# CHAPTER 12

## Lower Limb

It will be recalled that the upper limb is a specialized lateral protuberance from the lower four cervical and 1st thoracic segments of the body wall. The lower limb is a similar outgrowth from the 2nd lumbar through 3rd sacral segments. As such it contains no representation of the body cavity. Rather it is composed of striated muscles, bones, and the connective tissues associated with these structures, all covered by subcutaneous tissue and skin. The only visceral structures to be found in the lower limb are those associated with the body wall: vascular smooth muscle, arrector pili muscles, sweat glands, and sebaceous glands.

In the embryo the lower limb begins as an outpocketing of surface ectoderm that becomes filled with a mesenchyme derived from the subjacent lateral plate mesoderm. The bones of the girdle develop in this lateral plate mesoderm, but the mesenchyme of the bud itself is destined to form the dermis, fascia, vasculature, tendons, and all the bones that lie in the "free" part of the limb. Almost all the cells from hypaxial dermomyotomes L2-S3 migrate into the limb bud mesenchyme to become the actual striated muscles of the lower limb. It is true that a few cells from hypaxial dermomyotomes L2-L4 stay in the trunk where they become the quadratus lumborum, and some cells from hypaxial dermomyotomes S2-S3 stay in the trunk where they join cells from the S4 hypaxial dermomyotome to form the pelvic diaphragm and perineal musculature, but that's it. All the other cells from the L2-L4 and S2-S3 hypaxial dermomyotomes, and all the cells of the L5-S1 hypaxial dermomyotomes, migrate into the lower limb bud.

## ORGANIZATIONAL PATTERN OF THE LOWER LIMB MUSCULATURE AND OF THE MUSCULAR BRANCHES OF THE LUMBOSACRAL PLEXUS

The pattern of evolution and embryonic development of the lower limb is so similar to that of the upper limb that they are considered to be serially homologous structures. If you have not read the beginning of Chapter 11, do so now, for I shall concern myself here primarily with differences between the upper and lower limbs in expression of this pattern.

Obviously, most of the axons in ventral rami L2-S3 will pass into the lower limb for its innervation. However, rather than entering the limb as independent bundles, these ventral rami first participate in a complex exchange of axons that is called the **lumbosacral plexus**. During this exchange, ventral rami L2-S3 lose their individual identities; what emanates from the lumbosacral plexus is a secondary set of nerves (each of which contains axons from two or more ventral rami) that proceed to the innervation of the limb itself.

A characteristic that distinguishes the lumbosacral plexus from the brachial plexus is that the former is divisible into two portions (see Fig. 12-6). The interweaving of ventral rami L2-L4 is almost completely separate from that of ventral rami L5-S3. Thereby are created a **lumbar plexus** and a **sacral plexus**, connected only by a small bundle of axons that branches off from L4 and runs downward to join L5 before the latter participates in the sacral plexus. The product of this joining, although composed predominantly of L5 axons, is given the special name of **lumbosacral trunk**.

Some aspects of the lumbar and sacral plexuses were described in Chapter 5, because these plexuses are seen in dissections of the abdomen and pelvis. There we learned that a communication between L1 and L2 causes most anatomists to consider the ventral ramus of L1 as a participant in the lumbar plexus. However, I must emphasize that L1 is not concerned with the innervation of lower limb muscles. The only role of the L1 ventral ramus in the lower limb is to supply some proximal regions of its skin via the iliohypogastric, ilioinguinal, and genitofemoral nerves.

## Evolution and Development of the Pelvic Limb

The evolutionary origin of the tetrapod hind limb from the pelvic fin of an ancient fish is similar to that of the forelimb from the pectoral fin. Also, embryonic development of the human lower limb tends to recapitulate its evolutionary history.

The human lower limb begins as a dorsoventrally flattened protuberance with a cranial (**pre-axial**) border and a caudal (**postaxial**) border (Fig. 12-1*A*). Within this structure will develop a central skeletal axis that articulates with a flat pelvic girdle formed within the body wall at the base of the limb bud (see Fig. 12-1*C*). The girdle has an articular socket--the **acetabulum**--for reception of the central skeletal axis of the limb bud.

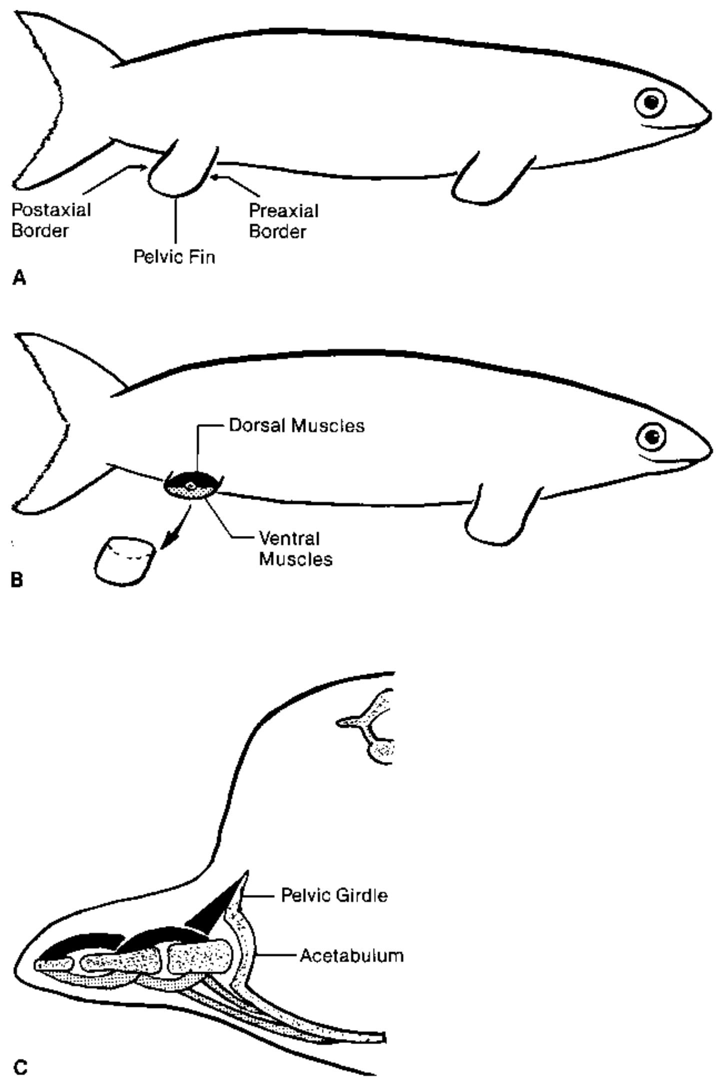



**Figure 12-1.** Pattern of muscle organization in the pelvic fin of A fish (or lower limb of early human embryo). *A*, A fish. *B*, The pelvic fin has been sectioned transversely to reveal the dorsal (*black*) and ventral (*gray*) blocks of limb musculature. *C*, Transverse section of the fish taken through its pelvic fin to reveal the relationship of the dorsal (*black*) and ventral (*gray*) blocks of musculature to the skeleton of the fin.

In both development and evolution, the fin-like pelvic appendage is transformed into a hind limb. This is accomplished by further elongation and the introduction of some bends separating off a **thigh** (with one axial bone), a **leg** (with two axial bones), and a **foot** (comprising a set of ankle bones from which five digits radiate) (Fig. 12-2). The digit lying along the pre-axial border is called the **hallux**.

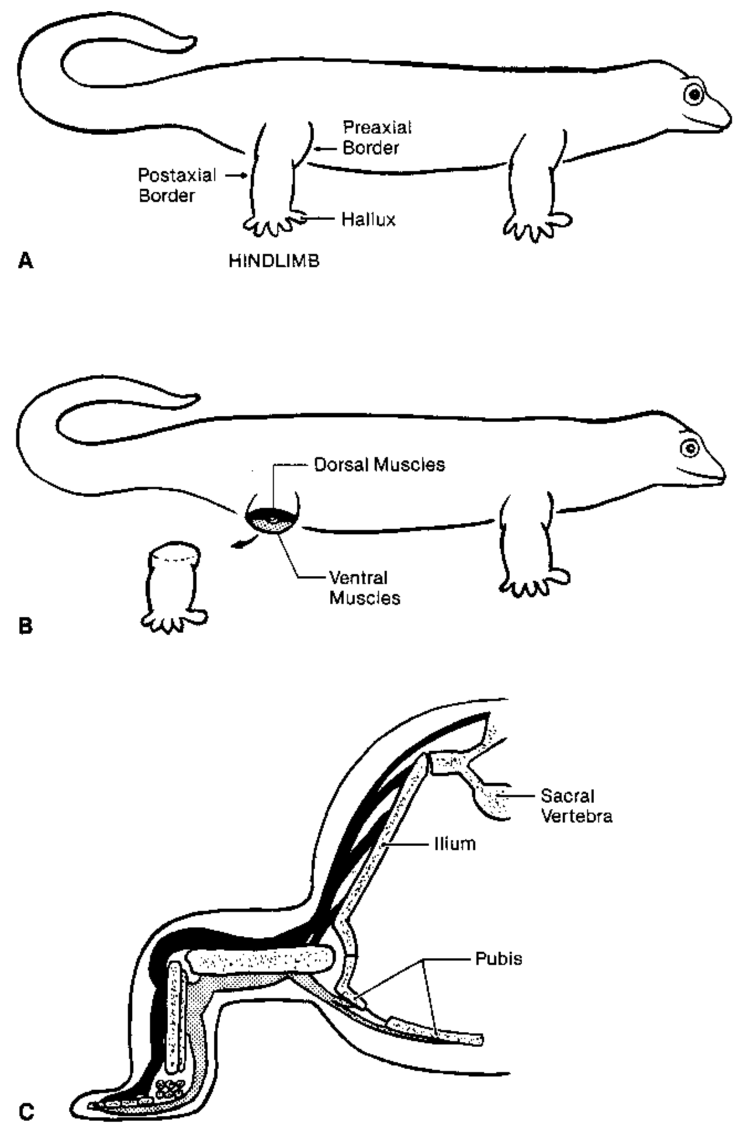



**Figure 12-2.** Pattern of muscle organization in the hind limb of a primitive tetrapod (dorsal muscles in *black*; ventral muscles in *gray*). Compare with Figure 12-1*A* through *C*.

Some portion of the tetrapod pelvic girdle extends dorsal to the acetabulum and approaches the vertebral column, with which it forms a joint. Some portion of the tetrapod pelvic girdle extends ventral to the acetabulum and approaches the midline, where it forms a joint with the girdle of the opposite side (see Fig. 12-2). The dorsal portion of the pelvic girdle will develop its own separate **iliac** ossification center, comparable to the scapular ossification center of the pectoral girdle. The ventral portion of the hind limb girdle develops two ossification centers (Fig. 12-3). The most cranial is called the **pubis**, comparable to the procoracoid center of the forelimb. The more caudal ossification center of the ventral part of the pelvic girdle is called the **ischium**, comparable to the coracoid of the forelimb. The three centers meet at the acetabulum. Whereas during the evolution of the mammalian pectoral girdle the procoracoid was eventually excluded from a contribution to the glenoid fossa and then lost, the pelvic girdle retains the pubis as a significant component assisting in the formation of the acetabulum. However, ventral to the acetabulum there occurs an unossified region where the pubis and ischium abut. This is called the **obturator foramen**.

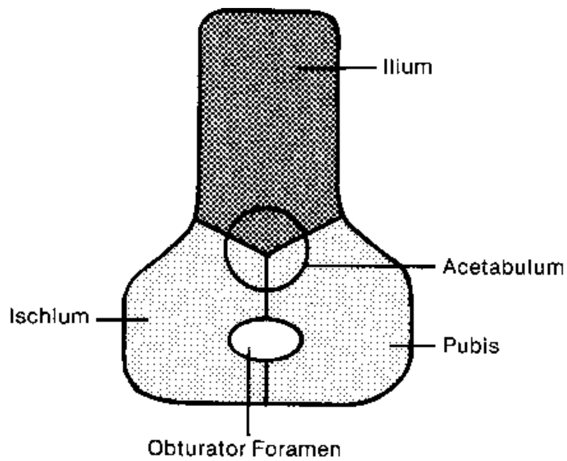


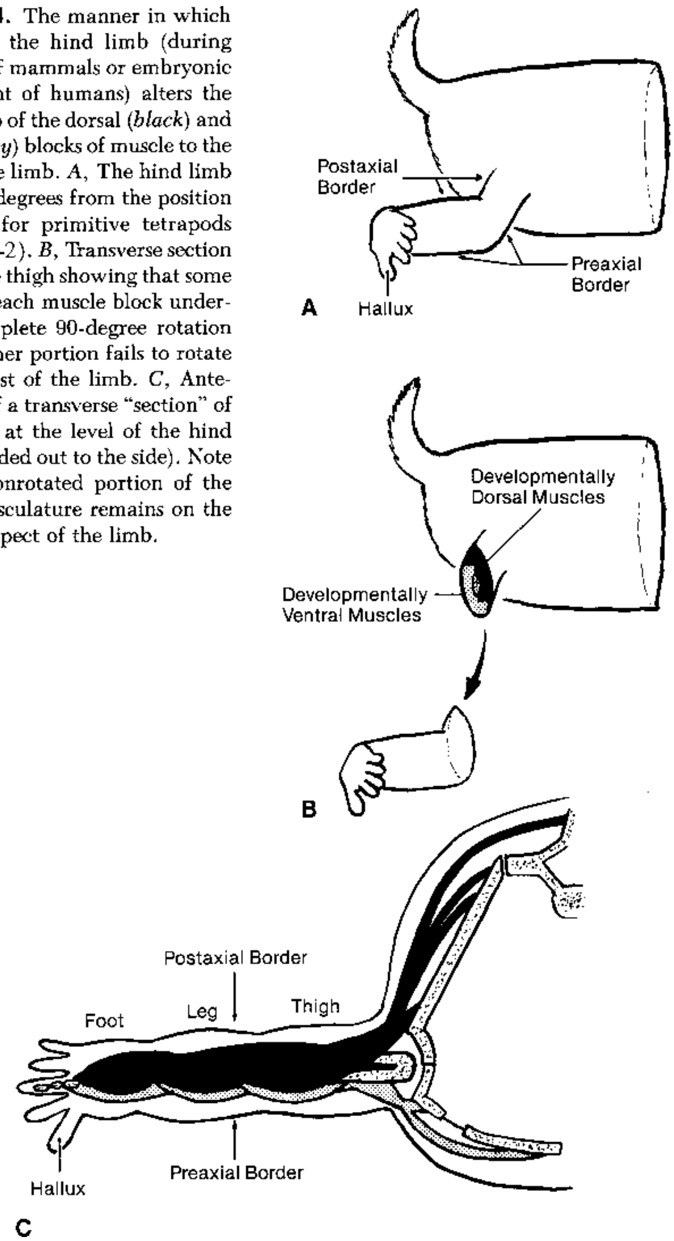

**Figure 12-3.** Lateral view of the pelvic girdle (schematic) of a typical tetrapod. Dorsal girdle element is in *dark gray*; ventral girdle elements are in *light gray*. Cranial is to the *right side* of the figure; caudal is to the *left side*.

Dermomyotome cells that enter the limb bud will become muscles that insert onto one of the long bones of the limb. As in the upper limb, such premuscle cells immediately divide into two groups. One group takes a position dorsal to the bony axis and the other ventral to it (see Fig. 12-2*C*). From the dorsal mass of premuscle cells will develop some muscles that gain an origin from the dorsal girdle element (**ilium**), or even migrate to arise from the vertebral column. From the ventral mass of premuscle cells will develop some muscles that gain attachment to the pubis or ischium. This fundamental dichotomy of a dorsal and ventral limb musculature will be maintained throughout the remainder of human development (or vertebrate evolution).

As was true for the forelimb, so it is the case for the hind limb, that during the transition from reptile to mammal there occurred a reorientation at the hip joint that brings the limb beneath the trunk, rather than sticking out to the side. This is accompanied by a rotation of the free limb around its proximodistal axis so as to allow it to function effectively in its new relation to the trunk. The rotation and repositioning occur together, but it is easier to consider their effects separately.

A major difference between forelimbs and hind limbs is that the direction of the rotation is opposite. Whereas the free part of the forelimb rotated 90 degrees so that its pre-axial border came to face dorsally and its postaxial border to face ventrally (see Fig. 11-4), the rotation of the hind limb occurs in the opposite direction, causing the pre-axial border to face ventrally and the postaxial border to face dorsally (Fig. 12-4). Thus, in the hind limb the developmentally dorsal musculature comes to lie cranial to the long bones, and the developmentally ventral muscles come to lie caudal to the long bones (see Fig. 12-4). Furthermore, whereas only a few muscles of the forearm lagged behind during rotation of the forelimb, this phenomenon of lagging characterizes substantially more muscles of the hind limb. Thus,

**Figure 12-4.** The manner in which rotation of the hind limb (during evolution of mammals or embryonic development of humans) alters the relationship of the dorsal (*black*) and ventral (*gray*) blocks of muscle to the bones of the limb. *A*, The hind limb rotated 90 degrees from the position illustrated for primitive tetrapods (see Fig. 12-2). *B*, Transverse section through the thigh showing that some portion of each muscle block undergoes a complete 90-degree rotation while another portion fails to rotate with the rest of the limb. *C*, Anterior view of a transverse "section" of a mammal at the level of the hind limb (extended out to the side). Note that the nonrotated portion of the ventral musculature remains on the pre-axial aspect of the limb.




some dorsal muscles fail to follow the others onto the cranial surface of the hind limb, instead remaining on its dorsal aspect, which is now associated with the limb's postaxial border (see Fig. 12-4*B*,*C*). Some of the ventral muscles fail to follow the others onto the caudal surface of the hind limb, instead remaining on its ventral aspect, which is now associated with the limb's pre-axial border (see Fig. 12-4*B*,*C*).

Having discussed the consequences of its rotation, we can consider the effect of bringing the hind limb under the trunk (Fig. 12-5). The relationship of dorsal and ventral muscles to the bony axis doesn't change further, but the pre-axial border becomes the medial border and the postaxial border becomes the lateral border. This is the hind limb of a four-footed mammal. To become human, our quadruped need only stand up on its hind limbs. The pre-axial border and hallux are still medial, the postaxial border is still lateral. However, what was the cranial surface in a quadruped is now the anterior surface of an upright human. What was the caudal surface of a quadruped is the posterior surface of a human. Therefore, without further changing their relationships to the bones, **the developmentally dorsal**

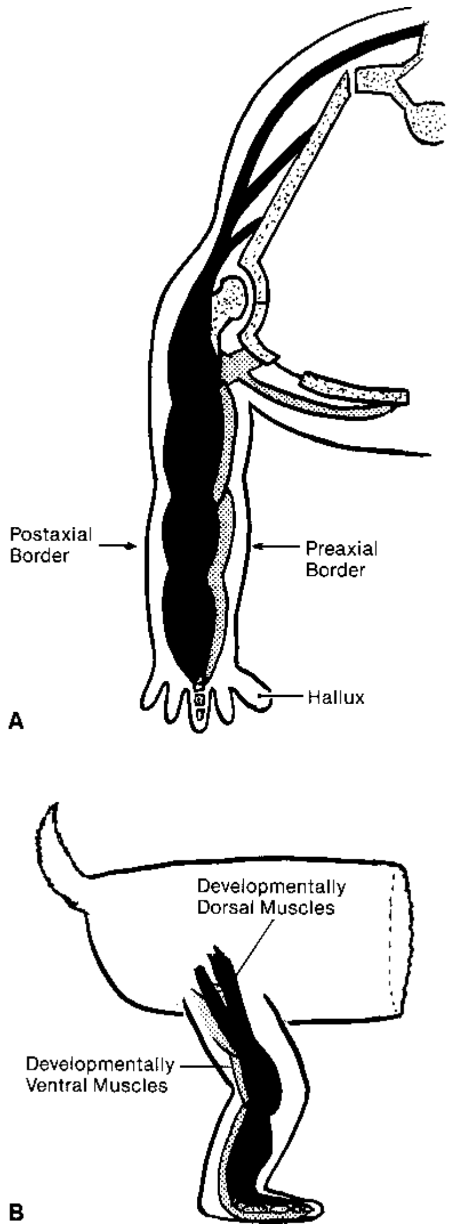



**Figure 12-5.** The mammalian hind limb brought beneath the trunk. Dorsal muscle block in *black*; ventral muscle block in *gray*. *A*, Anterior view of a transverse "section" of a mammal (as in Fig. 12-4*C*) with limb now under the trunk. *B*, Side view of the way the hind limb and its muscles are oriented in a mammal.

**muscles can be said to lie along the anterior and lateral aspects of the human lower limb, while the developmentally ventral muscles are found along its posterior and medial aspects**. Indeed, it is useful to speak of the lower limb musculature as being divided into four compartments--anterior, lateral, posterior, and medial--of which the first two are composed of developmentally dorsal muscles, and the last two of developmentally ventral muscles. At certain locations in the adult lower limb, one or more of these compartments may actually be separated from its neighbors by fibrous septa.

## How to Identify a Muscle of the Lower Limb as Being Either Developmentally Dorsal or Ventral

**First we identify a muscle as being of the lower limb if it attaches to one of the long bones**. Any muscle of the lower limb may be then classified as deriving from either the dorsal premuscle mass or the ventral premuscle mass.

***Developmentally Dorsal Muscles***

**A proximal muscle of the lower limb can be identified as being developmentally dorsal if it arises from either the ilium or vertebral column. A muscle of the free part of the lower limb is developmentally dorsal if it lies in either the anterior or lateral compartment of the limb**.

Dorsal muscles that can be identified as such because they arise from the ilium or vertebral column are:

Psoas major
Iliacus
Tensor Fasciae Latae
Gluteus minimus
Gluteus medius
Piriformis
Gluteus maximus
Sartorius

You will note that iliopsoas, after crossing the hip joint, is in the anterior compartment of the thigh. The sartorius is also an anterior compartment muscle, but this becomes less obvious in the distal part of the thigh. The other muscles that arise from the ilium and vertebral column are on the lateral (postaxial) aspect of the limb.

Dorsal muscles that can be identified as such because they clearly lie in the anterior compartment of the thigh are:

Quadriceps femoris (*note*: the rectus femoris also arises from the ilium)
Articularis genu

A dorsal muscle identifiable as such because it lies in the lateral compartment of the thigh is the:

Short head of biceps femoris[66]

The dorsal muscles that lie in the anterior compartment of the (lower) leg are:

Tibialis anterior
Extensor hallucis longus
Extensor digitorum longus
Peroneus tertius

The dorsal muscles that lie in the lateral compartment of the (lower) leg are :

Peroneus longus
Peroneus brevis

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[66] This muscle is derived from a muscle called the tenuissimus, which in lower primates arises from the sacrum.

Whereas no muscles of the hand are normally derived from the dorsal premuscle mass, there is an "anterior compartment" muscle beneath the skin of the dorsum of the foot:

Extensor digitorum brevis (whose belly for the big toe is often separately designated as the extensor hallucis brevis)

The lateral muscle compartment of the foot is empty.

***Developmentally Ventral Muscles***

**Any proximal muscle in the lower limb can be identified as being developmentally ventral if it has an origin from the pubis or ischium. A muscle in the free part of the lower limb is developmentally ventral if it lies in either the posterior or medial compartment**.

Ventral muscles that can be identified as such because they arise from the pubis are:

Gracilis
Pectineus
Adductor longus
Adductor brevis
Pubofemoral part of adductor magnus
Obturator externus

Most of these also comprise the muscles of the medial compartment of the thigh.

Ventral muscles identifiable as such because they arise from the ischium are:

Obturator internus
Superior gemellus
Inferior gemellus
Quadratus femoris
Long head of biceps femoris
Semitendinosus
Semimembranosus
Ischiocondylar part of adductor magnus

Many of these comprise the muscles of the posterior compartment of the thigh.

Feel your tibia and note that its medial surface is subcutaneous. The pre-axial (medial) group of developmentally ventral muscles is absent below the knee. Therefore, all the developmentally ventral muscles of the (lower) leg lie in the posterior compartment. These are:

Gastrocnemius
Soleus
Plantaris
Popliteus
Flexor digitorum longus
Tibialis posterior
Flexor hallucis longus

Since there are no medial (i.e., pre-axial) compartment muscles below the knee, there are none in the foot. Again, all the developmentally ventral muscles of the foot correspond to those lying in the posterior compartment. The extension of the posterior compartment of the leg into the foot constitute that structure's **plantar compartment**. Thus, all the muscles lying in the sole can be identified as being developmentally ventral. They are serially homologous to the intrinsic hand muscles.

## Relevance of the Dorsal/Ventral Dichotomy for Understanding the Lumbar and Sacral Plexuses

Of what interest is the development and evolution of the lower limb to someone who is only trying to understand the lumbar and sacral plexuses? The answer is that each ventral ramus participating in these plexuses begins by dividing into a **dorsal division** and a **ventral division**, which carry axons for developmentally dorsal and developmentally ventral muscles, respectively (Fig. 12-6)[67]. The dorsal division axons never rejoin the ventral division axons; thus, each muscular branch that leaves the lumbar or sacral plexus can be classified as either a ventral or dorsal division nerve, and whole groups of muscles eliminated as candidates for innervation by that nerve.

**The lumbar plexus gives rise to one dorsal division nerve--the femoral** (see Fig. 12-6). **It innervates the anterior compartment muscles of the hip and thigh** (Fig. 12-7). **Usually, the sole ventral division branch of the lumbar plexus is the obturator nerve** (see Fig. 12-6). **It innervates all the muscles that arise from the pubis (i.e., medial compartment muscles;** see Fig. 12-7**) except the pectineus. The pectineus is an anomaly; though developmentally a ventral muscle it is most often innervated by the femoral nerve**. However, about one quarter of the time its true history is revealed through its innervation by an accessory obturator nerve derived from ventral divisions of the lumbar plexus.

The sacral plexus plays a greater role in innervating the lower limb than does the lumbar plexus. Both plexuses send branches to muscles above the knee, but **the sacral plexus alone innervates muscles below the knee**.

The sacral plexus gives tiny dorsal division **twigs to the piriformis** (from S1 and S2) , and then gives rise to six separate branches for other muscles in the lower limb. Three of these branches carry only dorsal division axons; three carry only ventral division axons. **The three dorsal division nerves are the superior gluteal, inferior gluteal, and common peroneal** (see Fig. 12-6). **The superior gluteal nerve innervates gluteus medius, gluteus minimus, and tensor fasciae latae. The inferior gluteal nerve innervates gluteus maximus**. In this way all the lateral (postaxial) muscles arising from the ilium are taken care of. **The common peroneal nerve innervates the sole developmentally dorsal muscle along the lateral aspect of thigh** (see Fig. 12-7) **--short head of biceps femoris--and then enters the leg where it divides into superficial and deep peroneal nerves that together innervate all the developmentally dorsal muscles below the knee. Those of the anterior compartment are handled by the deep peroneal nerve** (see Fig. 12-7)**, those of the lateral compartment by the superficial peroneal nerve** (see Fig. 12-7).

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[67] I say the ventral begins by dividing into dorsal and ventral divisions, but it should not be forgotten that before they do this the ventral rami of S2-S4 give off pelvic splanchnic nerves, contributions to the pudendal nerve, and twigs to the levator ani. None of these are concerned with innervation of the lower limb.

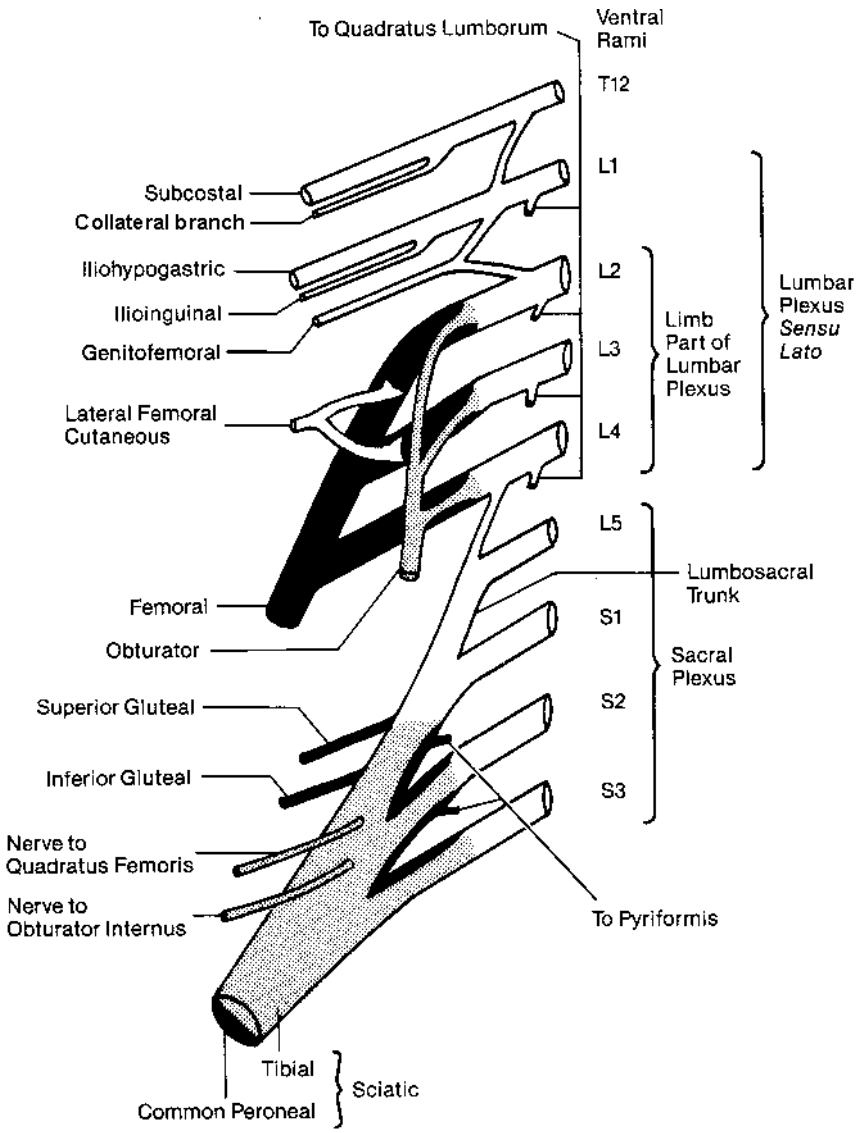


**Figure 12-6.** Formation of the lumbosacral plexus (anterior view). Dorsal division nerves are in *black*; ventral division nerves are in *gray.*

**The three ventral division nerves of the sacral plexus are the nerve to the obturator internus (and superior gemellus), the nerve to the quadratus femoris (and inferior gemellus), and the tibial nerve** (see Fig. 12-6)**. The first two mentioned nerves do precisely what their names suggest. The tibial nerve supplies all the ventral muscles of the posterior compartment of the thigh, leg, and foot** (see Fig. 12-7). Remember, the plantar compartment of the foot is a continuation of the lower leg's posterior compartment.

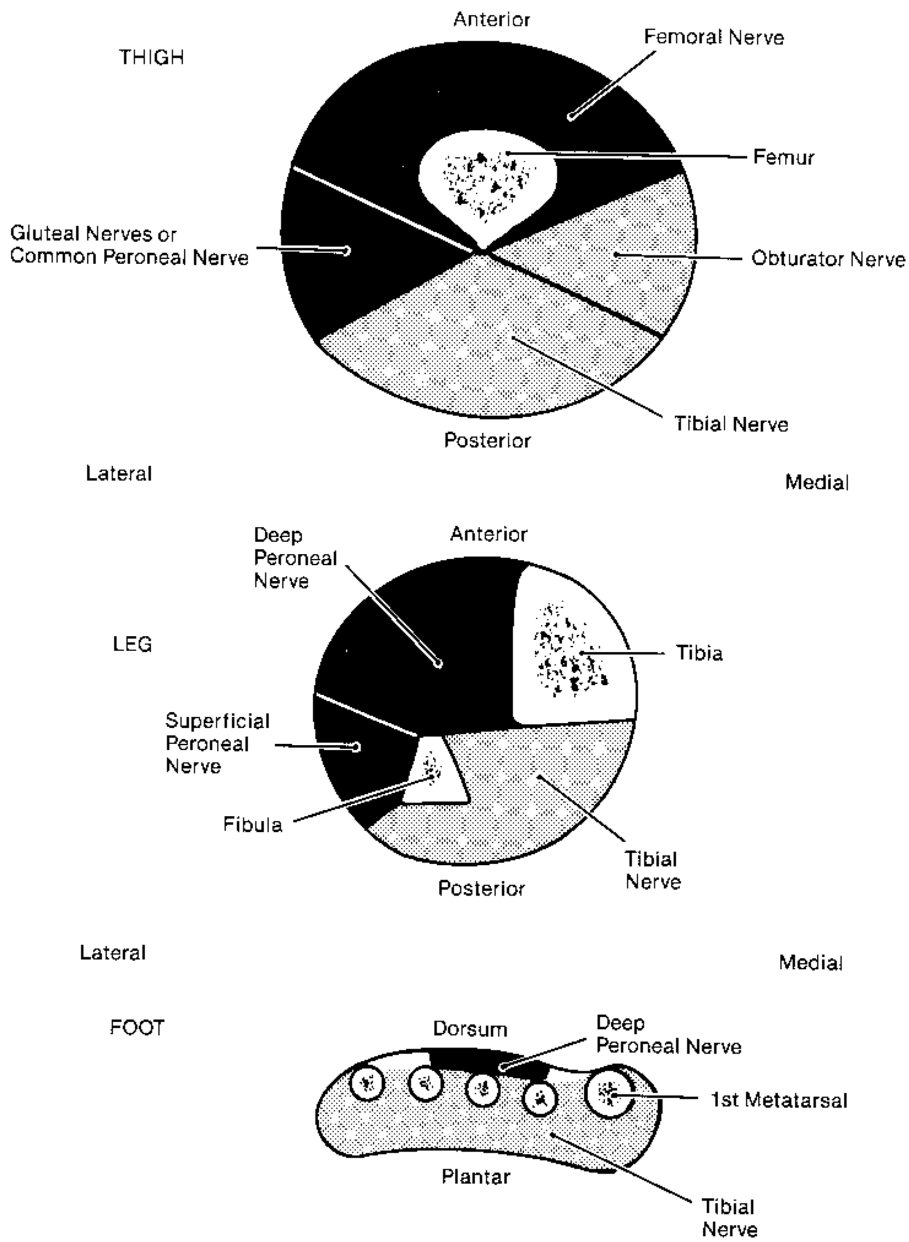


**Figure 12-7.** Muscle compartments of the lower limb seen in schematic transverse sections through the thigh, leg, and foot. Developmentally dorsal blocks of muscles are in *black*; developmentally ventral blocks of muscles are in *gray*.

## PELVIC GIRDLE (Figs. 12-8, 12-9)

The pelvic girdle of each side consists of three bones that are preformed in cartilage and begin to ossify in fetal life. The three bones are the **ilium, pubis, and ischium**. They meet at the **acetabulum** (see Fig. 12-8) where, before puberty, they are separated from one another by a three-armed (i.e., **triradiate**) cartilage. Additionally, the pubis and ischium surround a large hole that lies inferior to the acetabulum. This is the **obturator foramen**. In life it is almost completely bridged over by a thick connective sheet called the **obturator membrane**. The ossification center for the pubis and ischium also meet one another inferior to the obturator foramen (see Fig. 12-8). Here again a synchondrosis intervenes. At an age of 8-9

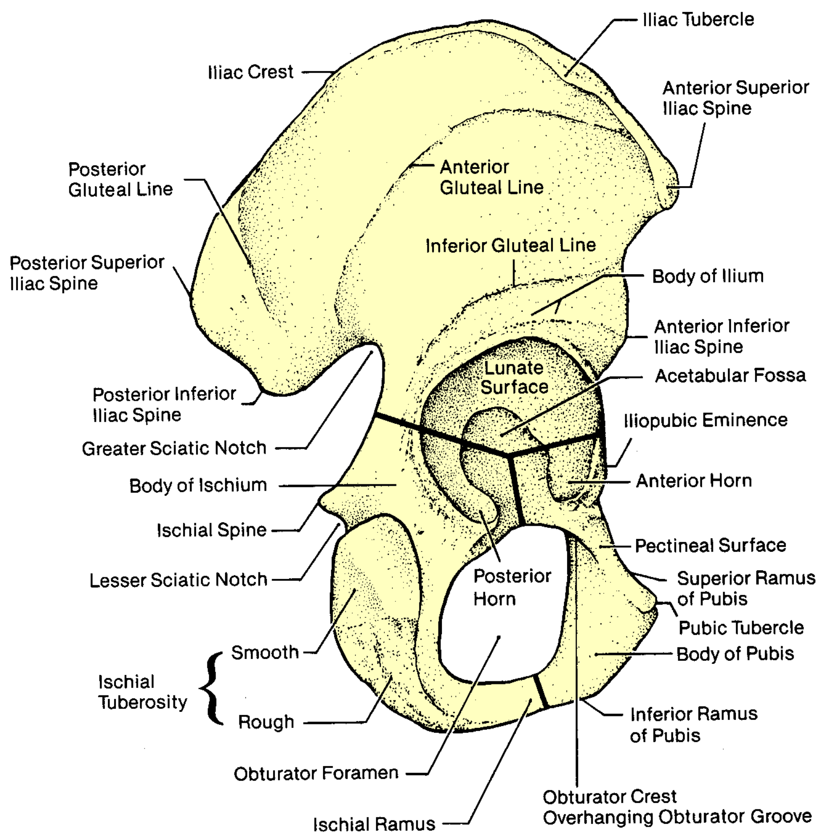


**Figure 12-8.** Lateral view of the right os coxae. *Thick black lines* passing through the acetabulum indicate the boundaries between the three major ossification elements.

years this ischiopubic synchondrosis is bridged by bone. Fusion of the ilium, ischium, and pubis at the acetabulum starts around puberty, with the result that a single hip bone called the **os coxae (innominate)** is formed.

Each of the three major components of the hip has one or more secondary centers of ossification (apophyses) for parts of the bone near its edge. The apophyses of the hip bone are among the last ossification centers in the body to fuse with their associated primary centers. Such fusion, occurring between the ages of 20-25, is useful in assessing the chronological age of excavated skeletal material.

## Ilium (see Figs. 12-8, 12-9)

The portion of the ilium that forms the superior two fifths of the acetabulum is called its **body**. Extending upward from the body is a broad flat **iliac blade**. The outer, **gluteal surface** of this blade is concave posteriorly and convex anteriorly. The concave portion faces posterolaterally whereas the more anteriorly lying convex portion faces directly laterally. The inward-facing surface of the iliac blade (see Fig. 12-9) is divided rather sharply into two regions by a ridge called the **linea limitans**. The larger anterior portion is concave and is called the **iliac fossa**. The posterior portion contains the L-shaped **auricular surface** for articulation with the sacrum, and above this auricular surface is a rough and protuberant area called the **iliac tuberosity**, for attachment of sacro-iliac ligaments. Extending downward and forward from the linea limitans is a rounded ridge called the **arcuate line**, which separates the iliac fossa from the part of the ilium that contributes to the lateral wall of the true pelvis.

The superior rim of the iliac blade is called the **iliac crest**, which is said to have outer and inner lips. It is S-shaped, reflecting the concavity and convexity of the blade itself.

