Neurological anatomy of the lower limb

Learning Objectives.
At the end of this course, you should be able to:

1. describe the basic anatomy of the spinal cord, and state how spinal nerves arise;
2. describe the constituents of the lumbo-sacral plexus;
3. discuss the course of the major nerves of the lower limb in relation to their sensory and motor function;
4. appreciate the role of dermatomes in clinical management.

The neurological supply to the lower limb is made up of spinal nerves, emanating from the vertebral column, where they exit the spinal cord. Those supplying the lower limb exit the vertebral column from the level of lumbar vertebra 4 (L4), and continue to exit at each vertebral level, via L5, and S1-4, and together (with an additional branch from T12) these are known as the lumbo-sacral plexus, which lies anterior-lateral to the vertebral column, and within the bony pelvis.

Spinal nerves connect the central nervous system to effector organs (receptors, muscles, glands). They emerge from the vertebral column via the intervertebral foramina between adjoining vertebrae. Some spinal nerves exit the spinal cord at a level higher than their corresponding vertebra. The spinal cord itself ends near the level of L2, therefore the nerves of the lower lumbar, sacral, and coccygeal vertebrae descend to reach their respective foramina before leaving the vertebral column. This group of nerves is known as the cauda equina.
A spinal nerve has two points where it arises from the spinal cord - a posterior (dorsal) root, and an anterior (ventral) root, which unite to form a spinal nerve. The posterior root contains sensory axons, whilst the anterior root contains motor axons, therefore spinal nerves originate as mixed nerves.

Shortly after leaving the intervertebral foramen the spinal nerve separates into a number of branches, known as rami;

- dorsal ramus - supplies deep muscles, and skin of the dorsal (back) surface of the trunk.
- ventral ramus - supplies muscles and structures of upper and lower limbs, plus lateral and ventral (front) surfaces of the
trunk. The ventral ramus further divides into anterior (ventral) and posterior (dorsal) divisions.

meningeal branch - re-enters the spinal canal and supplies vertebrae, vertebral ligaments, and blood vessels of the spinal cord and meninges.

rami communicantes - components of the autonomic nervous system, which connect with the sympathetic trunk, running from the base of the skull to the coccyx.

The ventral rami of the spinal nerves join together to form a network, or plexus, with ventral rami of adjacent spinal nerves.

**Lumbar plexus - made up of the ventral rami of L1-L4:**

- **Ilioinguinal nerve** - L1, supplying skin of superior medial thigh
- **Genitofemoral nerve** - L1-L2, supplying skin over middle anterior thigh
- **Lateral femoral cutaneous nerve** - supplying skin over lateral, anterior, and posterior thigh
- **Femoral nerve** - flexors of thigh, extensors of leg, skin over anterior and medial thigh, medial side of leg and foot
- **Obturator nerve** - adductor muscle group, skin over medial aspect of thigh
Sacral plexus - made up of ventral rami of L4-L5, S1-S4:

**Superior gluteal nerve** - L4-L5, S1, gluteus medius and minimus, tensor fascia latae

**Inferior gluteal nerve** - L5, S1-S2, gluteus maximus

**Posterior femoral cutaneous nerve** - S1-S3, skin over superior posterior thigh, superior calf

**Sciatic nerve** - L4-L5, S1-S3, made up of tibial and common peroneal nerves

**Tibial nerve** - L4-L5, S1-S3, gastrocnemius, plantaris, soleus, popliteus, tibialis posterior, FDL, FHL

**Medial plantar nerve** - abductor hallucis, FDB, FHB, skin over medial two thirds of plantar surface

**Lateral plantar nerve** - remaining intrinsic foot muscles, skin over lateral third of plantar surface

**Common peroneal nerve** - L4-L5, S1-S2, divides into superficial and deep branches

**Superficial peroneal nerve** - peroneus longus and brevis, skin over distal third of anterior leg, dorsum of foot

**Deep peroneal nerve** - tibialis anterior, EHL, peroneus tertius, EDL, EDB, skin over first and second inter-digital space
Nerve Distribution - Lumbar plexus

Lateral femoral cutaneous nerve

This arises from the dorsal divisions of L2 and L3. It emerges from the lateral border of the psoas major and crosses the iliacus muscle obliquely, towards the anterior superior iliac spine. It then runs under the inguinal ligament and over sartorius, and into the thigh, where it divides into an anterior and a posterior branch.

