1. Overview of the anatomy of the upper and lower limbs

Mr Andrew Unwin

The human skeleton is divided into:

- The axial skeleton – skull, spinal column + ribcage
- The appendicular skeleton – upper + lower limbs
- The upper limb = pectoral girdle, upper arm, forearm + hand
- The lower limb = pelvic girdle, thigh, leg + foot

Embryology of the limbs

Limb buds develop from the neural tube of the trunk, and take the nerves destined to supply those parts with them

- Arms C5-T1
- Legs L2-S2

The upper limb is relatively straightforward; the flexor muscles are anterior and the extensor muscles are posterior. There is no significant rotation of the limbs during development.

The lower limb is more complicated; there is internal rotation during development, therefore the extensor muscles are anterior, and the flexors are posterior.

**Limb Compartments**

The limbs are composed of compartments, which tend to do the same thing, and have the same nerve/blood supply.

Eg anterior compartment of the upper arm:

- Muscles = brachialis, biceps + coraco-brachialis
- Segmental nerve supply = C5/6
- Peripheral nerve supply = musculo-cutaneous nerve
- Artery = profundus brachii artery
- Function = flex elbow

Limb compartments can then be viewed as either anterior or posterior.

**Compartments of the upper limb:**

- Pectoral girdle
- Intrinsic shoulder
- Anterior upper arm
- Posterior upper arm
- Anterior forearm
- Posterior forearm
- Intrinsic hand

**Compartments of the lower limb:**

- Hip abductors
- Hip extensors
- Hip flexors
- Anterior thigh
- Medial thigh
- Posterior thigh
- Anterior leg
- Lateral leg
- Posterior leg
- Intrinsic foot
BLOOD SUPPLY
Blood supply is like a railway track; arterial, venous (superficial + deep)

Arterial supply of the upper limb
- The aorta divides into a number of branches with a different arrangement on each side of the body, but a subclavian artery passes towards each upper limb in the root of the neck. As it leaves the clavicle, it enters the axilla and forms the axillary artery.
- The axillary artery has numerous branches and anastomosis, but leaves the axilla and enters the upper arm to form the brachial artery.
- The brachial artery supplies the upper arm, and one of its major branches in the upper arm is the profunda brachii artery.
- At the level of the elbow, the brachial artery divides into the ulnar artery and radial artery.
- The radial artery supplies the lateral/radial aspect of the forearm and hand.
- The ulnar artery supplies the medial/ulnar aspect of the forearm and hand. It has a main branch; the common interosseous artery, which itself divides into anterior + posterior branches.
- The radial and ulnar arteries meet again via an anastomosis in the hand at the palmar carpal arch and the dorsal palmar arch. These arches give off metacarpal arteries and digital arteries to supply the fingers.

Venous drainage of the upper limb
The venous system of the upper limb largely follows the arteries. There is both a superficial and deep system.
The superficial system consists of the cephalic and basilic vein. They arise from the dorsal venous arch on the back of the hand.
- The basilic vein runs superficially on the medial (ulnar) aspect of the forearm and passes deep halfway up the arm to form the axillary vein.
- The cephalic vein runs superficially on the lateral (radial) aspect of the forearm + upper arm, and passes deep at the level of the shoulder to drain into the axillary vein.
The deep system consists of two venous pathways:
- The deep forearm veins pass from the forearm and drain into the basilica vein.
- The venae comitantes pass alongside the brachial artery in the upper arm and drain into the axillary vein.

THE NERVOUS SYSTEM
The nervous system can be divided topographically into the central nervous system and peripheral nervous system. It is divided functionally into:
- The somatic nervous system (motor to skeletal muscle + sensory from skin/muscle).
- The autonomic nervous system (motor/sensory from cardiac/smooth muscle, glands, gut etc).

Spinal nerve anatomy
Anatomically, the spinal cord ends at L2, therefore is shorter than the spinal column. This means that the spinal segments do not correspond directly to the vertebrae. There are 31 pairs of spinal nerves, each formed from the union between an anterior/ventral root (motor) and a dorsal/posterior root (Sensory) at the intervertebral foramen.
- 8 cervical (7 vertebrae)
- 12 thoracic
- 5 lumbar
- 5 sacral
- 1 coccygeal

Each spinal nerve splits into an anterior and posterior ramus immediately as it passes through the intervertebral foramen.
- The anterior rami merge to form the major plexi of the limbs.
- The posterior rami are smaller, less important, and are mainly cutaneous

Spinal nerve supply to the body is as follows...
- C1-4 > neck
- C5-T1 > upper limb
- T2-L1 > trunk
- L2-S2 > lower limb
- S2-C1 > perineum

Innervation of each muscle is both segmental (ie corresponding functional division from spinal cord) and peripheral (physical nerve that emerges from the plexus). Note different diseases may target each of these separately, ie MS targets different segments of the spinal cord, whereas trauma may only affect 1 peripheral nerve.

**Segmental supply**
Segmental supply tends to be the same for each compartment. Each compartment is supplied by a group of nerve cell bodies within the spinal cord, allowing an efficiency of action.

**Segmental motor supply** is from the ventral cell bodies within the spinal cord. In the foetus the limb bud grows out from the trunk and take the spinal nerves destined to supply those parts with them:
- C5-T1 > upper limb
- L2-S2 > lower limb

The anterior rami of spinal nerves form plexi, which then divide to form anterior and posterior peripheral nerves.
- Anterior nerves supply the flexor muscles
- Posterior nerves supply the extensor muscles

**Basic principles** of segmental spinal innervation of muscles are as follows...
- Most muscles are supplied by two adjacent segments of the spinal cord
- Muscles with the same primary action on a joint share the same spinal segmental nerve supply
- The opposing muscles also share a common segmental supply, either two segments above or below

<table>
<thead>
<tr>
<th>Upper limb component</th>
<th>Action + Segmental supply</th>
<th>Opposing action + supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td>Abduction (C5)</td>
<td>Adduction (C6/7/8)</td>
</tr>
<tr>
<td></td>
<td>External rotation (C5)</td>
<td>Internal rotation (C6/7/8)</td>
</tr>
<tr>
<td>Elbow</td>
<td>Flexion (C5/6)</td>
<td>Extension (C7/8)</td>
</tr>
<tr>
<td>Forearm</td>
<td>Supination (C6)</td>
<td>Pronation (C7/8)</td>
</tr>
<tr>
<td>Wrist</td>
<td>Flexion (C6/7)</td>
<td>Extension (C6/7)</td>
</tr>
<tr>
<td>Long tendons to hand</td>
<td>Flexion (C7/8)</td>
<td>Extension (C7/8)</td>
</tr>
<tr>
<td>Intrinsic hand</td>
<td>T1</td>
<td></td>
</tr>
</tbody>
</table>

NB: the 2 above/below rule for the upper limb does not hold very well, as below the elbow the nerves are organized to allow accurate hand and wrist movements

**Segmental sensory supply** is via dermatomes (patch of skin supplied by a spinal cord segment), which overlap considerably.
- In the upper limb, the skin uses C5-T1 via the brachial plexus. There is a regular order of dermatomal distribution in the upper limb
- In the lower limb, the embryological rotation complicates this order. However dermatomes correspond to T12-S3)

**Peripheral innervation**
Organization of the spinal nerves to form cables = peripheral nerves, via plexi
- The innervation of the upper limb is derived from the **brachial plexus**, which is derived from the anterior rami of C5-T1 spinal nerves.
- The innervation of the lower limbs is derived from the **lumbo-sacral plexus**, which is derived from the anterior rami of the lumbar and sacral spinal nerves.

The peripheral nerve supply distributes the segmental supply, and is usually formed by a mixture of both motor and sensory aspects.
2. The Shoulder and Upper Arm
Mr Andrew Unwin

**BONES**
There are 3 bones within this region:
- Scapula (posterior)
- Clavicle (anterior)
- Humerus (long bone of the upper arm)

**Clavicle**
The clavicle has an S-shaped contour, with a forward-facing convex medial part, and a forward-facing convex lateral part.
- The lateral end (acromial end) is flat, with a small oval facet on the end for articulation with the scapula = **acromioclavicular joint**
- The medial end (sternal end) is more robust, and has a much larger facet for articulation with the manubrium and 1st costal cartilage = **sternoclavicular joint**
- The shaft of the clavicle is divided into a medial 2/3rd and a lateral 1/3.
- The inferior surface of the lateral third has a distinct tuberosity = **conoid tubercle**, which is the site of attachment for the coracoclavicular ligament, and a **trapezoid line** which is a site of attachment for the trapezoid muscle
Scapula

The scapula is a large, flat triangular bone that consists of:
- 3 angles (lateral, superior + inferior)
- 3 borders (superior, lateral + medial)
- 2 surfaces (costal + posterior)
- 3 processes (acromion, spine + coracoid process)

The anterior/costal surface of the scapula is attached to the chest wall, and moves either up/down or over the shoulder along the posterior chest wall, moving the clavicle with it.

- The lateral angle of the scapula is marked by the glenoid fossa (Cavity) which articulates with the head of the humerus
  - Inferior to this fossa is the site of attachment of the long head of the triceps muscle = infraglenoid tubercle
  - Superior to the fossa is the site of attachment of the long head of the biceps muscle = supraglenoid tubercle
- The posterior surface is divided by the spine into the supraspinous fossa and infraspinous fossa
  - The acromion is a anterolateral projection of the spine, articulates with the clavicle
- The costal surface is unremarkable, characterized by the concave subscapular fossa
- The lateral border of the scapula is strong and thick for muscle attachment, whereas the medial and superior border are thin and sharp
  - The superior border is marked on its lateral end by the coracoid process; a hook-like structure that projects anterolaterally and is inferior to the lateral part of the clavicle. It is also marked by suprascapular notch, which is medial to the root of the coracoid process

Proximal Humerus
The proximal end of the humerus consists of the head, the anatomical neck, the greater and lesser tubercles, the surgical neck, and the superior half of the shaft of humerus
- The head is half-spherical in shape and projects medially and somewhat superiorly to articulate with the glenoid cavity of the scapula
- The anatomical neck is formed by the immediate narrow constriction distal to the head
LCRS Anatomy of the Limbs

- The **greater tubercle** is lateral in position, and has 3 large smooth facets for muscle tendon attachment:
  - The superior facet is for attachment of the supraspinatus muscle
  - The middle facet is for attachment of the infraspinatus muscle
  - The inferior facet is for attachment of teres minor
- The **lesser tubercle** is anterior in position and its surface is marked by a large impression for attachment of the subscapularis muscle
- A deep intertubercular sulcus (**bicipital groove**) separates the greater and lesser tubercles and runs inferiorly. The long head of the biceps brachii passes through this sulcus:
  - The pectoralis major muscle attaches to the lateral lip of this groove
  - The teres major attaches to the medial lip of this groove
  - The latissimus dorsi muscle attaches to the floor of the groove
- Midway along the lateral length, the bicipital groove becomes continuous with the **deltoid tuberosity**: the site of insertion of the deltoid muscle into the humerus
  - On the medial surface, there is also a thin vertical roughening for attachment of the coracobrachialis muscle
- The **surgical neck** marks the area between the expanded head and narrow shaft; it is weaker and thus a common site for fracture.

**JOINTS**

There are 3 joints that make up the shoulder complex. The stenoclavicular + acromioclavicular joints link the two bones of the pectoral girdle together and to the trunk. The glenohumera joint is the articulation between the humerus of the arm and the scapula.

**(Sterno-clavicular joint)** occurs between the proximal end of the clavicle and the clavicular notch of the manubrium of the sternum (+ small part of first CC), with an articular disc separating the articular cavity.

- The **function** of the SCJ is to allow movement of the pectoral girdle, acting as the only connection of the upper limb to the chest

**Acromioclavicular joint** is a small synovial joint between the oval facet on the medial surface of the acromion and a similar facet on the lateral end of the clavicle. This is surrounded by a joint capsule which is reinforced by:

- **Acromioclavicular ligament** which lies superirol
- **Coracoclavicular ligament** which spans the distance between the coracoid process of the scapula and the inferior surface of the acromial end of the clavicle. It comprises:
  - **Trapezoid ligament**, which attaches to the trapezoid line on the clavicle
  - **Conoid ligament**, which attaches to the relevant conoid tubercle on the clavicle
- The **coracoclavicular ligament**, which is not clinically important but often is a cause of impingement of the shoulder joint.

The ACJ is frequently injured by falls onto the outstretched hand

- More minor dislocations occur when the acromio-clavicular ligament alone is torn
- More severe dislocations occur when the coraco-clavicular ligaments are also torn

**Glenohumeral joint** is the shoulder joint; a synovial ball and socket articulation between the head of the humerus and the glenoid cavity of the scapula.