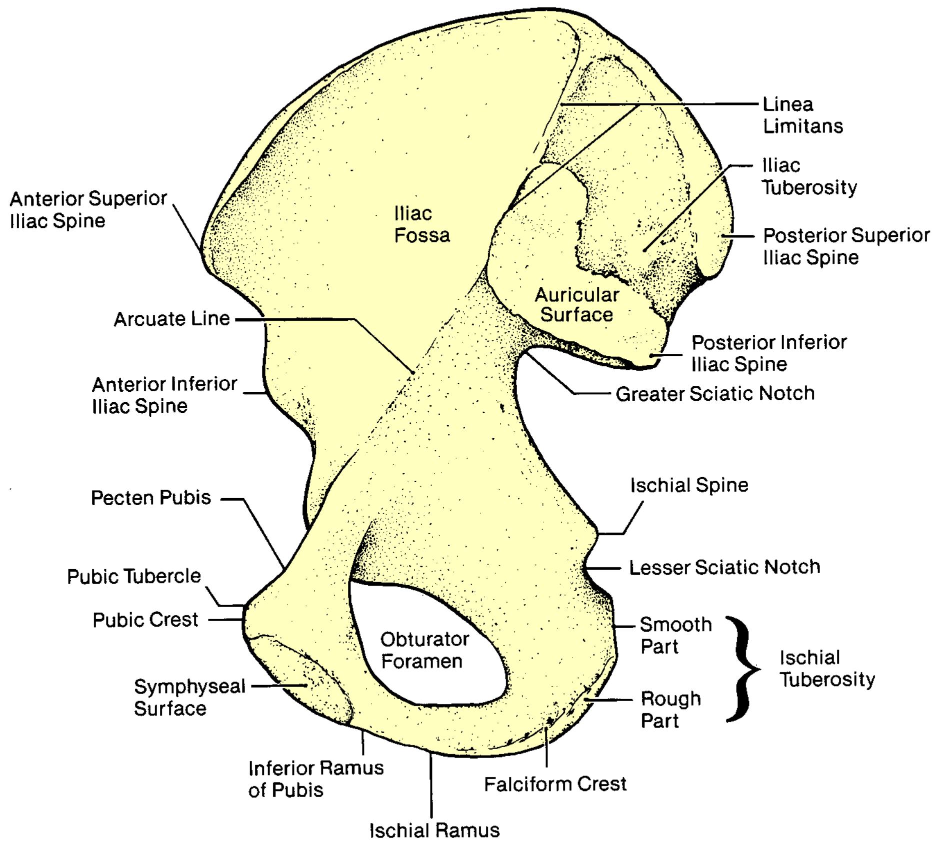


**Figure 12-9.** Medial view of the right os coxae.

***Bumps and Ridges on the Ilium (see Figs. 12-8, 12-9)***

The anteriorly projecting angle formed where the iliac crest meets the anterior edge of the iliac blade is called the **anterior superior iliac spine**. Below this spine, the anterior edge of the blade is hollowed out and then once again bulges forward just above the acetabulum. This second bulge is called the **anterior inferior iliac spine**.

The posteriorly projecting angle formed where the iliac crest meets the posterior edge of the blade is called the **posterior superior iliac spine**. Below this, a slight backward projection of the blade at the end of the auricular surface is called the **posterior inferior iliac spine**. Immediately below the posterior inferior iliac spine, the posterior edge of the blade turns sharply forward as the superior rim of the **greater sciatic notch**.

One final bump on the ilium occurs as a lateral projection of the outer lip of the iliac crest about two inches (5 cm) behind the anterior superior iliac spine. This is the **iliac tubercle** (see Fig. 12-8), not to be confused with the iliac tuberosity mentioned above.

I have already described two ridges--the linea limitans and the arcuate line--found on the inner aspect of the ilium. The gluteal surface of the iliac blade is marked by three ridges (see Fig. 12-8). These are caused by the attachments of tendons and are not nearly as marked as the inner-surface ridges, which separate off functionally different areas of the bone.

On the gluteal surface, a few centimeters in front of the posterior iliac spines, is a vertical ridge running from the iliac crest to the superior rim of the sciatic notch. It is called the **posterior gluteal line**, and it marks the attachment site of a deep tendon of origin of the gluteus maximus. The small region of the gluteal surface behind this line gives rise to fleshy fibers of gluteus maximus.

A curved ridge, starting at the outer lip of the iliac crest between the iliac tubercle and anterior superior spine, and running backward and then downward to the superior rim of the sciatic notch near its deepest point, is called the **anterior gluteal line**. It marks the attachment site of some tendinous fibers on the deep surface of gluteus medius. Between the anterior gluteal line, on the one hand, and the posterior gluteal line and outer lip of iliac crest, on the other, arise fleshy fibers of the gluteus medius.

Finally, starting at the notch between the anterior spines of the iliac blade and coursing backward and slightly downward is the **inferior gluteal line**, marking the attachment site of some tendinous fibers on the deep surface of gluteus minimus. The surface of the iliac blade between the anterior and inferior gluteal lines gives rise to fleshy fibers of the gluteus minimus.

## Ischium (see Fig. 12-8)

The portion of the ischium that contributes to the acetabulum and then descends inferiorly as a short but robust shaft of bone is called the **body**. Extending forward from the lowest part of the body, at about a 90-degree angle, is the relatively flat **ischial ramus**, which meets the pubic bone below the midpoint of the obturator foramen.

The ischial body is marked by two prominent bumps. At a level opposite the lower half of the acetabulum is the posteromedially projecting and pointy **ischial spine**, developed in response to the sacrospinous ligament. Immediately below the ischial spine, the posterior edge of the ischial body is said to form a **lesser sciatic notch**, which obviously appears notch-like only as a result of the projection of the spine above it. The lower half of the ischial body is said to form an **ischial tuberosity**. This tuberosity has a smooth-surfaced superior portion that actually bulges posterolaterally, and a rough-surfaced inferior portion that turns forward to merge imperceptibly with the flattened ischial ramus. The superior (smooth-surfaced) portion of the ischial tuberosity has relatively well-marked lateral, superior, and medial margins. Its inferior margin is less pronounced, existing only as a ridge between it and the rough surface of the lower, forward-curving part of the ischial tuberosity.

The smooth surface of the ischial tuberosity is itself divided into lateral and medial halves by a vertical ridge. The two regions give rise to different muscles (long head of biceps femoris and semitendinosus from the medial half, semimembranosus from the lateral half). The rough surface of the inferior part of the tuberosity is also divided into lateral and medial halves by a longitudinal ridge. A muscle (adductor magnus) arises from the lateral half; the medial half is covered only by fibrofatty tissue. The medial margin of the inferior part of the ischial tuberosity forms a sharp ridge that extends a short distance onto the medial margin of the smooth surface (see Fig. 12-9). This sharp ridge is called the **falciform crest** of the ischium. It marks the site of attachment of the sacrotuberous ligament.

### Pubis (see Figs. 12-8, 12-9)

The portion of the pubis that participates in the pubic symphysis is the **pubic body**. Extending laterally and backward from the body is the narrower **superior ramus of the pubis**, which in turn expands to contribute to the acetabulum. The short segment of the pubis running from the body to the ischial ramus is called the **inferior ramus of the pubis**. Together, the inferior pubic ramus and ischial ramus form the **ischiopubic ramus**.

The rounded arcuate line of the ilium continues across the iliopubic junction onto the upper surface of the superior pubic ramus as a sharp crest--the **pecten pubis**. The arcuate line and pecten pubis taken together form the **iliopectineal line (linea terminalis)** that demarcates the false pelvis from the true pelvis. The pecten pubis terminates medially at an anteriorly projecting bump called the **pubic tubercle**. Running medially from the tubercle is the upper edge of the body, called the **pubic crest**.

The surface of the pubis anterior to the pecten pubis is called its **pectineal surface**. It is continuous with the iliac fossa, although a bump--the **iliopubic (iliopectineal) eminence**--marks the site of juncture of the ilium and pubis. The pectineal surface of the pubis stops antero-inferiorly at a ridge of bone called the **obturator crest**. This crest runs from the pubic tubercle laterally toward the anterior part of the acetabulum. Near the acetabulum, the under surface of the superior pubis ramus is marked by a groove called the **obturator groove**. The obturator membrane does not fill in the groove, thereby creating an **obturator canal** located between the upper edge of the membrane and the inferior surface of the bone.

### Acetabulum (see Fig. 12-8)

The socket in which the thigh bone articulates with the os coxae is called the acetabulum. All three components of the hip bone contribute to its formation. The ilium and ischium each make up about two fifths of this socket, the pubis forms the remaining fifth. The acetabulum is rather dissimilar from the glenoid cavity of the scapula. First, it is much deeper. Second, although the acetabulum is hemispherical, the articular surface is confined to an incomplete band, 2-3 cm wide, adjacent to the equator of the hemisphere. This actual articular surface is called the **lunate surface**. Its defect inferiorly is called the **acetabular notch**. The parts of the lunate surface on either side of the notch are its **posterior and anterior horns**. The nonarticular region in the depth of the acetabulum is called the **acetabular fossa**.

In life a strong fibrous band--the **transverse acetabular ligament**--bridges across the acetabular notch, connecting the rounded tips of the lunate horns. Thus, the circle begun by the lunate surface is completed, and an **acetabular foramen** is created between the deep edge of the transverse acetabular ligament and the floor of the acetabular fossa. Through this foramen the acetabular fossa communicates with the region immediately external to the obturator foramen.

## SACRO-ILIAC JOINTS

The costal elements of the first three sacral vertebrae (see Fig. 3-1*D*) are specialized to articulate with the ilia (Fig. 12-10). The opposing articular surfaces appeared to some ancient anatomist to have the shape of the external ear and, thus, are called **auricular surfaces**, of which each ilium has one (see Fig. 12-9) and the sacrum has both a left and a right. Although the auricular surfaces of the ilia and sacrum are covered by cartilage and participate in a true synovial sacro-iliac joints, these surfaces are very bumpy and designed to permit very little motion. The motion that does occur is largely confined to a slight rotation of the sacrum around a transverse axis. The rotation is such that whenever a person

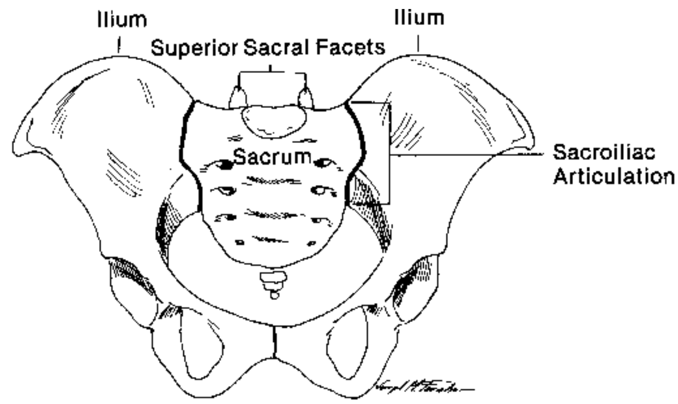


**Figure 12-10.** Sacro-iliac joints (anterior view). (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

assumes the erect position, the upper segments of the sacrum tend to be driven inferiorly by the imposed body weight while the lower sacral segments and coccyx tend to rise. This movement is prevented from progressing too far by some very powerful ligaments. Downward motion of the upper sacrum is stopped by **posterior and interosseous sacro-iliac ligaments** that run from the dorsal surface of the sacrum to the iliac tuberosity. Possibly they are assisted by **anterior sacro-iliac ligaments**, which are the thickened antero-inferior portions of the caypsules of each joint (Fig. 12-11). Upward motion of the lower sacral segments and coccyx is prevented by two ligaments--the sacrotuberous and sacrospinous.

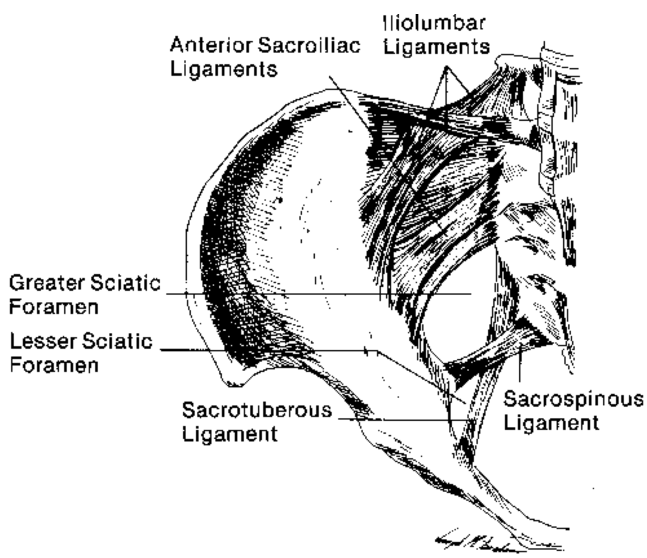


**Figure 12-11.** The anterior sacro-iliac ligaments and the ligamentous structures delimiting the greater and lesser sciatic foramina (seen in anterior view). (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

The **sacrotuberous ligament** is a powerful band of fibrous tissue that runs from the falciform crest on the inner edge of the ischial tuberosity upward and medially to the lateral borders and posterior surfaces of the lower sacral segments and upper part of the coccyx (see Fig. 12-11). The ligament also extends its attachment superiorly onto the posterior spines of the ilium, although clearly such fibers cannot limit sacral motion. Possibly this ischio-ilial bundle reduces bending stresses on the hip bone that arise as the sacrum tends to twist around a transverse axis.

The **sacrospinous ligament** fans out from the tip of the ischial spine toward an attachment to the lateral edges of the lower sacral segments and coccyx (see Fig. 12-11). It is a uniquely human structure, having arisen by conversion of muscle fibers on the posterior surface of the coccygeus muscle. Sometimes the entire muscle is replaced by fibrous tissue.

Movement at the sacro-iliac joints occurs during changes in body posture and locomotion. The muscles that cross the sacro-iliac joints (e.g., spinal and abdominal muscles) have no significant effect on this motion, nor are they designed to do so.

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**SCIATIC FORAMINA**

The existence of the sacrotuberous and sacrospinous ligaments creates osseoligamentous foramina out of the two sciatic notches that lie in the posterior edge of the os coxae (see Fig. 12-11).

The sacrospinous ligament, bridging between the ischial spine and sacrum, is a barrier between the lesser and greater sciatic notches that turns the latter into a **greater sciatic foramen**. The actual hole is made smaller by the fact that near the sacrum it is encroached upon by fibers of the sacrotuberous ligament as they sweep to their attachment on the posterior iliac spines (see Fig. 12-11).

The lesser sciatic notch, now separated from the greater notch by the sacrospinous ligament, is converted into a **lesser sciatic foramen** by the fibers of the sacrotuberous ligament as they course upward from their origin on the ischium (see Fig. 12-11).

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## INTERPUBIC JOINT

In the anterior midline the body of each pubic bone meets its counterpart from the other side at the so-called **pubic symphysis**. Although the elliptical symphyseal surface of pubic body is covered by hyaline cartilage, no synovial cavity exists between them. Instead, the hyaline cartilage gives way to an interpubic fibrocartilage that binds the two sides together. Short ligaments cross between the pubic bodies on the top, front, and inferior surface of this fibrocartilage. The inferior ligament is called the **arcuate ligament**. As was mentioned previously (p. 207; see Fig. 6-6, p. 200), it is the anterior boundary of a space through which the deep dorsal vein of the phallus passes into the pelvis.

The work of Pauwells[68] indicates that the interpubic joint is sometimes subjected to tension, sometimes to pressure, sometimes to pressure on the deep surface and tension superficially (or *vice versa*) and always to shear. Presumably a symphysis is better able to accommodate such stresses than a synostosis (i.e., bony fusion).

---

During pregnancy, the interpubic fibrocartilage and ligaments become looser, allowing some spread, ***which facilitates delivery.***

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No muscles cross the interpubic joint.

## FEMUR (Fig. 12-12)

The femur is the sole bone of the thigh. It has a long cylindrical shaft, expanded and highly modified at each end for articulation with other bones.

The proximal extremity of the femur consists of a hemispherical **head** covered by a smooth articular surface for the acetabulum. However, there does exist a nonarticular pit--the **fovea capitis femoris**--on the medial aspect of the head slightly posterior to its midpoint.

Whereas the head of the humerus is attached to the humeral shaft by a very short anatomical neck, the head of the femur is attached to the femoral shaft by a long **neck** set at an angle of 120-130 degrees to the axis of the shaft itself (females, on the average, have a slightly higher angle than do males).

It will be recalled that the short anatomical neck of the humerus separated the humeral head from two bumps (tubercles) at the proximal end of the humeral shaft. These tubercles served as sites for muscular attachment. The long femoral neck separates the femoral head from two bumps--called **trochanters,** at the proximal end of the femoral shaft. These are also sites of muscular attachment. The **greater trochanter** is simply a bulky prominence on the lateral aspect of the uppermost part of the shaft. The **lesser trochanter** is a projection from the posteromedial surface of the shaft at the base of the femoral neck.

A deep pit in the medial surface of the greater trochanter near its posterior edge is called the **trochanteric fossa**. The posterior edge of the greater trochanter continues downward as a curving ridge that meets the posterior surface of the lesser trochanter. This ridge is called the **intertrochanteric crest** (see Fig. 12-12*B*). On the anterior surface of the femur, at the junction of its neck and shaft, is a rough bony **intertrochanteric line** (see Fig. 12-12*A*). Although the intertrochanteric line contacts the greater trochanter superiorly, it ends inferiorly by passing onto the medial surface of the shaft anterior to the lesser trochanter.

The posterior surface of the femoral shaft, for several centimeters inferior to the lesser trochanter, is marked by low bumps, ridges, and grooves marking the sites of attachment of various

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[68] Pauwells, F: Beitrag zur Klärung der Beanspruchung des Beckens inbesondere der Beckenfugen. Z Anat Entwgesch 114:167-180, 1948.

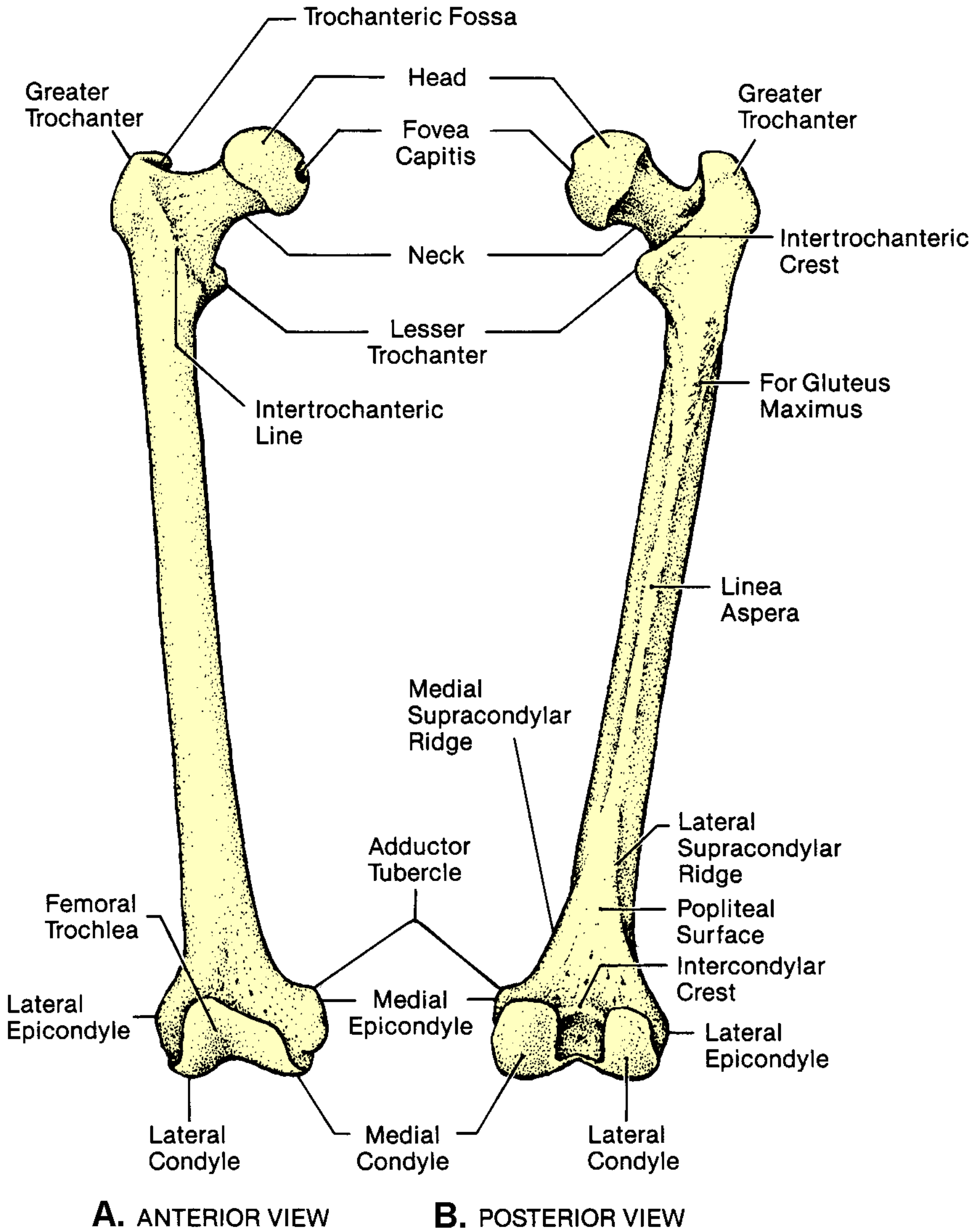


**Figure 12-12. Right femur seen in anterior and posterior views.**

muscles. About one third of the way down the shaft, the medial and lateral edges of this rough area converge to form a prominent linear crest on the back of the shaft in its middle third. This is the **linea aspera**, which is said to have medial and lateral lips. It is convenient to view the linea aspera as the posterior surface of the femur that has simply become very much narrowed. About two thirds of the way down the shaft the lips of the linea aspera once again diverge and the posterior surface of the femoral shaft becomes increasingly broad as the distal extremity of the bone is approached. This broad flat part of the posterior surface is called the **popliteal surface** of the femur. The continuations of the lips of the linea aspera that border the popliteal surface are called the **medial and lateral supracondylar ridges**. The lateral supracondylar ridge is unbroken and finally ends at a well-defined laterally projecting bump called the **lateral epicondyle** of the femur. The medial supracondylar ridge seems to lose its identity shortly after it leaves the linea aspera, and then starts up again to continue distally into a very prominent bump called the **adductor tubercle**. The adductor tubercle itself is a superior projection from a larger, but ill-defined, medially directed prominence called the **medial epicondyle**.

The distal end of the femur is greatly expanded, both from side to side and from front to back, so that it may carry the large articular surfaces for the patella and tibia. The deeply grooved articular surface for the patella (Fig. 12-13*A*; see Fig. 12-12*A*) starts on the anterior surface of the most distal part of the shaft and curves down onto the inferior aspect of the femur. Being deeply grooved, it is sometimes called the **femoral trochlea**. It has medial and lateral lips, of which the latter always projects further anteriorly. This enables one to differentiate between the lips of the femoral trochlea on a lateral radiograph of the knee.

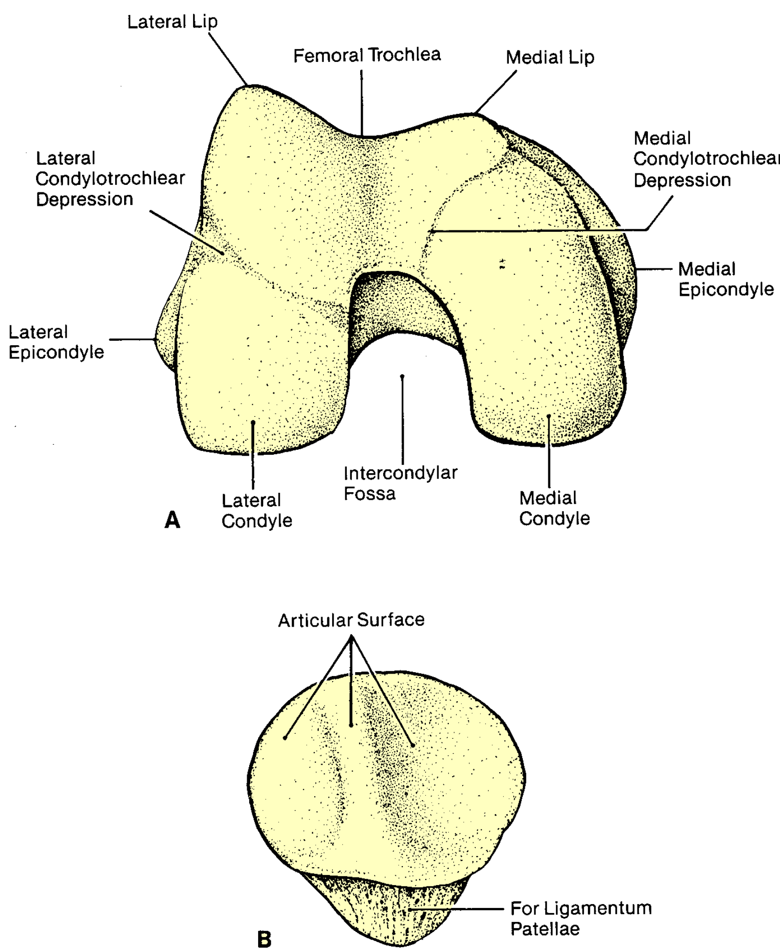


**Figure 12-13.** *A*, Distal view of right femur. *B*, Posterior view of right patella.

On the inferior aspect of the femur, the patellar surface merges with two separate articular surfaces that continue along the undersurfaces of two prominences, each of which extends well beyond the posterior surface of the shaft (see Figs. 12-12*B*, 12-13*A*). These two prominences are the **lateral and medial femoral condyles**. The gap between them is the **intercondylar fossa**. The articular surface of each condyle covers its rounded back surface.

Passing across the posterior surface of the femur from the upper limit of the medial condylar articular surface to the upper limit of the lateral condylar articular surface is a ridge of bone that separates the intercondylar fossa from the popliteal surface of the shaft. This is the **intercondylar crest** (see Fig. 12-12*B*).

On the inferior aspect of the femur, the demarcation between the patellar surface and the lateral condylar articular surface is usually well marked by a so-called **lateral condylotrochlear depression** (see Fig. 12-13*A*). A less well-defined, and somewhat more anteriorly placed, **medial condylotrochlear depression** marks the demarcation between the patellar surface and the medial condylar articular surface (see Fig. 12-13*A*). The articular surface of the medial condyle is longer and its inferior aspect more highly curved than that of the lateral condyle. By contrast, the lateral condylar surface is stopped short by its "premature" merger with the patellar surface, and its inferior aspect is relatively flat. These differences allow one to determine which is the lateral and which is the medial condyle on lateral radiographs of the knee.

A femur placed upright with its condyles resting on a flat surface simulates the position of the bone during erect posture (see Fig. 12-12). You will note that the shaft is not precisely vertical. Rather, it follows an oblique path downward and medially from the neck. This is a peculiarity of the human femur enabling the foot to be placed more nearly beneath the body's center of gravity during locomotion. The degree of obliquity is slightly greater in women than in men. This is a consequence of the fact that the pelvis of women is relatively wide compared with femur length, requiring their femora to incline more medially in order achieve the desired foot placement.

The downward and medial course of the femoral shaft causes humans to have a physiological (i.e., normal) knock-knee, which is more properly called **genu valgus**. Later I shall discuss the great significance of this fact for understanding the human predisposition to patellar dislocation.

The femur ossifies from one center for the shaft, two epiphyseal centers--one for the head and the other for the condyles, and two apophyseal centers -- one for each trochanter.

## PATELLA (Fig. 12-13*B*)

The patella is a bone formed within the tendon of the quadriceps femoris muscle. As such it is often spoken of as being nothing more than a large sesamoid bone. It is roughly triangular in shape, with the apex of the triangle pointing inferiorly and the rounded base forming a superior surface. The quadriceps tendon inserts into this superior surface, and into the lateral and medial margins of the bone. Some superficial fibers of these tendon pass downward across the anterior surface of the patella to merge with a very powerful ligament--the **ligamentum patellae** (**patellar tendon**)--that runs from the apex of the bone to the tibia.

Most of the posterior (i.e., deep) surface of the patella is free of any tendinous attachment. Instead it is covered by cartilage for an articulation with the femur. Only the deep surface of the apex is nonarticular, being the site of origin of the patellar tendon. The articular surface of the patella is divided into medial and lateral portions by a ridge that sits in the groove of the femoral trochlea. The lateral portion of the articular surface is wider than the medial portion, in keeping with the increased size of the corresponding surface on the femur due to the greater prominence of the lateral lip of the femoral trochlea.

## SUPERFICIAL VEINS OF THE LOWER LIMB

Within the subcutaneous tissue of the lower limb there is a network of veins unrelated to any arteries. These too have many valves, though less per unit length than the deep veins. Numerous communicating channels pass from the network of superficial veins through the deep fascia to join the deep veins.

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If the valves of the superficial veins become incompetent, these vessels become dilated and tortuous, i.e., **varicose**. Varicose veins are often the consequence of pregnancy, since the enlarged uterus compresses the common iliac veins and thereby elevates venous pressure within the lower limb.

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Most of the superficial veins of the lower limb have no name. However, two of the larger ones do--the great and small saphenous veins.

### Great Saphenous Vein

The great saphenous vein, being the major superficial vein along the preaxial surface of the limb, is clearly the lower extremity's version of the cephalic vein. It begins in the subcutaneous tissue anterior to the medial malleolus as a continuation of a large superficial vein from the medial side of the dorsum of the foot. It runs superiorly in the subcutaneous tissue immediately behind the posteromedial border of the tibia. Above the site where the sartorius crosses this border of the tibia, the great saphenous vein follows the posterior edge of the sartorius behind the knee and up toward the apex of the femoral triangle. Then the vessel virtually bisects the femoral triangle, running in its roof toward the site of the fossa ovalis of the fascia lata, through which the great saphenous dives deeply to empty into the femoral vein.

The small superficial veins that accompany the three superficial branches of the common femoral artery join the great saphenous vein just as it passes through the fossa ovalis.

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The great saphenous vein has particular clinical significance for coronary bypass surgery. Being long and easily located, it is resected so that segments of it may be used as grafts extending from the ascending aorta to various coronary arteries beyond the site of their occlusion.

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### Small Saphenous Vein

The small saphenous vein is less clearly the lower limb equivalent of the basilic vein. It begins in the subcutaneous tissue behind the lateral malleolus by a confluence of some smaller veins on the lateral side of the dorsum of the foot. From its origin, the small saphenous vein passes up the leg heading toward the midline of its posterior surface at midcalf. The vessel then continues in the posterior midline of the calf up to the popliteal fossa, where it dives deeply to enter the popliteal vein.

# THE DEEP FASCIA OF THE THIGH

## Fascia Lata and the Iliotibial Tract

As we know, the epimysium on the outer surface of a superficially placed limb muscle joins with the epimysium on the outer surface of its neighbors to form a deep fascial sleeve that envelops the whole limb. The deep fascial sleeve of the thigh is given the name of **fascia lata**. It is peculiar in being bilaminar over the lateral and anterior aspects of the thigh. Furthermore, the outer lamina is extremely strong, being itself composed of inner and outer layers of transversely oriented fibers between which is sandwiched a powerful band of longitudinal fibers that runs all the way from the iliac tubercle down to the anterolateral aspect of the lateral tibial condyle (Fig. 12-14). This band is called the **iliotibial tract**.

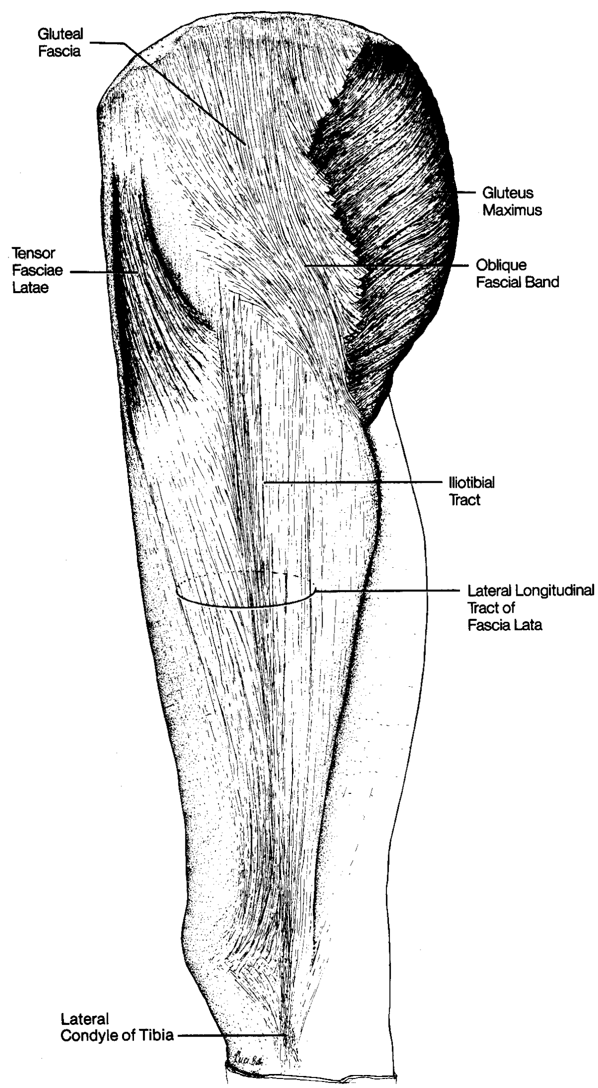


**Figure 12-14. Lateral aspect of the left hip and thigh depicting specializations in the fascia lata.**

If you assume the typical posture of a person standing at rest, with almost all the weight borne by one lower limb and the contralateral hip being allowed to drop, you can feel the tightness of the iliotibial tract on the supporting side. It probably assists in maintaining this posture. Another possible role for the iliotibial tract is related to the likelihood that tension is generated within it when the underlying quadriceps muscle swells upon contraction. Such tension, arising during bipedal locomotion, is supposed to reduce stresses on the femur by offsetting the tendency of the body weight to bend the bone in a direction that would produce a medial concavity of the femoral shaft.

## Lateral Longitudinal Tract of the Fascia Lata

Below the hip joint, the iliotibial tract is reinforced by tendinous fibers deriving both from the posterior portion of the tensor fasciae latae and (probably) from the superficial fibers of the upper portion of gluteus maximus (see Fig. 12-14). Immediately anterior to the iliotibial tract is an additional band of longitudinal tendinous fibers from the *anterior* portion of the tensor fasciae latae (see Fig. 12-14). The entire ensemble of longitudinal fibers formed by the iliotibial tract, the tendinous fibers that reinforce it, and the tendinous fibers that lie in front of it, is called the **lateral longitudinal tract of the fascia lata**.

## Fossa Ovalis (Saphenous Opening) of the Fascia Lata (Fig. 12-15)

Just below the inguinal ligament, just medial to that ligament's midpoint, is a peculiar elliptical region in which the outer, otherwise thick layer of the anterior fascia lata retains the thin character of unspecialized epimysium. The long (superoinferior) axis of the ellipse is about 2 fingerbreadths (fb) in length. The shorter transverse axis is about 1 fb wide. This elliptical region of thin fascia is called the **fossa ovalis** (describing its shape) or the **saphenous opening** (in deference to the name of a vein passing

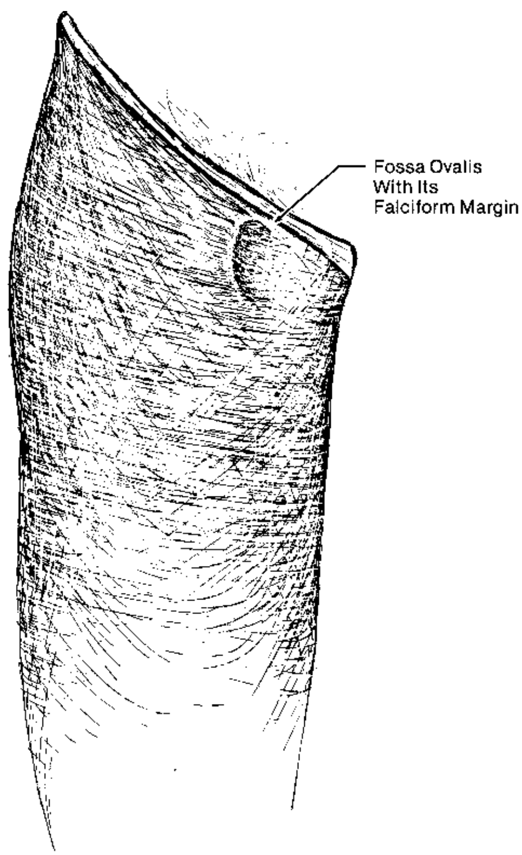


**Figure 12-15.** Anterior aspect of the right thigh, illustrating the fossa ovalis of the fascia lata.

through it). Because the medial margin of the fossa ovalis is located precisely at the site where the single layer of the medial fascia lata is becoming the doubled layer of the anterior fascia lata, the oval zone of thinness has only three thick edges--superior, lateral, and inferior. Together they form a sickle-shaped **falciform margin** to the fossa ovalis. The actual thin fascia that spans the fossa ovalis is called the **cribriform fascia** because it is has many holes caused by the passage small lymphatic vessels and a few arteries and veins.

## MUSCLES OF THE ANTERIOR AND MEDIAL COMPARTMENTS OF THE THIGH

### Anterior Compartment Muscles - Psoas Major, Iliacus, Sartorius, Quadriceps Femoris (including Articularis Genu)

***Psoas Major and Iliacus***

The origin of the psoas major from lumbar vertebrae, and its course through the greater pelvis toward the iliopubic eminence, were described in Chapter 5. The muscle is innervated by twigs from those branches of L2-L4 that will join to form the femoral nerve.

The iliacus (innervated by the femoral nerve) arises from most of the iliac fossa, partly behind the descending psoas fibers, but mainly lateral to them (Fig. 12-16). The fibers of iliacus descend to leave the abdominal cavity behind the inguinal ligament on the lateral surface of the psoas major, into whose tendon most iliacus fibers insert. The common tendon of insertion induces us to state that an **iliopsoas** muscle is formed. The lateral half of the retroligamentous space is filled with the fibers of iliopsoas passing out of the abdominal cavity. Becoming increasingly tendinous, the muscle descends anterior to the femoral head, using it as a "pulley" around which to turn backward and gain an insertion onto the tip of the lesser trochanter and nearby medial surface of the femur.

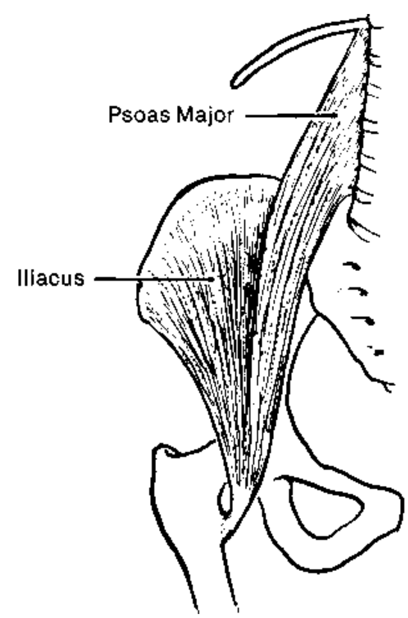


**Figure 12-16.** Anterior view of the right iliopsoas muscle.

Very obviously the major action of the iliopsoas is flexion at the hip. If you are standing, contraction of the iliopsoas will cause your thigh to be lifted; if you are lying on your back with your feet held down, contraction of the iliopsoas will cause your trunk to be lifted, as in a sit-up. The muscle is also a weak lateral rotator and abductor at the hip, but these actions are probably irrelevant in normal behaviors.

