THE MOUTH

• the ***vestibule*** is formed from the lips and cheeks, bounded within by the teeth & gums
• the opening to the ***parotid duct*** is adjacent the 2nd upper molar
• the potential space is minimised by facial muscle tone (VII)

• the ***mouth cavity*** is bounded by,

i. the alveolar ridge & teeth in front
ii. the hard & soft palate above
iii. the anterior 2/3 of the tongue & its mucosal fold onto the mandible below
iv. the oropharyngeal isthmus behind

• the mucosa of the floor has a midline *frenulum linguae*, either side of which are openings to the submandibular salivary glands
• the majority of these glands open as a series of small orifices along the *sublingual fold*, others drain into the *duct of the submandibular gland* (Wharton's duct)

▪ ***The Palate***

• the ***hard palate*** is comprised of the palatine processes of the maxilla and the horizontal plates of the palatine bones
• the mucous membrane is stratified squamous, closely adherent to the periosteum, forming a single sheet, the *mucoperiosteum*

• the ***soft palate*** is suspended from the free border of the hard palate
• centrally, its free edge bears the ***uvula*** and laterally it blends with the pharyngeal wall
• the mucous membrane covering is,

i. anterior - stratified squamous
ii. posterior - ciliated columnar

• the 'skeleton' of the soft palate is a thick fibrous membrane, the *palatine aponeurosis*
• this is continuous in front with the hard palate and laterally with the tendon of the ***tensor palati***

• there are 5 ***muscles*** of the ***soft palate***,

1. ***tensor palati***
   - arises from the scaphoid fossa at the root of the medial pterygoid plate, from the lateral side of the eustachian cartilage and the medial side of the spine of the sphenoid
   - descends passing *lateral* to the superior constrictor and medial pterygoid plate
   - ends in a tendon which pierces the pharynx, loops medially around the hook of the hamulus to insert into the palatine aponeurosis
   - acts to tighten and flatten the soft palate

2. ***levator palati***
   - arises from the under surface of the petrous temporal bone and the medial side of the Eustachian tube
   - inserts into the upper surface of the soft palate, meeting in the midline
   - elevates the soft palate
3. ***palatoglossus***
   - arises in the soft palate, descending in the ***palatoglossal fold***, blending with the side of the tongue
   - acts to approximate the palatoglossal folds
4. ***palatopharyngeus***
   - arises in the soft palate, descending in the ***palatopharyngeal fold***, blending with the side of the pharynx
   - some fibres insert into the side of the thyroid cartilage
   - acts to approximate the palatopharyngeal folds
5. ***musculus uvulae***
   - arises from the palatine aponeurosis, at the posterior nasal spine of the palatine bone and inserts into the uvulae
   - supplied by the cranial root of the accessory nerve, injury to which results in elevation of the uvula to the opposite side

NB: 1. ***tensor palati*** is supplied by the ***mandibular branch of V***, via the otic ganglion
2. the remaining muscles are supplied by the ***pharyngeal plexus***, which transmits cranial fibres from the ***accessory nerve***

- these muscles act to close the nasophayrnx during phonation and deglutition
- aided by contraction of the ***superior constrictor***, which produces a transverse ridge on the posterior and lateral walls of the pharynx, at the level of C_2, the ***ridge of Passavant***

▪ ***Cleft Palate***

- the palate develops from the ***premaxilla*** (usually contains all 4 incisor teeth, occasionally only 2), and a pair of ***lateral maxillary processes***
- all degrees of failure of fusion are seen, and may involve the posterior palate, or pass to one or both sides of the premaxilla

THE NOSE

- the ***external nose*** is formed by,
  - a. an upper framework of bone
    - the nasal bones
    - the nasal part of the frontal bones
    - the frontal part of the maxilla
  - b. a lower series of cartilages
  - c. a small zone of fibro-fatty tissue laterally, the *ala*

- the ***cavity of the nose*** is subdivided by the nasal septum into two halves
  - a. opening to the exterior through the ***nares***
  - b. opening into the nasopharynx through the posterior nasal apertures, or ***choanae***

- immediately within the nares is a small dilatation, the ***vestibule***
- each side of the nose has a roof, lateral & medial walls, and a floor,

  a. **the roof**
  - slopes up and backwards forming the bridge of the nose (nasal & frontal bones)
  - then passes horizontally (cribriform plate of the ethmoid bone)
  - finally curves downward (body of the sphenoid)

  b. **the floor**
  - slightly concave from side to side, and antero-posteriorly
  - formed from the palatine process of the maxilla and the horizontal plate of the palatine bone

  c. **medial wall** *or nasal septum*
  - formed from the septal cartilage, the perpendicular plate of the ethmoid superiorly and the vomer infero-posteriorly
  - deviation of the anterior septum is seen in ~ 75% of adults, males > females

  d. **lateral wall**
  - nasal aspect of the ethmoidal labyrinth above, the nasal surface of the maxilla infero-anteriorly, and the perpendicular plate of the palatine bone posteriorly
  - projects 3 ***chonchae***, or turbinate bones, each arching over a ***meatus***
  - the upper & middle chonchae arise from the ethmoidal labyrinth
  - the inferior choncha is a separate bone
  - houses the orifices of the paranasal sinuses & the nasolacrimal duct,

    i. sphenoid sinus
    - opens into the ***spheno-ethmoidal recess***
    - between the short superior choncha & the sphenoid body

    ii. posterior ethmoidal cells
    - into the superior meatus

    iii. middle ethmoidal cells
    - bulge into & open on the middle meatus = the ***bulla ethmoidalis***

    iv. maxillary sinus
    - ostium opens below the ***hiatus semilunaris***
    - this is situated below the bulla ethmoidalis

- the hiatus semilunaris curve forward in front of the bulla ethmoidalis as the ***infundibulum***, which drains the anterior ethmoidal air cells
- in ~ 50% the frontal sinus drains into the infundibulum via the frontonasal duct
- in the remainder this opens into the anterior extremity of the middle meatus
- the ***nasolacrimal duct*** opens by itself into the anterior end of the inferior meatus

The Paranasal Sinuses

i. maxillary
ii. sphenoid
iii. frontal
iv. ethmoidal

• considerable variation in size & drainage between individuals, and they are rarely symmetrical
• there are traces of the maxillary & sphenoid sinuses in the newborn
• the remainder become significant ~ 7-8 years, with eruption of the second dentition and lengthening of the face, being fully developed by adolescence

▪ ***Maxillary Sinus***

• largest, being pyramidal in shape, and occupying the body of the maxilla
• the *base* of the pyramid forms the lateral wall of the nasal cavity, and the apex points toward the zygomatic process
• the floor of the sinus extends to the alveolar process of the maxilla
• this is ~ 1.25 cm below the floor of the nose & contains bulges from the roots of,

i. at least the 1st & 2nd molars
ii. may include all teeth derived from the maxillary process
→ canine, premolars and molars

NB: the floor may actually be perforated by 1 or more of the roots

• the roof is formed by the orbital plane of the maxilla, which has a canal for the ***infraorbital branch*** of the maxillary nerve
• medially the antrum drains into the middle meatus, however due to the high position is inefficient

▪ ***Sphenoid Sinuses***

• lie adjacent in the body of the sphenoid, though, the intervening septum is usually incomplete
• occasionally extend into the basisphenoid or clinoid process
• drain into the spheno-ethmoidal recess

- ***Frontal Sinuses***

• lying above the orbits & nose in the frontal bone
• usually unequal & the dividing septum incomplete
• their extent does not relate to the size of the superciliary ridges
• drain through the frontonasal duct to the middle meatus

- ***Ethmoidal Sinuses***

• actually air-cells, usually 8-10 loculi suspended from the outer extremity of the cribriform plate of the ethmoid, bounded laterally by its orbital plate
• divided into anterior, middle & posterior by bony septa

Blood Supply

a. anterior and posterior ***ethmoidal aa***., branches of the ophthalmic artery
   → upper part of the nasal cavity

b. ***sphenopalantine*** branch of the maxillary artery (from ECA)
   → lower part of the nasal cavity, which joins,

c. septal branch of the ***superior labial*** branch of the facial artery
   • joins above on the antero-inferior aspect of the septum
   • ~ 90% of epistaxes occur in this region, Little's area

d. submucous venous plexus drains into the sphenopalantine, ophthalmic and facial veins

e. small tributaries also pass through the ***cribriform plate*** to joins vessels on the inferior surface of the frontal lobe of the brain (spread of infection)

Functions

a. respiratory pathway
   i. filter
   ii. heater / humidifier
   iii. inherent PEEP ~ 1-2 cmH_2O and may be varied subconsciously

b. olfaction

c. phonation

Nerve Supply

a. **olfactory zone** ~ 2 cm^2 olfactory nerve (I)

b. **the septum**
- long sphenopalantine nerve (V^2) via the sphenopalantine ganglion
- short sphenopalantine nerve (V^2)
- septal branch of the anterior ethmoidal nerve, from the nasociliary branch of V^1

c. **lateral wall**

i. superior & middle chonchae - short sphenopalantine nerves

ii. inferior choncha
- branches from the anterior superior dental nerve, from the maxillary nerve in the infraorbital canal
- branches from the greater palatine nerve, from the sphenopalantine ganglion

iii. anterior lateral wall by the ethmoidal branch of the nasociliary nerve
- this then leaves the cavity between the nasal bones & cartilage to become the external nasal nerve

d. **the floor**
- anterior superior dental nerve in front
- greater palatine nerve posteriorly

e. **vestibule**
- terminal fibres from the infraorbital branch of the maxillary nerve
- these also supply the skin immediately lateral to and below the nose

f. **paranasal sinuses**
- these are innervated by V^1 and V^2
- the ***maxillary sinus*** is supplied solely by the maxillary nerve,
  - infraorbital nerve - roof
  - greater palatine nerve - floor
  - short sphenopalantine nerve &
  - greater palatine nerve - medial wall
  - superior dental branches - anterior, posterior & lateral walls
- the remaining sinuses are supplied by the ophthalmic division, V^1
  - ethmoidal & sphenoidal sinuses - anterior & posterior ethmoidal nerves
  - frontal sinus - supraorbital & supratrochlear nerves

THE PHARYNX

Def'n: the pharynx is a wide ***muscular tube*** which forms the common upper pathway of the respiratory and alimentary tracts

• anteriorly it is in free communication with the nasal cavity, the mouth and the larynx, which forms the basis of its ***three divisions***
• it extends from the base of the skull above (basilar aspect of the occipital bone) to the origin of the oesophagus at the level of $\mathbf{C_6}$
• posteriorly it rests against the prevertebral fascia and cervical vertebrae

▪ *The Nasopharynx*

• lies behind the nasal cavity, above the soft palate
• communicates with the oropharynx through the ***pharyngeal isthmus***, which closes-off during the act of swallowing
• the ***Eustachian tube*** (pharyngotympanic) opening lies on the lateral wall ~ 1cm behind and just below the inferior choncha
• the underlying cartilage raises a small bulge, the ***tubal elevation***, on the posterior rim
• behind this is a small recess, the *fossa of Rosenmüller*
• the nasopharyngeal tonsils, ***adenoids***, lie on the roof and posterior wall, directly against the superior constrictor muscle
• they consist of lymphoid tissue covered with ciliated columnar epithelium and have ***no*** distinct fibrous capsule
• postero-superiorly the nasopharynx lies in the sphenoid sinus, which separates the pharynx from the sella turcica and pituitary gland

▪ *The Oropharynx*

• the cavity of the mouth leads to the oropharynx through the *oropharyngeal isthmus*, which is bounded by the ***palatoglossal arches***
• extends from the soft palate to the tip of the epiglottis
• the ***palatine tonsils*** are collections of lymphoid tissue which lie in a triangle formed by the *palatopharyngeal* and *palatoglossal arches*, and the dorsum of the tongue
• the free surface has 12-20 tonsillar pits, an intratonsillar cleft in the upper portion, and is covered with stratified squamous epithelium
• the histological appearance of stratified squamous epithelium & underlying lymphoid tissue is unique
• the deep surface may have lymphoid projections into the dorsum of the tongue, the soft palate or into the faucial pillars
• the deep aspect is bounded by a thick ***fibrous capsule***, from the pharyngeal aponeurosis, which is separated from the underlying superior constrictor muscle by a thin layer of connective tissue
• the principal blood supply is from the ***tonsillar branch*** of the facial artery, which is accompanied by 2 venae comitantes, which passes through the superior constrictor
• there are additional small branches from the lingual, ascending palatine, ascending pharyngeal and maxillary arteries
• the venous drainage enters the venae comitantes of the ***facial artery*** and also the ***paratonsillar vein***, the later being a frequent cause of venous bleeding following tonsillectomy

• the internal carotid artery is ~ 2.5 cm away from the tonsillar capsule
• lymphatic drainage is to the upper deep cervical nodes, especially the *jugulo-digastric node*, at the junction of the common facial and the internal jugular veins
• the palatine and pharyngeal tonsils, together with lymph collections on the posterior part of the tongue, form an almost continuous ring, ***Waldeyer's ring***

• the sensory nerve supply is,

1. glossopharyngeal - via the pharyngeal plexus
2. lesser palatine branch of the maxillary nerve
3. twigs from the lingual branch of the mandibular nerve

■ ***Laryngopharynx***

• extends from the tip of the epiglottis to the lower border of the cricoid at the level of C_6
• anteriorly it faces the laryngeal inlet, bounded by the aryepglottic folds, the arytenoid cartilages and the posterior aspect of the cricoid below
• the larynx bulges backwards into the pharynx, leaving the ***piriform fossae*** on each side
• the ***internal laryngeal nerve*** passes through the submucosa on each side, and sensory anaesthesia of the larynx, above the vocal cords, can be achieved by application of anaesthetic solutions

Structure

• there are 4 layers,

1. mucosa - ***stratified squamous***
   - except for the nasopharynx which is ***ciliated columnar***
   - numerous racemose glands
2. fibrous - relatively dense above, where the muscle wall is deficient
   - condenses to form the tonsillar capsule & posterior median raphe
3. muscles * see below
4. fascia - *buccopharyngeal fascia*, which is very thin

• ***Ludwig's angina*** results from inferior spread of infection of the mouth, teeth or tonsils, confined by the pharyngeal fascia
• similar spread of oedema may be seen postoperatively with operations in the floor of the mouth
• the subsequent swelling of the pharyngeal and laryngeal tissues may produce obstruction

Muscles of the Pharynx

a. the superior, middle and inferior constrictors

b. stylopharyngeus, salpingopharyngeus and palatopharyngeus

- the ***superior constrictor*** arises from (in descending vertical order),
    i. the lower part of the medial pterygoid plate
    ii. the pterygoid hamulus
    iii. the pterygomandibular ligament (raphe)
    iv. the posterior end of the mylohyoid line, on the inner aspect of the mandible

    NB: the space between its upper margin and the base of the skull allows passage of the Eustachian tubes

- the ***middle constrictor*** spreads out from,
    i. the lesser horn of the hyoid
    ii. the upper border of the greater horn
    iii. the lowermost part of the stylohyoid ligament

- the ***inferior constrictor***, which is the thickest of the three, arises from,
    i. the oblique line of the lamina of the thyroid cartilage
    ii. the tendinous arch over the cricothyroid muscle
    iii. the side of the cricoid cartilage

- the muscle is functionally in 2 parts,
    a. the upper portion, arising from the thyroid, has obliquely placed fibres and has a propulsive action
    b. the lower portion, or ***cricopharyngeus***, acts as a sphincter with its fibres arranged horizontally

- incoordination between these two is thought to be the origin of a pharyngeal pouch, classically developing at the point of weakness between the 2 portions, *Killian's dehiscence*
- the constrictors are supplied by the ***pharyngeal nerve plexus***, which contains fibres from,
    1. the ***accessory nerve***
    2. the pharyngeal branch of the ***vagus***

Deglutition **(Swallowing)**

Def'n: a complex, orderly series of ***reflexes***, with voluntary initiation but involuntary completion initiated by stimulation of the pharynx;
reflex control is within the deglutition centre of the medulla,
anaesthesia of the pharynx prevents normal co-ordination,
actions include,

i. conveys food into the oesophagus
ii. disposes of mucous, bacteria & foreign material from the respiratory tract
iii. opens the Eustachian tubes, allowing pressure equalisation

1. food is crushed by mastication and lubricated with saliva
2. the tongue & muscles of the floor of the mouth act to propel the contents through the pharyngeal isthmus into the oropharynx
3. the oral, nasal and laryngeal openings are effectively closed by their respective sphincters
   i. nasopharynx - elevation of the soft palate
      - contraction & apposition of the superior constrictor → the ridge of Passavant
      - tensor palati opens the orifice to the Eustachian tube
   ii. oropharynx - the isthmus is closed by palatoglossus on each side
      - the residual gap is filled by the dorsum of the tongue
   iii. laryngopharynx
      - forward elevation of the larynx (thyrohyoid, stylohyoid, stylopharyngeus, digastric and mylohyoid muscles)
      - apposition of the aryepglottic folds (aryepiglottic and oblique arytenoid muscles)
      - approximation of the walls of the vestibule by the thyroepiglottic muscles
      - apposition of the vocal cords by the interarytenoids and the lateral cricoarytenoid muscles
   iv. the epiglottis initially remains erect, effectively guiding the contents laterally into the piriform fossae, finally folding back over the laryngeal inlet only after the main food bolus has passed
4. there is reflex inhibition of respiration
5. cricopharyngeus relaxes, allowing the bolus to cross the pharyngo-oesophageal junction
   - fluid material tends to fall under the action of gravity
   - solid material is carried forward by peristalsis

THE LARYNX

Def'n: specialised organ which provides a ***protective sphincter*** at the inlet of the air passages and is responsible for the ***production of voice***;
continuous above with the laryngopharynx, and with the trachea below

Cartilages

1. ***thyroid cartilage***
   - 2 laminae of hyaline cartilage, meeting in a "V" anteriorly, extending posteriorly to form the ***superior*** and ***inferior cornu*** (horns)
   - the outer surface each laminae has an ***oblique line*** for attachment of the sternothyroid, thyrohyoid and inferior constrictor muscles
   - the inferior horn bears a circular facet on its inner surface for the cricoid cartilage
2. ***cricoid cartilage***
   - complete "signet" ring of hyaline cartilage lying below the thyroid c.
   - forms a narrow anterior ***arch*** and a thick posterior ***lamina***
   - 4 facets forming synovial joints
   i. 2 laterally with the thyroid cartilage
   ii. 2 postero-superiorly for the arytenoids
3. ***arytenoid cartilages***
   - paired, 3 sided pyramid-shaped cartilages, situated posteriorly
   - each has an ***apex*** above and a ***base*** below
   - each apex supports a ***corniculate cartilage***, the base articulates with the cricoid c.
   - two processes project from the base of each cartilage
   i. ***vocal processes*** - horizontally & forward, attaching to the vocal ligament
   ii. ***muscular process*** - laterally, attaching the posterior and lateral ***cricoarytenoid muscles***
4. ***corniculate cartilages***
   - paired small nodules which articulate with the apices of the arytenoids
   - give attachment to the ***aryepiglottic folds***
5. ***cuneiform cartilages***
   - paired, small rod-like cartilages, formed within the aryepiglottic folds
6. ***epiglottis***
   - leaf-shaped, elastic cartilage, situated behind the root of the tongue
   - attaches anteriorly to the hyoid bone, and posteriorly to the back of the thyroid c.
   - lateral borders attach to the arytenoid cartilages via the aryepiglottic folds
   - the upper border is free & the surface covered by mucous membrane
   - this is reflected anteriorly as the ***median glossoepiglottic fold*** and ***lateral glossoepiglottic folds***
   - the ***valleculae*** are depressions in the mucous membrane on either side of the glossoepiglottic fold

Membranes & Ligaments

NB: these may be functionally divided into ***extrinsic***, connecting the larynx to adjacent structures, and ***intrinsic***, linking the laryngeal cartilages

1. ***thyrohyoid membrane***
   - inferiorly attaches to the upper margin of the thyroid cartilage
   - superiorly, to the posterior & superior margin of the body and greater cornu of the hyoid bone
   - thickened in the midline to form the ***median thyrohyoid ligament*** and at the lateral margins to form the ***lateral thyrohyoid ligaments***, which connect the greater horn of the hyoid and the upper horn of the thyroid cartilages
   - bilaterally the membrane is pierced by the ***superior laryngeal vessels***, and the internal branch of the ***superior laryngeal nerve***
2. ***cricotracheal ligament***
   - connects the lower margin of the cricoid to the first tracheal ring
3. ***fibroelastic membrane***
   - lies beneath the mucous membrane of the larynx
   - the upper portion forms the ***quadrangular membrane*** (aryepiglottic fold)
     - extends between the epiglottis and the arytenoid cartilages
     - the lower margin is thickened, forming the ***vestibular ligaments***, which underlie the vestibular fold, or false vocal cord
   - the lower portion forms the ***cricovocal membrane*** (***conus elasticus*** - f.558)
     - the anterior aspect is thick, attaching below to the cricoid cartilage and in the midline to the thyroid cartilage above, the ***cricothyroid ligament***
     - the lateral aspect is thin, attaching below to the cricoid cartilage and extending superiorly on the medial surface of the thyroid cartilage
     - the free upper border forming the ***vocal ligament*** on each side
     - the anterior end of the vocal ligaments attaching to the thyroid cartilage
     - the posterior end attaching to the vocal processes of the arytenoid cartilages
4. ***hypoepiglottic ligament***
   - attaches the body of the epiglottis to the posterior aspect of the hyoid bone
5. ***thyroepiglottic ligament***
   - attaches the stem of the epiglottis to the thyroid cartilage

• the ***intrinsic ligaments*** comprise the capsules of the tiny synovial joints between the cricoid and arytenoid cartilages, and between the thyroid and cricoid cartilages
• 2 folds are seen in a bisected specimen, the ***vestibular*** and ***vocal folds*** (false & true cords), between which is the ***sinus*** of the larynx (f.557)
• from the anterior aspect of the sinus extends the ***saccule***, which ascends laterally as a pouch between the vestibular fold and the inner surface of the thyroid cartilage
• the ***fibroelastic membrane*** above is effectively divided into upper and lower portions by the sinus, and contributes to both the intrinsic and extrinsic ligaments

Laryngeal Inlet

- faces backwards and upwards into the laryngeal portion of the pharynx, bounded,
    a. anteriorly by the epiglottis
    b. laterally by the aryepiglottic folds
    c. posteriorly and below by the mucous membrane joining the arytenoid cartilages

Laryngeal Cavity

- extends from the inlet to the lower border of the cricoid cartilage, comprising 3 parts,
    1. ***vestibule*** - upper part
        - extends from the inlet to the vestibular folds
        - two thick folds of mucous membrane covering the vestibular ligaments
        - ***anterior wall*** formed by the posterior aspect of the epiglottis
        - ***posterior wall*** formed by the arytenoids and interarytenoid fold, the later containing the transverse arytenoid muscle
        - ***lateral walls*** formed by the aryepiglottic folds, containing the aryepiglottic muscles
        - inferiorly, the vestibular folds project medially, bounding the ***rima vestibuli***, and contain the vestibular ligament
    2. ***middle part***
        - from the vestibular folds to the vocal folds, containing the ***vocal ligaments***
        - each being the thickened upper portion of the ***cricothyroid ligament***
        - the ***rima glottidis*** is bounded in front by the vocal folds and behind by the vocal processes of the arytenoid cartilages
        - between the vestibular and vocal fold, on each side, is the ***sinus of the larynx***
        - from this the ***saccule of the larynx*** passes upward between the vestibular fold and the thyroid cartilage
    3. ***lower part***
        - extends from the vocal folds to the lower border of the cricoid cartilage
        - walls are formed by the inner surface of the cricothyroid ligament and cricoid c.

- the ***mucous membrane of the larynx*** is lined by ciliated columnar epithelium, except over the vocal folds, where it is stratified squamous
- there are abundant mucous glands, especially in the saccules, which effectively lubricate the vocal folds

Muscles of the Larynx

NB: these may be functionally divided into 2 groups,

- ***Extrinsic Muscles***

a. ***sternothyroid***
- attaches from the posterior aspect of the manubrium to the oblique line on the lateral surface of the thyroid cartilage
- supplied by the *ansa hypoglossi* and depresses the larynx

b. ***thyrohyoid muscle***
- passes upwards from the oblique line of the thyroid lamina to the inferior border of the greater horn of the hyoid and elevates the larynx
- supplied by fibres from C_1 conveyed in the hypoglossal nerve

c. ***the inferior constrictor***
- arises from the oblique line of the thyroid lamina, from a tendinous arch over the cricothyroid muscle and from the side of the pharynx
- the muscle acts solely as a constrictor of the pharynx (see previously)

d. there are in addition, two opposing groups of ***indirectly*** acting muscles,

i. ***elevators*** of the larynx
- digastric
- stylohyoid
- mylohyoid
- geniohyoid
+ stylopharyngeus, salpingopharyngeus, palatopharyngeus

ii. ***depressors*** of the larynx
- sternohyoid
- omohyoid

- ***Intrinsic Muscles***

NB: these have a 3 functions

i. opening the cords during inspiration
ii. closing the cords & laryngeal inlet during deglutition
iii. altering the tension of the vocal cords during speech

NB: controlled by two groups,

i. those controlling the ***laryngeal inlet***
- oblique arytenoid
- aryepiglottis

ii. those controlling the ***vocal cords***

Muscles Controlling the Vocal Cords				
Group	Origin	Insertion	Action	Innervation
cricothyroid[1]	cricoid, side	thyroid c., inf. cornu & lamina	tensor	***external laryngeal***
thyroarytenoid[2]	thyroid c., inner surface of angle	anterolateral surface, vocal & muscular processes + ***vocalis m.*** with ligament	relaxor	recurrent laryngeal
lateral cricoarytenoid	cricoid arch, upper border	muscular process of arytenoid cartilages	adductor	recurrent laryngeal
transverse arytenoid	arytenoid, back & medial surface	same on opposite cartilage	adductor	recurrent laryngeal
posterior cricoarytenoid	cricoid, back of lamina	muscular process of arytenoid cartilages	abductor	recurrent laryngeal

[1] this is the only intrinsic muscle of the larynx which lies ***outside*** of the cartilaginous framework

[2] some fibres of this muscle continue in the aryepiglottic fold as the ***thyroepiglottic muscle***, which assists in the sphincter mechanism of the laryngeal inlet;
muscle fibres from the deep aspect continue to be inserted into the vocal fold, as the ***vocalis muscle***

- ***Functional Groups***

1. ***abductors*** of the cords — posterior cricoarytenoids
2. ***adductors*** of the cords — lateral cricoarytenoids; interarytenoids
3. sphincters of the vestibule — aryepiglottics + oblique arytenoids; thyroepiglottics
4. regulators of cord tension — cricothyroid (tensors); thyroarytenoids (relaxors); vocales (fine adjustment)

Sphincteric Function of the Larynx

- there are 2 sphincters of the larynx,

1. at the ***laryngeal inlet***
   - used only during swallowing
   - the larynx is pulled forward and up under the tongue (extrinsic muscles)
   - inlet is narrowed by the ***oblique arytenoids*** and ***aryepiglottic muscles***
   - epiglottis folds back over the inlet, guiding food into the oesophagus
2. at the ***rima glottidis***
   - acts during coughing or sneezing

   i. cricothyroid → ↑ cord tension

   ii. transverse arytenoid & lateral cricoarytenoid muscles → adduction

- ***Movement With Respiration***

a. quiet respiration - rima glottidis is triangular, in neutral position

b. forced inspiration - diamond shaped due to lateral rotation of the arytenoids

Nerve Supply

NB: nerve supply to the larynx is by the ***vagus nerve***,
via its ***superior*** and ***recurrent laryngeal branches***

a. **sensory**
   i. ***internal laryngeal nerve***
      - branch of the superior laryngeal branch of the vagus nerve
      - mucous membranes of the larynx ***above*** the vocal folds
   ii. ***recurrent laryngeal nerve***
      - mucous membranes of the larynx ***below*** the vocal folds

b. **motor**
   i. ***recurrent laryngeal nerve***
      - intrinsic muscles of the larynx, except for the ***cricothyroid m.***
   ii. ***external laryngeal nerve***
      - branch of the superior laryngeal branch of the vagus nerve
      - supplies the ***cricothyroid m.***

▪ *Nerve Supply To The Larynx*

• the ***superior laryngeal nerve*** passes deep to both the internal and external carotid arteries, where it divides into,

1. a small external branch, which supplies the cricothyroid muscle
2. a larger internal branch, which pierces the thyrohyoid membrane

• runs beneath the mucosa of the ***pyriform fossae*** and may be blocked by topical local anaesthetics

• the ***recurrent laryngeal nerve,***

a. on the ***right*** → leaves the vagus as it crosses the right subclavian artery,
loops under the artery and ascends to the larynx, in a groove between the oesophagus and trachea

b. on the ***left*** → originates from the vagus as it crosses the aortic arch,
passing under the arch and entering to neck with the same relations as on the right side

Laryngeal Nerve Injury

• the ***external branch*** of the ***superior laryngeal nerve*** descends over the inferior constrictor, immediately deep to the superior thyroidal artery and veins, as these pass to the superior pole of the thyroid
• as this nerve supplies the ***cricothyroid muscle***, the sole tensor of the cords, injury results in hoarseness
• this is usually compensated for in time by increased activity of the other side

• the ***recurrent laryngeal nerve***, as it ascends in the tracheo-oesophageal groove, is covered by the lateral lobe of the thyroid, and is in close relationship with the inferior thyroid artery as this passes medially and behind the common carotid artery to the gland
• the artery may cross posterior or anterior to the nerve, or the nerve may pass between the terminal branches of the vessel
• on the right there is equal chance of any of these locations, on the left, the nerve is more likely to be posterior to the artery
• recurrent laryngeal nerve injury may therefore result from,

i. dissection at thyroidectomy
ii. involvement by malignancy
iii. involvement by benign enlargement of the thyroid (less often)
iv. enlarged lymph nodes, benign < malignant
v. cervical trauma

• the left recurrent laryngeal, due to its intrathoracic course, may also be injured by,

i. malignant tumours of the lung or oesophagus
ii. malignant or inflamed lymph nodes
iii. aortic aneurysm
iv. mitral stenosis - enlarged LA pushing the PA upwards against the aorta
v. ligation of a PDA - nerve lies immediately deep / distal to the ductus

• therefore, the left is injured ~ 2x as often as the right
• however, ~ 25% remain ***idiopathic***, presumably due to peripheral neuritis
• damage results in paralysis of the cord, which lies near the midline, at a slightly lower level
• unilateral lesions result in hoarseness, which is compensated for by overadduction of the contralateral cord
• bilateral paralysis may result in valve-like obstruction, worse during inspiration
• other causes of respiratory obstruction following thyroidectomy include,

i. direct trauma to the thyroid cartilages (tracheomalacia)
ii. haemorrhage deep to the investing fascia

Blood Supply

1. ***superior laryngeal artery***
   - branch of the superior thyroidal artery, the 1st branch of the external carotid
   - accompanies the internal branch of the superior laryngeal nerve, through the thyrohyoid membrane, to supply the upper half of the larynx
2. ***inferior laryngeal artery***
   - branch of the inferior thyroidal artery, from the thyrocervical trunk, which arises from the first part of the subclavian artery
   - accompanies the recurrent laryngeal nerve to supply the lower half of the larynx
3. the corresponding veins drain into the ***superior*** and ***inferior thyroidal veins***
4. ***lymphatic drainage*** is divided into upper and lower groups by the vocal cords,
   i. the supraglottic area drains to the upper deep cervical lymph nodes
   ii. the subglottic area drains to the lower deep cervical lymph nodes
   iii. the anterior, lower larynx also drains to the prelaryngeal & pretracheal nodes

NB: thus, the blood supply comes from the ***superior*** and ***inferior laryngeal vessels***, which are derived from the superior and inferior ***thyroidal vessels***, and which accompany the superior and inferior (recurrent) laryngeal nerves.

THE TRACHEA

• extends from the lower end of the larynx, at the level of $\mathbf{C_6}$, to its termination at the bronchial bifurcation and the ***carina***,

a.	on erect CXR	~ T_5 - quiet respiration ~ $\mathbf{T_6}$ - full inspiration
b.	cadaver specimens	~ T_4, or the manubriosternal junction
c.	length	~ 15 cm total ~ 5 cm above the suprasternal notch
d.	diameter varies with subject size	~ same diameter as index finger

• patency is maintained by 16-20 C-shaped cartilages, joined vertically by fibroelastic tissue, and closed posteriorly by unstriped ***trachealis muscle***

▪ ***Relations - Neck***

• lies exactly in the midline with its cervical course, but is deviated slightly to the right within the thorax by the arch of the aorta
• covered anteriorly by the skin and superficial and deep fascia
• the 2nd-4th rings are covered by the isthmus of the thyroid, along the superior border of which branches of the superior thyroid artery join from each side
• in the lower part of the neck there is some overlap by,

i. the sternohyoid and sternothyroid muscles
ii. the inferior thyroid veins as they course toward the innominate vein
iii. cross communication between the anterior jugular veins
iv. when present, the *thyroidea ima artery,* from the aorta or innominate artery

NB: the close relation to the innominate artery may result in profuse haemorrhage with erosion though the tracheal wall

• laterally the lobes of the thyroid intervene between the trachea and the carotid sheath
• posteriorly the trachea rests on the oesophagus, with the recurrent laryngeal nerves lying in the groove between the two
• due to the close proximity of the trachea and oesophagus, and the unsupported posterior tracheal wall, overinflation of a tracheal tube cuff may present as an obstruction within the oesophagus

Relations - Thorax

- ***anterior*** relations, from above downwards,
    i. the inferior thyroid veins
    ii. origins of the sternothyroid muscles from the back of the manubrium
    iii. the remains of the thymus
    iv. the innominate and left common carotid arteries
        - these separate the trachea from the left innominate vein
    v. the arch of the aorta

- ***posteriorly*** the trachea is in close apposition to the oesophagus, with the left recurrent laryngeal nerve lying between the two
- to the ***right*** is the mediastinal pleura, except where it is separated by the ***azygous vein*** and the right *vagus nerve*
- on the ***left***, the left common carotid and subclavian arteries, the aortic arch and the left vagus nerve lie between it and the mediastinal pleura
- large tracheobronchial lymph nodes lie each side of the trachea, and between the main bronchi

Blood Supply / Innervation

- the blood supply to the trachea is from the ***inferior thyroid vessels***
- lymphatic drainage is to the deep cervical, pretracheal, and paratracheal lymph nodes
- innervation is from the recurrent laryngeal branches of the vagus nerves
- sympathetic supply is from the middle cervical ganglion

Variations In Infants

i. the innominate artery is higher and crosses the trachea just as it descends behind the suprasternal notch
ii. the left innominate vein may project upwards into the neck to form an anterior relation to the cervical trachea
iii. in children ≤ 2 years the thymus is large, and lies in front of the lower part of the cervical trachea

- ***Tracheostomy***

    i. position the patient with the neck extended and maintain a straight line between the chin and suprasternal notch
    ii. cosmetically a small transverse incision is preferred, however, in an emergency an inexperienced operator may use a midline incision
    iii. providing incision and dissection are kept to the midline, the major vessels of the neck will be avoided
    iv. the thyroid isthmus may be able to be pushed superiorly, if not it may be divided and ligated
    v. the trachea is incised through the 2nd-3rd or the 3rd-4th rings, and a small opening made by removing small sections from the anterior wall
    vi. the largest tracheostomy tube which will fit comfortably should be used

MAIN BRONCHI

- ***Right Main Bronchus***

• compared with the left main bronchus, the right is,

    i. shorter - upper lobe bronchus origin is at ~ 2.5 cm
    ii. wider - as it supplies the larger lung, and
    iii. more vertically placed (25° vs. 45°), as the left has to pass laterally behind the aorta

• the right PA is first below, then in front of the RMB
• the azygous vein arches over the RMB

- ***Left Main Bronchus***

• ~ 5 cm long, passes,

    i. under the aortic arch
    ii. in front of the oesophagus, thoracic duct, and descending aorta

• the left PA is first above, then in front of the LMB

THE PLEURA

• during development, each lung invaginates the *coelomic* cavity to form a double-walled visceral, serous lined sac, which is the pleura
• this consists of a,

i. ***visceral layer***, which invests the lung itself, and
ii. ***parietal layer***, which lines the diaphragm, chest wall, the apex of the thoracic cavity and the mediastinum

• the two layers are continuous at the point of invagination, the ***hilum***, where the pleura hangs as a fold, the ***pulmonary ligament***
• the ***pleural cavity*** is a potential space, containing a thin film of serous fluid

▪ *The Pleural Reflections*

a. pleural apex ~ 4 cm above the midpoint of the clavicle
b. anterior midline ~ 2nd costal cartilage, retrosternally
c. the left pleura deflects laterally to the sternal edge at ~ 4th costal cartilage
   • this corresponds to the cardiac notch of the underlying lung
   • it then descends to the 6th costal cartilage
d. the right pleural edge continues vertically downward to just below the right costoxyphoid angle, then reflects laterally
e. the lower margin ~ 8th rib in the midclavicular line
   ~ 10th rib in the midaxillary line (lowermost level)
   ~ 12th thoracic vertebra posteriorly
f. parietal pleura does not extend to the attachment of the diaphragm and chest wall
g. the lung during quiet respiration does not fill the lowermost extremity of the pleural sac, leaving the slit-like ***costodiaphragmatic recess***

THE MEDIASTINUM

• this is the region between the two pleural sacs
• can be divided, for the purposes of description, into 4 compartments,

1. middle mediastinum - space occupied by the pericardium & its contents
2. anterior mediastinum - between this and the sternum
3. posterior mediastinum - behind the pericardium above & the diaphragm below
4. superior mediastinum - between the pericardium and the thoracic inlet

