

Central & peripheral nerve blockade neuraxial blockade anatomy.

Dr. Anuradha

Professor

Dept. of Anaesthesiology

Chengalpattu Medical College, Chengalpattu

Introduction:

Neuraxial blocks –spinal, epidural and caudal are the most widely used regional anaesthesia techniques. The main reasons for their popularity are that the blocks have well defined endpoints and anaesthesiologists can produce the blocks reliably with a single injection.

Vertebrae:

There are 33 vertebra from C1 to tip of coccyx

These are 7 cervical

12 thoracic

5 lumbar

The sacrum comprises five and Coccyx four fused segments.

The typical vertebrae are from T2-T8. Basic pattern is represented by the mid-thoracic vertebrae.

Parts:

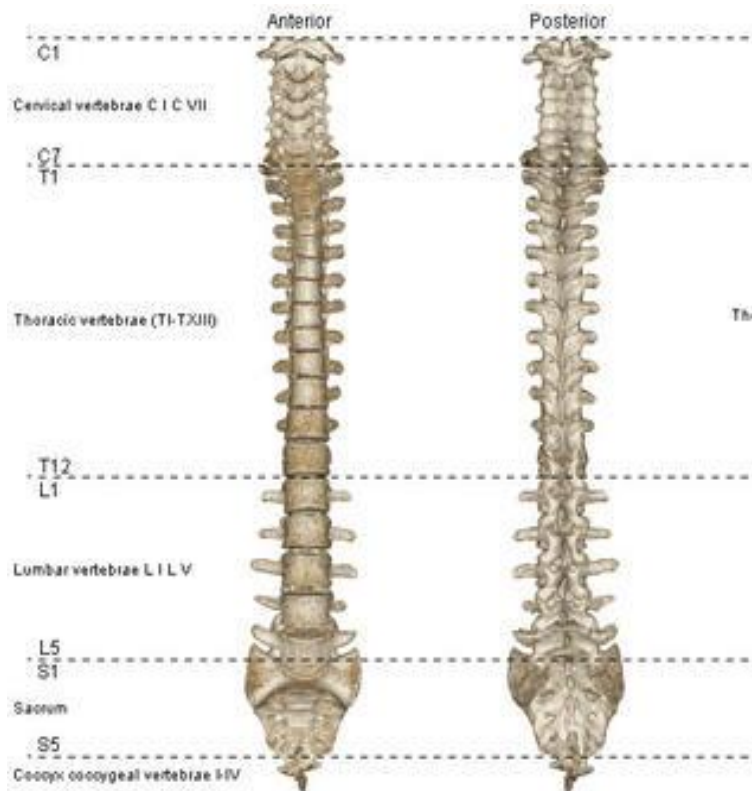
Body - through which the weight of the subject is transmitted,

Vertebral (or neural) arch -which surrounds and protects the spinal cord lying in the *vertebral foramen*. The arch comprises a *pedicle* and a *lamina* on each side, and a *dorsal spine*. Each lamina, in turn, carries a transverse process and superior and *inferior articular processes* that bear the *articular facets*. The pedicles are notched; the notches of each adjacent pair together form an intervertebral foramen through which emerges a spinal nerve.

Curvatures Of Spine:

Adult spine presents four curvatures:

Cervical and lumbar zones are convex forwards (lordosis), thoracic and sacral regions are concave (kyphosis).



Surface markings:

C7- Vertebra prominens

T3 -root of spine of scapula

T7-inferior angle of scapula

*4 Or L4 L5 Interspace-highest points of iliac crests
(Tuffiers line)*

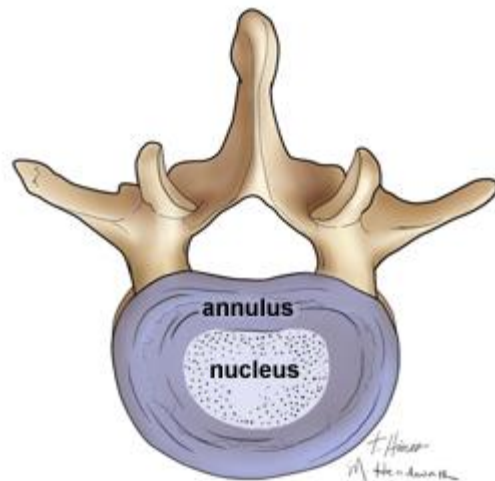
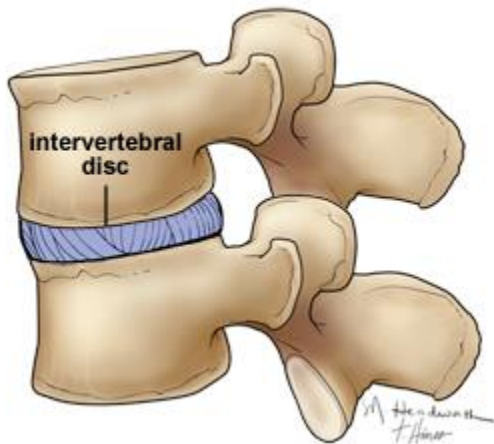
S2 vertebra –line between posterior superior iliac spines.

Vertebral column:

Cervical and lumbar vertebra, spinous process has horizontal orientation than in midthoracic region. The caudal angulation of the spinous process in midthoracic region highlights why needle puncture in this area requires a more cephalad needle angulation. The second most important feature is the angulation of lamina immediately lateral to the spinous process in the three regions. The vertebral bodies from cephalad to caudal becomes more vertical in orientation; this is important in walking the needle off lamina into the desired neuraxial locations.

INTERVERTEBRAL DISKS:

One quarter of the length of vertebral column is made up of intervertebral discs. Annular fibrosus-fibrocartilage arranged in concentric rings. Nucleus pulposus- central core of soft, pulpy elastic tissue enclosed by annular fibrosus.



Discs provide flexibility to vertebral column and acts as shock absorbers. Annulus may rupture causing pressure on nerve roots. Atrophy of the intervertebral discs in the elderly, coupled with osteoporosis of the vertebrae, which accounts both for the shrinking height and kyphotic deformity of old age.

Vertebral canal:

Vertebral canal housing the spinal cord is bounded by Posteriorly –spinous process and interspinous ligaments, laterally –pedicles, posterolaterally-lamina and ligamentum flavum, roof –ligamentum flavum meets at midline forms a steeply arched roof over the lumbar posterior extradural space. Mid saggital gap between ligamentum flava in midline is common in thoracic and cervical region, this contributes to loss of resistance in midline approach to enter extradural space.

CONTENTS:

1. spinal cord
2. spinal membranes
3. adipose tissue

4. blood vessels
5. cerebrospinal fluid
6. spinal nerve roots

Degenerative disease can narrow the intervertebral foramen and prevent the spread of local anaesthetics out of foramina resulting in greater longitudinal spread in extradural space.

Cervical vertebra:

Typical cervical vertebrae are C3–6

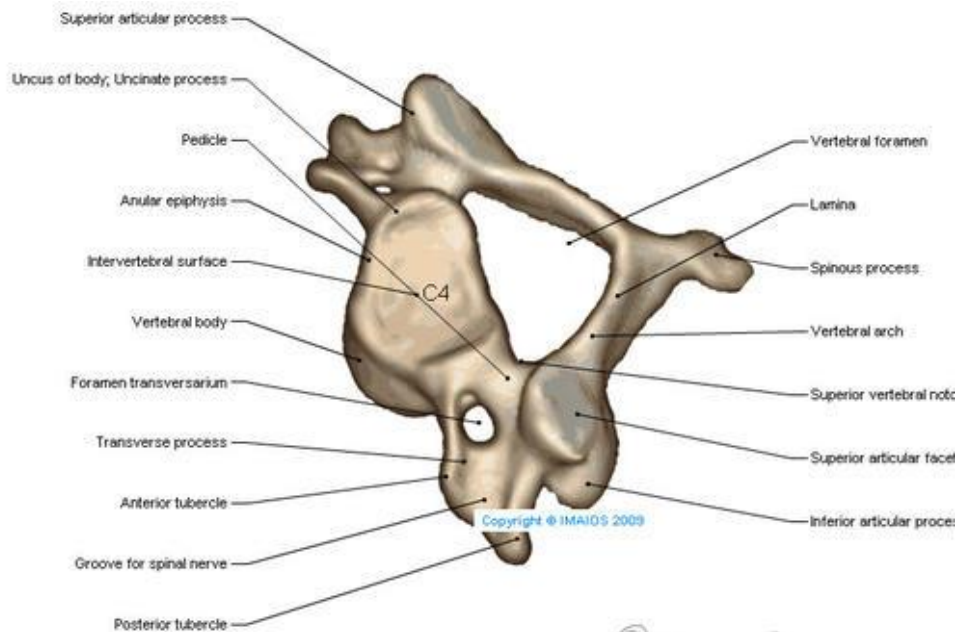
Small flattened body and a triangular, relatively large vertebral foramen.

The pedicles project laterally as well as backwards, Their superior and inferior notches are about equal. The transverse process is short and is pierced by **the foramen transversarium** which transmits the vertebral vessels; it consists of an anterior and posterior root, each ending laterally in a tubercle, and connected to each other lateral to the foramen transversarium by the costo-transverse bar.

The typical cervical spines are short and bifid.

The anterior tubercle of C6 is large (Chassaignac's tubercle)

Atlas:





The atlas, C1, has no body; instead it consists of an anterior and a posterior arch joined by a thick lateral mass, which bears the superior and inferior articular facets and the transverse process.

Axis:

Dens or *odontoid process* on the superior aspect of its body. The superior articular facets are large, oval and face upwards and outwards. The inferior facets are carried on the laminae and face downwards and forwards.

The vertebra prominens; C7:

There are eight cervical nerves: C1–7 emerge above their corresponding vertebrae, but C8 lies above the first thoracic vertebra; the remaining spinal nerves emerge *below* their corresponding vertebra.

Thoracic vertebra:

Typical thoracic body is the conventional heart shape; bodies of T5–8 are flattened on their left side; this asymmetry is produced by the pressure of the descending aorta.

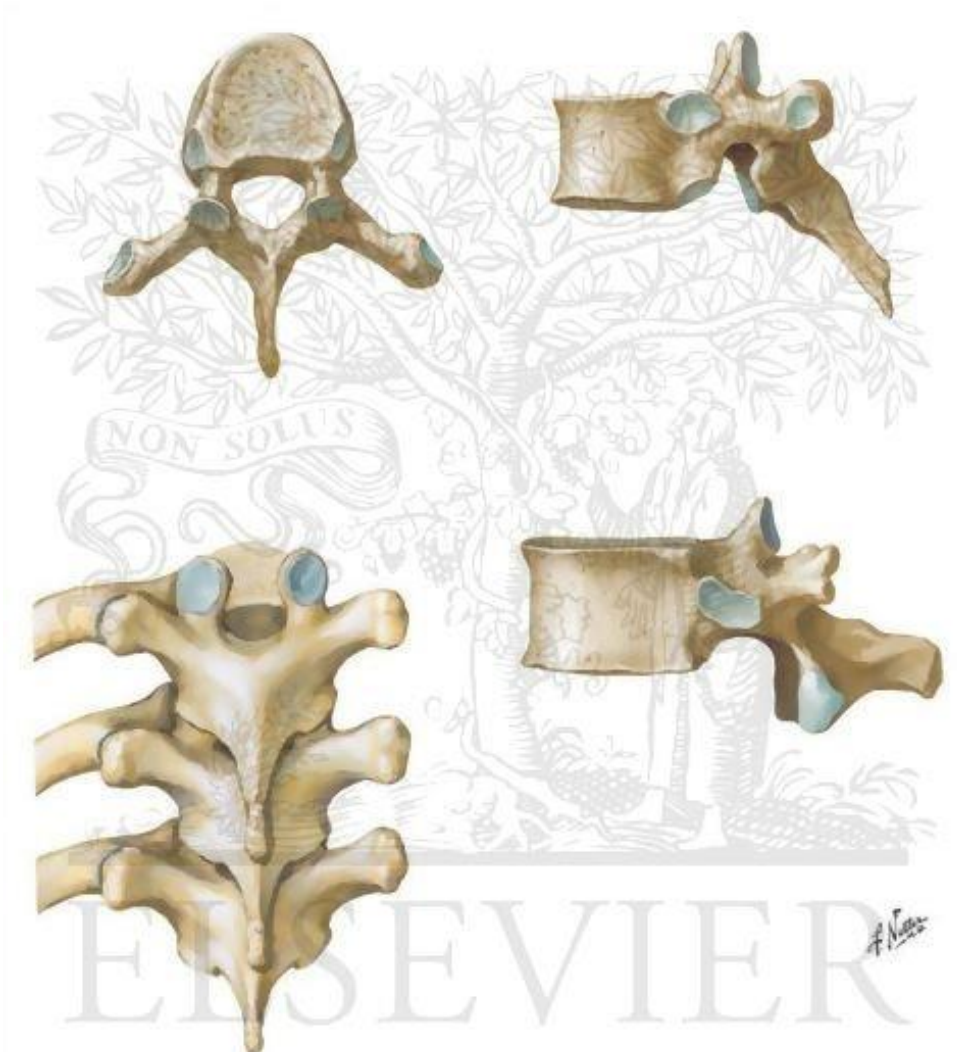
T1- Cervical vertebral type of body

A marked upper notch,

A complete upper facet for the 1st rib and a small demi-facet below;

Its spine is horizontal.

T9-



Usually typical but often fails to articulate with the 10th rib-head

T10-

Articulates only with the head of the 10th rib and therefore has only a superior demi-facet

T11-

Articulates only with its own rib-head, for which there is a circular facet near the upper border of its body. The transverse process is small and facet-free.

T12-

Lumbar-shaped body.

Its transverse process is small, without an articular facet.

Bearing superior, inferior and lateral tubercles like a lumbar vertebra.

The spine is horizontal and resembles that of a lumbar vertebra.

