MEDICAL EDUCATION RESOURCE

Sole of Foot: A-Z

Sole of the Foot

Introduction

- The **sole** forms the **inferior (plantar) surface** of the foot — specialized for **support, locomotion, and weight transmission**.
- Divided into **medial, lateral, and central regions** based on thickness of skin, fascia, and underlying muscles.
- The **skin, fascia, and arches** together provide **shock absorption and grip**.
- The region is supplied by **medial and lateral plantar nerves and arteries**, which are terminal branches of the **tibial nerve** and **posterior tibial artery** respectively.
- **Muscles in layers (superficial ? deep):**
    1. *Abductor hallucis, Flexor digitorum brevis, Abductor digiti minimi*
    2. *Quadratus plantae, Lumbricals*
    3. *Flexor hallucis brevis, Adductor hallucis, Flexor digiti minimi brevis*
    4. *Plantar and dorsal interossei*
- Functions: **Weight bearing, propulsion, protection, and balance.**

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Skin

- **Thick, hairless, and strongly bound** to underlying fascia by fibrous septa.
- Shows **deep flexion creases** at joints of toes.
- Contains numerous **sweat glands**, making it moist and resilient.
- No sebaceous glands ? dryness in this area leads to *cracked heels*.
- **Nerve supply:**
    - *Medial plantar nerve* ? medial three and half toes.
    - *Lateral plantar nerve* ? lateral one and half toes.
    - *Sural nerve* ? lateral margin.
    - *Saphenous nerve* ? medial border of foot up to ball of great toe.
    - *Calcanean branches of tibial nerve* ? heel.
- **Clinical relevance:**
    - Highly sensitive ? protective reflex against injury.
    - **Plantar reflex (Babinski's sign):** stroking sole ? normal flexion of toes; dorsiflexion indicates pyramidal tract lesion.

Fasciae of the Sole

The fasciae consist of **superficial fascia** and **deep fascia (plantar aponeurosis)**.

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Superficial Fascia

- **Composition:** Fibrofatty tissue containing **fat lobules**, **veins**, **nerves**, and **sweat glands** .
- Fat acts as a **shock absorber** and **insulator**, especially at the heel and ball of the foot.
- The **fibrous septa** anchor the skin to the **plantar aponeurosis**, preventing sliding during walking.
- **Clinical relevance:**
    - **Plantar abscesses** are localized due to tight fibrous septa.
    - **Heel pad atrophy** in elderly reduces cushioning ? heel pain.

Deep Fascia (Plantar Aponeurosis) – briefly introduced here

- Dense triangular sheet of deep fascia covering the **central part** of the sole.
- **Apex:** attached posteriorly to **medial process of calcaneal tuberosity**.
- **Base:** divides near the roots of toes into **five slips**, which enclose digital tendons.
- **Functions:**
    - Protects underlying vessels, nerves, and muscles.
    - Maintains **longitudinal arch** of foot.
    - Provides **firm grip** on the ground.

- **Clinical importance:** *Plantar fasciitis* — inflammation and microtears of aponeurosis ? heel pain.

Dissection (Superficial Layer)

- Place cadaver **supine with sole upward**.
- Make a midline incision from **heel to tip of middle toe**, with two transverse cuts across **toes and heel**.
- Reflect skin and superficial fascia carefully to expose:
    - **Plantar vessels and nerves** (cutaneous branches).
    - **Plantar aponeurosis** — thick fibrous structure in the center.
- Note:
    - Fat pads under **heel** and **heads of metatarsals**.
    - Fibrous septa connecting skin to fascia.
- Identify branches of **medial and lateral plantar nerves** supplying digital skin.

Deep Fascia of the Sole

- The deep fascia of the sole is **thick centrally** and **thin on the sides**.
- In the **central part**, it is **condensed to form the plantar aponeurosis**; on medial and lateral sides, it covers the respective muscular compartments.

- It acts as a **protective layer** and **maintains the arches of the foot** by keeping plantar structures firmly bound.