THE LUNGS

• each is roughly conical, with an apex, base, lateral (costal) and a medial surface, and with three borders, anterior, posterior and inferior
• each lies freely within the pleural cavity, apart from its attachment at the hilum
• the right is larger ~ 620 g cf. the left ~ 570 g
• the ***apex*** of each lung extends above the midpoint of the clavicle ~ 4 cm
• because of the obliquity of the thoracic inlet, the apex does not rise posteriorly above the neck of the 1st rib
• the apex is grooved by the subclavian artery, from which it is separated by the cervical pleura and Sibson's fascia
• the concave ***base*** rests against the dome of the diaphragm, thus, the larger right lung is more squat than the left
• the ***costal surface*** approximates the rib cage & this results in indentations in fixed specimens

• the ***hilum*** is the most prominent feature of the medial surface, which also bears impressions of the vertebral column posteriorly, and the major structures of the mediastinum anteriorly
• immediately below and anterior to the hilum the lung is deeply concave, forming the cardiac impression

a. left lung
- left atrium and ventricle
- the arch and descending thoracic aorta
- the left subclavian and common carotid arteries
- the left innominate vein
- the trachea and oesophagus
- the left branch of the vagus and the thoracic duct

b. right lung
- right atrium and part of the right ventricle
- superior and inferior vena cavae
- the azygous vein (as this arches over the hilum)
- the right margin of the oesophagus
- the right branches of the vagus and phrenic nerves

• the anterior borders of the lungs are thin and insituate themselves between the pericardium and the chest wall
• on the left this border bears the prominent ***cardiac notch***, which leaves an area of right ventricle which is in contact with the pericardium and chest wall

Surface Anatomy

• the surface projections are slightly less than those of the pleura and vary with respiration
• the apex closely follows the cervical pleura, as does the anterior border on the right
• the anterior border on the left is distinct due to the cardiac notch, passing behind the 5 th and 6th costal cartilages
• the lower lung border has an excursion of ~ 5-8 cm with extremes of respiration, however in neutral position approximates

i. 6th rib - in the midclavicular line
ii. 8th rib - in the midaxillary line
iii. 10th rib - adjacent to the vertebral column posteriorly

Lobes Of The Lung

• each lung is divided by an ***oblique fissure***, the right being further divided by a ***transverse fissure***
• the right oblique fissure leaves the vertebral column posteriorly at ~ the 5 th rib, and approximately follows, slightly lower, this landmark anteriorly to end at the costochondral junction in the 5 th interspace or at the 6th rib
• the left oblique fissure has a more variable origin, ~ 3rd-6th rib posteriorly, but then follows a course similar to that of the right

NB: with the arms held above the head, the vertebral border of the scapulae approximate the oblique fissures

• the ***transverse fissure*** is approximated by a horizontal line from the 4th right costal cartilage, reaching the oblique fissure in the midaxillary line, at the level of the 5th rib or interspace

• these are highly variable, notable exceptions being,

i. the transverse fissure may be absent (~ 10%), or incomplete (~ 50%)
ii. the right apex may be cleft by the azygous vein and its 'mesentery' of pleura
iii. the upper limit of the lingula may be indented to such an extent that there appears to be a left middle lobe

Relations of the Root Of The Lung

- the root or hilum of the lung transmits the following vessels,
    i. the pulmonary artery and two pulmonary veins
    ii. the main bronchus
    iii. the bronchial vessels, lymphatics, lymph nodes and nerves

- the relationship of these structures is governed by the following points,
    i. the bronchi lie in a plane behind the heart and roots of the great vessels
        - therefore the bronchi will lie ***behind*** the pulmonary vessels
    ii. the pulmonary arteries lie along the upper border of the atria,
    the pulmonary veins drain, 2 per side, into the atria
        - therefore the pulmonary arteries lie ***above*** the pulmonary veins
    iii. the bronchial vessels hug the posterior surface of the bronchi, and maintain this position in the hilum
    iv. the above structures are "sandwiched" between the anterior and posterior nerve plexuses
    v. on the right there is one additional structure, the right upper lobe bronchus, which lies above but still posterior to the pulmonary vessels

- the relations of the hilar themselves are,
    a. left
        - in front, the phrenic nerve
        - behind the descending aorta and the vagus nerve
        - above the aortic arch
        - below the pulmonary ligament
    b. right
        - in front, the phrenic nerve and the superior vena cava
        - behind the vagus nerve
        - above the azygous vein
        - below the pulmonary ligament

The Bronchopulmonary Segments

- functionally the lungs are divided into a series of bronchopulmonary segments
- each bronchus has its own blood supply from the PA, and its parenchyma is distinct from adjacent segments
- the arrangement of segments varies, but the principal distinction between the two sides is,

1. the ***lingular*** branches arise from the ***upper lobe bronchus*** on the left
2. the ***middle lobe*** branches arise from the lower part of the ***main bronchus*** on the right

Right Lung

1. RMB gives of the ***upper lobe bronchus*** at ~ 2.5 cm, which then trifurcates at ~ 1 cm,
   - i. *apical* (1) - passing up and laterally
   - ii. *posterior* (2) - passing up, back and laterally
   - iii. *anterior* (3) - forwards, laterally & slightly down
2. RMB continues as primary bronchus[1] for ~ 3 cm, the ***middle lobe bronchus*** branching forward and downwards, being ~ 1.5 cm and bifurcating into the division,
   - i. *lateral* (4)
   - ii. *medial* (5)
3. opposite & just below the middle lobe bronchus arises the bronchus to the *apical segment of the lower lobe* (6)
4. the *medial basal (cardiac) bronchus* (7) originates ~ 1.5 cm below, from the medial side of the lower part of the main stem bronchus, immediately following are the other basal bronchi,
   - i. *anterior basal* (8) - down, forward and laterally
   - ii. *lateral basal* (9) - down and laterally
   - iii. *posterior basal* (10) - down and back as a continuation

Left Lung

1. LMB continues for ~ 5 cm before branching off the *left upper lobe bronchus*, which after ~ 1 cm bifurcates into,
   - the *superior division*, which then trifurcates,
     - i. apical (1)
     - ii. posterior (2)
     - iii. anterior (3)
   - the *inferior division*, which supplies the ***lingula***, bifurcates after 1-2 cm,
     - i. superior (4)
     - ii. inferior (5)
   - this superior / inferior division is quite characteristically different from the right middle lobe division into medial / lateral

[1] this segment of bronchus has not been definitively named & is referred to as "lower part of the RMB", this is the portion crossed by the right PA, and hence the old name of *hyparterial bronchus*

2. the bronchi of the left lower lobe resemble the right, except that there is no medial basal (cardiac) branch (7)

i.	*apical*	(6)	- posterior and up
ii.	*anterior basal*	(8)	- down, forward and laterally
iii.	*lateral basal*	(9)	- down and laterally
iv.	*posterior basal*	(10)	- down and back as a continuation

Lung and Bronchial Structure

- the basic arrangement of the bronchial wall comprises,
    i. mucosa
    ii. basement membrane
    iii. submucous layer of elastic tissue
    iv. bronchial smooth muscle
    v. outer fibrous coat containing cartilage

- the lining epithelium of the trachea and larger bronchi is in several layers,
    i. basal layer, resting on a well defined basal membrane
    ii. intermediate zone of spindle shaped cells
    iii. superficial sheet of ciliated columnar cells, with interspersed mucous secreting goblet cells

- in chronic inflammatory states, the epithelium becomes stratified squamous without cilia
- these changes may also follow prolonged intubation
- in the more terminal bronchi, the cells become cuboidal, with fewer goblet cells
- the alveoli are lined by thin epithelial cells (***type I***) with basement membrane, which together with the capillary endothelium and BM comprise the 4 layers of the alveolar-capillary membrane
- alveoli also contain ***type II*** cells responsible for the secretion of ***surfactant***

Main Airway Branches & Zones	
trachea & main bronchi lobar bronchi segmental bronchi bronchioles terminal bronchioles	***conducting zone*** generations 1-16
respiratory bronchioles alveolar ducts atria alveolar sacs	***respiratory zone*** + primary lobule / or acinus generations 17-23

Pulmonary Blood Supply

1. pulmonary artery → gas exchange
2. bronchial arteries → nutrient supply - lung & bronchi
   - lymph nodes and visceral pleura

• venous drainage from the larger bronchi is via the bronchial veins
• drainage from the smaller bronchi, with the alveolar capillaries, is via the pulmonary veins
• therefore, although there is no communication between the pulmonary and bronchial arteries, a significant fraction of the bronchial supply is drained via the pulmonary system
• together with the Thesbian veins of the heart contributes to the ***physiological shunt*** (~ 1-2%)

• the ***pulmonary artery*** and its subdivisions closely follow the bronchial tree to the alveoli
• unlike the arteries, the ***pulmonary vein*** tributaries lie between lung segments, joining the artery at the ***apex*** of that bronchopulmonary segment and then continuing to the hilum
• there are 2 main pulmonary veins on each side which drain to the left atrium,

i. left - upper and lower lobe veins
ii. right - upper + middle, and lower lobe veins

• the ***bronchial arteries*** are variable in number and origin, usually 3 in total,

i. left - usually 2 vessels arising from the descending aorta
ii. right - usually 1, but of variable origin, including
   • the aorta, internal mammary, or right subclavian artery
   • 1st or 3rd intercostal (first aortic intercostal) arteries

• rarely all three arteries arise from a common trunk from the aorta
• they lie against the ***posterior*** walls of their respective bronchi, following the tree as far as the ***terminal bronchi***, ceasing with the appearance of alveoli in the bronchiolar walls
• the ***bronchial veins,*** usually 2 on each side, drain respectively to,

i. left → superior hemiazygous or left superior intercostal vein
ii. right → the azygous vein

• these drain blood from only the first 2-3 bifurcations of the bronchial tree
• this may be increased by acute pulmonary infections, bronchiectasis, or other pathology

• both arteries and veins pierce the muscle coat to supply the mucosa, therefore in conditions of mucosal swelling venous obstruction may occur, further accentuating the mucosal swelling
• a superficial lymphatic plexus drains the visceral pleura
• a deep plexus, alongside the pulmonary vessels drains the bronchi, but does not reach beyond the alveolar ducts
• both drain to the bronchopulmonary lymph nodes, at the bifurcations of the larger bronchi
• these, in turn, drain into the right and left ***bronchomediastinal trunks***
• the right may drain to the right lymphatic duct & the left to the thoracic duct, however, they frequently drain directly into the junction of the internal jugular & subclavian veins on each side

Innervation

• sympathetic (T_2-T_4) and parasympathetic (vagal) fibres form the ***posterior pulmonary plexus*** at the root of the lung
• fibres from here travel with the bronchial bifurcations,

a.	mucous glands	- parasympathetic secretomotor
b.	bronchial smooth muscle	- parasympathetic bronchoconstrictor - sympathetic bronchodilator
c.	bronchial vessels	- sympathetic vasomotor
d.	pulmonary vessels	* minimal neural control
e.	afferent specialised sensory	- vagus to the medullary centres

Embryology

• median ventral diverticulum forms from the foregut, the ***tracheobronchial groove***
• gradually deepens and separates from the primitive oesophagus, while caudal prolongation and division forms the two main bronchi
• further proliferations results in the ***lung bud*** on each side

Element	Appearance	Maturation
bronchi	16 / 52	~ 23 / 52
alveoli	17 / 52	post-partum
surfactant	24 / 52*	~ 36 / 52

NB: different composition unstable until 36/52
→ L/S ratio increases to 2:1 at term

THE PERICARDIUM

• the heart and roots of the great vessels are enclosed in the conical fibrous pericardium
• the apex is fused with the adventitia of the great vessels at the ***angle of Louis***, or the manubriosternal junction
• the anterior surface is attached by loose fibrous tissue, the ***sternopericardial ligament***
• inferiorly, the base blends with the central tendon of the diaphragm
• therefore, the position of the heart is dependent upon the position of the diaphragm, hence,

i. alters with the phase of respiration
ii. alters with position - supine versus erect
iii. is affected by changes in intra-abdominal contents
  • pregnancy
  • obesity
  • ascites

▪ ***Pericardial Relations***

a. anteriorly - the 3rd-6th costal cartilages on either side
  - thin anterior borders of both lungs
b. laterally - the mediastinal pleura and phrenic nerves
c. posteriorly - the oesophagus, descending aorta, and bronchi
  - vertebral bodies of T_5-T_8

• within the fibrous pericardial sac lies the ***serous pericardium***, which like other similar structures, is produced by invagination of the heart into a foetal serous sac, forming a double membrane,

i. the visceral layer, ***epicardium***, is closely adherent to the heart
ii. the parietal layer lines the fibrous pericardium

NB: the pericardium therefore has 3 layers

• the parietal layer is reflected around the great vessels to be continuous with the visceral layer
• these lines of reflection are on the posterior aspect of the heart (f.132, 145),

1. ***transverse sinus***, running horizontally between
  • the SVC and left atrium posteriorly
  • the pulmonary trunk and aorta anteriorly
2. ***oblique sinus***
  • bordered by the 2 right and 2 left pulmonary veins
  • reinforced below & on the right by the IVC
  • this forms a recess between the pericardium and left atrium

• the arrangement of these sinuses is due to the S-shaped kinking of the primitive foetal tubular heart

THE HEART

• is irregularly conical in shape and lies obliquely in the middle mediastinum
• its borders are formed as follows,

a.	right border	- formed entirely by the right atrium
b.	left border	- predominantly the left ventricle - auricular appendage of the left atrium
c.	inferior border	- predominantly the right ventricle - lower part of the right atrium, receiving the IVC - apex of the left ventricle - separated by the posterior ***interventricular groove***
d.	anterior surface	- predominantly the right ventricle - separated from the RA by the vertical ***atrioventricular groove*** - separated from the LV by the anterior ***interventricular groove***
e.	posterior surface	- or *base* - quadrilateral in shape - predominantly the LA and pulmonary veins - lesser extent from the right atrium

Chambers of the Heart

▪ ***Right Atrium***

• receives the SVC in its supero-posterior aspect, the IVC and the coronary sinus in its inferior aspect, and the cardiac vein (draining most of the front of the heart, RV), anteriorly (f.136,137)
• running ~ vertically between the venae cavae is a ridge, the ***crista terminalis***, with a corresponding groove on the outer aspect, the ***sulcus terminalis***
• this separates the smooth-walled posterior part of the RA, derived from the sinus venosus, from the rough-walled anterior portion which is prolonged into the ***auricular appendage***, derived from the foetal atrium
• the openings of the IVC and coronary sinus are covered by rudimentary valves
• that of the IVC is continuous with the annulus ovalis around the ***fossa ovalis***, which marks the site of the foetal foramen ovale

Right Ventricle

• communicates with the RA via the vertically placed ***tricuspid valve***, and with the pulmonary trunk through the ***pulmonary valve***
• the tricuspid valve admits ~ 3 fingers, and has 3 cusps (middle, anterior and inferior)
• these are triangular in shape and are attached by their base to the fibrous tricuspid annulus
• the pulmonary valve also has three cusps (posterior, right and left anterior)
• the muscular ***infundibulo-ventricular crest*** (supraventricular crest) separates the "inflow" and "outflow" (conus arteriosus) tracts of the ventricle
• the inner aspect of the inflow tract has a number of irregular muscular elevations, the ***trabeculae carneae***, from some of which project the ***papillary muscles***, attaching to the valve leaflets via the ***cordae tendineae***
• the ***moderator band*** (septomarginal trabecula) crosses the ventricular cavity from the septum to the free anterior wall, and conveys with it the right branch of the ***atrioventricular bundle***
• the outflow tract, or ***infundibulum***, is smooth walled and is directed upwards and to the right, towards the pulmonary valve

Left Atrium

• slightly smaller than the RA, but has thicker walls (f.141,142)
• the openings of the 4 pulmonary veins are present on the upper part of the posterior wall
• on the septal wall is the small depression of the fossa ovalis
• as for the RA, the majority of the cavity is smooth walled, but the surface of the auricle is marked by a number of ridges due to the underlying ***pectinate muscles***

Left Ventricle

• communicates with the LA via the ***mitral valve***
• this admits ~ 2 fingers, has a large anterior cusp and a smaller posterior cusp, which are attached to papillary muscles via chodae tendineae
• with the exception of the fibrous vestibule immediately below the ***aortic orifice***, the wall is marked by thick ***trabeculae carneae***
• the aortic valve has three semilunar cusps (anterior, left and right posterior), immediately above which are the dilated ***aortic sinuses***, from which come the origins of the coronary arteries

i. RCA - anterior sinus
ii. LCA - left posterior sinus

Conducting System

• specialised cardiac muscle is found in the ***sinoatrial node***, ***atrioventricular node*** and ***atrioventricular bundle*** of His (f.143,144),

1. SA node - situated in the upper part of the crista terminalis
   - just to the right of the opening of the SVC into the RA
2. AV node - atrial septum, immediately above the opening of the coronary sinus
3. AV bundle - divides at the junction of the muscular and membranous parts of the interventricular septum
   - branches run subendocardially

Blood Supply

▪ *Right Coronary Artery*

- originates from the ***anterior*** aortic sinus (f.132,133)
- runs forward between the PA and right atrial appendage, in the right atrioventricular groove
- branches include the,

a. anterior cardiac artery
b. acute marginal branch - inferior border of the heart (RV)
c. posterior interventricular artery, or PDA
d. branch to the SA node

- anastomoses with,

a. the circumflex artery - in the AV groove
b. the LAD via the PDA branch - in the interventricular septum

- dominant in 85-90% of patients, ie. it supplies the,

a. posterior septum
b. posterior wall of the LV
c. AV node

▪ *Left Coronary Artery*

- arises from the left ***posterior*** aortic sinus and is larger than the right
- passes first behind, then left of the PA, between this and the LA appendage in the AV groove
- runs for ~ 2 cm then branches into,

a. ***left anterior descending*** artery
   - passes down the anterior interventricular groove
   - supplies the LV, anterior septum, & some RV
   - also branches to form the,
   i. septal perforators
   ii. diagonal branches - variable number
   - supply the LV apex

b. ***left circumflex*** artery
   - passes around the left AV groove
   - anastomoses with a branch of the RCA
   - does not reach the PDA in > 80%
   - branches to form the ***obtuse marginal*** - supplies the posterior LV wall

- ***Venous Drainage***

• ~ 2/3 is via veins accompanying the coronary arteries and draining into the RA
• the remainder drains directly into the cardiac cavity by small veins, ***venae cordis minimae***
• the ***coronary sinus*** lies in the posterior AV groove and opens into the RA just to the left of the IVC, and receives,

1. the ***great cardiac vein*** - from the anterior interventricular groove
2. the ***middle cardiac vein*** - from the inferior interventricular groove
3. the ***small cardiac vein*** - accompanies the marginal artery
4. the ***oblique vein*** - descending from the LA

• the ***anterior cardiac vein*** enters the anterior AV groove and drains much of the anterior surface of the heart, opening directly into the RA

Nerve Supply

a. parasympathetic - cardioinhibitory fibres from the vagus
b. sympathetic - cervical and upper thoracic ganglia
- superficial and deep cardiac plexuses

Surface Markings

NB: the outline can be represented as an irregular quadrangle, bounded by,

1. the 2nd left costal cartilage ~ 1.25 cm from the sternal edge
2. the 3rd right costal cartilage ~ 1.25 cm from the sternal edge
3. the 6th right costal cartilage ~ 1.25 cm from the sternal edge
4. the 6th left intercostal space ~ 9 cm from the midline
- corresponding to the apex beat

• the left border (1-4) is formed almost entirely by the LV
• the lower border (3-4) by the RV and the apical part of the LV
• the right border (2-3) by the RA

- ***Radiographic Features***

a. transverse cardiac diameter < ½ thoracic width
   - inside ribs, PA, erect, inspiratory CXR
   - ~ 1.5 cm change in width with respiration

b. right mediastinal shadow
   i. right innominate vein
   ii. SVC ± azygous vein
   iii. right PA
   iv. RA

c. left mediastinal shadow
   i. aortic knuckle
   ii. angle between PA and aorta
   iii. pulmonary trunk & left PA
   iv. auricle of LA
   v. LV

VERTEBRAL COLUMN

Def'n: the central pillar of the body, serving to protect the spinal cord, and support the weight of the head and trunk, which it transmits to the hip joints and lower limbs;
composed of irregular bones, ***vertebrae***, separated by fibrocartilagenous ***intervertebral discs***, which comprise ~ ¼ of the total length;
the ***33 vertebrae*** being grouped as follows,

i.	cervical	7	
ii.	thoracic	12	
iii.	lumbar	5	
iv.	sacral	5	* fused to form the sacrum
v.	coccygeal	4	* lower 3 usually fused

- there are 4 curves, which have a significant influence on the spread of local anaesthetics,
  1. the ***cervical*** and ***lumbar*** - convex anteriorly
  2. the ***thoracic*** and ***sacral*** - convex posteriorly

- supine the high-points are at $\mathbf{C_5}$ and $\mathbf{L_5}$, while the low-points are at $\mathbf{T_5}$ and $\mathbf{S_2}$

Vertebral Characteristics - *General*

- despite regional differences, there is a common structure,
  1. vertebral ***body*** - rounded anterior
  2. vertebral ***arch*** - posterior, enclosing the vertebral foramen
     - formed from 2 ***pedicles*** laterally & 2 ***laminae*** posteriorly
     - the pedicles are notched, forming the ***superior*** and ***inferior vertebral notches***
     - superior & inferior notches of adjacent vertebrae form the ***intervertebral foramina***, which transmit the spinal nerves and blood vessels
     - the arch gives rise to 7 processes,
       - i. ***spinous process*** (1) - junction of the 2 laminae
       - ii. ***transverse processes*** (2) - junction of the pedicles & laminae laterally
       - iii. ***articular processes*** (4) - vertically arranged, 2 superior / 2 inferior
         - arise from the junction of the pedicles & laminae
         - covered with hyaline cartilage
         - form synovial joints with the adjacent vertebrae
     - these serve as levers for the attachment of muscles
  3. vertebral ***foramen*** - containing the spinal cord

Cervical Vertebrae

- the transverse processes,
    a. possess a ***foramen transversarium***, through which the vertebral vessels run (only through C_1-C_6)
    b. are gutter-shaped, with anterior and posterior ***tubercles***

- the spines are small and bifid
- the bodies are small and wide, cf. the anterior-posterior diameter
- the vertebral foramen is large and triangular
- the superior articular facets face upward and backward, are small and flat
- the inferior articular facets face downward and anteriorly
- the anterior tubercle of $\mathbf{C_6}$ is large, the carotid tubercle of ***Chassaignac***
- the anterior primary rami(us) of,
    a. $\mathbf{C_3}$-$\mathbf{C_7}$ - issue anterior to the articular facets
        - pass ***behind*** the vertebral artery
    b. $\mathbf{C_1}$-$\mathbf{C_2}$ - emerge behind their corresponding articular facets
    c. $\mathbf{C_1}$ - passes forwards and medial to the artery

- there are 8 cervical nerves, C_1-C_7 emerging ***above*** their corresponding vertebrae, C_8 above T_1
- the remaining spinal nerves emerge ***below*** their corresponding vertebrae
- cervical vertebrae 1, 2 and 7 are atypical,

1. $\mathbf{C_1}$ **Atlas:**
    - has no body and no spinous process, only a small posterior tubercle
    - simply a ring of bone, consisting of ***anterior*** and ***posterior arches***
    - each lateral mass has articular facets,
    i. ***atlanto-occipital joints*** - above with the occipital condyles
    ii. ***atlanto-axial joints*** - below with the axis (C_2)
    - the upper surface of the posterior arch bears a deep groove, immediately behind the articular facet, in which lies the vertebral artery and posterior primary ramus of the ***suboccipital nerve*** (C_1) below
2. $\mathbf{C_2}$ **Axis:**
    - has a peg-like ***odontoid process***, which surmounts the body, and lies against the articular facet of the anterior arch of the atlas
    - the transverse process is small, there is no differentiation into tubercles
    - the laminae are thick and the spine is large and bifid
3. $\mathbf{C_7}$ **Vertebra prominens:**
    - has the longest spinous process, which is not bifid
    - the transverse processes are large but the foramen tranversarium are small
    - these transmit the vertebral veins, and only rarely the artery

▪ ***Thoracic Vertebrae***

• increase in size from above downward
• the body is heart-shaped, and those of T_5-T_8 are flattened on their left side due to pressure from the descending aorta
• the intervertebral foramina are small and round
• the spines are long and inclined downward
• ***costal demifacets*** are present on the sides of adjacent bodies, where the heads of the ribs articulate
• articular facets are also present on the transverse processes for the ***tubercles*** of the ribs
• T_{11} & T_{12} have no transverse process facets
• the superior articular facets face postero-laterally, while the inferior facets face antero-medially
• except for the inferior facets of T_{12} which face laterally, as do those of the lumbar vertebrae

• atypical features of the thoracic vertebrae include,

1. **T_1** - has a cervical vertebral type body, and a horizontal spine
   - a marked upper notch, and a complete upper facet for the first rib
2. **T_9** - usually typical, but often fails to articulate with the 10^{th} rib head
3. **T_{10}** - articulates only with the 10^{th} rib & has only a superior demifacet
   - may have a complete facet if T_9 fails to articulate with R_{10}
4. **T_{11}** - articulates only with its own rib head, via a superior circular facet
   - the transverse process is small and facet-free
5. **T_{12}** - has a lumbar shaped body, with a complete facet below its upper border
   - the transverse process is small and without a facet
   - the inferior articular facets face outwards cf. lumbar vertebrae
   - the spinous process is horizontal

▪ ***Lumbar Vertebrae***

• the bodies are large and kidney shaped
• the pedicles are strong and project posteriorly, with shallow superior notches
• the laminae are also thick but do not overlap as in the thoracic region, and form triangular ***interlaminar foramina***
• the spinous process is short, flat and quadrangular, and projects directly backwards
• the transverse processes are slender and increase in size from L_1-L_3, decreasing thereafter
• each bears an ***accessory process*** on the postero-inferior aspect of its base, and a ***mammillary process*** adjacent to the superior articular process
• the superior articular facets face medially, while the inferior facets face laterally
• **L_5** is wedge shaped, thus producing the lumbosacral angle, and its transverse processes arise from the body in addition to the arch

Sacrum

• consists of five rudimentary vertebrae fused to form a triangular shaped bone, concave anteriorly
• the superior border, or ***base***, articulates with L_5, the inferior border with the coccyx
• the base has large lateral masses, or ***ala***, which articulate with the two innominate, or hip bones, forming the ***sacroiliac joints***
• the anterior margin of S_1 projects forward as the ***sacral promontory***, forming the posterior margin of the inlet to the pelvis

• the posterior surface is made of the fused vertebral arches, which form the roof of the sacral canal, resulting in the ***median crest***
• the vertebral foramina are present and together form the ***sacral canal***, which is roughly triangular due to relatively short pedicles and long laminae
• this contains part of the cauda equina, filum terminale and meninges at far as the bottom of S_2
• below S_2 the lower sacral and coccygeal nerve roots, the filum terminale and fibro-fatty tissue
• either side of the crest are fused laminae, each with a lateral articular crest, terminating below as the ***sacral cornu***
• the laminar arch of the 5th and occasionally the 4th vertebrae fail to join in the midline, forming the ***sacral hiatus***
• this is roofed by the ***sacrococcygeal ligament***, which is ~ 1-3 mm thick
• the anterior and posterior surfaces of the sacrum have 4 foramina on each side for passage of the anterior & posterior rami of the upper four sacral nerves
• these lie in an almost vertical line ~ 2 cm apart, the triangular shape being due to a reduction in the lateral masses
• the easiest to locate is S_2, which lies ~ 1 cm medial to the PSIS, or the sacral dimple

Coccyx

• consists of 4 vertebrae fused together, forming a small triangular bone, which articulates at its base with the lower border of the sacrum
• the 1st coccygeal vertebrae is commonly not fused, or incompletely so, with the 2nd

Sex Differences

i. the female sacrum is shorter and wider than the male
ii. its anterior surface is flattened above, then curve abruptly forward
iii. the body of S_1 is narrower in the female ~ 1/3 the base width, cf. the male where the body ~ ½

Joints of the Vertebral Column

• with the exception of C_1 / C_2, the remainder of mobile vertebrae articulate with each other by means of

i. fibrocartilagenous joints (discs) between their bodies
ii. synovial joints between their articular processes

▪ ***Intervertebral Discs***

• responsible for ~ 25% of the length of the spine
• thickest in the cervical & lumbar regions, where movement of the spine is greatest and the nerve roots are thickest
• they are of uniform depth in the thoracic region, where curvature is a function of the shape of the vertebral bodies
• in the cervical and lumbar regions, the discs are wedge-shaped & contribute to spinal curvature
• consist of a peripheral part, the ***annulus fibrosis***, and a central portion, the ***nucleosis pulposis***
• the later representing the remnant of the embryonal notochord
• the surfaces of adjacent vertebral bodies are covered with thin plates of ***hyaline cartilage***
• the annulus is composed of laminae of collagen fibres in a fibrocartilage base
• the nucleosis is a semifluid, gelatinous structure, with minimal collagen
• its water content decreases with age, as does the elasticity of the annulus
• no discs are found between C_1 / C_2, or in the sacrum or coccyx

▪ ***Cartilaginous Joints - Vertebral Bodies***

• the bodies of adjacent vertebrae are lined with hyaline cartilage, between which lies the intervertebral discs of fibrocartilage
• the collagen fibres of the disc strongly unites adjacent bodies
• in the lower cervical region, small ***synovial joints*** are present at the sides of the intervertebral disc, between the adjacent vertebral bodies
• the ***anterior*** and ***posterior longitudinal ligaments*** run as continuous bands from skull to sacrum
• the anterior is thick, wide & firmly attached from C_2 to the upper sacrum, while the posterior is narrow & weaker

■ *Synovial Joints - Vertebral Arches*

• superior and inferior articular processes of adjacent vertebrae, forming 4 joints per vertebra
• the articular facets are covered with hyaline cartilage & the joints surrounded by ***capsular ligament***, further supported by the following ligaments,

a. ***supraspinous ligament*** - attaches the tips of the vertebral spines C_7 to sacrum

b. ***interspinous ligament***

c. ***ligamentum flavae***
   - or "yellow ligament", connects adjacent laminae, running from the anterior margin of the lamina above to the posterior margin of the lamina below
   - laterally it begins at the root of the articular processes, passing posteromedially to the junction of the laminae at the base of the spinous process

• in the cervical region the supraspinous and interspinous ligaments are thickened to form the ***ligamentum nuchae***, which extends from the spine of C_7 to the occipital protuberance

■ *Atlanto-Occipital Joints*

• formed between the ***occipital condyles***, at each side of the foramen magnum above, with facets on the superior surface of the ***lateral masses*** of the atlas below
• the ***anterior atlanto-occipital membrane***, a continuation of the anterior longitudinal ligament, connects the anterior arch of the atlas to the anterior margin of the foramen magnum
• the ***posterior atlanto-occipital membrane***, similar to the ligamentum flavum, connects the posterior arch of the atlas to the posterior margin of the foramen magnum
• the predominant movement at this joint is flexion / extension

Atlanto-Axial Joints

• these are 3 in number,

i. the odontoid process of the axis with the anterior arch of the atlas, and
ii. 2 joints between the lateral masses of each vertebrae

• these are supported by the following ligaments,

a. ***apical ligament*** - apex of odontoid to the anterior margin of the foramen magnum

b. ***alar ligaments*** - one each side of the apical ligament
- connect the odontoid to the medial sides of the occipital condyles
- prevent excessive rotation of the skull

c. ***accessory alar ligaments***
- from the body of the axis to the lateral masses of the atlas

d. ***cruciate ligament***
- consists of a strong transverse part and a weak vertical part
- the ***transverse*** part connects the inner aspects of the lateral masses of the atlas, and binds the odontoid process forward on the anterior arch of the atlas
- the ***vertical*** part runs from the posterior surface of the body of the axis, to the anterior margin of the foramen magnum

e. ***membrana tectoria***
- is an upward continuation of the posterior longitudinal ligament
- attaches above to the occipital bone, just within the foramen magnum
- covers the posterior surface of the odontoid, the apical, alar & cruciate ligaments

f. ***posterior atlanto-occipital membrane***
- equivalent to the ligamentum flavum, connects the arch of the atlas to the occiput
- pierced by the vertebral artery and the dorsal ramus of C_1

Sacro-Coccygeal Joints

• a thin fibrocartilagenous disc lies between adjacent aspects of L_5-S_1
• linking their cornua is the ***posterior sacrococcygeal ligament***, which spreads out as a membrane covering the sacral hiatus, closing the sacral canal
• the ***anterior sacrococcygeal ligament*** is small and weak
• the ***lateral sacrococcygeal ligaments*** connect the inferior lateral angle of the sacrum to the transverse process of the coccyx
• this forms a roof over the 5^{th} sacral nerve as it emerges between the cornua of the sacrum and coccyx

Vertebral Anomalies

▪ *Embryology*

• mesodermal somites condense around the primitive notochord and neural tube
• each vertebral body originates from ½ of each of 2 adjacent somites fusing together
• the vertebrae are therefore formed ***intersegmentally***
• 1° ossification centres develop 1 each side of the vertebral arch, and 1 within the body
• rarely the later may comprise 2 centres which fail to unite
• defects in the vertebral bodies include,

i. additional vertebrae or hemivertebrae (with congenital scoliosis)
ii. anterior spina bifida - especially cervical and lumbar
iii. absence of vertebrae or of the lower sacrum
iv. fusion of 2^+ vertebrae - especially sacralisation of L_5
v. sacral separation - lumbarisation of S_1

▪ *Spina Bifida*

• results from failure of fusion of the 2 arch centres,

i. spina bifida occulta
- most common variant ~ 6-11% (L_5-S_2)
- failure of arch fusion only
- not associated with neurological abnormality

ii. meningocele
- protrusion of the meninges through vertebral defect
- no neural tissue involvement

iii. myelomeningocele
- neural tissue protrudes into the meningeal sac
- either the cord or nerve roots may be adherent

iv. myelocele
- failure of fusion of the neural tube, ***rachischisis***
- open spinal plate weeping CSF
- incompatible with survival

NB: (i) may also be seen as cranial extension of the sacral hiatus, ~ 45% extend to S_2

▪ *Spondylolisthesis*

• defect in the neural arch of L_5 enables the whole of the spinal column, together with the body, pedicles and superior articular facet to slip forward on S_1
• the laminae, spine and inferior articular facets remain attached to S_1
• the pedicles & upper articular processes separate with L_5
• rarely this may affect L_4

SPINAL CORD & MENINGES

Meninges

Dura Mater

• a dense, strong fibrous membrane which encloses the spinal cord and cauda equina
• fibres are arranged longitudinally and are continuous above, through the foramen magnum, with the ***meningeal layer*** of dura covering the brain
• the ***cranial dura*** consists of an outer ***endosteal layer***, which terminates at the foramen magnum, and an inner meningeal layer, which folds inward to form the ***falx cerebri***
• these two layers are closely united, except for where they part to form the great ***venous sinuses***
• the ***spinal dura*** ends at the **lower** border of $\mathbf{S_2}$, where it is pierced by the ***filum terminale***
• the dural sheath lies loosely in the vertebral canal, separated from the walls by the ***extradural space***, containing loose areolar tissue and the internal vertebral venous plexus of Batson
• anteriorly it has loose attachments to the posterior longitudinal ligament, posteriorly it is free
• it provides a thin extension along each nerve root, becoming continuous with the ***epineurium*** at the level of the dorsal root ganglion
• the inner surface is in contact with the ***arachnoid mater***

Arachnoid Mater

• a delicate impermeable neurovascular membrane, closely adherent to the dura, separated from the pia internally by the ***subarachnoid space***, filled with ***cerebrospinal fluid***
• there is a potential space between the dura and arachnoid, the ***subdural space***, which contains a minute quantity of serous fluid
• this space does ***not*** communicate directly with the CSF, but extends laterally over the nerve roots & ganglia, and is wider in the cervical region and is more accessible than elsewhere
• local solutions entering this space are said to ascend atypically, but only very slowly into the cranium, with which this space is ***continuous***
• the SAS is traversed by a number of fine strands of connective tissue
• continuous above with the arachnoid covering the brain
• inferiorly it ends on the filum terminale, at the **lower** border of $\mathbf{S_2}$
• continues along the spinal nerves as far as the ***dorsal root ganglia***, forming small lateral extensions of the SAS
• the arachnoid pushes small "granulations" through the dura, which may either indent upon epidural veins or contact epidural lymphatics
• the arachnoid is metabolically active and is capable of forming giant vacuoles, which may temporarily communicate with the subdural space or, the epidural space in the dural cuff region

Pia Mater

• a delicate, highly vascular membrane which is closely invests the spinal cord & brain
• thickened laterally between the nerve roots to form the ***ligamentum denticulatum***, which travels laterally to adhere to the arachnoid and dura, effectively suspending the cord centrally
• a large number of web-like trabeculae run between the pia and arachnoid
• it extends along each spinal nerve, becoming continuous with the connective tissue surrounding each spinal nerve

Subarachnoid Space

- bounded externally by the arachnoid & internally by the pia mater
- contains numerous ***arachnoid trabeculae*** and the ***ligamentum denticulatum***
- there are 3 divisions which are in free communication,
    i. cranial
    ii. spinal
    iii. nerve root

- the SAS extends separately along both dorsal & ventral spinal roots, each carrying all 3 layers of meninges to the level of the dorsal root ganglia
- from the ganglia, the arachnoid and pia continue as the ***perineural epithelium***
- the arachnoid of the nerve roots contains proliferations of cells, or ***arachnoid villi***

▪ ***Cerebrospinal Fluid***

- formed by secretion in the choroid arterial plexuses of the lateral third & fourth ventricles
- these are highly vascular invaginations of pia, covered by a single layer of ependymal epithelium
    i. rate ~ 0.3-0.4 ml/minute
    ~ 500 ml/day
    ii. inversely related to serum osmolality,
    ~ 1% increase in serum osmolality decreases formation ~ 6.7%
    iii. formation reduced by acetazolamide by up to 50%
    iv. frusemide may reduce formation in large doses
    v. steroids have an inconsistent effect