***Sartorius (see Fig. 12-17)***

The sartorius (innervated by the femoral nerve) is a flat, strap-like muscle that arises by a short tendon from the anterior edge of the ilium for about 2 cm below the apex of the anterior superior iliac spine. The fibers pass downward and medially, superficial to the origin of rectus femoris, and then across the hip to follow a spiral descent around the inner aspect of the thigh. The muscle approaches the knee by passing behind the medial epicondyle of the femur and then crosses the posteromedial side of the knee to enter the leg. Here the sartorius gives rise to flat tendon that curves anteriorly across the upper end of the subcutaneous surface of the tibia to insert on this surface near the lower part of the tibial tuberosity. From the posterior edge of the main sartorius tendon come fibers that fan out to attach to the subcutaneous surface of the tibia for some considerable distance below the tuberosity. These fibers are

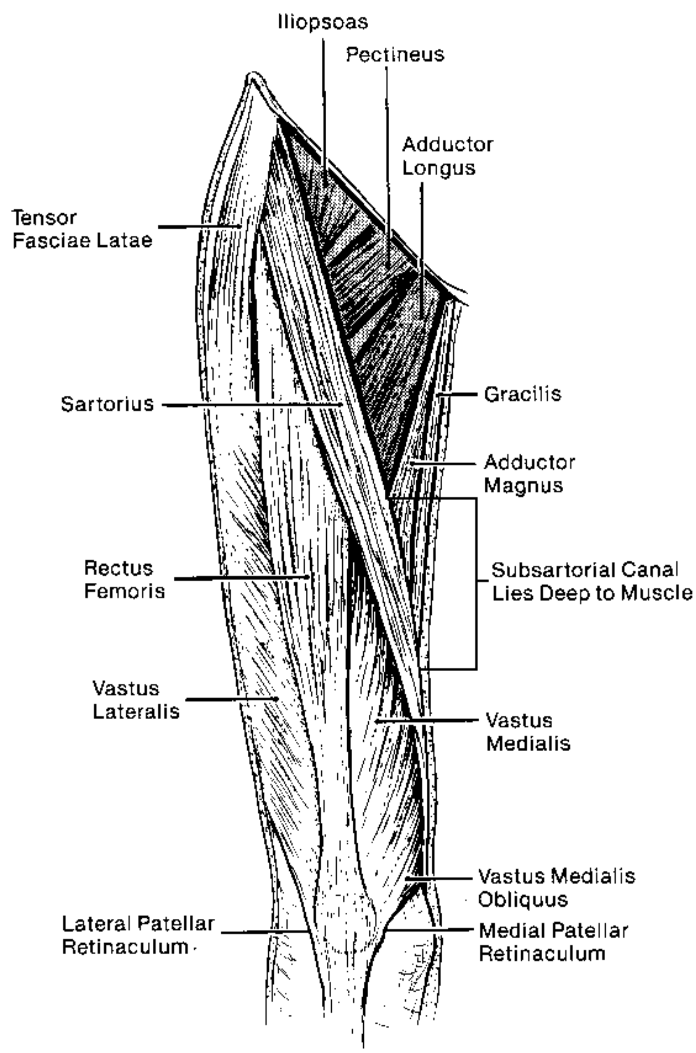


**Figure 12-17.** Muscles on the anterior aspect of the thigh. The femoral triangle *shaded*.

said to compose the **expansion** of the sartorius tendon. The sartorius tendon and its expansion are partly fused to the tendons and expansions of the gracilis (p. 535) and semitendinosus (p. 552). This creates a complex that reminded some ancient anatomist of the fan-shaped foot of a goose. Thus, the triple-tendon complex is called the **pes anserinus** (L. *anser*, a goose).

Crossing the hip and the knee, sartorius has actions at both joints. Its role in flexing and medially rotating the lower leg will be discussed later. Now, we are concerned only with its actions at the hip. Here, it is obviously a flexor. Strong attempts to abduct or laterally rotate the hip also recruit sartorius, although its role in these actions is not as important as other more powerful muscles. However, the name "sartorius" is linked to its three actions of flexion, abduction, and lateral rotation at the hip. "Sartorius" derives from the Latin *sartor*, meaning "tailor." It is said that tailors sit with the outer surface of one ankle resting on the anterior surface of the opposite thigh. In this position the elevated limb is in abduction, lateral rotation, and flexion at the hip.

***Quadriceps Femoris - The Extensor of the Knee***

There is one muscle with four heads that serves as the sole extensor of the knee. The muscle is called the quadriceps femoris. It is innervated by the femoral nerve. The four heads have separate origins, but all converge to an insertion on the patella and, via its ligamentum patellae, into the tibial tuberosity.

Three of the heads of quadriceps femoris (vastus lateralis, rectus femoris, and vastus medialis) lie superficially in the anterior compartment of the thigh The fourth head (vastus intermedius) lies deeply in this compartment.

**The quadriceps femoris is the only extensor of the knee. The three vasti have this as their only action.**

**Rectus Femoris.** Just as one head of the triceps brachii arises from the scapula and has an action across the shoulder joint, so one head of the quadriceps femoris arises from the ilium and has an action across the hip joint. This head is called the rectus femoris. It is the middle od the three superficial heads.

The rectus femoris arises tendinously from the upper half of the anterior inferior iliac spine, and from a ridge on the external surface of the iliac body running backward from the apex of this spine toward the posterior part of the acetabular rim (see Fig. 12-8). Sometimes there is a short gap between the spinous and iliac-body attachments of this tendon. In such cases, the tendon is said to have two heads: those fibers emanating from the anterior inferior iliac spine forming a **direct head**, those from the ridge posterior to the acetabular rim forming a **reflected head**. Regardless, the two heads join to form a single tendon from which the muscle fibers of the rectus femoris spring. These cross the front of the hip joint on the lateral surface of the iliopsoas (thus, anterior to the femoral neck) and enter the thigh to course straight down its anterior aspect immediately medial to its midline (Fig. 12-17). The muscle fibers eventually give rise to tendon fibers that insert into the superior surface of the patella.

The only significant action of the rectus femoris on the hip is one of flexion. It will always be used when active flexion of the hip is desired, unless this motion is combined with a requirement for strong knee flexion, which will inhibit use of rectus femoris. The muscle is most highly recruited when hip flexion and knee extension are performed simultaneously, such as in punting a football.

**Vastus Lateralis.** This muscle arises predominantly from the deep surface of an aponeurosis that has a linear attachment to the femur for nearly is whole length. The aponeurosis of origin of the vastus lateralis starts its femoral attachment on the front of the greater trochanter and passes down a line that crosses onto the posterior aspect of the femur immediately below the trochanter and then turns down to run toward the linea aspera by passing lateral to the insertion of gluteus maximus (see Fig. 12-12). The line of attachment continues down the lateral lip of the linea aspera and, below that, a variable distance along the lateral supracondylar ridge.

The muscle fibers of the vastus lateralis run toward the patella (see Fig. 12-17), giving rise to a strong flat tendon that predominantly inserts onto the superior surface of that bone. However, the most lateral fibers of the tendon skirt the lateral edge of the patella to reach the front of the lateral tibial condyle. These are fused to the underlying anterior capsule of the knee and are said to comprise a **lateral patellar retinaculum** (see Fig. 12-17).

**Vastus Medialis.** Like the vastus lateralis, this muscle arises predominantly from the deep surface of an aponeurosis that has a linear attachment to the femur for nearly is whole length. The line of attachment of the aponeurosis of origin of the vastus medialis starts on the medial side of the femoral shaft, immediately below the insertion of the lowest fibers of the iliofemoral ligament. The aponeurotic attachment then spirals posteriorly toward the medial lip of the linea aspera (see Fig. 12-12), which it follows down the femur. Below the linea aspera, there is a portion of the muscle that arises fleshily from the medial supracondylar ridge and the adjacent part of the medial shaft of the femur. This lower portion is unique to humans and, although it is not separated from the rest of the muscle by a fascial plane, is often called by the separate name of **vastus medialis obliquus** (**VMO**) (see Fig. 12-17).

Most of the vastus medialis gives rise to a tendon that inserts into the superior surface of the patella alongside the tendon of vastus lateralis. The VMO has a very short tendon that inserts into the upper part of the medial edge of the patella and also skirts this edge to insert onto the anterior surface of the medial tibial condyle. These latter tendinous fibers are fused to the anterior capsule of the knee and form a **medial patellar retinaculum** (see Fig. 12-17).

**Vastus Intermedius.** The deep head of the quadriceps femoris is the vastus intermedius. It usually arises fleshily from the anterior and lateral surfaces of the femoral shaft in its upper three quarters, but in some instances the origin may spread onto the medial surface as well. The fibers of the muscle are short, passing downward and superficially to insert onto the deep surface of a tendon that reaches the superior surface of the patella deep to the tendons of the superficial vasti. Some fibers of the vastus intermedius may insert into the tendons of the superficial vasti, making it difficult to effect a complete separation of the intermedius from these muscles.

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There is a special point to be made regarding the direction of pull of the vasti on the patella. Because these muscles arise from the femoral shaft, most of their fibers tend to pull the patella upward in a direction parallel to the shaft. You will recall that, as a result of the physiological valgus of the human knee, the femoral shaft deviates laterally as it passes upward from the knee. Thus, the pull of the quadriceps on the patella has a component directed laterally as well as one directed upward. The upward component is transmitted to the patellar tendon and is responsible for extending the knee. However, humans are then faced with a real problem of how to stop the lateral component of the vasti force from pulling the patella off the trochlea of the femur. This is accomplished by two methods. First, the lateral lip of the femoral trochlea is highly developed, resisting any tendency for patellar dislocation (see Fig. 12-13*A*). Second, humans have a VMO, which pulls medially on the patella and helps to offset the laterally directed component of all the other vasti fibers (see Fig. 12-17). Together these two mechanisms generally suffice. However, lateral patellar dislocation is not uncommon, and it occurs especially often in women, because their physiological valgus is slightly greater than that of men.

**Articularis Genu - A Specialized Bit of the Vastus Intermedius.** In humans there is a small bundle of fibers arising from the front of the femoral shaft a little bit below the origin of vastus intermedius. Although derived from the vastus intermedius, these fibers descend deep to its tendon in order to reach an insertion into the superior aspect of the articular capsule of the knee. They are said to constitute a separate articularis genu muscle. It has been suggested that the articularis genu prevents the capsule of the knee from getting caught between the patella and femur when the leg is brought from a position of flexion to one of extension.

## Medial Compartment Muscles - Pectineus, Adductor Longus, Adductor Brevis, Pubo-Femoral Part of Adductor Magnus (to which is added the Ischiocondylar Part from the Posterior Compartment), Gracilis, Obturator Externus

### *Pectineus (see Fig. 12-17)*

Pectineus (innervated by the femoral nerve or, sometimes, an accessory obturator nerve) is a flat quadrilateral muscle arising from the pectineal surface of the superior pubic ramus. The fibers pass in a parallel fashion laterally, downward and backward to gain an insertion into the posterior surface of the femur along a narrow strip extending inferiorly from the root of the lesser trochanter to about one quarter to one third of the way down the femur shaft. The action of the pectineus will be considered a bit later, together with the actions of the adductors.

### ***Adductor Longus*** (see Fig. 12-17)

The adductor longus (innervated by the obturator nerve) arises by a short tendon from the anterior surface of the superior pubic ramus along a line extending from the medial limit of the pectineus origin to the beginning of the gracilis origin. The muscle fibers pass laterally, downward and backward, fanning out remarkably as they do so, to gain a tendinous insertion on the linea aspera in the middle one-fifth of the femoral shaft. The insertion of the adductor longus is in line with, but inferior to that of the pectineus. Although the superior edge of adductor longus abuts the inferior edge of pectineus as they leave their origins, the abutting edges diverge slightly so that there is a gap of a few centimeters between the muscles at the sites of their insertions

### *Adductor Brevis*

This muscle (innervated by the obturator nerve) arises from the outer surface of the pubis deep to the origins of the adductor longus and the anterior fibers of gracilis. The adductor brevis passes laterally, downward and backward, fanning out slightly as it does so, to a tendinous insertion on the posterior surface of the femur along a narrow strip that runs from near the beginning of the pectineus insertion down to the beginning of the adductor longus insertion, but lateral to both. Throughout most of its course, the adductor brevis hugs the back surfaces of the pectineus and adductor longus (see Fig. 12-17).

**FEMORAL TRIANGLE** (Fig. 12-17)

Just inferior to the inguinal ligament is an intermuscular space called the femoral triangle. Its upper boundary (or **base**) is the inguinal ligament. Its medial boundary corresponds to the medial edge of the adductor longus muscle. The lateral border of the femoral triangle is the medial edge of the sartorius, which runs obliquely down the thigh. About one third of the way down the thigh, the medial edge of the sartorius contacts the medial edge of the adductor longus and the femoral triangle ends at its so-called **apex**.

The femoral triangle has a **roof** composed only of fascia lata overlain by subcutaneous tissue and skin. A muscular floor of the triangle is composed (superolaterally to inferomedially) of the iliopsoas, pectineus, and the adductor longus itself. Because the adductor longus and pectineus diverge from their origins toward their insertions, the more deeply placed adductor brevis forms a narrow segment of the floor between these two muscles.

The femoral triangle is noteworthy because the femoral artery and vein pass through it from its base to its apex (see Fig. 12-19). Although these vessels lie beneath the deep fascia of the roof, they are close to being subcutaneous. Medial to the femoral vein are the deep inguinal lymph nodes. The great saphenous vein runs in the subcutaneous tissue of the triangle's roof to pass through the fossa ovalis (see Fig. 12-15) and empty into the femoral vein. The profunda femoris artery and its two femoral circumflex branches arise in the triangle. The femoral nerve is another structure that enters the triangle through its base, but this nerve sprays out its branches very shortly thereafter. Only two of the branches--the nerve to vastus medialis and the saphenous nerve--continue all the way to the apex.

***Adductor Magnus (see Fig. 12-18)***

The human adductor magnus is the product of the fusion of two muscles that are separate in most nonhuman primates. One of these arises from the ischiopubic ramus and inserts into the femur lateral to the other adductors. Like the other adductors it is a member of the medial compartment of the thigh, innervated by the obturator nerve. The second muscle arises from the ischial tuberosity, like a hamstring, and goes to an insertion on the medial epicondyle of the femur. It is a developmentally ventral muscle of the posterior compartment, and, as such, is innervated by the tibial portion of the sciatic nerve.

The double evolutionary origin of the human adductor magnus is acknowledged by referring to an obturator-innervated pubofemoral part and a tibial-innervated ischiocondylar portion, even though they cannot usually be dissected apart. The **pubofemoral part of adductor magnus** arises from the outer surface of the ischiopubic ramus deep to the posterior fibers of the adductor brevis and, further backward, deep to gracilis. These fibers pass laterally, downward and backward, fanning out greatly as they do so, to an insertion onto the posterior surface of the femur along a narrow strip that starts a bit above the beginning of the pectineus insertion (i.e., at the level of the lesser trochanter) and runs down to a site at, or a bit below, the end of the adductor longus insertion. This strip is lateral to the insertions of the other adductors. The more anterior is the origin of an adductor magnus fiber, the more proximal is its insertion. The upper half of the pubofemoral part of the adductor magnus hugs the back surface of adductor brevis, the lower half hugs the back surface of adductor longus (see Fig. 12-17). In fact, many of the lower fibers insert into the back of the adductor longus tendon.

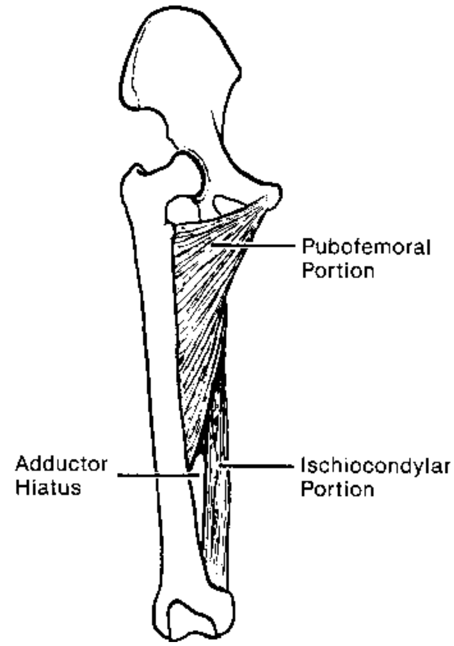


**Figure 12-18.** Anterior view of the right adductor magnus.

The **ischiocondylar part of adductor magnus** arises from the lateral half of the rough-surfaced portion of the ischial tuberosity. These fibers pass straight down the thigh eventually giving rise to a tendon that inserts into the distal part of medial supracondylar ridge and into the adductor tubercle of the femur.

Obviously, since the pubofemoral fibers pass to a different insertion than do the ischiocondylar fibers, the two portions of the adductor magnus diverge in the lower part of the thigh. We might expect a triangular gap to be formed between them. In fact, such is the case in many nonhuman primates. However, in humans, the superiorly directed apex of this gap is rounded off by the presence of a fibrous arch that bridges between the most distal point of the pubofemoral insertion and the most proximal point of the ischiocondylar insertion (see Fig. 12-18). Some ischiocondylar muscle fibers insert into this arch. Regardless, the gap still exists and is called the **adductor hiatus**.

## ADDUCTOR CANAL (SUBSARTORIAL CANAL, HUNTER'S CANAL)

The apex of the femoral triangle leads to the adductor canal. This canal is a narrow intermuscular space, triangular on cross section, that occurs in the middle third of the thigh as a result of the way muscles are packed together here. The sartorius itself forms the medial wall of this space, hence its alternate name of subsartorial canal (see Fig. 12-17) . Its posterior wall is formed first by the anterior surface of adductor longus and, lower down, by the anterior surface of adductor magnus. Its lateral wall is formed by the outer surface of vastus medialis. Through the canal pass the femoral artery and vein, and two branches of the femoral nerve--the nerve to vastus medialis and the saphenous nerve. In the inferior half of the adductor canal, a fibrous bridge stretches over the vessels from the vastus medialis to the tendon of the ischiocondylar part of adductor magnus, thereby reinforcing the otherwise purely muscular medial wall. The adductor canal ends inferiorly where its back wall has a gap formed by the hiatus in the adductor magnus (see

Fig. 12-18). The vessels leave the canal through this hiatus, but the saphenous nerve does not. It follows the deep surface of sartorius across the medial side of the knee. The superficial femoral artery gives off its descending genicular branch near the inferior end of the canal.

***Actions of Pectineus and the Adductors***

The pectineus, adductor longus, adductor brevis, and the pubofemoral part of adductor magnus have essentially the same actions. They adduct, medially rotate, and flex the thigh. The more anterior is the origin, the greater is the leverage for flexion and rotation. The ischiocondylar part of adductor magnus is also an adductor, but resembles its developmental cousins, the hamstrings, in being able to extend the thigh. It is probably also a weak medial rotator.

It is usually difficult for students to understand why the anterior adductors medially rotate the femur. That is because most of you will imagine that the axis for femoral rotation passes down the shaft of the bone, and knowing that vector pull of the adductor musculature is applied behind this axis, you will conclude that the muscles ought to laterally rotate the femur. In truth, the axis for rotation passes from the middle of the femoral head to the intercondylar fossa, well away from the shaft. Look at an articulated skeleton. You can see that the vector pull of the anterior adductor muscles passes in front of this actual axis. Thus, the anterior adductor muscles will medially rotate the thigh.

***Gracilis***

The gracilis (innervated by the obturator nerve) is a flat muscle broad at its origin and becoming increasingly narrower toward its insertion. It arises by short tendinous fibers from a line that starts adjacent to the midpoint of the pubic symphysis and then extends backward along the inferior margin of the ischiopubic ramus up to where it merges with the ischial tuberosity. The muscle fibers of gracilis descend straight down the medial surface of the thigh and encounter the posterior edge of sartorius about two thirds of the way down (see Fig. 12-17). The two muscles continue their descent, gracilis behind sartorius, until a site just superior to the medial epicondyle of the femur, where the gracilis gives way to a flat narrow tendon. This tendon either hugs the back edge of sartorius as it crosses the knee, or may take a position deep to sartorius. Below the knee, the gracilis and sartorius tendons curve forward and insert onto the medial surface of the subcutaneous shaft of the tibia near the lower end of its tuberosity. If the main tendon of sartorius has a long insertion, the gracilis will attach to the tibia posterior to the lower part of the sartorius tendon, fused to it. If the main tendon of sartorius has a short insertion, the gracilis inserts distal to the sartorius. From its lower edge, the gracilis tendon sends off a fibrous **expansion** that joins the sartorius expansion.

At the hip the gracilis is virtually a pure adductor. Its anterior fibers participate in the early stages of hip flexion. The muscle is also active in medial rotation of the hip, but is probably not nearly as important in this capacity as many other muscles. Of course, the gracilis crosses the knee, where, like the sartorius, it is a flexor and medial rotator.

***Obturator Externus***

The obturator externus (innervated by the obturator nerve) arises from the outer surfaces of the pubis and ischium along a strip of bone that lies behind, below and in front of the obturator foramen. The muscle also has a significant origin from the outer surface of obturator membrane. Obturator externus fibers pass laterally, and slightly upward, converging on a round tendon that crosses the posterior surface of the hip joint capsule to reach an insertion in the depths of the trochanteric fossa. When a person stands erect, the tendon of the obturator externus presses against the posterior surface of the femoral neck (with the joint capsule intervening). This pressure often produces a shallow groove running along the back of the femoral neck toward the trochanteric fossa.

Contraction of the obturator externus should cause adduction and lateral rotation of the femur at the hip. To my knowledge, the muscle has not been studied electromyographically in humans, so that we do not know those behaviors for which it is actually used.[69]

## FEMORAL ARTERY

The lower limb receives some of its blood supply from branches of the internal iliac artery, but most derives from the external iliac artery. Just as the subclavian artery changed its name to axillary artery upon entering the axilla, and the axillary artery changed its name to brachial artery upon leaving the axilla, so the external iliac artery changes its name to femoral artery upon entering the femoral triangle, and the femoral artery changes its name to popliteal artery upon leaving the subsartorial canal. These name changes are purely arbitrary and suggest no change in the conformation of the vessel.

The course of the external iliac artery along the medial surface of the psoas major takes it out of the abdominal cavity behind the inguinal ligament (at a site halfway between the anterior superior iliac spine and the pubic symphysis) and into the femoral triangle of the thigh (see Fig. 12-19). Immediately upon entering the femoral triangle, the vessel's name is changed to femoral artery. It passes through the femoral triangle to leave at its apex and enter the subsartorial canal. Upon reaching the adductor hiatus in the back wall of the canal, the femoral artery passes posteriorly through it medial to the shaft of the femur, and is henceforth called by the name popliteal artery.

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At its inception, just below a site halfway between the anterior superior iliac spine and the pubic symphysis, the femoral artery lies anterior to the head of the femur, separated from it by only the most medial fibers of iliopsoas and the capsule of the hip joint. It is at this site that the femoral pulse is most readily felt by pushing deeply so as to partly compress the vessel against the femoral head.

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Traveling almost straight down the thigh, the femoral artery crosses the anterior surfaces of the pectineus, then the adductor longus, and finally the adductor magnus, being pushed ever so slightly medially by the increasing bulk of the vastus medialis. In the upper part of its course the vessel is covered superficially by only fascia, subcutaneous tissue, and skin. However, the sartorius muscle follows an oblique path that brings it into contact with the anterior surface of the artery about one quarter of the way down the thigh (see Fig. 12-19). By the apex of the femoral triangle the sartorius completely intervenes between the femoral artery and fascia lata, at which point the vessel is said to lie in the subsartorial canal.

The femoral artery gives off tiny unnamed branches to nearby muscles, nerves, and skin. It has five to seven named branches.

[69] But, see the utterly fascinating paper: Stern JTJr & Larson SG 1993 Electromyographic study of the obturator muscles in nonhuman primates: implications for interpreting the obturator externus groove of the femur. J Hum Evol 24:403-427.

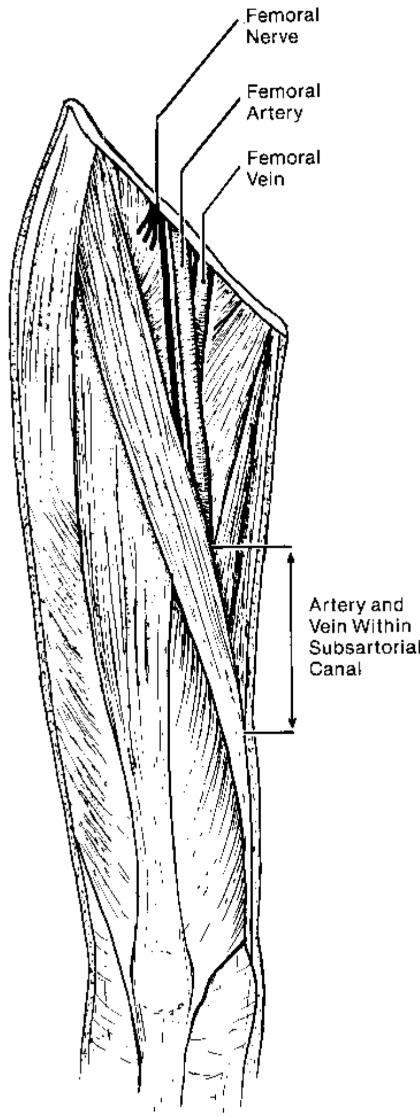


**Figure 12-19.** The paths of the femoral vessels and nerve through the femoral triangle (anterior view of right side).

## CLINICAL TERMINOLOGY FOR THE FEMORAL ARTERY

Several centimeters below the inguinal ligament, the femoral artery gives off its major branch in the thigh - the profunda femoris (i.e., deep femoral) artery (see below). Clinicians often use the term **common femoral artery** when referring to the femoral artery proximal to its profundus femoris branch. They use the term **superficial femoral artery** when referring to the femoral artery distal to its profunda femoris branch. I actually prefer this terminology to that used by anatomists.

## Branches of the Femoral Artery

### *Superficial Circumflex Iliac, Superficial Epigastric, and External Pudendal Arteries*

About 1 finger breadth (fb) below the inguinal ligament, the common femoral artery gives off three branches that pierce the deep fascial roof of the femoral triangle to follow courses in the subcutaneous tissue. These are the superficial circumflex iliac, superficial epigastric, and external pudendal arteries. They were described in Chapter 5 (p. 131) and Chapter 6 (p. 207) because they distribute to the abdominal wall and phallus.

### *Profunda Femoris Artery*

A little below the origin of the three superficial branches of the common femoral artery, as this vessel is crossing onto the anterior surface of pectineus, it gives off from its back side the profunda femoris artery, its largest branch. Almost immediately the profunda femoris gives rise to the **medial femoral circumflex and lateral femoral circumflex arteries**, but it should be noted that either or both of the femoral circumflex arteries may arise independently from the common or superficial femoral vessels. I will describe these femoral circumflex vessels later.

The profunda femoris artery passes downward behind the superficial femoral artery, sandwiched between it and the pectineus, until the lower border of that muscle. At this site, whereas the superficial femoral artery continues onto the anterior surface of adductor longus, the profunda femoris passes posterior to adductor longus onto the anterior surface of adductor brevis and, below this, adductor magnus. Thus, an adductor longus sandwich is made between the superficial and deep femoral arteries.

The profunda femoris artery terminates at the middle of the thigh by passing backward, piercing the adductor magnus en route, and then giving off muscular branches to the hamstrings and a slender vessel that descends to the back of the knee for anastomosis with other arteries around that joint.

While lying posterior to adductor longus, the profunda femoris artery gives off in sequence three so-called **perforating arteries**. Each of these passes backward, either by piercing the adductor brevis or adductor magnus, to enter the posterior compartment of the thigh wherein the hamstrings lie. The termination of the profunda femoris, just described , is generally described as a fourth perforating branch.

The perforating arteries give branches to the adductor musculature. Within the posterior compartment of the thigh, each vessel sends one branch superiorly and one inferiorly. These branches supply the hamstring muscles, but also the inferior branch of one perforating artery anastomoses with the superior branch of the next lower vessel. Obviously, the superior branch of the first perforating artery has no inferior perforating branch with which to anastomose, so it travels up to participate in the cruciate anastomosis described later. The inferior branch of the fourth perforating is none other than that slender vessel, previously mentioned, that descends to the anastomosis about the knee.

### *Medial Femoral Circumflex Artery*

This vessel, whether it arises from the deep, superficial, or common femoral arteries, passes straight backward between iliopsoas and pectineus, then between quadratus femoris and adductor magnus, to reach the deep surface of gluteus maximus, where it ends by participating in the cruciate anastomoses described further on. In addition to giving off muscular branches along the way, the medial femoral circumflex artery sends a branch to the obturator externus muscle that anastomoses with the obturator artery.

While passing backward, the medial femoral circumflex artery gives off some important branches that run medially along the surface of the femoral neck (deep to synovial membrane that covers it) toward the head of the femur. These are the major supply of blood to the head of the femur.

In adults, if the branches of the medial femoral circumflex artery to the femoral head are interrupted by fracture of the femoral neck, the small branch of the obturator artery to the head of the femur is usually insufficient to prevent necrosis.

***Lateral Femoral Circumflex Artery***

Whether arising from the deep, superficial, or common femoral arteries, the lateral femoral circumflex artery passes laterally, deep to sartorius and rectus femoris. While beneath rectus femoris, the vessel gives off two large muscular branches. One--the **descending branch**--passes inferiorly to supply the vastus lateralis, rectus femoris, and vastus intermedius. It ends in an anastomosis with other vessels about the knee. An **ascending branch** of the lateral femoral circumflex artery passes upward deep to tensor fascia latae, supplying structures en route and anastomosing with the superior gluteal artery.

After its ascending and descending branches have been given off, the much smaller continuation of the lateral femoral circumflex artery, called its **transverse branch**, follows a curving course around the side of the thigh sandwiched between the vastus lateralis and the fascia lata. Eventually the vessel reaches the posterior aspect of the thigh on the deep surface of gluteus maximus, where it too participates in the cruciate anastomosis.

***Descending (Supreme) Genicular Artery***

Just before passing through the adductor hiatus, the superficial femoral artery gives off its last named branch--the descending genicular artery. This vessel sends a twig that follows the saphenous nerve (see further on) and also gives rise to muscular branches for the lower part of vastus medialis. One or more of these branches participate in the arterial anastomosis about the knee.

## (COMMON) FEMORAL VEIN

The femoral artery has only a single large vena comitans - the **femoral vein** (though I prefer to distinguish superficial and common femoral veins in the same way as I did arteries). The superficial femoral vein lies posterior to the superficial femoral artery. Within the femoral triangle the vein moves to the medial side of the artery and thus the common femoral vein passes behind the inguinal ligament medial to the common femoral artery. (see Fig. 12-19). The common femoral vein is separated from the lacunar ligament by fat and lymphatics, which structures are said to occupy a space called the **femoral ring**. A connective tissue sleeve surrounding the artery, vein, fat, and lymphatics is called the **femoral sheath**. It is continuous with the transversalis fascia of the abdomen. Once within the abdominal cavity, the common femoral vein changes its name to the external iliac vein and again assumes a position posterior to its companion artery.

The deep veins of the lower limb are notable for their numerous valves. After all, in most waking postures the blood is constantly fighting gravity to get up the lower limb.

## OBTURATOR ARTERY AND VEIN

Within the pelvis the obturator artery passes into the obturator groove on the inferior surface of the superior pubic ramus and then continues above the edge of the obturator membrane into the upper thigh. It gives off branches to the obturator internus, obturator externus, and to the adductor muscles of the thigh. It also sends a twig deep to the transverse acetabular ligament (p. 518) into the acetabulum, where it follows the ligamentum teres (p. 593) to the femoral head. The artery is accompanied by a vena comitans.

## GENITOFEMORAL NERVE (L1-L2), ILIOINGUINAL NERVE (L1), LATERAL FEMORAL CUTANEOUS NERVE (L2-L3)

The skin overlying the femoral vessels just below the inguinal ligament is innervated by the genitofemoral nerve (Chapter 5, p. 134). The skin on the inner aspect of the thigh adjacent to the scrotum or labium majus is innervated by the ilioinguinal nerve, if it has a cutaneous distribution. Otherwise this region is taken over by the genitofemoral nerve. The lateral femoral cutaneous nerve leaves the abdominal cavity by passing posterior to the inguinal ligament very close to its attachment on the anterior superior iliac spine. The nerve descends along the anterolateral aspect of the thigh, giving branches to the skin of its lateral surface.

## FEMORAL NERVE (Dorsal Divisions of L2-l4)

The femoral nerve passes through the abdominal cavity lying in the groove between the iliacus and psoas major (see Fig. 5-34). Here it innervates the iliacus. Together, the femoral nerve and iliopsoas pass behind the inguinal ligament to enter the femoral triangle, the nerve lying about 1 cm lateral to the femoral artery (see Fig. 12-19). Almost immediately the femoral nerve sprays out its branches; thus it does not have any real course through the femoral triangle. Some branches pass into the subcutaneous tissue to innervate the skin on the front of the thigh and the inferior part of its medial surface. These constitute the **intermediate and medial cutaneous nerves of the thigh**. Other branches of the femoral nerve go directly to the pectineus, sartorius, rectus femoris, vastus lateralis, and vastus intermedius.[70]

Only two branches of the femoral nerve run with the superficial femoral artery all the way through the femoral triangle into the subsartorial canal. On the lateral surface of the artery is the **saphenous nerve**. The **nerve to the vastus medialis** is anterolateral to the saphenous nerve.

Within the subsartorial canal the nerve to the vastus medialis pierces that muscle to supply it. The saphenous nerve crosses anterior to the femoral artery to reach the deep surface of sartorius at the inferior end of the subsartorial canal. However, the saphenous nerve does not pass through the adductor hiatus to enter the popliteal fossa. Rather, it continues down the thigh deep to sartorius. Below the knee the saphenous nerve passes between sartorius and gracilis to becomes superficial alongside the great saphenous vein, and then passes downward supplying cutaneous branches to front and medial aspect of the lower leg from patella to the sole of the foot.

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[70] It has been noted that although the pectineus is from the ventral musculature of the limb bud, it is almost always innervated by the femoral nerve. However, about one quarter of the time, the pectineus is innervated by its own nerve--the accessory obturator--which is clearly derived from ventral divisions of the lumbar plexus.

### CLINICAL CONSIDERATIONS

The femoral nerve may be inadvertently cut during pelvic, groin, or hip surgeries. It may be stretched by a retractor during pelvic surgery. It may be compressed against the inguinal ligament during prolonged lithotomy position. Pelvic tumors, pelvic fractures, anterior hip dislocations, and penetrating injuries to the groin also place the nerve at risk.[71] The major effect of such damage arises from paralysis of the quadriceps femoris. Injury in the abdominopelvic cavity may also affect the iliacus. Motor tests for assessing the integrity of the femoral involve assessing the strength of hip flexion and knee extension. The gait of a person with a paralyzed quadriceps femoris was described above..

## OBTURATOR NERVE (Ventral Divisions of L2-L4)

The obturator nerve enters the obturator canal along with the obturator artery. While in the canal, the nerve divides into anterior and posterior divisions that emerge from the canal deep to the pectineus.

The **anterior division of the obturator nerve** immediately splits into two diverging branches, both of which pass onto the anterior surface of the adductor brevis. Both branches run downward between adductor longus and adductor brevis. One reaches the deep surface of gracilis, which it innervates. The other innervates adductor longus and adductor brevis. The anterior division of the obturator nerve also gives off a **cutaneous branch** that innervates the skin of the upper part of the inner thigh.

As it emerges from the obturator canal the **posterior division of the obturator nerve** gives off a branch to obturator externus. This division then passes downward behind adductor brevis onto the anterior surface of adductor magnus. Thus, **adductor brevis is sandwiched between the anterior and posterior divisions of the obturator nerve**. The posterior division dives into the adductor magnus to supply its pubofemoral portion.

### CLINICAL CONSIDERATIONS

The anterior division of the obturator nerve is of particular clinical significance in the symptomatic treatment of cerebral palsy. Children with this disorder may experience a severe impairment of gait due to spastic medial rotation and adduction of the thigh. Transection of the anterior division of the obturator nerve will paralyze gracilis, adductor longus, and adductor brevis; such paralysis actually has a salutatory effect on locomotion. Elimination of spasticity in the gracilis has the additional positive result of reducing the tendency of the knee to be held in a partly flexed posture.

The obturator is not often injured. Intrapelvic tumors may compress the obturator nerve. Sometimes the pressure exerted by the fetal head during parturition may damage the maternal obturator nerve. Fracture of the superior pubic ramus, or hernia of bowel

[71] Stewart JD. 1993. Focal Peripheral Neuropathies. Raven Press, NY.

through the obturator canal are other potential sources of injury. The symptom of obturator nerve damage is loss of strength of adduction of the thigh. One tests for damage to the nerve by assessing adductor strength. The gait of a person with paralyzed adductors was described above.

## THE OCCASIONALLY PRESENT ACCESSORY OBTURATOR NERVE (From the Ventral Divisions of L3-L4)

About one quarter of the time an accessory obturator issues from the lumbar plexus. It follows the medial surface of the psoas major out of the abdominal cavity and then passes directly to the nearby pectineus, which it supplies. There is no explanation for why the pectineus only sometimes receives its innervation from a ventral division branch of the lumbar plexus when this is what should happen all the time.

## MUSCLES OF THE GLUTEAL REGION

### Developmentally Dorsal Muscles of the Lateral Compartment - Gluteus Maximus, Gluteus Medius, Gluteus Minimus, Piriformis, Tensor Fasciae Latae

#### *Gluteus Maximus (Fig. 12-20; see Fig. 12-14)*

The gluteus maximus (innervated by the inferior gluteal nerve) is the large muscle beneath the fat of the buttock. The origin starts on the ilium behind the posterior gluteal line and then continues inferiorly onto the dorsal surface of the sacrotuberous ligament, the fascia covering the multifidus, and the ligaments attaching to the dorsum of the sacrum. The lowest fibers of the muscle arise from the coccyx almost down to its tip. Very often the most superior fibers of gluteus maximus expand their origin anteriorly onto the deep fascia covering the gluteus medius muscle.

The fibers of the gluteus maximus pass downward and laterally, forming a thick muscular sheet that enters the upper part of the thigh. They insert primarily by means of strong flat tendon that attaches to the lateral part of the posterior surface of the femur from the level of the lesser trochanter to about one third of the way down the shaft (see Fig. 12-12). Many fibers of the inferior half of the muscle bypass this tendon to gain an attachment to the fascia on the back surface of the vastus lateralis.

There is considerable difference of opinion concerning an insertion of the gluteus maximus into the fascia lata. My observations indicate that superficial fibers of the upper half of the muscle do end by sending tendinous bundles that join the iliotibial tract in its descent through the thigh (see Fig. 12-14). A colleague of mine (E. Paré) claims this insertion is trivial, if it exists at all. On the other hand, he has observed connections between the tendon of the gluteus maximus and the fascia lata that have the effect of redirecting the force of the upper fibers so that it follows a more or less vertical direction when the thigh is in a position of extension.

