corona mortis** ("crown of death").
- **Middle rectal artery:** often small/absent; chiefly supplies prostate/seminal vesicles and only the muscular coats of the lower rectum.
- **Inferior vesical/vaginal artery:** bladder trigone, prostate, seminal vesicles (male) or vagina/bladder base (female).
- **Uterine artery:** tortuous; crosses **anterior to the ureter** near the lateral fornix before ascending to anastomose with the ovarian artery and descending to form the azygos arteries of the vagina.
- **Internal pudendal and inferior gluteal arteries:** terminal branches of the anterior trunk, supplying the perineum/external genitalia and the buttock/posterior thigh respectively.
- **Iliolumbar, lateral sacral, superior gluteal arteries** (posterior trunk): supply psoas/iliacus, the sacral canal, and the gluteal muscles — superior gluteal is the largest branch of the entire internal iliac artery.

□ Fig 34.1 — Branches of the right internal iliac artery in a male (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.518)



DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label on a hemisected pelvis outline: common iliac artery → bifurcation → external iliac artery (lateral) and internal iliac artery (medial) → anterior division (superior vesical, obturator, inferior vesical/vaginal, middle rectal, uterine in female, inferior gluteal, internal pudendal) and posterior division (iliolumbar, lateral sacral, superior gluteal); mark the ureter crossing the bifurcation, the obliterated umbilical artery (medial umbilical ligament), and the superior rectal artery in the sigmoid mesocolon.

4. External iliac artery

- Continuation of the common iliac artery; larger in calibre than the internal iliac artery; runs along the **medial border of psoas major** from the common iliac bifurcation to the **mid-inguinal point**, where it becomes the femoral artery behind the inguinal ligament.
- Crossed by the ureter at its origin and subsequently by the gonadal vessels, genital branch of the genitofemoral nerve, deep circumflex iliac vein, and the ductus deferens (male)/round ligament (female).
- Has few pelvic branches: small twigs to psoas major and lymph nodes, then near its termination the **deep circumflex iliac artery** (laterally, anastomosing with the iliolumbar and superior gluteal arteries) and the **inferior epigastric artery** (which supplies the anterior abdominal wall and gives the pubic branch anastomosing with the obturator artery).

5. Vessels of the pelvis outside the internal iliac system

- ▶ **Ovarian artery:** arises from the abdominal aorta just below the renal artery; descends anterior to the ureter, **crosses the external iliac vessels** entering the lesser pelvis, and enters the **suspensory (infundibulopelvic) ligament**, dividing into ovarian and tubal branches that anastomose with the uterine artery. A **pampiniform plexus** at the hilum drains to the IVC (right) or **left renal vein** (left).
- ▶ **Testicular artery:** same aortic origin; likewise crosses the external iliac vessels before descending with its pampiniform plexus to the testis.
- ▶ **Superior rectal artery:** the direct continuation of the **inferior mesenteric artery** at the pelvic brim, medial to the left ureter; runs in the sigmoid mesocolon and divides opposite the **3rd sacral vertebra** into right and left branches supplying the rectum down to the internal anal sphincter; anastomoses (looped, in the anal columns) with the middle and inferior rectal arteries.
- ▶ **Median sacral artery:** a small branch from the back of the aorta just above its bifurcation; descends anterior to the sacrum/coccyx, supplying the posterior wall of the anorectal junction and anastomosing with the lateral sacral arteries.

6. Veins of the pelvis

- ▶ **Common iliac vein:** formed by union of external and internal iliac veins anterior to the sacroiliac joint; the two common iliac veins unite to the right of L5 to form the **inferior vena cava**; each receives iliolumbar and, often, lateral sacral veins; the **median sacral vein** usually drains into the left common iliac vein. The pelvic veins are **valveless**.
- ▶ **Internal iliac vein:** formed by convergence of several veins above the greater sciatic foramen; ascends posteromedial to the internal iliac artery to join the external iliac vein.

Venous plexus	Chief drainage
Vesical plexus	Vesical veins → internal iliac vein
Prostatic plexus	Receives the deep dorsal vein of the penis → vesical/internal iliac veins
Uterine (uterovaginal) plexus	Uterine veins → internal iliac vein (uterine veins enlarge greatly in pregnancy)
Vaginal plexus	Vaginal veins → internal iliac vein
Rectal (internal + external haemorrhoidal) plexus	Superior rectal vein → inferior mesenteric vein → portal system; middle rectal vein → internal iliac vein; inferior rectal vein → internal pudendal vein → systemic (caval) system

- ▶ Other tributaries of the internal iliac vein: superior and inferior gluteal, internal pudendal, obturator and lateral sacral veins (from outside the pelvis).
- ▶ **External iliac vein:** continuation of the femoral vein; ascends along the pelvic brim; crossed medially by the ureter and (female) ovarian vessels and round ligament; joins the internal iliac vein to form the common iliac vein. Tributaries: inferior epigastric, deep circumflex iliac and pubic veins.

- ▶ The internal rectal (haemorrhoidal) venous plexus is the classic site of **porto-systemic anastomosis** — its enlargement (with straining, pregnancy or portal hypertension) produces internal haemorrhoids.

Applied / Clinical anatomy

- ▶ **Ligation of the internal iliac artery** for intractable pelvic/postpartum haemorrhage does not abolish pelvic blood flow, owing to the rich anastomoses of its branches with adjacent arteries (lumbar–iliolumbar, gluteal–circumflex femoral, obturator–medial circumflex femoral); it lowers pulse pressure enough to allow haemostasis.
- ▶ **Ureteric injury during hysterectomy/oophorectomy**: the ureter is crossed **anteriorly** by the uterine artery near the lateral fornix/ischial spine, and lies close to the ovarian vessels at the pelvic brim — both are classic sites of inadvertent clamping or transection.
- ▶ **Corona mortis**: an abnormal obturator artery from the inferior epigastric/external iliac system, running along the free edge of the lacunar ligament — torrential haemorrhage if cut during femoral hernia repair.
- ▶ **Internal haemorrhoids** arise from dilatation of the internal rectal venous plexus, a valveless porto-systemic anastomotic site, worsened by straining, pregnancy and portal hypertension.
- ▶ **Left ovarian/testicular vein** drains at a right angle into the left renal vein (versus the oblique right-vein drainage into the IVC), predisposing to left-sided varicocele/pelvic congestion.
- ▶ **Uterine artery embolization** exploits the midline crossover of arcuate arteries and the uterine–ovarian anastomosis, permitting uterine artery occlusion for fibroids/PPH without compromising ovarian viability.

High-yield exam pointers

- ▶ Internal iliac artery = chief artery of the pelvis; divides at the greater sciatic foramen into **anterior** (visceral) and **posterior** (parieto-muscular) divisions.
- ▶ Anterior division: 6 branches in male, 7 in female (uterine artery is the extra branch; vaginal replaces inferior vesical).
- ▶ Posterior division: only 3 branches — iliolumbar, lateral sacral, superior gluteal (the largest branch of the whole internal iliac artery).
- ▶ Fetal internal iliac artery continues as the umbilical artery; postnatally becomes the medial umbilical ligament (proximal part persists as the superior vesical artery).
- ▶ Ovaries/testes are supplied from the **abdominal aorta**, not the internal iliac artery — why ovaries survive uterine artery ligation.
- ▶ Superior rectal artery = continuation of the inferior mesenteric artery, dividing at S3; anastomoses with middle/inferior rectal arteries — the site of porto-systemic anastomosis.
- ▶ Uterine artery crosses **anterior to the ureter** — the single most tested applied point in this topic.
- ▶ Corona mortis = anastomotic abnormal obturator artery from the inferior epigastric artery; dangerous during femoral hernia repair.
- ▶ Named pelvic venous plexuses (vesical, prostatic, uterine, vaginal, rectal) are valveless and intercommunicate, draining chiefly into the internal iliac vein.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 8e; Vishram Singh Textbook of Anatomy Vol 2 4e; Moore's Clinically Oriented Anatomy 9e.



Urinary Bladder

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction — The urinary bladder is a hollow, muscular, distensible reservoir of urine lying in the anterior part of the pelvic cavity. Its wall is formed chiefly by the **detrusor muscle**, smooth muscle fibres arranged in interlacing whorls and spirals that are suited to mass contraction (evacuation) rather than peristalsis. Its size, shape and relations vary continuously with the volume of urine it contains, and it is of major clinical importance because of its role in retention, cystitis, calculus formation, neurogenic dysfunction and carcinoma.

Situation

- ▶ Lies in the **anterior part of the lesser (true) pelvis**, immediately behind the **pubic symphysis**, and in front of the **rectum** (male) or the **uterus and vagina** (female).
- ▶ **Empty bladder**: lies entirely within the pelvis and is **tetrahedral** in shape, presenting an apex, a base (fundus), a neck, three surfaces (superior and two inferolateral) and four borders (two lateral, one anterior, one posterior).
- ▶ **Full bladder**: expands **anterosuperiorly into the abdominal cavity**, reaching up to (or beyond) the umbilicus, and becomes **ovoid**, with an apex directed upward, a neck directed downward, and only two surfaces (anterior and posterior).
- ▶ **In children**, the bladder is an abdominopelvic organ even when empty because the pelvic cavity is small; the internal urethral orifice lies at the level of the upper border of the pubic symphysis. It begins entering the enlarging pelvis around 6 years and does not become a wholly pelvic organ until after puberty.
- ▶ **Capacity**: mean **220 mL** (range 120–320 mL) in the adult. Filling beyond 220 mL produces the desire to micturate; the bladder is usually emptied at 250–300 mL; filling up to 500 mL may be tolerated but becomes painful beyond this. Referred pain of over-distension is felt in the lower anterior abdominal wall, perineum and penis (spinal segments **T11–L2 and S2–S4**).

Relations

The relations differ at the **apex, base and neck**.

Part	Relations
Apex	Directed forwards/upwards to the pubic symphysis; gives attachment to the median umbilical ligament (obliterated urachus), which ascends behind the anterior abdominal wall to the umbilicus.

Part	Relations
Base (fundus) — triangular, posteroinferior	Male: upper part covered by peritoneum and separated from the rectum by the rectovesical pouch (containing coils of ileum/sigmoid colon); lower part separated from the rectum by the seminal vesicles and terminal vasa deferentia (vasa lie medial to the vesicles); the triangular area between the two vasa is separated from the rectum by the rectovesical (Denonvilliers') fascia . Female: related to the cervix of the uterus and the vagina .
Neck	Lowest and most fixed part; pierced by the internal urethral orifice ; lies 3–4 cm behind the lower part of the pubic symphysis, just above the plane of the pelvic outlet. Male: rests on and is continuous with the base of the prostate ; surrounded by the smooth-muscle preprostatic sphincter (a distinct adrenergically-innervated collar with no parasympathetic supply, forming part of the proximal continence mechanism). Female: related to the pelvic fascia surrounding the upper urethra.

□ Fig 16.4 — Relations of the base of urinary bladder in males (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.686)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Posterior view of the male bladder base and its relations — label: **base (fundus) of bladder**, upper part of base covered by **peritoneum**, **ureter** entering posterosuperior angle, **vas deferens**, **ampulla of vas deferens**, **seminal vesicle**, **ejaculatory duct**, **prostate**, **urethra**. Add, in a second inset, the female relation of the base to the **cervix and vagina** with the **vesicouterine pouch** above.

Surfaces

- **Superior surface** — triangular; bounded by two lateral borders (apex to ureteric orifices) and a posterior border joining them.
 - **Male: completely covered by peritoneum**; in contact with the sigmoid colon and terminal coils of ileum; the peritoneum continues posteriorly into the rectovesical pouch and anteriorly into the median umbilical fold.
 - **Female: largely covered by peritoneum** except a small area near the posterior border related to the supravaginal cervix; here the peritoneum reflects onto the uterine isthmus (internal os) to form the **vesico-uterine pouch**.
- **Inferolateral surfaces (two)** — devoid of peritoneum; separated from each other anteriorly by the anterior border and from the superior surface by the lateral borders.
 - **In front:** retropubic space, pubic symphysis, **puboprostatic ligaments** (male) / **pubovesical ligaments** (female).
 - **Behind:** **obturator internus** muscle above and **levator ani** below.
 - As the bladder fills, these surfaces become the **anterior surface** and come into **direct contact with the anterior abdominal wall** (no intervening peritoneum) over a variable distance (commonly 5–7 cm) — the basis of suprapubic access to the bladder.

- **Retropubic space (cave of Retzius):** bounded in front by the pubic symphysis/rectus sheath, behind by the inferolateral surfaces of the bladder, above by the peritoneal reflection, and below by the puboprostatic/pubovesical ligaments.

Ligaments of the Bladder

Support of the bladder is chiefly by its fixed neck (continuous with the prostate/urethra); the "ligaments" are condensations of pelvic fascia (true) or peritoneal folds without supportive function (false).

Type	Ligament	Course / Attachment
True (condensed pelvic fascia, supportive)	Lateral ligament (paired)	Side of bladder → tendinous arch of pelvic fascia
	Puboprostatic (male) / Pubovesical (female) ligaments — lateral + medial, paired	Lateral: anterior end of tendinous arch → upper part of prostatic sheath. Medial: back of pubic bone (near symphysis) → prostatic sheath, forming the floor of the retropubic space
	Median umbilical ligament	Obliterated urachus; apex of bladder → umbilicus
	Posterior ligament (paired)	Base of bladder → lateral pelvic wall, along the vesical venous plexus
False (peritoneal folds, no support)	Median umbilical fold	Over the median umbilical ligament
	Medial umbilical folds (paired)	Over the obliterated umbilical arteries
	Lateral false ligament (paired)	Peritoneum of the paravesical fossa
	Posterior false ligament (paired)	Peritoneum of the sacrogenital folds

□ Fig 16.7 — True ligaments of the urinary bladder in females (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.691)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Transverse section at the level of the bladder neck — label: **urinary bladder, pubic symphysis, lateral ligament, pubovesical ligaments (lateral and medial), vesical venous plexus, posterior ligament, and (posteriorly) uterine cervix/rectum.**

Blood Supply and Nerve Supply

Arterial supply

- Chief supply: **superior and inferior vesical arteries**, branches of the anterior division of the internal iliac artery.
- Additional/minor contribution: **obturator and inferior gluteal arteries**; in females, the **uterine and vaginal arteries** substitute for the inferior vesical contribution.

Venous drainage

- ▶ Veins do not follow the arteries; they form a **vesical venous plexus** on the inferolateral surfaces (near the prostate in the male), which passes backward in the posterior ligaments of the bladder to drain into the **internal iliac veins**.
- ▶ Communicates with the **prostatic venous plexus** in males and with veins at the **base of the broad ligament** in females.

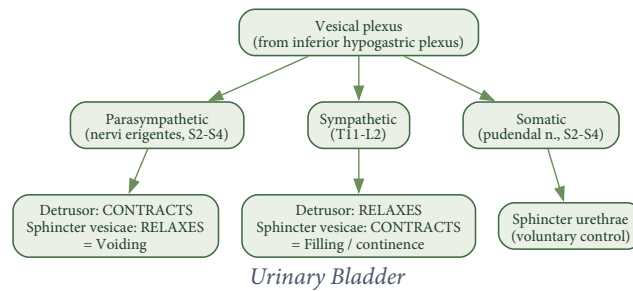
Lymphatic drainage

- ▶ Chiefly to the **external iliac lymph nodes**; a few vessels drain to the **internal iliac nodes** (including obturator fossa nodes) or to the **lateral aortic nodes**.

Nerve supply — via the **vesical plexus** (derived from the inferior hypogastric plexus), containing sympathetic, parasympathetic and somatic components, each with motor and sensory fibres.

Fibre type	Origin	Action
Parasympathetic (nervi erigentes)	S2, S3, S4	Motor to the detrusor ; inhibitory to the sphincter vesicae (internal urethral sphincter). Essential for normal micturition — its destruction abolishes voiding.
Sympathetic	T11, T12, L1, L2	Inhibitory to the detrusor ; motor to the sphincter vesicae/preprostatic sphincter — favours bladder filling and continence (and, in the male, prevents retrograde flow of semen).
Somatic (pudendal nerve)	S2, S3, S4	Motor to the sphincter urethrae (external urethral sphincter) — the only voluntary component.
Sensory	Runs mainly with parasympathetic, partly with sympathetic fibres	Pain of distension/spasm ascends via the lateral spinothalamic tract ; awareness of bladder filling ascends via the posterior (dorsal) columns — hence bilateral anterolateral cordotomy abolishes bladder pain while sparing the sensation of fullness and desire to void.

- ▶ **Mechanism of micturition (brief)**: bladder filling beyond ~220 mL stimulates stretch receptors → afferents to the **sacral (spinal) micturition centre** (S2–S4) → reflex parasympathetic contraction of detrusor with reciprocal relaxation of the internal and external sphincters → voiding. This spinal reflex is normally held in check, and can be voluntarily initiated, by the **cortical micturition centre** in the paracentral lobule acting through the pyramidal tracts.



Applied / Clinical anatomy

- ▶ **Rupture of the bladder:** a **full (distended) bladder** ruptures at its peritoneum-covered superior surface after lower abdominal trauma, causing **intra**peritoneal extravasation of urine and peritonitis; an **empty/partly-full bladder** is more likely to rupture **extra**peritoneally through the inferolateral surfaces, with urine tracking into the retropubic space and can often be managed conservatively.
- ▶ **Suprapubic cystostomy/aspiration:** on distension (≈ 300 mL) the bladder's inferolateral surfaces strip the peritoneum off the anterior abdominal wall and lie in direct contact with it; the bladder can therefore be punctured or opened **suprapubically without traversing the peritoneal cavity** — used for drainage, vesical stone removal, or retropubic prostatectomy.
- ▶ **Trabeculated bladder:** chronic outflow obstruction (benign prostatic hyperplasia, urethral stricture) causes detrusor hypertrophy; the interlacing muscle fasciculi coarsen into an open-weave pattern (trabeculation) and may herniate through weak points as **bladder diverticula**.
- ▶ **Neurogenic bladder** — a defect anywhere in the sensory/motor micturition pathway:
 - **Automatic (reflex) bladder:** complete cord transection above the sacral centre (upper motor neuron lesion) — after initial spinal shock, the bladder empties reflexly every 2–4 hours, uncontrolled by will.
 - **Autonomous bladder:** destruction of the S2–S4 segments themselves (lower motor neuron lesion) — detrusor is flaccid, capacity is greatly increased, and there is continuous overflow dribbling.
 - **Atonic (sensory) neurogenic bladder:** interruption of the sensory limb (e.g., tabes dorsalis) — painless distension with residual urine.
- ▶ **Urachal anomalies:** incomplete obliteration of the urachus (which normally forms the median umbilical ligament) gives a **patent urachus/urachal fistula** (urine discharge from the umbilicus), a **urachal cyst**, or a **urachal sinus**.
- ▶ **Cystoscopy:** the **interureteric ridge (bar of Mercier)**, on the mucosal trigone, is a reliable landmark for locating the ureteric orifices at cystoscopy.
- ▶ **Catheterisation:** the short (≈ 4 cm), straight female urethra makes catheterisation easier than in the male, whose urethra (18–20 cm) is longer and curved.
- ▶ **Stone formation and carcinoma:** the bladder is a common site for calculi because of urinary stasis; carcinoma (usually transitional cell) spreads along the lymphatic routes described above, chiefly to the external iliac nodes.

High-yield exam pointers

- ▶ Empty bladder = tetrahedral (apex, base, neck, 3 surfaces, 4 borders); full bladder = ovoid; mean capacity **220 mL** (120–320 mL); desire to void beyond 220 mL, tolerated up to 500 mL.
- ▶ Base relations: rectovesical pouch + seminal vesicles/vasa (male, separated from rectum by **Denonvilliers' fascia**) vs cervix/vagina (female).
- ▶ Neck = lowest, most fixed point, 3–4 cm behind pubic symphysis; continuous with prostate in the male.
- ▶ Superior surface fully peritonealised in the male; largely peritonealised in the female (reflects as the vesico-uterine pouch).
- ▶ True ligaments: lateral, puboprostatic/pubovesical, median umbilical, posterior — all condensations of pelvic fascia, supportive. False ligaments are mere peritoneal folds.
- ▶ Arterial supply: **superior + inferior vesical arteries** (anterior division of internal iliac); venous drainage via the **vesical venous plexus** → internal iliac veins; lymph → **external iliac nodes**.
- ▶ Nerve supply triad: **parasympathetic** (S2–4) contracts detrusor/relaxes sphincter (voiding), **sympathetic** (T11–L2) does the reverse (filling), **pudendal** (S2–4) gives voluntary control of the external sphincter.
- ▶ Applied triad to remember: suprapubic cystostomy (peritoneum stripped off on filling), interureteric ridge as a cystoscopic landmark, and the automatic vs autonomous vs atonic neurogenic bladder distinction.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e.



Prostate Gland — Parts, Coverings, Relations, Vasculature and Surgical Anatomy

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction

The prostate is the largest accessory genital gland in the male, a pyramidal (inverted-cone/chestnut-shaped) fibromuscular organ surrounding the first (prostatic) part of the male urethra just below the bladder neck. It lies in the lesser pelvis behind the lower pubic symphysis/pubic arch, in front of the rectal ampulla, embraced on each side by levator ani. Two-thirds of its substance is glandular (contributing ~20–30% of seminal fluid volume — acid phosphatase, PSA, citric acid, fibrinolysin, zinc) and one-third fibromuscular. Its role in BPH, carcinoma and pelvic/urological surgery makes its gross and surgical anatomy high yield.

1. Parts and external features

- ▶ **Shape/size:** inverted cone/pyramidal, chestnut-shaped; **base** 4 cm (transverse), **length** 3 cm (vertical), **thickness** 2 cm (antero-posterior); weighs ~8 g in the young adult (BPH raises this to 40 g, occasionally 150 g, after the fifth decade).
- ▶ **Base (superior):** directed upward, structurally continuous with the bladder neck; the junction is marked by a circular groove lodging venules of the vesical/prostatic plexus. Pierced postero-superiorly by the two ejaculatory ducts.
- ▶ **Apex (inferior):** directed downward, surrounds the junction of the prostatic and membranous urethra; rests on/blends with the external urethral sphincter (rhabdosphincter) in the deep perineal pouch; separated from the anal canal by the **perineal body** and the Y-shaped **rectourethralis** muscle.
- ▶ **Four surfaces:**
 - *Anterior* — narrow, convex side-to-side, ~2 cm behind the pubic symphysis (separated by the retropubic fat/space); connected to the pubic bones by the **puboprostatic ligaments**; pierced just above the apex by the emerging urethra; largely fibromuscular, deficient in glandular tissue.
 - *Posterior* — flat transversely, convex vertically; separated from the rectal ampulla by **Denonvilliers' fascia**; a shallow median sulcus partially divides it into two lateral lobes; pierced near its upper border by the ejaculatory ducts; palpable per rectum ~4 cm from the anal verge.
 - *Two inferolateral surfaces* — related to levator ani, whose anterior fibres embrace the gland as the pubourethral (levator prostatae) sling, separated from it by a thin sheet of connective tissue carrying the prostatic venous plexus and, more posterolaterally, the **neurovascular bundle**.
- ▶ **Structures traversing the gland:** the **prostatic urethra** (vertically, at the junction of the anterior 1/3 and posterior 2/3); the two **ejaculatory ducts** (postero-inferiorly, flanking the prostatic utricle, opening on the colliculus seminalis/verumontanum); the **prostatic utricle** (a 4–6 mm Müllerian-duct remnant, the "vagina masculina"); numerous **prostatic sinuses** (grooves flanking the urethral crest into which 12–20 prostatic ducts open).

□ Fig 17.2 — Location, features and relations of the prostate gland: (A) as seen in the sagittal section, (B) coronal section, (C) posterior surface (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.720)

2. Lobes and zonal (McNeal) anatomy

Traditionally five lobes were described (only distinguishable in the fetal gland before 20 weeks); by adulthood only **three lobes** remain useful clinically — **two lateral lobes** and a **median lobe** (the old anterior lobe/isthmus and posterior lobe are vestigial descriptive terms). The median lobe is the classic site of BPH; the posterior lobe was traditionally linked with carcinoma. Modern urological practice instead uses **McNeal's zonal classification**:

Zone	Volume	Location	Clinical significance
Peripheral zone	70%	Cup-shaped, posterior and postero-lateral, encloses the central/transitional zones	Commonest site of carcinoma ; the part felt on digital rectal examination (DRE)
Central zone	25%	Conical, surrounds the ejaculatory ducts, apex at the verumontanum	Wolffian-duct derived; rarely diseased
Transitional zone	5%	Periurethral, around the preprostatic urethra	Origin of benign prostatic hyperplasia (BPH)
Anterior fibromuscular stroma	non-glandular	Anterior, continuous with the bladder-neck/detrusor apron and external sphincter	Devoid of glands; forms the "isthmus"

On T2-weighted MRI the peripheral zone shows high signal; the central/transitional zones (the "central gland") show lower, more uniform signal.

□ Fig 32.7 — Different zones of the prostate gland (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.497)

3. Coverings — capsules and supports

- ▶ **True capsule:** condensation of the peripheral fibromuscular stroma of the gland itself; intimately adherent to the glandular tissue (absent as a distinct layer at the extreme base and apex).
- ▶ **False capsule (prostatic/periprostatic fascia, prostatic sheath):** derived from the visceral (endopelvic) layer of pelvic fascia; thin anteriorly (continuous with the puboprostatic ligaments), dense posteriorly (blends with Denonvilliers' fascia/rectovesical septum), and continued laterally as the **lateral prostatic fascia**, which encloses the **neurovascular bundle**.
- ▶ **Prostatic venous plexus** occupies the space between the true and false capsules (comparable relation, in reverse, to the thyroid — its venous plexus lies deep to both capsules).
- ▶ **Surgical (pathological) capsule:** as a BPH adenoma enlarges in the transitional zone, the compressed residual peripheral zone forms a pseudocapsule around it — the plane exploited during **enucleation** of the adenoma (open prostatectomy), which lies deep to both true and false capsules, leaving both capsules and the intervening venous plexus behind.
- ▶ **Supports:** the apex rests on the superior fascia of the urogenital diaphragm/perineal membrane; **puboprostatic ligaments** — a medial pair near the apex and a lateral pair near the base — anchor the false capsule to the pubic bones; **Denonvilliers' fascia** (formed by obliteration of the lower rectovesical pouch) tethers the gland posteriorly and separates it from the rectal ampulla and prerectal fat.

4. Relations (summary table)

Aspect	Related structure
Base (superior)	Neck of urinary bladder (structurally continuous)
Apex (inferior)	External urethral sphincter/deep perineal pouch; separated from anal canal by perineal body & rectourethralis
Anterior	Pubic symphysis/pubis arch, across the retropubic space (of Retzius) and the dorsal venous complex (Santorini's plexus); puboprostatic ligaments
Posterior	Ampulla of rectum, separated by Denonvilliers' fascia and the prerectal fat; ejaculatory ducts pierce this surface near the base
Inferolateral (×2)	Levator ani (pubourethral sling); neurovascular bundle in the intervening fascial plane

5. Vascular supply and lymphatic drainage

	Detail
Arteries	Branches of the internal iliac artery : chiefly the inferior vesical artery (urethral branches enter the prostatovesical junction posteriorly at 5 and 7 o'clock and anteriorly at 1 and 11 o'clock; capsular branches descend posterolaterally within the neurovascular bundle, perforating the gland perpendicularly — the apical perforator being the most constant landmark); supplemented by the internal pudendal and middle rectal arteries
Veins	Form the prostatic venous plexus (of Santorini) around the antero-lateral aspect between the true and false capsules; receives the deep dorsal vein of the penis ; communicates with the vesical venous plexus and internal pudendal vein, and — via valveless connections through the anterior sacral foramina — with the internal vertebral (Batson's) venous plexus ; drains ultimately into the internal iliac veins
Lymphatics	Chiefly to internal iliac, obturator and sacral nodes ; a lesser stream to the external iliac nodes

6. Nerve supply

The prostate is richly innervated from the **inferior hypogastric (pelvic) plexus** — sympathetic fibres (T12–L2, via the hypogastric nerve) and parasympathetic fibres (S2–S4, via pelvic splanchnic nerves) converge here and pass forward as the **periprostatic/neurovascular bundle**, applied to the postero-lateral surface of the gland (classically at the 4–5 and 7–8 o'clock positions, though roughly half of specimens show a more diffuse distribution). Beyond the apex these autonomic fibres continue as the

cavernous nerves to the corpora cavernosa (erection). The somatic **pudendal nerve** supplies the external urethral sphincter, entering at the 5 and 7 o'clock positions.

Applied / Clinical anatomy (Surgical anatomy of the prostate)

- ▶ **Benign prostatic hyperplasia (BPH)**: nodular hyperplasia of the **transitional zone** (median/lateral lobes clinically); the enlarging adenoma compresses the peripheral zone into a **surgical capsule**, obstructs the prostatic urethra/internal urethral orifice, and forms a **postprostatic (uvula) pouch** of residual urine. Presents with frequency, urgency, poor stream and incomplete emptying.
- ▶ **Approaches to prostatectomy**: **suprapubic (transvesical)**, **retropubic** (through the false capsule, via the space of Retzius, without opening the bladder), **perineal** (through the fascia of Denonvilliers), and **transurethral resection (TURP)** — the commonest today. In every open approach the adenoma is enucleated in the plane deep to both capsules, leaving the true capsule, false capsule and intervening venous plexus behind.
- ▶ **TURP bleeding landmarks**: bleeding at the **11 and 1 o'clock** positions is attributed to the urethral (bladder-neck) branches — **Flock's arteries**; bleeding at the **5 and 7 o'clock** positions arises from the capsular perforators — **Badenoch's arteries** — a direct application of the arterial anatomy above.
- ▶ **Radical prostatectomy** (for organ-confined carcinoma): the entire gland, capsule, seminal vesicles and ejaculatory ducts are removed. The **neurovascular bundles**, posterolateral to the prostate from the vesicoprostatic junction to the apex, are critical for **nerve-sparing** (Walsh's technique), preserved wherever oncologically safe to maintain **erectile function** and continence; vulnerable during posterolateral dissection, including in **robotic-assisted laparoscopic** prostatectomy. The gland's croissant- vs doughnut-shaped variation relative to the external sphincter dictates the vesico-urethral anastomosis line to avoid incontinence.
- ▶ **Digital rectal examination (DRE)**: the posterior surface/peripheral zone is directly palpable through the anterior rectal wall ~4 cm from the anal verge — the principal clinical method of screening for nodularity/carcinoma and estimating size in BPH.
- ▶ **Prostatic carcinoma**: arises chiefly in the peripheral zone; local spread may be limited posteriorly by Denonvilliers' fascia (rectal invasion is late/uncommon); lymphatic spread to internal iliac/obturator/sacral nodes; haematogenous spread along the valveless prostatic → internal vertebral (Batson's) venous plexus explains early **skeletal metastasis to the lumbar vertebrae, pelvis and skull** bypassing the lungs. Serum acid phosphatase and PSA aid diagnosis/monitoring.
- ▶ **Retropubic space (of Retzius)**: the surgical corridor for retropubic prostatectomy and suprapubic cystostomy, bounded anteriorly by the pubis and posteriorly by the bladder/prostate.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label a **median sagittal section of the male pelvis** showing: urinary bladder & internal urethral orifice; prostate — base, apex, true capsule, false (prostatic) capsule, prostatic venous plexus (Santorini's) between the two; prostatic urethra, verumontanum/colliculus seminalis, prostatic utricle; ejaculatory duct and seminal vesicle; membranous urethra & external urethral sphincter; puboprostatic ligament & retropubic space of Retzius; pubic symphysis; Denonvilliers' fascia, rectovesical pouch, rectal ampulla; perineal body & rectourethralis; levator ani; and the neurovascular bundle at the postero-lateral margin of the gland.

High-yield exam pointers

- ▶ Prostate = base (4 cm) × length (3 cm) × thickness (2 cm); ~8 g in youth.
- ▶ Three adult lobes (2 lateral + median) vs McNeal's four zones — **peripheral 70% (Ca), central 25%, transitional 5% (BPH)**.
- ▶ True capsule (glandular condensation) vs false capsule (pelvic fascia) — **venous plexus lies between them**; enucleation plane is deep to both.
- ▶ Anterior relation: pubic symphysis via retropubic space + puboprostatic ligaments. Posterior relation: rectal ampulla via Denonvilliers' fascia.
- ▶ Arteries: inferior vesical (chief), internal pudendal, middle rectal — all from internal iliac artery.
- ▶ Venous drainage → prostatic (Santorini's) plexus → internal iliac veins **and** Batson's valveless vertebral plexus → vertebral/spinal metastasis of carcinoma.
- ▶ Neurovascular bundle (postero-lateral, 4–5 & 7–8 o'clock) = key structure in nerve-sparing radical prostatectomy.
- ▶ TURP bleeding: 11 & 1 o'clock (Flock's arteries) vs 5 & 7 o'clock (Badenoch's arteries).
- ▶ Four surgical approaches to prostatectomy: suprapubic, retropubic, perineal, transurethral (TURP).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol. 2, 8e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh's Textbook of Anatomy Vol. 2, 4e.



Describe the gross anatomy of the rectum and anal canal

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction — The rectum and anal canal form the terminal 15 cm of the alimentary tract. The **rectum** is the pelvic part, extending from the rectosigmoid junction (S3) to the anorectal junction; it stores faeces and lacks the three surface hallmarks of colon (sacculations, appendices epiploicae, taeniae coli). The **anal canal** is the short perineal continuation, guarded by internal and external anal sphincters, through which faeces are expelled. Both are hindgut/cloacal derivatives and are described together because of their continuous vascular, lymphatic and neural planes.

Rectum — location, extent & dimensions

- ▶ **Situation:** posterior part of the lesser pelvis, in front of the lower 3 sacral pieces and coccyx.
- ▶ **Extent:** begins as continuation of sigmoid colon at the level of **S3 vertebra** (marked by the end of the sigmoid mesocolon); ends at the **anorectal junction**, 2–3 cm in front of and slightly below the tip of the coccyx (level with the apex of prostate in the male).
- ▶ **Length:** ~12 cm (clinically often taken as ~15 cm above the anal margin).
- ▶ **Diameter:** ~4 cm in its upper part (same as sigmoid colon); the lower part dilates into the **rectal ampulla**.
- ▶ **Surface features absent:** no sacculations, no appendices epiploicae, no taeniae coli — the taeniae fuse a few cm above the rectosigmoid junction into a continuous longitudinal muscle coat.
- ▶ **Course:** downwards and backwards, then downwards, then downwards and forwards — both ends lie in the median plane.

Curvatures of the rectum

Two anteroposterior curves

- ▶ **Sacral flexure** — follows the concavity of sacrum/coccyx.
- ▶ **Perineal flexure (anorectal angle)** — the backward bend at the anorectal junction; maintained by the tonic pull of **puborectalis**, and is central to faecal continence.

Three lateral curves

- ▶ Upper — convex to the **right**.
- ▶ Middle — convex to the **left**; the largest and most prominent.
- ▶ Lower — convex to the **right**.

□ Fig 19.2 — Curvatures (flexures) of the rectum (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.792)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sagittal outline of the rectum showing: rectosigmoid junction (S3) → sacral flexure → rectal ampulla → perineal flexure (anorectal angle) → anorectal junction → anal canal. Label the three lateral curves on a separate cross-sectional/frontal sketch (upper-right convex, middle-left convex/most prominent, lower-right convex).

Relations of the rectum**Peritoneal relations**

Part	Peritoneal covering
Upper 1/3	Front and sides
Middle 1/3	Front only
Lower 1/3 (ampulla)	None — lies below the rectovesical pouch (male) / rectouterine pouch (female)

- Distance from anus to floor of pouch: **7.5 cm in males, 5.5 cm in females.**

Visceral relations

Direction	Male	Female
Anterior, upper 2/3	Rectovesical pouch with coils of intestine/sigmoid colon	Rectouterine pouch (of Douglas), separating rectum from uterus and upper vagina
Anterior, lower 1/3	Base of bladder, terminal ureters, seminal vesicles, vas deferens, prostate	Lower vagina (rectovaginal septum)
Posterior (both sexes)	Lower 3 sacral pieces, coccyx, anococcygeal ligament; piriformis, coccygeus, levator ani; median sacral/superior rectal/lateral sacral vessels; sympathetic chain with ganglion impar, anterior primary rami S3–S5 & Co1, pelvic splanchnic nerves	—
Lateral (below peritoneal reflection)	Levator ani, obturator internus, ureters, internal iliac vessels, inferior hypogastric plexus	—

Mucosal folds, fascial relations & supports

- **Transverse (horizontal) folds / valves of Houston (plicae transversales)** — permanent, most marked on distension:
- 1st fold — near upper end, projects from left wall, ~7.5 cm above anus.
 - 2nd fold — largest and most constant, at upper end of ampulla, projects from anterior & right walls.

- 3rd fold — inconstant, 2.5 cm below the 2nd, projects from left wall.
- **Longitudinal folds** — transitory, seen only in the empty lower rectum, effaced on distension.
- **Fascial envelope / supports:**
 - **Mesorectum** — fat enclosed by the **mesorectal (fascia propria)**, carrying the superior rectal vessels and lymph nodes; bulkier posteriorly; the surgical plane of total mesorectal excision.
 - **Fascia of Waldeyer** (presacral fascia) — attaches rectal ampulla to sacrum, encloses superior rectal vessels.
 - **Lateral ligaments of the rectum** — condensed pelvic fascia carrying the middle rectal vessels and pelvic plexus branches.
 - **Denonvilliers' (rectovesical/rectoprostatic) fascia** — between rectum and prostate/seminal vesicles (male) or forms rectovaginal septum (female).
 - **Levator ani** (pelvic floor) and **perineal body** with its muscles.

Anal canal — extent, parts & interior

- **Situation:** below the pelvic diaphragm, in the anal triangle of the perineum, between the two ischioanal fossae.
- **Length:** ~3.8 cm (≈4 cm), from the anorectal junction to the anus; directed downwards and backwards.
- **Anus:** surface opening, ~4 cm below/in front of the coccyx tip, in the natal cleft; pigmented skin with radiating folds and a ring of circumanal apocrine glands.
- **Relations:** Anterior — perineal body (both sexes), membranous urethra & bulb of penis (male), lower vagina (female). Posterior — anococcygeal ligament, coccyx. Lateral — ischioanal fossae. All round — sphincter muscles.

Interior — three zones

Zone	Length	Epithelium	Key features
Upper (mucous)	~15 mm	Simple/stratified columnar (endodermal)	6–10 anal columns of Morgagni (contain superior rectal vein radicles) joined below by anal valves ; above each valve an anal sinus with anal glands; valves together form the pectinate/dentate line
Middle (pecten/transitional zone)	~15 mm	Stratified squamous, thin & pale, avascular-looking (dense subjacent venous plexus gives bluish tinge)	Lower limit = white line of Hilton (intersphincteric groove, between subcutaneous EAS and lower border of IAS)
Lower (cutaneous)	~8 mm	True skin (stratified squamous, keratinised)	Sebaceous & sweat glands, hair follicles

□ Fig 33.10 — Interior of the anal canal (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.510)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section of the anal canal labelling: anorectal junction, anal columns of Morgagni, anal valves, anal sinus, pectinate/dentate line, pecten (transitional zone), white line of Hilton, anal verge/anus, internal anal sphincter, external anal sphincter (subcutaneous/superficial/deep), conjoint longitudinal coat, corrugator cutis ani.

Musculature of the anal canal

- **Internal anal sphincter (IAS)** — involuntary; thickened continuation of circular smooth-muscle coat; surrounds upper 3/4 (~30 mm) of the canal, from its upper end to the white line of Hilton.
- **External anal sphincter (EAS)** — voluntary, striated; supplied by inferior rectal nerve and perineal branch of S4; surrounds the whole length of the canal; classically described in subcutaneous, superficial and deep parts (now regarded as a single functional/anatomical entity); deep fibres blend with puborectalis; anterior fibres decussate with superficial transverse perinei; posterior fibres attach to the anococcygeal raphe.
- **Conjoint longitudinal coat** — fusion of puborectalis with the longitudinal muscle of the rectum at the anorectal junction; lies between IAS and EAS; breaks up at the white line into fibroelastic septa forming the **corrugator cutis ani**, the perianal fascia (most lateral septum) and the anal intermuscular septum (most medial, attached to the white line).
- **Anorectal ring** — palpable muscular ring at the anorectal junction formed by fusion of puborectalis, uppermost EAS fibres and IAS; the anatomical basis of **rectal continence**; surgical division causes incontinence.

Blood supply, lymphatic drainage & nerve supply

Structure	Artery	Vein	Lymphatics	Nerve
Rectum	Superior rectal (chief; continuation of inferior mesenteric); middle rectal (internal iliac); median sacral	Superior rectal → inferior mesenteric → splenic vein; middle rectal → internal iliac vein	Upper half → pararectal/sigmoid → inferior mesenteric nodes; lower half → internal iliac nodes	Sympathetic L1–L2 (vasoconstrictor, motor to IAS) + parasympathetic S2–S4 (motor to rectal muscle, inhibitory to IAS); both carry pain, distension via parasympathetic
Anal canal, above pectinate line	Superior rectal	Internal rectal (haemorrhoidal) plexus → superior rectal vein	Internal iliac nodes	Autonomic — sympathetic (inferior hypogastric, L1,2) + parasympathetic (S2–4); insensitive to touch/pain, senses ischaemia/distension

Structure	Artery	Vein	Lymphatics	Nerve
Anal canal, below pectinate line	Inferior rectal	External rectal plexus → inferior rectal vein → internal pudendal vein	Superficial inguinal nodes (medial group)	Somatic — inferior rectal nerve (S2–4); sensitive to pain, touch, temperature

- ▶ **Portosystemic anastomosis:** internal rectal venous plexus (portal, via superior rectal vein) freely communicates with the external plexus (systemic, via middle & inferior rectal veins) — the pectinate line is the anatomical **watershed** between the two.
- ▶ Primary sites of internal piles: **3, 7 and 11 o'clock** (lithotomy position) — correspond to the terminal radicles of the superior rectal vein in the anal columns.

Applied / Clinical anatomy

- ▶ **Per-rectal (PR) examination** — palpable structures: posterior surface of prostate, seminal vesicles, vas deferens (male); perineal body, cervix, presenting fetal part (female); in both sexes — anorectal ring, coccyx/sacrum, ischioanal fossae, ischial spines.
- ▶ **Internal (true) piles** — above pectinate line, painless, bleed on straining (autonomic supply, portal radicles); **external piles** — below pectinate line, painful, do not bleed on straining.
- ▶ **Fissure-in-ano** — tear of an anal valve, usually posterior midline, from hard stool; very painful due to somatic innervation below the pectinate line, with sphincter spasm.
- ▶ **Fistula-in-ano** — from infection of intersphincteric anal glands opening into the anal sinuses; tracks into ischioanal fossa, perineal skin, or rectal lumen (Goodsall's-type tracks).
- ▶ **Rectal prolapse** — mucosal (incomplete) vs **proctidentia** (complete, full-thickness), favoured by lax pelvic floor, deep pouch of Douglas, poor presacral fixation.
- ▶ **Carcinoma rectum** — commonly at rectosigmoid junction (constricting) or ampulla (proliferating); treated by total mesorectal excision or abdominoperineal resection with permanent colostomy; TME plane runs between mesorectal fascia and presacral fascia, preserving the inferior hypogastric plexus.
- ▶ **Rectal continence** depends on the intact anorectal ring and anorectal angle (puborectalis tone); surgical injury to either causes incontinence.
- ▶ **Proctoscopy/sigmoidoscopy** — direct visualisation for piles, growths, ulcers, diverticula, and biopsy.

High-yield exam pointers

- ▶ Rectum: 12 cm, begins at S3, ends 2–3 cm in front of coccyx tip = apex of prostate level in males.
- ▶ 3 lateral curves (upper right, middle left/most prominent, lower right) + 2 AP curves (sacral, perineal).
- ▶ Peritoneum: upper 1/3 all-round front+sides, middle 1/3 front only, lower 1/3 bare.
- ▶ 3 valves of Houston — middle one largest/most constant, at upper end of ampulla.
- ▶ Anal canal 3.8 cm; three zones — 15 mm columnar (anal columns, valves, pectinate line) + 15 mm pecten (white line of Hilton) + 8 mm true skin.

- ▶ Chief artery = superior rectal (continuation of inferior mesenteric); pectinate line = arterial/venous/lymphatic/nerve watershed.
- ▶ Anorectal ring = puborectalis + EAS + IAS fusion — key to continence.
- ▶ Primary internal piles at 3, 7, 11 o'clock (lithotomy).

SOURCE & COVERAGE

BD Chaurasia — Human Anatomy Vol 2 (8e), Ch 33 "Rectum and Anal Canal"; Vishram Singh — Textbook of Anatomy Vol 2 (4e), Ch 19; Gray's Anatomy (Standring) 41e, Ch 66 "Large intestine" (Rectum, Mesorectum & rectal fasciae, Anal canal sections); Moore's Clinically Oriented Anatomy 9e (puborectalis/anorectal angle).



Describe the uterus in detail

Asked in: Paper I Nov 2016 — RGUHS MD/MS Anatomy

Definition / Introduction The uterus (Greek *hystera*; layman's "womb") is a hollow, thick-walled, pyriform (pear-shaped) muscular organ of the female pelvis that receives the fertilised oocyte, provides for implantation and nutrition of the conceptus, and expels the fetus at parturition. It lies in the lesser pelvis between the urinary bladder in front and the rectum behind, above the vagina and below the uterine tubes. It is divisible into a fundus, body, isthmus and cervix, and is held in its anteverted-anteflexed position by a combination of muscular and fibromuscular supports rather than by the peritoneal ligaments, which give it almost no support.

1. Position, Axis and Dimensions

- ▶ **Situation:** pelvic cavity, between the bladder (anteriorly) and rectum (posteriorly); below the peritoneal cavity, above the vagina.
- ▶ **Size:** about 7.5 cm long, 5 cm broad (at the fundus), 2.5 cm thick; weighs 30-40 g (nulliparous).
- ▶ **Shape:** pyriform, compressed anteroposteriorly; upper two-thirds form the **body**, lower one-third the **cervix**.
- ▶ **Axis/angulation:**
 - **Anteversion** – forward tilt of the uterine axis on the vaginal axis, forming an angle of about 90° opening forwards.
 - **Anteflexion** – forward flexion of the body on the cervix at the internal os, angle about 125°.
 - The uterus is normally deviated slightly to the right (**dextrorotation**).
 - The long axis of the uterus corresponds roughly to the axis of the pelvic inlet; the axis of the vagina to that of the pelvic cavity/outlet.
- ▶ **Communications:** superiorly with the uterine tubes on each side; inferiorly with the vagina.

2. Parts of the Uterus

Part	Extent / features
Fundus	Free, dome-shaped upper end above the level of the tubal openings; peritonealised; directed forwards when the bladder is empty; usual site of implantation of the fertilised ovum (posterior wall of fundus/upper body).
Body	Upper two-thirds; has an anterior (vesical) surface (flat, forms posterior wall of the uterovesical pouch) and a posterior (intestinal) surface (convex, forms anterior wall of the rectouterine pouch, related to sigmoid colon and coils of ileum); two rounded lateral borders giving attachment to the broad ligament, and receiving the uterine artery between the two peritoneal layers.
Cornu	Superolateral angle at the junction of fundus and body on each side; gives attachment to the uterine tube, the round ligament (anteroinferior to the tube) and the ligament of the ovary (posteroinferior to the tube).
Isthmus	A slight circular constriction marking the junction of body and cervix, corresponding internally to the internal os ; in pregnancy it unfolds (from the 2nd month) to form the lower uterine segment — the basis of lower-segment caesarean section (LSCS).
Cervix	Lower, cylindrical, less mobile one-third, about 2.5 cm long; projects into the vagina, dividing it into supravaginal and vaginal parts; cervical canal is fusiform, communicates above via the internal os and below via the external os (small & circular in nulliparous women; slit-like with anterior/posterior lips after childbirth); mucosal folds form the arbor vitae uteri .

Cavity: in sagittal section a mere slit (uterus compressed anteroposteriorly); in coronal section triangular, apex directed downward at the internal os, base receiving the two tubal openings at its superolateral angles.

□ Fig 31.6 — Posterosuperior view of the uterus and the right broad ligament (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.478)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Posterosuperior view of the uterus with the right broad ligament opened out. Label: **fundus, body, cornu, isthmus, cervix (supravaginal + vaginal parts), internal os, external os; uterine tube (infundibulum, ampulla, isthmus, intramural part) entering the cornu; ligament of the ovary and round ligament of uterus arising just below the tube; ovary attached by the mesovarium; broad ligament with its mesosalpinx (above the ovarian ligament) and mesometrium (below it); infundibulopelvic (suspensory) ligament of the ovary; uterine vessels ascending in the broad ligament; and the ureter running below the uterine artery near the lateral fornix.**

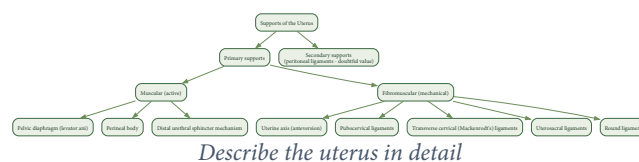
3. Relations of the Uterus

Aspect	Relations
Anterior (vesical surface)	Uterovesical pouch of peritoneum, then the superior surface of the urinary bladder.
Posterior (intestinal surface)	Rectouterine pouch (pouch of Douglas), coils of terminal ileum, sigmoid colon, and the rectum.
Lateral	The two layers of the broad ligament; between them, the uterine artery and veins, the round ligament, ligament of the ovary and (near the cervix, 2 cm lateral to it) the ureter , crossed above by the uterine artery ("water under the bridge").
Supravaginal cervix	Anteriorly — bladder base (separated by loose parametrium); posteriorly — rectouterine pouch with coils of intestine; laterally — ureter and uterine artery embedded in the parametrium (fibrofatty tissue between the two layers of the broad ligament, most abundant near the cervix).
Vaginal cervix	Surrounded by the four fornices of the vagina (anterior — shallowest; posterior — deepest; two lateral).
Superior	Related to coils of small intestine lying over the fundus within the peritoneal cavity.

4. Ligaments and Supports of the Uterus

Peritoneal ("secondary") ligaments — little/no real support	Fibromuscular ("primary") ligaments — true supports
Anterior ligament — uterovesical fold	Round ligaments of the uterus
Posterior ligament — rectovaginal (rectouterine) fold	Transverse cervical (cardinal/Mackenrodt's) ligaments
Broad ligaments (right & left)	Uterosacral ligaments
	Pubocervical ligaments

- **Broad ligament:** a double peritoneal fold from the lateral uterine margin to the pelvic side wall; contains the **uterine tube** (upper free border), **round ligament** and **ligament of the ovary**, **uterine vessels**, **ovarian vessels** (in the infundibulopelvic/suspensory ligament of the ovary), the **utero vaginal and ovarian nerve plexuses**, **epoophoron** and **paroophoron**, lymphatics/nodes, and the **parametrium**. The part between the tube and the ovarian ligament is the **mesosalpinx**; below the ovarian ligament, the **mesometrium**; the ovary hangs from the posterior layer by the **mesovarium**.
- **Round ligament:** fibromuscular band, 10-12 cm long, from the uterine cornu (anteroinferior to the tube) through the deep inguinal ring, inguinal canal, to the labium majus; keeps the fundus pulled forward, maintaining anteversion (may be accompanied in fetal life by a peritoneal process — persistence = **canal of Nuck**).
- **Transverse cervical (cardinal) ligaments of Mackenrodt:** fan-shaped condensations of endopelvic fascia, above the level of the levator ani and around the uterine vessels, connecting the lateral aspects of the cervix and upper vagina to the lateral pelvic wall — a "hammock" support.
- **Uterosacral ligaments:** condensed endopelvic fascia connecting the cervix to the sacral periosteum (S2-3), enclosed in the rectouterine folds; brace the cervix backward against the round ligaments' forward pull.
- **Uterine axis** itself (the anteverted position) is self-stabilising: a rise in intra-abdominal pressure pushes the uterus against the bladder, accentuating anteversion.



5. Blood Supply, Venous and Lymphatic Drainage

Arterial supply — chiefly the **uterine artery** (branch of the anterior division of the internal iliac artery), assisted by the **ovarian artery**.

- **Course:** runs medially in the base of the broad ligament, **crosses above the ureter** about 2 cm lateral to the cervix (superolateral to the lateral fornix), then ascends tortuously along the lateral uterine border, and turns laterally at the cornu to run in the mesosalpinx, ending by anastomosing with the ovarian artery.
- **Branches:** **ureteric, vaginal and cervical branches** near the cervix (cervical branches anastomose circularly around the isthmus); **arcuate (coronary) branches** along the body, which run transversely and anastomose in the midline; **tubal and ovarian branches** along the uterine tube. Overall it supplies the uterus, vagina, medial two-thirds of the uterine tube, the ovary, ureter and structures in the broad ligament.
- **Intrinsic circulation:** arcuate arteries → **radial arteries**, which pierce the myometrium centripetally and anastomose to form the **stratum vasculare** in the middle muscular coat → **basal arteries** (supply the regenerating basal endometrium) and **spiral arteries** (supply the functional endometrium shed at menstruation).

Venous drainage: a plexus along the lateral uterine border draining via uterine, ovarian and vaginal veins into the **internal iliac veins**. Retraction/interlacing of the middle (stratum vasculare) myometrial fibres around these vessels after delivery arrests bleeding — the so-called "**living ligature of the uterus**."

Lymphatic drainage — begins in three intercommunicating plexuses (endometrial, myometrial, subperitoneal):

Region	Draining nodes
Fundus & upper body	Mainly para-aortic (lumbar) nodes; a small part along the round ligament to superficial inguinal nodes
Lower part of body	External iliac nodes
Cervix	Internal iliac and sacral nodes

6. Nerve Supply

- ▶ Rich autonomic supply via the **inferior hypogastric (pelvic) plexus** and the **ovarian plexus**.
- ▶ **Sympathetic** — preganglionic fibres from T12-L1 segments; produce uterine contraction and vasoconstriction.
- ▶ **Parasympathetic** — preganglionic fibres from S2-S4 (pelvic splanchnic nerves); produce uterine inhibition and vasodilatation (effects overridden by hormonal control).
- ▶ **Pain:** fibres from the body of the uterus travel with the sympathetic supply; fibres from the cervix travel with the parasympathetic supply — hence labour pain (fundus/body-dominant contraction) is largely referred via T11-L1 (visceral, felt in the lower abdomen/back), while cervical dilatation pain travels via S2-4.

7. Microstructure and Age Changes

Three coats, from within outward:

- ▶ **Endometrium** (mucosa) — simple columnar epithelium with tubular glands; no submucosa; functional layer (shed) + basal layer (regenerates); passes through **proliferative, progestational (secretory) and menstrual** phases of the cycle.
- ▶ **Myometrium** — thick smooth muscle: outer and inner longitudinal coats and a thick middle circular coat rich in vessels (stratum vasculare).
- ▶ **Perimetrium** (serosa) — peritoneal covering, incomplete anteriorly at the isthmus/supravaginal cervix.

Age/reproductive changes: relatively larger cervix than body in fetal life; enlargement and descent at puberty with appearance of arbor vitae; slight enlargement/vascularity in menstruation; marked hypertrophy (and some hyperplasia) of myometrium in pregnancy with progressive thinning of the wall, followed by post-partum involution; atrophy, a denser texture and often an obliterated external/internal os in old age.

Applied / Clinical anatomy

- ▶ **Retroversion/retroflexion** of the uterus is common and usually asymptomatic, but may contribute to infertility or dyspareunia.

- ▶ **Prolapse of the uterus** follows weakening of its primary (muscular/fibromuscular) supports — most importantly tears of the levator ani/perineal body during childbirth — since the "secondary" peritoneal ligaments give negligible support.
- ▶ **Ureteric injury during hysterectomy**: the ureter passes below the uterine artery about 2 cm lateral to the cervix ("water under the bridge") and is vulnerable when the artery is clamped/ligated at the level of the internal os.
- ▶ **Uterine artery ligation** (or internal iliac artery ligation) is used to control intractable post-partum haemorrhage; the "living ligature" action of the interlacing myometrial (stratum vasculare) fibres is the physiological first line of haemostasis after placental separation.
- ▶ **Lower uterine segment**: formed from the isthmus from the second month of pregnancy; the site of the transverse incision in LSCS and the basis of the placenta previa classification.
- ▶ **Bimanual palpation** per vaginum is possible because the cervix is firm and thick-walled.
- ▶ **Intrauterine contraceptive device (IUCD)** prevents implantation; **Rubin's (insufflation) test** and **hysterosalpingography** assess tubal patency and the uterine cavity outline.
- ▶ **Fibroids (leiomyomas)** commonly arise in the myometrium of the body/fundus.
- ▶ **Congenital anomalies** (bicornuate, septate, unicornuate or didelphys uterus) result from incomplete fusion/canalisation of the paramesonephric (Müllerian) ducts.
- ▶ Spread of **carcinoma cervix** follows the lymphatic pathway of the cervix (parametrium → obturator/internal iliac → external iliac → para-aortic nodes), the anatomical basis for radical hysterectomy with pelvic lymphadenectomy.

High-yield exam pointers

- ▶ Uterus: $7.5 \times 5 \times 2.5$ cm, 30-40 g; parts — fundus, body, isthmus, cervix; angle of anteversion 90° , antelexion 125° .
- ▶ Isthmus becomes the lower uterine segment from the 2nd month of pregnancy — basis of LSCS/placenta previa.
- ▶ True (primary) supports are muscular + fibromuscular (levator ani, perineal body, transverse cervical, uterosacral, round ligaments); peritoneal ligaments (broad ligament) are only "secondary," doubtful supports.
- ▶ Broad ligament contents: tube, round ligament, ligament of ovary, uterine & ovarian vessels, uterovaginal/ovarian plexuses, epoophoron/paroophoron, parametrium.
- ▶ Uterine artery = branch of anterior division of internal iliac artery; crosses **above** the ureter 2 cm lateral to the cervix ("water under the bridge"); ends by anastomosing with the ovarian artery.
- ▶ Lymphatic drainage: fundus/upper body → para-aortic ($\pm$ inguinal along round ligament); lower body → external iliac; cervix → internal iliac + sacral.
- ▶ Nerve supply: sympathetic T12-L1 (contraction/vasoconstriction), parasympathetic S2-4 (inhibition/vasodilatation); pain from body via sympathetics, from cervix via parasympathetics.
- ▶ "Living ligature of the uterus" = interlacing stratum vasculare myometrial fibres controlling haemorrhage after placental separation.
- ▶ Three coats: endometrium (cyclical), myometrium (with stratum vasculare), perimetrium.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e; IB Singh — Textbook of Anatomy Vol 2 6e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen).



Give a detailed account of the Ovary

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction — The ovaries are the paired female gonads, homologous to the testes but much smaller, situated one on each side within the lesser pelvis. Almond-shaped and grey-pink, each ovary produces oocytes (gametogenic function) and secretes oestrogen and progesterone (endocrine function) through the reproductive lifespan of roughly 30 years, from menarche to menopause. A full account covers its location and external features, peritoneal/ligamentous relations, blood-nerve-lymph supply, development, microstructure and applied anatomy.

Location, size and external features

- ▶ **Situation:** each ovary lies in the **ovarian fossa** on the lateral pelvic wall, below the pelvic brim, in nulliparous women.
- ▶ **Boundaries of the ovarian fossa:**

Boundary	Structure
Anterior	Obliterated umbilical artery (medial umbilical fold)
Posterior	Ureter and internal iliac vessels
Superior	External iliac vessels
Floor	Crossed by the obturator nerve and vessels

- ▶ **Position:** in **nulliparous** women the long axis is nearly **vertical** (upper/tubal pole, lower/uterine pole); after childbirth, the pregnant uterus pulls the ovary so that in **multiparous** women the long axis becomes **horizontal** (upper pole lateral, lower pole medial), and the surface becomes irregular/scarred instead of smooth.
- ▶ **Size and colour:** almond-shaped, grey-pink; smooth before the onset of ovulation, becoming nodular and scarred thereafter from successive corpora lutea. Gray's Anatomy (41e) gives average dimensions of $4 \times 2 \times 3$ cm in reproductively mature women (more than doubling in pregnancy); the neonatal ovary measures $1.3 \times 0.6 \times 0.4$ cm; it is about one-third of adult size before menarche and regresses after menopause.
- ▶ **External features** — two poles, two borders, two surfaces:

Feature	Description
Superior (tubal) pole	Broader; related to the uterine tube and external iliac vein; gives attachment to the suspensory (infundibulopelvic) ligament; right ovary may relate to the appendix if pelvic in position
Inferior (uterine) pole	Narrower; directed to the pelvic floor; gives attachment to the ligament of the ovary, which connects it to the lateral angle of the uterus postero-inferior to the uterine tube
Anterior (mesovarian) border	Straight; attached to the posterior layer of the broad ligament by the mesovarium, which forms the hilum
Posterior (free) border	Convex; related to the uterine tube and the ureter
Lateral surface	Convex; contacts parietal peritoneum of the ovarian fossa, separating it from extraperitoneal tissue and the obturator nerve/vessels
Medial surface	Largely covered by the uterine tube; separated from it by the peritoneal recess — the ovarian bursa

□ Fig 18.2 — Location of ovary in the ovarian fossa. (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.744)

Peritoneal and ligamentous relations

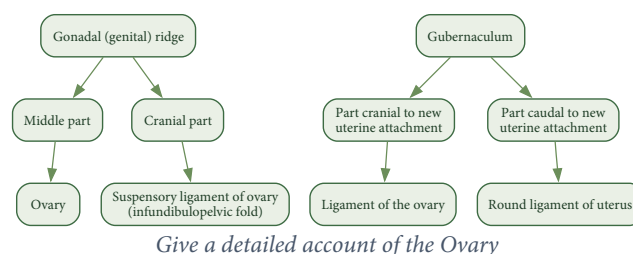
- ▶ The ovary is almost entirely covered by peritoneum **except along the mesovarian border**, where the peritoneum is reflected onto the posterior leaf of the broad ligament; the transition from flattened peritoneal mesothelium to cuboidal ovarian (germinal) epithelium is marked by the **white line of the ovary (line of Farré)**.
- ▶ **Mesovarium** — a short peritoneal fold connecting the ovary to the back of the broad ligament; conveys vessels and nerves to the hilum.
- ▶ **Suspensory (infundibulopelvic) ligament of the ovary** — the lateral part of the broad ligament, extending from the tubal infundibulum/upper pole of the ovary to the external iliac vessels; carries the ovarian vessels and nerves; as it passes over psoas major it also crosses the genitofemoral nerve and ureter.
- ▶ **Ligament of the ovary (utero-ovarian ligament)** — connects the lower/uterine pole to the lateral angle of the uterus, postero-inferior to the uterine tube; lies in the posterior leaf of the broad ligament, contains smooth muscle, and is continuous with the round ligament of the uterus (both are gubernacular remnants).
- ▶ **Broad ligament** is divided into three parts relative to the ovary: an upper **mesosalpinx** (below the tube), a posterior **mesovarium**, and an inferior **mesometrium** (bulk of the ligament, containing the ovarian vessels within the suspensory ligament).
- ▶ The uterine tube arches over the ovary along its mesovarian border, curves over the tubal pole, and descends along the free border and medial surface, its **ovarian fimbria** applied to the ovary.

Vascular supply, lymphatic drainage and nerve supply

Details	
Artery	Ovarian artery, a branch of the abdominal aorta arising just below the renal artery (~L1–L2 level); descends retroperitoneally, crosses the external iliac vessels at the pelvic brim, enters the suspensory ligament, and reaches the hilum via the mesovarium; ends by anastomosing with the uterine artery; a small additional ovarian branch of the uterine artery also supplies it via the mesovarium
Veins	Emerge at the hilum as a pampiniform plexus , condensing into a single ovarian vein near the pelvic brim; right ovarian vein drains into the inferior vena cava , left ovarian vein drains into the left renal vein
Lymphatics	Follow the ovarian vessels (communicating with lymphatics of the uterine tube and fundus) to the lateral aortic (para-aortic) and preaortic nodes near the origin of the renal vessels
Nerves	Ovarian plexus (from renal, aortic and hypogastric plexuses) accompanies the ovarian artery; sympathetic fibres (T10–T11) are afferent for pain and efferent/vasomotor; parasympathetic fibres (S2–S4) are vasodilator; visceral afferents run with sympathetic fibres to T10–T11, so ovarian pain is referred to the umbilical region

Development

The ovary develops from the **middle part of the gonadal (genital) ridge** only; it closely resembles the indifferent/testicular gonad early on, but female differentiation is slower, occurring in the absence of *SRY/SOX9* expression. Descent of the ovary is limited (not hormonally driven like the testis) — it never leaves the pelvis. The cranial part of the gonadal ridge becomes the **suspensory ligament of the ovary**; the gubernaculum, attached to the mesonephric fold, acquires a new attachment to the lateral uterine wall — its part cranial to this becomes the **ligament of the ovary**, and its part caudal to it becomes the **round ligament of the uterus**.



Microscopic structure

From surface inward:

- **Germinal (surface) epithelium** — single layer of cuboidal cells (misnomer — not the source of germ cells); continuous with peritoneal mesothelium at the white line.

- ▶ **Tunica albuginea** — thin, tough collagenous coat beneath the epithelium.
- ▶ **Cortex** — the bulk of the ovary; dense fibrocellular stroma containing ovarian follicles at all stages, corpora lutea and corpora albicantes.
- ▶ **Medulla** — loose fibrovascular connective tissue at the hilum, carrying the larger ovarian vessels and nerves.

Ovarian follicle stages

Stage	Key feature
Primordial follicle	Primary oocyte (~25 µm) arrested at diplotene of first meiotic prophase since 16–20 weeks fetal life, surrounded by a single flat follicular-cell layer
Primary follicle	Follicular cells become cuboidal and multilayer (granulosa); theca interna/externa differentiate from stroma; zona pellucida appears
Secondary (antral) follicle	Antrum forms from coalescing fluid-filled spaces (liquor folliculi); ~200 µm; oocyte reaches ~80 µm, eccentric within the cumulus oophorus
Tertiary (Graafian) follicle	Dominant follicle, ~2 cm; oocyte + corona radiata float free; first meiotic division completed at ovulation → secondary oocyte + first polar body; second meiotic division arrests at metaphase II until fertilization
Corpus luteum	Post-ovulatory; granulosa-lutein and theca-lutein cells secrete progesterone and oestrogen
Corpus albicans	Degenerated corpus luteum; hyalinized fibrous scar

Only one dominant follicle from a monthly activated cohort of up to 20 primordial follicles usually matures and ovulates; the rest become **atretic**.

Functions

- ▶ **Gametogenic** — liberates one secondary oocyte per ovarian cycle (ovulation, ~day 14 of a 28-day cycle); an oocyte is viable for 12–24 hours; ~400 oocytes are ovulated over reproductive life.
- ▶ **Endocrine** — oestrogen from follicular/granulosa cells; progesterone from the corpus luteum, both essential for the menstrual cycle.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Superior view of the broad ligament with right ovary in situ, labelling:

- ▶ Ovary — superior (tubal) pole, inferior (uterine) pole, anterior (mesovarian) border, posterior (free) border, lateral surface, medial surface
- ▶ Mesovarium, mesosalpinx, mesometrium (parts of broad ligament)
- ▶ Suspensory ligament of ovary (infundibulopelvic ligament) with ovarian vessels/nerves
- ▶ Ligament of the ovary → continuity with round ligament of uterus
- ▶ Uterine tube arching over the ovary; ovarian fimbria
- ▶ Ovarian fossa boundaries: obliterated umbilical artery (anterior), ureter/internal iliac vessels (posterior), external iliac vessels (superior)
- ▶ Ovarian artery anastomosing with uterine artery

□ Fig 31.5 — Histology of ovary (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.476)

Applied / Clinical anatomy

- ▶ **Ovarian torsion:** predisposed by an abnormally long mesovarium and suspensory ligament; presents as acute pelvic pain.
- ▶ **Referred pain:** ovarian visceral afferents travel with T10–T11 sympathetic fibres, so pain is referred to the **umbilical region**; intractable ovarian pain can be relieved by dividing the suspensory ligament (contains the afferents).
- ▶ **Prolapse of the ovary:** the ovary may descend into the recto-uterine pouch (of Douglas), where it is palpable on per-vaginal examination.
- ▶ **Ovarian cysts:** small cysts follow developmental arrest of follicles; a large corpus-luteum cyst produces anteroposterior abdominal bulging **without shifting dullness**, distinguishing it from ascites.
- ▶ **Ovarian carcinoma:** accounts for ~15% of all cancers and ~20% of gynaecological cancers; spreads early via the transcoelomic route and along ovarian lymphatics to para-aortic nodes.
- ▶ **Endometriosis/chocolate cyst:** the ovary is the commonest abdominal site for endometriosis, forming altered-blood-filled "chocolate cysts."
- ▶ **Stein–Leventhal syndrome (polycystic ovarian disease):** multiple small theca-lutein cysts in both ovaries with hirsutism and secondary amenorrhoea.
- ▶ **Teratoma:** pluripotent germ cells in the ovary may give rise to a (usually benign, cystic) teratoma.
- ▶ **Radiological shielding:** in girls, the ovary lies at or below the iliac crest, just medial to the anterior superior iliac spine, guiding gonadal shielding during abdominal/pelvic radiography.
- ▶ **Ultrasound/laparoscopy:** used to monitor ovulation and follicular development in the workup of infertility.

High-yield exam pointers

- ▶ Ovarian fossa boundaries: obliterated umbilical artery (anterior), ureter + internal iliac vessels (posterior), external iliac vessels (superior).

- ▶ Axis vertical in nullipara, horizontal in multipara.
- ▶ Three ligaments: mesovarium, ligament of the ovary, suspensory (infundibulopelvic) ligament — the last carries the ovarian vessels/nerves.
- ▶ Broad ligament subdivisions relative to ovary: mesosalpinx (upper), mesovarium (posterior), mesometrium (lower).
- ▶ Artery from aorta below the renal artery → anastomoses with uterine artery; right vein → IVC, left vein → left renal vein.
- ▶ Lymphatics → para-aortic/preaortic nodes (not pelvic nodes) — key for staging ovarian cancer spread.
- ▶ Nerve supply T10–T11 (sympathetic, pain) and S2–S4 (parasympathetic); referred pain to umbilicus.
- ▶ Layers from surface inward: germinal epithelium → tunica albuginea → cortex (follicles) → medulla (vessels).
- ▶ Ovary develops from the middle part of the gonadal ridge; cranial part → suspensory ligament; gubernaculum → ligament of ovary + round ligament of uterus.
- ▶ ~400 oocytes ovulated in a lifetime; ovulation ~day 14 of a 28-day cycle.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e.



Gross anatomy of testis

Asked in: Paper I May 2018 — RGUHS MD/MS Anatomy

Definition / Introduction The testes are the paired male gonads — ovoid, compressed organs suspended in the scrotum by the spermatic cords, responsible for spermatogenesis and androgen (testosterone) synthesis. Each testis develops retroperitoneally high on the posterior abdominal wall and descends into the scrotum before birth; this migration explains why its nerve, arterial and lymphatic connections all remain abdominal in adult life — a fact of major clinical importance in testicular tumour spread. Its scrotal position, with the counter-current pampiniform heat-exchange mechanism, keeps the testis 3–4°C below core temperature, essential for spermatogenesis. The testis is embryologically homologous with the ovary.

Location, Position & External Features

- ▶ **Location:** suspended in the scrotum by the spermatic cord; the **left testis lies slightly lower** than the right (the left spermatic cord is longer, and the left testis descends earlier).
- ▶ **Position:** long axis oblique — **upper pole** tilted forward and laterally, **lower pole** tilted backward and medially.

- **Shape/size (Gray's 41e):** ovoid, compressed side to side; length 4–5 cm, breadth 2–3 cm, anteroposterior diameter 3–4 cm; weight 12–20 g; volume 15–25 mL (classical teaching figures, BD Chaurasia: $3.75 \times 2.5 \times 1.8$ cm, weight 10–15 g).
- **Poles:** upper pole gives attachment to the spermatic cord and (via efferent ductules) the head of epididymis; lower pole gives attachment to the remnant of the gubernaculum (ligament of the testis/epididymis).
- **Borders:** **anterior** — convex, smooth, completely invested by tunica vaginalis; **posterior** — straight, only partly covered by tunica vaginalis, gives attachment to the epididymis and is the site of entry of vessels, nerves and ducts.
- **Surfaces:** medial and lateral — both convex and smooth.
- **Appendix of testis:** a small pedunculated oval body at the upper pole — a **paramesonephric (Müllerian) duct remnant**.
- **Sinus of the epididymis:** a slit-like extension of the tunica vaginalis cavity separating the epididymis from the posterolateral surface of the testis.

Coverings of the Testis

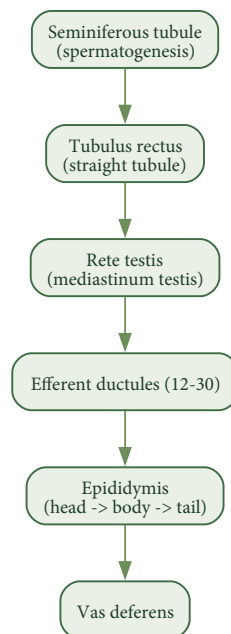
From without inwards, the testis is covered by the layers of the scrotum, and then by three coats proper to the gland.

Layer	Derived from / nature
Skin	continuation of abdominal skin
Dartos muscle & fascia	replaces superficial fascia; smooth muscle — thermoregulation
External spermatic fascia	external oblique aponeurosis
Cremasteric muscle & fascia	internal oblique muscle
Internal spermatic fascia	fascia transversalis
Tunica vaginalis	persistent distal part of the peritoneal processus vaginalis
Tunica albuginea	dense white fibrous capsule of the testis proper
Tunica vasculosa	innermost vascular coat lining the lobules

- **Tunica vaginalis:** a serous sac with **parietal and visceral layers** enclosing a potential cavity containing a thin film of serous fluid; invaginated by the testis from behind, it covers the whole testis **except the posterior border**. Obstruction of lymphatic drainage or inflammation distends the cavity → **hydrocele**.
- **Tunica albuginea:** dense collagenous capsule; posteriorly it thickens into an incomplete vertical ridge, the **mediastinum testis**, from which fibrous septa radiate inward.
- **Tunica vasculosa:** vascular connective-tissue layer lining the inner aspect of the tunica albuginea and the septa.

Internal Structure and Duct System

- ▶ Septa from the mediastinum testis incompletely divide the gland into **200–300 (~250) lobules**.
- ▶ Each lobule contains **2–4 highly coiled seminiferous tubules** embedded in loose interstitial tissue.
- ▶ Each seminiferous tubule is ~30–70 cm long when uncoiled; combined tubular length of one testis is classically quoted as ~500 m (BD Chaurasia/Vishram Singh), Gray's 41e gives ~250 m for 600–1200 tubules.
- ▶ Near the mediastinum the tubules straighten (**tubuli recti**), lose their spermatogenic lining, and anastomose within the mediastinum to form the **rete testis**.
- ▶ The rete testis gives rise to **12–30 efferent ductules** (Gray's 41e: 7–15) which pierce the tunica albuginea near the upper pole and carry spermatozoa into the head of the epididymis.
- ▶ **Sertoli cells**: tall columnar cells spanning the basal lamina to the lumen; support and nourish germ cells, form the **blood–testis barrier** via inter-Sertoli tight junctions, respond to FSH.
- ▶ **Leydig (interstitial) cells**: lie in clusters between tubules; secrete **testosterone**, under control of LH/ICSH.



Gross anatomy of testis

□ Fig 17.9 — Transverse section of the testis and epididymis (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.292)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a longitudinal/quarter section of testis with epididymis and spermatic cord; label: Spermatic cord; Coverings of testis; Sinus of epididymis; Appendix of testis; Appendix of head of epididymis; Epididymis (head/body/tail); Vas deferens; Efferent ductules; Rete testis; Straight (tubuli recti) seminiferous tubules; Convolutus seminiferous tubules; Lobule; Interlobular septum; Tunica albuginea; Mediastinum testis.

Relations, Epididymis & Spermatic Cord

- ▶ **Epididymis:** comma-shaped structure along the postero-superior/lateral aspect of the testis; **head** (highly coiled efferent ductules, connected to the upper pole), **body**, and **tail** (single coiled duct of epididymis, continuous below with the vas deferens).
- ▶ **Spermatic cord contents:** vas deferens, testicular artery, artery to the vas deferens, cremasteric artery, pampiniform plexus of veins, genital branch of the genitofemoral nerve, sympathetic (testicular plexus) fibres, lymphatics, and the remains of the processus vaginalis.
- ▶ **Embryological remnants** related to testis/epididymis (may form cysts):
 - Appendix of testis — paramesonephric duct remnant.
 - Appendix of epididymis (hydatid of Morgagni) — cranial mesonephric duct remnant.
 - Paradidymis (organ of Giraldes) — caudal mesonephric tubule remnants.
 - Superior and inferior aberrant ductules — upper/intermediate mesonephric tubule remnants.

Blood Supply, Lymphatic Drainage & Nerve Supply

Vessel	Origin / course
Testicular artery (~2/3 of supply)	from the abdominal aorta , just below the renal artery ($\approx$ L2); descends retroperitoneally, enters the deep inguinal ring in the spermatic cord; at the posterior border of the testis divides into medial and lateral branches which pierce the tunica albuginea and ramify in the tunica vasculosa
Artery to the vas deferens (vasal artery)	branch of the superior vesical artery (internal iliac artery)
Cremasteric artery	branch of the inferior epigastric artery; supplies the coverings/cremaster

A rich anastomosis at the head and tail of the epididymis links the testicular, epididymal, cremasteric and vasal arteries, so testicular viability can persist even if the testicular artery alone is compromised.

- ▶ **Venous drainage:** veins form the **pampiniform plexus** around the testicular artery (a counter-current heat-exchange device), condensing to ~4 veins at the superficial inguinal ring and 2 at the deep inguinal ring, finally uniting into a **single testicular vein** on each side. The **right** testicular vein drains into the **inferior vena cava** at an oblique/acute angle just below the renal vein; the **left** drains into the **left renal vein** at a right angle — the anatomical basis of left-predominant varicocele.

- **Lymphatic drainage:** follows the testicular vessels retroperitoneally (**not** to inguinal nodes) to the **preaortic and para-aortic lymph nodes at the level of L2**; more precisely (Gray's 41e), the right testis drains chiefly to the inter-aortocaval and paracaval nodes (with some crossover to left para-aortic nodes), and the left testis to the left para-aortic and inter-aortocaval nodes.
- **Nerve supply:** sympathetic afferent and efferent (vasomotor) fibres from spinal segments **T10–T11**, reaching the testis via the renal and aortic (testicular) plexuses; additional fibres travel with the vas deferens from the pelvic plexus. This T10 origin explains referred peri-umbilical pain in testicular torsion/epididymo-orchitis.

Descent of the Testis

Age (intra-uterine life)	Event
2nd month	Testis begins to descend from the posterior abdominal wall (mesonephric level, ~T10–L2/3)
3rd month	Reaches the iliac fossa
4th–6th month	Rests at the deep inguinal ring
7th month	Traverses the inguinal canal
8th month	Reaches the superficial inguinal ring
9th month / birth	Enters and reaches the base of the scrotum

- A peritoneal diverticulum, the **processus vaginalis**, precedes the testis into the scrotum; the testis invaginates it from behind. After descent, the proximal part obliterates while the distal part persists as the **tunica vaginalis**.
- The **gubernaculum**, a fibromuscular band from the lower pole of the testis to the scrotal floor, guides descent; its remnant after descent forms the **ligament of the testis/epididymis (scrotal ligament)**.
- Contributing factors: differential growth of the body wall, rising intra-abdominal pressure, hormones (fetal androgens acting on the gubernaculum, maternal gonadotropins), and gubernacular traction/elongation mediated by **calcitonin gene-related peptide (CGRP)** released from the genitofemoral nerve.
- Over 95% of full-term male neonates have fully descended testes; descent essentially does not continue after the first year of life.

Applied / Clinical anatomy

- **Cryptorchidism (undescended testis):** arrest anywhere along the pathway (lumbar, iliac, inguinal, or upper scrotal); associated with indirect inguinal hernia (patent processus vaginalis), impaired spermatogenesis due to raised temperature, and increased risk of malignant change; treated by **orchidopexy**.
- **Ectopic testis:** deviation from the normal path of descent to the abdominal wall, thigh, penis, perineum or femoral canal; the testis is usually normally developed.

- ▶ **Hydrocele:** fluid in the tunica vaginalis (vaginal, infantile, congenital, encysted types); tapping traverses skin → dartos → external spermatic fascia → cremaster → internal spermatic fascia → parietal tunica vaginalis. Blood/pus in the sac gives haematocele/pyocele.
- ▶ **Varicocele:** dilated, tortuous pampiniform plexus ("bag of worms"), predominantly left-sided (longer left vein, right-angle entry into left renal vein, compression by a loaded sigmoid colon); sudden-onset left varicocele in an older man warrants imaging the left kidney.
- ▶ **Testicular torsion:** twisting of the spermatic cord (often on a "bell-clapper" anomaly of excessive tunica vaginalis investment) cuts off the testicular blood supply — a surgical emergency requiring detorsion within hours to salvage the gland.
- ▶ **Testicular tumours** (seminoma, teratoma): spread lymphatically to **para-aortic/lumbar nodes**, not inguinal nodes — the anatomical basis for **radical inguinal orchiectomy** (never a trans-scrotal biopsy, which would open a new, aberrant lymphatic route to the inguinal nodes).
- ▶ **Epididymo-orchitis:** commonly tuberculous, filarial, gonococcal or other pyogenic infection.
- ▶ Anorchism (bilateral absence)/monorchism (unilateral absence); true and pseudo-hermaphroditism.
- ▶ Testis is palpated bimanually to assess size, consistency and nodularity.

High-yield exam pointers

- ▶ Three coats (out to in): tunica vaginalis (parietal + visceral) → tunica albuginea (with posterior mediastinum testis) → tunica vasculosa.
- ▶ Duct pathway: seminiferous tubule → tubulus rectus → rete testis → efferent ductules → epididymis → vas deferens.
- ▶ Blood supply is tripartite — testicular artery (2/3) + vasal artery (superior vesical) + cremasteric artery (inferior epigastric) (1/3), anastomosing at the epididymis.
- ▶ Right testicular vein → IVC (oblique angle); left testicular vein → left renal vein (right angle) → basis of left varicocele.
- ▶ Lymphatics drain to preaortic/para-aortic (L2) nodes, never to inguinal nodes — key to tumour biopsy/surgery planning.
- ▶ Nerve supply T10–T11 via aortic/renal plexus explains referred umbilical pain.
- ▶ Descent timetable: 2nd month (begins) → 3rd (iliac fossa) → 4th–6th (deep ring) → 7th (canal) → 8th (superficial ring) → 9th/birth (scrotum).
- ▶ Appendix of testis = paramesonephric remnant; appendix of epididymis = mesonephric duct remnant.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e.



Interior of anal canal

Asked in: Paper I Nov 2017 — RGUHS MD/MS Anatomy

Definition / Introduction. The **anal canal** is the terminal ~4 cm of the alimentary tract, extending from the anorectal junction (level of the puborectalis sling) to the anal verge, lying entirely within the anal triangle of the perineum. Its lumen is normally kept closed by the tone of two sphincters, and its lining shows a characteristic sequence of mucosal features that change abruptly at a single key landmark — the **pectinate (dentate) line**. This line marks the embryological junction between the hindgut (endoderm) above and the proctodeum (ectoderm) below, and is the single most important reference point governing the epithelium, blood supply, lymphatic drainage, nerve supply and disease pattern (piles, fissure, fistula) of the canal — making the "interior of the anal canal" a high-yield, frequently asked applied-gross-anatomy topic.

1. Overall plan — three zones of the interior

- ▶ The interior of the anal canal is classically described in **three parts**, each with a characteristic lining and each reacting differently to disease:
- ▶ **Upper mucous part** — about **15 mm** long, of hindgut (endodermal) origin.
- ▶ **Middle part (pecten / transitional zone)** — about **15 mm** long.
- ▶ **Lower cutaneous part** — about **8 mm** long.
- ▶ Together the middle and lower parts (~23 mm) constitute the ectodermal **proctodeal** derivative, so the canal is more fundamentally divided by the **pectinate line** into an **upper 15 mm (endodermal)** and a **lower 23 mm (ectodermal)** segment — a division that determines every subsequent feature (epithelium, vessels, nerves, lymphatics) discussed below.

2. Upper mucous part (15 mm)

- ▶ Lined by **columnar epithelium** continuous with that of the rectum, resting on a mobile, distensible submucosa carrying the internal rectal (haemorrhoidal) venous plexus.
- ▶ Shows **6–10 permanent vertical mucosal folds** — the **anal columns (columns of Morgagni)** — each containing a terminal radicle of the superior rectal vein and artery.
- ▶ The lower ends of adjacent columns are joined by short crescentic folds — the **anal valves (valves of Morgagni)**; their upward-directed free margins together trace the wavy **pectinate (dentate) line**, which lies opposite the middle of the internal anal sphincter.
- ▶ Above each valve is a small recess, the **anal sinus**, into whose floor open the ducts of the **anal glands** (branched, mucin-secreting, submucosal/intersphincteric tubular glands — on average about **twelve** in the adult canal, evenly spaced around the circumference). Retained secretion here is the source of the characteristic odour and, when infected, of most fistulae.
- ▶ The valves occasionally bear small epithelial projections, the **anal papillae** — vestiges of the embryonic **anal membrane**.

3. Middle part — pecten / transitional zone (15 mm)

- ▶ Also lined by mucous membrane, but **anal columns are absent** here; the mucosa looks **bluish** owing to a dense underlying venous plexus and is less mobile than above (more adherent to the muscle coat).

- ▶ Its epithelium is **stratified squamous, non-keratinised**, thin, pale and glossy, and devoid of skin appendages — this transitional (anal-transition-zone) epithelium bridges columnar mucosa above and true skin below.
- ▶ Its lower limit is often visibly **whitish** — **the white line of Hilton** — situated at the interval between the lower border of the internal sphincter and the subcutaneous part of the external sphincter (the palpable **intersphincteric groove**).

4. Lower cutaneous part (8 mm)

- ▶ Lined by **true, keratinised, hair-bearing skin** continuous with the perianal skin, containing sebaceous and (more peripherally) sweat glands and, in the adult, coarse hairs; it is pigmented.
- ▶ Numerous **somatic sensory nerve endings** here (touch, pain, temperature, pressure) make this the most sensitive strip of the entire canal — the basis for the pain of anal fissures and external piles.
- ▶ Subepithelial veins here form the **external haemorrhoidal (rectal) venous plexus**, visible as a ring around the anal margin on straining.

5. Upper vs lower anal canal — the pectinate line as watershed

Feature	Upper part (15 mm, endodermal)	Lower part (23 mm, ectodermal)
Development	Hindgut / primitive anorectal canal (endoderm)	Proctodeum — ectodermal invagination
Epithelium	Simple columnar	Stratified (transitional squamous → true skin)
Arterial supply	Superior rectal artery	Inferior rectal artery
Venous drainage	Internal rectal plexus → superior rectal v. → portal system	External rectal plexus → inferior rectal v. → systemic (caval) system
Lymphatic drainage	Internal iliac nodes	Medial group of superficial inguinal nodes
Nerve supply	Autonomic — sympathetic (inferior hypogastric plexus, L1–2) and parasympathetic (pelvic splanchnic, S2–4)	Somatic — inferior rectal nerve (S2–4)
Sensory to	Stretch/distension, spasm, ischaemia (relatively insensitive)	Touch, pain, temperature, pressure (highly sensitive)
Haemorrhoids	Internal piles — painless	External piles — painful

6. Muscular sleeve lining the interior

- ▶ **Internal anal sphincter** — an involuntary thickening of the circular smooth-muscle coat of the gut wall; surrounds roughly the upper three-fourths (~30 mm) of the canal, from the anorectal junction down to the white line of Hilton. It is tonically contracted at rest — sympathetic fibres (L1–2) cause contraction, parasympathetic fibres (S2–4) cause relaxation.

- ▶ **External anal sphincter** — voluntary striated muscle surrounding the whole length of the canal, supplied by the inferior rectal nerve and the perineal branch of S4; classically described in subcutaneous, superficial and deep parts, though these are now regarded as a single functional/anatomical sleeve.
- ▶ **Conjoint longitudinal coat** — formed by fusion of puborectalis with the longitudinal muscle of the rectum, lying between the two sphincters; at the level of the white line it fans out into fibroelastic septa — the most lateral forming the **perianal fascia**, the most medial the **anal intermuscular septum** (attached at Hilton's line), with further strands (**corrugator cutis ani**) piercing the subcutaneous external sphincter to blend with perianal skin.
- ▶ **Anorectal ring** — a palpable muscular ring at the anorectal junction formed by fusion of puborectalis, the internal sphincter and the uppermost (deep) part of the external sphincter; surgical division causes faecal incontinence, making its identification vital in anal surgery.

□ Fig 33.10 — Interior of the anal canal (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.510)

□ Fig 33.11 — Coronal section through the wall of the anal canal (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.511)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a longitudinally opened/coronal view of the anal canal and label, from above downward:

- ▶ Rectal mucosa continuing into the **upper mucous part** with 6–10 **anal columns** (of Morgagni)
- ▶ Anal valves, the anal sinuses above them, and an anal gland opening into an anal crypt
- ▶ The wavy **pectinate (dentate) line** formed by the valves
- ▶ **Pecten (transitional zone)** with its bluish, adherent mucosa
- ▶ The **white line of Hilton** at the intersphincteric groove
- ▶ **Lower cutaneous part** lined by true skin with hair and sebaceous glands
- ▶ **Internal anal sphincter** and **external anal sphincter** (three parts) surrounding the canal, with the **conjoint longitudinal coat** between them, and the **anorectal ring** at the upper limit

Applied / Clinical anatomy

- ▶ **Internal (true) piles:** saccular dilatations of the internal rectal venous plexus arising **above** the pectinate line, classically at the **3, 7 and 11 o'clock** positions (lithotomy) where the three main radicles of the superior rectal vein lie within the anal columns; being of endodermal/mucosal origin and autonomically innervated, they are **painless** but bleed freely on straining. Injection sclerotherapy and banding are painless here for the same reason.
- ▶ **External piles:** perianal hematomas from rupture of the radially arranged anal veins **below** the pectinate line; being covered by sensitive skin, they are acutely **painful**.
- ▶ **Fissure-in-ano:** a tear of the anal mucosa/skin, usually at the anal valve, most often in the **posterior midline** (a relatively poorly vascularised zone); intensely painful because it involves richly innervated skin below the pectinate line, and is accompanied by sphincter spasm.

- ▶ **Fistula-in-ano**: chronic track most often originating from infection of one of the ~12 **intersphincteric anal glands** opening at an anal crypt/valve (cryptoglandular hypothesis) — the pectinate line is thus the usual site of the internal fistulous opening.
- ▶ **Imperforate anus / anal agenesis**: failure of fusion/breakdown of the anal membrane between the endodermal (hindgut) and ectodermal (proctodeal) parts of the canal, reflecting the same developmental division that creates the pectinate line.
- ▶ **Digital and endoscopic correlate**: the **anorectal ring** and **white line of Hilton** are both palpable per rectum and are used as surgical/anaesthetic landmarks; the pectinate line is the key **watershed** for arterial supply, venous drainage (portosystemic anastomosis site), lymphatic drainage and somatic vs autonomic sensation.

High-yield exam pointers

- ▶ Anal canal ≈ 4 cm; three zones — **upper mucous (15 mm)** → **pecten/transitional (15 mm)** → **lower cutaneous (8 mm)**; fundamentally divided at the **pectinate line** into upper 15 mm (endoderm) and lower 23 mm (ectoderm).
- ▶ **Anal columns (6–10)** → **anal valves** → **pectinate/dentate line**; anal sinuses drain ~12 **anal glands** (cryptoglandular source of fistula).
- ▶ **White line of Hilton** = intersphincteric groove = lower limit of pecten, at the junction of internal sphincter's lower border and subcutaneous external sphincter.
- ▶ **Internal sphincter** (involuntary, smooth muscle, sympathetic-contracts/parasympathetic-relaxes) vs **external sphincter** (voluntary, striated, inferior rectal n. + S4 perineal branch) — fused with puborectalis and internal sphincter to form the palpable **anorectal ring** (division → incontinence).
- ▶ Pectinate line is the **watershed**: arterial (superior vs inferior rectal), venous (portal vs systemic), lymphatic (internal iliac vs superficial inguinal), and nerve supply (autonomic/insensate vs somatic/sensate).
- ▶ **Primary internal piles at 3, 7, 11 o'clock** (lithotomy) — sites of the three main superior rectal vein radicles in the anal columns.
- ▶ Development: upper canal from the **primitive anorectal canal (hindgut endoderm)**, lower canal from the **proctodeum (ectoderm)** — non-fusion/non-canalisation causes imperforate anus.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh's Textbook of Anatomy Vol 2 4e; IB Singh's Textbook of Human Histology 9e.



Male urethra

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction — The male urethra is a fibromuscular tube, 18–20 cm long, that conveys urine from the internal urethral orifice at the bladder neck to the external urethral orifice on the glans penis, and also serves as the passage for semen during ejaculation. It is conventionally divided into a short **posterior (proximal) urethra**, lying in the pelvis proximal to the corpus spongiosum and acted upon by the urogenital sphincter mechanisms, and a longer **anterior (spongy) urethra**, surrounded by the corpus spongiosum in the perineum and penis. Both parts function purely as a conduit; the posterior urethra additionally participates in continence and antegrade ejaculation.

Parts and dimensions

Division	Sub-part	Length	Location / boundaries
Posterior urethra (~4 cm)	Preprostatic	~1 cm	Bladder neck to base of prostate; vertical
	Prostatic	3–4 cm	Tunnels through prostate, nearer its anterior than posterior surface; angulates ~30–35° at verumontanum
	Membranous	1.5–2.5 cm (shortest, least dilatable, narrowest except EUO)	Prostate to bulb of penis, through perineal membrane, 2.5 cm postero-inferior to pubic symphysis
Anterior (spongy) urethra (~15–16 cm)	Bulbar	—	Widest part; within bulb, surrounded by bulbospongiosus
	Penile (pendulous)	—	Bulb to glans; dilates terminally as navicular fossa

- Fixed segments: prostatic urethra (by puboprostatic ligaments) and membranous urethra (by perineal membrane); the penile urethra is mobile with the shaft.
- **Widest and most dilatable part** — prostatic urethra. **Narrowest part** — external urethral orifice (a 6 mm sagittal slit). **Least dilatable/narrowest excluding EUO** — membranous urethra.
- Cross-sectional shape changes along its course (accounts for the "spiral" projectile urinary stream): crescentic/transversely-arched in the **prostatic** part, stellate in the **preprostatic and membranous** parts, transverse in the **bulbar and penile** parts, and sagittal at the **external orifice**.
- In the flaccid penis the urethra follows a double (S-shaped) curve; on erection the distal curve is lost and it becomes J-shaped.

Posterior urethra — detail

- **Preprostatic urethra**: ~1 cm, extends almost vertically from the bladder neck/trigone to the verumontanum level; surrounded by the **proximal (preprostatic) sphincter** — a distinct circular

collar of smooth muscle, richly adrenergic and largely devoid of parasympathetic fibres, separate from the detrusor. Small periurethral (BPH-associated) glands lie around it.

- ▶ **Prostatic urethra:** 3–4 cm, tunnels through the prostate. Its posterior wall bears a median **urethral crest**, flanked on each side by a shallow **prostatic sinus** perforated by 15–20 prostatic duct openings. At the middle of the crest is the **verumontanum (seminal colliculus)**, containing the slit-like orifice of the **prostatic utricle** with the two **ejaculatory duct** openings on or just within its margins.
 - *Prostatic utricle:* a 6 mm blind pouch running upward/backward in the prostate behind the median lobe; develops from the paramesonephric ducts/urogenital sinus; called *vagina masculina* (uterovaginal homologue).
- ▶ **Membranous urethra:** shortest, narrowest (bar EUO), least dilatable; passes through the perineal membrane. Its wall carries a thin inner smooth-muscle coat (continuous with the prostatic urethra) and an outer circular striated **rhabdosphincter** = the external urethral sphincter proper.

Anterior (spongy) urethra — detail

- ▶ Lies wholly within the corpus spongiosum; begins as the **bulbar urethra** (widest part, surrounded by bulbospongiosus) just below the perineal membrane, then curves down as the narrower **penile urethra**.
- ▶ The **bulbourethral (Cowper's) glands** lie within the sphincteric muscle lateral to the membranous urethra; their ~3 cm ducts open into the floor of the bulbar urethra about 2.5 cm below the perineal membrane, releasing lubricant mucus during sexual arousal.
- ▶ The urethra dilates terminally within the glans as the **navicular fossa**; the **external urethral orifice** is the narrowest point of the whole urethra, a 6 mm sagittal slit bounded by two labia.
- ▶ **Glands and recesses:** numerous small mucous **urethral glands (of Littre)**, most abundant in the spongy part, open into pit-like **lacunae** directed distally; the largest, the **lacuna magna**, lies on the roof of the navicular fossa and is guarded by a mucosal fold (**valvule of Guerin**).

Sphincteric mechanism

Mechanism	Location	Muscle type	Function
Proximal (preprostatic) sphincter	Bladder neck / preprostatic urethra	Smooth muscle, circular collar, sympathetically innervated	Prevents retrograde ejaculation; disrupted in TURP/bladder-neck surgery
Distal (external/membranous) sphincter	Membranous urethra	Smooth muscle (inner) + striated rhabdosphincter (outer, slow-twitch)	Main voluntary continence mechanism
Pubourethral part of levator ani	Around membranous urethra	Striated	Resists surges in intra-abdominal pressure (cough, exertion)

Microstructure — epithelial lining

Segment	Epithelium
Preprostatic and proximal prostatic urethra	Transitional (urothelium), continuous with bladder
Prostatic urethra (below colliculus), membranous urethra	Stratified/pseudostratified columnar
Bulbar and penile (spongy) urethra	Stratified columnar, with patches of pseudostratified columnar and stratified squamous
Navicular fossa and external meatus	Stratified squamous (non-keratinised)

- ▶ Continuity of urothelium with the bladder, prostatic ducts, bulbourethral gland ducts, seminal vesicles and vasa deferentia is clinically important for ascending spread of urinary/genital infection.
- ▶ **Glands of Littre** (mucous, tubular) lie throughout the wall, most numerous in the penile urethra; secretions lubricate the lumen before ejaculation.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 30.10 — Left view of a sagittal section through the male urethra showing its s (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.467)

Reproduce a left-sagittal-section diagram of the male urethra with these labels: internal urethral orifice/bladder neck — trigone — preprostatic urethra — prostate — prostatic urethra — urethral crest — prostatic sinus — verumontanum (seminal colliculus) — prostatic utricle orifice — ejaculatory duct openings — membranous urethra — perineal membrane — bulbourethral gland and duct — bulb of penis/bulbar urethra — corpus spongiosum — penile (pendulous) urethra — navicular fossa — lacuna magna — external urethral orifice.

Vascular supply, lymphatic drainage and nerve supply

Detail	
Arterial supply	Posterior urethra — prostatic branches of the inferior vesical artery . Anterior urethra — urethral artery (from internal pudendal/common penile artery, runs the length of the corpus spongiosum) and dorsal artery of the penis via circumflex branches; the artery to the bulb supplies the corpus spongiosum housing the bulbar urethra. Blood supply through the corpus spongiosum is so free that the urethra can be divided without compromising it.
Venous drainage	Anterior urethra → dorsal vein of penis → internal pudendal vein → prostatic venous plexus. Posterior urethra → prostatic and vesical venous plexuses → internal iliac veins.

	Detail
Lymphatic drainage	Prostatic and membranous urethra → internal iliac nodes (a few to external iliac). Anterior urethra → accompanies glans lymphatics → deep inguinal nodes (occasionally external iliac via the inguinal canal).
Nerve supply	Smooth muscle/preprostatic sphincter — sympathetic (superior hypogastric plexus, preganglionic from L1–L2) prevents retrograde ejaculation; parasympathetic preganglionic from S2–S4 (pelvic splanchnic/prostatic plexus) supplies detrusor-continuous smooth muscle. Rhabdosphincter (external sphincter) — somatic fibres from Onuf's nucleus (S2–S4) via the perineal branch of the pudendal nerve .

Applied / Clinical anatomy

- ▶ **Rupture of the urethra:** a fall-astride (straddle) injury classically ruptures the **bulbar urethra** at the perineal membrane/bulbar junction; a pelvic fracture more often injures the **membranous urethra**.
- ▶ **Extravasation of urine:** after bulbar urethral rupture, urine tracks between the perineal membrane and Colles' fascia; blocked posteriorly (fusion around superficial transverse perineal) and laterally (ischiopubic rami), so it spreads anteriorly into the scrotum, penis and anterior abdominal wall. Membranous urethral injury with an intact perineal membrane extravasates urine into the pelvic extraperitoneal tissue instead.
- ▶ **Urethral stricture:** narrowing, usually post-infective (gonococcal urethritis) or post-traumatic, commonly at the bulbomembranous junction and external meatus.
- ▶ **Catheterisation:** the operator must negotiate the double curvature of the flaccid urethra and its narrowest points (external meatus, membranous urethra); false passage risk is highest at the bulbomembranous junction.
- ▶ **Verumontanum** is the key endoscopic/surgical landmark for locating the external sphincter during transurethral resection of the prostate (TURP).
- ▶ **Prostatic utricle cystic dilatation** may present in childhood with UTI, epididymitis or haematuria; seen on micturating cystourethrogram.
- ▶ **Hypospadias** (~1 in 300 boys): urethra opens on the ventral aspect of the penis or perineum due to failure of urethral-fold fusion; associated chordee and abnormal (dorsal-hooded) prepuce.
- ▶ **Epispadias** (~1 in 100,000 boys): urethra opens dorsally; part of the exstrophy-epispadias complex.
- ▶ **Posterior urethral valves** (1 in 5000–8000 males): commonest cause of neonatal urinary outflow obstruction; abnormal mesonephric duct migration leaves valve cusps caudal to the verumontanum.
- ▶ **Urethral calculi** most often impact at the sites of physiological narrowing — membranous urethra, bulbar urethra and external meatus.

High-yield exam pointers

- ▶ Total length 18–20 cm; anterior (spongy) ~15–16 cm, posterior (pelvic) ~4 cm.
- ▶ Widest/most dilatable part = prostatic urethra; narrowest = external urethral orifice; narrowest excluding EUO = membranous urethra (also least dilatable and shortest of the three posterior segments).
- ▶ Verumontanum bears the prostatic utricle (midline) flanked by the two ejaculatory duct openings — classic viva diagram.
- ▶ Two sphincter mechanisms: proximal/preprostatic (smooth muscle, sympathetic, prevents retrograde ejaculation) and distal/membranous (rhabdosphincter, somatic via pudendal nerve, main continence mechanism).
- ▶ Epithelium changes from transitional (proximal) → stratified/pseudostratified columnar (middle) → stratified squamous (navicular fossa/meatus) — mirrors developmental origin (urogenital sinus endoderm vs surface ectoderm).
- ▶ Bulbourethral (Cowper's) glands open into the bulbar urethra; glands of Littre are scattered along the whole length, most numerous in the penile urethra.
- ▶ Fall-astride injury → bulbar urethral rupture → urine extravasates anteriorly into scrotum/penis/abdominal wall (Colles' fascia plane); pelvic fracture → membranous urethral injury → extraperitoneal pelvic extravasation.
- ▶ Prostatic urethra supplied by inferior vesical artery branches; anterior urethra by the urethral artery and dorsal penile artery (both ultimately from internal pudendal artery).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 2 8e; AK Datta Human Anatomy Vol 1; IB Singh Textbook of Anatomy Vol 2 6e and Textbook of Human Histology 9e; Vishram Singh Textbook of Anatomy Vol 2 4e and General Anatomy 4e.



Pelvic brim

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The pelvic brim (**pelvic inlet**, superior aperture of the pelvis) is the oblique bony ring that marks the plane of transition between the abdominal cavity above and the true pelvic cavity below. It is formed posteriorly by the sacral promontory, on each side by the **linea terminalis**, and anteriorly by the upper margin of the pubic symphysis, and it divides the bony pelvis into the **greater (false) pelvis** above and the **lesser (true, obstetric) pelvis** below. Because its size, shape and diameters determine the adequacy of the maternal bony birth canal, the brim is the single most important landmark of clinical and radiological pelvimetry and a classic RGUHS gross-anatomy/applied-anatomy question.

Boundaries of the pelvic brim

Boundary	Structure(s)
Posteriorly	Sacral promontory and the anterolateral margin (ala) of the sacrum
On each side	Linea terminalis — continued anteriorly from the ala of the sacrum along the arcuate line of the ilium, over the iliopubic eminence , along the pecten pubis (pectineal line) and the pubic crest
Anteriorly	Upper margin of the pubic symphysis

- The brim is thus a continuous curved line, not a flat ring: sacral promontory → ala of sacrum → arcuate line → iliopubic eminence → pecten pubis → pubic crest → pubic symphysis, and the mirror image on the opposite side.
- The linea terminalis is also the dividing line used to define the greater and lesser pelvis (see below), and it is a useful surgical/radiological reference line on a plain pelvic radiograph.

Plane, inclination and shape

- The pelvic inlet lies in an **oblique plane**, inclined at about **50°–60° (mean ≈ 55°)** to the horizontal in the erect anatomical position — it faces more forwards than upwards.
- **Shape**: heart-shaped in the male, widest in its **posterior** part (because of the prominent sacral promontory encroaching from behind); oval/rounded in the female, and widest more **anteriorly** because the promontory projects less into the cavity.

□ Fig 29.7 — Shape of pelvic inlet in the male and in the female (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.459)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A superior (bird's-eye) view of the pelvic inlet, outlining the brim and labelling:

- ▶ Sacral promontory (posterior boundary)
- ▶ Ala of sacrum
- ▶ Arcuate line of the ilium
- ▶ Iliopubic eminence
- ▶ Pecten pubis (pectineal line)
- ▶ Pubic crest
- ▶ Upper border of pubic symphysis (anterior boundary)
- ▶ The three diameters drawn across the inlet — **anteroposterior**, **transverse**, and **(right/left) oblique**

Greater (false) and lesser (true) pelvis

- ▶ The plane of the pelvic brim is the **line of division** between the greater and lesser pelvis.
- ▶ **Greater (false) pelvis:** formed by the alae of the ilia and the base of the sacrum *above* the linea terminalis; it has little anterior wall and is really part of the abdominal cavity — it lodges the lower abdominal viscera (caecum, sigmoid colon, ileal loops) and, in later pregnancy, the enlarging gravid uterus.
- ▶ **Lesser (true/obstetric) pelvis:** the bony canal *below* the brim, bounded anteriorly by the pubic bones and symphysis, posteriorly by the sacrum and coccyx, and laterally by the ilium/ischium below the arcuate line. It contains the pelvic viscera (bladder, rectum, internal genital organs) and constitutes the fixed bony passage the fetal head must traverse in labour — hence "obstetric pelvis." The true pelvis is further subdivided into the **inlet (brim)**, the **cavity**, and the **outlet**.

Diameters of the pelvic inlet

Diameter	How measured	Male (mean)	Female (mean)
Anteroposterior (true/anatomical conjugate)	Midpoint of the sacral promontory to the upper border of the pubic symphysis	≈10 cm	≈11.2 cm
Transverse	Maximum distance between the two sides of the brim	≈12.5 cm	≈13.1 cm (widest diameter of the inlet)
Oblique (right and left)	Iliopubic eminence of one side to the opposite sacroiliac joint	≈12 cm	≈12.5 cm

□ Fig 13.13 — Diameters at the pelvic inlet (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.612)

- ▶ **Clinical (diagonal) conjugate:** the anatomical (true) conjugate cannot be palpated directly per vaginam, so obstetric practice uses the **diagonal conjugate** — from the lower border of the pubic symphysis to the sacral promontory — normally **≥11.5 cm**; the true conjugate is estimated by subtracting **1.5–2 cm** from it.

- All values vary with body size and racial group and are, on average, larger in the female because of the wider, shallower true pelvis needed for parturition.

Structures crossing the pelvic brim

Region of the brim	Structure(s) crossing it
In the midline, over the sacral promontory	Median sacral vessels (continuation of the aorta/vein)
Posterolaterally, over the ala of the sacrum/sacroiliac region	Sympathetic trunk (continuing as the pelvic part of the sympathetic chain); lumbosacral trunk (L4, L5), which lies on the ala of the sacrum and crosses the brim to join the ventral ramus of S1; obturator nerve ; iliolumbar vessels (ascending from the internal iliac vessels to the iliac fossa)
At the bifurcation of the common iliac artery	Internal iliac artery and vein , which cross the brim to descend into the true pelvis (the external iliac vessels continue along the brim, out of the pelvis, towards the thigh)
More anteriorly, over the external iliac vessels	Ureter (crosses the bifurcation of the common iliac artery/beginning of the external iliac artery to leave the abdomen and enter the true pelvis); gonadal vessels — ovarian vessels in the female, within the suspensory (infundibulopelvic) ligament; vas deferens in the male, or the round ligament of the uterus in the female

Applied / Clinical anatomy

- **Clinical pelvimetry** — external: interspinous diameter (between the anterior superior iliac spines, 22–25 cm), intercrystal diameter (widest distance between the iliac crests, 25–28 cm), and the external (Baudelocque's) conjugate (spine of S5 to upper border of pubic symphysis, ≥ 19 cm); internal (digital, per vaginam): the diagonal conjugate is the key measurement used to infer the true conjugate of the brim, as detailed above.
- **Classification of female pelvic brim shapes (Caldwell–Moloy)**: **gynaecoid** (heart-shaped, the "normal" obstetric pattern), **android** (triangular brim, male-type — poorer prognosis for vaginal delivery), **anthropoid** (oval, AP diameter greater than transverse), and **platypelloid** (flat, transverse diameter greater than AP — historically associated with rickets). The shape of the brim is assessed clinically and is central to predicting the course of labour.
- **Cephalopelvic disproportion / contracted pelvis**: a reduced true conjugate (clinically, a diagonal conjugate < 11.5 cm) or an android/platypelloid brim predisposes to obstructed labour; imaging (X-ray or CT pelvimetry) can quantify the inlet diameters when clinical pelvimetry is equivocal.
- **Referred pain**: the obturator nerve crosses the pelvic brim/lateral pelvic wall close to the ovary and to a pelvic (retrocaecal) appendix; inflammation of either (pelvic appendicitis, oophoritis) can irritate the nerve and produce referred pain along the medial side of the thigh.
- **Surgical/radiological landmark**: the point where the ureter crosses the pelvic brim, at the bifurcation of the common iliac artery, is the key landmark used to identify and safeguard the

ureter during pelvic and gynaecological surgery (hysterectomy, oophorectomy, ligation of the internal iliac artery for post-partum haemorrhage).

- ▶ **Pelvic ring fractures:** the linea terminalis forms part of the structural "ring" that transmits body weight from the sacrum through the acetabula to the lower limbs; high-energy antero-posterior compression or lateral compression injuries characteristically disrupt this ring, often at more than one point.

High-yield exam pointers

- ▶ Pelvic brim = pelvic inlet = superior aperture of the pelvis; boundaries — sacral promontory (posterior), linea terminalis on each side (ala of sacrum, arcuate line, iliopubic eminence, pecten pubis, pubic crest), upper border of pubic symphysis (anterior).
- ▶ Oblique plane, inclined 50° – 60° ($\approx 55^{\circ}$) to the horizontal.
- ▶ Divides the **greater/false pelvis** (part of the abdominal cavity) from the **lesser/true (obstetric) pelvis**.
- ▶ Shape: **heart-shaped**, widest posteriorly, in the male; **oval**, widest anteriorly, in the female.
- ▶ Diameters: AP/true conjugate ≈ 11.2 cm (F)/10 cm (M); transverse ≈ 13.1 cm (F, the widest); oblique ≈ 12.5 cm (F).
- ▶ Diagonal conjugate (clinical, per vaginam) ≥ 11.5 cm; true conjugate = diagonal conjugate – 1.5–2 cm.
- ▶ Female brim shapes (Caldwell–Moloy): gynaecoid, android, anthropoid, platypelloid.
- ▶ Structures crossing the brim: median sacral vessels, sympathetic trunk, lumbosacral trunk, iliolumbar vessels, obturator nerve, internal iliac vessels, ureter, and gonadal vessels with vas deferens (male)/round ligament (female).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; IB Singh — Textbook of Anatomy Vol 2, 6e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Moore's Clinically Oriented Anatomy, 9e.



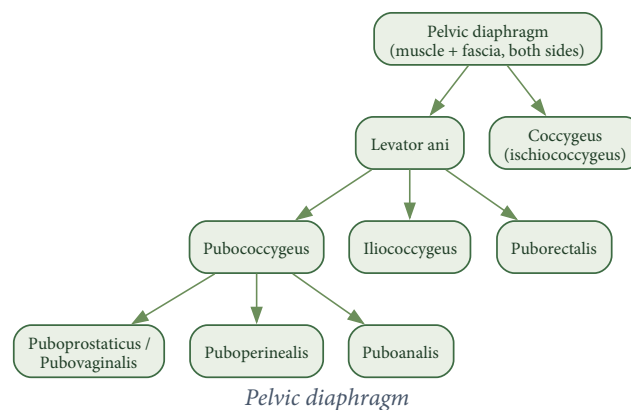
Pelvic diaphragm

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction The pelvic diaphragm is the musculofascial partition that forms the floor of the true (lesser) pelvis, separating the pelvic cavity above from the perineum below. Strictly, it comprises the **levator ani** and **coccygeus (ischiococcygeus)** muscles of both sides together with the fasciae that cover their superior (pelvic) and inferior (perineal) surfaces — muscle plus its two fascial coverings constitute the diaphragm proper. It is funnel- or hammock-shaped, sloping down and medially from the pelvic side walls toward the midline, where it is pierced by the urethra, the vagina (in the female) and the anal canal. Functionally it is the dynamic support of the pelvic viscera and a key component of urinary and faecal continence, making it one of the most clinically important muscular sheets in the body.

Formation, extent and morphology

- Formed on each side by the **levator ani** (large, anterior and more extensive) and **coccygeus** (small, posterior) together with their covering **superior and inferior pelvic diaphragmatic fascia**.
- The two muscles arise by a continuous linear origin from the **pelvic surface of the body of the pubis** anteriorly, along the **tendinous arch of levator ani** (arcus tendineus musculi levatoris ani — a condensation of obturator fascia) laterally, to the **ischial spine** posteriorly.
- Fibres slope downward, backward and medially, meeting fibres of the opposite side in the midline to create a gutter-shaped/hammock-like floor.
- The gap between the medial borders of the two levator ani and the ischiopubic rami is the **levator hiatus**; its part anterior to the perineal body (transmitting urethra and, in the female, vagina) is the **urogenital hiatus**. A second opening, the **hiatus rectalis** (between perineal body and anococcygeal raphe), transmits the anorectal junction.
- **Evolutionary/morphological note:** in quadrupeds these are tail-moving muscles (pubococcygeus pulls the tail forward; iliococcygeus and ischiococcygeus move it side to side). With loss of the tail and adoption of the erect posture in man, the same muscle sheet was redirected to support the pelvic viscera against gravity — hence the origin has shifted down onto the pelvic side wall, and the sacrospinous ligament is regarded as a degenerated aponeurotic remnant of coccygeus (the two are inversely developed).



□ Fig 31.16 — Superior view of the pelvic diaphragm (the levator ani and coccygeus) (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.484)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Inferior (perineal) view of the pelvic diaphragm, labelled with:

- ▶ **Pubococcygeus** (with its anterior sling around prostate/vagina)
- ▶ **Puborectalis** — sling behind the anorectal junction
- ▶ **Iliococcygeus**
- ▶ **Coccygeus (ischiococcygeus)** — posterior triangular muscle on the sacrospinous ligament
- ▶ **Tendinous arch of levator ani** (on obturator fascia)
- ▶ **Obturator internus and ischial spine**
- ▶ **Urogenital hiatus** (transmitting urethra ± vagina) and **hiatus rectalis** (anorectal junction)
- ▶ **Perineal body and anococcygeal ligament/raphe**
- ▶ **Pubic symphysis, coccyx, sacrospinous and sacrotuberous ligaments**

Levator ani — parts and attachments

Part	Origin	Insertion / course
Pubococcygeus (subdivided into puboperinealis, puboprostaticus/pubovaginalis, puboanal, and puborectalis)	Posterior aspect of the body of the pubis (anterior part of the linear origin)	Anterior fibres sling around the prostate (levator prostatae , male) or vagina (sphincter vaginae/pubovaginalis , female) and insert into the perineal body ; some fibres (puboanal) blend with the longitudinal muscle coat of the anal canal; posterior fibres pass to the anococcygeal ligament/raphe and tip of the coccyx
Puborectalis	Inner surface of the ischiopubic rami (adjacent to the perineal membrane); lies deep to pubococcygeus and is not visible from inside the pelvis	Fibres of the two sides form a U-shaped sling posterior to the anorectal junction, blending with the external anal sphincter and the longitudinal rectal coat
Iliococcygeus	Posterior part of the tendinous arch (obturator fascia) and the pelvic surface of the ischial spine	Anococcygeal raphe and the last two coccygeal segments

Coccygeus (ischiococcygeus)

- ▶ A small, triangular, partly muscular/partly tendinous sheet lying immediately **posterosuperior** to levator ani, on the pelvic aspect of the sacrospinous ligament (with which it may be fused).
- ▶ **Origin:** pelvic surface of the ischial spine and the sacrospinous ligament.
- ▶ **Insertion:** lateral margins of the coccyx and the lower (fifth) sacral segment.
- ▶ Represents the posterior, smaller part of the pelvic diaphragm.

