

# 1 Foot and Ankle Anatomy

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## Abstract

The foot and ankle comprise one of the most functionally important structures in the human body. Key to understanding the complex pathology and debilitating conditions is a solid foundation in foot and ankle anatomy. Containing 26 bones, 30 joints, and more than 100 tendons, ligaments, and muscles, the foot is intricate in design. The ankle is a constrained joint whose stability is afforded by a complex interplay between various ligaments, and our understanding of this interplay continues to evolve. This chapter outlines the unique anatomy of this fascinating region, emphasizes high-yield facts, and provides common test questions.

**Keywords:** foot, ankle, anatomy, bones, ligaments, tendons, joints

## 1.1 Ankle

### 1.1.1 Arthrology

#### Distal Tibiofibular Joint (Syndesmosis)

- Articulation between the convex medial side of distal fibula and the concave lateral aspect of distal tibia (► Fig. 1.1).<sup>1</sup>
- Allows for small degree of external rotation and proximal to distal translation of the fibula against the tibia.
- Serves to keep the ankle mortise intact by maintaining the spatial relationship of the distal tibia and the distal fibula.
- Borders of the ankle mortise includes the tibial plafond superiorly, medial malleolus medially, and the lateral malleolus laterally.
- Stabilized by syndesmotomic ligaments (see below). See Figure 1.2

## Ankle Joint

- Hinge-type joint between the distal tibia, distal fibula, and talus.
  - Primarily acts in plantar and dorsiflexion, but also components of internal and external rotation.
- Normal range of motion (ROM) is around 20 degrees dorsiflexion and 50 degrees plantar flexion.
- The talar dome has a biconcave surface with a central sulcus.
  - The talus is wider anteriorly than posteriorly, leading to increased instability in plantar flexion.
  - Ankle chondrocytes are uniformly horizontally aligned and stiff, have decreased permeability, are less responsive to catabolic mediators, and synthesize proteoglycans at a greater rate, which leads to increased repair capacity. Thus, there is a **lower incidence of primary ankle degenerative joint disease (DJD) compared to the knee and hip.**
  - Medial and lateral stability is provided by the robust deltoid ligament and strong lateral ligaments including the anterior talofibular ligament and calcaneofibular ligament.

### 1.1.2 Ligaments

#### Syndesmosis

- Four syndesmotomic ligaments (► Fig. 1.2)<sup>2,3</sup>:
  - Injury here indicates “**high ankle sprain.**”
  - Anterior inferior tibiofibular ligament (AITFL).
    - Origin: tibial anterolateral tubercle.
    - Insertion: fibular anterior tubercle.
    - Weakest syndesmotomic ligament.
  - Posteroinferior tibiofibular ligament (PITFL).
    - Origin: tibial posterior tubercle.
    - Insertion: posterior lateral malleolus.



Fig. 1.1 Ankle osteology.

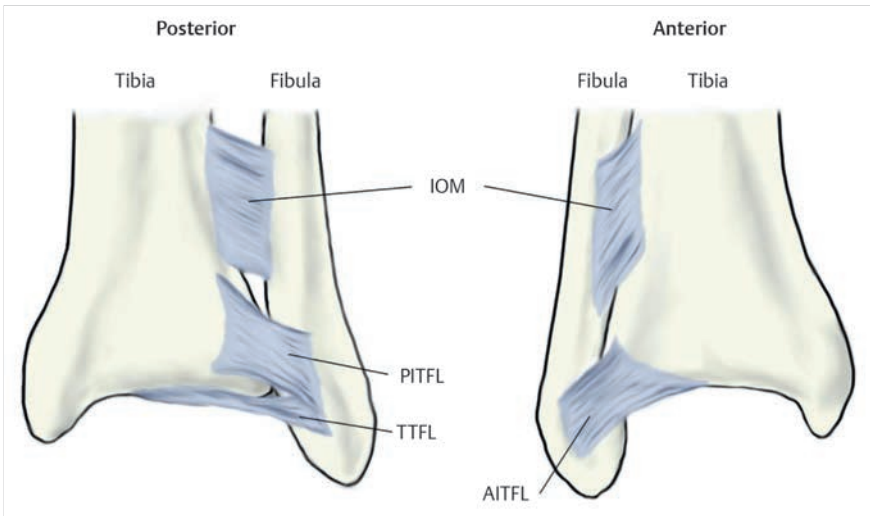


Fig. 1.2 Ankle syndesmosis.