- Joint **stability** is provided by the rotator cuff muscles, the long head of the biceps brachii and extracapsular ligaments
• Each articular facet in the joint is covered by hyaline cartilage
• The glenoid cavity is deepened and extended by a fibrocartilaginous collar = **glenoid labrum**. This is continuous with the long head of the biceps brachii muscle, which attaches to the supragnoid tubercle.
• The synovial membrane attaches to the margins of the articular surface and lines the fibrous membrane of the **joint capsule**. This fibrous membrane is then thickened:
  o Anterosuperiorly in 3 locations to form the superior, middle and inferior **glenohumeral ligaments**. These pass from the superomedial margin of the glenoid cavity to the lesser tubercle, and strengthen the anterior portion of the shoulder capsule
  o Superiorly between the base of the coracoid process and the greater tubercle of the humerus by the **coracohumeral ligament**. This strengthens the capsule superiorly.
  o Between the greater and lesser tubercles of the humerus by the transverse umeral ligament, which holds the tendon of the long head of the biceps brachii
• The joint capsule has a very important clinical arrangement. As well as extending from the glenoid to the humeral head, it has two extensions:
  o **Subacromial bursa** – the capsule extends above the humeral head to form a bursa between the humeral head and the overlying acromial process. This is often the site of pathology in impingement of the shoulder
  o An extension around the long head of the biceps brachii as it lies within the bicipital groove.
• The **coraco-acromial ligament** prevents the humerus from rising superiorly
• **Movements** at the joint include...
  o flexion (moving arms forward) – by clavicular head of pectoralis major, anterior fibres of deltoid
  o extension (moving arms backwards) – lattisimus dori and posterior deltoid
  o abduction (movement laterally) – first 15 degrees by supraspinatus, after 15 degrees by central fibres of central deltoid
  o adduction (movement medially) – by pectoralis major and lattissimus dorsi
  o external rotation (arms behind head or lifting forearms up when abducted) – by infraspinatus
  o internal rotation (undoing bra or moving forearms down when abducted) – by subscapularis
  o circumduction (cricket bowling)
• the shoulder also stabilized by rotator cuff muscles, deltoid, coraco-brachialis and the short + long head of the biceps brachii
Scapulo-thoracic joint (physiological not anatomical) represents the articulation between the scapula and the chest wall. The main movements of the scapula at the scapula-thoracic joint are as follows:

- Elevation – superior trapezius, levator scapulae, rhomboids
- Depression – inferior trapezius, pectoralis minor, serratus anterior
- Protraction (forward + lateral) – pectoralis minor, serratus anterior
- Retraction (backward + medial) – rhomboids, middle trapezius, lattisimus dorsi
- Upward rotation – superior trapezius, inferior trapezius, serratus anterior
- Downward rotation – pectoralis minor, lattisimus dorsi, rhomboids, levator scapulae

### MUSCULAR ANATOMY

In the shoulder + upper arm region, there are 5 groups of muscles:

- Anterior pectoral muscles
- Posterior pectoral muscles
- Intrinsic shoulder muscles
- Anterior compartment of upper arm
- Posterior compartment of upper arm

**Anterior pectoral muscles**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pectoralis major</strong></td>
<td>Clavicular head, sternum, CC 2-6</td>
<td>Greater tubercle + lateral lip of bicipital groove of humerus</td>
<td>Adducts + internally rotates humerus Upper fibres flex Lower fibres extend</td>
<td>Medial + lateral pectoral nerves (C5-7)</td>
</tr>
<tr>
<td><strong>Pectoralis minor (deep to pect major)</strong></td>
<td>Ribs 3-5</td>
<td>Coracoid process of scapula</td>
<td>Depression + protraction of the scapula</td>
<td>Medial pectoral nerve (C8, T1)</td>
</tr>
<tr>
<td><strong>Subclavius</strong></td>
<td>Rib 1</td>
<td>Inferior border of clavicle</td>
<td>Depresses and moves clavicle anteriorly Stabilizes pectoral girdle</td>
<td>Subclavian nerve (C5-6)</td>
</tr>
<tr>
<td><strong>Serratus anterior (inferior to pect minor)</strong></td>
<td>Superior 8/9th rib</td>
<td>Anterior surface of medial border of scapula</td>
<td>Hold scapula against ribcage, scapular protraction</td>
<td>Long thoracic nerve (C5-7)</td>
</tr>
</tbody>
</table>

**Posterior pectoral muscles**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trapezius</strong></td>
<td>Extensive origin (skull, vertebral spines of C7-T12)</td>
<td>Lateral portion of clavicle, acromion and scapular spine</td>
<td>Upper: extend head/neck, elevate shoulder Middle: adduct, stabilize scapula Lower: depress scapula</td>
<td>Accessory nerve (CNXI) and C3-C4</td>
</tr>
<tr>
<td><strong>Lattisimus dorsi</strong></td>
<td>Spinous processes of T7-L5, Ribs 8-10, thoracolumbar aponeurosis, iliac crest + inferior angle of scapula</td>
<td>Floor of the bicipital groove of the humerus</td>
<td>Extend, adduct + internally rotate shoulder</td>
<td>Long subscapular nerve (C6-8)</td>
</tr>
<tr>
<td><strong>Levator scapulae</strong></td>
<td>Transverse processes of C1-5</td>
<td>Posterior surface of medial border of</td>
<td>Elevates the scapula</td>
<td>Dorsal scapular nerve (C5) and</td>
</tr>
<tr>
<td>Muscle</td>
<td>Origin</td>
<td>Insertion</td>
<td>Action</td>
<td>Innervation</td>
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</tr>
<tr>
<td><strong>Deltoid</strong></td>
<td>Inferior edge of scapular spine, lateral margin of acromion, anterior border of lateral 1/3rd of clavicle</td>
<td>Deltoid tuberosity of humerus</td>
<td>Major abductor of arm past 15 degrees</td>
<td>Axillary nerve (C5/6)</td>
</tr>
<tr>
<td><strong>Teres Major</strong></td>
<td>Posterior surface of inferior angle of scapula</td>
<td>Medial lip of bicipital groove of humerus</td>
<td>Internal rotation + extension</td>
<td>Inferior subscapular nerve (C5-7)</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>Medial 2/3rd of supraspinous fossa</td>
<td>Most superior facet on greater tubercle of humerus</td>
<td>Rotator cuff muscle Initiation of abduction</td>
<td>Suprascapular nerve (C5/6)</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>Medial 2/3rd of infraspinous fossa</td>
<td>Middle facet on posterior surface of greater tubercle of humerus</td>
<td>Rotator cuff muscle External rotation</td>
<td>Suprascapular nerve (C5/6)</td>
</tr>
<tr>
<td>Teres minor</td>
<td>Upper 2/3rd of posterior scapula adjacent to lateral border</td>
<td>Inferior facet on posterior surface of greater tubercle of humerus</td>
<td>Rotator cuff muscle External rotation</td>
<td>Axillary nerve (C5/6)</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>Subscapular fossa</td>
<td>Lesser tubercle of humerus</td>
<td>Rotator cuff muscle Internal rotation</td>
<td>Superior + inferior subscapular nerve (C5/6)</td>
</tr>
</tbody>
</table>

The supraspinatus, infraspinatus, teres minor and subscapular form the rotator cuff muscles. This cuff stabilizes and holds the head of the humerus in the glenoid cavity of the scapula without compromising the arm’s flexibility and range of motion.

NB: sometimes easy to think as a summary...
- Abduction = C5
- Adduction = C6, 7, 8
- External rotation = C5
- Internal rotation = C6, 7, 8

### Anterior compartment

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps Brachii</td>
<td>Long head – supraglenoid tubercle of scapula Short head – apex of coracoid process</td>
<td>Radial tuberosity</td>
<td>Flexor of the elbow, supinator of arm (palms up)</td>
<td>Musculocutaneous nerve (C5-7)</td>
</tr>
<tr>
<td>Brachialis</td>
<td>Anterior aspect of humerus</td>
<td>Tuberosity of the ulna</td>
<td>Flexor of the forearm</td>
<td>Musculocutaneous nerve (C5/6) + little bit of radial</td>
</tr>
</tbody>
</table>
### Coraco-Brachialis

| Coraco-Brachialis (insignificant) | Apex of coracoid process | Linear roughening of midshaft of humerus on medial side | Flexor of arm | Musculocutaneous nerve (C5-7) |

### Posterior compartment

<table>
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<tr>
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<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Triceps brachii</strong></td>
<td>Long head – infraglenoid tubercle of scapula&lt;br&gt;Medial head – posterior surface of humerus&lt;br&gt;Lateral head – posterior surface of humerus</td>
<td>Olecranon (elbow bone, projection of ulna at joint)</td>
<td>Extension of the forearm&lt;br&gt;Long head can extend and adduct arm at shoulder</td>
<td>Radial nerve (C6-8)</td>
</tr>
<tr>
<td><strong>Aconeus</strong> (insignificant)</td>
<td>Lateral epicondyle of humerus (proximal end)</td>
<td>Lateral surface of olecranon</td>
<td>Stabilizes elbow during pronation and supination</td>
<td>Radial nerve (C6-8 + T1)</td>
</tr>
</tbody>
</table>

**Thing to note:** compartments that have opposing actions have segmental innervation with a two vertebrae difference. Compartments that are more distal but have the same action have a segmental innervation of a one vertebrae difference.
AXILLA
The axilla is a gateway to the upper limb. It is an irregularly shaped pyramidal space with 4 sides, an apex and floor.
- The floor is formed by skin, subcutaneous tissue and fascia extending from the arm to the chest
- The apex lies between the first rib, the clavicle and the superior border of the subscapularis muscle
- The anterior wall is formed by the pectoralis major + minor muscles
- The posterior wall is formed by the scapula/subscapularis (superiorly) and the teres minor + latissimus dorsi (inferiorly)
- The lateral wall is formed by the humerus
- The medial wall is formed by the upper thoracic wall (ribs 1-4) and the serratus anterior muscle

The contents of the axilla are:
- Arteries (axillary artery +its branches)
- Veins (axillary vein + tributaries)
- Lymphatic vessels + lymph nodes
- Nerves (brachial plexus)

BLOOD VESSELS
Arteries
- The subclavian artery arises from the right brachiocephalic artery (right side) or aorta (left side). It then runs in the root of the neck
- When the artery passes over the first rib, it becomes the axillary artery.
- This passes through the axillary region to become the brachial artery as it passes the inferior border of the teres major muscle
- The axillary artery is divided into 3 parts by the pectoralis minor muscle, giving a number of branches in the axilla
- The brachial artery is the main artery to the arm. It ends by dividing at the level of the elbow into the radial and ulnar arteries.
  - In the distal part of the limb it runs alongside the median nerve
  - In its course it gives a lot of branches, most notably the profunda brachii artery which follows the radial nerve
- There is an extensive arterial anastomosis at the level of the elbow

Veins
Superficial system
- 2 big superficial veins = medial basilic + lateral cephalic
- both orginate at the dorsal venous network of the hand, and travel up the base of the forearm to the elbow (basilic at medial/ulnar side, cephalic at lateral/radial side)
- the cephalic vein terminates via passing deep in the delto-pectoral triangle to join the axillary vein
- the basilic vein passes deep halfway up the arm (at level of 7th rib/inferior border of the teres major) to form the axillary vein along with the venae comitantes of the brachial artery
- there is also a connecting vein between the two; the median cubital vein, which passes through the cubital fossa and is clinically important for veneuncture

Deep system
- The axillary vein (deep) is formed as the basilic vein passes through the fascia to join the venae comitantes of the brachial artery
- The axillary vein ends at the first rib, where it becomes the subclavian vein
- The axillary vein receives a large number of tributaries, including the cephalic vein and some abdominal veins (which is important clinically if the abdominal veins become blocked by a tumour)
LYMPHATIC DRAINAGE

- Lymph drains from the hand via superficial lymphatics which run alongside the cephalic and basilic veins.
- Some lymphatics pass directly and superficially up the arm but there are also some cubital lymph nodes at the elbow.
- Similarly, there are some delto-pectoral lymph nodes alongside the cephalic vein.
- Ultimately the lymph drains into the axillary lymph nodes.
- There are also some deep lymphatics, which run alongside the deep veins, and which similarly terminate in the axillary lymph nodes.
- The axilla contains a large number of axillary lymph nodes, and these are of significant importance clinically in relation to carcinoma of the breast, as the lymphatic drainage of the breast includes these lymph nodes.
- There are five groups of axillary lymph nodes – apical, pectoral, subscapular, humeral and central. All the groups drain via the apical lymph nodes.
- The apical group of axillary lymph nodes drains into the subclavian lymphatic trunk, which join ultimately the right lymphatic duct (right side) or the thoracic duct (left side).
- The axillary lymph nodes are frequently dissected and “sampled” in patients with carcinoma of the breast. There are two nerves in close relation to the axillary lymph node region. These are;
  - the long thoracic nerve – supplies the serratus anterior muscle.
  - The thoraco-dorsal nerve – supplies the latissimus dorsi muscle.
- These nerves may be cut or damaged during axillary lymph node dissections. Section of the long thoracic nerve surprisingly does not produce too much disability but section of the thoraco-dorsal nerve does. Section of the long thoracic nerve causes paralysis of the serratus anterior muscle and as a result winging of the scapula.

NERVES

The brachial plexus is the plexus of the nerves that serves the upper limb. It is formed from the anterior primary rami of C5-T1 spinal nerves.

In summary the plexus consist of:

- roots - formed in the neck from the spinal nerve roots
- trunks - formed from the roots in the inferior portion of the neck
- divisions - formed from the trunks behind the clavicle
- cords - formed from the divisions in the axilla in close proximity to the axillary artery
- branches - the peripheral nerves supplying the upper limb itself.

In the pectoral and upper arm region are a number of nerves of importance:

- Long Thoracic Nerve – supplies serratus anterior
- Suprascapular Nerve – supplies supraspinatus and infraspinatus
- Lateral pectoral nerve – supplies pectoralis major
- Thoraco-dorsal nerve – latissimus dorsi
- The axillary nerve – supplies teres minor and then the deltoid as well as an area of skin over the deltoid.
- The musculo-cutaneous nerve
- The ulnar nerve
- The median nerve
- The radial nerve

The last four nerves (musculo-cutaneous, ulnar, radial and median nerves) are the main nerves to the arm.

- The musculo-cutaneous nerve (C5-7) is the nerve of the anterior compartment of the upper arm (coraco-brachialis, brachialis and biceps). It continues as the lateral cutaneous nerve of the forearm. It lies close to the subscapularis tendon anterior to the shoulder and can be damaged at the time of surgery to the front of the shoulder.
• The *ulnar nerve (C8+T1)* is one of the nerves that supplies the anterior compartment of the forearm but is mainly the nerve of the hand. It has no branches in the upper arm and passes though the upper arm in the anterior compartment initially but more distally in the posterior compartment. It lies posterior to the medial epicondyle of the elbow and can be damaged there.

• The *median nerve (C6-8+T1)* is one of the nerves that supplies the anterior compartment of the forearm and hand. It has no branches in the upper limb. It passes through the upper arm via the anterior compartment. At the level of the elbow it lies alongside the brachial artery and can be damaged there at the time of elbow fractures or dislocations.

