Relations to the Psoas muscle

From Gray's Anatomy.

Muscular system

Muscles of the Iliac Region

Although there is no 'iliac region' as such, this heading conveniently describes a group of three muscles that originate from the lumbar vertebral column (psoas major and minor) and the iliac bone (iliacus). Two (psoas major and iliacus) are attached together on the femur as flexors; psoas minor falls short of this and acts on the spine and sacro-iliac joint.

Iliac Fascia
The iliac fascia covers psoas and iliacus. It is thin above, but thickens progressively towards the inguinal ligament. The part covering psoas is thickened above as the medial arcuate ligament. Medially, the fascia over psoas is attached by a series of fibrous arches to the intervertebral discs, margins of vertebral bodies, and the upper part of the sacrum. Laterally, it blends with the fascia anterior to quadratus lumborum above the iliac crest, and with the fascia covering iliacus below the crest.
The iliac part is connected laterally to the whole of the inner lip of the iliac crest and medially to the pelvic brim, where it blends with the periosteum. It is attached to the iliopectineal eminence, where it receives a slip from the tendon of psoas minor, when that muscle is present. The external iliac vessels are anterior to the fascia but the branches of the lumbar plexus are posterior; it is separated from the peritoneum by loose extraperitoneal tissue. Lateral to the femoral vessels, the iliac fascia is continuous with the posterior margin of the inguinal ligament and the transversalis fascia. Medially it passes behind the femoral vessels to become the pectineal fascia, attached to the pecten pubis. At the junction of its lateral and medial parts it is attached to the iliopectineal eminence and the capsule of the hip joint. It thus forms a septum between the inguinal ligament and the hip bone, dividing the space here into a lateral part, the lacuna musculorum, containing psoas major, iliacus and the femoral nerve, and a medial part, the lacuna vasorum, transmitting the femoral vessels. The iliac fascia continues downward to form the posterior wall of the femoral sheath.

Psoas Major
Psoas major is a long muscle that lies on either side of the lumbar vertebral column and the pelvic brim. It arises:

- from the anterior surfaces and lower borders of the transverse processes of all the lumbar vertebrae
- by five digitations, each from the bodies of two adjoining vertebrae and their intervertebral disc. The highest slip arises from the lower margin of the body of the twelfth thoracic vertebra, the upper margin of the body of the first lumbar vertebra and the interposed thoracolumbar disc; the lowest from the adjacent margins of the bodies of the fourth and fifth lumbar vertebrae and the interposed disc
- from a series of tendinous arches extending across the narrow parts of the bodies of the lumbar vertebrae between the digitations already described. The

lumbar arteries and veins, and filaments from the sympathetic trunk, pass medial to these arches.
The upper four lumbar intervertebral foramina bear important relations to these attachments of the muscle. The foramina lie anterior to the transverse processes and posterior to the attachments to vertebral bodies, discs and tendinous arches. Thus, the roots of the lumbar plexus enter the muscle directly; the plexus is lodged within it, and its branches emerge from its borders and surfaces.
The muscle descends along the pelvic brim, continues posterior to the inguinal ligament and anterior to the capsule of the hip joint, and converges to a tendon which, having received on its lateral side nearly all the fibres of iliacus, becomes attached to the lesser trochanter of the femur. The large subtendinous iliac bursa, which occasionally communicates with the cavity of the hip joint, separates the tendon from the pubis and the capsule of the joint.

Variations

The complex vertebral attachments of psoas major sometimes display minor numerical variations.

Relations

The upper limit of psoas major is posterior to the diaphragm in the lowest part of the posterior mediastinum. It may be in contact with the posterior extremity of the pleural sac. In the abdomen its anterolateral surface is related to the medial arcuate ligament—an arched thickening in the general psoas fascia, extraperitoneal tissue and peritoneum, the kidney, psoas minor, renal vessels, ureter, testicular or ovarian vessels and genitofemoral nerve. In front the right psoas is overlapped by the inferior vena cava and traversed by the end of the ileum; the left is crossed by the colon. Its posterior surface is in relation with the transverse processes of the lumbar vertebrae and the medial edge of quadratus lumborum. As already noted, the lumbar plexus is embedded posteriorly in the substance of the muscle. Medially the muscle is related to the bodies of the lumbar vertebrae and lumbar vessels. Along its anteromedial margin it is in contact with the sympathetic trunk, aortic lymph nodes and, along the pelvic brim, with the external iliac artery. This margin is covered by the inferior vena cava on the right side, and lies posterior and lateral to the abdominal aorta on the left side. In the thigh it is related: in front, to the fascia lata and the femoral artery; by a bursa; behind, to the capsule of the hip joint, from which it is separated at its medial border, to pectineus and the medial circumflex femoral artery, and the femoral vein, which may overlap it slightly; at its lateral border, to the femoral nerve and iliacus.
The femoral nerve descends at first through the fibres of psoas major, and then in the furrow between it and iliacus.
Branches of the lumbar plexus diverge from the abdominal part of psoas. Emerging from the lateral border, from above downwards, are: the iliohypogastric, ilio-inguinal and lateral femoral cutaneous and femoral nerves; from the anterolateral surface, the genitofemoral nerve; from the medial border, the obturator and accessory obturator nerves and the upper root of the lumbosacral trunk.

Blood Supply

Lumbar arteries 1–4; variably arteria lumbalis ima; twigs from the renal artery; common iliac artery; external iliac artery; lumbar branch of iliolumbar artery; variably, obturator artery and medial circumflex femoral artery.

Nerve Supply

Ventral rami of the lumbar spinal nerves, L1, 2 and 3.

Actions

Psoas major acts together with iliacus, the combination being referred to as iliopsoas

Psoas Minor

Psoas minor lies anterior to psoas major, entirely within the abdomen. It arises from the sides of the bodies of the twelfth thoracic and first lumbar vertebrae and from the disc between them. It ends in a long, flat tendon which is attached to the pecten pubis and iliopectineal eminence and, laterally, to the iliac fascia.

Variations

The muscle is absent in about 40% of subjects.

Blood Supply

Lumbar arteries; arteria lumbalis ima; the lumbar branch of the iliolumbar artery; common iliac artery; sometimes the obturator artery and deep circumflex artery.

Nerve Supply

A branch from the first lumbar nerve.

Action

Psoas minor is probably a weak flexor of the trunk.

Iliacus

Iliacus is a triangular sheet of muscle which arises from the superior two-thirds of the concavity of the iliac fossa, the inner lip of the iliac crest, the ventral sacro-iliac and iliolumbar ligaments, and the upper surface of the lateral part of the sacrum. In front, it reaches as far as the anterior superior and anterior inferior iliac spines, and receives a few fibres from the upper part of the capsule of the hip joint. Most of its fibres converge into the lateral side of the strong tendon of psoas major, and the muscles then insert together into the lesser trochanter, but some fibres are attached directly to the femur for about 2.5 cm below and in front of the lesser trochanter.

Relations

In the abdomen, the anterior surface of iliacus is related to: its fascia, which separates the muscle from extraperitoneal tissue and peritoneum; the lateral femoral cutaneous nerve; on the right, the caecum; on the left, the iliac part of the descending colon. On its posterior surface is the iliac fossa; at its medial border, psoas major and the femoral nerve. In the thigh, its anterior surface is in contact with the fascia lata, rectus femoris, sartorius and arteria profunda femoris, its posterior surface with the capsule of the hip joint, from which it is separated by a bursa common to it and psoas major.

Blood Supply

Iliac branch of iliolumbar artery; iliac branches of obturator artery; lateral circumflex femoral artery; arteria profunda femoris.

Nerve Supply

Branches of the femoral nerve, L2 and 3.

Actions

Psoas major, acting from above together with iliacus, flexes the thigh upon the pelvis. Electromyographic studies do not support the common view that psoas major acts as a medial rotator of the hip joint, but activity has been described in lateral rotation, particularly in the young. When psoas major and iliacus of both sides act from below, they contract powerfully to bend the trunk and pelvis forwards against resistance, as in raising the trunk from the recumbent to the sitting posture.

Geometrical reasoning suggests that, with the body erect and the lower limb fixed, contraction of one psoas major might flex the trunk forwards and laterally; however, electromyography does not support such a prediction, but indicates maximum activity when the lumbar curvature is increased. Direct electromyographic recording from the

muscle during sympathectomy in the lumbar region suggests that in addition to its role as a hip flexor, psoas major is active in balancing the trunk while sitting.
In symmetrical standing, iliopsoas might be expected to act from below to maintain the vertebral column upright. This would be in accordance with the principle that a muscle which is so close to a joint centre is likely to have an important postural or stabilizing function. Basmajian and Greenlaw (1968) confirmed this by reporting continuous slight to moderate electrical activity during relaxed standing. The fact that there is so little activity in most subjects can be understood by drawing a vertical line through the centre of gravity of the body. Such a line falls behind the transverse axis of the hip joints, which are near their close-packed positions, with spiralization and tautening of the ligaments (especially the iliofemoral) and marked compression and congruence of the articular surfaces. Thus the extending torque exerted by the weight of the trunk is balanced mainly by passive mechanisms.

Clinical Anatomy

When the neck of the femur is fractured psoas major acts as a lateral rotator of the femur, producing a characteristic posture of the lower limb.

Quadratus Lumborum

Quadratus lumborum has an irregularly quadrilateral shape which is broader inferiorly. It is attached below by aponeurotic fibres to the iliolumbar ligament and the adjacent portion of the iliac crest for about 5 cm, and above to the medial half of the lower border of the twelfth rib, and by four small tendons to the apices of the transverse processes of the upper four lumbar vertebrae, and sometimes to the transverse process or body of the twelfth thoracic.

Variations

Occasionally a second layer of this muscle is found in front of the first: it passes from the upper borders of the transverse processes of the lower three or four lumbar vertebrae to the lower margin and the lower part of the anterior surface of the last rib.

Relations

Anterior to quadratus lumborum are the colon, kidney, psoas major and minor, and diaphragm; the subcostal, iliohypogastric and ilio-inguinal nerves are anterior to the fascia over the muscle, but are bound down to it by the medial continuation of the transversalis fascia.

Blood Supply

Lumbar arteries; arteria lumbalis ima; the lumbar branch of the iliolumbar artery; subcostal artery.

Nerve Supply

Ventral rami of the twelfth thoracic and upper three or four lumbar spinal nerves.

Actions

Quadratus lumborum fixes the last rib, and acts as a muscle of inspiration by helping to stabilize the lower attachments of the diaphragm. It has been suggested that this action might also provide a fixed base for controlled relaxation of the diaphragm in the precise adjustment of expiration needed for speech and singing (Taylor 1960). With the pelvis fixed, quadratus acts upon the vertebral column, flexing it to the same side. When both muscles contract they probably help to extend the lumbar part of the vertebral column.

Muscles of the Thigh—Medial Group

This group has evolved, as its nerve supply suggests, from both flexor and extensor columns. All five muscles—gracilis, pectineus, adductor longus, adductor brevis, and adductor magnus—cross the hip joint, but only gracilis reaches beyond the knee. They are known collectively as the adductors of the thigh, although their actions are more complex than this.

Gracilis

Gracilis is the most superficial of the adductor group. It is thin and flat, broad above, narrow and tapering below. It arises by a thin aponeurosis from the medial margins of the lower half of the body of the pubis, the whole of the inferior pubic ramus, and the adjoining part of the ischial ramus . The fibres descend vertically into a rounded tendon which passes across the medial condyle of the femur posterior to the tendon of sartorius. It then curves around the medial condyle of the tibia, where it fans out and attaches to the upper part of the medial surface of the tibia, just below the condyle. A few fibres from the lower part of the tendon continue into the deep fascia of the lower leg. The attachment is immediately proximal to that of semitendinosus, and its upper edge is overlapped by the tendon of sartorius, with which it is partly blended. It is separated from the tibial collateral ligament of the knee joint by the tibial intertendinous bursa.

Blood Supply

Obturator artery ; medial circumflex femoral artery; descending genicular artery; superior and inferior medial genicular arteries; femoral artery.

Nerve Supply

Obturator nerve, L2 and 3.

Actions

Gracilis flexes the leg and rotates it medially; it may also act as an adductor of the thigh.

Pectineus

Pectineus is a flat, quadrangular muscle in the femoral triangle. It arises from the pecten pubis, from the bone in front of it between the iliopectineal eminence and the pubic tubercle, and from the fascia on its own anterior surface. The fibres descend posterolaterally to attach along a line from the lesser trochanter to the linea aspera.

Variations

The muscle may be bilaminar, as it is in some other mammals, the two layers receiving separate nerve supplies (see below). Proximally it may be partially or wholly attached to the capsule of the hip joint.

Relations

It is related anteriorly to the fascia lata, which separates it from the femoral vessels and great saphenous vein; posteriorly to the capsule of the hip joint, adductor brevis, obturator externus and the anterior branch of the obturator nerve; laterally to psoas major and the medial circumflex femoral vessels; medially to the lateral margin of adductor longus.

Blood Supply

Obturator artery; medial circumflex femoral artery; first perforating branch of arteria profunda; deep external pudendal artery; femoral artery.

Nerve Supply

Femoral nerve, L2 and 3; and accessory obturator, L3, when present. Occasionally it receives a branch from the obturator nerve. The muscle may be incompletely divided into dorsal and ventral strata, supplied respectively by obturator and femoral (or accessory obturator) nerves. Woodburne (1960) found only 69 out of 800 cases with a partial supply from an accessory obturator nerve.

Actions

Pectineus adducts the thigh and flexes it on the pelvis.

Adductor Longus

Adductor longus, the most anterior of the three adductors, is a large, fan-shaped muscle in the same plane as pectineus. It arises by a narrow tendon with a flattened (sometimes C-shaped) cross-section, which is attached to the front of the pubis in the angle between the crest and the symphysis. It expands into a broad fleshy belly which descends posterolaterally and inserts by an aponeurosis into the linea aspera in the middle third of the femur, between vastus medialis and the other two adductors (magnus and brevis), usually blending with all of them.

Variations

The muscle is occasionally double.

Relations

Anterior to adductor longus are the spermatic cord, fascia lata (which separates it from the great saphenous vein) and, near its attachment, the femoral artery and vein and sartorius. Posterior to it are adductor brevis and adductor magnus, the anterior branch of the obturator nerve and, near its attachment, the profunda femoris vessels. Lateral is pectineus; medial is gracilis.

Blood Supply

Femoral artery; arteria profunda femoris, direct branches and, variably, first to third perforating arteries; medial circumflex femoral artery; obturator artery.

Nerve Supply

Anterior division of the obturator nerve, L2, 3 and 4.

Adductor Brevis

Adductor brevis lies posterior to pectineus and adductor longus. It arises by a narrow attachment from the external aspect of the body and inferior ramus of the pubis, between gracilis and obturator externus. Like adductor longus it is somewhat triangular, and expands as it descends posterolaterally to insert via an aponeurosis into the femur, along a line from the lesser trochanter to the linea aspera, and on the upper part of the linea immediately behind pectineus and the upper part of adductor longus.

Variations

Adductor brevis often has two or three separate parts, or it may be integrated into adductor magnus.

Relations

Anterior are pectineus, adductor longus, arteria profunda femoris, and the anterior branch of the obturator nerve; posterior are adductor magnus and the posterior branch of the obturator nerve. The upper border of adductor brevis is related to the medial circumflex femoral artery, obturator externus, and the conjoined tendon of psoas major and iliacus; its lower border, to gracilis and adductor magnus. The second, or first and second, perforating arteries pierce it near its femoral attachment.

Blood Supply

Femoral artery; arteria profunda femoris, direct branches and, variably, first to third perforating arteries; medial circumflex femoral artery; obturator artery.

Nerve Supply

Obturator nerve, L2, 3.

Adductor Magnus

Adductor magnus, a massive triangular muscle, arises from a small part of the inferior ramus of the pubis, from the conjoined ischial ramus, and from the inferolateral aspect of the ischial tuberosity. The short, horizontal fibres from the pubic ramus insert into the medial margin of the gluteal tuberosity of the femur, medial to gluteus maximus; this part of the muscle, in a plane anterior to the rest, is sometimes called adductor minimus. The fibres from the ischial ramus fan out downwards and laterally, to insert via a broad aponeurosis into the linea aspera and the proximal part of the medial supracondylar line. The medial part of the muscle, composed mainly of fibres from the ischial tuberosity, is a thick mass which descends almost vertically, and ends in the lower third of the thigh in a rounded tendon, which can be palpated proximal to its attachment to the adductor tubercle on the medial condyle of the femur. The tendon is connected by a fibrous expansion to the medial supracondylar line.

The long, linear attachment of the muscle is interrupted by a series of osseo-aponeurotic openings, bridged by tendinous arches attached to the bone. The upper four are small, and transmit the perforating branches and the termination of arteria profunda femoris. The lowest is large, and allows the femoral vessels to cross to the popliteal fossa.

