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THE
SUPERIOR
EXTREMITIES
1 INTRODUCTION

Adoption of the upright posture and bipedal mode of locomotion in human as well as in primates make the upper limbs free from the burden of weight bearing. The appearance of the clavicle in the pectoral girdle acts as a strut which facilitates the upper limb to move freely away from the chest wall.

The progressive separation of the thumb from the other fingers in higher primates permits opposition of the thumb, so that the hand is utilised for prehension to manipulate the environment by a grasping mechanism. For that purpose the forearm is endowed with variable range of pronation and supination, the shoulder joint is provided with very free mobility and this is further facilitated by the mobility of the pectoral girdle.

Human hand possesses three types of basic grips - power, hook and precision. Power and hook grips are more primitive and acquired by man from his arboreal ancestors. The precision grip is characteristics of man, in which finger tips and thumb are used to hold finer objects like pen, pencil or needle for skilful manipulation. The extensive development of somatotopic area for the fingers in the motor cortex of human brain is associated with precision movements by the lumbricals and interossei of hand which possess small motor units. The precision grips enrich human culture in arts and crafts.

Human hand is specialised as a tactile apparatus by the appearance of touch receptors, the Meissner's corpuscles, in the fingers. The size and shape of fine objects, when placed in hand, can be recognised by touch alone without the aid of vision.

The upper limb is connected to the trunk by the pectoral girdle, and consists of three segments — arm, forearm and hand, similar to those of the lower limb. The pectoral girdle is composed of scapula and clavicle on each side. The scapula is connected to the clavicle by the acromio-clavicular joint and by strong coraco-clavicular ligaments; it articulates with the humeral head at the gleno-humeral (shoulder) joint, but the medial border of scapula remains free from the vertebral column and is connected to the latter only by muscles. The clavicle meets the axial skeleton at the sterno-clavicular joint and is attached to the first costal cartilage by strong costo-clavicular ligament. Thus the upper limb and its girdle are connected to the trunk only through the sterno-clavicular joint. This enhances the mobility of the shoulder girdle and facilitates the wide range of movements of the upper limb. In elevation of the arm above the head, there is a harmonious collaboration of movements at shoulder, acromio-clavicular and sterno-clavicular joints.

Forces from the upper limb are transmitted to the axial skeleton by the clavicle, not by its two ends but through the coraco-clavicular and costo-clavicular ligaments.

For a morphological comparison between pelvic and shoulder girdles, the following features deserve attention. The pelvic girdle is formed by the hip bone (os innominatum) which consists of three components meeting at the acetabulum, separated initially by a triradiate cartilage which is subsequently replaced by bone. The dorsal component is formed by the ilium, and the ventral component by the pubis and ischium. In the shoulder girdle, the body of scapula including lower two-thirds of glenoid cavity forms the dorsal component and corresponds with the ilium; the coracoid process including upper one-third of glenoid cavity (but excluding its tip) represents the ventral component and corresponds with the ischium; the combination of two components enter in the formation of shoulder joint. The pubis is represented by the pre-coracoid bone at the tip of coracoid process, but it does not from the shoulder joint. The clavicle has no counterpart in the hip bone.

In the foetal position, elbows and knees project outwards at right angles to the body, and the distal
parts of the limbs bend ventrally so that the palms of the hands and the soles of the feet face each other. In the upper limb, the thumb and radius form the **pre-axial border**, and the little finger and ulna represent the **post-axial border**. In the lower limb, the great toe and tibia lie in the **pre-axial border**, and the little toe and fibula form the **post-axial border**.

When the anatomical position is restored, the upper and lower limbs undergo axial rotation through the angle of 90°, but in reverse direction. The upper limb rotates outwards, so that the palm is directed in front and the thumb is placed laterally. The lower limb rotates inwards, which allows the great toe to turn medially and the sole to face towards the ground.
CLAVICLE

The clavicle or collar bone is introduced as one of the bones of shoulder girdle in man and in those mammals who used their upper limbs for prehension. It has no homologue in pelvic girdle. The clavicle possesses the following functions:

1. It acts as a strut to place the scapula laterally, so that the upper limb can swing clearly from the side of the trunk.

2. It transmits the forces from the upper limb through the coraco-clavicular ligament and medial two-thirds of the bone to the axial skeleton.

3. Concave posterior surface of the medial two-thirds of the clavicle protects the neuro-vascular structures of the root of the neck.

4. It helps in various scapular movements and performs axial rotation around its long axis during elevation of arm above the head.

Peculiarities

1. The clavicle is a modified long bone, specially its medial two-thirds, because it transmits forces or weight from the upper limb to the axial skeleton. This is, however, an exception violating the following principles of a long bone:
   (a) It possesses no medullary cavity;
   (b) Ossifies mostly in membrane;
   (c) It is sometimes pierced by cutaneous (supra-clavicular) nerve.

2. It is the first bone to start ossification in the 5th or 6th week of intra-uterine life, and last bone to complete ossification usually after twenty-first year.

3. It is horizontally placed and is subcutaneous as well as subplatysmal, because it is covered by a sheet of platysma muscle. Therefore, the skin glides freely over the clavicle and fracture of the bone does not usually penetrate the skin to make the fracture compound.

Presenting parts

The clavicle presents two ends, sternal and acromial, and a shaft which is curved with the convexity in front in medial two-thirds and concavity in front in lateral one-third (Fig. 2.1, 2.2).

The sternal end is much enlarged, and directed medially with a slight forward and downward tilt. It articulates with the clavicular notch of manubrium sterni and first costal cartilage to form the sterno-clavicular joint. Its articular surface is convex vertically and slightly concave from before backward. It is covered with fibro-cartilage and gives attachment at the periphery to the fibrous capsule, above to the interclavicular ligament, and above and behind to the articular disc which divides the joint into two compartments. Close to the sternal end, the undersurface of the shaft presents a depression for the attachment of costo-clavicular ligament by which it is connected to the first rib and its cartilage (Fig. 2.3).

Fig. 2.1. Right Clavicle (Viewed from above).
The acromial end is flat and bears an oval facet which is directed laterally and downward. It articulates with a similar facet on the anterior part of medial border of acromial process of scapula to form acromio-clavicular joint. When the acromion is dislocated, it is driven under the clavicle.

Anterior border and the adjoining upper surface give origin to the anterior part of deltoid muscle; posterior border and the adjacent upper surface receive insertion of the anterior fibres of trapezius muscle. The conoid tubercle and trapezoid ridge of the lower surface give attachment respectively to the conoid and trapezoid parts of coraco-clavicular ligament.

Medial two-thirds—It presents anterior, posterior, superior and inferior surfaces without any limiting border.

Inferior surface exhibits a longitudinal groove in the middle one-third for the attachment of subclavius muscle and the two lips of the groove give attachment to the clavipectoral fascia. Close to the sternal end, the inferior surface presents a depressed area for the attachment of costoclavicular ligament.

Anterior surface gives origin to the pectoralis major in the medial half; between pectoralis major and deltoid, the clavicle forms the base of deltopectoral triangle.

Superior surface gives origin to the clavicular head of sternocleidomastoid in medial one-third; the gap between the trapezius and sternocleidomastoid forms the base of the posterior triangle of neck and gives attachment to the two lamellae of the investing layer of deep cervical fascia enclosing a supra-clavicular space.

In between the attachments of four muscles, the entire antero-superior surface of clavicle is palpable, and covered by the skin and platysma, and is crossed by the three branches of supracleavicular nerve (C3, C4); occasionally the intermediate branch pierces the bone.

Posterior surface is smooth and concave; close to the sternal end, it gives origin to a part of sternohyoid muscle.

Rest of the posterior surface is related to the following:
1. Internal jugular, subclavian and beginning of brachio-cephalic veins is the medial part;
2. Subclavian artery and trunks of brachial plexus in the lateral part;
3. Apex of the lung covered by the cervical pleura and supra-pleural membrane;
4. Supra-scapular vessels pass laterally along the upper part of this surface.

**Anatomical position**—Place the **enlarged sternal end medially**, and somewhat forward and downward, rough markings of the shaft and groove for the subclavus **inferiorly**, and the curvature of the anterior surface is **convexo-concave** from medial to lateral side.

**Ossification**—The shaft is ossified from **two primary centres**, medial and lateral, in membrane between the 5th and 6th weeks of intra-uterine life; the centres subsequently fuse to form a single centre. **It is the first bone to start ossification.**

A **secondary centre** for the sternal end appears in cartilage at about 18 years; its fusion with the shaft starts at about 21 years and is completed as late as 31 years. Therefore, **it is last bone to complete ossification.** The sternal end is the **growing end** and the nutrient vessels are directed laterally.

Sometimes a secondary centre appears for the acromial end.

**Applied anatomy**

It is probably the most common bone which is fractured by an indirect violence due to a fall on the outstretched hand. The fracture usually takes place at the junction of the two curvatures.

**Scapula**

The scapula is one of the bones of shoulder girdle. It is a flat bone, triangular in shape and is situated in the postero-lateral part of chest wall overlapping the **second to seventh ribs**.

![Diagram of Scapula](image-url)
The scapula presents two surfaces – costal and dorsal, three borders – lateral, medial and superior, three angles – lateral, inferior and superior, and three processes spine, acromion and coracoid.

The lateral angle, the junction between the superior and lateral borders, is truncated and bears a pear-shaped glenoid cavity (fossa) which articulates with the head of humerus and forms the shoulder joint. The glenoid cavity represents the head and rest of the bone forms the body of scapula. When the arm is pendent (anatomical position), it is directed laterally and slightly upward and forward (in raising the arm above the head) the glenoid cavity faces almost straight upward. The constricted portion, adjacent to the margin of glenoid cavity, forms its anatomical neck. The surgical neck of scapula is represented in front by a line extending from the suprascapular notch to the infraglenoid tubercle, and behind the same line passes through the spinoglenoid notch.

Costal surface—It presents a shallow concavity and is directed forward and medially. A narrow strip of bone extends along the medial border of this surface which forms raised triangular areas at the superior and inferior angles. The entire strip of bone receives the insertion of serratus anterior, so that the first digitation is attached to the upper triangular area, second and third digitations to the narrow strip, and the remaining five digitations converge on the lower triangular area at the inferior angle (Fig. 2.4). A rounded longitudinal ridge affects the costal surface close to the lateral border. Rest of the costal surface is concave, more so towards the glenoid cavity, and is marked out by three or more oblique ridges which run upward and laterally from the medial border. Subscapularis muscle arises by fleshy fibres from most of the costal surface including the rounded ridge but excluding the front of the neck of scapula. Oblique ridges give attachment to the intramuscular tendons of subscapularis to provide additional power for the anti-gravity action of the muscle during abduction. Longitudinal ridge acts as a lever when the lower digitations of serratus anterior rotate the scapula during elevation of the upper limb above the head.

Dorsal surface—It is divided by a triangular shelf-like projection, the spine of scapula, into a
smaller supra-spinous fossa and a larger infra-spinous fossa; both fossae communicate through the spino-glenoid notch which intervenes between the lateral border of spine of scapula and the dorsal surface of the neck; the spino-glenoid notch transmits supra-scapular vessels and nerve (Fig. 2.5).

Medial two-thirds of the supra-spinous fossa give origin to the supraspinatus muscle, and the margins of the fossa provide attachment to the overlying fascia.

The infra-spinous fossa presents a flattened strip along the lateral border. The upper two-thirds of the strip give origin to the teres minor which is interrupted by a transverse groove for the circumflex scapular vessels. The lower one-third of the strip is separated from the upper part by an oblique ridge and forms an oval area extending up to the inferior angle; it gives origin to the teres major, and the ridge between the teres major and minor muscles gives attachment to the fascia covering infraspinatus muscle.

Rest of the infra-spinous fossa including the lower surface of the spine, but excluding the dorsal surface of the neck, gives origin to the infraspinatus muscle. A strong infraspinatus fascia covers both infraspinatus and teres minor, and is attached to the margins of the fossa including the lower lip of the crest of scapular spine and the sinuous ridge along the lateral border of scapula, but it excludes teres major. In fracture of the blade of scapula, the resulting haematoma is confined beneath the fascia and forms a large swelling that is limited to the margin of the bone.

Lateral (axillary) border—It extends from the lower end of glenoid cavity to the inferior angle, and slopes downward, backward and medially. Close to the glenoid cavity it presents an infraglenoid tubercle which gives origin to the long head of triceps brachii muscle. Rest of the border provides attachments to the sub-capularis along the costal surface and to the teres minor and teres major along the dorsal surface.

The lateral border is monopolised by the origins of muscles, and is crossed by circumflex scapular vessels.

Medial (vertebral) border—It extends from the superior to the inferior angles and is somewhat arched due to the presence of apex of spine on its dorsal surface. Entire costal surface of the border provides insertion to serratus anterior. Dorsal surface of the border receives insertions of levator scapulæ from the superior angle to the apex of spine, rhomboideus minor opposite the apex and rhomboideus major to the rest of the border below the apex.

The medial border is monopolised by the insertions of the muscles. It is accompanied by the dorsal scapular nerve and descending branch of transverse cervical artery.

Superior border—It is thin and short, and extends from the superior angle to the root of coracoid process, where it presents a supra-scapular notch. Inferior belly of omohyoid muscle takes origin from the medial end of the notch. A transverse scapular ligament bridges across the notch to form a supra-scapular foramen which transmits the supra-scapular nerve to the supra-spinous fossa; the supra-scapular vessels, however, reach the fossa above the foramen and its ligament.

The circumflex scapular and supra-scapular arteries pass respectively across the lateral and superior borders, and descending branch of transverse cervical artery runs along the medial border of scapula. These vessels anastomose with one another on the costal and dorsal surfaces of scapula and on the dorsal surface of the acromial process, and establish a collateral anastomosis between the branches of the first part of subclavian artery and the third part of axillary artery.

Lateral angle—It is truncated and bears a pear-shaped shallow glenoid cavity which articulates with the head of humerus and forms the shoulder joint. The articular surface is narrow above and just above it a rough supraglenoid tubercle encroaches on the root of the coracoid process. The floor of glenoid cavity is covered by articular hyaline cartilage. The fossa is made deep by a fibro-cartilaginous rim, the glenoidal labrum, which is attached to its peripheral margin of the socket except at the supraglenoid tubercle; the latter provides intracapsular origin to the long head of biceps brachii. The anterior margin of the articular fossa is grooved for the tendon of subscapularis. The fibrous capsule of shoulder joint is attached around the periphery of glenoid cavity outside the labrum, so that it includes the supraglenoid tubercle but excludes the infraglenoid tubercle.

Inferior angle—It is the meeting place of the lateral and medial borders of scapula, and overlaps
the seventh rib or inter-costal space. It is palpable beneath the upper border of latissimus dorsi and moves round the thoracic wall during elevation of arm.

On the costal surface, the inferior angle receives the insertion of lower four or five digitations of serratus anterior; on the dorsal surface, it gives origin to the teres major and a few slips of latissimus dorsi.

Superior angle—It is the junction of medial and superior borders of scapula. The angle is deeply placed, overlapped by the trapezius and crossed dorsally beneath the muscle by the spinal part of accessory nerve.

Spine of scapula—It is a triangular bony projection from the dorsal surface of the body of scapula, and intervenes between the supra and infra-spinous fossae. The spine presents apex, base, upper and lower surfaces, and a posterior free border, crest of the spine.

The apex lies at the medial border of the bone at the level of $T_3$ spine. It presents a smooth triangular area upon which lower fibres of trapezius tendon glide separated by a bursa.

The base or lateral border is free and thick, and forms the posterior boundary of spon-glenoid notch.

Upper and lower surfaces participate in the formation of supra- and infra-spinous fossae, and provide origins to the supraspinatus and infraspinatus muscles respectively.

Crest of the spine is entirely subcutaneous and is continuous laterally with the upper surface of acromial process. The crest presents upper and lower lips. The upper lip is continuous laterally with the medial border of acromion and receives the insertion of the middle fibres of trapezius; the lowest fibres of trapezius converge on the lower lip superficial to the deltoid and is inserted into the deltoid tubercle. The lower lip is continuous with the lateral border of acromion at the acromial angle which acts as subcutaneous landmark for surface anatomy. The lower lip gives origin to the posterior fibres of deltoid.

Acromion—It projects forward as a flattened plate from the lateral end of the spine and overhangs the glenoid cavity. It is greatly strengthened by the base of the spine which fades away on its under surface. The acromion presents lateral and medial borders, tip, dorsal and undersurface.

The lateral border extends from the acromial angle to its tip and gives origin to the middle fibres of deltoid. This border presents four tubercles for the attachments of fibrous septa which provide additional origins to the fibres of deltoid; hence the middle fibres of the muscle possess multipennate arrangement. The tip of acromion, beneath the deltoid, gives attachment to the coraco-acromial ligament, the medial end of which is attached to the postero-lateral margin of the horizontal part of coracoid process. Thus the undersurface of the acromial process, coraco-acromial ligament and horizontal part of coracoid process form together the coraco-acromial arch which provides a hood-like protection for the shoulder joint (Fig. 2.6)

The medial border of acromion presents in the anterior part an oval facet for articulation with the lateral end of clavicle to form a plane synovial acromio-clavicular joint. Rest of the border is continuous with the upper lip of the crest of spine and receives insertion to the middle fibres of trapezius.
superior border of scapula, just above the glenoid cavity. It consists of lower vertical part and upper horizontal part; the latter ends in a blunt tip which is directed forward and slightly laterally in anatomical position, and is palpable through the anterior fibres of deltoid muscle about 2.5 cm below the clavicle at the junction of medial third-fourths and lateral one-fourth of the bone.

The vertical part is related to the subscapularis in front and supraspinatus behind. The supraglenoid tubercle gives intracapsular origin to the long head of biceps brachii; the transverse scapular ligament is attached to the root of coracoid process and converts the supra-scapular notch into a foramen.

The horizontal part bends forward and laterally from the vertical part and presents a conoid tubercle on the dorsal surface at the junction between the two parts. It presents superior and inferior surfaces, antero-medial and postero-lateral margins, and a tip. The upper surface and the adjoining antero-medial border receives insertion of pectoralis minor; the rest of the border gives attachment to the trapezoid part and the conoid tubercle to the conoid part of coracoclavicular ligament. The postero-lateral border gives attachment to the coraco-acromial and coraco-humeral ligaments from medial to lateral side.

The tip of coracoid process gives origin to the coraco-brachialis medially and short head of biceps brachii laterally.

Morphology of scapula—The scapula is a composite bone and formed by the fusion of dorsal element represented by the body of scapula, and ventral elements represented by the coracoid process and pre-coracoid bone at the tip of coracoid process. The body of scapula corresponds with the ilium, the coracoid process including upper one-third of glenoid cavity corresponds with the ischium and the pre-coracoid bone with the pubis of the pelvic girdle.

Special comments—Muscles attached to the ventral elements of scapula are supplied by nerves arising from the ventral divisions of brachial plexus. Muscles attached to the body of scapula representing the dorsal element are supplied by the nerves derived from the dorsal divisions of brachial plexus, with the exception of trapezius, levator scapulae and omohyoid. Because these muscles are migrated from the trunk and attached to the shoulder girdle for functional reasons.

Anatomical position of scapula—Hold the scapula by the same hand to which side it belongs, so that the costal surface is directed forward and medially, the glenoid cavity faces laterally with slightly forward and upward tilt, and the tip of the coracoid process is directed almost straight forward.

Ossification—The scapula is ossified from eight centres, of which one is primary and the rest are secondary.

The body of scapula including lower two-thirds of glenoid cavity is ossified from a primary centre in cartilage in the 8th week of intra-uterine life.

The centres of the coracoid process appear in the 1st year, the sub-coracoid including upper one-third of glenoid cavity by the age of puberty; these fuse with the body during the 15th year.

By the age of puberty, two-centres appear for the acromial process, one for the medial border, one for the inferior angle and one for the lower margin of glenoid cavity. These centres fuse with the body of scapula by about 20th year.

HUMERUS

The humerus is the bone of the arm, and is the longest of long bones of upper limb. It presents upper and lower ends, and an intervening shaft (Fig. 2.7, 2.8).

Upper end—It consists of head, lesser and greater tubercles, upper part of intertubercular sulcus and neck.

Head is articular, spheroidal and forms about one-third of a sphere. It is directed medially, backward and upward and articulates with the glenoid cavity of scapula to form the ball and socket shoulder (gleno-humeral) joint. The glenoid cavity is too shallow and less extensive for the humeral head, thus permitting wide range of movement. The head is covered by hyaline cartilage which is thickest at the centre and thinner at the periphery. The axis of humeral head makes an angle with the axis of the lower end of humerus which measures about 164° in adult; this is known as angle of humeral torsion.

Lesser tubercle (tuberosity) presents a smooth muscular impression which projects
forward just beyond the head. It receives the insertion of subscapularis tendon which extends slightly downwards into the shaft. The lateral margin of lesser tubercle is sharp and is separated from the greater tubercle by the upper part of the intertubercular sulcus, which attaches to the transverse humeral ligament to retain the long tendinous head of biceps brachii and its synovial sheath in position.

Greater tubercle (tuberosity) occupies the most lateral part of the upper end, and its convex lateral surface projects beyond the acromion and forms the rounded contour of the shoulder; this surface is covered by the deltoid muscle separated by the sub-acromial bursa. The upper and posterior surfaces of greater tubercle present three flat impressions for muscular attachments — the upper one for supraspinatus, the middle for infraspinatus, and the posterior one including a part of the shaft for teres minor. The tendons of four scapulo-humeral muscles (subscapularis, supraspinatus, infraspinatus and teres minor) around the upper end of humerus blend with the capsule of shoulder joint and form a rotator cuff which is indispensable for the stability of the joint.

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<td>Common flexor origin</td>
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<th>Fig. 2.8. Right Humerus (Dorsal view).</th>
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<td>Head of humerus</td>
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<td>Supraspinatus</td>
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<td>Fibrous capsule of shoulder joint</td>
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<td>Post. circumflex humeral art.</td>
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<td>Capsule of elbow joint</td>
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<td>Olecranon fossa</td>
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**Neck** — Humerus possesses three types of neck; anatomical, surgical and morphological. **Anatomical neck** is a constriction that immediately succeeds the head.

**Surgical neck** is a constriction between the expanded upper end and cylindrical shaft of humerus; it is embraced posteriorly by the axillary nerve and posterior circumflex humeral vessels. A fracture of surgical neck may involve the axillary nerve with consequent paralysis of deltoid muscle.

**Morphological neck** is represented by the epiphyseal line between the upper epiphysis and diaphysis of the young humerus. It is usually situated about 0.5 cm above the surgical neck. In adult the morphological neck disappears.

The **capsular ligament** of the shoulder joint is attached along the anatomical neck, except at two sites:

(a) at the upper end of intertubercular sulcus the capsule is deficient to allow the transmission
of the long head of biceps brachii accompanied by a synovial sheath;

(b) in the lower part the capsule extends about 1 cm below the head to encroach on the medial side of the surgical neck.

Shaft—The shaft of humerus is cylindrical in the upper half and triangular on cross-section in the lower half. The shaft presents three borders—antero-medial, antero-lateral and posterior.

Anterior border extends from the front of greater tubercle to the lower end of humerus in between the coronoid and radial fossae. Its upper third forms the lateral lip of the intertubercular sulcus; its succeeding part delimits the anterior limb of deltoid tuberosity. The lower half of the border is smooth and rounded.

Medial border extends from the tip of the medial epicondyle to the medial lip of the intertubercular sulcus. In the lower half it is sharp to form the medial supra-condylar ridge; near the middle of shaft it forms a rough strip. In the upper third, the border is continuous through the medial lip of intertubercular sulcus to the lesser tubercle.

Lateral border forms the lateral supra-condylar ridge which extends upward from the tip of lateral epicondyle. Close to the middle of the shaft, the border fades away by the lower end of spiral groove (radial groove). Further above, it extends behind the posterior limb of deltoid tuberosity and is continuous with the posterior margin of the greater tubercle.

Antero-medial surface: It intervenes between the anterior and medial borders.

Intertubercular sulcus (bicicipital groove) forms the upper one-third of this surface. It contains the long head of biceps brachii with its synovial sheath and an ascending branch of anterior circumflex humeral artery. The sulcus presents lateral and medial lips, and a floor. The lateral lip receives the bilaminar insertion of pectoralis major; the floor for the insertion of latissimus dorsi, and the medial lip for the teres major; out of the three muscles, the attachment of pectoralis major is the longest and that of the latissimus dorsi shortest.

The roughened strip in the middle of shaft receives the insertion of coracobrachialis, and close to it the medial border presents a foramen for the passage of nutrient branch of brachial artery which is directed towards the lower end of the bone.

In the lower half, the antero-medial surface together with the adjacent antero-lateral surface and rounded anterior border provide origin to the brachialis muscle. The brachialis embraces the V-shaped insertion of deltoid muscle and extends for attachment to the lower part of spiral groove.

The medial supra-condylar ridge gives attachment to the medial intermuscular septum which intervenes between the flexor and extensor compartments of the arm; traced above, the septum passes behind the coracobrachialis and subsequently fades away. The medial septum is

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**Fig. 2.9. Dorsal view of Scapulo-humeral muscles with Quadrangular and Triangular spaces.**
pierced near the middle of shaft by the **ulnar nerve** and **superior ulnar collateral artery**, and slightly above the medial epicondyle pierced by the **posterior branch** of the **inferior ulnar collateral artery**.

The lower part of medial supra-condylar ridge, in front of medial septum, gives origin to the humeral head of **pronator teres**.

Sometimes a hook-like **supra-condylar process** projects from the antero-medial surface about 5 cm above the medial epicondyle. It is connected by a fibrous band to the medial epicondyle. The fibrous band known as **ligament of Struthers** represents phylogenetic remnant of third head of coraco-brachialis. The median nerve or brachial artery or both may be compressed by this ligament. The foramen formed between the ligament of Struthers and the humerus resembles the endepitrochlear foramen of carnivores and some other mammals.

**Antero-lateral surface**—It intervenes between the anterior and lateral borders.

A v-shaped deltoid tuberosity affects this surface near the middle of the shaft. It receives the insertion of **deltoid muscle**. The part of the surface above the tuberosity is covered by the deltoïd, separated by an extension of subacromial bursa. Rest of the surface below the tuberosity provides origin to the **brachialis** (vide supra).

The **lateral supra-condylar ridge** presents a narrow rough strip along its anterior surface. The ridge gives attachment to the **lateral intermuscular septum** which is pierced by the **radial nerve** and **anterior descending branch of arteria profunda brachii**.

The upper two-thirds of the narrow strip gives origin to **brachioradialis** and lower one-third to **extensor carpi radialis longus**.

**Posterior surface** (Fig. 2.8, 2.9)—It is extensive and intervenes between medial and lateral borders. A **spiral (radial) groove** passes downward and laterally across the middle one-third of this surface. It transmits **radial nerve** and **profunda brachii vessels** along the groove towards the antero-lateral surface; the lower part of the floor of the groove is occupied by the origin of brachialis.

The spiral groove is bounded above by an oblique ridge which gives origin to the **lateral head of the triceps**. Upper one-third of the posterior surface above the oblique ridge is under cover of the deltoïd and is crossed transversely behind the surgical neck by the **axillary nerve** and **posterior circumflex humeral vessels**.

Rest of the surface below the spiral groove is extensive and smooth. It provides origin to the fleshy **medial head of triceps**, the tapering upper end of which extends above close to the lower attachment of teres major.

**Lower end**—It is enlarged transversely to form the **condyle** which consists of articular and non-articular parts.

The **articular part** forms the elbow joint with the participation of radius and ulna. It consists of capitulum laterally and trochlea medially.

The **capitulum** is less than half of a sphere, and is articular in front and below; but its posterior surface is non-articular and palpable through the skin in extended elbow. It articulates with the disc-like **upper surface of the head of radius**, which comes in contact with the inferior surface of capitulum in extension and with its anterior surface in flexion.

The **trochlea** forms an asymmetrical pulley and its articular area covers anterior, inferior and posterior surfaces. It articulates with the **trochlear notch of ulna**; the ulna comes in contact with the postero-inferior surface of trochlea in extension, but during flexion it slides on to the anterior surface of trochlea. The medial flange of trochlea is more broad on the anterior surface and its medial margin extends about 6 mm below the lateral margin. As a result, the forearm is deviated away from the upper arm in extended and supinated position forming the **carrying angle** which forms an obtuse angle on the lateral side and measures about 163°. This angle helps to carry a load grasped by the hand without any contact of the ulnar border of fore arm with the lateral surface of thigh. It is said that in female the deviation of fore arm is more pronounced due to the wider breadth of the pelvis. Carrying angle, however, disappears during flexion and pronation of forearm.

The **non-articular part** includes three fossae—radial, coronoid and olecranon, and medial and lateral epicondyles.

The **radial fossa** lies immediately above the capitulum on the anterior surface of lower end. It accommodates the margin of the head of radius in full flexion.
The coronoid fossa lies above the trochlea and medial to radial fossa. It is occupied by the anterior margin of coronoid process of ulna during flexion of elbow.

The olecranon fossa is a deep depression and situated on the posterior surface above the trochlea. It lodges the apex of the olecranon process in extended elbow. Sometimes the floor of the fossa is deficient.

All non-articular fossae are within the attachments of articular capsule and are covered with the synovial membrane.

The medial epicondyle forms a blunt palpable projection which is directed medially and slightly backward. The tip of the epicondyle gives attachment to the anterior and posterior bands of the ulnar collateral ligament. The antero-inferior surface of the epicondyle presents an impression for the common origin of the superficial group of flexor muscles of forearm. Posterior surface of the base of medial epicondyle is grooved for the lodgement of ulnar nerve, before the latter enters the forearm between the two heads of flexor carpi ulnaris; here the ulnar nerve can be rolled against the bone producing a characteristic tingling sensation.

The lateral epicondyle presents a less prominent projection which is directed laterally and slightly forward. Its tip gives attachment to the radial collateral ligament. An impression on its antero-lateral surface provides common origin to the superficial group of extensor muscles of forearm. Posterior surface of the epicondyle gives origin to the anconeus.

The attachment of the capsular ligament of elbow joint to the lower end of humerus is represented by a continuous line which excludes the two epicondyles and includes the three non-articular fossae.

Ossification—The humerus is ossified from one primary centre for the shaft, three secondary centres for the upper end and four secondary centres for the lower end.

The primary centre appears in the 8th week of intrauterine life near the middle of the shaft.

The secondary centre for the head appears in the 1st year, for the greater tubercle in the 3rd year and for the lesser tubercle in the 5th year. The three centres unite in the 6th year to form a compound upper epiphysis, which fuses with the shaft at about the 20th year.

The secondary centre for the medial epicondyle appears in about the 5th year, for the medial flange of trochlea in the 10th year, for the lateral flange of trochlea together with capitulum in the 2nd year, and for lateral epicondyle in the 12th year. The medial epicondyle fuses with the shaft by a separate epiphyseal line at about 16th or 17th year. The remaining three centres unite to form a compound single epiphysis which fuses with the shaft at about 18th year. Therefore, an wedge-shaped diaphysis extends into the lower end between the medial epicondyle and the rest of the epiphysis; the ulnar nerve rests on the diaphysis.

Special comments

(a) Scapulo-humeral muscles are attached around the head to the upper end of humerus.

(b) Thoraco-humeral muscles are attached along the intertubercular sulcus.

(c) Upper half of humerus receives only the insertions of muscles, except the lateral head of triceps.

(d) Lower half of humerus provides solely the origins of muscles.

(e) The nerves in direct contact with the humerus are: axillary nerve around the surgical neck; radial nerve in the spiral groove; ulnar nerve behind the medial epicondyle.

These nerves rest on diaphysis, and may be involved in fracture of the bone.

**Applied anatomy**

1. Common sites of fracture of humerus are at the surgical neck, middle of the shaft and at the supra-condylar region. Junction of the upper and middle thirds of the shaft possesses poor blood supply; hence a fracture at this region may be associated with delayed union or non-union.

2. Since the fusion of the upper epiphysis takes place later than that of the lower epiphysis, the upper end of humerus forms the growing end. In amputation of arm of young individual, sufficient amount of soft tissue should be left distal to the site of amputation and sutured, otherwise the progressive growth of humerus through the soft tissue might produce a painful conical stump.
BONES OF THE FORE ARM

Two long bones, radius and ulna, form the skeleton of fore arm. Radius lies lateral to ulna.

The ulna is enlarged above and tapers below, whereas the radius is narrow above and enlarged below. Both bones are united together by a strong interosseous membrane. Evidently, the ulna takes a greater share than the radius to form the elbow joint, and the radius alone, assisted by the articular disc of inferior radio-ulnar joint, enters in the formation of wrist joint.

RADIUS

The radius is the lateral bone of forearm. It is the pre-axial bone and corresponds with the tibia of lower limb. The radius presents upper and lower ends, and an intervening shaft (Fig. 2.10, 2.11).

Upper end—It consists of head, neck and a radial tuberosity.

The head is articular and presents a disc-like concave upper surface and a peripheral margin which is broader on the medial side. The upper surface articulates with the capitulum of humerus and forms the humero-radial part of elbow joint. Peripheral margin articulates medially with the radial notch of ulna and the rest of the margin is encircled by the annular ligament to form the superior radio-ulnar joint. Posterior surface of the radial head is palpable through a lateral depressed area on the posterior surface of extended elbow, where the bone is found moving during pronation and supination of forearm.

The neck of radius is a constricted area that succeeds the head and is encircled by the lower part of annular ligament; the latter is separated by the synovial protrusion of superior radio-ulnar joint which is supported by the quadrate liga-ment derived from the interlacement of the distal border of annular ligament.

The radial tuberosity lies on the medial side of the lower part of neck. The posterior part of
tuberosity is rough and receives the insertion of the tendon of biceps brachii in a twisted manner; its anterior part is smooth and separated from the biceps tendon by a bursa for supination of the fore arm. The lower end of the tuberosity gives attachment to the oblique cord.

Shaft—It is triangular on cross-section in the middle third, and presents three borders—anterior, posterior and interosseous, and three surfaces—anterior, posterior and lateral.

The anterior border is oblique in the upper part, sloping downward and laterally from the lower end of radial tuberosity; the lower part of the border is vertical and extends as a prominent ridge in the distal fourth of shaft, where it is continuous with the anterior border of styloid process. The upper oblique border gives origin to the radial head of flexor digitorum superficialis; lower vertical ridge provides attachment to the lateral end of extensor retinaculum.

The posterior border is prominent in the middle third and ill-defined in the upper and lower parts. Traced above, it slopes upward and medially to reach the postero-inferior part of the radial tuberosity.

The interosseous (medial) border is sharp and extends from a little below the radial tuberosity to the posterior margin of a triangular area on the medial surface of the lower end (see later). It is connected to the corresponding border of the shaft of ulna by a strong interosseous membrane. Upper margin of the membrane is free and the gap between it and the oblique cord transmits posterior interosseous vessels (but not the nerves). Lower margin of the membrane is continuous with the capsular ligament of inferior radio-ulnar joint and is separated in front from the deep fibres of pronator quadratus muscle by a synovial pouch, recessus saciformis, of that joint.

The anterior surface intervenes between the anterior and interosseous borders, and is gently concave. The nutrient foramen, pointing towards elbow, is situated near the middle of the shaft. Upper two-thirds of the surface gives origin to flexor pollicis longus. Lower one-fourth of the anterior surface along with a triangular medial area in front of the interosseous membrane provides insertion to pronator quadratus.
The **posterior surface**, between the posterior and interosseous borders, gives origin to the **abductor pollicis longus** in the upper part, and **extensor pollicis brevis** in the lower part.

The **lateral surface** is gently convex and its summit at the middle of the shaft presents a rough impression for the insertion of **pronator teres**. Upper part of the lateral surface encroaches on the anterior and posterior aspects, due to obliquity of anterior and posterior borders; it receives the insertion of superficial and deep parts of **supinator muscle**, with the deep part of radial nerve (posterior interosseous nerve) passing between the two sets of fibres. Rest of the lateral surface below the pronator teres is covered by the tendons of extensor carpi radialis longus and brevis.

**Lower end**—It is the widest part of the bone, and presents lateral, medial, anterior, posterior and inferior carpal articular surfaces.

The **lateral surface** is rough and projects downward as the **styloid process** which extends beyond that of ulna. The tip of styloid process gives attachment to the lateral carpal ligament. The **lateral surface**, proximal of styloid process, receives insertion of **brachioradialis** and is crossed obliquely downwards and forwards by the tendons of abductor pollicis longus and extensor pollicis brevis.

The **medial surface**, distal to the triangular area for deep fibres of pronator quadratus, presents an **ulnar notch** for articulation with the **head of ulna** to form inferior radio-ulnar joint. The junction between the ulnar notch and carpal articular surface gives attachment to the base of the triangular **articular disc** of inferior radio-ulnar joint, the apex of which is fixed to a depression between the inferior articular surface of the head of ulna and its styloid process. Thus the ulna is excluded from the formation of wrist joint.

The **anterior surface** is represented by a thick prominent ridge which is palpable through the overlying tendons. It gives attachment to the palmar radio-carpal ligament. **Pulsation of radial artery** is felt against this surface distal to the pronator quadratus.

The **posterior surface** of the lower end presents a palpable **dorsal tubercle** (of Lister) and displays three longitudinal grooves – one lateral to the dorsal tubercle, and two medial to the tubercle. The **lateral groove** is wide and lodges the tendons of **extensor carpi radialis longus** and more medially **extensor carpi radialis brevis**, with a ridge intervening between them. The groove just medial to the dorsal tubercle is conspicuous and transmits the tendon of **extensor pollicis longus**, which utilises the dorsal tubercle as a pulley before reaching the thumb. The groove placed more medially is shallow and is occupied by the tendons of **extensor digitorum** and more deeply by the **extensor indicis** along with the **posterior interosseous** (deep branch of radial) **nerve**. All the above structures pass beneath the **extensor retinaculum** which gives a slip of attachment to the dorsal tubercle.

The **inferior carpal articular surface** is concave and subdivided by a ridge into lateral triangular and medial quadrilateral areas. The lateral area articulates with the **scaphoid** and medial area with the **lunate**, in order to form the radio-carpal or wrist joint. The **fibrous capsule** of wrist joint is attached along the periphery of the carpal articular surface, and at the ulnar notch of radius it is attached to the anterior and posterior margins of the articular disc of the inferior radio-ulnar joint.

**Side determination** place the disc-like head of radius above, gentle concavity of shaft in front, and the styloid process lateral which determines the side of the bone.

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**ULNA**

The ulna is the medial bone of forearm and represents the post-axial bone which corresponds with the fibula of lower limb.

The ulna consists of upper and lower ends, and an intervening shaft (Fig. 2.10, 2.11)

**Upper end**—It presents a hook-like massive bone with the concavity directed in front. The upper end consists of olecranon and coronoid processes, and two articular areas – trochlear and radial notches.

The **olecranon process** projects upward and possesses beak-like summit which occupies the olecranon fossa of humerus in extended elbow. It presents upper, medial, lateral, posterior and anterior surfaces.

The upper surface is rough and gives attachment from before backwards to the **capsular ligament** of elbow joint and the insertion of
**triceps brachii** with a bursa intervening between them. The posterior end of upper surface forms the point of elbow which lies in a horizontal line joining the medial and lateral epicondyles of the humerus in extended elbow; but during flexion the lines joining these three bony points form an isosceles triangle.

The medial surface is continuous with the corresponding surface of coronoid process and the shaft of ulna. It gives attachments to the following structures from before backwards:

(a) capsular ligament of elbow joint;
(b) posterior and oblique bands of the ulnar collateral ligament;
(c) a slip of origin of **flexor carpi ulnaris**;
(d) highest origin of **flexor digitorum profundus**.

The lateral surface is continuous with the posterior surface of the ulnar shaft. It gives attachments from before backwards to:

(a) capsular ligament of elbow joint;
(b) radial collateral ligament;
(c) insertion of **anconeus**.

The posterior surface is smooth, triangular and subcutaneous; from the apex of the triangle posterior border of the shaft extends downward. Sometimes between the skin and the bone a bursa intervenes.

The anterior surface is articular and forms the upper part of trochlear notch to fit with the trochlea of humerus. The **articular surface** is divided into three parts by vertical lines. Medial and intermediate parts come in contact respectively with the medial and lateral flanges of the trochlea in most of the movements of elbow; the lateral narrow strip makes contact with the trochlea only in extension.

The **coronoid process** forms a bracket-like forward projection below the trochlear notch. Its **upper surface** is articular and forms the lower part of the trochlear notch; the latter is subdivided by a ridge into medial and lateral parts to adjust with the respective flanges of the trochlea. The sharp anterior margin of the upper surface comes in contact with the coronoid fossa of humerus in flexed elbow.

The anterior surface of the coronoid process is rough and triangular with an elevation known as **ulnar tuberosity** in the lower part; the entire surface receives the insertion of **brachialis**. The lower end of ulnar tuberosity is connected with the corresponding part of radial tuberosity by the **oblique cord** which slopes downward and laterally, and represents the degenerated remnant of flexor pollicis longus. The medial margin of the anterior surface is sharp and presents a sublime tubercle in the upper part. From above downwards the medial margin gives origin to the following:

(a) a part of **flexor digitorum superficialis**;
(b) ulnar head of **pronator teres**;
(c) occasional head of **flexor pollicis longus**.

The lateral surface of the coronoid process presents, adjacent to the trochlear notch, a **radial notch** which articulates with the medial part of peripheral margin of head of the radius (see later). Rest of the surface below the notch presents a triangular depression which is limited behind by a raised margin, the **supinator crest**, for the origin of deep part of **supinator** muscle; the depressed area makes room for the movements of radial tuberosity during supination and pronation.

The **trochlear notch** is contributed by the anterior surface of olecranon process and the upper surface of coronoid process, and articulates with the trochlea of humerus to form the humero-ulnar part of elbow joint. The notch is constricted at the junction of the two processes where it presents a non-articular strip. The peripheral margin of the notch gives attachment of the capsular ligament of elbow joint.

Laterally, the trochlear notch is continuous with the **radial notch** of ulna, which articulates with the medial part of the peripheral margin of the head of radius to form superior radio-ulnar joint. Anterior and posterior ends of the radial notch give attachment to the **annular ligament** which embraces the rest of the peripheral margin; the radial head rotates around a vertical axis within the osseo-ligamentous ring.

**Shaft**—It diminishes progressively from above downward, except at its lower end. The shaft presents double curve. It is gently convex dorsally throughout the entire extent. From side to side, it describes a medial concavity in the upper part and a lateral concavity in the lower part. The **shaft** is triangular on cross-section in the proximal three-fourths and cylindrical in the distal one-fourth.

It presents **three borders**—anterior, posterior and interosseous, and **three surfaces**—anterior, medial and posterior.
The **anterior border** is rounded and ill-defined. It extends from the lower end of ulnar tuberosity to the front of the ulnar styloid process.

The **posterior border** is entirely subcutaneous and sinuously curved. It extends from the apex of the subcutaneous posterior surface of the olecranon process to the back of the styloid process. The posterior border gives attachment to the **deep fascia of forearm** and through the deep fascia provides origins to the following muscles:

(a) **flexor digitorum profundus** in the proximal three-fourths;
(b) **flexor carpi ulnaris** in the proximal half;
(c) **extensor carpi ulnaris** in the middle one-third.

The **interosseous** (lateral) **border** presents a conspicuous ridge, except in the lower part. Traced above, it is continuous with the supinator crest. The border gives attachment to the **interosseous membrane** which presents a gap between the upper free border of the membrane and oblique cord; the gap gives passage to the **posterior interosseous vessels**.

The **anterior surface** intervenes between the interosseous and anterior borders; it is continuous with the **medial surface** in the interval between the anterior and posterior borders. Upper three-fourths of anterior and medial surfaces along with the medial surface of olecranon and coronoid processes provide origin to the **flexor digitorum profundus**. Lower one-fourth of the anterior surface gives origin to the **pronator quadratus**.

The **posterior surface** intervenes between the posterior and interosseous borders. An oblique ridge, extending from the junction of upper one-fourth and lower three-fourths of the posterior border to the posterior lip of radial notch of ulna, divides the posterior surface into upper small and lower large areas. Upper area together with the lateral surface of olecranon process receives insertion of **anconeus**. Lower large area is subdivided by a vertical ridge into a lateral narrow part and medial broad part. The lateral part gives origin from above downwards to **abductor pollicis longus**, **extensor pollicis longus** and **extensor indicis**. The medial part is overlapped by the extensor carpi ulnaris.

**Lower end**—It is somewhat expanded, and presents head of ulna and a styloid process extending downward from the postero-medial aspect of the head.

**Head of ulna** is rounded and articular. Its lateral surface fits in the ulnar notch of radius and forms the inferior radio-ulnar joint. Lower surface of the head comes in contact with the articular disc of inferior radio-ulnar joint, thus preventing the head of ulna from forming the wrist joint. The apex of the disc is attached to a depression between the undersurface of the ulnar head and its styloid process.

A groove between the styloid process and posterior surface of head of ulna lodges the tendon of **extensor carpi ulnaris**. The styloid process gives attachment to the ulnar collateral ligament of wrist joint. The radial styloid lies about 2 cm below the ulnar styloid.

**Side determination**—Place the olecranon process above, trochlear notch in front and the sharp interosseous border lateral which determines the side of the bone.

**Ossification** of the bones of forearm

**Radius**—It ossifies from one primary centre and two secondary centres, one for each end.

The **primary centre** for the shaft appears in the 8th week of intra-uterine life.

The **secondary centre** for the lower end appears in the 1st year and unites with the shaft in the 20th year.

The **secondary centre** for the head appears in the 5th year and fuses with the shaft in the 18th year.

Therefore the lower end of the radius is the growing end.

**Ulna**—It ossifies from one primary centre and two secondary centres, one for each end.

The **primary centre** for the shaft appears in the 8th week of intra-uterine life.

The **secondary centre** for the lower end appears in the 5th year and unites with the shaft in the 18th year.

A scale-like **epiphyseal centre** for the upper surface of olecranon process appears in the 10th year and unites with the shaft in 15th or 16th year. The upper epiphysis is a **traction epiphysis**.

Therefore, the lower end of ulna is the growing end.
APPLIED ANATOMY OF FOREARM BONES

1. Since the radius is the force transmitting bone, it is commonly fractured about 2 cm above its lower end, due to a fall on the outstretched hand. This is known as Colles’ fracture in which the distal fragment is displaced upwards, backwards and laterally producing a classical dinner fork deformity.

2. Sudden traction on the hand of a child in the semi-pronated forearm may produce partial dislocation of the head of radius from the grip of annular ligament. This is known as subluxation or pulled elbow, because in children under six years the diameters of the head and neck are almost similar.

The sub-luxation is corrected by the forcible supination, which brings the head into the proper place again.

3. Fracture of the shafts of both radius and ulna is not uncommon. The object of surgical treatment is to prevent the cross-union between the two bones, in order to preserve the movements of pronation and supination.

4. The alteration of positions of three bony points (medial and lateral epicondyles, and olecranon) from the normal, indicates the dislocation of elbow joint. (see the olecranon process).

SKELETON OF THE HAND

The hand consists of carpal bones at the wrist, metacarpal bones in the palm, and phalangeal bones in the digits (Fig. 2.12, 2.13).

Carpal bones—These are short bones, eight in number, and arranged in proximal and distal rows, each row presenting four bones. From lateral to medial side, bones of proximal row are: scaphoid, lunate, triquetral and pisiform; bones of distal row are: trapezium, trapezoid, capitate and hamate.

Peculiarities of carpal bones—

1. Each bone is roughly cuboidal, presenting six surfaces, out of which palmar and dorsal surfaces are rough and non-articular, the rest are articular. This statement is, however, not applicable to triquetral and pisiform bones, because the dorsal surface of pisiform articulates with the palmar surface of triquetral.

2. The dorsal surface of carpal bones is more extensive than the palmar surface, except in lunate bone where the pattern is reversed. Therefore, palmar dislocation of lunate may take place, compressing upon the median nerve.

3. The free surfaces at the marginal bones of the carpus are non-articular, which involves the radial surfaces of scaphoid and trapezium, and the ulnar surfaces of trapezoid, pisiform and hamate.

4. Articulated carpus presents a concavity on the palmar (volar) aspect. The lateral pillar of the concavity is formed by the tubercle of the scaphoid and crest of the trapezium, and the medial pillar by the pisiform and hook of hamate bones. Both pillars are connected by the flexor retinaculum which acts as a tie-beam and converts the palmar concavity into a carpal tunnel; the latter transmits the tendons of flexor digitorum superficialis, flexor digitorum profundus, flexor pollicis longus and the median nerve. The tendon of flexor carpi radialis passes through the flexor retinaculum, splitting the latter into superficial and deep parts, and lodges in a groove on the palmar surface of the trapezium.

5. The proximal articular surfaces of the lateral three bones of proximal row (except pisiform) form a common convex ovoid surface for the wrist joint. Scaphoid and lunate articulate with the distal surface of the lower end of radius, and the triquetral with the articular disc of inferior radioulnar joint.

6. Infero-laterally directed distal articular surface of scaphoid is convex and fits with the trapezium and trapezoid. Head of the capitate, largest carpal bone, fits in a concavity formed by the distal surfaces of scaphoid and lunate. The edge of hamate articulates with the lunate bone, in between the capitate and triquetral. Thus, between the proximal and distal rows of carpal bones a mid-carpal joint is formed, which is sinuously curved and convexo-concave from lateral to medial side; this joint permits flexion and extension, but limits abduction and adduction.

7. Distal row of carpal bones articulates with the bases of five metacarpal bones. The trapezium presents a saddle-shaped articular surface for the first metacarpal and provides a separate joint cavity for wide range of movements, specially for the opposition of the thumb. The base of the second metacarpal bone is deeply wedged to articulate with the trapezium, trapezoid and capitate; this makes the bone immobile. The distal
surface of the capitare articulates mainly with the third, and partly with the second and fourth metacarpal bones. The hamate articulates with the fourth and fifth metacarpal bones.

8. Bases of second, third, fourth and fifth metacarpal bones articulate with each other.

9. The constricted waist of the scaphoid may be fractured due to a fall on outstretched hand. This may produce avascular necrosis of the proximal fragment, due to interruption of blood supply which is derived mostly from the distal part of the bone.

10. Ossification of carpal bones appears after birth in a spiral manner as follows:
Capitate and hamate—1st year,
Triquetral—3rd year, Lunate—4th year, Scaphoid—5th year,
Trapezium—6th year, Trapezoid—7th year, and Pisiform—12th year.

The capitate is the largest bone and starts ossification first. The pisiform is the smallest bone and is ossified last; it is said to be a sesamoid bone ossified in the tendon of flexor carpi ulnaris.

**Important structures** attached to the carpus

1. **Lateral pillar** of the carpal arch presents a vertical ridge and is formed by the tubercle of scaphoid and the crest of trapezium. The ridge gives origins from above downwards to: abductor pollicis brevis, opponens pollicis and flexor pollicis brevis. The flexor retinaculum is attached to the entire ridge and also to the inner lip of the groove of trapezium, thus producing an osseo-fibrous canal for the tendon of flexor carpi radialis.

2. **Medial pillar** is formed by the pisiform and hook of hamate; the latter presents a laterally directed tip and a convex medial surface. Deep branches of ulnar nerve and artery wind laterally below the hook.

Antero-medial surface of the pisiform receives insertion of the flexor carpi ulnaris in the upper part, and gives origin to the abductor digiti minimi in the lower part. The convex medial surface of the hook of hamate provides origin to the opponens digiti minimi and flexor digiti minimi.

A vertical ridge on the palmar surface of the pisiform along with the hook of hamate gives attachment to the flexor retinaculum. In addition, the pisiform provides attachment to the extensor retinaculum.

3. Palmar surfaces of the capitare and trapezoid give origin to a part of oblique head of adductor pollicis.

**BRIEF DESCRIPTION OF INDIVIDUAL CARPAL BONES**

**Scaphoid**—It is boat-shaped, long axis is oblique and presents a tubercle which is directed laterally, downwards and forwards.

The tubercle determines the side of the bone; it gives attachment to abductor pollicis brevis and flexor retinaculum.

*Articulations* (with 5 bones)—
  - Proximally—radius;
  - Distally—trapezium and trapezoid;
  - Medially—lunate and head of capitare.

**Lunate**—It is semilunar in shape, with a convex articular upper surface, broader non-articular palmar surface, and a lateral semilunar articular surface which determines the side of the bone.

*Articulations* (with 5 bones)—
  - Proximally—radius;
  - Distally—head of capitare and edge of hamate;
  - Laterally—scaphoid;
  - Medially—triquetral.

**Trapezoid**—It is somewhat wedge-shaped, and presents an oval facet on the palmar surface, a convexo-concave distal articular surface, and a quadrilateral articular facet on the supero-lateral surface which determines the side of the bone.

*Articulations* (with 3 bones)
  - Proximally—articular disc of inferior radioulnar joint;
  - Distally—hamate;
  - Supero-laterally—Lunate;
  - Anteriorly—pisiform.

**Pisiform**—It is pea-shaped and presents only one oval articular facet on the upper part of its dorsal surface for articulation with the triquetral. The palmar surface is divided by a vertical ridge into a small antero-lateral part and a large anteromedial part.

*Side determination*—Place the articular facet behind, non-articular end below, and the narrower antero-lateral surface determines the side.
Trapezium—It is quadrilateral in shape, and presents a saddle-shaped distal articular surface and a vertical groove on the palmar surface, the lateral margin of which forms a prominent crest; the latter determines the side of the bone.

Articulations (with 4 bones)
Proximally—scaphoid;
Distally—base of first metacarpal;
Medially—trapezoid and base of second metacarpal.

Trapezoid—It resembles the shape of a boot, and presents a large distal articular surface which is divided by an antero-posterior ridge into two sloping surfaces and a small non-articular palmar surface which exhibits a tail-like infero-lateral extension resembling the heel of the boot. The heel helps in determination of the side.

Articulations (with 4 bones)
Proximally—scaphoid;
Distally—base of second metacarpal;
Laterally—trapezium;
Medially—capitate

Capitate—It is the largest bone, with the head directed above, less extensive non-articular surface in front, and the constricted neck on the lateral side determines the side of the bone.

Articulations (with 7 bones)
Proximally—scaphoid and lunate;
Distally—second, third and fourth metacarpals;
Laterally—trapezium;
Medially—hamate.

Hamate—It is wedge-shaped, with the edge directed above and the hook projects from the anterior (palmar) surface with its concavity directed laterally. The direction of tip of the hook determines the side.

Articulations (with 5 bones)—
Proximally—the edge fits with lunate;
Distally—bases of fourth and fifth metacarpal bones;
Laterally—capitate; Supero-medially-triquetral.

METACARPAL BONES

These are miniature long bones, five in number and are numbered from lateral to medial side. Each metacarpal possesses a diaphysis and a single epiphysis. The epiphyses of all meta-carps are directed towards the head, except in the first where it is located towards the base, similar to that of phalangeal bones. Therefore, some authors consider that the first metacarpal is a modified phalanx.

Each metacarpal bone consists of head, shaft and base. The head is articular, directed below, and is convex extending more on the palmar surface and articulates with the base of the proximal phalanx. The head is slightly larger than the base, and forms the knuckles of the hand.

The shaft gets narrower from the head to the base. It is slightly concave proximo-distally on the palmar surface, which is subdivided by a longitudinal ridge into antero-medial and antero-lateral sloping areas. The dorsal surface presents a triangular flattened area with the apex pointing towards the base. Such triangular flattening is not observed on the dorsal surface of first metacarpal bone.

The base of the metacarpals articulates with the distal row of carpal bones. The first metacarpal articulates with the saddle-shaped distal articular surface of the trapezium forming a metacarpo-phalangeal joint, which is completely isolated from other metacarpo-phalangeal joints for free movements of thumb. The base of second metacarpal is grooved to fit in an antero-posterior ridge of the distal surface of trapezoid. Moreover, the trapezoid does not project so far distally as the other carpal bones. Eventually, the base of second metacarpal is mortised between the trapezium and capitate; this makes the metacarpal more immobile and rigid. The base of third metacarpal articulates with the plane surface of capitate and its mobility is restricted like that of second. The bases of fourth and fifth metacarpals articulate with the two concave facets of the distal surface of hamate. So they enjoy greater range of hinge movements than the other metacarpals, except the first.

Position of first metacarpal bone—The first metacarpal is placed on a more anterior plane than the rest of metacarpal bones, and is rotated medially around its long axis through angle of about 90°. This is advantageous for the free movements of first metacarpal bone.

Ossifications—The primary centre for the shaft appears in the 9th week of foetal life. The
secondary centre for the head of second to fifth metacarpals, and for the base of first metacarpal appear at about 2nd year. The fusion between epiphysis and diaphysis takes place between 16 and 18 years.

**Description of individual metacarpal bones**

**First metacarpal**—It is short and stout. The articular head presents medial and lateral tubercles on the palmar surface, on which sesamoid bones glide; the lateral tubercle is more prominent.

The palmar surface of the shaft presents larger antero-lateral area and smaller antero-medial area; antero-lateral area receives insertion of opponens pollicis, and antero-medial area gives origin to the radial head of first dorsal interosseous muscle. The dorsal surface of shaft is rounded from side to side and presents no triangular flattening.

The base presents a saddle-shaped articular surface which articulates with reciprocally curved distal surface of trapeziun to form the first carpo-metacarpal joint. Radial side of the base receives insertion of abductor pollicis longus; ulnar side of the base provides origin to the first palmar interosseous.

**Side determination**—Place the head below, concavity of the shaft in front, and the larger antero-lateral area of the palmar surface determines the side.

**Anatomical position**—Place the dorsal surface of shaft lateral, the lateral border in front and the head below and lateral.

**Second metacarpal bone**—It is the longest metacarpal bone and is identified by a grooved base which fits in a corresponding ridge of trapezoid. The medial lip of the groove is prominent and articulates with the capitate; more distally the medial surface presents an indented facet for the **third metacarpal**. A quadrilateral facet on the dorso-lateral aspect of the base articulates with the trapeziun.

**Side determination**—Place the head below, concavity of the shaft in front, and the quadrilateral facet of the grooved base determines the side.
Attachments

1. Antero-lateral and antero-medial areas of the shaft give origins respectively to the ulnar head of first dorsal interosseous and radial head of second dorsal interosseous muscles.

2. A narrow strip along the antero-medial area of palmar surface of shaft gives origin to the second palmar interosseus.

3. Palmar surface of the base receives a slip of insertion of flexor carpi radialis.

4. Dorsal surface of the base receives insertion of extensor carpi radialis longus.

Third metacarpal bone—It is identified by a styloid process which projects upward from the radial side of dorsal surface of its base. The base articulates proximally with the capitate, laterally by an indented facet with the second metacarpal and medially by two discrete facets with the fourth metacarpal.

Side determination—Place the head below, concavity of the shaft in front, and the position of the styloid process of the base determines the side.

Attachments

1. Antero-lateral and antero-medial areas of the shaft give origins respectively to the ulnar head of second dorsal interosseous and radial head of third dorsal interosseous muscles.

2. Vertical palmar ridge of the shaft gives origin to the transverse head of adductor pollicis.

3. Palmar surface of the base along with the adjacent second metacarpal bone receives insertion of flexor carpi radialis, which is partially encircled more distally by the origin of oblique head of adductor pollicis.

4. Dorsal surface of the base, close to the styloid process, provides insertion of extensor carpi radialis brevis.

Fourth metacarpal bone—It is identified by a quadrilateral articular facet on the proximal surface of its base. The base articulates proximally with the hamate, laterally by two discrete facets with the third metacarpal, and medially by a flattened strip with the fifth metacarpal.

Side determination—The two facets of a quadrilateral base determine the side.

Attachments

1. Antero-lateral and antero-medial areas of the shaft give origins respectively to the ulnar head of third dorsal interosseous and radial head of fourth dorsal interosseous muscles.

2. A narrow strip along the antero-lateral area of palmar surface of shaft gives origin to third palmar interosseous muscle.

Fifth metacarpal bone—It is identified by a non-articular tubercle on the medial side of its
base. The base articulates proximally with the hamate and laterally by a narrow strip with the fourth metacarpal.

**Side determination**—Place the head below, concavity of shaft in front and the side is determined by the direction opposite to non-articular tubercle.

**Attachments**

1. Antero-lateral area of the shaft gives origin to the ulnar head of the **fourth dorsal interosseous**, and more ventrally provides origin to the **fourth palmar interosseous**.

2. Antero-medial area of the shaft receives insertion of **opponent digiti minimi**.

3. Non-articular tubercle of the base gives attachment to piso-metacarpal ligament on the palmar surface, and receives insertion of **extensor carpi ulnaris** on the dorsal surface.

**PHALANGEAL BONES**

Total number of phalangeal bones are 14, 3 for each medial four fingers and 2 for the thumb. These bones are referred to as proximal, middle and distal phalanges.

Each phalanx is a **miniature long bone**, and possesses a diaphysis and a single epiphysis directed towards the base (like the first metacarpal bone).

Each phalanx presents proximo-distally base, shaft and head.

The base of the **proximal phalanx** is concave and articulates with the head of metacarpal to form metacarpo-phalangeal joint. Each of the bases of **middle and distal phalanges** convey two concave facets separated by a ridge and articulates with the adjacent phalanges to form proximal and distal interphalangeal joints.

The dorsal surface of the **shaft** is smooth and transversely convex; over the proximal and middle phalanges it is covered by **extensor expansion**. The palmar surface of the shaft is gently concave from above downwards opposite the proximal and middle phalanges; it is limited at the sides by sharp margins for the attachments of **fibrous flexor sheaths**.

The **heads** of proximal and middle phalanges are articular and pulley-like. The head of distal phalanx presents on the palmar surface a non-articular horse-shoe shaped tuberosity for the attachments of pulp of the finger tips. The dorsal surface of the tip of distal phalanx is smooth and covered by finger nails.

**Note:** It is easy to identify proximal, middle and distal phalanges, but it is not possible to determine their sides.

**Attachments**

1. **Distal phalanges** of medial four fingers
   - **Palmar surface** of the base—insertions of flexor digitorum profundus;
   - **Dorsal surface** of the base—insertion of a slip of dorsal digital expansion;

2. **Distal phalanx** of thumb
   - **Palmar surface** of base—insertion of flexor pollicis longus;
   - **Dorsal surface** of base—insertion of extensor pollicis longus;

3. **Middle phalanx**—At the two sides of shaft: insertion of flexor digitorum superficiales;
   - **Dorsal surface** of the base: A slip of insertion of dorsal digital expansion;

4. **Proximal phalanges** (All attachments are to the bases):
   (i) Thumb
      - **Radial side**: Abductor pollicis brevis, and flexor pollicis brevis;
      - **Ulnar side**: Adductor pollicis, and first palmar interosseous;
      - **Dorsally**: Extensor pollicis brevis;
   (ii) Index finger
        - **Radial side**: First dorsal interosseous muscle;
        - **Ulnar side**: Second palmar interosseous muscle;
   (iii) Middle finger
        - **Radial side**: Second dorsal interosseous;
        - **Ulnar side**: Third dorsal interosseous;
   (iv) Ring finger
        - **Radial side**: Third palmar interosseous;
        - **Ulnar side**: Fourth dorsal interosseous;
   (v) Little finger
        - **Radial side**: Fourth palmar interosseous;
        - **Ulnar side**: Abductor digitii minimi, and flexor digitii minimi.
Note: Lumbricals, extensor indicis and extensor digiti minimi are not attached directly to the proximal phalanx, because they enter in the formation of dorsal digital expansion.

Ossification—The primary centres appear for the shafts of distal phalanges in the 8th week, the proximal phalanges in the 10th week, and the middle phalanges in the 11th week of intrauterine life. The secondary centres for the bases of all phalanges appear in about 2nd year. The fusion between the diaphysis and epiphysis of all phalanges takes place at about 16-18 years.

Digital formula—The most projecting finger of the hand is the middle finger; next to it the order of digital lengths are the ring, index, little fingers and the thumb. Therefore, the digital formula runs as $3 > 4 > 2 > 5 > 1$. In 33% individuals, however, the index finger exceeds the ring finger.

Axial line of hand—A line drawn through the middle finger, third metacarpal and capitate bones represents the axial line of hand. Therefore the middle finger is already adducted. Any movement of fingers away from the axial line means abduction; dorsal interossei are abductors of the middle three fingers; for the thumb and little fingers separate abductor muscles are provided. Finger movements towards the axial line produce adduction. Palmar interossei act as adductors of the fingers and these muscles are not attached to the third metacarpal and third digit. For wide range of adduction of thumb, a separate adductor pollicis is provided.
3

SUPERFICIAL STRUCTURES OF THE UPPER LIMB

Skin—The skin of extensor surface of upper limb is somewhat thicker, more hairy and less sensitive than that of the flexor surface. The flexor lines or skin creases are present in front of elbow, wrist and interphalangeal joints.

Cleavage lines of Langer (lines of tension) are more or less transversely oriented around the elbow and wrist, whereas they are more oblique on the flexor surface and almost vertical on the extensor surface.

Superficial fascia—It consists of fibro-areolar tissue and interspersed with fat. In the pectoral region, it splits to enclose the mammary gland.

The superficial fascia is traversed by blood vessels, lymphatics and cutaneous nerves.

VEINS

The veins of upper limb consist of superficial and deep sets. The deep sets accompany the arteries and are arranged in pairs as venae comitantes, except the axillary vein. The superficial sets are variable in disposition, lie in the superficial fascia, communicate with the deep veins and finally drain in the axillary vein. Both sets are provided with valves.

Superficial veins—These include the cephalic, basilic, median cubital and median antebrachial veins.

Blood from the hand drains chiefly into the dorsal venous network on the back of the hand. This network is formed by the three dorsal metacarpal veins, which are formed by the union of dorsal digital veins. The latter communicate with palmar digital veins by oblique intercapitular veins passing between the metacarpal heads.

At the lateral end, the dorsal venous network joins with the dorsal digital veins from the radial side of the index finger and from both sides of the thumb and is prolonged upwards as the cephalic vein. At the medial end, the dorsal digital vein from the ulnar side of the little finger joins the venous network and continues upward as the basilic vein.

Cephalic vein

It is formed in the anatomical snuff box from the radial side of dorsal venous network and undergoes a spiral course upward around the radial border of lower forearm. It appears in front of the elbow, where it is connected to the basilic vein by median cubital vein (Fig. 3.1).

In its further upward course, the cephalic vein runs along the lateral side of the biceps and thereafter in the groove between the deltoid and pectoralis major, where it accompanies the deltoid branch of thoraco-acromial artery and pierces the deep fascia. In the delto-pectoral triangle, it pierces the clavicular fascia, makes a right-angled bend and drains into the axillary vein. Sometimes the cephalic vein joins with the external jugular vein superficial to the clavicle.

Applied Anatomy

Cardiac catheterisation through the cephalic vein is usually not preferred, because of possible obstruction of the venous catheter at the communication between cephalic and axillary veins.

Basilic vein

It begins from the ulnar side of the dorsal venous network, ascends along the medial side of the forearm, and in front of medial epicondyle it is connected with the cephalic vein by median cubital vein.

In its further upward course, the basilic vein accompanies the medial border of biceps and
pierces the deep fascia at the middle of the arm, where the vein passes from superficial to deep and the medial cutaneous nerve of the arm appears from deep to superficial. Beneath the deep fascia the basilic vein accompanies the venae comitantes of the brachial artery. Finally the three veins assemble to form the axillary vein.

**Applied Anatomy**

Cannulation through the basilic vein for cardiac catheterisation is preferable, because of its continuity with axillary vein without angulation.

Median cubital vein—It is an anastomosing channel in front of the elbow that passes upward and medially from the cephalic to basilic vein. It lies in front of bicipital aponeurosis, which separates the vein from the brachial artery and median nerve.

Usually the median cubital vein lies between the lateral and medial cutaneous nerves of the forearm, and communicates with the deep veins of the forearm. Sometimes it receives here a tributary of median antebrachial vein. The latter drains the blood from the superficial palmar plexus, ascends on the front of forearm and joins median cubital or basilic vein or bifurcates to join with both cephalic and basilic veins.

**Applied Anatomy**

1. Median cubital vein is usually selected for withdrawal of blood, intravenous injection, blood transfusion and cardiac catheterisation.

2. *Internal artero-venous fistulae* are sometimes established for haemodialysis in chronic renal failure between the cephalic vein and radial artery above the wrist, to permit repeated venepuncture access to the blood stream.

**Lymphatic Drainage**

Lymphatic vessels of the upper limb consist of superficial and deep sets. The superficial
vessels lie in the subcutaneous tissue and accompany the superficial veins, whereas the deep vessels lie beneath the deep fascia and accompany the arteries.

**Superficial lymphatics**—There are two subcutaneous lymphatic plexuses, one on the dorsum of hand and another in the palm. Digital lymph vessels join with the dorsal plexus, which also receive vessels from the distal palmar plexus through the webs of fingers.

Lymphatic channels of both sets of plexuses accompany the basilic and cephalic veins. The vessels draining from medial three fingers and medial side of hand and forearm follow the basilic vein and are intercepted mostly by the supratrochlear lymph nodes which lie slightly above the medial epicondyle; efferent vessels from the latter drain into lateral group of axillary lymph nodes.

The lymphatics from the thumb and index fingers and from the lateral side of hand and forearm pass along the cephalic vein, and drain into infra-clavicular lymph nodes in the deltopectoral groove and thence into apical group of axillary nodes after piercing the clavipectoral fascia.

**Deep lymphatics**—These communicate with the superficial lymphatics in places, accompany the radial, ulnar and brachial arteries and drain into lateral group of axillary nodes.

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**Applied anatomy**

Palpable and enlarged supratrochlear lymph node is of diagnostic value in secondary syphilis, which is associated with generalised lymphatic enlargement.

**Axillary lymph nodes**

The axillary nodes, about 20 to 30 in number, drain the lymphatics from:

(i) the upper limb,

(ii) most of the mammary gland, and

(iii) cutaneous lymphatics from the trunk above the level of umbilicus (Fig. 3.2, 3.3).

The axillary nodes are arbitrarily divided in five groups—anterior, posterior, lateral, central and apical.

**Anterior or pectoral group**—They lie along the lateral thoracic vein at the lower border of pectoralis minor, and drain most of the lymphatics from the breast. **Axillary tail of spence**, when present, is in direct contact with these nodes. Carcinoma affecting this part of the breast may be wrongly diagnosed as the enlarged lymph node.

**Posterior or subscapular group**—They lie along the subscapular vessels in the posterior wall of axilla on subscapularis muscle.
Afferent vessels received by the posterior group are derived from the dorsal part of trunk as far below as the iliac crest.

Lateral group—These are situated in the lateral wall of axilla postero-medial to the axillary vein.

They receive afferent vessels from the entire upper limb, except those lymphatics which accompany the cephalic vein.

Central group—These are situated close to the base of axilla embedded in fat, and receive afferent lymphatics from the preceding three groups.

Efferent vessels from the central group drain into the apical group.

The intercosto-brachial nerve passes through the central nodes. Compression of this nerve, due to enlargement of these nodes from carcinoma of the breast, may be manifested by referred pain along the medial side of the arm.

Apical group—These nodes are situated at the apex of axilla medial to the axillary vein, and occupy an area bounded below by the first intercostal space, above by the axillary vein and in front by the clavipectoral fascia.

They receive afferent vessels from:

(a) subcutaneous lymphatics of upper limb that accompany the cephalic vein;
(b) the upper margin of the mammary gland;
(c) all other groups of axillary lymph nodes.

Efferents from the apical group form the subclavian trunk which drains as follows:

(a) mostly at the junction of subclavian and internal jugular veins;
(b) sometimes joins with the right lymphatic duct or thoracic duct on the left side;
(c) a few efferents terminate into inferior deep cervical lymph nodes.

Applied anatomy

1. Since the apical group acts as terminal lymphatic barrier of the upper limb or mammary gland, the enlargements of apical nodes due to infection or metastatic spread are palpated as follows: The fingers of one hand are pushed upward from the base of axilla towards its apex, while the fingers of the other hand are approached from above behind the clavicle.

2. Axillary lymph nodes are contained in a fascial tent which covers the wall of the axilla in the following manner:

   In front, pectoralis minor and clavipectoral fascia;
   Behind, subscapularis muscle;
   Medially, the fascia covering intercostal muscles and serratus anterior; the long thoracic nerve descends deep to the fascia;
   Apex, directed above where the fasciae meet;
   Base, is open and directed below.

A block dissection of axillary lymph nodes, when required, is envisaged by keeping the fascial tent intact.

![Fig. 3.3. Schematic presentation of Afferent and Efferent lymphatics of Axillary nodes.](image-url)
Currently due to clinical importance, a simplified version of the grouping of axillary lymph nodes is adopted according to their locations with respect to the pectoralis minor muscle:

(a) those lying below the muscle are called the low nodes at the level 1;
(b) the nodes situated behind the muscle belong to the middle group at the level 2;
(c) those lying above the muscle and extending up to the lower surface of the clavicle are named as the upper or apical nodes at the level 3;
(d) a few nodes intervening between the pectoralis minor and major muscles are known as the Rotter's nodes.

CUTANEOUS NERVES OF THE UPPER LIMB
(Figs. 3.4, 3.5)

Front of the chest including pectoral region
- Medial and intermediate branches of the supraclavicular nerve;
- Anterior cutaneous branches of upper six intercostal nerves, and lateral cutaneous branches of third to sixth intercostal nerves.

Shoulder region
- Lateral branches of supraclavicular nerve;
- Axillary nerve and its upper lateral cutaneous branch.

Scapular region
- Dorsal primary rami of lower cervical and upper thoracic nerves in cranio-caudal sequence.

Note: 1. Dorsal rami of lower two cervical nerves (C₆ and C₇) do not supply the skin.
2. Dorsal primary ramus of a spinal nerve does not supply the skin proper of a limb, and never supplies limb musculature.

Front of the arm
- Intercosto-brachial nerve;
- Medial cutaneous nerve of arm;
- Upper and lower lateral cutaneous nerves of the arm.

Back of the arm
- Posterior cutaneous nerve of the arm;
- Posterior cutaneous nerve of the forearm;
- In addition, supplied by the nerves from the front of arm.

Fig. 3.4. Cutaneous nerves of upper limb (Frontal view).

Front of the forearm
- Medial cutaneous nerve of forearm;
- Lateral cutaneous nerve of forearm;
- Palmar cutaneous branches of median and ulnar nerves, close to the wrist.

Back of the forearm
- Posterior cutaneous nerve of forearm;
- Assisted by the medial and lateral cutaneous branches of forearm.

Palm of the hand
- Ulnar side of the palm including medial one and a half of the fingers, are supplied by the superficial branch of the ulnar nerve, the latter also supplies the dorsal surface of the distal one and a half of phalanges of the above-mentioned fingers.
• Radial side of the palm including lateral three and one-half of the fingers, are supplied by the median nerve; the latter also supplies the dorsal surface of the distal one and a half of phalanges of the aforesaid fingers.

• Centre of the palm is innervated by the palmar branch of median nerve, which perforates the deep fascia proximal to flexor retinaculum.

![Diagram of cutaneous nerves of upper limb](image)

**Fig. 3.5. Cutaneous nerves of upper limb (Frontal view).**

**Dorsum of hand**

• Ulnar side of the dorsum and medial one and a half of fingers, by the dorsal branch of ulnar nerve;

• The lateral three and a half of the fingers, by the superficial branch of radial nerve.

**Dermatomes of upper limb bud**

The dermatome is the area of skin supplied by a single segment of spinal cord. The upper limb buds develop as lateral outgrowths of the body wall opposite the lower four cervical and first thoracic spinal segments. Therefore, the overlying skin of the upper limb bud is supplied by the ventral rami of C5, C6, C7, C8 and T1 spinal nerves through the brachial plexus (Fig. 3.6 (a), (b)).

The **pre-axial border** of upper limb is placed cranially and represented by the thumb; it is marked out by the position of cephalic vein. The **post-axial border** is placed caudally and represented by the little finger; it corresponds to the position of basilic vein.

![Diagram of dermatomes of upper limb](image)

**Fig. 3.6. Dermatomes of upper limb.**

The dermatomes along the pre-axial border are supplied by more cranially disposed spinal segments, and those along the post-axial border by more caudally disposed segments. But the central dermatome of the limb plexus is placed at the peripheral end of the limb. Thus the dermatome along the radial side of the arm is supplied by C5 segment, and that along the radial side of forearm including the thumb is supplied by C6 segment, whereas the area of little finger and ulnar side of forearm gets innervation from C8 segment and the ulnar side of arm from T1 segment. C, dermatome, (central dermatome) involves middle three fingers and their adjacent palmar and dorsal surfaces. The dermatomes overlying the deltoid and bottom of
the axilla are borrowed from the neck and trunk and are supplied respectively from $C_4$ and $T_2$ segments.

Adjacent dermatomes overlap one another, so that the cutaneous sensations are not significantly affected in interruption of nerve supply of a particular dermatome. But when the discontinuous dermatomes meet, the axial lines are formed across which there is no cutaneous overlap; this helps the clinicians during investigation of cutaneous paraesthesia of segmental origin.

Two axial lines, anterior and posterior, can be marked out in the upper limb. The anterior axial line extends from the sternal angle (of Louis) across the second costal cartilage and along the front of the limb as far below as the wrist. The posterior axial line is believed to commence from the seventh cervical spine, makes a gentle convex curve across the scapula and then passes down along the back of arm as far as the elbow.
The breast is present bilaterally in the pectoral region of both sexes. In male and immature female, the breasts are rudimentary; in both the nipple is small but the areola is fully formed. After puberty, the female breasts are well developed, and this becomes more marked during pregnancy and lactation. The shape varies in adult female, which may be hemispherical, conical or pendulous; but its circular base remains fairly constant.

The breast or mamma is a modified sweat gland and lies in the superficial fascia of pectoral region, and has no distinct fibrous capsule.

**FEMALE BREAST**

**(adult)**

**Extent**—The circular base extends:

Vertically, from the second to the sixth rib in the mid-clavicular line;

Horizontally, from the lateral border of sternum to the mid-axillary line along the fourth rib;

**Mammary bed** (Fig. 4.1)—The base of the gland rests upon the following structures:

- **Axillary tail of spence**
- **Pectoralis major**
- **Mammary gland**
- **Areola**
- **Nipple**
- **Foramen of langer**
- **Digitations of serratus anterior**
- **External oblique over rectus sheath**

*Fig. 4.1. Adult female breast of right side and mammary bed.*

_Pectoralis major_, in medial two thirds; _serratus anterior_, in lateral one-third; _external oblique aponeurosis_, in the infero-medial quadrant; it separates the breast from rectus abdominis.

Deep projections from the glandular parenchyma sometimes penetrate the superficial part of pectoralis major.

A _retro-mammary space_ containing loose connective tissue intervenes between the base of the gland and the deep fascia covering the structures of the mammary bed. As a result, the normal breast can be moved freely over the pectoralis major. In invasion of breast carcinoma, the gland is fixed to the pectoralis major.