Lumbar vertebra:

The bodies of the lumbar vertebrae are large and kidney-shaped. The vertebral foramen is roughly triangular, larger than in the thoracic but smaller than in the cervical region. The pedicles are thick, with shallow superior notches. The transverse processes are slender; they increase in length from L1 to L3, then become shorter again so that the third transverse process is longest. An accessory process on the postero-inferior aspect of its base and a mammillary process adjacent to the superior articular process. The laminae are short, broad and strong, but they do not overlap each other as in the thoracic region. The superior articular facets face backwards and inwards. The inferior facets correspondingly face forwards and outwards. The lumbar spines are horizontal and oblong.

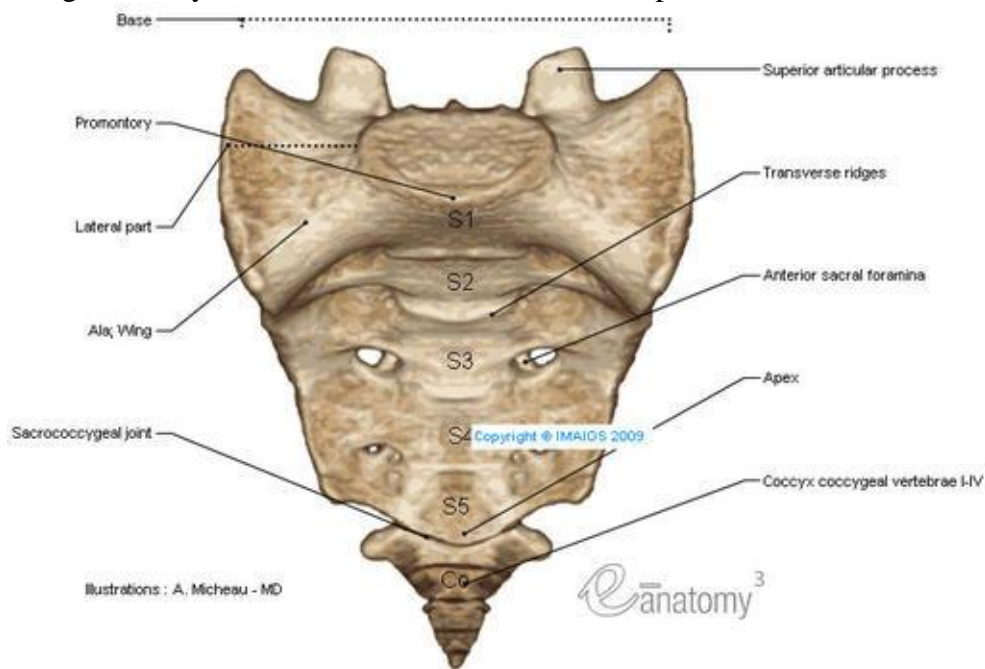


L5 vertebra: Produces the **lumbosacral angle**, is wedge-shaped. Its transverse processes, although short, are thick and strong, and arise not only from the arch but also from the side of the vertebral body. **Interlaminar gap** is increased by forward flexion of the spine: a combination of circumstances that makes lumbar puncture possible.

Sacrum:

The sacrum consists of five fused vertebrae. It is wedge-shaped and presents markedly concave anterior and convex posterior surfaces. The anterior surface bears four transverse lines which

terminate on each side in the four anterior sacral foramina, lateral to which is the fused lateral mass. The anterior primary rami of the upper four sacral spinal nerves, as they emerge from the anterior foramina, produce distinct neural grooves on the lateral mass. The posterior surface of the sacrum is made up of the fused vertebral arches which form the roof of the sacral canal. A median crest of fused spines, represented by small spinous tubercles. On either side of this crest are the fused laminae which bear laterally an articular crest composed of fused articular facets, each represented by a small tubercle. Each articular crest terminates below in the sacral cornu. The last laminar arch (or more) is missing, leaving the sacral hiatus. Lateral to the articular tubercles are the four posterior sacral foramina, which lie directly opposite their corresponding anterior foramina. The lateral mass bears on its upper outer aspect a large auricular surface which articulates with the corresponding auricular surface of the ilium. The upper surface (or base) of the sacrum shows the features of a rather modified vertebra. The body is oval in section, its anterior edge forming the sacral promontory. The sacral canal is triangular in section, produced by very short pedicles and long laminae. The superior auricular facet faces backwards and inwards to receive the inferior facet of L5. The upper surface of the lateral mass is termed the ala and is grooved by the lumbosacral cord of the sacral plexus.



Sacral hiatus:

The sacral hiatus results from failure of fusion of the laminae of the 5th sacral segment.

Boundaries:

Above -fused laminae of the 4th sacral segment

Roof-posterior sacrococcygeal ligament (about 1–3 mm thick), subcutaneous fat and skin

Laterally-margins of the deficient laminae of S5, which below bear the sacral cornua

Inferiorly- lies the posterior surface of the body of the 5th sacral segment.

The sacral hiatus usually lies 5 cm above the tip of the coccyx and directly beneath the uppermost limit of the natal cleft.

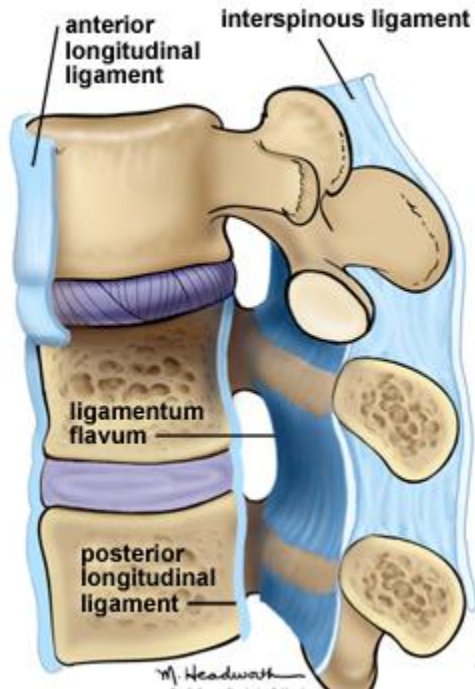
Coccyx:

Four fused rudimentary vertebrae

Ligaments:

Anterior longitudinal ligament:

Runs along the front of the vertebral bodies from C2 to the upper sacrum,



Posterior longitudinal ligament:

Extends along the posterior surfaces of the vertebral bodies.

Ligamenta flava:

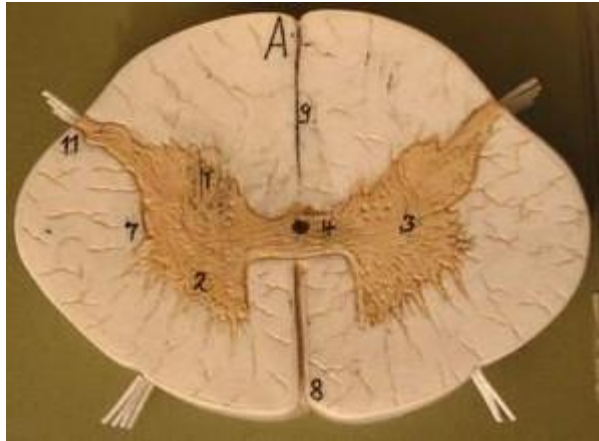
Ligaments of perpendicularly aligned elastic fibres which connect the adjacent laminae. They become progressively thicker from above downward. In elderly patients the elasticity of the ligamentum flavum tends to be lost and calcification of this structure may occur.

The interspinous ligaments:

Connect the shafts of the adjacent spines. They are thin and tenuous, particularly in the cervical region.

Supraspinous ligament:

Powerful column of fibrous tissue that connects the tips of the spines from C7 to the sacrum. This ligament may become ossified in elderly patients so that a midline spinal puncture becomes difficult.



The *ligamentum nuchae*:

Representing the upward continuation of the supraspinous ligament.

Which stretches from C7 to the external occipital protuberance.

SPINAL CORD

The spinal cord is 45 cm long in the adult. Cylindrical shape. Bears cervical and lumbar

enlargements that correspond to the origins of the brachial and lumbo-sacral plexuses. The spinal cord tapers into the *conus medullaris*, from which a glistening thread, the *filum terminale*, continues down to become attached to the coccyx. Up to the third fetal month, the cord extends to the length of the vertebral canal. The vertebrae then grow considerably faster than the cord, so that the cord terminates in the newborn at the lower border of the 3rd lumbar vertebra and in the adult, on average, at the disc between the 1st and 2nd lumbar vertebral bodies. This differential growth results in the lumbar and sacral nerve roots becoming considerably elongated to reach their corresponding intervertebral foramina, thus forming the *cauda equinae*.

Approximate levels of the cord segments.

Cord segment	Vertebral body
C8	C7
T6	T4
T12	T9
L5	T12
Sacral	L1

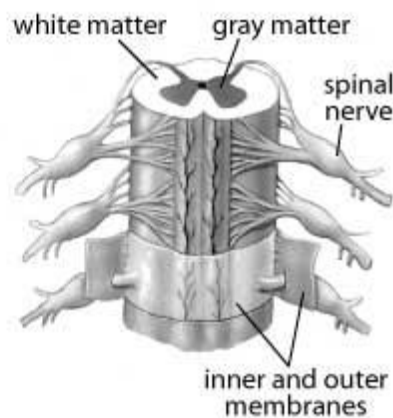
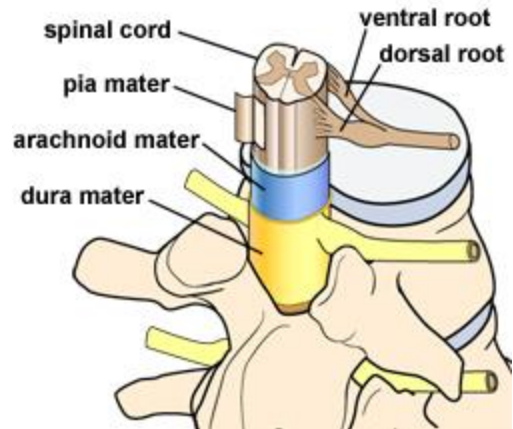
Structure of spinal cord:

In transverse section the cord comprises a *central canal*, an H-shaped zone of *grey matter* (nerve cells) and an outer zone of *white matter* (nerve fibres).

The amount of white matter declines progressively from the cervical down to the lumbar region. Grey matter is greatly increased in both the cervical and lumbar enlargements, which correspond to the zones of origin of the motor nerves to the upper and lower limbs.

Central canal: Central canal continues downwards from the 4th ventricle as a narrow tube, lined with ciliated ependymal cells and containing CSF. It traverses the whole length of the cord, dilates somewhat within **the conus medullaris**, and continues for a short distance within **the filum terminals**.

Grey matter: Cross-limb of the 'H' of grey matter is termed the **transverse commissure**. Each lateral limb consists of a short, broad **anterior column**, containing large motor cells and a thinner, pointed **posterior column**, which is capped by the **substantia gelatinosa**. These columns are referred as the anterior and posterior horns, respectively.



White matter: White matter consists, to a large extent, of longitudinally disposed medullated nerve fibres divided by their relationship to the central grey matter, into the posterior, lateral and anterior white columns. Important tracts in the white matter are as follows:

Descending tracts:

1 The *lateral cerebrospinal* or

pyramidal tract

2 The *anterior cerebrospinal, direct pyramidal* or *uncrossed motor tract*

Ascending tracts:

1 Medial *fasciculus gracilis* of Goll and lateral *fasciculus cuneatus* of Burdach

2 The *spinothalamic tracts*

3 The *anterior* and *posterior spinocerebellar tracts*

Spinal meninges:

Spinal cord has three covering membranes or meninges.

Dura mater

Arachnoid mater

Pia mater

Dura mater:

The dura mater that encloses the cord consists of a continuation of the inner (meningeal) layer of the cerebral dura. The outer endosteal layer being represented by the periosteum lining the vertebral canal. The dural sac usually extends to the level of the 2nd segment of the sacrum.

Arachnoid mater: Thin transparent sheath closely applied to the dura. Surrounds the cranial and spinal nerves as far as their points of exit from the skull and vertebral canal.

Piamater: The innermost of the three membranes. Vascular connective tissue sheath that closely invests the brain and spinal cord, and projects into their sulci and fissures. Spinal pia is thickened anteriorly into the *linea splendens*. On either side, it forms the *ligamentum denticulatum*, a series of triangular fibrous strands attached at their apices to the dural sheath. Inferiorly, the pia is continued downwards as the *filum terminal*, which pierces the lower end of the dural sac and then continues to the coccyx with a covering sheath of dura.

Compartments related to spinal meninges:

- 1) Subarachnoid - between arachnoid and pia mater
- 2) Subdural - between dura and arachnoid
- 3) Epidural spaces - between spinal dura and periosteum.

Boundaries of the Epidural space:

Superiorly - foramen magnum

Inferiorly - sacrococcygeal membrane

Posteriorly - anterior surface of lamina and their connecting ligaments, roots of vertebral spines and ligamentum flava.

Anteriorly - posterior longitudinal ligament

Laterally - pedicles and intervertebral foramina.

The capacity of the epidural space is far greater than that of the subarachnoid space at the same level.

Spinal segments:

-Cord is divided into segments by the pairs of spinal nerves arising from it

-31 pairs

1. 8 cervical
2. 12 thoracic
3. 5 lumbar
4. 5 sacral
5. 1 coccygeal

Blood supply of spinal cord:

The arteries supplying the spinal cord are the anterior and posterior spinal arteries

Anterior spinal artery: branch from each vertebral artery. Larger of the two vessels and supplies the whole of the cord in front of the posterior grey columns.

Posterior spinal arteries: one or two vessels on either side derived from the posterior inferior cerebellar arteries. They supply the posterior grey and white columns on either side. These arteries are reinforced serially by spinal branches of the vertebral, deep cervical, intercostal, lumbar, ilio-lumbar and lateral sacral arteries. One of the anterior radicular arteries is of considerable size and termed the **arteria radicularis magna, or artery of Adamkiewicz.**

It usually arises in the lower thoracic or upper lumbar region. This is usually single and in the majority of cases arises on the left-hand side. On reaching the spinal cord, this artery sends a branch to join both the anterior and the posterior spinal artery and may be responsible for most of the blood supply of the lower two-thirds of the spinal cord.