Plantar Aponeurosis

- **Shape:** Strong, triangular fibrous sheet in the middle of the sole.
- **Apex (posterior end):**
  - Attached to the **medial process of calcaneal tuberosity** and blends with **tendo calcaneus**.
- **Base (anterior margin):**
  - Splits near the heads of metatarsals into **five digital slips**.
  - Each slip divides into **superficial** and **deep layers**:
    - *Superficial part* joins the skin at the base of toes.
    - *Deep part* divides into two laminae that enclose the **flexor tendons**, **digital vessels**, and **nerves**.
- **Medial and lateral borders:**
  - Send vertical **intermuscular septa** separating the sole into **three compartments**:
    - **Medial compartment:** abductor hallucis and flexor hallucis brevis.
    - **Lateral compartment:** abductor digiti minimi and flexor digiti minimi brevis.

        - **Central compartment:** flexor digitorum brevis, tendons of long flexors, lumbricals, and vessels.

- **Functions:**
    - Protects underlying muscles, vessels, and nerves.
    - Provides firm grip for weight-bearing.
    - Supports **longitudinal arch** of the foot.
    - Acts as an attachment for **skin septa**, limiting spread of infection.

Deep Transverse Metatarsal Ligaments

- Short, strong **fibrous bands** connecting the **plantar plates** of all metatarsophalangeal joints.
- Situated along the **heads of the metatarsals**.
- Bind together the anterior ends of metatarsal bones ? maintain the **transverse arch** of foot.
- Give attachment to **fibrous digital sheaths** of the toes.
- **Clinical note:** These ligaments prevent **splaying of forefoot** during standing or walking.

Fibrous Flexor Sheaths

- Strong fibrous tunnels enclosing the **flexor tendons** on the plantar side of the toes.
- Extend from the **heads of metatarsals** to the **bases of distal phalanges**.

- Each sheath forms an **osteofibrous canal** along with the phalanges and plantar plates.
- **Contents (within sheath):**
  - *Flexor digitorum longus* and *flexor digitorum brevis* tendons.
  - Each tendon is surrounded by a **synovial sheath** to minimize friction.
- **Function:**
  - Prevent bow-stringing of tendons during toe flexion.
  - Provide stability and smooth movement of flexor tendons.
- **Clinical note:**
  - Infection of these sheaths ? **tenosynovitis**, causing swelling along the affected toe.
  - Spread may extend to **mid-palmar space** in severe cases.

Clinical Anatomy

- **Plantar Fasciitis:**
  - Inflammation and micro-tearing of plantar aponeurosis due to overuse or tight calf muscles.
  - Causes severe **heel pain** (especially on first step in morning).
- **Calcaneal Spur:**
  - Bony outgrowth from the calcaneal tuberosity where aponeurosis attaches.

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- Often accompanies chronic plantar fasciitis.

- **Plantar Abscess:**
  - Deep infection limited by tight fibrous septa ? swelling is tense and very painful.
  - Incision must follow the line of septa to avoid damaging neurovascular bundles.

- **Rupture of Plantar Aponeurosis:**
  - Sudden overstretching (e.g., jumping) may cause tearing ? localized pain and loss of arch support.

- **Flat Foot (Pes planus):**
  - Weakening of plantar aponeurosis and ligaments ? collapse of medial longitudinal arch.

- **Diabetic Ulcers:**
  - Common over pressure areas of sole due to loss of protective sensation and poor vascularity.

Muscles of the Sole of Foot

The sole contains **20 muscles arranged in four layers**.
All are supplied by branches of the **medial and lateral plantar nerves** (terminal branches of the tibial nerve).

First Layer (Superficial Layer)

Muscles:

1. **Abductor hallucis** – from medial calcaneal tuberosity ? base of proximal phalanx of great toe.
   Nerve: Medial plantar nerve.
   Action: Abducts and flexes great toe.

2. **Flexor digitorum brevis** – from calcaneal tuberosity ? four tendons into middle phalanges of lateral four toes.
   Nerve: Medial plantar nerve.
   Action: Flexes lateral four toes at PIP joints.