• The *radial nerve (C5-8+T1)* supplies the posterior compartment of the upper arm as well as the posterior compartment of the forearm. It lies on the humerus in the radial groove and can be damaged there. Just above the level of the elbow it divides into the *superficial radial nerve* (sensory) and the *posterior interosseous nerve* (motor).

For **CLINICAL CORRELATES** of the shoulder and upper arm, look at Gray’s Anatomy
3. The Elbow, Forearm and Wrist
Mr Andrew Unwin

BONES + JOINTS
The relevant bones here include: the distal humerus, radius, ulna and carpal bones.

The Shaft + Distal Humerus
Cross-section of the humerus reveals a triangular shape with an antero-medial, antero-lateral and posterior surface.
- The posterior surface is marked by a linear roughening for the **attachment of the lateral head of triceps** brachii muscle. This begins just inferior to the surgical neck, and passing diagonally across the bone to the **deltoid tuberosity**.
- The middle posterior surface and adjacent part of the anterolateral surface are marked by the **radial groove**, which passes parallel to the posterior margin of the deltoid tuberosity. The radial nerve and profunda brachii artery lie in this groove.
- **Intermuscular septa** attach to the medial and lateral borders, separating the anterior and posterior compartments of the arm.
  - Distally, these borders become expand to form the medial and lateral **supraepicondylar ridge**.
- The distal end of the humerus consists of a condyle, two epicondyles and 3 fossae.

The condyle
The two articular parts of the condyle are the capitulum and trochlea.
- The capitulum articulates with the radius on the lateral side of the arm. (remember, CA + RA + LA, therefore lateral). This is visible on the anterior aspect, and is hemispheric in shape.
- The **trochlea** articulates with the ulna, on the medial side. It is visible from both the anterior and posterior aspect, and is pulley shaped.

The epicondyles lie adjacent and superior to the condyle...
- The **medial** epicondyle is a large bony protuberance (very palpable on the elbow). It has a large oval impression for the attachment of muscles in the anterior compartment of the
Joint capsule + Associated Ligaments

- The articular surfaces of the bones are covered with hyaline cartilage.
- The synovial membrane originates from the edge of the articular cartilage and lines the joint. It is separated from the fibrous membrane of the joint capsule by fat pads overlying the 3 fossae of the distal humerus. These fat pads accommodate the related bony processes during movement of the joint.
- The fibrous membrane of the joint capsule surrounds the synovial membrane, and is thickened laterally and medially, forming radial and ulnar collateral ligaments, which support flexion and extension movements.
**Movements of the elbow joint**
- Flexion = brachialis, biceps, brachioradialis, pronator teres
- Extension = triceps, aconeus

**The proximal radioulnar joint**
- The external surface of the joint capsule is reinforced at the lateral side by the annular ligament, which surrounds the head of the radius, blending with the fibrous membrane and radial collateral ligament.
- The annular ligament and related joint capsule allow the radial head to slide against the radial notch of the ulna and pivot on the capitulum during pronation and supination
  - A pocket of synovial membrane protrudes from the free inferior margin of the joint capsule facilitating this rotation

**Shaft and distal radius**
- The shaft is broader distally to form the distal end. Throughout its length, the shaft is triangular in cross-section with an anterior, posterior and lateral surface.
- The anterior surface is smooth and unremarkable, except for the sharp ridge (oblique line of the radius) which forms the anterior border
- The lateral surface of the radius is diamond-shaped and extends distally to form the radial styloid process
- The distal end of the bone is marked by two facets for articulation with two carpal bones (scaphoid and lunate), as well as the on the medial surface for articulation with the ulna

**Shaft and distal ulna**
- The shaft is narrow distally, and like the radius is triangular in cross section, with an anterior, posterior and medial surface.
- The distal end has a rounded head and an ulnar styloid process which projects distally.
The distal and anterolateral part of the head is covered by articular cartilage, and there is an additional distal fibrous articular disc therefore the ulna does not articulate with the carpal bones of the hand via a synovial joint.

**Distal Radioulnar Joint**
- This occurs between the anterolateral articular surface of the head of the ulna, the ulnar notch on the radius, and the fibrous articular disc on the distal end of the ulna (separating this joint from the wrist joint)
- Synovial membrane is attached to the margins of the joint, and is covered on its external surface by a fibrous joint capsule
- This joint allows the distal end of the radius to move anteromedially over the ulna
- In the proximal radioulnar joint, the bones are held together by the joint capsule and the annular ligament. However in the distal radio-ulnar joint, the bones are mainly held together by the *interosseus membrane.*
  - The *interosseus membrane* is a thin fibrous sheet that connects the medial and lateral borders of the radius and ulna, respectively.

**The Carpal Bones**
The carpal bones form the first two rows of bones in the hand, and their articulation with the distal end of the forearm forms the wrist joint.

**Proximal row** (lateral – medial)
- Scaphoid (boat-shaped)
- Lunate (crescent shape)
- Triquetrum (3 sided)
- Pisiform (pea shaped)

**Distal row** (lateral – medial)
- Trapezium (irregular 4 sided)
- Trapezoid (4 sided)
- Capitate (has a head)
- Hamate (with a hook)

**Pneumonic** to remember them:
- Proximal row = Sluts Like To Pull
- Distal row = Team Ted Cant Hump
- All Carpals = Some Lovers Like Trying Positions That They Cant Handle
- Carpals – *SO LONG TO PINKY, HERE COMES THE THUMB*

The carpal bones have numerous articular surfaces; all of them articulate with one another, and the expansive proximal surfaces of the scaphoid and lunate articulate with the radius to form the wrist joint.

**The Wrist Joint**
- The wrist joint is a synovial joint between the distal end of the radius and the articular disc overlying the distal ulna, and the scaphoid, lunate and triquetrum.
- The wrist joint allows movement around two axes:
  - Flexion
  - Extension
  - Radial Deviation
  - Ulnar Deviation
  - Pronation
  - Supination

**NB:** the radial styloid process extends further distally than the ulnar styloid process, therefore the hand can be ulnar deviated to a greater extent.

**MUSCULAR ANATOMY**

**Review of the arm**
- The anterior (flexor) compartment of the arm is supplied by the musculocutaneous nerve (C5,6) and consists of the biceps brachii, brachialis and coraco-brachialis.
- The posterior (extensor) compartment of the arm is supplied by the radial nerve (C7,8), and consists of the triceps brachii, and the aconeus.
Anterior compartment of the forearm
The anterior compartment of the forearm consists of flexors and pronators, which all originate just distal to the medial epicondyle of the humerus. There are 5 superficial muscles, and 3 deep ones.

Superficial muscles
To remember these, supinate your left hand, and place your right hand on your left medial epicondyle with your fingers facing distally.

• Thumb = pronator teres, which pronates the forearm
  o This has two heads; the 2nd originates from the proximal ulna
• 2nd finger = flexor carpi radialis, which assists radial deviation
• little finger = flexor carpi ulnaris, which assists ulnar deviation
• middle finger = palmaris longus, which flexes the palm
• ring finger = flexor digitorum superficialis, which flexes the middle joint of the fingers

Deep muscles
• Flexor digitorum profundus, which flexes the distal joint of the fingers
• Flexor pollicis longus – flexes the thumb
• Pronator quadratus (which lies horizontally across the wrist) – pronation of the hand

NB: the palmar carpal ligament is a distal thickening of fascia which lies horizontally over the wrist, ensuring that all the tendons of the flexors do not protrude.

Posterior compartment of the forearm
The posterior compartment of the forearm consists of extensors and supinators. These have a common extensor origin; just distal to the lateral epicondyle. We do not need to know these in as much detail, but we need to know that these include:

• Muscles that move the wrist joint
• Muscles that move the digits
• Muscles that move the thumb
• The brachioradialis
• Supinator, which is assisted by the biceps during supination

These all attach to the back of the wrist, underneath the extensor atinaculum (thickened fascia which prevents the tendons from boasting)

 Movements of the wrist joint
 Flexion
• Flexor carpi radialis + Flexor carpi ulnaris
• Long flexors of thumb + fingers
• (palmaris longus + abductor pollicis longus)
Extension
- Extensor carpi radialis longus, radialis brevis and ulnaris
- Long extensors of thumb + fingers

Radial deviation
- Flexor carpi radialis
- Abductor pollicis longus
- Extensor carpi radialis longus + brevis

Ulnar deviation
- Flexor carpi ulnaris
- Extensor carpi ulnaris

BLOOD VESSELS
Arterial Supply
The aorta divides into a number of branches with a different arrangement on each side of the body, but a subclavian artery passes towards each limb in the root of the neck
- As it passes over the first rib, it becomes the axillary artery. This passes through the axilla, with a number of branches and extensive anastomosis
- As the axillary artery passes the lower border of the teres major, it becomes the brachial artery
- The brachial artery supplies the upper arm, and one of its major branches in the upper arm is the profunda brachii artery
- At the level of the elbow, the brachial artery divides into the ulnar artery and the radial artery
- The radial artery supplies the lateral aspect of the forearm and hand
- The ulnar artery supplies the medial aspect of the forearm. It has a major branch, the common interosseous artery, which then itself divides into the anterior interosseus artery and the posterior interosseus artery
- The radial and ulnar arteries again meet via an anastomosis in the hand at the palmar carpal arch and the dorsal palmar arch. These arches give off metacarpal arteries and digital arteries to supply the fingers

Venous Supply
The venous supply consists of a superficial and deep system, which follow the arteries. The superficial system is made up of the basilic and cephalic vein (basilica is medial, cephalic is lateral)
- At the elbow, the basilic vein joins the vena comitantes to form the axillary vein in the arm
- The cephalic vein joins the axillary vein in the axilla
- The axillary vein becomes the subclavian vein at the level of the first rib
NB: the cephalic and basilic veins join at the elbow via the medial cubital vein

LYMPHATIC DRAINAGE
The lymphatic system follows the venous supply to the upper limb, with a superficial and deep system which run with the veins, as well as some cubital lymph nodes

NERVES
The Brachial Plexus
Spinal nerves C5-T1 form the brachial plexus, which passes under the clavicle forming 5 main terminal branches:
- (Axillary (C5))
- Musculocutaneous (C5-7)
- Radial (C5-8, T1)
- Median (C6-8, T1)
- Ulnar (C8, T1)

Review of nerve-movement relationships:
- Flexion of shoulder = C5, flexion of forearm = C5/6, flexion of wrist = C6/7
- Extension of shoulder = C7, extension of forearm = C7/8, extension of wrist = C8/T1
**Axillary nerve**: is often ignored, as it only supplies the deltoïd muscle

**Musculocutaneous nerve**: supplies all the anterior compartment of the arm, as well as sensory innervation to the lateral forearm

**Median nerve** courses through the anterior compartment of the arm, lying anterior to the elbow by the brachial artery (easily damaged).
- This is the main supply to flexor muscles of the forearm, EXCEPT the flexor carpi ulnaris + medial ½ of the flexor digitorum profundus (supplied by ulnar nerve)
- It passes through the pronator teres at the level of the elbow

**Ulnar nerve** courses the posterior compartment of the arm, lying behind the medial epicondyle at the elbow (Easily damaged).
- It is the main supply to the hand, as well as the flexor carpi ulnaris and medial ½ of the flexor digitorum profundus
- It passes through the flexor carpi ulnaris at the level of the elbow

The **Radial Nerve** supplies all extensor/posterior compartment of arm and forearm.
- It has a superficial and deep branch; the superficial supplies all the fascia, and the deep supplies the muscles
- It passes around the body of the humerus in the radial groove, coursing the anterior compartment distally. At the level of the elbow, it passes through the supinator and divides into:
  - The deep posterior interosseus nerve (motor)
  - The superficial radial nerve (Sensory)

NB: when nerves pass through muscles, this is a vulnerable site for damage

For **CLINICAL CORRELATES**, look at Gray’s Anatomy
BASIC PRINCIPLES
The upper limb and its limb girdle get sensory and motor nerve supplies from spinal segments C4-T1 (T2 supplies axilla). Muscles are supplied on the basis of overlapping pairs of segments as followed.

- C4-C7 = shoulder girdle muscles
- C5-C6 = shoulder joint muscles and elbow flexors
- C7-C8 = elbow joint extensors
- C6-C8 = wrist movements + course hand movements
- C8-T1 = fine hand movements (intrinsic hand muscles)

The function of the brachial plexus is to rearrange the nerve fibres in C5-T1 into bundles travelling to appropriate parts of the limb.

THE BRACHIAL PLEXUS

Minor branches
- Root branches
  - long thoracic (supplies serratus anterior)
  - dorsal scapular (supplies rhomboids + part of levator scapulae)
- Trunk branches
  - suprascapular (supplies supraspinatus + infraspinatus)
- Cord branches
  - lateral pectoral (supplies pectoral muscles) + medial pectoral (supplies pectoral muscles)
  - thoracodorsal (supplies latissimus dorsi)
  - upper + lower subscapular (supplies subscapularis + teres major)
  - AXILLARY (supplies deltoid)
NB: the names given to the three cords refer to their orientation around the axillary artery.

Major Terminal Branches

The Musculocutaneous Nerve arises from the lateral cord, supplies the anterior compartment of the arm (elbow flexors).

- The biceps are also the key muscle in supination
- This nerve is very deep within the biceps, therefore is usually well protected. However it may be cut during surgery for breast cancer. This results in a loss of flexion and supination

The Median Nerve arises from both the lateral and median cords, therefore acquiring C6-T1 fibres. This nerve supplies most of the wrist and finger flexors in the forearm, and most of the small muscles of the thumb and index finger.

- Its sensory fibres supply the lateral part of the hand, so injury or entrapment makes delicate hand activities such as writing difficult or impossible
- The median nerve is well protected from extrinsic injury, but often becomes entrapped as it passes through the carpal tunnel between the wrist and hand
- Carpal tunnel syndrome is the commonest serious neurological problem of the upper limb, fortunately it usually responds well to surgical release of the trapped nerve. It causes wasting of the thenar eminence as well as loss of both sensation and fine movement in the lateral digits which is a serious disability

The Ulnar Nerve arises from the medial cord, acquiring C8-T1 fibres. It is the motor nerve of most of the small muscles of the hand.