Variations

The vertical, ischiocondylar part of the muscle varies in its degree of separation from the rest. The upper border of adductor magnus may fuse with quadratus femoris.

Relations

Anterior are pectineus, adductor brevis and adductor longus, the femoral and profunda vessels, and the posterior branch of the obturator nerve; a bursa separates the proximal part of the muscle from the lesser trochanter of the femur. Posterior are the sciatic nerve, gluteus maximus, biceps femoris, semitendinosus and semimembranosus. The superior border is parallel with quadratus femoris, the transverse branch of the medial circumflex femoral artery passing between the muscles. The medial border is related to gracilis, sartorius and the fascia lata.

Blood Supply

Femoral artery; arteria profunda femoris, direct branches and all perforating arteries; medial circumflex femoral artery; obturator artery.

Nerve Supply

Adductor magnus is composite and is doubly innervated by the obturator nerve and the tibial division of the sciatic nerve (L2, 3 and 4); the latter nerve supplies the ischiocondylar part. Both nerves are derived from anterior divisions in the lumbrosacral plexus, indicating a primitive flexor origin for both parts of the muscle.

Actions

Extensive or forcible adduction of the femur is not often called for, and although the adductors can act in this way when required, they are more commonly synergists in the complex patterns of gait activity, and to some degree controllers of posture. They are, for example, active during flexion and extension of the knee (Janda & Stara 1965). Magnus and longus are probably medial rotators of the thigh, according to de Sousa and Vitti (1966), who also observed that whereas the adductors are inactive

during adduction of the abducted thigh in the erect posture (when gravity assists), they are active in other postures, such as the supine position, or during adduction of the flexed thigh when standing. The adductors are also active during flexion (longus) and extension (magnus) of the thigh at the hip joint. In symmetrical easy standing their activity is minimal.

Deep Gluteal muscles

Piriformis

Piriformis occupies a central position in the buttock, where it lies in the same plane as gluteus medius. It arises from the anterior surface of the sacrum by three digitations, which are attached to the portions of bone between the pelvic sacral foramina, and to the grooves leading from the foramina: it also arises from the gluteal surface of the ilium near the posterior inferior iliac spine, from the capsule of the adjacent sacro-iliac joint and sometimes from the upper part of the pelvic surface of the sacrotuberous ligament. The muscle passes out of the pelvis through the greater sciatic foramen, which it substantially fills; here it constitutes an important point of reference for structures that emerge above and below it. It inserts into the medial side of the upper border of the greater trochanter of the femur via a rounded tendon, which lies behind and above, but is often partially blended with, the common tendon of obturator internus and the gemelli. The muscle itself may be fused with gluteus medius.

Relations

Within the pelvis: the anterior surface of piriformis is related to the rectum (especially on the left), the sacral plexus of nerves and branches of the internal iliac vessels; the posterior surface is against the sacrum. Outside the pelvis: its anterior surface is in contact with the posterior surface of the ischium and capsule of the hip joint; its posterior surface, with gluteus maximus. Its upper border is in contact with gluteus medius, and the superior gluteal vessels and nerve; its lower border, with coccygeus and gemellus superior. The inferior gluteal and internal pudendal vessels, the sciatic, posterior femoral cutaneous and pudendal nerves, and muscular branches from the sacral plexus appear in the buttock in the interval between piriformis and gemellus superior. The muscle is frequently pierced by the common peroneal nerve, which may divide it into two parts.

Variations

The variable relationship between the sciatic nerve and piriformis has been documented by Anson (1963) and by Lee and Tsai (1974). They observed variations in which the undivided nerve emerged above the muscle, through the muscle, with its divisions above and below, or with one division between the heads of a divided muscle and one division either above or below; the last was the most common configuration.

Blood Supply

In the pelvis: inferior gluteal artery; superior gluteal artery ; internal pudendal artery; lateral sacral artery. In the buttock: inferior gluteal artery; superior gluteal artery; internal pudendal artery; vessels forming the cruciate anastomosis .

Nerve Supply

Branches from L5, S1 and 2.

Actions

Piriformis rotates the extended thigh laterally, but abducts the flexed thigh.

Obturator Membrane

The obturator membrane is a thin aponeurosis which closes (obturates) most of the obturator foramen, leaving an anterosuperior aperture, the obturator canal, through which the obturator vessels and nerve leave the pelvis and enter the thigh. The membrane is attached to the sharp margin of the obturator foramen except at its inferolateral angle, where it is fixed to the pelvic surface of the ischial ramus, i.e. internal to the foramen. Its fibres are arranged mainly transversely in interlacing bundles; the uppermost bundle, which is attached to the obturator tubercles, completes the obturator canal. The two surfaces of the obturator membrane provide attachment for the two obturator muscles, internus and externus, and some fibres of the pubofemoral ligament of the hip joint are attached to the external surface.

Obturator Internus

Obturator internus is situated partly within the true pelvis and partly posterior to the hip joint. It arises from the internal surface of the anterolateral wall of the lesser pelvic cavity; its attachments, which almost surround the obturator foramen, are to the inferior ramus of the pubis, the ischial ramus, and the pelvic surface of the hip bone below and behind the pelvic brim, to the upper part of the greater sciatic foramen above and behind, to the obturator foramen below and in front. It also arises from the medial part of the pelvic surface of the obturator membrane, from the tendinous arch which completes the obturator canal, and, to a small extent, from the obturator fascia that covers the muscle. The fibres converge rapidly towards the lesser sciatic foramen and end in four or five tendinous bands on the deep surface of the muscle; these bands make a lateral right-angled turn around the grooved surface of the ischium between its spine and tuberosity. The grooved surface is covered with a smooth layer of hyaline cartilage and is separated from the tendon by a bursa; ridges on the surface correspond to furrows between the tendinous bands. These bands leave the pelvis through the lesser sciatic foramen and unite to form a single flattened tendon, which passes horizontally across the capsule of the hip joint. The gemelli fuse with this tendon before it inserts into an anterior impression on the medial surface of the greater trochanter anterosuperior to the trochanteric fossa. A long, narrow bursa is usually interposed between the tendon and the capsule of the hip joint; it occasionally communicates with the bursa between the tendon and the ischium.

Relations

Within the pelvis, the anterolateral surface of the muscle is in contact with the obturator membrane and inner surface of the lateral wall of the pelvis; its posteromedial surface contacts the obturator fascia, the origin of levator ani, and the sheath that surrounds the internal pudendal vessels and pudendal nerve, and forms the lateral wall of the ischiorectal fossa. Outside the pelvis, the muscle is covered by gluteus maximus, is crossed posteriorly by the sciatic nerve and passes behind the hip joint. As the tendon of obturator internus emerges from the lesser sciatic foramen it is overlapped both above and below by the two gemelli, which form a muscular canal for it; near its termination the gemelli pass anterior to the tendon and form a groove in which it lies.

Blood Supply

In the pelvis: inferior gluteal artery; superior gluteal artery; internal pudendal artery. In the buttock: inferior gluteal artery; vessels forming the cruciate anastomosis.

Nerve Supply

Nerve to obturator internus, L5 and S1.

Actions

Considered below with obturator externus.

Gemellus Superior

Gemellus superior, the smaller of the two gemelli, arises from the dorsal surface of the ischial spine, blends with the upper border of the tendon of obturator internus, and inserts with it into the medial surface of the greater trochanter. It is sometimes absent.

Gemellus Inferior

Gemellus inferior arises from the upper part of the ischial tuberosity, immediately below the groove for the obturator internus tendon. It blends with the lower border of this tendon, and inserts with it into the medial surface of the greater trochanter.

The two gemelli can be regarded as accessory to obturator internus, to which they add attachments external to the pelvis.

Blood Supply

Both gemelli are supplied by the inferior gluteal artery, superior gluteal artery, internal pudendal artery and vessels forming the cruciate anastomosis.

Nerve Supply

Gemellus superior is supplied by the nerve to obturator internus, L5 and S1; gemellus inferior is supplied by the nerve to quadratus femoris, L5 and S1.

Actions

The gemelli rotate the extended thigh laterally; they abduct the flexed thigh.

Quadratus Femoris

Quadratus femoris is a flat, quadrilateral muscle lying between gemellus inferior and the upper margin of adductor magnus, from which it is separated by the transverse branch of the medial circumflex femoral artery. It arises from the upper part of the external aspect of the ischial tuberosity and passes behind the hip joint and the neck of the femur, separated from them by the tendon of obturator externus and the ascending branch of the medial circumflex femoral artery. It inserts into a small tubercle a little above the middle of the trochanteric crest of the femur and into the bone for a short distance below. A bursa is often present between the muscle and the lesser trochanter. The muscle may be absent.

Blood Supply

Internal pudendal artery; inferior gluteal , lateral and medial circumflex femoral, and first perforating arteries, i.e. vessels forming the cruciate anastomosis.

Nerve Supply

Nerve to quadratus femoris, L5 and S1.

Action

Lateral rotation of the thigh.

Obturator Externus

Obturator externus is a flat, triangular muscle covering the external surface of the anterior pelvic wall. It arises from the medial two-thirds of the external surface of the obturator membrane, and from the adjacent bone of the pubic and ischial rami, extending for a short distance onto their pelvic surfaces between the margin of the obturator foramen and the obturator membrane (see above). The whole muscle, and the tendon into which its fibres converge, spirals backwards, laterally and upwards, and crosses the back of the neck of the femur and lower part of the capsule of the hip

joint to end in the trochanteric fossa of the femur. A bursa, which communicates with the hip joint, may be interposed between this tendon and the hip joint capsule and femoral neck. The obturator vessels lie between the muscle and the obturator membrane; the anterior branch of the obturator nerve reaches the thigh by passing in front of the muscle, and the posterior branch by piercing it.

Blood Supply

Obturator artery; medial circumflex femoral artery, particularly its ascending branch; at the insertion of the muscle, anastomosis of the latter with branches of the gluteal and lateral circumflex femoral arteries.

Nerve Supply

Posterior branch of the obturator nerve, L3 and 4.

Actions

It has been suggested that the short muscles around the hip joint—pectineus, piriformis, obturators, gemelli and quadratus femoris—are more important as postural muscles than as prime movers, acting as adjustable ligaments to maintain the stability and integrity of the hip. However, these muscles are largely inaccessible to direct observation, and because of the hazards presented by their close relationship to important neurovascular structures there is a total lack of electromyographic data in man. A comparative electromyographic study of the obturator muscles, conducted mainly in apes, has indicated that earlier speculations about the function of these muscles may be inaccurate (Stern & Larson 1993). In both bipedal walking and vertical climbing obturator externus was recruited during the early part of swing phase: in climbing it effected lateral rotation of the thigh, and in walking it probably counteracted the tendency to medial rotation produced by the anterior adductor muscles at this stage of the cycle. Obturator internus differed from externus in its pattern of use but its role in bipedal walking remains unclear. Its attachments suggest that it—like the gemelli—is a lateral rotator of the extended thigh and an abductor of the flexed thigh; these actions may be used to antagonize unwanted components of movement produced by the primary locomotor muscles.

Diaphragm

The diaphragm is a curved musculofibrous sheet that separates the thoracic from the abdominal cavity, its mainly convex upper surface facing the former, and its concave inferior surface directed towards the latter. Its muscle fibres arise from the highly oblique circumference of the thoracic outlet, the attachments being low posteriorly and laterally, but high anteriorly. Although it is a continuous sheet the muscle can be considered to form three parts—sternal, costal and lumbar—based on the regions of peripheral attachment. The sternal part arises by two fleshy slips from the back of the xiphoid process; it is not always present. The costal part arises from the internal surfaces of the lower six costal cartilages and their adjoining ribs on each side, interdigitating with transversus abdominis. The lumbar part arises from two aponeurotic arches, the medial and lateral arcuate ligaments (sometimes termed lumbocostal arches) and from the lumbar vertebrae by two pillars or crura (sing. crus).

The lateral arcuate ligament, a thickened band in the fascia that covers quadratus lumborum, arches across the upper part of that muscle. It is attached medially to the front of the transverse process of the first lumbar vertebra, and laterally to the lower margin of the twelfth rib near its midpoint.

The medial arcuate ligament is a tendinous arch in the fascia that covers the upper part of psoas major. Medially, it is continuous with the lateral tendinous margin of the corresponding crus, and is thus attached to the side of the body of the first or second lumbar vertebra; laterally, it is fixed to the front of the transverse process of the first lumbar vertebra.

The crura are tendinous at their attachments, and blend with the anterior longitudinal ligament of the vertebral column. The right crus is broader and longer than the left. It arises from the anterolateral surfaces of the bodies and intervertebral discs of the upper three lumbar vertebrae. The left crus arises from the corresponding parts of the upper two lumbar vertebrae. The medial tendinous margins of the crura meet in the midline to form an arch across the front of the aorta at the level of the thoracolumbar disc; this median arcuate ligament is often poorly defined.

From these circumferential attachments the fibres of the diaphragm converge into a central tendon. Fibres from the xiphoid process are short, and run almost horizontally; they are occasionally aponeurotic. Fibres from the medial and lateral arcuate ligaments, and more especially those from the ribs and their cartilages, are longer; they rise almost vertically at first and then curve towards their central attachment. Fibres from the crura diverge, the most lateral becoming more lateral as they ascend to the central tendon. Medial fibres of the right crus embrace the oesophagus where it passes through the diaphragm, the more superficial fibres ascending on the left and deeper fibres covering the right margin. This important structure will be returned to again. Sometimes a fleshy fasciculus from the medial side of the left crus crosses the aorta and runs obliquely through the fibres of the right crus towards the vena caval opening, but this fasciculus does not continue upwards around the oesophageal passage on the right side (Low 1907).

The central tendon of the diaphragm is a thin but strong aponeurosis of closely interwoven fibres situated near the centre of the muscle, but closer to the front of the thorax, so that the posterior muscular fibres are longer. In the centre it lies immediately below the pericardium, with which it is partially blended. Its shape is trifoliate. The middle, or anterior, leaf has the form of an equilateral triangle with the apex directed towards the xiphoid process. The right and left folia are tongue-shaped and curve laterally and backwards, the left being a little narrower. The central area of the tendon consists of four well-marked diagonal bands fanning out from a thick central node where compressed tendinous strands decussate in front of the oesophagus and to the left of the vena cava.

The Diaphragmatic Apertures

Structures pass between the thorax and abdomen through apertures in the diaphragm. There are three large openings—for the aorta, the oesophagus and the vena cava —and a number of smaller ones.

The aortic aperture is the lowest and most posterior of the large openings; it is at the level of the lower border of the twelfth thoracic vertebra and the thoracolumbar intervertebral disc, slightly to the left of the midline. It is an osseo-aponeurotic opening defined by the diaphragmatic crura laterally, the vertebral column posteriorly and the diaphragm anteriorly. Strictly speaking, therefore, it lies behind the diaphragm and its median arcuate ligament (when present). Occasionally some tendinous fibres from the medial parts of the crura also pass behind the aorta, converting the opening into a fibrous ring. The aortic opening transmits the aorta and the thoracic duct and sometimes the azygos and hemiazygos veins; some lymphatic trunks also descend through it from the lower posterior thoracic wall.

The oesophageal aperture is located at the level of the tenth thoracic vertebra, above, in front, and a little to the left of the aortic opening. It transmits the oesophagus, gastric nerves, oesophageal branches of the left gastric vessels and some lymphatic vessels. The elliptical opening, whose long axis is slightly oblique, is bounded by muscle fibres that originate in the medial part of the right crus and cross the midline (Low 1907). These fibres form a chimney about 2.5 cm long, which accommodates the terminal portions of the oesophagus. The outermost fibres run in a craniocaudal direction, and the innermost fibres are arranged circumferentially (Mittal 1990). There is no direct continuity between the oesophageal wall and the muscle around the oesophageal opening. The fascia on the inferior surface of the diaphragm, which is continuous with the transversalis fascia and is rich in elastic fibres, extends upwards into the opening as a flattened cone to blend with the wall of the oesophagus 2 to 3 cm above the oesophagogastric (squamocolumnar) junction. Some of its elastic fibres penetrate to the submucosa of the oesophagus. This peri-oesophageal areolar tissue is referred to as the phreno-oesophageal ligament; it connects the oesophagus flexibly to the diaphragm, permitting some freedom of movement during swallowing and respiration and at the same time limiting upward displacement of the oesophagus (Allison 1951; Hayward 1961).

The vena caval aperture, the highest of the three large openings, lies at about the level of the disc between the eighth and ninth thoracic vertebrae. It is quadrilateral, and located at the junction of the right leaf with the central area of the tendon, so its margins are aponeurotic. It is traversed by the inferior vena cava, which adheres to the margin of the opening, and some branches of the right phrenic nerve.

