Gray's Anatomy for Students, Third Edition

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Pelvis and Perineum

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Conceptual overview

General description

The pelvis and perineum are interrelated regions associated with the pelvic bones and terminal parts of the vertebral column. The pelvis is divided into two regions:

- The superior region related to upper parts of the pelvic bones and lower lumbar vertebrae is the **false pelvis (greater pelvis)** and is generally considered part of the abdomen (Fig. 5.1).

  ![Fig. 5.1 Pelvis and perineum.](image)

  - The **true pelvis (lesser pelvis)** is related to the inferior parts of the pelvic bones, sacrum, and coccyx, and has an inlet and an outlet.

The bowl-shaped **pelvic cavity** enclosed by the true pelvis consists of the pelvic inlet, walls, and floor. This cavity is continuous superiorly with the abdominal cavity and contains elements of the urinary, gastrointestinal, and reproductive systems.

The perineum (Fig. 5.1) is inferior to the floor of the pelvic cavity; its boundaries form the **pelvic outlet**. The perineum contains the external genitalia and external openings of the genitourinary and gastrointestinal systems.

**Functions**
Contains and supports the bladder, rectum, anal canal, and reproductive tracts

Within the pelvic cavity, the bladder is positioned anteriorly and the rectum posteriorly in the midline.

As it fills, the bladder expands superiorly into the abdomen. It is supported by adjacent elements of the pelvic bone and by the pelvic floor. The urethra passes through the pelvic floor to the perineum, where, in women, it opens externally (Fig. 5.2A) and in men it enters the base of the penis (Fig. 5.2B).
Fig. 5.2
The pelvis and perineum contain and support terminal parts of the gastrointestinal, urinary, and reproductive systems.  

A. In women. B. In men.

Continuous with the sigmoid colon at the level of vertebra SIII, the rectum terminates at the anal canal, which penetrates the pelvic floor to open into the perineum. The anal canal is angled posteriorly on the rectum. This flexure is maintained by muscles of the pelvic floor and is relaxed during defecation. A skeletal muscle sphincter is associated with the anal canal and the urethra as each passes through the pelvic floor.

The pelvic cavity contains most of the reproductive tract in women and part of the reproductive tract in men.

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In women, the vagina penetrates the pelvic floor and connects with the uterus in the pelvic cavity. The uterus is positioned between the rectum and the bladder. A uterine (fallopian) tube extends laterally on each side toward the pelvic wall to open near the ovary.

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In men, the pelvic cavity contains the site of connection between the urinary and reproductive tracts. It also contains major glands associated with the reproductive system—the prostate and two seminal vesicles.

Anchors the roots of the external genitalia

In both genders, the roots of the external genitalia, the clitoris and the penis, are firmly anchored to:

- the bony margin of the anterior half of the pelvic outlet, and

- a thick, fibrous, perineal membrane, which fills the area (Fig. 5.3).

The perineum contains and anchors the roots of the external genitalia. A. In women. B. In men.

The roots of the external genitalia consist of erectile (vascular) tissues and associated skeletal muscles.

Component parts

Pelvic inlet

The pelvic inlet is somewhat heart shaped and completely ringed by bone (Fig. 5.4). Posteriorly, the inlet is bordered by the body of vertebra SI, which projects into the inlet as the sacral promontory. On each side of this vertebra, wing-like transverse processes called the alae (wings) contribute to the margin of the pelvic inlet. Laterally, a prominent rim on the pelvic bone continues the boundary of the inlet forward to the pubic symphysis, where the two pelvic bones are joined in the midline.
Structures pass between the pelvic cavity and the abdomen through the pelvic inlet.

During childbirth, the fetus passes through the pelvic inlet from the abdomen, into which the uterus has expanded during pregnancy, and then passes through the pelvic outlet.

**Pelvic walls**

The walls of the true pelvis consist predominantly of bone, muscle, and ligaments, with the sacrum, coccyx, and inferior half of the pelvic bones forming much of them.

Two ligaments—the sacrospinous and the sacrotuberous ligaments—are important architectural elements of the walls because they link each pelvic bone to the sacrum and coccyx (Fig. 5.5A). These ligaments also convert two notches on the pelvic bones—the greater and lesser sciatic notches—into foramina on the lateral pelvic walls.
Pelvic walls. **A.** Bones and ligaments of the pelvic walls. **B.** Muscles of the pelvic walls.
Completing the walls are the \textit{obturator internus} and \textit{piriformis} muscles (Fig. 5.5B), which arise in the pelvis and exit through the sciatic foramina to act on the hip joint.

\textbf{Pelvic outlet}

The diamond-shaped pelvic outlet is formed by both bone and ligaments (Fig. 5.6). It is limited anteriorly in the midline by the pubic symphysis.

\textbf{Pelvic outlet}

On each side, the inferior margin of the pelvic bone projects posteriorly and laterally from the pubic symphysis to end in a prominent tuberosity, the \textit{ischial tuberosity}. Together, these elements construct the pubic arch, which forms the margin of the anterior half of the pelvic outlet. The sacrotuberous ligament continues this margin posteriorly from the ischial tuberosity to the coccyx and sacrum. The pubic symphysis, ischial tuberosities, and coccyx can all be palpated.

\textbf{Pelvic floor}

The pelvic floor, which separates the pelvic cavity from the perineum, is formed by muscles and fascia (Fig. 5.7).
Two levator ani muscles attach peripherally to the pelvic walls and join each other at the midline by a connective tissue raphe. Together they are the largest components of the bowl- or funnel-shaped structure known as the pelvic diaphragm, which is completed posteriorly by the coccygeus muscles. These latter muscles overlie the sacrospinous ligaments and pass between the margins of the sacrum and the coccyx and a prominent spine on the pelvic bone, the ischial spine.

The pelvic diaphragm forms most of the pelvic floor and in its anterior regions contains a U-shaped defect, which is associated with elements of the urogenital system.

The anal canal passes from the pelvis to the perineum through a posterior circular orifice in the pelvic diaphragm.

The pelvic floor is supported anteriorly by:

- the perineal membrane, and
- muscles in the deep perineal pouch.

The perineal membrane is a thick, triangular fascial sheet that fills the space between the arms of the pubic arch, and has a free posterior border (Fig. 5.7). The deep perineal pouch is a narrow region superior to the perineal membrane.

The margins of the U-shaped defect in the pelvic diaphragm merge into the walls of the associated viscera and with muscles in the deep perineal pouch below.

The vagina and the urethra penetrate the pelvic floor to pass from the pelvic cavity to the perineum.

**Pelvic cavity**

The pelvic cavity is lined by peritoneum continuous with the peritoneum of the abdominal cavity that drapes over the superior aspects of the pelvic viscera, but in most regions, does not reach the pelvic floor (Fig. 5.8A).
The pelvic viscera are located in the midline of the pelvic cavity. The bladder is anterior and the rectum is posterior. In women, the uterus lies between the bladder and rectum (Fig. 5.8B). Other structures, such as vessels and nerves, lie deep to the peritoneum in association with the pelvic walls and on either side of the pelvic viscera.

**Perineum**
The perineum lies inferior to the pelvic floor between the lower limbs (Fig. 5.9). Its margin is formed by the pelvic outlet. An imaginary line between the ischial tuberosities divides the perineum into two triangular regions.

**Perineum.** **A.** In women. **B.** In men.
Anteriorly, the urogenital triangle contains the roots of the external genitalia and, in women, the openings of the urethra and the vagina (Fig. 5.9A). In men, the distal part of the urethra is enclosed by erectile tissues and opens at the end of the penis (Fig. 5.9B).

Posteriorly, the anal triangle contains the anal aperture.

**Relationship to other regions**

**Abdomen**

The cavity of the true pelvis is continuous with the abdominal cavity at the pelvic inlet (Fig. 5.10A). All structures passing between the pelvic cavity and abdomen, including major vessels, nerves, and lymphatics, as well as the sigmoid colon and ureters, pass via the inlet. In men, the ductus deferens on each side passes through the anterior abdominal wall and over the inlet to enter the pelvic cavity. In women, ovarian vessels, nerves, and lymphatics pass through the inlet to reach the ovaries, which lie on each side just inferior to the pelvic inlet.
Areas of communication between the true pelvis and other regions. A. Between the true pelvis, abdomen, and lower limb. B. Between the perineum and other regions.

Lower limb

Three apertures in the pelvic wall communicate with the lower limb (Fig. 5.10A):

- the obturator canal,
- the greater sciatic foramen, and
- the lesser sciatic foramen.

The obturator canal forms a passageway between the pelvic cavity and the adductor region of the thigh, and is formed in the superior aspect of the obturator foramen, between bone, a connective tissue membrane, and muscles that fill the foramen.

The lesser sciatic foramen, which lies inferior to the pelvic floor, provides communication between the gluteal region and the perineum (Fig. 5.10B).

The pelvic cavity also communicates directly with the perineum through a small gap between the pubic symphysis and the perineal membrane (Fig. 5.10B).

Key features

The pelvic cavity projects posteriorly

In the anatomical position, the anterior superior iliac spines and the superior edge of the pubic symphysis lie in the same vertical plane (Fig. 5.11). Consequently, the pelvic inlet is angled 50°–60° forward relative to the horizontal plane, and the pelvic cavity projects posteriorly from the abdominal cavity.
Meanwhile, the urogenital part of the pelvic outlet (the pubic arch) is oriented in a nearly horizontal plane, whereas the posterior part of the outlet is positioned more vertically. The urogenital triangle of the perineum therefore faces inferiorly, while the anal triangle faces more posteriorly.

**Important structures cross the ureters in the pelvic cavity**

The ureters drain the kidneys, course down the posterior abdominal wall, and cross the pelvic inlet to enter the pelvic cavity. They continue inferiorly along the lateral pelvic wall and ultimately connect with the base of the bladder.

An important structure crosses the ureters in the pelvic cavity in both men and women—in women, the uterine artery crosses the ureter lateral to the cervix of the uterus (Fig. 5.12A), and in men, the ductus deferens crosses over the ureter just posterior to the bladder (Fig. 5.12B).
Fig. 5.12

Structures that cross the ureters in the pelvic cavity. A. In women. B. In men.

The prostate in men and the uterus in women are anterior to the rectum

In men, the prostate gland is situated immediately anterior to the rectum, just above the pelvic floor (Fig. 5.13). It can be felt by digital palpation during a rectal examination.

Fig. 5.13
Position of the prostate gland.

In both sexes, the anal canal and the lower rectum also can be evaluated during a rectal examination by a clinician. In women, the cervix and lower part of the body of the uterus also are palpable. However, these structures can more easily be palpated with a bimanual examination where the index and middle fingers of a clinician's hand are placed in the vagina and the other hand is placed on the lower anterior abdominal wall. The organs are felt between the two hands. This bimanual technique can also be used to examine the ovaries and uterine tubes.

The perineum is innervated by sacral spinal cord segments

Dermatomes of the perineum in both men and women are from spinal cord levels S3 to S5, except for the anterior regions, which tend to be innervated by spinal cord level L1 by nerves associated with the abdominal wall (Fig. 5.14). Dermatomes of L2 to S2 are predominantly in the lower limb.

Most of the skeletal muscles contained in the perineum and the pelvic floor, including the external anal sphincter and external urethral sphincter, are innervated by spinal cord levels S2 to S4.

Much of the somatic motor and sensory innervation of the perineum is provided by the pudendal nerve from spinal cord levels S2 to S4.

Nerves are related to bone

The pudendal nerve is the major nerve of the perineum and is directly associated with the ischial spine of the pelvis (Fig. 5.15). On each side of the body, these spines and the attached sacrospinous ligaments separate the greater sciatic foramina from the lesser sciatic foramina on the lateral pelvic wall.
The pudendal nerve leaves the pelvic cavity through the greater sciatic foramen and then immediately enters the perineum inferiorly to the pelvic floor by passing around the ischial spine and through the lesser sciatic foramen (Fig. 5.15). The ischial spine can be palpated transvaginally in women and is the landmark for administering a pudendal nerve block.

**Parasympathetic innervation from spinal cord levels S2 to S4 controls erection**

The parasympathetic innervation from spinal cord levels S2 to S4 controls genital erection in both women and men (Fig. 5.16). On each side, preganglionic parasympathetic nerves leave the anterior rami of the sacral spinal nerves and enter the **inferior hypogastric plexus** (pelvic plexus) on the lateral pelvic wall.
Pelvic splanchnic nerves from spinal levels S2 to S4 control erection.

The two inferior hypogastric plexuses are inferior extensions of the abdominal prevertebral plexus that forms on the posterior abdominal wall in association with the abdominal aorta. Nerves derived from these plexuses penetrate the pelvic floor to innervate the erectile tissues of the clitoris in women and the penis in men.

Muscles and fascia of the pelvic floor and perineum intersect at the perineal body

Structures of the pelvic floor intersect with structures in the perineum at the perineal body (Fig. 5.17). This poorly defined fibromuscular node lies at the center of the perineum, approximately midway between the two ischial tuberosities. Converging at the perineal body are:
Fig. 5.17
Perineal body.

- the levator ani muscles of the pelvic diaphragm, and

- muscles in the urogenital and anal triangles of the perineum, including the skeletal muscle sphincters associated with the urethra, vagina, and anus.

The course of the urethra is different in men and women

In women, the urethra is short and passes inferiorly from the bladder through the pelvic floor and opens directly into the perineum (Fig. 5.18A).

Course of the urethra. A. In women. B. In men.
In men the urethra passes through the prostate before coursing through the deep perineal pouch and perineal membrane and then becomes enclosed within the erectile tissues of the penis before opening at the end of the penis (Fig. 5.18B). The penile part of the male urethra has two angles:

- The more important of these is a fixed angle where the urethra bends anteriorly in the root of the penis after passing through the perineal membrane.
- Another angle occurs distally where the unattached part of the penis curves inferiorly—when the penis is erect, this second angle disappears.

It is important to consider the different courses of the urethra in men and women when catheterizing patients and when evaluating perineal injuries and pelvic pathology.

Regional anatomy

The pelvis is the region of the body surrounded by the pelvic bones and the inferior elements of the vertebral column. It is divided into two major regions: the superior region is the false (greater) pelvis and is part of the abdominal cavity; the inferior region is the true (lesser) pelvis, which encloses the pelvic cavity.

The bowl-shaped pelvic cavity is continuous above with the abdominal cavity. The rim of the pelvic cavity (the pelvic inlet) is completely encircled by bone. The pelvic floor is a fibromuscular structure separating the pelvic cavity above from the perineum below.

The perineum is inferior to the pelvic floor and its margin is formed by the pelvic outlet. The perineum contains:

- the terminal openings of the gastrointestinal and urinary systems,
- the external opening of the reproductive tract, and
- the roots of the external genitalia.

Pelvis

Bones

The bones of the pelvis consist of the right and left pelvic (hip) bones, the sacrum, and the coccyx. The sacrum articulates superiorly with vertebra LV at the lumbosacral joint. The pelvic bones articulate posteriorly with the sacrum at the sacro-iliac joints and with each other anteriorly at the pubic symphysis.

Pelvic bone

The pelvic bone is irregular in shape and has two major parts separated by an oblique line on the medial surface of the bone (Fig. 5.19A):
Fig. 5.19

Right pelvic bone. A. Medial view. B. Lateral view.
The pelvic bone above this line represents the lateral wall of the false pelvis, which is part of the abdominal cavity.

The pelvic bone below this line represents the lateral wall of the true pelvis, which contains the pelvic cavity.

The linea terminalis is the lower two-thirds of this line and contributes to the margin of the pelvic inlet.

The lateral surface of the pelvic bone has a large articular socket, the acetabulum, which, together with the head of the femur, forms the hip joint (Fig. 5.19B).

Inferior to the acetabulum is the large obturator foramen, most of which is closed by a flat connective tissue membrane, the obturator membrane. A small obturator canal remains open superiorly between the membrane and adjacent bone, providing a route of communication between the lower limb and the pelvic cavity.

The posterior margin of the bone is marked by two notches separated by the ischial spine:

- the greater sciatic notch, and
- the lesser sciatic notch.

The posterior margin terminates inferiorly as the large ischial tuberosity.

The irregular anterior margin of the pelvic bone is marked by the anterior superior iliac spine, the anterior inferior iliac spine, and the pubic tubercle.

Components of the pelvic bone

Each pelvic bone is formed by three elements: the ilium, pubis, and ischium. At birth, these bones are connected by cartilage in the area of the acetabulum; later, at between 16 and 18 years of age, they fuse into a single bone (Fig. 5.20).

![Fig. 5.20](image)

Ilium, ischium, and pubis.

Ilium

Of the three components of the pelvic bone, the ilium is the most superior in position.
The ilium is separated into upper and lower parts by a ridge on the medial surface (Fig. 5.21A).

Posteriorly, the ridge is sharp and lies immediately superior to the surface of the bone that articulates with the sacrum. This sacral surface has a large L-shaped facet for articulating with the sacrum and an expanded, posterior roughened area for the attachment of the strong ligaments that support the sacro-iliac joint (Fig. 5.21).

Anteriorly, the ridge separating the upper and lower parts of the ilium is rounded and termed the arcuate line.

The arcuate line forms part of the linea terminalis and the pelvic brim.

The portion of the ilium lying inferiorly to the arcuate line is the pelvic part of the ilium and contributes to the wall of the lesser or true pelvis.

The upper part of the ilium expands to form a flat, fan-shaped “wing,” which provides bony support for the lower abdomen, or false pelvis. This part of the ilium provides attachment for muscles functionally associated with the lower limb. The anteromedial surface of the wing is concave and forms the iliac fossa. The external (gluteal) surface of the wing is marked by lines and roughenings and is related to the gluteal region of the lower limb (Fig. 5.21B).

The entire superior margin of the ilium is thickened to form a prominent crest (the iliac crest), which is the site of attachment for muscles and fascia of the abdomen, back, and lower limb and terminates anteriorly as the anterior superior iliac spine and posteriorly as the posterior superior iliac spine.

A prominent tubercle, the tuberculum of the iliac crest, projects laterally near the anterior end of the crest; the posterior end of the crest thickens to form the iliac tuberosity.

Inferior to the anterior superior iliac spine of the crest, on the anterior margin of the ilium, is a rounded protuberance called the anterior inferior iliac spine. This structure serves as the point of attachment for the rectus femoris muscle of the anterior compartment of the thigh and the iliofemoral ligament associated with the hip joint. A less prominent posterior inferior iliac spine occurs along the posterior border of the sacral surface of the ilium, where the bone angles forward to form the superior margin of the greater sciatic notch.
In the clinic
Bone marrow biopsy
In certain diseases (e.g., leukemia), a sample of bone marrow must be obtained to assess the stage and severity of the problem. The iliac crest is often used for such bone marrow biopsies. The iliac crest lies close to the surface and is easily palpated. A bone marrow biopsy is performed by injecting anesthetic in the skin and passing a cutting needle through the cortical bone of the iliac crest. The bone marrow is aspirated and viewed under a microscope. Samples of cortical bone can also be obtained in this way to provide information about bone metabolism.

Pubis
The anterior and inferior part of the pelvic bone is the pubis (Fig. 5.21). It has a body and two arms (rami).

- The body is flattened dorsoventrally and articulates with the body of the pubic bone on the other side at the pubic symphysis. The body has a rounded pubic crest on its superior surface that ends laterally as the prominent pubic tubercle.

- The superior pubic ramus projects posterolaterally from the body and joins with the ilium and ischium at its base, which is positioned toward the acetabulum. The sharp superior margin of this triangular surface is termed the pecten pubis (pectineal line), which forms part of the linea terminalis of the pelvic bone and the pelvic inlet. Anteriorly, this line is continuous with the pubic crest, which also is part of the linea terminalis and pelvic inlet. The superior pubic ramus is marked on its inferior surface by the obturator groove, which forms the upper margin of the obturator canal.