**Axillary tail of spence**—Sometimes a tail-like projection from the upper and outer quadrant of the gland enters the axilla through an opening in the axillary fascia known as _foramen of Langer_. This process comes in contact with the anterior group of axillary lymph nodes, and when enlarged, may be mistaken for a lipoma.

**Symmetry of breasts**—Breasts of both sides are more often equal in size. If one is larger and lower, it is usually the right.

**Features in the skin** overlying the breast (Fig. 4.2)

**Nipple**—It is a conical or cylindrical projection below the centre of the breast, at the level of fourth intercostal space in nulliparous females. The nipple is pierced by 15-20 lactiferous ducts, and contains circular and longitudinally disposed smooth muscles. The circular muscle retracts the nipple for suckling; the longitudinal muscle retracts the nipple.

It possesses rich nerve supply and is provided with sensory receptors for suckling.

**Areola**—It is a pigmented circular area of skin around the base of the nipple. The pigmentation is irreversibly darkened after first pregnancy. Outer margin of the areola contains a number of modified sebaceous glands, which are enlarged during
pregnancy and lactation and are known as tubercles of Montgomery. Oily secretion of these glands provides protective lubricant during lactation. Besides these glands, the areolar contains sweat glands and accessory mammary glands. The skin of the areola and nipple is devoid of hair and subcutaneous fat.

Fig. 4.2. Anterior view of adult female breast.

Beneath the areola each lactiferous duct is dilated to form lactiferous sinus, before passing through the nipple. A sub-areolar lymphatic plexus of Sappey collects the lymph from the areola and nipple.

Male breast

It is essentially composed of duct system without alveoli and is supported by fibro-fatty tissue. The breast tissue does not extend beyond the margin of areola.

Abnormal and bilateral hypertrophy of male breasts (gynaecomastia) are occasionally observed in Klinefelter's syndrome (47, XXY), endocrine disorders or impaired liver function.

Male breasts are richly drained by lymphatics. Prognosis of breast carcinoma of male is worse than that of female.

Structure of the breast

The breast is made up of three components (Fig. 4.3)—

1. Glandular tissue of tubulo-alveolar type and arranged in lobes;

2. Fibrous tissue supports the lobes and forms a number of septa which anchor the parenchyma to the overlying skin and the underlying pectoral fascia. These fibrous bands are known as suspensory ligaments of Cooper. The growth of malignant cells from breast cancer may extend along these ligaments and produce dimples of the overlying skin or fixation of the lump to the pectoralis major.

3. Interlobar fatty tissue makes the organ rounded in contour. Fat is, however, absent beneath the areola and nipple.

Glandular tissue (Fig. 4.4-a, b)—it consists of 15 to 20 pyramidal lobes, each being drained by a separate lactiferous duct. The lobes are arranged in radiating manner and converge toward the areola, where each duct dilates to form the lactiferous sinus possibly to act as reservoir of milk; finally the ducts open on to the nipple. Each duct drains a segmental system of smaller ducts and lobules. Each segmental duct divides into a number of terminal ducts; from the latter numerous secretory glands pouch out to form grape-like clusters. The area of breast parenchyma drained by one terminal duct is known as the lobule. Therefore each lobe or segment of breast connected to the individual lactiferous duct contains numerous lobules. The lobules are surrounded by a breast-specific hormonally responsive fibro-fatty stroma along with vessels and nerves. The lobules and their acini gain their functional maturity only with the onset of pregnancy.

Fig. 4.3. Sagittal view of adult female breast.
The ducts possess myoepithelial cells resting on a basal lamina; larger ducts are lined by columnar epithelium of two or more layers and at the papillary openings lined by keratinized stratified squamous epithelium. Carcinoma of breasts usually arises from the larger ductal epithelium, whereas the distal smaller ducts are the sites of benign fibro-adenoma.

Structural differentiation of mammary gland varies with age, pregnancy and lactation.

From birth to pre-pubertal life—Presence of lactiferous ducts without alveoli.

At puberty—The ducts undergo branching and peripheral branches form solid, spheroidal masses of cells which are the precursors of alveoli.

In pregnancy—During this period further proliferation and epithelial growth of terminal ducts and lobules take place with increase in the number of alveoli per lobule. After about sixth month of pregnancy the breast expands further due to increase in blood flow and secretion of colostrum, so that total weight of each breast reaches about 400 gm. The secreting alveoli enlarge with the accumulation of milk. Milk secreted in later part of pregnancy and for a few days after parturition is known as colostrum, which is poor in nutrients and contains fat globules and colostrum corpuscles; the latter may be derived from fatty degeneration of primitive alveoli or from macrophage cells containing phagocytosed fat.

True milk secretion starts after a few days of parturition, with the suckling of the newborn.

During lactation—The distended alveoli are lined by a single layer of epithelium, which is separated from the basement membrane by myoepithelial cells. The epithelium may be cuboidal in resting condition or columnar in lactation.

Ultra-structurally, the alveolar cells possess basophilic cytoplasm and contains rER, mitochondria, free ribosomes, lysosomes, Golgi apparatus and two types of secretory vacuoles—protein vacuoles (containing caseins and lactalbumen) are secreted through the intact cell membrane in merocrine manner; lipid vacuoles are discharged with a covering of cell membrane and cytoplasm like apocrine glands.

After lactation—When lactation stops (usually 6 months after birth), the alveoli shrink, the remaining milk is absorbed and the glandular tissue returns to the resting condition.

Hormones acting on glandular tissue

Oestrogen—stimulates the growth and branching of the ducts;

Progestosterone—stimulates the alveolar formation at the ends of the branching ducts;

Oestrogen and progesterone (Placental)—for the formation of true secretory alveoli during pregnancy;

Prolactin and growth hormone—maintain lactation;

Oxytocin—helps milk ejection, initiated by suckling reflex;

Maternal oestrogen—circulating in neonates of both sexes through the placenta, stimulates the ductal epithelium of their breasts to secrete a fat-free fluid in the first one or two weeks after birth. This is known as witch’s milk.

Arterial supply of the breast (Fig. 4.5)

1. Lateral thoracic branch of axillary artery (2nd part) provides the lateral mammary branches, which wind round the pectoralis major and supply the lateral part of the gland.

2. Superior thoracic artery from the 1st part of axillary, supplies upper part of the gland.

3. Perforating branches of the internal thoracic artery to the 2nd, 3rd and 4th intercostal spaces form the medial mammary branches, which supply the medial part of the breast.
Fig. 4.5. Arterial supply of mammary gland.

4. Lateral branches of the 2nd, 3rd and 4th intercostal arteries supply the deep surface of the gland.

Venous drainage (Fig. 4.6)—The veins form a plexus, circulus venosus, beneath the areola. From this plexus the veins radiate to the periphery in close proximity to the skin, and drain into the axillary, internal thoracic and intercostal veins. Through the intercostal and azygos veins the blood may communicate via the internal vertebral venous plexus (Batson) with intra-cranial sagittal and transverse sinuses, and establish venous communications with the clavicle, humerus and cervical vertebrae. Breast cancer may spread to these bones by the retrograde venous flow.

Nerve supply—The nerves are derived from the anterior and lateral cutaneous branches of 4th to 6th intercostal nerves, which also convey sympathetic fibres. The somatic fibres supply the overlying skin; sympathetic fibres are primarily vaso-motor.

Lymphatic drainage—The lymphatics of mammary gland are of two sets—
- those draining the parenchyma of the breast including areola and nipple.
- those draining the overlying skin excluding areola and nipple.

From the parenchyma (Fig. 4.7)

The lymph vessels form plexuses in the interlobular connective tissue and walls of lactiferous ducts. These join with the subareolar plexus of Sappey which collects the lymph from the areola and nipple. Contrary to the previous view, the subareolar plexus does not form the collecting zone for parenchymal lymphatics.

Some of the lymphatics from the deep surface of the gland are said to join with a plexus of minute vessels which ramify on the underlying deep fascia. In healthy breast such connections do not form the usual pathway to the regional nodes. They only form alternate routes when normal channels are obstructed by the spread of cancer cells.

Drainage

1. About 75% of lymphatics from the gland drain into axillary nodes. Majority of vessels accompany the lateral thoracic artery and are received by the anterior (pectoral) group, and a few vessels following

Fig. 4.6. Venous drainage of mammary gland.
From the overlying skin (Fig. 4.8)

The integumental lymphatics, excluding areola and nipple, pass in radial manner and drain into the following peripheral nodes:

1. From the outer part—**axillary nodes**;

2. From the upper part—**supra-clavicular group** of lower deep cervical nodes. Some vessels reach the cephalic nodes in the deltopectoral triangle and thence drain into **apical group** of axillary nodes after piercing the clavipectoral fascia.

3. From the inner part—**parasternal nodes** in relation to internal thoracic vessels in upper four or five intercostal spaces.

The cutaneous lymphatics communicate across the middle line with those of the opposite breast; a unilateral disease of the breast becomes bilateral by this route.

4. From the lower part—the lymphatics communicate with those of rectus sheath and form a **sub-peritoneal plexus** by piercing the upper part of linea alba. These vessels drain into **sub-diaphragmatic nodes** and some pass through the falciform ligament to reach the **hepatic nodes** around the bile duct. Enlargement of those nodes by metastatic spread may produce obstructive jaundice.
On rare occasions, the cancer cells from the sub-peritoneal plexus drop into the general peritoneal cavity, undergo transcoelomic migration and produce secondary deposits specially on the surface of ovary forming Krukenberg’s tumour.

**Clinical anatomy of cancer breast**

- Infiltration of cancer cells along the suspensory ligaments of Cooper and subsequent fibrosis make retraction of the overlying skin and fixation of the tumour to the underlying pectoral fascia.
  - Extension of the growth along the lactiferous ducts and subsequent fibrosis lead to retraction of the nipple.
  - **Peau d’orange** is a condition where the hair follicles over the lump appear to be retracted, and is caused by obstruction of the cutaneous lymphatics with stagnation of lymph and oedema of skin around the hair follicles. This resembles the skin of an orange; hence the name.
  - In unilateral cancer breast, the axillary nodes of both sides should be examined for enlargements.
  - Secondary deposits on ovaries in cancer breast make the prognosis worse.

**Prenatal development of the breast**—It is developed from two sources; the epithelial lining of the ducts and alveoli is derived from the surface ectoderm, and the fibro-fatty stroma from the underlying mesoderm (Fig. 4.9).

In the seventh week of intra-uterine life two ectodermal milk ridges appear on each side of the ventral body wall and extend from the axillae to the inguinal regions. In the human, the milk ridges in the pectoral regions persist and give rise to the development of breasts; rest of the ridges regress. The axillary tail of breast may represent its cephalic end.

**Applied Anatomy**

- Breast lump may be mobile or fixed, soft or hard, and solid or cystic. A hard and fixed lump goes in favour of malignancy, which is a common disease in post-menopausal women. A mobile and soft lump is sometimes observed in young females as benign fibro-adenoma due to an over growth of a lobule. In any case the diagnosis can be made by fine needle aspiration cytology (FNAC), mammography and ultra-sonography.
  - Breast lump upto 4 cm in diameter with signs of malignancy is usually treated by tumour excision with conservation of rest of breast tissue along with removal of axillary lymph nodes and application of radiotherapy. The skin is incised along the skin creases of Langer’s line for cosmetic purposes.

  Larger lumps are to be treated by modified radical mastectomy which includes total removal of breast with all axillary nodes in a fascial tent, and preservation of nerve supply to serratus anterior, latissimus dorsi and pectoralis major and minor muscles. This is followed by treatment with radiotherapy and chemotherapy.
  - Blood-stained nipple discharge without a palpable mass is usually caused by an intraductal papilloma which is non-malignant in most of the cases. It is treated after circumareolar incision by excision of the affected duct in radial manner, since lactiferous ducts are radially arranged.

**Fig. 4.9. The Milk lines of the developing breast.**

The pectoral portion of the ridge presents a surface depression, mammary pit, from the bottom of which about 15 to 20 epithelial cords grow into the underlying dermis. The epithelial cords form the rudiments of lactiferous ducts. Deeper ends of the cords subdivide further and terminate as ampullated ends. The cords are canalised by the end of the foetal life. Shortly before birth the pit is evaginated by the growth of the underlying mesoderm and forms the nipple. The areola becomes apparent during the fifth month of foetal life.
It is observed in prenatal development of breasts of both sexes that the mammary lines in humans are visible by day 37, invagination of mammary pits in pectoral region by day 49 with involution of the rest of mammary lines, nipple formation begins at day 56, sprouting of the primitive ducts develops at day 84 with canalisation appearing at about day 150.

At birth transient hyperplasia of the duct system and secretion of 'witch's milk' take place by the combined action of foetal prolactin and maternal oestrogen.

**Congenital anomalies**

**Amastia**—Bilateral agenesis of mammary glands is a rare anomaly.

**Polythelia**—Supernumerary nipples may be found irregularly over the breast and not along the milk ridges.

**Polymastia**—Accessory breasts may occur along the milk ridge, and on rare occasions are functional.

**Post-natal development**—From puberty onwards the breast development takes place exclusively in female by the branching of ducts and lobule formation from the terminal ducts. Externally visible post pubertal growth of female breast or *thelarche* is classified chronologically into five phases:

1. *Phase 1* shows elevation of the nipple;
2. In *phase 2* both the nipple and subareolar glandular breast tissue project forward from the chest wall as a visible single mass;
3. In *phase 3* the growth of the breast becomes palpable with increase in diameter and pigmentation of the areola;
4. In *phase 4* further pigmentation and enlargement of the areola allow the nipple and areola to form a separate projectile mass in front of the main breast tissue;
5. *Phase 5* shows smooth contour of the hemispherical breast with the deposition of fatty tissue.
The superficial fascia of pectoral region is fibro-fatty, and it encloses the mammary gland. The platysma muscle occupies its upper part, and sweeps upward and forward superficial to the clavicle towards the neck, after taking origin from the underlying pectoral fascia.

The deep fascia known as pectoral fascia is attached to the clavicle and sternum, invests the pectoralis major and at the floor of the axilla it is thickened to form the axillary fascia and thence splits into two layers to enclose the latissimus dorsi. The hollow of the arm pit formed by the axillary fascia is maintained by the attachment of suspensory ligament of axilla to its summit.

**Muscles of Pectoral Region**

These include pectoralis major, pectoralis minor and subclavius; the serratus anterior is also mentioned here, because it connects the thoracic wall to the scapula.

**Pectoralis major**

It is a thick triangular muscle, broad at its sternoclavicular origin and narrow at its insertion to the upper part of humerus. It forms the anterior wall of axilla. The upper border of the muscle is separated from the anterior border of deltoid by a delto-pectoral (infra-clavicular) triangle, and the rounded and twisted lower border of the muscle forms the anterior fold of axilla (Fig. 5.1).

**Origins**

- **Clavicular head**—From the medial half of the anterior surface of clavicle;
- **Sterno-costal head**
  - (i) From the lateral part of the anterior surface of sternum, up to the 6th costal cartilage;
  - (ii) Second to sixth costal cartilages;
  - (iii) From the aponeurosis of external oblique over the upper attachment of rectus abdominis.

**Insertions**—The muscle converges to form a flat bilaminar tendon about 5 cm broad, and is inserted into the lateral lip of intertubercular sulcus (bicipital groove) of humerus in a U-shaped manner, at the lower border of which both laminae are continuous.

The anterior lamina is thick and consists of superficial, intermediate and deep fibres. The clavicular head forms the superficial fibres; those from manubrium form the intermediate fibres, and those from the sternal margin and 5th costal cartilage are continuous with the deep fibres.

Fig. 5.1. Attachments of Pectoralis major with bilaminar insertion.

The posterior lamina is contributed by the rest of sternocostal fibres and the fibres from the external oblique. These fibres join the posterior lamina in a twisted manner, so that the fibres which are lowest at the origin become highest at the insertion. The costal fibres, however, do not twist. The upper limit of posterior lamina is higher than that of anterior lamina, and reaches the capsule of shoulder joint.

**Nerve supply**—Pectoralis major is supplied by both medial and lateral pectoral nerves. The former reaches the muscle after piercing pectoralis
Fig. 5.2. Pectoralis minor, subclavius and clavipectoral fascia (After removal of Pectoralis major and Deltoid).

minor; the latter reaches by piercing the clavipectoral fascia.

**Actions**

1. Acting as a whole, the muscle produces **medial rotation** and **adduction** of the shoulder joint.

2. Clavicular head produces **flexion** of shoulder joint, as in pushing.

3. Sterno-costal head helps in extension to bring the flexed humerus to the side, as in climbing.

4. It acts as **accessory muscle** of **inspiration**, when the humerus is fixed in abduction.

**Rectus sternalis muscle**

It is an occasional muscle, disposed longitudinally along the side of sternum and in front of pectoralis major. It is a derivative of superficial part of rectus abdominis and supplied segmentally by intercostal nerves.

\[/\text{Pectoralis minor}\]—It is a triangular muscle and lies beneath the pectoralis major. The axillary artery is subdivided into three parts by pectoralis minor; the second part of the artery lies behind the muscle (Fig. 5.2, 5.3).

Its upper border gives attachment to the **clavipectoral fascia** and is accompanied by superior thoracic artery. The lower border of the muscle gives attachment to the **suspensory ligament** of axilla and is accompanied by the lateral thoracic artery.

**Origins**—From the **third to fifth ribs** (not from costal cartilages) and from the intervening fascia covering external intercostal muscles.

Fig. 5.3. Sagittal section through pectoral region (Anterior wall of Axilla).

**Insertion**—The muscle converges upward and laterally to form a flat tendon and is inserted to the **medial border** and **upper surface of the coracoid process**. Occasionally, part of the
tendon may be continuous with coraco-humeral ligament.

**Nerve supply**—It is supplied by both medial and lateral pectoral nerves; the medial pectoral supplies by piercing the muscle.

**Actions**

1. Assisted by serratus anterior, the pectoralis minor protracts the scapula.
2. It depresses the shoulder, along with the levator scapulae and rhomboids.

**Subclavius**

**Origin**—It is a triangular muscle and arises from the junction of the first rib and its costal cartilage.

**Insertion**—To a groove on the undersurface of the middle third of the clavicle.

**Nerve supply**—From the nerve to subclavius, a branch of the upper trunk of brachial plexus (Erb’s point), carrying fibres from C₅ and C₆.

**Action**—It steadies the clavicle during the movements of shoulder joint.

**Clavipectoral fascia**—It is a strong sheet of fascia which stretches from the pectoralis minor to the clavicle.

**Medially**, it fuses with the anterior intercostal membrane of upper two spaces.

**Laterally**, it is attached to the coracoid process and blends with the coraco-clavicular ligament. **Above**, the fascia splits to enclose the subclavius and is attached to the two lips of subclavian groove of clavicle; the posterior layer blends with the axillary sheath and extends upward to anchor the inferior belly of omohyoid to the clavicle. The portion of the fascia along the lower border of subclavius and extending from the coracoid process to the first costo-chondral junction is thickened to form **costo-coracoid ligament**. **Below**, the fascia splits to enclose the pectoralis minor, re-unites at the lower border of the muscle and extends downward as **suspensory ligament of axilla**, which blends with the summit of axillary fascia and maintains the hollow of the arm pit.

**Structures piercing the fascia**

1. Cephalic vein.
2. Lymphatics from the infra-clavicular nodes and from the breast to the apical group of axillary nodes;

3. Lateral pectoral nerve;
4. Thoraco-acromial vessels; the artery divides into the following four branches before or after piercing the fascia—pectoral, deltoid, acrominal and clavicular. Their corresponding veins join with the cephalic vein, usually before the latter pierces the clavipectoral fascia. Eventually, the thoraco-acromial vein may not pierce the fascia.

**Serratus anterior**—It is a broad sheet of muscle, which forms the medial wall of axilla and is covered by a well-developed fascia (Fig. 5.4).

**Origin**—The muscle arises in front by **eight fleshy digitations** from the outer surfaces and upper borders of **upper eight ribs** and from the fascia covering the intervening intercostal muscles.

![Fig. 5.4. Attachments of Serratus anterior (Medial wall of Axilla).](image)

The first digitation **appears in the posterior triangle of neck** and arises from the outer border of the first rib and from a rough impression of the second rib. Lower four slips interdigitate with the costal origins of external oblique of abdomen.

**Insertion**—All digitations of muscle pass backwards around the chest wall and reach the costal surface along the medial (vertebral) border of scapula for insertion in the following manner:

(a) First digitation is attached to an area from the superior angle to the root of the scapular spine.

(b) Second and third digitations (may be fourth) are inserted to a narrow strip along the medial border of scapula.
(c) Remaining four or five digitations converge for insertion into a large triangular area on the inferior angle.

Nerve supply—It is supplied by the long thoracic nerve (nerve of Bell) which conveys fibres from \( C_5, C_6, \) and \( C_7 \) roots of brachial plexus. The nerve enters through the apex of axilla behind the first part of axillary artery and passes downward along the medial wall of axilla behind the mid-axillary line and beneath the deep fascia; thus the nerve is not usually involved in the operation of axilla.

The \( C_5 \) root supplies upper two digitations, \( C_6 \) root next two and \( C_7 \) root supplies lower four digitations.

Actions

1. When the entire muscle contracts along with the pectoralis minor, it protracts the scapula around the chest wall in pushing and punching movements. This action of serratus anterior is antagonised by the contractions of rhomboids and middle fibres of trapezius, which act as retractor of scapula. Therefore paralysis of serratus anterior results in winged scapula.

2. Contraction of lower four or five digitations of serratus anterior with the assistance of the upper and lower fibres of trapezius, rotates the scapula forward and upward so that the glenoid cavity is turned upward during the elevation of arm above the head.
The axilla or arm pit is a pyramidal-shaped space between the upper part of arm and the lateral thoracic wall. It presents apex, base and four walls — anterior, posterior, medial and lateral. The apex is truncated, and directed upward and medially to the root of the neck (Fig. 6.1).

**Boundaries**

**Apex** — It is also known as cervico-axillary canal, triangular in shape, and is bounded in front by the clavicle, behind by the superior border of scapula, and medially by the outer border of first rib. *Structures passing through the apex* are: Axillary vessels and cords of the brachial plexus enclosed in an axillary sheath derived from prevertebral fascia, long thoracic nerve and efferent subclavian lymph trunk extending from the apical group of axillary nodes (See Fig. 2.3).

**Base (Floor)** — It is directed below and presents a concavity which is bounded in front by the anterior axillary fold, behind by the posterior axillary fold, and medially by the chest wall. The base is formed, in addition to skin and superficial fascia, by the axillary fascia (deep fascia) which extends from the anterior to the posterior axillary folds and supported from above by the suspensory ligament of axilla.

**Fig. 6.1. Schematic shape of axilla.**

The anterior axillary fold is formed by the spirally arranged lower border of pectoralis major. The posterior axillary fold, extending slightly below the anterior fold, is formed by the latissimus

**Fig. 6.2. Posterior wall of Axilla and related nerves.**
dorsi in the medial part and teres major in the lateral part.

**Anterior wall**—It is formed by (See Fig. 5.3):
(i) Pectoralis major – in superficial plane;
(ii) Pectoralis minor, subclavius, clavipectoral fascia and suspensory ligament of axilla – in deep plane.

**Posterior wall**—It is formed from above downwards by: Subscapularis, latissimus dorsi, and teres major (Fig. 6.2).

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**Medial wall**—It is broad and formed by (See Fig. 5.4):
(i) Upper four or five ribs and their intercostal muscles;
(ii) Upper part of serratus anterior muscle, covered by a strong fascia; **long thoracic nerve** passes downward along this wall deep to the fascia and behind the mid-axillary line.

**Intercostobrachial nerve**, undivided lateral cutaneous branch of second intercostal nerve,

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**Fig. 6.3. Axilla on cross-section.**

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**Fig. 6.4. Contents of Axilla with relative disposition of major structures.**
pierces the medial wall of axilla and passes laterally close to the base of the arm pit to supply the postero-medial part of the arm.

Lateral wall—It is narrow and both anterior and posterior walls of the axilla converge on it. The lateral wall is formed by (Fig. 6.3):

(i) The intertubercular sulcus of the shaft of humerus which contains long tendon of biceps brachii;

(ii) This is assisted by coracobrachialis and short head of biceps.

Contents of axilla (Fig. 6.4)
- Axillary artery and its branches;
- Axillary vein and its tributaries;
- Cords of brachial plexus and their branches; long thoracic and intercosto-brachial nerves;
- Axillary lymph nodes and their afferent and efferent connections;
- Axillary fat and occasionally axillary tail of the breast.
DESCRIPTION OF THE ESSENTIAL CONTENTS

AXILLARY ARTERY

It begins as a continuation of the third part of subclavian artery at the outer border of first rib, and ends at the lower border of teres major, where it continues as the brachial artery. Throughout its course, the artery is accompanied infero-medially by the axillary vein and is closely related to the cords of brachial plexus and their branches. An axillary sheath, derived from the prevertebral layer deep cervical fascia, encloses the proximal part of axillary artery and vein together with the brachial plexus.

When the arm is at the side, the artery presents a bold convex curve directed upward and laterally. With the arm rotated laterally and abducted to 90°, the artery assumes a straight course, and when the arm is raised above the head, it is concave upward.

The pectoralis minor crosses in front of the artery and divides it into three parts – first part proximal to the muscle, second part behind, and third part distal to the muscle.

Relations of axillary artery

First part

In front (from before backwards)—
- Skin, superficial fascia with platysma and supraclavicular nerves;
- Pectoral fascia, pectoralis major and clavipectoral fascia;
- A loop of communication between lateral and medial pectoral nerves;
- Crossed by cephalic and thoraco-acromial veins;
- Anterior wall of axillary sheath;

Behind—
- First and second digitations of serratus anterior;
- Long thoracic nerve, medial cord of brachial plexus with medial pectoral nerve;

Laterally—
- Lateral and posterior cords of brachial plexus;

Medially – Axillary vein;

Second part

In front (from behind forward)—
- Pectoralis minor;
- Pectoralis major and its covering fascia and overlying skin.

Behind—
- Posterior cord of brachial plexus and subscapularis muscle;

Laterally – Lateral cord;

Medially – Medial cord;

Third part

In front—
- Pectoralis major, in the upper part; here it is crossed by the medial root of the median nerve;
- Skin and fasciae, in the lower part.

Behind—
- Subscapularis, latissimus dorsi and teres major;
- Axillary and radial nerves, between the artery and the above mentioned muscles;

Laterally—
- Lateral root and trunk of median nerve;
- Musculo-cutaneous nerve;
- Coracobrachialis muscle.

Medially—
- Axillary vein;
- Between the vein and artery, medial cutaneous nerve of forearm in front and ulnar nerve behind.
- Medial cutaneous nerve of arm, lying along the medial surface of the axillary vein and receiving communications from intercosto-brachial nerve.

Branches—From the first part one branch, superior thoracic artery; from the second part two branches, thoraco-acromial and lateral thoracic, occasionally third branch, alar thoracic artery; from the third part three branches, subscapular, anterior and posterior circumflex humeral (Fig. 6.5).

Superior thoracic artery—It is a small vessel arising from the first part. It runs along the upper
border of pectoralis minor and anastomoses with the internal thoracic and upper intercostal arteries.

**Thoraco-acromial artery**—It is a branch of the second part, pierces the clavipectoral fascia and divides into four branches — pectoral, acromial, clavicular and deltoid. These branches radiate at right angles from each other.

The pectoral branch passes downward and medially between pectoralis major and minor muscles, supplies them and anastomoses with the neighbouring arteries.

The acromial branch passes upward and laterally deep to the deltoid, crosses the tip of coracoid process and reaches the acromion where it anastomoses with the neighbouring arteries.

The clavicular branch ascends medially between the pectoralis major and clavipectoral fascia, and supplies the sterno-clavicular joint and subclavius.

The deltoid branch accompanies the cephalic vein in the deltopectoral groove and supplies both muscles.

**Lateral thoracic artery**—It is a branch of the second part, accompanies the lower border of pectoralis minor, and provides in female large lateral mammary branches to supply the breast.

**Alar thoracic artery**—It occasionally arises from the second part and supplies axillary lymph nodes and fat.

**Subscapular artery**—It is derived from the third part and largest of all branches. It runs along the lower border of subscapularis to the inferior angle of scapula, where it anastomoses with the lateral thoracic, intercostal and deep branch of transverse cervical artery. The artery is accompanied in the lower part by the thoraco-dorsal nerve.

It gives a dorsal branch, **circumflex scapular artery**, which winds round the lateral border of scapula and appears in the infraspinous fossa after traversing through the **triangular space**, which is bounded above by the subscapularis, below by the teres major and laterally by the long head of triceps.

**Anterior circumflex humeral artery**—It is a branch of the third part and passes laterally deep to the coraco-brachialis, short and long heads of biceps around the surgical neck of humerus, and anastomoses with the posterior circumflex humeral artery. *En route* it gives an **ascending branch** which runs along the intertubercular sulcus to supply the humerus and shoulder joint.

**Posterior circumflex humeral artery**—It is a fairly large branch of the third part and leaves the posterior wall of axilla through the quadrangular space, which presents the following boundaries — *Above* (from before backwards), subscapularis, capsule of shoulder joint and teres minor; *Below*, teres major; *Medially*, long head of triceps; *Laterally*, surgical neck of humerus. The artery is accompanied by the axillary nerve while passing through the quadrangular space, and curves laterally under cover of the deltoid around the dorsal surface of surgical neck of humerus and anastomoses with the anterior circumflex humeral artery. Here it gives a **descending branch** which anastomoses with the deltoid branch of *arteria profunda brachii*.

**Scapular anastomosis**

Around the scapula, **collateral anastomoses** are observed between the branches of the first part of subclavian artery and the third part of axillary artery in the following regions (Fig. 6.6):

**In each of subscapular, supraspinous and infraspinous fossae**

(a) Suprascapular, and
(b) Deep branch of transverse cervical arteries (from thyrocervical trunk of subclavian artery);
(c) **With** Circumflex scapular artery (from third part of axillary artery).

**Over the acromial process**

(a) Acromial branch of suprascapular artery (from subclavian artery), **with**
(b) Thoraco-acromial, and
(c) Posterior circumflex humeral arteries (from axillary artery).

**AXILLARY VEIN**

It begins as a continuation of basilic vein at the lower border of teres major, and ends at the outer border of first rib where it is continuous with the subclavian vein. **Three veins** assemble at its commencement, basilic and a pair of venae comitantes accompanying the brachial artery.

The vein lies on the medial side of the axillary artery, and receives tributaries which correspond
with the branches of axillary artery. *Cephalic vein* opens in the upper part of axillary vein. It is said that the axillary vein is not a content of axillary sheath in order to allow expansion during increased venous return (R.J.Last).

**APPLIED ANATOMY**

1. The part of the vein in front of the first part of axillary artery may be compressed by the subclavius muscle during abduction. This may account for *axillary vein thrombosis* when the arm is held in prolonged abduction above the head during painting of a ceiling.

2. Occasionally, a muscular band known as *axillary arch* extends from the latissimus dorsi to the pectoralis major and compresses upon axillary vessels, causing venous thrombosis.

**BRACHIAL Plexus**

(*infra-clavicular part*)

The brachial plexus supplies the upper limb, and is formed by the ventral rami of lower four cervical nerves and the first thoracic nerve (C_5, C_6, C_7, C_8, T_1). It consists of roots, trunks, divisions and cords (Fig. 6.7).

**Roots**—The roots are basically five in number (C_5–T_1). They emerge downwards and laterally between the scalenus anterior and medium muscles. Sometimes C_4 root joins with C_5, when the plexus is called *pre-fixed type*. On occasions, T_2 root joins with T_1 with the disappearance of C_4 root; this forms the *post-fixed type* of the plexus.

**Trunks**—These are three – upper, middle and lower, and appear in the posterior triangle of neck. The C_5 and C_6 roots unite to form the *upper trunk*, the C_6 and T_1 roots join to form the *lower trunk*, and the C_7 root continues as the *middle trunk*.

**Divisions**—On approaching the clavicle, even before entering the axilla, each of the three trunks splits into *anterior* and *posterior division*, in order to supply the muscles of flexor and extensor compartments respectively. Anterior divisions of upper and middle trunks unite to form the *lateral cord*, anterior division of lower trunk continues as the *medial cord*, and posterior divisions of all the three trunks assemble to form the *posterior cord*. Therefore, lateral cord contains the fibres from C_5, C_6, C_7, medial cord carries fibres from C_8 and T_1, and posterior cord conveys the fibres of C_5, C_6, C_7, C_8 and T_1.

**Cords**—The three cords enter the axilla and are arranged according to their names around the second and third parts of axillary artery. Relations of the cord with the first part of axillary artery are,
however, different; the lateral and posterior cords lie lateral to the artery, whereas the medial cord passes behind the artery.

Branches of the brachial plexus

These are divided into supraclavicular and infraclavicular branches.

Supraclavicular branches:

From the roots
- Dorsal scapular nerve – C₅
- A branch to join the phrenic nerve – C₅
- Long thoracic nerve – C₅, C₆, C₇.
- Muscular branches to longus colli and scaleni;

From the trunks

Two branches, from the upper trunk only;
- Nerve to subclavius;
- Suprascapular nerve.

Dorsal scapular nerve (Nerve to the rhomboids)—It carries the fibres from C₅, pierces the scalenus medius, passes downward and backward beneath the levator scapulae accompanied by the descending scapular artery and supplies both rhomboideus major and minor muscles from the deep surface; it may give a twig to the levator scapulae.

Long thoracic nerve (Nerve to serratus anterior)—It arises from the dorsal aspects of C₅, C₆ and C₇ roots. The C₅ and C₆ roots pierce the scalenus medius and pass downwards behind the brachial plexus. They unite and enter the apex of axilla behind the first part of axillary artery, where the C₇ root joins to form the trunk of the nerve. The nerve is closely applied to the serratus anterior, descends posterior to the mid-axillary line and supplies the muscles segmentally.

Applied anatomy

Injury to the long thoracic nerve (nerve of Bell) produces the winging of the scapula, when punching movement at the shoulder is attempted due to unopposed action of the rhomboids and the trapezius (middle fibres).

Nerve to the subclavius—It arises from the upper trunk of brachial plexus (Erb’s point) and conveys fibres from C₅ and C₆. It descends in front of the brachial plexus and subclavian vessels, supplies subclavius muscle from behind and occasionally contributes C₅ fibres of accessory phrenic nerve.

Suprascapular nerve—it is a prominent branch of the upper trunk of brachial plexus and conveys fibres from C₅ and C₆. The nerve passes backward above the clavicle and disappears beneath the anterior border of trapezius. It enters through the suprascapular foramen below the transverse scapular ligament, supplies the supraspinatus, winds round the spino-glenoid notch to supply the infraspinatus and gives an articular twig to the capsule of the shoulder joint.

Infraclavicular branches:

From the lateral cord (Three branches)
  (i) Lateral pectoral;
  (ii) Musculo-cutaneous;
  (iii) Lateral root of median nerve;

From the medial cord (Five branches)
  (i) Medial pectoral;
  (ii) Medial cutaneous nerve of the fore arm;
  (iii) Medial cutaneous nerve of the arm;
  (iv) Ulnar nerve (C₇, C₈, T₁);
  (v) Medial root of median nerve;

From the posterior cord (Five branches)
  (i) Upper subscapular nerve (C₅, C₆);
  (ii) Thoraco-dorsal nerve (C₆, C₇, C₈);
  (iii) Lower subscapular nerve (C₅, C₆);
  (iv) Axillary nerve (C₅, C₆);
  (v) Radial nerve (C₅, C₆, C₇, C₈, T₁)

Lateral pectoral nerve—it is a branch of the lateral cord and conveys the fibres from C₅, C₆ and C₇. It makes a loop of communication with the medial pectoral nerve in front of first part of axillary artery, pierces the clavipectoral fascia, and supplies the pectoralis major and minor muscles.

Musculo-cutaneous nerve—it is derived from the lateral cord and conveys the fibres from C₅, C₆ and C₇. The nerve initially accompanies the lateral side of the third part of axillary artery and pierces the coracobrachialis muscle; it supplied the coracobrachialis even before piercing the muscle and the fibres are derived from C₇.
The nerve then passes downward and laterally across the front of the arm in between the biceps brachii and brachialis. It supplies both heads of the biceps and the medial major part of the brachialis; through the nerve to the brachialis it gives articular twigs to the elbow joint and a nutrient branch to the bumerus.

Just below the elbow it pierces the deep fascia lateral to the tendon of biceps brachii, and extends further downward as the lateral cutaneous nerve of the forearm to supply the skin of the anterolateral region of forearm as far distally as the base of the thenar eminence.

*Note:* The coracobrachialis is a tricipital muscle in some mammals, and homologous with the adductors of the thigh. In human, the lowest head is suspended and the upper two heads arising from the coracoid process are fused and the musculo-cutaneous nerve passes between them.

**Median nerve**—It consists of lateral and medial roots. The lateral root is the continuation of the lateral cord and conveys the fibres from (C5), C6 and C7. The medial root is derived from the medial cord, carries the fibres from C8, T1, and joins with the lateral root after crossing the front of the third part of axillary artery. The trunk of median nerve, thus formed, descends on the lateral side of the axillary artery. Before leaving the axilla some fibres from C7 conveyed by the median nerve are handed over to the ulnar nerve which is a branch of the medial cord. (Subsequent course and distribution of the median nerve are dealt with in appropriate chapters).

**Medial pectoral nerve**—It is the first branch of the medial cord and arises when the latter lies behind the first part of axillary artery. The nerve passes forward between the axillary artery and vein, joins with the lateral pectoral nerve to form a loop in front of the artery. It then pierces the pectoralis minor, supplies it and ends by distributing fibres to the pectoralis major.

**Medial cutaneous nerve of the forearm**—It is derived from the medial cord, and runs downward between the third part of axillary artery and vein. The nerve accompanies the medial side of brachial artery and pierces the deep fascia along with the basilic vein in the middle of the arm, where it divides into anterior and posterior branches. The anterior branch passes in front of or behind the median cubital vein, and the posterior branch spirals medially in company with the basilic vein. Both branches supply the skin of the lower part of the arm and antero-medial surface of the forearm up to the wrist.

**Medial cutaneous nerve of the arm**—It is the smallest branch of the medial cord, accompanies the medial side of the axillary vein and receives a communication from the intercosto-brachial nerve (derived from the undivided lateral cutaneous branch of second intercostal nerve). It follows the medial side of the brachial artery and basilic vein, pierces the deep fascia near the middle of the arm, and supplies the skin of the medial side of the distal third of the arm.

**Ulnar nerve**—It is a branch of the medial cord and conveys fibres from C8 and T1; it receives an additional contribution from C5 via the median nerve. The fibres from C5 supply the flexor carpi ulnaris in the forearm.

In the axilla the ulnar nerve descends between the third part of axillary artery and the axillary vein, and lies on a more posterior plane than the medial cutaneous nerve of the forearm. (It does not give any named branches in the axilla, except vasomotor twigs to the neighbouring blood vessels; this is applicable to all branches derived from the cords of brachial plexus).

**Upper subscapular nerve**—It is a branch of the posterior cord, conveys fibres from C5 and C6, and supplies the upper part of subscapularis.

**Lower subscapular nerve**—It arises from the posterior cord, carries fibres from C5 and C6, and supplies the lower part of subscapularis and teres major. The branch to the teres major runs in the angle between subscapular and circumflex scapular arteries.

**Thoraco-dorsal nerve**—It is a fairly large branch of the posterior cord, arises in between upper and lower subscapular nerves and conveys fibres from C6 to C8. The nerve descends along the posterior wall of axilla in company with the subscapular artery and supplies the latissimus dorsi near the distal border of the muscle. Before reaching the muscle it lies in front of subscapular artery and is brought into prominence in abducted arm.
Therefore the nerve is in danger in operation of axilla.

Axillary (circumflex) nerve—It is a stout branch of the posterior cord and conveys fibres from C₅ and C₆. The nerve is situated behind the third part of axillary artery and on the lateral side of radial nerve. It leaves the posterior wall of axilla along with the posterior circumflex humeral vessels through the quadrangular space which presents the following boundaries: above, subscapularis, capsule of shoulder joint and teres minor (from before backwards); below, teres major; medi ally, long head of the triceps; and laterally, surgical neck of the humerus.

The trunk of the axillary nerve while passing through the quadrangular space gives its first branch, an articular twig to the shoulder joint. Thereafter the nerve divides into anterior and posterior branches. The anterior branch, accompanied by the posterior circumflex humeral vessels, winds round the posterior surface of the surgical neck of humerus under cover of the deltoid up to its anterior border, supplies the muscle and provides a few cutaneous branches which pierce the muscle and supply the skin of its lower part. The posterior branch supplies the teres minor where it forms a pseudoganglion (reasons not known), and the posterior part of deltoid; it then pierces the deep fascia and turns upward to supply the skin along the posterior border of deltoid as the upper lateral cutaneous nerve.

Peculiarity: The axillary nerve obeys the Hilton's law which enunciates that a nerve which supplies a joint, also innervates the muscle and the skin overlying that joint. Thus overstretching of the inferior part of shoulder capsule during sudden over-abduction is prevented by the reflex inhibition of the deltoid through the axillary nerve.

Applied anatomy

Injury to the axillary nerve due to fracture of the surgical neck of humerus results in inability to abduct the arm with loss of sensation over the lower part of the deltoid.

Radial nerve—It is the continuation of the posterior cord and largest branch of brachial plexus. It conveys the fibres from C₅, C₆, C₇, C₈ and (T₁). The nerve passes downward behind the third part of axillary artery and in front of the muscles of posterior wall of axilla. It leaves the axilla through a triangular space which is bounded above by the teres major, medially by the long head of triceps and laterally by the shaft of humerus.

In the axilla, the radial nerve gives three branches:
(a) A branch to the long head of triceps;
(b) One branch to the medial head of triceps which accompanies the ulnar nerve; hence known as the ulnar collateral nerve;
(c) Posterior cutaneous nerve of the arm which supplies the skin of the posterior surface of the arm up to the olecranon process.

(For further course and distribution of the radial nerve see the appropriate chapters).

Axillary lymph nodes—(See chapter 3)

Applied anatomy of axilla

To open a deep seated axillary abscess, the knife should be placed at the base of axilla midway between the anterior and posterior axillary folds, and more towards the thoracic side. This is adopted in order to avoid injury to the lateral thoracic, subscapular and axillary vessels in the anterior, posterior and lateral walls of axilla respectively.
These muscles connect the vertebral column and the upper limb, and are arranged into the first and second layers. The first layer of muscles includes trapezius and latissimus dorsi, and the second layer includes levator scapulae, rhomboideus major and minor (Fig. 7.1).

**Trapezius**—It is triangular and flat, and takes origin from:

1. The medial one-third of the superior nuchal line of occipital bone;
2. Along the middle line from the entire ligamentum nuchae and from the spinous processes and supraspinous ligaments of all twelve thoracic vertebrae. The muscles of both sides form a diamond-shaped aponeurotic area opposite the upper thoracic spines.

**Insertions**

1. Upper or occipital fibres slope downwards and laterally forming the posterior boundary of posterior triangle of the neck, and are inserted into the posterior border of the lateral one-third of the clavicle.
2. Middle fibres extend horizontally outward and are attached to the medial border of the

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**Fig. 7.1. Muscles of the Back.**
acromion and upper lip of the crest of the spine of scapula.

3. Lower fibres pass upwards and laterally and are inserted by a narrow recurved tendon to the deltoid tubercle, after gliding over a triangular surface at the medial end of the spine of scapula separated by a bursa.

The total outline of the two muscles forms a trapezoid, from which the name of muscle is derived.

Nerve supply—Motor fibres are derived from the spinal part of accessory nerve (XI cranial); proprioceptive fibres are conveyed by the ventral rami of C₅ and C₆ nerves.

Actions

1. The upper and lower fibres of trapezius acting together rotate the scapula so that the glenoid cavity faces upwards; this action is assisted by the lower four or five digitations of serratus anterior.

2. Upper fibres of trapezius along with levator scapulae elevate the scapula.

3. Middle fibres of trapezius and the rhomboids together retract the scapula.

Latissimus dorsi—It is a large flat muscle, triangular in outline and possesses extensive origin and narrow insertion. It is a muscle of upper limb, supplied by a branch from the brachial plexus and migrated to the trunk for functional reasons.

Origins

1. From the lower six thoracic spines and supraspinous ligaments, highest being from the T₇ spine. Here it is overlapped by the trapezius;

2. From the spines and supraspinous ligaments of all lumbar and sacral vertebrae, where the muscle becomes aponeurotic and blends with the posterior layer of thoraco-lumbar fascia;

3. From the outer lip of the iliac crest lateral to erector spinae and from the lower three or four ribs, interdigitating with the external oblique of abdomen;

4. Lateral border of the muscle slopes upward and laterally, and the upper border passes horizontally outward to overlap the inferior angle of scapula from which the muscle takes a few slips of origin.

Insertion—The muscle fibres converge towards the posterior fold of axilla, where the fibres spiral around the inferior border of teres major and appear on the anterior surface of that muscle. Finally the latissimus dorsi forms a narrow tendon and is inserted into the floor of intertubercular sulcus (bicipital groove). Therefore, in the process of spiral insertion the lowest fibres become highest and the highest fibres assumed lowest position.

Nerve supply—From the thoracodorsal nerve of the posterior cord.

Actions

1. It extends the shoulder joint and rotates the humerus medially;

2. In combination with the pectoralis major it is a powerful adductor;

3. When the arms are raised above the head, it assists in elevating the trunk during climbing.

4. Costal fibres help in inspiration by elevating the lower ribs, but rest of the fibres act as muscle of expiration.

Peculiarities

1. A muscular slip known as axillary arch is occasionally found to extend from the lower border of latissimus dorsi across the front of the axillary vessels and nerves to join with the pectoralis major, coracobrachialis or biceps brachii.

2. Two triangles are associated with the latissimus dorsi;

(a) Lumbar triangle (of Petit)—It is situated above the iliac crest and presents the following boundaries: in front, posterior border of the external oblique; behind, lateral border of latissimus dorsi; base, by the iliac crest; apex directed above and formed by the convergence of external oblique and latissimus dorsi; and floor, by the internal oblique.

This triangle is a potentially weak area of the abdominal wall, through which herniation may take place.

(b) Triangle of auscultation—It is a triangular area close to the chest wall and presents the following boundaries: below, upper horizontal border of latissimus dorsi; medially, lateral border of trapezius; laterally, vertebral border of scapula and part of the rhomboideus major. The floor of
the triangle is formed by the 6th and 7th ribs, and the intercostal space between them.

Deep to this triangle lies the **cardiac orifice of stomach** on the left side. By the use of stethoscope sometimes the splash of swallowed liquids is heard in oesophageal obstruction.

The apex of lower lobe of both lungs lies beneath this triangle.

**Levator scapulae**—It is a strap muscle and arises from the posterior tubercles of transverse processes of the upper four cervical vertebrae. It slopes downward and backward along the floor of the posterior triangle of neck and is inserted to the dorsal aspect of vertebral border of scapula extending from the upper angle to the apex of the scapular spine.

**Nerve supply**—Supplied by the ventral rami of C3 and C4 nerves; in addition it receives a twig from C5 through the dorsal scapular nerve.

**Actions**—In combination with upper part of trapezius it elevates the scapula.

**Rhomboideus major**—It arises from the spinous processes of T2 to T5 and their supraspinous ligaments. The muscle is **inserted** by a tendinous sheet to the dorsal aspect of the medial border of scapula extending from the inferior angle to the root of the scapular spine.

**Rhomboideus minor**—It lies just above and parallel with the rhomboid major. It **arises** from the lower part of ligamentum nuchae and from the spinous processes of C6 and T1. The muscle is **inserted** to the medial border of scapula at the apex of scapular spine; sometimes it presents a U-shaped attachment to enclose the lower border of levator scapulae.

**Nerve supply**—Both rhomboid muscles are supplied from the deep surface by the dorsal scapular nerve which carries the fibres from C5.

**Actions**

1. Rhomboid muscles combined with the middle fibres of trapezius **retract** the scapula;
2. Together with levator scapulae they **rotate** the scapula and **depress** the shoulder.
The dorsal surface of scapula and the outer surface of shoulder region are occupied by the deltoid, supraspinatus, infraspinatus and teres minor muscles.

**Deltoid muscle**—It is a powerful muscle and shaped like inverted delta. It forms the rounded contour of the shoulder, because the muscle overlaps the upper end of humerus (Fig. 8.1).

**Origins**—The muscle takes an extensive linear origin from—
(a) the anterior border and upper surface of the flattened lateral one-third of the clavicle;
(b) lateral border of the acromion; and
(c) from the whole length of the lower lip of the crest of the spine of scapula.

**Insertions**—All fibres converge for insertion to the **deltoid tuberosity**, which is a V-shaped impression involving the lateral surface of the shaft of humerus and extends up to the middle of the bone.

The lateral border of the acromion presents four tubercles from which **four fibrous septa** descend into the muscle. From the deltoid tuberosity **three fibrous septa** ascend and intervene between the four, and the adjacent surfaces between these septa provide origins of series of multipennate muscle fibres. Anterior and posterior fibres of the deltoid are long and arranged in **parallel bundles**, whereas the acromial fibres are **multipennate** which diminishes the range of contraction but increases the force of pull.

**Nerve supply**—Supplied by the axillary nerve (C₅, C₆) from the posterior cord of brachial plexus.

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**Fig. 8.1. Deltoid muscle and lateral view of muscles of arm and forearm.**
SCAPULAR AND DELTOID REGIONS

Actions

1. Acromial fibres act as prime mover of abduction of shoulder joint (antigravity muscle), and the anterior and posterior fibres act as guy ropes to steady the abducted arm.

2. Clavicular fibres, together with the pectoralis major, produce flexion, adduction and medial rotation of shoulder joint.

3. Posterior fibres assist in extension, adduction and lateral rotation of the arm.

Structures under cover of the deltoid

Bones—Coracoid process; lesser and greater tubercles, intertubercular sulcus, upper part of the shaft and surgical neck of humerus;

Muscles—Pectoralis minor, coracobrachialis, both heads of biceps brachii; Pectoralis major, latissimus dorsi and teres major (in intertubercular sulcus); Subscapularis (in lesser tubercle); Supraspinatus, infraspinatus and teres minor (in greater tubercle); long head of triceps (from infraglenoid tubercle);

Vessels and nerves—Anterior and posterior circumflex humeral vessels and axillary nerve (around surgical neck of humerus);

Joints and ligaments—Shoulder joint and its ligaments; coraco-acromial ligament;

Bursa—Subacromial bursa intervening between coraco-acromial arch and supraspinatus; the same bursa may extend as subdeltoid bursa between the deltoid and the greater tubercle of humerus.

Supraspinatus

Origin—It arises from the medial two-thirds of the supraspinous fossa of scapula and from the dense fascia which covers the muscle.

Insertion—The muscle passes laterally as a tendon beneath the coraco-acromial arch from which it is separated by the subacromial bursa, blends with the capsule of shoulder joint and is inserted into the upper flattened area of greater tubercle of humerus.

Nerve supply—From suprascapular nerve (C₅, C₆) of the brachial plexus;

Actions

1. It is suggested as a strong candidate to initiate the abduction of shoulder joint to the extent of first 15°.

2. Along with other short scapular muscles, it maintains stability of the shoulder joint.

Infraspinatus

Origin—It arises from the medial two-thirds of the infraspinous fossa of scapula under cover of a strong infraspinous fascia.

Insertion—The muscle passes laterally and upward behind the capsule of shoulder joint, where it is replaced by the tendon and is inserted in the middle impression of the greater tubercle of humerus. Sometimes a bursa beneath its tendon communicates with the shoulder joint.

Nerve supply—From the suprascapular nerve which supplies the muscle after passing through the spino-glenoid notch.

Actions

1. It acts as lateral rotator of shoulder joint.

2. Subscapularis, infraspinatus and teres minor assists abduction of shoulder joint by retaining the humeral head within the glenoid fossa, when the middle fibres of deltoid and supraspinatus contract.

Teres minor

Origin—It arises from the upper two-thirds of a flat strip on the dorsal surface of the lateral border of the scapula.

Insertion—It passes upward and laterally along the lower border of infraspinatus, and behind the long head of triceps and the capsule of shoulder joint. The muscle is inserted by a tendon into the lowest impression of the greater tubercle of humerus and extends slightly below to encroach on the shaft of the bone.

The lower border of teres minor lies edge to edge with the teres major at its origin. But the teres major passes forward and laterally in front of the long head of triceps for its insertion into the interscapedular sulcus and is separated from the teres minor by a triangular gap, which is subdivided by the long head of triceps into a quadrangular space laterally and a triangular space medially (see later).

Nerve supply—From the posterior branch of axillary nerve (C₅, C₆), where it presents a pseudo-ganglion.

Actions

1. It acts as lateral rotator of humerus;
2. Along with subscapularis and infraspinatus it helps abduction of shoulder joint (vide supra).

**Quadrangular and triangular spaces** (Fig. 8.2)

**Quadrangular space**

**Boundaries**

*Above* (from before backwards)

Subscapularis, lower part of capsule of shoulder joint, and teres minor;

*Below*—Teres major;

*Medially*—Long head of triceps;

*Laterally*—Surgical neck of humerus.

**Structures passing**

1. Axillary nerve;
2. Posterior circumflex humeral vessels.

**Triangular space**

**Boundaries**

*Above*, teres minor;

*Below*, teres major;

*Laterally*, long head of triceps (it represents the base);

*Apex*, lateral border of scapula, where teres major and minor muscles converge.

**Structures passing**

Circumflex scapular vessels, branches of subscapular vessels.

**Lower triangular space**

Diagonally opposite the above-mentioned triangular space, another triangular space is established presenting the following boundaries;

*Above*, teres major;

*Medially*, long head of triceps;

*Laterally*, shaft of the humerus.

The lower triangular space transmits the *radial nerve* and *profunda brachii vessels* to the spiral groove of humerus.
The arm (upper arm) or brachium is enveloped by a sleeve of deep fascia (brachial fascia), which projects into its interior as medial and lateral intermuscular septa and divides the arm into anterior and posterior compartments. These septa are well defined in the lower part of the arm and provide additional surface areas for the attachments of muscles. The deep fascia of the arm is continuous with the deep fascia of the forearm beyond the elbow.

The medial intermuscular septum is attached along the medial supracondylar ridge of humerus and extends up to the medial epicondyle. It is pierced in the middle of the arm by the ulnar nerve and superior ulnar collateral artery, and above the medial epicondyle by the posterior branch of inferior ulnar collateral artery. The lateral septum is attached to the lateral supracondylar ridge of humerus and is pierced at the junction of upper and middle thirds by the radial nerve and the radial collateral branch of the profunda brachii artery. The anterior surface of the lateral septum provides additional origins to the brachioradialis and extensor carpi radialis longus muscles.

ANTERIOR COMPARTMENT

Contents

Muscles—Coracobrachialis, biceps brachii and brachialis; Brachioradialis and extensor carpi radialis longus (in lower part).

Arteries—Brachial artery;

Nerves—Musculo-cutaneous, median, ulnar and part of radial nerves; other structures – Basilic vein, cutaneous nerves of arm.

Description of the contents

MUSCLES

Coracobrachialis

Origin: It arises from the tip of coracoid process in common with the short head of the biceps brachii (Fig. 9.1).

Insertion: It is inserted by fleshy fibres to the medial border of the middle of the shaft of humerus, where the nutrient foramen of the bone is usually located.

Nerve supply—Supplied by the musculo-cutaneous nerve, a branch from the lateral cord of brachial plexus; the nerve pierces the muscle and supplies it before piercing.

Action—It is a weak flexor of shoulder joint.

Morphology—The coracobrachialis represents adductor muscle of the arm, but such action is insignificant in man.

In some mammals it is tricipital in origin. Upper two heads are fused to take origin from the
coracoid process and enclose the musculo-cutaneous nerve between them. The lower head is usually suppressed in man. Sometimes it is represented by a fibrous band, the ligament of Struthers, which extends from an occasional bony projection, the supratrochlear spur, from the antero-medial surface of the lower part of humerus to the medial epicondyle. Median nerve or brachial artery may pass beneath the ligament which compresses upon them producing vascular spasm or median nerve palsy.

Biceps brachii—It is an elongated fusiform muscle and arises by two tendinous heads, short and long.

Origins

1. **Short head** arises from the tip of the coracoid process along with the coracobrachialis muscle on its medial side.

2. **Long head** arises within the fibrous capsule of shoulder joint from the supra-glenoid tubercle of the scapula and the adjacent labrum. The tendon curves laterally above the humeral head enclosed in a tubular synovial sheath and emerges beneath the transverse humeral ligament at the upper end of the intertubercular sulcus. Here it is accompanied by the synovial sheath which extends up to the surgical neck of humerus.

Both heads expand into fusiform bellies which lie side by side and do not join until about 7 cm above the elbow joint, where a flat tendon is formed.

**Insertion** (Fig. 9.2)—The tendon passes through the cubital fossa, undergoes twisting so that the anterior surface becomes lateral and is inserted into the posterior part of the radial tuberosity; a bursa separates the tendon from the anterior part of the tuberosity. Before insertion, the medial border of the tendon presents a fibrous expansion, the bicipital aponeurosis, which extends downward and medially across the brachial artery and is attached to the upper part of the subcutaneous posterior border of ulna by way of the deep fascia of the forearm.

**Nerve supply**—Supplied by the musculo-cutaneous nerve;

**Actions**

1. It is a powerful supinator of the forearm.

2. It is a flexor of the elbow joint by 'spurt action' and flexes best in supinated position.

Through the bicipital aponeurosis it pulls the ulna along with the radius during flexion.

3. Long head of the biceps keeps the humeral head in contact with the glenoid fossa during abduction of shoulder joint by the deltoid.

![Fig. 9.2. Insertion of Biceps tendon and the manner of its supination.](image)

**Brachialis**

**Origins** : It lies beneath the biceps brachii and arises from—

1. Antero-medial and antero-lateral surfaces of the lower half of the shaft of the humerus;

2. It embraces the deltoid insertion and takes origin from the lower part of the spiral groove;

3. Some fibres arise from the medial intermuscular septum.

**Insertion** : The broad muscle covers the anterior part of elbow joint and forms a flat tendon which is inserted into the anterior surface of coronoid process and tuberosity of ulna.

**Nerve supply**—Major part of the muscle is supplied by the musculo-cutaneous nerve, and the small lateral part of the muscle by the radial nerve.

**Action** : It flexes the elbow joint.

**Brachioradialis and extensor carpi radialis longus** – Both muscles belong to the superficial group of extensor muscles of the forearm, and appear in the anterior compartment of the arm for functional reasons.

**Brachioradialis** arises from the upper two-thirds of the lateral supracondylar ridge and the adjacent lateral septum.
**Extensor carpi radialis longus** arises from the lower one-third of the lateral supracondylar ridge and the lateral intermuscular septum. (For further details see the chapter of the forearm).

**BRACHIALARTERY**

It begins as a continuation of axillary artery at the distal border of teres major, runs downward at first medial to the humerus and then inclines to lie in front of the bone until it appears in the cubital fossa, where it ends at the level of the neck of radius by dividing into radial and ulnar arteries.

The artery is superficial throughout its course in the arm, lying immediately deep to the deep fascia and is accompanied by a pair of venae comitantes.

**Relations** (Fig. 9.3)

**In front**—Median nerve crosses in front of the artery from lateral to medial side, at the middle of the arm. At the cubital fossa it is crossed by the bicipital aponeurosis which separates the artery from the median cubital vein.

![Fig. 9.3. Structure of the front of arm.](image)

**Behind** (from above downwards)—Long head of the triceps, separated by the radial nerve and arteria profunda brachii; medial head of triceps; coracobrachialis, and brachialis.

**Laterally**—Median nerve and coracobrachialis (in the upper part); Biceps brachii and its tendon (in the lower part).

**Medially**—Medial cutaneous nerve of the forearm and ulnar nerve (in the upper part); median nerve and basilic vein lying superficial to the deep fascia (in the lower part).

**Note:** Basilic vein pierces the deep fascia in the middle of the arm and continues upward medial to the artery. At the distal border of the teres major it joins with the venae comitantes around the brachial artery and continues as the axillary vein.

**Branches**

1. **Arteria profunda brachii**—It is a large branch arising from the posterior surface of the proximal part of the artery, and follows the radial nerve to enter the spiral groove on the posterior surface of humerus between the long head and medial head of the triceps (Fig. 9.4).

   ![Fig. 9.4. Anastomosis around the elbow.](image)

2. **Nutrient artery**—It arises close to the insertion of coracobrachialis, and enters the nutrient foramen of the humerus which is directed
distally indicating that the upper end of humerus is the growing end.

3. Superior ulnar collateral artery—It arises a little distal to the middle of the arm, and pierces the medial intermuscular septum along with the ulnar nerve to appear in the posterior compartment between the medial septum and the medial head of triceps. Behind the medial epicondyle it makes an anastomosis with the posterior ulnar recurrent and inferior collateral arteries.

4. Inferior ulnar collateral artery (Supratrochlear artery)—It arises from the brachial artery about 5 cm above the elbow and divides into anterior and posterior branches. The anterior branch descends in front of the medial epicondyle and anastomoses with the anterior ulnar collateral artery. The posterior branch pierces the medial intermuscular septum and provides a transverse and a descending branch. The transverse branch curves laterally and anastomoses close to the olecranon fossa with the middle collateral branch of the artery profunda brachii; the descending branch passes behind the medial epicondyle and anastomoses with the superior ulnar collateral and posterior ulnar recurrent arteries.

5. Muscular branches, supply the muscles of the anterior compartment of the arm.

**Applied Anatomy**

Pulsation of the brachial artery is felt or auscultated in front of the elbow; this helps as standard method of recording the blood pressure.

**Nerves**

Musculo-cutaneous nerve—After piercing the coracobraclialis, the nerve passes obliquely downward and laterally between the biceps brachii and brachialis. Just below the elbow, it pierces the deep fascia and continues downward as the lateral cutaneous nerve of the forearm (see Fig. 9.1).

In the arm, the nerve supplies coracobraclialis (before piercing the muscle), biceps and the medial major part of the brachialis.

(For further details see the brachial plexus).

Median nerve—After its formation in the axilla by the union of medial and lateral roots, the trunk of the nerve descends along the lateral side of the third part of axillary artery and appears in the arm (Fig. 9.5).

In the upper part of the arm the nerve lies lateral to the brachial artery. In the middle of the arm, opposite the insertion of coracobraclialis, it crosses in front of the artery from lateral to the medial side. Thereafter the nerve accompanies the medial side of the artery and appears in the cubital fossa. The median nerve leaves the cubital fossa between the two heads of pronator teres and appears between the superficial and deep groups of flexor muscles of the forearm.

Branches in the arm: Except the nerve to the pronator teres and some vascular branches to the brachial artery, the median nerve does not provide any significant branches.

Ulnar nerve—It is a branch of the medial cord of brachial plexus and appears in the arm,

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**Fig. 9.5. Transverse section of the arm slightly proximal to the epicondyles.**
accompanied by the medial cutaneous nerve of the forearm, along the medial side of the upper part of brachial artery. At the middle of the arm these two nerves separate from the artery; while the medial cutaneous nerve pierces the deep fascia and becomes cutaneous, the ulnar nerve pierces the medial intermuscular septum and extends downward in front of the medial head of triceps to appear in the interval between the olecranon process and medial epicondyle. Here the ulnar nerve lies in a groove on the posterior surface of medial epicondyle and appears in the forearm between the two heads of flexor carpi ulnaris.

In the arm the ulnar nerve does not give any significant branches except articular twigs to the elbow joint.

**Radial nerve**—It is the continuation of the posterior cord of brachial plexus, and appears in the front of the arm twice.

In the upper part of the arm the radial nerve lies behind the brachial artery. Accompanied by the arteria profunda brachii it enters the spiral groove at the back of the arm through a gap between long head and medial head of triceps.

It appears in the front of the arm for the second time after piercing the lateral intermuscular septum and passes downward in an intermuscular interval between the brachioradialis and extensor carpi radialis longus on the lateral side and brachialis on the medial side. In this part of the course, the radial nerve supplies **brachioradialis**, **extensor carpi radialis longus** and the **lateral part of brachialis**. On reaching the front of lateral epicondyle the nerve ends by dividing into superficial and deep branches.

**POSTERIOR COMPARTMENT**

The posterior compartment of the arm contains principally the triceps, radial nerve, profunda brachii vessels and a part of ulnar nerve after piercing the medial intermuscular septum.

**Triceps brachii**—It monopolises the posterior compartment of the arm and arises by three heads—long, lateral and medial.

**Origins**

1. The **long head** arises from the infraglenoid tubercle of scapula (extracapsular), passes downward between the teres major and minor muscles on the medial side of the humerus and superficial to (behind) the medial head of triceps.

2. The **lateral head** arises from an oblique ridge along the lateral lip of the spiral groove and behind the deltoid tuberosity.

3. The **medial head** arises by fleshy fibres from the entire posterior surface of the humerus below the spiral groove and from both lateral and medial intermuscular septa.

**Insertion**—The long and lateral heads converge to form a flat tendon which lies superficial to the medial head and is inserted into the **posterior part of the upper surface of the olecranon process**.

The fibres of medial head are inserted partly into the olecranon and partly in the deep part of the aforesaid flat tendon.

A **bursa** intervenes between the insertion of triceps and the capsule of elbow joint.

**Nerve supply**—Supplied by the radial nerve, partly before reaching the spiral groove and partly from the spiral groove.

**Actions**

1. It is an **extensor** of elbow joint.

2. The **long head** supports the humeral head in abducted shoulder joint.

**Structures passing between the heads of triceps**

*Between the long and medial heads:*
- Radial nerve and the arteria profunda brachii;
*Between the lateral and medial heads:*
  - (In the spiral groove)
  - Radial nerve and profunda brachii artery;
*Between the lateral and long heads:*
- An ascending branch of arteria profunda brachii to anastomose with the descending branch of posterior circumflex humeral artery.

**Radial nerve**—Before reaching the spiral groove on the posterior surface of humerus, the radial nerve accompanied by the arteria profunda brachii traverses at first the **lower triangular space**, which is bounded above by the teres major, medially by the long head of triceps and laterally by the shaft of the humerus. Thereafter, both the nerve and vessels enter the spiral groove between the long and medial heads of triceps, and run downwards and laterally along the groove in between the lateral and medial heads of triceps.
In the lower part of the groove they are separated from the bone by the origin of a part of brachialis muscle (Fig. 9.6).

The radial nerve along with the radial collateral branch of the profunda brachii artery appear in the anterior compartment of the arm after piercing the lateral intermuscular septum.

**Note:** The course of radial nerve and the direction of spiral groove do not perfectly correspond, because the entry of nerve does not take place through the medial window of the spiral groove.

**Branches in the spiral groove**

In the spiral groove the radial nerve provides three sets of branches – muscular, articular and cutaneous.

**Muscular branches**—These supply the lateral and medial heads of triceps. The branch to the medial head, while passing down through the substance of the muscle, supplies the anconeus, and gives articular branches to the elbow joint.

The long head and part of the medial head of triceps receive branches from the radial nerve in the axilla.

**Cutaneous branches**

1. **Lower lateral cutaneous branch of the arm** pierces the lateral head of triceps and supplies the skin of the lateral part of the lower half of the arm.

2. **Posterior cutaneous branch of the forearm** pierces the lateral head of triceps and supplies the dorsal surface of the forearm as far as the wrist.

   *Arteria profunda brachii*—It is a large branch of brachial artery and appears in the spiral groove accompanied by the radial nerve.

**Branches:** In the spiral groove the artery presents the following branches:

1. Muscular branches to the adjacent muscles;
2. **Nutrient branch** to the humerus;
3. An **ascending** or deltoid branch passes between the lateral and long head of the triceps and anastomoses with a descending branch of posterior circumflex humeral artery.
4. The **middle collateral branch** which descends through the medial head of triceps and anastomoses behind the lateral epicondyle with the interosseous recurrent artery.
5. The **radial collateral branch** pierces the lateral intermuscular septum and anastomoses in front of the lateral epicondyle with the radial recurrent artery.

**Structural changes at the middle of the arm**

1. Cross-sectional change of the humeral shaft from the upper cylindrical part to the lower triangular part;
2. Insertion of the coracobrachialis and the deltoid muscles;
3. Well-defined upper attachments of the medial and lateral intermuscular septa from this level downwards;
4. Position of the nutrient foramen of humerus;
5. Change of position of brachial artery from the medial side to the front of the arm;
6. Median nerve crosses the front of brachial artery from lateral to medial side;
7. Ulnar nerve and superior ulnar collateral artery pierce the medial intermuscular septum at this level, and both structures pass downward in the posterior compartment of the arm.
8. Entry of the radial nerve and arteria profunda brachii into the spiral groove close to this level;
9. Basilic vein pierces the deep fascia and undergoes a sub-fascial course above that level;
10. Medial cutaneous nerve of forearm pierces the deep fascia and becomes subcutaneous below that level.

**CUBITAL FOSSA**

It is a triangular space in front of the elbow.

**Boundaries** (Fig. 9.7)

- **Medially**, the lateral border of pronator teres;
- **Laterally**, the medial border of brachioradialis;
- **Apex**, directed below and is formed by the convergence of marginal muscles;
- **Base**, formed by an imaginary line joining both epicondyles of humerus;

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![Cubital fossa diagram](image-url)
Floor, brachialis in the upper and medial part, and supinator in the lower and lateral part;

Roof, formed by the deep fascia of the forearm and reinforced on the medial side by the bicipital aponeurosis. Superficial to the bicipital aponeurosis lie median cubital vein, medial and lateral cutaneous nerves of the forearm.

Contents—These are better exposed after retracting the boundaries of the fossa. From medial to lateral side, the contents are: median nerve, brachial artery and its two terminal branches, tendon of biceps, and the radial nerve.

Median nerve—It passes straight downwards, provides usually a branch to the pronator teres above the elbow and leaves the cubital fossa between the humeral and ulnar heads of the pronator teres.

Brachial artery—It is central in position and lies just medial to the tendon of biceps. Opposite the neck of radius, it divides into radial and ulnar arteries.

The radial artery passes downward and laterally resting on the tendon of biceps, supinator and pronator teres. It appears in the front of the forearm through the apex of cubital fossa. While in the fossa the artery gives a branch, the radial recurrent artery, which ascends between the superficial and deep branches of radial nerve and anastomoses with the radial collateral branch of artery profunda brachii in front of the lateral epicondyle.

The ulnar artery, the larger terminal branch of the brachial, passes downward and medially, and leaves the cubital fossa deep to the ulnar head of pronator teres which separates the artery from the median nerve. While in the fossa, the ulnar artery provides the following three branches;

(a) anterior ulnar recurrent artery ascends in front of the medial epicondyle and anastomoses with the inferior ulnar collateral artery;

(b) posterior ulnar recurrent artery passes upward behind the medial epicondyle and makes anastomosis with the ulnar collateral and interosseous recurrent arteries;

(c) common interosseous artery inclines downward and at the upper border of the interosseous membrane divides into anterior and posterior interosseous arteries.

Tendon of biceps brachii—It is inserted in a twisted manner in the posterior part of radial tuberosity and separated by a bursa from the anterior part of the tuberosity. Before insertion, the bicipital aponeurosis extends downward and medially from the medial margin of the tendon (For further details see the biceps brachii).

Radial nerve—A short course of radial nerve crosses the supero-lateral angle of the fossa between the brachioradialis and brachialis muscles. Opposite the lateral epicondyle, the nerve divides into deep and superficial branches. The deep branch (posterior interosseous nerve) passes downward and laterally between the superficial and deep strata of supinator muscle and appears in the extensor compartment of forearm. Before supplying the supinator, the deep branch provides its first twig to the extensor carpi radialis brevis. The superficial branch is cutaneous and passes downward under cover of the brachioradialis.

Note: In some text-books the radial nerve is not included as a content. But it would be an omission if the nerve is not observed in the dissection of cubital fossa.

Anastomosis around the elbow (Cubital anastomosis)

The arterial anastomosis around the elbow between the branches of the brachial artery and the proximal parts of radial and ulnar arteries should be liberal, because during flexion of elbow joint the brachial artery is likely to be kinked with sluggish blood flow through that vessel. In order to provide copious blood supply to the distal part of the upper limb, the cubital anastomosis is imperative.

The anastomosis is arranged as follows (see Fig. 9.4):

1. In front of the medial epicondyle— Inferior ulnar collateral artery and a branch from superior ulnar collateral artery (both derived from brachial artery), with anterior ulnar recurrent branch of the ulnar artery;

2. Behind the medial epicondyle—Superior ulnar collateral artery and a branch from inferior ulnar collateral artery, both derived from the brachial,
with posterior ulnar recurrent branch of the ulnar artery;

3. **In front of the lateral epicondyle**—The radial collateral branch (anterior descending branch) of profunda brachii (from brachial),

   with the radial recurrent branch of radial artery;

4. **Behind the lateral epicondyle**—The posterior descending branch of arterio profunda brachii,

   with the interosseous recurrent branch of the posterior interosseous artery (from ulnar artery);

5. **Above the olecranon fossa**—A transverse anastomosis between the middle collateral branch of profunda brachii, and a transverse branch from the posterior division of the inferior ulnar collateral artery.
The forearm is invested by the antebraclial fascia (deep fascia) which is attached to the olecranon and subcutaneous posterior border of ulna. A number of septa extend from its deep surface between the muscles and reach the bones. At the roof of cubital fossa, the antebraclial fascia is reinforced by the bicipital aponeurosis. Close to the wrist the deep fascia is thickened to form flexor and extensor retinacula which retain the digital tendons in position.

The fore arm is divided into anterior or flexor compartment, and posterior or extensor compartment. The flexor muscles are more massive than the extensors, because they work against gravity and act as antigravity muscles.

ANTERIOR (FLEXOR) COMPARTMENT OF THE FOREARM

The floor of the anterior compartment is formed by the anterior surface of the radius, anterior and medial surfaces of the ulna, and the introversous membrane between them. Medially, it is demarcated from the posterior compartment by the olecranon process and the posterior border of the ulna. Laterally, it is marked off from the extensor region by the anterior border of the radius.

The limiting medial and lateral borders of flexor and extensor compartments are not crossed by motor nerves. Hence, they act as internervous lines through which the deep parts of the forearm may be explored.

Contents of the anterior compartment

It is occupied by the muscles, vessels and nerves.

Muscles—These are arranged in superficial and deep groups. The superficial muscles are five in number and take a common origin from the medial epicondyle of humerus and therefore cross the elbow joint. The deep muscles are three in number and their origins are confined to the radius and ulna. However, according to the position, the flexor digitorum superficialis of the superficial group may be described as intermediate layer of muscles.

Vessels—The radial and ulnar arteries form the main vessels of the forearm. The common introversous branch of the ulnar artery divides into anterior and posterior introversous branches which supply the deep structures of both the front and the back of the forearm.

Nerves—The median and ulnar nerves supply the muscles of the anterior compartment. The median nerve and its anterior introversous branch supply all flexor muscles of the forearm, except flexor carpi ulnaris and medial part of flexor digitorum profundus which are supplied by the ulnar nerve.

The superficial division of the radial nerve appears in the front of the forearm, but it is cutaneous and mainly supplies the dorsum of the hand (Fig. 10.1).

Flexor Muscles of the forearm

Superficial flexor muscles

These are five in number and named from lateral to medial: pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris and flexor digitorum superficialis. The first four muscles lie superficial to the flexor digitorum superficialis, which is often described as intermediate layer of muscles.

Pronator teres

Origins: It arises by humeral (superficial) and ulnar (deep) heads.

The humeral head—from the lower part of the medial supracondylar ridge of humerus and from
the anterior and lower part of the medial epicondyle as common origin of the superficial flexor muscles;

The **ulnar head**—from the medial border of the coronoid process of ulna distal to the origin of flexor digitorum superficialis.

The median nerve lies between the two heads.

**Insertion**: The two heads join, proceed downwards and laterally forming the medial boundary of the cubital fossa, and are inserted by a flat tendon to the **middle of the lateral surface of the shaft of the radius**, where the bone presents a maximum lateral convexity.

**Nerve supply**—From the median nerve, usually before the latter passes between the two heads of pronator teres.

**Actions**—It helps in **pronation** of the forearm and acts as **weak flexor** of the elbow joint.

**Flexor carpi radialis**

**Origin**: From the medial epicondyle as common origin of the superficial flexor muscles, as well as from the antebrachial fascia and the adjacent fascial septa. The muscle forms a fusiform belly which is replaced by a tendon about half way down the middle of forearm. Above the wrist it is accompanied laterally by the tendon of brachioradialis and the radial artery intervenes between the two tendons.

**Insertion**: The tendon of flexor carpi radialis perforates the flexor retinaculum, descends in an osseo-fibrous canal lodging in a groove on the trapezium within a synovial sheath, and is inserted into the palmar surface of the bases of the second and third metacarpal bones. The oblique head of adductor pollicis overlaps the sites of insertion.

**Nerve supply**—From the median nerve;

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**Fig. 10.1.** *Superficial flexor muscles, vessels and nerves in the front of forearm.*
Actions—It is a flexor of the wrist. Combined actions of flexor carpi radialis and extensor carpi radialis longus and brevis produce abduction of the wrist.

**Palmaris longus**

**Origin**—It arises in common with the superficial flexor muscles from the medial epicondyle and forms a long slender tendon.

**Insertion**: The tendon passes in front of the flexor retinaculum and is continuous with the central part of palmar aponeurosis.

**Morphology**: The palmar aponeurosis is the degenerated distal part of palmaris longus. It is a regressive muscle in the higher vertebrate phylogeny.

**Nerve supply**—From the median nerve;

**Action**—It is a weak flexor of the wrist.

**Importance**: Just proximal to the wrist the median nerve projects laterally deep to the palmaris longus, and lies in between the flexor carpi radialis and palmaris longus.

**Flexor carpi ulnaris**

**Origins**: It arises by two heads, humeral and ulnar. The **humeral head** arises from the medial epicondyle in common with the superficial group of flexor muscles.

The **ulnar head** takes origin from the medial margin of olecranon process and upper two-thirds of the posterior border of ulna through a common aponeurosis for the attachments of flexor carpi ulnaris and flexor digitorum profundus.

A **tendinous arch** connects the two heads and beneath the arch pass the ulnar nerve and posterior ulnar recurrent artery.

**Insertion**: The fleshy part is replaced by a tendon in the lower part of forearm. The ulnar vessels and nerve lie lateral to the tendon. The tendon is inserted into the **pisiform bone** and through the pisohamate and pisometacarpal ligaments gain attachment to the hook of the hamate and the base of the fifth metacarpal bones.

**Nerve supply**—From the ulnar nerve;

**Actions**: It acts as a flexor of the wrist; combined actions of flexor and extensor carpi ulnaris produce adduction of the wrist joint.