The upper and lower halves of the gluteus maximus have very different actions, and this has been confirmed electromyographically. The lower fibers, which apply force to both the tendon of the muscle

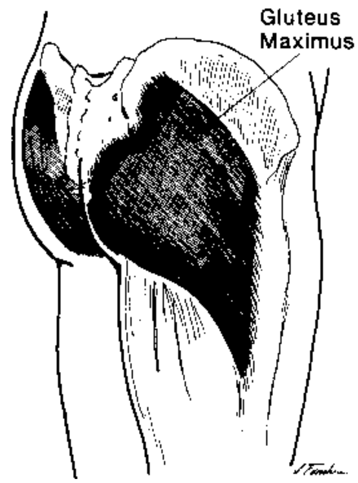


**Figure 12-20.** Origin of the gluteus maximus (seen in posterolateral view). (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

and to the fascia on the back of the vastus lateralis, are clearly powerful extensors and lateral rotators of the thigh. As extensors, they are used only when the demand for force is high, such as in running or climbing. When a person bends forward at the hip, as if to touch the toes, the gluteus maximus is not active to slow the flexion produced by gravity. On the other hand, it is used on the way back up from the toe-touch position in order to help provide the greater amount of force needed for this movement.

The superior portion of gluteus maximus acts as an abductor and lateral rotator of the thigh. The lateral rotatory action diminishes as the thigh passes from extension to about 45 degrees of flexion. The large size and iliac origin of the upper part of gluteus maximus are traits unique to humans. They have evolved because the bipedal locomotion of humans requires an additional abductor to assist gluteus medius and gluteus minimus.

***Gluteus Medius and Gluteus Minimus - The Lesser Gluteal Muscles***

The gluteus medius and gluteus minimus are often grouped together as the lesser gluteal muscles, in distinction to the gluteus maximus. Both lesser gluteal muscles are supplied by the superior gluteal nerve.

The **gluteus medius** arises from the gluteal surface of the iliac blade in the region lying between the posterior and anterior gluteal lines. Although the bony surface of origin for the anterior fibers is relatively small, this part of the muscle is added to by fibers arising from the overlying deep fascia (called **gluteal fascia**). The muscle fibers converge on the greater trochanter and give rise to tendon that attaches to its lateral surface along a broad ridge that runs downward and forward from its posterosuperior corner. A bursa separates this tendon from the anterosuperior part of the trochanter's lateral surface.

The **gluteus minimus** lies deep to the medius. It arises from the broad area of the iliac blade between the anterior and inferior gluteal lines. Its fibers also converge toward the greater trochanter. They give rise to a tendon that attaches to the anterolateral edge of the trochanter, separated from its anterior surface by a bursa.

When the lesser gluteal fibers shorten, they act to abduct the thigh, i.e., swing it out to the side. But this action consequent upon muscle shortening is not nearly so important as the function that these muscles have in their capacity to resist being lengthened. Whenever you lift one foot off the ground you eliminate that limb's ability to help support the weight of the trunk. Thus, there is a very substantial tendency for the unsupported side of the pelvis to drop (Fig. 12-21). The dropping of the unsupported side produces an *adduction* of the contralateral hip, i.e., the one on the side where the limb is still on the ground. If one could prevent this adduction, one could obviously prevent the drop of the pelvis. **The most important *function* of the lesser gluteal muscles is to keep the pelvis level by preventing adduction of the hip of the supporting limb when the opposite foot is off the ground**. Later, we shall discuss the necessity of this function in locomotion.

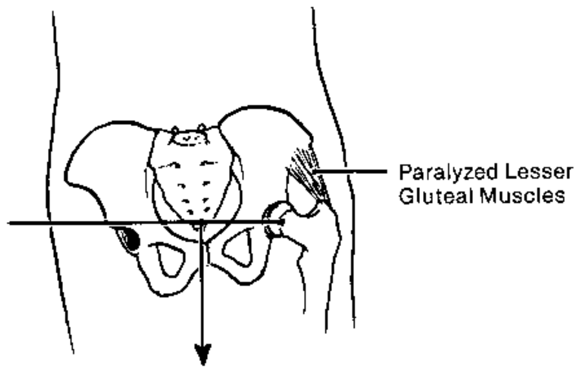


**Figure 12-21.** Anterior view of the bony pelvis in a person with paralyzed left lesser gluteal muscles who is attempting to stand on his or her left lower limb. Note how the unsupported right side of the pelvis drops because the contralateral muscles cannot hold it level. (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

Although the lesser gluteal muscles are classified as abductors, they also have other actions at the hip. The anterior fibers of both gluteus medius and gluteus minimus are used for medial rotation. (If the thigh is flexed, the posterior parts of these muscles also become medial rotators.) The gluteus minimus (particularly its anterior portion) is also a flexor of the thigh, whereas most of the gluteus medius (and particularly its posterior portion) extends the thigh. The differences between gluteus medius and minimus in producing flexion/extension is reflected in the precise timing of their use during locomotion.[72]

***Piriformi***s

The piriformis (innervated by twigs from S1 and S2) is a small muscle that seems to have arisen in evolution by a splitting off of the most posterior fibers of gluteus medius. The muscle arises from the ventral surface of the sacrum cranial, lateral and caudal to the 2nd and 3rd ventral sacral foramina. The muscle fibers pass laterally out the pelvis through the greater sciatic foramen, converging on a short tendon that inserts onto the posterior part of the superior edge of greater trochanter.

No one knows what the piriformis really does. Its shortening should produce lateral rotation, abduction, and extension of the thigh, but it hardly seems big enough to be needed in these capacities. Piriformis has a relatively high concentration of muscle spindles and may be more important as a proprioceptive organ than as a mover of the limb.[73]

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[72] Paré, EB: Interindividual Electromyographic Variation and the Functional Roles of the Human Hip Abductor Musculature. Ph.D. Dissertation, Department of Anatomical Sciences, State University of New York at Stony Brook, NY, 1985.

[73] Peck, D, Buxton, DF, and Nitz, A: A comparison of spindle concentrations in large and small muscles acting in parallel combinations. J Morph 180:243-252, 1984.

***Tensor Fasciae Latae (see Figs. 12-14 and 12-17)***

The tensor fasciae latae (innervated by the superior gluteal nerve) has a tendinous origin from the outer lip of the iliac crest between the anterior superior iliac spine and iliac tubercle. The muscle fibers pass inferiorly into the thigh, fanning out slightly as they do so. About one quarter of the way down the thigh the muscle fibers give rise to tendon fibers that join the iliotibial tract and also descend in the fascia lata just anterior to it.

Despite the fact the tensor fasciae latae generates a force within the lateral longitudinal tract of the fascia lata, which in turn crosses the knee, no one has ever demonstrated convincingly that the muscle is used because of any action it might have across the knee. Instead, one can explain the results of electromyographic studies on the tensor fasciae latae solely on the basis of its ability to produce movement at the hip.

Although not a large muscle, the tensor fasciae latae is functionally bipartite. The anterior fibers act to flex the thigh, the posterior fibers act primarily to medially rotate the thigh. Both parts have the ability to contribute to abductor force, but it is not clear how important this is in routine behaviors.

## Developmentally Ventral  Muscles of the Posterior Compartment – Obturator Internus, Gemelli, Quadratus Femoris

***Obturator Internus and Gemelli***

The **obturator internus** (innervated by its own nerve) arises from the deep surface of the ischiopubic ramus along a strip of bone inferior to obturator foramen, from the deep surface of the obturator membrane, and from a broad strip of bone on the deep surface of the pelvis between the obturator foramen and the arcuate line. The muscle fibers pass posteriorly, converging toward the lesser sciatic notch, where they give rise to a thick tendon that uses this notch as a pulley to execute a 90-degree turn and then run laterally across the back of the hip joint to insert onto the medial surface of the greater trochanter anterosuperior to the trochanteric fossa ( Fig. 12-22).

The **gemelli** (twins) are two tiny muscles that arise from the lesser sciatic notch, one above and one below the obturator internus tendon. The fibers of the gemelli pass laterally alongside the tendon of obturator internus, inserting into that tendon near the greater trochanter (Fig. 12-22). For obvious reasons, the muscle that hugs the superior edge of the obturator internus tendon is the **superior gemellus**; the muscle that hugs its inferior edge is the **inferior gemellus**. The former is innervated by the nerve to the obturator internus; the latter is innervated by the nerve to the quadratus femoris.

The obturator internus and gemelli can be presumed to have the same actions, though the gemelli are very much weaker and, like piriformis, have been speculated to be more important as proprioceptive organs than as movers of the limb. Neither the obturator internus nor the gemelli have been examined electromyographically in humans, so we are left with deducing from their anatomical relationships that they are essentially pure lateral rotators of the thigh.

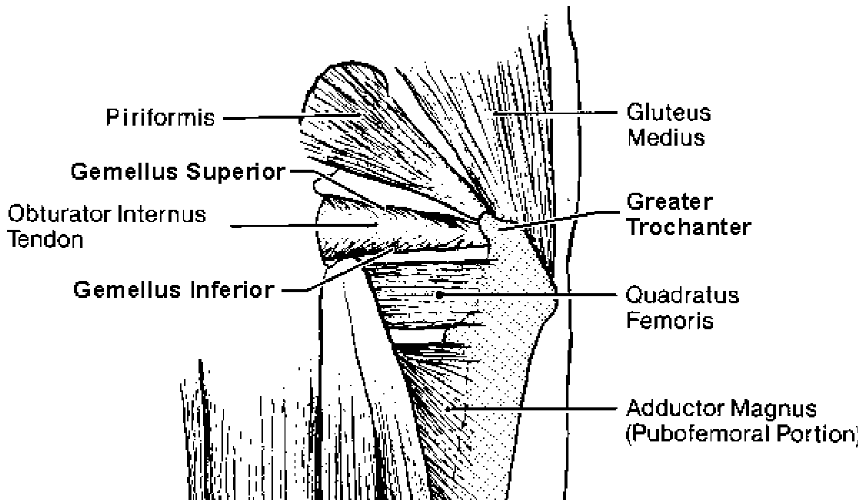


**Figure 12-22.** Deep muscles of gluteal region, posterior view, right side.

***Quadratus Femoris (Fig. 12-22)***

Quadratus femoris (innervated by its own nerve) is a rectangular muscle whose fibers arise from the external surface of the ischial body in front of its tuberosity and pass straight laterally to insert onto the posterior surface of femur superior to the upper limit of the adductor magnus insertion.

By deduction, we can assert that the quadratus is yet another lateral rotator of the thigh. It should also have the ability to adduct. Since most of the other adductors medially rotate, we could expect that simultaneous contraction of the quadratus femoris and the named adductors allows adduction without rotation.

## INFERIOR AND SUPERIOR GLUTEAL ARTERIES - TWO BRANCHES OF THE INTERNAL ILIAC ARTERY TO THE LOWER LIMB

Three branches of the internal iliac artery play a role in supplying certain muscles around the hip. These are the obturator, inferior gluteal , and superior gluteal arteries. The latter two are found in the gluteal region. (The obturator artery was discussed on p. 540.)

### Superior Gluteal Artery

This branch of the internal iliac artery leaves the pelvis through the greater sciatic notch above the superior border of the piriformis. Thus, the vessel is brought into contact with the deep surface of the upper gluteus maximus, to which it gives a so-called **superficial branch**. The continuation of the superior gluteal is said to constitute its **deep branch**. This vessel turns forward and immediately passes deep to the gluteus medius. Here it gives off an upper branch that follows the anterior gluteal line (thus, lying at the upper limit of origin of gluteus minimus) and a lower branch that crosses the superficial surface of the gluteus minimus passing forward to the tensor fascia latae. The deep branch of the superior gluteal artery supplies the tissues along its path.

### Inferior Gluteal Artery

This branch of the internal iliac artery leaves the pelvis through the greater sciatic foramen inferior to the piriformis. Here the inferior gluteal artery gives branches to nearby muscles, the most important of which is the overlying gluteus maximus. The vessel also gives off a twig that runs down with the sciatic nerve, and another small vessel that passes onto the back of the quadratus femoris for participation in the cruciate anastomosis (described later).

## INFERIOR AND SUPERIOR GLUTEAL VEINS

By now you are familiar with the concept that arteries to limbs are accompanied by one or two venae comitantes. The vena comitantes for the gluteal arteries end in the internal iliac vein.

## ANASTOMOSES BETWEEN BRANCHES OF THE ILIAC AND FEMORAL ARTERIES IN THE VICINITY OF THE HIP

Branches of the femoral artery make anastomotic connections with other branches of the external iliac artery, but these are relatively trivial:

5. Superficial circumflex iliac from the common femoral with deep circumflex iliac from the external iliac, and

6. Superficial epigastric from the common femoral with inferior epigastric from the external iliac.

More important are the connections between the femoral and internal iliac arteries. These are:

1. Ascending branch of the lateral femoral circumflex with the superior gluteal

2. Medial femoral circumflex with the obturator

3. External pudendal with internal pudendal

4. Sciatic branches of the perforating branches of profunda femoris with the sciatic branch of inferior gluteal, and

5. The **cruciate anastomosis** (Fig. 12-23), located on the back of the thigh at the lower border of quadratus femoris, formed by the medial femoral circumflex, transverse branch of the lateral femoral circumflex, superior branch of the first perforating branch of profunda femoris, and a branch of the inferior gluteal artery

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Despite the fact that five such anastomoses can be named, they are not nearly as extensive as the corresponding anastomoses about the scapula and shoulder. Ligation of the common femoral artery is very likely to lead to some death of lower limb tissues. Even slow occlusion localized to the common femoral artery is not well tolerated.

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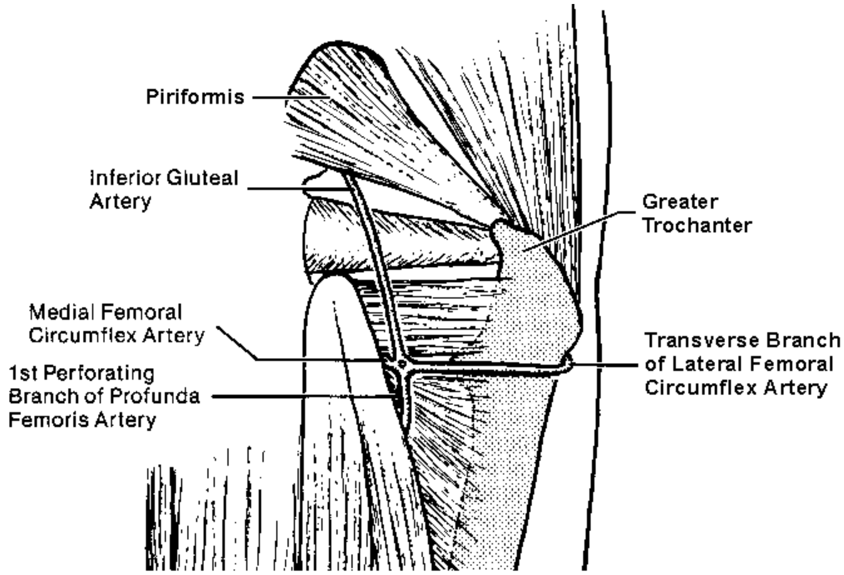


**Figure 12-23.** Cruciate anastomosis lying deeply on the posterior aspect of the thigh (right side).

## NERVES OF THE GLUTEAL REGION

### Cutaneous Innervation of the Buttock

The skin of the buttock receives innervation from four sources. That covering the upper posterior part of the buttock is innervated by dorsal rami of L1-L3 and S1-S3 (see Fig. 3-10). That covering the lower posterior part of the buttock is innervated by the perforating cutaneous nerve (S2, S3), a small branch of the sacral plexus that leaves the pelvis by perforating the sacrotuberous ligament. Skin on the lateral side below the iliac crest is innervated by the lateral cutaneous branches of the subcostal and iliohypogastric nerves. The skin over the rounded lower part of the buttock receives its nerve supply through branches of the posterior cutaneous nerve of the thigh (see below) that turn around the edge of gluteus maximus.

### Superior Gluteal Nerve (From the Dorsal Divisions of L4-S1)

The superior gluteal nerve exits the pelvis alongside the superior gluteal artery, i.e., through the greater sciatic foramen superior to the upper edge of piriformis. Unlike the artery, the nerve has no superficial branch to the gluteus maximus. Rather it distributes with the deep branch of the artery to the gluteus medius, gluteus minimus, and tensor fasciae latae.

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#### CLINICAL CONSIDERATIONS

While only rarely involved by peripheral disease, the symptoms of superior gluteal nerve damage are those of lesser gluteal paralysis. To test for damage to the nerve, one assesses strength of abduction of the thigh. Normally, when a person is requested to stand supported by only one limb, he or she should be able to maintain a level pelvis. If the unsupported side of the pelvis drops, this is said to be a **positive Trendelenburg**

**sign**, indicating weakness of the contralateral lesser gluteal muscles. The gait of a person with paralyzed lesser gluteal muscles was described above.

## Inferior Gluteal Nerve (From the Dorsal Divisions of L5-S2)

The inferior gluteal nerve leaves the pelvis on the dorsal surface of either the sciatic or posterior femoral cutaneous nerves (which, after all, leave side by side). It immediately divides into two or three branches that fan out on the deep surface of gluteus maximus and then pierce the muscle for its supply.

### CLINICAL CONSIDERATIONS

Though rarely injured, inferior gluteal nerve damage will lead to symptoms resulting from paralysis of the gluteus maximus, i.e., loss of strength of thigh extension. To test for damage to the nerve one asks the prone patient to flex the knee and then raise the thigh off the examining table against resistance by the examiner. Flexion of the knee is requested because it causes the hamstring muscles to operate in unfavorable regions of their length-tension curves and, therefore, enables a purer test of gluteus maximus strength. The muscle should be palpated as the test is performed. The gait of a person with a paralyzed gluteus maximus was described above.

## Sciatic Nerve (With a Common Peroneal Portion From the Dorsal Divisions of L4-S2 and a Tibial Portion From the Ventral Divisions of L4-S3)

The sciatic is a large nerve with two portions surrounded by a common epineurial sheath. The common peroneal portion comprises the lateral fibers of the sciatic, the tibial portion comprises its medial fibers.

The sciatic is the largest and most lateral of the nerves exiting the pelvis through the greater sciatic foramen below the inferior edge of piriformis (see Fig. 12-27, p. 557). It follows a course deep to gluteus maximus, crossing the posterior surfaces of superior gemellus, obturator internus, inferior gemellus, and quadratus femoris. It gives no branches in the gluteal region. Its course in the thigh will be described later (p. 556).

## Posterior Femoral Cutaneous Nerve (Posterior Cutaneous Nerve of the Thigh) (S1-S3)

The posterior cutaneous nerve of the thigh exits the pelvis through the greater sciatic foramen below the inferior edge of the piriformis and immediately medial to the much larger sciatic nerve (see Fig. 12-27). It descends alongside the sciatic nerve,  nestled in its concavity, deep to gluteus maximus, at the lower border of which the posterior femoral cutaneous nerve gives some branches to the skin over the lower part of the buttock. It then continues a descent beneath the deep fascia along the posterior midline of the thigh and knee down to the lower limit of the popliteal fossa. The nerve distributes branches to the skin along its entire course.

### Nerve to Obturator Internus, Which Also Innervates the Superior Gemellus (From the Ventral Divisions of L5-S2)

This small nerve leaves the pelvis through the greater sciatic foramen medial to the posterior cutaneous nerve of the thigh (see Fig. 12-27). It immediately crosses the base of the ischial spine to turn round its lower edge and pass through the lesser sciatic foramen onto the surface of obturator internus in the ischiorectal fossa. The nerve gives a twig to superior gemellus and ends by supply of obturator internus.

### Nerve to Quadratus Femoris, Which Also Innervates the Inferior Gemellus (From the Ventral Divisions of L4-S1)

This small nerve leaves the pelvis on the deep surface of the sciatic nerve. Whereas the latter immediately passes onto the posterior surfaces of the gemelli and obturator internus to reach the back of the quadratus femoris, the nerve to quadratus femoris passes anterior to these muscles to reach the deep surface of the quadratus femoris, supplying it and the inferior gemellus *en route*.

## MUSCLES OF THE POSTERIOR COMPARTMENT OF THE THIGH

Although the ischiocondylar part of the adductor magnus is evolutionarily a muscle of the posterior compartment of the thigh, as revealed by its innervation from the tibial portion of the sciatic nerve, it was considered previously along with its pubofemoral partner (p. 534). The unadulterated posterior compartment muscles are the hamstrings, defined as muscles arising from the ischium and inserting on one of the lower leg bones. The three hamstrings are the long head of biceps femoris, the semitendinosus, and the semimembranosus. Inserting into the tendon of the long head of biceps femoris is a lateral compartment muscle - the short of head of biceps femoris, which will also be discussed at this time

### Long Head of Biceps Femoris (see Fig. 12-24)

The long head of biceps femoris (innervated by the tibial portion of the sciatic nerve) arises by means of a strong tendon, which it shares with semitendinosus, from the medial part of the smooth area of the ischial tuberosity. After several centimeters, the tendon gives way to a fleshy belly that passes downward and laterally along the posterior aspect of the thigh. Below midthigh, these fibers gradually give rise to a flat tendon that crosses the posterolateral aspect of the knee and then ends on the head of the fibula (with a small expansion to the deep fascia over the lateral tibial condyle superior to the fibula).

The long head of biceps femoris crosses both the hip and knee joints. Its primary action at the hip is one of extension. Unlike gluteus maximus, the long head of biceps femoris (and, for that matter, the other hamstrings) is called into use for hip extension even if the force requirement is not great. Thus, it is active to slow-down flexion at the hip when a person bends forward as if to touch the toes. The long head of biceps femoris also has the ability to laterally rotate the hip and to adduct it from a prior position of abduction. Its action at the knee is one of flexion and lateral rotation.

### Short Head of Biceps Femoris - a Muscle of the Lateral Compartment of the Thigh

The short head of the biceps femoris (innervated by the peroneal portion of the sciatic nerve) arises by short tendinous fibers from the posterior surface of the femur along a narrow strip lateral to the insertion of the adductor magnus roughly in the middle third of the shaft. Muscle fibers of the short head also take origin from the aponeurosis on the back of the vastus lateralis.

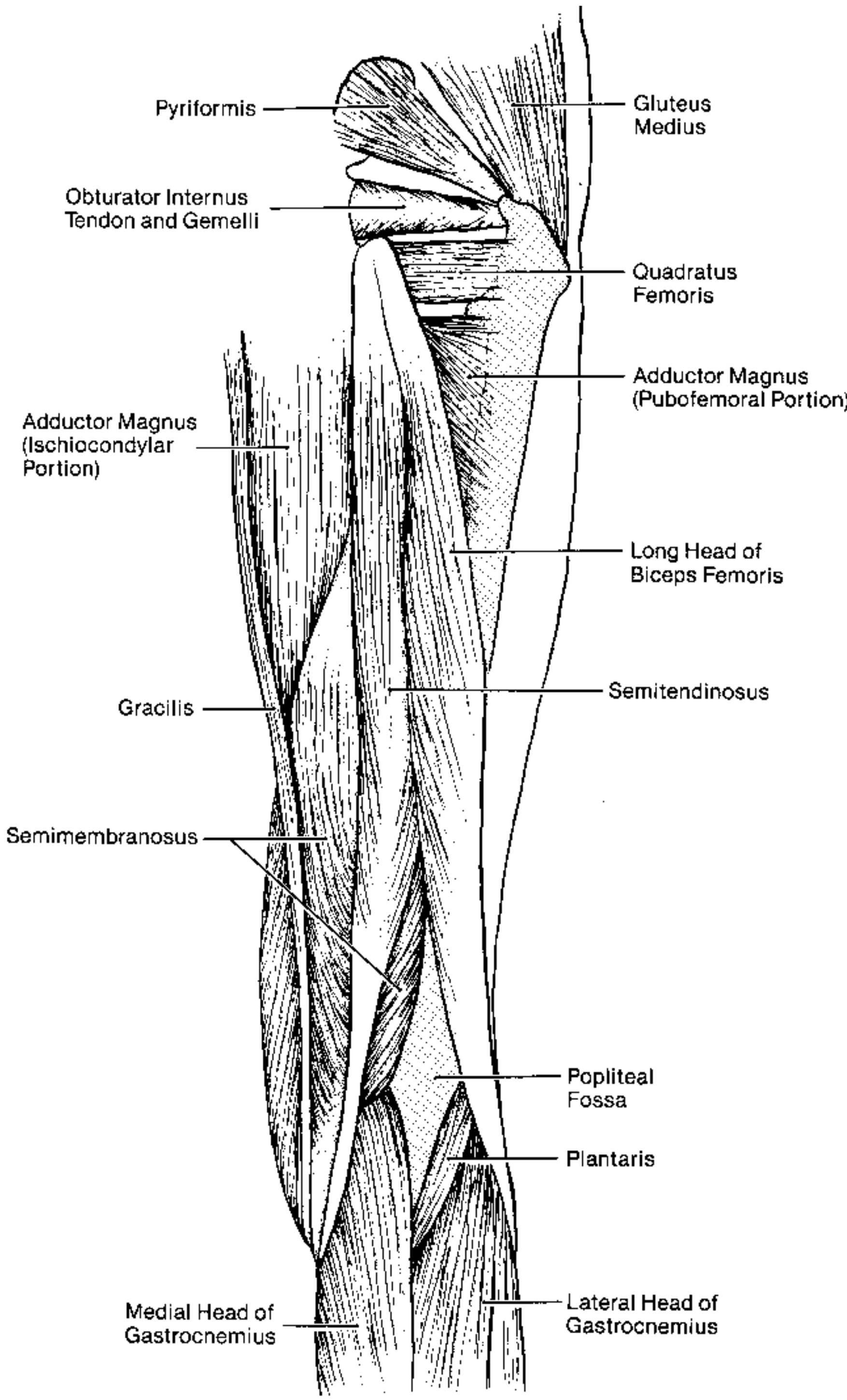


**Figure 12-24.** Muscles on the posterior aspect of the right thigh.

The fibers of the short head of biceps femoris pass downward and slightly laterally to insert onto the deep surface of the tendon of the long head from the site where the flesh of that muscle stops down to the level of the knee joint itself.

The short head of the biceps femoris is the only knee flexor that can act without producing some effect on the hip. It, like the long head, is also a lateral rotator of the leg.

## Semitendinosus (see Fig. 12-24)

The semitendinosus (innervated by the tibial portion of the sciatic nerve) arises by means of a strong tendon, shared with the long head of biceps femoris, from the medial region of the smooth-surfaced part of the ischial tuberosity. The muscle fibers pass straight down the back of the thigh, just medial to its midline. About three quarters of the way down, they give rise to a cord-like tendon that continues behind the medial condyle of the femur into the leg. Once in the leg the semitendinosus tendon sweeps forward along the posterior edge of the gracilis tendon. Near the tibia the semimembranosus tendon flattens out, more or less fuses to the gracilis tendon, and inserts immediately below it into the subcutaneous surface of the tibia. Like the tendons of sartorius and gracilis, that of the semitendinosus sends an **expansion** from its lower border that extends its tibial attachment further distally. The expansions of  the three muscles are fused.

The fusion between the tendons and expansions of the sartorius, gracilis, and semitendinosus creates a complex that reminded some ancient anatomist of the fan-shaped foot of a goose. Thus, the triple-tendon complex is called the **pes anserinus** (L. *anser*, a goose).

Like the long head of biceps femoris, semitendinosus is a major extensor of the hip, acting even when no great force is required. It too is an adductor of the abducted hip. Unlike the long head of biceps, semitendinosus medially rotates rather than laterally rotates the thigh, though the relevance of this distinction in routine behaviors has yet to be determined. The semitendinosus, like its partners in forming the pes anserinus, is a flexor and medial rotator of the lower leg.

## Semimembranosus (see Fig. 12-24)

The semimembranosus (innervated by the tibial portion of the sciatic nerve) arises from a very long flat tendon that springs from the lateral part of the smooth region of the ischial tuberosity. Immediately below the ischium this tendon crosses deep to the long head of biceps femoris and takes up a position against the deep and lateral surfaces of semitendinosus. It holds this position to about midthigh, where muscle fibers of the semimembranosus begin. In the distal half of the thigh, the large belly of the muscle lies deep to the semitendinosus, seeming to make a bed in which the latter and its tendon rest. Together semimembranosus and semitendinosus descend posterior to the medial femoral condyle, at which site the tendon of insertion of semimembranosus forms. At the level of the knee joint itself, the semimembranosus tendon forks (Fig. 12-25). One branch turns forward to insert onto the medial surface of the medial tibial condyle. The other branch continues downward to attach to an oblique line on the back surface of the tibia a centimeter or two below the medial condyle, at the upper edge of the popliteus muscle. Superficial fibers of this branch continue into the fascia on the posterior surface of the popliteus. Sometimes, rather than forking, the tendon of semimembranosus merely fans out to these two insertions and to the tibial surface between them. It must also be mentioned that, in addition to its direct attachment to the tibia, the tendon of semimembranosus sends a strong band of fibers upward and laterally into the back of the capsule of the knee joint (see Fig. 12-25).

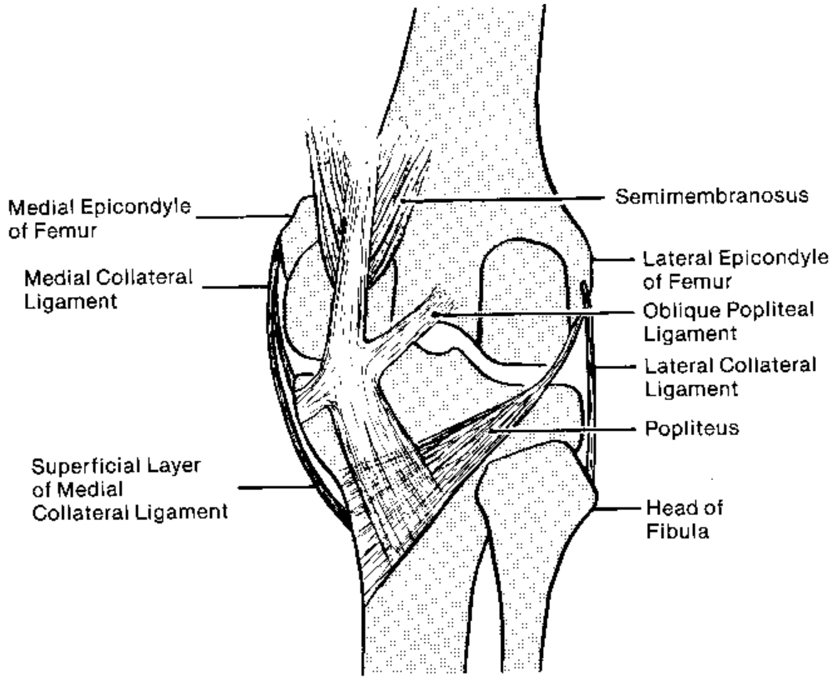


**Figure 12-25.** Insertion of the semimembranosus (posterior view of right side). The termination of the oblique politeal ligament by blending with the posterior capsule of the knee is not shown.

The actions of the semimembranosus at the hip are the same as those of the semitendinosus, extension being the primary of them. At the knee the semimembranosus is a medial rotator and flexor.

## POPLITEAL FOSSA

The defect (i.e., the adductor hiatus) in posterior wall of the subsartorial canal leads to the popliteal fossa. The popliteal fossa is a diamond-shaped intermuscular space behind the lower end of the femur and upper end of the tibia (see Fig. 12-24). It has a superiorly directed apex from which superomedial and superolateral borders diverge down toward the knee. It has an inferiorly directed apex from which inferomedial and inferolateral borders diverge up toward the knee. The superomedial border is formed by the semimembranosus muscle with the semitendinosus tendon lying on its surface; the superolateral border is formed by the biceps femoris; the inferomedial border is formed by the medial head of gastrocnemius; the inferolateral border is formed by the plantaris and lateral head of gastrocnemius. Like the femoral triangle, the popliteal fossa has a roof composed only of deep fascia, subcutaneous tissue, and skin. Its floor is the popliteal surface of the femur and the posterior capsule of the knee.

Entering the popliteal fossa from the subsartorial canal are the femoral artery and vein, which change their names to popliteal artery and vein once in the fossa. Entering the popliteal fossa at its superior apex, from a position deep to the hamstrings, is the sciatic nerve, which branches immediately into its tibial and common peroneal branches (see Fig. 12-27). The popliteal artery gives off certain branches within the popliteal fossa, the vein receives certain tributaries, among them the small saphenous vein. The tibial and common peroneal nerves give off sural branches within the popliteal fossa.

# BLOOD VESSELS OF THE POSTERIOR COMPARTMENT OF THE THIGH AND THE POPLITEAL FOSSA

## Perforating Arteries from the Profunda Femoris (and Vena Comitantes)

As was described previously (p. 538), while coursing through the medial compartment of the thigh, the profunda femoris artery gives off in sequence three perforating arteries. Each of these passes backward, either by piercing the adductor brevis or adductor magnus, to enter the posterior compartment of the thigh wherein the hamstrings lie. The termination of the profunda femoris is generally described as a fourth perforating branch.

Within the posterior compartment of the thigh, each perforating artery sends one branch superiorly and one inferiorly. These branches supply the hamstring muscles, but also the inferior branch of one perforating artery anastomoses with the superior branch of the next lower vessel. Obviously, the superior branch of the first perforating artery has no inferior perforating branch with which to anastomose, so it travels up to participate in the cruciate anastomosis (p. 547). The inferior branch of the fourth perforating descends to an anastomosis about the knee (p. 554).

Each of the arteries mentioned above is accompanied by one or two vena comitantes that empty into the profunda femoris vein.

## Popliteal Artery and Vein

After the superficial femoral artery passes through the adductor hiatus, it is called the popliteal artery. The popliteal artery passes deep to semimembranosus to reach the posterior surface of the femur near the upper end of the popliteal fossa. Here the vessel turns straight downward again and crosses the back of the knee onto the posterior surface of the popliteus. A single popliteal vein accompanies the artery and quite consistently lies posterior to it. It becomes the superficial femoral vein after it passes through the adductor hiatus into the subsartorial (adductor) canal.

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Because the popliteal artery is the deepest of the neurovascular structures passing through the popliteal fossa it is particularly susceptible to injury if the distal end of the femur is fractured.

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The popliteal artery gives a number of branches to the muscles bounding the popliteal fossa and one that pierces the posterior capsule of the knee to supply the cruciate ligaments. At the lower border of the popliteus muscle, the popliteal artery terminates by bifurcating into its terminal branches (see below, p. 571 and pp.579-580).

### *Genicular Branches of the Popliteal Artery and the Genicular Anastomosis (Fig. 12-26)*

One of the larger muscular branches of the popliteal artery passes forward through the muscles on the medial side of the lowermost thigh to reach the front of the limb. Another passes through the muscles on the lateral side of the lowermost thigh to reach the front. A third passes through the muscles on the medial side of the uppermost leg to reach the front. A fourth passes through the muscles at the lateral side of the uppermost leg to reach the front. These four arteries are called, respectively, **superior**

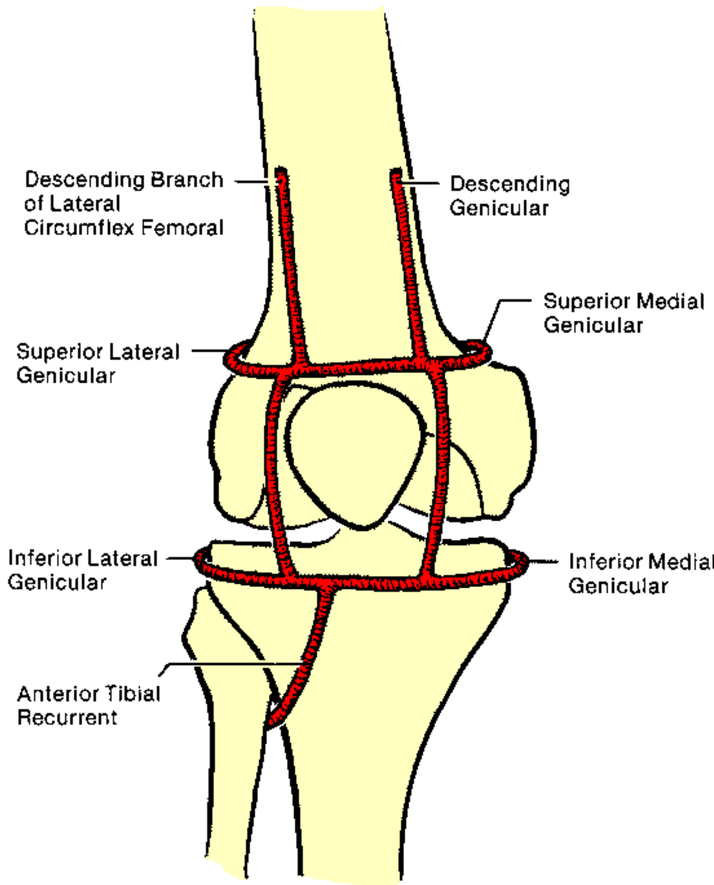


**Figure 12-26.** Arterial anastomoses around the patella (anterior view of right side).

**medial genicular, superior lateral genicular, inferior medial genicular, and inferior lateral genicular**. The two superior genicular arteries, having reached the deep tissues on the front of the lower limb just above the knee, anastomose with each other, with the descending branch of lateral femoral circumflex artery, and with the descending genicular artery from the superficial femoral. The two inferior genicular arteries, having reached the deep tissues on the front of the lower limb just below the knee, anastomose with each other and with a recurrent branch from the anterior tibial artery (see p. 572). Finally, the complex genicular anastomosis is completed by anastomotic channels running from the superior to the inferior genicular arteries near the margins of the patella, and by a connection on the back of the knee to the fourth perforating branch of the profunda femoris to the hamstring muscles.

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In theory, occlusion of the superficial femoral artery would not deprive the popliteal artery of blood because such occlusion could be compensated for by dilatation of the anastomotic connections between the popliteal artery on the one hand, and the lateral femoral circumflex and fourth perforating arteries on the other. An occlusion of the superficial femoral as it passes through the adductor hiatus makes possible yet another anastomotic route between the popliteal and the descending genicular arteries. However, the anastomoses between the superficial femoral and popliteal arteries are usually not sufficiently extensive to prevent tissue death if occlusion of the superficial femoral is rapid. They do better if the blockage develops slowly. The same holds true for any occlusion of the popliteal artery between the origins of its superior and inferior genicular branches.

## NERVES OF THE POSTERIOR COMPARTMENT OF THE THIGH AND THE POPLITEAL FOSSA (Fig. 12-27)

### Sciatic Nerve

As you will recall, the **sciatic nerve (composed of tibial and common peroneal portions)** exits the pelvic cavity through the greater sciatic foramen. It runs inferiorly deep to gluteus maximus, crossing the posterior surfaces of the gemelli, obturator internus tendon, and quadratus femoris to take up residence of the posterior surface of adductor magnus. Just before reaching the lower border of gluteus maximus, the sciatic nerve passes onto the deep surface of the long head of biceps femoris as this muscle passes inferolaterally from its origin on the ischial tuberosity. Once the crossing by the long head of biceps femoris is completed, the sciatic nerve finds itself at the superior apex of the popliteal fossa, where its common peroneal and tibial portions separate from one another as separate nerves (see Fig. 12-27).