Nerve supply

- ▶ **Levator ani** has a characteristic **dual supply**:

- ▶ From its **pelvic (superior) surface** — the **nerve to levator ani**, a direct branch chiefly from the **fourth sacral ventral ramus (S4)**, with a variable smaller contribution from S3 (some texts describe the perineal branch of S4 alone).
- ▶ From its **perineal (inferior) surface** — the **inferior rectal (perineal) branch of the pudendal nerve (S2–S4)**, supplying puborectalis/pubococcygeus from below.
- ▶ **Coccygeus** is supplied directly by the ventral rami of the **fourth and fifth sacral nerves (S4, S5)**.
- ▶ These are the "long muscular branches" of the sacral plexus to levator ani and coccygeus, distinct from the short twigs (S1, S2) supplying piriformis.

Relations

- ▶ **Superior (pelvic) surface:** covered by the **superior fascia of the pelvic diaphragm** (part of the parietal pelvic fascia); related to the urinary bladder, prostate (or uterus and vagina in the female), rectum, and pelvic peritoneum, separated from these viscera only by fascia (superior pelvic diaphragmatic, visceral and extraperitoneal fascia).
- ▶ **Inferior (perineal) surface:** covered by the thinner **inferior fascia of the pelvic diaphragm**; forms the medial wall of the **ischio-anal (ischioanal) fossa** and the roof of its anterior recess.
- ▶ **Anterior borders** of the two levator ani are separated by the urogenital hiatus, transmitting the urethra and, in females, the vagina.
- ▶ **Posterior border** is free and abuts the anterior margin of coccygeus, separated from the coccyx by areolar tissue.
- ▶ The combination of levator ani (muscle) plus its superior and inferior fascial coverings is, by definition, the **pelvic diaphragm**; the parietal pelvic fascia elsewhere continues as the obturator fascia (laterally) and the fascia over piriformis (posterolaterally).

Actions / Functions

- ▶ Together, the levatores ani and coccygei **close the posterior part of the pelvic outlet** and provide the principal **dynamic support of the pelvic viscera** against gravity and against raised intra-abdominal pressure (coughing, sneezing, lifting, straining).
- ▶ **Puborectalis** forms a sling that pulls the anorectal junction forward, maintaining the **anorectal angle** and preventing untimely descent of faeces — its tone is central to faecal continence.
- ▶ **Pubococcygeus/puboperinealis** fixes the perineal body and exerts a **sphincteric action** on the vagina (pubovaginalis) and urethra, contributing to urinary continence.
- ▶ During **micturition, defaecation and parturition**, the relevant pelvic outlet opens while contraction of the muscle around the other openings resists the raised intra-abdominal pressure and prevents prolapse through the pelvic floor.
- ▶ **Coccygeus** assists levator ani in visceral support and helps to draw the coccyx forward again after it is pushed back during defaecation or childbirth.
- ▶ Like the thoracic (abdomino-thoracic) diaphragm — but unlike the flat abdominal muscles — levator ani shows tonic activity and is also active in the **inspiratory phase of quiet respiration**, contracting together with the abdominal wall muscles and diaphragm to raise intra-abdominal pressure when needed.

- ▶ In pregnancy, the shape of the pelvic floor helps guide the descending fetal head into the antero-posterior diameter of the pelvic outlet during labour.

Applied / Clinical anatomy

- ▶ **Obstetric injury:** during vaginal childbirth the pelvic floor supports the fetal head while the cervix dilates; the perineum, levator ani (especially **pubococcygeus** and **puborectalis**, the most medial parts encircling urethra, vagina and anal canal) and the pelvic fascial ligaments may be overstretched or torn. This weakens support for the bladder, vagina, uterus and rectum, and can alter bladder-neck/urethral position.
- ▶ **Pelvic organ prolapse:** weakening of the diaphragm and its fascia (including tearing of the perineal body) permits descent/prolapse of the bladder (cystocele), urethra (urethrocele), uterus (uterine prolapse) or rectum (rectocele/rectal prolapse) through the urogenital or rectal hiatus.
- ▶ **Urinary and faecal incontinence:** stretching injury produces **stress urinary incontinence** (dribbling on coughing/lifting due to altered urethrovesical support), while tearing of puborectalis (loss of the anorectal angle) causes degrees of **faecal incontinence**.
- ▶ **Surgical division:** the iliococcygeal raphe posterior to the anorectal junction must be divided to permit wide excision of the anorectal canal during **abdominoperineal resection** for rectal malignancy.
- ▶ **Pudendal nerve block:** performed where the pudendal nerve crosses the lateral aspect of the sacrospinous ligament near the **ischial spine** — a bony landmark shared with the origin of coccygeus — to relieve perineal pain in the second stage of labour or for perineal surgery.
- ▶ **Kegel (pelvic floor) exercises:** voluntary, repeated contraction of the levator ani/perineal muscles (as taught antenatally, or via interrupting the urinary stream) is used to strengthen the pelvic diaphragm and reduce the risk of postpartum prolapse and stress incontinence, though efficacy evidence is debated.
- ▶ **Levator ani/coccygeal pain syndromes:** chronic spasm of levator ani (levator ani syndrome/proctalgia) is a recognised cause of chronic perineal/anorectal pain.

High-yield exam pointers

- ▶ Pelvic diaphragm = **levator ani + coccygeus** (both sides) + **their covering superior and inferior fasciae**; separates pelvic cavity from perineum.
- ▶ Levator ani parts, from behind forwards — mnemonic "**Could I Please Pee**": Coccygeus, Iliococcygeus, Puborectalis, Pubococcygeus.
- ▶ Continuous linear origin: **body of pubis** → **tendinous arch of levator ani (obturator fascia)** → **ischial spine**.
- ▶ Two openings: **urogenital hiatus** (urethra ± vagina, anterior) and **hiatus rectalis** (anorectal junction).
- ▶ Nerve supply of levator ani is **dual** — nerve to levator ani (S4, ± S3) from above, and inferior rectal/perineal branch of pudendal nerve (S2–S4) from below; **coccygeus by S4, S5** directly.
- ▶ **Puborectalis sling** → **anorectal angle** → **faecal continence**; pubovaginalis/puboperinealis → perineal body & vaginal/urethral support.

- ▶ Applied triad to remember: **obstetric tearing** → **prolapse/incontinence**; **iliococcygeal raphe** **divided in abdominoperineal resection**; **pudendal nerve block at the ischial spine**.
- ▶ Evolutionarily a tail-moving muscle group in quadrupeds, redirected to visceral support with erect posture in humans; sacrospinous ligament = degenerate coccygeus aponeurosis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore's Clinically Oriented Anatomy, 9e.



Perineal body

Asked in: Paper I Apr 2006 — RGUHS MD/MS Anatomy

Definition / Introduction

The perineal body (syn. central point of the perineum, central tendon of the perineum; Latin *centrum tendineum perinei*) is a fibromuscular node situated in the median plane at the junction between the urogenital triangle (anterior perineum) and the anal triangle (posterior perineum). Strictly, it is not a discrete anatomical "structure" but an aggregation of interlacing fibromuscular tissue formed by the convergence of about ten perineal and pelvic-floor muscles. It is the single most important point of structural support of the pelvic floor, particularly in the female, where its integrity is essential for supporting the vagina, uterus, bladder and rectum.

Location and surface anatomy

- ▶ Corresponds to the midpoint of the line joining the two ischial tuberosities — the **central point of the perineum**.
- ▶ Lies about **1.25 cm (½ inch) anterior to the anal margin**.
- ▶ In the **male**: lies close to the bulb of the penis, deep to the scrotal (perineal) raphe.
- ▶ In the **female**: lies posterior to the vestibule of the vagina/lower vaginal wall, close to the posterior wall of the vestibule, and is overlaid by the **posterior commissure of the labia majora**.
- ▶ The distance between the posterior vulval commissure and the anus (2.5–3 cm) is termed the "**gynaecological perineum**", and its floor is essentially the perineal body.
- ▶ It is deep to the skin with relatively little intervening subcutaneous tissue; the skin over it is characteristically puckered, being tethered to it via the superficial perineal (Colles') fascia.

Shape, composition and relations

- ▶ Described as a **wedge-shaped/pyramidal fibromuscular node** (Vishram Singh, IB Singh) — an irregular mass, variable in size and consistency, containing collagenous and elastic fibres together with both skeletal and smooth muscle (Moore).
- ▶ Its **apex** (superior end) receives the attachment of the recto-vesical (male)/recto-vaginal (female) septum.
- ▶ **Anteriorly**: continuous with the posterior border of the **perineal membrane**.

- **Posterolaterally**: continuous with the **superficial perineal fascia**, which in turn runs forward into the skin (perineal raphe in the male scrotum; posterior labial commissure in the female).
- **Posteriorly**: merges with fibres of the anterior part of the external anal sphincter and, deeper, receives the **rectourethralis** — a Y-shaped slip of the outer longitudinal rectal muscle coat that inserts into the perineal body at the anorectal junction.
- **Superiorly**: continuous with the recto-vesical/recto-vaginal septum and, through it, with the pelvic fascia.

Development

- Forms at the site where the **urorectal septum** meets the cloacal membrane during partitioning of the cloaca.
- This division produces a dorsal ano-rectal canal and a ventral urogenital sinus, splitting the cloacal membrane into anal and urogenital parts; the **nodal centre of this division becomes the site of the future perineal body**.

Muscles converging in the perineal body

About ten muscle slips interlace here — remembered by the mnemonic **BELT**:

Group	Muscle	Number	Remarks
B	Bulbospongiosus	Paired (2)	Fibres decussate in the perineal body; in the female it arises <i>only</i> from the perineal body
E	External anal sphincter (subcutaneous + superficial parts)	Unpaired	Anterior fibres attach here; posteriorly to the anococcygeal ligament
L	Levator ani (pubococcygeus fibres — pubovaginalis/levator prostatae)	Paired (2)	Fixes the perineal body; along with EAS, maintains pelvic-floor integrity
L	Longitudinal muscle coat of the anal canal (incl. rectourethralis slip)	Unpaired	Smooth-muscle continuation from the rectal wall
T	Superficial transverse perinei	Paired (2)	Run from ischial tuberosity to perineal body
T	Deep transverse perinei	Paired (2)	Deep to the above; decussate with contralateral fibres and with sphincter urethrae

Additional female-specific attachment: the **sphincter urethrovaginalis** arises from the perineal body and passes forward on either side of the urethra/vagina.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 15.15 — ■ Perineal body. Note various muscles (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.667)

Reproduce by hand with these exact labels (median/inferior view of the perineum):

- ▶ Perineal body (centre, labelled as the node of convergence)
- ▶ External anal sphincter (converging posteriorly)
- ▶ Levator ani (pubococcygeus fibres, converging from either side)
- ▶ Bulbospongiosus (converging anteriorly)
- ▶ Superficial transverse perineal muscle (from each ischial tuberosity)
- ▶ Deep transverse perineal muscle (deep to the above, from ischiopubic ramus)
- ▶ Longitudinal muscle coat of anal canal / rectourethralis
- ▶ Perineal membrane (anterior boundary)
- ▶ Ischial tuberosity and ischiopubic ramus (bony landmarks)
- ▶ Anus and vaginal orifice/bulb of penis (adjacent viscera, for orientation)

Blood supply and nerve supply

- ▶ **Artery:** perineal artery, a branch of the **internal pudendal artery**; its transverse branch supplies the transverse perinei, the perineal body and the posterior attachment of the bulb of the penis/vestibule, anastomosing with the contralateral vessel and with posterior scrotal/labial and inferior rectal arteries.
- ▶ **Vein:** perineal veins draining into the internal pudendal vein.
- ▶ **Nerve:** perineal branch of the pudendal nerve (S2–S4) supplies motor fibres to all muscles converging on it.
- ▶ **Lymphatics:** skin and superficial tissue over the perineal body drain to the **superficial inguinal lymph nodes**.

Sex differences

Feature	Male	Female
Related structure anteriorly	Bulb of the penis	Vestibule of vagina / lower vaginal wall
Overlying skin	Perineal raphe (continuous with scrotal raphe)	Posterior commissure of labia majora
Bulbospongiosus	Single muscle in midline, median raphe	Two separate muscles, each from perineal body, embracing vaginal orifice
Extra muscular attachment	—	Sphincter urethrovaginalis
Clinical vulnerability	Rare direct trauma	High — obstetric tears, episiotomy

Applied / Clinical anatomy

- ▶ **Obstetric support:** in the female, the perineal body maintains integrity of the pelvic diaphragm and supports the uterus, bladder and rectum; stimulation of the perineal body causes the pelvic floor as a whole to contract.
- ▶ **Perineal tears:** during a difficult/precipitate second stage of labour, if the foetal head is too large for the vagina to stretch around, the perineal body and overlying skin tear; spontaneous lacerations are often associated with damage to the anterior fibres of the external anal sphincter (obstetric anal sphincter injury).
- ▶ **Episiotomy** — a deliberate incision to enlarge the vaginal orifice and prevent irregular tears:
 - *Median (midline) episiotomy:* begins at the fourchette/frenulum of labia minora and extends posteriorly in the midline towards the external anal sphincter; cuts skin, vaginal wall, perineal body and superficial transverse perinei; may inadvertently extend into the external anal sphincter/anal canal (higher risk of 3rd/4th-degree tear).
 - *Mediolateral episiotomy:* begins at the fourchette and is directed postero-laterally at ~45°; cuts skin, vaginal wall and bulbospongiosus, deliberately angled away from the anal sphincter to avoid sphincteric injury.
- ▶ **Unrepaired/mal-repaired damage:** widens the urogenital hiatus, allowing pelvic viscera to descend — leading to **prolapse of the uterus, bladder (cystocele) and rectum (rectocele)**.
- ▶ **Perineorrhaphy/perineoplasty:** surgical reconstruction of a torn or deficient perineal body, performed to restore pelvic-floor support and correct symptomatic prolapse.
- ▶ **Digital examination:** the perineal body is readily palpable per vaginam/per rectum between the vaginal orifice and the anus, and is used clinically to assess perineal integrity and pelvic-floor tone.
- ▶ **Imaging landmark:** used to position radiological markers in defecography and dynamic MRI/ultrasound assessment of pelvic-floor dysfunction.
- ▶ **Surgical landmark:** important relation during perineal prostatectomy and posterior perineal/anorectal dissections because of its intimate continuity with the rectourethralis and external anal sphincter — injudicious dissection risks a recto-urethral fistula.

High-yield exam pointers

- ▶ Perineal body = central point of the perineum = central tendon of the perineum; midpoint of the inter-ischial-tuberosity line, ~1.25 cm anterior to the anus.
- ▶ Not a discrete structure — an aggregation of interlacing fibromuscular tissue; developmentally marks the site of urorectal septum fusion with the cloacal membrane.
- ▶ Ten muscles converge — mnemonic **BELT** (Bulbospongiosus, External anal sphincter, Levator ani + longitudinal anal coat, Transverse perinei — superficial and deep).
- ▶ Blood supply: perineal artery (branch of internal pudendal artery); nerve supply: perineal nerve (branch of pudendal nerve, S2–S4).
- ▶ "Gynaecological perineum" = 2.5–3 cm distance between posterior vulva and anus, whose base is the perineal body.

- ▶ Clinically the single most important perineal structure in obstetrics — damaged in perineal tears/episiotomy; unrepaired damage → uterine/bladder/rectal prolapse.
- ▶ Median episiotomy cuts the perineal body directly (higher sphincter-injury risk); mediolateral episiotomy is angled away from it to protect the anal sphincter.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 8e; Vishram Singh — Textbook of Anatomy Vol 2 4e; Moore's Clinically Oriented Anatomy 9e; IB Singh — Textbook of Anatomy Vol 2 6e.



Prostatic venous plexus

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

Definition / Introduction — The prostatic venous plexus is a rich, plexiform network of valveless veins that surrounds the prostate on its anterior, lateral and basal aspects, lying within the fibrous sheath of the gland between its true (fibromuscular) capsule and false (fascial) capsule. Its anterior, prepubic part — the largest confluence, receiving the deep dorsal vein of the penis — is also called the **plexus of Santorini**, clinically termed the **dorsal vascular (venous) complex (DVC)**. The plexus is functionally part of the pelvic (vesicoprostatic) venous plexus and is of outsized clinical importance: it is the principal source of haemorrhage in radical prostatectomy, and — through its valveless communication with the vertebral venous plexus of Batson — the classical route by which prostatic carcinoma metastasises to the vertebral column and skull.

Extent, situation and relations

- ▶ Lies **between the true capsule** (condensed peripheral stroma of the gland) **and the false capsule** (derived from the endopelvic/pelvic fascia) — on each side the plexus is sandwiched in this interval, so that when an enlarged adenoma is enucleated (retropubic prostatectomy), both capsules — and the venous plexus lying between them — are deliberately left behind in the patient.
- ▶ **Anteriorly**, the plexus (Santorini's plexus / DVC) intervenes between the anterior surface of the prostate and the back of the pubic symphysis and pubic arch, separated from bone by loose retropubic fat; this interval is the **retropubic space of Retzius**. Superiorly it is related to the puboprostatic ligaments, which anchor the false capsule to the pubis.
- ▶ **At the base**, venules of the plexus lodge in the circular groove marking the junction of the prostatic base with the bladder neck.
- ▶ **Laterally**, the plexus separates the prostate from the pubourethral (anterior) fibres of levator ani that sling around the gland.
- ▶ **Posteriorly**, the plane between prostate and rectum (fascia of Denonvilliers, the obliterated recto-vesical pouch) is comparatively avascular — the plexus is thin here, which is why the posterior/perineal surgical planes bleed far less than the anterior one.

Formation and tributaries

Tributary	Course / notes
Deep dorsal vein of the penis (chief tributary)	Runs in the midline groove between the corpora cavernosa, passes beneath the arcuate pubic ligament below the symphysis, and divides into two (occasionally more) divisions that fan out into the plexus in the angle between bladder and prostate
Circumflex and cavernous (emissary) veins	Drain the corpora cavernosa and corpus spongiosum into the deep dorsal vein before it joins the plexus
Anterior vesical veins (rami)	Small venous rami connecting the plexus with the vesical venous plexus
Capsular (prostatic) veins	Drain the substance of the gland itself, corresponding to the subcapsular arterial plexus supplying the prostate

- The plexus communicates freely on each side with the **vesical venous plexus** and with the **internal pudendal vein**.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

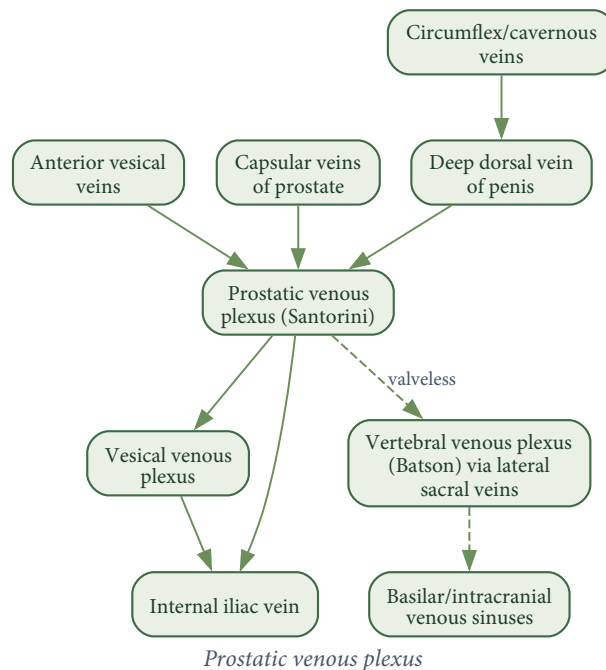
□ Fig 32.9 — Ligaments and venous plexus of prostate gland (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.498)

Sagittal/coronal schematic — label: pubic symphysis; retropubic (Retzius) space; puboprostatic ligament; true capsule; false capsule; prostatic venous plexus (between the two capsules); deep dorsal vein of penis entering the plexus; urinary bladder and bladder neck; prostate; membranous urethra; pubourethral part of levator ani; vesical venous plexus continuing into internal iliac vein.

Drainage

- The plexus drains chiefly into the **vesical venous plexus**, and, together with direct prostatic tributaries, empties into the **internal iliac (hypogastric) veins**.
- A minor pathway runs alongside the inferior vesical vessels to reinforce the vesical plexus before common termination in the internal iliac vein.

Communications and their significance



Communication	Route	Clinical significance
Vesical venous plexus	Anterior vesical rami	Common termination pathway into internal iliac vein
Internal pudendal vein	Direct anastomosis	Alternative outflow; relevant to penile venous surgery
Vertebral venous plexus (Batson's plexus)	Via lateral sacral veins traversing the ventral sacral foramina into the internal (epidural) vertebral plexus	Valveless, bidirectional — the classical route of spread of prostatic carcinoma to lumbar vertebrae, and thence, via the valveless vertebral system, upward to the skull and basilar venous sinuses, producing cranial/cerebral secondaries without antecedent pulmonary metastasis
Superficial dorsal vein → great saphenous vein	Via superficial external pudendal veins (superficial to Buck's fascia)	Anastomotic escape route independent of the deep (prostatic) system

- Because the plexus and the vertebral venous system are **valveless**, a rise in intra-abdominal/intrathoracic pressure (coughing, straining, defecation) can reverse flow and drive tumour emboli or infected material from the pelvis into the vertebral column — the same mechanism explains spread of pelvic sepsis and, conversely, spinal tuberculosis seeding from a pelvic focus.

Applied / Clinical anatomy

- **Metastatic spread of carcinoma prostate:** malignant cells shed into the prostatic venous plexus reach the internal iliac veins directly, and separately ascend via the valveless connections through

the ventral sacral foramina into Batson's vertebral venous plexus, producing early osteoblastic secondaries in the lumbar vertebrae, pelvis and skull — classically presenting as low backache or sciatica in an elderly man, sometimes before urinary symptoms dominate. Because this route bypasses the pulmonary capillary filter, cerebral and calvarial metastases can occur without lung involvement.

- ▶ **Radical prostatectomy (open retropubic or robot-assisted laparoscopic):** the anterior dorsal vascular complex (Santorini's plexus) overlying the prostatic apex and anterior bladder neck is the single most important source of intra-operative haemorrhage; a key operative step is early suture-ligation (or stapling) of the DVC before the urethra and prostatic apex are divided, both to control bleeding and to protect the external urethral sphincter and the postero-lateral neurovascular bundles that carry the cavernous nerves.
- ▶ **Retropubic enucleation of benign prostatic adenoma (Millin's operation):** the plane of cleavage lies within the surgical (adenomatous) capsule; the true and false capsules, with the venous plexus sandwiched between them, are deliberately left behind — haemostasis is secured by trigone-to-capsule mucosal sutures rather than by excising the plexus.
- ▶ **Transurethral resection of the prostate (TURP):** resection through a vascular adenoma opens prostatic venous sinuses, permitting systemic absorption of hypotonic irrigant — the basis of dilutional hyponatraemia in the "TURP syndrome."
- ▶ **Retropubic space of Retzius:** the extraperitoneal space anterior to the plexus is the surgical corridor for retropubic prostatectomy, bladder-neck suspension procedures, and is also the site into which extraperitoneal bladder rupture (e.g. pelvic fracture) tracks, explaining peri-vesical/peri-prostatic urinary extravasation.
- ▶ **Per-rectal examination and transrectal prostatic biopsy:** an engorged plexus in an inflamed or malignant prostate can bleed with vigorous palpation or needle biopsy.

High-yield exam pointers

- ▶ Prostatic venous plexus lies **between the true and false capsules** of the prostate — left behind, together with the capsules, on enucleation of a BPH adenoma.
- ▶ **Chief tributary = deep dorsal vein of the penis**, which divides into two as it enters the plexus in the angle between bladder and prostate.
- ▶ Anterior/prepubic part = **plexus of Santorini = dorsal vascular complex (DVC)** — key structure ligated early in radical prostatectomy to control bleeding.
- ▶ Anteriorly separated from the pubic symphysis by the **retropubic space of Retzius**.
- ▶ Drains into the **vesical venous plexus and internal iliac veins**.
- ▶ **Valveless communication with the vertebral venous plexus (Batson)** via lateral sacral veins through the ventral sacral foramina — the classical route for skeletal (vertebral, skull) and cerebral metastasis from carcinoma prostate, independent of the lung.
- ▶ Communicates also with the internal pudendal vein and, via the superficial dorsal vein, with the great saphenous system.
- ▶ Clinically central to three surgeries: radical prostatectomy (DVC control), retropubic prostatectomy (capsule-plexus left in situ), and TURP (venous sinus opening → TURP syndrome).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 2 (8e).



Pudendal canal

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction — The pudendal canal (Alcock's canal) is a horizontal fascial tunnel in the lateral wall of the ischioanal (ischiorectal) fossa that transmits the pudendal nerve and the internal pudendal vessels — the chief neurovascular bundle of the perineum — from the gluteal region into the perineum. It is named after Benjamin Alcock, the 19th-century Irish anatomist who first described it. Clinically it is the anatomical basis of the pudendal nerve block and of pudendal (Alcock's canal) neuralgia, and it is a key surgical landmark in perineal and anorectal dissection.

1. Location and formation

- ▶ Lies in the lateral wall of the ischioanal (ischiorectal) fossa, about 2.5 cm (1 inch) above the ischial tuberosity.
- ▶ Formed by a **splitting of the obturator fascia** that covers the medial surface of obturator internus — the two laminae enclose the neurovascular bundle; alternatively described as being formed by **separation between the obturator fascia and the lunate (falciform) fascia** of the fossa.
- ▶ Essentially it is a condensation/duplication of the obturator fascia binding the internal pudendal vessels and pudendal nerve to the fascia over obturator internus (Gray's Anatomy 41e).
- ▶ Runs an essentially **horizontal** course, unlike the vertically oriented ischioanal fossa itself.

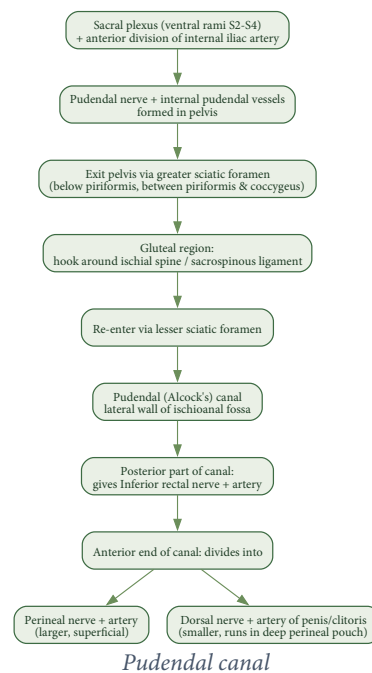
2. Extent and boundaries

Feature	Description
Posterior limit	Lesser sciatic foramen (below the ischial spine), where the bundle re-enters the perineum from the gluteal region
Anterior limit	Posterior border of the perineal membrane / posterior limit of the deep perineal pouch
Lateral wall	Obturator internus muscle and the obturator fascia covering it
Medial wall	The fascia forms a septum with the perianal fascia, separating the canal from the ischiorectal fat pad of the fossa
Roof (upper part)	Continuous above with the lunate (fascia lunata), which arches over the ischiorectal fat as the "tegumentum"

3. Course of the pudendal nerve and internal pudendal vessels

The pudendal canal is only the perineal segment of a longer neurovascular pathway; the full course is asked together in most exam answers.

- **Origin:** pudendal nerve arises from the ventral rami of **S2, S3, S4** on the sacral plexus, within the pelvis; the internal pudendal artery is the smaller terminal branch of the anterior division of the internal iliac artery.
- **Exit from pelvis:** both leave through the **greater sciatic foramen**, below piriformis and between piriformis and coccygeus — the nerve lying **medial** to the vessels.
- **Gluteal region:** the bundle hooks around the **ischial spine / sacrospinous ligament** (dorsal aspect), covered by gluteus maximus; here the nerve of obturator internus lies lateral to the vessels and the pudendal nerve medial to them.
- **Re-entry into perineum:** through the **lesser sciatic foramen** to enter the pudendal canal in the lateral wall of the ischioanal fossa.
- **Within the canal:** gives off the **inferior rectal nerve and artery** in the **posterior part**, then continues forward to terminate by dividing into the **perineal nerve/artery** and the **dorsal nerve/artery of the penis or clitoris** near the **anterior end** of the canal.



4. Contents of the pudendal canal

Structure	Detail within the canal
Pudendal nerve (S2–S4)	Chief nerve of the perineum; in the posterior part gives off the inferior rectal nerve, then divides into the perineal nerve (larger terminal branch) and the dorsal nerve of the penis/clitoris (smaller terminal branch), the latter running above the vessels

Structure	Detail within the canal
Internal pudendal artery	Larger in the male; gives off the inferior rectal artery early in the canal, then the perineal artery near the anterior end, and continues beyond the canal as the artery of the penis/clitoris (common penile/clitoral artery)
Internal pudendal vein(s)	Venae comitantes accompanying the artery; tributaries mirror the arterial branches and drain ultimately into the internal iliac vein
Nerve to obturator internus	Accompanies the bundle as it enters the canal at the lesser sciatic notch before leaving to supply obturator internus (noted in Moore's Clinically Oriented Anatomy and Gray's Anatomy)

□ Fig 15.15 — Section through the ischioanal fossa and the pudendal canal (IB Singh — Textbook of Anatomy Vol 2 — 6e, p.201)

□ Fig 15.22 — Course and branches of the pudendal nerve. (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.677)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section through the anal triangle at the level of the ischioanal fossa — label:

- ▶ Anal canal (centre) with external anal sphincter
- ▶ Levator ani forming the medial wall/roof of the fossa
- ▶ Ischioanal (ischioanal) pad of fat filling the fossa
- ▶ Lunate fascia arching over the fat as the tegmentum, separating supra-tegmental space above from the tegmental (ischioanal) space below
- ▶ Obturator internus muscle and its covering obturator fascia forming the lateral wall
- ▶ **Pudendal (Alcock's) canal** in the split obturator fascia of the lateral wall, containing (from above down or side by side): internal pudendal vein, internal pudendal artery, pudendal nerve
- ▶ Perianal fascia and perianal space medial to the canal
- ▶ Ischial tuberosity below, marking the ~2.5 cm reference point for the canal

Applied / Clinical anatomy

- ▶ **Pudendal nerve block:** the nerve is anaesthetised as it hooks around the **ischial spine**, using a transvaginal (finger-guided, e.g., Kobak needle) or transperineal approach; it anaesthetises the S2–S4 dermatomes of the perineum and the inferior quarter of the vagina, used for episiotomy, perineal repair, and instrumental (forceps/vacuum) delivery. It does **not** block pain from the superior birth canal (uterine contractions), which travels with visceral afferents to higher segments.
- ▶ **Pudendal (Alcock's) canal syndrome / pudendal neuralgia:** entrapment/compression of the nerve within the fascial canal produces chronic perianal and perineal pain, classically worse on sitting and relieved by standing; recognised after prolonged cycling, pelvic trauma, or pelvic floor surgery, and treated by nerve block or surgical decompression of the canal.

- ▶ **Stretch injury in childbirth:** traction of the pudendal nerve over the ischial spine and sacrospinous ligament during prolonged/traumatic vaginal delivery can cause pudendal neuropathy, contributing to anorectal and stress urinary incontinence.
- ▶ **Spread of anorectal sepsis:** the inferior rectal vessels and nerve cross the ischioanal fossa from the pudendal canal; ischiorectal abscesses arising in the fossa can track along fascial planes related to the canal and may burst on either side of the anal canal to form a **horseshoe abscess/fistula-in-ano**.
- ▶ **Surgical landmark:** the ischial spine — the point at which the neurovascular bundle hooks into the lesser sciatic foramen to enter the canal — is an important landmark in sacrospinous ligament fixation for pelvic organ prolapse, where the pudendal vessels/nerve are at risk of injury.

High-yield exam pointers

- ▶ Pudendal canal = **Alcock's canal**; fascial tunnel formed by splitting of the **obturator fascia** in the lateral wall of the ischioanal fossa.
- ▶ Located about **2.5 cm (1 inch)** above the **ischial tuberosity**.
- ▶ Extends from the **lesser sciatic foramen** (posteriorly) to the **posterior border of the perineal membrane** (anteriorly).
- ▶ Contains the **pudendal nerve (S2–S4)** and the **internal pudendal artery and vein** — the chief neurovascular bundle of the perineum.
- ▶ Order of branching within the canal: **inferior rectal** nerve/artery (posterior part) → terminal division into **perineal** and **dorsal (penile/clitoral)** branches (anterior end).
- ▶ Nerve to obturator internus accompanies the bundle only at the canal's entrance.
- ▶ Basis of the **pudendal nerve block** (landmark: ischial spine) used in obstetric anaesthesia.
- ▶ Applied importance: pudendal (Alcock's canal) neuralgia, childbirth-related pudendal neuropathy/incontinence, and spread of ischiorectal sepsis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh's Textbook of Anatomy Vol 2 4e; IB Singh's Textbook of Anatomy Vol 2 6e; Moore's Clinically Oriented Anatomy 9e.

Coverage note: this topic is classified under Neuroanatomy in the spec, but the neuroanatomy specialty texts (Snell, Vishram Singh Clinical Neuroanatomy, IB Singh Human Neuroanatomy) carry no dedicated coverage of the pudendal canal — it is conventionally taught in the Gross Anatomy "Perineum" chapters. Content above is therefore drawn from Gray's Anatomy (spine) and the gross-anatomy perineum chapters of BD Chaurasia, Vishram Singh, IB Singh and Moore, all of which describe the canal consistently.



Sphincters of the anal canal

Asked in: Paper I Nov 2016 — RGUHS MD/MS Anatomy

Definition / Introduction The anal canal is the terminal 3.8 cm part of the large intestine, lying in the anal triangle of the perineum between the two ischiorectal fossae, distal to the anorectal junction. Unlike the rectum, it has no sacculations, teniae coli or appendices epiploicae, and is kept habitually closed by two concentric muscular tubes — an inner **involuntary internal anal sphincter** (smooth muscle) and an outer **voluntary external anal sphincter** (striated muscle) — reinforced above by the puborectalis sling of levator ani. Together these, with the intervening conjoint longitudinal coat, constitute the **anal sphincter complex**, the anatomical basis of faecal continence and defaecation.

Extent and key landmarks of the anal canal

- Begins at the **anorectal junction** (surrounded by puborectalis, producing a 90° forward perineal flexure) and passes downward and backward to the **anal orifice**, about 4 cm below and in front of the tip of the coccyx.
- Relations: **anteriorly** — perineal body, bulb of penis/spongy urethra (male) or lower vagina (female); **posteriorly** — anococcygeal raphe and coccyx; **laterally** — ischiorectal fossae.
- The **pectinate (dentate) line**, marked by the anal valves, divides the canal into an upper (endodermal, hindgut) and lower (ectodermal, proctodeum) part — the embryological site of the former anal membrane and the "watershed line" of the canal.

Feature	Upper anal canal	Lower anal canal
Development	Endoderm of hindgut	Ectoderm of proctodeum
Epithelium	Simple columnar	Non-keratinized stratified squamous → keratinized skin
Innervation	Autonomic — insensitive to pain/temperature	Somatic — sensitive to pain/temperature
Arterial supply	Superior rectal artery	Inferior rectal artery
Venous drainage	Superior rectal vein → portal system	Inferior rectal vein → caval system
Lymphatic drainage	Internal iliac nodes	Superficial inguinal nodes (horizontal group)
Haemorrhoids	Internal (painless)	External (painful)

- Upper part shows **anal columns of Morgagni** (6–10 permanent mucosal folds containing radicles of the superior rectal vein), **anal valves** (crescentic folds joining the lower ends of adjacent columns — their scalloped line of attachment is the pectinate line) and **anal sinuses**, into whose floor the anal glands open.
- The lower part is subdivided by **Hilton's white line** (the intersphincteric groove, at the junction of the subcutaneous external sphincter and the lower end of the internal sphincter) into an upper "pecten" (bluish, non-keratinized squamous epithelium, adherent to underlying tissue) and a lower skin-lined zone bearing sweat/sebaceous glands and, in males, coarse hair.

Internal anal sphincter (IAS)

- ▶ A specialised, thickened, white continuation of the **inner circular smooth-muscle coat** of the gut, surrounding the **upper two-thirds** of the anal canal.
- ▶ Continuous above with the circular muscle of the rectum; ends below at the level of the **white line of Hilton**, corresponding to the proximal limit of the subcutaneous part of the external sphincter.
- ▶ Surrounded externally by the deep and superficial parts of the external anal sphincter (skeletal muscle).
- ▶ **Involuntary**: tonically contracted at rest; relaxes reflexly on rectal distension (**recto-anal inhibitory reflex**, mediated chiefly through the enteric nervous system) and during postprandial rectal contractions (the "sampling" reflex), permitting rectal contents to reach the sensitive upper anal mucosa while the external sphincter maintains continence.
- ▶ **Nerve supply**: sympathetic fibres (upper lumbar segments, via the hypogastric plexus) → **contraction** (α -adrenergic); parasympathetic fibres (S2–S4, via the inferior hypogastric plexus) → **relaxation** (cholinergic-muscarinic). Nitroergic fibres also mediate relaxation — the rationale for topical nitroglycerine in conditions of raised resting anal tone (e.g. chronic anal fissure). Blood supply: terminal branches of the superior and inferior rectal vessels.
- ▶ Thicker in males and in chronic constipation; congenital failure of relaxation (absent recto-anal inhibitory reflex, aganglionic segment) underlies Hirschsprung's disease.

External anal sphincter (EAS)

- ▶ A band of **striated (voluntary) muscle** surrounding the **entire length** of the anal canal, forming the bulk of the sphincter complex, lying outside the internal sphincter.
- ▶ **Classical description — three parts** (still asked in exams):
- ▶ **Deep part** — surrounds the upper part of the internal sphincter; no bony attachment; blends posteriorly with **puborectalis** to form a sling around the anorectal junction, attached anteriorly to the pubis — this sling accentuates the anorectal angle and is central to continence.
- ▶ **Superficial part** — elliptical; arises from the tip of the coccyx and anococcygeal raphe, surrounds the lower internal sphincter, and inserts into the perineal body anteriorly.
- ▶ **Subcutaneous part** — a flat band (~15 mm broad), lying in the perianal space below the internal sphincter, with no bony attachment; traversed by fibroelastic septa from the conjoint longitudinal coat.
- ▶ **Modern concept (Gray's Anatomy, 41e)**: the classical three-part division is no longer considered anatomically valid — the EAS is now regarded as a **single functional entity** of slow-twitch fibres adapted for sustained tonic contraction, with its upper fibres blending with puborectalis and its lower fibres traversed by the terminal fibres of the conjoint longitudinal muscle.
- ▶ **Nerve supply**: the **inferior rectal nerve** (pudendal nerve, S2–S4) and the **perineal branch of S4**; the upper part may also receive fibres from the nerve to levator ani. Being striated muscle it is under **voluntary** control, though also tonically active at rest (postural reflex). Blood supply: inferior rectal vessels, with a small contribution from the median sacral artery.

Conjoint longitudinal muscle and the anorectal ring

□ Fig 28.5 — The external and internal anal sphincters (BD Chaurasia — Human Anatomy Vol 2 — 8e, p.440)

- ▶ The **conjoint longitudinal muscle (coat)** is formed at the anorectal junction by the fusion of the outer longitudinal smooth muscle of the rectum with striated fibres from **puborectalis** (levator ani) — hence "conjoint" (smooth + striated).
- ▶ It descends vertically **between the internal and external anal sphincters**; at the level of the white line of Hilton it breaks up into fibroelastic septa that fan out through the subcutaneous part of the external sphincter to attach to the perianal skin (via the **corrugator cutis ani**).
 - The most lateral septum forms the **perianal fascia**, passing laterally to the obturator fascia (forming the medial wall of the pudendal canal).
 - The most medial septum forms the **anal intermuscular septum**, attaching to Hilton's line.
- ▶ Functionally, its contraction during defaecation **shortens and widens** the anal canal, everts the anal orifice, and flattens the anal cushions; it relaxes afterwards, allowing the canal to re-elongate.
- ▶ The **anorectal ring** is the palpable muscular ring at the anorectal junction, about 2.5 cm (1 inch) above the anal margin, felt as a distinct thickening by the flexed finger on per-rectal examination. It is formed by fusion of the **deep external sphincter, the internal sphincter, and puborectalis**. Surgical division (e.g. an over-zealous fistulotomy) causes **faecal incontinence** — its preservation is a cardinal principle in anorectal surgery.
- ▶ Related surgical spaces: paired **ischiorectal fossae** (fat-filled, lateral to the canal); **perianal space** (below Hilton's line, between perianal fascia and skin — contains subcutaneous EAS, fat, external rectal plexus, terminal inferior rectal vessels/nerve; site of perianal abscess); **submucous space** (above Hilton's line, between mucosa and IAS, containing the internal rectal venous plexus).

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section through the anal canal — label: rectal ampulla/anorectal junction; internal anal sphincter (upper two-thirds); external anal sphincter — deep part (fused with puborectalis sling), superficial part (coccyx/anococcygeal raphe to perineal body), subcutaneous part (perianal space); conjoint longitudinal muscle (between the two sphincters) with its fibroelastic septa (perianal fascia, anal intermuscular septum); anorectal ring; white line of Hilton (intersphincteric groove); pectinate/dentate line with anal columns, anal valves and anal sinuses above it; levator ani (puborectalis); ischiorectal fossa (each side); perianal space and submucous space; perineal body.

Nerve supply and the continence mechanism

Feature	Internal anal sphincter	External anal sphincter
Muscle type	Smooth (involuntary)	Striated (voluntary)
Continuity	Circular smooth-muscle coat of rectum	Puborectalis / levator ani (deep part)
Extent	Upper two-thirds of canal, to Hilton's line	Entire length of canal

Feature	Internal anal sphincter	External anal sphincter
Sympathetic supply	Upper lumbar segments (hypogastric plexus) → contraction	—
Parasympathetic/nitrergic supply	S2–S4 (inferior hypogastric plexus) and nitrergic fibres → relaxation	—
Somatic supply	—	Inferior rectal nerve + perineal branch of S4 (pudendal nerve, S2–S4)
Key reflex	Recto-anal inhibitory reflex (relaxes on rectal distension)	Voluntary contraction; "closing reflex" after defaecation

- ▶ **Resting continence:** tone derives mainly from sympathetically-mediated IAS contraction, augmented by tonic EAS contraction (postural reflex); anal cushions add a hydraulic seal.
- ▶ **Sampling:** rectal distension transiently relaxes the IAS (recto-anal inhibitory reflex), letting contents reach the sensitive mucosa above Hilton's line for conscious discrimination of flatus/faeces, while the EAS contracts voluntarily to preserve continence.
- ▶ **Defaecation:** sustained IAS relaxation + voluntary puborectalis relaxation (straightens the anorectal angle) + conjoint longitudinal muscle contraction (shortens/widens canal, flattens anal cushions) + EAS relaxation together permit evacuation; afterwards EAS contracts (closing reflex) and IAS/postural tone are restored.

Applied / Clinical anatomy

- ▶ **Anal fissure:** a tear (commonly of an anal valve) from passage of hard faeces, classically **posterior midline** (relatively deficient epithelial arterial supply there, worsened by IAS hypertonicity). Below the pectinate line → exquisitely painful (somatic innervation), bleeds as streaks on stool. Chronic fissure is managed by lowering IAS tone — topical nitrates (nitrergic pathway) or **lateral internal sphincterotomy**.
- ▶ **Haemorrhoids (piles):** variceal dilatations of submucosal venous plexuses. **Internal** — above the pectinate line, superior rectal vein radicles in the anal columns, classically **3, 7, 11 o'clock** (lithotomy); painless (autonomic), bleed on straining. **External** — below the pectinate line, inferior rectal vein tributaries; painful (somatic), do not bleed.
- ▶ **Fistula-in-ano:** epithelialized track between an infected ischiorectal/intersphincteric abscess and the skin; low tracks through the lower superficial EAS are commonest. Its relation to the **anorectal ring** governs operability — a track above the ring must not be laid open in one stage, since dividing the ring causes incontinence.
- ▶ **Perianal abscess:** pus in the perianal space, usually from infected anal glands opening in the anal sinuses.
- ▶ **Faecal incontinence:** pudendal nerve (S2–S4) stretch injury in difficult labour, or direct obstetric tears of the EAS/perineal body.
- ▶ The **anorectal ring** is the key palpable landmark of the anorectal junction on per-rectal examination.

High-yield exam pointers

- ▶ Anal canal = terminal 3.8 cm of gut; pectinate line divides an endodermal upper two-thirds from an ectodermal lower one-third.
- ▶ **IAS**: smooth, involuntary, continuation of circular rectal coat, upper two-thirds down to Hilton's line; tonically contracted, relaxes via the recto-anal inhibitory reflex.
- ▶ **EAS**: striated, voluntary, whole canal length; classically deep/superficial/subcutaneous parts (Gray's 41e now regards it as one functional slow-twitch entity).
- ▶ Deep EAS fuses with **puborectalis** forming the anorectal sling, maintaining the anorectal angle.
- ▶ **Conjoint longitudinal muscle** = rectal longitudinal coat + puborectalis fibres between the two sphincters; septates at Hilton's line (perianal fascia laterally, anal intermuscular septum medially).
- ▶ **Anorectal ring** = deep EAS + IAS + puborectalis, ~2.5 cm above the anal margin; division causes incontinence.
- ▶ Nerve supply: IAS — sympathetic (contracts) + parasympathetic/nitrergic (relaxes); EAS — inferior rectal nerve + perineal branch of S4.
- ▶ Resting tone is mainly IAS (sympathetic), reinforced by EAS; pectinate line separates painless internal from painful external haemorrhoids.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; BD Chaurasia — Human Anatomy Vol 2, 8e (source of the embedded figure).



Superficial and deep perineal pouches

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

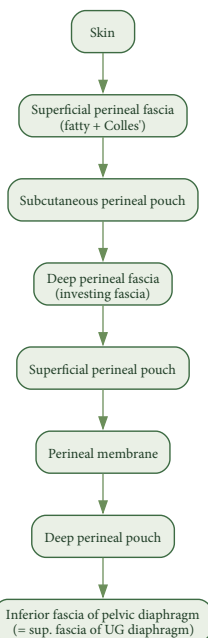
Definition / Introduction The urogenital (anterior) triangle of the perineum is divided by a tough fascial sheet, the **perineal membrane**, into an upper **deep perineal pouch** and a lower **superficial perineal pouch**. A third, more superficial space — the **subcutaneous perineal pouch** — lies between the superficial perineal fascia and the deep perineal (investing) fascia, below Colles' fascia. Each pouch houses a characteristic set of erectile tissue, muscle, gland, vessel and nerve, and the arrangement differs slightly between the two sexes. Clinically, this three-tier fascial architecture dictates the classic pathways along which extravasated urine and blood track after urethral or pelvic trauma, making the topic a perennial applied-anatomy favourite.

Fascial planes of the urogenital triangle

From superficial to deep:

Layer	Composition	Space it bounds
Skin	—	—

Layer	Composition	Space it bounds
Superficial perineal fascia	Fatty superficial layer + membranous deep layer (Colles' fascia), continuous with Scarpa's fascia of the abdominal wall and Dartos fascia of scrotum/labia	Floor of subcutaneous pouch
Subcutaneous perineal pouch	Thin areolar tissue between Colles' fascia and deep perineal fascia	Distends with blood/urine after trauma
Deep perineal fascia (investing fascia of superficial perineal muscles)	Overlies ischiocavernosus, bulbospongiosus, superficial transverse perineal muscles	Roof of subcutaneous pouch; roof of superficial pouch
Superficial perineal pouch	Between deep perineal fascia above...	...and perineal membrane below
Perineal membrane	Tough triangular fibrous sheet, thickened anteriorly as the transverse perineal ligament (a small gap here transmits the deep dorsal vein of the penis/clitoris); posteriorly fixed to the perineal body	Separates the two pouches
Deep perineal pouch	Between perineal membrane below and...	...continuation of the inferior fascia of the pelvic diaphragm (classically the "superior fascia of the urogenital diaphragm") above



Superficial and deep perineal pouches

Note on terminology — classically (BD Chaurasia, Vishram Singh) the deep perineal pouch is described as enclosed within a **urogenital diaphragm**, a triangular musculo-fascial sheet of sphincter urethrae + deep transverse perineal muscles sandwiched between a superior and an inferior (= perineal membrane)

fascial layer. Gray's Anatomy (Standring, 41e) has revised this view: serial-section studies show no continuous superior fascial layer, so the "urogenital diaphragm" as a discrete three-layered structure does not truly exist; the urethral sphincter mechanism is instead an intrinsic smooth-and-striated muscle complex (**distal urethral sphincter**, with compressor urethrae and sphincter urethrovaginalis as arch-shaped extensions in the female) lying within a **thin, open-above deep perineal space**. Both descriptions remain acceptable for the exam; state the classical version first and add the revised view for extra marks.

Deep perineal pouch — boundaries and contents

Boundaries

- ▶ Inferior: perineal membrane
- ▶ Superior: inferior fascia of the pelvic diaphragm (classically, superior fascia of the urogenital diaphragm) — open/thin, not a firm floor in the revised view
- ▶ Lateral, each side: ischiopubic rami / obturator fascia

Contents	Male	Female
Tube(s) traversing	Membranous urethra (narrowest, least dilatable part of urethra, 1.5–2 cm long)	Urethra and vagina
Muscle (skeletal)	Sphincter urethrae (voluntary external urethral sphincter) + deep transverse perineal muscle	Sphincter urethrae, deep transverse perineal muscle, plus compressor urethrae and sphincter urethrovaginalis (arch-shaped extensions onto the vaginal wall)
Glands	Bulbourethral (Cowper's) glands , one each side of the membranous urethra; ducts pierce the perineal membrane to open into the bulbous urethra	None
Vessels	Internal pudendal vessels dividing here into artery to the bulb, urethral artery, dorsal and deep arteries of the penis	Corresponding branches to the clitoris
Nerves	Dorsal nerve of the penis, muscular branches of the perineal nerve	Dorsal nerve of the clitoris, muscular branches of the perineal nerve

Superficial perineal pouch — boundaries and contents

Boundaries

- ▶ Superior: perineal membrane
- ▶ Inferior: Colles' fascia (deep membranous layer of superficial perineal fascia)
- ▶ Lateral, each side: ischiopubic rami

Contents	Male	Female
Erectile root	Root of penis — bulb of penis (covered by bulbospongiosus) + two crura (covered by ischiocavernosus)	Root of clitoris — bulbs of vestibule (covered by bulbospongiosus, one each side of vaginal orifice) + two crura (covered by ischiocavernosus)
Muscles	Ischiocavernosus, bulbospongiosus, superficial transverse perineal muscle	Same three muscles
Tube	Urethra, in the root of the penis	Urethra and vagina both cross this pouch
Glands	Ducts of bulbourethral glands pass through en route to the bulbous urethra	Greater vestibular (Bartholin's) glands , one each side of the vaginal orifice, opening into the groove between the labium minus and the hymen
Vessels	Perineal artery branches — posterior scrotal, artery to the bulb, dorsal and deep arteries of the penis	Perineal artery branches — posterior labial, artery to the bulb of vestibule, dorsal and deep arteries of the clitoris
Nerves	Perineal nerve branches (posterior scrotal nerve, muscular branches), dorsal nerve of the penis	Perineal nerve branches (posterior labial nerve, muscular branches), dorsal nerve of the clitoris

This is a **fully closed compartment**: bleeding into its contents (e.g. from a fractured penile root) is confined here and does not communicate with the deep or subcutaneous pouches unless a fascial boundary is torn.

Structures piercing the perineal membrane

Male	Female
Urethra (~2–3 cm behind the pubic symphysis)	Urethra and vagina
Ducts of bulbourethral glands	Ducts of Bartholin's glands lie just superficial (near the introitus)
Artery to the bulb of the penis, urethral artery	Artery to the bulb of the vestibule, urethral artery
Dorsal artery of the penis	Dorsal artery of the clitoris
Deep artery of the penis	Deep artery of the clitoris
Posterior scrotal vessels and nerves	Posterior labial vessels and nerves
Muscular branches of the perineal nerve	Muscular branches of the perineal nerve

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section through the male (or female) urogenital triangle at the level of the bulb of the penis/vestibule, labelling from superficial to deep:

- ▶ Skin and superficial (fatty) perineal fascia
- ▶ Colles' fascia (floor of subcutaneous pouch)
- ▶ **Superficial perineal pouch** — bulbospongiosus over the bulb of the penis, ischiocavernosus over the crus, superficial transverse perineal muscle, bulbourethral gland duct (or Bartholin's gland)
- ▶ Ischiopubic ramus (lateral wall) on each side
- ▶ **Perineal membrane** (draw as a horizontal fibrous sheet spanning the two ischiopubic rami)
- ▶ **Deep perineal pouch** — sphincter urethrae around the membranous urethra, deep transverse perineal muscle, bulbourethral gland
- ▶ Inferior fascia of the pelvic diaphragm / levator ani above
- ▶ Label the urethra centrally, pierced through both pouches

embed: ![Fig 6.66 — Muscles of perineum. A. Muscles of superficial perineal pouch. B. Muscles of deep perineal pouch (Moore — Clinically Oriented Anatomy — 9e, p.1074)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/c61c56af61102144.jpg)

embed: ![Fig 15.8 — Coronal section of the urogenital region showing contents of the superficial and deep perineal pouches (Vishram Singh — Textbook of Anatomy Vol 2 — 4e, p.659)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/5c9e90a3b8884de4.jpg)

Applied / Clinical anatomy

- ▶ **Extravasation of urine** (rupture of the penile/bulbar urethra, e.g. straddle injury): urine escapes into the superficial perineal pouch, and since this pouch is continuous with Colles' fascia anteriorly, urine tracks into the scrotum, penis and up onto the anterior abdominal wall deep to Scarpa's fascia — producing a characteristic "butterfly" perineal/scrotal swelling. It **cannot** spread posteriorly into the ischio-anal fossa or laterally onto the thigh because Colles' fascia is firmly tethered to the ischiopubic rami and the posterior edge of the perineal membrane.
- ▶ **Rupture of the membranous urethra** (commonly with pelvic fracture) causes **deep extravasation**: urine and blood collect above the perineal membrane, spreading into the extraperitoneal (retropubic) space around the bladder and prostate and thence into the anterior abdominal wall — it does *not* enter the superficial pouch unless the perineal membrane itself is torn.
- ▶ The **membranous urethra**, running through the deep perineal pouch, is the narrowest and least distensible part of the male urethra and the segment most vulnerable to iatrogenic catheter trauma.

- ▶ **Pudendal nerve block** (for episiotomy/instrumental delivery) is given at the ischial spine, targeting the nerve just before it enters the pudendal canal and supplies both pouches.
- ▶ **Episiotomy** deliberately divides the perineal body/perineal skin (usually mediolateral) to enlarge the vaginal outlet and avoid uncontrolled tears through the anal sphincter; the perineal body receives contributions from muscles of both pouches (bulbospongiosus, deep and superficial transverse perineal, external anal sphincter) and its damage during childbirth can lead to pelvic organ prolapse.
- ▶ **Bartholin's gland cyst/abscess**, presenting as a superficial pouch swelling in the posterior labium majus, arises from duct obstruction of the greater vestibular glands.
- ▶ **Bulbourethral gland secretions** (pre-ejaculatory fluid) are delivered via ducts that must traverse the perineal membrane from the deep into the superficial pouch — a useful structural link tested in vivas.
- ▶ Surgical drainage of a perineal/ischio-anal abscess must respect these fascial boundaries; failure to recognise the closed nature of the superficial pouch can lead to unexpected spread of infection anteriorly rather than posteriorly.

High-yield exam pointers

- ▶ Perineal membrane = the fascial partition between deep (above) and superficial (below) perineal pouches; thickened anteriorly as the transverse perineal ligament.
- ▶ Deep pouch contents (male): sphincter urethrae, deep transverse perineal muscle, bulbourethral glands, membranous urethra, internal pudendal vessel/nerve branches.
- ▶ Superficial pouch contents (male): root of penis (bulb + crura) with bulbospongiosus/ischiocavernosus, superficial transverse perineal muscle, ducts of bulbourethral glands.
- ▶ Female superficial pouch additionally contains Bartholin's glands and is crossed by both urethra and vagina; deep pouch additionally has compressor urethrae and sphincter urethrovaginalis.
- ▶ Superficial pouch is a closed compartment bounded by Colles' fascia below, perineal membrane above, ischiopubic rami laterally.
- ▶ Superficial extravasation of urine spreads into scrotum/penis/anterior abdominal wall but never into the thigh or ischio-anal fossa (Colles' fascia attachments).
- ▶ Gray's 41e revised view: no true "urogenital diaphragm"; deep perineal space is a thin, open space and the urethral sphincter mechanism is intrinsic (distal urethral sphincter).
- ▶ Perineal body is the common attachment point for muscles from both pouches and is clinically vital in labour (episiotomy, prolapse prevention).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2, 8e; Vishram Singh — Textbook of Anatomy Vol 2, 4e; Moore's Clinically Oriented Anatomy, 9e.



Head & neck



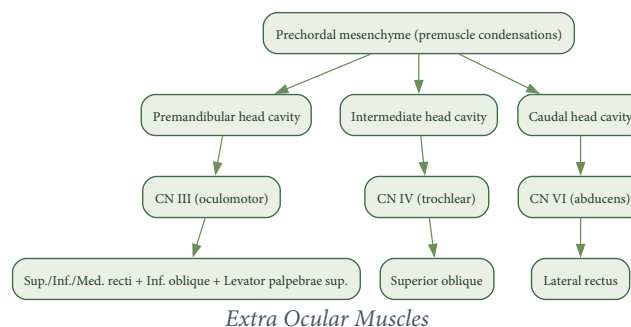
Extra Ocular Muscles

Asked in: Paper I May 2019 · Paper I May 2018 · Paper I Oct 2006 (3×) — RGUHS MD/MS Anatomy

Definition / Introduction The extraocular (extrinsic) muscles are seven skeletal muscles of the orbit that position and move the eyeball and elevate the upper eyelid. They comprise the **four recti** (superior, inferior, medial, lateral), the **two obliques** (superior, inferior) and the **levator palpebrae superioris** (LPS). The four recti and inferior oblique rotate the globe about three orthogonal axes (horizontal, vertical, anteroposterior); the superior oblique adds torsion and depression; LPS raises the upper lid. Six of the seven are supplied by the oculomotor, trochlear and abducent nerves (CN III, IV, VI) and act in tightly coordinated pairs to keep both visual axes aligned on a single object.

1. Development of the extraocular muscles

- Development is complex, involving coordinated juxtaposition of muscle precursors from **prechordal mesenchyme**, outgrowing cranial motor nerves, and **neural crest** mesenchyme (which later forms the sclera, EOM tendons and orbit).
- During gastrulation, prechordal-plate cells migrate laterally to form premuscle condensations within three transient "**head cavities**" adjacent to the neural tube — premandibular, intermediate and caudal.
- Each head cavity is associated with, and its condensation induced by, the cranial nerve growing towards the developing eye at that level.



- This nerve-muscle pairing established in the embryo persists in the adult innervation pattern (see section 4), which is why the classic mnemonic "SO4, LR6, rest 3" works.

2. Common tendinous ring and attachments

- The **common tendinous ring (annulus/anulus of Zinn)** is a fibrous ring at the orbital apex that surrounds the optic canal and the medial part of the superior orbital fissure, and gives origin to the **four recti**.
- The optic nerve and ophthalmic artery lie within the ring (via the optic canal); the superior and inferior divisions of CN III, the nasociliary nerve and CN VI also lie within the ring but enter via the superior orbital fissure.

- CN IV and the frontal and lacrimal branches of the ophthalmic nerve enter through the superior orbital fissure but lie **outside** the ring; LPS and superior oblique attach **external** to the ring, though closely related to it.
- Only the four recti take origin from the ring itself — **superior oblique** arises from the body of sphenoid superomedial to the optic canal, **inferior oblique** arises from the orbital plate of the maxilla (the only EOM not arising near the orbital apex), and **LPS** arises from the lesser wing of sphenoid.

□ Fig 11.3 — Schematic anterior view of the orbit to show the attachments of extraocular muscles (IB Singh — Textbook of Anatomy Vol 3 — 6e, p.199)

Muscle	Origin	Insertion
Superior rectus	Upper part of common tendinous ring, above/lateral to optic canal; some fibres from dural sheath of optic nerve	Sclera, ~8 mm from limbus, upper part of eyeball (medial margin more anterior)
Inferior rectus	Common tendinous ring, below the optic canal	Sclera, ~6.5 mm from limbus, below the cornea
Medial rectus	Medial part of common tendinous ring; some fibres from dural sheath of optic nerve	Sclera, ~5.5 mm from limbus, slightly anterior to the other recti
Lateral rectus	Lateral part of common tendinous ring (bridges superior orbital fissure); a second slip from a spine on the greater wing of sphenoid	Sclera, ~7 mm from limbus
Superior oblique	Body of sphenoid, superomedial to optic canal, medial to origin of superior rectus	Tendon passes through the trochlea (fibrocartilaginous pulley on the frontal bone), turns posterolaterally under superior rectus, and inserts in the superolateral part of the posterior quadrant, behind the equator
Inferior oblique	Orbital surface of maxilla, lateral to the nasolacrimal fossa	Inferolateral part of posterior quadrant, behind the equator, between inferior and lateral recti (its tendon is barely distinct)
Levator palpebrae superioris	Lesser wing of sphenoid, above and anterior to the optic canal, external to the tendinous ring	Aponeurosis to superior tarsus and skin of the upper eyelid; smooth-muscle slip (superior tarsal muscle) to upper margin of superior tarsus

The insertions of the four recti, taken in sequence from medial to superior rectus, trace a curve of progressively increasing distance from the limbus — the **spiral of Tillaux** (medial < inferior < lateral < superior rectus) — a point used surgically in strabismus (recession–resection) operations and in choosing safe needle sites for peribulbar/retrobulbar injection.

3. Fascial relations

- **Fascia bulbi (Tenon's capsule)** envelops the eyeball from the optic nerve to the corneoscleral junction; it is pierced by the EOM tendons and reflected onto each as a tubular muscular fascia (sheath).
- Expansions of the medial and lateral rectus sheaths attach to the lacrimal and zygomatic bones respectively as the **medial and lateral check ligaments**, limiting the range of the two recti.
- The sheaths of inferior rectus and inferior oblique fuse with these check ligaments to form the **suspensory ligament of the eye (of Lockwood)**, slung like a hammock beneath the globe.
- The fused sheath of levator palpebrae superioris and superior rectus, and the **transverse (Whitnall's) ligament**, couple upper-lid elevation to upgaze.
- Current evidence supports an "active pulley" system — collagenous sleeves of orbital connective tissue near the equator, elastically coupled to the orbital walls, stabilise the paths of the recti during ocular rotation.

4. Nerve supply, blood supply and actions

Muscle	Nerve supply	Arterial supply	Action (primary → secondary → tertiary)
Superior rectus	Superior division, CN III	Ophthalmic artery + supraorbital branch	Elevation → adduction → intorsion
Inferior rectus	Inferior division, CN III	Ophthalmic artery + infraorbital branch of maxillary	Depression → adduction → extorsion
Medial rectus	Inferior division, CN III	Ophthalmic artery	Adduction
Lateral rectus	CN VI (abducens)	Ophthalmic artery + lacrimal branch	Abduction
Superior oblique	CN IV (trochlear)	Ophthalmic artery + supraorbital branch	Intorsion → depression → abduction
Inferior oblique	Inferior division, CN III	Ophthalmic artery + infraorbital branch of maxillary	Extorsion → elevation → abduction
Levator palpebrae superioris	Superior division, CN III (striated part); sympathetic fibres (superior tarsal muscle)	Ophthalmic artery + supraorbital branch	Elevates upper eyelid

- **Axes of rotation:** the horizontal axis governs elevation/depression, the vertical axis adduction/abduction, and the anteroposterior axis intorsion/extorsion.
- The medial and lateral recti lie essentially parallel to the visual axis in the primary position and so act almost purely about the **vertical axis** (adduction/abduction).
- Because the orbital axis diverges from the visual axis (primary position) by about 23°, superior and inferior recti give elevation/depression as their primary action but also adduct and torque the globe; they become pure elevators/depressors only when the eye is first **abducted ~23°**.

- ▶ The two obliques pull from in front (trochlea/anterior maxilla) posterior to the vertical axis, so both add abduction as a secondary/tertiary action. Superior oblique elevates the back of the globe and so depresses the visual axis (plus intorsion); inferior oblique depresses the back of the globe and so elevates the visual axis (plus extorsion). Both act as pure elevator/depressor and torsor only when the eye is first **adducted**.
- ▶ **Synergist pairs:** superior rectus + inferior oblique are synergists for pure elevation; inferior rectus + superior oblique are synergists for pure depression (their opposing torsional actions cancel).

Yoke muscles / six cardinal (diagnostic) positions of gaze — for conjugate (version) movement, one muscle in each eye acts as the prime mover and its partner in the other eye as the yoke muscle:

Direction of gaze	Right eye — prime mover	Left eye — yoke muscle
Right	Right lateral rectus	Left medial rectus
Right and up	Right superior rectus	Left inferior oblique
Right and down	Right inferior rectus	Left superior oblique
Left	Left lateral rectus	Right medial rectus
Left and up	Left superior rectus	Right inferior oblique
Left and down	Left inferior rectus	Right superior oblique

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Anterior view of the left orbital apex (as in the plate above) — label: **optic canal** (centre); **superior orbital fissure** (lateral to it); the **common tendinous ring** encircling both and marked "Annulus of Zinn"; origins of **superior rectus** (upper ring), **inferior rectus** (lower ring), **medial rectus** (medial ring) and **lateral rectus** (lateral ring, with its accessory head from the greater wing of sphenoid); origin of **superior oblique** (body of sphenoid, outside the ring, superomedial to the canal); origin of **levator palpebrae superioris** (lesser wing of sphenoid, outside the ring); and, passing through/beside the ring, **CN III (superior and inferior divisions)**, **CN IV**, **CN VI** and the **nasociliary nerve**, marked as lying inside or outside the ring as appropriate.

Applied / Clinical anatomy

- ▶ **Testing individual muscles (diagnostic positions of gaze):** the eye is first abducted by lateral rectus, isolating superior/inferior recti (and CN III) as pure elevator/depressor; it is then adducted by medial rectus, isolating superior/inferior oblique (CN IV and inferior division of CN III) as pure torsor/elevator-depressor.
- ▶ **Oculomotor (CN III) nerve palsy:** complete ptosis (LPS paralysed, unopposed orbicularis oculi), the eye deviates "down and out" (unopposed lateral rectus and superior oblique), and a fixed, dilated pupil with loss of accommodation (loss of parasympathetic supply to sphincter pupillae and ciliaris).

- ▶ **Trochlear (CN IV) nerve palsy:** paralysis of superior oblique causes extorsion of the eyeball and weakness of downward gaze, most marked on attempted downward-and-inward gaze (e.g. descending stairs, reading); vertical/torsional diplopia results.
- ▶ **Abducent (CN VI) nerve palsy:** unopposed medial rectus produces a convergent squint with failure of abduction; horizontal diplopia worsens on gaze towards the affected side, and the patient may turn the face towards the paralysed eye to compensate.
- ▶ **Strabismus (squint):** misalignment of the visual axes is classified as convergent (esotropia), divergent (exotropia) or vertical (hyper-/hypotropia), depending on which muscle balance is disturbed.
- ▶ **Orbital floor ("blow-out") fracture:** leaves the orbital rim intact but entraps orbital floor soft tissue (classically inferior rectus/inferior oblique), producing diplopia and restricted ocular motility on upgaze, with enophthalmos and infraorbital nerve numbness.
- ▶ **Thyroid eye disease (Graves' ophthalmopathy):** increased orbital fat and EOM swelling (especially inferior and medial recti) produce a restrictive myopathy and proptosis (exophthalmos).
- ▶ Congenital absence of the EOMs (severe congenital fibrosis syndrome) and rare deep orbital "supernumerary" muscle bands have been reported.

High-yield exam pointers

- ▶ Seven skeletal EOMs: 4 recti + 2 obliques + LPS; only the recti arise from the **common tendinous ring (annulus of Zinn)**.
- ▶ Nerve-supply mnemonic: "**SO4, LR6, rest 3**" — superior oblique by CN IV, lateral rectus by CN VI, all the rest (SR, IR, MR, IO, LPS) by CN III.
- ▶ **Inferior oblique** is the only EOM arising anteriorly, from the orbital plate of maxilla, not from the orbital apex.
- ▶ Distance of rectus insertion from the limbus increases $MR (5.5 \text{ mm}) < IR (6.5 \text{ mm}) < LR (7 \text{ mm}) < SR (8 \text{ mm})$ — the **spiral of Tillaux**.
- ▶ **Superior oblique** is the only EOM that changes direction through a pulley (the **trochlea**) before inserting behind the equator.
- ▶ Actions are analysed about three axes — horizontal (elevation/depression), vertical (adduction/abduction), anteroposterior (intorsion/extorsion); pure elevators/depressors are tested in abduction (recti) or adduction (obliques).
- ▶ Elevator synergists: SR + IO; depressor synergists: IR + SO (their opposing torsional components cancel).
- ▶ Developmental origin: prechordal mesenchyme in the premandibular (CN III), intermediate (CN IV) and caudal (CN VI) head cavities.
- ▶ CN III palsy = ptosis + "down and out" + fixed dilated pupil; CN IV palsy = defective depression in adduction with extorsion; CN VI palsy = convergent squint with failed abduction.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 3–4 8e; Moore's Clinically Oriented Anatomy 9e; IB Singh Textbook of Anatomy Vol 3 6e; Vishram Singh Textbook of Anatomy Vol 3 4e; Vishram Singh Clinical Neuroanatomy 4e.



Ansa cervicalis

Asked in: Paper I Oct 2010 · Paper I May 2010 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction The **ansa cervicalis** (ansa hypoglossi) is a U-shaped (loop-shaped) nerve formed by the union of a **superior root** and an **inferior root**, carrying fibres from the ventral rami of the **first three cervical spinal nerves (C1–C3)**. It is one of the deep (muscular) branches of the **cervical plexus** and lies embedded in the anterior wall of the **carotid sheath** in the carotid triangle of the neck. It supplies all the infrahyoid ("strap") muscles of the neck except thyrohyoid, and is of considerable surgical importance as a donor nerve and as a structure at risk during neck dissection.

Location, situation and general relations

- ▶ Lies in the region of the **carotid triangle**, embedded in (or applied to) the **anterior wall of the carotid sheath**, superficial to the common/internal carotid artery.
- ▶ Situated opposite the **lower part of the larynx**; the two roots unite anterior to the common carotid artery at approximately the **level of the cricoid cartilage**.
- ▶ The **internal jugular vein** lies related to it laterally — the inferior root winds around the vein before turning forward to join the superior root.
- ▶ Because it is superficial and applied to the front of the carotid sheath, the ansa is one of the first structures encountered on opening the sheath during carotid triangle dissection.

Formation — the two roots

The ansa cervicalis is formed by a superior and an inferior root that unite in front of the common carotid artery.

Root	Alternative name	Composition / origin	Course
Superior root	Descendens hypoglossi	Fibres of the C1 ventral ramus that "hitch-hike" for a short distance with the hypoglossal nerve (CN XII)	Leaves the hypoglossal nerve where it curves around the occipital artery; descends anterior to (or within) the carotid sheath, over the internal and then the common carotid artery

Root	Alternative name	Composition / origin	Course
Inferior root	Descendens cervicalis (nervus descendens cervicalis)	Union of branches from the C2 and C3 ventral rami	Descends on the lateral side of the internal jugular vein, winds/crosses around it a little below the middle of the neck, then passes anteroinferiorly to join the superior root in front of the common carotid artery

□ Fig 4.15 — Ansa cervicalis, and branches of the first cervical nerve distributed through the hypoglossal nerve (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.127)

Although the superior root's fibres travel briefly with CN XII, they are **true C1 spinal (cervical plexus) fibres**, not hypoglossal (motor cranial nerve) fibres — CN XII merely provides a physical conduit.

Course, union and relations in situ

- ▶ The superior root descends over the internal carotid artery and then the common carotid artery, lying within/on the anterior aspect of the carotid sheath.
- ▶ The inferior root, after winding around the internal jugular vein, crosses it and runs forward to meet the superior root **anterior to the common carotid artery**, at the level of the cricoid cartilage — this union constitutes the "ansa" (loop) proper, also called the **dependent loop**.
- ▶ Throughout its course the loop is closely related to the **vagus nerve** (posteriorly, within the carotid sheath) and to the **common/internal carotid arteries** and **internal jugular vein**, all contained within the same fascial sheath.
- ▶ The cervical **sympathetic trunk** lies posteromedial to the carotid sheath, deep to the ansa.

□ Fig 6.8 — Location and relations of the ansa cervicalis (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.318)

Distribution (branches)

The classical scheme of distribution, followed by most Indian textbooks, is:

Source	Muscle supplied
Superior root (before the two roots unite)	Superior belly of omohyoid
Ansa cervicalis proper (the united loop)	Sternohyoid and sternothyroid
Inferior root	Inferior belly of omohyoid

- ▶ Together, therefore, the ansa cervicalis (its roots and loop combined) supplies **all four named infrahyoid muscles except thyrohyoid** — i.e., sternohyoid, sternothyroid, and both bellies of omohyoid.
- ▶ **Thyrohyoid and geniohyoid are NOT supplied by the ansa cervicalis.** Both receive an independent branch carrying C1 fibres that continue distally along the hypoglossal nerve itself (nerve to thyrohyoid, nerve to geniohyoid) — a frequently tested negative fact, since it is easy to wrongly assume all "C1-derived" strap-muscle innervation passes through the ansa.

Functional significance

- ▶ The infrahyoid muscles innervated by the ansa fix or depress the hyoid bone and larynx, working in coordination with the suprahyoid muscles to stabilise the hyoid during **mastication**, and to depress the larynx/hyoid after their elevation in **deglutition** (swallowing) and during **phonation** (vocal movements).
- ▶ The ansa cervicalis therefore has an important, if largely automatic, role in normal swallowing and speech mechanics, even though isolated clinical syndromes from its lesion are uncommon.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a lateral neck outline (mastoid process to clavicle) and reproduce the loop with these exact labels:

- ▶ Hypoglossal nerve (CN XII) curving around the **occipital artery**, giving off the **superior root (descendens hypoglossi)** carrying C1 fibres.
- ▶ **Ventral rami of C1, C2, C3** contributing fibres.
- ▶ **Inferior root (descendens cervicalis)**, formed by C2 + C3, winding around the **internal jugular vein**.
- ▶ The two roots uniting **anterior to the common carotid artery** at the level of the **cricoid cartilage**, forming the **ansa cervicalis (dependent loop)**, embedded in the **carotid sheath**.
- ▶ Branches labelled separately: superior root → **superior belly of omohyoid**; loop → **sternohyoid, sternothyroid**; inferior root → **inferior belly of omohyoid**.
- ▶ Separate branch (NOT from ansa) from CN XII distal to the superior root → **nerve to thyrohyoid and nerve to geniohyoid**.
- ▶ Surrounding landmarks: **internal/external/common carotid arteries, internal jugular vein, vagus nerve, carotid triangle boundaries**.

Applied / Clinical anatomy

- ▶ **Nerve graft for recurrent laryngeal nerve (RLN) repair**: a segment of the ansa cervicalis (or its branches) is used as an interposition nerve graft to reconstitute a divided recurrent laryngeal nerve — most relevant when the **left RLN is inadvertently transected during thyroidectomy**, since ansa fibres lie in the same operative field and are readily harvested.
- ▶ **Ansa cervicalis-to-RLN neurotisation (laryngeal reinnervation)**: the same principle underlies the surgical technique of transferring an ansa cervicalis branch directly onto the distal RLN stump/adductor branch to reinnervate the vocalis muscle in cases of unilateral vocal fold paralysis, restoring some degree of tone and reducing dysphonia/aspiration risk.
- ▶ **Vulnerable during neck surgery**: because it is superficial, embedded in the anterior wall of the carotid sheath within the carotid triangle, the ansa cervicalis is commonly encountered — and at risk of injury — during **radical/functional neck dissection**, carotid endarterectomy, and other carotid-sheath surgery.
- ▶ **Surgical landmark**: its position on the anterolateral aspect of the carotid sheath makes it a guide to the underlying internal jugular vein and carotid arteries during dissection of the carotid triangle.

- ▶ **Relatively "silent" on isolated injury:** because the infrahyoid muscles it supplies play an accessory (rather than essential) role in deglutition and phonation, division of the ansa cervicalis during surgery (e.g., when harvested as a graft) is generally well tolerated without significant swallowing or voice deficit — which is precisely why it is a favoured, expendable donor nerve.

High-yield exam pointers

- ▶ Ansa cervicalis = ansa hypoglossi = loop of C1–C3 ventral rami fibres; a deep/muscular branch of the **cervical plexus**, NOT a branch of the hypoglossal nerve itself.
- ▶ **Superior root** = descendens hypoglossi (C1, via CN XII); **Inferior root** = descendens cervicalis (C2, C3).
- ▶ The two roots unite **anterior to the common carotid artery**, at the level of the **cricoid cartilage**, embedded in the **carotid sheath**.
- ▶ Distribution: superior root → superior belly of omohyoid; loop → sternohyoid + sternothyroid; inferior root → inferior belly of omohyoid.
- ▶ **Thyrohyoid and geniohyoid are supplied directly by C1 fibres via the hypoglossal nerve — NOT by the ansa cervicalis.**
- ▶ Clinically prized as a **donor/graft nerve for recurrent laryngeal nerve repair and reinnervation**, and as a landmark structure at risk in neck dissection.
- ▶ Functionally allows fixation/depression of the hyoid bone and larynx during swallowing and phonation.

SOURCE & COVERAGE

BD Chaurasia's Human Anatomy Vol 3-4 (8e); Vishram Singh — Textbook of Anatomy Vol 3 (4e); IB Singh — Textbook of Anatomy Vol 3 (6e); Moore's Clinically Oriented Anatomy (9e); Gray's Anatomy (Standring) 41e.



Intrinsic muscles of larynx

Asked in: Paper I 14-Jul-2020 · Paper I Nov 2017 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction — The intrinsic muscles of the larynx are a group of small skeletal muscles whose origin and insertion are both confined entirely within the laryngeal skeleton (unlike the extrinsic muscles, which connect the larynx to the hyoid bone/sternum and move the larynx as a whole). There are nine intrinsic muscles (five paired, one unpaired) grouped functionally into three sets — those that alter the width of the rima glottidis (abductors/adductors), those that alter the length and tension of the vocal folds (tensors/relaxors), and those that act as a sphincter/dilator of the laryngeal inlet. Together they regulate the calibre of the airway, protect it during swallowing, and produce and modulate the voice.

List and classification of intrinsic muscles

- ▶ **Cricothyroid** (paired) — the only intrinsic muscle visible on the *outer* surface of the larynx; called the "tuning fork of the larynx."

- **Posterior cricoarytenoid (PCA)** (paired) — the sole abductor; called the "safety muscle of the larynx."
- **Lateral cricoarytenoid (LCA)** (paired)
- **Transverse arytenoid / interarytenoid** — the only **unpaired** intrinsic muscle.
- **Oblique arytenoid** (paired) — lies superficial to transverse arytenoid; its fibres continue into the aryepiglottic fold as the aryepiglotticus.
- **Thyroarytenoid** (paired), with its deeper medial part forming the **vocalis** muscle, and its upper fibres prolonging into the aryepiglottic fold as **thyroepiglotticus**.

Attachments (origin, course, insertion)

Muscle	Origin	Course of fibres	Insertion
Cricothyroid	External surface/arch of cricoid cartilage	Two parts — lower "oblique" fibres pass backward-laterally; upper "straight" fibres ascend more steeply	Anterior border of inferior cornu (oblique part) and lower border of thyroid lamina (straight part)
Posterior cricoarytenoid	Posterior surface of cricoid lamina	Fibres ascend laterally and converge	Posterior aspect of muscular process of arytenoid cartilage
Lateral cricoarytenoid	Upper border of the arch of cricoid	Ascends obliquely backward	Anterior aspect of muscular process of arytenoid cartilage
Transverse arytenoid	Posterior surface of one arytenoid	Transverse fibres bridging the gap between the two cartilages	Posterior surface of the other arytenoid
Oblique arytenoid + aryepiglotticus	Muscular process of one arytenoid	Crosses obliquely, superficial to transverse arytenoid	Apex of the opposite arytenoid; continuing fibres pass round into the aryepiglottic fold to the epiglottic margin
Thyroarytenoid (+ vocalis, + thyroepiglotticus)	Lower half of thyroid angle and adjoining cricothyroid ligament	Fibres pass backward, laterally and upward; deepest/medial fibres form vocalis, parallel to the vocal ligament; uppermost fibres prolong into aryepiglottic fold as thyroepiglotticus	Anterolateral surface of arytenoid cartilage (vocalis onto the vocal process/fovea oblonga); thyroepiglotticus onto the epiglottic margin

Nerve supply

- **Recurrent laryngeal nerve (RLN)** — a branch of the vagus — supplies **all** intrinsic muscles *except* cricothyroid: posterior cricoarytenoid, lateral cricoarytenoid, transverse arytenoid, oblique arytenoid, thyroarytenoid, vocalis and thyroepiglotticus.

- ▶ **External branch of the superior laryngeal nerve** — supplies **cricothyroid alone**; this is the *only* intrinsic muscle not supplied by the RLN.
- ▶ Thyroarytenoid and transverse arytenoid additionally receive small, functionally-debated communicating twigs from the internal laryngeal nerve (largely sensory/proprioceptive rather than true additional motor supply).
- ▶ **Sensory supply**: internal laryngeal nerve above the vocal folds; RLN below the vocal folds — the vocal fold itself is the sensory "watershed."

Blood supply

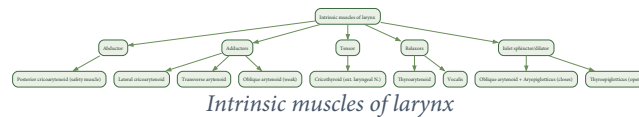
- ▶ **Superior laryngeal artery** (from superior thyroid artery) supplies the larynx above the level of the vocal folds, including most of the laryngeal musculature.
- ▶ **Inferior laryngeal artery** (from inferior thyroid artery) supplies the region below the vocal folds, especially around cricothyroid and posterior cricoarytenoid, with rich anastomosis between ipsi- and contralateral vessels.

Actions — functional groups

Functional group	Muscle(s)	Effect on rima glottidis / vocal fold
Abductor (opens glottis)	Posterior cricoarytenoid (only one)	Rotates the arytenoid laterally about the cricoarytenoid joint axis → separates the vocal processes → rima glottidis widens (becomes triangular); also pulls the arytenoids backward, assisting lengthening
Adductors (close glottis)	Lateral cricoarytenoid, transverse arytenoid, oblique arytenoid	LCA rotates the arytenoid medially, bringing the vocal processes together ("medial compression") and also shortens/relaxes the fold; transverse arytenoid pulls the two arytenoids together, closing the posterior (intercartilaginous) part of the glottis; oblique arytenoid is a weaker adductor
Tensors (lengthen/stiffen the fold)	Cricothyroid	Rocks/tilts the thyroid cartilage forward-downward at the cricothyroid joint, increasing the distance between thyroid angle and vocal process → lengthens and tenses the vocal fold; some authors also attribute it a weak adductive/paramedian action

Functional group	Muscle(s)	Effect on rima glottidis / vocal fold
Relaxors (shorten the fold)	Thyroarytenoid, vocalis	Draw the arytenoid toward the thyroid cartilage, shortening and relaxing the vocal ligament while also rotating the arytenoid medially (adduction); the vocalis component finely regulates residual tension/mass of the fold and thereby controls pitch and timbre
Sphincter of laryngeal inlet	Oblique arytenoid + aryepiglotticus	Adduct the aryepiglottic folds and approximate the arytenoids to the epiglottic tubercle, narrowing the inlet (protective, during swallowing)
Dilator of laryngeal inlet	Thyroepiglotticus	Widens the laryngeal inlet by its pull on the aryepiglottic fold

- During **whispering**, transverse arytenoid relaxes while lateral cricoarytenoid contracts — the anterior (intermembranous) part of the glottis closes but the posterior (intercartilaginous) part stays open, allowing turbulent airflow without vocal-fold vibration.
- Posterior cricoarytenoid alone opens the airway; the mass of muscle devoted to adduction/tension far exceeds that devoted to abduction — clinically relevant, since a single unopposed adductor pull dominates when abduction fails.



DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the **posterior view of the larynx** (cricoid lamina in the midline, arytenoid cartilages perched on its upper border) and label:

- ▶ Lamina of cricoid cartilage; arch of cricoid cartilage
- ▶ Arytenoid cartilage — muscular process and vocal process
- ▶ Posterior cricoarytenoid — fanning from cricoid lamina to muscular process
- ▶ Transverse arytenoid — single unpaired sheet bridging the two arytenoids
- ▶ Oblique arytenoid — crossing superficial to transverse arytenoid, continuing into aryepiglottic fold
- ▶ Thyroid cartilage (posterior border/lamina) as a reference
- ▶ Vocal ligament and rima glottidis (in an inset lateral/horizontal view) to show lateral cricoarytenoid and cricothyroid pulling the vocal/muscular processes in opposite directions.

 Fig 35.10 — *The intrinsic muscles of the larynx in posterior or lateral views, with actions shown alongside in superior view (Gray's Anatomy — Standring — 41e, p.823)*

Applied / Clinical anatomy

- ▶ **Bilateral RLN palsy:** both vocal folds fall into the **cadaveric position** (midway between abduction and adduction, since only the unopposed cricothyroid and gravity act) — phonation is lost, and breathing becomes difficult through the narrowed, partially-opened glottis (may need emergency tracheostomy).
- ▶ **Unilateral RLN palsy:** the affected fold lies paramedian/immobile; the healthy fold compensates by crossing the midline during phonation, so voice is preserved but hoarse, and the forceful, explosive phase of coughing is lost (since posterior cricoarytenoid on that side cannot abduct).
- ▶ **External laryngeal nerve injury** (isolated) causes only mild voice weakness/monotony — loss of the tightening/tensing action of cricothyroid — because all the adductor/abductor muscles (RLN-supplied) remain intact.
- ▶ **Surgical risk during thyroidectomy:** the external laryngeal nerve runs close to the superior thyroid vessels near the upper pole, and the recurrent laryngeal nerve runs close to the inferior thyroid artery near the lower pole/tracheo-oesophageal groove — both must be identified and preserved.
- ▶ The **left RLN** has a longer intrathoracic course (looping below the arch of structures in the mediastinum) and is therefore more often compressed by mediastinal/bronchogenic tumours than the right, which is given off in the root of the neck.
- ▶ **Posterior cricoarytenoid** is termed the safety muscle because it is the sole abductor keeping the airway patent; because it is a single, functionally-critical muscle, it shows the earliest degenerative/denervation change in laryngeal disease.
- ▶ **Reinke's space** (superficial lamina propria overlying vocalis/thyroarytenoid) is the site of vocal-fold oedema and of "singer's/screamer's nodules," related to vocal abuse and to the vibratory stresses transmitted through thyroarytenoid–vocalis.

- ▶ Indirect laryngoscopy allows direct visual assessment of vocal-fold mobility and position, which localises the level and side of a suspected RLN or external laryngeal nerve lesion.

High-yield exam pointers

- ▶ 9 intrinsic muscles: cricothyroid, posterior cricoarytenoid, lateral cricoarytenoid, transverse arytenoid (unpaired), oblique arytenoid, aryepiglotticus, thyroarytenoid, vocalis, thyroepiglotticus.
- ▶ **Only abductor** = posterior cricoarytenoid ("safety muscle of larynx").
- ▶ **Only muscle outside the larynx/visible externally** = cricothyroid ("tuning fork of larynx").
- ▶ **Only muscle NOT supplied by RLN** = cricothyroid (supplied by external laryngeal nerve); all others by RLN.
- ▶ **Only unpaired intrinsic muscle** = transverse (inter)arytenoid.
- ▶ Vocalis = deeper/medial part of thyroarytenoid, running parallel to the vocal ligament; fine-tunes vocal-fold tension and pitch.
- ▶ Bilateral RLN palsy → cadaveric position, aphonia, respiratory distress; unilateral RLN palsy → hoarseness with compensation, loss of explosive cough.
- ▶ Whispering: transverse arytenoid relaxed + lateral cricoarytenoid contracted → anterior glottis closed, posterior glottis open.
- ▶ Sensory watershed of the larynx = the vocal fold (internal laryngeal nerve above, RLN below); it is also the lymphatic watershed (true vocal cord has no lymphatics — best-prognosis site for glottic carcinoma).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 8e; IB Singh's Textbook of Anatomy Vol 3 6e; Vishram Singh's Textbook of Anatomy Vol 3 4e.



Nasal septum

Asked in: Paper I 07-May-2022 · Paper I May 2009 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction The nasal septum is the median osseocartilaginous partition that divides the nasal cavity into right and left halves. It is rarely exactly median, being more often deflected to one side (commonly the right) due to differential overgrowth of its constituent bony and cartilaginous parts. Each half of the septum is covered by mucoperiosteum/mucoperichondrium and forms the medial wall of the corresponding nasal cavity. It possesses four borders (superior, inferior, anterior, posterior) and two surfaces (right and left), and is of major clinical importance as the commonest site of nosebleed (Little's area) and of symptomatic deviation (DNS).

Extent and relations

- ▶ The septum extends from the external nasal aperture (nostrils) anteriorly to the **posterior nasal apertures (choanae)** posteriorly; its free posterior border, formed by the vomer, separates the right and left choanae.

- **Superiorly**, it is related to the **cribriform plate of the ethmoid** (perforated by the olfactory nerve filaments) and to the undersurface of the nasal bones and the nasal spine of the frontal bone.
- **Inferiorly**, it rests on the **nasal crest** formed by the palatine processes of the maxillae and the horizontal plates of the palatine bones, i.e. the roof of the hard palate.
- **Posteriorly**, the bony septum is continuous with the **sphenoidal crest and rostrum**, which articulate with the ala of the vomer.
- It has **four borders** (superior, inferior, anterior, posterior) and **two surfaces** (right and left), each surface covered by mucoperiosteum (over bone) or mucoperichondrium (over cartilage) continuous with the rest of the nasal mucosa.

Composition — bony, cartilaginous and membranous parts

Part	Constituents
Bony part (posterior two-thirds)	Perpendicular plate of the ethmoid — forms the posterosuperior part; Vomer — forms the posteroinferior part. Minor contributions: nasal spine of the frontal bone, crest formed by the nasal bones, sphenoidal crest/rostrum, and the nasal crest formed by the palatine processes of the maxillae and horizontal plates of the palatine bones
Cartilaginous part (anterior)	Septal (quadrangular) cartilage — fits into the angle between the vomer and the perpendicular plate of ethmoid; Septal processes (medial crura) of the two major alar cartilages
Membranous/columellar part	Lower, freely mobile part formed by a double layer of skin with fibrofatty tissue and no bony/cartilaginous support, lying between the columella and the caudal border of the septal cartilage

□ Fig 17.5 — Formation of the nasal septum. (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.746)

The junction where the septal cartilage, perpendicular plate of the ethmoid and the nasal bones meet is termed the **keystone area** and provides essential structural support to the nasal dorsum — a point of surgical relevance in rhinoplasty.

Arterial supply — Little's area / Kiesselbach's plexus

Region of septum	Artery	Parent trunk
Anterosuperior	Anterior and posterior ethmoidal arteries	Ophthalmic artery (from internal carotid artery)
Posterosuperior	Sphenopalatine artery — the chief artery of the septum, the "artery of epistaxis"	Maxillary artery
Posteroinferior	Septal branch of the greater palatine artery (ascends through the incisive canal)	Maxillary artery

Region of septum	Artery	Parent trunk
Anteroinferior (vestibule)	Septal branch of the superior labial artery	Facial artery

All of the above arteries anastomose in the **anteroinferior part of the septum**, just above the vestibule, forming a dense capillary network called **Kiesselbach's plexus**; the region is clinically known as **Little's area** and is the commonest site of epistaxis, particularly in children and young adults (often from finger-nail trauma).

□ Fig 17.6 — Arterial supply of the nasal septum. (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.748)

Venous drainage

- ▶ Veins form a plexus that is most marked in the lower part of the septum (Little's area).
- ▶ Anteriorly the plexus drains into the **facial vein**.
- ▶ Posteriorly it drains through the **sphenopalatine vein** into the **pterygoid venous plexus**.

Nerve supply

Region / area	Nerve	Source
Upper one-third (olfactory area, below the cribriform plate)	Olfactory nerves (fila olfactoria — bipolar neurons)	Cranial nerve I
Anterosuperior part	Internal nasal branch of the anterior ethmoidal nerve	Nasociliary nerve (ophthalmic division, V1)
Posterosuperior part	Medial posterior superior nasal branches	Pterygopalatine ganglion (maxillary nerve, V2)
Posteroinferior part — the main (general sensory) nerve of the septum	Nasopalatine nerve	Pterygopalatine ganglion (V2); runs in a groove on the vomer to the incisive canal
Posterior part	Nasal branch of the greater palatine nerve	Maxillary nerve (V2)
Anteroinferior part	Anterior superior alveolar nerve	Maxillary nerve (V2)

Thus the septum receives **special sensory (olfactory)** supply to its upper third and **general sensory (trigeminal)** supply — via both the ophthalmic (anterosuperior) and maxillary (rest of the septum) divisions — to the remainder.

□ Fig 17.7 — Nerve supply of the nasal septum. (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.749)

Lymphatic drainage

- ▶ Anterior half of the septum → **submandibular lymph nodes**.
- ▶ Posterior half of the septum → **retropharyngeal and deep cervical lymph nodes**.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A sagittal (median) section of the lateral wall/septum region, labelled with:

- ▶ Four borders (superior, inferior, anterior, posterior) and the two surfaces
- ▶ Bony components: **perpendicular plate of ethmoid** (posterosuperior), **vomer** (posteroinferior), with subsidiary contributions (nasal spine of frontal, nasal crest of maxilla/palatine, sphenoidal crest/rostrum)
- ▶ Cartilaginous component: **septal (quadrangular) cartilage**; **septal process of major alar cartilage**; columellar/membranous part
- ▶ Arterial anastomosis at **Little's area**: anterior + posterior ethmoidal, sphenopalatine, greater palatine, superior labial arteries converging anteroinferiorly
- ▶ Nerve fields: **olfactory area** (upper third), **anterior ethmoidal nerve** (anterosuperior), **nasopalatine nerve** (posteroinferior), medial posterior superior nasal branches, greater palatine nerve, anterior superior alveolar nerve

Applied / Clinical anatomy

- ▶ **Epistaxis**: Little's area (Kiesselbach's plexus) in the anteroinferior septum is the commonest site of nasal bleeding, especially in children (typically from digital trauma); the **sphenopalatine artery** is regarded as the principal "artery of epistaxis" for posterior/severe bleeds, and its endoscopic ligation (near the posterior/inferior end of the middle turbinate) is used to control refractory epistaxis.
- ▶ **Deviated nasal septum (DNS)**: a common cause of nasal obstruction, more frequent in males, resulting from trauma or developmental disproportion between the growth of the septal cartilage and the bony vault. Severe DNS causing obstruction, sinusitis, headache or snoring is corrected surgically by **septoplasty** or **submucous resection (SMR)**.
- ▶ Because the septal cartilage forms the major support of the lower two-thirds of the external nose, **excessive cartilage removal during SMR can cause supratip depression** (loss of dorsal/tip support) of the external nose — an important surgical-anatomical caution.
- ▶ The **keystone area** (junction of septal cartilage, perpendicular plate of ethmoid and nasal bones) is a critical support zone preserved in rhinoplasty to prevent dorsal collapse.
- ▶ The rich, axial blood supply of the septal mucosa from the **sphenopalatine artery** is exploited surgically to raise a pedicled **nasoseptal (mucoperichondrial) flap**, now the workhorse reconstructive flap in endoscopic transnasal skull-base surgery.
- ▶ Clinical examination of the septum is by **anterior rhinoscopy** (septum, conchae, meatuses, floor) and **posterior rhinoscopy** (posterior border of septum, choanae, conchae).

High-yield exam pointers

- ▶ Septum = **bony (posterior 2/3) + cartilaginous (anterior) + membranous/columellar** parts; bony = perpendicular plate of ethmoid (posterosuperior) + vomer (posteroinferior).
- ▶ **4 borders, 2 surfaces**; deviates more commonly to the **right**.

- ▶ **Sphenopalatine artery** = main/chief artery of the septum and the "artery of epistaxis" (posterosuperior part).
- ▶ **Little's area** = **Kiesselbach's plexus**, in the anteroinferior septum — anastomosis of anterior + posterior ethmoidal, sphenopalatine, greater palatine and superior labial arteries; commonest site of epistaxis.
- ▶ Venous drainage: anteriorly → facial vein; posteriorly → sphenopalatine vein → pterygoid venous plexus.
- ▶ Nerve supply: olfactory (upper 1/3) + trigeminal — anterior ethmoidal nerve (V1, anterosuperior) and **nasopalatine nerve** (V2, posteroinferior — the main nerve).
- ▶ Lymphatics: anterior half → submandibular nodes; posterior half → retropharyngeal/deep cervical nodes.
- ▶ DNS is corrected by septoplasty/SMR; over-resection of septal cartilage risks supratip (saddle) deformity.
- ▶ Sphenopalatine-artery-based nasoseptal flap is used for skull-base reconstruction (modern surgical anatomy correlate).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4 8e; Vishram Singh — Textbook of Anatomy Vol 3 4e; Moore's Clinically Oriented Anatomy 9e; AK Datta — Human Anatomy Vol 2 (Head & Neck).



Auditory tube

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The auditory tube — also called the **pharyngotympanic tube** or **Eustachian tube** (after the 16th-century Italian anatomist Bartolomeo Eustachi) — is an osseocartilaginous, trumpet-shaped channel connecting the anterior wall of the tympanic cavity (middle ear) to the lateral wall of the nasopharynx. It is about **36 mm (~4 cm)** long and passes downwards, forwards and medially from the ear to the pharynx. Its functions are ventilation of the middle ear (air-pressure equalisation across the tympanic membrane), mucociliary drainage of middle-ear secretions, and protection of the middle ear from nasopharyngeal reflux — functions whose failure underlies otitis media, one of the commonest applied questions on this topic.

1. Extent, direction and parts

Feature	Bony part	Cartilaginous part
Extent of tube	Posterior and lateral 1/3	Anterior and medial 2/3
Length	~12 mm	~24–25 mm

Feature	Bony part	Cartilaginous part
Location	Petrous temporal bone, near the tympanic plate	Sulcus tubae — a groove between the greater wing of sphenoid and the apex of the petrous temporal bone
Wall	Bony canal; lateral end wide, opening on the anterior wall of the tympanic cavity; medial end narrow (isthmus), jagged for attachment of the cartilage	Triangular plate of elastic cartilage curled to form the superior and medial walls; lateral wall and floor completed by a fibrous membrane (membranous lamina)
Free/attached end	Lateral end opens into the middle ear	Apex fused to the medial end of the bony part at the isthmus; base is free and raises the tubal elevation (torus tubarius) in the nasopharynx
Lumen	Oblong, widest side-to-side	Widest at the pharyngeal end (the widest part of the whole tube)

- The whole tube is directed downwards, forwards and medially, making an angle of 45° with the sagittal plane and 30° with the horizontal plane.
- The **isthmus**, at the bony–cartilaginous junction, is the narrowest part of the tube and the site most liable to functional obstruction.

□ Fig 18.7 — Section through long axis of the petromastoid bone showing pharyngotympanic tube, middle ear (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.787)

2. Relations

Aspect	Bony part	Cartilaginous part
Superior	Canal for tensor tympani	Tensor veli palatini is attached along the anterolateral membranous wall, including the isthmus
Medial	Carotid canal	Posteromedially: petrous temporal bone and levator veli palatini (which arises partly from the medial lamina of the tube)
Lateral	Chorda tympani, spine of sphenoid, auriculotemporal nerve, temporomandibular joint	Anterolaterally: tensor veli palatini separates the tube from the otic ganglion, the mandibular nerve and its branches, the chorda tympani, and the middle meningeal artery; also related to the medial pterygoid plate
Muscle attachments	—	Levator veli palatini attached to its inferior surface; salpingopharyngeus attached to its inferior part near the pharyngeal opening

3. Nasopharyngeal (pharyngeal) opening

- ▶ Lies on the **lateral wall of the nasopharynx**, at the level of, and about **1.25 cm (10 mm) behind and below**, the posterior end of the **inferior nasal concha**.
- ▶ Its upper and posterior margins are raised as the **tubal elevation (torus tubarius)**, produced by an underlying mass of lymphoid tissue, the **tubal tonsil** (one of the four components of Waldeyer's ring, along with the palatine, lingual and pharyngeal tonsils).
- ▶ Two mucosal folds pass from the torus tubarius:
 - **Salpingopharyngeal fold** — descends vertically, contains salpingopharyngeus, fades on the lateral pharyngeal wall.
 - **Salpingopalatine fold** — passes downwards and forwards to the soft palate, contains levator veli palatini.
- ▶ **Pharyngeal recess (fossa of Rosenmüller)** — a deep depression immediately behind the torus tubarius; clinically important as the commonest site of origin of nasopharyngeal carcinoma.
- ▶ The nasopharyngeal mucosa here is respiratory-type, **pseudostratified ciliated columnar epithelium**.

4. Muscles related to the tube

Muscle	Nerve supply	Attachment to tube	Action on the tube
Tensor veli palatini	Mandibular nerve (V3), via the nerve to medial pterygoid	Along the anterolateral membranous wall, including the isthmus	Primary dilator — its "dilator tubae" fibres actively open the tube during swallowing and yawning, equalising middle-ear pressure; the only palatal muscle NOT supplied by the vagoad accessory complex
Levator veli palatini	Pharyngeal plexus (vagus)	Inferior surface of the cartilaginous part	Little or no direct effect on the tube; may permit passive opening
Salpingopharyngeus	Pharyngeal plexus (vagus)	Arises from the inferior part of the cartilage near the pharyngeal opening	Elevates the pharynx and may assist tensor veli palatini in opening the cartilaginous end during swallowing
Tensor tympani	Mandibular nerve (via otic ganglion)	Arises partly from the cartilaginous part of the tube	Tenses the tympanic membrane; shares a bony septum and canal with the tube but is not a tubal dilator

5. Vascular supply, lymphatic drainage and nerve supply

- ▶ **Arteries:** ascending pharyngeal artery, middle meningeal artery, and the artery of the pterygoid canal.

- ▶ **Veins:** drain into the pharyngeal and pterygoid venous plexuses.
- ▶ **Lymphatics:** drain to the retropharyngeal nodes.
- ▶ **Nerve supply** (three levels along the tube):
- ▶ At the ostium — pharyngeal branch of the **pterygopalatine ganglion**, suspended from the maxillary nerve.
- ▶ Cartilaginous part — the **nervus spinosus** branch of the mandibular nerve.
- ▶ Bony part — the **tympanic plexus** (formed by the glossopharyngeal nerve).
- ▶ The glossopharyngeal nerve thus contributes to both the pharyngeal and the middle-ear mucosa — the anatomical basis of earache referred from throat infections.

6. Histology

- ▶ The tube is lined throughout by mucosa continuous with that of the middle ear and the nasopharynx.
- ▶ Most of its length is lined by **ciliated pseudostratified columnar epithelium**, about **one-fifth of the cells being goblet cells**; cilia beat towards the nasopharynx, providing mucociliary clearance of middle-ear secretions.
- ▶ The cartilage of the medial wall is **elastic cartilage, J-shaped (hook-shaped) in transverse section**; the lateral wall and floor are fibrous (membranous lamina), reinforced by Ostmann's fat pad.
- ▶ Submucosal seromucous glands and lymphoid aggregates (tubal tonsil) are concentrated near the pharyngeal end.

7. Development

- ▶ The tube and middle ear develop from the **tubotympanic recess**, an endodermal outgrowth of the **first pharyngeal pouch** (with a contribution from the adjoining second-arch/pouch region), seen from as early as a 4–6 mm embryo, lying between the first and second pharyngeal arches.
- ▶ Forward growth of the **third pharyngeal arch** keeps the proximal part of the recess narrow — this becomes the **auditory tube**; its more lateral, widened part becomes the **tympanic cavity**.
- ▶ **Auditory ossicles:** malleus and incus develop from **first-arch** mesenchyme (malleus from the dorsal end of Meckel's cartilage); stapes develops from **second-arch** mesenchyme, except its footplate and annular ligament, which come from the otic capsule.
- ▶ The **mastoid antrum** appears as a dorsal expansion of the tympanic cavity in the sixth–seventh month.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled schematic (lateral/sagittal scheme) of the auditory tube, with:

- ▶ Tympanic cavity (middle ear) — tube's lateral opening
- ▶ Bony part (in petrous temporal bone) and Cartilaginous part (in sulcus tubae)
- ▶ **Isthmus** at the bony–cartilaginous junction
- ▶ Tensor veli palatini (dilator tubae) and Levator veli palatini — attached to the tube
- ▶ Salpingopharyngeus
- ▶ Nasopharynx with the pharyngeal opening at the level of the inferior nasal concha
- ▶ Torus tubarius (tubal elevation) with the tubal tonsil
- ▶ Salpingopharyngeal fold and Salpingopalatine fold
- ▶ Fossa of Rosenmüller (pharyngeal recess) behind the torus tubarius
- ▶ Direction arrow (downwards, forwards, medially) with angles: 45° to the sagittal plane, 30° to the horizontal plane

Applied / Clinical anatomy

- ▶ **Route of otogenic infection:** the tube is the principal route by which nasopharyngeal infection (upper respiratory infection, tonsillitis, adenoiditis) spreads to the middle ear, causing **acute otitis media**.
- ▶ **Referred earache:** the glossopharyngeal nerve supplies both the pharyngeal mucosa and, via the tympanic plexus, the middle ear — so pharyngitis/tonsillitis commonly presents with referred otalgia, aggravated by swallowing.
- ▶ **Child vs adult tube:** in infants and children the tube is **shorter, wider, straighter and more horizontal** than in adults, so infection spreads more readily from throat to middle ear — the reason otitis media is far commoner in children.
- ▶ **Tubal obstruction:** adenoid hypertrophy, allergic rhinitis, or an upper respiratory infection swells the tubal mucosa and obstructs the ostium (commonly blocked in children by an enlarged tubal tonsil); the resulting negative middle-ear pressure promotes transudation and **otitis media with effusion** ("glue ear"), splinting the tympanic membrane and causing conductive hearing loss. Treated by myringotomy with insertion of a ventilation tube (grommet), and adenoidectomy if adenoids are causative.
- ▶ **Eustachian catarrh:** inflammation of the tube secondary to a common cold or sore throat, causing earache aggravated by swallowing (tubal blockage); relieved by nasal decongestant drops, which help open the ostium.
- ▶ **Barotrauma:** failure to equalise pressure (e.g. on aircraft descent or diving) causes painful retraction of the tympanic membrane (barotitis media); relieved by autoinflation manoeuvres — Valsalva, Toynbee, or politzerisation.
- ▶ **Patulous Eustachian tube:** an abnormally patent tube (e.g. after weight loss) causes autophony.
- ▶ **Fossa of Rosenmüller**, immediately behind the torus tubarius, is the commonest site of origin of **nasopharyngeal carcinoma**; a tumour here can obstruct the tubal orifice — unilateral serous

otitis media in an adult is therefore a red-flag sign requiring nasopharyngoscopy to exclude malignancy.

- ▶ The **isthmus** is the narrowest, most collapsible segment and the usual site of functional tubal obstruction.

High-yield exam pointers

- ▶ Auditory tube = pharyngotympanic tube = Eustachian tube; connects middle ear to nasopharynx; ~36 mm (4 cm) long.
- ▶ Two parts: bony (posterolateral 1/3, 12 mm) and cartilaginous (anteromedial 2/3, ~25 mm); junction = isthmus, the narrowest point.
- ▶ Direction: downwards, forwards, medially; 45° to the sagittal plane, 30° to the horizontal plane.
- ▶ Primary tube-opening muscle = **tensor veli palatini** (dilator tubae fibres), supplied by V3; levator veli palatini and salpingopharyngeus (both vagus, pharyngeal plexus) assist only passively.
- ▶ Develops from the **tubotympanic recess** — endoderm of the first pharyngeal pouch.
- ▶ Pharyngeal opening: level of 1.25 cm behind the inferior nasal concha; guarded by the torus tubarius (tubal tonsil), with salpingopharyngeal and salpingopalatine folds; fossa of Rosenmüller lies behind it.
- ▶ Nerve supply at three levels: ostium — pterygopalatine ganglion (via maxillary nerve); cartilaginous part — nervus spinosus (mandibular nerve); bony part — tympanic plexus (glossopharyngeal nerve).
- ▶ In children the tube is shorter, wider and more horizontal — hence more otitis media.
- ▶ Clinically: principal route of otogenic infection, cause of otitis media with effusion and barotrauma, and — when the effusion is unilateral in an adult — a red flag for nasopharyngeal carcinoma at the fossa of Rosenmüller.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4, 8e; Vishram Singh — Textbook of Anatomy Vol 3, 4e; IB Singh — Textbook of Anatomy Vol 3, 6e; AK Datta — Human Anatomy Vol 2 (Head & Neck); Ross Histology — A Text and Atlas, 7e; Junqueira's Basic Histology, 17e.



Blood supply of face

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction — The face is one of the most richly vascular regions of the body, an adaptation that permits rapid wound healing and supports the mobile muscles of facial expression. Its arterial supply is derived predominantly from branches of the **external carotid artery** (facial, superficial temporal and maxillary arteries), with a subsidiary contribution from the **ophthalmic artery** (a branch of the internal carotid artery). Venous drainage is chiefly by the valveless **facial vein**, which communicates freely — both directly and through the pterygoid venous plexus — with the intracranial cavernous sinus, giving the face major clinical importance.

SOURCE & COVERAGE

Parent trunk	Named branches reaching the face
External carotid artery (direct)	Facial artery — the chief artery of the face
External carotid artery, via superficial temporal artery	Transverse facial artery, zygomatico-orbital artery
External carotid artery, via maxillary artery	Buccal, infraorbital and mental arteries
Internal carotid artery, via ophthalmic artery	Supratrochlear, supraorbital, lacrimal (→ zygomaticofacial, zygomaticotemporal), medial palpebral and dorsal (external) nasal arteries

The posterior scalp margin additionally receives the occipital and posterior auricular arteries, but the face proper is supplied by the four sources above, which anastomose freely with one another and across the midline.

Facial artery

- ▶ Formerly termed the **external maxillary artery**; it is the principal artery of the face.
- ▶ **Origin**: a branch of the external carotid artery, given off in the carotid triangle just above the level of the tip of the greater cornu of the hyoid bone.
- ▶ **Cervical part**: passes deep to the submandibular gland in the submandibular region before turning to enter the face.
- ▶ **Entry into the face**: winds around the lower border of the mandible and pierces the deep cervical fascia at the **anteroinferior angle of masseter**. Its pulsation is palpable here, and it is therefore called the "**anaesthetist's artery**", used to monitor pulse during oral/maxillofacial procedures.
- ▶ **Facial course**: runs tortuously upward and forward to a point about **1.25 cm lateral to the angle of the mouth**, then ascends along the side of the nose to the medial angle of the eye, where it terminates as the **angular artery**, anastomosing with the dorsal nasal branch of the ophthalmic artery.
- ▶ **Tortuosity**: allows the vessel wall a reserve of length so that it is not stretched unduly during movements of the mandible, lips and cheeks.
- ▶ **Relations**: lies between the superficial and deep facial muscles — deep to skin/buccal fat and (near the angle of the mouth) zygomaticus major and risorius; superficial to buccinator and

levator anguli oris. The **facial vein** lies **posterior** to the artery, taking a straighter course; the two vessels contact at the anterior border of masseter.

Branches on the face

Branch	Course / termination	Supplies / anastomoses
Premasseteric (inconstant)	Ascends along anterior border of masseter	Overlying soft tissue
Inferior labial	Arises near angle of mouth, passes deep to depressor anguli oris, then between orbicularis oris and mucosa	Lower lip, mucosa, labial glands; anastomoses with its fellow and the mental branch of inferior alveolar artery
Superior labial	Larger and more tortuous; runs along the upper labial margin	Upper lip; gives alar and septal branches to the anteroinferior nasal septum; anastomoses with its fellow
Lateral nasal	Given off at the side of the nose	Ala and dorsum of nose; anastomoses with its fellow (may replace it)
Angular (terminal part)	Continues along the side of the nose to the medial canthus	Lacrimal sac; anastomoses with the dorsal nasal branch of the ophthalmic artery — an important external-internal carotid anastomosis

The large anterior (labial) branches anastomose freely across the midline — cut lip arteries characteristically spurt from both ends. Small, unnamed posterior branches anastomose with the transverse facial and infraorbital arteries. Occasionally the facial artery ends before reaching the angle of the mouth, its distal territory then being supplied by an enlarged transverse facial artery and by branches of the opposite facial artery.

Other arteries of the face

Artery	Parent vessel	Course and area supplied
Transverse facial	Superficial temporal artery (within the parotid gland)	Crosses masseter between the parotid duct and zygomatic arch with the buccal branch of the facial nerve; supplies parotid gland/duct, masseter, overlying skin
Zygomatico-orbital	Superficial temporal artery	Runs along the upper border of the zygomatic arch to the lateral orbital angle; supplies orbicularis oculi
Buccal	Maxillary artery, 2nd part	Crosses buccinator; supplies the cheek

Artery	Parent vessel	Course and area supplied
Infraorbital	Maxillary artery, 3rd part	Through infraorbital foramen; lower eyelid, lateral nose, upper lip
Mental	Terminal branch of inferior alveolar artery	Through mental foramen; chin
Supratrochlear	Ophthalmic artery	At frontal notch; medial forehead, upper eyelid, scalp
Supraorbital	Ophthalmic artery	Through supraorbital notch/foramen; forehead, upper eyelid, scalp
Zygomaticofacial / zygomaticotemporal	Lacrimal artery	Through zygomatic bone/lateral orbital wall; cheek prominence and temple
Medial palpebral	Ophthalmic artery	Tarsal arches of the eyelids
Dorsal (external) nasal	Anterior ethmoidal artery (ophthalmic)	Skin of the external nose

The superficial temporal artery (smaller terminal branch of the external carotid artery) arises within the parotid gland, becomes superficial over the posterior root of the zygoma (a palpable pulse point), and divides into frontal and parietal branches to the scalp and side of the face.

□ Fig 2.17 — Arteries of the face (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.94)

Venous drainage of the face

- The **facial vein** is the largest vein of the face and, uniquely, is **devoid of valves** throughout its course — a fact of major clinical importance.
- **Formation:** the supratrochlear and supraorbital veins unite near the medial canthus of the eye to form the **angular vein**, which continues downward as the facial vein.
- **Course:** passes obliquely downward alongside the nose, deep to zygomaticus major, risorius and platysma, crosses the anteroinferior angle of masseter, then descends over the surface of masseter and across the body of the mandible into the neck. On the face it lies posterior to the more tortuous facial artery; it crosses the artery near the lower border of the mandible.
- **Termination:** joins the anterior division of the retromandibular vein to form the **common facial vein**, which drains into the **internal jugular vein**.
- **Tributaries:** supraorbital and supratrochlear veins (forming the angular vein), nasal veins, inferior palpebral, superior and inferior labial, buccinator, parotid and masseteric veins, and — of great surgical importance — the **deep facial vein**, which connects the facial vein to the **pterygoid venous plexus** in the infratemporal fossa.
- The **superficial temporal vein** descends in front of the tragus, enters the parotid gland and joins the **maxillary vein** to form the **retromandibular vein**, which divides into an anterior division (→ facial vein → common facial vein → internal jugular vein) and a posterior division (→ posterior auricular vein → external jugular vein).

- ▶ On each side, the veins of the scalp and face together describe a "W"-shaped pattern, each limb of the W prolonged upward into the scalp and downward into the neck.

Deep/dural communication	Route	Clinical significance
Direct	Angular vein ↔ supraorbital vein ↔ superior ophthalmic vein ↔ cavernous sinus	Short, direct retrograde route from medial face to cavernous sinus
Indirect	Facial vein → deep facial vein → pterygoid venous plexus → emissary veins (foramen ovale, foramen lacerum, foramen of Vesalius) → cavernous sinus	Longer route; also relevant to spread of odontogenic/infratemporal infection

Because the facial vein and its tributaries are valveless, blood (and infection) can flow in either direction; a rise in intracranial pressure or a septic focus on the face can therefore propagate straight back into the dural venous sinuses.

Applied / Clinical anatomy

- ▶ **Dangerous area of the face:** the region of the **upper lip and the sides (root) of the external nose**. Because of the valveless facial–ophthalmic–cavernous connections above, squeezing a furuncle or pustule in this area can force infected material retrogradely along the angular and deep facial veins into the cavernous sinus, producing **septic cavernous sinus thrombosis** — presenting with proptosis, chemosis and ophthalmoplegia (III, IV, VI nerves lie in the sinus wall).
- ▶ **Anaesthetist's artery:** the facial artery pulse, palpable at the anteroinferior angle of masseter on the lower border of the mandible, is a standard site for monitoring pulse during oral and maxillofacial surgery.
- ▶ **Surface marking** (clinically used in planning facial-artery-based flaps): a line from the point on the mandible at the anteroinferior angle of masseter, through a point 1.25 cm lateral to the angle of the mouth, to the medial angle of the eye (a point midway between the ala of the nose and the red margin of the upper lip lying on this line).
- ▶ **Collateral circulation / ligation:** the facial artery may be ligated in severe facial haemorrhage or head-and-neck cancer resections without significant tissue loss, owing to rich anastomoses — its own contralateral fellow, the transverse facial and infraorbital arteries, and (via the angular–dorsal nasal anastomosis) the ophthalmic artery, an important **external–internal carotid collateral pathway**.
- ▶ **Variant anatomy:** the facial artery may occasionally end before the angle of the mouth; its distal territory is then taken over by an enlarged transverse facial artery and contralateral facial branches — relevant to planning a facial-artery-based (nasolabial) flap, whose vascularity comes from facial artery perforators rather than one axial vessel.