**Flexor digitorum superficialis** (sublimis)—It is a broad sheet of muscle and lies deep to other superficial flexor muscles.

**Origins** (Fig. 10.2)—It arises by two heads, humero-ulnar and radial. A fibrous arch connects the two heads and transmits beneath it the median nerve and ulnar artery. The median nerve is practically plastered to the deep surface of the muscle.

The **humero-ulnar head** arises from the medial epicondyle as a common tendon, from the anterior band of ulnar collateral ligament and from the medial margin of the coronoid process of ulna proximal to the origin of pronator teres.

The **radial head** takes origin from the whole length of anterior oblique line of the radius.

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Fig. 10.2. **Flexor digitorum superficialis and disposition of its digital tendons.**

Above the wrist, the fleshy fibres form four tendons for the medial four fingers. The tendons are arranged in superficial and deep strata. The **superficial stratum**, derived mostly from the radial head, **includes the tendons for the middle and ring fingers**; the **deep stratum** forms the tendons for index and little fingers.
**Insertions**: The four tendons, arranged in pairs, pass beneath the flexor retinaculum within the carpal tunnel. On reaching the palm they diverge. At the base of the proximal phalanx, each digital tendon splits into two in a twisted manner with reversal of surfaces to allow the passage of the profundus tendon. The split slips then reunite and partially decussate, and finally re-split for attachments to the sides of the shaft of middle phalanx of the medial four digits.

**Nerve supply**—From the median nerve;

**Actions**—It produces flexion of the middle phalanx at the proximal interphalangeal joints. On prolonged contraction, the muscle flexes the metacarpo-phalangeal and wrist joints.

**Deep flexor muscles**

These are three in number and consist of flexor pollicis longus, flexor digitorum profundus and pronator quadratus (Fig. 10.3).

(b) From the adjacent interosseous membrane;
(c) Occasional slip of origin from the lower part of the medial margin of coronoid process of ulna; the oblique cord represents the degenerated primitive origin of the muscles.

The fleshy fibres slope downward and medially, and just above the wrist form a tendon on the ulnar side of the muscle.

**Insertion**: The tendon passes beneath the flexor retinaculum within the carpal tunnel and then proceeds distally between opponens pollicis and oblique head of adductor pollicis for its insertion into the palmar surface of the base of distal phalanx of the thumb.

**Nerve supply**—From the anterior interosseous branch of the median nerve.

**Action**—It is a flexor of the thumb.

**Flexor digitorum profundus**—It is the bulkiest muscle of the forearm and takes origin from:

(a) Anterior and medial surfaces of the upper three-fourths of the shaft of the ulna, including the medial surfaces of the coronoid and olecranon processes;
(b) From the adjacent interosseous membrane;
(c) From the upper three-fourths of the posterior border of ulna by an aponeurosis in common with the flexor and extensor carpi ulnaris.

The muscle ends below into four tendons for the medial four fingers. The tendon for the index finger separates early in the forearm, but rest of the tendons remain united until they appear in the palm after passing beneath the flexor retinaculum within the carpal tunnel. Early separation of the flexor tendon for the index finger shows the emergence of a separate muscle in progressive phylogeny.

**Insertion**: As the four digital tendons separate in the palm, they provide origins to four lumbrical muscles. Each tendon enters within the fibrous flexor sheath of the digit and opposite the proximal phalanx it passes distally through the perforated digital tendon of flexor digitorum superficialis. Finally each tendon is inserted to the palmar surface of the base of terminal phalanx of the medial four fingers.

**Nerve supply**—Medial part of the muscle is supplied by the ulnar nerve, and the lateral part by the anterior interosseous branch of the median nerve.
Actions—It flexes the terminal phalanges, whereas flexor superficialis flexes the middle phalanges. On prolonged contraction, both long flexor tendons produce flexion at the metacarpophalangeal and carpal joints.

Pronator quadratus—It is a quadrilateral muscle and extends across the lower part of both bones of the forearm in front of the interosseous membrane.

Origin: From a bony ridge on the anteromedial surface of the lower one-fourth of the ulna.

Insertion

1. The superficial fibres slope laterally with a downward inclination and are inserted to the anterior surface of lower one-fourth of radius and the adjoining anterior border of the bone above its styloïd process.

2. The deep fibres are inserted to a triangular area just above the ulnar notch.

A synovial pouch, the sacciform recess, of the inferior radio-ulnar joint intervenes between the deep surface of the muscle and the interosseous membrane.

Nerve supply—From the anterior interosseous branch of the median nerve.

Actions

1. Superficial fibres are the principal pronator of the forearm.

2. Deep fibres prevent separation of the lower parts of radius and ulna, when a thrust is applied due to a fall on the outstretched hand.

Functional classification of the flexor muscles of the forearm—

1. Flexors of the wrist—Flexor carpi radialis and flexor carpi ulnaris;

2. Flexors of the middle phalanges—Flexor digitorum superficialis;

3. Flexors of the distal phalanges—Flexor digitorum profundus and flexor pollicis longus;

4. Pronators of the forearm—Pronator teres and pronator quadratus.

Space of Parona

It is a fascial lined potential space deep to the long flexor tendons of the forearm, where the proximal parts of the synovial sheath of the flexor tendons of the hand extend.

Boundaries

In front—Flexor digitorum profundus and flexor pollicis longus;

Behind—Pronator quadratus and interosseous membrane;

Above—Oblique origin of flexor digitorum superficialis;

On each side—The space is limited by the outer and inner borders of the forearm.

Applied Importance

Accumulation of pus from the infected synovial sheaths of flexor tendons may extend to the space of Parona. The pus is drained by incisions along the borders of the forearm, which are not crossed by the motor nerves and act as internervous lines.

Blood vessels of the front of forearm

The radial and ulnar arteries are the chief arterial trunks of the forearm, but they are mainly engaged to supply the hand through the superficial and deep palmar arches. The common interosseous branch of the ulnar artery divides into anterior and posterior interosseous branches, which are the main sources of blood supply to the forearm.

Radial artery—It is the smaller terminal branch of the brachial artery and begins in the cubital fossa about 1 cm below the bend of elbow at the level of the neck of radius and just medial to the tendon of biceps brachii (See Fig. 10.1).

Course: The course of the artery is divided into three parts— in the forearm, at the wrist, and in the hand. The artery is accompanied by a pair of venae comitantes along the entire extent. In the forearm, it extends downward with a lateral convexity from its origin to the front of the styloïd process at the distal end of radius, where the pulsation of the artery is usually felt. The artery leaves the apex of cubital fossa, where it is overlapped partially by the brachioradialis. In the rest of the course it runs sub-fascially and intervenes between the tendons of brachioradialis and flexor carpi radialis.

At the wrist, the artery winds dorsally beneath the tendons of abductor pollicis longus and extensor pollicis brevis, crosses the ‘anatomical
snuff box’ and leaves the dorsal surface of the wrist through a triangular gap between the two heads of first dorsal interosseous muscle, where the artery is crossed superficially by the extensor pollicis longus tendon.

In the hand, the artery appears in the palm usually between the oblique and transverse heads of adductor pollicis and anastomoses with the deep branch of ulnar artery to complete the deep palmar arch.

Relations

In the forearm

In front, brachioradialis overlaps the artery in the upper part; rest of the artery is covered only by the skin, superficial and deep fasciae.

Behind, the following structures form the bed for the artery in order from above downwards—
(a) tendon of biceps;
(b) supinator muscle;
(c) pronator teres, at its insertion;
(d) flexor digitorum superficialis (radial head);
(e) flexor pollicis longus;
(f) pronator quadratus;
(g) lower end of radius, where pulsation of the artery is usually felt.

Laterally, brachioradialis along its entire extent; superficial branch of radial nerve, in the middle one-third.

Medially, pronator teres in the upper one-third, flexor carpi radialis in lower two-thirds.

Branches of radial artery

1. Radial recurrent artery—It ascends between superficial and deep branches of radial nerve and anastomoses in front of the lateral epicondyle with the radial collateral branch of profunda brachii artery.

2. Muscular branches—supply the adjacent muscle;

3. Palmar carpal branch—It passes medially across the anterior surface of the distal end of radius and behind the long flexor tendons, and anastomoses with the corresponding carpal branch of ulnar artery to form the palmar carpal arch (see later).

4. Dorsal carpal branch—It passes medially across the posterior surface of the lower end of radius under cover of the extensor tendons of the wrist, and forms the dorsal carpal arch after joining with the dorsal carpal branch of ulnar artery. The dorsal carpal arch provides three dorsal metacarpal arteries (see later).

5. Superficial palmar branch—It arises from the radial artery before the latter curves laterally over the carpus. The artery descends through or over the thenar muscles and may form the superficial palmar arch after joining with the ulnar artery.

6. First dorsal metacarpal artery—It arises just before the radial artery passes between the two heads of first dorsal interosseous muscle. The artery divides to supply the adjacent sides of the thumb and index fingers.

7. Arteria princeps pollicis—It arises from the radial artery in the palm and runs distally beneath the oblique head of adductor pollicis along the first metacarpal bone to which it provides nutrient branch. On reaching the proximal phalanx of the thumb, the artery divides into two branches to supply both sides of the thumb and forms a plexus in the digital pulp.

8. Arteria radialis indicis—It arises in the palm and runs distally between the transverse head of adductor pollicis and the first dorsal interosseous, and supplies the radial side of the index finger.

Ulnar artery — It is the larger terminal branch of brachial artery and arises in the cubital fossa about 1 cm below the bend of elbow (Fig. 10.4).

Course: In the upper one-third of the forearm, the ulnar artery is deeply placed and passes downward and medially beneath the superficial flexor muscles of the forearm. In this part of its course, the medially placed ulnar nerve is separated from the artery by a considerable distance.

From the lower two-thirds of forearm, the artery descends vertically and undergoes a sub-fascial course between the flexor carpi ulnaris medially and flexor digitorum superficialis laterally. The ulnar nerve lies medial to the artery along the lower two-thirds of the forearm. It is accompanied by a pair of venae comitantes along the entire extent.

The artery (along with the ulnar nerve on its medial side) crosses the flexor retinaculum between the superficial and main sets of fibres, and enters the palm on the radial side of pisiform bone. Here it divides into superficial and deep
branches. The superficial branch forms the **superficial palmar arch**, and the deep branch ends by forming the **deep palmar arch** (see later).

**Relations**

**In front—**

**In the proximal half,** (covered by):

(a) Pronator teres; median nerve is separated from the artery by the ulnar head of the muscle;

(b) Flexor carpi radialis;

(c) Palmaris longus;

(d) Flexor digitorum superficialis;

(e) Flexor carpi ulnaris.

**In the distal half,** covered by—

Skin, superficial and deep fasciae, and the palmar cutaneous branch of ulnar nerve.

**Behind**—The artery rests on: Brachialis at its beginning, and flexor digitorum profundus in the rest of its course.

**Medially**—Ulnar nerve, and flexor carpi ulnaris;

**Laterally**—Flexor digitorum superficialis.

**Branches of ulnar artery**

1. **Anterior ulnar recurrent artery**—It ascends beneath the pronator teres and anastomoses with inferior ulnar collateral artery in front of medial epicondyle.

2. **Posterior ulnar recurrent artery**—It ascends behind the medial epicondyle between the superficial and deep groups of flexor muscles, and anastomoses with the ulnar collateral and intersosseous recurrent arteries.

3. **Common intersosseous artery**—It is the largest branch and arises in the cubital fossa. On reaching the gap above the intersosseous membrane, the artery divides into anterior and posterior intersosseous branches.

(a) **Anterior intersosseous artery** descends in close contact with the intersosseous membrane between the flexor digitorum profundus and flexor pollicis longus, and is accompanied by the anterior intersosseous branch of the median nerve. At the upper border of pronator quadratus it pierces the intersosseous membrane, anastomoses with the posterior intersosseous artery in the back of forearm and enters in the formation of **posterior carpal arch**.
During its course the artery supplies the neighbouring muscles, nutrient branches to the radius and ulna, a descending branch before piercing the interosseous membrane to join with the anterior carpal arch, and occasionally provides a branch which accompanies the median nerve (arteria nervi mediana).

(b) **Posterior interosseous artery**—enters the posterior compartment of forearm between the oblique cord and the upper border of interosseous membrane. It is closely applied to the posterior surface of interosseous membrane and is accompanied by the deep branch of radial nerve (posterior interosseous nerve). The artery runs down between superficial and deep groups of extensor muscles of forearm and joins in the lower part with the anterior interosseous artery; the combined arterial trunk forms the posterior carpal arch.

In the upper part, the posterior interosseous artery gives off the **interosseous recurrent artery** which anastomoses behind the lateral epicondyle with the middle collateral branch of artery profunda brachii, posterior ulnar recurrent and ulnar collateral arteries (cubital anastomosis).

4. **Palmar and dorsal carpal branches.** They take part in the formation of anterior and posterior carpal arches.

5. **Muscular branches**—supply the adjacent muscles.

Anastomosis around the wrist joint—Both radial and ulnar arteries give origins to the palmar and dorsal carpal branches close to the wrist. These anastomose with each other deep to the long tendons and form palmar and dorsal carpal arches.

**Palmar (anterior) carpal arch** (See Fig. 10.4)—It is a transverse anastomosis across the lower ends of radius and ulna and formed principally by the palmar carpal branches of radial and ulnar arteries. The arterial arch is assisted by a branch from anterior interosseous artery and a recurrent branch from the deep palmar arch; this makes the arch cruciform in outline. It supplies the distal ends of radius and ulna, and carpal articulations.

**Dorsal (posterior) carpal arch**—It is a transverse anastomosis across the dorsal surface of the carpus, and is formed by the union of the dorsal carpal branches of radial and ulnar arteries, assisted by the anterior and posterior interosseous arteries.

It gives origin to the **three dorsal metacarpal arteries** which run distally over the second to fourth dorsal interosseous muscles and divide into dorsal digital branches to supply the medial four fingers.

**Nerves of the front of forearm**

**Median nerve**—In the cubital fossa the median nerve lies medial to the brachial artery and the biceps tendon, and rests on the brachialis.

It enters the front of the forearm between the humeral and ulnar heads of pronator teres. Here it crosses the front of ulnar artery from medial to lateral side and is separated from the artery by the ulnar head of pronator teres. The nerve passes downward under cover of the fibrous arch between the origins of the humero-ulnar and radial heads of flexor digitorum superficialis and appears between the superficial and deep groups of flexor muscles.

It descends vertically along the mid-line of the forearm and is closely applied to the posterior surface of flexor digitorum superficialis. About 5 cm above the flexor retinaculum the nerve emerges from the lateral border of flexor digitorum superficialis, and lies between and deep to the tendons of palmaris longus and flexor carpi radialis. A branch from anterior interosseous artery usually accompanies the median nerve in the lower forearm. The median nerve enters the palm deep to the flexor retinaculum in the carpal tunnel.

**Branches in the forearm**

1. **Muscular branches**—
   (a) The nerve to the pronator teres usually arises proximal to the elbow joint.
   (b) Branches to the palmaris longus, flexor carpi radialis and flexor digitorum superficialis (except flexor carpi ulnaris) usually arise proximal to the pronator teres; branch for the superficialis tendon of the index finger arises in the middle of forearm.

2. **Anterior interosseous branch**—It arises distal to the pronator teres and descends in front of the interosseous membrane between the flexor pollicis longus and flexor digitorum profundus. The nerve is accompanied by an artery of the same name derived from common interosseous artery.
The anterior interosseous nerve supplies flexor pollicis longus, lateral half of the flexor digitorum profundus forming the digital tendons for the index and middle fingers, and provides a branch to supply the pronator quadratus from its deep surface. It also supplies articular twigs to the inferior radio-ulnar, wrist and carpal joints.

3. Articular branches—Supply elbow, superior and inferior radio-ulnar joints along with the interosseous membrane, and wrist joint.

4. Cutaneous branch—It is known as the palmar cutaneous branch which pierces the deep fascia and supplies the skin of the thenar eminence and central region of palm.

5. Communicating branches—Connect the median and ulnar nerves at multiple sites. These probably explain abnormal distribution of muscular branches in the hand.

Ulnar nerve—At the elbow, the ulnar nerve lodges in a groove on the dorsal surface of the base of the medial epicondyle. Here it is accompanied by the superior ulnar collateral artery and rests on the diaphysis of the humerus.

The nerve enters the forearm between the two heads of flexor carpi ulnaris and lies superficial to the posterior and oblique bands of ulnar collateral ligament. It passes straight downward along the medial side of the front of forearm and rests on the flexor digitorum profundus. In the upper half it is deeply placed and covered by the flexor carpi ulnaris; in the lower half it passes subfascially lateral to the tendon of flexor carpi ulnaris and is closely related to the ulnar artery on the radial side of the nerve.

The ulnar nerve, accompanied by ulnar artery, enters the palm on the radial side of pisiform bone and superficial to the flexor retinaculum. It passes beneath the palmaris brevis in the proximal part of hypothenar eminence and divides into superficial and deep terminal branches. (See the chapter of the palm.)

Branches in the forearm

The ulnar nerve (C7, C8, T1) gives off muscular, articular, dorsal, palmar cutaneous, and superficial and deep terminal branches.

Muscular branches—They supply flexor carpi ulnaris and the medial half of flexor digitorum profundus.

(i) Nerve to flexor carpi ulnaris arises close to the elbow and conveys fibres from the ventral ramus of C7.

(ii) Branches to the flexor digitorum profundus supply those fibres which form the tendons for the ring and little fingers.

Articular branches—Supply the elbow joint.

Dorsal branch—It arises about 5 cm above the wrist, passes dorsally deep to the flexor carpi ulnaris tendon and appears in the dorsum of the hand after piercing the deep fascia. (For distribution see the dorsum of the hand).

Palmar cutaneous branch—It arises near the middle of forearm and accompanies the ulnar artery to which it provides vascular branches. The nerve pierces the deep fascia and supplies the skin of the proximal part of hypothenar eminence. (Vasomotor supply of the upper limb is derived from the sympathetic. The preganglionic fibres are located in the lateral horn cells of T2–T7 segments; the postganglionic fibres reach the blood vessels via the peripheral nerves of the brachial plexus).

Superficial and deep terminal branches—
(See the chapter of the hand).

Radial nerve—In front of the lateral epicondyle of the humerus the radial nerve divides into superficial and deep branches. The deep branch (posterior interosseous nerve) appears in the posterior compartment of forearm, after passing between the superficial and deep strata of fibres of supinator muscle. (For further course and distribution see posterior compartment of forearm).

The superficial branch of radial nerve passes straight downward along the antero-lateral aspect of upper two-thirds of forearm. In this part it is under cover of the brachioradialis and rests behind successively on the supinator, pronator teres, flexor digitorum superficialis and flexor pollicis longus. In the middle one-third of forearm, the nerve is closely related to the lateral side of radial artery.

About 7 cm above the wrist the nerve curves downward and laterally behind the brachioradialis, pierces the deep fascia and appears in the dorsum of hand where the nerve usually divides into five dorsal digital branches. (For distribution consult the dorsum of the hand).
POSTERIOR (EXTENSOR) COMPARTMENT
OF THE FOREARM

The posterior compartment contains the extensor muscles, nerves and blood vessels. It is covered by the deep fascia which is thickened at the back of the wrist to form the extensor retinaculum. The compartment is floored by the posterior surfaces of radius and ulna with the intervening interosseous membrane and is limited medially by the subcutaneous posterior border of ulna. Bones palpable at the back of forearm are: posterior surface of olecranon process and posterior border of ulna, ulnar head and its styloid process; head and styloid process of radius; and the dorsal tubercle at the distal end of radius.

The extensor muscles of the forearm are arranged in superficial and deep groups. Most of the superficial muscles, except three (Brachioradialis, extensor carpi radialis longus, anconeus) take a common origin from the front of the lower part of lateral epicondyle of humerus.

The main nerve supply of the posterior compartment is derived from the posterior interosseous branch (deep branch) of radial nerve. In fact all extensor antebrachial muscles are innervated by the posterior interosseous nerve, except three muscles (Brachioradialis, extensor carpi radialis longus and anconeus) which are directly supplied by the trunk of radial nerve.

The principal arterial supply comes from the posterior interosseous artery, but in the lower part it is supplemented by the anterior interosseous artery.

Superficial group of extensor muscles

The superficial muscles are altogether seven in number and subdivided into lateral and posterior groups.

The lateral group consists of (i) brachioradialis, (ii) extensor carpi radialis longus, and (iii) extensor carpi radialis brevis (three muscles); they extend along the radial border of forearm. The posterior group includes from lateral to medial the following muscles: (iv) extensor digitorum (communis), (v) extensor digiti minimi (vi) extensor carpi ulnaris, and (vii) anconeus (four muscles).

The abductor pollicis longus, extensor pollicis brevis and extensor pollicis longus (belonging to deep group of extensor muscles) emerge downward and laterally from undercover of the posterior group and wind superficial to the lateral group of muscles before reaching the thumb for insertion (Fig. 10.5).

1. Brachioradialis

Origin: It arises from the upper two-third of lateral supracondylar ridge and from the lateral intermuscular septum.

Insertion: The muscle passes downward along the pre-axial border of the forearm and is inserted by a tendon to the base of the styloid process of the radius. The lower part of the tendon is crossed superficially by the abductor pollicis longus and extensor pollicis brevis as they spiral down to the thumb.

Proximal part of brachioradialis forms the lateral boundary of cubital fossa, and overlaps the radial nerve and a part of radial artery.

Nerve supply—Supplied by the radial nerve above the elbow.

Action—It is a flexor of elbow joint, and acts best in mid-prone position (Shunt muscle), but it is not a pronator or supinator of forearm.

2. Extensor carpi radialis longus

Origin:

1. From lower one-third of the lateral supracondylar ridge;

2. From the lateral intermuscular septum.

Insertion: The muscle passes downward under cover of brachioradialis along with extensor carpi radialis brevis on the deep surface. The tendons of the two radial extensors pass beneath the extensor retinaculum, lodge in a broad sulcus on the dorsal surface of the lower end of radius lateral to the dorsal tubercle of Lister and occupy the floor of the snuff-box.

The radialis longus tendon is inserted into the dorsal surface of the base of second metacarpal bone.

Nerve supply—From the radial nerve above the elbow.

3. Extensor carpi radialis brevis

Origin: It arises from a common extensor origin from the front of the lateral epicondyle and from the radial collateral ligament of the elbow.

Insertion: It passes downward deep to the extensor carpi radialis longus in naked contact
with the shaft of radius and is inserted into the dorsal surface of the bases of second and third metacarpal bones.

**Nerve supply**—It is supplied by the posterior interosseous nerve (deep branch of radial nerve), before the latter passes between the two strata of supinator muscle.

**Actions** of extensor carpi radialis longus and brevis:
1. Both radial extensors along with extensor carpi ulnaris produce extension of the wrist.
2. Both radial extensors along with flexor carpi radialis act as abductors of the wrist.

4. **Extensor digitorum (communis)**

**Origin and Course**: It arises from the front of lateral epicondyle as common extensor origin and forms a rounded belly in the middle of forearm, where it divides into four digital tendons for the medial four fingers. The crowded tendons of extensor digitorum along with the extensor indicis tendon on the deep surface lodge in the most medial groove on the dorsal surface of the lower end of radius under cover of extensor retinaculum.

On the dorsum of the hand, the four flat tendons diverge and reach the corresponding medial four fingers. The common tendons of the index and little fingers are joined on the ulnar (medial) sides by the tendons or extensor indicis and extensor digiti minimi respectively.

**Three oblique intertendinous bands** (vincula) inclining infero-laterally connect the four tendons proximal to the knuckles. These intertendinous connections restrict the independent action of the fingers.

**Insertion**: Each extensor tendon covers the dorsal surface of the metacarpal head and proximal phalanx and forms a triangular dorsal digital expansion (Fig. 10.6).

The **base** of the expansion forms a hood over the metacarpal head and each basal angle is
anchored to the deep transverse metacarpal ligament; this helps to retain the extensor tendon in the mid-line of the digit. A fibro-areolar ribbon connects the hood with the base of the proximal phalanx (Grant’s method of Anatomy).

The apex of the expansion, close to the distal end of proximal phalanx, trifurcates into a median and two lateral bands. The median band is inserted into the base of the middle phalanx, and the lateral bands extend further distally and unite before insertion into the base of the distal phalanx.

![Diagram of the anatomical structure of the forearm](image)

**Fig. 10.6. Dorsal digital expansion.**

The margins of the expansion are thickened on the lateral side by the insertions of the tendons of lumbricals and interosseous muscles, and on the medial side by the interosseous only. The attachments of intrinsic muscles to the dorsal digital expansion are described as ‘wing tendons’, which may be proximal and distal. The proximal wings are contributed by the tendons of palmar and dorsal interossei which join with the basal angles of the extensor expansion close to the metacarpophalangeal joint. The interossei tendons pass dorsal to the deep transverse metacarpal ligament and are attached partly to the base of proximal phalanx and partly join with the extensor expansion. The distal wings are formed by the tendons of lumbricals which join with the lateral band of the digital expansion close to the proximal interphalangeal joint. The lumbral tendons pass ventral to the deep transverse metacarpal ligament and join with the extensor expansion without any attachment to the proximal phalanx (Fig. 10.7).

![Diagram showing the anatomy of the forearm](image)

**Fig. 10.7. Lateral view of dorsal digital expansion and long flexor tendons of digit.**

**Nerve supply**—From the posterior interosseous branch (deep branch) of radial nerve.

**Actions**
- Tendons of extensor digitorum act as prime movers for extension at the metacarpophalangeal and interphalangeal joints, but extensions at the interphalangeal joints are completed only by the contractions of lumbricals and interossei, especially the former, due to synergistic actions.
- Both interossei and lumbricals produce flexion at the metacarpophalangeal joint by arched disposition of fibres at the hood of dorsal expansion, and extension at the interphalangeal joints. These movements are useful for precision work. But the lumbricals are more powerful flexors at the metacarpophalangeal joints, because their tendons are more ventrally and distally placed with respect to the metacarpophalangeal joints.
- Interossei, due to their attachments to the bases of proximal phalanx, produce side shifting
of the fingers. Dorsal interossei act as abductors, and palmar interossei adductors of the digits. (see the chapter of the hand).

5. Extensor digiti minimi

It is a slender muscle, arises from the common extensor tendon, passes distally along the medial side of extensor digitorum and appears beneath the extensor retinaculum behind the inferior radioulnar joint.

The tendon of digiti minimi accompanies the medial side of the common extensor tendon for the little finger and join with the dorsal digital expansion of that finger.

Nerve supply—From posterior interosseous nerve;

Action—It extends the little finger and assists the action of extensor digitorum.

6. Extensor carpi ulnaris

Origin:

1. From the lateral epicondyle as common extensor origin;

2. From the subcutaneous posterior border of ulna by an aponeurosis in common with the origin of flexor carpi ulnaris.

Insertion: The tendon of the muscle passes distally under cover of extensor retinaculum and lodges in a groove between the ulnar head and its styloid process. The tendon is inserted into a tubercle on the medial side of the base of fifth metacarpal bone.

Nerve supply—From posterior interosseous nerve;

Actions

1. Extensor carpi ulnaris, contracting simultaneously with extensor carpi radialis longus and brevis, produces extension of the wrist, which is pre-requisite for grasping any object.

2. Combined actions of extensor and flexor carpi ulnaris produce adduction of the wrist.

7. Anconeus

Origin: It is a triangular muscle and arises from the posterior surface of the lateral epicondyle.

Insertion: The muscle is inserted by its broad base to the lateral surface of the olecranon process and upper one-fourth of the posterior surface of the shaft of ulna.

The lower fibres of the muscle are vertical and its upper fibres are almost horizontal.

Nerve supply—From the radial nerve in the spiral groove through the nerve to the medial head of triceps.

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Fig. 10.8. Deep group of extensor muscles at the back of forearm and posterior interosseous nerve.

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Actions

1. It is an extensor of elbow joint, and assists the action of the triceps.

2. Upper horizontal fibres help abduction of the ulna during pronation of forearm.

Deep group of extensor muscles of forearm

The deep group of extensor muscles include the supinator, abductor pollicis longus, extensor pollicis longus and brevis, and extensor indicis (Fig. 10.8).

Supinator—It wraps the upper one-third of radius and consists of superficial and deep strata of fibres; the posterior interosseous branch of
radial nerve appears from the cubital fossa to the back of forearm between superficial and deep strata of the muscle.

**Origin**

1. Fibres of superficial stratum arise from the lateral epicondyle, radial collateral ligament and annular ligament.

2. Deep stratum takes origin from the supinator crest of ulna and from the depressed triangular area of the bone in front of the crest.

**Insertion:**

1. Superficial fibres slope downward and forward, and are attached to the upper one-third of the anterior part of the lateral surface of radius, above the anterior oblique line.

2. Deep fibres are horizontally disposed, wrap the radius from behind and are inserted into the bone between the anterior and posterior oblique lines.

**Nerve supply**—Supplied by the posterior interosseous nerve, before the latter passes between the two strata of muscle.

**Actions**

1. It acts as a supinator in extended elbow;
2. It fixes the forearm in supination.

**Abductor pollicis longus**

**Origin:** It arises from the posterior surfaces of both radius and ulna, and from the intervening interosseous membrane. Its radial origin involves middle third of the bone, distal to the supinator. The ulnar origin extends up to the anconeus.

**Insertion:** The muscle emerges downward and laterally between posterior and lateral groups of superficial extensor muscles, and forms a round tendon which spirals around the brachioradialis and radial extensors of the wrist. The tendon is inserted into the radial side of the base of the first metacarpal bone.

**Nerve supply**—From the posterior interosseous nerve;

**Action**—It is an abductor and extensor of the thumb.

**Extensor pollicis brevis**

**Origin:** It arises from the posterior surface of the radius below the abductor pollicis longus and from the adjacent interosseous membrane.

**Insertion:** It lies medial to and closely follows the course of abductor pollicis longus. The tendons of both muscles lodge in groove on the lateral side of the distal end of radius.

The pollicis brevis tendon is inserted into the dorsal surface of the base of the proximal phalanx of the thumb.

**Nerve supply**—From posterior interosseous nerve;

**Action**—It extends the proximal phalanx of the thumb.

**Extensor pollicis longus**

**Origin:** It arises from the posterior surface of the shaft of ulna below the abductor pollicis longus and from the adjacent interosseous membrane. The origin of the longus extends higher and overlaps the brevis muscle.

**Insertion:** The muscle forms an elongated tendon which passes beneath the extensor retinaculum and lodge in a groove just medial to the dorsal tubercle of radius. The dorsal tubercle acts as a pulley around which the tendon changes direction and passes downward and laterally crossing superficial to the extensor carpi radialis longus and brevis.

Finally the tendon is inserted into the dorsal surface of the base of distal phalanx of the thumb.

**Nerve supply**—From posterior interosseous nerve;

**Action**—It extends the distal phalanx of the thumb.

**Applied anatomy**

Close to the dorsum of the wrist the tendon is supplied by local branches of the interosseous artery. Occlusion of these vessels in Colles’ fracture may produce spontaneous rupture of the tendon due to avascular necrosis. This produces hammer thumb due to unopposed action of flexor pollicis longus.

**Extensor indicis**

**Origin:** It arises from the posterior surface of ulna distal to extensor pollicis longus and from the adjacent interosseous membrane.

**Insertion:** The tendon of the muscle passes beneath the extensor retinaculum and lodges in a
compartment deep to the tendons of extensor digitorum with which it shares a common synovial sheath.

Close to the head of second metacarpal bone, it joins with the index tendon of extensor digitorum on its ulnar side and enters in the formation of dorsal digital expansion of the index finger.

Nerve supply—From posterior interosseous nerve;
Action—It extends the index finger.

Anatomical snuff box

It is a triangular depression on the radial side of the wrist and becomes visible when the thumb is fully extended (See Fig. 10.5).

Boundaries

Laterally, tendons of abductor pollicis longus and extensor pollicis brevis;
Medially, tendon of extensor pollicis longus;
Roof, formed by skin and fasciae; beginning of cephalic vein lies, on the roof, which is crossed by the superficial branch of radial nerve.
Floor, formed by styloid process of radius, scaphoid, trapezium and the base of first metacarpal bone.

Content—Radial artery lies across the floor.

Extensor retinaculum

It is an oblique fibrous band, derived from the deep fascia and stretches across the dorsal surface of the wrist to retain the extensor tendons in position (Fig. 10.9).

Attachments

Laterally, to the anterior border of radius above its styloid process;
Medially, the fibres slope downward and medially, and are attached to the pisiform and triquetral bone. The retinaculum is not attached to the ulna, otherwise it would prevent pronation.

Structures beneath the retinaculum

The deep surface of extensor retinaculum gives rise to septa to the radius and medial carpals, forming six osseo-fascial compartments for nine tendons (Fig. 10.10).

From lateral to medial side structures in each compartment are as follows:

1. **Abductor pollicis longus** and **extensor pollicis brevis** lie in a groove on the lateral surface of the distal end of radius; each tendon is invested by a separate synovial sheath.

![Fig. 10.9. Extensor retinaculum with underlying tendons.](image)

2. **Extensor carpi radialis longus** and **brevis**, lodging in a groove lateral to the dorsal tubercle; each tendon receives a separate synovial sheath.

3. **Extensor pollicis longus tendon** with its synovial sheath occupies just medial to the dorsal tubercle.

4. **Four tendons of extensor digitorum** and the **tendon of extensor indicis** deep to them, lodge in a shallow groove of radius. All the five tendons are invested with a common synovial sheath.

5. Tendon of **extensor digiti minimi** with its synovial sheath lies behind the inferior radio-ulnar joint.

6. Tendon of **extensor carpi ulnaris** with its synovial sheath lodges in a groove between the ulnar head and its styloid process.

Posterior interosseous nerve

It is the deep terminal branch of radial nerve and arises in front of the lateral epicondyle. The nerve appears in the back of forearm between the superficial and deep strata of supinator muscle, and winds round the lateral side of radius. Before passing through the supinator, it provides
branches to the extensor carpi radialis brevis and supinator; the latter gets additional supply when the nerve passes through the muscle (See Fig. 10.8).

While descending in the back of forearm between superficial and deep groups of extensor muscles, the nerve divides into three short branches and two longer branches.

The short branches supply the extensor digitorum, extensor digiti minimi and extensor carpi ulnaris. The longer branches subdivide into medial and lateral sets. The medial set supplies extensor pollicis longus and extensor indicis. The lateral set supplies abductor pollicis longus and extensor pollicis brevis.

Traced distally, the nerve passes deep to extensor pollicis longus, lies on the interosseous membrane and dorsal surface of the carpus where it presents a terminal enlargement or pseudo-ganglion. Branches from the ganglion supply the carpal ligaments and joints.

Branches
1. Muscular branches, as described above;
2. Articular branches, to the wrist, inferior radio-ulnar and intercarpal joints;
3. Sensory branches, to the interosseous membrane, radius and ulna.

Posterior interosseous artery — (See the branches of ulnar artery).

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**Fig. 10.10.** Tendons with their synovial sheaths beneath the extensor retinaculum (After cross-section through the distal ends of radius and ulna of right side).
Human hand is a **prehensile organ** and is endowed with **grasping, precision movements** for skilled works and acts as a **chief tactile apparatus**. The opposition of thumb to the index finger and other digits is highly evolved in mankind for grasping and finer movements. This is contributed by high degree of neuro-muscular co-ordination and larger cortical representation of hand in the sensori-motor cortex of the brain. Thus human hand represents a ‘revolution in evolution’.

Tactile receptors like Meissner’s corpuscles are richly distributed in the hand and these are more numerous to the apices of the digits. The hand can see in the dark.

The hand presents a **palmar** or **grasping surface** and a **dorsal surface**.

On the **palmar surface** the skin is thick, devoid of hairs (glabrous) and sebaceous glands. It is connected to the underlying deep fascia or palmar aponeurosis by numerous fibrous septa (skin ligaments) which restrict the mobility of skin for proper grip. Beneath the palmar aponeurosis lie in succession thenar and hypothenar muscles at the two sides, and in the central part superficial palmar arch, palmar digital branches of median nerve and superficial branch of ulnar nerve, long flexor tendons with lumbrical muscles attached to the profundus tendons. On a deeper plane the central part presents deep palmar arch along with deep branch of ulnar nerve, adductor pollicis, palmar and dorsal interosseous muscles. The long flexor tendons increase the power of the grip and the intrinsic muscles are concerned with delicate skillful movements. Indeed, the lumbricals of hand, by producing flexion at the metacarpophalangeal joints and extension at the interphalangeal joints, help in writing, stitching and any other forms of precision work. Hence, philosophically it may be said that actions of lumbricals of hand are the indices of civilization of a race.

On the **dorsum of the hand**, the skin is thin, hairy and provided with sebaceous and sweat glands. It moves freely over the underlying tendons and bones. Beneath the skin lie dorsal digital nerves and a dorsal venous arch or plexus, which collect the blood from the dorsal surface as well as from the palm in order to avoid the pressure of the grip.

**Palm of the Hand**

**Skin**—It is thick, glabrous, devoid of sebaceous glands, but is provided with numerous sweat glands. The palmar skin is **immobile**, because it is firmly attached to the underlying palmar aponeurosis by fibrous bands which entangle the subcutaneous fat in loculi under pressure. This acts as ‘water-cushion’ to withstand considerable pressure.

**Crepusae** or lines of the palmar skin including digits are of three varieties: Flexure lines, papillary ridges, cleavage lines.

**Flexure lines** form visible markings close to synovial joints, where the skin is tightly adherent to the deep fascia.

(a) In each of the medial four digits, the interphalangeal creases are two, out of which **proximal one marks the joint**.

(b) The **creases between the fingers and the palm** do not represent the level of metacarpophalangeal joints, which lie about 2 cm proximal to the crease.

(c) The most distal skin crease in front of the wrist overlies the proximal border of flexor retinaculum; the median nerve descends behind the mid-point of the skin crease.

**Papillary ridges** or **finger prints** affect the flexor surfaces of the terminal phalanges of the digits. Each ridge corresponds to the pattern of the underlying dermal papillae, which varies from person to person and in different digits of the same person. Along the ridges ducts of sweat glands open at regular interval. Basically the
papillary ridges are of three types—*whorl*, *loop* and *arch*. Pattern of finger prints is constant in an individual, and it helps in personal identity and is sometimes applied in legal matters. Science of finger prints known as **dermatoglyphics** is one of the tools in the study of genetics.

**Langer’s lines** of cleavage are produced by the bundles of collagen fibres of the dermis. On the dorsum of the fingers they are transverse, but on the palmar surface they are longitudinal. An incision along the direction of these lines produces minimal scar and is utilised for reconstructive surgery.

**Superficial fascia**—The subcutaneous tissue contains fat in small tight compartments between the fibrous band, **palmaris brevis** across the base of hypothenar eminence, and **superficial transverse ligament of the palm** across the roots of the medial four fingers.

**Palmaris brevis** is a subcutaneous striated muscle across the base of hypothenar eminence, arises from flexor retinaculum and central part of palmar aponeurosis and is inserted to the dermis of the ulnar border of the hand. It is supplied by the superficial branch of ulnar nerve and improves the grip by steadying the skin on the ulnar side. The palmaris brevis is a remnant of **panniculus carnosus**.

The **superficial transverse ligament** of the palm stretches across the free margins of the webs between the medial four fingers. The digital vessels and nerves lie immediately deep to the superficial transverse ligament.

**Deep fascia**—The palmar deep fascia is thickened to form three specialised parts: flexor retinaculum, palmar aponeurosis and fibrous flexor sheaths of the digits.

**Flexor retinaculum**—It is a strong fibrous band which acts as a tie-beam and converts the anterior concave surface of the carpus into an osseo-fibrous **carpal tunnel**. The tunnel contains digital flexor tendons and median nerve (Fig. 11.1).

**Attachments**:

- Medially, pisiform bone and hook of the hamate;
- Laterally, tubercle of scaphoid and the crest of trapezium;

**On each side**, the retinaculum presents a slip of attachment. Laterally, a **deep slip** is attached along the medial lip of the groove of trapezium; osseo-fibrous tunnel, thus formed, lodges the tendon of flexor carpi radialis and its synovial sheath. Medially, a **superficial slip** is attached to the pisiform bone; ulnar vessels and nerve pass deep to this slip.

**Proximally**, it blends with both the antebrachial fascia in superficial plane and with the fascia covering the flexor digitorum superficialis on a deeper plane.

**Distally**, it is continuous with the palmar aponeurosis and palmar fascia, and provides origins to the thenar and hypothenar muscles.

**Relations**:

**Structures passing superficial** to the flexor retinaculum

(a) Palmaris longus tendon;
(b) Palmar cutaneous branch of median nerve;

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![Fig. 11.1. Flexor retinaculum and the structures superficial to it.](image-url)
Palmar cutaneous branch of ulnar nerve;
(d) Superficial palmar branch of radial artery;
(e) Ulnar nerve and ulnar vessels;

**Structures passing deep to the retinaculum** (Fig. 11.2)
(a) Median nerve, closely applied to the posterior surface of the retinaculum;
(b) Tendons of flexor digitorum superficialis;
(c) Tendons of flexor digitorum profundus;
(d) Tendon of flexor pollicis longus;
(e) Flexor carpi radialis tendon lies on the groove of the trapezium between superficial and deep slips of the retinaculum.

**Synovial sheaths of flexor tendons** within the carpal tunnel

Two synovial sheaths are encountered around the digital flexor tendons within the carpal tunnel.

1. One for flexor pollicis longus known as radial bursa; it extends about 2.5 cm proximal to the flexor retinaculum and is continuous with the digital synovial sheath of the thumb enveloping the tendon upto its insertion.

2. The other forms a common synovial sheath known as ulnar bursa for four superficialis and four profundus tendons. The ulnar bursa extends about 2.5 cm proximal to the flexor retinaculum. Distally the common bursa is usually continuous with the digital synovial sheath of little finger, but extends as blind diverticula about halfway along the second, third and fourth metacarpal bones without communicating with the digital synovial sheaths of other fingers.

The continuity of the digital synovial sheath of the thumb with the radial bursa and that of the little finger with the ulnar bursa depends upon the free range of finger movements and the shortness of their metacarpal bones. Sometimes the radial bursa joins with the common ulnar bursa within the carpal tunnel. In such case, infection from the little finger may extend to the thumb through this route.

The parietal layer of common synovial sheath of ulnar bursa lines the flexor retinaculum and the floor of the carpal tunnel. It is reflected as visceral layer from the radial side over the ventral and dorsal aspects of the superficialis and profundus tendons respectively; thereafter the visceral layer projects from the ulnar side as a recess to a variable extent between the superficialis and profundus tendons.

**Applied Anatomy**

The median nerve may be compressed in the carpal tunnel by the long continued swelling of the synovial sheaths. This is known as the carpal tunnel syndrome, and is manifested by weakness and wasting of the thenar muscles with the loss of power of opposition, and loss of cutaneous sensations of the palmar surface involving lateral three and a half of the digits.

**Palmar aponeurosis**—It is the deep fascia of the palm and consists of central, medial and lateral parts. The central part is thick and forms the palmar aponeurosis proper; it protects the vessels and nerves and prevents the underlying long flexor tendons from bow-stringing. The medial and lateral parts cover hypothenar and thenar muscles and are necessarily thin to allow movements of the marginal metacarpal bones and their digits. Along the radial and ulnar margins of the palm the aponeurosis is continuous with the deep fascia on the dorsum of the hand.

![Fig. 11.2. Transverse section of the carpal tunnel showing disposition of the flexor tendons and their synovial sheaths.](image)
Central part of palmar aponeurosis (Fig. 11.3)—It is triangular in shape, the apex is directed proximally and blends with the distal border of flexor retinaculum and is continuous with the tendon of palmaris longus. Distally, the aponeurosis fans out as a thick sheet and at the bases of the fingers splits into four digital slips for the medial four fingers. Each slip divides into superficial and deep sets of fibres. The superficial fibres join with the dermis and blend with the superficial transverse ligament of palm. The deep set of fibres of each slip divides into two bands, which are attached to the deep transverse ligament of the palm, palmar ligaments of metacarpophalangeal joints, the bases of proximal phalanges, and blends with the fibrous flexor sheaths. The intervals between the digital slips are connected by transverse fibres and traversed by digital vessels, nerves and lumbrical tendons. In forcible extension of fingers, the soft tissues of palm bulge as cushions in the three intervals between the four slips.

Medial and lateral palmar septa extend dorsally from the respective margins of the central part of the aponeurosis. The medial septum is attached to the palmar surface of the shaft of fifth metacarpal bone, and the lateral septum to the first metacarpal bone. These septa subdivide the palm into fascial lined spaces.

Functions

1. The palmar aponeurosis provides firm attachment to the overlying skin to improve the grip.

2. It protects the palmar vessels and nerves and prevents the flexor tendons from bow-stringing.

3. It provides origin to the palmaris brevis from its apex for stronger grip on the ulnar side.

4. The palmar septa attached to the aponeurosis subdivide the palm into a number of potential spaces, which are surgically important when infected.

5. Plantar aponeurosis of foot presents five digital slips, whereas the palmar aponeurosis presents four due to the absence of digital slip to the thumb. This becomes imperative to allow free movement of the thumb.

Morphology—The palmar aponeurosis is the degenerated primitive insertion of the palmaris longus tendon.

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Fig. 11.3. Palmar aponeurosis.
Applied Anatomy

Inflammation of palmar aponeurosis may produce thickening and contracture of the aponeurosis. As a result the proximal and middle phalanges are acutely flexed because the palmar fascia is attached to them. The terminal phalanges, however, remain unaffected. The ring finger is most commonly involved. The inflammatory contracture of the aponeurosis is known as Dupuytren’s contracture.

Fibrous flexor sheaths of the digits

To retain the flexor tendons in position, all five digits are provided with a strong unyielding fibrous sheath which extends from the metacarpal head to the base of the distal phalanx. Fibrous sheath of the thumb contains the tendon of flexor pollicis longus only. In the medial four fingers, the sheaths are occupied by two tendons—flexor profundus to reach the base of distal phalanx, and flexor superficialis which splits to spiral around the profundus tendon and is inserted into the sides of middle phalanx. Each sheath crosses three joints: metacarpo phalangeal, proximal and distal interphalangeal. The sheaths present a series of thick zones over the phalanges and thin zones over the joints. Recent analysis shows that the thicker zones are arranged proximo-distally as five annular pulleys and four intervening cruciate pulleys (Fig. 11.4).

Digital synovial sheaths

In order to avoid friction of flexor tendons against the osseo-fibrous canals of the digits, each tendon is enveloped by a tubular synovial sheath, which is closed at both ends and consists of parietal and visceral layers. The parietal layer lines the walls of osseofibrous canal and the visceral layer covers the flexor tendons; the continuity of the two layers is initially made by a mesotendon which conveys blood vessels to the tendon. But most of the mesotendon disappears due to frequent movements of the tendon, except at certain areas where it persists as vinculae. The vinculae are of two types, vincula brevia and vincula longa. Each finger presents two vincula brevia and three vincula longa. The vincula brevia are triangular folds; one connecting the superficial tendon to the proximal phalanx and proximal interphalangeal joint, and the other connecting the profundus tendon to the middle phalanx and distal interphalangeal joint. The vincula longa are filiform folds; two attached to each slip of superficial tendon, and one to the profundus tendon. Those connected to the superficial tendon are attached to the proximal end of the proximal phalanx, and that for profundus tendon is attached to the distal end of the proximal phalanx (Fig. 11.5, 11.6, 11.7).
of the thumb is continuous with the radial bursa (vide supra). But the synovial sheaths of the index, middle and ring fingers are independent and extend proximally up to the level of metacarpal heads. The length of digital synovial sheaths depends upon the excursions of the contained flexor tendons. and arise together from the flexor retinaculum and from the two lateral bony pillars of carpal tunnel.

**Abductor pollicis brevis**—It is the most lateral thenar muscle and arises from:
(a) flexor retinaculum;
(b) tubercles of scaphoid and trapezium;
(c) and from the tendon of abductor pollicis longus.

The muscle is inserted into the radial side of the base of the proximal phalanx of thumb and partly into the tendon of extensor pollicis longus.

**Actions**: It abducts the thumb at right angles to the plane of the palm and rotates the thumb medially. Both movements take place at carpometacarpal and metacarpo-phalangeal joints.

**Flexor pollicis brevis**—It lies medial to abductor pollicis brevis and arises by two heads, superficial and deep.

The superficial head arises from the flexor retinaculum and crest of trapezium, accompanies the radial side of the tendon of flexor pollicis longus and is inserted by a tendon to the radial side of the base of proximal phalanx, interrupted by a sesamoid bone.

The deep head arises from the trapezoid and capitate bones, passes deep to the flexor pollicis longus tendon and joins with the superficial head at the sesamoid bone for insertion.

**Nerve supply**—Superficial head is supplied by the recurrent branch of median nerve; deep head is supplied by the deep branch of ulnar nerve.

**Action**—It flexes the proximal phalanx of the thumb across the palm.

**Opponens pollicis**—It lies deep to abductor pollicis brevis, arises from the flexor retinaculum and crest of trapezium, and is inserted into the lateral half of the palmar surface of the shaft of first metacarpal bone.

**Action**—It flexes and medially rotates the first metacarpal bone, and thereby helps opposition of thumb to bring the latter in contact with the semiflexed pulps of the other fingers.

**Nerve supply to the three thenar muscles**

This is derived from a recurrent branch of median nerve which hooks around the distal border of flexor retinaculum and reaches the thenar muscles superficial to the tendon of flexor pollicis longus. Therefore, an incision of the synovial
sheath of the flexor pollicis longus over the metacarpal bone should be made more distally in order to avoid division of this nerve.

Adductor pollicis—It is a muscle of deeper stratum and lies beneath the long flexor tendons and lumbrical muscles. The deep palmar arch divides its origin into a distal transverse head and a proximal oblique head (Fig. 11.10).

Origins:

Transverse head arises from the longitudinal ridge on the palmar surface of third metacarpal bone.

Oblique head arises from the bases of second and third metacarpals, and the adjoining trapezoid and capitate by a crescentic origin which embraces the insertion of the flexor carpi radialis.

Insertion: Both the heads converge into a tendon for insertion to the ulnar side of the base of proximal phalanx of the thumb with a sesamoid bone intervening.

Nerve supply—From the deep branch of ulnar nerve;

Action—It approximates the thumb to the index finger, from any position of the thumb.

Peculiarity—The distal border of the adductor pollicis appears subfascially in the cleft between the thumb and index finger in front of first dorsal interosseous muscle. The space between the two muscles can be opened surgically to drain the pus from the infected fascial space.

2. Hypothenar muscles—These are three short muscles of hypothenar eminence and arise from the flexor retinaculum and from the two medial bony pillars of carpal tunnel. They consist of abductor and flexor digiti minimi in superficial plane, and opponens digiti minimi in deeper plane.

Abductor digiti minimi—It lies on the ulnar side and arises from the pisiform bone, tendon of flexor carpi ulnaris and piso-hamate ligament.
It is inserted by one slip to the ulnar side of the base of proximal phalanx of little finger, and the other slip joins the ulnar border of the dorsal digital expansion of the little finger.

**Flexor digiti minimi**—It lies on the radial side of the former muscle, and arises from the flexor retinaculum and hook of the hamate.

It is inserted along with the abductor digiti minimi to the ulnar side of the base of proximal phalanx of little finger.

**Opponens digiti minimi**—It lies deep to the above mentioned hypothenar muscles, and arises from the flexor retinaculum and hook of the hammate.

The muscle is inserted to the ulnar side of the palmar surface of the shaft of fifth metacarpal bone.

**Nerve supply**—The three hypothenar muscles are supplied by the deep branch of ulnar nerve, when the latter passes between the origins of abductor and flexor digiti minimi and then turns laterally through the opponens digiti minimi to lodge in a groove below the hook of hamate bone.

**Action**—It may improve the palmar grip.

3. **Lumbrical muscles**—These are four small muscles resembling the shape of earthworms; hence the name. They are numbered from lateral to medial side (See Fig. 11.9, 10.7). The lumbricals take origin in the palm from the four tendons of flexor digitorum profundus, pass distally along the radial side of the corresponding metacarlo-phalangeal joint in front of the deep transverse metacarpal ligament. Each muscle forms a narrow tendon, runs in a fascial canal and on reaching the dorsal surface of proximal phalanx joins the radial margin of the dorsal digital expansion as **distal wing tendon**.

**Origins**: First and second lumbricals are unipennate and arise from the radial side of profundus tendons for the index and middle fingers.

Third and fourth lumbricals are bipennate and arise from the adjacent sides of profundus tendons for the middle, ring and little fingers.
Note: In the middle of the palm the profundus tendons for the index, middle and ring fingers are not provided with the digital synovial sheath and common carpal synovial sheath (ulnar bursa) over a short distance. It is from this area of bare tendon the lumbricals take origin; the fourth lumbral obliterates the synovial sheath along its origin from the tendon of the little finger.

**Insertion:** Into the radial side of the dorsal digital expansion of the medial four finger; through the dorsal expansion the lumbricals are inserted into the dorsal surface of the bases of the middle and distal phalanges.

**Nerve supply**

1. First and second lumbricals are supplied by the median nerve from their superficial surfaces.

2. Third and fourth lumbricals are supplied by the deep branch of unlar nerve from their deep surfaces; occasionally third lumbrical possesses double nerve supply from both ulnar and median nerves.

The proportion of distribution by ulnar and median nerves to the lumbricals follows that of the parent bellies of flexor profundus tendons in the forearm.

**Actions**—Lumbricals act as link muscles since they connect the deep flexor tendons to the extensor tendons of the fingers via dorsal digital expansion, after passing obliquely in front of the transverse axis of the metacarpophalangeal joints.

Therefore, they flex the digits at the metacarpophalangeal joints and extend at the interphalangeal joints. This produces up and down strokes of fingers for skilled works.

4. **Interosseous muscles**—These consist of four palmar and four dorsal interossei, and are numbered from lateral to medial sides. Palmar interossei are unipennate muscles, arise only from one and their own metacarpal bone, and act as adductors of fingers. Dorsal interossei are bipennate muscles, arise from the adjacent metacarpal bones and act as abductors of fingers.

The **axis of the palm** passes through the third metacarpal bone and middle finger. On the basis of functional requirements, the palmar interosseous does not arise from the third metacarpal and does not provide any attachment to the middle finger, because the latter lies in the axial line and requires no adduction. Although the thumb possesses its own adductor, it is supplemented by the first palmar interosseous.

**Dorsal interosseous muscles** concentrate their attachments to the middle three fingers (index, middle and ring) and are attached on both sides of the third digit, since the thumb and little finger possess separate abductor muscles in the thenar and hypothenar eminences.

**Palmar interossei** (See Fig. 2.12)

**Origins:**

(a) First palmar, from the ulnar side of the base of first metacarpal;

(b) Second palmar, from the ulnar side of the shaft of second metacarpal;

(c) Third and fourth palmar, from the radial side of the shaft of the fourth and fifth metacarpal bones respectively.

**Insertions:** All palmar interossei are inserted partly to the base of the proximal phalanx of the corresponding digit on the side of their origins, and partly attached to the dorsal digital expansion.

**Dorsal interossei**—They are visible from the palmar aspect of interosseous spaces. The muscles fill up the four intermetacarpal spaces and take bipennate origins from the palmar surface of shafts of adjacent metacarpal bones. The gap between the two heads of first dorsal interosseous transmits radial artery from dorsal to palmar surface; through the similar gaps of the other dorsal interossei pass the proximal perforating arteries (See Fig. 2.13).

**Insertions**—The tendons of dorsal interossei along with the palmar interossei descend dorsal to the deep palmar metacarpal ligaments and are inserted as follows:

1. First and second dorsal interossei are partly attached to the radial side of the bases of proximal phalanges of the index and middle fingers respectively, and partly join with the dorsal digital expansion of the corresponding digits.

2. Third and fourth dorsal interossei are attached partly to the ulnar side of the bases of proximal phalanges of the middle and ring fingers, and partly join with the extensor expansion of the corresponding digits.

**Nerve supply**—Both palmar and dorsal interossei are supplied by the deep branch of the ulnar nerve.
Actions

(a) Palmar interossei are adductors of the fingers, and act as flexors of the metacarpophalangeal joints and extensors of the interphalangeal joints.

(b) Dorsal interossei are abductors of the middle three fingers; in addition they help flexion at the metacarpophalangeal joints and extension of the interphalangeal joints.

Long flexor tendons and their digital attachments

Long flexor tendons in the palm consist of four tendons of flexor digitorum superficialis, four tendons of flexor digitorum profundus, and tendon of flexor pollicis longus. After their origins in the flexor (anterior) compartment of forearm, these nine tendons are crowded in the carpal tunnel beneath the flexor retinaculum. Beyond the distal border of flexor retinaculum, the tendons diverge for their digital attachments.

The tendon of flexor pollicis longus passes straight between the opponens pollicis and oblique head of adductor pollicis for its insertion into the palmar surface of the base of the distal phalanx of the thumb. The entire tendon, extending from the carpal tunnel to the site of its insertion, is enveloped by a tubular synovial sheath (radial bursa).

Each of the four superficial and four deep flexor tendons enter the flexor fibrous sheaths of the corresponding medial four digits. Each superficial digital tendon at the base of proximal phalanx splits into two to allow the passage of deep flexor tendon, then reunites and partially decussates and finally re-splits for insertion to the two sides of the shaft of middle phalanx. The deep flexor tendon in each of the medial four fingers passes distally through the tunnel made by the splitting of the superficial flexor tendon and is inserted to the palmar surface of the base of the terminal phalanx (See Fig. 10.7).

Within the carpal tunnel the four superficial and four profundus tendons are enveloped by a common synovial sheath (ulnar bursa), which extends proximally about 2.5 cm above the flexor retinaculum. Distally the common sheath is usually continuous with the digital synovial sheath of the little finger, but such continuity is not established in index, middle and ring fingers (See Fig. 11.7).

The common synovial sheath ends as blind diverticula opposite the three middle fingers and extends up to the mid-metacarpal level, and the digital synovial sheaths of these three fingers extend proximally up to the level of metacarpal heads. Each digital synovial sheath presents two vincula brevia and three vincula longa. (For further details consult the relevant chapters).

ARTERIES OF THE PALM

The terminal parts of ulnar and radial arteries on reaching the palm, anastomose with each other to form superficial and deep palmar arches.

Superficial palmar arch—The ulnar artery, accompanied by ulnar nerve on its medial side, enters the palm superficial to the flexor retinaculum and on the radial side of pisiform bone. Beneath the palmaris brevis the artery divides into superficial and deep branches. The superficial branch is the direct continuation of the ulnar artery and forms the main contribution of the superficial palmar arch (See Fig. 11.8).

Superficial palmar arch is an arterial arcade which lies beneath the palmar aponeurosis and in front of long flexor tendons, lumbrical muscles and palmar digital branches of median nerve. The arch is formed by the superficial terminal branch of ulnar artery and completed on the lateral side by one of the following arteries—

(a) superficial palmar branch of radial artery;
(b) arteria princeps pollicis;
(c) arteria radialis indicis; or
(d) arteria nervi mediana which accompanies the median nerve.

The convexity of the arch is directed distally on a level with the distal border of outstretched thumb.

Branches:

Four palmar digital arteries arise from the convexity of the arch. The most medial digital branch passes along the ulnar side of the little finger. The remaining three branches form the common palmar digital arteries which proceed distally to the web between the fingers, where each joins with the palmar metacarpal artery of the deep palmar arch and then divides into two proper palmar digital arteries to supply the adjacent fingers.
Therefore, the superficial palmar arch does not supply the radial side of index finger and both sides of the thumb.

Deep palmar arch—It is an arterial arcade formed by the anastomosis between the terminal end of radial artery and the deep branch of ulnar artery. The radial artery enters the hand between the two heads of first dorsal interosseous muscle, appears in the palm between the oblique and transverse heads of adductor pollicis and continues as the deep palmar arch. In the interval between the first dorsal interosseous and adductor muscles, the radial artery give off two branches — *arteria princeps pollicis* and *arteria radialis indicis*. The former divides into two palmar digital branches to supply the two sides of the thumb; the latter supplies the radial side of the index finger. The deep branch of ulnar artery, accompanied by the deep branch of ulnar nerve, passes deeply between the abductor and flexor digiti minimi and then turns laterally below the hook of hamate bone to complete the deep palmar arch (See Fig. 11.10).

The deep palmar arch lies deep to the oblique head of adductor pollicis, long flexor tendons and lumbrical muscles, and passes across the bases of metacarpals and interossei. The convexity of the deep arch corresponds with the level of the proximal border of outstretched thumb, about 1 cm proximal to the superficial arch. The deep branch of ulnar nerve accompanies the concavity of the deep arch.

**Branches:**

(a) **Three palmar metacarpal arteries**—These arise from the convexity of the arch, pass distally on the interosseous muscles of second to fourth spaces and in the webs between the fingers anastomose with the common palmar digital branches of the superficial arch.

(b) **Three perforating arteries** pass dorsally between the two heads of second to fourth dorsal interossei, and anastomose with the dorsal metacarpal arteries. Their accompanying veins drain most of the blood of the palm into the dorsal venous plexus.

(c) **Recurrent branches** extend proximally in front of the carpal bones and anastomose with the anterior carpal arch.

**NERVES OF THE PALM**

**Median nerve**—The median nerve enters the palm beneath the distal border of flexor retinaculum, where it enlarges and flattens before,
dividing into lateral and medial branches. Prior to
division the nerve provides a recurrent muscular
branch from its lateral side which curls upward
around the distal border of flexor retinaculum and
superficial to the tendon of flexor pollicis longus
to supply the three muscles of the thenar eminence
(abductor and flexor pollicis brevis, opponens
pollicis) (Fig. 11.11, See Fig. 11.8).

The lateral branch subdivides into three
proper palmar digital nerves to supply the skin
of both sides of the thumb and radial side of the
index finger; the branch to the index finger provides
a muscular twig to the first lumbrical.

The medial branch subdivides into two common
palmar digital nerves which pass distally deep to
superficial palmar arch and between the long flexor
tendons. Lateral common digital nerve gives a
branch to the second lumbrical and divides into
two proper digital nerves to supply the adjacent
sides of the index and middle fingers. Medial
common digital nerve receives a communicating
twig from the common palmar digital branch of
ulnar nerve and divides into two proper digital
nerves to supply the adjacent sides of the middle
and ring fingers; sometimes it gives a twig to the
third lumbrical.

Summary of distribution of median nerve in
the hand – It supplies five muscles (three thenar
muscles, first and second lumbricals) and the skin
of the lateral three and one-half of the digits,
including the joints of the digits and local blood
vessels.

Palmar digital nerves—These are derived
from median and superficial branch of ulnar nerves.
Initially the digital nerves lie deep to the superficial
palmar arch. As they pass distally along with the
palmar digital vessels in the inter-digital clefts,
both vessels and nerve lie between superficial and
deep transverse metacarpal ligaments. Here the
palmar digital nerves appear in front of or
superficial to the vessels and maintain that
relationship along the digits. This is due to the
fact that the nerves provide rich communication
to the sensitive pulp of the finger tips, and the
digital arteries are directed towards the nail bed
to avoid the pressure of gripping.

Each proper digital nerve gives articular
branches to the metacarpophalangeal and
interphalangeal joints, supplies the skin of the
palmar aspect of the digit including the pulp
space, nail bed and provides dorsal branches to
supply the skin over the dorsal surface of middle
and terminal phalanges. In the thumb, however,
the dorsal branch supplies the skin over the distal
phalanx only.

Ulnar nerve—The ulnar nerve, accompanied
by ulnar artery on its lateral side, appears in the
palm superficial to the flexor retinaculum and on
the radial side of the pisiform bone. Beneath the palmaris brevis in the proximal part of hypothenar eminence, the nerve divides into superficial and deep terminal branches (See Fig. 11.18, 11.11).

The superficial terminal branch gives a muscular twig to the palmaris brevis, and subdivides into two branches:

(a) a proper palmar digital nerve which supplies the ulnar side of the little finger, and

(b) a common palmar digital nerve which receives a communication from the nearest common digital branch of median nerve and then subdivides into two proper digital nerves to supply the adjacent sides the ring and little fingers.

The digital nerves supply, in addition to palmar skin, metacarpophalangeal and interphalangeal joints, local blood vessels, pulp spaces and nail beds and the skin of the dorsal surface over the middle and terminal phalanges of the medial one and a half of the digits.

The deep terminal branch of ulnar nerve, accompanied by corresponding branch of ulnar artery, passes deeply between the origins of abductor and flexor digiti minimi, pierces the opponens digiti minimi and then turns laterally lodging in a groove below the hook of hamate bones (Fig. 11.12). It follows the concavity of the deep palmar arch and passes deep to the long flexor tendons.

The deep branch supplies muscular branches to the three hypothenar muscles, third and fourth lumbricals, all dorsal and palmar interossei, adductor pollicis and occasionally to the deep part of flexor pollicis brevis. It also provides articular branches to the intercarpal and carpometacarpal joints, and vascular branches to the deep palmar arch and its branches.

**Summary of ulnar nerve distribution** in the hand—It supplies all intrinsic muscles of the hand, except three thenar muscles and first and second lumbricals, and the cutaneous branches to the medial one and half the fingers including the ulnar side of the hand.

**Fascial spaces in the palm**

Three fascial lined potential spaces limited by fibrous septa warrant attention in the palm and the palmar aspect of terminal phalanges, because of their surgical importance. These are mid-palmar and thenar spaces, and pulp spaces.

The central hollow of the palm between the thenar and hypothenar eminences is occupied by palmar aponeurosis, long flexor tendons covered by synovial sheaths and lumbrical muscles. Deep to the long flexor tendons and lumbrical muscles there lies a large fascial lined central palmar space which is limited at the sides by the medial and lateral palmar septa (vide infra). This space is subdivided by an intermediate fibrous septum extending from the fascia covering the undersurface of the flexor tendons to the palmar surface of third metacarpal bone into the mid-palmar space on the ulnar side and the thenar space on the radial side. The spaces become more apparent when pus is collected.

**Mid-palmar space**—It is triangular in shape and presents the following boundaries (Fig 11.13, 11.14):

(a) Flexor tendons of the little, ring and middle fingers with their synovial sheaths;
(b) Third and fourth lumbrical muscles;

**Behind**—The dense fascia covering the

![Fig. 11.12. Course and distribution of deep branch of ulnar nerve.](image-url)
interossei and the metacarpal bones of third and fourth spaces;

**Laterally**—The intermediate fibrous septum as described above;

**Medially**—Hypothenar muscles separated by the *medial palmar septum*; the latter extends from the medial margin of palmar aponeurosis to the fifth metacarpal bone.

**Proximally**, the space is practically closed by the attachment of the parietal layer of ulnar bursa to the floor of the carpal tunnel.

Sometimes it is continuous with the space of Parona of the forearm.

**Distally**, the space extends as diverticula to the webs of the fingers along the fascial sheaths of third and fourth lumbral muscles.

**APPLIED ANATOMY**

Pus in the mid-palmar space can be drained surgically by splitting the web between the third and fourth or fourth and fifth digits, and exploring the lumbral canal.

**Thenar space**—It is triangular in shape, lies on the radial side of the mid-palmar space and presents the following boundaries (Fig. 11.13, 11.14):

**In front**
(a) Muscles of thenar eminence;
(b) Flexor tendon of the index finger;
(c) First and second lumbral muscles.

**Behind**—Adductor pollicis; around the distal border of the muscle, in the web of the thumb, the thenar space is continuous with a slit-like interval between adductor pollicis and first dorsal interosseous muscle.

**Laterally**—Tendon of flexor pollicis longus and its sheath; this tendon is separated from the thenar muscles by the *lateral palmar septum* which extends dorsally from the lateral margin of palmar aponeurosis to the first metacarpal bone.

**Medially**—The intermediate fibrous septum.

**Proximally**—The extent is same as in the mid-palmar space.

**Distally**—The space extends as fascial diverticula along first and second lumbral tendons to the interdigital clefts. Sometimes the second lumbral canal is connected with the mid-palmar space.

Proximal ends of the digital synovial sheaths of index, middle and ring fingers extend to the distal limits of mid-palmar and thenar spaces.
(without diverticula). Therefore pus from the infected flexor sheath may burst into and distend the palmar spaces.

Pulp spaces—These are the spaces which intervene between the palmar skin and distal phalanges of all the digits of the hand, and lie distal to the fibrous sheaths of flexor tendons. In each pulp space the skin is connected to the periosseum of the distal phalanx by numerous radiating fibrous septa which subdivide the space into a number of tight compartments containing sub-cutaneous fat and blood vessels (Fig. 11.15-a, b).

**Fig. 11.15 (a) Longitudinal section of pulp space.**

The distal four-fifth of the distal phalanx receives the blood supply from the digital arteries by penetrating the dense fibrous septa. But the proximal one-fifth of the bone gets separate blood supply without traversing the septa.

**Fig. 11.15 (b) Transverse section of pulp space.**

**Applied Anatomy**

Infection of the pulp space is known as whitlow which is associated with severe throbbing pain due to increased tension in the tight interseptal spaces.

Infection of the pulp space is drained by a lateral incision which opens all interseptal compartments without damaging the sensitive skin of pulp. In neglected cases, it may lead to avascular necrosis of the distal four-fifth of terminal phalanx, but the basal one-fifth of the bone remains unaffected.

**DORSUM OF THE HAND**

**Skin**—The skin of the dorsum of the hand is thin, hairy and moves freely over the underlying extensor tendons and deep fascia.

**Superficial fascia**—It presents a dorsal subcutaneous space which contains the dorsal venous arch and the dorsal digital nerves derived from the superficial terminal branch of radial nerve and dorsal branch of ulnar nerve.

**Dorsal venous arch**—The dorsal digital veins from the adjacent sides of the fingers join in the interdigital clefts to form three dorsal metacarpal veins which unite with each other and form a dorsal venous network proximal to the metacarpal heads. This network receives the blood from the radial side of index finger and both sides of the thumb as well as from the ulnar side of little finger. Most of the blood from the palm also reaches dorsal venous plexus through the perforating veins in order to avoid pressure during grasping. From the radial side of the venous plexus the blood is conveyed proximally by the cephalic vein and from the ulnar side by the basilic vein.

**Superficial terminal branch of radial nerve** (Fig. 11.16)—It pierces the deep fascia after winding round the lateral side of radius and appears in the dorsum of the hand, where the nerve usually divides into five dorsal digital branches. The lateral three are proper digital nerves and medial two are common digital nerves. The proper digital nerves supply individually the skin of both sides of the thumb and radial side of index finger. The common digital nerves divide to supply the adjacent sides of the index, middle and ring fingers, and provide communicating branches to the dorsal digital branch of ulnar nerve.

The dorsal digital nerves to the thumb reach only to the root of the nail, those to the index finger extend to the middle of the middle phalanx, and the branches to the middle and radial side of ring fingers do not extend beyond the proximal interphalangeal joints (Fig. 11.17).
Dorsal branch of ulnar nerve (See Figs. 11.16, 11.17)—It appears on the medial side of the back of the wrist after piercing the deep fascia, and divides usually into two dorsal digital nerves—one proper digital nerve to supply the skin on the ulnar side of the little finger; and the other is a common digital nerve which divides into two branches to supply the adjacent sides of the little and ring fingers and receives communications from the nearest digital branch of radial nerve.

Proximally at the back of the wrist, it is continuous with the extensor retinaculum, and at the sides continuous with the palmar fascia.

A dorsal subaponeurotic space intervenes between the deep fascia and the dorsal surfaces of metacarpal bones and dorsal interossei muscles. The space is occupied by the extensor tendons of the hand, dorsal digital expansions, dorsal carpal arch and their dorsal metacarpal branches (See Fig. 11.13)

Extensor tendons (See Fig. 10.5)

1. Distal to extensor retinaculum, the tendons of extensor carpi radialis longus and brevis are inserted respectively to the base of second and third metacarpal bones; the tendon of extensor carpi ulnaris is attached to the base of fifth metacarpal bone.

2. The four tendons of extensor digitorum fan out and enter into the formation of dorsal digital expansion over the proximal phalanges of the corresponding median four fingers.

On the dorsum of hand the digital tendons blend with the deep fascia and are interconnected close to the metacarpal heads by three intertendinous bands (vincula). Over the second metacarpal bone two tendons pass side by side; lateral from extensor digitorum and medial from extensor indicis. Two tendons over the fifth metacarpal bone are usually derived from the splitting of tendon of extensor digiti minimi; contribution of the extensor digitorum tendon to the little finger initially lies on the fourth metacarpal bone.

3. Dorsal digital expansion (See Figs. 10.6, 10.7 in chapter 10).

Dorsal (posterior) carpal arch and dorsal metacarpal arteries—(See the anastomosis around wrist joint in chapter 10).

Finger nails—The nail are hard and translucent plates, somewhat rectangular in outline, and overlie the dorsal aspect of distal phalanges. They protect the sensitive tips of digits. The nails are derived from hardening of the horny zone of the epidermis. They develop in the focius as epidermal thickenings that under-cut the skin to form folds from which the horny substance of nail grows distally.

The nail consists of a proximal hidden part or root, exposed part or body, and a distal free border. The root is covered by a proximal nail fold made of
soft keratin and is known as eponychium. The sides of the body are bordered by lateral nail folds known as paronychium.

The root of the nail rests on a germinal matrix which is composed of a thick plate of living epithelial cells, and extend distally beneath the body of nail as a pale crescentic area known as lunula. Major portion of the body is firmly attached to the underlying epidermal nail bed or sterile matrix where the dermis is highly vascular; this accounts for the pink colour of nail. The crescentic area of skin connected to the under-
surface of the distal border of nail is called hyponychium.

**APPLIED ANATOMY**

When pus is formed due to infection of paronychium or eponychium, it can be drained by lifting the nail fold with a needle.

In infection of nail bed, the eponychium is pushed back and the portion of nail overlying the pus is excised.
These three nerves of upper limb are described in parts in different regions. Now a total projection of their courses, relations and branches becomes essential to understand their clinical importances (See Figs. 6.4, 6.7, 9.3, 9.5, 9.7, 10.2, 11.8, 11.11, 11.17).

**MEDIAN NERVE**

**Formation**: It is formed in the axilla by the union of medial and lateral roots. The **medial root** is derived from the medial cord of brachial plexus and conveys the fibres from C₈ and T₁; it crosses downward and laterally in front of the third part of axillary artery and joins with the lateral root. The **lateral root** is the continuation of lateral cord of brachial plexus and conveys fibres from C₅, C₆ and C₇.

Some fibres from C₇ of the lateral root often join with the ulnar nerve, after passing behind the medial root and in front of the axillary artery.
Root values—These are derived from the ventral branches of ventral rami of C5, C6, C7, C8 and T1.

Course: After its formation the median nerve descends along the lateral side of the third part of axillary artery and proximal part of brachial artery. At the middle of the arm, opposite the insertion of coracobrachialis, the nerve crosses from lateral to medial usually in front of the artery and then accompanies along the medial side of the brachial artery.

It appears in the cubital fossa beneath the bicipital aponeurosis and rests on the brachialis. The nerve leaves the cubital fossa through a gap between superficial and deep heads of pronator teres. While doing so the nerve crosses the lateral side of ulnar artery and is separated from the latter by the deep head of pronator teres.

The median nerve enters the flexor compartment of forearm under cover of the tendinous arch between the humero-ulnar and radial heads of flexor digitorum superficialis. As the nerve descends it intervenes between the flexores digitorum superficialis and profundus, and is closely applied to the posterior surface of the former muscle. In the forearm it is accompanied by a branch (arteria nervi mediana) from the anterior interosseous artery. About 5 cm above the flexor retinaculum the nerve emerges from under cover of the lateral border of flexor digitorum superficialis and becomes more superficial as it approaches the wrist. Here it lies between the tendons of flexor carpi radialis and palmaris longus. Sometimes the nerve is mistaken for the palmaris longus tendon; but they can be differentiated because the tendon is glistening and avascular, while the nerve is dull in appearance and accompanied by an artery.

It enters the carpal tunnel deep to the flexor retinaculum and in front of the common synovial

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Fig. 12.2. Upper limb (From the back).
sheath (ulnar bursa) enveloping the tendons of flexor digitorum superficialis and profundus. Here the nerve may be compressed due to inflammatory condition or anterior dislocation of the lunate bone giving rise to carpal tunnel syndrome.

The median nerve reaches the palm beyond the distal border of flexor retinaculum, and divides into lateral and medial branches. The lateral branch gives off a recurrent muscular branch to supply the three thenar muscles (abductor pollicis brevis, flexor pollicis brevis and opponens pollicis), and then subdivides into three proper palmar digital nerves to supply the two sides of the thumb and radial side of the index finger; the branch to the index finger provides a branch to the first lumbrical. The medial branch subdivides into two common palmar digital nerves, lateral and medial. The lateral common nerve gives a branch to the second lumbrical and sub-divides to supply the adjacent sides of the index and middle fingers. The medial common nerve receives a communicating branch from the nearest palmar digital nerve from the superficial branch of ulnar nerve, and then subdivides to supply the adjacent sides of the middle and ring fingers.

Branches of the median nerve—These are muscular, cutaneous, articular and vascular.

Muscular branches

In the arm—Nerve to the pronator teres above the elbow;

In the forearm

1. to the pronator teres, flexor carpi radialis, palmaris longus and flexor digitorum superficialis—by direct branches from the trunk of the nerve.

2. to the flexor pollicis longus, lateral half of flexor digitorum profundus which sends tendons to the index and middle fingers, and pronator quadratus by the anterior interosseous nerve. The anterior interosseous nerve arises from the median nerve just distal to pronator teres and descends in front of interosseous membrane (accompanied by anterior interosseous artery) between the flexor pollicis longus and flexor digitorum profundus and passes deep to pronator quadratus.

In the palm—to five intrinsic muscles: abductor pollicis brevis, flexor pollicis brevis, opponens pollicis, first and second lumbricals.

Cutaneous branches

In the forearm—The palmar cutaneous branch arises just above the flexor retinaculum and supplies the central part of palm and the adjacent part of thenar eminence.

In the hand—The palmar digital nerves supply lateral three and one-half of the digits; digital branches to the thumb supply also the dorsal skin over the terminal phalanx, and those to the other fingers supply dorsal skin over the middle and terminal phalanges.

Articular branches—to the elbow, superior and inferior radio-ulnar, and wrist joints.

Vascular branches—Supply vaso-motor twigs to the axillary, brachial and other neighbouring arteries.

Summary of distribution

1. Median nerve supplies all muscles of the flexor compartment of the forearm, except flexor carpi ulnaris and medial half of flexor digitorum profundus.

2. It supplies five intrinsic muscles of the hand—three thenar muscles, and first and second lumbricals.

3. It supplies the palmar aspect of the hand and lateral three and a half of the digits including the distal portions of dorsum of these digits.