- The inferior ramus projects laterally and inferiorly to join with the ramus of the ischium.

Ischium
The ischium is the posterior and inferior part of the pelvic bone (Fig. 5.21). It has:

- a large body that projects superiorly to join with the ilium and the superior ramus of the pubis, and

- a ramus that projects anteriorly to join with the inferior ramus of the pubis.

The posterior margin of the bone is marked by a prominent ischial spine that separates the lesser sciatic notch, below, from the greater sciatic notch, above.

The most prominent feature of the ischium is a large tuberosity (the ischial tuberosity) on the posteroinferior aspect of the bone. This tuberosity is an important site for the attachment of lower limb muscles and for supporting the body when sitting.

Sacrum
The sacrum, which has the appearance of an inverted triangle, is formed by the fusion of the five sacral vertebrae (Fig. 5.22). The base of the sacrum articulates with vertebra LV, and its apex articulates with the coccyx. Each of the lateral surfaces of the bone bears a large L-shaped facet for articulation with the ilium of the pelvic bone. Posterior to the facet is a large roughened area for the attachment of ligaments that support the sacro-iliac joint. The superior surface of the sacrum is characterized by the superior aspect of the body of vertebra SI and is flanked on each side by an expanded wing-like transverse process termed the ala. The anterior edge of the vertebral body projects forward as the promontory. The anterior surface of the sacrum is concave; the posterior surface is convex. Because the transverse processes of adjacent sacral vertebrae fuse lateral to the position of the intervertebral foramina and lateral to the bifurcation of spinal nerves into posterior and anterior rami, the posterior and anterior rami of spinal nerves S1 to S4 emerge from the sacrum through separate foramina. There are four pairs of anterior sacral foramina on the anterior surface of the sacrum for anterior rami, and four pairs of posterior sacral foramina on the posterior surface for the posterior rami. The sacral canal is a continuation of the vertebral canal that terminates as the sacral hiatus.
Coccyx

The small terminal part of the vertebral column is the coccyx, which consists of four fused coccygeal vertebrae (Fig. 5.22) and, like the sacrum, has the shape of an inverted triangle. The base of the coccyx is directed superiorly. The superior surface bears a facet for articulation with the sacrum and two horns, or cornua, one on each side, that project upward to articulate or fuse with similar downward-projecting cornua from the sacrum. These processes are modified superior and inferior articular processes that are present on other vertebrae. Each lateral surface of the coccyx has a small rudimentary transverse process, extending from the first coccygeal vertebra. Vertebral arches are absent from coccygeal vertebrae; therefore no bony vertebral canal is present in the coccyx.

In the clinic

Pelvic fracture

The pelvis can be viewed as a series of anatomical rings. There are three bony rings and four fibro-osseous rings. The major bony pelvic ring consists of parts of the sacrum, ilium, and pubis, which forms the pelvic inlet. Two smaller subsidiary rings are the obturator foramina. The greater and lesser sciatic foramina formed by the greater and lesser sciatic notches and the sacrospinous and sacrotuberous ligaments form the four fibro-osseous rings. The rings, which are predominantly bony (i.e., the pelvic inlet and the obturator foramina), are brittle rings. It is not possible to break one side of the ring without breaking the other side of the ring, which in clinical terms means that if a fracture is demonstrated on one side, a second fracture should always be suspected. Fractures of the pelvis may occur in isolation; however, they usually occur in trauma patients and warrant special mention. Owing to the large bony surfaces of the pelvis, a fracture produces an area of bone that can bleed significantly. A large hematoma may be produced, which can compress organs such as the bladder and the ureters. This blood loss may occur rapidly, reducing the circulating blood volume and, unless this is replaced, the patient will become hypovolemic and shock will develop. Pelvic fractures may also disrupt the contents of the pelvis, leading to urethral disruption, potential bowel rupture, and nerve damage.

Joints

Lumbosacral joints

The sacrum articulates superiorly with the lumbar part of the vertebral column. The lumbosacral joints are formed between vertebra LV and the sacrum and consist of:
the two zygapophysial joints, which occur between adjacent inferior and superior articular processes, and

an intervertebral disc that joins the bodies of vertebrae LV and SI (Fig. 5.23A).

Fig. 5.23


These joints are similar to those between other vertebrae, with the exception that the sacrum is angled posteriorly on vertebra LV. As a result, the anterior part of the intervertebral disc between the two bones is thicker than the posterior part.

The lumbosacral joints are reinforced by strong iliolumbar and lumbosacral ligaments that extend from the expanded transverse processes of vertebra LV to the ilium and the sacrum, respectively (Fig. 5.23B).

Sacro-iliac joints

The sacro-iliac joints transmit forces from the lower limbs to the vertebral column. They are synovial joints between the L-shaped articular facets on the lateral surfaces of the sacrum and similar facets on the iliac parts of the pelvic bones (Fig. 5.24A). The joint surfaces have an irregular contour and interlock to resist movement. The joints often become fibrous with age and may become completely ossified.
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Each sacro-iliac joint is stabilized by three ligaments:

- **the anterior sacro-iliac ligament**, which is a thickening of the fibrous membrane of the joint capsule and runs anteriorly and inferiorly to the joint (Fig. 5.24B);

- **the interosseous sacro-iliac ligament**, which is the largest, strongest ligament of the three, and is positioned immediately posterosuperior to the joint and attaches to adjacent expansive roughened areas on the ilium and sacrum, thereby filling the gap between the two bones (Fig. 5.24A,C); and

- **the posterior sacro-iliac ligament**, which covers the interosseous sacro-iliac ligament (Fig. 5.24C).

**Pubic symphysis joint**

The pubic symphysis lies anteriorly between the adjacent surfaces of the pubic bones (Fig. 5.25). Each of the joint's surfaces is covered by hyaline cartilage and is linked across the midline to adjacent surfaces by fibrocartilage. The joint is surrounded by interwoven layers of collagen fibers and the two major ligaments associated with it are:
Pubic symphysis and associated ligaments.

- the superior pubic ligament, located above the joint, and
- the inferior pubic ligament, located below it.

In the clinic
Common problems with the sacro-iliac joints
The sacro-iliac joints have both fibrous and synovial components, and as with many weight-bearing joints, degenerative changes may occur and cause pain and discomfort in the sacro-iliac region. In addition, disorders associated with the major histocompatibility complex antigen HLA-B27, such as rheumatoid arthritis, psoriasis, and inflammatory bowel disease, can produce specific inflammatory changes within these joints.

Orientation
In the anatomical position, the pelvis is oriented so that the front edge of the top of the pubic symphysis and the anterior superior iliac spines lie in the same vertical plane (Fig. 5.26). As a consequence, the pelvic inlet, which marks the entrance to the pelvic cavity, is tilted to face anteriorly, and the bodies of the pubic bones and the pubic arch are positioned in a nearly horizontal plane facing the ground.
Differences between men and women

The pelvises of women and men differ in a number of ways, many of which have to do with the passing of a baby through a woman's pelvic cavity during childbirth.

- The pelvic inlet in women is circular (Fig. 5.27A) compared with the heart-shaped pelvic inlet (Fig. 5.27B) in men. The more circular shape is partly caused by the less distinct promontory and broader alae in women.

- The angle formed by the two arms of the pubic arch is larger in women (80°–85°) than it is in men (50°–60°).
The ischial spines generally do not project as far medially into the pelvic cavity in women as they do in men.

**True pelvis**

The true pelvis is cylindrical and has an inlet, a wall, and an outlet. The inlet is open, whereas the pelvic floor closes the outlet and separates the pelvic cavity, above, from the perineum, below.

**Pelvic inlet**

The pelvic inlet is the circular opening between the abdominal cavity and the pelvic cavity through which structures traverse between the abdomen and pelvic cavity. It is completely surrounded by bones and joints (Fig. 5.28). The promontory of the sacrum protrudes into the inlet, forming its posterior margin in the midline. On either side of the promontory, the margin is formed by the alae of the sacrum. The margin of the pelvic inlet then crosses the sacro-iliac joint and continues along the linea terminalis (i.e., the arcuate line, the pecten pubis or pectineal line, and the pubic crest) to the pubic symphysis.

![Fig. 5.28 Pelvic inlet.](image)

**Pelvic wall**

The walls of the pelvic cavity consist of the sacrum, the coccyx, the pelvic bones inferior to the linea terminalis, two ligaments, and two muscles.

**Ligaments of the pelvic wall**

The sacrospinous and sacrotuberous ligaments (Fig. 5.29A) are major components of the lateral pelvic walls that help define the apertures between the pelvic cavity and adjacent regions through which structures pass.
Sacrosinous and sacrotuberous ligaments. A. Medial view of right side of pelvis. B. Function of the ligaments.

▪ The smaller of the two, the sacrosinous ligament, is triangular, with its apex attached to the ischial spine and its base attached to the related margins of the sacrum and the coccyx.

▪ The sacrotuberous ligament is also triangular and is superficial to the sacrosinous ligament. Its base has a broad attachment that extends from the posterior superior iliac spine of the pelvic bone, along the dorsal aspect and the lateral margin of the sacrum, and onto the dorsolateral surface of the coccyx. Laterally, the apex of the ligament is attached to the medial margin of the ischial tuberosity.

These ligaments stabilize the sacrum on the pelvic bones by resisting the upward tilting of the inferior aspect of the sacrum (Fig. 5.29B). They also convert the greater and lesser sciatic notches of the pelvic bone into foramina (Fig. 5.29A,B).

▪ The greater sciatic foramen lies superior to the sacrosinous ligament and the ischial spine.

▪ The lesser sciatic foramen lies inferior to the ischial spine and sacrosinous ligament between the sacrosinous and sacrotuberous ligaments.

Muscles of the pelvic wall

Two muscles, the obturator internus and the piriformis, contribute to the lateral walls of the pelvic cavity. These muscles originate in the pelvic cavity but attach peripherally to the femur.

Obturator internus

The obturator internus is a flat, fan-shaped muscle that originates from the deep surface of the obturator membrane and from associated regions of the pelvic bone that surround the obturator foramen (Fig. 5.30 and Table 5.1).
Obturator internus and piriformis muscles (medial view of right side of pelvis).

Table 5.1
Muscles of the pelvic walls

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obturator internus</td>
<td>Anterolateral wall of true pelvis (deep surface of obturator membrane and surrounding bone)</td>
<td>Medial surface of greater trochanter of femur</td>
<td>Nerve to obturator internus L₅, S₁</td>
<td>Lateral rotation of the extended hip joint; abduction of flexed hip</td>
</tr>
<tr>
<td>Piriformis</td>
<td>Anterior surface of sacrum between anterior sacral foramina</td>
<td>Medial side of superior border of greater trochanter of femur</td>
<td>Branches from S₁, and S₂</td>
<td>Lateral rotation of the extended hip joint; abduction of flexed hip</td>
</tr>
</tbody>
</table>

The muscle fibers of the obturator internus converge to form a tendon that leaves the pelvic cavity through the lesser sciatic foramen, makes a 90° bend around the ischium between the ischial spine and ischial tuberosity, and then passes posterior to the hip joint to insert on the greater trochanter of the femur.

The obturator internus forms a large part of the anterolateral wall of the pelvic cavity.

Piriformis

The piriformis is triangular and originates in the bridges of bone between the four anterior sacral foramina. It passes laterally through the greater sciatic foramen, crosses the posterosuperior aspect of the hip joint, and inserts on the greater trochanter of the femur above the insertion of the obturator internus muscle (Fig. 5.30 and Table 5.1).

A large part of the posterolateral wall of the pelvic cavity is formed by the piriformis. In addition, this muscle separates the greater sciatic foramen into two regions, one above the muscle and one below. Vessels and nerves coursing between the pelvic cavity and the gluteal region pass through these two regions.
Apertures in the pelvic wall

Each lateral pelvic wall has three major apertures through which structures pass between the pelvic cavity and other regions:

- the obturator canal,
- the greater sciatic foramen, and
- the lesser sciatic foramen.

Obturator canal

At the top of the obturator foramen is the obturator canal, which is bordered by the obturator membrane, the associated obturator muscles, and the superior pubic ramus (Fig. 5.31). The obturator nerve and vessels pass from the pelvic cavity to the thigh through this canal.

Greater sciatic foramen

The greater sciatic foramen is a major route of communication between the pelvic cavity and the lower limb (Fig. 5.31). It is formed by the greater sciatic notch in the pelvic bone, the sacrotuberous and the sacrospinous ligaments, and the spine of the ischium.

The piriformis muscle passes through the greater sciatic foramen, dividing it into two parts.

- The superior gluteal nerves and vessels pass through the foramen above the piriformis.
Passing through the foramen below the piriformis are the inferior gluteal nerves and vessels, the sciatic nerve, the pudendal nerve, the internal pudendal vessels, the posterior femoral cutaneous nerves, and the nerves to the obturator internus and quadratus femoris muscles.

**Lesser sciatic foramen**

The lesser sciatic foramen is formed by the lesser sciatic notch of the pelvic bone, the ischial spine, the sacrospinous ligament, and the sacrotuberous ligament (Fig. 5.31). The tendon of the obturator internus muscle passes through this foramen to enter the gluteal region of the lower limb.

Because the lesser sciatic foramen is positioned below the attachment of the pelvic floor, it acts as a route of communication between the perineum and the gluteal region. The pudendal nerve and internal pudendal vessels pass between the pelvic cavity (above the pelvic floor) and the perineum (below the pelvic floor), by first passing out of the pelvic cavity through the greater sciatic foramen and then looping around the ischial spine and sacrospinous ligament to pass through the lesser sciatic foramen to enter the perineum.

**Pelvic outlet**

The pelvic outlet is diamond shaped, with the anterior part of the diamond defined predominantly by bone and the posterior part mainly by ligaments (Fig. 5.32). In the midline anteriorly, the boundary of the pelvic outlet is the pubic symphysis. Extending laterally and posteriorly, the boundary on each side is the inferior border of the body of the pubis, the inferior ramus of the pubis, the ramus of the ischium, and the ischial tuberosity. Together, the elements on both sides form the pubic arch.

![Pelvis and Perineum](image)

**Fig. 5.32**

*Pelvic outlet.*

From the ischial tuberosities, the boundaries continue posteriorly and medially along the sacrotuberous ligament on both sides to the coccyx.

Terminal parts of the urinary and gastrointestinal tracts and the vagina pass through the pelvic outlet.

The area enclosed by the boundaries of the pelvic outlet and below the pelvic floor is the **perineum**.

In the clinic
Pelvic measurements in obstetrics
Transverse and sagittal measurements of a woman's pelvic inlet and outlet can help in predicting the likelihood of a successful vaginal delivery. These measurements include:
the sagittal inlet (between the promontory and the top of the pubic symphysis),

the maximum transverse diameter of the inlet,

the bispinous outlet (the distance between ischial spines), and

the sagittal outlet (the distance between the tip of the coccyx and the inferior margin of the pubic symphysis).

These measurements can be obtained using magnetic resonance imaging, which carries no radiation risk for the fetus or mother (Fig. 5.33).

Pelvic floor

The pelvic floor is formed by the pelvic diaphragm and, in the anterior midline, the perineal membrane and the muscles in the deep perineal pouch. The pelvic diaphragm is formed by the levator ani and the coccygeus muscles from both sides. The pelvic floor separates the pelvic cavity, above, from the perineum, below.

The pelvic diaphragm

The pelvic diaphragm is the muscular part of the pelvic floor. Shaped like a bowl or funnel and attached superiorly to the pelvic walls, it consists of the levator ani and the coccygeus muscles (Fig. 5.34 and Table 5.2).
Table 5.2
Muscles of the pelvic diaphragm

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levator ani</td>
<td>In a line around the pelvic wall beginning on the posterior aspect of the pubic bone and extending across the obturator internus muscle as a tendinous arch (thickening of the obturator internus fascia) to the ischial spine</td>
<td>The anterior part is attached to the superior surface of the perineal membrane; the posterior part meets its partner on the other side at the perineal body, around the anal canal, and along the anococcygeal ligament</td>
<td>Branches direct from the anterior ramus of S4, and by the inferior rectal branch of the pudendal nerve (S2 to S4)</td>
<td>Contributes to the formation of the pelvic floor, which supports the pelvic viscera; maintains an angle between the rectum and anal canal; reinforces the external anal sphincter and, in women, functions as a vaginal sphincter</td>
</tr>
<tr>
<td></td>
<td>Ischial spine and pelvic</td>
<td>Lateral margin of coccyx</td>
<td>Branches</td>
<td>Contributes to the formation of the pelvic floor</td>
</tr>
</tbody>
</table>
Coccygeus surface of the sacrospinous ligament and related border of sacrum from the floor, which supports the anterior rami of S3 and S4 coccyx forward after defecation.

The pelvic diaphragm's circular line of attachment to the cylindrical pelvic wall passes, on each side, between the greater sciatic foramen and the lesser sciatic foramen. Thus:

- the greater sciatic foramen is situated above the level of the pelvic floor and is a route of communication between the pelvic cavity and the gluteal region of the lower limb; and
- the lesser sciatic foramen is situated below the pelvic floor, providing a route of communication between the gluteal region of the lower limb and the perineum.

**Levator ani**

The two levator ani muscles originate from each side of the pelvic wall, course medially and inferiorly, and join together in the midline. The attachment to the pelvic wall follows the circular contour of the wall and includes:

- the posterior aspect of the body of the pubic bone,
- a linear thickening called the **tendinous arch**, in the fascia covering the obturator internus muscle, and
- the spine of the ischium.

At the midline, the muscles blend together posterior to the vagina in women and around the anal aperture in both sexes. Posterior to the anal aperture, the muscles come together as a ligament or raphe called the **anococcygeal ligament** (anococcygeal body) and attaches to the coccyx. Anteriorly, the muscles are separated by a U-shaped defect or gap termed the **urogenital hiatus**. The margins of this hiatus merge with the walls of the associated viscera and with muscles in the deep perineal pouch below. The hiatus allows the urethra (in both men and women), and the vagina (in women), to pass through the pelvic diaphragm (Fig. 5.34).

The levator ani muscles are divided into at least three collections of muscle fibers, based on site of origin and relationship to viscera in the midline: the pubococcygeus, the puborectalis, and the iliococcygeus muscles.

- The **pubococcygeus** originates from the body of the pubis and courses posteriorly to attach along the midline as far back as the coccyx. This part of the muscle is further subdivided on the basis of association with structures in the midline into the **puboprostaticus** (levator prostatae), the **pubovaginalis**, and the **puboanalis muscles**.

- A second major collection of muscle fibers, the **puborectalis** portion of the levator ani muscles, originates, in association with the pubococcygeus muscle, from the pubis and passes inferiorly on each side to form a sling around the terminal part of the gastrointestinal tract. This muscular sling maintains an angle or flexure, called the **perineal flexure**, at the anorectal junction. This angle functions as part of the mechanism that keeps the end of the gastrointestinal system closed.

- The final part of the levator ani muscle is the **iliococcygeus**. This part of the muscle originates from the fascia that covers the obturator internus muscle. It joins the same muscle on the other side in the midline to form a ligament or raphe that extends from the anal aperture to the coccyx.

The levator ani muscles help support the pelvic viscera and maintain closure of the rectum and vagina. They are innervated directly by branches from the anterior ramus of S4 and by branches of the pudendal nerve (S2 to S4).