There are two lesser apertures in each crus; one transmits the greater and the other the lesser splanchnic nerve. The ganglionated trunks of the sympathetic usually enter the abdominal cavity behind the diaphragm, deep to the medial arcuate ligament. Openings for minute veins frequently occur in the central tendon.

On each side of the diaphragm are small areas where the muscle fibres are replaced by areolar tissue. One, between the sternal and costal parts, contains the superior epigastric branch of the internal thoracic artery and some lymph vessels from the abdominal wall and convex surface of the liver. The other, between the costal part and the fibres springing from the lateral arcuate ligament, is less constant; when it is present, the posterosuperior surface of the kidney is separated from the pleura only by areolar tissue.

Shape and Relations of the Diaphragm

The upper surface of the diaphragm lies in relation to three serous membranes: on each side, the pleura separates it from the base of the corresponding lung, and over the middle folium of the central tendon the pericardium is interposed between it and the heart. The latter area, which is almost flat, is referred to as the cardiac plateau; it extends more to the left than the right. In anteroposterior view the superior profile of the diaphragm rises on either side of the cardiac plateau to a smooth convex dome or cupola, the cupola on the right being higher and slightly broader. Most of the inferior surface is covered by peritoneum. The right side is accurately moulded over the convex surface of the right lobe of the liver, the right kidney and right suprarenal gland; the left side conforms to the left lobe of the liver, the fundus of the stomach, the spleen, the left kidney and the left suprarenal gland. (In view of these differences in the profile and anatomical relationships of the right and left diaphragm, the side should always be specified in clinical descriptions.)

Blood Supply

Musculophrenic arteries; superior epigastric arteries ; pericardiacophrenic arteries; inferior phrenic arteries; upper three right lumbar arteries; upper two left lumbar arteries; superior phrenic branches of lower descending thoracic aorta; right and left lower three posterior intercostal arteries.

Nerve Supply

The diaphragm receives its motor supply via the phrenic nerves. Sensory fibres are distributed to the peripheral part of the muscle by the lower six or seven intercostal nerves. It has been suggested that the motor innervation of the crural fibres comes from intercostal nerves, but Shehata (1966) has confirmed that the phrenic nerves are the source of supply. The right crus of the diaphragm, whose fibres divide to the right and left of the oesophageal opening, is innervated by both right and left phrenic nerves. Although the crural fibres are not innervated separately from the rest of the diaphragm, there is some evidence that this part of the diaphragm contracts slightly before the costal part (Mittal 1990), and this may be functionally significant (see below).

Actions

During inspiration the lowest ribs are fixed, and contraction of the diaphragm draws the central tendon downwards. In this movement the curvature of the diaphragm is scarcely altered; the cupolae move downwards and a little forwards almost parallel to their original positions. The associated downward displacement of the abdominal viscera is permitted by the extensibility of the abdominal wall, but the limit of this is soon reached. The central tendon, its motion arrested by the abdominal viscera, then becomes a fixed point from which the fibres of the diaphragm continue to contract, elevating the lower ribs and through this action pushing forwards the body of the sternum and the upper ribs. The right cupola of the diaphragm, which lies on the liver, has a greater resistance to overcome than the left, which lies over the stomach, but in compensation for this the right crus and the fibres of the right side are more substantial than those of the left. The balance between descent of the diaphragm and protrusion of the abdominal wall ('abdominal' breathing) and elevation of the ribs ('thoracic' breathing) varies in different individuals and with the depth of respiration. The thoracic element is usually more marked in females, but increases in both sexes during deep inspiration. The essential role of the diaphragm in breathing is considered further in The movements of respiration.

The diaphragm lends additional power to all expulsive efforts. Thus, sneezing, coughing, laughing, crying, urinating, defaecating, and expelling the fetus from the uterus, are all preceded by a deep inspiration. A deep inspiration, followed by closure of the glottis, is a common preliminary to powerful recruitment of the trunk muscles, as in lifting heavy weights, the raised intra-abdominal pressure providing pneumatic bracing of the vertebral column. Any of these activities could cause gastric contents to reflux into the oesophagus, with risk of inhalation into the lungs. This is normally prevented by a physiological antireflux barrier located at the gastro-oesophageal junction. The major components of this barrier are the specialized smooth muscle of the wall of the lower oesophagus and the encircling fibres of the crural diaphragm. These structures exert a radial pressure that can be measured by a sensing device as it is withdrawn from the stomach into the oesophagus. If reflux is to be prevented, this pressure must always exceed the difference between the pressures on either side of the junction, i.e. the difference between intra-abdominal pressure (transferred to the stomach, and augmented by any contraction of the stomach wall itself) and intrathoracic pressure (transferred to the oesophagus). During expiration, pressure exerted by tonic contraction of the smooth muscle of the lower oesophagus is

normally sufficient to oppose the gastro-oesophageal pressure gradient. During inspiration, intra-abdominal pressure rises and intrathoracic pressure becomes more negative, increasing the risk of reflux. This tendency is opposed by additional pressure exerted by contraction of the crural fibres of the diaphragm. (Activation of the crural diaphragm slightly before the costal diaphragm would ensure that contraction of peri-oesophageal fibres preceded the increase in gastro-oesophageal pressure gradient.) The antireflux barrier must of course be lowered for swallowing and vomiting. Swallowing is followed immediately by expiration, which relaxes the crural fibres and allows the oesophageal contents to be transferred to the stomach by peristaltic movement (Whillis 1931). Vomiting is produced by bursts of activity involving co-contraction of the diaphragm, intercostal and abdominal muscles in a pattern distinct from that of respiration; this activity is coordinated with relaxation of the crural fibres around the oesophagus (see Miller 1990).

Diaphragmatic excursion is about 1.5 cm in quiet breathing; during deep respiration the maximum movement ranges from 6 to 10 cm (Campbell 1958). After a forced inspiration, as when breathing is partially obstructed, the right cupola of the diaphragm can descend to about the level of the eleventh thoracic vertebra, while the left cupola may reach the level of the body of the twelfth. After a forced expiration the right cupola of the diaphragm is level anteriorly with the fourth costal cartilage, laterally with the fifth, sixth and seventh ribs, and posteriorly with the eighth; the left cupola is a little lower.

The level of the diaphragm is affected not only by the phase and depth of respiration but also by the degree of distension of the stomach and intestines and the size of the liver. Radiographs show that the height of the diaphragm within the thorax also varies considerably with posture. It is highest when the body is supine, and in this position it performs the largest respiratory excursions with normal breathing. When the body is erect the diaphragm is lower, and its respiratory movements become smaller. The diaphragmatic profile is still lower in the sitting posture, and respiratory excursions are smallest under these conditions. When the body is horizontal and on one side, the two halves of the diaphragm do not behave in the same way. The uppermost half sinks to a lower level even than in sitting, and moves little with respiration; the lower half rises higher in the thorax than it does even in the supine position, and its respiratory excursions are considerably greater.

Clinical Relevance

Changes in the level of the diaphragm with alterations in posture explain why patients with severe dyspnoea are most comfortable and least short of breath when sitting up (see also The movements of respiration. Paradoxical movements of the diaphragm can result from unilateral disease of the pleura or lungs, and (more commonly) from viral or surgical damage to one phrenic nerve. This is best observed fluoroscopically, with the patient first in the upright position (diaphragm unloaded) and then supine with a small weight on the abdomen (diaphragm loaded). Electrical stimulation of the diaphragm, by 'pacing' of one or both phrenic nerves, has been used with some success in infants with central alveolar hypoventilatory syndrome ('Ondine's Curse'; Ibawi et al 1985) and in patients with high cervical lesions of the spinal cord, in whom the diaphragm is paralysed but the lower motor neurons are intact (Glenn et al 1984). Electrodes are placed adjacent to the nerves, sometimes in the neck but more usually in the chest, and a respiratory rhythm is established by trains of stimuli delivered by an implanted device (Glenn et al 1984; Elefteriades et al 1992). Because this is an unphysiological way of recruiting the muscle, the fibres must be

'conditioned' during the initial period of stimulation so that they acquire the necessary resistance to fatigue.

Abdominal organs, usually the stomach, may herniate through the diaphragm into the thorax. There are three sites at which such hernias can occur: posterolateral (Bochdalek's), subcostosternal (Morgagni's) and oesophageal. The posterolateral hernia occurs as a result of a defect in the posterior diaphragm in the region of the 10th or 11th ribs. It is more common on the left and presents with abdominal contents in the left hemithorax at birth. Respiratory distress often results and the condition is life-threatening. Subcostosternal hernias, first described by Morgagni, are uncommon and occur through a defect in the anterior diaphragm just lateral to the xiphoid process. They are frequently asymptomatic. Oesophageal hernias, known as hiatal hernias, are common: when the oesophagogastric junction slides into the thorax, it is termed a sliding hernia; when the stomach herniates into the thorax alongside the oesophagus, it is termed a para-oesophageal hernia.

Because of common nerve root origins in the neck, diaphragmatic pain is frequently felt at the tip of the scapula.

Nervous system

Spinal nerves

Lumbar Ventral Rami

Lumbar ventral rami increase in size from first to last and are joined, near their origins, by grey rami communicantes from the four lumbar sympathetic ganglia. These rami, long and slender, accompany the lumbar arteries round the sides of the vertebral bodies, behind the psoas major. Their arrangement is irregular: one ganglion may give rami to two lumbar nerves, one lumbar nerve may receive rami from the ganglia; rami often leave the sympathetic trunk between ganglia. The first and second, and sometimes the third, lumbar ventral rami are each connected with the lumbar sympathetic trunk by a white ramus communicans. The lumbar ventral rami descend laterally into the psoas major. The first three and most of the fourth form the lumbar plexus; the smaller moiety of the fourth joins the fifth as a lumbosacral trunk, which joins the sacral plexus. The fourth is often termed the nervus furcalis, being divided between the two plexuses; but the third is occasionally the nervus furcalis; or both third and fourth may be furcal nerves, when the plexus is termed prefixed. More frequently the fifth nerve is furcal, the plexus then being termed postfixed. These variations modify the sacral plexus. Piasecka-Kacperska and Gladyskowska-Rzeczycka (1972) have reviewed the variations in primates, including man.

Lumbar Plexus

This plexus is in the posterior part of the psoas major, anterior to the lumbar transverse processes. It is formed by the first three lumbar ventral rami and most of the fourth; the first receives a branch from the last thoracic. The paravertebral part of psoas major has a posterior mass attached to the transverse processes and an anterior mass attached to the lips of the vertebral bodies, intervertebral discs and tendinous arches; the lumbar plexus is between these masses and hence in 'line' with the intervertebral foramina.

In its usual arrangement the plexus is formed as follows: the first lumbar ramus, joined by a branch from the twelfth thoracic, bifurcates; the upper and larger part divides again into iliohypogastric and ilio-inguinal nerves; the lower unites with a second lumbar branch to form the genitofemoral nerve. The remainder of the second, third and the part of the fourth ramus joining the plexus divide into ventral and dorsal branches. Ventral branches of the second to fourth rami form the obturator nerve. Dorsal branches of the second and third rami each divide into smaller and larger parts; the smaller parts unite as the lateral femoral cutaneous nerve, the larger join with the dorsal branch of the fourth to form the femoral nerve. The accessory obturator, when it exists, arises from the third and fourth ventral branches. For details of the blood supply of the lumbar plexus see Day (1964).

The branches of the lumbar plexus are:

Muscular	T12, L1, 2, 3, 4
Iliohypogastric	L1
Ilio-inguinal	L1
Genitofemoral	L1, 2
Dorsal divisions:	
Lateral femoral cutaneous	L2, 3
Femoral	L2, 3, 4
Ventral divisions:	
Obturator	L2, 3, 4
Accessory obturator	L3, 4

Muscular Branches
These supply the quadratus lumborum (T12, L1–4), psoas minor (L1), psoas major (L2, 3(4)) and iliacus (L2, 3).

Iliohypogastric Nerve (L1)
This emerges from the upper lateral border of the psoas major, crosses obliquely behind the lower renal pole and in front of the quadratus lumborum . Above the iliac crest it perforates the posterior part of the transversus abdominis, dividing between this and the internal oblique into lateral and anterior cutaneous branches, also supplying both muscles. The lateral cutaneous branch pierces the internal and external oblique muscles above the iliac crest a little behind the iliac branch of the twelfth thoracic nerve; it is distributed to the posterolateral gluteal skin. The anterior cutaneous branch runs between and supplies the internal oblique and the transversus, pierces the internal oblique about 2 cm medial to the anterior superior iliac spine, and the external oblique aponeurosis about 3 cm above the superficial inguinal ring; it is distributed to the suprapubic skin. The iliohypogastric nerve connects with the subcostal and ilio-inguinal nerves.

Ilio-Inguinal Nerve
Smaller than the iliohypogastric, this arises with it from the first lumbar ventral ramus, emerges from the lateral border of the psoas major, with or just caudal to the iliohypogastric, passes obliquely across the quadratus lumborum and the upper part of the iliacus and perforates the transversum abdominis near the anterior end of the iliac crest, sometimes connecting with the iliohypogastric. It then pierces the internal oblique, supplying it, traverses the inguinal canal below the spermatic cord, emerging with it from the superficial inguinal ring to supply the proximomedial skin of the thigh and either that over the penile root and upper part of the scrotum or that covering the mons pubis and the adjoining labium majus.
The ilio-inguinal and iliohypogastric nerves are reciprocal in size. The former is occasionally very small and ends by joining the iliohypogastric, a branch of the latter taking its place; or the ilio-inguinal may be absent. By analogy the ilio-inguinal may be regarded as the collateral branch of the first lumbar nerve (Davies 1935) and the iliohypogastric as the main trunk, providing the lateral cutaneous branch.

Genitofemoral Nerve (L1, 2)
This descends obliquely forwards through the psoas major, emerging on the abdominal surface near its medial border, opposite the third or fourth lumbar vertebra; it descends subperitoneally on the psoas major, crosses obliquely behind the ureter, dividing variably above the inguinal ligament into genital and femoral branches. It often divides close to its origin, its branches then emerging separately from the psoas major. The genital branch crosses the lower part of the external iliac artery, enters the inguinal canal by its deep ring and supplies the cremaster and the scrotal skin. In females it accompanies the round ligament and ends in the skin of the mons pubis and labium majus. The femoral branch descends lateral to the external iliac artery, sending a few filaments round it; then crosses the deep circumflex iliac artery, passes behind the inguinal ligament, enters the femoral sheath lateral to the femoral artery, pierces the anterior layer of the femoral sheath and fascia lata and supplies the skin anterior to the upper part of the femoral triangle. It connects with the femoral intermediate cutaneous nerve and supplies the femoral artery.
Injury to the Iliohypogastric, Ilio-Inguinal or Genitofemoral Nerves
Damage to the iliohypogastric, ilio-inguinal or genitofemoral nerves is nearly always a result of direct injury, usually the result of surgery, particularly during inguinal herniorrhaphy or the exploration of a retrocaecal appendix.

Lateral Femoral Cutaneous Nerve
This comes from the dorsal branches of the second and third lumbar ventral rami, and emerges from the lateral border of psoas major, crossing the iliacus obliquely towards the anterior superior iliac spine. It supplies the parietal peritoneum in the iliac fossa. The right nerve passes posterolateral to the caecum, separated from it by the fascia iliaca and peritoneum; the left passes behind the lower part of the descending colon. Both pass behind or through the inguinal ligament, variably medial to the anterior superior iliac spine (commonly about 1 cm) and anterior to or through the sartorius into the thigh, dividing into anterior and posterior branches. The anterior branch becomes superficial about 10 cm distal to the anterior superior iliac spine, supplying the skin of the anterior and lateral thigh as far as the knee. It connects terminally with the cutaneous branches of the anterior division of the femoral nerve and the infrapatellar branch of the saphenous nerve, forming the patellar plexus. The posterior branch pierces the fascia lata higher than the anterior, dividing to supply the skin on the lateral surface from the greater trochanter to about midthigh. It may also supply the gluteal skin.
Lesions of the Lateral Cutaneous Nerve of the Thigh
This nerve is seldom involved in its retroperitoneal course through the pelvis. It leaves the pelvis just medial to the anterior superior iliac spine and either passes through or deep to the inguinal ligament, where it may become compressed. There is an area of impaired sensation, often with pain and paraesthesiae on the anterolateral aspect of the thigh (meralgia paraesthetica). The area involved is immensely variable, but is usually confined to the distal cutaneous distribution of the anterior branch of the lateral cutaneous nerve. This area does not extend across the midline anteriorly, it does not extend below the knee and it does not extend behind the hamstring tendons laterally. Exceptionally the posterior branch of the lateral cutaneous nerve of the thigh may be affected separately; this supplies a thin strip from the greater trochanter of the femur down about two-thirds of the way to the knee. This branch leaves the main trunk of the nerve, usually distal to the inguinal

ligament, and it then turns laterally to pierce the tensor fasciae latae muscle where it may become entrapped.