4. Median nerve is called the labourer’s nerve since it supplies most of the large flexor muscles of the forearm.

Applied anatomy

Manifestations due to median nerve involvement depend on the sites of lesion.

1. (a) When the nerve is divided above its muscular and anterior interosseous branches, there is loss of flexion of second phalanges of all digits due to paralysis of flexor digitorum superficialis, and loss of flexion of terminal phalanges of index and middle fingers because of paralysis of lateral half of flexor digitorum profundus.

   (b) The thumb remains extended and adducted, due to unopposed actions of extensors pollicis longus and brevis, and adductor pollicis.
Cutaneous sensation is lost on the palmar surfaces of lateral three and a half of the digits and the dorsal surfaces of the same digits over the middle and distal phalanges, except in the thumb where it affects the dorsal surface of terminal phalanx only.

(d) There is loss of movements of the three intrinsic thenar muscles and wasting of thenar eminence. This is associated with unopposed action of extensor pollicis longus, which resembles an ape-like hand.

2. When the nerve is injured at the middle of the forearm, the branch of flexor digitorum superficialis to the index finger may be involved. This may be associated with weakness of flexion of index finger, and the unopposed extension of that finger is manifested by pointing index finger.

3. The median nerve is commonly compressed in the carpal tunnel due to any condition diminishing this space. This is manifested as the carpal tunnel syndrome by weakness and wasting of the thenar muscles with loss of power of opposition and loss of cutaneous sensations of the palmar surface involving lateral three and a half of the digits.

4. Tests for median nerve lesion—The most reliable sign is loss of abduction and opposition of the thumb. The patient will not be able to hold a paper between the thumb and index finger. Sensory loss is present but with subjective variation.

ULNAR NERVE

Formation—The ulnar nerve is formed in the axilla as a continuation of medial cord of brachial plexus and conveys fibres from C₇ and T₁. Often it receives a contribution from C₇ through the lateral root of median nerve; the fibres from C₇ supply the flexor carpi ulnaris.

Course and relations: After its formation the nerve passes downward along the medial side of third part of axillary artery in the interval between the axillary artery and its vein, where the medial cutaneous nerve of the forearm lies on a more anterior plane.

The ulnar nerve accompanies the medial side of brachial artery in the proximal half of the arm.

Near the middle of the arm, the nerve pierces the deep brachial fascia, medial intermuscular septum along with intrinsic muscles, and passes over the superior ulnar collateral artery, descends between the ulnar head of the triceps and flexor digitorum profundus, and appears in the interval between the medius deep flexor tendon and olecranon. Here the nerve lodges in a groove on the dorsal surface of the triceps brachii. It is related to the base of the olecranon, on a triangulation projection of diaphysis at the lower end of the humerus.

The nerve enters the forearm between the two heads of extensor carpi ulnaris and lies superficial to the posterior and oblique bands of the collateral ligament. It descends along the medial side of the flexor digitorum profundus and is overlapped by the flexor carpi ulnaris; here it is separated from the ulnar side of the ulna artery by a considerable interval. In the lower two-thirds of the forearm the nerve becomes more superficial and is covered by skin and fascia and runs along the lateral side of flexor carpi ulnaris; here it is accompanied by the ulnar artery on its radial side.

Both the ulnar nerve and its companion artery pass distally superficial to the flexor retinaculum and on the radial side of the pisiform bone. On reaching the proximal part of hypotenar eminence the nerve passes beneath the palmaris brevis and divides into superficial and deep terminal branches.

The superficial terminal branch supplies the palmaris brevis and subcutaneous branch of the palmar digital nerve and a lateral common palmar digital nerve. The proper digital nerve supplies the ulnar side of the little finger. The common digital nerve receives a communicating branch from the nearest palmar digital branch of median nerve and then divides into branches to supply the adjacent sides of the little and ring fingers. The digital nerves supply the palmar aspect of the medial one and a half of fingers as well as dorsal surfaces of the middle and terminal phalanges of the fingers and only the terminal palanx of the little finger.

The deep terminal branch passes deeply between the abductor and flexor digiti minimi. It pierces the opponens digiti minimi and turns laterally lodging in a groove below the hook of the hamate bone. It passes beneath the long flexor tendons and occupies the concavity of the deep palmar arch. In its course,

Muscular branches—In the forearm the ulnar nerve gives off three branches to the flexor muscles of the forearm, except the second lumbrical of the index finger.

Cutaneous branches—In the forearm the ulnar nerve gives off two cutaneous branches, one to the hypothenar eminence and the other from the hypotenar eminence to the ulnar side of the pisiform bone.

ARTERIES

Arterial twigs to the ulnar nerve arise from the ulnar artery at the fascial line of the forearm and from the anterior branch of the deep ulnar artery.

VASCULAR SUPPLY

Notable peripheral nerve cells contain ganglia for the ganglionated plexus.
the deep branch of ulnar nerve supplies the three intrinsic muscles of hypothenar eminence, third and fourth lumbricals, all dorsal and palmar interossei, adductor pollicis and occasionally gives a twig to the deep fibres of flexor pollicis brevis. It also supplies the intercarpal, carpometacarpal and metacarpophalangeal joints.

**Branches of ulnar nerve**—These are muscular, cutaneous, articular and vascular.

**Muscular branches**

**In the forearm**—To the flexor carpi ulnaris at the elbow, and medial half of the flexor digitorum profundus which gives rise to the tendons of the ring and little fingers.

**In the hand**—All intrinsic muscles of the hand, except the three thenar muscles and first and second lumbricals.

**Cutaneous branches**

**In the forearm**—

(a) A **dorsal branch** arises about 5 cm above the wrist. It passes deep to the tendon of flexor carpi ulnaris, pierces the deep fascia and appears along the medial side of the dorsum of the hand, where it divides usually into two dorsal digital nerves to supply the dorsal aspect of the medial one and a half of the fingers, excluding the distal two phalanges of the ring finger and terminal phalanx only of the little finger.

(b) A **palmar cutaneous branch** arises proximal to the flexor retinaculum, ramifies over the ulnar artery to provide vascular branches, pierces the deep fascia and supply the skin of the medial aspect of the palm.

**In the palm**—(See before)

**Articular branches**—to the elbow, intercarpal, carpometacarpal joints.

**Vascular branches**—It provides vasomotor twigs to axillary, brachial, ulnar arteries and deep palmar arch.

*Note*: Vascular branches conveyed by the peripheral nerves of brachial plexus are derived from the post-ganglionic sympathetic fibres from the inferior cervical and first thoracic ganglia. The preganglionic vaso-motor fibres for the upper limb arise from the lateral horn cells of T5–T7 segments of spinal cord.

**Summary of distribution**

(a) It supplies flexor carpi ulnaris, medial half of flexor digitorum profundus, all intrinsic muscles of hand, except the three thenar muscles and first and second lumbricals.

Since most of the intrinsic muscles of hand are used by a violinist, the ulnar nerve is called the **musician’s nerve**.

(b) It supplies the skin of the medial one and a half of the fingers.

**Applied anatomy**

The common sites of compression or division of the ulnar nerve are: behind the medial epicondyle producing **cubital tunnel syndrome**; at the wrist between the pisiform and the flexor retinaculum; below the hook of hamate bone.

1. In **cubial tunnel syndrome** manifestations are as follows:

(a) On attempting to flex the wrist, the hand is **abducted** due to unopposed action of flexor carpi radialis.

(b) Medial four fingers cannot be **abducted** and **adducted** due to paralysis of dorsal and palmar interossei. Due to similar reasons the fingers are **extended** at the metacarpophalangeal joints by the action of common digital extensors and this results in passive flexion of the inter-phalangeal joints.

**Claw hand** is a condition seen in ulnar nerve injury in which the medial two fingers are extended at the metacarpophalangeal joints and partially flexed at the interphalangeal joints.

(c) The thumb cannot be **adducted** due to paralysis of adductor pollicis.

(d) There is **wasting of hypothenar muscles**, and loss of sensation of the medial one and a half of digits and the adjoining medial side of the hand.

2. Manifestations of ulnar nerve involvement at or below the wrist are almost same as the previous one, except the following:

(a) Adduction and abduction of the wrist will not be affected.

(b) The condition of **claw hand** becomes more visible because nerve supply to the flexor
digitorum profundus is spared. As a result the extension of the metacarpophalangeal joint is associated with active flexion of the interphalangeal joints of the medial two digits. This is known as ulnar paradox in which a more proximal injury of the ulnar nerve at the elbow appears to produce lesser degree of claw hand than at the wrist.

3. Test for ulnar nerve lesion—The patient will not be able to hold a sheet of paper between index and middle fingers.

The patient will not be able to adduct and abduct the medial four digits, while placing the flat hand on a table.

RADIAL NERVE

(See Figs. 6.2, 6.4, 6.7, 8.2, 9.3, 9.5, 9.6, 9.7, 10.1, 10.8, 11.16, 11.17)

Formation: The radial nerve is the largest branch of brachial plexus and begins in the axilla as a continuation of the posterior cord, just distal to the origin of axillary nerve. It conveys fibres from the dorsal branches of the ventral rami of C₅, C₆, C₇, C₈ and T₁, and is a nerve of extensor compartments of the arm and forearm.

Course and relations—After its formation, the nerve descends behind the third part of axillary artery and proximal part of brachial artery, and in front of subscapularis, latissimus dorsi and teres major in the posterior wall of axilla.

Accompanied by the arteria profunda brachii, the nerve inclines dorsally through a triangular space which is bounded above by the teres major, medially by the long head of the triceps and laterally by the humeral shaft. The nerve along with its companion artery enters the spiral groove on the dorsal surface of the humerus between the long and medial heads of the triceps. In the spiral groove it passes downward and laterally in naked contact with the bone, between the lateral and medial heads of triceps. It pierces the lateral intermuscular septum and enters the anterior compartment of lower arm, where the nerve descends in an intermuscular interval between the brachioradialis and extensor carpi radialis longus laterally, and the brachialis medially. On reaching the front of lateral epicondyle about 1 cm lateral to biceps tendon, the nerve divides into superficial and deep terminal branches.

The superficial terminal branch is essentially sensory and runs downward along the lateral aspect of the front of forearm. It lies under cover of the brachioradialis and rests successively on supinator, pronator teres, flexor digitorum superficialis and flexor pollicis longus; in the middle-third of forearm the nerve is related to the radial artery on its medial side. About 7 cm above the wrist it passes deep to the tendon of brachioradialis, winds round the lateral side of radius, and pierces the deep fascia. The nerve descends over the abductor pollicis longus, extensor pollicis brevis and longus, and appears in the dorsum of hand superficial to the extensor retinaculum. Subsequently it divides usually into five dorsal digital nerves to supply the lateral two-thirds of the dorsum of hand and the dorsal aspect of lateral three and a half of digits, excluding the terminal and sometimes middle phalanges of these digits which are supplied by the digital branches of median nerve.

The deep terminal branch known as the posterior interosseous nerve is a mixed nerve but essentially motor. It winds round the lateral side of radius between superficial and deep strata of the supinator, and then descends in the back of the forearm between superficial and deep groups of extensor muscles. Before piercing the supinator the posterior interosseous nerve provides its first branch to the extensor carpi radialis brevis and then to the supinator which also receives additional supply from the same nerve while passing through the muscle.

In the back of the forearm the nerve divides into three short and two long branches. The short branches supply the extensor digitorum, extensor digiti minimi and extensor carpi ulnaris. The long branches subdivide into lateral and medial divisions. The lateral division supplies abductor pollicis longus and extensor pollicis brevis; the medial division supplies extensor pollicis longus and extensor indicis. Finally the nerve presents a terminal pseudo-ganglion at the back of the wrist and supplies the neighbouring joints.

Branches: The radial nerve presents four types of branches—muscular, cutaneous, articular and vascular. But for the purpose of description these are described region by region.

Branches in the axilla—It provides three branches, two muscular and one cutaneous.
1. A branch to the long head of triceps;

2. A branch to the medial head of triceps. It passes beneath the deep fascia of the arm and accompanies behind the ulnar nerve; hence known as **ulnar collateral nerve**.

3. **Posterior cutaneous nerve of the arm**—It pass medial to the long head of triceps pierces the deep fascia and supplies the skin of the dorsal surface of the arm up to the olecranon process.

**Branches in the spiral groove**—These are muscular, articular and cutaneous.

1. **Muscular branches** supply lateral and medial heads of triceps. Nerve to the medial head is a long branch which descends through the substance of the muscle, gives *articular twigs* to the elbow joint and ends by supplying anconeus muscle.

2. **Posterior cutaneous branch of the forearm** pierces the lateral head of triceps and passes straight downward behind the elbow to supply the skin of the dorsal surface of forearm as far as the wrist.

3. **Lower lateral cutaneous nerve of the arm** pierces the lateral head of triceps and supplies the skin of the lateral side of the lower half of the arm.

**Branches in the lower part of arm**—These are all *muscular*, and supply the brachioradialis, extensor carpi radialis longus and the lateral part of the brachialis.

**Superficial terminal branch**—(See before)

**Deep terminal branch**—(See before)

**Summary of distribution**—The radial nerve supplies all extensor muscles of arm and forearm, and the skin on the dorsal aspect of the proximal parts of the lateral three and a half digits including the lateral two-thirds of the dorsum of the hand.

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**Applied anatomy**

The radial nerve is often injured in fracture of the humerus in the region of spiral groove or by the pressure of a crutch in the axilla. Compression of the nerve against the spiral groove by placing the outstretched arm on an arm-chair under drunken condition, may be associated with temporary radial nerve palsy; this is known as *saturday night palsy*.

1. When paralysed, the hand becomes flaccid and is flexed at the wrist, producing *wrist drop*.

2. The digits are flexed at the proximal phalanges, but the middle and terminal phalanges may be extended by the actions of lumbricals and interossei.

3. Extension of the elbow is lost when the triceps is paralysed.

4. Loss of cutaneous sensation on the dorsum of hand will affect a relatively small area due to overlapping of the adjacent dermatomes.
Joints of the shoulder girdle

The shoulder or pectoral girdle connects the bones of the upper limb with the axial skeleton. The girdle consists of clavicle and scapula. The clavicle meets the sternum at the sternoclavicular joint, and unites with the scapula at the acromio-clavicular joint. The scapula has no direct connection with the axial skeleton, but is attached to the latter only by the muscles. The glenoid cavity of the scapula articulates with the head of humerus to form the shoulder joint.

The joints of the shoulder girdle, sternoclavicular and acromio-clavicular, always permit the movements of clavicle and scapula. Moreover, they facilitate the movements of the shoulder joint in raising the arm above the head (see later).

STERNO-CLAVICULAR JOINT

It is a saddle type of synovial joint.

Bones forming the joint

1. Sternal end of the clavicle, which is covered by a fibro-cartilage; the articular surface is convex from above downward and slightly concave from before backward (Fig. 13.1).

2. Clavicular notch of manubrium sterni and upper surface of the first costal cartilage form a continuous articular surface covered by fibro-cartilage.

The clavicular articular surface is more extensive than the sternal notch, and the two surfaces are not perfectly congruent. An articular disc divides the joint cavity into two compartments.

Ligaments

1. The capsular ligament envelopes the joint and is attached to the peripheral margins of the articulating bones. The capsule is thickened in front and behind by the anterior and posterior sternoclavicular ligaments; below it is composed of loose areolar membrane.

2. The fibres of anterior and posterior sternoclavicular ligaments slope downward and medially, and resist medial displacement of clavicle.

3. The articular disc, made of fibro-cartilage, intervenes between the clavicle and the sternal notch. It is attached above to the postero-superior part of the sternal end of the clavicle, below to the first costal cartilage, and at the periphery blends with the fibrous capsule.

The disc divides the joint into a supero-lateral or menisco-clavicular compartment, and an infero-medial or menisco-sternal compartment. The capsule around the lateral compartment is more lax than that of medial compartment. The articular disc prevents medial displacement of clavicle when a force is applied to the shoulder region.

4. Interclavicular ligament stretches across the supra-sternal notch and connects the non-articular upper part of sternal ends of both clavicles. Some fibres gain attachment to the supra-sternal notch of manubrium.

5. Costo-clavicular ligament is attached below to the first costal cartilage and its rib, and above to a rough impression on the inferior surface close to the sternal end of clavicle. The ligament
consists of anterior and posterior laminae which fuse laterally; medially they are separated by a bursa and merge with the capsule. The fibres of the anterior lamella are directed upwards and laterally, and those of the posterior lamella upwards and medially.

The costo-clavicular ligament acts as a fulcrum for the translatory and rotatory movements of scapula.

Arterial supply—From internal thoracic and supra scapular arteries;

Nerve supply—From medial supra-clavicular nerve and nerve to the subclavious.

ACROMIO-CLAVICULAR JOINT

It is a plane synovial joint. Bones forming the joint are: the lateral end of the clavicle, and clavicular facet on the medial margin of the acromial process of scapula (Fig. 13.1).

Both bones possess small, oval articular surfaces which are covered with fibrocartilage. The clavicular facet faces laterally and downward to meet the acromial facet which is inclined in opposite direction. Therefore, in dislocation of the joint the acromial process is driven below the lateral end of the clavicle. Sometimes the joint cavity is divided by an incomplete articular disc (meniscus) which projects from the upper part of the fibrous capsule.

Ligaments—The joint possesses fibrous capsule and coraco-clavicular ligament.

The fibrous capsule envelopes the joint and is attached to the periphery of the articular surfaces of both bones. The capsule is thickened above to form the acromio-clavicular ligament.

The coraco-clavicular ligament suspends the scapula from the lateral third of the clavicle and forms a strong bond of union between them, subserving the function of fibrous joint (syndesmosis). It consists of conoid and trapezoid parts.

The conoid part is an inverted cone. Its apex is attached to the root of coracoid process above the supra-scapular notch, and its base is attached to the conoid tubercle on the undersurface of the clavicle at the junction of the medial two-thirds and lateral one-third of the bone.

The trapezoid part lies antero-lateral to the conoid part and quadrilateral in outline. It is attached below to the upper surface of the coracoid process and above to the trapezoid ridge on the undersurface of the lateral third of the clavicle. The anterior border of the trapezoid part is free and horizontal, and its posterior border meets the conoid part at an angle directed in front.

The weight of the upper limb is transmitted to the medial two-thirds of the clavicle and thence to the axial skeleton through the coraco-clavicular ligament.

Arterial supply—From suprascapular and thoraco-acromial arteries;

Nerve supply—From suprascapular and lateral supraclavicular nerves.

Movements of the shoulder girdle

Both acromio-clavicular and sterno-clavicular joints allow gliding (translatory) and rotatory movements of scapula, with associated clavicular excursion.

The scapular gliding includes elevation and depression, protraction and retraction; the scapular rotation may be forward or backward as expressed by the movements of inferior angle of scapula.

Elevation of scapula—This is observed in 'shrugging' the shoulder, and produced by the contraction of the upper part of trapezius and levator scapulae (Fig. 13.2).

![Fig. 13.2. Elevation and depression of Scapula.](image)

Mechanism: When the muscles contract, slight upward swing of the clavicle takes place at the acromio-clavicular joint. This is associated with downward rotation of the sternal end of the clavicle above the articular disc in the menisco-clavicular compartment around an antero-posterior axis which passes through the clavicle above the medial attachment of the costo-clavicular ligament.

The downward movement of the clavicular sternal end is checked by: tension of antagonist muscles, tension of the costoclavicular ligament, and lower part of fibrous capsule.

Depression of scapula—This is usually brought about by the weight of the upper limb,
but can be actively produced by the lower part of serratus anterior and pectoralis minor.

**Mechanism**—During depression, the sternal end of clavicle is rotated upward above the articular disc in the menisco-clavicular compartment around the same axis as observed in scapular elevation.

Upward movement of the sternal end is checked by: tension of antagonist muscles, inter clavicular and sterno-clavicular ligaments and articular disc. It appears, therefore, that the inter-clavicular ligament suspends the depressed clavicle.

**Protraction or forward movement** of scapula—This takes place in pushing or punching movement in which the scapula glides forward around the chest wall. The muscles concerned are serratus anterior and pectoralis minor which maintain a continuous apposition of the medial border of scapula in contact with the chest wall; this is assisted by the upper part of latissimus dorsi which acts as a strap over the inferior angle of scapula (Fig. 13.3).

![Fig. 13.3. Protraction and retraction of Scapula.](image)

**Mechanism**—In protraction, the lateral end of clavicle along with the acromial process advances forward to a limited extent. This is associated with a backward swing of the sternal end of clavicle along with the articular disc in the menisco-sternal compartment of the sterno-clavicular joint. The movement takes place around a vertical axis which passes through the medial attachment of costoclavicular ligament.

Backward translation of the sternum is checked by: tension of antagonist muscles, anterior sterno-clavicular and posterior lamina of costo-clavicular ligaments.

Retraction of scapula—It is reverse to the mechanism of protraction and produced by the middle portion of trapezius and the rhomboids.

Here forward swing of the clavicle at the sternoclavicular joint is checked by: tension of antagonist muscles, posterior sternoclavicular and anterior lamina of costo-clavicular ligaments.

Forward rotation of scapula—This movement is observed in elevation of the arm above the head, during abduction or flexion of the shoulder joint. It is manifested by the lateral swing of the inferior angle of scapula so that the glenoid cavity is directed almost vertically upward (Fig. 13.4).

Forward scapular rotation is produced by the upper and lower parts of the trapezius, and lower five digitations of serratus anterior.

**Mechanism**—During 180° overhead elevation of the arm in abduction, humerus moves 120° at the shoulder joint and scapula undergoes 60° forward rotation at the joints of shoulder girdle.

![Fig. 13.4. Forward rotation of Scapula and axial rotation of clavicle at sternoclavicular joint.](image)

The scapular rotation is initiated at the acromioclavicular joint. Further rotating is checked by the tension of coracoclavicular ligament; the rotating force is now transmitted to the sternoclavicular joint along the long axis of the clavicle. The clavicular rotation takes place in the meniscoclavicular compartment. Out of 60° of scapular rotation, the acromioclavicular joint permits 20° and the sternoclavicular joint remaining 40° (Inman et al, 1944).

**Backward or return rotation** of scapula—It restores the resting position by active lengthening of trapezius and serratus anterior, and assisted by the gravity.

The return rotation is actively produced during chopping wood by the pectoralis minor, levator scapulae and rhomboids.

In all scapular movements the clavicle is kept steady possibly by the contraction of subclavius muscle.
SHOULDER (GLENOHUMERAL) JOINT

It is a multi-axial ball-and-socket type of synovial joint, and possesses three degrees of freedom of movements.

The ball is represented by the spheroidal head of humerus, which forms one-third of a sphere. The head is directed medially, upward and backward, and covered by hyaline articular cartilage which is thickest in the centre and thinner at the periphery.

The socket is formed by the pear-shaped small and shallow glenoid cavity of scapula which faces laterally, upward and forward. Only one-third of the humeral head comes in contact with the glenoid cavity at any position. The narrow upper end of the glenoid cavity encroaches on the root of the coracoid process, where the supraglenoid tubercle provides intra-capsular origin of the long head of the biceps brachii. The anterior margin of the glenoid fossa is notched for the tendon of subscapularis. The fossa is covered by hyaline articular cartilage which is thin in the centre and thick at the periphery. The glenoid fossa is deepened by a fibro-cartilaginous rim of glenoidal labrum which is attached to its peripheral margin. The joint becomes close-packed with full congruence of the articulating bones in abduction and lateral rotation.

Ligaments—The shoulder joint presents the following ligaments (Fig. 13.5):

1. Fibrous capsule—It forms a loose envelope which permits free movements. Medially, it is attached to the peripheral margin of the glenoid cavity outside the labrum and includes the origin of the long head of biceps from the supra-glenoid tubercle. Laterally, the capsule is attached around the anatomical neck of humerus, except at two areas:
   (a) at the upper end of the intertubercular sulcus where the capsule is deficient for the passage of the tendon of the long head of the biceps;
   (b) infero-medially it extends about 1 cm below to encroach on the surgical neck of humerus.

The fibrous capsule is supported by expansions from the tendons of the following short muscles – in front, subscapularis; above, supraspinatus; behind, infraspinatus and teres minor. These four short muscles act as rotator cuff which subserves the functions of dynamic ligaments. The lower part of the capsule, however, is least supported and separated from the long head of the triceps by axillary nerve and posterior circumflex humeral vessels. Lower capsule is stretched in abduction and forms a common site for dislocation of the humeral head in violent abduction.

![Diagram of Shoulder Joint and its Ligaments](image)

Fig. 13.5. Shoulder joint and its ligaments.

The synovial membrane lines the capsule and is reflected along the intra-capsular part of the neck up to the articular cartilage of humeral head. A synovial sheath traverses within the joint along the tendon of long head of biceps brachii and extends to the intertubercular sulcus upto the surgical neck of humerus (Fig. 13.6). In addition, through the openings of fibrous capsule the joint cavity communicates in front with the subscapular bursa, and occasionally behind with the infraspinatus bursa.

2. Gleno-humeral ligaments—These are three fibrous bands derived from the thickening of the anterior part of fibrous capsule and can be seen from within the joint. All gleno-humeral ligaments converge upward and medially to the superomedial margin of the glenoid cavity and blend with the glenoidal labrum.

The superior band lies parallel to the anterior edge of biceps tendon and is attached to the upper end of the lesser tubercle of humerus. The middle band is attached to the lower part of lesser tubercle, and the subscapular bursa communicates with the joint cavity between the superior and middle bands. The inferior band gains attachment to the lower part of anatomical neck of humerus.

3. Glenoidal labrum—It is a fibro-cartilaginous rim, triangular on cross-section, and attached to the peripheral margin of the glenoid
cavity except above, where the long head of biceps tendon monopolarises the supraglenoid tubercle. The labrum deepens the glenoid fossa and forms a pliable cushion for the ball to roll.

4. Coraco-humeral ligament—It is a thick band in the upper part of fibrous capsule and extends from the lateral border of the coracoid process to the anatomical neck of humerus between the greater and lesser tubercles. The ligament resists the lateral rotation and adduction.

5. Transverse humeral ligament—It connects the two lips of the upper part of the intertubercular sulcus, and acts as a retinaculum to keep the long tendon of the biceps in position.

When the arm is pendent, the long tendon of biceps passes across the front of the head of humerus. In lateral rotation of humerus, the tendon occupies the summit of the humeral head and helps abduction by preventing the upward displacement of the head.

Stability of shoulder joint—The laxity of the fibrous capsule, and small and shallow glenoid cavity permit greater range of mobility, sacrificing stability of the joint.

The stability is, however, maintained by the following factors:

(a) Supraspinatus and tension of the upper part of the capsule and coraco-humeral ligament prevent the downward displacement of the humerus.

(b) Four short muscles around the joint—subscapularis, supraspinatus, infraspinatus and teres minor—blend with the fibrous capsule and act as musculo-tendinous rotator cuff, the tonic contraction of which keeps the ball in contact with the socket (guardian of the joint).

(c) In abduction of humerus, the lower weak part of the capsule is supported by the long head of triceps and the teres major.

(d) The glenoidal labrum deepens the socket and prevents skidding of the ball from its socket.

(e) Upward displacement of the humeral head is prevented by the long tendon of biceps and by the coracoacromial arch.

The coraco-acromial arch is formed by the coracoid and acromial processes of the scapula connected by a triangular coracoacromial ligament, which extends from the tip of the acromion to the lateral border of the coracoid process. The arch is separated from the supraspinatus muscle by an extensive subacromial bursa which acts as a secondary socket for the head of humerus and allows lateral rotation of humerus in raising the arm above the head, when the greater tubercle impinges on the lateral border of the coraco-acromial arch.

Relations of the joint (Fig. 13.7):

Above—Supraspinatus, subacromial bursa and coraco-acromial arch;

Below—Quadrangular space transmitting axillary nerve and posterior circumflex humeral vessels, long head of the triceps;

In front—Subscapularis, coracobrachialis and short head of the biceps;
Behind—Infraspinatus and teres minor;  
Within the capsule—Long head of biceps tendon.

Deltoid muscle covers the joint in front, behind and laterally.

Bursae in relation to shoulder joint

1. **Subscapular bursa** intervenes between the tendon of subscapularis and the fibrous capsule and communicates with the joint cavity through an oval gap between the superior and middle glenohumeral ligaments.

2. **Infraspinatus bursa**, sometimes communicates with the joint from behind.

3. A **synovial sheath** around the long tendon of biceps extends from the joint along the intertubercular sulcus upto the surgical neck of humerus.

4. **Subacromial bursa** intervenes between the supraspinatus and coraco-acromial arch, and extends further laterally between the deltoid and the greater tubercle of humerus. It does not communicate with the joint. It acts as secondary socket to allow the lateral rotation of humerus during over-head elevation of the arm.

5. A number of non-communicating bursae may be found in the following areas:
   (a) Above the acromial process;
   (b) Between the capsule and the coracoid process;
   (c) Behind the coracobrachialis;
   (d) Between the teres major and long head of triceps;
   (e) In front and behind the tendon of latissimus dorsi.

Arterial supply—From anterior and posterior circumflex humeral, and suprascapular arteries.

Nerve supply

1. **Axillary (circumflex) nerve**, supplying lower and anterior part;
2. **Suprascapular nerve**, in the upper and posterior part;
3. **Lateral pectoral nerve**, in the upper and anterior part.

Movements

Active movements permitted at the shoulder joint are: flexion and extension, abduction and adduction, circumduction, medial and lateral rotations. These movements are combinations of spin and swing.

The humeral movements are analysed with reference to the body of scapula, unlike the conventional planes of the trunk.

The **flexion and extension** take place at right angles to the plane of the body of scapula **around an axis** which passes through the humeral head and perpendicular to the centre of the glenoid.
cavity. Flexion moves the arm forward and medially, and extension backward and laterally (Fig. 13.8a).

The abduction and adduction take place parallel to the plane of the body of scapula around an axis which passes through the head of humerus and parallel to the glenoid cavity. Therefore, abduction carries the arm laterally and forward and adduction medially and backward.

The circumduction is a succession of the above mentioned four movements in an order, so that the distal end of the humerus describes the base of the cone and the humeral head forms its apex.

The medial and lateral rotations take place around a vertical axis which extends from the centre of the humeral head to the centre of capitulum. Humeral rotation is tested after flexing the elbow joint in order to avoid confusion from supination and pronation of forearm. Medial rotation carries the hand medially, and lateral rotation moves the hand outwards.

Muscles producing movements

Flexion—Clavicular head of pectoralis major, anterior fibres of deltoid, assisted by coraco-brachialis and biceps brachii;

Extension—Posterior fibres of deltoid and teres major;

From full flexion, extension up to the coronal plane is mainly done by the latissimus dorsi and sterno-costal head of pectoralis major.

Abduction (Fig. 13.8b)—It is a complex movement, and is performed by the conjoint actions of prime movers and synergists.

Prime movers are middle fibres of deltoid and supraspinatus. Some authorities believe that supraspinatus initiates abduction, because if the tendon is torn, abduction is impossible unless the patient tilts the body towards the injured side so that the arm is abducted away from the trunk by gravity, after which the deltoid can maintain abduction. Inman et al (1944), however, shows clearly from the study of action potential curves that both muscles act together.

![Diagram showing the shoulder joint with muscles](image)

Fig. 13.8 (b) Abduction at shoulder joint by the muscles of couple force.

Synergists include subscapularis, infraspinatus and teres minor. When the middle fibres of deltoid contract, humeral head tends to skid upward from its socket and the greater tubercle might impinge on the under surface of acromial process, producing hindrance to abduction. To counter-act such tendency, the aforesaid three muscles act synergistically and keep the humeral head in contact with its socket by exerting traction downward and medially. As a result, the conjoint actions of five muscles exert a couple force and produce real abduction.

The range of abduction is only 60° when the humerus is rotated medially. Its range is increased to about 90°, when the humerus moves in the plane of the body of scapula. The abduction range is further increased to about 120°, when the humerus rotates laterally by the contraction of infraspinatus and teres minor in the subacromial bursa on the undersurface of the coraco-acromial arch.
Adduction—Anterior and posterior fibres of the deltoide, pectoralis major, teres major, latissimus dorsi, coracobrachialis and long head of triceps.

Medial rotation—Anterior fibres of deltoide, pectoralis major, teres major, latissimus dorsi and subscapularis.

Lateral rotation—Infraspinatus, teres minor and posterior fibres of deltoide.

Spinal cord segments regulating shoulder movements—\(C_4, C_5, C_7, C_8\).

(Flexion, abduction and lateral toation \(C_5, C_6\).)

(Extension, adduction and medial rotation—\(C_6, C_7, C_8\)).

Mechanism of elevation of arm above the head

Elevation of arm through 180° from dependent position to vertical position can take place in abduction or in flexion.

Elevation in abduction—Out of total 180° elevation, humerus moves 120° at the shoulder joint and the remaining 60° is done by the scapula at the joints of shoulder girdle. In every 15° elevation, shoulder joint contributes 10° and girdle joints 5°, in the ratio of 2:1. The ‘scapulo-humeral rhythm’ starts concurrently, except in the initial 25°–30° when only humerus moves at the shoulder joint (Inman et al, 1944) (Fig. 13.9–a, b).

Abduction is performed by the couple force of five muscles: two as prime movers, deltoide (middle fibres) and supraspinatus; three as synergists—subscapularis, infraspinatus and teres minor (see earlier). Abduction in scapular plane is restricted to about 90°. Further abduction of 30° (with a total range of 120°) is made by lateral rotation of humerus, in order to overcome impingement of greater tubercle against the acromial process and to bring more available articular surface of humeral head for moving over the glenoid fossa. Infraspinatus and teres minor perform the lateral rotation. At this stage, the long tendon of biceps helps abduction.

Scapular movement contributes 60° of elevation; it takes place at both acromioclavicular and sternoclavicular joints. According to Kapandji (1974), scapular rotation consists of initial elevation of the acromial end of clavicle, followed by axial rotation of clavicle.

Elevation of the clavicle ranges about 30°. Acromioclavicular joint permits slight elevation, but the main movement takes place by downward swing of the sternal end of clavicle at the meniscoclavicular compartment of sternoclavicular joint. Muscles for elevation are upper fibres of trapezius and levator scapulae.

Further elevation is checked by the tension of coracoclavicular ligament. Eventually, the scapular rotation is associated with axial rotation of clavicle at the sternoclavicular joint permitting further 30° elevation. This allows the glenoid cavity to face vertically upward. The scapular rotation is performed by the contraction of upper and lower fibres of trapezius along with the lower five digitations of serratus anterior; the middle fibres of trapezius stabilize the scapula during abduction. [Observe the difference of views of

![Fig. 13.9. Scapular rotation during elevation of arm above the head in abduction.](image)
scapular movements by Inman et al (1944) and Kapandji (1974).

**Elevation in flexion**—Full flexion of humerus at right angle to the scapular plane ranges about 90°. Further elevation is not possible, unless the flexed humerus abducts to reach the scapular plane.

However, elevation of flexed humerus in sagittal plane becomes full and straight without lateral rotation of humerus.

**APPLIED ANATOMY**

1. **Dislocation** of the shoulder joint is common, due to laxity of the ligaments and disproportionate articular surfaces. Initially the dislocation is inferior or sub-glenoid, and this is followed by sub-coracoid, sub-clavicular or in other areas. The **axillary nerve** may be affected in inferior dislocation.

2. Sometimes **recurrent dislocation** takes place anteriorly through a tear in the antero-inferior part of glenoidal labrum (Bankart lesion) or due to shortening of subscapularis tendon by fibrosis. In recurrent dislocation the patient is occasionally able to reduce his own dislocation.

3. **Painful arc syndrome**—It is characterised by a chronic thickening of the tendon of the supraspinatus in which pain is experienced between 60° and 120° abduction, resulting from the impingement of the tendon against the coraco-acromial arch.

4. **Frozen shoulder**—This results from tendinitis involving entire rotator cuff. Eventually all shoulder movements are restricted due to adhesions.

5. In **arthrodesis** of shoulder (Surgical fixation), the optimum position is about 45° abduction and 20° flexion. Partial abduction allows the arm to be brought to the side by the movements of scapula.

6. In **ankylosis** of shoulder joint due to osteoarthritis, joint replacement by metallic prosthesis is now made successfully. Such replacement can be carried out as a hemiarthroplasty in which joint surface of the humerus only is replaced, or as a total arthroplasty in which glenoid surface is also replaced.

**ELBOW JOINT**

It is a compound joint and consists of **humero-ulnar** and **humero-radial** parts; the latter is continuous with the **superior radio-ulnar joint**. All the three components possess one synovial cavity and are collectively known as **cubital articulation** (Fig. 13.10a). But for functional consideration, the elbow joint is restricted to the humero-ulnar and humero-radial parts and basically forms a **hinge joint**, permitting flexion and extension.

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**Fig. 13.10(a) Frontal view of elbow joint.**

**Humero-ulnar part** (Fig. 13.10b)—It is formed by the articulation between the **trochlea** of humerus and the **trochlear notch** of ulna.

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**Fig. 13.10(b) Lateral view of elbow joint.**
The trochlea resembles a pulley, is set obliquely and lies on a more anterior plane than the shaft of the bone. A spiral groove divides it into medial and lateral flanges. Posteriorly the trochlea is wider and more symmetrical. Anteriorly its medial flange is more broad and the projecting medial edge lies about 6 mm below the lateral edge. As a result the humero-ulnar joint is of hinge variety, but the plane of the joint slopes downward and medially about 2 cm distal to the intercondylar line. Just above the trochlea, the lower end of humerus presents two non-articular depressions – coronoid fossa in front, and deeper and triangular olecranon fossa behind. The coronoid fossa accommodates the anterior margin of the ulnar coronoid process in flexion; the tip of the olecranon process of ulna occupies the olecranon fossa in extension.

The trochlear notch of ulna is reciprocally saddle-shaped and formed by the articular surfaces of olecranon and coronoid processes, separated by a non-articular narrow strip. The notch is not perfectly congruent with the trochlea. In full extension the medial part of the articular surface of olecranon process is not in contact with the trochlea; similarly a narrow lateral strip of olecranon process loses contact in flexion.

Humero-radial part—Structurally, it is ball and socket type. The ball is represented by the capitulum of humerus which is articular in front, and below. The disc-like concave upper surface of the head of radius forms its socket. The radial head comes in contact with the lower surface of capitulum in extension and rotates on its anterior surface during flexion; in full flexion peripheral rim of the head lodges in a depression, radial fossa, above the capitulum. The margin of the disc-like head fits in a groove along the lateral lip of trochlea; this prevents the medial displacement of the radius.

Ligaments of elbow joint—It possesses capsular ligament, ulnar and radial collateral ligaments.

Capsular ligament—The fibrous capsule envelopes the joint completely. It is thin in front and behind to permit flexion and extension, and is thickened at the two sides in the form of collateral ligaments in order to provide stability of the joint.

Proximally, the fibrous capsule is attached to the lower end of humerus in a continuous line, which excludes the two epicondyles but includes the three fossae to gain attachments along the upper margins of the coronoid and radial fossae, and falling short of upper limit of olecranon fossa. Distally, it is attached to the margins of the trochlear notch and blends with the annular ligament of the superior radio-ulnar joint (Fig. 13.10-a, b).

**Fig. 13.11. Medial profile of elbow joint.**

The synovial membrane lines the inner surface of fibrous capsule and the bones within the capsule including the three fossae and extends up to the periphery of articular cartilage. Cushions of extra-synovial fat fill up the three fossae. A crescentic synovial fold projects partially from behind between radius and ulna. The synovial membrane bulges below the lower free margin of annular ligament and surrounds the neck of radius as a blind pouch (see later).

**Ulnar collateral** (Medial) ligament—It is triangular in shape and extends from the lower part of medial epicondyle to the medial margin of trochlear notch. The ligament consists of three bands—anterior, posterior and inferior (Fig. 13.11). The anterior band is attached to a tubercle on the medial margin of the coronoid process; the posterior band is attached to the medial margin of olecranon process; the inferior band extends obliquely between the olecranon and coronoid processes, and forms a foramen between the band and the trochlear notch through which the extra-capsular fat is continuous with the intra-capsular fat. The intermediate fibres extending from the medial epicondyle fill up the interval between the three bands.
The medial ligament is overlapped by the triceps, flexor carpi ulnaris and flexor digitorum superficialis, and is closely related with ulnar nerve.

**Radial collateral (Lateral) ligament**—It forms a triangular expansion and extends from the lateral epicondyte to the annular ligament. It is intimately related to the supinator and extensor carpi radialis brevis muscles (Fig. 13.12).

![Fig. 13.12. Lateral profile of elbow joint.](image)

**Relations of elbow joint**

**In front**: Brachialis, tendon of biceps, median nerve and brachial artery;

**Behind**: Triceps and anconeus;

**Medially**: Common origin of superficial flexor muscles of forearm, flexor carpi ulnaris and ulnar nerve;

**Laterally**: Common origin of superficial extensor muscles of forearm, supinator, extensor carpi radialis brevis, radial nerve and its superficial and deep branches.

**Bursae in relation to the joint**—

1. Above the olecranon, between the triceps tendon and capsule of the joint;

2. A subcutaneous bursa on the dorsal triangular surface of olecranon process;

3. Between the biceps tendon and the smooth anterior part of radial tuberosity.

**Arterial supply**—From numerous peri-articular branches derived from the anastomosis around the elbow.

**Nerve supply**—The joint is mainly supplied by:

1. **Musculo-cutaneous nerve** supplies the anterior part of capsule through the branch to the brachialis.

2. **Radial nerve** to the posterior and lateral part of the capsule through the nerve to anconeus and the ulnar collateral branch;

3. **Ulnar nerve** to the ulnar collateral ligament.

**Movements**—The chief movements at the elbow joint are flexion and extension. Since the axis of the humero-ulnar joint is not truly transverse but slopes medially and downward, the ulna not only swings in flexion-extension movements but also undergoes slight conjunct rotation. The ulna is slightly pronated in extension and supinated in flexion.

The range of **flexion** is about 150°, and is limited only when the flexor surfaces of the arm and forearm approximate. **Hand to mouth movement** consists of flexion at the elbow, and medial rotation at the shoulder joint or pronation of the radius at the radio-ulnar joints.

**Full extension** at the elbow is reached when the arm and the forearm assume a straight line. Extension makes the joint **close-packed** and is limited by the tension of the anterior part of the capsule and the muscles in front of the joint along with the accommodation of the tip of the olecranon in the olecranon fossa.

![Fig. 13.13. Carrying angle.](image)

**Carrying angle** (Fig. 13.13)—When the elbow is fully extended and the forearm supinated, the arm and the forearm form an obtuse angle which is open on the lateral side. This is known as **carrying angle** which measures about 163°, so that the ulnar border of the forearm does not come in close contact with the lateral surface of the thigh and this facilitates to carry a heavy object grasped by the hand. The carrying angle varies considerably in different individuals, but does not show much differences between males and
females. The angulation is caused partly by the medial edge of the trochlea projecting below the lateral edge and partly by the obliquity of the superior articular surface of the coronoid process. The carrying angle disappears when the elbow is flexed and the forearm pronated.

**Muscles producing movements**

**Flexion**—Brachialis, biceps brachii and brachioradialis; chief flexor muscle is brachialis. The biceps acts best when the forearm is supinated and acts as spurt muscles; the brachioradialis acts best in mid-prone position and represents a shunt muscle. In flexion against resistance, pronator teres and flexor carpi radialis come into play.

**Extension**—Triceps, anconeus and assisted by gravity.

**Spinal segments** controlling movements

- Flexion — C₅ and C₆;
- Extension — C₇ and C₈.

**Applied anatomy**

1. **Supra-condylar fracture** of humerus is common in children, and usually occurs due to a fall on the outstretched hand. The lower fragment is often tilted backward, and the sharp edge of the anteriorly displaced upper fragment may injure the brachial artery which may undergo vasospasm. This results in ischaemia affecting deep group of flexor muscles of forearm. This culminates into a phenomenon known as **Volkmann's ischaemic contracture**.

2. The **dislocation of the elbow** occurs in adults. The joint dislocates posteriorly and is occasionally associated with fracture of the coronoid process. This disturbs the triangular relationship between the two humeral epicondyles and the olecranon process.

3. An injury to the epiphysis of lateral epicondyle produces an increase in lateral deviation of the forearm. This decreases the carrying angle which is known as **cubitus valgus**. As a result the ulnar nerve is gradually stretched over the medial epicondyle, resulting in **ulnar neuropathy**.

4. **Tennis elbow**—Abrupt pronation during tennis play may produce sprain or partial tear of the radial collateral ligament, and is manifested by pain and tenderness over the lateral epicondyle.

5. **Golfer's elbow**—It is an inflammation of the common flexor tendon at the medial epicondyle of humerus that results from repetitive flexion and pronation of the forearm at the elbow.

**RADIO-ULNAR JOINTS**

The radius and the ulna are united by three radio-ulnar joints—superior, middle and inferior. Whereas the superior and inferior joints are synovial, the middle radio-ulnar joint connecting the shafts of radius and ulna by the interosseous membrane is a syndesmosis type of fibrous joint.

**Superior radio-ulnar joint**—It is a pivot joint between the strip of the articular circumference of the head of radius and the osseo-fibrous ring, formed by the radial notch of ulna and the annular ligament. The radial head rotates within the ring; one-fifth of the ring is bony and four-fifth fibrous.

**Annular ligament** (Fig. 13.14)—It keeps the radial head in position and is attached to the two ends of radial notch of ulna. The ligament is somewhat cup-shaped presenting smaller circumference below. The annular ligament is continuous above with the fibrous capsule of elbow joint. A few fibres from its distal border form a thin **quadrature ligament** which covers the synovial membrane reflected on to the radial neck.

![Fig. 13.14. Osseo-fibrous ring of Superior radio-ulnar joint.](image)

Along the area of contact with the head of radius the annular ligament is covered internally by cartilage. Externally it blends with the radial collateral ligament and is overlapped by the supinator and anconeus muscles.
Middle radio-ulnar joint—It connects the shafts of radius and ulna by *syndesmosis* which consists of oblique cord and interosseous membrane.

Oblique cord—It is a thin fibrous band on the deep head of supinator and extends downward and laterally at right angle to the fibres of interosseous membrane from the lateral side of ulnar tuberosity to the lower end of radial tuberosity. It is said to be a remnant of flexor pollicis longus.

Interosseous membrane—It is a broad fibrous sheet extending between interosseous borders of radius and ulna. Upper border of the membrane is free and presents a triangular gap between it and the oblique cord for the transmission of posterior interosseous vessels. Its lower part is attached to the posterior lip of radial interosseous border, and further below it blends with the fibrous capsule of the inferior radio-ulnar joint. It presents an oval gap close to the lower part for the transmission of anterior interosseous vessels to the back of the forearm.

The fibres of the membrane slope downward and medially from radius to ulna, except in the lower part where they are arranged in reverse direction. It appears that such fibre-arrangements withstand transmission of forces from hand to humerus through the radius, ulna and intact interosseous membrane. However, forces from the pronated hand can be transferred directly to the humerus through the radius alone. The interosseous membrane is stretched in mid-prone position, and is relaxed in extremes of supination and pronation. This suggests why an individual prefers to use the hand in mid-prone position while inflicting blows by closed fist.

**Relations**

In front: In upper three-fourths—Flexor digitorum profundus and flexor pollicis longus with intervening anterior interosseous vessels and nerve.

In lower one-fourth—Pronator quadratus and *recessus saciformis*, which is a synovial pouch of inferior radio-ulnar joint and extends between the membrane and pronator quadratus.

Behind: Supinator, abductor pollicis longus, extensor pollicis longus and brevis, extensor indicis, anterior interosseous vessels and posterior interosseous nerve.

**Inferior radio-ulnar joint**—It is a uni-axial pivot joint, contributed by the articular surface of the head of ulna and the concave ulnar notch of the radius. Both bones are enclosed in an articular capsule and connected below by an articular disc.

The fibrous capsule forms a loose envelope around the joint and the underlying synovial membrane projects upward as a cul-de-sac known as *recessus saciformis* for a variable distance, between the pronator quadratus and the interosseous membrane.

Articular disc—It is a triangular plate of fibrocartilage and separates the head of ulna from the wrist joint. The disc is attached by its apex to a depression between the distal articular surface of the head of ulna and its styloid process.

Its base is attached to a ridge between the ulnar notch and the carpal articular surface of the radius, and its peripheral margins blend with the fibrous capsules of the inferior radio-ulnar and wrist joints.

The upper surface of the disc permits rotation of the inferior radio-ulnar joint around a vertical axis, whereas the lower surface allows angular movements of the wrist joint. Sometimes the centre of the disc is perforated by wear and tear.

**Movements**—The radio-ulnar joints permit the movements of pronation and supination of the forearm. In anatomical position the palm is directed in front and the forearm is *supinated* so that the radius and ulna lie side by side and almost parallel to each other (Fig. 13.15–a, b).

During pronation the head of radius spins within the annular ligament around a more or less a vertical axis and retains its position lateral to the ulna. But the lower end of radius, carrying the hand with it, rotates forward and medially across the lower part of ulna. In this process the interosseous membrane is spiralled.

In supination, the rotation is reversed, the lower end of radius regains its original position lateral to the ulna and the interosseous membrane is despiralled.

The range of pronation and supination, with the flexed elbow, is about 140°–150°. But with extended elbow the range of movement is increased to about 360°, due to associated rotation of humeral head at the shoulder joint and scapular movement. The power of supination is more strong than that of pronation. Eventually all screw-
introducing devices are made to use supination for mechanical advantages.

**Spinal segments** controlling movements
- Supination – C₆;
- Pronation – C₇, C₈;

**Applied Anatomy**

Dislocation of the head of radius through the annular ligament is produced by sudden traction on the wrist or hand when the forearm is semi-pronated. This is known as the **pulled elbow** of childhood. The condition affects the children under six, because up till then the diameters of the head and neck of the radius are very similar. Only a part of the head of radius slips out of the annular ligament in pulled elbow. Forcible supination screws half-dislocated head back into place.

**Wrist (Radio-Carpal) Joint**

It is a **bi-axial ellipsoid** joint. The proximal articular surface presents an elliptical socket, formed by the distal articular surface of the radius and the articular disc of the inferior radio-ulnar joint.

The **distal articular surface** is convex with reciprocal outline and is formed by the scaphoid, lunate and triquetral bones with interosseous ligament connecting the carpal bones together (Fig. 13.16).

**Ligaments**—The wrist joint possesses capsular ligament with synovial membrane, radial and ulnar collateral ligaments.

**Capsular ligament**—The fibrous capsule surrounds the joint and is attached close to the peripheral margin of the proximal and distal articular surfaces including the articular disc. Thus the head of ulna is excluded from the joint by the articular disc.

The capsule blends in front and behind the **palmar** and **dorsal radio-carpal ligaments**. Both ligaments extend infero-medially from the lower end of radius to the corresponding surfaces of the proximal row of carpal bones and to the capitate. This is to ensure the maximum functional use of the hand during pronation and supination.

**Radial collateral ligament**—It is a thickening of the lateral part of the capsule and extends from the styloid process of radius to the scaphoid and trapezium.

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**Muscles producing movements**

**Pronation**—Pronator quadratus, assisted by pronator teres, flexor carpi radialis and gravity. **Anconeus assists lateral displacement of ulna in full pronation**.

**Supination**—Supinator in extension, and biceps brachii in flexion.

**Note** : Brachioradialis does not act in pronation or supination.
Ulnar collateral ligament—It extends from the ulnar styloid process to the triquetral and pisiform bones.

Arterial supply—Supplied by the palmar and dorsal carpal arches, derived from the anterior interosseous, anterior and posterior carpal branches of radial and ulnar arteries, and recurrent branches of the deep palmar arch.

Nerve supply—From anterior and posterior interosseous nerves.

Relations of the wrist

In front (proximal to flexor retinaculum)—Beneath the deep fascia structures are mentioned from lateral to medial side and arranged in superficial, intermediate and deep planes;

Superficial—Flexor carpi radialis, palmaris longus, flexor carpi ulnaris;

Intermediate—Radial artery (resting on anterior surface of distal part of radius), median nerve (between flexor carpi radialis and palmaris longus, and postero-lateral to the tendon of palmaris longus) four tendons of flexor digitorum superficialis; (tendons for middle and ring fingers in superficial plane, tendons for index and little fingers in deep plane), ulnar vessels and ulnar nerve;

Deep—Flexor pollicis longus, anterior interosseous vessels and nerve, flexor digitorum profundus.

Behind—(beneath the extensor retinaculum)—The retinaculum bridges over the grooves on the dorsal aspect of the radius and ulna and is attached to the ridges in between the grooves; thus dividing into six osseo-fibrous compartments.

Structures within the compartments are mentioned from lateral to medial side:

Abductor pollicis longus and extensor pollicis brevis, extensor carpi radialis longus and brevis, extensor pollicis longus (medial to dorsal tubercle of Lister), extensor digitorum and deep to it extensor indicis along with the posterior interosseous nerve and anterior interosseous artery, extensor digitii minimi, extensor carpi ulnaris (between the head and the styloid process of ulna).

Movements: Movements at the wrist joint are associated with considerable range of movements at the mid-carpal joint, because they are produced by the same groups of muscles. Combination of wrist and mid-carpal joints is considered as link joint.

Active movements permitted at the joint complex are flexion, extension, abduction, adduction, and circumduction. Axial rotation is not possible because of ovoid outline of the wrist joint.

Flexion—Its range is about 85°, and takes place more at the mid-carpal joint than at the wrist joint. With flexed fingers, carpal flexion is diminished due to increased tension in the extensors.

Extension—It is more limited in range of about 60°, and occurs mainly at the wrist joint. This explains why the proximal articular surfaces of the scaphoid and lunate bones are more extensive on the posterior surface.

Adduction (ulnar deviation)—It is more extensive than abduction due to short ulnar styloid process. Range of adduction is about 45°, and it is mostly done at the wrist joint.
Abduction (radial deviation)—Its extent is only about 15°; it takes place almost exclusively at the mid-carpal joint.

Circumduction—It is a combination of flexion, adduction, extension and abduction or in reverse order.

Muscles producing movements

Flexion—Flexor carpi radialis and ulnaris act as prime movers, and assisted by flexor digitorum superficialis and profundus, flexor pollicis longus and abductor pollicis longus.

Extension—Extensor carpi radialis longus and brevis, extensor carpi ulnaris act as prime movers, and assisted by extensor digitorum, extensor indicis, extensor pollicis longus and extensor digit minimi.

Adduction—Simultaneous contractions of flexor and extensor carpi ulnaris.

Abduction—Abductor pollicis longus, and simultaneous contractions of flexor carpi radialis, extensor carpi radialis longus and brevis.

Note: In the working position of hand, the most usual movements at the wrist are a combination of extension-abduction and flexion-adduction. Extension—abduction is an antigravity movement; hence two extensor muscles are provided on the radial side to increase the power.

Spinal segments controlling wrist movement—

Flexion—C6, C7
Extension—C6, C7

JOINTS OF THE HAND

These consist of:
- Intercarpal joints;
- Midcarpal joint;
- Carpo-metacarpal and intermetacarpal joints;
- Carpo-metacarpal joint of the thumb;
- Interphalangeal joints;

Intercarpal and midcarpal joints—These include joints of the carpus between the individual bones of proximal row, between the individual bones of distal row, and the midcarpal joint between the proximal and distal rows.

They are basically plane synovial joints and present palmar, dorsal and interosseous ligaments. The joint between the pisiform and triquetral bones is separate. Rest of the intercarpal joints along with the midcarpal joint form a common joint cavity which is continuous distally with the carpometacarpal and intermetacarpal joints of the medial four fingers. First carpometacarpal joint (of thumb), however, possesses separate joint cavity.

The interosseous ligaments of the proximal row connect the scaphoid, lunate and triquetral bones close to their proximal surfaces, and prevent the communication of wrist joint from intercarpal joints. For functional reason, the midcarpal joint is devoid of interosseous ligament.

Midcarpal joint—It intervenes between the proximal and distal rows of carpal bones, and presents a sellar articular surface which is composed of medial and lateral parts.

The medial parts is formed by the convex articular surface of the head of capitate along with the edge of the hamate; both are received by the concavity of the scaphoid, lunate and part of the triquetral bone. The lateral part is formed by the distal surface of the scaphoid articulating with the trapezium and trapezoid (See Fig. 13.16).

The ligaments of midcarpal joints are palmar, dorsal, and medial and lateral collateral ligaments.
The synovial cavity of midcarpal joint presents two projections in between the scaphoid, lunate and triquetral bones of the proximal row, and three projections between the four bones of distal row. Distal projections usually communicate with the carpometacarpal and intermetacarpal joints of the medial four fingers due to absence of interosseous ligament between trapezium and trapezoid.

Flexion and abduction of the wrist take place mainly at the midcarpal joint.

**Applied Anatomy**

The scaphoid acts as an intracarpal bridge to transmit the movements of the distal row to the proximal row of carpal bones. Therefore, a fall on the wrist in extension may fracture the scaphoid along the waist of the bone which lies partly in each row of carpal bones.

**Carpometacarpal joint of the thumb**—The first carpometacarpal joint is a saddle or sellar type of synovial joint and permits greater range of movement due to the nature of the articular surface and arrangements of the ligaments. It possesses separate joint cavity from other carpometacarpal joints (See Fig. 13.16).

**Bones forming the joint**—Distal articular surface of the trapezium and the base of the first metacarpal bone; both bones are convexo-concave and reciprocally curved.

The first metacarpal bone lies on a more anterior plane than the other metacarpal bones, and undergoes medial rotation through an angle of about 90° so that its dorsal surface is lateral and palmar surface medial.

**Ligaments of the joint**—It possesses capsular ligament, lateral, dorsal and palmar ligaments.

The capsular ligament is loose but strong, and envelops the joint completely. It is attached close to the articular surfaces of the trapezium and the base of the first metacarpal bone.

The lateral ligament connects the lateral surface of the trapezium to the radial side of the base of the first metacarpal bone.

The dorsal and palmar ligaments form oblique bands, and extend from the corresponding surface of the trapezium to converge for attachment on the ulnar side of the base of the first metacarpal bone.

**Relations**

**In front**: Abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis;

**Behind**: Extensor pollicis longus and brevis;

**Lateral**: Abductor pollicis longus, and extensor pollicis brevis;

**Medial**: First dorsal interosseous muscle and the entry of the radial artery into the palm through the triangular gap between the two heads of that muscle.

**Movements**—Active movements permissible at the first carpometacarpal joints are: Flexion and extension, adduction and abduction, circumduction, conjunct medial and lateral rotation, and opposition (Fig. 13.17).

Due to anatomical disposition of the first metacarpal bone (as stated above), flexion and extension take place parallel to the plane of the palm around an antero-posterior axis. Similarly abduction and adduction take place at right angles to the palm around a transverse axis. The combination of flexion, abduction, extension and adduction in any order is known as circumduction.

The flexion, except at the initial stage, is associated with conjunct medial rotation. This is due to the geometry of the articular surfaces and the tension of the dorsal ligament so that the ulnar side of the base of first metacarpal bone becomes fixed but its radial side is free to move. On further contraction of flexor pollicis brevis and opponens pollicis as muscles of flexor group, medial rotation takes place spontaneously. Due to similar reasons, the extension is accompanied by conjunct lateral rotation of the first meta-carpal bone, because palmar ligament becomes taut which makes the ulnar side of the base fixed, but the radial side remains free to perform lateral rotation.

The opposition is a combination of abduction, flexion and medial rotation at the first carpometacarpal joint, so that the pulp of the thumb can be brought in contact across the palm with the semiflexed tip of other fingers for grasping.

**Muscles producing movements**

**Flexion**: Flexor pollicis brevis and opponens pollicis, assisted by the flexor pollicis longus;

**Extension**: Abductor pollicis longus and extensor pollicis brevis, assisted by extensor pollicis longus in full extension.
Abduction: Abductor pollicis longus and brevis; in full abduction the thumb and the first metacarpal bone are not in the same line because the movement takes place at both metacarpophalangeal and carpometacarpal joints.

Fig. 13.17. Movements of the thumb at the first carpometacarpal joint.

Adduction: Adductor pollicis;

Opposition: Initiated by abductor pollicis longus and brevis, and maintained by the flexor pollicis brevis and opponens pollicis. The force of digital pressure in opposition is increased by the adductor pollicis and flexor pollicis longus.

Blood supply — Radial artery;
Nerve supply — Median nerve;

Metacarpophalangeal joints—These are ellipsoid type of synovial joints, and formed by the union between the convex articular head of the metacarpal bones with the reciprocally curved articular base of proximal phalanx.

Each joint possesses capsular ligament, palmar ligament, medial and lateral collateral ligaments and deep transverse metacarpal ligaments.

The capsular ligament is thick in front and defective behind where dorsal digital expansion, assisted by the lumbricals and interossei, fills the gap.

The palmar ligament forms fibrocartilaginous plate which replaces the anterior part of the capsule and blends with deep transverse metacarpal ligaments.

The deep transverse metacarpal ligaments are three strong flat bands and connect the palmar ligaments of the second to the fifth metacarpal bones. Each band is related in front to the lumbricals and palmar digital vessels and nerves, and behind with the tendons of dorsal and palmar interossei.

The collateral ligaments are placed as oblique bands on each side of the joint. Each extends downward and forward from the metacarpal head to the base of the proximal phalanx. The collateral ligaments are taut in flexion and relaxed in extension.

Movements and the muscles producing:

Flexion—Lumbricals and interossei;
Extension—Extensors of the fingers;
Adduction—Palmar interossei;
Abduction—Dorsal interossei;

Interphalangeal joints—These are typical uniaxial hinge joints, and each joint possesses capsular, palmar and collateral ligaments. Long extensor tendon replaces the dorsal part of the capsule. Each of the medial four fingers presents two interphalangeal joints (proximal and distal); the thumb finger, however, presents a single interphalangeal joint.

The arrangements of ligaments are similar to that of the metacarpo-phalangeal joints. Only differences to note are that the palmar fibrocartilaginous plate is weak and the length of the oblique bands of collateral ligaments is constant during the movements of fingers.

Therefore to avoid the stiffness of the joints the fingers are immobilised in extension at the interphalangeal joints and in flexion at the metacarpo-phalangeal joints.
Movements: Active movements at the interphalangeal joints are flexion and extension.

Muscles involved are:

- Flexion—Flexor digitorum profundus at the distal interphalangeal joints;
- Flexor digitorum superficialis at the proximal interphalangeal joints;
- Flexor pollicis longus at the interphalangeal joint of the thumb.

Extension—For the thumb, extensor pollicis longus and brevis;

For the medial four fingers, extensor digitorum along with the lumbricals and interossei through the digital expansion; these involve both proximal and distal interphalangeal joints.

Note: Lumbricals and interossei produce flexion at the metacarpophalangeal joints and extension at both interphalangeal joints. This allows the fingers to grip a finer object for precision movements.

When medial four fingers flex individually at the metacarpophalangeal and proximal interphalangeal joints, the pad of each finger tip reaches the same point at the thenar eminence. This shows that during the flexion of fingers there is concomitant adduction. Similarly, when the extension of the fingers takes place at the metacarpophalangeal joints by the actions of extensor digitorum, extensor indicis and extensor digiti minimi there is associated abduction of the fingers.

If the extensor tendon is cut at the level of the distal interphalangeal joints, the unopposed action of the flexor digitorum profundus on the distal phalanx will produce a mallet finger deformity.

Positions of the hand

At rest—The forearm is in semiprone position, the wrist is slightly extended, the medial four fingers are partially flexed although the flexion of the index finger is less marked, and the plane of thumb nail lies at right angle to the plane of other finger nails.

Working position of hand—It is a position where the hand is about to grasp an object by a process of opposition of thumb against semiflexed other fingers. It may be a power grip, precision or hook grip.

Human hand may be divided functionally into two units radial tripod and medial hook.

The radial tripod involves the assembly of the finger tips of the thumb, index and middle fingers. This method is employed for precision work and is contributed by those muscles which are supplied by the median nerve.

The medial hook is primarily done by the flexion of the ring and little fingers to perform a hook grip so as to carry a suitcase. The muscles concerned in this action are supplied by the ulnar nerve.
THE
INFERIOR
EXTREMITIES
The lower limb is connected to the trunk by the pelvic girdle and possesses three segments – thigh, leg and foot which correspond respectively with the arm, forearm and hand of the upper limb. The pelvic girdle is formed by two hip bones which articulate with each other in front at the symphysis pubis, but are separated behind by the lateral mass of sacrum. The pelvic girdle and the sacrum together form the rigid bony pelvis. Man is unique among the primates since he has adopted an upright posture and a bipedal mode of locomotion. The bony pelvis transmits the body weight through the acetabulum to the lower limb and at the same time mediates the propulsive thrust from the lower limb to the body. In sitting, the body weight is transmitted to the ischial tuberosities and the legs remain free. The upright posture assumed by the mankind has brought out several specialisation in the skeleton, joints and muscles of the lower limb.

Three principal synovial joints – hip, knee and ankle intervene between the pelvis and thigh, thigh and leg, leg and foot respectively. In upright position the line of centre of gravity passes behind the hip joint, but in front of knee and ankle joints (Fig. 14.1). Natural tendency of backward tilting of the pelvis at the hip joint is prevented by the tension of strong ilio-femoral ligament. Hyper-extension at the knee is counter-acted by the tension of various ligaments and antagonistic muscles. At the ankle joint forward dislocation of leg bones from the talus is prevented by two factors, bony and muscular. The anterior part of the superior articular surface of the talus is broader than its posterior part; this prevents the tendency of forward dislocation of leg bones. The calcaneus projects much more backward than the rest of the tarsal bones to provide insertion of calf muscles (soleus and gastrocnemius) on its posterior surface. The tonic contraction of calf muscles also prevents forward dislocation, and the phasic contraction of the muscles increases the propulsive force for locomotion.

Fig. 14.1. Line of centre of gravity of lower limb in upright position.
HIP BONE

The hip bone or innominate bone is irregular in shape and presents a constricted central part which carries a cup-shaped depression, the acetabulum, on the outer surface. The bone is expanded above and below the acetabulum, and exhibits an oval or triangular obturator foramen below and in front of the acetabulum. The hip bone consists of one dorsal component, the ilium, and two ventral components, the ischium and pubis. The three components join at the acetabulum which is separated initially by a triradiate cartilage and the latter is subsequently replaced by bone from secondary ossific centres. The acetabulum articulates with the head of femur to form the hip joint which is more stable than the shoulder joint of upper limb at the expense of certain loss of mobility for circumduction.

Ilium—The ilium projects upward from the acetabulum as an expanded plate and presents two ends—upper and lower, three borders—anter ior, posterior and medial, and three surfaces—iliac fossa, sacro-pelvic and gluteal (Fig. 15.1, 15.2).

The upper end is represented by a curved border, the ili ac crest, which extends from the anterior superior iliac spine to the posterior superior iliac spine, and presents an upward convexity. The iliac crest consists of a ventral segment in anterior two-thirds with an outward convexity and a dorsal segment in posterior one-third with an outward concavity. The ventral segment presents an outer lip, intermediate area and an inner lip. The tubercle of ili ac crest affects the outer lip about 5 cm behind the anterior superior iliac spine. From outside inwards, the ventral segment gives attachment to the following structures:

(a) fascia lata (deep fascia) of thigh including the ilio-tibial tract,
(b) the tensor fasciae latae extending from the anterior superior iliac spine to the iliac tubercle,
(c) obliquus externus abdominis in the anterior two-thirds of the outer lip, and more behind leaving a gap for the base of lumbar triangle to the latissimus dorsi.

Fig. 15.1. Right hip bone (Medial view).
(d) **obliquus internus abdominis** in the entire intermediate area of ventral segment,

(e) **transversus abdominis** in the anterior two-thirds and **quadratus lumborum** in the posterior one-third of the inner lip,

(f) **fascia transversalis**,  

(g) **fascia iliaca** (Fig. 15.3). The summit of the iliac crest lies slightly behind the mid-point between the anterior and posterior superior iliac spines, and a horizontal line joining the summits of both sides forms a supra-cristal plane which passes through the lower border of \( L_4 \) spine. The **anterior superior iliac spine** forms a palpable projection and gives attachment to the lateral end of the inguinal ligament and origin to sartorius muscle which also encroaches on the notch below the spine.

The **dorsal segment** of iliac crest is divided by a ridge into outer and inner rough surfaces. The outer surface provides origin to the gluteus maximus and the inner surface to the erector spinae; the ridge between them gives attachment to the posterior layer of the thoraco-lumbar fascia. The **posterior superior iliac spine** corresponds to a skin dimple at the back and a line joining the spines of both sides passes through \( S_4 \) spine which is a landmark of the caudal end of the sub-arachnoid space.

The iliac crest is crossed transversely by the following nerves from before backwards: Lateral cutaneous branch of subcostal nerve, lateral cutaneous branch of ilio-hypogastric nerve, lateral cutaneous branches of the dorsal rami of the upper three lumbar nerves.

The **lower end** of ilium is connected with the ischium and pubis in the floor of the acetabular cavity, separated initially by a Y-shaped cartilage, the limbs of which diverge in front and the stem behind. The cartilage is ossified by the time of puberty, after which the three segments of hip bone undergo bony fusion. Roughly, upper two-fifths of the acetabulum is contributed by the ilium, lower two-fifths by the ischium and anterior one-fifth by the pubis.

The **anterior border** of the ilium extends from the anterior superior iliac spine and forms a notch immediately below it, then projects forwards as the anterior inferior iliac spine and finally reaches the upper margin of the acetabulum. The **anterior inferior iliac spine** gives attachment to the straight head of rectus femoris in the upper part and the stem of the ilio-femoral ligament in the lower part. The notch between the anterior superior and anterior inferior iliac spines transmits the lateral femoral cutaneous nerve under cover of the inguinal ligament.

The **posterior border** extends downward and forward from the posterior superior iliac spine as a rough border up to the posterior inferior iliac spine; thereafter it forms the upper and anterior border of the deeply concave **greater sciatic notch** and thence is continuous with the dorsal
border of the body of ischium. The upper rough part of the border including the posterior inferior iliac spine gives attachment to the upper end of the sacrotuberosus ligament. The upper border of greater sciatric notch gives origin to a few fibres of piriformis. The greater sciatric notch is limited below by the ischial spine and is converted into the greater sciatric foramen which is completed by the sacro-tuberosus ligament from behind and by the sacro-spinous ligament from below. The greater sciatric foramen transmits in the gluteal region the piriformis muscle with a number of vessels and nerves emerging above and below the muscle (See Fig. 15.5). The structures appearing above the piriformis are: superior gluteal vessels and superior gluteal nerve. Altogether eight structures emerge below the piriformis and these are mentioned from lateral to medial side:

(a) sciatic nerve,
(b) the nerve to quadratus femoris under cover of sciatic nerve,
(c) posterior femoral cutaneous nerve,
(d) inferior gluteal nerve,
(e) inferior gluteal vessels,
(f) nerve to obturator internus,
(g) internal pudendal vessels, and
(h) pudendal nerve.

Out of these, the medial three structures appear for a while in the gluteal region resting on the ischial spine and then pass forward through the lesser sciatric foramen.

The medial border of the ilium passes downward, forward and medially, and separates the iliac fossa from the sacro-pelvic surface. The posterior one-third of the border is rough for the attachments of ilio-lumbar and dorsal sacro-iliac ligaments, the middle one-third is sharp to form the upper margin of the auricular (articular) surface of ilium, and the anterior one-third of the border forms a rounded arcuate line which is continuous in front with the pectineal line of pubis (pecten pubis) at the ilio-pubic eminence; the latter represents the fusion between the ilium and superior ramus of pubis. The arcuate line along with the pecten pubis and pubic crest is known as the linea terminalis which forms the lateral boundary of the pelvic inlet. The structures which cross the linea terminalis in order to pass into the lesser pelvis are as follows from behind forwards:

(a) internal iliac vessels (vein behind the artery),
(b) ureter,
(c) ovarian vessels in the suspensory ligament of ovary,
(d) vas deferens or round ligament of uterus,
(e) obliterated umbilical artery, and
(f) median umbilical ligament behind the symphysis pubis.

In addition, on the right side the linea terminalis is crossed by the terminal part of ileum and occasionally the pelvic type of vermiform appendix, and on the left side by the junction of descending and sigmoid colon. The medial border of ilium provides attachments to the fascia iliaca and the parietal layer of the pelvic fascia.

The **iliac fossa** presents a shallow concave surface. It is limited above by the inner lip of the ventral segment of the iliac crest, below and behind by the medial border of ilium, and is continuous below with the front of thigh through a groove between the anterior inferior iliac spine and ilio-pubic eminence. The upper two-thirds of the fossa gives origin to the iliacus muscle and its lower part is separated from the muscle by the iliac branches of the ilio-lumbar vessels (Fig. 15.4). The medial part of the fossa is occupied by the psoas major which passes along the upper limit of the pelvic inlet in order to enter the thigh for insertion. Both iliacus and psoas major are covered in front by the fascia iliaca. Beneath the iliac fascia, the trunk of femoral nerve lodges in a groove between the iliacus and psoas major, and the lateral femoral cutaneous nerve passes obliquely downward and laterally in front of the iliacus. Superficial to the fascia iliaca and in front of the psoas major lie external iliac vessels in the extra-peritoneal tissue; rest of the fossa is occupied on the right side by the caecum and vermiform appendix, and on the left side by the descending colon.

The **sacro-pelvic surface** consists of sacral part dorsally and pelvic part ventrally. The **sacral part** presents an articular **auricular surface** in front and a rough elevated **tuberosity of ilium** behind. The auricular surface is covered with articular cartilage and articulates with the corresponding surface of
the lateral mass of sacrum forming a plane synovial sacro-iliac joint. The weight transmission from the trunk to the lower limb passes through this joint; therefore its mobility is sacrificed to improve its stability which is maintained by strong ligaments. The tuberosity of ilium gives attachments from behind forward, to the ilio-lumbar, dorsal sacro-iliac and interosseous sacro-iliac ligaments; the interosseous ligament is one of strongest ligament of the body. The pelvic part of sacro-pelvic surface is smooth and continuous with the pelvic surface of ischium to form the lateral wall of true pelvis. Just in front of the auricular surface, it presents a pre-auricular sulcus which is more conspicuous in parous females because the ventral sacro-iliac ligament which is attached to the sulcus undergoes stretching during pregnancy. In front of the sulcus and close to the upper border of greater sciatic notch a few fibres of the piriformis take origin. Rest of the pelvic surface provides origin to a part of obturator internus.

The gluteal surface on the outer aspect of the ilium is divided into four areas by three gluteal lines—posterior, anterior and inferior. All gluteal lines radiate from the upper margin of the greater sciatic notch. The posterior gluteal line meets the dorsal segment of the iliac crest; the anterior gluteal line joins close to the tubercle of the iliac crest and the inferior gluteal line meets the upper end of anterior inferior iliac spine. The area behind the posterior gluteal line gives origin to a part of gluteus maximus in the upper part and the proximal attachment of sacrotuberous ligament in the lower part. The area between the posterior and anterior gluteal lines gives origin to the gluteus medius. The
area between the anterior and inferior gluteal lines is monopolised by the origin of **gluteus minimus**. The area between the inferior gluteal line and the upper margin of the acetabulum provides origin to the **reflected head of rectus femoris** (Fig. 15.5).

**Ischium**—The ischium consists of a body and a ramus.

The **body** of ischium presents two ends—upper and lower, three borders — anterior, lateral and posterior, and three surfaces — femoral, dorsal and pelvic.

The **upper end** is osseoosely united with the ilium and pubis along the floor of the acetabular cavity. The **lower end** is occupied by the caudal part of ischial tuberosity.

The **anterior border** is formed by the posterior margin of obturator foramen and gives attachment to the obturator membrane. The **lateral border** is notched in the upper part close to the lower margin of the acetabulum. It gives attachment to the ischio-femoral ligament and lodges the tendon of the obturator externus. Rest of the border is represented by the lateral margin of the ischial tuberosity. The **posterior border** is continuous above with the posterior border of ilium. It presents a triangular projection, the **ischial spine**, which divides the border into greater sciatic notch above (vide supra) and lesser sciatic notch below. The tip of the ischial spine is directed backward and medially, and gives attachment to the **sacrospinous ligament**. The pelvic surface of the spine provides origin to the posterior fibres of **levator ani** and **coccygeus** muscles, and is related to the pelvic part of the ureter. The dorsal surface of the spine is crossed from lateral to medial side by the nerve to obturator internus, internal pudendal artery with a pair of veins comitantes on each side, and the pudendal nerve. Close to the lesser sciatic notch, the dorsal surface of the base of ischial spine gives origin to the **gemellus superior** muscle. The lesser sciatic notch extends from the ischial spine to the upper part of ischial tuberosity; the **gemellus inferior** muscle arises from the lower end of the notch. The notch is converted into the **lesser sciatic foramen** with the assistance of the sacro-tuberous and sacrospinous ligaments. The foramen transmits the tendon of obturator internus along with the nerve to obturator internus, internal pudendal vessels and pudendal nerve. At the lesser sciatic foramen the obturator internus tendon makes a right angled bend before its insertion into the greater trochanter of femur. The friction between the notch and the tendon is minimised by the presence of a fibro-cartilage covering the notch and by a bursa.

The **femoral surface** is directed forward and laterally, and intervenes between the anterior and lateral borders. Close to the obturator foramen it gives origin to the obturator externus, and along the lateral border of ischial tuberosity to the quadratus femoris. The **dorsal surface** is continuous above with the gluteal surface of ilium, and is divided by a slightly arched transverse groove into upper and lower areas. The **upper area** is somewhat convex, overlapped by the piriformis and comes in direct contact with the sciatic nerve and nerve to the quadratus femoris. The transverse groove is continuous medially with the lesser sciatic notch and laterally with a notch below the acetabular margin. Medial part of the groove is occupied by the tendon of obturator internus and its lateral part by the tendon of obturator externus. The **lower area** of the dorsal surface presents the **ischial tuberosity**, which is rough and divided by a transverse ridge into upper quadrilateral part and lower triangular part (Fig. 15.6). The upper part is subdivided by an oblique ridge into an upper and lateral area for the origin of **semimembranosus**, and a lower and medial area for the common origin of **semitendinosus** and **long head of biceps femoris**. The lower part is subdivided by a vertical ridge into lateral and medial area. The lateral area gives origin to the **hamstring part of adductor magnus**, and the medial area is covered by the fibro-fatty tissue and transmits the body weight in sitting position; medial margin of this area is sharp and gives attachment to the lower end of the sacro-tuberous ligament which extends forward as a falciiform margin. The **pelvic surface** of ischium is smooth and intervenes between the anterior and posterior borders. The upper part of the surface gives origin to the **obturator internus** and its lower part is related to the converging fibres of the muscle which becomes tendinous and turns abruptly lateral-ward through the lesser sciatic foramen. Here the obturator internus muscle and its covering fascia form the lateral wall of ischio-rectal fossa; the obturator fascia splits to form the pudendal canal (of Alcock) which contains internal pudendal vessels and pudendal nerve. It is worth mentioning that the outline of the total origin of obturator internus resembles
the shape of pancreas and involves the pelvic surface of body of pubis and ischio-pubic ramus bordering the obturator foramen; it also includes the pelvic surface of obturator membrane except the obturator canal, upper part of pelvic surface of ischium and adjoining ilium extending as far behind as the pre auricular sulcus.