Venous drainage:

Plexus of anterior and posterior spinal veins drain along the nerve roots. Into the segmental veins; the vertebral veins in the neck, the azygos veins in the thorax, lumbar veins in the abdomen and lateral sacral veins in the pelvis. At the foramen magnum, they communicate with the medullary veins.

Cerebrospinal fluid:

Csf production

- 1) Ultrafiltration and secretion by cells of choroid plexus
- 2) passage of water, electrolytes, and other substances across
- 3) Ependymal cells around blood vessels and ventricles

CSF is therefore a direct extension of ECF compartment of the CNS.

Csf circulation:

Secreted in the *lateral ventricles* passes first into the *third Ventricle*-- → *aqueduct of Sylvius* → *fourth ventricle*.

Two *lateral foramina of Luschka* and a *midline foramen Magendie*-->, *cisterna magna*, a fluid space that lies behind the medulla and beneath the cerebellum.

Almost all the cerebrospinal fluid then flows upward from the *cisterna magna* through the subarachnoid spaces surrounding the cerebrum

CSF is absorbed from microscopic arachnoid villi and macroscopic arachnoid granulations within the duramater and bordering venous sinusoids and sinuses

PERIPHERAL NERVE BLOCKADE ANATOMY

There are 31 pairs of spinal nerves, 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal.

Each is formed by the fusion of an anterior and posterior spinal root.

The **anterior (ventral) roots**: Are motor.

Emerge in series from the anterior grey column of the spinal cord.

The **posterior (dorsal) roots** : Are sensory.

Each posterior root carries a ganglion, immediately distal to which the anterior and posterior roots meet to form a spinal nerve.

In addition to this, the spinal cord bears a third and lateral set of nerve roots: the series of filaments from the upper four to six cervical segments that unite to form the spinal root of the accessory nerve.

The **spinal nerves** :

Each give off a small meningeal branch, which re-enters the intervertebral canal and supplies the adjacent blood vessels and ligaments, divide into anterior and posterior primary rami.

The arrangement of a 'typical' spinal nerve is as follows:

1. The posterior primary ramus passes backwards between the transverse processes and then divides into a medial and lateral branch.

These supply the adjacent vertebral muscles and send (from one or other branch) a cutaneous supply to the overlying skin.

2. The anterior primary ramus is linked to the sympathetic chain by a white and grey ramus communicans.

The nerve ends anteriorly by becoming the anterior cutaneous branch which supplies an area of skin adjacent to the midline.

This 'typical' plan is seen only in the thoracic segments; elsewhere it is modified, especially in relation to the formation of the great nerve plexuses from the anterior primary rami.

Meningeal relations :

Both the anterior and posterior nerve roots bear prolongations of the pia and arachnoid mater which end where the roots separately pierce the dura.

Vertebral relations :

The posterior root ganglia lie in the intervertebral foramina.

The only exceptions to this rule are those of C1 and 2, which lie on the posterior arches of their sacral canal.

The 1st cervical nerve emerges between the occiput and the posterior arch of the atlas; it is appropriately termed the suboccipital nerve.

Nerves C2–7 similarly emerge above their respective vertebrae, but C8 passes through the intervertebral canal between the 7th cervical and 1st thoracic vertebra.

Below this level each spinal nerve emerges *below* its corresponding vertebra.

The posterior primary rami :

The posterior primary rami of the spinal nerves are concerned with the innervation of the skin and muscles of the back. Those of C1 and 2 are quite exceptional.

1. The posterior primary rami supply motor and sensory fibres to serially segmental areas.

These segments overlap, anaesthetic block of one single nerve does not reliably produce a corresponding band of cutaneous anaesthesia.

2. Unlike the anterior primary rami, the posterior rami do not extend into either the upper or the lower limb and do not form plexuses.
3. With the exception of C1, S4, S5 and Coccygeal nerve 1, each posterior primary ramus divides into a medial and a lateral branch within the dorsal muscle mass.

The cutaneous component is contained, in segments T6 and above, in the medial branch, but below T6 is transmitted in the lateral branch.

No cutaneous fibres at all are conveyed by C1, C6–8 or L4–5.

The cervical posterior primary rami:

The posterior primary ramus of C1 : Larger than the corresponding anterior primary ramus, is entirely motor.

It is sandwiched between bone and the vertebral artery, to enter the suboccipital triangle, where it supplies the three surrounding muscles: the superior oblique, inferior oblique and rectus capitis posterior major.

The posterior primary ramus of C2: The largest of the cervical posterior primary rami.

The medial branch is **the greater occipital nerve**, is joined by a filament from the medial branch of C3, supply the skin of the occipital region as far as the vertex.

Anteriorly, it overlaps with the lesser occipital nerve, derived from the anterior primary ramus of C2. It gives a branch to semispinalis.

This nerve is sometimes involved in cervicogenic headache. Infiltration of the greater occipital nerve with local anaesthetic may produce analgesia.

However, it must be borne in mind that it is possible for C2 pain to be referred to areas supplied by the trigeminal nerve.

The lateral branch is entirely **motor**; it partly supplies the posterior cervical muscles.

The medial branch C3 : The *third occipital nerve*; supplies the skin of the lower occiput.

The lateral branch is motor to the posterior cervical muscles.

In addition, the medial branches of C4 and 5 supply the overlying skin.

The thoracic posterior primary rami:

All the thoracic posterior primary rami divide into medial and lateral branches, all of which supply the dorsal muscles.

The medial branches of the upper six thoracic nerves: supply the skin immediately adjacent to the vertebral spines,

The lateral branches of the lower six thoracic nerves are cutaneous as well as motor.

The cutaneous branches : T1 supplies an area immediately inferior to its corresponding vertebra,

T10 and 11 innervate the skin over the loin,

T12 runs along the iliac crest, then sends twigs over the upper gluteal region.

The lumbar posterior primary rami :

All the lumbar posterior rami divide into medial and lateral branches that supply the overlying lumbar muscles.

The sacral and coccygeal posterior primary rami:

The posterior rami of S1–4 emerge through the posterior sacral foramina;

S5 emerges from the bifurcation of the main nerve trunk.

These nerves are small, and become successively smaller from above downwards. They all supply sacrospinalis;

Only the upper three divide to give lateral branches which reach the skin over the sacrum.

Coccygeal nerve 1 is small, is undivided and, appropriately, supplies the skin over the coccyx.

The anterior primary rami :

The anterior primary rami supply the arm, the leg and the front and sides of the neck, thorax and abdomen with their motor and sensory innervation.

The trunk is supplied by the segmentally placed thoracic anterior rami;

The neck and limbs are served by the cervical, brachial, lumbar and sacral plexuses.

CERVICAL PLEXUS:

The anterior rami of the upper four cervical nerves forms a series of loops to form the cervical plexus.

Formation of the plexus:

Loops are three in number

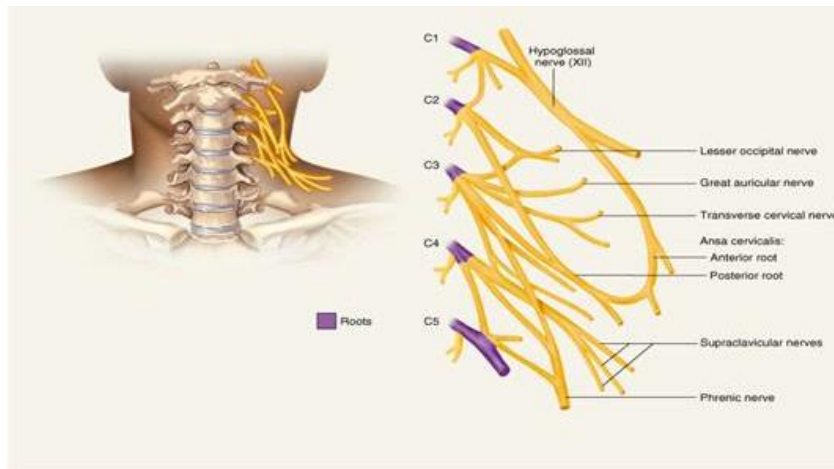
C1–2,

C2–3 and

C3–4, with a further loop

(C4–5) often present to connect the cervical plexus with the brachial plexus.

- anterior primary ramus of C1 is entirely motor. The nerve descends to form a loop with the ascending branch of C2 in front of the transverse process of the atlas.
- join the hypoglossal nerve at the level of the atlas; supplies the geniohyoid and thyrohyoid muscles, then runs downwards as the *descendens hypoglossi*, supplying anterior belly of omohyoid.
- Descendens hypoglossi joins *descendens cervicalis*, derived from C2 and 3, to form a loop termed **the ansa cervicalis**, which lies on the carotid sheath - supply sternohyoid, sternothyroid and the posterior belly of omohyoid.
- anterior primary ramus of C2 - divides into an ascending branch, which joins C1, and a descending branch which loops to join C3.
- anterior primary ramus of C3 - divides into an ascending branch, which joins C2, and a descending branch which loops to join C4.



Summary of branches :

The branches of the cervical plexus can be divided into four groups.

1. **Communicating branches:** Pass to the hypoglossal nerve and also pass to the vagus and to the cervical sympathetic chain.
2. **Superficial branches:** Supply cutaneous fibres to the neck.
3. **Deep branches:** To the neck muscles.
4. **The Phrenic nerve:** The motor nerve of the diaphragm, transmits proprioceptive fibres from the central part of this muscle.

The superficial cervical plexus:

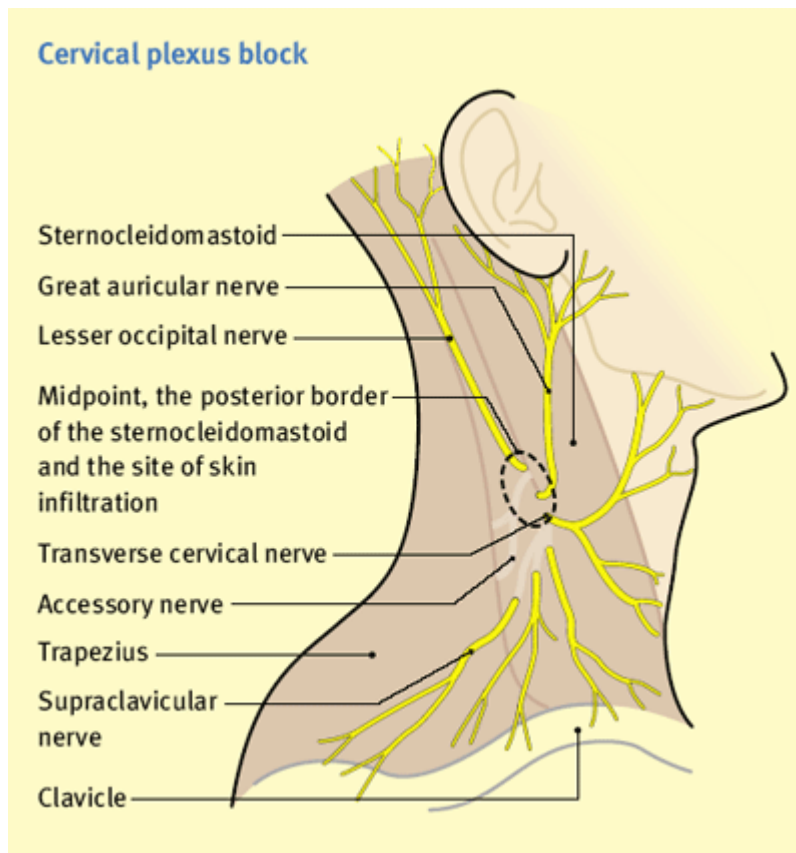
Comprises **superficial branches divided into three groups:**

- *Ascending* - lesser occipital nerve (C2); great auricular nerve (C2, 3).
- *Transverse* - anterior cutaneous nerve of neck (C2, 3).
- *Descending* - the supraclavicular nerves (C3, 4).

The deep cervical plexus :

This supplies:

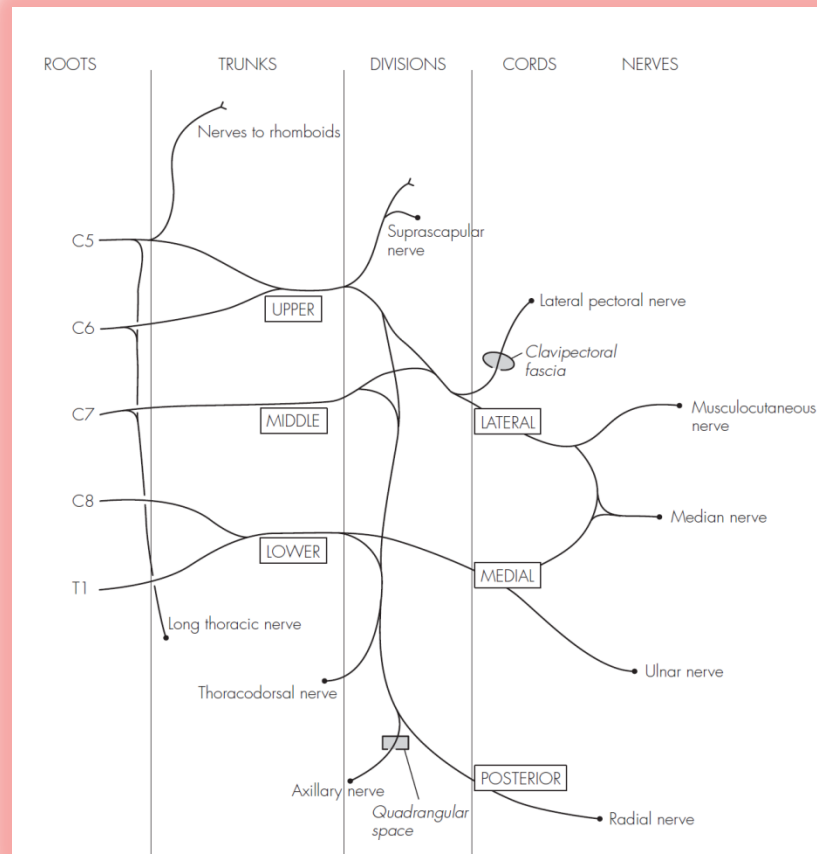
- the anterior vertebral muscles - the recti capitis, longus capitis and longus cervicis, as well as giving contributions to scalenus medius.
- levator scapulae (C3, 4) and
- sternocleidomastoid (C2, 3) and trapezius (C3, 4).