- CSF escapes from the 4th ventricle into the cerebral subarachnoid space respectively through,
    i. the median ***foramen of Magendie*** - cisterna cerebello-medularis
    ii. the lateral ***foramina of Lushka*** - cisterna pontis

    iii. about 80% is reabsorbed by the ***arachnoid villi***, which pierce the dura and lie immediately beneath the endothelium

- ***Composition (Cousins)***

i. clear, colourless ultrafiltrate of blood
ii. volume ~ 120-150 ml
- 25-35 ml in the spinal SAS
- majority is distal to the spinal cord in the cauda equina
iii. SG ~ 1.003-1.009
iv. protein ~ 23-28 mg/dl
- upper limit ranges from 9 to 58 mg/dl & laboratory dependent
v. pH ~ 7.32
vi. P_{CO2} ~ 48 mmHg
vii. HCO_3^- ~ 23 mmol/l
viii. cells ≤ lymphocytes/mm^3

CSF Composition[1]

Substance		CSF	Plasma	Ratio
Na^+	mmol/l	147	150	0.98
Mg^{++}	mmol/l	1.1	0.8	1.39
Ca^{++}	mmol/l	1.15	2.35	0.49
Cl^-	mmol/l	113	99	1.14
HCO_3^-	mmol/l	25.1	24.8	1.01
P_{CO2}	mmHg	50.2	39.5	1.28
pH		7.33	7.4	
Osmolality	mosm/kg	289	289	1
Protein	mg/dl	20	6,000	0
Glucose	mg/dl	64	100	0.64
Phosphate	mg/dl	3.4	4.7	0.73

[1] Ganong, 13th Edition

Epidural Space

- ***Boundaries***

a. superior - foramen magnum

b. inferior - sacral hiatus and sacrococcygeal membrane

c. lateral - periosteum of the pedicles of the vertebra, and
- intervertebral foramina & areolar tissue

d. anterior - posterior longitudinal ligament
- vertebral bodies and intervertebral discs

e. posterior - periosteum of the anterior surfaces of the laminae
- the articular processes and their connecting ligaments
- the roots of the vertebral spines
- the interlamina spaces filled with ligamentum flava

- ***Spread Of Injected Solutions***

a. superior and inferior between ligamentum flava and dura

b. superiorly to the ***foramen magnum***
- low MW drugs may cross into the cerebral CSF

c. inferiorly to the ***sacral hiatus***, caudal canal & through the anterior sacral foramina

d. laterally through the intervertebral foramina to the ***paravertebral space***
- rapid access to the CSF at the "dural cuff" region & then the spinal cord CSF
- produces paravertebral spinal nerve root blockade
- density of areolar tissue & "tightness" of foramina vary
  → decreasing leak and dosage requirements with advancing age

e. anteriorly, in the thin space between the posterior longitudinal ligament & the dura

Surface Anatomy	
C_7	• vertebra prominens
T_3	• root of spine of scapula
T_7	• inferior angle of scapula
L_1	• rib margin 10 cm from midline
L_4	• superior margin of iliac crests
S_2	• posterior superior iliac spines

Relations of Epidural Space	
Epidural space	• widest in midlumbar region ~ 5-6 mm • narrower at articular processes → dura & ligamentum flavum almost touch • widens laterally where spinal nerve surrounded by dural cuff • communicates with paravertebral space through foramina • catheter may stimulate nerve with unisegmental paraesthesia
Spinal nerve	• encountered with needle insertion past lamina on same side • encountered on opposite side with needle insertion across midline, through ligamentum flavum toward foramina
Spinal arteries	• only 1 anterior artery • thoracolumbar region fed principally by ***radicularis magna*** • usually enters on the left at T_{11-12} (**T_8-L_3**) • supply to anterior cord in discontinuous with other levels • sharp demarcation between anterior & posterior artery territory

Anatomical Features - Cervico Thoracic Epidural	
Spinous process	• at C_7 (vertebra prominens) virtually horizontal • inferior border C_7 adjacent widest point of C_7-T_1 space
Lamina	• shaped like a narrow rectangle
Interlaminar space	• accessible with midline puncture in neck flexion
Ligamentum flavum	• thinner than in any other region
Epidural space	• at T_1 ~ 3-4 mm • at C_{3-6} ~ 2 mm • increased width with neck flexion • usually marked negative pressure, increased if sitting

Anatomical Features - MidThoracic Epidural	
Spinous process	• small posterior surface & close together - difficult to identify • extreme caudal anglulation • paraspinous technique technically easier • inferior border opposite midpoint of ***lamina below***
Interspinous ligament	• spinous processes close together - difficult to identify
Lamina	• broader than lumbar laminae but shorter vertically • large area available for location of depth of ligamentum flavum • less chance of accidental dural puncture
Ligamentum flavum	• thick but less so than in the mid-lumbar region
Epidural space	• 3-5 mm depth in the midline • narrow laterally

Anatomical Features - Lumbar Epidural	
Spinous process	• widest in the midlumbar region • angled only slightly caudally • narrower superiorly $\rightarrow$ guide paraspinous needle to midline • inferior border opposite the widest point of interlaminar space • superior border opposite upsloping lamina
Interspinous ligament	• well defined above L_4 • below L_4 narrower and less dense $\rightarrow$ less resistance
Lamina	• posterior surface slopes down and back • needle may encounter lamina at superficial or deep plane
Interlaminar space	• increased by flexion of the spine • larger "target" midline & in the midlumbar region • smaller target laterally
Articular facets	• encountered if needle $\rightarrow$ laterally through interlaminar space • results in severe pain & muscle spasm
Ligamentum flavum	• thickest in the midline & in the midlumbar region • cadaver studies show a large % may retain a midline cleft • however, in life the highly elastic halves usually meet tightly • attaches to the anteroinferior aspect of lamina above • attaches to the posterosuperior aspect of lamina below • needle entering inferior margin may encounter lamina below

Segmental Levels		
Landmark	Segment	Clinical significance
little finger	C_8	• all cardioaccelerator fibres
inner aspect of arm & forearm	T_{1-2}	• some cardioaccelerator fibres • skin above the nipple has dual innervation from C_{3-4} • residual T_1 motor activity - interossei (C_8-T_1)
apex of axilla	T_3	
nipple line & midsternum	T_{4-5}	• possibility of cardioaccelerator blockade
xiphysternum	T_7	• splanchnic sympathetics (T_5-L_1)
umbilicus	T_{10}	• sympathetic blockade limited to lower limbs
inguinal ligament	T_{12}	
outer side of foot	S_1	• no lumbar sympathetic blockade • most difficult nerve root to block

Epidural Blockade: Applied Anatomy

- ***Vertebrae***

• the central alignment of the ***inferior aspect*** of the vertebral spine varies with segmental level,

i. lumbar → widest point of interlaminar space
ii. thoracic → opposite the lamina of the vertebra below
iii. cervical → inferior aspect of interlaminar space

- ***Laminae & Articular Processes***

• form the boundaries of the ***interlaminar foramen***
• in the lumbar spine the articular facets align in a near ***vertical*** plane, such that flexion results in enlargement of the interlaminar foramen, which becomes diamond shaped
• in the midthoracic spine the articular facets align in a near ***horizontal*** plane, such that flexion is minimal, allowing the vertebral bodies to rotate

Ligamentum Flavum

• should be entered in the centre of the interlaminar gap, irrespective of the initial approach (paraspinous or median)
• laterally the ligament blends with the joint capsule of the articular processes
• entry laterally increases the risk of puncture of both the dura and epidural veins
• entry at the inferior margin may encounter the superior margin of the inferior lamina
• developmentally the laminae at each level fuse to form the base of the spinous process, as do the two halves of the ligamentum flavum
• cadaver specimens suggest that a midline cleft may be retained in a high percentage of cases
• this would provide support for the paramedian approach, as identification of the depth of the lamina is an accurate guide to the depth of the ligament
• Cousins states however, that "in life it is likely that the elastic ligamenta flava come tightly together in the midline in cases when the two 'halves' remain potentially separated"

Pedicles

• notched superiorly and inferiorly such that adjacent pedicles form the ***intervertebral foramina***
• the epidural space is continuous with the paraspinous space & epidural anaesthesia can be produced by injection close to a foramen
• the degree of patency of the foramina (58 in total) influences the spread of local anaesthetic
• the density of the areolar tissue around the foramina varies considerably
• with advancing age forms a recognisable ***operculum*** which effectively obstructs the foramen
• this is thought to play a role in the decreasing dose requirements with age

Epidural Space

• reasons for inability to pass catheter after "successful" loss of resistance,

i. partial passage through the ligament with exit obstruction
ii. entry at the superior margin & lamina above & bony obstruction
iii. passage laterally & obstruction with a spinal nerve

• ***midline width*** varies with vertebral level,

i.	midlumbar	~ 5-6 mm - narrow adjacent to articular processes
ii.	midthoracic	~ 3-5 mm
iii.	low cervical	~ 1.5-2 mm ~ 4 mm below C_7 with neck flexion

• variable amount of adipose tissue, most abundant posteriorly
• there is a rich capillary supply & this tissue has a high affinity for lipid soluble local anaesthetics such as bupivacaine & etidocaine
• effectively determines resistance in the epidural space & the amount of "back-leakage" of local anaesthetics
• a fibreoptic study of 48 cadavers displayed a midline posterior connective tissue band, of varying thickness, in all cases (Blomberg, A&A, 1986)

■ ***Epidural Veins***

• most prominent in the ***lateral*** portion of the epidural space
• the internal venous plexus communicates,

a. superiorly → occipital, sigmoid and basilar venous sinuses of the cranium
b. inferiorly → sacral venous plexus to the uterine & iliac veins
c. segmentally → thoracic and abdominal veins

• therefore, pressure changes within these cavities are transmitted directly to the epidural space
• increased flow in the vertebral plexus is mainly accommodated by the ***azygous vein***, which runs in the right hemithorax, over the root of the right lung to enter the vena cava
• thus, small doses of LA injected rapidly into an epidural vein may pass directly into the vertebrobasilar system & a cerebral venous sinus
• this is most likely to occur in the presence of caval obstruction in the supine position (pregnancy)
• caval obstruction will also decrease the effective volume of the epidural space, reducing the required dose, and increase the capillary & venous area, increasing the rate of absorption

• Cousins suggests 3 safety measures given these effects,

1. the ligamentum flavum should be traversed in the ***midline***
2. needle insertion, catheter insertion and injection of local anaesthetics should be avoided during episode of marked increase in intra-abdominal / intrathoracic pressure
3. in the presence of vena caval obstruction there should be a reduction in dose, a decreased rate of injection and an increased care in testing for intravascular injection

• in the region of the dural cuffs, bulbs of arachnoid protrude through the dura into epidural space, where they frequently invaginate the walls of epidural veins
• the primary function of these granulations is to drain CSF, however, they also serve as a portal of transfer of local anaesthetic into the CSF

■ ***Spinal Arteries***

• enter intervertebral foramina and pierce dural cuffs to reach the spinal nerves
• territory supplied by the anterior artery is most vulnerable
• entry of ***radicularis magna*** usually on ***left***, at $\mathbf{T_5}$-$\mathbf{L_3}$

■ ***Lymphatic Drainage***

• rich network which rapidly conveys material through the vertebral foramina to lymph channels in front of the vertebral bodies

■ ***Epidural Pressure***

• principal cause in the ***lumbar region*** is due to ***tenting*** of the dura by the advancing needle
• this pressure increases as the needle is advanced across the epidural space toward the dura
• slow introduction of the needle produces the greatest pressure
• Eaton produced pressures of up to -14 cmH_2O by introducing a blunt stylet in the interspace above

• Bryce-Smith was able to demonstrate an increase in the negative pressure with ***deep inspiration***
• this varied from ~ 0 at rest to -2 to -8 cmH_2O, therefore is less than that produced by dural tenting, but may contribute with large intrathoracic changes

> ***NB:*** a number of investigators have been able to show an ***absence*** of negative epidural pressure in a significant percentage of patients on initial entry of the space

• Cousins & Bromage therefore suggest that a "loss of resistance" technique is superior to the "hanging-drop"
• further, if the later is used, pressure within the lumbar CSF should be minimised, ie. they should be in the lateral position & not pregnant

• in the ***thoracic region*** the major determinant is the transmission of the negative intrathoracic pressure, by way of the paravertebral and intervertebral spaces
• Usubaiga and others have reliably demonstrated negative pressure on initial entry, therefore the "hanging-drop" technique is reasonable for ***cervico-thoracic*** procedures

■ ***Hanging-Drop Precautions***

a. severe lung disease → negativity may be abolished, especially laterally
b. raised intra-abdominal pressure or caval obstruction, ie. pregnancy
   • this has minimal effects on thoracic pressures, especially sitting
c. coughing or valsalva manoeuvres

Spinal Cord

• a white structure beginning above the foramen magnum, in continuation with the ***medulla oblongata***, terminating in the,

i. neonate → **lower** border of $\mathbf{L_3}$
ii. child → **upper** border of $\mathbf{L_3}$
iii. adult → **lower** border of $\mathbf{L_1}$
~ 45 cm in length (cf. femur, vas, lips-cardia)

• it is roughly cylindrical in shape, and is flattened slightly antero-posteriorly
• there are fusiform ***cervical*** and ***lumbar enlargements***, where the brachial and lumbrosacral plexuses respectively arise
• inferiorly it tapers into the conical ***conus medullaris***, from the apex of which a projection of the pia mater, the ***filum terminale*** descends to attach to the back of the coccyx
• there is a deep ***anterior median fissure***, and a shallow ***posterior median sulcus***, from which a ***posterior median septum*** extends ~ ½ way into the cord
• at either side of the posterior sulcus lie the ***postero-lateral sulci***, along which the posterior nerve rootlets emerge
• the anterior rootlets emerge from a number of nerve tufts, not marked by a line of origin
• in transverse section the cord comprises,

i. a ***central canal***
   - continuation of the 4th ventricle as a narrow tube
   - lined with ciliated ependymal cells and containing CSF
   - traverses the entire cord, enlarging within the conus medullaris
   - continues within the filum terminale for a short distance

ii. a H-shaped zone of ***grey matter***
   - the bridging limb of the "H" being the ***transverse commissure***
   - short broad ***anterior column*** (horn), containing motor cells
   - thin, longer ***posterior column*** (horn), capped by the ***substantia gelatinosa***

iii. an outer zone of ***white matter***
   - longitudinally disposed myelinated nerve fibres
   - divided into posterior, lateral and anterior white columns
   - the 2 anterior white columns are connected by a thin anterior commissure

• the proportion of white matter progressively declines from cervical to lumbar regions
• the grey matter being greatly increased in the cervical and lumbar enlargements

- ***Descending Tracts***

a. lateral cerebrospinal, or pyramidal tract
   - also termed the crossed motor tract
   - lies in the posterior part of the lateral column, and is the principal motor tract
   - originates in the pyramidal cells of the motor cortex
   - crosses in the ***pyramidal decussation*** of the medulla
   - then descends in the contralateral pyramidal tract
   - fibres synapse directly on anterior horn cells of the cord

b. anterior cerebrospinal, or direct pyramidal tract
   - also termed the uncrossed motor tract
   - represents those pyramidal fibres which do not decussate (~ ¼ of total)
   - lies in the anterior column, immediately adjacent to the anterior median fissure
   - fibres cross in the anterior white commisure, in approximately the upper half of the cord & synapse on anterior horn cells in the *contralateral* grey matter

- ***Ascending Tracts***

a. posterior column
   i. the medial ***fasciculus gracilis***, of Goll, and
   ii. the lateral ***fasciculus cuneatus***, of Burdach
   - convey sensory fibres of fine touch and proprioception, predominantly ipsilateral
   - pass to the ***gracile & cuneate nuclei*** of the medulla
   - decussate in the medullary sensory decussation, then pass to the ***thalamus*** in the ***medial lemniscus***, and are then relayed to the sensory cortex
   - some medullary fibres pass to the cerebellum in the inferior cerebellar peduncle

b. spinothalamic tracts
   - pain, temperature, plus some tactile afferent fibres enter the posterior roots, ascend 1-2 segments then relay in the ***substantia gelatinosa***
   - they cross the cord to ascend in the contralateral tract to the thalamus,

   i. pain & temperature → ***lateral spinothalamic tract*** anterior to the pyramidal tract

   ii. touch → ***anterior spinothalamic tract*** immediately anterior to the anterior horn

c. anterior and posterior spinocerebellar tracts
   - lie on the outer margin of the lateral white column
   - these convey *ipsilateral* proprioceptive sensory fibres, which ascend to the cerebellum via the superior and inferior cerebellar peduncles respectively

■ ***Clinical Features***

• ***local anaesthetics*** injected epidurally are found in sufficient concentration in the cord to produce neural blockade
• recent evidence for the ready availability of epidural drugs to the cord has been demonstrated with epidural narcotics
• the peripheral part of the spinal cord in the ***dorsolateral funiculus*** contains fibres from,

i. descending excitatory sympathetic pathways
ii. descending pyramidal tracts
iii. medullary reticulospinal tracts

• the pyramidal tract fibres synapse in Rexed's laminae IV, V, and VI, which are involved in ***modulation*** of sensory input
• blockade of these fibres may result in expansion of segmental receptive fields and a relative "antianalgesic" state

• ***complete transection*** results in,

i. total sensory loss below the lesion
ii. initial flaccid muscle paralysis, followed by spasticity
iii. voluntary sphincter control is lost but reflex emptying returns, providing the centres in the sacral cord are intact

• ***hemisection***, or Brown-Séquard syndrome results in,

i. ipsilateral muscle paralysis then spasticity
ii. ipsilateral loss of proprioception and tactile discrimination
iii. contralateral loss of pain, temperature

• ***syringomyelia***, or cystic degeneration of the upper cord results in,

i. destruction of the sensory decussations of the spinothalamic tracts
ii. bilateral loss of pain and temperature sense in the upper limbs

• ***cordotomy***, for intractable pain, involves section of the contralateral lateral white column, ***anterior*** to the denticulate ligament, thus preserving the pyramidal tract which lies posterior to this structure
• relief is generally only temporary, presumably due to alternative pain pathways

Blood Supply

• the spinal cord receives blood supply from,

a. the arteries of the brain above (vertebral)

b. spinal branches of the subclavian, aorta and iliac arteries below (deep and ascending cervical, posterior intercostal, lumbar and lateral sacral arteries)

• the ***segmental arteries*** divide upon entering the intervertebral foramina, into anterior and posterior ***radicular arteries***, which then feed into the anterior & posterior spinal arteries
• the major purpose of these branches is to supply the ***spinal nerve roots***, and only a few make a significant contribution to the anterior spinal artery supply

■ ***Posterior Spinal Arteries***

• arise directly or indirectly (PICA) from the ***vertebral arteries***, dividing into 2 descending branches
• these run on either side of the cord, one in front of, and one behind the attachments of the posterior nerve rootlets, ie. there are ***4 in total***
• they are fed by 25 to 40 radicular arteries

■ ***Anterior Spinal Artery***

• a single midline artery, formed between the pyramids of the medulla oblongata by the union of a terminal part of each ***vertebral artery***, which descends in front of the anterior median fissure and the corresponding vein
• supplemented by a number of the ***radicular arteries***

■ ***Radicular Contributions***

• only ~ 6-7 of these make a significant contribution to the anterior artery, effectively dividing supply of the cord into three discrete large segments
• the largest of these vessels, the ***radicularis magna*** (artery of Adamkiewicz), supplies the cord in the area of the lumbar enlargement
• this enters the cord by way of a single intervertebral foramen (78% left) between $\mathbf{T_8}$-$\mathbf{L_3}$
• damage to this vessel may result in ischaemia of the cord in this region, due to the poor vertical anastomosis of the anterior artery, with resulting predominantly a motor deficit
• in a small number of cases (~15%) the artery takes off high (T_5) and the usually slender contributions from the iliac vessels enlarge & effectively supply the lower cord & conus
• ligation of the iliac tributaries at surgery, or damage during epidural anaesthesia may result in subsequent ischaemia
• in the thoracic region, small feeders enter between T_4-T_9 and flow is appears least at ~ T_4

■ ***Venous Drainage***

• the veins of the spinal cord drain into the ***internal vertebral venous plexus*** of Batson
• these are most prominent along the lateral walls of the spinal canal, in the epidural space
• they are valveless and communicate extensively with the intrathoracic and abdominal veins

SPINAL NERVES

- there are **31 pairs** of spinal nerves (cf. vertebrae = 33),
    - i. 8 cervical (7)
    - ii. 12 thoracic (12)
    - iii. 5 lumbar (5)
    - iv. 5 sacral (5)
    - v. 1 coccygeal (4)

- these attach along the length of the cord by,
    - i. the *motor* or ***anterior roots***, and
    - ii. the *sensory* or ***posterior roots***

- each root is attached to the cord by a series of ***rootlets***, which extend the whole length of the corresponding segment of the cord
- studies on the size of the dorsal roots show a considerable variation in size, with larger roots at $\mathbf{C_8}$ & $\mathbf{S_1}$ and a "valley" between these in the thoracic region
- in addition, studies of the proportion of myelinated / nonmyelinated fibres in the ventral roots, also reveal a peak in S_1 and the lower cervical roots, $C_{5\text{-}8}$
- both of these contribute to the relative resistance of the lower cervical region and S_1 to blockade
- each posterior root posses a ***posterior root ganglion***, in which cell bodies reside
- in addition the cord bears a 3rd, lateral set of rootlets, from the upper 4-6 cervical segments, which unite to form the spinal root of the ***accessory nerve***
- these ascend along the cord through the foramen magnum

- the spinal roots pass from the cord to their respective intervertebral foramina, where they unite to form the corresponding ***spinal nerve***
- each gives off a small ***meningeal branch***, which re-enters the intervertebral canal, supplying the adjacent blood vessels and ligaments
- on emerging from the foramina, these then divide into ***anterior*** and ***posterior rami***, which contain both motor and sensory fibres

a. <u>posterior primary ramus</u>
- pass backwards between the transverse processes
- divides into medial and lateral branches
- these supply the vertebral muscles and overlying skin

b. <u>anterior primary ramus</u>
- linked to the sympathetic chain by a ***white*** and a ***grey ramus communicans***
- then runs in the body wall, giving off the ***lateral cutaneous branch*** ~ ½ way
- this then divides into anterior and posterior divisions
- this format is only strict in the thoracic area, being modified in other regions by the formation of the major plexuses (see later)

■ ***Vertebral Relationships***

• due to the disproportionate growth of the cord and vertebral column, the length of the roots increases caudally, such that in the lumbar region they form a bundle of nerves around the filum terminale, collectively called the ***cauda equina***
• this region is especially sensitive to local anaesthesia, due to,

i. the greater surface area of nerves in this region, and
ii. as they are invested with only a thin layer of pia mater

Cord Segment	Vertebral Body
C_8	C_7
T_6	T_4
T_{12}	T_9
L_5	T_{12}
Sacral	L_1

• the posterior root ganglia lie in the intervertebral foramina, with the exception of,

1. C_1 and C_2 which lie on the posterior arches of their respective vertebrae
2. the sacral and coccygeal ganglia, which remain in the sacral canal

• C_1 emerges between the occiput and the posterior arch of the atlas, as the ***suboccipital nerve***
• C_2-C_7 similarly emerge ***above*** their respective vertebrae, C_8 passing between C_7-T_1
• below C_8 the nerves emerge ***below*** their respective vertebrae

Posterior Primary Rami

• these are concerned with the innervation of the paravertebral muscles and the skin
• C_1 & C_2 are exceptional, but the remainder generally follow,

1. posterior 1° rami supply motor and sensory fibres to serially segmented areas which slope down and outwards from the respective vertebral level,
   these segments overlap, such that segmental blockade *does not* produce corresponding sensory analgesia
2. unlike the anterior rami, they do not extend into either the upper or lower limbs, and do not form plexuses,
   with the exception of C_1 & C_2, the posterior rami are smaller
3. with the exception of C_1, S_4, S_5, and Co_1, each posterior ramus divides into a ***medial*** and ***lateral*** branch within the dorsal muscle mass, the cutaneous component is contained > T_6 in the medial branch, and below T_6 in the lateral branch
4. no cutaneous fibres are conveyed in C_1, C_{6-8}, and L_{4-5}

■ ***Cervical Posterior Primary Rami***

• **C_1** is larger than the anterior ramus, is entirely ***motor***, and does not divide into medial and lateral branches
• emerges over the posterior arch of the atlas, between bone and the vertebral artery, thus entering the suboccipital triangle to supply the 3 muscles,

i. superior oblique
ii. inferior oblique
iii. rectus capitus posterior major

• additional branches pass to rectus capitus posterior minor and semispinalis capitis

• **C_2** largest of the cervical posterior rami
• emerges between the posterior arch of the atlas and the lamina of the axis, then curves around the inferior border of inferior oblique (to which it sends a branch) and then divides into,

1. large medial branch - ***greater occipital nerve***
   - pierces semispinalis capitis then trapezius, and is joined by a branch from C_3
   - ascends with the occipital artery to supply the skin as far as the vertex
   - anteriorly it overlaps with the lesser occipital nerve, derived from the anterior ramus of C_2
   - gives a branch to semispinalis capitis
2. small lateral branch - entirely motor to suboccipital triangle

• the **C_3** medial branch constitutes the ***3rd occipital nerve***, supplying the skin over the lower occiput and a motor branch to the posterior cervical muscles

• **C_4-C_8** medial and lateral branches supply the posterior cervical muscles
• the medial branches of C_{4-5} also supply the overlying skin
• the trapezius receives small branches from C_{3-4}, in addition to its main motor innervation from the accessory nerve

■ ***Thoracic Posterior Primary Rami***

• all divide into medial and lateral branches, all of which supply the dorsal muscles
• the ***medial*** branches of T_{1-6} supply the skin immediately adjacent to the vertebral spines
• the ***lateral*** branches of T_{7-12} are cutaneous as well as motor
• the cutaneous branches descend for an increasing distance before supplying the skin, thus,

i. T_1 - area immediately adjacent to T_1 spine
ii. T_{10-11} - skin overlying the loin
iii. T_{12} - over the iliac crest, with twigs to the upper gluteal region

- ***Lumbar Posterior Primary Rami***

• all divide into medial and lateral branches, which supply the overlying lumbar muscles
• the lateral branches of L_{1-3}, in addition, reach the skin over the posterior superior iliac spine and supply the adjacent gluteal region

- ***Sacral & Coccygeal Posterior Primary Rami***

• S_{1-4} emerge through the posterior sacral foramina
• S_5 from the bifurcation of the main nerve trunk as it emerges through the cornua of the sacrum and coccyx
• all supply the ***sacrospinalis***, only S_{1-3} giving lateral branches to the overlying sacral skin
• Co_1 is small, undivided, and supplies the skin over the coccyx

The Anterior Primary Rami

• these supply sensory and motor innervation to,

1. the front and sides of the neck - ***cervical plexus***
2. the arm - ***brachial plexus***
3. the leg - ***lumbar & sacral plexuses***
4. the thorax and abdomen - ***segmentally arranged thoracic rami***

THE CERVICAL PLEXUS

• formed from the anterior rami of the upper four cervical roots, $\mathbf{C_{1-4}}$
• these connect via a number of loops (3) and innervate the muscles and skin of the neck and the diaphragm
• there is often an additional loop from C_{4-5}, thus joining this with the brachial plexus
• the loops lie on the ***scalenus medius***, and ***levator scapulae*** muscles, under the cover of ***sternomastoid***

• the $\mathbf{C_1}$ **ramus** is entirely motor
• emerging in the groove in the posterior arch of the atlas, immediately behind the superior articular facet, between the posterior arch and the vertebral artery
• then runs forward on the lateral mass, lying ***medial*** to vertebral artery as this emerges from the foramen transversarium
• branches to rectus capitus lateralis, rectus capitus anterior and longus capitus arise before the nerve descends to join the ascending branch of C_2, in front of the transverse process of the atlas
• the majority of fibres from this loop join the ***hypoglossal nerve*** at the level of the atlas
• through this link with cranial XII, C_1 supplies,

i. ***geniohyoid*** and ***thyrohyoid***
ii. the anterior belly of ***omohyoid*** via the ***descendens hypoglossi***

• this later nerve joins the ***descendens cervicalis***, derived from C_{2-3}, forming a long loop, the ***ansa cervicalis***, which lies on the carotid sheath
• from the ansa, fibres pass to supply,

i. ***sternohyoid*** and ***sternothyroid***
ii. the posterior belly of ***omohyoid***

• the $\mathbf{C_2}$ **ramus** emerges posterior to the superior articular process of the axis, then passes forwards on the ***lateral*** side of the vertebral artery
• divides into an ascending branch which joins C_1 and a descending branch which loops to join C_3

• the remaining cervical anterior primary rami emerge from their intervertebral foramina, anterior to the articular pillars and lateral to the vertebral artery
(ie. between the articular pillar and the foramen transversarium, then winding around the artery)
• each root receives a grey ramus communicans from the ***superior cervical ganglion***

Branches of the Cervical Plexus

1. communicating branches
   - i. the hypoglossal nerve XII
   - ii. the vagus nerve X
   - iii. the cervical sympathetic chain
2. superficial branches - cutaneous fibres to the neck
3. deep branches - motor supply to the neck muscles
4. phrenic nerve ($C_{3,4,5}$) - motor supply to the diaphragm
   - proprioception from the diaphragm

Superficial Cutaneous Branches

• these can be subdivided into,

1.	ascending	- lesser occipital nerve	**(C_2)**
		- great auricular nerve	**(C_{2-3})**
2.	transverse	- anterior cutaneous nerve of the neck	**(C_{2-3})**
3.	descending	- the supraclavicular nerves	**(C_{3-4})**

■ ***Lesser Occipital Nerve***

• hooks around the spinal accessory nerve (XI) then ascends along the posterior border of sternomastoid
• pierces the deep fascia in the upper part of the posterior triangle, dividing into 3 branches

1. auricular - upper 1/3 of the medial aspect of the external ear
2. mastoid - skin over the mastoid process
3. occipital - occipital area immediately above & behind the mastoid process

■ ***Great Auricular Nerve***

• is the largest cutaneous branch of the cervical plexus
• hooks around the midpoint of the posterior border of sternomastoid, then passes across it parallel to the angle of the mandible, dividing into,

1. *auricular* - lower 2/3 of the medial aspect of the external ear
2. *mastoid* - skin over the mastoid process
3. *facial* - skin over the masseter and parotid gland

- ***Anterior Cutaneous Nerve of the Neck***

• emerges closely below the great auricular nerve, at the posterior border of sternomastoid
• then passes forward on the muscle, usually deep to the external jugular vein, rarely superficial
• pierces the deep fascia at the anterior border of sternomastoid, dividing into branches supplying most of the anterior skin of the neck

- ***Supraclavicular Nerves***

• arise as a common stem from behind sternomastoid, immediately below the other cutaneous nerves of the plexus
• passes inferiorly, dividing into 3 branches → medial, intermediate, and lateral
• these pierce the deep fascia above the clavicle, crossing this bone to supply the skin over the upper sternum, chest wall as far as the 3rd rib, and the upper deltoid (overlap with T_{2-3})

- ***Deep Muscular Branches***

1. anterior vertebral muscles - recti capitis, longus capitus & longus cervicus
2. contribution to scalenus medius * main supply from the brachial plexus
3. levator scapulae (C_{3-4})
4. sternomastoid (C_{2-3}) and trapezius (C_{3-4}) * main from spinal accessory nerve

- ***Phrenic Nerve***

• the most important branch of the cervical plexus (C_{3-4-5})
• provides motor innervation to and receives proprioceptive input from the diaphragm
• additional filaments are supplied to the pericardium and pleura
• the principal component is from **C_4**, with contributions from **C_3 & C_5**
• these unite at the lateral border of ***scalenus anterior***, then running downwards and medially over the front of this muscle, covered by the ***prevertebral fascia***

• on scalenus anterior, the nerve is,

i. overlapped by the internal jugular vein and sternomastoid
ii. crossed by the inferior belly of omohyoid
iii. crossed by the transverse cervical and transverse scapular arteries
   - branches of the 1st part of the subclavian artery
iv. crossed by the thoracic ducts, on the left side

• the nerve then passes over the 1st part of the subclavian artery, behind the subclavian vein, entering the thorax
• crosses the internal mammary artery (posteriorly) from lateral to medial, where it is accompanied by pericardiophrenic branch of this vessel

■ ***Phrenic Nerve***

• within the thorax, the course differs from right to left,

a. right phrenic nerve
   - hugs the great venous pathway, approaching from behind
   - descending on the lateral sides of the right innominate vein, the SVC, the RA, and the intrathoracic part of the IVC
   - covered throughout laterally by the mediastinal pleura
   - pierces the central tendon of the diaphragm immediately lateral to the IVC, some fibres actually passing with the IVC

b. left phrenic nerve
   - has a longer, more oblique course
   - passes between the left subclavian and common carotid arteries
   - crosses the arch of the aorta, passing in front of the vagus nerve
   - descending anterior to the lung hilum on the pericardial covering of the LV
   - covered throughout laterally by the mediastinal pleura
   - pierces the diaphragm ~ 1 cm lateral to the attachment of the fibrous pericardium

• both sides then supply the muscle of the diaphragm on its ***abdominal surface***
• the contribution from C_5 may occasionally come as an ***accessory phrenic nerve***, either direct from the C_5 root across scalenus anterior or from the nerve to subclavius
• in the later, the nerve crosses anterior (rarely posterior) to the subclavian vein, joining the phrenic nerve behind the 1st costal cartilage

Cervical Plexus Blockade

■ ***Superficial Cervical Plexus Block***

• block at the midpoint of the posterior border of the sternomastoid
• 4 distinct nerves, just below the emergence of the accessory nerve,

i. lesser occipital nerve
ii. great auricular nerve
iii. anterior cutaneous nerve of the neck
iv. suprascapular nerves

• ***lignocaine 1.0% 5-10 ml*** → cutaneous anaesthesia,

i. superiorly the anterior and posterior of the ear, and the mandible
ii. medially to the midline, from the chin to the suprasternal notch
iii. inferiorly to the level of the 2nd rib
iv. laterally over the deltoid
v. posteriorly to the spine of the scapula

■ ***Deep Cervical Plexus Block***

• this is in effect a ***paravertebral block*** of C_{2-4}
• each nerve lies in a sulcus in the transverse process of its respective vertebra
• the traditional approach was to insert 3 needles, 1 at each level, given by the landmarks,

1. reference line from the ***mastoid process*** to ***Chassaignac's tubercle*** (C_6)
   • at the level of the cricoid cartilage
2. C_2 ~ 1 finger-breadth below the mastoid process
   C_{3-4} ~ same interval
   C_4 ~ intersection of horizontal from lower border of mandible (*Cousins*)
   or,
3. C_2 ~ 1 cm below the mastoid process
   C_4 ~ midway between the mastoid and clavicle
   C_3 ~ midway between the mastoid and C_4 (*Ellis & Feldman*)
4. needles are directed medially and ***caudally***,
   caudally to avoid unintentional entrance of the intervertebral foramina,
   the endpoint of insertion is the bony landmark & paraesthesia are sought
5. lignocaine 1.0% ~ 3-4 ml per level, or
   lignocaine 1.0% ~ 6-8 ml 1 level single injection

• single injection techniques are possible due to the free communication of the paravertebral space in the cervical region
• cervical plexus block can also be achieved by a single injection technique, as for interscalene brachial plexus blockade at the C_6 level, by using a head-down position and maintaining distal digital pressure during injection

■ ***Clinical Uses***

i. carotid endarterectomy
ii. removal of cervical lymph nodes
iii. thyroidectomy[§]
iv. tracheostomy[§]

NB: [§]stated by Cousins, but bilateral blockade relatively contraindicated ???