**In the clinic**

**Defecation**

At the beginning of defecation, closure of the larynx stabilizes the diaphragm and intraabdominal pressure is increased by contraction of abdominal wall muscles. As defecation proceeds, the puborectalis muscle surrounding the anorectal junction
relaxes, which straightens the anorectal angle. Both the internal and the external anal sphincters also relax to allow feces to move through the anal canal. Normally, the puborectal sling maintains an angle of about 90° between the rectum and the anal canal and acts as a “pinch valve” to prevent defecation. When the puborectalis muscle relaxes, the anorectal angle increases to about 130° to 140°. The fatty tissue of the ischio-anal fossa allows for changes in the position and size of the anal canal and anus during defecation. During evacuation, the anorectal junction moves down and back and the pelvic floor usually descends slightly. During defecation, the circular muscles of the rectal wall undergo a wave of contraction to push feces toward the anus. As feces emerge from the anus, the longitudinal muscles of the rectum and levator ani bring the anal canal back up, the feces are expelled, and the anus and rectum return to their normal positions.

**Coccygeus**

The two coccygeus muscles, one on each side, are triangular and overlie the sacrospinosus ligaments; together they complete the posterior part of the pelvic diaphragm (Fig. 5.34 and Table 5.2). They are attached, by their apices, to the tips of the ischial spines and, by their bases, to the lateral margins of the coccyx and adjacent margins of the sacrum.

These coccygeus muscles are innervated by branches from the anterior rami of S3 and S4 and participate in supporting the posterior aspect of the pelvic floor.

**The perineal membrane and deep perineal pouch**

The *perineal membrane* is a thick fascial, triangular structure attached to the bony framework of the pubic arch (Fig. 5.35A). It is oriented in the horizontal plane and has a free posterior margin. Anteriorly, there is a small gap (blue arrow in Fig. 5.35A) between the membrane and the *inferior pubic ligament* (a ligament associated with the pubic symphysis).
The perineal membrane is related above to a thin space called the **deep perineal pouch** (deep perineal space) (**Fig. 5.35B**), which contains a layer of skeletal muscle and various neurovascular elements.

The deep perineal pouch is open above and is not separated from more superior structures by a distinct layer of fascia. The parts of the perineal membrane and structures in the deep perineal pouch, enclosed by the urogenital hiatus above, therefore contribute to the pelvic floor and support elements of the urogenital system in the pelvic cavity, even though the perineal membrane and deep perineal pouch are usually considered parts of the perineum.

The perineal membrane and adjacent pubic arch provide attachment for the roots of the external genitalia and the muscles associated with them (**Fig. 5.35C**).

The urethra penetrates vertically through a circular hiatus in the perineal membrane as it passes from the pelvic cavity, above, to the perineum, below. In women, the vagina also passes through a hiatus in the perineal membrane just posterior to the urethral hiatus.

Within the deep perineal pouch, a sheet of skeletal muscle functions as a sphincter, mainly for the urethra, and as a stabilizer of the posterior edge of the perineal membrane (**Fig. 5.36** and **Table 5.3**).
Fig. 5.36
Muscles in the deep perineal pouch. A. In women. B. In men.

Table 5.3
Muscles within the deep perineal pouch

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>External urethral sphincter</td>
<td>From the inferior ramus of the pubis on each side and adjacent walls of the deep perineal pouch</td>
<td>Surrounds membranous part of urethra</td>
<td>Perineal branches of the pudendal nerve (S2 to S4)</td>
<td>Compresses the membranous urethra; relaxes during micturition</td>
</tr>
<tr>
<td>Deep transverse perineal</td>
<td>Medial aspect of ischial ramus</td>
<td>Perineal body</td>
<td></td>
<td>Stabilizes the position of the perineal body</td>
</tr>
<tr>
<td>Compressor urethrae (in women only)</td>
<td>Ischiopubic ramus on each side</td>
<td>Blends with partner on other side anterior to the urethra</td>
<td></td>
<td>Functions as an accessory sphincter of the urethra</td>
</tr>
<tr>
<td>Sphincter urethrovaginalis (in women only)</td>
<td>Perineal body</td>
<td>Passes forward lateral to the vagina to blend with partner on other side anterior to the urethra</td>
<td>Perineal branches of the pudendal nerve (S2 to S4)</td>
<td>Functions as an accessory sphincter of the urethra (also may facilitate closing the vagina)</td>
</tr>
</tbody>
</table>
Anteriorly, a group of muscle fibers surround the urethra and collectively form the **external urethral sphincter**.

Two additional groups of muscle fibers are associated with the urethra and vagina in women. One group forms the **sphincter urethrovaginalis**, which surrounds the urethra and vagina as a unit. The second group forms the **compressor urethrae**, on each side, which originate from the ischiopubic rami and meet anterior to the urethra. Together with the external urethral sphincter, the sphincter urethrovaginalis and compressor urethrae facilitate closing of the urethra.

In both men and women, a **deep transverse perineal muscle** on each side parallels the free margin of the perineal membrane and joins with its partner at the midline. These muscles are thought to stabilize the position of the perineal body, which is a midline structure along the posterior edge of the perineal membrane.

**Perineal body**

The perineal body is an ill-defined but important connective tissue structure into which muscles of the pelvic floor and the perineum attach (Fig. 5.37). It is positioned in the midline along the posterior border of the perineal membrane, to which it attaches. The posterior end of the urogenital hiatus in the levator ani muscles is also connected to it.

![Perineal body](image)

The deep transverse perineal muscles intersect at the perineal body; in women, the sphincter urethrovaginalis also attaches to the perineal body. Other muscles that connect to the perineal body include the external anal sphincter, the superficial transverse perineal muscles, and the bulbospongiosus muscles of the perineum.

**In the clinic**

**Episiotomy**

During childbirth the perineal body may be stretched and torn. Traditionally it was felt that if a perineal tear is likely, the obstetrician may proceed with an episiotomy. This is a procedure in which an incision is made in the perineal body to allow the head of the fetus to pass through the vagina. There are two types of episiotomies: a median episiotomy cuts through the perineal body, while a mediolateral episiotomy is an incision 45° from the midline. The maternal benefits of this procedure have been thought to be less traumatic to the perineum and to result in decreased pelvic floor dysfunction after childbirth. However, more recent evidence suggests that an episiotomy should not be performed routinely. Review of data has failed to show a decrease in pelvic floor damage with routine use of episiotomies.

**Viscera**

The pelvic viscera include parts of the gastrointestinal system, the urinary system, and the reproductive system. The viscera are arranged in the midline, from front to back; the neurovascular supply is through branches that pass medially from vessels and nerves associated with the pelvic walls.

**Gastrointestinal system**
Pelvic parts of the gastrointestinal system consist mainly of the rectum and the anal canal, although the terminal part of the sigmoid colon is also in the pelvic cavity (Fig. 5.38).

Fig. 5.38
Rectum and anal canal. A. Left pelvic bone removed. B. Longitudinal section.
Rectum

The rectum is continuous:

- above, with the sigmoid colon at about the level of vertebra SIII, and
- below, with the anal canal as this structure penetrates the pelvic floor and passes through the perineum to end as the anus.

The rectum, the most posterior element of the pelvic viscera, is immediately anterior to, and follows the concave contour of the sacrum.

The anorectal junction is pulled forward (perineal flexure) by the action of the puborectalis part of the levator ani muscle, so the anal canal moves in a posterior direction as it passes inferiorly through the pelvic floor.

In addition to conforming to the general curvature of the sacrum in the anteroposterior plane, the rectum has three lateral curvatures; the upper and lower curvatures to the right and the middle curvature to the left. The lower part of the rectum is expanded to form the rectal ampulla. Finally, unlike the colon, the rectum lacks distinct taeniae coli muscles, omental appendices, and sacculations (haustra of the colon).

In the clinic

Digital rectal examination

A digital rectal examination (DRE) is performed by placing the gloved and lubricated index finger into the rectum through the anus. The anal mucosa can be palpated for abnormal masses, and in women, the posterior wall of the vagina and the cervix can be palpated. In men, the prostate can be evaluated for any extraneous nodules or masses. In many instances the digital rectal examination may be followed by proctoscopy or colonoscopy. An ultrasound probe may be placed into the rectum to assess the gynecological structures in females and the prostate in the male before performing a prostatic biopsy.

Anal canal

The anal canal begins at the terminal end of the rectal ampulla where it narrows at the pelvic floor. It terminates as the anus after passing through the perineum. As it passes through the pelvic floor, the anal canal is surrounded along its entire length by the internal and external anal sphincters, which normally keep it closed.

The lining of the anal canal bears a number of characteristic structural features that reflect the approximate position of the anococcygeal membrane in the fetus (which closes the terminal end of the developing gastrointestinal system in the fetus) and the transition from gastrointestinal mucosa to skin in the adult (Fig. 5.38B).

- The upper part of the anal canal is lined by mucosa similar to that lining the rectum and is distinguished by a number of longitudinally oriented folds known as anal columns, which are united inferiorly by crescentic folds termed anal valves. Superior to each valve is a depression termed an anal sinus. The anal valves together form a circle around the anal canal at a location known as the pectinate line, which marks the approximate position of the anal membrane in the fetus.

- Inferior to the pectinate line is a transition zone known as the anal pecten, which is lined by nonkeratinized stratified squamous epithelium. The anal pecten ends inferiorly at the anocutaneous line (“white line”), or where the lining of the anal canal becomes true skin.

In the clinic

Carcinoma of the colon and rectum

Carcinoma of the colon and rectum (colorectum) is a common and often lethal disease. Recent advances in surgery, radiotherapy, and chemotherapy have only slightly improved 5-year survival rates. The biological behavior of tumors of the colon and rectum is relatively predictable. Most of the tumors develop from benign polyps, some of which undergo malignant change. The overall prognosis is related to:

- the degree of tumor penetration through the bowel wall,
- the presence or absence of lymphatic dissemination, and
the presence or absence of systemic metastases.

Given the position of the colon and rectum in the abdominopelvic cavity and its proximity to other organs, it is extremely important to accurately stage colorectal tumors: a tumor in the pelvis, for example, could invade the uterus or bladder. Assessing whether spread has occurred may involve ultrasound scanning, computed tomography, and magnetic resonance imaging.

**Urinary system**

The pelvic parts of the urinary system consist of the terminal parts of the ureters, the bladder, and the proximal part of the urethra (Fig. 5.39).

**Ureters**

The ureters enter the pelvic cavity from the abdomen by passing through the pelvic inlet. On each side, the ureter crosses the pelvic inlet and enters the pelvic cavity in the area anterior to the bifurcation of the common iliac artery. From this point, it continues along the pelvic wall and floor to join the base of the bladder.

In the pelvis, the ureter is crossed by:

- the ductus deferens in men, and
- the uterine artery in women.

**Bladder**

The bladder is the most anterior element of the pelvic viscera. Although it is entirely situated in the pelvic cavity when empty, it expands superiorly into the abdominal cavity when full (Fig. 5.39).
The empty bladder is shaped like a three-sided pyramid that has tipped over to lie on one of its margins (Fig. 5.40A). It has an apex, a base, a superior surface, and two inferolateral surfaces.

- **Apex**: The apex of the bladder is directed toward the top of the pubic symphysis; a structure known as the median umbilical ligament (a remnant of the embryological urachus that contributes to the formation of the bladder) continues from it superiorly up the anterior abdominal wall to the umbilicus.

- **Base**: The base of the bladder is shaped like an inverted triangle and faces posteroinferiorly. The two ureters enter the bladder at each of the upper corners of the base, and the urethra drains inferiorly from the lower corner of the base. Inside, the mucosal lining on the base of the bladder is smooth and firmly attached to the underlying smooth muscle coat of the wall—unlike elsewhere in the bladder where the mucosa is folded and loosely attached to the wall. The smooth triangular area between the openings of the ureters and urethra on the inside of the bladder is known as the trigone (Fig. 5.40B).

- **Inferolateral surfaces**: The inferolateral surfaces of the bladder are cradled between the levator ani muscles of the pelvic diaphragm and the adjacent obturator internus muscles above the attachment of the pelvic diaphragm. The superior surface is slightly domed when the bladder is empty; it balloons upward as the bladder fills.
**Neck of bladder**

The neck of the bladder surrounds the origin of the urethra at the point where the two inferolateral surfaces and the base intersect.

The neck is the most inferior part of the bladder and also the most “fixed” part. It is anchored into position by a pair of tough fibromuscular bands, which connect the neck and pelvic part of the urethra to the posteroinferior aspect of each pubic bone.

- In women, these fibromuscular bands are termed **pubovesical ligaments** (Fig. 5.41A). Together with the perineal membrane and associated muscles, the levator ani muscles, and the pubic bones, these ligaments help support the bladder.

- In men, the paired fibromuscular bands are known as **puboprostatic ligaments** because they blend with the fibrous capsule of the prostate, which surrounds the neck of the bladder and adjacent part of the urethra (Fig. 5.41B).
Although the bladder is considered to be pelvic in the adult, it has a higher position in children. At birth, the bladder is almost entirely abdominal; the urethra begins approximately at the upper margin of the pubic symphysis. With age, the bladder descends until after puberty when it assumes the adult position.

In the clinic

**Bladder stones**

In some patients, small calculi (stones) form in the kidneys. These may pass down the ureter, causing ureteric obstruction, and into the bladder (Fig. 5.42), where insoluble salts further precipitate on these small calculi to form larger calculi. Often, these patients develop (or may already have) problems with bladder emptying, which leaves residual urine in the bladder. This urine may become infected, which alters the pH of the urine, permitting further precipitation of insoluble salts. If small enough, the stones may be removed via a transurethral route using specialized instruments. If the stones are too big, it may be necessary to make a suprapubic incision and enter the bladder retroperitoneally to remove them.

**Fig. 5.42**

Intravenous urogram demonstrating a stone in the lower portion of the ureter. **A.** Control radiograph. **B.** Intravenous urogram, postmicturition.

In the clinic

**Suprapubic catheterization**

In certain instances it is necessary to catheterize the bladder through the anterior abdominal wall. For example, when the prostate is markedly enlarged and it is impossible to pass a urethral catheter, a suprapubic catheter may be placed. The bladder is a retroperitoneal structure and when full lies adjacent to the anterior abdominal wall. Ultrasound visualization of the bladder may be useful in assessing the size of this structure and, importantly, differentiating this structure from other potential abdominal masses. The procedure of suprapubic catheterization is straightforward and involves the passage of a small catheter on a needle in the midline approximately 2 cm above the pubic symphysis. The catheter passes easily into the bladder without compromise of other structures and permits free drainage.

In the clinic

**Bladder cancer**

Bladder cancer (Fig. 5.43) is the most common tumor of the urinary tract and is usually a disease of the sixth and seventh decades, although there is an increasing trend for younger patients to develop this disease. Approximately one-third of bladder tumors are multifocal; fortunately, two-thirds are superficial tumors and amenable to local treatment. Bladder tumors may spread through the bladder wall and invade local structures, including the rectum, uterus (in women), and lateral walls of the pelvic cavity. Prostatic involvement is not uncommon in male patients. The disease spreads via the internal iliac lymph nodes. Spread to distant metastatic sites rarely includes the lung. Treatment for early-stage tumors includes local resection with preservation of
the bladder. Diffuse tumors may be treated with local chemotherapy; more extensive tumors may require radical surgical removal of the bladder and, in men, the prostate. Large bladder tumors may produce complications, including invasion and obstruction of the ureters. Ureteric obstruction can then obstruct the kidneys and induce kidney failure. Moreover, bladder tumors can invade other structures of the pelvic cavity.

**Urethra**

The urethra begins at the base of the bladder and ends with an external opening in the perineum. The paths taken by the urethra differ significantly in women and men.

**In women**

In women, the urethra is short, being about 4 cm long. It travels a slightly curved course as it passes inferiorly through the pelvic floor into the perineum, where it passes through the deep perineal pouch and perineal membrane before opening in the vestibule that lies between the labia minora (Fig. 5.44A).
The urethral opening is anterior to the vaginal opening in the vestibule. The inferior aspect of the urethra is bound to the anterior surface of the vagina. Two small para-urethral mucous glands (Skene's glands) are associated with the lower end of the urethra. Each drains via a duct that opens onto the lateral margin of the external urethral orifice.

In men

In men, the urethra is long, about 20 cm, and bends twice along its course (Fig. 5.44B). Beginning at the base of the bladder and passing inferiorly through the prostate, it passes through the deep perineal pouch and perineal membrane and immediately enters the root of the penis. As the urethra exits the deep perineal pouch, it bends forward to course anteriorly in the root of the penis. When the penis is flaccid, the urethra makes another bend, this time inferiorly, when passing from the root to the body of the penis. During erection, the bend between the root and body of the penis disappears.

The urethra in men is divided into preprostatic, prostatic, membranous, and spongy parts.

Preprostatic part.

The preprostatic part of the urethra is about 1 cm long, extends from the base of the bladder to the prostate, and is associated with a circular cuff of smooth muscle fibers (the internal urethral sphincter). Contraction of this sphincter prevents retrograde movement of semen into the bladder during ejaculation.

Prostatic part.

The prostatic part of the urethra (Fig. 5.44C) is 3 to 4 cm long and is surrounded by the prostate. In this region, the lumen of the urethra is marked by a longitudinal midline fold of mucosa (the urethral crest). The depression on each side of the crest is the prostatic sinus; the ducts of the prostate empty into these two sinuses.

Midway along its length, the urethral crest is enlarged to form a somewhat circular elevation (the seminal colliculus). In men, the seminal colliculus is used to determine the position of the prostate gland during transurethral transection of the prostate.
A small blind-ended pouch—the **prostatic utricle** (thought to be the homologue of the uterus in women)—opens onto the center of the seminal colliculus. On each side of the prostatic utricle is the opening of the ejaculatory duct of the male reproductive system. Therefore the connection between the urinary and reproductive tracts in men occurs in the prostatic part of the urethra.

**Membranous part.**

The membranous part of the urethra is narrow and passes through the deep perineal pouch ([Fig. 5.44B](#)). During its transit through this pouch, the urethra, in both men and women, is surrounded by skeletal muscle of the **external urethral sphincter**.

**Spongy urethra.**

The spongy urethra is surrounded by erectile tissue (the **corpus spongiosum**) of the penis. It is enlarged to form a bulb at the base of the penis and again at the end of the penis to form the **navicular fossa** ([Fig. 5.44B](#)). The two bulbo-urethral glands in the deep perineal pouch are part of the male reproductive system and open into the bulb of the spongy urethra. The external urethral orifice is the sagittal slit at the end of the penis.

In the clinic

**Bladder infection**

The relatively short length of the urethra in women makes them more susceptible than men to bladder infection. The primary symptom of urinary tract infection in women is usually inflammation of the bladder (cystitis). The infection can be controlled in most instances by oral antibiotics and resolves without complication. In children under 1 year of age, infection from the bladder may spread via the ureters to the kidneys, where it can produce renal damage and ultimately lead to renal failure. Early diagnosis and treatment are necessary.

In the clinic

**Urethral catheterization**

Urethral catheterization is often performed to drain urine from a patient's bladder when the patient is unable to micturate. When inserting urinary catheters, it is important to appreciate the gender anatomy of the patient. In men:

- The spongy urethra is surrounded by the erectile tissue of the bulb of the penis immediately inferior to the deep perineal pouch. The wall of this short segment of urethra is relatively thin and angles superiorly to pass through the deep perineal pouch; at this position the urethra is vulnerable to damage, notably during cystoscopy.

- The membranous part of the urethra runs superiorly as it passes through the deep perineal pouch.

- The prostatic part of the urethra takes a slight concave curve anteriorly as it passes through the prostate gland.

In women, it is much simpler to pass catheters and cystoscopes because the urethra is short and straight. Urine may therefore be readily drained from a distended bladder without significant concern for urethral rupture. Occasionally, it is impossible to pass any form of instrumentation through the urethra to drain the bladder, usually because there is a urethral stricture or prostatic enlargement. In such cases, an ultrasound of the lower abdomen will demonstrate a full bladder ([Fig. 5.45](#)) behind the anterior abdominal wall. A suprapubic catheter may be inserted into the bladder with minimal trauma through a small incision under local anesthetic.
Reproductive system

In men

The reproductive system in men has components in the abdomen, pelvis, and perineum (Fig. 5.46A). The major components are a testis, epididymis, ductus deferens, and ejaculatory duct on each side, and the urethra and penis in the midline. In addition, three types of accessory glands are associated with the system:
Fig. 5.46


- a single prostate,
- a pair of seminal vesicles, and
- a pair of bulbo-urethral glands.