3. **Abductor digiti minimi** – from calcaneal tuberosity ? base of proximal phalanx of fifth toe.
   Nerve: Lateral plantar nerve.
   Action: Abducts and flexes little toe.

Second Layer

Muscles and tendons present:

1. **Flexor digitorum longus** (from posterior leg) – divides into four tendons ? distal phalanges of lateral four toes.

2. **Flexor digitorum accessorius (Quadratus plantae)** – two heads from calcaneum ? tendon of FDL.
   Nerve: Lateral plantar nerve.
   Action: Straightens the oblique pull of FDL.

3. **Lumbricals (four small muscles)** – arise from tendons of FDL.
   Nerve:

    - 1st lumbrical ? Medial plantar nerve.

- Remaining three ? Lateral plantar nerve.
  Action: Flex MTP joints and extend IP joints.

4. **Flexor hallucis longus tendon** (from leg) – runs medial to FDL; gives tendinous slip to it.

Third Layer

Muscles:

1. **Flexor hallucis brevis** – from cuboid and lateral cuneiform ? medial and lateral sides of base of proximal phalanx of great toe.
   Nerve: Medial plantar nerve.
   Action: Flexes proximal phalanx of great toe.

2. **Adductor hallucis** – two heads:

   - *Oblique head:* from bases of 2nd–4th metatarsals and sheath of peroneus longus.

   - *Transverse head:* from plantar ligaments of lateral three MTP joints.
     Insertion: Lateral side of base of proximal phalanx of great toe.
     Nerve: Deep branch of lateral plantar nerve.
     Action: Adducts great toe, maintains transverse arch.

3. **Flexor digiti minimi brevis** – from base of 5th metatarsal ? base of proximal phalanx of little toe.
   Nerve: Superficial branch of lateral plantar nerve.
   Action: Flexes proximal phalanx of little toe.

Fourth Layer

Muscles:

1. **Plantar interossei (3)** – unipennate; arise from medial sides of 3rd–5th metatarsals.
   Action: Adduct toes (PAD – plantar adduct).
   Nerve: Deep branch of lateral plantar nerve.

2. **Dorsal interossei (4)** – bipennate; arise from adjacent sides of metatarsals.
   Action: Abduct toes (DAB – dorsal abduct).
   Nerve: Deep branch of lateral plantar nerve.

Also present:

- Tendons of **peroneus longus** (crossing obliquely to medial cuneiform and 1st metatarsal).

- **Tibialis posterior** insertion slip to medial cuneiform and navicular.

Plantar Vessels and Nerves

1. Medial Plantar Artery

- Smaller terminal branch of posterior tibial artery.

- Lies along medial border between *abductor hallucis* and *flexor digitorum brevis*.

- *Branches:* Cutaneous, muscular, and 3 small superficial digital arteries joining plantar arch.

2. Lateral Plantar Artery

- Larger branch; crosses sole to 5th metatarsal ? curves medially to form **plantar arch**, completed by dorsalis pedis.

- *Branches:*

- 4 plantar metatarsal arteries ? divide into plantar digital arteries for adjacent sides of toes.
- A branch to lateral side of little toe.
- Calcaneal and anastomotic branches.

3. Medial Plantar Nerve (L4–S1)

- Larger terminal branch of tibial nerve.
- Between *abductor hallucis* and *flexor digitorum brevis*.
- *Supplies:*
  - Muscles: Abductor hallucis, Flexor digitorum brevis, Flexor hallucis brevis, First lumbrical.
  - Skin: Medial 3½ toes.

4. Lateral Plantar Nerve (S1–S3)

- Smaller terminal branch of tibial nerve.
- Runs obliquely to 5th metatarsal between 1st and 2nd layers.
- Divides into:
  - **Superficial branch:** to flexor digiti minimi brevis and skin of 1½ lateral toes.
  - **Deep branch:** accompanies plantar arch, supplies interossei, adductor hallucis, and 3 lateral lumbricals.