High-yield exam pointers

- ▶ Facial artery = external maxillary artery = chief artery of the face; arises from the external carotid artery in the carotid triangle above the greater cornu of the hyoid.

- ▶ Enters the face winding round the lower border of the mandible at the anteroinferior angle of masseter — palpable here as the "anaesthetist's artery."
- ▶ Named facial branches: premassesteric, inferior labial, superior labial, lateral nasal; terminates as the angular artery at the medial canthus.
- ▶ Angular artery anastomoses with the dorsal nasal branch of the ophthalmic artery — a key external–internal carotid anastomosis.
- ▶ Four sources of arterial supply to the face: facial artery, superficial temporal artery (transverse facial), maxillary artery (buccal, infraorbital, mental), ophthalmic artery (supratrochlear, supraorbital, lacrimal, medial palpebral, dorsal nasal).
- ▶ Facial vein is the largest vein of the face and has **no valves**.
- ▶ Facial vein + anterior division of retromandibular vein = common facial vein → internal jugular vein.
- ▶ Facial vein communicates with the cavernous sinus both directly (via supraorbital/superior ophthalmic vein) and indirectly (via deep facial vein → pterygoid venous plexus → emissary veins).
- ▶ "Dangerous area of the face" = upper lip and sides of the nose — basis of septic cavernous sinus thrombosis from facial infection.
- ▶ Veins of the face and scalp together form a characteristic "W"-shaped pattern.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Labelled scheme — Arterial and venous supply of the (left) face, with exact labels:

- ▶ External carotid artery → **Facial artery** (entering at lower border of mandible, anteroinferior angle of masseter)
- ▶ Facial artery branches: **Inferior labial artery**, **Superior labial artery**, **Lateral nasal artery**, **Angular artery** (with anastomosis to dorsal nasal artery of ophthalmic artery)
- ▶ Superficial temporal artery → **Transverse facial artery**, **Zygomatico-orbital artery**
- ▶ Maxillary artery → **Buccal artery**, **Infraorbital artery**, **Mental artery**
- ▶ Ophthalmic artery → **Supratrochlear artery**, **Supraorbital artery**
- ▶ **Angular vein** (union of supratrochlear + supraorbital veins) → **Facial vein**
- ▶ **Deep facial vein** → **Pterygoid venous plexus**
- ▶ **Superficial temporal vein** + **Maxillary vein** → **Retromandibular vein** (anterior/posterior divisions)
- ▶ **Common facial vein** → **Internal jugular vein**
- ▶ Shade and label the "**Dangerous area of the face**" (upper lip + sides of nose) with a dashed arrow to the **Cavernous sinus**

□ Fig 2.18 — *Dangerous area of the face (stippled). Spread of infection from this area (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.96)*

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e — "Face and scalp" chapter (arterial supply, venous drainage, cavernous sinus communications); BD Chaurasia's Human Anatomy Vol 3–4, 8e (facial and transverse facial arteries, veins of the face, "dangerous area," anaesthetist's artery, W-shaped venous pattern); AK Datta's Human Anatomy Vol 2 (Head & Neck) (facial artery synonym, surface marking, pulse points).



Boundaries and contents of carotid triangle

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction

The carotid triangle is one of the four subdivisions of the anterior triangle of the neck, produced by the digastric and omohyoid muscles crossing the sternocleidomastoid-to-midline space. It is so named because it contains all three carotid arteries — common, internal and external — together with the internal jugular vein, the last three cranial nerves (vagus, accessory, hypoglossal), the cervical sympathetic chain and the ansa cervicalis. Clinically it is the single most important region of the neck for the postgraduate to master, being the surgical corridor for carotid endarterectomy, radical neck dissection and central venous access, and the site of the carotid pulse, carotid sinus reflex and carotid body tumours.

Boundaries and extent

Boundary	Formed by
Anterosuperior	Posterior belly of digastric, reinforced by stylohyoid
Anteroinferior	Superior belly of omohyoid
Posterior	Anterior border of sternocleidomastoid
Apex	Point where digastric and omohyoid bellies approach the sternocleidomastoid

- ▶ Best demonstrated by retracting the posterior boundary (sternocleidomastoid) slightly backwards, which brings all the vessels and nerves into full view.
- ▶ In life it is usually visible as a small triangular depression, particularly on head rotation to the opposite side.

Roof and floor

- ▶ **Roof** (superficial to deep):
 - Skin
 - Superficial fascia containing platysma, the cervical branch of the facial nerve, and the transverse cutaneous (cervical) nerve of the neck (a branch of the cervical plexus)
 - Investing layer of deep cervical fascia

- ▶ **Floor** (from above downwards): four muscles covered by the buccopharyngeal fascia —
- ▶ Hyoglossus
- ▶ Middle constrictor of pharynx
- ▶ Inferior constrictor of pharynx
- ▶ Thyrohyoid membrane and thyrohyoid muscle

Contents

The triangle is overlapped by the anterior border of sternocleidomastoid, deep to which lie:

Category	Structures
Arteries	Common carotid artery (terminal part); internal carotid artery (no branches in the neck); external carotid artery with its first five branches — ascending pharyngeal (first branch), superior thyroid, lingual, facial and occipital arteries; carotid sinus and carotid body at the bifurcation
Veins	Internal jugular vein, receiving the common facial vein, lingual vein, superior thyroid vein and (variably) a pharyngeal vein
Nerves	Vagus (X); hypoglossal (XII) with its superior root of ansa cervicalis; spinal accessory (XI); cervical sympathetic trunk
Other	Ansa cervicalis (superior + inferior roots); carotid sheath; deep cervical lymph nodes (jugulodigastric and jugulo-omohyoid nodes) along the internal jugular vein

Disposition of the principal contents

- ▶ The common carotid artery ascends within the carotid sheath, under cover of sternocleidomastoid, in front of the transverse processes of the lower four cervical vertebrae, and terminates by dividing into external and internal carotid arteries at the level of the upper border of the thyroid cartilage.
- ▶ The external carotid artery lies anteromedial to the internal carotid at first, then curves back to become superficial to it as both vessels ascend; the internal carotid gives no branch in the neck.
- ▶ The internal jugular vein lies posterolateral to the carotid arteries and is partly hidden by the posterior edge of sternocleidomastoid.
- ▶ The vagus nerve descends vertically on a plane deeper than the vessels, at first between internal carotid artery and internal jugular vein, then between common carotid artery and internal jugular vein; within the triangle it gives a pharyngeal branch (to the pharyngeal plexus) and the superior laryngeal nerve, which divides into internal (sensory, pierces thyrohyoid membrane) and external (motor to cricothyroid and inferior constrictor) laryngeal nerves.
- ▶ The hypoglossal nerve hooks around the origin of the occipital artery and runs forward, crossing superficial to the internal carotid, external carotid and the loop of the lingual artery, to reach

hyoglossus above the hyoid; as it crosses the internal carotid it gives off the superior root of the ansa cervicalis (descendens hypoglossi) and a branch to thyrohyoid.

- ▶ The accessory nerve crosses the upper part of the triangle superficial to the internal jugular vein, running backward to enter and supply sternocleidomastoid.
- ▶ The carotid sheath encloses the common and internal carotid arteries and the internal jugular vein, with the vagus lying between artery and vein on a deeper plane; the ansa cervicalis is embedded in its anterior wall, while the cervical sympathetic trunk lies just deep to its posterior wall on the prevertebral fascia — thus outside the sheath proper.
- ▶ **Summary rule:** all major contents (three carotid arteries, internal jugular vein, last three cranial nerves) lie deep to sternocleidomastoid, and good exposure of the triangle requires retracting this muscle backwards.

Ansa cervicalis

- ▶ A U-shaped nerve loop lying in the carotid triangle, embedded in the anterior wall of the carotid sheath; derived from the ventral rami of C1–C3.
- ▶ **Superior root** (descendens hypoglossi): a branch of the hypoglossal nerve carrying C1 fibres; descends over the internal and common carotid arteries.
- ▶ **Inferior root** (descendens cervicalis): from C2 and C3; winds around the internal jugular vein and passes anteroinferiorly to join the superior root in front of the common carotid artery, near the cricoid cartilage.
- ▶ Supplies all infrahyoid (strap) muscles — sternohyoid, sternothyroid, and both bellies of omohyoid — except thyrohyoid, which is supplied directly by C1 fibres travelling with the hypoglossal nerve.
- ▶ Functionally important for phonation and deglutition (fixing the hyoid bone) and is used as a nerve graft to repair a divided recurrent laryngeal nerve.

□ Fig 8.16 — Boundaries of carotid triangle (IB Singh — Textbook of Anatomy Vol 3 — 6e, p.150)

□ Fig 8.17 — Contents of carotid triangle (IB Singh — Textbook of Anatomy Vol 3 — 6e, p.150)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the triangle with sternocleidomastoid retracted backward and label:

- ▶ Boundaries — posterior belly of digastric + stylohyoid (anterosuperior), superior belly of omohyoid (anteroinferior), anterior border of sternocleidomastoid (posterior)
- ▶ Floor — hyoglossus, middle constrictor, inferior constrictor, thyrohyoid membrane/muscle
- ▶ Common, internal and external carotid arteries with the carotid sinus and carotid body at the bifurcation
- ▶ First five branches of the external carotid artery — ascending pharyngeal, superior thyroid, lingual (with its characteristic loop over the hyoid), facial, occipital
- ▶ Internal jugular vein with its tributaries — common facial, lingual, superior thyroid veins
- ▶ Vagus (X), hypoglossal (XII) with superior root of ansa cervicalis, and accessory (XI) nerves
- ▶ Ansa cervicalis (superior + inferior roots) and cervical sympathetic trunk posterior to the sheath
- ▶ Carotid sheath outline and deep cervical (jugulodigastric, jugulo-omohyoid) lymph nodes

Applied / Clinical anatomy

- ▶ **Carotid pulse:** palpated by placing the index and middle fingers posterolateral to the larynx at the upper border of the thyroid cartilage (or over the external carotid midway between the thyroid cartilage and the greater cornu of the hyoid); it is among the strongest pulses in the body and is the pulse checked during CPR — its absence signals cardiac arrest.
- ▶ **Carotid tubercle (Chassaignac's tubercle):** the prominent anterior tubercle of the transverse process of C6, about 4 cm above the sternoclavicular joint; the common carotid artery can be digitally compressed against it (medially and posteriorly) to control haemorrhage.
- ▶ **Carotid sinus syndrome:** hypersensitivity of the carotid sinus baroreceptor causes reflex bradycardia, hypotension and syncope on neck rotation or a tight collar/tie; relieved by periarterial neurectomy. The same reflex underlies therapeutic carotid sinus massage used to terminate supraventricular tachycardia.
- ▶ **Carotid body tumour (chemodectoma):** a painless, slow-growing tumour of the chemoreceptor tissue at the carotid bifurcation; splay the internal and external carotid arteries apart (the angiographic "lyre sign") and may infiltrate adjacent nerves and vessels.
- ▶ **Surgical corridor:** the carotid triangle is the classical operative approach to the carotid arterial system — used for carotid endarterectomy (stripping atherosclerotic plaque from the internal carotid intima in cases of stenosis/TIA) and for exposure of the internal jugular vein, vagus, hypoglossal and accessory nerves and the cervical sympathetic trunk during radical neck dissection and central line placement.
- ▶ **Iatrogenic nerve injury:** because the vagus, hypoglossal, accessory and the ansa cervicalis all traverse this small space, surgery here risks voice change (vagus/recurrent or superior laryngeal nerve), tongue deviation (hypoglossal), or shoulder drop (accessory).

- ▶ **Surface marking of the carotid sheath:** a line joining the sternoclavicular joint to a point midway between the mastoid process and the angle of the mandible.
- ▶ **Descendens hypoglossi graft:** the superior root of the ansa cervicalis is used to bridge a divided recurrent laryngeal nerve, most often injured during thyroidectomy.

High-yield exam pointers

- ▶ Carotid triangle = one of four subdivisions of the anterior triangle (others: submental, digastric/submandibular, muscular); it lies between digastric/stylohyoid above, omohyoid below, and sternocleidomastoid behind.
- ▶ Contains all three carotid arteries, internal jugular vein, the last three cranial nerves (vagus X, accessory XI, hypoglossal XII), the cervical sympathetic trunk and the ansa cervicalis — all deep to sternocleidomastoid.
- ▶ First branch of the external carotid artery in the triangle = ascending pharyngeal artery.
- ▶ Common carotid divides into external and internal carotid arteries at the upper border of the thyroid cartilage.
- ▶ Ansa cervicalis: superior root (descendens hypoglossi, C1 via XII) + inferior root (descendens cervicalis, C2–C3); supplies all infrahyoid muscles except thyrohyoid.
- ▶ Carotid sinus = baroreceptor (glossopharyngeal-mediated reflex); carotid body = chemoreceptor — both innervated by IX, X and sympathetics.
- ▶ Ansa cervicalis lies in the anterior wall of the carotid sheath; sympathetic trunk lies posterior to it, outside the sheath, on the prevertebral fascia.
- ▶ Chassaignac's (carotid) tubercle — anterior tubercle of C6 transverse process, ~4 cm above the sternoclavicular joint — landmark for carotid compression.
- ▶ The triangle is the operative field for carotid endarterectomy and radical neck dissection; its floor and vessels are also the surgical route to expose the pharynx and larynx from outside.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3–4 8e; Vishram Singh — Textbook of Anatomy Vol 3 4e; IB Singh — Textbook of Anatomy Vol 3 6e; Moore's Clinically Oriented Anatomy 9e.



Dangerous area of face and scalp

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The "dangerous area" of the **face** is the triangular zone bounded by the root of the nose above and the two angles of the mouth below (apex at the root of the nose, base at the upper lip) — it includes the lower nose, upper lip and adjoining cheek. The "dangerous area" of the **scalp** is its fourth layer, the loose areolar tissue. Both are called dangerous because they drain, through **valveless veins**, into the **cavernous sinus** — so pyogenic infection of the face or scalp can spread retrogradely to cause septic cavernous sinus thrombosis and meningitis. The unifying anatomical basis is the absence of valves in the facial vein, its deep connections, and the emissary veins.

1. Layers of the scalp (mnemonic — SCALP)

Layer	Structure	Clinical note
S – Skin	Thick, hairy, rich in sweat and sebaceous glands	Common site of sebaceous cysts; wounds bleed profusely (vessels tethered, cannot retract) but heal well (rich blood supply)
C – Connective tissue (superficial fascia)	Dense, fibrofatty; binds skin to aponeurosis; carries vessels/nerves	Haemorrhage here is limited (dense fascial septa) → little swelling, much pain
A – Aponeurosis (epicranial aponeurosis / galea aponeurotica) with occipitofrontalis	Frontal belly (facial nerve – temporal branch) and occipital belly (facial nerve – posterior auricular branch)	Transverse wounds gape because occipitofrontalis pulls the cut edges apart
L – Loose areolar tissue ("dangerous area of the scalp")	Subaponeurotic space; contains emissary veins	Infection/blood here spreads freely — see below
P – Pericranium	Periosteum of the vault; loosely attached to bone but firmly adherent at sutures	Subperiosteal collections (cephalhaematoma) are limited by sutures

The first three layers (Skin, Connective tissue, Aponeurosis) move together as one unit and are called the **scalp proper / surgical layers** (scalp flaps are raised in this plane).

□ Fig 3.2 — ■ Layers of the scalp. (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e*, p.189)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section through the scalp, labelling from superficial to deep: Skin → Superficial fascia (Connective tissue) → Epicranial aponeurosis (galea aponeurotica) with occipitofrontalis → Loose areolar tissue (subaponeurotic space) → Pericranium → Skull (outer table–diploë–inner table). Mark an **emissary vein** traversing the loose areolar layer and pericranium/skull to reach a dural venous sinus, and mark the **frontalis muscle's absence of bony origin** at the anterior end (continuity of the loose areolar plane into the eyelid).

2. Why the loose areolar layer is the "dangerous area of the scalp"

- ▶ It is traversed by numerous **emissary veins** (valveless) that directly connect the scalp veins to the **intracranial dural venous sinuses**; extracranial (scalp) infection can therefore spread intracranially through this layer.
- ▶ The space extends **anteriorly into the eyelids** (because the frontalis muscle has no bony origin) and posteriorly to the superior nuchal line — so blood or pus collected here can track forward into the eyelid and subconjunctival tissue, producing a "**black eye**", and the posterior limit of such spontaneous spread is not seen (a locally-caused haematoma, in contrast, does show a defined posterior limit).
- ▶ Because the collection spreads widely in this plane rather than being confined, it does **not compress the brain**, so this layer is also termed the **safety layer/safety-valve layer** of the scalp.
- ▶ Contrast with the pericranial (5th) layer: a subperiosteal collection (**cephalhaematoma**) is limited to the surface of one bone because the pericranium is adherent at the sutures — it therefore takes the shape of the bone.

3. The facial venous system (route from the face)

- ▶ The **facial vein** is the largest, valveless vein of the face. It begins as the **angular vein** at the medial angle of the eye, formed by union of the **supratrochlear** and **supraorbital veins**.
- ▶ It runs down and back (straighter and more superficial than the facial artery), crosses the mandible, and joins the anterior division of the retromandibular vein to form the **common facial vein**, which drains into the **internal jugular vein**.
- ▶ Because it lies directly on the muscles of facial expression and has no valves, contraction of these muscles (or manipulation — e.g., squeezing a pimple) can drive septic emboli in either direction, including **retrogradely towards the skull**.
- ▶ **Deep connections** of the facial vein: (i) angular vein ↔ **superior ophthalmic vein**; (ii) **deep facial vein** ↔ **pterygoid venous plexus**. Both of these deep connections lead, in turn, to the cavernous sinus.

4. The danger triangle (dangerous area) of the face

- ▶ **Boundaries:** a triangle with its **apex at the root of the nose** and its **base at the upper lip** (i.e., bridge of nose above, angles of the mouth on each side) — comprising the lower nose, upper lip and adjoining cheek.

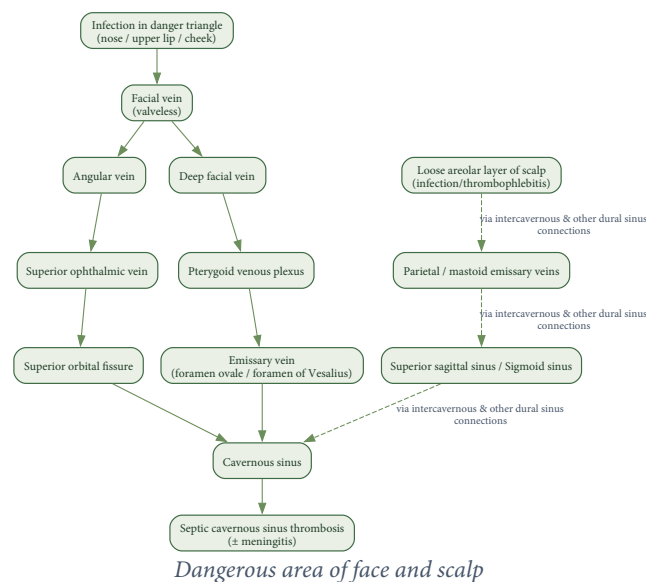
- Skin over this region drains predominantly into the facial vein and its deep connections rather than into lymphatics alone, and lies close to the valveless ophthalmic veins.
- Infection here (boils/furuncles of the nose, upper lip, or a squeezed pimple on the cheek) can spread **retrogradely** — via the angular/superior ophthalmic vein, or via the deep facial vein–pterygoid plexus route — to the cavernous sinus, causing **septic cavernous sinus thrombosis**.

□ Fig 3.19 — ■ *Dangerous area of the face.* (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e, p.230*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Frontal view of the face: outline the **danger triangle** (apex at root of nose, base along the upper lip/angles of mouth, stippled). Label **angular vein**, **facial vein**, **superior/inferior ophthalmic veins**, **deep facial vein**, **pterygoid venous plexus**, and an arrow tracing retrograde flow from the triangle into the **cavernous sinus** (shown as a paired sinus flanking the sella turcica).

5. Routes of spread to the cavernous sinus



6. Emissary veins connecting scalp/face veins to dural venous sinuses

Emissary vein (foramen)	Connects extracranial vein to	Sinus reached
Parietal emissary vein (parietal foramen)	Scalp veins	Superior sagittal sinus
Mastoid emissary vein (mastoid foramen)	Posterior auricular/occipital veins	Sigmoid sinus
Posterior condylar emissary vein (condylar canal)	Suboccipital venous plexus	Sigmoid sinus
Emissary vein of foramen ovale	Pterygoid venous plexus	Cavernous sinus
Sphenoidal emissary vein (foramen of Vesalius)	Pterygoid venous plexus	Cavernous sinus

Emissary vein (foramen)	Connects extracranial vein to	Sinus reached
Emissary vein of foramen lacerum	Pharyngeal/pterygoid veins	Cavernous sinus
Vein of foramen caecum (when patent)	Nasal mucosal veins	Superior sagittal sinus
Condylar/hypoglossal canal emissary vein	Vertebral venous plexus	Basilar venous plexus

All emissary veins are **valveless**, permitting bidirectional flow — the anatomical basis for retrograde spread of extracranial sepsis into the dural sinuses from both the "dangerous" scalp layer and the "dangerous" facial triangle.

Applied / Clinical anatomy

- ▶ **Cavernous sinus thrombosis:** the sinus contains the internal carotid artery and abducent nerve (VI) within it, and the oculomotor (III), trochlear (IV), and ophthalmic/maxillary divisions of the trigeminal nerve (V1, V2) embedded in its lateral wall. Septic thrombophlebitis can therefore produce **ophthalmoplegia** (III, IV, VI palsy), **proptosis/chemosis** (obstructed ophthalmic venous drainage), and **sensory loss over V1/V2 distribution**; infection may spread to the opposite sinus via the intercavernous sinuses, and to the meninges (meningitis).
- ▶ **Why squeezing is dangerous:** pustules/boils of the nose or upper lip, or manipulation of a furuncle, can dislodge septic emboli into the valveless facial vein; because facial expression muscle contraction "massages" the vein, this favours retrograde spread — hence patients are classically warned never to squeeze pimples in this triangle.
- ▶ **Black eye (periorbital ecchymosis):** haemorrhage in the loose areolar layer of the scalp tracks anteriorly into the eyelid because frontalis has no bony origin; the posterior extent of such spontaneous spread is not visible, unlike a purely local injury.
- ▶ **Cephalhaematoma vs subaponeurotic haemorrhage:** a subperiosteal bleed is limited to one bone (sutures fix the pericranium) and takes the shape of that bone; a subaponeurotic bleed spreads freely across the whole loose areolar layer without brain compression (the "safety-valve" property).
- ▶ **Scalp lacerations/avulsions:** bleed profusely (fibrous septa prevent vessel retraction) but the rich anastomotic blood supply (from both internal and external carotid systems, anastomosing at the temple) allows even avulsed scalp flaps to be successfully replanted.
- ▶ **Surgical plane:** scalp flaps for craniotomy are raised in the loose areolar plane, separating the "scalp proper" (skin + connective tissue + aponeurosis) from the pericranium.

High-yield exam pointers

- ▶ Danger area of **face** = danger triangle: apex at root of nose, base at upper lip; danger area of **scalp** = loose areolar tissue (4th of 5 layers, mnemonic SCALP).
- ▶ Common link: **valveless veins** — facial vein and its deep connections, and emissary veins — permitting retrograde spread to the **cavernous sinus**.

- ▶ Two deep routes from face to cavernous sinus: (1) angular vein → superior ophthalmic vein → cavernous sinus; (2) deep facial vein → pterygoid venous plexus → emissary vein (foramen ovale/Vesalius) → cavernous sinus.
- ▶ Loose areolar layer of scalp = "safety layer" (haemorrhage spreads without compressing brain) and communicates via parietal/mastoid emissary veins with superior sagittal/sigmoid sinuses.
- ▶ Frontalis has no bony origin → loose areolar plane continuous into eyelid → black eye from scalp haemorrhage.
- ▶ Cephalhaematoma (subperiosteal) is limited by sutures; subaponeurotic haemorrhage is not.
- ▶ Cavernous sinus thrombosis clinically: ophthalmoplegia (III, IV, VI), proptosis, chemosis, V1/V2 sensory loss ± meningitis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4 (8e); Vishram Singh — Textbook of Anatomy Vol 3 (4e); IB Singh — Textbook of Anatomy Vol 3 (6e); IB Singh — Textbook of Human Neuroanatomy; Moore's Clinically Oriented Anatomy (9e).

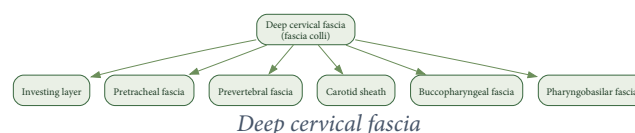


Deep cervical fascia

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The deep cervical fascia (fascia colli) is the sheet of dense fibroareolar connective tissue lying deep to the platysma that invests the muscles, glands, vessels and viscera of the neck, binding them into definite compartments and cleavage planes. It is distinct from the superficial cervical fascia, a loose subcutaneous layer containing fat and platysma that shows no true fascial condensation. By convention the deep cervical fascia is described in six parts — the **investing** (superficial) layer, the **pretracheal fascia**, the **prevertebral fascia**, the **carotid sheath**, and the **buccopharyngeal** and **pharyngobasilar** fasciae — which together arrange the neck into an anterior visceral column (pretracheal fascia), a posterior fascio-osteomuscular column (prevertebral fascia) and two lateral fascioneurovascular columns (the paired carotid sheaths). Its principal surgical importance is that it provides natural planes of dissection and dictates the routes by which infection spreads within the neck and into the mediastinum.

1. Classification of the layers



2. Investing layer

- ▶ Lies immediately deep to platysma and encircles the neck like a collar; forms the **roof of both the anterior and posterior triangles**.
- ▶ **Attachments** — Posteriorly: ligamentum nuchae and spine of C7. Anteriorly: symphysis menti and hyoid bone (continuous with the opposite side above and below the hyoid). Superiorly:

external occipital protuberance/superior nuchal line, mastoid process, zygomatic arch, lower border of the mandible, and (between the angle of mandible and mastoid process) it splits to enclose the **parotid gland**. Inferiorly: acromion, spine of scapula, clavicle and manubrium sterni.

- ▶ **The "2-2-2-2" rule** — it splits to enclose **2 muscles** (trapezius, sternocleidomastoid), **2 glands** (parotid, submandibular), **2 spaces** (suprasternal, supraclavicular), and is thickened twice to form the **parotidomasseteric fascia** and the **stylomandibular ligament**; it also forms two fascial slings/pulleys for the intermediate tendons of digastric and omohyoid.
- ▶ **Suprasternal space (space of Burns)** — formed where the fascia splits above the manubrium; contains the sternal heads of both sternocleidomastoids, the jugular venous arch, a lymph node, and the interclavicular ligament.
- ▶ **Supraclavicular space** — formed where the fascia splits above the middle third of the clavicle; traversed by the terminal part of the external jugular vein, the supraclavicular nerves, and cutaneous lymphatics.

□ Fig 4.9 — Diagrammatic transverse section through neck at the level of the 6th cervical vertebra (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e, p.262*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Transverse section through the neck at the C6 vertebral level, labelling: **investing layer, pretracheal layer, prevertebral layer, carotid sheath, alar fascia**; viscera — trachea, oesophagus, recurrent laryngeal nerve; infrahyoid muscles — sternohyoid, sternothyroid, omohyoid (superior belly); sternocleidomastoid; roots of ansa cervicalis; sympathetic trunk; ventral ramus of a cervical spinal nerve; prevertebral muscles — scalenus anterior, scalenus medius, levator scapulae, splenius capitis; trapezius; ligamentum nuchae; and the roofs of the anterior and posterior triangles.

3. Pretracheal fascia

- ▶ Lies in front of the trachea; encloses and **suspends the thyroid gland, forming its false capsule**; continuous with the buccopharyngeal fascia above.
- ▶ **Attachments** — Superiorly: hyoid bone in the midline, oblique line of the thyroid cartilage, and the cricoid cartilage laterally. Inferiorly: descends behind the thyroid, encloses the inferior thyroid veins, passes behind the brachiocephalic veins and blends with the arch of the aorta and fibrous pericardium; at the thoracic inlet it is continuous with the suprapleural membrane (**Sibson's fascia**). Laterally: forms the anterior wall of the carotid sheath and fuses with the fascia deep to sternocleidomastoid.
- ▶ The thickened posterior part of the thyroid capsule forms the **ligament of Berry**, attached mainly to the cricoid (and sometimes the thyroid) cartilage; it anchors the gland and prevents descent into the mediastinum, but the capsule is weak along the posterior border of each lobe. The **recurrent laryngeal nerve** ascends close to this ligament in the tracheo-oesophageal groove, making the area surgically hazardous during thyroidectomy.
- ▶ Splits around the infrahyoid muscles to form the "omohyoid fascia," tethering the intermediate tendon of omohyoid to the clavicle.

- Function: provides a slippery surface allowing free movement of the trachea and larynx during swallowing — the basis of the clinical sign that thyroid swellings move with deglutition.

4. Prevertebral fascia

- Lies anterior to the prevertebral muscles and forms the **floor of the posterior triangle**.
- **Attachments** — Superiorly: base of the skull. Inferiorly: extends into the superior mediastinum and splits into an anterior (alar) layer that blends with the buccopharyngeal fascia, and a posterior layer attached to the anterior longitudinal ligament and the body of the **4th thoracic vertebra**. Anteriorly it is separated from the buccopharyngeal fascia by the retropharyngeal space. Laterally it lies deep to trapezius.
- **Axillary sheath** — a tubular prolongation of the prevertebral fascia that carries the trunks of the brachial plexus and the subclavian/axillary artery through the interscalene interval into the axilla; the subclavian and axillary **veins lie outside the sheath**, allowing them to dilate during increased venous return (the anatomical basis of the interscalene brachial plexus block).
- Structures related to it: the cervical and brachial plexuses lie deep to it (four cutaneous branches of the cervical plexus pierce it to become superficial); the **cervical sympathetic trunk lies plastered to it, behind the carotid sheath**; the dorsal scapular, long thoracic and phrenic nerves run entirely deep to it.
- Function: provides a fixed base against which the pharynx, oesophagus and carotid sheaths glide during neck movement and swallowing.

5. Carotid sheath

- A tubular condensation of fibroareolar tissue formed **anteriorly by the pretracheal fascia and posteriorly by the prevertebral fascia**; it is overlapped by the anterior border of sternocleidomastoid and fused to the adjoining layers of deep fascia.
- **Contents** — the common/internal carotid artery, internal jugular vein and vagus nerve (the sheath is thin over the vein); the **ansa cervicalis lies embedded in its anterior wall**; in its upper part, cranial nerves IX, XI and XII pierce the sheath at different points.
- **Relations** — the cervical sympathetic chain lies immediately behind it, plastered to the prevertebral fascia.

6. Buccopharyngeal and pharyngobasilar fasciae

- **Buccopharyngeal fascia** covers the pharyngeal constrictor muscles externally, extends onto the superficial aspect of buccinator, and is attached to the pharyngeal tubercle of the occipital bone; the retropharyngeal space lies posterior to it.
- **Alar fascia** is an ancillary layer (the anterior lamina of the prevertebral fascia) that subdivides the retropharyngeal space into (i) the true retropharyngeal space anteriorly, between the buccopharyngeal and alar fasciae, and (ii) the "**danger space**" posteriorly, between the alar and prevertebral fasciae — the danger space communicates directly and unimpeded with the posterior mediastinum.
- **Pharyngobasilar fascia** is the fibrous membrane thickened between the upper border of the superior constrictor and the skull base, lying deep to the pharyngeal musculature.

7. Fascial spaces of the neck

Space	Boundaries	Contents	Clinical note
Retropharyngeal space	Ant.: buccopharyngeal fascia; Post.: prevertebral fascia (fused in midline); Sides: carotid sheath; Sup.: skull base; Inf.: open, continuous with superior mediastinum	Retropharyngeal lymph nodes, pharyngeal venous/nerve plexus, loose areolar tissue	Acute (nodal) abscess — paramedian; chronic/cold (vertebral TB) abscess — median
Danger space	Between alar fascia (ant.) and prevertebral fascia (post.)	Loose areolar tissue	Unobstructed spread of infection down to the diaphragm/posterior mediastinum
Lateral pharyngeal (parapharyngeal) space	Medial: pharynx; Posterolateral: parotid gland; Anterolateral: medial pterygoid; Posterior: carotid sheath	Branches of maxillary artery, fibrofatty tissue	Route of spread of deep neck infection; risk to carotid sheath contents
Suprasternal space (space of Burns)	Split of investing layer above the manubrium	Sternal heads of both SCM, jugular venous arch, lymph node, interclavicular ligament	—
Submandibular space	Bounded by investing layer's attachment to mandible and hyoid bone	Submandibular gland, lymph nodes	Ludwig's angina

Applied / Clinical anatomy

- **Ludwig's angina** — cellulitis of the floor of the mouth confined to the submandibular region because the investing layer is firmly attached to the two halves of the mandible and to the hyoid bone posteriorly; produces a tense, triangular, brawny swelling that pushes the tongue upward and backward, threatening airway obstruction.
- **Collar-stud abscess** — tuberculous deep cervical lymph nodes may suppurate and the pus pierces a small area of the investing layer, producing two connected pus collections — one deep and one superficial to the fascia — communicating through a narrow track.
- **Retropharyngeal abscess** — the acute (nodal) abscess bulges to one side of the midline because the prevertebral and buccopharyngeal fasciae are fused in the median plane; the chronic (tuberculous, vertebral-caries) abscess bulges in the midline. Pus may track down the true retropharyngeal space (checked near T4) or, more dangerously, via the danger space straight to the diaphragm, or laterally deep to the prevertebral fascia through the axillary sheath to point in the posterior triangle or axilla.
- **Air embolism** — division of the external jugular vein within the taut supraclavicular space prevents retraction and closure of the cut vein ends (the fascia is firmly adherent to the vein), risking fatal air embolism.

- ▶ **Parotid and submandibular gland swellings** are intensely painful because the dense, unyielding investing-layer capsule leaves no room for glandular expansion.
- ▶ **Submandibular gland excision** — the external carotid artery must be secured before dividing it, as it may retract through the stylomandibular ligament (a thickening of the investing layer) and cause serious bleeding.
- ▶ **Ligament of Berry and the recurrent laryngeal nerve** — during thyroidectomy, the nerve's close relationship to the ligament (and to the inferior thyroid artery) near the posterior capsule of the gland makes this the commonest site of iatrogenic nerve injury.
- ▶ **Thyroid swellings move with deglutition** because the pretracheal fascia binds the gland to the laryngeal/tracheal cartilages — a key clinical sign distinguishing thyroid masses from other anterior neck swellings.
- ▶ **Axillary sheath and interscalene block** — because the brachial plexus and subclavian artery share a single prevertebral fascial sleeve, local anaesthetic deposited within this sheath (interscalene approach) spreads to block the whole plexus.
- ▶ **Surgical and radiological relevance** — the well-defined fascial layers are exploited as bloodless planes of dissection in neck surgery (radical neck dissection proceeds deep to the investing layer); on cross-sectional imaging (CT/MRI) they appear as fat-density planes that help localise and stage the spread of deep neck infection and head-neck malignancy.

High-yield exam pointers

- ▶ Deep cervical fascia has **six parts**: investing, pretracheal, prevertebral, carotid sheath, buccopharyngeal, pharyngobasilar.
- ▶ Investing layer — remember the "**2-2-2-2**" **rule**: 2 muscles (trapezius, SCM), 2 glands (parotid, submandibular), 2 spaces (suprasternal, supraclavicular), 2 thickenings (parotidomasseteric fascia, stylomandibular ligament).
- ▶ Carotid sheath = pretracheal fascia (front) + prevertebral fascia (back); contains CCA/ICA, IJV, vagus; ansa cervicalis in its anterior wall.
- ▶ Ligament of Berry (pretracheal fascia) fixes the thyroid to the cricoid cartilage — surgically important because of the adjacent recurrent laryngeal nerve.
- ▶ Axillary sheath = tubular prolongation of prevertebral fascia around the brachial plexus and subclavian/axillary vessels; subclavian vein lies outside it.
- ▶ Alar fascia divides the retropharyngeal space into the true retropharyngeal space (limited near T4) and the danger space (extends to the diaphragm).
- ▶ Ludwig's angina and collar-stud abscess are classic viva questions linked to the investing layer.
- ▶ Space of Burns lies within the split investing layer above the manubrium; contains the jugular venous arch.

SOURCE & COVERAGE

BD Chaurasia — Human Anatomy Vol 3–4 (8e); AK Datta — Human Anatomy Vol 2 (Head & Neck); IB Singh — Textbook of Anatomy Vol 3 (6e); Vishram Singh — Textbook of Anatomy Vol 3 (4e); Gray's Anatomy (Standing) 41e; Moore's Clinically Oriented Anatomy 9e.



Cavernous Sinus

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction. The cavernous sinus is a paired, trabeculated dural venous sinus situated in the middle cranial fossa on either side of the body of the sphenoid bone and the pituitary fossa. It is anatomically unique among the cranial venous sinuses in being traversed directly by the **internal carotid artery** and by **four cranial nerves (III, IV, V1, V2)**, and in communicating freely — through valveless channels — with the veins of the face, orbit, pharynx and the opposite side. This dual character, a major venous drainage channel that is also a neurovascular thoroughfare, explains both its surgical importance and its role as the classic route by which facial and orbital sepsis reaches the intracranial cavity.

1. Situation, extent and development

- ▶ **Situation:** in the middle cranial fossa, one on each side of the body of the sphenoid bone and the hypophysis cerebri (pituitary gland/sella turcica).
- ▶ **Extent:** anteriorly it reaches the medial end of the **superior orbital fissure**; posteriorly it extends to the **apex of the petrous temporal bone**.
- ▶ **Dimensions:** about **2 cm long and 1 cm wide** on each side.
- ▶ **Named "cavernous"** because its interior is traversed by delicate fibrous trabeculae that subdivide the lumen into a number of small interconnecting spaces or "caverns" (trabeculae are more conspicuous on the cadaver than in the living).
- ▶ **Development:** each sinus develops from the cephalic part of the **primary head vein**, the rostral continuation of the anterior cardinal vein; incorporation of plexiform venous tributaries during development accounts for the trabeculated, multi-channelled interior of the adult sinus.

2. Formation of the sinus and its walls

- ▶ The cavity is formed where the **two layers of dura mater** covering the anterior aspect of the pituitary gland separate from one another at the lateral margin of the sella turcica:
 - The outer **endosteal (periosteal) layer** continues laterally to form the **anterior/sphenoidal wall and, together with the floor, the medial wall** of the sinus.
 - The inner **meningeal layer** remains attached to the pituitary gland and sweeps back towards the dorsum sellae, forming the **medial (sellar) wall posteriorly** and continuing as the **roof and lateral wall** of the sinus.

Wall	Formation	Notable feature
Roof	Dura between the anterior and posterior clinoid processes and the petrous apex ("oculomotor triangle")	Pierced posteriorly by III and IV nerves; anteriorly overlapped by the anterior clinoid process, which also roofs the paraclinoid ICA
Lateral wall	Meningeal dura, from the superior orbital fissure to the petrous apex	Contains III, IV, V1, V2 (from above down); separates the sinus from Meckel's cave (cavum trigeminale) , which lies inferoposterior to it
Medial wall	Anterior part = endosteal dura over the sella; posterior part = meningeal dura over the dorsum sellae	Related to the hypophysis cerebri and, more laterally, the sphenoidal air sinus
Floor	Endosteal dura	Rests on the junction of the body and greater wing of the sphenoid
Posterior wall	Dura behind the dorsum sellae and upper clivus	Shared with, and continuous with, the basilar venous plexus

3. External relations

Direction	Related structures
Superiorly	Optic tract and optic chiasma, olfactory tract, part of the internal carotid artery, anterior perforated substance
Inferiorly	Foramen lacerum; junction of the body and greater wing of the sphenoid
Medially	Hypophysis cerebri; sphenoidal air sinus (separated by a thin plate of bone)
Laterally	Cavum trigeminale (Meckel's cave) containing the trigeminal ganglion; uncus of the temporal lobe
Anteriorly	Superior orbital fissure and the apex of the orbit
Posteriorly	Apex of the petrous temporal bone; crus cerebri of the midbrain

4. Structures within the sinus (contents)

Four cranial nerves are embedded in the **lateral wall**, from above downward: the **oculomotor (III)**, **trochlear (IV)**, **ophthalmic division of the trigeminal (V1)**, and **maxillary division of the trigeminal (V2)** — the last leaving anteriorly through the foramen rotundum. Running **within the substance of the sinus itself**, surrounded by a sympathetic plexus, is the **internal carotid artery**, with the **abducent nerve (VI)** lying inferolateral to it. All these structures are separated from the circulating blood by the endothelial lining of the sinus.

Site	Structures (superior → inferior)
Lateral wall	Oculomotor nerve (III) → Trochlear nerve (IV) → Ophthalmic nerve (V1) → Maxillary nerve (V2)
Within the sinus (medial part)	Internal carotid artery + pericarotid sympathetic plexus, with the Abducent nerve (VI) inferolateral to it

Mnemonic — O-TOM-CAT: Oculomotor, Trochlear, Ophthalmic, Maxillary in the lateral wall; Carotid Artery and abducens (T) within the sinus.

The cavernous segment of the internal carotid artery (short ascending → posterior genu → horizontal → anterior genu) gives off the **meningohypophyseal trunk** (inferior hypophyseal, tentorial and dorsal meningeal arteries) and the **inferolateral trunk**, which supplies the nerves of the lateral wall. The successive curves of the petrous, cavernous and cerebral parts of the internal carotid artery together form the S-shaped **carotid siphon** seen on angiography.

□ Fig 16.3 — Coronal section of cavernous sinus showing its relations and contents (Vishram Singh — *Clinical Neuroanatomy* — 4e, p.587)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a coronal section through the middle cranial fossa at the level of the pituitary fossa, and label:

- ▶ Body of sphenoid and **pituitary fossa/hypophysis cerebri** in the midline, with **sphenoidal air sinus** below
- ▶ The **cavernous sinus** as a trabeculated venous space on each side
- ▶ **Internal carotid artery** with its surrounding **sympathetic plexus**, in the medial part of the sinus
- ▶ **Abducent nerve (VI)**, inferolateral to the carotid artery, within the sinus
- ▶ **Lateral wall**, from above down: **Oculomotor (III)**, **Trochlear (IV)**, **Ophthalmic (V1)**, **Maxillary (V2)**
- ▶ **Cavum trigeminale (Meckel's cave)** and **uncus of temporal lobe**, lateral to the sinus
- ▶ The endothelial lining separating the neural/arterial structures from the venous blood

5. Tributaries (incoming channels)

- ▶ **From the orbit**
 - Superior ophthalmic vein
 - A branch of, or sometimes the whole of, the inferior ophthalmic vein
 - The central vein of the retina (occasionally drains directly into the sinus rather than into the superior ophthalmic vein)
- ▶ **From the cerebral hemisphere**
 - Superficial middle cerebral vein
 - A few inferior cerebral veins from the temporal lobe
- ▶ **From the meninges**

- Sphenoparietal sinus
- The frontal (anterior) trunk of the middle meningeal vein (variably; it may instead drain into the pterygoid plexus through the foramen ovale)

6. Communications (draining channels)

- ▶ Posteriorly, to the transverse sinus — via the **superior petrosal sinus**.
- ▶ Posteroinferiorly, to the internal jugular vein — via the **inferior petrosal sinus** and a venous plexus around the internal carotid artery in the carotid canal.
- ▶ Inferiorly, to the **pterygoid venous plexus** — via emissary veins passing through the **foramen ovale, foramen lacerum, and the emissary sphenoidal foramen (of Vesalius)**.
- ▶ Anteriorly, to the **facial vein** — by two routes: (i) the superior ophthalmic vein and angular vein; (ii) the pterygoid venous plexus and deep facial vein.
- ▶ With the **opposite cavernous sinus** — via the **anterior and posterior intercavernous sinuses** and the **basilar venous plexus**; the intercavernous sinuses lie in the anterior and posterior attached margins of the diaphragma sellae and, together with the two cavernous sinuses, form a **complete circular sinus** around the sella turcica.
- ▶ Superiorly, to the **superior sagittal sinus** — via the superficial middle cerebral vein and the superior anastomotic vein (of Trolard).

All these connections are **valveless**, so blood can flow through them in either direction. Expulsion of blood from the sinus is aided by the expansile pulsation of the internal carotid artery within it, by gravity, and by the position of the head.

□ Fig 16.4 — Tributaries and communications of the cavernous sinus (Vishram Singh — *Clinical Neuroanatomy* — 4e, p.587)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a **schematic of the cavernous sinus with arrows for direction of flow**: tributaries entering anteriorly (superior/inferior ophthalmic veins, central retinal vein) and from above (superficial middle cerebral vein, sphenoparietal sinus, middle meningeal vein); outflow posteriorly (**superior petrosal sinus** → transverse sinus; **inferior petrosal sinus** → internal jugular vein) and inferiorly (emissary veins through **foramen ovale/lacerum/Vesalius** → **pterygoid plexus**); cross-communication with the opposite sinus via the **intercavernous sinuses/basilar plexus**; and the anterior link to the **facial vein** via the superior ophthalmic vein — the "dangerous area" route.

Applied / Clinical anatomy

- ▶ **"Dangerous area of the face"**: the facial vein (draining the medial canthus, upper lip, and side of the nose) communicates with the superior ophthalmic vein, which in turn drains into the cavernous sinus. Because this entire venous chain is **valveless**, infection from a furuncle or septic focus in this area (bridge of nose, upper lip, medial canthus) can spread retrogradely into the cavernous sinus.
- ▶ **Septic cavernous sinus thrombosis**: arises from spread of infection from the dangerous area of the face, the nasal cavity, or the paranasal air sinuses (especially sphenoid/ethmoid). It produces:

- Severe pain in the eye and forehead in the distribution of the ophthalmic nerve (V1).
- **Ophthalmoplegia** from involvement of the III, IV and VI nerves.
- Marked **oedema of the eyelids** with **exophthalmos** (proptosis) and chemosis, from congestion of the orbital veins.
- Because the two sinuses intercommunicate via the intercavernous sinuses, a unilateral thrombosis can rapidly become **bilateral**.
- ▶ **Caroticocavernous fistula (CCF)**: a direct communication between the intracavernous internal carotid artery and the sinus, typically from severe head trauma (basal skull fracture) or rupture of an intracavernous aneurysm. Arterial pressure transmitted into the sinus produces **pulsatile exophthalmos**, chemosis, periorbital oedema, and ophthalmoplegia (III, IV, VI palsies), often with a **loud systolic bruit (murmur)** audible over the temporal region. Treatment is typically endovascular — a catheter passed up the carotid artery to occlude the fistula with detachable balloons or coils.
- ▶ **Abducent nerve as the earliest sign**: because the VI nerve runs free within the substance of the sinus (unlike III, IV, V1, V2, which are protected within the lateral wall), it is often the first cranial nerve affected by a cavernous sinus lesion (thrombosis, fistula, or tumour).
- ▶ **Gradenigo's syndrome**: thrombosis of the inferior petrosal sinus, secondary to petrous apicitis from middle-ear/mastoid infection, produces ipsilateral VI nerve palsy together with trigeminal (V) nerve pain, since both structures cross the petrous apex close to the cavernous sinus outflow.
- ▶ **Tumours of the cavernous sinus**: meningiomas, haemangiomas and schwannomas may arise within it; **pituitary adenomas** may invade its medial wall, a factor of major importance in trans-sphenoidal pituitary surgery.
- ▶ **Surgical access**: transcranial microsurgical approaches enter the sinus through its lateral wall (infratrochlear/Parkinson's triangle, between the trochlear and ophthalmic nerves) or its roof (oculomotor triangle); endoscopic endonasal approaches access it through the anterior (sphenoidal) and medial (sellar) walls.

High-yield exam pointers

- ▶ Paired dural sinus lateral to the sella/pituitary and body of sphenoid; extends from the **superior orbital fissure to the petrous apex**, ~2 cm × 1 cm.
- ▶ Formed by **splitting of the two dural layers over the pituitary** — endosteal layer forms floor + medial wall; meningeal layer forms roof + lateral wall.
- ▶ **Lateral wall (top→bottom)**: III, IV, V1, V2. **Within the sinus**: internal carotid artery + sympathetic plexus, and the abducent nerve (VI) — mnemonic **O TOM CAT**.
- ▶ The **only dural venous sinus directly traversed by an artery** (the internal carotid) as well as by four cranial nerves.
- ▶ **Tributaries**: superior/inferior ophthalmic veins, central retinal vein, superficial middle cerebral vein, inferior cerebral veins, sphenoparietal sinus, middle meningeal vein.
- ▶ **Communications**: transverse sinus (via superior petrosal sinus); internal jugular vein (via inferior petrosal sinus); pterygoid venous plexus (via emissary foramina — ovale, lacerum, Vesalius); facial vein (via superior ophthalmic vein — the "dangerous area" route); opposite sinus

(via intercavernous sinuses + basilar plexus, forming the circular sinus around the sella); superior sagittal sinus (via superficial middle cerebral vein).

- ▶ All communications are **valveless and bidirectional** — the anatomical basis for retrograde spread of facial/orbital infection.
- ▶ Clinical triad to remember: **septic cavernous sinus thrombosis** (from the dangerous area of the face), **caroticocavernous fistula** (pulsatile exophthalmos + bruit), and **Gradenigo's syndrome** (VI + V involvement via petrous apex/inferior petrosal sinus).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3-4 8e; AK Datta's Human Anatomy Vol 2 (Head & Neck); IB Singh's Textbook of Anatomy Vol 3 6e; Vishram Singh's Clinical Neuroanatomy 4e.



Describe pituitary gland in detail

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The pituitary gland, or **hypophysis cerebri**, is a small, unpaired endocrine gland lodged in the hypophyseal fossa (sella turcica) of the sphenoid bone and suspended from the floor of the third ventricle by the infundibulum. It is often called the "**master gland**" because its trophic hormones regulate the thyroid, adrenal cortex, and gonads, besides directly controlling body growth, lactation, water balance, and uterine contraction. Structurally and developmentally it is really two glands fused into one: the **adenohypophysis**, an up-growth of oral ectoderm (Rathke's pouch), and the **neurohypophysis**, a down-growth of the diencephalon — a dual origin that explains its distinct histology, blood supply, and hormone repertoire.

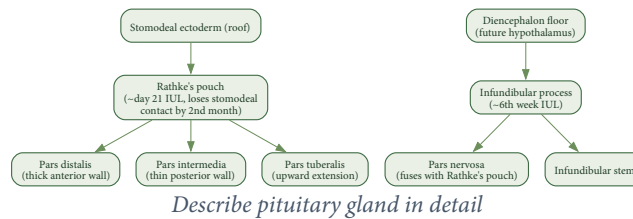
Location, shape and dimensions

- ▶ Lies in the **hypophyseal fossa (pituitary/sella turcica)** on the superior surface of the body of the sphenoid, in the middle cranial fossa.
- ▶ Connected to the tuber cinereum of the hypothalamus by a hollow, conical **infundibulum (pituitary stalk)**, which pierces the **diaphragma sellae** — a circular fold of dura roofing the fossa.
- ▶ The meninges blend with the pituitary capsule and are not separate layers over the gland itself.
- ▶ Oval in shape; measures approximately **12 mm transversely × 8 mm anteroposteriorly × 6 mm vertically**; weighs about **500 mg** in the adult.

Development

- ▶ **Adenohypophysis**: arises as an upward diverticulum of the ectodermal roof of the stomodeum, **Rathke's pouch**, which begins as a thickening on about day 21 of intrauterine life (IUL) and grows dorsally toward the diencephalon; by the 2nd month it loses contact with the stomodeum. Its thick anterior wall proliferates into the **pars distalis**, its thin posterior wall forms the **pars intermedia**, and an upward extension forms the **pars tuberalis**. The obliterated lumen of the pouch persists as the **intraglandular (hypophyseal) cleft**.

- **Neurohypophysis:** arises as a downward **infundibular process** from the floor of the diencephalon (future hypothalamus) around the 6th week of IUL; it grows toward, and fuses with, Rathke's pouch, forming the **pars nervosa**, with the connecting **infundibular stem**.
- Histogenesis of the gland begins in the 4th month IUL; acidophils differentiate first, followed by basophils and chromophobes; neuroglial cells (future pituicytes) appear in the neurohypophysis by the 4th month, followed by axonal ingrowth from the supraoptic and paraventricular hypothalamic nuclei.
- Persistence of communication along the pouch's track (the craniopharyngeal canal) or ectopic pouch remnants underlie important congenital anomalies (see Applied anatomy).



Parts and subdivisions

The gland has two major parts, each divisible further:

Major part	Subdivision	Origin/character
Adenohypophysis	Pars anterior (pars distalis)	Largest part; anastomosing cords of secretory cells around sinusoids
	Pars intermedia	Thin zone, separated from pars distalis by the intraglandular cleft (Rathke's pouch remnant)
	Pars tuberalis	Upward tubular extension surrounding the infundibulum
Neurohypophysis	Pars posterior (pars nervosa)	Smaller, lies in the concavity of the anterior lobe
	Infundibular stem + median eminence	Neural connections with the hypothalamus

□ Fig 12.11 — Parts of the hypophysis cerebri as seen in a sagittal section (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.240)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Median sagittal section through the sella turcica, labelling:

- ▶ Optic chiasma and diaphragma sellae (superiorly)
- ▶ Infundibulum/pituitary stalk piercing the diaphragma sellae
- ▶ Pars anterior (pars distalis) — bulk of the gland, anteriorly
- ▶ Pars intermedia — thin strip at the intraglandular cleft
- ▶ Pars tuberalis — collar around the infundibulum
- ▶ Pars nervosa (posterior lobe) — posterior concavity
- ▶ Sella turcica/hypophyseal fossa of sphenoid, with sphenoidal air sinus below
- ▶ Cavernous sinus flanking the gland on each side (label in cross-section inset)

Relations

Direction	Structure(s) related
Superior	Diaphragma sellae, then optic chiasma; tuber cinereum; infundibular recess of the 3rd ventricle
Inferior	Venous channels in the floor of the hypophyseal fossa, then the sphenoidal air sinuses (separated only by a thin bony plate)
On each side (lateral)	Cavernous sinus with its contents — internal carotid artery, and cranial nerves III, IV, VI, and the ophthalmic (V1) and maxillary (V2) divisions of the trigeminal nerve
Anterior/posterior boundaries of fossa	Tuberculum sellae (anterior) and dorsum sellae with posterior clinoid processes (posterior); anterior and posterior intercavernous sinuses cross through the diaphragma sellae in front of and behind the infundibulum, connecting the two cavernous sinuses

Blood supply and the hypothalamo-hypophyseal portal system

- ▶ **Arterial supply** — both superior and inferior hypophyseal arteries arise from the **internal carotid artery**:
 - **Superior hypophyseal artery** (one each side): supplies the median eminence and upper infundibulum directly, and the lower infundibulum via a descending **trabecular artery**.
 - **Inferior hypophyseal artery** (one each side): divides into medial and lateral branches that anastomose across the midline to form an **arterial ring around the infundibulum/posterior lobe**, supplying the neurohypophysis directly.
- ▶ **The pars distalis (anterior lobe) has no direct arterial supply.** It is supplied exclusively by **portal vessels** arising from capillary tufts of the superior hypophyseal arteries at the median eminence — the **hypothalamo-hypophyseal portal system**:
 - **Long portal vessels** drain the median eminence and upper infundibulum.

- **Short portal vessels** drain the lower infundibulum.
- These portal vessels carry hypothalamic releasing/inhibiting hormones directly to the sinusoids of the pars distalis, allowing tight neuroendocrine control of anterior-lobe secretion.
- ▶ **Venous drainage:** short veins emerge from the gland's surface and drain into the neighbouring dural venous sinuses (cavernous and intercavernous sinuses), carrying the secreted hormones into the systemic circulation.
- ▶ **Hypothalamo-hypophyseal (neurosecretory) tract:** unmyelinated axons from the supraoptic and paraventricular nuclei of the hypothalamus descend through the infundibulum and terminate in the pars nervosa as dilated nerve terminals (**Herring bodies**), which store and release ADH and oxytocin close to the sinusoids.

Histology and hormones

- ▶ **Pars distalis** — cords of cells around vascular sinusoids; **chromophobe cells** (~50%) are small, poorly stained, and represent inactive/exhausted or precursor cells; **chromophil cells** (~50%) are stainable and secretory, subdivided into acidophils (~43%) and basophils (~7%).
- ▶ **Pars intermedia** — narrow zone of basophil and chromophobe cells surrounding colloid-filled vesicles; secretes melanocyte-stimulating hormone (MSH).
- ▶ **Pars nervosa** — unmyelinated axons of the hypothalamo-hypophyseal tract, **pituicytes** (modified glial cells), and Herring bodies; does not itself synthesise hormone, only stores and releases it.

Cell type (pars distalis)	Hormone	Target / effect	Hypothalamic releasing factor	Inhibitor
Somatotrophs (acidophil)	Growth hormone (GH)	Body growth and metabolism	GHRH	Somatostatin
Mammotrophs/ lactotrophs (acidophil)	Prolactin	Mammary gland growth and milk secretion	—	Dopamine
Corticotrophs (basophil)	ACTH	Suprarenal (adrenal) cortex	CRH	—
Thyrotrophs (basophil)	TSH	Thyroid gland	TRH	Somatostatin
Gonadotrophs (basophil)	FSH, LH (ICSH in males)	Gonads — follicular growth/spermatogenesis, ovulation/steroidogenesis	GnRH (pulsatile)	GnIH
Pars intermedia cells	MSH	Melanocytes	—	—

Cell type (pars distalis)	Hormone	Target / effect	Hypothalamic releasing factor	Inhibitor
Pars nervosa (stored, made in hypothalamus)	ADH (vasopressin)	Renal distal/collecting tubules — water reabsorption	—	—
Pars nervosa (stored, made in hypothalamus)	Oxytocin	Uterine smooth muscle contraction; milk ejection	—	—

Applied / Clinical anatomy

- ▶ **Pituitary adenoma** is the commonest pituitary tumour; its symptoms fall into two groups:
 - **Pressure effects on surrounding structures:** enlargement/erosion of the sella turcica; compression of the central part of the optic chiasma producing the classic **bitemporal hemianopia**; hypothalamic pressure effects, including **Fröhlich's (adiposogenital) syndrome** in tumours arising from Rathke's pouch remnants; a large suprasellar extension may obstruct the third ventricle and raise intracranial pressure; lateral extension into the cavernous sinus can cause **exophthalmos and ophthalmoplegia** (III, IV, VI, V1/V2 palsy).
 - **Endocrine effects specific to cell of origin:** acidophil (somatotroph) adenoma → **gigantism** (before epiphyseal fusion) or **acromegaly** (after fusion); basophil (corticotroph) adenoma → **Cushing's syndrome**; chromophobe adenoma → non-secreting, presents with **hypopituitarism** from compression.
- ▶ **Hyposecretion:** GH deficiency in infancy/childhood causes proportionate **pituitary dwarfism** with preserved mental development; posterior-lobe/hypothalamic damage causes **diabetes insipidus** (large-volume dilute polyuria, 5–10 L/day, with polydipsia) from ADH deficiency.
- ▶ **Developmental anomalies:** persistence of the tract of Rathke's pouch as the craniopharyngeal canal predisposes to **craniopharyngioma** (bimodal incidence, childhood 5–14 years and adulthood 50–70 years), arising in relation to the sphenoid near the roof of the nasopharynx; ectopic pouch remnants in the posterior nasopharyngeal wall may form an accessory **pharyngeal hypophysis**; failure of pouch development causes **pituitary agenesis/hypoplasia**.
- ▶ **Surgical approaches** to the pituitary fossa exploit its relations: the **trans-sphenoidal approach** (transnasal–trans-sphenoidal, or transorbital–transethmoidal–trans-sphenoidal) enters the fossa from below through the sphenoidal air sinus and is the preferred, most direct route; the **transfrontal (subfrontal) approach**, elevating the frontal lobe through the anterior cranial fossa, is reserved for large suprasellar extensions.
- ▶ The intimate relation of the gland to the **cavernous sinus** and **optic chiasma** explains why visual field charting and cranial-nerve examination are essential in any suspected pituitary mass lesion.

High-yield exam pointers

- ▶ Dual embryological origin: **adenohypophysis from Rathke's pouch** (oral ectoderm); **neurohypophysis from the diencephalon floor** (neuroectodermal down-growth).

- ▶ Located in the hypophyseal fossa (sella turcica) of the sphenoid; roofed by the diaphragma sellae, pierced by the infundibulum; $\sim 12 \text{ mm} \times 8 \text{ mm} \times 6 \text{ mm}$, $\sim 500 \text{ mg}$.
- ▶ Superior relation = optic chiasma (separated by diaphragma sellae) — the anatomical basis of bitemporal hemianopia in pituitary tumours.
- ▶ Lateral relation = cavernous sinus on each side, with the internal carotid artery and cranial nerves III, IV, VI, V1, V2.
- ▶ **Pars distalis has no direct artery of its own** — supplied only via the hypothalamo-hypophyseal portal system (long and short portal vessels) — a uniquely important exam point.
- ▶ Posterior lobe hormones (ADH, oxytocin) are **synthesised in the hypothalamus** (supraoptic/paraventricular nuclei) and only **stored and released** from the pars nervosa via Herring bodies.
- ▶ Classic triad of a pituitary adenoma: enlarged sella + bitemporal hemianopia + a cell-specific endocrine syndrome (acidophil $\rightarrow$ acromegaly/gigantism; basophil $\rightarrow$ Cushing's; chromophobe $\rightarrow$ hypopituitarism).
- ▶ Craniopharyngioma arises from remnants of Rathke's pouch along the craniopharyngeal canal; trans-sphenoidal surgery is the standard operative approach to the gland.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4, 8e; Vishram Singh's Textbook of Anatomy Vol 3, 4e; Vishram Singh's General Anatomy, 4e; Sontakke's Textbook of Human Embryology.



Submandibular Salivary Gland

Asked in: Paper I May 2011 — RGUHS MD/MS Anatomy

Definition / Introduction The submandibular gland is the second largest of the three paired major salivary glands (after the parotid, larger than the sublingual), lying in the anterior part of the digastric triangle of the neck. It is a **mixed seromucous gland**, **predominantly serous**, hook- or J-shaped because the posterior border of **mylohyoid** indents it into a large **superficial part** and a small **deep part**. Its secretion is carried to the floor of the mouth by the **submandibular (Wharton's) duct**, and it is a frequent PG exam topic because of its close, clinically important relations to the lingual, hypoglossal and facial nerves, the facial artery, and the parasympathetic submandibular ganglion.

Development

- ▶ The gland develops as a solid **endodermal** epithelial outgrowth from the floor of the primitive mouth, at the **linguogingival (alveololingual) sulcus**, appearing by about the **5th–6th week** of intra-uterine life.
- ▶ It arises from a **single large bud** (unlike the sublingual gland, which arises from multiple small buds); the bud canalises and its connection to the floor of the mouth elongates and narrows to become the single **submandibular duct** — explaining why the gland drains by one duct while the sublingual gland drains by several.

- This endodermal origin (shared with the sublingual gland) contrasts with the **ectodermal** origin of the parotid gland (an outgrowth of the oral vestibule near the angle of the mouth), which correlates with the submandibular gland's mixed seromucous histology versus the parotid's purely serous acini.

Gross Features, Capsule & Parts

- **Location:** digastric triangle, partly lodged in the submandibular fossa on the medial surface of the body of the mandible.
- **Size/weight:** about the size of a walnut, weighing approximately **10–20 g**.
- **Shape:** irregular, hook- or J-shaped, indented by the posterior free border of mylohyoid into a larger **superficial part** and a smaller **deep part**, the two being continuous with each other around this border.
- **Capsule:** the gland is partially enclosed between two layers of the **investing layer of deep cervical fascia**, both slung from the greater cornu of the hyoid bone — the **superficial layer** covers the inferior surface and attaches to the lower border of the mandible; the **deep layer** covers the medial surface and attaches to the mylohyoid line on the mandible.
- **Microanatomy (brief):** tubulo-acinar gland with predominantly serous acini and a lesser proportion of mucous tubules capped by crescentic serous **demilunes**; ducts pass from intercalated → striated → collecting (excretory) segments before draining into the main duct.

Superficial Part — Extent & Relations

Feature	Detail
Extent	Fills the digastric triangle; reaches forward to anterior belly of digastric, back to the stylomandibular ligament (separating it from the parotid gland); extends up medial to the body of mandible; overlaps stylohyoid and posterior belly of digastric below
Inferior surface	Covered by skin, superficial fascia, platysma and deep fascia; crossed by the facial (common facial) vein and the cervical branch of the facial nerve ; submandibular lymph nodes lie in contact with, and some embedded within, the gland here
Lateral surface	Related to the submandibular fossa of the mandible, the mandibular insertion of medial pterygoid , and the facial artery , which grooves its postero-superior part
Medial surface — anterior part	Mylohyoid, with the mylohyoid nerve/vessels and the submental branch of the facial artery intervening
Medial surface — middle (intermediate) part	Hyoglossus and styloglossus, with the lingual artery , lingual nerve , submandibular ganglion , hypoglossal nerve and a pair of venae comitantes intervening (sequentially from above down)

Feature	Detail
Medial surface — posterior part	Styloglossus, stylohyoid ligament, and the glossopharyngeal nerve , separating it from the pharynx (posterior belly of digastric and middle constrictor also related here)

Real plate for the superficial-surface relations described above:

□ Fig 9.15 — ■ *Relations of the superficial (inferior) surface of submandibular sal* (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e, p.413*)

Deep Part — Extent & Relations

- ▶ Small in size; lies between **mylohyoid** (laterally) and **hyoglossus/styloglossus** (medially); extends forward from the posterior border of mylohyoid to the posterior end of the sublingual gland.

Direction	Structure
Laterally	Mylohyoid
Medially	Hyoglossus (and styloglossus)
Above	Lingual nerve and submandibular ganglion
Below	Hypoglossal nerve, with its venae comitantes

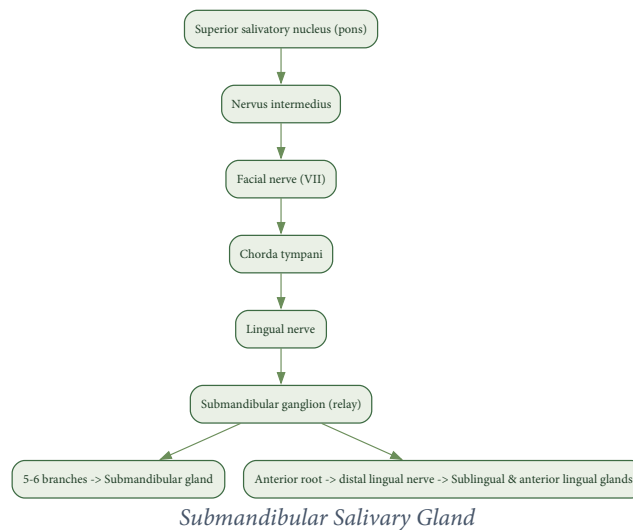
Submandibular (Wharton's) Duct

- ▶ About **5 cm long**, thin-walled (thinner than the parotid duct); begins from numerous tributaries in the superficial part, on its deep (medial) surface, just behind the posterior border of mylohyoid.
- ▶ It first runs upward and slightly backward for about **4–5 mm**, forming a sharp bend over the free edge of mylohyoid, the **genu** of the duct (proposed, though disputed, as a site predisposing to salivary stasis and stone formation).
- ▶ It then traverses the deep part of the gland and runs forward between mylohyoid and hyoglossus, then between the sublingual gland and genioglossus.
- ▶ Relation to the **lingual nerve**: the nerve first lies above the duct, then winds around it from lateral to medial side (crossing it), and finally ascends on its medial side to reach the tongue.
- ▶ It opens on the floor of the mouth at the summit of the **sublingual papilla**, at the side of the frenulum of the tongue.
- ▶ Clinically visualised by **sialography** (contrast injected into the duct orifice).

Nerve Supply & Submandibular Ganglion

The gland receives **secretomotor** (parasympathetic), **vasomotor** (sympathetic) and **sensory** innervation, all relayed through the **submandibular ganglion** — a small fusiform peripheral parasympathetic ganglion lying on hyoglossus, above the deep part of the gland, suspended from the lingual nerve by an anterior and a posterior root. It is topographically related to the lingual nerve but functionally connected to the facial nerve via the chorda tympani.

- ▶ **Posterior root (parasympathetic/motor root)** — carries preganglionic secretomotor fibres from the superior salivatory nucleus (pons) via the nervus intermedius, facial nerve and chorda tympani, joining the lingual nerve and reaching the ganglion for relay.
- ▶ Postganglionic fibres leave via **5–6 branches** directly to the submandibular gland and duct; fibres for the sublingual and anterior lingual glands re-enter the lingual nerve through the **anterior root** and travel in its distal part.
- ▶ **Sympathetic root** — postganglionic vasomotor fibres from the superior cervical ganglion, via the plexus around the facial artery, pass through the ganglion **without synapsing**.
- ▶ **Sensory fibres** reach the ganglion via the lingual nerve.



Blood Supply & Lymphatic Drainage

- ▶ **Arterial supply:** branches of the **facial artery** and the **lingual artery**. The facial artery arises from the external carotid just above the tip of the greater cornu of the hyoid, ascends deep to the posterior belly of digastric and stylohyoid, and grooves the posterosuperior part of the gland; it then makes a characteristic **S-shaped (double) loop** — first winding down over the gland, then up and over the base of the mandible at the antero-inferior angle of masseter — before continuing onto the face.
- ▶ **Venous drainage:** veins accompany the arteries and drain via the (anterior) facial vein and the lingual vein into the internal jugular vein.
- ▶ **Lymphatic drainage:** to the **submandibular lymph nodes**, which lie both around and embedded within the gland substance, and thence to the deep cervical group of nodes (particularly the jugulo-omohyoid/jugulodigastric nodes).

Applied / Clinical anatomy

- ▶ **Sialolithiasis:** submandibular secretion is more viscous (mucus-rich) and its duct runs upward against gravity, both favouring stasis and **calculus (sialolith) formation** — the commonest site for salivary stones of any gland; the duct's genu has also been proposed as a predisposing site, though this remains debated.

- ▶ **Bimanual palpation:** the enlarged gland (from calculus or tumour) or an enlarged submandibular lymph node is palpated with one finger in the floor of the mouth and one finger below the body of the mandible.
- ▶ **Sialography:** the duct system can be outlined radiographically after injecting a radio-opaque contrast medium via the duct orifice — used to demonstrate an impacted calculus.
- ▶ **Nodal metastasis:** submandibular (level Ib) nodes lying within/around the gland are a common site of spread from carcinoma of the tongue or floor of mouth; the gland is therefore removed **en bloc** with the nodes in neck dissection for such disease.
- ▶ **Surgical excision:** for calculus or tumour, the gland is approached through a skin incision placed **more than 4 cm below the angle of the mandible**, because the marginal mandibular branch of the facial nerve passes postero-inferior to the angle before crossing it superficially — a higher incision risks its injury (lower-lip drooping).
- ▶ **Skull-base correlate:** the chorda tympani lies medial to the spine of the sphenoid (the auriculotemporal nerve to the parotid lies lateral to it); a fracture through this region can injure both nerves, abolishing secretion from all three major salivary glands on that side.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label, on a horizontal (axial) section through the submandibular region, and a lateral dissection view:

- ▶ Body of mandible and submandibular fossa
- ▶ Mylohyoid muscle (posterior free border) — the indenting structure
- ▶ Superficial part of gland (superficial to mylohyoid) and Deep part of gland (deep to mylohyoid, extending to the posterior end of the sublingual gland)
- ▶ Hyoglossus and styloglossus muscles (medial relations of the deep part)
- ▶ Facial artery — S-shaped loop grooving the posterior part of the gland
- ▶ Facial vein and cervical branch of facial nerve (on the inferior surface)
- ▶ Lingual nerve — crossing the duct from lateral to medial side
- ▶ Submandibular ganglion — suspended from the lingual nerve by two roots
- ▶ Hypoglossal nerve with venae comitantes (below the deep part)
- ▶ Submandibular (Wharton's) duct — showing its genu at the posterior border of mylohyoid
- ▶ Sublingual gland and sublingual papilla — where the duct opens beside the frenulum of the tongue
- ▶ Submandibular lymph nodes — around and within the gland

High-yield exam pointers

- ▶ Mixed **seromucous, predominantly serous** gland; second largest major salivary gland; endodermal in origin (single bud → single duct), unlike the ectodermal parotid.
- ▶ Mylohyoid's posterior free border divides it into superficial (large) and deep (small) parts, continuous around this border.

- ▶ Duct = **Wharton's duct**, ~5 cm, thin-walled, has a **genu** at the mylohyoid border, crossed by the lingual nerve (lateral → medial), opens at the sublingual papilla.
- ▶ Secretomotor pathway: superior salivatory nucleus → nervus intermedius → facial nerve → **chorda tympani** → lingual nerve → **submandibular ganglion** (relay) → gland.
- ▶ Submandibular ganglion: parasympathetic; suspended from lingual nerve by two roots; sympathetic fibres pass through **without relay**.
- ▶ Arterial supply: **facial + lingual arteries**; facial artery makes an S-shaped loop related to the gland.
- ▶ Lymphatic drainage: submandibular nodes (within/around gland) → deep cervical (jugulo-omohyoid) nodes — clinically important in tongue carcinoma.
- ▶ Commonest site of salivary calculi in the body (viscous secretion + duct runs against gravity).
- ▶ Surgical incision for excision kept >4 cm below the angle of mandible to protect the marginal mandibular branch of the facial nerve.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4, 8e; AK Datta's Human Anatomy Vol 2 (Head & Neck); IB Singh's Textbook of Anatomy Vol 3, 6e; Vishram Singh's Textbook of Anatomy Vol 3, 4e and Textbook of Clinical Embryology.



Describe the anatomy of extra ocular muscles. Add a note on conjugatory movement of eye balls

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction — The orbit contains **seven skeletal (voluntary) extraocular muscles**: four **recti** (superior, inferior, medial, lateral), two **obliques** (superior, inferior), and the **levator palpebrae superioris (LPS)**. The six recti/obliques rotate the globe about three axes (vertical, transverse, antero-posterior) to direct the visual axis; LPS elevates the upper eyelid. All except LPS take origin near the orbital apex and are supplied by the oculomotor (III), trochlear (IV) and abducent (VI) nerves. Coordinated, simultaneous action of the corresponding muscles of both eyes produces **conjugate (version) movements**, which keep the two visual axes parallel and prevent diplopia.

1. General Arrangement and the Common Tendinous Ring (Annulus of Zinn)

- ▶ The recti form a **muscle cone** from the orbital apex to the globe; adjoining areolar sheaths fuse into a continuous **musculo-fascial cone**.
- ▶ **Common tendinous ring** (annular tendon/ligament of Zinn): a fibrous ring attached to a tubercle/spine on the orbital surface of the **greater wing of sphenoid**; it encircles the **superior, medial and inferior margins of the optic canal** and continues across the **inferior and medial part of the superior orbital fissure (SOF)**.

- **Inferior rectus**, part of **medial rectus** and the **lower fibres of lateral rectus** attach to the lower part of the ring; **superior rectus**, part of **medial rectus** and the **upper fibres of lateral rectus** attach to the upper part.
- **Lateral rectus** has a second small tendinous slip from the greater wing of sphenoid, lateral to the ring; the **abducent nerve** passes between its two heads.
- **Structures within the ring:** optic nerve (II) in its dural sheath, ophthalmic artery, superior and inferior divisions of the oculomotor nerve (III), nasociliary nerve (V1), and the abducent nerve (VI).
- **Structures outside the ring:** trochlear nerve (IV), frontal and lacrimal nerves (V1), and the superior ophthalmic vein — LPS and superior oblique also arise outside/above the ring, close to the apex.
- **The fascial sheath of the eyeball (Tenon's capsule)** extends from the conjunctival fornices to the optic nerve, is pierced by the muscle tendons, and is reflected onto each as a tubular sheath; triangular expansions form the **medial and lateral check ligaments** (to lacrimal and zygomatic bones), which fuse with the sheaths of inferior rectus/inferior oblique to form the hammock-like **suspensory ligament (of Lockwood)**.

2. Origin, Insertion and Nerve Supply

Muscle	Origin	Insertion	Nerve supply
Levator palpebrae superioris	Lesser wing of sphenoid, above and in front of the optic canal	Bilaminar aponeurosis — superficial lamina to skin of upper lid; deep (smooth-muscle) lamina, the superior tarsal muscle , to upper margin of superior tarsus	Superior division of CN III (striated part); sympathetic fibres (superior tarsal muscle)
Superior rectus	Upper part of common tendinous ring	Sclera, ~7.7 mm from the limbus	Superior division of CN III
Inferior rectus	Lower part of common tendinous ring	Sclera, ~6.5–6.6 mm from the limbus	Inferior division of CN III
Medial rectus (shortest, strongest)	Medial part of common tendinous ring	Sclera, ~5.5 mm from the limbus	Inferior division of CN III
Lateral rectus	Lateral part of ring + second head from greater wing of sphenoid	Sclera, ~6.9–7 mm from the limbus	Abducent nerve (CN VI)

Muscle	Origin	Insertion	Nerve supply
Superior oblique	Body of sphenoid, superomedial to the optic canal	Tendon passes through the trochlea (fibrocartilaginous pulley on the frontal bone), turns posterolaterally, and inserts into sclera in the postero-superolateral quadrant, deep to superior rectus	Trochlear nerve (CN IV)
Inferior oblique	Orbital surface of maxilla, lateral to the nasolacrimal fossa (the only EOM not arising near the apex)	Sclera in the postero-inferolateral quadrant, deep to lateral rectus, close to but slightly behind the superior oblique insertion	Inferior division of CN III

- Joining the four recti insertion points (medial rectus 5.5 mm → inferior rectus 6.6 mm → lateral rectus 7 mm → superior rectus 7.7 mm) in a clockwise line traces the **spiral of Tillaux**, a useful surgical landmark.
- **Mnemonic** for nerve supply: "**LR6 SO4, rest 3**" — lateral rectus by VI, superior oblique by IV, all remaining EOMs (LPS, SR, MR, IR, IO) by III.
- Vascular supply of all EOMs is chiefly from the **ophthalmic artery** (direct and via its supraorbital/lacrimal branches); inferior rectus and inferior oblique receive additional supply from the **infraorbital branch of the maxillary artery**.

3. Actions of the Individual Muscles

Muscle	Transverse axis	Vertical axis	A-P axis
Superior rectus	Elevates	Adducts	Intorts
Inferior rectus	Depresses	Adducts	Extorts
Superior oblique	Depresses	Abducts	Intorts
Inferior oblique	Elevates	Abducts	Extorts
Medial rectus	—	Adducts	—
Lateral rectus	—	Abducts	—

- Because the **orbital axis diverges from the visual (optical) axis** by ~23–25°, superior and inferior recti (whose pull is medial to the vertical axis in the primary position) also adduct, while the obliques (attaching behind the equator) also produce a horizontal (abducting) component.
- **Pure (single) movements** require synergistic pairs whose unwanted rotatory components cancel: elevation = SR + IO; depression = IR + SO; adduction = MR (+SR+IR); abduction = LR (+SO+IO); intorsion = SO + SR; extorsion = IO + IR.
- **Clinical (H-test)**: with the eye first **abducted** by lateral rectus, superior/inferior recti act as pure elevator/depressor (testing CN III); with the eye first **adducted** by medial rectus,

superior/inferior oblique act as pure depressor/elevator (testing CN IV and the inferior division of CN III). This is the basis of testing extraocular muscles along an "extended-H" pattern.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 11.3 — Schematic anterior view of the orbit to show the attachments of extraocular muscles (IB Singh — *Textbook of Anatomy Vol 3 — 6e, p.199*)

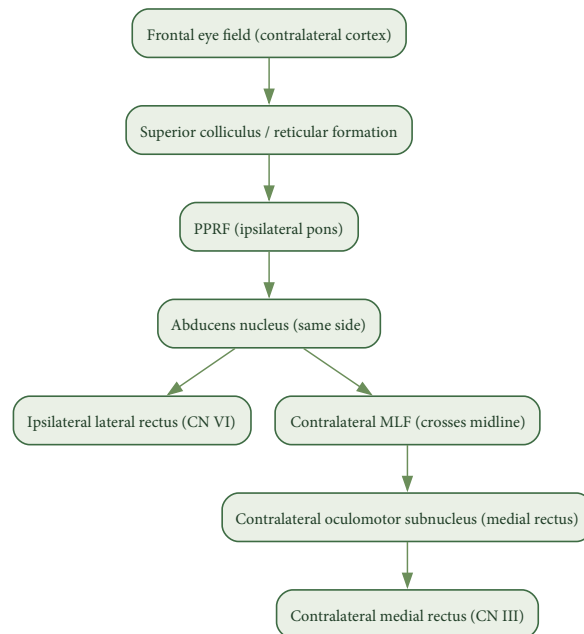
Labels for hand reproduction (anterior view of globe with muscle insertions):

- ▶ Cornea and corneoscleral limbus (centre)
- ▶ Equator of eyeball
- ▶ Superior rectus insertion — 7.7 mm from limbus
- ▶ Inferior rectus insertion — 6.5–6.6 mm from limbus
- ▶ Medial rectus insertion — 5.5 mm from limbus
- ▶ Lateral rectus insertion — 6.9–7 mm from limbus
- ▶ Superior oblique insertion — postero-superolateral quadrant, behind equator
- ▶ Inferior oblique insertion — postero-inferolateral quadrant, behind equator, close to but posterior to superior oblique
- ▶ Clockwise line joining MR→IR→LR→SR insertions = **spiral of Tillaux**

4. Conjugate Movements of the Eyeballs (Note)

- ▶ **Definition:** harmonious, coordinated movements of both eyes in the same direction, keeping the visual axes parallel (or symmetrically adjusted), so that a single, non-diplopic image is maintained — termed **conjugate ocular (version) movements**.
- ▶ **Versions vs vergences:** movements of the two eyes in the *same* direction are **versions** (conjugate); movements in *opposite* directions are **vergences** (convergence/divergence), used to adjust fixation between near and far objects.
- ▶ **Yoke muscles:** for every version movement, a specific muscle in one eye is paired with its **contralateral synergist** to swing both visual axes together — e.g., gaze to the right is produced by the **right lateral rectus** and **left medial rectus** acting as yoke muscles; the six cardinal (diagnostic) positions of gaze are each driven by one such pair.
- ▶ **Reciprocal innervation:** as a prime mover contracts, its antagonist in the same eye relaxes simultaneously, ensuring smooth, unopposed rotation — the same principle by which agonist–antagonist pairs act elsewhere in the body.
- ▶ **Vergence/near reflex:** convergence of the two medial recti, pupillary constriction, and accommodation of the lens together constitute the **near reflex** for near vision.
- ▶ **Neural control of conjugate gaze:**
 - The **abducens nucleus** (pons) is the final common integrating centre for horizontal gaze — it contains motor neurones to the ipsilateral lateral rectus and interneurons that cross and ascend in the contralateral **medial longitudinal fasciculus (MLF)** to the oculomotor subnucleus supplying the medial rectus.
 - The **paramedian pontine reticular formation (PPRF)**, adjoining the abducens nucleus, generates ipsilateral horizontal saccades.

- Vertical gaze is integrated by the **rostral interstitial nucleus of the MLF** in the midbrain, together with the oculomotor and trochlear nuclei.
- The **frontal eye field** (Brodmann areas 6, 8, 9) initiates voluntary conjugate saccades to the *opposite* side via the superior colliculus and reticular formation; the occipital (visual) cortex drives smooth pursuit.



Describe the anatomy of extra ocular muscles. Add a note on conjugatory movement of eye balls

Applied / Clinical anatomy

- ▶ **Oculomotor (III) nerve palsy:** ptosis, "down-and-out" eye (unopposed lateral rectus and superior oblique), dilated fixed pupil (mydriasis), loss of accommodation, slight proptosis, and diplopia.
- ▶ **Trochlear (IV) nerve palsy:** defective depression of the adducted eye; diplopia characteristically on looking downwards (e.g., descending stairs); vision remains single above the horizontal plane.
- ▶ **Abducent (VI) nerve palsy:** unopposed medial rectus pulls the eye medially, producing an **internal (convergent) strabismus** and diplopia on attempted lateral gaze.
- ▶ **Internuclear ophthalmoplegia (INO):** a lesion of the MLF disconnects the abducens nucleus from the contralateral oculomotor subnucleus — on attempted lateral gaze the ipsilateral lateral rectus abducts normally, but the contralateral medial rectus fails to adduct, often with nystagmus of the abducting eye; seen in multiple sclerosis, brainstem infarcts and tumours.
- ▶ **Squint (strabismus): concomitant** (usually congenital; no limitation of movement, no diplopia) versus **paralytic** (acquired; limited movement, diplopia and vertigo, compensatory head turn toward the paralysed muscle's field of action).
- ▶ **Horner syndrome:** loss of sympathetic supply to the superior (and inferior) tarsal muscles causes mild ptosis and a narrowed palpebral fissure.
- ▶ **Graves' ophthalmopathy:** inflammatory swelling of the extraocular muscles increases orbital volume and produces **exophthalmos** (proptosis).

- **Surgical relevance:** the insertion distances (spiral of Tillaux) guide recession–resection procedures in strabismus surgery; the trochlea is the key surgical landmark in superior oblique tuck/tenotomy.

High-yield exam pointers

- **Seven EOMs:** 4 recti + 2 obliques + LPS; six of them move the globe about three axes, LPS elevates the upper lid.
- Nerve-supply mnemonic — "LR6 SO4, rest 3".
- **Common tendinous ring (annulus of Zinn)** gives origin to the four recti; encircles the optic canal and medial SOF.
- **Inferior oblique** is the only EOM not arising from the orbital apex.
- Insertion distances from the limbus (**spiral of Tillaux**): MR 5.5 mm, IR 6.5–6.6 mm, LR 6.9–7 mm, SR 7.7 mm.
- Superior oblique tendon passes through the **trochlea** before inserting behind the equator.
- Pure elevation/depression is best tested with the eye first abducted (recti) or adducted (obliques) — basis of the clinical H-test.
- **Conjugate (version) movement** = both eyes move in the same direction via **yoke muscle** pairs (e.g., right LR + left MR for right gaze); **vergence** = opposite-direction movement (convergence/divergence).
- **INO** = MLF lesion = failure of adduction on contralateral gaze with nystagmus of the abducting eye.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 3–4 8e; IB Singh Textbook of Anatomy Vol 3 6e; Moore's Clinically Oriented Anatomy 9e; Snell's Clinical Neuroanatomy 7e; Vishram Singh General Anatomy 4e.



Describe the anatomy of middle ear cavity and add a note on mechanism of hearing

Asked in: Paper I May 2011 — RGUHS MD/MS Anatomy

Definition / Introduction — The **middle ear (tympanum / tympanic cavity)** is a narrow, air-filled, mucosa-lined space in the petrous part of the temporal bone, interposed between the tympanic membrane laterally and the internal ear medially. It houses the chain of auditory ossicles and two small muscles, and its essential function is to transmit and amplify airborne sound vibrations from the tympanic membrane to the fluid-filled internal ear, converting a weak aerial vibration into an effective fluid-borne one. It communicates anteriorly with the nasopharynx (auditory/pharyngotympanic tube) and posteriorly with the mastoid antrum and air cells.

Location, shape and parts

- Lies within the petrous temporal bone between the external and internal ear.

- ▶ Shaped like a **biconcave cube**, compressed side-to-side: lateral and medial walls are broad and closest to each other centrally, the other four walls are narrow.
- ▶ Vertical and anteroposterior diameters are each about **15 mm**; the transverse (lateral-to-medial) diameter is only about **6 mm near the roof, 2 mm in the centre and 4 mm near the floor**.
- ▶ Subdivided into two parts:
 - **Tympanic cavity proper** — opposite the tympanic membrane.
 - **Epitympanic recess (attic)** — above the level of the tympanic membrane; lodges the head of malleus and body/short process of incus.

Communications

- ▶ **Anteriorly** — with the nasopharynx through the **auditory (pharyngotympanic/eustachian) tube**, which equalises pressure across the tympanic membrane.
- ▶ **Posteriorly** — with the **mastoid antrum and mastoid air cells** through the **aditus to the mastoid antrum**, an opening in the upper part of the posterior wall.
- ▶ The cavity is often likened to a **pistol lying on its side**: the tympanic cavity proper is the "trigger", the auditory tube is the "outlet/barrel", and the aditus with the mastoid antrum/air cells forms the sloping "handle".
- ▶ Lined by mucous membrane which invests all contents and raises vascular folds, giving the cavity a honeycombed appearance.

Boundaries (six walls)

Wall	Also called	Key features
Roof	Tegmental wall	Thin plate of bone, the tegmen tympani , separating the cavity from the middle cranial fossa (temporal lobe); continued forward as roof of the tensor tympani canal. In children an unossified petrosquamous suture may leave a gap in direct contact with the meninges.
Floor	Jugular wall	Thin bony plate separating the cavity from the superior bulb of the internal jugular vein ; presents the tympanic canaliculus transmitting the tympanic branch of the glossopharyngeal nerve.

Wall	Also called	Key features
Anterior	Carotid wall	Narrow wall; bears (from above down) the opening of the canal for tensor tympani, the opening of the auditory tube, and inferiorly a thin plate separating the cavity from the internal carotid artery (perforated by caroticotympanic nerves and the tympanic branch of the internal carotid artery). The septum between the tensor-tympani and auditory-tube canals continues on the medial wall as the processus cochleariformis , around which the tensor tympani tendon turns.
Posterior	Mastoid wall	Superiorly, the aditus to the mastoid antrum ; the fossa incudis for the short process of incus; the pyramid , a conical projection near the medial wall giving passage to the tendon of stapedius; and, lateral to the pyramid, the posterior canaliculus for the chorda tympani .
Lateral	Membranous wall	Mainly the tympanic membrane with its tympanic ring/sulcus, and, at the epitympanic recess, the squamous temporal bone. The petrotympanic fissure lodges the anterior process of malleus and transmits the tympanic branch of the maxillary artery; the anterior canaliculus for the chorda tympani lies in or just in front of this fissure.
Medial	Labyrinthine wall	The promontory (bulge of the first turn of the cochlea, grooved by the tympanic plexus); fenestra vestibuli (oval window), closed by the stapes footplate, leading to the vestibule; fenestra cochleae (round window), closed by the secondary tympanic membrane, opening into the scala tympani; the prominence of the facial canal above the fenestra vestibuli; the prominence of the lateral semicircular canal ; and the sinus tympani behind the promontory.

Contents

- ▶ Three **ear ossicles** — malleus, incus, stapes.
- ▶ **Synovial joints** between the ossicles.
- ▶ Two **muscles** — tensor tympani and stapedius.
- ▶ **Vessels** supplying/draining the cavity.
- ▶ **Nerves** — chorda tympani and the tympanic plexus.
- ▶ **Air**, continuous with the nasopharynx via the auditory tube.

Ear ossicles

- ▶ **Malleus** ("hammer") — largest and most lateral; has a rounded **head** (in the epitympanic recess, articulating with the incus, giving attachment to superior/lateral ligaments), a **neck** (related medially to the chorda tympani), an **anterior process** (tethered by the anterior ligament to the petrotympanic fissure), a **lateral process**, and a **handle** fused to the upper half of the tympanic membrane.
- ▶ **Incus** ("anvil") — resembles a molar tooth; a **body** articulating with the malleus head, and a **long process** ending in a **lentiform nodule** that articulates with the head of stapes.
- ▶ **Stapes** ("stirrup") — smallest, most medial ossicle; **head**, **neck** (gives insertion to stapedius tendon), **anterior and posterior crura**, and an oval **footplate** fitting the fenestra vestibuli.
- ▶ **Joints**: incudomalleolar (saddle type) and incudostapedial (ball-and-socket) — both synovial, stabilised by capsular and accessory ligaments.

Muscles, nerve supply and blood supply

Muscle	Canal/course	Nerve supply	Action
Tensor tympani	Lies above the auditory tube; tendon turns around the processus cochleariformis to insert on the handle of malleus	Nerve to medial pterygoid (via mandibular nerve/otic ganglion)	Damps high-intensity sound; protects internal ear
Stapedius	Lies within the pyramid on the posterior wall; tendon emerges at its apex to insert on the neck of stapes	Facial nerve	Damps high-intensity sound; protects internal ear

Both muscles act simultaneously (the **acoustic/attenuation reflex**) to reduce transmission of loud sound.

- ▶ **Arterial supply** — anterior tympanic branch of maxillary artery (through petrotympanic fissure); posterior tympanic branch of stylomastoid artery (through stylomastoid foramen); petrosal and superior tympanic branches of middle meningeal artery; branches of ascending pharyngeal artery; tympanic branches of internal carotid artery.
- ▶ **Venous drainage** — superior petrosal sinus and pterygoid venous plexus.
- ▶ **Lymphatic drainage** — preauricular and retropharyngeal nodes.

- **Nerve supply** — the **tympanic plexus** over the promontory, formed chiefly by the tympanic branch of the glossopharyngeal nerve (which also gives off the lesser petrosal nerve and supplies the mucosa of the middle ear, auditory tube, mastoid antrum and air cells), plus the superior and inferior caroticotympanic (sympathetic) nerves, which are vasomotor.

□ Fig 18.11 — Ear ossicles. (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e*, p.795)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Medial (labyrinthine) wall of the middle ear, with labels:

- Promontory
- Fenestra vestibuli (oval window) with stapes footplate
- Fenestra cochleae (round window) with secondary tympanic membrane
- Prominence of the facial canal
- Prominence of the lateral semicircular canal
- Sinus tympani
- Pyramid (tendon of stapedius)
- Processus cochleariformis with tendon of tensor tympani
- Aditus to mastoid antrum (posterosuperior)
- Tympanic plexus over the promontory
- Chorda tympani nerve crossing the field

NOTE — FOR REFERENCE, NOT TO BE WRITTEN IN THE EXAM

- ▶ **Air conduction pathway:** sound waves in air set the **tympanic membrane** vibrating; vibrations pass through the ossicular chain — **malleus** → **incus** → **stapes** — and the **footplate of the stapes**, fitting the fenestra vestibuli, transmits them to the **perilymph** of the vestibule and thence the **scala vestibuli**.
- ▶ Each inward movement of the stapes footplate generates a pressure wave that travels the length of the **scala vestibuli**, passes round the **helicotrema** at the cochlear apex, and continues along the **scala tympani** to reach the **secondary tympanic membrane** at the fenestra cochleae, which bulges outward into the middle ear — this compensatory round-window movement is essential because the cochlear fluids are incompressible.
- ▶ **Amplification (impedance matching):** air is of low density/high compliance and internal-ear fluid is incompressible, so energy must be concentrated to cross this junction efficiently. The lever action of the ossicular chain, together with the disproportion between the tympanic membrane and the stapes footplate, **increases the intensity of the sound wave roughly ten-fold**; the ossicles amplify intensity only — the **frequency of the sound is not altered**.
- ▶ **Protective reflex:** the tensor tympani and stapedius contract reflexly and simultaneously in response to loud sound, damping ossicular movement and limiting transmission of excessive vibration to the internal ear.
- ▶ **Cochlear transduction:** vibration of the perilymph sets the **basilar membrane** and the **organ of Corti** oscillating; this produces a **travelling wave** along the basilar membrane whose point of maximal amplitude varies systematically with the frequency and intensity of the sound (a tonotopic, base-to-apex frequency map — high frequencies maximally displace the stiffer basal turn, low frequencies the more compliant apical turn).
- ▶ Local vibration of the basilar membrane moves the **endolymph**, deflecting the stereocilia of the **hair cells** of the organ of Corti against the overlying tectorial membrane; this causes an ionic exchange between endolymph and hair cell, **depolarising** the hair cell and triggering neurotransmitter release at its base.
- ▶ The stimulated **cochlear nerve afferents** (peripheral processes of bipolar neurons of the spiral ganglion) carry the impulse centrally as the **cochlear nerve**, and thence to the brainstem cochlear nuclei and the central auditory pathway.

Applied / clinical anatomy

- ▶ **Fracture of the middle cranial fossa** can break the tegmen tympani, rupturing the tympanic membrane and causing bleeding and CSF discharge from the ear.
- ▶ **Otitis media:** throat infection commonly spreads to the middle ear via the auditory tube. Pus may (a) discharge through a ruptured tympanic membrane, (b) erode the roof, causing meningitis/brain abscess, (c) erode the floor, causing thrombosis of the sigmoid sinus/internal jugular vein, or (d) spread posteriorly via the aditus to cause **mastoid abscess**; it is more common in children.

- ▶ **Eustachian catarrh** — auditory tube obstruction after a common cold causes earache aggravated by swallowing; relieved by nasal decongestant drops.
- ▶ **Otosclerosis** — bony fixation of the stapes footplate to the margins of the fenestra vestibuli causes conductive deafness; treated by stapedectomy and prosthesis.
- ▶ **Hyperacusis** — facial nerve palsy paralyses stapedius, so ossicular damping is lost and sounds are perceived as abnormally loud/distorted.
- ▶ **Chorda tympani** crosses the medial surface of the tympanic membrane (lateral to the long process of incus, medial to the neck of malleus) and is at risk during myringotomy (classically placed in the postero-inferior quadrant) — injury abolishes taste from the anterior two-thirds of the tongue and reduces submandibular/sublingual salivation.
- ▶ **Facial nerve** runs in the medial wall above the fenestra vestibuli and descends behind the posterior wall; it is vulnerable during mastoid/middle-ear surgery.
- ▶ **Tympanic canaliculus** (glossopharyngeal, floor) explains referred otalgia in pharyngeal/tonsillar disease via the tympanic plexus.

High-yield exam pointers

- ▶ Middle ear = biconcave cube, 15 mm vertical/AP, 2–6 mm transverse; tympanic cavity proper + epitympanic recess.
- ▶ Six walls: roof (tegmen tympani), floor (jugular bulb), anterior (carotid, auditory tube opening), posterior (aditus, pyramid, fossa incudis), lateral (tympanic membrane), medial (promontory, oval and round windows, facial canal prominence).
- ▶ Ossicles: malleus–incus–stapes; incudomalleolar (saddle) and incudostapedial (ball-and-socket) synovial joints.
- ▶ Two muscles: tensor tympani (nerve to medial pterygoid, V3) and stapedius (facial nerve, VII) — both dampen loud sound.
- ▶ Nerve supply via tympanic plexus (glossopharyngeal, IX) on the promontory; chorda tympani (VII) crosses the cavity but does not supply it.
- ▶ Ossicular chain amplifies sound intensity ~10-fold without changing frequency; round window bulges to compensate for stapes-driven perilymph waves.
- ▶ Otosclerosis fixes the stapes footplate at the oval window; otitis media spreads via the auditory tube and aditus to mastoid antrum.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 8e; IB Singh's Textbook of Anatomy Vol 3 6e; Vishram Singh's Textbook of Anatomy Vol 3 4e.



Describe the anatomy of soft palate and discuss the mechanism of deglutition

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The soft palate (velum palatinum) is the mobile, musculo-fibrous posterior one-third of the palate, suspended from the posterior border of the hard palate and sloping postero-inferiorly to separate the nasopharynx from the oropharynx. It has no bony basis, ends freely in the midline uvula, and — together with the tongue and pharyngeal constrictors — forms the essential valvular mechanism that seals the nasal and oral pathways during swallowing and speech. Its five paired muscles and the fibro-elastic palatine aponeurosis make it the key structure regulating the pharyngeal (involuntary) stage of deglutition.

1. Location, extent and surfaces

- ▶ Attached anteriorly to the posterior border of the hard palate; laterally continuous with the wall of the pharynx.
- ▶ Free posterior border bears the conical median **uvula**.
- ▶ Two mucosal folds run from each lateral margin: the anterior **palatoglossal arch** (to the side of the tongue) and the posterior **palatopharyngeal arch** (to the pharyngeal wall); between them lies the **tonsillar fossa** containing the palatine tonsil.
- ▶ Has an antero-inferior **oral surface** and a postero-superior **nasal surface**.
- ▶ Forms the **floor of the nasopharynx** and, with the tongue base, bounds the **oropharyngeal isthmus** (soft palate above, posterior tongue below, palatoglossal folds laterally); its posterior border with the posterior pharyngeal wall bounds the **pharyngeal isthmus** (communication between naso- and oropharynx).

2. Structure

- ▶ **Palatine aponeurosis** — the expanded tendon of tensor veli palatini, winding around the pterygoid hamulus; thick and stiff in the anterior (aponeurotic) part, thinning posteriorly to blend with muscle — forms the fibrous skeleton of the palate and gives attachment to the other four palatine muscles.
- ▶ **Muscular layer** — the posterior two-thirds is predominantly muscular (five muscles, below).
- ▶ **Mucous glands** — a thick sheet of racemose mucous (palatine) glands lies on the oral aspect, accounting for almost half the thickness of the palate.
- ▶ **Mucosa**: oral surface — stratified squamous epithelium; nasal surface — ciliated pseudostratified columnar (respiratory) epithelium, except its posterior part which is repeatedly apposed to the pharyngeal wall during swallowing and is therefore also stratified squamous (friction-adapted).

3. Muscles of the soft palate

Muscle	Origin	Insertion	Nerve supply	Main action
Tensor veli palatini	Scaphoid fossa of medial pterygoid plate, spine of sphenoid, cartilage of auditory (pharyngotympanic) tube	Winds round pterygoid hamulus (acting as a pulley) → palatine aponeurosis	Nerve to medial pterygoid, mandibular nerve (CN V ₃) via otic ganglion	Tenses anterior soft palate; opens the auditory tube during swallowing/yawning
Levator veli palatini	Petrous temporal bone + cartilage of auditory tube	Upper surface of palatine aponeurosis (fibres from both sides interlace, forming a sling)	Pharyngeal plexus — vagus/cranial root of accessory nerve	Elevates the posterior soft palate, bringing it against the posterior pharyngeal wall
Palatoglossus	Palatine aponeurosis	Side of tongue	Pharyngeal plexus	Elevates posterior tongue, approximates palatoglossal folds — closes oropharyngeal isthmus
Palatopharyngeus	Two fasciculi from palatine aponeurosis (separated by levator's insertion)	Lateral wall of pharynx/thyroid cartilage	Pharyngeal plexus	Draws pharyngeal wall up, forwards and medially; approximates palatopharyngeal folds; tenses palate
Musculus uvulae	Posterior nasal spine and palatine aponeurosis	Mucosa of uvula	Pharyngeal plexus	Shortens and retracts the uvula, thickening the midline of the soft palate

- **Passavant's muscle (palatopharyngeal sphincter)**: fibres from the anterior palatine aponeurosis that blend with the upper border of superior constrictor and encircle the pharynx; its contraction raises a variable ridge — **Passavant's ridge** — on the posterior nasopharyngeal wall, against which the elevated soft palate seals.
- Note the differential innervation: **tensor veli palatini alone is supplied by CN V₃** (1st arch derivative); all the other four muscles are supplied through the **pharyngeal plexus** (vagal/cranial-accessory, 4th/6th arch pattern) — a frequently tested point.

4. Nerve supply

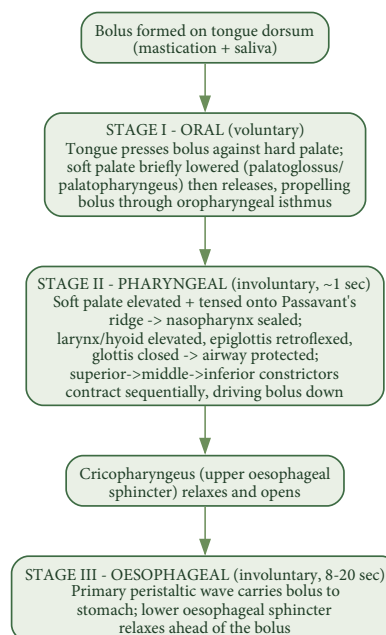
- **Motor**: pharyngeal plexus (cranial part of accessory nerve travelling via the vagus) to levator veli palatini, palatoglossus, palatopharyngeus and musculus uvulae; tensor veli palatini alone by the mandibular nerve (CN V₃) via the otic ganglion.

- **General sensory:** lesser (middle and posterior) palatine nerves — branches of the maxillary nerve via the pterygopalatine ganglion — supply the soft palate, uvula and tonsil; the greater palatine nerve supplies the hard palate.
- **Taste:** from the soft-palate mucosa, fibres pass in the palatine nerves through the pterygopalatine ganglion without relay, then via the greater petrosal nerve to the geniculate ganglion (facial nerve/nervus intermedius) → gustatory nucleus of the tractus solitarius.
- **Secretomotor (parasympathetic)** to the palatine mucous glands: preganglionic fibres from the superior salivatory nucleus travel in the facial nerve → greater petrosal nerve → relay in the pterygopalatine ganglion → postganglionic fibres in the palatine nerves.

5. Blood supply and lymphatic drainage

- **Ascending palatine artery** (branch of facial artery) — chief artery of the soft palate.
- **Lesser palatine artery** (from the greater palatine, itself from the descending palatine branch of the maxillary artery) — emerges through lesser palatine foramina to supply the soft palate.
- **Palatine branch of ascending pharyngeal artery** — additional supply.
- **Veins** drain mainly into the pterygoid venous plexus (some into the tonsillar/paratonsillar vein).
- **Lymphatics** drain to the deep cervical (and retropharyngeal) lymph nodes.

6. Mechanism of deglutition



Describe the anatomy of soft palate and discuss the mechanism of deglutition

Deglutition is a programmed motor act, traditionally divided into three stages:

- **Oral (buccal) stage — voluntary.** The bolus is held on the tongue against the hard palate; the tongue tip is fixed against the incisors/alveolar ridge while the mylohyoid and intrinsic lingual muscles produce a wave of contact of tongue against palate, from front to back, squeezing the bolus posteriorly through the oropharyngeal isthmus. Initially the soft palate is depressed (by palatoglossus/palatopharyngeus) against the tongue base to prevent premature leakage of the

bolus into the oropharynx before the airway is protected; this seal releases as the bolus is delivered to the oropharynx, initiating the next stage.

- ▶ **Pharyngeal stage — involuntary, most critical, ~1 second.** Triggered by the bolus contacting the fauces/oropharynx (afferents via glossopharyngeal and vagus nerves to the medullary swallowing centre). Two events occur simultaneously:
 - **Nasopharyngeal closure** — levator veli palatini elevates the posterior soft palate; tensor veli palatini and palatopharyngeus tense it; it is pressed against **Passavant's ridge** on the posterior pharyngeal wall, sealing off the nasopharynx and preventing nasal regurgitation.
 - **Laryngeal closure** — the hyoid and larynx are elevated and drawn forward (suprahyoid muscles, stylopharyngeus, salpingopharyngeus, palatopharyngeus), the epiglottis is retroflexed over the laryngeal aditus, and the vocal folds adduct; respiration is briefly inhibited.
 - **Bolus transport** — the superior, middle and inferior constrictors contract in sequence, producing a "stripping wave" that drives the bolus caudally; this is assisted by the tongue-driving pressure and by the negative (suction) pressure created in the hypopharynx as the larynx is elevated.
 - The **cricopharyngeus** (upper oesophageal sphincter) relaxes just before the bolus arrives and is opened further by the forward-upward pull of the elevated larynx, allowing the bolus to pass into the oesophagus.
- ▶ **Oesophageal stage — involuntary, 8–20 seconds.** A primary peristaltic wave (continuous with pharyngeal peristalsis) carries the bolus through the oesophagus; the lower oesophageal sphincter relaxes ahead of the advancing bolus (vagally-mediated receptive relaxation). Secondary peristalsis clears any residue if the primary wave is incomplete.

The soft palate is thus central to Stage II: its elevation/tensing against Passavant's ridge is the anatomical basis of velopharyngeal closure, without which food and fluid would reflux into the nose during every swallow.

□ Fig 8.88 — Muscles of soft palate. (Moore — Clinically Oriented Anatomy — 9e, p.1515)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Median sagittal section through the soft palate (inferior/oral aspect view), labelling:

- ▶ Posterior border of hard palate — attachment of soft palate
- ▶ Palatine aponeurosis (anterior, stiff part)
- ▶ Pterygoid hamulus (with tensor veli palatini tendon winding around it)
- ▶ Tensor veli palatini, Levator veli palatini, Palatoglossus, Palatopharyngeus, Musculus uvulae (all five muscles, correctly sited)
- ▶ Uvula (free posterior end)
- ▶ Palatoglossal arch and palatopharyngeal arch, with the tonsillar fossa/palatine tonsil between them
- ▶ Posterior pharyngeal wall showing the site of Passavant's ridge

Applied / Clinical anatomy

- ▶ **Vagus (CN X) nerve palsy:** on saying "Ah", the paralysed side of the soft palate fails to elevate and the uvula is pulled towards the **normal (healthy) side** — the "curtain sign."
- ▶ **Velopharyngeal insufficiency** (cleft palate, post-adenoidectomy scarring, bulbar/pseudobulbar palsy) causes nasal regurgitation of food/fluid and hypernasal speech (rhinolalia aperta) because the pharyngeal isthmus fails to close in Stage II.
- ▶ **Cleft palate:** failure of fusion of the palatine shelves leaves the oral and nasal cavities continuous; an infant cannot generate the negative oral pressure needed to suck because air from the nose enters the mouth through the cleft, and the palatoglossi cannot shut off the oral cavity from the pharynx.
- ▶ **Obstructive sleep apnoea/snoring:** reduced tone of pharyngeal dilators and the soft palate during sleep causes palatal flutter/pharyngeal collapse; surgical reduction and stiffening of the soft palate (uvulopalatopharyngoplasty) is used to relieve symptomatic snoring/OSA.
- ▶ **Tonsillectomy risk:** the glossopharyngeal nerve lies immediately lateral to the muscular wall of the tonsillar fossa (at risk of injury/oedema); the paratonsillar vein is a common source of post-tonsillectomy haemorrhage; the internal carotid artery lies only about 25 mm posterolateral to the tonsil.
- ▶ **Killian's dehiscence,** between the thyropharyngeal and cricopharyngeal parts of the inferior constrictor, is a site of potential weakness where incoordination between pharyngeal peristalsis and cricopharyngeal relaxation predisposes to a **pharyngeal (Zenker's) pouch/diverticulum**.
- ▶ **Gag reflex:** afferent limb via the glossopharyngeal nerve (posterior third of tongue/oropharynx), efferent limb via the vagus (pharyngeal muscles including soft-palate elevators) — used clinically to test the integrity of CN IX and X.

High-yield exam pointers

- ▶ Soft palate has 5 muscles; **tensor veli palatini alone is supplied by CN V₃** (via otic ganglion) — all four others (levator veli palatini, palatoglossus, palatopharyngeus, musculus uvulae) are supplied by the **pharyngeal plexus** (vagus/cranial accessory).

- ▶ **Palatoglossus** is the only "tongue" muscle NOT supplied by the hypoglossal nerve.
- ▶ Palatine aponeurosis = expanded tendon of tensor veli palatini — the fibrous skeleton of the soft palate; tensor's pull is redirected ~90° around the pterygoid hamulus (acting as a pulley/trochlea).
- ▶ **Passavant's ridge** = contraction of the palatopharyngeal sphincter (Passavant's muscle) + upper superior-constrictor fibres; the elevated soft palate seals against it to close the pharyngeal isthmus.
- ▶ Deglutition = 3 stages: oral (voluntary) → pharyngeal (involuntary, ~1 sec, airway-protective) → oesophageal (involuntary, peristaltic, 8–20 sec).
- ▶ Nasopharyngeal seal in Stage II needs BOTH elevation (levator veli palatini) AND tensing (tensor veli palatini, palatopharyngeus) of the soft palate against Passavant's ridge.
- ▶ Cricopharyngeus is the main component of the upper oesophageal sphincter; incoordination here predisposes to Zenker's diverticulum at Killian's dehiscence.
- ▶ Uvula deviates to the **normal** side in unilateral vagal (CN X) palsy.
- ▶ Tensor and levator veli palatini also dilate/open the pharyngotympanic (auditory) tube during swallowing/yawning, equalising middle-ear pressure.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; IB Singh — Textbook of Anatomy Vol 3 6e; Moore's Clinically Oriented Anatomy 9e.



Describe the anatomy of the larynx and add a note on the production of sound

Asked in: Paper I Nov 2018 — RGUHS MD/MS Anatomy

Definition / Introduction The larynx (Gk. *larynges* = upper windpipe) is the organ of phonation, a sphincter guarding the lower airway, and an air passage extending from the root of the tongue to the trachea. It is a musculo-cartilaginous box — nine cartilages linked by synovial joints, ligaments and fibro-elastic membranes, moved by extrinsic and intrinsic muscles, and lined by mucous membrane — lying in the anterior midline of the neck, continuous above with the laryngopharynx and below with the trachea.

Situation, extent and dimensions

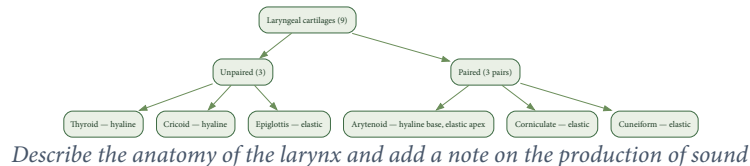
- ▶ **Level:** opposite the 3rd–6th cervical vertebrae in the adult male; one vertebral level higher in children and in the adult female.
- ▶ **Length:** 44 mm (male), 36 mm (female) — pubertal growth is marked in males (laryngeal prominence/"Adam's apple", low-pitched voice) but negligible in females (higher-pitched voice).
- ▶ **Internal diameter:** 3 mm up to age 3 years, increasing ~1 mm/year to reach the adult 12 mm by age 12.

- **Relations:** anteriorly, infrahyoid strap muscles; posteriorly, laryngopharynx; laterally, thyroid lobes and carotid sheath; mobile — rises/falls with deglutition.

Skeletal framework — cartilages of the larynx

The larynx has **nine cartilages** — three unpaired (median) and three paired.

Cartilage	Number	Shape	Histological type
Thyroid	1	Shield-shaped; two laminae fused anteriorly	Hyaline (may ossify after 25 y)
Cricoid	1	Complete ring — narrow anterior arch, broad posterior lamina	Hyaline (ossifies later than thyroid)
Epiglottis	1	Leaf-shaped, elastic, projects behind tongue/hyoid	Elastic (never ossifies)
Arytenoid	2	Pyramid-shaped, sits on cricoid lamina	Hyaline base; elastic apex
Corniculate (of Santorini)	2	Small conical nodules on arytenoid apices	Elastic
Cuneiform (of Wrisberg)	2	Small rods in the aryepiglottic fold	Elastic



Describe the anatomy of the larynx and add a note on the production of sound

Key attachments

- **Thyroid:** anterior angle 90°(M)/120°(F) forms the laryngeal prominence; superior cornu → lateral thyrohyoid ligament, inferior cornu → cricothyroid joint; oblique line gives attachment to thyrohyoid, sternothyroid, thyropharyngeus; inner aspect to thyroepiglottic ligament, both folds, thyroarytenoid, vocalis.
- **Cricoid:** "foundation stone" of the larynx; arch gives origin to cricothyroid and lateral cricoarytenoid; lamina gives origin to posterior cricoarytenoid ("safety muscle") and articulates above with the arytenoids.

□ Fig 16.2 — Cartilages of the larynx: Posterior view (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.306)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label, anterior view: Hyoid bone (body, greater/lesser cornu) — Thyrohyoid membrane — Lateral & median thyrohyoid ligaments — Superior cornu of thyroid — Laryngeal prominence — Thyroid notch — Laminae of thyroid cartilage — Inferior cornu — Cricothyroid joint — Arch of cricoid — Median cricothyroid (conus elasticus) ligament — First tracheal ring — Cricotracheal ligament. Label, posterior view: Epiglottis — Thyroid lamina — Arytenoid cartilage — Corniculate cartilage — Cricoarytenoid joint — Lamina of cricoid — Cricothyroid joint — Tracheal rings (deficient posteriorly).

Laryngeal joints, ligaments and membranes

Joint	Type	Articulation	Movement	Effect
Cricothyroid	Synovial	Inferior cornu of thyroid ↔ side of cricoid	Rotation (transverse axis) + gliding	Rocks thyroid fwd/down → tenses/relaxes vocal cords
Cricoarytenoid	Synovial	Base of arytenoid ↔ upper border of cricoid lamina	Rotation (vertical axis) + gliding	Adduction/abduction of vocal cords

Extrinsic (connect larynx to neighbouring structures): thyrohyoid membrane (thyroid → hyoid, thickened as median/lateral thyrohyoid ligaments; pierced by the internal laryngeal nerve and superior laryngeal vessels); hyoepiglottic ligament (epiglottis → hyoid); cricotracheal ligament (cricoid → first tracheal ring).

Intrinsic — together the **fibroelastic membrane of the larynx**, interrupted on each side by the laryngeal sinus:

- ▶ **Quadrangular membrane** (above the sinus): arytenoid → epiglottis; lower free border = **vestibular ligament** (vestibular fold), upper border = **aryepiglottic fold**.
- ▶ **Conus elasticus/cricovocal membrane** (below the sinus): from the cricoid arch upward; thickened anterior part = **median cricothyroid ligament**; upper free border = **vocal ligament** (vocal fold).