The anterior branch becomes superficial about 10 cm below the inguinal ligament, and divides into branches which are distributed to the skin of the anterior and lateral parts of the thigh, extending to the knee. The terminal filaments of this nerve frequently communicate with the anterior cutaneous branches of the femoral nerve, and with the infrapatellar branch of the saphenous nerve, forming with them the peripatellar plexus.

The posterior branch pierces the fascia lata, and subdivides into filaments which pass backward across the lateral and posterior surfaces of the thigh, supplying the skin from the level of the greater trochanter at the hip, to the middle of the thigh.

Femoral nerve

The femoral nerve arises from the dorsal divisions of the ventral rami of L2-4. It descends through Psoas major, emerging from the muscle at the lower part of its lateral border, and passes down between it and Iliacus. It continues beneath the inguinal ligament and enters the femoral triangle, where it splits into an anterior and a posterior division.
**Anterior division** - this gives off anterior cutaneous and muscular branches. The anterior cutaneous branches are the intermediate cutaneous nerve and medial cutaneous nerve. The muscular branches are the nerve to pectineus which arises immediately below the inguinal ligament, and passes behind the femoral sheath to enter the anterior surface of the muscle. The nerve to sartorius arises together with the intermediate cutaneous nerve.

**Posterior division** - this division gives off the saphenous nerve, and muscular and articular branches.

The saphenous nerve is the largest cutaneous branch of the femoral nerve. It lies in front of the femoral artery, and follows the adductor canal (sub-sartorial canal) as far as the adductor foramen. At this point it leaves the course of the artery and emerges from behind the lower edge of the aponeurotic covering of the canal. It passes directly down along the medial side of the knee, pierces the fascia lata, between the tendons of the Sartorius and Gracilis, and becomes subcutaneous at this point. It then passes along the tibial side of the leg, accompanied by the great saphenous vein, descends behind the medial border of the tibia,
and, at the lower third of the leg, divides into a further two branches. One continues its course along the margin of the tibia, and ends at the ankle, whilst the other passes in front of the ankle, and is distributed to the skin on the medial side of the foot, as far as the first metatarsal phalangeal joint, where it communicates with the medial branch of the superficial peroneal nerve.

The muscular branches supply the four parts of the quadriceps compartment. The branch to rectus femoris enters the upper part of the deep surface of the muscle. The branch to vastus lateralis accompanies the descending branch of the lateral circumflex artery to the lower part of the muscle. The branch to vastus medialis descends laterally to the femoral vessels together with the saphenous nerve, before it enters the muscle belly. The branches to vastus intermedius enter the anterior surface of the muscle at mid-thigh level.

There are three articular branches to the knee-joint. The first is a long slender filament, derived from the nerve to vastus lateralis, which penetrates the knee joint capsule of the joint on its anterior aspect. A further branch, derived from the nerve to vastus medialis, runs downward on the surface of this muscle to near the joint where it penetrates the muscular fibers, and accompanies the articular branch of one of the genicular arteries, and supplies the synovial membrane. The third branch is derived from the nerve to vastus intermedius.

Obturator nerve
This is formed from the anterior branches of L2-4. It descends through the fibers of Psoas major, and emerges from its medial border near the pelvic brim (pelvic aperture). It then passes behind the common iliac vessels, and on the lateral side of the hypogastric vessels and ureter, which separate it from the ureter, and runs along the lateral wall of the lesser pelvis (area below the pelvic brim), above and in front of the obturator vessels, to the upper part of the obturator foramen. It passes through the obturator canal
and enters the thigh. Here it divides into an anterior and a posterior branch. The Obturator nerve is responsible for the sensory innervation of the skin of the medial aspect of the thigh. In terms of motor supply, it innervates the adductor muscles - external obturator, adductor longus, adductor brevis, adductor magnus, and gracilis.