- It is most vulnerable to compression, cuts and fractures where it passes posterior to the medial epicondyle of the humerus at the elbow (funny bone). This produces weakness and wasting of many small muscles of the hand, though this is less serious than expected
- Another likely location of damage is at the wrist. This occurs often following attempted suicide, and will cause an ulnar claw (whereby the ring + little fingers are flexed with the other fingers extended – caused by complete de-innervation of the lumbricals)
- NB: The Ulnar Paradox – the ulnar nerve also innervates the medial half of the flexor digitorum profundus. If the ulnar nerve lesion occurs more proximally, the FDP may also be denervated. As a result, flexion of the IP joints is weakened which reduces the claw-like appearance of the hand. This is called a paradox because one would expect a more debilitating injury to result in a more deformed appearance

NB: The Axillary Nerve is a relatively major branch of the posterior cord. It winds round the neck of the humerus to supply C5+C6 fibres to the deltoid and teres minor.

- It is particular easily damaged through anterior shoulder dislocation. Here the head of the humerus may compress the nerve, as well as surrounding vessels. Significant damage to the shoulder joint will cause wasting of the deltoid (losing roundness of the shoulder), as well as loss of sensation of the skin innervated by the lateral cutaneous nerve (branch of axillary nerve supplying the regimental patch of skin)

The Radial Nerve is supplied by the posterior divisions of all trunks, therefore acquiring C6-T1 fibres.

- It winds posterior to the humerus in the radial groove under the cover of the triceps
- It can be damaged by fractures of the humerus, leading to loss of function in the extensor muscles. This results in two visible deficits:
  - Wrist drop, caused by loss of supply to extensor muscles of posterior forearm. An important consequence of this.
  - Loss of sensation in lateral dorsum of hand (anatomical snuff box)
NERVE ROOT INJURIES
If all roots (C5-T1) are damaged, the whole limb will be paralysed and anaesthetic. There will also be Horner’s syndrome due to loss of sympathetic supply via T1 segment. This presents as the triad of partial ptosis (upper eyelid drooping), miosis (pupillary constriction) and hemifacial anhidrosis (absence of sweating)

Erb’s Lesion
This is a lesion of the C5 + C6 roots of the brachial plexus, damaging primarily the axillary and musculocutaneous nerve. The most common cause of Erb’s palsy is dystocia, an abnormal or difficult childbirth or labor. This
- A similar injury may be observed at any age including adults, following a traumatic fall onto the side of the head and shoulder, whereby the nerves of the plexus are violently stretched: the upper trunk of the plexus sustains the greatest injury, and the subsequent paralysis may be confined to the muscles supplied by the fifth nerve.
- The brachial plexus may also be injured by direct violence or gunshot wounds, by violent traction on the arm, or by efforts at reducing a dislocation of the shoulder joint; the amount of paralysis will depend upon the amount of injury to the constituent nerves

It presents as
- loss of sensation in the regimental patch
- atrophy of the deltoid, biceps + brachialis
- the position of the limb is characteristic; waiters tip. The arm cannot be abduction, and the power of flexion + supination is lost

Klumpke’s Lesion
This is a lesion of the C8 + T1 nerve roots, damaging primarily the median and ulnar nerve. An easy way to remember Klumpke paralysis (or Klumpke’s Palsy) is by remembering the phrase “Klumpke the monkey hung from a tree", as a method of injury is catching oneself on a tree branch when falling.
The subsequent paralaxis affects:
- The intrinsic muscles of the hand
- The flexors of the wrist and fingers
- Forearm pronators

The classic presentation is the “claw hand” where the forearm is supinated and the wrist and the fingers are flexed.

DEEP TENDON REFLEXES
A muscle is supplied by one or more spinal cord segments or nerve roots. When the tendon of the muscle is taped (thus causes stretch of muscle spindles) it results in an involuntary contraction in the muscle. Presence of reflex activity indicates the integrity of the nerve pathway in a particular spinal cord segment

Biceps tendon reflex (musculocutaneous nerve C5-C6)
- Subject is asked to semi-flex the elbow whilst the hand is pronated.
- Examiner places thumb on the biceps tendon and tap the thumb briskly with a knee hammer
- If the reflex arc is in tact, there will be a brisk contraction of the biceps causes further elbow flexion

Triceps tendon reflex (radial nerve C7-C8)
- Subject is asked to semi-flex the elbow whilst the hand is pronated
- The examiner should support the elbow with one hand, and tap the triceps tendon with the hammer
- If the reflex arc is intact there will be a brisk contraction of the triceps causing elbow extension
**SENSORY NERVE SUPPLY**

**Segmental innervation**
The body wall muscles and skin are supplied segmentally by the spinal nerves. This is true for the limbs as well.

- An area of skin supplied by a single nerve root or spinal cord level is called a dermatome
- A similarly innervated region of skeletal muscle is called a myotome

On the skin, adjacent dermatomes overlap considerably. Therefore a loss of a single spinal nerve root will not produce any detectable sensory loss in that dermatome

- Most muscles are also supplied by more than one spinal nerve root
- Integrity of the nerve supply of myotomes can be evaluated by testing the joint movement or the muscle action

**Peripheral nerves**
Peripheral nerves carry nerve components from several spinal segments to muscles and skin areas.

- Therefore damage to a peripheral nerve may result in a wide ranging effect on more than one dermatomal area or myotomes which may include large areas of skin and several muscles
6. The Hip, Buttock + Thigh

**BONES, JOINTS + ASSOCIATED LIGAMENTS**
The relevant bones of this region are the sacrum, pelvis (also known as innominate/hip bone. Consists of the ilium, ischium + pubis) and the femur

**The Bony Pelvis**
Each pelvic bone (innominate bone = no name) is formed by 3 bones which fuse (no visible fusion lines in adult skeleton) during childhood:

- Superiorly, the ilium
- Antero-inferiorly, the pubis
- Postero-inferiorly, the ischium

![Diagram of the hip, buttock, and thigh bones](image-url)
Ilium
The ilium is the largest of the 3 components of the hip bone. It is composed of the superior ala (expanded wing) and inferior body.

- The body helps form the acetabulum; the socket for the head of the femur
- The superior border of the ilium is called the iliac crest. This ends anteriorly in the ASIS (anterior superior iliac spine) and posteriorly in the PSIS (posterior superior iliac spine)
  - Below the ASIS is the anterior inferior iliac spine
  - Below the PSIS is the posterior inferior iliac spine (point of attachment for tendons of the muscles of the trunk, hi and thighs)
- Below the posterior inferior iliac spine is the greater sciatic notch, through which nerves + vessels running from the pelvis to thigh pass through (eg sciatic nerve)
- The medial surface of the ilium contains the iliac fossa, with the iliac tuberosity (also known as tubercle) posterior to this. The auricular surface also lies posterior to this fossa, forming the sacro-iliac joint with the sacrum (synovial joint)
- Projecting anteriorly and inferiorly from the articular surface is a ridge called the arcuate line
- Other markings include the 3 gluteal lines (posterior, anterior and inferior) which are present on the lateral surface and form the sites for attachment of the gluteal muscles

Ischium
The ischium forms the inferior, posterior portion of the hip bone. It is comprised of a superior body and inferior ramus.

- The ramus is the portion of the ischium that fuses with the pubis
- Feature of the ilium include the prominent ischial spine, a lesser sciatic notch below the spine, and a rough/thickened ischial tuberosity
  - The ischial tuberosity is the part of the hip bone you sit on
- Together the ramus and the pubis surround the obturator foramen (which is nearly completely covered in the fibrous obturator membrane on which muscles are attached. Some vessels/nerves pass through this canal, but it is mostly completely covered)

Pubis
The pubis is the anterior and inferior part of the hip bone. It consists of a superior and inferior ramus, with a body between the rami

- The anterior, superior border of the body is the pubic crest, with the pubic tubercle projecting at its lateral end.
  - This tubercle marks the beginning of a raised line, the pectineal line, which extends superiorly and laterally along the superior ramus to merge with the arcuate line of the ilium
- The pubis symphysis is the joint between the two pubes of the hip bones; it consists of a disc of fibrocartilage.
  - Inferior to this joint, the inferior rami of the two inferior rami converge to form the pubic arch.

Acetabulum
The acetabulum is a deep fossa formed by the ilium, ischium and pubis.

- It functions as the socket that accepts the rounded head of the femur
- Together, the acetabulum and the femoral head forms the hip joint
On the inferior side of the acetabulum is a deep indentation, the acetabular notch, that forms a foramen through which blood vessels and nerves pass.
  - This also serves as a point of attachment for ligaments of the femur

Proximal Femur
The proximal end of the femur consists of a rounded head that articulated with the acetabulum of the hip bone to form the hip/coxal joint
  - The head contains a small centred depression called the fovea capitis (site of attachment of ligament of head of femur)
  - The neck of the femur is a constricted region distal to the head
  - The axis of the head is away from the axis of the neck. The axis of the head + neck are also at an angle to the axis of the distal condyles (this is about 12% antverted in adults. In children it is more than 30 degrees medially. This is why you often see toddlers intoeing)
  - The greater trochanter and lesser trochanter are projections from the junction of the neck and shaft that serve as points of attachment for the tendons of some of the thigh and buttock muscles
    - The greater trochanter is the prominence felt on the widest part of your hip. It is commonly used to locate the site for intramuscular injection
    - The lesser trochanter is inferior and medial to the greater trochanter
    - Between the anterior surfaces of the trochanters is a narrow intertrochanteric line
    - A ridge called the intertrochanteric crest appears between the posterior surfaces of the trochanters
  - Inferior to the intertrochanteric crest on the posterior surface of the shaft of the femur is a vertical ridge called the gluteal tuberosity, which blends into the linea aspera. Both ridges serve as attachment points for the tendons of several thigh muscles
Clinical Significance:

- **Blood supply to the femoral head and neck:** An extracapsular arterial ring is formed around the base of the femoral neck, posteriorly by a branch of the medial femoral circumflex artery and anteriorly by smaller branches of the lateral femoral circumflex artery.
  
  - This extracapsular arterial ring is further enhanced by blood supply from the superior and inferior gluteal arteries. They give rise to ascending branches that run along the femoral neck. From these branches, additional retinacular branches enter a subsynovial intra-articular ring.
  
  - The blood supply to the femoral head and neck is then further enhanced by the artery of the ligamentum teres which is derived from the medial femoral circumflex artery or the obturator artery.

Femoral fractures: you must be able to distinguish between a fracture of the femoral neck, and an intertrochanteric fracture:

- Most **femoral neck fractures** are intracapsular and disrupt the cervical vessels formed from the subsynovial intra-articular ring. The femoral head may therefore necrose (avascular necrosis). In certain cases this requires either hemiarthroplasty or total hip replacement.

- **Intertrochanteric fractures** does not involve the femoral neck, therefore preserves the blood supply and does not render the femoral head ischaemic. These types of fractures are repaired usually using a femoral plate and pin, which runs through the central portion of the femoral neck to obtain alignment.

The Hip Joint

The hip joint is a synovial articulation between the head of the femur and the acetabulum of the pelvic bone.

- It is a multi-axial ball and socket joint designed for stability and weight-bearing at the expense of mobility.

- Movements at the joint include flexion, extension, abduction, adduction, medial + lateral rotation and circumduction.
• The articular surfaces of the hip joint are the spherical head of the femur, and the lunate surface of the acetabulum.
  o The entire articular surface of the acetabulum is covered in hyaline cartilage
  o The entire head of the femur except the fovea is also covered in hyaline cartilage
  o The rim of the acetabulum is raised slightly by a fibro-cartilignous collar (the acetabular labrum)
• The ligament of the head of the femur is a flat band of delicate connective tissue that attaches at one end to the fovea on the head of the femur, and at the other end to the acetabular fossa. It carries a small branch of the obturator artery, which contributes to the blood supply to the head of the femur
• The synovial membrane attaches to the margins of the articular surfaces, and lines the fibrous membrane of the joint

Ligaments
3 ligaments reinforce the external surface of the fibrous membrane and stabilize the joint:
• Iliofemoral ligament – anterior to the hip joint, attached to ilium between acetabulum and anterior inferior iliac spine, and base on intertrochanteric line of femur
• Pubofemoral ligament – anteroinferior to the hip joint, base attached medially to iliopubic eminence, and laterally blends with the fibrous membrane
• Ischiofemoral ligament – reinforces the posterior aspect of the fibrous membrane, attached medially to the ischium posteroinferior to the acetabulum and laterally to the greater trochanter
• Anterior + posterior sacroiliac ligaments
• Iliolumbar + lumbosacral

Sciatic foramina
The sacrospinous ligament has a broad base, formed by the lateral margins of the sacrum and coccyx, and forms its apex at the ischial spine. The sacrotuberous ligament runs from the inferior margin of the sacrum to the tuberosity of the ischium.
• The greater sciatic foramen lies with 4 boundaries. It is the foramen through which all vessels and nerves entering the thigh from the back will pass. The 4 boundaries include:
  o The greater sciatic notch of the ilium (anterolaterally)
  o Sacrotuberous ligament (posteromedial)
  o Sacrospineous ligament (inferiorly)
  o Anterior sacroiliac ligament (superiorly)
• The lesser sciatic foramen lies within 3 boundaries. It is through which all vessels and nerves entering the perineum from the back will pass. The 3 boundaries include:
  o The tuberosity of the ischium (anterior)
  o Sacrospineous ligament (superior)
  o Sacrotuberous ligament (posteriorly)

FASCIA
The Fascia of the Region
In the thigh, there are 2 layers of fascia:
• A superficial fascia, i.e. subcutaneous tissue or fat
• Deep fascia, called the fascia lata. This is very thick and tough, and extends like a stocking beneath the skin.
A lateral thickened area of the fascia lata is called the **ilio-tibial tract**. This descends along the lateral margin of the limb from the iliac tubercle to just below the knee.