Interior of the larynx

- ▶ **Inlet of larynx**: obliquely placed, opening into the laryngopharynx; bounded anteriorly by the epiglottis, posteriorly by the interarytenoid fold, and laterally by the aryepiglottic folds.
- ▶ Two mucosal folds on each side divide the cavity into three parts:

Region	Boundary	Space between folds
Vestibule (supraglottis)	Above vestibular fold	Rima vestibuli
Sinus/ventricle of the larynx	Between vestibular and vocal folds	—
Infraglottis	Below vocal fold	Rima glottidis

- ▶ The **sacculus** ("oil-can of the larynx") is a diverticulum of the ventricle between the vestibular fold and thyroid lamina, with mucous glands that lubricate the vocal folds.
- ▶ **Vocal fold**: attached anteriorly to the thyroid angle, posteriorly to the vocal process of the arytenoid; contains the vocal ligament and vocalis muscle.
- ▶ **Rima glottidis** — narrowest part of the airway; anterior ~3/5 **intermembranous** (between the folds proper) and posterior ~2/5 **intercartilaginous** (between the arytenoids); 23 mm (male)/17 mm (female). Shape varies with function: triangular/quadrangular at rest, a chink on phonation, diamond-shaped on forced inspiration, funnel-shaped on whispering.
- ▶ **Mucous membrane**: stratified squamous over the vocal folds, upper epiglottis and upper aryepiglottic folds (friction areas); ciliated columnar elsewhere. Glands absent over the vocal folds, plentiful on the epiglottis, cuneiform region and vestibular folds.

Muscles of the larynx

Extrinsic: elevators — thyrohyoid, mylohyoid; depressors — sternothyroid, sternohyoid. **Intrinsic** (nerve = recurrent laryngeal nerve, RLN, unless stated):

Muscle	Origin → Insertion	Nerve	Action
Cricothyroid	Cricoid arch → inferior cornu/lower border of thyroid	External laryngeal n.	Tensor ("tuning fork of larynx") — only intrinsic muscle outside the larynx
Posterior cricoarytenoid	Cricoid lamina → muscular process of arytenoid	RLN	Only abductor — "safety muscle"
Lateral cricoarytenoid	Cricoid arch → muscular process of arytenoid	RLN	Adductor
Transverse arytenoid (unpaired)	Arytenoid → opposite arytenoid	RLN	Adductor (intercartilaginous part)
Oblique arytenoid + aryepiglottic	Muscular process → opposite apex → epiglottis	RLN	Closes laryngeal inlet
Thyroarytenoid + thyroepiglottic	Thyroid angle/cricothyroid lig. → arytenoid/epiglottis	RLN	Relaxor; opens inlet
Vocalis	Vocal process → vocal ligament/thyroid angle	RLN	Fine tension, anterior cord

□ Fig 16.10 — Muscles of larynx: Posterior view (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.312)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label, lateral/posterior dissection: Epiglottis — Aryepiglottic fold and muscle — Cuneiform cartilage — Corniculate cartilage — Arytenoid cartilage — Posterior cricoarytenoid — Thyroepiglottic — Thyroarytenoid — Thyroid cartilage — Lateral cricoarytenoid. Label, horizontal schematic (to show abduction/adduction): Thyroid cartilage — Thyroarytenoid muscle — Arytenoid — Vocal process — Muscular process — Posterior cricoarytenoid (abductor, arrow rotating vocal process laterally) — Lateral cricoarytenoid (adductor, arrow rotating vocal process medially).

Nerve supply, blood supply and lymphatic drainage

- ▶ **Motor:** RLN → all intrinsic muscles except cricothyroid; external laryngeal nerve → cricothyroid only.
- ▶ **Sensory** (both vagal branches): internal laryngeal nerve → mucosa **above** the vocal folds; RLN → mucosa **below** the vocal folds.
- ▶ **Arterial:** above the folds — superior laryngeal artery (from superior thyroid artery, piercing thyrohyoid membrane with the internal laryngeal nerve); below the folds — inferior laryngeal artery (from inferior thyroid artery). Veins drain likewise into the superior/inferior thyroid veins.
- ▶ **Lymphatics:** above the folds → pierce thyrohyoid membrane → antero-superior deep cervical nodes; below the folds → postero-inferior deep cervical nodes (a few via prelaryngeal nodes, piercing cricothyroid membrane). **Vocal folds have no lymphatics** — a watershed, so glottic carcinoma has the best prognosis of laryngeal cancers.

NOTE — FOR REFERENCE, NOT TO BE WRITTEN IN THE EXAM

Phonation is the larynx's most specialised function, requiring the coordinated action of **four processes** (the classical scheme) mapped onto a validated physical mechanism:

- ▶ **Power source — expired air:** expiratory muscles plus elastic recoil of lung/rib-cage force air through the larynx; **loudness** depends on subglottic pressure and how long the glottis stays open per cycle.
- ▶ **Vibrator — the vocal folds:** lateral cricoarytenoid and interarytenoid adduct the folds while cricothyroid (aided by vocalis) tenses them, closing the rima glottidis. Sub-glottic pressure rises until it forces the folds apart momentarily; as pressure falls and the gap narrows, the **Bernoulli effect** (fast airflow through a narrow chink lowers lateral pressure) sucks the folds back together. This repeating cycle is the **aerodynamic-myoelectric theory** of vocal-fold vibration — the accepted mechanism generating the fundamental tone. **Pitch** depends on cord length/tension: cricothyroid (rocking the thyroid at the cricothyroid joint) lengthens/tenses the cords for the initial setting, vocalis fine-tunes — a longer, more tensed cord vibrates faster (rubber-band, not tuning-fork, analogy).
- ▶ **Resonators:** the air column in the pharynx, oral/nasal cavities and paranasal sinuses resonates with the laryngeal note, amplifying overtones to give the voice its individual **quality/timbre**.
- ▶ **Articulators:** palate, tongue, teeth and lips shape the resonated sound into speech — vowels from vocal-fold vibration, consonants from articulators narrowing/stopping the airstream (labial — pa/ba/ma; dental — ta/da/na; palatal — ka/ga).

The vestibular (false) folds take little part in normal phonation — mainly protective, closing over the true folds during effort closure (straining, coughing). The process is under cortical (motor speech area) control with continuous auditory-feedback adjustment.

Applied / Clinical anatomy

- ▶ **Foreign bodies** lodge most often at the rima glottidis, the narrowest part of the airway; large ones obstruct the inlet causing suffocation, small ones trapped in the ventricle trigger reflex glottic closure.
- ▶ **Laryngitis** → hoarseness; **laryngeal oedema** of the loose supraglottic submucosa can obstruct breathing but spares the vocal folds (mucosa tightly bound there). **Singer's/teacher's nodules** form at the junction of the anterior one-third and posterior two-thirds of the vocal fold — the point of maximal vibratory amplitude.
- ▶ **Piriform fossa** ("smuggler's fossa") lies between the quadrangular membrane/thyroid cartilage, traversed by the internal laryngeal nerve; a common site for impacted fish bones, causing vagally-mediated referred otalgia.
- ▶ **RLN palsy:** unilateral → hoarseness (opposite cord compensates); bilateral → cords in the cadaveric position, causing aphonia and severe dyspnoea (posterior cricoarytenoid, the sole abductor, lost bilaterally). Left RLN loops under the aortic arch (vulnerable to mediastinal tumours); right loops under the subclavian artery.

- ▶ **External laryngeal nerve injury** (e.g., thyroidectomy) paralyses cricothyroid — voice fatigue, loss of ability to raise pitch, no hoarseness at rest.
- ▶ **Glottic carcinoma** has the best prognosis of laryngeal cancers (no lymphatics at the true cords delay spread); supra-/subglottic tumours spread early via the rich lymphatics on either side of this watershed.
- ▶ **Airway access**: emergency cricothyroidotomy through the median cricothyroid ligament; elective tracheostomy lower, through the 2nd–4th tracheal rings. Larynx is examined by indirect (mirror) or fiberoptic laryngoscopy.

High-yield exam pointers

- ▶ Nine laryngeal cartilages: 3 unpaired (thyroid, cricoid, epiglottis) + 3 paired (arytenoid, corniculate, cuneiform); thyroid/cricoid/arytenoid base = hyaline (ossify after 25 y), the rest = elastic (never ossify).
- ▶ **Cricothyroid** = only intrinsic muscle outside the larynx; only one supplied by the external laryngeal nerve; tensor ("tuning fork of larynx").
- ▶ **Posterior cricoarytenoid** = only abductor of the vocal cord ("safety muscle").
- ▶ Recurrent laryngeal nerve supplies all intrinsic muscles except cricothyroid; sensation divides at the vocal folds (internal laryngeal nerve above, recurrent laryngeal nerve below).
- ▶ Rima glottidis is the narrowest part of the larynx — 23 mm (male)/17 mm (female); anterior 3/5 intermembranous, posterior 2/5 intercartilaginous.
- ▶ Vocal folds have no lymphatics (watershed) — best-prognosis site for laryngeal carcinoma.
- ▶ Two synovial joints: cricothyroid (tension/relaxation) and cricoarytenoid (adduction/abduction).
- ▶ Phonation = aerodynamic–myoelastic theory (subglottic pressure + Bernoulli effect) on cords tensed by cricothyroid; pitch, loudness and quality are controlled independently by the vibrator, power source and resonators.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e — Chapter 35, Larynx (skeleton, cartilages, and the mechanism of phonation/aerodynamic–myoelastic theory); BD Chaurasia's Human Anatomy Vol 3–4, 8e — Chapter 16, Larynx (cartilages, joints, ligaments/membranes, interior, muscles, nerve/blood/lymphatic supply, clinical anatomy, mechanism of speech).



Describe the anatomy of tongue in detail. Add a note on its role in speech and mastication

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction — The tongue is a highly muscular organ occupying the floor of the mouth, concerned with taste, mastication, deglutition, speech and cleansing of the oral cavity. It has a root (attached to the mandible, hyoid bone, styloid process and soft palate), a tip, and a body whose curved dorsum is divided by a V-shaped **sulcus terminalis** into an anterior oral (presulcal) two-thirds and a posterior pharyngeal (postsulcal) one-third — parts that differ in mucosa, innervation and developmental origin. It is composed of four extrinsic and four intrinsic paired skeletal muscles, richly supplied by the lingual vessels and by three cranial nerves that reflect its branchial-arch development.

1. Gross anatomy and external features

- ▶ **Parts:** root, tip and body (curved dorsum + inferior surface, oral part only).
- ▶ **Root** is attached above to the styloid process and soft palate, below to the mandible (genial tubercles) and hyoid bone via the geniohyoid/mylohyoid.
- ▶ **Sulcus terminalis:** a faint V-shaped groove whose two limbs run anterolaterally to the palatoglossal arches and meet posteriorly at a median pit, the **foramen caecum** — the site of origin of the thyroid diverticulum in the embryo.
- ▶ **Oral (presulcal) part** — rough, papillated dorsum; margins in contact with teeth/gums show 4–5 vertical **foliate papillae** just anterior to the palatoglossal arch; inferior surface is smooth, with a median **frenulum linguae**, flanked by the deep lingual veins and the **plica fimbriata**.
- ▶ **Pharyngeal (postsulcal) part/base** — devoid of papillae, studded with lymphoid follicles constituting the **lingual tonsil** (part of Waldeyer's ring); forms the anterior wall of the oropharynx.
- ▶ **Posteriormost part** is connected to the epiglottis by a median and two lateral **glossoepiglottic folds**, the intervening depressions being the **valleculae**.
- ▶ **Papillae of the dorsum (anterior 2/3 only):** filiform (most numerous, conical, keratinised, no taste buds — velvety texture), fungiform (near tip/margins, bright red, taste buds on apex), foliate (leaf-shaped folds at lateral border, vestigial), and circumvallate/vallate (8–12 large papillae in a V-shaped row just anterior to the sulcus terminalis, each ringed by a sulcus draining serous glands of von Ebner — maximum taste-bud density).

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the dorsum of the tongue and label: tip, foramen caecum, sulcus terminalis, circumvallate papillae, foliate papillae, fungiform papillae, filiform papillae, palatoglossal arch, lingual tonsil, median glossoepiglottic fold, vallecula, epiglottis, palatine tonsil.

2. Muscles of the tongue

A median fibrous **lingual septum** divides the tongue into symmetrical halves, each with four intrinsic and four extrinsic muscles.

Muscle	Attachment	Nerve	Action
Genioglossus (extrinsic, fan-shaped)	Upper genial tubercle of mandible → inferior fibres to hyoid, middle fibres to dorsum, superior fibres to tip	Hypoglossal (XII)	Protrudes the tongue (net action of whole muscle — the "safety/life-saving" muscle); individually depresses the centre of the dorsum
Hyoglossus (extrinsic, quadrilateral)	Whole length of greater cornu and body of hyoid → side of tongue, between styloglossus and inferior longitudinal	XII	Depresses the tongue, retracts a protruded tongue
Styloglossus (extrinsic)	Tip/anterior surface of styloid process → side of tongue (longitudinal + oblique parts)	XII	Draws the tongue upwards and backwards (retraction)
Palatoglossus (extrinsic)	Palatine aponeurosis of soft palate → side of tongue at oral-pharyngeal junction, forming the palatoglossal arch	Cranial root of accessory via pharyngeal plexus (vagal fibres)	Elevates the root of the tongue, approximates the palatoglossal arches, closes the oropharyngeal isthmus
Superior longitudinal (intrinsic)	Submucous fibrous tissue/septum → mucosa of dorsum	XII	Shortens tongue, makes dorsum concave
Inferior longitudinal (intrinsic)	Root/hyoid → tip, deep to genioglossus/hyoglossus	XII	Shortens tongue, makes dorsum convex
Transverse (intrinsic)	Median septum → submucosa of lateral margins	XII	Narrows and elongates the tongue
Vertical (intrinsic)	Dorsal submucosa → inferior surface, anterior part	XII	Flattens and broadens the tongue

- All intrinsic muscles + three extrinsic muscles (genioglossus, hyoglossus, styloglossus) are supplied by the **hypoglossal nerve** — only **palatoglossus** is an exception (vagoaccessory supply).
- Acting alone or in combination, the intrinsic muscles give the tongue precise, highly varied mobility essential for both alimentary function and speech.

3. Nerve supply

Motor: as above (XII to seven of eight muscles; palatoglossus by the pharyngeal plexus).

Sensory and taste (correlates exactly with developmental arch of origin):

Region	General sensation	Taste	Arch of origin
Anterior 2/3 (excluding circumvallate papillae)	Lingual nerve (mandibular division of trigeminal, V)	Chorda tympani (facial, VII)	1st arch
Posterior 1/3, including circumvallate papillae	Glossopharyngeal (IX)	Glossopharyngeal (IX)	3rd arch
Posteriormost part, vallecula and epiglottis	Internal laryngeal branch of vagus (X)	Internal laryngeal branch of vagus (X)	4th arch

Taste pathway: peripheral taste fibres reach the geniculate ganglion (VII, via chorda tympani) or the inferior ganglia of IX/X → central processes converge on the **nucleus and tractus solitarius** in the medulla → second-order solitariothalamic fibres join the trigeminal (medial) lemniscus → relay in the **ventral posteromedial (VPM) nucleus of the thalamus** → third-order fibres to the taste area at the lowest part of the postcentral gyrus (parietal operculum).

4. Blood supply and venous drainage

- **Arterial:** chiefly the **lingual artery** (branch of external carotid, markedly tortuous to permit free tongue/pharyngeal movement), giving **dorsal lingual arteries** (2–3, to pharyngeal dorsum, palatoglossal arch, tonsil, soft palate, epiglottis), the **sublingual artery** (to sublingual gland, mylohyoid, gingivae; anastomoses with submental branch of facial artery), and the **deep lingual artery** (terminal part, near the frenulum — chief artery of the anterior tongue). Both sides anastomose freely across the midline (unilateral resection does not devascularise the tongue). Root additionally supplied by the tonsillar and ascending palatine branches of the **facial artery** and by the **ascending pharyngeal artery**.
- **Venous drainage:** dorsal lingual veins, venae comitantes of the lingual artery, the deep lingual vein (tip) and the vena comitans of the hypoglossal nerve unite near the posterior border of hyoglossus to form the **lingual vein**, usually joining the facial and retromandibular veins before draining into the **internal jugular vein**.

5. Lymphatic drainage

Four working rules (high clinical relevance for oral cancer):

- **Tip** → drains bilaterally to the **submental** nodes.
- **Remainder of the anterior 2/3** (each half) → drains unilaterally to the **submandibular** nodes; a few central lymphatics drain bilaterally to the **deep cervical** nodes.
- **Posterior 1/3 and posteriormost part** → drain bilaterally into the **upper deep cervical nodes**, including the jugulodigastric node.
- All lymph ultimately converges on the **jugulo-omohyoid node** — traditionally called "the lymph node of the tongue."

□ Fig 8.96 — Lymphatic drainage of tongue. A. Dorsum of tongue. B. Overview. Lymph drains to the submental, submandibular and deep cervical nodes (Moore — Clinically Oriented Anatomy — 9e, p.1524)

6. Development of the tongue

- Appears at about the **4th week** as three 1st-arch swellings — two **lateral lingual swellings** and a median **tuberculum impar** — plus a second median swelling, the **copula (hypobranchial eminence)**, from mesoderm of the 2nd, 3rd and part of the 4th arches.
- Lateral lingual swellings enlarge, overgrow the tuberculum impar and fuse to form the **anterior two-thirds (body)** — mucosa is 1st-arch, hence sensation via the lingual nerve and taste via the chorda tympani (pre-trematic nerve of the 2nd arch).
- **Posterior one-third (root)** develops from the ventral hypobranchial eminence (3rd arch); since 3rd-arch tissue overgrows the underlying 2nd arch, both sensation and taste here are by the **glossopharyngeal nerve**. The **posteriormost part/epiglottis** (4th arch) is supplied by the **internal laryngeal branch of the vagus**.
- **Musculature** derives from migrating myoblasts of the **occipital myotomes**, carrying the **hypoglossal (XII) nerve** — hence its supply to seven of eight muscles; **palatoglossus** (6th-arch mesoderm) is supplied instead via the vagoaccessory pharyngeal plexus. Connective tissue/septum arise from local mesenchyme.
- **Foramen caecum**, at the tuberculum impar–copula junction, marks the origin of the thyroid diverticulum; a persistent thyroglossal remnant or undescended primordium here gives a **lingual thyroid**.

7. Role of the tongue in speech and mastication

Speech: the tongue is the principal articulator. Its intrinsic muscles (transverse, vertical, longitudinal) give precise, rapid shape changes — elongation, curling, flattening, grooving — essential to speech as well as swallowing. The tip/blade contacts the alveolar ridge/palate for lingual consonants; the dorsum approximates the soft palate for velar sounds, and **palatoglossus** (elevating the root, approximating the palatoglossal arches) assists oropharyngeal closure separating oral/nasal airflow. Extrinsic muscles position the tongue mass to shape the oral resonating chamber (vowel quality) while intrinsic muscles superimpose fine consonant articulation. **Hypoglossal palsy** causes dysarthria from loss of fine tongue movement. **Ankyloglossia** (frenulum extending onto the mandibular alveolus) is classically linked to impaired articulation, though Gray's notes the evidence that frenulotomy specifically improves speech is scanty.

Mastication: the tongue and buccinator act together to keep the bolus on the occlusal table between the molars, repeatedly returning strayed food onto the grinding surfaces and guarding the tongue from being bitten. Transverse/vertical intrinsic muscles mould chewed food and saliva into a cohesive bolus; genioglossus and hyoglossus reposition it through the chewing cycle. On completion, the tongue elevates against the palate and is drawn up-and-back (styloglossus) while palatoglossus closes the oropharyngeal isthmus, propelling the bolus into the oropharynx to initiate deglutition. Rich general and taste innervation gives continuous reflex feedback regulating chewing and protecting the mucosa.

Applied / Clinical anatomy

- **Genioglossus — the "safety muscle":** when relaxed (unconsciousness, general anaesthesia, obstructive sleep apnoea) the unsupported tongue falls back and obstructs the airway; relieved by lateral ("tonsil") positioning or jaw-thrust/tongue traction.

- ▶ **Hypoglossal (XII) palsy:** the intact genioglossus pushes the tongue base across, so on protrusion the tip deviates **towards the side of the lesion**, with ipsilateral wasting/fasciculation (LMN lesion) — the standard bedside test of XII integrity.
- ▶ **Lingual nerve** is at risk during extraction of impacted lower third molars and submandibular gland/duct surgery, causing anaesthesia and taste loss over the ipsilateral anterior two-thirds and floor of mouth.
- ▶ **Carcinoma of the tongue** favours the lateral border of the anterior two-thirds and spreads first to submandibular then deep cervical nodes (hemiglossectomy + block neck dissection); posterior one-third growths are more dangerous owing to early **bilateral** lymphatic spread and late presentation.
- ▶ **Glossitis:** anaemias (iron/B12/folate deficiency) cause a smooth, bald tongue from filiform papillary atrophy; acute glossitis causes gross swelling (loose submucosa, rich lymphatics) that can obstruct the airway.
- ▶ **Sublingual drugs** (e.g., glyceryl trinitrate/sorbitrate for angina) are absorbed rapidly via the tongue's rich venous plexus, bypassing hepatic first-pass metabolism.
- ▶ **Referred pain** from posterior-tongue lesions is felt in the ear (shared IX/X supply); the undersurface of the tongue (with the bulbar conjunctiva) is a useful site to detect early jaundice.
- ▶ **Ankyloglossia** (short/tight frenulum) and **macroglossia** (Down syndrome, hypothyroidism, lymphangioma, acromegaly) are important anomalies affecting feeding and speech.

High-yield exam pointers

- ▶ Genioglossus alone protrudes the tongue — the "safety muscle"; tests XII integrity (deviates towards the lesion side on protrusion).
- ▶ 7 of 8 muscles by hypoglossal nerve; **palatoglossus alone** via the pharyngeal plexus (vagoaccessory) — matches its 6th-arch origin.
- ▶ Taste/sensation follows the arch of origin: ant. 2/3 → lingual (V)/chorda tympani (VII); post. 1/3 + circumvallate papillae → glossopharyngeal (IX, both modalities); posteriormost/epiglottis → internal laryngeal vagus (X).
- ▶ Circumvallate papillae: 8–12, V-shaped row anterior to the sulcus terminalis, highest taste-bud density, drained by glands of von Ebner.
- ▶ Lymphatics: tip → submental; ant. 2/3 → submandibular (+ some bilateral deep cervical); post. 1/3 → bilateral deep cervical; all → jugulo-omohyoid node.
- ▶ Foramen caecum = site of thyroid diverticulum origin — landmark for lingual thyroid/thyroglossal remnants.
- ▶ Sulcus terminalis is the anatomical AND developmental boundary (1st-arch body vs 3rd-arch root).
- ▶ Intrinsic muscles give fine shape-control for speech; extrinsic muscles give gross positioning for both speech and mastication.
- ▶ Lingual artery is markedly tortuous, permitting free movement without vascular compromise.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4, 8e; Moore's Clinically Oriented Anatomy, 9e; Langman's Medical Embryology (Sadler), 14e.



Describe the deep fascias of the neck

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The deep fascia of the neck (fascia colli) is a condensation of loose areolar tissue lying deep to the platysma and superficial (subcutaneous) fascia. It ensheathes the neck muscles, invests the great vessels, nerves and viscera, forms capsules for the salivary and thyroid glands, and creates a series of potential "fascial spaces" that channel the spread of infection. Classically it is described as three layers — investing, pretracheal and prevertebral — together with three further derivatives — the carotid sheath, buccopharyngeal fascia and pharyngobasilar fascia. Its clinical importance lies almost entirely in how its planes and the spaces between them direct pus and localise or spread neck sepsis.

Classification of the deep cervical fascia

Classical layer	Also called (Gray's modern terminology)	Structures enclosed/ensheathed
Investing (superficial) layer	Superficial layer of deep cervical fascia (SLDCF) / parotidomasseteric fascia	Sternocleidomastoid, trapezius, parotid & submandibular glands
Pretracheal fascia	Middle layer of deep cervical fascia (MLDCF) — muscular part (strap muscles) + visceral part (pretracheal + buccopharyngeal fascia)	Infrahyoid strap muscles; thyroid, larynx, trachea, pharynx, oesophagus
Prevertebral fascia	Deep layer of deep cervical fascia (DLDCF) — dorsal (prevertebral) and ventral (alar) laminae	Prevertebral & scalene muscles; forms axillary sheath
Carotid sheath	Carotid space	Common/internal carotid artery, internal jugular vein, vagus nerve, ansa cervicalis
Buccopharyngeal fascia	Part of the visceral (middle) layer	Pharyngeal constrictors and buccinator externally
Pharyngobasilar fascia	Submucosal fibrous coat of pharynx	Anchors superior constrictor to the skull base

(Standring notes the terminology has genuinely varied since Grodinsky & Holyoke's 1938 description — surgical/radiological literature and classical gross-anatomy texts use different synonyms for the same planes.)

Investing (superficial) layer of deep cervical fascia

Lies deep to platysma and encircles the neck completely like a collar.

- ▶ **Attachments** — Superiorly: external occipital protuberance, superior nuchal line, mastoid process, and the whole lower border of the mandible; between the mandible and mastoid process it is related to the parotid gland and continues up as the stylomandibular ligament to the styloid process. Inferiorly: spine of scapula, acromion, clavicle, and manubrium sterni. Anteriorly (in the midline): symphysis menti and hyoid bone, becoming continuous with the fascia of the opposite side above and below the hyoid. Posteriorly: ligamentum nuchae and the spine of C7.
- ▶ **Splits to enclose two muscles** — trapezius (forming the roof of the posterior triangle) and sternocleidomastoid (forming part of the roof of the anterior triangle).
- ▶ **Splits to enclose two glands** — the parotid (superficial lamina = parotidomasseteric fascia to the zygomatic arch; deep lamina to the tympanic plate/styloid process) and the submandibular gland (superficial lamina to the lower border of the mandible; deep lamina to the mylohyoid line).
- ▶ **Splits to enclose two spaces** (below the hyoid) —

Space	Boundaries	Contents
Suprasternal space (of Burns)	Two laminae of the investing layer above the manubrium, attached to its anterior and posterior borders	Sternal heads of both sternocleidomastoids, jugular venous arch, interclavicular ligament, occasional lymph node
Supraclavicular space	Two laminae above the middle third of the clavicle	Terminal part of the external jugular vein, supraclavicular nerves

- ▶ **Forms two fascial pulleys/slings** — for the intermediate tendon of digastric and the inferior belly of omohyoid.

Pretracheal fascia (visceral fascia)

Covers the front and sides of the trachea and is continuous with the buccopharyngeal fascia.

- ▶ **Attachments** — Superiorly to the hyoid bone (in the median plane), the oblique line of the thyroid cartilage, and the cricoid cartilage. Laterally it forms the front of the carotid sheath and fuses with the fascia deep to sternocleidomastoid. Inferiorly it encloses the inferior thyroid veins, passes behind the brachiocephalic veins, and blends with the arch of the aorta and fibrous pericardium.
- ▶ **Splits to enclose the thyroid gland**, forming its false capsule; the thickened posterior part condenses as the **ligament of Berry**, which anchors the lateral lobe to the cricoid cartilage and prevents the gland sinking into the mediastinum.
- ▶ Provides a slippery surface allowing the trachea (and thyroid) to move freely during swallowing.

Prevertebral fascia

Lies immediately in front of the prevertebral muscles (longus colli, longus capitis) and forms the **floor of the posterior triangle**.

- ▶ **Attachments** — Superiorly to the base of the skull. Inferiorly it descends in front of longus colli into the superior mediastinum, where it blends with the anterior longitudinal ligament

(extending to about T3–T4). Laterally it covers the scalene muscles, splenius capitis and levator scapulae as the "fascial carpet" of the posterior triangle.

- ▶ Ventral rami of the cervical (and brachial) plexus lie deep to it; as the brachial plexus trunks and subclavian artery emerge between scalenus anterior and medius, they carry a tubular prolongation of this fascia into the axilla as the **axillary sheath** (the subclavian/axillary veins lie outside the sheath, permitting free dilatation).
- ▶ Its ventral (anterior) lamina is the **alar fascia**, separated from the true prevertebral fascia by the "danger space" (see below) and fusing anteriorly with the buccopharyngeal fascia.

Carotid sheath and other fascial derivatives

- ▶ **Carotid sheath** — a tubular condensation formed by contributions from all three layers (investing anteriorly, pretracheal medially, prevertebral posteriorly), extending from the base of the skull to the arch of the aorta. Contents: common/internal carotid artery, internal jugular vein and vagus nerve (vagus lies posterior, between artery and vein); cranial nerves IX, XI and XII lie within its upper part only. The ansa cervicalis is embedded in its anterior wall; the cervical sympathetic trunk lies plastered to its posterior wall on the prevertebral fascia. It is thin over the vein to permit its distension.
- ▶ **Buccopharyngeal fascia** — covers the pharyngeal constrictors externally and continues onto the buccinator; attached to the pharyngeal tubercle of the skull base.
- ▶ **Pharyngobasilar fascia** — the thickened submucous coat of the pharynx, deep to the muscular wall, anchoring the superior constrictor to the skull base.

Fascial (tissue) spaces of the neck

These potential spaces, filled with loose areolar tissue, determine how neck infection tracks — there is no horizontal barrier, so pus can spread the entire length of the neck.

Space	Location/boundaries	Clinical significance
Suprasternal (of Burns)	Between the two laminae of investing layer above the manubrium	Rarely infected; anterior cervical lymph node here
Retropharyngeal space	Anterior: buccopharyngeal fascia; posterior: prevertebral/alar fascia; sides: carotid sheath; extends skull base to about C6–T4, where it fuses and is continuous with the superior mediastinum	Contains retropharyngeal lymph nodes; acute retropharyngeal abscess (from suppurating nodes) bulges paramedian in the posterior pharyngeal wall
"Danger space"	Between alar fascia (anteriorly) and true prevertebral fascia (posteriorly); skull base to the posterior mediastinum/diaphragm	Loose areolar tissue gives infection a rapid, unimpeded route into the posterior mediastinum

Space	Location/boundaries	Clinical significance
Prevertebral space	Between prevertebral fascia and the vertebral column; skull base to coccyx	Tubercular caries of the cervical spine → cold (Pott's) abscess; pus may track laterally along the axillary sheath into the posterior triangle/axilla
Pretracheal (anterior visceral) space	Within the visceral part of the middle layer, in front of trachea/thyroid	Oesophageal perforation or thyroid sepsis spreads here into the anterior mediastinum
Carotid space	Within the carotid sheath	Infection may track from the parapharyngeal space down into the mediastinum along the great vessels
Submandibular/sublingual/submental spaces	Bounded by the investing layer between the two halves of the mandible and the hyoid bone	Cellulitis here (classically from lower molar teeth) produces the brawny bilateral swelling of Ludwig's angina , which may push the tongue upward and threaten the airway

Diagram — real plate (Vishram Singh, Textbook of Anatomy Vol 3, 4e):

□ Fig 4.9 — Diagrammatic transverse section through neck at the level of the 6th cervical vertebra (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.262)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A transverse section of the neck at the C6/C7 level, labelling:

- ▶ Skin and superficial (subcutaneous) fascia with platysma
- ▶ Investing layer of deep cervical fascia — enclosing sternocleidomastoid and trapezius
- ▶ Pretracheal fascia — enclosing thyroid gland, trachea and oesophagus
- ▶ Buccopharyngeal fascia — around the pharynx/oesophagus
- ▶ Prevertebral fascia — covering longus colli/prevertebral and scalene muscles, and the vertebral body
- ▶ Carotid sheath — with common carotid artery, internal jugular vein and vagus nerve
- ▶ Retropharyngeal space (between buccopharyngeal and prevertebral/alar fascia)
- ▶ Anterior and posterior triangles (roof formed by investing layer)

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- ▶ **Ludwig's angina** — bilateral cellulitis of the submandibular, sublingual and submental spaces (usually odontogenic, from the lower 2nd/3rd molars); confined anteriorly by the investing layer's attachment to the mandible and hyoid, producing a tense, painful, board-like swelling of the floor of the mouth that elevates the tongue and threatens airway obstruction.
- ▶ **Retropharyngeal abscess** — suppuration of retropharyngeal lymph nodes causes a paramedian bulge in the posterior pharyngeal wall (fusion of buccopharyngeal to prevertebral fascia in the

midline prevents a central bulge); must be distinguished from a midline cold (tubercular) abscess of the cervical spine, which lies in the prevertebral space.

- ▶ **Danger space spread** — because it is closed superiorly, inferiorly and laterally but filled with loose areolar tissue, infection entering it (from retropharyngeal, parapharyngeal or prevertebral spaces) can descend rapidly to the posterior mediastinum, causing mediastinitis.
- ▶ **Thyroid surgery** — the pretracheal fascia's ligament of Berry tethers the gland to the cricoid cartilage close to the recurrent laryngeal nerve, making this the danger point during thyroidectomy; because it is deficient posteriorly, an enlarging goitre bulges backward to compress the oesophagus (dysphagia) or trachea.
- ▶ **Air embolism** — the external jugular vein is bound to the investing layer within the supraclavicular space; if lacerated, the fascia holds the vein open, permitting air to be sucked in on inspiration (a surgical emergency).
- ▶ **Deep cervical lymph node dissection (block dissection of the neck)** — malignant/tuberculous nodes may become adherent to the internal jugular vein within the carotid sheath, requiring the sheath to be opened and part of the vein resected.
- ▶ **Regional/local anaesthetic blocks** — knowledge of the prevertebral and carotid fascial planes guides cervical plexus blocks for thyroidectomy, parathyroidectomy and carotid endarterectomy.
- ▶ **Axillary sheath** — the prolongation of prevertebral fascia around the subclavian artery and brachial plexus explains why supraclavicular brachial plexus blocks or cervical rib pathology can produce sheath-confined symptoms extending into the axilla.

High-yield exam pointers

- ▶ **Three classical layers:** investing, pretracheal, prevertebral — plus three derivatives: carotid sheath, buccopharyngeal fascia, pharyngobasilar fascia.
- ▶ Investing layer is the "layer of 2's": 2 muscles (SCM, trapezius), 2 glands (parotid, submandibular), 2 spaces (suprasternal, supraclavicular), 2 pulleys (digastric, omohyoid).
- ▶ Pretracheal fascia → capsule of thyroid → ligament of Berry → explains upward movement of thyroid/goitre on swallowing.
- ▶ Prevertebral fascia → floor of posterior triangle → continues as the axillary sheath.
- ▶ Carotid sheath is formed by contributions of all three layers; thin over the IJV, thick around the arteries; ansa cervicalis on its anterior wall, sympathetic chain behind it.
- ▶ Retropharyngeal space vs danger space vs prevertebral space — know the boundaries of each to explain the direction of spread of infection (paramedian pharyngeal bulge vs rapid descent to posterior mediastinum vs Pott's/cold abscess).
- ▶ Ludwig's angina = submandibular/sublingual/submental space cellulitis limited by the investing layer's attachment to mandible and hyoid.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3–4, 8e; Vishram Singh — Textbook of Anatomy Vol 3, 4e; IB Singh — Textbook of Anatomy Vol 3, 6e.



Describe the features, blood supply and nerve supply of lateral wall of the nasal cavity

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction — The lateral wall of the nasal cavity is the irregular, complex wall of each nasal fossa, made undulating by three shelf-like bony projections, the **conchae (turbinates)**, which increase mucosal surface area for air-conditioning of inspired air. It separates the nasal cavity from the orbit above (ethmoidal sinuses intervening), the maxillary sinus below, the lacrimal sac/nasolacrimal duct in front, and the pterygopalatine fossa behind. Nearly every paranasal sinus drains onto this wall, and its neurovascular supply is conventionally described by dividing the wall into four **quadrants** — this quadrant scheme is the key to the blood and nerve supply and is a favourite exam device.

1. Extent, relations and skeletal framework

- ▶ The nasal cavity runs from the anterior nares to the posterior nasal apertures (choanae); each half is about 5 cm high, 5–7 cm long, and 1.5 cm wide near the floor (only 1–2 mm near the roof).
- ▶ Relations of the lateral wall: **orbit** above (ethmoidal air cells intervening), **maxillary sinus** below, **lacrimal sac and nasolacrimal duct** anteriorly, **pterygopalatine fossa** posteriorly (through the sphenopalatine foramen).
- ▶ **Bones** forming the lateral wall, from before backwards:
 - ▶ Nasal bone
 - ▶ Frontal process of maxilla
 - ▶ Lacrimal bone
 - ▶ Labyrinth of ethmoid (bearing the superior and middle conchae)
 - ▶ Inferior nasal concha (an independent bone, made of spongy bone only)
 - ▶ Perpendicular plate of the palatine bone with its orbital and sphenoidal processes
 - ▶ Medial pterygoid plate of the sphenoid
- ▶ **Cartilages**: the superior (lateral) nasal cartilage, the inferior (major alar) nasal cartilage, and 3–4 minor alar cartilages. The lower cuticular part is fibrofatty tissue covered by skin.

2. Features — vestibule, atrium, conchae and meatuses

The lateral wall is divided into three areas:

- ▶ **Vestibule** — a small depressed anterior area lined by skin bearing stiff, curved hairs (**vibrissae**), which filter coarse particles.
- ▶ **Atrium of the middle meatus** — a shallow area just behind the vestibule, bounded above by a mucosal ridge, the **agger nasi**; the mucocutaneous junction between vestibule and atrium is the **limen nasi**.
- ▶ **Posterior part** — bears three (occasionally four) scroll-like **conchae**, with a **meatus** below each.

Conchae: superior and middle conchae are projections of the ethmoidal labyrinth; the **inferior concha** is an **independent bone**; a rudimentary fourth, the **concha suprema**, may be present. The inferior concha is the largest, the superior the smallest.

Meatuses (passages beneath the overhanging conchae):

Meatus	Location	Special features / opening
Inferior meatus	Below inferior concha; largest meatus	Nasolacrimal duct opens at the junction of its anterior 1/3 and posterior 2/3, guarded by the mucosal lacrimal fold (Hasner's valve)
Middle meatus	Below middle concha	Bears the ethmoidal bulla (bulge of middle ethmoidal cells) and, below it, the hiatus semilunaris , whose anterior end continues as the infundibulum ; frontal sinus opens at the anterior end of the hiatus (via infundibulum/frontonasal duct), anterior ethmoidal cells behind it, and maxillary sinus at the posterior end (often by two ostia)
Superior meatus	Below superior concha; shortest, shallowest	Receives openings of the posterior ethmoidal air cells
Sphenoethmoidal recess	Triangular fossa above and behind the superior concha	Receives the opening of the sphenoidal sinus

Diagram to draw — Lateral wall after removing the conchae, showing: superior/middle/inferior conchae (cut ends), superior/middle/inferior meatus, sphenoethmoidal recess, agger nasi, ethmoidal bulla, hiatus semilunaris, infundibulum, openings of frontal, anterior and posterior ethmoidal, maxillary and sphenoidal sinuses, and the nasolacrimal duct opening (Hasner's valve) in the inferior meatus.

□ Fig 15.8 — Lateral wall of the nasal cavity seen after removing the conchae (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.293)

3. Arterial supply

The lateral wall is supplied by branches of the **ophthalmic, maxillary and facial arteries**, conventionally described in four quadrants:

Quadrant	Artery	Parent trunk
Anterosuperior	Anterior ethmoidal artery (assisted by posterior ethmoidal artery)	Ophthalmic artery
Anteroinferior	Branches of the facial artery	External carotid artery
Posterosuperior	Branches of the sphenopalatine artery	Maxillary artery (terminal branch)
Posteroinferior	Branches of the greater palatine artery , which pierce the perpendicular plate of the palatine bone and ascend through the incisive fossa	Maxillary artery

The **sphenopalatine artery** enters through the sphenopalatine foramen posterior to the superior meatus and divides into posterior lateral nasal and posterior septal branches; it is the **principal artery supplying the nasal mucosa**, ramifying over the conchae and meatuses and anastomosing with the ethmoidal arteries.

Diagram to draw — Lateral wall with the four vascular quadrants marked and labelled: anterior/posterior ethmoidal artery (anterosuperior), facial artery branches (anteroinferior), sphenopalatine artery (posterosuperior), greater palatine artery (posteroinferior); show the sphenopalatine foramen and its posterior lateral nasal branches ramifying over the conchae.

□ Fig 17.11 — Arterial supply of the lateral wall (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.754)

4. Venous drainage

- ▶ Veins form a submucosal plexus that drains **anteriorly into the facial vein**, **posteriorly into the pharyngeal venous plexus**, and from the **middle part into the pterygoid venous plexus**.
- ▶ Veins accompanying the anterior ethmoidal vessels drain the anterior nose into the ophthalmic (and thence facial) veins; a few veins traverse the cribriform plate to connect with veins on the orbital surface of the frontal lobe, and, when the foramen caecum is patent, to the superior sagittal sinus — the anatomical basis for rare intracranial spread of nasal sepsis.

5. Nerve supply

Two functional components supply the lateral wall — **special sensory (olfactory)** and **general sensory (trigeminal)**:

- ▶ **Olfactory nerves** supply the upper third of the lateral wall, just below the cribriform plate up to the level of the superior concha.
- ▶ **General sensory nerves**, all ultimately from the **trigeminal nerve**, follow the same quadrant pattern as the arteries:

Quadrant	Nerve	Parent division
Anterosuperior	Anterior ethmoidal nerve	Nasociliary branch of ophthalmic (V1)
Anteroinferior	Anterior superior alveolar nerve	Continuation of the infraorbital nerve, maxillary (V2)
Posterosuperior	Lateral posterior superior nasal branches	Pterygopalatine ganglion (maxillary, V2)
Posteroinferior	Nasal (posterior inferior lateral nasal) branches of the greater palatine nerve	Pterygopalatine ganglion (maxillary, V2)

Diagram to draw — Lateral wall with the four sensory quadrants labelled: anterior ethmoidal nerve (anterosuperior), anterior superior alveolar nerve (anteroinferior), posterior superior lateral nasal branches (posterosuperior), nasal branches of greater palatine nerve (posteroinferior); shade the olfactory area in the upper third with olfactory nerve rootlets piercing the cribriform plate.

□ Fig 17.12 — Nerve supply of the lateral wall of the nose (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.755)

6. Lymphatic drainage

- ▶ Anterior half of the lateral wall → **submandibular lymph nodes** (draining with the external nasal skin).
- ▶ Posterior half → **retropharyngeal and upper deep cervical nodes**.

Applied / Clinical anatomy

- ▶ **Osteomeatal complex (OMC)**: the region around the hiatus semilunaris/infundibulum in the middle meatus is the common drainage channel for the frontal, maxillary and anterior ethmoidal sinuses; obstruction here (mucosal oedema, a concha bullosa, or a deviated uncinate process) is the pivotal mechanism in recurrent rhinosinusitis and the key target of **functional endoscopic sinus surgery (FESS)**.
- ▶ **Concha bullosa** (aeration of the middle concha) and other conchal/meatal variants are frequently seen on coronal CT of the paranasal sinuses and can predispose to sinus outflow obstruction.
- ▶ **Epistaxis**: anterior bleeds classically arise from **Little's area/Kiesselbach's plexus** on the antero-inferior septum, where septal branches of the anterior ethmoidal, sphenopalatine, greater palatine and superior labial arteries anastomose. Posterior/severe bleeds in elderly hypertensive patients arise from **Woodruff's plexus**, located on the lateral wall in the posterior part of the inferior meatus, formed by anastomoses of the pharyngeal, sphenopalatine, posterior nasal and posterior septal arteries; refractory bleeding is controlled by endoscopic **sphenopalatine artery ligation/cautery**, or by ligation/embolization of the anterior/posterior ethmoidal or maxillary arteries.
- ▶ **Hasner's valve** at the inferior meatal opening of the nasolacrimal duct: an imperforate valve at birth causes **dacryocystocele/epiphora** in neonates.
- ▶ **Allergic rhinitis**: hypertrophy of the mucosa over the inferior concha causes nasal blockage, sneezing and watery discharge; chronic hypertrophy may need turbinate reduction.
- ▶ **Nasal polyps** typically arise from the ethmoidal sinus mucosa and prolapse through the middle meatus.
- ▶ **Cribriform plate fracture** (roof, continuous with the upper lateral wall) tears olfactory rootlets and dura, producing **CSF rhinorrhoea** and anosmia risk.
- ▶ **Sinus surgery landmarks**: knowledge of the quadrant-wise vascular supply guides safe dissection and haemostasis around the middle turbinate, uncinate process and sphenopalatine foramen.

High-yield exam pointers

- ▶ Lateral wall features three areas — vestibule, atrium (with agger nasi/limen nasi), and the conchae/meatus region.
- ▶ Only the **inferior concha is an independent bone**; superior and middle conchae are ethmoidal projections.
- ▶ **Nasolacrimal duct** → **inferior meatus** (guarded by Hasner's valve); **frontal, anterior ethmoidal, maxillary sinuses** → **middle meatus** (via hiatus semilunaris/infundibulum); **posterior ethmoidal sinus** → **superior meatus**; **sphenoidal sinus** → **sphenoethmoidal recess**.

- ▶ Arterial and nerve supply both follow the **same four-quadrant plan**: anterosuperior (anterior ethmoidal), anteroinferior (facial artery / anterior superior alveolar nerve), posterosuperior (sphenopalatine artery / lateral posterior superior nasal nerve), posteroinferior (greater palatine artery/nerve).
- ▶ **Sphenopalatine artery** is the principal artery of the nasal mucosa, entering via the sphenopalatine foramen.
- ▶ Olfactory nerves supply only the **upper one-third** of the lateral wall (up to the superior concha).
- ▶ Venous drainage: anterior → facial vein; posterior → pharyngeal plexus; middle → pterygoid venous plexus.
- ▶ Lymphatics: anterior half → submandibular nodes; posterior half → retropharyngeal/deep cervical nodes.
- ▶ Clinically distinguish **Little's area** (anterior septal epistaxis, young patients) from **Woodruff's plexus** (posterior lateral-wall epistaxis, elderly/hypertensive).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 8e; Vishram Singh's Textbook of Anatomy Vol 3 4e.



Describe the interior of the pharynx and explain its sensory innervation

Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction The pharynx is a fibromuscular, musculo-membranous tube, about 12–14 cm long, that forms the common upper end of the respiratory and digestive tracts. It extends from the base of the skull above to the lower border of the cricoid cartilage below (opposite the sixth cervical vertebra), where it becomes continuous with the oesophagus. Because the air and food passages cross within it, its interior is conventionally divided into three parts — nasopharynx, oropharynx and laryngopharynx — each with distinctive surface features and a distinctive sensory nerve supply, both of which are of major applied importance in otorhinolaryngology and neurology.

1. General organisation and boundaries

- ▶ **Shape/extent**: an inverted-cone-shaped tube; widest above (~3.5 cm at the nasopharynx, non-collapsible) and narrowest below (~1.5 cm at the pharyngo-oesophageal junction — the narrowest part of the gut tube apart from the vermiform appendix).
- ▶ **Superior boundary**: base of skull — posterior part of the body of sphenoid and basilar part of the occipital bone, in front of the pharyngeal tubercle.
- ▶ **Anterior wall**: incomplete; communicates in turn with the nasal cavity (via the choanae), the oral cavity (via the oropharyngeal isthmus) and the laryngeal inlet.
- ▶ **Posterior wall**: glides freely on the prevertebral fascia, separated from it by the retropharyngeal space (loose areolar tissue permitting movement during swallowing).

- **Lateral relations:** styloid process and styloid muscles, the carotid sheath (carotid arteries, internal jugular vein, IX–XII cranial nerves and sympathetic chain), and, in the neck, the lateral lobe of the thyroid gland.
- Functionally, the upper part (nasopharynx) conducts air only, the lower part (laryngopharynx, below the laryngeal inlet) conducts food only, while the middle part (oropharynx) is a common channel — the basis of the three-part division.

2. Interior of the pharynx

Feature	Nasopharynx (epipharynx)	Oropharynx (mesopharynx)	Laryngopharynx (hypopharynx)
Extent	Base of skull to soft palate	Soft palate to upper border of epiglottis	Upper border of epiglottis to lower border of cricoid
Anterior communication	Nasal cavity via choanae	Oral cavity via oropharyngeal isthmus	Laryngeal inlet
Roof/posterior wall	Continuous sloping surface over body of sphenoid, basi-occiput and anterior arch of atlas	Vertebral level C2–C3	Vertebral level C3–C6
Lateral wall	Pharyngeal (Eustachian) opening of pharyngotympanic tube, torus tubarius (tubal elevation), tubal tonsil, salpingopharyngeal and salpingopalatine folds, pharyngeal recess (fossa of Rosenmüller) behind the tubal elevation	Tonsillar fossa bounded by palatoglossal arch in front and palatopharyngeal arch behind, lodging the palatine tonsil	Piriform fossa, bounded medially by the aryepiglottic fold and laterally by the thyroid cartilage/thyrohyoid membrane; internal laryngeal nerve lies beneath its mucosa
Roof/other features	Pharyngeal (nasopharyngeal) tonsil/adenoid in roof and posterior wall; pharyngeal bursa (of Luschka), a notochordal remnant	Vallecula (between tongue and epiglottis, separated by median and two lateral glossoepiglottic/pharyngoepiglottic folds)	Laryngeal inlet — bounded above by the epiglottis, below/behind by the interarytenoid fold, laterally by the aryepiglottic folds; posterior surfaces of arytenoid and cricoid cartilages below it
Floor	Upper surface of soft palate	Dorsum of posterior third of tongue	—
Epithelium	Ciliated pseudostratified columnar (respiratory) anteriorly, changing to non-keratinised stratified squamous posteriorly	Non-keratinised stratified squamous	Non-keratinised stratified squamous

Feature	Nasopharynx (epipharynx)	Oropharynx (mesopharynx)	Laryngopharynx (hypopharynx)
Function	Respiratory passage only	Common passage — air and food	Food passage (air passes anteriorly through the laryngeal inlet)

- ▶ The **pharyngeal isthmus** (junction of naso- and oro-pharynx) lies between the free border of the soft palate in front, Passavant's ridge behind, and the palatopharyngeal arches on each side; it is closed during swallowing/blowing by elevation of the soft palate (levator/tensor veli palatini) and approximation of Passavant's ridge.
- ▶ **Waldeyer's lymphoid ring** encircles the naso-oropharyngeal isthmus obliquely: pharyngeal tonsil (postero-superiorly), paired tubal tonsils and palatine tonsils (laterally), and the lingual tonsil (antero-inferiorly) — together forming the first immunological barrier of the aerodigestive tract.
- ▶ **Wall structure** (mucosa to outside): mucous membrane → submucosa, thickened above the superior constrictor as the **pharyngobasilar fascia** (closes the sinus of Morgagni between the base of skull and superior constrictor, and is pierced by the auditory tube) → **muscular coat** — outer circular (superior, middle, inferior constrictors, each overlapping the one above) and inner longitudinal (stylopharyngeus, salpingopharyngeus, palatopharyngeus) layers → **buccopharyngeal fascia**, external to the constrictors, on which lies the **pharyngeal plexus** of nerves and veins (chiefly over the middle constrictor).

3. Sensory innervation of the pharynx

Pharyngeal plexus. Almost the entire motor and sensory supply of the pharynx (and soft palate) is carried by the **pharyngeal plexus**, situated on the external (buccopharyngeal-fascial) surface of the pharynx, mainly over the middle constrictor. It is formed by three contributions:

- ▶ The **pharyngeal branch of the vagus (X)** — chiefly motor, traditionally described as carrying fibres of the cranial part of the accessory nerve (though Gray's 41e notes contemporary evidence does not support a true separate accessory contribution to this pathway).
- ▶ The **pharyngeal branches of the glossopharyngeal nerve (IX)** — predominantly sensory.
- ▶ A branch from the **superior cervical ganglion** of the sympathetic trunk — vasomotor.

Sensory supply is regional, matching the three interior subdivisions:

Region	Sensory nerve	Notes
Nasopharynx	Maxillary nerve (V2) , via the pharyngeal branch of the pterygopalatine ganglion (fibres pass through the ganglion without synapsing)	Supplies mucosa behind/around the torus tubarius and roof; reaches the pharynx through the palatovaginal canal with the pharyngeal branch of the maxillary artery
Oropharynx	Glossopharyngeal nerve (IX) , via the pharyngeal plexus	Principal sensory nerve of the pharynx as a whole

Region	Sensory nerve	Notes
Soft palate and tonsillar region	Lesser palatine nerve (V2, via pterygopalatine ganglion) for most of the soft palate, and tonsillar/pharyngeal branches of the glossopharyngeal nerve for the posterior palate and tonsil; both combine around the tonsil as the circulus tonsillaris	Taste from the oral surface of the soft palate travels in the lesser palatine nerve but originates as fibres of the greater petrosal nerve (facial, VII) passing through the pterygopalatine ganglion without synapsing
Laryngopharynx (piriform fossa, aryepiglottic fold, epiglottis, vallecula)	Internal laryngeal nerve (internal branch of the superior laryngeal nerve, from the vagus)	Also carries taste from the vallecula and epiglottic region; lies directly beneath the piriform fossa mucosa
Pharyngotympanic tube	Tympanic plexus (glossopharyngeal) + pharyngeal branch of the pterygopalatine ganglion	Explains referred otalgia in tubal/nasopharyngeal disease

Motor supply (for completeness). The pharyngeal branch of the vagus supplies all muscles of the pharynx and soft palate except **stylopharyngeus** (glossopharyngeal nerve) and **tensor veli palatini** (nerve to medial pterygoid, mandibular division of trigeminal). Cricopharyngeus additionally receives fibres from the recurrent and external laryngeal nerves. **Secretomotor (parasympathetic)** fibres to pharyngeal mucous glands are derived from the lesser palatine branches of the pterygopalatine ganglion.

Clinically important consequence — the pharyngeal (gag) reflex: touching the oropharyngeal mucosa/posterior third of tongue is sensed by the glossopharyngeal nerve (afferent limb), and the reflex elevation/constriction of the pharynx is produced via the vagus through the pharyngeal plexus (efferent limb) — a bedside test of the integrity of IX and X.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Median sagittal section through the head and neck showing the interior of the pharynx, labelled:

- ▶ Nasal septum, hard palate, soft palate and uvula, tongue
- ▶ Pharyngeal (nasopharyngeal) tonsil in the roof of the nasopharynx; pharyngeal bursa
- ▶ Torus tubarius (tubal elevation) with pharyngeal opening of the auditory tube; tubal tonsil; fossa of Rosenmüller
- ▶ Palatoglossal and palatopharyngeal arches with the palatine tonsil between them (tonsillar fossa)
- ▶ Epiglottis, vallecula, aryepiglottic fold, piriform fossa
- ▶ Hyoid bone, thyroid cartilage, cricoid cartilage, oesophagus
- ▶ Prevertebral fascia/retropharyngeal space posteriorly, with vertebral levels C1 (atlas) to C6 marked against the three subdivisions (nasopharynx, oropharynx, laryngopharynx)

□ Fig 34.3 — A, The interior of the pharynx, exposed by removal of the mucous membrane, sagittal section (Gray's Anatomy — Standring — 41e, p.792)

Applied / Clinical anatomy

- ▶ **Fossa of Rosenmüller** (lateral pharyngeal recess) is the commonest site of origin of **nasopharyngeal carcinoma**; spread into the parapharyngeal space can involve the carotid sheath contents (IX, X, XI, XII, sympathetic chain), producing combined lower cranial nerve palsies (e.g. Vernet's/Villaret's syndromes) and snoring from nasopharyngeal narrowing.
- ▶ **Adenoid hypertrophy** (enlarged pharyngeal tonsil, most marked in early childhood) obstructs the choanae causing mouth-breathing and "adenoid facies," and may occlude the pharyngotympanic tube causing secretory otitis media.
- ▶ During **tonsillectomy**, the glossopharyngeal nerve (lying immediately lateral to the tonsillar bed) is at risk and commonly transiently affected by post-operative oedema; the paratonsillar (external palatine) vein may bleed if injured. Because tonsillar sensory supply is diffuse (circulus tonsillaris), tonsillectomy is feasible under local infiltration rather than nerve block.
- ▶ **Referred otalgia** in tonsillitis/pharyngeal disease occurs because the glossopharyngeal nerve supplies both the tonsillar bed and (via its tympanic branch/tympanic plexus) the middle ear mucosa.
- ▶ Foreign bodies impacted in the **piriform fossa** can damage the underlying internal laryngeal nerve, producing anaesthesia of the supraglottic larynx and increasing the risk of aspiration.
- ▶ **Glossopharyngeal neuralgia** presents as severe paroxysmal pain in the tonsil/throat/ear, precipitated by swallowing, reflecting the shared IX territory of the oropharynx, tonsil and middle ear.
- ▶ **Killian's dehiscence**, between the oblique (thyropharyngeus) and transverse (cricopharyngeus) parts of the inferior constrictor, is a site of weakness attributed partly to their differing nerve supply (thyropharyngeus via pharyngeal plexus vs cricopharyngeus via recurrent laryngeal nerve); neuromuscular incoordination here produces a **pharyngeal (Zenker's) pulsion diverticulum**.

- ▶ Loss of pharyngeal sensory/motor integrity (e.g. bulbar/pseudobulbar palsy, lower cranial nerve injury) causes **dysphagia** and loss of the gag reflex, with aspiration risk.

High-yield exam pointers

- ▶ Pharynx: ~12–14 cm musculomembranous tube, base of skull to lower border of cricoid cartilage (C6); widest at nasopharynx, narrowest at pharyngo-oesophageal junction.
- ▶ Three parts — nasopharynx (respiratory only), oropharynx (common channel), laryngopharynx (food only, larynx anterior).
- ▶ Nasopharynx epithelium: ciliated columnar (respiratory); oro- and laryngopharynx: non-keratinised stratified squamous.
- ▶ Fossa of Rosenmüller — clinically the commonest site of nasopharyngeal carcinoma.
- ▶ Piriform fossa harbours the internal laryngeal nerve beneath its mucosa.
- ▶ **Sensory rule:** Nasopharynx → maxillary nerve (V2) via pterygopalatine ganglion; Oropharynx → glossopharyngeal (IX); Laryngopharynx → internal laryngeal nerve (branch of vagus, X).
- ▶ Pharyngeal plexus = pharyngeal branches of IX + X + sympathetic contribution from superior cervical ganglion, lying on the middle constrictor.
- ▶ Motor: vagus supplies all pharyngeal/palatal muscles except stylopharyngeus (IX) and tensor veli palatini (V3).
- ▶ Waldeyer's ring: pharyngeal, tubal, palatine and lingual tonsils.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 (Head & Neck) 8e; AK Datta's Essentials of Human Anatomy — Head & Neck (Vol 2).



Describe the intrinsic muscles of larynx under the heading of attachments, nerve supply, action and applied importance

Asked in: Paper I May 2009 — RGUHS MD/MS Anatomy

Definition / Introduction The larynx is the skeletal-cartilaginous "voice box" of the upper respiratory tract, its cartilages (thyroid, cricoid, paired arytenoids, epiglottis, corniculate and cuneiform) united by joints, ligaments and membranes. Its muscles are divided into **extrinsic muscles**, which attach the larynx to the hyoid bone/sternum/pharynx and move the larynx as a whole during deglutition and phonation, and **intrinsic muscles**, which attach one laryngeal cartilage to another and thereby (a) open or close the laryngeal inlet, (b) abduct or adduct the vocal folds, and (c) increase or decrease the tension of the vocal folds — i.e., they control the calibre of the rima glottidis and the pitch of the voice. There are **nine intrinsic muscles** acting principally through two synovial joints — the cricothyroid joint and the paired cricoarytenoid joints.

Classification of the intrinsic muscles

Group (by joint/function)	Muscle(s)
Acting at the cricothyroid joint (tensor)	Cricothyroid
Acting at the cricoarytenoid joint (abductor/adductor of vocal fold)	Posterior cricoarytenoid (abductor); Lateral cricoarytenoid (adductor)
Interarytenoid muscles (sphincter of the inlet)	Transverse arytenoid (unpaired); Oblique arytenoid (paired) with its continuation, Aryepiglotticus
Muscles of the vocal fold (relaxor/fine tension)	Thyroarytenoid with its continuation, Thyroepiglotticus; Vocalis

□ Fig 9.39 — Muscles of larynx. (Moore — Clinically Oriented Anatomy — 9e, p.1647)

Attachments of the intrinsic muscles

Muscle	Origin	Direction of fibres	Insertion	Special feature
Cricothyroid	Lower border and lateral surface of the cricoid arch	Backwards and upwards	Inferior cornu and lower border of the thyroid cartilage	The only intrinsic muscle lying outside the larynx; called the " tuning fork of the larynx "
Posterior cricoarytenoid	Posterior (triangular) surface of the lamina of the cricoid cartilage	Upwards and laterally	Posterior aspect of the muscular process of the arytenoid	The " safety muscle " of the larynx
Lateral cricoarytenoid	Lateral part of the upper border of the cricoid arch	Upwards and backwards	Anterior aspect of the muscular process of the arytenoid	—

Muscle	Origin	Direction of fibres	Insertion	Special feature
Transverse arytenoid	Posterior surface of one arytenoid cartilage	Transverse	Posterior surface of the other arytenoid	Single unpaired muscle
Oblique arytenoid	Muscular process of one arytenoid	Oblique (crosses its fellow, forming an X)	Apex of the opposite arytenoid	Some fibres continue as aryepiglotticus
Aryepiglotticus	Continuation of oblique arytenoid fibres	Curves upward	Lateral margin of the epiglottis	Completes the aryepiglottic fold
Thyroarytenoid	Inner surface of the thyroid angle and the adjoining cricothyroid ligament	Backwards and upwards	Anterolateral surface of the arytenoid cartilage	Upper fibres continue as thyroepiglotticus
Thyroepiglotticus	Upper fibres of thyroarytenoid	Curves upward into the aryepiglottic fold	Lateral margin of the epiglottis	Widens the laryngeal inlet
Vocalis	Vocal process of the arytenoid cartilage	Forwards, parallel to and deep to the vocal ligament	Vocal ligament and thyroid angle	Deepest, medial fibres of thyroarytenoid; permits graded, differential tensing of parts of the fold

Nerve supply

- ▶ All nine intrinsic muscles are supplied by the recurrent laryngeal nerve (a branch of the vagus, CN X) except the cricothyroid.
- ▶ Cricothyroid is supplied by the external laryngeal nerve, one of the two terminal branches of the superior laryngeal nerve (itself a branch of the vagus).
- ▶ Sensory supply of the laryngeal mucosa: above the level of the vocal folds by the internal laryngeal nerve (the other terminal branch of the superior laryngeal nerve, which pierces the thyrohyoid membrane with the superior laryngeal vessels); below the vocal folds by the recurrent laryngeal nerve.
- ▶ The synovial joints of the larynx (cricothyroid and cricoarytenoid) are likewise innervated by branches of the recurrent laryngeal nerve.

Actions

The muscular process and vocal process of the arytenoid cartilage move in **opposite directions** at the cricoarytenoid joint: a muscle pulling the muscular process medially swings the vocal process (and attached vocal fold) laterally — **abduction**; a muscle pulling the muscular process forward/laterally swings the vocal process medially — **adduction**.

Action	Muscle(s) responsible
Abduction of vocal folds (opens rima glottidis)	Posterior cricoarytenoid — the only abductor ("safety muscle of the larynx")
Adduction of vocal folds	Lateral cricoarytenoid; transverse arytenoid; oblique arytenoid
Tension/elongation of vocal folds (raises pitch)	Cricothyroid — rocks and glides the thyroid cartilage forwards/downwards at the cricothyroid joint, increasing the distance between the anterior commissure and the vocal process
Relaxation/shortening of vocal folds (lowers pitch)	Thyroarytenoid and vocalis — pull the arytenoid forward, approximating its attachments
Fine, graded control of vocal-fold tension	Vocalis — selective contraction of medial fibres modulates pitch during speech/singing
Closure of the laryngeal inlet (airway protection during swallowing)	Oblique arytenoid and aryepiglotticus
Opening/widening of the laryngeal inlet	Thyroepiglotticus

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Label on a posterior/lateral view of the larynx: **thyroid cartilage**, **cricoid cartilage** (arch and lamina), **arytenoid cartilage** (muscular process, vocal process), **epiglottis**, **cricothyroid joint**, **cricoarytenoid joint**, **vocal ligament**; and the nine muscles — **cricothyroid**, **posterior cricoarytenoid**, **lateral cricoarytenoid**, **transverse arytenoid**, **oblique arytenoid**, **aryepiglotticus**, **thyroarytenoid**, **thyroepiglotticus**, **vocalis** — with arrows showing the direction of pull of the posterior and lateral cricoarytenoids to demonstrate the lever action producing abduction versus adduction of the vocal process.

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- ▶ **Superior laryngeal nerve lesions:** injury to the **external laryngeal nerve** paralyses cricothyroid, causing loss of the tensing effect on the vocal fold — a weak voice that tires easily, with defective pitch control (common after upper-pole thyroid vessel ligation, since the nerve runs close to the superior thyroid artery). Injury to the **internal laryngeal nerve** produces anaesthesia of the supraglottic mucosa, abolishing the protective cough reflex, so foreign bodies and secretions above the vocal folds are readily aspirated.
- ▶ **Recurrent laryngeal nerve (RLN) palsy:**
 - *Unilateral* — the affected fold is fixed in the **paramedian position** (pulled towards the midline by the still-intact, unopposed cricothyroid) producing **hoarseness**; the healthy fold compensates by crossing the midline in phonation, but the forceful, explosive phase of voluntary/reflex coughing is lost.
 - *Bilateral RLN palsy with cricothyroid intact* — both folds lie fixed near the midline (paramedian) → severe **stridor and dyspnoea**, a respiratory emergency that may need urgent

tracheostomy, though phonation can be relatively preserved because the folds lie close together.

- *Combined bilateral RLN + external laryngeal nerve palsy* (e.g., high vagal injury) — all intrinsic muscles are paralysed and the folds assume the **cadaveric position** (midway between abduction and adduction) → **aphonia**, with breathing comparatively less obstructed through the partially open glottis.
- **Semon's law** (classical teaching): in a gradually progressive RLN lesion, the abductor (posterior cricoarytenoid) is affected before the adductors, so adduction is preserved longer than abduction. This was traditionally explained by supposed selective vulnerability of abductor nerve fibres; Gray's Anatomy (41e) notes this mechanistic explanation is now considered questionable, since laryngeal motor axons are not topographically segregated within the recurrent laryngeal nerve — the clinical observation of the vocal-fold position, however, remains classical exam teaching.
- **Surgical/course-related vulnerability**: the right RLN loops around the subclavian artery and the left loops around the arch of the aorta (ligamentum arteriosum) before both ascend in the tracheo-oesophageal groove intimately related to the **inferior thyroid artery** near the lower pole of the thyroid — hence the RLN is at risk during **thyroidectomy**, producing hoarseness or (if bilateral) aphonia/stridor. Because the **left** RLN has a long intrathoracic course under the aortic arch, it (not the right, which stays entirely in the neck) is vulnerable to compression by **mediastinal tumours or an aortic aneurysm**.
- **Glottic carcinoma**: the true vocal fold (glottis) has **no lymphatics**, so carcinoma confined to it has the best prognosis among laryngeal cancers, unlike supra-/subglottic growths that spread early via the rich lymphatic drainage on either side of the fold (watershed).
- **Piriform fossa tumours** cause dysphagia and referred otalgia (vagal sensory overlap between the pharynx/larynx and the external acoustic meatus/tympanic membrane).
- **Indirect/direct laryngoscopy** allows clinical assessment of vocal-fold mobility and position — the principal bedside method for localising the level of a vagal/RLN/SLN lesion described above.

High-yield exam pointers

- **9 intrinsic muscles**: cricothyroid, posterior cricoarytenoid, lateral cricoarytenoid, transverse arytenoid, oblique arytenoid (+ aryepiglotticus), thyroarytenoid (+ thyroepiglotticus), vocalis.
- **Cricothyroid** is the only intrinsic muscle lying outside the larynx and the only one supplied by the **external laryngeal nerve**; all the rest are supplied by the **recurrent laryngeal nerve**.
- **Posterior cricoarytenoid** = **sole abductor** ("safety muscle of the larynx"); adductors = lateral cricoarytenoid + transverse + oblique arytenoids.
- **Tensor** = **cricothyroid** ("tuning fork of the larynx"); **relaxors** = **thyroarytenoid + vocalis**.
- **Sphincter** (closes inlet) = oblique arytenoid + aryepiglotticus; **dilator** (opens inlet) = thyroepiglotticus.
- **Unilateral RLN palsy** → paramedian cord, hoarseness; **bilateral RLN palsy** (cricothyroid spared) → paramedian, stridor/emergency tracheostomy; **combined RLN + SLN loss** → cadaveric position, aphonia.

- **Semon's law** — abductor fibres classically lost first in a progressive RLN lesion (classical teaching, now debated).
- Glottis has no lymphatics → best-prognosis site for laryngeal carcinoma.
- Left RLN (long intrathoracic course, loops under aortic arch) is vulnerable to mediastinal disease; right RLN stays in the neck and is spared.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3-4, 8e; AK Datta's Human Anatomy Vol 2 (Head & Neck); Moore's Clinically Oriented Anatomy 9e; Vishram Singh's Textbook of Anatomy Vol 3, 4e.



Describe the muscles of larynx and discuss the movements of vocal cords

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

Definition / Introduction

The larynx is a musculo-cartilaginous organ of phonation and airway protection situated between the root of the tongue/hyoid bone above and the trachea below, opposite C3-C6 vertebrae. Its cartilaginous skeleton (thyroid, cricoid, paired arytenoids, epiglottis) is moved as a whole by **extrinsic muscles** and moved internally — altering the laryngeal inlet, the position, and the tension of the vocal cords — by **intrinsic muscles**. Movements of the vocal cords (abduction for respiration, adduction and tensing for phonation) are produced entirely by the intrinsic muscles acting through two synovial joints, and are clinically important because a single muscle, the posterior cricoarytenoid, is the sole abductor and hence the "safety muscle" of the airway.

1. Classification of the laryngeal muscles

Group	Attachment	Main role
Extrinsic muscles	Connect the laryngeal skeleton (mainly thyroid cartilage/hyoid) to surrounding structures	Move the whole larynx up or down during swallowing/phonation
Intrinsic muscles	Connect the laryngeal cartilages to one another	Alter the laryngeal inlet, and the position/tension of the vocal cords

Extrinsic muscles (action on the larynx as a whole)

Movement	Muscles
Elevation of larynx	Thyrohyoid, mylohyoid (assisted by the other suprahyoid muscles and stylopharyngeus/palatopharyngeus)
Depression of larynx	Sternothyroid, sternohyoid

2. Laryngeal joints — the mechanical basis of vocal-cord movement

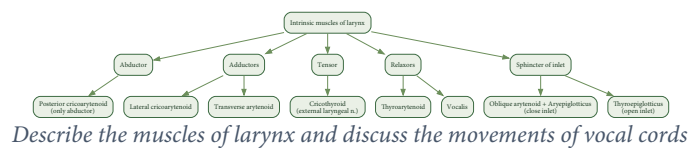
Both are synovial joints, and all movement of the vocal cords is ultimately rotation/gliding at these two joints:

- **Cricothyroid joint** — between the inferior cornu of the thyroid cartilage and the side of the cricoid cartilage. Permits **rotatory movement around a transverse axis** passing through both joints, producing a rocking (forward-tilting) of the thyroid cartilage on the cricoid; also permits some gliding. This is the joint that **tenses and relaxes** the vocal cords.
- **Cricoarytenoid joint** — between the base of the arytenoid cartilage and the upper border of the cricoid lamina. Permits **rotatory movement around a vertical axis**, plus gliding in all directions. Rotation of the arytenoid swings its vocal process medially or laterally, producing **adduction/abduction** of the vocal cords.

3. Intrinsic muscles — attachments, nerve supply and action

Muscle	Origin	Insertion	Nerve supply	Action
Cricothyroid ("tuning fork of the larynx")	Lower border and lateral surface of cricoid cartilage	Inferior cornu and lower border of thyroid cartilage	External laryngeal nerve (the only exception to the RLN rule)	Tilts thyroid cartilage forward/down on the cricoid → tenses and lengthens the vocal cords. Only intrinsic muscle lying outside the larynx
Posterior cricoarytenoid	Posterior surface of the cricoid lamina	Muscular process of the arytenoid (posterior aspect)	Recurrent laryngeal nerve	Pulls muscular process medially/upward → vocal process swings laterally → sole abductor of the vocal cords ("safety muscle")
Lateral cricoarytenoid	Lateral part of upper border of the cricoid arch	Muscular process of the arytenoid (anterior aspect)	Recurrent laryngeal nerve	Pulls muscular process forward/laterally → vocal process swings medially → adductor
Transverse arytenoid (unpaired)	Posterior surface of one arytenoid	Posterior surface of the other arytenoid	Recurrent laryngeal nerve	Approximates the arytenoid cartilages → adductor (closes the intercartilaginous part of the rima glottidis)

Muscle	Origin	Insertion	Nerve supply	Action
Oblique arytenoid + aryepiglotticus	Muscular process of one arytenoid	Apex of the opposite arytenoid; fibres continue as aryepiglotticus to the edge of the epiglottis	Recurrent laryngeal nerve	Sphincteric — closes the laryngeal inlet (aryepiglottic fold)
Thyroarytenoid + thyroepiglotticus	Thyroid angle and adjacent cricothyroid ligament	Anterolateral surface of the arytenoid; upper fibres curl up as thyroepiglotticus to the epiglottic edge	Recurrent laryngeal nerve	Pulls arytenoid forward → relaxes the vocal cord; thyroepiglotticus opens the laryngeal inlet
Vocalis (deepest fibres of thyroarytenoid)	Vocal process of the arytenoid	Vocal ligament and thyroid angle	Recurrent laryngeal nerve	Fine, graded relaxation/shortening of the anterior vocal ligament — controls pitch during phonation



□ Fig 16.10 — Muscles of larynx: Posterior view (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.312)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Posterior view of the larynx showing the intrinsic muscles — label: epiglottis, thyrohyoid membrane, superior cornu and lamina of thyroid cartilage, aryepiglotticus, oblique arytenoid, transverse arytenoid, corniculate cartilage, muscular process and vocal process of arytenoid, posterior cricoarytenoid, lamina of cricoid cartilage, trachea. Add small inset arrows on a cross-section of the cricoarytenoid joint showing (a) medial rotation of the muscular process by posterior cricoarytenoid → lateral swing of the vocal process = **abduction**, and (b) the reverse pull by lateral cricoarytenoid/transverse arytenoid = **adduction**.

4. Nerve supply of the larynx

Nerve	Origin	Distribution	Functional type
Internal laryngeal nerve	Larger terminal branch of the superior laryngeal nerve (from the vagus), pierces the thyrohyoid membrane	Mucosa of the larynx above the vocal folds	Sensory (predominantly)

Nerve	Origin	Distribution	Functional type
External laryngeal nerve	Smaller terminal branch of the superior laryngeal nerve, runs with the superior thyroid artery, pierces inferior constrictor	Cricothyroid muscle only (also gives twigs to inferior constrictor/pharyngeal plexus)	Motor
Recurrent laryngeal nerve (continues as the inferior laryngeal nerve)	Branch of the vagus; right nerve hooks under the right subclavian artery, left nerve hooks under the arch of the aorta (hence longer on the left)	All intrinsic muscles except cricothyroid; mucosa below the vocal folds	Mixed (motor + sensory)

There is a small zone of sensory overlap between the internal laryngeal and recurrent laryngeal territories exactly at the level of the vocal folds. Blood supply runs in step with the nerve supply — the superior laryngeal artery (from the superior thyroid) accompanies the internal laryngeal nerve above the folds, and the inferior laryngeal artery (from the inferior thyroid) accompanies the recurrent laryngeal nerve below the folds.

5. Movements of the vocal cords

Movement	Muscle(s) responsible	Mechanism	Physiological role
Abduction (widening the rima glottidis)	Posterior cricoarytenoid (only abductor)	Contraction rotates the muscular process of the arytenoid medially/upward at the cricoarytenoid joint, swinging the vocal process — and with it the vocal cord — laterally	Quiet and deep respiration; the position of full abduction is adopted for forced inspiration
Adduction (approximating the cords)	Lateral cricoarytenoid + transverse arytenoid	Lateral cricoarytenoid pulls the muscular process forward/laterally, swinging the vocal process medially; transverse arytenoid directly approximates the two arytenoid cartilages, closing the posterior (cartilaginous) part of the rima	Phonation, effort closure (Valsalva, coughing, straining, lifting)

Movement	Muscle(s) responsible	Mechanism	Physiological role
Tension / lengthening	Cricothyroid	Rotation at the cricothyroid joint tilts the thyroid cartilage forward and down on the cricoid, increasing the distance between the thyroid angle and the vocal process and stretching the vocal ligament	Raises the pitch of the voice; cricothyroid is the principal pitch-control muscle, hence "tuning fork of the larynx"
Relaxation / shortening	Thyroarytenoid, vocalis	Pulls the arytenoid forward toward the thyroid angle, slackening the vocal ligament; vocalis produces fine, graded shortening of only its anterior part	Lowers pitch; vocalis allows fine control of the vibrating segment during singing/speech
Opening the laryngeal inlet	Thyroepiglotticus	Pulls the aryepiglottic fold laterally, widening the inlet	Quiet respiration
Closing the laryngeal inlet	Oblique arytenoid + aryepiglotticus	Approximate the aryepiglottic folds like a sphincter over the inlet	Deglutition — protects the airway from aspiration

In summary, the rima glottidis is widest (fully abducted) in forced inspiration, intermediate in quiet respiration, and narrowest (adducted and tensed) in phonation — the entire range being produced by the reciprocal action of the posterior cricoarytenoid against the lateral cricoarytenoid/transverse arytenoid at the cricoarytenoid joint, modulated by the cricothyroid/thyroarytenoid pair at the cricothyroid joint.

Applied / Clinical anatomy

- **Posterior cricoarytenoid — the "safety muscle" of the larynx.** Being the sole abductor, its bilateral paralysis (e.g. in bilateral recurrent laryngeal nerve injury) leaves the cords adducted/paramedian and unopposed, producing severe inspiratory stridor and airway obstruction that may need emergency tracheostomy.
- **Unilateral recurrent laryngeal nerve palsy** — the affected cord lies fixed in the **paramedian position**; the healthy cord usually compensates by crossing the midline, so phonation is preserved though the voice is hoarse and weak.
- **Bilateral recurrent laryngeal nerve palsy** — both cords lie paramedian; phonation is severely affected and breathing is compromised, with inspiratory stridor being the presenting feature.
- **Cadaveric (intermediate) position** — when both the recurrent laryngeal nerve and the external laryngeal nerve are lost on both sides (e.g. a complete, high vagal lesion), all intrinsic muscles including cricothyroid are paralysed and the cords lie midway between abduction and adduction,

causing complete loss of phonation with some difficulty in deep breathing through the partially open glottis.

- ▶ **Semon's law** — in slowly progressive lesions of the recurrent laryngeal nerve (e.g. malignant infiltration, thoracic aortic aneurysm, bronchogenic carcinoma, thyroid malignancy), the abductor fibres (to posterior cricoarytenoid) are affected before the adductor fibres, so the cord initially assumes an adducted/paramedian position.
- ▶ **Thyroidectomy risk** — the recurrent laryngeal nerve runs close to the inferior thyroid artery and posteromedial to the thyroid lobe, and is vulnerable during ligation of the inferior thyroid pedicle; the external laryngeal nerve runs close to the superior thyroid vessels near the upper pole and is at risk during ligation of the superior thyroid pedicle.
- ▶ **External laryngeal nerve injury (isolated)** — paralyzes cricothyroid alone; the voice becomes weak, low-pitched and easily fatigued (loss of the tensing mechanism) without significant airway compromise — an important occupational hazard for singers and public speakers ("the singer's nerve").
- ▶ **Left recurrent laryngeal nerve palsy is clinically more common** than right because of its longer intrathoracic course looping under the arch of the aorta, exposing it to mediastinal masses, aortic aneurysm, and bronchogenic carcinoma.
- ▶ **Laryngeal oedema/inflammation** spreads freely above the vocal folds (loose submucosa) but is checked at the vocal fold itself, where the mucosa is firmly adherent to the vocal ligament — surgically and clinically relevant in croup/epiglottitis.

High-yield exam pointers

- ▶ **Posterior cricoarytenoid = only abductor = safety muscle**; its bilateral palsy is a respiratory emergency.
- ▶ **Lateral cricoarytenoid + transverse arytenoid = adductors**; **cricothyroid = only tensor**; **thyroarytenoid/vocalis = relaxors**.
- ▶ **Cricothyroid is the only intrinsic muscle outside the larynx** and the only one supplied by the **external laryngeal nerve** — every other intrinsic muscle is supplied by the **recurrent laryngeal nerve**.
- ▶ Two synovial joints govern all movement: **cricothyroid joint** (transverse axis → tension/relaxation) and **cricoarytenoid joint** (vertical axis → abduction/adduction).
- ▶ **Internal laryngeal nerve** = sensory above the cords; **recurrent laryngeal nerve** = sensory below the cords; overlap occurs exactly at the vocal folds.
- ▶ Right recurrent laryngeal nerve loops under the **subclavian artery**; left loops under the **arch of the aorta** — hence longer course and higher palsy risk on the left.
- ▶ Vocal cord positions to remember: **median** (phonation) → **paramedian** (unilateral or bilateral RLN palsy) → **cadaveric/intermediate** (combined RLN + external laryngeal nerve loss) → **fully abducted** (forced inspiration).
- ▶ **Semon's law**: abductor fibres of the recurrent laryngeal nerve are affected earliest in slowly compressive lesions.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3-4 8e; Vishram Singh — Textbook of Anatomy Vol 3 4e; Moore's Clinically Oriented Anatomy 9e; IB Singh — Textbook of Human Neuroanatomy.



Describe the parotid salivary gland

Asked in: Paper I Sep 2007 — RGUHS MD/MS Anatomy

Definition / Introduction

The parotid gland is the largest of the three paired major salivary glands (parotid, submandibular, sublingual) and is purely **serous** in its secretion, weighing approximately **25 g**. It lies in the **parotid region**, below the external acoustic meatus, wedged between the ramus of the mandible and the sternocleidomastoid, and overlapping masseter anteriorly. Its clinical importance is out of proportion to its size because the extracranial facial nerve, the retromandibular vein and the external carotid artery all run through its substance, and it is enclosed within an unyielding fibrous capsule that makes its inflammations (mumps, sialadenitis) and swellings exquisitely painful.

1. Location, Shape, Weight & Surfaces

- ▶ **Location:** parotid region, inferior to the external acoustic meatus, between the ramus of the mandible (anteriorly) and sternocleidomastoid (posteriorly); the gland overlaps masseter in front.
- ▶ **Shape:** an irregular, lobulated, inverted three-sided pyramid with its apex directed downward; overall outline is variable — roughly triangular in about half of specimens, of even width with rounded poles in others.
- ▶ **Weight:** ~25 g.
- ▶ **Skin over the gland** is supplied by the **great auricular nerve** (C2, C3).

Surface	Description	Chief relations
Superior (base)	small, concave upper end	cartilaginous part of the external acoustic meatus; posterior aspect of the temporomandibular joint; superficial temporal vessels; auriculotemporal nerve curving round the neck of the mandible
Superficial	largest of the four surfaces	skin; superficial fascia (anterior branches of great auricular nerve, pre-auricular/superficial parotid lymph nodes, posterior fibres of platysma and risorius); the thick, adherent parotid fascia; a few deep parotid lymph nodes embedded in the gland

Surface	Description	Chief relations
Antero-medial	grooved by the posterior border of the mandibular ramus	masseter; lateral surface of the TMJ; posterior border of the mandibular ramus; medial pterygoid; emerging branches of the facial nerve
Postero-medial	moulded to the mastoid and styloid processes	mastoid process with sternocleidomastoid and posterior belly of digastric; styloid process and its attached muscles/ligaments; external carotid artery and facial nerve enter the gland here; internal carotid artery lies deep to the styloid process

Border	Structures emerging / related
Anterior	parotid duct; most terminal branches of the facial nerve; transverse facial vessels; the accessory parotid gland lies on the duct close to this border
Posterior	overlaps the sternocleidomastoid
Medial (pharyngeal edge)	related to the lateral wall of the pharynx

The **apex** (lower pole) overlaps the posterior belly of digastric and the adjoining part of the carotid triangle; the cervical branch of the facial nerve and the two divisions of the retromandibular vein emerge close to it.

2. Parotid Capsule (Parotid Fascia)

- ▶ Formed by a split in the **investing layer of deep cervical fascia** between the angle of the mandible and the mastoid process; the capsule itself is supplied by the great auricular nerve — hence acute sialadenitis/mumps produces exquisite pre-auricular pain from capsular stretch, worse at mealtimes.
- ▶ **Superficial lamina** (parotidomasseteric fascia): thick and firmly adherent to the gland, attached above to the zygomatic arch.
- ▶ **Deep lamina**: thin, attached to the styloid process, the tympanic plate, and the angle and posterior border of the mandibular ramus.
- ▶ A thickened part of the deep lamina, stretching between the styloid process and the mandible, forms the **stylomandibular ligament**, which separates the parotid gland from the submandibular gland and is pierced by the external carotid artery.

3. Structures Within the Gland

Three structures traverse the substance of the gland, entering through its postero-medial surface and running forward to emerge near the anterior border; arranged from deep (medial) to superficial (lateral):

- ▶ **External carotid artery** — the deepest structure within the gland; within its substance it gives off the maxillary artery (leaves via the antero-medial surface) and the superficial temporal artery, which gives the transverse facial artery and emerges at the antero-superior part of the gland.
- ▶ **Retromandibular vein** — formed within the gland by union of the superficial temporal and maxillary veins; in the lower part of the gland it divides into anterior and posterior divisions, which emerge close to the apex.
- ▶ **Facial nerve** — the most superficial of the three; enters the postero-medial surface, crosses the retromandibular vein and external carotid artery, and behind the neck of the mandible divides into **temporofacial** and **cervicofacial** trunks. These give five terminal branches — temporal, zygomatic, buccal, marginal mandibular and cervical — which emerge along the anterior border and apex, intercommunicating to form the **parotid plexus (pes anserinus)**. The facial nerve supplies no structure within the gland itself; it merely traverses it.

□ Fig 8.4 — ■ Horizontal section through parotid gland showing its relations and (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.373)

The gland is thus divisible into a large **superficial part** and a small **deep part**, joined by a narrow **isthmus** around which the facial nerve divides — the anatomical basis of the **faciovenous (Patey's) plane** used to preserve the nerve during parotidectomy.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Lateral-view line diagram of the parotid region — label:

- ▶ Zygomatic arch, external acoustic meatus, ramus/angle of mandible, masseter, sternocleidomastoid
- ▶ Outline of parotid gland, apex towards angle of mandible
- ▶ Facial nerve trunk (stylomastoid foramen) → temporofacial/cervicofacial divisions → 5 terminal branches (temporal, zygomatic, buccal ×2, marginal mandibular, cervical) forming the parotid plexus
- ▶ Retromandibular vein and external carotid artery deep to the nerve
- ▶ Parotid duct crossing masseter, turning medially, piercing buccinator opposite the upper 2nd molar
- ▶ Accessory parotid gland above the duct; transverse facial vessels; great auricular nerve (C2, C3); pre-auricular lymph nodes

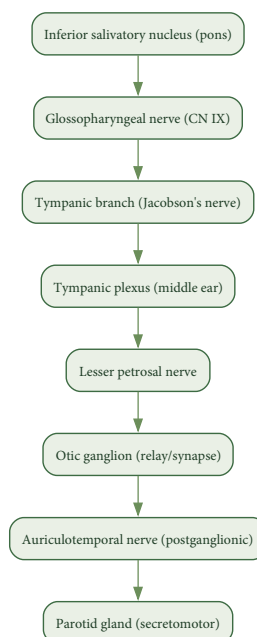
4. Parotid Duct (Stensen's Duct)

- ▶ Thick-walled, about **5 cm long and 3 mm wide**; formed by the confluence of two main tributaries in the antero-superior part of the gland; it emerges at the middle of the anterior border.
- ▶ Runs forward on masseter, approximately midway between the zygomatic arch and the angle of the mouth.
 - **Related superiorly to:** the accessory parotid gland, the transverse facial vessels, and the upper buccal branch of the facial nerve.
 - **Related inferiorly to:** the lower buccal branch of the facial nerve.

- At the anterior border of masseter, the duct turns sharply medially and pierces, in order, the **buccal pad of fat**, the **buccopharyngeal fascia** and the **buccinator** (obliquely). This oblique passage through buccinator acts as a valve, preventing inflation of the duct during blowing/raised intraoral pressure.
- Runs a short distance between the buccinator and oral mucosa, then opens into the **vestibule of the mouth** (gingivobuccal sulcus) opposite the crown of the **upper second molar tooth**.
- May receive the **accessory parotid duct** from the accessory parotid gland.
- Its ductal pattern can be outlined radiographically after cannulating the oral opening and injecting radio-opaque contrast (**sialography**).

5. Nerve Supply

Parasympathetic (secretomotor) — traced as follows:



Describe the parotid salivary gland

- **Sympathetic:** postganglionic, vasomotor fibres derived from the plexus around the middle meningeal artery (and branches of the external carotid/maxillary arteries); these begin in the lateral horn of the T1 spinal segment and synapse in the **superior cervical ganglion**.
- **Sensory:** the gland substance is supplied by the **auriculotemporal nerve**; the overlying **parotid fascia** is supplied by the **great auricular nerve** (C2, C3).

6. Blood Supply & Lymphatic Drainage

- **Arterial supply:** the external carotid artery and its branches (maxillary, superficial temporal) that arise within the gland.
- **Venous drainage:** via the retromandibular vein, whose anterior and posterior divisions ultimately drain to the external and internal jugular veins.
- **Lymphatics:** roughly **ten parotid lymph nodes**, mostly lying superficial to the plane of the facial nerve — pre-auricular/superficial nodes in the overlying fascia plus a few deep nodes embedded in the gland. They drain the temple, side of the scalp, lateral surface of the auricle, external

acoustic meatus, middle ear, upper part of the cheek, parts of the eyelids/orbit, and the parotid gland itself. Efferents pass to the **upper deep cervical lymph nodes**.

7. Development & Microstructure

- ▶ **Ectodermal** in origin — unlike the submandibular and sublingual glands, which develop from endoderm — the parotid arises as an epithelial outgrowth from the **buccal ectoderm just lateral to the angle of the mouth**. Repeated branching of this outgrowth forms the ductal tree and acini, while the surrounding mesenchyme forms the capsule and intervening connective-tissue septa.
- ▶ **Histology**: purely **serous** acini (in contrast to the mixed submandibular gland and the purely mucous sublingual gland); the intercalated ducts are long and the striated ducts well developed; the gland is divided into lobules by fibrous septa that carry the intraglandular branches of the facial nerve, vessels and deep parotid lymph nodes.

Applied / Clinical anatomy

- ▶ **Mumps (viral parotitis)**: viral sialadenitis, characteristically non-suppurative, causing severe pain because of the unyielding parotid capsule; complications include orchitis and pancreatitis.
- ▶ **Parotid abscess**: drained by a horizontal incision, or by **Hilton's method** (blunt dissection through small openings) below the angle of the mandible, kept parallel to the course of the facial nerve branches to avoid injuring them.
- ▶ **Sialography and calculi**: parotid calculi may form within the gland or in Stensen's duct; a sialogram (radio-opaque dye via the oral duct orifice) demonstrates ductal obstruction, stricture or displacement.
- ▶ **Mixed parotid tumour (pleomorphic adenoma)**: a slow-growing, lobulated, painless swelling without facial nerve involvement; pain, rapid growth, fixity/hardness, facial nerve weakness and cervical lymphadenopathy suggest malignant change.
- ▶ **Parotidectomy**: superficial (conservative) parotidectomy removes the superficial lobe after first identifying and preserving the facial nerve trunk (traced from the stylomastoid foramen forwards), dissecting along the faciovenous (Patey's) plane through the isthmus that connects the superficial and deep parts.
- ▶ **Frey's syndrome (gustatory sweating/auriculotemporal syndrome)**: develops after parotid surgery or trauma that opens the parotid capsule; aberrant regeneration of parasympathetic secretomotor axons of the auriculotemporal nerve into the sympathetically-innervated sweat glands/vessels of the overlying skin (great auricular nerve territory) produces sweating, warmth and redness of the cheek at the sight, smell or taste of food.
- ▶ **Accessory parotid gland (pars accessoria/socia parotidis)**: a detached lobule lying on the duct between the zygomatic arch and the duct, and a recognised (though uncommon) site for calculi or tumours outside the main gland; other described accessory processes are the pterygoid process (between the mandibular ramus and medial pterygoid), the glenoid process (between the external acoustic meatus and TMJ), and a poststyloid process.
- ▶ **Bell's palsy vs tumour palsy**: a sudden, isolated facial nerve palsy at the stylomastoid foramen (Bell's palsy) must be distinguished from the gradual facial weakness of malignant parotid infiltration of the nerve.

High-yield exam pointers

- ▶ Largest, purely serous, **ectodermal** salivary gland; weighs ~25 g; situated below the external acoustic meatus between the mandibular ramus and sternocleidomastoid.
- ▶ Enclosed in an unyielding parotid (investing) fascia — explains the severe pain of mumps/acute sialadenitis.
- ▶ Structures within the gland, deep to superficial: **external carotid artery** → **retromandibular vein** → **facial nerve**; the facial nerve supplies nothing within the gland, it only traverses it.
- ▶ Facial nerve divides into **temporofacial and cervicofacial** trunks → five terminal branches (temporal, zygomatic, buccal, marginal mandibular, cervical) forming the parotid plexus (pes anserinus).
- ▶ Parotid duct (Stensen's) ~5 cm long, 3 mm wide; opens opposite the **upper second molar**; oblique passage through buccinator prevents inflation on blowing.
- ▶ Secretomotor pathway: inferior salivatory nucleus → glossopharyngeal nerve → tympanic branch → tympanic plexus → lesser petrosal nerve → **otic ganglion** (relay) → auriculotemporal nerve → gland.
- ▶ Skin over the gland: great auricular nerve (C2, C3); capsule pain of sialadenitis is transmitted along this nerve.
- ▶ Lymph: ~10 parotid nodes (mostly superficial to the facial nerve plane) → upper deep cervical lymph nodes.
- ▶ Frey's syndrome = aberrant parasympathetic regeneration into the cutaneous sympathetic pathway after parotid surgery/trauma; superficial parotidectomy uses the faciovenous (Patey's) plane through the isthmus to preserve the facial nerve.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3-4 8e; Vishram Singh Textbook of Anatomy Vol 3 4e.



Describe the peculiarities of dural venous sinuses. Describe the cavernous sinus in detail

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction — Dural venous sinuses are venous channels enclosed between the endosteal (outer) and meningeal (inner) layers of the cranial dura mater. They collect venous blood from the brain, meninges, skull bones and orbit, and ultimately drain it into the internal jugular veins. Unlike ordinary systemic veins, they are not free-standing vessels with their own muscular wall but rigid, endothelium-lined spaces fixed within the split dura — a structural peculiarity that underlies most of their functional and clinical importance, best exemplified by the **cavernous sinus**, the most complex and clinically important of the paired sinuses.

General peculiarities of dural venous sinuses

- ▶ **Wall formed by split dura, not by a true venous wall** — the sinus is a space between the endosteal and meningeal dural layers, lined internally by a single layer of endothelium; there is no separate fibrous/muscular venous coat as in ordinary veins.
- ▶ **Devoid of muscular tissue in their walls** — hence they cannot contract to regulate their own calibre.
- ▶ **No valves anywhere** — consequently, blood flow direction within and between sinuses is not fixed and can reverse with changes in posture, gravity or venous pressure (e.g., the intercavernous sinuses can be obliterated without clinical consequence because flow simply redirects through other valveless channels).
- ▶ **Largely plexiform, not simple tubes** — many sinuses (superior and inferior sagittal, straight, and to a lesser extent transverse) develop as venous plexuses and retain a plexiform, multi-channelled arrangement even in the adult; this is most marked in infancy.
- ▶ **Receive CSF as well as venous blood** — arachnoid villi and granulations project into the superior sagittal sinus and its venous lacunae, so cerebrospinal fluid is returned directly into sinus blood, a function no peripheral vein performs.
- ▶ **Free, valveless communication with extracranial veins via emissary veins** (parietal, mastoid, condylar, and through the foramen ovale/foramen lacerum for the cavernous sinus) — this helps keep intracranial venous pressure relatively constant, but also gives infection a direct valveless route from the scalp/face into the skull.
- ▶ **Considerable individual and age-related variation and asymmetry** — e.g., the two transverse sinuses are commonly asymmetrical (usually right > left), and infantile sinuses show exuberant plexiform channels (e.g., falx cerebelli plexus augmenting the occipital sinus); clinically this variability must be mapped by CT/MR venography before surgery.
- ▶ **Some sinuses transmit cranial nerves and even an artery through their lumen** — uniquely, the cavernous sinus carries the internal carotid artery (with its peri-arterial sympathetic plexus) and the abducens nerve directly through the blood-filled space, while oculomotor, trochlear and ophthalmic (and, classically, maxillary) nerves run in its lateral wall — no other vein in the body has this relationship.

- **Richly pain-sensitive in places** — the large venous sinuses and their draining cortical (bridging) veins are among the few pain-sensitive intracranial structures; their traction or distension is a recognised mechanism of headache.

Classification of dural venous sinuses

There are 23 individual dural venous sinuses in all — 8 types are paired (16 sinuses) and 7 are unpaired/median.

Unpaired (median) sinuses	Paired sinuses
1. Superior sagittal sinus	1. Cavernous sinus
2. Inferior sagittal sinus	2. Superior petrosal sinus
3. Straight sinus	3. Inferior petrosal sinus
4. Occipital sinus	4. Transverse sinus
5. Anterior intercavernous sinus	5. Sigmoid sinus
6. Posterior intercavernous sinus	6. Sphenoparietal sinus
7. Basilar venous plexus	7. Petrosquamous sinus
	8. Middle meningeal sinus/veins

embed: ![Fig 8.31 — Venous sinuses of dura mater. A. Relationship of sinuses to falx cerebri (Moore — Clinically Oriented Anatomy — 9e, p.1411)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/07ea1290a930442c.jpg)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a lateral/oblique view of the skull interior with falx cerebri and tentorium cerebelli in place, and label: **superior sagittal sinus** (along attached margin of falx), **inferior sagittal sinus** (free margin of falx), **straight sinus** (falx–tentorium junction), **confluence of sinuses** (torcular Herophili), **right and left transverse sinuses**, **sigmoid sinus** (each side, grooving mastoid), **occipital sinus** (falx cerebelli), **cavernous sinus** (either side of sella), **superior and inferior petrosal sinuses**, **sphenoparietal sinus**, **basilar venous plexus** (on clivus), **anterior and posterior intercavernous sinuses**, and the **internal jugular vein** as the final common outflow.

Cavernous sinus — location, extent and formation

- The **cavernous sinus** is a large, paired, trabeculated venous space lying in the middle cranial fossa on either side of the **body of the sphenoid bone** and the pituitary fossa.
- **Extent:** from the medial end of the **superior orbital fissure** anteriorly to the **apex of the petrous temporal bone** posteriorly; average dimensions are about **2 cm long and 1 cm wide**.
- **Formation:** it arises where the two layers of dura covering the front of the pituitary gland split apart at the lateral margin of the sella — the outer (endosteal) layer continues laterally as the anterior (sphenoidal) wall of the sinus, while the inner (meningeal) layer remains applied to the gland and sweeps back to the dorsum sellae, forming the medial (sellar) wall.

- Its interior is broken up by fibrous **trabeculae** into a number of interconnecting spaces or "caverns" (hence the name); the trabeculae are much less conspicuous in the living than in cadaveric dissection.
- The **floor and medial wall** are formed by endosteal dura; the **lateral wall and roof** by meningeal dura. The **roof** is formed anteriorly by dura over the anterior clinoid process (clinoid triangle) and further back by the oculomotor triangle. The **posterior wall** lies behind the dorsum sellae/upper clivus and is continuous with the basilar plexus. The **lateral wall** separates the sinus from Meckel's cave (containing the trigeminal ganglion), which lies posteroinferior to it.

Relations of the cavernous sinus

Direction	Structures related
Superior	Optic tract, optic chiasma, olfactory tract, internal carotid artery, anterior perforated substance
Inferior	Foramen lacerum; junction of body and greater wing of sphenoid
Medial	Hypophysis cerebri (pituitary gland); sphenoidal air sinus
Lateral	Temporal lobe, with the uncus
Below, laterally	Mandibular nerve
Anterior	Superior orbital fissure; apex of the orbit
Posterior	Apex of petrous temporal bone; crus cerebri of the midbrain

embed: ![Fig 16.3 — Coronal section of cavernous sinus showing its relations and contents. (Vishram Singh — Clinical Neuroanatomy — 4e, p.587)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/5971b5b7374fff7c.jpg)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a coronal section at the level of the pituitary fossa and label: **hypophysis cerebri** (medially), **sphenoidal air sinus** (below hypophysis), **body of sphenoid**, **cavernous sinus** on each side with its trabeculae, **internal carotid artery** (with peri-arterial sympathetic plexus) lying within the medial part of the sinus, **abducens nerve (VI)** inferolateral to the carotid artery, and in the **lateral wall**, from above downwards: **oculomotor nerve (III)**, **trochlear nerve (IV)**, **ophthalmic nerve (V1)**, **maxillary nerve (V2)** — with **trigeminal ganglion (Meckel's cave)** shown projecting into the posterior part of the wall; **temporal lobe with uncus** lateral to the sinus.

Contents of the cavernous sinus

Structures in the lateral wall (superior → inferior)	Structures within/traversing the sinus
Oculomotor nerve (III) — divides anteriorly into superior and inferior divisions	Internal carotid artery (cavernous segment), with its peri-vascular venous and sympathetic plexus

Structures in the lateral wall (superior → inferior)	Structures within/traversing the sinus
Trochlear nerve (IV) — crosses superficial to III	Abducens nerve (VI) — passes inferolateral to the carotid artery, entering via Dorello's canal
Ophthalmic nerve (V1) — divides into lacrimal, frontal, nasociliary branches	—
Maxillary nerve (V2) — leaves via foramen rotundum	—
Trigeminal ganglion — may project into the posterior part of the wall	—

- ▶ All structures in the lateral wall and the carotid/abducens complex medially are separated from the blood in the sinus only by the **endothelial lining**.
- ▶ Four named venous compartments surround the carotid artery within the sinus — **superior** (receives the superior petrosal sinus), **posterior** (receives the basilar plexus and inferior petrosal sinus), **inferior** (receives the ophthalmic veins) and **lateral** (receives the superficial middle cerebral vein, inferior cerebral veins and sphenoparietal sinus).
- ▶ Mnemonic (superior to inferior in the lateral wall, then the two structures inside the sinus): **O-T-O-M** (Oculomotor, Trochlear, Ophthalmic, Maxillary) **C-A** (Carotid artery, Abducens) — commonly recalled as "**OTOM CAT**."
- ▶ **Note:** BD Chaurasia and most Indian texts describe the maxillary nerve as running in the lower part of the lateral wall before leaving via foramen rotundum; Gray's Anatomy (41e) instead describes it coursing beneath the dura of the middle fossa just below the sinus rather than within the wall proper. Either description is acceptable at PG level, but the distinction is worth knowing.

Tributaries and venous communications of the cavernous sinus

Category	Vessels
Tributaries from the orbit	Superior ophthalmic vein; (a branch of) the inferior ophthalmic vein; central vein of the retina (variably drains here or into the superior ophthalmic vein)
Tributaries from the brain	Superficial middle cerebral vein; inferior cerebral veins from the temporal lobe
Tributaries from the meninges	Sphenoparietal sinus; frontal tributary of the middle meningeal vein (variable)
Draining channel → transverse sinus	Via the superior petrosal sinus
Draining channel → internal jugular vein	Via the inferior petrosal sinus, and via a plexus around the internal carotid artery
Draining channel → pterygoid venous plexus	Via emissary veins through foramen ovale, foramen lacerum, and the emissary sphenoidal foramen (canal of Vesalius)
Draining channel → facial vein	Via the superior ophthalmic vein

Category	Vessels
Sinus-to-sinus communication	Right and left cavernous sinuses communicate via the anterior and posterior intercavernous sinuses and the basilar venous plexus ; the cavernous and intercavernous sinuses together constitute the circulus sinus

- ▶ All these communications are **valveless**, so blood can flow in either direction.
- ▶ Expulsion of blood from the sinus is aided by: (i) expansile pulsations of the internal carotid artery within it, (ii) gravity, and (iii) position of the head.

Applied / Clinical anatomy

- ▶ **Cavernous sinus thrombosis** — most often septic, arising from infection in the "dangerous area of the face" (upper lip, nose, paranasal sinuses), reaching the sinus retrogradely via the valveless facial → superior ophthalmic vein route. Presents with **nervous symptoms** (severe pain in the ophthalmic nerve distribution, and paralysis from involvement of the III, IV and VI cranial nerves) and **venous symptoms** (oedema of the eyelids, cornea and root of the nose, with exophthalmos from congestion of orbital veins).
- ▶ **Cavernous sinus syndrome** — any expanding lesion within the sinus (pituitary adenoma invading the medial wall, meningioma, aneurysm of the cavernous carotid, schwannoma) can produce a combination of III, IV, VI and V1 palsies because all these structures share the confined lateral-wall space.
- ▶ **Carotico-cavernous fistula (CCF)** — an abnormal direct communication between the cavernous segment of the internal carotid artery and the sinus, usually following severe head trauma or rupture of an intracavernous aneurysm, producing **pulsating exophthalmos**, ptosis, chemosis and ophthalmoplegia; treated by endovascular balloon/coil occlusion.
- ▶ **Surgical importance** — the lateral wall (infratrochlear/Parkinson's triangle, between the trochlear and ophthalmic nerves) and the roof (oculomotor triangle) are the standard microsurgical corridors into the sinus; endoscopic endonasal approaches enter via its anterior (sphenoidal) and medial (sellar) walls — relevant to trans-sphenoidal hypophysectomy for pituitary tumours abutting the medial wall.
- ▶ **General sinus pathology** — because all dural sinuses are valveless and richly connected to extracranial veins, thrombosis of any major sinus (e.g., superior sagittal sinus) raises intracranial pressure, impairs CSF absorption through the arachnoid granulations, and can present with headache, papilloedema and seizures.

High-yield exam pointers

- ▶ Dural sinuses: endothelium-lined, no muscle coat, **no valves**, lie between endosteal and meningeal dura — flow direction reversible.
- ▶ 23 sinuses in all: **8 paired types** (cavernous, superior/inferior petrosal, transverse, sigmoid, sphenoparietal, petrosquamous, middle meningeal) + **7 unpaired** (superior/inferior sagittal, straight, occipital, anterior/posterior intercavernous, basilar plexus).
- ▶ Cavernous sinus: paired, **2 cm × 1 cm**, extends superior orbital fissure → petrous apex, on either side of the sphenoid body/pituitary fossa.

- ▶ Lateral wall (top→bottom): III, IV, V1, V2 ("OTOM CAT"); **internal carotid artery + sympathetic plexus and VI nerve** pass through the sinus itself.
- ▶ Right and left cavernous sinuses + intercavernous sinuses = **circulus sinus**.
- ▶ Drainage: → transverse sinus (superior petrosal); → IJV (inferior petrosal); → pterygoid plexus (emissary veins via foramen ovale/lacerum); → facial vein (superior ophthalmic vein).
- ▶ "**Dangerous area of face**" — septic spread via valveless facial/ophthalmic veins causes cavernous sinus thrombosis.
- ▶ CS thrombosis = III, IV, VI palsy + V1 pain/anaesthesia + exophthalmos + lid/orbital oedema.
- ▶ Carotico-cavernous fistula = **pulsating exophthalmos** + bruit + chemosis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 (8e); Vishram Singh's Clinical Neuroanatomy (4e); Vishram Singh's Textbook of Anatomy Vol 3 (4e); Moore's Clinically Oriented Anatomy (9e) — for the dural venous sinus figure.



Discuss the temporomandibular joint

Asked in: Paper I Apr 2006 — RGUHS MD/MS Anatomy

Definition / Introduction The temporomandibular joint (TMJ) is a synovial joint between the mandibular (glenoid) fossa and articular tubercle of the temporal bone above and the head (condyle) of the mandible below. It is unique among synovial joints in two respects — its articular surfaces are covered by fibrocartilage rather than hyaline cartilage (because both bones ossify in membrane), and an interposed fibrocartilaginous articular disc divides the cavity into separate upper and lower compartments. Functionally it is a bilateral, compound joint: the right and left TMJs must move synchronously, and together with the disc they convert what is basically a hinge joint into one capable of combined rotation and gliding — essential for mastication, speech and deglutition.

1. Type and articular surfaces

Feature	Description
Type	Synovial joint, condylar variety; functionally a modified hinge joint (gliding/translation plus a small degree of rotation, in addition to elevation and depression)
Upper articular surface	Articular tubercle (eminence) and anterior part of the mandibular fossa of the temporal bone (the posterior, non-articular part is formed by the tympanic plate)
Lower articular surface	Head (condyle) of the mandible — convex anteroposteriorly, gently convex side to side; long axes of the two heads converge posteromedially towards the anterior margin of the foramen magnum

Feature	Description
Covering	White fibrocartilage on both surfaces (not hyaline cartilage), reflecting membranous ossification of the temporal squama and mandible; this tissue is less prone to degeneration and retains life-long proliferative/repair capacity
Joint cavity	Divided by the articular disc into a superior (discotemporal / meniscotemporal) and an inferior (discomandibular / meniscomandibular) compartment, each with its own synovial lining

2. Articular disc

- ▶ Oval, predominantly **fibrocartilaginous** plate; concavo-convex on its upper surface (to fit the eminence and fossa) and concave below (to cap the condyle).
- ▶ Divided in sagittal section into an **anterior band**, a thin **intermediate zone**, and a thick **posterior band**.
- ▶ Posteriorly it splits into two laminae (the **bilaminar zone/posterior attachment**): the upper lamina is fibroelastic and attaches to the squamotympanic fissure; the lower lamina is fibrous and attaches to the back of the condylar neck. A venous plexus lies between the laminae.
- ▶ Periphery fused to the fibrous capsule; anteriorly it blends with the insertion of lateral pterygoid (the disc represents its degenerated primitive insertion).
- ▶ **Central part of the disc is avascular and has no nerve supply**; the periphery and bilaminar zone are richly vascularised and innervated (proprioceptive fibres regulate mandibular posture and movement).
- ▶ Function: distributes load over a larger contact area, reduces friction between the incongruent bony surfaces, acts as a shock absorber, and stabilises the condyle.

□ Fig 6.8 — Subdivisions and attachments of the articular disc of temporomandibula (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.149)

3. Fibrous capsule and ligaments

Ligament	Attachments	Note
Fibrous capsule	Above — articular tubercle, margin of mandibular fossa, squamotympanic fissure behind; Below — neck of mandible	Loose above the disc, tight below it; lined by synovial membrane except over the cartilage/disc
Lateral (temporomandibular) ligament	Tubercle of the root of the zygoma → posterolateral neck of mandible; fibres directed inferoposteriorly	True/intrinsic ligament; reinforces the lateral capsule and limits posterior displacement of the condyle

Ligament	Attachments	Note
Sphenomandibular ligament (accessory)	Spine of the sphenoid → lingula of the mandibular foramen	Represents a remnant of Meckel's cartilage of the 1st pharyngeal arch; lies lateral to chorda tympani and the pharyngeal wall, medial to lateral pterygoid, the auriculotemporal nerve and the maxillary artery; pierced near its lower end by the mylohyoid nerve and vessels
Stylomandibular ligament (accessory)	Styloid process → angle/posterior border of the ramus of mandible	A thickened band of deep cervical fascia; separates the parotid from the submandibular gland; does not materially restrict movement

□ Fig 32.13 — The left temporomandibular joint. A, Lateral aspect. B, Medial aspect. (Gray's Anatomy — Standring — 41e, p.735)

4. Relations

Direction	Structures
Lateral	Skin and fascia; parotid gland; temporal branches of the facial nerve
Medial	Lateral pterygoid; auriculotemporal nerve enclosing the middle meningeal artery; spine of the sphenoid with the sphenomandibular ligament; chorda tympani nerve
Anterior	Lateral pterygoid (its two heads occupy the upper infratemporal fossa); masseteric nerve and vessels
Posterior	Parotid gland (separating the joint from the external acoustic meatus); superficial temporal vessels; auriculotemporal nerve; tympanic plate and tegmen tympani (separating it from the middle ear)
Superior	Thin roof of the mandibular fossa (~1 mm) separating the upper joint space from the middle cranial fossa; middle meningeal vessels
Inferior	Maxillary artery and vein

5. Blood, nerve and lymphatic supply

- **Arterial supply** — branches of the **superficial temporal** and **maxillary arteries** (notably the deep auricular branch of the maxillary artery).
- **Venous drainage** — into the **pterygoid venous plexus**.
- **Lymphatic drainage** — to the upper deep cervical (parotid/preauricular) lymph nodes.
- **Nerve supply** — the **auriculotemporal nerve** (posterior division of the mandibular nerve, articular twigs entering posteriorly) and the **masseteric nerve** (anterior division, entering anteriorly). The capsule, lateral ligament, bilaminar zone and periarticular tissue carry rich

mechanoreceptor and nociceptor innervation important for proprioception and reflex control of mandibular posture; the central disc itself is insensate.

6. Movements and muscles producing them

Movement	Prime movers
Depression (opening)	Lateral pterygoid (both sides), assisted by digastric, geniohyoid and mylohyoid; gravity also contributes
Elevation (closing)	Masseter, temporalis, medial pterygoid
Protrusion (protraction)	Lateral and medial pterygoid of both sides acting together
Retrusion (retraction)	Posterior (near-horizontal) fibres of temporalis — the only true retractors; assisted by deep masseter and digastric
Side-to-side (grinding/chewing)	Alternating contraction of lateral and medial pterygoid of one side; the working-side condyle rotates while the opposite condyle and disc glide forward, swinging the chin towards the working side

Movement is compartmentalised: gliding (translation) of the disc–condyle complex on the temporal surface occurs in the **upper (meniscotemporal)** compartment, while hinge-like rotation of the condyle on the undersurface of the disc occurs in the **lower (meniscomandibular)** compartment. In wide opening, an initial hinge movement is followed by forward gliding until the condyle lies under the articular tubercle; closure reverses the sequence. Stability is maintained by (i) bone — the articular tubercle resists forward and the postglenoid tubercle resists backward displacement; (ii) the lateral ligament — resists posterior displacement; (iii) muscle tone — temporalis limits excess protrusion, lateral pterygoid tension limits excess retrusion; and (iv) the occluded (bite) position of the mandible.

7. Development (brief)

Unlike most synovial joints, where a single mesenchymal blastema cavitates to give rise to both articulating bones, the temporal and condylar components of the TMJ develop **separately**, each as an independent condensation of **neural-crest mesenchyme**, cavitating between the **8th and 12th intrauterine week**. This separate origin explains why a proliferative (growth) layer of cells persists on each articular surface throughout life, permitting condylar remodelling well into adulthood.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sagittal section through the TMJ (in addition to the plates above) — label: articular tubercle (eminence), mandibular (glenoid) fossa, squamotympanic fissure, head/condyle of mandible, fibrocartilage covering, articular disc (anterior band – intermediate zone – posterior band – bilaminar zone), superior (meniscotemporal) compartment, inferior (meniscomandibular) compartment, fibrous capsule, synovial membrane, lateral pterygoid insertion onto disc/pterygoid fovea.

Applied / Clinical anatomy

- ▶ **Dislocation of the TMJ** — during wide yawning/biting or a blow on an open jaw, excessive lateral pterygoid contraction/traction throws the condyle anterior to the articular tubercle into the infratemporal fossa; the mouth is locked open and cannot be closed. Reduced by depressing the jaw (thumbs on the last molars) while elevating the chin. Posterior dislocation is rare, resisted by the postglenoid tubercle and the lateral ligament (usually the condylar neck fractures first in a direct blow).

□ Fig 6.14 — Dislocation of the head of mandible (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.153)

- ▶ **Internal derangement/disc displacement** — anteromedial displacement of the disc (commonest) causes **clicking (crepitus)** on opening/closing and may restrict movement; attributed to delayed anterior disc movement relative to the condyle.
- ▶ **TMJ arthritis** (degenerative/rheumatoid) — produces pain, crepitus and malocclusion.
- ▶ **Referred pain** — because the auriculotemporal nerve supplies both the TMJ and the parotid sheath/external ear, parotid disease (e.g. mumps) can mimic TMJ pain, and vice versa.
- ▶ **Surgical importance** — the facial nerve's temporal/zygomatic branches lie superficial to the capsule and the articular branches of the auriculotemporal nerve enter its posterior part; both must be preserved during arthroplasty/arthroscopy. The thin fenestrable roof of the mandibular fossa risks middle-cranial-fossa breach during surgery for ankylosis.
- ▶ **Locking/trismus** — submasseteric space infection from a lower third molar tracks deep to masseter, causing painful trismus without visible facial swelling.
- ▶ **Imaging** — TMJ arthrography, arthrocentesis and arthroscopy exploit the two separate synovial compartments; CT/MRI in open- and closed-mouth positions assesses condylar translation and disc position.

High-yield exam pointers

- ▶ TMJ = synovial, condylar/modified-hinge joint; **only synovial joint with fibrocartilage-covered surfaces** (membranous ossification).
- ▶ Articular disc divides cavity into upper (gliding/meniscotemporal) and lower (rotatory/meniscomandibular) compartments — write this first, it is the single most examined concept.
- ▶ Central disc = avascular, no nerve supply; bilaminar zone = vascular + richly innervated.
- ▶ Ligaments: capsule + **lateral ligament** (true); **sphenomandibular** (Meckel's cartilage remnant) + **stylomandibular** (deep cervical fascia thickening) (accessory).