- ***Specific Complications***

a. intra-arterial injection
- due to proximity of vertebral artery
- convulsions, transient blindness, unconsciousness
- may occur with as little as 0.5 ml

b. phrenic nerve block
- invariably occurs to some degree
- relative contraindication to bilateral blockade
- C&B state similar ↓ ventilation to high spinal

c. epidural injection → bilateral effects

d. intrathecal injection → "high" spinal

e. Horner's syndrome
- sympathetic chain lies ***in front*** of prevertebral fascia
- large volume injections or incorrect injection
- may be associated with recurrent laryngeal involvement
- often associated with ***failed block***

i. ptosis

ii. miosis

iii. enophthalmos - paralysis of levator palpebrae superioris (via III)

iv. conjunctival & nasal mucosal injection
? increased lacrimation (MCQ)

v. anhidrosis & flushing of the face

BRACHIAL PLEXUS

- the nerves entering the upper limb provide the following functions,
    i. sensory innervation of the skin & deep structures
    ii. motor innervation of the muscles
    iii. sympathetic vasomotor control of blood vessels
    iv. sympathetic secretomotor supply to sweat glands

- the skin over the shoulder is supplied by descending branches of the cervical plexus, and that over the posteromedial aspect of the upper arm by the ***intercostobrachial branch*** of the 2nd intercostal nerve
- formed in the ***posterior triangle*** of the neck, by the union of the ***anterior rami*** of $\mathbf{C_5}$ - $\mathbf{T_1}$
- variations include,
    a. frequently receives a small contribution from C_4 and T_2
    b. ***prefixed plexus*** - derived from C_4-C_8
        - associated with the presence of a cervical rib
    c. ***postfixed plexus*** - derived from C_6-T_2
        - associated with an anomalous first rib

- for descriptive purposes only, the plexus may be divided into roots, trunks, divisions and cords
- the ***roots, trunks*** & ***divisions*** lie within the anteroinferior angle of the ***posterior triangle***
- the ***cords*** within the axilla

■ ***Roots***

- those from $C_{5\text{-}6\text{-}7}$ pass ***behind*** the foramen transversarium and the vertebral vessel, lying between the ***anterior*** and ***posterior tubercles*** of the corresponding transverse process
- all 5 roots enter the ***posterior triangle***, "sandwiched" between the fascia of the scalenus anterior and scalenus medius muscles
- these muscles divide the prevertebral layer of the deep cervical fascia , forming a virtual sheath
- at this level the roots lie above the 2nd part of the subclavian artery
- these form the ***trunks*** & the plexus proper, ***prior*** to emerging from the scalene muscles

- ***Trunks***

1. ***superior trunk*** = $C_5 + C_6$
2. ***middle trunk*** = C_7
3. ***inferior trunk*** = $C_8 + T_1$

• together with the subclavian artery, these invaginate the scalene fascia, forming the ***subclavian perivascular sheath***, which becomes the ***axillary sheath***
• they lie close together in a vertical line at the upper border of the 1st rib
• at this level, the plexus lies above & behind the 2nd & 3rd parts of the ***subclavian artery***
• Ellis states that the lower trunk may lie behind the artery, and may groove the rib immediately posterior to the subclavian groove
• anteromedial to the inferior trunk, and posteromedial to the artery lies the dome of the ***pleura***
• superficially they are covered only by skin, platysma, and deep fascia, however, they are crossed by the following structures,

1. inferior belly of omohyoid
2. external jugular vein
3. transverse cervical artery
4. supraclavicular nerves

- ***Divisions & Cords***

• at the lateral edge of the 1st rib, the trunks divide into ***anterior*** and ***posterior divisions***
• they lie behind the clavicle, the subclavius muscle and the suprascapular vessels
• they then pass inferior to the midpoint of the clavicle & enter the axilla through its apex
• these then reunite to form the cords, in relation to the axillary artery, as follows,

a. ***posterior cord*** ← posterior divisions of all 3 trunks
b. ***lateral cord*** ← anterior divisions of superior & middle trunks
c. ***medial cord*** ← anterior division of inferior trunk

• at first the medial cord lies behind the artery, with the posterior and lateral cords laterally
• they assume their descriptive relationships behind ***pectoralis minor***

NB: they divide forming the nerves of the upper arm,
at the lateral border of pectoralis minor

Branches From the Brachial Plexus

- ***Roots***

a.	***cervical sympathetic chain***	*branches ***from***
b.	***dorsal scapular nerve***	- C_5
c.	***long thoracic nerve***	- C_{5-6-7}
d.	direct branches	
i.	to ***longus cervicus***	- $C_{5-6-7-8}$
ii.	to the ***scalenes***	- $C_{5-6-7-8}$
iii.	contribution to the ***phrenic nerve***	- $\mathbf{C_5}$

- ***Superior Trunk***

a.	***suprascapular nerve***	- C_{5-6}
b.	***nerve to subclavius***	- C_{5-6}

- ***Lateral Cord***

a.	***lateral pectoral nerve***	- C_{5-6-7}
b.	***musculocutaneous nerve***	- C_{5-6-7}
c.	***lateral root of the median nerve***	- $C_{5-6-7-8}$, T_1

- ***Medial Cord***

a.	***medial pectoral nerve***	- C_8, T_1
b.	***medial cutaneous nerve of the arm***	- C_8, T_1
c.	***medial cutaneous nerve of the forearm***	- C_8, T_1
d.	***medial root of median nerve***	- $C_{5-6-7-8}$, T_1
e.	***ulnar nerve***	- C_{7-8}, T_1

- ***Posterior Cord***

a.	***upper & lower subscapular nerves***	- C_{5-6}
b.	***thoracodorsal nerve***	- C_{6-7-8}
c.	***axillary (circumflex) nerve***	- C_{5-6}
d.	***radial nerve***	- $C_{5-6-7-8}$, T_1

Distribution of the Brachial Plexus

Supraclavicular Branches

a. ***cervical sympathetic chain***
   - via grey rami communicantes
   - middle cervical ganglion - C_{5-6}
   - inferior cervical ganglion - C_{6-7}
   - T_1 ganglion - T_1

b. ***dorsal scapular nerve*** - C_5
   - or *nerve to rhomboids*
   - arises from the C_5 root & pierces the scalenus medius
   - crosses the deep aspect of levator scapulae, which it supplies, reaching the rhomboids

c. ***long thoracic nerve*** - C_{5-6-7}
   - or the *nerve to* ***serratus anterior****,* or *the nerve of Bell*
   - arises from the anterior rami of C_{5-6-7}, though the C_7 contribution is inconsistent
   - the C_{5-6} origins pierce scalenus medius, that from C_7 passing in front
   - enters the axilla over the lateral border of the 1st rib, lying behind the axillary vessels and brachial plexus
   - passes along the lateral border of serratus anterior, which it supplies

d. ***suprascapular nerve*** - C_{5-6}
   - arises from the superior trunk
   - passes with the suprascapular vessels through the ***supraspinous fossa***
   - supplies the supraspinatus and infraspinatus muscles

e. ***nerve to subclavius*** - C_{5-6}
   - arises from the superior trunk
   - travels inferiorly, in front of the plexus and the 3rd part of the subclavial artery
   - leaves the posterior triangle passing behind the scapula & in front of the subclavian vein (Ellis states *behind* the vein, Gray & Snell in front)
   - may contain ***accessory phrenic fibres***, which join the phrenic in the superior mediastinum

Infraclavicular Branches

- ***Branches of the Lateral Cord***

a. ***lateral pectoral nerve*** - C_{5-6-7}
- crosses the axillary vessels and pierces the clavipectoral fascia to supply pectoralis major
- the clavipectoral fascia encloses pectoralis minor below and stretches to the clavicle, ensheathing subclavius
- the fascia is also pierced by the cephalic vein, the acromio-thoracic trunk of the axillary artery, and lymphatics

b. ***musculocutaneous nerve*** - C_{5-6-7}
- continuation of the lateral cord, after its branch to the median nerve
- supplies the ***coracobrachialis*** & leaves the axilla through that muscle
- then descends downwards and laterally between ***biceps & brachialis***, supplying both these muscles (brachialis also receiving supply from the radial nerve)
- emerges between the biceps tendon and brachioradialis, pierces the deep fascia of the antecubital fossa, becoming the ***lateral cutaneous nerve of the forearm***
- this then divides into anterior and posterior branches, which continue to the wrist

c. ***lateral root of the median nerve*** - $C_{5-6-7-8}$ & T_1
- no branches in the axilla & descends with the brachial artery in the upper arm
- at the elbow joint: pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis
- ant. interosseous nerve: flexor pollicis longus, flexor digitorum profundus (lat.), pronator quadratus and fibres to the wrist joint
- palmar cutaneous branch: 3 thenar muscles, lumbricals 1&2, palmar digital branches to lateral 3½ fingers

- ***Branches of the Medial Cord***

a. ***medial pectoral nerve*** - C_8, T_1
- arises in the apex of the axilla, passing between the artery and vein
- often receives a twig from the lateral pectoral nerve
- supplies and pierces pectoralis minor, then supplies pectoralis major

b. ***medial cutaneous nerve of the arm*** - C_8, T_1
- smallest branch of the brachial plexus, originating between the artery and vein
- crosses either in front or behind the vein, running on its medial aspect
- joined by the ***intercostobrachial nerve*** (ex 2nd intercostal nerve) and pierces the deep fascia at the midpoint of the arm to supply the skin on the medial side

c. ***medial cutaneous nerve of the forearm*** - C_8, T_1

- descends first between the artery & vein, then in front of the axillary artery
- pierces the deep fascia at the midpoint of the arm, dividing into 2 branches,
  - *the **anterior branch*** usually crosses anterior to the ***median cubital vein*** in the antecubital fossa, supplying the skin of the antero-medial forearm to the wrist
  - *the **posterior branch*** descends on the medial side of the basilic vein, reaching the back of the forearm, supplying the skin of the postero-medial forearm to the wrist

d. ***medial root of median nerve*** *see above

- crosses in front of the 3rd part of the axillary artery & joins the lateral root
- supply cf. described above

e. ***ulnar nerve*** - C_{7-8}, T_1

- descends in-between the axillary artery and vein
- gives off no branches in the axilla, later supplies
- the elbow joint, flexor carpi ulnaris & flexor digitorum profundus (medial half)
- ulnar artery, palmar cutaneous branch, posterior cutaneous branch, supplying medial 1½ fingers, and fibres to the wrist joint
- muscles of hypothenar eminence, ***adductor pollicis***, 3 & 4th lumbricals, the interossei and joints of the hand
- palmaris brevis and palmar digital branches to medial 1 ½ fingers

- ***Branches of the Posterior Cord***

a. ***upper & lower subscapular nerves*** - C_{5-6}
- supply the upper & lower parts of the subscapularis muscle
- the lower also supplies the teres major muscle

b. ***thoracodorsal nerve*** - C_{6-7-8}
- also called the *nerve to* ***latissimus dorsi***
- arises between the upper & lower subscapular nerves
- accompanies the subscapularis vessels along the belly of that muscle, to the latissimus dorsi which it supplies

c. ***axillary (circumflex) nerve*** - C_{5-6}
- arises in common with the radial nerve, as the cord bifurcates, just beyond pectoralis minor
- passes laterally behind the axillary artery, in front of subscapularis, through the ***quadrilateral space***[§] with the posterior circumflex humeral artery
- [§]bounded by,
  - subscapularis & teres minor above
  - teres major below
  - long head of triceps medially
  - surgical neck of the humerus laterally
- after giving a branch to the ***shoulder joint***, it divides into the anterior and larger posterior branches
- the anterior runs around the surgical neck of the humerus, deep to the ***deltoid*** which it supplies
- the posterior division supplies ***teres minor*** and the posterior part of the deltoid, curving around the back of this muscle to become the ***upper lateral cutaneous nerve of the arm***
- there is considerable overlap in cutaneous supply, and conduction blockade results in only a small patch of anaesthesia, plus inability to abduct the arm

d. ***radial nerve*** - $C_{5-6-7-8}$, T_1
- direct continuation of the posterior cord
- lies behind the axillary artery and is the ***largest*** branch of the brachial plexus
- in the axilla it gives branches to the long & medial heads of triceps, and the posterior cutaneous nerve of the arm
- arm: lower lateral cutaneous nerve of the arm and posterior cutaneous nerve of the forearm, branches to triceps (lat. & med.), brachialis, brachioradialis, extensor carpi radialis longus and the elbow joint
- forearm: superficial branch to skin of the lateral side & dorsum of the lateral 3 ½ fingers, branches to extensor carpi radialis brevis, supinator, extensor digitorum, extensor digiti minimi, extensor carpi ulnaris, ***abductor pollicis longus***, extensor pollicis longus, extensor pollicis brevis and extensor indicis

Ulnar Nerve

• contributions from C_{7-8} and T_1, but in ~ 15% of cases there is no contribution from C_7
• continuing from the ***medial cord*** of the brachial plexus, travels between the axillary artery and vein, then on the medial side of the brachial artery, as far as the middle of the arm
• at the insertion of ***coracobrachialis***, it pierces the medial fascial septum, accompanied by the ***superior ulnar collateral artery***, entering the posterior compartment of the arm
• there are ***no branches*** in the anterior compartment
• the nerve then descends, covered posteriorly by the medial head of triceps, with the superior ulnar collateral vessels
• at the elbow it lies behind the ***medial epicondyle*** of the humerus, upon the medial ligament of the elbow joint
• at the elbow it gives of ***articular branches***
• enters the front of the forearm between the 2 heads of origin of ***flexor carpi ulnaris***
• continues down the forearm between flexor carpi ulnaris and flexor digitorum profundus
• in the lower 2/3 of the forearm, the nerve is ***medial*** to the ***ulnar artery***
• about mid-forearm it gives off the ***palmar cutaneous nerve***, which descends on the anterior aspect of the ulnar artery, piercing the deep fascia above the wrist to supply the hypothenar eminence
• the ***dorsal branch*** arises ~ 5-7.5 cm above the wrist, passing backwards under the tendon of flexor carpi ulnaris, perforating the deep fascia to supply the border of the dorsum of the hand and medial 1½ fingers
• occasionally sends an additional branch to the adjacent dorsal sides of the 3 rd & 4th fingers, normally supplied by the radial nerve
• at the level of the wrist, the nerve lies superficially between the tendons of flexor carpi ulnaris and flexor digitorum superficialis
• it then enters the hand, passing in front and ***lateral*** to the ***pisiform bone***, superficial to the flexor retinaculum (though it may be covered by a few fibres), with the ulnar artery laterally
• as it crosses the flexor retinaculum, it divides into the ***superficial*** and ***deep terminal branches***

■ ***Superficial Branch of the Ulnar Nerve***

• enters the palm, passing in the subcutaneous tissue between the ***pisiform*** bone and the hook of the ***hamate***
• again the ulnar artery is on the lateral aspect, ie. the nerve is closest to the ulnar border
• it gives the following branches,

a.	muscular branch	- to ***palmaris brevis***
b.	cutaneous branches	- palmar aspect of the medial 1 ½ fingers, plus - dorsal aspect of terminal ½ of the medial 1½ fingers

• the 2 palmar digital nerves pass ***beneath*** the palmar aponeurosis, deep to the corresponding arterial digital branches of the superficial palmar arch
• each digital artery passes behind its corresponding digital nerve along the fingers
• the nerve lies alongside the flexor sheath, in a plane immediately anterior to the phalanx

Deep Branch of the Ulnar Nerve

• runs inwards, between the ***abductor digiti minimi*** and the ***flexor digiti minimi***, accompanied by the deep branch of the ulnar artery
• pierces the opponens digiti minimi, winds around the lower border of the hook of the hamate, then passes laterally within the concavity of the deep palmar arch
• here it lies beneath the long flexor tendons, upon the metacarpal bones and interossei
• it gives rise to ***muscular branches*** to,

i. muscles of the hypothenar eminence
   - abductor digiti minimi, flexor digiti minimi and opponens digiti minimi

ii. all palmar and dorsal interossei

iii. 3rd & 4th lumbricals

iv. both heads of the ***adductor pollicis*** muscle

Branches & Distribution

1. ***muscular branches***
   - flexor carpi ulnaris & flexor digitorum profundus (medial half)
   - all of the intrinsic muscles of the hand, except the lateral 2 lumbricals and the 3 muscles of the thenar eminence

   i. hypothenar eminence
   ii. adductor pollicis
   iii. 3 & 4th lumbricals
   iv. interossei - palmar & dorsal
   v. palmaris brevis

2. ***cutaneous branches*** - ulnar artery
   - palmar cutaneous branch
   - posterior cutaneous branch, supplying medial 1 ½ fingers
   - palmar digital branches to medial 1 ½ fingers

3. ***articular branches*** - the elbow joint
   - fibres to the wrist joint and joints of the hand

NB: the ulnar nerve gives off no branches in the axilla or upper arm

Median Nerve

• contributions from ***all roots*** of the plexus, lateral (C_{5-6-7}) and medial (C_8, T_1) heads, from the medial and lateral cords respectively
• these unite in front of the 3rd part of the axillary artery, then run down on the ***lateral*** aspect of the ***brachial artery*** to the midpoint of the arm where, at the insertion of ***coracobrachialis***, it crosses (usually in front of) the artery and continues on the ***medial*** side

• other anatomical features of the ***midpoint of the arm*** include,

1. coracobrachialis inserts into the medial shaft of the humerus
2. the lowermost fibres of deltoid insert into the lateral shaft of the humerus
3. the nutrient artery from profunda brachii enters the humerus
4. the medial cutaneous nerve of the forearm pierces the deep fascia
5. the ulnar nerve & ulnar collateral branch of the brachial artery enter the posterior compartment of the arm, through the intermuscular septum

• the nerve, like the artery is superficial at the elbow, lying on brachialis, being crossed by the ***bicipital aponeurosis*** and the ***median cubital vein***
• there are no branches in the upper arm, except a small vasomotor branch to the brachial artery

• it leaves the cubital fossa between the 2 heads of ***pronator teres***
• passes behind the humeral head of pronator teres, and is separated from the ***ulnar artery*** by the deep ulnar head
• the ulnar artery crosses deep to the nerve & pronator teres, latero-medially from its origin from the brachial artery, to accompany the ulnar nerve in the medial aspect of the forearm
• the nerve continues deep to ***flexor digitorum superficialis***, attached to its posterior surface by connective tissue, between it and ***flexor digitorum profundus***
• it is accompanied at this level by the anterior interosseous branch of the ulnar artery
• at the wrist it emerges from the ***lateral*** border of flexor digitorum superficialis, lying behind the tendon of ***palmaris longus***, with flexor carpi radialis laterally
• it then enters the palm passing behind the flexor retinaculum, where it immediately divides into ***lateral*** and ***medial branches*** (see below)

- ***Branches***

a. muscular
- pronator teres (only branch above the elbow)
- flexor carpi radialis
- flexor digitorum superficialis & palmaris longus

b. articular branch - at the elbow

c. ***anterior interosseous nerve***
- arises at the two heads of pronator teres
- travels on the anterior surface of the interosseous membrane, between flexor pollicis longus & flexor digitorum profundus, with the *anterior interosseous a*.

i. muscular
- flexor pollicis longus & pronator quadratus
- lateral half of flexor digitorum profundus

ii. articular
- wrist and inferior radio-ulnar joints
- carpal joints

d. ***palmar cutaneous branch***
- divides at the lower part of the forearm & pierces the deep fascia above the wrist
- passes superficial to the flexor retinaculum §, dividing into 2 branches
- supplies the skin over the ball of the thumb and the palm of the hand

e. ***lateral terminal branch***

i. muscular
- ***abductor*** pollicis brevis, ***opponens*** pollicis & flexor pollicis brevis
- the 1st lumbrical

ii. cutaneous
- both sides of the anterior surface of the thumb
- lateral side of the index finger (ie. 3 palmar digital nerves)

f. ***medial terminal branch***

i. muscular - the 2nd lumbrical

ii. cutaneous
- 2 palmar digital nerves, which bifurcate
- adjacent sides of the middle/index & middle/ring fingers
* also the dorsal aspect of the distal half of the first 3 ½ fingers

NB: §there are 6 structures which cross ***superficial*** to the flexor retinaculum,

1. palmaris longus tendon
2. 2 vessels
   i. the ulnar artery, and
   ii. its venae commitantes
3. 3 nerves
   i. ulnar nerve
   ii. palmar cutaneous branch of the ulnar nerve
   iii. palmar cutaneous branch of the median nerve

Radial Nerve

- ***Upper Arm***

• has its origin behind the 3rd part of the axillary artery, continuing from the ***posterior cord*** of the brachial plexus, crossing anterior to, in turn,

i. subscapularis
ii. teres major
iii. latissimus dorsi

• passes between the long (scapular) & medial (humeral) heads of triceps into the posterior compartment of the arm, accompanied by the profunda branches of the brachial vessels
• winds around, in the ***spiral groove*** with the ***profunda artery***, in direct contact with the humerus
• at this level it lies between a superficial muscle plane, formed first by the long head and then by the lateral head of triceps, and a deep plane formed by the medial head of triceps
• pierces the ***lateral fascial septum*** about a hands breadth above the elbow and continues down into the ***cubital fossa***, lying between ***brachialis*** and ***brachioradialis***
• at this level the nerve is susceptible to compression injury, especially from a low placed tourniquet

- ***Branches in the Upper Arm***

a. in the **axilla:**
   - to the long and medial heads of triceps
   - the ***posterior cutaneous nerve of the arm***

b. in the **spiral groove:**
   - to the lateral and medial heads of triceps and to the anconeus
   - the ***lower lateral cutaneous nerve of the arm***, supplies skin over the lateral & anterior aspects of the lower arm
   - the ***posterior cutaneous nerve of the forearm***, runs down the middle of the back of the forearm as far as the wrist

c. in the **anterior compartment:**
   - after piercing the lateral fascial septum supplies branches to
     → brachialis, brachioradialis and extensor carpi radialis longus
   - gives off articular branches to the elbow joint

■ ***Branches in the Lower Arm***

• after piercing the lateral intermuscular septum in the lower part of the arm, passes downward in front of the septum and lateral epicondyle into the cubital fossa
• its relations at this level are,

a. medially - brachialis

b. laterally - brachioradialis & extensor carpi radialis longus

• branches from this level are,

a. muscular - brachioradialis & extensor carpi radialis longus
- small branch to the lateral part of brachialis

b. articular - elbow joint

• at the level of the ***lateral epicondyle*** it terminates into ***superficial*** & ***deep branches***

■ ***Deep Branch of the Radial Nerve***

• or the ***posterior interosseous nerve*** is, apart from articular twigs, entirely motor
• winds around the neck of the radius, between the superficial and deep layers of ***supinator*** around the lateral side of the radial shaft, to reach the posterior compartment of the forearm
• emerges from the body of supinator and descends in the interval between the superficial and deep muscle groups, in company with the ***posterior interosseous artery***
• it eventually reaches the posterior surface of the interosseous membrane, where it runs with the posterior interosseous artery
• terminates at the carpus in an enlargement which gives off branches to the carpal joints
• before it enters supinator branches to supply supinator & extensor carpi radialis brevis
• on emerging from supinator branches to supply all the extensor group,

a. muscular branches - extensor carpi radialis brevis and supinator
- extensor carpi ulnaris
- extensor digitorum and extensor digiti minimi
- extensor pollicis longus & extensor pollicis brevis
- abductor pollicis longus & extensor indicis

b. articular branches - wrist and carpal joints

■ ***Superficial Branch of the Radial Nerve***

- this is the direct continuation of the nerve at the elbow and is entirely ***sensory***
- descends beneath brachioradialis, lying upon supinator and pronator teres
- lies close to the lateral side of the radial artery in the middle third of the forearm
- remaining on the lateral side of the artery until ~ 7.5 cm above the wrist
- in the lower third, it leaves the artery and passes backward under the tendon of brachioradialis
- then reaches the posterior surface of the wrist, where it divides into its dorsal digital nerves, which then supply,

1. the dorsal aspect of the base of the thumb
2. the radial side of the back of the hand (lateral 2/3)
3. the backs of the thumb, index, middle, and radial half of the ring fingers, as far as their distal interphalangeal joints

Segmental Innervation of the Upper Limb - Sensory	
C_{3-4}	• upper shoulder region, supraclavicular nerves
C_5	• deltoid region and lateral part of the arm
C_6	• lateral forearm and thumb
C_7	• the hand and middle 3 fingers
C_8	• 5th finger, medial side of the hand & forearm
T_1	• medial side of the lower arm and upper forearm
T_2	• medial side of the upper arm, intercostobrachial nerve

Segmental Innervation of the Upper Limb - Motor [1]	
C_5	• abductors and lateral rotators of the shoulder
C_{6-7-8}	• adductors and medial rotators of the shoulder
C_{5-6}	• the elbow flexors
C_{7-8}	• the elbow extensors
C_6	• pronators and supinators of the forearm
C_{6-7}	• long flexors & extensors of the wrist
C_{7-8}	• long flexors & extensors of the fingers
T_1	• intrinsic muscles of the hand

[1] Last, 1978

BRACHIAL PLEXUS BLOCKADE

• factors requiring consideration prior to performance of the block include,

1. preoperative visit, assessment and consent
2. premedication
3. intraoperative sedation
4. posture of the blocked limb
5. postoperative pain relief

Supraclavicular Brachial Plexus Blockade

- ***Advantages***

  i. the plexus is tightly compacted - smaller volumes of local required
     - faster onset
  ii. position of the arm is less important
  iii. blocks all of the brachial plexus reliably

- ***Limitations***

  i. reliable block is only achieved if ***paraesthesiae*** are elicited
  ii. more difficult to describe / learn due to variability around 1 st rib
  iii. potential for pneumothorax
  iv. potential for phrenic nerve block

- ***Relative Contraindications***

  i. uncooperative patients
  ii. short, difficult stature, where landmarks are obscured
  iii. patients in whom a pneumothorax or phrenic nerve block are unacceptable
  iv. requirement for bilateral blockade
  v. inexperienced operator

- ***Relevant Anatomy***

  i. the plexus unites in a bundle which is ***inferior*** to the clavicle in its midpoint, on the posterolateral margin, superior to the subclavian artery

  ii. the artery can often be palpated as a valuable landmark

  iii. the 1st rib is a valuable landmark
  - preventing the needle passing medially and entering the dome of the pleura
  - although deeply curved, that portion in relation to the artery & plexus is effectively antero-posterior in direction

- ***Technique***

1. secure reliable IV access
2. position the patient
   - supine without a pillow
   - arms to the side
   - shoulder depressed slightly
     (± rolled towel between shoulders)
   - head turned to the opposite side
3. aseptic technique
4. insertion is at a point ~ 1 cm behind the midpoint of the clavicle (classical)
   - in some patients this may result in too posterior a needle direction
   - insertion ~ 2-3 cm behind the clavicle may make identification of the interscalene groove easier
   - insertion directly behind the clavicle will almost invariable lie outside the 1st rib
   - the midpoint of the clavicle is approximated by where the straight portion of the external jugular would cross the clavicle, if continued
   - asking the patient to lift their head will accentuate the sternomastoid, posterior to which the interscalene groove can be found
5. infiltrate the insertion point with local anaesthetic
6. the needle is inserted downward, backward and medially
   - "rib walking" to achieve paraesthesia is necessary for reliable blockade
   - this should be done in the antero-posterior plane, not latero-medially
   - palpation of the subclavian artery, or pulsation of the needle is a reliable guide
   - alternatively a nerve stimulator may be used
   - inward, medial inclination of the needle can easily penetrate the pleura
   - ***the more lateral the insertion, and the more medial the inclination the greater the risk of pleural puncture***
7. injection of local anaesthetic ~ 15-25 ml

- ***Complications***

a. pneumothorax
   - incidence varies with level of training ~ 0.5-6.0%
   - serious complications seldom follow
   - more common in thin, tall patients with high pleural domes
   - reduced by experience, fewer random passes, and smaller needles
   - fine needles limit the ability to elicit paraesthesiae & detect intravascular injection
   - the majority develop over 12-24 hours and seldom progress further after this time
   - rarely presents acutely
   - treatment depends upon the patients underlying condition & the size of the leak

b. phrenic nerve block
   - occurs in ~ 40-60% and usually causes no symptoms
   - may be problematic with preexisting respiratory disease or bilateral blockade

c. Horner's syndrome → stellate ganglion block
   - occurs in ~ 70-90% with the use of large volumes of solution (≥ 50 ml)
   - no active treatment is required

d. nerve damage or neuritis
   - the most common cause is poor positioning of the arm during surgery or in the immediate postoperative period, occasional other causes,
     i. trauma 2° to the needle
     ii. prolonged ischaemia of the nerve 2° to vasoconstrictor drugs, or
     iii. too high a concentration of local anaesthetic
   - treatment is supportive with physiotherapy to prevent muscle contractures

e. vascular puncture ± haematoma

f. systemic local anaesthetic toxicity
   i. inadvertent intravascular injection → most common
   ii. absolute overdose

g. allergy

Interscalene Brachial Plexus Blockade

- ***Advantages***

  i. suitable for ***shoulder surgery***, where block of the cervical plexus is required
  ii. can be performed with the arm in almost any position
  iii. reduced risk of pneumothorax
  iv. the landmarks are usually well defined, even in "solid" individuals

- ***Limitations***

  i. essential to elicit ***paraesthesiae or effect nerve stimulation***
  ii. unless large volumes are used, the lower trunk may be missed, requiring supplementary ***ulnar*** nerve blockade
  iii. uncommon but potentially serious complications (see later)

- ***Relevant Anatomy***

  i. the roots lie in "gutters" in the transverse processes of the vertebrae
  ii. the anterior and posterior tubercles of the transverse processes give rise to the anterior and middle scalene muscles respectively
  iii. the transverse processes angle downward at ~ 45° and tend to overlap
  → offering some protection to the intervertebral foramina, however not from a ***horizontally*** directed needle

- ***Technique***

1. secure reliable IV access
2. position the patient
   - supine without a pillow
   - arms to the side
   - shoulder depressed slightly (± towel between shoulders)
   - head turned to the opposite side
3. aseptic technique
4. the ***interscalene groove*** is palpated, rolling the fingers posteriorly off sternomastoid, at the level of C_6
   - located by direct palpation, or by a line drawn posteriorly from the level of the ***cricoid cartilage***
   - the external jugular vein frequently overlies this point
5. infiltrate the insertion point with local anaesthetic
6. the needle is inserted ~ perpendicular to the floor of the transverse process "gutter", ~ 45° caudad and slightly backward

7. paraesthesias or nerve stimulation are sought
   - the transverse process is usually quite superficial ~ 1.5-2.0 cm
   - if this is encountered without paraesthesiae, then the needle should be "walked" antero-posteriorly
   - if bony contact is reached only at a deep level, then it is most likely vertebral body
8. injection of local anaesthetic ~ 10-40 ml
   - depending upon the extent of blockade required and the stature of the patient
   - contrast studies suggest that,
   i. **~ 20 ml** will block the lower cervical nerves and most of the brachial plexus
   ii. ~ 40 ml will block both the cervical and brachial plexuses
   - digital pressure during injection will aid in downward spread of solution

- ***Complications***

a. inadvertent epidural or spinal anaesthesia
b. vertebral artery injection
c. phrenic nerve blockade
d. vagus, recurrent laryngeal or cervical sympathetic nerve blockade
   - associated with failed block, as these are anterior to the prevertebral fascia
e. nerve damage or neuritis
f. systemic local anaesthetic toxicity
g. haematoma, bruising
h. local infection

Axillary Brachial Plexus Blockade

- ***Advantages***

i. good operating conditions for forearm and hand surgery
ii. less risk than the former techniques
iii. not imperative to seek paraesthesiae

- ***Limitations***

i. the arm must be abducted to perform the block
ii. blockade is insufficient for upper arm or shoulder surgery
iii. the circumflex and musculocutaneous nerves are occasio nally missed

- ***Relevant Anatomy***

  i. at the level of the anterior axillary fold the neurovascular bundle is compact

  ii. on its medial (superficial) surface it is covered only by skin & connective tissue
  - being behind biceps / coracobrachialis and in front of triceps

  iii. the median nerve tends to lie ***anterior*** to the artery,
  the ulnar nerve ***posterior*** to the artery, and
  the radial nerve ***postero-lateral*** to the artery

  iv. the axillary vein overlies the artery on its medial aspect

  v. the ***musculocutaneous nerve*** lies in the body of ***coracobrachialis***

- ***Technique***

  1. secure reliable IV access

  2. position the patient - supine with the head turned to the opposite side
  - subject arm abducted to ~ 90°
  - the forearm is flexed to ~ 90°

  3. aseptic technique

  4. the ***brachial artery*** is identified as far proximal as possible and fixed distally between the fingers and the humerus

  5. infiltrate the insertion point with local anaesthetic

  6. a 22G short-bevel needle is inserted toward the apex of the axilla, in the line of the neurovascular bundle
  - a "pole-needle" and nerve stimulator, or a catheter-over-needle may be used
  - a "fascial click" may be felt on entry into the sheath
  - paraesthesiae may be elicited but are not required for adequate blockade, Selander *et al*. have demonstrated they may be associated with an increased incidence of post-anaesthetic neuropathy
  - arterial puncture defines entry into the sheath and a transfixing technique used
  - oscillation of the needle with arterial pulsation may also indicate placement within the sheath

  7. either a single injection, or a double injection technique may be used
  - maintaining distal pressure on the sheath during injection
  - depositing 3-5 ml of solution in the body of ***coracobrachialis***
    → the ***medial cutaneous nerve of the arm***

  i. ***single injection***
  - ≥ 40 ml of solution is required to reach the ***coracoid process*** in the adult, which is the approximate level of exit of the ***musculocutaneous nerve***
  - volumes much larger than this *do not* increase spread above this level
  - prevention of needle movement is important
  - a catheter technique may be used, allowing extension of blockade for prolonged procedures

ii. ***double injection***
- most of the earlier descriptions describe injection on both sides of the artery
- Thompson & Rorie demonstrated that the sheath may be divided into ***fascial compartments***, limiting circumferential spread
- if the musculocutaneous nerve is blocked separately , then only 10-15 ml per nerve is required
- either one or two needles may be used

iii. ***continuous injection***
- has been advocated as the technique of choice for prolonged cases
- no cases of local anaesthetic toxicity have been reported
- infusions of bupivacaine 0.25% ~ 10 ml/hr are usually adequate following a standard initial dose, starting ~ 1 hour later

8. promotion of central flow within the sheath
   i. distal digital pressure
   ii. angling the needle toward the axilla
      - Winnie suggested using a 37 mm needle directed at ~ 20 ° to the artery
   iii. once the injection is complete the arm should be adducted
      - this removes the pressure of the humeral head, which may limit proximal spread
   iv. use of a distal tourniquet is of marginal value and uncomfortable for the patient

- ***Complications***

a. intravascular injection - artery or overlying vein
b. haematoma
c. infection
d. local anaesthetic toxicity
e. direct neural trauma

Peripheral Blocks

- the requirement for an upper arm tourniquet is a relative contraindication
- ≤ 30 minutes is usually well tolerated, with ≤ 60 with the use of sedation / analgesia
- the method of application seems most important, being better applied with the use of an Esmarch bandage after skin preparation
- only hand anaesthesia results from blocking the 3 major nerves, therefore there is little value in blockade at the elbow, especially as block at the wrist is usually easier to perform
- onset is usually quicker if paraesthesiae are sought, however, intraneural injection should be avoided

Median Nerve Block

- suitable for surgery on the radial side of the palm, or radial 3 ½ fingers

At The Elbow

1. the intercondylar line is drawn across the cubital fossa
2. the brachial artery is palpated and marked
3. a 23G SB needle inserted just ***medial*** to the artery, perpendicular to the skin
   - paraesthesiae should be sought with medial walking of the needle
   - immediately beneath deep fascia (cf. radial close to bone, beneath brachioradialis)
4. local anaesthetic ~ 3-5 ml

At The Wrist

1. the radial side of ***palmaris tendon*** is marked ~ 2 cm proximal to the distal wrist crease
   - being prominent with forced flexion of the wrist with extended fingers
   - if this tendon is absent, then the use a point ~ 1 cm medial to the ulnar edge of flexor carpi radialis
2. slightly extend the wrist
3. a 25G needle inserted perpendicular to the skin should result in paraesthesiae ≤ 1 cm
   - if absent, paraesthesiae should be sought beneath the palmaris tendon
4. local anaesthetic ~ 3-5 ml
   - 1 ml should be deposited in the subcutaneous tissue to block the ***palmar cutaneous branch***

Ulnar Nerve Block

- suitable for the ulnar border of the hand and 1 ½ fingers
- block at the wrist is more reliable and has a lower complication rate
- blockade at the elbow is reported to be associated with a higher incidence of neuritis
- therefore, either a small volume (≤ 1 ml) of solution, or blockade 2-3 cm proximal to the medial epicondyle is preferable

At The Elbow

1. the arm is flexed across the chest
2. a point 2-3 cm proximal to the medial epicondyle & ulnar groove
3. a 23G SB needle is inserted perpendicular to the skin
   - paraesthesiae should be sought with walking across the line of the nerve
   - absence of paraesthesiae will result in prolonged onset or inadequate anaesthesia
4. local anaesthetic ~ 5-8 ml

- ***At The Wrist***

1. under cover of the flexor carpi ulnaris, just proximal to the pisiform bone
   - lies on the ulnar side of, but deep to the artery
   - prior to its termination into deep motor and superficial sensory branches
   - the palmar cutaneous and dorsal branches have already left
2. injection may be approached from the radial or ulnar sides of this tendon
3. a 25G needle is used and paraesthesiae should be sought
4. local anaesthetic ~ 3-5 ml
5. the 2 cutaneous branches can be blocked prior to removing the needle
   - the dorsal branch by injecting 2-3 ml along the ulnar border of the carpus
   - the palmar branch by injecting 1-2 ml across the volar aspect of the wrist, as far as the radial side of flexor carpi ulnaris

Radial Nerve Block

- useful for the radial side of the dorsum of the hand, and proximal parts of the radial 3 ½ fingers
- blockade at the elbow is less certain, but may be used in conjunction with block of the lateral cutaneous nerve of the forearm for AV fistula, or to supplement brachial plexus block, particularly for fractures of the radius

- ***At The Elbow***

1. blocked as it passes over the lateral epicondyle, close to the bone
2. the intercondylar line is marked and a point taken ~ 2 cm lateral to the edge of the biceps tendon
3. a long 23G SB needle is inserted to bone
4. local anaesthetic ~ 2-4 ml injected as the needle is withdrawn 0.5-1.0 cm
5. (3-4) repeated several times, moving the needle direction slightly medially

- ***At The Wrist***

1. this is a ***field block*** of the terminal branches as they pass over the carpus
2. the tendons of extensor pollicis brevis and longus are marked
   - extension of the thumb, borders of the "anatomical snuff box"
3. insertion is made over the extensor pollicis longus tendon, opposite the base of the 1st metacarpal
4. a 32mm 23G needle is directed proximally along the tendon to the dorsal radial tubercle, injecting ~ 2-3 ml of local anaesthetic
5. the needle is then withdrawn and redirected 90 ° across the "snuffbox", just past the brevis tendon and a further 1-2 ml of solution injected

Musculocutaneous Nerve

- used either in combination with radial nerve block or as a supplement to brachial plexus block
- it may be blocked at a number of levels,

1. as the main nerve trunk in the body of ***coracobrachialis***
2. where the terminal sensory ***lateral cutaneous nerve of the forearm*** emerges between brachialis and biceps ~ 5 cm proximal to the elbow crease
3. as a subcutaneous field block in the forearm
4. lateral to the biceps tendon, in the intercondylar line

NB: Olsen showed in 64 cadaver dissections that the nerve, rather than emerging from the brachialis / biceps groove and running down the cubital fossa superficially and laterally to the biceps tendon, stays deep to the fascia and close under the cover of the lateral edge of the biceps tendon, becoming superficial at a variable distance from the elbow crease

At Biceps Tendon

1. the intercondylar line and the biceps tendon are marked
2. a 25G needle is inserted at the lateral border of the tendon
3. local anaesthetic ~ 2-3 ml