- The tensor fasciae latae is partially enclosed by and inserts into the superior and anterior aspects of the iliotibial tract
- Most of the gluteus maximus inserts into the posterior aspect of the iliotibial tract.

These muscles hold the leg in extension once other muscles have extended, as well as helping to stabilize the hip joint by preventing lateral displacement of the proximal end of the femur away from the acetabulum.

**MUSCULAR ANATOMY**

**The Gluteal Region** lies posterolateral to the bony pelvis and the proximal end of the femur. Muscles in this region mainly abduct, extend and externally rotate the femur relative to the pelvic bone (ie move the hip)

- **Gluteus maximus**
- **Gluteus minimus**
- **Gluteus medius**

The muscles consists of the superficial gluteal muscles, and the deep short external rotators of the hip.

The deep muscles include (don't need origins and insertions)

- **Piriformis** – most superior; function is to externally rotate and abduct the femur at the hip joint
- **Obturator internus** – function is to externally rotate and abduct the femur at the hip joint
- **Gamelli** – the gamellus superior and inferior are associated with the obturator internus. They act with the obturator internus to externally rotate and abduct the femur at the hip joint
- **Quadratus femoris** – most inferior; function is to externally rotate the femur at the hip joint
The gluteal muscles include (need to know origins and insertions)

- **Gluteus minimus** is a fan-shaped muscle that originates from the external surface of the expanded upper part of the ilium, between the inferior and anterior gluteal line.
  - The muscle fibres converge to form a tendon which inserts into a broad linear facet on the anterolateral aspect of the greater trochanter
  - Function – abduct the lower limb at the hip joint, and reduce pelvic drop over the opposite (swing) limb during walking by securing the position of the pelvis on the stance limb
  - Innervated by superior gluteal nerve

- **Gluteus medius** overlies the gluteus minimus and is also fan-shaped. It has a broad origin from the external surface of the ilium between the anterior and posterior gluteal line
  - It inserts on an elongate facet on the lateral surface of the greater trochanter
  - Function – same as gluteus minimus
  - Innervated by superior gluteal nerve

- **Gluteus maximus** is the largest muscle in the superficial gluteal region, and it overlies most of the other gluteal muscles
  - It has a broad origin extending from a roughened area of the ilium behind the posterior gluteal line and along the dorsal surface of the lower sacrum (and lambar fascia) to the sacrotuberous ligament
  - Laterally, it inserts into the iliotibial tract. The deep distal parts of the muscle insert into the gluteal tuberosity of the femur
  - Function – extends the flexed thigh at the hip joint. Its insertion into the iliotibial tract, it also stabilizes the knee and hip joints.
  - Innervated by inferior gluteal nerve

Note: **The sciatic nerve** enters the gluteal region through the greater sciatic foramen inferior to the piriformis muscle.

- It descends in the plane between the superficial and deep group of gluteal region muscles, crossing the posterior surfaces of the first obturator internus and associated gemellus muscles and then the quadratus femoris to enter the thigh posteriorly.
- **Clinical importance**: intramuscular injection – a typical site for IM injection is the gluteal region, which can be divided up into 4 quadrants
- We must remember that the sciatic nerve lies in the inferior medial quadrant, therefore IM injection should always take place in the upper lateral quadrant (high on the side of the hip) to avoid trauma to the sciatic nerve

**Testing the Hip Abductors – The Trendelenberg Test**

- Subject stands upright on both feet. Examiner stands behind. Not the level of both iliac crests
- Subject is asked to stand on one leg. A drop in the level of the iliac crest on the unsupported side indicates weakness of the hip abductors on the stance side
- If the right hip abductors are paralysed then the left hip will drop due to lack of lifting support. When walking the pelvis will drop on the left (non-affected side)

The thigh can be divided into an anterior, medial and posterior compartment.

- The **anterior compartment** is innervated by the femoral nerve, and consists of the hip flexors and knee extensors.
• The **medial compartment** is innervated by the obturator nerve, and consists of muscles which mainly adduct the thigh (like kicking a football)
• The **posterior compartment** of the thigh is innervated by the sciatic nerve, and consists of muscles which flex the knee

**The Anterior Compartment of the Thigh**
The anterior compartment consists of the ilio-psoas, pectineus, tensor fasciae latae, Sartorius and the 4 quadriceps femoris (rectus femoris, vastus medialis, vastus intermedius, vastus lateralis). These muscles can be grouped as to whether they are flexors of the hip joint, or extensors of the knee.

**Flexors of the Hip Joint**
The **pectineus** is a flat quadrangular muscle in the superomedial aspect of the thigh.
• It often appears to be composed of a superficial and deep layer, which are generally innervated by different nerves. Because of the dual nerve supply and the muscles actions (it adducts + flexes the thigh as well as assisting in medial rotation of the thigh) it is often considered a transitional muscle of both the anterior and medial compartment.
• Origin – superior ramus of pubis
• Insertion – pectineal line of femur, just inferior to lesser trochanter

The **ilio-psoas muscles** consist of the psoas major and iliacus.
• The psoas major originates on the posterior abdominal wall, and travels anteriorly
• The iliacus muscle arises from the iliac fossa of the pelvis
• Their tendons fuse, and insert into the lesser trochanter of the femur
• These flex the thigh at the hip joint

The **tensor fasciae latae**, stabilizes the knee in extension.
• Working with the gluteus maximus, it also stabilizes the hip joint by holding the head of the femur in the acetabulum
• It is innervated by the superior gluteal nerve.

The **Sartorius** is a long ribbon-like muscle that passes from lateral to medial on the superoanterior part of the thigh.
• It lies superficially, with a distinct facial sheath which extends to the medial side of the knee. It is the longest muscle in the body, and acts both on the
hip joint (flexor) and the knee joint (flexor). It also weakly abducts the thigh and laterally rotates it. An example of the action includes bringing the limbs into a cross-legged position

- Origin – anterior superior iliac spine, and superior part of notch inferior to it
- Insertion – superior part of medial surface of tibia

Knee Extensors
The quadriceps femoris (four-headed femoral muscle) forms the main bulk of the anterior thigh muscles. It consists of four parts:

- Rectus femoris
- Vastus lateralis
- Vastus medialis
- Vastus intermedius

The tendons of the four parts of the quadriceps unit in the distal portion of the thigh to form a single, strong, broad quadriceps tendon.

- The patellar tendon, attached to the tibial tuberosity, is the continuation of the quadriceps tendon in which the patella is embedded.
- The medial and lateral vasti muscles also attach independently to the patella and form aponeuroses, the medial and lateral patellar retinacula, which reinforce the joint capsule of the knee joint on either side of the patella en route to attachment to the anterior border of the tibial plateau. These also play a role in keeping the patella aligned over the patellar surface of the femur.

Testing the quadriceps is performed with the person in the supine position with the knee partly flexed. The person extends the knee against resistance. During the test, contraction of the rectus femoris should be observable and palpable if the muscle is acting normally, indicating that its nerve supply is intact.

The rectus femoris runs straight down the thigh, crossing both the hip and knee joint. It is thus capable of flexing the thigh at the hip and extending the leg at the knee. It is the ONLY one of the quadriceps muscles which crosses the hip joint.

- Origin – the anterior inferior iliac spine, and ilium superior to acetabulum

The names of the vastus muscles indicate their position around the femoral shaft.

- **Vastus lateralis;** the largest component of the quadriceps, lies on the lateral side of the shaft. Its origin is the greater trochanter + lateral lip of the linea aspera of the femur
- **Vastus medialis** covers the medial side of the thigh. Its origin is the intertrochanteric line and the medial lip of the linea aspera of the femur.
- **Vastus intermedius** lies deep to the rectus femoris, between the vastus medialis and lateralis. Its origin is the anterior and lateral surface of the femur shaft.

It is difficult to isolate the function of the three vastus muscles.

NB: all the muscles of the anterior compartment of the thigh are supplied by the FEMORAL nerve (except the pectineus which often has a dual supply with the obturator nerve)
Medial Compartment of the Thigh

These muscles are the adductor muscles of the hip joint (movement of the leg laterally towards the opposite leg), including the adductor longus, adductor brevis, adductor magnus, gracilis and obturator externus.

- All the adductor muscles, except the “hamstring part” of the adductor magnus and part of the pectineus are supplied by the OBTURATOR nerve

The adductor longus is the most anterior adductor. It covers the anterior aspects of the adductor brevis and middle of the adductor magnus.

- Origin – strong tendon from the anterior aspect of the body of the pubis just inferior to the pubic tubercle
- Insertion – middle third of linea aspera

The adductor brevis lies deep to the pectineus and adductor longus

- Origin – body + inferior ramus of pubis
- Insertion – pectineal line and proximal part of linea aspera
- NB: as the obturator nerve emerges from the obturator canal to enter the medial compartment of the thigh, it splits into an anterior and posterior division. The two division pass anterior and posterior to the adductor brevis. This unique relationship is useful in identifying the muscle during dissection in anatomical cross-sections

The adductor magnus is the most powerful and most posterior adductor muscle. It is a triangular muscle that consists of two parts; adductor part and hamstring part.

- The ADDUCTOR PART originates from the inferior ramus of the pubis, and fans out widely for aponeurotic insertion from the gluteal tuberosity, along the entire length of the linea aspera and onto the medial supracondylar ridge of the femur. It acts to adduct the thigh.
- The HAMSTRING PART originates from the ischial tuberosity, and forms a tendinous insertion onto the adductor tubercle of the femur
  - The hamstring part is innervated by the tibial part of the sciatic nerve, and acts to extend the thigh

The Gracilis is the most medial muscle of the thigh, and most superficial and weak adductor.

- It is also the ONLY one of the group to cross the knee joint as well as the hip joint. It is synergistic with other muscles to adduct the thigh, flex the knee and internally rotate the leg when the knee is flexed.
- Origin – the body + inferior ramus of the pubis
- Insertion – superior part of medial surface of tibia
The **obturator externus** is deeply placed in the superomedial part of the thigh.
- Origin – margins of the obturator foramen and obturator membrane
- It extends to the posterior aspect of the greater trochanter, passing directly under the acetabulum and neck of the femur to insert in the trochanteric fossa of the femur

**The Posterior Compartment of the Thigh**
Three of the muscles in the posterior compartment are collectively known as the “Hamstrings”, which are the primary hip extensors and knee flexors.
- They include the semitendinosus, semimembranosus and biceps femoris
- They share some common features: they all originate from the ischial tuberosity deep to the gluteus maximus, and are innervated by the sciatic nerve

NB: the short head of the biceps femoris does not meet these common characteristics.

The **semitendinosus** has a fusiform belly that is interrupted by a tendinous intersection and a long cord-like tendon that begins $2/3$rd of the way down the thigh
- It inserts into the medial surface of the superior part of the tibia

The **semimembranosus** is so named because of its flattened membranous form of its proximal attachment to the ischial tuberosity.
- The tendon forms around the middle of the thigh and descends to insert into the posterior part of the medial condyle of the tibia
- The tendon divides distally into 3 parts: a direct attachment to the posterior aspect of the medial tibial condyle, a part that blends with the popliteal fascia and a reflected part that reinforces the intercondylar part of the joint capsule (this is known as the oblique popliteal ligament)

The **biceps femoris** is a fusiform muscle consisting of a long head and a short head. In the inferior part of the thigh, these both become tendinous and fuse.
The common tendon insets to the lateral side of the head of the fibula, but is split at this site by the fibular collateral ligament.
• The LONG HEAD originates from the ischial tuberosity, and offers protection for the sciatic nerve after it descends from the gluteal region into the posterior aspect of the thigh.
• The SHORT HEAD arises from the lateral lip of the inferior third of the linea aspera and supracondylar ridge of the femur.
• The long head is supplied by the tibial division of the sciatic nerve, whereas the short head is supplied by the fibular division of the sciatic nerve. This dual nerve supply means it is possible to have paralysis of one head and not the other.

NEUROVASCULAR STRUCTURES

The Femoral Triangle
The femoral triangle is a subfascial formation that is useful in dissection to understand relationships in the groin. In living people it appears as a triangular depression inferior to the inguinal ligament when the thigh is flexed, abducted and laterally rotated. It is bounded:

- **Superiorly** by the inguinal ligament (forming the base)
- **Medially** by the lateral border of the adductor longus
- **Laterally** by the medial border of the Sartorius

NB: the apex of the triangle is where the medial border of the Sartorius crosses the lateral border of the adductor longus. The **floor** of the triangle is formed by the ilio-psoas and pectineus, and the **roof** is formed by the fascia lata.

The **contents** of the femoral triangle (from lateral to medial) are:
- The femoral nerve and its branches
- The femoral sheath and its contents:
  - The femoral artery and several branches
  - The femoral vein and its proximal tributaries
  - The deep inguinal lymph nodes and is associated lymphatic vessels

A mnemonic used to learn the orientation of the contents of the femoral triangle from lateral to medial is NAVY (n=nerve, a=artery, v=vein, y=Y-fronts, ie underwear)

**Clinical importance:** coronary angiogram uses the femoral artery as the site of contrast entry, and the femoral vein is often used to administer IV medications centrally

The Adductor Canal
Also known as the subsartorial canal or Hunter's canal, the adductor canal is a long (approx. 15cm) narrow passageway in the middle 1/3rd of the thigh.