The design of the reproductive system in men is basically a series of ducts and tubules. The arrangement of parts and linkage to the urinary tract reflects its embryological development.

Testes

The testes originally develop high on the posterior abdominal wall and then descend, normally before birth, through the inguinal canal in the anterior abdominal wall and into the scrotum of the perineum. During descent, the testes carry their vessels, lymphatics, and nerves, as well as their principal drainage ducts, the ductus deferens (vas deferens) with them. The lymph drainage of the testes is therefore to the lateral aortic or lumbar nodes and pre-aortic nodes in the abdomen, and not to the inguinal or pelvic lymph nodes.

Each ellipsoid-shaped testis is enclosed within the end of an elongated musculofascial pouch, which is continuous with the anterior abdominal wall and projects into the scrotum. The spermatic cord is the tube-shaped connection between the pouch in the scrotum and the abdominal wall.

The sides and anterior aspect of the testis are covered by a closed sac of peritoneum (the tunica vaginalis), which originally connected to the abdominal cavity. Normally after testicular descent, the connection closes, leaving a fibrous remnant.
Each testis (Fig. 5.46B) is composed of seminiferous tubules and interstitial tissue surrounded by a thick connective tissue capsule (the tunica albuginea). Spermatozoa are produced by the seminiferous tubules. The 400 to 600 highly coiled seminiferous tubules are modified at each end to become straight tubules, which connect to a collecting chamber (the rete testis) in a thick, vertically oriented linear wedge of connective tissue (the mediastinum testis), projecting from the capsule into the posterior aspect of the gonad. Approximately 12 to 20 efferent ductules originate from the upper end of the rete testis, penetrate the capsule, and connect with the epididymis.

In the clinic

Testicular tumors

Tumors of the testis account for a small percentage of malignancies in men. However, they generally occur in younger patients (between 20 and 40 years of age). When diagnosed at an early stage, most of these tumors are curable by surgery and chemotherapy. Early diagnosis of testicular tumor is extremely important. Abnormal lumps can be detected by palpation, and diagnosis can be made using ultrasound. Simple ultrasound scanning can reveal the extent of the local tumor, usually at an early stage. Surgical removal of the malignant testis is often carried out using an inguinal approach. The testis is not usually removed through a scrotal incision, because it is possible to spread tumor cells into the subcutaneous tissues of the scrotum, which has a different lymphatic drainage than the testis.

Epididymis

The epididymis courses along the posterolateral side of the testis (Fig. 5.46B). It has two distinct components:

- the efferent ductules, which form an enlarged coiled mass that sits on the posterior superior pole of the testis and forms the head of the epididymis; and
- the true epididymis, which is a single, long coiled duct into which the efferent ductules all drain, and which continues inferiorly along the posterolateral margin of the testis as the body of the epididymis and enlarges to form the tail of the epididymis at the inferior pole of the testis.

During passage through the epididymis, spermatozoa acquire the ability to move and fertilize an egg. The epididymis also stores spermatozoa until ejaculation. The end of the epididymis is continuous with the ductus deferens.

Ductus deferens

The ductus deferens is a long muscular duct that transports spermatozoa from the tail of the epididymis in the scrotum to the ejaculatory duct in the pelvic cavity (Fig. 5.46A). It ascends in the scrotum as a component of the spermatic cord and passes through the inguinal canal in the anterior abdominal wall.

After passing through the deep inguinal ring, the ductus deferens bends medially around the lateral side of the inferior epigastric artery and crosses the external iliac artery and the external iliac vein at the pelvic inlet to enter the pelvic cavity.

The duct descends medially on the pelvic wall, deep to the peritoneum, and crosses the ureter posterior to the bladder. It continues inferomedially along the base of the bladder, anterior to the rectum, almost to the midline, where it is joined by the duct of the seminal vesicle to form the ejaculatory duct.

Between the ureter and ejaculatory duct, the ductus deferens expands to form the ampulla of the ductus deferens. The ejaculatory duct penetrates through the prostate gland to connect with the prostatic urethra.

In the clinic

Vasectomy

The ductus deferens transports spermatozoa from the tail of the epididymis in the scrotum to the ejaculatory duct in the pelvic cavity. Because it has a thick smooth muscle wall, it can be easily palpated in the spermatic cord between the testes and the superficial inguinal ring. Also, because it can be accessed through skin and superficial fascia, it is amenable to surgical dissection and surgical division. When this is carried out bilaterally (vasectomy), the patient is rendered sterile—this is a useful method for male contraception.

Seminal vesicle

Each seminal vesicle is an accessory gland of the male reproductive system that develops as a blind-ended tubular outgrowth from the ductus deferens (Fig. 5.46A). The tube is coiled with numerous pocket-like outgrowths and is encapsulated by connective tissue to form an elongate structure situated between the bladder and rectum. The gland is immediately lateral to and follows the course of the ductus deferens at the base of the bladder.

The duct of the seminal vesicle joins the ductus deferens to form the ejaculatory duct (Fig. 5.47). Secretions from the seminal vesicle contribute significantly to the volume of the ejaculate (semen).

Prostate
The prostate is an unpaired accessory structure of the male reproductive system that surrounds the urethra in the pelvic cavity (Figs. 5.46A and 5.47). It lies immediately inferior to the bladder, posterior to the pubic symphysis, and anterior to the rectum.

**Fig. 5.47**

*The prostate gland. Zonal anatomy.*

The prostate is shaped like an inverted rounded cone with a larger base, which is continuous above with the neck of the bladder, and a narrower apex, which rests below on the pelvic floor. The inferolateral surfaces of the prostate are in contact with the levator ani muscles that together cradle the prostate between them.

The prostate develops as 30 to 40 individual complex glands, which grow from the urethral epithelium into the surrounding wall of the urethra. Collectively, these glands enlarge the wall of the urethra into what is known as the prostate; however, the individual glands retain their own ducts, which empty independently into the prostatic sinuses on the posterior aspect of the urethral lumen (see Fig. 5.44C).

Secretions from the prostate, together with secretions from the seminal vesicles, contribute to the formation of semen during ejaculation.

The ejaculatory ducts pass almost vertically in an anteroinferior direction through the posterior aspect of the prostate to open into the prostatic urethra.

**Bulbo-urethral glands**

The bulbo-urethral glands (see Fig. 5.46A), one on each side, are small, pea-shaped mucous glands situated within the deep perineal pouch. They are lateral to the membranous part of the urethra. The duct from each gland passes inferomedially through the perineal membrane, to open into the bulb of the spongy urethra at the root of the penis.

Together with small glands positioned along the length of the spongy urethra, the bulbo-urethral glands contribute to lubrication of the urethra and the pre-ejaculatory emission from the penis.

In the clinic

Prostate problems

Prostate cancer is one of the most commonly diagnosed malignancies in men, and often the disease is advanced at diagnosis. Prostate cancer typically occurs in the peripheral zone of the prostate (see Fig. 5.47) and is relatively asymptomatic. In many cases, it is diagnosed by a digital rectal examination (DRE) (Fig. 5.48B) and by blood tests, which include serum acid phosphatase and serum prostate-specific antigen (PSA). In rectal exams, the tumorous prostate feels “rock” hard. The diagnosis is usually made by obtaining a number of biopsies of the prostate. Ultrasound is used during the biopsy procedure to image the prostate for the purpose of taking measurements and for needle placement. Benign prostatic hypertrophy is a disease of the prostate that occurs with increasing age in most men (Fig. 5.48B). It generally involves the more central regions of the prostate (see Fig. 5.47), which gradually enlarge. The prostate feels “bulky” on DRE. Owing to the more central hypertrophic change of the prostate, the urethra is compressed, and a urinary outflow obstruction develops in a number of patients. With time, the bladder may become hypertrophied in response to the urinary outflow obstruction. In some male patients, the obstruction becomes so severe that urine cannot be passed and transurethral or suprapubic catheterization is necessary.
Despite being a benign disease, benign prostatic hypertrophy can therefore have a marked effect on the daily lives of many patients.

Fig. 5.48
Axial T2-weighted magnetic resonance images of prostate problems. A. A small prostatic cancer in the peripheral zone of a normal-sized prostate. B. Benign prostatic hypertrophy.

In women
The reproductive tract in women is contained mainly in the pelvic cavity and perineum, although during pregnancy, the uterus expands into the abdominal cavity. Major components of the system consist of:

- an ovary on each side, and
a uterus, vagina, and clitoris in the midline (Fig. 5.49).

Fig. 5.49
Reproductive system in women.

In addition, a pair of accessory glands (the greater vestibular glands) are associated with the tract.

Ovaries

Like the testes in men, the ovaries develop high on the posterior abdominal wall and then descend before birth, bringing with them their vessels, lymphatics, and nerves. Unlike the testes, the ovaries do not migrate through the inguinal canal into the perineum, but stop short and assume a position on the lateral wall of the pelvic cavity (Fig. 5.50).
Fig. 5.50

Ovaries and broad ligament.

The ovaries are the sites of egg production (oogenesis). Mature eggs are ovulated into the peritoneal cavity and normally directed into the adjacent openings of the uterine tubes by cilia on the ends of the uterine tubes.

The ovaries lie adjacent to the lateral pelvic wall just inferior to the pelvic inlet. Each of the two almond-shaped ovaries is about 3 cm long and is suspended by a mesentery (the mesovarium) that is a posterior extension of the broad ligament.

In the clinic

Ovarian cancer

Ovarian cancer remains one of the major challenges in oncology. The ovaries contain numerous cell types, all of which can undergo malignant change and require different imaging and treatment protocols and ultimately have different prognoses. Ovarian tumors most commonly originate from the surface epithelium that covers the ovary and is continuous at a sharp transition zone with the peritoneum of the mesovarium. Many factors have been linked with the development of ovarian tumors, including a strong family history. Ovarian cancer may occur at any age, but more typically it occurs in older women. Cancer of the ovaries may spread via the blood and lymphatics, and frequently metastasizes directly into the peritoneal cavity. Such direct peritoneal cavity spread allows the passage of tumor cells along the paracolic gutters and over the liver from where this disease may
disseminate easily. Unfortunately, many patients already have metastatic and diffuse disease (Fig. 5.51) at the time of diagnosis.

*Fig. 5.51*

**Sagittal magnetic resonance image demonstrating ovarian cancer.**

In the clinic

**Imaging the ovary**

The ovaries can be visualized using ultrasound. If the patient drinks enough water, the bladder becomes enlarged and full. This fluid-filled cavity provides an excellent acoustic window, behind which the uterus and ovaries may be identified by transabdominal scanning with ultrasound. This technique also allows obstetricians and technicians to view a fetus and record its growth throughout pregnancy. Some patients are not suitable for transabdominal scanning, in which case a probe may be passed into the vagina, permitting close visualization of the uterus, the contents of the recto-uterine pouch (pouch of Douglas), and the ovaries. The ovaries can also be visualized laparoscopically.

**Uterus**

The **uterus** is a thick-walled muscular organ in the midline between the bladder and rectum (see Fig. 5.50). It consists of a body and a cervix, and inferiorly it joins the vagina (Fig. 5.52). Superiorly, uterine tubes project laterally from the uterus and open into the peritoneal cavity immediately adjacent to the ovaries.

*Fig. 5.52*

**Uterus. Anterior view. The anterior halves of the uterus and vagina have been cut away.**

The body of the uterus is flattened anteroposteriorly and, above the level of origin of the uterine tubes (Fig. 5.52), has a rounded superior end (fundus of the uterus). The cavity of the body of the uterus is a narrow slit, when viewed laterally, and is shaped like an inverted triangle, when viewed anteriorly. Each of the superior corners of the cavity is continuous with the lumen of a uterine tube; the inferior corner is continuous with the central canal of the cervix.
Implantation of the blastocyst normally occurs in the body of the uterus. During pregnancy, the uterus dramatically expands superiorly into the abdominal cavity.

In the clinic

Hysterectomy

A hysterectomy is the surgical removal of the uterus. This is usually complete excision of the body, fundus, and cervix of the uterus, though occasionally the cervix may be left in situ. In some instances the uterine (fallopian) tubes and ovaries are removed as well. This procedure is called a total abdominal hysterectomy and bilateral salpingo-oophorectomy. Hysterectomy, oophorectomy, and salpingo-oophorectomy may be performed in patients who have reproductive malignancy, such as uterine, cervical, and ovarian cancers. Other indications include a strong family history of reproductive disorders, endometriosis, and excessive bleeding. Occasionally the uterus may need to be removed postpartum because of excessive postpartum bleeding. A hysterectomy is performed through a transverse suprapubic incision (Pfannenstiel's incision). During the procedure tremendous care is taken to identify the distal ureters and to ligate the nearby uterine arteries without damage to the ureters.

Uterine tubes

The uterine tubes extend from each side of the superior end of the body of the uterus to the lateral pelvic wall and are enclosed within the upper margins of the mesosalpinx portions of the broad ligaments (see p. 483). Because the ovaries are suspended from the posterior aspect of the broad ligaments, the uterine tubes pass superiorly over, and terminate laterally to, the ovaries.

Each uterine tube has an expanded trumpet-shaped end (the infundibulum), which curves around the superolateral pole of the related ovary (Fig. 5.53). The margin of the infundibulum is rimmed with small finger-like projections termed fimbriae. The lumen of the uterine tube opens into the peritoneal cavity at the narrowed end of the infundibulum. Medial to the infundibulum, the tube expands to form the ampulla and then narrows to form the isthmus, before joining with the body of the uterus.

Fig. 5.53

Uterine tubes.

The fimbriated infundibulum facilitates the collection of ovulated eggs from the ovary. Fertilization normally occurs in the ampulla.

In the clinic

Tubal ligation

After ovulation, the unfertilized egg is gathered by the fimbriae of the uterine tube. The egg passes into the uterine tube where it is normally fertilized in the ampulla. The zygote then begins development and passes into the uterine cavity where it implants in the uterine wall. A simple and effective method of birth control is to surgically ligate (clip) the uterine tubes, preventing spermatozoa from reaching ova. This simple short procedure is performed under general anesthetic. A small laparoscope is passed into the peritoneal cavity and special equipment is used to identify the tubes.

Cervix
The cervix forms the inferior part of the uterus and is shaped like a short, broad cylinder with a narrow central channel. The body of the uterus normally arches forward (anteflexed on the cervix) over the superior surface of the emptied bladder (Fig. 5.54A). In addition, the cervix is angled forward (anteverted) on the vagina so that the inferior end of the cervix projects into the upper anterior aspect of the vagina. Because the end of the cervix is dome shaped, it bulges into the vagina, and a gutter, or fornix, is formed around the margin of the cervix where it joins the vaginal wall (Fig. 5.54B). The tubular central canal of the cervix opens, below, as the external os, into the vaginal cavity and, above, as the internal os, into the uterine cavity.

In the clinic
Carcinoma of the cervix and uterus
Carcinoma of the cervix (Fig. 5.55) and uterus is a common disease in women. Diagnosis is by inspection, cytology (examination of the cervical cells), imaging, biopsy, and dilatation and curettage (D&C) of the uterus. Carcinoma of the cervix and uterus may be treated by local resection, removal of the uterus (hysterectomy), and adjuvant chemotherapy. The tumor spreads via lymphatics to the internal and common iliac lymph nodes.

Fig. 5.55
Picture taken through a speculum inserted into the vagina demonstrating cervical cancer. See Fig. 5.83E on p. 524 for a view of the normal cervix.
Vagina

The vagina is the copulatory organ in women. It is a distensible fibromuscular tube that extends from the perineum through the pelvic floor and into the pelvic cavity (Fig. 5.56A). The internal end of the canal is enlarged to form a region called the vaginal vault.
The anterior wall of the vagina is related to the base of the bladder and to the urethra; in fact, the urethra is embedded in, or fused to, the anterior vaginal wall.

Posteriorly, the vagina is related principally to the rectum.

Inferiorly, the vagina opens into the vestibule of the perineum immediately posterior to the external opening of the urethra. From its external opening (the introitus), the vagina courses posterosuperiorly through the perineal membrane and into the pelvic cavity, where it is attached by its anterior wall to the circular margin of the cervix.

The vaginal fornix is the recess formed between the margin of the cervix and the vaginal wall. Based on position, the fornix is subdivided into a posterior fornix, an anterior fornix, and two lateral fornices (Fig. 5.56A and see Fig. 5.54).

The vaginal canal is normally collapsed so that the anterior wall is in contact with the posterior wall. By using a speculum to open the vaginal canal, a physician can see the domed inferior end of the cervix, the vaginal fornices, and the external os of the cervical canal in a patient (Fig. 5.56B).

During intercourse, semen is deposited in the vaginal vault. Spermatozoa make their way into the external os of the cervical canal, pass through the cervical canal into the uterine cavity, and then continue through the uterine cavity into the uterine tubes where fertilization normally occurs in the ampulla.

**Fascia**

Fascia in the pelvic cavity lines the pelvic walls, surrounds the bases of the pelvic viscera, and forms sheaths around blood vessels and nerves that course medially from the pelvic walls to reach the viscera in the midline. This pelvic fascia is a continuation of the extraperitoneal connective tissue layer found in the abdomen.

**In women**
In women, a **rectovaginal septum** separates the posterior surface of the vagina from the rectum ([Fig. 5.57A](#)). Condensations of fascia form ligaments that extend from the cervix to the anterior (**pubocervical ligament**), lateral (**transverse cervical or cardinal ligament**), and posterior (**uterosacral ligament**) pelvic walls ([Fig. 5.57A](#)). These ligaments, together with the perineal membrane, the levator ani muscles, and the perineal body, are thought to stabilize the uterus in the pelvic cavity. The most important of these ligaments are the transverse cervical or cardinal ligaments, which extend laterally from each side of the cervix and vaginal vault to the related pelvic wall.

**In the clinic**

- **The recto-uterine pouch**
  - The recto-uterine pouch (**pouch of Douglas**) is an extremely important clinical region situated between the rectum and uterus. When the patient is in the supine position, the recto-uterine pouch is the lowest portion of the abdominopelvic cavity and is a site where infection and fluids typically collect. It is impossible to palpate this region transabdominally, but it can be examined by transvaginal and transrectal digital palpation. If an abscess is suspected, it may be drained through the vagina or the rectum without necessitating transabdominal surgery.
Fig. 5.57

Pelvic fascia. **A. In women. B. In men.**
In men

In men, a condensation of fascia around the anterior and lateral region of the prostate (prostatic fascia) contains and surrounds the prostatic plexus of veins and is continuous posteriorly with the rectovesical septum, which separates the posterior surface of the prostate and base of the bladder from the rectum (Fig. 5.57B).

Peritoneum

The peritoneum of the pelvis is continuous at the pelvic inlet with the peritoneum of the abdomen. In the pelvis, the peritoneum drapes over the pelvic viscera in the midline, forming:

- pouches between adjacent viscera, and
- folds and ligaments between viscera and pelvic walls.

Anteriorly, median and medial umbilical folds of peritoneum cover the embryological remnants of the urachus and umbilical arteries, respectively (Fig. 5.58). These folds ascend out of the pelvis and onto the anterior abdominal wall. Posteriorly, peritoneum drapes over the anterior and lateral aspects of the upper third of the rectum, but only the anterior surface of the middle third of the rectum is covered by peritoneum; the lower third of the rectum is not covered at all.
In women

In women, the uterus lies between the bladder and rectum, and the uterine tubes extend from the superior aspect of the uterus to the lateral pelvic walls (Fig. 5.58A). As a consequence, a shallow vesico-uterine pouch occurs anteriorly, between the bladder and uterus, and a deep recto-uterine pouch (pouch of Douglas) occurs posteriorly, between the uterus and rectum. In addition, a large fold of peritoneum (the broad ligament), with a uterine tube enclosed in its superior margin and an ovary attached posteriorly, is located on each side of the uterus and extends to the lateral pelvic walls.