- Strongest syndesmotomic ligament.
- o Interosseous ligament (IOL).
- o Inferior transverse ligament (ITL).

### Lateral Ligaments

- Anterior talofibular ligament (► Fig. 1.3):
  - o Attaches the anterior distal fibula to the talar neck.

- o Resists inversion in plantar flexion.
- o Most commonly injured in “low ankle sprains.”
- Calcaneofibular ligament:
  - o Attaches the distal fibula to the calcaneus, crossing the subtalar joint.
  - o Runs deep to the peroneal tendons.
  - o Resists inversion in neutral or dorsiflexion.

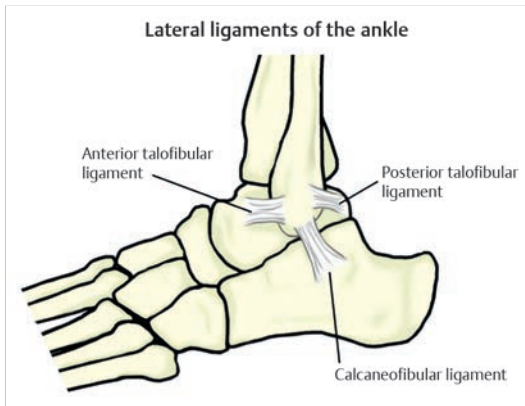


Fig. 1.3 Ankle lateral ligaments.

- Second most commonly injured in low ankle sprains.
- Posterior talofibular ligament:
  - Attaches the posterolateral distal fibula to the posterolateral talus.
  - Strongest lateral ligament.
  - Rarely torn.
- Lateral talocalcaneal ligament:
  - Attaches the talar lateral process to the lateral calcaneus.

## Medial Ligaments

- Thickest and strongest ligaments in the ankle (► Fig. 1.4).
- Superficial deltoid:
  - Four parts: anterior tibiotalar, tibionavicular, tibiocalcaneal, and posterior tibiotalar.
  - Origin on the anterior colliculus of the medial malleolus.
  - Resists ankle eversion.
- Deep deltoid:
  - Origin on the posterior colliculus of the medial malleolus.
  - Resists external rotation and lateral translation.
  - Stronger than the superficial deltoid.
- Spring ligament.
- Calcaneonavicular ligament.
  - Connects the sustentaculum tali of the calcaneus to the plantar navicular.
  - Plays important role in maintaining the medial longitudinal arch by

acting as a sling to support the talar head.

## 1.2 Hindfoot

### 1.2.1 Osteology

#### Talus

- Around 60% covered with articular cartilage (► Fig. 1.1).<sup>4</sup>
- No tendinous attachments.
- Divided into the talar head, neck, body, and posterior and lateral processes.
- Blood supply is through three main arteries: posterior tibial artery, dorsalis pedis artery, and perforating peroneal artery.
  - Dominant blood supply to the body is through the artery of the tarsal canal, a branch of the posterior tibial artery.
  - Retrograde blood flow from the neck places the body at risk of avascular necrosis with talar neck fractures.
- The lateral process is at risk of fracture in **snowboarders**.
  - Attachment site of the lateral talocalcaneal ligament.

#### Calcaneus

- Largest bone in the foot:
  - Posterior projection for Achilles tendon attachment acts as a lever

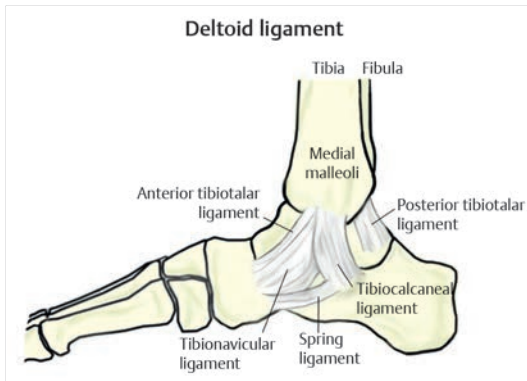


Fig. 1.4 Medial ankle ligaments.

arm to increase force of plantar flexion.