- ▶ Nerve supply: auriculotemporal (posterior) + masseteric (anterior) branches of mandibular nerve.
- ▶ Movements: depression/elevation, protrusion/retrusion, side-to-side; retrusion is produced solely by posterior temporalis fibres.
- ▶ Bilateral joints must be described as acting **synchronously** — a common examiner probe.
- ▶ Applied: anterior dislocation (lateral pterygoid pulls condyle beyond the articular tubercle) is far commoner than posterior dislocation.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 8e; IB Singh's Textbook of Anatomy Vol 3 6e; Vishram Singh's Textbook of Anatomy Vol 3 4e; AK Datta's Human Anatomy Vol 2 (Head & Neck); Moore's Clinically Oriented Anatomy 9e.



Dural venous Sinuses

Asked in: Paper I May 2007 — RGUHS MD/MS Anatomy

Definition / Introduction

The dural venous sinuses are endothelium-lined venous channels enclosed between the periosteal (endosteal) and meningeal layers of the cranial dura mater, formed either by a simple **separation of the two dural layers** or by a **reduplication (splitting) of the meningeal layer** alone. They collect venous blood from the brain, the cranial meninges and the bones of the skull, and finally empty it into the **internal jugular vein**. Because their walls are devoid of valves and of smooth muscle, and because they communicate freely with extracranial veins through valveless emissary veins, they are of major clinical importance in the spread of infection and in intracranial venous thrombosis.

1. General characteristic features

- ▶ **Lining:** endothelium, continuous with the endothelial lining of ordinary veins.
- ▶ **Wall:** no muscular coat; **no valves** — blood can flow in either direction and reverses with posture/pressure change.
- ▶ **Tributaries:** cerebral veins, diploic veins, and some meningeal veins.
- ▶ **Drainage:** ultimately into the **internal jugular vein** (via the sigmoid sinus).
- ▶ **Communications:** connect with extracranial veins through valveless **emissary veins** passing through skull foramina — keeps intrasinus pressure constant, but is also a route for spread of infection into the cranial cavity.
- ▶ **CSF absorption:** arachnoid villi/granulations project chiefly into the superior sagittal sinus and its venous lacunae and mediate CSF absorption into venous blood.

2. Classification

Type	Sinuses
Unpaired (median)	Superior sagittal, Inferior sagittal, Straight, Occipital, Anterior intercavernous, Posterior intercavernous, Basilar venous plexus
Paired	Cavernous, Superior petrosal, Inferior petrosal, Transverse, Sigmoid, Sphenoparietal, Petrosquamous ($\pm$ middle meningeal sinus/veins)

BD Chaurasia enumerates 23 dural venous sinuses in all — 8 paired (16 sinuses, one on each side) and 7 unpaired.

3. Unpaired sinuses

Sinus	Course/location	Tributaries	Termination
Superior sagittal sinus (SSS)	Along the upper convex, attached (superior) margin of the falx cerebri; begins at the foramen caecum (communicating with nasal veins when patent) and runs back to the internal occipital protuberance	8–12 superior cerebral veins, parietal emissary veins, venous lacunae (which first receive diploic and meningeal veins)	Turns to the right (usually) to become the right transverse sinus
Inferior sagittal sinus (ISS)	Posterior two-thirds of the free (lower) border of the falx cerebri	Veins from the medial surfaces of the cerebral hemispheres	Joins the great cerebral vein (of Galen) to form the straight sinus
Straight sinus	Along the line of junction of the falx cerebri with the tentorium cerebelli	ISS + great cerebral vein; a few superior cerebellar veins	Turns to the left (usually) at the internal occipital protuberance to become the left transverse sinus
Occipital sinus	Smallest sinus; in the attached margin of the falx cerebelli, from the confluence of sinuses to the foramen magnum	—	Communicates with the internal vertebral venous plexus
Anterior & posterior intercavernous sinuses	Cross in the diaphragma sellae, in front of and behind the pituitary stalk	Connect the two cavernous sinuses	Together with the cavernous sinuses form the circular sinus
Basilar venous plexus	Over the clivus	Connects the two inferior petrosal sinuses	Communicates with the internal vertebral venous plexus

Confluence of sinuses (torcular Herophili): at the internal occipital protuberance the superior sagittal, straight and occipital sinuses meet and typically continue asymmetrically — SSS chiefly to the **right** transverse sinus, straight sinus chiefly to the **left** transverse sinus.

4. Paired sinuses, with the cavernous sinus in detail

Sinus	Course	Drains into
Sphenoparietal sinus	Along the posterior free margin of the lesser wing of sphenoid	Anterior part of cavernous sinus
Superior petrosal sinus	Attached margin of tentorium cerebelli, along the superior border of the petrous temporal bone	Connects cavernous sinus → transverse sinus
Inferior petrosal sinus	Groove between petrous temporal bone and clivus	Connects cavernous sinus → superior bulb of internal jugular vein
Transverse sinus	Posterior attached margin of tentorium cerebelli, grooving the occipital bone; right usually continues SSS, left usually continues straight sinus	Continues as sigmoid sinus
Sigmoid sinus	S-shaped continuation of transverse sinus; grooves the mastoid part of temporal bone (thin bony plate separates it from the mastoid antrum)	Internal jugular vein (at the jugular foramen)
Petrosquamous sinus	Small, along the petrosquamous suture (mainly seen in infants)	Transverse sinus, via petrosquamous emissary vein

Cavernous sinus (clinically the most important):

- ▶ A short, wide venous space on either side of the body of the sphenoid and sella turcica, about **2 cm antero-posteriorly** and **1 cm transversely**, extending from the medial end of the superior orbital fissure anteriorly to the apex of the petrous temporal bone posteriorly; its interior is trabeculated.
- ▶ **Formation:** roof, medial and lateral walls from the meningeal layer of dura; floor from the endosteal layer.
- ▶ **Relations:** medially — hypophysis cerebri and sphenoidal air sinus; laterally — uncus of the temporal lobe; superiorly — the carotid siphon (loop of internal carotid artery); inferiorly — greater wing of sphenoid; posteriorly — apex of petrous temporal bone and crus cerebri.
- ▶ **Contents traversing the sinus (medial part), covered by endothelium:** the **internal carotid artery** with its sympathetic plexus, and the **abducent (VI) nerve**, lying inferolateral to the artery.
- ▶ **Structures in the lateral wall, from above downward:** **oculomotor (III) → trochlear (IV) → ophthalmic (Va) → maxillary (Vb) nerves** (and the trigeminal ganglion may project into its posterior part).
- ▶ **Tributaries:** superior ophthalmic vein ($\pm$ inferior ophthalmic vein), sometimes the central vein of the retina, superficial middle cerebral vein, a few inferior cerebral veins, sphenoparietal sinus, occasionally the anterior (frontal) trunk of the middle meningeal vein.
- ▶ **Communications (all valveless, bidirectional):** superior petrosal sinus → transverse sinus; inferior petrosal sinus → internal jugular vein; emissary veins through **foramen ovale, foramen**

lacerum and the emissary sphenoidal (Vesalius) foramen → pterygoid venous plexus; superior ophthalmic vein → facial vein; basilar venous plexus and anterior/posterior intercavernous sinuses → opposite cavernous sinus.

- **Factors aiding venous return from the sinus:** pulsations of the internal carotid artery within it, gravity, and posture of the head.

5. Dural folds and the sinuses they enclose

Dural fold	Shape	Sinus(es) enclosed
Falx cerebri	Sickle-shaped	Superior sagittal, inferior sagittal, straight
Tentorium cerebelli	Tent-shaped	Transverse, superior petrosal
Falx cerebelli	Sickle-shaped	Occipital
Diaphragma sellae	Horizontal	Anterior and posterior intercavernous

6. Emissary veins — extracranial communications

Sinus	Emissary route	Extracranial vein
Superior sagittal sinus	Parietal emissary vein; foramen caecum	Scalp veins; nasal veins
Transverse sinus	Petrosquamous emissary vein	External jugular vein
Sigmoid sinus	Mastoid emissary vein; posterior condylar vein	Posterior auricular / suboccipital venous plexus
Cavernous sinus	Emissary veins (foramen ovale, lacerum, Vesalius)	Pterygoid venous plexus
Cavernous sinus	Superior ophthalmic vein	Facial vein
Inferior petrosal / sigmoid sinus	Direct continuity	Internal jugular vein

□ Fig 21.15 — Intracranial dural venous sinuses and their connections, lateral view (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.935)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Lateral-view line diagram of the intracranial dural venous sinuses, labelling:

- ▶ Superior sagittal sinus (along falx cerebri) → confluence of sinuses
- ▶ Inferior sagittal sinus → joins great cerebral vein → straight sinus
- ▶ Straight sinus (along falx–tentorium junction)
- ▶ Confluence of sinuses (torcular Herophili) at internal occipital protuberance
- ▶ Occipital sinus (in falx cerebelli, to foramen magnum)
- ▶ Right and left transverse sinuses (in tentorium cerebelli)
- ▶ Sigmoid sinus (S-shaped, grooving mastoid part of temporal bone) → internal jugular vein
- ▶ Cavernous sinus (beside sella turcica) with superior and inferior petrosal sinuses
- ▶ Sphenoparietal sinus (along lesser wing of sphenoid)
- ▶ Superior ophthalmic vein entering cavernous sinus anteriorly
- ▶ Emissary veins (parietal, mastoid, condylar) shown piercing the skull to extracranial veins

Applied / Clinical anatomy

- ▶ **Cavernous sinus thrombosis:** spreads from sepsis in the "danger area" of the face, nose or paranasal sinuses via valveless facial/ophthalmic veins. Presents with severe periorbital pain, chemosis and eyelid oedema (venous congestion), and ophthalmoplegia from involvement of the III, IV and VI nerves in/around its lateral wall.
- ▶ **Pulsating exophthalmos:** a carotico-cavernous fistula (rupture of the intracavernous internal carotid artery, usually after a basal skull fracture) drives arterial blood into the sinus, producing a pulsatile, protruding, chemotic eyeball synchronous with the pulse.
- ▶ **Superior sagittal sinus thrombosis:** infection spreading from the nose, scalp or diploë raises intracranial tension (impaired CSF absorption), causes convulsions/delirium (congested superior cerebral veins), and — from bilateral paracentral lobule involvement — an upper-motor-neuron type paraplegia.
- ▶ **Sigmoid sinus thrombosis:** a well-known complication of otitis media/mastoiditis, since the sinus is separated from the mastoid antrum by only a thin bony plate; surgeons must safeguard it during mastoid surgery. Spread of such thrombosis to the superior sagittal sinus can impair CSF drainage and produce **otitic hydrocephalus**.
- ▶ **Intracranial venous (sinus) thrombosis in general:** presents with headache, seizures and focal deficits, or venous infarction (with haemorrhage) on imaging; risk factors include pregnancy, oral contraceptives, dehydration and inherited hypercoagulable states.
- ▶ **CSF absorption/meningioma:** arachnoid granulations projecting into the superior sagittal sinus/lacunae are the principal site of CSF absorption and the classical site of origin of meningiomas.
- ▶ **Surgical/positional relevance:** the confluence of sinuses (torcular Herophili) is a key posterior-fossa landmark; the cavernous sinus is traversed during the transsphenoidal approach to the

pituitary; valveless dural sinuses and emissary veins are why scalp wounds and facial infections (e.g., "danger triangle" of the face) can seed intracranial sepsis.

High-yield exam pointers

- ▶ Dural venous sinuses are endothelium-lined, valveless, muscle-free channels between the two dural layers; formed by splitting of the two layers OR reduplication of the meningeal layer alone.
- ▶ Classified as **unpaired** (SSS, ISS, straight, occipital, anterior/posterior intercavernous, basilar plexus) and **paired** (cavernous, superior/inferior petrosal, transverse, sigmoid, sphenoparietal, petrosquamous) — 23 in all by BD Chaurasia's count.
- ▶ All sinuses ultimately drain into the **internal jugular vein**, mainly via the sigmoid sinus.
- ▶ **Confluence of sinuses (torcular Herophili)** at the internal occipital protuberance — SSS usually continues as right transverse sinus, straight sinus as left transverse sinus.
- ▶ **Cavernous sinus**: $\sim 2 \times 1$ cm; contains ICA + sympathetic plexus + VI nerve medially; III, IV, Va, Vb in its lateral wall (superior to inferior order).
- ▶ Communicates with extracranial veins via **valveless emissary veins** (parietal, mastoid, condylar, sphenoidal/Vesalius, ophthalmic-facial route) — the anatomical basis of intracranial spread of scalp/facial/middle-ear infection.
- ▶ Arachnoid villi/granulations projecting into the SSS mediate **CSF absorption**; overgrowth = meningioma risk.
- ▶ Clinical triad to remember: cavernous sinus thrombosis (III, IV, VI palsy + chemosis), sigmoid sinus thrombosis (otitis media/mastoiditis $\rightarrow$ otitic hydrocephalus), and carotico-cavernous fistula (pulsating exophthalmos).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3–4, 8e; Vishram Singh — Clinical Neuroanatomy, 4e; Vishram Singh — Textbook of Anatomy Vol 3, 4e; IB Singh — Textbook of Anatomy Vol 3, 6e.



Emissary veins

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction. Emissary veins are small, **valveless** veins that traverse cranial apertures (foramina, canals, and irregular gaps in sutures) to make direct venous connections between the **intracranial dural venous sinuses** and the **extracranial veins** of the scalp, face, and neck. Some are constant and named (parietal, mastoid, condylar, and others); many are small, inconstant, and unnamed. Because they are valveless, blood in them can flow in either direction according to the prevailing pressure gradient — normally outward, away from the brain — and this bidirectionality is what gives emissary veins their major clinical importance: they are a recognised route by which extracranial (scalp, face, middle-ear) infection can spread inward to cause dural venous sinus thrombosis.

1. General characters

- ▶ Thin-walled, **valveless** veins — permit free, direction-reversible flow.
- ▶ Traverse a cranial foramen, canal, or an inconstant sutural aperture; some (e.g. through foramen ovale, foramen lacerum) form a small venous **plexus** within the foramen rather than a single vessel.
- ▶ Connect the intracranial dural venous sinuses (superior sagittal, cavernous, sigmoid, transverse, occipital, basilar plexus) with extracranial veins (scalp veins, posterior auricular vein, occipital vein, pterygoid venous plexus, pharyngeal venous plexus, internal/external jugular veins).
- ▶ Distinct from **diploic veins**, which run within the diploë (cancellous bone between the two tables of the cranial vault) and drain the bone itself into the dural sinuses; diploic veins typically communicate with the exterior *through* emissary veins, so the two systems are linked but not identical.
- ▶ Numbers and calibre are variable between individuals; some (parietal, mastoid) are almost constantly present, others (foramen caecum, petrosquamous) are present only in a minority of skulls.

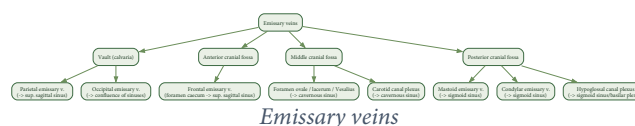
2. Classification by region and named emissary veins

Emissary veins are conventionally grouped by the region of the skull they pierce — the vault (calvaria), and the three cranial fossae at the base.

Emissary vein	Foramen / canal traversed	Extracranial vein(s)	Intracranial sinus
Frontal emissary vein	Foramen caecum (patent in only a small minority of adults; more often patent in children)	Veins of the nasal mucosa/upper nose	Superior sagittal sinus
Parietal emissary vein	Parietal foramen (near sagittal suture)	Veins of the scalp	Superior sagittal sinus
Mastoid emissary vein	Mastoid foramen (near occipitomastoid suture)	Posterior auricular vein / occipital vein	Sigmoid sinus

Emissary vein	Foramen / canal traversed	Extracranial vein(s)	Intracranial sinus
Occipital emissary vein	Foramen near the external occipital protuberance	Occipital vein / occipital diploic vein	Confluence of sinuses
Condylar (supracondylar) emissary vein	Posterior condylar canal	Suboccipital venous plexus	Sigmoid sinus
Venous plexus of the hypoglossal canal	Hypoglossal canal	Internal jugular vein	Sigmoid sinus / basilar plexus
Venous plexus of foramen ovale	Foramen ovale	Pterygoid venous plexus	Cavernous sinus
Emissary veins of foramen lacerum (2–3 small veins)	Foramen lacerum	Pharyngeal venous plexus / pterygoid plexus	Cavernous sinus
Vein of the sphenoidal emissary foramen (of Vesalius) — present only in a proportion of skulls, medial to foramen ovale	Emissary sphenoidal foramen	Pterygoid venous plexus	Cavernous sinus
Internal carotid venous plexus	Carotid canal	Internal jugular vein	Cavernous sinus
Petrosquamous sinus	Petrosquamous fissure, over the petrous temporal bone	Retromandibular vein	Transverse sinus (before its confluence with the superior petrosal sinus)

- ▶ A small, inconstant emissary vein through the **foramen rotundum** is also described alongside the maxillary nerve.
- ▶ The **superior ophthalmic vein** is regarded as "potentially emissary" since it directly connects the cavernous sinus (intracranial) with the facial venous system (extracranial) via the angular vein, even though it does not pass through a bony foramen.
- ▶ Grouped by cranial fossa: **anterior fossa** — frontal emissary vein (foramen caecum); **middle fossa** — emissary veins of foramen ovale, foramen lacerum, foramen of Vesalius, carotid canal; **posterior fossa** — mastoid, condylar/supracondylar, and hypoglossal-canal emissary veins; **vault** — parietal and occipital emissary veins.



3. Functions of emissary veins

- ▶ **Pressure buffering** — provide a low-resistance outlet that helps keep intracranial venous pressure relatively constant, buffering sudden rises (e.g. straining, coughing, changes in posture).
- ▶ **Collateral venous drainage** — offer an alternative pathway for cerebral venous outflow if a dural sinus becomes thrombosed, compressed, or surgically ligated.

- ▶ **Selective cooling of the brain** — allow cooler blood from scalp/facial veins to enter the cranial venous circulation, contributing to intracranial thermoregulation.
- ▶ Because they are valveless, all of the above depend on the ability of blood to move in **either direction**, which is also the basis of their principal clinical hazard (below).

□ Fig 2.6 — *The veins of the scalp, face and their deep connections with the cavernous sinus and their clinical significance (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.85)*

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A parasagittal/coronal schematic of the skull and scalp, labelling:

- ▶ The layers of the scalp, with the **loose areolar tissue layer** ("**danger area of scalp**") and emissary veins traversing it
- ▶ **Parietal foramen** with the parietal emissary vein connecting scalp veins to the **superior sagittal sinus**
- ▶ **Mastoid foramen** with the mastoid emissary vein connecting the posterior auricular/occipital vein to the **sigmoid sinus**
- ▶ **Posterior condylar canal** (condylar emissary vein) linking the suboccipital venous plexus to the sigmoid sinus
- ▶ **Foramen ovale, foramen lacerum, foramen of Vesalius** with their emissary veins draining the pterygoid venous plexus into the **cavernous sinus**
- ▶ Arrows on each emissary vein showing that flow is **normally outward but reversible** (no valves)

Applied / Clinical anatomy

- ▶ **Route of infection spread (the single most important clinical fact)** — because emissary veins are valveless, extracranial sepsis can travel retrogradely to infect a dural venous sinus.
 - Scalp infection in the loose areolar layer ("**dangerous area of the scalp**") can track along **parietal emissary veins** into the **superior sagittal sinus**, producing sagittal sinus thrombosis.
 - Infection from the "**dangerous area of the face**" (bridge of nose, upper lip, medial canthus) spreads via the facial vein → deep facial vein → **pterygoid venous plexus** → the emissary veins of foramen ovale/foramen lacerum/foramen of Vesalius → **cavernous sinus**, producing **cavernous sinus thrombosis** (proptosis, chemosis, ophthalmoplegia from III, IV, VI and V1/V2 involvement). Squeezing a furuncle/pustule in this triangle is classically discouraged for this reason.
 - Middle-ear/mastoid suppuration can spread along the **mastoid emissary vein** to cause **sigmoid (lateral) sinus thrombosis**, a recognised complication of chronic suppurative otitis media/mastoiditis.
- ▶ **Collateral pathway in venous sinus thrombosis** — the same valveless connections that transmit infection can, conversely, allow venous drainage to bypass an occluded or ligated sinus, partly protecting against the consequences of sinus thrombosis or surgical sacrifice of a sinus.
- ▶ **Surgical/positional importance** — emissary and diploic veins are encountered during craniotomy and scalp surgery; their variable position (e.g. parietal or mastoid foramen) is

relevant to safe placement of burr holes and to neurosurgical approaches to the posterior fossa (retrosigmoid/presigmoid routes relative to the sigmoid sinus and its mastoid/condylar emissary connections).

- ▶ **Radiological correlate** — emissary foramina/canals (parietal, mastoid, condylar, hypoglossal, foramen of Vesalius) may be visualised on CT/CT-venogram as small vascular channels traversing bone, and an enlarged or asymmetrical one is a normal variant, not necessarily pathological.

High-yield exam pointers

- ▶ **Definition:** valveless veins connecting intracranial dural venous sinuses with extracranial veins through cranial foramina/canals.
- ▶ **Named list to reproduce:** frontal (foramen caecum), parietal (parietal foramen), mastoid (mastoid foramen), occipital, condylar/supracondylar (posterior condylar canal), hypoglossal canal plexus, foramen ovale/lacerum/Vesalius plexuses, internal carotid (carotid canal) plexus, petrosquamous sinus.
- ▶ **Valveless → bidirectional flow** — normally outward, but reversible; this is the anatomical basis for retrograde spread of infection.
- ▶ **Three named clinical routes:** scalp danger area → parietal emissary vein → superior sagittal sinus thrombosis; face danger triangle → pterygoid plexus → cavernous sinus thrombosis; middle ear/mastoid → mastoid emissary vein → sigmoid sinus thrombosis.
- ▶ **Functions:** equalise/buffer intracranial venous pressure, provide collateral drainage if a sinus is occluded, aid selective brain cooling.
- ▶ Distinguish from **diploic veins** (intraosseous, drain diploë, communicate with the exterior via emissary veins) — a common confusion in exams.
- ▶ Clinically the **most important single fact:** emissary veins are the anatomical basis of retrograde spread of extracranial sepsis to cause dural venous sinus thrombosis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3-4 8e; AK Datta's Human Anatomy Vol 2 (Head & Neck); Vishram Singh's Textbook of Anatomy Vol 3 4e; IB Singh's Textbook of Human Neuroanatomy; Moore's Clinically Oriented Anatomy 9e.



Fascial sheath of eyeball

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The fascial sheath of the eyeball — the bulbar fascia or fascia bulbi, universally known by its eponym **Tenon's capsule** — is a thin, loose membranous sheath of condensed orbital connective tissue that envelops the eyeball from the optic nerve posteriorly to the corneoscleral (sclerocorneal) junction, the limbus, anteriorly. It separates the globe from the surrounding orbital fat and forms a smooth-walled socket within which the eyeball rotates freely, while its posterior and anterior expansions — the check ligaments and the suspensory ligament of Lockwood — suspend and stabilise the globe within the bony orbit. Together with the periorbita (orbital periosteum) and the orbital septum, it is one of three named fasciae of orbital connective tissue, each with a distinct location and surgical significance.

Extent and relation to the sclera

- ▶ Extends from the **optic nerve** (posteriorly) to the **corneoscleral junction/limbus** (anteriorly), enveloping the entire globe except the cornea.
- ▶ Its ocular (deep) aspect is separated from the sclera by the **episcleral space** (Tenon's space) — a potential space crossed by delicate bands of loose episcleral connective tissue; posteriorly this space is also traversed by the **ciliary vessels and nerves**.
- ▶ The sheath is **firmly attached** to the sclera at only two points: (i) posteriorly, where it fuses with the sclera and with the sheath of the optic nerve as the nerve enters the globe, and (ii) anteriorly, just behind the limbus.
- ▶ Elsewhere the attachment is loose, which is what permits the eyeball to rotate freely within the sheath — the arrangement functions as a **ball-and-socket**.
- ▶ Anteriorly the fascial sheath lies deep to the **bulbar conjunctiva**; together the two form the suspensory apparatus of the globe, of which the fascial sheath is the more substantial component.

Distinction from periorbita and orbital septum

- ▶ **Periorbita** is the periosteum of the bony orbit — loosely attached to bone, continuous posteriorly with the dura mater around the optic nerve and anteriorly with the periosteum of the orbital margin. It lines the orbital walls, whereas the fascial sheath of the eyeball is confined to investing the globe itself.
- ▶ The **orbital septum** is a separate membranous sheet derived from periorbita at the orbital margins, extending into each eyelid to blend with the tarsal plates; it is the surgical plane separating pre-septal from post-septal (orbital) infection, and lies anterior to, and distinct from, the fascial sheath of the eyeball.
- ▶ All three fasciae are, however, continuous with one another through their shared origin in orbital connective tissue, and the fascial sheath's radial septa link it to the periorbita.

Structures piercing the sheath

- ▶ The tendons of all **six extraocular muscles** — the four recti and the two obliques.
- ▶ The **ciliary vessels and nerves**, close to the point of entry of the optic nerve.

Muscular fascia and the fascial ring

- ▶ As each extraocular muscle tendon pierces the fascia bulbi, the fascia is reflected onto it as a tubular **muscular fascia** (fascial sleeve).
- ▶ The sheaths of the four recti are thick anteriorly but thin posteriorly to a delicate perimysium.
- ▶ Just before merging with the fascia bulbi, the sheaths of adjacent recti become confluent, forming a **fascial ring** — an important surgical landmark separating the anterior (sub-Tenon) from the posterior (intraconal) orbital compartments.
- ▶ The sheath of superior oblique is prolonged to the fibrous pulley (**trochlea**).

Check ligaments and the suspensory ligament of Lockwood

Structure	Derived from	Bony attachment	Functional role
Medial check ligament	Sheath of medial rectus	Lacrimal bone (posterior lacrimal crest)	Limits abduction
Lateral check ligament	Sheath of lateral rectus	Zygomatic bone (Whitnall's tubercle)	Limits adduction
Suspensory ligament of the eye (of Lockwood)	Union of sheaths of inferior rectus and inferior oblique with the medial and lateral check ligaments	Slung between the two check-ligament attachments	Hammock-like support of the globe from below
Transverse ligament of the eye (of Whitnall)	Extensions of fascia bulbi passing medially and laterally, superior counterpart	Medial and lateral orbital walls	Presumed to help elevate the conjunctival fornix in upgaze; fulcrum for levator action

- ▶ The suspensory ligament is expanded centrally and narrows towards its two extremities; it supports the globe so effectively that **even if the orbital floor (maxilla) is fractured or surgically removed, the eyeball does not sag**.
- ▶ Numerous finer fasciae form **radial septa** running from the fascia bulbi and the muscle sheaths to the orbital periosteum; these compartmentalise the orbital fat and prevent its gross displacement, which is essential for maintaining accurate binocular alignment of the two eyes.

Extensions related to the eyelids

- ▶ The sheath of **levator palpebrae superioris** is thickened anteriorly; just behind its aponeurosis it fuses inferiorly with the sheath of superior rectus, and extends forward between the two muscles to attach to the **upper conjunctival fornix**.
- ▶ The fused sheath of **inferior rectus and inferior oblique** sends an anterior expansion into the lower eyelid; augmented by fibres of orbicularis oculi, it attaches to the inferior tarsus as the **inferior tarsal muscle** — so contraction of inferior rectus in downgaze also draws the lower lid downward.

Orbital connective-tissue pulleys

- ▶ The traditional view that the recti act only from origin to scleral insertion has been revised: an encircling collagenous sleeve — a **pulley** — lies within the fascia bulbi near the equator of the globe for each rectus muscle, containing elastic fibres and smooth muscle for rigidity.
- ▶ Fibres from the orbital surface of each muscle insert into its pulley sleeve, permitting small longitudinal movements — the "**active pulley hypothesis**" (Demer, Miller) — which better explains the observed stability of rectus-muscle paths during ocular rotation than the older passive-pulley model.

□ Fig 13.3 — Fascial sheath of the eyeball as seen in coronal section (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.252)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Coronal section through the orbit at the equator of the globe, labelling:

- ▶ Levator palpebrae superioris and superior rectus (superiorly)
- ▶ Tenon's capsule encircling the globe
- ▶ Episcleral space between capsule and sclera
- ▶ Lateral check ligament (right) and medial check ligament (left)
- ▶ Suspensory ligament of the eye slung below the globe
- ▶ Inferior rectus and inferior oblique muscles (inferiorly, within the suspensory ligament)

Applied / Clinical anatomy

- ▶ **Sub-Tenon's (Parker's) anaesthesia:** local anaesthetic is injected via a blunt cannula into the episcleral space between the fascia bulbi and the sclera; this has become a popular technique for cataract and other ophthalmic surgical procedures, avoiding the sharp-needle risks of retrobulbar/peribulbar blocks.
- ▶ **Enucleation and ocular prosthesis:** if Tenon's capsule is preserved during enucleation of the eye, an artificial eye subsequently implanted within its socket retains the ability to move, since the muscle sheaths and check ligaments remain intact and functional.
- ▶ **Orbital floor injury:** the suspensory ligament of Lockwood keeps the globe supported even when the maxilla (orbital floor) is fractured or surgically removed, explaining why isolated floor injury does not always cause immediate globe descent unless the ligament and orbital fat herniate through the fracture.
- ▶ **Enophthalmos:** conditions that reduce retrobulbar fat (starvation, cachexia) diminish the cushioning/supportive function of the fascial septa and fat, allowing the eyeball to sink posteriorly into the orbit.
- ▶ **Strabismus surgery:** the fascial (pulley) sleeves around each rectus muscle determine its effective line of pull; slipped or "lost" muscle at reoperation reflects disruption of this pulley-fascia relationship, and the fascial ring is the key landmark for safe intraconal dissection.

High-yield exam pointers

- ▶ Fascial sheath of eyeball = fascia bulbi = **Tenon's capsule**; extends from optic nerve to corneoscleral junction (limbus).

- ▶ Separated from sclera by the **episcleral space**, crossed by ciliary vessels/nerves; firmly attached only posteriorly (at optic nerve) and anteriorly (at limbus).
- ▶ Pierced by tendons of all six extraocular muscles; reflected onto each as tubular muscular fascia.
- ▶ Confluence of adjacent recti sheaths forms the **fascial ring**.
- ▶ **Medial check ligament** → lacrimal bone (posterior lacrimal crest); **lateral check ligament** → zygomatic bone (Whitnall's tubercle).
- ▶ **Suspensory ligament of Lockwood** = inferior rectus + inferior oblique sheaths united with both check ligaments; hammock support of the globe.
- ▶ **Transverse ligament of Whitnall** is the superior counterpart connecting the medial and lateral extensions.
- ▶ Clinical pearls: site for sub-Tenon's anaesthesia; preserved capsule permits prosthesis movement after enucleation; supports globe against orbital floor fractures; "active pulley hypothesis" of Demer and Miller.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4, 8e; AK Datta's Human Anatomy Vol 2 (Head & Neck); Vishram Singh's Textbook of Anatomy Vol 3, 4e; Moore's Clinically Oriented Anatomy, 9e.



Innervation of parotid gland

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction — The parotid gland, the largest of the three paired salivary glands, receives a **triple nerve supply** — **parasympathetic (secretomotor)**, **sympathetic (vasomotor)** and **general sensory** — all of which converge on a single final common pathway, the **auriculotemporal nerve**, after the parasympathetic component has relayed in the **otic ganglion**. A point frequently tested and frequently confused: although the **facial nerve (CN VII)** runs directly through the substance of the gland (dividing it into superficial and deep parts as it forms the parotid plexus), it merely traverses the gland on its way to the muscles of facial expression and **does not innervate the parotid gland itself**. The true secretomotor supply originates from the **glossopharyngeal nerve (CN IX)**, making the parotid unique among the three major salivary glands in its cranial-nerve source.

1. Overview of the three components

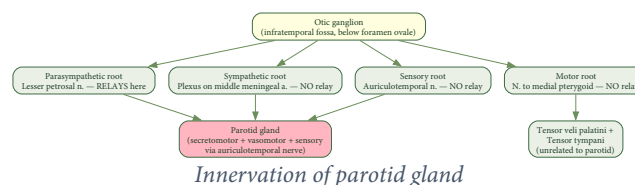
Component	Fibre type	Central/ preganglionic origin	Pathway to the gland	Principal action
Parasympathetic	Secretomotor; preganglionic → relays in otic ganglion → postganglionic	Inferior salivatory nucleus (medulla)	CN IX → tympanic branch (nerve of Jacobson) → tympanic plexus (on the promontory) → lesser petrosal nerve → otic ganglion (relay) → auriculotemporal nerve → gland	Thin, watery (serous) secretion — the dominant secretomotor drive
Sympathetic	Postganglionic, vasomotor; passes through otic ganglion without relay	Lateral horn, T1 segment of spinal cord → synapses in superior cervical ganglion	Plexus on the middle meningeal artery → through otic ganglion (no relay) → auriculotemporal nerve, and also along branches of the external carotid/maxillary arteries → gland	Vasoconstriction of glandular vessels; modulates blood flow and hence volume/consistenc y of saliva
Sensory	General somatic afferent	—	Auriculotemporal nerve to the gland substance; great auricular nerve (C2, C3) to the overlying parotid fascia/capsule	Pain and pressure sensation — explains the marked pain of parotid swellings

2. Parasympathetic (secretomotor) supply — the main pathway

- ▶ Preganglionic fibres begin in the **inferior salivatory nucleus** in the medulla and leave the brainstem in the **glossopharyngeal nerve (CN IX)**.
- ▶ CN IX gives off its **tympenic branch (Jacobson's nerve)**, which enters the tympanic canaliculus and ends in the **tympenic plexus** on the promontory of the middle ear.
- ▶ From the tympanic plexus, fibres continue as the **lesser petrosal nerve**, which crosses the middle cranial fossa and leaves the skull through the **foramen ovale** to reach the otic ganglion in the infratemporal fossa.
- ▶ The lesser petrosal nerve **relays in the otic ganglion**, situated just below the foramen ovale.
- ▶ **Postganglionic secretomotor fibres** leave the ganglion and join the **auriculotemporal nerve**, which carries them to the parotid gland, producing a **thin, watery serous secretion** — the physiological basis of "mouth-watering" reflex salivation.

3. The otic ganglion — the relay station

- ▶ A small (2–3 mm) parasympathetic ganglion lying in the infratemporal fossa, **just below the foramen ovale**, medial to the mandibular nerve and lateral to tensor veli palatini; it surrounds the origin of the nerve to medial pterygoid.
- ▶ **Topographically** it is closely applied to the mandibular nerve, but **functionally it belongs to the glossopharyngeal nerve** — the parasympathetic pathway described above.
- ▶ Four sets of fibres pass through/relay in it, only three of which are relevant to the parotid gland's innervation:
 - **Parasympathetic (motor) root** — the lesser petrosal nerve; the **only root that actually relays** here.
 - **Sympathetic root** — postganglionic vasomotor fibres from the plexus on the middle meningeal artery (ultimately from the superior cervical ganglion); pass through **without relay**.
 - **Sensory root** — from the auriculotemporal nerve; also passes through without relay, and is sensory to the parotid gland.
 - A fourth, **motor root** (from the nerve to medial pterygoid) also traverses the ganglion without relay, but supplies tensor veli palatini and tensor tympani — it plays **no part** in the innervation of the parotid gland.



4. Sympathetic (vasomotor) supply

- ▶ Preganglionic fibres arise from the **lateral horn of the T1 spinal segment**, ascend the cervical sympathetic chain, and synapse in the **superior cervical ganglion**.
- ▶ Postganglionic fibres travel as a plexus around the **middle meningeal artery**, pass **through the otic ganglion without synapsing**, and join the **auriculotemporal nerve** to reach the gland;

additional postganglionic fibres travel directly along branches of the **external carotid and maxillary arteries** that supply the gland.

- ▶ These fibres are purely **vasomotor** — they cause vasoconstriction of the gland's blood vessels, thereby reducing glandular blood flow and modulating the volume/consistency of saliva, rather than driving true secretomotor activity (that role belongs to the parasympathetic supply).

5. Sensory supply

- ▶ **General sensory fibres to the gland substance itself** are carried by the **auriculotemporal nerve** (a branch of the posterior division of the mandibular nerve).
- ▶ **The parotid fascia/capsule**, in contrast, is supplied by the **great auricular nerve** (C2, C3), a branch of the cervical plexus. This distinction explains why parotid swellings (e.g. mumps, abscess) are so exquisitely painful — the tight, unyielding fascial capsule is richly innervated and becomes stretched by any increase in glandular volume.

6. Auriculotemporal nerve — the final common pathway

- ▶ Arises by **two roots** from the posterior division of the **mandibular nerve**, which run backwards and **encircle the middle meningeal artery** before uniting into a single trunk.
- ▶ Passes backwards between the neck of the mandible and the sphenomandibular ligament, above the maxillary artery; behind the neck of the mandible it turns upward and ascends over the **superior surface of the parotid gland**, behind the superficial temporal vessels, onto the temple.
- ▶ Within/at the gland it carries **all three functional components to the parotid** — postganglionic parasympathetic (secretomotor), sympathetic (vasomotor) and sensory fibres.
- ▶ Beyond the gland, its auricular part supplies the skin of the tragus and the upper parts of the pinna, external acoustic meatus and tympanic membrane; its temporal part supplies skin of the temple; it also supplies the **temporomandibular joint**.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 5.6 — Parasympathetic nerve supply to the parotid gland (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.138)

Reproduce this figure by hand with the following labels:

- ▶ Glossopharyngeal nerve (IX), with its **tympanic branch**
- ▶ Tympanic plexus on the promontory (middle ear)
- ▶ Lesser petrosal nerve, exiting through/near the foramen ovale
- ▶ Mandibular nerve through the foramen ovale
- ▶ Otic ganglion (mark clearly as the site of relay)
- ▶ Auriculotemporal nerve, shown looping below the otic ganglion (its two roots encircling the middle meningeal artery, which may be added as a dashed circle)
- ▶ Parotid gland, with the auriculotemporal nerve's terminal secretomotor twigs entering its substance

Applied / Clinical anatomy

- ▶ **Frey's syndrome (gustatory sweating / auriculotemporal syndrome)**: after parotidectomy or penetrating injury to the gland, severed postganglionic parasympathetic (secretomotor) fibres of the auriculotemporal nerve undergo **aberrant regeneration** and grow along the sheaths of the cutaneous fibres of the **great auricular nerve** to reach the sweat glands and cutaneous vessels of the overlying skin. Consequently, a stimulus meant for salivation (e.g. the sight, smell or taste of food, or chewing) produces **flushing and sweating** over the skin of the parotid/temporal region instead.
- ▶ **Preservation of the facial nerve in parotidectomy**: since CN VII merely traverses the gland (dividing it into superficial and deep lobes at the "isthmus") without supplying it, the surgical plane of cleavage is developed by tracing the facial nerve trunk forward from the stylomastoid foramen, allowing the gland to be removed in two parts while the nerve — and hence facial expression — is preserved.
- ▶ **Referred otalgia**: because the auriculotemporal nerve also supplies the tympanic membrane, external acoustic meatus and temporomandibular joint, disease of the parotid gland, TMJ dysfunction, or dental/third-molar pathology can present as referred ear pain along this shared nerve.
- ▶ **Auriculotemporal nerve block**: used for regional anaesthesia of the temporomandibular joint and posterior scalp/temple region; its close relation to the superficial temporal artery (just behind which it ascends) is a key surgical landmark.
- ▶ **Painful parotid swelling**: mumps (viral parotitis) and parotid abscess are notably painful because the tight parotid fascia (sensory territory of the great auricular nerve) does not distend, so any glandular enlargement stretches richly innervated fascia.

High-yield exam pointers

- ▶ Three components: **parasympathetic (secretomotor)**, **sympathetic (vasomotor)**, **sensory** — all reach the gland via the **auriculotemporal nerve**.

- ▶ Parasympathetic pathway (must write in sequence): **Inferior salivatory nucleus** → CN IX → **tympenic branch (Jacobson's n.)** → **tympenic plexus** → **lesser petrosal n.** → **relay in otic ganglion** → **auriculotemporal n.** → **parotid gland**.
- ▶ Otic ganglion: situated just below the foramen ovale; only the **parasympathetic (lesser petrosal) root relays** here — sympathetic, sensory and the medial-ptyergoid motor root merely pass through.
- ▶ Sympathetic fibres: T1 lateral horn → superior cervical ganglion → plexus on middle meningeal artery → through otic ganglion (no relay) → auriculotemporal nerve; purely vasomotor.
- ▶ Sensory supply: **gland substance** → auriculotemporal nerve; **fascia/capsule** → great auricular nerve (C2, C3).
- ▶ Auriculotemporal nerve arises by two roots that **encircle the middle meningeal artery**, from the posterior division of the mandibular nerve.
- ▶ CN VII (facial nerve) **does NOT supply the parotid gland** — it only passes through it (parotid plexus, terminal branches) — a classic "trap" point.
- ▶ **Frey's syndrome** = aberrant regeneration of parasympathetic secretomotor fibres of the auriculotemporal nerve joining the great auricular nerve's sweat-gland/cutaneous territory after parotid surgery.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 (8e); Vishram Singh's Textbook of Anatomy Vol 3 (4e); IB Singh's Textbook of Anatomy Vol 3 (6e); Moore's Clinically Oriented Anatomy (9e).



Interior of the larynx

Asked in: Paper I Nov 2016 — RGUHS MD/MS Anatomy

Definition / Introduction — The laryngeal cavity extends from the laryngeal inlet (aditus laryngis), where it opens into the laryngopharynx, down to the lower border of the cricoid cartilage, where it becomes continuous with the trachea. Two pairs of mucosal folds projecting into the lumen — the vestibular folds above and the vocal folds below — divide the cavity into three parts. The cavity is lined throughout by mucous membrane reflected over an internal fibroelastic membrane (quadrangular membrane above, conus elasticus below), and its detailed interior anatomy underlies phonation, airway protection, and the clinical staging of laryngeal disease.

1. Laryngeal inlet and the fibroelastic framework

- ▶ The **laryngeal inlet (aditus laryngis)** is an obliquely placed, roughly triangular aperture facing backwards and upwards (because the anterior wall of the larynx, formed by the epiglottis, is much longer than the posterior wall).
- ▶ Boundaries of the inlet: **anteriorly** — upper border of the epiglottis; **posteriorly** — mucosal fold between the two arytenoid cartilages (posterior commissure/interarytenoid fold); **on each side** —

the **aryepiglottic fold**, running from the side of the epiglottis to the apex of the arytenoid cartilage.

- Deep to the mucosa, a discontinuous sheet of fibroelastic tissue supports the interior: its **upper part (quadrangular membrane)** lies in the wall of the vestibule, passing from the epiglottis to the arytenoid cartilage — its free lower border thickens into the **vestibular ligament** and its free upper border forms the **aryepiglottic ligament**. Its **lower part (conus elasticus/cricovocal membrane)** lies in the wall of the infraglottic cavity, running from the cricoid arch upward — its thickened free upper edge forms the **vocal ligament**, and its anteromedian thickened part is the **cricothyroid ligament**.
- The two membranes are separated on each side by a gap corresponding to the **laryngeal ventricle**, which is why the vestibular and vocal folds mark the interruption between them.

2. The two folds and the fissures between them

Feature	Vestibular fold (false cord)	Vocal fold (true cord)
Formed by	Mucosa over the vestibular ligament (lower border of quadrangular membrane)	Mucosa over the vocal ligament (upper free border of conus elasticus) + thyroarytenoid/vocalis muscle
Attachments	Thyroid angle (below epiglottic cartilage) to anterolateral arytenoid surface	Thyroid angle (midlevel) to vocal process of arytenoid cartilage
Colour in vivo	Pink (loose, vascular mucosa)	Pearly white (mucosa adherent to ligament)
Space between the pair	Rima vestibuli	Rima glottidis (glottis)
Function	Protective; little role in phonation	Primary organ of phonation

- The **rima glottidis** is the narrowest part of the larynx. It has an **anterior intermembranous part** (~3/5 of its length), bounded by the vocal folds/ligaments, and a **posterior intercartilaginous part** (~2/5), bounded by the vocal processes of the arytenoid cartilages.
- Average sagittal diameter: **23 mm in the adult male, 17 mm in the adult female**; width varies with respiration/phonation. In the neonate the intramembranous proportion is relatively smaller (the vocal cords are only 4–4.5 mm long).

3. Three-part division of the laryngeal cavity (the core answer)

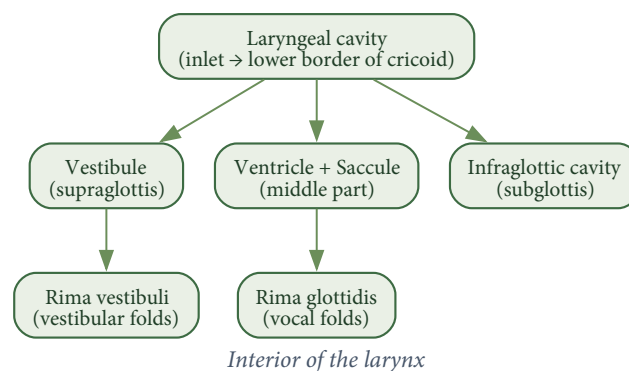
Part	Extent	Key interior features
Vestibule (supraglottis)	Laryngeal inlet down to the vestibular folds/rima vestibuli	Wide above, narrow below, higher anteriorly than posteriorly. Anterior wall = posterior surface of epiglottis (its lower tubercle bulges backward); lateral walls = medial surfaces of aryepiglottic folds; posterior wall = interarytenoid mucosa above the vestibular folds.

4. Mucous membrane and epithelium lining the interior

- ▶ The mucosa is continuous with the pharynx above and the trachea below, lining the entire interior including the ventricle and saccule.
- ▶ **Epithelium:** predominantly **ciliated pseudostratified columnar (respiratory) epithelium**, giving mucociliary clearance. **Non-keratinised stratified squamous epithelium** covers the surfaces subject to mechanical friction/contact — the **vocal folds**, the upper (lingual) and adjoining posterior surface of the epiglottis, and the upper parts of the aryepiglottic folds.
- ▶ **Glands:** absent along the free margins of the vocal folds, which instead depend on lubricating secretion expressed from the saccular glands; plentiful over the epiglottis (pitting the cartilage), the aryepiglottic folds (arytenoid glands), and in the saccule/ventricular folds.
- ▶ **Attachment:** loosely bound to the underlying cartilage/ligaments throughout most of the interior (permitting rapid oedema), but firmly adherent over the vocal ligaments and the posterior epiglottic surface/vallecula floor.

5. Nerve supply of the interior (sensory mucosa)

- ▶ **Above the vocal folds** (vestibule, ventricle, saccule): **internal laryngeal nerve** (branch of the superior laryngeal nerve, itself from the vagus) — purely sensory, also carrying taste fibres from the epiglottis.
- ▶ **At and below the vocal folds** (glottis, infraglottic cavity): **recurrent laryngeal nerve** — sensory, with an overlap zone at the level of the vocal cords themselves.
- ▶ This sensory territory underlies the intense cough reflex triggered by contact of foreign material with the laryngeal mucosa.



□ Fig 15.4 — Interior of larynx. (Sontakke — Textbook of Human Histology — 2e, p.201)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a coronal (opened posterior) view of the larynx and label:

- ▶ Epiglottis (top) and greater cornu of hyoid bone
- ▶ Thyrohyoid membrane
- ▶ Aryepiglottic fold
- ▶ Vestibular fold (with rima vestibuli between the two sides)
- ▶ Ventricle of the larynx
- ▶ Saccule of the larynx
- ▶ Vocal fold (with rima glottidis between the two sides)
- ▶ Thyroid cartilage (lateral wall)
- ▶ Cricoid cartilage
- ▶ Trachea (below)

Shade the three compartments (vestibule / ventricle-saccule / infraglottic cavity) in different colours and mark the epithelium type (squamous vs ciliated columnar) at the vocal fold versus elsewhere.

Applied / Clinical anatomy

- ▶ **Foreign body impaction:** fish bones commonly scratch the mucosa of the vallecula or piriform fossa, producing a dull visceral foreign-body sensation; large foreign bodies impacted at the laryngeal inlet can cause fatal airway obstruction, while small foreign bodies lodging in the ventricle can trigger reflex glottic closure and sudden suffocation ("café coronary").
- ▶ **Piriform fossa** ("smuggler's fossa"), lying lateral to the aryepiglottic fold between the quadrangular membrane and the thyroid cartilage, is traversed by the internal laryngeal nerve and is a recognised site for both foreign-body lodgement and, curiously, concealment of contraband.
- ▶ **Referred otalgia:** because the laryngeal mucosa and the auricle share vagal innervation (auricular branch of the vagus), laryngeal lesions (including carcinoma) commonly present with referred ear pain.
- ▶ **Reinke's oedema:** the loose superficial lamina propria deep to the vocal-fold mucosa (Reinke's space) accumulates fluid in chronic vocal abuse/smoking, producing a flabby, hoarse voice; oedema here can compromise the airway because of poor lymphatic drainage at the vocal-fold edge.
- ▶ **Singer's/teacher's nodules:** chronic vocal-fold nodules develop at the junction of the anterior one-third and posterior two-thirds of the fold — the point of maximum vibratory contact.
- ▶ **Laryngocele / saccular cyst:** herniation or mucus-filled dilatation of the saccule expands into the paraglottic space and may pierce the thyrohyoid membrane to present as a neck swelling that enlarges with raised intralaryngeal pressure (classically in trumpet players); presents with hoarseness, stridor or dysphagia.

- ▶ **Subglottic stenosis and croup:** the infraglottic mucosa is loosely attached and vascular, especially in infants, and swells readily; since the cricoid cartilage is the only complete ring in the airway, oedema here (viral laryngotracheobronchitis/croup, or post-intubation injury) produces critical, fixed narrowing of the airway — the paediatric equivalent of the adult glottis as the "danger point."
- ▶ **Laryngoscopy:** indirect/fibreoptic laryngoscopy visualises the pink vestibular folds, pearly-white vocal folds and the rima glottidis directly — the standard clinical method of examining the interior; microlaryngoscopy under the operating microscope is used for vocal-fold surgery.
- ▶ **Tumour spread and staging:** the three-part division (supraglottis/glottis/subglottis) is the basis of clinical TNM staging of laryngeal carcinoma. Glottic (vocal fold) tumours remain localised longer because vocal-fold lymphatics are sparse, giving early hoarseness with late nodal spread; supraglottic and subglottic tumours have richer lymphatics and spread more readily through the paraglottic/pre-epiglottic spaces.

High-yield exam pointers

- ▶ Laryngeal cavity = inlet → lower border of cricoid; divided by **two pairs of folds** (vestibular, vocal) into **three parts**: vestibule, ventricle+sacculae, infraglottic cavity.
- ▶ **Rima vestibuli** (between vestibular folds) vs **rima glottidis** (between vocal folds) — glottis is the narrowest part of the larynx.
- ▶ Rima glottidis = $\frac{3}{5}$ intermembranous + $\frac{2}{5}$ intercartilaginous; sagittal diameter **23 mm (male)** / **17 mm (female)**.
- ▶ **Ventricle (sinus of Morgagni)** opens anteriorly into the **sacculae** ("oil can of larynx," 60–70 glands) — vocal folds themselves have no glands.
- ▶ Epithelium: **stratified squamous** over vocal folds and friction surfaces (epiglottis tip, upper aryepiglottic fold); **ciliated pseudostratified columnar** elsewhere.
- ▶ Sensory nerve supply: **internal laryngeal nerve above** the vocal folds, **recurrent laryngeal nerve below**, with overlap at the cords.
- ▶ Cricoid cartilage = **only complete ring** in the airway → clinical basis of paediatric subglottic narrowing (croup).
- ▶ Know the applied triad: laryngocele/saccular cyst, Reinke's oedema, singer's nodules — each maps to a specific interior structure.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 8e; Vishram Singh's Textbook of Anatomy Vol 3 4e; Moore's Clinically Oriented Anatomy 9e; Sontakke's Textbook of Human Histology 2e (figure).



Internal ear

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction. The internal ear (labyrinth) is the organ of hearing and balance, lodged in the petrous part of the temporal bone. It consists of a closed system of bony cavities — the **bony (osseous) labyrinth** — lined by periosteum, within which lies a corresponding system of membranous sacs and ducts, the **membranous labyrinth**. The membranous labyrinth is filled with **endolymph**; the space between it and the bony labyrinth wall is filled with **perilymph**. The bony labyrinth has three parts — vestibule, cochlea and semicircular canals — and the membranous labyrinth has corresponding parts specialised for hearing (organ of Corti) and static/kinetic balance (maculae and cristae).

Bony (osseous) labyrinth

Part	Position	Salient features
Vestibule	Central; medial to tympanic cavity, posterior to cochlea, anterior to semicircular canals	Ovoid, flattened transversely; ~5 mm antero-posteriorly and vertically, ~3 mm across. Lateral wall: oval window (fenestra vestibuli) for the stapes footplate. Medial wall: spherical recess (saccul) and elliptical recess (utricle), separated by the vestibular crest ; crest splits below to enclose the cochlear recess . Vestibular aqueduct opens below the elliptical recess, transmitting the endolymphatic duct + a vein. Posterior wall: five openings for the three semicircular canals; anterior wall opens into the scala vestibuli.
Cochlea	Anterior-most part, in front of the vestibule	Snail-shaped; base at the fundus of the internal acoustic meatus (perforated for the cochlear nerve), apex (cupula) anterosuperior. Central conical bony core = modiolus ; the osseous spiral lamina projects from it, partially dividing the canal into scala vestibuli (above) and scala tympani (below), completed by the basilar membrane. Spirals $2\frac{3}{4}$ turns, 35 mm long uncoiled; base ~9 mm across, ~5 mm base-to-apex. The two scalae communicate at the apex via the helicotrema . Rosenthal's canal , in the modiolus, houses the spiral ganglion . The cochlear aqueduct connects the scala tympani to the subarachnoid space.

Part	Position	Salient features
Semicircular canals	Posterosuperior to the vestibule	Three — anterior (superior) , posterior , lateral (horizontal) — roughly at right angles; each describes about two-thirds of a circle, dilated at one end into an ampulla (~2× canal diameter). Anterior 15–20 mm (deep to the arcuate eminence), posterior 18–22 mm, lateral 12–15 mm. Non-ampullated ends of anterior + posterior canals unite as the crus commune (~4 mm). The lateral canals of both sides lie in one plane; the anterior canal of one side is roughly parallel to the posterior canal of the other (basis of caloric testing).

Membranous labyrinth

Lies within, and is smaller than, the bony labyrinth; the intervening perilymphatic space contains a fine vascular web. It has two major regions — the **vestibular apparatus** and the **cochlear duct**.

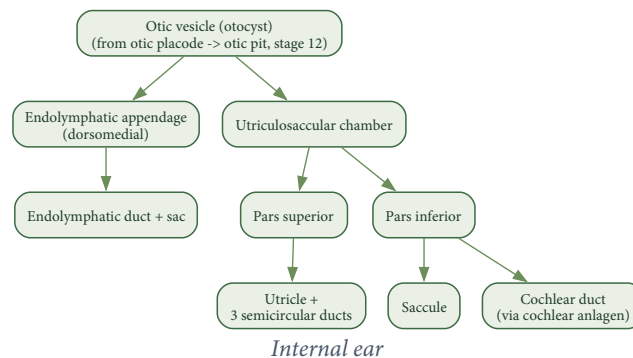
Vestibular apparatus

- ▶ **Utricle** — larger sac, occupies the elliptical recess/posterosuperior vestibule; receives the three semicircular ducts through five openings.
- ▶ **Sacculle** — smaller, globular, lies in the spherical recess; connected to the cochlear duct by the narrow **ductus reuniens**.
- ▶ Utricle and sacculle communicate via the Y-shaped **utriculosaccular duct**, which gives off the **endolymphatic duct** → dilates into the **endolymphatic sac** (lies under the dura on the posterior surface of the petrous temporal bone) — the principal site of endolymph resorption (into adjacent veins/CSF).
- ▶ **Semicircular ducts** — follow their bony canals, attached to the bony wall, about one-quarter the diameter of the osseous canal; each dilates into an **ampulla**.
- ▶ Sensory epithelia: **maculae** (utricle, sacculle) — patches of hair + supporting cells under the gelatinous **otolithic (statoconial) membrane** studded with calcium-carbonate **otoconia**; a **striola** separates pars interna/externa. Utricular macula is horizontal (horizontal linear acceleration); saccular macula is vertical (vertical acceleration/gravity). **Cristae ampullares** — one per ampulla, a ridge of hair + supporting cells capped by the gelatinous **cupula**, deflected by endolymph flow during angular head rotation.
- ▶ Hair cells: **Type I** (flask-shaped, enclosed by a chalice/calyceal afferent ending) and **Type II** (cylindrical, bouton-type endings); both bear graded stereocilia + a tall kinocilium linked by **tip links** — deflection toward the kinocilium depolarises the cell.

Cochlear duct (scala media) — triangular in cross-section, blind-ending superiorly at the **lagena** (attached to the cupula) and narrowing inferiorly into the ductus reuniens.

- ▶ Roof: thin **vestibular (Reissner's) membrane**, separating it from the scala vestibuli.

- Floor: basilar membrane (widens towards the apex), carrying the **organ of Corti** — inner and outer hair cells, inner (~6000) and outer (~4000) **pillar cells** enclosing the **tunnel of Corti**, **Deiters' cells**, all joined apically to form the **reticular lamina**; overlying the stereocilia is the gelatinous **tectorial membrane** (from interdental cells of the spiral limbus, marked by **Hensen's stripe**).
- Outer wall: **spiral ligament** and, above it, the **stria vascularis** — a vascular epithelium of marginal (dark), intermediate (light) and basal cells that generates endolymph and the +80 mV **endocochlear potential**.
- The **spiral ganglion** (bipolar neurons, in Rosenthal's canal) sends peripheral processes through the habenula perforata to the organ of Corti hair cells, and central processes that form the cochlear nerve.



□ Fig 8.119 — Bony and membranous labyrinths of internal ear (Moore — Clinically Oriented Anatomy — 9e, p.1566)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the left bony labyrinth in lateral/anterolateral view with the membranous labyrinth projected onto it, and label: **cochlea** (base, apex/cupula, 2¾ turns), **vestibule**, **oval window**, **round window**, **anterior**, **posterior** and **lateral semicircular canals** with their **ampullae**, **crus commune**; then, in a second colour for the membranous labyrinth — **utricle**, **sacculle**, **utriculosaccular duct**, **ductus reuniens**, **cochlear duct**, **endolymphatic duct** and **endolymphatic sac**, and the three semicircular ducts with their ampullae.

Fluid compartments — perilymph vs endolymph

Feature	Perilymph (bony labyrinth)	Endolymph (membranous labyrinth)
Location	Between bony wall and membranous labyrinth	Within the membranous labyrinth
Resembles	Extracellular fluid / CSF	Intracellular fluid (cytosol-like)
K ⁺	~5 mM	~150 mM
Na ⁺	~150 mM	~2 mM
Cl ⁻	~120 mM	~130 mM
Ca ²⁺	~1.5 mM	~20 µM

Feature	Perilymph (bony labyrinth)	Endolymph (membranous labyrinth)
Potential	Reference (0 mV)	~+80 mV (endocochlear potential) more positive
Source	Partly plasma filtrate (scala vestibuli), partly CSF via cochlear aqueduct (scala tympani)	Secreted by marginal cells of stria vascularis and dark cells of the vestibule
Drainage	Cochlear aqueduct → subarachnoid space; vestibular aqueduct veins	Endolymphatic sac (resorption into adjacent vascular plexus)

This ionic gradient and the endocochlear potential are essential for mechanotransduction by the hair cells; potassium is recycled from perilymph back to endolymph via gap junctions (connexins) in the spiral ligament and stria vascularis — mutations here are an important cause of hereditary hearing loss.

Blood and nerve supply

- **Arterial supply** — chiefly the **labyrinthine (internal auditory) artery**, a branch of the basilar artery (occasionally of the anterior inferior cerebellar artery, AICA); it divides at the fundus of the internal acoustic meatus into a **cochlear branch** (12–14 twigs to the spiral lamina, basilar membrane, stria vascularis and other cochlear structures) and a **vestibular branch** (to utricle, saccule, semicircular ducts). The **stylomastoid branch** of the occipital/posterior auricular artery also supplies the semicircular canals.
- **Venous drainage** — vein of the vestibular aqueduct → sigmoid or inferior petrosal sinus; vein of the cochlear aqueduct (inferior cochlear vein, formed by the common modiolar and vestibulocochlear veins) → inferior petrosal sinus or jugular bulb; an inconstant labyrinthine vein may drain to the superior petrosal or transverse sinus.
- **Nerve supply** — **vestibulocochlear nerve (CN VIII)**: emerges at the cerebellopontine angle with the facial nerve, nervus intermedius and labyrinthine vessels, enters the internal acoustic meatus, and divides into an **anterior cochlear** and a **posterior vestibular trunk**. Cochlear nerve fibres are the central processes of bipolar neurons of the **spiral ganglion** (peripheral processes to the organ of Corti); they end in the dorsal and ventral cochlear nuclei. Vestibular nerve fibres are the central processes of bipolar neurons of the **vestibular (Scarpa's) ganglion** in the internal acoustic meatus (peripheral processes to the maculae and cristae); they end in the vestibular nuclear complex, which projects to the cerebellum (via the inferior cerebellar peduncle), to ocular and spinal motor nuclei (III, IV, VI, XI) mediating the vestibulo-ocular and vestibulospinal reflexes, and via the thalamus to a cortical vestibular area near the intraparietal sulcus.

Development

The membranous labyrinth is entirely **ectodermal**. Two **otic placodes** appear lateral to the hindbrain (adjacent to rhombomeres 5–6, dorsal to the 2nd pharyngeal cleft); each invaginates as an **otic pit**, which is pinched off from the surface ectoderm to form the **otic vesicle (otocyst)**. A dorsomedial diverticulum becomes the **endolymphatic duct and sac**; the remaining **utrículosaccular chamber** differentiates into an expanded **pars superior** (utricle + 3 semicircular ducts) and a narrower **pars inferior** (saccule + cochlear duct, via a ventral outgrowth, the cochlear anlage). WNT and BMP signalling from the

surrounding mesenchyme pattern the otic placode, and retinoic acid contributes to later patterning. The **bony labyrinth** ossifies from the surrounding periotic (otic capsule) mesenchyme, closely moulded on the membranous labyrinth.

Applied / Clinical anatomy

- ▶ **Benign paroxysmal positional vertigo (BPPV)** — otoconia dislodged from the utricular macula settle in (usually) the posterior semicircular duct/ampulla, making the cupula gravity-sensitive; positional testing provokes vertigo + nystagmus. Treated by **Epley's canalith-repositioning manoeuvre** (>80% cure), which has largely replaced surgical singular neurectomy/canal occlusion.
- ▶ **Endolymphatic hydrops (Ménière's disease)** — damage to, or blockage of, the endolymphatic sac causes endolymph to accumulate, disturbing both cochlear and vestibular function (episodic vertigo, tinnitus, sensorineural hearing loss).
- ▶ **Vestibular schwannoma (acoustic neuroma)** — a Schwann-cell tumour of CN VIII, classically at the cerebellopontine angle/internal acoustic meatus; enlargement compresses the closely related facial nerve, producing combined VIIIth (deafness, vertigo) and VIIth (lower motor neurone facial palsy) nerve deficits.
- ▶ **Otosclerosis** — abnormal ossification fixing the stapes footplate/anular ligament at the oval window — the commonest cause of conductive deafness in adults.
- ▶ **Hereditary deafness** — connexin gene mutations (gap junctions of the spiral ligament/stria vascularis) impair endolymphatic K^+ recycling; melanocyte disorders (e.g., Waardenburg syndrome) affect endolymph production by the stria vascularis; tip-link protein mutations cause **Usher syndrome** (deafness + retinitis pigmentosa); fibrocyte degeneration in the spiral ligament underlies late-onset DFN3 hearing loss.
- ▶ Vascular loops of the AICA in the internal acoustic meatus have been implicated in pulsatile tinnitus.
- ▶ The scala tympani/round-window route is the surgical corridor for **cochlear implant** electrode insertion, exploiting the tonotopic (base = high frequency, apex = low frequency) organisation of the cochlear duct.

High-yield exam pointers

- ▶ Bony labyrinth = **vestibule + cochlea + semicircular canals** (perilymph); membranous labyrinth = **utricle, saccule, 3 semicircular ducts, cochlear duct** (endolymph).
- ▶ Cochlea: **$2\frac{3}{4}$ turns**, ~35 mm long, base 9 mm, apex/base height 5 mm; modiolus, osseous spiral lamina, helicotrema, Rosenthal's canal (spiral ganglion).
- ▶ Vestibule ~5 × 5 × 3 mm; oval window (stapes) laterally; spherical recess (saccule) and elliptical recess (utricle) medially.
- ▶ 3 semicircular canals set at right angles, each ~ $\frac{2}{3}$ circle, ampulla ~2× canal diameter; anterior + posterior unite as crus commune.
- ▶ Endolymph is K^+ -rich/ Na^+ -poor (cytosol-like, +80 mV endocochlear potential); perilymph is Na^+ -rich/ K^+ -poor (CSF-like) — key to hair-cell transduction.

- ▶ CN VIII splits into cochlear nerve (spiral ganglion) and vestibular nerve (Scarpa's ganglion) at the internal acoustic meatus.
- ▶ Labyrinthine artery (from basilar/AICA) is the sole arterial supply of most of the labyrinth — end-artery, vulnerable to ischaemia.
- ▶ Membranous labyrinth develops from ectodermal otic placode → otic vesicle → pars superior (utricle + SCCs) / pars inferior (sacculle + cochlear duct).
- ▶ Clinical triad to remember: BPPV (otoconia + posterior canal, Epley's), Ménière's disease (endolymphatic hydrops), vestibular schwannoma (CPA, CN VIII + VII).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 8e; Vishram Singh's Textbook of Anatomy Vol 3 4e; Moore's Clinically Oriented Anatomy 9e (figure).



Investing layer of deep cervical fascia

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction

The deep cervical fascia (fascia colli) is the condensed connective-tissue sheath that invests the muscles, vessels, viscera and glands of the neck. It is conventionally divided into an **investing (superficial) layer**, a **pretracheal layer**, a **prevertebral layer**, and the **carotid sheath**. The investing layer — also called the external/superficial layer of deep cervical fascia or *lamina superficialis* — is the most superficial of these; the name "investing" (= complete covering) reflects the fact that it forms an unbroken collar encircling the whole neck deep to the superficial fascia and platysma.

Extent and general disposition

- ▶ Lies immediately deep to platysma and the superficial fascia; encircles the entire neck like a collar.
- ▶ Interlaces in the midline with the fascia of the opposite side, both above and below the level of the hyoid bone, and blends with the aponeurotic fibres of platysma and the fascia covering the strap muscles.
- ▶ Its behaviour is best described along two axes:

Disposition	Course
Horizontal (traced from its posterior attachment round the neck)	Splits to enclose trapezius → rejoins as a single layer that roofs the posterior triangle → splits again to enclose sternocleidomastoid (SCM) → forms a single layer roofing the anterior triangle → merges with its fellow in the midline anteriorly
Vertical (traced upward from the neck)	Covers the submandibular region, splitting to enclose the submandibular gland ; posterior to this, between the mandible and mastoid process, it splits again to enclose the parotid gland

Attachments

Border	Attachment
Superior	External occipital protuberance and periosteum of the superior nuchal line, mastoid process, base of the mandible throughout its length, symphysis menti, and hyoid bone. Between the angle of the mandible and the anterior border of SCM it is particularly strong. Between the mandible and mastoid process it splits to enclose the parotid gland.
Inferior	Spine of the scapula, acromion process, clavicle, and manubrium sterni. It splits twice near this attachment (see spaces below).
Posterior	Ligamentum nuchae and the spinous process of the 7th cervical vertebra .
Anterior	Interlaces with the fascia of the opposite side in the midline, both above and below the hyoid bone.

Structures enclosed by splitting

- ▶ **Muscles** — trapezius and sternocleidomastoid (the "fasciomuscular column"/deep fascial cylinder of the neck).
- ▶ **Salivary glands**
 - **Parotid gland**: the superficial lamina (parotid fascia/parotidomasseteric fascia) is thick, dense, and attached to the zygomatic arch; the deep lamina is thin and attached to the styloid process, tympanic plate and mandible. Between the styloid process and the angle of the mandible the deep lamina thickens to form the **stylomandibular ligament**, which separates the parotid from the submandibular gland and is pierced by the external carotid artery.
 - **Submandibular gland**: the superficial lamina attaches to the lower border of the body of the mandible, the deep lamina to the mylohyoid line.
- ▶ **Potential spaces**, formed where the layer splits inferiorly:

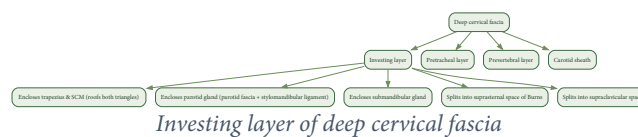
Space	Boundaries	Contents
Suprasternal space of Burns	Between the anterior layer (to anterior border of manubrium) and posterior layer (to posterior border of manubrium + interclavicular ligament), just above the manubrium	Sternal heads of both SCMs, jugular venous arch, lower ends of the anterior jugular veins, a lymph node, some fat
Supraclavicular space	Between anterior (superficial) and posterior (deep) laminae attaching to the anterior and posterior aspects of the clavicle	Part of the external jugular vein (piercing the deep fascia to drain into the subclavian vein), supraclavicular nerves, cutaneous vessels/lymphatics

- It also forms **pulleys** that bind the intermediate tendon of digastric and the intermediate tendon of omohyoid in position, forms the **roof of both the anterior and posterior triangles** of the neck, and gives rise to the stylomandibular ligament and parotidomasseteric fascia described above.
- The **accessory (XI) nerve** runs closely applied to the deep aspect of the investing layer as it crosses the posterior triangle — a key applied point (see below).

Relation to the other layers of deep cervical fascia

The investing layer is the outermost of a nested series of fascial "columns." Within the cylinder it forms lie the pretracheal fascia anteriorly (enclosing thyroid, larynx, trachea, pharynx, oesophagus — continuous inferiorly with the fibrous pericardium) and the prevertebral fascia posteriorly (covering the prevertebral and scalene muscles, continuing laterally as the axillary sheath); the carotid sheath, formed from contributions of all layers, lies between the two, enclosing the common/internal carotid artery, internal jugular vein and vagus nerve.

Layer	Also known as	Extent (brief, for contrast)
Investing	External/superficial layer, <i>lamina superficialis</i>	Encircles whole neck; encloses SCM, trapezius, parotid, submandibular gland
Pretracheal	Middle layer, visceral fascia	Anterior neck only; encloses infrahyoid muscles and thyroid/larynx/trachea/pharynx/oesophagus
Prevertebral	Deep layer, <i>lamina prevertebralis</i>	Behind pharynx/oesophagus; covers prevertebral & scalene muscles; forms axillary sheath
Carotid sheath	—	Formed from investing + pretracheal + prevertebral contributions; encloses carotid vessels, IJV, vagus



□ Fig 4.10 — ■ Investing layer of the deep cervical fascia (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.264)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a **transverse section** through the neck at the level of the 7th cervical vertebra, and label:

- ▶ Skin and superficial fascia (with platysma)
- ▶ **Investing layer of deep cervical fascia**, shown splitting to enclose SCM (anterolaterally) and trapezius (posterolaterally)
- ▶ Single-layer roof of the **posterior triangle** (between trapezius and SCM) and of the **anterior triangle** (in front of SCM)
- ▶ Pretracheal fascia enclosing strap muscles + thyroid/trachea/oesophagus (centrally)
- ▶ Prevertebral fascia over the prevertebral/scalene muscles and vertebral body (posteriorly)
- ▶ Carotid sheath (CCA, IJV, vagus) lateral to the visceral compartment
- ▶ Midline fusion of the investing layer anteriorly and posteriorly

A second small inset diagram — a **sagittal/vertical schematic** — should show the investing layer's superior attachment splitting around the parotid gland (superficial lamina to zygomatic arch, deep lamina to styloid process/tympanic plate, stylomandibular ligament between parotid and submandibular gland) and its inferior attachment splitting twice to enclose the suprasternal space of Burns and the supraclavicular space.

Applied / Clinical anatomy

- ▶ **Ludwig's angina**: Infection of the submandibular/sublingual space (usually of dental origin) is confined to a triangular area bounded by the two halves of the mandible and, posteriorly, by the hyoid bone, because of the firm attachments of the investing layer to these bony points. The resulting brawny, board-like swelling (Ludwig's angina) can push the tongue upward and backward, threatening the airway — a surgical emergency.
- ▶ **Parotid gland pain**: The superficial lamina of the investing layer forming the parotid fascia (capsule) is thick, dense and unyielding. In acute sialadenitis (e.g. mumps, calculus obstruction), the encapsulated gland cannot expand, so pressure builds within the tight capsule, stretching it and stimulating the great auricular nerve — producing severe pre-auricular pain that is characteristically worsened at mealtimes (gustatory stimulation of the gland).
- ▶ **Collar-stud abscess**: An infected deep cervical lymph node may erode through a localised weak point in the investing layer, producing two communicating collections of pus — one deep to the fascia, one superficial to it, connected by a narrow track through the fascia.
- ▶ **Fascial planes and spread of infection**: The investing layer's cleavage planes with the pretracheal and prevertebral layers restrict the spread of superficial neck infections into deep neck spaces or the mediastinum; once the layer is breached, however, infection can track along fascial planes (e.g. along the axillary sheath, or into the suprasternal space).
- ▶ **Accessory nerve vulnerability**: Because the spinal accessory nerve runs superficially, just deep to the investing layer, across the posterior triangle, it is at risk during lymph-node biopsy or surgery in this region — injury produces a winged scapula and weakness of shoulder shrug (trapezius palsy).

- ▶ **Surgical planes:** The investing layer is one of the layers deliberately incised during tracheostomy (skin → superficial fascia/platysma → investing layer → strap muscles → pretracheal fascia) and forms an important superficial surgical plane in radical/functional neck dissection, where SCM (ensheathed by the investing layer) is a key surgical landmark.
- ▶ **Suprasternal space of Burns:** Clinically relevant during low tracheostomy/mediastinoscopy, since it may contain an enlarged jugular venous arch that is at risk of injury.

High-yield exam pointers

- ▶ Also called the external/superficial layer of deep cervical fascia (*lamina superficialis*); "investing" = complete covering.
- ▶ Forms a complete collar around the neck deep to platysma; posteriorly fixed to ligamentum nuchae + spine of C7; interlaces in the midline anteriorly above and below the hyoid.
- ▶ Splits to enclose SCM and trapezius, forming the roof of both the anterior and posterior triangles.
- ▶ Splits to enclose the parotid gland (→ parotid fascia + stylomandibular ligament) and submandibular gland.
- ▶ Splits twice at its inferior attachment to create two potential spaces: **suprasternal space of Burns** (above manubrium) and **supraclavicular space** (above clavicle).
- ▶ Forms pulleys for digastric and omohyoid tendons.
- ▶ Accessory nerve lies just deep to it in the posterior triangle — vulnerable in lymph node biopsy.
- ▶ Clinically linked to Ludwig's angina, parotid abscess pain, and collar-stud abscess.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 3–4 8e; IB Singh Textbook of Anatomy Vol 3 6e; Vishram Singh Textbook of Anatomy Vol 3 4e; Moore's Clinically Oriented Anatomy 9e.



Lacrimal apparatus

Asked in: Paper I 14-Jul-2020 — RGUHS MD/MS Anatomy

Definition / Introduction — The lacrimal apparatus is the functional unit responsible for the secretion, spread and drainage of tears over the ocular surface. It comprises a **secretory component** (the main lacrimal gland with its accessory glands of Krause and Wolfring) and an **excretory/drainage pathway** (lacrimal puncta → canaliculi → lacrimal sac → nasolacrimal duct → inferior nasal meatus). It protects the cornea, provides its oxygen/nutrition, and clears debris and micro-organisms from the ocular surface.

1. Lacrimal gland — location and parts

- ▶ Lodges in the **fossa for the lacrimal gland** on the medial aspect of the zygomatic process of the frontal bone, in the superolateral part of the orbit, just within the orbital margin.

- ▶ Comma/J-shaped, almond-sized (~2 cm) **serous, tubulo-acinar gland**, divided by the lateral expansion of the aponeurosis of **levator palpebrae superioris** into:
 - **Orbital part** — larger, lies above LPS and (laterally) above lateral rectus; upper surface related to orbital periosteum, anterior border to the orbital septum, posterior border to orbital fat.
 - **Palpebral part** — about one-third the size, lies below the LPS aponeurosis in the lateral part of the upper lid, extending to the superior conjunctival fornix; visible on everting the lid.
- ▶ The two parts are **continuous posterolaterally** around the concave lateral edge of the LPS aponeurosis (not two separate glands).
- ▶ **Accessory lacrimal glands** (Krause and Wolfring) lie near the fornices, more numerous in the upper lid; they keep the ocular surface moist even after excision of the main gland.
- ▶ Microstructure: lobulated, **tubulo-acinar** gland similar to a salivary gland; secretory acini drain into intercalated ducts; **myoepithelial cells** around acini/ducts aid expulsion of tears; interstitium is rich in plasma cells (IgA-secreting).

2. Ducts and the lacrimal drainage pathway

Structure	Length / size	Key points
Excretory ducts of gland	8–12 (about a dozen)	Discharge into the lateral part of the superior conjunctival fornix ; ducts of the orbital part pierce/traverse the palpebral part — so excision of the palpebral part is functionally equivalent to removing the whole gland
Lacrimal puncta	—	One on each lid margin, on the summit of the lacrimal papilla , sited about one-sixth of the way along the lid margin from the medial canthus (junction of medial 1/6 and lateral 5/6)
Lacrimal canaliculus (each)	~10 mm (vertical part ~2 mm + horizontal part ~8 mm)	Widens into an ampulla at the bend; superior canaliculus is shorter/narrower than the inferior; the two almost always unite into a common canaliculus before opening into the lateral wall of the sac
Lacrimal sac	~12 mm long	Closed, laterally-flattened blind upper end; lower rounded part continues as the nasolacrimal duct; canaliculi enter near its upper end

Structure	Length / size	Key points
Nasolacrimal duct	~18 mm long	Narrowest in its middle; runs in a bony canal (maxilla + lacrimal bone + inferior nasal concha), directed downwards, backwards and a little laterally, to open in the inferior nasal meatus through an imperfect mucosal fold, the valve of Hasner (plica lacrimalis)
Total tear volume	~7 μ L (1–2 μ L precorneal film + 5–6 μ L marginal tear strips)	Secretion $\approx$ 1 mL/day; much is lost by evaporation, the rest drains via the canaliculi

- Mucosa of the sac/duct: bilaminar/pseudostratified **columnar epithelium**, ciliated in places.
- Tears reach the lacrimal lake at the medial canthus, are drawn into the puncta by **capillary action**, and pumped along by the **lacrimal part of orbicularis oculi** ("lacrimal pump"), which is attached to the sac; its contraction on blinking alternately expands and compresses the sac, sucking fluid in and expelling it towards the duct.

□ Fig 3.25 — Lacrimal apparatus (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.239)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- Orbital part of lacrimal gland; Palpebral part of lacrimal gland
- Levator palpebrae superioris (tendon indenting the gland)
- Excretory ducts of lacrimal gland
- Conjunctival sac
- Lacrimal punctum (superior and inferior); Lacrimal canaliculus
- Lacrimal sac
- Nasolacrimal duct
- Lacrimal fold / valve of Hasner
- Opening into inferior meatus of nose

3. Relations of the lacrimal sac (surgical importance)

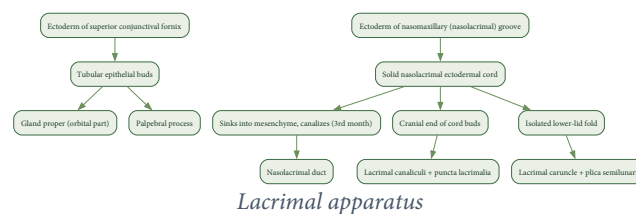
Direction	Relation
Anterior	Medial palpebral ligament (and, deep to it, the lacrimal part of orbicularis oculi)
Posterior	Lacrimal fascia and the lacrimal part of orbicularis oculi
Medial	Lacrimal groove; upper half related to the anterior ethmoidal sinuses, lower half to the anterior part of the middle meatus

Direction	Relation
Lateral	Lacrimal fascia (continuous with orbital periosteum), with a plexus of minute veins between fascia and sac

- ▶ The sac lies in the **lacrimal fossa**, bounded in front by the **anterior lacrimal crest of the maxilla** and behind by the **posterior lacrimal crest of the lacrimal bone** — the crests and fossa are the surgical landmark for **dacryocystorhinostomy (DCR)**.

4. Development

- ▶ **Lacrimal gland**: the ectodermal epithelium of the **superior conjunctival fornix** proliferates into tubular buds forming two groups — one for the **gland proper**, the other for its **palpebral process**.
- ▶ **Lacrimal sac and nasolacrimal duct**: arise from surface ectoderm in the **nasomaxillary/nasolacrimal groove** (between the lateral nasal process and the maxillary process). This ectoderm thickens into a **solid nasolacrimal cord**, which sinks into the mesenchyme and **canalizes in the 3rd month** to form the duct.
- ▶ **Lacrimal canaliculi** bud off the **cranial end** of the cord and establish openings (**puncta lacrimalia**) on the lid margins; the inferior canaliculus isolates a small part of the lower lid that forms the **lacrimal caruncle** and **plica semilunaris**.



5. Vascular supply and lymphatic drainage

- ▶ **Artery**: **lacrimal branch of the ophthalmic artery**; the gland may also receive a twig from the **infra-orbital artery**.
- ▶ **Vein**: drains into the **superior ophthalmic vein**.
- ▶ **Lymphatics**: with the lateral halves of the eyelids and conjunctiva, drainage is to the **preauricular (superficial parotid) lymph nodes**.

6. Nerve supply — the lacrimation reflex

- ▶ **Sensory supply**: **lacrimal nerve** (branch of the ophthalmic nerve, CN V1).
- ▶ **Secretomotor (parasympathetic) pathway**:
 - Preganglionic fibres arise from the **lacrimal nucleus (superior salivatory nucleus)** in the pons → travel in the **nervus intermedius** of the facial nerve → **geniculate ganglion** → **greater petrosal nerve** → join deep petrosal (sympathetic) to form the **nerve of the pterygoid canal** → relay in the **pterygopalatine ganglion**.
 - Postganglionic fibres pass via the **maxillary nerve** → **zygomatic nerve** → **zygomaticotemporal branch** → **communicating branch** → **lacrimal nerve** to reach the gland.

- ▶ **Sympathetic** fibres arise from the **superior cervical ganglion**, reach the pterygopalatine ganglion via the **deep petrosal nerve** (pass through without synapsing), and modulate glandular blood flow/secretion.
- ▶ **Reflex arc**: afferent limb via branches of the ophthalmic nerve (with an infraorbital nerve contribution from the lower-lid conjunctiva) on conjunctival/corneal irritation → central connections in the brainstem → efferent parasympathetic outflow as above. Emotional lacrimation occurs via higher (limbic) connections without ocular irritation.

□ Fig 14.14 — Innervation of the lacrimal gland (IB Singh — *Textbook of Human Neuroanatomy*, p.234)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

- ▶ Lacrimary nucleus (pons) — Trigeminal nerve, Facial nerve (labelled at the brainstem)
- ▶ Nervus intermedius → Geniculate ganglion → Greater petrosal nerve
- ▶ Nerve of the pterygoid canal → Pterygopalatine ganglion (site of relay)
- ▶ Maxillary nerve → Zygomatic nerve → Lacrimal nerve
- ▶ Lacrimal gland
- ▶ Use a solid line for preganglionic and a dashed line for postganglionic parasympathetic fibres

Applied / Clinical anatomy

- ▶ **Epiphora** (overflow of tears onto the cheek) results from: (i) hyperlacrimation (irritation, emotion, spicy food), (ii) obstruction anywhere along the punctum–canaliculus–sac–duct pathway, or (iii) **ectropion** of the lower lid (senile or facial-palsy related), which turns the punctum away from the lacrimal lake so tears can no longer be aspirated.
- ▶ **Dacryocystitis** — inflammation of the lacrimal sac, usually secondary to **obstruction/stenosis of the nasolacrimal duct**; may be acute, chronic, or congenital, and predominantly affects older individuals.
- ▶ **Congenital nasolacrimal duct atresia** — failure of canalization of the nasolacrimal cord; causes clinically obstructive symptoms in roughly **6% of neonates**, usually from a persistent membrane at the valve of Hasner; most resolve with lacrimal-sac massage, a minority need probing.
- ▶ **Dacryocystorhinostomy (DCR)** — the surgical bypass procedure for a blocked nasolacrimal duct, creating a new osteotomy between the lacrimal sac and the middle meatus of the nose; success depends on the surgical relations of the sac (anterior/posterior lacrimal crests, ethmoidal sinuses medially).
- ▶ **Traumatic canalicular laceration** (e.g. lid tears near the medial canthus) requires microsurgical approximation of the cut ends, or DCR if repair fails.
- ▶ **Bell's palsy** (facial nerve palsy proximal to the geniculate ganglion) reduces lacrimal secretion, since the preganglionic parasympathetic (greater petrosal) fibres are interrupted; artificial tears are used to prevent corneal desiccation — a useful localising sign together with loss of taste (chorda tympani) and hyperacusis (nerve to stapedius).
- ▶ **Sjögren's syndrome** — chronic autoimmune destruction of the lacrimal (and salivary) glands producing **keratoconjunctivitis sicca** (dry eye).

- ▶ The **lacrimal fossa** in the lacrimal bone is thin and closely related to the **anterior ethmoidal sinuses** and **nasal cavity**, so sinonasal or facial (nasoethmoidal) fractures may involve the lacrimal system, sometimes with traumatic telecanthus.

High-yield exam pointers

- ▶ Gland is comma/J-shaped; orbital + palpebral parts continuous around the lateral border of the LPS aponeurosis — NOT two separate glands.
- ▶ Ducts of the orbital part traverse the palpebral part → excising the palpebral part removes the whole gland functionally.
- ▶ Canaliculus ≈ 10 mm (2 mm vertical + 8 mm horizontal); sac ≈ 12 mm; duct ≈ 18 mm — classic "10-12-18" numbers.
- ▶ Valve of Hasner guards the lower opening of the nasolacrimal duct in the inferior meatus.
- ▶ Lacrimal sac develops from a solid ectodermal cord in the nasolacrimal groove, canalizing in the 3rd month; canaliculi bud from its cranial end.
- ▶ Secretomotor pathway: lacrimatory nucleus → nervus intermedius → greater petrosal nerve → nerve of pterygoid canal → pterygopalatine ganglion (relay) → zygomatic → zygomaticotemporal → lacrimal nerve → gland.
- ▶ Relations of the sac (ant./post./med./lat.) are the anatomical basis of DCR surgery.
- ▶ Epiphora = hypersecretion, obstruction, or ectropion; Dacryocystitis = inflamed sac from NLD obstruction.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3–4 8e; Vishram Singh — Textbook of Anatomy Vol 3 4e; IB Singh — Textbook of Anatomy Vol 3 6e and Textbook of Human Neuroanatomy; Moore — Clinically Oriented Anatomy 9e; Moore — The Developing Human 9e; Ross Histology — A Text and Atlas 7e.



Lateral wall of nasal cavity

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction — The lateral wall of the nasal cavity is the most complex and surgically important wall of the nose. It is built from seven bones and three cartilages, and its surface is thrown into three shelf-like **conchae (turbinates)** that increase mucosal surface area for warming, humidifying and filtering inspired air. Below each concha lies a **meatus** that receives the drainage openings of the paranasal sinuses and the nasolacrimal duct, which is why this wall is the anatomical basis of functional endoscopic sinus surgery (FESS) and a common site of epistaxis.

1. Skeletal framework of the lateral wall

Component	Contribution
Nasal bone	Anterosuperior bony part

Component	Contribution
Frontal process of maxilla	Anterior bony part; grooved by nasolacrimal duct
Lacrimal bone	Anterosuperior; forms part of fossa for lacrimal sac
Labyrinth of ethmoid	Gives superior and middle conchae ; forms upper/middle part
Inferior nasal concha	Independent bone (not part of ethmoid); largest concha
Perpendicular plate of palatine bone (+ orbital & sphenoidal processes)	Posterior bony part
Medial pterygoid plate of sphenoid	Posterior-most bony part

- ▶ **Cartilages:** lateral nasal (upper) cartilage, major alar (lower) cartilage, and 3–4 small cartilages of the ala.
- ▶ The lower, cuticular part of the wall is fibrofatty tissue covered by skin.
- ▶ The wall separates the nasal cavity from the **orbit** above (via ethmoidal air cells), the **maxillary sinus** below, and the **lacrimal sac/nasolacrimal duct** in front.

2. Three regions of the lateral wall

- ▶ **Vestibule** — anterior, dilated part just inside the naris; lined by skin bearing stiff curved hairs (**vibrissae**) that filter coarse particles.
- ▶ **Atrium of the middle meatus** — a shallow depression above the vestibule, limited above by the **agger nasi**, a low mucosal ridge running forward and down from the anterior end of the middle concha. The curved mucocutaneous junction between vestibule and atrium is the **limen nasi**.
- ▶ **Conchae/meatus proper** — the posterior, mucosa-lined part bearing the three conchae and the meatuses beneath them.

3. Conchae (turbinates)

Concha	Origin	Size	Notes
Superior	Projection of ethmoid labyrinth	Smallest	Lies above the posterior part of the middle concha; olfactory mucosa extends onto it
Middle	Projection of ethmoid labyrinth	Intermediate	May be pneumatized (concha bullosa) or have a concave medial surface (paradoxical turbinate)
Inferior	Independent bone	Largest	Articulates with maxilla and perpendicular plate of palatine
Supreme (occasional 4th)	Ethmoid labyrinth	Rudimentary	Present in a minority; lies above the superior concha

Each concha curves inferomedially and roofs a corresponding air passage — the **meatus** — that becomes visible only once the conchae are removed.

4. Meatuses, recesses and their openings

Site	Bounded by / features	Opening(s) received
Sphenoethmoidal recess	Triangular fossa above and behind the superior concha	Opening of the sphenoidal air sinus
Superior meatus	Smallest and shortest meatus, below superior concha	Opening of the posterior ethmoidal air sinuses
Middle meatus	Bulla ethmoidalis (rounded elevation from middle ethmoidal cells) above; hiatus semilunaris (deep semicircular sulcus bounded by the uncinate process anteriorly and the bulla posteriorly) below; ethmoidal infundibulum at its anterior end	Anterior part of hiatus — frontal sinus (via fronto-nasal duct/infundibulum); middle part — anterior ethmoidal sinus ; posterior part — maxillary sinus ostium (often a second, accessory ostium); bulla surface — middle ethmoidal sinus
Inferior meatus	Largest meatus; lies below the inferior concha, extends almost the whole length of the wall	Opening of the nasolacrimal duct , at the junction of its anterior 1/3 and posterior 2/3, guarded by a mucosal fold — Hasner's valve

Osteomeatal complex: the region around the uncinate process, ethmoidal infundibulum, hiatus semilunaris and bulla ethmoidalis is the final common drainage pathway for the frontal, maxillary and anterior ethmoidal sinuses, and is the key surgical target in FESS. The uncinate process attaches variably — to the lateral nasal wall (~50%), the anterior cranial base (~25%), or the middle concha (~25%) — and this attachment determines whether the frontal sinus drains directly into the middle meatus or through the ethmoidal infundibulum toward the maxillary ostium.

□ Fig 9.8 — Lateral wall of the nasal cavity after removing the conchae (IB Singh — Textbook of Anatomy Vol 3 — 6e, p.168)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Lateral wall of the nasal cavity with conchae removed — label:

- ▶ Sphenothmoidal recess → opening of sphenoidal sinus
- ▶ Superior meatus → opening of posterior ethmoidal sinuses
- ▶ Bulla ethmoidalis → opening(s) of middle ethmoidal sinus
- ▶ Hiatus semilunaris (anterior, middle, posterior parts) → openings of frontal sinus, anterior ethmoidal sinus, maxillary sinus
- ▶ Uncinate process; ethmoidal infundibulum; agger nasi
- ▶ Middle meatus, inferior meatus
- ▶ Opening of nasolacrimal duct (with Hasner's valve) in inferior meatus
- ▶ Choana (posterior nasal aperture) and opening of the pharyngotympanic (auditory) tube on the lateral pharyngeal wall behind it

5. Arterial supply and venous drainage

The lateral wall is conventionally described in four quadrants:

Quadrant	Artery	Parent trunk
Anterosuperior	Anterior ethmoidal artery (assisted by posterior ethmoidal artery)	Ophthalmic artery (from internal carotid)
Anteroinferior	Branches of the facial artery	External carotid
Posterosuperior	Sphenopalatine artery	Terminal branch of maxillary artery
Posteroinferior	Branches of the greater palatine artery (pierces the perpendicular plate of palatine, ascends through the incisive fossa)	Maxillary artery

- ▶ Venous drainage forms a submucosal plexus: anteriorly to the facial vein, posteriorly to the pharyngeal venous plexus, and from the middle part to the pterygoid venous plexus.

6. Nerve supply

Quadrant / area	Nerve	Source
Anterosuperior	Anterior ethmoidal nerve	Nasociliary branch of ophthalmic (V1)
Anteroinferior	Anterior superior alveolar nerve	Infraorbital branch of maxillary (V2)
Posterosuperior	Lateral posterior superior nasal branches	Pterygopalatine ganglion (from maxillary, V2)
Posteroinferior	Nasal branches of the greater palatine nerve	Pterygopalatine ganglion (from maxillary, V2)

Quadrant / area	Nerve	Source
Upper 1/3 (special sensory)	Olfactory nerve filaments through the cribriform plate, down to the level of the superior concha	Olfactory epithelium

All general sensory fibres are ultimately branches of the trigeminal nerve; the olfactory area straddles both the lateral wall (down to the superior concha) and the septum.

7. Lymphatic drainage

- ▶ Anterior half of the lateral wall → **submandibular lymph nodes**.
- ▶ Posterior half → **retropharyngeal and upper deep cervical lymph nodes**.

Applied / Clinical anatomy

- ▶ **Allergic rhinitis** — mucosal hypertrophy over the inferior concha causes nasal blockage, sneezing and watery discharge; a classic clinical feature tested with this topic.
- ▶ **Osteomeatal complex and sinusitis/FESS** — because the frontal, maxillary and anterior ethmoidal sinuses all funnel into the narrow middle-meatus region (infundibulum/hiatus semilunaris/bulla), mucosal oedema here causes obstructive, recurrent sinusitis; endoscopic surgery is directed at re-establishing this drainage pathway.
- ▶ **Concha bullosa / paradoxical middle turbinate** — anatomical variants of the middle concha that narrow the osteomeatal complex and predispose to sinus infection; frequently seen on coronal CT/endoscopy.
- ▶ **Posterior epistaxis** — bleeding from **Woodruff's venous plexus**, situated on the lateral wall in the posterior part of the inferior meatus; fed by anastomoses of the sphenopalatine, pharyngeal, posterior nasal and posterior septal arteries. Typically seen in elderly hypertensive patients, is brisk, and often needs posterior nasal packing; swallowed blood may present as melaena.
- ▶ **Anterior epistaxis** — although Kiesselbach's/Little's area is on the septum, it receives septal branches of vessels that also supply the lateral wall (anterior ethmoidal, sphenopalatine, greater palatine), so lateral-wall vascular anatomy is examined together with septal bleeding.
- ▶ **Nasolacrimal duct obstruction / dacryocystitis** — related to a persistent or imperforate Hasner's valve at the inferior meatus opening, causing epiphora and lacrimal sac infection.
- ▶ **Rhinoscopy** — anterior rhinoscopy (via the naris) shows the middle and inferior conchae/meatuses, septum and floor; posterior rhinoscopy (via the pharynx) shows the choanae, conchae and the posterior septal border.
- ▶ **Turbinate surgery** — inferior turbinate reduction (for chronic hypertrophic rhinitis) and middle turbinate surgery must respect the mucosal blood supply and the osteomeatal complex to avoid iatrogenic sinusitis or atrophic rhinitis.

High-yield exam pointers

- ▶ Three conchae (superior, middle from ethmoid labyrinth; inferior an independent bone) with three meatuses beneath them; occasional 4th — concha suprema.

- ▶ Sphenothmoidal recess → sphenoidal sinus; superior meatus → posterior ethmoidal sinus; middle meatus → frontal, anterior ethmoidal and maxillary sinuses (via hiatus semilunaris/bulla); inferior meatus → nasolacrimal duct (Hasner's valve).
- ▶ Middle meatus components: agger nasi, bulla ethmoidalis, hiatus semilunaris, ethmoidal infundibulum, uncinate process — the "osteomeatal complex," key to FESS.
- ▶ Arterial supply by four quadrants: anterosuperior (anterior ethmoidal), anteroinferior (facial), posterosuperior (sphenopalatine), posteroinferior (greater palatine).
- ▶ Nerve supply mirrors the same quadrants via ophthalmic (V1) and maxillary (V2) divisions of trigeminal; olfactory nerve supplies the upper third (down to superior concha).
- ▶ Woodruff's plexus (posterior inferior meatus) = classic site of posterior epistaxis in the elderly; Kiesselbach's plexus is on the septum.
- ▶ Venous drainage: anterior → facial vein; posterior → pharyngeal plexus; middle → pterygoid plexus.
- ▶ Lymphatics: anterior half → submandibular nodes; posterior half → retropharyngeal/deep cervical nodes.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3–4 8e; Vishram Singh — Textbook of Anatomy Vol 3 4e; IB Singh — Textbook of Anatomy Vol 3 6e (figure); Moore's Clinically Oriented Anatomy 9e.



Middle ear

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The middle ear (tympanic cavity, tympanum) is a narrow, air-filled, mucosa-lined space in the petrous part of the temporal bone, interposed between the external ear (tympanic membrane laterally) and the internal ear (medially). It communicates anteriorly with the nasopharynx through the auditory (pharyngotympanic) tube and posteriorly with the mastoid antrum and air cells through the aditus ad antrum. It houses the chain of three auditory ossicles — malleus, incus and stapes — together with two small muscles, nerves (chorda tympani, tympanic plexus) and vessels, and its essential function is to transmit and amplify sound vibrations from the tympanic membrane to the perilymph of the internal ear at the fenestra vestibuli.

1. Location, subdivisions and dimensions

- ▶ Situated in the petrous temporal bone; shaped like a biconcave lens/cube compressed side-to-side — lateral and medial walls are large and nearly parallel, the intervening walls (roof, floor, anterior, posterior) are narrow.
- ▶ Subdivided into three parts:
 - **Epitympanum (attic/epitympanic recess)** — above the level of the tympanic membrane; contains the head of malleus and the body and short process of incus.

- **Mesotympanum (tympanic cavity proper)** — opposite the tympanic membrane.
 - **Hypotympanum** — in the floor, between the jugular bulb and the lower margin of the tympanic membrane.
- Dimensions: vertical and anteroposterior diameters are each ~15 mm; transverse diameter is 6 mm at the roof, 4 mm at the floor, narrowing to only 2 mm opposite the umbo (centre) — hence its biconcave, "pistol-shaped" profile.
- Communications: anteriorly with the nasopharynx via the auditory tube (equalizes air pressure across the tympanic membrane, drains mucus by ciliary transport); posteriorly with the mastoid antrum and air cells via the aditus. In the popular "pistol" analogy — the tympanic cavity is the trigger, the auditory tube the outlet, and the aditus + antrum the handle.
- Mucosa lining the cavity invests all contents and raises vascular folds, giving the interior a honeycombed appearance.

2. Boundaries of the tympanic cavity

Wall	Alternative name	Key features
Roof	Tegmental wall	Thin plate of bone, the tegmen tympani , separating cavity from the middle cranial fossa; continued forward as roof of the canal for tensor tympani. In children the petrosquamous suture is unossified — direct contact with the meninges; in adults it transmits a vein to the superior petrosal sinus.
Floor	Jugular wall	Thin bony plate separating the cavity from the superior bulb of the internal jugular vein; may be deficient, leaving only mucosa + fibrous tissue. Bears the tympanic canaliculus transmitting the tympanic branch of the glossopharyngeal nerve.
Anterior	Carotid wall	Narrow (medial and lateral walls converge here). Upper part opens into the canal for tensor tympani; below it, the opening of the auditory tube; lowest part is a thin plate forming the posterior wall of the carotid canal, perforated by caroticotympanic nerves and the tympanic branch of the internal carotid artery. The septum between the tensor tympani and auditory-tube canals continues back on the medial wall as the processus cochleariformis , a pulley for the tensor tympani tendon.

Wall	Alternative name	Key features
Posterior	Mastoid wall	Wider above than below. Bears (top to bottom) the aditus to the mastoid antrum; the fossa incudis (lodges the short process of incus); the pyramid (hollow projection housing stapedius, pierced at its apex for the stapedius tendon); and, lateral to the pyramid, the posterior canaliculus for chorda tympani .
Lateral	Membranous wall	Formed mainly by the tympanic membrane with its tympanic ring/sulcus, and partly (in the epitympanic region) by squamous temporal bone. Near the tympanic notch lie the petrotympanic fissure (lodges the anterior process of malleus, transmits the anterior tympanic artery) and the anterior canaliculus for chorda tympani .
Medial	Labyrinthine wall	The promontory (bulge of the basal turn of cochlea), grooved by the tympanic plexus; fenestra vestibuli (oval window, closed by the stapes footplate); fenestra cochleae (round window, closed by the secondary tympanic membrane); the prominence of the facial nerve canal running above the fenestra vestibuli to the aditus, then descending in the posterior wall; the prominence of the lateral semicircular canal ; and the sinus tympani , a depression behind the promontory.

3. Contents of the middle ear

- ▶ Three auditory ossicles — malleus, incus, stapes.
- ▶ Two synovial joints between the ossicles.
- ▶ Two muscles — tensor tympani and stapedius.
- ▶ Nerves — chorda tympani and the tympanic plexus.
- ▶ Vessels supplying and draining the cavity.
- ▶ Air (continuous with the auditory tube and mastoid air-cell system).

Auditory ossicles

Ossicle	Parts	Distinguishing points
Malleus (hammer) — largest, most lateral	Head (in epitympanic recess, articulates with incus), neck, handle/manubrium (fused to the tympanic membrane down to the umbo), anterior process (tethered to petrotympanic fissure by the anterior ligament), lateral process (gives attachment to the malleolar folds)	Handle firmly attached to the medial surface of the tympanic membrane; tensor tympani inserts near the root of the handle.
Incus (anvil) — resembles a premolar tooth with two roots	Body (saddle facet for the malleus head), long process (descends parallel to the malleus handle, ends in the lenticular process articulating with the stapes head), short process (tethered in the fossa incudis)	The long process has a single nutrient vessel with no collateral supply — vulnerable to aseptic necrosis after middle-ear infection.
Stapes (stirrup) — smallest, most medial	Head, neck (stapedius tendon inserts posteriorly), two crura (anterior — shorter, less curved; posterior — longer), footplate/base	Footplate occupies the fenestra vestibuli, held by the annular ligament — the site of fixation in otosclerosis .

- **Joints:** incudomalleolar joint (saddle type) and incudostapedial joint (ball-and-socket) — both synovial, stabilised by accessory ligaments (three for the malleus, one each for incus and stapes).

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Ear ossicles — the articulated chain (see embedded plate below); label: **Malleus** — head, neck, anterior process, lateral process, handle (manubrium); **Incudomalleolar joint**; **Incus** — body, short process, long process, lentiform nodule; **Incudostapedial joint**; **Stapes** — head, neck, anterior crus, posterior crus, foot plate.

□ Fig 18.11 — ■ Ear ossicles. (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e*, p.795)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Medial (labyrinthine) wall of the tympanic cavity — label: **Promontory**, **Fenestra vestibuli** (with stapes footplate), **Fenestra cochleae** (with secondary tympanic membrane), **Prominence of facial nerve canal**, **Prominence of lateral semicircular canal**, **Sinus tympani**, **Pyramid** (stapedius), **Aditus to mastoid antrum**, **Processus cochleariformis**.

4. Muscles of the middle ear

Muscle	Situation / course	Insertion	Nerve supply	Action	Arch of origin
Tensor tympani	Bony canal above the auditory tube; tendon bends around the processus cochleariformis pulley	Handle of malleus	Nerve to medial pterygoid (mandibular division of trigeminal), passing through the otic ganglion without relay	Draws the malleus handle medially, tenses the tympanic membrane, pushes the stapes footplate more tightly into the fenestra vestibuli	First (mandibular) branchial arch mesoderm
Stapedius	Bony canal within the pyramid on the posterior wall; tendon emerges at the apex of the pyramid	Posterior surface of the neck of stapes	Facial nerve (branch given off in the facial canal)	Damps the ossicular chain, opposes tensor tympani; paralysis → hyperacusis	Second (hyoid) branchial arch mesoderm

- Both muscles contract reflexly (**stapedial/tensor tympani reflex**) in response to loud sound and just before speech, damping excessive ossicular movement and protecting the internal ear; afferent limb via the cochlear (VIII) pathway, efferent limb via facial (stapedius) and mandibular (tensor tympani) nerves.
- Net effect of the ossicular lever + area ratio between the tympanic membrane and the stapes footplate: sound intensity is boosted roughly **tenfold** across the middle ear, with no change in frequency.

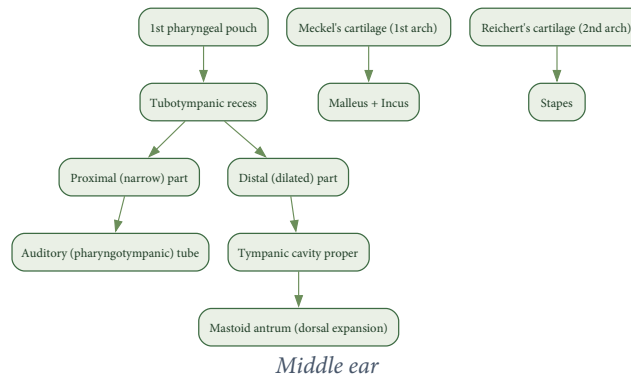
5. Nerve supply and vascular supply

- **Tympanic plexus**, lying on the promontory, is formed chiefly by the **tympanic branch of the glossopharyngeal nerve** (nerve of Jacobson), whose fibres supply the mucosa of the middle ear, auditory tube, mastoid antrum and air cells, and which also gives off the **lesser petrosal nerve** (to the otic ganglion). The plexus additionally receives the **superior and inferior caroticotympanic nerves** from the sympathetic plexus around the internal carotid artery — vasomotor to the mucosa.

- ▶ **Chorda tympani** (a branch of the facial nerve) crosses the medial surface of the tympanic membrane between the neck of the malleus and the long process of the incus; it enters through the posterior canaliculus and leaves through the anterior canaliculus at the medial end of the petrotympanic fissure to join the lingual nerve (taste, anterior two-thirds of tongue; secretomotor to submandibular and sublingual glands). Its variable, superficial course makes it liable to injury during myringotomy, stapes surgery and mastoid surgery.
- ▶ **Arterial supply:** anterior tympanic branch (of the maxillary artery, entering via the petrotympanic fissure); posterior tympanic branch (of the stylomastoid artery, via the stylomastoid foramen); petrosal and superior tympanic branches (of the middle meningeal artery); branches of the ascending pharyngeal artery; tympanic branches of the internal carotid artery.
- ▶ **Venous drainage:** superior petrosal sinus and pterygoid venous plexus.
- ▶ **Lymphatic drainage:** preauricular and retropharyngeal nodes.

6. Mastoid antrum, air cells and development

- ▶ The **mastoid antrum** is a small air space (~10 mm diameter, capacity ~1 mL) in the petrous temporal bone, already of near-adult size at birth. Boundaries: roof — tegmen tympani (middle cranial fossa/temporal lobe beyond); floor — mastoid process with air cells; anterior — aditus (related medially to the ampullae of the superior and lateral semicircular canals); posterior — thin plate separating it from the sigmoid sinus; medial — petrous temporal bone; lateral — squamous temporal bone corresponding to the **suprameatal (Macewen's) triangle**, a surgical landmark, only 2 mm thick at birth but thickening ~1 mm/year to 12–15 mm in the adult.
- ▶ **Mastoid air cells** are variable intercommunicating spaces that develop within the mastoid process after birth, extending occasionally into the squamous or petrous parts of the temporal bone.
- ▶ **Development:** the first pharyngeal pouch forms the tubotympanic recess — its narrow proximal part becomes the auditory (pharyngotympanic) tube, and its dilated distal part becomes the tympanic cavity proper; the mastoid antrum forms as its dorsal expansion. The malleus and incus ossify from the dorsal end of Meckel's cartilage (first/mandibular arch); the stapes ossifies from the dorsal segment of the hyoid-arch (second-arch/Reichert's) cartilage — consistent with tensor tympani (first-arch, trigeminal supply) and stapedius (second-arch, facial supply) muscle derivation above. In the newborn the auditory tube runs an almost horizontal course, becoming more oblique (downward, forward and medial) only with growth — a key reason young children are prone to ascending middle-ear infection.



Applied / Clinical anatomy

- ▶ **Otitis media** — ascending infection from the nasopharynx via the auditory tube (more common and severe in children owing to the shorter, more horizontal infantile tube); pus may burst laterally through the tympanic membrane, or spread: upward through the tegmen tympani/unossified petrosquamous suture (meningitis, temporal lobe abscess), backward via the aditus (mastoiditis), or downward through the floor (thrombophlebitis of the sigmoid sinus and internal jugular vein).
- ▶ **Otitis media with effusion ("glue ear")** — persistent middle-ear effusion from tubal obstruction, treated by myringotomy with insertion of a ventilation tube (grommet).
- ▶ **Mastoiditis / Bezold's abscess** — spread of infection along the aditus into the mastoid air cells, with risk of subperiosteal (postauricular) abscess or spread to the sigmoid sinus, temporal lobe or cerebellum; surgical drainage via the suprameatal triangle risks injuring the facial nerve as it descends anteroinferior to the antrum.
- ▶ **Otosclerosis** — bony fixation of the stapes footplate to the margin of the fenestra vestibuli, producing conductive deafness; treated by stapedectomy/stapedotomy with prosthesis.
- ▶ **Hyperacusis** — abnormal loudness perception due to stapedius paralysis, seen in facial nerve (Bell's) palsy.
- ▶ **Aseptic necrosis of the long process of incus** after middle-ear infection, owing to its single end-artery supply.
- ▶ **CSF otorrhoea** — longitudinal fracture of the middle cranial fossa breaching the tegmen tympani and rupturing the tympanic membrane.
- ▶ **Chorda tympani injury** during myringotomy, stapes surgery or mastoid surgery, owing to its variable superficial course on the tympanic membrane.
- ▶ **Congenital ossicular anomalies** contribute to conductive hearing loss when middle-ear development is disturbed.

High-yield exam pointers

- ▶ Middle ear = tympanic cavity, in the petrous temporal bone; three parts — epitympanum, mesotympanum, hypotympanum; dimensions ~15 mm (vertical/AP) and 2–6 mm transversely.
- ▶ Six walls — roof (tegmen tympani), floor (jugular wall), anterior (carotid wall, tensor tympani + auditory tube openings), posterior (mastoid wall, aditus/pyramid/fossa incudis), lateral (tympanic membrane), medial (promontory, oval and round windows, facial canal prominence).

- ▶ Contents: malleus–incus–stapes chain; tensor tympani (trigeminal, 1st arch) and stapedius (facial, 2nd arch); chorda tympani; tympanic plexus (glossopharyngeal + caroticotympanic nerves).
- ▶ Communicates anteriorly with nasopharynx (auditory tube) and posteriorly with mastoid antrum (aditus).
- ▶ Ossicular chain + area ratio amplify sound ~tenfold with no change in frequency; stapedial/tensor tympani reflex protects against loud sound.
- ▶ Develops from the 1st pharyngeal pouch (tubotympanic recess) — ossicles from Meckel's (malleus, incus) and Reichert's (stapes) cartilages.
- ▶ Clinical triad to remember: otitis media → mastoiditis (via aditus) → intracranial spread (via tegmen tympani/petrosquamous suture); otosclerosis (stapes fixation); hyperacusis (stapedius palsy); incus aseptic necrosis.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 3–4 8e (Ear chapter); Vishram Singh — Textbook of Anatomy Vol 3 4e; Langman's Medical Embryology (Sadler) 14e.



Modiolus

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction

The modiolus is the conical, spongy bony central axis of the cochlea, lying in the petrous part of the temporal bone, around which the osseous cochlear canal winds for about $2\frac{3}{4}$ turns like the thread of a screw. From it projects the osseous spiral lamina, and within it lie the neurovascular channels of the cochlea — the tractus spiralis foraminosus, Rosenthal's canal housing the spiral (cochlear) ganglion, and the vessels supplying the organ of Corti. As the neurovascular hub of the cochlea, the modiolus is central both to the physiology of hearing and to the surgical anatomy of cochlear implantation.

1. Location, Shape and Dimensions

Feature	Description
Location	Central bony core of the cochlea, the most anterior part of the bony labyrinth, embedded in the petrous part of the temporal bone
Shape	Elongated cone of spongy (cancellous) bone
Base	Broad; faces the fundus (lateral end) of the internal acoustic meatus; perforated by numerous foramina (the tractus spiralis foraminosus) for fascicles of the cochlear nerve

Feature	Description
Apex	Narrow; directed anterolaterally (and slightly inferiorly) toward the anterosuperior part of the medial wall of the tympanic cavity; overlaid by the apical turn (cupula) of the cochlear canal
Turns of cochlear canal around it	2¾ turns
Length of osseous cochlear canal	About 35 mm, coiled around the modiolus
Diameter of canal	About 3 mm at the base, progressively narrowing towards the apex
Related landmark	The bulging basal turn of the cochlear canal produces the promontory on the labyrinthine wall of the tympanic cavity

2. Osseous Spiral Lamina — the Ledge Projecting from the Modiolus

- ▶ A delicate bony ledge, the **osseous (primary) spiral lamina**, projects from the modiolus into the cochlear canal like the thread of a screw, partially dividing the canal into an upper and lower passage.
- ▶ Its free edge splits into an upper (**vestibular**) and lower (**tympanic**) lip: the thin **vestibular membrane (Reissner's membrane)** runs from the vestibular lip to the outer cochlear wall, and the **basilar membrane** runs from the tympanic lip to the outer wall — together enclosing the triangular **cochlear duct (scala media)** between the **scala vestibuli** (above) and **scala tympani** (below).
- ▶ Apically, the lamina ends in a hook-shaped **hamulus**, partly bounding the **helicotrema** — the narrow slit at the modiolar apex where the scala vestibuli and scala tympani communicate.
- ▶ A **secondary spiral lamina** projects inward from the outer cochlear wall (opposite the primary lamina in the basal turn) but does not reach the modiolus.

3. Canals Within the Modiolus

Canal	Course and content
Tractus spiralis foraminosus	Spiral tract of small foramina in the floor of the internal acoustic meatus, at the broad base of the modiolus; the fascicles for the first 1½ turns of the cochlear nerve pass through the small peripheral holes, while fibres for the apical turn pass through the single central hole
Rosenthal's canal (canalis spiralis modioli)	Formed where the small canals ascending from the tractus spiralis foraminosus enlarge and fuse; spirals within the modiolus following the course of the osseous spiral lamina; lodges the spiral (cochlear) ganglion
Habenula perforata	Numerous minute canals radiating from Rosenthal's canal outward through the osseous spiral lamina to its rim; each transmits one nerve fascicle through the foramen nervosum to the organ of Corti

Canal	Course and content
Canalis centralis modioli	The main tract continuing axially through the centre of the modiolus to the cochlear apex, carrying the trunk of the cochlear nerve and its accompanying vessels
Canaliculi perforantes	Fine accessory canaliculi in the modiolar and peripheral bone of the spiral lamina, providing a perilymph communication pathway with the scala tympani

4. Contents of the Modiolus — Spiral Ganglion and Cochlear Nerve Fibres

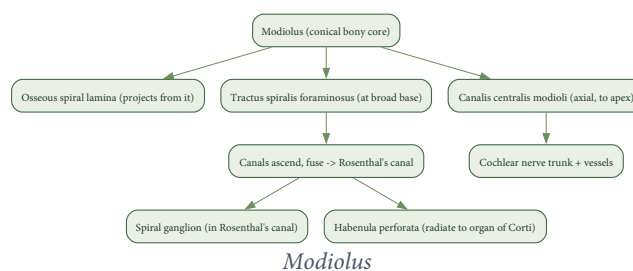
- ▶ The **spiral (cochlear) ganglion** — the cell station of the bipolar afferent neurons of hearing — lies coiled within Rosenthal's canal in the modiolus, at the base of the osseous spiral lamina.
- ▶ **Type I ganglion cells** (90–95%) are large, myelinated, bipolar neurons; each supplies peripheral dendrites to a single **inner hair cell**, with about ten Type I cells converging on each inner hair cell.
- ▶ **Type II ganglion cells** (the remaining 5–10%) are smaller and unmyelinated; each sends a peripheral process that innervates multiple **outer hair cells** (one fibre to more than ten outer hair cells — a divergent supply).
- ▶ The central processes of both cell types pass through the tractus spiralis foraminosus and unite to form the trunk of the **cochlear nerve**.
- ▶ **Efferent (olivocochlear) fibres**, arising from the superior olivary complex, enter the modiolus and form the **intraganglionic spiral bundle** at the periphery of the spiral ganglion before distributing chiefly to the outer hair cells.

5. Blood Supply

- ▶ The cochlear branch of the **labyrinthine artery** (a branch of the anterior inferior cerebellar artery, occasionally the basilar artery) divides into **12–14 twigs** that traverse the canals within the modiolus.
- ▶ These twigs form a capillary plexus supplying the spiral lamina, basilar membrane and stria vascularis.