ANATOMY RELATED TO UPPER LIMB NERVE BLOCKS

BRACHIAL PLEXUS:

- The plexus is formed by the anterior primary rami of C5–8 together with T1.
- C4–8 (pre-fixed plexus) or from C6–T2 (post-fixed plexus).



The composition of the brachial plexus:

1. Five roots (between the scalene muscles)

(a) the anterior primary rami of C5–8 and T1.

2. Three trunks (in the posterior triangle):

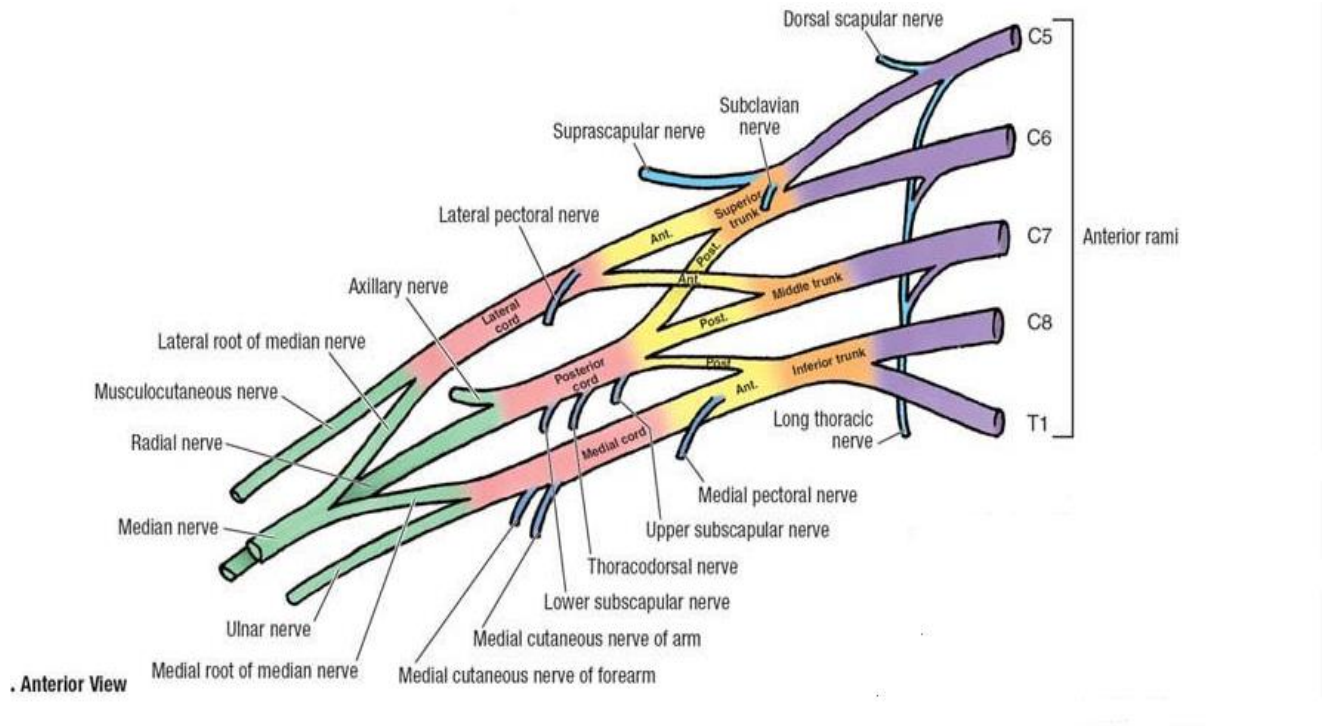
- (a) *upper*, C5 and 6;
- (b) *middle*, C7 alone;
- (c) *lower*, C8 and T1.

3. Six divisions (behind the clavicle) :

(a) each trunk divides into an anterior and posterior division.

4. Three cords (within the axilla):

- (a) **lateral**, the fused anterior divisions of upper and middle trunks (C5–7);
- (b) **medial**, the anterior division of the lower trunk (C8, T1);
- (c) **posterior**, formed by the union of the posterior divisions of all three trunks (C5–T1).



The branches of the brachial plexus :

1. The **roots** receive:

- (a) grey rami from the cervical sympathetic chain;
- (b) C5 and 6 from the middle cervical ganglion;
- (c) C7 and 8 from the inferior cervical ganglion;
- (d) T1 from the ganglion of T1;

and give branches:

- (a) to longus cervicis (C5–8);
- (b) to the scalene muscles (C5–8);
- (c) nerve to rhomboids (C5);
- (d) nerve to serratus anterior (C5–7);
- (e) contribution to the phrenic nerve (C5).

2. The **trunks** give:

- (a) nerve to subclavius (C5, 6);
- (b) suprascapular nerve (C5, 6).

3. The **cords** give:

(a) **Lateral cord :**

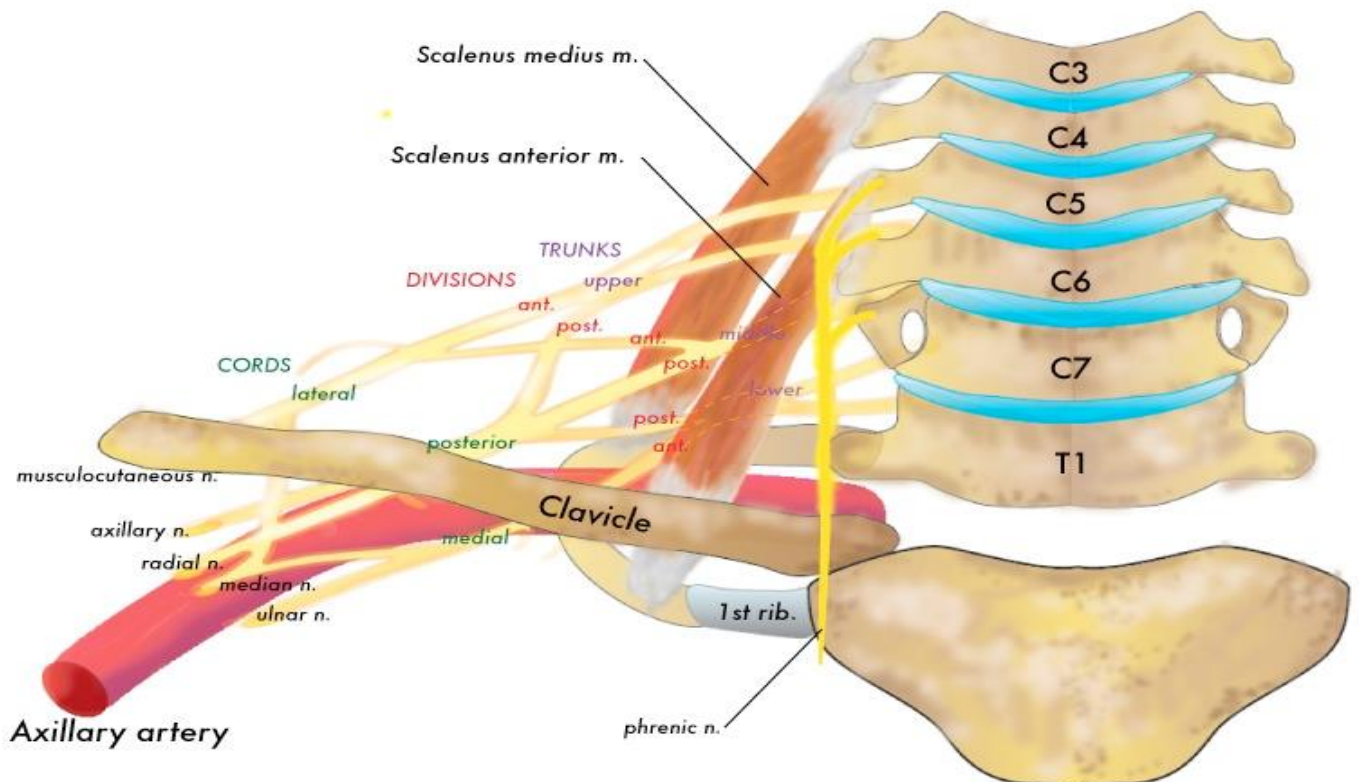
lateral pectoral nerve (C5–7);
musculocutaneous nerve (C5–7);
lateral head of median nerve (C6, 7);

(b) **Medial cord :**

medial pectoral nerve (C8, T1);
medial cutaneous nerve of arm (C8, T1);
medial cutaneous nerve of forearm (C8, T1);
medial head of median nerve (C8, T1);
ulnar nerve (C7–8, T1);

(c) **Posterior cord :**

upper subscapular nerve (C5, 6);
nerve to latissimus dorsi (thoracodorsal nerve) (C6–8);
lower subscapular nerve (C5, 6);
axillary nerve (C5, 6);
radial nerve (C5–8, T1).

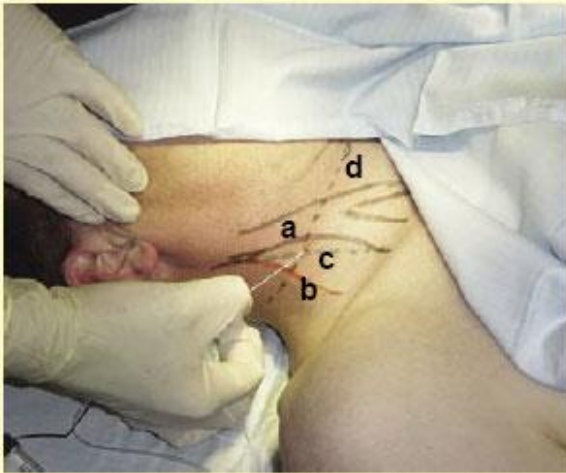


Brachial plexus blocks

Approach	Level	Sensory block	Complications	Remarks
Interscalene	Roots	Shoulder, upper arm, elbow	Phrenic nerve palsy, Horner's syndrome, subarachnoid/epidural injection, vertebral artery injection (rare)	Technically difficult, many side-effects, spares the ulnar territory, phrenic nerve palsy may lead to respiratory compromise
Supraclavicular	Trunks and proximal divisions	Entire arm	Pneumothorax, phrenic nerve palsy, Horner's syndrome	Highest pneumothorax incidence, phrenic nerve palsy may lead to respiratory compromise
Classic infraclavicular	Cords/terminal branches	Forearm, wrist, hand	Intravascular injection, pneumothorax	Painful in the awake patient, landmarks are sometimes not easy to identify
Vertical infraclavicular	Cords	Forearm, wrist, hand	Pneumothorax, intravascular injection	Lateral bony landmark must be identified correctly
Axillary	Terminal branches	Forearm, wrist, hand	Haematoma formation, intravascular injection	Easy, low complication rate, but often spares the musculocutaneous nerve

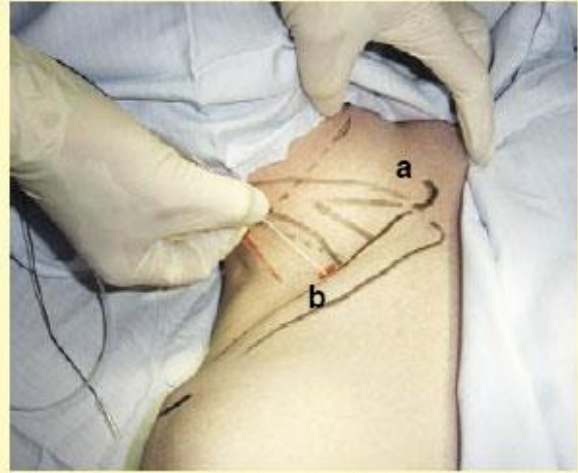
Common approaches to the brachial plexus

Interscalene approach



a Posterior border of sternocleidomastoid muscle, b external jugular vein, c interscalene groove, d level of cricoid.

Supraclavicular approach



a Sternal notch, b pulsation of subclavian artery (mid-point clavicle).

Vertical infraclavicular block



a Sternal notch, b mid-point, c ventral apophysis of acromion. Note: needle entry at right angles to table.

Axillary approach



a Axillary artery, b needle entry at lateral border of pectoralis major.

The musculocutaneous nerve (C5–7):

- The lateral cord gives off the lateral head of the median nerve at the lower border of pectoralis minor & continues as musculocutaneous nerve.
- It first supplies and then pierces coracobrachialis, then descends downwards and laterally between biceps and brachialis, supplying both these muscles. (Brachialis, in addition, receives a nerve supply from the radial nerve.)
- The nerve emerges between biceps tendon and brachioradialis, pierces the deep fascia of the antecubital fossa and continues downwards as the *lateral cutaneous nerve of the forearm*.
- The musculocutaneous nerve in addition sends a twig to the elbow joint.

The ulnar nerve (C7, 8, T1):

- the continuation of the medial cord after this has given off the medial head of the median nerve.
- At the elbow joint, the nerve passes behind the medial epicondyle of the humerus, where it can be rolled against the bone, then dives between the humeral and ulnar heads of flexor carpi ulnaris.
- At the wrist, the nerve crosses the flexor retinaculum immediately lateral to the pisiform bone, covered here by some superficial fibres of the retinaculum. Ulnar artery & flexor carpi ulnaris tendon lies lateral to the nerve.