Obturator Nerve

The obturator nerve arises from the ventral branches of the second to fourth lumbar ventral rami, that from the third being the largest, the one from the second often very small. It descends in the psoas major, emerging from its medial border at the pelvic brim to pass behind the common iliac and lateral to the internal iliac vessels. It then descends forwards along the lesser pelvic lateral wall on the obturator internus, anterosuperior to the obturator vessels, to the obturator foramen, entering the thigh by its upper part. Near the foramen it divides into anterior and posterior branches, separated at first by part of the obturator externus, lower down by the adductor brevis.

The anterior branch leaves the pelvis anterior to the obturator externus, descending in front of the adductor brevis, behind the pectineus and adductor longus; at the lower border of the latter it communicates with the medial cutaneous and saphenous branches of the femoral nerve, forming a subsartorial plexus, which supplies the skin on the medial side of the thigh. It descends on the femoral artery, which its termination supplies. Near the obturator foramen the anterior branch supplies the hip joint. Behind the pectineus it innervates the adductor longus, gracilis, usually the adductor brevis and often the pectineus; it connects with the accessory obturator nerve when present. Occasionally the communicating branch to the femoral medial cutaneous and saphenous branches continues as a cutaneous branch to the thigh and leg, emerging from behind the distal border of the adductor longus to descend along the posterior margin of the sartorius to the knee, where it pierces the deep fascia, connects with the saphenous nerve and supplies the skin halfway down the medial side of the leg. The posterior branch pierces the obturator externus anteriorly, supplies it and passes behind the adductor brevis to the front of the adductor magnus, dividing into branches to this and the adductor brevis when the latter is not supplied by the anterior division. It usually sends an articular filament to the knee joint which perforates the adductor magnus distally or traverses its opening with the femoral artery to enter the popliteal fossa. Here it descends on the popliteal artery to the back of the knee, pierces its oblique posterior ligament and supplies the articular capsule. It gives filaments to the popliteal artery.

Accessory Obturator Nerve

Occasionally present, this is small and arises from the ventral branches of the third and fourth lumbar ventral rami. It descends along the medial border of the psoas major, crosses the superior pubic ramus behind the pectineus and divides into branches, one entering the deep surface of the pectineus, another supplying the hip joint and a third connecting with the anterior branch of the obturator nerve; sometimes the accessory obturator nerve is very small and supplies only the pectineus. Any branch may be absent and others occur, one sometimes supplying the adductor longus. An accessory obturator nerve appeared in 69 of 800 dissections.

Lesions of the Obturator Nerve

Isolated lesions of the obturator nerve are extremely rare, but may occasionally occur as a result of direct trauma. The obturator nerves may be involved together with the femoral nerve in retroperitoneal lesions close to their origins from the lumbar plexus.

Femoral Nerve
The femoral nerve, the largest branch of the lumbar plexus, arises from the dorsal branches of the second to fourth lumbar ventral rami. It descends through the psoas major, emerging low on its lateral border, and then passes between the psoas and iliacus, deep to the iliac fascia; passing behind the inguinal ligament into the thigh, it splits into anterior and posterior divisions. Behind the inguinal ligament it is separated from the femoral artery by part of the psoas major. In the abdomen the nerve supplies small branches to the iliacus and pectineus and a branch to the proximal part of the femoral artery; the latter branch may arise in the thigh.

Nerve to the Pectineus
This branches from the medial side of the femoral nerve near the inguinal ligament, passes behind the femoral sheath and enters the anterior aspect of the muscle.
Anterior Division
The anterior division of the femoral nerve supplies intermediate and medial cutaneous femoral nerves and branches to the sartorius.
Intermediate Femoral Cutaneous Nerve
This pierces the fascia lata about 8 cm below the inguinal ligament, either as two branches or as one trunk which quickly divides into two; these descend on the front of the thigh, supplying the skin as far as the knee and ending in the patellar plexus. The lateral branch of the intermediate cutaneous communicates with the femoral branch of the genitofemoral, frequently piercing the sartorius and sometimes supplying it.

Medial Femoral Cutaneous Nerve
At first lateral to the femoral artery, this crosses anterior to it at the apex of the femoral triangle, dividing into anterior and posterior branches. Before this it sends a few rami through the fascia lata to supply the skin of the medial side of the thigh, near the long saphenous vein; one ramus emerges via the saphenous opening, another becomes subcutaneous about midthigh. The anterior branch descends on the sartorius, perforates the fascia lata beyond midthigh and divides into a branch supplying the skin as low as the medial side of the knee and another which crosses to the lateral side of the patella and connects with the infrapatellar branch of the saphenous nerve. The posterior branch descends along the posterior border of the sartorius to the knee, pierces the fascia lata, connects with the saphenous nerve and supplies several cutaneous rami, some as far as the medial side of the leg. Deep to the fascia lata, at the lower border of the adductor longus, it forms a subsartorial plexus with branches of the saphenous and obturator nerves. When the communicating branch of the obturator nerve is large and reaches the leg, the posterior branch of the medial cutaneous nerve is small, ending in the plexus and giving rise to a few cutaneous filaments.

Nerve to the Sartorius
This arises in common with the intermediate femoral cutaneous nerve.
Posterior Division
The posterior division of the femoral nerve supplies the saphenous nerve and branches to the quadriceps femoris and the knee joint.

Saphenous Nerve
The largest femoral cutaneous branch, this descends lateral to the femoral artery into the adductor canal, where it crosses anteriorly to become medial to the artery. At the distal end of the canal it leaves the artery, emerging through the aponeurotic covering with the saphenous branch of the descending genicular artery. It proceeds vertically along the medial side of the knee behind the sartorius, pierces the fascia lata between the tendons of the sartorius and gracilis and becomes subcutaneous. Thence it descends the medial side of the leg with the long saphenous vein along the medial tibial border and divides distally into a branch continuing along the tibia to the ankle and into another passing anterior to the ankle to supply the skin on the medial side of the foot, often as far as the hallucial metatarsophalangeal joint; it connects with the medial branch of the superficial peroneal nerve. Near midthigh the saphenous nerve gives a branch to the subsartorial plexus. As it leaves the adductor canal an infrapatellar branch pierces the sartorius and fascia lata to supply the prepatellar skin; proximal to the knee it connects with medial and intermediate femoral cutaneous nerves; distal to it, it connects with other branches of the saphenous nerve; laterally it connects with the lateral cutaneous femoral nerve, forming a patellar plexus.

Muscular Branches
These branches of the posterior division of the femoral nerve supply the quadriceps femoris. A branch to the rectus femoris enters its proximal posterior surface, also supplying the hip joint. A larger branch to the vastus lateralis forms a neurovascular bundle with the descending branch of the lateral circumflex femoral artery in its distal part and also supplies the knee joint. A branch to the vastus medialis descends through the proximal part of the adductor canal, lateral to the saphenous nerve and femoral vessels; it enters the muscle at about its midpoint, sending a long articular filament distally along the muscle to the knee. Two or three branches to the vastus intermedius enter its anterior surface about midthigh; a branchlet from one descends through the muscle to the articularis genu and the knee joint.

Vascular Branches
These branches of the femoral nerve supply the femoral artery and its branches .

Femoral Neuropathy
The femoral nerve is not subject to an entrapment neuropathy, but may be compressed by retroperitoneal tumours, retroperitoneal haemorrhage in patients on anticoagulants or with a bleeding diathesis. A localized lesion of the femoral nerve may occur in diabetes mellitus (one of the forms of diabetic amyotrophy). The striking feature of femoral neuropathy is wasting and weakness of the quadriceps femoris muscles which cause considerably difficulty in walking with a tendency for the leg to collapse. Pain and paraesthesiae may occur on the anterior and medial aspect of the thigh, extending down the medial aspect of the leg in the distribution of the saphenous branch of the femoral nerve. This branch may be the subject of an entrapment neuropathy as it leaves Hunter's canal.

Sacral Plexus
The sacral plexus is formed by the lumbosacral trunk, the first to third sacral ventral rami and part of the fourth, the remainder of the last joining the coccygeal plexus.

The lumbosacral trunk comprises part of the fourth and all the fifth lumbar ventral rami; it appears at the medial margin of the psoas major, descending over the pelvic brim anterior to the sacro-iliac joint to join the first sacral ramus. These rami converge to the greater sciatic foramen and unite with little intermingling to form upper and lower bands. The upper, larger one is the union of the lumbosacral trunk with the first, second and greater part of the third sacral rami; it becomes the sciatic nerve. The lower band, smaller and more plexiform, is mainly the junction of the smaller part of the third sacral ramus with part of the fourth; it becomes the pudendal nerve; it has a small contribution from the second sacral ramus. The sciatic comprises tibial and common peroneal nerves, which usually separate in the thigh but can be pulled apart to their origins, when it can be demonstrated that the tibial is formed by the union of the ventral divisions of the lumbosacral trunk and the first three sacral rami, while the common peroneal is formed by dorsal divisions of the lumbosacral trunk and the first two sacral rami. The sciatic nerve may, however, divide anywhere; when division is at the plexus the common peroneal nerve usually pierces the piriformis in the greater sciatic foramen.

Relations of the Sacral Plexus

The sacral plexus adjoins the posterior pelvic wall anterior to the piriformis (8.383), posterior to the internal iliac vessels and ureter and to the sigmoid colon on the left and the terminal ileal coils on the right. The superior gluteal vessels lie between the lumbosacral trunk and first sacral ventral ramus or between the first and second sacral rami, while the inferior gluteal vessels lie between the first and second or second and third sacral rami.

Lesions of the Lumbosacral Plexus

Malignant infiltration is the most common cause of involvement of the lumbosacral plexus, usually due to spread of carcinoma from the cervix, uterus or rectum. The plexus may also be involved in the reticuloses or be affected by plexiform neuromas. Pain, which may be diffuse, is the most common feature, and there is clear involvement of several roots.

Branches of the Sacral Plexus

The branches of the sacral plexus are:

	Ventral divisions	Dorsal divisions
To quadratus femoris and gemellus inferior	L4, 5, S1	
To obturator internus and gemellus superior	L5, S1, 2	
To piriformis		S(1), 2
Superior gluteal		L4, 5, S1
Inferior gluteal		L5, S1, 2
Posterior femoral cutaneous	S2, 3	S1, 2
Tibial (sciatic)	L4, 5, S1, 2, 3	
Common peroneal (sciatic)		L4, 5, S1, 2
Perforating cutaneous		S2, 3
Pudendal	S2, 3, 4	
To levator ani, coccygeus and sphincter ani externus	S4	
Pelvic splanchnic	S2, 3, (4)	

Lumbar Part of the Sympathetic System

The lumbar part of each sympathetic trunk, usually containing four interconnected ganglia, runs in the extra-peritoneal connective tissue anterior to the vertebral column and along the medial margin of the psoas major. Superiorly it is continuous with the thoracic trunk posterior to the medial arcuate ligament; inferiorly, passing posterior to the common iliac artery, it becomes the pelvic trunk. On the right side it is overlapped by the inferior vena cava and on the left by the lateral aortic lymph nodes. It is anterior to most of the lumbar vessels but may pass behind some lumbar veins.

The first, second and sometimes third lumbar ventral spinal rami send white rami communicantes to the corresponding ganglia. Grey rami communicantes, passing from all ganglia to the lumbar spinal nerves, are long and accompany the lumbar arteries round the sides of the vertebral bodies, medial to the fibrous arches to which the psoas major is attached.

Usually four lumbar splanchnic nerves pass from the ganglia to join the coeliac, intermesenteric (abdominal aortic) and superior hypogastric plexuses. The first lumbar splanchnic nerve, from the first ganglion, joins the coeliac, renal and intermesenteric plexuses. The second nerve, from the second and sometimes the third ganglion, joins the inferior part of the intermesenteric plexus; the third nerve issues from the third or fourth ganglion, passing anterior to the common iliac vessels to join the superior hypogastric plexus. The fourth lumbar splanchnic, from the lowest ganglion, passes dorsal to the common iliac vessels to join the lower part of the superior hypogastric plexus or the hypogastric 'nerve'.

Vascular branches from all lumbar ganglia join the intermesenteric (aortic) plexus. Fibres of the lower lumbar splanchnic nerves pass to the common iliac arteries, forming a plexus continued along the internal and external iliac arteries as far as the proximal part of the femoral artery. Many postganglionic fibres in the grey rami, connecting the lumbar ganglia to the spinal nerves, travel in the femoral nerve to its muscular, cutaneous and saphenous branches, supplying vasoconstrictor nerves to the femoral artery and its branches in the thigh. Other postganglionic fibres travel via the obturator nerve to the obturator artery. Considerable uncertainties persist regarding sympathetic supplies to the lower limb (Wilde 1951; Wyburn 1956; Pick 1970).

Vascular system : Arterial system

Abdominal Aorta

The abdominal aorta begins at the median, aortic hiatus of the diaphragm, anterior to the twelfth thoracic vertebra's inferior border and the thoracolumbar intervertebral symphysis ('disk'), descending anterior to the vertebrae to end at the fourth lumbar, a little left of the midline, by dividing into two common iliac arteries. It diminishes rapidly in calibre, since its branches are large. Measurements of casts of the abdominal aorta in 100 individuals, from 16–70 years, showed a widening with age. In males superior and inferior ends measured 9.8–14.1 mm and 8.1–14.6 mm; in females luminal diameters were 9.7–15.7 mm and 9.1–14.6 mm (Aleksandrowicz et al 1974). These values conflict with radiological observation of 61 adults (17–41 years) by Leithner et al (1975), who recorded 26 mm and 19 mm (averages) for both ends of the abdominal aorta; they also gave a mean value of 37 for the angle of aortic bifurcation. Dimensions are of interest in attempts to estimate a suspected hydrodynamic ('haemodynamic') factor in the genesis of atherosclerosis (Newman et al 1971; Lallemand & Newman 1973). Theoretically, the pressure pulse wave in arteries is reflected at any junction, at certain values of combined arterial luminal areas of the branch or branches relative to that of the parent vessel; this is the area ratio of a junction. At an equal bifurcation, such as the aortic, with an area ratio of 1:1.5, reflection of the pressure pulse wave is near to zero; the vessels are said to be 'matched'. Oscillations and possibly turbulence set up by 'mismatching' (at other ratios), perhaps also influenced by asymmetry of bifurcation, may cause intimal damage, predisposing to aortic atheroma. Luminal and other dimensions of the bifurcation may assume special significance, as may changes in these during life. Measurement of aortico–iliac junctions in humans, dogs and domestic fowls (free from vascular disease) has shown area ratios usually close to the theoretical value for 'matching' and independent of age in dog and fowl (Gosling et al 1971). However, the human aortic bifurcation appears to be 'matched' only in infancy; it is 1.11 ± 0.02 at birth, diminishing with advancing age to a value of about 0.7 in the fifth decade, at which theory predicts a 'mismatch' reflecting pulse pressure wave at about one-third of its amplitude. These studies give special interest to a study of the geometry of aortic bifurcation by Shah et al (1978), containing the most extensive data so far recorded, including diameters and angles of deviation, iliac lengths and curvatures and dorsal angulations of these vessels as they enter the pelvis. Unfortunately, diameters were external and only on a small series of cadavers at autopsy, and cannot be compared with those cited above. These interesting observations should be carried further with improved techniques and greater cohesion between different groups involved.

Relations

The abdominal aorta has at first anterior to it the coeliac trunk and its branches, with the coeliac plexus and the lesser sac (omental bursa) which intervenes between it and the hepatic papillary process and lesser omentum. Below this the superior mesenteric artery leaves the aorta, crossing anterior to the left renal vein. The body of the pancreas, with splenic vein applied posteriorly, extends obliquely up and left across the abdominal aorta, separated from it by the superior mesenteric artery and left renal vein. Below the pancreas, the proximal parts of its testicular (or ovarian) arteries, and the horizontal part of the duodenum are anterior. In its lowest part it is covered by the posterior parietal peritoneum and crossed by the oblique parietal attachment of the mesentery.

Posterior to the abdominal aorta are the thoracolumbar intervertebral 'disk', the upper four lumbar vertebrae, intervening intervertebral discs and the anterior longitudinal ligament. Lumbar arteries, arising from its dorsal aspect, and the third and fourth (sometimes second) left lumbar veins, crossing behind it to reach the inferior vena cava, separate it from the ligament. It may overlap the anterior border of the left psoas major.
On the right the aorta is related above to the cisterna chyli and thoracic duct, azygos vein and right crus of diaphragm, which overlaps and separates it from the inferior vena cava and right coeliac ganglion. Below the second lumbar vertebra it adjoins the inferior vena cava.
On the left it is related above to the left diaphragmatic crus and left coeliac ganglion. Level with the second lumbar vertebra are the duodenojejunal flexure and sympathetic trunk descending, at its left side, and the ascending duodenum and inferior mesenteric vessels.