6. Development (brief)

- ▶ The modiolus, like the rest of the bony labyrinth, forms by ossification of the cartilaginous **otic capsule** that chondrifies around the membranous labyrinth; ossification of the otic capsule occurs between the 16th and 23rd weeks of intrauterine life.



embed: ![Fig 28.4 — Section of cochlea, showing the modiolus, its spiral turns, the cochlear nerve and helicotrema. (Sontakke — Textbook of Human Histology — 2e, p.374)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/aacc67132554d012.jpg)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a radial (mid-modiolar) section through the cochlea and label:

- ▶ Petrous part of temporal bone (outer bony wall)
- ▶ **Modiolus** — central conical bony core
- ▶ Osseous (primary) spiral lamina — projecting from modiolus
- ▶ Vestibular membrane (Reissner's membrane)
- ▶ Basilar membrane
- ▶ Scala vestibuli (perilymph)
- ▶ Scala media / cochlear duct (endolymph)
- ▶ Scala tympani (perilymph)
- ▶ Organ of Corti (on basilar membrane)
- ▶ Tectorial membrane
- ▶ Spiral ganglion — within Rosenthal's canal in the modiolus
- ▶ Cochlear nerve fibres — emerging from modiolar canals
- ▶ Helicotrema — at the apex, between scala vestibuli and scala tympani

Applied / Clinical anatomy

- ▶ **Cochlear implantation:** the electrode array is passed via a cochleostomy or through the round window into the scala tympani. "**Perimodiolar**" electrode designs are shaped to hug the modiolar wall, bringing the contacts closer to the spiral ganglion dendrites in Rosenthal's canal — this improves the electrode–neural interface, lowers stimulation thresholds and reduces power consumption of the implant.
- ▶ **Pre-operative HRCT temporal bone:** the modiolus is specifically assessed before cochlear implantation. A **deficient or absent modiolus with reduced cochlear turns (fewer than the normal 2.5–2.75)** is the hallmark of **Mondini dysplasia** (an incomplete-partition cochlear malformation); it predisposes to a perilymphatic ("CSF") gusher at cochleostomy/stapedectomy and alters optimal electrode placement.
- ▶ **Sensorineural hearing loss (presbycusis, noise-induced, ototoxic):** progressive loss of spiral ganglion neurons within the modiolus parallels hair-cell degeneration and determines the residual neural population available for electrical stimulation by an implant.
- ▶ **Vestibular schwannoma / cerebellopontine-angle lesions:** compression of the cochlear nerve fascicles near the modiolar base (at the tractus spiralis foraminosus, within the internal acoustic meatus) produces a retrocochlear sensorineural hearing loss.
- ▶ **Electrocochleography:** the compound action potential recorded from the round window/promontory reflects the summed, synchronous firing of spiral ganglion neurons lying

within the modiolus — used to test cochlear nerve function intra-operatively and in auditory neuropathy work-up.

- ▶ **Otosclerosis:** cochlear (retrofenestral) otosclerotic foci can extend toward the modiolus and correlate with a greater sensorineural component of the hearing loss.

High-yield exam pointers

- ▶ Modiolus = conical, spongy bony central axis of the cochlea; cochlear canal winds around it for $2\frac{3}{4}$ turns (~35 mm long, ~3 mm diameter at base).
- ▶ Base faces the fundus of the internal acoustic meatus and is perforated by the **tractus spiralis foraminosus**; apex points anterolaterally toward the middle ear.
- ▶ **Osseous spiral lamina** projects from the modiolus like the thread of a screw, splitting into vestibular and tympanic lips that anchor the vestibular and basilar membranes.
- ▶ Canals within the modiolus fuse to form **Rosenthal's canal**, which lodges the **spiral ganglion** (Type I 90–95% → inner hair cells; Type II 5–10% → outer hair cells).
- ▶ **Habenula perforata** carries individual nerve fascicles from Rosenthal's canal to the organ of Corti.
- ▶ Cochlear branch of the labyrinthine artery gives **12–14 twigs** that traverse modiolar canals to supply the spiral lamina, basilar membrane and stria vascularis.
- ▶ Clinically pivotal in **perimodiolar cochlear implant electrodes** and in diagnosing **Mondini dysplasia** (deficient modiolus + reduced turns) on HRCT before implantation.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 3-4 8e; AK Datta Human Anatomy Vol 2 (Head & Neck); Vishram Singh Textbook of Anatomy Vol 3 4e; Moore's Clinically Oriented Anatomy 9e; Larsen Human Embryology 6e (Mondini dysplasia/otic capsule development); Sontakke Textbook of Human Histology 2e (figure).



Movements of vocal cards

Asked in: Paper I Apr 2008 — RGUHS MD/MS Anatomy

Definition / Introduction. The vocal folds (vocal cords) are paired mucosa-covered bands that stretch from the angle of the thyroid cartilage anteriorly to the vocal process of each arytenoid cartilage posteriorly, bounding the **rima glottidis** — the narrowest part of the airway. Their movements are not intrinsic to the fold itself but result from active repositioning of the mobile arytenoid cartilages at the **cricoarytenoid joints**, and from tilting of the thyroid on the cricoid at the **cricothyroid joints**, brought about by the intrinsic muscles of the larynx. These movements alter the shape and diameter of the rima glottidis for three purposes — respiration (abduction), phonation/protection (adduction, tensing, relaxing) and sphincteric closure of the laryngeal inlet.

Joints that produce the movement

Joint	Type	Movement	Effect
Cricoarytenoid joint	Synovial (elliptical, convex facets on cricoid lamina)	Combined rotation ("rocking") of the arytenoid about an axis oblique to the long axis of the cricoid facet, plus a gliding movement by which the two arytenoids approach or recede from each other	Medial rotation + medial gliding → vocal processes swing towards midline = adduction ; lateral rotation + lateral gliding → vocal processes swing apart = abduction . The two components are always coupled (Gray's Anatomy 41e)
Cricothyroid joint	Synovial	Rotation of thyroid/cricoid about a transverse axis passing through both joints ("closing the visor"), with a small gliding component	Approximates the thyroid lamina and cricoid arch; lengthens and tenses the vocal folds , provided the arytenoids are stabilised at the cricoarytenoid joint

A simple working rule (BD Chaurasia): on each arytenoid cartilage, the **vocal process and muscular process move in opposite directions** — any muscle pulling the muscular process medially swings the vocal process laterally (**abduction**); any muscle pulling the muscular process forward/laterally swings the vocal process medially (**adduction**).

Mechanism of abduction and adduction

embed: ![Fig 16.9a — Abduction of vocal cords Fig. 16.9b: Adduction of vocal cords (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.311)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/91bb46b1e8306674.jpg)

embed: ![Fig 16.9a — Abduction of vocal cords Fig. 16.9b: Adduction of vocal cords (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.311)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/bd4c2a8825244e17.jpg)

(Left plate — abduction: muscular process rotated medially/downward by posterior cricoarytenoid, vocal process swings laterally. Right plate — adduction: muscular process rotated forward/laterally by lateral cricoarytenoid, vocal process swings medially.)

Intrinsic muscles — attachments, nerve supply, action

Muscle	Origin	Insertion	Nerve supply	Principal action
Cricothyroid ("tuning-fork of the larynx"; only intrinsic muscle outside the larynx)	Lower border/lateral surface of cricoid arch	Inferior cornu and lower border of thyroid lamina	External laryngeal nerve	Tenses and lengthens the vocal folds
Posterior cricoarytenoid (PCA)	Posterior surface of cricoid lamina	Muscular process of arytenoid (posterior aspect)	Recurrent laryngeal nerve (RLN)	Only abductor of the vocal folds ("safety/life-saving muscle")
Lateral cricoarytenoid (LCA)	Upper border of cricoid arch	Muscular process of arytenoid (anterior aspect)	RLN	Adductor — medial compression of the ligamentous rima; also relaxes the fold slightly
Transverse arytenoid (single, unpaired)	Posterior surface of one arytenoid	Posterior surface of the other arytenoid	RLN	Adductor — closes the intercartilaginous (posterior) rima ("adductive tensing")
Oblique arytenoid + aryepiglotticus	Muscular process of one arytenoid	Apex of opposite arytenoid; fibres continue into aryepiglottic fold	RLN	Weak adductor of folds; sphincter of the laryngeal inlet
Thyroarytenoid + vocalis	Thyroid angle and cricothyroid ligament	Anterolateral surface of arytenoid; vocalis to vocal process/ligament	RLN	Relaxes/shortens the vocal fold; vocalis fine-tunes tension and pitch/timbre
Thyroepiglotticus (part of thyroarytenoid)	Thyroid angle	Margin of epiglottis via aryepiglottic fold	RLN	Widens the laryngeal inlet

Nerve-supply rule: every intrinsic muscle is supplied by the recurrent laryngeal nerve **except cricothyroid**, which alone is supplied by the external (motor) branch of the superior laryngeal nerve — both are branches of the vagus.

Functional (action-based) classification

Group	Muscles	Effect
Abductor	Posterior cricoarytenoid (only pair)	Widens rima glottidis
Adductors	Lateral cricoarytenoid, transverse arytenoid, oblique arytenoid	Narrow/close rima glottidis
Tensor	Cricothyroid	Lengthens and tenses the fold, raises pitch
Relaxors	Thyroarytenoid, vocalis	Shorten/relax the fold, lower pitch
Sphincter of laryngeal inlet	Oblique arytenoid, aryepiglotticus (closing); thyroepiglotticus (opening)	Protects airway during swallowing

Gray's Anatomy groups the same muscles physiologically into three sets: (i) posterior/lateral cricoarytenoid + oblique/transverse arytenoid — vary **abduction–adduction**; (ii) cricothyroid, posterior cricoarytenoid, thyroarytenoid, vocalis — regulate **length and tension**; (iii) oblique arytenoid, aryepiglotticus, thyroepiglotticus — modify the **laryngeal inlet**. Because the cricoarytenoid facets are oblique, the two functions overlap — shortening the fold also produces a degree of adduction.

Positions of the rima glottidis during different acts

embed: ![Fig 15.12 — Variations in the size and shape of rima glottidis during different (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.677)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/e988d7a0103ff88a.jpg)

- **Quiet respiration:** intermembranous (anterior) part triangular, intercartilaginous (posterior) part quadrangular — overall **pentagonal** glottis.
- **Forced inspiration:** both parts triangular; the entire rima becomes **lozenge/diamond-shaped** — vocal folds are **fully abducted** (posterior cricoarytenoid at maximum action).
- **Phonation (high-pitched voice/speech):** both folds fully adducted; the rima is reduced to a narrow **linear chink**.
- **Whispering:** the intermembranous part is closed (folds approximated anteriorly) but the intercartilaginous part remains widely open — a **funnel-shaped** glottis that allows air leak without vibration (transverse arytenoid relaxes while lateral cricoarytenoid holds the anterior folds together).
- Vocal fold **length** is 4–4.5 mm at birth and reaches about **23 mm in the adult male** and **17 mm in the adult female** — the longer, thicker male fold explains the lower pitch and laryngeal prominence.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Posterior view of the larynx with intrinsic muscles (as in the standard exam sketch):

- ▶ Outline: **thyroid cartilage lamina** (cut open posteriorly), **cricoid cartilage** (signet-ring, broad lamina behind), **arytenoid cartilages** — each with **vocal process** (anterior) and **muscular process** (lateral)
- ▶ Label **posterior cricoarytenoid** — fan-shaped, from cricoid lamina to muscular process
- ▶ Label **transverse arytenoid** — single muscle bridging both arytenoids
- ▶ Label **oblique arytenoid** — crossing X pattern superficial to transverse arytenoid, continuing as **aryepiglotticus**
- ▶ Label **lateral cricoarytenoid** (lateral/anterior view inset) — from cricoid arch to muscular process
- ▶ Add small **arrows** showing direction of pull on the muscular process and the resulting opposite swing of the vocal process (abduction vs adduction), as in the mechanism plates above
- ▶ Inset: **cricothyroid** on the outer surface of the larynx (straight + oblique fibre bundles) with arrow showing thyroid tilting towards cricoid to lengthen the fold

Applied / Clinical anatomy

- ▶ **Unilateral RLN palsy** (e.g. accidental division during thyroidectomy): the affected cord is fixed in the **paramedian position** (unopposed pull of the intact cricothyroid, which is supplied by the external laryngeal nerve). The healthy cord compensates and even crosses the midline — voice is **hoarse** but respiration is not distressed.
- ▶ **Bilateral RLN palsy**: both cords fixed in the paramedian position; patient becomes **aphonic**, with dyspnoea on exertion — may require tracheostomy.
- ▶ **Combined RLN + external laryngeal nerve palsy (bilateral)**: all intrinsic muscles including cricothyroid are paralysed, and the cords take up the **cadaveric (intermediate) position**, midway between abduction and adduction. Phonation is lost, but paradoxically the wide, immobile glottis permits relatively easier breathing than the paramedian bilateral-RLN-only picture.
- ▶ **Semon's law**: in slowly progressive/chronic compression of the recurrent laryngeal nerve (mediastinal growth, aortic aneurysm, thyroid malignancy), the **abductor (posterior cricoarytenoid)** is **paralysed before the adductors** — attributed to the more selective vulnerability of the thinner, more numerous abductor nerve fibres. This is why a cord may be found fixed near the midline even before complete nerve palsy.
- ▶ **Posterior cricoarytenoid** = "**safety muscle of the larynx**." Being the sole abductor, its bilateral paralysis leaves the adductors unopposed, closing the glottis and producing severe inspiratory stridor and dyspnoea — a laryngological emergency.
- ▶ **External laryngeal nerve injury** (e.g. during upper pole ligation in thyroidectomy) paralyses cricothyroid alone: the voice becomes weak, low-pitched and easily fatigued (loss of tensing/lengthening for high notes), though the airway is not compromised.

- ▶ **Vocal cord mobility testing** by indirect or fibre-optic laryngoscopy is a mandatory pre-operative and post-thyroidectomy check, since RLN palsy is medico-legally significant.
- ▶ **Vibrators of voice:** the vocal folds are set into vibration by the expiratory air column; pitch varies directly with the length, tension and rate of vibration of the folds (thin/tense/fast-vibrating cords → high pitch), and with mass (thicker male cords → lower pitch); loudness depends on expiratory force.
- ▶ **Singer's/screamer's nodules** occur at the junction of the anterior one-third and posterior two-thirds of the vocal fold — the point of maximum vibration amplitude during phonation.
- ▶ The true vocal folds have **no lymphatics**, making the glottis a lymphatic watershed — glottic carcinoma therefore carries the best prognosis among laryngeal cancers and spreads late.

High-yield exam pointers

- ▶ Movements of vocal folds occur at the **cricoarytenoid joint** (rotation + gliding → abduction/adduction) and **cricothyroid joint** (tilting → length/tension).
- ▶ **Posterior cricoarytenoid** is the ONLY abductor — the "safety muscle" of the larynx.
- ▶ **Lateral cricoarytenoid, transverse arytenoid and oblique arytenoid** are the adductors.
- ▶ **Cricothyroid** tenses/lengthens (raises pitch); **thyroarytenoid/vocalis** relax/shorten (lower pitch).
- ▶ **All intrinsic muscles are RLN-supplied except cricothyroid**, which alone is supplied by the external laryngeal nerve.
- ▶ Four classic glottic shapes: **pentagonal** (quiet breathing), **diamond/lozenge** (forced inspiration, full abduction), **linear chink** (phonation), **funnel-shaped** (whisper).
- ▶ **Semon's law** — abductors paralysed before adductors in gradually progressive RLN compression.
- ▶ Unilateral RLN palsy → cord paramedian, hoarse voice, normal breathing; bilateral RLN palsy → aphonia + stridor; combined (RLN + external laryngeal) bilateral palsy → cadaveric position.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 3–4 8e; AK Datta Human Anatomy Vol 2 (Head & Neck); Vishram Singh Textbook of Anatomy Vol 3 4e; Moore's Clinically Oriented Anatomy 9e (figure cross-reference).



Muscles of Mastication

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction The muscles of mastication are four **principal muscles** — temporalis, masseter, medial pterygoid and lateral pterygoid — that act on the temporomandibular joints (TMJs) to produce the movements of the mandible required for chewing (elevation, depression, protrusion, retraction and side-to-side grinding). All four develop from the mesoderm of the **first (mandibular) pharyngeal arch** and are therefore supplied by the **mandibular division of the trigeminal nerve (V3)**, the nerve of that arch. Temporalis and masseter lie superficially (temporal fossa and the lateral surface of the ramus respectively), while medial and lateral pterygoid lie deep, within the infratemporal fossa.

Shared features and development

- ▶ **Location:** all lie in or around the infratemporal fossa/ramus of the mandible.
- ▶ **Insertion:** temporalis, masseter and medial pterygoid insert onto the ramus/coronoid process; lateral pterygoid is the exception, inserting onto the **neck** of the mandible and TMJ disc/capsule.
- ▶ **Nerve supply:** all four by branches of the **mandibular nerve (V3)** — the nerve of the first arch, supplying every structure derived from it.
- ▶ **Development:** all arise from **first pharyngeal (mandibular) arch** mesoderm, migrating with the mandibular nerve.
- ▶ **Accessory muscles of mastication:** **buccinator** (facial nerve) keeps the bolus between the occlusal surfaces and prevents its accumulation in the vestibule; **digastric, mylohyoid and geniohyoid** depress the mandible when the hyoid is fixed by the infrahyoid muscles.

Temporalis

A fan-shaped muscle occupying the temporal fossa.

- ▶ **Origin:** whole floor of the temporal fossa up to the inferior temporal line (except the part formed by the zygomatic bone), and the deep surface of the temporal fascia.
- ▶ **Course/insertion:** fibres converge into a tendon that passes between the zygomatic arch and the side of the skull, to insert on the medial surface, apex and anterior/posterior borders of the **coronoid process**, and the anterior border of the ramus almost to the third molar. Anterior fibres run vertically, posterior fibres almost horizontally, intermediate fibres obliquely (fan arrangement).
- ▶ **Nerve supply:** anterior, middle and posterior **deep temporal nerves**, branches of the anterior division of the mandibular nerve.
- ▶ **Blood supply:** deep temporal branches of the maxillary artery (anterior branch supplies ~20% of the muscle anteriorly, posterior branch ~40% mid-muscle) and the middle temporal branch of the superficial temporal artery (~40% posteriorly) — an axial supply with rich intramuscular anastomoses.
- ▶ **Actions:** elevates the mandible (closes the mouth, approximates the teeth) — requires the upward pull of anterior fibres together with the backward pull of posterior fibres, since the mandibular condyle rests on the articular eminence when the mouth is open; contributes to side-to-side grinding; the almost-horizontal posterior fibres are the **only source of mandibular retrusion**, retracting a protruded mandible.

Masseter

A quadrilateral muscle of three layers that blend anteriorly, covering the outer surface of the ramus (leaving the condylar process bare).

- ▶ **Superficial layer** (largest): thick aponeurosis from the maxillary process of the zygomatic bone and anterior two-thirds of the inferior border of the zygomatic arch → fibres pass down and back to the angle and lower posterior half of the ramus; intramuscular tendinous septa here produce ridges on the bone.
- ▶ **Middle layer**: medial aspect of the anterior two-thirds of the arch and the lower border of its posterior third → central part of the ramus.
- ▶ **Deep layer**: deep surface of the zygomatic arch → upper ramus and the coronoid process; its vertical fibres are exposed just anterior to the TMJ.
- ▶ **Nerve supply**: **masseteric nerve**, from the anterior division of the mandibular nerve, entering the deep surface over the mandibular notch with the masseteric artery.
- ▶ **Blood supply**: masseteric branch of the maxillary artery, the facial artery and the transverse facial branch of the superficial temporal artery.
- ▶ **Actions**: elevates the mandible to occlude the teeth in mastication; small contribution to protraction, retraction and side-to-side movement; minimal electrical activity with the jaw at rest.

□ Fig 32.18 — Masseter and temporalis muscles (Gray's Anatomy — Standring — 41e, p.740)

Medial pterygoid

A thick quadrilateral muscle with two heads, mirroring masseter but lying medial to the ramus.

- ▶ **Deep head** (main component): medial surface of the lateral pterygoid plate of the sphenoid — deep to the lower head of lateral pterygoid.
- ▶ **Superficial head** (small): maxillary tuberosity and the pyramidal process of the palatine bone — lies on the lower head of lateral pterygoid.
- ▶ **Insertion**: by a strong tendinous lamina onto the posteroinferior part of the medial surface of the ramus and angle of the mandible, as high as the mandibular foramen.
- ▶ **Nerve supply**: the nerve to medial pterygoid, from the main (undivided) trunk of the mandibular nerve; this branch also gives a motor root to the **otic ganglion** that passes through without relay to supply tensor veli palatini and tensor tympani.
- ▶ **Blood supply**: pterygoid branches of the maxillary artery.
- ▶ **Actions**: assists elevation of the mandible; acting with lateral pterygoid, protrudes the mandible; unilateral medial + lateral pterygoid action of one side rotates the mandible forward and toward the opposite side (about a vertical axis through the opposite condyle); alternating bilateral action produces the side-to-side grinding movements used to triturate food. Medial pterygoid and masseter together form the **pterygomasseteric sling** that supports the mandibular angle.

Lateral pterygoid

A short, thick, two-headed muscle — unlike the other three, it is **not pennate** and has few Golgi tendon organs.

- ▶ **Upper head:** infratemporal surface and infratemporal crest of the greater wing of the sphenoid.
- ▶ **Lower head:** lateral surface of the lateral pterygoid plate.
- ▶ **Insertion:** both heads converge and pass backward and laterally to the **pterygoid fovea** on the front of the neck of the mandible; part of the upper head may also attach to the TMJ capsule and the anterior/medial borders of the articular disc.
- ▶ **Nerve supply:** nerves to lateral pterygoid (one per head) from the anterior division of the mandibular nerve, arising deep to the muscle — the upper head and lateral part of the lower head via a branch of the buccal nerve, the medial part of the lower head directly from the anterior trunk.
- ▶ **Blood supply:** pterygoid branches of the maxillary artery and the ascending palatine branch of the facial artery.
- ▶ **Actions:** bilateral contraction pulls both condyles forward and slightly down (protrusion), assisting mouth opening (digastric and geniohyoid remain the prime jaw-openers); unilateral contraction rotates the mandible about a vertical axis through the opposite condyle, pulling the jaw medially to the opposite side — together with the ipsilateral medial pterygoid this provides the strong medial component used in grinding. During clenching, reciprocal activity of its two heads (the lower head active in opening, the upper head in closing) stabilises the condyle against the articular eminence.
- ▶ **Key relation:** the buccal nerve and maxillary artery pass between its two heads.

□ Fig 6.5 — *The lateral and medial pterygoid muscles* (BD Chaurasia — *Human Anatomy Vol 3-4 — 8e, p.145*)

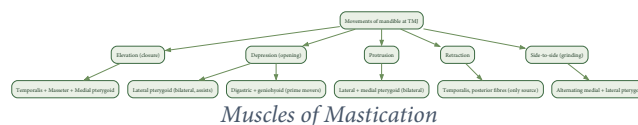
DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A lateral dissection of the infratemporal region after removal of the zygomatic arch and part of the ramus, labelled with:

- ▶ **Temporalis** — filling the temporal fossa, tendon passing deep to the zygomatic arch to the coronoid process
- ▶ **Masseter** (cut and reflected) — from zygomatic arch to the angle/ramus
- ▶ **Lateral pterygoid** — upper head (greater wing of sphenoid) and lower head (lateral pterygoid plate) converging on the pterygoid fovea of the mandibular neck
- ▶ **Medial pterygoid** — deep head (lateral pterygoid plate) and superficial head (maxillary tuberosity) to the medial ramus/angle
- ▶ **Mandibular nerve** and its branches — masseteric, deep temporal, buccal, nerve to lateral pterygoid, nerve to medial pterygoid
- ▶ **Maxillary artery** — crossing the region, giving masseteric and pterygoid branches
- ▶ **Temporomandibular joint** with condyle and articular disc

Movements at the TMJ — muscle actions

Muscle	Origin	Insertion	Nerve supply	Main action
Temporalis	Temporal fossa, temporal fascia	Coronoid process, anterior ramus	Deep temporal nn. (ant. division, V3)	Elevation (ant./mid. fibres); retraction (post. fibres — only source)
Masseter	Zygomatic arch	Angle & lateral ramus, coronoid process	Masseteric n. (ant. division, V3)	Elevation (forceful bite)
Medial pterygoid	Lateral pterygoid plate; maxillary tuberosity	Medial ramus & angle	N. to medial pterygoid (main trunk, V3)	Elevation, protrusion, grinding (with lateral pterygoid)
Lateral pterygoid	Greater wing of sphenoid; lateral pterygoid plate	Pterygoid fovea of mandibular neck; TMJ disc/capsule	N. to lateral pterygoid (ant. division, V3)	Protrusion/depression (bilateral); grinding, contralateral deviation (unilateral)



Applied / Clinical anatomy

- ▶ **Clinical testing:** motor V3 is tested by clenching the teeth while palpating masseter and temporalis bilaterally; pterygoid activity by moving the chin side-to-side.
- ▶ **Unilateral paralysis:** with one lateral pterygoid paralysed (e.g., mandibular motor root lesion), the jaw **deviates to the paralysed side** on opening, since only the normal contralateral muscle protrudes its condyle.
- ▶ **Pterygoid sign:** in TMJ dysfunction, spasm of lateral pterygoid causes tenderness on palpation behind the maxillary tuberosity, high in the buccal sulcus.
- ▶ **Submasseteric space infection:** infection from a mandibular third molar can track behind the ramus and localise deep to masseter, producing severe trismus with little visible swelling.
- ▶ **Trismus from injection:** an inferior alveolar nerve block can occasionally bleed into medial pterygoid, producing painful trismus.
- ▶ **Gillies' approach:** a depressed zygomatic arch fracture is elevated via an incision above the hairline, using the plane between temporal fascia and temporalis to lever the fragment back.
- ▶ **Muscle hypertrophy:** unilateral/bilateral masseter or temporalis hypertrophy causes cosmetic prominence; treated with botulinum toxin or surgical reduction.
- ▶ **Temporalis flap:** its axial blood supply permits use as a pedicled flap for facial reconstruction and reanimation of facial paralysis.
- ▶ **Pterygomasseteric sling:** the combined attachment of masseter and medial pterygoid at the mandibular angle resists surgical lengthening of the ramus, a consideration in orthognathic surgery.

High-yield exam pointers

- ▶ Four principal muscles — **temporalis, masseter, medial pterygoid, lateral pterygoid** — all from first (mandibular) arch mesoderm, all supplied by **mandibular nerve (V3)**.
- ▶ Lateral pterygoid is the odd one out: not pennate, inserts onto the **neck** of the mandible/TMJ disc (not the ramus), and is the principal muscle assisting jaw **opening** (protrusion) as well as grinding.
- ▶ Elevators (jaw closure): **temporalis + masseter + medial pterygoid**; protrusors: **lateral + medial pterygoid**; the only retractor: **posterior fibres of temporalis**.
- ▶ Accessory muscles of mastication: **buccinator** (facial nerve), **digastric, mylohyoid, geniohyoid** (jaw-opening accessories).
- ▶ Nerve to medial pterygoid relays a motor root through the **otic ganglion** to tensor veli palatini and tensor tympani, without synapsing.
- ▶ Clinical deviation rule: on opening, the jaw deviates **toward** the side of a paralysed lateral pterygoid/masseter.
- ▶ Applied triad to remember: **Gillies' approach** (zygomatic arch fracture), **submasseteric space infection/trismus**, and the **pterygoid sign** of TMJ dysfunction.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4, 8e; Vishram Singh — Textbook of Anatomy Vol 3, 4e; IB Singh — Textbook of Anatomy Vol 3, 6e.



Name the parts of larynx. Describe the intrinsic muscles of the larynx and their role in phonation

Asked in: Paper I Oct 2006 — RGUHS MD/MS Anatomy

Definition / Introduction The larynx is the organ of phonation and a sphincteric valve guarding the lower respiratory tract. It lies in the anterior neck opposite the C3–C6 vertebrae, opens above into the laryngopharynx, and is continuous below with the trachea. It is a cartilaginous box lined by mucosa, connected to surrounding structures and moved as a whole by **extrinsic muscles**, while its internal skeleton and vocal folds are regulated by **intrinsic muscles** — these govern the position, length and tension of the vocal folds, which are the true sound source of the voice.

1. Parts of the larynx — skeletal framework

The larynx contains **nine cartilages** — three unpaired (median) and three paired — plus an inconstant accessory pair.

Cartilage	Number	Type	Salient feature
Thyroid	1 (unpaired)	Hyaline (calcifies with age)	Largest; two laminae fuse anteriorly at ~90° (male) / ~120° (female) forming the laryngeal prominence ("Adam's apple"); superior and inferior cornua project posteriorly
Cricoid	1 (unpaired)	Hyaline (calcifies)	The only complete cartilaginous ring of the airway — signet-ring shaped, narrow arch in front, broad lamina behind
Epiglottis	1 (unpaired)	Elastic (does not calcify)	Leaf-shaped; stalk attached by the thyroepiglottic ligament to the back of the thyroid angle; guards the laryngeal inlet

Cartilage	Number	Type	Salient feature
Arytenoid	2 (paired)	Hyaline base, elastic apex/vocal process	Pyramidal; base articulates with the cricoid lamina; vocal process gives attachment to the vocal ligament, muscular process to posterior/lateral cricoarytenoid
Corniculate	2 (paired)	Elastic	Cap the arytenoid apices, lie within the aryepiglottic fold
Cuneiform	2 (paired)	Elastic	Rod-like, in the aryepiglottic fold anterosuperior to the corniculate cartilages
Cartilago triticea (accessory)	2 (inconstant)	Elastic	Small nodules in the lateral thyrohyoid ligament

Joints:

- ▶ **Cricothyroid joint** (synovial) — rotation ($\pm$ gliding) of the thyroid on the cricoid ("visor" movement) — lengthens and tenses the vocal folds.
- ▶ **Cricoarytenoid joint** (synovial) — combined rotation and gliding of the arytenoid on the cricoid facet — produces abduction/adduction of the vocal folds.
- ▶ **Arytenocorniculate joint** — small synovial/cartilaginous joint.

Ligaments and membranes:

- ▶ **Extrinsic** (larynx to neighbouring structures): thyrohyoid membrane (thickened medially as the median thyrohyoid ligament, laterally as the lateral thyrohyoid ligaments), hyoepiglottic ligament, cricotracheal ligament.
- ▶ **Intrinsic** (the fibroelastic membrane of the larynx, deep to the mucosa): **quadrangular membrane** (upper) whose free lower border forms the **vestibular ligament** (within the false/vestibular fold) and whose free upper border forms the aryepiglottic ligament; and the **conus elasticus** (lower), whose thickened median part is the cricothyroid (median cricothyroid) ligament and whose free upper edges form the **vocal ligaments** (within the true vocal fold).

Cavity of the larynx — extends from the laryngeal inlet to the lower border of the cricoid, where it becomes continuous with the trachea, and is divided by the vestibular and vocal folds into:

- ▶ **Vestibule** — laryngeal inlet down to the vestibular (false vocal) folds.
- ▶ **Ventricle and saccule** — a recess between the vestibular and vocal folds.
- ▶ **Infraglottic cavity** — vocal folds down to the cricoid, continuous with the trachea.

The gap between the vocal folds is the **rima glottidis**, made up of an anterior **intermembranous part** (between the vocal ligaments, phonatory) and a posterior **intercartilaginous part** (between the

arytenoid bases, respiratory). Clinically the larynx is divided into supraglottis, glottis and subglottis for tumour staging.

2. Muscles of the larynx — extrinsic and intrinsic

Extrinsic muscles connect a laryngeal cartilage to a neighbouring structure and move the larynx as a whole, chiefly during deglutition and phonation: the infrahyoid strap muscles (**sternothyroid**, **sternohyoid**, **thyrohyoid**), the **inferior constrictor** of the pharynx, and **stylopharyngeus** and **palatopharyngeus**. They raise or lower the larynx and thereby alter the pitch and tone of the voice, though their role in quiet respiration is minimal.

Intrinsic muscles attach one laryngeal cartilage to another and act directly on the vocal folds and the laryngeal inlet. There are seven named intrinsic muscles, all but the transverse arytenoid being paired: **cricothyroid**, **posterior cricoarytenoid**, **lateral cricoarytenoid**, **transverse arytenoid** (unpaired), **oblique arytenoid** (continuing as **aryepiglotticus**), **thyroarytenoid** (with its **vocalis** part), and **thyroepiglotticus**.

Functionally they fall into three groups:

- ▶ **Abductors/adductors of the vocal folds** (vary the rima glottidis): posterior cricoarytenoid (abductor); lateral cricoarytenoid and the oblique/transverse arytenoids (adductors).
- ▶ **Tensors/relaxers of the vocal folds** (regulate length and tension): cricothyroid and posterior cricoarytenoid (tensors); thyroarytenoid and vocalis (relaxers).
- ▶ **Muscles of the laryngeal inlet**: oblique arytenoid/aryepiglotticus (sphincter) and thyroepiglotticus (dilator).

3. Intrinsic muscles — attachments, nerve supply and action

Muscle	Attachments	Nerve supply	Main action
Cricothyroid	Arch of cricoid → inferior cornu and lower border of thyroid lamina (oblique + straight parts); the only intrinsic muscle on the <i>outer</i> aspect of the larynx	External laryngeal nerve (the only intrinsic muscle NOT supplied by the recurrent laryngeal nerve)	Tilts/glides the thyroid forward relative to the cricoid → lengthens and tenses the vocal folds → raises pitch ; chief tensor of the voice
Posterior cricoarytenoid	Posterior surface of cricoid lamina → muscular process of arytenoid	Recurrent laryngeal nerve	The only abductor of the vocal folds — the "safety muscle" of the larynx; also assists cricothyroid in tensing the folds
Lateral cricoarytenoid	Upper border of cricoid arch → muscular process of arytenoid	Recurrent laryngeal nerve	Rotates the arytenoid opposite to posterior cricoarytenoid → adducts the vocal folds (medial compression, approximates vocal processes)

Muscle	Attachments	Nerve supply	Main action
Transverse arytenoid (unpaired)	Between the posterior surfaces of the two arytenoid cartilages	Recurrent laryngeal nerve	Draws the arytenoids together → closes the intercartilaginous rima glottidis
Oblique arytenoid + aryepiglotticus	Muscular process of one arytenoid → apex of the opposite arytenoid, continuing into the aryepiglottic fold	Recurrent laryngeal nerve	Sphincter of the laryngeal inlet; weak accessory adductor of the vocal folds
Thyroarytenoid (and vocalis)	Angle of thyroid cartilage/cricothyroid ligament → anterolateral surface of arytenoid (vocalis: vocal process and vocal ligament)	Recurrent laryngeal nerve	Draws arytenoid towards thyroid → relaxes and shortens the vocal fold; vocalis makes fine adjustments of tension and mass that fix pitch and timbre
Thyroepiglotticus	Fibres of thyroarytenoid continuing into the aryepiglottic fold to the epiglottic margin	Recurrent laryngeal nerve	Widens the laryngeal inlet

□ Fig 16.10 — Muscles of larynx: Posterior view (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.312)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A posterior view of the larynx with the intrinsic muscles labelled:

- ▶ **Thyroid cartilage** (laminae, superior/inferior cornua)
- ▶ **Cricoid cartilage** (arch in front, lamina behind)
- ▶ **Arytenoid cartilages** — muscular process, vocal process, apex
- ▶ **Corniculate cartilage** capping each arytenoid apex
- ▶ **Posterior cricoarytenoid** — from cricoid lamina to muscular process
- ▶ **Lateral cricoarytenoid** — from cricoid arch to muscular process (shown on a lateral/coronal inset)
- ▶ **Transverse arytenoid** — bridging the two arytenoids
- ▶ **Oblique arytenoid** — crossing X-fashion superficial to transverse arytenoid, continuing as aryepiglotticus
- ▶ **Cricothyroid** — on the outer surface, from cricoid arch to thyroid lamina/inferior cornu
- ▶ **Vocal ligament and vocal process** — label the attachment site

Role of the intrinsic muscles in phonation

At rest during quiet respiration, the rima glottidis is held open by tonic activity of posterior cricoarytenoid. Phonation begins with the **adductors** — lateral cricoarytenoid and the oblique/transverse arytenoids — closing the glottis, while **cricothyroid and vocalis** set fold length and tension ("tensors"). Expiratory airflow then builds subglottic pressure until it forces the adducted folds

momentarily apart; the accelerated airstream through the narrowed rima glottidis lowers local pressure by the **Bernoulli effect**, which, with elastic recoil, sucks the folds back together. This adduction–blow-apart–Bernoulli-closure cycle repeats many times per second, chopping the expiratory air column into a train of puffs that is the laryngeal sound source — the **aerodynamic–myoelastic theory** of vocal fold vibration.

The three perceptual qualities of the voice are each governed by specific intrinsic muscle actions:

- ▶ **Pitch (frequency)** — determined by the length and tension of the vocal folds. **Cricothyroid** is the principal tensor, lengthening the folds by up to 50% of resting length to set the initial pitch; **vocalis**, aided by posterior cricoarytenoid, makes the finer, continuous adjustments of tension needed to hold a note. Average fundamental frequency is about 120 Hz in men, 200 Hz in women and 270 Hz in children (range 60–500 Hz).
- ▶ **Loudness (intensity)** — depends chiefly on subglottic pressure and the glottal "opening quotient" (about 0.5 in normal speech, falling to ~0.3 in loud speech); this is regulated more by the respiratory (expiratory) muscles than by the intrinsic laryngeal muscles themselves.
- ▶ **Timbre (voice quality)** — determined by the mass and stiffness of the vocal folds (chiefly the vocalis) and the resulting mucosal wave, further shaped by resonance in the supralaryngeal vocal tract (pharynx, oral and nasal cavities).

The **oblique arytenoid/aryepiglotticus** and **thyroepiglotticus** additionally regulate the laryngeal inlet — sphincteric closure aids effort closure (Valsalva, coughing, straining) and supports forceful phonation such as shouting or singing, while the extrinsic muscles raise or lower the whole larynx to modify resonance and contribute further to pitch and voice quality.

Applied / Clinical anatomy

- ▶ **Recurrent laryngeal nerve (RLN) palsy** (thyroidectomy, mediastinal/bronchogenic malignancy, aortic aneurysm on the left): unilateral injury fixes the cord **paramedian** — weak, hoarse voice, usually compensated as the mobile cord crosses midline; bilateral injury fixes both cords paramedian — aphonia with inspiratory stridor, may need tracheostomy.
- ▶ A complete high vagal lesion affecting **both superior and recurrent laryngeal nerves** fixes the cord in the **cadaveric position** (midway between abduction and adduction) — breathy, weak voice with loss of pitch control.
- ▶ **External laryngeal nerve injury** (risked during ligation of superior thyroid vessels in thyroidectomy) paralyzes cricothyroid — weak, low-pitched, easily fatigued voice ("singer's nerve").
- ▶ **Internal laryngeal nerve injury** abolishes mucosal sensation above the vocal folds, predisposing to silent aspiration.
- ▶ **Posterior cricoarytenoid**, the only abductor, is the "safety muscle"; bilateral paralysis leaves adductors unopposed — acute airway obstruction, a surgical emergency needing cricothyroidotomy/tracheostomy through the cricothyroid membrane.
- ▶ **Vocal (singer's) nodules** occur at the junction of the anterior one-third and posterior two-thirds of the vocal fold — the point of maximum vibratory amplitude — from chronic phonotrauma.

- ▶ Total **laryngectomy** for laryngeal cancer removes the intrinsic sound source; rehabilitation is by oesophageal speech, a tracheo-oesophageal valve, or an electrolarynx.
- ▶ **Subglottic stenosis** (congenital cricoid malformation or post-intubation scarring) is critical since the cricoid is the only complete airway ring.
- ▶ Puberty growth of the thyroid cartilage (especially in males) lengthens the vocal folds and lowers fundamental frequency — the voice "breaks."

High-yield exam pointers

- ▶ 9 laryngeal cartilages: 3 unpaired (thyroid, cricoid, epiglottis) + 3 paired (arytenoid, corniculate, cuneiform); cartilago triticea is an inconstant accessory pair.
- ▶ **Cricoid = only complete cartilaginous ring** of the airway.
- ▶ **Cricothyroid = only intrinsic muscle supplied by the external laryngeal nerve** (all others by the recurrent laryngeal nerve).
- ▶ **Posterior cricoarytenoid = only abductor of the vocal folds** ("safety muscle").
- ▶ **Transverse arytenoid = only unpaired intrinsic muscle.**
- ▶ Vocal ligament = free upper edge of the conus elasticus; vestibular ligament = free lower edge of the quadrangular membrane.
- ▶ Rima glottidis = intermembranous (phonatory) + intercartilaginous (respiratory) parts.
- ▶ Voice production = aerodynamic–myoelastic theory (subglottic pressure + elastic recoil + Bernoulli effect); pitch set by cricothyroid, fine-tuned by vocalis.
- ▶ Unilateral RLN palsy → paramedian cord; bilateral → paramedian + stridor; combined SLN+RLN lesion → cadaveric position.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy, Vol 3-4, 8e; Vishram Singh — Textbook of Anatomy, Vol 3, 4e; IB Singh — Textbook of Anatomy, Vol 3, 6e.



Paranasal air sinuses

Asked in: Paper I Nov 2018 — RGUHS MD/MS Anatomy

Definition / Introduction Paranasal air sinuses (PNS) are paired, mucosa-lined, air-filled diverticula of the nasal cavity that pneumatize the frontal, maxillary, ethmoidal and sphenoidal bones around the nose. They are lined by the same pseudostratified ciliated columnar (respiratory) epithelium as the nasal cavity, into which each sinus drains through a bony/mucosal ostium. They lighten the skull, warm/humidify inspired air, add resonance to the voice, and are of major surgical importance because sinusitis is one of the commonest ENT/head-and-neck conditions encountered clinically.

Classification, lining and functions

- ▶ **Four pairs:** frontal, maxillary, ethmoidal (a labyrinth of cells, not a single cavity) and sphenoidal — named after the bone each occupies.

- ▶ All develop as **mucosal outpouchings of the nasal cavity that invade the adjoining bone**; hence all are lined by **respiratory (pseudostratified ciliated columnar) epithelium** continuous with that of the nasal cavity, with fewer goblet cells and thinner, less vascular mucosa than the nasal mucosa proper.
- ▶ **Relationship to the orbit** (surface landmark): frontal sinus — *above* the orbit; maxillary sinus — *below* the orbit; ethmoidal sinus — *medial* to the orbit; sphenoidal sinus — *behind* the orbit.
- ▶ **Functions**: reduce skull weight without loss of strength/contour; warm and humidify inspired air; add resonance to the voice (altered in sinusitis); may buttress the face during eruption of permanent teeth.
- ▶ Rudimentary or absent at birth; enlarge chiefly around 6–8 years (eruption of permanent teeth) and again after puberty; growth is by expansion of surrounding bone, and in old age by resorption of cancellous bone.

Frontal sinus

- ▶ **Site**: between the outer and inner tables of the frontal bone, deep to the medial part of the superciliary arch; a *frontal part* extends up above the medial eyebrow and an *orbital part* extends back into the medial roof of the orbit.
- ▶ **Shape/size**: triangular; right and left sinuses are rarely symmetrical (septum deviates from the midline); average height, width and antero-posterior depth are each about **2.5 cm**.
- ▶ **Drainage**: opens into the **middle meatus** at the anterior end of the hiatus semilunaris, via the **ethmoidal infundibulum** (frontonasal duct/recess) — or medial to the hiatus if the uncinate process is attached to the lateral wall.
- ▶ **Development**: absent/rudimentary at birth; the last sinus to pneumatize (from ~2 years); appreciable only after age 5; reaches adult size only after puberty; unilateral absence in ~15%, bilateral absence in ~5% of adults.
- ▶ **Vessels/nerve**: artery — supraorbital (+ anterior ethmoidal); veins — supraorbital and superior ophthalmic veins; lymphatics — submandibular nodes; nerve — supraorbital nerve (general sensation, ophthalmic division of trigeminal) + orbital branches of the pterygopalatine ganglion (secretomotor).

Maxillary sinus (antrum of Highmore)

- ▶ **Largest** paranasal sinus; occupies the body of the maxilla; **pyramidal**, base directed medially (forms much of the lateral wall of the nose), apex directed laterally into the zygomatic process.
- ▶ **Average size**: height 3.5 cm, width 2.5 cm, antero-posterior depth 3.5 cm.
- ▶ **Roof** = floor of the orbit, grooved/traversed by the infraorbital nerve. **Floor** = alveolar process of the maxilla, about 1 cm below the level of the nasal floor (corresponding to the lower border of the ala of the nose); marked by conical elevations from roots of the upper premolar/molar teeth, which may even project into the sinus beneath the mucosa.
- ▶ **Drainage**: opens high on its medial wall into the lower part of the **hiatus semilunaris** → **middle meatus**, via the **maxillary ostium**. In the intact skull the wide maxillary hiatus is reduced to 3–4 mm by the uncinate process and descending lacrimal bone above, the inferior concha below, and the perpendicular plate of the palatine bone behind — and further narrowed by nasal mucosa.

Because the ostium lies near the *roof*, gravity cannot drain the sinus; drainage depends entirely on ciliary action.

- ▶ The **first paranasal sinus to develop** (already present at birth).
- ▶ **Vessels/nerve:** arteries — facial, infraorbital and greater palatine (branches of the maxillary artery); veins — facial vein and pterygoid venous plexus; lymphatics — submandibular nodes; nerve — posterior superior alveolar branches of the maxillary nerve + anterior/middle superior alveolar branches of the infraorbital nerve (general sensation), and nasal branches of the pterygopalatine ganglion (secretomotor).

Ethmoidal sinus complex

- ▶ Numerous small, thin-walled, intercommunicating **air cells** within the ethmoidal labyrinth (classically taught in **three groups** — anterior, middle and posterior); bounded above by the orbital plate of the frontal bone (fovea ethmoidalis), laterally by the paper-thin **lamina papyracea** (poor barrier to spread of infection into the orbit), medially by the superior/middle conchae, and posteriorly by the sphenoidal conchae.
- ▶ **Anterior group** (1–11 cells) → opens into the anterior part of the **hiatus semilunaris/ethmoidal infundibulum** (middle meatus); includes the constant **agger nasi cells** anteriorly and the largest, least variable cells forming the **ethmoidal bulla**.
- ▶ **Middle group** (1–7 cells) → opens into the **middle meatus**, typically at/above the ethmoidal bulla.
- ▶ **Posterior group** (1–7 cells) → opens into the **superior meatus** (occasionally the supreme meatus); lies close to the optic canal/nerve — a **sphenoethmoidal (Onodi) cell** here is a recognised surgical hazard to the optic nerve during endoscopic surgery.
- ▶ *Note:* current international terminology (Gray's 41e) groups ethmoidal cells into only **anterior and posterior** divisions, the older "middle group" now being included with the anterior group — both schemes are described here as the topic may be examined either way.
- ▶ **Vessels/nerve:** arteries — anterior and posterior ethmoidal branches of the ophthalmic artery + nasal branches of the sphenopalatine artery; nerve — anterior ethmoidal nerve (anterior/middle cells) and posterior ethmoidal nerve (posterior cells), both ophthalmic division, plus orbital branches of the pterygopalatine ganglion (secretomotor); lymphatics — anterior group to submandibular nodes, posterior group to retropharyngeal nodes.

Sphenoidal sinus

- ▶ Paired, irregular cavities within the **body of the sphenoid**, posterior to the upper nasal cavity; separated from each other by a septum that usually deviates from the midline (unequal sinuses).
- ▶ **Average size:** vertical height 2 cm, transverse breadth 1.8 cm, antero-posterior depth 2.1 cm.
- ▶ **Drainage:** opens high on the anterior wall into the **sphenoethmoidal recess** (above the superior concha), not into a meatus.
- ▶ **Relations:** superiorly — optic chiasma and hypophysis cerebri; laterally, on each side — internal carotid artery and cavernous sinus. Pneumatization is highly variable and may partially encircle the optic canal.

- **Vessels/nerve:** arteries — posterior ethmoidal (ophthalmic) + internal carotid/sphenopalatine branches; veins — pterygoid venous plexus and cavernous sinus; lymphatics — retropharyngeal nodes; nerve — posterior ethmoidal nerve + orbital branches of the pterygopalatine ganglion.

Ostiomeatal complex — the common drainage pathway

Sinus	Site of opening	Meatus/recess
Frontal	Anterior end of hiatus semilunaris (via infundibulum)	Middle meatus
Maxillary	Lower part of hiatus semilunaris	Middle meatus
Anterior ethmoidal	Hiatus semilunaris/infundibulum	Middle meatus
Middle ethmoidal	At/above ethmoidal bulla	Middle meatus
Posterior ethmoidal	Variable apertures	Superior meatus (occ. supreme meatus)
Sphenoidal	High on anterior wall	Sphenoethmoidal recess

The **ostiomeatal complex (OMC)** — comprising the maxillary ostium, ethmoidal infundibulum and hiatus semilunaris — is the shared functional drainage channel for the maxillary sinus and anterior ethmoidal cells (and, where the uncinate process is attached to the lateral wall, the frontal sinus too); obstruction here (e.g. a large agger nasi cell, concha bullosa, deviated septum) is the commonest anatomical basis of recurrent sinusitis, and is the key target of Functional Endoscopic Sinus Surgery (FESS).

□ Fig 17.10 — Lateral wall of the nose with conchae removed showing openings of various air sinuses (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e, p.753*)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Lateral wall of the nose with conchae removed — label:

- Frontal air sinus and its opening (frontonasal duct/infundibulum)
- Bulla ethmoidalis and hiatus semilunaris
- Opening of anterior, middle and posterior ethmoidal air sinuses
- Opening of maxillary air sinus (in hiatus semilunaris)
- Sphenoidal air sinus and its opening (into sphenoethmoidal recess)
- Opening of nasolacrimal duct and of the pharyngotympanic (Eustachian) tube

Applied / Clinical anatomy

- **Sinusitis:** the maxillary sinus is most commonly involved (largest sinus, ostium lies higher than the dependent floor, so natural gravity drainage is poor and relies on ciliary action alone); infection reaches it from the nose or from a carious upper premolar/molar tooth whose root projects into the floor. Frontal sinusitis, draining through the same osteomeatal complex, often leads on to maxillary sinusitis.

- ▶ **Referred pain:** maxillary sinusitis refers pain to the upper teeth and infraorbital skin (maxillary division of trigeminal); ethmoidal/frontal sinusitis refers pain to the forehead (ophthalmic division) — both sinus groups share the trigeminal nerve's divisions with the referred area.
- ▶ **Surgical drainage of the maxillary sinus:** (i) **antral (antrum) puncture** — the lateral wall of the inferior meatus is punctured and fluid is irrigated out through the natural ostium with the head dependent; (ii) **Caldwell–Luc operation** — a permanent opening is made through the canine fossa via the oral vestibule (deep to the upper lip), bypassing the high natural ostium.
- ▶ **Spread of infection:** the middle meatus is the common drainage pathway for the frontal, maxillary and anterior ethmoidal sinuses, and the superior meatus/sphenoethmoidal recess for the posterior ethmoidal and sphenoidal sinuses; when mucociliary clearance fails, infected mucus stagnates. Dehiscences in the paper-thin **lamina papyracea** (orbit), **cribriform plate** (anterior cranial fossa) and lateral wall of the sphenoid can let infection spread by septic thrombophlebitis to the orbit, meninges/frontal lobe (abscess) and cavernous sinus (thrombosis) — a pre-antibiotic-era cause of death.
- ▶ **Carcinoma of the maxillary sinus** spreads according to the wall breached: orbital floor → proptosis/diplopia ($\pm$ infraorbital nerve palsy → facial numbness); floor → palatal bulge/ulceration; anteriorly → obliterated canine fossa/facial swelling; posteriorly → palatine nerve pain referred to the upper teeth; medially → nasal obstruction, epistaxis, epiphora; laterally → cheek swelling with a palpable labiogingival mass.
- ▶ **FESS landmarks:** the uncinate process (removed to open the infundibulum), agger nasi cell ("uncapping the egg" for frontal recess access), ethmoidal bulla, and crista ethmoidalis (a reliable landmark just anterior to the sphenopalatine foramen); a large sphenoethmoidal (Onodi) cell risks optic nerve injury during posterior ethmoidectomy.
- ▶ **Diagnosis:** transillumination and radiography (a diseased sinus appears opaque); CT is now the imaging of choice for defining anatomical variants before sinus surgery.

High-yield exam pointers

- ▶ Four pairs — frontal, maxillary, ethmoidal, sphenoidal — all lined by respiratory epithelium continuous with the nasal mucosa.
- ▶ Maxillary sinus = largest and first to develop; frontal sinus = last to develop, absent unilaterally in ~15% and bilaterally in ~5% of adults.
- ▶ Middle meatus is the common drainage pathway for frontal, maxillary and anterior/middle ethmoidal sinuses (the ostiomeatal complex).
- ▶ Posterior ethmoidal sinus drains into the superior meatus; sphenoidal sinus drains into the sphenoethmoidal recess (not a meatus).
- ▶ Maxillary sinus ostium lies near its roof, not its floor — the anatomical reason natural drainage is poor and sinusitis is commonest here.
- ▶ Two surgical drainage routes for the maxillary sinus: antral puncture (inferior meatus) and Caldwell–Luc (canine fossa).
- ▶ Lamina papyracea and cribriform plate are the thin bony barriers responsible for orbital/intracranial spread of sinus infection.

- ▶ Sphenoidal sinus relations: optic chiasma/hypophysis above, internal carotid artery/cavernous sinus laterally — vital in trans-sphenoidal pituitary surgery.
- ▶ Referred pain follows trigeminal nerve territory: maxillary sinus → upper teeth/infraorbital skin; ethmoid/frontal → forehead.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4 8e; Vishram Singh — Textbook of Anatomy Vol 3 4e; IB Singh — Textbook of Anatomy Vol 3 6e.



Pharynx

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The **pharynx** (Gk./Latin *throat*) is a **12–14 cm long musculomembranous tube** situated behind the nasal cavity, oral cavity and larynx, extending from the base of the skull above to the lower border of the cricoid cartilage below, where it becomes continuous with the oesophagus. It is a shared passage for both **air and food**, and is divided into three parts — the **nasopharynx, oropharynx and laryngopharynx** — each with a distinct function, epithelial lining and nerve supply. Its wall is built of an outer circular (constrictor) and inner longitudinal muscular coat, and it forms an integral part of the deglutition mechanism and of Waldeyer's lymphoid ring.

Location, extent, dimensions and boundaries

- ▶ **Extent:** from the base of the skull (posterior part of the body of sphenoid and basilar part of occipital bone, in front of the pharyngeal tubercle) down to the lower border of the cricoid cartilage (opposite the **6th cervical vertebra**), where it is continuous with the oesophagus.
- ▶ **Width:** widest at its upper (nasopharyngeal) end (~3.5 cm) and **non-collapsible** there; narrows through its middle; the **pharyngo-oesophageal junction is the narrowest part of the entire gastrointestinal tract** (except the vermiform appendix).
- ▶ **Boundaries:**
 - *Superior* — base of skull.
 - *Inferior* — continuous with the oesophagus at the lower border of the cricoid cartilage (C6).
 - *Posterior* — glides freely on the prevertebral fascia, which separates it from the cervical vertebral bodies (retropharyngeal space intervening).
 - *Anterior* — incomplete; opens into the nasal cavity, oral cavity and larynx in turn.
 - *On each side* — attached to the medial pterygoid plate, pterygomandibular raphe, mandible, tongue, hyoid bone, and thyroid and cricoid cartilages; communicates with the middle ear through the auditory (pharyngotympanic) tube; related to the styloid process and its muscles, and to the common, internal and external carotid arteries with their accompanying cranial nerves.

Parts of the pharynx

The pharyngeal cavity is divided into three continuous parts.

Feature	Nasopharynx	Oropharynx	Laryngopharynx
Situation	Behind the nose	Behind the oral cavity	Behind the larynx
Extent	Base of skull to soft palate	Soft palate to upper border of epiglottis	Upper border of epiglottis to lower border of cricoid cartilage
Anterior communication	Posterior nasal apertures (choanae)	Oral cavity (oropharyngeal isthmus)	Inlet of the larynx
Posterior relation	Body of sphenoid, basiocciput, anterior arch of atlas	Body of C2–C3 vertebrae	C4–C5 (partly C3, C6) vertebrae
Lateral wall	Opening of auditory tube; tubal elevation with tubal tonsil ; fossa of Rosenmüller (lateral pharyngeal recess) behind the salpingopharyngeal fold	Tonsillar fossa containing the palatine tonsil , between palatoglossal and palatopharyngeal arches	Piriform fossa on each side of the laryngeal inlet, bounded medially by the aryepiglottic fold and laterally by the thyroid cartilage/thyrohyoid membrane; the internal laryngeal nerve lies submucosally in its floor
Epithelium	Ciliated pseudostratified columnar (respiratory)	Stratified squamous non-keratinised	Stratified squamous non-keratinised
Nerve supply	Pharyngeal branch of the maxillary nerve via the pterygopalatine ganglion	Glossopharyngeal (IX) and vagus (X)	Glossopharyngeal (IX) and vagus (X)
Function	Passage for air only	Common passage for air and food	Passage for food (with the laryngeal inlet closed to air during swallowing)

Waldeyer's lymphatic ring

An incomplete ring of lymphoid aggregations guards the naso-oropharyngeal isthmus:

- **Pharyngeal (nasopharyngeal/adenoid) tonsil** — posterosuperior, in the roof/posterior wall of the nasopharynx; largest at ~5 years, regresses after puberty.
- **Tubal tonsils** (paired) — around the pharyngeal opening of the auditory tube.
- **Palatine tonsils** (paired, "the tonsils") — in the tonsillar fossa between the palatoglossal and palatopharyngeal arches; medial surface bears 12–15 crypts, the largest being the intratonsillar cleft; bed formed (deep to superficial) by pharyngobasilar fascia, superior constrictor and palatopharyngeus, buccopharyngeal fascia, styloglossus (lower part) and the glossopharyngeal nerve; supplied mainly by the **tonsillar branch of the facial artery**; drains to the **jugulodigastric node**; has efferent but **no afferent lymphatics**.
- **Lingual tonsil** — anteroinferior, over the posterior third (pharyngeal part) of the tongue.

- Mnemonic: "PPLT" — Pharyngeal, Palatine, Lingual, Tubal.

Structure of the pharyngeal wall

From within outward, the wall has five layers:

- **Mucosa**
- **Submucosa** — contains mucous glands and lymphoid tissue.
- **Pharyngobasilar fascia** (pharyngeal aponeurosis) — a fibrous sheet deep to the muscles; thickest superiorly, where it bridges the gap between the free upper border of the superior constrictor and the skull base (**sinus of Morgagni**), and posteriorly where it forms the pharyngeal raphe.
- **Muscular coat** — an outer circular layer (the three constrictors) and an inner longitudinal layer (stylopharyngeus, salpingopharyngeus, palatopharyngeus).
- **Buccopharyngeal fascia** — covers the outer surface of the constrictors and continues forward over the buccinator; the pharyngeal venous and nervous plexuses lie between it and the muscular coat.

Muscles of the pharynx

Three **circular constrictors** (arranged so that the inferior overlaps the middle, which overlaps the superior) and three **longitudinal (elevator) muscles**, all developed from the 4th and 6th pharyngeal arches.

Muscle	Origin	Insertion	Nerve supply	Action
Superior constrictor	Pterygoid hamulus, pterygomandibular raphe, posterior end of mylohyoid line of mandible, side of tongue	Median pharyngeal raphe and pharyngeal tubercle of occipital bone	Pharyngeal plexus (vagus, carrying cranial root of accessory)	Constricts upper pharynx during swallowing
Middle constrictor	Lower part of stylohyoid ligament, lesser and greater cornua of hyoid bone	Median raphe	Pharyngeal plexus	Constricts middle pharynx
Inferior constrictor — <i>thyropharyngeus</i> part	Oblique line of thyroid cartilage lamina, tendinous band over cricothyroid, inferior cornu of thyroid cartilage	Median raphe	Pharyngeal plexus ($\pm$ external laryngeal twig)	Propulsive; constricts lower pharynx
Inferior constrictor — <i>cricopharyngeus</i> part	Cricoid cartilage	Continuous with circular fibres of oesophagus	Recurrent laryngeal nerve	Sphincteric — functional upper oesophageal sphincter

Muscle	Origin	Insertion	Nerve supply	Action
Stylopharyngeus	Styloid process	Passes between superior and middle constrictors to blend with the inner aspect of the constrictors and thyroid cartilage	Glossopharyngeal nerve (IX) — the sole exception	Elevates the pharynx and larynx
Salpingopharyngeus	Cartilaginous part of the auditory tube	Blends with palatopharyngeus	Pharyngeal plexus	Elevates the pharynx; may open the auditory tube
Palatopharyngeus	Palatine aponeurosis (in the palatopharyngeal arch)	Posterior border of the thyroid cartilage lamina and the wall/raphe of the pharynx	Pharyngeal plexus	Pulls up and shortens the pharynx during swallowing

□ Fig 14.9b — Sagittal section of pharynx (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.273)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a lateral view of the pharynx (base of skull to oesophagus) and label:

- ▶ The three **constrictors** — **superior, middle and inferior** — shown overlapping (inferior over middle over superior), with the **median pharyngeal raphe** posteriorly and the **pharyngeal tubercle** of the occipital bone superiorly.
- ▶ The three **longitudinal muscles** — **stylopharyngeus** (from the styloid process), **salpingopharyngeus** (from the auditory tube) and **palatopharyngeus** (from the soft palate) — passing deep to (internal to) the constrictors.
- ▶ The four **gaps** with their contents (see table below), clearly marked at each level.
- ▶ **Hyoid bone, thyroid cartilage and cricoid cartilage** as skeletal landmarks for muscle attachments.
- ▶ **Killian's dehiscence**, marked as the weak triangular area between the thyropharyngeus and cricopharyngeus parts of the inferior constrictor.

Structures passing through gaps in the pharyngeal wall

Gap	Structures transmitted
Between skull base and free upper border of superior constrictor (sinus of Morgagni , closed by strong pharyngobasilar fascia)	Auditory tube, levator veli palatini muscle, ascending palatine artery, palatine branch of ascending pharyngeal artery
Between superior and middle constrictors	Stylopharyngeus muscle and glossopharyngeal nerve (IX)
Between middle and inferior constrictors (through the thyrohyoid membrane)	Internal laryngeal nerve and superior laryngeal vessels

Gap	Structures transmitted
Between the lower border of inferior constrictor and the oesophagus	Recurrent laryngeal nerve and inferior laryngeal vessels

Nerve supply

- ▶ Almost all motor and sensory innervation is via the **pharyngeal plexus**, lying chiefly on the outer surface of the middle constrictor, formed by:
 - ▶ The **pharyngeal branch of the vagus** (carrying fibres of the cranial root of the accessory nerve) — motor.
 - ▶ **Pharyngeal branches of the glossopharyngeal nerve** — sensory.
 - ▶ **Pharyngeal branches of the superior cervical sympathetic ganglion**.
- ▶ **Motor:** cranial accessory fibres via the vagus supply **all pharyngeal muscles except stylopharyngeus**, which is supplied by the glossopharyngeal nerve. The inferior constrictor receives additional fibres — the propulsive thyropharyngeus chiefly via the pharyngeal plexus, the sphincteric cricopharyngeus via the **recurrent laryngeal nerve**.
- ▶ **Sensory (general):** mostly via the glossopharyngeal nerve, partly via the vagus; the **nasopharynx**, however, is supplied by the **maxillary nerve** through the pterygopalatine ganglion, and the soft palate/tonsil by the lesser palatine and glossopharyngeal nerves.
- ▶ **Taste** from the vallecula and epiglottic region travels via the internal laryngeal branch of the vagus.
- ▶ **Secretomotor (parasympathetic)** fibres reach pharyngeal mucous glands via the lesser palatine branches of the pterygopalatine ganglion.

Blood supply and lymphatic drainage

- ▶ **Arteries:** ascending pharyngeal branch of the external carotid artery (main supply); ascending palatine and tonsillar branches of the facial artery; dorsal lingual branches of the lingual artery; greater palatine, pharyngeal and pterygoid branches of the maxillary artery.
- ▶ **Veins:** form a pharyngeal venous plexus on the posterolateral aspect of the pharynx (receiving also from the soft palate and prevertebral region), draining into the **internal jugular and facial veins**.
- ▶ **Lymphatics:** drain to the **retropharyngeal** and **deep cervical** lymph nodes (the palatine tonsil in particular to the **jugulodigastric node**).

Role in deglutition

The pharyngeal muscles act during the **involuntary second and third stages of swallowing**: the soft palate and Passavant's ridge close the nasopharyngeal isthmus; the aryepiglottic folds close the laryngeal inlet; the longitudinal muscles elevate the larynx and pharynx and shorten the pharynx over the bolus ("pulling a sleeve over the hand"); and sequential, wave-like contraction of the superior → middle → inferior constrictors propels the bolus into the oesophagus, with the cricopharyngeus relaxing just ahead of the advancing bolus.

Applied / Clinical anatomy

- ▶ **Killian's dehiscence and pharyngeal (Zenker's) diverticulum:** the lower part of the thyropharyngeus is a single unsupported sheet, not overlapped by the superior/middle constrictors, forming a weak area (Killian's dehiscence) between the propulsive thyropharyngeus (pharyngeal plexus) and the sphincteric cricopharyngeus (recurrent laryngeal nerve). Neuromuscular incoordination between the two — the cricopharyngeus failing to relax as the thyropharyngeus contracts — pushes the bolus backward and produces a posterior herniation (pharyngeal pouch), presenting with dysphagia, regurgitation of undigested food and halitosis; demonstrated on a barium swallow.
- ▶ **Fascial spaces:** the **retropharyngeal space**, between the buccopharyngeal and prevertebral fasciae, contains retropharyngeal lymph nodes; suppuration here (especially in children) produces a retropharyngeal abscess that can track down behind the oesophagus into the posterior mediastinum. The **lateral (para-) pharyngeal space**, lateral to the pharynx, may be infected from tonsillar or dental sepsis and can spread to the carotid sheath and mediastinum.
- ▶ **Referred otalgia:** because the glossopharyngeal nerve supplies both the oropharynx/tonsil and the middle ear (via the tympanic plexus), pharyngitis and tonsillitis characteristically produce pain referred to the ear.
- ▶ **Piriform fossa:** a common site for impaction of sharp foreign bodies (e.g., fish bones); the internal laryngeal nerve lies submucosally in its medial wall and is at risk during endoscopic removal, injury causing anaesthesia of the supraglottic larynx and predisposing to aspiration.
- ▶ **Fossa of Rosenmüller:** the lateral pharyngeal recess of the nasopharynx is the most common site of origin of **nasopharyngeal carcinoma**, which may obstruct the auditory tube (unilateral serous otitis media) or invade the skull base.
- ▶ **Adenoid and tubal tonsil hypertrophy:** enlargement of the pharyngeal tonsil obstructs the choanae, producing mouth breathing, adenoid facies and, in children, obstructive sleep symptoms; enlargement of the tubal tonsil occludes the pharyngotympanic tube ostium, predisposing to otitis media with effusion.
- ▶ **Vagus nerve lesions:** paralysis of the ipsilateral pharyngeal (and palatal) muscles causes dysphagia, nasal regurgitation of fluids, a nasal twang to the voice, flattening of the palatal arch and deviation of the uvula to the normal side.
- ▶ **Reduced dilator tone:** physiological reduction of pharyngeal dilator muscle tone during sleep narrows the airway and underlies **snoring and obstructive sleep apnoea**.

High-yield exam pointers

- ▶ Pharynx = 12–14 cm musculomembranous tube, base of skull to C6 (lower border of cricoid); widest at the nasopharynx, narrowest at the pharyngo-oesophageal junction.
- ▶ Three parts — **naso-, oro-, laryngo-pharynx** — nasopharynx transmits air only, oropharynx and laryngopharynx (until the closed laryngeal inlet) transmit both air and food.
- ▶ **Waldeyer's ring** = "PPLT": Pharyngeal, Palatine, Lingual, Tubal tonsils.
- ▶ **3 circular constrictors** (superior, middle, inferior — inferior overlaps middle overlaps superior) + **3 longitudinal muscles** (stylopharyngeus, salpingopharyngeus, palatopharyngeus).

- ▶ All pharyngeal muscles are supplied by the pharyngeal plexus (vagus/cranial XI) EXCEPT stylopharyngeus, which is supplied by the glossopharyngeal nerve (IX); cricopharyngeus additionally by the recurrent laryngeal nerve.
- ▶ Sinus of Morgagni transmits the auditory tube, levator veli palatini and ascending palatine artery.
- ▶ Killian's dehiscence — between thyropharyngeus and cricopharyngeus — is the site of pharyngeal (Zenker's) diverticulum.
- ▶ Main artery of the pharynx = **ascending pharyngeal artery**; lymph drains to **retropharyngeal and deep cervical (jugulodigastric) nodes**.
- ▶ Tonsillar pain refers to the ear because the **glossopharyngeal nerve (IX)** supplies both.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 3-4 8e; Moore's Clinically Oriented Anatomy 9e; Vishram Singh Textbook of Anatomy Vol 3 4e; IB Singh Textbook of Anatomy Vol 3 6e.



Pineal gland

Asked in: Paper I Oct 2010 — RGUHS MD/MS Anatomy

Definition / Introduction The pineal gland (epiphysis cerebri) is a small, unpaired, cone-shaped neuroendocrine gland of the **epithalamus** that projects backward from the roof of the third ventricle, lying in the groove between the two superior colliculi, just below the splenium of the corpus callosum. It is derived from the roof plate of the diencephalon and, although structurally part of the brain, functions purely as an endocrine gland — converting light/dark information into the circadian hormone **melatonin**. Its clinical importance is twofold: it modulates the onset of puberty and other endocrine axes, and its age-related calcification is one of the most useful radiological landmarks for detecting midline shift of the brain.

Location, shape and size

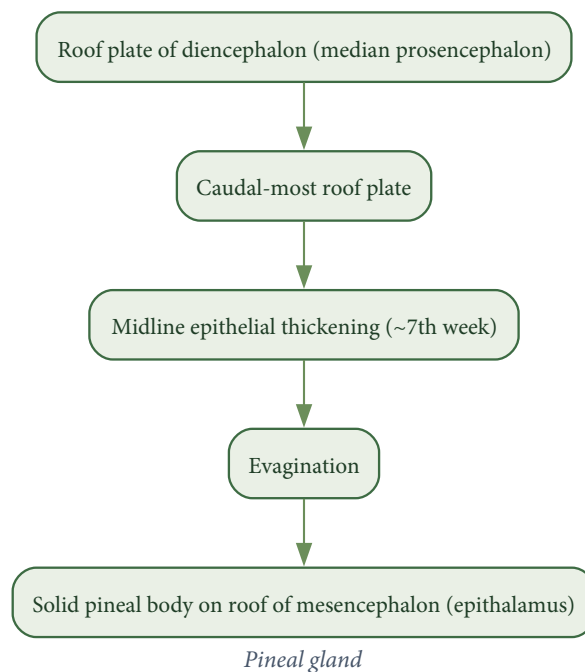
- ▶ Lies in the depression between the two **superior colliculi**, inferior to the **splenium of the corpus callosum**, from which it is separated by the tela choroidea of the third ventricle and the contained internal cerebral veins/great cerebral vein.
- ▶ Small, reddish-grey, cone/pea-shaped body; classically described as about **8 mm long** (Gray's Anatomy), or **~7 mm × 6 mm × 3 mm** (Vishram Singh).
- ▶ Its base, directed anteriorly, is attached by a short peduncle (stalk) that divides into a **superior lamina**, continuous with the **habenular commissure**, and an **inferior lamina**, continuous with the **posterior commissure**; the two laminae are separated by the **pineal recess** of the third ventricle.
- ▶ Covered by pia mater, which sends fine septa into the gland dividing it into lobules and carrying blood vessels and unmyelinated sympathetic axons.

Relations

Direction	Structure(s) related
Anterosuperior	Pineal recess of 3rd ventricle; superior lamina/habenular commissure
Anteroinferior	Inferior lamina/posterior commissure
Posterosuperior	Splenium of corpus callosum (via tela choroidea, internal cerebral veins, great cerebral vein)
Inferior	Superior colliculi (tectal plate); opening of cerebral aqueduct nearby
Lateral	Pulvinar of thalamus; habenular trigone/habenular nuclei

Embryological development

- ▶ The diencephalon develops from the median part of the prosencephalon and is regarded as having a roof plate and two alar plates.
- ▶ The **caudal-most part of the diencephalic roof plate** forms the pineal body: it first appears, around the **7th week**, as a midline epithelial thickening, which then **evaginates** and becomes a solid, cellular organ lying on the roof of the midbrain (mesencephalic tectum).
- ▶ Because it arises from neuroectoderm of the diencephalic roof (like the choroid plexus, which develops from the more rostral roof plate), the pineal is properly a diencephalic derivative, not a true cerebral hemisphere structure — hence its topographic placement as part of the **epithalamus**.



Microscopic structure (histology)

Cell type	Proportion	Key features
Pinealocytes	~95%	Modified neurones; pale nuclei; long cytoplasmic processes ending in bulbous "terminal expansions" near fenestrated capillaries or ependyma of the pineal recess; contain rough endoplasmic reticulum, mitochondria and dense-core vesicles storing melatonin; possess synaptic ribbons and are coupled by gap junctions; synthesize melatonin and its precursor serotonin (5-HT) from tryptophan
Interstitial (glial) cells	~5%	Astrocyte-like; smaller, elongated, more deeply staining nuclei than pinealocytes; form the bulk of the pineal stalk

- ▶ **Corpora arenacea ("brain sand")**: multilaminar, concentrically-arranged concretions of calcium and magnesium phosphates/carbonates deposited in the extracellular matrix, beginning to appear from the **second decade** of life and increasing in number and size with age; they do **not** indicate degeneration and do not affect the gland's secretory activity — but they are the single most useful feature radiologically.
- ▶ Rich capillary bed — fenestrated endothelium with a tenuous/incomplete basal lamina, i.e., the gland lies **outside the blood–brain barrier**.

 Fig 20.24 — Pineal gland. (Junqueira's Basic Histology — Text & Atlas — 17e, p.1045)

Blood supply and innervation

- ▶ **Arterial supply**: pineal branches of the **medial posterior choroidal arteries**, themselves branches of the posterior cerebral artery (Vishram Singh's General Anatomy describes this simply as the posterior choroidal artery).
- ▶ **Venous drainage**: numerous pineal veins draining into the **internal cerebral veins** and/or the **great cerebral vein** (of Galen).
- ▶ **Nerve supply — nervus conarii**: postganglionic **sympathetic (adrenergic)** fibres arising from the **superior cervical ganglion**, entering the dorsolateral aspect of the gland near the tentorium cerebelli, deep to the endothelium of the straight sinus.
- ▶ This is the **unique feature** of the pineal gland: it is the only part of the brain innervated by a nerve whose cell bodies lie entirely **outside** the central nervous system.

Functions

- ▶ Synthesizes and secretes **melatonin** (and serotonin) with a marked **circadian rhythm** — plasma levels rise during darkness and fall during daylight, driven by the retino-hypothalamic pathway (retina → suprachiasmatic nucleus → sympathetic outflow → superior cervical ganglion → nervus conarii → pinealocytes).

- ▶ Melatonin **inhibits gonadotrophin-releasing hormone (GnRH)** release from the hypothalamus, thereby restraining gonadotrophin secretion and **delaying the onset of puberty** until an appropriate age.
- ▶ Exerts a broadly **inhibitory** influence on the adenohypophysis, neurohypophysis, thyroid, parathyroids, adrenal cortex and medulla, endocrine pancreas and gonads — reaching these targets via both the cerebrospinal fluid and the bloodstream.
- ▶ Overall, it functions as the principal **photoneuroendocrine transducer**, entraining the body's diurnal/circadian rhythms to the ambient light–dark cycle.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Mid-sagittal diagram of the pineal region (relations), labelling:

- ▶ Splenium of corpus callosum
- ▶ Great cerebral vein / internal cerebral veins (within tela choroidea)
- ▶ Pineal body (with stalk)
- ▶ Superior lamina — continuing as habenular commissure
- ▶ Inferior lamina — continuing as posterior commissure
- ▶ Pineal recess of 3rd ventricle
- ▶ Superior colliculi (tectal plate)
- ▶ Cerebral aqueduct
- ▶ Third ventricle cavity
- ▶ Habenular trigone / pulvinar of thalamus (lateral relation)

□ Fig 11.8 — (A) The pineal gland in relation to the third ventricle and habenular and posterior commissures.
(Vishram Singh — *Clinical Neuroanatomy* — 4e, p.409)

Applied / Clinical anatomy

- ▶ **Radiological landmark:** from the second decade onward, calcified corpora arenacea render the pineal gland visible on plain skull X-ray (lateral view, roughly 5 cm above the external auditory meatus) and on CT in a majority of adults; pineal and choroid plexus calcifications are the commonest incidental intracranial calcifications seen on CT.
- ▶ **Midline shift:** because the pineal normally sits in the midsagittal plane, **lateral displacement of the calcified pineal shadow** is a classical indicator of a space-occupying lesion (tumour, haematoma, abscess) pushing the brain from the midline.
- ▶ **Pineal region tumours (pinealoma):** compress the tectum/superior colliculi to produce **Parinaud's (dorsal midbrain) syndrome** — paralysis of upward conjugate gaze, with pupillary light–near dissociation and convergence–retraction nystagmus; may also obstruct the **cerebral aqueduct**, causing obstructive (non-communicating) hydrocephalus.
- ▶ **Puberty disorders:** destructive pineal lesions abolish the melatonin brake on GnRH and cause **precocious puberty**; conversely, a functioning melatonin-secreting tumour can delay puberty.
- ▶ Because the gland lies outside the blood–brain barrier (fenestrated capillaries with an incomplete basal lamina), circulating melatonin readily reaches its central and peripheral targets — the structural basis for its role as a freely diffusible hormonal signal rather than a purely neural one.

High-yield exam pointers

- ▶ Epithalamic structure in the groove between the superior colliculi, below the splenium of the corpus callosum; ~8 mm long; stalk splits into superior lamina (habenular commissure) and inferior lamina (posterior commissure), separated by the pineal recess.
- ▶ Develops from the **caudal-most roof plate of the diencephalon**, evaginating by the 7th week.
- ▶ Two cell types: **pinealocytes (95%)** — modified neurones secreting melatonin/serotonin — and **glial cells (5%)**.
- ▶ **Corpora arenacea ("brain sand")** appear from the 2nd decade; calcium/magnesium phosphate-carbonate deposits; do not impair function; key radiological landmark for midline shift.
- ▶ Arterial supply: medial posterior choroidal artery (branch of PCA); venous drainage: internal cerebral vein/great cerebral vein.
- ▶ **Nervus conarii** — postganglionic sympathetic fibres from the superior cervical ganglion — the only CNS part supplied by a nerve arising entirely outside the brain.
- ▶ Melatonin inhibits GnRH → delays puberty; broadly inhibitory on other endocrine glands; lies outside the blood–brain barrier.
- ▶ Pineal region tumour → Parinaud's syndrome (upward gaze palsy) ± precocious puberty ± aqueductal hydrocephalus.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — Textbook of Anatomy Vol 3 4e (Diencephalon and third ventricle); Vishram Singh — General Anatomy 4e; Vishram Singh — Clinical Neuroanatomy 4e; IB Singh — Textbook of Anatomy Vol 3 6e; IB Singh — Textbook of Human Neuroanatomy; Junqueira's Basic Histology 17e; Sontakke — Textbook of Human Histology 2e; Brijesh Kumar — Histology Text & Atlas 3e; Langman's Medical Embryology (Sadler) 14e; BD Chaurasia — Human Anatomy Vol 3-4 8e.



Relations and innervations of parotid gland

Asked in: Paper I 29-Jul-2021 — RGUHS MD/MS Anatomy

Definition / Introduction The **parotid gland** is the largest of the three paired major salivary glands and is purely **serous**. It weighs about 25 g, lies in the **parotid bed (retromandibular fossa)** in front of and below the ear, and is shaped like an inverted three-sided pyramid. Its exam importance rests on two linked facts: it has an unusually rich set of surgical relations, and it is traversed — but never innervated — by the **facial nerve**, its own secretomotor supply instead reaching it by a long parasympathetic detour via the **glossopharyngeal nerve and otic ganglion**.

Location, capsule and external features

- ▶ **Parotid bed:** bounded anteriorly by the posterior border of the ramus of the mandible, posteriorly by the mastoid process, superiorly by the external acoustic meatus/TMJ, and medially by the styloid process; lined by masseter/medial pterygoid, sternocleidomastoid/posterior belly of digastric, and the styloid muscles respectively.

- **Extent:** from the external acoustic meatus above to the upper carotid triangle below, medially to the styloid process/pharyngeal wall; a detached anterior extension along the duct forms the **accessory parotid gland** (between the zygomatic arch and the duct).
- **Parotid capsule:** from the investing layer of deep cervical fascia, which splits to enclose the gland — a thick, adherent **superficial lamina** (*parotidomasseteric fascia*, to the zygomatic arch) and a thin **deep lamina** (to the styloid process/tympanic plate) that thickens into the **stylomandibular ligament**, separating parotid from submandibular gland and pierced by the external carotid artery.
- **Shape:** apex directed downwards; **four surfaces** (superior/base, superficial, anteromedial, posteromedial) separated by **three borders** (anterior, posterior, medial/pharyngeal).

Relations of the parotid gland

Part	Related to	Structures emerging / entering
Apex	Posterior belly of digastric; carotid triangle	Cervical branch of facial nerve; retromandibular vein divisions
Superior surface (base), concave	Cartilaginous EAM; posterior TMJ	Superficial temporal vessels; auriculotemporal nerve
Superficial surface, largest	Skin → superficial fascia (great auricular nerve, preauricular nodes, platysma) → parotid fascia → deep parotid nodes	—
Anteromedial surface	Grooved by ramus of mandible; masseter, medial pterygoid, TMJ	Facial nerve branches (deep to anterior margin)
Posteromedial surface	Mastoid process/SCM/digastric; styloid process and its muscles (separating gland from ICA, IJV, last 4 cranial nerves)	Facial nerve trunk (upper) and external carotid artery (lower) enter here
Anterior border	Separates superficial from anteromedial surface	Above duct: temporal, zygomatic branches, transverse facial vessels; at duct: parotid duct + accessory gland; below duct: lower buccal, marginal mandibular branches
Posterior border	Overlaps sternocleidomastoid	Posterior auricular vessels and nerve branch
Medial/pharyngeal border	Separates anteromedial from posteromedial surface	Lateral wall of the pharynx

□ Fig 8.4 — Horizontal section through the parotid gland showing its relations and the structures passing through it (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e*, p.373)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A horizontal (axial) section through the parotid gland at the level of the ramus of the mandible, labelled: ramus of mandible with masseter (lateral)/medial pterygoid (medial); superficial and deep lobes joined by the isthmus; the three intraglandular structures superficial→deep — facial nerve trunk, retromandibular vein, external carotid artery; styloid process with its three muscles separating the gland from the internal carotid artery/internal jugular vein; mastoid process with sternocleidomastoid/posterior belly of digastric; lateral wall of pharynx (medial border); and skin → superficial fascia → parotid fascia layering superficially, with the parotid duct emerging anteriorly.

Structures within the substance of the gland

Three structures traverse the gland and branch within it, arranged **superficial to deep**:

- ▶ **Facial nerve** — most superficial (its intraglandular course is detailed below).
- ▶ **Retromandibular vein** — intermediate plane; formed *within* the gland by union of the superficial temporal and maxillary veins; divides near the apex into an anterior division (joins the facial vein → common facial vein) and a posterior division (joins the posterior auricular vein → external jugular vein).
- ▶ **External carotid artery** — deepest; enters the lower part of the posteromedial surface and divides within the gland into the **maxillary artery** (leaves via the anteromedial surface) and the **superficial temporal artery** (gives off the transverse facial artery within the gland).

Patey's facio-venous plane: the gland consists of a large **superficial lobe** and a small **deep lobe**, connected by an **isthmus** around which the facial nerve divides, giving the gland an H-shaped or "collar-stud" appearance on coronal section. This neurovenous plane (facial nerve + retromandibular vein) is the surgical plane of cleavage used in **superficial parotidectomy** to remove the superficial lobe while preserving the facial nerve intact.

Nerve supply (innervation) of the parotid gland

The facial nerve merely **courses through** the parotid gland — it supplies no structure within it. The gland's own innervation is purely autonomic (secretomotor/vasomotor) plus a separate sensory supply:

Component	Pathway	Effect
Parasympathetic (secretomotor)	Inferior salivatory nucleus (medulla) → glossopharyngeal nerve → tympanic branch (Jacobson's) → tympanic plexus → lesser petrosal nerve → relay in otic ganglion → postganglionic via auriculotemporal nerve → gland	Watery, profuse secretion

Component	Pathway	Effect
Sympathetic	Lateral horn T1 → synapse in superior cervical ganglion → postganglionic vasomotor fibres via periarterial plexus on external carotid/middle meningeal arteries → gland	Thick, sticky secretion
Sensory	Auriculotemporal nerve (gland); great auricular nerve C2, C3 (skin and fascia/capsule)	Pain — explains tenderness of parotid swellings

□ Fig 5.6 — Parasympathetic nerve supply to the parotid gland (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.138)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A flowchart of the secretomotor (parasympathetic) pathway to the parotid gland, labelled in sequence: Inferior salivatory nucleus (medulla) → Glossopharyngeal nerve (CN IX) → Tympanic branch (Jacobson's nerve) → Tympanic plexus → Lesser petrosal nerve → Otic ganglion (relay) → Auriculotemporal nerve (postganglionic) → Parotid gland

Facial nerve: relation to the gland and its extracranial course

- Emerges through the **stylomastoid foramen** (the only cranial nerve traversing two skull foramina — internal acoustic meatus and stylomastoid foramen), immediately giving off the **posterior auricular nerve** (auricularis posterior, occipital belly of occipitofrontalis, intrinsic auricular muscles) and branches to the **posterior belly of digastric** and **stylohyoid**.
- Curves round the styloid process, enters the **posteromedial surface of the gland high up**, runs forward superficial to the retromandibular vein for ~1 cm, then divides into **temporofacial** and **cervicofacial** trunks.
- These form the **parotid plexus (pes anserinus)**, giving five terminal branches that radiate through the anteromedial surface/anterior border and apex:

Branch	Course	Supplies
Temporal	Crosses zygomatic arch	Auricularis anterior/superior, frontalis, orbicularis oculi, corrugator supercilii
Zygomatic	Runs across zygomatic bone	Orbicularis oculi
Buccal (upper & lower)	Upper runs above, lower below the parotid duct	Buccinator and adjacent muscles of the cheek/upper lip
Marginal mandibular	Runs below angle of mandible, deep to platysma	Muscles of the lower lip and chin
Cervical	Emerges from apex of gland, runs into the neck	Platysma

- **Applied point:** although the facial nerve is intimately related to the gland, it is not its nerve supply — this dissociation between the "nerve within" and the "nerve to" the gland is a favourite viva/theory distinction.

Parotid duct, blood supply and lymphatic drainage

- ▶ **Parotid (Stenson's) duct:** ~5 cm long, ~3 mm wide; emerges from the middle of the anterior border, crosses masseter between the upper and lower buccal branches of the facial nerve, turns medially at almost a right angle at the anterior border of masseter, and pierces the buccal pad of fat, buccopharyngeal fascia and buccinator obliquely (a valve-like arrangement preventing ductal inflation during blowing), opening in the vestibule opposite the crown of the **upper second molar tooth**. Surface marking: middle third of the line from the tragus to the midpoint between the ala of the nose and the red margin of the upper lip.
- ▶ **Blood supply:** arterial from the **external carotid artery** and its branches within the gland; venous drainage via the **retromandibular vein** to the external jugular/common facial system.
- ▶ **Lymphatic drainage:** the only salivary gland with **two layers of lymph nodes** — superficial (preauricular) and deep (intraglandular, ~10 nodes, mostly superficial to the facial nerve plane) — draining the temple, scalp, auricle, external acoustic meatus, middle ear, eyelids and cheek besides the gland itself, to the **upper deep cervical lymph nodes**.
- ▶ **Development:** **ectodermal** in origin (unlike the endodermal submandibular/sublingual glands) — a cord of cells proliferates from the oral epithelium near the angle of the mouth around the 6th week, grows backwards towards the ear, and branches to form the duct system and acini; surrounding mesenchyme forms the connective-tissue septa.

Applied / Clinical anatomy

- ▶ **Mumps (viral parotitis):** paramyxovirus infection causes painful, non-suppurative diffuse swelling, worsened by jaw movement/gustatory stimuli because of the unyielding capsule; adult complications include orchitis, oophoritis and pancreatitis.
- ▶ **Painful parotid swellings:** the tough, unyielding capsule stretches under pressure and stimulates the sensory great auricular nerve.
- ▶ **Parotid abscess (Hilton's method):** drained by a horizontal blunt incision below the angle of the mandible, parallel to the facial nerve branches, to avoid injuring them.
- ▶ **Pleomorphic adenoma (mixed tumour):** commonest parotid neoplasm — slow-growing, painless, lobulated, arising in the superficial lobe; pain, rapid growth, facial palsy and fixity suggest malignant change. A **deep-lobe tumour** presents as a lateral pharyngeal wall swelling, not a facial one.
- ▶ **Parotidectomy:** superficial or total, performed along **Patey's facio-venous plane**, tracing the facial nerve from its trunk forward to preserve it.
- ▶ **Frey's syndrome (gustatory sweating):** after parotid surgery/trauma, aberrant regeneration of severed parasympathetic secretomotor fibres of the auriculotemporal nerve into the sudomotor sheaths of the great auricular nerve causes facial flushing/sweating on eating.
- ▶ **Sialography and Bell's palsy:** ductal calculi are localised by injecting radiopaque dye via the duct opening; a facial nerve lesion at the stylomastoid foramen causes lower-motor-neurone facial paralysis, hence its epithet, the "**queen of the face**."

High-yield exam pointers

- ▶ Parotid = largest, purely **serous** salivary gland; ~25 g; inverted pyramid, apex down, 4 surfaces, 3 borders; deep fascia thickens into the **stylomandibular ligament**.
- ▶ Structures within the gland, **superficial** → **deep**: **facial nerve** → **retromandibular vein** → **external carotid artery**; facial nerve traverses the gland but supplies **nothing** within it.
- ▶ Facial nerve forms the **parotid plexus (pes anserinus)** in the gland → 5 terminal branches (temporal, zygomatic, buccal ×2, marginal mandibular, cervical).
- ▶ Secretomotor pathway: inferior salivatory nucleus → glossopharyngeal → tympanic branch (Jacobson's) → tympanic plexus → lesser petrosal → **otic ganglion** → **auriculotemporal nerve** → gland.
- ▶ Sympathetic supply from the **superior cervical ganglion** via the periarterial plexus; sensory supply via auriculotemporal (gland) and **great auricular nerve C2, C3** (skin/fascia).
- ▶ Otic ganglion is the only parasympathetic ganglion with **four roots** (incl. a motor root); the **geniculate ganglion** is sensory, not parasympathetic — a common distractor.
- ▶ Patey's facio-venous plane separates the superficial/deep lobes (joined by the isthmus) — the surgical plane for parotidectomy.
- ▶ Parotid duct (~5 cm) opens opposite the **upper second molar**; parotid is the only salivary gland with two layers of lymph nodes; facial nerve is the only cranial nerve traversing **two skull foramina**.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4, 8e; Vishram Singh — Textbook of Anatomy Vol 3, 4e; Moore's Clinically Oriented Anatomy, 9e.



Sternocleidomastoid muscle

Asked in: Paper I Nov 2016 — RGUHS MD/MS Anatomy

Definition / Introduction — The sternocleidomastoid (SCM, "sternomastoid") is a large, strap-like, cruciate and slightly spiralized superficial muscle of the neck that arises by two heads from the manubrium sterni and clavicle and inserts on the mastoid process and superior nuchal line. It is the **key muscular landmark of the neck** because it divides each side of the neck diagonally into the anterior and posterior (lateral) triangles. SCM and trapezius are derived from the same embryonic (branchiomic) muscle sheet and share their motor innervation from the accessory nerve, which explains their combined involvement in torticollis and in radical neck dissection palsy.

Origin, insertion and relations at attachment

Head	Origin	Course
Sternal head	Rounded tendon from the superolateral part of the front of the manubrium sterni, below the suprasternal notch	Ascends posterolaterally, superficial and in front of the sternoclavicular joint
Clavicular head	Flat, musculotendinous, from the medial third of the superior surface of the clavicle	Ascends almost vertically, spiralling deep to the sternal head, blending with it below the middle of the neck to form a thick fusiform belly

- ▶ The two heads are separated near their origin by a small triangular gap, the **lesser supraclavicular fossa**, which overlies the terminal part of the **internal jugular vein** (used for central-line access).
- ▶ **Insertion:** (1) a thick tendon on the lateral surface of the **mastoid process**, from its tip to its superior border, and (2) a thin aponeurosis into the **lateral half of the superior nuchal line** of the occipital bone.
- ▶ Mnemonic: sterno- (sternum) + cleido- (clavicle) → -mastoid (mastoid process).

Nerve supply

- ▶ **Motor:** the **accessory nerve (CN XI)**. Current understanding (Gray's 41e; Moore 9e, citing Lachman et al. 2002) is that the traditional "spinal root" of CN XI is the *whole* accessory nerve — the old "cranial root" fibres are now regarded as part of the **vagus nerve**, so CN XI is functionally a purely spinal nerve supplying only SCM and trapezius.
- ▶ The nerve crosses the transverse process of the atlas, is crossed by the occipital artery, enters the deep surface of the upper part of SCM, and anastomoses there with C2/C3 fibres (**ansa of Maubrac**; occasionally also the C1 **McKenzie branch**).
- ▶ It emerges a little above the midpoint of the posterior border of SCM, about 4–6 cm from the tip of the mastoid process and within ~2 cm of the great auricular nerve, before crossing the posterior triangle to reach trapezius 3–5 cm above the clavicle.
- ▶ **Proprioceptive/sensory:** ventral rami of C2 and C3 (the "ansa of Maubrac").

Blood supply

Four sternocleidomastoid branches, one to each part of the muscle:

Part of muscle	Artery
Upper	Occipital and posterior auricular arteries
Middle	Superior thyroid artery
Lower	Suprascapular artery

Actions

Contraction	Effect
Unilateral	Tilts/laterally flexes the head toward the same shoulder and rotates the face toward the opposite side (as in an upward sideways glance)
Bilateral	Draws the head forward (lifting head off a pillow, chin-to-chest flexion); with longus colli, flexes the neck against resistance; with the neck fixed, elevates the manubrium and clavicles, acting as an accessory muscle of forced inspiration

- Clinical test: patient turns the head to the opposite side against resistance (examiner's hand on chin) — the contracting SCM becomes visible and palpable.

Relations

	Superficial	Deep (upper → lower)
Coverings	Skin, superficial fascia, platysma, investing layer of deep cervical fascia	—
Nerves	Great auricular, transverse cervical (crossing obliquely)	Occipital artery, digastric (posterior belly), splenius/longissimus capitis (upper); vagus, accessory nerve, cervical plexus, brachial plexus, ansa cervicalis, phrenic nerve (middle/lower)
Vessels	External jugular vein, superficial cervical lymph nodes	Common/internal/external carotid arteries, internal jugular vein, anterior jugular vein (lower)
Glands	Parotid gland (overlaps near insertion)	Thyroid gland, deep cervical lymph nodes
Muscles (deep)	—	Sternohyoid, sternothyroid, omohyoid, scaleni, levator scapulae, splenius capitis

The whole muscle is enclosed in the **investing layer of deep cervical fascia** and is pierced by the accessory nerve and by the sternocleidomastoid arteries.

Triangles of the neck

SCM runs obliquely from the mastoid process to the sternum/clavicle, splitting the quadrilateral side of the neck into:

- ▶ **Anterior triangle** — in front of SCM (subdivided into digastric, muscular, carotid and submental triangles).
- ▶ **Posterior triangle** — behind SCM, bounded anteriorly by its posterior border, posteriorly by the anterior border of trapezius, and inferiorly by the middle third of the clavicle; apex at the superior nuchal line where SCM meets trapezius. Subdivided by the inferior belly of omohyoid into the **occipital** (upper) and **subclavian/supraclavicular** (lower) triangles.
- ▶ Key contents of the posterior triangle: the **spinal accessory nerve** (lying just deep to the roof — the only structure NOT protected by the fascial carpet), the **third part of the subclavian artery**, the **cervical part of the brachial plexus**, and chains of **lymph nodes**.

□ Fig 3.10 — The boundaries of posterior triangle of neck with its contents (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.112)

□ Fig 5.4 — ■ Actions of the sternocleidomastoid muscle. (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.282)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled lateral-neck diagram showing the origin/insertion of SCM and the triangles it creates. Label exactly:

- ▶ Manubrium sterni (sternal head origin) and superior surface of medial third of clavicle (clavicular head origin)
- ▶ Lesser supraclavicular fossa (between the two heads, overlying internal jugular vein)
- ▶ Mastoid process and lateral half of superior nuchal line (insertion)
- ▶ Anterior border and posterior border of SCM
- ▶ Accessory nerve entering deep surface (upper part) and emerging at mid-posterior border
- ▶ Anterior triangle (in front) and Posterior triangle (behind), with apex at superior nuchal line and base at clavicle
- ▶ Nerve point of the neck (junction of upper and middle third of posterior border)

Applied / Clinical anatomy

- ▶ **Torticollis (wry neck)**: head tilted to the affected side, chin/face rotated to the opposite side.
 - **Congenital muscular torticollis / fibromatosis colli**: a fibrous tissue "tumour" develops within SCM before or shortly after birth (may follow breech position or birth trauma with intramuscular haematoma that can entrap a branch of CN XI); presents as a firm neck lump in the first weeks of life, resolving with physiotherapy in most infants, occasionally requiring **surgical release of the inferior SCM attachments** if unresolved.
 - **Spasmodic torticollis** (cervical dystonia): painful adult-onset spasm of SCM ± trapezius, often precipitated by cold exposure or a maladjusted pillow.
 - **Reflex torticollis**: irritation of the accessory nerve by inflamed/suppurating cervical lymph nodes.

- ▶ **Accessory nerve palsy:** because the nerve lies superficially just beneath the fascial roof of the posterior triangle, it is the structure most often damaged during **lymph-node biopsy/excision in the posterior triangle**, producing trapezius paralysis — inability to shrug the shoulder or raise the arm above the horizontal (e.g., difficulty combing hair) — while SCM itself is spared, since it is supplied before the nerve enters the triangle.
- ▶ **Nerve point of the neck:** at the mid-posterior border of SCM, the four cutaneous branches of the cervical plexus (lesser occipital, great auricular, transverse cervical, supraclavicular) plus the accessory nerve emerge — the site for **cervical plexus block**.
- ▶ **Virchow's (Troisier's) node:** enlargement of the left supraclavicular lymph nodes in the posterior triangle from metastasis of gastric, testicular or other abdominal malignancy; the posterior triangle is also the commonest site of tuberculous cervical lymphadenopathy ("cold abscess" tracking along the axillary sheath).
- ▶ **Landmark for vascular/regional access:** the **subclavian artery pulse** is felt behind the clavicle at the posterior border of SCM (and can be compressed against the first rib to control upper-limb haemorrhage); the lesser supraclavicular fossa overlies the **internal jugular vein**, the classical site for central venous cannulation.
- ▶ **Reconstructive surgery:** SCM can be raised as a superiorly based **myocutaneous flap** (perforator-based skin paddle) for reconstruction of the lip, floor of mouth or cheek, though largely superseded by microvascular free flaps.

High-yield exam pointers

- ▶ SCM = **key muscle of the neck**; divides it into anterior and posterior triangles.
- ▶ Two heads — sternal (manubrium) and clavicular (medial 1/3 clavicle); insertion — mastoid process + superior nuchal line.
- ▶ Motor supply: **accessory nerve** (now considered purely spinal — old "cranial root" belongs to the vagus); C2, C3 give proprioceptive fibres only.
- ▶ Four sternocleidomastoid arteries: occipital + posterior auricular (upper), superior thyroid (middle), suprascapular (lower).
- ▶ Unilateral action = ipsilateral tilt + contralateral rotation; bilateral = neck flexion + accessory muscle of inspiration.
- ▶ Accessory nerve emerges ~4–6 cm below the mastoid tip at mid-posterior border of SCM — the **most vulnerable nerve** in posterior-triangle lymph node biopsy.
- ▶ Congenital torticollis = **fibromatosis colli**; spasmodic torticollis = cervical dystonia.
- ▶ Nerve point of the neck (cervical plexus block site) lies at the junction of upper and middle third of the posterior border of SCM.
- ▶ Most common cause of a posterior-triangle swelling: enlarged (supraclavicular/Virchow's) lymph nodes.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — Textbook of Anatomy Vol 3, 4e; BD Chaurasia — Human Anatomy Vol 3-4, 8e; Moore's Clinically Oriented Anatomy 9e.



Structure of eye ball

Asked in: Paper I 12-Nov-2019 — RGUHS MD/MS Anatomy

Definition / Introduction The eyeball (bulbus oculi) is the peripheral receptor organ of the visual pathway, lodged in the anterior part of the bony orbit. It is almost spherical, with an anteroposterior diameter of about 2.5 cm, and its wall is built of **three concentric coats** — an outer fibrous coat, a middle vascular (uveal) coat, and an inner nervous coat (retina) — enclosing three transparent **refracting media** held taut by an intraocular pressure of about 15 mmHg. Light entering the eye passes, from before backwards, through the **cornea** → **aqueous humour** → **lens** → **vitreous body** before striking the retina, where the optical image is transduced into the neural signal carried by the optic nerve.

Coats of the eyeball — overview

Coat	Components	Chief function	Embryological origin
Outer / fibrous coat	Sclera (posterior 5/6) + Cornea (anterior 1/6)	Protection; maintains shape; cornea is the chief refracting surface	Neural crest mesenchyme (sclera, corneal stroma & endothelium) + surface ectoderm (corneal epithelium)
Middle / vascular coat (uveal tract)	Choroid + Ciliary body + Iris	Nutrition of retina; accommodation; regulates light entry	Neural crest/mesoderm (stroma, muscle) + neuroectoderm (ciliary & iridial epithelium, continuous with retina)
Inner / nervous coat	Retina (pigmented + neural layers)	Photoreception and initial visual processing	Neuroectoderm — outer layer of the optic cup → pigment epithelium; inner layer → neural retina

Outer fibrous coat: sclera and cornea

Sclera

- ▶ Opaque, dense fibrous coat forming the posterior five-sixths of the globe; gives the eyeball its shape and rigidity.
- ▶ Thickest at the posterior pole (~1 mm), thins towards the equator (about half this thickness ~6 mm behind the limbus, where the recti are inserted), and is **weakest at the lamina cribrosa** — the sieve-like area perforated by optic nerve fascicles and the central retinal vessels.

- ▶ Pierced by: the **optic nerve** (postero-medial to the posterior pole); short and long **posterior ciliary vessels/nerves** around the optic nerve; **anterior ciliary vessels** near the limbus; and **four venae vorticosae** just behind the equator.
- ▶ External surface: covered by loose, vascular **episclera**, Tenon's capsule, and (anteriorly) conjunctiva. Internal surface: separated from the choroid by the **suprachoroid lamina (lamina fusca)**.
- ▶ Continuous anteriorly with the cornea at the **corneoscleral junction (limbus)**, whose deep part contains the **canal of Schlemm (scleral venous sinus)**.
- ▶ Provides insertion for the recti (in front of the equator) and obliques (behind the equator).

Cornea

- ▶ Transparent, avascular anterior one-sixth of the outer coat (~7% of ocular surface); more sharply curved (radius ≈ 7.8 mm) than the sclera (≈ 11.5 mm), so a shallow *sulcus sclerae* marks the limbus.
- ▶ Thickness ≈ 520 μm centrally, ≈ 670 μm peripherally; nourished by tear film, aqueous humour and limbal capillary loops (conjunctiva/episclera end near the limbus).
- ▶ Richly innervated by the ophthalmic nerve (long ciliary nerves) — **pain is its only sensory modality**.
- ▶ **Five histological layers** (front to back): corneal epithelium (stratified squamous, non-keratinised) $\rightarrow$ anterior limiting lamina (**Bowman's membrane**) $\rightarrow$ substantia propria/stroma (bulk of thickness; regularly stacked collagen lamellae responsible for transparency) $\rightarrow$ posterior limiting lamina (**Descemet's membrane**) $\rightarrow$ endothelium (single layer of squamous/hexagonal cells).

Middle vascular coat (uvea): choroid, ciliary body, iris

The **uveal tract** is a continuous pigmented, vascular sheet — choroid posteriorly, ciliary body in the middle, iris anteriorly — lining the internal aspect of the fibrous coat.

Part	Extent / gross features	Structural layers	Key function / innervation
Choroid	Thin, highly vascular pigmented layer lining the posterior $\frac{5}{6}$ of the globe internal to the sclera; ends anteriorly at the ora serrata ; pierced posteriorly by the optic nerve	Suprachoroid lamina $\rightarrow$ vascular layer (outer large-vessel Haller's layer + inner small-vessel Sattler's layer) $\rightarrow$ choriocapillaris $\rightarrow$ lamina vitrea (Bruch's membrane)	Choriocapillaris nourishes the avascular outer retina by diffusion; drains via the 4 vortex veins

Part	Extent / gross features	Structural layers	Key function / innervation
Ciliary body	Triangular on cross-section; connects the choroid to the root of the iris; two parts — anterior ridged pars plicata (~70–80 ciliary processes) and posterior smooth pars plana	Bilaminar ciliary epithelium (inner non-pigmented, outer pigmented) → stroma → ciliary muscle (meridional/longitudinal, radial, circular fibres) → supraciliary layer	Ciliary processes secrete aqueous humour; ciliary muscle contraction relaxes the zonule → lens becomes more convex (accommodation); parasympathetic supply via Edinger–Westphal nucleus → oculomotor nerve → ciliary ganglion → short ciliary nerves
Iris	Circular pigmented diaphragm between cornea and lens with a central aperture, the pupil ; divides the anterior segment into anterior and posterior chambers	Anterior border layer → stroma (contains sphincter pupillae) → two pigmented epithelial layers (anterior layer forms dilator pupillae)	Sphincter pupillae (circular, parasympathetic via short ciliary nerves) constricts the pupil; dilator pupillae (radial, sympathetic via long ciliary nerves) dilates it; major & minor arterial circles supply the iris; stromal pigment content determines iris colour

Inner nervous coat: retina

- Extends from the **optic disc** posteriorly to the **ora serrata** anteriorly, where the nervous (optic) part ends and a non-nervous, two-layered epithelial retina continues forward over the ciliary body and iris.
- **Optic disc**: ~1.5 mm diameter, devoid of rods/cones — the physiological "blind spot."
- **Macula lutea**: ~3 mm lateral to the disc, diameter 5–6 mm, avascular and yellow-pigmented; its centre is further depressed as the **fovea centralis**, the thinnest part of the retina, containing cones only and giving maximum visual acuity.
- **Photoreceptors**: rods (contain rhodopsin/visual purple; scotopic, dim-light vision; concentrated peripherally, absent at the fovea) and cones (photopic, colour vision; maximal density at the foveola, absent in the far periphery).

Ten histological layers (outer to inner):

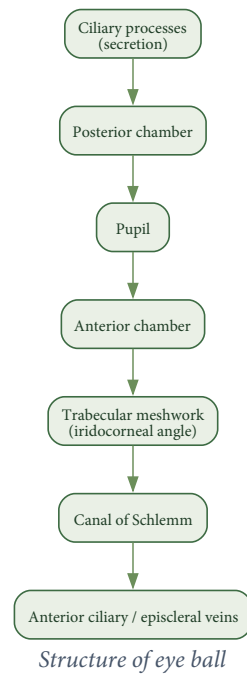
#	Layer
1	Pigment epithelium (retinal pigment epithelium)
2	Layer of rods and cones (photoreceptor inner/outer segments)
3	External limiting membrane

#	Layer
4	Outer nuclear layer
5	Outer plexiform layer
6	Inner nuclear layer (bipolar, horizontal, amacrine cell bodies)
7	Inner plexiform layer
8	Ganglion cell layer
9	Nerve fibre layer (ganglion cell axons)
10	Internal limiting membrane

- **Blood supply:** the outer five layers (pigment epithelium to outer plexiform layer) are avascular and nourished by diffusion from the **choriocapillaris**; the inner five layers are supplied by the **central retinal artery**, a true end-artery (branch of the ophthalmic artery) that divides at the disc into superior and inferior, then nasal and temporal, branches. This dual-source split explains why **retinal detachment** classically occurs between the outer pigmented layer (which stays with the choroid) and the inner nine nervous layers — reflecting their separate embryological origins from the outer and inner layers of the optic cup respectively.

Refracting media and chambers of the eye

- **Sequence of media:** cornea (with its tear film) → aqueous humour → lens → vitreous body.
- **Aqueous humour:** clear fluid secreted by the ciliary processes into the **posterior chamber**, passes through the pupil into the **anterior chamber**, and drains at the **iridocorneal (filtration) angle** through the trabecular meshwork into the **canal of Schlemm**, thence to the anterior ciliary/episcleral veins. It nourishes the avascular cornea and lens and maintains an intraocular pressure of ~15 mmHg.
- **Chambers:** anterior chamber (cornea to iris), posterior chamber (iris to lens/zonule) — both containing aqueous humour and communicating through the pupil — and the much larger **vitreous chamber** (lens to retina).
- **Lens:** transparent, avascular, biconvex, encapsulated body, ~9–10 mm (≈ 1 cm) equatorial diameter in the adult; has an anterior pole, posterior pole, axis and equator. Composed of an elastic **capsule**, a single anterior layer of cuboidal **epithelium**, and concentrically arranged **lens fibres** forming a firmer central **nucleus** (oldest fibres) and a softer peripheral **cortex** (youngest fibres). Suspended from the ciliary body by the **zonule of Zinn (suspensory ligament)**. Together with the cornea, it contributes to the eye's total refractive power of ~58–60 dioptres — the cornea/tear film provides roughly two-thirds (~40 D, fixed), and the lens the remainder (~15–20 D), the only *variable* component, adjusted during accommodation.
- **Vitreous body:** colourless, transparent gel (~99% water, hyaluronan and type II collagen) enclosed in the hyaloid membrane; occupies the posterior four-fifths of the globe; attached firmly at the optic disc and at the ora serrata (vitreous base); traversed by the **hyaloid canal**, the remnant of the fetal hyaloid artery.



□ Fig 19.1 — Sagittal section through the eyeball (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.346)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A sagittal section through the eyeball, labelled with:

- ▶ Sclera and Cornea (outer coat) with the **corneoscleral junction (limbus)**
- ▶ Choroid, Ciliary body (with ciliary processes and zonular fibres) and Iris (uveal coat)
- ▶ Pupil, Anterior chamber and Posterior chamber
- ▶ Canal of Schlemm at the iridocorneal angle
- ▶ Lens, suspended by the **suspensory ligament (zonule)**
- ▶ Vitreous body occupying the posterior segment
- ▶ Retina, terminating anteriorly at the **ora serrata**
- ▶ Optic disc and Optic nerve; Macula lutea with central fovea centralis
- ▶ Conjunctiva covering the anterior sclera

Applied / Clinical anatomy

- ▶ **Glaucoma:** impaired aqueous outflow at the trabecular meshwork/canal of Schlemm raises intraocular pressure, causing cupping of the optic disc (the weak lamina cribrosa bulges) and pressure atrophy of the retina.
- ▶ **Cataract:** age-related lens opacification; the lens is avascular and immune-privileged, so extraction/replacement is definitive treatment.
- ▶ **Retinal detachment:** an inter-retinal split between the outer pigment epithelium (stays with choroid) and the inner nine nervous layers, reflecting their separate optic-cup origins; treated by scleral buckling/banding.
- ▶ **Central retinal artery occlusion:** being an end-artery to the inner retina, its occlusion causes sudden, painless, irreversible blindness.

- ▶ **Corneal grafting:** the avascular, immune-privileged cornea rarely triggers rejection — the most successful of all human tissue transplants.
- ▶ **Refractive errors:** myopia (eye too long, image focuses in front of retina) and hyperopia (eye too short, image behind retina); presbyopia follows age-related loss of lens elasticity.
- ▶ **Fundoscopy:** through the dilated pupil, disc, macula and retinal vessels are visualised — used to detect papilloedema and diabetic/hypertensive retinopathy.
- ▶ **Pars plana**, ~4 mm posterior to the limbus, is the safe surgical entry point for intravitreal injection and vitreoretinal surgery.

High-yield exam pointers

- ▶ Three coats — outer **fibrous** (sclera + cornea), middle **vascular/uveal** (choroid + ciliary body + iris), inner **nervous** (retina) — each with a distinct embryological origin.
- ▶ Diameter $\approx$ 2.5 cm; refracting media in order — cornea, aqueous humour, lens, vitreous body.
- ▶ Cornea: **5 layers** (epithelium, Bowman's, stroma, Descemet's, endothelium); retina: **10 layers** (pigment epithelium to internal limiting membrane).
- ▶ Ciliary muscle and sphincter pupillae — **parasympathetic** (CN III $\rightarrow$ ciliary ganglion $\rightarrow$ short ciliary nerves); dilator pupillae — **sympathetic** (long ciliary nerves).
- ▶ Outer 5 retinal layers nourished by choroidal diffusion; inner 5 by the **central retinal artery** (an end-artery) — basis of the retinal detachment plane and CRAO blindness.
- ▶ Aqueous pathway: ciliary processes $\rightarrow$ posterior chamber $\rightarrow$ pupil $\rightarrow$ anterior chamber $\rightarrow$ trabecular meshwork $\rightarrow$ canal of Schlemm $\rightarrow$ episcleral veins.
- ▶ Total refractive power $\approx$ 58–60 D: fixed ~40 D from the cornea, variable ~15–20 D from the lens (accommodation).
- ▶ Optic disc = blind spot (no photoreceptors); fovea centralis = maximum acuity (cones only).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4, 8e.



Submandibular Salivary gland

Asked in: Paper I 07-May-2022 — RGUHS MD/MS Anatomy

Definition / Introduction The submandibular salivary gland is one of the three paired major salivary glands, situated partly in the digastric triangle of the neck and partly deep to the mylohyoid muscle. It is a mixed (seromucous) gland, predominantly serous, roughly the size of a walnut, and is J-shaped because the posterior border of mylohyoid indents it into a larger superficial part and a smaller deep part. It is of major applied importance because of its high susceptibility to calculus formation and its involvement in floor-of-mouth infections and tongue carcinoma spread.

Location, size and parts

- ▶ Lies in the **submandibular (digastric) triangle**, bounded above by the lower border of the mandible, posteroinferiorly by the posterior belly of digastric and stylohyoid, and anteroinferiorly by the anterior belly of digastric.
- ▶ **Size/weight**: about the size of a walnut, weighing **15–20 g**; roughly half the size of the parotid gland.
- ▶ **Type**: mixed (seromucous) gland, serous acini predominating over mucous acini (unlike the purely serous parotid and the purely mucous sublingual gland).
- ▶ **Parts**, produced by the indentation of the posterior border of mylohyoid:
- ▶ **Superficial part** — large, fills the anterior part of the digastric triangle, extends up to the mylohyoid line.
- ▶ **Deep part** — small, lies on hyoglossus deep to mylohyoid; continuous with the superficial part around the posterior border of mylohyoid; extends anteriorly up to the posterior end of the sublingual gland.
- ▶ **Fascial covering**: partially enclosed between two layers of the investing layer of deep cervical fascia — the superficial layer covers the inferior surface and attaches to the base of the mandible; the deep layer covers the medial surface and attaches to the mylohyoid line.

Relations of the superficial part

Surface	Relations
Inferior (superficial)	Skin → superficial fascia (platysma, cervical branch of facial nerve) → deep fascia → facial (common facial) vein → submandibular lymph nodes
Lateral	Submandibular fossa of the mandible; medial pterygoid muscle (near its insertion); facial artery (grooves the posterior end of the gland, then loops down and forward, then up around the base of the mandible)
Medial — anterior part	Mylohyoid muscle, mylohyoid nerve and vessels, submental branch of facial artery
Medial — intermediate part	Hyoglossus and styloglossus muscles; lingual nerve; hypoglossal nerve; submandibular ganglion; lingual artery

Surface	Relations
Medial — posterior part	Styloglossus, stylopharyngeus, stylohyoid ligament, glossopharyngeal nerve, wall of the pharynx

Relations of the deep part

- Lies between **mylohyoid (laterally)** and **hyoglossus (medially)**.
- **Above:** lingual nerve with the submandibular ganglion suspended from it.
- **Below:** hypoglossal nerve, accompanied by the venae comitantes of the hypoglossal nerve.
- Posteriorly continuous with the superficial part; anteriorly reaches the posterior end of the sublingual gland.

Submandibular (Wharton's) duct

- About **5 cm long**, thin-walled; emerges at the anterior end of the deep part of the gland.
- Runs forward on hyoglossus, **between the lingual nerve (above) and the hypoglossal nerve (below)**.
- Near the anterior border of hyoglossus it is **crossed by the lingual nerve**, which winds from its lateral to its medial side.
- Continues forward between the sublingual gland (laterally) and genioglossus (medially), lying just deep to the oral mucosa.
- Opens on the **summit of the sublingual papilla**, at the side of the frenulum of the tongue.