The **ramus** of ischium extends from the lower end of the body upward, forward and medially and meets the inferior rami of pubis, separated initially by a plate of cartilage which is replaced by bone after 7 or 8 years. The **conjoined ischio-pubis ramus** presents upper and lower borders, and outer and inner surfaces.

The **upper border** forms a part of obturator foramen and gives attachment to the obturator membrane. The **lower border** forms the lateral boundary of subpubic angle and is everted more in male, for the extensive attachment of crus penis. It gives attachment to the fascia lata of thigh and the fascia of Colles of perineum.

The **outer surface** of the conjoint ramus gives linear attachments to the following muscles from below upwards: gracilis, adductor brevis, non-hamstring part of adductor magnus, and obturator externus (See Fig. 15.5).

The **inner surface** is subdivided by upper and lower oblique bony ridges into three areas – upper, intermediate and lower. The upper ridge gives attachment to the superior fascia of uro genital diaphragm (a derivative of pelvic fascia), and the lower ridge to the perineal membrane or inferior fascia of urogenital diaphragm (See Figs. 15.1, 15.4).

The **upper area** provides origin to the obturator internus, the **intermediate area** to the sphincter urethrae in front and transversus perinei profundus behind, and the **lower area** gives attachment from before backwards to crus penis or clitoridis, ischio-cavernosus and transversus perinei superficialis. **To summarise**, the entire inner surface of the ischio-pubic ramus including upper and lower borders gives attachments to the following from above downwards: obturator membrane, obturator internus, superior fascia of urogenital diaphragm, sphincter urethrae and transversus perinei profundus, perineal membrane, crus penis/clitoridis with ischio-cavernosus and transversus perinei superficialis, fascia of Colles, and fascia lata.

**Pubis**—The pubic bone (os pubis) lies ventromedial to ilium and ischium, and consists of a body and superior and inferior rami.

The **body** of pubis is quadrilateral in outline and presents **three surfaces** – anterior or femoral, posterior or pelvic, medial or symphysial, a **pubic crest** at the upper border and a lateral border at
the obturator foramen. The anterior surface is directed downward, forward and laterally, and provides a rounded tendinous origin of adductor longus from a depression at the junction of pubic crest and symphysial surface. Rest of the surface gives attachments medio-laterally to the gracilis, adductor brevis and obturator externus muscles, each of which extends further downwards along the outer surface of the ischio-pubic ramus.

The posterior surface is smooth and forms the anterior wall of the bony pelvis; close to its centre the surface gives origin to the anterior fibres of levator ani, and more laterally to a part of obturator internus muscle. The pelvic surface is separated from the antero-lateral wall of the urinary bladder by a retro-pubic space which is filled with fibrofatty tissue and a plexus of veins.

The medial surface is covered by a plate of hyaline cartilage and articulates with the similar surface of the opposite bone separated by a fibro-cartilaginous interpubic disc. The joint thus formed is known as the symphysis pubis which is a secondary cartilaginous joint and resists the force of medial thrusts of femoral heads by acting as a shock-absorber.

The pubic crest is the thickened upper border of the body of pubis and its lateral end projects forward as the pubic tubercle.

The pubic crest gives attachment from before backwards to the following:
(a) fascia lata,
(b) anterior wall of the rectus sheath,
(c) origin of lateral head of rectus abdominis and pyramidalis muscle in front of it (if present),
(d) the conjoint tendon, and
(e) fascia transversalis.

The linea alba is attached to the upper end of symphysis pubis and the adjoining pubic crest. The pubic tubercle gives attachment to the following: medial end of inguinal ligament, lateral crus of the superficial inguinal ring, super-rior crus of the saphenous opening, apex of the lacunar ligament, reflected part of the inguinal ligament, and ascending limb of U-shaped loops of cremaster muscle (in male). The pubic tubercle acts, as a guide to differentiate the inguinal hernia which lies above and medial to the tubercle, from the femoral hernia which bulges below and lateral to the tubercle.

The superior ramus of pubis arises from the supero-lateral angle of the body, extends laterally above the obturator foramen and ends at the ilio-pubic eminence where it joins with the ilium. The ramus is triangular on cross-section, and presents three borders – anterior, posterior and inferior, and intervening three surfaces – pectineal, pelvic and obturator. The anterior border or obturator crest extends from the pubic tubercle to the adjacent acetabular margin; close to the acetabulum it gives attachment to the pubo-femoral ligament.

The posterior border or pectineal line (pecten pubis) extends laterally as a sharp line and is continuous with the arcuate line of ilium in the posterior part of ilio-pubic eminence. The pecten pubis is divided into medial and lateral parts to arrange the attachment of structures. The medial part gives attachments to the following from before backwards: lacunar ligament, reflected part of the inguinal ligament, conjoint tendon, and fascia transversalis. The lateral part provides attachment from behind forward to the pectineal ligament of Cooper, pectineus muscle and its covering fascia. At the ilio-pubic eminence, it receives the insertion of psoas minor, when present.

The inferior border forms the upper margin of the obturator foramen and gives attachment to the obturator membrane leaving a gap for obturator canal.

The pectineal surface intervenes between the obturator crest and pecten pubis, and gives origin to the pectineus muscle in the upper part. The pelvic surface is featureless, covered by the peritoneum and is crossed sub-peritoneally by the obliterated umbilical artery, and more laterally by the vas deferens or round ligament of uterus.

The obturator surface is grooved and forms the upper boundary of obturator canal which is limited below by the upper free margin of obturator membrane; the canal transmits from above downwards obturator nerve, artery and vein.

The inferior ramus of pubis extends downward and laterally from the lower part of the body and joins with the ramus of ischium to form the ischio-pubic ramus (vide supra).

Obturator foramen—It is oval and larger in male, triangular and smaller in female. The obturator membrane is attached along the margin of the foramen except above where the margin presents a tubercle on each side for the attachment of the free margin of the membrane.
Acetabulum—It is a cup-shaped depression on the outer surface of the constricted central part of hip bone where its three components meet and subsequently fuse. The acetabulum receives the head of femur and forms poly-axial hip joint. Its peripheral margin is sharp and gives attachment to a fibro-cartilaginous rim, the acetabular labrum except below where the margin is deficient and forms the acetabular notch. The two ends of the notch give attachment to the transverse acetabular ligament and the base of ligamentum teres femoris. The gap between the ligament and the notch transmits acetabular branches of obturator and medial circumflex femoral vessels. A horse-shoe shaped articular surface, the lunate surface, occupies the periphery of the acetabular cavity. The floor of the cavity below the lunate surface is non-articular and forms the acetabular fossa which is filled with a pad of fat. The acetabular fat is covered with synovial membrane; therefore it is intracapsular but extrasynovial and is in liquid condition at body temperature.

Anatomical position—When the hip bone is held in correct orientation, (i) the anterior superior iliac spine and the upper end of symphysis pubis lie in the same coronal plane, (ii) the symphysial surface of pubis faces downward, forward and medially, (iii) the acetabulum is directed downward, forward and laterally, and (iv) the ischial tuberosity occupies the lowest position. (v) A vertical line joining the tubercle of iliac crest and the lowest point of ischial tuberosity, passes through the centre of acetabular cavity.

In sitting position, however, the anterior superior iliac spine tilts somewhat backward, so that the vertical line joining the ischial tuberosity and the centre of acetabular cavity now passes through the anterior superior iliac spine.

Lines of buttress—In standing, the line of buttress for weight transmission extends obliquely from the auricular surface at the sacro-iliac joint to the acetabulum at the hip joint along the arcuate line of ilium. In sitting, the line extends vertically downward from the auricular surface to the ischial tuberosity. The hip bone is necessarily more thick along these two buttress lines.

Sex differentiation—(See the chapter of Bony Pelvis in the author’s book “Essentials of Human Anatomy – Thorax and Abdomen”).

Ossification—The hip bone is ossified from three primary centres, one for the ilium appearing at about second month of intra-uterine life, one for the body of ischium appearing at about fourth month, and one for the body of pubis appearing between the fourth and fifth months. Rest of the bone remains cartilaginous at birth. At about seventh or eighth year the ischio-pubic ramus is formed after replacement of the intervening cartilage.

With the onset of puberty, the secondary centres appear in the iliac crest, triradiate cartilage at the bottom of acetabulum, ischial tuberosity, anterior inferior iliac spine and symphysial surface of pubis. The iliac crest and triradiate cartilage present two ossific centres for each, the rest possesses a single ossific centre for each. The complete hip bone is expected to be found between fifteenth and twenty-fifth years.

Special comments on hip bone—The ilium represents the dorsal component of hip bone and the muscles arising therefrom are supplied by the dorsal division of lumbar or sacral plexus. This explains why the gluteal muscles including tensor fasciae latae which have their origins from the ilium are supplied by the dorsal division (inferior gluteal nerve for the gluteus maximus, and superior gluteal nerve for the glutei medius et minimus and tensor fasciae latae).

Both pubis and ischium represent the ventral components of hip bone and the muscles arising from them are innervated by the ventral division of the limb plexus. The adductors including gracilis arise from the pubis and are supplied the ventral division via the obturator nerve. The flexors of the knee (hamstrings) owe their origins from the ischial tuberosity and are supplied by the tibial component (ventral division) of the sciatic nerve.

Femur

The femur or thigh bone is the longest bone of the body and about 45 cm (18 inches) long in an average man, that means, approximately one-fourth of the height of the individual. The body of the femur is buried in the muscles and obliquely placed, since the two femora are widely separated by the pelvis but lie close together at the knees. The femur presents upper and lower ends, and an intervening shaft (Fig. 15.7, 15.8).

Upper end—The upper end consists of head, neck, greater and lesser trochanters, intertrochanteric line and inter-trochanteric crest.
The **head** is articular, forms two-thirds of a sphere and fits as a ball in the acetabular socket to form the hip joint. It is covered with articular hyaline cartilage; except near its centre where a pit or **fovea** exists for the attachment of the ligamentum teres femoris. The **neck**, about 5 cm long, connects the head with the shaft and is directed upward, medially and slightly forward. The neck is an extension of the shaft (diaphysis) and meets the latter at an angle of about 125° in adult, but the angle is wider (about 160°) in a child. The elongated neck and neck -shaft angle allow the lower limb to swing clearly away from the pelvis and increase the range of movement at the hip joint. On close inspection a number of oblique bony ridges are found to affect the anterior surface of the neck for the attachment of retinacular fibres of fibrous capsule. The posterior surface of the neck presents a faint groove running obliquely upward and laterally to the trochanteric fossa; the groove lodges the tendon of obturator externus separated by a bursa.

The **greater trochanter** is a quadrilateral elevation projecting upward from the junction of the neck and shaft. It lies about 10 cm (4 inches) below the tubercle of the iliac crest. The tip of greater trochanter, centre of the head of femur and the pubic tubercle lie in the same horizontal plane. The greater trochanter presents three surfaces – anterior, lateral and medial, and two borders – upper and posterior (Fig. 15.9). The **anterior surface** is rough and receives the insertion of **gluteus minimus**. The **lateral surface** is quadrilateral and is divided diagonally by an oblique ridge passing downward and forward into upper and lower triangular areas. The oblique ridge receives the insertion of **gluteus medius**, and the upper and lower triangular areas are occupied by the trochanteric bursa for gluteus medius and gluteus maximus respectively. The **medial surface** presents a depression, the **trochanteric fossa**, at its junction with the neck; the fossa receives the insertion of **obturator externus** and is a site for

![Fig. 15.7. Right femur (Anterior view).](image-url)
the formation of trochanteric anastomosis of arteries. A second depression is present above and in front of trochanteric fossa; it receives the conjoint insertions of obturator internus along with gemelli superior and inferior which may extend to the upper margin. The upper border of greater trochanter presents an inturnd end at the postero-superior angle for the insertion of the piriformis. From behind forward, the upper border receives the insertions of piriformis, gemellus inferior, tendon of obturator internus and gemellus superior. The posterior border is continuous with the intertrochanteric crest (vide infra).

The lesser trochanter is a conical projection arising from the postero-medial surface of the neck-shaft angle, and is directed medially with backward inclination. Its anterior surface near the tip receives the insertion of psoas major tendon; the iliacus muscle is attached to its base and extends for a short distance to the shaft. The posterior surface of lesser trochanter is smooth and convex, and related to the upper margin of adductor magnus separated by a bursa.

The intertrochanteric line separates the anterior surface of neck from the shaft, and extends as a ridge downward and medially from the upper border of the neck and is continuous below with the spiral line. It gives attachment to two ligaments — capsular and ilio-femoral, and two muscles — highest origin of vastus lateralis in the upper and lateral part, and highest origin of vastus medialis in the lower and medial part.

The intertrochanteric crest separates the posterior surface of the neck from the shaft, and extends from the postero-superior angle of greater trochanter to the tip of lesser trochanter. The crest is overlapped by the gluteus maximus and presents near the middle a quadratus tubercle for the inser-tion of the quadratus femoris.

The capsular ligament of hip joint is attached to the upper end of femur in a continuous line.
along the intertrochanteric line, upper margin of the neck near the root of greater trochanter, lower margin of the neck a little infract and above the lesser trochanter, and to the posterior surface of the neck along a line about 1 cm medial to and parallel with the intertrochanteric crest. Behind the neck the capsule fits, like a tight collar and presents a gap between the capsule and the bone through which the synovial membrane of hip joint comes out to act as a bursa for the tendon of obturator externus.

Shaft—The shaft of femur is gently convex infract and the convexity is maximum in the middle one-third where the shaft is narrowest. Basically the femoral shaft presents three surfaces—anterior, medial and lateral, separated by three borders—medial, lateral and posterior. The posterior border is represented by a prominent crest, the linea aspera, in the middle-third of the shaft where it acts as a buttress to resist the compressive forces for the anterior bowing of the bone. The linea aspera presents inner and outer lips, and an intermediate area. Traced above, the two lips diverge and enclose a triangle posterior surface in the upper-third of the shaft; the medial lip is continuous with the spiral line and the lateral lip with a prominent ridge, the gluteal tuberosity, which extends up to the root of greater trochanter. Similarly, the two lips of linea aspera diverge below and form a triangular popliteal surface in the lower-third of the shaft; the medial lip is continuous with the medial supra-condylar line which extends up to the adductor tubercle, and the lateral lip is continuous with the more prominent lateral supra-condylar line. Therefore, the shaft presents altogether five surfaces—anterior, medial, lateral, posterior in upper-third and popliteal in lower-third.

The upper three-fourths of the anterior surface and the adjoining lateral surface provide origin to the vastus intermedius. The articularis genu arises by a few small slips from the anterior surface immediately below the vastus intermedius and is inserted to the summit of a synovial pouch, the suprapatellar bursa, which covers the lower part of the anterior surface. The medial surface of the shaft is covered by the vastus medialis, but does not provide origin to the muscle.

The vastus medialis arises by a line which runs along the lower part of inter-trochanteric line, spiral line, medial lip of linea aspera and extends up to the upper two-thirds of the medial supra-condylar line. The origin of vastus lateralis is linear; it passes along the upper part of inter-trochanteric line, anterior and lower part of the root of greater trochanter, lateral margin of gluteal tuberosity and lateral lip of linea aspera extending up to the middle of femoral shaft.

The gluteal tuberosity receives the insertion of about one-fourth of fibres of gluteus maximus.

The structures attached to the linea aspera are assessed as follows (Fig. 15.10):

The medial lip gives attachment to the medial intermuscular septum and more medially to the vastus medialis. The intermediate lip gives attachment to the posterior intermuscular septum, and the area between the medial and posterior
septa receives insertions of adductor brevis in the upper part, adductor longus in the lower part and more lateral to them adductor magnus. The lateral lip gives attachment to the lateral intermuscular septum and more laterally to the vastus lateralis. The area between the posterior and lateral septa gives origin to the short head of biceps femoris which also arises from upper two-thirds of lateral supra-condylar line. The arrangements of attached structure to the linea aspera are the following from medial to lateral side - vastus medialis, medial intermuscular septum, adductor brevis in the upper part and adductor longus in the lower part, adductor magnus, posterior inter-muscular septum, short head of biceps femoris, lateral intermuscular septum, and vastus lateralis.

The lateral and medial borders of femur are rounded and arbitrary lines separating the surfaces. In fact, the linea aspera is formed by fusion of three primitive borders since all the intermuscular septa of thigh converge to the linea aspera.

The posterior surface in the upper-third of the shaft is limited between spiral line and gluteal tuberosity. The surface gives attachment to the following from medial to lateral side: vastus medialis, a part of iliacus, pectineus, adductor brevis, adductor magnus and gluteus maximus.

The popliteal surface intervenes between the medial and lateral supracondylar lines, and forms the upper part of the floor of popliteal fossa. The popliteal vessels, while passing downward and laterally, rest on this surface separated by a layer of fibrofatty tissue, and the artery lies next to the bone. In flexion of the knee the blood flow through the popliteal artery may be sluggish due to acute angulation of the artery. In order to avoid retardation of blood flow distal to the knee, the nature provides a liberal arterial anastomosis around the knee.

Infra-medial angle of the popliteal surface is rough and gives origin to the medial head of gastrocnemius muscle. Infra-lateral angle, close to the lateral supracondylar line, provides origin to the plantaris.

The medial supracondylar line gives attachments to three structures: medial intermuscular septum and adductor magnus muscle along its entire length except an opening in the adductor magnus for the passage of popliteal vessels as a continuation of femoral vessels, and vastus medialis muscle in upper two-thirds. The lateral supracondylar line provides attachments to three

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Fig. 15.10. Linea aspera with attachment of structures.
structures: lateral intermuscular septum along the entire length, short head of biceps femoris in upper two-thirds, and plantaris muscle in lower one-third.

Lower end—The lower end of the femur is enlarged to form the medial and lateral condyles which form the knee joint by articulating with the patella in front and the corresponding condyles of tibia below and behind. Both condyles project backwards separated by the intercondylar fossa. Outer surfaces of both condyles are rough and convex and the most prominent points on the convexity are known as the epicondyles.

A V-shaped articular surface affects the anterior, inferior and posterior surfaces of both condyles. Apex of the V is known as the patellar surface which occupies the anterior surface of two condyles and articulates with the patella. Rest of the articular surface, known as the tibial surface, comes in contact with the corresponding condyle of tibia separated by a meniscus. The patellar surface is saddle shaped; its lateral part is more broad and extends to a higher level than the medial part in order to adjust with the articular surface of patella. A narrow strip of patellar surface extends to the tibial surface of medial condyle along the intercondylar notch; the patella comes in contact with this strip in extreme flexion of knee joint (Fig. 15.11).

The lateral epicondyle gives attachment to the upper end of the fibular collateral ligament. A curved groove below the lateral epicondyle is intra-capsular; its anterior part gives attachment to the popliteus muscle, and the posterior part of the groove is occupied by the tendon of that muscle in flexed position of the knee. Above the lateral epicondyle and groove for popliteus, there lies a depression for the origin of lateral head of gastrocnemius (Fig. 15.12).

The medial epicondyle gives attachment to the upper end of the tibial collateral ligament. An adductor tubercle at the lower end of the medial supracondylar ridge lies above the medial condyle. The adductor tubercle is thrice unique: it receives the insertion of the tendon of ischial part (hamstring) of adductor magnus; the epiphyseal line of the lower end passes through the tubercle; it forms a bony landmark for surface anatomy.

The intercondylar fossa presents medial and lateral walls, and a floor limited by upper and lower margins. Medial wall of the fossa gives attachment to the upper end of the posterior cruciate ligament in its antero-inferior part. Lateral wall gives attachment in its postero-superior part to the upper end of the anterior cruciate ligament. The upper margin of its floor provides attachment to the fibrous capsule and oblique popliteal ligament; the lower margin gives attachment to the apex of infra-patellar synovial fold where the two alar folds meet. A more depressed subsidiary notch affects the lateral part of the intercondylar fossa. It accommodates the anterior cruciate ligament in extended knee and is a characteristic feature of mankind due to the adoption of upright posture.

Fig. 15.11. Inferior surface of the distal end of right femur.
The lateral condyle is more massive but bulges with less prominence than the medial condyle, because it bears the larger share of weight transmission.

![Diagram](image)

**Fig. 15.12. Lateral surface of lateral femoral condyle of right side.**

The **capsular ligament** of knee joint is attached as a continuous line along the upper border of the intercondylar notch and adjoins articular margins of medial and lateral condyles, along the medial surface of medial condyle about 1 cm above the articular margin, along the lateral surface of lateral condyle about 1 cm above the articular margin so that the line of attachment passes above the groove for the origin of popliteus but below the origin of lateral head of gastrocnemius. On reaching the anterior surface of the lower end, the capsule is **deficient** above the patellar surface for the upward extension of supra-patellar bursa.

**Anatomical position**—Place the head of femur upward, medially and slightly forward, convexity of the shaft in front, and lower surface of both femoral condyles on a horizontal surface so that the direction of shaft of femur is oblique sloping downward and medially.

**Ossification**—The femur is ossified from **one primary centre** for the shaft, **three secondary centres** for the upper end – one each for head, greater trochanter and lesser trochanter, **one secondary centre** for the lower end.

The primary centre appears in the middle of the shaft at about **seventh week of intra-uterine life.** The centre for the head appears at about **sixth month to one year** after birth, that for the greater trochanter at about **fourth year,** and for lesser trochanter at about **fourteenth year.** The lesser trochanter unites with the diaphysis during sixteenth year, the greater trochanter at the seventeenth year and the head at about eighteenth year. The neck is derived from the primary centre as a extension of the shaft. The epiphysial plate between the head and neck is initially horizontal and becomes oblique by the age of eight to twelve years.

The epiphysial centre for the lower end is **unique** since it appears just before birth in the **ninth month of inter-uterine life.** This bears some medico-legal importance because its appearance shows maturity of the focus.

The epiphysial line passes through the adductor tubercle and is replaced by bone by the age of **twenty years.** Therefore, the **lower ends is the growing end** of femur.

The head and lower end are **pressure epiphyses,** whereas the greater and lesser trochanters are **traction epiphyses.**

**Special comments**

The **bony trabeculae** in the interior of the upper end of femur are arranged to withstand the weight of the body transmitted through the femoral head. A series of **compression lamellae** arise at right angles from the articular surface of the head and converge to a central dense wedge; the latter is supported by strong lamellae which extend to the upper and lower borders of the neck. To counteract the outer thrusts of the compressive force at the neck-shaft angle, a series of **tension lamellae** extend in arched manner from the lesser trochanter to the lateral end of the upper border of the neck. A thin vertical plate of bone, the **calcar femorale,** arises from the compact wall of the linea aspera and extends in the interior of the neck where it separates into medial and lateral strands; the former blends with the inner aspect of the posterior wall of the neck and the latter extends into the greater trochanter (Fig. 15.13). The strength of these bony lamellae is such that the neck of femur in an average male can withstand a load of about 300 kg. during walking. In old age the reduction of the trabeculae due to osteoporosis makes the femoral neck vulnerable to fracture with insignificant trauma.

The linea aspera provides the attachment of **three intermuscular septa** – medial, lateral and posterior. These septa blend at the periphery with the deep fascia or fascia lata of the thigh and
plexus, whereas the lower limb muscles are supplied by lumbar and sacral plexuses. Each limb plexus gives rise to a number of nerves derived from ventral and dorsal divisions which supply basically the flexor and extensor muscles respectively. Subsequently, some of the flexor muscles are incorporated into adductor compartment. Branches from the sacral plexus \((L_4, S_2,3)\) do not supply the quadriceps and adductors which are derived from the ‘borrowed muscles of the trunk’ (R.J.Last).

PATELLA

The patella is the largest sesamoid bone ossified in the tendon of quadriceps femoris and lies in front of the knee joint; hence called the knee-cap bone.

The patella is somewhat triangular in outline and presents an apex, a base or upper border, medial and lateral borders, anterior and posterior surfaces (Figs. 15.14, 15.15).

From the foetal position of flexion, the lower limb has become more extended and rotated medially. Consequently, the extensor muscles of quadriceps femoris supplied by the dorsal division of lumbar plexus (femoral) lie in front, and the adductor muscles supplied by the ventral division of lumbar plexus (obturator) are shifted more medially. It is significant to note that the muscles of the upper limb are all innervated by the brachial

![Fig. 15.13. Bony trabeculae at the upper end of femur](https://via.placeholder.com/150)

![Fig. 15.14. Right patella (Anterior surface).](https://via.placeholder.com/150)
The lateral border receives the insertion of vastus lateralis in upper one-third and the rest gives attachment to the lateral patellar retinaculum. Therefore, the vastus medialis is attached more along the medial border, whereas the vastus lateralis is inserted more along the upper border. During extension of knee joint, the patella moves upward with a lateral inclination on the femur. To counteract the natural tendency of lateral displacement of patella, the vastus medialis exerts more medial traction by its prolonged attachment along the medial border of patella. Due to similar reason the linear origin of vastus medialis from the femur is more prolonged in downward direction than that of vastus lateralis.

![Diagram of Right Patella](image)

**Fig. 15.15. Right patella (Posterior surface).**

The anterior surface is subcutaneous and is covered by a downward extension of the superficial part of tendon of quadriceps femoris. A subcutaneous pre-patellar bursa separates the anterior surface from the overlying skin. This surface presents a number of longitudinal ridges in a dry bone; the ridges represent ossified fibres of the tendon of quadriceps femoris.

The posterior surface is mostly articular, except a small portion close to the apex for the attachment of ligamentum patellae. The articular surface is primarily divided by the vertical ridge into a large lateral part and a small medial part in order to fit with the reciprocal patellar articular surface of femur. The medial part of the articular surface is further separated by a vertical ridge from the most medial narrow strip, which comes in contact with the undersurface of medial condyle of femur along the intercondylar fossa in full flexion of knee joint. Rest of the medial part along with entire lateral part of articular surface is further subdivided by two horizontal lines into lower two, middle two and upper two areas. The lower areas come in contact with the patellar surface of femur in ordinary extension, the middle areas in semi-flexion and upper areas in ordinary flexion of knee joint. In a relaxed knee with full extension, the patella floats in the joint and does not make contact with the femur.

**Side determination**—Place the apex of patella below, articular surface behind, and the larger lateral part of articular surface determines the side to which the bone belongs.

When you place the articular surface of patella on a flat surface with its apex away from you, the bone tilts to its own side.

**Ossification**—The patella starts ossification between three and six years, initially from several centres which coalesce quickly (For further details see the chapter of knee joint).

**Tibia**

Skeleton of the leg is formed by two long bones, tibia and fibula; the former lies medial to the latter. The tibia is more massive and represents pre-axial bone; the fibula is much slender and represents post-axial bone. The tibia alone participates in the formation of knee joint, whereas the lower ends of both tibia and fibula articulate with the talus and form the ankle or talo-crural joint after forming the tibio-fibular mortice. Therefore, the tibia transmits much of the body weight and thereby accounts for its bulky size (Fig. 15.16, 15.17).

**Presenting parts**—The tibia presents upper and lower ends, and an intervening shaft or body.

The upper end is expanded and bears prominent medial and lateral condyles which articulate with the corresponding femoral condyles separated by the fibro-cartilaginous menisci. The upper surfaces of both condyles are articular; the articular surface is large and ovoid in outline over the medial condyle, and somewhat small and circular over the lateral condyle. The articular surfaces of both condyles present shallow concavity and are covered with hyaline cartilage. The peripheral part of articular surface is flat upon which the corresponding meniscus rests. An intercondylar area intervenes between the two articular surfaces; the area is narrow in the middle presenting intercondylar eminence and wider in front and behind. Anterior and posterior parts of the intercondylar area provide the attachments to the following structures from before
**Fig. 15.16. Right tibia and fibula (Viewed from the front).**

**backwards**: anterior horn of the medial meniscus, anterior cruciate ligament, anterior horn of the lateral meniscus, posterior horn of the lateral meniscus, posterior horn of the medial meniscus, and posterior cruciate ligament (Fig. 15.18).

The anterior surface of the lateral condyle presents a triangular flattening for the attachment of the lower end of ilio-tibial tract. The posterior surface of lateral condyle presents a groove for the tendon of popliteus where the fibrous capsule is deficient. Infero-laterally, the lateral condyle presents an oval or circular facet for articulation with the head of fibula to form the superior tibio-fibular joint.

The posterior surface of medial condyle presents a horizontal groove for the principal insertion of the semimembranosus.

The anterior surface of both condyles displays a triangular area, the apex of which is directed below and forms a tibial tuberosity for the attachment of ligamentum patellae.

The tibial attachment of capsular ligament of knee joint is represented by a continuous line along the peripheral margins of the articular surfaces of both condyles including the posterior margin of the intercondylar area, except at two sites—

(a) behind the lateral condyle the capsule is deficient for the tendon of popliteus;
(b) in front of both condyles the capsule is carried downward up to the tibial tuberosity and blends with the ligamentum patellae, iliotibial tract, medial and lateral patellar retinacula.

The shaft of tibia is triangular on cross-section and presents three borders anterior, medial and lateral (interosseous), and three surfaces—medial, lateral and posterior (Fig. 15.19). The anterior or shin border is entirely subcutaneous and sinuous in course. It extends from the tibial tuberosity and is continuous below with the anterior border of the medial malleolus. It gives attachment to the deep fascia of the leg (fascia cruris) and close to the malleolus provides attachment to the superior extensor retinaculum.

The medial border is continuous below with the posterior margin of the medial malleolus and
gives attachment to the deep fascia of the leg in its entire extent. In addition, it provides attachments to the following structures from above downwards: superficial part of tibial collateral ligament, popliteus muscle and its covering fascia, a part of soleus muscle below the soleal line in the middle-third of the border, deep transverse fascia of the leg, and medial end of flexor retinaculum at the medial malleolus.

The lateral or interosseous border is sharp and gives attachment to the interosseous membrane, which unites the tibia with fibula. The border begins below the facet for the head of fibula and ends below by dividing into a triangular rough notch for the attachment of the interosseous inferior tibio-fibular ligament.

The medial surface faces antero-medially, intervenes between the anterior and medial borders and is entirely subcutaneous. The lower third of the medial surface is crossed obliquely upwards and backwards by the great saphenous
vein and the saphenous nerve. Close to the medial border, the upper part of the medial surface receives from before backwards – the hockey-stick insertion of sartorius, linear insertions of gracilis and semitendinosus. The origins, nerve supply and actions of the three muscles are entirely different. The sartorius arises from the anterior superior iliac spine and the notch below it, is supplied by the femoral nerve, and acts as weak flexor of hip and knee joints, abductor and lateral rotator of the thigh at the hip joint. The gracilis arises from the anterior surface of the body and inferior ramus of pubis, is supplied by the obturator nerve, and acts as adductor of the thigh and flexor of the knee joint. The semitendinosus arises from the ischial tuberosity in common with the long head of the biceps femoris, is supplied by the tibial division of the sciatic nerve, and acts as extensor of the hip and flexor of the knee joints. But the combined actions of the three muscles acting from the tibia are to stabilize the bony pelvis by exerting as three ‘guy ropes’.

The lateral surface of the shaft is directed antero-laterally and intervenes between the anterior and interosseous borders. The upper two-thirds of the lateral surface is monopolised by the origin of the tibialis anterior. The lower third of the surface forms the anterior surface of the lower end of tibia over which extensor tendons and neuro-vascular bundle pass from the leg to the dorsum of foot. The structures related to the anterior surface of the lower end are as follows from medial to lateral side: tibialis anterior, extensor hallucis longus, anterior tibial artery with venae comitantes on each side, deep peroneal (anterior tibial) nerve, extensor digitorum longus, and peroneus tertius.

The posterior surface intervenes between medial and lateral borders, and is subdivided by the soleal line into an upper small triangular area and a lower large area. The upper area receives the insertion of the popliteus muscle. The lower area is subdivided by a vertical ridge into medial and lateral parts; the former provides origin to the flexor digitorum longus and the latter to the tibialis posterior. The soleal line extends downward and medially, and meets the medial border at the junction of the upper one-third and lower two-thirds. It gives attachment to the soleus muscle, fascia covering the popliteus through which the fibres from the semimembranosus extend, and deep transverse fascia of the leg. The posterior surface of the medial malleolus is grooved for the tendon of tibialis posterior, and beneath the flexor retinaculum is related to the following from medial to lateral side: tibialis posterior, flexor digitorum longus, posterior tibial artery with venae comitantes on each side, tibial nerve, flexor hallucis longus.

The lower end of tibia is expanded and projects medially as the medial malleolus. The superior surface of the lower end including medial malleolus is articular and receives the body of talus. Peripheral margin of the articular surface gives attachment to the capsular ligament of ankle joint. In addition, the deltoid ligament is attached to the lower margin of medial malleolus.

Ossification—The tibia is usually ossified from three centres, one primary centre for the shaft and two secondary centres – one for each end.

The centre for the shaft appears at about seventh week of intra-uterine life, near the middle of the shaft.

The centre for the upper end appears either at birth or shortly after birth and it extends as a tongue like projection to include the upper part of the tibial tuberosity.

The centre for the lower end starts between one and two years. The lower epiphysis fuses with the shaft at about fifteen to sixteen years, and the fusion of the upper epiphysis takes place between seventeen and eighteen years.

**FIBULA**

The fibula lies lateral to the tibia, and consists of upper and lower ends, and an intervening shaft (See Figs. 15.16, 15.17).

The upper end or head is expanded and presents three features:

(a) an oval or circular facet for articulation with the lateral condyle of tibia;

(b) a styloid process postero-lateral to the articular facet for the attachments of fibular collateral ligament and arcuate ligament; and

(c) a sloping surface in front of the styloid process for the insertion of biceps femoris tendon.

The neck of fibula is a constriction connecting the head with the shaft. It comes in direct contact
with the common peroneal nerve on the lateral side, and is related medially with the anterior tibial vessels when the latter pass forward through a gap above the interosseous membrane.

The shaft of fibula presents **three borders** – anterior, interosseous and posterior, and **three surfaces** – medial, lateral and posterior (See Fig. 15.19).

The **anterior border** gives attachment to the anterior intermuscular septum which is pierced in the upper part by the deep peroneal nerve. Traced below, the border splits to enclose sub-cutaneous triangular surface which extends over the lateral surface of the lower end. The anterior border of the triangular area gives attachment to the superior extensor retinaculum and its posterior border to the superficial peroneal retinaculum.

The **interosseous or medial border** gives attachment to the interosseous membrane leaving a gap in the upper part for the passage of anterior tibial vessels. The border is continuous below with an elevated, rough triangular surface which is connected with the fibular notch of tibia by interosseous inferior tibio-fibular ligament.

The **posterior border** gives attachment to the posterior intermuscular septum and is continuous below with the lateral lip of a groove on the posterior surface of the lateral malleolus.

The **medial or extensor surface** is narrow and intervenes between anterior and interosseous borders. It gives origin to the extensor digitorum longus in upper three-fourths, extensor hallucis longus in middle two-fourth medial to the extensor digitorum longus, and peroneus tertius in the lower one-fourth.

The **peroneal or lateral surface** intervenes between the anterior and posterior borders. It provides origin to the peroneus longus in upper two-thirds and the peroneus brevis in lower two-thirds; in the middle third peroneus brevis lies in front of peroneus longus.

The **posterior or flexor surface** is extensive and intervenes between the interosseous and posterior borders. It is divided by the medial crest into anterior concave part and posterior flattened part. The anterior part gives origin to the tibialis posterior, and the posterior part to the soleus in upper one-fourth and flexor hallucis longus in lower three-fourths excluding an area of the lower part of the shaft. The **medial crest** is accompanied by the peroneal vessels.

The lower end of fibula is expanded anteroposteriorly to form the **lateral malleolus** which presents lateral, medial and posterior surfaces, anterior border and a tip.

The **lateral surface** is subcutaneous and continuous above with a triangular subcutaneous surface formed by the spitting of the anterior border. The **medial surface** presents a triangular articular surface in front, and a depression, the **malleolar fossa**, below and behind (Fig. 15.20). The triangular facet articulates with the lateral surface of the body of talus and completes the ankle joint after forming the tibio-fibular mortice. The malleolar fossa gives attachment to the inferior transverse tibio-fibular ligament and posterior talo-fibular ligament.

The **posterior surface** presents a groove for the lodgement of the tendons of peroneus brevis and peroneus longus; the former lies deep to the latter. Both tendons are enveloped by a common synovial sheath beneath the superior peroneal retinaculum which is attached along the lateral margin of the groove.

The **anterior border** gives attachment to the anterior talofibular ligament. The tip of lateral malleolus lies about 1 cm below that of medial malleolus. It presents a notch for the attachment of calcaneo-fibular ligament.

![Fig. 15.20. Medial surface of the lower end of right fibula.](image)

**Anatomical position**—Identify the end of fibula which presents non-articular malleolar fossa and place that end below. The malleolar fossa occupies the posterior part of medial surface, behind and below the triangular articular facet. Therefore, looking at the malleolar fossa one can determine the side of fibula.
Hold the fibula vertically by the same hand to which side it belongs, so that the triangular facet of the lower end faces medially.

Ossification—The fibula is ossified from three centres - one primary for the shaft and two secondary, one for each end.

The centre for the shaft appears at about eighth week of intra-uterine life. The epiphysial centre for the lower end appears earlier between one and two years, and that for the upper end starts later between three and four years. The fusion of lower epiphysis with the shaft takes place between fifteen and seventeen years, whereas at the upper end fusion takes place between seventeen and nineteen years. That means, in fibula 'law of union of epiphysis' is violated.

In order to explain the cause of violation of the law, one should note that when a long bone possesses two types of epiphyses, pressure and traction, the ossific centre of pressure epiphysis appears earlier than that of traction epiphysis; but in presence of similar types of epiphyses at both ends the centres appear, as a rule, in proximo-distal direction. In fibula, the upper end is a traction epiphysis produced by the pull of the biceps femoris, whereas the lower end is a pressure epiphysis transmitting weight through the ankle joint. Thus the epiphysial centre of the lower end of fibula appears earlier than that of the upper end. Since the growing end of fibula lies at its upper end (according to the direction of nutrient foramen), it unites with the diaphysis last although its epiphysial centre also appears last.

Functions of fibula
1. It provides the surface area for the attachments of most of the extensor, flexor and peroneal muscles;
2. It completes the ankle joint from the lateral side;
3. Lateral malleolus acts as a pulley for the tendons of peroneus longus and brevis, otherwise eversion of the foot would not be possible;
4. The head of fibula articulates with the lateral condyle of the tibia and forms a plane synovial superior tibio-fibular joint. This joint permits upward gliding of the fibula during extreme dorsiflexion of the foot.

Subdivision of leg
The interossseous membrane, anterior and posterior intermuscular septa along with the tibia, fibula and overlying deep fascia divide the leg into three compartments – extensor, peroneal and flexor.

The extensor compartment lies in front of the interosseous membrane and medial to the anterior intermuscular septum. Muscles of extensor compartment are supplied by the deep peroneal (anterior tibial) nerve.

The peroneal compartment lies along the lateral surface of fibula and intervenes between the anterior and posterior intermuscular septa. Muscles of this compartment are supplied by the superficial peroneal (musculo-cutaneous) nerve.

The flexor compartment lies posterior to tibia, fibula and interosseous membrane, and medial to the posterior intermuscular septum. The tibial nerve (posterior tibial) is the nerve of this compartment.

Medial rotation of the lower limb from foetal position, brings the extensor muscles to the front and the flexor muscles to the back of the leg. It also alters the disposition of pre-axial bone, the tibia, on the medial side and post-axial bone, the fibula, on the lateral side. The peroneal muscles are functionally separated from extensor muscles, since both are supplied by the dorsal divisions of the sacral plexus.

SKELETON OF THE FOOT

The foot is set at right angle to the leg. This permits the sole to have a proper grip on the ground. The skeleton of foot is composed proximo-distally of tarsal, metatarsal and phalangeal bones.

Tarsal bones
These are short bones, seven in number and are arranged in three rows – talus and calcaneus in the proximal row, navicular bone in the middle row, and three cuneiform (medial, intermediate and lateral) and cuboid bones in the distal row (Figs. 15.21, 15.22).

The talus forms a connecting link between the bones of the foot and the leg. It is situated on the upper surface of the anterior two-thirds of the calcaneus. The talus presents head, neck and body. The head is directed forward, medially and slightly downward; its convex articular surface articulates in front with the navicular bone and below with the upper surface of the sustentaculum
tali of calcaneus by two facets. The unsupported lower surface of the head rests on the plantar calcaneo-navicular or spring ligament. Therefore the head of talus is received in a socket formed by the navicular bone, sustentaculum tali of calcaneus and the spring ligament; it enters in the formation of a synovial talo-calcaneo-navicular joint which is structurally a ball-and-socket joint. The neck of talus is non-articular and it projects from the body forward and medially making an angle of about 150° in adult, and about 130°-140° in the new born. Inferior surface of the neck presents a groove, sulcus tali, which when faced with the corresponding groove of calcaneus, is converted into an oblique bony tunnel, the sinus tarsi; the latter gives attachment to interosseous talocalcaneal ligament. The superior surface and adjacent medial and lateral surfaces of the body of the talus are received by the tibio-fibular mortice and form the ankle joint. The inferior surface of the body of talus carries an obliquely placed concave facet which articulates with reciprocally convex facet on the upper surface of middle-third of calcaneus and forms a plane synovial sub-talar joint. The posterior surface is marked by a groove which is bounded by medial and posterior tubercles; the groove transmits the tendon of flexor hallucis longus. All attachments of the talus are ligamentous and not muscular. Therefore, the talus articulates with four bones – tibia, fibula, calcaneus and navicular, and forms three joints – supra-talar or ankle joint, sub-talar or posterior talo-calcanean joint, and pre-talar or talocalcaneo-navicular joint.

The calcaneus is the largest of tarsal bones, situated below the talus and extends behind the talus. It is directed forward and laterally with an upward inclination. The anterior surface is articular and saddle shaped; it articulates with the proximal surface of the cuboid which is reciprocally curved and forms a saddle-shaped calcaneo-cuboid joint. A triangular projection known as the calcanean angle of cuboid extends backward below the calcaneo-cuboid joint and maintains the upward tilt of the anterior surface of calcaneus. The talo-calcaneo-navicular and calcaneo-cuboid joints collectively form the mid-tarsal or transverse tarsal joint; a bifurcated ligament
however, separates the two joint cavities. The **posterior surface** of calcaneus is large and receives the attachments of tendo-calcaneus and plantaris tendon in the middle one-third. The **plantar surface** of calcaneus is rough and marked by three tubercles – anterior and two posterior tubercles, medial and lateral. The medial tubercle strikes the ground on standing. The triangular area between the three tubercles gives attachment to the **long plantar ligament**, and the groove in front of the anterior tubercle gives attachment to the **short plantar ligament**. The dorsal or **upper surface** of the calcaneus is divided into three areas: **anterior third** is rough and somewhat depressed; it gives attachments to the bifurcated ligament, stem of inferior extensor retinaculum and extensor digitorum brevis muscle; **middle third** is articular and forms sub-talar joint; **posterior third** is separated from the tendo-calcaneus by fibro-fatty tissue and a bursa. The **medial surface** of calcaneus is concave which is accentuated in the antero-superior part by the **sustentaculum tali**. The upper surface of the sustentaculum tali presents two facets to articulate with the head of the talus, and the lower surface is grooved for the lodgement of the tendon of flexor hallucis longus.

The medial surface of the sustentaculum gives attachment to the spring ligament, deltoid ligament, a slip of tibialis posterior tendon and medial talocalcaneal ligament; this surface is related to the tendon of flexor digitorum longus. The **lateral surface** of calcaneus is flat and marked by two tubercles, posterior and anterior. The posterior tubercle gives attachment to the calcaneo-fibular ligament. The anterior tubercle or **peroneal trochlea** gives attachment to the inferior peroneal retinaculum, and presents above and below the tubercle two oblique grooves slanting forward and downward; upper groove lodges the tendon of peroneus brevis and lower groove the tendon of peroneus longus.

The **navicular bone** belongs to middle row of tarsal bones and occupies the medial margin of foot. It articulates behind by a concave facet with the head of talus, and in front with the medial, intermediate and lateral cuneiform bones by three triangular facets. Laterally, it joins with the cuboid bone partly by articular facet and partly by intertarsal ligaments. **Medial surface** of the navicular bone presents a rough tuberosity which receives principal attachment of the tendon of the tibialis posterior. Dorsal surface is convex and rough, and provides
attachment of dorsal ligament. Plantar surface receives distal attachment of plantar calcaneo-
navicular ligament.

Three cuneiform bones are medial, intermediate and lateral. Each bone is wedge shaped; the edges of intermediate and lateral cuneiform are directed to the plantar surface and that of medial cuneiform to the dorsal surface. All the cuneiforms articulate behind with the navicular bone, and in front with the bases of first, second and third metatarsal bones medio-laterally. Distal articular surface of the intermediate cuneiform falls short of the other two bones. Hence the base of second metatarsal bone fits in a depression and articulates with all the cuneiform bones. This explains the stability of the second metatarsal bone and its second toe; therefore the axial line of foot passes through the second toe and movements of abduction or adduction of the toes are mentioned with reference to the second toe. Cuneiform bones articulate with one another by synovial inter-cuneiform joints. Lateral surface of the lateral cuneiform bone articulates with the cuboid bone. The base of the first metatarsal and medial cuneiform receive infero-medially the insertion of tendon of tibialis anterior, and infero-laterally the tendon of peroneus longus.

The cuboid bone occupies the lateral margin of foot and somewhat cubical in shape, lateral surface being narrower than medial surface. Behind it articulates by a saddle-shaped facet with the calcaneus, and in front articulates with the bases of fourth and fifth metatarsal bones. The lateral surface is notched for the tendon of peroneus longus. The medial surface joins with lateral cuneiform and navicular bones. The dorsal surface is flat and gives attachment to dorsal ligaments. The plantar surface is divided by an oblique ridge into a posterior sloping part and an anterior grooved part. The posterior part gives attachment to the short plantar ligament, the oblique ridge to the long plantar ligament, and the oblique groove transmits the tendon of peroneus longus enveloped by a synovial sheath in an osseo-fibrous tunnel; sometimes a sesamoid bone appears in the tendon of peroneus longus in this region.

Ossification of tarsal bones

All tarsal bones ossify within 2 or 3 years after birth, except talus, calcaneus and cuboid which start ossification in intra-uterine life. The centre for talus appears in the 6th month, calcaneus in the 7th month and cuboid in the 9th month of prenatal life. For the posterior surface of calcaneus, however, a scale-like secondary centre appears about the 10th year.

Comparison between carpal and tarsal bones

Both carpal bones of hand and tarsal bones of foot are short bones. Carpal bones are eight in number and arranged in proximal and distal rows. Bones of proximal row are from lateral to medial side-scaphoid, lunate, triquetral and pisiform. Bones of distal row from lateral to medial sides are – trapezium, trapezoid, capitate and hamate. As mentioned earlier, tarsal bones are seven in number and arranged in proximal, middle and distal rows.

Before comparing carpal and tarsal bones, one should look to the general plan of short bones of pentadactyl hand and foot of terrestrial vertebrates. There are three short bones in the proximal row, the middle one is known as intermediate; five bones in the distal row and a group of central bones between the two rows known as ossa centralia.

In mankind, among the bones of proximal row talus corresponds with scaphoid, calcaneus with triquetral, os intermedium is represented by lunate bone of hand and lateral tubercle of talus of foot. Pisiform is a sesamoid bone ossified in the tendon of flexor carpi ulnaris and does not possess homologous tarsal bone. Out of five bones of distal row, 4th and 5th bones along the post-axial border unite to form a single bone which is represented by the cuboid and hamate bones. Remaining three bones retain individual entity. Medial cuneiform corresponds with trapezium, intermediate cuneiform with trapezoid, and lateral cuneiform with capitale. One of os centralis persists in human as navicular bone of foot and as a tubercle which fuses with the dorsal surface of scaphoid bone of hand.

Metatarsal bones

These are five miniature long bones, and are numbered from medial to lateral side. The first metatarsal is shortest and strongest, and the second is the longest. Each metatarsal bone presents a head in front, a base behind and a shaft between them. The base articulates with the distal row of tarsal bones forming synovial tarso-
metatarsal joints. The head articulates with the base of proximal phalanx and forms synovial metatarso-phalangeal joint. The shaft gets narrower from base of head, except in first metatarsal bone. Plantar surface of the shaft is concave from before backward. The inferior surface of head of the first metatarsal presents two longitudinal grooves for the lodgement of two tendons of flexor hallucis brevis in which sesamoid bones appear. The heads of all meta-tarsal bones are connected by four bands of deep transverse metatarsal ligaments. The base of the first metatarsal bone receives insertions of tendon of tibialis anterior inferior-medially, and that of peroneus longus infero-laterally. The base of the fifth metatarsal presents a bony projection laterally for the insertion of the tendon of peroneus brevis; dorsally it receives insertion of peroneus tertius, and its plantar surface gives origin to the flexor digiti minimi brevis and presents groove for the lodgement of tendon of abductor digiti minimi. Plantar surfaces of the bases of the second, third and fourth metatarsal bones give origin to the oblique head of adductor hallucis. Four dorsal interossei are bipennate muscles and arise from the adjacent surfaces of the shafts of five metatarsal bones. Three plantar interossei are unipennate muscles and arise from the medial side of plantar surface of the shafts of third, fourth and fifth metatarsal bones (See Figs. 15.21, 15.22).

Ossification of metatarsals

All metatarsals are ossified from two centres, primary and secondary. The secondary (epiphyseal) centres of all metatarsals are directed towards the head, except in first metatarsal which is directed toward the base. Secondary centres usually appear 2 or 3 years after birth, and fuse with the diaphysis at about 17 or 18 years.

Phalangeal bones

The phalangeal bones are miniature long bones, and altogether fourteen in number. In each toe, except the great toe, there are three phalanges — Proximal, middle and terminal. The great toe possesses only proximal and terminal phalanges. Middle and terminal phalanges are practically rudiments of bones; in the little tow they are occasionally fused. Each phalanx is ossified from two centres, primary and secondary. The secondary or epiphyseal centres of all phalanges are directed towards the base, identical with the first metatarsal bone. Fusion between epiphysis and diaphysis takes place at about 17 or 18 years.

The base of the proximal phalanx bears a concave facet to articulate with the head of the metatarsal bone, and forms the metatarso-phalangeal joint. The articular surface of its distal end is trochlea-like and articulates with the middle phalanx in the lateral four toes and with the terminal phalanx in the great toe. The great toe possesses one interphalangeal joint, and rest of the toes two interphalangeal joints, proximal and distal. The basal and distal articular surfaces of the middle phalanx are trochlea-like. The distal extremity of each terminal phalanx bears a rough tuberosity on its plantar surface and provides attachment to the pulp of toe-tip.

Attachments of structures to the base of the proximal phalanx of different toes:

1. Great toe — Medially, abductor hallucis and medial tendon of flexor hallucis brevis;
   Laterally, adductor hallucis and lateral tendon of flexor hallucis brevis;
   Dorsally, tendon of extensor hallucis brevis.

2. Second toe — Medially, first dorsal interosseous;

Differences between metatarsals and metacarpals

<table>
<thead>
<tr>
<th>Metatarsals</th>
<th>Metacarpals</th>
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<tbody>
<tr>
<td>1. Head—It is generally smaller than the base, and is directed in front.</td>
<td>1. Head—It is generally larger than the base, and is directed below.</td>
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<tr>
<td>2. Shaft.</td>
<td>2. Shaft—</td>
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<tr>
<td>(a) it gets narrower from base to the head,</td>
<td>(a) it increases in size from base to the head,</td>
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<tr>
<td>(b) concave surface is directed below,</td>
<td>(b) concavity of shaft is directed in front,</td>
</tr>
<tr>
<td>(c) dorsal surface of the shaft presents no flattening,</td>
<td>(c) dorsal surface presents triangular flattening,</td>
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<tr>
<td>3. These are numbered from medial to lateral side.</td>
<td>3. They are numbered from lateral to medial side.</td>
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Laterally, second dorsal interosseous;

3. Third toe—Medially, first plantar interosseous;

Laterally, third dorsal interosseous;

4. Fourth toe—Medially, second plantar interosseous;

Laterally, fourth dorsal interosseous;

5. Little toe—Medially, third plantar interosseous;

Laterally, abductor digiti minimi and flexor digiti minimi brevis.

Note: 1. Out of four dorsal interossei, the first is attached to the medial side of the second toe, and the rest are attached to the lateral side of the base of proximal phalanx of second, third, and fourth toes. Therefore, the dorsal interossei are abductors of middle three toes.

2. Each of the three plantar interossei is attached to the medial side of the base of proximal phalanx of third, fourth and fifth toes, and produces adduction of the lateral three toes towards the second toe which forms the axial line of foot.

3. To summarise, the numbers of muscles attached to the proximal phalanges of toes are as follows: great toe – 4, second toe – 2, third toe – 2, fourth toe – 2, and fifth toe – 3.

Structures attached to the middle phalanx of lateral four toes:

Dorsal aspect of the base-middle slip of extensor digitorum longus along with lumbricals and interossei through the dorsal expansion.

On each side of the plantar surface of the shaft—flexor digitorum brevis.

Structures attached to the base of terminal phalanx:

Great toe—

Plantar surface, flexor hallucis longus;

Dorsal surface, extensor hallucis longus.

Lateral four toes—

Plantar surface, tendons of flexor digitorum longus;

Dorsal surface, terminal slip of tendons of extensor digitorum longus along with lumbricals and interossei through the dorsal expansion.
SUPERFICIAL STRUCTURES

Skin—The skin of the lower limb is thick and tough on the exposed surfaces and on surfaces subjected to pressure or friction, such as in buttock, lateral aspects of thigh and leg and the bearing points of the sole of foot.

Superficial fascia—It consists of loose areolar tissue and contains a variable amount of fat, cutaneous nerves, great saphenous vein and its terminal tributaries, the cutaneous branches of the femoral artery, and inguinal lymph nodes with their associated lymph vessels.

The membranous layer of the superficial fascia of the abdominal wall (Scarpa’s fascia) extends into the upper part of thigh and becomes attached to the fascia lata (deep fascia of thigh) at the flexure skin crease of the hip joint, where attachment of skin to the fascia lata prevents its further descent. The line of fusion of the Scarpa’s fascia and the fascia lata extends laterally from the pubic tubercle below the inguinal ligament, so that the saphenous opening of the fascia lata lies below this line and a femoral hernia emerging from the saphenous opening does not receive any covering derived from the fascia of Scarpa.

Close to the inguinal ligament the superficial fascia of thigh splits into superficial and deep layers. The superficial layer is fatty and continuous with the Camper’s fascia of the abdominal wall; the deep layer consists of a fibro-elastic stratum which closes the saphenous opening and forms the cribriform fascia. The latter is pierced by the great saphenous vein, other blood and lymph vessels and presents a sieve-like appearance; hence the name cribriform.

Cutaneous nerves

The cutaneous nerves of the front of thigh are derived from the lumbar plexus and convey the fibres from the ventral rami of the first three lumbar nerves. They are as follows (Fig. 16.1) :

1. The lateral femoral cutaneous nerve, usually a direct branch of the lumbar plexus;

2. The intermediate and medial femoral cutaneous nerves, and the saphenous nerve are the branches of femoral nerve.

Note:

(i) The lateral, intermediate, medial femoral cutaneous nerves, and saphenous nerve pierce the fascia lata along an oblique line that roughly corresponds with the course of sartorius muscle.

(ii) The posterior branch of the lateral femoral cutaneous nerve extends to the gluteal region; the posterior branch of the medial femoral cutaneous nerve extends to the medial side of the calf; the saphenous nerve extends more caudally to supply the skin on the tibial side of the front of the leg and the medial side of the dorsum of the foot up to the head of the first metatarsal bone.

3. A branch from the anterior division of the obturator nerve, after forming subsartorial plexus, supplies the skin on the medial side of the middle of thigh and occasionally extends to the calf.

4. The skin overlying the femoral triangle is supplied by:

(a) the ilio-inguinal nerve after emerging through the superficial inguinal ring;

(b) the femoral branch of genito-femoral nerve pierces the femoral sheath and overlying fascia lata and supplies an area of skin below the middle of inguinal ligament.

The lateral femoral cutaneous, genito-femoral and ilio-inguinal nerves are described separately, and rest of the cutaneous nerves are mentioned with femoral and obturator nerves.
Lateral femoral cutaneous nerve—It is a branch of the lumbar plexus and conveys fibres from the dorsal branches of ventral rami of L₂ and L₃ spinal nerves. After emerging from the lateral border of psoas major, the nerve passes across the iliac fossa beneath the fascia iliaca and reaches the notch on the medial side of the anterior superior iliac spines, where it passes behind, or through the substance of the inguinal ligament and enters the thigh. Sometimes the nerve is incorporated within the substance of fascia iliaca and lodges in a fibrous tunnel of the inguinal ligament. The irritation of the nerve in the fibrous tunnel is expressed as pain on the lateral side of thigh and the condition is known as the meralgia paraesthetica; freeing of the nerve from the tunnel in the inguinal ligament and from the fascia iliaca will relieve the symptoms.

The posterior branch conveys the fibres from L₂, pierces the fascia lata at a higher level than the anterior branch, supplies the skin of the gluteal region, and postero-lateral aspect of thigh along the ilio-tibial tract.

Genito-femoral nerve—It is derived from the lumbar plexus and conveys fibres from L₁ and L₂. The nerve pierces the psoas major and the overlying fascia iliaca in the posterior abdominal wall, passes subperitoneally downward and laterally behind the ureter and divides at a variable level into genital and femoral branches. The genital branch carries the fibres from L₂, enters the inguinal canal through the deep inguinal ring, supplies the cremaster muscle in male and the terminal filaments distribute to the scrotum or mons pubis and labium majus.

The femoral branch conveys the fibres from L₁, enters the lateral compartment of the femoral sheath lying at first lateral and then in front of the femoral artery, and finally pierces the anterior wall of femoral sheath and the fascia lata to supply the area of skin, the size of the palm of the hand, below the middle of inguinal ligament. It would have been more appropriate if the nerve is named femoro-genital, instead of genito-femoral, in conformity with the root values of the nerve (Last, R.J.).

Ilio-inguinal nerve—It is derived from the lumbar plexus and conveys the fibres from L₁. The ilio-inguinal is the collateral branch of ilio-hypogastric nerve and hence, does not provide any lateral cutaneous branch. After traversing around the anterior abdominal wall in the neuro-vascular plane between internal oblique and transversus abdominis, the nerve pierces the internal oblique about 2.5 cm medial to and below the anterior superior iliac spine and enters the inguinal canal superficial to the spermatic cord or round ligament of uterus. Finally the nerve emerges through the superficial inguinal ring, pierces the external spermatic fascia and supplies the skin of the upper and medial part of the front of thigh, root of the penis and upper part of the scrotum in male or mons pubis and upper part of labium majus in female.

Veins of the lower limb

The lower limb presents anatomically and functionally three distinguishable sets of veins—superficial, deep and perforating.
The superficial veins lie in the superficial fascia and consist essentially of the great and small saphenous veins which represent respectively the pre-axial and post-axial veins of the developing limb bud.

The deep veins are surrounded and supported by the powerful muscles which are enclosed in a tube of thick non-elastic deep fascia. The deep veins accompany the arteries and include the tibial, peroneal, popliteal and femoral. Below the knee the deep veins are arranged as pair of venae comitantes along the arteries, but above that level they form a single major vein.

The perforating veins communicate superficial with deep veins by piercing the deep fascia and following the intermuscular septa. The positions of perforators are worthy to note, because of their role in the formation of varicose veins. In fact, the great and small saphenous veins represent long perforating veins.

All veins of the lower limb are provided with valves to direct the blood flow to the heart particularly against gravity in upright posture. The valves are more numerous in the deep veins than in the superficial veins. The veins from the muscles draining into the deep veins are valved, except those in the soleus where they are arranged in the form of venous sinuses. The blood flow is sluggish in the soleal sinuses when the muscles are at rest. Prolonged rest in bed, as adopted by some patients after surgical operation, is unwise because it may develop deep vein thrombosis and culminate into severe complication of pulmonary embolism. The perforating veins are valved at each end and permit the blood flow from superficial to deep veins and not in opposite direction.

It is worthwhile to note that the venous blood of the foot flows from the deep veins in the sole to the superficial veins on the dorsum of the foot. However, in the leg and thigh the blood flows from superficial to deep veins as directed by the valves of the perforators.

Factors helping venous return from the lower limb:

1. In upright position, the chief factors is the contraction of the calf muscles known as ‘calf pump’ which acts a peripheral heart within the tight sleeve of deep fascia and squeezes the blood upwards along the deep veins. The venous return is further facilitated by the transmitted pulsation of the adjacent arteries and arrangements of valves in the veins. Moreover, the competency of valves in the perforating veins prevents the reflux of blood into the low pressure superficial veins during the contraction of calf muscles.

2. In recumbent position, the vis-a-tergo produced by the contraction of the heart and the suction action of the diaphragm during inspiration are sufficient to maintain the venous return.

Great saphenous vein

The great (long) saphenous vein is the longest vein of the body and represents the pre-axial vein of the lower limb (Fig. 16.2-a).

Course:

It begins as a continuation of the medial end of the dorsal venous arch of the foot, supplemented by the medial marginal vein. The vein passes upward about 2.5 cm infront of the tibial malleolus, crosses obliquely the medial surface
of the lower third of tibia and then ascends about a finger's breadth behind the medial border of tibia to reach the knee. It occupies the postero-medial aspect of the knee joint, about one hand-breadth posterior to the patella and runs upward along the medial side of the thigh to reach the saphenous opening (fossa ovalis), the centre of which lies about 3 cm below and lateral to the pubic tubercle.

![Diagram of the saphenous vein system]

**Tributaries:**

Just below the knee—

1. **Posterior arch vein**—It collects the blood from the postero-medial aspect of the calf and consists of a series of venous arcades connecting the three medial ankle-perforating veins.

2. **Anterior leg veins** extend diagonally across the shin and join the great saphenous vein.

3. A few veins from the calf which communicate with the small saphenous vein.

In the thigh—

4. **Antero-lateral vein** commences from a venous plexus on the lower part of the front of thigh, crosses the apex of femoral triangle and joins the great saphenous vein in the upper part of thigh.

5. **Postero-medial vein,** sometimes called the **accessory saphenous vein,** drains the posterior and medial aspects of thigh and joins with the great saphenous vein; sometimes it communicates below with the small saphenous vein.

Just before piercing the cribiform fascia—

6. **Superficial epigastric;**

7. **Superficial circumflex iliac;**

8. **Superficial external pudendal vein.**

These veins accompany the corresponding superficial branches of femoral artery. The superficial epigastric and superficial circumflex iliac veins drain the blood from the lower part of abdominal wall below the umbilicus. The superficial external pudendal vein passes superficial to the spermatic cord and drains part of the scrotum and receives blood from the superficial dorsal vein of penis.

A **thoraco-epigastric vein** runs along the antero-lateral wall of the trunk and occasionally connects the superficial epigastric vein with the lateral thoracic vein and establishes a communication between the femoral and axillary veins.

Deep to the saphenous opening

9. The **deep external pudendal vein** passes deep to the spermatic cord after draining the blood from the anterior part of perineum and finally terminates into the great saphenous vein, just before the latter opens into the femoral vein.

**Perforating veins**—A fairly constant numbers of perforating veins with fixed positions are found to connect the tributaries of saphenous veins with
the deep veins after piercing the deep fascia. The perforators are provided with valves at each end and direct the blood from superficial to deep veins (Fig. 16.3).

Positions of the perforators are as follows (See Fig. 16.2 a, b):

1. A **mid-hunter perforator**—It connects the great saphenous vein with the femoral vein in the Hunter’s (adductor) canal.

2. A **knee perforator** connects the great saphenous vein with the posterior tibial vein just below the knee and close to the medial border of tibia.

3. **Three medial ankle perforators**—They are situated close to the medial border of the lower third of tibia and connect the great saphenous vein with the posterior tibial veins.

   The upper one lies at the junction of the middle and lower third of tibia, the lower one is situated below and behind the medial malleolus, and the middle perforator intervenes midway between them. The medial ankle perforators join with one another by a series of arcades which form the **posterior arch vein**.

4. **One lateral ankle perforator** communicates the short saphenous vein with the peroneal vein and is situated at the junction of middle and lower third of the leg.

**Valves** in the great saphenous vein:

About **ten to twenty valves** are present in the great saphenous vein, out of which one valve lies just before it pierces the cribriform fascia and the terminal valve is located at its junction with the femoral vein. The **sapheno-femoral valve** presents functional importance. In about 80% of the people the external iliac vein presents a valve which protects the sapheno-femoral junction against high pressure. The remaining 20% of the unfortunate people possesses no such valve and becomes the victim of varicose vein commencing from the sapheno-femoral junction and extending gradually downward.

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**Applied Anatomy of Superficial Veins**

1. The superficial veins of lower limb are often dilated and tortuous, and become varicose. Over the area of varicosity the skin becomes pigmented and suffers from lack of nutrition which culminates in varicose ulcer. Such an ulcer often bleeds profusely and warrants immediate surgical attention to treat the varicose veins with an equal importance as though the heart bleeds from the back flow of blood.

The principal causes of varicosities are:

(a) Thrombosis of the deep veins;
(b) Persistent elevation of intra-abdominal pressure due to abdominal tumours or multiple pregnancies;
(c) Incompetency of valves in perforating veins, or superficial veins or both; this is the commonest cause.

**Incompetency of the sapheno-femoral valve** will throw great strain on the more distal valves and within a matter of time the whole great saphenous vein becomes varicose. Under such circumstances, the great saphenous vein is detached from the femoral vein at its point of entry and its tributaries in the groin are ligated individually; otherwise varicosity will recur (Trendelenburg’s operation).

**Incompetency of valves in the perforating veins** produces ‘high pressure leaks’ from the deep to the superficial veins with eventual varicosity of the superficial vein. Identification of the exact sites of the defective perforators is
essential before putting ligatures to such perforators. When numerous perforators are involved, the entire length of great saphenous vein is removed by ‘stripping’ operation. A flexible wire is introduced into the vein from the level of the medial malleolus to the groin where it is brought out of the superficial vein, after disconnecting the latter from the saphenofemoral junction. The wire stripper is pulled proximally and the entire vein is avulsed by turning it inside out.

Recognition of the sites of incompetent valves can be made by the tourniquet test. The patient lies with the lower limbs exposed and the affected limb is elevated above the level of heart to empty the varicose veins. A rubber tubing is applied firmly around the upper thigh to occlude the saphenous vein but not the femoral vein. The patient is now allowed to stand and produce gentle exercises.

(a) If the varicosities remain empty for 30 seconds, the communicating veins below the tubing are competent; when filling takes place within this time the communicating veins are incompetent.

(b) When the collapsed veins fill at once on removal of the tubing, the saphenofemoral valve is incompetent.

2. In aortic-coronary by-pass operation for improving the ischaemia of heart, the great saphenous vein with some of its tributaries is removed for arterial grafting. Due to the presence of valves, the vein has to be reversed to replace an arterial obstruction.

The small saphenous vein may possess variable termination:

(a) Sometimes it joins the great saphenous vein in the upper third of thigh either directly or through the accessory saphenous vein;

(b) It may bifurcate, one joining the great saphenous vein and the other ending in the popliteal or the deep posterior veins of the thigh;

(c) Occasionally it fails to reach the knee and ends in the great saphenous vein or deep veins of the leg.

The small saphenous vein is provided with seven to thirteen valves.

### Inguinal lymph nodes

The inguinal nodes are arranged into two groups, superficial and deep, with respect to the deep fascia (fascia lata) of thigh.

**Superficial inguinal nodes**—These are situated in the subcutaneous fat, and consist of upper and lower groups (See Fig. 16.4).

The **upper group**, containing five or six nodes, forms a chain immediately below the inguinal ligament. The **lateral members** of upper group receive **afferent lymphatics** from:

(a) the gluteal region, and

(b) the adjoining anterior abdominal wall below the umbilicus.

The **medial members** of upper group receive **afferents** from:

(i) the subcutaneous tissue of the anterior abdominal wall below the umbilicus,

(ii) penis including prepuce and scrotum in male, vulva and vagina below the hymen in female,

(iii) perineum and lower part of the anal canal below the pectinate line, and

(iv) a few uterine lymphatics which accompany the round ligament of uterus. **(Note that the lymphatics of testes do not drain in the inguinal nodes).**

The **lower (vertical) group**, about four or five in number, accompanies the lateral side of the termination of great saphenous vein. It receives **afferents** from all superficial lymph vessels of lower limb, except the vessels that follow the small saphenous vein and end in the popliteal nodes.
drain into external iliac nodes; some traverse the femoral canal and are intercepted by the deep inguinal nodes, and some pass in front of or lateral to the femoral vessels and reach straight to their destination. Therefore, a femoral hernia bulging through the femoral canal does not cause lymphatic obstruction of the lower limb.

Deep inguinal nodes—These vary from one to three in number, and lie on the medial side of the femoral vein. When three are present, the lowest one is situated below the junction of the great saphenous and femoral veins, the middle in the femoral canal (gland of Cloquet) and the highest in the lateral part of femoral ring within the femoral septum (Fig. 16.5).

The afferent vessels received by the deep nodes are derived from:

(a) the deep lymph vessels which accompany the femoral vessels,
(b) glans penis or glans clitoridis,
(c) a few efferent vessels from the superficial inguinal nodes.

The efferents from deep inguinal nodes drain into external iliac nodes after piercing the femoral septum which closes the femoral ring.

**Fig. 16.4. Superficial inguinal lymph nodes and their areas of drainage.**

The efferent vessels, about twenty or more in number, from all superficial inguinal lymph nodes

**Fig. 16.5. Inguinal lymph nodes and termination of their efferent vessels.**

**Applied Anatomy**

The upper goup of superficial inguinal nodes may be enlarged due to spread of infection or malignant growth extending from the lymphatic territory drained by these nodes. This includes the infra-umbilical part of
abdominal wall, gluteal region, perineal region including external genitalia, vagina below the hymen and anal canal below the pectinate line.

The lower group of superficial nodes are enlarged in diseases affecting the lower limb, save the area that follows the small saphenous vein.

Therefore, syphilitic lesion of the prepuce involves the medial members of upper group of superficial nodes, whereas that of glans penis produces enlargement of deep inguinal nodes (of Cloquet).

Deep fascia of thigh—The deep fascia is also named as the **fascia lata** because of its wide extent. It encloses the entire thigh like a stocking. The fascia lata is thickened along the lateral surface of the thigh to form the **iliotibial tract** and presents an oval gap, the **saphenous opening**, slightly below and lateral to the pubic tubercle.

![Diagram of the deep fascia of the thigh](image)

**Fig. 16.6. Proximal attachment of fascia lata in an oblique circle along the pelvic girdle and its ligaments.**

**Attachments (Fig. 16.6)—**Proximally, the fascia is attached to the pelvic girdle in a continuous line which describes an oblique circle. Starting from the pubic tubercle and extending outwards, the fascia is successively attached to the undersurface of the inguinal ligament, outer lip of the entire iliac crest, dorsal surface of the sacrum and coccyx, sacrotuberous ligament and ischial tuberosity. Traced further antero-medially, it is attached to the lower margin of the ischio-pubic ramus, anterior margin of symphysial surface of pubis, pubic crest and on reaching the pubic tubercle the fascia passes beneath the tubercle and inguinal ligament, covers the anterior surface of pectineus and gains attachment to the pecten pubis. **Three features** are to be noted in the proximal attachment of fascia lata:

1. The inguinal ligament is curved with the convexity towards the thigh due to the pull of fascia lata in standing.

2. The fascia splits twice along the iliac crest, to enclose the tensor fasciae latae and gluteus maximus, and forms a single thickened sheet, the **gluteal aponeurosis**, between them which covers the gluteus medius.

3. Around the saphenous opening, the fascia lata is arranged into superficial and deep strata. The **superficial stratum** is attached to the inguinal ligament and extends infero-laterally from the pubic tubercle as a **falciform margin** which forms the upper, lateral and lower margins of the saphenous opening. The **deep stratum** forms the ill-defined medial margin of the saphenous opening and spirals upward on the pectineus to gain attachment to the pecten pubis; it is prolonged downwards in front of adductor muscles and is continuous with the medial intermuscular septum. The superficial and deep strata of fascia lata lie respectively in front of and behind the femoral sheath.

**Saphenous opening (Fig. 16.7)—**It is an oval and twisted gap in the fascia lata, the centre of which lies about 3 cm below and lateral to the pubic tubercle and its vertical height measures about 3 to 4 cm. The saphenous opening resembles a double-breasted jacket between the superficial and deep strata of fascia lata. Its upper, lateral and lower borders are sharp and crescentic, but its medial border is ill-defined. The opening is closed by an areolar membrane, the **cribriform fascia**, which is pierced by a number of structures making it sieve-like appearance; hence the name.

**Structures passing through the saphenous opening:**

(a) great saphenous vein;

(b) superficial epigastric and superficial external pudendal arteries (not the corresponding veins);

(c) a few lymph vessels connecting the superficial and deep inguinal lymph nodes;

(d) a few branches of medial femoral cutaneous nerve.
Distally, the fascia lata is attached to the patella and to the inferior margins of the tibial condyles and the head of fibula. It forms the roof of popliteal fossa (popliteal fascia) and is continuous with the deep fascia (fascia cruris) of the leg.

**Ilio-tibial tract** (Fig. 16.8)—It forms a thickened band of fascia lata about 2.5 cm in width, which extends from the level of greater trochanter and passes vertically along the postero-lateral aspect of thigh. Above, the tract splits into two layers to enclose the **insertion of tensor fasciae latae**; the superficial layer is attached to the iliac crest and the deep layer blends with the lateral part of the capsule of hip joint. Posteriorly, the ilio-tibial tract receives **insertion of three-fourths of the fibres of gluteus maximus**. Traced below, the tract is attached to a triangular flattened area on the anterior surface of the lateral condyle of tibia. The inner surface of the tract gives attachment to the lateral intermuscular septum, through which it is connected to the lateral lip of linea aspera and lateral supracondylar line.

**Functions:**

1. When the knee is straight, the tract maintains the knee in extended position because the tract lies in front of the axis of flexion.

2. In semiflexed knee, the tract pass behind the axis of flexion and exerts an antigravity force to support the knee joint in walking and running. The antigravity pull on the ilio-tibial tract elongates the gluteus maximus which contracts more strongly as the movement proceeds.

**Surgical importance**—A strip of ilio-tibial tract is sometimes used for replacement of lost tissue during surgical repair work.

**Subdivisions of thigh**

In the lower part of thigh, the fascia lata sends three intermuscular septa—lateral, medial and posterior, which converge towards the linea aspera of femur and subdivide the thigh muscles into three groups; the lateral septum is the strongest. The **extensor group** intervenes between the lateral and medial septa and is supplied by the femoral nerve. The **adductor group** occupies the interval between the medial and posterior septa and is supplied by the obturator nerve. The **flexor group** intervenes between the posterior and lateral septa and is supplied by the tibial component of sciatic nerve.

**Deep structures of the front of thigh**

After removal of the fascia lata, the extensor and adductor compartments of the front of thigh are exposed with their contained muscles, vessels and nerves. These structures are described in succession as the femoral triangle, adductor canal, quadriceps femoris and adductor region.
Femoral triangle

It is a triangular depression below the inguinal ligament with the apex directed below, and involves the upper one-third of the front of thigh (Fig. 16.9, 16.10).

Boundaries:
Laterally, medial border of the sartorius;
Medially, medial border of the adductor longus;
Floor—It is gutter-shaped and formed from lateral to medial side by: iliacus, tendon of psoas major, pectineus and adductor longus. Sometimes the adductor brevis with anterior division of obturator nerve peeps forward in the narrow interval between pectineus and adductor longus. Muscles of the floor pass to the posterior aspect of femur, and make the floor gutter shaped.

Between the iliacus and psoas major intervenes the trunk of femoral nerve; the gap between the psoas and pectineus transmits the medial circumflex femoral vessels; the profunda
femoris vessels pass through the interval between pectineus and adductor longus.

**Roof**—Formed by the fascia lata;

**Base**—Formed by the inguinal ligament;

**Apex**—It is formed by the meeting point of sartorius and adductor longus, and is continuous below with the adductor canal.

A sharp knife penetrating deeply through the apex involves beneath the fascia lata the following structures from superficial to deep: medial femoral cutaneous nerve, femoral artery, femoral vein, adductor longus, profunda femoris vein and profunda femoris artery.

(Grant's Method of Anatomy describes that the apex of femoral triangle is formed where the sartorius crosses the lateral border of adductor longus, and thereby excludes the adductor longus from the floor. Femoral triangle without adductor longus may be called the geometric triangle, but with adductor longus forms the anatomic triangle. This book follows the description of the anatomic triangle).

**Contents**:

(a) Femoral artery and its branches;

(b) Femoral vein and its tributaries;

-Proximal 3 to 4 cm of the femoral vessels are enveloped by the femoral sheath.

(c) Deep inguinal lymph nodes;

(d) Femoral nerve and its branches;

(e) A part of lateral femoral cutaneous nerve;

(f) Femoral branch of genito-femoral nerve;

(g) Some fibro-fatty tissue.

**Femoral artery**—It is the continuation of external iliac artery and enters the femoral triangle behind the inguinal ligament midway between the anterior superior iliac spine and symphysis pubis (mid-inguinal point). The artery passes downward and medially and leaves the femoral triangle through its apex beneath the sartorius. It traverses the adductor canal and finally appears in the popliteal fossa as the popliteal artery after passing through the fifth osseo-aponeurotic opening of adductor magnus. The proximal 3 to 4 cm of the artery along with femoral vein are enclosed in femoral sheath (Fig. 16.11).

The course of the artery in the femoral triangle and adductor canal is represented topographically by the upper two-thirds of a line joining the mid-inguinal point and the adductor tubercle. The pulsation of the artery may be felt just below the inguinal ligament, where it can be compressed against the superior ramus of pubis separated only by the psoas tendon.

**Relations in femoral triangle**:

**In front**

(i) Skin, superficial fascia, superficial inguinal lymph nodes, superficial circumflex iliac vein;

(ii) Fascia lata, femoral sheath, femoral branch of genito-femoral nerve before piercing the femoral sheath;

(iii) Crossed by medial femoral cutaneous nerve from lateral to medial side, close to the apex of the triangle.

**Behind**

(i) Proximo-distally, the artery rests on psoas tendon, pectineus and adductor longus;

(ii) Psoas tendon intervenes between the artery and the capsule of hip joint; the artery is separated from the psoas by the femoral sheath and the nerve to the pectineus;

(iii) Separated from the pectineus by the profunda femoris vessels;

(iv) Separated from the adductor longus by the femoral vein.