Superior Mesenteric Artery
The superior mesenteric artery is by far the most important of the arteries to the alimentary tract, as it supplies the whole of the small intestine from the superior part of the duodenum to the midtransverse colon, and is functionally an end artery. It leaves the front of the aorta about 1 cm below the coeliac trunk, at the level of the L1–L2 vertebral disk, and is crossed anteriorly by the splenic vein and the body of the pancreas, separated from the aorta by the left renal vein. It runs downwards and forwards, anterior to the uncinate process, and passes in front of the transverse part of the duodenum. This can sometimes be seen on a radiograph as an area of translucency, running across the duodenum, and was at one time thought to represent a sphincter (the sphincter of Ochsner) to which all manner of symptoms were attributed. Endoscopy has disproved this concept. As it descends in the root of the small bowel mesentery, the artery crosses in front of the inferior vena cava, the right ureter, and psoas major, becoming steadily narrower in its course, and eventually joins its own ileocolic branch. It is accompanied by the superior mesenteric vein and is surrounded by a plexus of nerves. A fibrous strand from the region of its last branch runs to the umbilicus, and represents a vestige of the embryonic artery which originally connected it to the yolk sac.

Ileocolic Artery
The last branch from the right side of the superior mesenteric, it descends to the right under the parietal peritoneum to the right iliac fossa, where it divides; its superior branch anastomoses with the right colic, the inferior with the end of the superior mesenteric. The ileocolic artery crosses anterior to the right ureter, testicular or ovarian vessels and psoas major. Its inferior branch approaches the superior border of the ileocolic junction and branches as follows:
- ascending (colic) passing up on the ascending colon
- anterior and posterior caecal
- an appendicular artery, descending behind the terminal ileum to enter the mesoappendix; after giving off a recurrent branch anastomosing with one from the posterior caecal artery, it runs close to and then in the edge of the mesoappendix, its terminal part being in actual contact with the appendix
- an ileal branch ascending to the left on the lower ileum, supplying it and anastomosing with a terminal twig of the superior mesenteric artery.

Right Colic Artery
This is a small vessel and it may be absent. It arises near the middle of the superior mesenteric, or in common with the ileocolic and passes to the right behind the parietal peritoneum and anterior to the right ovarian or testicular artery and vein, right ureter and psoas major, towards the ascending colon. Sometimes it is higher and crosses the descending duodenum and right inferior renal pole. Near the colon it divides into a descending branch, which anastomoses with the ileocolic, and an ascending branch anastomosing with the middle colic. These form arches, from which vessels are distributed to the ascending colon, supplying its upper two-thirds and the right colic flexure.

Inferior Mesenteric Artery
The inferior mesenteric artery supplies the left third of the transverse colon, all the descending colon, sigmoid colon and most of the rectum. It is smaller than the superior mesenteric, arising 3 or 4 cm above the aortic bifurcation, posterior to the horizontal part of the duodenum. It descends behind the peritoneum, at first anterior to the aorta, then on its left, crosses the left common iliac artery medial to the left ureter and then enters and continues in the sigmoid mesocolon into the lesser pelvis as the superior rectal artery. Distally the inferior mesenteric vein is lateral. The artery has left colic, sigmoid and superior rectal branches.

Left Colic Artery
It ascends subperitoneally to the left, anterior to the psoas major, and divides into ascending and descending branches. The trunk and its branches cross the left ureter and ovarian or testicular vessels. The ascending branch passes anterior to the left kidney into the transverse mesocolon, where it anastomoses with the middle colic artery; the descending branch anastomoses with the highest sigmoid artery. From arches thus formed, branches supply the left half of the transverse and the descending colon. Territories of supply by middle and left colic arteries show reciprocal variation; the left branch of the middle colic may take over the supply of the splenic flexure (in 19 of 100 cadavers, according to Sierocinski 1975).
Sigmoid (Inferior Left Colic) Arteries
Two or three in number, they descend obliquely to the left under the peritoneum anterior to the left psoas major, ureter and testicular or ovarian vessels. Branches supply the lower descending colon and sigmoid colon, anastomosing above with the left colic artery, below with the superior rectal artery.

Anterolateral Visceral Arteries

Middle Suprarenal Arteries
These two small vessels arise laterally from each side of the aorta, level with the superior mesenteric, ascending slightly over the crura of the diaphragm to the suprarenal glands, where each anastomoses with the suprarenal branches of the phrenic and renal arteries. The right passes behind the inferior vena cava and near the right coeliac ganglion; the left is related to the left coeliac ganglion, splenic artery and superior border of the pancreas.

Renal Arteries
These two large vessels branch laterally from the aorta just below the inferior mesenteric; both cross the corresponding crus at right angles to the aorta. The right

is longer and often higher, passing posterior to the inferior vena cava, right renal vein, head of the pancreas and descending part of the duodenum. The left is a little lower; it passes behind the left renal vein, the body of the pancreas and splenic vein and may be crossed anteriorly by the inferior mesenteric vein. Nearing its renal hilum, each divides into four or five branches, most between the renal vein and ureteric pelvis, the vein being anterior, the pelvis posterior, but one or more usually behind the pelvis. Each renal artery supplies small inferior suprarenal branches and also the ureter, surrounding cellular tissue and muscles.

Surface Anatomy
The renal arteries can be projected as broad lines running laterally for 4 cm from the aorta just inferior to the transpyloric plane; the left inclines across the plane.
Variations
One or two accessory renal arteries frequently occur, especially on the left, usually from the aorta above or below the main artery, the former slightly more often. They usually enter above or below the renal hilum; if below, the vessel crosses anterior to the ureter and, on the right, usually also anterior to the inferior vena cava.

Testicular Arteries
These two long, slender vessels arise anteriorly from the aorta a little inferior to the renal arteries. Each passes inferolaterally under the parietal peritoneum on the psoas major; the right lies anterior to the inferior vena cava and posterior to the horizontal part of the duodenum, right colic and ileocolic arteries, root of the mesentery and terminal ileum; the left testicular artery lies posterior to the inferior mesenteric vein, left colic artery and lower part of the descending colon. Each crosses anterior to the genitofemoral nerve, ureter and the lower part of the external iliac artery, passing to the deep inguinal ring to enter the spermatic cord with other constituents, via which the vessel traverses the inguinal canal to the scrotum. At the posterosuperior aspect of the testis it divides into two branches on its medial and lateral surfaces, which pass through its tunica albuginea to ramify in the tunica vasculosa. Terminal branches enter the testis over its surface. Some pass into the mediastinum testis and loop back before reaching their distribution (Harrison & Barclay 1948). In the abdomen the testicular artery supplies perirenal fat, ureter and iliac lymph nodes; in the inguinal canal it supplies the cremaster. Sometimes the right testicular artery passes posterior to the inferior vena cava. Both arteries represent persistent lateral splanchnic aortic branches, which enter the mesonephros and cross ventral to the supracardinal but dorsal to the subcardinal vein. Normally the lateral splanchnic artery which persists as the right testicular passes caudal to the suprasubcardinal anastomosis forming part of the inferior vena cava. When it passes cranial to this, the right testicular artery is behind the inferior vena cava.
Clinical Anatomy
The testicular artery is not the sole supply to the testis, which also receives some blood from the cremasteric branch of the inferior epigastric artery. Thus interference with the testicular artery high in the abdomen usually leaves the testis unharmed, whereas interruption in the region of the spermatic cord involves both sets of vessels and leads to infarction.

Ovarian Arteries
These correspond to the testicular arteries but enter the pelvis to supply the ovaries. Initially they resemble the testicular arteries but at the brim of the lesser pelvis each

crosses the lower external iliac artery and vein to enter the true pelvic cavity, turning medially in the ovarian suspensory ligament to continue into the uterine broad ligament, below the uterine tube. At ovarian level it passes back in the mesovarium and divides into branches to the ovary. Small branches supply the ureter and uterine tube and one passes to the side of the uterus to unite with the uterine artery. Others accompany the round ligament through the inguinal canal to the skin of the labium majus and the inguinal region.
Early in intrauterine life, when testes or ovaries flank the vertebral column inferior to the kidneys, the testicular and ovarian arteries are relatively short; but with descent of the gonads into the pelvis and beyond, they gradually lengthen.
(Inferior) Phrenic Arteries
These two small vessels help to supply the diaphragm, They may arise separately from the aorta, just above its coeliac trunk, by a common aortic stem or from the coeliac trunk; sometimes one is from the aorta, the other from a renal artery. Each artery ascends laterally anterior to a crus of the diaphragm, near the medial border of the suprarenal gland. The left passes behind the oesophagus and forwards on the left side of its diaphragmatic opening. The right phrenic passes posterior to the inferior vena cava then along the right of its opening. Near the posterior border of the diaphragm's central tendon each divides into medial and lateral branches. The medial curves forwards to anastomose with its fellow in front of the central tendon and with the musculophrenic and pericardiacophrenic arteries; the lateral approaches the thoracic wall, anastomosing with the lower posterior intercostal and musculophrenic arteries. The lateral branch of the right artery supplies the inferior vena cava while the left sends ascending branches to the oesophagus. Each has two or three small superior suprarenal branches. The liver and spleen also receive small branches from the phrenic arteries.

Lumbar Arteries
These are in series with the posterior intercostal arteries. Usually four on each side, they arise posterolaterally from the aorta, opposite the lumbar vertebrae. A fifth, smaller pair occasionally arise from the median sacral artery but lumbar branches of the iliolumbar arteries usually take their place. The lumbar arteries run posterolaterally on the four upper lumbar vertebral bodies, behind the sympathetic trunks, to intervals between the lumbar transverse processes and continue into the abdominal wall. The right arteries pass posterior to the inferior vena cava; the upper two right and first left are also posterior to the corresponding crus. Arteries of both sides pass under tendinous arches (which span the lateral concavities of the vertebral bodies, for attachment of psoas major, proceeding posterior to the muscle and the lumbar plexus. They then cross the quadratus lumborum, the upper three posterior, the last usually anterior to it. At its lateral border they pierce the posterior aponeurosis of the transversus abdominis, advancing between it and the internal oblique. They anastomose with one another and the lower posterior intercostal, subcostal, iliolumbar, deep circumflex iliac and inferior epigastric arteries.
Branches
Each lumbar artery has a dorsal branch passing back between the adjacent transverse processes to supply the dorsal muscles, joints and skin; this also has a spinal branch entering the vertebral canal to supply its contents and adjacent vertebra, anastomosing with the arteries above and below it and across the midline. The spinal branch of the first lumbar supplies the terminal spinal cord itself; the remainder supply the cauda equina, meninges and vertebral canal. Branches of the

lumbar arteries and their dorsal branches supply the adjacent muscles, fasciae, bones, red marrow, ligaments and joints (symphyses, syndesmoses and synovial joints).

Median Sacral Artery
This small posterior branch leaves the aorta a little above its bifurcation. It descends in the midline, anterior to the fourth and fifth lumbar vertebrae, sacrum and coccyx, ending in the coccygeal body. At fifth lumbar level it is crossed by the left common iliac vein and often gives off a small lumbar artery (arteria lumbalis ima), minute branches of which reach the rectum. Anterior to the last lumbar vertebra the median sacral anastomoses with a lumbar branch of the iliolumbar; anterior to the sacrum it anastomoses with the lateral sacral arteries and sends branches into the anterior sacral foramina.

Common Iliac Arteries
The abdominal aorta bifurcates, anterolateral to the left side of the fourth lumbar vertebral body, into the right and left common iliac arteries. These diverge as they descend to divide near the level of the lumbosacral intervertebral disc (between the last lumbar and first sacral vertebrae) into external and internal iliac arteries; the former supplies most of the lower limb, the latter the pelvic viscera and walls, perineum and gluteal region. The division of the common iliac is anterior to its sacro-iliac joint.
A collateral circulation may be established, in young adults, after ligature of the common iliac artery; when arterial walls degenerate in older patients it is unlikely to supply the leg adequately.

Right Common Iliac Artery
This is about 5 cm long and passes obliquely across part of the fourth and the fifth lumbar vertebral body. Anteriorly, it is crossed by the sympathetic rami to the pelvic plexus and, at its division, by the ureter; it is covered by the parietal peritoneum, which separates it from the coils of the small intestine. Posteriorly, it is separated from the fourth and fifth lumbar vertebral bodies and their intervening disc by the sympathetic trunk, the terminal parts of the common iliac veins and the commencement of the inferior vena cava; the obturator nerve, lumbosacral trunk and iliolumbar artery are also posterior, traversing fatty tissue between the fifth lumbar vertebra and the psoas major. Lateral to its upper part are the inferior vena cava and the right common iliac vein to which it has a surgically important relationship (see above); lateral to its lower part is the right psoas major; medial to its upper part is the left common iliac vein.

Left Common Iliac Artery
The artery is about 4 cm long. Anterior are the peritoneum, ileum, the sympathetic rami to the pelvic plexus, the superior rectal artery and, at its terminal bifurcation, the ureter. Posterior are the sympathetic trunk, fourth and fifth lumbar vertebral bodies and intervening disc; the obturator nerve, lumbosacral trunk and iliolumbar artery are more posterior (i.e. deeply situated). The left common iliac vein is partly medial, partly posterior to the artery; lateral and closely related is the left psoas major.
Surface Anatomy
The vessel corresponds to the superior third of a broad line from the aortic bifurcation to a point midway between the anterior superior iliac spine and the pubic symphysis.

The external iliac artery corresponds to the inferior two-thirds of this line, which is laterally slightly convex.
Branches
In addition to the terminal branches, each common iliac artery gives small branches to the peritoneum, psoas major, ureter, adjacent nerves and surrounding areolar tissue; occasionally it has the iliolumbar and accessory renal arteries as branches.

Internal Iliac Arteries
Each internal iliac artery, about 4 cm long, begins at the common iliac bifurcation, level with the lumbosacral intervertebral disc and anterior to the sacro-iliac joint; it descends posteriorly to the superior margin of the greater sciatic foramen, dividing here into: an anterior trunk, which continues in the same line towards the ischial spine; and a posterior trunk, passing back to the foramen (Braithwaite 1952). Anterior are the ureter and, in females, the ovary and fimbriated end of the uterine tube; posterior are the internal iliac vein, lumbosacral trunk and sacro-iliac joint; lateral is the external iliac vein, between the artery and the psoas major and inferior to this the obturator nerve; medial is the parietal peritoneum, separating it from the terminal ileum on the right and the sigmoid colon on the left, and tributaries of the internal iliac vein.
In the fetus the internal iliac artery is twice the size of the external and is the direct continuation of the common iliac. It ascends on the anterior abdominal wall to the umbilicus, converging on its fellow. Having traversed the opening, the two arteries, now umbilical, enter the umbilical cord, coil round the umbilical vein and ultimately ramify in the placenta. At birth, when placental circulation ceases, only the pelvic segment remains patent as the internal iliac artery and part of the superior vesical, the remainder becoming a fibrous medial umbilical ligament raising the peritoneal medial umbilical fold from the pelvis to the umbilicus. In males, the patent part usually gives off an artery to the ductus deferens (see below).

Branches of Posterior Trunk of Internal Iliac Artery

Iliolumbar Artery
This ascends laterally anterior to the sacro-iliac joint and lumbosacral trunk, posterior to the obturator nerve and external iliac vessels, to reach the medial border of psoas major, dividing behind it into the lumbar and iliac branches. The lumbar branch supplies the psoas major and quadratus lumborum, anastomoses with the fourth lumbar artery and sends a small spinal branch through the intervertebral foramen between the fifth lumbar and first sacral vertebrae, which supplies the cauda equina. The iliac branch supplies the iliacus; between the muscle and bone it anastomoses with the iliac branches of the obturator. A large nutrient branch enters an oblique canal in the ilium; others skirt the iliac crest, supplying the gluteal and abdominal muscles and anastomosing with the superior gluteal, circumflex iliac and lateral circumflex femoral arteries.

External Iliac Arteries
The external iliac arteries are larger than the internal. Each descends laterally along the medial border of the psoas major from the common iliac bifurcation (anterior to the sacro-iliac joint at lumbosacral disc level) to a point midway between the anterior superior iliac spine and the symphysis pubis, entering the thigh posterior to the inguinal ligament to become the femoral artery.

Anteromedially the artery is related to the parietal peritoneum and extraperitoneal tissue, separating the right from the terminal ileum and often the appendix, the left from the sigmoid colon and coils of the small intestine. At its origin the artery may be crossed by the ureter, in females by ovarian vessels. Testicular vessels are anterior for some distance near its distal end, and it is crossed here by the genital branch of the genitofemoral nerve, the deep circumflex iliac vein and the ductus deferens or round ligament. Posteriorly the iliac fascia separates it from the medial border of the psoas major. The external iliac vein is partly posterior to its upper part, medial to it below. Laterally it is related to the psoas major, the iliac fascia lying between them. Numerous lymph vessels and nodes lie on its front and sides.
Branches
Apart from very small vessels to the psoas major and neighbouring lymph nodes, the artery has no branches until the inferior epigastric and deep circumflex iliac arise near to its termination. Besides supplying the psoas major and neighbouring lymph nodes, the artery has inferior epigastric and deep circumflex iliac branches.