NB: failure generally results from too deep an injection,
this level is more reliable and faster than block in the brachialis / biceps groove

Field Block - Cutaneous Nerves of the Forearm

Lateral Cutaneous Nerve

- does not pierce the deep fascia until it is distal to the elbow crease
- infiltration ~ 5 cm distal, from a line in continuation with the biceps tendon, laterally for ~ 4 cm

Medial Cutaneous Nerve

- arises from the medial cord of the plexus, piercing the deep fascia with the basilic vein in the mid-arm, bifurcating into its anterior and posterior branches, which pass between the biceps tendon and the medial epicondyle
- subcutaneous infiltration should span from the tendon to the medial epicondyle, in the intercondylar line

Posterior Cutaneous Nerve

- arises from the radial nerve, piercing the deep fascia above the elbow
- subcutaneous infiltration should extend from the lateral epicondyle to the olecranon

Digital Nerve Block

• the ***common digital nerves*** are derived from the ulnar and median nerves, and divide in the distal palm into the ***volar digital nerves*** to supply,

i. the adjacent sides of the fingers
ii. the palmar aspect
iii. the tip and nail-bed area

• accompanied by the digital vessels, these run in the ventro-lateral aspect of the finger, alongside the flexor tendon sheath
• small ***dorsal digital nerves***, from the ulnar and radial nerves run on the dorso-lateral aspect of the finger, supplying the back of the fingers as far as the proximal joint
• block of both nerves may be achieved using a 25G needle inserted from the dorsal aspect

NB: ~ 1.0 ml injected into the volar aspect and ~ 0.5 ml dorsally

• the common digital nerves may be blocked using a 25G 16 mm needle, inserted 2-3 mm dorsal to the finger web and inserted directly backwards in line with the fingers, using ~ 2.0 ml
• redirection of the needle to the dorsal nerves may be achieved from the same insertion
• a metacarpal approach may be used, inserting the needle between the metacarpal heads, as far as the palmar skin

NB: all of these blocks must be performed ***without added vasoconstrictor***

■ ***Thumb Blockade***

• this may be achieved by combined radial and medial nerve block at the wrist
• alternatively by "ring" block at the base of the thumb

■ ***Factors In Ischaemic Necrosis***

a. addition of vasoconstrictor solution
b. volume of solution used - especially at the base of a digit
c. use of tourniquets ≤ 15 minutes duration
- C/I in Raynaud's phenomena
? shouldn't use digital tourniquets
d. peripheral vascular disease
e. direct vascular damage

Brachial Plexus Injuries

- ***Upper Plexus***

Def'n: Erb-Duchenne paralysis
arm by the side, forearm pronated with the palm backwards ("waiter's tip"), sensory loss is confined to a small area over the deltoid

1. C_{5-6} may be torn by excessive traction of the head during delivery
2. in the adult by falls onto the head and shoulder, distracting the two (*Rugby)
3. during operation from pressure from too closely sited shoulder rests in the head-down position
4. during operation, especially paralysed, with the arm unsupported over the edge of the table

- ***Lower Plexus***

Def'n: Klumpke's paralysis
extension of the metacarpo-phalangeal joints with flexion of the interphalangeal joints due to unopposed action of the long flexors and extensors ("claw hand")

1. forcible breech delivery
2. excessive abduction during anaesthesia
3. cervical rib
4. Pancoast's tumour or supraclavicular lymph nodes

NB: may be associated with a ***Horner's syndrome*** due to disruption of the white ramus from T_1 to the stellate ganglion

- ***Entire Plexus***

• occasionally results from violent injuries or from gunshot wounds
• the arm is entirely paralysed and anaesthetic, except for the upper shoulder and inner arm
• integrity of serratus anterior can help in localisation, damage occurring to the roots if this is non-functional

Radial Nerve Injuries

1. against the humeral shaft
    i. "Saturday night palsy" and "crutch palsy"
    ii. overinflation of a tourniquet
    iii. pressure against the edge of an operating table
    iv. fracture of the humerus
2. in the forearm
    i. fractures / dislocations of the radial head
    ii. too distal an incision to expose the radial head

• damage to the trunk results in,
    i. loss of supination of the ***extended*** forearm (biceps acts during flexion)
    ii. wrist drop
    iii. sensory anaesthesia on the dorsum between the 1 st and 2nd metacarpals

• damage below the elbow (to the posterior interosseous nerve) leaves extensor carpi radialis longus intact, and therefore has no wrist drop

Ulnar Nerve Injuries

1. at its origin, the trunk may be injured if the arm is abducted > 90 ° or behind the trunk
2. behind the medial epicondyle of the humerus
   i. fractures / dislocations of the elbow
   ii. valgus deformity (malunited supracondylar fracture)
   iii. pressure from unpadded arm restraints
3. superficially at the wrist, usually by lacerations

- division at the ***wrist***, causes
  i. paralysis of all intrinsic muscles of the hand,
  except the radial 2 lumbricals & the 3 muscles of the thenar eminence
  ii. inability to adduct the thumb → Froment's sign, marked flexion of the thumb trying to grasp paper between the thumb & palm
  iii. resulting in a "clawed hand", less severe in the index and middle fingers
  → "main en griffe" deformity
  iv. sensory loss over the ulnar 1 ½ fingers
  v. the main nerve and its palmar cutaneous branch are usually severed,
  the posterior cutaneo us branch usually remains intact

- if divided at the ***elbow***
  i. ***flexor digitorum profundus*** to fingers 4 & 5 is also paralysed
  ii. less intense clawing of the hand = "the ***ulnar paradox***"
  iii. sensory loss is greater (palmar cutaneous & dorsal branches)

- usually the hand has reasonable function due to compensatory movements

Median Nerve Injuries

1. severe lacerations of the wrist
2. compression within the carpal tunnel
3. dislocations of the lunate, or in Colles' fracture
4. occasionally in supracondylar fractures

- division at the ***wrist*** results in,
    - i. paralysis of the 2 radial lumbricals
    - ii. the thenar muscles, excluding adductor pollicis
        - inability to abduct the thumb at 90 °
    - iii. ***anaesthesia*** over the palm, thumb and 2 ½ fingers
        - this is the major disability of the lesion

- division at the ***elbow*** produces serious muscle impairment,
    - i. loss of pronation of the forearm
    - ii. weak wrist flexion with ulnar deviation
        - dependent on flexor carpi radialis & the ulnar half of flexor digitorum profundus
    - iii. loss of flexion of the thumb, index & middle fingers
        - wasting of the thenar eminence & a flattened "monkey's hand"

THE THORACIC NERVES

• there are 12 pairs of anterior thoracic rami, the upper 11 comprising the ***intercostal nerves***, the 12th the ***subcostal nerve***
• these are responsible for innervation of the,

i. intercostal muscles
ii. abdominal wall muscles
iii. cutaneous supply of the skin of the medial aspect of the upper arm
iv. cutaneous supply of the anterior and lateral aspects of the trunk
  • from the level of the angle of Louis to just above the groin
v. sympathetic supply via grey and white rami communicates

• the 3rd-6th thoracic nerve are "typical", the remainder exhibiting variation

■ ***Intercostal Nerves #3-6***

• enter their intercostal spaces across the anterior aspect of the corresponding superior costotransverse ligament, to lie ***below*** the intercostal vessels
• initially between the posterior intercostal membrane and the pleura, then from the angles of the ribs, between the internal intercostal and the intracostal muscles
• near the margin of the sternum, they pass in front of the internal mammary vessels and sternocostalis, pierce the internal intercostal muscle and anterior intercostal membrane, and the overlying pectoralis major to become ***anterior cutaneous nerves*** of the thorax
• branches from these typical nerves include,

i. muscular - to the intercostal muscles
ii. collateral - running along the lower border of each space
  - either rejoining the main nerve, or
  - forming separate anterior cutaneous nerves
iii. lateral cutaneous - reaching the skin in the midaxillary line
  - dividing into anterior and posterior branches

■ ***Intercostal Nerve #1***

• sends a large contribution across the front of the neck of the 1st rib, lateral to the superior intercostal artery, to join the brachial plexus
• the remaining, smaller part of the nerve, constitutes the 1st intercostal nerve
• it has no lateral cutaneous branch, and the anterior cutaneous branch, if present, is small

■ ***Intercostal Nerve #2***

• differs from the "typical" nerves only in that its lateral cutaneous branch crosses the axilla to supply the medial upper arm, the ***intercostobrachial nerve***

Intercostal Nerves #7-11

• enter the abdominal wall between the interdigitations of the diaphragm and transversus abdominus
• the 7th and 8th nerves pass directly into the posterior rectus sheath, pierce the rectus abdominus and anterior sheath, to terminate on the overlying skin
• the 9th, 10th and 11th nerves travel between transversus abdominus and the internal oblique, penetrate the posterior rectus sheath, traverse rectus abdominus and the anterior sheath to reach the surface
• the 7th and 8th nerves slope upward and medially in their short abdominal course
• the 9th nerve travels almost horizontally
• the 10th and 11th nerves slope downwards, the 10th supplying the region of the umbilicus
• these nerves are roughly similar to "typical" nerves, branches being,

i. muscular - abdominal and intercostal muscles
ii. collateral (additional anterior cutaneous) branch
iii. lateral cutaneous

• sensory filaments from the 7th-11th nerves supply the periphery of the ***diaphragm***

Intercostal Nerve #12

• runs along the lower border of the 12th rib, below the subcostal vessels
• passes behind the lateral arcuate ligament, then in front of quadratus lumborum, behind the kidney and colon
• then passes between transversus abdominus and internal oblique, following a similar course to the lower intercostals
• one difference is that the lateral cutaneous branch descends without dividing, to supply the skin over the lateral aspect of the buttock

Intercostal Nerve Block

- may be performed wherever a rib is palpable, usual sites including,
    - i. posteriorly - at the lateral margin of the sacrospinalis muscle
      - also blocks the lateral cutaneous branch
    - ii. anterior axillary line

- relevant points to the technique include,
    - i. block at the inferior border of the relevant rib
        - walking off the rib supero-inferiorly
    - ii. always have a syringe attached to the needle in case of pleural puncture
    - iii. aspirate to exclude intravascular placement
    - iv. 2-5 mls of solution is usually adequate
    - v. injection at the posterior rib angle will produce paravertebral spread
        - Nunn & Salvin 1980, blockade of 2 or more segments ***bilaterally***
        - catheter techniques for continuous pain relief

- clinical uses include,
    - i. pain relief for fractured ribs, malignant disease etc.
    - ii. field block anaesthesia for upper abdominal operations (cholecystectomy)
        - this requires bilateral lower 6 intercostal and coeliac plexus block
        - the later may be performed after the abdomen is opened
        - muscle relaxation is less cf. epidural or GA

LUMBAR PLEXUS

- formed in the ***psoas muscle*** from the ***anterior roots*** of the upper 4 lumbar nerves
    i. ~ 50% may receive an additional contribution from T_{12}
    ii. as for the brachial plexus, it may be - prefixed, from T_{12}-L_3
    - postfixed, from L_2-L_5

- the anterior rami receive grey rami communicantes from the ***sympathetic chain***
- the upper 2 roots give off white rami communicantes to the chain

Formation of The Plexus

- the plexus assembles in front of the transverse processes of the lumbar vertebrae, within the substance of the ***psoas muscle***
- L_1 (+ T_{12} ~50%) divides into,

1. upper division - ***iliohypogastric*** and ***ilioinguinal nerves***
2. lower division - ***genitofemoral nerve*** with a branch from L_2

- the remainder of L_2 together with L_3 and L_4 divide into dorsal and ventral divisions,

1. dorsal division - L_{2-3} form the ***lateral cutaneous nerve of the thigh***
    - L_{2-3-4} form the ***femoral nerve***
2. ventral division - L_{2-3-4} form the ***obturator nerve***
    - L_{3-4} form the *accessory obturator nerve*, when present

- in addition, muscular branches are given to,
    i. psoas major and minor
    ii. iliacus
    iii. quadratus lumborum

- ***branches*** emerge from the ***psoas muscle*** at its lateral & medial borders, and the anterior surface,

a. **<u>lateral border</u>** * in order
    i. *iliohypogastric* - **L_1**
    ii. *ilioinguinal* - **L_1**
    iii. *lateral cutaneous nerve of the thigh* - **$L_{2,3}$**
    iv. ***femoral nerve*** - **$L_{2,3,4}$**

b. **<u>medial border</u>**
    i. ***obturator nerve*** - **$L_{2,3,4}$**
    ii. 4^{th} lumbar root *descends to join S_1 in formation of the sacral plexus

c. **<u>anterior surface</u>**
    - *genitofemoral nerve* - **$L_{1,2}$**

Distribution of the Lumbar Plexus

Iliohypogastric & Ilioinguinal Nerves

• the ***iliohypogastric*** pierces the internal oblique, immediately above and in front of the ***anterior superior iliac spine***, runs deep to the external oblique, just above the inguinal canal
• supplies the skin of the lower abdominal wall (suprapubic region)

• the ***ilioinguinal*** also pierces the internal oblique, then passes through the inguinal canal in front of the spermatic cord
• it emerges through the external ring, or the adjacent external oblique aponeurosis, to supply the upper thigh and scrotum (or labium majus)

Genitofemoral Nerve

• emerges from the front of the psoas muscle at ~ L_3, passes behind the ureter and peritoneum, and just above the inguinal ligament, divides into its terminal branches,

1. *genital branch*
   - crosses the termination of the external iliac artery and enters the spermatic cord
   - supplies the cremaster muscle and skin over the scrotum and adjacent thigh
   - in the female, the nerve accompanies the round ligament and supplies the skin over the anterior labium majus and mons vernis
2. *femoral branch*
   - descends on the external iliac artery, passes under the inguinal ligament, pierces the deep fascia just lateral to the origin of the femoral artery
   - supplies a small area of skin (~ a hands size) immediately below the groin crease

NB: this is the pathway involved in the ***cremasteric reflex*** in males

Lateral Cutaneous Nerve Of The Thigh

• emerges from the lateral border of psoas, immediately ***below*** the ilioinguinal nerve
• crosses the iliac fossa in front of the iliacus muscle and enters the thigh behind the lateral end of the inguinal ligament, over the origin of sartorius, dividing into the,

1. *anterior branch*
   - supplies the antero-lateral aspect of the thigh to the knee
   - links with branches of the intermediate cutaneous nerve of the thigh and the infrapatella branch of the saphenous nerve, to form the ***patella plexus***
2. *posterior branch*
   - penetrates the fascia lata to supply the lateral leg, from the greater trochanter to the mid-thigh

• occasionally arises from the femoral nerve, not separately from the plexus
• may pierce, rather than pass beneath the inguinal ligament, with resulting ***meralgia paraesthetica***

Femoral Nerve L_{2-3-4}

- the largest nerve of the lumbar plexus, supplying the muscles and skin of the anterior thigh
- emerges from the lateral border of psoas, running between the psoas and iliacus muscles
- supplies branches to both of these muscles
- enters the thigh beneath the ***fascia iliaca***, lying on iliacus, behind the inguinal ligament
- it is ~1 cm ***lateral*** to the femoral sheath, separated from the femoral artery by a portion of psoas
- terminates into its two divisions ~ 4cm below the ligament,

1. ***anterior division*** * 2 muscular & 2 cutaneous branches
   i. nerve to ***sartorius***
   ii. nerve to ***pectineus***
   iii. *medial cutaneous nerve of the thigh*
   iv. *intermediate cutaneous nerves*
2. ***posterior division***
   i. ***saphenous nerve***
   ii. muscular branches to the ***quadriceps muscles***
   iii. articular branches to the hip and knee

- the ***lateral, intermediate*** and ***medial cutaneous nerves*** penetrate the deep fascia in order, roughly along an oblique line formed by sartorius
- the ***intermediate cutaneous nerve*** supplies skin over the anterior thigh to the knee
- the ***medial cutaneous nerve*** passes medially across the femoral vessels, dividing into anterior and posterior branches
  - the *anterior branch* supplies skin over the medial, lower thigh as far as the knee, where it joins the patella plexus
  - the *posterior branch* runs behind sartorius, piercing the deep fascia at the knee, supplying skin over the medial side of the leg (with the obturator nerve)

- the ***muscular branches of the posterior division*** supply the quadriceps femoris
- rectus femoris is the only muscle of the group to also act on the hip, and its nerve is the only one to supply an articular branch to the hip in addition to the knee (Hilton's law)
- the other 3 nerves send articular branches to the knee only

- the ***saphenous nerve*** is the largest of the cutaneous branches, and the only one to emanate from the posterior division
- arises in the femoral triangle and runs inferomedially, descending lateral to the artery
- enters the adductor canal of Hunter, where it crosses the artery to lie on its medial side
- it then pierces the deep fascia on the medial side of the knee, after emerging between the tendons of gracilis and sartorius
- from there it runs down the medial side border of the tibia, ***posterior*** to the great saphenous vein
- passes in front of the medial malleolus, anterolateral to the vein, terminating in the region of the ball of the great toe
- extensive cutaneous supply to the ***medial*** side of the knee, leg, ankle and foot
- immediately on leaving the adductor canal it gives of an infrapatella branch, which pierces sartorius and is distributed to the knee as a part of the patella plexus

■ ***Obturator Nerve*** L_{2-3-4}

• emerges from the medial border of psoas, at the pelvic brim, in front of the SI joints
• it then crosses this muscle in its downward and forward course to the obturator canal
• on the lateral wall of the pelvis, it lies behind the common iliac vessels, emerging between the internal & external branches
• leaves the pelvis through the ***obturator canal***, above and anterior to the obturator vessels, which are derived from the internal iliacs
• the obturator canal is the upper part of the ***obturator foramen*** which is devoid of membrane
• here it divides into anterior and posterior divisions

1. ***anterior division***
   - enters the thigh above, and passes down in front of obturator externus
   - descends upon ***adductor brevis***[§], first behind pectineus then adductor longus
   - ends as a filament which runs along the femoral artery

   i. muscular branches - gracilis, adductor longus, frequently adductor brevis
   - occasionally pectineus

   ii. articular branches to the hip

   iii. a small terminal branch which supplies the femoral artery

2. ***posterior division***
   - pierces and supplies obturator externus
   - then descends on adductor magnus, behind ***adductor brevis***[§]
   - supplies adductor magnus and brevis (if not by the anterior branch)
   - ***adductor magnus*** also receives supply from the sciatic nerve
   - it then descends along the adductor canal to the popliteal fossa

   i. muscular branches - to obturator externus
   - the adductor portion of adductor magnus
   - occasionally adductor brevis

   ii. terminal articular branches to the knee joint

■ ***Clinical Relevance***

1. obturator hernia - nerve pressure and referred pain to hip
2. referred pain from the hip to the knee (femoral and obturator nerves)
3. ***obturator nerve block***
   - patient supine with the legs slightly abducted
   - the pubic spine is located and skin infiltrated ~ 1-1.5 cm below and laterally
   - needle insertion vertically through this point usually contacts the horizontal ramus of the pubic bone
   - the needle is then walked (~ 80°) up and outwards past the bony ramus to the obturator foramen
   - ~10-15 ml is injected as the needle is moved inward, better results with I/I

■ ***Accessory Obturator Nerve***

• present in ~33%, appears at the medial border of psoas and crosses the superior pubic ramus
• supplies branches to the hip joint and pectineus, and has a communicating branch to the anterior division of the obturator nerve

SACRAL & COCCYGEAL PLEXUSES

1. ***sacral plexus*** → the anterior rami of L_{4+5} and $S_{1,2,3} \pm S_4$
2. ***coccygeal plexus*** → remainder of S_4, plus S_5, and the anterior ramus of Co_1

■ ***Formation***

• the contribution from L_4 joins L_5 as the ***lumbrosacral trunk***, at the medial border of psoas
• this passes into the pelvis, in front of the SI joint and joins the anterior rami of the sacral nerves as they emerge from the anterior sacral foramina
• large contributions from $S_{1,2,3}$ join the lumbosacral trunk to form the ***sciatic nerve***
• S_5 appears from between the inferior angle of the sacrum and the transverse process of the coccyx, and Co_1 emerges below the transverse process, piercing the coccygeal muscle

■ ***Relations***

a. anteriorly
- the parietal pelvic fascia
- separates the plexus from the internal iliac vessels & branches
- the ureter
- sigmoid colon on the left & loops of ileum on the right
- the rectum

b. posteriorly
- the piriformis muscle and pelvic wall

• within the pelvic basin, the plexus is pierced by 4 arteries and veins,

1. the ilio-lumbar vessels - between L_{4-5}
2. superior gluteal vessels - between the lumbosacral trunk & S_1, or S_{1-2}
3. inferior gluteal vessels - between S_{1-2}, or S_{2-3}
4. internal pudendal vessels - between the sciatic and pudendal nerves

- ***Plexus Branches***

a. **lower limb**

i. ***sciatic nerve*** - $\mathbf{L_{4,5} + S_{1,2,3}}$
- largest nerve of the body

ii. *superior gluteal nerve* - gluteus medius and minimus
- tensor fascia lata

iii. *inferior gluteal nerve* - gluteus maximus

iv. *nerve to quadratus femoris m.* + the inferior gemellus m.

v. *nerve to obturator internus m.* + the superior gemellus m.

vi. ***posterior cutaneous n. of the thigh***- skin of the buttock and back of thigh

b. **pelvis** * muscles, viscera and perineum

i. ***pudendal nerve*** - $\mathbf{S_{2,3,4}}$
- exits the pelvis through the greater sciatic foramen
- enters the perineum via the lesser sciatic foramen

ii. *nerve to piriformis m.*

iii. *nerves to levator ani, coccygeus* and *the external anal sphincter* **(S_4)**

iv. *pelvic splanchnic nerves* - sacral parasympathetic outflow ($S_{2,3,4}$)
- all pelvic viscera

c. ***perforating cutaneous nerve*** - skin of the lower medial buttock

Muscular Collateral Branches

• ***nerve to quadratus femoris*** **(L_{4-5}, S_1)**, passes through the lower compartment of the great sciatic foramen, between the ischium and deep aspect of the sciatic nerve
• descends over the back of the hip joint, beneath the gamelli and obturator internus tendon
• ends supplying quadratus femoris, giving branches to the gemellus inferior & hip
• ***nerve to obturator internus*** **(L_5, S_{1-2})**, passes into the buttock through the great sciatic foramen, below piriformis
• crosses the ischial spine between the internal pudendal vessels medially and the sciatic nerve laterally
• supplies gemellus superior, then passes through the lesser sciatic foramen into the lateral wall of the ischio-rectal fossa, there supplying obturator internus
• ***nerve to piriformis*** **(S_{1-2})**, has a short pelvic course, directly to the muscle, occasionally bifid
• ***superior gluteal nerve*** **(L_{4-5}, S_1)**, accompanies the superior gluteal vessels, as the only structure passing through the upper compartment of the great sciatic foramen, above piriformis
• supplies gluteus medius and minimus, and the tensor fascia lata
• ***inferior gluteal nerve*** **(L_5, S_{1-2})**, passes through the lower compartment of the great sciatic foramen, to enter the deep aspect of gluteus maximus
• ***muscular branches from S_4***, pass from the trunk of S_4 to the levator ani and coccygeus
• the *perineal branch* of S_4 pierces coccygeus entering the ischiorectal fossa, and descends to supply the external anal sphincter

Cutaneous Collateral Branches

• the ***posterior cutaneous nerve of the thigh*** **(S_{1-2-3})**, emerges through the greater sciatic foramen below piriformis, on the ***medial*** side of the sciatic nerve
• descends over the back of the leg as far as the mid-calf, giving off branches to,

i. posterior aspect of the thigh, popliteal fossa and upper calf
ii. gluteal region, which hook around the lower border of gluteus maximus, to supply the infero-lateral aspect of the buttock
iii. the perineum, passing between the ischial tuberosity and the scrotum (or labium)

• the ***perforating cutaneous nerve*** **(S_{2-3})**, pierces the sacrotuberous ligament, hooks around the lower border of gluteus maximus, to supply the infero-medial aspect of the buttock
• may arise from the posterior cutaneous nerve of the thigh, or from the pudendal nerve

Collateral Visceral Branches

• the pelvic splanchnic nerves (S_{2-3}), are the white rami communicantes which transmit parasympathetic fibres to the pelvic autonomic plexuses, then the pelvic viscera

Terminal Branches - SCIATIC NERVE

• **(L_{4-5}, S_{1-2-3})** is the largest peripheral nerve of the body ≥ 1 cm wide at its flattened origin
• essentially it is composed of the ***medial & lateral popliteal nerves***, within a common fibrous sheath, dividing into these components at the apex of the popliteal fossa
• this division may occur at any level proximally, and may exist for the entire course (~10%)
• descending within the substance is the ***arteria commitans***, derived from the inferior gluteal artery

■ *Course*

• leaves the posterior pelvic wall through the greater sciatic foramen below ***piriformis***, and enters the buttock, slightly medial to the midpoint between the greater trochanter and ischial tuberosity
• descends vertically down the midline as far as the apex of the popliteal fossa
• anteriorly it rests on the following structure, in order,

i. dorsum of the ischium (nerve to quadratus femoris against the bone)
ii. gemellus superior
iii. tendon of obturator internus
iv. gemellus inferior
v. quadratus femoris
vi. adductor magnus

• the upper part is under the cover of gluteus maximus, below which it is immediately subfascial
• it is then crossed superficially, obliquely, and from the medial to the lateral side of the long head of biceps femoris

■ *Surface Markings*

• may be represented by a line commencing midway between the ischial tuberosity and the PSIS
• this curves outward and downward, to a point just medial to the midpoint between the ischial tuberosity and the greater trochanter
• from there it continues in a straight vertical line down the middle of the posterior thigh

■ *Branches*

1. muscular, *nerves to*
   i. *semitendinosus*
   ii. *semimembranosus*
   iii. *adductor magnus*
   iv. *biceps femoris*
2. articular to the hip joint
3. terminal
   i. *common peroneal nerve* - lateral popliteal
   ii. *tibial nerve* - medial popliteal

• the true hamstring muscles, which arise from the ischium, have their supply from the medial popliteal component (semitendinosus, semimembranosus, the long head of biceps)
• the ischial head of origin of adductor magnus may also be considered as a part of the hamstrings, and is similarly supplied
• the true adductor component arises from the ramus of the ischium, and is supplied by the obturator nerve
• the ***short head of biceps***, originating from the posterior femoral shaft, is developmentally part of gluteus maximus, and is the only muscle of the group innervated by the ***lateral popliteal*** component

NB: thus, only one muscular branch arises from the lateral side of the nerve

■ ***Terminal Divisions***

1.	***tibial nerve***	- medial popliteal nerve - posterior tibial below popliteus
2.	***common peroneal nerve***	- lateral popliteal nerve
	i. *superficial peroneal*	- musculocutaneous
	ii. *deep peroneal*	- anterior tibial

Tibial Nerve (medial popliteal)

• derived from roots **$L_{4\text{-}5}$, $S_{1\text{-}2\text{-}3}$**
• larger of the 2 terminal branches, usually arising at the apex of the popliteal fossa
• traverses the popliteal fossa, crossing from above downwards,

1. popliteal surface of the femur
2. posterior aspect of the capsule of the knee
3. the popliteus muscle

• above the nerve is overlapped by,

a. medially - semimembranosus & semitendinosus
b. laterally - biceps femoris
c. inferiorly - the 2 heads of gastrocnemius

• initially it lies lateral to the popliteal vessels, crossing them superficially

- ***Branches Popliteal Fossa***

1. muscular, *nerves to*
   i. *popliteus*
   ii. *gastrocnemius*
   iii. *soleus*
   iv. *plantaris*
2. cutaneous, *the* ***sural nerve***
   - arises in the popliteal fossa between the 2 heads of gastrocnemius
   - pierces the deep fascia ~ half way down the leg
   - receives the communicating branch of the common peroneal
   - descends behind the lateral malleolus, along the lateral side of the foot to the 5 th toe
3. articular to the knee

- all of the muscular branches within the popliteal fossa, arise from the lateral border (??p224)
- after giving off the sural nerve, the tibial nerve continues distal to the lower margin of popliteus
- passes under the arch of origin of soleus, to descend first on tibialis posterior, then in the lower leg, directly on the posterior tibial shaft
- above the nerve is covered by the bellies of gastrocnemius and soleus
- below it lies under the deep fascia
- the posterior tibial vessels lie initially lateral to the nerve, then cross deep (anterior) just below popliteus to lie on the medial side
- the medial → lateral → medial relationship of the vessels to the nerve is due to their lateral displacement by the anterior tibial vessels, as they pass above the interosseous membrane
- divides into its terminal branches as it passes under the medial malleolus

→ ***medial & lateral plantar nerves***

- here it lies beneath the flexor retinaculum, ~ ½ way between the malleolus and tendoarchilles

- the structures passing behind the ***medial malleolus*** are then in order,

1. tendon of tibialis posterior
2. tendon of flexor digitorum longus
3. posterior tibial vein & artery
4. posterior tibial nerve
5. tendon of flexor hallicus longus

- ***Branches Tibial Component***

1. muscular, *nerves to*
   i. *tibialis posterior*
   ii. *flexor digitorum longus*
   iii. *flexor hallicus longus*
   iv. *soleus* - dual supply, superficial and deep
2. cutaneous, the ***medial calcaneal nerve***
   - pierces the flexor retinaculum to supply the skin over the medial foot and sole
3. articular to the ankle joint
4. terminal
   i. ***medial plantar nerve***
   ii. ***lateral plantar nerve***

- ***Medial Plantar Nerve***

- is the larger, with a distribution similar to that of the median nerve in the hand, with 2 differences,
   i. the medial plantar supplies only 1, not 2 lumbricals
   ii. instead of an opponens muscle, it supplies flexor digitorum brevis

- passes deep to abductor hallicus with the medial plantar vessels, to lie between this and flexor digitorum brevis, where it breaks into its terminal branches,

1. muscular, *nerves to,*
   i. *abductor hallicus*
   ii. *flexor digitorum brevis*
   iii. *flexor hallicus brevis*
   iv. *first lumbrical*
2. cutaneous branches to,
   i. medial 2/3 of the sole of the foot
   ii. plantar aspects of the medial 3½ toes (cf. median in hand)

- ***Lateral Plantar Nerve***

• resembles approximately the ulnar nerve
• lies first under abductor hallicus, passing with the lateral plantar vessels, between flexor digitorum brevis (1st muscle layer) and flexor accessorius (2nd layer) to the base of the 5th toe
• at the lateral side of the foot, the plantar digital nerves have their origin
• the deep part of the nerve then continues back across the sole of the foot, in company with the vessels, between adductor hallicus (3rd layer) and the interossei (4th layer), supplying,

1. muscular to all those not supplied by the medial branch, *nerves to*
   i. all the *interossei*
   ii. *lumbricals 2, 3, and 4*
   iii. *adductor hallicus*
   iv. *flexor digiti minimi brevis*, and *flexor accessorius*
   v. *abductor digiti minimi*
2. cutaneous branches to,
   i. lateral 1/3 of the sole of the foot
   ii. plantar aspects of the lateral 1½ toes

Common Peroneal Nerve (lateral popliteal)

• **(L_{4-5}, S_{1-2})**, and is ~ ½ the diameter of the medial popliteal branch
• from the apex of the fossa, it passes obliquely along the medial border of biceps (ie. passing laterally), between this and the lateral head of gastrocnemius
• winds around the neck of the fibula, deep to peroneus longus, dividing into its terminal branches, the ***deep & superficial peroneal nerves***
• at this point it is the only nerve of the leg which is readily palpable and is prone to injury

- ***Branches***

1. cutaneous
   i. *the sural communicating nerve*
   ii. *lateral cutaneous nerve of the calf*
2. articular to the knee
3. terminal
   i. *deep peroneal nerve* - anterior tibial
   ii. *superficial peroneal nerve* - musculocutaneous

• the *sural communicating nerve* arises in the popliteal fossa, descends over the lateral head of gastrocnemius to join the sural nerve
• occasionally it fails to communicate and is distributed separately to the lateral side of the leg and ankle
• the *lateral cutaneous nerve of the calf*, follows the same course to supply the skin over the antero-lateral and postero-lateral aspects of the upper calf

■ ***Deep Peroneal Nerve*** ***Anterior Tibial***

• arises from the bifurcation between the neck of the fibula and peroneus longus
• passes deep to the upper part of extensor digitorum longus, reaching the anterior interosseus membrane, then in the lower 1/3 it lies on the front of the tibia
• crossing in front of the ankle joint, it forms its terminal branches
• initially the nerve lies between extensor digitorum longus and tibialis anterior
• however, extensor hallicus longus arises from the fibula (2-3/4) medial to extensor digitorum longus, and thus becomes the lateral relation to the nerve
• tibialis anterior remains the medial relation throughout
• under the extensor retinaculum, the nerve is crossed latero-medially by the extensor hallicus longus tendon, such that beneath the retinaculum, from medial to lateral structures are,

i. tibialis anterior tendon
ii. extensor hallicus longus tendon
iii. anterior tibial artery
iv. ***deep peroneal nerve***
v. extensor digitorum longus tendon(s)

• the anterior tibial artery is initially medial, as it is at the ankle, but may pass laterally behind the nerve in the middle third of the leg
• branches include,

1. muscular branches, *nerves to,*
   i. *tibialis anterior*
   ii. *extensor hallicus longus*
   iii. *extensor digitorum longus*
   iv. *peroneus tertius*
2. articular branches to the ankle joint
3. terminal branches,
   i. *medial terminal branch*
   ii. *lateral terminal branch*
   iii. *to digitorum brevis*
   iv. articular branches to the foot joints

• the *medial terminal branch* accompanies the dorsalis pedis (medial) until it passes between the bases of metatarsals 1 & 2, continuing to the web of the first 2 toes where it divides to supply the adjacent sides
• this small patch is the only sensory area of the deep peroneal nerve
• the *lateral terminal branch* passes deep to extensor digitorum brevis, which it supplies, then breaks up into branches to the joints of the foot

■ ***Superficial Peroneal Nerve*** ***Musculocutaneous***

• arises in common with the anterior tibial nerve at the neck of the fibula
• descends along the intermuscular (anterior fascial) septum, between the peroneal muscles, longus and brevis laterally, and extensor digitorum longus medially
• branches are,

1. muscular, *nerves to*
   i. *peroneus longus*
   ii. *peroneus brevis*
2. cutaneous branches to the outer aspect of the lower leg
3. terminal branches
   i. *medial terminal branch*
   ii. *lateral terminal branch*

• the *medial terminal branch* crosses in front of the ankle, then divides into a medial division which continues to the hallux, and a lateral division which splits up to supply the adjacent sides of the 2nd and 3rd toes
• the *lateral terminal branch* supplies the dorsum of the foot, then gives 2 dorsal digital branches, one to the 3rd + 4th, and one to the 4th + 5th toes

• thus, the innervation of the dorsum of the toes may be summarised,

1. sural nerve - lateral side of the 5th toe
2. deep peroneal - adjacent sides of the 1st & 2nd toes
3. superficial peroneal the remainder

Terminal Branches - Pudendal Nerve

• **(S_{2-3-4})**, provides the principal innervation of the perineum
• passes briefly from the pelvis, via the greater sciatic foramen below piriformis, through the gluteal region, accompanied laterally by the internal pudendal vessels
• crosses the dorsum of the ischial spine and re-enters the lesser sciatic foramen
• passes on the lateral wall of the ischiorectal fossa, still in company with the internal pudendal vessels, within a distinct fascial compartment on the medial aspect of obturator internus, termed the ***pudendal canal*** (Alcock's canal)
• within the canal it gives off the ***inferior rectal nerve***, which crosses the fossa to innervate the external anal sphincter and perianal skin
• then divides into the perineal nerve and the dorsal nerve of the penis (clitoris)

• the ***perineal nerve*** is the larger bifurcating almost immediately into deep & superficial branches
• the deep branch enters the deep pouch and supplies the sphincter urethrae and the muscles of the anterior perineum (ischiocevernosus, bulbospongiosus, superficial and deep transverse perinei)
• the superficial branch innervates the skin of the posterior scrotum

• the ***dorsal nerve of the penis (clitoris)***, traverses the deep perineal pouch, pierces the perineal membrane near its apex and the suspensory ligament of the penis to supply the dorsum of this structure

■ ***Pudendal Block***

• the pudendal nerve provides sensory supply to the perineum and vagina
• pain from uterine contractions is conveyed via the visceral sympathetic afferents from **T_{10}-L_1**
• sensation to the anterior perineum is not abolished by pudendal block, as this region is supplied by the ***ilioinguinal & genitofemoral nerves***, and requires local infiltration
• pudendal block is of use for,

i. low forceps delivery
ii. episiotomy and repair * especially where epidural or GA is impracticable

1. **transvaginal**
   - landmark is the ischial spine, which may be palpated either vaginally or PR
   - aspiration prior to injection of ~7-10 ml of solution
   - procedure is performed on both sides
2. **perineal approach**
   - useful when the engaged head makes vaginal palpation difficult
   - landmark is the tuberosity of the ischium, the needle being inserted slightly medial, for ~2.5 cm, paraesthesiae are seldom elicited
   - up to 8 ml of solution is injected, aiming to block the nerve in Alcock's canal
   - the needle is then withdrawn and redirected along the edges of the vulva, blocking the ilioinguinal and genitofemoral nerves
   - procedure is performed on both sides

The Sciatic Foramina

• the boundaries of these two structures are as follows,

1. ***greater sciatic foramen*** - margins of the greater sciatic notch
   - sacrotuberous ligament
   - sacrospinous ligament
2. ***lesser sciatic foramen*** - lesser sciatic notch
   - sacrotuberous ligament
   - sacrospinous ligament

• the largest structure exiting the greater foramen is the ***piriformis muscle***, which divides the foramen into upper and lower compartments, each conveying,

1. upper compartment
   - superior gluteal vessels
   - superior gluteal nerve
2. lower compartment
   * from lateral to medial
   - the sciatic nerve, overlying the
   - nerve to quadratus femoris
   - inferior gluteal nerve
   - inferior gluteal vessels
   - posterior cutaneous nerve of the thigh
   - nerve to obturator internus §
   - internal pudendal vessels §
   - the pudendal nerve §