In the midline, the peritoneum descends over the posterior surface of the uterus and cervix and onto the vaginal wall adjacent to the posterior vaginal fornix. It then reflects onto the anterior and lateral walls of the rectum. The deep pouch of peritoneum formed between the anterior surface of the rectum and posterior surfaces of the uterus, cervix, and vagina is the recto-uterine pouch. A sharp sickle-shaped ridge of peritoneum (recto-uterine fold) occurs on each side near the base of the recto-uterine pouch. The recto-uterine folds overlie the uterosacral ligaments, which are condensations of pelvic fascia that extend from the cervix to the posterolateral pelvic walls.

Broad ligament

The broad ligament is a sheet-like fold of peritoneum, oriented in the coronal plane that runs from the lateral pelvic wall to the uterus, and encloses the uterine tube in its superior margin and suspends the ovary from its posterior aspect (Fig. 5.58A). The uterine arteries cross the ureters at the base of the broad ligaments, and the ligament of the ovary and round ligament of the uterus are enclosed within the parts of the broad ligament related to the ovary and uterus, respectively. The broad ligament has three parts:
the mesometrium, the largest part of the broad ligament, which extends from the lateral pelvic walls to the body of the uterus;

the mesosalpinx, the most superior part of the broad ligament, which suspends the uterine tube in the pelvic cavity; and

the mesovarium, a posterior extension of the broad ligament, which attaches to the ovary.

The peritoneum of the mesovarium becomes firmly attached to the ovary as the surface epithelium of the ovary. The ovaries are positioned with their long axis in the vertical plane. The ovarian vessels, nerves, and lymphatics enter the superior pole of the ovary from a lateral position and are covered by another raised fold of peritoneum, which with the structures it contains forms the suspensory ligament of the ovary (infundibulopelvic ligament).

The inferior pole of the ovary is attached to a fibromuscular band of tissue (the ligament of the ovary), which courses medially in the margin of the mesovarium to the uterus and then continues anterolaterally as the round ligament of the uterus (Fig. 5.58A). The round ligament of the uterus passes over the pelvic inlet to reach the deep inguinal ring and then courses through the inguinal canal to end in connective tissue related to the labium majus in the perineum. Both the ligament of the ovary and the round ligament of the uterus are remnants of the gubernaculum, which attaches the gonad to the labioscrotal swellings in the embryo.

In men

In men, the visceral peritoneum drapes over the top of the bladder onto the superior poles of the seminal vesicles and then reflects onto the anterior and lateral surfaces of the rectum (Fig. 5.58B). A rectovesical pouch occurs between the bladder and rectum.

Nerves

Somatic plexuses

Sacral and coccygeal plexuses

The sacral and coccygeal plexuses are situated on the posterolateral wall of the pelvic cavity and generally occur in the plane between the muscles and blood vessels. They are formed by the ventral rami of S1 to Co, with a significant contribution from L4 and L5, which enter the pelvis from the lumbar plexus (Fig. 5.59). Nerves from these mainly somatic plexuses contribute to the innervation of the lower limb and muscles of the pelvis and perineum. Cutaneous branches supply skin over the medial side of the foot, the posterior aspect of the lower limb, and most of the perineum.
Fig. 5.59  

**Sacral and coccygeal plexuses.**

**Sacral plexus**

The sacral plexus on each side is formed by the anterior rami of S1 to S4, and the lumbosacral trunk (L4 and L5) (Fig. 5.60). The plexus is formed in relation to the anterior surface of the piriformis muscle, which is part of the posterolateral pelvic wall. Sacral contributions to the plexus pass out of the anterior sacral foramina and course laterally and inferiorly on the pelvic wall. The lumbosacral trunk, consisting of part of the anterior ramus of L4 and all of the anterior ramus of L5, courses vertically into the pelvic cavity from the abdomen by passing immediately anterior to the sacro-iliac joint.
Gray rami communicantes from ganglia of the sympathetic trunk connect with each of the anterior rami and carry postganglionic sympathetic fibers destined for the periphery to the somatic nerves (Fig. 5.61). In addition, special visceral nerves (pelvic splanchnic nerves) originating from S2 to S4 deliver preganglionic parasympathetic fibers to the pelvic part of the prevertebral plexus (Figs. 5.59 and 5.60).
Fig. 5.61

**Sympathetic trunks in the pelvis.**

Each anterior ramus has ventral and dorsal divisions that combine with similar divisions from other levels to form terminal nerves (Fig. 5.60). The anterior ramus of S4 has only a ventral division.

Branches of the sacral plexus include the sciatic nerve and gluteal nerves, which are major nerves of the lower limb, and the pudendal nerve, which is the nerve of the perineum (Table 5.4). Numerous smaller branches supply the pelvic wall, floor, and lower limb.

Table 5.4

<table>
<thead>
<tr>
<th>Branch</th>
<th>SACRAL PLEXUS</th>
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<td>Sciatic</td>
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**Spinal segments**

**Motor function**

All muscles in the posterior or hamstring compartment of the thigh (including the hamstring part of the adductor magnus) except for the short
Pelvis and Perineum

Tibial part
Skin on posterolateral and lateral surfaces of foot and sole of foot

L4 to S3

head of the biceps

All muscles in the posterior compartment of the leg

All muscles in the sole of the foot

Sensory (cutaneous) function

Motor function
Short head of biceps in the posterior compartment of the thigh

All muscles in the anterior and lateral compartments of the leg

Extensor digitorum brevis in the foot (also contributes to the supply of the first dorsal interosseous muscle)

Common fibular part
Skin on the anterolateral surface of the leg and dorsal surface of the foot

L4 to S2

Sensory (cutaneous) function

Motor function
Skeletal muscles in the perineum including the external urethral and anal sphincters and levator ani (overlaps in supply of the levator ani and external sphincter with branches directly from ventral division of S4)

Pudendal
Most skin of the perineum. Penis and clitoris

S2 to S4

Sensory (cutaneous) function

Superior gluteal
Gluteus medius, gluteus minimus, and tensor fasciae latae

L4 to S1

Motor function

L5 to S2

Motor function
**Inferior gluteal**
Gluteus maximus

L5 to S2  **Motor function**

**Nerve to obturator internus and superior gemellus**
Obturator internus and superior gemellus

L4 to S1  **Motor function**

**Nerve to quadratus femoris and inferior gemellus**
Quadratus femoris and inferior gemellus

S1, S3  **Sensory (cutaneous) function**

**Posterior femoral cutaneous (posterior cutaneous nerve of thigh)**
Skin on the posterior aspect of the thigh

S2, S3  **Sensory (cutaneous) function**

Perforating cutaneous
Skin over gluteal fold (overlaps with posterior femoral cutaneous)

S1, S2  **Motor function**

**Nerve to piriformis**
Piriformis muscle

**Motor function**
Nerves to levator ani, coccygeus, and external anal sphincter

Small patch of skin between anus and coccyx

S4 Levator ani, coccygeus, and external anal sphincter. (Overlaps with pudendal nerve)

Sensory (cutaneous) function

Motor (visceral) function

Visceral motor (preganglionic parasympathetic) to pelvic part of prevertebral plexus

Pelvic splanchnic nerves

S2, S3 (4) Stimulate erection, modulate mobility in gastrointestinal system distal to the left colic flexure, inhibitory to internal urethral sphincter

Sensory (visceral) function

Visceral afferents (that follow the parasympathetics) from pelvic viscera and distal parts of colon. Pain from cervix and possibly from bladder and proximal urethra

COCCYGEAL PLEXUS

S4 to Co Sensory (cutaneous) function

Anococcygeal nerves

Perianal skin

Most nerves originating from the sacral plexus leave the pelvic cavity by passing through the greater sciatic foramen inferior to the piriformis muscle, and enter the gluteal region of the lower limb. Other nerves leave the pelvic cavity using different routes; a few nerves do not leave the pelvic cavity and course directly into the muscles in the pelvic cavity. Finally, two nerves that leave the pelvic cavity through the greater sciatic foramen loop around the ischial spine and sacrospinous ligament and pass medially through the lesser sciatic foramen to supply structures in the perineum and lateral pelvic wall.

Sciatic nerve.

The sciatic nerve is the largest nerve of the body and carries contributions from L4 to S3 (Figs. 5.59 and 5.60). It:

- forms on the anterior surface of the piriformis muscle and leaves the pelvic cavity through the greater sciatic foramen inferior to the piriformis;
- passes through the gluteal region into the thigh, where it divides into its two major branches, the common fibular nerve (common peroneal nerve) and the tibial nerve—dorsal divisions of L4, L5, S1, and S2 are carried in the common fibular part of the nerve and the ventral divisions of L4, L5, S1, S2, and S3 are carried in the tibial part;
- innervates muscles in the posterior compartment of the thigh and muscles in the leg and foot; and
- carries sensory fibers from the skin of the foot and lateral leg.

Pudendal nerve.

The pudendal nerve forms anteriorly to the lower part of the piriformis muscle from ventral divisions of S2 to S4 (Figs. 5.59 and 5.60). It:
leaves the pelvic cavity through the greater sciatic foramen, inferior to the piriformis muscle, and enters the gluteal region; 

courses into the perineum by immediately passing around the sacrospinous ligament, where the ligament joins the ischial spine, and through the lesser sciatic foramen (this course takes the nerve out of the pelvic cavity, around the peripheral attachment of the pelvic floor, and into the perineum); 

is accompanied throughout its course by the internal pudendal vessels; and 

innervates skin and skeletal muscles of the perineum, including the external anal and external urethral sphincters.

In the clinic
Pudendal block
Pudendal block anesthesia is performed to relieve the pain associated with childbirth. Although the use of this procedure is less common since the widespread adoption of epidural anesthesia, it provides an excellent option for women who have a contraindication to neuraxial anesthesia (e.g., spinal anatomy, low platelets, too close to delivery). Pudendal blocks are also used for certain types of chronic pelvic pain. The injection is usually given where the pudendal nerve crosses the lateral aspect of the sacrospinous ligament near its attachment to the ischial spine. During childbirth, a finger inserted into the vagina can palpate the ischial spine. The needle is passed transcutaneously to the medial aspect of the ischial spine and around the sacrospinous ligament. Infiltration is performed and the perineum is anesthetized.

Other branches of the sacral plexus.

Other branches of the sacral plexus include:

motor branches to muscles of the gluteal region, pelvic wall, and pelvic floor (superior and inferior gluteal nerves, nerve to obturator internus and superior gemellus, nerve to quadratus femoris and inferior gemellus, nerve to piriformis, nerves to levator ani); and 

sensory nerves to skin over the inferior gluteal region and posterior aspects of the thigh and upper leg (perforating cutaneous nerve and posterior cutaneous nerve of the thigh) (Figs. 5.59 and 5.60).

The superior gluteal nerve, formed by branches from the dorsal divisions of L4 to S1, leaves the pelvic cavity through the greater sciatic foramen superior to the piriformis muscle and supplies muscles in the gluteal region—gluteus medius, gluteus minimus, and tensor fasciae latae (tensor of fascia lata) muscles.

The inferior gluteal nerve, formed by branches from the dorsal divisions of L5 to S2, leaves the pelvic cavity through the greater sciatic foramen inferior to the piriformis muscle and supplies the gluteus maximus, the largest muscle in the gluteal region.

Both superior and inferior gluteal nerves are accompanied by corresponding arteries.

The nerve to the obturator internus and the associated superior gemellus muscle originates from the ventral divisions of L5 to S2 and leaves the pelvic cavity through the greater sciatic foramen inferior to the piriformis muscle. Like the pudendal nerve, it passes around the ischial spine and through the lesser sciatic foramen to enter the perineum and supply the obturator internus muscle from the medial side of the muscle, inferior to the attachment of the levator ani muscle.

The nerve to the quadratus femoris muscle and the inferior gemellus muscle, and the posterior cutaneous nerve of the thigh (posterior femoral cutaneous nerve) also leave the pelvic cavity through the greater sciatic foramen inferior to the piriformis muscle and course to muscles and skin, respectively, in the lower limb.

Unlike most of the other nerves originating from the sacral plexus, which leave the pelvic cavity through the greater sciatic foramen either above or below the piriformis muscle, the perforating cutaneous nerve leaves the pelvic cavity by penetrating directly through the sacrotoberous ligament and then courses to skin over the inferior aspect of the buttocks.

The nerve to the piriformis and a number of small nerves to the levator ani and coccygeus muscles originate from the sacral plexus and pass directly into their target muscles without leaving the pelvic cavity.
The obturator nerve (L2 to L4) is a branch of the lumbar plexus. It passes inferiorly along the posterior abdominal wall within the psoas muscle, emerges from the medial surface of the psoas, passes posteriorly to the common iliac artery and medially to the internal iliac artery at the pelvic inlet, and then courses along the lateral pelvic wall. It leaves the pelvic cavity by traveling through the obturator canal and supplies the adductor region of the thigh.

Coccygeal plexus

The small coccygeal plexus has a minor contribution from S4 and is formed mainly by the anterior rami of S5 and Co, which originate inferiorly to the pelvic floor. They penetrate the coccygeus muscle to enter the pelvic cavity and join with the anterior ramus of S4 to form a single trunk, from which small anococcygeal nerves originate (Table 5.4). These nerves penetrate the muscle and the overlying sacrospinous and sacrotuberous ligaments and pass superficially to innervate skin in the anal triangle of the perineum.

Visceral plexuses

Paravertebral sympathetic chain

The paravertebral part of the visceral nervous system is represented in the pelvis by the inferior ends of the sympathetic trunks (Fig. 5.62A). Each trunk enters the pelvic cavity from the abdomen by passing over the ala of the sacrum medially to the lumbosacral trunks and posteriorly to the iliac vessels. The trunks course inferiorly along the anterior surface of the sacrum, where they are positioned medially to the anterior sacral foramina. Four ganglia occur along each trunk. Anteriorly to the coccyx, the two trunks join to form a single small terminal ganglion (the ganglion impar).
The principal function of the sympathetic trunks in the pelvis is to deliver postganglionic sympathetic fibers to the anterior rami of sacral nerves for distribution to the periphery, mainly to parts of the lower limb and perineum. This is accomplished by gray rami communicantes, which connect the trunks to the sacral anterior rami.

In addition to gray rami communicantes, other branches (the sacral splanchnic nerves) join and contribute to the pelvic part of the prevertebral plexus associated with innervating pelvic viscera (Fig. 5.62A).

Fig. 5.62

**Pelvic extensions of the prevertebral plexus.** **A.** Anterior view. **B.** Anteromedial view of right side of plexus.
The pelvic parts of the prevertebral plexus carry sympathetic, parasympathetic, and visceral afferent fibers (Fig. 5.62A). Pelvic parts of the plexus are associated with innervating pelvic viscera and erectile tissues of the perineum.

The prevertebral plexus enters the pelvis as two hypogastric nerves, one on each side, that cross the pelvic inlet medially to the internal iliac vessels (Fig. 5.62A). The hypogastric nerves are formed by the separation of the fibers in the superior hypogastric plexus, into right and left bundles. The superior hypogastric plexus is situated anterior to vertebra LV between the promontory of the sacrum and the bifurcation of the aorta.

When the hypogastric nerves are joined by pelvic splanchnic nerves carrying preganglionic parasympathetic fibers from S2 to S4, the pelvic plexuses (inferior hypogastric plexuses) are formed (Fig. 5.62). The inferior hypogastric plexuses, one on each side, course in an inferior direction around the pelvic walls, medially to major vessels and somatic nerves. They give origin to the following subsidiary plexuses, which innervate the pelvic viscera:

- the rectal plexus,
- the uterovaginal plexus,
- the prostatic plexus, and
- the vesical plexus.

Terminal branches of the inferior hypogastric plexuses penetrate and pass through the deep perineal pouch and innervate erectile tissues of the penis and the clitoris in the perineum (Fig. 5.62B). In men, these nerves, called cavernous nerves, are extensions of the prostatic plexus. The pattern of distribution of similar nerves in women is not entirely clear, but they are likely extensions of the uterovaginal plexus.

**Sympathetic fibers**

Sympathetic fibers enter the inferior hypogastric plexuses from the hypogastric nerves and from branches (sacral splanchnic nerves) of the upper sacral parts of the sympathetic trunks (Fig. 5.62A). Ultimately, these nerves are derived from preganglionic fibers that leave the spinal cord in the anterior roots, mainly of T10 to L2. These fibers:

- innervate blood vessels,
- cause contraction of smooth muscle in the internal urethral sphincter in men and the internal anal sphincters in both men and women,
- cause smooth muscle contraction associated with the reproductive tract and with the accessory glands of the reproductive system, and
- are important in moving secretions from the epididymis and associated glands into the urethra to form semen during ejaculation.

**Parasympathetic fibers**

Parasympathetic fibers enter the pelvic plexus in pelvic splanchnic nerves that originate from spinal cord levels S2 to S4 (Fig. 5.62A). They:

- are generally vasodilatory,
- stimulate bladder contraction,
▪ ▪
stimulate erection, and
▪ ▪
modulate activity of the enteric nervous system of the colon distal to the left colic flexure (in addition to pelvic viscera, some of the fibers from the pelvic plexus course superiorly in the prevertebral plexus, or as separate nerves, and pass into the inferior mesenteric plexus of the abdomen).

**Visceral afferent fibers**

Visceral afferent fibers follow the course of the sympathetic and parasympathetic fibers to the spinal cord. Afferent fibers that enter the cord in lower thoracic levels and lumbar levels with sympathetic fibers generally carry pain; however, pain fibers from the cervix and some pain fibers from the bladder and urethra may accompany parasympathetic nerves to sacral levels of the spinal cord.

In the clinic

**Prostatectomy and impotence**

It may be necessary to perform radical surgery to cure cancer of the prostate. To do this, the prostate and its attachments around the base of the bladder, including the seminal vesicles, must be removed en masse. Parts of the inferior hypogastric plexus in this region give rise to nerves that innervate the erectile tissues of the penis. Impotence may occur if these nerves cannot be or are not preserved during removal of the prostate. For the same reasons, women may experience sexual dysfunction if similar nerves are damaged during pelvic surgery, for example, during a total hysterectomy.

**Blood vessels**

**Arteries**

The major artery of the pelvis and perineum is the internal iliac artery on each side (Fig. 5.63). In addition to providing a blood supply to most of the pelvic viscera, pelvic walls and floor, and structures in the perineum, including erectile tissues of the clitoris and the penis, this artery gives rise to branches that follow nerves into the gluteal region of the lower limb. Other vessels that originate in the abdomen and contribute to the supply of pelvic structures include the median sacral artery and, in women, the ovarian arteries.
Internal iliac artery

The internal iliac artery originates from the common iliac artery on each side, approximately at the level of the intervertebral disc between LV and SI, and lies anteromedial to the sacro-iliac joint (Fig. 5.63). The vessel courses inferiorly over the pelvic inlet and then divides into anterior and posterior trunks at the level of the superior border of the greater sciatic foramen. Branches from the posterior trunk contribute to the supply of the lower posterior abdominal wall, the posterior pelvic wall, and the gluteal region. Branches from the anterior trunk supply the pelvic viscera, the perineum, the gluteal region, the adductor region of the thigh, and, in the fetus, the placenta.

Posterior trunk

Branches of the posterior trunk of the internal iliac artery are the iliolumbar artery, the lateral sacral artery, and the superior gluteal artery (Fig. 5.63).