Relations of the Femoral Artery in the Femoral Triangle
Anterior to the artery are the skin, superficial fascia, superficial inguinal lymph nodes, fascia lata, femoral sheath, superficial circumflex iliac vein (crossing in the superficial fascia) and the femoral branch of the genitofemoral nerve (at first lateral then anterior). Near the apex the medial femoral cutaneous nerve crosses the artery from the lateral to the medial side. Posterior are the femoral sheath and the tendons of psoas, pectineus and adductor longus. The artery is separated from the hip joint by the tendon of psoas major, from the pectineus by the femoral vein and profunda vessels and from the adductor longus by the femoral vein. Proximally, the nerve to the pectineus passes medially behind the artery; lateral to it is the femoral nerve. The femoral vein is medial in the proximal part of the triangle, becoming posterior near its apex, distally.

Medial Circumflex Femoral Artery
Originating usually from the posteromedial aspect of the profunda but often the femoral artery, this artery supplies the adductor muscles and curves medially round the femur between pectineus and psoas major and then obturator externus and adductor brevis, finally appearing between quadratus femoris and upper border of adductor magnus, dividing into transverse and ascending branches. The transverse branch takes part in the cruciate anastomosis. The ascending branch ascends on the tendon of the obturator externus, anterior to the quadratus femoris, to the trochanteric fossa, where it anastomoses with branches of the gluteal and lateral circumflex femoral arteries. An acetabular branch at the proximal edge of the adductor brevis enters the hip joint under the transverse acetabular ligament with one from the obturator artery; it supplies the fat in the fossa, and reaches the femoral head along its ligament. For blood supply of the proximal end of the femur consult Crock (1965).

Vascular system : Venous system

Inferior Vena Cava
The inferior vena cava conveys blood to the right atrium from all structures below the diaphragm. It is formed by the junction of the common iliac veins anterior to the fifth lumbar vertebral body, a little to its right. It ascends anterior to the vertebral column, to the right of the aorta. Reaching the liver, it is contained in a deep groove on its posterior surface or sometimes in a tunnel completed by a band of liver tissue. It perforates the tendinous part of the diaphragm between its median and right 'leaves' and inclines slightly anteromedially. Passing through the fibrous pericardium and through a posterior inflexion of the serous pericardium it opens into the inferoposterior part of the right atrium. Anterior and left of its atrial orifice is a semilunar valve of the inferior vena cava, relatively less prominent in adults, but large and overtly functional in the fetus. The vessel is otherwise devoid of valves.

Relations of the Abdominal Part
Anteriorly the inferior vena cava is overlapped at its commencement by the right common iliac artery and covered, below the horizontal part of the duodenum, by the posterior parietal peritoneum. It is crossed obliquely by the root of the mesentery and its contained vessels and nerves and by the right testicular or ovarian artery. It ascends behind the head of the pancreas and then the superior part of the duodenum, separated from it by the common bile duct and portal vein. Above the duodenum it is again covered by peritoneum of the posterior wall of the epiploic foramen, separating it from the right free border of the lesser omentum and its contents. Above this the liver is anterior.
Posterior are the lower three lumbar vertebral bodies, their intervening 'discs' and the anterior longitudinal ligament, the right psoas major, right sympathetic trunk, and third and fourth right lumbar arteries; superior to these are the right crus (partially separated by the medial part of the right suprarenal gland and the right coeliac ganglion) and the right renal, suprarenal and inferior phrenic arteries.
Right lateral are the right ureter, the descending part of the duodenum, the medial border of the right kidney and right lobe of the liver. Left lateral are the aorta and above this the right crus and caudate lobe.

Lumbar Veins
Four pairs of lumbar veins collect blood by dorsal tributaries from lumbar muscles and skin, and by abdominal tributaries from the walls of the abdomen, where they connect with the epigastric veins. Near the vertebral column they drain the vertebral plexuses and are connected by the ascending lumbar vein, a longitudinal vessel anterior to the roots of the lumbar transverse processes. The third and fourth lumbar veins pass forward on the sides of the corresponding vertebral bodies to enter the posterior aspect of the inferior vena cava; the left veins pass behind the abdominal aorta and are therefore longer. First and second lumbar veins may join the inferior vena cava, ascending lumbar, or lumbar azygos veins; the first does not usually enter the inferior vena cava; it may turn down to join the second and so open into it indirectly, but more often it ends in the ascending lumbar vein or passes forward over the first lumbar vertebral body to the lumbar azygos vein. The second lumbar vein may join the inferior vena cava at or near the level of the renal veins; sometimes it joins the third lumbar vein or may end in the ascending lumbar. First and second

lumbar veins are often connected to each other, to contralateral veins and to right and left lumbar azygos veins by a plexus on the upper lumbar vertebral bodies.

Ascending Lumbar Vein

It connects the common iliac, iliolumbar and lumbar veins. It lies between psoas major and roots of the lumbar transverse processes. Superiorly it joins the subcostal vein and the vessel so formed turns forward over the twelfth thoracic vertebral body and, passing deep to the crus, ascends as the azygos vein on the right and as the hemiazygos on the left. There is an angle on the vessel as it turns up; it is usually joined here by a small vessel from the back of the inferior vena cava (or left renal vein on the left). This little vein represents the azygos line, already described as the lumbar azygos vein. Sometimes the ascending lumbar vein ends in the first lumbar, which then skirts the first lumbar vertebra with the first lumbar artery to join the lumbar azygos vein, the subcostal vein then joining the azygos vein on the right and the hemiazygos on the left.

Testicular Veins

They emerge posteriorly from the testis, drain the epididymis and unite to form the pampiniform plexus, a chief component of the spermatic cord, ascending anterior to the ductus deferens. Distal to the superficial inguinal ring the plexus is drained by three or four veins traversing the inguinal canal to the abdomen through the deep inguinal ring; they coalesce into two veins, which ascend anterior to psoas major and ureter, behind the peritoneum, on each side of the testicular artery. These veins join and open into the inferior vena cava on the right at an acute angle just inferior to the level of the renal veins; the left testicular vein opens into the left renal vein at a right angle. The testicular veins contain valves; the left passes behind the lower descending colon and inferior margin of the pancreas and is crossed by the left colic vessels; the right passes behind the terminal ileum and horizontal part of the duodenum and is crossed by the root of the mesentery, ileocolic and right colic vessels.

Clinical Anatomy

The testicular veins are frequently varicose; varicocele, which is almost always on the left, is perhaps due to the orthogonal junction of the left testicular and renal veins. There is evidence that the presence of a varicocele raises testicular temperature and impairs fertility, which is why an operation to correct it is often advised. After removal of a varicocele, venous return is by the small veins of the ductus deferens, cremaster and scrotal tissues.

Ovarian Veins

Each of them forms a plexus in the broad ligament near the ovary and uterine tube, communicating with the uterine plexus. Two veins issue from this and ascend across the external iliac artery with the ovarian artery. Their further course is like that of the testicular veins. Valves may occur in them. Like the uterine veins, they are much enlarged in pregnancy.

Inferior Mesenteric Vein

It drains the rectum, and sigmoid and descending parts of the colon. It begins as the superior rectal vein, from the rectal plexus, through which it connects with middle and inferior rectal veins. The superior rectal vein leaves the pelvis and crosses the left common iliac vessels medial to the left ureter with the superior rectal artery,

continuing up as the inferior mesenteric vein. This is left of its artery, ascending behind the peritoneum anterior to the left psoas major; it may cross the testicular or ovarian vessels or be medial to them and then passes above, or behind, the duodenojejunal flexure, opening into the splenic vein posterior to the body of the pancreas; sometimes it ends at the union of the splenic and superior mesenteric veins. If a duodenal or paraduodenal fossa exists, the vein is usually in its anterior wall. Its tributaries are sigmoid veins from the sigmoid colon and the left colic vein from the descending colon and the left colic flexure.

Alimentary system

Mesentery (of the Small Intestine)
A broad, fan-shaped fold, it connects the coils of the jejunum and ileum to the posterior abdominal wall. The attached, parietal border is the root of the mesentery about 15 cm (6 in.) long and directed obliquely down from the duodenojejunal flexure (left of the second lumbar vertebra) to the upper part of the right sacro-iliac joint. (Schmidt 1974 measured the mesenteric 'root' in 44 cadavers, finding a mean length of 13.9 cm, with extremes of 7.4 and 19.3 cm.) It passes successively in front of the horizontal part of the duodenum (where the superior mesenteric vessels enter it), the abdominal aorta, inferior vena cava, right ureter and right psoas major. The intestinal border is about 6 m (20 ft) long and compactly plicated. The plication diminishes towards the posterior abdominal wall where the attachment is almost along a straight line. The central part is longest (measured from its root to the intestinal border), attaining a maximum of about 20 cm (8 in.); it shortens towards each end. The mesentery consists of two layers of peritoneum, a right and a left, enclosing the jejunal and ileal branches of the superior mesenteric vessels, with their accompanying neural plexuses, lymph vessels (here called lacteals), mesenteric lymph nodes, loose connective and adipose tissue. Fat is most abundant in its lower part and here extends from the root to the intestinal border; the upper mesentery contains less fat, with a tendency to accumulate near the root, leaving rounded, translucent, fat-free areas adjoining the upper jejunum. At the intestinal border, the layers separate to enclose the gut, as its visceral peritoneum. At the mesenteric root the right layer is reflected in its lower part to the posterior abdominal wall and ascending colon and in its upper part to become continuous with the inferior layer of the transverse mesocolon; the left layer passes to the posterior abdominal wall and descending colon. (This arrangement helps to distinguish between the proximal and distal coils of the small intestine when in situ.)

Sigmoid Mesocolon
This is a peritoneal fold attaching the sigmoid colon to the pelvic wall, the attachment being an inverted V with an apex near the division of the left common iliac artery; the left limb descends medial to the left psoas major and the right passes into the pelvis to end in the midline at the level of the third sacral vertebra. Sigmoid and superior rectal vessels run between its layers and the left ureter descends into the pelvis behind its apex.

Duodenal Relations
Superior (First) Part
About 5 cm long, it is the most mobile section, extending from the pylorus to the neck of the gallbladder. Peritoneum covers its anterior aspect but it is bare of this posteriorly, except for about 2.5 cm near the pylorus where it takes a small part in the formation of the anterior wall of the omental bursa; here the lesser omentum is attached to its upper border and the greater omentum to its lower (proximal half). It is related above and in front with the quadrate lobe of the liver and gallbladder and more posteriorly above with the epiploic foramen, behind with the gastroduodenal artery, bile duct and portal vein and posteroinferiorly with the head and neck of the pancreas. It is usually stained by leakage of bile after death especially on its anterior surface where it is related to the gallbladder.

Descending (Second) Part
From 8–10 cm long, it descends from the neck of the gallbladder along the right side of the vertebral column to the lower border of the third lumbar vertebral body. Crossed by the transverse colon, it is connected to it by some loose connective tissue and above and below this attachment it is covered in front with peritoneum. It is related in front, from above downwards: to the right lobe of the liver, transverse colon and the root of its mesocolon and to the jejunum; behind it is variably related to the right kidney near its hilum (being connected to it by loose connective tissue) to the right renal vessels, the edge of the inferior vena cava and psoas major. Medial to it are the head of the pancreas and bile duct, while lateral is the right colic flexure. A small part of the pancreatic head is sometimes embedded in the duodenal wall. The bile and pancreatic ducts come into contact at its medial side, entering its wall obliquely and uniting to form the hepatopancreatic ampulla. The narrow, distal end of this opens on the summit of the major duodenal papilla, sited posteromedially in the descending duodenum, 8–10 cm distal to the pylorus. An accessory pancreatic duct may open about 2 cm above to the major papilla on a minor duodenal papilla.

Horizontal (Inferior or Third) Part
About 10 cm long, this passes from the right of the lower border of the third lumbar vertebra, sloping slightly up and to the left across the inferior vena cava, to end in the fourth part in front of the abdominal aorta. Its anterior surface is crossed with peritoneum, except in the median plane where it is crossed by the superior mesenteric vessels and mesenteric root. Its posterior surface is covered by peritoneum only at its left end, where the left layer of the mesentery sometimes covers it. The posterior surface rests upon: the right ureter, right psoas major, right testicular (or ovarian) vessels, the inferior vena cava and the abdominal aorta (with the origin of the inferior mesenteric artery). Its superior aspect is related to the head of the pancreas, its inferior to coils of the jejunum.

Ascending (Fourth) Part
About 2.5 cm long, it ascends on or immediately to the left of the aorta, to the level of the upper border of the second lumbar vertebra, where it turns forwards into the jejunum at the duodenojejunal flexure; it is anterior to the left sympathetic trunk, left psoas major, left renal and gonadal vessels and the inferior mesenteric vein. To the right it gives attachment to the upper part of the root of the mesentery, its left layer being continued over the duodenum's anterior surface and left side. To its left are the left kidney and ureter; above is the body of the pancreas; in front are the transverse colon and transverse mesocolon, the latter separating the duodenojejunal flexure from the omental bursa and stomach.

Large Intestine
The large intestine, extending from the distal end of the ileum to theanus, is about 1.5 m long; its calibre is greatest near the caecum and gradually diminishes to the rectum, where it enlarges just above the anal canal. Its function is chiefly absorption of fluid and solutes, and it differs in structure, size and arrangement from the small intestine in the following ways:
- it has a greater calibre
- it is for the most part more fixed in position
- its longitudinal muscle, though a complete layer, is concentrated into three longitudinal taeniae coli

- the colonic wall is puckered into sacculations (haustrations) by the taeniae (so it is said) but sacculation is probably not thus fully explained.

Small adipose projections, appendices epiploicae, are scattered over the free surface of the whole colon, but are absent from the caecum, vermiform appendix and rectum.

The large intestine curves around the coils of the small intestine, commencing in the right iliac region as a dilated caecum (intestinum crassum caecum). (The term caecum, like rectum, duodenum, etc. is an adjective, used by linguistic abbreviation as a noun.) The caecum leads to the vermiform appendix and colon, the latter ascending in the right lumbar and hypochondriac regions to the inferior aspect of the liver; here it bends (right colic flexure) to the left and, with an antero-inferior convexity, loops across the abdomen as the transverse colon to the left hypochondriac region, where it curves again (left colic flexure) to descend through the left lumbar and iliac regions to the lesser pelvis. Here it forms a sinuous loop, the sigmoid colon, continuing along the lower posterior pelvic wall as the rectum and anal canal.

Caecum

The caecum lies in the right iliac fossa; its surface projection occupies the triangular area between the right lateral and transtubercular planes and the inguinal ligament. It is a large cul-de-sac continuous with the ascending colon at the level of the ileal opening on the medial side and below this with the vermiform appendix. Its average axial length is about 6 cm and its breadth about 7.5 cm. It is superior to the lateral half of the inguinal ligament, resting posteriorly on the right iliacus (with the lateral cutaneous nerve of the thigh interposed) and psoas major, separated from both by covering fasciae and peritoneum. Posterior to it is the retrocaecal recess, frequently containing the vermiform appendix. Anteriorly, it usually contacts the anterior abdominal wall, but the greater omentum and, when it is empty, some coils of the small intestine may intervene. Usually it is entirely covered by peritoneum, but sometimes incompletely, when the upper part of the posterior surface is sessile and connected to the iliac fascia by loose connective tissue. Commonly, however, the caecum is mobile, and may even herniate through the right inguinal canal. It can also usually be delivered through an appropriate incision in the anterior abdominal wall at appendicectomy.

Caecal Variations

The caecum has been classified into four types (Treves 1885). In early fetal life it is short, conical and broad at the base, with an apex turned superomedially towards the ileocaecal junction. As the fetus grows, the caecum increases more in length than breadth, to form a longer tube with a narrower base but retaining the same inclination. Distal growth later ceases, but the proximal part continues to grow in breadth, so that at birth a narrow vermiform appendix extends from the apex of a conical caecum. This infantile form persists throughout life in about 2%, regarded by Treves as the first type; the three taeniae coli start from the appendix and are equidistant from each other. In the second type, the conical caecum becomes quadrate by outgrowth of a saccule on each side of the anterior taenia; these saccules are of equal size and the appendix arises from the depression between them instead of from the apex of a cone. This type occurs in about 3%. In the third type (normal in humans) the two saccules grow at unequal rates, the right more rapidly, forming a new 'apex'; the original apex, with the appendix attached, is pushed towards the ileocaecal junction; the taeniae still start from the appendicular base but are not equidistant, the growth of the right saccule pushing between the anterior and

posterolateral taeniae. This type occurs in about 90%. The fourth type is merely an exaggeration of the third, the right saccule growing still further and the left atrophying so that the original caecal apex and appendix are near the ileocaecal junction, the anterior taenia also turning medially to it. This type occurs in about 4%. In a more recent study (Pavlov & Pétrov 1968) of 82 males and 44 females (adolescent and adult), the third type was designated ampullary, accounting for 78%. An infundibular type, approximating to the infantile conical category, occurred in 13%; 9% were intermediate. The caecum was mobile 20% more often in females. (For further analyses consult Balthazar & Gade 1976.)