Clinical Anatomy

- **Morton’s Neuroma:**
  - Painful thickening of plantar digital nerve (usually between 3rd and 4th metatarsals) due to compression by transverse metatarsal ligament.
- **Nerve Entrapment:**
  - Medial plantar nerve entrapment ? pain along medial sole (“Jogger’s foot”).
  - Lateral plantar nerve entrapment ? pain in lateral sole and toes.
- **Plantar Fascial Conditions:**
  - *Plantar fasciitis* and *calcaneal spur* cause heel pain radiating to sole.
- **Diabetic Neuropathy:**
  - Loss of sensation on sole ? trophic ulcers at pressure points.
- **Loss of Arches:**
  - Weakening of plantar ligaments or muscles leads to *flat foot (pes planus)*.

Medial Plantar Artery

Origin:

- Smaller terminal branch of the **posterior tibial artery**.

Course:

- Runs forward along the **medial border of the foot**, between *abductor hallucis* and *flexor digitorum brevis*.

Termination:

- Ends by dividing into several **superficial digital branches** that anastomose with **plantar metatarsal arteries** from the plantar arch.

Branches:

- **Cutaneous branches** – to skin of medial sole.
- **Muscular branches** – to *abductor hallucis* and *flexor digitorum brevis*.
- **Three superficial digital branches** – join the first, second, and third plantar metatarsal arteries.

Functional note:

- Supplies medial part of sole and medial 3½ toes through its branches.

Lateral Plantar Artery

Origin:

- Larger terminal branch of the **posterior tibial artery**.

Course:

- Runs obliquely across the sole to the **base of the 5th metatarsal**, where it gives a superficial branch and continues medially as the **plantar arch**.

Branches:

- **Muscular branches** – to adjacent muscles.
- **Cutaneous branches** – to skin and fascia of lateral sole.
- **Anastomotic branches** – connect with arteries on the dorsum of foot.
- **Calcanean branch** – occasionally to heel region.

Functional note:

- Chief vessel forming the **plantar arch** and supplying the greater part of the sole.

Plantar Arch

Formation:

- Formed by the continuation of the **lateral plantar artery** after giving its superficial branch.
- Completed on the medial side by the **deep plantar branch of the dorsalis pedis artery**.

Course:

- Extends from the **base of the 5th metatarsal** to the **proximal part of the 1st intermetatarsal space**.
- Lies between the **third and fourth layers** of the sole.

- Accompanied by **venae comitantes** and the **deep branch of the lateral plantar nerve** in its concavity.

Branches:

1. **Four plantar metatarsal arteries**, one in each intermetatarsal space ? divide into **plantar digital arteries** for adjacent sides of toes.
2. **First plantar metatarsal artery** also gives a branch to the medial side of great toe.
3. **Lateral side of little toe** gets a direct branch from the **lateral plantar artery**.

Function:

- Principal arterial network of the sole ensuring rich collateral circulation with the dorsalis pedis artery.

Clinical Anatomy

- **Morton's Neuroma:**
  - Painful thickening (neuroma) of the plantar digital nerve, usually between **3rd and 4th metatarsals**.
  - Produces sharp burning pain during walking.
- **Ischemic Pain of Sole:**
  - Spasm or occlusion of plantar arteries causes cramp-like pain (common in diabetic and atherosclerotic patients).

- **Plantar Hematoma:**
    - Injury to plantar vessels may lead to deep hematoma due to tight fascia, producing severe pressure and pain.
- **Vascular Insufficiency:**
    - In diabetes, diminished perfusion of plantar arteries ? delayed healing and ulceration over metatarsal heads.

? Facts to Remember — Sole of the Foot

- The **sole of the foot** is specialized for **support, protection, and locomotion**.
- The **skin** is thick, hairless, and firmly anchored to deep fascia by **fibrous septa**.
- The **superficial fascia** is fibrofatty and acts as a **shock absorber**.
- The **deep fascia** is thickened centrally as the **plantar aponeurosis**, providing protection and maintaining the longitudinal arch.
- The **sole** is divided into **three compartments** by septa from the aponeurosis: medial, lateral, and central.
- **Muscles of the sole (20 total)** are arranged in **four layers** and supplied by **medial and lateral plantar nerves**.
- **Medial plantar nerve** = equivalent to median nerve of hand (supplies 4 muscles and 3½ toes).