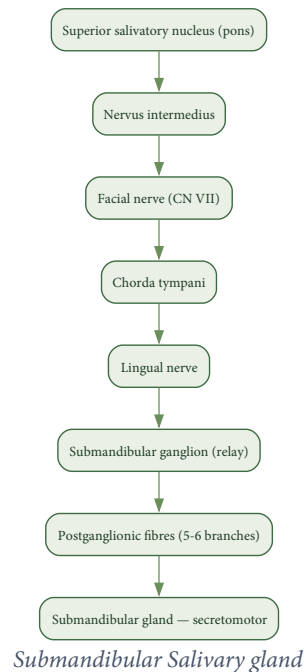
Blood supply and lymphatic drainage

- **Arterial supply:** chiefly the **facial artery**, which grooves the posterior part of the gland during its cervical course before winding around the base of the mandible; contribution also from branches of the **lingual artery** (sublingual/submental territory).
- **Venous drainage:** into the common facial vein and lingual vein.
- **Lymphatic drainage:** to the **submandibular lymph nodes** (lying both within and around the gland), and thence to the **deep cervical (jugulodigastric/jugulo-omohyoid) lymph nodes**.

Nerve supply

The gland receives three components — secretomotor (parasympathetic), vasomotor (sympathetic) and sensory fibres — all reaching it through the **submandibular ganglion**, which is topographically suspended from the lingual nerve but functionally connected to the chorda tympani.

- **Parasympathetic (secretomotor)** — preganglionic fibres arise in the **superior salivatory nucleus** (pons), travel via nervus intermedius, the facial nerve, its **chorda tympani** branch, and the **lingual nerve** to relay in the submandibular ganglion; postganglionic fibres pass directly from the ganglion (5–6 branches) to supply the gland.
- **Sympathetic (vasomotor)** — postganglionic fibres from the **superior cervical ganglion** travel in the plexus around the facial artery, pass through the submandibular ganglion without relay, and are vasomotor to the gland's vessels.
- **Sensory** — via the lingual nerve.



Submandibular ganglion

- ▶ A small, fusiform **parasympathetic peripheral ganglion**, lying on hyoglossus just above the deep part of the gland, suspended from the lingual nerve by two roots (anterior and posterior).
- ▶ **Posterior root**: carries preganglionic secretomotor fibres from the lingual nerve into the ganglion for relay.
- ▶ **Anterior root**: carries postganglionic fibres that re-enter the lingual nerve to be distributed (via its distal part) to the **sublingual and anterior lingual glands**; postganglionic fibres to the **submandibular gland itself** pass **directly** from the ganglion without re-entering the lingual nerve.
- ▶ Sympathetic fibres pass through the ganglion without synapsing.

Development

- ▶ The submandibular gland develops from **endoderm** (unlike the ectodermal parotid gland).
- ▶ During the **6th week**, a solid endodermal outgrowth arises from the floor of the stomodeum, from the floor of the **alveololingual (linguogingival) groove**.
- ▶ This cord canalises to form the **submandibular duct**; its deep (lingual) end proliferates and branches repeatedly to form the ductules and acini of the gland.
- ▶ (The sublingual gland develops slightly later, in the 7th week, as multiple endodermal outgrowths from the linguogingival sulcus and from the submandibular duct itself — explaining why some of its ducts join the submandibular duct.)

Microanatomy (histology)

- ▶ A **compound tubuloacinar (racemose) gland**, enclosed in a connective-tissue capsule that sends septa dividing it into lobes and lobules.

- ▶ **Mixed acini** — serous acini predominate; mucous acini are present, each frequently capped by a crescent of serous cells, the **serous demilunes of Giannuzzi**, which drain into the mucous lumen via fine intercellular canaliculi.
- ▶ **Myoepithelial (basket) cells** surround the acini and intercalated ducts, aiding expulsion of secretion.
- ▶ **Duct system:** intercalated ducts → **striated ducts** (more prominent here than in the parotid, lined by columnar cells with basal striations) → interlobular/excretory ducts lined progressively by columnar, then non-keratinised stratified squamous epithelium near the oral opening.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Real gross-anatomy plate (embed and reproduce by hand):

embed: ![Fig 9.12 — Left submandibular and sublingual salivary glands (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.409)](C:/Users/Harshad/Documents/anatomy-notes/answer-bank/rguhs-anatomy/answers/figures/plates/34f4b4e692006856.jpg)

In addition, draw a **horizontal (axial) section through the submandibular region** and label:

- ▶ Body of mandible
- ▶ Mylohyoid muscle
- ▶ Hyoglossus muscle
- ▶ Superficial part of submandibular gland
- ▶ Deep part of submandibular gland
- ▶ Sublingual gland
- ▶ Submandibular duct (Wharton's duct)
- ▶ Lingual nerve
- ▶ Hypoglossal nerve
- ▶ Genioglossus muscle
- ▶ Facial artery

Applied / Clinical anatomy

- ▶ **Sialolithiasis (calculi):** the submandibular gland's secretion is more mucous and viscous, and Wharton's duct runs uphill against gravity — both favour stasis and stone formation; an impacted duct stone is demonstrable on plain radiograph or sialogram, and presents as painful swelling that worsens with eating (salivary colic).
- ▶ **Ludwig's angina:** inflammatory oedema of the floor of the mouth, arising from submandibular-region infection (often dental), spreads rapidly through this space to cause life-threatening generalised swelling of the neck and floor of mouth.
- ▶ **Bimanual palpation:** the gland can be palpated with one finger in the floor of the mouth and one finger externally below the body of the mandible; enlarged submandibular lymph nodes on/within the gland are palpated the same way.

- ▶ **Surface marking:** an oval marked by joining a point at the angle of the mandible (A) to a point on the midpoint of the base of the mandible (B) by a line convex upward (~1.5 cm above the mandibular base) for the upper border, and by a line convex downward (reaching just below the greater cornu of the hyoid, point C) for the lower border.
- ▶ **Lymph node involvement in tongue cancer:** submandibular nodes lie both within and around the gland; carcinoma of the tongue or floor of mouth metastasising to these nodes is an indication for excising the gland along with the nodes (submandibular block dissection).
- ▶ **Surgical excision:** performed via an incision placed **more than 4 cm below the angle of the mandible**, because the marginal mandibular branch of the facial nerve passes posteroinferior to the angle before crossing the body of the mandible — a more superficial incision risks nerve injury with resultant lip-depressor weakness.
- ▶ **Chorda tympani injury:** since it carries secretomotor fibres to both submandibular and sublingual glands, its injury (e.g., at the spine of the sphenoid, or in middle-ear surgery) abolishes secretion from both glands and taste from the anterior two-thirds of the tongue.
- ▶ **Sialogram:** the duct system can be outlined radiographically by cannulating the duct orifice and injecting radio-opaque contrast, useful in localising calculi or ductal strictures.

High-yield exam pointers

- ▶ Mixed (seromucous) gland, serous-predominant; endodermal in origin (unlike ectodermal parotid).
- ▶ J-shaped, divided by **mylohyoid** into superficial (large) and deep (small) parts.
- ▶ Duct = Wharton's duct, ~5 cm, runs between lingual (above) and hypoglossal (below) nerves; crossed by the lingual nerve near hyoglossus' anterior border; opens at the sublingual papilla.
- ▶ Blood supply mainly by the **facial artery**; venous drainage to common facial/lingual veins.
- ▶ Secretomotor pathway: superior salivatory nucleus → nervus intermedius → facial nerve → chorda tympani → lingual nerve → **submandibular ganglion** → gland.
- ▶ Submandibular ganglion — posterior root brings preganglionic fibres in; anterior root sends postganglionic fibres back into the lingual nerve for the sublingual/anterior lingual glands, while the submandibular gland is supplied directly.
- ▶ Histological hallmark: **serous demilunes of Giannuzzi** capping mucous acini.
- ▶ Clinically prone to calculi (viscous secretion + uphill duct flow); risk of marginal mandibular nerve injury during excision.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4, 8e; Vishram Singh — Textbook of Anatomy Vol 3, 4e; IB Singh — Textbook of Anatomy Vol 3, 6e; IB Singh — Textbook of Human Histology, 9e; Sontakke — Textbook of Human Embryology.



Tentorium cerebelli

Asked in: Paper I May 2011 — RGUHS MD/MS Anatomy

Definition / Introduction

The tentorium cerebelli is the largest and strongest of the four dural septa (the others being the falx cerebri, falx cerebelli and diaphragma sellae). It is a wide, crescentic, tent-like fold of the meningeal layer of dura mater — its shape recalling a single-poled tent, from which its name derives. It roofs over the posterior cranial fossa, intervening between the occipital lobes of the cerebral hemispheres above and the cerebellum below, and thereby divides the cranial cavity into a **supratentorial** compartment (forebrain) and an **infratentorial** compartment (hindbrain). By supporting the weight of the cerebrum, it protects the underlying cerebellum from compression, and its free margin, borders, surfaces and related venous sinuses are all of major clinical importance.

1. Location, shape and general description

- ▶ Lies obliquely, sloping downward and outward from the midline (attached anteriorly higher, posteriorly lower), like the sloping roof of a tent over the posterior fossa.
- ▶ Separates the cerebellum (below) from the occipital lobes of the cerebral hemispheres (above), lying in the transverse (cerebral) fissure.
- ▶ Has **two borders** (an outer attached border and an inner free border) and **two surfaces** (upper/superior and lower/inferior).
- ▶ In the midline, its posterior part blends with the falx cerebri above and gives attachment to the falx cerebelli below — it is thus continuous with, and structurally related to, the other three dural septa.
- ▶ Because of its size, tension and lattice-like collagen architecture, it is the dural fold most often responsible for restraining (and, when pressure rises, for injuring) the brain — the basis of transtentorial herniation (see below).

2. Borders and attachments

Border	Description	Attachment
Attached (outer, convex) border	Long, curved, fixed to bone throughout	Posteriorly — lips of the transverse sulci of the occipital bone and the postero-inferior angles of the parietal bones (encloses the transverse sinus); laterally — superior border of the petrous temporal bone (encloses the superior petrosal sinus); continues forward as the posterior petroclinoid ligament to the posterior clinoid process

Border	Description	Attachment
Free (inner, concave) border	"U"-shaped; bounds an oval gap, the tentorial notch (incisura)	Occupied by the midbrain and the anterior part of the superior surface of the cerebellar vermis; its two anterior ends cross the attached border and are anchored, via the anterior petroclinoid ligament , to the anterior clinoid processes on each side

- ▶ The tentorial notch separates the free border from the dorsum sellae anteriorly by a wide hiatus, through which the midbrain connects the forebrain to the hindbrain.
- ▶ Where the free border crosses the attached border near the apex of the petrous temporal bone, the intervening dura (between the anterior and posterior petroclinoid ligaments) forms the **roof of the cavernous sinus**.
- ▶ Near the apex of the petrous temporal bone the lower dural layer of the tentorium is evaginated anterolaterally beneath the superior petrosal sinus to form **Meckel's cave**, which houses the trigeminal ganglion and its posterior (sensory) root.

3. Surfaces and relations

Surface	Faces / supports	Key relations
Upper (superior) surface	Occipital lobes of the cerebral hemispheres	In the midline, receives the posterior (broad) part of the falx cerebri along a line that carries the straight sinus ; the great cerebral vein (of Galen) drains into the straight sinus close to this junction
Lower (inferior) surface	Superior surface of the cerebellum	In the midline, gives attachment to the base of the falx cerebelli , which encloses the occipital sinus; laterally related to the superior vermis and cerebellar hemispheres

4. Dural venous sinuses related to the tentorium

Sinus	Site on the tentorium
Transverse sinus (right & left)	Posterior/posterolateral part of the attached border
Superior petrosal sinus (right & left)	Anterolateral part of the attached border; drains the cavernous sinus into the transverse sinus, crossing above the trigeminal nerve
Straight sinus	Superior surface, along the midline junction with the falx cerebri
Occipital sinus	Within the falx cerebelli, whose base is attached to the inferior surface of the tentorium

Sinus	Site on the tentorium
Confluence of sinuses (torcular herophili)	Posterior midline point where the superior sagittal, straight and occipital sinuses meet both transverse sinuses

5. Cranial nerve relations at the free margin

- ▶ **Oculomotor nerve (III)** — emerges from the midbrain between the posterior cerebral and superior cerebellar arteries, runs forward just below the free edge of the tentorium, and pierces the dural roof of the cavernous sinus (between the anterior and posterior petroclinoid ligaments) to enter its lateral wall. This intimate relation to the free margin is why the nerve is compressed early in uncal herniation.
- ▶ **Trochlear nerve (IV)** — winds around the cerebral peduncle close to the tentorial edge and pierces the dura just behind the posterior clinoid process, at the junction of the free and attached borders, before running in the lateral wall of the cavernous sinus.
- ▶ **Trigeminal nerve (V)** — its posterior (sensory) root and ganglion lie in Meckel's cave, the recess formed by the evaginated lower layer of the tentorium near the petrous apex.
- ▶ **Nerve supply of the tentorium itself** — the *nervus tentorii*, a recurrent meningeal branch of the ophthalmic division of the trigeminal nerve, supplies the tentorium cerebelli and the supratentorial falx cerebri.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 15.4 — Superior view of the diaphragma sellae and tentorium cerebelli. Note *t* (Snell — *Clinical Neuroanatomy* — 7e, p.451)

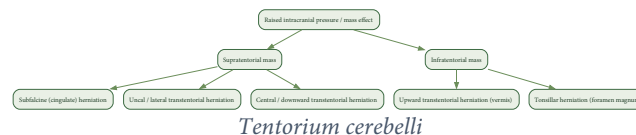
Label on your own hand-drawn superior view of the opened cranial cavity:

- ▶ Attached (outer) border of tentorium — with transverse sinus and superior petrosal sinus
- ▶ Free (inner) border of tentorium — the tentorial notch/incisura
- ▶ Anterior clinoid process (anchor of free border) and posterior clinoid process (anchor of attached border)
- ▶ Dorsum sellae and diaphragma sellae
- ▶ Falx cerebri (cut edge) meeting the tentorium in the midline
- ▶ Straight sinus and great cerebral vein (of Galen)
- ▶ Confluence of sinuses (torcular herophili)
- ▶ Midbrain lying within the tentorial notch
- ▶ Superior petrosal sinus running to the transverse sinus

Applied / Clinical anatomy

- ▶ **Transtentorial (uncal) herniation** — a supratentorial space-occupying lesion (tumour, extradural/subdural haematoma, abscess) raises pressure and pushes the medial temporal lobe, particularly the **uncus**, through the tentorial notch. This compresses the oculomotor nerve (ipsilateral fixed, dilated pupil and ptosis — the earliest sign), the midbrain, and the posterior cerebral artery (risking occipital lobe infarction). It is a life-threatening neurosurgical emergency.

- ▶ **Kernohan's notch phenomenon** — in severe uncal herniation the contralateral crus cerebri may be compressed against the opposite free edge of the tentorium, producing hemiparesis on the *same* side as the mass lesion — a recognised false localising sign.
- ▶ **Central (downward) transtentorial herniation** — diffuse or bilateral supratentorial swelling pushes the diencephalon symmetrically through the incisura; stretching of paramedian perforating vessels can cause secondary brainstem (Duret) haemorrhages.
- ▶ **Upward transtentorial herniation** — an infratentorial mass forces the cerebellar vermis upward through the tentorial notch, compressing the midbrain/superior cerebellar peduncles and the cerebral aqueduct (obstructive hydrocephalus).
- ▶ **Tonsillar herniation** — raised infratentorial pressure may instead push the cerebellar tonsils down through the foramen magnum, compressing the medulla and vertebral arteries.
- ▶ **Subdural haematoma** — because it tracks along the dural reflections, an acute subdural collection typically follows the line of the falx and tentorium on CT, appearing biconcave/crescentic rather than lentiform (the shape typical of extradural haematomas, which cannot cross a dural attachment such as the tentorium).
- ▶ **Tentorial meningioma** — arises from the tentorium itself and can compress the brainstem, cerebellum or straight sinus depending on its site.
- ▶ **Meckel's cave** — the trigeminal ganglion lying in this tentorial recess is the target of percutaneous procedures (radiofrequency rhizotomy, balloon compression, glycerol rhizolysis) for trigeminal neuralgia.
- ▶ **Surgical relevance** — the free margin and tentorial notch are key surgical landmarks in the supracerebellar-infratentorial and subtemporal (uncal) approaches to pineal-region and petroclival tumours; deliberate tentorial incision is used to gain supra-/infratentorial access.



High-yield exam pointers

- ▶ Tentorium cerebelli is the **largest** of the four cranial dural septa (falx cerebri, falx cerebelli, diaphragma sellae, tentorium cerebelli).
- ▶ Tent-shaped fold separating cerebellum (below) from occipital lobes (above); divides the cranial cavity into supra- and infratentorial compartments.
- ▶ Free border is "U"-shaped, forms the **tentorial notch/incisura**, transmits the midbrain, and is anchored anteriorly to the anterior clinoid processes.
- ▶ Attached border encloses the **transverse sinus** posteriorly and the **superior petrosal sinus** anterolaterally; the **straight sinus** runs along its superior-surface junction with the falx cerebri.
- ▶ Gives attachment to the falx cerebelli (inferior surface, midline) and merges with the falx cerebri (superior surface, midline).
- ▶ Lower dural layer near the petrous apex evaginates to form **Meckel's cave** (trigeminal ganglion).
- ▶ Both the **oculomotor** and **trochlear** nerves are intimately related to its free margin — clinically vulnerable in uncal herniation.

- Nerve supply: **nervus tentorii** (recurrent branch of the ophthalmic division of the trigeminal nerve).
- Clinically the anchor point for **uncal, central, upward and tonsillar herniation syndromes** and for the false-localising **Kernohan's notch** sign.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; IB Singh — Textbook of Human Neuroanatomy; Vishram Singh — Clinical Neuroanatomy 4e; BD Chaurasia — Human Anatomy Vol 3–4 8e; Moore's Clinically Oriented Anatomy 9e; Snell — Clinical Neuroanatomy 7e (figure, p.451).



Back & vertebral column



Atlanto Axial Joints

Asked in: Paper I May 2010 — RGUHS MD/MS Anatomy

Definition / Introduction — The atlanto-axial joint complex is the articulation between the first (atlas) and second (axis) cervical vertebrae, and together with the atlanto-occipital joints it constitutes the **craniovertebral joints**. It is not a single joint but a functional unit of **three separate synovial joints** — one median and two lateral — that act simultaneously to produce almost pure rotation of the head and atlas around the odontoid process (dens) of the axis. This rotation, the '**No**' movement, contributes about half of all cervical rotation, and the integrity of its ligaments — especially the transverse ligament of the atlas — is of great applied importance because the spinal cord and medulla lie directly behind the median joint.

Overview and Classification

The atlas articulates with the axis at three synovial joints:

Joint	Type	Location
Median atlanto-axial joint	Pivot (trochoid) synovial joint	Between the dens of the axis and the osseoligamentous ring formed by the anterior arch of the atlas (in front) and the transverse ligament of the atlas (behind)
Lateral atlanto-axial joints (paired)	Plane (gliding) synovial joints	Between the inferior articular facets of the atlas (above) and the superior articular facets of the axis (below)

All three joints move together as a single functional unit; there is no independent movement of one without the others.

Articular Surfaces and Capsules

Median atlanto-axial joint

- ▶ The joint has **two separate synovial cavities**:
 - **Anterior compartment** — a small, vertically ovoid facet on the anterior surface of the dens articulates with a corresponding facet on the posterior surface of the anterior arch of the atlas; enclosed by a loose fibrous capsule.
 - **Posterior compartment** — a larger, horizontally ovoid facet on the posterior surface of the dens articulates with the cartilage-covered anterior surface of the transverse ligament; this compartment is often described as a **synovial bursa**, and its cavity not infrequently communicates with one or both atlanto-occipital joint cavities.

Lateral atlanto-axial joints

- ▶ Reciprocally curved facets: the inferior facet of the lateral mass of the atlas (above) meets the superior articular facet of the axis (below). Classically taught as flat, plane-type facets; more precisely, the bony surfaces are reciprocally concave in the coronal plane and slightly convex (particularly on the axis) in the sagittal plane.
- ▶ Each has a **loose fibrous capsule** attached to the articular margins, reinforced by the lateral part of the **anterior longitudinal ligament** and the **ligamentum flavum**, and by a **posteromedial accessory ligament** running from the body of the axis near the base of the dens to the lateral atlantal mass near the transverse ligament.

Ligaments

Ligament	Attachment	Function
Transverse ligament of the atlas	Arches behind the dens between tubercles on the medial aspect of each atlantal lateral mass (mean length $\approx$ 20 mm)	Retains the dens against the anterior arch of the atlas; the single most important stabiliser — "the strongest ligament" of the complex
Cruciform (cruciate) ligament	Transverse ligament + a superior longitudinal band (to the basiocciput, between the apical ligament and membrana tectoria) + an inferior longitudinal band (to the posterior body of the axis)	Together, divides the atlantal ring into an anterior third (dens) and posterior two-thirds (spinal cord and meninges)
Apical ligament of the dens	Apex of the dens to the anterior margin of the foramen magnum	Represents the cranial remnant of the notochord; weak, contributes little to stability
Alar ("check") ligaments, paired	Posterolateral aspect of the apex of the dens ($\approx$ 11 mm long) to the medial side of the occipital condyle	Principal limiters of atlanto-axial rotation — the contralateral ligament becomes taut on rotation to one side; also checks excessive flexion

Ligament	Attachment	Function
Membrana tectoria	Upward continuation of the posterior longitudinal ligament; body of axis below to the basilar occipital bone above (posterior to the transverse ligament)	Broad supporting band linking axis to occiput
Anterior longitudinal ligament	Anterior tubercle of the atlas to the front of the axial body	Supports the lateral joints and front of the column

Movements and Muscles Producing Them

- Movement is **simultaneous at all three joints** and consists almost exclusively of **rotation about a vertical axis** passing through the dens: the atlas (carrying the skull) rotates around the fixed dens as a pivot — the familiar 'No' movement of the head.
- As rotation occurs, the axis ascends slightly into the atlantal ring, which limits stretch on the lateral joint capsules.
- Rotation is limited mainly by the **alar ligaments**, with a minor contribution from the accessory atlanto-axial ligament; the normal range of atlanto-axial rotation is about **40°**, and **roughly 50% of all cervical rotation** occurs at this joint complex — far more than at any other single cervical level.
- **Muscles producing rotation:** ipsilateral **obliquus capitis inferior**, **rectus capitis posterior major** and **splenius capitis**, acting together with the **contralateral sternocleidomastoid**.

Blood Supply, Nerve Supply and Stability

- **Arterial supply:** an anastomosis between branches of the **deep cervical, occipital and vertebral arteries**. The dens itself receives paired anterior and posterior longitudinal channels from the vertebral artery (entering near its base and apex), reinforced anteriorly by twigs from the external carotid artery via longus colli — this rich supply explains why avascular necrosis is uncommon after a fracture of the base of the dens.
- **Nerve supply:** branches of the **ventral primary ramus of the second cervical (C2) spinal nerve**.
- **Stability** depends chiefly on the **transverse ligament** (strongest), assisted by the weaker **alar ligaments**, the fibrous capsules, the membrana tectoria, ligamentum nuchae and the posterior neck (suboccipital) muscles, which additionally provide proprioceptive/postural control.
- **Relations:** the most important 'at-risk' structure is the **spinal cord**, lying immediately posterior to the median joint (protected only by the posterior two-thirds of the atlantal ring); anteriorly, the joint complex is separated from the retropharyngeal space, buccopharyngeal fascia and superior constrictor by longus capitis, longus colli and the prevertebral fascia.

□ Fig 7.22 — Atlanto-axial joint (includes one median atlanto-axial joint and two lateral atlanto-axial joints) (Vishram Singh — Textbook of Anatomy Vol 3 — 4e, p.362)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A median sagittal section through the foramen magnum and upper three cervical vertebrae, labelling: basiocciput and foramen magnum; **apical ligament of the dens**; **dens (odontoid process)** of the axis; **anterior arch of the atlas** with the small anterior synovial joint; **transverse ligament of the atlas** passing behind the dens, with the posterior synovial cavity (bursa) between dens and ligament; the **superior and inferior longitudinal bands** completing the **cruciform ligament**; **membrana tectoria** running posterior to the transverse ligament from the axis body to the basiocciput; **alar ligament** (one side) from the apex of the dens to the occipital condyle; body of the axis; and the spinal cord occupying the posterior two-thirds of the atlantal ring behind the transverse ligament.

Applied / Clinical anatomy

- ▶ **Judicial hanging / mechanism of death:** the sudden jerk ruptures the **transverse ligament of the atlas**, allowing the dens to dislocate posteriorly with great force, crushing the lower medulla oblongata (vasomotor and respiratory centres) and adjoining spinal cord — the anatomical basis of instantaneous death in execution hanging. Hanging may also cause a bilateral fracture through the pars interarticularis of the axis (**hangman's fracture**), fracture of the odontoid process, or traumatic separation of C2 from C3.
- ▶ **Hangman's fracture:** bilateral fracture of the pars interarticularis of the axis; the second most common axial fracture; a severe hyperextension injury (classically from a fall or road-traffic accident, named for the position of the hangman's knot). Because the vertebral canal is widened by forward displacement of the axis body, the spinal cord is only rarely compressed.
- ▶ **Fracture of the odontoid process:** the most common fracture of the axis, usually following a fall or blow on the head; excessive mobility of the fractured dens, especially with associated rupture of the transverse ligament, risks cord compression.
- ▶ **Atlanto-axial instability/subluxation:** pathological softening or destruction of the transverse and adjacent ligaments (classically in **rheumatoid arthritis**) widens the atlanto-dens interval on flexion-extension radiographs and may cause spinal cord injury; because the transverse ligament is stronger than the dens itself, the dens usually fractures before the ligament ruptures, whereas the weaker alar ligaments may be avulsed by combined flexion-rotation injury, increasing rotation to the opposite side by about a third.
- ▶ **Developmental laxity/anomalies:** failure of the apical or bilateral ossification centres of the dens to fuse can leave a separate **os odontoideum**; hypoplasia of the dens is often accompanied by atlanto-occipital assimilation and basilar invagination — all of these predispose to atlanto-axial subluxation/instability (clinically important, for example, before general anaesthesia/neck manipulation in Down syndrome, in which atlanto-axial instability is a recognised association).
- ▶ **Pseudosubluxation:** in children under 8 years, physiological ligamentous laxity combined with facet orientation can mimic subluxation on lateral cervical radiographs (typically at C2/C3) — a trap for the unwary reporting officer.

- ▶ **Cervical dislocation without fracture:** uniquely possible in the cervical region (compared with thoracic/lumbar levels) because the articular facets are inclined more horizontally, permitting the articular processes to override without breaking.

High-yield exam pointers

- ▶ Three synovial joints: **1 median (pivot) + 2 lateral (plane)**; median joint has **two synovial cavities** (anterior — dens/anterior arch; posterior — dens/transverse ligament, often a bursa).
- ▶ **Transverse ligament** = strongest stabiliser (part of the cruciform ligament); **alar ligaments** = principal limiters of rotation ("check ligaments"), ≈ 11 mm long; **apical ligament** = notochord remnant.
- ▶ Movement = **rotation only** ('No' movement), normal range about **40°**; $\approx 50\%$ of **total cervical rotation** occurs here.
- ▶ Muscles: ipsilateral obliquus capitis inferior + rectus capitis posterior major + splenius capitis, with contralateral sternocleidomastoid.
- ▶ Nerve supply: **ventral ramus of C2**; arterial supply: anastomosis of deep cervical, occipital and vertebral arteries.
- ▶ Death in judicial hanging = transverse ligament rupture $\rightarrow$ posterior dislocation of dens $\rightarrow$ medullary crush.
- ▶ Rheumatoid arthritis is the classic cause of acquired atlanto-axial instability; dens is weaker than the transverse ligament (fractures before it ruptures).
- ▶ Contrast with atlanto-occipital joint: ellipsoid type, permits flexion/extension ('Yes' movement) + limited lateral flexion — the two craniovertebral joint sets together allow head "nodding" and "shaking."

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4 (8e); Vishram Singh — Textbook of Anatomy Vol 3 (4e); Moore's Clinically Oriented Anatomy 9e.



Costal element

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction The costal element (**pleurapophysis**) is the ventral, rib-homologous component of the developing vertebral column — one of the two morphological components that together make up the transverse process of a "typical" vertebra, the other being the **true (transverse) element**. It arises from sclerotomal mesenchyme that condenses in the body wall lateral to the neural arch. Only in the thoracic region does it remain a separate, free bone — the **rib**; at every other level (cervical, lumbar, sacral) it stays rudimentary and fuses with the true transverse element, though its contribution can still be identified developmentally and morphologically. The concept explains the architecture of the foramen transversarium, the "transverse process" of a lumbar vertebra, the sacral ala, and clinically important anomalies such as cervical and lumbar ribs.

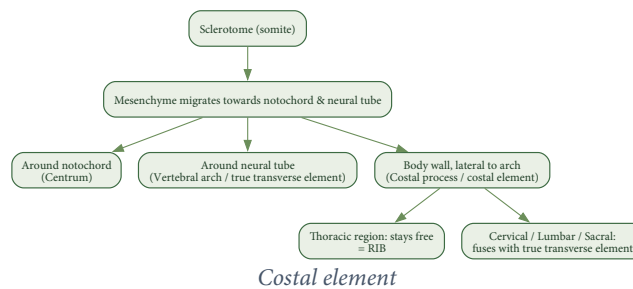
General principle — two elements of the transverse process

- ▶ Descriptively, the "transverse process" of a vertebra looks like a single projection; morphologically it is a **composite of two elements** — the costal element and the true transverse element.
- ▶ The costal element develops as a basic part of the vertebral (neural) arch in mammalian embryos, in the body wall adjacent to the pedicle; comparative anatomists term it the **pleurapophysis** (ventral/parapophyseal bar), as opposed to the true transverse element, the **diapophyseal** (dorsal) bar.
- ▶ In the **thoracic region alone** the two elements remain distinct — the costal element becomes an independent free bone, the rib, articulating with the true transverse element (the descriptive transverse process, which bears the facet for the tubercle of the rib).
- ▶ In the **cervical, lumbar and sacral regions** the costal element remains rudimentary and fuses with the true transverse element, so no free rib forms, though its position and derivatives remain identifiable region by region.

Embryological development

- ▶ Somites differentiate into a ventromedial **sclerotome** and a dorsolateral dermomyotome; sclerotomal cells become mesenchyme and migrate medially toward the notochord and neural tube.
- ▶ This mesenchyme condenses in three sites: (i) around the **notochord** → **centrum** (vertebral body); (ii) around the **neural tube** → **vertebral (neural) arch**, giving pedicles, laminae, spine, articular processes and the **true transverse process**; (iii) in the **body wall lateral to the neural arch** → **costal process (costal element)**.
- ▶ Each vertebra is an **intersegmental** structure, formed from the caudal half of one sclerotome and the cranial half of the sclerotome below (the less-condensed parts fusing, while the condensed central parts form the perichordal disc/annulus fibrosus). Each rib similarly forms from the caudal half of one sclerotome and the cranial half of the next subjacent sclerotome, with the head of the rib contributed by somitocoele cells; this resegmentation places the developing rib opposite the intervertebral disc level and allows the myotome (future intercostal muscle) to bridge the disc, giving the spine its capacity for movement.

- Chondrification of the mesenchymal vertebra begins around the **6th week** of intrauterine life; ossification then proceeds in a craniocaudal progression from primary centres and continues, with secondary centres, up to about **25 years** of age.



Regional derivatives of the costal element

Region	Costal element forms	True transverse element forms
Cervical (typical, C3–C7)	Ventral bar + anterior tubercle ; with the intervening costal (intertubercular) lamella, morphologically represents the capitulum, neck and tubercle of a rudimentary rib; forms the anterior/lateral wall of the foramen transversarium	Dorsal bar + posterior tubercle , attached at the pediculo-laminar junction; forms the posterior/medial wall of the foramen transversarium
Thoracic	Remains a free bone — the rib (head/capitulum, neck, tubercle, shaft)	The descriptive transverse process , bearing the facet that articulates with the tubercle of the rib
Lumbar	Forms the whole of the long, descriptive "transverse process" of a lumbar vertebra	Reduced to the small accessory process at the dorsal root of the transverse process
Sacral	Forms the anterior (ventral) part of the lateral mass/ala , including the auricular surface for the sacroiliac joint; costal elements of adjoining segments fuse to form longitudinal bars between the pelvic sacral foramina	Forms the posterior part of the lateral mass , fusing across segments to raise the lateral sacral crest with its row of transverse tubercles

- The foramen transversarium of a cervical vertebra thus lies **between the ventral (costal) and dorsal (transverse) bars** — the reason a cervical rib, when present, still relates to the same neurovascular plane.
- In the lumbar region, what descriptive anatomy calls the "transverse process" is **not** homologous with the thoracic transverse process — it is the **costal element**; the true transverse element there is reduced to the vestigial accessory process, while the separate **mammillary process** (on the superior articular process) gives attachment to multifidus.

□ Fig 8.4 — Transverse and costal elements of transverse processes of cervical, thoracic, lumbar and sacral vertebrae (Vishram Singh — General Anatomy — 4e, p.338)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Four small paired schematics (cervical, thoracic, lumbar and sacral vertebra, superior/posterior aspect), colour the **costal element** and **true transverse element** differently and label:

- ▶ **Cervical:** anterior tubercle (costal), posterior tubercle (transverse), foramen transversarium between the two bars
- ▶ **Thoracic:** rib (costal), transverse process with facet for tubercle of rib (transverse)
- ▶ **Lumbar:** descriptive "transverse process" = costal element; accessory process = true transverse element; mammillary process (separate, on superior articular process)
- ▶ **Sacral:** ala — anterior part = costal element (bearing auricular surface), posterior part = transverse element (lateral sacral crest)

Rib formation from the thoracic costal element

- ▶ In the thoracic region the costal processes grow anterolaterally from the ventral part of the pedicles (near the centrum) and from the neighbouring perichordal disc, at most levels with accessions from the next adjacent caudal pedicle, expanding to meet the tips of the transverse processes; they come to lie between the myotomic muscle plates.
- ▶ Each costal process first elongates to form a **cartilaginous costal arch**, which is then replaced by endochondral ossification to form the definitive rib.
- ▶ Two joints form from the mesenchyme around the costal process: the **capitular (head) costovertebral joint**, between its proximal end and the perichordal disc/adjoining vertebral bodies, and the **costotransverse joint**, between its distal end and the true transverse element.
- ▶ Ribs 1–7 (**vertebrosternal/true ribs**) curve round the body wall to reach the sternum directly; ribs 8–10 (**vertebrochondral/false ribs**) are more oblique and shorter, joining the costal cartilage of the rib above and contributing to the costal margin; ribs 11–12 (**floating ribs**) are free, with cone-shaped cartilaginous tips.
- ▶ Ossification: a primary centre appears for the shaft of each typical rib prenatally; secondary centres appear at puberty for the head and the tubercle and fuse by about the 25th year. The first rib similarly has a primary centre for the shaft and secondary centres for the head and tubercle.
- ▶ The costal element of the **first lumbar vertebra** occasionally elongates instead of remaining rudimentary, forming a short **lumbar rib** that articulates with the transverse process but not usually the body of the vertebra; the sacrum acquires additional epiphyses for its costal elements (uniting with the half neural arch between the 2nd and 5th years, and with the centrum by about the 8th year), and the fifth lumbar vertebra often shows scale-like epiphyses on the tips of its costal-element-derived transverse processes.

Applied / Clinical anatomy

□ Fig 1.54 — Cervical rib causing pressure on the lower trunk of the brachial plexus (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.74)

- ▶ **Cervical rib:** an accessory rib arising from the overgrown costal element of the **7th cervical vertebra**; occurs in about **0.5–1%** of individuals, may be unilateral or bilateral, and may be complete (synostosis or diarthrosis with the anterior or posterior root of the C7 transverse

process, reaching the sternum) or incomplete (ending in a fibrous band to the first rib). It narrows the space through which the lower trunk of the brachial plexus (C8, T1) and the subclavian artery pass, producing **superior thoracic outlet syndrome** — neurovascular symptoms from pressure on the eighth cervical and first thoracic spinal nerves, and on the subclavian vessels.

- ▶ **Lumbar rib:** the **commonest rib anomaly**, formed from an overgrown costal element of L1 (occasionally L2); it articulates with the transverse process but not usually the vertebral body, and is almost always symptomless, being an incidental radiographic finding.
- ▶ **Sacralization/lumbarization** of the lumbosacral junction reflect variable fusion between the costal element of L5 and the sacral ala, an important pitfall in vertebral-level counting on plain films.
- ▶ **Foramen transversarium variants:** an incompletely formed costal (intertubercular) lamella at a cervical level leaves the foramen transversarium deficient anteriorly — relevant when planning surgery or imaging around the vertebral artery.
- ▶ **Radiological/surgical relevance:** recognising the costal-element origin of the "transverse process" in the lumbar region, and of accessory cervical/lumbar ribs, helps in correctly interpreting and reporting anomalies on chest and spine radiographs/CT before spinal-level localisation and instrumentation.

High-yield exam pointers

- ▶ Costal element = **pleurapophysis**; ventral, rib-homologous derivative of sclerotomal mesenchyme in the body wall lateral to the neural arch.
- ▶ The "transverse process" of a typical vertebra = **costal element + true transverse element**; the two stay separate only in the **thoracic** region, where the costal element becomes the free rib.
- ▶ **Cervical:** costal element → anterior tubercle + ventral bar (anterior wall of foramen transversarium); transverse element → posterior tubercle + dorsal bar.
- ▶ **Lumbar:** costal element → the entire descriptive transverse process; transverse element → the small accessory process.
- ▶ **Sacral:** costal element → anterior part of ala/auricular surface; transverse element → posterior part/lateral sacral crest.
- ▶ **Cervical rib** (from C7 costal element, ~0.5–1%) → compresses lower trunk of brachial plexus + subclavian artery → superior thoracic outlet syndrome.
- ▶ **Lumbar rib** (from L1 costal element) → commonest rib anomaly, usually asymptomatic.
- ▶ Ribs pass through a cartilaginous costal-arch stage before endochondral ossification; the head is contributed by somitocoele cells, and rib ossification (secondary centres for head and tubercle) is complete by ~25 years.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 1, 8e; BD Chaurasia — Human Anatomy Vol 3-4, 8e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — General Anatomy, 4e; Vishram Singh — Textbook of Clinical Embryology; Moore's Clinically Oriented Anatomy, 9e; Sontakke — Textbook of Human Embryology.

**Intervertebral disc**

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction The intervertebral (IV) disc is a fibrocartilaginous pad that unites the adjacent surfaces of vertebral bodies from the axis (C2) down to the sacrum, forming a secondary cartilaginous joint (symphysis) at each level. It is morphologically a **segmental** structure, in contrast to the vertebral body, which is **intersegmental**. There are **23 discs** in the vertebral column — 6 cervical, 12 thoracic and 5 lumbar (the last, "L5", lying between L5 and S1) — with none between the occiput–C1 or C1–C2. Discs together form about one-quarter of the length of the postaxial vertebral column and are the principal sites of flexibility and shock absorption in the spine.

Number, distribution and general features

- ▶ Present between C2/3 and S1 — 23 in all: 6 cervical, 12 thoracic, 5 lumbar.
- ▶ Absent at the atlanto-occipital and atlanto-axial joints (these are synovial, not symphyseal).
- ▶ Shape corresponds to that of the vertebral bodies it unites (oval in cervical/lumbar, more circular in thoracic region).
- ▶ **Thickness** varies by region and within the same disc:
 - Cervical and lumbar discs are thicker anteriorly than posteriorly — this wedge shape contributes to the cervical and lumbar lordoses.
 - Thoracic discs are of nearly uniform thickness; the anterior concavity there is due mainly to the vertebral bodies.
 - Thinnest in the upper thoracic region; thickest in the lumbar region.
- ▶ Discs contribute proportionately more to column length in the cervical and lumbar regions than in the thoracic region, making these regions more pliant.

Gross structure

Each disc has three structural components:

Component	Location	Composition	Key features
Nucleus pulposus	Central, closer to the posterior surface of the disc	Hydrated collagen (type II)–proteoglycan gel; remnant of the notochord	Soft, gelatinous, ~90% water at birth, falling to ~70% in old age; contains a few multinucleated notochordal cells in the first decade, later replaced by fibrocartilage; acts as a hydraulic shock-absorber under constant tension
Anulus fibrosus	Peripheral, encircling the nucleus	Outer narrow collagenous zone + wider inner fibrocartilaginous zone, arranged in concentric lamellae	Lamellae are incomplete collars, convex peripherally; fibres run obliquely at ~65° to the vertical and cross in alternating directions in successive lamellae (like plywood), limiting rotation; about half the lamellae are incomplete, especially posterolaterally — a site of relative weakness predisposing to herniation
Vertebral (cartilage) end-plates	Thin plates above and below the nucleus, between disc and vertebral body	Hyaline cartilage nearer the bone, fibrocartilage nearer the disc	Do not reach the periphery of the body (encircled by the bony ring apophysis); the disc is otherwise avascular and is nourished by diffusion through these end-plates

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

□ Fig 8.9 — Structure of an intervertebral disc: (A) anterior view and (B) superior view (Vishram Singh — *General Anatomy* — 4e, p.347)

Reproduce a vertical (coronal) section through a lumbar disc and label:

- ▶ Vertebral body (above and below)
- ▶ Vertebral (cartilaginous) end-plate — hyaline cartilage layer
- ▶ Ring apophysis
- ▶ Anulus fibrosus with its concentric, obliquely-crossing lamellae
- ▶ Nucleus pulposus (central, gelatinous)
- ▶ Anterior longitudinal ligament and posterior longitudinal ligament, showing their blending with the outer anulus fibres
- ▶ Adjacent spinal nerve root emerging at the intervertebral foramen (posterolateral to the disc)

Development

- ▶ The nucleus pulposus is derived from the embryonic **notochord**, which persists centrally within each developing disc while regressing elsewhere along the vertebral column.
- ▶ The anulus fibrosus differentiates from the surrounding sclerotomal mesenchyme as a fibrocartilaginous condensation around the notochordal remnant.
- ▶ Notochordal cells disappear during the first decade of life; the mucoid nuclear material is then progressively replaced by fibrocartilage derived from the anulus and from the cartilaginous end-plates, so the nucleus becomes less distinct from the anulus with age and progressively loses its water-binding capacity.

Vascular and nerve supply

- ▶ **Blood supply:** Normal discs are essentially **avascular**. Small offshoots of the segmental (spinal) branches of arteries supplying the vertebral column form an anastomosis on the outer surface of the anulus fibrosus and supply only its most peripheral fibres. The bulk of the disc depends on **diffusion** — from vertebral bone through the end-plates, and from the peripheral anulus.
- ▶ **Venous drainage:** via the external and internal vertebral venous plexuses to the intervertebral veins, and thence to the segmental veins draining the vertebral column.
- ▶ **Nerve supply** (best studied in the lumbar region):
 - The outer one-third of the anulus fibrosus is innervated by the **sinuvertebral (recurrent meningeal) nerves**. Each sinuvertebral nerve supplies the disc at the level of its own spinal nerve of origin **and** the disc one level above.
 - The anterior part of the anulus is supplied by the sympathetic system (preganglionic fibres via the grey rami communicantes) rather than by the mixed spinal nerve.
 - The nucleus pulposus and the inner two-thirds of the anulus are normally non-innervated; in damaged or degenerate discs, nerve fibres may grow in and penetrate more centrally, contributing to discogenic pain.

Functions

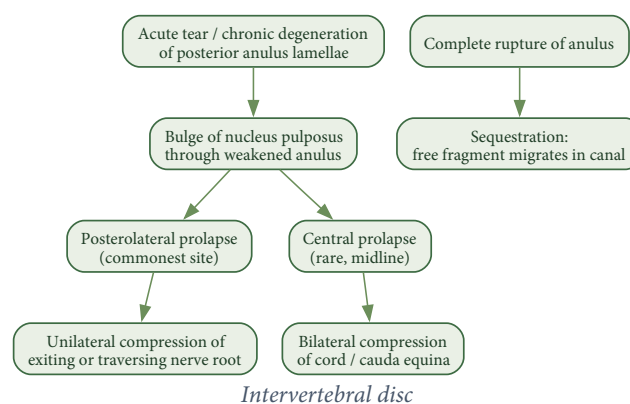
- ▶ Chief bond between adjacent vertebral bodies from C2 to the sacrum, giving overall shape to the vertebral column.
- ▶ Acts as a hydraulic **shock absorber**, distributing compressive loads evenly across the vertebral end-plates during weight-bearing and movement.
- ▶ Permits and limits movement: allows flexion, extension and lateral flexion; the crossing oblique annulus fibres restrict rotation.
- ▶ Contributes to the primary and secondary curvatures of the vertebral column (anterior wedge shape in cervical and lumbar discs).
- ▶ Diurnal variation: the nucleus expels water under load during the day and re-imbibes it at rest, so a person is measurably taller in the morning than at night.

Relations of the disc ('at-risk' structures)

- ▶ **Posterolaterally** — forms the anterior boundary of the intervertebral foramen on each side; closely related to the spinal nerve and its accompanying vessels — the commonest site of clinically significant prolapse.
- ▶ **Posteriorly (centrally)** — related to the dura mater covering the spinal cord/cauda equina, separated by the posterior longitudinal ligament and epidural fat/veins.
- ▶ **Anteriorly** — relations vary with level; important structures at risk include the pharynx and oesophagus (cervical level) and the descending aorta and inferior vena cava (thoraco-lumbar level).
- ▶ **Laterally** — the parietal pleura in the thorax; the sympathetic trunk and psoas major in the lumbar region.

Applied / Clinical anatomy

- ▶ **Prolapsed intervertebral disc (PIVD)**: most common in the 20–55-year age group; commonest at L4/5 and lumbosacral (L5/S1) levels; also affects cervical discs, particularly C5/6 and C6/7; thoracic disc prolapse is rare. Acute tearing or chronic degeneration of the weaker posterior lamellae of the annulus allows the nucleus to bulge or herniate.



- ▶ **Exiting vs traversing nerve root**: at each disc/foramen level there are two nerve roots to consider — the **traversing** root (crossing behind the disc en route to exit one level below) and the **exiting** root (already leaving at that level). In the lumbar spine the traversing root is usually compressed,

so an L5/S1 disc prolapse classically compresses the **S1** nerve root, not L5. A far-lateral (extraforaminal) prolapse instead compresses the exiting root at its own level. In the cervical spine, because roots leave almost horizontally, the exiting root (numbered for the vertebra below the disc) is usually affected.

- ▶ Clinical presentation is dermatomal pain and sensory loss (sensory changes usually precede motor loss), classically radiating from the low back into the buttock and leg along the sciatic nerve distribution ("sciatica") in lumbar prolapse.
- ▶ **Internal disc disruption** (without frank prolapse) is now recognised as a common cause of chronic low back pain — the nucleus decompresses and the inner annular lamellae collapse into it, without gross herniation.
- ▶ **Cervical spondylosis**: degenerative disc and facet/uncovertebral joint disease beginning in the third decade, most often affecting the **C5/6** disc space, causing neck stiffness and nerve-root pain.
- ▶ Disc height and hydration are readily assessed on **MRI**, the imaging modality of choice for suspected prolapse (loss of disc signal, annular tear, extruded fragment).
- ▶ The disc's segmental (versus the vertebral body's intersegmental) developmental pattern explains why hemivertebrae and other segmentation anomalies characteristically occur at disc, not vertebral-body, level.

□ Fig 8.10 — Slipped disc (prolapse/herniation of nucleus pulposus): posterior and lateral views showing nerve root compression (Vishram Singh — *General Anatomy* — 4e, p.349)

High-yield exam pointers

- ▶ 23 discs total: 6 cervical + 12 thoracic + 5 lumbar; none between occiput–C1 or C1–C2.
- ▶ Nucleus pulposus = notochordal remnant; water content 90% at birth → 70% in old age.
- ▶ Anulus fibrosus fibres cross obliquely at ~65° in alternating directions between lamellae — limits rotation; posterolateral lamellae are relatively incomplete → common site of prolapse.
- ▶ Disc is avascular except for the outer anulus periphery; nourished chiefly by diffusion through the cartilaginous end-plates.
- ▶ Outer 1/3 anulus supplied by sinuvertebral nerve, which supplies the disc at its own level and one level above; anterior anulus supplied by sympathetic grey rami.
- ▶ Commonest prolapse sites: L4/5 and L5/S1 (lumbar), C5/6 and C6/7 (cervical); thoracic prolapse rare.
- ▶ Traversing nerve root (not exiting) is usually compressed in lumbar prolapse — so L5/S1 prolapse compresses the S1 root.
- ▶ Joints between vertebral bodies (united by IV discs + anterior/posterior longitudinal ligaments) are secondary cartilaginous joints (symphyses).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia's Human Anatomy Vol 2 8e; Vishram Singh — General Anatomy 4e; AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen); Vishram Singh — Textbook of Anatomy Vol 2 4e.

♦ ♦ ♦

Sub-occipital triangle

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction. The suboccipital triangle is a paired, deep muscular space situated in the suboccipital region of the back of the neck, bounded by three of the four suboccipital muscles. It lies almost in the horizontal plane when the head is in the anatomical position. It is of major applied importance because it transmits the third part of the vertebral artery and the suboccipital nerve (dorsal ramus of C1), both vulnerable at the atlanto-occipital/atlando-axial junction.

Suboccipital muscles (form the boundaries)

Four small muscles connect the occipital bone to the atlas and axis; three of them bound the triangle.

Muscle	Origin	Insertion	Nerve supply
Rectus capitis posterior major	Spine of axis	Lateral part of inferior nuchal line and occipital bone below it	Suboccipital nerve (dorsal ramus C1)
Rectus capitis posterior minor	Posterior tubercle of atlas	Medial part of inferior nuchal line, between it and foramen magnum	Suboccipital nerve
Obliquus capitis inferior (larger of the two obliques)	Spine and adjoining lamina of axis	Transverse process of atlas	Suboccipital nerve
Obliquus capitis superior	Transverse process of atlas	Occipital bone between superior and inferior nuchal lines, lateral to semispinalis capitis	Suboccipital nerve

All four are supplied by the suboccipital nerve and are mainly postural/extensor muscles of the head; acting alone, rectus capitis posterior major and obliquus capitis inferior also rotate the head to the same side.

Boundaries

- **Superomedial** — rectus capitis posterior major, supplemented medially by rectus capitis posterior minor (the two recti posteriores minores are visible in the small triangular gap between the two major muscles of either side).
- **Superolateral** — obliquus capitis superior.
- **Inferior** — obliquus capitis inferior.

Roof (superficial to deep)

- Thick skin and dense fibrous **superficial fascia**, which contains the greater and third occipital nerves and the terminal part of the occipital artery with its veins.
- **Trapezius** (fibres running downward and laterally) and, laterally, overlap of sternocleidomastoid.
- **Splenius capitis**, then **semispinalis capitis** — the latter forms the immediate roof medially; **longissimus capitis** lies over the lateral part of the triangle.

- ▶ A layer of dense fibrous/adipose tissue directly covers the triangle deep to semispinalis capitis.

Floor

- ▶ Posterior arch of the atlas.
- ▶ Posterior atlanto-occipital membrane.

Contents

Content	Key points
Third part of the vertebral artery	Emerges from the foramen transversarium of the atlas, winds backwards and medially behind the lateral mass of the atlas, grooves the upper surface of the posterior arch of the atlas, and leaves the triangle by passing deep to the (lower/lateral edge of the) posterior atlanto-occipital membrane to become the fourth (intracranial) part.
Dorsal ramus of the first cervical nerve (suboccipital nerve)	Emerges between the posterior arch of the atlas and the vertebral artery (nerve lies below/medial to the artery, separating it from the arch); purely motor — unlike other spinal nerves, C1 has no sensory (dorsal root ganglion) component, so it gives no cutaneous branch.
Suboccipital venous plexus	Lies in and around the triangle; drains muscular veins, occipital veins, the internal vertebral venous plexus and a condylar emissary vein into the deep cervical and vertebral veins.

Relations and course of contents

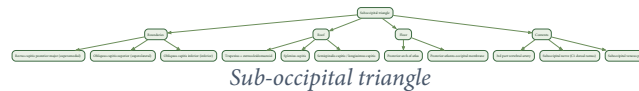
- ▶ **Medially:** the triangle is covered by a layer of dense adipose tissue deep to semispinalis capitis.
- ▶ **Laterally:** it lies deep to longissimus capitis and sometimes splenius capitis, both of which overlap obliquus capitis superior.
- ▶ The vertebral artery and the dorsal ramus of C1 lie together in a groove on the upper surface of the posterior arch of the atlas; the nerve lies below the artery and separates it from the bone.
- ▶ The **suboccipital nerve**, after emerging, breaks up to supply the four suboccipital muscles and semispinalis capitis; its branch to obliquus capitis inferior sends a communicating twig to the greater occipital nerve.
- ▶ The **greater occipital nerve** (large medial branch of the C2 dorsal ramus) is *not* a content but a closely related structure: it winds round the lower border of obliquus capitis inferior, crosses the suboccipital triangle, and pierces semispinalis capitis and trapezius to supply the scalp — the thickest cutaneous nerve in the body.
- ▶ Muscular branches of the third part of the vertebral artery supply the suboccipital muscles, and its meningeal branches supply the posterior cranial fossa dura.

□ Fig 10.5 — Right suboccipital triangle: Boundaries, floor and contents (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.221)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw the right suboccipital region in posterior view and label:

- ▶ The three boundary muscles — rectus capitis posterior major (superomedial), obliquus capitis superior (superolateral), obliquus capitis inferior (inferior) — with rectus capitis posterior minor shown medial to major.
- ▶ Floor — posterior arch of atlas + posterior atlanto-occipital membrane.
- ▶ Contents in the floor of the triangle — third part of vertebral artery (grooving the atlas) and dorsal ramus of C1 (suboccipital nerve) lying below/medial to it.
- ▶ Related structures crossing the triangle — greater occipital nerve (C2) and occipital artery, spine of axis, transverse process of atlas, semispinalis capitis and longissimus capitis forming the roof.

**Applied / Clinical anatomy**

- ▶ **Vertebral artery vulnerability:** the third part of the vertebral artery is relatively unprotected as it winds through the triangle, grooving the atlas before piercing the posterior atlanto-occipital membrane — this segment is the classic surgical/radiological landmark for the vertebral artery at the craniovertebral junction.
- ▶ **Purely motor suboccipital nerve:** because C1 has no sensory root, lesions/entrapment of the suboccipital nerve present with suboccipital muscle weakness/spasm rather than a sensory deficit.
- ▶ **Greater occipital neuralgia:** a syndrome of pain and paraesthesiae in the distribution of the greater occipital nerve (which crosses the triangle before piercing semispinalis capitis and trapezius); it is usually due to damage/irritation of the nerve, and a similar picture can arise from upper (C2) facet-joint arthritis — a common cause of occipital headache.
- ▶ **Collateral (cruciate) arterial anastomosis:** around semispinalis capitis, the descending branch of the occipital artery (from the external carotid) anastomoses with the deep cervical artery (from the costocervical trunk of the subclavian) — an important collateral channel between the external carotid and subclavian systems in this region.
- ▶ **Surface/dissection landmark:** the triangle is exposed only after reflecting trapezius, splenius capitis and semispinalis capitis in sequence — a standard sequence tested in viva and useful for localising posterior neck pain generators.

High-yield exam pointers

- ▶ Triangle bounded by **rectus capitis posterior major** (superomedial), **obliquus capitis superior** (superolateral) and **obliquus capitis inferior** (inferior); rectus capitis posterior minor lies medial to, not as a true boundary of, the triangle.

- ▶ Floor = **posterior arch of atlas + posterior atlanto-occipital membrane**; roof (superficial to deep) = trapezius/sternocleidomastoid → splenius capitis → semispinalis capitis/longissimus capitis.
- ▶ Contents = **3rd part of vertebral artery, suboccipital nerve (C1 dorsal ramus), and suboccipital venous plexus.**
- ▶ Suboccipital nerve is **purely motor** (no cutaneous branch) — supplies the four suboccipital muscles + semispinalis capitis.
- ▶ **Greater occipital nerve (C2)** crosses the triangle superficially but is not one of its contents; it is the thickest cutaneous nerve in the body and is clinically linked to occipital neuralgia.
- ▶ All four suboccipital muscles are supplied by the suboccipital nerve and act mainly as postural extensors of the head at the atlanto-occipital/atlando-axial joints.
- ▶ The vertebral artery's third part is a key surgical/radiological landmark at the craniovertebral junction.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia — Human Anatomy Vol 3-4 8e; Vishram Singh — Textbook of Anatomy Vol 3 4e; IB Singh — Textbook of Anatomy Vol 3 6e; Moore's Clinically Oriented Anatomy 9e.



History, anthropology & comparative anatomy



Anatomical act

Asked in: Paper I May 2018 · Paper I Oct 2009 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction — The **Anatomy Act** is the legal instrument that authorises a recognised medical/teaching institution to obtain, hold and use human dead bodies for the purposes of **anatomical examination, dissection and medical education**, while laying down the safeguards under which this may be done. It was first enacted in the United Kingdom (Anatomy Act, 1832) to end the illegal trade in exhumed and murdered corpses that had fed the anatomy schools of that era. In India, each state subsequently enacted its own version — the **Bombay Anatomy Act, 1949** being the earliest and the model statute — governing the supply of **unclaimed bodies** to medical colleges, and today running alongside voluntary **body-donation (bequeathal)** programmes.

Historical background — from body-snatching to legislation

- ▶ Through the 18th century, the only bodies legally available for dissection in Britain were those of executed murderers (Murder Act, 1752) — far too few to meet the needs of expanding anatomy schools.
- ▶ This shortage gave rise to "**resurrectionists**"/**body-snatchers**, who exhumed freshly buried corpses and sold them to anatomists.

- ▶ Between 1827–1828, **William Burke and William Hare** of Edinburgh went a step further, murdering victims (16 in number) to supply cadavers to Dr Robert Knox's anatomy school; Burke was tried, convicted and executed, and the scandal provoked national outrage.
- ▶ The public revulsion at "Burke-and-Hare"-style murders for anatomical trade directly led to the **Anatomy Act, 1832** in the UK, which **legalised the use of unclaimed bodies** from workhouse and hospital mortuaries for teaching, and instituted its own **Inspectorate of Anatomy** to regulate schools — ending the body-snatching trade.
- ▶ This 1832 Act became the historical template for the "unclaimed body" model of cadaver procurement that most Commonwealth countries, including India, later adopted in their own legislation.

The Anatomy Act — purpose and key terms

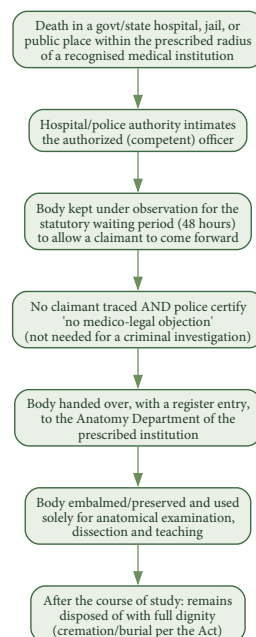
- ▶ Purpose (as stated in the Act): *"An Act to provide for the supply of unclaimed bodies of deceased persons to hospitals and medical and teaching institutions for the purpose of anatomical examination and dissection."*
- ▶ In India, the **Bombay Anatomy Act, 1949** was the earliest such enactment; most other states subsequently framed their own Anatomy Act (broadly modelled on it, with local rules) to regulate cadaver supply to medical colleges within their jurisdiction.

Term	Meaning
Unclaimed body	Body of a deceased person for whom no relative/legal claimant comes forward within the statutory period after death
Prescribed institution	A medical/teaching institution recognised under the Act as eligible to receive bodies for anatomical use
Authorized/competent officer	Official (e.g., medical superintendent/police authority) empowered to certify and release an unclaimed body
Anatomical examination	Dissection and related study of the body for undergraduate/postgraduate medical education

SOURCE & COVERAGE

Feature	Unclaimed body (Anatomy Act route)	Bequeathed / donated body
Consent	No ante-mortem consent — body of a person dying without a traced claimant	Voluntary ante-mortem pledge by the individual (donor pledge/card), honoured by next-of-kin at death
Legal basis	State Anatomy Act (Bombay Anatomy Act, 1949 model)	Same Act's body-donation provision / institution's body-donation programme
Formalities	Statutory waiting period + police "no claimant, no medico-legal objection" certificate	Donor card/registration + death certificate + kin's consent; no waiting period needed
Ethical standing	Historically criticised — the burden fell disproportionately on the unclaimed poor/destitute	Regarded as ethically superior — respects individual autonomy and informed consent
Present-day trend	A shrinking source in most states	Increasingly the preferred/major source for modern medical colleges

Legal procedure for procurement of an unclaimed body



Anatomical act

- The 48-hour clearance and police "no objection" step exists specifically to **exclude medico-legal cases** — a body needed for a criminal investigation or unidentified-death inquiry cannot be released for teaching until that process is complete.
- Only a **recognised/notified ("prescribed") institution** may receive the body; a register recording identity (if known), cause of death and date of receipt must be maintained.

- ▶ The Act binds the institution to **dispose of the remains with dignity** (cremation/burial as per the deceased's presumed faith, or as prescribed) once the anatomical study is complete — this is a statutory obligation, not a courtesy.

Body donation (bequeathal) programme

- ▶ A living individual voluntarily pledges, in advance, to donate their body after death for anatomical teaching/research, and is issued a **donor pledge card** by the institution.
- ▶ At death, the next-of-kin informs the institution, produces the death certificate and donor card, and the body is accepted with the family's consent — **no statutory waiting period or police clearance is required**, since ante-mortem consent already exists.
- ▶ Body donation must be distinguished from **organ donation** under the Transplantation of Human Organs Act (THOA), 1994 — the latter governs retrieval of specific organs/tissues (often from a brain-dead or living donor) for **transplantation into a recipient**, whereas body-donation under the Anatomy Act supplies the **whole body** for **gross anatomical dissection and teaching**, not transplantation.
- ▶ Because of the declining supply of unclaimed bodies and growing ethical emphasis on consent, bequeathal programmes are now actively promoted by anatomy departments and are becoming the dominant source of cadavers in many medical colleges.

Regulatory and institutional responsibility

- ▶ Only an institution formally recognised ("prescribed") under the state's Anatomy Act may lawfully receive and dissect a human body; an **authorized officer** (typically the Head of Anatomy or an institutional nominee) is responsible for verifying legal formalities, maintaining the body-receipt register, and ensuring lawful disposal after use.
- ▶ Regulatory bodies overseeing medical education (the National Medical Commission, formerly the Medical Council of India) require an adequate, properly documented supply of cadavers relative to student strength for practical dissection training to be permitted in a recognised medical college.
- ▶ The same legal principles — identification, written/implied consent, police no-objection, and a death certificate — also govern the closely allied procedures of **embalming** and preparation of **museum specimens** from a cadaver.

Applied / Clinical anatomy

- ▶ **Ethical aspects of cadaveric dissection:** the cadaver is often described as the student's "**first teacher**"; many medical schools require students to take a formal **oath before beginning dissection**, pledging to uphold the dignity of the deceased and to use the knowledge gained only for the advancement of medical science.
- ▶ Honouring the **donor and family** is regarded as the prime responsibility of every anatomy student and teacher — "the dead teach the living," and dissected remains are disposed of/cremated with full dignity once teaching is complete.
- ▶ **Medico-legal safeguard:** the mandatory police clearance before release of an unclaimed body prevents destruction of evidence in an unresolved criminal or unidentified-death case.

- ▶ **Shortage of cadavers:** falling numbers of legally releasable unclaimed bodies (better tracing of relatives, faster claim processing) have driven institutions toward body-donation drives, greater use of embalmed/preserved specimens, plastinated models, and digital/virtual dissection resources to supplement hands-on cadaveric teaching.
- ▶ **Distinction from organ transplantation law:** candidates must not conflate the Anatomy Act (whole-body procurement for teaching) with the Transplantation of Human Organs Act (organ/tissue procurement for clinical transplantation) — a common source of confusion in exams.

High-yield exam pointers

- ▶ Anatomy Act = statute enabling lawful supply of **unclaimed bodies** to recognised institutions for **anatomical examination and dissection**.
- ▶ Historical origin: UK **Anatomy Act, 1832**, enacted after public outrage over the **Burke and Hare** murders (Edinburgh, 1827–28) committed to supply cadavers for dissection.
- ▶ Indian model statute: **Bombay Anatomy Act, 1949** — most states enacted their own version on similar lines.
- ▶ "**Unclaimed body**" = one for which no claimant appears within the statutory waiting period (48 hours) after death in a notified government hospital/public place within the institution's prescribed radius.
- ▶ Release requires **police certification of no claimant and no medico-legal objection** before the body is handed to the anatomy department.
- ▶ Two sources of cadavers: (1) **unclaimed bodies** (Anatomy Act route) and (2) **bequeathed/donated bodies** (voluntary pledge) — the latter is ethically preferred and increasingly the major source today.
- ▶ After teaching use, the Act mandates **disposal of remains with dignity** (cremation/burial).
- ▶ **Body donation ≠ organ donation** — the latter is governed by the Transplantation of Human Organs Act, 1994.
- ▶ Ethical practice around dissection: oath-taking, honouring the donor/family, treating the cadaver as the "first teacher."

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; Vishram Singh — General Anatomy 4e; Haldar — Notes on Embalming & Museum Techniques; BD Chaurasia — Human Anatomy Vol 3-4, 8e.

Coverage note: The available corpus confirms the core historical facts (Burke & Hare, UK Anatomy Act 1832, Bombay Anatomy Act 1949 and its unclaimed-body procedure) and the ethical/"first teacher" material verbatim, but does not carry the full statutory text of individual Indian state Anatomy Acts (section numbers) or a specific NMC/MCI cadaver-to-student ratio figure; the general legal-procedure and body-donation administrative points are presented as standard, universally-taught PG Anatomy curriculum content consistent with these confirmed sources.



Andreas Vesalius

Asked in: Paper I Nov 2018 · Paper I Nov 2016 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction Andreas Vesalius (AD 1514–1564) was a Brussels-born Renaissance anatomist who served as **Professor of Anatomy at the University of Padua**, Italy, and is universally regarded as the **"Father of Modern Anatomy"** (also called the **"Reformer of Anatomy"**). His masterwork, **De Humani Corporis Fabrica Libri Septem* ("On the Workings of the Human Body, in Seven Books"), written when he was only 28 years old and published in 1543, was based on his own systematic human dissections and boldly corrected the centuries-old errors of Galen, thereby refounding anatomy as an empirical, observation-based science and remaining the authoritative anatomical text for two centuries*.

1. Historical setting — the Renaissance and the University of Padua

- ▶ The **Renaissance** (14th–16th century AD) was the transitional period between the Middle Ages ("Dark Ages," beginning with the fall of Rome in AD 476) and the modern age of science, marked by a revival of both arts and sciences.
- ▶ Vesalius's immediate predecessor in this timeline was **Leonardo da Vinci** (AD 1452–1519) — painter, sculptor and anatomist — who drew outstanding anatomical sketches, made wax casts of the cerebral ventricles, is considered the originator of cross-sectional anatomy, and first described the moderator band of the right ventricle; da Vinci's own notebooks, however, were lost for over four centuries and had no influence on 16th-century anatomy.
- ▶ **Vesalius was born in Brussels** into a family of physicians.
- ▶ He became **Professor of Anatomy at the University of Padua** in Italy — at the time the foremost centre of anatomical teaching in Europe.
- ▶ Breaking from the medieval tradition in which the professor merely read from Galen's text while a barber-surgeon dissected, **Vesalius performed the human dissections himself** and personally demonstrated structures to his students.
- ▶ He also **initiated the use of live models** to determine the surface landmarks of internal structures — an early root of what is taught today as "living anatomy" / surface anatomy.

2. Position in the historical timeline of anatomical contributors

Contributor	Period	Key contribution
Galen	cir. AD 130–216	Most influential Roman-era medical writer ("Prince of Physicians"); work based largely on animal dissection, hence containing many errors; his authority dominated anatomy for ~1,500 years (the "Galenic age")
Leonardo da Vinci	AD 1452–1519	Outstanding anatomical sketches; wax cast of cerebral ventricles; originator of cross-sectional anatomy; described the moderator band of the right ventricle

□ Fig 1.9 — Andreas Vesalius. (Vishram Singh — General Anatomy — 4e, p.65)

5. Personal traits and enduring legacy

- ▶ Unlike other prominent anatomists of his era who attached their own names to the structures they described (e.g., **Jacobus Sylvius**, **Fallopian**, **Eustachius**), **Vesalius deliberately chose not to have his name attached to the body parts he described.**
- ▶ He remained a teacher of anatomy and a bachelor throughout his life.
- ▶ Vesalius is remembered as the **greatest anatomist of his time**, and is honoured today as the "**Father of Modern Anatomy**" and the "**Reformer of Anatomy**."
- ▶ Ironically, despite his own wish not to be eponymised, later anatomists did attach his name to one skull foramen — the **foramen of Vesalius** (see below) — which is still taught and examined today.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Base of the skull (norma basalis), greater wing of sphenoid region, labelling:

- ▶ Foramen ovale
- ▶ Foramen spinosum (posterolateral to foramen ovale, at the root of the spine of the sphenoid)
- ▶ Foramen rotundum (anteromedial to foramen ovale)
- ▶ **Emissary sphenoidal foramen (foramen of Vesalius)** — mark as an inconstant small foramen medial to / between the foramen ovale and the scaphoid fossa
- ▶ Scaphoid fossa
- ▶ Spine of sphenoid
- ▶ Canaliculus innominatus (when present, between foramen ovale and foramen spinosum)

Applied / Clinical anatomy

- ▶ **Foramen of Vesalius (emissary sphenoidal foramen):** an inconstant (present only in some skulls) small foramen in the greater wing of the sphenoid, situated **medial to the foramen ovale** (between the foramen ovale and the scaphoid fossa). When present, it transmits an **emissary vein connecting the cavernous sinus with the pterygoid venous plexus.**
- ▶ Clinically, this emissary vein provides one of several **potential valveless communications between the extracranial pterygoid venous plexus and the intracranial cavernous sinus**, and is therefore relevant (along with the foramen ovale itself, and other emissary foramina) as a route by which **infection from the face/pterygoid region (e.g., from dental or facial infections) can spread intracranially to cause cavernous sinus thrombosis** — a classic viva/applied-anatomy cross-link from the history question to skull-base gross anatomy.
- ▶ Its **inconstancy** and small variable position are a favourite "spot" viva item at skull-base osteology stations, often confused with the **canaliculus innominatus** (which instead transmits the lesser petrosal nerve when it does not pass through the foramen ovale) — the two must be distinguished.

- ▶ **Methodological legacy:** Vesalius's insistence on **first-hand human dissection** (rather than relying on animal dissection or textual authority, as Galen had) is the direct methodological ancestor of the **modern dissection-based gross-anatomy curriculum** followed in medical schools today, including the MD/MS Anatomy course itself.
- ▶ His use of **live models to map surface landmarks** anticipates the modern discipline of **living/surface anatomy**, now indispensable for clinical examination, surface marking of viscera and vessels, and image-guided procedures.
- ▶ The **richly illustrated woodcut plates** of the *Fabrica* set the standard for anatomical illustration and are the historical forerunner of the labelled atlas-style figures used in every modern anatomy textbook.

High-yield exam pointers

- ▶ Andreas Vesalius, AD 1514–1564; born in **Brussels**; Professor of Anatomy at the **University of Padua**.
- ▶ Authored ***De Humani Corporis Fabrica Libri Septem** — *written at age 28, published 1543; remained authoritative for two centuries**.
- ▶ **Personally performed human dissections** and used **live models** to map surface landmarks of internal structures.
- ▶ **Boldly refuted hundreds of Galen's errors** (Galen's anatomy was based on animal, not human, dissection) — provoked bitter controversy with Galenic anatomists (e.g., Sylvius); destroyed much unpublished work and stopped dissecting under the strain of attacks.
- ▶ Titled the **"Father of Modern Anatomy"** / **"Reformer of Anatomy."**
- ▶ Chose **not** to attach his own name to any structure — unlike contemporaries Sylvius, Fallopius, Eustachius — yet the **foramen of Vesalius (emissary sphenoidal foramen)** survives as his eponym today.
- ▶ Wrote in **Latin** (as Galen had written in Greek) — root of Greco-Latin anatomical nomenclature.
- ▶ Preceded by **Leonardo da Vinci** (anatomical sketches); succeeded by **William Harvey** (circulation of blood) in the historical timeline of anatomy.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (History of Anatomy chapter); AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen), Introduction; BD Chaurasia — Human Anatomy Vol 3–4 8e (foramen of Vesalius, skull); Vishram Singh — Textbook of Anatomy Vol 3 4e (foramen of Vesalius, base of skull).

Coverage note: Gray's Anatomy (Standring) 41e's own "Historical introduction" chapter narrates the editorial history of the *Gray's Anatomy* textbook itself (its successive editors and editions), not the life and work of Vesalius or the *De Humani Corporis Fabrica*; it is therefore not cited for biographical content here. The Vesalius biography above is grounded in Vishram Singh's General Anatomy history-of-anatomy chapter and corroborated by AK Datta's citation of the *Fabrica* preface and by the "foramen of Vesalius" eponym independently taught in the standard gross-anatomy texts (BD Chaurasia, Vishram Singh Vol 3).



Galen

Asked in: Paper I May 2009 · Paper I Oct 2006 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction Claudius Galen (c. AD 130–216) of Pergamon was a Greek physician of the Roman period and, after Hippocrates, the most influential writer of antiquity on medical subjects — anatomy, physiology, pathology, symptomatology and treatment. Because human dissection was forbidden in Rome, his anatomical descriptions were derived almost entirely from the dissection of animals and extrapolated to man, so that alongside genuine, classic observations his system also carried many errors. For roughly 1,500 years — the "Galenic age" — his writings were accepted as unquestionable medical authority, until Vesalius's *De Humani Corporis Fabrica* (1543) and Harvey's demonstration of the circulation (1628) dismantled the errors and closed the era. He remains a pivotal figure bridging the Alexandrian school of Herophilus and the Renaissance revival of human anatomy.

1. Time, place and standing in the history of anatomy

- ▶ Born in Pergamon (a Greek city of Asia Minor); trained in the Alexandrian medical tradition before settling in Rome.
- ▶ Served early in his career as physician to the gladiators of Pergamon — giving him first-hand exposure to deep wounds, fractures and living anatomy — and later became physician to the Roman imperial court, most notably to Emperor Marcus Aurelius.
- ▶ Called the "**Prince of Physicians**"; regarded as the foremost practitioner of his time and the most influential medical author of all time.
- ▶ A prolific writer who theorised on anatomy, physiology, pathology, symptomatology and treatment; his corpus dominated Western and, through Arabic translation, Islamic medicine for centuries.
- ▶ His place in the standard history-of-anatomy timeline, positioned between the Alexandrian and Renaissance schools:

Contributor	Period	Contribution
Hippocrates	460–377 BC	Hippocratic oath; Father of Medicine
Aristotle	384–322 BC	First account of embryology; named the aorta; differentiated arteries from veins
Herophilus	c. 325 BC	"Father of anatomy"; brain recognised as seat of intelligence; first to distinguish sensory from motor nerves
Galen	c. AD 130–216	Most influential medical writer of antiquity; anatomy based on animal dissection
Leonardo da Vinci	AD 1452–1519	Outstanding anatomical sketches; originator of cross-sectional anatomy
Vesalius	AD 1514–1564	Refuted Galen's errors; <i>De Humani Corporis Fabrica</i> ; "Father of Modern Anatomy"
Harvey	AD 1578–1657	Demonstrated the circulation of blood, overturning Galen's ebb-and-flow doctrine

□ Fig 1.7 — Claudius Galen. (Vishram Singh — *General Anatomy* — 4e, p.62)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A labelled horizontal timeline for the history of anatomy, with Galen boxed at the Roman-period midpoint: Hippocrates (460–377 BC) → Aristotle (384–322 BC) → Herophilus (c.325 BC) → [GALEN, c. AD 130–216] → Leonardo da Vinci (AD 1452–1519) → Vesalius (AD 1514–1564) → Harvey (AD 1578–1657)

- ▶ Draw a bracket spanning from the Galen box to the Vesalius box, labelled "Galenic age — c. 1,500 years of unquestioned authority."
- ▶ Draw a small side-note off the Galen box: "Anatomy from animal dissection (human dissection forbidden in Rome)."
- ▶ Draw a second short bracket from Vesalius to Harvey labelled "Errors progressively corrected — *De Fabrica* (1543) → circulation (1628)."

2. Sources and method — why his anatomy was flawed

- ▶ Roman law of his time prohibited dissection of the human body; Galen therefore dissected animals — chiefly the Barbary ape, and also pigs, oxen and goats — and transferred the findings to human anatomy by analogy.
- ▶ This comparative-anatomical method allowed him genuine, careful observations (some still regarded as classics) but also embedded systematic species-specific errors into human anatomy that went uncorrected for centuries because no one dissected a human body to check them.

- ▶ His authority was such that discrepancies between his texts and what dissectors later observed in humans were, for centuries, blamed on the "degeneration of the human body since antiquity" rather than on Galen's error — illustrating how dogma, once institutionalised, resisted correction.

3. Doctrine of the three spirits ("pneumata") and blood physiology

- ▶ Galen elaborated a tripartite physiological scheme built on the older humoral doctrine (Hippocrates' four humours: blood, phlegm, yellow bile, black bile):

Spirit (pneuma)	Organ of origin	Vessel/carrier	Presumed function
Natural spirit	Liver (from digested nutriment)	Veins	Nutrition and growth
Vital spirit	Heart (via inspired air)	Arteries	Innate heat, vital force
Animal (psychic) spirit	Brain	Nerves	Sensation and voluntary movement

- ▶ He held that venous blood is manufactured in the liver from ingested food and flows outward, ebbing and flowing through the vessels like a tide, being consumed by the tissues rather than returning — there was no concept of a closed circulation.
- ▶ He believed a small quantity of blood seeped from the right to the left ventricle through invisible pores in the interventricular septum, there to mix with air (pneuma) drawn in from the lungs and become arterial (vital-spirit-laden) blood.
- ▶ This ebb-and-flow, septal-pore model was accepted for roughly 1,500 years and was only definitively overturned when William Harvey demonstrated the continuous, one-way circulation of blood (*De Motu Cordis*, 1628) — the same corpus that records Harvey being "severely criticised for his deviation from Galenic philosophy."

4. Neuromuscular contributions

- ▶ Building on Herophilus's earlier localisation of intelligence to the brain, Galen used vivisection and clinical observation (including the effects of spinal injuries in gladiators) to demonstrate experimentally that the brain and spinal cord, not the heart (as Aristotle had taught), govern sensation and voluntary movement.
- ▶ He performed transverse sections of the spinal cord at different levels in animals and correlated the level of section with the resulting pattern of paralysis — an early exercise in localising function within the nervous system.
- ▶ He is traditionally credited with describing several pairs of cranial nerves (fewer than the twelve recognised today) and with a classic demonstration — ligating/sectioning the recurrent laryngeal nerve in a living animal to show that this nerve, and not the heart or diaphragm, controls phonation.
- ▶ He wrote systematically on the actions of muscles and the form of bones, correctly recognising muscle contraction as the basis of movement.

5. Classic errors traceable to animal-based dissection

Galenic teaching (from animal dissection)	Actual human anatomy	Corrected by
Interventricular septal pores allowing blood to pass ventricle-to-ventricle	Septum is solid; no such pores	Vesalius (1543) questioned it; Harvey (1628) disproved the underlying ebb-flow physiology
Blood ebbs and flows; no true circulation	Blood circulates continuously in a closed system	William Harvey
<i>Rete mirabile</i> (a vascular network at the base of the brain, present in ungulates such as the ox) described as present in man	No rete mirabile at the base of the human brain	Renaissance anatomists (culminating with Vesalius)
Multi-lobed liver (as seen in dog/ape)	Human liver has two principal lobes (right and left)	Vesalius
Mandible described as two separate bones (as in some animals)	Human mandible is a single fused bone	Vesalius

- These errors persisted precisely because the Galenic corpus was treated as dogma rather than as a hypothesis to be tested by human dissection — the central lesson this topic teaches about the scientific method in anatomy.

6. The "Galenic age" and its end

- For c. 1,500 years after Galen, medieval and early-Renaissance anatomy teaching in Europe (and, through Arabic translation and scholars such as Ibn Sīnā/Avicenna, in the Islamic world) treated his writings as unquestionable authority; human dissection remained rare, so his errors were transmitted uncorrected generation after generation.
- The Galenic age ended when Andreas Vesalius, professor of anatomy at Padua, personally performed human dissections and, in *De Humani Corporis Fabrica Libri Septem* (1543), documented and corrected hundreds of Galen's errors — provoking bitter opposition from entrenched "Galenic anatomists."
- William Harvey's demonstration of the circulation of the blood (1628) completed the dismantling of Galenic physiology, replacing the ebb-and-flow model with a closed, one-way circulatory system.

Applied / Clinical anatomy

- **Eponym — great cerebral vein of Galen:** a single median vein formed by the union of the right and left internal cerebral veins, running below the splenium of the corpus callosum and draining into the straight sinus; it is the standard eponymous survival of Galen's name in modern gross anatomy nomenclature.
- **Vein of Galen malformation:** a well-recognised neonatal/paediatric arteriovenous malformation involving this vein, presenting classically with high-output cardiac failure in the neonate or macrocephaly/hydrocephalus in infancy — commonly cited in cross-sectional/radiological anatomy teaching as the clinical face of this eponym.

- ▶ Galen's episode is the classic teaching case for why **cadaveric human dissection, not extrapolation from animal models, is indispensable to clinically accurate anatomy** — a point of continuing relevance in modern anatomy curricula and museum/dissection-hall pedagogy.
- ▶ His three-spirits/humoral framework underlies pre-modern therapeutic practices (e.g., bloodletting) whose vocabulary persists informally in clinical parlance even though the physiological basis has been discarded.

High-yield exam pointers

- ▶ Claudius Galen, c. AD 130–216, Pergamon (Asia Minor) → Rome; called the "Prince of Physicians"; most influential medical writer after Hippocrates.
- ▶ Anatomy based on **animal dissection** (Barbary ape, pig, ox) because human dissection was banned in Rome — the single root cause of his errors.
- ▶ Doctrine of **three spirits**: natural (liver/veins), vital (heart/arteries), animal (brain/nerves) — an extension of Hippocrates' four-humour theory.
- ▶ Believed blood passed right-to-left ventricle through **invisible septal pores** and ebbed and flowed rather than circulating — disproved by **William Harvey (1628)**.
- ▶ Classic errors: interventricular septal pores, *rete mirabile*, multi-lobed liver, two-piece mandible — all corrected by **Vesalius, De Humani Corporis Fabrica (1543)**.
- ▶ "**Galenic age**" = c. 1,500 years of unquestioned Galenic authority in Western/Islamic medicine, ended by Vesalius (anatomy) and Harvey (physiology).
- ▶ Demonstrated experimentally (spinal cord section, recurrent laryngeal nerve section) that the **brain/nervous system, not the heart, controls sensation and movement**.
- ▶ Modern eponym: **great cerebral vein of Galen** (union of internal cerebral veins → straight sinus); clinically important as the **vein of Galen malformation** in neonates.
- ▶ Occupies the Roman-period slot in the standard history-of-anatomy sequence: Hippocrates → Aristotle → Herophilus → **Galen** → Leonardo da Vinci → Vesalius → Harvey.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (Chapter 1, "Introduction and History of Anatomy" — biographical table and Roman-period account of Galen; portrait Fig. 1.7); IB Singh — Textbook of Human Neuroanatomy (eponyms table: Galen, Claudius — great cerebral vein); BD Chaurasia — Human Anatomy Vol 3–4, 8e (great cerebral vein of Galen — formation and termination). Gray's Anatomy (Standring) 41e was checked for a dedicated history-of-anatomy account but, as expected, treats "Galen" only via the vein/venous-system eponym, not as a biographical topic.

Coverage note: the corpus's dedicated biographical treatment of Galen is a single historical account (Vishram Singh, General Anatomy 4e) rather than a full monograph. The doctrine of the three spirits, the recurrent-laryngeal-nerve and spinal-section experiments, the specific classic errors (rete mirabile, multi-lobed liver, two-piece mandible), and the end-dates of the Galenic era are standard, universally-accepted history-of-medicine facts supplied to complete a full 10-mark answer, and are consistent with (not contradictory to) everything the corpus states about Galen.



Herophilus

Asked in: Paper I 07-May-2022 · Paper I May 2018 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction Herophilus (fl. **cir. 325 BC**) was a Greek teacher of anatomy at the School of Medicine at **Alexandria**, then the capital of Egypt, and is traditionally honoured in the anatomical curriculum as the "**Father of Anatomy**." He is credited as the first scientist to dissect the human body in a truly systematic, teaching-oriented manner, converting anatomy from philosophical speculation into an observational discipline built on human dissection (and, uniquely for his era, vivisection). His descriptions of the brain, eye, nerves and abdominal viscera — and his naming of the duodenum — are still cited in modern anatomy, and the confluence of the dural venous sinuses is eponymously named the **torcular Herophili** after him.

1. Historical setting — the Alexandrian school of anatomy

- ▶ Herophilus belongs to the Hellenistic (Ptolemaic) period of Egypt, placed in the traditional timeline of "Contributors to the Science of Anatomy" between **Aristotle** (384–322 BC) and **Galen** (cir. AD 130–216).
- ▶ He taught at the **School of Medicine at Alexandria**; under the Ptolemies, Alexandria became the leading centre of anatomical study in the ancient world.
- ▶ Anatomy flourished uniquely at Alexandria because, unlike anywhere else in antiquity, **both dissection of human cadavers and vivisection (dissection of living human beings) were sanctioned**.
- ▶ These vivisections were performed on **condemned criminals**, with the express permission of **King Ptolemy I Soter (cir. 366–282 BC)**.
- ▶ The reasoning of the time: bodily function is best understood by studying the living body; a condemned criminal could "repay society" through the use of his body for such study.

- ▶ Herophilus is reputed to have vivisected/dissected close to **600 living human beings** over his career — reflecting the unprecedented scale of the Alexandrian dissection programme.
- ▶ On this basis he is recorded as the **first scientist to dissect the human body** and is titled the **Father of Anatomy** — a designation distinct from Vesalius (Father of *Modern* Anatomy, 16th century AD), Hippocrates (Father of Medicine) and Sushruta (Father of Surgery).

2. Position in the timeline of anatomical contributors

Contributor	Period	Key contribution
Hippocrates	cir. 460–377 BC	Hippocratic Oath; attributed disease to natural causes; "Father of Medicine"
Aristotle	384–322 BC	Comparative anatomist; first recorded anatomical illustration; wrote the first-ever account of embryology; coined the term <i>anatome</i> ("cutting up"); held the heart (not brain) as seat of intelligence
Herophilus	cir. 325 BC	Remarkable work on the nervous system; recognised the brain as the centre of the nervous system and the seat of intelligence; "Father of Anatomy"
Galen	cir. AD 130–216	Most influential Roman-era medical writer; "Prince of Physicians"; wrote on anatomy, physiology, pathology and treatment
Vesalius	16th century AD	<i>De Humani Corporis Fabrica</i> ; "Father of Modern Anatomy" / "Reformer of Anatomy"

3. Contributions to gross and visceral anatomy

- ▶ Gave detailed descriptions of the **skull**.
- ▶ Gave detailed descriptions of the **eye**.
- ▶ Described various **visceral (abdominal) organs and their relationships** to one another.
- ▶ **Named the duodenum** (cir. 300 BC) — so called because its length was found to approximate the combined width of **12 finger-breadths**. The term is the Latin corruption of the Greek *do-deka-daktulos*, meaning "twelve fingers."

4. Contributions to neuroanatomy

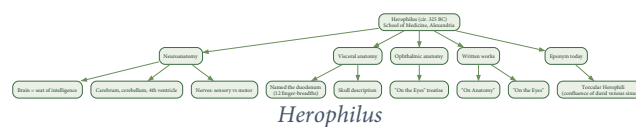
- ▶ Regarded the **brain** — **not the heart** — as the "seat of intelligence," directly opposing the cardiocentric view of his older contemporary Aristotle.
- ▶ Described the **functional relationship of the spinal cord to the brain**.

- ▶ Described several structures of the brain, including the **cerebrum, cerebellum, and the fourth ventricle**.
- ▶ Was the **first scholar to identify that nerves are functionally of two kinds — sensory and motor** — an early functional classification of the nervous system, many centuries ahead of its eventual physiological confirmation.

5. Written works

- ▶ Two monumental treatises are attributed to Herophilus: "**On Anatomy**" and "**On the Eyes**" (the latter reflecting his detailed study of ocular structure).
- ▶ Neither work survives in complete original form; his descriptions are known to us through the historical/anatomical tradition preserved and transmitted in later anatomical writing.

6. Diagram — contributions of Herophilus (classification)



7. Eponym surviving in modern anatomy — Torcular Herophili

- ▶ The **confluence of the dural venous sinuses** is eponymously termed the **torcular Herophili**, after Herophilus.
- ▶ It is the meeting place of the posterior end of the **superior sagittal sinus**, the **straight sinus**, and the **occipital sinus** with the **right and left transverse sinuses**.
- ▶ Situated close to the **internal occipital protuberance**, usually deviated to the **right** side.
- ▶ The **right transverse sinus** is usually the direct continuation of the confluence; the **left transverse sinus** communicates with it through a comparatively narrow channel — hence the right transverse/sigmoid sinus is more often dominant.
- ▶ The term "**torcula**" strictly denotes the bony gutter housing the confluence, though it is commonly (if loosely) used for the venous confluence itself.

□ Fig 21.15 — Intracranial dural venous sinuses and their confluence (torcular Herophili) (Vishram Singh — *Textbook of Anatomy Vol 3 — 4e*, p.935)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Sagittal outline of the interior of the skull vault with the dural venous sinus scheme, labelling:

- ▶ Superior sagittal sinus
- ▶ Inferior sagittal sinus
- ▶ Straight sinus
- ▶ Great cerebral vein (of Galen)
- ▶ Occipital sinus
- ▶ **Confluence of sinuses (torcular Herophili)** — mark at/near internal occipital protuberance
- ▶ Right and left transverse sinuses
- ▶ Sigmoid sinus
- ▶ Cavernous sinus, superior and inferior petrosal sinuses
- ▶ Internal jugular vein (termination)

Applied / Clinical anatomy

- ▶ **Torcular Herophili — surgical/radiological importance:** its position is variable (usually to the right of the internal occipital protuberance), which is important when planning a **posterior-fossa craniotomy or occipital burr-hole**, so as to avoid catastrophic venous sinus injury and air embolism.
- ▶ The right-dominant drainage and left-sided narrow communication described for the confluence explain why **unilateral (commonly left-sided) transverse-sinus hypoplasia/atresia** is a frequent incidental finding on **CT/MR venography** and must not be mistaken for sinus thrombosis.
- ▶ The confluence is a key landmark in **dural venous sinus thrombosis** — clot at or near the torcular produces a mixed picture of raised intracranial pressure with variable focal deficits depending on which tributary sinuses are involved; its location is also used as a surface/radiological reference point (e.g., in **Twining's line**, drawn from the tuberculum sellae to the torcular, used to assess ventricular size on a lateral skull radiograph).
- ▶ **Duodenal naming and clinical anatomy:** the "12 finger-breadths" description that Herophilus gave the duodenum remains the traditional teaching mnemonic for its length; the first (superior) part — the site most vulnerable to **peptic (duodenal) ulceration** — lies related to the gallbladder, the gastroduodenal artery posteriorly, and the neck of the pancreas, relations that are taught with reference to this same anatomical unit that Herophilus first delineated and named.
- ▶ **Sensory/motor distinction:** Herophilus's functional division of nerves anticipates, by many centuries, the modern **dorsal (sensory)/ventral (motor) root** organisation of the spinal nerve, formally established only in the 19th century (Bell–Magendie law) — a favourite viva "did you know" cross-link.
- ▶ **Brain vs heart as the seat of intelligence:** Herophilus's cerebrocentric view, opposed to Aristotle's cardiocentric one, is the conceptual ancestor of all subsequent clinical neuroanatomy and neurosurgery, and is a commonly asked comparative viva point.

High-yield exam pointers

- ▶ Herophilus, cir. 325 BC, Greek anatomist; taught at the **School of Medicine, Alexandria**.
- ▶ Titled the "**Father of Anatomy**"; first to practise **systematic human dissection and vivisection** (reputedly ~600 subjects), performed on **condemned criminals** under the sanction of **King Ptolemy I Soter**.
- ▶ Regarded the **brain (not the heart) as the seat of intelligence**; described the **cerebrum, cerebellum, and fourth ventricle**.
- ▶ First to state that **nerves are of two functional types — sensory and motor**.
- ▶ Described the **functional link between spinal cord and brain**; gave detailed accounts of the **skull, eye, and visceral organs**.
- ▶ **Named the duodenum** — "twelve finger-breadths" (Greek *do-deka-daktulos*).
- ▶ Two monumental works: "**On Anatomy**" and "**On the Eyes**."
- ▶ Surviving eponym: **torcular Herophili** = confluence of the dural venous sinuses.
- ▶ Contrast in the same historical timeline: Aristotle (coined "anatome," cardiocentric view), Galen ("Prince of Physicians"), Vesalius ("Father of *Modern Anatomy*").

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (History of Anatomy chapter); Vishram Singh — Textbook of Anatomy Vol 3 4e; IB Singh — Textbook of Anatomy Vol 3 6e; IB Singh — Textbook of Human Neuroanatomy (Eponyms); Gray's Anatomy (Standring) 41e (confluence of the sinuses / torcular herophili).

Coverage note: Herophilus is a history-of-medicine figure and is not discussed in Gray's Anatomy's clinical chapters as such; the biographical/historical content above is grounded in Vishram Singh's General Anatomy history-of-anatomy chapter, and the surviving anatomical eponym (torcular Herophili) is independently corroborated in Gray's Anatomy and in the gross/neuroanatomy texts.



Hippocrates

Asked in: Paper I Nov 2017 · Paper I Oct 2009 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction Hippocrates (cir. 460–377 BC) was a Greek physician of the Grecian period, traditionally honoured in the anatomical curriculum's "History of Anatomy" chapter as the "**Father of Medicine**." He earned this title not through systematic human dissection — his personal exposure to dissection was limited — but by establishing sound, rational principles of medical practice, chief among them the doctrine that disease arises from **natural causes** rather than divine displeasure, and the **humoral theory** of body organisation. His name is permanently memorialised in the **Hippocratic Oath**, the code of professional ethics still administered to graduating medical students worldwide. In the traditional timeline of "Contributors to the Science of Anatomy," he is placed between **Sushruta** (cir. 1,000 BC) and **Aristotle** (384–322 BC).

1. Historical setting — the Grecian period

- ▶ Hippocrates belongs to the **Grecian period** of the history of anatomy, following the early-civilisation contributors Menes (cir. 3,400 BC, first anatomy manual) and Sushruta (cir. 1,000 BC, Father of Surgery).
- ▶ He was a famous **Greek physician** who is regarded as the **Father of Medicine** because he established sound principles of medical practice at a time when disease causation was widely attributed to supernatural forces.
- ▶ Unlike the later Alexandrian anatomist **Herophilus** (cir. 325 BC), who dissected and vivisected hundreds of human subjects under royal sanction, Hippocrates had only **limited exposure to human dissection**; his contribution was chiefly conceptual and clinical rather than descriptive-anatomical. This distinction is a favourite examiner's contrast point (and the basis of a standard MCQ distractor: "He had wide exposure to human dissections" — **false**).
- ▶ His epigrammatic dictum, quoted in the anatomy curriculum itself, captures his view of anatomy's place in medicine: "*Anatomy is the basis of medical discourse.*"

2. The humoral theory — Hippocrates' theory of body organisation

Hippocrates proposed that the human body is constituted of **four body humours** (four elements of body fluid) that together form the physiological and pathological basis of health and disease.

Humour	Associated organ
Blood	Liver
Yellow bile	Gallbladder
Phlegm	Lungs
Black bile	Spleen

- ▶ A **healthy person** was thought to have a balance of all four humours.
- ▶ **Disease** resulted from an imbalance among the humours.
- ▶ According to Hippocrates, this balance could be **maintained or restored by proper diet, hygiene and lifestyle** — an early articulation of preventive and lifestyle medicine.

- ▶ The humoral concept has **long since been discarded** as physiological fact, but it dominated Western medical thought for **over 2,000 years**, influencing medicine through the Galenic and medieval periods until it was progressively displaced by cellular and germ-theory pathology.

3. Greatest contribution — disease attributed to natural, not supernatural, causes

- ▶ Prior to Hippocrates, illness was commonly explained as punishment or displeasure of the gods.
- ▶ Hippocrates' **greatest and most enduring contribution** was to attribute disease to **natural causes**, to be investigated by observation and reason rather than appeased by ritual.
- ▶ His application of **logic and reason to disease** is regarded as the **beginning of present-day scientific medicine** — the conceptual root of clinical anatomy, pathology and evidence-based practice as they are taught today.

4. The Hippocratic Oath

- ▶ Hippocrates is most often remembered by the medical fraternity for the **Hippocratic Oath**, which bears his name.
- ▶ The Oath embodies a **code of ethics** that all medical professionals are expected to follow in practice.
- ▶ It became the **standard ethical norm for the medical profession and continues to be administered to graduating medical students worldwide even today**, usually at the "white-coat" or convocation ceremony marking entry into clinical practice.
- ▶ Traditionally, its core tenets are understood to include **non-maleficence** ("first, do no harm"), **beneficence** toward the patient, **maintenance of patient confidentiality**, and **professional integrity** — principles that persist, in modernised form, in contemporary declarations of medical ethics.

5. Position in the timeline of anatomical contributors

Contributor	Period	Title / key contribution
Sushruta	cir. 1,000 BC	Recorded weight of tongue and length of intestine; Father of Surgery
Hippocrates	cir. 460–377 BC	Hippocratic Oath ; disease from natural causes ; humoral theory; " Father of Medicine "
Aristotle	384–322 BC	Comparative anatomist; first recorded anatomical illustration; first account of embryology; coined the term <i>anatome</i> ; held heart (not brain) as seat of intelligence
Herophilus	cir. 325 BC	Systematic human dissection/vivisection at Alexandria; brain = seat of intelligence; " Father of Anatomy "

Contributor	Period	Title / key contribution
Galen	cir. AD 130–216	"Prince of Physicians"; most influential Roman-era medical writer; work based on animal dissection
Vesalius	AD 1514–1564	<i>De Humani Corporis Fabrica</i> ; refuted Galen; "Father of Modern Anatomy"

6. Diagram — the humoral theory (classification)

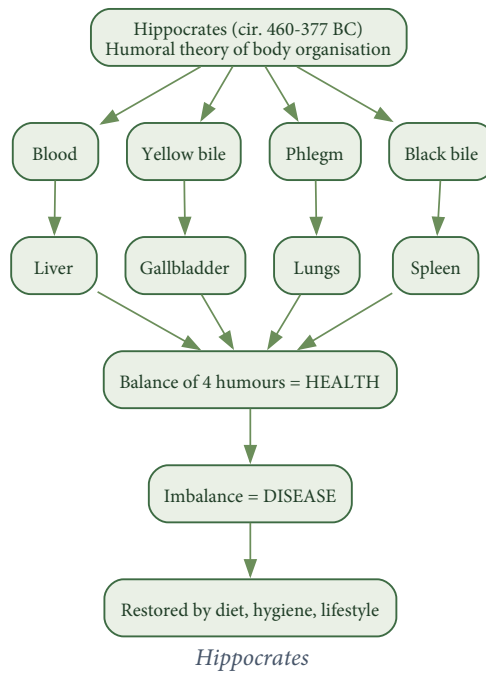


Fig 1.4 — Hippocrates (Vishram Singh — General Anatomy — 4e, p.57)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A simple labelled outline of the human trunk showing the four humours mapped to their organs, for quick hand reproduction:

- ▶ Liver — humour: Blood
- ▶ Gallbladder — humour: Yellow bile
- ▶ Lungs — humour: Phlegm
- ▶ Spleen — humour: Black bile
- ▶ Central label: "Balance of humours = Health; Imbalance = Disease"
- ▶ Side note: "Restored by diet, hygiene, lifestyle" (Hippocrates, cir. 460–377 BC)

Applied / Clinical anatomy

- ▶ **Modern medical ethics:** the Hippocratic Oath is the historical ancestor of every modern professional code of medical ethics (e.g., the Declaration of Geneva, and national medical council

codes of conduct); its principles of non-maleficence, beneficence and confidentiality remain examinable cornerstones of clinical practice and are still invoked at graduation ceremonies.

- ▶ **Legacy of the humoral theory in language and teaching:** although discarded as physiology, the four humours survive in everyday and historical-medical vocabulary — "sanguine" (blood), "choleric" (yellow bile), "phlegmatic" (phlegm) and "melancholic" (black bile) — used to describe the four classical temperaments, a frequently asked "did you know" viva link between anatomy history and general physiology/psychology teaching.
- ▶ **Shift from supernatural to natural causation:** Hippocrates' insistence on natural causation is the conceptual foundation of the entire modern clinical method — history-taking, examination and investigation replacing appeasement of the gods — and underlies the rationale for teaching applied/clinical anatomy alongside descriptive anatomy.
- ▶ **Contrast with "Father of Anatomy" (Herophilus):** because Hippocrates had only limited exposure to human dissection, he is honoured as the **Father of Medicine** (clinical practice and ethics) rather than the **Father of Anatomy** (systematic dissection), a distinction commonly tested to check whether candidates confuse the two eponymous titles.
- ▶ **Preventive-medicine principle:** his teaching that humoral balance — and hence health — is maintained by diet, hygiene and lifestyle anticipates modern preventive and lifestyle medicine, a point often drawn upon in community medicine and public-health correlation questions.

High-yield exam pointers

- ▶ Hippocrates, cir. 460–377 BC, Greek physician of the **Grecian period**; positioned in the anatomy-history timeline between **Sushruta** and **Aristotle**.
- ▶ Regarded as the "**Father of Medicine**" for establishing sound principles of medical practice — **not** for systematic human dissection (his exposure to dissection was **limited**).
- ▶ Greatest contribution: attributed **disease to natural causes** rather than divine displeasure — the acknowledged **beginning of scientific medicine**.
- ▶ Propounded the **humoral theory**: four humours — **blood (liver)**, **yellow bile (gallbladder)**, **phlegm (lungs)**, **black bile (spleen)**; health = balance, disease = imbalance; restored by diet, hygiene and lifestyle.
- ▶ Humoral theory has been **discarded** as physiological fact but dominated medical thought for **over 2,000 years**.
- ▶ Name memorialised in the **Hippocratic Oath** — a code of medical ethics still administered to graduating students worldwide today.
- ▶ Contrast in the same timeline: Sushruta (Father of Surgery), Herophilus (Father of Anatomy), Vesalius (Father of Modern Anatomy), Galen (Prince of Physicians).
- ▶ Quoted maxim in the anatomy curriculum: "*Anatomy is the basis of medical discourse.*"

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (Chapter 1, "Introduction and History of Anatomy," pp. 54–59).

Coverage note: Hippocrates is a history-of-medicine figure and is not discussed in Gray's Anatomy's clinical chapters as such; the biographical, humoral-theory and Hippocratic-Oath content above is grounded entirely in Vishram Singh's General Anatomy history-of-anatomy chapter, which is the corpus's dedicated source for this topic.



History of purposeful dissection of human body

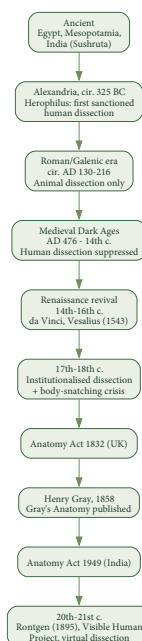
Asked in: Paper I May 2018 · Paper I May 2010 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction Anatomy is derived from the Greek **anatome*, "to cut up" (term first used by Aristotle); *dissection* is its Latin equivalent. For most of history, anatomical knowledge has come almost entirely from the *purposeful dissection of cadavers** — deliberate, systematic cutting-open of the dead (and briefly, in antiquity, the living) body to reveal structure for teaching and for advancing medicine. The history of purposeful dissection is thus the history of anatomy itself, conventionally traced through ancient, Grecian, Roman, medieval, Renaissance, post-Renaissance and modern periods, each defined by a changing degree of social/legal sanction for cutting open the human body.

1. Timeline at a glance

Period	Figure / event	Significance for purposeful dissection
cir. 3400 BC	Menes (Egypt)	First anatomy manual, before the pyramids
cir. 1000 BC	Sushruta (India)	<i>Sushruta Samhita</i> ("Sharira Sthana"); 300 bones, ~500 muscles; Father of Surgery
460–377 BC	Hippocrates	Limited human dissection; humoral theory; Father of Medicine
384–322 BC	Aristotle	Coined <i>anatome</i> ; animal dissection; first embryology account
cir. 325 BC	Herophilus, Alexandria	First state-sanctioned human dissection + vivisection; Father of Anatomy
cir. AD 130–216	Galen	Animal dissection only (human banned) — errors unquestioned ~1,500 years
AD 1452–1519	Leonardo da Vinci	Careful cadaveric dissection; cross-sectional anatomy pioneer

Period	Figure / event	Significance for purposeful dissection
AD 1514–1564	Vesalius	Personally dissected humans; <i>De Humani Corporis Fabrica</i> (1543); Father of Modern Anatomy
AD 1578–1657	William Harvey	Dissection-based proof of blood circulation
1750–1832	Body-snatching era (UK)	Illegal corpse trade; Burke & Hare , 16 murders (1828)
1832	Anatomy Act (UK)	Legalised unclaimed-body dissection; ended body-snatching
1858	Henry Gray	<i>Anatomy: Descriptive and Surgical</i> (" Gray's Anatomy ")
1895	Röntgen	X-rays — first non-dissective view of the living body
1949	Anatomy Act, India (Bombay Anatomy Act)	Unclaimed bodies to Indian medical colleges for dissection
20th–21st c.	Visible Human Project, cyber-cadavers	Digital/imaging-based dissection alongside cadaveric dissection



History of purposeful dissection of human body

2. Ancient period — before organised human dissection

- **Mesopotamia** ("Cradle of Civilization," settled cir. 4000 BC): **earliest recorded anatomical observations** — clay models of a sheep's liver, over 3,000 years ago (liver held to be the seat of emotion).

- ▶ **Egypt: embalming/mummification** (cir. 3400 BC) required evisceration, giving incidental exposure to internal organs, though its purpose was religious, not scientific. **Menes** (cir. 3400 BC) wrote the **first anatomy manual**, before the pyramids.
- ▶ **India: Sushruta** (cir. 1000 BC), teaching at Kashi (Varanasi), authored the **Sushruta Samhita* ("Sharira Sthana"). Described ~300 bones, ~500 muscles, tongue weight, intestinal length, vessels (Dhamnis, Siras), lungs, rectum, bladder, uterus, and joints. "Father of Surgery."*
- ▶ **China:** no systematic dissection; best-known contribution is **acupuncture** (365 meridian points), not dissection-derived knowledge.

3. Grecian period and Alexandria — purposeful human dissection begins

- ▶ **Hippocrates** (460–377 BC), "Father of Medicine," had only **limited human dissection exposure**; taught the **humoral theory** (blood–liver, phlegm–lungs, yellow bile–gallbladder, black bile–spleen). Attributed disease to **natural causes**, not divine displeasure — origin of scientific medicine; remembered for the **Hippocratic oath**.
- ▶ **Aristotle** (384–322 BC): comparative (animal) dissection; **first recorded illustration of anatomy**; **first account of embryology** (heart development); **named the aorta**; differentiated arteries from veins; **first to use the term anatome**. **Erroneously held the heart**** (not brain) to be the seat of intelligence.

□ Fig 1.6 — Herophilus. (Vishram Singh — *General Anatomy* — 4e, p.60)

- ▶ **Herophilus** (cir. 325 BC), School of Medicine, Alexandria — the pivotal figure: with **King Ptolemy I Soter's** permission, **human dissection and vivisection of condemned criminals** were formally sanctioned — the **first official state approval** of systematic human dissection in recorded history. Said to have dissected ~600 living humans. Described the **skull, eye, viscera**; recognised the **brain** as seat of intelligence; described **cerebrum, cerebellum, fourth ventricle**; linked spinal cord to brain; **first to distinguish sensory from motor nerves**. Works: **On Anatomy, On the Eyes. "Father of Anatomy"; first scientist to dissect the human body.**

4. Roman period — the Galenic hiatus in human dissection

- ▶ **Galen** (cir. AD 130–216), "Prince of Physicians," was the **most influential medical writer of all time**. Since **human dissection was not permitted** in Rome, his anatomy was based mainly on **non-human animals** — producing many errors when applied to humans.
- ▶ His authority went **unquestioned for ~1,500 years** (the "Galenic age"), during which **purposeful human dissection essentially disappeared**; teaching relied on Galenic text, not direct observation. This hiatus continued through the medieval "Dark Ages" (from the fall of Rome, AD 476, for close to a millennium), a period of little progress in arts or science.

5. Renaissance revival of human dissection (14th–16th century)

- ▶ The **Renaissance** (14th–16th century) — transition from the "Dark Ages" to modern science — **re-established purposeful human dissection** as the basis of anatomical knowledge.
- ▶ **Leonardo da Vinci** (AD 1452–1519) **carefully observed cadaveric dissections**; his **60 notebooks** (~500 diagrams) remained lost for four centuries, published only in 1898, so had no

contemporary influence. **Originator of cross-sectional anatomy**; first to describe the **moderator band of the right ventricle**; made wax models of heart valves.

□ Fig 1.9 — *Andreas Vesalius*. (Vishram Singh — *General Anatomy* — 4e, p.65)

- ▶ **Andreas Vesalius** (AD 1514–1564), Professor of Anatomy, **University of Padua**, most decisively re-legitimised human dissection: unlike predecessors who merely read Galen aloud while a barber-surgeon cut, **Vesalius personally performed the dissections** and used **live models** for surface landmarks. His **De Humani Corporis Fabrica* (1543, written at age 28) *refuted hundreds of Galen's animal-derived errors, provoking bitter controversy with Galenists*. "Father of Modern Anatomy"/"Reformer of Anatomy."^{*}

6. 17th–19th century — institutionalised dissection and the Anatomy Act

- ▶ 17th–18th centuries: purposeful dissection gained **unparalleled acceptance**, even public/theatrical status. **William Harvey** (1578–1657) used dissection/experiment to prove **continuous blood circulation**. **Leeuwenhoek** (1632–1723) refined the microscope (270×), describing blood cells, spermatozoa, skeletal muscle; **Malpighi** (1628–1694), "Father of Histology," took dissection to the **microscopic level**. **John Hunter** (1728–1793) and brother **William Hunter** (founder, London anatomical theatre, 1768) institutionalised dissection teaching via the **Hunterian museums**.
- ▶ Demand for cadavers **outstripped legal supply**: 1750–1832, an illegal corpse trade flourished in Britain/Ireland; some resorted to **murder** — most notoriously **Burke and Hare**, convicted of **16 murders** (1828).
- ▶ This crisis produced the **Anatomy Act, 1832**: legalised requisitioning of **unclaimed bodies** from workhouse/hospital mortuaries, created an Inspectorate of Anatomy, closed disreputable private schools, and led to new **purpose-built dissection rooms**.
- ▶ Dissection became **compulsory for medical students** in the 19th century (e.g., Edinburgh, Maryland). **Henry Gray** (1827–1861), with illustrator Henry Carter, published **Anatomy: Descriptive and Surgical in 1858 (750 pages, 363 figures) — later known as "Gray's Anatomy."*^{*}

7. Modern era — legalised donation, imaging and virtual dissection

- ▶ India's parallel legislation, the **Anatomy Act (1949)** (e.g. **Bombay Anatomy Act**), supplies **unclaimed bodies** to medical/teaching institutions for dissection: death must occur in a state hospital or a public place within the institute's prescribed zone, **and** police must declare, after **48 hours**, that there are no claimants.
- ▶ Alongside unclaimed bodies, modern medical education increasingly relies on consent-based **voluntary/willed body donation** — reflecting today's ethical emphasis on the cadaver as a **respected donor**.
- ▶ **Röntgen** (1845–1923) accidentally discovered **X-rays (1895)** — first non-dissective visualisation of internal structure in the **living**; Nobel Prize in Physics, 1901.
- ▶ **20th century**: electron microscope extends dissection to ultrastructure; nomenclature standardised; newer imaging (CT, USG, MRI, PET) expands radiological anatomy. **21st century**: virtual "**cyber-cadaver**" dissection and the **NIH Visible Human Project** (digital cross-sectional image library) supplement — but do not replace — traditional cadaveric dissection.

Applied / Clinical anatomy

- ▶ **Legal basis today:** Indian colleges obtain cadavers chiefly under the state **Anatomy Act** (unclaimed bodies, 48-hour police "no claimants" declaration), increasingly supplemented by consent-based **body donation programmes**.
- ▶ **Cadaver ethics:** a "dissection oath" and emphasis on donor respect/confidentiality are the direct ethical descendants of the body-snatching era that the Anatomy Act 1832 was enacted to end.
- ▶ **Preservation science:** embalming/plastination lets one donated cadaver serve successive student batches, extending purposeful dissection's practical yield.
- ▶ **Forensic link:** the "unclaimed body" route ties the anatomy department to police/forensic-medicine procedures before release for dissection.
- ▶ **Imaging complements, not replaces:** CT/MRI/virtual-dissection tables and the Visible Human Project aid radiological anatomy, but cadaveric dissection remains irreplaceable for **3-D, tactile understanding** and stays mandatory in the MD/MS Anatomy curriculum.
- ▶ **Methodological legacy:** Vesalius's insistence on first-hand human dissection (not animal dissection or textual authority, as with Galen) is the direct ancestor of today's dissection-based gross-anatomy course.

High-yield exam pointers

- ▶ ***Anatome** (Greek) = "to cut up," coined by Aristotle; *dissection** = Latin equivalent.
- ▶ **Menes** (Egypt, cir. 3400 BC): **first anatomy manual**, before the pyramids.
- ▶ **Sushruta** (cir. 1000 BC) = **Father of Surgery**; *Sushruta Samhita*; anatomy = "Sharira Sthana."
- ▶ **Herophilus** (cir. 325 BC), Alexandria = **Father of Anatomy**; **first to dissect the human body**; sanctioned by **King Ptolemy I Soter**.
- ▶ **Galen** (cir. AD 130–216): **animal dissection only** — errors unquestioned ~1,500 years ("Galenic age") since human dissection was banned.
- ▶ **Vesalius** (1514–1564) = **Father of Modern Anatomy**; **De Humani Corporis Fabrica** (1543); personally dissected humans, refuting Galen.
- ▶ **Burke & Hare**, 16 murders (1828) → **Anatomy Act, 1832 (UK)**: legalised **unclaimed-body** dissection.
- ▶ **India: Anatomy Act (1949)**, e.g. **Bombay Anatomy Act** — unclaimed body usable only after **48-hour** "no claimants" police declaration.
- ▶ **Henry Gray**: *Anatomy: Descriptive and Surgical* → "**Gray's Anatomy**" (1858); **Röntgen**: X-rays (1895).
- ▶ **21st century: Visible Human Project**, virtual/cyber-cadaver dissection — supplement, not replacement, for traditional dissection.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (Introduction and History of Anatomy chapter) — primary source for the full chronology: ancient civilisations, Sushruta, Grecian period, Herophilus, Galen, Renaissance, Vesalius, Harvey, Leeuwenhoek, Malpighi, Hunter, body-snatching era, Anatomy Act 1832, Henry Gray, Röntgen, 20th–21st century. Halder — Notes on Embalming & Museum Techniques (Anatomy Act, 1949, India). Gray's Anatomy (Standring) 41e — Historical Introduction (corroborates the Anatomy Act 1832/body-snatching context only; this chapter otherwise narrates the editorial history of the *Gray's Anatomy* textbook, not the general history of dissection).

Coverage note: the corpus does not contain material on Erasistratus (Herophilus's Alexandrian contemporary) or Mondino de' Luzzi (medieval reviver of dissection at Bologna); these are omitted rather than stated from unverified memory.



Vesalius

Asked in: Paper I May 2007 · Paper I Apr 2006 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction Andreas Vesalius (AD 1514–1564) was a Brussels-born anatomist who became **Professor of Anatomy at the University of Padua**, Italy, in the 16th century, and is universally regarded as the "**Father of Modern Anatomy**" (also titled the "**Reformer of Anatomy**"). His life's masterwork, **De Humani Corporis Fabrica Libri Septem* ("*On the Workings of the Human Body, in Seven Books*"), published in 1543 when he was only 28 years old, was built on his own first-hand human dissections rather than on animal dissection or received textual authority, and it boldly corrected hundreds of the centuries-old errors of Galen. It revolutionised the teaching of anatomy and remained the authoritative anatomical text for two centuries*, marking the decisive break between the Galenic and the modern, observation-based eras of anatomical science.

1. Family, training and career at Padua

- ▶ Vesalius was **born in Brussels** into a family of physicians.
- ▶ He became **Professor of Anatomy at the University of Padua** in Italy, the leading centre of anatomical teaching in Renaissance Europe.
- ▶ He broke from the customary practice of his day, in which the professor merely read aloud from Galen's text while a barber-surgeon performed the actual dissection at a distance; instead, **Vesalius performed the human dissections himself** and demonstrated structures directly to his students.
- ▶ He also **initiated the use of live models** to work out the surface landmarks of internal structures — an early antecedent of what is taught today as living/surface anatomy.
- ▶ He **remained a teacher of anatomy and a bachelor throughout his life**.