**Posterior femoral cutaneous nerve**
The posterior cutaneous nerve of the thigh arises from the sacral plexus. It arises partly from the dorsal divisions of the first and second, and from the ventral divisions of the second and third sacral nerves. It leaves the pelvis through the greater sciatic foramen below the piriformis, before descending beneath gluteus maximus with the inferior gluteal artery, and running down the back of the thigh beneath the fascia lata, and over the long head of the biceps femoris to the back of the knee. At this point it passes through the deep fascia and runs with the short saphenous vein to about the middle of the back of the leg, where it communicates with the sural nerve.

Its branches are all cutaneous, and are distributed to the gluteal region, the perineum, and the back of the thigh and leg. The main part to the back of the thigh and leg consists of numerous filaments derived from both sides of the nerve, and distributed to the skin covering the back and medial side of the thigh, the popliteal fossa, and the upper part of the back of the leg.

**Sciatic nerve**
The sciatic supplies almost all of the skin of the leg, the muscles of the back of the thigh, and those of the leg and foot. It is derived from spinal nerves L4-5, and S1-S3. It contains fibres from both the anterior and posterior divisions of the lumbosacral plexus, giving off articular and muscular branches.

The **articular branches** (*rami articales*) arise from the upper part of the nerve and supply the hip, perforating the posterior part of its capsule; they are sometimes derived from the sacral plexus.
The muscular branches (*rami musculares*) are distributed to biceps femoris, semitendinosus, semimembranosus, and adductor magnus. The nerve to the short head of the biceps femoris comes from the common peroneal part of the sciatic, while the other muscular branches arise from the tibial portion. The muscular branch eventually gives off the tibial nerve and common peroneal nerve, which innervates the muscles of the leg. The tibial nerve goes on to innervate all muscles of the foot except the extensor digitorum brevis (which is innervated by the peroneal nerve).
**Tibial nerve**

The tibial nerve passes through the popliteal fossa to pass below the arch of soleus. In the popliteal fossa the nerve gives off branches to gastrocnemius, popliteus, soleus and plantaris muscles. Additionally, there are articular branches to the knee joint, and a cutaneous branch which subsequently becomes the sural nerve. The sural nerve is joined by fibres from the common fibular nerve and runs down the lateral side of the leg to supply the lateral side of the foot.

Below soleus the nerve runs close to the tibia, and supplies the muscle of the deep flexor compartment - tibialis posterior, flexor digitorum longus and the flexor hallucis longus. The nerve passes into the foot running behind the medial malleolus, together with the posterior tibial artery. They pass under the flexor retinaculum via the tarsal tunnel.

**Medial plantar nerve (internal plantar nerve),**

This is the larger of the two terminal divisions of the tibial nerve, and follows the route medial plantar artery.

From its origin under the lacinate ligament it passes under Abductor hallucis, and, appearing between this muscle and the Flexor digitorum brevis, gives off a proper digital plantar nerve and finally divides opposite the bases of the metatarsals into three common digital plantar nerves.

The branches of the medial plantar nerve are cutaneous, muscular, articular, a proper digital nerve to the medial side of the great toe, and three common digital nerves.

**Cutaneous branches** - The cutaneous branches pierce the plantar aponeurosis between Abductor hallucis and Flexor digitorum brevis and are distributed to the skin on the plantar aspect of the foot.

**Muscular branches** - These supply Abductor hallucis, Flexor digitorum brevis, Flexor hallucis brevis, and the first Lumbricalis. The branches supplying Abductor hallucis and Flexor digitorum brevis
arise from the trunk of the nerve near its origin and enter the deep surfaces of the muscles; the branch of the Flexor hallucis brevis springs from the proper digital nerve to the medial side of the great toe, and that for the first Lumbricalis from the first common digital nerve.

Articular branches - The articular branches supply the articulations of the mid- and fore-foot.

Proper digital nerve of the great toe - The proper digital nerve of the first toe supplies Flexor hallucis brevis and the skin on the medial side of the first toe.

Common digital nerves - these three run between the divisions of the plantar aponeurosis, and each splits into two proper digital nerves—those of the first common digital nerve supply the adjacent sides of the great and second toes; those of the second, the adjacent sides of the second and third toes; and those of the third, the adjacent sides of the third and fourth toes. The third common digital nerve receives a communicating branch from the lateral plantar nerve; the first gives a small branch to the first Lumbricalis.