Relatively early in its course, soon after the sciatic nerve has passed onto the posterior surface of adductor magnus, its tibial portion gives branches to each of the hamstrings (long head of biceps femoris, semitendinosus, and semimembranosus) and to the ischiocondylar part of adductor magnus. At about midthigh, the common peroneal portion sends a branch to innervate the short head of biceps femoris.

It is not unusual for the common peroneal and tibial portions of the sciatic nerve to lose their common epineurial sheath superior to the popliteal fossa. In fact, they occasionally leave the sacral plexus as individual nerves and descend the thigh adjacent to one another without forming a true sciatic nerve. When this occurs, the common peroneal nerve will almost always leave the pelvis by piercing the piriformis rather than by passing below its inferior border.

### CLINICAL CONSIDERATIONS

Damage to the entire sciatic nerve may occur in major traumatic injury to the buttock or thigh, fractures or dislocations of the hip, and during hip surgery. Intrapelvic tumors and very poorly placed injections in the buttock can produce partial injuries. Compression of the nerve can arise from sitting for a long time wedged in a toilet seat (usually associated with inebriation), or in emaciated patients that lie supine on an operating table for a long time, or during bicycling, or from prolonged sitting on one's thick wallet[74] (usually associated with being a professor). Paralysis of lower leg muscles supplied by both the common peroneal and tibial nerves should cause one to think of damage to the sciatic, rather than separate damage to its branches. Paralysis of the hamstrings is a sign of damage above the proximal thigh.

[74] Stewart JD. 1993 *Focal Peripheral Neuropathies*. Raven Press, NY.

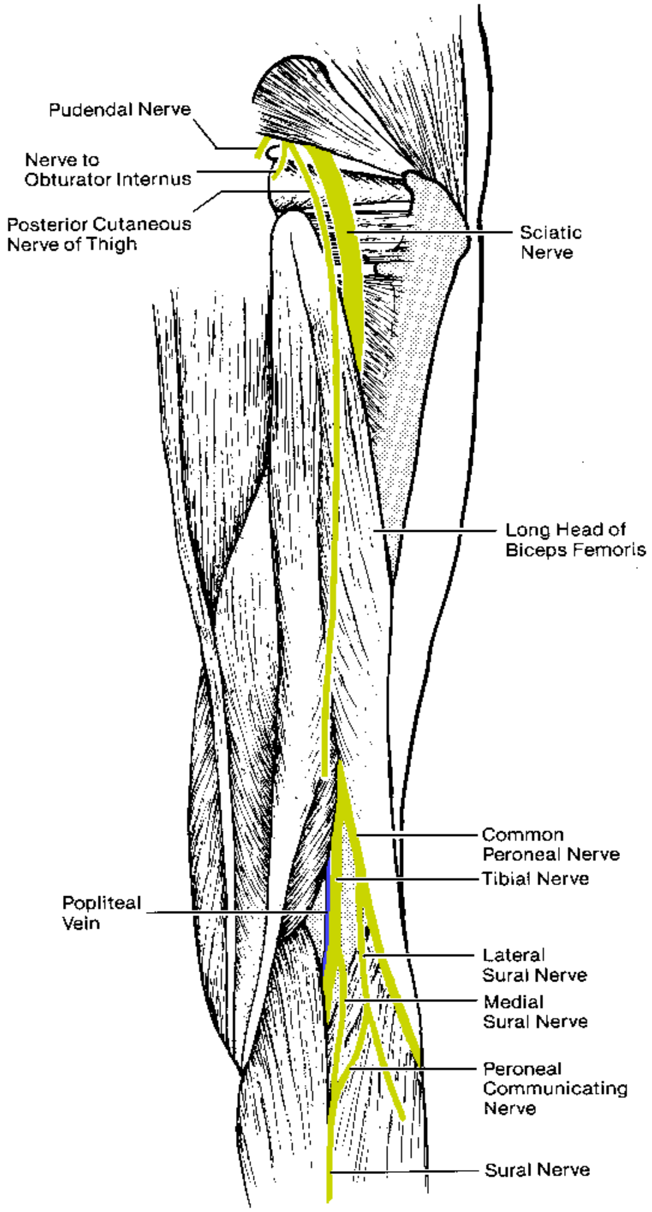


**Figure 12-27.** The paths of some nerves exiting the pelvis via the greater sciatic foramen inferior to the pyriformis (posterior view of right side). The inferior gluteal nerve and the nerve to quadratus femoris are not figured. The popliteal vein is seen deep to the tibial nerve in the popliteal fossa. The popliteal artery, being deep to the vein, is hidden from view.

Some tests for motor function of the sciatic nerve are the same as those for its common peroneal and tibial branches (see further on). However, assessing strength of knee flexion can give an indication of the integrity of its supply to the hamstrings and short head of biceps femoris. So that the examiner can distinguish weakness of knee flexion due to sartorius or gracilis paralysis from that due to muscles innervated by the sciatic nerve, palpation of the hamstrings is essential.

## Early Course of the Common Peroneal Nerve (from the Dorsal Divisions of L4-S2)

Separating from the sciatic nerve at the superior apex of the popliteal fossa (usually), the common peroneal nerve follows the medial surface of biceps femoris downward and laterally toward the knee (see Fig. 12-27). Just above the knee the nerve encounters the posterior edge of the biceps tendon, which it follows down to that muscle's insertion on the fibular head. At this site, the common peroneal nerve pierces the peroneus longus muscle to pass onto the lateral surface of the neck of the fibula, where it divides into its terminal branches - the superficial and deep peroneal nerves (see below). Within the popliteal fossa the only branch of the common peroneal nerve is the **lateral sural cutaneous nerve.**

### *Lateral Sural Cutaneous Nerve*

In the upper part of the popliteal fossa the common peroneal nerve gives off the lateral sural cutaneous nerve (see Fig. 12-27). This nerve may do one of three things: (1) It may descend beneath the deep fascia behind the knee to become superficial for supply of the skin on the lateral aspect, and the lateral half of the anterior aspect, of the proximal half of the lower leg. (2) Some of its fibers may do this, yet others may leave as a bundle that joins the medial sural cutaneous branch of the tibial nerve (see Fig. 12-27) to form the sural nerve. This bundle is called the **peroneal communicating nerve**; the site where it joins the medial sural cutaneous nerve is highly variable. (3) All the axons of the lateral sural cutaneous nerve may join the medial sural cutaneous nerve in the popliteal fossa, in which case we are forced to say that the common peroneal nerve has only a peroneal communicating branch and that no lateral sural cutaneous nerve really exists. In such cases, the medial sural cutaneous branch of the tibial nerve is nothing more than the tibial nerve's contribution to the sural nerve, which is then the source of actual twigs to the skin.

## Early Course of the Tibial Nerve (from the Ventral Divisions of L4-S3)

The tibial nerve arises at the superior apex of the popliteal fossa and descends through it (see Fig. 12-27). The popliteal artery and vein, which enter the fossa more medially, take a position deep to the nerve (see Fig. 12-27). With the tibial nerve being the most superficial member of the neurovascular triad, they all pass toward the inferior apex of the popliteal fossa, where they dive deep to the gastrocnemius. While in the popliteal fossa, the tibial nerve gives off a **medial sural cutaneous nerve** and several muscular branches to nearby muscles of the posterior compartment of the lower leg.

### *Medial Sural Cutaneous and Sural Nerves*

The medial sural cutaneous nerve, given off in the popliteal fossa, passes into the calf on the posterior surface of the gastrocnemius. It assumes a position just beneath the deep fascia in the groove between the heads of this muscle (see Fig. 12-27). At about the middle of the leg, the nerve enters the subcutaneous tissue to meet the lesser saphenous vein, which it follows downward and laterally behind the lateral malleolus and then forward onto the dorsum of the foot. During its descent through the leg, the medial sural cutaneous nerve supplies branches to the skin on the back of the calf. As the nerve crosses the ankle it supplies the skin on the lateral aspect of the heel. Finally, while running in the subcutaneous tissue on the dorsal aspect of the lateral side of the foot, it supplies the overlying skin and then terminates in a **dorsal digital branch** to the lateral side of the little toe (or less commonly, in dorsal digital branches to the lateral 1½ toes).

As has been mentioned earlier, somewhere along its course the medial sural cutaneous nerve is usually joined by the peroneal communicating branch of the lateral sural cutaneous nerve. The product of this joining is called the **sural nerve**. Thus, my description of the course and branches of the medial sural cutaneous nerve apply equally to the sural nerve from the point of its formation distally.

**CLINICAL CONSIDERATIONS**

The sural nerve is of clinical significance above and beyond its role in supply of skin. It is easily located alongside the lesser saphenous vein behind the lateral malleolus. The nerve can be traced upward from this point and removed virtually in its entirety for use as a source of bridging segments during attempts to repair damage to more important nerves of the body.

## BONES OF THE (LOWER) LEG

The two long bones of the lower leg are the robust tibia and the slender fibula. The tibia lies along the pre-axial border of the leg and, thus, must be viewed as serially homologous to the radius of the forearm. The fibula is serially homologous to the ulna. However, because of the completely different functions of the leg and forearm (notable among which is that the demand on the leg to support weight is so great as to make any supination/pronation movement highly destabilizing), the structure and articular relationships of the two leg bones are very different from those of their homologous forearm bones.

### Tibia (Figs. 12-28, 12-29)

It will be recalled that the radius is only mildly expanded at its proximal end for articulations with both the humerus and ulna, and that these articulations are designed to allow maximum rotation but otherwise influence elbow movement negligibly. In distinction to this arrangement, the tibia is greatly expanded at its proximal end to assume the full responsibility for articulation with the femur. The expanded proximal end of the tibia is its **head**, the superior surface of which is called the **tibial plateau**. The tibial plateau presents two separate articular surfaces: a large semicircular medial surface for articulation with the medial femoral condyle, and a smaller oval-shaped lateral surface for articulation with the lateral femoral condyle (see Fig. 12-29). The chunk of bone surmounted by the medial articular surface is called the **medial tibial condyle;** the chunk of bone surmounted by the lateral articular surface is called the **lateral tibial condyle**. Thus, the two condyles form the head of the bone. The posterolateral region of the lateral tibial condyle forms a projecting "shelf," the underside of which presents a smooth flat oval region for articulation with proximal end of the fibula.

In the middle of the tibial plateau, interposed between the two articular surfaces, is a superiorly projecting complexly shaped bump called the **intercondylar eminence**. Its medial and lateral margins are more prominent, forming so-called **medial and lateral intercondylar tubercles**. In front of the intercondylar eminence, the nonarticular surface of the tibial plateau is called the **anterior intercondylar fossa**. Behind the eminence is the nonarticular **posterior intercondylar fossa**.

Below its broad condylar region, the tibia narrows to a shaft that is roughly triangular in cross-section. As such, it has three surfaces delineated by three borders. In general, the surfaces face anteromedially, laterally, and posteriorly. However, at the upper end of the shaft the surface that we call

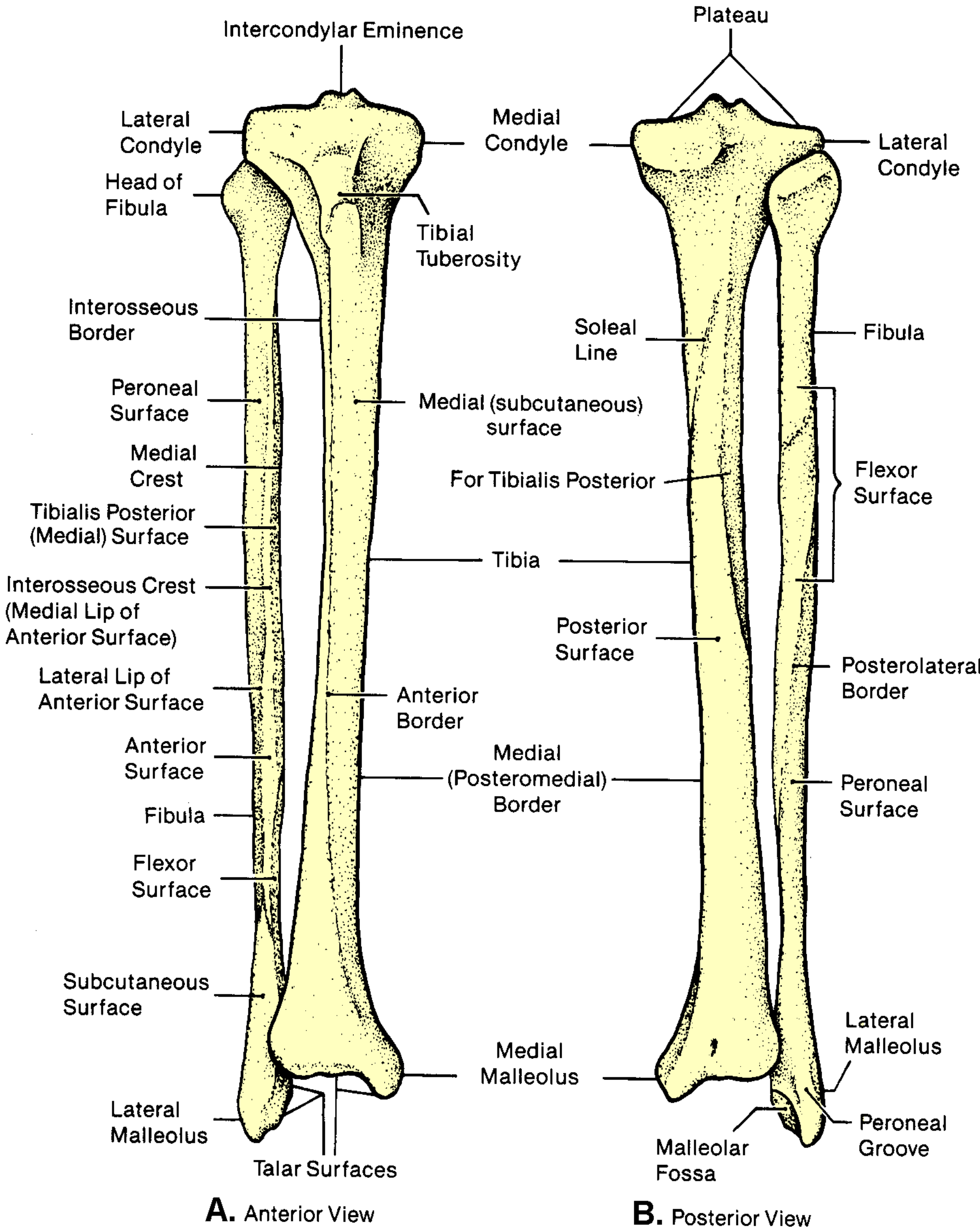


**Figure 12-28.** Right leg bones seen in anterior and posterior views.

posterior is very much wider than elsewhere and is curved so as to have an additional laterally facing component. Additionally, near the distal extremity of the shaft the borders between surfaces execute a spiral turn causing the anteromedial surface to face directly medially, posterior surface to face posterolaterally, and the lateral surface to face anteriorly.

The anteromedial/medial surface lies directly beneath the subcutaneous tissue of the lower leg and, consequently, is more often called the **subcutaneous surface**. Separating the subcutaneous and lateral surfaces of the tibia is the anterior, more commonly called **subcutaneous, border**. It is sharp for most of the length of the bone, but becomes much less prominent toward the lower end, where it spirals medially.

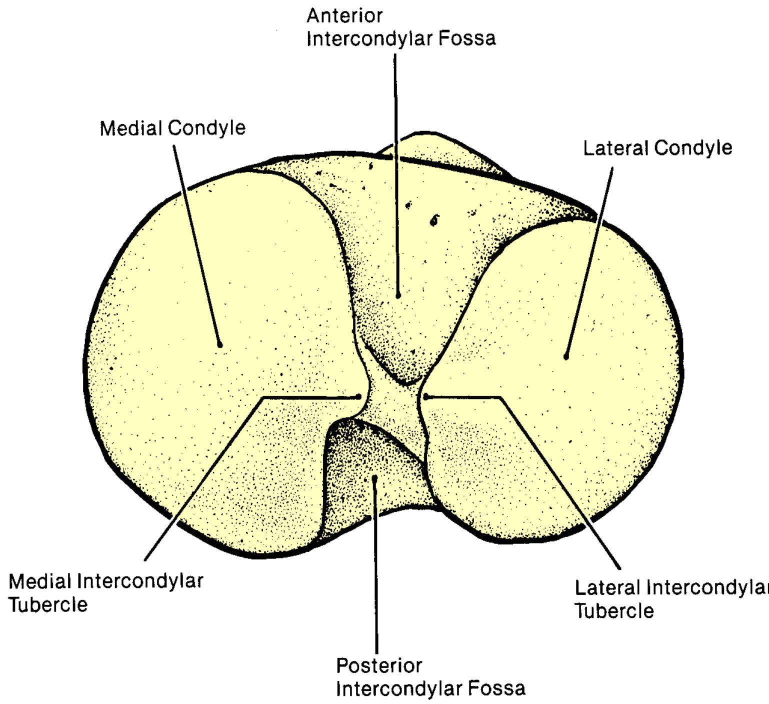


**Figure 12-29.** Superior view of right tibial plateau.

A **posteromedial border** separates the subcutaneous surface from the posterior surface. It is relatively sharp in the distal half of the shaft, but more rounded above this.

Finally, separating the lateral and posterior surfaces is the sharp **interosseous border**, so called because it serves as the attachment site for a fibrous sheet running between the tibia and fibula.

In its proximal half, the posterior tibial surface is marked by a prominent rugose crest that starts several centimeters below the posterior intercondylar fossa and passes obliquely downward and medially to terminate by joining the posteromedial border just above midshaft. This is called the **soleal line**, but a careful inspection often shows it to have separate proximal and distal components (see Fig. 12-28*B*), only the latter of which is actually due to attachment of the soleus. Passing straight down the posterior surface of the shaft from the site where the two components of the soleal line meet is another, less well-developed, ridge having no name. This ridge is, in fact, the distal continuation of the proximal component of the soleal line and both are due to the fibrous origin of the tibialis posterior.

Along the anterior aspect of the tibia, a few centimeters distal to the anterior intercondylar fossa, the shaft has a very prominent bulge called the **tibial tuberosity**. Its roughened surface is for attachment of the patellar tendon.

The distal end of the tibia is expanded to articulate with the foot. The subcutaneous surface of the bone is continued beyond the rest of the shaft onto an inferiorly directed process called the **medial malleolus**. The medial malleolus of the tibia is equivalent to the styloid process of the radius, but is more highly developed. The distal articular surface of the tibia lies along the inferior aspect of the shaft and also passes onto the inner aspect of the medial malleolus.

On its lateral side the distal extremity of the tibia exhibits a notch concave from front to back. This is the **fibular notch**. It is not smooth for it does not actually participate in a synovial joint with the distal end of the fibula.

The tibia ossifies from three centers--one center for the shaft, one epiphysis for the head, and one epiphysis for the distal extremity of the bone. The tibial tuberosity ossifies either by extension from the proximal epiphysis or by developing a separate center that eventually fuses with the proximal epiphysis.

### Fibula (see Fig. 12-28)

The fibula is a very slender bone because, for all practical purposes, it serves no weight-bearing function. It exists as a rigid structure to which ligaments of the knee and ankle can attach, and from which certain muscles of the foot can arise. In animals like horses and cows, which do not have grasping feet, the fibula is rudimentary. A human who sustains a minor fracture of the fibula will not generally require a cast because the bone is subject to such minimal stresses. The bone's middle third may be removed for use in other areas of the body that require bone implants.

The proximal end of the fibula is expanded to form its **head**. Although surmounted by a flat oval articular surface for the tibia, the fibular head is chiefly important as an attachment site for the lateral collateral ligament of the knee and the tendon of the biceps femoris muscle.

A description of the **fibular shaft** is not for the faint-hearted. The proximal half of the fibular shaft is roughly triangular in cross-section. As such, it has three surfaces and three borders. The surfaces are medial, posterior, and anterolateral. The anterior border has a certain width so that it is often considered to represent a fourth, very narrow, **anterior surface with medial and lateral lips** (see Fig. 12-28*A*). It becomes wider, and more obviously forms a surface in the distal part of the shaft (see Fig. 12-28*A*).

When the tibia and fibula are articulated, the anterior surface of the fibula lies on the same coronal plane as the interosseous line of the tibia (see Fig. 12-7*B*). The interosseous membrane of the leg attaches to the medial lip of the anterior surface of the fibula, which is therefore called the **interosseous crest**. In the upper half of the shaft, the ridge between the medial and posterior surfaces is called the **medial crest**. As it passes down the fibula the medial crest spirals anteriorly, eventually running into the interosseous crest about three quarters of the way down the shaft (see Fig. 12-28*A*). Separating the posterior from the anterolateral surface in the upper part of the shaft is the posterolateral border. However, it takes a course down the shaft that parallels the spiral path of the medial crest (at a fixed distance), thereby passing across the back of the bone to assume a posteromedial position in its distal one quarter (see Fig. 12-28*B*). Finally, just below the junction of the proximal three quarters and distal one quarter of the shaft, the lateral lip of the anterior surface bifurcates, giving off one fork that continues the path of its parent and a second fork that spirals backward around the lateral side of the shaft to become a new posterolateral border (see Fig. 12-28*A*).

These movements of borders are responsible for major changes in fibular shape and major problems in fibular nomenclature. First, what we called the medial surface in the proximal shaft becomes obliterated three quarters of the way down the bone. Second, what we called the posterior surface in the proximal shaft comes to face medially in the distal one quarter of the bone. Third, what we called the anterolateral surface of the proximal shaft comes to face posteriorly lower down. Finally, between the two forks of the lateral lip of the anterior border, a new lateral surface of the distal shaft forms.

Because of the fact that surfaces of the fibula change the directions in which they face as they pass down the shaft, anatomists often refer to them by names that avoid all terms of direction (see Fig. 12-28). Thus, the medial surface can be called the **tibialis posterior surface** because it gives rise to that muscle. The posterior surface is called the **flexor surface** because it gives rise to two flexor muscles. The anterolateral surface is called the **peroneal surface** because it gives rise to two peroneal muscles. The surface between the forks of the lateral lip of anterior surface is called the **subcutaneous surface** because it is subcutaneous.

The distal end of the fibula is expanded as the **lateral malleolus**, which projects further distally than does the medial malleolus of the tibia. The peroneal surface of the fibula is continued onto the back of the lateral malleolus as a groove for the peroneal tendons. The subcutaneous surface of the fibular shaft is continued onto the lateral surface of the lateral malleolus as its subcutaneous surface. The flexor surface of the shaft is continuous with the medial surface of the malleolus, although a prominent rugose bump just above the malleolar expansion indicates where muscle origin stops and ligamentous attachments begin. The medial surface of the malleolus itself is characterized by a triangular articular surface for the talus. Behind the inferiorly directed apex of this facet is a large pit--the **malleolar fossa**--marking the site of ligamentous attachments. Since the articular surface faces medially and the malleolar fossa is posteriorly placed, a fibula can easily be identified as to side by an examination of its malleolar region.

The fibula ossifies from one center for the shaft and two epiphyses, one for each end of the bone.

## TIBIOFIBULAR JOINT, INTEROSSEOUS MEMBRANE, AND TIBIOFIBULAR SYNDESMOSIS

A flat synovial joint is formed between the head of the fibula and the inferior aspect of the overhanging lateral tibial condyle. This is the only synovial joint between the tibia and fibula. It has a strong capsule and a few extracapsular ligaments that limit the amount of sliding that can occur.

A further restriction on tibiofibular movement is provided by a strong **interosseous membrane** that crosses from the interosseous crest of one bone to that of the other. It starts a couple of centimeters below the tibiofibular joint and continues all the way down to the ankle. The fibers of this interosseous membrane, like those of the interosseous membrane of the forearm, run from **pr**oximal on the **pr**e-axial bone (tibia, radius) to distal on the postaxial bone (fibula, ulna).

The portion of the interosseous membrane just above the ankle is thicker than the rest, and is said to form an interosseous ligament. Additionally, a ligament connects the anterior edge of the lateral malleolus to the front of the distalmost tibial shaft, and another ligament runs from the posterior edge of the lateral malleolus to the back of the distalmost tibial shaft. These and the interosseous ligament are said to form a **tibiofibular syndesmosis**.

Movement between the tibia and fibula is minimal. Because the talar trochlea is widest toward its anterior end (see Fig. 12-30), dorsiflexion of the foot causes the lateral malleolus to be pushed slightly away from the tibia. Presumably the existence of a tibiofibular joint enables the whole bone to respond to this push, rather than being subjected to the bending stress that would result if the upper end of the fibula were fused to the tibia.

In the upper limb, muscles exist to produce the rotatory movement possible between radius and ulna. There being no significant movement between the tibia and fibula, there are no muscles of the lower limb designed to produce tibiofibular movement.

## BONES OF THE FOOT

### Tarsal Bones (Figs. 12-30, 12-31)

There are seven irregularly shaped tarsal bones. Homologies between tarsal bones and carpal bones can be made. These are particularly clear for the distal rows of the two sets. There are four distal carpal bones (trapezium, trapezoid, capitate, and hamate) of which the most postaxial (hamate) articulates with two metacarpals. Similarly, there are four distal tarsal bones (**medial cuneiform, intermediate cuneiform, lateral cuneiform, and cuboid**) of which the most postaxial (cuboid) articulates with two metatarsals. The three proximal bones of the wrist (scaphoid, lunate, and triquetrum) correspond to only two tarsal bones. The **talus** of advanced tetrapods is believed to be the product of the fusion of two separate tarsal bones serially homologous to the scaphoid and lunate of the wrist. The postaxial member of the proximal row of carpals--the triquetrum--is represented in the foot by the **calcaneus**, which, however, has been excluded from articulation with the bones of the leg. The tarsus lacks any bone homologous to the pisiform, but possesses another bone--the **navicular**--corresponding to some tiny wrist bones called centralia, most of which are lost during evolution of the mammalian wrist, and one of which fuses to the scaphoid. Like carpal centralia, the navicular is interposed between the proximal and distal rows of bones.

I shall mention a few notable facts about the tarsal bones.

#### ***Talus (Fig. 12-32*A*; see Fig. 12-30)***

The talus is composed of a chunk of bone called the **body**, from which a stout, roughly cylindrical **neck** projects downward, forward, and medially. The talar neck expands at its end to form a **head** for the bone.

The superior aspect of the body is characterized by a large grooved articular surface for the ridged inferior surface of the tibia. For obvious reasons, the superior articular facet of the talus is often called the **talar trochlea** (see Fig. 12-30). The medial lip of the talar trochlear is continuous with a medially facing facet for the medial malleolus of the tibia. The lateral lip of the talar trochlear is continuous with a larger, laterally facing facet for the lateral malleolus of the fibula.

The inferior surface of the talar body presents a mediolaterally broad and concave facet for the calcaneus (see Fig. 12-32*A*). This is but one of three sites for articulation with the calcaneus and is called the **posterior calcaneal facet**.

The distal surface of the talar head, the inferior surface of the talar head, and the inferior surface of the talar neck present a continuous articular surface that can usually be identified as having five facets lying at different angles to one another (see Fig. 12-32*A*). The rounded facet on the distal surface of the head is for articulation with the socket of the navicular. On the inferior surface of the talar head are three flat, or mildly rounded, facets that lie in a row side by side. The most medial of these is for the deltoid ligament of the ankle; the middle facet is for the spring ligament of the ankle; the most lateral of the three is the **anterior calcaneal facet**. Extending backward from the anterior calcaneal and spring ligament facets, along the inferior aspect of the talar neck is the **middle calcaneal facet**. In some tali, the

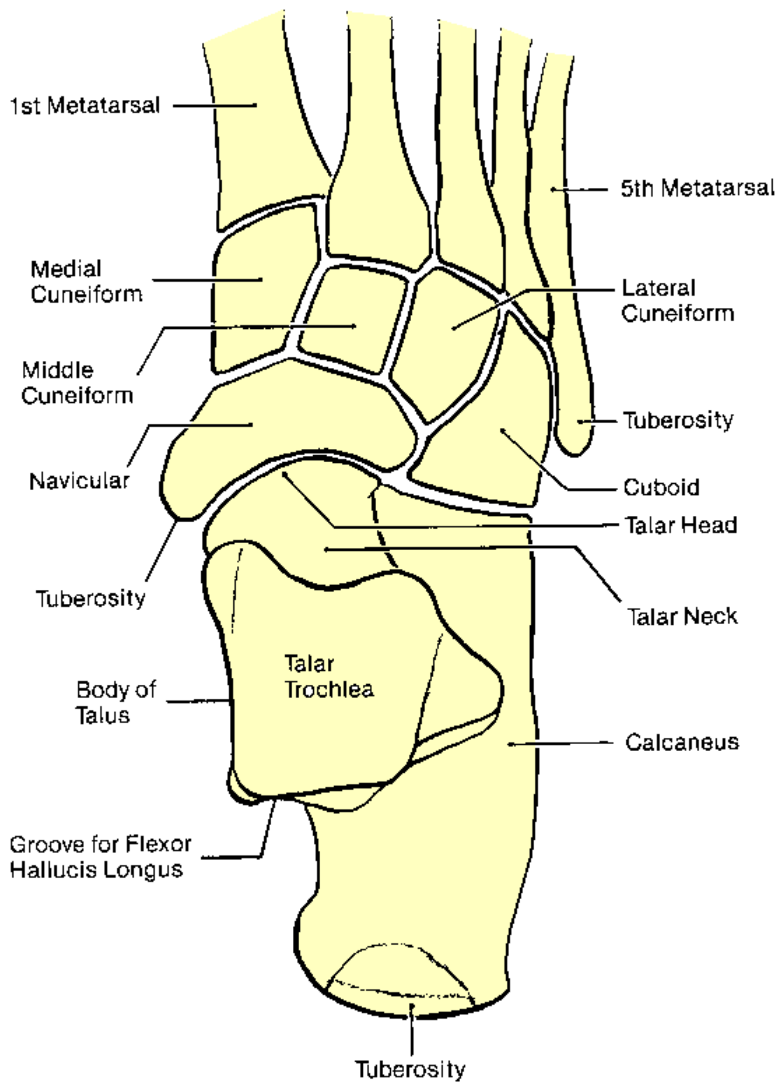


**Figure 12-30.** Tarsal bones of right foot seen in superior view.

distinction between the anterior and middle calcaneal facets is blurred. This occurs in conjunction with a variation in the calcaneus itself (see further on).

The middle and posterior calcaneal facets are separated by a nonarticular groove on the undersurface of the talus at the junction of its body and neck. This is the **talar sulcus**, to the floor of which a ligament attaches.

***Calcaneus (see Figs.12-30, 12-31, 12-32B)***

The calcaneus is an elongate box-like bone whose inferior half projects further distally than its superior half. Additionally, from the site where the superior half stops, it and the inferior half contribute to a medially directed shelf of bone called the **sustentaculum tali**.

The posterior aspect of the inferior half of the calcaneus bulges backward and downward as the **calcaneal tuberosity**. Its upper part is smooth, for attachment of the Achilles tendon; its lower part is

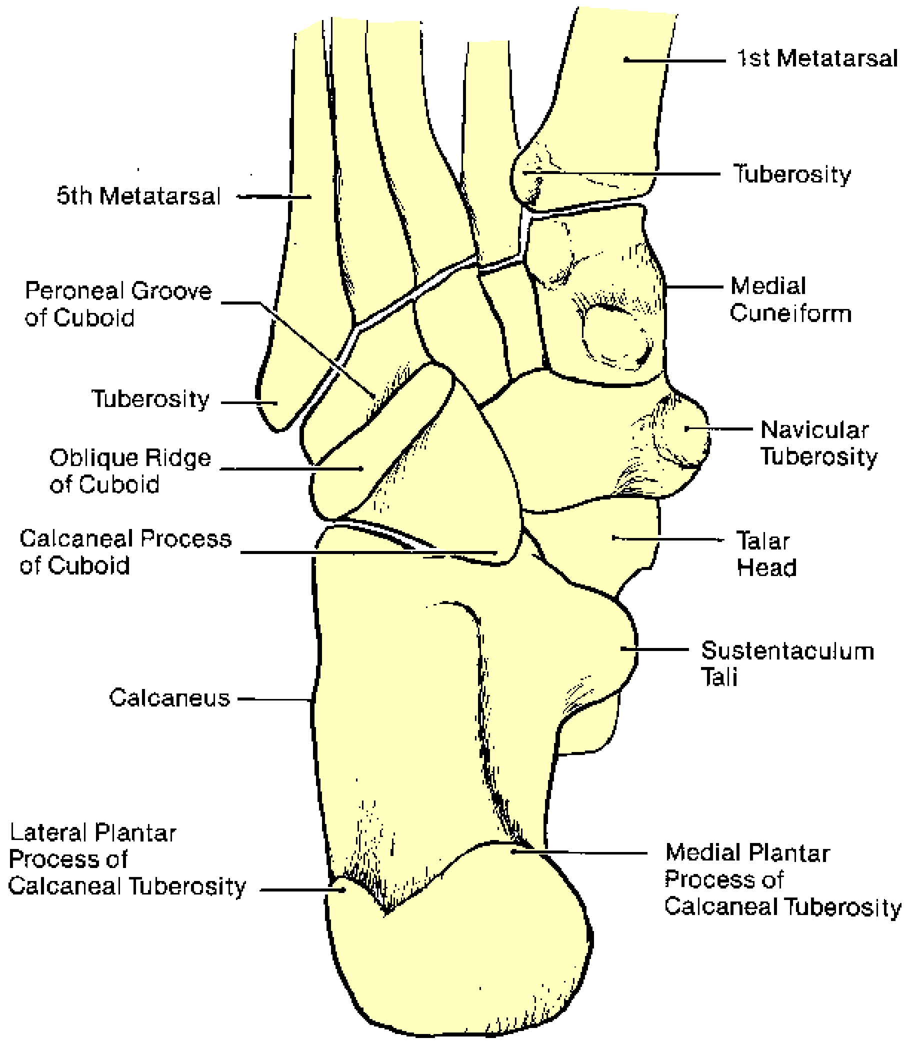


**Figure 12-31.** Tarsal bones of right foot seen in inferior view.

rough and sends two processes along the margins of the inferior surface of the bone. The larger of these is the **medial plantar process**; the smaller is the **lateral plantar process**.

The superior half of the calcaneus terminates distally in curved articular surface, the medial part of which is directed superiorly and the lateral part of which faces more forward (see Fig. 12-32*B*). This is the **posterior talar facet**, for articulation with the posterior calcaneal facet of the talus. The anterosuperior surface of the sustentaculum tali presents an oval, generally concave, **middle talar facet** for the middle calcaneal facet of the talus. The projecting inferior half of the calcaneus presents two articular surfaces. The one that caps its distal end is for the cuboid bone. A small, oval, and generally flat articular facet on the superior aspect of this anterior calcaneal shelf, just distal to the sustentaculum, is the **anterior talar facet** for the anterior calcaneal facet of the talus.

In some individuals the anterior and middle talar facets of the calcaneus are confluent. It is in the same individuals that the corresponding facets on the talus are difficult to distinguish (see earlier).

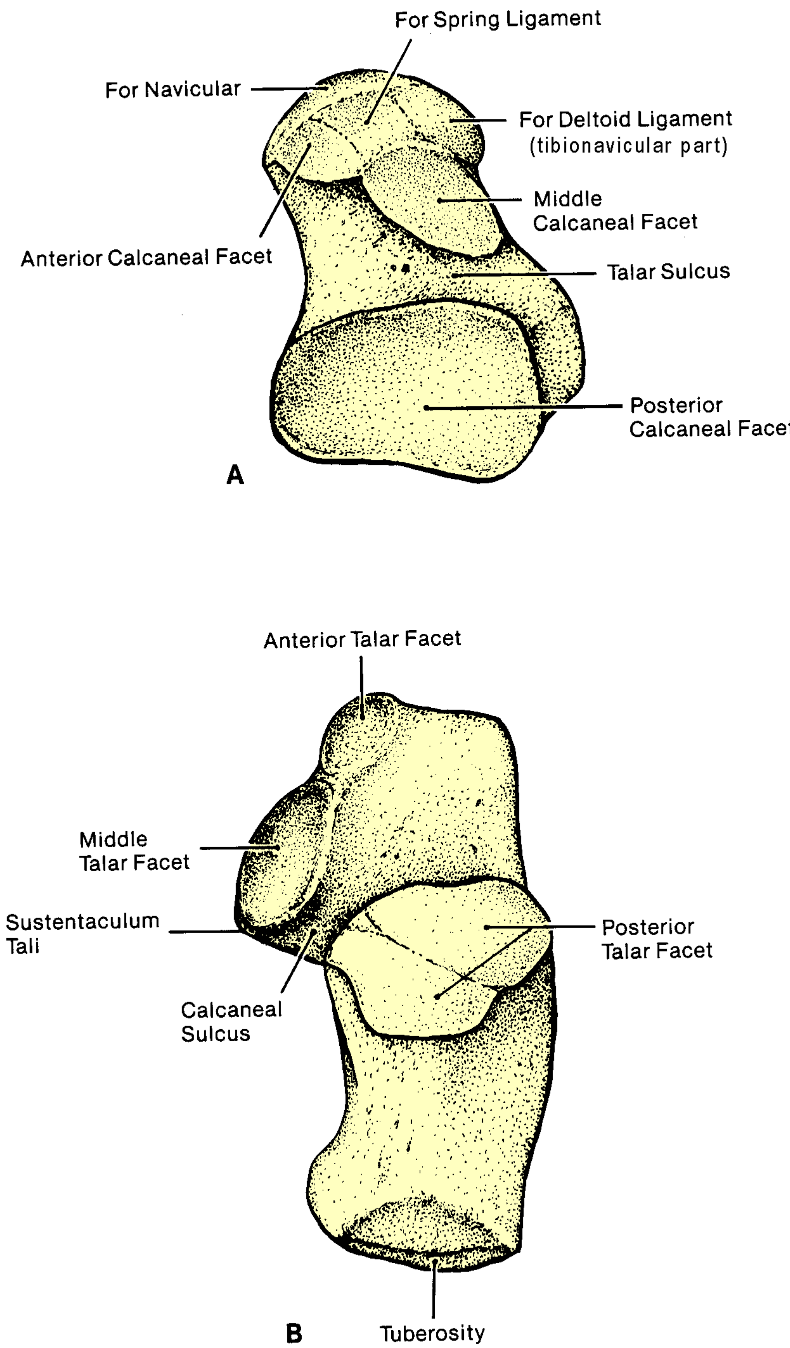


**Figure 12-32.** *A*, Inferior aspect of right talus. *B*, Superior aspect of right calcaneus.

The posterior and middle talar facets of the calcaneus are always separated by a nonarticular **calcaneal sulcus**. When the talus and calcaneus are articulated, as in life, the talar and calcaneal sulci enclose a space called the **tarsal sinus**, which houses a ligament.

### *Navicular (see Figs. 12-30, 12-31)*

This is a relatively flat (from front to back) bone interposed between the talar head and the three cuneiforms. Its proximal surface is concave for reception of the navicular facet of the talus. The distal surface of the navicular presents three confluent, but easily identifiable facets, one for each of the three cuneiform bones. The facet for the lateral cuneiform is continuous with a small flat facet on the inferolateral aspect of the navicular for articulation with the cuboid. The only other noteworthy feature of the navicular is a rather large **tuberosity** coming off its inferomedial angle.