The ulnar nerve supplies the following:

1 Muscular branches

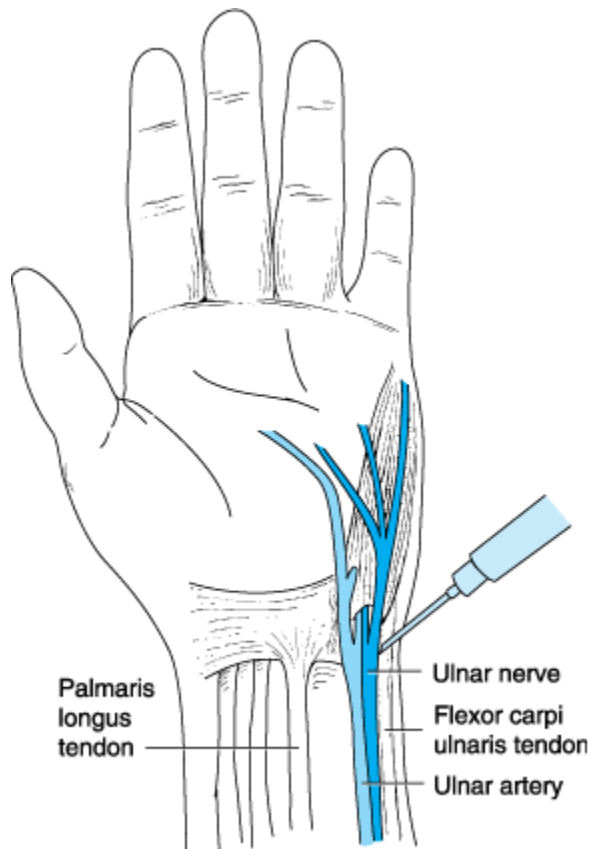
- (a) to flexor carpi ulnaris,
- (b) the medial half of flexor digitorum profundus
- (c) all the intrinsic muscles of the hand apart from the lateral two lumbricals and the three muscles of the thenar eminence.

2 Cutaneous branches

- (a) to the dorsal and palmar aspects of the medial side of the hand and of the medial 1 1/2 fingers.

3 Articular branches

- (a) to elbow and wrist.



The median nerve (C5–8, T1):

- carries fibres from all the roots of the brachial plexus.
- The nerve descends through the arm, first on the lateral side of the brachial artery, then on its medial side, crossing the artery at the mid-point of the upper arm.
- At the wrist, the tendon of flexor carpi radialis lying laterally and those of flexor digitorum superficialis and palmaris longus medially.

The median nerve supplies the following:

1 Muscular branches

- 2 to pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis, the three muscles of the thenar eminence and the lateral two lumbricals.

(A) Its anterior interosseous branch innervates flexor pollicis

longus, the lateral half of flexor digitorum profundus and pronator quadratus.

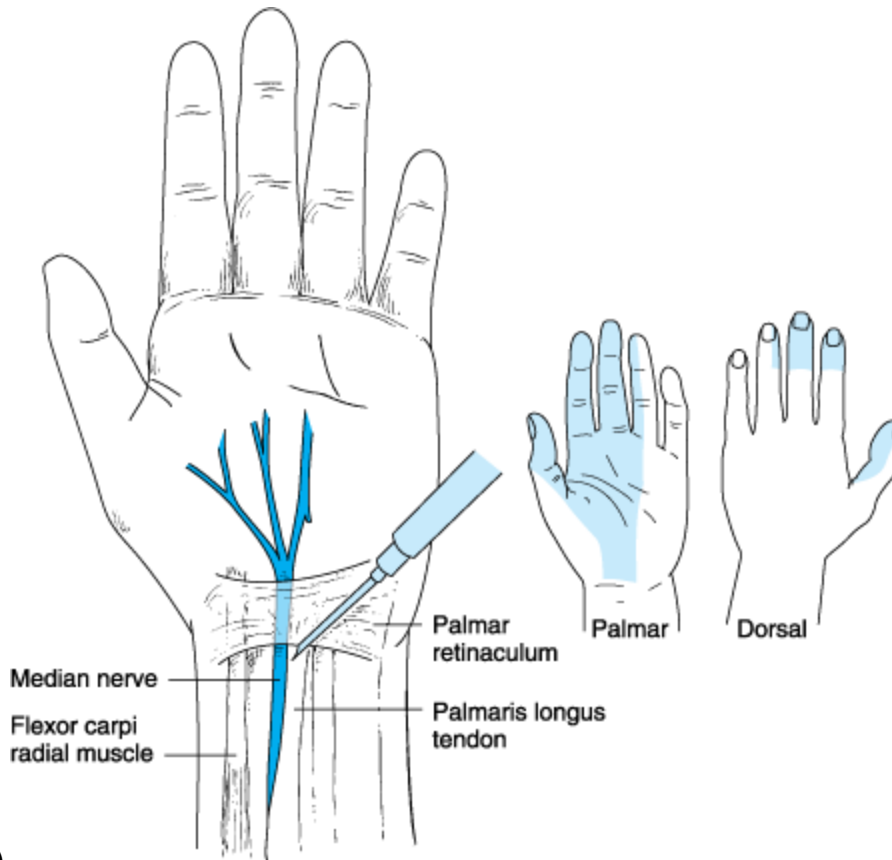
2 Cutaneous branches

(A) to the thenar eminence of the palm,

(B) the anterior aspects of the radial three digits and the skin over the dorsal aspect of their distal phalanges.

3 Articular branches

(A) to the elbow and wrist.



(B)

The radial nerve (C5–8, T1) :

- transmits fibres from all the roots of the brachial plexus.

The branches of the radial nerve are muscular, cutaneous, articular (to the elbow) and terminal.

The *muscular branches* are conveniently divided into.

1 The medial group(arising in the axilla) supplies:

- (a) long head of triceps;
- (b) medial head of triceps.

2 The posterior group(arising in the spiral groove) supplies:

- (a) medial head of triceps;
- (b) lateral head of triceps;
- (c) anconeus.

3 The lateral group supplies:

- (a) brachialis (together with the musculocutaneous nerve);
- (b) brachioradialis;
- (c) extensor carpi radialis longus.

The *cutaneous branches* are three in number:

1 The *posterior cutaneous nerve of the arm*, which arises in the axilla and supplies the skin over the proximal one-third of the posterior aspect of the arm.

2 The *posterior cutaneous nerve of the forearm*, which arises in the spiral groove, perforates the lateral head of triceps, descends over the lateral aspect of the forearm to the wrist and supplies the skin over the postero lateral aspect of the forearm.

3 The *lower lateral cutaneous nerve of the arm*, a branch of the latter, also pierces the lateral head of the triceps and supplies an area of skin over the lateral aspect of the arm just above the elbow.

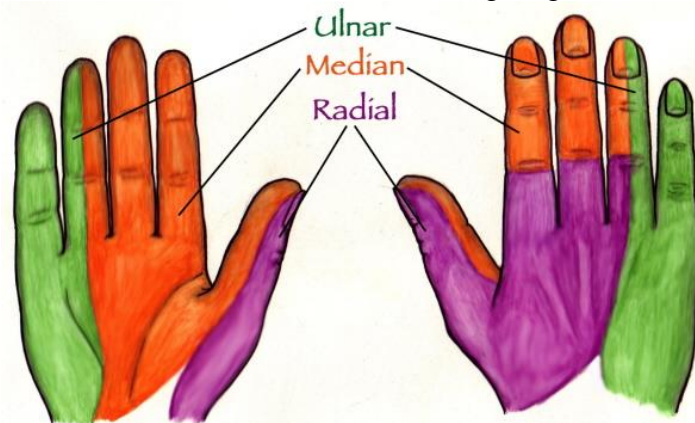
The two *terminal branches* are the posterior interosseous nerve and the superficial radial nerve.

The *posterior interosseous nerve*, apart from articular twigs, is entirely muscular.

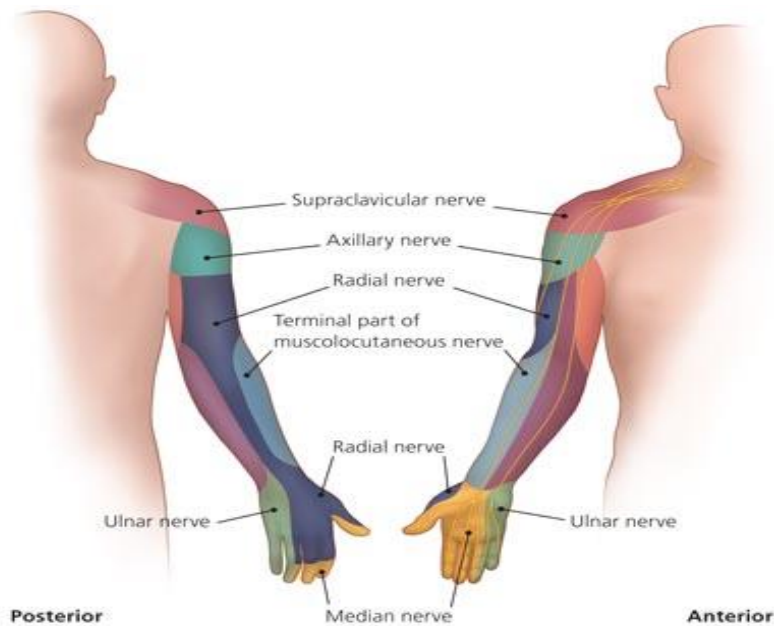
- muscular branches are those that arise before the nerve enters supinator, supplying supinator and extensor carpi radialis brevis, and those which arise when the nerve emerges from supinator, supplying extensor digitorum, extensor digiti minimi, extensor carpi ulnaris, extensor pollicis longus, extensor pollicis brevis, extensor indicis and abductor pollicis longus.
- One articular twig to wrist joint

The *superficial radial nerve* is entirely sensory.

- supply the dorsal aspect of the thumb base, the radial side of the back of the hand and the backs of the thumb, index, middle and radial half of the ring finger as far as their distal



interphalangeal joints.



Variations:

- The ulnar nerve may supply part or even all of the thenar muscles, or the median nerve may innervate adductor pollicis and the 1st dorsal interosseous muscle in addition to the three muscles of the thenar eminence. The radial nerve never innervates the intrinsic muscles of the hand.
- The ulnar supply to the dorsum may even, on occasion, be completely deficient. On the palmar aspect, the ulnar nerve may extend its area to innervate the whole of the ring finger or even reach the ulnar side of the middle finger. In other cases it may be confined to the sensory supply of only the 5th finger.

Nerve palsy:

Median nerve - wasting of the thenar eminence, absence of abduction of the thumb, and absence of opposition of the thumb.

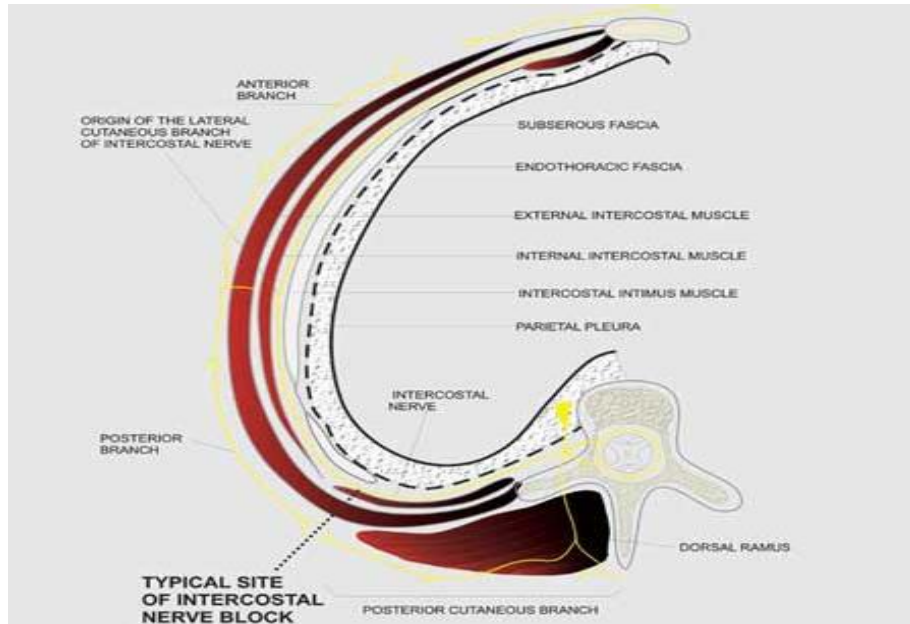
Ulnar nerve -- wasting of the hypothenar eminence, absent flexion of the distal interphalangeal joints of the little and ring fingers, and absent abduction and adduction of the fingers. The thumb is unaffected.

Radial nerve - wrist drop (the inability to extend the wrist upward when the hand is palm down); numbness of the back of the hand and wrist; and inability to voluntarily straighten the fingers. Loss of extension is due to paralysis of the posterior compartment of forearm muscles.

THE THORACIC NERVES

Anterior primary rami

12 pairs of thoracic anterior primary rami: the upper 11 comprise the intercostal nerves and the 12th is termed the subcostal nerve.