Ileocaecal Valve

The ileum opens into the posteromedial aspect of the large intestine, at the junction of the caecum and colon. A surface marking of this structure is the intersection of the right lateral and transtubercular planes; about 2 cm below this the vermiform appendix opens into the caecum. The ileocaecal orifice has a so-called 'valve', consisting of two flaps projecting into the lumen of the large intestine. In the distended, fixed caecum the flaps are semilunar. The upper, approximately horizontal, is attached to the junction of the ileum and colon, the lower, longer and more concave, to the junction of the ileum and caecum. At their ends the flaps coalesce, continuing as narrow membranous ridges, the frenula of the valve. The anterior or left end of the aperture is rounded, the right or posterior is narrow and pointed. In the natural state the valvular lips project as thick folds into the caecal lumen, the orifice appearing like a slit or oval. Circular and longitudinal muscle layers of the terminal ileum continue into the valve to form a sphincter. However, direct observation of the living ileocaecal 'valve' does not corroborate this description (Rosenberg & DiDio 1969); in nine cases, studied by caecostomy, the ileal projection was papillary in shape. Radiological evidence also contradicts the concept of an effective ileocaecal valve at this junction.

Accumulations of circular fibres, sometimes described as sphincters, have been observed at various levels in all parts of the colon (DiDio & Anderson 1968; Rosenberg & DiDio 1969). The functional reality of most of these remains doubtful. Such sphincteric mechanisms must, of course, be balanced by antagonistic, dilatatory actions.

The margin of the ileocaecal valve is a reduplication of the intestinal mucosa and circular muscle; longitudinal muscle fibres are partly reduplicated as they enter the valve (Jit & Singh 1956), but the more superficial fibres and the peritoneum continue uninterruptedly from the small to the large intestine. The ileal valvular surfaces are covered with villi and have the structure of the mucosa of the small intestine; their caecal aspects display no villi but numerous orifices of tubular glands peculiar to the colonic mucosa. It is usually said that the valve not only prevents reflux from the caecum to the ileum but is probably also a sphincter regulating the passage of ileal contents into the caecum; the valve is kept in tonic contraction by sympathetic innervation. Entry of food into the stomach initiates contraction of the small intestine, expelling ileal contents into the large intestine (the gastro-ileal reflex).

Vermiform Appendix

The vermiform appendix is a narrow, vermian (worm-shaped) tube, arising from the posteromedial caecal wall, 2 cm or less below the end of the ileum. It may occupy one of several positions:

- behind the caecum and lower ascending colon (retrocaecal and retrocolic);
- dependent over the pelvic brim (pelvic or descending), in females in close relation to the right uterine tube and ovary;
- lying below the caecum (subcaecal);
- in front of the terminal ileum when it may be in contact with the anterior abdominal wall;
- behind the terminal ileum.

In 10,000 subjects (Wakeley 1933) the vermiform appendix was retrocaecal and retrocolic (65.28%), pelvic (31.01%), subcaecal (2.26%), pre-ileal (1.0%) and postileal (0.4%). Subsequent literature, anatomical and surgical, shows much contradiction of this classic study. Buschard and Kjaeldgaard (1973), reporting a short series (234 autopsies), compared the results of several studies dating from 1885–1973, Wakeley's remaining by far the largest. They classified all positions as either anterior (pelvic and ileocaecal) or posterior (retrocaecal and subcaecal). All but three of 11 series quoted found anterior positions more frequent. Like Wakeley they observed posterior positions more commonly in their own Danish series; in German autopsies the finding was reversed. Collins (1932), in the second largest series (4680), returned percentages the reverse of Wakeley's, the ratio of anterior to posterior being 78.5% to 21.5% (Collins) and 32.4% to 67.6% (Wakeley). In view of these disagreements, such figures are of dubious value. Perhaps observers have used differing criteria or possibly there are demographic variations. For the present, however, such percentages remain unreliable.

The usual surface marking for the appendicular base is the junction of the lateral and middle thirds of the line joining the right anterior superior iliac spine to the umbilicus (McBurney's point); but this is merely a useful surgical approximation, with considerable variation. The three taeniae coli on the ascending colon and caecum converge on the base of the appendix, merging into its longitudinal muscle. The anterior caecal taenia is usually distinct and traceable to the appendix, affording a guide to it. The appendix varies from 2–20 cm in length, the average being about 9 cm. It is longer in children and may atrophy or diminish after mid-adult life. It is connected by a short mesoappendix to the lower part of the ileal mesentery. This fold is usually triangular, extending almost to the appendicular tip along the whole tube. The main appendicular artery, a branch from the lower division of the ileocolic, runs behind the terminal ileum to enter the mesoappendix a short distance from the appendicular base. Here it gives off a recurrent branch which anastomoses at the base of the appendix with a branch of the posterior caecal artery, the anastomosis sometimes being large. The main appendicular artery approaches the tip of the organ, at first near to and then in the edge of the mesoappendix. The terminal part of the artery, however, lies on the wall of the appendix and may be thrombosed in appendicitis, resulting in distal gangrene or necrosis. The arterial supply of the appendix may vary considerably. Accessory arteries are common; in 80% of subjects there are two or more arteries of supply (Solanke 1968).

The canal of the appendix is small and opens into the caecum by an orifice lying below and a little behind the ileocaecal opening. The orifice is sometimes guarded by a semilunar mucosal fold forming a valve. The lumen may be partially or wholly obliterated in the later decades of life. In view of its rich vascularity and histological differentiation, the appendix is probably a specialized rather than a degenerate or vestigial structure. The caecum and appendix in man and anthropoid apes is considered to be less primitive than in monkeys. A comparative study of the primate vermiform appendix has been made by Scott (1980).

Microstructure of the Appendix

The layers of the appendix wall are essentially as in the rest of the large intestine. The serosa is a complete investment, except along the mesenteric attachment; there is a subserous layer of connective tissue. The longitudinal muscular fibres form a complete, uniformly thick layer, except over a few small areas where both muscular layers are deficient, leaving the serosa and submucosa in contact. At the base the longitudinal muscle thickens to form rudimentary taeniae continuous with those of the caecum and colon. The circular muscular fibres form a thicker layer separated from the longitudinal by connective tissue. The submucosa is well developed, containing many lymphoid masses which cause the mucosa to bulge into the lumen, narrowing it irregularly. The mucosa is covered by columnar epitheliocytes and attenuated antigen-transporting 'M' cells (Owen & Nemanic 1978). Glands (crypts similar to those of the colon) are few and penetrate deeply into the lymphoid tissue, which in the normal human appendix is situated primarily in the lamina propria and extends into the submucosa; follicular and parafollicular zones containing B- and T-lymphocytes can be distinguished; clustered lymphocytes also appear between the epithelial cells, where some may possibly differentiate into plasma cells (Gorgollón 1978). Lymphoid tissue in the lamina propria contains many plasma cells, with lymphocytes, eosinophils and other leucocytes, mast cells and macrophages embedded in a fibrocellular reticulum. The submucosal follicles (germinal centres) are organized like those of other examples of gut-associated lymphoid tissue. The lymphoid masses are a local defence against infection; it has also been suggested that they may be a homologue of the avian bursa of Fabricius concerned in the acquisition of immunological competence by certain lymphocytes. However, experimental evidence argues against this function. In many mammals, particularly herbivores, the caecum and appendix are large and constitute a highly important site of digestion of cellulose by symbiotic bacteria.

Colon

The colon is conveniently considered in four parts: ascending, transverse, descending and sigmoid.

Ascending Colon

About 15 cm long and narrower than the caecum, it ascends to the inferior surface of the right lobe of the liver, on which it makes a shallow depression; here it turns abruptly forwards and to the left, at the right colic flexure. In surface projection it ascends lateral to the right lateral plane from the transtubercular to midway between the subcostal and transpyloric planes. It is covered by peritoneum except where its posterior surface is connected by loose connective tissue to the iliac fascia, and to the iliolumbar ligament, quadratus lumborum, aponeurosis of transversus abdominis and the perirenal fascia on the front of the inferolateral area of the right kidney. Crossing behind it are the lateral femoral cutaneous nerve, usually the fourth lumbar artery, and sometimes the ilio-inguinal and iliohypogastric nerves. Sometimes it possesses a distinct but narrow mesocolon. In a series of 100 subjects, 52% had neither an ascending nor descending mesocolon, 14% had both, 12% an ascending and 22% a descending mesocolon (Treves 1885). Anteriorly it is in contact with the coils of the ileum, the greater omentum and the anterior abdominal wall.

Right Colic Flexure
This is found at the junction of the ascending and transverse colon; the latter turns down, forwards and to the left. Posterior is the inferolateral part of the anterior surface of the right kidney; above and anterolaterally is the right lobe of the liver; anteromedially are the descending part of the duodenum and fundus of the gallbladder. Its posterior aspect is not covered by peritoneum and is in direct contact with renal fascia. It is not so acute as the left colic flexure.

Transverse Colon
About 50 cm long, it extends from the right colic flexure in the right lumbar region, across into the left hypochondriac region, here curving sharply down and backwards below the spleen as the left colic flexure. The transverse colon describes an arch, its concavity usually directed back and up; near its splenic end an abrupt U-shaped curve may descend lower than the main arch. Its surface projection extends from a point situated just lateral to the right lateral plane, and midway between the subcostal and transpyloric planes, to the umbilicus and then up and left to a point just superolateral to the intersection of the left lateral and transpyloric planes. A precise projection is difficult to define, varying much even in the same individual. Commonly it is in the lower umbilical or upper hypogastric region. It frequently descends in a V-shaped manner, the apex being well below the level of the iliac crests. In a radiological assessment in the upright position, its lowest level in 1000 young adults was found to vary much, even reaching the true pelvis; levels varied as much as 17 cm in the same individual between upright and recumbent positions (Moody 1927). The posterior surface at its right end is devoid of peritoneum and is attached by loose connective tissue to the front of the descending part of the duodenum and the head of the pancreas; but from the latter to the left colic flexure it is almost completely invested by peritoneum, connecting it to the anterior border of the body of the pancreas by the transverse mesocolon. Above the transverse colon are the liver and gallbladder, the greater gastric curvature and the lateral end of the spleen; below is the small intestine, in front are the posterior layers of the greater omentum and behind are the descending part of the duodenum, the head of the pancreas, the upper end of the mesentery, the duodenojejunal flexure and coils of the jejunum and ileum.

Left Colic Flexure
This is the junction of the transverse colon and descending colon in the left hypochondriac region; it is related to the lower part of the spleen and pancreatic tail above and medially with the front of the left kidney. It is so acute that the end of the transverse colon usually overlaps the front of the descending colon. The left flexure is above and on a more posterior plane than the right flexure and is attached to the diaphragm level with the tenth and eleventh ribs by the phrenicocolic ligament, which lies below the anterolateral pole of the spleen.

Descending Colon
About 25 cm long, it descends through the left hypochondriac and lumbar regions, at first following the lower part of the lateral border of the left kidney and then descending in the angle between the psoas major and quadratus lumborum to the iliac crest; it then curves downwards and medially in front of the iliacus and psoas major to end in the sigmoid colon at the inlet of the lesser pelvis. (It is sometimes described as ending at the iliac crest, the part between this and the pelvic inlet being

named the iliac colon.) In surface projection it descends just lateral to the left lateral plane, from a little above and left of the intersection of the transpyloric and left lateral planes as far as the inguinal ligament. Peritoneum covers all but its posterior surface, which is connected by loose connective tissue to fascia over the inferolateral region of the left kidney, the aponeurosis of transversus abdominis, the quadratus lumborum, iliacus and psoas major. Crossing behind it are the following left structures: subcostal vessels and nerve, iliohypogastric and ilio-inguinal nerves, fourth lumbar artery (usually), the lateral femoral cutaneous, femoral and genitofemoral nerves, the testicular (or ovarian) vessels and the external iliac artery. The descending colon is smaller in calibre, more deeply placed, and more frequently covered behind by peritoneum than the ascending colon. Anteriorly are the coils of the jejunum, except for its lower part which is palpable when the abdominal muscles are relaxed.

Sigmoid Colon (Pelvic Colon)

It begins at the pelvic inlet, continuing in the descending part; it forms a variable loop of about 40 cm and is normally in the lesser pelvis. The loop first descends in contact with the left pelvic wall, then crosses the pelvic cavity between the rectum and bladder in males, and rectum and uterus in females, and may reach the right pelvic wall; finally it turns back to the midline level with the third piece of the sacrum, where it bends downwards and ends in the rectum. It is closely surrounded by peritoneum, forming a mesentery, the sigmoid mesocolon, which diminishes in length from the centre towards its ends, where it disappears; the loop is fixed at its junctions with the descending colon and rectum but quite mobile between them. Its relations are therefore variable. Laterally are: the left external iliac vessels, the obturator nerve, ovary or ductus deferens and the lateral pelvic wall; posteriorly the left internal iliac vessels, ureter, piriformis and sacral plexus; inferiorly the bladder in males or uterus and bladder in females; superiorly and to the right it is in contact with terminal coils of the ileum.

The position and shape of the sigmoid colon vary much, depending on:

- its length
- the length and mobility of its mesocolon
- the degree of distension (when distended it rises into the abdominal cavity, sinking again into the lesser pelvis when empty)
- the condition of the rectum, bladder and uterus (when these are distended the sigmoid colon tends to rise and to fall when they are empty).

Racial variation has been noted (Lisowski 1969): in some groups, particularly Ethiopians, the incidence of a suprapelvic loop, perhaps conducive to volvulus, is particularly high.

Rectum

The rectum is continuous with the sigmoid colon at the level of the third sacral vertebra, the junction being at the lower end of the sigmoid mesocolon. The rectum descends along the sacrococcygeal concavity, with an anteroposterior curve, the sacral flexure of the rectum. It thus curves down and back, then downwards, and finally down and forwards to join the anal canal by passing through the pelvic diaphragm. The anorectal junction is 2–3 cm in front of and slightly below the tip of the coccyx; from this level (in males opposite the apex of the prostate) the anal canal passes down and backwards from the lower end of the rectum, this backward bend of

the gut being termed the perineal flexure of the rectum. The rectum also deviates in three lateral curves: the upper is convex to the right, the middle (the most prominent) bulges to the left and the lower is convex to the right. Both ends of the rectum are in the median plane.

The rectum is about 12 cm long, with the same diameter as the sigmoid colon above (about 4 cm in the empty state), but its lower part is dilated as the rectal ampulla. The rectum differs from the sigmoid colon in having no sacculations, appendices epiploicae or mesentery; the taeniae blend about 5 cm above the rectosigmoid junction, forming two wide muscular bands which descend, anterior and posterior, in the rectal wall. The peritoneum is related only to the upper two-thirds, covering its front and sides above, and lower down only its front, from which it is reflected on to the bladder in males, forming the rectovesical pouch, and on to the posterior vaginal wall in females, forming the recto-uterine pouch. The level of this reflexion is higher in males, the rectovesical pouch being about 7.5 cm (about the length of the index finger) from the anus; in females the recto-uterine pouch is about 5.5 cm from the anus. In the male fetus, peritoneum extends on to the front of the rectum as far as the lower limit of the prostate. On the sigmoid colon, peritoneum is firmly attached to the muscle layer by fibrous connective tissue but as it descends on to the rectum it is more loosely attached by fatty connective tissue, allowing for considerable expansion.

In the empty rectum, the mucosa in its lower part presents a number of longitudinal folds which become effaced during distension. There are also permanent semilunar transverse or horizontal folds, most marked in rectal distension. Two forms of horizontal fold have been recognized (Jit 1961); one consists of the mucosa, a circular muscle layer and part of the longitudinal muscle, and an indentation on the rectal exterior; the other is devoid of longitudinal muscle and has no external marking. Their number is variable but there are commonly three folds. An upper one, near the beginning of the rectum, may be either on the left or right; occasionally it encircles the gut, constricting its lumen. The middle fold is largest and most constant; it lies immediately above the ampulla, projecting from the anterior and right wall just below the level of the anterior peritoneal reflexion; the circular muscle is more marked in this fold than in the others. The lowest fold, inconstant and on the left, is about 2.5 cm below the middle fold. Sometimes a fourth occurs on the left about 2.5 cm above the middle fold.