- Comprising the body, sustentaculum tali, and several articular facets (anterior, middle, and posterior).
  - The body includes the tuberosity, medial and lateral processes, and the peroneal tubercle.
- Calcaneal tuberosity is the attachment site for the Achilles tendon:
  - Medial and lateral processes serve as origins for the abductor hallucis and the abductor digiti minimi.
- Peroneal tendons pass through the peroneal tubercle:
  - The sustentaculum tali is a medial projection that supports the anteromedial talus.
    - **The flexor hallucis longus (FHL) tendon runs beneath.**
- Articular facets for the subtalar joint and calcaneocuboid joint.

## Navicular

- Named for its “boat” shape.
- Articulates with the talus proximally, cuboid laterally, and three cuneiforms distally.
- Blood supply is mainly through the branches of the dorsalis pedis.
- **Prone to stress fractures, tenuous blood supply in the middle third.**
- Insertion of the posterior tibial tendon medially.

## Cuboid

- Wedge-shaped bone with three articular surfaces.
- Posterior articulation with the calcaneus.
- Medial articulation with the lateral cuneiform.
- Anterior articulations with the fourth and fifth metatarsals.
- Inferior groove for passage of the peroneus longus tendon.

## 1.2.2 Arthrology

### Subtalar Joint

- The talus and calcaneus articulate through three processes: posterior, middle, and anterior articular processes.
- **The posterior process is the largest and the most commonly injured.**
- The middle facet located on the sustentaculum tali.
- Primary motion is inversion/eversion.

### Transverse Tarsal Joint (Chopart’s Joint)

- Comprises the talonavicular and calcaneocuboid joints.
  - Along with the subtalar joint, the main function is to allow flexibility and stability during the gait cycle.
    - When the subtalar joint is inverted during push-off, the axes of the talonavicular and calcaneocuboid

- joint are not aligned and functionally “locked,” allowing for creation of a stiff lever arm for push-off. This action is facilitated by the posterior tibial tendon.
- When the subtalar joint is everted during heel strike, the axes of the talonavicular and calcaneocuboid joint are aligned and functionally “unlocked,” allowing for a supple foot, which accommodates the ground reaction forces.

## 1.3 Midfoot

### 1.3.1 Osteology

#### Cuneiforms

- Medial, middle (intermediate), and lateral cuneiforms (► Fig. 1.5):
  - Trapezoid-shaped structures.
  - Wider plantarly than dorsally to provide strength to the “Roman arch” configuration of the tarsometatarsal joints.

- *Medial cuneiform*: Partial insertions of the tibialis anterior, peroneus longus, and posterior tibial tendon.
- *Intermediate cuneiform*: Shortest; allows for the base of the second metatarsal to “key” in.
- Articulations between the cuneiforms, navicular, cuboid, and metatarsal bases 1 to 3.

#### Tarsometatarsal Joint (Lisfranc Complex)

- The midfoot and its articulations allow for transference of force from the hindfoot to the forefoot during gait (► Fig. 1.6). It provides both the stability and the flexibility needed for normal walking.
- Comprises three columns.
  - *Medial*: First metatarsocuneiform joint.
  - *Middle*: Second and third metatarsocuneiform joint.
    - Most rigid of the columns to allow for stable push-off.



Fig. 1.5 Foot osteology.

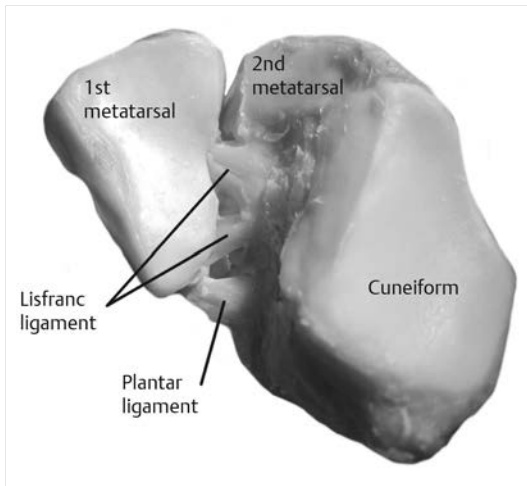


Fig. 1.6 Lisfranc ligament.