Intercostal nerves 3–6 (the ‘typical’ intercostal nerves):

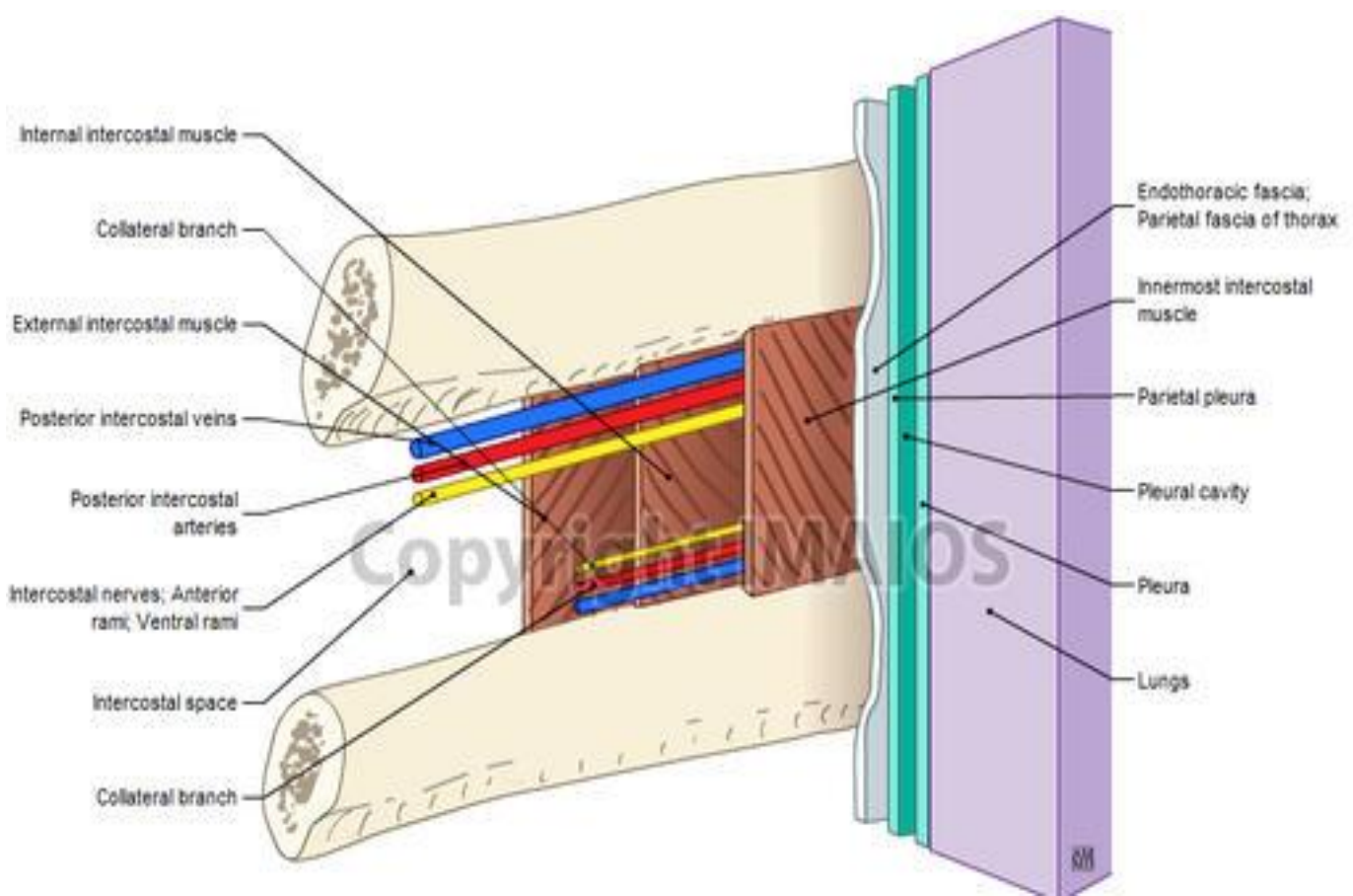
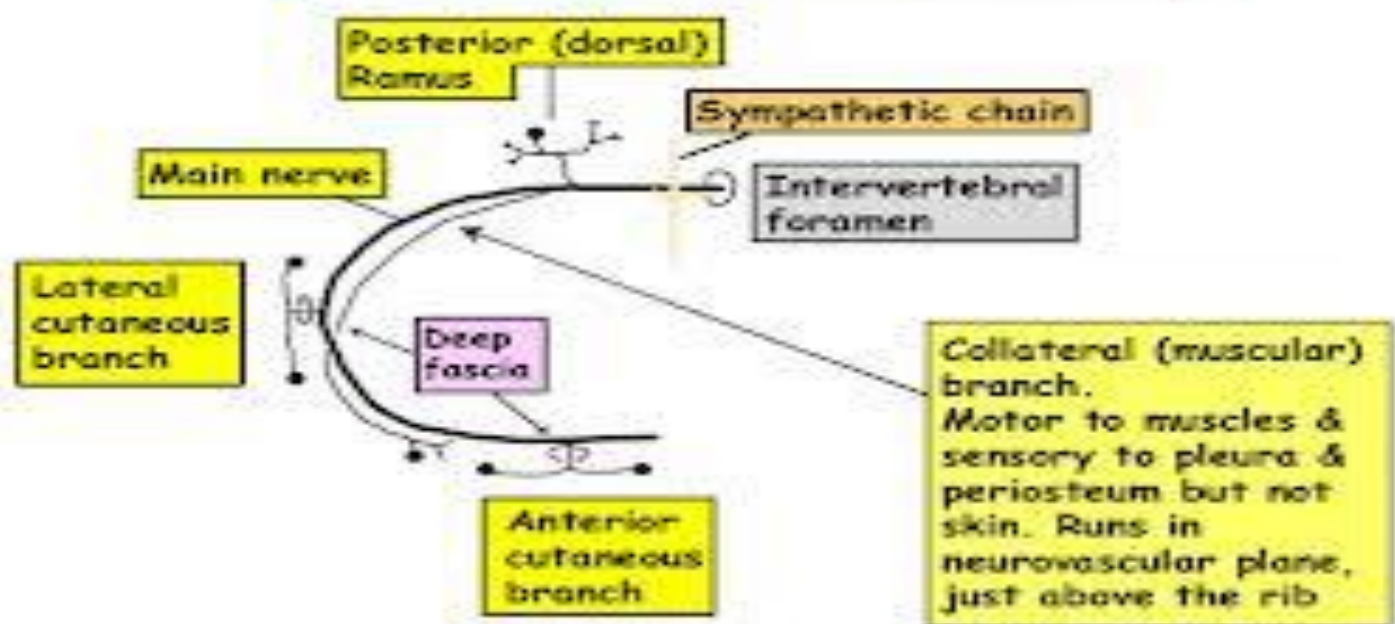
enter their intercostals spaces across the anterior aspect of the corresponding superior costotransverse ligament to lie below the intercostal vessels.

Branches from these four ‘typical’ intercostal nerves are:

- **Muscular** - to the intercostal muscles.
- **Collateral** - which run along the lower border of each intercostal space, and either rejoin the main nerve or end as separate anterior cutaneous nerves.
- **Lateral cutaneous** - which reach the skin in the mid-axillary line and divide into anterior and posterior branches.

Near the sternal margin, pierces the internal intercostal muscle, anterior intercostals membrane and the overlying pectoralis major to become an *anterior cutaneous nerve* of the thorax.

TYPICAL INTERCOSTAL NERVE



1st intercostal nerve (T1):

- sends a large contribution which passes across the front of the 1st rib, lateral to the superior intercostal artery, to enter into the composition of the brachial plexus.
- no lateral cutaneous branch and its anterior cutaneous branch, if indeed present at all, is small.

2nd intercostal nerve:

- lateral cutaneous branch crosses the axilla to supply the skin over the medial aspect of the upper arm; this branch is termed the *intercostobrachial nerve*.

7th to 11th intercostal nerves:

- Enter the abdominal wall between the interdigitations of the diaphragm with transversus abdominis.
- Motor branches supply the abdominal as well as the intercostal muscles.
- Each nerve has a collateral (additional anterior cutaneous) and a lateral cutaneous branch.
- Sensory filaments of the 7th to 11th intercostal nerves supply the periphery of the diaphragm.

12th thoracic (subcostal) nerve:

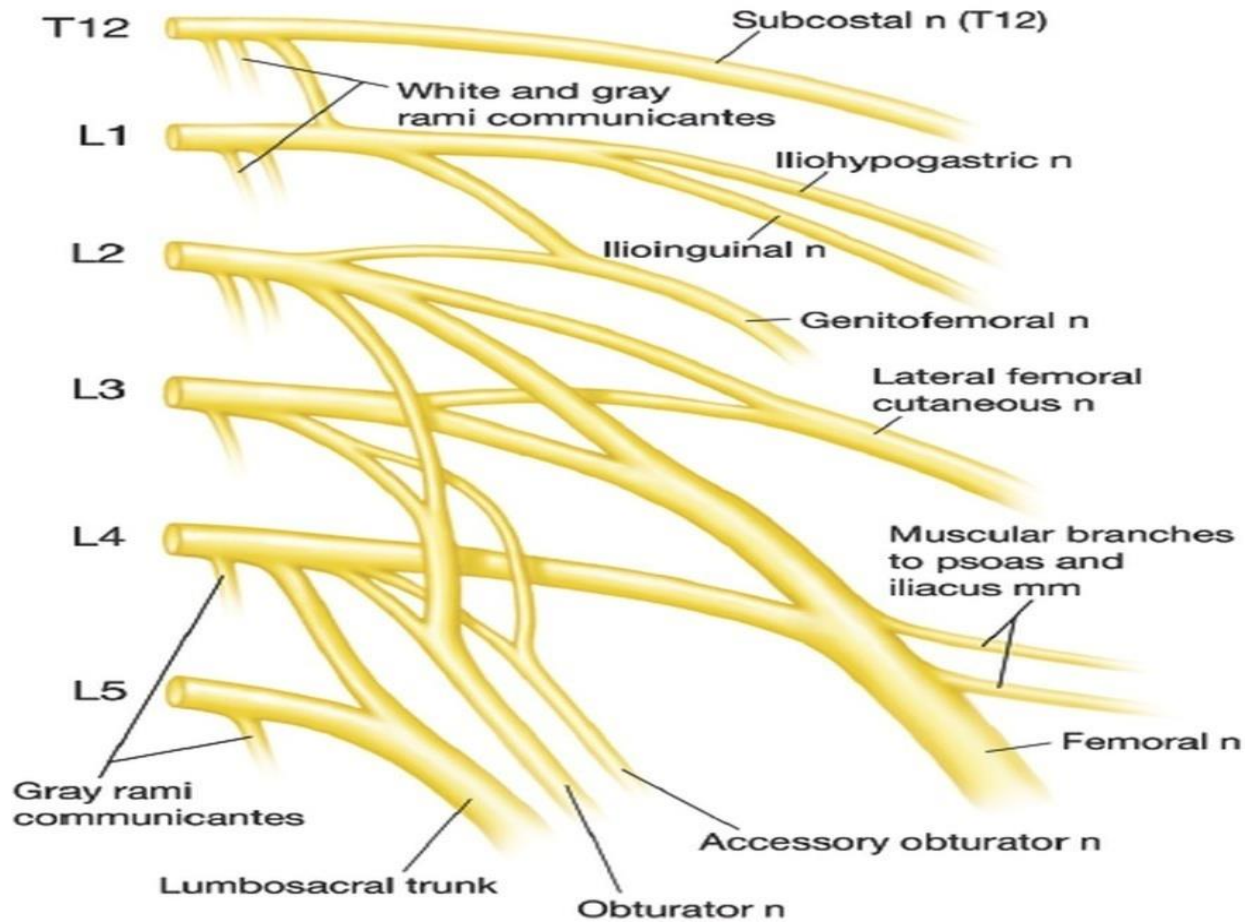
- Runs along the lower border of the 12th rib below the subcostal vessels, passes behind the lateral arcuate ligament to run in front of quadratus lumborum behind the kidney and colon.
- Course and distribution which are similar to the lower intercostal nerves.

THE LUMBAR PLEXUS

The lumbar plexus is derived from the anterior primary rami of the 1st, 2nd, 3rd and part of the 4th lumbar nerve roots. It may be pre-fixed, with its lowest contribution from L3, or post-fixed, when it extends to L5.

Formation of the plexus:

Assembles in front of the transverse processes of the lumbar vertebrae within the substance of the psoas major.



Branches of the lumbar plexus:

- Iliohypogastric L1
- Ilio-inguinal L1
- Genitofemoral L1, 2

Dorsal divisions

- lateral cutaneous nerve of thigh L2, 3
- femoral nerve L2-4

Ventral divisions

- obturator nerve L2-4
- accessory obturator nerve L3, 4

In addition, muscle branches are given to:

1. Psoas major;
2. Psoas minor;
3. Iliacus;
4. Quadratus lumborum.

The iliohypogastric nerve :

Pierces the internal oblique immediately above and in front of the anterior superior iliac spine, runs deep to the external oblique, just superior to the inguinal canal, and ends by supplying the suprapubic skin.

The ilio-inguinal nerve :

Pierces the internal oblique and then traverses the inguinal canal in front of the spermatic cord.

It emerges either through the external ring itself or through the adjacent external oblique aponeurosis to supply the skin of the scrotum (or labium majus) together with the adjacent upper thigh.

Genitofemoral nerve (L1, 2):

- penetrates the psoas to appear on its anterior surface at the level of the lower border of the 3rd lumbar vertebra.
- **Femoral branch** -- innervates an area of skin the size of one's hand immediately below the crease of the groin.
- **Genital branch** -- traverses the inguinal canal within the spermatic cord, supplies the cremaster muscle & supply the skin over the scrotum and adjacent thigh.
- In the female, the nerve accompanies the round ligament and supplies the skin over the anterior part of the labium majus and the mons pubis.

Lateral cutaneous nerve of the thigh (L2, 3):

- The anterior branch supplies the skin over the antero-lateral aspect of the thigh down to the knee.
- The posterior branch penetrates the fascia lata to innervate the skin of the lateral aspect of the leg from the greater trochanter to the mid-thigh.

Femoral nerve (L2–4):

supplies the muscles and the skin of the anterior compartment of the thigh.

At the base of the femoral triangle, the nerve lies on iliacus, a finger's breadth lateral to the femoral artery, from which vessel it is separated by a portion of the psoas.

Anterior division

Muscular branches to:

- 1 pectineus;
- 2 sartorius.