NB: the 3 most medial structures § cross the sacrospinous ligament, or ischial spine, then re-enter the lesser foramen gaining access to the perineum

• the lesser foramen also transmits the tendon of obturator internus
• the 5 more lateral structures all cross the dorsum of the ischium and remain in the buttock or descend into the thigh

The Coccygeal Plexus

• this is small, composed of part of S_4, all of S_5 and Co_1
• forming a single trunk, the ***anococcygeal nerve***, which pierces the sacrotuberous ligament to supply the skin over the coccyx

Segmental Innervation of the Lower Limb - Sensory	
L_{1-2-3}	• supply the front of the thigh from above down
L_4	• antero-medial aspect of the leg
L_5	• antero-lateral aspect of the leg • extends onto the ***medial*** side of the foot
S_1	• ***lateral*** side of the foot and sole
S_2	• posterior surface of the leg and thigh
S_{3-4}	• buttock and perianal region
S_3 L_1	• posterior scrotum (or vulva) • anterior scrotum (or vulva)

Segmental Innervation of the Lower Limb - Motor [1]	
L_{2-3}	• flexors, adductors and medial rotators of the hip
L_{3-4}	• extensors, abductors and lateral rotators of the hip • extensors of the knee
L_5-S_1	• flexors of the knee
L_{4-5}	• dorsiflexors of the ankle
S_{1-2}	• plantar flexors of the ankle
L_4	• invertors of the ankle
L_5-S_1	• evertors of the ankle

[1] Last, 1978

NB: each joint of the lower limb is supplied by 4 consecutive roots, innervation of each joint begins at 1 level lower than the joint above, viz:

1.	hip	- flexion	L_{1-2}
		- extension	L_{3-4}
2.	knee	- extension	L_{2-3}
		- flexion	L_{4-5}
3.	ankle	- dorsiflexion	L_{3-4}
		- plantarflexion	L_5-S_1

THE AUTONOMIC NERVOUS SYSTEM

1. cerebrospinal system - brain and spinal cord
   - peripheral cranial and spinal nerves
2. autonomic system → *vegetative, visceral, or involuntary*
   - non-skeletal muscle of the heart, vessels, bronchi, GIT and pupils
   - the sweat glands
   - the adrenal medulla

• the autonomic system may be divided into ***sympathetic*** and ***parasympathetic***, on an anatomical, functional and pharmacological basis

a. **anatomical**
   - the sympathetic system has its motor cell in the lateral grey column of the thoracic and upper 2 lumbar segments of the cord
   - parasympathetics are less well defined, having a cranial outflow from nerves III, VII, IX and X, and a sacral outflow, with cell stations in the 2 nd, 3rd and occasionally the 4th sacral segments of the cord

b. **functionally**
   - the sympathetic system is concerned primarily with stress responses, and tends to have a "mass action" effect
   - the parasympathetic effects generally antagonise the sympathetic, and are more localised in their effects (see over)
   - effects are not so much "antagonistic" as reciprocal
   - not all organs receive dual innervation

c. **pharmacologically**
   - sympathetic postganglionic terminals release adrenaline and noradrenaline, with the single exception of the sweat glands (ACh)
   - parasympathetic postganglionic terminals release acetylcholine

■ *Autonomic Afferents*

• concerned with the afferent arcs of autonomic reflexes, and with the transmission of pain
• cell stations are in the ***dorsal root ganglia*** of the spinal nerves or ganglia of the cranial nerves
• fibres from the viscera ascend through the autonomic plexuses, those from the body wall are conveyed in the peripheral spinal nerves
• the afferent course of any structure is therefore along the same route as the efferent supply
• these fibres ascend centrally to the hypothalamus, then to the orbital and frontal gyri of the cortex, along unknown pathways

Physiological Responses to Cholinergic Stimulation	
Tissue	**Response**
Heart	
SA node	decrease spontaneous rate
Atria	decrease in contractility
AV node	decrease in conduction ± block
Ventricle	?? ± decrease in contractility
Lung	
Bronchial smooth muscle	constriction
Bronchial glands	increased secretion
Eye	
Sphincter muscle (iris)	contraction - myosis
Ciliary muscle	contraction - near vision
Stomach	
Gastric smooth muscle	increased motility & tone
Sphincters	relaxation
Gastric glands	increased secretion
Intestines	
Intestinal smooth muscle	increased motility & tone
Sphincters	relaxation
Intestinal glands	increased secretion
Bladder	
Detrusor	contraction
Trigone & internal sphincter	relaxation
Adrenal Medulla	increased secretion NA & A
Exocrine glands	
Pancreas	increased secretion
Salivary	increased secretion
Lacrimal	increased secretion
Pharyngeal	increased secretion
Sweat Glands	increased secretion
Sexual organs	erection (male)

SYMPATHETIC SYSTEM

• efferent fibres from the CNS arise in the ***lateral grey column*** of the thoracic and upper 2 lumbar segments of the cord
• small ***myelinated*** axons → ***anterior primary ramus***
→ ***white ramus communicates*** to the ***sympathetic trunk***

• spinal segments tend to overlap, but may be approximated by,

1. head and neck ~ T_{1-2}
2. upper limb ~ T_{2-7}
3. thoracic viscera ~ T_{1-4}
4. abdominal viscera ~ T_4-L_2
5. lower limb ~ T_{11}-L_2

■ ***The Sympathetic Trunk***

• lies in close relation to the vertebral column on each side ~ 2.5 cm from the midline
• a ganglionated nerve chain which extends from the base of the skull to the coccyx
• commences in the ***superior cervical ganglion*** beneath the skull base, descending closely behind the carotid sheath, in front of the vertebral transverse processes
• the chain enters the thorax anterior to the neck of the 1 st rib, descending over the heads of the upper ribs, coming to lie on the lateral bodies of the last 3-4 thoracic vertebrae
• within the chest it is covered by the pleura, and crosses in front of the intercostal vessels
• passes into the abdomen behind the ***medial arcuate ligament***, lying in a groove between psoas major and the vertebral bodies
• it lies in front of the lumbar arteries, but may be crossed by the lumbar veins
• the left chain is overlapped by the abdominal aorta, the right by the IVC, both passing behind the common iliac vessels to enter the pelvis anterior to the ala of the sacrum
• the trunks pass medial to the sacral foramina, terminating at the ***ganglion impar*** on the anterior surface of the coccyx

• the trunk bears a series of ganglia, containing motor cells with which preganglionic myelinated fibres synapse, and the postganglionic, nonmyelinated fibres arise
• developmentally there is 1 ganglia for each spinal nerve, however during maturation these fuse, such that there is approximately,

i. 3 cervical
ii. 12 or less thoracic
iii. 2-4 lumbar, and
iv. 4 sacral ganglia

• only the ganglia of **T_1-L_2** receive white rami directly, the remaining ganglia receive rami through ascending or descending preganglionic fibres, which traverse their respective segmental level
• other preganglionic fibres traverse the ganglia at their level, synapsing with their postganglionic cell at the target organ level

• therefore there are 3 possible courses for preganglionic myelinated (white) fibres,

1. synapse in their respective segmental ganglion
2. ascend or descend in the sympathetic chain to synapse in higher or lower ganglia
3. traverse the ganglia intact, synapsing in the target organ

• the branches of the sympathetic ganglion are divided into somatic and visceral

■ ***Somatic Afferents***

• each spinal nerve receives 1 or more ***grey rami*** from a sympathetic ganglion
• these carry postganglionic, nonmyelinated fibres which are distributed in the segmental sensory distribution of the nerve,

1. vasoconstrictor to skin arterioles
2. sudomotor to sweat glands
3. pilomotor to errectores pilorum

■ ***Visceral Afferents***

• postganglionic fibres to the head and neck ascend along the internal carotid and vertebral arteries
• those to the thoracic viscera descend to, and are distributed by the ***cardiac***, ***pulmonary*** and ***oesophageal plexuses***
• the abdominal and pelvic viscera are supplied differently, having their postganglionic cell bodies in peripheral ganglia, the ***coeliac***, ***hypogastric*** and ***pelvic plexuses***, which receive their preganglionic fibres from the ***splanchnic nerves***

■ ***Adrenal Medulla***

• has a unique supply, preganglionic fibres passing without relay through the coeliac ganglion
• the preganglionic fibres terminate directly on medullary ***chromaffin cells***, which release adrenaline and noradrenaline in response to ACh
• these cells are therefore regarded as postganglionic neurones, without axonal projections

GANGLIA of the SYMPATHETIC TRUNK

Cervical Ganglia

- 3 in total, receiving preganglionic fibres from $\mathbf{T_1}$-$\mathbf{T_7}$, supplying the head, neck and upper limb
- distributed either with the spinal nerves or with the carotid & vertebral arteries

■ ***Superior Cervical Ganglion***

- lies opposite C_{2-3} and is ~ 2.5 cm long, representing the fused ganglia of C_{1-4}
- its fibres are distributed,

1. grey rami communicantes to the upper 4 cervical nerves
2. branches forming the ***internal carotid plexus***,
   i. deep petrosal nerve to the sphenopalantine ganglion
   ii. root branch to the ciliary ganglion → dilator pupillae
   iii. fibres to the cerebral vessels and pituitary
3. branches forming the ***external carotid plexus*** and the ***otic ganglion***
   - these are vasomotor to the salivary glands
4. grey rami pass to cranial nerves - VII, IX, X, XII
5. the ***superior cardiac nerve*** descends on the,
   i. left side → superficial cardiac plexus
   ii. right side → deep cardiac plexus

■ ***Inferior Cervical Ganglion***

- lies opposite the C_7-T_1 disc space, representing C_{7-8}, immediately posterior to the vertebral vessels, or to the upper border of the subclavian artery if this is highly arched
- it is fused with the ***T_1 ganglia*** in ~ 80% to form the ***stellate ganglion***
- communicates with the middle cervical ganglion (see over) not only by the chain, but also the ***ansa subclavia***, which loops around the inferior margin of the subclavian artery, passing upwards anteriorly
- its fibres are distributed,

i. grey rami communicantes to C_{7-8}
ii. branches to the ***vertebral plexus***, travelling to the brain
iii. the ***inferior cardiac nerve*** → the deep cardiac plexus

- ***Middle Cervical Ganglion***

- lies at the level of C_6 and represents the fused ganglia of C_{5-6}
- this is small and not always present, its fibres are distributed,
    - i. grey rami communicantes to C_{5-6}
    - ii. a thyroid branch, with the inferior thyroid artery
    - iii. the ***middle cardiac nerve*** → the deep cardiac plexus

The Thoracic Ganglia

- usually 12 however may be reduced by fusion, most commonly T_1 with the inferior cervical
- each ganglia is connected to its spinal nerve by white and grey rami communicantes
- its fibres are distributed,

1. grey rami communicantes to intercostal nerves
2. branches from $\mathbf{T_{2-3-4}}$ to the cardiac, posterior pulmonary, and oesophageal plexuses
3. fibres to the wall of the aorta
4. the splanchnic nerves, which originate as follows,
    - i. ***the greater splanchnic nerve*** - $\mathbf{T_{5-9}}$ ($\pm T_{10}$)
        - passes obliquely downward on the sides of the vertebral bodies
        - lies on the lateral side of the azygous and hemiazygous veins
        - pierces the crus of the diaphragm to join the ***coeliac ganglion***
    - ii. ***the lesser splanchnic nerve*** - $\mathbf{T_{9-10}}$ or $\mathbf{T_{10-11}}$
        - also pierces the crus of the diaphragm to join the ***coeliac ganglion***
    - iii. ***the least (lower) splanchnic nerve*** - $\mathbf{T_{11-12}}$ or $\mathbf{T_{12}}$
        - arises from the lowest available thoracic ganglia
        - either pierces the crus, or passes behind the medial arcuate ligament to join the ***renal plexus***

The Lumbar Ganglia

- usually 4 in total, the upper 2 receiving white rami from the corresponding spinal nerves
- lies on the antero-lateral vertebral bodies, separated from these by the anterior ligament
- overlapped by the aorta on the left and the IVC on the right
- its fibres are distributed,

1. grey rami communicantes to lumbar nerves
2. branches to the ***aortic plexus***
3. branches along the common iliac vessels to the ***hypogastric plexus***

The Cardiac Plexus

- divided into superficial and deep parts, which communicate freely
- the ***superficial cardiac plexus*** lies in front of the PA, sheltered by the arch of the aorta
- it receives the,
    i. superior cardiac nerve from the left superior cervical ganglion
    ii. lower cardiac branch of the left vagus

- branches pass to the deep cardiac plexus, the left anterior pulmonary plexus, and a plexus along the right coronary artery
- the ***deep cardiac plexus*** lies in front of the tracheal bifurcation, behind the aortic arch
- it receives branches from,
    i. all input from the ***cervical ganglia***, except the left superior
        - all of the right cervical ganglia
        - the middle and inferior cervical ganglia on the left
    ii. the upper 4 ***thoracic ganglia***
    iii. cardiac branches from both ***vagi***

- branches pass to the pulmonary plexuses at the lung hila, and along plexuses with the left and right coronary arteries

The Coeliac Plexus

- is the largest sympathetic plexus, surrounding the root of the coeliac artery at ~ $\mathbf{L_1}$
- a dense felt of fibres condense into right and left ganglia, each ~ 2.5 cm diameter, which lie on the crura of the diaphragm
- the right is overlapped by the IVC, the left by the pancreas and splenic artery
- it receives the greater and lesser splanchnic nerves, and the coeliac branch of the right vagus
- a large contribution traverses the plexus passing to the ***adrenal medulla***
- the remainder of the plexus spreads over the aorta, as the ***aortic plexus***, which receives rami communicantes from the lumbar nerves
- this then forms the respective plexuses of the ***aortic branches***,
    i. phrenic
    ii. hepatic
    iii. splenic
    iv. left gastric
    v. renal
    vi. mesenteric, and
    vii. testicular (ovarian) plexuses

The Pelvic Sympathetic Trunk

- continuous above, behind the common iliac vessels, with the abdominal sympathetic trunk
- runs behind the rectum on the front of the sacrum, ***medial*** to the sacral foramina
- the trunk has 4-5 segmentally arranged ganglia before uniting in front of the coccyx
- branches of the trunk include

a. grey rami communicantes - sacral & coccygeal spinal nerves

b. fibres to the pelvic plexus

NB: ***no white rami*** communicantes pass to this part of the sympathetic trunk

Superior Hypogastric Plexus (Presacral Nerve)

- lies retroperitoneally, in front of the sacral promontory, between the common iliac arteries
- formed from the aortic sympathetic plexus and branches of the lumbar sympathetic ganglia
- as it enters the pelvis it divides into right & left branches, the ***inferior hypogastric plexuses***, which then join the pelvic sympathetic trunk
- each inferior hypogastric plexus runs on the medial side of the internal iliac vessels and lateral to the rectum, and is joined by ***parasympathetic fibres*** from the ***pelvic splanchnic nerves***
- thus, they contain both sympathetic & parasympathetic fibres, which are distributed along with the vessels

Higher Sympathetic Centres

- located in the brainstem, hypothalamic and cerebrocortical levels
- those of the brainstem are situated close to the midline, in the floor of the pons and 4 th ventricle, forming the ***vasomotor centres***
- the cortical and hypothalamic centres form the ***limbic system***, made up of,

i. the cingulate gyrus
ii. the hippocampal gyrus and uncus
iii. the anterior thalamic nuclei
iv. the amygdala and hypothalamus

- fibres can be traced from the ***lateral grey columns***, through the medulla to the limbic area

Stellate Ganglion Blockade CervicoThoracic

■ *Regional Anatomy*

• lies in a fascial space limited posteriorly by the fascia over the prevertebral muscles, and anteriorly by the carotid sheath
• derived from T_{1-6} levels, which converge and pass anterior to the neck of the 1 st rib
• the first thoracic and lower cervical ganglia may be separate, or fused as the "stellate" ganglion
• covered anteriorly in its lower aspect by the dome of the pleura, and above by the vertebral artery
• block of the ganglion alone may be ***unsuccessful*** due to,

1. the diverse origin of fibres in the thoracic cord, and
2. some preganglionic fibres bypass the stellate ganglion completely

NB: for best results local anaesthetic must fill the space in front of the prevertebral fascia to the level of T_4,
requiring injection of ~ 15-20 ml at the C_6 transverse process level

■ *Technique*

• there is little advantage in attaining a C_7 needle placement, as the risk of pneumothorax increases
• therefore use the C_6 technique described by ***Leriche***, relying on a large volume of dilute solution

1. secure reliable IV access
2. posture - supine
   - head slightly forward on a thin pillow to
   - mouth slightly open to relax the neck muscles
3. the trachea and carotid pulse are palpated between the trachea and sternomastoid, to find Chassaignac's tubercle on C_6 (~ the level of the cricoid cartilage), these two fingers then gently pull aside the carotid and sternomastoid
4. the skin is infiltrated with local anaesthetic
5. a 22G SB needle is inserted perpendicular to the skin, until it reaches bone, ie. the junction of the C_6 body and transverse process, the needle is then withdrawn ~ 2 mm and aspirated
6. a test dose of ~ 2 ml of solution is injected
   - Cousins, ≤ 0.5 ml directly into the vertebral artery may result in convulsion
7. the full dose of 15-20 ml of dilute solution is injected
   - the patient must not talk during injection
   - they will usually feel a lump in the throat & may be temporarily hoarse
   - foods and fluids should be withheld while laryngeal reflexes are impaired

- ***Signs Of A Successful Block ® Horner's Syndrome***

1. ptosis, myosis, enophthalmos
2. unilateral nasal congestion
3. flushing of the skin and conjunctiva
4. anhidrosis

- ***Complications***

1. ***common***
   - i. temporary hoarseness, "lump" in the throat
     - recurrent laryngeal nerve blockade
   - ii. Horner's syndrome - not a complication but a side-effect (NB: MCQ)
   - iii. haematoma
   - iv. neuralgia - along the anterior chest wall & upper arm
2. ***uncommon***
   - i. brachial plexus involvement
   - ii. phrenic nerve block
   - iii. pneumothorax
   - iv. oesophageal perforation, laceration
   - v. transverse process osteitis
3. ***severe***
   - i. vertebral artery injection → CNS symptoms
   - ii. intradural injection

- ***Chemical Stellate Ganglion Block***

- usually use 1-2 ml of 6% aqueous phenol, or 10% phenol in Conray dye
- this will interrupt the cervical chain but not produce complete cervicothoracic sympathetic blockade
- this is not a commonly practised technique due to the proximity of the pleura and somatic nerves
- the arm may partially escape, requiring supplementation of the block at T_{2-3}

Lumbar Sympathetic Blockade

Regional Anatomy

• lies in a fascial plane close to the antero-lateral vertebral bodies, separated from the somatic nerves by the ***psoas muscle*** and fascia
• theoretically 1 injection at L_2 or L_3 should be adequate to achieve longitudinal spread
• however, many still use a multiple injection technique, especially with neurolytic agents, as this limits lateral spread
• Cherry, in a blind cadaver study, found,

1. the position of the chain to be remarkably constant
2. 95% of blind passes being through the lumbar chain
3. 90% of those which missed passed lateral to the chain

Two Needle Technique Mandl

• first introduced by Mandl in 1926

1. secure reliable IV access
2. posture - lateral on a table with a C-arm image intensifier
3. the spinous processes of L_1-L_4 are marked as reference points,
   - L_1 ~ line between lower borders of 12th ribs
   - L_4 ~ line between the posterior superior iliac crests
   - checked under I/I using radiopaque marker for neurolytic blockade
4. a subcutaneous wheel is raised 8-10 cm lateral to the midpoint of L_2 and L_4 also injected subcutaneously and IM at ~ 45 ° toward the transverse process
5. a 12 cm 19-20G needle in introduced until it reaches the transverse process
   - this distance is usually ~ ½ the distance to the vertebral body
   - some use a rubber marker set at 2x the distance
6. the needle is then reintroduced and directed slightly medially, to pass between the transverse processes, with the bevel facing the vertebral body
   - when bone is reached the needle angle is changed slightly to allow the needle to "slip-off" the anterior aspect of the vertebral body
   - correct position can be verified by a "loss of resistance" technique with saline
7. the needle is then aspirated and a small amount of radiographic contrast injected to confirm placement

8. solution is injected according to type of blockade required,
   i. local anaesthesia - bupivacaine 0.25% 10-20 ml per level, or 20-30 ml at one level
      - eg. for renal colic
   ii. diagnostic block - 1-5 ml of local anaesthetic mixed with Conray
   iii. neurolysis ~ 2 ml of 7-10% phenol in Conray per level
      • absolute alcohol → high incidence of L_1 neuralgia
   iv. continuous catheter techniques
9. immediately prior to needle removal, ~ 0.5 ml of air is injected to prevent tracking phenol backwards along the needle path (possibly near somatic roots)
10. patients are kept on their sides for ~ 5 minutes to prevent the solution tracking,
    i. laterally and involving the ***genitofemoral nerve***
    ii. posteriorly between the slips of origin of psoas major and along the fibrous tunnel occupied by the ***rami communicantes*** of the spinal nerves
11. patients should be observed in recovery for at least 1 hour

- ***Complications***

1. puncture of a major vessel or the renal pelvis
2. subarachnoid injection
3. neuralgia ~ 5-10% pain in the groin (genitofemoral nerve)
4. somatic nerve damage ~ 1% neuralgia
5. perforation of a disc
6. stricture of the ureter following neurolytic injection
7. infection from continuous catheter techniques
8. failure of ejaculation - bilateral block in young males
9. chronic back pain

NB: old, frequently severely debilitated patients with concomitant diseases, major risks, even with sedation

Intravenous Regional Sympathetic Blockade

• ***guanethedine***, Ismelin, has a high affinity for sympathetic nerve endings, where it displaces noradrenaline from presynaptic vesicles and prevents its re-uptake
• intravenous regional sympathetic blockade (IVRS) based upon a "Bier's block" technique results in long-lasting blockade
• guanethedine has the advantage over ***reserpine*** that,

1. it ***does not*** cross the BBB, and
2. controlled studies have shown that only the former significantly increased skin temperature following "cold-challenge", and that this effect lasted 3 days

• further, comparative studies with stellate ganglion block in the management of RSD, showed IVRS produced similar clinical effects, when performed every 4 days, to the former when performed every other day
• placebo studies have shown an increase in skin blood flow, but not temperature 7 days post-blockade

IVRS Advantages

1. less "invasive" and uncomfortable for patients
2. results in a significant modification of noradrenergic activity
   - increase skin blood flow and decreased pain
3. the effects last longer than those of stellate ganglion blockade
   - 4-7 days cf. 1 day or less !
   - however, ***cholinergic activity*** is not altered (sweating unchanged)

Technique

1. secure reliable IV access in both arms
2. place a double tourniquet on the affected arm & esanguinate the limb prior to inflation
3. ***guanethedine 10-20 mg*** in 25 ml of normal saline + 500 ^{U} of heparin
   - injected slowly & the cuff kept inflated for 10-15 minutes
   - some dilute the drug in prilocaine 0.5% to reduce patient discomfort
4. the cuff is deflated slowly, observing the patients, who remains supine until the BP has stabilised

PARASYMPATHETIC SYSTEM

• ***myelinated preganglionic fibres*** synapse with ganglion cells located in, or close to, the target viscera
• postganglionic cells are therefore short, and the pattern of stimulation tends to be ***discrete***

■ ***Cranial Outflow***

• conveyed in cranial nerves III, VII, IX, and X, of which the later is the most widely distributed
• functions of this group include,

i. oculomotor (III)
   - relayed by the ***ciliary ganglion***
   - innervates the ***sphincter pupillae*** and the ***ciliary muscle*** (accommodation)

ii. facial (VII)
   - relayed by the ***sphenopalantine & submandibular ganglia***
   - secretomotor to the salivary and lacrimal glands

iii. glossopharyngeal (IX)
   - relayed by the ***otic ganglion***
   - secretomotor to the parotid gland

iv. vagus (X)
   - contributes to all of the above, except innervation of the eye and secretomotor to the salivary and lacrimal glands
   - functions being sensory, motor and secretomotor
   - distributed to cardiac, pulmonary and alimentary plexuses
   - also to the mesenteric plexuses of Meissner and Auerbach

■ ***Pelvic Splanchnic Nerves Nervi Erigentes***

• constitute the pelvic ***parasympathetic*** outflow and contain ***preganglionic*** fibres from $S_{2,3,4}$
• some fibres ascend in the inferior hypogastric plexuses, reaching the superior hypogastric, aortic and ***inferior mesenteric*** plexuses
• fibres are then distributed along the inferior mesenteric artery to supply the colon from the left colic flexur to the upper half of the anal canal
• the postganglionic cell bodies are located in either the inferior mesenteric plexus or in the walls of the viscera

■ ***Afferent Parasympathetic Fibres***

• visceral afferent fibres from the heart, lung and GIT are conveyed via the vagus to the ***nodose ganglion***, and then to the ***dorsal nucleus of the vagus***
• sacral afferents are responsible for visceral pain from the bladder, prostate, rectum and uterus

• although afferent fibres travel in both sympathetic and parasympathetic systems, they ***do not*** relay in autonomic ganglia, but terminate in the dorsal nuclei of spinal and cranial nerves

THE CRANIAL NERVES

• there are 12 pairs of cranial (peripheral) nerves emerging from the brain
• the first 2 are atypical,

1. ***olfactory nerve*** - an unmyelinated central process of the olfactory sensory cells
2. ***optic nerve*** - represents a tract drawn down from the brain during development

• the remaining 10 pairs have a somewhat similar architecture
• the nuclei of the "true" cranial nerves are situated in the pons and medulla
• as for the spinal cord, these receive afferent input into the dorsal grey columns and relay to postsynaptic efferent cells in the anterior grey columns
• thus the cranial nuclei may be grouped into ***posterior afferent***, and ***anterior efferent*** groups
• in development, the primitive tubular hindbrain resembles the spinal cord, being divided into a dorsal (alar) lamina, and a ventral (basal) lamina, separated by the sulcus limitans
• near the ***pons***, the roof becomes stretched and the floor flattened, forming the ***4th ventricle***

■ *Basal Lamina Ventral*

• within this 3 discontinuous columns of motor cells develop,

1. **somatic efferent column**
   - the most ventrally placed and is equivalent to the spinal anterior horn cells
   - represented by the motor nuclei of III, IV, VI and XII
   - innervates those muscles of the head which are of ***myotomic origin***,

   i. extrinsic muscles of the eye
   ii. muscles of the tongue

2. **branchial efferent column**
   - placed rather more dorsally, and has no equivalent in the spinal column
   - innervates the muscles derived from the ***branchial arches***,

   i. 1st arch - motor nucleus of V
   ii. 2nd arch - motor nucleus of VII
   iii. 3rd arch - motor nucleus of IX
   iv. 4th + 6th arches - nucleus ambiguus of X

3. **general visceral efferent column**
   - most dorsal of the 3, comparable to the lateral grey column of the spinal cord, and similarly is concerned with visceral autonomic innervation,

   i. Edinger-Westphal nucleus - III
   ii. superior salivary nucleus - VII
   iii. inferior salivary nucleus - IX
   iv. dorsal motor nucleus of X - X

■ ***Alar Lamina Dorsal***

• 4 cells groups which receive afferent fibres can be distinguished,

1. **special somatic afferent column**
   - or audio-lateral column, is most dorsally placed
   - receives input from the ***cochlea & vestibular apparatus***
2. **general somatic afferent column**
   - is next in line, and is concerned with sensory innervation of the face
   - comprises the sensory nucleus of V
3. **special visceral afferent column**
   - receives input mediating ***taste***
   - lies in the nucleus of the tractus solitarius, in the central grey matter of the medulla

   i. chordae tympani fibres of VII

   ii. gustatory fibres from IX and X
4. **general visceral afferent column**
   - is placed nearest the equator of the medulla and receives visceral afferents
   - represented by the sensory component of the dorsal nucleus of the vagus

THE OLFACTORY NERVE I

• unlike other visceral afferent fibres, fibres are the central processes of the olfactory cells
• not the peripheral processes of a central group of ganglion cells
• the central processes of the olfactory receptors pass upwards from the olfactory mucosa, in ~ 20 nerve bundles, through the cribriform plate and terminate synapsing with dendrites of ***mitral cells*** in the ***olfactory bulbs***
• as the bundles pierce the cribriform plate, they receive a sheath of meninges, which blends with the extracranial neurilemma
• axons of these cells pass backwards in the ***olfactory tract***, terminating in the cortex of the ***uncus*** and the region of the anterior perforated space

■ ***Clinical Features***

• the hippocampus-fornix system *is not* directly associated with olfaction
• unilateral anosmia may be an important early sign of frontal lobe tumours
• tumours in the uncinate region may produce fits with olfactory hallucinations
• bilateral anosmia may result from cribriform plate fractures
• the continuation of the meninges & extracranial neurilemma provides a route for ***infection***

THE OPTIC NERVE II

• this is not a true cranial nerve, but a ***tract of the CNS***, drawn out from the cerebrum
• it develops along with the ***retina***, as a lateral diverticulum of the forebrain
• its fibres are devoid of neurilemmal sheaths, and like other brain fibres, are incapable of regeneration after division
• an extension of the meninges, containing CSF, fuses with the connective tissue of the sclera
• functionally the retina has 3 cell layers,

1. a receptor cell layer - containing rods and cones
2. an intermediate layer - of bipolar cells
3. a ganglion cell layer

• fibres from the later converge on the ***optic disc***, piercing the sclera to form the ***optic nerve***
• this passes backwards & medially to the ***optic groove*** on the dorsum of the body of the ***sphenoid***
• the *intraorbital* part of the nerve is ~ 2.5 cm long, surrounded by the extraocular muscles and periorbital fat, with the ***ciliary ganglion*** lying laterally
• in the ***optic foramen*** the nerve lies supero-medially to the ophthalmic artery
• the central artery and vein of the retina enter the nerve ~ ½ way along this segment
• the *intracranial* part is ~ 1.25 cm long, passing medial to the internal carotid to reach the ***optic chiasma***, in which,

a. fibres from the ***medial*** retina cross over, passing back in the ***contralateral*** optic tract
b. fibres from the ***lateral*** retina continue in the ***ipsilateral*** optic tract

• most fibres of the ***optic tract*** end in the 6 layered ***lateral geniculate body*** of the thalamus
• a small number, serving pupillary and ocular reflexes, bypass the geniculate body to reach the ***superior corpus quadrigeminum***
• from the geniculate body, fibres sweep back & laterally as the ***optic radiation***, to the ***occipital visual cortex,*** such that the upper & lower halves of the retina are represented in the upper & lower lips of the fissure respectively
• the central retina (macula) has a far greater cortical representation, in keeping with its greater visual acuity

■ ***Clinical Features***

• lesions of the retina or optic nerve result ***unilateral*** visual defects in the affected segment
• lesions of the optic tract or central pathways produce ***homonymous*** field defects
• lesions of the optic chiasma result in ***bitemporal*** hemianopia

■ ***Optic Nerve - Anatomical Pathway***

i. retina
ii. optic nerve
iii. optic decussation at chiasma
iv. lateral geniculate body in thalamus
v. optic radiation
vi. calcarine cortex (occipital lobes)

THE OCULOMOTOR NERVE III

• supplies all of the ***extrinsic muscles of the eye***, except the lateral rectus & superior oblique
• conveys preganglionic sympathetic fibres for the ***sphincter pupillae & ciliary muscle***
• its nucleus of origin lies in the floor of the cerebral aqueduct, at the level of the superior corpus quadrigeminum, and consists of 2 parts,

1. somatic efferent nucleus - supplying the extraocular muscles
2. Edinger-Westphal nucleus - of the general visceral efferent column

• the somatic nuclei of the 3 nerves controlling the extraocular muscles have identical central connections,

1. ***voluntary*** eye movements are controlled by fibres which descend in the pyramidal tract from the contralateral motor cortex
2. ***reflex*** eye movements depend upon impulses received from the visual cortex and vestibular apparatus, thus, the 3 nuclei are linked to the,
   i. occipital cortex by the superior corpus quadrigeminum and the tectobulbar tract
   ii. vestibular part of VIII by the medial longitudinal bundle

• in addition, the Edinger-Westphal nucleus of III receives fibres from the optic nerve, via the superior corpus quadrigeminum, which subserve the ***light reflex***
• from the 2 nuclei of III, fibres pass vertically through the midbrain tegmentum, emerging medial to the cerebral peduncle
• passing forwards between the superior cerebellar peduncles and the posterior cerebral arteries, the nerve pierces the dura to run in the lateral wall of the ***cavernous sinus*** to the superior orbital fissure
• before entering the fissure, it divides into a ***superior & inferior branch***, both of which enter the orbit through the common tendinous ring of the extraocular muscles, to supply,

a. superior branch - superior rectus muscle & levator palpebrae superioris
   - crosses lateral to the optic nerve
b. inferior branch - the medial rectus, inferior rectus and inferior oblique
   - carries parasympathetic fibres to the ***ciliary ganglion***

■ ***Clinical Features***

• complete division of III results in,

1. ptosis - due to paralysis of levator palpebrae superioris
2. divergent squint - unopposed action of the lateral rectus and superior oblique
3. mydriasis - unopposed action of the sympathetic fibres
4. cycloplegia & loss of light reflexes, due to ciliary muscle paralysis
5. double vision

THE TROCHLEAR NERVE IV

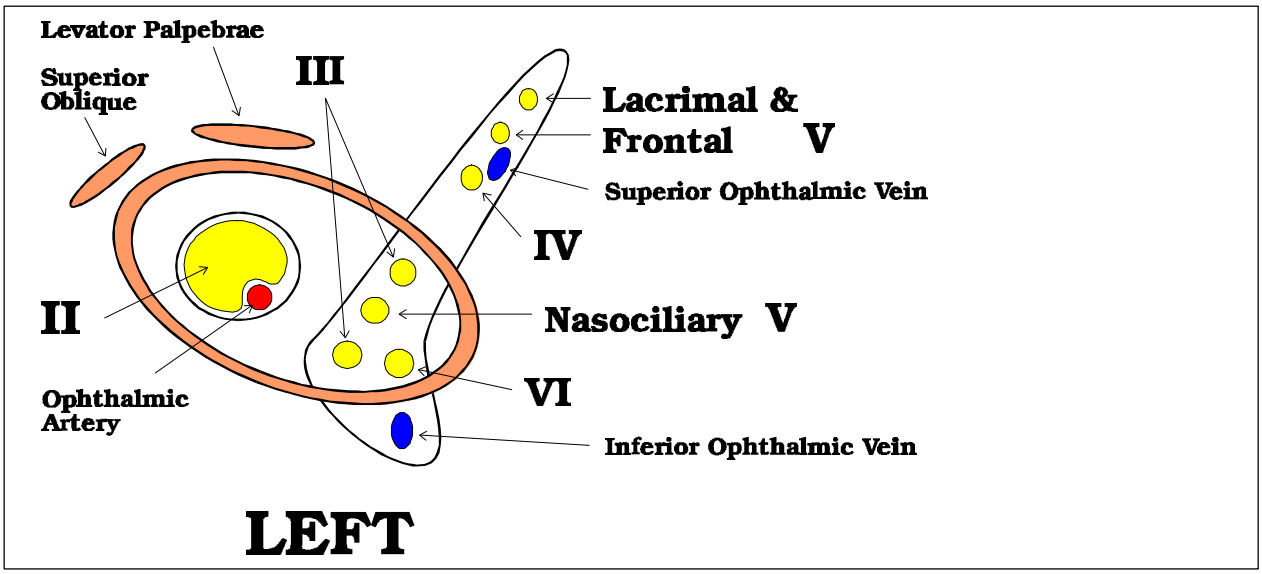
- smallest of the cranial nerves, supplying only 1 muscle, the ***superior oblique***
- its nucleus lies in about the same position as that of III
- fibres pass dorsally around the cerebral aqueduct, and decussate in the superior medullary velum
- fibres emerge immediately behind the inferior corpus quadrigeminum, wind around the cerebral peduncle, passing forwards between the superior cerebellar peduncles and the posterior cerebral arteries to pierce the dura
- it runs in the lateral wall of the cavernous sinus, between III and V
- enters the superior orbital fissure, outside and lateral to the common tendinous ring
- passing medially over the optic nerve to enter the superior oblique muscle

THE ABDUCENT NERVE VI

- also supplies only 1 eye muscle, the ***lateral rectus***
- its nucleus is part of the somatic efferent column, and lies in the floor of the 4 th ventricle
- fibres pass through the pontine tegmentum, to emerge on the base of the brain at the junction of the pons and medulla, then forward to the cavernous sinus
- here it lies lateral to the internal carotid, and medial to III, IV, and V
- enters the orbit via the superior orbital fissure, through to the common tendinous ring, just below the oculomotor nerve, then to the deep surface of the lateral rectus

- ***Clinical Significance***

1. trochlear nerve palsy → ***diplopia***, looking down & laterally
2. due to the long and oblique course of VI, it is frequently involved in fractures of the base of the skull → ***diplopia & convergent squint***



THE TRIGEMINAL NERVE V

- largest of the cranial nerves → a large sensory and small motor root associated with four autonomic ganglia

a. *sensory branches*,
   - the face and scalp as far back as the vertex
   - mucosa of the nasal cavity, accessory nasal sinuses and much of the nasopharynx
   - the orbit and eyeball
   - mucosa of the mouth, gums and palate
   - the anterior 2/3 of the tongue and teeth
   - meningeal branches to the middle and anterior cranial fossae

b. *motor branches*,
   - the muscles of mastication
   - mylohyoid, and anterior belly of digastric
   - tensors palati and tympani

c. *ganglionic branches*,
   - ciliary, sphenopalantine, submandibular and otic ganglia