***Cuboid (see Figs. 12-30, 12-31)***

The cuboid presents two noteworthy features. First its proximal articular surface, for the calcaneus, has a beak-like projection emanating from its posteromedial region (see Fig. 12-31). This is called the **calcaneal process of the cuboid**, and it fits beneath the lip of the calcaneus bearing the anterior talar facet. On the inferior (plantar) surface of the cuboid is a prominent **oblique ridge** distal to which is the so-called **peroneal groove**.

***Medial Cuneiform (see Figs. 12-30, 12-31)***

This is the most interesting of the cuneiforms because it articulates with the hallux and receives the insertion of several important muscles. The medial cuneiform is flattened from side to side and much narrower superiorly than inferiorly. The inferior (plantar) surface presents two bumps (see Fig. 12-31), one proximal and one distal, separated by a shallow depression. The proximal bump appears as if it were a continuation of the navicular tuberosity on the other side of the naviculocuneiform joint.

## Metatarsals

The basic plan of a metatarsal is like that of a metacarpal (see Chapter 11, p. 454). Each bone has an expanded **base** passing into a narrower **shaft** that terminates distally in a **head**. The hallucal metatarsal is far more robust than the others. Its base presents a prominent ventrally projecting **tuberosity** that appears to serve as a continuation of the distal bump on the plantar surface of the medial cuneiform (see Fig. 12-31). Whereas in the hand, the base of the pollical metacarpal comes nowhere close to articulating with the base of the index metacarpal, the adducted position of the human big toe brings the bases of the medial two metatarsals so close together that sometimes the opposing surfaces show smooth spots (covered in life by cartilage) where a joint is almost formed.

The head of the hallucal metatarsal is marked on its ventral aspect by two longitudinal grooves, each of which articulates with a large sesamoid bone formed within the capsule of the MP joint. The two sesamoid bones, and the thick tissues separating them from the sole of the foot, are responsible for the prominence we call the ball of the big toe.

The lateral four metatarsals differ most notably from the finger metacarpals in having mediolaterally compressed heads that are no wider than the shafts. The base of the 5th metatarsal is characterized by a prominent inferolaterally projecting **tuberosity** (see Fig. 12-31).

Like a metacarpal of a finger, each of the lateral four metatarsals ossifies from one center for the shaft and base, and one epiphysis for the head. The hallucal metatarsal resembles the pollical metacarpal in having one ossification center for the shaft and head, and one epiphysis for the base.

## Phalanges

The phalanges of the foot are structured on the same plan as those of the hand (see Chapter 11. p. 456). The hallucal phalanges are very close in length to those of the thumb, but are far more robust, indicating the great importance of the big toe in weight-bearing. On the other hand, the phalanges of the lateral four toes are shorter than those of the fingers. The shafts of the pedal proximal phalanges are also narrower from side to side than are the shafts of the manual proximal phalanges. The middle phalanges of the foot are quite rudimentary (more so the further you go toward the little toe), consisting of a head affixed to a base with little or no shaft. The distal phalanges also have a remarkably short shaft; sometimes these little bones appear to be no more than an ungual tuberosity affixed to a base. The highly rudimentary middle phalanx of the 5th toe is often fused to its distal phalanx.

The pedal phalanges resemble their manual counterparts in ossifying from one center for the shaft and head, and one epiphysis for the base.

## MUSCLES OF THE ANTERIOR TIBIAL COMPARTMENT - Tibialis Anterior, Extensor Hallucis Longus, Extensor Digitorum Longus, Peroneus Tertius

### Tibialis Anterior

Tibialis anterior (innervated by the deep peroneal nerve) arises from the lateral surface of the tibial shaft in its upper half, and from the front of the adjacent part of the interosseous membrane. The muscle fibers give rise to tendon that descends across the anterior surface of the distal tibia just lateral to the medial malleolus. The tendon then crosses the ankle joint and continues downward across the medial side of the foot to reach an insertion into the distal tuberosity of the medial cuneiform and the tuberosity of the first metatarsal.

Tibialis anterior is both the most powerful dorsiflexor and the most powerful invertor of the foot. It is always used to dorsiflex unless a conscious attempt is made to evert simultaneously; it is always used to invert, unless a conscious attempt is made to plantarflex simultaneously.

### Extensor Digitorum Longus and Peroneus Tertius

Arising from the entire length of the narrow anterior surface of the fibula, largely by means of an aponeurosis attached near its lateral lip, is a flat muscle sheet (innervated by the deep peroneal nerve) whose lower third has a different name than its upper two thirds. The upper two thirds portion is called the **extensor digitorum longus**. Its fibers usually give rise to two tendons that descend across the front of the ankle joint just lateral to a point midway between the malleoli and then pass onto the dorsum of the foot. Here the larger, more medial of the two tendons splits into three bands, which participate in the extensor expansions (as described for the hand) for the middle three toes. The smaller, more lateral tendon enters into the extensor expansion for the little toe.

The inferior third of the muscle sheet is called the **peroneus tertius**. It is somewhat more well developed than the rest of the muscle and has a unique insertion. The peroneus tertius tendon descends across the front of the ankle along the lateral side of the extensor digitorum longus tendon for the little toe. But, rather than going to that toe, peroneus tertius ends in an insertion into the dorsal aspect of the base of the 5th metatarsal.

The extensor digitorum longus and peroneus tertius are dorsiflexors and evertors of the foot. Of course, we cannot forget that the former muscle acts to extend the lateral four toes, whereas the peroneus tertius obviously lacks any such action.

### Extensor Hallucis Longus

Sandwiched between the extensor digitorum longus and tibialis anterior in the middle of the leg is the **extensor hallucis longus** (innervated by the deep peroneal nerve). The fibers arise largely from the interosseous membrane, but also some have a bony origin from the narrow anterior surface of the fibula. They give rise to a tendon that descends across the front of the ankle lateral to the tibialis anterior tendon and then proceeds across the dorsum of the foot to insert onto the base of the distal phalanx of the big toe (in a manner corresponding to the extensor pollicis longus of the upper limb).

The extensor hallucis longus is a dorsiflexor of the foot and extensor of the big toe. Although no evidence exists on its other actions, it probably is an invertor, like the nearby tibialis anterior.

## MUSCLES OF THE LATERAL TIBIAL COMPARTMENT - Peroneus Longus, Peroneus Brevis

The lateral compartment of the leg contains two muscles--peroneus longus and peroneus brevis. Both are innervated by the superficial peroneal nerve. The longus arises from the upper two thirds of the peroneal surface of the fibula; the brevis from its lower two thirds. Obviously, in the middle third of the fibula, the origins of the muscles overlap, with the longus being posterior to the brevis. Each muscle gives rise to a tendon that descends toward the posterior surface of the lateral malleolus. The peroneus brevis tendon is applied to posterior surface of the malleolus; the peroneus longus tendon is applied to the posterior surface of the brevis tendon. Below the malleolus, the two tendons turn a bit forward and cross the lateral surface of the calcaneus heading toward the cuboid bone. The peroneus brevis tendon, being the more anterior of the two, passes lateral to the cuboid to reach the tuberosity of the 5th metatarsal, where it inserts. The longus tendon, upon reaching the inferolateral aspect of the cuboid, turns into the sole of the foot and immediately enters the osseofibrous tunnel distal to the oblique ridge of the cuboid. Placed deeply within the sole, the peroneus longus tendon continues in an anteromedial direction toward the tuberosity of the 1st metatarsal, where it inserts. Often there is an additional tendon slip to the distal tuberosity of the medial cuneiform.

Although the peroneus longus and brevis can plantarflex and evert the foot, my own electromyographic studies indicate that eversion is the more important of these actions. The muscles are used under all instances of powerful eversion, even if this motion is accompanied by active dorsiflexion. They are generally used during plantarflexion, excepting instances when a simultaneous attempt is made to invert. One cannot rule out the possibility that peroneal activity during plantarflexion of the neutral foot serves the role of counteracting the tendency of triceps surae to invert the subtalar joint.

## EXTENSOR AND PERONEAL RETINACULA IN THE VICINITY OF THE ANKLE

the tendons of extrinsic manual extensors are prevented from bowstringing at the wrist by the extensor retinaculum, which is merely a region of thickened deep fascia at the level of the distal radius and ulna. In the lower limb also, the extrinsic tendons of the foot are held in place around the ankle by thickened regions of deep fascia called retinacula.

Two extensor retinacula exist. The **superior extensor retinaculum** runs across the front of the lower leg between the tibia and fibula superior to their malleoli. The **inferior extensor retinaculum** is shaped like a Y lying on its side. The stem attaches to the superolateral edge of the front part of the calcaneus and sweeps medially onto the dorsum of the foot, where it bifurcates into an upper band that proceeds to the medial malleolus and a lower band that continues across the foot and turns down on its medial side to blend with fascia near the navicular. The superior and inferior extensor retinacula hold the tendons of the anterior compartment muscles in place.

Passing backward from the lateral malleolus to reach the lateral surface of the calcaneus is a **superior peroneal retinaculum**, holding the tendons of peroneus brevis and longus against the back surface of the lateral malleolus. Where the peroneal tendons cross the lateral surface of calcaneus they are held in place by an **inferior peroneal retinaculum** that bridges from an attachment to the calcaneus above these tendons to one below them. The inferior peroneal retinaculum sends a septum to the bone between the tendons, so that each runs in a separate osseofibrous tunnel on the lateral surface of the calcaneus.

## SYNOVIAL SHEATHS OF THE EXTRINSIC PEDAL MUSCLES

The tendons of the extrinsic pedal muscles are surrounded by **synovial sheaths** as they pass beneath the various retinacula that hold them in place. The peroneus longus has a second synovial sheath where it passes through the osseofibrous tunnel formed by the cuboid and long plantar ligament (see p. 603).

## MUSCLES ON THE DORSUM OF THE FOOT - Extensor Digitorum Brevis (Including a Portion to the Big Toe That Is Often Called Extensor Hallucis Brevis)

Whereas the hand normally contains no representative of the developmentally dorsal musculature of the limb bud, the foot always has such a muscle--the extensor digitorum brevis. The extensor digitorum brevis (innervated by the deep peroneal nerve) arises tendinously from the superior surface of the calcaneus just lateral to the anterior talar articular facet (see Fig. 12-32*B*). The muscle fibers pass distally, deep to the tendons of peroneus tertius and extensor digitorum longus, and separate into four bellies, the most medial of which is the largest. At the level of the tarsometatarsal joints each belly gives rise to a tendon. The tendon of the most medial belly courses out to an insertion on the dorsal aspect of the base of the hallucal proximal phalanx (in a manner corresponding to the extensor pollicis brevis of the upper limb). The tendons of the other three bellies are destined for the 2nd, 3rd, and 4th toes, respectively. Over the MP joints of these toes, the extensor digitorum brevis tendon joins the lateral side of the extensor digitorum longus tendon to form the dorsal extensor aponeurosis.

In that the medial belly of extensor digitorum brevis is largest and inserts somewhat differently than the other bellies, it is often referred to as comprising a separate **extensor hallucis brevis**.

The entire extensor digitorum brevis participates in extension of the medial four toes.

## BLOOD VESSELS OF THE ANTERIOR TIBIAL COMPARTMENT, LATERAL TIBIAL COMPARTMENT, AND DORSUM OF THE FOOT

### Anterior Tibial and Dorsalis Pedis Arteries (which have vena comitantes)

In the posterior compartment of the lower leg the popliteal artery terminates at the lower border of the popliteus by bifurcating into an anterior tibial artery and tibioperoneal trunk (see pp. 579-580). The **anterior tibial artery** passes anterolaterally through the gap between the neck of the fibula and the tibial shaft, superior to the edge of the interosseous membrane. Now in the anterior compartment of the leg, the vessel turns downward to run on the anterior surface of the interosseous membrane between the origins of tibialis anterior and the extrinsic digital extensor muscles. The anterior tibial artery follows the lateral edge of the tibialis anterior tendon onto the anterior surface of the tibial shaft just above the ankle joint (where its pulse can be felt) (Fig. 12-33), and then follows a course straight down across the ankle and dorsum of the foot to the proximal part of the first intermetatarsal cleft. However, at the level of the ankle joint the vessel is crossed superficially by the tendon of extensor hallucis longus as this tendon is passing toward the big toe (see Fig. 12-33). Below the point of crossing, we change the name of the artery from anterior tibial to **dorsalis pedis**. Thus, it is the dorsalis pedis artery that lies lateral to the extensor hallucis longus tendon on the dorsal surfaces of the tarsal bones. Its pulse may be felt here (however, the vessel is minuscule in 10 to 15 percent of cases).

Upon reaching the proximal part of the 1st intermetatarsal space the dorsalis pedis artery changes its name to the **deep plantar artery** and dives ventrally between the first two metatarsals to reach the sole of the foot. This should remind you of the radial artery passing into the palm of the hand by passing through the proximal part of the 1st intermetacarpal space. Indeed, once in the sole, the deep plantar artery participates in formation of a deep plantar arch just as the radial artery helped to form a deep palmar arch.

No major vessels run in the lateral compartment of the leg. The muscles contained therein are supplied by branches of the anterior tibial and peroneal (see p. 580) arteries.

***Branches of the Anterior Tibial Artery***

Shortly after it arises, the anterior tibial artery gives off two recurrent branches that turn up toward the knee to participate in the genicular anastomosis.

The first is the **posterior tibial recurrent artery**, which comes off the anterior tibial before it crosses into the anterior compartment of the leg. The posterior tibial recurrent artery passes upward deep to the popliteus muscle toward the back of the knee. The second recurrent branch of the anterior tibial artery is called the **anterior tibial recurrent artery**. It is given off in the anterior compartment of the leg immediately after its parent vessel crosses above the upper edge of the interosseous membrane. The anterior tibial recurrent artery travels superiorly to join in the anastomosis on the front of the knee (see Fig. 12-26).

From the site of origin of its anterior tibial recurrent branch down to just above the ankle, the anterior tibial artery gives off only unnamed branches for muscles, nerves, and skin.

At the level of the ankle joint, as it is being crossed by the extensor hallucis longus, the anterior tibial artery gives off its two other named branches (see Fig. 12-33). One passes laterally toward the tissues around the distal fibula and is called the **lateral anterior malleolar artery**. A vessel directed medially toward the tissues around the medial malleolus is named the **medial anterior malleolar artery**.

***Branches of the Dorsalis Pedis Artery (see Fig. 12-33)***

Having crossed in front of the ankle joint and changed its name to dorsalis pedis, the artery gives off **lateral and medial tarsal branches** for the bones and ligaments of the tarsus, and, of course, for the muscles, tendons, and skin on the dorsum of the tarsus. At the level of the base of the second metatarsal, the dorsalis pedis gives rise to its **arcuate branch**. This branch is the foot's equivalent of the dorsal carpal arch. It passes toward the lateral side of the foot giving off **dorsal metatarsal arteries** that in turn

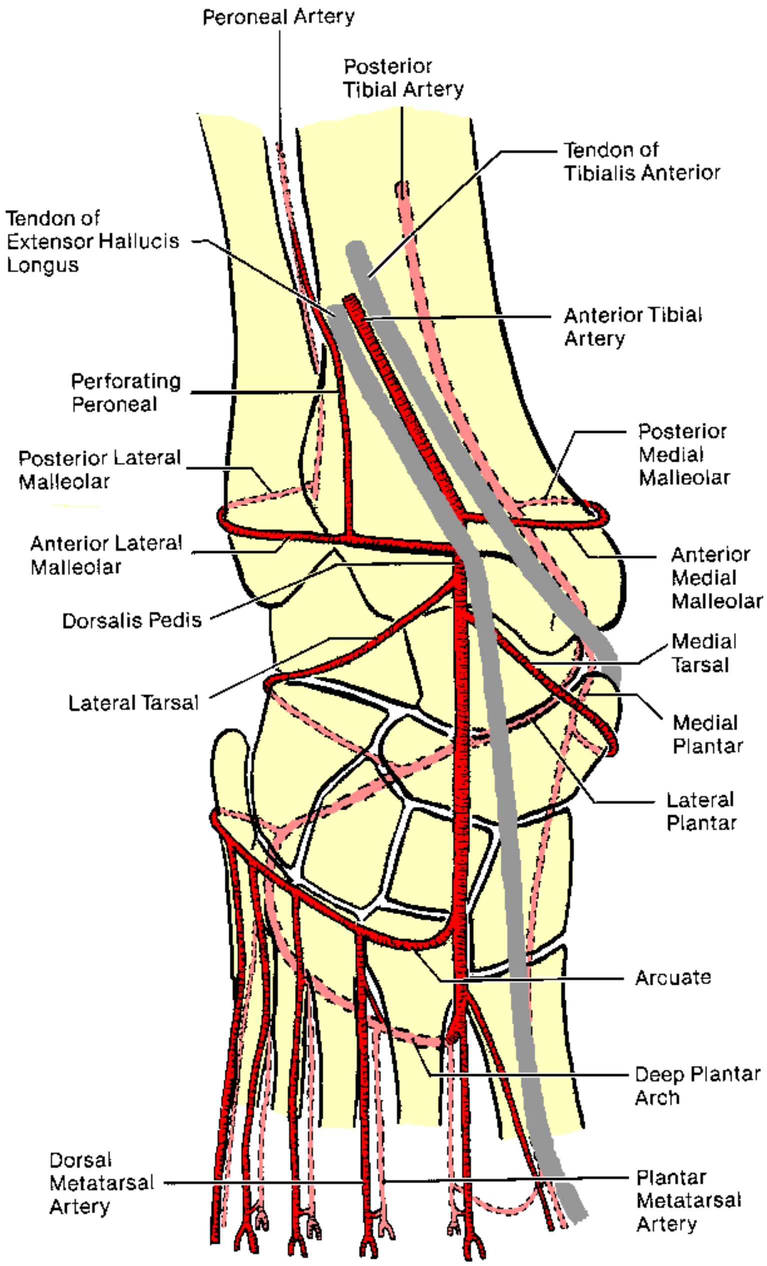


**Figure 12-33.** Arterial anastomoses around the ankle and foot (superior view of right side).

divide into **dorsal digital branches** for the toes. However, the first (largest and most medial) dorsal metatarsal artery arises from the dorsalis pedis directly, just beyond the origin of the arcuate branch. After this, the dorsalis pedis artery is known as the **deep plantar artery**. The dorsal metatarsal arteries are connected to the deep plantar arch by communicating channels in the same way that the dorsal metacarpal arteries were connected to the deep palmar arch.

Once in the sole of the foot, the deep plantar artery behaves as does the radial artery in the palm of the hand, i.e., it gives off branches to the hallux and 2nd toe, then participates in formation of a deep plantar arch from which emanate **plantar metatarsal arteries** that in turn give rise to **plantar digital arteries** for the toes. The plantar metatarsal and dorsal metatarsal arteries communicate in the webs between the toes just as palmar and dorsal metacarpal arteries communicated.

## NERVES OF THE ANTERIOR TIBIAL COMPARTMENT, LATERAL TIBIAL COMPARTMENT, AND DORSUM OF THE FOOT

As it crosses the neck of the fibula within the substance of peroneus longus, the common peroneal nerve trifurcates into a recurrent articular branch (for the knee and superior tibiofibular joints), the superficial peroneal nerve, and the deep peroneal nerve.

### Superficial Peroneal Nerve

The superficial peroneal nerve arises within the substance of the peroneus longus at the neck of the fibula. It passes toward the fibrous septum that separates the lateral and anterior compartments of the lower leg, and then descends next to this septum within the lateral compartment as far as the junction of its middle and lower thirds. Here the nerve enters the subcutaneous tissue to travel across the dorsum of the ankle into the foot. Sometimes, shortly before becoming subcutaneous, the superficial peroneal nerve pierces the lateral intermuscular septum to run a short course in the anterior tibial compartment.

As it runs in the intermuscular septum between the anterior and lateral compartments of the leg, the superficial peroneal nerve supplies the peroneus longus and peroneus brevis muscles. After the nerve becomes superficial it has a cutaneous distribution in the distal half of the leg comparable to that of the lateral sural cutaneous nerve in the proximal half (i.e., lateral aspect and lateral half of anterior aspect). Once in the foot, the superficial peroneal nerve innervates the skin of most of its dorsum and provides **dorsal digital nerves** to the medial 4 ½ (or 3 ½) toes, with the important exception that dorsal digital nerves for the adjacent sides of the 1st and 2nd toe are derived from the deep peroneal nerve.

### Deep Peroneal Nerve

Arising /within the substance of the peroneus longus muscle, the deep peroneal nerve continues the course of its parent across the lateral surface of the fibular neck to pierce the extensor digitorum longus and thereby gain entry to the anterior tibial compartment. It gives off a recurrent branch that innervates the upper fibers of tibialis anterior, the superior tibiofibular joint, and the knee joint. Then the deep peroneal nerve joins the anterior tibial artery in its descent through the anterior compartment on the anterior surface of the interosseous membrane sandwiched between the origins of tibialis anterior and the extrinsic digital extensors. It supplies the muscles of the anterior tibial compartment. At the ankle joint, where the nerve and artery are both crossed by the tendon of extensor hallucis longus, the nerve divides into lateral and medial branches. The **lateral branch** passes onto the deep surface of extensor digitorum brevis for its supply. The **medial branch** accompanies the dorsalis pedis artery and its first dorsal metatarsal branch to terminate in **dorsal digital nerves** to the adjacent sides of the big and $2^{nd}$ toes. Together the superficial and deep peroneal nerves have a cutaneous distribution in the foot that roughly parallels that of the superficial radial nerve in the hand.

**CLINICAL CONSIDERATIONS**

The common peroneal nerve is the most frequently injured nerve of the lower limb. Its portion of the sciatic is more likely to be damaged by errant intragluteal injections owing to the more lateral position of the common peroneal fibers within that giant nerve. However, most injury to the common peroneal nerve is linked to its close relation to the head and neck of the fibula. Fractures of the fibular neck may traumatize the nerve directly, or it may be entrapped in the callus that forms during healing. Peculiar postures, such as the lotus position of yoga, can cause the common peroneal nerve to be compressed against the neck of the fibula. Plaster casts, or the supports used to hold up the legs in the lithotomy position, can also compress the nerve.[75] Prolonged maintenance of the squatting position, such as employed during picking fruits or vegetables that grow close to the ground, can lead to compression of the common peroneal nerve against the fibula by the tight tendon of the biceps femoris. All these injuries yield motor symptoms of anterior tibial compartment paralysis, and often weakness of the peroneus longus and brevis as well.

The motor tests for the common peroneal nerve involve assessment of the strength of ankle dorsiflexion and toe extension (providing information about the deep peroneal branch) and of the strength of eversion (providing information about the superficial peroneal branch). Asking the patient to walk on his or her heels is another way to test adequacy of the dorsiflexors. The gait of a person with paralyzed anterior tibial muscles was described above.

The first sign that an anterior tibial syndrome is developing is malfunctioning of the deep peroneal nerve, revealed by tingling or diminished sensation in the dorsal web of skin between the first and second toes. Such sensation should be regularly assessed in any person having suspected buildup of pressure in the anterior tibial compartment

## THE SUPERFICIAL POSTERIOR COMPARTMENT OF THE (LOWER) LEG

The superficial posterior compartment of the leg contains only the triceps surae (gastrocnemius and soleus) and plantaris muscles. There are no major nerves or vessels that run in this compartment. Branches of the tibial arising in the popliteal fossa innervate the muscles. (The soleus also gets a branch from the tibial nerve after it has entered the deep posterior compartment.) They receive blood supply from the inferior genicular branches of the popliteal artery and lower down from the tibial and peroneal arteries.

### Triceps Surae - Gastrocnemius and Soleus

The triceps surae is composed of three muscular bellies all of which insert onto a common tendon (the **tendo calcaneus, or Achilles tendon**) that attaches to the calcaneal tuberosity. Two of the bellies are superficial and together comprise the **gastrocnemius** muscle. The deep belly is the **soleus**.

[75] Stewart JD. 1993 *Focal Peripheral Neuropathies*. Raven Press, NY.

***Gastrocnemius (Fig. 12-34; see Fig. 12-24)***

The gastrocnemius (innervated by the tibial nerve) is composed of medial and lateral heads with separate origins but a common tendon of insertion. Some fibers of the **medial head** arise from the popliteal surface of the femur immediately superior to the medial femoral condyle, and from the capsule of the knee joint below this. However, the bulk of the medial gastrocnemius muscle fibers come from the deep surface of a tendon that springs from the femur just behind the adductor tubercle and passes down into the calf for about one third of its length. Similarly, although some muscle fibers of the **lateral head** of gastrocnemius arise from the capsule of the knee over the back of the lateral femoral condyle, the great majority of fibers arise from the deep surface of a tendon that springs from the posterior surface of the upper part of the lateral epicondyle of the femur and then descends into the calf.[76]

The tendon of insertion of the gastrocnemius begins immediately below the knee joint as a septum between the two heads. The septum also spreads out onto the deep surfaces of the muscular heads. As the tendon of insertion continues down the calf, it receives muscle fibers that arise from progressively lower portions of the tendons of origin. By about midcalf the muscle fibers of the gastrocnemius have all given way to tendon.

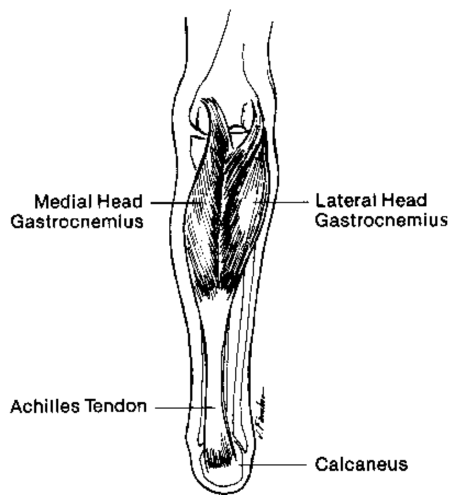


**Figure 12-34.** Posterior view of the right gastrocnemius. (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

***Soleus***

This muscle (innervated by the tibial nerve) arises from the posterior (flexor) surface of the proximal third of the fibula and (by tendinous fibers) from the lateral part of the soleal line of the tibia. Between the proximal extremes of the fibular and tibial origins spans a fibrous arch from which soleus muscle fibers also arise. Finally, descending from this arch is an aponeurosis from whose superficial surface many additional muscle fibers take origin.

Muscle fibers of the soleus descend through the calf and insert onto the deep surface of an aponeurosis that covers the back of the muscle for most of its length. At midcalf this aponeurosis merges with the overlying gastrocnemius tendon to form the **tendo calcaneus (Achilles tendon)** that inserts into

[76] Within the tendon of origin of the lateral head of gastrocnemius, near its femoral attachment, there often forms a sesamoid bone called the **fabella**. When it is present, there also occurs a fabellofibular ligament connecting it to the head of the fibula.

the calcaneal tuberosity. The lower soleus fibers extend to about three quarters or more the way down the calf and can be said to insert into the Achilles tendon.

The triceps surae is the major plantarflexor of the foot. Its gastrocnemial heads cross the knee and are able to flex it, but this potential has little to do with their recruitment in routine behaviors. The pull of the Achilles tendon in relation to the subtalar joint produces inversion. It is said that the soleus tends to invert the subtalar joint more so than does the gastrocnemius.

### Plantaris

The plantaris (innervated by the tibial nerve) is a very small muscle that arises from the popliteal surface of the femur immediately above the lateral condyle (see Fig. 12-24). The fibers pass downward and medially across the back of the knee adjacent to the medial edge of the lateral head of gastrocnemius. Just below the head of the tibia they give rise to a thin tendon that passes into the interval between gastrocnemius and soleus and continues downward and medially to emerge from this interval at about midcalf. From midcalf downward, the plantaris tendon runs alongside the medial edge of the Achilles tendon all the way to the calcaneal tuberosity, where they both insert. The plantaris is absent from 5 - 10% of the time.

The plantaris has the potential for flexing the knee, plantarflexing the ankle, and inverting the subtalar joint. Its small size suggests to many that any such actions are trivial. Some authors[77] believe that the plantaris may be more useful as a sensory organ, using its muscle spindles to register slight positional changes of the ankle and knee. Regardless, it is a clinically significant structure for two reasons. First, rupture of the plantaris tendon is a highly painful condition, and, second, its tendon may be removed to be used as a graft for repair of badly damaged tendons in the hand.

## MUSCLES OF THE DEEP POSTERIOR COMPARTMENT OF THE (LOWER) LEG - Popliteus, Flexor Digitorum Longus, Flexor Hallucis Longus, Tibialis Posterior

### Popliteus

The popliteus (innervated by the tibial nerve) arises from the back surface of the tibia superior to the soleal line (see Fig. 12-25). Its fibers pass upward and laterally, converging on a tendon that crosses the posterior surface of the lateral tibial condyle, and then pierces the capsule of the knee to follow an intracapsular course upward and laterally toward an insertion into a pit located on the side of the lateral femoral condyle below its epicondyle. During the intracapsular portion of its course the popliteal tendon at first crosses the posterolateral "corner" of the lateral meniscus and then, superior to it, lies between the synovial membrane and the capsule itself.

Everybody agrees that the popliteus can medially rotate the tibia. Of course, medial rotation of the tibia relative to the femur is equivalent to lateral rotation of the femur relative to the tibia, and one often reads that the muscle produces lateral rotation of the femur on the fixed tibial plateau. Some authors suggest that the popliteus can also flex the knee, but I am aware of no evidence that it is actually used to do so. Other authors claim that the popliteus has the ability to help the posterior cruciate ligament prevent anterior displacement of the femur on the tibial plateau, and they report on electromyographic

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[77] Peck, D, Buxton, DF, and Nitz, A: A comparison of spindle concentrations in large and small muscles acting in parallel combinations. J Morph 180:243-252, 1984.

studies supporting this view. However, my own electromyographic research indicates that recruitment of the popliteus can be explained solely on the basis of its rotatory action.

Why do we need a medial rotator of the tibia when the ligamentous apparatus of the knee joint is designed to permit almost no medial rotation? One possible answer is related to the "terminal locking" lateral tibial rotation (medial femoral rotation) that was described earlier. Some authors say that the knee cannot be brought out of complete extension unless it is "unlocked" by a contraction of the popliteus producing lateral rotation of the femur relative to the tibia. My own electromyographic studies on standing subjects asked to perform knee-bends showed that popliteus was used to “unlock” the knee at the beginning of the movement only when the individual was standing with a maximally extended knee. Many of my subjects stood comfortably without such extreme extension at the knee, and they did not use popliteus when dropping into a knee-bend. It is my belief that the primary *function* of popliteus is not to produce motion, be it lateral rotation of the femur relative to the tibia or medial rotation of the tibia relative to the femur. Rather, I think the muscle functions chiefly to prevent motion, specifically to prevent any tendency for the tibia to rotate laterally relative to the femur whenever powerful muscles that medially rotate the femur at the hip are called into action while the foot is planted on the ground. Such medial rotation at the hip cannot effectively produce forces on the ground unless the tendency of the femur to uselessly rotate on the tibial plateau is prevented. The popliteus contracts to stop this lateral rotation of the tibia relative to the femur, and thereby it enables effective transmission to the ground of medially rotatory torques applied to the femur.

## Flexor Digitorum Longus

This muscle (innervated by the tibial nerve) arises from the medial half of the posterior surface of the tibial shaft between the soleal line and a point about two thirds down the length of the bone. Its fibers give rise to a tendon that crosses the posterior surface of the distal tibia just lateral to the tibialis posterior. In that the flexor digitorum longus arises medial to the tibialis posterior, but its tendon leaves the leg lateral to the tendon of tibialis posterior, clearly the two muscles must cross in the lower part of the leg. Whichever muscle is more superficial at the point of crossing will tend to compress the deeper member against the back of the tibia. Thus, it makes sense to have the weaker muscle be the one to cross superficial to the stronger, and indeed this is the case--the flexor digitorum longus being weaker than the tibialis posterior and crossing superficial to it.

Once past the malleolus, the flexor digitorum longus tendon turns forward alongside the back edge of the tibialis posterior tendon. The flexor tendon crosses the medial surface of the sustentaculum tali and then turns into the sole of the foot, where it divides into four slips, one for each of the four lateral toes. The tendon slips of the flexor digitorum longus behave in the foot as do the tendons of flexor digitorum profundus in the hand.

## Flexor Hallucis Longus

The flexor hallucis longus (innervated by the tibial nerve) arises from the lower two thirds of the flexor surface of the fibula. You will recall that this surface twists from facing posteriorly to facing medially as it passes down the shaft (see Fig. 12-28). Some fibers also arise from the fascia on the posterior surface of the tibialis posterior and thus cover the lateral half of this muscle.

The tendon of flexor hallucis longus passes down onto the posterior surface of the distal tibia a centimeter or so lateral to the flexor digitorum longus tendon. The flexor hallucis longus tendon continues across the back of the ankle joint onto the medial part of the posterior surface of the talus, where a groove marks its location (see Fig. 12-30). Below the talus, the tendon of flexor hallucis longus turns forward inferior to the sustentaculum tali to reach the sole of the foot. Upon entering the sole, the tendon passes more or less straight forward to the big toe, inserting onto its distal phalanx, just as the flexor pollicis longus of the hand inserts onto the distal phalanx of the thumb.

In that the flexor hallucis longus tendon lies lateral to the flexor digitorum longus tendon as they cross the ankle, but the flexor hallucis then proceeds to the most medial of the toes, it is clear that the two tendons must cross prior to reaching their destinations. Again, logic suggests that the action of one muscle will interfere least with the action of the other if the weaker of the two muscles crosses superficial to the stronger. Indeed, flexor digitorum longus being the weaker, does cross superficial to the tendon of flexor hallucis longus as they enter the sole of the foot.

### Tibialis Posterior

The tibialis posterior (innervated by the tibial nerve) arises from the lateral half of the posterior surface of the tibial shaft between the soleal line and a point about two thirds down the length of the bone (see Fig. 12-28), from the medial surface of the fibular shaft in its upper two thirds, and from the back surface of the interosseous membrane stretching between these bony origins. The fibers give rise to a tendon that passes behind the medial malleolus of the tibia (where a groove marks its course--see Fig. 12-28) and then turns forward on the superficial surface of the deltoid ligament to reach the tuberosity of the navicular. Most fibers of the tendon insert here, but some continue to the proximal tuberosity of the medial cuneiform, while others fan out more widely to reach the plantar surfaces of other distal tarsal bones.

## FLEXOR RETINACULUM OF THE ANKLE

The flexor retinaculum of the ankle is a region of thickened deep fascia passing from the medial malleolus to the medial plantar process of the calcaneal tuberosity and, also, into the fascia deep to the Achilles tendon. It holds the tendons of the tibialis posterior, flexor digitorum longus, and flexor hallucis longus in position. These tendons are enveloped by synovial sheaths to enable their easy gliding beneath the retinaculum. The digital flexor tendons have additional synovial sheaths as they course through the osseofibrous tunnels deep to the fibrous digital flexor sheaths of the toes.

It was mentioned above that the tendons from muscles of the anterior tibial and lateral compartments of the lower leg are surrounded by **synovial sheaths** as they pass beneath the various retinacula that hold them in place. The same is true for the tendons of muscles of the deep posterior compartment of the lower leg.

## BLOOD VESSELS OF THE DEEP POSTERIOR COMPARTMENT OF THE (LOWER) LEG

It was mentioned above that the popliteal artery crosses onto the posterior surface of the popliteus and at that muscle's inferior edge terminates by dividing into two branches. Anatomists call these terminal branches by the names "anterior tibial" and "posterior tibial" arteries. We further say that soon after its origin, the posterior tibial artery gives off a large branch called the peroneal artery, then continues on its merry way. Clinicians use a somewhat different nomenclature for the terminal branches of the popliteal artery. They say that the popliteal artery ends by bifurcating into an anterior tibial artery and a short "tibioperoneal trunk", the latter of which soon splits into posterior tibial and peroneal arteries. I prefer the clinical terminology. (It goes without saying that all the arteries I am about to describe have vena comitantes.)

## Tibioperoneal Trunk

The tibioperoneal trunk is essentially the downward continuation of the popliteal artery. It passes beneath the fibrous arch of the soleus origin and attains the posterior surface of the tibialis posterior deep to soleus. Almost immediately upon contacting the tibialis posterior the artery bifurcates into two branches. They diverge a little and then descend parallel to one another through the calf. The more medial of the two branches is the posterior tibial; the other is called the peroneal artery.

### ***Posterior Tibial Artery***

The posterior tibial artery passes down the calf on the posterior surface of the tibialis posterior (deep to the soleus) and between the lateral edge of the flexor digitorum longus and medial edge of flexor hallucis longus. The vessel stays in the interval between flexor digitorum longus and flexor hallucis longus as their tendons form, as these tendons pass behind the ankle, and then as they turn forward deep to the flexor retinaculum. While deep to flexor retinaculum the posterior tibial artery bifurcates into its two terminal branches--the **lateral and medial plantar arteries**, which enter the sole of the foot.

**Branches of the Posterior Tibial Artery in the Lower Leg.**.The posterior tibial artery gives off unnamed branches to muscles, nerves and skin. It also supplies the nutrient artery to the tibia and sends one or two twigs laterally to communicate with the peroneal artery. Just above the ankle joint it gives off a **posterior medial malleolar artery** that communicates with the anterior medial malleolar branch of the anterior tibial artery (see Fig. 12-33).

### ***Peroneal Artery***

The peroneal artery arises from the posterior tibial artery just as the latter vessel passes onto the posterior surface of the tibialis posterior deep to the fibrous arch of the soleus. The peroneal artery gradually deviates to the lateral side, passing deep to the flexor hallucis longus to contact the fibula. With this relationship, the vessel runs down the leg to terminate in the tissues of the lateral heel.

**Branches of the Peroneal Artery.** The peroneal artery gives off unnamed branches to muscles, nerves, and skin. It also supplies the nutrient artery to the fibula. While behind the tibiofibular syndesmosis, it gives rise to a **posterior lateral malleolar branch** that anastomoses with the anterior lateral malleolar branch of the anterior tibial artery (see Fig. 12-33).

One of the most important branches of the peroneal artery arises a short distance above the ankle and pierces the lower end of the interosseous membrane to reach the anterior tibial compartment. Here it anastomoses with the anterior lateral malleolar branch of the anterior tibial artery (see Fig. 12-33). This so-called **perforating peroneal artery** is often very large and by appropriating the stem of the anterior lateral malleolar artery can take over completely the supply of blood to the dorsalis pedis. In such cases the anterior tibial artery gets progressively smaller as it passes down the leg, ending in a tiny anterior medial malleolar branch.

## NERVES OF THE DEEP POSTERIOR COMPARTMENT OF THE (LOWER) LEG

It will be recalled that **tibial nerve** arises from the sciatic nerve at the superior apex of the popliteal fossa and descends through this fossa lying superficial to the popliteal vessels. At the inferior apex of the popliteal fossa the tibial nerve, popliteal vein, and popliteal artery dive deep to the gastrocnemius and onto the posterior surface of the popliteus. We have learned that the popliteal artery ends at the lower border of the popliteus by dividing into an anterior tibial artery and a tibioperoneal trunk. The tibial nerve stays with the tibioperoneal trunk and together they pass deep to the soleus. When the arterial trunk divides into its posterior tibial and peroneal branches, the tibial nerve stays with the former. Together the tibial nerve and posterior tibial vessels pass onto the posterior surface of the tibialis posterior, and then travel down the calf on this muscle's posterior surface, interposed between the flexor digitorum longus and flexor hallucis longus. The nerve and vessels eventually pass behind the distal tibia between the tendons of these flexor muscles (the nerve being lateral to the artery), and then course deep to the flexor retinaculum, where the nerve (as does the artery) terminate by dividing into **medial and lateral plantar branches** that enter the sole of the foot.