**Medially**—Femoral vein lies medial to the artery in the upper part, and behind the artery in the lower part.

**Laterally**—In the upper part lies the trunk of the femoral nerve, outside the femoral sheath;

Medial femoral cutaneous nerve and saphenous nerve, branches of femoral, accompany lateral side of the artery in the lower part. Medial cutaneous nerve crosses the front of the artery at the apex of femoral triangle, and the saphenous nerve crosses the front of the artery from lateral to medial side in the middle of the adductor canal.

**Branches of femoral artery**

1. **Superficial epigastric artery** pierces the femoral sheath and the cribiform fascia, runs upward across the inguinal ligament to the umbilicus and lies between the two layers of superficial fascia of the abdominal wall to supply the skin and the adjoining subcutaneous tissue.

2. **Superficial circumflex iliac artery** pierces the femoral sheath and the fascia lata lateral to
the saphenous opening, passes laterally below the inguinal ligament to the anterior superior iliac spine where it forms a *spinosus anastomosis* with the deep circumflex iliac, deep branch of superior gluteal and ascending branch of lateral circumflex femoral arteries.

3. **Superficial external pudendal artery** pierces the femoral sheath and the cribriform fascia, and passes medially in front of the spermatic cord or round ligament of uterus to supply the skin of scrotum or labium majus and anastomoses with the branches of internal pudendal artery.

4. **Deep external pudendal artery** pierces the fascia lata more medially and passes behind the spermatic cord to supply the scrotum or labium majus.

5. **Muscular branches** supply the adjoining muscles.

6. **Profunda femoris artery** (Fig. 16.12)—It is the largest branch of femoral artery and provides the principal supply to the extensor, adductor and flexor muscles of thigh. It arises from the lateral side of femoral artery about 3.5 cm below the inguinal ligament and spirals medially behind the femoral vessels. The artery leaves the femoral triangle between pectineus and adductor longus, and descends successively between adductor longus and adductor brevis, between adductor longus and adductor magnus. Finally it pierces the adductor magnus as the **fourth perforating artery** and anastomoses with the superior muscular branch of the popliteal artery. In the femoral triangle the profunda femoris gives off lateral and medial circumflex femoral arteries. During rest of the course it provides muscular branches and three perforating arteries.

**Branches of profunda femoris artery**

(a) **Lateral circumflex femoral artery** passes laterally between the anterior and posterior divisions of femoral nerve, and disappears from the femoral triangle beneath the sartorius and rectus femoris. Here it divides into ascending, transverse and descending branches.
The descending branch runs steeply downwards behind the rectus femoris along the anterior border of vastus lateralis and takes part in \textit{anastomosis around the knee} by joining with the superior lateral genicular branch of popliteal artery.

(b) Medial circumflex femoral artery winds round the medial side of femoral shaft and passes successively between the psoas and pectineus, adductor brevis and obturator externus, quadratus femoris and upper border of adductor magnus. It divides mainly into transverse and ascending branches.

The transverse branch emerges from the upper border of adductor magnus and forms \textit{cruciate anastomosis} which takes place between the transverse branches of lateral and medial circumflex femoral arteries, ascending branch of the first perforating artery and descending branch of inferior gluteal artery.

The perforating arteries are four in number, the last one being the continuation of the profunda femoris artery. The perforating arteries pierce the adductor magnus and lateral intermuscular septum, supply the adductor and hamstring muscles and \textit{end in the vastus lateralis} muscles where they are connected to one another by a series of anastomoses.

The first perforating artery lies above the adductor brevis, the second in front of the brevis and the third lies immediately below it. The second perforating artery pierces both adductor brevis and magnus, and provides
usually the **nutrient artery** of femur. In cases of two nutrient arteries, they are derived from the first and third perforating arteries. At the back of thigh each perforating artery divides into ascending and descending branches close to the insertion of adductor magnus. They anastomose with one another, the highest one communicating with cruciate anastomosis and the lowest with the popliteal artery. Thus an arterial chain is established at the back of thigh which is **more potential than actual**.

7. **Descending genicular artery** arises from the femoral in the lower part of adductor canal, gives off a saphenous branch and is continued down in the substance of vastus medialis to anastomose with the superior medial genicular branch of popliteal artery.

The **saphenous branch** pierces the roof of the adductor canal and accompanied by the saphenous nerve appears on the medial side of the knee between sartorius and gracilis, and anastomoses with the inferior medial genicular branch of popliteal artery.

**Applied Anatomy**

If the femoral artery is ligatured **proximal to the origin of profunda femoris artery**, the collateral circulation is established through the anastomosis between the branches of profunda femoris and internal and external iliac arteries in the following situations:

1. At the cruciate anastomosis — inferior gluteal branch of internal iliac artery with medial and lateral circumflex femoral and first perforating branches of profunda femoris artery.

2. At the trochanteric anastomosis — superior and inferior gluteal branches of internal iliac with medial and lateral circumflex femoral branches of profunda arteries.

3. At the spinous anastomosis — superior gluteal branch of internal iliac and deep circumflex iliac branch of external iliac with superficial circumflex iliac branch of femoral and lateral circumflex femoral branch of profunda arteries.

4. Around the origin of obturator externus — obturator branch of internal iliac with medial circumflex femoral branch of profunda arteries.

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Fig. 16.12B. Anastomosis between Profunda femoris and internal and external iliac arteries.
5. In the perineum – internal pudendal branch of internal iliac with superficial and deep external pudendal branches of femoral arteries.

**Femoral vein**—From the adductor canal the vein enters the femoral triangle through its apex, where the vein lies behind the femoral artery. As the vein ascends it shifts to the medial side of the artery, and continues as the external iliac vein beneath the inguinal ligament.

In the femoral triangle the femoral vein receives two important tributaries, profunda femoris and great saphenous veins, and is provided with valves above each tributary. The sapheno-femoral valve is functionally more important.

**Femoral sheath**

**Formation**—It is a funnel-shaped fascial prolongation around the proximal part of femoral blood vessels and blends with the tunica adventitia of the vessels about 3 to 4 cm below the inguinal ligament. The sheath is derived from the extra-peritoneal connective tissue in which the external iliac vessels lie in the interval between the fascia transversalis and fascia iliaca, before they extend beneath the inguinal ligament as femoral vessels. Necessarily, the anterior wall of the sheath is formed by the fascia transversalis and its posterior wall by the fascia iliaca. On the other hand the femoral nerve is not incorporated within the sheath, because it passes entirely beneath the fascia iliaca (Figs. 16.13, 16.14-a,b).

**Function**: The femoral sheath allows the femoral vessels to glide freely in and out beneath the inguinal ligament during the movements of hip joint. The sheath is rudimentary in the new born due to foetal position of flexion, but is prolonged below the inguinal ligament when extension of thigh becomes habitual.

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**Fig. 16.13. Femoral sheath.**

**Fig. 16.14-a,b. Stages of formation of femoral sheath.**
**Subdivision**—The lateral wall of the sheath is vertical and the medial wall slopes downward and laterally. Two antero-posterior septa divide the sheath into three compartments—lateral, intermediate, and medial. The lateral compartment contains femoral artery and femoral branch of genitofemoral nerve; the intermediate compartment contains femoral vein. The medial compartment known as the **femoral canal** is conical and about 1.25 cm long. Its base is directed above and forms an oval shaped **femoral ring**, which is bounded in front by the inguinal ligament, behind by the pectineus muscle and its covering fascia, medially by the base of lacunar ligament and laterally by the femoral vein. The femoral ring is closed by the **femoral septum** which is formed by the condensation of extra-peritoneal tissue and is pierced by lymph vessels connecting deep inguinal with external iliac lymph nodes; a peritoneal depression known as the **femoral fossa** lies above the septum.

The ring is wider in female, because of the greater breadth of female pelvis and narrower diameter of femoral vessels; hence the femoral hernia bulging through the femoral ring is more common in females than in males.

The femoral canal is a potential or dead space containing a lymph node and some loose areolar tissue. The canal allows **expansion of femoral vein** during increased venous return from the lower limb.

**Structures piercing the femoral sheath**:

1. Laterally—femoral branch of genitofemoral nerve;
2. In front—superficial epigastric, superficial circumflex iliac and superficial external pudendal branches of femoral artery (not the corresponding veins).
3. Medially—great saphenous vein.

**Relationship of saphenous opening** with femoral sheath:

Falciform upper, lateral and lower margins of saphenous opening lie in front of femoral sheath, whereas ill-defined medial margin of the opening passes behind the sheath. Therefore, the cribriform fascia covers the antero-medial surface of femoral sheath.

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**Applied Anatomy**

The femoral hernia covered by a pouch of peritoneum bulges **downward** through the femoral ring into the femoral canal, then **pushes forward** through the saphenous opening and finally **turns upward** (when complete) around the upper falciform margin of saphenous opening towards the inguinal ligament (Fig. 16.15). The change of direction is to be followed in reverse order during manual reduction of the hernia, with the thigh passively flexed to obtain sufficient relaxation.

The **coverings of complete femoral hernia** are as follows from within outwards—

(a) peritoneum of the hernial sac;
(b) femoral septum;
(c) anterior wall of femoral sheath;
(d) cribriform fascia;
(e) superficial fascia and skin.

In surgical treatment of strangulated femoral hernia, the femoral ring (usual site of stricture) is enlarged in upward and medial direction by incising the lacunar ligament between two haemostatic clamps in order to avoid bleeding, if abnormal obturator artery is present above the lacunar ligament.

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![Fig. 16.15. Femoral canal and direction of femoral hernia.](image)

**Femoral nerve**

It is the largest branch of the lumbar plexus and is a nerve of the extensor compartment of thigh (Fig. 16.16).

**Root value**: It arises from the **ventral rami** of L₂, L₃, and L₄ spinal nerves.

**Course**: The trunk of femoral nerve appears in the iliac fossa under cover of fascia iliaca in the interval between the psoas major and iliacus. It
enters the femoral triangle behind the inguinal ligament on the lateral side of femoral sheath and is separated from the femoral artery by a part of psoas major tendon. The trunk of the nerve splits about 2 to 3 cm below the inguinal ligament by the lateral circumflex femoral artery into anterior and posterior divisions.

Branches:

From the trunk—It provides three branches: to the iliacus, pectineus, and a few vascular branches which ramify on the proximal part of femoral artery.

The nerve to pectineus passes medially deep to the inguinal ligament and behind the femoral sheath, and supplies the lateral part of pectineus muscle from its anterior surface.

From the anterior division—The nerve gives off two cutaneous branches, intermediate and medial femoral cutaneous nerves, and one muscular branch to the sartorius.

Intermediate femoral cutaneous nerve—It pierces the fascia lata about 8 cm below the inguinal ligament either as single trunk or as lateral and medial branches; in the latter event the lateral branch pierces sartorius muscle before appearing in the superficial fascia. Both branches supply the front of thigh and form the patellar plexus after joining with the adjacent cutaneous nerves.
Medial femoral cutaneous nerve—It accompanies the lateral side of femoral artery and at the apex of femoral triangle crosses the front of the artery from lateral to medial side, and thereafter divides into anterior and posterior branches. Before dividing, the medial cutaneous nerve gives a few branches which pierce the cribiform fascia and supply the skin of the upper part of the medial side of thigh.

The anterior branch descends in front of the sartorius, pierces the fascia lata at the junction of middle and lower third of thigh, and divides into two branches; one branch reaches the medial side of the knee and the other branch reaches the lateral side of patella and communicates with the infrapatellar branch of saphenous nerve.

The posterior branch accompanies the posterior border of sartorius, provides a few twigs to join with the sub-sartorial plexus, pierces the fascia lata at the knee, communicates with the saphenous nerve and supplies the skin of the medial side of the upper part of the leg.

Nerve to the sartorius—It arises either independently or reaches the muscle through the intermediate femoral cutaneous nerve.

From the posterior division—It gives one cutaneous branch, the saphenous nerve, and the rest are muscular branches to supply the quadriceps femoris.

Saphenous nerve—It is the longest cutaneous nerve of the body and extends downward along the lateral side of femoral artery in the femoral triangle and upper part of the adductor canal. The nerve crosses the front of femoral artery from lateral to medial side in the middle of adductor canal and leaves the lower part of the canal by piercing its fascial roof accompanied by the saphenous branch of descending genicular artery; in the roof of adductor canal it gives off a branch to form the subsartorial plexus of nerves.

On reaching the postero-medial surface of the knee, the saphenous nerve pierces the fascia lata between the sartorius and gracilis, and gives off an infra-patellar branch which pierces the sartorius and supplies the skin in front of patella after joining with the lateral, intermediate and medial femoral cutaneous nerves.

Thereafter the nerve accompanies the great saphenous vein, lying first behind and then in front of the vein, and passes down on the medial side of the leg along the medial border of tibia. In the lower third of the leg it divides into two branches. One follows the medial border of tibia and extends upto the ankle; the other branch passes in front of the ankle and supplies the skin on the medial side of the dorsum of the foot upto the first metatarso-phalangeal joint (ball of the great toe).

Muscular branches to quadriceps femoris—

1. The nerve to rectus femoris enters the deep surface of the upper part of the muscle, and gives a proprioceptive branch to the hip joint.

2. The nerve to vastus medialis is a fairly large branch which accompanies lateral side of femoral artery in the femoral triangle and upper part of adductor canal, where it sinks in the substance of the muscle and provides a significant proprioceptive branch to the knee joint.

3. The nerve to vastus lateralis passes steeply downward behind the rectus femoris and forms a prominent neurovascular bundle along with the descending branch of lateral circumflex femoral artery, and follows the anterior border of vastus lateralis. The nerve supplies the muscle and gives an articular twig to the knee joint.

4. The nerve to vastus intermedius enters the anterior surface of the upper part of the muscle. In addition to vastus intermedius, it supplies the articularis genu muscle and gives articular branches to the knee joint.

Muscles in relation to femoral triangle (See Fig. 16.9)

Sartorius—It is the longest strap muscle and its parallel fibres extend along the whole length of the muscle. The muscle arises from the anterior superior iliac spine and the notch immediately below it.

The muscle spirals obliquely across the thigh forming lateral boundary of the femoral triangle and then passes down lying on the roof of adductor canal separated by subsartorial plexus of nerve. It occupies the posterior aspect of medial condyle of femur, whence its tendon proceeds forward for insertion into the upper part of subcutaneous medial surface of the shaft to tibia, in front of gracilis and semitendinosus tendons. The insertion of sartorius resembles an upright hockey-stick with the concavity facing below. It is worthwhile to note that the tendons of three
muscles on way to their insertion to the tibia drag the deep fascia in front of them, thus making this portion of tibia not truly subcutaneous.

The sartorius is pierced by two nerves, intermediate femoral cutaneous nerve and infrapatellar branch of saphenous nerve.

Nerve supply—It is supplied by the anterior division of femoral nerve either directly or through intermediate femoral cutaneous nerve.

Actions
1. On hip joint—It is a flexor, abductor and lateral rotator of thigh at the hip joint.
2. On knee joint—It flexes and medially rotates the knee in semi-flexed position. When the sartorius contracts bilaterally, the lower limbs are brought into the position of the tail. The name sartorius is derived from a Latin word sartor which means a tailor.

Iliacus—It is a triangular muscle and arises from upper two-thirds of the iliac fossa up to the inner lip of the iliac crest, from the ventral sacroiliac ligament and from the adjoining ala of the sacrum. The muscle converges below along the lateral side of psoas major and is inserted into the psoas tendon and to the shaft of femur for about 2.5 cm below and in front of lesser trochanter.

Nerve supply—From the trunk of femoral nerve carrying fibres from L₂ and L₃.

Actions—It is a flexor of hip joint and rotates the femur medially.

Psoas major—It is a long fusiform muscle, arises from the sides of lumbar vertebrae, descends along and above the pelvic brim and converges to form a round tendon for insertion into the anterior surface of lesser trochanter of femur.

Both iliacus and psoas are covered in front by the fascia iliaca, and separated behind from the capsule of hip joint by a bursa which usually communicates with the hip joint through a gap between pubo-femoral and medial band of iliofemoral ligaments.

Nerve supply—Psoas major is supplied directly from the lumbar plexus, carrying fibres from L₂ and L₃.

Actions—Acting from above and assisted by the iliacus, it is the chief flexor of hip joint.

Acting from below, it assists in raising the trunk from recumbent to sitting position.

When the foot is on the ground, the ilio-psoas acts as medial rotator of hip joint; but when the foot is above the ground, it acts as lateral rotator of the joint. Electromyographically, the rotatory action of ilio-psoas on hip joint is, however, conflicting. But when the neck of femur is fractured, the distal fragment of the bone is rotated laterally.

Comments—The term ilio-psoas is recommended because both have common insertion and similar functions. But psoas major is a body wall muscle (pre-vertebral rectus) and gains attachment to the femur for functional reasons, whereas the iliacus is a thigh muscle and migrated to the iliac fossa for requisite functions.

Pectineus—It is a quadrilateral muscle and arises from the pecten pubis and from the narrow area of bone in front of it. The muscle slopes downward, backward and laterally and is inserted to the femoral shaft in a vertical line extending from the lesser trochanter to the linea aspera.

The anterior surface of the muscle is covered by an infolding of fascia lata that passes beneath the falciform margin of the saphenous opening. Its posterior surface overlaps the obturator externus and adductor brevis with the anterior division of obturator nerve.

Nerve supply—The ventral stratum of the muscle is supplied by a branch from the trunk of femoral nerve which passes behind the femoral sheath; the dorsal stratum is supplied by twigs from the obturator nerve and accessory obturator nerve, when present.

The multiple sources of nerve supply indicate that the muscle is composite or hybrid in development, and is formed by the amalgamation of muscles of adductor and extensor compartments.

Actions—It acts as flexor and adductor of the hip joint.

Adductor longus—It is triangular in outline, and lies medial to and in the same plane of the pectineus.

The muscle arises by a round tendon from a circular area in the angle between the pubic crest and the symphysis; a sesamoid bone known as rider's bone is occasionally developed in its tendinous origin. The muscle slopes downward, backward and laterally as a broad fleshy belly, and is inserted into the medial lip of linea aspera in the middle third of the shaft of femur.
In front it is covered by a thin areolar membrane, the **medial intermuscular septum**, which intervenes between the adductor longus and the vastus medialis. The posterior surface of the muscle overlaps the adductor brevis and magnus muscles, and is related to the obturator nerve and profunda femoris vessels.

**Nerve supply**—It is supplied by the anterior division of the obturator nerve.

**Actions**—The adductor longus is a powerful **adductor** and **medial rotator** of the hip joint. It also assists in flexion of the joint.

**Adductor canal**

It is also known as **Hunter’s canal** or **sub-sartorial canal**. It is a musculo-aponeurotic tunnel, triangular on cross-section, and extends from the apex of femoral triangle to the fifth osseo-aponeurotic opening of the adductor magnus, through which the femoral vessels reach the popliteal fossa as popliteal vessels. The adductor canal occupies the middle one-third of the medial side of thigh (Fig. 16.17, 16.18).

**Boundaries**:

- **Antero-laterally**—vastus medialis;
- **Posteriorly** (floor)—adductor longus above and adductor magnus below;

**Roof**—formed by a strong fascia which extends across the above mentioned muscles; the sartorius muscle lies on the fascial roof and the subsartorial plexus of nerves intervenes between them. The roof is pierced by the saphenous nerve and the saphenous branch of the descending genicular artery.

The **subsartorial plexus of nerves** is formed by branches from the saphenous nerve, posterior branch of the medial femoral cutaneous nerve and anterior division of obturator nerve. Through this plexus the obturator nerve provides cutaneous branches to the medial side of the lower part of the thigh.

**Apex or edge**—Since the canal is triangular on cross section, the apex or edge is formed by the medial lip of linea aspera, where vastus medialis and adductor muscles meet.

John Hunter utilised this region as the site of compression of femoral blood vessels by applying tourniquet against the bony resistance of linea aspera to arrest bleeding in the operation of aneurysm of popliteal vessels or in amputation of lower limb below the knee. Hence, the surgical name of adductor canal is Hunter’s canal.

**Contents**:

(a) Femoral artery and femoral vein;
(b) Saphenous nerve;

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**Fig. 16.17.** A cross-section of middle one-third of thigh, showing adductor canal and compartments of thigh.
(c) Nerve to vastus medialis;
(d) Occasionally, posterior division of obturator nerve;
(e) Terminal part of profunda femoris vessels.

The femoral artery extends from the apex of femoral triangle to the fifth opening of the adductor magnus, and gives off the descending genicular branch before leaving the adductor canal.

The femoral vein lies behind the artery in the upper part of the canal, and postero-lateral to the artery in the lower part of the canal.

The saphenous nerve accompanies lateral to the artery in the upper part of the canal; it then crosses in front of the artery and descends on the medial side of the latter until the nerve leaves the adductor canal by piercing the fibrous roof.

The nerve to the vastus medialis accompanies lateral to the artery in the upper part of the canal until it penetrates the substance of the muscle.

**Note:** The spiral course of saphenous nerve and femoral vein with respect to femoral artery in the adductor canal can be explained by the fact that the lower limb undergoes medial rotation from the foetal position.

**Quadriceps femoris** (See Fig. 15.7, 15.8, 16.9)

It is a powerful extensor muscle of knee joint and consists of four parts: rectus femoris and three vasti—medialis, lateralis and intermedius. The rectus femoris arises from the ilium and the three vasti from the shaft of femur.

The quadriceps is the biggest muscle of the body, covers the front and sides of femur and is inserted into the tubercle of the tibia by a round tendon. A sesamoid bone, the patella, is developed in the tendon of quadriceps femoris when the latter passes in front of the lower end of femur. Distal to the patella, the tendon is known as the ligamentum patellae.

Rectus femoris—It is a long fusiform muscle and the superficial fibres are bipennate in arrangement.

**Origins:** It arises from the ilium by two heads, straight and reflected.

The straight head arises from the upper part of the anterior inferior iliac spine, above the attachment of ilio-femoral ligament. It represents secondary attachment of the muscle associated with the erect posture of man.

The reflected head arises from a groove above the acetabulum and from the fibrous capsule of hip joint. It represents the primary attachment of the muscle and is present in quadrupeds.

**Insertion:** Both heads meet at an acute angle and form an aponeurosis which extends downward on the anterior surface of the muscle; the latter provides bipennate origin of its fleshy fibres which wind round the borders of the muscle and end in a broad aponeurosis in the lower part of its posterior surface. Finally the flattened tendon is inserted into the base of patella. A few fibres pass in front of the patella and are continuous with the ligamentum patellae.
Peculiarities—

(a) The aponeurosis on the posterior surface of the lower part of the muscle allows gliding on the anterior surface of the vastus intermedius.

(b) Bipennate arrangement increases the number of fibres, and therefore, its power.

Nerve supply—It is supplied by branches from the posterior division of femoral nerve, which also provides articular twigs to the hip joint.

Actions—It extends the knee and flexes the hip.

Vastus medialis

Origins: It covers the medial surface of the shaft of femur and takes a continuous linear origin from the following:—lower part of the intertrochanteric line, spiral line, medial lip of linea aspera and upper two-thirds of the medial supra-condylar line, where it blends with the tendon of adductor magnus below the hiatus for femoral vessels.

Insertion: The muscle fibres slope downward and forward and end in an aponeurosis on the deep surface of the muscle. The aponeurosis is inserted into the medial one-third of the upper border and upper two-thirds of the medial border of patella. From its lower attachment it sends a fibrous expansion, the medial patellar retinaculum, to the medial condyle of the tibia.

The anterior border of the muscle is free and rests on the vastus intermedius. The lowest fibres of the muscle are horizontal and are directly inserted into the medial border of the patella.

Nerve supply—It is supplied by the nerve to the vastus medialis, which is the thickest muscular branch of the posterior division of femoral nerve. It also provides articular twigs to the knee joint. The nerve to the vastus medialis is a partial content of the adductor canal. Most of the proprioceptive fibres from the knee joint are conveyed by this nerve and this accounts for its large size.

Actions:

1. It is an extensor of the knee joint.

2. Horizontal lower fibres of the muscle prevent natural tendency for lateral displacement of patella during the extension of knee, and are therefore indispensable for the stability of the patella.

Vastus lateralis

Origins: It takes a linear aponeurotic origin from the following—upper part of the intertrochanteric line, anterior and lower borders of the root of greater trochanter, lateral lip of gluteal tuberosity and lateral lip of linea aspera extending up to the middle of the shaft of femur. In addition, it arises from the lateral intermuscular septum.

Insertion: The muscle fibres spiral downwards and end in an aponeurosis on the deep surface of the muscle which glides on the vastus intermedius. The aponeurosis joins with the quadriceps tendon and is inserted into the lateral two-thirds of the upper border and upper one-third of the lateral border of the patella. It gives a fibrous expansion of lateral patellar retinaculum to the lateral condyle of tibia and blends with the ilio-tibial tract and capsule of the knee joint.

The anterior border of vastus lateralis lies free on the vastus intermedius, and the shallow groove between the two is occupied by the neurovascular bundle formed by the descending branch of lateral circumflex femoral artery and the nerve to the vastus lateralis.

Nerve supply—Supplied by the posterior division of femoral nerve.

Action—It is an extensor of knee joint.

Vastus intermedius

Origin: It arises from the anterior and lateral surfaces of the upper two-thirds of the shaft of femur, medial surface of which is a bare bone.

Insertion: The muscle ends in an aponeurosis on the anterior surface of the muscle; the aponeurosis forms the deep part of quadriceps tendon and is inserted into the upper border of patella.

Nerve supply—Supplied by the posterior division of femoral nerve.

Action—As a component of quadriceps femoris, it is an extensor of knee joint.

Articularis genu

Origin: It is a detached part of vastus intermedius, and arises by three or four slips from the anterior surface of the lower part of shaft of femur.

Insertion: It is inserted into the summit of the supra-patellar bursa.

Nerve supply—Supplied by a twig from the nerve to the vastus intermedius.

Action—It keeps the suprapatellar bursa in position by pulling upward the apex of the synovial fold.
Adductor region

It occupies the medial part of the thigh and intervenes between the medial and posterior intermuscular septa, which converge for attachment to the linea aspera. The medial septum separates the extensor compartment from the adductor compartment. The posterior septum, which separates the adductor from the flexor (hamstring) compartments, is incomplete because the adductor magnus is a composite muscle formed by the fusion of adductor and hamstring components.

Contents of the adductor region:

Muscles—Pectineus, adductor longus and gracilis in superficial plane; obturator externus and adductor brevis in intermediate plane; Adductor magnus in deep plane.

Nerve—Obturator nerve;

Arteries—Obturator and profunda femoris arteries.

Description of the contents:

Pectineus—(See the muscles in relation to femoral triangle). To recapitulate, the muscle slopes downward, backward and laterally from the pectineal surface of pubis and is inserted along a line extending from the base of the lesser trochanter to the upper end of linea aspera.

Adductor longus—(See muscles in relation to femoral triangle). To recapitulate, the triangular muscle lies edge to edge with and medial to the pectineus, and is inserted into the medial lip of linea aspera.

Gracilis

Origins: It is a long flat muscle, and arises from the medial margin of the lower part of the body of pubis and from the adjoining ischio-pubic ramus.

Insertion: The muscle narrows in the lower third of thigh to form a cylindrical tendon which lies behind the sartorius across the medial condyle of femur. It then curves forward round the medial condyle of tibia and is inserted into the upper part of medial surface of tibia in between the hockey-stick attachment of sartorius in front and linear insertion of semitendinosus behind. The adductor magnus appears in the gap between adductor longus and gracilis.

Actions:
1. It is an adductor of hip joint.
2. It assists in flexion of knee and acts as medial rotator of semiflexed knee joint.
3. Convergence of tendons of three muscles (sartorius, gracilis and semitendinosus) to the tibia from the three constituents of hip bone acts as three guy ropes to stabilise the mobile pelvis on the tibia.
4. Since the gracilis is an adductor of hip and flexor of knee, it is considered whimsically as the ‘custodian of virginity’.

Obturator externus

Origins: It arises from the outer surface of the obturator membrane and from adjacent bones along the medial margin of obturator foramen, except the obturator notch in the upper part where a short canal is left for the passage of obturator vessels and nerve.

Insertion: The fibres converge backwards, laterally and upwards to form a tendon which spirals in contact with the back of the neck of femur, and is inserted into the trochanteric fossa. The tendon is separated from the capsule of hip joint by a communicating bursa, which intervenes between the collar-like fitting of the fibrous capsule and the femoral neck.

Actions: It is a lateral rotator of hip joint. As a short muscle around the hip joint, it stabilises the joint as a postural muscle.

Adductor brevis—It is situated below and medial to the obturator externus and lies in the same plane. The medial circumflex femoral artery winds backward in the gap between adductor brevis and obturator externus.

Origin: It arises from the front of the body and inferior ramus of pubis, between the origins of gracilis and obturator externus.

Insertion: The muscle passes downward, backward and laterally in triangular form and is inserted along a line extending from the base of the lesser trochanter to the upper part of linea aspera, just lateral to the pectineus.

The adductor brevis is overlapped in front by the pectineus and adductor longus, and rests behind on the adductor magnus. The anterior and posterior divisions of obturator nerve descend vertically along the respective surfaces of the muscle. The adductor brevis is usually supplied by the anterior division of obturator nerve.

Action: It adducts the thigh at the hip joint.

Adductor magnus—It is a composite muscle and is formed by the fusion of the adductor and the hamstring muscle masses; the fifth osseo-aponeurotic opening of adductor magnus for the passage of femoral vessels intervenes between the two masses.
Hence the continuity of the posterior intermuscular septum of the thigh is disrupted (Fig. 16.19).

**Origins**: The adductor magnus is an extensive triangular muscle, and both components of muscle take a continuous origin from the external surface of the ischio-pubic ramus and from the infero-lateral aspect of ischial tuberosity.

**Insertions**:

1. Fibres from the ischio-pubic ramus represent the adductor component and are inserted into the femoral shaft in a continuous line along the medial margin of glutal tuberosity, medial lip of linea aspera and upper part of medial supracondylar line upto the hiatus for the femoral vessels. The pubic fibres are horizontal in direction, pass behind the lesser trochanter (often separated by a bursa), and lie edge to edge with the lower border of quadratus femoris; the interval between the two muscles transmits the transverse branch of medial circumflex femoral artery for the formation of cruciate anastomosis. The pubic fibres of the muscle are sometimes named as the adductor minimus.

2. Fibres from the ischial tuberosity represent the hamstring component and pass vertically downward to form a rounded tendon which is inserted into the adductor tubercle of the femur and provides a fibrous expansion to the lower part of medial supracondylar line below the hiatus for femoral vessels.

In some vertebrates the hamstring part of the muscle is directly inserted to the tibia, and is known as the **Presemimembranosus**. In man, however, the lower part of the tendon degenerates to form the **tibial collateral ligament** of knee joint.

Extensive linear insertion of the adductor magnus to the femur presents usually five osseous-aponeurotic openings. Upper four openings are small and transmit the perforating branches and terminal part of the profunda femoris artery; the fifth opening gives passage to the femoral vessels.

**Nerve supply**: Adductor part of the muscle is supplied by the obturator nerve, and the hamstring part by the tibial division of the sciatic nerve.

**Actions**: In addition to the adduction of thigh, the adductor longus and magnus muscles are said to act as **medial rotators** of the hip joint.

**Obturator nerve**

It is a branch of the lumbar plexus, and is formed by the **ventral branches of the ventral rami of L₂, L₃, and L₄** spinal nerves. It is a nerve of adductor compartment and lies within the psoas major at its formation (Fig. 16.19).

**Course**: The obturator nerve passes down-ward and appears beneath the medial border of psoas major to the upper surface of the ala of sacrum, where it lies behind the common iliac vessels. It crosses

**Fig. 16.19. Adductor region and obturator nerve.**
the pelvic brim and runs downward and forward subperitoneally along the lateral pelvic wall, and leaves the pelvic cavity through the obturator canal where it is accompanied below and behind by the obturator vessels. Close to the sacro-iliac joint the nerve lies lateral to the internal iliac vessels and pelvic part of ureter, and occupies the floor or lateral wall of ovarian fossa in female.

On entering the thigh through the obturator canal, the nerve splits into anterior and posterior divisions; the adductor brevis and a part of obturator externus muscles intervene between the two divisions.

**Distribution:** The anterior divisions descends in front of obturator externus and adductor brevis, and behind the pectineus and adductor longus. At the lower border of adductor brevis it joins with the subartorial plexus of nerves and communicates with the medial cutaneous and saphenous branches of femoral nerve. Through this plexus the obturator nerve supplies the skin of the medial side of lower part of thigh; sometimes the cutaneous branch extends downwards to supply the skin of the medial side of the upper part of the leg. Finally, the branches of anterior division ramify on the femoral artery and provide vaso-motor twigs.

Close to the obturator canal the anterior division gives articular twigs to the hip joint. It distributes muscular branches to the adductor longus, gracilis, medial part of pectineus and usually the adductor brevis. To sum up, the anterior division provides four types of branches: muscular, articular, cutaneous and vascular.

The posterior division of obturator nerve pierces the anterior surface of obturator externus, passes downward behind the adductor brevis and lies in front of adductor magnus. It supplies the obturator externus, adductor component of adductor magnus and adductor brevis, if the latter is not supplied by the anterior division. The terminal part of the posterior division forms a genicular branch which pierces the adductor magnus or passes through the hiatus for the femoral vessels to appear in the popliteal fossa; it descends along the popliteal vessels, pierces the oblique popliteal and capsular ligaments of the knee and distributes fibres to the articular capsule and cruciate ligaments in the interior of the joint. To sum up, the posterior division distributes three types of branches: muscular, articular, and vascular to the popliteal vessels.

**Applied Anatomy**

1. In diseases of hip joint, pain may be referred to the medial side of the thigh or the knee joint along the obturator nerve, since the latter supplies both the joints.

2. Surgical division of the obturator nerve may be necessary to relieve the spasm of adductor muscles in spastic paralysis.

3. In inflammation of the ovary, localised peritonitis may affect the ovarian fossa with eventual irritation of obturator nerve. Pain may be referred in such condition to the hip, knee or inner side of the thigh.

**Obturator artery**—It is a branch of the anterior division of internal iliac artery and appears in the adductor region through the obturator canal, where the artery divides into medial and lateral branches. Both branches encircle the origin of obturator externus and anastomose with each other and with the medial circumflex femoral artery.

The lateral branch gives off an acetabular twig which enters the hip joint through a gap between the acetabular notch and transverse acetabular ligament. This branch supplies the acetabular fat and provides a slender vessel to the femoral head along the ligament of the head of femur.

**Profunda femoris artery**—(See the branches of femoral artery).

**Internervous lines of the thigh**—An internervous line intervenes between the motor territories of the femoral and gluteal nerves. Surgically the hip joint may be approached from the front by an incision along this line, which extends vertically downward from the anterior superior iliac spine for about 10 cm. The sartorius muscle is retracted medially and the tensor fasciae latae laterally; this results in exposure of the anterior inferior iliac spine. Thereafter the glutaei medius and minimus are retracted backward, the rectus femoris and iliacus forward, and the hip joint is exposed from the front. Along the line of incision the posterior branch of lateral femoral cutaneous nerve and the transverse branch of lateral circumflex femoral artery have to be sacrificed, but no motor nerve crosses the internervous line.

Another internervous line between the territories of femoral and obturator nerves may be represented by joining the mid-inguinal point and the adductor tubercle. It has no significant surgical importance, except the exposure of the contents of adductor canal.
The prominence of buttock is unique in man due to adoption of upright posture and bipedal mode of locomotion. The gluteal prominence is accounted for the massive development of gluteus maximus and abundant deposition of subcutaneous fat (panniculus adiposus).

**Extent of gluteal region:**

**Above,** entire length of the iliac crest;

**Below,** gluteal fold which is a transverse skin crease for the hip joint and does not correspond to the lower oblique border of gluteus maximus;

**Behind,** sacral spines in mid-dorsal line;

**In front,** an imaginary vertical line extending downward from the anterior superior iliac spine to the anterior edge of greater trochanter.

**Skeletal framework:**

Bony floor of the gluteal region is contributed by:

1. Dorsal surface of sacrum and coccyx;
2. Gluteal surface of the ilium, dorsal surface of the ischium with ischial tuberosity, ischial spine, greater and lesser sciatic notches;
3. Posterior surface of the upper part of femur including the neck, greater and lesser trochanters and the gluteal tuberosity.

The following **ligaments** are encountered in the bony floor: Sacrotuberous, sacrospinous, dorsal sacro-iliac, and posterior part of capsular ligaments of hip joint.

**Important bony landmarks:**

**Highest point of iliac crest** corresponds to the 4th lumbar spine, and this helps in counting the vertebral spines for lumbar puncture.

The **posterior superior iliac spine** lies deep to a skin dimple. A line joining posterior spines of both sides passes through the 2nd sacral spine, where the spinal dura and arachnoid mater end with the contained cerebrospinal fluid in the subarachnoid space.

The **tip of greater trochanter** lies about one hand’s breadth below the tubercle of iliac crest.

The **ischial tuberosity** lies vertically below the posterior superior iliac spine and at a lower level than the tip of coccyx. With extended thigh the ischial tuberosity is covered by the gluteus maximus. But when the thigh is flexed, the muscle slips over the tuberosity exposing the lower part of the bone which is covered by a cushion of fibro-fatty tissue and transmits the body weight in sitting position.

**Superficial fascia**—It is thick and fatty, and the subcutaneous fat is abundant in adult female which makes the characteristic rounded contour of the buttock.

The **cutaneous nerves** in the superficial fascia convey the fibres from the ventral and dorsal primary rami of the spinal nerves, and are derived from several sources (Fig. 17.1).

**From above,** crossing the iliac crest (before backward):

(i) Lateral cutaneous br. of subcostal nerve (T_{12});
(ii) Lateral cutaneous br. of ilio-hypogastric nerve (L_{1});
(iii) Lateral branches of dorsal rami from L_{1}, L_{2}, L_{3} spinal nerves;

**From below**

(iv) Gluteal branches of posterior femoral cutaneous nerve (S_{1}, S_{2}, S_{3}), which recur around the lower border of gluteus maximus;
(v) Perforating branches of S_{2}, S_{3} nerves which appear after piercing the sacrotuberous ligament;

**From the front**

(vi) Posterior br. of lateral femoral cutaneous nerve (L_{2});
From behind

(vii) Lateral branches of dorsal rami from $S_1$, $S_2$, $S_3$ spinal nerves.

**Note:** It is thus evident that the area of skin supplied by the ventral rami are derived from widely separated segments – upper and lateral part of gluteal region by subcostal and iliohypogastric nerves ($T_{12}$, $L_1$); lower and lateral part by lat. femoral cutaneous nerve ($L_2$); lower and medial part by post. femoral cutaneous and perforating cutaneous nerves ($S_1$, $S_2$, $S_3$).

Therefore, the dermatomes between $L_2$ and $S_1$ remain-unrepresented in the gluteal region. The **posterior axial line** of lower limb intervenes between the discontinuous dermatomes; this line is said to extend with bold convexity upward and medially to the 4th lumbar interspace, which is the site of lumbar puncture.

**Deep fascia**—It is attached above to the iliac crest and behind to the sacrum. The fascia splits twice along the iliac crest, to enclose the tensor fasciae latae and gluteus maximus, and forms a thickened sheet, the **gluteal aponeurosis**, between them which covers the gluteus medius. The layers which enclose gluteus maximus are connected to each other by numerous fibrous septa which pass through the fasciculi of the muscle. When the superficial lamella overlying gluteus maximus is removed in dissection, the discrete fasciculi of the muscle are prominently displayed. Traced laterally, the deep fascia is continuous with the ilio-tibial tract (vide supra).

**Muscles of gluteal region**

The muscles are arranged in three layers from superficial to deep: gluteus maximus and tensor fasciae latae in **superficial layer**; gluteus medius, piriformis, tricipital tendon of obturator internus with gemelli superior and inferior, quadratus femoris, upper part of adductor magnus and the origins of hamstring muscles in **intermediate layer**; gluteus minimus with the reflected head of rectus femoris under cover of it, and the tendinous insertion of obturator externus in the **deep layer**.

**Gluteus maximus**

It is the largest and most superficial muscle of the gluteal region, rhomboidal in outline and possesses coarse muscle fasciculi. The muscle slopes downward and laterally from the pelvis across the buttock at an angle about $45^\circ$ (Fig. 17.2).

The lower border of the muscle extends from the tip of coccyx across the ischial tuberosity to the shaft of the femur, at the junction of upper one-third and lower two-thirds. The oblique lower border does not correspond with the gluteal fold, which is a somewhat horizontal skin crease of the hip joint.

The upper border of the muscle extends from the posterior superior iliac spine parallel to the lower border and lies about 2.5 cm above the greater trochanter.

**Origins**:

1. From the gluteal surface of the ilium above and behind the posterior gluteal line, and from
the outer sloping surface of the dorsal segment of iliac crest;

(a) **Trochanteric bursa**, between the greater trochanter and the muscle;
(b) **Gluteo-femoral bursa**, between the vastus lateralis and the muscle;
(c) Occasionally **ischial bursa**, between the ischial tuberosity and the muscle.

**Nerve supply**: 
Gluteus maximus is supplied by the **inferior gluteal nerve** which conveys fibres from dorsal branches of the ventral rami of L₅, S₁, S₂. The nerve enters its deep surface close to the centre.

**Blood supply**: It is supplied by both superior and inferior gluteal arteries. The veins form an extensive plexus beneath the muscle.

**Actions**: 
1. It is an **extensor of hip joint** at the extremes of hip movement, such as, in running and climbing upstairs. But in standing and quiet walking it remains **inactive**, and the hamstrings alone act as hip extensor.
2. Gluteus maximus acts as the chief anti-gravity muscle of the hip in the act of sitting from standing. In such position by **paradoxical action**, it regulates the **flexion** of hip joint.
3. It is a strong **lateral rotator** of hip joint.
4. Through the ilio-tibial tract it **maintains the extended** position of knee joint.
5. Upper fibres of gluteus maximus act as powerful **abductor** of hip joint.

**Tensor fasciae latae**

**Origin**: It arises from the outer lip of iliac crest extending from the anterior superior iliac spine to the tubercle of the crest.

**Insertion**: The muscle passes downward and slightly backward, and is inserted by an aponeurosis to the upper part of ilio-tibial tract distal to the greater trochanter.

The gluteus medius with its overlying fascia, gluteal aponeurosis, intervenes in the triangular gap between the gluteus maximus and the tensor fasciae latae.

**Nerve supply**: 
It is supplied by the superior gluteal nerve (L₄, L₅, S₁ – dorsal branches of ventral rami).
**GLUTEAL REGION**

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**Fig. 17.3.** Muscles of gluteal region, after partial removal of gluteus maximus and other muscles.

**Action:** It **abducts** the hip joint, and through the iliobibial tract maintains extended position of knee joint.

**Structures deep to gluteus maximus**

(A) Bones and ligaments – ilium, sacrum, coccyx, ischial tuberosity, greater trochanter, sacrotuberous ligament and dorsal sacro-iliac ligament;

(B) Bursae—Three in number (cited above);

(C) Muscles (from above downwards) (Fig. 17.3).

(i) Gluteus medius and beneath it gluteus minimus;

(ii) Piriformis;

(iii) Tricipital tendon of obturator internus along with gemellus superior and inferior; tendinous insertion of obturator externus lies beneath the tricipital tendon;

(iv) Quadratus femoris;

(v) Upper part of adductor Magnus, and origins of semimembranosus, semitendinosus and long head of biceps femoris from the ischial tuberosity.

(D) Blood vessels and nerves (Fig. 17.4)

**Emerging from the upper border of piriformis:**

Superior gluteal vessels and nerve; they leave the pelvis through the greater sciatic foramen.

**Emerging from the lower border of piriformis**

(from lateral to medial side):

(i) Sciatic nerve, and beneath it lies nerve to quadratus femoris;

(ii) Posterior femoral cutaneous nerve, lying superficial or medial to sciatic nerve;

(iii) Inferior gluteal vessels and nerve;

The above structures leave the pelvis through the greater sciatic foramen.

(iv) Nerve to obturator internus;

(v) Internal pudendal vessels;

(vi) Pudendal nerve.

The **medial three structures** rest on ischial spine or sacrospinous ligament, appear through the greater sciatic foramen, undergo a short course in the gluteal region and finally disappear through the lesser sciatic foramen.

**Note:** The lower border of piriformis acts as a **key line** of gluteal region, because as many as eight structures emerge beneath it; most lateral and most medial structures are occupied by nerves.
The key line is represented by joining the mid-point of a line extending from posterior superior iliac spine to the tip of coccyx, to the tip of greater trochanter.

(E) Two arterial anastomosis
Trochanteric and cruciate.

Description of the rest of the muscles

**Gluteus medius**—Posterior one-third of the muscle lies under cover of gluteus maximus, and its anterior two-thirds is superficial and covered by the thick gluteal aponeurosis.

**Origin** : The gluteus medius arises from the outer surface of ilium which is limited above by the iliac crest, behind by the posterior gluteal line and in front by the anterior gluteal line. It also arises from the gluteal aponeurosis.

**Insertion** : The muscle converges downward, forward and laterally into a flattened tendon which is inserted to the lateral surface of the greater trochanter along an oblique ridge extending diagonally downward and forward from the tip of greater trochanter. The triangular area of bone in front of the oblique ridge is occupied by the trochanteric bursa of gluteus medius.

The projecting tip of greater trochanter is caused by the pull of gluteus medius.

**Gluteus minimus**—It lies completely beneath the gluteus medius and is triangular in outline.

**Origin** : The muscle arises from the gluteal surface of ilium between the anterior and inferior gluteal lines and extending up to the margin of the greater sciatic notch.

**Insertion** : It is attached by a tendon to a ridge on the lateral part of the anterior surface of greater trochanter and the medial part of the bone is separated from the tendon by a bursa.

The anterior borders of gluteus medius and minimus lie edge to edge from origin to insertion. Between the glutseii medius and minimus intervene the superior gluteal nerve and deep branch of superior gluteal vessels. Beneath the gluteus minimus lie the reflected head of rectus femoris and capsule of hip joint.

**Nerve supply** : Both gluteus medius and gluteus minimus along with tensor fasciae latae are supplied by the superior gluteal nerve.
Actions:

1. Acting from above both glutei medius and minimus are abductors of hip joint;

2. Acting from below both muscles prevent the unsupported side of the pelvis from sagging downward during locomotion. Thereby they maintain horizontal level of pelvis while walking or running by alternate lifting of feet from the ground. If the skeletal frame-work of the hip joint and neck-shaft angle of the femur are normal, the integrity of actions of both gluteii medius and minimus of the supporting leg are essential to maintain the trunk upright. When a patient stands on the affected limb with paralysis of medius and minimus muscles, the pelvis sinks on the unsupported side. This is clinically known as Trendelenberg’s sign. The affected person walks with a lurching gait.

3. The anterior fibres of both medius and minimus muscles act as medial rotators of hip joint to increase the forward stride during locomotion.

Piriformis—It lies partly within the pelvis in its posterior wall and partly in the gluteal region posterior to the hip joint. It is the key muscle of gluteal region.

Origins: The muscle takes origin by fleshy fibres from—

1. The front of sacrum by three digitations from the bars of bones between the anterior sacral foramina as well as from the area of bone lateral to the foramina;

2. Gluteal surface of ilium close to the posterior inferior iliac spine;

3. The capsule of sacro-iliac joint and adjoining pelvic surface of sacro-tuberosus ligament;

4. Upper margin of the greater sciatic notch.

Insertion: The muscle appears in the gluteal region after emerging laterally through the greater sciatic foramen and is inserted by a round tendon to the posterior inturned upper border (apex) of the greater trochanter. Some of its fibres extend forward along the whole length of the upper border of greater trochanter.

The upper border of piriformis lies along the gluteus medius and its lower border along the gemellus superior.

Relations:

With in the pelvis

In front: sacral plexus of nerves intervening between the muscle and the parietal layer of pelvic fascia; branches of internal iliac vessels in front of the pelvic fascia, and rectum in the middle line.

Behind: the sacrum;

In the gluteal region:

In front: dorsal surface of the ischium, and the capsule of hip joint.

Behind: gluteus maximus.

Emerging from upper border (vide supra);

Emerging from lower border (vide supra);

Sometimes the tibial and common peroneal components of the sciatic nerve separate early in the pelvis. In such condition, the tibial component emerges below the piriformis and the common peroneal component pierces the muscle.

Nerve supply: It is supplied from the pelvis by twigs from S₁ and S₂ nerves.

Actions:

1. In extended thigh it acts as lateral rotator;

2. In flexed thigh it acts as an abductor.

Obturator internus

Origins: The muscle presents an extensive origin from the antero-lateral wall of the lesser pelvis which includes the following:

1. The inner surface of the obturator membrane excluding the obturator canal in the upper part of the membrane;

2. From the adjoining ischio-pubic ramus and upper part of the pelvic surface of the body of ischium extending into an area between the pelvic brim and the upper margin of the greater sciatic notch.

Insertion: The muscle fibres converge below to form a tendon which makes a right-angled bend at the lesser sciatic foramen and appears in the gluteal region. The tendon presents four or five bands which lodge in the corresponding ridged groove of the ischium. To minimise friction the bony groove is covered by cartilage and is separated from the tendon by a bursa.

In the gluteal region the tendon is reinforced by the gemelli superior and inferior muscles which
arise respectively from the upper and lower margins of the lesser sciatic notch. The tricipital tendon thus formed passes transversely across the posterior surface of the neck of femur and is inserted to the medial surface of the greater trochanter, above and in front of the trochanteric fossa.

**Relations:**

*Within the pelvis*—Inner surface of the obturator internus is covered by the obturator fascia which is derived from the parietal layer of pelvic fascia. Origin of levator ani (pelvic diaphragm) from the obturator fascia along the tendinous arch or white line divides the latter into upper and lower parts.

The upper part forms the lateral wall of the true pelvis, is covered by the parietal peritoneum and is traversed sub-peritoneally by the obturator nerve, pelvic part of ureter and internal iliac vessels and their branches.

The lower part of obturator fascia forms the lateral wall of ischio-rectal fossa and presents a pudendal canal (of Alcock) for the transmission of internal pudendal vessels and pudendal nerve and its branches.

**In the gluteal region—**

*Posteriorly*, the tricipital tendon is crossed by the sciatic nerve;

*Anteriorly*, the nerve to quadratus femoris and the tendon of obturator externus.

**Nerve supply**: From the nerve to obturator internus which conveys fibres from the ventral branches of ventral rami of \( L_5, S_1 \text{ and } S_2 \).

**Gemellus superior**—It arises from the spine of the ischium and is inserted to the upper margin of obturator internus tendon.

**Nerve supply**: From the nerve to obturator internus.

**Gemellus inferior**—It arises from the lower margin of lesser sciatic notch at the upper end of ischial tuberosity, and is inserted to the lower border of obturator internus tendon.

**Nerve supply**: From the nerve to quadratus femoris which conveys fibres from the ventral branches of ventral rami of \( L_4, L_5 \text{ and } S_1 \).

**Peculiarities of the gemelli**:

Both gemelli form a muscular groove anterior to the tendon of obturator internus. Thereby they tend to minimise friction between the tendons of obturator internus and externus muscles.

**Action of tricipital tendon**: They act as lateral rotators of hip joint.

**Quadratus femoris**—It is a rectangular muscle; its upper border lies edge to edge with the gemellus inferior and its lower border with the upper margin of the adductor magnus.

**Origin**: It takes linear origin from the external surface of ischial tuberosity.

**Insertion**: The muscle extends laterally and is inserted into the quadrat tubercle near the middle of the inter-trochanteric crest and to the bone that extends vertically downward for a short distance. The lower border of quadras femoris bisects the lesser trochanter.

The elevation of quadrat tubercle represents the site of fusion of the epiphysis of greater trochanter, and is not produced by the pull of the muscle.

**Relation**: Cruciate anastomosis of arteries takes place at the root of greater trochanter in the interval between the quadratus femoris and the upper border of the adductor magnus.

**Nerve supply**: From the nerve to quadratus femoris which conveys fibres from the ventral branches of ventral rami of \( L_5, L_4 \text{ and } S_1 \). The nerve reaches the muscle from its deep surface; it also supplies twigs to the gemellus inferior.

**Action**: It is a later rotator of hip joint.

**Adductor magnus**—(See Adductor region).

**Hamstring muscles**—(See back of the thigh).

**Nerves of the gluteal region** (See Fig. 17.4)

**Superior gluteal nerve**—It is formed by the dorsal branches of ventral rami of \( L_4, L_5 \text{ and } S_1 \), and emerges through the greater sciatic foramen above the piriformis. The nerve curves upward and forward between the gluteus medius and minimus muscles, supplies both of them and ends by distributing the tensor fasciae latae from its deep surface.

It provides an articular branch to the hip joint, and does not give any cutaneous branch.

**Note**: Muscles supplied by the superior gluteal nerve are abductors and medial rotators of hip joint.

**Sciatic nerve**—It is the widest nerve of the body, about 2 cm broad and consists of tibial and
common peroneal components, both of which form initially a common trunk. The tibial component is derived from the ventral branches of the ventral rami of L₄, L₅, S₁, S₂, and the common peroneal component from the dorsal branches of the ventral rami of L₄, L₅, S₁, S₂.

The sciatic nerve emerges through the greater sciatic foramen below the piriformis and curving infero-laterally descends beneath the gluteus maximus midway between the ischial tuberosity and the greater trochanter. In the gluteal region it rests successively on the dorsal surface of the body of ischium separated by nerve to quadratus femoris, tricipital tendon of obturator internus with gemelli superior and inferior, quadratus femoris and adductor magnus. At the back of thigh the nerve is crossed superficially by the long head of biceps femoris, and close to the upper angle of popliteal fossa it divides into tibial and common peroneal nerves.

Sometimes the division of sciatic nerve takes place in the pelvic cavity. In such case the common peroneal nerve pierces the piriformis and the tibial nerve emerges below the muscle.

**Branches:**

1. **Muscular** branches supply long head of biceps femoris, semitendinosus, semimembranosus, and ischial part of adductor magnus (hamstring muscles). All muscular branches arise from the medial side of the nerve.

2. **Articular** branches to the hip joint.

*Note:* Lateral side of the nerve is safe and the medial side is of danger due to involvement of muscular branches.

**Applied anatomy**

The sciatic nerve may be injured by penetrating wounds, in posterior dislocation or fracture-dislocation of the hip. When the injury is complete, all muscles below the knee are paralysed associated with foot-drop, and all cutaneous sensations below the knee are lost except the area supplied by the saphenous nerve.

Nerve to quadratus femoris—It is derived from the ventral branches of ventral rami of L₄, L₅, S₁, and emerges below the piriformis beneath the sciatic nerve. The nerve rests on the ischium, descends deep to the tendon of obturator internus and the two gemelli, gives a motor twig to the gemellus inferior and supplies the quadratus femoris from the deep surface. It gives an articular branch to the hip joint.

**Posterior femoral cutaneous nerve**—It conveys fibres from the dorsal branches of S₁ and S₂, and ventral branches of S₂ and S₃, and appears below the piriformis superficial or medial to the sciatic nerve. The nerve descends in the back of thigh beneath the fascia lata and superficial to the long head of biceps femoris. On reaching the popliteal fossa it pierces the fascial roof, and accompanies the small saphenous vein down to the middle of the calf where it communicates with the sural nerve.

**Branches:** It provides three sets of cutaneous branches—gluteal, perineal and perforating.

1. **Gluteal branches**, three or four in number, curl around the lower border of gluteus maximus and supplies the skin of the lower and lateral part of gluteal region.

2. **Perineal branch** curves ventro-medially superficial to the hamstring muscles below the ischial tuberosity, pierces the fascia lata and fascia of Colles of the perineum, and appears in the superficial perineal pouch to supply the posterior part of scrotum or labium majus.

3. **Perforating branches** pierce the fascia lata and supply the skin of the back of thigh, popliteal fossa and upper part of the back of the leg.

**Inferior gluteal nerve**—It arises from the dorsal branches of ventral rami of L₅, S₁, S₂ and after emerging from the lower border of piriformis it curves upward to supply the gluteus maximus from the deep surface close to its origin. This nerve has no cutaneous branch.
Since the finer branches of inferior gluteal nerve reach the superficial surface of the muscle, the gluteus maximus is usually selected for intramuscular injection.

Nerve of obturator internus—It arises from the ventral branches of the ventral rami of L₅, S₁, S₂, and makes a short visit in the gluteal region. It emerges below the piriformis from the greater sciatic foramen, rests on the dorsal surface of the base of ischial spine and then passes forward through the lesser sciatic foramen deep to the fascia covering obturator internus and supplies the muscle. On its way the nerve gives a twig to the gemellus superior.

Pudendal nerve—It is derived from the ventral branches of the ventral rami of S₅, S₆, S₇ and passes below the piriformis through the greater sciatic foramen. It crosses just medial to the ischial spine around the sacro-spinous ligament and winds forward through the lesser sciatic foramen to enter the pudendal canal (of Alcock) and to supply the perineum.

Blood vessels of the gluteal region

Superior gluteal artery—it is a branch of the posterior division of internal iliac artery and appears in the gluteal region above the piriformis accompanied by the superior gluteal nerve. But unlike of nerve, the artery divides into superficial and deep branches. The superficial branch passes between the gluteus medius and maximus muscles and supplies both of them. The deep branch passes laterally between the gluteus medius and minimus muscles, and subdivides into upper and lower branches. The upper branch forms a spinous anastomosis close to the anterior superior iliac spine by joining with the superficial and deep circumflex iliac arteries, ascending branch of lateral circumflex femoral artery and the iliac branch of ilio-lumbar artery. The lower branch joins with the trochanteric anastomosis.

Inferior gluteal artery—it is a branch of the anterior division of internal iliac artery and appears in the gluteal region below the piriformis accompanied by the inferior gluteal nerve. It breaks up mainly into three sets of branches:
(a) muscular branches to supply the adjacent muscles;
(b) anastomotic branches to join the cruciate and trochanteric anastomoses;
(c) arteria nervi ischiadici, which accompanies and supplies the sciatic nerve; it is a remnant of axis artery of the lower limb.

Internal pudendal artery—it is a branch of the anterior division of internal iliac artery and makes a brief appearance in the gluteal region below the piriformis. The artery crosses the tip of the dorsal surface of the ischial spine accompanied on each side by a pair of venae comitantes. Here the vessels are related laterally with the nerve to the obturator internus, and medially with the pudendal nerve. The vessels then curve forwards through the lesser sciatic foramen, enter the pudendal canal along with the pudendal nerve and supply the structures of perineum.

To control haemorrhage in the perineum, the internal pudendal artery may be compressed against the ischial spine.

Cruciate anastomosis (See Fig. 17.4)—Close to the root of greater trochanter a cruciate anastomosis is formed in the inter-muscular interval between the quadratus femoris and upper margin of the adductor magnus by the meeting of the following arteries:
(a) transverse branch of the medial circumflex femoral;
(b) transverse branch of the lateral circumflex femoral;
(c) ascending branch of first perforating; and
(d) descending branch of inferior gluteal arteries.

This anastomosis establishes a collateral circulation between the branches of internal iliac and profunda femoris arteries, in case of ligation of the femoral artery proximal to the origin of profunda femoris artery.

Trochanteric anastomosis—in the trochanteric fossa an anastomosis is formed by the union of the following arteries:
(a) descending branch of superior gluteal;
(b) ascending branches of lateral and medial circumflex femoral, and
(c) a branch from inferior gluteal artery.

The trochanteric anastomosis provides the chief source of blood supply to the head of femur along the retinacular fibres of the femoral neck.
The back of thigh extends from the lower limit of gluteal region to the back of the knee.

**Boundaries:**

Floor—formed by *adductor magnus* and *vastus lateralis*; the latter is covered by the *lateral intermuscular septum* which intervenes between the extensor and flexor compartments of thigh. The separation between the flexor and adductor compartments by the posterior intermuscular septum is incomplete, because adductor magnus is formed by the fusion of flexor and adductor components.

Roof—formed by the fascia lata covering the back of thigh.

**Contents:**

- Hamstring muscles;
- Short head of biceps femoris;
- Sciatic nerve;
- Posterior femoral cutaneous nerve;
- A chain of vascular anastomosis at the back of adductor magnus.

**Hamstring muscles**

These include semimembranosus, semitendinosus, long head of biceps femoris and ischial fibres of adductor magnus (Fig. 18.1).

Hamstring muscles fulfill the following criteria;

(a) they take origin from the ischial tuberosity;
(b) are inserted beyond the knee joint to the tibia, fibula or both bones;
(c) are supplied by the tibial division of sciatic nerve;
(d) act as flexors of knee joint and extensors of hip joint. Semimembranosus and semitendinosus are *true hamstrings* because they satisfy all the above criteria.

Long head of biceps femoris and ischial part of adductor magnus are *modified hamstrings* because of the following reasons:

1. The long head of biceps takes its primitive origin from ilium and sacrum, and this is subsequently shifted to the ischial tuberosity, leaving behind the *sacrotuberous ligament* as its morphological remnant.

2. Ischial part of adductor magnus is primitively inserted to the medial condyle of tibia. This is subsequently shifted to the adductor tubercle of femur, so that the *tibial collateral ligament* represents its divorced primitive insertion.

**Semimembranosus**

**Origin:** It arises from the upper and lateral part of quadrilateral area of ischial tuberosity by a flat tendon which passes deep to the long head of biceps femoris. It remains membranous in the upper half and becomes fleshy in the lower half, upon which cord-like tendon of semitendinosus rests.

**Insertion:** The fleshy part converges below to form a cylindrical tendon which is inserted to a horizontal groove on the posterior surface of medial condyle of tibia deep to the tibial collateral ligament of knee; sometimes a bursa intervenes between the bone and the tendon.

From the insertion its gives **three tendinous expansions:**

(a) a fibrous band, the *oblique popliteal ligament*, extends upward and laterally behind the fibrous capsule of the knee and is attached to the intercondylar line and the adjacent lateral condyle of femur;
(b) a few fibres extend downward and laterally through the fascia covering popliteus to the soleal line of tibia;
(c) some fibres are attached to the medial border of upper part of tibia behind the tibial collateral ligament.
Fig. 18.1 *Sciatic nerve with the muscles at the back of thigh and gluteal region.*

**Semitendinosus**

**Origin**: It arises along with the long head of biceps femoris from the lower and medial part of quadrilateral area of ischial tuberosity.

It is fleshy in the upper part and forms a cord-like tendon in the lower part which rests on semimembranosus muscle.

**Insertion**: The tendon passes behind the medial condyle of femur and then curves forward and downward for insertion into the upper part of medial surface of tibia, behind the insertion of sartorius and gracilis.

**Biceps femoris**—It arises by two heads, long and short. Long head is a hamstring muscle; short head does not belong to the hamstring group because it does not take origin from ischial tuberosity and is supplied by the common peroneal division of the sciatic nerve. Morphologically the short head represents extensor muscle and appears in the flexor compartment for functional reason.

**Origins**:

1. Long head arises in common with the semitendinosus from the lower and medial part of quadrilateral area of ischial tuberosity, and passes obliquely downward and laterally to meet the short head on its deep surface.

2. Short head takes origin from the lower part of lateral lip of linea aspera and from the
upper two-thirds of lateral supracondylar line of femur.

Through the gap between the two heads passes the sciatic nerve.

**Insertions:** The conjoint tendon of the two heads slopes downward and laterally, and is inserted into the head of fibula in front of the styloid process and provides a slip of attachment to the lateral condyle of tibia across the superior tibio-fibular joint.

At the insertion the biceps tendon overlaps the fibular collateral ligament, the pressure of which splits the tendon into anterior and posterior parts. The tendon is separated from the ligament by a bursa.

**Adductor magnus**—(See the adductor region of thigh).

**Actions of hamstring muscles**

1. They act as prime mover of flexion of knee joint, and help extension of hip joint especially in standing and walking.

2. In semi-flexed knee, the semimembranosus and semitendinosus act as medial rotators, and biceps femoris acts as lateral rotator of tibia on femur.

**Sciatic nerve**

In the back of thigh the sciatic nerve emerges from the lower border of gluteus maximus and passes straight downward deep to the long head of biceps femoris, resting on the adductor magnus. Beneath the biceps, at a variable distance above the popliteal fossa, it divides into two terminal branches — tibial and common peroneal nerves. Sometimes the division of the nerve takes place in the pelvic cavity; in such case the tibial nerve emerges below the piriformis and the common peroneal nerve pierces the piriformis. (For origin and course of the nerve beneath the gluteus maximus, see the gluteal region) (See Fig. 18.1).

**Branches in the back of thigh:**

1. **Motor branches** to the hamstring muscles; they arise from the medial side of the nerve, pass deep to the origins of muscles and convey the fibres from the tibial component ($L_4, L_5, S_1, S_2, S_3$) of the sciatic nerve.

2. Nerve to short head of biceps femoris; it arises from the lateral side of the nerve and conveys fibres from the common peroneal component ($L_4, L_5, S_1, S_2$).

**Special feature**—In the angle between gluteus maximus and long head of biceps, the sciatic nerve undergoes a sub-fascial course and is readily accessible.

**Posterior femoral cutaneous nerve**—It passes vertically downward along the middle line of back of thigh beneath the deep fascia and superficial to the long head of biceps femoris. After piercing the popliteal fascia, it becomes cutaneous and extends to the upper part of the back of leg.

Along the sub-fascial course in the back of thigh, it gives numerous cutaneous branches to supply the overlying skin. (For further details see the gluteal region).

**A chain of arterial anastomosis**—Close to the posterior surface of insertion of adductor magnus, a chain of anastomosis is formed by the ascending and descending branches of four perforating arteries from the profunda femoris artery (last perforating is its own continuation). These join with one another; the lowest branch anastomoses with the superior muscular branch of popliteal artery, and the highest branch enters is the formation of cruciate anastomosis (See Fig. 17.4).

The anastomotic chain is more potential than actual. But in ligation of femoral artery above the profunda femoris branch, it maintains efficient collateral circulation.
The popliteal fossa is a diamond-shaped space behind the knee, and becomes apparent as a depression in flexed knee.

**Boundaries**

Above and medially—Semitendinosus and semimembranosus;

Above and laterally—Tendon of biceps femoris;

Below and medially—Medial head of gastrocnemius;

Below and laterally—Plantaris and lateral head of gastrocnemius (Figs. 19.1, 19.2);

Floor (anterior wall)—It is formed from above downward by:

(a) Popliteal surface of femur;
(b) Oblique popliteal ligament;
(c) Posterior part of upper end of tibia;
(d) Fascia covering the popliteus muscle.

Opposite the oblique popliteal ligament, the **floor is pierced** by the middle genicular vessels, middle genicular nerve, and genicular branch of the posterior division of obturator nerve.

![Diagram of popliteal fossa](image)

**Fig. 19.1. Peripheral boundaries of popliteal fossa.**

Roof (posterior wall)—It is formed by a strong popliteal fascia which established a continuity between the fascia lata and fascia cruris.

The **roof is pierced** by the small saphenous vein and posterior femoral cutaneous nerve.

![Diagram of floor of popliteal fossa](image)

**Fig. 19.2. Floor of popliteal fossa.**
Contents of popliteal fossa (Fig. 19.3):
(a) Popliteal artery and vein;
(b) Tibial nerve;
(c) Common peroneal nerve;
(d) Termination of small saphenous vein;
(e) Posterior femoral cutaneous nerve, before it becomes cutaneous;
(f) Genicular branch of posterior division of obturator nerve;
(g) Popliteal lymph nodes;
(h) Pad of fat.

The contents are exposed when the boundaries of the fossa are separated, especially the two heads of gastrocnemius.

Description of the principal contents:

Popliteal artery—It extends obliquely as a continuation of femoral artery from the fifth osseo-aponeurotic opening of adductor magnus to the lower border of popliteus muscle, where it divides into anterior and posterior tibial arteries. The artery is about 20 cm long, and passes downward and laterally in close contact with the floor of popliteal fossa.

The popliteal vein accompanies the artery but undergoes less oblique course, so that in the upper part vein lies posterolateral to the artery, then crosses behind (superficial to) the artery and in the lower part runs medial to the artery.

The tibial nerve passes vertically from the upper to the lower angles of popliteal fossa; during the course the nerve crosses behind (superficial to) the popliteal vessels in the middle of the fossa from lateral to medial side so that the vein intervenes between the artery and nerve.

Fig. 19.3. Contents of popliteal fossa.
Relations of popliteal artery:

Deep surface (from above downwards)
- Popliteal surface of femur separated by a layer of fat;
- Oblique popliteal ligament of knee joint;
- Fascia covering popliteus muscle.

Superficial surface
- In proximal part,
  Overlapped by the semimembranosus;
- In distal part,
  Overlapped by both heads of gastrocnemius and plantaris;
- In the middle,
  Crossed from lateral to medial side by the popliteal vein and tibial nerve.

Laterally
- In proximal part,
  Biceps femoris, tibial nerve, popliteal vein and lateral femoral condyle;
- In distal part,
  Plantaris and lateral head of gastrocnemius.

Medially
- In proximal part,
  Semimembranosus and medial femoral condyle;
- In distal part
  Popliteal vein, tibial nerve and medial head of gastrocnemius.

Variations of termination:
1. The popliteal artery may terminate at the upper border of popliteus; in such case the anterior tibial artery passes in front of the popliteus.
2. The artery may terminate at the distal border of popliteus as anterior tibial and peroneal arteries, or trifurcates into anterior tibial, posterior tibial and peroneal arteries.

Branches: These are cutaneous, muscular and articular (genicular).

Cutaneous branches pierce the roof of the fossa and supply the skin of the back of leg. One branch (sural branch) may accompany the small saphenous vein.

Muscular branches supply the adjacent muscles. Branch to the gastrocnemius begins as a single trunk which descends in the form of Y and supplies both heads of muscles.

Articular branches supply the knee joint by five genicular arteries and form an anastomosis (genicular anastomosis) around the knee.

Superior medial and lateral genicular arteries encircle the upper ends of femoral condyles; inferior medial and lateral genicular arteries encircle the tibial condyles, and the middle genicular artery pierces the oblique popliteal ligament.

Genicular anastomosis (Fig. 19.4)

Superior medial genicular artery arches upward and medially across the medial head of gastrocnemius, deep to the tendon of adductor magnus and anastomoses with the descending genicular branch of femoral artery and inferior medial genicular artery.

Superior lateral genicular artery passes upward and laterally across the lateral head of gastrocnemius, crosses the lateral supra-condylar line beneath the tendon of biceps femoris and anastomoses with the descending branch of lateral circumflex femoral artery and inferior lateral genicular artery.

Both the superior genicular arteries and descending genicular branches anastomose transversely across the lower end of femur.

Inferior medial genicular artery passes along the upper border of popliteus and deep to medial head of gastrocnemius. It curves forward below the medial tibial condyle, deep to tibial collateral ligament and anastomoses with the superior medial genicular and saphenous branch of descending genicular arteries.

Inferior lateral genicular artery passes deep to lateral head of gastrocnemius across the tendon of popliteus, and turns forward along the lateral tibial condyle, above the head of fibula and under cover of fibular collateral ligament. It anastomoses with the superior lateral genicular artery, anterior and posterior tibial recurrent branches of anterior tibial artery, and circumflex fibular branch of posterior tibial artery.

Both inferior genicular arteries anastomose with each other by transverse arches deep to the ligamentum patellae.
Function of genicular anastomosis

During extreme flexion of knee joint, the popliteal artery undergoes kinking with eventual sluggish blood flow. To compensate for such narrowing, a copious blood flow is maintained by collateral anastomosis around the knee.

Tibial nerve in popliteal fossa (Medial popliteal nerve)—

It is the larger terminal branch of sciatic nerve and conveys fibres from the ventral branches of the ventral rami of L₄, L₅, S₁, S₂, and S₃. From the back of thigh the tibial nerve passes vertically downward along the middle line of popliteal fossa. In the lower part of the fossa it is overlapped by the two heads of gastrocnemius and enters the posterior crural region accompanied by the posterior tibial vessels under cover of the tendinous origin of soleus muscle (See Fig. 19.3).

In the popliteal fossa, the nerve lies lateral to the popliteal vessels in the upper part, crosses medially behind or superficial to the vessels at the knee, and in the lower part it accompanies the vessels in the area. In the middle of the fossa, the popliteal vein intervenes between the deeply placed artery and superficially placed nerve.

Branches:

These are muscular, articular, cutaneous and vascular.

Muscular branches supply both heads of gastrocnemius, plantaris, soleus and popliteus. All muscular branches arise from the lateral side of the tibial nerve, except the nerve to the medial head of gastrocnemius which arises from the medial side. Therefore the lateral side of the nerve is of danger, and the medial side is fairly safe.

Branches to the plantaris, lateral head of gastrocnemius and soleus pass downward and laterally superficial to the plantaris and reach to supply the respective muscles. Branch to the popliteus passes downward and laterally crossing superficial to the popliteal vessels and deep to the plantaris tendon; then it winds round the distal border of popliteus to supply the muscles from the deep surface. Thereafter the nerve to popliteus supplies the superior tibio-fibular joint, provides a twig to the tibialis posterior, gives a descending branch to supply interosseous membrane and inferior tibio-fibular syndesmosis and furnishes a medullary branch to the tibia through the nutrient foramen.

Articular branches are three: superior and inferior medial genicular nerves which accompany the corresponding vessels and supply the knee joint. The middle genicular nerve pierces the oblique popliteal ligament and supplies the interior of knee joint.

Cutaneous branch forms the sural nerve which pierces the deep fascia of leg and joins with the sural communicating branch of common peroneal nerve.

Vascular branches convey post-ganglionic sympathetic fibres from T₁₀—L₂ cord segments and supply the vaso-motor fibres to the popliteal vessels.
Articular branches are three, superior and inferior lateral genicular nerves, and recurrent genicular nerve.

The superior and inferior lateral genicular nerves accompany the corresponding vessels and supply the knee joint. The recurrent genicular nerve arises from the bifurcation of common peroneal nerve, pierces the tibialis anterior and supplies the antero-lateral part of the capsule of knee joint and superior tibio-fibular joint.

Common peroneal nerve (Lateral popliteal nerve)

It is the smaller terminal branch of sciatic nerve and conveys fibres from the dorsal branches of ventral rami of L₅, S₁, S₂. The nerve appears in the fossa beneath the long head of the biceps, and slopes downward and laterally along the medial margin of the biceps tendon. At the lateral angle of the popliteal fossa it crosses superficial to the plantaris, lateral head of gastrocnemius and on reaching the back of head of fibula the nerve rests on a thin fleshy sheet of soleus where it can be rolled against the bone.

Finally the nerve curves forward on the lateral side of the neck of fibula deep to peroneus longus and divides into two terminal branches, deep and superficial peroneal nerves.

Branches:

The common peroneal nerve in the popliteal fossa gives off two sets of branches – cutaneous and articular.

Cutaneous branches are two, the sural communicating nerve and the lateral sural nerve (lateral cutaneous branch of the calf).

The sural communicating nerve arises opposite the head of fibula and joins with the sural nerve after crossing the lateral head of gastrocnemius.

The lateral sural nerve breaks up into branches after piercing the deep fascia and supplies the skin of the upper part of the lateral side of the leg.

Applied anatomy

Injury to the common peroneal nerve is most common, because it may be involved by fracture of neck of the fibula or by pressure of a plaster cast.

When the nerve is completely severed, the following manifestations are observed:

1. Motor paralysis affects all muscles of peroneal and extensor compartments of leg including extensor digitorum brevis. This results in 'foot drop' because the ankle is fully plantar-flexed and the foot is held in inversion and adduction. Dorsiflexion of the middle and terminal phalanges of the lateral four toes are retained by the contraction of interossei and lumbrical muscles.

2. Sensory loss is observed on most of the dorsum of foot and outer surface of the lower third of the front of leg.

Popliteal lymph nodes—These are usually six in number, embedded in popliteal fat and are arranged in three groups:

1. One is situated beneath the popliteal fascia at the junction of small saphenous vein and popliteal vein. It drains the cutaneous lymphatics from the lateral margin of foot including little toe and from the adjacent side of the back of leg; the lymphatics accompany the small saphenous vein.

2. A few nodes intervene between the knee joint and popliteal artery; they receive the lymphatics from the knee following genicular vessels.

3. Rest of the nodes are situated on both sides of popliteal vessels. They drain the lymphatics which accompany the anterior and posterior tibial vessels.

Efferents: From all popliteal nodes the efferent vessels accompany the femoral vessels and drain into deep inguinal lymph nodes.
Skin and superficial fascia

The superficial fascia contains subcutaneous fibro-fatty and areolar tissue and is traversed by cutaneous nerves, small saphenous vein and its communications, and the lymphatics which accompany the small saphenous vein.

Cutaneous nerves:

1. Termination of posterior femoral cutaneous nerve supplies the upper part of the back of the leg, after piercing the fascial roof of the popliteal fossa and accompanying the terminal part of small saphenous vein.

2. Sural nerve, a branch of tibial nerve in the popliteal fossa, and sural communicating branch of common peroneal nerve meet near the middle of the back of leg after piercing the deep fascia, and accompany the small saphenous vein along the lateral margin of tendo-calcaneeus to supply the lower part of the skin of the calf.

3. Lateral cutaneous branches of the calf, derived from the common peroneal nerve, supply upper and lateral part of the back of leg.

4. Medial side of the calf is supplied by branches of saphenous nerve.

5. Posterior surface of the calcaneus and weight bearing area of the heel are supplied by the calcanean branch of tibial nerve.

Small saphenous vein—(See superficial veins of lower extremity in the Chapter of the front of thigh).

Superficial lymphatics—Cutaneous lymphatics from the lateral border of the foot including little toe and from the lateral side of the lower part of the calf accompany the small saphenous vein and drain into popliteal lymph nodes after piercing the popliteal fascia.

Deep fascia—The deep fascia or fascia cruris encloses the extensor, peroneal and flexor compartments of the leg in a tight sleeve. It is attached in front to the anterior border of tibia and its malleolus, behind along the medial border of tibia extending upto medial malleolus where it is thickened to form the flexor retinaculum. The latter stretches from medial malleolus to the back of the calcaneous and bridges the deep flexor tendons and neuro-vascular bundle. At the lower end of the fibula it is attached to the anterior and posterior margins of the subcutaneous triangular area. Above, the deep fascia is continuous with the popliteal fascia. Anterior and posterior intermuscular septa blend at the periphery with the inner surface of the fascia cruris.

Flexor compartment of leg

Boundaries:

In front – Posterior surfaces of the tibia and fibula, and the interosseous membrane stretching between them;

Behind—Deep fascia of the leg;

Laterally—Posterior intermuscular septum.

Subdivision—The flexor compartment is subdivided into superficial and deep parts by the deep transverse fascia of the leg (Fig. 20.1).