- It extends from the apex of the femoral triangle, providing an intermuscular passage for the femoral artery, femoral vein and saphenous nerve to the popliteal fossa where they become popliteal vessels

It is bounded:
- Anteriorly + laterally by the vastus medialis
- Posteriorly by the adductor longus and adductor magnus
- Medially by the Sartorius, which also forms the roof of the canal
7. The Knee, Popliteal Fossa, Leg and Foot
Mr Andrew Unwin

**BONES**

The **Distal Femur**

- The posterior border of the shaft of the femur forms a broad roughened crest = linea aspera
- At the distal end of the femur, the linea aspera forms the floor of the popliteal fossa, and its margins form the medial and lateral supracondylar lines which terminate on the superior aspect of the condyles (medial condyle is larger + more inferior)
  - The adductor tubercle is just superior to the medial condyle, for the attachment of the adductor magnus
- The condyles are separated posteriorly by an inter-condylar fossa. On each condyle is a shallow oblique groove that separates the surface that articulates with the tibia from the surface that articulates with the patella
  - The surfaces that articulate with the tibia are rounded posteriorly and become flatter inferiorly
  - The surfaces that articulate with the patella form a V-shaped trench
- The walls of the intercondylar fossa bear two facets for the site of cruciate ligament attachment
  - The lateral surface of the medial wall has a large oval facet for the posterior cruciate ligament
  - The medial surface of the lateral wall has a smaller oval facet for the anterior cruciate ligament
- Epicondyles are the site of attachment of the collateral ligaments

The **patella** is a large sesamoid bone (bone formed within the tendon of a muscle) in the boyd, and it is formed within the tendon of the quadriceps femoris muscle. It is triangular:

- Apex points inferiorly for attachment to patellar ligament which connects it to the tibia
- Base is for the attachment of the quadriceps femoris
- Posterior surface articulates with the femur

The **Tibia** is the medial and larger of the two leg bones, and is the only one which articulates with the knee joint.

The **proximal end** is expanded in the lateral dimension

- It has both a medial and lateral condyle, both of which are flattened + overhang the shaft = tibial plateau
• The superior surfaces of the medial and lateral condyles are articular and separated by an intercondylar region
• There are also 2 tibial spines, on the medial side of the lateral condyle and the lateral side of the medial condyle
• There are no epicondyles
• On the lateral side, you can palpate the tibial plateau – feels like a dent in the leg
• On the anterior surface, there is the tibial tuberosity which can be palpated on the anterior surface which is the site of attachment for the patellar tendon (quadriceps femoris)

Tibial condyles and intercondylar areas
• The medial condyle is larger than the lateral condyle; its superior surface is oval for articulation with the medial condyle of the femur. The superior surface of the lateral condyle is circular and articulates with the lateral condyle of the femur
• It is the outer margins of the concave superior surfaces of the condyles which are in contact with the menisci of fibrocartilage in the knee joint
• The intercondylar region of the tibial plateau lies between the articular surfaces of the medial and lateral condyles. It bears 6 facets for the attachment of menisci and cruciate ligaments.
  • In addition to these 6 attachment sites, there is a large anterolateral region of the intercondylar area that is roughened and perforated by numerous small nutrient foramina for blood vessels. This lies against infrapatellar connective tissue

Shaft of tibia
• The anterior border is sharp and descends from the tibial tuberosity
• The interosseous border is a subtle vertical ridge that descends along the lateral aspect of the tibia from the region of bone anteroinferior to the articular facet for the head of the fibula
• The medial border is indistinct superiorly, but sharp in its midshaft
• The large medial surface is subcutaneous, and bears a subtle roughened elongate elevation = site of attachment of Sartorius, gracilis and semitendinosus
• The posterior surface of the shaft (between medial + interosseous borders) is crossed by a roughened oblique line = the soleal line.

Distal end of tibia
• Shaped like a rectangular box with a bony protuberance of the medial side = medial malleolus, the upper part of the box is continuous with the shaft, and the lower surface and medial malleolus articulate with one of the tarsal bones (talus) to form a large part of the ankle joint
• The posterior surface is marked by a vertical groove, which continues onto the posterior surface of the medial malleolus = groove for tendon of tibialis posterior
• The lateral surface has a deep triangular notch = fibular notch, to which the fibula is anchored

The fibula
The fibula is the lateral bone of the leg and does not take part in formation of the knee joint or in weightbearing. It is much smaller than the tibia, and has a small proximal head, narrow neck, and a delicate shaft which extends at the lateral malleolus at the ankle
The proximal end is the globe-like expansion = head (can be palpated on the posterolateral aspect of the knee).
• A circular facet on the superomedial surface is for articulation above with a similar facet on the lateral condyle of the tibia.
  • Just posterolateral to this facet is a superior protrusion = styloid process
• The lateral surface of the head bears a large impression for the attachment of the biceps femoris muscle
• The neck of the fibula separates the head from the shaft. The common fibular nerve wraps around the posterolateral aspect of the neck and can be palpated here.
The shaft of the fibula again has 3 borders and 3 surfaces.

- The medial border (interosseous border) faces and is attached to the interosseous membrane.
- Intermuscular septa attach to the anterior and posterior borders, forming the muscle compartments of the leg
- The posterior surface is divided into 2 by the medial crest. Each part is attached to a different deep flexor muscle

The distal end of the fibula expands to form the lateral malleolus.

- The medial surface of the lateral malleolus bears a facet for articulation with the lateral surface of the talus
  - Just superior to this is a triangular area which fits into the fibular notch on the distal tibia.

Bones of the foot

The foot can be subdivided into the ankle, the metatarsus and the digits. There are 5 digits consisting of the medial great toe (digit I; hallux) and the four laterally placed digits ending with the little toe (digit V)

- The foot has a superior surface (dorsum) and inferior surface (sole)
- There are 3 groups of bones in the foot: the tarsal bones, metatarsals and phalanges

Tarsal Bones

These are arranged in a proximal + distal group with an intermediate bone between the two on the medial side.

The PROXIMAL group consists of...

- The talus (ankle bone) – most superior, articulates with the tibia and fibula, and projects forward to articulate with the intermediate tarsal bone on the medial side of the foot (navicular)
- The calcaneus (heel bone) – largest bone, projects forward to articulate with one of the distal groups of tarsal bones (cuboid) on the lateral side of the foot
The INTERMEDIATE tarsal bone...
- This is known as the navicular, and lies on the medial side of the foot.
- It articulates behind with the talus, and in front with the distal group of tarsal bones.

The DISTAL group consists of...(from lateral to medial)
- The cuboid - articulates with the calcaneous, lateral cuneiform and bases of two lateral metatarsals
- 3 cuneiforms: lateral, intermediate + medial – articulate with each other, the navicular bone + medial three metatarsals

Metatarsals - There are 5 metatarsals, the shortest/thickest associated with the great toe, and the longest/thinnest with the second toe. They all have a distal head, shaft and proximal base.

Phalanges – each toe has 3 phalanges (proximal, middle, distal) except for the great toe, which only has 2. Each phalynx consists of a base, shaft and distal head.

THE KNEE + POPLITEAL FOSSA

The Knee Joint
This is the largest synovial joint in the body. It is a hinge joint that meanly allows flexion + extension, and is reinforced by collateral and cruciate ligaments. It consists of:
- The articulation between the femur + tibia (weightbearing)
- The articulation between the patella + femur (allows patellar tendon to move over the knee without wearing)
Two fibrocartilagenous menisci (one on each side between the femoral condyles and the tibia) accommodate changes in shape of the articular surfaces during joint movements

- The **articular surfaces** of the bones that contribute to the knee joint are covered in hyaline cartilage. The major surfaces involved are the two femoral condyles and adjacent surfaces of the superior aspect of the tibial condyles
- There are two **menisci** (lateral + medial), which are fibrocartilagenous C-shaped cartilages, in the knee joint. Both are attached at each end to facets in the intercondylar region of the tibial plateau
  - The medial meniscus is also attached to the capsule of the joint + the tibial collateral ligament, whereas the lateral meniscus is unattached and thus more mobile
  - These act to improve congruency between the femoral and tibial condyles during joint movements where the surfaces of the femoral condyles articulating with the tibial plateau change from small curved surfaces (flexion) to flat surfaces (Extension)
- The **synovial membrane** of the knee is enclosed within a fibrous membrane.
  - Anteriorly, the synovial membrane is separated from the patellar ligament by an infrapatellar fat pad. On either side of this pad, the synovial membrane forms a fringed alar fold.
  - The synovial membrane of the knee joint forms 2 different pouches to provide low friction surfaces for the movement of tendons associated with the joint.
    - The smallest is the subpopliteal recess – extends posterolaterally between lateral meniscus and the tendon of the popliteal muscle
    - Suprapatellar bursa – continuation of the cavity superiorly between distal femur and quadriceps femoris. This is pulled away during extension.
- The **fibrous membrane** of the knee is extensive and partly formed by extensions from tendons of surrounding muscles
  - It is reinforced anterolaterally by a fibrous extension of the iliotibial tract, and posteromedially by the oblique popliteal ligament

**Ligaments of the Knee**

- **Patellar Ligament** is the continuation of the quadriceps femoris tendon inferior to the patellar. It is attached to the tibial tuberosity distally.
- **Collateral Ligaments** are on either side of the joint, and stabilize the hinge-like motion
  - The **fibular collateral ligament** is attached to the lateral femoral epicondyle and to a depression on the lateral surface of the fibula head
  - The **tibial collateral ligament** is attached to the medial epicondyle of the femur and the medial surface of the tibia
- **Two cruciate ligaments** are in the intercondylar region of the knee, and they interconnect the femur and the tibia.
  - The **anterior cruciate ligament** (ACL) attaches to a facet on the anterior part of the intercondylar area and ascends posteriorly to attach to the lateral wall of the intercondylar fossa of the femur
    - Prevents anterior displacement of the tibia relative to the femur
  - The **posterior cruciate ligament** (PCL) attaches to the posterior aspect of the intercondylar area, and ascends anteriorly to attach to the medial wall of the intercondylar fossa of the femur
    - Prevents posterior displacement of the tibia relative to the femur

**Vascular Supply + Innervation of the Knee**

Vascular supply to the knee joint is predominantly through:

- descending and genicular branches from the femoral, popliteal, and lateral femoral arteries from the thigh
- the circumflex fibular artery
- recurrent branches from the anterior tibial artery

These vessels form an anastomotic network around the joint. The knee joint is then innervated by branches from the obturator, femoral, tibial and common fibular nerves
Proximal Tibiofibular Joint
The small proximal tibiofibular joint is synovial in type and allows very little movement. The opposing surfaces of the joint (the undersurface of the lateral condyle of the tibia + the superomedial surface of the head of the fibula) are flat and circular. The capsule is then reinforced by anterior and posterior ligaments.

The Popliteal Fossa
This is an important area of transition between the thigh and leg; the major route by which structures pass from one region to another. It is a diamond shaped space behind the knee joint, with 6 boundaries:

- Superior medial margin: distal ends of semitendinosus/semimembranosus
- Superior lateral margin: biceps femoris
- Inferior margin: medial + lateral head of the gastrocnemius muscle
- Floor: femur, knee joint capsule
- Roof: deep fascia

Contents of the popliteal fossa include:
- The two major branches of the sciatic nerve:
  - The tibial nerve descends vertically and exits deep to the margin of the plantaris to enter the posterior compartment of the leg
  - The common fibular/peroneal nerve exits by following the patellar tendon to the lateral margin of the fossa to supply the lateral compartment
- The popliteal artery appears on the upper medial side, descending obliquely. It is the deepest of the neurovascular structures in the popliteal fossa, and is therefore difficult to palpate. However a pulse can usually be detected by deep palpation medial to the midline
- The popliteal vein is superficial and travels with the popliteal artery

JOINTS
Intertosseus membrane of the leg
This is a tough fibrous sheet of connective tissue that spans the distance between the facing interosseus borders of the tibial and fibular shafts, with obliquely descending collagen fibres (from tibia to fibula)

- The distal ends of the fibular and tibia are held together by the inferior aspect of the membrane, holding together the fibular notch of the tibia and the corresponding surface on the fibula.
- This expanded end is reinforced by anterior and posterior tibiofibular ligaments

Ankle Joint
- The ankle joint is synovial in type and involves the talus of the foot and the tibia and fibula of the leg
- The articular surfaces are covered by hyaline cartilage, and the joint is stabilized by medial and lateral ligaments

Joints of the foot
- INTERTARSAL JOINTS – synovial joints, except the joint between the cuboid and navicular, which is normally fibrous.
- The SUBTALAR JOINT (between the posterior talus and posterior calcaneus) – synovial joint enclosed by a synovial membrane covered in a fibrous membrane
- TALOCALCANEONAVICULAR JOINT (between talus, calcaneus + navicular) – synovial joint reinforced by the calcaneonavicular and talocalcaneal ligaments. This is also known as the transverse tarsal joint/mid-tarsal joint. Movement at this joint
contributes to inversion/eversion of the foot together with movement of the subtalar joint
• CALCANEOCUBOID JOINT – synovial
• TARSOMETATARSAL JOINT – plane joints
• METATARSO-PHALANGEAL JOINTS – ellipsoid synovial joints
• INTERPHALANGEAL JOINTS – hinge joints reinforced by ligaments

NB: Arches of the foot
The bones of the foot do not lie in a horizontal plane. Instead they form arches which absorb and distribute downward forces from the body during standing and moving on different surfaces
• The LONGITUDINAL ARCH is formed between the posterior end of the calcaneus and the heads of the metatarsals. It is highest on the medial side and lowest on the lateral side (forming a medial + lateral arch)
• The TRANSVERSE ARCH is highest in a coronal plane that cuts through the head of the talus and disappears near the head of the metatarsals

MUSCULAR ANATOMY OF THE LEG + FOOT
• The leg can be divided into an anterior, posterior and lateral compartment
• The intrinsic muscles of the foot can be divided into the 4 muscle layers of the sole, and the 2 muscle layers of the dorsum

Anterior Compartment of the Leg
• Function is to dorsi-flex, extend digits of foot (+ aid eversion)
• Innervation: deep peroneal/fibular nerve (L4-L5)
• Vascular supply: anterior tibial artery
• Muscles involved:
  o tibialis anterior
  o extensor digitorum longus
  o extensor hallucis longus
  o (+ fibularis tertius)

Lateral Compartment of the Leg
• Function is to evert foot (+ may aid dorsiflexion)
• Innervation: superficial peroneal/fibular nerve (L5-S2)
• Vascular supply: peroneal/fibular artery
• Muscles involved:
  o Peroneus longus
  o Peroneus brevis
**Posterior Compartment of the Leg**

- Function is to plantar-flex + flex digits of foot (+ aid inversion)
- Innervation: tibial nerve (L4-S2)
- Vascular supply: posterior tibial artery
- Superficial division muscles:
  - Gastrocnemius
  - Soleus
  - Plantaris

NB: the Achilles tendon is the continuation of the gastrocnemius + soleus tendons which fuse. Testing this reflex tests the S1-S2 segmental supply specifically.