While in the popliteal fossa, the tibial nerve gives off a **medial sural cutaneous nerve** and muscular branches to the two heads of gastrocnemius, the plantaris, the soleus, and the popliteus. In its course down the leg deep to the soleus, additional branches are sent to the soleus and to the muscles of the deep posterior compartment. Naturally, the tibial nerve supplies vessels, bones, and ligaments. Just before passing deep to the flexor retinaculum, it gives cutaneous branches to the heel.

## MUSCLES OF THE SOLE OF THE FOOT

The foot contains a set of intrinsic muscles that more or less correspond to those found in the hand. Of course we know that the developmentally dorsal extensor digitorum brevis has no normal counterpart in the hand, but also there are some differences between the foot and hand regarding the plantar (i.e., developmentally ventral) muscles:

1. The muscle in the lower limb that corresponds to the flexor digitorum superficialis of the forearm lies not in the leg, but in the foot, where it is called flexor digitorum brevis.

2. There is one muscle in the foot - the quadratus plantae (flexor accessorius) - that has no counterpart anywhere in the upper limb.

3. Unlike the thumb, the big toe has no opponens muscle.

4. Whereas the palmar and dorsal interossei of the hand are organized to produce adduction toward or abduction away from the 3$^{rd}$ digit, the corresponding muscles of the foot are organized to produce adduction toward or abduction away from 2$^{nd}$ toe; thus, the 2$^{nd}$ toe has two dorsal and no plantar interossei, the 3$^{rd}$ and 4$^{th}$ toes each have one dorsal and one plantar interosseous, and the 5$^{th}$ toe has only a plantar interosseous.

The intrinsic muscles of the sole of the foot lie in three fascial compartments. One compartment corresponds to the thenar eminence of hand and contains abductor hallucis and flexor hallucis brevis. Another corresponds to the hypothenar eminence of the hand and contains abductor digiti quinti, flexor digiti quinti brevis and, occasionally, an opponens digiti quinti. The central compartment lies between these two peripheral compartments and is said to be organized into four layers from superficial to deep. The most superficial (i.e., first) layer contains the flexor digitorum brevis; the second contains the quadratus plantae and lumbricals; the third contains the adductor hallucis; and the deepest contains the pedal interossei.

## Muscles of the Medial Compartment of the Sole of the Foot - Abductor Hallucis and Flexor Hallucis Brevis

### *Abductor Hallucis*

This muscle (innervated by the medial plantar nerve) arises from the medial edge of the medial plantar process of the calcaneal tuberosity (see Fig. 12-31) and from the flexor retinaculum that attaches to it. The muscle fibers travel distally along the medial edge of the sole. About halfway through the foot they give rise to a stout tendon that inserts onto the medial aspect of the base of the proximal phalanx of the big toe. Abductor hallucis abducts and also slightly flexes the big toe at its MP joint. However, this action would not seem to be important compared with the ability of the abductor hallucis to help sustain the medial part of the longitudinal arch during locomotion.

### *Flexor Hallucis Brevis*

This muscle (innervated by the medial plantar nerve) has an origin predominantly from the ventral surface of the medial cuneiform but also spreading out onto nearby ligaments and tendons. The muscle is comprised of two heads, corresponding to the deep and superficial heads of the flexor pollicis brevis. It will be recalled that the heads of the flexor pollicis brevis received their names from their relationship to the flexor pollicis longus tendon. The heads of the flexor hallucis brevis are named according to their relationship to the flexor hallucis longus tendon. From what is essentially a contiguous area of origin deep to this tendon, the two heads diverge slightly so that one parallels the medial edge of the flexor hallucis longus tendon and the other parallels its lateral edge. Thus, the heads are named medial and lateral according to their relationship to this tendon. The **medial head** of the flexor hallucis brevis gives rise to a tendon that inserts partly into the medial sesamoid of the hallucal MP joint and partly with the abductor hallucis tendon. The **lateral head** gives rise to a tendon that inserts partly into the lateral sesamoid of the hallucal MP joint and partly with the adductor hallucis into the lateral aspect of the base of the proximal phalanx of the big toe.

The flexor hallucis brevis acts to flex the MP joint of the hallux. It would seem that the muscle crosses too few joints to play any role in arch support during locomotion.

## Muscles of the Lateral Compartment of the Sole of the Foot - Abductor Digiti Quinti, Flexor Digiti Quinti Brevis, and the Occasionally Present Opponens Digiti Quinti

### *Abductor Digiti Quinti*

This muscle (innervated by the lateral plantar nerve) arises from the lateral edge of *medial* plantar process of the calcaneal tuberosity and from the entire edge of its lateral plantar process. The muscle fibers run along the lateral margin of the sole of the foot, giving rise to a tendon that inserts into the lateral aspect of the base of the proximal phalanx of the little toe. Occasionally, the most laterally arising fibers are "interrupted" by the tuberosity of the 5th metatarsal as they "attempt" to pass by it. In such cases the muscle has some fibers that run from the calcaneus to 5th metatarsal and other fibers that run from 5th metatarsal to the proximal phalanx.

The abductor digit quinti does indeed abduct the little toe. However, it probably has a more significant role in maintaining tarsal stability during locomotion.

*Flexor Digiti Quinti Brevis*

This muscle (innervated by the lateral plantar nerve) arises from the ventral aspect of the base of the 5th metatarsal and also a little from the termination of the long plantar ligament. The fibers pass distally, giving rise to a tendon that inserts into the inferolateral aspect of the base of the proximal phalanx of the little toe. One may deduce that the action of this muscle is to flex the little toe at the MP joint.

*Opponens Digiti Quinti*

Occasionally there exists a muscle arising from the termination of the long plantar ligament and coursing deep to flexor digiti quinti brevis to gain an insertion along the plantarlateral aspect of the 5th metatarsal shaft. This is an opponens digiti quinti, and your guess is as good as mine concerning its action. When present, it is innervated by the lateral plantar nerve.

## Muscles of the Central Compartment of the Sole of the Foot - Flexor Digitorum Brevis, Quadratus Plantae (Flexor Accessorius), Lumbricals, Adductor Hallucis, Interossei

*Layer 1 - Flexor Digitorum Brevis*

This muscle (innervated by the medial plantar nerve) lies immediately deep to the plantar aponeurosis. Its fibers arise from the anterior and medial edges of the medial plantar process of the calcaneal tuberosity (see Fig. 12-31), and from the deep surface of the plantar aponeurosis. The muscle fibers pass forward, superficial to the tendon of flexor digitorum longus, to about midsole, where they diverge into four bundles, each of which very soon gives way to a tendon that passes to one of the four lateral toes. Each tendon of flexor digitorum brevis insert on the middle phalanx of a toe in a manner similar to the insertion of flexor digitorum superficialis into the middle phalanx of a finger. While obviously acting to flex the toes at the MP and proximal IP joints, the flexor digitorum brevis is equally well suited to support the longitudinal arch during locomotion.

*Layer 2 - Quadratus Plantae (Flexor Accessorius) and Lumbricals*

The quadratus plantae (innervated by the lateral plantar nerve) is a muscle of the foot that has no counterpart anywhere in the upper limb. It has two heads of origin that merge into a single belly with a common insertion. The very much larger **medial head** arises fleshily from a depressed area on the medial surface of the calcaneus between the calcaneal tuberosity and the sustentaculum. These fibers pass forward, deep to flexor digitorum brevis, and are joined on their lateral edge by a much smaller **lateral head** that arises tendinously from the lateral surface of the calcaneus. All the fibers of quadratus plantae insert into the tendon of flexor digitorum longus as it is fanning out into its four slips to the lateral four toes.

The quadratus plantae and the distal part of the flexor digitorum longus tendon form a second *functional* short flexor of the toes. By that I mean that a second toe flexor capable of operating independent of ankle position is created. Quadratus plantae and flexor digitorum brevis always act together. It seems that they are the muscles called upon first to flex the toes, and are particularly important when plantarflexion of the ankle causes the flexor digitorum longus to operate in an undesirable portion of its length tension curve.

There are four **lumbricals** in the foot, just as there were four lumbricals in the hand. The 1st pedal lumbrical is innervated by the medial plantar nerve; the remaining lumbricals are innervated by the lateral plantar nerve. The pedal lumbricals arise from the four slips of the flexor digitorum longus tendon. Each muscle passes distally, crossing the plantar surface of a deep metatarsal ligament along the medial (pre-axial) side of its corresponding MP joint. Some authors state that the pedal lumbricals insert into the extensor aponeurosis, as do the lumbricals of the hand. Other authors claim that the primary insertion of each pedal lumbrical is into the medial side of the proximal phalanx. Possibly there is interindividual variation in this regard.

The function of the pedal lumbricals is unknown, although if they insert as do their counterparts in the hand, they may have a similar role in digital extension. It has been suggested (F. Bojsen-Møller, personal communication) that the pedal lumbricals are sensory proprioceptive organs.

***Layer 3 - Adductor Hallucis***

Just as an adductor pollicis with transverse and oblique heads is found deeply in the palm, an adductor hallucis with oblique and transverse heads is found deeply in the sole of the foot. It is innervated by the lateral plantar nerve.

The **oblique head** of the adductor hallucis is very much larger than the transverse head. The former arises from the bones and ligaments on either side of the 2nd-4th tarsometatarsal joints. The fibers pass distally, lying lateral and adjacent to the lateral head of flexor hallucis brevis. They give rise to a tendon that inserts onto the lateral aspect of the base of the proximal phalanx of the hallux. The **transverse head** arises from ventral aspect of the capsules of the 3rd and 4th MP joints and from the bands of the deep transverse metacarpal ligament attaching to these capsules. The fibers pass straight medially, converging on the tendon of the oblique head. Generally, a considerable gap separates the oblique and transverse heads, except near their insertion.

I presume that the adductor hallucis has the action that its name suggests. I have no idea about its function.

***Layer 4 - Plantar and Dorsal Interossei of the Foot***

I have already mentioned how there are three plantar interossei, one each to adduct the 3rd, 4th, and 5th toes toward the 2nd toe. The origin of a plantar interosseous is from the metatarsal of the toe it adducts. There are four dorsal interossei, one to medially abduct the 2nd toe, one to laterally abduct the 2nd toe, one to abduct the 3rd toe, and one to abduct the 4th toe. The bellies of the dorsal interossei fill the intermetatarsal spaces. They arise from adjacent surfaces of the metatarsals that border these spaces (except for the 1st dorsal interosseous, which only occasionally has an origin from the 1st metatarsal). All the pedal interossei are innervated by the lateral plantar nerve.

The main structural difference between pedal interossei and manual interossei is that all the pedal interossei have insertions into the bases of proximal phalanges. It is said that any contribution to the extensor aponeurosis of the toes is trivial. Although some persons can abduct and adduct their toes, the actual function of the pedal interossei is anyone's guess.

## BLOOD VESSELS OF THE SOLE OF THE FOOT

Deep to the flexor retinaculum of the ankle the posterior tibial artery divides into its two terminal branches - the lateral and medial plantar arteries. These are accompanied by vena comitantes.

### Medial Plantar Artery

The medial plantar artery passes toward the first toe along the lateral edge of the "hallucal eminence" muscles (i.e., abductor hallucis and flexor hallucis brevis) (see Fig. 12-33). Mostly it expends itself in supply of deep tissues along the medial side of the sole. However, it may give off a superficial branch that passes into the plane deep to the plantar aponeurosis, where it forms a partial superficial plantar arch supplying common plantar digital arteries that end by joining the plantar metatarsal arteries in the web of skin between the toes.

### Lateral Plantar Artery

The lateral plantar artery is the larger of the two terminal branches of the posterior tibial artery. It enters the sole by passing deep to abductor hallucis. Once in the sole, the lateral plantar artery passes obliquely toward the base of the 5th metatarsal (see Fig. 12-33). This course takes it parallel, but posterior, to the tendon of flexor digitorum longus, interposed between the first and second layers of the central compartment, i.e., sandwiched between flexor digitorum brevis and quadratus plantae. Upon reaching a point medial to the 5th metatarsal base, the vessel behaves as the foot's equivalent of the deep branch of the ulnar artery, giving off a proper digital branch to the lateral side of the little toe and then turning medially across the metatarsals at the junction of their bases and shafts to join the deep plantar artery (a branch of the dorsalis pedis) in formation of the **deep plantar arch** (see Fig. 12-33).

## ANASTOMOSES ABOUT THE ANKLE AND FOOT (see Fig. 12-33)

The anastomoses between anterior tibial, posterior tibial, and peroneal arteries around the ankle and foot are fairly extensive. They are illustrated in Fig. 12-33.

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Although the anastomoses about the ankle and foot do not have the same capacity as those of the wrist and hand, they will suffice to sustain tissue life in slow occlusive disease of the anterior tibial, posterior tibial, or peroneal arteries.

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## NERVES OF THE SOLE OF THE FOOT

Deep to the flexor retinaculum of the ankle the tibial nerve divides into its two terminal branches - the lateral and medial plantar nerves.

### Medial Plantar Nerve

The medial plantar nerve follows the medial plantar artery into the sole of the foot. There the vessel and nerve run distally along the lateral edge of the "hallucal eminence" muscles. The role of the medial plantar nerve in the foot resembles that of the median nerve in the hand. It supplies the hallucal eminence muscles and the 1st lumbrical. It also gives off cutaneous branches to the medial side of the sole and sends **plantar digital nerves** to the medial 3 ½ toes. The only differences between the medial plantar nerve in the foot and the median nerve in the hand are that (1) the medial plantar nerve is also the source of supply to the flexor digitorum brevis, whereas the corresponding muscle of the upper limb lies in the forearm and receives its branches from the median nerve in the forearm; (2) the medial plantar nerve innervates only the 1st pedal lumbrical, whereas the median nerve innervates two manual lumbricals; and (3) the medial plantar nerve usually innervates both heads of flexor hallucis brevis, whereas the median nerve usually innervates only the superficial head of flexor pollicis brevis.

## Lateral Plantar Nerve

The lateral plantar nerve follows the lateral plantar artery into the sole of the foot, where both vessel and nerve run toward the base of the fifth metatarsal by passing in the interval between the first and second layers of the central compartment. Upon reaching a site medial to the 5th metatarsal base, both the vessel and nerve dive deeply and curve back toward the medial side of the foot on the plantar surface of the interosseous muscles.

The lateral plantar nerve performs a function in the foot corresponding to the ulnar nerve of the hand. It innervates the "hypohallucal eminence" muscles, some lumbricals, the interossei, and the adductor hallucis. It also supplies the skin of the lateral sole and sends **plantar digital nerves** to the lateral 1 ½ toes. Its supply of the 2nd lumbrical and its failure to supply the lateral head of the flexor hallucis brevis represent differences (albeit trivial) between what the lateral plantar nerve actually does and what we would have predicted on the basis of our knowledge of the ulnar nerve. Additionally, the lateral plantar nerve innervates quadratus plantae, a muscle that has no counterpart in the hand.

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**CLINICAL CONSIDERATIONS**

The tibial nerve may be injured by wounds to the popliteal fossa or back of the leg , fractures at the knee, or dislocations of the knee. It can be compressed by a Baker's cyst[78], which is a fluid-filled pouch derived either from one of the bursae at the back of the knee or from an outpocketing of synovial membrane through the posterior capsule of the joint. Whatever the cause, damage to the tibial nerve in the popliteal fossa leads to symptoms dominated by paralysis of the triceps surae. Inversion of the foot and toe flexion are also lost. One tests for damage to the tibial nerve by assessing the patient's strength of ankle plantarflexion, foot inversion, and toe flexion. Asking the patient to walk on the toes is another good test for the strength of the triceps surae. Some physicians ask the patient to spread the toes apart in an attempt to assess the intrinsic muscles of the foot, however, many of us healthy persons cannot perform this maneuver. The gait of a person with a paralyzed triceps surae was described above.

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[78] Stewart JD. 1993 *Focal Peripheral Neuropathies*. Raven Press, NY.

## MAINTENANCE OF BIPEDAL POSTURE

Humans are constructed so as to be able to stand upright with very little need of muscular effort to prevent the joints of the lower limb from collapsing.

When standing upright, it is necessary that the trunk (to which the head and upper limbs are attached) be balanced on the femoral heads so that it neither falls forward into flexion nor backward into hyperextension. With the upper limbs comfortably at the side, the center of gravity of that portion of the body above the hip joints lies just in front of the 11th thoracic vertebra. A line dropped down from this point coincides with the vector pull of gravity. Such a "line of gravity" passes slightly behind the center of the hip joint, resulting in a minimal tendency for the trunk to fall backward into hyperextension. This is resisted by the iliofemoral ligament and by slight activity in the iliopsoas muscle.

The line of gravity for that portion of the body above the knees passes slightly in front of these joints, with the result that there is a tendency for the knees to be hyperextended during quiet upright posture. This is resisted by tension in all the ligaments (especially the anterior cruciate) and the posterior capsule of the knee.

The line of gravity for that portion of the body above the ankles passes a goodly distance in front of these joints. Therefore, the ankles tend to collapse into dorsiflexion. There are no ligaments that can prevent this. Thus, all persons must recruit a plantarflexor to maintain balance at the ankle. The soleus is the muscle of choice because it is composed primarily of slow twitch fibers that can maintain a constant force with little energy consumption. There are reports that some persons also use the gastrocnemius muscles during quiet standing. It is conceivable that these persons need muscular assistance to prevent hyperextension at the knee and that the gastrocnemius can, so to speak, kill two birds with one stone.

The arch of the foot, which tends to flatten under the weight of the body, requires no muscles for its maintenance during simple standing. In fact, because ligaments alone fulfill this role (see pp. 601-603), prolonged periods of standing are more threatening to the integrity of the arch than is locomotion.

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Overweight persons who must stand at their jobs for long periods may eventually stretch the spring ligament to such a degree that the longitudinal arch "collapses." In these persons, intrinsic plantar muscles will be recruited to compensate for a deficient ligamentous support. Such muscles, being unaccustomed to continuous activity, become fatigued. Their fatigue leads to the pain of flat foot. The easiest symptomatic remedy is to place pads in the shoes that provide external support to the arch, and thereby allow the muscles to relax.

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## USE OF LOWER LIMB MUSCLES IN WALKING

Because the upper limb is a manipulative appendage, the function of an upper limb muscle is often the same as its action. However, free movements of the lower limb are not nearly so important as its use in bipedal locomotion. Walking is a very low-cost mode of progression in which kinetic and potential energies are exchanged and muscles function more to control the effects of gravity and momentum than to propel the body forward. Such control is exerted by a muscle's ability to resist lengthening. Thus, the function of a lower limb muscle in walking will not be the same as its defined action.

Let us now consider the function of each muscle during walking and, where easily described, the consequences for gait when that muscle is paralyzed. The step cycle is broken down into a period of **support**, during which the relevant limb is in contact with the ground, and a period of **swing**, when that limb is being brought forward again (Fig. 12-35). Support phase begins with heel-strike and ends with toe-off. Swing phase begins with toe-off and ends with heel-strike. Figure 12-36 is a highly diagrammatic representation of when various lower limb muscles act during walking (based on my own studies and those reported in Basmajian[79]).

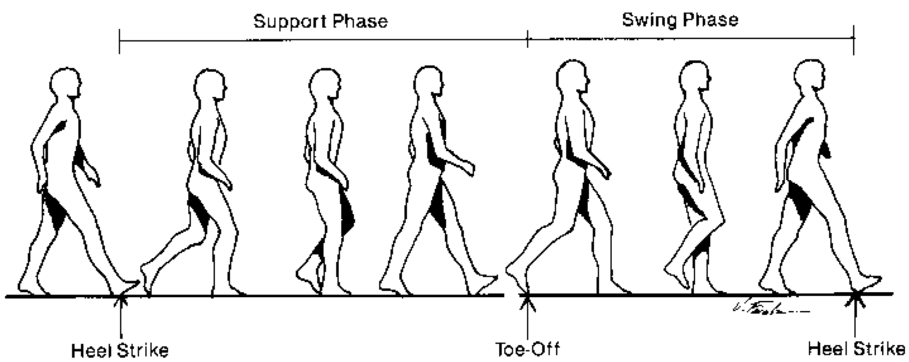


**Figure 12-35.** Gait cycle of right lower limb. (Modified from Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

## Lesser Gluteal Muscles

The gluteus medius and minimus are used during most of support phase. Their common primary function is to prevent the ipsilateral hip from collapsing into adduction when the contralateral limb is off the ground. Such a collapse tends to occur as gravity pulls down on the trunk that is now supported only on one side (see Fig. 12-21).

If the lesser gluteal muscles of one side (e.g., the right) are paralyzed, or if they are prevented from effective function by dislocation of the hip, the subject exhibits a very characteristic gait. When the good limb (in our example, the left) enters its swing phase, its side of the pelvis drops because the right lesser gluteal muscles cannot hold the pelvis level. Such a drop of the pelvis on the left side would ordinarily shift the entire trunk toward the left, with the result that the body's center of gravity is no longer over the supporting right foot. This is intolerable, for the person would then tend to fall over to his or her left side. In order to prevent this fall, our patient will laterally flex the lumbar spine toward the right, once again bringing the center of gravity of the trunk over the right foot. This manner of walking, involving drop of the contralateral hip and lateral flexion of the trunk toward the paralyzed side, is called a **Trendelenburg gait**.

[79] Basmajian, JV: Muscles Alive, ed 5. Williams & Wilkins, Baltimore, 1985.

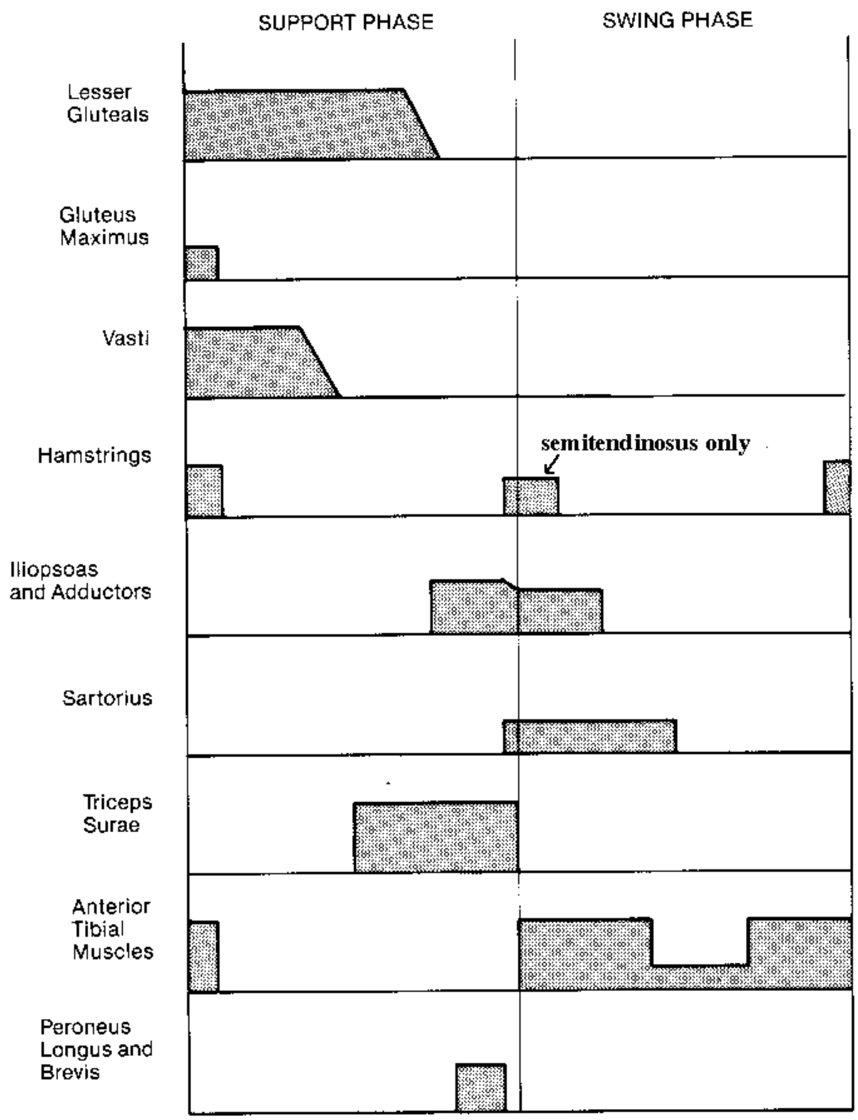


**Figure 12-36.** Schematic representation of muscle activity patterns during bipedal walking. Shaded areas indicate periods of time when a muscle group is active. The height of any such area represents relative amplitude of muscle activity. See text for further discussion.

## Gluteus Maximus

This muscle is used very little during walking, there occurring only a short burst of activity beginning near heel-strike. It has been suggested that the gluteus maximus is used then to resist the tendency of the trunk to collapse forward into flexion at the hip. Such a tendency arises owing to the forward momentum of the trunk at the moment that heel strike applies a braking force to the acetabulum.

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Some authors report no effect on gait of a paralyzed gluteus maximus. Others state that the patient tends to lean backward at the moment of heel-strike so as to use gravity to counteract the tendency of the trunk to "jack-knife" forward. Activities such as rising from the seated position, or climbing stairs, are far more seriously impaired by gluteus maximus paralysis than is walking.

## Vasti

During normal walking, the knee is slightly flexed at the moment of heel-strike and yields a bit more as weight is transferred completely to the supporting limb. The vasti act during this early part of support to prevent the knee from collapsing into complete flexion. Later in the support phase, the forward momentum of the body tends to carry the thigh and trunk over the knee, i.e., tends to extend the knee, thus eliminating the need for muscular effort by the vasti.

Persons with paralyzed vasti find it impossible to land normally with the supporting limb because they cannot prevent it from collapsing into flexion at the knee. Instead, they modify the swing phase to allow the forward momentum of the lower leg to carry the knee into complete extension just before heel-strike, and then they subtly lean forward at heel-strike so that their center of gravity stays in front of the knee throughout support phase. Thus, the knee is completely extended throughout support phase and is kept that way by gravity. If this compensation is inadequate, the patient may need to use a hand applied to the front of the thigh to force the knee into extension at heel-strike.

## Hamstrings

The hamstrings act from just before heel-strike to shortly thereafter, presumably to slow-down the swinging limb and then, like gluteus maximus, to prevent the forward momentum of the trunk from causing it to jack-knife at the hip. Semitendinosus has an additional activity at toe-off in order to flex the knee at the beginning of swing phase. In this instance, we have a case of a muscle doing something useful by actually shortening.

Paralysis of the hamstrings forces the patient to lean backward at the moment of heel-strike so as to use gravity to counteract the tendency of the trunk to "jack-knife" forward.

## Iliopsoas and Adductors

These muscles act in the latter part of support phase and in the early part of swing phase. During the last part of support phase they are regulating the extension of the hip that arises because the ground exerts a force on the limb that passes behind the joint. The iliopsoas and adductors may also be contributing to genuine adduction of the hip that occurs near the end of support phase. These muscles continue to act through toe-off into early swing phase by shortening to produce the flexion of the hip needed to bring the swinging limb forward.

I have never seen persons with paralyses of these muscles. I found only one reference that describes their gaits[80]. It says that paralysis of the iliopsoas makes walking virtually impossible because the limb cannot be brought forward in swing phase. On the other hand, paralysis of the adductors seems to have a much less deleterious effect of walking than one might imagine. Apparently the major problem is that flexion of the hip early in swing phase is accompanied by a certain degree of abduction.

### Sartorius

Sartorius is used at toe-off and well into swing phase to flex the hip and knee. This is another case of a muscle actually doing its job by shortening.

### Triceps Surae

This muscle is used during the latter half of support phase to control the tendency of the ankle to collapse into dorsiflexion. Such a tendency arises due to the fact that the center of gravity of the body above the ankle is passing progressively further in front of that joint.

Persons with a paralyzed triceps surae find it impossible to have a normal second half of support phase. They may choose to take short steps, leaning back on their heels, so that the body is not allowed to pass forward over the ankle until the opposite limb is ready to touch down. Or they may walk very toed-out, so that the latter half of support phase entails not an increasing tendency of the ankle to dorsiflex but rather an increasing tendency for the foot to invert. This tendency to inversion can be resisted by the intact peroneus longus and brevis.

### Muscles of the Anterior Tibial Compartment

All the anterior tibial muscles act at the same time during walking. They function as dorsiflexors, at first to lift the forefoot from the ground at toe-off and in early swing phase, then to dorsiflex the foot so that the heel strikes the ground first and the forefoot does not slap down following heel-strike. The inverting effect of the tibialis anterior is balanced by the everting effects of the extensor digitorum longus and the uniquely human peroneus tertius.

When there is a paralysis of the anterior tibial muscles, the patient must compensate in two ways. First, since the ankle cannot be actively dorsiflexed but the requirement still

[80] Gowers, WR: A Manual of Diseases of the Nervous System, ed 2. 1893. Reprinted by Hafner Publ, Darien, CT, 1970.

exists for the forefoot to clear the ground during swing phase, it must be lifted by excessive flexion at the hip and knee. This produces the so-called **"high-stepping" gait**. Second, since the foot cannot be actively dorsiflexed, normal landing on the heel is impossible. When walking slowly, the patient will land on the front part of a foot that cannot be dorsiflexed. During quick walking, the longer stride enables landing on the heel even though the foot is not dorsiflexed, but following heel-strike the front part of the foot slaps down onto the ground.

**ANTERIOR TIBIAL SYNDROME**

I am sure we are all aware that muscles become swollen and tender after an unaccustomed period of strenuous use. Normally, a few days' rest resolves these symptoms. However, swelling of the anterior tibial muscles is potentially a more serious problem because the deep fascia bridging between the tibia and fibula anterior to these muscles is very thick and unyielding. When the anterior tibial muscles are overused, as might occur during a long walk by an otherwise sedentary person, the resulting swelling will lead to an increase in pressure with the anterior compartment of the leg. Not only is this painful, but the pressure may rise high enough to compress the veins and capillaries in the compartment. If this happens, the diminished capillary flow results in ischemia of the contained structures. Nerves are most sensitive to such ischemia, and the first sign that compartmental pressure has reached dangerous levels is tingling or diminished sensation in the areas of skin supplied by intracompartmental nerves. The compartmental ischemia leads to muscle damage and further swelling, so that the pressure buildup becomes increasingly worse. If untreated, all the compartmental contents may die. Muscles killed in this way become fibrotic and shortened. Not only are they nonfunctional, but the shortening results in deformities. Obviously, one wishes to diagnose what is happening before the cycle of damage has progressed this far.

The ever-worsening condition produced by increased pressure within the anterior tibial compartment is called **anterior tibial syndrome**. What was described above is an exertional variety of this syndrome, but the same cascade of events may arise following trauma (like a broken bone) that causes bleeding into the compartment. A third cause of compartment syndrome is reperfusion injury. When a structure is deprived of blood, the capillaries become more permeable. If blood flow is suddenly restored, the reperfused structure will swell. One must be on the lookout for reperfusion compartment syndromes of the leg following surgical procedures that improve circulation, or those that restrict circulation during the procedure itself.

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## Peroneus Brevis and Longus

These muscles act together near the end of support phase, when the weight is being transferred onto the ball of the big toe. Apparently they resist the tendency of force applied to the ball of the big toe by the ground to invert the foot. It has also been suggested that the everting action of the peroneal muscles on the forefoot and the inverting action of the triceps surae on the hindfoot act together to lock the transverse tarsal joint in a position of great stability.

### Intrinsic Plantar Muscles[81]

Activity of the flexor digitorum brevis and quadratus plantae is confined to the very end of support phase, from the moment when the heel is lifted off the ground nearly to toe-off. It has not been determined if this activity reflects a role in assisting the plantar aponeurosis to support the longitudinal arch, or merely controls the rate of MP joint extension that occurs at this time.

Abductor hallucis and abductor digiti quinti are used during the support phase of walking, but there is great variation in the precise timing and degree of activity from step to step and among different individuals. There is some indication that the two abductors are used asynchronously, and this is very clearly the case when persons change direction while walking. Each muscle is probably contributing to intertarsal stabilization, but in different ways. They appear to be more active in persons with flat or hypermobile feet.

## MAJOR JOINTS OF THE LOWER LIMB

### Hip Joint

The joint between the head of the femur and the lunate surface of the acetabulum is the hip joint. The two horns of the lunate surface are connected by the **transverse acetabular ligament** that completes the socket for reception of the femoral head. This socket is deepened somewhat by a fibrocartilaginous ring--the **acetabular labrum**--attached to the acetabular rim and lateral edge of the transverse acetabular ligament. The addition of the labrum converts the socket into slightly more than a hemisphere.

A weak ligament travels down from the fovea of the femoral head to attach to the medial edges of the transverse acetabular ligament and nearby lunate horns (Fig. 12-37). This **ligamentum teres of the femur (ligament of the head of the femur)** is enveloped by a sleeve of synovial membrane that is attached at one end to the edges of the fovea capitis and at the other end spreads out to attach to the inner edges of the transverse acetabular ligament and entire lunate surface. Thus, the fat and vessels that lie within this fossa are outside the synovial space of the joint.

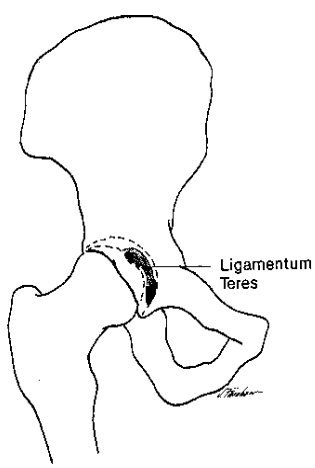


**Figure 12-37.** Ligamentum teres of the femur. (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

[81] Reeser LA, Susman RL, Stern JTJr. 1983 Electromyographic studies of the human foot: experimental approaches to hominid evolution. Foot & Ankle **3**:391-407.

The ligamentum teres of humans is too slender a band to have any effect on hip motion. Furthermore, it tends to become tight only in very peculiar positions. That it might be a nuisance if we were to adopt such peculiar positions with regularity is evinced by orangutans, which are the only primates to lack a ligamentum teres and who also have an extraordinarily mobile hip enabling the assumption of bizarre postures in the trees.

The capsule of the hip joint has a broad attachment to the outer surface of the bony acetabular rim and inferior surface of the transverse acetabular ligament. The capsule's femoral attachment starts at the top of the intertrochanteric line, passes down this ridge onto the rough area on the medial surface of the femoral shaft in front of the lesser trochanter (see Fig. 12-12), then runs up again along the back of the neck about a centimeter medial to the intertrochanteric crest, and finally courses across the top of the neck medial to the trochanteric fossa. As is typical, a synovial membrane lines the inner surface of this capsule. Atypically, the membrane does not end on the femur where the capsule attaches; rather, upon contacting the femur at this site, the synovial membrane of the hip joint turns medially to form a sleeve all around the femoral neck up to the margin of the femoral head, where the membrane does indeed attach to bone. Thus, although the femoral neck is intracapsular, it is outside the synovial cavity.

Over most of its extent the capsule of the hip joint is very thick. Owing to different fiber directions at different sites in the capsule, anatomists have identified various capsular ligaments. The two most important of these are the iliofemoral and ischiofemoral ligaments. The **iliofemoral ligament** (see Fig. 12-38) is a very thick band of capsular fibers that arises from the lower part of the anterior inferior iliac spine and the adjacent bone just above the acetabular rim. The fibers of the iliofemoral ligament pass downward and laterally, fanning out to an insertion along the whole length of the intertrochanteric line. The **ischiofemoral ligament** (see Fig. 12-39) arises from the sulcus between ischial tuberosity and acetabular rim. The fibers pass upward and laterally to attach to the superior aspect of the femoral neck. These two ligaments--the extraordinarily powerful iliofemoral and the less developed ischiofemoral--are made taut by extension of the femur beyond vertical. You will note that such movement is the most limited of all that can occur at the hip joint. As we shall see later, such a limitation is very important for the ability to walk on two legs.

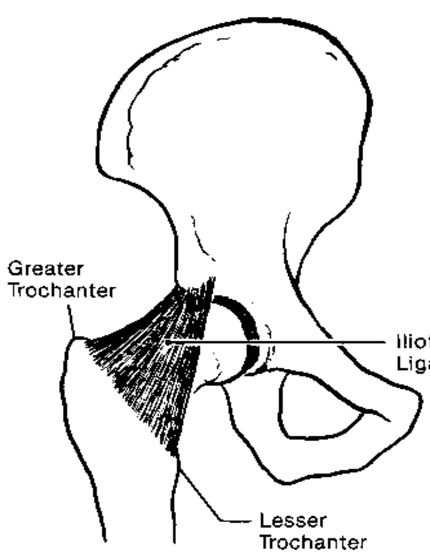


**Figure 12-38.** Iliofemoral ligament (anterior view).

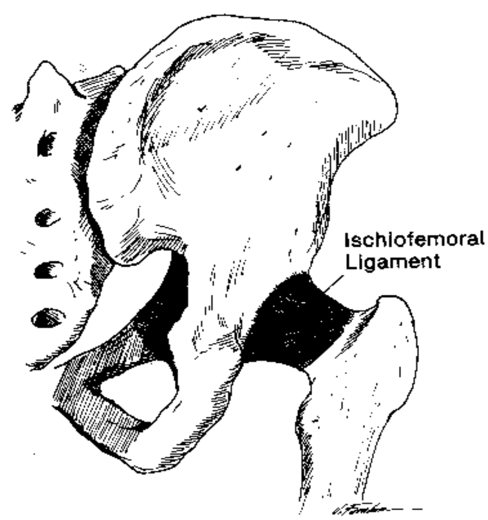


**Figure 12-39.** Ischiofemoral ligament (posterior view). (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

There is one region of the hip joint capsule that is quite thin. This lies in front of the femoral head medial to the edge of the iliofemoral ligament (see Fig. 12-38). Normally the iliopsoas muscle covers this thin part of the capsule and, thus, acts as an anterior reinforcement to the joint. In some cases the fibrous capsule is actually absent here, and then a pocket of synovial membrane will protrude upward deep to the iliopsoas and establish a communication with the bursa between the iliopsoas muscle and the iliopubic eminence.

The integrity of the hip joint is provided by its deep socket and strong capsule. Movement in all directions can occur but is sooner or later stopped by tightening of one part of the capsule or another. We have already discussed the specializations for limiting extension. Flexion is the freest of all movements. If the knee is flexed, flexion of the hip can continue until the thigh hits the abdomen. If the knee is extended, tightness in the hamstring muscles limits flexion at the hip.

## Knee Joint

The knee is a joint consisting of two articulations: that between the femur and the patella, and that between the femur and the tibia. Both articulations are contained within a single synovial cavity. The capsule of the knee attaches to the femur near the margins of its articular surfaces. However, the attachment of the posterior capsular fibers does not dip into the intercondylar notch, but instead passes straight across the intercondylar ridge. The tibial attachment of the capsule encircles the tibial plateau.

The anterior fibers of the knee joint capsule have three specializations worthy of note. First, there is an oval hole in the anterior capsule in which the patella sits. The capsular fibers are attached all around the margin of the articular surface of the patella. Second, from their site of origin on the femur just proximal to the trochlea, capsular fibers loop upward for 2 or 3 centimeters and then turn down toward the patella. Finally, these capsular fibers, and those on either side of the patella, are fused to the deep surface of the quadriceps tendon; capsular fibers inferior to the patella are fused to the deep surface of the patellar tendon.