- the ***motor nucleus***, which belongs to the branchial efferent column, is situated in the upper pons, immediately below the floor of the 4 th ventricle
- it receives corticobulbar fibres from ***both sides*** of the cerebral motor cortex, predominantly from the contralateral side

- the ***sensory nucleus***, which belongs to the general somatic afferent column, is in 3 parts,

1. *mesencephalic nucleus of the trigeminal nerve*
   - ascending fibres in the central grey matter of the midbrain
   - subserves mainly proprioception
2. *superior (principal) sensory nucleus of V*
   - ascending fibres in the central grey matter of the midbrain
   - lies on the lateral side of the motor nucleus, separating this from the superior cerebellar peduncle
   - subserves mainly touch
3. *nucleus of the spinal tract of V*
   - descending fibres running the whole length of the pons and medulla constitute the spinal tract
   - this blends inferiorly with the substantia gelatinosa, where afferent nerves synapse with the lateral reticular formation
   - these nerves "cap" the posterior horn of the spinal grey matter
   - the nucleus lies immediately deep to the tract, and runs from the superior nucleus rostrally to the spinal cord caudally
   - subserves mainly pain and temperature

• within the nucleus of the ***spinal tract*** there is an orderly representation of the 3 divisions of V,

1. the ophthalmic (V_1) fibres terminate caudally
2. the maxillary (V_2) follow, and
3. the mandibular (V_3) terminate most rostrally

NB: the fibres are distributed in echelon, such that V_3 are dorsal and V_1 ventral
ie., they are layered in inverse order, V_3 top & back, V_1 bottom & anterior

• this localisation of pain & temperature fibres dorsally is the basis of medullary tractotomy for trigeminal neuralgia, hopefully preserving other sensory modalities to the face
• the 2 roots of the nerve emerge from the ventro-lateral aspect of the pons, near its upper border
• the larger, lateral root is sensory, and the s maller, ***m***edial root is ***m***otor
• the nerve passes ventrally through the ***cisterna pontis***, and travels for ~ 1cm before the sensory root enlarges as the ***trigeminal ganglion***

■ ***The Trigeminal Ganglion***

• also termed the semilunar or ***Gasserian ganglion***
• equivalent to a spinal dorsal root ganglion, being the 1st cell station for sensory neurones
• situated within an invaginated pocket of dura, ***Meckel's cave***, which contains CSF
• this is immediately inferior to the anterior attachment of the tentorium cerebelli
• it lies in the ***middle cranial fossa***, in a hollow near the apex of the petrous temporal bone, and overlaps onto the cartilage which fills the foramen lacerum
• the motor root and the greater superficial petrosal nerve both pass deep to the ganglion
• above lies the hippocampal gyrus of the temporal lobe, medially the internal carotid artery and the posterior part of the cavernous sinus
• from the antero-inferior aspect of the ganglion the 3 branches of V emerge,

1. **V_1** ***ophthalmic division***
   - dividing into 3 branches - lacrimal
     - frontal
     - nasociliary
   - passing forward and upwards through the ***superior orbital fissure***
2. **V_2** ***maxillary division***
   - passing through the ***foramen rotundum*** into the pterygopalantine fossa
3. **V_3** ***mandibular division***
   - passing downward through the ***foramen ovale*** into the infratemporal fossa

■ ***Trigeminal Ganglion Blockade***

• under XRay control, a 8-10 cm 22G needle is inserted,

i. ~ 1.5 cm lateral to the border of the mouth
~ opposite the 2nd molar

ii. next to the medial border of the masseter muscle

iii. directed rostrally and medially → midpoint of the zygomatic arch laterally
midpoint of the pupil anteriorly

• this will usually reach the roof of the infratemporal fossa (floor of middle cranial fossa)
• the needle is then adjusted until it passes through the ***foramen ovale***, which frequently causes paraesthesiae, advancing ≤ 1 cm
• paraesthesiae in V_3 may be elicited in the infratemporal fossa, and V_2 or V_1 sensation is required to confirm placement
• prior to injection, aspiration is mandatory due to the proximity of the dura
• complications include,

i. facial pain for several days following the procedure ± bruising

ii. CSF injection
- as little as 0.25 ml of 1% lignocaine has resulted in unconsciousness and ipsilateral cranial nerve paralysis
- hyperbaric solutions tend to spill over the free margin of the tentorium cerebelli, affecting immediately VI, VIII, IX, X, XI, and XII

iii. ~ 10-20% develop some degree of corneal hypoaesthesia

iv. paresis of the muscles of mastication occurs rarely and is usually transient

The Ophthalmic Nerve V_1

• this is entirely sensory, supplying,

i. the eyeball and conjunctiva

ii. the upper eyelid and adjacent lacrimal gland

iii. skin of the forehead, nose and scalp as far back as the vertex

iv. mucous membranes of the medial & lateral walls of the anterior part of the nose

v. the adjacent ethmoid and frontal sinuses

• it passes along the lateral wall of the cavernous sinus, below III and IV, reaching the superior orbital fissure, where it divides into its *lacrimal*, *frontal* and *nasociliary branches*

• the ***lacrimal nerve*** is the smallest of the 3, entering the lateral part of the superior orbital fissure above the common fibrous ring
• it supplies a branch to the lacrimal gland, containing parasympathetic secretomotor fibres
• these are derived from the sphenopalantine ganglion, via a communicating branch to the zygomatic branch of V_2
• then emerges at the lateral extremity of the orbit, supplying the conjunctiva and a patch of skin of the upper lid, adjacent the outer canthus

• the ***frontal nerve*** is the largest branch, passing through the superior orbital fissure above the orbital ring and levator palpebrae superioris
• within the orbit it divides into its *supraorbital & supratrochlear branches*
• the ***supraorbital nerve*** ascends through the notch (± foramen) in the supraorbital ridge
• then supplies branches to the medial side of the upper eyelid, forehead and scalp to the vertex
• the ***supratrochlear nerve*** passes above the pulley of the superior oblique to supply the skin and conjunctiva of the upper eyelid near the inner canthus, the medial part of the forehead just above the orbit, and the root of the nose

• the ***nasociliary nerve*** passes through the superior orbital fissure within the common tendinous ring, then passes above the optic nerve to the medial wall of the orbit
• here it enters the anterior ethmoidal foramen, becoming the ***anterior ethmoidal nerve***
• this runs along the anterior cranial fossa on the cribriform plate, entering the nasal cavity through an aperture near the crista galli, dividing into ***septal & lateral branches***
• the septal branch supplies the mucosa of the anterior nasal septum
• the lateral branch supplies the lateral anterior wall, then emerges between the nasal bone and cartilage as the ***external nasal nerve***, supplying the skin over the tip and ala of the nose
• thus, it supplies the tip of the nose on both inner and outer aspects
• other branches of the nasociliary nerve are,

i. sensory to the *ciliary ganglion*
ii. two *long ciliary nerves*[§]
   - enter the back of the globe & carry sympathetic ***dilator pupillae*** fibres

iii. the *posterior ethmoidal nerve*
   - branches as the nerve reaches the medial wall of the orbit
   - supplies branches to the posterior ethmoidal air cells

iv. the *infratrochlear nerve*
   - branches immediately prior to the anterior ethmoidal foramen
   - leaves the orbit below the trochlear and innervates the side of the nose and the conjunctive near the inner canthus

■ ***The Ciliary Ganglion***

• lies near the apex of the orbit, between the optic nerve and the lateral rectus ~ 1mm diameter

1. parasympathetic component
   - derived from the Edinger-Westphal nucleus via III (inferior oblique branch)
   - postganglionic fibres pass in the *short ciliary nerves* (~ 6)
   - these supply the sphincter pupillae and ciliary muscles
   - stimulation results in myosis & accommodation
2. sympathetic component
   - from the superior cervical ganglion via the internal carotid plexus
3. sensory component
   - from the nasociliary branch of V_1
   - sensory & sympathetic fibres traverse the ganglion to the short ciliary nerves
   - supply sensation to the globe and dilator to sphincter pupillae

NB: most dilator fibres to the sphincter pupillae pass in the long ciliary nerves above [§]

The Maxillary Nerve V_2

- this is intermediate between V_1 and V_3 in both position and size and is entirely sensory
- it traverses 4 anatomical zones,
    i. the skull base
    ii. the pterygopalantine fossa
    iii. the infraorbital canal
    iv. the subcutaneous tissues of the cheek

- initially runs on the lower lateral wall of the cavernous sinus, below the ophthalmic nerve
- leaves the skull base through the ***foramen rotundum*** → ***pterygopalantine fossa***
- here it becomes the ***infraorbital nerve***, lying in the infraorbital groove, then the infraorbital canal of the orbital aspect of the maxilla
- emerges from the ***infraorbital foramen***, where it lies beneath levator labii superioris, dividing into branches which supply the lower eyelid, side of the nose, the cheek and upper lip
- the branches are divided into 4 groups, in accordance with its anatomical location,

1. <u>intracranial</u>
    i. ***meningeal branch*** - dura of the middle cranial fossa
2. <u>pterygopalantine fossa</u>
    i. *zygomatic nerve* - *zygomaticotemporal nerve*
    - *zygomaticofacial nerve*
    ii. *sphenopalantine nerve* - 2 roots to the sphenopalantine ganglion
    iii. *posterior superior dental nerve*
        - may be double, gives branches to each molar
        - branches to the mucosa of the maxillary sinus
3. <u>infraorbital canal</u>
    i. *middle superior dental nerve* - 2 upper premolars
    ii. *anterior superior dental nerve* - upper canine and incisor teeth
        - small branch to the mucosa of the anterior nasal floor
        - passes through the lateral wall of the inferior meatus
4. <u>facial</u>
    i. *palpebral branch* - skin of the lower eyelid and conjunctiva
    ii. *nasal* and *labial branches*

- the ***zygomatic nerve*** passes through the inferior orbital fissure, running on the lateral wall of the orbit, where it divides into its 2 branches
- the ***zygomaticotemporal nerve*** traverses the zygomaticotemporal canal to enter the temporal fossa, from where it ascends to supply the skin of the temporal region
- while still in the orbit, it gives a twig to the lacrimal nerve, carrying parasympathetic secretomotor fibres from the sphenopalantine ganglion
- the ***zygomaticofacial nerve*** pierces the zygomaticofacial foramen at the lateral aspect of the orbital floor, to reach the skin over the prominence of the cheek

The Sphenopalantine Ganglion

• closely associated with the maxillary nerve, in the deep part of the ***pterygopalantine fossa***

1. **parasympathetic component**
   - derived from the ***greater superficial petrosal nerve***, from the *geniculate ganglion* of the facial nerve
   - this traverses the petrous temporal bone, then runs on its anterior border deep to the trigeminal ganglion to enter the *foramen lacerum*
   - joined by a deep petrosal nerve, to form the ***nerve of the pterygoid canal***
   - this traverses its canal to join the ganglion
   - on leaving the ganglion these fibres are transmitted in,

   i. the zygomaticotemporal branch of V_2 to the lacrimal branch of V_1

   ii. finally to the ***lacrimal gland***

2. **sympathetic component**
   - from the internal carotid plexus, forming the ***deep petrosal nerve***, reaching the ganglion through the pterygoid canal

3. **sensory component**
   - derived from the 2 sphenopalantine branches of the maxillary nerve

• the sensory and sympathetic fibres are distributed to the nose, nasopharynx, palate and orbit, via the following branches,

a. the ***long sphenopalantine nerve***
   - passes medially through the sphenopalantine foramen, crosses the roof of the nasal cavity, then passes down and forward over the nasal septum, through the incisive foramen to reach the roof of the mouth anteriorly
   - supplies the posterior nasal roof, the septum, the gums and anterior palate in relation to the incisor teeth

b. the ***short sphenopalantine nerve***
   - also passes through the sphenopalantine foramen
   - supply the superior and middle conchae and the posterior nasal septum

c. the ***greater palatine nerve***
   - descends through the greater palatine canal, emerges on the hard palate from the greater palatine foramen
   - supplies the gums and mucosa of the hard palate to the canine teeth
   - other fibres pass back to serve both aspects of the *soft palate*
   - nasal branches pierce the perpendicular plate of the palatine bone to serve the inferior concha

d. the ***lesser palatine nerves***
   - usually 2, pass in the greater palatine canal but emerge through separate foramina on the postero-lateral hard palate, through the tubercle of the palatine bone
   - supply the soft palate, uvula and tonsil

e. the ***pharyngeal nerve***
   - passes posteriorly through the pharyngeal canal to supply the nasopharyngeal mucosa, immediately behind the orifice of the Eustachian tube

f. the ***orbital branches***
   - usually 2-3 small twigs passing through the superior orbital fissure
   - supply the adjacent periosteum, plus some secretomotor fibres to the lacrimal gland

The Pterygopalantine Fossa

- this is an elongated, narrow, pyramidal shaped space below the apex of the orbit, lying between,

1. the upper part of the posterior surface of the ***maxilla*** anteriorly
2. the greater wing and the root of the pterygoid process of the ***sphenoid*** posteriorly
3. the inferior surface of the body of the sphenoid supero-medially
   - the lateral roof is deficient, opening into the ***superior orbital fissure***
4. the vertical plate of the ***palatine bone*** medially
5. laterally the wall is deficient, opening into the ***infratemporal fossa***
6. inferiorly the anterior and posterior walls meet, closing the base of the fossa

- communications through this fossa are grouped accordingly,

1. **anteriorly**
   - the ***inferior orbital fissure*** leads from the upper end of the fossa into the orbit
   - this transmits the
     - maxillary nerve
     - zygomatic nerve
     - orbital branches of the sphenopalantine ganglion
     - infraorbital vessels
2. **laterally**
   - the pterygomaxillary fissure leads to the infratemporal fossa
   - this is the inlet for the maxillary artery
   - the posterior superior dental branch of V_2 exits here to enter the posterior dental canal in the maxilla
3. **inferiorly**
   - the greater palatine canal transmits the greater and lesser palatine nerves and vessels, which appear on the hard palate through the greater and lesser palatine foramina

Maxillary Nerve Block

• block of the main trunk is achieved as the nerve traverses the pterygopalantine fossa
• an 8 cm 22G needle is inserted laterally below the midpoint of the zygomatic arch, through the coronoid notch of the mandible, into the infratemporal fossa
• directed medially the needle will strike the ***lateral pterygoid plate*** at ~ 5 cm
• from there the needle is "walked" ***anteriorly*** until it enters the pterygopalantine fossa
• the needle is advanced ~ 1 cm further, and paraesthesiae are not sought
• injection of ~ 5 ml of solution usually results in blockade
• aspiration is important due to a plexus of veins in this region, the fossa containing the 5 branches of the maxillary artery and venae comitantes, plus the infraorbital veins
• complications include,

i. haematoma and a "black-eye"
ii. spread into the orbit with transient "blindness"

• an alternative technique is via the orbit
• a needle is inserted through the inferior, lateral margin of the orbit, along its floor into the inferior orbital fissure (~ 4 cm)
• the eye is held above the needle path by the suspensory ligament of Lockwood

• the branches of the maxillary nerve may be blocked as they exit the skull
• this is achieved by local infiltration about their exit foramina, entry into the foramina is unnecessary

The Mandibular Nerve V_3

• the largest branch and has the widest distribution
• is the only branch with a ***motor*** component, and provides

1. sensory supply to,
   i. the temporal region, the tragus and front of the helix
   ii. the skin over the mandible and lower lip
   iii. mucosa of the anterior 2/3 of the tongue and the floor of the mouth
2. motor supply to,
   i. muscles of mastication
   ii. tensor tympani and tensor palati
   iii. mylohyoid and anterior belly of digastric

• the sensory and motor roots pass individually through the ***foramen ovale***, uniting immediately to a short trunk, which lies deep to the lateral pterygoid muscle, and upon tensor palati
• the later muscle separates it from the Eustachian tube
• the ***otic ganglion*** is situated immediately medial to the nerve, and the middle meningeal artery immediately behind

- ***Branches***

• after a short course it divides into a smaller anterior and larger posterior trunk,

a. **undivided trunk**

i. *nervus spinosus* - sensory
- enters the ***foramen spinosum*** with the middle meningeal vessels to the dura

ii. *nerve to internal (medial) pterygoid*
- also has motor fibres to the otic ganglion, to tensor palati and tensor tympani

b. **anterior trunk**

i. *buccal nerve* - sensory
- passes between the heads of the lateral pterygoid, running deep to temporalis, reaching the subcutaneous tissues at the anterior margin of the ramus of the mandible
- supplies the skin of the anterior cheek and the mucous membrane and gum adjacent the molar teeth

ii. *masseteric nerve*
- above the upper border of the lateral pterygoid, passing laterally through the mandibular notch to the masseter
- also supplies a twig to the temporomandibular joint

iii. *deep temporal nerves*
- anterior, posterior ± middle, pass above the upper border of the lateral pterygoid to the temporal muscle

iv. *nerve to lateral pterygoid*

3. **posterior trunk**

i. *auriculotemporal nerve* - sensory

ii. *lingual nerve* - sensory

iii. *inferior dental nerve* - mixed

NB: together with branches from the otic and submandibular ganglia

• the ***auriculotemporal nerve*** arises from 2 roots from the posterior trunk near its origin
• these encircle the middle meningeal artery, join together as a common trunk which passes backwards deep to the lateral pterygoid, then the neck of the mandible, where it lies between bone and the sphenomandibular ligament
• this thin ligament stretches from the spine of the sphenoid to the lingula, immediately in front of the mandibular foramen, medial to the TMJ
• other structures passes between this and the mandible include,

i. auriculotemporal nerve
ii. insertion of the lateral pterygoid
iii. maxillary vessels
iv. inferior dental vessels and nerve
v. deep lobule of the parotid gland

• the nerve emerges behind the neck of the mandible, just below the TMJ, deep to the parotid
• then ascends over the zygomatic arch in front of the ear, immediately behind the superficial temporal vessels which serve as a landmark
• branches of the ***auriculotemporal nerve*** include,

1. auricular - to the skin of the tragus and adjacent helix
2. superficial temporal - temporal region and lateral scalp
3. branches to the external auditory meatus (usually 2)
4. articular - to the TMJ
5. parotid - secretomotor, sympathetic and sensory

• the ***lingual nerve*** commences between the medial and lateral pterygoid muscles
• receives the ***chorda tympani*** branch of the facial nerve
• at the lower border of the lateral pterygoid it passes forward between the ramus of the mandible and the medial pterygoid, to reach the floor of the mouth
• passes below the origin of the superior pharyngeal constrictor, lying immediately under the gum on the inner surface of the roots of the 3 rd molar
• passes forwards to the base of the tongue,

a. crossing in turn the lateral aspects of, styloglossus, hyoglossus, and genioglossus
b. deep to mylohyoid and above the deep portion of the submandibular gland
c. looping below and around Wharton's duct from lateral to medial
d. the terminal ramifications lying under the mucosa of the tongue

• in its course it supplies,

i. mucous membrane of the anterior 2/3 of the tongue
ii. side wall and floor of the mouth
iii. secretomotor (chorda tympani) to submandibular and sublingual glands
iv. taste sensation of the anterior 2/3 of the tongue

• the ***inferior dental nerve*** is the largest branch of the mandibular nerve, travelling between the medial and lateral pterygoid muscles, immediately ***posterior*** to the lingual nerve
• at the lower margin of the lateral pterygoid it passes with the inferior dental vessels between the sphenomandibular ligament and the mandible, to enter the ***mandibular foramen***
• traverses the mandibular canal, supplying each molar and premolar tooth
• between the roots of the premolars it divides into,

i. the *incisive branch*, passing in the same canal to the incisor teeth
ii. the *mental branch*, passing through the mental canal and foramen, supplying the skin and mucous membrane of the lower lip

• prior to entering the mandibular canal, it gives off the ***mylohyoid branch***, which runs between the inner mandible and the medial pterygoid in the mylohyoid groove, supplying this muscle and the anterior belly of digastric
• block of this nerve inside the mandible frequently also blocks the lingual nerve

The Otic Ganglion

- unique among the trigeminal nerve ganglia, having a ***motor*** component

1. **parasympathetic component**
   - originates in the inferior salivary nucleus of the glossopharyngeal nerve, passing in the tympanic branch, then the lesser superficial petrosal nerve, through the foramen ovale or the canaliculus innominatus (medial to foramen spinosum)
   - these fibres relay in the ganglion and pass to the auriculotemporal nerve
   - they are secretomotor to the ***parotid gland***
2. **sympathetic component**
   - from the superior cervical ganglion, via the middle meningeal artery plexus
   - vasoconstrictor to the parotid gland
3. **sensory component**
   - via the auriculotemporal nerve and supply the parotid gland
4. **motor component**
   - from the nerve to the medial pterygoid (ex mandibular)
   - supplies the ***tensor tympani & tensor palati***

The Submandibular Ganglion

- suspended below the ***lingual nerve***, as this crosses the superior surface of hyoglossus

1. **parasympathetic component**
   - originates in the superior salivary nucleus of VII, passing in the nerve intermedius to join the main facial nerve
   - these fibres compose the ***chorda tympani*** by which they join the lingual nerve
   - they are secretomotor to the submandibular and sublingual glands
   - also carries fibres subserving taste sensation from the anterior 2/3 of the tongue
2. **sympathetic component**
   - from the superior cervical ganglion, via the facial artery plexus
   - they are vasoconstrictor to the submandibular and sublingual glands
3. **sensory component**
   - contributed by the lingual nerve
   - sensory to the salivary glands and the floor of the mouth

Clinical Features

- complete section of the mandibular nerve results in,

1. anaesthesia of
   - the skin of the face
   - the anterior part of the scalp & auricle
   - mucous membranes of the nose, mouth and anterior 2/3 tongue
2. paralysis of the muscles of mastication

THE FACIAL NERVE VII

1. motor supply - the muscles of facial expression
2. secretomotor fibres - to the lacrimal, submandibular and sublingual glands
3. taste fibres - from the anterior 2/3 of the tongue

NB: separate pontine nuclei are responsible for each of these functions

• the ***motor nucleus*** belongs to the branchial efferent column, and is situated in the reticular formation of the lower pons, ventrimedial to the spinal tract of V
• it receives corticobulbar fibres from the motor cortex,

a. the lower aspect, which controls the upper facial muscles, receives fibres from both contralateral & ipsilateral hemispheres
b. the upper nuclear cells receive ***only*** contralateral fibres

NB: thus, unilateral lesions of the motor cortex, affect only the contralateral ***lower face***

• from the nucleus, fibres pass dorsally, winding medially around the nucleus of VI in the floor of the 4th ventricle, forming the ***facial colliculus***
• they then pass downwards and anteriorly to emerge from the lower border of the pons, between the olive and inferior cerebellar peduncle

• fibres transmitting ***taste*** relay first in the ***geniculate ganglion***, which projects centrally to the upper part of the tractus solitarius (special visceral afferent)
• fibres then cross to the opposite lateral thalamic nuclei, and the facial region of the post-central sensory cortex
• the ***sensory*** fibres emerge as a separate root, the ***nervus intermedius***, which has its origin between the motor root of VII medially and the auditory nerve (VIII) laterally

• the 2 roots of VII pass with VIII into the internal auditory meatus
• at the bottom of this canal they diverge to enter the facial canal, running laterally over the vestibule before reaching the medial wall of the epitympanic recess
• then bends sharply backwards over the promontory of the middle ear, forming the ***genu***
• this marks the ***geniculate ganglion***, from which secretomotor fibres to the lacrimal gland leave as the ***greater superficial petrosal nerve*** ($\rightarrow$ zygomaticotemporal br. V_2 $\rightarrow$ lacrimal br. V_1)
• then passes down the posterior wall of the tympanic cavity, to reach the ***stylomastoid foramen***
• just prior to entering this it gives off the ***chorda tympani***, which pierces the posterior wall close to the inner surface of the tympanic membrane
• runs forward over the pars flaccida and neck of the malleus, immediately beneath the mucous membrane
• passes out of the middle ear, piercing the bone at the inner end of the pterygotympanic fissure
• it emerges from this fissure to join the lingual nerve ~ 2.5 cm below the skull base
• conveys taste to the anterior 2/3 of the tongue and secretomotor fibres to the submandibular ganglion
• on emerging from the stylomastoid foramen, the facial nerve is entirely motor

- ***Branches***

1. within the cranium
   i. ***greater superficial petrosal nerve***
   ii. ***nerve to stapedius***
   iii. ***chorda tympani***
2. on exiting the stylomastoid foramen
   i. ***posterior auricular nerve***
      - runs back over the mastoid process
      - auricular branch to the extrinsic muscles of the ear
      - continues as the occipital branch to occipito-frontalis

   ii. *branch to digastric* - posterior belly
   iii. *branch to stylohyoid*
3. terminal
   i. ***temporal branches***[§]
      - cross the arch of the zygoma and supply the muscles of the ear, the frontal belly of occipito-frontalis, and orbicularis oculi

   ii. ***zygomatic branches***[§] [§]***temporofacial division***
      - cross the zygoma and supply orbicularis oculi

   iii. ***buccal branches*** - *either*
      - pass horizontally forward to bucinator and the labial muscle

   iv. ***mandibular branches***[‡]
      - runs deep to platysma below the angle of the mandible
      - cross superficially to the submandibular gland in the digastric triangle
      - then runs forward over the mandible to the muscles of the lower lip and chin

   v. ***cervical branches***[‡] [‡]***cervicofacial division***
      - pass down and forward into the neck to supply platysma

- exiting the stylomastoid foramen, the trunk of the nerve winds ***lateral*** to,
   i. the styloid process
   ii. external carotid artery and the posterior facial vein

NB: in a cleft between the mastoid process and bony external auditory meatus

- just beyond this point it enters the posterior aspect of the parotid gland, bifurcating almost immediately into 2 divisions, the ***temporofacial*** and ***cervicofacial***

- through the parotid, the nerve is ***superficial*** to other structures traversing the gland
   i. posterior facial vein = superficial temporal + maxillary veins
   ii. external carotid artery

- the terminal branches all emerge from the margins of the gland, and none from the superficial aspect which may be completely excised

■ ***Clinical Features***

• both nuclear and infranuclear palsies will result in complete facial paralysis
• in supranuclear palsies there is no involvement of muscles above the palpebral fissure due to bilateral innervation
• however, in such cases the patient will retain involuntarily, but not voluntary movement

1. supranuclear palsies
   - cerebral haemorrhage, tumours, infarction
   - involvement of the corticobulbar pathways
2. nuclear palsies
   - poliomyelitis
   - motor neurone disease
   - GBS, CIP
   - botulism
3. infranuclear palsies
   - cerebellopontine angle compression
   - acoustic neuroma
   - temporal bone fractures
   - malignant invasion of the parotid
   - Bell's palsy

NB: with ***intracranial*** nerve involvement, there is usually loss of anterior 2/3 taste sensation plus involvement of the auditory nerve

THE AUDITORY NERVE

• consists of 2 sets of fibres, ***cochlear*** and ***vestibular***

■ *Cochlear Fibres*

• represent the central projections of bipolar ***spiral ganglion cells*** of the cochlea, which traverse the internal auditory meatus to reach the lateral aspect of the medulla
• centrally they terminate in the ***dorsal & ventral cochlear nuclei***, from which the majority of fibres cross to the opposite side,

a. dorsal nucleus → the ***auditory striae*** in the floor of the 4th ventricle

b. ventral nucleus → the ***trapezoid body*** in the ventral pons

• most of these fibres terminate in the ***nuclei of the trapezoid body***, either on the same or opposite side, from which they then ascend in the ***lateral lemniscus*** either to,

a. ***inferior corpus quadrigeminum***
→ motor nuclei of the cranial nerves forming the auditory reflex pathways

b. ***medial geniculate body***
→ auditory radiation, to the auditory cortex on the superior temporal gyrus

■ *Vestibular Fibres*

• enter the medulla just medial to the cochlear division, and terminate on the ***vestibular nuclei***
• many of the efferent fibres pass in the inferior cerebellar peduncle, along with fibres which bypass the vestibular nuclei
• other vestibular connections are to,

a. the nuclei of nerves III, IV, VI and XI, via the ***medial longitudinal bundle***

b. upper cervical cord via the vestibulospinal tract

■ *Clinical Features*

• lesions of the cochlear division are accompanied by deafness, which may or may not be accompanied by tinnitus
• apart from lesions to the cochlear nerve itself, lesions of the brainstem auditory pathways do not seriously affect hearing due to the bilaterallity of projections
• temporal lobe tumours may give rise to auditory hallucinations
• lesions of the vestibular pathways result in vertigo, ataxia and nystagmus
• MS classically results in demyelination within the medial longitudinal bundle & pons

→ ***"internuclear ophthalmoplegia"***

• may also be involved in brainstem CVA's with specific patterns,

1. medial & lateral pontine syndromes
2. divided into superior, mid-pontine and inferior

THE GLOSSOPHARYNGEAL NERVE IX

1. sensory fibres to the pharynx, tonsillar region, and posterior 1/3 of the tongue
2. taste to the posterior 1/3 of the tongue
3. motor supply to stylopharyngeus
4. secretomotor fibres to the parotid gland
5. innervation of the carotid sinus & body

• correspondingly there are 4 nuclei of origin in the brainstem,

1. rostral part of the nucleus ambiguus (X - branchial efferent column)
   - effectively "borrowed" as stylopharyngeus is a 3 rd branchial arch derivative
2. inferior salivary nucleus (general visceral efferent)
   - rostral to the dorsal motor nucleus of X, general visceral efferent
3. nucleus of the tractus solitarius (special visceral afferent)
   - shared with X taste fibres, and the chorda tympani fibres of VII
4. dorsal sensory nucleus of X (X - general visceral afferent)

• emerges from the upper part of the medulla, from 4-5 rootlets, along a groove between the olive and inferior cerebellar peduncle
• passes forwards and laterally, leaving the skull by bending sharply downwards to pass through the ***jugular foramen***, lying in front of the vagus and accessory nerves, in a separate dural sheath
• within the jugular foramen, it bears ***superior & inferior ganglia***, which are the first cell stations for taste fibres and common sensation
• also within the foramen it gives off its ***tympanic branch***
• below the foramen it courses down and forwards, between the internal carotid artery and internal jugular vein, deep to the styloid process and its muscles
• then curves forward between the internal and external carotids, across stylopharyngeus to enter the pharynx between the superior and middle constrictors
• from here it divides into terminal branches which supply the pharynx, tonsil and tongue
• the ***tympanic branch*** is continued as the *lesser superficial petrosal nerve*, conveying preganglionic parasympathetic secretomotor fibres to the ***otic ganglion*** (parotid)
• the ***carotid branch*** arises just below the skull, runs down the internal carotid to supply the carotid sinus and body, serving as the afferent limb of the baroreceptor and chemoreceptor reflexes respectively

• nerve supply to the ***carotid sinus & body*** is derived from,

i. the carotid branch of **IX**
ii. branches to the carotid body from the inferior ganglion of **X**
iii. sympathetic branches from the superior cervical ganglion

■ *The Carotid Sinus*

• a small oval bulge at the commencement of the internal carotid artery
• the arterial wall is thin and has a rich nerve supply from the glossopharyngeal (± vagus)
• responsible for the afferent limb of ***baroreceptor reflex*** changes in HR / BP

■ *The Carotid Body*

• oval, reddish-brown structure ~ 5 mm in length
• lies deep to the common carotid bifurcation
• with the aortic body, it is sensitive to changes in blood chemistry, particularly P_{O2}
• these are small neurovascular organs, whose perfusing blood comes in contact with special sensory cells, ***glomus cells*** (SIF), which have a large content of ***dopamine***
• these are actually ***inhibitory interneurones***, generating impulses in afferent nerve terminals
• these tissues have an extremely high blood supply relative to their size and metabolic needs
• they are sensitive to a low P_{aO2}, i.e., stimulation results from a decrease in carotid and aortic body tissue P_{O2} (tension, not content)

1. arterial hypoxia - decreased P_{aO2}
2. ischaemia - eg. from marked hypotension

• they are also stimulated by,

a. an increased tissue P_{CO2} > 10 mmHg
b. decreased tissue pH > 0.1-0.2 units
c. metabolic poisons - eg. cyanide (CN^-) poisoning
d. drugs - eg. nicotine, lobeline

■ *Clinical Features*

• complete section rarely occurs in isolation, usually with vagal signs, but results in,

i. sensory loss to the pharynx
ii. loss of taste and common sensation to the posterior 1/3 of the tongue
iii. some pharyngeal weakness
iv. loss of salivation from the parotid gland

• ***glossopharyngeal neuralgia*** results in severe pain in the tonsillar region, triggered by yawning or mastication
• it is amenable to blockade of the nerve as it emerges from the jugular foramen, before it turns deep to the styloid process
• this usually causes some effect in adjacent cranial nerves (XI, X, XII), however is seldom troublesome
• bilateral block should however, not be performed

THE VAGUS NERVE X

- the largest and the most widely distributed of the cranial nerves
- the only cranial nerve which is not symmetrical

1. *motor branches to,*
   - i. the larynx
   - ii. bronchial muscles
   - iii. alimentary tract - to the splenic flexure
   - iv. heart - cardioinhibitory
2. *sensory branches to,*
   - i. the ***dura***
   - ii. external auditory meatus
   - iii. respiratory tract
   - iv. alimentary tract - to the ascending colon
   - v. heart
   - vi. epiglottis - gustatory
3. *secretomotor to,*
   - i. bronchial mucous glands
   - ii. alimentary tract and its adnexae

- it has three nuclei of origin,

1. ***the dorsal nucleus of the vagus***
   - floor of the 4th ventricle in the central grey matter of the caudal medulla
   - it is a general visceral, mixed sensory and motor centre
   - forms the cell station for motor fibres of the heart, bronchi and alimentary tract
   - receives sensory fibres from the pharynx, larynx, lungs, heart and GIT
2. ***the nucleus ambiguus***
   - branchial efferent, providing motor fibres to IX, X, XI
   - supplies the voluntary muscles of branchial origin in the pharynx, larynx and palate
   - lies deep within the reticular formation of the medulla
3. ***the nucleus of the tractus solitarius***
   - special afferent concerned with gustatory impulses
   - situated in the central grey matter of the medulla
   - its anterior part receives the chorda tympani fibres of VII, the middle part fibres from IX, and the posterior part fibres from X
   - the later receives fibres from the epiglottis and valleculae, along the internal branch of the superior laryngeal nerve

• from the medulla the vagus emerges via ~ 10 rootlets, in series with the glossopharyngeal nerve, in the postero-lateral sulcus between the olive and the inferior cerebellar peduncle
• these rapidly unite to a single trunk which passes through the jugular foramen in a common dural sheath with the ***accessory nerve*** (XI), separated from IX by a fibrous septum
• antero-posteriorly the ***jugular foramen*** transmits,

i. the inferior petrosal sinus
ii. IX, X, XI in this order
iii. the internal jugular vein

• it bears 2 ganglia, 1 within the foramen, the other on emerging from it,

1. these contain unipolar cells equivalent to the dorsal root sensory cells of the spinal nerves
2. the jugular, or ***superior ganglion*** communicates with IX and the superior cervical sympathetic ganglion
3. the inferior, or ***ganglion nodosum***, communicates with XII and with a loop which connects the anterior rami of C_1 & C_2
4. beyond the inferior ganglion the nerve receives its major communication, with the ***cranial root of the accessory nerve***, which is the probable source of the innervation of the muscles of the palate, pharynx and larynx

Course & Relations

• descends through the neck within the ***carotid sheath***, lying between and just posterior to the internal carotid artery and IJV, then the common carotid and IJV
• the cervical sympathetic chain lies behind the carotid sheath, both being separated from longus capitis and longus cervicis by the ***prevertebral fascia***

■ ***The Right Vagus***

• crosses in front of the 1st part of the subclavian artery, giving off the recurrent laryngeal branch
• then passes behind the innominate vein, descending into the thorax against the lateral aspect of the trachea, on which it is crossed by the azygous vein
• this is the only structure to separate the nerve from the pleura and lung
• passes behind the root of the lung, where it branches to form the ***right posterior pulmonary plexus***, along with sympathetic fibres
• from this plexus, 2 or more cords emerge onto the posterior aspect of the oesophagus, which receives a contribution from the ***left vagus*** to form the ***posterior oesophageal plexus***
• from this plexus, containing fibres of ***both vagi***, the right (posterior) vagal trunk is formed, passing into the abdomen through the oesophageal hiatus of the diaphragm
• it gives branches to the anterior and posterior aspects and the upper body of the stomach
• the bulk of the nerve continues as the ***coeliac branch***, which passes along the left gastric artery to the coeliac plexus
• from the ganglia it supplies the intestines and associated organs, the kidneys and adrenals

The Left Vagus

- enters the thorax between the internal carotid and subclavian arteries, behind the innominate vein
- it crosses the aortic arch, more posterior and lateral than the phrenic nerve, being separated by the left superior intercostal vein
- at the lower border of the arch it gives off its recurrent laryngeal branch
- passes behind the root of the lung, breaking-up into the ***left posterior pulmonary plexus***
- from this, 2 or more cords descend in front of the oesophagus, forming the ***anterior oesophageal plexus***, from which the anterior vagal trunk emerges
- as for the right, this contains fibres from both vagi, and passes into the abdomen through the oesophageal hiatus, though in much closer apposition than the right/posterior trunk
- supplies branches to the cardia and lesser curve of the stomach, and gives off a ***hepatic branch***
- this in turn gives a branch to the antrum and pylorus, the ***nerve of Latarjet***

- the different courses are due to,

1. the development of the aortic arch and its branches
2. the rotation of the gut such that the left lateral wall comes to lie anteriorly

Branches of the Vagi

1. from the jugular fossa, the
   - i. *meningeal branch*
   - ii. *auricular branch*
2. in the neck, the
   - i. *pharyngeal branch*
   - ii. *superior laryngeal nerve*
   - iii. *right recurrent laryngeal nerve*
   - iv. *cardiac branches*
3. in the thorax, the
   - i. *cardiac branches*
   - ii. *left recurrent laryngeal nerve*
   - iii. *anterior and posterior pulmonary branches*
   - iv. *pericardial branches*
   - v. *oesophageal branches*
4. in the abdomen, the
   - i. *gastric branches*
   - ii. *hepatic branch*
   - iii. *coeliac branch*