Cutaneous branches:

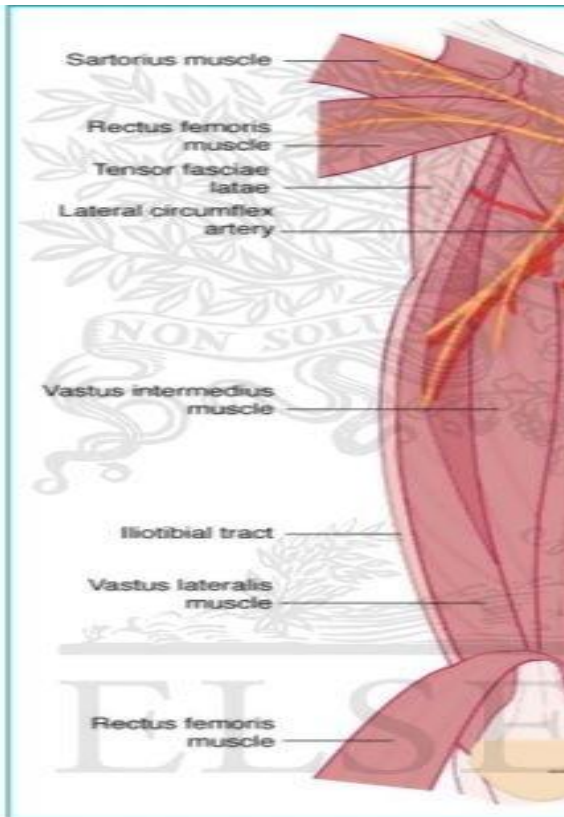
- 1 intermediate cutaneous nerve of thigh;
- 2 medial cutaneous nerve of thigh.

Posterior division

Muscular branches to quadriceps femoris.
Cutaneous branch - saphenous nerve.

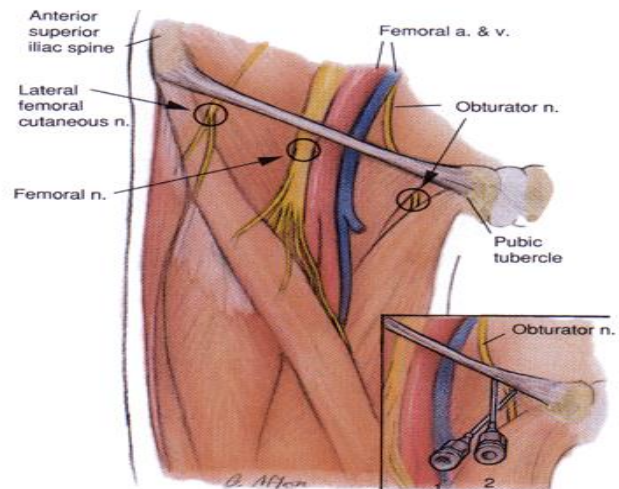
Articular branches to:

- 1 hip;
- 2 knee.



Obturator nerve (L2-4):

The nerve enters the obturator canal above and anterior to the obturator vessels. Within the canal the nerve divides into its anterior and posterior branches:

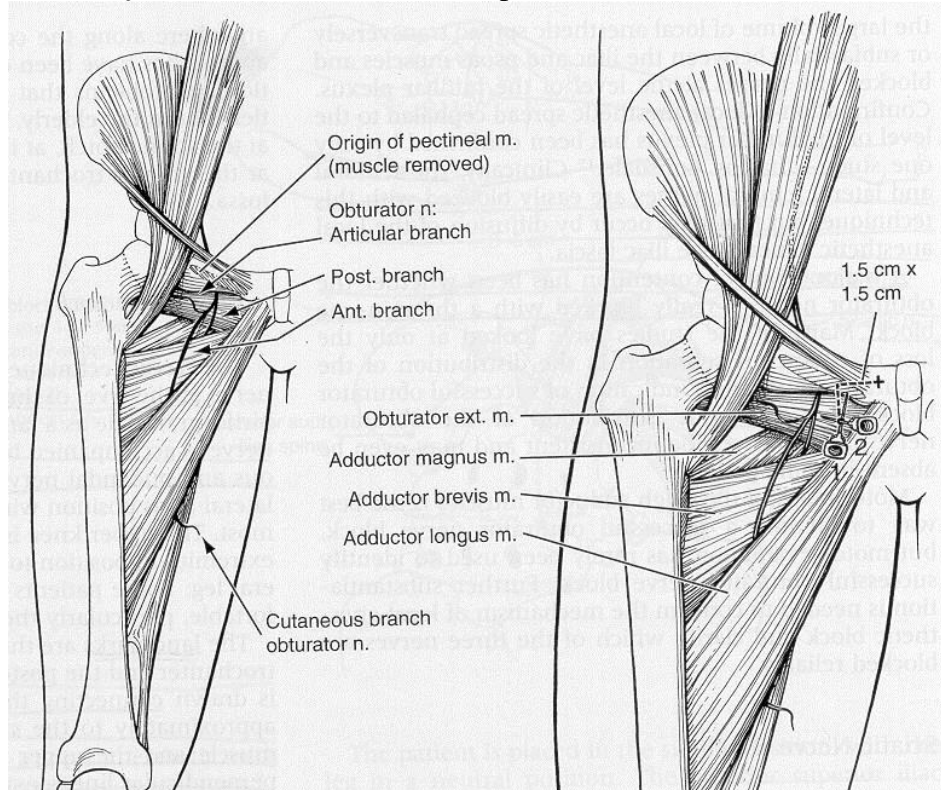


Anterior branch – supplies adductor longus and gracilis, and frequently adductor brevis; it also sends an articular branch to the hip.

At the lower border of adductor longus, the nerve communicates with the medial cutaneous and saphenous branches of the femoral nerve, forming a so-called subsartorial plexus from which twigs supply the skin of the medial side of the thigh.

Posterior branch -- pierces and supplies obturator externus. The posterior branch supplies adductor magnus and also brevis, if the latter is not supplied by the anterior branch. Adductor magnus, in addition, receives a supply from the sciatic nerve. It ends by supplying the knee joint.

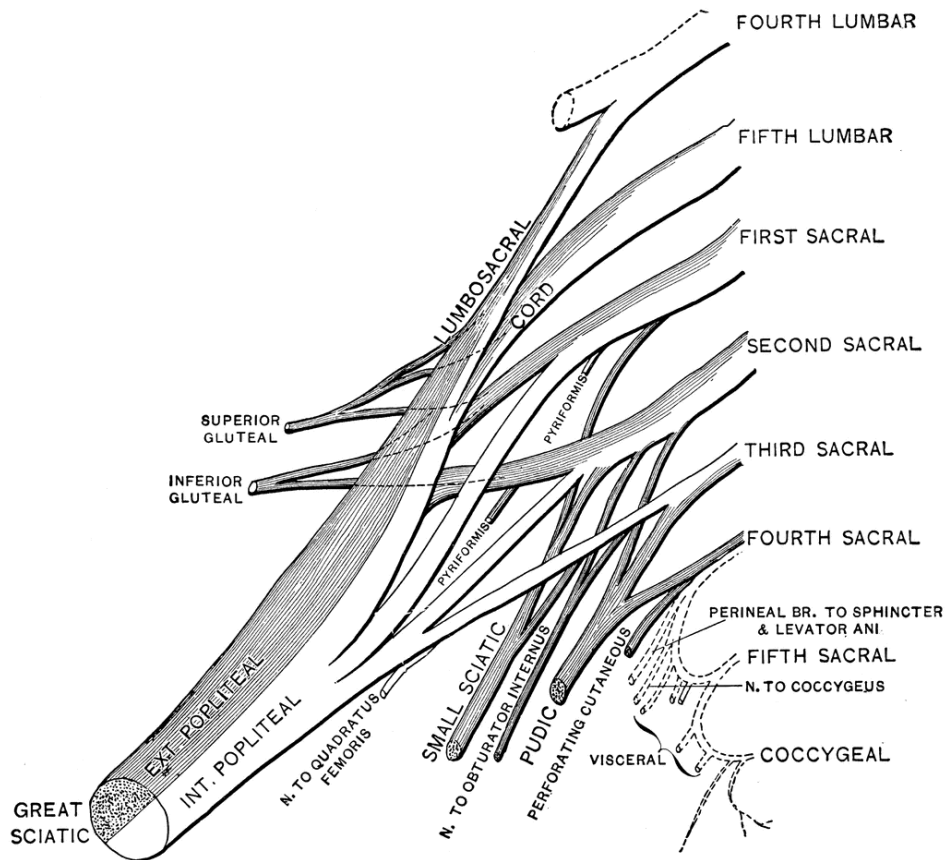
Accessory obturator nerve (L3, 4) is present in about one-third of cases.



THE SACRAL AND COCCYGEAL PLEXUSES

The sacral plexus is formed from a contribution of L4, from the entire L5, S1,2 and 3 anterior primary rami, and from a part of S4.

The coccygeal plexus receives the rest of S4, together with S5 and the anterior primary ramus of the coccygeal nerve.



The branches of the sacral plexus are classified into collateral and terminal.

1 Collateral:

- (a) muscular;
- (b) cutaneous;
- (c) visceral (parasympathetic to the pelvic plexus).

2 Terminal:

- (a) sciatic;
- (b) pudendal.

The collateral branches :

The collateral branches and their roots of origin are as follows:

1 Muscular:

- (a) nerve to quadratus femoris L4, 5, S1;
- (b) nerve to obturator internus L5, S1, 2;
- (c) nerve to piriformis S1, 2;
- (d) superior gluteal nerve L4, 5, S1;
- (e) inferior gluteal nerve L5, S1, 2;
- (f) nerves to levator ani, coccygeus and external anal sphincter S4.

2 Cutaneous:

- (a) posterior cutaneous nerve of thigh S1, 2, 3;
- (b) perforating cutaneous nerve S2, 3.

3 Visceral:

(a) pelvic splanchnics S2, 3.

The terminal branches :

sciatic nerve (L4, 5, S1–3) :

the largest peripheral nerve in the body.

Branches :

The branches of the sciatic nerve can be grouped into the following:

1 Muscular to:

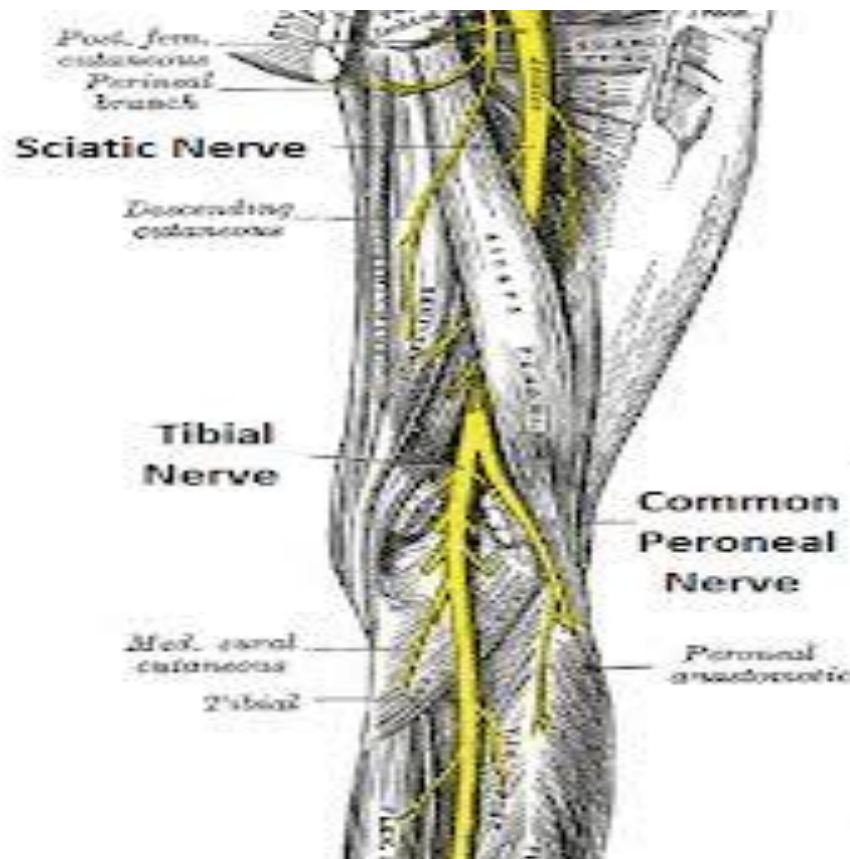
- (a) semitendinosus;
- (b) semimembranosus;
- (c) adductor magnus;
- (d) biceps femoris.

2 Articular to:

- (a) the hip joint.

3 Terminal to:

- (a) common peroneal (lateral popliteal) nerve;
- (b) tibial (medial popliteal) nerve.



Tibial (medial popliteal) nerve (L4, 5, S1–3):

Branches in the popliteal fossa

1 Muscular to:

- (a) popliteus;
- (b) gastrocnemius;
- (c) soleus;
- (d) plantaris.

2 Cutaneous:

- (a) the sural nerve.

3 Articular:

- (a) to the knee.

Sural nerve(L5, S1, 2) :

Supplies a wide area over the posterolateral part of the lower third of the calf, as well as the lateral side of the foot and of the 5th toe.

The tibial nerve ends behind the medial malleolus by dividing into its terminal branches, the medial and lateral plantar nerves.

Branches of the tibial nerve in the calf and foot

1 Muscular to:

- (a) tibialis posterior;
- (b) flexor digitorum longus;
- (c) flexor hallucis longus;
- (d) soleus.

2 Cutaneous:

- (a) the medial calcaneal nerve.

3 Articular:

- (a) to the ankle joint.

4 Terminal:

- (a) medial plantar nerve;
- (b) lateral plantar nerve.

Medial calcaneal nerve :Pierces the flexor retinaculum to supply the skin over the medial side of the sole of the foot.

Medial plantar nerve :

The medial plantar nerve supplies the following:

1 Muscular branches to:

- (a) abductor hallucis;
- (b) flexor digitorum brevis;
- (c) flexor hallucis brevis;
- (d) 1st lumbrical (from the 1st plantar digital nerve).