It has been suggested (Paterson 1912) that the rectum consists of two functional parts, above and below the middle fold, the upper containing faeces and being free to distend into the peritoneal cavity, the lower more confined, enclosed in a tube of condensed extraperitoneal tissue and (except during defaecation) normally empty; in chronic constipation or after death it may contain faeces. (Note that the rectum above the middle fold is considered to develop from the hindgut and the part below, with the upper anal canal, to originate from the cloaca or postallantoic gut.) Others (O'Beirne 1833; Hurst 1919) have considered the sigmoid colon a faecal reservoir, the rectum being normally empty and the entry of faeces into it exciting defaecation.

Experimental distension of the rectum and anal canal results in the desire to defaecate and causes the relaxation of the anal sphincters (Denny-Brown & Robertson 1935).

Relations of the Rectum

Posterior to the rectum in the median plane are: the lower three sacral vertebrae, coccyx, median sacral vessels, ganglion impar and branches of the superior rectal vessels; while on each side, particularly on the left, are: the piriformis, the anterior

rami of the lower three sacral and coccygeal nerves, sympathetic trunk, lower lateral sacral vessels, the coccygei and the levatores ani. The rectum is attached to the sacrum along the lines of the anterior sacral foramina by fibrous connective tissue enclosing: the sacral nerves and the pelvic splanchnic nerves from the anterior rami of the second to fourth sacral nerves, which join the pelvic plexuses on the rectal wall; rami of the superior rectal vessels, lymphatic vessels, lymph nodes; and loose perirectal fat. Anterior in males above the site of the peritoneal reflexion from the rectum are the upper parts of the base of the bladder and of the seminal vesicles, the rectovesical pouch and its contents (terminal coils of the ileum and sigmoid colon); below the reflexion are: the lower parts of the base of the bladder and of the seminal vesicles, deferent ducts, terminal parts of the ureters and the prostate. In females, above the reflexion are: the uterus, upper vagina, recto-uterine pouch and contents (terminal coils of the ileum and sigmoid colon), while below the reflexion is the lower part of the vagina. Laterally, the upper part of the rectum is related to the pararectal fossa and contents (sigmoid colon or lower ileum), while below the peritoneal reflexion laterally are the pelvic sympathetic plexuses, coccygei and levatores ani and branches of the superior rectal vessels.

Urinary system

The Kidneys

The kidneys excrete the final products of metabolic activities and excess water, both of these actions being essential to the control of concentrations of various substances in the body fluids, for example maintaining electrolyte and water balance approximately constant in the tissue fluids. They also have endocrine functions producing and releasing erythropoietin which affects blood formation, renin which influences blood pressure and 1,25-hydroxycholecalciferol, which is involved in the control of calcium metabolism and a derivative of vitamin D, perhaps modifying the action of the parathyroid hormone (O'Riordan 1978), and various other soluble factors with metabolic actions. The kidneys in the fresh state are reddish-brown, are situated posteriorly behind the peritoneum on each side of the vertebral column and are surrounded by adipose tissue. Superiorly they are level with the upper border of the twelfth thoracic vertebra, inferiorly with the third lumbar. The right is usually slightly inferior to the left, probably due to its relationship to the liver. The left is a little longer and narrower than the right and lies nearer the median plane. The long axis of each kidney is directed inferolaterally and the transverse axis posteromedially. Hence the anterior and posterior aspects usually described are in fact anterolateral and posteromedial. The transpyloric plane passes through the superior part of the right renal hilum and the inferior part of the left.

Each kidney is about 11 cm in length, 6 cm in breadth and 3 cm in anteroposterior dimension. In adult males the average weight is about 150 g, in adult females 135 g. In thin individuals with a lax abdominal wall the lower pole may just be felt in full inspiration by bimanual lumbar examination; usually, however, it is impalpable.

Renal Surface Projections

In a recumbent posture, each renal profile can be projected to the anterior or posterior surface of the body as follows, the right kidney being about 1.25 cm lower than the left:

- Anterior surface. The hilar centre is approximately at the transpyloric plane, about 5 cm from the midline and slightly medial to the tip of the ninth costal cartilage. The left hilum is just above the plane, the right just below it (13.1). In relation to the position of the hilum, a reniform profile can be drawn 11 cm long and 4.5 cm broad, the upper pole being about 2.5 cm and the lower 7.5 cm from the midline. Since the transverse axis is oblique, the width thus shown is 1.5 cm less than the actual width of the kidney.
- Posterior surface. The hilar centre is opposite the lower border of the spinous process of the first lumbar vertebra and about 5 cm from the midline. In relation to this point, a reniform profile can be similarly traced, the lower pole being usually about 2.5 cm above the summit of the iliac crest. The kidneys are about 2.5 cm lower in the standing than in the recumbent position; they ascend and descend a little with respiration.

Renal Relations

The convex anterior surface in reality faces anterolaterally. Its relations differ on the two sides of the body.

(1) Anterior surface of right kidney. A small area of the superior pole contacts the right suprarenal gland, which may overlap it or the upper part of the medial border. A large area below this (about three-quarters of the surface) adjoins the renal impression on the right lobe of the liver and a narrow medial area is related to the

descending part of the duodenum. Inferiorly the anterior surface is in contact laterally with the right colic flexure and medially with part of the small intestine. The areas related to the small intestine and almost all those in contact with the liver are covered by peritoneum (with the renal fascia subjacent); the suprarenal, duodenal and colic areas are devoid of peritoneum.

(2) Anterior surface of left kidney. A small medial area of the superior pole is related to the left suprarenal gland and approximately the upper two-thirds of the lateral half of the anterior surface is related to the spleen. A central quadrilateral area lies in contact with the pancreatic body and splenic vessels. Above this a small variable triangular region, between the suprarenal and splenic areas, is in contact with the stomach. Below the pancreatic and splenic areas the lateral region is related to the left colic flexure and the beginning of the descending colon, while the medial region adjoins the coils of the jejunum. The latter region is extensive but the colic area is an irregular, narrow strip adjoining the lateral border of the kidney. The gastric area is covered with the peritoneum of the omental bursa and the splenic and jejunal areas are covered by the peritoneum of the greater sac; behind the jejunal area's peritoneum, branches of the left colic vessels are related to the kidney. The suprarenal, pancreatic and colic areas are devoid of peritoneum, there being no independent movement of organs here.

The posterior surface, in reality posteromedial, is embedded in fat and devoid of peritoneum. It is anterior to the diaphragm and to the medial and lateral arcuate ligaments, psoas major, quadratus lumborum and the aponeurotic tendon of transversus abdominis, to the subcostal vessels and subcostal, iliohypogastric and ilio-inguinal nerves. The upper pole of the right kidney is level with the twelfth rib, that of the left with the eleventh and twelfth. The diaphragm separates the kidney from the pleura which descends to form the costodiaphragmatic recess; sometimes its muscle is defective or absent in a triangle immediately above the lateral arcuate ligament, allowing perirenal adipose tissue to contact the diaphragmatic pleura.

The superior poles are thick, round, nearer the midline than the inferior poles, and each is related to its suprarenal gland. The inferior poles, smaller and thinner, extend to within 2.5 cm of the iliac crests. The lateral borders are convex, the left covered superiorly by greater sac peritoneum, so separating it from the spleen, and below this is in contact with the descending colon; the right lateral border is separated by the peritoneum of the greater sac from the liver (right lobe). The medial borders are convex adjacent to the poles, concave between them and slope inferolaterally. In each a deep vertical fissure opens anteromedially as the hilum, bounded by anterior and posterior lips and containing the renal vessels and nerves and the renal pelvis of the ureter. The relative positions of the main hilar structures are: the renal vein anterior, the renal artery intermediate and the pelvis of the kidney posterior. Commonly an arterial branch enters behind the renal pelvis and a renal venous tributary often leaves the hilum in the same plane. Above the hilum the medial border is related to the suprarenal gland and below to the commencement of the ureter.

The hilum leads into a central renal sinus, lined by the renal capsule and almost filled by the renal pelvis and vessels; numerous renal papillae indent the wall of the sinus. The collecting tubules open onto the summits of the renal papillae and drain into the funnel-shaped expansions of the upper urinary tract, named the minor calyces. The 7–13 minor calyces terminate in two or three major calyces which in turn open into the renal pelvis. The renal calyces and pelvis are described in detail on page 1827.

The kidney and its vessels are embedded in perirenal (perinephric) fat, which is thickest at the renal borders and prolonged at the hilum into the renal sinus. Fibrous connective tissue surrounding this fat is condensed as renal fascia.

Renal Fascia

At the lateral renal borders the anterior and posterior layers of renal fascia fuse. The anterior extends medially in front of the kidney and its vessels to merge with connective tissue enclosing the aorta and inferior vena cava, but it is thin and does not ascend above the superior mesenteric artery. The posterior layer passes medially between the kidney and the fascia on quadratus lumborum and psoas major, attaching to this fascia at the lateral and medial borders of the psoas, and to the vertebrae and intervertebral discs. A deeper stratum unites the anterior and posterior layers at the medial renal border and is pierced by the renal vessels (Martin 1942); this may account for the failure of perirenal effusions to cross the midline although injected air does diffuse along this route (Grossman 1954). Above the suprarenal gland the two layers of renal fascia fuse and blend with the diaphragmatic fascia; it is generally agreed that below the kidney they are separate, enclosing the ureter, the anterior fading into the extraperitoneal tissue of the iliac fossa, the posterior blending with the iliac fascia although this has also been denied (Mitchell 1950). The renal fascia is connected to the renal capsule by numerous trabeculae which traverse the perirenal fat and are strongest near the lower pole. Behind the renal fascia is a mass of fat, the pararenal (paranephric) body. The kidney is held in position partly by renal fascia but principally by the apposition of neighbouring viscera.

Ureters

Ureters are muscular tubes whose peristaltic contractions convey urine from the kidneys to the urinary bladder. Each measures 25–30 cm in length and is thick-walled, narrow and continuous superiorly with the funnel-shaped renal pelvis; a slight constriction may mark this junction. Each descends slightly medially anterior to psoas major, entering the pelvic cavity to open into the base of the urinary bladder. Its surface projection is an almost vertical line from a point on the transpyloric plane, 5 cm from the midline to the pubic tubercle. Its diameter is about 3 mm but slightly less at its junction with the renal pelvis, the brim of the lesser pelvis near the medial border of psoas major, and where it traverses the vesical (bladder) wall (its narrowest part). The renal pelvis has already been described.

The ureter's abdominal part descends posterior to the peritoneum on the medial part of psoas major, which separates it from the tips of the lumbar transverse processes. Anterior to the muscle it crosses in front of the genitofemoral nerve and is obliquely crossed by the gonadal vessels. It enters the lesser pelvis anterior to either the end of the common or the beginning of the external iliac vessels.

At its origin the right ureter is usually overlapped by the descending part of the duodenum; it descends lateral to the inferior vena cava, crossed anteriorly by the right colic and ileocolic vessels; near the superior aperture of the lesser pelvis it passes behind the lower part of the mesentery and terminal ileum. The left ureter, crossed by the left colic vessels, passes posterior to the sigmoid colon and its mesentery in the posterior wall of the intersigmoid recess. At operation, the abdominal part of the left ureter is hence easier to expose than the right.

The pelvic part, about the same length as the abdominal, lies in both sexes in extraperitoneal areolar tissue. At first it descends posterolaterally on the lateral wall

of the lesser pelvis along the anterior border of the greater sciatic notch. Opposite the ischial spine it turns anteromedially into fibrous adipose tissue above the levator ani to reach the base of the bladder. On the pelvic wall it is anterior to the internal iliac artery and the beginning of its anterior trunk, posterior to which are the internal iliac vein, lumbosacral nerve and sacro-iliac joint. Laterally it lies on the fascia of obturator internus. It progressively crosses and is medial to the umbilical artery, the obturator nerve, artery and vein, the inferior vesical and middle rectal arteries. In males, in the anteromedial part of its descent, the pelvic ureter is crossed anterosuperiorly, from lateral to medial, by the ductus deferens. Then it passes in front of and slightly above the upper pole of the seminal vesicle to traverse the bladder wall obliquely before opening at the ipsilateral trigonal angle. Its terminal part is surrounded by tributaries of the vesical veins. In females, the pelvic part at first has the same relations as in males, but anterior to the internal iliac artery it is immediately behind the ovary, forming the posterior boundary of the ovarian fossa. In the anteromedial part of its course to the bladder it is related to the uterine artery, uterine cervix and vaginal fornices. It is in extraperitoneal connective tissue in the inferomedial part of the broad ligament of the uterus; here the uterine artery is anterosuperior to the ureter for 2.5 cm and then crosses to its medial side to ascend alongside the uterus. The ureter turns forwards slightly above the lateral vaginal fornix and is here generally 2 cm lateral to the supravaginal part of the uterine cervix. It then inclines medially to reach the bladder, with a variable relation to the front of the vagina. As the uterus is commonly deviated to one side, one ureter may be more extensively apposed to the vagina, usually the left, which may cross the midline; the reverse may occur and sometimes one ureter is not anterior to the vagina, a much longer part of the other then being in front of it.

In the distended bladder, in both sexes, the ureteric openings are about 5 cm apart, somewhat less when the bladder is empty. In its oblique course through the wall of the bladder, the ureter is compressed and flattened as the bladder distends, perhaps preventing regurgitation, though ureteric peristalsis is also a factor.

Female Reproductive system

Reproductive Organs of the Female

The female reproductive system consists of the internal and external genitalia. The internal organs situated within the lesser pelvis, are the ovaries, uterine tubes, uterus and vagina. The external organs lying in front of and below the pubic arch, are the mons pubis, labia majora and labia minora pudendi, clitoris, bulb of the vestibule, greater vestibular glands and the vestibule itself.

Ovaries

The ovaries are paired structures, homologous with the testes, developing like them from the genital ridges. Situated one on each side of the uterus close to the lateral pelvic wall, they are attached to the posterior aspect of the broad uterine ligament of the uterus near its upper limit by a double fold of peritoneum, the mesovarium, behind and mainly below the lateral part of the uterine tube. In the living they are greyish-pink and present a smooth exterior before regular ovulation begins, but thereafter their surfaces are distorted by the scarring which follows the degeneration of successive corpora lutea. Each ovary is classically described as almond-shaped (amygdaloid), about 3 cm long, 1.5 cm wide and 1 cm thick, with a volume of approximately 6 cm3. (However, ultrasonic measurements of the ovaries in situ, in a large number of women (Cohen et al 1990) have given higher values for the volume of the ovaries: about 11 cm3 in the reproductively mature state, 6 cm3 postmenopausally and 3 cm3 before menarche (the first menstrual period).) Ovarian position varies much in women who have borne children; the ovaries are displaced in the first pregnancy and usually never return to their original location. They are also variably mobile and may change their position to some extent according to the state of the surrounding organs such as the intestines. The description given in the subsequent account refers to the ovarian condition in nulliparous women, except where otherwise stated.

With the body in the upright position, the long axis of each ovary is vertical; it has lateral and medial surfaces, tubal (superior) and uterine (inferior) extremities or poles, and mesovarian (anterior) and free (posterior) borders. It occupies the ovarian fossa, on the lateral pelvic wall, bounded anteriorly by the obliterated umbilical artery and posteriorly by the ureter and internal iliac artery.

Attached to its upper, tubal extremity, near the external iliac vein, are the ovarian fimbria of the uterine tube and a peritoneal suspensory ligament of the ovary, which contains the ovarian vessels and nerves and passes superiorly over the external iliac vessels to join the peritoneum on psoas major, posterior to the caecum or descending colon (depending on whether it is right or left). The uterine (inferior) extremity is directed downwards towards the pelvic floor; it is usually narrower than the tubal extremity and is attached to the lateral angle of the uterus, postero-inferior to the uterine tube, by a rounded ovarian ligament, which lies in the broad ligament and contains some smooth muscle cells. The lateral surface of the ovary contacts parietal peritoneum in the ovarian fossa, behind which are extraperitoneal tissue and the obturator vessels and nerve. The uterine tube largely covers the medial surface; the peritoneal recess here, between the ovary and overlapping mesosalpinx, is termed the ovarian bursa.

The mesovarian border is straight and is directed towards the obliterated umbilical artery. It is attached to the back of the broad ligament by a short peritoneal fold, the

mesovarium, in which blood vessels and nerves reach the ovarian hilum. The convex free border of the ovary faces the ureter. The uterine tube arches over the ovary, ascending in relation to its mesovarian border, to curve over its tubal end and pass down on its posterior, free border and medial surface.
In embryonic and early fetal life the ovaries are, like the testes, situated in the lumbar region near the kidneys, but they gradually descend into the lesser pelvis. Accessory ovaries may occur in the mesovarium or in the adjacent part of the broad ligament.