2. Vesalius in the historical timeline of anatomy

Contributor	Period	Key contribution
Claudius Galen	cir. AD 130–216	"Prince of Physicians"; most influential medical writer of antiquity; his anatomical descriptions were based mainly on animal dissection and therefore contained many errors, yet his authority dominated anatomy unquestioned for ~1,500 years (the "Galenic age")
Leonardo da Vinci	AD 1452–1519	Outstanding anatomical sketches; wax cast of the cerebral ventricles; considered an originator of cross-sectional anatomy; first to describe the moderator band of the right ventricle — but his notebooks remained lost for four centuries and had no influence on 16th-century anatomy
Andreas Vesalius	AD 1514–1564	*De Humani Corporis Fabrica (1543); refuted Galen's errors through direct human dissection; "Father of Modern Anatomy" / "Reformer of Anatomy"*
William Harvey	AD 1578–1657	Demonstrated the continuous circulation of blood (1628); gave anatomy a physiological orientation; like Vesalius, was severely criticised for deviating from Galenic philosophy

3. De Humani Corporis Fabrica Libri Septem — the magnum opus

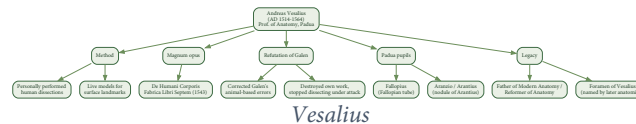
- Full title: **De Humani Corporis Fabrica Libri Septem ("On the Workings of the Human Body"), written in seven books**.
- Composed at the young age of **28 years** and published in **1543** at Basel; based directly on Vesalius's own systematic human cadaveric dissections.
- The various body systems and individual organs were **beautifully illustrated and described** — the accompanying woodcut plates are themselves landmark works of anatomical art and set the standard for the labelled anatomical illustration used in every modern textbook.
- It **revolutionised the teaching of anatomy** and remained the **authoritative anatomical text** for two centuries.

4. Refutation of Galenic anatomy and the resulting controversy

- Galen's anatomy, authoritative for ~1,500 years, rested chiefly on **non-human (animal)** dissection and consequently contained numerous errors when extrapolated to the human body.

- ▶ Through his own direct human dissections, Vesalius **boldly challenged hundreds of Galen's erroneous concepts** that had, until then, been taught as established fact.
- ▶ This provoked **bitter controversy between Vesalius and the entrenched Galenic anatomists** of his time.
- ▶ Vesalius became so **incensed by the relentless attacks** on him that he **destroyed much of his own unpublished work and stopped performing dissections**.
- ▶ Nevertheless, by freeing anatomy from many of Galen's errors, Vesalius **laid the foundation on which subsequent advances in medicine and surgery were built**.

□ Fig 1.9 — ■ *Andreas Vesalius*. (Vishram Singh — *General Anatomy* — 4e, p.65)



5. The Paduan school — contemporaries and pupils

- ▶ Two anatomists who trained under Vesalius at Padua went on to hold professorships and to leave their own eponyms: **Gabriele Fallopio** (Fallopius, AD 1523–1562), later Professor of Anatomy at Padua and eponym of the **Falloppian (uterine) tube**; and **Julio Caesar Aranzio** (Arantius, AD 1530–1589), Professor of Medicine and Surgery at Bologna and eponym of the **nodule of Arantius** on the aortic valve cusps.
- ▶ Unlike these contemporaries — **Jacobus Sylvius**, **Fallopius**, **Eustachius** and others, whose names became attached to the structures they described — **Vesalius deliberately chose not to have his own name attached to any body part**.
- ▶ Ironically, later anatomists nonetheless honoured him with an eponym of their own choosing (see Applied anatomy below).

6. Enduring legacy

- ▶ Vesalius is remembered as the **greatest anatomist of his time** and is honoured today as the **"Father of Modern Anatomy"** and the **"Reformer of Anatomy."**
- ▶ His method — first-hand cadaveric dissection as the basis of anatomical truth, rather than reliance on classical textual authority — became the founding methodological principle of **modern, dissection-based gross-anatomy teaching**, which persists unchanged in medical curricula (including the MD/MS Anatomy course) to this day.
- ▶ By dismantling Galenic dogma, he opened the way for the next great leap in anatomical science: **William Harvey's** demonstration of the circulation of blood (1628), which gave anatomy its physiological orientation.

Applied / Clinical anatomy

- ▶ **Foramen of Vesalius (sphenoidal emissary foramen)**: a small, **inconstant** foramen in the greater wing of the sphenoid bone, situated **anteromedial to the foramen ovale** (between the foramen ovale and the scaphoid fossa). When present, it transmits an **emissary vein** linking the **pterygoid venous plexus** in the infratemporal fossa with the **cavernous sinus** in the middle cranial fossa.

- ▶ This eponym was attached to the foramen by later anatomists in Vesalius's honour — he himself, notably, had declined to name any structure after himself.
- ▶ Clinically, the emissary vein through this foramen is one of several valveless communications by which **infection from the face or infratemporal region can spread intracranially to the cavernous sinus**, contributing to conditions such as cavernous sinus thrombosis — a classic applied-anatomy cross-link from this history question to skull-base osteology.
- ▶ The foramen of Vesalius must be distinguished from the neighbouring **canaliculus innominatus**, an inconstant medial accessory canal to the foramen spinosum that, when present, transmits the lesser petrosal nerve.
- ▶ Vesalius's insistence on direct human dissection and his use of live models for surface landmarks are the historical roots of two subjects still taught today — **gross (cadaveric) anatomy** and **living/surface anatomy** — both indispensable for clinical examination and surgical planning.

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Base of skull (norma basalis interna), greater wing of sphenoid region, with labels:

- ▶ Foramen ovale
- ▶ Foramen spinosum (posterolateral to the foramen ovale)
- ▶ Foramen rotundum (anteromedial to the foramen ovale)
- ▶ **Foramen of Vesalius (sphenoidal emissary foramen)** — mark as an inconstant small foramen between the foramen ovale and the scaphoid fossa
- ▶ Scaphoid fossa
- ▶ Spine of the sphenoid
- ▶ Cavernous sinus and pterygoid venous plexus (linked by the emissary vein through the foramen of Vesalius)

High-yield exam pointers

- ▶ Andreas Vesalius, AD 1514–1564; born in **Brussels**; **Professor of Anatomy, University of Padua**.
- ▶ Authored **De Humani Corporis Fabrica Libri Septem* — *seven books, written at age 28, published 1543; authoritative for two centuries.**
- ▶ **Personally performed human dissections; used live models** to map surface landmarks.
- ▶ **Refuted hundreds of Galen's errors** (Galen's anatomy rested on animal, not human, dissection); provoked bitter controversy, destroyed unpublished work, and stopped dissecting under the strain of attacks.
- ▶ Titled the **"Father of Modern Anatomy"** / **"Reformer of Anatomy."**
- ▶ Trained pupils **Fallopian** (Fallopian tube) and **Aranzio/Arantius** (nodule of Arantius) at Padua.
- ▶ Declined to attach his own name to any structure — yet the **foramen of Vesalius (sphenoidal emissary foramen)** survives as his eponym.
- ▶ Preceded by **Leonardo da Vinci** and succeeded by **William Harvey** in the historical timeline of anatomy.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (History of Anatomy chapter); Gray's Anatomy (Standring) 41e (eponym dictionary — foramen of Vesalius, Fallopius, Aranzio; and reference-list citation of *De humani corporis fabrica libri septem*, Basel, 1543).

Coverage note: Gray's Anatomy (Standring) 41e's own "Historical introduction" chapters (ch. 1–2) narrate the editorial history of the *Gray's Anatomy* textbook itself, not the life and work of Vesalius; the biographical content above is therefore grounded chiefly in Vishram Singh's General Anatomy history-of-anatomy chapter, corroborated by the "foramen of Vesalius" and Paduan-pupil eponyms independently recorded in Gray's own eponym dictionary and bibliography.



Andreas Vesalius

Asked in: Paper I 07-Jul-2023 — RGUHS MD/MS Anatomy

Definition / Introduction Andreas Vesalius (AD 1514–1564) was a Brussels-born Renaissance physician who held the chair of anatomy at the **University of Padua**, Italy, and is universally acknowledged as the "**Father of Modern Anatomy**" (also called the "**Reformer of Anatomy**"). Working from his own systematic dissections of the human cadaver rather than from animal dissection or received textual authority, he produced the seven-volume *De Humani Corporis Fabrica Libri Septem* (1543), which corrected hundreds of Galen's errors and re-founded anatomy as an empirical, observation-based science. His name survives in modern gross anatomy through the eponymous **foramen of Vesalius** and the alternative name **ligament of Vesalius** for the inguinal ligament, making him a recurrent "history of anatomy" question in the PG Anatomy curriculum.

1. Historical setting — from the Galenic age to the Renaissance

- ▶ For roughly 1,500 years (the so-called "**Galenic age**"), the anatomical writings of the Roman-era physician **Galen** were accepted as unquestionable authority, even though Galen's descriptions were based chiefly on the **dissection of animals**, not humans, and therefore contained many errors when applied to human structure.
- ▶ The **Renaissance** (14th–16th century AD) was the transitional period between the medieval "Dark Ages" (which began with the fall of Rome, AD 476) and the modern age of science, marked by a revival of both the arts and the sciences.
- ▶ Vesalius's immediate predecessor in this Renaissance timeline was **Leonardo da Vinci** (AD 1452–1519) — painter, sculptor and anatomist — who observed human dissections carefully, made a wax cast of the cerebral ventricles, is considered an originator of cross-sectional anatomy, and was first to describe the moderator band of the right ventricle. Da Vinci's own 60 notebooks of nearly 500 anatomical drawings, however, remained undiscovered for over four centuries (published only in 1898) and so had no influence on 16th-century anatomical teaching.
- ▶ It was against this backdrop of unchallenged Galenic dogma that Vesalius, in the following generation, undertook to verify anatomical teaching against the human body itself.

2. Vesalius: chair, method, and the human cadaver

- ▶ Vesalius was **born in Brussels** into a family of physicians.
- ▶ He became **Professor of Anatomy at the University of Padua**, then the foremost centre of anatomical teaching in Europe.
- ▶ He **personally performed human dissections** himself, rather than merely lecturing while an assistant dissected, and he **initiated the use of live models** to work out the surface landmarks of internal structures — an early root of what is taught today as "living"/surface anatomy.
- ▶ This first-hand, cadaver-based method — rather than reliance on Galen's animal-derived descriptions — is what allowed him to identify and correct the errors that had gone unquestioned for over a millennium.

□ Fig 1.9 — ■ *Andreas Vesalius. (Vishram Singh — General Anatomy — 4e, p.65)*

3. De Humani Corporis Fabrica Libri Septem (1543)

- ▶ Full title: **De Humani Corporis Fabrica Libri Septem — "On the Workings of the Human Body," in seven books**.
- ▶ Written at the young age of **28 years** and printed in **1543** by Johannes Oporinus at Basel (as recorded in Gray's Anatomy's own bibliographic citation of the work).
- ▶ Each of the seven books systematically described and **beautifully illustrated** a body system/region, based directly on Vesalius's own dissections.
- ▶ In its 1543 preface Vesalius wrote: *"Anatomy should rightly be regarded as the firm foundation of the whole art of Medicine and its essential preliminary"* — a line still quoted to justify anatomy's place at the start of the medical curriculum.
- ▶ The *Fabrica* **revolutionised the teaching of anatomy** and remained the **authoritative anatomical text for two centuries**.
- ▶ Like Galen before him, Vesalius wrote in **Latin** (Galen had written in Greek) — one reason classical anatomical terminology carries both Greek and Latin roots.

4. Refutation of Galen and the resulting controversy

- ▶ Through direct human dissection, Vesalius **boldly challenged hundreds of Galen's erroneous concepts** that had, until then, been taught as established fact.
- ▶ This provoked **bitter controversy between Vesalius and the entrenched Galenic anatomists** of his day.
- ▶ Vesalius became so **incensed by the relentless attacks** on his work that he **destroyed much of his unpublished material** and, for a period, **abandoned dissection altogether**.
- ▶ Nevertheless, by freeing anatomy from many of Galen's errors, **Vesalius laid the foundation on which subsequent advances in medicine and surgery were built**.

5. Vesalius among his contemporaries and successors

Figure	Period	Relationship to Vesalius	Contribution
Leonardo da Vinci	AD 1452–1519	Predecessor	Anatomical sketches; wax cast of cerebral ventricles; described moderator band
Jacobus Sylvius, Eustachius	16th c.	Contemporaries	Attached their own names to structures they described (unlike Vesalius)
Gabrielle Fallopio	AD 1523–1562	Pupil, later Professor of Anatomy, Padua	Described the uterine (Fallopian) tube
Julio Caesar Aranzio (Arantius)	AD 1530–1589	Pupil, later Professor of Medicine & Surgery, Bologna	Described structures now bearing his name (e.g., ductus venosus of Arantius)
William Harvey	AD 1578–1657	Successor	Demonstrated the continuous circulation of blood; gave anatomy a physiological orientation

- Despite training pupils who themselves went on to attach their names to structures (Fallopian, Arantius), Vesalius himself **deliberately chose not to have his own name attached** to any body part he described, remaining a **teacher of anatomy and a bachelor throughout his life**.
- He is remembered as the greatest anatomist of his time and is regarded as having considered the human body "God's most beautiful creation."

6. Vesalius's name in gross anatomy today

Eponym	Modern structure	Description
Foramen of Vesalius	Emissary sphenoidal foramen	An inconstant small foramen in the greater wing of the sphenoid, situated anteromedial/medial to the foramen ovale (between the foramen ovale and the scaphoid fossa); when present it transmits an emissary vein connecting the cavernous sinus with the pterygoid venous plexus
Vesalius' ligament	Inguinal ligament	Alternative eponymous name for the inguinal ligament, alongside Poupart's ligament

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Base of skull (norma basalis / greater wing of sphenoid region) — label:

- ▶ Foramen ovale
- ▶ Foramen spinosum (posterolateral to foramen ovale)
- ▶ Foramen rotundum (anteromedial to foramen ovale)
- ▶ **Emissary sphenoidal foramen (foramen of Vesalius)** — mark as an inconstant small foramen between the foramen ovale and the scaphoid fossa
- ▶ Scaphoid fossa
- ▶ Spine of the sphenoid

Applied / Clinical anatomy

- ▶ **Foramen of Vesalius**, when present, transmits an emissary vein that provides a valveless communication between the extracranial **pterygoid venous plexus** and the intracranial **cavernous sinus**; it is therefore relevant, together with the foramen ovale, as one potential route by which facial/pterygoid infection can spread intracranially to cause cavernous sinus thrombosis — a common applied-anatomy cross-link from this history question to skull-base gross anatomy.
- ▶ Its **inconstancy** (present in only some skulls) makes it a favourite osteology "spot" item; it must be distinguished from the nearby **canaliculus innominatus**, which instead transmits the lesser petrosal nerve when this does not use the foramen ovale.
- ▶ The **ligament/foramen eponyms** illustrate how, despite Vesalius's own wish to avoid eponymy, posterity nonetheless attached his name to structures still examined in gross anatomy today.
- ▶ **Methodological legacy**: Vesalius's insistence on first-hand human dissection, rather than reliance on animal dissection or textual authority, is the direct ancestor of the **modern dissection-based gross anatomy curriculum**, and his use of live models for surface landmarks anticipates today's **living/surface and clinical anatomy** teaching correlated with imaging.

High-yield exam pointers

- ▶ Andreas Vesalius, AD 1514–1564; born in Brussels; Professor of Anatomy, University of Padua.
- ▶ Authored *De Humani Corporis Fabrica Libri Septem* (seven books) — written at age 28, printed 1543 (Oporinus, Basel); authoritative for two centuries.
- ▶ Personally performed human dissections; used live models to map surface landmarks of internal structures.
- ▶ Boldly refuted hundreds of Galen's errors (Galen's anatomy was animal-based) — provoked bitter controversy with Galenic anatomists; destroyed unpublished work and stopped dissecting under the strain of attacks.
- ▶ Titled the "Father of Modern Anatomy" / "Reformer of Anatomy."
- ▶ Refused to attach his own name to any structure, unlike his pupils Fallopius and Arantius — yet the **foramen of Vesalius** (emissary sphenoidal foramen) and **ligament of Vesalius** (inguinal ligament) bear his name today.

- ▶ Wrote in Latin (as Galen had written in Greek) — root of Greco-Latin anatomical nomenclature.
- ▶ Preceded by Leonardo da Vinci (anatomical sketches); succeeded by William Harvey (circulation of blood) in the historical timeline of anatomy.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (Ch 1, Introduction and history of anatomy); Gray's Anatomy (Standring) 41e (eponyms appendix and skull-base descriptions, greater wing of sphenoid); AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen), Introduction; BD Chaurasia — Human Anatomy Vol 3–4 8e (foramen of Vesalius, norma basalis); IB Singh — Textbook of Anatomy Vol 2 and Vol 3, 6e (inguinal ligament synonym; foramen of Vesalius).

Coverage note: Gray's Anatomy (Standring) 41e's own historical-introduction chapters narrate the editorial history of the *Gray's Anatomy* textbook itself, not the life and work of Vesalius; the biographical narrative above is therefore drawn from Vishram Singh's General Anatomy history-of-anatomy chapter and AK Datta's citation of the *Fabrica* preface, while the "foramen of Vesalius" and "ligament of Vesalius" eponyms are independently confirmed across Gray's Anatomy, BD Chaurasia, and IB Singh.



Antonie van Leeuwenhoek

Asked in: Paper I 26-May-2025 — RGUHS MD/MS Anatomy

Definition / Introduction — Antonie van Leeuwenhoek (AD 1632–1723) was a self-taught Dutch tradesman of Delft who, without any formal scientific training, ground the finest lenses of his age and used them to refine the **simple (single-lens) microscope** to magnifications never before achieved. Working alone, he became the first human being to see and describe living cells, blood corpuscles, spermatozoa, striated muscle fibres and micro-organisms, opening an entirely new microscopic dimension to the science of anatomy. For this he is honoured in the history of anatomy as the "**Father of Microscopy**", and, because of his discovery of "animalcules" (bacteria and protozoa), is also regarded as the founding figure of microbiology.

1. Life and background

- ▶ Born 1632, died 1723 (AD 1632–1723), in Delft, the Dutch Republic — a contemporary of Malpighi and slightly younger than William Harvey.
- ▶ By profession a **draper/cloth merchant**; he originally used simple magnifying lenses to count threads in fabric, which kindled his lifelong interest in lens-grinding.
- ▶ Entirely **self-taught** — no university education, no knowledge of Latin (the scientific language of the time) — yet he became the most skilled lens-grinder of the 17th century.
- ▶ Held municipal posts in Delft (including chamberlain to the sheriffs), which gave him the leisure and modest means to pursue microscopy as a private passion for over 50 years.
- ▶ Communicated his observations to the **Royal Society of London** through a long series of descriptive letters (written in Dutch and translated), and was elected a **Fellow of the Royal**

Society in recognition of his discoveries — the era's principal channel through which microscopic anatomy entered mainstream science.

- ▶ He guarded his lens-grinding technique jealously and never revealed it fully in his lifetime; on his death he had reportedly built several hundred microscopes, most bequeathed to the Royal Society.

2. The Leeuwenhoek microscope — instrument and technique

- ▶ Table of historical contributors (Vishram Singh, *General Anatomy*) credits him thus: "Leeuwenhoek, AD 1632–1723 — Refined microscope. Described cells and tissues."
- ▶ Unlike the **compound (two-lens)** microscope of Robert Hooke (AD 1665), which used an objective and an eyepiece lens together but achieved only modest magnification (about **42 times**) and suffered from chromatic and spherical aberration, Leeuwenhoek's instrument was a **simple microscope** — a single, tiny, almost spherical biconvex lens, hand-ground and mounted between two flat brass or silver plates riveted together.
- ▶ The specimen was impaled or smeared on a sharp adjustable pin fixed in front of the lens; two screws allowed fine focusing — one moving the pin toward/away from the lens, the other adjusting its height — and the whole instrument was held close to the eye and pointed toward a light source.
- ▶ By this design he **achieved a magnification of up to 270 times** (Vishram Singh, *General Anatomy* 4e) — other texts (IB Singh, *Human Histology* 9e) record magnifications of up to **300 times** — either figure representing the highest resolving power of any instrument of his era, for which he is regarded as the "**Father of Microscopy**" (Sontakke, *Human Histology* 2e; IB Singh, *Human Histology* 9e).
- ▶ His instrument built on an earlier lineage: the first compound microscope is credited to the Dutch spectacle-makers **Zacharias and Hans Janssen** (AD 1590); the term "microscope" was coined by **Giovanni Faber** (AD 1625); Robert Hooke's compound microscope and his coining of the word "**cell**" (AD 1665) preceded Leeuwenhoek's single-lens refinement by a decade.
- ▶ Because a single, precisely-ground small lens has far fewer optical aberrations than the crude compound systems of the time, Leeuwenhoek's tiny simple lenses actually out-resolved contemporary compound instruments — a paradox of 17th-century optics.

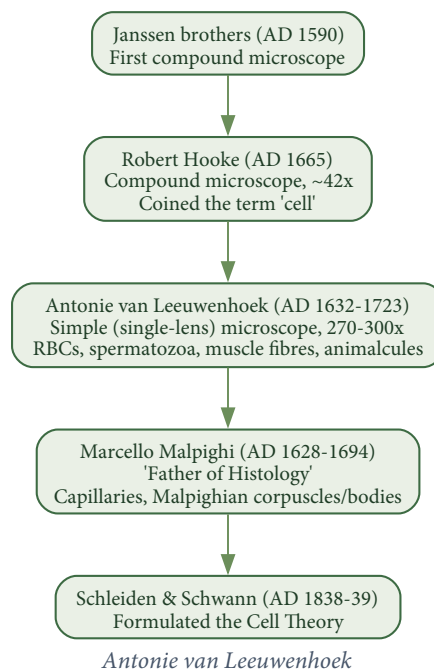
3. Major anatomical and biological discoveries

Structure / phenomenon first described	Significance for anatomy
Blood cells (red corpuscles)	First microscopic description of circulating blood cells, giving Harvey's theory of circulation a visible cellular basis
Spermatozoa (with the medical student Johan Ham van Arnheim)	First observation of human sperm; both believed each sperm contained a miniature preformed human being ("homunculus") — supporting the now-discredited theory of preformationism
Skeletal (striated) muscle fibres	First description of the fine fibrillar/striated structure of voluntary muscle

Structure / phenomenon first described	Significance for anatomy
Capillaries (blood flow through the smallest vessels)	Corroborated Malpighi's demonstration of capillary circulation, closing the last gap in Harvey's account of continuous blood flow
"Animalcules" — bacteria and protozoa in rainwater, pond water and dental scrapings	First human observation of micro-organisms, laying the empirical foundation of microbiology and protozoology
Techniques for examining tissues under high magnification	Established microscopy as a reproducible method of anatomical/histological study, later systematised by Malpighi and the 19th-century cell theorists

- These contributions are summarised in Vishram Singh's *General Anatomy* as: "(a) Development of techniques for examining tissues (b) Description of blood cells, spermatozoa, and skeletal muscle."
- Moore's *The Developing Human* and Vishram Singh's *Clinical Embryology* independently confirm the spermatozoa observation: "*Johan Ham van Arnheim and Anton van Leeuwenhoek were first to observe a human sperm... they thought sperms contain a miniature preformed human being that gets enlarged when sperm is deposited in the female genital tract.*"

4. Place in the history of anatomy — a timeline



- Leeuwenhoek is thus the essential empirical bridge between the **gross, naked-eye anatomy** of Vesalius and Harvey (16th–17th century) and the **microscopic anatomy/cell theory** era inaugurated by Malpighi and completed by Schleiden and Schwann in the 19th century.
- He extended anatomy beyond what the unaided eye could resolve, converting it for the first time into a science of the cell and tissue rather than of the organ alone.

□ Fig 1.10 — Antonie van Leeuwenhoek, with a photograph of one of his original single-lens microscopes. (Vishram Singh — *General Anatomy* — 4e, p.67)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a simple line diagram of the **Leeuwenhoek single-lens microscope** and label:

- ▶ Tiny, almost-spherical **biconvex lens** (ground by hand, embedded at the top)
- ▶ **Brass/silver mounting plate** (two flat plates riveted together, holding the lens)
- ▶ **Specimen pin/stage** — sharp adjustable pin on which the specimen is impaled or smeared, positioned directly behind the lens
- ▶ **Focusing screw** — moves the pin toward or away from the lens
- ▶ **Positioning screw** — raises/lowers the pin for centring the specimen
- ▶ **Handle** — held close to the eye, pointed toward a light source (candle/window)

Applied / Clinical anatomy

- ▶ Leeuwenhoek's demonstration of erythrocytes and capillary blood flow underlies the modern clinical disciplines of **haematology** and **microcirculation physiology**.
- ▶ His discovery of animalcules is the historical starting point of **clinical microbiology** — the Gram stain, culture, and microscopy-based diagnosis of infectious disease all trace their lineage to his rainwater and dental-plaque observations.
- ▶ His pursuit of magnification is the direct ancestor of the modern **light, electron (SEM/TEM) and confocal microscopes** that are now indispensable in diagnostic histopathology, cytopathology and ultrastructural research.
- ▶ The principle that a well-figured single lens can outperform a crude compound system is still invoked when explaining the optical superiority of modern **high numerical-aperture (apochromatic) objective lenses** in the compound light microscope used in every histology laboratory today.
- ▶ His single-handed, correspondence-based method of scientific communication with the Royal Society is a frequently cited historical example of how anatomical/biological knowledge diffused before the era of formal scientific journals.

High-yield exam pointers

- ▶ **Antonie van Leeuwenhoek**, AD 1632–1723, Delft (Dutch Republic); by trade a draper, entirely self-taught.
- ▶ Refined the **simple (single-lens) microscope**; achieved a magnification of **270–300 times**, the highest of his era — hence called the "**Father of Microscopy**."
- ▶ Described **blood (red) cells**, **spermatozoa** (with Johan Ham, supporting the preformationist "homunculus" theory), **striated skeletal muscle fibres**, **capillary blood flow**, and **micro-organisms** ("animalcules") — the last earning him recognition as a founder of microbiology.
- ▶ Elected **Fellow of the Royal Society, London**; reported his findings through a long series of letters rather than formal papers.
- ▶ Contemporary of **Robert Hooke** (coined the term "cell," AD 1665, compound microscope ~42×) and **Marcello Malpighi** ("Father of Histology," described capillaries and Malpighian corpuscles/bodies) — do not confuse the three in MCQs.

- ▶ His work is the empirical bridge between **gross anatomy** (Vesalius, Harvey) and **microscopic anatomy/cell theory** (Malpighi → Schleiden & Schwann, AD 1838–39).
- ▶ Golden fact for quick recall: **Leeuwenhoek = Father of Microscopy** (NOT Father of Histology — that is Malpighi; NOT coiner of "cell" — that is Hooke).

SOURCE & COVERAGE

Vishram Singh — *General Anatomy* 4e (primary — "History of Anatomy" chapter, Table 1.1 and narrative account); IB Singh — *Textbook of Human Histology* 9e; Sontakke — *Textbook of Human Histology* 2e; Moore — *The Developing Human* 9e; Vishram Singh — *Textbook of Clinical Embryology*. **Coverage note:** Gray's Anatomy (Standring) 41e does not carry a dedicated history-of-anatomy chapter, so this answer is grounded primarily in the specialty text's historical account, cross-checked against the histology and embryology texts above; a small number of well-established, universally-accepted history-of-science details (birth/death years, Royal Society fellowship, draper profession) supplement the corpus where the RGUHS textbook library is silent.



Aristotle

Asked in: Paper I Sep 2007 — RGUHS MD/MS Anatomy

Definition / Introduction Aristotle (384–322 BC) was a Greek philosopher, zoologist and teacher of the Grecian period of the history of anatomy, positioned in the standard timeline of anatomical contributors immediately after Hippocrates and immediately before Herophilus. Working chiefly through the careful, comparative examination of animals (with references to humans), he is credited as a comparative anatomist, the first to leave a recorded illustration of anatomy, and the author of the first-ever treatise on embryology — earning him the title "Founder of Embryology." He also coined the term *anatome* (Greek "cutting up," the root of the modern word "anatomy"), named the aorta, and was the first to differentiate arteries from veins — even as he perpetuated the erroneous **cardiocentric** view that the heart, not the brain, was the seat of intelligence.

1. Historical setting — life, era and place in the timeline

- ▶ Aristotle belongs to the **Grecian period** of the history of anatomy, the same broad era as Hippocrates ("Father of Medicine"), but writing a generation later.
- ▶ By long-established historical tradition he was a **pupil of Plato** (confirmed as a true statement about him in the standard MCQ bank), and is traditionally held to have tutored Alexander the Great and founded the Lyceum at Athens — standard biographical background to the anatomical contributions tested below.
- ▶ The standard text describes him as "a great Greek philosopher," who was also "**a zoologist, a renowned teacher and an accomplished writer.**"
- ▶ His method was empirical and comparative: he "**made careful examinations of all kinds of animals, including references to humans**" — rather than relying purely on speculation, foreshadowing the observational method later systematised by Vesalius.

- ▶ His immediate historical predecessor, **Hippocrates**, had already made the first recorded embryological *observation* (the incubated hen's-egg method); Aristotle's own writings extend this into the first true written *treatise* on the subject (Section 5).
- ▶ His immediate historical successor, **Herophilus** of Alexandria, directly overturned Aristotle's cardiocentric doctrine of intelligence by correctly localising it to the brain (Section 6).

2. Position in the timeline of anatomical contributors

Contributor	Period	Key contribution
Hippocrates	cir. 460–377 BC	Humoral theory; Hippocratic Oath; first recorded embryological observation (hen's-egg incubation); "Father of Medicine"
Aristotle	384–322 BC	<i>*Comparative anatomist; first recorded anatomical illustration; first-ever treatise on embryology; coined the term anatome; named the aorta; differentiated arteries from veins; held the heart as the seat of intelligence*</i>
Herophilus	cir. 325 BC	Recognised the brain (not the heart) as the seat of intelligence; systematic human dissection/vivisection; "Father of Anatomy"
Galen	cir. AD 130–216	Most influential Roman-era medical writer; "Prince of Physicians"; authority for ~1,500 years
Vesalius	AD 1514–1564	<i>De Humani Corporis Fabrica</i> ; "Father of Modern Anatomy"

3. Contributions to comparative anatomy and anatomical terminology

- ▶ Aristotle is titled a **comparative anatomist** on the strength of his systematic, comparative examination of many species of animals, with extension of his observations to man.
- ▶ He is credited in the standard historical table with the **first recorded illustration of anatomy** — an early precedent for the labelled anatomical figure used in every modern textbook.
- ▶ His single most durable linguistic legacy is the term ***anatome** (Greek ana- "up" + tome "cutting"); *he was the first person recorded to use this term, which is the direct root of the modern word "anatomy."**
- ▶ This observational, dissection-oriented vocabulary — rather than purely descriptive/clinical language — set a precedent that, nearly two millennia later, culminated in Vesalius earning the title "Reformer of Anatomy."

4. Contributions to cardiovascular anatomy — arteries, veins and the aorta

- ▶ Aristotle was the **first to differentiate arteries from veins** as distinct classes of vessel — a foundational distinction of the entire vascular system, still taught in essentially the same conceptual form today.
- ▶ He also **named the aorta**, a term that survives unchanged into modern gross anatomy as the name of the great systemic outflow vessel of the left ventricle.
- ▶ The very word "**artery**" — meaning "**air tube**" — was first used by Aristotle. This arose from a post-mortem observation: by the time of dissection, **rigor mortis** had usually passed, so the liquid blood had drained into and pooled within the more distensible veins, while the arteries — emptied by their own elastic recoil, and sometimes showing decomposition gas bubbles — appeared to contain only air. This is a classic exam "why" point: it explains an ancient terminological error (arteries do not, of course, carry air) that nonetheless survives unchanged in modern nomenclature.

5. Contributions to embryology — first treatise, "Founder of Embryology"

- ▶ Building on Hippocrates' earlier hen's-egg incubation method, Aristotle **wrote the first-ever treatise on embryology**, describing the development of the **chick and other embryos**; in doing so he gave a specific, first-ever account of the **development of the heart within the embryo**.
- ▶ On the strength of this treatise he is honoured as the "**Founder of Embryology**" — a title distinct from **Karl Ernst von Baer**, who is separately titled the "**Father of Modern Embryology**" (19th century).
- ▶ Aristotle's own theory of generation held that the embryo develops from a **formless mass** — described as a "**less fully concocted seed with a nutritive soul and all bodily parts**" — arising from **menstrual blood after activation by male semen**.
- ▶ This Aristotelian theory of generation was so influential that, transmitted through Galen and the medieval tradition, it **survived essentially unchanged until the late 18th century**, long after Aristotle's own death — one of the longest-lived theories in the entire history of biological science.

6. Errors and limitations — the cardiocentric view

- ▶ In spite of his tremendous achievements, Aristotle **perpetuated some erroneous views of anatomy**.
- ▶ Most importantly, he held that the **heart, and not the brain, was the seat of intelligence** (the **cardiocentric doctrine**) — an error that stood essentially unopposed until Herophilus, a generation later at Alexandria, correctly identified the **brain** as the seat of intelligence and described its principal parts (cerebrum, cerebellum, fourth ventricle).
- ▶ This **Aristotle-versus-Herophilus** contrast (heart vs brain as the seat of intelligence) is one of the most frequently tested comparative points in the history-of-anatomy syllabus.

7. Diagram — contributions of Aristotle (classification)



□ Fig 1.5 — ■ Aristotle. (Vishram Singh — General Anatomy — 4e, p.59)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Cross-section comparison — **artery vs vein** (the structural distinction first drawn by Aristotle), labelling on each:

- ▶ Tunica intima (endothelium + subendothelial layer)
- ▶ Tunica media — mark as **thick**, with abundant smooth muscle/elastic tissue in the **artery**; **thin** in the **vein**
- ▶ Tunica adventitia
- ▶ Lumen — **round and patent** in the artery; **oval/collapsed** in the vein
- ▶ Valve — present at intervals in medium/large **veins** (absent in arteries)
- ▶ Vasa vasorum, penetrating deeper into the (thicker) arterial wall

Applied / Clinical anatomy

- ▶ **Terminological legacy:** the word "anatomy" used every day in the medical curriculum descends directly from Aristotle's Greek *anatome*; the great vessel of the systemic circulation is still called the **aorta**, exactly as he named it — both are standing, everyday clinical/anatomical terms of direct Aristotelian origin.
- ▶ **"Artery" as a living misnomer:** the term "air tube" is retained despite being physiologically incorrect, and the post-mortem observation that produced it (empty, air-containing-looking arteries versus blood-filled, distended veins after death) remains a real, testable **forensic/anatomical fact** relevant to autopsy findings, and helps explain why arterial bleeding is bright-red/pulsatile while venous bleeding is dark/continuous in the living.
- ▶ **Artery–vein wall differences** that Aristotle first recognised remain of direct clinical relevance: the thick muscular/elastic media of arteries underlies arterial pulsation, aneurysm formation, and the use of arteries (radial, femoral) for **pulse palpation and catheter access**, whereas the thin wall and valves of veins underlie venous stasis, **varicose veins**, and the preferred use of veins for **cannulation/blood sampling**.
- ▶ **Cardiocentric-vs-cerebrocentric legacy:** Aristotle's placement of intelligence in the heart, though anatomically wrong, persists culturally in everyday language ("learn by heart," "heartfelt," "broken heart") and is a useful teaching contrast against Herophilus's correct cerebrocentric view that founded modern clinical neuroanatomy.
- ▶ His **theory of generation** (formless mass activated by semen), though physiologically incorrect, dominated embryological thought for roughly **two thousand years** (into the late 18th century) — a standard illustration, still quoted in the opening history section of modern embryology texts, of how a plausible but untested theory can delay scientific progress until displaced by direct observation (later achieved by Wolff and von Baer).

- ▶ His comparative, dissection-based method — "careful examination of all kinds of animals" — is the distant methodological ancestor of the dissection-based, comparative approach still used to teach gross and comparative anatomy in the medical curriculum today.

High-yield exam pointers

- ▶ Aristotle, Greek philosopher and zoologist, 384–322 BC; positioned between **Hippocrates** and **Herophilus** in the standard historical timeline of anatomy.
- ▶ Titled a **comparative anatomist**; credited with the **first recorded illustration of anatomy**.
- ▶ Coined the term ***anatome** (Greek "*cutting up*") — *direct root of the modern word "anatomy."**
- ▶ **Named the aorta and first differentiated arteries from veins**; coined the term "**artery**" ("air tube") from the post-mortem finding of blood-emptied arteries.
- ▶ Wrote the **first-ever treatise on embryology** (development of the chick and the heart in the embryo) — titled "**Founder of Embryology**" (contrast: **Karl Ernst von Baer** = "**Father of Modern Embryology**").
- ▶ His **theory of generation**: embryo develops from a "formless mass"/"less fully concocted seed" arising from menstrual blood activated by male semen — survived, via Galen, until the **late 18th century**.
- ▶ Erroneous **cardiocentric view**: held the **heart**, not the brain, as the seat of intelligence — corrected a generation later by **Herophilus** (cerebrocentric view).
- ▶ Predecessor: **Hippocrates** (Father of Medicine, first recorded embryological observation).
Successor: **Herophilus** (Father of Anatomy, cerebrocentric view).

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (History of Anatomy chapter — Table 1.1 and biographical text, including the etymology of "artery"); Vishram Singh — Textbook of Clinical Embryology (history-of-embryology section); Moore — The Developing Human 9e (history-of-embryology section); Sontakke — Textbook of Human Embryology ("Interesting Facts").

Coverage note: Gray's Anatomy (Standring) 41e's own "Historical introduction" chapters narrate the editorial history of the *Gray's Anatomy* textbook itself (its successive editors and editions), not the life and work of Aristotle, and are therefore not cited for biographical content here — consistent with the topic spec's grounding hint. The Aristotle biography above is grounded in Vishram Singh's General Anatomy history-of-anatomy chapter and independently corroborated for the embryology content by Moore's *The Developing Human* and Vishram Singh's *Textbook of Clinical Embryology* history sections, and by Sontakke's embryology text.



De Humani Corporis Fabrica (Vesalius, 1543)

Asked in: Paper I Oct 2008 — RGUHS MD/MS Anatomy

Definition / Introduction **De Humani Corporis Fabrica Libri Septem* — "On the Fabric (Structure) of the Human Body, in Seven Books," commonly asked in exam papers by the reversed short form "*De Fabrica Corporis Humani*" — is the anatomical treatise written by Andreas Vesalius and published in 1543, when he was only 28 years old and Professor of Anatomy at the University of Padua. Built on his own systematic human cadaveric dissections rather than on Galen's animal-derived doctrine, it is regarded as the single most important book in the history of anatomy: it refuted hundreds of Galenic errors, married accurate illustration to accurate text for the first time, and remained the authoritative anatomical text for two centuries*, marking the decisive turning point from Galenic to modern, observation-based anatomical science.

1. The author and the setting that produced the book

- ▶ **Andreas Vesalius (AD 1514–1564)** was born in **Brussels** into a family of physicians and became **Professor of Anatomy at the University of Padua, Italy** — Renaissance Europe's foremost centre for anatomical teaching.
- ▶ The medieval tradition he inherited split a dissection into three separate roles: a **lector** read Galen's text aloud from a raised chair, an **ostensor** pointed to structures, and a lowly **barber-surgeon (sector)** did the actual cutting — none of these three ever compared what was said with what dissection actually showed.
- ▶ Vesalius broke this tradition decisively: he **performed the human dissections himself** while lecturing, and he **used live models** to demonstrate the surface landmarks of internal structures — an early root of what is taught today as living/surface anatomy.
- ▶ Like Galen (who had written in Greek), Vesalius composed his treatise in **Latin**, the scholarly language of Renaissance Europe.

2. Bibliographic facts of the treatise

- ▶ Full Latin title: **De Humani Corporis Fabrica Libri Septem* — literally "the fabric/structure of the human body, in seven books" — printed by **Johannes Oporinus at Basel in 1543** (so recorded in *Gray's Anatomy's own historical bibliography*: "Vesalius A 1543 De humani corporis fabrica libri septem. ex off J Oporini: Basel").
- ▶ Composed and published at the young age of **28 years**; it **revolutionised the teaching of anatomy** and **remained an authoritative text for two centuries**.
- ▶ In its preface, Vesalius himself set out anatomy's place at the head of medicine: "*Anatomy should rightly be regarded as the firm foundation of the whole art of Medicine and its essential preliminary.*" This sentence is still quoted to justify why anatomy is taught first in the medical curriculum.

3. Structure and content of the "Seven Books" (Libri Septem)

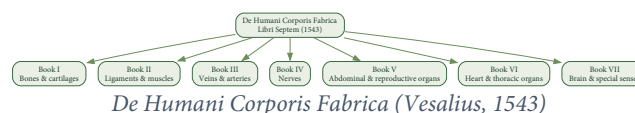
The treatise is organised systemically, moving from the hard framework of the body up through soft tissue to the viscera and finally to the "seat of reason":

Book	Content
I	Bones and cartilages (osteology)
II	Ligaments and muscles (myology)
III	Blood vessels — veins and arteries (angiology)
IV	Nerves (neurology)
V	Organs of nutrition and generation — abdominal and reproductive viscera
VI	Heart and organs of the thorax
VII	Brain and organs of the special senses

- Various body systems and individual organs were **beautifully illustrated and systematically described** in this sequence — the same osteology → myology → angiology/neurology → viscera → brain progression that still underlies the layout of modern regional and systemic gross-anatomy textbooks.

4. What made the *Fabrica* revolutionary

- **Illustration made co-equal with text:** for the first time, large, anatomically accurate woodcut plates were integrated directly with the descriptive text, rather than treated as a decorative afterthought — the direct ancestor of every modern labelled anatomical atlas.
- **First-hand human dissection replaced textual authority:** Vesalius's descriptions were drawn from what he personally saw on the human cadaver, not copied from Galen or from animal dissections (ox, dog, ape, Barbary macaque) that Galen had wrongly extrapolated to humans.
- **Systematic correction of Galenic error:** Vesalius **boldly challenged hundreds of Galen's erroneous concepts** that had been taught as unquestioned fact for ~1,500 years (the "Galenic age"). Well-known instances include his demonstration that the human **mandible is a single bone** (Galen, working from animals such as the dog, had described it as two separate halves) and his denial that humans possess a **rete mirabile** at the base of the brain (a vascular network Galen had described in animals such as the ox but which does not exist in man).
- **Anatomy given primacy over authority:** rather than reconciling discrepancies in Galen's favour, Vesalius trusted his own dissection findings — the methodological birth of anatomy as an empirical, observation-based science.



□ Fig 1.9 — Andreas Vesalius. (Vishram Singh — *General Anatomy* — 4e, p.65)

5. Reception, controversy and Vesalius's personal legacy

- The *Fabrica*'s open challenge to Galen provoked **bitter controversy with entrenched Galenic anatomists** of the day (e.g., Jacobus Sylvius).
- Vesalius became so **incensed by the relentless personal attacks** that he **destroyed much of his unpublished work** and, for a period, **gave up dissection altogether**.

- ▶ Nevertheless, by freeing anatomy from Galen's errors, **Vesalius laid the foundation on which nearly all subsequent advances in medicine and surgery were built.**
- ▶ Unlike contemporaries such as **Jacobus Sylvius, Fallopius and Eustachius**, who attached their own names to the structures they described, **Vesalius deliberately chose not to eponymise himself**; he remained a **teacher of anatomy and a bachelor throughout his life.**
- ▶ He is honoured today as the **"Father of Modern Anatomy"** and the **"Reformer of Anatomy."**

Applied / Clinical anatomy

- ▶ **Foramen of Vesalius (emissary sphenoidal foramen):** an inconstant small foramen in the greater wing of the sphenoid, situated medial to the foramen ovale, transmitting an emissary vein that connects the cavernous sinus to the pterygoid venous plexus — the one eponym posterity did attach to Vesalius, ironic given his own wish not to be named after any structure; clinically relevant as a potential route by which facial/pterygoid infection can spread intracranially toward the cavernous sinus.
- ▶ **Methodological legacy:** Vesalius's insistence on first-hand human dissection (rather than reliance on animal dissection or textual authority) is the direct ancestor of the **modern dissection-based gross-anatomy curriculum**, including the MD/MS Anatomy course itself.
- ▶ **Living/surface anatomy:** his use of live models to map surface landmarks anticipates the modern discipline of surface anatomy, indispensable today for physical examination, surface marking and image-guided procedures.
- ▶ **Atlas pedagogy:** the *Fabrica*'s union of accurate illustration with accurate text set the template later followed by Henry Gray's own *Anatomy: Descriptive and Surgical* (1858) and by every modern labelled-figure atlas used in anatomy teaching today.
- ▶ **Mandible correction and development:** Vesalius's demonstration that the adult human mandible is a single bone is a useful cross-link to developmental gross anatomy — the mandible does in fact ossify from **paired membranous centres** either side of Meckel's cartilage that fuse at the symphysis menti in the **first two years of postnatal life**, so a young infant's mandible genuinely is bilateral, a nuance beyond what either Galen or Vesalius could have appreciated.

High-yield exam pointers

- ▶ ***De Humani Corporis Fabrica Libri Septem** — "*the fabric of the human body, in seven books*" — by *Andreas Vesalius*, printed by *Johannes Oporinus* at Basel, 1543, written at age 28*.
- ▶ Based on Vesalius's own **human** dissections (not animal, as Galen's had been); **remained authoritative for two centuries.**
- ▶ Organised in **seven books**: I–bones/cartilages, II–ligaments/muscles, III–vessels, IV–nerves, V–abdominal/reproductive organs, VI–heart/thorax, VII–brain/special senses.
- ▶ First treatise to make **illustration co-equal with text** — ancestor of the modern anatomical atlas.
- ▶ **Boldly refuted hundreds of Galen's errors** (e.g., single-bone mandible, absence of the rete mirabile in man) — provoked bitter controversy with Galenists such as Sylvius.
- ▶ Preface quote: "*Anatomy should rightly be regarded as the firm foundation of the whole art of Medicine and its essential preliminary.*"

- ▶ Vesalius declined to attach his own name to any structure, yet the foramen of Vesalius (emissary sphenoidal foramen) survives as his eponym.
- ▶ Vesalius is titled the "Father of Modern Anatomy" / "Reformer of Anatomy."

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (History of Anatomy chapter); AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen), Introduction; Gray's Anatomy (Standring) 41e — Historical Bibliography; BD Chaurasia — Human Anatomy Vol 3–4 8e (foramen of Vesalius).

Coverage note: Gray's Anatomy (Standring) 41e's own "Historical introduction" narrates the editorial history of the *Gray's Anatomy* textbook (its successive editors and editions), not Vesalius's life or the *Fabrica* itself; it is cited here only for its Historical Bibliography entry confirming the treatise's exact Latin title, printer and year. The book-by-book (I–VII) content breakdown and the two illustrative examples of Galenic error (mandible, rete mirabile) are standard, universally accepted history-of-anatomy knowledge supplementing Vishram Singh's account, which describes the treatise's impact and structure ("seven volumes") without itemising each book's contents.



Gregor Mendel

Asked in: Paper I 24-Sep-2025 — RGUHS MD/MS Anatomy

Definition / Introduction Johann Gregor Mendel (22 July 1822 – 6 January 1884) was an Austrian Augustinian monk who, through meticulous **hybridisation experiments on the garden pea plant* (*Pisum sativum*) carried out in the monastery garden over several years, worked out the fundamental numerical rules governing the transmission of hereditary characters from one generation to the next — at a time when the nucleus, chromosomes and cell division were still unknown. He published his results in 1866, and is universally honoured today as the "Father of Modern Genetics." His deduced principles — the Law of Segregation and the Law of Independent Assortment — remain the foundation of transmission (Mendelian) genetics* and of modern human clinical genetics.

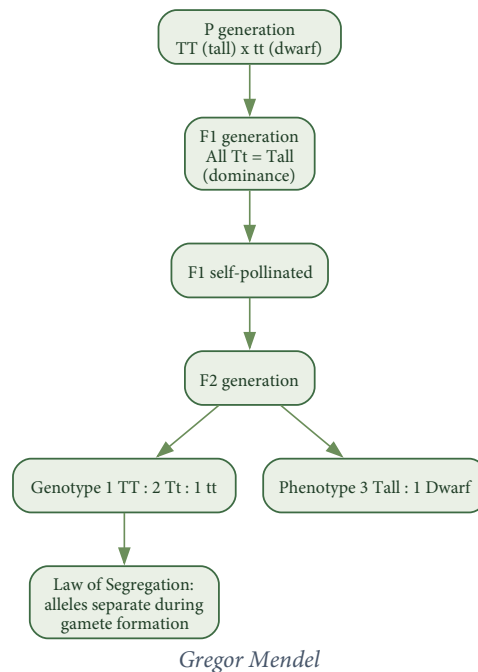
1. Historical background

- ▶ Mendel worked as a monk in an **Austrian monastery**, where he undertook systematic, quantitative breeding experiments on the garden pea (*Pisum sativum*) — chosen for its short generation time, easily distinguishable contrasting traits, and ability to be strictly self- or cross-pollinated.
- ▶ He published his findings as a research paper in 1866, based on results of **monohybrid, dihybrid, and — to further validate his deductions — trihybrid crosses**.
- ▶ A key conceptual point (favourite viva point): **Mendel never used the words "gene" or "chromosome"** — these entities and terms were unknown in his time. He referred to the hereditary determinants simply as "**factors**" and to the observed characteristics as "**traits**." The term "gene" was coined only decades later, once his factors were equated with segregating units on chromosomes.

- ▶ Mendel's work went unrecognised for over three decades; it gained its rightful place only after the turn of the 20th century, when hybridisation researchers working independently arrived at the same conclusions and rediscovered his original paper, after which "Mendelian inheritance" entered mainstream biology and medicine.
- ▶ In medicine, the British physician **Archibald Garrod** was among the first to recognise that **Mendel's laws of inheritance could explain the recurrence of certain clinical disorders within families**, launching the discipline of medical/clinical genetics that grew from a small subspecialty into a core component of modern diagnosis and management.

2. The monohybrid cross — Law of Segregation

- ▶ A **monohybrid cross** studies the inheritance of **one pair of contrasting characters** (Gk. *mono* = single; L. *hybrida* = offspring of parents with differing qualities).
- ▶ Mendel crossed **pure-breeding tall** pea plants with **pure-breeding dwarf** plants to study inheritance of stem height.
- ▶ **F1 generation:** all offspring were **tall** — the "hidden" dwarf character did not blend in but was completely masked.
- ▶ **F2 generation:** F1 plants were allowed to **self-pollinate**; the dwarf character **reappeared**, and the F2 plants segregated in an approximate ratio of **75% tall : 25% dwarf (3 : 1 phenotypic ratio)**.
- ▶ Mendel explained this using paired "factors": tall (T, dominant) and dwarf (t, recessive). The F2 **genotypic ratio** was **1 TT : 2 Tt : 1 tt**, giving the observed 3 : 1 phenotypic ratio (both TT and Tt appear tall; only tt appears dwarf).
- ▶ From this, Mendel concluded that the two factors for a character **do not blend**, but **separate (segregate) from each other during gamete formation**, so that each gamete carries only **one, unaltered** factor — this is **Mendel's First Law, the Law of Segregation: alleles of a gene segregate from one another during gametogenesis, and each gamete receives only one allele of the pair**.
- ▶ This monohybrid cross also yielded, as a direct corollary, the **principle of dominance and recessiveness**: a **dominant** factor (T) is expressed whenever present (whether homozygous TT or heterozygous Tt), while a **recessive** factor (t) is expressed only when present in the homozygous state (tt), in the absence of the dominant factor.



□ Fig 1.2 — Progeny of tall and dwarf plant (homozygous) in F1 followed by self-pollination of F1 giving 3:1 ratio in F2 (Gangane — Human Genetics — 5e, p.19)

3. The dihybrid cross — Law of Independent Assortment

- ▶ A **dihybrid cross** studies inheritance of **two pairs of contrasting characters simultaneously**.
- ▶ Mendel cross-pollinated pea plants with **yellow, round seeds (YYRR)** and **green, wrinkled seeds (yyrr)**.
- ▶ **F1 generation:** all offspring were **yellow and round (YyRr)** — showing that yellow is dominant to green, and round dominant to wrinkled.
- ▶ **F2 generation (F1 self-pollinated):** four phenotypes appeared in the ratio **9 yellow-round : 3 yellow-wrinkled : 3 green-round : 1 green-wrinkled (9:3:3:1)**, corresponding to **9 genotypic combinations**.
- ▶ Two important points emerged: (i) as in the monohybrid cross, characters masked in F1 reappeared in F2; and (ii) **new combinations of characters not present in either parent** appeared in F2 (yellow-wrinkled and green-round) — showing that the factor for seed colour and the factor for seed shape had **assorted independently of each other** while forming gametes.
- ▶ This gave **Mendel's Second Law, the Law of Independent Assortment:** *alleles of different genes (located on different chromosome pairs) segregate/assort independently of one another during gamete formation*, producing new combinations of traits in the progeny.
- ▶ Mendel further verified dominance, segregation, and independent assortment as fundamental rules of inheritance by performing **trihybrid cross** experiments as well.

Cross type	Traits studied	F1 phenotype	F2 phenotypic ratio	Law demonstrated
Monohybrid	1 pair (height)	All tall (dominant)	3 : 1	Law of Segregation (+ dominance/recessiveness)

Cross type	Traits studied	F1 phenotype	F2 phenotypic ratio	Law demonstrated
Dihybrid	2 pairs (colour, shape)	All yellow-round	9 : 3 : 3 : 1	Law of Independent Assortment
Trihybrid	3 pairs	—	(confirmatory)	Confirms both laws hold for multiple traits

4. Working tools derived from Mendel's crosses

- ▶ **Back cross:** a cross between an **F1 individual** and **one of its parents**, used to cross-check the allelic constitution of the heterozygote and confirm segregation of alleles.
- ▶ **Test cross:** a special type of back cross in which the **F1 individual is crossed with the homozygous recessive parent**; this "tests" whether an individual showing the dominant phenotype is homozygous (TT) or heterozygous (Tt), since a 1:1 ratio in the progeny reveals heterozygosity while an all-dominant progeny indicates homozygosity.
- ▶ **Punnett square:** a grid method of squares used to work out the genotypes/phenotypes resulting from monohybrid, dihybrid, or higher-order crosses — the **gametes of one parent are arrayed along the rows and of the other parent along the columns**, and each cell shows the resulting zygotic combination. It is named after the British geneticist **Reginald Crundall Punnett**, who devised this method to analyse cross results (illustrative $Aa \times Aa$ square: cells AA, Aa, Aa, aa).

5. Beyond the two laws — allelic behaviour and later refinements

- ▶ Mendel's "factors" are now understood as **alleles** — alternate forms of a gene at a given chromosomal locus; humans, being diploid, carry two alleles of each gene (one per homologous chromosome), which may be **identical (homozygous)** or **different (heterozygous)**.
- ▶ Beyond simple complete dominance/recessiveness, alleles of the same gene can also show **incomplete dominance, over-dominance, or codominance** (later additions built upon Mendel's original dominance concept as more allelic relationships were studied).
- ▶ Mendel's original "factors" were later shown to correspond to **genes located on chromosomes**, providing the physical/cytological basis for his purely mathematical laws and giving rise to the modern **chromosomal theory of inheritance**.

Applied / Clinical anatomy

- ▶ Mendelian ("single-gene") inheritance is the direct clinical descendant of Mendel's laws: human **single-gene disorders** follow the same segregation/independent-assortment logic and are classified into **four basic patterns** — **autosomal dominant, autosomal recessive, X-linked dominant, and X-linked recessive** inheritance.
- ▶ **Archibald Garrod** was among the first to apply Mendel's laws to human disease, recognising that certain hereditary metabolic conditions recur in families in a Mendelian (recessive) pattern — the historical bridge between Mendel's pea-plant genetics and modern **clinical/medical genetics**.
- ▶ **Pedigree analysis** in a genetic clinic — recording the family history of the **proband/propositus (male)/proposita (female)**, first-degree relatives, consanguinity, and ethnicity — is the clinical

tool used to determine the **mode of Mendelian inheritance** operating in a family and to calculate **recurrence risk** for genetic counselling.

- ▶ The **Punnett square**, directly derived from Mendel's cross methodology, remains the standard bedside/classroom tool for predicting genotype and phenotype ratios in offspring of a known mating, including for **autosomal and sex-linked (X-linked) human traits**.
- ▶ **Blood group inheritance (ABO system)** in humans is a classic clinically-relevant illustration of multiple alleles (IA, IB, IO) at a single locus, building directly on Mendelian allele concepts taught using the pea-plant model.
- ▶ Modern **molecular and chromosomal genetics** (karyotyping, chromosomal disorders such as trisomy 21, molecular diagnosis of single-gene disorders) has grown directly out of the transmission-genetics framework Mendel first established, making his laws the conceptual foundation of the entire discipline of human/medical genetics taught in the Anatomy/Genetics curriculum.

High-yield exam pointers

- ▶ **Johann Gregor Mendel (1822–1884)** — Austrian monk; "**Father of Modern Genetics**"; worked with the garden pea, **Pisum sativum*; *published his results in 1866**.
- ▶ Mendel used the terms "**factors**" and "**traits**" — NOT "gene" or "chromosome" (these were unknown in his time).
- ▶ **Monohybrid cross** (tall × dwarf) → F1 all tall → F2 self-pollinated → **3 : 1 phenotypic ratio** (genotype 1 TT : 2 Tt : 1 tt) → gives **Law of Segregation** + principle of dominance/recessiveness.
- ▶ **Dihybrid cross** (YYRR × yyrr) → F1 all yellow-round → F2 → **9 : 3 : 3 : 1 ratio**, with new trait combinations → gives **Law of Independent Assortment**.
- ▶ **Two Mendelian Laws**: (1) Law of Segregation, (2) Law of Independent Assortment; verified further by **trihybrid crosses**.
- ▶ **Back cross** = F1 × either parent; **Test cross** = F1 × homozygous recessive parent (reveals genotype of the dominant-phenotype individual).
- ▶ **Punnett square** — named after **Reginald Crundall Punnett**; gametes of the two parents arrayed on the two axes of a grid.
- ▶ Beyond Mendel: alleles may show **incomplete dominance, over-dominance, codominance** in addition to simple complete dominance/recessiveness.
- ▶ Clinical link: **Archibald Garrod** first applied Mendelian laws to explain familial recurrence of human disease; human single-gene disorders are classed as **autosomal dominant/recessive** and **X-linked dominant/recessive**, analysed clinically by **pedigree/proband analysis**.

SOURCE & COVERAGE

IB Singh — Textbook of Anatomy Vol 3 6e ("Mendelian Laws of Inheritance" and "Alleles" chapters); Gangane — Human Genetics 5e (monohybrid-cross figure; modes-of-inheritance/pedigree chapter); Thompson & Thompson — Genetics in Medicine 8e (historical introduction — Garrod and the clinical application of Mendel's laws).

Coverage note: Gray's Anatomy (Standring) 41e does not cover the history of genetics and was not cited here, consistent with the spec's note that this topic is covered in the genetics texts rather than the gross-anatomy spine. The widely-taught historical detail that Mendel's work was independently rediscovered around 1900 is standard genetics history but is not itself verbatim in the retrieved corpus passages, so it has been given only brief mention rather than elaborated with names/dates not directly confirmed on disk.



Henry Gray

Asked in: Paper I May 2019 — RGUHS MD/MS Anatomy

Definition / Introduction — Henry Gray (1827–1861) was an English anatomist and surgeon of St George's Hospital, London, remembered chiefly as the original author of *Anatomy, Descriptive and Surgical* (1858) — the book known worldwide today simply as **Gray's Anatomy**. Written with the anatomical artist Henry Vandyke Carter, it is a landmark in the history of anatomical publishing: the longest continuously published anatomy textbook in existence, now in its 41st edition (Standring, 2015), and still the spine reference of undergraduate and postgraduate anatomy teaching, including the RGUHS curriculum.

1. Henry Gray — the man

- ▶ Born in 1827 in Windsor, London, United Kingdom; died in 1861 at the early age of 34.
- ▶ Trained and later taught at **St George's Hospital Medical School**, near Hyde Park Corner, London, where the shortcomings of existing student textbooks first impressed themselves on him in the early 1840s.
- ▶ Highly able and ambitious: elected **Fellow of the Royal Society (FRS)** at age 25 — a rare distinction for so young a man — and was also a **Fellow of the Royal College of Surgeons (FRCS)**.
- ▶ At the time he conceived the new book (1855) he was 28 years old and a Lecturer/teacher at St George's, already possessed of a "glittering career" on the hospital wards and in the dissecting room.
- ▶ Died in June 1861 after contracting **smallpox** while nursing his nephew; a more virulent strain overcame the immunity from his childhood vaccination, and the disease became confluent within days.
- ▶ One of the noted 19th-century anatomists of the era of cell theory and comparative anatomy, alongside Astley Cooper, Georges Cuvier and Meckel.

2. Genesis of the book — Gray and Henry Vandyke Carter

- ▶ Gray shared the idea of a new, practical anatomy manual with a talented colleague on the St George's teaching staff, **Henry Vandyke Carter**, in **November 1855**. Carter, from a family of Scarborough artists, was himself a skilled artist and microscopist who had already illustrated Gray's scientific papers.
- ▶ The book was conceived as a *practical* guide — to encourage students, help them pass exams, and prepare them (in the era of the Crimean War) to operate on real patients and battlefield casualties — not merely a descriptive textbook.
- ▶ The two worked together through 1856 and into 1857: **Gray wrote the text, Carter executed every illustration**, and the dissections on which the drawings were based were undertaken jointly. Their working days ran the full length of daylight, eight to nine hours at a stretch.
- ▶ Gray publicly and warmly acknowledged Carter's contribution in the first-edition preface (1858): *"the great services he has derived... from the assistance of his friend, Dr H.V. Carter... All the drawings from which the engravings were made were executed by him."*
- ▶ Historical backdrop: the disreputable era of body-snatching was being left behind; the **Anatomy Act of 1832** had legalised requisition of unclaimed bodies, and the **General Medical Council** was established in 1858 to regulate professional education — the same year Gray and Carter's book appeared.

3. The First Edition (1858)

- ▶ Title: ***Anatomy, Descriptive and Surgical**, published at the end of August 1858 by JW Parker & Son*, West Strand, London.
- ▶ **750 pages, 363 illustrations** — wood-engravings by Butterworth and Heath, faithfully reproduced from Carter's original drawings; format was a portable "royal octavo" (~24 × 15 cm), larger and clearer than the small, densely-typed student manuals of the day (e.g. Quain's *Elements of Anatomy*, Knox's *Manual*).
- ▶ Carter's innovation was **diagrammatic, directly-labelled illustration** — name and structure united at a glance — replacing the older "proxy-label" convention (tiny numbered keys referred to a separate footnote legend), a genuinely modern advance for 1858.
- ▶ Immediate acclaim: highly complimentary reviews in *The Lancet* and the *British Medical Journal*; the first print-run of 2000 copies sold out swiftly, and a parallel American edition followed in 1859.
- ▶ Remuneration was starkly unequal: Gray was paid **£150 per thousand copies** sold, while Carter received only a **one-off fee** at publication (with which he is thought to have bought the microscope he took to India) and no ongoing royalty — despite the book's success resting heavily on his illustrations.
- ▶ As the book went to press in 1858, **Carter sailed for India**, having been appointed **Professor of Anatomy and Physiology at Grant Medical College, Bombay**; Gray left a trusted colleague, Timothy Holmes, to see the proofs through the press.

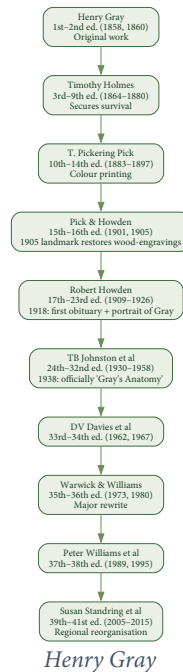
4. Gray's death and the survival of the book

- ▶ An enlarged **second edition** appeared in **December 1860**, with Gray himself expanding the "general anatomy" (histology) and "development" (embryology) sections.
- ▶ In **June 1861**, at the height of his powers, **Henry Gray died of smallpox**, aged 34, contracted while nursing his nephew.
- ▶ Curiously, **no obituary of Gray ever appeared in Gray's Anatomy** — attributed to an undercurrent of professional rivalry between Gray and Timothy Holmes, who had both applied for the same vacant Assistant Surgeon post at St George's shortly before Gray's death.
- ▶ The book's survival was secured when publisher **JW Parker & Son** invited **Timothy Holmes** (1825–1907), the St George's colleague who had proof-read the first edition, to edit the **third edition (1864)** onward; the Parker firm's stock and copyrights subsequently passed to **Longman**.
- ▶ **Henry Vandyke Carter** himself continued a distinguished career in India — Deputy Surgeon-General, Honorary Surgeon to Queen Victoria (1890) — and became a noted bacteriologist, described the fungal cause of mycetoma, and helped confirm Hansen's, Koch's and Laveran's discoveries. He died in 1897, likewise without an obituary in the book.

5. Succession of editors and landmark editions

Edition(s)	Year(s)	Editor(s)	Landmark change
1st–2nd	1858, 1860	Henry Gray	Original work; 2nd edition expanded histology/embryology
3rd–9th	1864–1880	Timothy Holmes	Ensured survival; volume grew from 788 to 960 pages
10th–14th	1883–1897	T. Pickering Pick	Integrated histology/embryology into main text; colour printing introduced (11th ed., 1887)
15th–16th	1901, 1905	Pick & Robert Howden	1905 (16th) landmark edition — restored wood-engraved illustration style over inferior half-tones
17th–23rd	1909–1926	Robert Howden (sole)	Retitled <i>Anatomy Descriptive and Applied</i> ; Carter's name dropped from title page; >1000 illustrations; 1918 (20th ed.) — first historical note and portrait photograph of Henry Gray, ~60 years after his death

Edition(s)	Year(s)	Editor(s)	Landmark change
24th–32nd	1930–1958	TB Johnston (with Whillis, Davies)	1938 (27th ed.) — officially retitled "Gray's Anatomy" ; X-ray plates added (1938); electron micrographs added (1958, 32nd ed.); nomenclature controversy compromise reached (1955/1958)
33rd–34th	1962, 1967	DV Davies (with F Davies, RE Coupland)	Post-war "formulaic" expansion; era ended by unexpected deaths of successive editors
35th–36th	1973, 1980	Roger Warwick & Peter Williams	Major modern rewrite — over 780 of 1471 pages newly written; re-typeset in double columns; first bibliography added
37th–38th	1989, 1995	Peter Williams & Editorial Board	Continued modernisation with an expanding editorial board
39th–40th	2005, 2008	Susan Standring & Editorial Board	Reorganised from systemic to regional anatomy ; retitled <i>The Anatomical Basis of Clinical Practice</i>
41st	2015	Susan Standring & Editorial Board	Current edition — spine reference text



6. Significance — "The Doctors' Bible"

- ▶ Gray's Anatomy has been in **continuous publication on both sides of the Atlantic since 1858** — an exceptionally long era for any textbook, and a rarity in publishing history.
- ▶ Its cultural stature was captured by novelist Sinclair Lewis in *Arrowsmith* (1925), who ranked it alongside the Bible and Shakespeare as essential to a doctor's education — hence its popular epithet, "**the Doctors' Bible.**"
- ▶ Although the modern volume looks utterly different from the slim 1858 original, its direct lineage — every edition updated by Henry Gray's editorial successors — is unbroken.

Applied / Clinical anatomy

- ▶ The book's own evolution mirrors changing clinical practice: the **shift from systemic to regional organisation** (39th edition, 2005) was driven explicitly by the rise of cross-sectional imaging (CT, ultrasound, MRI), which increased the clinical importance of regional anatomical relationships — the same rationale underlying the RGUHS Paper IV emphasis on radiological/cross-sectional anatomy.
- ▶ The retitling to "**The Anatomical Basis of Clinical Practice**" formalised the book's orientation toward surgical and clinical application rather than pure descriptive anatomy.
- ▶ Carter's original innovation of **directly-labelled illustration** (label fused to structure, rather than a numbered key) set a standard still followed by every modern clinical atlas, minimising the ambiguity that matters at the operating table or in viva demonstration.
- ▶ The book's evolving "Notes on Applied Anatomy" (introduced 1909, 17th edition) established the template later generalised across anatomy texts of pairing pure descriptive anatomy with a clinical-correlation section — the same structure this model-answer format itself follows.

High-yield exam pointers

- ▶ Henry Gray (1827–1861): English anatomist/surgeon, St George's Hospital, London; FRS at age 25.
- ▶ First edition (1858): *Anatomy, Descriptive and Surgical*; co-created with illustrator **Henry Vandyke Carter**; published by JW Parker & Son; 750 pages, 363 illustrations.
- ▶ Gray wrote the text and performed dissections jointly with Carter; **Carter executed every illustration** but received only a one-off fee, no royalty.
- ▶ Gray died in **1861 of smallpox** (age 34), contracted while nursing his nephew; **no obituary of Gray ever appeared in the book itself**.
- ▶ **Timothy Holmes** (3rd–9th editions, 1864–1880) secured the book's survival after Gray's death.
- ▶ Book officially retitled "**Gray's Anatomy**" in **1938 (27th edition)**, under TB Johnston.
- ▶ Major modern rewrite: **1973, 35th edition**, by Roger Warwick and Peter Williams.
- ▶ Reorganised **systemic** → **regional** anatomy in the **39th edition (2005)** under **Susan Standring**, retitled *The Anatomical Basis of Clinical Practice*; current edition is the **41st (2015)**.
- ▶ Nicknamed the "**Doctors' Bible**" — the longest continuously published anatomy textbook (since 1858).

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e — Historical Introduction (The First Edition; The Book Survives; The Missing Obituary; A Succession of Editors; Key Edition: 1905; The Nomenclature Controversy; After World War II; Key Edition: 1973; The Doctors' Bible); Vishram Singh — General Anatomy 4e (Introduction and History of Anatomy).



Hippocrates

Asked in: Paper I Oct 2009 — RGUHS MD/MS Anatomy

Definition / Introduction Hippocrates of Cos (cir. 460–377 BC) was a Greek physician of the Grecian period who is universally regarded as the "**Father of Medicine**" for establishing sound, rational principles of medical practice at a time when disease was otherwise attributed to divine displeasure. Though he had only **limited exposure to human dissection**, he propounded the influential **humoral theory** of body organisation, gave the first recorded embryological observations, and his name is permanently memorialised in the **Hippocratic Oath**, still administered to graduating medical students worldwide. He occupies a foundational position in the standard historical timeline of contributors to the science of anatomy and medicine, immediately following Sushruta and preceding Aristotle, Herophilus and Galen.

1. Era, school and place in the historical timeline of anatomy

- ▶ Hippocrates belongs to the **Grecian period** of the history of anatomy, and is traditionally associated with the island of Cos (hence "Hippocrates of Cos"), one of the great centres of Greek medical learning.

- ▶ He had only **limited exposure to human dissection** — his system was built substantially on clinical observation and philosophical reasoning about body function rather than on cadaveric dissection, unlike the later Alexandrian anatomists.
- ▶ His immediate historical predecessor was **Sushruta** (cir. 1,000 BC), the Indian "Father of Surgery," who practised on the banks of the Ganges and authored the *Sushruta Samhita*.
- ▶ His successors in the standard timeline are **Aristotle** (384–322 BC) — comparative anatomist and author of the first-ever treatise on embryology — and **Herophilus** (cir. 325 BC) of Alexandria, who performed extensive human (and living) dissection and is titled the "**Father of Anatomy**." Several centuries later, **Galen** (AD 130–216) was, in the words of the standard text, "perhaps the best physician after Hippocrates."

Contributor	Period	Key contribution
Sushruta	cir. 1,000 BC	Described ~300 bones, ~500 muscles; blood vessels as <i>Dhamnis/Siras</i> ; "Father of Surgery"
Hippocrates	cir. 460–377 BC	Humoral theory; Hippocratic Oath; "Father of Medicine"
Aristotle	384–322 BC	Comparative anatomist; first recorded illustration of anatomy; first-ever account of embryology
Herophilus	cir. 325 BC	Remarkable work on the nervous system; recognised brain as seat of intelligence; "Father of Anatomy"
Galen	AD 130–216	Most influential ancient writer on anatomy/medicine; "best physician after Hippocrates"; authority for ~1,500 years

2. Doctrine of the Four Humours (humoral theory)

- ▶ Hippocrates proclaimed a popular **theory of body organisation called the humoral theory**: the human body is constituted of **four body humours** — **blood, phlegm, yellow bile and black bile**.
- ▶ Each humour was associated with a particular organ: **blood with the liver, yellow bile with the gallbladder, phlegm with the lungs, and black bile with the spleen**.
- ▶ A **healthy person** was thought to have a **balance of these four humours**; disease resulted from humoral imbalance.
- ▶ The balance between the four humours could be **maintained or restored by proper diet, hygiene and lifestyle** — an early anticipation of preventive medicine.
- ▶ The concept of humours has **long since been discarded** as physiologically incorrect, but it **dominated medical thought for over 2,000 years**, well into the Renaissance.

3. The naturalistic method — birth of rational, clinical medicine

- ▶ Perhaps Hippocrates' **greatest contribution** was that he **attributed diseases to natural causes rather than to the displeasure of the Gods** — a decisive break from the prevailing temple-medicine of his time.
- ▶ His **application of logic and reason to disease** is regarded as **the beginning of present-day scientific medicine**.
- ▶ He placed great emphasis on **bedside clinical observation** using the physician's own senses, memorably captured in the epigraph "*Eye, ear, nose and palpating fingers are the gems of a physician. An intact brain is the necklace*" — attributed to Hippocrates in the standard gross-anatomy text.
- ▶ The body of writings compiled under his name and that of his school forms the **Hippocratic Corpus**, a collection of medical treatises covering clinical observation, prognosis, and professional ethics, which shaped Western medicine for centuries.

4. The Hippocratic Oath

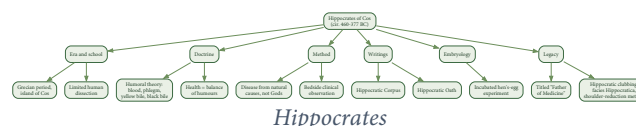
- ▶ Hippocrates is most often remembered by the medical fraternity for the **Hippocratic Oath**, which **embodies a code of ethics that all medical professionals must follow in their practice**.
- ▶ The oath became a **standard norm for all medical professionals** and **continues to be administered to medical students worldwide even today**, typically at graduation or white-coat ceremonies.
- ▶ His name is thus **memorialised** in medical tradition through an ethical instrument rather than through an anatomical eponym — in contrast to later contributors (Herophilus, Vesalius, Malpighi) who are remembered chiefly for descriptive/structural discoveries.

5. Contribution to embryology

- ▶ Hippocrates also made the **first recorded embryological observation** in Western medicine. To understand how the human embryo develops, he recommended a simple comparative-incubation experiment:

> *"Take twenty or more eggs and let them be incubated by two or more hens. Then each day from the second to that of hatching, remove an egg, break it, and examine it. You will find exactly as I say, for the nature of the bird can be likened to that of man."*

- ▶ This chick-egg incubation method — examining a fertilised hen's egg on successive days to track staged development — was reasoned by Hippocrates to be **analogous to human embryonic development**, and is cited in standard embryology texts as the earliest documented developmental (embryological) study.
- ▶ In the historical sequence of embryology's founders, Hippocrates' egg-incubation observation **precedes Aristotle**, who subsequently wrote the first-ever treatise describing the development of the chick and other embryos in greater anatomical detail.



□ Fig 1.4 — ■ *Hippocrates*. (Vishram Singh — *General Anatomy* — 4e, p.57)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Nail profile — **normal vs Hippocratic clubbing** (the anatomical basis of the clinical sign first described by Hippocrates), labelling:

- ▶ Nail plate
- ▶ Proximal nail fold
- ▶ Hyponychial (Lovibond) angle — mark as **160°** in the **normal** profile
- ▶ Same angle in **clubbing** — mark as **increased, approaching or exceeding 180°**
- ▶ Convex bulge of the nail plate produced by hypertrophy of the nail-bed soft tissue in clubbing
- ▶ Distal phalanx (base) for orientation

Applied / Clinical anatomy

- ▶ **Hippocratic clubbing** ("Hippocratic fingers"): digital clubbing was first described by Hippocrates in patients with empyema, and the eponym persists in clinical practice today. Its anatomical basis is **hypertrophy of the nail bed**, which increases the convexity of the nail plate; the **angle between the nail plate and the proximal nail fold**, normally about **160°**, **increases and approaches or exceeds 180°** in clubbing — seen in chronic suppurative diseases such as lung abscess, bronchiectasis and osteomyelitis.
- ▶ **Facies Hippocratica**: the classic facial appearance of a moribund patient — sunken eyes, hollow cheeks and temples, dry retracted lips, and cold, drawn features — was originally described by Hippocrates as an ominous prognostic sign, and the term remains part of clinical teaching on terminal illness.
- ▶ **Hippocratic method of reduction**: traction-counter-traction techniques for reducing an anteriorly dislocated shoulder (using the heel/foot placed in the axilla while traction is applied to the abducted limb) are attributed to Hippocrates and are still taught; safe execution demands sound knowledge of the anatomy of the **glenohumeral joint**, **axillary nerve** and **axillary vessels** to avoid iatrogenic neurovascular injury during reduction.
- ▶ **The Hippocratic Oath's living legacy**: its ethical core survives in the modern **World Medical Association's Declaration of Geneva (Physician's Pledge)**, and continues to be administered — sometimes alongside the *Charak Shapath* in Indian medical colleges — at graduation ceremonies, directly linking this history question to professional ethics teaching in the current curriculum.
- ▶ **Foundational relevance to anatomy teaching**: Hippocrates' own epigrammatic dictum, "*Anatomy is the basis of medical discourse*," is quoted at the very opening of standard gross-anatomy textbooks to justify anatomy's place as the first subject in the medical curriculum, while his naturalistic, cause-and-effect approach to disease underlies the modern clinical method (history-taking, examination and prognosis) that anatomy training ultimately serves.

High-yield exam pointers

- ▶ **Hippocrates of Cos**, Greek physician, **cir. 460–377 BC** — the "**Father of Medicine**."

- ▶ Historical position: succeeds **Sushruta** (Father of Surgery, cir. 1,000 BC, India); precedes **Aristotle** (comparative anatomist/embryologist), **Herophilus** (Father of Anatomy) and **Galen** ("best physician after Hippocrates").
- ▶ Had **limited exposure to human dissection**; his system was doctrinal and clinical, not dissection-based.
- ▶ Propounded the **humoral theory** — four humours (**blood–liver, phlegm–lungs, yellow bile–gallbladder, black bile–spleen**); health = humoral balance, restorable by diet/hygiene/lifestyle.
- ▶ Greatest conceptual contribution: **attributed disease to natural causes, not divine displeasure** — foundation of rational/scientific medicine.
- ▶ Figurehead of the **Hippocratic Corpus** and author of the **Hippocratic Oath**, still administered to graduating medical students worldwide.
- ▶ Gave the **first recorded embryological observation** — the incubated hen's-egg experiment, likening chick development to human development; historically precedes Aristotle's embryology treatise.
- ▶ Clinical eponyms: **Hippocratic clubbing/fingers** (nail-bed hypertrophy, angle $160^\circ \rightarrow \geq 180^\circ$), **facies Hippocratica**, **Hippocratic method** of shoulder-dislocation reduction.
- ▶ Memorable quote: "*Anatomy is the basis of medical discourse.*"

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (History of Anatomy chapter — Table 1.1, "Golden Facts to Remember," and skin-appendages chapter for the clubbing angle); Vishram Singh — Textbook of Clinical Embryology (history-of-embryology section); Moore — The Developing Human 9e (history-of-embryology section, corroborating the hen's-egg account); BD Chaurasia — Human Anatomy Vol 1 8e (chapter epigraph on clinical observation).

Coverage note: Gray's Anatomy (Standring) 41e's own historical-introduction material narrates the editorial history of the *Gray's Anatomy* textbook itself (its successive editors/editions), not the life and work of Hippocrates, and is therefore not cited for biographical content here — consistent with the topic spec's grounding hint. The eponymous clinical correlations (Hippocratic clubbing, facies Hippocratica, Hippocratic method of shoulder reduction, the Declaration of Geneva) are standard, universally-taught facts of medical history rather than verbatim extracts of a single corpus chapter; the specific clubbing-angle values (160° normal / $\geq 180^\circ$ in clubbing) are, however, confirmed against Vishram Singh's General Anatomy skin-appendages chapter.



History of anatomical illustrations

Asked in: Paper I Nov 2017 — RGUHS MD/MS Anatomy

Definition / Introduction Anatomical illustration is the visual (pictorial, sculpted or, latterly, photographic/digital) representation of body structure, and its history runs in parallel with — and is largely dictated by — the changing status of human dissection through the ages. It evolved from unillustrated or crudely schematic textual descriptions in antiquity, through the dissection-based, artist-collaborated woodcuts of the Renaissance, to the engraved copper-plate atlases of the 17th–18th centuries, the wood-engraved and photographic textbooks of the 19th–20th centuries, and finally to the cross-sectional, digital and virtual-reality imagery of the present day. Each stylistic shift tracked a parallel advance in printing technology, in the social acceptance of dissection, and in the professionalisation of medical art. The subject is examined because every anatomy student's own understanding of the body is mediated through such illustrations, and because the great illustrated atlases (Vesalius, Gray, Netter) remain the working tools of the specialty today.

1. Ancient and Graeco-Roman foundations

Era / contributor	Approx. period	Contribution to anatomical depiction
Menes (Egypt)	c. 3400 BC	Credited with the first anatomy manual (text, unillustrated)
Egyptian papyri / Babylonian clay liver models	Antiquity	Case descriptions in words (papyri); clay liver models for hepatoscopy — the earliest 3-D anatomical models , not teaching aids
Sushruta (India)	c. 1000 BC	<i>Sushruta Samhita</i> ("Sharira Sthana") — ~300 bones, ~500 muscles, viscera and joints described in prose; Father of Surgery
Hippocrates	c. 460–377 BC	Father of Medicine; humoral theory; little direct dissection
Aristotle	384–322 BC	Coined <i>anatome</i> ("cutting up"); first recorded illustration of anatomy ; first account of embryology
Herophilus	c. 325 BC	Alexandria School; human dissection and vivisection under Ptolemy I; described brain, eye, nerves; "Father of Anatomy"
Galen	AD 130–216	Animal-based descriptions, copied for ~1,500 years (the "Galenic age") without fresh human illustration

- Illustration here was secondary to text; where figures existed, they were schematic and copied down the generations rather than drawn afresh from the cadaver — unbroken until the Renaissance.

2. Medieval period — East and West

- **Islamic Golden Age:** Greek texts were preserved/extended (Ibn Sina's *Canon of Medicine*); Al-Zahrawi's *Al-Tasrif* illustrated surgical instruments rather than the body.
- **Persian five-figure series:** Mansur ibn Ilyas's *Tashrih-i-Mansuri* (14th century) — among the earliest dedicated anatomical atlases, with separate schematic diagrams of the skeletal, muscular, nervous, arterial and venous systems, plus a gravid figure.
- **European tradition:** Mondino de Luzzi's *Anathomia* (Bologna, 1316), the first Western text based on actual human dissection, though later printed copies added only crude, stylised diagrams.
- Recurring mnemonic genres — the "Wound Man" (annotated with every battlefield/surgical injury, a visual index for the surgeon) and the "Zodiac Man" (body parts linked to astrological signs, used to time bloodletting) — were didactic, not dissection-based.

3. The Renaissance revolution — Leonardo and Vesalius

- **Leonardo da Vinci (AD 1452–1519):** observed human dissections directly and produced nearly 500 anatomical diagrams across 60 notebooks, intent on structural accuracy; he is considered an originator of **cross-sectional anatomy** and the first to describe the moderator band of the right ventricle. His notebooks were lost at his death and not published until 1898, so they had no influence on contemporary anatomical teaching.
- **Andreas Vesalius (AD 1514–1564):** Professor of Anatomy at Padua; performed dissections himself rather than delegating them, and used live models to correlate surface landmarks with deep structures. His seven-volume *De Humani Corporis Fabrica* (1543) was the first great atlas to marry accurate, first-hand dissection with equally accurate, large-format woodcut illustration — the muscle-men and skeletons posed against Italian landscapes, traditionally attributed to an artist from Titian's Venetian workshop. The *Fabrica* boldly overturned many Galenic errors and is the true starting point of illustration-led modern anatomy; Vesalius is regarded as the **Father of Modern Anatomy / Reformer of Anatomy**.

□ Fig 1.9 — Andreas Vesalius (Vishram Singh — *General Anatomy* — 4e, p.65)

4. The golden age of engraved atlases (16th–18th century)

Atlas / illustrator	Date	Illustrative advance
Eustachi, <i>Tabulae Anatomicae</i>	Engraved c. 1552, published 1714	Fine copper-plate engravings; delayed publication blunted its influence
Casserio, <i>Tabulae Anatomicae</i>	1627 (posthumous)	Elaborate, theatrically posed copper engravings

Atlas / illustrator	Date	Illustrative advance
Bidloo (art: de Lairese), <i>Anatomia Humani Corporis</i>	1685	Naturalistic copper plates; republished uncredited by Cowper (1698) — a noted plagiarism episode
Cheselden, <i>Osteographia</i>	1733	Skeletal plates traced via camera obscura for geometric accuracy
Albinus (art: Wandelaar), <i>Tabulae Sceleti et Musculorum</i>	1747	Grid/perspective-correction method; fantastical backgrounds (a famous rhinoceros)
William Hunter (art: van Rymsdyk), <i>Anatomy of the Human Gravid Uterus</i>	1774	Life-size, dissection-accurate obstetric plates
John Hunter	1728–1793	Hunterian museums (London, Glasgow) — the specimen itself as 3-D "illustration"

- The same period saw Harvey's demonstration of the circulation (1628) and Leeuwenhoek's improved microscope (~270×), opening microscopic structure to illustration; Malpighi ("Father of Histology") and Hooke (coined "cell", 1665) produced the earliest microscopic anatomical drawings.

5. The 19th century — Gray and Carter, and the modern printed textbook

- **Henry Gray** (1827–1861) collaborated with artist-anatomist **Henry Vandyke Carter**, Demonstrator of Anatomy at St George's Hospital, to produce *Anatomy, Descriptive and Surgical* (750 pages, 363 figures), published by JW Parker & Son in August 1858.
- Gray wrote the text while Carter drew from their joint dissections; Carter's drawings were transferred to inscribed wood-blocks and reproduced as **wood engravings**, prized for bold clarity of line and lettering — a deliberate improvement on the button-sized figures of contemporary pocket manuals (Quain, Wilson, Knox).
- Carter left for India (Indian Medical Service) as the first edition went to press; later editions were carried on by successive editors (Holmes, then Pick and Howden).

□ Fig 1.13 — Henry Gray (Vishram Singh — *General Anatomy* — 4e, p.71)

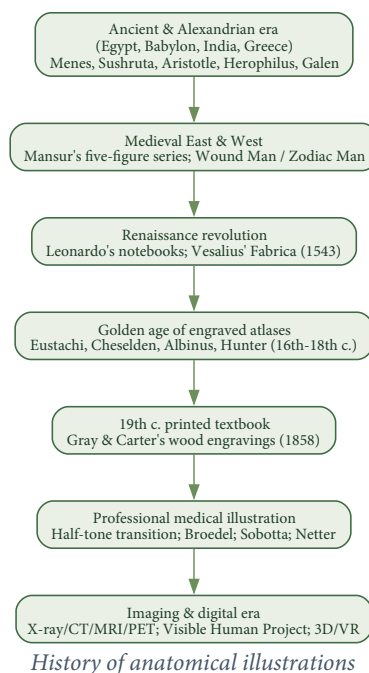
6. Photographic transition and the birth of professional medical illustration (late 19th–20th century)

- Publishers trialled cheaper **half-tone photographic** illustration in the early 1900s, but editors Pick and Howden judged it inferior to Carter's wood engravings and reverted to engraving-style line drawings for the 1905 (16th) edition; Howden (sole editor from 1909, 17th edition) pushed illustrations past 1,000 and began an editorial board.
- Germany's **Sobotta atlas** (from 1904) set a new standard for precise, colour-printed plates.

- ▶ **Max Brödel** (1870–1941) founded the first academic Department of Art as Applied to Medicine (Johns Hopkins, 1911) and developed the carbon-dust technique — the father of modern medical illustration.
- ▶ **Frank H. Netter** produced almost 4,000 gouache paintings for the *CIBA Collection*, later reorganised as the *Netter Atlas of Human Anatomy* (first published 1989) — now among the most widely used anatomy atlases worldwide.

7. The imaging revolution and the digital/virtual era (20th–21st century)

- ▶ **Wilhelm Röntgen** discovered X-rays in 1895 (Nobel Prize, 1901), founding **radiological anatomy** — a non-invasive "illustration" of the living body.
- ▶ Later cross-sectional imaging — **CT, ultrasonography, MRI, PET** — progressively supplemented, and in living-anatomy teaching partly supplanted, the printed plate.
- ▶ The **Visible Human Project** (US NIH) built a digital cross-sectional image library from serially sectioned cadavers — a computational descendant of Leonardo's cross-sectional principle.
- ▶ The 21st century adds **3D digital sculpting/printing** of patient-specific models and **virtual/augmented-reality dissection** of "cyber-cadavers."



DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

A simple horizontal timeline strip (exam-drawable in under a minute), labelled left to right with these milestones and one keyword under each:

- ▶ **Ancient Egypt / India / Greece** — "text, no dissection-based figures"
- ▶ **Alexandria (Herophilus, c. 325 BC)** — "human dissection begins"
- ▶ **Galen (AD 130–216)** — "animal-based, copied for 1500 yrs"
- ▶ ***Vesalius, De Humani Corporis Fabrica (1543)*** — "dissection-based woodcuts"
- ▶ **Albinus/Cheselden atlases (18th c.)** — "engraved, camera-obscura accuracy"
- ▶ **Gray & Carter (1858)** — "wood-engraved textbook"
- ▶ **Half-tone photography (early 1900s)** — "photographic plates trialled"
- ▶ **Netter (20th c.)** — "professional gouache atlas art"
- ▶ **X-ray → CT/MRI/PET** — "living, radiological anatomy"
- ▶ **Visible Human Project / 3D-VR (21st c.)** — "digital, cross-sectional, virtual"

Applied / Clinical anatomy

- ▶ **Surgical/operative illustration:** operative notes, consent diagrams and surgical atlases descend from the Vesalian tradition of dissection-based figures, and remain essential for planning and medico-legal documentation.
- ▶ **Radiological anatomy teaching:** CT/MRI cross-sectional atlases are a core teaching modality, continuing Leonardo's cross-sectional principle — directly relevant to Paper IV's radiological-anatomy emphasis.
- ▶ **3D-printed, patient-specific models:** used for pre-operative planning in complex craniofacial, cardiac and orthopaedic surgery — a modern equivalent of Cheselden's and Albinus's quest for structural accuracy.
- ▶ **Virtual/augmented-reality dissection:** "cyber-cadaver" platforms and simulators are used where cadaver supply is limited, echoing the historic tension (since the Anatomy Act of 1832) between real dissection and practical/ethical constraints.
- ▶ **Museum/specimen-based teaching:** the Hunterian museum tradition persists in every medical college's own anatomy museum, the wet specimen itself functioning as 3-D "illustration."

High-yield exam pointers

- ▶ **Father of Anatomy** — Herophilus (Alexandria); **Father of Modern Anatomy** — Vesalius; **Father of Surgery** — Sushruta; **Father of Medicine** — Hippocrates; **Father of Histology** — Malpighi; **Father of modern medical illustration** — Max Brödel.
- ▶ **Aristotle** — first recorded illustration of anatomy; coined the term *anatome*.
- ▶ ***Vesalius, De Humani Corporis Fabrica (1543)*** — seven volumes, age 28, refuted Galen, dissection-based woodcut illustration — the pivotal event in the history of anatomical illustration.
- ▶ **Leonardo da Vinci** — ~500 diagrams in 60 notebooks, undiscovered/unpublished until 1898, so no contemporary influence.

- ▶ **Gray & Carter, 1858** — *Anatomy, Descriptive and Surgical*, 750 pages, 363 wood-engraved figures; Carter drew, Gray wrote.
- ▶ **Röntgen (1895)** — X-rays, founding radiological anatomy; first Nobel Prize in Physics (1901).
- ▶ **Netter** — nearly 4,000 gouache paintings; *Netter Atlas of Human Anatomy* first published 1989.
- ▶ **Visible Human Project (NIH)** and modern 3D/VR tools — the current, digital phase of anatomical illustration.
- ▶ Overall sequence to recall: **text-only (antiquity)** → **schematic manuscript (medieval)** → **dissection-based woodcut (Vesalius, 1543)** → **engraved atlas (17th–18th c.)** → **wood-engraved textbook (Gray, 1858)** → **photographic/professional art (Brödel, Netter)** → **radiological/digital/virtual (X-ray to VR)**.

SOURCE & COVERAGE

Vishram Singh — General Anatomy, 4e (History of Anatomy chapter — Sushruta, Hippocrates, Aristotle, Herophilus, Galen, Leonardo da Vinci, Vesalius, Harvey, Leeuwenhoek, Malpighi, John Hunter, Röntgen, Henry Gray, Visible Human Project); Gray's Anatomy (Standring) 41e — Historical Introduction chapters (Gray and Carter's collaboration, wood-engraving process, the 1905/1909 half-tone-to-engraving transition, Pick, Howden, Johnston).

Coverage note: the corpus's dedicated "History of Anatomy" material (Vishram Singh, and Gray's own historical-introduction chapters) covers the ancient-to-19th-century timeline and the Gray/Carter illustration story in detail, but does not itself narrate the wider post-Vesalian atlas tradition (Eustachi, Cheselden, Albinus, Hunter), the Brödel/Sobotta era, or 21st-century 3D/VR tools. These sections are composed from universally-accepted, standard history-of-medicine facts widely taught alongside this topic, not fabricated detail.



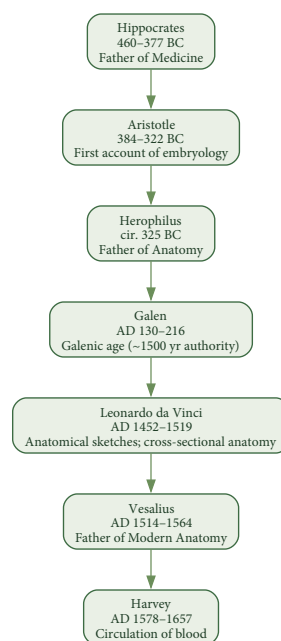
Leonardo da Vinci

Asked in: Paper I 06-Apr-2026 — RGUHS MD/MS Anatomy

Definition / Introduction Leonardo da Vinci (AD 1452–1519) was an Italian Renaissance genius — painter, sculptor, architect, musician and anatomist — best remembered artistically for the *Mona Lisa*, and remembered in medicine for producing the most accurate and extensive anatomical drawings of his age. Working during the Renaissance (14th–16th century AD), the transitional period between the medieval "dark ages" and the modern age of science, he occupies a pivotal position in the history of anatomy: he broke from centuries of unquestioned Galenic authority by observing dissections directly and recording what he actually saw, and in doing so anticipated several structures and methods — the moderator band, cross-sectional anatomy, quantitative embryology — that were only formally credited to later workers. His own anatomical manuscripts, however, were lost for over four centuries, so his direct influence on the discipline was delayed until long after his death.

1. Historical setting — Leonardo's place in the timeline of anatomy

- The history of anatomy is conventionally traced through **Early civilisation** (Sushruta, Menes) → **Grecian period** (Hippocrates, Aristotle, Herophilus) → **Roman period** (Galen) → **Renaissance** (Leonardo da Vinci) → **16th century** (Vesalius) → **17th–18th centuries** (Harvey, Leeuwenhoek).
- For roughly **1,500 years** (the "Galenic age") Galen's animal-based, error-laden anatomical writings were accepted as unquestionable authority; the Renaissance revival of arts and science (14th–16th century AD) created the intellectual climate in which this authority could finally be challenged by direct human observation.
- Leonardo da Vinci is the pivotal transitional figure of this period: chronologically and methodologically, he stands between the last defender of Galenic doctrine and Andreas Vesalius (AD 1514–1564), who explicitly refuted Galen's errors and is regarded as the Father of Modern Anatomy.



Leonardo da Vinci

2. Leonardo's method of studying anatomy

- ▶ He observed dissections performed on human cadavers **very carefully**, in an era when direct human dissection was itself a hard-won concession from the Church and the state.
- ▶ He planned to co-author an illustrated textbook of anatomy with **Marcantonio della Torre**, professor of anatomy at Pavia; the project failed only because della Torre died prematurely at the age of **31 years** — otherwise the two would have produced a formally published, illustrated anatomy text more than a generation before Vesalius.
- ▶ He was "intent on accuracy," and his illustrations were designed to show the **structural relationships of organs** to one another rather than isolated, schematic parts — a methodological advance over the largely textual, non-illustrated anatomy of the Galenic tradition.
- ▶ His approach fused the discipline of the artist (precise draughtsmanship, proportion) with the discipline of the empirical observer (dissection, measurement), which is why he is described equally as a painter, sculptor, architect, musician **and** anatomist.

□ Fig 1.8 — ■ *Leonardo da Vinci*. (Vishram Singh — *General Anatomy* — 4e, p.63)

3. Major anatomical contributions

System / area	Contribution of Leonardo da Vinci
Cardiovascular system	First to describe the moderator band (septomarginal trabecula) of the right ventricle ; constructed different models of the heart valves to demonstrate their mechanism of action
Neuroanatomy	Made a wax cast of the ventricles of the brain to study their three-dimensional shape — an early "corrosion-cast" style technique
Sectional / topographic anatomy	Considered an originator of cross-sectional anatomy — depicting structures cut in a transverse/sectional plane rather than only from the external surface
Embryology / fetal anatomy	Made accurate drawings of the dissected pregnant uterus containing a fetus ; introduced the quantitative approach to embryology by taking measurements of prenatal growth
General method	Produced illustrations intended to show the structural relationships of many organs , prioritising observational accuracy over inherited textual dogma

- ▶ These contributions span at least four systems (cardiovascular, nervous, reproductive/developmental) and a whole sub-discipline (sectional anatomy), which is unusual breadth for a single Renaissance-era observer and reflects his combined artistic and empirical rigour.
- ▶ His fetal drawings — showing a fetus within an incised, opened gravid uterus — are among the earliest attempts to depict human prenatal anatomy accurately, and his introduction of **measurement** into the study of prenatal growth anticipates the modern discipline of fetal biometry.

4. Fate of Leonardo's anatomical notebooks

- ▶ Leonardo's anatomical sketches were **lost when he died** and remained **undiscovered for over four centuries**.
- ▶ His **60 notebooks**, containing nearly **500 anatomical diagrams**, were eventually published only in 1898.
- ▶ Because these notebooks were unavailable to the anatomists who followed him, several of his original observations (such as the moderator band) had to be independently rediscovered by later workers.
- ▶ Had Leonardo's notebooks been available to the world at the time of his death, the advancement of the science of anatomy would have been **accelerated by many years** — a point repeatedly stressed in the history-of-anatomy literature to illustrate how the transmission of knowledge, and not merely its discovery, drives scientific progress.

5. Legacy and place in the history of anatomy

- ▶ Leonardo da Vinci represents the transition from Galenic authority (accepted uncritically for ~1,500 years) to the empirical, illustrated, dissection-based anatomy that Andreas Vesalius formalised a generation later in *De Humani Corporis Fabrica Libri Septem* (published when Vesalius was 28 years old).
- ▶ Although Leonardo's own manuscripts did not directly influence Vesalius (they remained unpublished), both men shared the same essential method — direct human dissection combined with accurate illustration — making Leonardo the artistic-scientific forerunner of the Vesalian reform, even though credit for founding "modern anatomy" formally belongs to Vesalius.
- ▶ His recognition as an originator of **cross-sectional anatomy** foreshadows a technique whose full clinical importance was realised only centuries later, with the advent of computed tomography (CT), magnetic resonance imaging (MRI) and ultrasonography, all of which depend on interpreting the body in transverse/sectional planes exactly as Leonardo first attempted by hand.

Applied / Clinical anatomy

- ▶ **Moderator band (septomarginal trabecula)**: the structure Leonardo first described carries the **right bundle branch of the atrioventricular (AV) bundle** across the right ventricular cavity from the interventricular septum to the base of the **anterior papillary muscle**, where it ramifies into **Purkinje fibres** supplying the anterior wall of the right ventricle. It is of major applied importance in cardiac conduction (right bundle branch block localisation) and is a recognised **echocardiographic landmark** in the right ventricle that must not be mistaken for an intracavitary thrombus.
- ▶ **Cross-sectional anatomy**: the discipline Leonardo pioneered by hand is now the conceptual basis of all modern cross-sectional imaging (CT, MRI, USG) reporting and of radiological anatomy teaching, where structures are routinely described and identified in transverse, coronal and sagittal planes.
- ▶ **Heart-valve models**: Leonardo's constructed models to study valve-cusp action anticipate the modern hemodynamic and prosthetic-valve studies of cuspal and chordal mechanics used in cardiac surgery and valve-replacement design.

- ▶ **Fetal/embryological drawings:** his depiction of the fetus within the opened gravid uterus, together with his quantitative measurements of prenatal growth, are historical forerunners of modern obstetric ultrasound biometry (crown–rump length, fetal growth charting).
- ▶ **Loss and rediscovery of the notebooks (1898)** is itself a teaching point in the history of medical science — it illustrates how scientific priority and clinical credit can be separated by centuries when observations are not published in a timely manner, a caution still relevant to how anatomical and clinical discoveries are disseminated today.

High-yield exam pointers

- ▶ Leonardo da Vinci: **AD 1452–1519**, Italian Renaissance genius — painter, sculptor, architect, musician **and anatomist**; best known artistic work is the *Mona Lisa*.
- ▶ Planned a jointly authored, illustrated anatomy textbook with **Marcantonio della Torre** (Professor of Anatomy, Pavia); the plan failed after della Torre's premature death at **age 31**.
- ▶ First to describe the **moderator band (septomarginal trabecula) of the right ventricle**; also constructed **models of heart valves** and made a **wax cast of the cerebral ventricles**.
- ▶ Regarded as an **originator of cross-sectional anatomy**.
- ▶ Contributed to embryology: accurate drawings of the dissected **gravid uterus with fetus**; **introduced the quantitative (measurement-based) approach to embryology**.
- ▶ His **60 notebooks (~500 anatomical diagrams)** were lost at his death and remained undiscovered for **over four centuries**, being published only in **1898** — delaying the impact of his work on the progress of anatomy.
- ▶ Chronological position in the history of anatomy: follows the ~1,500-year **Galenic age** and immediately precedes **Andreas Vesalius** (AD 1514–1564), the Father of Modern Anatomy.

SOURCE & COVERAGE

Vishram Singh — General Anatomy 4e (Chapter 1, "Introduction and History of Anatomy" — table of historical contributors and biographical account of Leonardo da Vinci); Moore — The Developing Human 9e (historical note on Leonardo's drawings of the dissected gravid uterus and quantitative embryology); Vishram Singh — Textbook of Clinical Embryology (historical account and figures of Leonardo da Vinci's fetal drawings); AK Datta — Human Anatomy Vol 1 (Thorax & Abdomen) and BD Chaurasia — Human Anatomy Vol 1 8e (structure and conduction-system significance of the moderator band/septomarginal trabecula, used for the Applied anatomy section).

NOTE — FOR REFERENCE, NOT TO BE WRITTEN IN THE EXAM

Gray's Anatomy (Standing) 41e's own historical/introductory material narrates the publishing history of *Gray's Anatomy* itself rather than the broader history of anatomy or Leonardo da Vinci, and was therefore not usable as grounding for this topic; the answer is instead grounded in Vishram Singh's dedicated "History of Anatomy" chapter (the prescribed General Anatomy specialty text) together with the embryology textbooks' historical notes on Leonardo's fetal drawings.



Applied & clinical anatomy



Cervical Rib

Asked in: Paper I May 2010 · Paper IV Apr 2008 (2×) — RGUHS MD/MS Anatomy

Definition / Introduction — A **cervical rib** is a congenital skeletal anomaly in which the **costal element of the transverse process of the seventh cervical vertebra** persists as a separate bony, cartilaginous or fibrous structure instead of fusing into the vertebra, producing an extra "rib" in the root of the neck. It usually runs from the C7 transverse process to the **first rib**, close to the insertion of **scalene anterior**, and by narrowing the **scalene triangle** it may compress the **subclavian artery** and the **lower trunk of the brachial plexus** (C8, T1) — the classic cause of **thoracic outlet syndrome** (TOS). The condition was first described by **Astley Cooper** (1817), and most cervical ribs remain entirely asymptomatic.

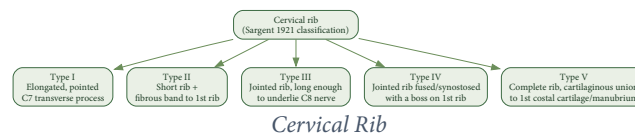
1. Developmental basis

- ▶ Each typical cervical vertebra develops from a **centrum**, two **neural arch centres**, and an **anterior costal element** that normally fuses with the transverse process to form the anterior tubercle, the bar in front of the foramen transversarium, and part of the transverse process itself.
- ▶ At C7, this costal element is homologous with a true rib (as at thoracic levels) but is normally the **last cervical costal element to fuse**; if it fails to fuse and instead **enlarges and remains separate**, it forms a cervical rib.
- ▶ **Ossification**: a separate centre for the costal element appears during the **sixth month of intra-uterine life** and normally fuses with the body and transverse process during the **fifth to sixth year of life** (BD Chaurasia); persistence of a large, separate centre gives the spectrum of cervical rib seen radiologically.
- ▶ Gray's Anatomy notes that the **occasional co-occurrence of a cervical rib with a rudimentary or absent twelfth rib** points to a **homeotic shift** affecting a larger segment of the vertebral column during development — i.e. a mismatch between the morphological and positional identity of vertebrae at the cervicothoracic and thoracolumbar junctions.
- ▶ An analogous anomaly at the other end of the vertebral column is the **lumbar (gorilla) rib**, from a persistent costal element of L1; it is commoner than the cervical rib but usually asymptomatic and may mimic a fractured L1 transverse process radiologically.

2. Morphology and Sargent's classification

The cervical rib is **rarely symmetrical**, is **more often unilateral** than bilateral, and occurs **somewhat more frequently on the right side**. Its extent varies from a mere pointed elongation of the transverse process to a complete rib indistinguishable from a first thoracic rib. **Sargent (1921)**, cited in Gray's Anatomy, classified this spectrum into five types:

Type	Morphology
I	Prolongation and pointing of the C7 transverse process only
II	A short rib that articulates with the transverse process, continued by a fibrous band to the first rib
III	A jointed (articulated) rib long enough to carry/underlie the eighth cervical nerve
IV	A jointed rib whose free end is fused to, or forms a synchondrosis/synostosis with, a bony boss on the first rib, roughly at its mid-shaft
V	A complete seventh cervical rib with cartilaginous union to the first costal cartilage or to the manubrium



Only **types III–V** (a rib long enough to reach, or fuse with, the first rib) are of real clinical significance; a fibrous band alone (type II) can be just as compressive as a bony rib, since it is the **narrowing of the scalene triangle**, not the bone itself, that produces symptoms. Reported incidence of a cervical rib in the general population varies widely between sources — from **0.004% to 1%** (Gray's Anatomy) to **about 5%** of individuals when milder, radiologically-detected forms are included (Vishram Singh); the great majority are asymptomatic incidental findings.

3. Anatomical relations — the scalene triangle

Boundary	Structure
Anterior	Scalenus anterior
Posterior	Scalenus medius
Base (floor)	Upper surface of the first rib , on which the lower trunk of the brachial plexus rests

- ▶ Through this narrow gap pass the **subclavian artery** and the **roots/trunks of the brachial plexus**; a cervical rib (or a fibrous band from it) effectively **raises the floor of the triangle**, angulating and stretching these structures over its edge.
- ▶ On the first rib, scalenus anterior inserts on a tubercle; the **subclavian artery** lies in a groove **posterior** to this tubercle, and the **ventral ramus of T1/lower trunk** grooves the rib just posterior

to the artery. The **subclavian vein**, by contrast, crosses the rib **anterior** to the scalenus anterior tubercle — which is why a cervical rib characteristically spares the vein and rarely causes venous thoracic outlet syndrome.

- ▶ Medial to scalenus anterior lies the **scalenovertebral triangle (triangle of the vertebral artery)** — bounded medially by longus colli, laterally by scalenus anterior, with its apex at the C6 transverse process and its base at the first part of the subclavian artery; the cervical pleura and lung apex project into it, which is why an unusually low apical pleura combined with a cervical rib can further crowd the outlet.

□ Fig 1.54 — Cervical rib causing pressure on the lower trunk of the brachial plexu (BD Chaurasia — Human Anatomy Vol 3-4 — 8e, p.74)

DIAGRAMS TO DRAW — IMAGE SUGGESTIONS

Draw a coronal/oblique view of the root of the neck and label:

- ▶ **Scalenus anterior** (anterior boundary of the scalene triangle) and its insertion tubercle on the first rib
- ▶ **Scalenus medius** (posterior boundary)
- ▶ **First rib** forming the floor/base of the triangle
- ▶ **Cervical rib** arising from the transverse process of C7, with a **fibrous band** running down to the first rib
- ▶ **Subclavian artery**, arched up and over the cervical rib/band (post-stenotic dilatation may be shown distally)
- ▶ **Subclavian vein**, running anterior to scalenus anterior — undisturbed
- ▶ **Lower trunk of the brachial plexus (C8, T1 roots)**, angulated over the rib
- ▶ **Cervical (Sibson's) pleura and lung apex**, projecting up medial to scalenus anterior

4. Mechanism of neurovascular compression

- ▶ A long cervical rib (or its fibrous continuation) **narrows and raises the scalene triangle**, forcing the subclavian artery and the lower trunk of the brachial plexus to arch more sharply over a bony/fibrous edge instead of the smoothly-curved first rib.
- ▶ The **subclavian artery** is distorted and constricted by a leash formed by the tendon of scalenus anterior at the point of contact with the rib; **post-stenotic dilatation**, and even a true **aneurysm**, may develop just distal to the constriction.
- ▶ The **lower trunk (C8, T1)** is stretched/angulated over the same edge; chronic traction produces the neurological picture, which characteristically **s pares the upper and middle trunks (C5–C7)**.
- ▶ Because the subclavian vein runs anterior to the scalenus anterior tubercle, it is **not directly related to the cervical rib**, so isolated cervical-rib-related **venous** thoracic outlet syndrome is uncommon (unlike costoclavicular or effort-related venous TOS/Paget-Schroetter syndrome, which are separate entities).

5. Clinical features

Feature	Arterial TOS (rare, dramatic)	Neurogenic TOS (much rarer with true motor loss)
Typical patient	Young woman	Young to middle-aged woman
Presenting symptom	Raynaud-like blanching, coldness, digital ischaemia/gangrene from embolisation	Pain along medial forearm and hand; paraesthesia
Pulse	Feeble/absent radial pulse; bruit/thrill over subclavian artery	Usually normal
Motor findings	Usually none	Wasting of thenar and other intrinsic hand muscles; weak ulnar-innervated forearm flexors
Sensory findings	None	Blunted sensation over medial forearm/hand and little finger; little finger often shorter than normal
Danger	Thrombosis with distal embolisation; rarely embolisation proximally to carotid causing contralateral hemiplegia	Slow, often incomplete recovery even after decompression

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- **Diagnosis:** clinical suspicion from the classic triad of neck swelling/bony prominence, feeble/absent radial pulse, and pain along the C8/T1 dermatome; confirmed radiologically (a chest/cervicothoracic X-ray demonstrating the rib — a plain cervical spine film may look normal if it does not include the C7–T1 region) and, where vascular compromise is suspected, by **Doppler ultrasound, duplex scan, CT/MR angiography, and MRI/MR neurography** of the brachial plexus for the neurogenic form.
- **Adson's test:** the seated patient takes a deep breath, extends the neck and turns the face towards the affected side while the examiner palpates the radial pulse; a marked reduction or disappearance of the pulse is a **positive test**, supporting arterial compression at the scalene triangle.
- **Differential diagnosis:** cervical disc prolapse/spondylotic radiculopathy, a **Pancoast (superior sulcus) tumour** infiltrating the lower trunk, carpal tunnel syndrome (a far commoner cause of thenar wasting that was historically confused with cervical-rib syndrome), and syringomyelia.
- **Management:** asymptomatic cervical ribs need no treatment. Mild/early neurogenic symptoms are managed conservatively with physiotherapy and postural correction. Persistent or vascular cases require **surgical excision of the rib/fibrous band with decompression of the scalene triangle** (transaxillary, supraclavicular or posterior approaches, with or without first-rib resection and scalenectomy); the **periosteum of the excised rib must be stripped/removed** to prevent regrowth. Established aneurysm or thrombosis of the subclavian artery needs vascular reconstruction in addition to rib excision.

- **Complications if untreated:** progressive intimal damage, thrombosis and distal embolisation causing digital ischaemia/gangrene, aneurysm formation, and — rarely — proximal embolisation to the carotid circulation causing contralateral hemiplegia.

Recent advances

- A current literature review of **neurogenic thoracic outlet syndrome** notes that surgical decompression (transaxillary, supraclavicular or minimally invasive) remains standard for patients failing conservative therapy, and that **rib-sparing decompression techniques are increasingly favoured for their lower complication rates**, with an emerging role for robotic-assisted approaches (Attaar & Pascarella, *Am Surg* 2025) [PMID: 40626394].
- A 17-year single-centre review of **62 first-rib resections** for TOS (including **7 cases with a cervical rib**) reported excellent/good symptom resolution in 84% of patients by Derkash's classification, confirming that first-rib resection can be performed safely with good outcomes even outside specialist tertiary units (Farquharson et al, *Ann R Coll Surg Engl* 2023) [PMID: 36779445].
- A cohort undergoing a **posterior intermuscular surgical approach** for neurogenic TOS caused specifically by an accessory rib or an elongated C7 transverse process showed marked improvement in DASH and pain scores by 3–6 months, supporting posterior decompression as an effective option when a bony anomaly is the underlying cause (Tolga et al, *Oper Neurosurg* 2023) [PMID: 37747340].
- In a paediatric/young-adult series, **first or cervical rib resection with scalenectomy via a supraclavicular approach** allowed 86% of operated patients to return to their pre-symptom sporting/activity level, underscoring that cervical rib-related TOS is not confined to adults (Bach et al, *J Hand Surg Am* 2024) [PMID: 38310509].
- **Magnetic resonance neurography** of the brachial plexus is refining pre-operative diagnosis of neurogenic TOS, directly visualising C8/T1 nerve-root or lower-trunk impingement by a cervical rib, rib synostosis or post-traumatic callus, and is increasingly used for surgical planning (Davidson et al, *Muscle Nerve* 2024) [PMID: 39253948].
- An Indian series specifically addressing cervical-rib-related TOS describes the **trans-cervical surgical approach** as a safe, effective option for rib/band excision, alongside a review of incidence, presentation and diagnostic manoeuvres relevant to Indian surgical practice (Kushwaha et al, *Indian J Otolaryngol Head Neck Surg* 2024) [PMID: 39130261].

(According to PubMed; DOIs:
 [10.1177/00031348251358432](https://doi.org/10.1177/00031348251358432),
 [10.1308/rcsann.2023.0002](https://doi.org/10.1308/rcsann.2023.0002),
 [10.1227/ons.0000000000000922](https://doi.org/10.1227/ons.0000000000000922),
 [10.1016/j.jhsa.2023.12.013](https://doi.org/10.1016/j.jhsa.2023.12.013),
 [10.1002/mus.28246](https://doi.org/10.1002/mus.28246),
 [10.1007/s12070-024-04597-9](https://doi.org/10.1007/s12070-024-04597-9).)

High-yield exam pointers

- ▶ Cervical rib = persistent **costal element of the C7 transverse process**; ossification centre appears in the 6th intra-uterine month, normally fuses by the 5th–6th year of life.
- ▶ **Sargent's classification**: Type I (elongated TP) → Type V (complete rib with cartilaginous union to the manubrium/1st costal cartilage); a fibrous band (Type II) can compress just as effectively as bone.
- ▶ Structures at risk pass through the **scalene triangle** (scalenus anterior anteriorly, scalenus medius posteriorly, first rib as base): the **subclavian artery** and the **lower trunk of the brachial plexus (C8, T1)**; the **subclavian vein is spared** as it lies anterior to the scalenus anterior insertion.
- ▶ Clinical picture = **thoracic outlet syndrome**: arterial form → feeble/absent radial pulse, bruit, Raynaud-like ischaemia, risk of aneurysm/embolisation and rare contralateral hemiplegia; neurogenic form → pain/paraesthesia along the medial forearm and hand, wasting of intrinsic hand muscles, short little finger.
- ▶ **Adson's test** — reduced/absent radial pulse on deep inspiration with neck extension and rotation to the affected side — supports the diagnosis.
- ▶ Diagnosis is confirmed by a chest/cervicothoracic radiograph (a cervical spine film alone may miss it) plus Doppler/duplex or CT/MR angiography (arterial) or MR neurography (neurogenic).
- ▶ Chief differentials: cervical disc prolapse, **Pancoast tumour**, and carpal tunnel syndrome (historically confused with cervical-rib wasting).
- ▶ Management: observation if asymptomatic; excision of the rib/band with the **periosteum stripped to prevent regrowth**, ± first-rib resection/scalenectomy, for persistent or vascular disease.
- ▶ Analogous anomaly: **lumbar (gorilla) rib** from a persistent L1 costal element — commoner, usually asymptomatic.

SOURCE & COVERAGE

Gray's Anatomy (Standring) 41e; BD Chaurasia Human Anatomy Vol 1 8e and Vol 3-4 8e; Vishram Singh Textbook of Anatomy Vol 1 4e and Vol 3 4e; IB Singh Textbook of Anatomy Vol 2 6e.