- Deep division muscles:
  - Popliteus
  - Flexor digitorum longus
  - Flexor digitorum longus
  - Tibialis posterior

**Intrinsic muscles of the foot**

We do not need to know the detailed anatomy of the foot, but we need to have an understanding that the intrinsic muscles can be divided into:

- those of the sole of the foot (4 layers supplied by branches of the tibial nerve)
- those of the dorsum of the foot (2 layers supplied by branches of the deep + superficial fibular nerve)

Also NB: plantar interossei adduct (PAD), dorsal interossei abduct (DAB)

**THE GAIT CYCLE**

Locomotion of walking is a complex function. The movements of the lower limbs during walking on a level surface may be divided into alternating swing and stance phases.

- The gait cycle consists of one cycle of swing and stance by one limb
  - The **stance phase** begins with a heel strike, and ends with a push-off by the forefoot (60% of cycle)
  - The **swing phase** begins after push-off when the toes leave the ground, and ends with the heel hitting the ground (40% of cycle)
• The stance phase is longer because it begins and ends with short periods of double support, i.e., when both feet are on the ground and the weight is transferred from one to the other.

**Stance** is divided into four phases:

1) **Heel strike to foot flat**
   - Mechanical goal = lower forefoot to ground
   - Active muscle groups = ankle dorsiflexors
   - Example of muscle = tibialis anterior

2) **Foot flat through midstance** (loading response)
   - Mechanical goal = accept weight + stabilize pelvis
   - Active muscle groups = knee extensors + hip abductors
   - Examples of muscles = quadriceps + gluteus minimus/medius; tensor fasciae latae

3) **Midstance through Heel off** (terminal stance)
   - Mechanical goal = accelerate mass + stabilize pelvis
   - Active muscle groups = ankle plantarflexors + hip abductors
   - Examples of muscles = triceps surae + gluteus minimus/medius; tensor fasciae latae

4) **Heel off to Toe off** (pre-swing)
   - Mechanical goal = accelerate mass
   - Active muscle groups = long flexors of digits
   - Examples of muscles = flexor hallucis longus/digitorum longus

**Swing** is divided into two phases:

1) **Acceleration to midswing** (initial swing)
   - Mechanical goal = accelerate high + clear foot
   - Active muscle groups = hip flexors + ankle dorsiflexors
   - Examples of muscles = iliopsoas, rectus femoris + tibialis anterior

2) **Midswing to deceleration** (terminal swing)
   - Mechanical goal = position foot + extend knee to place foot
   - Active muscle groups = ankle dorsiflexors + knee extensors
   - Examples of muscle = tibialis anterior + quadriceps

By evaluating each individual phase of the gait cycle, a physical therapist obtains clues into specific muscular weaknesses and shortening. Addressing these issues in a rehabilitation program will lead to a more efficient gait pattern, resulting in decreased risk of injury, less energy expenditure, greater functional independence, and improved muscular balance.
VESSELS

Arterial supply

- The abdominal aorta bifurcates at the level of L4 to form the common iliac artery. This travels infero-laterally along the medial border of the psoas muscle (for about 4cm), before bifurcating again at the pelvic brim to form the internal iliac and external iliac.
- The internal iliac then goes on to supply the pelvis and perineum.
- The external iliac continues its course, with 2 branches that are given off before it reaches the inguinal ligament. As the artery travels deep to the inguinal ligament to enter the femoral triangle, it becomes the femoral artery.
- NB: other vessels supplying parts of the lower limb include the superior and inferior gluteal artery, and the obturator artery. These are all branches of the internal iliac.
  - The superior and inferior gluteal arteries supply the gluteal region, leaving the pelvis through the greater and lesser sciatic foramen respectively.
  - The obturator artery passes through the obturator canal to enter and supply the medial compartment of the thigh.
- The femoral artery branches supply most of the thigh, all of the leg and foot.
  - It is palpable in the femoral triangle just inferior to the inguinal ligament midway between the ASIS + pubic symphysis.
- A cluster of four small branches originate from the femoral artery in the femoral triangle and supply cutaneous regions of the upper thigh, lower abdomen and perineum.
- The femoral artery passes vertically through the femoral triangle and then continues down the adductor canal. On the lateral side of the femoral artery, a branch is given off = profunda femoris artery. This is the largest branch of the femoral artery and is the main source of blood supply to the thigh.
- The profunda femoris then passes deeply between the pectineus and adductor longus (in the adductor canal), descending posterior to the latter on the medial side of the femur. In the middle 1/3rd of the thigh, it gives off perforating arteries that wrap around the posterior aspect of the femur.
- The continuation of the femoral artery now continues on the medial/anterior aspect of the thigh as the superficial femoral artery.
- As the superficial femoral artery leaves the adductor canal and adductor hiatus, it forms the popliteal artery which passes round to the back of the knee.
  - It is the deepest of the neurovascular structures in the popliteal fossa, and therefore is difficult to palpate; however a pulse can usually be detected by deep palpation medial to the midline.
  - 5 genicular branches of the popliteal artery supply the capsule and ligaments of the knee joint. Other contributors to this are the descending genicular artery (branch of femoral), descending branch of lateral femoral circumflex artery + anterior tibial recurrent artery (branch of anterior tibial).
- The popliteal artery is relatively short, and quickly bifurcates into the anterior tibial artery, posterior tibial artery, and peroneal/fibular artery.
- The anterior tibial artery passes forward through the aperture in the upper part of the interosseous membrane and enters + supplies the anterior compartment of the leg, continuing inferiorly on the dorsal aspect of the foot as the dorsalis pedis artery (palpable). This artery divides into a number of arteries to supply the foot.
- The posterior tibial artery supplies the posterior compartment of the leg (descending on the superficial surfaces of the tibialis posterior and flexor digitorum longus). It continues into the sole of the foot, behind the medial malleolus (palpable), where it then divides in the foot to form the medial and lateral plantar arteries.
- The plantar arch in the foot is formed from the arteries derived from the anterior and posterior tibial arteries, to supply the foot and toes.
The peroneal/fibular artery (branch of posterior tibial) supplies the lateral compartment of the leg. It is much smaller than the other two arteries of the leg.

- The circumflex fibular artery passes laterally through the soleus around the neck of the fibula to connect with the anastomotic network of vessels surrounding the knee.
- The fibular artery parallels the course of the posterior tibial artery. It supplies adjacent muscles and bone in the posterior compartment of the leg and also branches to supply the fibularis muscle in the lateral compartment.
- The fibular artery passes behind the distal attachments of the distal tibia/fibula and terminates in a network of vessels over the lateral surface of the calcaneus.

**Venous Supply**

**Superficial veins**

The superficial veins lie in the subcutaneous tissue, and have valves to prevent the backflow of blood.

- The **dorsal venous arch** receives most of the blood from the foot.
- the **long saphenous vein** starts as the continuation of the medial portion of the dorsal venous arch of the foot. It lies 2cm anterior and proximal (superior) to the medial malleolus.
  - it runs proximally along the medial aspect of the leg, passing behind the medial femoral condyle of the knee.
  - As it passes up the leg, there are a number of very important tributaries to the deep venous system. These are called perforating veins.
    - Physiological blood should flow from the superficial to deep venous system, and there are valves in these perforating veins to ensure that there is no
back-flow from the deep to superficial venous system. If these valves do not exist or are incompetent, back-flow occurs resulting in VARICOSE VEINS.

- The vein then runs along the medial thigh to merge with the femoral vein at the SAPHENOFEMORAL JUNCTION. It passes through the cribriform fascia at the saphenous opening, 3cm below and lateral to the pubic tubercle.
- The long saphenous vein has many valves (about 20) throughout its length, mostly below the knee although some are present above the knee

- At the saphenofemoral junction, there are a number of venous tributaries which join the vein as it merges with the femoral vein
- The short saphenous vein drains the lateral aspect of the dorsal venous arch.
  - It passes with the sural nerve at the back of the leg in the midline and passes into the popliteal vein at the popliteal fossa. This then drains into the femoral vein midway up the thigh.
  - It communicates at several levels with the long saphenous vein

### Deep veins

The deep veins lie within the deep fascia, and in general run alongside the arteries. The deep veins also have valves to prevent backflow of blood. Usually two veins run alongside each artery.

- The venae committantes of the anterior and posterior tibial arteries and the popliteal artery form the popliteal vein
- The deep veins are mainly within muscle, and the “muscle pump” contributes towards the venous return from the lower limb to the abdomen
- The popliteal vein also receives the short saphenous vein at the level of the popliteal fossa
  - The popliteal vein passes into the popliteal fossa, lying between the popliteal artery and tibial nerve
- Midway up the thigh, the popliteal vein becomes the femoral vein, which passes behind the femoral artery and lies medial to it at the level of the inguinal ligament
  - Just proximal to the inguinal ligament, it is joined by the profunda femoris veins and then by the long saphenous vein. Once passed beneath the inguinal ligament it forms the external iliac vein

### CLINICAL APPLICATIONS OF VESSELS

- **Arterial pulses**
  - FEMORAL ARTERY – can be palpated just inferior to the inguinal ligament half way between the ASIS and pubic symphysis (just medial to the nerve and lateral to the vein)
  - POPLITEAL ARTERY – can be palpated using both hands by pushing the inferior popliteal fossa deep towards the tibia
  - POSTERIOR TIBIAL ARTERY – can be palpated just posterior and inferior to the medial malleolus
  - DORSALIS PEDIS ARTERY – can be palpated lateral to the extensor hallucis longus tendon

- **Arterial emboli** may cause acute ischaemia of the leg (with full occlusion) or intermittent claudication (with partial occlusion/narrowing = pain in legs on exercising)
- **Venous cannulation** (can be used for resuscitation)
- **Cut-down** at the medial malleolus of the long saphenous vein – in a shocked patient, venous cannulation may not be easy or possible. Here, a small incision is made at the ankle, and a venous cannula can be placed under direct vision of the vein for resuscitation

- **Compartment syndrome**
  - There are three compartments in the leg, the anterior, posterior and lateral compartments. Each compartment is bound by a very tight fascia, which only let the enclosed muscles swell to a certain degree before resisting any further expansion and then increase the pressure in the muscle itself.
  - If the pressure in the muscle increases too far, the arterial supply and venous return of the muscle in that compartment is cut off, resulting in muscle death, with resulting loss of movement and contractures in the limb = compartment syndrome
Acute compartment syndrome occurs after trauma to a limb, e.g. fractures, muscle damage. Unless the fascia is released urgently by a fasciotomy (whereby the septa dividing the compartments are cut) the muscle will die with disastrous consequences

- Note that the arterial pulse is not lost in acute compartment syndromes. The tissue pressure is only 25mmHg and pressure need only to rise to 50-60mmHg to cause a compartment syndrome. The diastolic blood pressure is 80mmHg and the systolic 120mmHg!

Chronic compartment syndrome occurs in athletes where the muscles swell during exercise and causes activity-related pain. Elective fasciotomy can relieve the pain of this condition.

- Varicose veins and deep venous insufficiency
  - As explained above, the superficial veins in the limb have valves which prevent backflow of blood. However, as well as this, the deep veins and the perforating veins also have valves. Probably the most important valve is at the sapheno-femoral junction in the groin. If this valve is incompetent, then blood can easily flow back into the superficial venous system, causing varicose veins. Most operations for varicose veins involve tying off the sapheno-femoral junction.
  - Varicose veins are dilated and tortuous superficial veins. They can be painful, causing an aching discomfort on standing. However, they are also pathological in that the increased pressure within the superficial venous system can cause increased pressure in the superficial circulation, causing skin changes (lipodermatosclerosis) and often skin ulcers. Most skin ulcers are due to venous insufficiency of this type.

- Deep venous thrombosis
  - Blood can clot (thrombose) in the superficial and deep veins of the lower limb. When it occurs in the deep veins, this is termed deep venous thrombosis (DVT).
  - DVT is often “silent” but may present with pain and swelling in the calf or the proximal thigh. A distal DVT occurs in the calf whilst a proximal DVT extends into the thigh and pelvis. A proximal DVT is very dangerous, as there is a high risk of propagation of the clot into the lungs.
  - DVT is very important clinically. It can occur idiomatically (i.e. without an obvious cause) but is often associated with immobility, trauma, surgery within the abdomen, pelvis or limbs, obesity, malignancy, pregnancy or with the use of the oral contraceptive pill. DVT has two main consequences;
  - the clot may propagate into the pulmonary circulation, causing a pulmonary embolus (PE). A PE may be fatal and for this reason DVT’s are usually treated by anticoagulation to prevent this complication occurring
  - The clot in the deep veins may cause increased back pressure in the deep veins, causing venous insufficiency and leg ulcers (the post-phlebitic syndrome)
  - The superficial veins may also clot or become inflamed/infected. This causes superficial thrombophlebitis. This is not so dangerous as DVT but can be very painful. The treatment is usually symptomatic (analgesia, rest, ice etc) rather than with anticoagulation.

- The superficial veins as grafts in elective surgery
  - The saphenous veins are often used in cardiac and vascular surgery as grafts to replace arteries. Obviously the veins need to be orientated correctly due to the valves present within them.
  - As there is such an excellent anastomosis in the leg, the removal of the superficial veins rarely causes a problem.

LYMPHATICS
NB: there are popliteal + femoral lymph nodes which are easily palpable in infection, malignancy etc.
NERVES

Lumbo-sacral plexus + Peripheral Innervation

The anterior rami of spinal nerves L2-S2 merge to form the lumbosacral plexus (the details of the plexus are not required to the same degree as the brachial plexus, but the general organization should be understood.