■ ***Branches of the Vagi***

• the ***meningeal branch*** arises from the superior ganglion, passing backwards through the jugular foramen to supply the dura

• the ***auricular branch*** arises from the superior ganglion, entering a tiny canal on the lateral wall of the jugular fossa, through the temporal bone to emerge between the mastoid process and the tympanic plate
• supplies the medial aspect of the auricle, the external auditory meatus and the outer surface of the tympanic membrane
• communicates with the facial nerve, both in the petrous temporal bone and with the posterior auricular branch of VII, on emerging from the bone ("Alderman's nerve")
• this may form part of the relationship between otic stimulation and vomiting in children
• also the presentation of acute otitis as nausea and vomiting

• the ***pharyngeal branch*** arises from the inferior ganglion, its fibres being chiefly derived from the cranial root of XI
• passes down and forward between the internal and external carotid arteries, to reach the middle constrictor of the pharynx, where it contributes to the ***pharyngeal plexus***
• this plexus receives fibres from the superior cervical ganglion, and supplies,

i. the superior, middle and inferior constrictors of the pharynx
ii. palatoglossus, palatopharyngeus, levator palati
    • ie., all the palatal muscles except ***tensor palati*** (V_3)
iii. sensory fibres to the pharyngeal mucosa

• the ***cardiac branches*** arise in the neck and mediastinum
• the cervical branches are usually 2, one from the upper vagus, the other from the root of the neck
• on the right, these descend behind the subclavian artery, along the trachea to join the deep cardiac plexus
• on the left, they accompany the vagus, the upper passing along the trachea to join the deep cardiac plexus, the lower crossing in front of the arch to reach the superficial cardiac plexus
• other cardiac branches arise from both vagi within the thorax, and from the recurrent laryngeal nerves, all of which pass to the deep cardiac plexus

• the ***pulmonary branches*** are divided into anterior and posterior groups
• the anterior are 2-3, originating just above the hilum then to the anterior pulmonary plexus
• the posterior are larger and more numerous, forming the posterior pulmonary plexus
• both of these plexuses have sympathetic components

- ***Communications of the Vagus***

1.	the trunk and its ganglia	- **IX, XI, XII** - the superior cervical sympathetic ganglion - the anterior primary rami of C_1 & C_2
2.	the auricular branch	- **VII**
3.	the pharyngeal plexus	- **IX** - the superior cervical ganglion
4.	the cardiac, pulmonary, oesophageal and gastric branches with the sympathetic outflow to these viscera	

THE ACCESSORY NERVE

• comprises a small ***cranial root***, which is distributed via **X** to the muscles of the palate, pharynx and larynx, and a larger ***spinal root*** which supplies sternomastoid and trapezius
• the cranial root fibres are derived from the lower part of the nucleus ambiguus, leaving the medulla caudal to the vagus in 4-5 rootlets
• prior to leaving the skull through the ***jugular foramen***, it accepts the spinal root, formed by the union of fibres from an elongated nucleus in the anterior horn of the upper 5 cervical segments
• these leave the cord midway between the anterior and posterior roots, combine, and then pass upwards through the foramen magnum
• the 2 roots are united for only a short distance, the cranial root joining the vagus immediately below the skull
• this may be considered as a detached caudal part of the vagus, and is probably the source of innervation of the palate, pharynx and larynx
• the spinal root usually passes backwards, over the IJV, crosses the transverse process of the atlas and is itself crossed by the occipital artery, to reach the sternomastoid
• it supplies and pierces this muscle to descend the posterior triangle of the neck, supplying trapezius ~ 5 cm above the clavicle

- ***Clinical Features***

• isolated lesions of the cranial root are rare, usually it is involved with the vagus, resulting in dysphonia and dysphagia
• division of the spinal fibres results in paralysis of the sternomastoid and trapezius, and commonly follows block dissections of the neck with clearance of the posterior triangle lymph nodes
• the surface markings of the nerve are approximated by a line drawn from the tragus to the anterior border of trapezius ~ 5 cm above the clavicle
• this line will cross the transverse process of the atlas and the middle of the posterior border of sternomastoid

THE HYPOGLOSSAL NERVE XII

• supplies all of the extrinsic and intrinsic muscles of the tongue, except ***palatoglossus***, which is supplied by the pharyngeal branch of X
• its nucleus lies in the floor of the 4 th ventricle (somatic efferent column), medial to the dorsal nucleus of X, and a series of ~ 12 rootlets leave the medulla between the olive and the pyramid
• these unite and leave the skull via the ***anterior condylar, or hypoglossal, canal***
• lies deep to the ICA and IJV, passing downward between these 2 structures
• at the level of the angle of the mandible, it passes forwards over the ICA and ECA, across the loop of the lingual artery
• then passes upwards and forwards upon hypoglossus, deep to the tendon of digastric, stylohyoid and mylohyoid
• on hypoglossus it lies adjacent to the deep part of the submandibular gland, and then lies inferior to the submandibular duct and lingual nerve
• then passes on to genioglossus, ending by being distributed to the muscles of the tongue

• receives an important contribution from the anterior primary ramus of $\mathbf{C_1}$ at the level of the atlas
• the majority of the C_1 fibres continue as the ***descendens hypoglossi***, which branches as the nerve crosses the ICA
• this continues down on the carotid sheath, and is joined by the ***descendens cervicalis*** (from C_{2-3}), to form the ***ansa hypoglossi***
• this loop supplies omohyoid, sternothyroid and sternohyoid
• other C_1 fibres pass in XII to be distributed to thyrohyoid and geniohyoid

■ *Clinical Features*

• division of the nerve, or involvement of its nucleus result in ipsilateral paralysis and wasting of the muscles of the tongue
• supranuclear paralysis (corticobulbar pathways) leads to paresis but not atrophy, of the muscles of the contralateral side

THE THORACIC INLET

▪ *Contents*

a. the apices of the lungs and trachea

b. the oesophagus

c. the great vascular trunks
- innominate arteries and veins
- left carotid and subclavian arteries
- the thoracic duct

d. the vagi, phrenic nerves, and cervical sympathetic chains

NB: immediately behind the inlet on each side is the ***brachial plexus***

▪ *Outlines And Boundaries*

• the inlet is kidney shaped due to the body of T_1 vertebra ~ 10 cm transverse
~ 5 cm antero-posterior

• its boundaries are,

i. the thoracic vertebra

ii. the first ribs and their costal cartilages

iii. the upper border of the manubrium sterni

• it slopes downwards & forwards at ~ 60° to the horizontal
• such that the anterior border is ~ 4 cm lower than the posterior, and is adjacent T_{2-3}
• during quiet respiration this level barely alters, but during forced respiration the anterior margin moves ~ 1 vertebral body in each direction

▪ *The First Rib*

• the shortest, fattest and most curved of the ribs
• this flattening & curving producing broad upper and lower surfaces, with sharp inner and outer borders, the inner bearing the ***scalene tubercle*** (of Lisfranc)
• has a rounded *head* with a single *facet* for the body of T_1, and a long *neck* and prominent *tubercle* which articulates with the transverse process of T_1
• structures crossing the ***neck*** are,

1. medially - the sympathetic trunk
2. intermediate - the superior intercostal artery and vein
3. laterally - large branch of T_1 to the brachial plexus

• the ***scalene tubercle*** provides for the insertion of the ***anterior scalene*** tendon, its relations being,

1. anterior groove - for the subclavian vein
   - lies below & behind the clavicle due to the downward slope
2. posterior groove - for the subclavian artery & lower trunk of the brachial plexus
   - larger when the brachial plexus is "post-fixed" (T_2)
   - posterior groove margin is the insertion of scalenus medius

• the inner margin of the 1st rib is attached to the ***suprapleural membrane***, Sibson's fascia
• this is a tough sheet of fibrous tissue, extending from its origin on the transverse process of C_7, to form a covering of the apical pleura
• the ***subclavius muscle*** arises from the anterior extremity of the upper surface of the rib, and inserts into the under side of the clavicle
• ***serratus anterior*** and the intercostals of the 1st space attach to the lateral margin of the rib
• its inferior aspect lies against the cervical pleura
• ***Sibson's fascia*** spreads from the transverse process of C_7 over the apex of the lung, to attach to the inner aspect of the 1st rib

■ ***Cervical Ribs***

• occur in ~ 0.5% and may represent,

1. an enlarged costal process of C_7, continuing as a fibrous strand to the 1st rib just beyond the scalene tubercle (most common), or
2. a true rib, articulating with the body and transverse process of C_7, again with a fibrous connection to the 1st rib, or
3. a complete rib, which articulates and fuses with the front of the 1st rib and has the scalene muscle attached to it

• these are usually asymptomatic, but may be associated with vascular or neurological symptoms
• in the presence of a complete cervical rib the plexus is usually unaffected, as it tends to be "prefixed", being derived from C_4-C_8
• conversely the plexus may be "postfixed" and associated with an anomalous first thoracic rib, which is rudimentary and replaced by a fibrous strand

• the lower cord of the plexus may be compressed over the fibrous strand of an incomplete cervical rib, with resultant paraesthesiae in C_8-T_1 (ulnar border of the hand and forearm), plus wasting of the small muscles of the hand, especially the thenar eminence

• the subclavian artery must arch over a complete cervical rib, when it is usually prominent & may be mistaken for an aneurysm
• often forms a post-stenotic dilatation which is prone to thrombosis, and it is emboli from this source which usually results in peripheral vascular insufficiency seen (Ross 1958)

THE DIAPHRAGM

• constitutes the great muscular septum between thorax and abdomen, peculiar to mammals
• consists of a peripheral muscle with a trefoil shaped tendon of interlacing bundles, continuous above with the ***fibrous pericardium***
• the ***crura*** arise from the lumbar vertebral bodies,

1. left - from the 1st and 2nd
2. right - from the 1st, 2nd and 3rd

• the ***arcuate ligaments*** comprise the,

1. *median* - fibrous arch joining the 2 ***crura***
2. *medial* - thickening of the fascia over ***psoas***
3. *lateral* - thickening of the fascia over ***quadratus lumborum***
   - ending laterally at the tip of the 12 th rib

• the ***costal origin*** is from the tips of the last 6 costal cartilages
• the ***xiphoid origin*** comprises 2 slips from the posterior aspect of the xiphoid

• the ***diaphragmatic foramina***, comprise 3 major openings for,

1. the inferior vena cava ~ $\mathbf{T_8}$
2. the oesophagus ~ $\mathbf{T_{10}}$ with the vagi and oesophageal vessels
3. the aorta ~ $\mathbf{T_{12}}$ with the thoracic duct and azygous vein, behind the median arcuate ligament

• other structures traversing the diaphragm include,

i. the sympathetic trunk passes behind the medial arcuate ligament
ii. the hemiazygous vein drains through the left crus
iii. the superior epigastric vessels pass between the xiphoid and costal origins
iv. the lower intercostal nerves & vessels enter the anterior abdominal wall through the interdigitations of the diaphragm & transversus abdominus
v. lymphatics from the retroperitoneal structures pass through the posterior diaphragm to the mediastinum

• the ***oesophageal hiatus*** is reinforced by muscle fibres from the ***right crus***, usually with a few fibres from the left (NB: MCQ)
• occasionally the sling is formed totally from the left crus

■ *Nerve Supply*

• motor supply is from the ***phrenic nerve*** **(C_{3-4-5})**, apart from an unimportant contribution to the crura from T_{11-12}
• section of this nerve is followed by complete atrophy of the corresponding hemidiaphragm, although the periphery of this muscle has its sensory supply from the lower thoracic nerves
• the phrenic also transmits proprioceptive fibres from the central tendon
• the right phrenic pierces the diaphragm lateral to the IVC, some fibres travelling with this structure
• the left pierces the muscle ~ 1 cm lateral to the junction of the pericardium
• terminal fibres from each branch supply the abdominal surface of the muscle

■ *Respiration*

• the apex of the dome of the diaphragm reaches the 5 th rib in the mid-clavicular line
• this is ~ 2.5 cm below the nipple line

NB: a good CXR should show 5 interspaces, otherwise underexpanded / collapsed

• the right hemidiaphragm is slightly higher than the left, and both rise with supine posture
• other factors elevating the diaphragm, thus limiting respiration include,

i. pregnancy
ii. obesity
iii. ascites
iv. pneumoperitoneum
v. large abdominal tumours

• in inspiration the dome moves down (more than the central tendon), in a piston-like action
• this also everts the lower costal margin, expanding the base of the thorax
• this accounts for ~ 60-70% of tidal volume respiration, moving **~ 1.5 cm**
• however, complete bilateral paralysis causes little difficulty with quiet respiration
• during forced respiration diaphragmatic movement may be up to 7-13 cm
• other functions of the diaphragm include,

1. raising intra-abdominal pressure
   - defecation
   - micturition
   - vomiting
   - parturition
2. maintaining the cardiac sphincter

The Cardiac Sphincter

• during forced inspiration the pressure difference across the lower oesophageal sphincter may be as high as **80 mmHg**
• the exact contribution of the various factors is uncertain,

1. the physiological sphincter at the lower oesophagus
2. the plug-like action of mucosal folds at the cardia
3. the valve-like effect of the obliquity of the oesophago-gastric angle
4. the diaphragmatic sling, which maintains the normal position of the cardia and has a valve-like effect on the lower oesophagus
5. positive intra-abdominal pressure which tends to close the walls of the lower, intra-abdominal oesophagus

• although a true "anatomical" sphincter cannot be shown at dissection, a physiological sphincter can be demonstrated as a high pressure area at the lower oesophagus
• the crural ring around the lower oesophagus is important in maintaining the normal position of the cardio-oesophageal junction below the diaphragm

Development of the Diaphragm

• formed in the embryo by the fusion of the,

i. ***septum transversum*** - becoming the central tendon
ii. dorsal oesophageal mesentery
iii. peripheral rim from the body wall
iv. ***pleuroperitoneal membranes***

• the later close the primitive communications between the pleural and peritoneal cavities
• the septum transversum is mesoderm, which is actually derived from the head of the embryo, being carried to its location during folding of the head
• this accounts for the long course of the phrenic nerve
• despite this course, congenital abnormalities are rare, but include,

1. foramen of Morgagni - anteriorly between the costal & xiphoid origins
2. foramen of **B**ochdalek - pleuroperitoneal canal lying posteriorly
   - **B**ack
3. deficiency of the entire central tendon
4. congenitally large oesophageal hiatus

• more common are acquired ***hiatal herniae*** (sliding >> rolling or para-oesophageal)

THE INTERCOSTAL SPACES

■ *Intercostal Muscles*

• these are disposed in 3 layers, corresponding with the 3 layers of the abdominal wall

1. **external intercostals**
   - pass down & forward from the lower border of 1 rib to the next
   - extend from the tubercle of the rib posteriorly, to the costochondral junction
   - anteriorly each is continued as the ***anterior intercostal membrane*** to the sternum
2. **internal intercostals**
   - extend from the sternum, and costal cartilages in the lower spaces, to the angle of the rib posteriorly, fibres angled postero-inferiorly
   - here each is replaced by the ***posterior intercostal membrane***
3. **innermost intercostal layer**
   i. *sternocostalis* anteriorly, which fans out from the side of the lower sternum to the costal cartilages of ribs 2-6
   ii. *intracostalis* (intercostales intimi) laterally, which blend with the internal intercostals, but span 2-3 spaces
   iii. *the subcostals* posteriorly, made of small slips near the angles of the lower ribs, running the same direction as the internal intercostals, but span 2-3 spaces

   - these muscle slips of the internal layer are linked together by a fibrous layer, which is continuous superiorly with Sibson's fascia
   - the *endothoracic fascia*, equivalent to the transversalis fascia of the abdominal wall, is only a fine layer of areolar connective tissue between the intercostal muscles and the parietal pleura

■ *Intercostal Muscles & Respiration*

• during inspiration the intercostals contract in proportion to respiratory effort
• there is elevation and eversion of the ribs, with increased A-P and lateral thoracic diameter
• the muscles of the lower spaces also contract during forcible expiration
• in addition, contraction maintains the rigidity of the thoracic wall during forced expiration
• rigid fixation of the thoracic wall, such as ankylosing spondylitis, reduces MBC ~ 20-30%

■ *The Neurovascular Bundle*

• from above → down, the posterior intercostal vein, artery, and nerve (VAN)
• these are protected by the costal groove of the upper rib
• posteriorly these lie between the pleura and posterior intercostal membrane, passing between the internal intercostal and intracostal muscles at the angle of the rib

■ ***Blood Vessels of the Chest Wall***

• the ***posterior intercostal arteries*** of spaces 3-11 arise directly from the aorta
• the 1st and 2nd from the superior intercostal artery, a branch of the costocervical trunk, which arches over Sibson's fascia to cross the neck of the 1st rib
• at this point the sympathetic trunk is medial, and the 1st thoracic root of the brachial plexus lateral
• each intercostal gives off a collateral branch, and these 2 vessels anastomose with the 2 anterior intercostal arteries in the upper 9 spaces

• the ***posterior intercostal veins*** lie above their corresponding arteries and have a variable termination,

1. 1st space - into either the vertebral or subclavian vein
2. 2nd & 3rd ± 4th
   - join to form the ***superior intercostal vein***
   - on the right this enters the azygous vein
   - on the left crosses the arch of the aorta, between the phrenic and vagus nerves, to the left innominate vein
3. lower 8 veins
   - on the right, all 8 enter the azygous vein
   - on the left, 4 into the superior and 4 the inferior hemiazygous veins

• the ***internal mammary artery*** arises from the 1st part of the subclavian artery, descends behind the upper 6 costal cartilages, ~ 1.5 cm lateral to the sternal border
• initially it lies directly against the pleura, then at the 3rd space it passes beneath sternocostalis which covers it until its termination
• terminates dividing into the ***superior epigastric*** and the ***musculophrenic arteries***

• ***perforating branches*** pierce each intercostal space to supply the overlying pectoralis major, skin and breast (2nd-4th) in the female
• in each of the upper 9 spaces, 2 ***anterior intercostals arteries*** are given off,

i. the upper 6 are derived from the internal mammary
ii. the 7th-9th from its musculophrenic branch

• the ***internal mammary vein*** accompanies the artery and drains into the innominate vein

■ ***Lymphatics***

• lymph nodes lie alongside the internal mammary vessels
• these receive drainage from the breast, and drain into the thoracic duct or mediastinal lymph trunk

THE ABDOMINAL WALL

■ *Landmarks*

i.	the xiphoid	~ the body of T_9
ii.	costal margin	- from the xiphoid to the lower border of the 10 th rib - lower border of thoracic cage (subcostal plane)
iii.	subcostal plane	~ the body of L_3
iv.	transpyloric plane	- lies ½ way between the suprasternal notch & pubis ~ the body of L_1
v.	iliac crests	~ the body of L_4
vi.	umbilicus	~ the L_{3-4} interspace but inconstant - lower in pregnancy, in obese and children

■ *Fascia*

• there is no deep fascia over the trunk, this would embarrass abdominal distension
• the superficial fascia (or fat) over the lower abdomen is thicker on its inner aspect,

1. the more superficial subcutaneous tissue is termed ***Camper's fascia***
2. the deeper fibrous tissue ***Scarpa's fascia***

NB: there is no true anatomical differentiation into these layers

Muscles of the Abdominal Wall

■ *Rectus Abdominis*

• has a narrow (~ 1") origin from the pubic crest, and a wider insertion into the 5 th, 6th and 7th costal cartilages
• its segmental development is retained as 3 fibrous bands, 1 each at the umbilicus and xiphoid, the other ½ way between the two
• these are present only on the anterior of the muscle, where it adheres to the anterior rectus sheath
• ***pyramidalis*** is a small, inconstant triangular muscle which arises from the pubis, lies in front of the rectus and is inserted into the linea alba

• the ***rectus sheath*** is in the main, a split in the *internal oblique aponeurosis*
• posteriorly this is reinforced by the aponeurosis of transversus abdominus, and anteriorly by that of the external oblique
• this basic arrangement is altered at each end,

1. above the costal margin, the rectus lies directly on the costal cartilages,
   the anterior sheath consists only of the external oblique aponeurosis
2. for 5-8 cm below the costal margin, transversus abdominus is mainly muscular, almost to the midline,
   these fibres can be distinctly seen in the posterior wall of the upper sheath
3. halfway between the umbilicus and pubis (arcuate line of Douglas) the aponeuroses of all three muscles pass in front of the rectus,
   here the muscle rests against the transversalis fascia, extraperitoneal fat & peritoneum

• thus, from above downward, the posterior sheath is composed principally of,

i. cartilaginous - above the costal margin
ii. muscular - where transversus extends into the sheath
iii. aponeurotic - for the majority
iv. areolar - below the arcuate line of Douglas

NB: the aponeuroses forming the sheath fuse from the pubis to the xiphoid in an almost avascular midline ***linea alba***

■ ***The Lateral Muscles of the Abdominal Wall***

• these 3 muscles fill the space between the rectus anteriorly, the lumbar muscles behind, the costal margins superiorly and the iliac crests inferiorly
• their medial extensions form the rectus sheath and the linea alba
• above the level of the iliac crests, the fibres of

1. ***external oblique*** - pass downwards and medially
2. ***internal oblique*** - pass upwards and medially
3. ***transversus abdominis*** - transversely

NB: below this level all of the muscle are ***aponeurotic*** and all of their fibres pass down and medially in the formation of the inguinal canal

• they are accessory muscles of respiration, principally during forced expiration and coughing
• they act by increasing intra-abdominal pressure, and by drawing the lower ribs down and medially
• EMG studies show they are inactive during ***inspiration***

Blood Supply

- there is a rich blood supply
- of major importance is the position of,

1. the ***inferior epigastric artery***
   - derived from the external iliac artery
   - skirts medially to the inguinal ring, and enters the posterior rectus sheath, beneath the arcuate line of Douglas
2. the ***superior epigastric artery***
   - smaller, and enters the upper rectus sheath behind the 7 th costal cartilage
   - it is a terminal branch of the internal mammary artery
   - runs vertically downward, to anastomose with the inferior artery

- the surface markings of these vessels is a line which curves gently from the femoral pulse in the groin, to a point ~ 1.5 cm lateral to the umbilicus, then vertically upwards to the costal margin
- these are important as they may be damaged during a rectus sheath block

Nerve Supply

- innervated by the anterior primary rami of **T_7-L_1**

i. T_7 ~ the xiphoid
ii. T_{10} ~ the umbilicus
iii. L_1 ~ the groin

- the ***intercostal nerves*** (T_7-T_{11}) and the ***subcostal nerve*** (T_{12}) enter the abdominal wall between the interdigitations of the diaphragm and transversus abdominis
- they maintain the same relationship to the abdominal muscles, as for the intercostal muscles,

1. in their thoracic course they lie between the 2 nd & 3rd layers of intercostal muscles
   - ie., the internal intercostals and innermost intercostals
2. in their abdominal course they also lie between the 2 nd & 3rd layers
   - ie., the internal oblique and transversus abdominis

NB: from here the nerves continue medially behind the rectus, which they pierce to supply the overlying skin

- in contrast, the ***first lumbar nerve*** divides in front of quadratus lumborum into ,
    1. the ***iliohypogastric nerve***
        - pierces the internal oblique, immediately above and in front of the ASIS
        - runs deep to the external oblique, just above the inguinal canal
        - supplies the skin of the lower abdominal wall (suprapubic region)
    2. the ***ilioinguinal nerve***
        - also pierces the internal oblique, then passes through the inguinal canal in front of the spermatic cord
        - it emerges through the external ring, or the adjacent external oblique aponeurosis, to supply the upper thigh and scrotum (or labium majus)

- each nerve, <u>except</u> the ilioinguinal, gives off a ***lateral cutaneous branch*** in the midaxillary line
    a. those of T_7-T_{11} then divide into anterior and posterior branches, which supply the skin from the lateral edge of rectus to the erector spinae behind
    b. those of T_{12} and the iliohypogastric do not divide, but run downwards to supply the skin of the lateral buttock

- each nerve from T_7-T_{12} gives off a small collateral branch which runs parallel with it
- by analogy, the ilioinguinal nerve is equivalent to the collateral branch of the iliohypogastric

THE ANTECUBITAL FOSSA

• triangle limited by,

i. ***pronator teres*** - infero-medially
ii. ***brachioradialis*** - infero-laterally, and
iii. ***intercondylar line*** - superiorly

• the ***roof*** is formed by the deep fascia, reinforced by the bicipital aponeurosis
• upon this deep fascia lies the ***median cubital vein***
• this is crossed superficially (occ. deep) by the ***medial cutaneous nerve of the forearm***
• laterally lie the ***cephalic vein*** and the ***lateral cutaneous nerve of the forearm***
• medially courses the ***basilic vein***

■ ***Contents***

• with the muscular walls of the fossa retracted, from the medial to lateral walls,

i. the median nerve
ii. brachial artery - bifurcates at the level of the radial neck
iii. biceps tendon
iv. radial nerve - gives off its posterior interosseous branch

■ ***The Superficial Veins***

• the ***cephalic vein*** drains tributaries from the radial border of the forearm
• ascends over the lateral border of brachioradialis, to lie in a groove at the lateral edge of biceps
• pierces the deep fascia at the lower border of pectoralis major, lying in a groove between this muscle and deltoid
• then finally pierces the ***clavipectoral fascia*** to enter the ***axillary vein***
• the groove between pectoralis major and deltoid is a useful site for venous cut-down
• catheters passed along the cephalic vein frequently fail to enter the axillary vein, due to the sharp bend as it passes through the clavipectoral fascia and the frequent presence of a valve at this site
• however, SVC cannulation is said to be more successful on the ***right*** than if the basilic vein is used

• the ***basilic vein*** drains the ulnar side of the forearm, then ascends along the medial border of biceps to pierce the deep fascia at the middle of the upper arm
• from here it runs up to the lower border of the axilla, where it is joined by the venae comitantes of the brachial artery to form the ***axillary vein***

• the ***median cubital vein*** usually arises from the cephalic vein ~ 2.5 cm distal to the lateral epicondyle, then runs proximal and medially to join the basilic vein ~ 2.5 cm proximal to the elbow crease, giving a skewed "H" arrangement
• it receives a number of tributaries from the forearm, in addition it gives off a deep median vein, which pierces the roof of the fossa, to join the venae comitantes of the brachial artery
• a frequent variation of this arrangement is for one of the forearm tributaries to bifurcate just distal to the fossa, giving a branch to both basilic and cephalic veins, giving an "M" pattern

■ ***The Bicipital Aponeurosis***

• arises from the medial border of the lower end of the biceps muscle and its tendon
• passes down and medially to blend with the deep fascia covering the origin of the flexor muscles of the forearm
• the upper edge is quite distinct and can be palpated when the arm is flexed & supinated
• it forms a "shield" between the brachial artery and the median cubital vein

■ ***The Brachial Artery***

• McCormack, Cauldwell & Anson (1953, 750 dissections) found,

1. the artery may bifurcate high in the arm, even at the axilla, into,
   i. a main trunk, which continues into the forearm as the common interosseus artery
   ii. a common stem, termed the superficial brachial artery, which divides at a variable level into its terminal branches, the radial and ulnar (~1%)
2. a superficial radial artery may be given off in the upper arm, however usually has the same course cf. normal (~14%)
3. a superficial ulnar artery may be given off in the arm (~2%) and usually descends superficial to the common flexor origin at the elbow, lying immediately beneath the median cubital vein where it is subject to accidental injection
   • fortunately this aberrant artery usually does not give rise to the common interosseus artery, the later arising from the radial

■ ***Sites For Arterial Cannulation***

1. ***radial artery*** at the wrist, just lateral to flexor carpi radialis
   • the deep branch of the ulnar artery, via the deep palmar anastomosis usually supplies the intrinsic muscles of the thumb & index finger
   • the effectiveness of an Allen's test is subject to debate
   • preferably the patients non-dominant hand should be used
2. the ***dorsal branch of the radial artery***, lateral to the scaphoid at the base of the 1st metacarpal is a safe alternative in patients with a dominant radial artery
3. the ***dorsalis pedis artery***
4. the femoral, brachial and axillary arteries may be used, providing small catheters are used, however the risk of complications is greater

THE GREAT VESSELS OF THE NECK

▪ *Internal Jugular Vein*

• origin from the ***sigmoid sinus*** at the jugular foramen to its junction with the subclavian vein, behind the sternal end of the clavicle
• it lies lateral first to the internal, then the common carotid arteries, within the ***carotid sheath***
• the upper part lies superficial in the anterior triangle of the neck, above the external carotid
• then descends deep to sternomastoid, in close proximity to the deep cervical lymph chain
• the vagus lies between the artery and vein within the sheath
• the cervical sympathetic chain lies behind the carotid sheath
• ***tributaries*** draining directly into the IJV include,

i. the pharyngeal venous plexus
ii. common facial vein
iii. lingual vein
iv. superior and middle thyroid veins

• the superficial veins are highly variable, but approximate the following,

a. the *superficial temporal* and the *maxillary veins* join to form the *posterior facial vein*
b. this branches while traversing the parotid gland,
   i. the posterior division forming the *external jugular vein*
   ii. the anterior joining the *anterior facial vein*, which joins the IJV

▪ *External Jugular Vein*

• crosses the sternomastoid in the superficial fascia, traversing the roof of the posterior triangle
• pierces the deep fascia ~ 2.5 cm above the clavicle to enter the subclavian vein
• here it tends to be splinted open and with trauma is a potential site for ***air embolism***

▪ *Anterior Jugular Vein*

• runs vertically down, just lateral to the midline of the neck to the level of the thyroid isthmus, where it diverges laterally
• then runs deep to sternomastoid to enter the *external jugular vein*

▪ *Subclavian Vein*

• the continuation of the ***axillary vein***
• extends from its commencement at the outer border of the 1 st rib to the medial border of scalenus anterior, where it joins the IJV to form the ***innominate vein***
• it crosses and slightly grooves the 1 st rib, then arches forward and down to its termination behind the sternoclavicular joint and subclavius muscle
• on the ***left*** it receives the termination of the ***thoracic duct***

■ ***The Innominate Veins***

- formed behind the sternoclavicular joints by the junction of the IJV and subclavian veins
- each lies lateral to the common carotid artery in front of scalenus anterior
- each side receive tributaries corresponding to the branches of the 1 st part of the subclavian artery

→ vertebral, inferior thyroid and internal mammary veins

- the ***right innominate vein*** is ~ 3 cm in length, descending almost vertically behind the right border of the sternum
- the right phrenic nerve descends along its lateral border, separating it from the pleura
- the ***left innominate vein*** is ~ 6 cm in length, descending obliquely behind the sternum to join the right at the lower border of the 1 st costal cartilage, forming the ***superior vena cava***
- it crosses above the arch of the aorta, in front of the left common carotid artery, the trachea and innominate artery

NB: the dome of the pleura & Sibson's fascia extend above the clavicle ~ 2.5 cm

■ ***Common Carotid Artery***

- right arises from the ***innominate artery***, behind the sternoclavicular joint
- left arises from the ***aortic arch*** in the superior mediastinum
- both run upward and posteriorly through the neck, from the sternoclavicular joint to the upper border of the thyroid cartilage, at the level of $\mathbf{C_{4\text{-}5}}$ (NB: MCQ)
- embedded in the carotid sheath with the IJV and vagus nerve
- at the junction with the ICA dilates to form the ***carotid sinus***
- the carotid body lying deep to the bifurcation

■ ***External Carotid Artery***

- begins at the upper level of the thyroid cartilage
- terminates in the substance of the parotid gland, behind the neck of the mandible where it divides into the ***superficial temporal*** and ***maxillary arteries***
- first lies medial to the ICA, then passes behind and laterally
- branches include,

i. superior thyroidal artery
ii. ascending pharyngeal artery
iii. lingual artery
iv. facial artery
v. occipital artery
vi. posterior auricular artery
vii. superficial temporal artery
viii. maxillary artery

■ ***Internal Carotid Artery***

- begins at the upper level of the ***thyroid cartilage*** ($\mathbf{C_4}$)
- ascends in front of the upper 3 cervical vertebra
- enters the cranium through the ***carotid canal*** in the petrous temporal bone
- lies embedded in the carotid sheath with the IJV and vagus nerve lying laterally
- gives off ***no branches*** in the neck, those from other portions being,

1.	petrous portion	- caroticotympanic - pterygoid
2.	cavernous portion	- cavernous - hypophyseal - meningeal - ophthalmic
3.	cerebral	- anterior cerebral - middle cerebral - posterior communicating - anterior choroidal

■ ***Carotid Sheath***

i. carotid arteries
ii. internal jugular vein
iii. vagus nerve
iv. sympathetic trunk ? posterior
v. deep cervical lymph nodes

■ ***Subclavian Artery***

- the right arises from the ***innominate artery***, behind the sternoclavicular joint
- the left arises from the ***aortic arch***, behind the left common carotid
- both curve behind scalenus anterior, becoming the axillary artery at the outer border of the 1 st rib
- divided into 3 parts by ***scalenus anterior***,

1. first part - origin to medial border of scalenus anterior
   - i. anterior
     - common carotid
     - ansa subclavia
     - vagus nerve
     - IJV and vertebral veins
     - cardiac branches of the vagus & sympathetic nerves
   - ii. posterior
     - dome of the cervical pleura & apex of the lung
     - ansa subclavia
     - right recurrent laryngeal nerve
   - iii. branches
     - vertebral artery
     - thyrocervical trunk
     - internal thoracic artery (internal mammary)
2. second part - behind scalenus anterior
   - i. posterior - dome of the cervical pleura & apex of the lung
   - ii. branches - costocervical trunk
     - superior intercostal
     - deep cervical
3. third part - lateral border of scalenus anterior to outer border of the 1 st rib
   - i. anterior
     - deep & superficial fascia, platysma
     - supraclavicular nerves, and nerve to subclavius
     - EJV & its tributaries
     - suprascapular artery & clavicle
   - ii. posterior
     - lower trunk of brachial plexus
     - scalenus medius
   - iii. inferior - the 1st rib
   - iv. superior - upper & middle trunks of brachial plexus
   - v. branches - usually there are ***none***

■ ***Axillary Artery***

• continuation of the subclavian artery → ***brachial artery*** at the lower border of ***teres major***
• enclosed with brachial plexus in ***axillary sheath***, a continuation of the prevertebral fascia
• crossed anteriorly by ***pectoralis minor***, which divides it into 3 parts

1. first part - outer border of the 1st rib to medial border pectoralis minor
   - i. anterior - pectoralis major & covering fascia
     - the cephalic vein
   - ii. posterior - long thoracic nerve (to serratus anterior)
   - iii. laterally * the 3 cords of the brachial plexus
   - iv. medially - the axillary vein
2. second part - lies behind pectoralis minor
   - i. anterior - pectoralis minor, major & covering fascia
   - ii. posterior - posterior cord of the brachial plexus
     - subscapularis muscle
     - laterally - lateral cord of the brachial plexus
     - medially - medial cord of the brachial plexus & axillary vein
3. third part - lower border pectoralis minor to lower border of teres major
   - i. anterior - pectoralis major for a short distance
     - medial root of the median nerve lower down
   - ii. posterior - subscapularis, teres major & latissmus dorsi muscles
     - axillary and radial nerves
   - iii. laterally - coracobrachialis, biceps and the humerus
     - lateral root of the median & musculocutaneous nerves
   - iv. medially - the ulnar & medial cutaneous nerve of the arm
     - the axillary vein
4. ***branches***
   - i. highest thoracic artery
   - ii. thoracoacromial artery
   - iii. lateral thoracic artery
   - iv. subscapular artery
   - v. anterior circumflex humeral artery
   - vi. posterior circumflex humeral artery

■ ***Axillary Vein***

• formed at the lower border of teres major by union of the ***venae commitantes of the brachial artery*** and the ***basilic vein*** → ***subclavian vein*** at outer border of the 1st rib
• travels on the ***medial*** border of the artery within the sheath
• receives contributions from branches of the artery above, plus the ***cephalic vein***
• has a pair of semilunar valves, plus valves for the cephalic and subscapular veins
• medial cutaneous nerve of the arm is adjacent medially

Venous Drainage of Upper Arm

- ***Superficial Drainage***

1. veins of the hand
   - i. dorsal digital veins
   - ii. dorsal metacarpal veins
   - iii. dorsal venous network
   - iv. palmar digital veins → communicate with dorsal digital veins
     → ***median vein of the forearm***
2. ***cephalic vein***
   - begins at the radial aspect of the dorsal venous network
   - → ***median cubital vein*** in front of the elbow, which receives a branch from the deep veins and communicates with the basilic vein
   - crosses above the lateral cutaneous nerve of the forearm
   - receives contribution from the accessory cephalic vein
   - ascends between biceps & brachioradialis, the deltoid & pectoralis major
   - pierces the clavipectoral fascia, crosses the axillary artery & joins the axillary vein
3. ***basilic vein***
   - begins at the ulnar aspect of the dorsal venous network
   - ascends on the posterior aspect of the forearm, until just below the elbow where it winds anteriorly
   - joined by the ***median vein of the forearm*** and the ***median cubital vein***
   - fibres of the median cutaneous nerve of the forearm pass both superficially and deep to the vein at the antecubital fossa
   - continues on the medial side of biceps, piercing the deep fascia in the middle 1/3 to travel on the medial aspect of the brachial artery

- ***Deep Drainage***

NB: generally follow the arteries as their venae commitantes, usually paired, 1 each side, usually small as most of the blood is drained by the superficial system

1. deep veins of the hand
   - accompany the superficial and deep palmar arches, cf. the arteries
   - drain to the dorsal venous network and the radial veins
2. deep veins of the forearm & arm
   - venae commitantes of the radial and ulnar arteries
   - continuations of the deep and superficial palmar arches
   - unite in front of the elbow to form the brachial veins, 1 each side of the artery
   - increase in size, receiving multiple tributaries proximally
   - continue as the axillary vein, the subclavian vein