- *Lateral*: Fourth and fifth metatarsocuboid joint:
  - Most mobile of the columns to allow for flexibility when walking on uneven surfaces.
- Osseous anatomy creates a “Roman arch” structure in which the base of the second metatarsal acts as the “keystone” as it articulates with the recessed middle cuneiform.
- Tarsometatarsal ligamentous stability is provided by three layers:
  - **The interosseous layer is the strongest and contains the Lisfranc ligament, which connects the medial cuneiform to the plantar aspect of the second metatarsal.**
  - Plantar ligaments between the medial cuneiform and the second and third metatarsals help provide transverse stability.
- Dorsal ligaments are the weakest.
- Intermetatarsal articulations:
  - Intermetatarsal ligaments run between the second and fifth metatarsal bases, but there is no ligament connecting the first and second metatarsal bases.
- Cuneiforms are connected by plantar, dorsal, and IOLs.
- Allows for a minimal amount of gliding.

- Naviculocuneiform and intercuneiform articulations:
  - Minimal motion.

## 1.4 Forefoot

### 1.4.1 Osteology

#### Metatarsals

- Each metatarsal has a base, shaft, neck, and head.
- Distal intermetatarsal ligaments between metatarsals 2 and 5 provide length and alignment stability.
- First metatarsal:
  - Shortest and widest of the metatarsals.
  - Bears up to 50% of the weight of the forefoot.
  - The metatarsal head has a crista that separates the two sesamoids (► Fig. 1.7).
- Second metatarsal:
  - Longest of the metatarsals and most prone to stress fractures.
- Third metatarsal:
  - **Rarely fractures in isolation.**
- Fourth and fifth metatarsals:
  - Flexible articulation with the cuboid.
- The fifth metatarsal base has a tenuous blood supply in the watershed area, leading to risk of nonunion. Vascularity

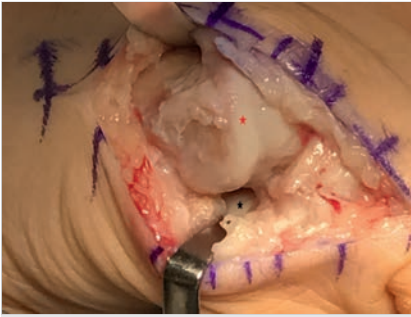


Fig. 1.7 Medial approach to the first metatarsal head showing the metatarsal-sesamoid articulation. *Black star*: The medial sesamoid. *Red star*: The metatarsal head.

is through the metaphyseal vessels and diaphyseal nutrient artery.

## Phalanges

- Long bones in the foot distal to the metatarsals.
- The great toe contains two phalanges (proximal and distal).
- The small toes contain three phalanges (proximal, middle, and distal).

## Joints

- *Metatarsophalangeal (MTP)*: Between the metatarsal and the proximal phalanx.
  - *Proximal interphalangeal (PIP)*;
    - ▶ Fig. 1.8): Between the proximal and middle phalanges.<sup>3,5,6,7</sup>
  - *Distal interphalangeal (DIP)*: Between the middle and distal phalanges.<sup>3,5,6,7</sup>
  - *Interphalangeal (IP)*: Between the proximal and distal phalanges (great toe).

## Plantar Plate

- Protects the metatarsal heads from pressure and prevents toe overextension.
  - **Turf toe**: Injury caused by hyperextension of the plantar plate and metatarsophalangeal joint (MTPJ) sesamoid damage.



Fig. 1.8 Lesser toe proximal interphalangeal (PIP) joint. *Black star*: The head of the proximal phalanx. *Red star*: The split extensor tendon. *Blue star*: The collateral ligament.

- Strong supporting ligament of the toes.
- Located on the ball of the foot.