The **lumbar plexus** is derived from L1-L4 anterior rami. It has the following peripheral nerve branches:

- Iliohypogastric + ilioinguinal nerves (L1)
- Genitofemoral nerve (L1-2)
- Lateral cutaneous nerve of the thigh (L2-3)
- **Femoral nerve** (L2-4, posterior fibres)
- **Obturator nerve** (L2-4, anterior fibres)
- Lumbosacral trunk (L4-5) – this feeds the SACRAL plexus

The **sacral plexus** is derived from the lumbosacral trunk (L4-5) and the S1-4 anterior rami. It has the following branches:

- **Sciatic nerve** (L3-5, S1-3, anterior + posterior fibres)
- nerve to piriformis (S1-2)
- posterior cutaneous nerve of the thigh (S1-3)
- pelvic splanchnic nerves (S2-4 – parasympathetic)
- nerve to obturator internus (L5, S1-2)
- **superior gluteal nerve** (L4-5, S1)
- **Inferior gluteal nerve** (L5, S1-2)

The **femoral nerve** carries contributions from the anterior rami of L2-L4, and leaves the abdomen by passing through the gaps between the inguinal ligament and the superior margin of the pelvis to enter the femoral triangle on the anteromedial aspect of the thigh.

- It innervates all muscles in the anterior compartment of the thigh
- In the abdomen, it gives rise to branches that innervate the iliacus and pectineus
- It innervates skin over the anterior aspect of the thigh

The terminal cutaneous branch of the femoral nerve is the **saphenous nerve**, which accompanies the femoral artery and vein through the adductor canal and passes between the Sartorius and gracilis to become superficial at the adductor hiatus.

- It then runs anteroinferiorly to supply the skin and fascia on the anteromedial aspects of the knee, leg and foot.

**NB:** muscles supplied by the femoral nerve include: ilio-psoas, pectineus, Sartorius, rectus femoris, vastus medialis, vastus intermedius, vastus lateralis

The **obturator nerve** originates from L2-L4. It descends along the posterior abdominal wall through the psoas major muscle, passes through the pelvic cavity and enters the thigh by passing through the obturator canal. It innervates:

- All muscles in the medial compartment of the thigh EXCEPT the hamstring part of the adductor magnus and the pectineus (supplied by the sciatic + femoral respectively)
The cutaneous branch supplies the medial side of the thigh

NB: muscles supplied by the obturator nerve include: obturator externus, adductor brevis, adductor longus, adductor part of adductor magnus, gracilis

The **sciatic nerve** is the largest nerve of the body and carries contributions from L4-S3. It leaves the pelvis through the greater sciatic foramen inferior to the piriformis, passes through the gluteal region and then enters the posterior compartment of the thigh where it divides into two major branches near the apex of the popliteal fossa:

- Common fibular/peroneal nerve (carries posterior divisions of L4-S2)
- Tibial nerve (carries anterior divisions of L4-S3)

The sciatic nerve then innervates:

- All muscles in the posterior compartment of the thigh
- The hamstring part of the adductor magnus

NB: muscles supplied by the sciatic nerve include:

The **tibial nerve** is the medial terminal branch of the sciatic nerve, and is the most superficial of the components of the popliteal fossa, lying immediately deep to the fascia.

- It descends the leg on the tibialis posterior muscle, supplying all the muscles in the posterior compartment of the leg.
- It then leaves the posterior compartment of the leg by passing deep to the flexor retinaculum in the interval between the medial malleolus and the calcaneus
- Posteriorinferior to the medial malleolus, the tibial nerve divides into the medial and lateral plantar nerves. These supply all the intrinsic muscles of the foot

The **common fibular/peroneal nerve** is the lateral and smaller of the two terminal branches of the sciatic nerve. It leaves the popliteal fossa, passing over the posterior aspect of the head of the fibula before winding around the lateral surface of the neck of this bone (palpable here).

- It then runs deep to the superior part of the fibularis longus, and divides into the superficial and deep peroneal/fibular nerve
- The **deep peroneal nerve** runs inferomedially, piercing the interosseus membrane to descend the anterior compartment of the leg. It supplies all the muscles in the anterior compartment, as well as the skin between the first and second toes
- The **superficial peroneal nerve** lies anterolateral to the fibula between the fibularis and extensor digitorum longus. It supplies the lateral compartment of the leg, and pierces the deep fascia to become superficial in the distal 1/3rd of the leg. It then supplies the distal part of the anterior surface of the leg, nearly all the dorsum of the foot and most of the digits

The **gluteal nerves** are the major motor nerves of the gluteal region.

- The **superior gluteal nerve** carries contributions from the anterior rami of L4-S1. It leaves the pelvis through the greater sciatic foramen to innervate the gluteus medius, gluteus minimus and tensor fasciae latae muscles
- The **inferior gluteal nerve** is formed by contributions from L5-S2, leaves through the lesser sciatic foramen and enters the gluteal region to supply the gluteus maximus.

<table>
<thead>
<tr>
<th>Peripheral Motor Innervation of the Lower Limb</th>
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<tbody>
<tr>
<td><strong>Femoral Nerve</strong></td>
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<tr>
<td>Ilio-psoas</td>
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<tr>
<td>Pectineus</td>
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<tr>
<td>Sartorius</td>
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<td>Rectus femoris</td>
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<td>Vastus medialis</td>
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<td>Vastus intermedius</td>
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<td>Vastus lateralis</td>
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Cutaneous innervation of the lower limb

<table>
<thead>
<tr>
<th>Tibial Nerve</th>
<th>Common Peroneal/Fibular Nerve</th>
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<tbody>
<tr>
<td>• Gastrocnemius</td>
<td>Deep branch</td>
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<tr>
<td>• Soleus</td>
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<tr>
<td>• Popliteus</td>
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<tr>
<td>• Tibialis posterior</td>
<td>• Tibialis anterior</td>
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<tr>
<td>• Flexor hallucis longus</td>
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<td>• Flexor digitorum brevis</td>
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<tr>
<td>• Abductor hallucis</td>
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<td>• All of the interossei + lumbricals</td>
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<tr>
<td>• Tibial, medial calcanean branches</td>
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<td>• Deep peroneal</td>
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<td>• Medial plantar</td>
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<td>• Lateral plantar</td>
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Segmental Innervation of the Lower Limb

Skeletal muscles are innervated by groups of motor nerve cell bodies within the spinal cord, allowing an efficiency of action.

- In the fetus the limb buds grow out from the trunk and take the nerves destined to supply those parts with them (lower limb = L2-S2). The nerves form plexi, and the anterior divisions of the plexi supply flexor muscles, with the posterior divisions supplying extensor muscles.
- In the upper limb, the flexor muscles are anterior and the extensor muscles are posterior. However in the lower limb, the limb undergoes extension and internal rotation during development. As a consequence, extensor muscles are anterior and flexor muscles are posterior.
There are some basic principles to the segmental spinal innervation of muscles:
- Most muscles are supplied by two adjacent segments of the spinal cord
- Muscles with the same primary action on a joint share the same spinal segmental supply
- Opposing muscles also share a common segmental supply, either two above or two below.
- The more distal a joint in a limb, the more caudal are the spinal segments controlling the muscles acting upon that joint.

Thus the **segmental motor supply** of the lower limb is as follows:
- HIP: flex (L2-3), extend (L4-5)
- KNEE: extend (L3-4), flex (L5-S1)
- ANKLE: dorsal-flex (L4-L5), plantar-flex (S1-S2)
- NB: eversion (L4), inversion (L5,S1)

**Segmental sensory supply**
Each segment of skin supplied by a single spinal nerve is termed a **DERMATOME**.
- Each dermatome overlaps considerably, and thus mostly the loss of one spinal nerve is not appreciably noticed by the patient.
- However there are areas, termed axial lines, where the dermatomes are not linked at the spinal level, eg S2 + L2 lie side by side in the posterior thigh.

Clinically relevant sensory segmental innervation includes:
- L2 – upper lateral thigh
- L3 – front of thigh (3 to the knee)
- L4 – front of leg + medial great toe (4 to the floor)
- L5 – antero-lateral aspect of leg, dorsum of foot, dorsum of 2nd-4th toes
- S1 – lateral aspect of foot, sole + heel
- S2 – posterior leg + thigh
- S3 – gluteal region

**Autonomic Segmental Supply**
The sympathetic supply to the lower limb is via the T11-L2 portion of the thoraco-lumbar outflow. There is no significant parasympathetic outflow to the lower limbs.

**CLINICAL APPLICATIONS OF NERVES**

**Assessment of Nerve Function:**
To assess nerve function, regardless of whether the injury is at the root or peripheral nerve, you must assess:
- Motor function
- Sensory function
- Reflexes
- Autonomic function (most commonly minimal in lower limb)
Deep tendon reflexes
A muscle is supplied by one or more spinal cord segments or nerve roots. When the tendon of the muscle is tapped (thus causing stretch of muscle spindles), it results in an involuntary contraction (jerk) in the muscle. Presence of reflex activity indicates the integrity of nerve pathway of the particular spinal cord segment

Patellar tendon reflex (knee jerk) – femoral nerve, tests L2-L4
• As the subject to sit comfortably with the legs dangling on the edge of the couch. The examiner should strike the patellar tendon (ligament) with a knee hammer.
• If the reflex arc is intact, a brisk extension of the knee joint should be seen. Simultaneous contraction of the quadriceps should be palpated (by the examiner) on the anterior surface of the thigh.
• Repeat the test on the opposite side and compare the responses
• The absence or decrease of this reflex is known as Westphal’s sign

Calcaneal (Achilles) tendon reflex (Ankle jerk) – sciatic nerve, tests S1-S2
• Ask the subject to lie supine with legs relaxed and outstretched. The examiner should bend one of the subject’s knees and cross the foot over the other calf. The examiner should then hold the crossed foot in a dorsi-flexed position (the subject should relax the foot completely) and strike the Achilles tendon with a knee hammer.
• If the reflex arc is intact, a brisk plantar flexion of the foot should be seen.
• Repeat the test on the opposite side and compare the responses
• The ankle jerk may be absent or diminished if the S1 spinal nerve root is affected (for example in a prolapse of lumbar intervertebral disc) or in tibial nerve damage.

Peripheral Nerve injuries
Femoral Nerve (L2-L4)
The femoral nerve enters the thigh behind the inguinal ligament, a fingerbreadth lateral to the palpable femoral artery pulse.
• It supplies the ilio-psoas and the anterior compartment of the thigh, therefore to test the integrity of its motor function, you can extend the knee (with gravity, against gravity + against resistance)
• Its terminal branch is the saphenous nerve, which is sensory to the medial aspect of the leg, therefore test both fine + crude touch on this area.
It is relatively superficial in the groin but is rarely damaged except by doctors (iatrogenic injuries), such as:
• via tracton injuries during hip replacements
• laproscopic repair of inguinal hernias
• erroneous attempted cannulations of the femoral artery or femoral vein

Obturator Nerve (L2-L4)
The obturator nerve enters the thigh through the upper part of the obturator foramen. The obturator nerve is rarely damaged.
• It supplies the adductor (medial) compartment of the thigh, therefore to test the integrity of its motor function, you can adduct the hip (with gravity, against gravity + against resistance)
• It is also sensory to parts of the pelvis and the medial aspect of the superior thigh, therefore test fine + crude touch on these areas
Beware of pain in the distribution of the obturator as it can be indicative of malignancy in the pelvis.
Sciatic Nerve (L4-S3)
The sciatic nerve leaves the pelvis through the greater sciatic foramen to enter the gluteal region. It contains the tibial and the common fibular nerves. It is likely to be damaged in hip fractures, dislocations of the hip joint, or wrongly administered intramuscular injections in the gluteal region

- The sciatic nerve proper supplies the hamstring muscles in the posterior compartment of the thigh, therefore motor function can be tested by flexing the knee (with gravity, against gravity + against resistance)
- It also has some sensory branches to the back of the thigh (crude + light touch)
The commonest cause today of injury to the sciatic nerve is following hip replacement. Other causes of damage are trauma (eg hip dislocations or acetabular fractures), pelvis disease or intramuscular injections. To avoid this damage, always give an intramuscular injection in the upper lateral quadrant of the buttoc.
- Sciatica refers to the pain, weakness, numbness or tingling felt in the leg following sciatic nerve injury/compression

Common fibular (peroneal) nerve (L4-S3)
The common fibular nerve leaves the popliteal fossa and winds around the neck of the fibula, where it is easily damaged.

- It supplies the anterior and lateral compartments of the leg, therefore motor function can be tested by dorsi-flexing the foot (with gravity, against gravity + against resistance)
- It is sensory to the anterior and lateral aspects of the leg, and the dorsum of the foot (fine + crude touch can be evaluated)
As well as being damaged at the level of the hip (where it is part of the sciatic nerve), the common peroneal is highly vulnerable to damage at the level of the fibular neck, around which it winds. Causes of damage are trauma, knee replacements and external pressure, eg from plasters or during surgical procedures.
- Damage to this nerve typically results in foot drop

Tibial nerve (L4-S3)
The tibial nerve leaves the popliteal fossa deep to the gastrocnemius and soleus muscle

- It supplies the posterior compartment of the leg and most of the intrinsic muscles of the foot, therefore motor function can be tested by plantar flexion + curling of toes (with gravity, against gravity + against resistance)
- It is sensory to the back of the leg and the sole of the foot
As it is very deep, it is rarely damaged in isolation.

Other peripheral nerve injuries:
- Lateral cutaneous nerve of the thigh – this superficial nerve passes 2cm medial to the ASIS at the level of the inguinal ligament. It can be compressed at this level causing meralgia paraesthetics (also known as Bernhardt-Roth syndrome = numbness/pain in outer thigh caused by nerve injury not thigh trauma)
- Superior gluteal nerve – supplies the gluteus medius and minimus muscles. If this nerve is damaged, the result is a Trendelenberg gait
- Saphenous nerve – injury is surprisingly common; can be damaged at medial malleolus (varicose vein surgery) or at knee (ACL surgery)