The iliolumbar artery ascends laterally back out of the pelvic inlet and divides into a lumbar branch and an iliac branch. The lumbar branch contributes to the supply of the posterior abdominal wall, psoas and quadratus lumborum muscles, and cauda equina, via a small spinal branch that passes through the intervertebral foramen between LV and SI. The iliac branch passes laterally into the iliac fossa to supply muscle and bone.
The lateral sacral arteries, usually two, originate from the posterior division of the internal iliac artery and course medially and inferiorly along the posterior pelvic wall. They give rise to branches that pass into the anterior sacral foramina to supply related bone and soft tissues, structures in the vertebral (sacral) canal, and skin and muscle posterior to the sacrum.

The superior gluteal artery is the largest branch of the internal iliac artery and is the terminal continuation of the posterior trunk. It courses posteriorly, usually passing between the lumbosacral trunk and anterior ramus of S1, to leave the pelvic cavity through the greater sciatic foramen above the piniformis muscle and enter the gluteal region of the lower limb. This vessel makes a substantial contribution to the blood supply of muscles and skin in the gluteal region and also supplies branches to adjacent muscles and bones of the pelvic walls.

Anterior trunk

Branches of the anterior trunk of the internal iliac artery include the superior vesical artery, the umbilical artery, the inferior vesical artery, the middle rectal artery, the uterine artery, the vaginal artery, the obturator artery, the internal pudendal artery, and the inferior gluteal artery (Fig. 5.64).
The first branch of the anterior trunk is the **umbilical artery**, which gives origin to the superior vesical artery and then travels forward just inferior to the margin of the pelvic inlet. Anteriorly, the vessel leaves the pelvic cavity and ascends on the internal aspect of the anterior abdominal wall to reach the umbilicus. In the fetus, the umbilical artery is large and carries blood from the fetus to the placenta. After birth, the vessel closes distally to the origin of the superior vesical artery and eventually becomes a solid fibrous cord. On the anterior abdominal wall, the cord raises a fold of peritoneum termed the **medial umbilical fold**. The fibrous remnant of the umbilical artery itself is the **medial umbilical ligament**.

The **superior vesical artery** normally originates from the root of the umbilical artery and courses medially and inferiorly to supply the superior aspect of the bladder and distal parts of the ureter. In men, it also may give rise to an artery that supplies the ductus deferens.

The **inferior vesical artery** occurs in men and supplies branches to the bladder, ureter, seminal vesicle, and prostate. The **vaginal artery** in women is the equivalent of the inferior vesical artery in men and, descending to the vagina, supplies branches to the vagina and to adjacent parts of the bladder and rectum.

The **middle rectal artery** courses medially to supply the rectum. The vessel anastomoses with the superior rectal artery, which originates from the inferior mesenteric artery in the abdomen, and the inferior rectal artery, which originates from the internal pudendal artery in the perineum.

The **obturator artery** courses anteriorly along the pelvic wall and leaves the pelvic cavity via the obturator canal. Together with the obturator nerve, above, and obturator vein, below, it enters and supplies the adductor region of the thigh.
The **internal pudendal artery** courses inferiorly from its origin in the anterior trunk and leaves the pelvic cavity through the greater sciatic foramen inferior to the piriformis muscle. In association with the pudendal nerve on its medial side, the vessel passes laterally to the ischial spine and then through the lesser sciatic foramen to enter the perineum. The internal pudendal artery is the main artery of the perineum. Among the structures it supplies are the erectile tissues of the clitoris and the penis.

The **inferior gluteal artery** is a large terminal branch of the anterior trunk of the internal iliac artery. It passes between the anterior rami S1 and S2 or S2 and S3 of the sacral plexus and leaves the pelvic cavity through the greater sciatic foramen inferior to the piriformis muscle. It enters and contributes to the blood supply of the gluteal region and anastomoses with a network of vessels around the hip joint.
The *uterine artery* in women courses medially and anteriorly in the base of the broad ligament to reach the cervix (Figs. 5.64B and 5.65). Along its course, the vessel crosses the ureter and passes superiorly to the lateral vaginal fornix. Once the vessel reaches the cervix, it ascends along the lateral margin of the uterus to reach the uterine tube, where it curves laterally and anastomoses with the ovarian artery. The uterine artery is the major blood supply to the uterus and enlarges significantly during pregnancy. Through anastomoses with other arteries, the vessel contributes to the blood supply of the ovary and vagina as well.

**Fig. 5.65**

*Uterine and vaginal arteries.*

**Ovarian arteries**

In women, the gonadal (ovarian) vessels originate from the abdominal aorta and then descend to cross the pelvic inlet and supply the ovaries. They anastomose with terminal parts of the uterine arteries (Fig. 5.65). On each side, the vessels travel in the **suspensoy ligament of the ovary** (the infundibulopelvic ligament) as they cross the pelvic inlet to the ovary. Branches pass through the mesovarium to reach the ovary and through the mesometrium of the broad ligament to anastomose with the uterine artery. The ovarian arteries enlarge significantly during pregnancy to augment the uterine blood supply.

**Median sacral artery**
The median sacral artery (Figs. 5.64A and 5.65) originates from the posterior surface of the aorta just superior to the aortic bifurcation at vertebral level LIV in the abdomen. It descends in the midline, crosses the pelvic inlet, and then courses along the anterior surface of the sacrum and coccyx. It gives rise to the last pair of lumbar arteries and to branches that anastomose with the iliolumbar and lateral sacral arteries.

Veins

Pelvic veins follow the course of all branches of the internal iliac artery except for the umbilical artery and the iliolumbar artery (Fig. 5.66A). On each side, the veins drain into internal iliac veins, which leave the pelvic cavity to join common iliac veins situated just superior and lateral to the pelvic inlet.
Fig. 5.66

Pelvic veins. **A.** In a man with the left side of the pelvis and most of the viscera removed. **B.** Veins associated with the rectum and anal canal.
Within the pelvic cavity, extensive interconnected venous plexuses are associated with the surfaces of the viscera (bladder, rectum, prostate, uterus, and vagina). Together, these plexuses form the pelvic plexus of veins. The part of the venous plexus surrounding the rectum and anal canal drains via superior rectal veins (tributaries of inferior mesenteric veins) into the hepatic portal system, and via middle and inferior rectal veins into the caval system. This pelvic plexus is an important portacaval shunt when the hepatic portal system is blocked (Fig. 5.66B).

The inferior part of the rectal plexus around the anal canal has two parts, an internal and an external. The internal rectal plexus is in connective tissue between the internal anal sphincter and the epithelium lining the canal. This plexus connects superiorly with longitudinally arranged branches of the superior rectal vein that lie one in each anal column. When enlarged, these branches form internal hemorrhoids, which originate above the pectinate line and are covered by colonic mucosa. The external rectal plexus circles the external anal sphincter and is subcutaneous. Enlargement of vessels in the external rectal plexus results in external hemorrhoids.

The single **deep dorsal vein** that drains erectile tissues of the clitoris and the penis does not follow branches of the internal pudendal artery into the pelvic cavity. Instead, this vein passes directly into the pelvic cavity through a gap formed between the arcuate pubic ligament and the anterior margin of the perineal membrane. The vein joins the prostatic plexus of veins in men and the vesical (bladder) plexus of veins in women. (Superficial veins that drain the skin of the penis and corresponding regions of the clitoris drain into the external pudendal veins, which are tributaries of the great saphenous vein in the thigh.)

In addition to tributaries of the internal iliac vein, median sacral veins and ovarian veins parallel the courses of the median sacral artery and ovarian artery, respectively, and leave the pelvic cavity to join veins in the abdomen:

- The **median sacral veins** coalesce to form a single vein that joins either the left common iliac vein or the junction of the two common iliac veins to form the inferior vena cava.

- The **ovarian veins** follow the course of the corresponding arteries; on the left, they join the left renal vein and, on the right, they join the inferior vena cava in the abdomen.

**Lymphatics**

Lymphatics from most pelvic viscera drain mainly into lymph nodes distributed along the internal iliac and external iliac arteries and their associated branches (Fig. 5.67), which drain into nodes associated with the common iliac arteries and then into the lateral aortic or lumbar nodes associated with the lateral surfaces of the abdominal aorta. In turn, these lateral aortic or lumbar nodes drain into the lumbar trunks, which continue to the origin of the thoracic duct at approximately vertebral level TXII.
Fig. 5.67

Pelvic lymphatics.

Lymphatics from the ovaries and related parts of the uterus and uterine tubes leave the pelvic cavity superiorly and drain, via vessels that accompany the ovarian arteries, directly into lateral aortic or lumbar nodes and, in some cases, into the pre-aortic nodes on the anterior surface of the aorta.

In addition to draining pelvic viscera, nodes along the internal iliac artery also receive drainage from the gluteal region of the lower limb and from deep areas of the perineum.

Perineum

The perineum is a diamond-shaped region positioned inferiorly to the pelvic floor between the thighs. Its peripheral boundary is the pelvic outlet; its ceiling is the pelvic diaphragm (the levator ani and coccygeus muscles); and its narrow lateral walls are formed by the walls of the pelvic cavity below the attachment of the levator ani muscle (Fig. 5.68A).
The perineum is divided into an anterior urogenital triangle and a posterior anal triangle.
The urogenital triangle is associated with the openings of the urinary systems and the reproductive systems and functions to anchor the external genitalia.

The anal triangle contains the anus and the external anal sphincter.

The pudendal nerve (S2 to S4) and the internal pudendal artery are the major nerve and artery of the region.

**Borders and ceiling**

The margin of the perineum is marked by the inferior border of the pubic symphysis at its anterior point, the tip of the coccyx at its posterior point, and the ischial tuberosities at each of the lateral points (Fig. 5.68A). The lateral margins are formed by the ischiopubic rami anteriorly and by the sacrotuberous ligaments posteriorly. The pubic symphysis, the ischial tuberosities, and the coccyx can be palpated on the patient.

The perineum is divided into two triangles by an imaginary line between the two ischial tuberosities (Fig. 5.68A). Anterior to the line is the urogenital triangle and posterior to the line is the anal triangle. Significantly, the two triangles are not in the same plane. In the anatomical position, the urogenital triangle is oriented in the horizontal plane, whereas the anal triangle is tilted upward at the transtubercular line so that it faces more posteriorly.

The roof of the perineum is formed mainly by the levator ani muscles that separate the pelvic cavity, above, from the perineum, below. These muscles, one on each side, form a cone- or funnel-shaped pelvic diaphragm, with the anal aperture at its inferior apex in the anal triangle.

Anteriorly, in the **urogenital triangle**, a U-shaped defect in the muscles, the **urogenital hiatus**, allows the passage of the urethra and vagina.

**Perineal membrane and deep perineal pouch**

The perineal membrane (see pp. 457–459) is a thick fibrous sheet that fills the urogenital triangle (Fig. 5.68B). It has a free posterior border, which is anchored in the midline to the perineal body and is attached laterally to the pubic arch. Immediately superior to the perineal membrane is a thin region termed the deep perineal pouch, containing a layer of skeletal muscle and neurovascular tissues. Among the skeletal muscles in the pouch (see p. 459, Fig. 5.36) is the external urethral sphincter.

The perineal membrane and deep perineal pouch provide support for the external genitalia, which are attached to its inferior surface. Also, the parts of the perineal membrane and deep perineal pouch inferior to the urogenital hiatus in the levator ani provide support for the pelvic viscera, above.

The urethra leaves the pelvic cavity and enters the perineum by passing through the deep perineal pouch and perineal membrane. In women, the vagina also passes through these structures posterior to the urethra.

**Ischio-anal fossae and their anterior recesses**

Because the levator ani muscles course medially from their origin on the lateral pelvic walls, above, to the anal aperture and urogenital hiatus, below, inverted wedge-shaped gutters occur between the levator ani muscles and adjacent pelvic walls as the two structures diverge inferiorly (Fig. 5.69). In the anal triangle, these gutters, one on each side of the anal aperture, are termed **ischio-anal fossae**. The lateral wall of each fossa is formed mainly by the ischium, obturator internus muscle, and sacrotuberous ligament. The medial wall is the levator ani muscle. The medial and lateral walls converge superiority where the levator ani muscle attaches to the fascia overlying the obturator internus muscle. The ischio-anal fossae allow movement of the pelvic diaphragm and expansion of the anal canal during defecation.
Fig. 5.69

Ischio-anal fossae and their anterior recesses. **A.** Anterolateral view with left pelvic wall removed. **B.** Inferior view. **C.** Anterolateral view with pelvic walls and diaphragm removed.
The ischio-anal fossae of the anal triangle are continuous anteriorly with recesses that project into the urogenital triangle superior to the deep perineal pouch. These anterior recesses of the ischio-anal fossae are shaped like three-sided pyramids that have been tipped onto one of their sides (Fig. 5.69C). The apex of each pyramid is closed and points anteriorly toward the pubis. The base is open and continuous posteriorly with its related ischio-anal fossa. The inferior wall of each pyramid is the deep perineal pouch. The superomedial wall is the levator ani muscle, and the superolateral wall is formed mainly by the obturator internus muscle. The ischio-anal fossae and their anterior recesses are normally filled with fat.

In the clinic
Abscesses in the ischio-anal fossae
The anal mucosa is particularly vulnerable to injury and may be easily torn by hard feces. Occasionally, patients develop inflammation and infection of the anal canal (sinuses or crypts). This infection can spread between the sphincters, producing intersphincteric fistulas. The infection can tract superiorly into the pelvic cavity or laterally into the ischio-anal fossae.

Anal triangle
The anal triangle of the perineum faces posteroinferiorly and is defined laterally by the medial margins of the sacrotuberous ligaments, anteriorly by a horizontal line between the two ischial tuberosities, and posteriorly by the coccyx. The ceiling of the anal triangle is the pelvic diaphragm, which is formed by the levator ani and coccygeus muscles. The anal aperture occurs centrally in the anal triangle and is related on either side to an ischio-anal fossa. The major muscle in the anal triangle is the external anal sphincter.

The external anal sphincter, which surrounds the anal canal, is formed by skeletal muscle and consists of three parts—deep, superficial, and subcutaneous—arranged sequentially along the canal from superior to inferior (Fig. 5.68B, Table 5.5). The deep part is a thick ring-shaped muscle that circles the upper part of the anal canal and blends with the fibers of the levator ani muscle. The superficial part also surrounds the anal canal, but is anchored anteriorly to the perineal body and posteriorly to the coccyx and anococcygeal ligament. The subcutaneous part is a horizontally flattened disc of muscle that surrounds the anal aperture just beneath the skin. The external anal sphincter is innervated by inferior rectal branches of the pudendal nerve and by branches directly from the anterior ramus of S4.

In the clinic
Hemorrhoids
A hemorrhoid is an engorgement of the venous plexus at or inside the anal sphincter. It is a common complaint and has prevalence of approximately 4% in the United States. Hemorrhoids have a slight genetic predisposition; however, straining during bowel movements, obesity, and sedentary lifestyle can also produce hemorrhoids. The symptoms include irritation, pain, and swelling. Hemorrhoids occurring at the anal verge (distal boundary of the anal canal) are typically called external hemorrhoids. Internal hemorrhoids occur inside the rectum and have a tendency to bleed. Prolapsed hemorrhoids are internal hemorrhoids that pass outside the anal canal and form lumps, which may undergo thrombosis and become painful. There are many treatments for hemorrhoids, which include ligation above the pectinate (dentate) line using simple rubber bands or surgical excision. Surgery to this region is not without complications and care must be taken to preserve the internal anal sphincter. In the back of every physician's mind is the concern that the rectal bleeding or symptoms may not be attributable to hemorrhoids. Therefore, excluding a tumor within the bowel is as important as treating the hemorrhoids.

Table 5.5

Muscles of the anal triangle

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Function</th>
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<tbody>
<tr>
<td>EXTERNAL ANAL SPHINCTER</td>
<td></td>
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<tr>
<td>Deep part</td>
<td>Surrounds superior aspect</td>
<td>Pudendal nerve (S2 and S3) and</td>
<td>Closes anal canal</td>
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</tr>
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<td></td>
<td>of anal canal</td>
<td>branches directly from S4</td>
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</tr>
<tr>
<td>Superficial part</td>
<td>Surrounds lower part of</td>
<td>Anchored to perineal body and</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>anal canal</td>
<td>anococcygeal body</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcutaneous part</td>
<td>Surrounds anal aperture</td>
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</tbody>
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Urogenital triangle

The urogenital triangle of the perineum is the anterior half of the perineum and is oriented in the horizontal plane. It contains the roots of the external genitalia (Fig. 5.70) and the openings of the urogenital system.
Fig. 5.70
Erectile tissues of clitoris and penis. A. Clitoris. B. Penis.

The urogenital triangle is defined:

- laterally by the ischiopubic rami,
- posteriorly by an imaginary line between the ischial tuberosities, and
- anteriorly by the inferior margin of the pubic symphysis.

As with the anal triangle, the roof or ceiling of the urogenital triangle is the levator ani muscle.

Unlike the anal triangle, the urogenital triangle contains a strong fibromuscular support platform, the perineal membrane and deep perineal pouch (see pp. 457–459), which is attached to the pubic arch.
Anterior extensions of the ischio-anal fossae occur between the deep perineal pouch and the levator ani muscle on each side.

Between the perineal membrane and the membranous layer of superficial fascia is the **superficial perineal pouch**. The principal structures in this pouch are the erectile tissues of the penis and clitoris and associated skeletal muscles.

**Structures in the superficial perineal pouch**

The superficial perineal pouch contains:

- erectile structures that join together to form the penis in men and the clitoris in women, and

- skeletal muscles that are associated mainly with parts of the erectile structures attached to the perineal membrane and adjacent bone.

Each erectile structure consists of a central core of expandable vascular tissue and its surrounding connective tissue capsule.

**Erectile tissues**

Two sets of erectile structures join to form the penis and the clitoris.

A pair of cylindrically shaped **corpora cavernosa**, one on each side of the urogenital triangle, are anchored by their proximal ends to the pubic arch. These attached parts are often termed the **crura** (from the Latin for "legs") of the clitoris or the penis. The distal ends of the corpora, which are not attached to bone, form the body of the clitoris in women and the dorsal parts of the body of the penis in men.

The second set of erectile tissues surrounds the openings of the urogenital system.

- In women, a pair of erectile structures, termed the **bulbs of the vestibule**, are situated, one on each side, at the vaginal opening and are firmly anchored to the perineal membrane (**Fig. 5.70A**). Small bands of erectile tissues connect the anterior ends of these bulbs to a single, small, pea-shaped erectile mass, the **glans clitoris**, which is positioned in the midline at the end of the body of the clitoris and anterior to the opening of the urethra.

- In men, a single large erectile mass, the **corpus spongiosum**, is the structural equivalent to the bulbs of the vestibule, the glans clitoris, and the interconnecting bands of erectile tissues in women (**Fig. 5.70B**). The corpus spongiosum is anchored at its base to the perineal membrane. Its proximal end, which is not attached, forms the ventral part of the body of the penis and expands over the end of the body of the penis to form the glans penis. This pattern in men results from the absence of a vaginal opening and from the fusion of structures across the midline during embryological development. As the originally paired erectile structures fuse, they enclose the urethral opening and form an additional channel that ultimately becomes most of the penile part of the urethra. As a consequence of this fusion and growth in men, the urethra is enclosed by the corpus spongiosum and opens at the end of the penis. This is unlike the situation in women, where the urethra is not enclosed by erectile tissue of the clitoris and opens directly into the vestibule of the perineum.

**Clitoris**

The clitoris is composed of two corpora cavernosa and the **glans clitoris** (**Fig. 5.70A**). As in the penis, it has an attached part (root) and a free part (body).

- Unlike the root of the penis, the **root of the clitoris** technically consists only of the two crura. (Although the bulbs of the vestibule are attached to the glans clitoris by thin bands of erectile tissue, they are not included in the attached part of the clitoris.)