## 1.5 Muscle Anatomy

### 1.5.1 Leg Compartments

#### Anterior Compartment

- *Neurovascular contents*: Deep peroneal nerve and anterior tibial vessels (▶ Fig. 1.9).
- *Muscle innervation*: Deep peroneal nerve
- *Tibialis anterior*:
  - *Origin*: Proximal lateral tibia.
  - *Insertion*: Medial cuneiform and plantar base of the first metatarsal.
  - *Action*: Ankle dorsiflexion and foot inversion.
- *Extensor hallucis longus (EHL)*:
  - *Origin*: Medial fibula and interosseous membrane.
  - *Insertion*: Great toe distal phalanx.



**Fig. 1.9** Anterior ankle exposure. *Black star:* The superficial peroneal nerve. *Red star:* The tibialis anterior tendon. *Green star:* The extensor hallucis longus tendon. *Blue star:* The extensor digitorum longus tendon. *Black circle:* The extensor retinaculum.



**Fig. 1.10** Posterior leg with the Achilles tendon cut/reflecting and fascia to deep posterior compartment incised. *Black star:* The Achilles tendon. *Red star:* The plantaris. *Green star:* The flexor digitorum longus tendon. *Blue star:* The flexor hallucis longus muscle belly.

- *Action:* Great toe dorsiflexion and extension.
- Extensor digitorum longus:
  - *Origin:* Lateral tibial condyle and proximal fibula.
  - *Insertion:* Middle and distal phalanges 2 to 4.
  - *Action:* Dorsiflexion and extension of digits 2 to 4.
- Peroneus tertius:
  - *Origin:* Distal fibula and interosseous membrane.
  - *Insertion:* Fifth metatarsal base.
  - *Action:* Dorsiflex and foot eversion.

### Lateral Compartment

- *Neurovascular contents:* Superficial peroneal nerve.
- *Muscle innervation:* Superficial peroneal nerve.
- Peroneus longus:

- *Origin:* Fibular head and proximal lateral fibula shaft.
- *Insertion:* Plantar medial cuneiform and base of the first metatarsal.
- *Action:* Foot eversion, ankle plantar flexion, and supports the arch of the foot.
- Peroneus brevis:
  - *Origin:* Distal lateral fibula shaft.
  - *Insertion:* Fifth metatarsal base.
  - *Action:* Foot eversion and ankle plantar flexion.

### Superficial Posterior Compartment

- *Neurovascular contents* (► Fig. 1.10): sural nerve.
  - *Muscle innervation:* Tibial nerve.
- Gastrocnemius:
  - *Origin:* Medial and lateral femoral condyles.



- *Insertion*: Posterior calcaneus as the Achilles tendon.
  - The Achilles tendon is the largest tendon in the body. **Rupture can be misdiagnosed as ankle sprain in up to 25% of cases.**
- *Action*: Ankle plantar flexion.
- Soleus:
  - *Origin*: Proximal posterior fibular head and medial tibial shaft.
  - *Insertion*: Posterior calcaneus as the Achilles tendon.
  - *Action*: Ankle plantar flexion.
- Plantaris:
  - *Origin*: Supracondylar line of the lateral femur.
  - *Insertion*: Calcaneus.
  - *Action*: Weak ankle plantar flexion.

## Deep Posterior Compartment

- *Neurovascular contents* (► Fig. 1.11): Tibial nerve, posterior tibial vessels, and peroneal vessels:
  - *Muscle innervation*: Tibial nerve.
- Popliteus:
  - *Origin*: Lateral surface of the lateral femoral condyle.
  - *Insertion*: Proximal posterior tibia.
  - *Action*: Internal rotation of the tibia/knee during initiation of knee flexion.
- FHL:
  - *Origin*: Inferior posterior fibula.
  - *Insertion*: Great toe distal phalanx.
  - *Action*: Great toe plantar flexion (► Fig. 1.12).
- Flexor digitorum longus (FDL)