I have already mentioned the fact that the semimembranosus tendon sends a strong band of fibers upward and laterally onto the surface of the posterior capsule. This band is often referred to as the **oblique popliteal ligament**.

### *Two Intracapsular (and Intrasynovial) Fibrocartilages of the Knee--The Medial and Lateral Menisci (Fig. 12-40)*

The articular surfaces of the tibial condyles seem completely unmatched to the curvature of the femoral condyles that sit upon them. To a large extent this mismatch is overcome by placing a specially shaped fibrocartilage--called a **meniscus**--on top of each tibial condyle. Each meniscus is thickest near the periphery of the joint and thins out rapidly toward its interior. Thus, these fibrocartilages help create concave receptacles for the convex femoral condyles. The synovial membrane that lines the capsule of the knee joint does not extend onto the menisci, which, after all, are subjected to great compressive stress. Thus, the menisci are bathed by synovial fluid and are said to be *intrasynovial* as well as being intracapsular.

Each meniscus forms part of a circle, leaving a region of each tibial condyle near to the intercondylar eminence for direct articulation with the femur. Forming only part of a circle, a meniscus is said to have **anterior and posterior horns** where the circle is broken. The horns are attached to the tibia by short ligaments. The **lateral meniscus** forms a more complete circle than the **medial meniscus**. Its posterior horn is attached to the tibia just behind the lateral intercondylar tubercle, the anterior horn just

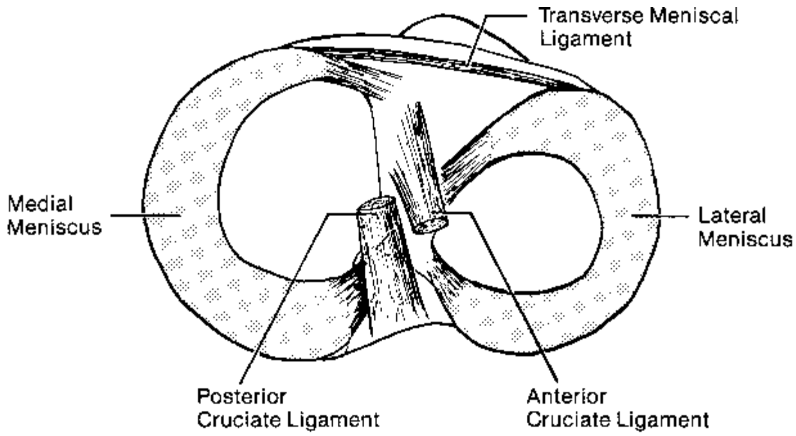


**Figure 12-40.** Superior view of the menisci and cruciate ligaments of the right knee.

in front of it. The medial meniscus forms only slightly more than half a circle. Its posterior horn is attached just behind the medial intercondylar tubercle, but its anterior horn is attached near the anterior margin of the medial condyle.[82]

Where the circumference of each meniscus contacts the inner surface of the joint capsule, the capsule and meniscus are bound together. Thus, the menisci are prevented from moving inward and getting trapped between the femoral condyles and tibial plateau. The very short portion of the capsule between the circumference of a meniscus and the tibia is often called the **coronary ligament of the meniscus**. A highly variable **transverse meniscal ligament** may run from side to side between the most anterior points of the two menisci.

***Two Intracapsular (but Extrasynovial) Ligaments of the Knee--The Cruciate Ligaments***

There being no osseous interlocking between the femur and tibia to limit movement of the knee, it has more than its share of powerful ligaments. Two of these have an intracapsular position near the center of the joint. They are called **cruciate ligaments** because their courses cause them to pass by one another at right angles (see Fig. 12-40). The **posterior cruciate ligament** runs from the posterior intercondylar fossa upward and forward to attach to the inner surface of the medial femoral condyle (Fig. 12-41). The anterior cruciate ligament runs from the anterior intercondylar fossa upward and backward to the inner surface of the lateral femoral condyle (see Fig. 12-41). Lachman[83] suggests a trick to remember this. Stand up and place your *right* foot directly in front of your left. Your lower limbs now run the course of the cruciate ligaments of your *right* knee.

At the back of the knee the synovial membrane sweeps away from the capsule to loop around the front of the cruciate ligaments. Thus, these ligaments are located in a plane between the joint capsule and

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[82] I use a mnemonic to help me remember the different shapes of the menisci. The professors who taught me anatomy are Ronald Singer and Charles Oxnard. Their initials -RSCO -remind me that if I could peer through my femur down onto the top of the tibial plateau of my **R**ight **S**ide, I would see letters **C** and **O** formed by the medial and lateral menisci, respectively. The value of this mnemonic to persons not trained by Singer and Oxnard is unclear.

[83] Lachman, E: Case Studies in Anatomy. Oxford University Press, New York, 1965.

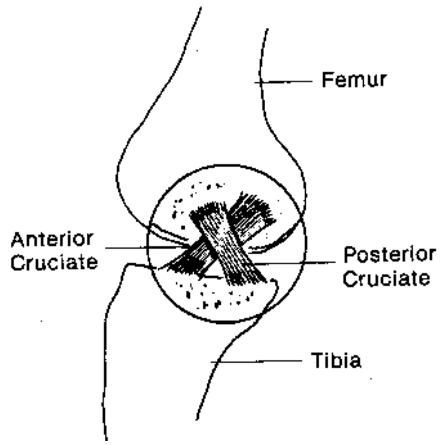


**Figure 12-41.** Schematic medial view of the cruciate ligaments of the right knee. (From Norkin CC, Levangie PK. 1983. Joint Structure and Function: A Comprehensive Analysis. FA Davis, Philadelphia.)

synovial membrane. Consequently, the cruciate ligaments are not bathed by synovial fluid. Although they are intracapsular, they are *extrasynovial*. [84]

### *Infrapatellar Fat Pad and Occasional Synovial Septum*

On the anterior aspect of the knee joint, just inferior to the patella, a fair amount of fat is deposited in the connective tissue of the synovial membrane. This fat is still covered by the thin secretory layer of the synovial membrane, which is thereby caused to bulge posteriorly into the joint space. The membrane covered fatty protrusion is called the **infrapatellar fat pad.** It is not uncommon for the synovial membrane along the posterior edge of the fat pad to extend backward and meet that on the front edge of the anterior cruciate ligament, creating a partial synovial-membrane septum between the left and right sides of the joint.

### *Two Extracapsular Ligaments of the Knee - the Medial and Lateral Collateral Ligaments*

Running from the posterior aspect of the lower half of the lateral epicondyle of the femur straight down to the lateral aspect of the fibular head is the **lateral collateral ligament of the knee of the knee** (see Fig. 12-25). This ligament is outside of, and completely separate from, the capsule of the knee.

Running from the most prominent region of the medial epicondyle of the femur straight down to the tibia is the **medial collateral ligament of the knee** (see Fig. 12-25). Its deeper fibers adhere to the capsule of the joint and attach with it immediately below the medial margin of the tibial plateau, thus just superior to the insertion of the anterior fork of the semimembranosus tendon. The more superficial fibers of the medial collateral ligament pass superficial to this tendon and gain an attachment to medial border of the tibial shaft for several centimeters below the condylar expansion.

### *Movements Permitted at the Knee*

The projection of the intercondylar eminence of the tibia into the intercondylar notch of the femur certainly restricts side-to-side motion of one bone relative to the other. However, the fundamental stability of the joint, and its nearly pure function as a hinge, is largely determined by the cruciate and collateral ligaments. There have been numerous studies on the relative tightness of these ligaments, or portions of them, at different degrees of knee flexion. It turns out that some portion of each cruciate

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[84] We shall see later that the tendon of the popliteus muscle is another intracapsular but extrasynovial structure.

ligament is always tight regardless of the degree of knee flexion. However, most of the anterior cruciate ligament is tight in extension, and most of the posterior ligament is tight in flexion. Overall tension within the cruciate ligaments is probably least about halfway between complete extension and complete flexion. Some portion of fibers within the superficial layer of the medial collateral ligament is also tight in all positions of knee flexion. It has been suggested that the deep fibers relax as flexion proceeds. More certainly, the lateral collateral ligament of the knee does become slack during flexion.

**What Restricts Extension and Flexion?** Extension of the knee is stopped by tension that develops in all the ligaments, especially the anterior cruciate, and in the posterior fibers of the capsule. Flexion of the knee is limited primarily by tension in the posterior cruciate ligament and contact of the soft tissues of the calf with those of the thigh.

**What Restricts Anterior and Posterior Sliding?** As one could predict from their attachments, the anterior cruciate ligament restricts forward shift of the tibial plateau relative to the femur, whereas the posterior cruciate ligament prevents posterior displacement of the tibia relative to the femur.

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The clinical tests for the cruciate ligaments involve the examiner making an attempt to pull the tibial plateau forward or push it backward on the undersurface of the femur (with the patient supine and the knee flexed). If the anterior cruciate ligament is torn, the tibial plateau can be pulled forward more than a centimeter; this is the so-called **positive anterior drawer sign**. A torn posterior cruciate ligament gives a **positive posterior drawer sign**, meaning the tibial plateau can be pushed posteriorly more than a centimeter.

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**What Restricts Abduction and Adduction?** The medial collateral ligament is the first line of defense against abduction of the tibia in all positions of the knee. The most important part of the medial collateral ligament comprises its superficial fibers that attach below the tibial condyle. However, a blow to the lateral aspect of the knee may very well rupture both the superficial and deep fibers of the medial collateral ligament, and also the medial capsule to which the deep fibers adhere. In turn, damage to the capsule may result in a tear of the medial meniscus, which is, after all, attached to it.

The lateral collateral ligament resists adduction of the knee, most effectively when the joint is extended.

The two cruciate ligaments also resist abduction/adduction movements of the tibia, more so when the knee is extended than flexed. Blows to the lateral side of the knee may strain or tear the cruciate ligaments as well as damaging the medial collateral ligament.

**What Restricts Medial and Lateral Rotation?** The first line of defense against excessive axial rotation at the knee is provided by the collateral ligaments. The slackness of the lateral ligament when the knee is flexed means that tibial rotation is freest in this position. The cruciates, particularly the anterior, also have a role in restricting medial rotation of the tibia. This fact can be demonstrated if you once again stand up with your right foot placed in front of your left so as to simulate the cruciate ligaments of your right knee. The floor is now the tibial plateau. If you twist your trunk to the right, simulating medial rotation of the tibia relative to the femur, your lower limbs lock against one another. Twisting your trunk to the left simulates lateral rotation of the tibia, and this is unresisted by the cruciate ligaments.

**The So-Called "Terminal Locking" Motion of the Knee.** At the very end of normal knee extension there naturally occurs a slight medial rotation of the femur relative to the tibia (or, if you wish, lateral rotation of the tibia relative to the femur). Some authors attribute this to the fact that the part of the medial femoral condyle articulating with the tibia is longer than the corresponding part of the lateral femoral condyle. Other authors claim that this rotation at the end of extension is imposed upon the system by the interaction between the intercondylar eminence of the tibia and the intercondylar notch of the femur. Regardless, such rotation is said to constitute a "screw-home" or "terminal locking" motion that results in a more stable weight-bearing position than would otherwise occur. From a position of complete extension, flexion of the knee begin with lateral rotation of the femur relative to the tibia, the so-called unlocking motion.

### *Bursae About the Knee*

A bursa is a thin connective tissue sac, lined by fluid-secreting synovial membrane, which is placed so as to reduce friction between two structures that would otherwise rub against each other. A variety of bursae lie deep to the muscles and tendons crossing the knee, but I will mention only two. First, I have already described a pouch-like extension of the joint capsule superior to the patella and deep to the quadriceps tendon. Like other parts of the capsule, this is lined by synovial membrane. It is often referred to as a **suprapatellar bursa** that communicates with the main part of the synovial cavity. Another important bursa is the **deep infrapatellar bursa**, which is interposed between the patellar tendon and the anterior surface of the tibia just above its tuberosity. The deep infrapatellar bursa does not communicate with the joint space..

There are two superficial bursae of the knee that are of particular significance. One of these is the **prepatellar bursa**, which lies in the subcutaneous tissue anterior to the lower end of the patella. The other is the **superficial infrapatellar bursa**, which lies in the subcutaneous tissue anterior to the site of insertion of the patellar tendon into the tibial tuberosity.

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One or both of the superficial bursae of the knee may become inflamed and swollen during prolonged episodes of working while in the kneeling position. The resulting condition is known as **housemaid's knee**.

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## Joints of the Foot (see Figs. 12-30, 12-31)

### *Ankle, Intertarsal, and Tarsometatarsal Joints*

The talus participates in three separate joints:

1. The superior articular surface of the talus articulates with the distal articular facets of the tibia and fibula to form the **ankle** joint. It is surrounded by a single thin capsule.

2. The posterior calcaneal surface on the underside of the talus forms a separate **talocalcaneal joint** with the upper surface of the calcaneus.

3. The articulation of the middle and anterior calcaneal facets of the talus with the calcaneus are included within the same joint cavity as is the articulation of the talar head with the navicular. The correct name for this joint is the **talocalcaneonavicular joint**.

Directly lateral to the talonavicular articulation, and sometimes communicating with it, is the **calcaneocuboid joint** between the distal surface of the calcaneus and proximal surface of the cuboid.

Despite the existence of a common talocalcaneonavicular joint cavity distinct from both the talocalcaneal joint cavity and (usually) the calcaneocuboid joint cavity, functional anatomists generally eschew this terminology in favor of one that reflects sites of coordinated movement. Thus, the three talocalcaneal articulations (posterior, middle, and anterior) are said to compose a functional **subtalar joint**, at which the talus and calcaneus move relative to one another. The talonavicular and calcaneocuboid articulations are grouped together as the functional **midtarsal** (**transverse tarsal**) **joint**, at which the forefoot moves relative to the hindfoot.

Distal to the transverse tarsal joint are the **naviculocuneiform, intercuneiform, cuboidocuneiform, cuneiometatarsal, cuboidometatarsal, and intermetatarsal articulations**. Only the articulation between the medial cuneiform and the hallux has its own cavity and capsule. All the other articulations lie in one or the other of two larger joint cavities, which need not be described.

**Movements At the Ankle Joint.** The osseoligamentous structure of the ankle constrains permissible movements to those of dorsiflexion and plantarflexion. The top of the talus is "grasped" firmly by the socket formed by the distal tibia and fibula, preventing side to side and rotatory motion of the talus. Anteroposterior sliding and abduction/adduction are prevented by ligaments. There are four such ligaments on the medial side of the joint and three on the lateral side. The four ligaments on the medial side of the ankle appear to form a single fan-shaped complex radiating out from the medial malleolus. The name given to the entire complex is the **deltoid ligament**. Its middle fibers are primarily responsible for preventing abduction of the foot at the ankle; its anterior and posterior fibers resist fore and aft sliding. The names of its four components are given in Fig. 12-42. Each name reflects the bones to which that component attaches. Some fibers of the tibionavicular ligament also have an attachment to the medial edge of the spring ligament, which is not part of the deltoid ligament.

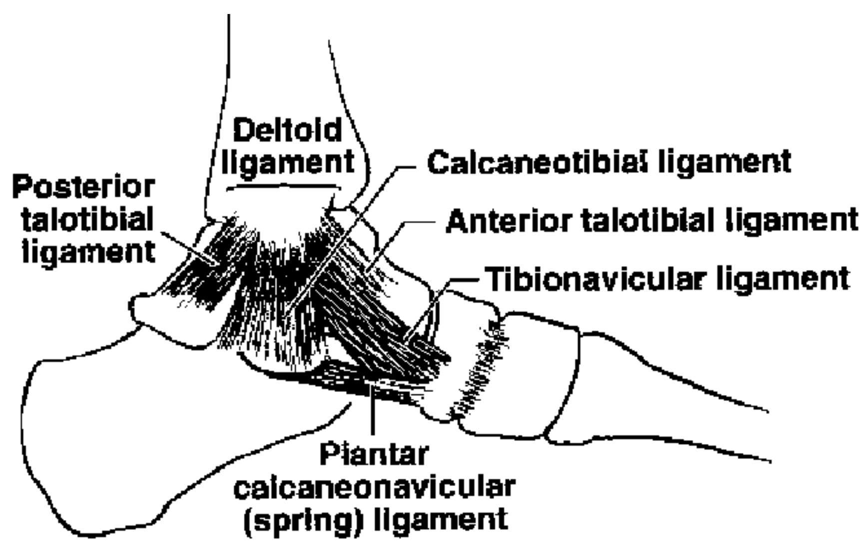


**Figure 12-42.** Deltoid ligament (with its four components) on the medial aspect of the ankle. The spring ligament is not part of the deltoid.

On the lateral side of the foot there are **anterior talofibular, calcaneofibular, and posterior talofibular ligaments** (Fig. 12-43) that emanate from the lateral malleolus and correspond more or less to their medial counterparts. These three ligaments are more obviously separate than their medial counterparts, and, thus, no lateral deltoid ligament exists. The calcaneofibular ligament resists adduction of the foot at the ankle; the anterior talofibular ligament resists forward sliding of the foot on the leg; the posterior talofibular ligament resists backward sliding of the foot.

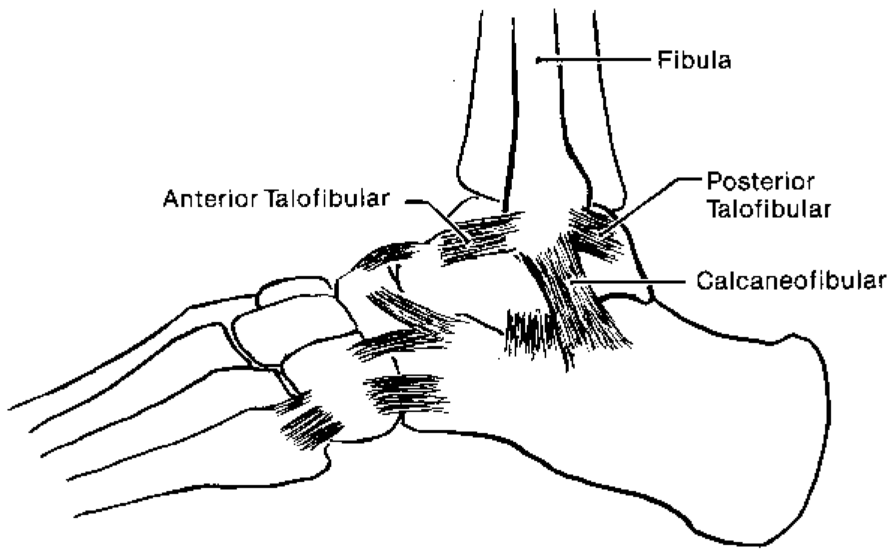


**Figure 12-43.** Ligaments on the lateral aspect of the ankle (left foot).

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The lateral ligaments of the ankle are more frequently sprained than is the deltoid ligament. A physician tests for the integrity of these ligaments by manually trying to move the foot in a way that an intact ligament would resist. If the calcaneofibular ligament is torn, the examiner will be able to adduct the foot far more than is otherwise possible. The test for the anterior talofibular ligament is for the examiner to place one hand on the front of the leg and then attempt to pull the foot forward by pressure applied to the heel. If the foot can be pulled forward relative to the leg, this is said to be a **positive anterior drawer sign of the ankle**, indicating a torn anterior talofibular ligament.

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**Movements at the Intertarsal Joints; the Longitudinal Arch of the Foot.** A large number of ligaments bind the tarsal bones to one another. There seems little point in describing all of them. They exist for the purpose of providing a relatively rigid structure that nonetheless is permitted some degree of motion, the bulk of which motion we describe as either inversion or eversion and which occurs primarily at the subtalar and transverse tarsal joints.

When I say the foot must be rigid, I mean that it should be able to apply forces to the ground with its ball and not deform. Of course, the kind of deformation that such forces tend to produce is a dorsiflexion of the front part of the foot relative to its back part. Such deformation is resisted far better by an arched structure than by a flat structure. As a result, the human foot is arched from front to back, i.e., has a **longitudinal arch**. Many texts also note that the foot has a second arching from side to side. However, this transverse arch is mainly a by-product of the fact that longitudinal arch is higher on the medial side than on the lateral side. The different curvatures of the medial and lateral portions of the longitudinal arch reflect the greater forces applied to the ground by the ball of the foot at the base of the big toe than by the more lateral region of the ball.

The three most important intertarsal ligaments exist for the purpose of maintaining the longitudinal arch of the foot. Of these, the medial arch-supporting ligament is more important than the two lateral ligaments.

The major support of the medial part of the longitudinal arch is the **plantar calcaneonavicular ligament**, more commonly called the **spring ligament** (Fig. 12-44). It runs from the distal edge of the sustentaculum tali to the tuberosity and inferior surface of the navicular. Its medial part is an especially thick fibroelastic band whose superior surface contains fibrocartilage for actual articulation with the head of the talus. The deltoid ligament of the ankle is attached to its medial edge. In that the downward force of the body's weight is applied to the talus, there is a tendency for the talar head to act as a wedge driving

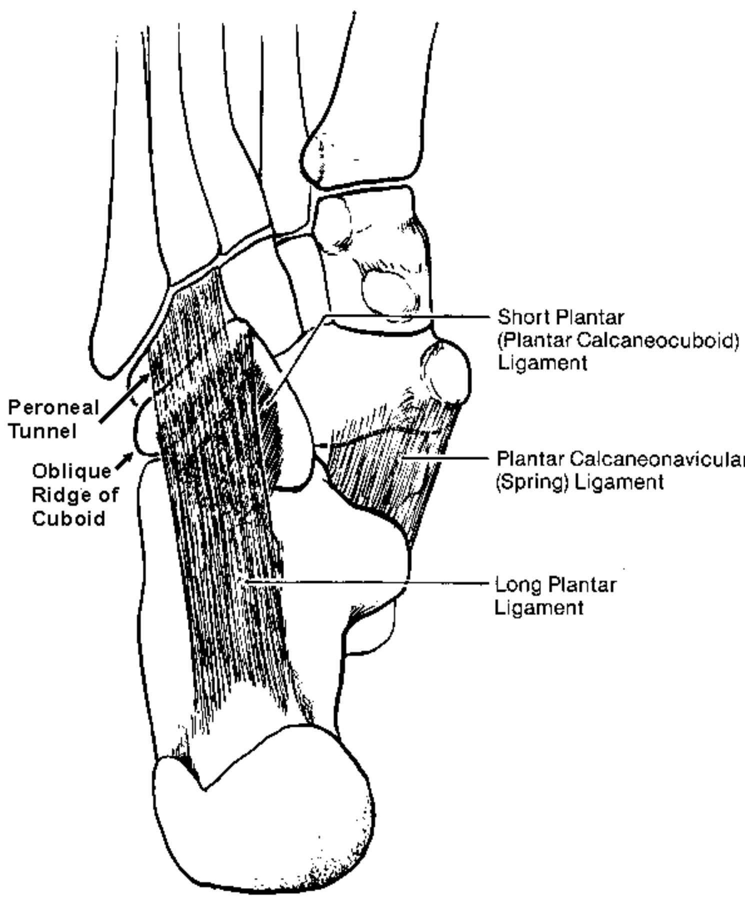


**Figure 12-44.** The three major arch-supporting ligaments on the plantar aspect of the tarsus (right foot).

the navicular and calcaneus apart, with loss or diminution of the medial longitudinal arch. This tendency is resisted by the spring ligament.

When overweight persons stand for long periods of time, the spring ligament may be stretched and the talar head drop downward and medially. This is the condition described as **flat-foot**. It is recognizable not only by diminution of the arch but also by a medially directed bulge produced by the displaced talar head.

The lateral portion of the longitudinal arch is maintained by two ligaments that run from the plantar surface of the calcaneus to the plantar surface of the cuboid (see Fig. 12-44). The more superficial is called the **long plantar ligament**. It runs from most of the inferior surface of the calcaneus in front of its tuberosity to the oblique ridge on the inferior surface of the cuboid. Some of the superficial fibers of the long plantar ligament pass beyond the cuboid ridge to reach the inferior lip of the bone's distal articular surface. In this way the groove on the undersurface of the cuboid distal to the ridge is formed into an osseofibrous **peroneal tunnel**.

A more deeply placed **short plantar ligament** runs from a depression on the inferior surface of the calcaneus just behind its distal articular surface to the inferior surface of the cuboid behind and medial to its oblique ridge. For some peculiar reason, the name **plantar calcaneocuboid ligament** is reserved for this structure.

**The Plantar Aponeurosis and Its Role in Maintenance of the Longitudinal Arch.** Just as there is a thick fibrous palmar aponeurosis deep to the subcutaneous tissue of the palm of the hand, there is a thick fibrous plantar aponeurosis deep to the subcutaneous tissue of the sole of the foot. However, whereas the palmar aponeurosis has no mechanical effect on the joints of the wrist, the plantar aponeurosis is very clearly linked to maintenance of the longitudinal arch of the foot.[85]

The fibers of the plantar aponeurosis arise from the medial plantar process of calcaneal tuberosity and pass forward, gradually fanning out and diverging into five bands, each of which runs into the fibrous digital flexor sheath of a toe. Through these sheaths the plantar aponeurosis gains an attachment to each of the proximal phalanges (Fig. 12-45). The important consequence of these attachments is that whenever the toes are dorsiflexed at the MP joint, the plantar aponeurosis is tightened. Tightening of the plantar aponeurosis causes the metatarsal heads to be pushed toward the calcaneal tuberosity, producing a plantar flexion at the tarsometatarsal and naviculocuneiform articulations with resulting elevation of the arch. This is observable (but not consequential) when the foot is off the ground and the toes are dorsiflexed. Its significance arises when the toes are dorsiflexed while the foot is bearing weight, as occurs at the end of a step in walking, or when a person stands on his or her toes. Then the plantar aponeurosis actually becomes the major support of the longitudinal arch.

The plantar aponeurosis is under tension and plays a significant role in arch support even when a person is simply standing with the weight evenly distributed between the ball of the foot and the heel. You can demonstrate this fact by noting that it is more difficult to extend the MP joints of the toes (either by active muscular effort or just by pulling on them) when weight is borne by the foot than when the foot is off the ground.

[85] Hicks, JH: The mechanics of the foot. II. The plantar aponeurosis and the arch. J Anat 88:25-30, 1954.

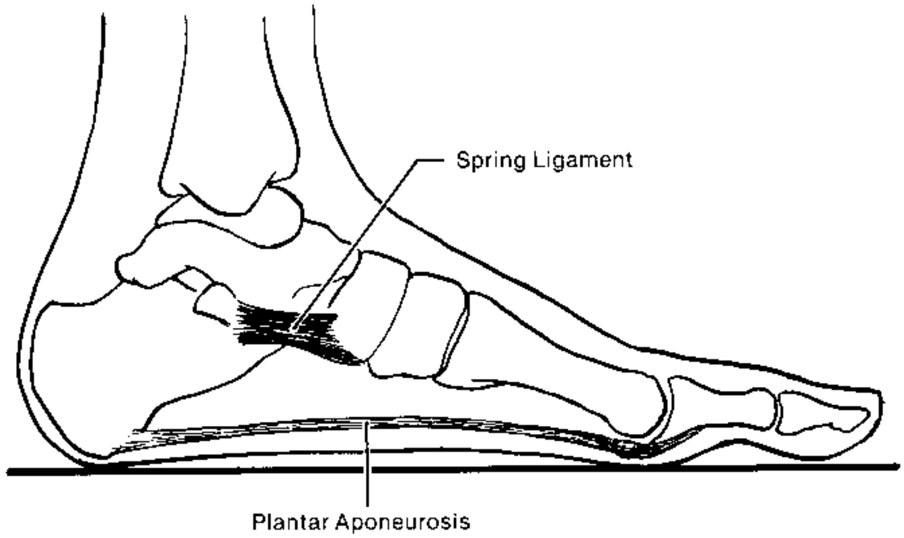


**Figure 12-45.** Schematic side view of the plantar aponeurosis.

***Intermetatarsal, Metatarsophalangeal (MP), and Interphalangeal (IP) Joints***

These do not differ in any significant way from the corresponding joints in the hand. The capsules of the MP and IP joints have a thickened region corresponding to the palmar plates of the hand. Of course, in the foot they are called **plantar plates**. Protruding ventrally from the plantar plate of the 1st MP joint are a medial and a lateral sesamoid bone. Similar but smaller sesamoids may occur in association with the other MP joints.

One significant difference between the hand and foot is related to the permanently adducted position of the big toe. Although only rarely is there a true synovial intermetatarsal joint between the bases of the 1st and 2nd metatarsals, nonetheless the plantar plate of the 1st MP joint is bound to that of the 2nd MP joint by a **deep transverse metatarsal ligament**. It will be recalled that in the hand, deep transverse metacarpal ligaments only exist between the palmar plates of the MP joints of the fingers.

## LYMPHATICS OF THE LOWER LIMB

### Groups of Lymph Nodes

***Superficial and Deep Inguinal Nodes***

Lying in the subcutaneous tissue of the thigh just inferior to the inguinal ligament are the **superficial inguinal nodes**. These were also discussed in Chapter 5 (p. 181) because they drain all the subcutaneous tissue and skin below a transverse plane through the umbilicus. A **superior group** of superficial inguinal nodes lies along the parts of the superficial circumflex iliac and superficial epigastric vessels below the inguinal ligament; an **inferior group** lies along the termination of the great saphenous vein.

The superficial inguinal nodes send their efferent lymphatic vessels through the fossa ovalis to reach the **deep inguinal nodes**, which lie medial to the femoral vein from just below the site where it receives the great saphenous vein up to the femoral ring. The deep inguinal nodes also drain those deep structures of the lower limb fed by the femoral artery and all its branches.

Some of the efferent vessels from the superficial inguinal nodes bypass the deep inguinal nodes to pass through the femoral ring and drain directly to **external iliac nodes**, which are also the recipients of lymph from deep inguinal nodes.

***Internal Iliac Nodes***

The internal iliac nodes not only receive lymph from pelvic organs, but also from those deep structures of the lower limb that derive their blood supply from the gluteal and obturator arteries. Some of these nodes lie alongside the obturator vessels and nerve. The nerve is at risk when removing these "obturator nodes" during surgery for uterine or ovarian cancer.

***Other Deep Nodes of the Lower Limb***

There occur occasional nodes along the deep vessels of the lower limb. The most important of these are a few nodes around the popliteal vein that drain not only deep structures of the leg and foot, but also drain some superficial lymph vessels that accompany the small saphenous vein.

## SURFACE ANATOMY OF THE LOWER LIMB

### Soft-Tissue Landmarks

The horizontal crease that separates the rounded inferior aspect of the buttock from the posterior surface of the thigh is called the **gluteal fold**. It does not correspond to the lower edge of the gluteus maximus, which passes obliquely downward and laterally from the tip of the coccyx to the junction of the upper and middle thirds of the thigh. The gluteal fold does cross the lower border of gluteus maximus at about their midpoints.

Of course, in well-muscled persons or thin persons of average build, a variety of muscles and tendons make their presence known by producing bulges or ridges beneath the skin. I shall mention only those few that can be used as landmarks for other structures in the lower limb.

The intermuscular space we call the femoral triangle is recognized as a depression inferior to the inguinal ligament. Its precise lateral border, formed by the sartorius, can be seen by eliciting contraction of this muscle. Running through the femoral triangle from its base to its apex are the femoral artery and vein. Alongside the femoral vein are the deep inguinal lymph nodes. The femoral nerve enters the triangle through its base, but about 1 cm lateral to the femoral artery. Two branches of this nerve (i.e., saphenous and nerve to the vastus medialis) continue all the way down to the triangle's apex. The great saphenous vein courses in the roof of the femoral triangle to pass through the fossa ovalis, located just below and slightly medial to the midpoint of the inguinal ligament.

Sartorius is also the guide to the subsartorial canal in the middle third of the thigh. In this canal lie the superficial femoral artery, superficial femoral vein, saphenous nerve, and the nerve to vastus medialis.

The tendons of biceps femoris and semitendinosus are readily palpable on the back of the thigh just above the knee. The space between them is the popliteal fossa. Its precise lower limit cannot be felt, but the general region where the heads of the gastrocnemius begin their common insertion is palpable. The tibial nerve, popliteal vein, and popliteal artery, from superficial to deep, run the length of the popliteal fossa. The common peroneal nerve runs along its superolateral border.

Upon extension of the toes the extensor hallucis longus tendon is particularly well visualized and serves as the guide to the more laterally lying dorsalis pedis artery.

## Bony Landmarks

### *Ilium*

The crest of the ilium, its two superior spines, and its tubercle are palpable. The presence of the posterior superior spine is also indicated by a dimple in the skin of the back.

Most of the palpable structures on the ilium serve as guides to vertebral levels relevant in a study of the abdomen and pelvis (see Chapter 5, p. 183)). Of course, in the context of abdominal anatomy, the anterior superior iliac spine is also notable as the origin of the inguinal ligament. As a guide to lower limb structures, this bony prominence can be used to judge the sites or origin of the tensor fasciae latae (from the crest behind the spine) and sartorius (just below the spine). The iliac tubercle is the guide to the origin of the iliotibial tract. The posterior superior iliac spine marks the origin of the most superior fibers of gluteus maximus, but is probably more valuable for the fact that it lies 1 fb superior to the upper limit of the greater sciatic foramen.

### *Ischium and Pubis*

As we learned in Chapter 5, the ischial spine is palpable through the vagina or rectum. This fact enables it to serve as a landmark for identifying the pudendal nerve as it enters the pudendal canal through the lesser sciatic foramen.

The ischial tuberosity is easily felt by placing a finger in the medial part of the gluteal fold and pushing upward and forward. Extending anteriorly from the tuberosity is the ischiopubic ramus, which is palpable in the perineum. The region of the pubic symphysis can be felt in the anterior midline, above the penis in males and deep to the mons pubis in females. The pubic crests, extending laterally from the symphysis, and the pubic tubercles at the ends of the crests, are also palpable.

### *Femur*

The lateral surface of the greater trochanter, covered by tendons, can be felt deep to the skin where the hips are widest. At the lower end of the femur its two epicondyles are palpable. With the knee flexed the femoral trochlea (for the patella) can be felt on the anterior aspect of the bone, and the inferior surfaces of the femoral condyles are discernible on either side of the patella.

### *Patella*

It is obvious to everyone that the anterior surface of the kneecap can be felt in its entirety.

### *Tibia and Fibula*

On either side of the apex of the patella one can palpate the fronts and sides of the tibial condyles. The palpable part of the lateral condyle ends in a very prominent bony bulge on the posterolateral aspect of the leg; this is, in fact, the head of the fibula. Inferior to the patella, the ligamentum patellae leads to the easily recognizable tibial tuberosity.

The entire subcutaneous surface of the tibia, ending in the medial malleolus, can be palpated, as can most of the anterior and posteromedial borders of the tibia that bound this surface.

The lateral malleolus of the fibula is easily felt. Above it lies the subcutaneous surface of the shaft between the origins of peroneus tertius and peroneus brevis.

### *Foot Bones*

The calcaneal tuberosity is palpable through the thick tissues of the heel. More interestingly, about 1 fb inferior to the medial malleolus one can feel the sustentaculum tali. Directly anterior to sustentaculum is the even more prominent tuberosity of the navicular. Superior to a line between the sustentaculum and navicular tuberosity one can palpate the head of the talus.

On the lateral border of the foot, about midway between the heel and the base of the little toe, is the laterally projecting tuberosity of the 5th metatarsal, into which the peroneus brevis inserts.

## Arterial Pulses

### *Femoral Artery*

The pulse of the femoral artery is readily felt immediately below the inguinal ligament at a point halfway between the anterior superior iliac spine and the pubic symphysis. The vessel is pushed deeply so as to compress it against the head of the femur (the most medial fibers of iliopsoas and the capsule of the hip joint intervening).

### *Popliteal Artery*

One attempts to feel the popliteal pulse by compressing the vessel against the posterior surface of the distal femur. The knee must be partly flexed so as to reduce tension in the deep fascia that bridges across the popliteal fossa. Even then, the very deep position of the vessel makes it quite difficult to sense a pulse. In fact, it is far easier to obtain pulses from the smaller posterior tibial and anterior tibial arteries where they are relatively superficial in the distal part of the limb.

### *Anterior Tibial Artery*

The anterior tibial pulse is taken over the anterior surface of the distal tibia just above the ankle joint. The vessel is being crossed by the extensor hallucis tendon here and it is necessary to place a finger medial to the tendon and push it laterally at the same time as you try to compress the anterior tibial artery against the bone. It should be borne in mind that if the dorsalis pedis artery is a branch of the peroneal artery, the anterior tibial artery will be so small at the site described that no pulse will be palpable.

### ***Posterior Tibial Artery***

The posterior tibial pulse is best felt by imagining a line between the medial malleolus and the heel, then placing two fingertips side by side on the part of the line adjacent to the medial malleolus.

### ***Dorsalis Pedis Artery***

When the dorsalis pedis artery is a sizable vessel (about 85 to 90 percent of the time) its pulse is the most easily felt of all the pulses around the ankle joint. The examiner should places his or her fingers lateral to the extensor hallucis longus tendon just proximal to the first intermetatarsal space.

## Superficial Veins and Cutaneous Nerves

The small saphenous vein and sural nerve can be located surgically just posterior to the lateral malleolus.

The great saphenous vein is found in front of the medial malleolus and then crosses the inferior end of the subcutaneous surface of the tibia to assume a position immediately behind the posteromedial border of the bone, where it runs up to the posterior border of sartorius and then follows this behind the knee and to the apex of the femoral triangle. The great saphenous vein is located in the subcutaneous tissue of the femoral triangle from its apex up to the fossa ovalis, which lies an inch or two below the inguinal ligament and a bit medial to its midpoint.

The saphenous nerve accompanies the great saphenous vein from just above the knee down to the foot.

## Major Deep Nerves

### ***Femoral Nerve***

The femoral nerve enters the femoral triangle about 1 cm lateral to the femoral artery. The nerve immediately sprays out its branches, only two of which--the saphenous and the nerve to the vastus medialis--continue in the triangle to its apex.

### ***Sciatic Nerve***

The surface anatomy of the sciatic nerve is important to keep in mind so that the nerve is not inadvertently injured by injections or surgical procedures. At the level of the posterior superior iliac spine the sciatic nerve is still deep within the pelvis. Injections given at this level present no threat to the nerve, especially if one takes the extra precaution of inserting the needle more toward the front of the hip. In other words, the upper outer quadrant of the gluteal region is that portion furthest removed from the greater sciatic notch and thus favored for intramuscular injections.

After the sciatic nerve emerges from the greater sciatic foramen it passes downward deep to the gluteus maximus. Here the nerve is located approximately halfway between the inner edge of the ischial tuberosity and the outer surface of the greater trochanter. It then descends through the thigh, placed deeply in its posterior midline, to reach the superior apex of the popliteal fossa, where the sciatic nerve divides into its tibial and common peroneal branches.

***Common Peroneal Nerve***

This nerve at first lies on the medial surface of the biceps femoris in the popliteal fossa, but the mass formed by the lateral head of gastrocnemius arising from the posterior capsule of the knee acts to "push" the nerve onto the posterior edge of the biceps tendon, which it follows across the knee and down to the neck of the fibula.

***Tibial Nerve***

The tibial nerve is the most superficial of the structures running through the popliteal fossa. It follows a path from the superior apex to the inferior apex. It dives deeply at this point, but again becomes relatively superficial as it crosses the ankle. Here it lies posterolateral to the tibial artery, whose pulse can be palpated.