- The **body of the clitoris**, which is formed only by the unattached parts of the two corpora cavernosa, angles posteriorly and is embedded in the connective tissues of the perineum.

The body of the clitoris is supported by a suspensory ligament that attaches superiorly to the pubic symphysis. The glans clitoris is attached to the distal end of the body and is connected to the bulbs of the vestibule by small bands of erectile tissue. The glans clitoris is exposed in the perineum and the body of the clitoris can be palpated through skin.

**Penis**
The penis is composed mainly of the two corpora cavernosa and the single corpus spongiosum, which contains the urethra (Fig. 5.70B). As in the clitoris, it has an attached part (root) and a free part (body):

- The root of the penis consists of the two crura, which are proximal parts of the corpora cavernosa attached to the pubic arch, and the bulb of the penis, which is the proximal part of the corpus spongiosum anchored to the perineal membrane.

- The body of the penis, which is covered entirely by skin, is formed by the tethering of the two proximal free parts of the corpora cavernosa and the related free part of the corpus spongiosum.

The base of the body of the penis is supported by two ligaments: the suspensory ligament of the penis (attached superiorly to the pubic symphysis), and the more superficially positioned fundiform ligament of the penis (attached above to the linea alba of the anterior abdominal wall and split below into two bands that pass on each side of the penis and unite inferiorly).

Because the anatomical position of the penis is erect, the paired corpora are defined as dorsal in the body of the penis and the single corpus spongiosum as ventral, even though the positions are reversed in the nonerect (flaccid) penis.

The corpus spongiosum expands to form the head of the penis (glans penis) over the distal ends of the corpora cavernosa (Fig. 5.70B).

**Erection**

Erection of the penis and clitoris is a vascular event generated by parasympathetic fibers carried in pelvic splanchnic nerves from the anterior rami of S2 to S4, which enter the inferior hypogastric part of the prevertebral plexus and ultimately pass through the deep perineal pouch and perineal membrane to innervate the erectile tissues. Stimulation of these nerves causes specific arteries in the erectile tissues to relax. This allows blood to fill the tissues, causing the penis and clitoris to become erect.

Arteries supplying the penis and clitoris are branches of the internal pudendal artery; branches of the pudendal nerve (S2 to S4) carry general sensory nerves from the penis and clitoris.

**Greater vestibular glands**

The greater vestibular glands (Bartholin's glands) are seen in women. They are small, pea-shaped mucous glands that lie posterior to the bulbs of the vestibule on each side of the vaginal opening and are the female homologues of the bulbo-urethral glands in men (Fig. 5.70). However, the bulbo-urethral glands are located within the deep perineal pouch, whereas the greater vestibular glands are in the superficial perineal pouch.

The duct of each greater vestibular gland opens into the vestibule of the perineum along the posterolateral margin of the vaginal opening.

Like the bulbo-urethral glands in men, the greater vestibular glands produce secretion during sexual arousal.

**Muscles**

The superficial perineal pouch contains three pairs of muscles: the ischiocavernosus, bulbospongiosus, and superficial transverse perineal muscles (Fig. 5.71 and Table 5.6). Two of these three pairs of muscles are associated with the roots of the penis and clitoris; the other pair is associated with the perineal body.
Fig. 5.71

Muscles in the superficial perineal pouch. A. In women. B. In men.

Table 5.6
Muscles of the superficial perineal pouch

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischiocavernosus</td>
<td>Ischial tuberosity and ramus&lt;br&gt; In women: perineal body&lt;br&gt; In men: perineal body, midline</td>
<td>Crus of penis and clitoris&lt;br&gt; In women: bulb of vestibule, perineal membrane, body of clitoris, and corpus cavernosum&lt;br&gt; In men: bulbospongiosus, perineal membrane, corpus</td>
<td>Pudendal nerve (S2 to S4)</td>
<td>Move blood from crura into the body of the erect penis and clitoris&lt;br&gt; Move blood from attached parts of the clitoris and penis into the glans In men: removal of residual urine from urethra after urination; pulsatile emission of semen</td>
</tr>
</tbody>
</table>
The two ischiocavernosus muscles cover the crura of the penis and clitoris (Fig. 5.71). Each muscle is anchored to the medial margin of the ischial tuberosity and related ischial ramus and passes forward to attach to the sides and inferior surface of the related crus, and forces blood from the crus into the body of the erect penis and clitoris.

**Bulbospongiosus**

The two bulbospongiosus muscles are associated mainly with the bulbs of the vestibule in women and with the attached part of the corpus spongiosum in men (Fig. 5.71).

In women, each bulbospongiosus muscle is anchored posteriorly to the perineal body and courses anterolaterally over the inferior surface of the related greater vestibular gland and the bulb of the vestibule to attach to the surface of the bulb and to the perineal membrane (Fig. 5.71A). Other fibers course anterolaterally to blend with the fibers of the ischiocavernosus muscle, and still others travel anteriorly and arch over the body of the clitoris.

In men, the bulbospongiosus muscles are joined in the midline to a raphe on the inferior surface of the bulb of the penis. The raphe is anchored posteriorly to the perineal body. Muscle fibers course anterolaterally, on each side, from the raphe and perineal body to cover each side of the bulb of the penis and attach to the perineal membrane and connective tissue of the bulb. Others extend anterolaterally to associate with the crura and attach anteriorly to the ischiocavernosus muscles.

In both men and women, the bulbospongiosus muscles compress attached parts of the erect corpus spongiosum and bulbs of the vestibule and force blood into more distal regions, mainly the glans. In men, the bulbospongiosus muscles have two additional functions:

- They facilitate emptying of the bulbous part of the penile urethra following urination (micturition).
- Their reflex contraction during ejaculation is responsible for the pulsatile emission of semen from the penis.

**Superficial transverse perineal muscles**

The paired superficial transverse perineal muscles follow a course parallel to the posterior margin of the inferior surface of the perineal membrane (Fig. 5.71). These flat band-shaped muscles, which are attached to ischial tuberosities and rami, extend medially to the perineal body in the midline and stabilize the perineal body.

**Superficial features of the external genitalia**

**In women**

In women, the clitoris and vestibular apparatus, together with a number of skin and tissue folds, form the vulva (Fig. 5.72). On either side of the midline are two thin folds of skin termed the labia minora. The region enclosed between them, and into which the urethra and vagina open, is the vestibule. Anteriorly, the labia minora each bifurcate, forming a medial and a lateral fold. The medial folds unite to form the frenulum of the clitoris, that joins the glans clitoris. The lateral folds unite ventrally over the glans clitoris and the body of the clitoris to form the prepuce of the clitoris (hood). The body of the clitoris extends anteriorly from the glans clitoris and is palpable deep to the prepuce and related skin. Posterior to the vestibule, the labia minora unite, forming a small transverse fold, the frenulum of the labia minora (the fourchette).
Within the vestibule, the vaginal orifice is surrounded to varying degrees by a ring-like fold of membrane, the hymen, which may have a small central perforation or may completely close the vaginal opening. Following rupture of the hymen (resulting from first sexual intercourse or injury), irregular remnants of the hymen fringe the vaginal opening.

The orifices of the urethra and the vagina are associated with the openings of glands. The ducts of the para-urethral glands (Skene's glands) open into the vestibule, one on each side of the lateral margin of the urethra. The ducts of the greater vestibular glands (Bartholin's glands) open adjacent to the posterolateral margin of the vaginal opening in the crease between the vaginal orifice and remnants of the hymen.

Lateral to the labia minora are two broad folds, the labia majora, which unite anteriorly to form the mons pubis. The mons pubis overlies the inferior aspect of the pubic symphysis and is anterior to the vestibule and the clitoris. Posteriorly, the labia majora do not unite and are separated by a depression termed the posterior commissure, which overlies the position of the perineal body.

In men

Superficial components of the genital organs in men consist of the scrotum and the penis (Fig. 5.73). The scrotum is the male homologue of the labia majora in women. In the fetus, labioscrotal swellings fuse across the midline, resulting in a single scrotum into which the testes and their associated musculofascial coverings, blood vessels, nerves, lymphatics, and drainage ducts descend from the abdomen. The remnant of the line of fusion between the labioscrotal swellings in the fetus is visible on the skin of the scrotum as a longitudinal midline raphe that extends from the anus, over the scrotal sac, and onto the inferior aspect of the body of the penis.
Fig. 5.73


The **penis** consists of a root and body. The attached root of the penis is palpable posterior to the scrotum in the urogenital triangle of the perineum. The pendulous part of the penis (body of penis) is entirely covered by skin; the tip of the body is covered by the glans penis.

The external urethral orifice is a sagittal slit, normally positioned at the tip of the glans. The inferior margin of the urethral orifice is continuous with a midline **raphe of the penis**, which represents a line of fusion formed in the glans as the urethra develops in the fetus. The base of this raphe is continuous with the **frenulum of the glans**, which is a median fold of skin that attaches the glans to more loosely attached skin proximal to the glans. The base of the glans is expanded to form a raised circular margin (the **corona of the glans**); the two lateral ends of the corona join inferiorly at the midline raphe of the glans. The depression posterior to the corona is the neck of the glans. Normally, a fold of skin at the neck of the glans is continuous anteriorly with thin skin that tightly adheres to the glans and posteriorly with thicker skin loosely attached to the body. This fold, known as the prepuce, extends forward to cover the glans. The prepuce is removed during male circumcision, leaving the glans exposed.

**Superficial fascia of the urogenital triangle**

The superficial fascia of the urogenital triangle is continuous with similar fascia on the anterior abdominal wall.

As with the superficial fascia of the abdominal wall, the perineal fascia has a membranous layer on its deep surface. This membranous layer (**Colles’ fascia**), is attached:
posteriorly to the perineal membrane and therefore does not extend into the anal triangle (Fig. 5.74), and to the ischiopubic rami that form the lateral borders of the urogenital triangle and therefore does not extend into the thigh (Fig. 5.74).

It defines the external limits of the superficial perineal pouch, lines the scrotum or labia, and extends around the body of the penis and clitoris.
Anteriorly, the membranous layer of fascia is continuous over the pubic symphysis and pubic bones with the membranous layer of fascia on the anterior abdominal wall. In the lower lateral abdominal wall, the membranous layer of abdominal fascia is attached to the deep fascia of the thigh just inferior to the inguinal ligament.

Because the membranous layer of fascia encloses the superficial perineal pouch and continues up the anterior abdominal wall, fluids or infectious materials that accumulate in the pouch can track out of the perineum and onto the lower abdominal wall. This material will not track into the anal triangle or the thigh because the fascia fuses with deep tissues at the borders of these regions.

In the clinic
Urethral rupture
Urethral rupture may occur at a series of well-defined anatomical points. The commonest injury is a rupture of the proximal spongy urethra below the perineal membrane. The urethra is usually torn when structures of the perineum are caught between a hard object (e.g., a steel beam or crossbar of a bicycle) and the inferior pubic arch. Urine escapes through the rupture into the superficial perineal pouch and descends into the scrotum and up onto the anterior abdominal wall deep to the superficial fascia. In association with severe pelvic fractures, urethral rupture may occur at the prostatomembranous junction above the deep perineal pouch. The urine will extravasate into the true pelvis. The worst and most serious urethral rupture is related to serious pelvic injuries where there is complete disruption of the puboprostatic ligaments. The prostate is dislocated superiorly not only by the ligamentous disruption but also by the extensive hematoma formed within the true pelvis. The diagnosis can be made by palpating the elevated prostate during a digital rectal examination.

Somatic nerves
Pudendal nerve
The major somatic nerve of the perineum is the pudendal nerve. This nerve originates from the sacral plexus and carries fibers from spinal cord levels S2 to S4. It leaves the pelvic cavity through the greater sciatic foramen inferior to the piriformis muscle, passes around the sacrospinous ligament, and then enters the anal triangle of the perineum by passing medially through the lesser sciatic foramen. As it enters and courses through the perineum, it travels along the lateral wall of the ischio-anal fossa in the pudendal canal, which is a tubular compartment formed in the fascia that covers the obturator internus muscle. This pudendal canal also contains the internal pudendal artery and accompanying veins.

The pudendal nerve (Fig. 5.75) has three major terminal branches—the inferior rectal and perineal nerves and the dorsal nerve of the penis or clitoris—which are accompanied by branches of the internal pudendal artery (Fig. 5.76).
Fig. 5.75

Pudendal nerve. **A. In men. B. In women.**
The inferior rectal nerve is often multiple, penetrates through the fascia of the pudendal canal, and courses medially across the ischio-anal fossa to innervate the external anal sphincter and related regions of the levator ani muscles. The nerve is also general sensory for the skin of the anal triangle.
The perineal nerve passes into the urogenital triangle and gives rise to motor and cutaneous branches. The motor branches supply skeletal muscles in the superficial and deep perineal pouches. The largest of the sensory branches is the posterior scrotal nerve in men and the posterior labial nerve in women.

The dorsal nerve of the penis and clitoris enters the deep perineal pouch (Fig. 5.75). It passes along the lateral margin of the pouch and then exits by passing inferiorly through the perineal membrane in a position just inferior to the pubic symphysis where it meets the body of the clitoris or the penis. It courses along the dorsal surface of the body to reach the glans. The dorsal nerve is sensory to the penis and clitoris, particularly to the glans.

Other somatic nerves

Other somatic nerves that enter the perineum are mainly sensory and include branches of the ilio-inguinal, genitofemoral, posterior femoral cutaneous, and anococcygeal nerves.

Visceral nerves

Visceral nerves enter the perineum by two routes:

Those to the skin, which consist mainly of postganglionic sympathetics, are delivered into the region along the pudendal nerve. These fibers join the pudendal nerve from gray rami communicantes that connect pelvic parts of the sympathetic trunks to the anterior rami of the sacral spinal nerves (see p. 487 and Fig. 5.61).

Those to erectile tissues enter the region mainly by passing through the deep perineal pouch from the inferior hypogastric plexus in the pelvic cavity (see p. 494 and Fig. 5.62B). The fibers that stimulate erection are parasympathetic fibers, which enter the inferior hypogastric plexus via pelvic splanchnic nerves from spinal cord levels of S2 to S4 (see Fig. 5.62A, B).

Blood vessels

Arteries

The most significant artery of the perineum is the internal pudendal artery (Fig. 5.76). Other arteries entering the area include the external pudendal, the testicular, and the cremasteric arteries.

Internal pudendal artery

The internal pudendal artery originates as a branch of the anterior trunk of the internal iliac artery in the pelvis (Fig. 5.76). Along with the pudendal nerve, it leaves the pelvis through the greater sciatic foramen inferior to the piriformis muscle. It passes around the ischial spine, where the artery lies lateral to the nerve, enters the perineum by coursing through the lesser sciatic foramen, and accompanies the pudendal nerve in the pudendal canal on the lateral wall of the ischio-anal fossa.

The branches of the internal pudendal artery are similar to those of the pudendal nerve in the perineum and include the inferior rectal and perineal arteries, and branches to the erectile tissues of the penis and clitoris (Fig. 5.76).

Inferior rectal arteries

One or more inferior rectal arteries originate from the internal pudendal artery in the anal triangle and cross the ischio-anal fossa medially to branch and supply muscle and related skin (Fig. 5.76). They anastomose with middle and superior rectal arteries from the internal iliac artery and the inferior mesenteric artery, respectively, to form a network of vessels that supply the rectum and anal canal.

Perineal artery

The perineal artery originates near the anterior end of the pudendal canal and gives off a transverse perineal branch, and a posterior scrotal or labial artery to surrounding tissues and skin (Fig. 5.76).

Terminal part of the internal pudendal artery

The terminal part of the internal pudendal artery accompanies the dorsal nerve of the penis or clitoris into the deep perineal pouch and supplies branches to the tissues in the deep perineal pouch and erectile tissues.

Branches that supply the erectile tissues in men include the artery to the bulb of the penis, the urethral artery, the deep artery of the penis, and the dorsal artery of the penis (Fig. 5.76).
The artery of the bulb of the penis has a branch that supplies the bulbo-urethral gland and then penetrates the perineal membrane to supply the corpus spongiosum.

A urethral artery also penetrates the perineal membrane and supplies the penile urethra and surrounding erectile tissue to the glans.

Near the anterior margin of the deep perineal pouch, the internal pudendal artery bifurcates into two terminal branches. A deep artery of the penis penetrates the perineal membrane to enter the crus and supply the crus and corpus cavernosum of the body. The dorsal artery of the penis penetrates the anterior margin of the perineal membrane to meet the dorsal surface of the body of the penis. The vessel courses along the dorsal surface of the penis, medial to the dorsal nerve, and supplies the glans penis and superficial tissues of the penis; it also anastomoses with branches of the deep artery of the penis and the urethral artery.

Branches that supply the erectile tissues in women are similar to those in men.

Arteries of the bulb of the vestibule supply the bulb of the vestibule and related vagina.

Deep arteries of the clitoris supply the crura and corpus cavernosum of the body.

Dorsal arteries of the clitoris supply surrounding tissues and the glans.

External pudendal arteries

The external pudendal arteries consist of a superficial vessel and a deep vessel, which originate in the femoral artery in the thigh. They course medially to enter the perineum anteriorly and supply related skin of the penis and scrotum or the clitoris and labia majora.

Testicular and cremasteric arteries

In men, the testicular arteries originate from the abdominal aorta and descend into the scrotum through the inguinal canal to supply the testes. Also, cremasteric arteries, which originate from the inferior epigastric branch of the external iliac artery, accompany the spermatic cord into the scrotum.

In women, small cremasteric arteries follow the round ligament of the uterus through the inguinal canal.

Veins

Veins in the perineum generally accompany the arteries and join the internal pudendal veins that connect with the internal iliac vein in the pelvis (Fig. 5.77). The exception is the deep dorsal vein of the penis or clitoris that drains mainly the glans and the corpora cavernosa. The deep dorsal vein courses along the midline between the dorsal arteries on each side of the body of the penis or clitoris, passes though the gap between the inferior pubic ligament and the deep perineal pouch, and connects with the plexus of veins surrounding the prostate in men or bladder in women.
External pudendal veins, which drain anterior parts of the labia majora or the scrotum and overlap with the area of drainage of the internal pudendal veins, connect with the femoral vein in the thigh. Superficial dorsal veins of the penis or clitoris that drain skin are tributaries of the external pudendal veins.
Lymphatics

Lymphatic vessels from deep parts of the perineum accompany the internal pudendal blood vessels and drain mainly into internal iliac nodes in the pelvis.

Lymphatic channels from superficial tissues of the penis or the clitoris accompany the superficial external pudendal blood vessels and drain mainly into superficial inguinal nodes, as do lymphatic channels from the scrotum or labia majora (Fig. 5.78). The glans penis, glans clitoris, labia minora, and terminal inferior end of the vagina drain into deep inguinal nodes and external iliac nodes.

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Fig. 5.78
Lymphatic drainage of the perineum.

Lymphatics from the testes drain via channels that ascend in the spermatic cord, pass through the inguinal canal, and course up the posterior abdominal wall to connect directly with lateral aortic or lumbar nodes and pre-aortic nodes around the aorta, at approximately vertebral levels L1 and L2. Therefore disease from the testes tracks superiorly to nodes high in the posterior abdominal wall and not to inguinal or iliac nodes.

Surface anatomy

Surface anatomy of the pelvis and perineum

Palpable bony features of the pelvis are used as landmarks for:

- locating soft tissue structures,
- visualizing the orientation of the pelvic inlet, and
defining the margins of the perineum.

The ability to recognize the normal appearance of structures in the perineum is an essential part of a physical examination.

In women, the cervix can be visualized directly by opening the vaginal canal using a speculum.

In men, the size and texture of the prostate in the pelvic cavity can be assessed by digital palpation through the anal aperture.