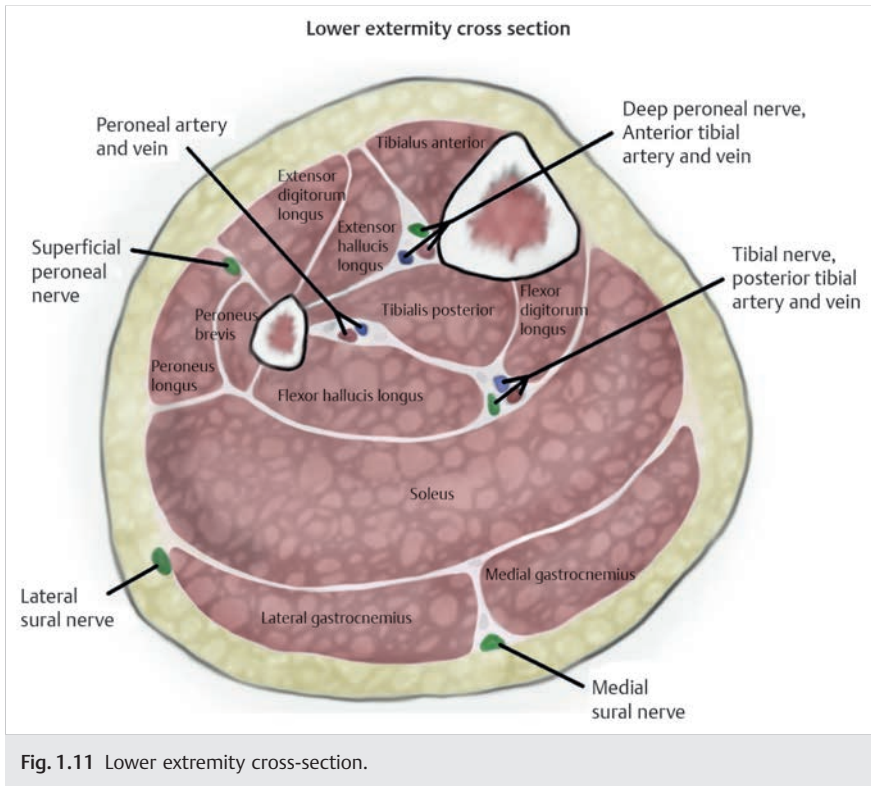




Fig. 1.12 Flexor hallucis longus at its distal insertion and at the knot of Henry.

- *Origin:* Posterior tibia.
- *Insertion:* Distal phalanges 2 to 5.
- *Action:* Toes 2 to 5 plantar flexion.
- Tibialis posterior (TP):
  - *Origin:* Posterior tibia, fibula, and interosseous membrane.
  - *Insertion:* Plantar navicular cuneiforms and metatarsals.
  - *Action:* Foot inversion, adduction, and ankle plantar flexion. Primary source of dynamic arch support.
  - **Posterior tibial tendon insufficiency is the most common cause of adult-acquired flatfoot deformity.**
- Posterior tibial tendon has three terminal limbs:
  - *Anterior limb:* Insertion on the first cuneiform and navicular tuberosity.
  - *Middle limb:* Insertion on cuneiforms 2 to 3, cuboid, and metatarsals 2 to 4.
  - *Posterior limb:* Insertion on anterior sustentaculum tali.

## 1.5.2 Layers of the Foot Compartments

- Nine compartments described by Manoli and Weber (controversial).
- Medial.
- Superficial.
- Lateral.
- Adductor.
- Calcaneal.
- Four interosseous.

### Plantar Fascia

- Divided into three bands.
- Central band or plantar aponeurosis:
  - Originates at the medial calcaneal tuberosity and divides to insert on each toe (flexor tendon sheaths superficially and deep transverse metatarsal ligaments deep).
- Medial band.
- Lateral band:
  - Stabilizes the arch, especially during toe-off, via the **windlass mechanism** and protects deeper structures of the foot.
- Common injuries include **plantar fasciitis** and **fibromatosis**.