The deep transverse fascia stretches across the leg between superficial and deep groups of flexor muscles. It is attached medially to the medial border of tibia, laterally to the posterior border of fibula, and above to the soleal line of tibia and to the fibula beneath the origin of soleus. In the interval between the bones, it is continuous with the fascia covering popliteus muscle. Traced below and on each side of the tendo-calcaneeus, the deep transverse fascia and the investing layer of deep fascia blend, and are continuous with the flexor retinaculum on the tibial side and with the superior peroneal retinaculum on the fibular side.

Contents of flexor compartment (See Fig. 20.1)

Superficial part:

Gastrocnemius, Plantaris and Soleus muscles;
Deep part:

(a) Popliteus, Flexor digitorum longus,
   Flexor hallucis longus and Tibialis posterior
   muscles;
(b) Posterior tibial and peroneal vessels;
(c) Tibial nerve

Some authorities subdivide the deep part into intermediate and deepest strata by the fascia
covering the popliteus and another fascial sheet
covering the tibialis posterior. Virtually, the popliteus
and tibialis posterior lie in the skeletal plane.

Muscles of the superficial group (Fig. 20.2)

Gastrocnemius

Origin: It arises from the condyles of femur
by two tendinous heads which form the lower half
of popliteal fossa. The medial head is larger and
arises from the upper and posterior part of medial
condyle and from the infero-medial angle of the
popliteal surface of the femur. The lateral head
arises from a depressed area on the lateral surface
of lateral condyle above the lateral epicondyle and
the groove for the origin of popliteus. Both heads
are also attached to the fibrous capsule of knee
joint. A bursa intervenes between the medial head
and the capsule over of medial condyle of femur.
It always communicates with knee joint and
sometimes with semimembranosus bursa.

Insertion: Each head descends to form a
tendinous expansion and from their anterior
surfaces two fleshy bellies descend to form the fullness of the calf. At the middle of the leg the two fleshy bellies unite to form a broad aponerotic on the anterior surface of muscle and blend with the tendon of the soleus to form the **tendo-calcaneus**; through the latter the muscle is inserted into the middle one-third of the posterior surface of the calcaneus. The medial head is longer at each end. The two heads of gastrocnemius and soleus are collectively named as the **triceps surae**.

**Nerve supply**—Both heads are supplied by the tibial nerve in the popliteal fossa.

**Plantaris**—It is a small fusiform muscle with a long slender tendon and intervenes between the gastrocnemius and the soleus.

**Origin** : It arises from the lower third of lateral supra-condylar ridge and the adjoining popliteal surface of femur.

**Insertion** : The fleshy belly accompanies the lateral head of gastrocnemius and ends into an elongated slender tendon which passes downward and medially between gastrocnemius and soleus, and blends with the medial margin of tendo-calcaneus.

The plantaris is a vestigial muscle in man. In lower mammals its distal part is continuous with the plantar aponeurosis.

**Nerve supply**—From the tibial nerve in the popliteal fossa.

**Soleus**—It is a multipennate muscle and is shaped like the sole of foot. It lies beneath the gastrocnemius muscle.

**Origin** : It is horse-shoe shaped in origin and arises from:

(i) posterior surface of the head and upper one-fourth of the shaft of fibula;
(ii) soleal line and middle one-third of the medial border of tibia, below that line;
(iii) the tendinous arch between tibia and fibula, beneath which popliteal vessels and tibial nerve pass.

**Insertion** : The bulk of the muscle intervenes between anterior and posterior aponeurotic lamellae. The muscle fibres slope downward from anterior to posterior lamellae, and the fleshy fibres are visible at both margins of the muscle. The posterior lamella is continuous below with the **tendo-calcaneus** where it blends superficially with the tendon of gastrocnemius and is inserted into the middle one-third of the posterior surface of the calcaneus. The tendon is separated from the upper third of the calcaneus by a bursa.

**Tendo-calcaneus** (Tendo-Achillis) is the strongest tendon of the human body and about 15 cm long. It is the conjoint tendon of insertion of triceps surae, and acts as prime mover of plantar-flexion of the foot at the ankle joint.

**Nerve supply**—Soleus is supplied by the tibial nerve in the popliteal fossa from its superficial surface, and by the same nerve in the flexor compartment of leg from its deep surface.

**Characteristics of the soleus**—The muscle is pierced by the perforating veins which communicate the superficial with the deep veins of the leg, and are guarded by valves to direct the blood flow from superficial to deep. The soleus contains a rich plexus of small veins which are valveless. The contraction of the muscle squeezes the venous blood centripetally and acts as a **peripheral heart**.

Morphologically, the soleus corresponds with the flexor digitorum superficialis of the forearm. Flexor digitorum brevis of the sole represents the detached distal part of soleus by the posterior projection of the calcaneus.

**Actions of triceps surae**

1. Gastrocnemius and soleus along with plantaris produce **plantar-flexion** of the ankle joint. Gastrocnemius is a strap and white muscle; so it increases the range of movement and not the power. Soleus is a multipennate and red muscle; therefore it increases the power to overcome the inertia of the body weight and not the range. Gastrocnemius acts as a ‘top gear’ for jumping and soleus acts as a ‘bottom gear’ for strolling.

2. Gastrocnemius and plantaris, in addition, produce **flexion** of the knee joint.

**Muscles of the deep group** (Fig. 20.3)

**Popliteus**—It is a triangular muscle and forms the floor of the popliteal fossa.

**Origin** : Its origin is **intracapsular** and arises by a tendon from the anterior part of a groove on the lateral surface of the lateral femoral condyle. The posterior part of the groove is occupied by the tendon of popliteus in full flexion.

**Insertion** : The tendon passes downward and medially between the fibular collateral ligament and the lateral meniscus, where it pierces the
fibrous capsule and is accompanied by synovial pouch. The tendon emerges beneath the arcuate ligament and flares out to form a fleshy part which is inserted to the triangular area on the posterior surface of tibia above the soleal line.

**Insertion**: The bipennate muscle converges below to form a central tendon which crosses superficial to the tendon of tibialis posterior in the lower part of the leg from medial to lateral side.

After passing beneath the flexor retinaculum, the flexor digitorum longus tendon appears in the sole, where it crosses superficial to the tendon of flexor hallucis longus from medial to lateral side. The common tendon, before splitting into four digital tendons for lateral four toes, receives the attachment of flexor digitorum accessorius on its lateral side. Four lumbrical muscles take origin from the sides of four digital tendons. Finally each digital tendon enters the fibrous flexor sheath, pierces the tendon of flexor digitorum brevis and is inserted into the plantar surface of the base of terminal phalanx of lateral four toes.

**Nerve supply**—From the tibial nerve in the posterior crural region.

**Actions**—It plantar-flexes lateral four toes and on prolonged action produces plantar flexion of ankle joint.

Along with other deep group of calf muscles, it maintains longitudinal arch of foot.

**Flexor hallucis longus**

**Origin**: It arises from the lower two-thirds of the posterior surface of the shaft of fibula behind the medial crest, the adjacent interosseous membrane, from the fascia covering the tibialis posterior and from the posterior intermuscular septum.

The muscle is so bulky that it overlaps the tibialis posterior and conceals the peroneal artery.

**Insertion**: The tendon of bipennate muscle rests on the posterior surface of lower end of tibia beneath the flexor retinaculum, and midway between the two malleoli. It lodges in a groove between the medial and posterior tubercles of talus, curves forward along the undersurface of sustentaculum tali of the calcaneus and passes straight for insertion into the base of the distal phalanx of the great toe.

In the sole the tendon of flexor hallucis longus is crossed superficially by the tendon of flexor digitorum longus from medial to lateral side, where the hallucis tendon gives strong slips to the digitorum tendons for the second and third toes.
Nerve supply—From the tibial nerve in the posterior crural region;

Actions—It plantar-flexes the great toe and secondarily acts as plantar flexor of ankle joint.

It maintains the medial longitudinal arch like a bow-string, and increases the force of take-off point of the foot for propulsion.

Tibialis posterior—It is the deepest flexor muscle of the calf, covered posteriorly by a strong fascia, and intervenes between the flexor digitorum longus and flexor hallucis longus.

Origin: It arises from:
(i) upper two-thirds of the interosseous membrane,
(ii) the lateral part of the posterior surface of the shaft of tibia below the soleal line,
(iii) the adjacent posterior surface of the shaft of fibula in its proximal two-thirds.

The muscle presents an angular gap in the upper part between the two heads of origin; through the gap the anterior tibial vessels traverse forward above the interosseous membrane and enter the anterior crural region.

Insertion: In the lower part of leg the bipennate muscle forms a round tendon, which is crossed superficially by the tendon of flexor digitorum longus so that tibialis posterior occupies its medial side and lodges in a groove behind the tibial malleolus and beneath the flexor retinaculum. Using the tibial malleolus as a 'pulley' the tendon passes downward and forward along the medial side of the sustentaculum tali of calcaneus and is inserted as follows:
(a) two-thirds of the tendon are attached to the tuberosity of navicular bone;
(b) remaining one-third passes below the navicular bone and presents a number of tentacular attachments to the sustentaculum tali of calcaneus and to the plantar surface of all tarsal and metatarsal bones, except the talus and the bases of first and occasionally the fifth metatarsal bones.

Nerve supply—From the tibial nerve in the posterior crural region;

Actions:
1. It acts as invertor and adductor of the fore part of foot;
2. Maintains the medial longitudinal arch of foot;
3. It acts as plantar flexor of foot at the ankle joint.

Posterior tibial artery

It is the larger of the two terminal branches of popliteal artery and begins at the lower border of the popliteus. The artery enters the posterior compartment of leg under cover of the tendinous arch of the origin of the soleus, and ends beneath the flexor retinaculum by dividing into medial and lateral plantar arteries (Fig. 20.4, 20.5).

![Fig. 20.4. Vessels and nerve in the posterior compartment of leg.]

Along the entire course the artery is accompanied by a pair of venae comitantes which establish frequent communications with each other around the artery.

Relations:

Anteriorly—it rests successively upon tibialis posterior, flexor digitorum longus, tibia and ankle joint;

Posteriorly—in the upper part, the artery is covered by the gastrocnemius, soleus and deep transverse fascia; in the lower part, it is covered only by the skin and fasciae, and lies parallel with and somewhat anterior to the medial border of tendo-calcaneus.

At the sides—the tibial nerve lies medial to the artery in the upper part and further below runs
Fig. 20.5. Structures beneath the flexor retinaculum and superior peroneal retinaculum.

lateral to the artery after crossing the vessel superficially.

Branches:

1. **Circumflex fibular artery**—It encircles the lateral side of the fibular neck through the soleus, and anastomoses with the inferior lateral genicular and anterior tibial recurrent arteries.

2. **Peroneal artery**—It is a large vessels and arises about 2.5 cm distal to the commencement of posterior tibial artery. It descends along the medial crest of fibula in a fibrous canal between the tibialis posterior and flexor hallucis longus, passes behind the inferior tibio-fibular joint and ends on the lateral surface of calcaneus as the lateral calcanean artery.

   The peroneal artery gives off the following branches:
   (a) Muscular branches to the flexor and peroneal compartments of leg;
   (b) Nutrient branch to the fibula;
   (c) Communicating branch to join with the posterior tibial artery;
   (d) **Perforating branch** pierces the interosseous membrane, appears in the extensor compartment in front of the inferior tibiofibular joint and forms the lateral malleolar network by anastomosing with the lateral malleolar branch of anterior tibial artery and lateral tarsal branch of dorsalis pedis artery. Some-times the perforating artery continues as the dorsalis pedis artery.
   (e) Lateral calcanean artery is the terminal branch which forms a contribution of lateral malleolar network.

3. Nutrient artery—It is one of the largest nutrient arteries and enters the nutrient foramen of tibia below the soleal line.

4. Muscular branches—to the adjacent muscles of flexor compartment;

5. Communicating branch joins with the similar branch of peroneal artery about 5 cm above the ankle;

6. Medial malleolar branch passes towards the medial malleolus and joins with the medial malleolar network.

7. Calcanean branch pierces the flexor retinaculum and supplies the skin and subcutaneous fibro-fatty tissue of the heel.

8. Medial plantar artery; and

9. Lateral plantar artery (See the chapter of the sole of foot).

**Tibial nerve**

It enters from the popliteal fossa to the posterior compartment of leg undercover of the tendinous arch of the origin of soleus along with the posterior tibial vessels. The nerve ends by dividing into medial and lateral plantar nerves beneath the flexor retinaculum; the division of the nerve takes place a little lower than the division of the posterior tibial artery (See Figs. 20.4, 20.5).

The tibial nerve lies medial to the posterior tibial vessels in the upper part of the leg; as the nerve descends it crosses behind (superficial) the
vessels and then accompanies lateral to the vessels up to the terminal division.

**Branches:**

1. **Muscular branches** to the tibialis posterior, flexor digitorum longus, flexor hallucis longus and soleus from its deep surface;

2. **Articular branches** to the ankle joint;

3. Medial calcanean branch which pierces the flexor retinaculum and supplies the weight bearing area of the skin of the heel.

**To sum up,** the structures passing under cover of flexor retinaculum are as follows (medial to lateral)—

Tibialis posterior tendon, flexor digitorum longus tendon, posterior tibial artery with a pair of venae comitantes, tibial nerve, and flexor hallucis longus tendon.

The relations can be memorised by following the mnemonic “Tom, Dick, AN Harry”.

Sole of the Foot

Skin—Both epidermis and dermis of the skin are much thicker on the sole as well as on the palm than the other parts of the body. This becomes apparent at birth, and the thickness of skin increases due to intermittent pressure. Moreover in both regions the skin is devoid of hairs and sebaceous glands, but is provided with numerous sweat glands.

Superficial fascia—It is composed of subcutaneous fat in a meshwork of fibrous septa which anchor the skin to the underlying plantar aponeurosis. This ensures proper grip of the sole. The cushion of the fibro-fatty tissue is more abundant beneath the posterior tubercles of calcaneus, metatarsal heads and the pulp of the terminal digits.

Cutaneous nerve supply (Fig. 21.1)

1. Over the weight-bearing area of heel, the skin is supplied by the calcaneal branch of tibial nerve;

2. Medial part of the sole including the plantar surface of the medial three and half of the toes—by the medial plantar nerve;

3. Lateral part of the sole including the plantar surface of the lateral one and half of the toes—by the lateral plantar nerve.

Cutaneous branches reach the skin by piercing the medial and lateral margins of the central part of plantar aponeurosis and through the plantar digital nerves.

Deep fascia (Fig. 21.2)—The deep fascia or plantar aponeurosis is composed of compact bundles of collagen fibres, which are mostly longitudinal with appearance of transverse fibres in places. Plantar aponeurosis consists of three parts—central, medial and lateral. The central part is thick and covers the flexor digitorum brevis; medial and lateral parts are thin and cover respectively abductor hallucis and abductor digiti minimi. Some authorities reserve the name of plantar aponeurosis for the central part, and the medial and lateral parts are named as the plantar fascia.

Attachments

The central part of the aponeurosis is narrow in the posterior part and is attached to the medial tubercle of the calcaneus. The broader anterior part splits into five bands, one for each digit, proximal to the metatarsal heads. The digital slips are held together by transverse fibres which protect the plantar digital vessels and nerves. Opposite the metatarsal head, each digital band separates into superficial and deep strata. The superficial stratum is attached to the dermis by sagittally oriented skin ligaments and blends with superficial transverse metatarsal ligaments. The deep stratum of each digital slip splits into two bands which embrace the flexor tendons and blend with the fibrous sheath of the flexor tendons and with the deep transverse metatarsal ligaments. Four cushions of fat fill up the webs between the digits to protect the plantar vessels and nerves; these fat pads are isolated from one another by vertical strands extending from the fibrous flexor sheaths to the superficial transverse metatarsal ligaments.
Medial and lateral intermuscular septa extend deeply in vertical planes from the junction of the central part with the medial and lateral parts of the aponeurosis. **Medial intermuscular septum** is subdivided into proximal, intermediate and distal segments; the distal segment splits to enclose the tendon of flexor hallucis longus and is attached to the first metatarsal bone. **Lateral intermuscular septum** in the distal part is attached to the fifth metatarsal bone. The two intermuscular septa divide the plantar muscles into medial, intermediate and lateral groups. **Horizontal septa** extends from these vertical septa to separate the plantar muscles in layers.

![Plantar aponeurosis](image)

**Fig. 21.2. Disposition of plantar aponeurosis.**

**Medial part** of plantar aponeurosis covers the abductor hallucis. It is continuous posteriorly with the flexor retinaculum, and medially with the deep fascia of the dorsum of foot.

**Lateral part** of the aponeurosis covers the abductor digiti minimi and is continuous laterally with the deep fascia of the dorsum of foot. Posteriorly, the lateral part is sometimes thickened to form a fibrous band extending from lateral tubercle of calcaneus to the base of the fifth metatarsal bone.

**Morphology:** The central part of plantar aponeurosis represents distal continuation of plantaris tendon.

**Functions** of plantar aponeurosis:

1. It maintains the longitudinal arches of foot acting as tie-beam. Dorsiflexion of the toes in walking makes the plantar aponeurosis taut.
2. It provides origins to the superficial groups of plantar muscles.
3. It protects the plantar vessels and nerves from compression.
4. It subdivides the sole into compartments and sub-compartments.

**PLANTAR MUSCLES**

Muscles of the sole are conventionally described in **four layers**, as encountered in dissection. The **first layer** lies beneath the plantar aponeurosis and consists of three intrinsic muscles that extend from heel to toes. The **second layer** consists of long flexor tendons of the toes, and the intrinsic muscles connected to the tendons. The **third layer** is localised to the metatarsal region of foot and consists of short muscles of great and little toes. The **fourth layer** includes dorsal and plantar interossei along with the tendons of peroneus longus and Tibialis posterior.

The trunks of **neuro-vascular bundles** (medial and lateral plantar vessels and nerves) intervene between the first and second layers, whereas the deep branches of lateral plantar vessels and nerve lie between the third and fourth layers.

**First layer**

It consists of three short muscles which lie side by side along the sole, and all arise from the calcaneus (Fig. 21.3). The muscles are: Abductor hallucis, Flexor digitorum brevis and Abductor digitii minimi (from medial to lateral).

**Abductor hallucis**

**Origin:** From the medial tubercle of calcaneus, flexor retinaculum, plantar aponeurosis and from medial intermuscular septum.

**Insertion:** The muscle overlaps the origins of plantar vessels and nerves, proceeds forward along the medial border of the foot, and is inserted by a tendon to the medial side of the base of proximal phalanx of the great toe.

**Nerve supply:** From the trunk of the medial plantar nerve.

**Action:** It abducts the great toe; this movement is retained in bare-footed peoples, but is practically lost in shoe-wearing races.
Flexor digitorum brevis

Origin: It lies deep to the central part of plantar aponeurosis, and arises from the medial tubercle of calcaneus, plantar aponeurosis and from the adjacent medial and lateral intermuscular septa.

Insertion: Traced distally, the muscle divides into four tendons for the lateral four toes. Each tendon enters the fibrous flexor sheath of the corresponding digit, splits and spirals around the long flexor tendon, re-unites and partially decussates, and finally splits for insertion into the sides of the middle phalanx. The mode of insertion is identical with the flexor digitorum superficialis of the hand.

Nerve supply: From the trunk of the medial plantar nerve.

Action: It produces plantar-flexion of the lateral four toes in any position of the ankle joint.

Abductor digiti minimi

Origin: It arises from both lateral and medial tubercles of the calcaneus beneath the flexor digitorum brevis, and from the plantar aponeurosis and adjacent septum.

Insertion: It passes forward along the lateral border of foot and its tendon glides over a groove on the plantar surface of the base of fifth metatarsal bone. Finally the tendon is inserted to the lateral side of the base of proximal phalanx of the little toe, in common with the tendon of flexor digiti minimi brevis.

Sometimes the medial fibres of the muscle are inserted into the tubercle of fifth metatarsal bone (Wood's muscle).

Nerve supply: From the trunk of the lateral plantar nerve.

Action: It is more a plantar flexor than abductor of little toe in shoe-wearing peoples.

Second layer

It consists of two extrinsic tendons—flexor hallucis longus and flexor digitorum longus, and two sets of intrinsic muscles—flexor digitorum accessorius and four lumbricals (Fig. 21.4).

Tendon of flexor hallucis longus

The tendon reaches the sole beneath the flexor retinaculum and abductor hallucis, and runs forward lodging in a groove on the undersurface of the sustentaculum tali of calcaneus. It is
crossed superficially from medial to lateral side by the tendon of flexor digitorum longus. At the area of crossing some of the tendinous fibres of flexor hallucis longus are transferred to the digital tendons of flexor digitorum longus for the second and third toes.

Thereafter the tendon of flexor hallucis passes straight forward between the two sesamoid bones of flexor hallucis brevis and finally is inserted into the plantar surface of the base of the distal phalanx of the great toe.

**Tendon of flexor digitorum longus**

The tendon appears in the sole beneath the flexor retinaculum and abductor hallucis. It passes forward and laterally crossing superficial to the tendon of flexor hallucis longus. Thereafter the common tendon separates into four digital tendons for insertion into the base of the terminal phalanges of lateral four toes. Before insertion each digital tendon enters the fibrous flexor sheath and perforates the tendon of flexor digitorum brevis.

**Flexor digitorum accessorius (Quadratus plantae)**

**Origin**: It arises by two heads, medial and lateral. The **medial head** is fleshy and arises from the medial surface of the calcaneus and from the medial tubercle. The **lateral head** is tendinous, arises from the lateral tubercle of calcaneus and meets the medial head, separated by a triangular gap which is occupied by the long plantar ligament.

**Insertion**: Conjoined muscle belly is inserted into the lateral side of the common tendon of flexor digitorum longus.

**Nerve supply**: From the trunk of the lateral plantar nerve.

**Action**:

1. It corrects the diagonal pull of the flexor digitorum longus into a direct plantar flexion of the lateral four toes.
2. It permits plantar flexion of lateral four toes in any position of ankle joint.

**Lumbrical muscles**—Lumbricals are four small muscles, and numbered from medial to lateral side.

**Origins**: They arise from the adjacent sides of the digital tendons of flexor digitorum longus, except the first lumbrical which arises only from the medial side of the first tendon. Therefore the first lumbrical is unipennate, whereas other muscles are bipennate in origin.
**Insertion**: Each lumbrical passes forward as a narrow tendon on the medial side of the base of the proximal phalanx of corresponding lateral four toes. It joins with the dorsal digital expansion through which it is inserted into the dorsal surface of the base of middle and terminal phalanges of the lateral four toes.

**Nerve supply**:  
1. First lumbral is supplied by the medial plantar nerve;  
2. Rest of the lumbricals are supplied by the deep branch of the lateral plantar nerve.

**Actions**:  
1. Lumbricals produce plantar flexion at the metatarso-phalangeal joints and dorsi-flexion at the interphalangeal joints of lateral four toes. This increases the grip of the metatarsal heads on the ground for forward thrust of the body at each step.  
2. They prevent the toes from buckling under, during walking and running (Fig. 21.5-a, b).

![Fig. 21.5. Actions of lumbricals of Foot.](image)

**Third layer**

The muscles of this layer are three in number; two for the great toe and one for the little toe. They are located within the confines of the metatarsal regions (Fig. 21.6).

**Flexor hallucis brevis**  
**Origin**: It possesses a bifurcated tendon of origin. The lateral band arises from the plantar surface of the cuboid bone proximal to the tendon of peroneus longus; the medial band is attached to the three cuneiform bones blending with the insertion of the tibialis posterior tendon.

**Insertion**: It forms a bipennate muscle which covers the plantar surface of the first metatarsal bone and is inserted distally by splitting into two narrow tendons, each being intercepted by a sesamoid bone. The medial tendon is inserted to the medial side of the base of the proximal phalanx of the great toe in common with the tendon of the abductor hallucis; the lateral tendon is attached to the lateral side of the base of the proximal phalanx of the great toe in common with the insertion of the adductor hallucis.

![Fig. 21.6. Muscles of the third layer of sole and related structure.](image)

The tendon of flexor hallucis longus lodges in the groove of the bipennate muscle and between the two sesamoid bones of the flexor hallucis brevis.

**Nerve supply**: From the medial plantar nerve.

**Action**: It produces plantar flexion of the metatarso-phalangeal joint of the great toe.

**Adductor hallucis**

**Origin**: It arises by two heads, oblique and transverse. The oblique head arises from the base of the second to fourth metatarsal bones, and from the sheath of peroneus longus. The transverse head has no bony origin, and arises from the deep
transverse metatarsal ligaments and from the plantar metatarso-phalangeal ligaments of the third to fifth toes.

Plantar arterial arch and deep branch of lateral plantar nerve lie deep to the oblique head; nerve to the second lumbrical passes deep to the transverse head before supplying the muscle.

**Insertion**: Both heads meet at an acute angle, and the tendon thus formed is inserted into the lateral side of the base of the proximal phalanx of the great toe.

**Nerve supply**: From the deep branch of lateral plantar nerve.

**Action**: It adducts the great toe towards axial line of the foot, which passes through the second toe.

**Flexor digiti minimi brevis**

**Origin**: It arises from the plantar surface of the base of the fifth metatarsal bone and from the sheath of peroneus longus.

**Insertion**: The muscle passes along the undersurface of the fifth metatarsal bone, and is inserted by a narrow tendon to the lateral side of the base of the proximal phalanx of the little toe in common with the tendon of abductor digiti minimi.

The floor of the triangular gap between the two heads of adductor hallucis and flexor digiti minimi brevis is occupied by the muscles of the fourth layer, plantar metatarsal vessels and branches from the deep division of lateral plantar nerve.

**Nerve supply**: From the superficial branch of lateral plantar nerve.

**Action**: It helps in plantar flexion of the little toe.

**Fourth layer**

**It presents**: (a) Seven intrinsic muscles – four dorsal interossei and three plantar interossei;

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Fig. 21.7. *Fourth layer of the sole and related structures.*
(b) Two extrinsic tendons – peroneus longus and tibialis posterior (Fig. 21.7).

**Dorsal interossei**—These are four bipennate muscles and are numbered from medial to lateral side. They are *abductors of the toes.*

**Origin** : Each muscle arises from the adjacent sides of the shafts of five metatarsal bones and fills up the intermetatarsal space. The triangular gap between the two heads of origin of first dorsal interosseous transmits dorsalis pedis artery to complete the plantar arterial arch. The similar gaps between the heads of other dorsal interossei transmit the proximal perforating arteries.

**Insertion** : Each dorsal interosseous forms a narrow tendon and passes forward in the cleft between the toes.

1. First dorsal interosseous is inserted partly to the *medial side* of the base of the proximal phalanx of the second toe, and partly joins with the dorsal digital expansion for insertion into the dorsal surface of the bases of the middle and terminal phalanges.

2. Second, third and fourth dorsal interossei are respectively inserted to the *lateral side* of the base of proximal phalanx of second, third and fourth toes, in addition to joining with the dorsal digital expansion.

**Nerve supply**—All dorsal interossei along with the plantar interossei are supplied by the deep branch of lateral plantar nerve, except those occupying the fourth inter-metatarsal space (fourth dorsal and third plantar interossei) which are supplied by the superficial branch of lateral plantar nerve. In addition, first and second dorsal interossei may be supplied by the terminal branches of the deep peroneal nerve.

**Actions** : Since the axial line of the foot passes through the second metatarsal bone and second toe, any movement of the toe away from the axial line produces abduction. Therefore, abduction of the middle three toes is performed by the dorsal interossei.

For abduction of the great and little toes, separate muscles of the first layer are engaged.

**Plantar interossei**—These are three unipennate muscles and act as *adductors* of the lateral three toes. Since the axis of the foot passes through the second toe, the latter is already adducted and lies in zero position. Therefore the second metatarsal bone does not provide origin to the plantar interosseous muscle. The great toe is provided with separate adductor muscle.

**Origin** : Plantar interossei arise from the medial side of the plantar surface of the shafts of the lateral three metatarsal bones; the first plantar from the third, second from the fourth, and third from the fifth metatarsal bones.

**Insertion** : Each muscle passes forward on the medial side of the lateral three toes, and is inserted mainly to the medial side of the base of the proximal phalanx of the corresponding toe and partly joins with the dorsal digital expansion.

**Nerve supply**—(See dorsal interossei)

**Actions**—(Vide supra)

**Peculiarities** : In the web between the toes the tendons of lumbricals, plantar and dorsal interossei, plantar and dorsal digital vessels and nerves intervene. The lumbricals and plantar digital vessels and nerves lie below the deep transversus metatarsal ligament, whereas the plantar and dorsal interosseous muscles and dorsal digital vessels and nerves lie above that ligament.

**Tendons of peroneus longus and tibialis posterior**

**Peroneus longus** tendon lodges in a groove beneath the cuboid bone in an osseo-fibrous tunnel, passes forward and medially across the sole and is inserted into the lateral surface of the base of the first metatarsal and adjacent medial cuneiform bones.

**Tibialis posterior** tendon is principally inserted into the tuberosity of navicular bone and the rest of the tendinous fibres spread forward and laterally for insertion into the plantar surface of all tarsal and metatarsal bones except the talus and the bases of the first and fifth metatarsal bones.

Tendons of peroneus longus and tibialis posterior cross each other like the letter of ‘X’, the tibialis posterior lies deep to the peroneus longus. The tendons of both muscles maintain the longitudinal and transverse arches of foot. Whereas the peroneus is an extensor, the tibialis posterior acts as an invertor.

**Nerves of the sole**

These are derived from the *medial* and *lateral plantar nerves,* which are the terminal branches of the tibial nerve. The nerves are accompanied by the medial and lateral plantar arteries which are the terminal branches of the posterior tibial
artery. The divisions of both nerves and arteries take place under cover of the flexor retinaculum, the arteries divide earlier than the nerves because the plantar arteries follow the marginal side of the corresponding nerves (See Fig. 21.4).

Medial plantar nerve—It is the larger terminal branch of the tibial nerve and accompanied by the medial plantar artery on its medial side appears in the sole beneath the abductor hallucis (Fig. 21.8).

The trunk of the nerve passes forward between the abductor hallucis and flexor digitorum brevis, and appears in the interval between them. Here it divides into a proper digital nerve to the medial side of the hallux and three common plantar digital nerves near the base of the metatarsals.

The nerve trunk gives branches to the abductor hallucis and flexor digitorum brevis.

The digital nerve to the hallux provides cutaneous branches to the medial side of the great toe and gives a muscular branch to the flexor hallucis brevis.

The common digital nerves pass forward between the slips of plantar aponeurosis and each divides into two plantar digital nerves. The first common digital nerve supplies the skin of the adjacent sides of the great and second toes, and provides a muscular branch to the first lumbrical muscle; the second supplies the adjacent sides of the second and third toes; the third supplies the adjacent sides of third and fourth toes and receives a communicating branch from the nearest digital branch of the superficial division of lateral plantar nerve. The digital nerves supply, in addition to skin, the interphalangeal joints and provide dorsal branches which supply the structures around the nail bed.

**Distribution**

1. Medial plantar nerve supplies four muscles: Abductor hallucis, flexor digitorum brevis, flexor hallucis brevis and first lumbrical.

2. It supplies the skin of the medial part of the sole including medial three and a half of the digits. The cutaneous branches reach the skin by piercing the plantar aponeurosis. The large cutaneous distribution accounts for the large size of the medial plantar nerve.

3. It provides articular branches to the tarsometatarsal, metatarso-phalangeal and interphalangeal joints.

4. Dorsal branches supply the region of the nail bed.

Lateral plantar nerve—It is the smaller terminal branch of tibial nerve and appears in the sole deep to the abductor hallucis accompanied by the lateral plantar artery on its lateral side (See Fig. 21.8).

![Fig. 21.8. Distribution of medial and lateral plantar nerves (Schematic).](image)

The trunk of the nerve passes forward and laterally to the base of the fifth metatarsal bone in between the first and second layers of muscles. This part supplies the flexor digitorum accessorius and abductor digiti minimi, and gives cutaneous branches to the lateral margin of the sole by piercing the plantar aponeurosis. On reaching the interval between the flexor digitorum brevis and abductor digiti minimi, the trunk divides into superficial and deep branches.

The superficial branch splits into two plantar digital nerves. The lateral branch supplies the skin of the lateral side of the little toe and gives motor branches to the flexor digiti minimi brevis and to the two interosseous muscles of the fourth intermetatarsal space. The medial branch subdivides into two branches to supply the skin of the adjacent sides between the fourth and little toes, and communicates with the nearest common plantar digital branch of the medial plantar nerve.
The **deep branch** passes forward and medially accompanied by the deep branch of lateral plantar artery beneath the oblique head of adductor hallucis, that means, between the third and fourth layers of muscles of the sole. The deep branch lies within the concavity of the plantar arterial arch, and supplies both heads of adductor hallucis, second to fourth lumbrical muscles and all dorsal and planter interossei muscles except those occupying the fourth intermetatarsal space. The branches to the second and occasionally third lumbricals pass forward deep to the transverse head of adductor hallucis, curl round its distal border to reach the muscles.

**Distribution**

1. Muscular branches—**From the trunk**, abductor digiti minimi and flexor digitorum accessorius; from the **superficial branch**, flexor digiti minimi brevis, third plantar and fourth dorsal interossei; from the **deep branch**, both heads of adductor hallucis, second to fourth lumbricals, dorsal and plantar interossei except those of the fourth interosseous space.

2. Cutaneous branches—Supply the lateral margin of the sole and lateral one and a half of the digits. Dorsal branches of plantar digital nerves also supply the region of the nail beds.

3. Articular branches—Supply the intertarsal, tarso-metatarsal, metatarso-phalangeal and inter-phalangeal joints.

**Arteries of the sole**

These are derived from the medial and lateral plantar arteries, which are the terminal branches of the posterior tibial artery. The division of the arteries takes place beneath the flexor retinaculum (Fig. 21.9).

**Medial plantar artery**—It is the smaller branch of posterior tibial artery, and appears in the sole deep to the abductor hallucis accompanied by the trunk of the medial plantar nerve on its lateral side. The artery provides muscular branches to abductor hallucis and flexor digitorum brevis, and on reaching the interval between them the artery presents a **superficial stem** which divides into the following branches:

   1. One branch passes distally along the medial border of great toe and anastomoses with a branch of first metatarsal artery.

   2. Rest of the superficial stem splits into three **superficial digital branches** which anastomose with the first to third plantar metatarsal arteries.

**Lateral plantar artery** (Fig. 21.10)—It is larger terminal branch of posterior tibial artery, and the arterial trunk passes forward and laterally between the first and second layers of muscles of the sole and accompanies the lateral (marginal) side of the trunk of lateral plantar nerve. The trunk of the artery supplies the adjacent muscles and provides cutaneous branches by piercing the lateral part of plantar aponeurosis. On reaching the base of the fifth metatarsal bone, the trunk divides into superficial and deep branches.

The **superficial branches** appear along the lateral intermuscular septum and supply the integuments of the lateral side of the sole and little toe. They provide anastomotic branches to join with the lateral tarsal and arcuate branches of dorsalis pedis artery.
The deep branch turns forward and medially as a continuation of the main trunk beneath the oblique head of adductor hallucis, and on reaching the gap between the two heads of first dorsal interosseous muscle anastomoses with the termination of dorsalis pedis artery, thus completing the plantar arterial arch (See Fig. 21.9).

The plantar arch is convex distally across the bases of fourth, third and second metatarsal bones and intervenes between the third and fourth layers of muscles of the sole.

Branches of plantar arch

1. Three proximal perforating arteries— These ascend dorsally through the gaps between the heads of second, third and fourth dorsal interosseous muscles, and anastomose with the corresponding dorsal metatarsal arteries.

2. Four plantar metatarsal arteries—They pass forwards in the intermetatarsal spaces in contact with the interossei, and in the clefts between the toes each divides into two plantar digital arteries to supply the adjacent sides of the toes. The first plantar metatarsal artery sends a branch to the medial side of the great toe. Close to the metatarsal heads each plantar metatarsal artery sends dorsally a distal perforating artery which anastomoses with the corresponding dorsal metatarsal artery.

Along with the proximal and distal perforating arteries corresponding perforating veins pass and drain the venous blood from the sole to the dorsal venous arch.

Special features of the sole:

1. Main neuro-vascular bundle along with long flexor tendons of the toes enter the sole beneath the flexor retinaculum. The interval between the flexor retinaculum and the calcaneus forms the main gate of the sole; hence called porta pedis.

2. The entry of the tendon of peroneus longus beneath the groove of the cuboid resembles the side gate of the sole.

3. Passage of the proximal and distal perforating vessels resembles the windows of the sole.
This region intervenes between the interosseous membrane and deep fascia of the leg, and is bounded medially by the extensor surface of the tibia and laterally by the extensor surface of fibula and anterior intermuscular septum.

Contents (Fig. 22.1):

1. Four extensor muscles, each of which is a pennate muscle. These are tibialis anterior, extensor digitorum longus, extensor hallucis longus and peroneus tertius. Each muscle, when traced below, is converted into a tendon and passes distally in front of ankle joint for terminal attachment on the dorsum of the foot. All muscles of the extensor compartment are supplied by the deep peroneal nerve.

To retain the tendons in position in front of the ankle joint, the deep fascia is thickened to form superior extensor retinaculum which is attached laterally to the lower part subcutaneous anterior border of fibula. Medially the retinaculum splits to enclose the tendon of tibialis anterior and is attached to the anterior border of tibia above the medial malleolus. Here the tibialis anterior possesses a synovial sheath which extends down to its insertion.

2. Anterior tibial vessels;
3. Deep peroneal nerve.

Muscles:

Tibialis anterior—It is a spindle-shaped multi-pennate muscle.

Origin: From the upper two-thirds of the lateral surface of the shaft of the tibia, the adjacent interosseous membrane and from the overlying deep fascia of the upper part of the leg.

Insertion: The muscle fibres converge below into a central tendon which pierces the superior extensor retinaculum where it is invested by a synovial sheath. On the dorsum of foot the tibialis anterior tendon and its sheath are embraced by the inferior extensor retinaculum, and the tendon is inserted into infero-medial side of the base of first metatarsal bone and the adjacent medial cuneiform bone. The pressure of the tendon makes the anterior border of tibia round.

Actions

1. It dorsi-flexes the foot at the ankle joint;
2. Maintains the medial longitudinal arch of foot, acting as a sling from above;
3. Acts as invertor of foot at the mid-tarsal and sub-talar joints.
Extensor digitorum longus

**Origin**: From the upper three-fourths of medial (extensor) surface of shaft of fibula and from a small area of lateral tibial condyle across the superior tibiofibular joint. It also arises from the interosseous membrane, anterior intermuscular septum and overlying deep fascia.

**Insertion**: Its fibres descend to form a tendon along its anterior border, and the tendon lies on the lower part of tibia beneath the superior extensor retinaculum. On the dorsum of foot the tendon passes within the loop of inferior extensor retinaculum and splits into four digital slips for insertion into lateral four toes. The digital tendons lie superficial to the extensor digitorum brevis.

Above the metatarso-phalangeal joints of second to fourth toes, the tendons of extensor digitorum longus join laterally with the lateral three digital slips of extensor digitorum brevis and form the dorsal digital expansion. The latter occupies the dorsal surface of the proximal phalanx, receives the attachments of lumbricals and interossei muscles. At the proximal interphalangeal joints each dorsal expansion trifurcates into a median and two collateral slips. The median slip is inserted into the base of the middle phalanx, and the collateral slips join for insertion into the base of the terminal phalanx.

**Action**: It acts as dorsiflexor of the ankle joint, and also dorsiflexes lateral four toes.

Extensor hallucis longus

**Origin**: It is a unipennate muscle and arises from middle two-fourths of the medial surface (extensor) of the shaft of fibula medial to the origin of extensor digitorum longus and also from the adjacent interosseous membrane.

**Insertion**: The tendon of the muscle emerges in the lower part of the leg between the tibialis anterior and extensor digitorum longus, and crosses in front of anterior tibial vessels and deep peroneal nerve from lateral to medial side.

The tendon passes beneath the superior extensor retinaculum and is embraced by the inferior extensor retinaculum. It runs forward along the medial side of the dorsum of foot and is inserted into the base of the terminal phalanx of great toe without forming dorsal digital expansion.

**Action**: It dorsiflexes the great toe and stretches the plantar aponeurosis around the puffy of the head of the metatarsal bone; thus it increases concavity of the medial longitudinal arch.

Peroneus tertius

**Origin**: From the lower one-fourth of the medial surface of the shaft of the fibula, as a continuation of the origin of extensor digitorum longus.

**Insertion**: The tendon passes downward beneath the superior extensor retinaculum and through the stem of inferior extensor retinaculum, and is inserted into the dorsal surface of the base of fifth metatarsal bone. It may be considered as the fifth tendon of the extensor digitorum longus.

**Action**: It is a dorsiflexor of the ankle joint and acts as a weak evertor of the foot.

**Structures passing beneath the superior extensor retinaculum and in front of the ankle joint are as follows** (medial to lateral):

Tibialis anterior, extensor hallucis longus, anterior tibial vein, artery and vein, deep peroneal nerve, extensor digitorum longus, peroneus tertius.

Anterior tibial artery

It is one of the terminal branches of popliteal artery and arises at the lower border of the popliteus. The artery passes forward between the two heads of tibialis posterior and through an oval gap above the interosseous membrane. It appears in the anterior crural region on the medial side of the neck of fibula and descends in front of the interosseous membrane accompanied by a pair of venae comitantes. In the lower part of the leg the artery rests on the lower end of tibia midway between the medial and lateral malleoli, and appears on the dorsum of the foot as dorsalis pedis artery (Fig. 22.2).

**Relations**

**Behind**: Interosseous membrane in the upper two-thirds, and lower end of tibia and ankle-joint in lower one-third.

**In front**: In upper two-thirds, covered by the adjoining muscles and deep fascia; in lower one-third, covered by deep fascia and extensor retinacula. Above the ankle joint, the artery is crossed superficially by the tendon of extensor hallucis longus from lateral to medial side.

**Medially**: Tibialis anterior,
Laterally—Extensor digitorum longus, peroneus tertius and deep peroneal nerve. The nerve lies although lateral to the artery, except in the middle third where it overlaps the front of the artery.

Branches:

1. Posterior tibial recurrent artery—It arises from the anterior tibial artery before the latter appears in the anterior crural region, and anastomoses with the genicular branches of popliteal artery.

2. Anterior tibial recurrent artery—It ascends through the tibialis anterior and anastomoses with the genicular branches of popliteal and circumflex fibular arteries.

3. Muscular branches—They supply the adjacent muscles and pierce the deep fascia to supply the skin.

4. Medial malleolar artery—It arises about 5 cm above the ankle joint, passes deep to the extensor hallucis longus and tibialis anterior tendons, and anastomoses with the branches of posterior tibial and medial plantar arteries.

5. Lateral malleolar artery—It passes deep to tendons of extensor digitorum longus and peroneus tertius, and anastomoses on the lateral side of the ankle with the perforating branches of posterior tibial and ascending branches of lateral tarsal artery.

Deep peroneal (anterior tibial) nerve—It arises from the bifurcation of common peroneal (lateral popliteal) nerve on the lateral side of the neck of fibula, and initially lies in the peroneal compartment beneath the peroneus longus. It spirals around the neck of fibula, pierces the anterior intermuscular septum and appears in the anterior crural region deep to the fibres of extensor digitorum longus in front of the interosseous
membrane and on the lateral side of the anterior tibial vessels.

The nerve descends through the leg down to the ankle joint and passes further distally beneath the extensor retinacula on the dorsum of foot where it divides into medial and lateral terminal branches (see the dorsum of foot).

In the proximal third of the leg it intervenes between the tibialis anterior and extensor digitorum longus, in the middle third between the tibialis anterior and extensor hallucis longus, and in the distal third the neuro-vascular bundle lies between the tendons of extensor hallucis longus and extensor digitorum longus. Throughout the leg the nerve lies lateral to the anterior tibial vessels, except in the middle third where the nerve lies in front of the vessels.

Branches:

Muscular branches to all muscles of the anterior crural region;

Articular branches to the ankle joint.

**Applied Anatomy**

1. **Anterior leg syndrome**—Excessive accumulation of tissue fluid in the anterior compartment of leg due to marked exertion produces the anterior leg syndrome. The increased fluid pressure is manifested by deep, aching pain in the anterior compartment of leg and this becomes more severe in dorsiflexion of foot. Venous return is diminished, arterial pulsation of the dorsalis pedis artery disappears and loss of cutaneous sensations may be noticed due to compression effect of the deep peroneal nerve.

A longitudinal incision through the deep fascia decompresses the area and relieves the symptoms.

2. **Shin splints**—Sometimes the athletes experience pain in front of the leg without swelling of the anterior compartment. It is believed to be caused by the stress fracture of the tibia.
Boundaries: The peroneal compartment is bounded medially by the peroneal surface of the fibula, laterally by the deep fascia, in front and behind respectively by the anterior and posterior intermuscular septa.

Contents (Fig. 23.1):

Muscles—Peroneus longus and peroneus brevis;

Artery—Peroneal branch of posterior tibial artery, which appears in this compartment after piercing the flexor hallucis longus and posterior intermuscular septum.

Veins—Mostly drain into the short saphenous vein.

Peroneus longus—It is a bipennate muscle in the upper part and unipennate in the lower part.

Origin: From the upper two-thirds of the peroneal surface of the fibula, from the adjacent surface of the lateral condyle of the tibia across the superior tibio-fibular joint, and from the adjoining intermuscular septa.

Insertion: The muscle converges below to form a long tendon which lies superficial to the tendon of peroneus brevis and lodges in a groove behind the lateral malleolus, being separated from the latter by the peroneus brevis tendon. Both tendons pass beneath the superior peroneal retinaculum and possess a common synovial sheath.

From the lateral malleolus the peroneus longus tendon passes downward and forward lodging in a separate groove below the peroneal trochlea of calcaneus under cover of inferior, peroneal retinaculum, where it receives a separate synovial sheath.

On reaching the lateral side of the cuboid bone, the peroneus longus tendon changes direction for the second time and turns forward and medially across the sole lodging in an osseo-fibrous tunnel on the plantar surface of the cuboid with an envelope of synovial sheath. Finally the tendon is inserted into the infero-lateral surface of the base of first metatarsal bone and the adjacent medial cuneiform bones. Sometimes a sesamoid fibro-cartilage develops in the peroneus longus tendon on the cuboid bone.

Nerve supply—From the superficial peroneal nerve;

Actions

1. It acts as evertor of the foot; on prolonged action it is a plantar flexor of the foot;
2. It maintains the lateral longitudinal arch of foot by acting as a sling from above;
3. It maintains the transverse arch of foot.

**Peroneus brevis**

**Origin**: It is a bipennate muscle and arises from the lower two-thirds of the peroneal surface of fibula and from the adjoining intermuscular septa. In the middle third of fibula its origin lies in front of peroneus longus.

**Insertion**: The tendon lodges in a groove behind the lateral malleolus in close contact with the bone, and in company with the peroneus longus tendon on its dorsal side passes beneath the superior peroneal retinaculum enveloped by a common synovial sheath.

The lateral malleolus acts as a pulley around which the peroneus brevis tendon passes downward and forward, lodges in a groove above the peroneal trochlea of calcaneus under cover of inferior peroneal retinaculum and finally is inserted into a tubercle at the base of the fifth metatarsal bone.

**Nerve supply**: From the superficial peroneal nerve;

**Actions**: It acts as evertor of foot, and maintains the lateral longitudinal arch.

**Superior peroneal retinaculum**—It is a fibrous band derived from the deep fascia of leg and extends from the lateral malleolus to the calcaneus. It plasters the tendons of peroneus longus and brevis in contact with the lateral malleolus of fibula.

**Inferior peroneal retinaculum**—It is attached to the peroneal trochlea and to the calcaneus above and below the peroneal tendons.

The tendons of peroneus longus and brevis possess a common synovial sheath from the lateral malleolus to the peroneal trochlea; thereafter the sheath divides to enclose each tendon separately up to its insertion.

**Superficial peroneal (musculo-cutaneous) nerve**—It arises from the superficial division of common peroneal nerve on the lateral side of the neck of fibula and lies initially deep to the peroneus longus. The nerve passes downward between peroneus longus and brevis, supplies both muscles, and pierces deep fascia behind the anterior intermuscular septum at the junction between the upper two-thirds and the lower third of leg.

In the superficial fascia the nerve supplies the skin of the lower part of leg, and divides into medial and lateral branches to supply most of the skin of the dorsum of foot (See dorsum of the foot).
Skin and superficial fascia—The subcutaneous layer of dorsum of foot contains little fat, and hence superficial veins and dorsal venous arch are easily seen in most of the people. The superficial fascia also contains the cutaneous nerves and superficial lymphatics.

Cutaneous innervation—The skin of the dorsum is supplied by four sets of nerves (Fig. 24.1-a,b):

1. Most of the dorsum is supplied by the superficial peroneal (musculo-cutaneous) nerve, which pierces the deep fascia of the front of leg in the lower third, divides into medial and lateral branches above the ankle joint and appears on the dorsum of foot. The medial division subdivides into branches which supply the medial side of the great toe, and the adjacent sides of the second and third toes. The lateral division subdivides into branches to supply the clefts between the third and fourth toes, and the fourth and fifth toes.

2. The cleft between the great and second toes is supplied by the medial terminal branches of deep peroneal (anterior tibial) nerve.

3. The lateral margin of the dorsum including that of the little toe is supplied by the sural nerve.

4. The medial margin of the dorsum up to the head of first metatarsal bone is supplied by the saphenous nerve.

Dorsal venous arch—Typically, the dorsal venous arch describes a convex curve directed distally, across the proximal parts of the metatarsal bones and is formed by the union of four dorsal metatarsal veins. Each dorsal metatarsal vein receives blood in the clefts between the toes from the dorsal digital veins, and through the proximal and distal perforating veins conveys most of the blood from the plantar surface of foot.

Great (long) saphenous vein begins from the medial end of dorsal venous arch and is supplemented by the medial marginal vein draining blood from the sole. Small (short)
Superficial lymphatics of the dorsum

1. Most of the lymphatics of the dorsum including those of medial four toes accompany the great saphenous vein and drain into the vertical set of superficial inguinal lymph nodes.

2. The lymphatics from the little toe and the lateral margin of the dorsum accompany the small saphenous vein and drain into the popliteal lymph nodes.

Deep fascia—On the dorsum of foot the deep fascia is thin and continuous at the margins with the plantar aponeurosis. Proximally the deep fascia is thickened to form inferior extensor retinaculum which keeps the extensor tendons in position as they pass in front of the ankle joint.

Inferior extensor retinaculum (Fig. 24.2)—It forms a Y-shaped band in front of the ankle. The stem of the Y is attached to the anterior part of the upper surface of the calcaneus, anterior to the sulcus calcanei. The fibres of the retinaculum loop medially around the tendons of peroneus tertius and extensor digitorum longus, and return to the sulcus calcanei. The stem splits into upper and lower limbs. The upper limb is attached to the tibial malleolus and loops around the tendons of extensor hallucis longus and tibialis anterior. The lower limb arches medially over the tendons of the dorsum and blends with the plantar aponeurosis.

The inferior extensor retinaculum prevents the tendons from bow-stringing forward and medially. All the extensor tendons are enclosed in synovial sheaths as they pass through the retinaculum.

Structures beneath the deep fascia:

(A) Extrinsic tendons of muscles from the anterior crural region: tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius (see the anterior crural region).

(B) Intrinsic muscle of the dorsum of the foot, extensor digitorum brevis:

Extensor digitorum brevis

Origin: The fleshy belly arises from the anterior part of the upper surface of the calcaneus and from the stem of inferior extensor retinaculum.

Insertion: It passes forward and medially deep to the tendons of peroneus tertius and extensor digitorum longus, and splits into four tendons for insertion into medial four toes. The most medial tendon is known as extensor hallucis brevis and is inserted separately into the base of the proximal phalanx of the great toe. The remaining three tendons join with the dorsal digital expansion of the second, third and fourth toes, and finally are inserted into the dorsal surface of the bases of middle and terminal phalanges.

Nerve supply—It is supplied by a pseudo-ganglion from the lateral terminal branch of deep peroneal nerve.

Action—It dorsiflexes the medial four toes in dorsiflexed position of the ankle joint, just before take off of the foot in walking or running.

(C) Dorsalis pedis artery—It begins as a continuation of anterior tibial artery distal to the ankle, and passes forward along the medial side of the dorsum to the gap between the two heads of the first dorsal interosseous muscle. Here the artery enters the sole and forms the plantar arch by joining with the deep branch of lateral plantar artery (Fig. 24.3).

Relations:

Below—The artery rests successively on the capsule of ankle joint, talus, navicular and intermediate cuneiform bones.

Above—Covered by skin, superficial and deep fasciae and is crossed close to its termination by the tendon of extensor hallucis brevis.

Medially—Tendon of extensor hallucis longus;

Laterally—Medial terminal branch of deep peroneal nerve, and digital tendon of extensor digitorum longus for the second toe.

Fig. 24.2. Extensor and peroneal retinacula.
Branches

Lateral tarsal, medial tarsal, arcuate and first dorsal metatarsal arteries:

Lateral tarsal artery—It arises from the dorsalis pedis artery opposite the navicular bone, passes laterally beneath the extensor digitorum brevis and forms a lateral malleolar network by anastomosing with the arcuate, lateral malleolar branch of anterior tibial, lateral plantar and perforating branches of the peroneal arteries (Fig. 24.4-b).

Medial tarsal arteries—These are two or three in number, and form a medial malleolar network by anastomosing with medial malleolar branch of anterior tibial, medial plantar, malleolar and calcanean branches of posterior tibial arteries (Fig. 24.4 a-b).

Arcuate artery—It arises opposite the intermediate cuneiform bone, passes laterally across the bases of metatarsal bones deep to the extensor tendons and anastomoses with the lateral tarsal and branches of lateral plantar arteries. It describes a curve with the convexity in front and gives off second to fourth dorsal metatarsal arteries. Each dorsal metatarsal artery proceeds distally on the corresponding dorsal interosseous muscle and in the cleft between the toes divides into dorsal digital arteries. Along the course dorsal metatarsal arteries anastomose with the plantar arch by three proximal perforating arteries, and with the corresponding plantar metatarsal arteries by four distal perforating arteries.

First dorsal metatarsal artery—It arises from the dorsalis pedis artery just before the latter
enters the sole, and extends forward in the cleft between the great and second toes to divide into dorsal digital arteries. En route it provides a branch to the medial side of the great toe.

(D) Terminal branches of deep peroneal nerve—Deep peroneal nerve reaches the dorsum of the foot beneath the extensor retinacula, accompanies the lateral side of the dorsalis pedis artery and intervenes between the tendon of extensor hallucis longus and first tendon of extensor digitorum longus. On its way the nerve divides into lateral and medial terminal branches (Fig. 24.3).

The lateral terminal branch passes laterally deep to the extensor digitorum brevis and forms a pseudo-ganglion through which it supplies the overlying muscle and divides distally into three interosseous branches to supply tarsal and metatarso-phalangeal joints of middle three toes; the first branch gives a twig to the second dorsal interosseous muscle.

The medial terminal branch passes forward lateral to the dorsalis pedis artery, provides twigs to the first dorsal interosseous muscle and first metatarso-phalangeal joint, and pierces the deep fascia to supply the skin of the adjacent sides of great and second toes.
HIP JOINT

The hip joint is a multi-axial ball and socket type of synovial joint.

Bones forming the joint—The ball is represented by the head of femur which is spheroidal with some flattening of its upper surface and resembles about two-third of a sphere. The head of femur is articular except a pit or fovea close to its centre, which gives attachment to the ligament of head of femur. The articular surface is covered with hyaline cartilage which is thickest in the centre and thinner at the periphery; the cartilage extends to cover a small area on the anterior surface of the neck of femur. The head is connected to the shaft of femur by an elongated neck, which is directed upward, medially and some what forward. The neck-shaft angle in adult it about 125°, and in a child about 160°. The forward tilt of head and neck is about 12°-15° in adult, and 35° in a new born. The neck-shaft angle deter-mines the range of mobility of hip joint.

Fig. 25.1. A coronal section through right hip joint.

The socket is formed by a cup-shaped depression, the acetabulum of hip bone, where ilium, ischium and pubis meet, separated by a triradiate Y-shaped cartilage. The cartilage starts ossification after 12th year, and by 20th year ossification is complete. The acetabulum is surrounded by a margin except below where it presents a notch. The acetabular margin gives attachment to a fibro-cartilaginous rim, the labrum, which deepens the socket; the acetabular notch gives attachment to transverse acetabular ligament and the base of the ligament of head of femur. The gap between the bony notch and the transverse ligament transmit the acetabular branches of obturator and medial circumflex femoral vessels. The acetabulum presents a horse-shoe shaped articular surface, the lunate surface, which involves anterior, posterior and upper parts of the socket. The thickest part of the articular surface is postero-superior which acts as a shelf-like buttress in standing. Such buttress develops in the 2nd month of intrauterine life; a failure of development of the shelf produces congenital dislocation of hip joint, which affects preferentially the females. The floor of the acetabulum is non-articular and forms acetabular fossa which is filled with a cushion of fibro-fatty tissue. The acetabular fat is covered with synovial membrane; so it is intracapsular but extra-synovial. The acetabular fat also known as the Haversian fat is in liquid condition at body temperature; it fills up the vacuum in case the joint space tends to increase during any movement.

Ligaments of the joint:

1. Capsular ligament with synovial membrane;
2. Acetabular labrum and transverse acetabular ligament;
3. Ligament of the head of femur;

Capsular ligament (Fig. 25.1):

It envelops the joint; the fibres are spirally arranged and taut in extension, and unspiralled
and relaxed during flexion. **Attachments**—
Proximally, the capsule is attached close to the acetabular margin extending about 5 to 6 mm above the labrum, and blends with the anterior surface of the labrum in front and with the transverse acetabular ligament below.

Distally, it covers the anterior surface of the femoral neck completely and is attached along the intertrochanteric line. Above and below the neck, the capsule is attached close to the root of greater trochanter and a little above and in front of the lesser trochanter respectively. The capsule covers the medial part of the posterior surface of the neck and fits like a tight collar along a line which lies about 1 cm medial to and parallel with the trochanteric crest. Between collar-like fitting of the capsule and the femoral neck intervenes a space through which synovial membrane of the joint comes out to act as a bursa for obturator externus tendon. From the intertrochanteric line, a few fibres of the capsule are reflected upward and medially along the neck and beneath the synovial membrane as retinacular fibres. These fibres convey blood vessels to the neck and head of femur. In intra-capsular fracture of the neck the blood vessels may be interrupted and this culminates into non-union of fracture.

The deep fibres of the fibrous capsule are circularly arranged and form **zona orbicularis** which produces an hour-glass constriction around the neck. Some of the spiral fibres of ischio-femoral ligament are continuous with the zona orbicularis.

Infero-medial part of the fibrous capsule is **weakest** and this part may be stretched in abduction. Therefore, when the hip joint is forcefully hyper-abducted, femoral head may be dislocated from its socket after tearing the capsule.

**Synovial membrane (See Fig. 25.1):**
It lines the inner surface of the fibrous capsule, both surfaces of the acetabular labrum and the intra-capsular part of the neck of femur, but it ceases at the periphery of articular cartilage. The synovial membrane invests the ligament of the head of femur as a flattened cone and is attached to the femoral head at the peripheral margin of the fovea. Traced towards the transverse acetabular ligament, the layers of the membrane diverge: inferior layer covers the fibrous capsule, and superior layer covers the acetabular fat.

Sometimes the synovial membrane comes out through an oval gap on the anterior surface of the capsule between the pubo-femoral and ilio-femoral ligaments and acts as a bursa for the psoas major tendon.

**Acetabular labrum:**
It is a fibro-cartilaginous rim attached to the acetabular margin and is triangular on cross-section. The labrum not only deepens the socket, but grasps the femoral head tightly beyond the equator. When the fibrous capsule is disconnected, the labrum retains the head in position. In traumatic posterior dislocation of hip joint the free margin of the labrum may be out-turned or inturned; in the latter condition surgical correction of dislocation creates difficulty.

**Transverse acetabular ligament:**
It extends across the acetabular notch and blends with the base of ligament of head of femur and the lower part of fibrous capsule. It represents a part of the labrum without cartilage cells.

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**Fig. 25.2. Head of femur, seen from the acetabular cavity with attachment of the ligament of head of femur (Schematic).**

**Ligament of the head of femur (Ligamentum teres femoris)**
It is a triangular fibrous band ensheathed by a conical reflexion of synovial membrane. The apex is attached to the fovea of the femoral head, and its base is attached to the two ends of the acetabular notch and blends with the transverse acetabular ligament (Fig. 25.2). The ligamentum
teres is stretched in adduction of semiflexed hip, and is relaxed in abduction.

The ligament does not increase the stability of the joint. The function of the ligament, if any, is to convey blood vessels to the head of femur (Fig. 25.3). In elephant and rhinoceros the ligamentum teres is absent.

**Ilio-femoral ligament** (Ligament of Bigelow):

It is one of the strongest ligament, strengthens the anterior part of the fibrous capsule and is triangular or inverted Y-shaped. The apex or stem is attached to the anterior inferior iliac spine, and its base diverges below as medial and lateral bands. The medial band is vertical and attached to the lower part of intertrochanteric line; the lateral band is oblique and attached to a tubercle in the upper part of intertrochanteric line (Fig. 25.4). The intermediate stratum is thin and attached to the rest of line; it is usually pierced by the ascending branch of lateral circumflex femoral artery.

In erect posture the line of gravity passes slightly behind the centres of both femoral heads. In order to prevent the natural tendency of backward tilting of the pelvis at the hip joints, the anterior part of the capsule is made strong by the intervention of the strongest ilio-femoral ligament. The tension of the ligament prevents hyper-extension of the hip joint. Intact ilio-femoral ligament in dislocated hip acts as a fulcrum to set the femoral head in acetabular socket.

![Fig. 25.3. Interior of acetabulum.](image)

**Pubo-femoral ligament**:

It is triangular and covers the infero-medial part of the capsule. It is attached close to the acetabular margin to the ilio-pubic eminence and obturator crest, and blends with the capsule deep to the medial band of ilio-femoral ligament. Sometimes the capsule presents an oval gap between the pubo-femoral and medial band of ilio-femoral ligaments. The psoas bursa communicates with the joint through the gap.

**Ischio-femoral ligament** (Fig. 25.5):

It is attached to the ischium close to the acetabular margin. The fibres pass spirally upward and laterally behind the neck of femur; most of the fibres are continuous with the zona orbicularis.

**Movements and mechanism**:

Active movements permitted at the hip joint are flexion and extension, adduction and abduction, circumduction, medial and lateral rotation.

Flexion and extension take place around the axis of the neck of femur (more or less a transverse axis) which passes through the centre of femoral head. Such axis coincides with the mechanical axis of the hip joint and hence the movement of neck is in the form of a ‘spin’. But due to neck-shaft angle, distal end of femur swings forward in flexion or backward in extension. **Flexion** of hip with extended knee joint is limited to about 90°—100° due to tension of hamstring muscles, but the range
of flexion is increased to about 120° when the knee is flexed; passive flexion of hip until the thigh meets the abdomen is associated with some degree of flexion of the vertebral column. Flexion makes the joint loose-packed and the capsule is relaxed.

With the foot on the ground, medial rotation allows the medial femoral condyle to rotate backward and simultaneously permits the greater trochanter to rotate forward around the aforesaid vertical axis. Reverse movements occur in lateral rotation.

Muscles producing movements:

**Flexion**—Ilio-psoas act as prime mover; lateral part of pectineus, rectus femoris and sartorius assist the movement. Adductor longus comes into play in the initial phase.

**Extension**—Gluteus maximus and hamstring muscles; gluteus maximus contracts when the movement takes place against resistance, that means, in raising the trunk from sitting position or in climbing upstairs. Hamstring muscles maintain extension in normal standing and walking.

**Adduction**—Adductor longus, brevis and non-ischial part of adductor magnus; this is assisted by medial part of pectineus and gracilis.

**Abduction**—Anterior part of gluteus medius and minimus, tensor fasciae latae and sartorius.

**Medial rotation**—This is mainly done by the anterior fibres of gluteus medius and minimus, and tensor fasciae latae. Abductors, as a rule, act as medial rotators; they not only prevent dropping of the pelvis on the unsupported side, but increase forward stride during locomotion by medial rotation.

Psoas major acts as a medial rotator when the foot is on the ground because its insertion lies lateral to the axis of rotation. But when the foot is off the ground it may act as a lateral rotator due to the shifting of the axis.

Electromyographic studies reveal that the adductors act as medial rotators, and contradict the static anatomical view.

**Lateral rotation**—Gluteus maximus acts as a strong lateral rotator. Muscles under cover of gluteus maximus, such as, piriformis, obturator internus et externus, gemelli and quadratus femoris are lateral rotators.

Relations of hip joint

In front: Lateral part of pectineus, psoas major, iliacus and straight head of rectus femoris; trunk of the femoral nerve in the groove between iliacus

![Ischio femoral ligament](image)

**Synovial membrane projects behind the femoral neck and acts as a bursa for obturator externus**

Fig. 25.5. Hip joint (from behind).
and psoas major, femoral artery in front of psoas tendon, and femoral vein in front of pectineus (Fig. 25.6).

**Behind**: Piriformis, obturator externus and internus, gemelli, quadratus femoris and gluteus maximus; superior gluteal vessels and nerve above the piriformis; sciatic nerve, posterior femoral cutaneous nerve, nerve to quadratus femoris, inferior gluteal vessels and nerve below the piriformis.

**Above**: Reflected head of rectus femoris in the medial part and gluteus minimus in the lateral part.

**Below**: Pectineus and obturator externus.

**Arterial supply**

Hip joint is supplied by branches from medial and lateral circumflex femoral, obturator, superior and inferior gluteal arteries.

The intracapsular neck and head receive blood supply from **three main sources**:

1. Acetabular branch from obturator artery enters through the gap between the acetabular notch and transverse acetabular ligament. It supplies the acetabular fat and provides a branch, **medial epiphyseal artery**, which accompanies ligamentum teres and supplies a variable area of femoral head (See Fig. 25.3).

2. Several branches derived mainly from the medial circumflex femoral artery pierce the capsule and accompany beneath the synovial membrane along the retinacular fibres and supply the superior aspect of the neck. A few terminal branches enter the head proximal to the epiphyseal cartilage and supply upper and lateral part of the head as the **lateral epiphyseal arteries**.

3. Some of the branches of medial circumflex femoral artery accompany the retinacular fibres along the infero-medial aspect of the neck, and supply the lower or metaphyseal part of the head of femur.

The epiphyseal arteries of the femoral head anastomose with one another, and after disappearance of epiphyseal cartilage establish some communications with the diaphyseal arteries of the proximal end of femur. The lateral epiphyseal arteries are predominant; in adduction fracture of the femoral neck these arteries may be interrupted producing greater incidence of necrosis of the femoral head.

**Nerve supply**

Hip joint is supplied by femoral nerve via nerve to the rectus femoris, a branch from anterior division of obturator nerve, accessory obturator
nerve if present, a branch from nerve to quadratus femoris, occasionally a twig from sciatic nerve, and a branch from superior gluteal nerve.

Infero-medial part of the capsule which is rendered taut by the abductors, is supplied by the obturator nerve, which supplies the adductors, and thereby the capsule is protected.

Four consecutive spinal cord segments (L₂, L₃, L₄, L₅) control hip movements. While L₂ and L₃ segments regulate flexion, adduction and medial rotation, L₄ and L₅ segments regulate extension, abduction and lateral rotation.

Applied anatomy

The head of femur is ossified from a secondary centre which usually appears during the first year; the neck of femur is an extension of diaphysis and is ossified from a primary centre in the 7th week of intra-uterine life. The epiphyseal cartilage between the head and neck lies at first in a horizontal plane, but later it inclines downward and medially although it does not conform exactly to the margins of the articular surface of the femoral head. Eventually the lower part of the head is metaphyseal and the supero-medial part of the neck is epiphyseal. Therefore, the projections of diaphyseal spur acts as a ledge on which the epiphysis can rest. Delayed formation of the effective spur makes the neck weak so that it gradually bends producing coxa vara.

In Perthe's disease the femoral head undergoes avascular necrosis in childhood, possibly resulting from trauma.

Coxa vara is a condition when neck-shaft angle is diminished. This may result from Perthe's disease, softening of the neck due to rickets or delayed formation of the diaphyseal spur. Coxa vara produces interference of action of gluteus medius with dropping of the pelvis on the unsupported side, and marked limitation of abduction due to early impingement of greater trochanter on the ilium.

Congenital dislocation of hip occurs mostly in girls. This is due to the fact that the lateral wall of the pelvis is more vertical, acetabular cavity is shallow and the shelf-like buttress of the upper part of the acetabulum is poorly developed. As a result femoral head is dislocated towards the gluteal surface of ilium, neck-shaft angle is exaggerated producing coxa valga and adduction movement is limited.

In tuberculous disease of the hip joint the primary focus is mostly situated in a small triangular area known as Babcock's triangle which involves the inferior surface of the neck of femur close to the epiphyseal cartilage of the head.

Fracture of the neck of femur may take place through the proximal narrow part or the distal broad part along the trochanteric line. Subcapital fracture commonly occurs in elderly persons due to indirect violence of trivial nature. The fracture is entirely intracapsular and if the fractured ends are impacted, inspite of slight shortening of the lower limb, bony union will take place and no special treatment is called for. In most cases, however, the fragments are completely separated and the affected limb is much shortened and rotated laterally by the contraction of gluteus maximus and other lateral rotators. Reduction of the fracture is best secured by traction to overcome the shortening, by wide abduction to bring the fragments in line, followed by strong medial rotation to bring the fractured surfaces into apposition. Even after accurate reduction, non-union of the capital fragment is occasionally observed in old people due to avascular necrosis. Fracture through the distal part of the neck is more common in adults who might be exposed to severe trauma on the greater trochanter. Such fracture unites without difficulty.

Since the hip joint is not easily examined due to its depth from the surface surrounded by thick muscles, certain lines are employed to estimate the relative position of the bony parts around the joint.

1. Nelaton's line is drawn by joining the anterior superior iliac spine and the ischial tuberosity; it passes through the highest part of the greater trochanter. If the greater trochanter is found to lie above or below that line, some deformity of femoral neck or dislocation of hip joint is suspected. Localisation of ischial tuberosity is difficult in stout persons; hence the value of this line becomes less.

2. Bryant's line is measured as a vertical distance between the highest point of greater
trochanter and a horizontal line passing through the anterior superior iliac spines. Normally the distance is about 5 cm. A departure from the normal indicates deformity, unilateral or bilateral.

3. Shenton's line—In a radiograph of the hip region, the Shenton's line is represented by a curve where the upper border of the obturator foramen is normally continuous with the lower margin of the neck of femur.

KNEEJOINT

The knee joint is formed by the condyles of femur and tibia, and posterior articular surface of the patella. It is a compound and complex synovial joint. In fact, the knee joint is a combination of three primitive joint cavities—femoro-patellar, and medial and lateral condylar. The condylar articulations, between the respective medial and lateral condyles of femur and tibia, are subdivided incompletely by the menisci or semilunar cartilages.

Condylar articulations are primitively separated from each other by a sagittally oriented intercondylar septum, which is subsequently divided by an intercondylar foramen into a short anterior segment and a long posterior segment. The anterior segment persists as infra-patellar synovial fold, and the posterior segment of the septum gives rise to the development of anterior and posterior cruciate ligaments of knee joint. The femoro-patellar joint communicates with each condylar joint through a semilunar space between the femoral condyle and free lateral margins (alar folds) of infra-patellar fold.

Functionally, the knee joint is a condylar and modified hinge-joint. It is a modified hinge-joint because of two reasons:

(i) Transverse axis of movement is not fixed, and moves forward during extension and translates backward in flexion;

(ii) Along with extension and flexion, there is a conjunct rotation of femur on tibia (and vice versa) around a more or less vertical axis.

Bones forming the joint

Condyles of femur

Both medial and lateral condyles of femur bulge backwards and are separated from each other by the intercondylar notch. Posterior, inferior and anterior surfaces of each condyle possess a continuous articular surface, which is more convex in the posterior part. Anterior surface of both condyles form a patellar articular surface, which is saddle shaped and concave from side to side, but convex from above downwards. Patellar surface of the femur articulates with the posterior articular surface of the patella. Patellar surface extends much higher over the lateral femoral condyle. Rest of the articular surface of both femoral condyles is known as the tibial surface, which articulates with the upper surface of the respective tibial condyles and their menisci. The patellar surface of femur, however, extends to

![Diagram of knee joint](image-url)

Fig. 25.7. Flexed knee, viewed from the front (After division of the quadriceps and downward reflection of patella).
the undersurface of the medial femoral condyle in a **semilunar impression** close to the intercondylar notch; the most medial articular facet of patella comes in contact with this impression of femur during full flexion of knee joint (Fig. 25.7). Viewed in lateral profile, tibial articular surface of each femoral condyle accommodates the arcs of numerous circles with different radii. When the centres of all circles are joined a curved line is formed which is known as the **evolute of the profile**. The transverse axis of the knee joint changes from moment to moment during extension and flexion along the evolute (Fig. 25.8).

**Fig. 25.8. Evolute of the profile of femoral condyle.**

The lateral condyle of femur is more massive than the medial condyle, because most of the body weight is transmitted from the hip to knee joints through the lateral condyle. However, the medial condyle bulges more medially than the outward bulging of the lateral condyle. Summit of the medial convexity of the medial femoral condyle is known as the **medial epicondyle** which gives attachment to the upper end of tibial collateral ligament. Maximum convexity of the lateral surface of lateral femoral condyle is known as the **lateral epicondyle** which provides the upper attachment to the fibular collateral ligament. Below the lateral epicondyle, there lies a curved groove which is intra-capsular; lower and anterior part of the groove gives origin to the popliteus muscle, but upper and posterior part of the same groove is occupied by the tendon of popliteus during flexion of the knee joint.

The lateral wall of the intercondylar notch of the femur receives the upper attachment of the anterior cruciate ligament in the postero-superior part. The medial wall of the intercondylar notch gives attachment to the upper end of the posterior cruciate ligament in the antero-inferior part. Lower margin of the anterior part of intercondylar notch gives attachment to the apex of infrapatellar synovial fold; upper margin of the notch provides attachment to the capsular ligament and oblique popliteal ligament of knee joint. On close inspection, a **subsidiary notch** is observed in the lateral part of lower margin of the intercondylar notch; it lodges the anterior surface of the stretched anterior cruciate ligament at the end of the extension of knee joint. (See Fig. 15.11).

In anatomical position, lower surfaces of both femoral condyles assume a horizontal position and articulate with the corresponding condyles of the tibia and their menisci. Therefore, in adults the long axes of femur and tibia meet each other forming an angle of about 170°, which is open laterally.

**Condyles of tibia**—The upper articular surfaces of both medial and lateral condyles of tibia are concave, but much shallower than the corresponding condyles of femur. However, the tibial concavity is somewhat deepened by the medial and lateral menisci, which occupy the peripheral two-thirds of both condyles. The articular surface of the medial condyle is ovoid and that of the lateral condyle is circular in outline; medial condylar surface is longer antero-posteriorly than its lateral counter part. The posterior margin of articular surface of lateral condyle is grooved for the tendon of popliteus.

An **intercondylar area** intervenes between the articular surfaces of both condyles. This area is wide in front and behind, but constricted in the middle which is occupied by the intercondylar eminence presenting medial and lateral tubercles. The anterior part of the intercondylar area gives attachment from before backwards to anterior horn of the medial meniscus, lower attachment of anterior cruciate ligament and anterior horn of the lateral meniscus. The posterior part of the area provides attachment to the following from before backwards: posterior horn of the lateral meniscus, posterior horn of the medial meniscus and lower attachment of the posterior cruciate ligament (See Fig. 15.18).

The posterior surface of the medial condyle of tibia presents an extra-capsular transverse groove for the attachment of semimembranosus. Postero-laterally, the lateral condyle presents an articular facet for articulation with the head of fibula forming a plane synovial superior tibio-fibular joint. Anterior surface of the lateral condyle presents a triangular flattened area for the
attachment of the ilio-tibial tract. Anterior surface of both condyles is triangular with the apex directed below and formed by the upper part of the tubercle of tibia, where ligamentum patellae is attached; medial and lateral patellar retinacula are attached to the respective margins of the triangle.

Articular surface of patella—Posterior surface of the patella is mostly articular, except close to the apex where ligamentum patellae is attached. The articular surface comes in contact with the patellar surface of femur. The articular surface is primarily divided into a large lateral and a small medial area by a vertical ridge which fits into the corresponding groove of the patellar surface of femur. The medial area presents most medially a narrow strip separated by a faint vertical ridge. Lateral and medial areas are further subdivided by two faint horizontal lines into lower two, middle two and upper two facets. Therefore, altogether seven facets are present on the articular surface.

The articular facets come in contact with the femur in different movements of knee joint in the following manner: lower two facets in ordinary extension, middle two facets in semi-flexion, upper two facets in ordinary flexion, and undivided medial-most facet (seventh facet) occupies a semilunar area on the undersurface of the medial femoral condyle in full flexion (See Fig. 15.15). In full extension of knee, the patella remains free from the femur and can be moved from side to side by manipulation.

The patella is a sesamoid bone and is ossified usually from a single centre in the tendon of quadriceps femoris in the third year of post-natal life. Being a sesamoid bone, it is devoid of periosteum. Hence, when fractured bony union does not take place.

During extension of knee, the patella moves upward and laterally due to obliquity of the shaft of femur. The natural tendency of lateral displacement of patella is prevented by two factors (bony and muscular):

1. Raised lateral margin of the patellar articular surface of femur;
2. Insertion of vastus medialis along the medial margin of patella extends more below than the corresponding insertion of vastus lateralis to its lateral margin. Contraction of vastus medialis from the medial side, therefore, prevents lateral displacements of patella.

3. Clinically, the Q-angle is represented by the intersection of a line drawn from the anterior superior iliac spine to the centre of patella and another line extending upward from the tibial tuberosity through the centre of patella. When the angle is greater than 15°, the quadriceps pull increases the forces for lateral displacement of patella.

Functions of the patella

1. Patella protects the knee joint from the front, but it is not essential for the movements of the joint.
2. It hinders the beginning of extension from extreme flexion, because it is sandwiched between the advancing condyles of femur and tibia.
3. Patella, however, facilitates the end of extension by keeping the ligamentum patellae away from the transverse axis of the joint and increases the momentum of the quadriceps pull.

Ligaments of knee joint

1. Capsular ligament with synovial membrane;
2. Ligamentum patellae;
3. Tibial and fibular collateral ligaments;
4. Oblique popliteal and arcuate ligaments;
5. Anterior and posterior cruciate ligaments;
6. Coronary ligaments, transverse ligament and menisco-femoral ligaments;
7. Medial and lateral menisci (semilunar cartilages).