**Orientation of the pelvis and perineum in the anatomical position**

In the anatomical position, the anterior superior iliac spines and the anterior superior edge of the pubic symphysis lie in the same vertical plane. The pelvic inlet faces anterosuperiorly. The urogenital triangle of the perineum is oriented in an almost horizontal plane and faces inferiorly, whereas the anal triangle is more vertical and faces posteriorly (Figs. 5.79 and 5.80).

---

**Fig. 5.79**

*Lateral view of the pelvic area with the position of the skeletal features indicated. The orientation of the pelvic inlet, urogenital triangle, and anal triangle is also shown. A. In a woman. B. In a man.*

**Fig. 5.80**

*Anterior view of the pelvic area. A. In a woman showing the position of the pubic symphysis. B. In a man showing the position of the pubic tubercle, pubic symphysis, and anterior superior iliac spine.*
How to define the margins of the perineum

The pubic symphysis, ischial tuberosities, and tip of the sacrum are palpable on patients and can be used to define the boundaries of the perineum. This is best done with patients lying on their backs with their thighs flexed and abducted in the lithotomy position (Fig. 5.81).

Fig. 5.81
Inferior view of the perineum in the lithotomy position. Boundaries, subdivisions, and palpable landmarks are indicated. A. In a man. B. In a woman.

- The ischial tuberosities are palpable on each side as large bony masses near the crease of skin (gluteal fold) between the thigh and gluteal region. They mark the lateral corners of the diamond-shaped perineum.
- The tip of the coccyx is palpable in the midline posterior to the anal aperture and marks the most posterior limit of the perineum.
- The anterior limit of the perineum is the pubic symphysis. In women, this is palpable in the midline deep to the mons pubis. In men, the pubic symphysis is palpable immediately superior to where the body of the penis joins the lower abdominal wall.
Imaginary lines that join the ischial tuberosities with the pubic symphysis in front, and with the tip of the coccyx behind, outline the diamond-shaped perineum. An additional line between the ischial tuberosities divides the perineum into two triangles, the urogenital triangle anteriorly and anal triangle posteriorly. This line also approximates the position of the posterior margin of the perineal membrane. The midpoint of this line marks the location of the perineal body or central tendon of the perineum.

**Identification of structures in the anal triangle**

The anal triangle is the posterior half of the perineum. The base of the triangle faces anteriorly and is an imaginary line joining the two ischial tuberosities. The apex of the triangle is the tip of the coccyx; the lateral margins can be approximated by lines joining the coccyx to the ischial tuberosities. In both women and men, the major feature of the anal triangle is the anal aperture in the center of the triangle. Fat fills the ischio-anal fossa on each side of the anal aperture (Fig. 5.82).

**Identification of structures in the urogenital triangle of women**

The urogenital triangle is the anterior half of the perineum. The base of the triangle faces posteriorly and is an imaginary line joining the two ischial tuberosities. The apex of the triangle is the pubic symphysis. The lateral margins can be approximated by lines joining the pubic symphysis to the ischial tuberosities. These lines overlie the ischiopubic rami, which can be felt on deep palpation.

In women, the major contents of the urogenital triangle are the clitoris, the vestibule, and skin folds that together form the vulva (Fig. 5.83A, B).
Structures in the urogenital triangle of a woman. A. Inferior view of the urogenital triangle of a woman with major features indicated. B. Inferior view of the vestibule. The labia minora have been pulled apart to open the vestibule. Also indicated are the glans clitoris, the clitoral hood, and the frenulum of the clitoris. C. Inferior view of the vestibule showing the urethral and vaginal orifices and the hymen. The labia minora have been pulled further apart than in Figure 5.83B. D. Inferior view of the vestibule with the left labium minus pulled to the side to show the regions of the vestibule into which the greater vestibular and para-urethral glands open.

E. View through the vaginal canal of the cervix. F. Inferior view of the urogenital triangle of a woman with the erectile tissues of the clitoris and vestibule and the greater vestibular glands indicated with overlays.

Two thin skin folds, the labia minora, enclose between them a space termed the vestibule into which the vagina and the urethra open (Fig. 5.83C). Gentle lateral traction on the labia minora opens the vestibule and reveals a soft tissue mound on which the urethra opens. The para-urethral (Skene’s) glands, one on each side, open into the skin crease between the urethra and the labia minora (Fig. 5.83D).

Posterior to the urethra is the vaginal opening. The vaginal opening (introitus) is ringed by remnants of the hymen that originally closes the vaginal orifice and is usually ruptured during the first sexual intercourse. The ducts of the greater vestibular (Bartholin’s) glands, one on each side, open into the skin crease between the hymen and the adjacent labium minus (Fig. 5.83D).

The labia minora each bifurcate anteriorly into medial and lateral folds. The medial folds unite at the midline to form the frenulum of the clitoris. The larger lateral folds also unite across the midline to form the clitoral hood or prepuce that covers the glans clitoris and distal parts of the body of the clitoris. Posterior to the vaginal orifice, the labia minora join, forming a transverse skin fold (the fourchette).

The labia majora are broad folds positioned lateral to the labia minora. They come together in front to form the mons pubis, which overlies the inferior aspect of the pubic symphysis. The posterior ends of the labia majora are separated by a depression termed the posterior commissure, which overlies the position of the perineal body.

The cervix is visible when the vaginal canal is opened with a speculum (Fig. 5.83E). The external cervical os opens onto the surface of the dome-shaped cervix. A recess or gutter, termed the fornix, occurs between the cervix and the vaginal wall and is further subdivided, based on location, into anterior, posterior, and lateral fornices.

The roots of the clitoris occur deep to surface features of the perineum and are attached to the ischiopubic rami and the perineal membrane.

The bulbs of the vestibule (Fig. 5.83F), composed of erectile tissues, lie deep to the labia minora on either side of the vestibule. These erectile masses are continuous, via thin bands of erectile tissues, with the glans clitoris, which is visible under the clitoral hood. The greater vestibular glands occur posterior to the bulbs of the vestibule on either side of the vaginal orifice.

The crura of the clitoris are attached, one on each side, to the ischiopubic rami. Each crus is formed by the attached part of the corpus cavernosum. Anteriorly, these erectile corpora detach from bone, curve posteroinferiorly, and unite to form the body of the clitoris.

The body of the clitoris underlies the ridge of skin immediately anterior to the clitoral hood (prepuce). The glans clitoris is positioned at the end of the body of the clitoris.

Identification of structures in the urogenital triangle of men

In men, the urogenital triangle contains the root of the penis. The testes and associated structures, although they migrate into the scrotum from the abdomen, are generally evaluated with the penis during a physical examination.

The scrotum in men is homologous to the labia majora in women. Each oval testis is readily palpable through the skin of the scrotum (Fig. 5.84A). Posterolateral to the testis is an elongated mass of tissue, often visible as a raised ridge that contains lymphatics and blood vessels of the testis, and the epididymis and ductus deferens. A midline raphe (Fig. 5.84B) is visible on the skin separating left and right sides of the scrotum. In some individuals, this raphe is prominent and extends from the anal aperture, over the scrotum and along the ventral surface of the body of the penis, to the frenulum of the glans.
Fig. 5.84

Structures in the urogenital triangle of a man. **A.** Inferior view. **B.** Ventral surface of the body of the penis. **C.** Anterior view of the glans penis showing the urethral opening. **D.** Lateral view of the body of the penis and glans. **E.** Inferior view of the urogenital triangle of a man with the erectile tissues of the penis indicated with overlays.

The root of the penis is formed by the attached parts of the corpus spongiosum and the corpora cavernosa. The corpus spongiosum is attached to the perineal membrane and can be easily palpated as a large mass anterior to the perineal body. This mass, which is covered by the bulbospongiosus muscles, is the bulb of penis.

The corpus spongiosum detaches from the perineal membrane anteriorly, becomes the ventral part of the body of the penis (shaft of penis), and eventually terminates as the expanded glans penis (Fig. 5.84C,D).

The crura of the penis, one crus on each side, are the attached parts of the corpora cavernosa and are anchored to the ischiopubic rami (Fig. 5.84E). The corpora cavernosa are unattached anteriorly and become the paired erectile masses that form the dorsal part of the body of the penis. The glans penis caps the anterior ends of the corpora cavernosa.

**Clinical cases**

**Case 1**

**Varicocele**

A 25-year-old man visited his family physician because he had a “dragging feeling” in the left side of his scrotum. He was otherwise healthy and had no other symptoms. During examination, the physician palpated the left testis, which was normal, although he noted soft nodular swelling around the superior aspect of the testes and the epididymis. In his clinical notes, he described these findings as a “bag of worms” (Fig. 5.85). The bag of worms was a varicocele.

The venous drainage of the testis is via the pampiniform plexus of veins that runs within the spermatic cord. A varicocele is a collection of dilated veins that arise from the pampiniform plexus. In many ways, they are similar to varicose veins that develop in the legs. Typically, the patient complains of a dragging feeling in the scrotum and around the testis, which is usually worse toward the end of the day. The family physician recommended surgical treatment, with a recommendation for surgery through an inguinal incision. A simple surgical technique divides the skin around the inguinal ligament. The aponeurosis of the external oblique muscle is divided in the anterior abdominal wall to display the spermatic cord. Careful inspection of the spermatic cord reveals the veins, which are surgically ligated. Another option is to embolize the varicocele. In this technique, a small catheter is placed via the right femoral vein. The catheter is advanced along the external iliac vein and the common iliac vein and into the inferior vena cava. The catheter is then positioned in the left renal vein, and a venogram is performed to demonstrate the origin of the left testicular vein. The catheter is advanced down the left testicular vein into the veins of the inguinal canal and the pampiniform plexus. Metal coils to occlude the vessels are injected, and the catheter is withdrawn. The patient asked how blood would drain from the testis after the operation. Although the major veins of the testis had been occluded, small collateral veins running within the scrotum and around the outer aspect of the spermatic cord permitted drainage without recurrence of the
varicocele.

Fig. 5.85

Left testicular venogram demonstrating the pampiniform plexus of veins.

Case 2
Sciatic nerve compression

A young man developed pain in his right gluteal region, in the posterior aspect of the thigh and around the posterior and lateral aspects of the leg. On further questioning, he reported that the pain also radiated over the lateral part of the foot, particularly around the lateral malleolus. The areas of pain correspond to dermatomes L4 to S3 nerves. Over the following weeks, the patient began to develop muscular weakness, predominantly footdrop. These findings are consistent with loss of the motor function and sensory change in the common fibular nerve, which is a branch of the sciatic nerve in the lower limb. A computed tomography (CT) scan of the abdomen and pelvis revealed a mass in the posterior aspect of the right side of the pelvis. The mass was anterior to the piriformis muscle and adjacent to the rectum. On the anterior belly of the piriformis muscle, the sciatic nerve is formed from the roots of L4 to S3 nerves. The mass in the patient's pelvis compressed this nerve, producing his sensory and motor dysfunction. During surgery, the mass was found to be a benign nerve tumor and was excised. This patient had no long-standing neurological deficit.

Case 3
Pelvic kidney
A young woman visited her family practitioner because she had mild upper abdominal pain. An ultrasound demonstrated gallstones within the gallbladder, which explained the patient's pain. However, when the technician assessed the pelvis, she noted a mass behind the bladder, which had sonographic findings similar to a kidney (Fig. 5.86). What did the sonographer do next? Having demonstrated this pelvic mass behind the bladder, the sonographer assessed both kidneys. The patient had a normal right kidney. However, the left kidney could not be found in its usual place. The technician diagnosed a pelvic kidney. A pelvic kidney can be explained by the embryology. The kidneys develop from a complex series of structures that originate adjacent to the bladder within the fetal pelvis. As development proceeds and the functions of the various parts of the developing kidneys change, they attain a superior position in the upper abdomen adjacent to the abdominal aorta and inferior vena cava, on the posterior abdominal wall. A developmental arrest or complication may prevent the kidney from obtaining its usual position. Fortunately, it is unusual for patients to have any symptoms relating to a pelvic kidney. This patient had no symptoms attributable to the pelvic kidney and she was discharged.

Case 4
Left common iliac artery obstruction

A 65-year-old man was examined by a surgical intern because he had a history of buttock pain and impotence. On examination he had a reduced peripheral pulse on the left foot compared to the right. On direct questioning, the patient revealed that he experienced severe left-sided buttock pain after walking 100 yards. After a short period of rest, he could walk another 100 yards before the same symptoms recurred. He also noticed that over the past year he was unable to obtain an erection. He smoked heavily and was on no other drugs or treatment. The pain in the left buttock is ischemic in nature. He gives a typical history relating to lack of blood flow to the muscles. A similar finding is present when muscular branches of the femoral artery are occluded or stenosed. Such patients develop similar (ischemic) pain in the calf muscles called intermittent claudication. How does the blood get to the gluteal muscles? Blood arrives at the aortic bifurcation and then passes into the common iliac arteries, which divide into the internal and external iliac vessels. The internal iliac artery then divides into anterior and posterior divisions, which in turn give rise to vessels that leave the pelvis by passing through the greater sciatic foramen and supply the gluteal muscles. The internal pudendal artery also arises from the anterior division of the internal iliac artery and supplies the penis. The patient's symptoms occur on the left side, suggesting that an obstruction exists on that side only. Because the patient's symptoms occur on the left side only, the lesion is likely in the left common iliac artery (Fig. 5.87) and is preventing blood flow into the external and internal iliac arteries on the left side. "How will I be treated?" asked the patient. The patient was asked to stop smoking and begin regular exercise. Other treatment options include unblocking the lesion by ballooning the blockage to reopen the vessels or by a surgical bypass graft. Stopping smoking and regular exercise improved the patient's walking distance. The patient underwent the less invasive procedure of ballooning the vessel (angioplasty) and as a result he was able to walk unhindered and to have an erection.
Case 5
Iatrogenic ureteric injury
A 50-year-old woman was admitted to hospital for surgical resection of the uterus (hysterectomy) for cancer. The surgeon was also going to remove all the pelvic lymph nodes and carry out a bilateral salpingo-oophorectomy (removal of uterine tubes and ovaries). The patient was prepared for this procedure and underwent routine surgery. Twenty-five hours after surgery, it was noted that the patient had passed no urine and her abdomen was expanding. An ultrasound scan demonstrated a considerable amount of fluid within the abdomen. Fluid withdrawn from the abdomen was tested and found to be urine. It was postulated that this patient's ureters had been damaged during the surgery.

The pelvic part of the ureter courses posteroinferiorly and external to the parietal peritoneum on the lateral wall of the pelvis anterior to the internal iliac artery. It continues in its course to a point approximately 2 cm superior to the ischial spine and then passes anteromedially and superior to the levator ani muscles. Importantly, the ureter closely adheres to the peritoneum. The only structure that passes between the ureter and the peritoneum in men is the ductus deferens. In women, however, as the ureter descends on the pelvic wall, it passes under the uterine artery. The ureter continues close to the lateral fornix of the vagina, especially on the left, and enters the posterosuperior angle of the bladder. It was at this point that the ureter was inadvertently damaged. Knowing the anatomy and recognizing the possibility of ureteric damage enabled the surgeons to reestablish continuity of the ureter surgically. The patient was hospitalized a few days longer than expected and made an uneventful recovery.

Case 6
Ectopic pregnancy
A 25-year-old woman was admitted to the emergency department with a complaint of pain in her right iliac fossa. The pain had developed rapidly over approximately 40 minutes and was associated with cramps and vomiting. The surgical intern made an initial diagnosis of appendicitis. The typical history for appendicitis is a central abdominal, colicky (intermittent waxing and waning) pain, which over a period of hours localizes to become a constant pain in the right iliac fossa. The central colicky pain is typical for a poorly localized visceral type of pain. As the parietal peritoneum becomes inflamed, the pain becomes localized. Although this patient does have right iliac fossa pain, the history is not typical for appendicitis (although it must be remembered that patients may not always have a classical history for appendicitis). The surgical intern asked a more senior colleague for an opinion. The senior colleague considered other anatomical structures that lie within the right iliac fossa as a potential cause of pain. These include the appendix, the cecum, and the small bowel. Musculoskeletal pain and referred pain could also be potential causes. In women, pain may also arise from the ovary, fallopian tube, and uterus. In a young patient, diseases of these organs are rare. Infection and pelvic inflammatory disease may occur in the younger patient and need to be considered. The patient gave no history of these disorders. Upon further questioning, however, the patient revealed that her last menstrual period was 6 weeks before this examination. The senior physician realized that a potential cause of the abdominal pain was a pregnancy outside the uterus (ectopic pregnancy). The patient was rushed for an abdominal

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**Fig. 5.87**

*Digital subtraction aorto-iliac angiogram. A. Normal circulation pattern. B. Occluded left common iliac artery.*
ultrasound, which revealed no fetus or sac in the uterus. She was also noted to have a positive pregnancy test. The patient underwent surgery and was found to have a ruptured fallopian tube caused by an ectopic pregnancy. Whenever a patient has apparent pelvic pain, it is important to consider the gender-related anatomical differences. Ectopic pregnancy should always be considered in women of childbearing age.

Case 7
Uterine tumor

A 35-year-old woman visited her family practitioner because she had a “bloating” feeling and an increase in abdominal girth. The family practitioner examined the lower abdomen, which revealed a mass that extended from the superior pubic rami to the level of the umbilicus. The superior margin of the mass was easily palpated, but the inferior margin appeared to be less well defined. This patient has a pelvic mass. When examining a patient in the supine position, the observer should uncover the whole of the abdomen. Inspection revealed a bulge in the lower abdomen to the level of the umbilicus. Palpation revealed a hard and slightly irregular mass with well-defined superior and lateral borders and a less well-defined inferior border, giving the impression that the mass continued into the pelvis. The lesion was dull to percussion. Auscultation did not reveal any abnormal sounds. The doctor pondered which structures this mass may be arising from. When examining the pelvis, it is important to remember the sex differences. Common to both men and women are the rectum, bowel, bladder, and musculature. Certain pathological states are also common to both sexes, including the development of pelvic abscesses and fluid collections. In men, the prostate cannot be palpated transabdominally, and it is extremely rare for it to enlarge to such an extent in benign diseases. Aggressive prostate cancer can spread throughout the whole of the pelvis, although this is often associated with bowel obstruction and severe bladder symptoms. In women, a number of organs can develop large masses, including the ovaries (solid and cystic tumors), the embryological remnants within the broad ligaments, and the uterus (pregnancy and fibroids). The physician asked further questions. It is always important to establish whether the patient is pregnant (occasionally, pregnancy may come as a surprise to the patient). This patient's pregnancy test was negative. After the patient emptied her bladder, there was no change in the mass. The physician thought the mass might be a common benign tumor of the uterus (fibroid). To establish the diagnosis, he obtained an ultrasound scan of the pelvis, which confirmed that the mass stemmed from the uterus. The patient was referred to a gynecologist, and after a long discussion regarding her symptomatology, fertility, and risks, the surgeon and the patient agreed that a hysterectomy (surgical removal of the uterus) would be an appropriate course of therapy. The patient sought a series of opinions from other gynecologists, all of whom agreed that surgery was the appropriate option. The fibroid was removed with no complications.

Case 8
Uterine fibroids

A 52-year-old woman was referred to a gynecologist. Magnetic resonance imaging (MRI) indicated the presence of uterine fibroids. After a long discussion regarding her symptomatology, fertility, and risks, she was offered the choice between a hysterectomy (surgical removal of the uterus) or uterine artery embolization. A uterine artery embolization is a procedure where an interventional radiologist uses a catheter to inject small particles into the uterine arteries. This reduces the blood supply to the fibroids and causes them to shrink. The patient opted for the uterine artery embolization. An MRI performed 6 months after the embolization procedure showed a favorable reduction in the size of the uterine fibroids (Fig. 5.88).

Fig. 5.88
Sagittal MRI of the pelvic cavity. A. Measurement of a fibroid before the uterine artery embolization. B. Measurement of a fibroid 6 months after the embolization. The size of the fibroid has decreased.