### First Plantar Layer

- **Most superficial layer.**
- Muscles:
  - Abductor hallucis.
    - *Origin:* Medial process of calcaneal tuberosity.
    - *Insertion:* Base of the proximal phalanx of the great toe.
    - *Innervation:* Medial plantar nerve.
    - *Action:* Abduction of the great toe.
  - Flexor digitorum brevis (FDB).
    - *Origin:* Medial process of calcaneal tuberosity.
    - *Insertion:* Middle phalanges of toes 2 to 5.
    - *Innervation:* Medial plantar nerve.
    - *Action:* Flexion of toes 2 to 5.
  - Abductor digiti minimi (ADM).
    - *Origin:* Medial and lateral processes of calcaneal tuberosity.

- *Insertion:* Lateral base of the fifth toe proximal phalanx.
- *Innervation:* Lateral plantar nerve.
- *Action:* Abduction of the fifth toe.

## Second Plantar Layer

- Muscles:
  - Quadratus plantae:
    - *Origin:* Plantar calcaneus.
    - *Insertion:* Lateral tendon of the FDL.
    - *Innervation:* Lateral plantar nerve.
    - *Action:* Aids toe flexion (with FDL).
  - Lumbrical muscles:
    - *Origin:* Branches of the FDL.
    - *Insertion:* Proximal phalanges.
    - *Innervation:* Medial and lateral plantar nerves.
    - *Action:* Flexion of the MTP joints and extension of the IP joints.
- Tendons:
  - FDL.
  - FHL.
    - ***Knot of Henry:*** The FDL crosses over the FHL at the level of the navicular, and the tendons are connected via multiple attachments.
- Neurovasculature:
  - Terminal branches of the tibial nerves.
  - Medial and lateral plantar nerves.
  - Medial plantar artery.
  - Lateral plantar artery.

## Third Plantar Layer

- Muscles:
  - Flexor hallucis brevis (FHB):
    - *Origin:* Cuboid and lateral cuneiform.
    - *Insertion:* Proximal phalanx of great toe.
    - *Innervation:* Medial plantar nerve.
    - *Action:* Flexion of the great toe MTP joint.
- Adductor hallucis:
  - Oblique and transverse heads:
    - *Origin:* Two to four metatarsals (oblique) and lateral four MTP (transverse).
    - *Insertion:* Proximal phalanx of the great toe.
    - *Innervation:* Lateral plantar nerve.

- *Action:* Adduction of the great toe.
- **Implicated in hallux valgus deformity.**

- Flexor digiti minimi brevis (FDMB):
  - *Origin:* Fifth metatarsal base.
  - *Insertion:* Proximal phalanx of the small toe.
  - *Innervation:* Lateral plantar nerve.
  - *Action:* Flexion of MTP of the small toe.

## Fourth Plantar

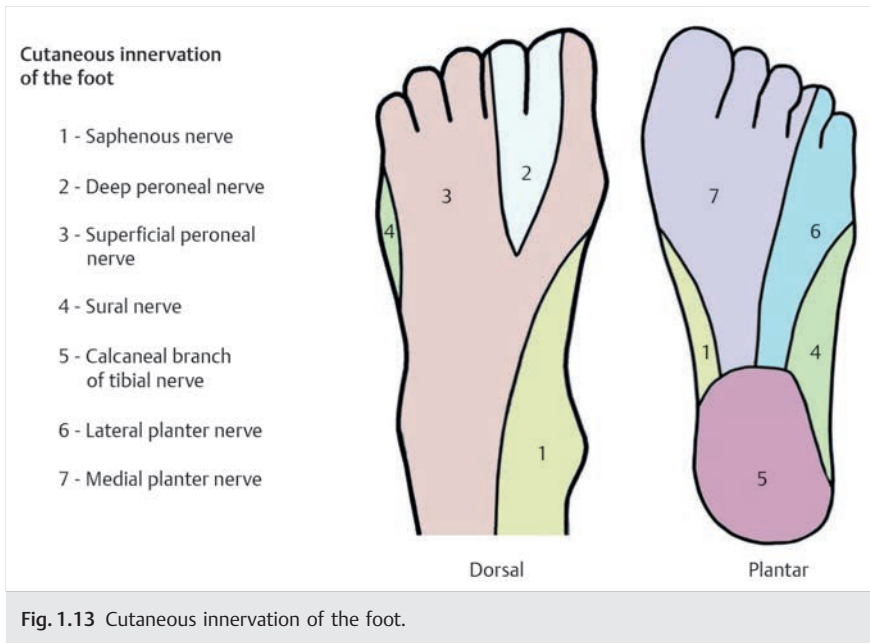
- Deepest layer.
- Muscles:
  - Dorsal interosseous muscle:
    - *Origin:* Adjacent metatarsals.
    - *Insertion:* Lateral proximal phalanx 2 to 4 and medial proximal phalanx 2.
    - *Innervation:* Lateral plantar nerve.
    - *Action:* Toe abduction.
  - Plantar interosseous muscle:
    - *Origin:* Medial metatarsals 3 to 5.
    - *Insertion:* Medial proximal phalanges 3 to 5.
    - *Innervation:* Lateral plantar nerve.
    - *Action:* Toe adduction, MTPJ flexion, and LPJ extension.
- Tendons:
  - Travel through the fibro-osseous tunnels.
  - Peroneus longus.
  - TP.