Capsular ligament—It envelops the joint, but deficient above the patella where it is pierced by the suprapatellar bursa and behind the lateral condyle of tibia where it is pierced by the tendon of popliteus and its accompanying bursa. The capsule is strengthened posteriorly by the oblique popliteal ligament, medially by the tibial collateral ligament, anteromedially by the medial patellar retinaculum, antero-laterally by the lateral patellar retinaculum and the ilio-tibial tract. The fibrous capsule is attached in front to the peripheral margins of the patella and blends with ligamentum patellae. The fibular collateral ligament, however, is separated from the lateral side of the capsule by an interval which is occupied by the tendon of popliteus. Inner surface of the fibrous capsule provides attachment to the peripheral margins of both medial and lateral menisci.

Upper attachment of the capsule—Posteriorly, it is attached to the upper margin of intercondylar notch and close to the articular margins of medial and lateral femoral condyles.
Medial attachment is represented by a continuous line along the medial surface of medial condyles about 1 cm above and parallel with the articular margin. Laterally, it is attached along the lateral surface of lateral condyle about 1 cm above the articular margin so that the line of attachment includes the origin of popliteus but excludes the origin of the lateral head of gastrocnemius (See Fig. 15.12). Above the patellar articular surface of femur, the capsule is deficient for communication with supra-patellar bursa.

*Lower attachment of the capsule*—It is attached posteriorly to the posterior margin of intercondylar area of tibia and the adjoining articular margins of medial and lateral condyles; behind the lateral condyle, however, the capsule is deficient for the passage of tendon of popliteus. On both sides the capsule is attached to the corresponding tibial condyles close to the articular margins. In front it is attached to the two sides of triangular surface of the tibia blending with medial and lateral patellar retinaculum and to the tubercle of tibia where it blends with the ligamentum patellae.

The *synovial membrane* lines the inner surface of the fibrous capsule and the portion of the bones within the capsule, but it ceases at the periphery of the articular artilages, medial and lateral menisci (Fig. 25.9, 25.10). Traced above, from the upper margin of patella it is continuous with the supra-patellar bursa, which is synovial pouch intervening between the quadriceps femoris muscle and the anterior surface of lower part of the shaft of femur above the patellar articular surface. The apex of the bursa is kept in position by the attachment of *articularis genu* muscle.

![Fig. 25.9. Inter-condylar septum and its foramen (Schematic).](image)

A triangular fold of synovial membrane, the *infra-patellar fold*, extends upward and backward and intervenes between the femoro-patellar and both condylar parts of the knee joint. The apex of the fold is attached to the lower margin of the intercondylar notch of femur. Its base is directed towards the ligamentum patellae and extends from the apex of patella to the anterior part of intercondylar area of the tibia; some fibro-fatty tissue enters the fold through the base. The lateral margins of the infra-patellar fold are free and form

![Fig. 25.10. Right knee joint (coronal section).](image)
alar folds which contain fibro-fatty tissue. The semilunar intervals between the alar folds and the condyles of femur communicate the femoropatellar compartment with each condylar part of the joint.

From the posterior part of the fibrous capsule, the synovial membrane projects forward in the intercondylar region as a cul-de-sac to envelop the sides of both cruciate ligaments and the front of anterior cruciate ligament. Such a cul-de-sac forms an incomplete partition between the two condylar joints. An intercondylar foramen, however, communicates both condylar joints. The foramen is bounded in front by the posterior surface of the infra-patellar fold and behind by the synovial membrane covering the front of the anterior cruciate ligament (Fig. 25.11).

Ligamentum patellae—It is derived from the tendon of quadriceps femoris and extends from the apex of patella to the upper part of the tubercle of tibia. Subcutaneous and deep infra-patellar bursae lie close to its lower end. When the knee joint is locked at the end of extension, all ligaments are taut except the ligamentum patellae.

Tibial collateral ligament (Fig. 25.12)—Morphologically, it represents the detached lower part of tendon of ischial fibres of adductor magnus. The ligament consists of superficial and deep parts. Both parts are attached above to the medial epicondyle of femur. The superficial part extends
downward and forward as a flattened band and is attached to the medial condyle and upper part of the medial border of shaft of tibia along a rough strip of bone. The lower part of the ligament is crossed superficially by the sartorius, gracilis and semitendinosus muscles. The deep part of the ligament is triangular in shape, and its base is attached to the medial condyle of tibia along the upper margin of the groove for semimembranosus muscle. The deep part blends with the fibrous capsule and is attached to the peripheral margin of the medial meniscus. In the interval between superficial and deep parts lie the inferior medial genicular vessels and nerve, and a part of semimembranosus muscle.

**Fibular collateral ligament** (Fig. 25.13)—It extends as a fibrous cord downward and backward from the lateral epicondyle of femur to the head of fibula close to its styloid process. The ligament is overlapped superficially by the tendon of biceps femoris. The deep surface of the ligament is not adherent to the fibrous capsule, and the gap between them is occupied by the tendon of popliteus and inferior lateral genicular vessels and nerve.

The fibular collateral ligament is morphologically derived from the primitive origin of peroneus longus muscle.

**Oblique popliteal ligament**—It is an expansion derived from the insertion of semimembranosus, and extends upward and laterally from the posterior surface of the medial condyle of tibia to the lateral part of intercondylar line of femur. It blends with the posterior surface of the fibrous capsule, forms the floor of popliteal fossa and is pierced by middle genicular vessels and nerve, and by the genicular branch of the posterior division of obturator nerve.

**Arcuate ligament** (Fig. 25.14)—It forms a Y-shaped fibrous band. The stem is fixed to the styloid process of head of fibula. The posterior band arches over the tendon of popliteus and is attached to the lateral condyle of tibia. The anterior band, often deficient, passes deep to fibular collateral ligament and is attached to the lateral condyle of femur.

**Cruciate ligaments** (See Figs. 25.7, 25.9, 25.10)—The anterior and posterior cruciate ligaments are intra-capsular but extrasynovial. They cross like the letter ‘X’, hence called cruciate. They are named as anterior and posterior, according to their tibial attachments. Both ligaments are taut at the extremes of flexion and extension of the joint. The cruciate ligaments are developed from the posterior part of primitive intercondylar septum.

**Anterior cruciate ligament** (ACL)

Attachment: Below, it is attached to the anterior part of intercondylar area of tibia in between the anterior horns of medial and lateral menisci.

Above, it is attached to the posterior part of medial surface of lateral condyle of femur. It is oblique in direction and extends upward, backward and laterally.

**Functions**

1. It binds the bones together;

---

Fig. 25.13. Lateral view of right knee joint (After removal of fibrous capsule).
2. It is stretched during extension and therefore prevents hyper-extension (Fig. 25.15-a).

3. It prevents forward displacement of tibial condyles.

4. Since it is taut during extension, it forms a vertical axis around which femur rotates on tibia during extension or flexion of knee joint. In standing the anterior cruciate ligament lodges in a subsidiary notch in the lateral part of intercondylar notch of femur.

**Posterior cruciate ligament (PCL)**

Attachments: Below, it is attached to the posterior part of intercondylar area of tibia behind the posterior horns of medial and lateral meniscus.

Above, attached to the anterior part of lateral surface of medial condyle of femur. It extends upward, forward and medially, and is less oblique than the anterior cruciate ligament.

**Functions:**

1. It binds the bones of the joint;
2. It is stretched during flexion, and prevents backward displacement of tibial condyles (Fig. 25.15-b).
3. Both cruciate ligaments prevent side to side displacement of femur and tibia.

**Coronary ligaments**—These are parts of the fibrous capsule which provide attachment to the peripheral margins of medial and lateral menisci.

**Transverse ligament**—It extends transversely and connects the anterior horn of medial meniscus to the anterior margin of lateral meniscus. Such inter-meniscal ligament is present in about 40% subjects.

**Menisco-femoral ligament** (See Fig. 25.14)—The posterior horn of lateral meniscus is connected to the medial condyle of femur by anterior and posterior menisco-femoral ligaments. The anterior ligament (ligament of Humphry) passes in front of posterior cruciate ligament; the posterior ligament (ligament of Wrisberg) passes behind the posterior cruciate ligament. The menisco-femoral ligament regulates the forward movement of the lateral meniscus during extension of the knee.

**Medial and lateral menisci**—The medial and lateral menisci (semilunar cartilages) are composed
of fibro-cartilage, and project from the fibrous capsule as incomplete partition and intervene between the condyles of femur and tibia. Each meniscus divides the condylar part of the joint into menisco-femoral and menisco-tibial compartments.

**Medial meniscus** (See Fig. 25.11)—It is semilunar in shape and longer antero-posteriorly than the lateral meniscus. It presents anterior and posterior horns, upper and lower surfaces, medial and lateral margins. The anterior horn is narrower than the posterior one, and both horns are attached to the intercondylar area of tibia by ligaments. Upper surface is concave and lower surface flat. Medial margin is convex and attached to the capsular ligament and tibial collateral ligament. Lateral margin is concave and free.

**Lateral meniscus** (See Fig. 25.11)—It forms four-fifth of a circle, and presents anterior and posterior horns, upper and lower surfaces, lateral and medial borders. Both horns are of equal width and attached to the tibial intercondylar area by ligaments. Posterior horn provides, in addition, the attachment of menisco-femoral ligaments and a few fibres of popliteus. The menisco-femoral ligaments regulate forward gliding of lateral meniscus on tibial plateau during extension; popliteus pulls the meniscus backward and prevents it from being trapped at the beginning of flexion. Upper surface of the meniscus is concave and lower surface flat. Lateral margin is convex and attached to the fibrous capsule; posteriorly it is grooved for the tendon of popliteus. Medial margin is free and concave.

**Functions of the menisci**

1. They increase the concavity of tibial condyles for better adaptation with femoral condyles.

2. They maintain a potential joint space for flushing of synovial fluid to provide nutrition to the articular cartilages.

3. Presumably the menisci act as shock absorber to protect articular cartilages during weight transmission and locomotion between two longest bones of the body.

4. The menisci help in the complex mechanism of gliding and angular movements. During extension-flexion movements, the upper surface of medial meniscus permits rolling, spinning and rotation, and that of lateral meniscus participates only in rolling and spinning; the lower surface of lateral meniscus permits forward gliding in extension and backward gliding in flexion of the joint. In active medial and lateral rotations of semi-flexed knee, the lower surfaces of both menisci perform the movements in the menisco-tibial compartment (see mechanism of move-ments).

5. Peripheral attached part of the menisci is vascular and gets nutrition from the capsular arteries, and inner free part is avascular and receives nutrition from synovial fluid. The semilunar cartilages can re-grow, provided the entire cartilage is removed surgically.

**Movements and their mechanism**

Active movements performed at the knee joint are extension and flexion, medial and lateral rotation.

**Extension** or straightening continues until leg and thigh are in the same vertical lines. Since the line of gravity passes slightly in front of the centre of knee joint, the natural tendency of hyper-extension is prevented by the tension of all ligaments (except ligamentum patellae) and tension of antagonistic muscles. At the extreme extension the joint becomes close-packed and locked. In symmetrical standing the extended knee occupies slightly short of close-packed position, thereby the nutrition of articular cartilage is maintained. In asymmetrical standing, however, the joint is fully extended for a short period. The rage of extension beyond the vertical axis is about 5°–10°.

The range of flexion with extended hip is about 120°, and with flexed hip it increases to about 140°. Passive flexion can be carried to about 160° until the back of the leg comes in contact with the back of thigh.

Medial and lateral rotations may be **conjoint** or **adjunct**. Conjoint rotation takes place automatically during extension-flexion movements of the joint due to geometry of the articular surfaces and tension of the ligaments; its range is about 20°. Adjunct rotation takes place in semi-flexed knee by the active contraction of muscles and its range varies between 50° and 70°.

**Sequences of movements** from full flexion to full extension (Fig. 25.16)

1. In extreme flexion, the more convex posterior parts of both femoral condyles rest on the posterior horns of both menisci.
2. As extension starts, both femoral condyles roll forwards on the upper surface of both menisci and the transverse axis of the joint moves forward along the evolute of the profile.

3. Thereafter the forward movement of transverse axis is arrested by the tension of the posterior part of fibrous capsule, oblique popliteal ligament and posterior cruciate ligament.

4. Now, around a fixed transverse axis both femoral condyles spin forward on the upper surface of both menisci.

5. Since the lateral meniscus is shorter than medial meniscus in antero-posterior extent, the lateral femoral condyle reaches the upper surface of anterior horn of the lateral meniscus earlier and completely occupies the lateral menisco-femoral compartment.

6. At this stage full extension falls short of 30°, and anterior horn of the medial meniscus is not yet reached by the medial femoral condyle. Meanwhile the anterior cruciate ligament is stretched and acts as a vertical axis, around which medial femoral condyle rotates in an arc backward and medially and reaches the anterior horn of medial meniscus and completely obliterates the medial menisco-femoral compartment. Simultaneously lateral femoral condyle carrying the lateral meniscus with it glides forward in the lateral menisco-tibial compartment; too much forward gliding is checked by the tension of the menisco-femoral ligament.

Completion of last 30° of full extension is thus achieved by conjunct rotation which is known as the ‘locking mechanism’ or ‘screwhome movement’. When the joint is locked, most of the ligaments are stretched, joint is maximally congruent and the extensor muscles cease active contraction to restore energy.

When flexion starts from full extension, the joint is first unlocked by lateral rotation of medial femoral condyle upon the upper surface of anterior horn of medial meniscus around the taut vertical axis of the anterior cruciate ligament. At the same time the lateral meniscus carrying the lateral femoral condyle glides backward in the menisco-tibial compartment and this is assisted by the contraction of popliteus muscle. Therefore the popliteus initiates flexion by unlocking the locked knee. Rest of the flexion is completed by the spinning and backward rolling of both femoral condyles in the menisco-femoral compartments. Since the anterior horn of the medial meniscus is the site of rotation of medial condyle of femur during locking and unlocking of the joint, it undergoes wear and tear. Hence, the anterior horn of medial meniscus is narrower than its posterior horn.

Above mentioned sequences in extension and flexion are described when the foot is on the ground, that means, when the tibia is fixed. But when the foot is off the ground, the medial tibial condyle with its meniscus rotates laterally in extension or medially during flexion.

Muscles producing the movements

Extension—Quadriceps femoris and assisted by the tensor fasciae latae.

Flexion—Prime movers: Semimembranosus, semitendinosus, biceps femoris;

Initiated by, popliteus;

Assisted by, sartorius, gracilis, both heads of gastrocnemius and plantaris;

Medial rotation—Semimembranosus, semitendinosus, popliteus, sartorius and gracilis.

Lateral rotation—Biceps femoris.

Relations of knee joint

In front—Quadriceps femoris;

Antero-medially—Medial patellar retinaculum;

Antero-laterally—Lateral patellar retinaculum, iliotibial tract;

Postero-medially—Sartorius, gracilis, semimembranosus and semitendinosus;

Postero-laterally—Tendon of biceps femoris and common peroneal nerve;
Behind—Popliteal vessels, tibial nerve, both heads of gastrocnemius and plantaris.

**Bursae around knee joint**

**In front**—Four (4) bursae;

Subcutaneous pre-patellar bursa—It intervenes between the skin and anterior surface of patella. Sometimes the bursa is swollen in house-maid due to washing the floor by adopting kneel-down position; hence called *house-maid's bursa*.

Subcutaneous infra-patellar bursa—It intervenes between the skin and the tubercle of tibia where ligamentum patellae is attached.

This bursa is sometimes swollen in perons during praying in kneel-down position with the trunk upright; hence called *clergyman's bursa*.

Deep infra-patellar bursa—It lies behind the patellar ligament in the interval between the former and anterior surface of the upper end of tibia.

Supra-patellar bursa—It intervenes between the quadriceps femoris and the lower end of femur, and communicates with the joint.

**Laterally**—Four (4) bursae;

(i) Between the lateral head of gastrocnemius and the capsule;
(ii) Between the tendon of biceps femoris and fibular collateral ligament;
(iii) Between the fibular collateral ligament and tendon of popliteus;
(iv) Between the lateral condyle of tibia and tendon of popliteus; it communicates with the knee joint and sometimes with the superior tibiofibular joint.

**Medially**—Three or four bursae;

(i) Between the medial head of gastrocnemius and the capsule; it communicates with the knee joint;
(ii) Between the superficial part of tibial collateral ligament and the sartorius, gracilis and semitendinosus;
(iii) Between the superficial and deep parts of tibial collateral ligament;
(iv) Sometimes between the insertion of semimembranosus and medial condyle of tibia; it may communicate with the knee joint.

**Arterial supply**—The joint is richly supplied by anastomotic network formed by genicular branches of popliteal, descending genicular branch of femoral, descending branch of lateral circumflex femoral, recurrent branches of anterior tibial and circumflex fibular branch of posterior tibial arteries.

**Nerve supply**—The knee joint is supplied by ten (10) nerves—three from femoral nerve through the nerves to the vastii, three from the tibial nerve through the superior and inferior medial genicular nerves and middle genicular nerve, three from the common peroneal through the superior and inferior lateral genicular nerves, and recurrent genicular nerve, and one from the posterior division of obturator nerve.

*Four consecutive spinal cord segments (L₃, L₄, L₅, S₁) control knee movements; L₃ and L₄ regulate extension and L₅ and S₁ regulate flexion.*
meniscus and the ACL (the terrible triad).

- A blow to the lateral aspect of the knee when the foot is on the ground may sprain the tibial collateral ligament; the attached medial meniscus may also be torn.
- Patients with a medial meniscus tear have pain when the leg is medially rotated at the knee.
- ACL tears may occur when the tibial collateral ligament and the medial meniscus are injured; a blow to the anterior aspect of the flexed knee may tear only the ACL.
- Patients with a torn ACL exhibit anterior displacement of the tibia from the femur in the flexed knee.

2. Injuries to the menisci commonly occur in flexed knee as a result of forcible rotation or abduction. The medial meniscus suffers more frequently than the lateral, because of greater range of movements enjoyed by the latter. The medial fibres of popliteus pull the posterior horn of the lateral meniscus backward and prevent it from being trapped between the articular surfaces. The injury may be in the form of a tear in the cartilage, or its peripheral margin may be detached from the capsule (bucket-handle tear) and displaced towards the centre of the joint arresting all movements. Surgical removal of the entire meniscus ameliorates the symptoms and allows the meniscus to re-grow.

3. Rupture of cruciate ligaments is less common; anterior cruciate ligament is an occasional victim. If both cruciate ligaments are torn, excessive forward and backward gliding of the tibia, abduction and adduction of the joint are noticed.

4. Fracture of the patella is a frequent traumatic problem which cripples the knee movements with collection of blood within the joint. Patellar fracture is mostly caused by indirect violence and the line of fracture passes transversely dividing the bone into upper and lower fragments; usually the lower fragment is smaller than the upper one. During walking the supporting lower limb occasionally slips forward and tends to fall on that side. In order to avert the fall the advancing lower limb which is in a position of knee flexion in the swing
TIBIO-FIBULAR JOINTS

Tibio-fibular joints are three – superior, middle, and inferior.

**Superior tibio-fibular joint** is a plane synovial joint. It is formed by an oval or circular articular facet on the posterolateral part of lateral condyle of tibia and a reciprocal articular surface of the head of fibula. Both surfaces are covered with hyaline cartilage. The joint is enveloped by fibrous capsule and lined by synovial membrane.

It is supplied by the nerve to the popliteus and a branch from the common peroneal nerve.

The joint permits some gliding movement during dorsiflexion of the foot (See mechanism of movements of ankle joint).

**Middle tibio-fibular joint** is a fibrous joint and formed by the crural intersosseous membrane connecting intersosseous borders of the shafts of both tibia and fibula. Traced below, the membrane is continuous with the intersosseous ligament of the inferior tibio-fibular joint. Upper border of the intersosseous membrane is free, above which the anterior tibial vessels pass in the anterior crural region along the medial side of the neck of fibula. A little above the inferior tibio-fibular joint the membrane is pierced by the perforating branch of the peroneal artery.

Most of the fibres of the intersosseous membrane are directed downward and laterally, except in the upper part where they are directed medially and downward.

Relations: In front, tibialis anterior, extensor hallucis longus, extensor digitorum longus, peroneus tertius, anterior tibial vessels and deep peroneal nerve;

Behind, tibialis posterior and flexor hallucis longus.

**Inferior tibio-fibular joint** is a syndesmosis type of fibrous joint. It connects the concave triangular rough surface of the lower end of tibia with the convex triangular rough surface of the lower end of fibula. The ligaments of the joint are interosseous, anterior and posterior tibio-fibular.

The **interosseous ligament** is a strong and short band which connects the opposing rough surfaces of the tibia and fibula. A small synovial recess of ankle joint extends upward for about 4 mm in the lower part the interosseous ligament.

The **anterior tibio-fibular ligament** passes downward and laterally in front of the interosseous ligament.

The **posterior tibio-fibular ligament** extends downward and laterally behind the interosseous ligament. A few fibres of the posterior ligament are continuous with the inferior transverse ligament which extends horizontally from the malleolar fossa of the fibula to the posterior margin of the lower end of tibia and its malleolus. The **inferior transverse ligament** extends below the articular surface and accentuates the concavity of the tibio-fibular mortise of the ankle joint.

During dorsiflexion of the foot, the ligaments of the inferior tibio-fibular joint are stretched and the lower end of fibula is displaced laterally and slightly rotated outward (See mechanism of movement of ankle joint).

The joint is supplied by the deep peroneal nerve, nerve to the popliteus and tibial nerve.

ANKLE JOINT

The ankle (talo-crural joint) is a uni-axial synovial joint. Since the axis of movement is basically transverse with a slight downward inclination on the lateral side, it is a modified hinge joint.

Bones forming the joint

**Above**, inferior articular surface of the lower end of tibia with its medial malleolus and lateral malleolus of fibula; articular surfaces of both bones form a **tibio-fibular mortise**, the posterior margin of which is deepened by the inferior transverse tibio-fibular ligament. The mortise receives the body of talus from below. The tip of the lateral malleolus lies about 2 cm below that of the medial malleolus. The epiphysial plate of the
lateral malleolus corresponds with the joint space, and that of the medial malleolus is situated about 1.25 cm above the joint (Fig. 25.17).

Below, the trochlear upper surface of the body of talus with comma-shaped facet for tibial malleolus and a triangular facet for fibular malleolus; these three articular areas form a continuous surface known as trochea tali. The upper surface of the talus is convex from before backward and gently concave from side to side; it is broader in the anterior part. The comma-shaped facet is restricted to the upper part of the medial surface. The triangular facet for fibula occupies the entire lateral surface of talus, is gently concave from above downward and faces upward and laterally.

The posterior part of lateral margin of talus, between the trocheleal and fibular facets, forms a triangular flattening which comes in contact with the inferior transverse tibio-fibular ligament.

Ligaments of the joint
1. Capsular ligament with synovial membrane;
2. Medially, deltoid ligament;
3. Laterally, anterior and posterior talo-fibular and calcaneo-fibular ligaments.

Capsular ligament:
The fibrous capsule envelops the joint completely; it is thin in front and behind, and becomes thickened on both sides where it blends with the collateral ligament.

The capsule is attached above to the bones of the tibio-fibular mortise close to the periphery of the articular surface. Below it is attached to the peripheral margin of the trochea tali, but in the anterior part it extends somewhat to the dorsal rough surface of the neck of talus.

Synovial membrane lines the inner surface of the fibrous capsule but ceases at the periphery of the articular cartilage. A small synovial recess extends upward in the inferior tibio-fibular syndesmosis.

Deltoid or medial ligament is a strong triangular band which blends with the fibrous capsule, and it consists of superficial and deep parts (Fig. 25.18).

The apex of the superficial part is attached above to the tip and the adjoining margins of the tibial malleolus. Anterior part of its base passes downward and forward and is attached to the tuberosity of navicular bone and blends with the medial margin of the spring or plantar calcaneo-navicular ligament (tibio-navicular part); the intermediate part extends vertically downward and is attached along the medial surface of sustentaculum tali of calcaneus (tibio-calcanean part); the posterior part extends downward and backward and gains attachment to the medial tubercle of talus (posterior tibio-talar part).

![Ankle joint diagram](image)

**Fig. 25.17.** A coronal section through right ankle joint.
Calcaneo-fibular ligament extends downward and backward as a fibrous cord from a notch near the tip of fibular malleolus to an elevation on the lateral surface of the calcaneus. It is crossed superficially by the tendons of peroneus longus and peroneus brevis.

**Movements and mechanism:**

In symmetrical standing, the line of gravity passes slightly in front of the centre of ankle joint. Therefore, there is a natural tendency for forward dislocation of leg bones from the talus. This is prevented mainly by two factors, bony and muscular. The broader anterior part of the trochlear surface of talus and the tonic contraction of triceps surae through the tendo-calcaneus nullify the forward dislocation.

Active movements permitted at the ankle joint are dorsi-flexion and plantar-flexion. Normally the leg meets the foot forming a right-angled bend. The dorsi-flexion diminishes the angle between them so that the heel strikes the ground and toes lie above the ground. The range of dorsi-flexion is about 10°, and when assisted by the tarsal joints, it may be increased to about 20°. The plantar flexion increases the angle between the leg and foot, so that one stands on the toes. It accelerates the forward thrust during locomotion. The range of plantar flexion at the ankle joint is about 20°, but it increases to about 40° with the assistance of tarsal joints. *In walking heel must strikes the ground, whereas in running toes only touch the ground.*

During dorsi-flexion, the wider anterior part of the trochlear surface of talus comes in contact with the tibio-fibular mortise. Necessarily the lower end of fibula is displaced somewhat laterally by outward rotation for accommodation of talus. This produce stretching of inferior tibio-fibular syndesmosis and concomitant upward gliding of fibula at the superior tibio-fibular joint (Fig. 25.20–a, b). This explains why the superior tibio-fibular joint is a plane synovial joint. Therefore, dorsi-flexion of foot takes place at the ankle joint with the assistance of inferior and superior tibio-fibular joints. The ankle joint becomes close-packed in dorsi-flexion, which provides maximum stability of the joint. When one descends along the sloping surface of a hill, he always places the heel first in order to avoid side shifting of the foot.
In plantar flexion the ankle joint becomes loose-packed, because some joint space is available between the tibio-fibular mortise and the narrower posterior part of the trochlear surface of the talus. Therefore, accessory movements like adduction and abduction are possible in plantar flexion, which makes the joint insecure. Surgical immobilisation of ankle joint should be made in slight plantar flexion which provides flushing of synovial fluid for nourishment of the articular cartilages. High-heel shoes, as used by most of the modern ladies, keep the ankle joints in plantar flexion which definitely improves the speed of locomotion, but at the same time increases the risks of the side shifting and forward dislocation. Such risks are, however, compensated by the intermittent contraction of the calf muscles which increases the feminine beauty of the leg by establishing the rounded contour of the calf.

Muscles producing movements

Dorsi-flexion—Tibialis anterior, extensor digitorum longus, extensor hallucis longus and peroneus tertius.

Fig. 25.20. Fibular movements in dorsi-flexion at ankle joint.

Plantar flexion—Gastrocnemius and soleus through the tendo-calcaneus act as prime movers, and assisted by tibialis posterior, flexor digitorum longus and flexor hallucis longus. Peroneus longus and brevis come into play in extreme plantar flexion. Gastrocnemius initiates plantar flexion since it is a white muscle, and soleus maintains it since it is a red muscle.

Relations of ankle joint

In front—From medial to lateral side the structures are:

- Tendons of tibialis anterior, extensor hallucis longus, anterior tibial vessels and deep peroneal nerve, tendons of extensor digitorum longus and peroneus tertius (Fig. 25.21).

Behind—Tendo-calcaneus in the middle, separated from the joint by fibro-fatty tissue;

Behind the tibial malleolus (from medial to lateral side)—Tendon of tibialis posterior, flexor digitorum longus, posterior tibial vessels, tibial nerve, and tendon of flexor hallucis longus:

Behind the fibular malleolus—Tendons of peroneus brevis and peroneus longus; the former is deep to the latter and both are enveloped by a common synovial sheath.

Arterial supply—The joint is supplied by the malleolar branches of the anterior tibial and peroneal arteries.

Nerve supply—Branches from the deep peroneal and tibial nerves. Ankle centre is located in the L₄, L₅, S₁ and S₂ segments of spinal cord. L₂ and L₃ segments control dorsi-flexion, and S₁ and S₂ segments regulate plantar flexion.

Fig. 25.21. A horizontal section through right ankle joint.
JOINTS OF THE FOOT

The joints encountered from before backward in the skeleton of foot are as follows: interphalangeal, metatarso-phalangeal, tarso-metatarsal, intermetatarsal, intertarsal, transverse or midtarsal, and sub-talar joints.

The interphalangeal joints are typical hinge joints and each possesses capsular ligament and collateral ligaments. Active movements permitted are dorsi-flexion and plantar flexion; proximal interphalangeal joints are endowed with greater range of movements.

The metatarso-phalangeal joints are ellipsoidal type of synovial joints, and each possesses capsular, collateral, plantar and deep transverse metatarsal ligaments. The articular surface of metatarsal head is convex and extends more on the plantar surface; the base of the proximal phalanx is reciprocally concave. The plantar surface of the first metatarsal head presents two longitudinal grooves for the transmission of the bifurcated tendons of flexor hallucis brevis in which sesamoid bones appear, one on each side. Two collateral ligaments strengthen the sides of each joint. Four deep transverse metatarsal ligaments connect the plantar ligaments of adjacent metatarso-phalangeal joints.

Active movements at these joints are dorsi-flexion, plantar flexion, adduction and abduction. The range of dorsiflexion (50°–60°) is greater than that of plantar flexion (30°–40°), and this facilitates walking. Mere placing of the foot on the ground induces a movement of dorsi-flexion at the metatarso-phalangeal joints of about 25°. Movement of adduction and abduction are mentioned with reference to the axis passing through the second toe, because second metatarsal bone is least mobile.

The tarso-metatarsal joints are plane synovial, and are connected by dorsal, plantar and interosseous cuneo-metatarsal ligaments. Although the tarso-metatarsal joints are five in number, the first joint possesses a separate synovial cavity, the second and third joints assemble to form one cavity, and the fourth and fifth joints unite to form a separate joint cavity. These joints permit limited gliding movements.

The intertarsal joints between the neighbouring cuneiform bones and between the lateral cuneiform and the cuboid are plane synovial joints. Altogether six synovial cavities are encountered in the tarsus and metatarsus:

(a) subtalar;
(b) talo-calcaneo-navicular;
(c) calcaneo-cuboid;
(d) a joint cavity comprising cuneo-navicular, intercuneiform, cuneocuboid, and articulations of intermediate and lateral cuneiform bones with the bases of 2nd and 3rd metatarsal bones, and adjacent surfaces of the bases of 2nd, 3rd and 4th metatarsal bones;
(e) between the medial cuneiform and the base of 1st metatarsal bones;
(f) between the cuboid and the bones of 4th and 5th metatarsal bones.

Mid-tarsal or transverse tarsal joint

It consists of two components with separate joint cavities—medially talo-calcaneo-navicular joint, and laterally calcaneo-cuboid joint. Both components are connected by the bifurcated ligament and move as one unit during inversion and eversion of the foot (Fig. 25.22).

Talo-calcaneo-navicular joint—It is a restricted ball-and-socket joint. The ball is contributed by the spheroidal head of the talus, and the socket is formed by the concave posterior surface of navicular bone, upper surface of the plantar calcaneonavicular ligament and the anterior two talar facets on the upper surface of the sustentaculum tali of calcaneus.
The ligaments of the joint are capsular, talonavicular, plantar calcaneo-navicular and calcaneo-navicular part of bifurcated ligaments.

The capsular ligament loosely envelops the joint. The talo-navicular ligament covers the capsule and connects the dorsal surface of the navicular and the neck of talus.

The plantar calcaneo-navicular (spring) ligament connects the plantar surface of the navicular with the sustentaculum tali of calcaneus. Medially, it is continuous with the superficial fibres of deltoid ligament which curves round its medial margin. Laterally, it is continuous with the short plantar ligament. Lower surface of the plantar calcaneo-navicular ligament is related to a slip of tibialis posterior tendon, and the tendons of flexor digitorum longus and flexor hallucis longus. Upper surface of the ligament is covered by a plate of cartilage which articulates with the head of talus; therefore the ligament is made up of fibro-cartilaginous tissue. When the foot is on the ground, the downward displacement of the head of talus is resisted by the plantar calcaneo-navicular ligament which is itself supported from below by the tendon of tibialis posterior in particular. On standing, the ligament is somewhat stretched and lessens the height of medial longitudinal arch of the foot; but when the foot is off the ground the medial arch is restored to the original position. On the basis of this observation the plantar calcaneo-navicular ligament is popularly called the spring ligament, but such name appears to be erroneous because it is not composed of elastic tissue. Permanent stretching of the ligament, however, produces flat foot.

**Calcaneo-cuboid joint**

It is a saddle or sellar joint and formed between the anterior surface of the calcaneus and the posterior surface of the cuboid. The articular surfaces of both bones are concavo-convex and reciprocally curved. The calcanean angle of the cuboid extends backward below the anterior articular surface of the calcaneus, and supports the upward tilt of the long axis of the calcaneus.

The ligaments of the joint are articular capsule, bifurcated ligaments, short and long plantar ligaments.

The capsular ligament envelops the joint and is strengthened on its dorsal surface by the dorsal calcaneocuboid ligament.

The bifurcated ligament is Y-shaped and intervenes between the talocalcaneo-navicular and the calcaneo-cuboid joints. The stem of the ligament is attached to the upper surface of the anterior part of the calcaneus; the limbs diverge in front and are attached medially to the dorsolateral aspect of the navicular bone as the calcaneo-navicular ligament, and laterally to the dorsomedial aspect of the cuboid as the calcaneo-cuboid ligament.

The short plantar ligament connects the adjacent plantar aspects of the calcaneus in front of the anterior tubercle with the cuboid bone behind the oblique ridge.

The long plantar ligament lies superficial or below the short plantar ligament. It is attached behind to the plantar surface of the calcaneus in a triangular area between the anterior and the two posterior tubercles (medial and lateral), and in front to the oblique ridge on the plantar surface of the cuboid. Some of the superficial fibres extend further in front forming an osseo-fibrous tunnel beneath the cuboid bone for the tendon of peroneus longus and are attached to the bases of the 2nd, 3rd, 4th and sometime 5th metatarsal bones. It is the longest and strongest of the tarsal ligaments and limits the flattening of the lateral longitudinal arch of the foot.

**Subtalar joint**—The subtalar joint also known as the posterior talo-calcanean joint is a modified multi-axial synovial joint. It is formed between the
obliquely placed concave articular facet involving the lower surface of the body of talus and similarly oriented convex articular area on the upper surface of the middle-third of the calcaneus.

The ligaments of the joint are capsular, medial and lateral talo-calcanean, interosseous talo-calcanean, and cervical ligaments. The interosseous talo-calcanean ligament fills up the bony canal of sinus tarsi, and separates the posterior talo-calcanean joint from the talocalcaneo-navicular joint. The medial fibres of the interosseous ligament are taut in inversion.

The cervical ligament lies lateral to the interosseous ligament and connects the upper surface of the calcaneus with the lateral surface of the neck of talus. This ligament is rendered taut in inversion.

The subtalar joint takes up a major share in the movements of inversion and eversion of the foot.

Inversion and eversion of the foot—The inversion is a process by which the medial margin of the foot is raised above the ground so that the sole is directed downward and medially. Conversely, in eversion the lateral margin of the foot is raised above the ground and the sole faces downward and laterally. Inversion and eversion are best demonstrated when the foot is off the ground. Inversion is associated with plantar flexion and eversion with the dorsiflexion of the foot.

These movements are essential in plantigrade animals to adjust the foot while walking on an uneven surface. The chief function of the invertor and evertor muscles is to maintain an efficient shift of weight distribution among the heads of metatarsal bones during locomotion.

**Mechanism (Fig. 25.23):**

Inversion and eversion take place at the mid-tarsal (talocalcaneo-navicular) and calcaneocuboid) and subtalar joints. Both movements are complex and consist of two components. In

Figure 25.23. Axis of rotation at sub-talar joint in inversion and eversion of foot.

inversion, the fore part of the foot is initially adducted at the mid-tarsal joint, this is followed by the lateral rotation or supination of the foot at the subtalar joint. Conversely, during eversion the fore part of the foot is initially abducted at the mid-tarsal joint, followed by the medial rotation or pronation of the foot at the subtalar joint. The rotatory components form the greater part of these movements and take place at the subtalar and talocalcaneo-navicular joints. Since both the joints are curved in opposite directions, a line joining the centres of curvatures of the two joints forms the axis of rotation. The axial line passes obliquely upward, forward and medially from the heel end of the calcaneus through the sinus tarsi to the dorsomedial surface of the neck of the talus (Shepheard, 1951). The mechanism of these movements is similar to those of pronation and supination of the forearm at the superior and inferior radio-ulnar joints.

When the foot is on the ground, typical inversion and eversion are not observed; rather the foot is supinated to raise the medial margin above the ground or pronated to the raise the lateral margin above the ground. Therefore, the supination of the foot is not equivalent to inversion; similarly pronation and eversion of the foot are not synonymous. Muscles producing **inversion** are; tibialis anterior and tibialis posterior; those producing **eversion** are peroneus longus and brevis, assisted by peroneus tertius.
Human foot performs two basic functions—
(a) supports the weight of the body;
(b) serves as a lever to propel the body forward
during locomotion in walking and running.

Both the functions are carried out efficiently,
since the skeleton of the foot is composed of a
series of small bones. If the foot were provided
with a single piece of strong bone, it could sustain
the body weight and serve as a rigid lever for
forward propulsion. But the foot could not adapt
itself to move on an uneven surface, and the
forward propulsion would depend entirely on the
activities of the gastrocnemius and soleus
muscles. However, such hazards are avoided by
the composition of the foot with a series of small
bones which make the foot a segmented lever with
multiple joints. The foot is thus made pliable and
can adapt itself to uneven surfaces. Moreover,
the long flexor muscles and the intrinsic muscles
of the foot can exert their actions on the bones of
the fore-part of the foot and assist greatly the
propulsive action of the gastrocnemius and soleus
muscles (Fig. 26.1).

![Diagram of foot showing muscle actions](image)

**Fig. 26.1. Foot as a segmented level.**

The skeleton of the foot is arched, both
longitudinally and transversely, with the concavity
directed to the plantar surface.

Longitudinal and transverse arches become
apparent in late foetal life, although the deposition
of subcutaneous fat in the sole of the newborn
makes the foot apparently flat in contour.

**Functions of arches of the foot**

1. They help in proportional distribution of
   **body weight** to the ground. A person possessing
   a body weight, say 120 pounds, transmits in
   standing position 60 pounds of weight through
each foot which is initially received by the talus.
   Thereafter, the weight is distributed equally
   through the posterior and anterior parts of foot.
   About 30 pounds pass through the calcaneus in
   the posterior part, and the remaining 30 pounds
   are distributed to the heads of five metatarsal
   bones in the anterior part. Heads of five metatarsal
   bones possess six bearing points, since two
   sesamoid bones beneath the head of the first
   metatarsal transmit part of the weight. Each bearing
   point transmits, about 5 pounds of weight.
   Therefore first metatarsal head takes up double
   load than other metatarsal heads. The bulky size
   of calcaneus and stoutness of first metatarsal in
   comparison with other metatarsal testify
   proportional distribution in accordance with the
   work-load. (Morton, D.J.: The Human Foot,

2. Arched foot acts as **segmented level** which
   helps in propulsive mechanism of soleus and
gastrocnemius and allows long flexor and short
   flexor muscles of the sole to exert their actions in
   the fore part of the foot, during take-off point.
The lumbricals prevent the toes from buckling
under when pulled upon by the flexor digitorum
longus (See Fig. 21.5-a,b).

3. Plantar concavity of the arches **protects** the
   plantar vessels and nerves from compression. In
   flat foot the nerves may be compressed producing
   pain in the metatarsal region of the foot and
   radiating towards the toes; this condition is known
   as **metatarsalgia**.
4. Arched foot is **dynamic** and **pliable**. When the foot is on the ground the arches flatten somewhat, but when off the ground they restore the original contour. Therefore, the foot acts as a **spring board** which helps jolting and jumping from a height.

5. Invertor and evertor muscles of the foot produce a **shift of weight distribution** among the heads of the metatarsals, in order to adapt the foot while moving on an uneven surface.

**Longitudinal arch**—The longitudinal arch is subdivided into medial and lateral arches.

**Medial longitudinal arch** (Fig. 26.2):

It represents the big arc of a small circle; therefore the summit of the arch lies at a higher level. The bones of the medial arch are contributed by the following from behind forward—calcaneus, talus, navicular, three cuneiform and medial three metatarsal bones up to their heads including two sesamoid bones beneath the first metatarsal head.

**Lateral longitudinal arch** (Fig. 26.3):

It represents the small arc of a big circle; so the summit is low. The following bones enter in the formation of lateral arch from behind forward: calcaneus, cuboid, and fourth and fifth metatarsal bones up to their heads.

![Fig. 26.3. Lateral longitudinal arch (Right foot).](image)

The **summit** of the arch lies at the subtalar joint.

The **posterior pillar** is formed by the medial tubercle of calcaneus when both longitudinal arches meet; the **anterior pillar** is formed by the heads of the fourth and fifth metatarsal bones.

The **most vulnerable part** of the arch is formed by the calcaneo-cuboid joint, beneath which lie long and short plantar ligaments.

Since less number of bones and less joints participate in the formation of lateral arch, **rigidity** is the characteristic of this arch. The lateral arch flattens out at the hinge surface between the cuboid and the bases of lateral two metatarsal bones, and commonly bears the body weight before the medial arch comes into play. This can be easily appreciated by noting the foot print of a normal foot.

**Transverse arch**—When the medial borders of both feet are approximated, a complete transverse arch is formed because the lateral longitudinal arches lie lower than the medial arches. Therefore each foot presents a half-dome with the concave directed downward and medially. In fact, the transverse arch consists of a series of arches which involve the bases of metatarsal bones, cuboid and three cuneiform bones (Fig. 26.4-a,b).

Since all metatarsal heads make contact with the ground, they do not participate in the formation of transverse arch.
concave proximal surface of navicular bone and rests below on the sustentaculum tali of calcaneus.

2. Intersegmental tiers—A number of plantar ligaments bind together the lower edges of interlocking bones like metal staples. The most important ligament supporting the medial arch is the plantar calcaneo-navicular or spring ligament (See transverse tarsal joint), on the upper surface of which rests the unsupported part of the head of talus; the spring ligament itself is supported from below by a slip of tibialis posterior tendon. When this ligament is permanently stretched, it culminates in the formation of flat foot.

3. Factors acting as tie-beams—The structures which prevent separation of the pillars of the medial arch are as follows: Plantar aponeurosis, abductor hallucis, medial part of flexor digitorum brevis, tendon of flexor hallucis longus, medial part of the tendon of flexor digitorum longus and flexor hallucis brevis.

4. Suspending the arch from above—Tendon of tibialis anterior and superficial fibres of the deltoid ligament of ankle joint exert sling action. Tendon of tibialis posterior and its tentacular insertions of the plantar surface of most of the tarsal and metatarsal bones support the arch from below and exert sustentacular action.

Maintenance of lateral longitudinal arch

1. Shape of bones—A triangular projection of bone known as the calcanean angle of cuboid projects backward from the inferior border of the proximal articular surface of the cuboid and occupies the lower part of the anterior articular surface of the calcaneus. This bony projection maintains the upward tilt of the long axis of the calcaneus.

2. Intersegmental tiers—The long and short plantar ligaments act as important binding agents for the lateral arch.

3. Factors acting as tie-beams—Plantar aponeurosis, abductor digiti minimi, lateral part of flexor digitorum brevis and longus tendons, and flexor digiti minimi brevis.

4. Acting from above—Tendons of peroneus brevis and tertius exert sling action. Since the tendon of peroneus longus winds round the lateral surface of the cuboid and then proceeds forward and medially along the plantar surface of the cuboid, it maintains the lateral arch by sustentacular mechanism.
Maintenance of transverse arch

1. Shape of bones—Typical wedge-shaped nature of three cuneiform bones and bases of the middle three metatarsal bones accentuate the transverse arch.

2. Intersegmental tiers—Plantar surfaces of tarsal and metatarsal bones are tied together by the deep transverse ligaments, other intrinsic plantar ligaments, dorsal interossei, and oblique and transverse heads of the adductor hallucis muscles.

3. Acting as tie-beams—Tendons of peroneus longus and tibialis posterior.

4. Acting from above—Peroneus tertius and peroneus brevis on lateral side, and tibialis anterior on medial side; in fact, the factors which maintain the longitudinal arches also maintain the transverse arch.

After considering all the above factors acting as arch support, it is pertinent to observe which factors take up the important role. In standing, plantar ligaments and plantar aponeurosis bear the greatest stress and shoulder the maximum brunt of arch support. Electromyographically it has been demonstrated that tibialis anterior, peroneus longus and intrinsic muscles of the foot take no active role in the normal static support (Basmajian and Stecko). However, during locomotion these muscles become very active. When the great toe is passively dorsiflexed at the metatarsophalan-gal joint, the plantar aponeurosis by means of ‘windlass action’ approximates the heads of metatarsals to the heel, and thereby increases the height of the arch (Hicks, J. H.: The plantar aponeurosis and the arch. J. Anat., 88:25, 1954).

Failure of arch support depends upon the duration of the stress and not upon the severity of the stress. Individuals who stand immobile for long periods, especially if overweight, exert excessive stress on the plantar ligaments and are prone to develop flat foot. Athletes and those who walk much, put great stress on their arches intermittently; they will be able to maintain their arches with adequate training to develop the muscle tone.

Propulsive mechanism of the foot—

In walking, the weight borne by the foot is successively transferred along the heel, lateral border and the ball of the foot, and the last part to leave the ground is the anterior pillar of the medial longitudinal arch and the medial three digits. The gradual extension of the medial toes increases the height of the medial arch by the ‘windlass action’ of the plantar aponeurosis. Extension of the great toe elongates the flexor hallucis and flexor digitorum longus muscles, and this increases the force of their subsequent contraction. Contraction of both long and short flexor muscles of toes, increases the force of take-off by pressing the toes on the ground. The lumbricals prevent the toes from buckling when pulled by the flexor digitorum longus.

In running the heel remains above the ground, but the take-off point is maintained by the anterior pillar of the medial longitudinal arch.

Walking cycle

In walking, a person makes about 1700 to 1800 foot strikes in every mile, and it is estimated that the average man walks 70,000 miles in his life-time (Clinical symposia – Ciba, 37, 1985).

Normal walking on level ground consists of a series of swing and stance phases in succession. The swing phase takes place when the lower limb is off the ground, and in stance phase the foot strikes the ground and bears weight. A walking cycle includes the period from the heel-strike of one foot to the heel-strike of the same foot (Fig. 26.6).

During each cycle the head is displaced upward twice in stance phase, by alternate uses of lower limbs and undergoes corresponding downward movement in swing phase. These vertical displacements are known as the ‘bobbing’ of the head. The amount of vertical displacement is about 5 cm.

During locomotion lateral displacement of about 5 cm is evident when a person is viewed from the front or from behind. In swing phase the person bends the trunk to the side on which he stands for the purpose of balancing, and the trunk displacement is reversed when the other lower limb bears the weight alternately. Simultaneously the arm undergoes alternate forward swing with the opposite leg.

Sequence of movements in walking cycle

In the first part of swing phase the hip, knee and ankle are flexed. The limb then begins to extend and is fully extended until the heel of the advancing foot
strikes the ground. Hip flexors are most active during the early part of the swing, and the hip extensors are maximally active at heel-strike. Dorsiflexors of the foot are active at the beginning of swing phase to clear the foot from the ground, and after heel-strike to prevent it from slapping the ground.

At the beginning of stance phase the knee flexes slightly when the weight is fully borne. It again undergoes full extension at the end of the stance phase, as a preparatory to the push-off of the succeeding swing phase. The foot is then bent at the metatarso-phalangeal joints. The plantar flexors of the foot are most active during the later half of stance, particularly during take-off. During the same period the toes tend to flex and grip the ground. The long extensors and the intrinsic muscles of the foot stabilize the toes and provide fixed origins for the long flexors and extensors to act on the leg. Invertors and evertors of foot are the important stabilizers in stance phase and produce a shift of weight distribution among the heads of the metatarsals.

The downward pelvic tilt on the unsupported side due to the effect of gravity, is minimised by the abductors of the hip on the stance side. During walking, this pelvic tilt alternates from side to side.

During walking, slight rotation takes place at the hip and knee joints. Femur rotates medially on tibia during knee extension when the foot is on the ground or rotates in reverse order where the foot is off the ground. As the limb advances, the femur rotates laterally at the hip joint to keep the foot straight ahead.

Walking is a laboriously learned and automatic activity, depending upon the reflex patterns mediated by the spinal cord and controlled by the brain. The walking reflexes are regulated by a variety of sensory informations of tactile, ligamentous, articular and musculo-tendinous nerve endings. The pattern of walking may be altered by individual style, poor posture, overweight, foot wear, apart from many other factors. Disturbances of gait are important signs in many disorders of the central nervous system.

Disturbances of gaits may be encountered in the following conditions:

1. Ataxic gait—This is observed in tabes dorsalis which involves degeneration of the posterior white funiculi of spinal cord, resulting in loss of proprioceptive sense from the lower extremities. The patients walk on a wide base, lift the advancing leg too high and slap their feet on the ground and fix their eyes to the ground to see the location of their feet. With eyes closed, the ataxia is much worse.

2. Hemiplegic gait—The affected leg is rigid and is swung from the hip in a semicircle by the movements of the trunk. The patient leans to the affected side and the arm on that side is held in semiflexed position. Since the toes of hemiplegic lower limb tend to be forced down, abduction and circumduction of the limb are necessary to move it forward.
3. **Scissors gait**—In spastic paraplegia, the legs are adducted, crossing alternately in front of one another with the knees scraping together.

4. **Staggering Gait**—This is observed in drunken state or in drug poisoning or in flocculonodular lobe syndrome. Balancing of the trunk is disturbed and the patient is unable to walk on a straight line.

5. **Waddling Gait**—This results from dislocation of hips or muscular dystrophies with weakness of the hips. The waddle results from difficulty in maintaining the pelvis at a proper angle to the weight-bearing extremity, with downward tilt of the pelvis to the unsupported side which produces exaggerated compensatory sway of the trunk toward the weight bearing side.

6. **Cerebellar Gait**—It is characterised by marked irregularity and unsteadiness associated with vertigo and a tendency to reel to one side.

7. **Propulsion Gait**—In Parkinsonism with lesions in basal ganglia, the patients have a stooped posture, walk with short quick steps so that they appear to be chasing their centre of gravity. Beginning of the movement is slow and they are unable to stop the movement when required.

8. **Limping Gait**—When a patient experiences pain by weight bearing on an affected lower limb, he takes short steps to get rid of weight from the painful limb. Eventually the sound limb is brought forward quickly to land on the floor, and thus produces limping gait.

**Deformities of the foot**

**Flat Foot**—Flat foot or pes planus is the commonest of all foot troubles and is associated with disappearance of arches of foot. Abnormal distribution of the body weight on to the arch, such as rapid increase in body weight, or loss of tone in the leg muscles from prolonged standing or fatigue may result in flattening. Faulty foot-wear, bad walking and long slender rapidly growing foot often seen in adolescents are predisposing factors of flat foot (Fig. 26.7).

**Pes cavus**—It is an exaggeration of the longitudinal arch and there is plantar flexion at the transverse tarsal joint, so that the anterior part of the foot drops below the level of the posterior part. When the patient walks with the highly arched foot, the toes are dorsiflexed at the metatarso-phalangeal joint and plantar flexed at the interphalangeal joints. Such deformity associated with pes cavus in known as claw-foot.

**Fig. 26.7. Deformities of foot.**

**Club foot**—The club foot or talipes may be congenital or acquired, and four primary types are recognised:

1. **Talipes equinus**, in which the foot is fixed in plantar flexed position and the toes are directed to the ground. The affected individuals practically run using the fore part of the feet similar to a horse.

2. **Talipes calcaneus**, in which the heel is on the ground and the toes remain upturned, because the foot is fixed in dorsiflexed position at the ankle joint.

3. **Talipes varus** is a deformity in which the foot is fixed in inversion and adduction, primarily at the subtalar and the talocalcaneo-navicular joints.

4. **Talipes valgus**, in which the foot is fixed in eversion and abduction.

Combinations of the primary deformities may take place in the form of talipes equino-varus, talipes calcaneovalgus and so on. Talipes equino-varus is probably the most common type in which the patient walks on the lateral border of the foot. Congenital talipes is occasionally associated with spina bifida. Factors involved in the development of congenital club foot may be due to failure of muscle growth to keep pace with skeletal growth, and imbalance in the growth of different muscles or tendons.

**March foot**—Sometimes the neck of the intermediate metatarsals undergo decalcification, when they are subjected to continuous strain. A minor injury may lead to pathological fracture in the neck of the affected bone. This is commonly observed in soldiers who, after a period of sedentary
occupation, are forced to walk for prolonged time; hence called march fracture.

**Hallux valgus** (Fig. 26.8)—In this condition the great toe is adducted towards the midline of the foot. Primary defect lies in some degree of abduction of the first metatarsal, and the deviation of the great toe appears subsequently by the wearing of narrow pointed shoes. This results in undue prominence of the medial part of the metatarsal head. A bursa or bunion usually forms in the subcutaneous tissues overlying the prominent area.

**Hammer toe** (Fig. 26.9)—This deformity usually affects the second or third toe, and it is often associated with hallux valgus. In this deformity the metatarsophalangeal and the distal interphalangeal joints are hyperextended, but the proximal interphalangeal joint is acutely flexed.
Rudimentary pairs of upper and lower limb buds grow out from the dorso-lateral body wall as paddle-shaped cylindrical structures (Fig. 27.1-a). The upper limb bud appears at 24 days opposite the pericardial sac and extends from the fourth cervical to the second thoracic somites. The lower limb bud develops at 28 days opposite the lumbo-sacral somites and is situated slightly caudal to the attachment of the umbilical cord. Each limb bud is covered by the surface ectoderm and contains a mesodermal core which is derived from the somatopleureic layer of the lateral plate under the inductive influence of the adjacent somites. The core mesoderm of the lateral plate differentiates to form the bones, ligaments, joints and vasculature of the limbs, whereas the limb musculature is derived from the mesodermal somites that migrate into the developing limb bud.

The interzonal mesenchyme between the cartilaginous models of the contiguous bones becomes loose, and develops cleft-like spaces which subsequently coalesce to form the synovial joint. Joints appear in the limbs during the third month. Limb development takes place over a period of 4 weeks from the fifth to the eighth weeks. The upper limbs develop slightly in advance of the lower limbs.

The distal end of each limb bud presents an expanded and flattened hand-plate or foot-plate, which is separated from the rest of the limb by a constriction. The expanded plate exhibits five longitudinal mesodermal condensations or digital rays separated by grooves. The disintegration of the grooves by apoptosis makes the digits free. Another constriction divides the rest of limb into upper and lower segments.

The limb musculature is derived from the mesodermal somites that migrate into the developing limb bud during the fifth week. The
Fig. 27.1-b – Ventral and dorsal muscle masses of the limb bud.

muscles are arranged into a ventral and a dorsal muscle mass with respect to the axial precursor of bones and joints (Fig. 27.1-b). The ventral muscle mass gives rise to the flexors and pronators of the upper limb, and to the flexors and adductors of the lower limb. The dorsal muscle mass gives rise to the extensors and supinators of the upper limb, and to the extensors and abductors of the lower limb. Some muscles, however, migrate from their site of origin and perform different functions.

The limb muscles are innervated by the branches from the ventral primary rami of spinal nerves; C₅ to T₁ for the upper limb, and L₄ to S₃ for the lower limb. Muscles derived from the dorsal mass are supplied by the dorsal branches of the ventral primary rami, whereas muscles originating in the ventral mass are supplied by the ventral branches of the ventral rami. The motor axons that innervate the limbs arrive at the base of the limb bud, where they join in a specific pattern to form the brachial plexus of the upper limb and lumbo-sacral plexus of the lower limb. The base of the limb bud acts as a decision-making region for the axons. Thereafter, the axons from the nerve plexus follow the growth cones of the limb bud along permissive pathways and reach the appropriate muscle compartment. The innervation of a specific muscle is probably regulated by cues produced by the muscle itself. Once the motor fibres have found their target muscles, the sensory fibres grow along the motor axons and innervate the sensory end organs in the limbs.

Initially, each limb bud projects laterally at right angles from the trunk, and presents a pre-axial and a post-axial border. The pre-axial border is supplied by the upper nerves and the post-axial...
border by the lower nerves of the limb plexus (brachial or lumbo-sacral). The distal end of the limb is, however, supplied by the intermediate nerves of the plexus (Fig. 27.2). With the developments of the elbow and knee, the fore arm and the leg are bent ventrally. Thereafter, both the upper and lower limbs are adducted to the trunk. During this process the upper limb is rotated laterally and the elbow is pointed on the dorsal side; consequently the flexor surface of the upper limb faces ventrally, and the pre-axial thumb finger and the radius occupy the lateral position. Simultaneously, the lower limb is rotated in reverse direction i.e., medially and the knee is directed on the ventral side; this allows the flexor surface of the lower limb to appear dorsally, and the pre-axial hallux and the tibia occupy the medial position.
SUPERIOR EXTREMITY

The visible landmarks are produced mostly by the bones. The palpable landmarks felt through the skin are represented by the muscles, tendons, arteries by their pulsations, and the nerves by rolling against bones. Muscles become palpable when they contract against resistance offered by the examiner.

Surface landmarks (Fig. 28.1, 28.2, 28.3):

The clavicle, the spinous, and the acromial processes of scapula are conspicuous around the shoulder girdle, because they are sub-cutaneous.

Tip of the acromion can be easily felt lateral to the acromio-clavicular joint.

Acromial angle is located where the lower border of the crest of spine of the scapula meets the lateral border of the acromion. It is an important landmark to measure the length of the upper limb.

The sub-cutaneous crest of spine, when traced medially, meets the medial (vertebral) border of the scapula at the level of third thoracic (T₃) spine. This is an important landmark at the back for the starting point of oblique fissure of the lung, about 2.5 cm lateral to the T₃ spine.

Inferior angle of scapula overlaps the seventh intercostal space and lies opposite the seventh thoracic (T₇) spine. It is felt beneath the upper part of latissimus dorsi and found to move laterally during abduction of the shoulder joint.

The tip of the coracoid process of the scapula projects almost straight forward, and is palpable about 2.5 cm below the junction of medial three-fourth and lateral one-fourth of the clavicle. It is overlapped by the anterior fibres of the deltoïd.

Lesser tubercle of the humerus is felt through the deltoïd at a point about 3 cm below the tip of the acromion.

Greater tubercle of the humerus is felt as the...
most lateral bony point in the rounded contour of
the shoulder region.

**Anterior fold of the axilla** becomes prominent
when the arm is adducted against resistance from
the abducted position. It is formed by the rolled up
lower border of the pectoralis major.

**Posterior fold of the axilla** lies at a lower level
and is more rounded than the anterior fold. Posterior
fold is formed by the latissimus dorsi medially and
teres major laterally; it is palpable by adopting the
similar procedure for the anterior fold.

**Insertion of the deltoid** can be easily felt at
the middle of lateral side of the shaft of the humerus, when the arm is maintained in abducted
position.

**Coracobrachialis** can be identified as a
muscular prominence in abducted arm, along the
proximal half of the medial margin of the biceps
brachii.

**Tendon of biceps brachii** becomes prominent
and can be grasped in the cubital fossa, when the
elbow is flexed against resistance.

**Medial epicondyle** of humerus is easily felt as
a conspicuous landmark in a flexed elbow.

When the posterior aspect of the extended
elbow is palpated, three bony features can be
identified:

**Apex of the olecranon process** is felt on the
inner side of the middle line.

**Lateral epicondyle** of humerus is readily
palpable in the upper part of a depression on the
lateral side of the olecranon process.

**Head of the radius** is situated below the lateral
epicondyle in the depression or dimple described
above; it can be felt to move during supination
and pronation of the forearm.

When the elbow is flexed, the lines joining the
tip of the olecranon and the two epicondyles form
an isosceles triangle.

**Head of the ulna** forms a rounded bony
elevation on the medial side of the back of the
wrist in a pronated hand.

The **styloid process of ulna** projects downword
from the ulnar head on the medial side of the
wrist.

The **styloid process of radius** is palpable by
following the lower part of the lateral border of
the radius, and about 1.25 cm below and the
slightly on a more anterior plane than the styloid
process of ulna.

**Tendons of flexor carpi radialis and palmaris
longus**—When the wrist joint is flexed against
resistance, two tendons become prominent on the
lateral side of the front of the wrist; the lateral one
for flexor carpi radialis and the medial one for
palmaris longus.

**Tendon of flexor carpi ulnaris** stands out
prominently along the medial side of the wrist,
when the joint is flexed against resistance. Traced below the tendon reaches the pisiform bone.

**Anatomical snuff box**—It is seen as a depression in the extended thumb on the lateral side of the wrist. The box is bounded *in front* by the tendons of abductor pollicis longus and extensor pollicis brevis, and *behind* by the tendon of extensor pollicis longus.

**Dorsal tubercle of lister** is palpable on the posterior surface of the lower end of radius near its middle, and lies in line with the cleft between the middle and index fingers.

**Pisiform bone** is felt as an elevation at the base of the hypothenar eminence, where the tendon of the flexor carpi ulnaris reaches for attachment.

**Hook of the hamate bone** is palpable by gentle pressure through the hypothenar eminence about 2 cm below the pisiform bone, and lies in line with the ulnar border of the ring finger.

**Tubercle of the scaphoid** is felt at the base of the thenar eminence; it is overlapped partly by the tendon of flexor carpi radialis.

**Crest of the trapezium** is palpable on deep pressure through the thenar eminence, and lies about 2 cm below the tubercle of the scaphoid.

**Heads of the metacarpals** are demarcated by the prominence of knuckles.

**Metacarpo-phalangeal joint** lies about 2 cm distal to the creases at the junction between the digits and the palm.

**Axillary artery**

The arm is held at right angle to the trunk and the palm is directed upward (Fig. 28.1).

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![Diagram: Front of the fore arm and palm](image)

**Key:**

1. Medial epicondyle
2. Lateral epicondyle
3. Tendon of biceps brachii
4. Bifurcation of brachial art.
5. Point at the junction of upper $\frac{1}{2}$ and lower $\frac{2}{3}$ of a line joining medial epicondyle and pisiform bone
6. Point 7 cm above the wrist
7. Point at the pulsation of radial art.
8. Point on radial side of pisiform bone
9. Pisiform bone
10. Tubercle of scaphoid
11. Crest of trapezium
12. Hook of hamate
13. Point in the middle of palm along the distal border of extended thumb
14. Flexor Retinaculum
15. Tendon of Flexor carpi radialis
16. Tendon of Palmaris longus
17. Tendon of Flexor carpi ulnaris

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Fig. 28.3. *Front of the fore arm and palm.*
Points

1. Take a point at the middle of the lower border of the clavicle;
2. Another point at the junction of anterior one-third and posterior two-thirds of the lateral wall of the axilla, where the pulsation of the artery is felt immediately below the prominence of the coraco-brachialis muscle.

Join the two points by a straight line which represents the axillary artery.

Note: When the arm is placed by the side of the trunk, the line for the artery describes a gentle curve with the convexity directed upward and laterally. On raising the arm above the head, the line presents a concavity upward and medially.

At the wrist

1. In addition to the last point in the forearm, take a point in the anatomical snuff box just below the tip of the styloid process of the radius;
2. A point in the proximal part of the first intermetacarpal space, where the artery enters the palm.

Join these point by a line to represent the artery. In this part artery passes obliquely downward and laterally deep to the tendons of abductor pollicis longus, extensor pollicis brevis and longus and superficial to the lateral ligament of the wrist joint, and finally disappears between the two heads of the first dorsal interosseous muscle.

Ulnar artery

1. Take a point about 1 cm below the bend of the elbow, just medial to the tendon of biceps brachii;
2. A point on the radial side of the pisiform bone. Join this point to the medial epicondyle by a straight line; take a point on this line at the junction of upper one third and lower two-thirds. Wipe out the proximal part of the line above this point (Fig. 28.3).

Join this new point with the first point by a line which slopes downward and medially, and the rest of the line extends vertically downwards. The total course of the ulnar artery is thus represented by the oblique upper part and vertical lower part of the composite line.

Superficial palmar arch

1. A point on the radial side of the pisiform bone;
2. A point on the hook of the hamate bone about 2 cm below the first point and in line with the ulnar border of the ring finger;

Draw a horizontal helping line across the palm along the distal border of the extended thumb (Fig. 28.3).
3. Take a point near the middle of the thenar eminence.

Join the points (1) and (2) by a vertical line, and the points (2) and (3) by a curved line which is convex distally; but the summit of the convexity does not extend below the horizontal line drawn across the palm. Finally, wipe out the horizontal line.
Thus the superficial palmar arch is represented by a “J” shaped curved line.

**Deep palmar arch**

1. Take a point just distal to the hook of the hamate bone.

Draw a horizontal line from this point 4 cm laterally. This represents the deep palmar arch, which lies about 1.25 cm proximal to the superficial palmar arch and describes a slight convexity towards the fingers.

**Radial nerve**

**In the arm**

1. A point at the junction of the anterior $\frac{1}{4}$rd and posterior $\frac{3}{4}$rd of the lateral wall of axilla, where the pulsation of the axillary artery is felt (see the terminal point for the axillary artery);

2. A point at the junction of upper $\frac{1}{4}$rd and lower $\frac{3}{4}$rd of a line joining the insertion of the deltoid and the lateral epicondyle of the humerus;

3. Put a point on the front of the elbow at the level of lateral epicondyle, about 1 cm lateral to the tendon of biceps brachii (Fig. 28.2). Join the points (1) and (2) by an oblique line in the back of the arm across the elevation produced by the long and lateral head of the triceps. It corresponds to the radial nerve in the spiral groove, and the second point demarcates the site where the nerve pierces the lateral intermuscular septum. The line is continued by joining the points (2) and (3) to mark the course of the nerve in the anterior compartment of the arm.

**In the fore arm**

1. Put a point 1 cm lateral to the tendon of biceps brachii at the level of the lateral epicondyle;

2. A point at the junction of upper two-thirds and lower one-third of the lateral border of the fore arm;

3. A point in the anatomical snuff box.

Join these points by a line which represents superficial terminal branch of the radial nerve in the fore arm.

**Posterior interosseous nerve**

*(Deep terminal branch of Radial nerve)*:

1. A point 1 cm lateral to the tendon of biceps brachii at the level of lateral epicondyle;

2. Put a point at the junction of upper one-third and lower two-thirds of a line joining the dorsal aspect of the head of radius to the dorsal tubercle of Lister;

3. A point on the dorsal tubercle of Lister.

Join these points by a line which crosses the elevation produced by brachioradialis and superficial extensor muscles in the upper part.

**Ulnar nerve**

**In the arm**

1. A point at the termination or axillary artery (see above);

2. A point at the middle of the medial border of the arm;

3. Put a point behind the base of the medial epicondyle by rolling the nerve against the bone.

Join these points by a line which represents the ulnar nerve in the arm. The second point is the site where the nerve pierces the medial intermuscular septum and then descends behind the medial epicondyle.

**In the fore arm**

1. As mentioned before, a point on the dorsal aspect of the base of the medial epicondyle;

2. A point on the radial side of the pisiform bone.

A line joining these points represents the ulnar nerve in the fore arm.

**Median nerve**

1. A point at the termination of axillary artery (see the axillary artery);

2. A point about 1 cm below the bend of the elbow, just medial to the tendon of biceps brachii;

3. Put a point in front of the wrist in between the tendons of palmaris longus and flexor carpi radialis; these tendons are made prominent by producing flexion of the wrist against resistance.

The line joining these points represents the entire course of median nerve.

**Axillary nerve** *(Circumflex nerve)*

Mark a point 2 cm above the mid-point of a line joining the tip of the acromion and the insertion of the deltoid muscle.

Draw a *horizontal line* through this point across the rounded prominence of the deltoid; this corresponds with the axillary nerve.
Musculo-cutaneous nerve

1. Take a point about 3 cm above the termination of axillary artery. (see axillary artery);

2. Put another point lateral to the tendon of biceps brachii about 2 cm above the bend of the elbow, where the nerve pierces the deep fascia and continues as the lateral cutaneous nerve of the fore arm.

Join these points by an oblique line which crosses the prominence of coracobrachialis and the biceps brachii.

Flexor retinaculum of the hand

1. A point on the pisiform bone;
2. A point on the tubercle of the scaphoid;
3. Put a point on the hook of the hamate;
4. A point on the crest of the trapezium.

Join the first and second points by a line concave upward; it represents the upper limit of flexor retinaculum and corresponds to the lower of the two transverse creases in front of the wrist. Join the third and fourth points by a line concave downwards and represents the lower limit of the retinaculum; it lies about 2 cm below the upper limit (Fig. 28.3).

Extensor retinaculum

1. Put a point on the salient lower part of the anterior border of the radius;
2. Take a point 2 cm above the first point;
3. A point on the tip of the styloid process of the ulna;
4. Take a point 2 cm below the third point on the medial side of the carpus.

Join the second and third points by a line, and first and fourth points by another line. Both the lines slope downwards and medially across the back of the wrist, and represent the upper and lower limits of the extensor retinaculum.

Common synovial sheath of the flexor tendons of the digits:

1. Draw the outlines of the flexor retinaculum as described above;
2. Take a point 2.5 cm above the retinaculum on the lateral edge of the tendon of the flexor carpi ulnaris, and another point at the same distance above the retinaculum on the medial edge of the tendon of flexor carpi radialis.

Join these points by a line which is extended towards and through the retinaculum. Continue the medial portion of the sheath distally along the tendon of the little finger up to the base of the distal phalanx, but the rest of common synovial sheath does not extend in the palm distal to the level of extended thumb.

Digital synovial sheaths of the middle three fingers:

Each digital sheath extends from the base of the distal phalanx to the head of the corresponding metacarpal bone.

INFERIOR EXTREMITY

Front of the thigh

Surface landmarks (Fig. 28.4):

Fold of the groin—It is an oblique skin crease, which marks the junction of the front of thigh and the anterior abdominal wall, and corresponds to the inguinal ligament.

Anterior superior iliac spine—It forms a palpable, occasionally visible, elevation at the lateral end of the fold of groin.

Pubic tubercle—It is palpable as a small elevation at the medial end of the fold of groin.

Mid-inguinal point represents the mid-point between the anterior superior iliac spine and the top of the symphysis pubis.

Adductor tubercle—It is the highest point on the medial condyle of femur, and can be identified by placing the hand flat, with the fingers pointing below, on the medial side of the thigh and tracing downwards to the knee. During such procedure the tip of the middle finger comes in contact with the adductor tubercle, where cord-like tendon of adductor magnus recognised on deep pressure reaches the tubercle.

Centre of the saphenous opening (fossa ovalis)—

It is represented by a point about 3 to 4 cm below and lateral to the pubic tubercle.

Femoral artery

1. Find out a point midway between the anterior superior iliac spine and the symphysis pubis (mid-inguinal point);
2. Another point in the adductor tubercle; join these points by a line;

**Upper two-thirds of the line** represents the **femoral artery**, which should be drawn when the thigh is flexed, slightly abducted and rotated laterally (Fig. 28.4).

**Femoral vein:**

After surface projection of the femoral artery, the **femoral vein** lies close to the medial side of the artery in the upper part, and behind the artery in most of its course with slight lateral inclination in the lower part.

**Femoral nerve:**

Take a point about 1.2 cm lateral to the midinguinal point, and draw a vertical line from that point for a distance of about 2.5 cm. This represents the femoral nerve.

**Great saphenous vein in the thigh** (Fig. 28.4)

It is represented by a line joining the adductor tubercle and the centre of the saphenous opening (vide supra).

**Gluteal region and back of the thigh**

**Surface landmarks** (Fig. 28.5):

**Iliac crest**—It extends from the anterior superior to posterior superior iliac spines and represents the junction of the back of the trunk and gluteal region.

**Tubercle of iliac crest** lies about 5 cm behind and above the anterior superior iliac spine; **transstribucular plane** joining the tubercles of both iliac crests passes through the upper border of **fifth lumbar spine**.

**Supra-crystal plane** is represented by a line joining the highest point of both iliac crests, and passes behind through the **fourth lumbar spine**.

**Posterior superior iliac spine** is represented by a **skirt dimple** at the back. A horizontal line joining posterior superior spines of both sides passes through the **second sacral spine**, where spinal dura and arachnoid mater end, and subarachnoid space filled with C.S.F. extends.
Greater trochanter of femur—It lies about a hand’s breadth below the tubercle of the iliac crest.

Gluteal fold—It is a horizontal skin fold which marks the upper limit of the back of thigh. It does not correspond to the lower border of gluteus maximus, and is formed by the fibrous adhesion between the skin and deep fascia.

Tuberosity of the ischium—It is palpable in semiflexed hip joint about 5 cm above the gluteal fold and the same distance from the median plane.

Nelaton’s line—It is represented by a line joining the anterior superior iliac spine and the most prominent part of ischial tuberosity. Under normal condition, the Nelaton’s line crosses the apex of the greater trochanter and the centre of the acetabulum.

Bryant’s triangle
(a) Draw a horizontal line from the anterior superior iliac spine backwards, with the subject in recumbent posture;
(b) Drop a perpendicular line from the above mentioned horizontal line to the top of greater trochanter;
(c) Complete the triangle by joining the anterior superior iliac spine and the top of greater trochanter.

When the sides of Bryant’s triangles are compared between the sound and the affected sides, upward or backward displacement of the greater trochanter can be assessed in dislocation of hip joint.

Sciatic nerve
(a) Draw a line joining the posterior superior iliac spine and ischial tuberosity. Take a point about 2.5 cm lateral to the mid-point of that line, which represents entry of the sciatic nerve in the gluteal region (Fig. 28.5).
(b) Take another point just medial to the mid-point of a line joining ischial tuberosity to the apex of greater trochanter.
(c) Put a point at the upper angle of popliteal fossa.

Join these points by a broad line which passes downwards and laterally, and represents the sciatic nerve.

LEG AND FOOT
Surface landmarks (Figs. 28.6, 28.7, 28.8):

Tubercle of tibia—It is a subcutaneous projection of the upper end of tibia, where the ligamentum patellae is attached in its upper part and the subcutaneous anterior border of tibia extends below.

Head of the fibula—It is a slight elevation on the posterolateral aspect of the upper part of leg, and lies vertically below the posterior part of the lateral condyle of the femur.

Neck of the fibula—It is a constriction below the head of fibula, where the common peroneal nerve can be rolled against it.

Medial malleolus—It is visible prominence at the lower end of the subcutaneous medial surface of the shaft of the tibia.

Lateral malleolus—It is a conspicuous projection on the lateral side of the ankle, and lies at a lower level and on a more posterior plane than the medial malleolus.

![Fig. 28.6. Foot and leg – medial side.](image-url)
Tubercle at the base of the fifth metatarsal can be felt half-way along the lateral border of the foot.

**Anterior tibial artery**

(a) Take a point 2.5 cm below the medial side of the head of the fibula (Fig. 28.8).
(b) Put another point midway between the medial and lateral malleoli.

Join these points by a line which passes downwards and slightly medially.

**Deep peroneal nerve (anterior tibial):**

(a) Put a point on the lateral side of the neck of fibula.
(b) Take two points, as mentioned above, for the anterior tibial artery.

Join these points by a line, which passes downwards and medially in the upper part and then follows vertically in line with the anterior tibial artery.

**Superficial peroneal nerve (musculo-cutaneous):**

(a) A point on the lateral aspect of the neck of fibula;
(b) Another point at the junction of the middle and lower one-third of the leg, on the anterior border of the peroneus longus where the nerve pierces the deep fascia. The peroneus longus is made prominent by eversion and plantar flexion of the foot.

Join these points by a line.

**Dorsalis pedis artery**

(a) A point midway between the two malleoli;
(b) Another point at the proximal end of the first intermetatarsal space (Fig. 28.8).

Join these points by a line which represents the artery.

**Superior extensor retinaculum**

It is represented by a broad band 3 cm wide from the anterior border of the subcutaneous triangular area of fibula to the lower part of the anterior border of tibia (Fig. 28.8).

**Inferior extensor retinaculum**

The stem of the retinaculum is represented by a band about 1.5 cm wide, which extends medially from the anterior part of the upper surface of the calcaneus across the dorsum of the foot (Fig. 28.8).

On the medial side of the tendon of extensor digitorum longus the band divides into two diverging limbs, each about 1 cm wide. The upper limb is attached to the medial malleolus; the lower
limb passes round the medial side of the foot and blends with the plantar aponeurosis.

**Popliteal artery**

The artery is represented by joining the following points (Fig. 28.8).

(b) Take a point at the lower limit of popliteal fossa.

Join these points by a line which represents the nerve; at first the nerve lies lateral to the popliteal artery and then descends on its medial side after crossing dorsal to the vessel.

**Tibial nerve (posterior tibial) in the leg**

(a) A point at the lower limit of popliteal fossa;
(b) Another point midway between the medial malleolus and the tendon calcaneus (Fig. 28.9).

A line joining these points represents the posterior tibial nerve.

**Common peroneal nerve (lateral popliteal nerve)**

(a) A point at the upper angle of the popliteal fossa;
(b) A point at the back of the head of fibula;
(c) Another point on the lateral side of the neck of fibula;

A line joining these points represents the nerve, which accompanies the medial side of the tendon of biceps femoris (Fig. 28.5).

**Posterior tibial artery**

(a) A point in the middle line of leg at the level of the neck of fibula, in line with the tibial tubercle;
(b) Another point midway between the tibial malleolus and the tendon calcaneous.

A line joining these points represents the artery (Fig. 28.9).
Flexor retinaculum

It is represented by a broad band, 2.5 cm wide, which extends downwards and backwards from the medial malleolus to the medial side of the heel. The lower border of the retinaculum passes from the tip of the malleolus to the medial tubercle of the calcaneus (Fig. 28.10).

Medial plantar artery and nerve

(a) Mark a point midway between the medial malleolus and the prominence of the heel.
(b) Take another point in the first interdigital cleft as far as the navicular bone.

Join these points by a line which extends forward (Fig. 28.10).

Lateral plantar artery and nerve

(a) A point midway between the medial malleolus and the prominence of the heel;
(b) A point about 2.5 cm medial to the tubercle at the base of fifth metatarsal bone;
(c) A point at the proximal end of the first intermetatarsal space (Fig. 28.10).

A line joining these points passes first forward and laterally, and then turns medially.