- **Lateral plantar nerve** = equivalent to ulnar nerve of hand (supplies 14 muscles and 1½ toes).
- **Plantar arteries** (medial and lateral plantar) are terminal branches of the posterior tibial artery.
- The **lateral plantar artery** forms the **plantar arch** with dorsalis pedis artery.
- **Tendons crossing sole:**
    - *Flexor hallucis longus* ? to great toe.
    - *Flexor digitorum longus* ? to lateral four toes.
    - They are connected by a tendinous slip.
- **Peroneus longus tendon** runs obliquely across the sole to maintain the **transverse arch**.
- **Abductor hallucis** and **abductor digiti minimi** maintain the medial and lateral longitudinal arches respectively.
- **Plantar interossei (PAD)** adduct toes; **Dorsal interossei (DAB)** abduct toes.
- **Plantar aponeurosis** prevents over-stretching of the arch during weight bearing.
- **Pulse of posterior tibial artery** can be felt midway between medial malleolus and heel.
- The **plantar reflex** (L5, S1) tests integrity of corticospinal tract.
- **Foot drop** results from paralysis of dorsiflexors (anterior compartment); **claw toes** from paralysis of intrinsic muscles of sole.

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- **Flat foot (pes planus)** results from weakening of plantar aponeurosis, ligaments, and intrinsic muscles.

- **Morton's neuroma** involves digital nerve in 3rd intermetatarsal space due to chronic compression.

?? Clinicoanatomical Problems (20 Key Cases)

1. **Plantar Fasciitis** — Overuse inflammation of plantar aponeurosis ? heel pain, worse on first morning steps.

2. **Calcaneal Spur** — Chronic traction at calcaneal tuberosity causes bony spur formation ? point tenderness on heel.

3. **Plantar Abscess** — Deep infection limited by tight septa ? swelling localized but extremely painful.

4. **Morton's Neuroma** — Fibrosis around digital nerve between 3rd and 4th metatarsals ? burning pain on walking.

5. **Jogger's Foot** — Entrapment of medial plantar nerve under abductor hallucis ? medial sole pain.

6. **Baxter's Neuropathy** — Entrapment of first branch of lateral plantar nerve ? pain near heel mimicking plantar fasciitis.

7. **Diabetic Ulcer (Plantar)** — Pressure sores due to neuropathy and ischemia, especially under metatarsal heads.

8. **Flat Foot (Pes Planus)** — Collapse of medial longitudinal arch due to weak ligaments or muscle fatigue.

9. **Pes Cavus (High Arch)** — Exaggerated arch due to overactive tibialis posterior or contracture of plantar fascia.

10. **Rupture of Plantar Aponeurosis** — Sudden jump or sprint causes tearing ? acute pain and flattening of arch.

11. **Tarsal Tunnel Syndrome** — Compression of tibial nerve beneath flexor retinaculum ? radiating sole pain.

12. **Claw Toes** — Paralysis of lumbricals and interossei ? hyperextension at MTP joints, flexion at IP joints.

13. **Hallux Valgus** — Deviation of great toe laterally, compressing medial plantar digital nerves.

14. **Hallux Rigidus** — Degenerative arthritis of first MTP joint ? restricted great toe movement.

15. **Plantar Fibromatosis (Ledderhose Disease)** — Fibrosis in plantar fascia ? nodular thickening, painful lumps.

16. **Metatarsalgia** — Pain under metatarsal heads due to inflamed digital nerves or collapsed transverse arch.

17. **Foreign Body in Sole** — Difficult to remove due to dense fascia; infection easily localized by septa.

18. **Gangrene of Toes** — Arterial insufficiency from diabetes or peripheral vascular disease ? tissue necrosis.

19. **Venous Congestion of Sole** — Prolonged standing causes venous stasis ? throbbing pain and swelling.

20. **Posterior Tibial Artery Occlusion** — Loss of plantar pulses; ischemia causes pain and coldness in sole.