Each proper digital nerve gives off cutaneous and articular filaments; and opposite the last phalanx sends upward a dorsal branch, which supplies the structures around the nail plate.

Lateral plantar nerve (external plantar nerve)
This is a branch of the tibial nerve, supplying the skin of the fifth digit and lateral half of the fourth, as well as most of the deep muscles. It runs obliquely forward with the lateral plantar artery to the lateral side of the foot, lying between Flexor digitorum brevis and Quadratus plantæ before dividing into a superficial and a deep branch. Before its division, it supplies Quadratus plantæ and abductor digiti minimi. Afterwards it supplies the skin of the fifth and fourth digits, as the fourth and fifth common digital nerves, themselves giving off cutaneous and articular branches.
Common fibular nerve (common peroneal nerve; external popliteal nerve; peroneal nerve)
This nerve forms a smaller branch of the sciatic nerve with it’s original spinal derivation being the dorsal branches of L4-5, and S1-2. It runs downward obliquely along the lateral side of the popliteal fossa to the head of the fibula, close to the medial border of the biceps femoris muscle. It lies between the tendon of the biceps femoris and lateral head of the gastrocnemius muscle, and winds around the neck of the fibula (where it is relatively superficial), between the peroneus longus and the bone. At this level is gives off articular and lateral sural cutaneous branches, before it divides beneath peroneus longus into the superficial fibular nerve (superficial peroneal nerve) and deep fibular nerve (deep peroneal nerve).

Articular branches - there are three, two of which accompany the superior and inferior lateral genicular arteries to the knee. The third articular nerve is given off at the point of division of the common fibular nerve and ascend to the front of the knee.

Lateral sural cutaneous nerve - this supplies the skin on the posterior and lateral surfaces of the leg.
**Superficial fibular nerve (superficial peroneal nerve)**

This innervates fibularis longus (peroneus longus) and fibularis brevis (peroneus brevis) together with the skin over the greater part of the dorsum of the foot (with the exception of the first inter-digital space). It passes forward between the fibularis muscles and extensor digitorum longus, pierces the deep fascia at the lower third of the leg, and finally divides into a medial dorsal cutaneous nerve and an intermediate dorsal cutaneous nerve. As well as this, the nerve gives off muscular branches to fibularis longus and brevis muscles, and cutaneous filaments to the lower leg.

**Deep fibular nerve (deep peroneal nerve)**

This runs between the upper section of the fibula and upper part of fibularis longus, passing infero-medially, and deep to extensor digitorum longus, to the anterior surface of the interosseous membrane. Here it runs with the anterior tibial artery, first lying on the lateral side of the artery, then in front of it, and again on its lateral side at the ankle-joint. The nerve and artery descend together to pass anterior to the ankle joint. From here it divides into a lateral and a medial terminal branch. In the leg, the deep fibular nerve supplies muscular branches to tibialis anterior, extensor digitorum longus, fibularis tertius (if present), and extensor hallucis longus, and an articular branch to the ankle joint.
Dermatomes and cutaneous distribution.

Each spinal nerve carries both sensory and motor neurones, and serves a specific and constant section of the body. The area of skin supplied by a single spinal nerve is called a dermatome. Cutaneous distribution refers to an area supplied by an anatomical nerve, such as the femoral nerve, which itself is made up of a number of spinal nerves, and therefore the femoral nerve has distribution relating to all of the dermatomal areas of the spinal nerves which contribute to the femoral nerve (L2, L3, L4).

The nerve supply to adjacent dermatomes does overlap, therefore if a single spinal nerve is damaged there is not necessarily complete loss of sensation in its related dermatome.

A myotome represents the skeletal muscles supplied by a single spinal nerve, and osteotome refers to the areas on bony innervation supplied by a single spinal nerve.

There is value in being aware of dermatomal and myotomal distribution as functional loss in these areas may well correspond to the level of damage within the spinal cord.
In the diagram below, the coloured areas represent cutaneous distribution, whereas the dermatomes are indicated by the black outlines.