2 *Cutaneous branches:*

(a) to the medial two-thirds of the sole of the foot and the plantar aspect of the medial 3 1/2 toes.

Lateral plantar nerve

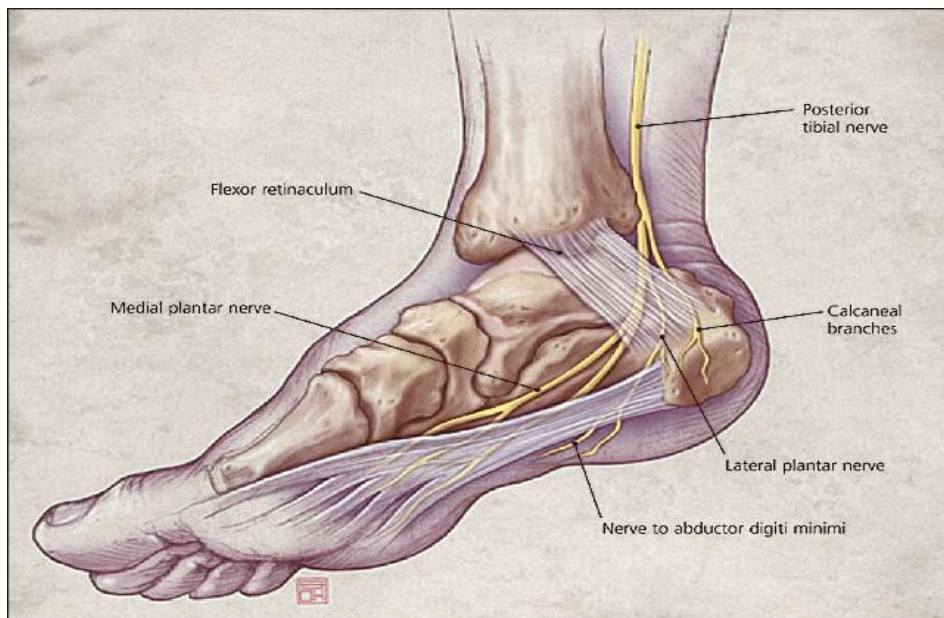
lateral plantar nerve supplies the following:

1 *Muscular branches* to:

- (a) all the interossei;
- (b) lumbricals 2, 3 and 4;
- (c) adductor hallucis;
- (d) flexor digiti minimi brevis;
- (e) flexor accessorius;
- (f) abductor digiti minimi.

(That is, all the small muscles of the sole of the foot not innervated by the medial plantar nerve.)

2 *Cutaneous branches* to the lateral one-third of the sole of the foot and the plantar aspect of the lateral 1 1/2 toes.



common peroneal (lateral popliteal) nerve (L4, 5, S1, 2)

It winds round the neck of the fibula, deep to peroneus longus, there to divide into its terminal branches - the deep peroneal and the superficial peroneal nerves.

Branches:

The branches of the common peroneal nerve can be grouped into the following:

1 *Cutaneous:*

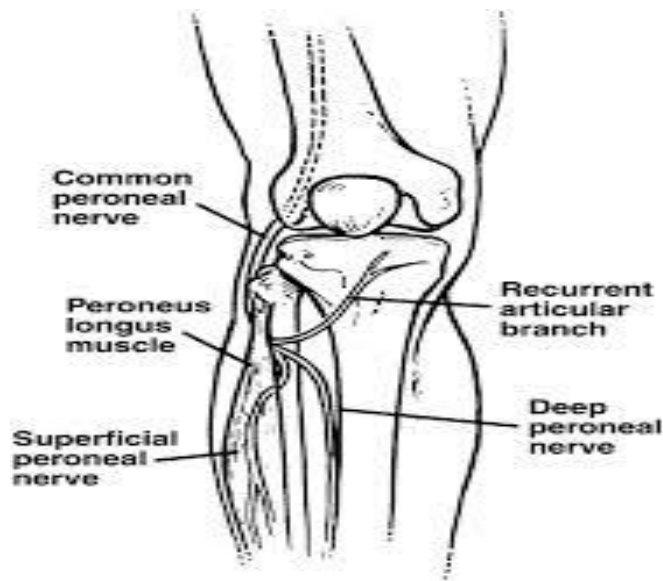
- (a) sural communicating nerve;
- (b) lateral cutaneous nerve of calf.

2 *Articular:*

- (a) to the knee.

3 Terminal:

- (a) deep peroneal (anterior tibial) nerve;
- (b) superficial peroneal (musculocutaneous) nerve.



The **deep peroneal nerve** -- arises at the bifurcation of the common peroneal nerve between the neck of the fibula and the peroneus longus.

The deep peroneal nerve supplies the following:

1 **Muscular branches** to:

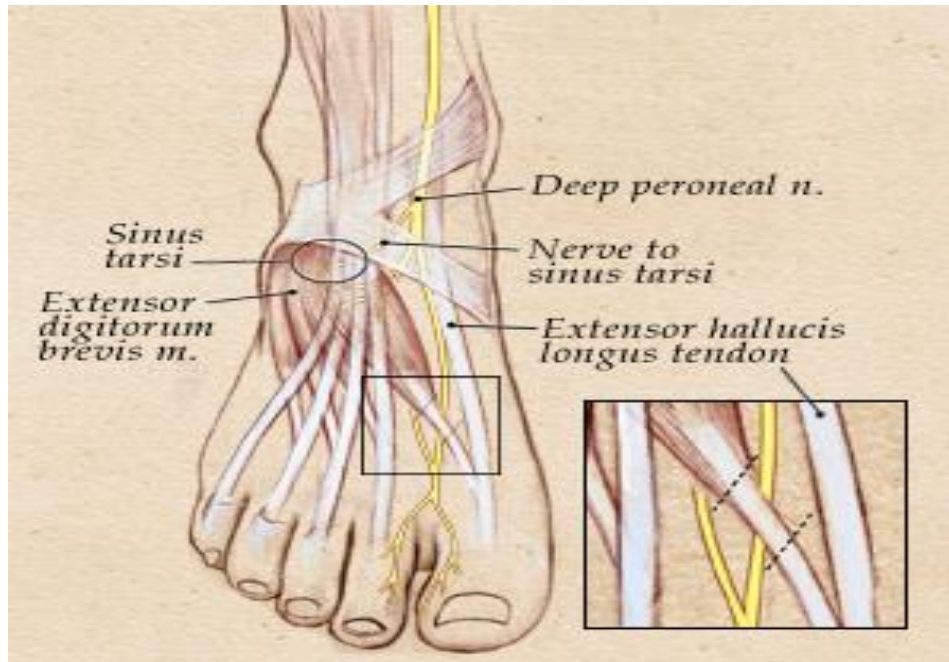
- (a) tibialis anterior;
- (b) extensor hallucis longus;
- (c) extensor digitorum longus;
- (d) peroneus tertius.

2 **Articular branch:**

- (a) to the ankle joint.

3 **Terminal branches:**

- (a) medial - cutaneous to the adjacent sides of the 1st and 2nd toes;
- (b) lateral - motor to extensor digitorum brevis and articular to foot joints.



The **superficial peroneal** nerve supplies the following:

1 Muscular branches to:

- (a) peroneus longus;
- (b) peroneus brevis.

2 Cutaneous branches:

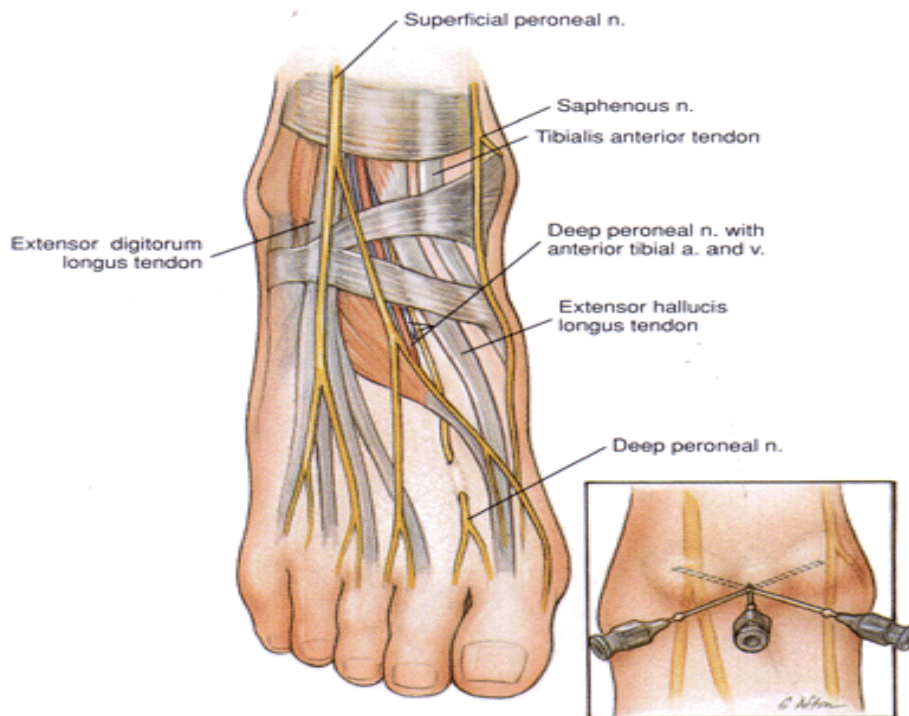
- (a) to the lower outer aspect of the leg.

3 Terminal branches:

- (a) medial - to dorsum of foot and toes;
- (b) lateral - to dorsum of foot and toes.

The *medial terminal branch* crosses the front of the ankle and then divides into the more medial division runs to the medial side of the hallux; the more lateral splits to supply the adjacent sides of the backs of the 2nd and 3rd toes.

The *lateral terminal branch* supplies the dorsum of the foot, then gives two dorsal digital branches, one to the adjacent sides of the 3rd and 4th toes, the other to the adjacent sides of the 4th and 5th toes.



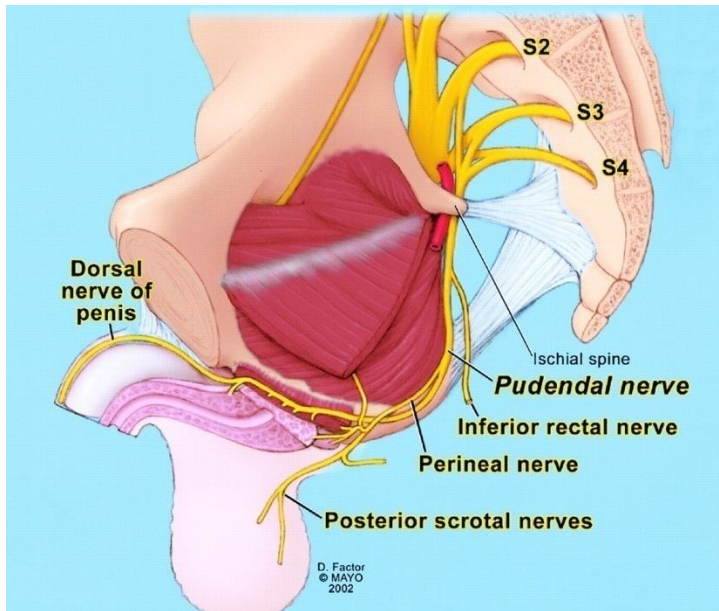
The **puddental nerve** (S2–4) : Provides the principal innervation of the perineum.

The pudental nerve leaves the pelvis through the greater sciatic foramen below piriformis. It appears briefly in the buttock region, accompanied laterally by the internal pudental vessels, merely to cross the dorsum of the ischial spine and straightaway disappear through the lesser sciatic foramen into the perineum.

Within the pudental canal, it first gives off the *inferior rectal nerve* which crosses the ischiorectal fossa to innervate the external anal sphincter and the perianal skin, then divides into the perineal nerve and the dorsal nerve of the penis or clitoris.

The *perineal nerve* – deeper branch enters the deep pouch and there supplies sphincter urethrae and the other muscles of the anterior perineum (the ischiocavernosus, bulbospongiosus and the superficial and deep transverse perinei). Its more superficial branch innervates the skin of the posterior aspect of the scrotum.

The *dorsal nerve of the penis (or clitoris)* -- traverses the deep perineal pouch, pierces the perineal membrane near its apex, then penetrates the suspensory ligament of the penis to supply the dorsal aspect of this structure.



The sciatic foramina: The boundaries and contents of the greater and lesser sciatic foramina.

The **greater foramen** : Bounded by the margins of the greater sciatic notch and by the sacrotuberous and sacrospinous ligaments;

The **lesser foramen** : Bounded by the lesser sciatic notch and the same two ligaments (Fig. 148).

The largest structure which emerges through the greater foramen is **piriformis**, which divides this outlet into an upper and a lower compartment.

The upper compartment transmits:

- 1 the superior gluteal vessels;
- 2 the superior gluteal nerve.

The lower compartment transmits (from the lateral to medial side):

- 1 the sciatic nerve; overlying
- 2 nerve to quadratus femoris; and deep to
- 3 posterior cutaneous nerve of the thigh;
- 4 the inferior gluteal nerve;
- 5 the inferior gluteal vessels;
- 6 nerve to obturator internus;
- 7 the internal pudendal vessels;
- 8 the pudendal nerve.

The three most medial structures (the nerve to obturator internus and the pudendal vessels and nerves) all cross the sacrospinous ligament or ischial spine, then plunge forthwith through the inferior sciatic foramen to enter the perineum.

The only other structure transmitted by the lesser foramen is the tendon of obturator internus.

The five more lateral structures emerging through the greater foramen all cross the dorsum of the ischium and remain in the buttock or descend into the thigh.

The coccygeal plexus

The coccygeal plexus is tiny; made up of a part of S4 together with the whole of S5 and Coccygeal nerve 1, it forms a single trunk ('the anococcygeal nerve') which pierces the sacrotuberous ligament to supply the skin over the coccyx.