## Dorsal Layer

- Extensor digitorum brevis (EDB):
  - *Origin:* Dorsolateral calcaneus.
  - *Insertion:* Proximal phalanges 2 to 4.
  - *Innervation:* Deep peroneal nerve.
  - *Action:* MTPJ 2 to 4 extension.
- Extensor hallucis brevis:
  - *Origin:* Dorsolateral calcaneus.
  - *Insertion:* Proximal phalanx of great toe.
  - *Innervation:* Deep peroneal nerve.
  - *Action:* MTPJ great toe extension.

## 1.5.3 Neural Anatomy

There are five main nerves that supply the foot and ankle (► Fig. 1.13).



### Tibial Nerve

- Runs posterior to the medial malleolus into the tarsal tunnel, then divides into the medial calcaneal branch and medial and lateral plantar nerves.
- Medial calcaneal branch:
  - Supplies sensation to the plantar heel.

### Medial Planter Nerve

- Sensation to the medial plantar foot and toes, motor to the abductor hallucis, FDB, medial lumbricals, and FHB.

### Lateral Planter Nerve

- Sensation to the plantar lateral foot and toes, motor to the abductor digiti minimi (via **Baxter's nerve**, which is the first branch and is often implicated in heel pain), quadratus plantae, lateral lumbricals, adductor hallucis, FDMB, and dorsal and plantar interosseous muscles.

### Superficial Peroneal Nerve

- Dorsal foot and medial great toe sensation. **Can be injured during the lateral approach to the ankle and also the anterolateral arthroscopy portal.**

### Deep Peroneal Nerve

- Sensation to the first dorsal webspace and motor to the EDB and EHL.

### Sural Nerve

- Dorsolateral foot sensation.

### Saphenous Nerve

- Medial foot sensation.

## 1.5.4 Vascular Anatomy

- Three major arteries in the foot and ankle:
  - *Posterior tibial artery*: Supplies the medial malleolus and calcaneus.

Two terminal branches are the medial and lateral plantar arteries. These have further branches that anastomose to form the **deep plantar arch**.

- **Anterior tibial artery:** Supplies the medial and lateral malleolus along with the dorsum of the foot. Also gives way to the **dorsalis pedis** artery in the foot.
- **Peroneal artery:** Supplies the posterior talus, lateral malleolus, and the calcaneus via a perforating artery that goes through the interosseous membrane.

Bones with tenuous blood supply include the talus, navicular, and the base of the fifth metatarsal.

## 1.6 Key Testing Facts

- The anterior talofibular ligament is the most commonly injured ligament in ankle sprains.
- Artery of the tarsal canal, a branch of the posterior tibial artery is the major arterial supply to the talus.
- Posterior tibial tendon insufficiency is the most common cause of adult acquired flatfoot deformity.
- The Flexor hallucis longus tendon runs beneath the sustentaculum tali.
- The insertion of the tibialis anterior is the medial cuneiform and the base of the first metatarsal. The contents of the tarsal tunnel from anteromedial to posterolateral: tibialis posterior, FDL, posterior tibial artery, posterior tibial vein, tibial nerve, and FHL.

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