CHAPTER 6
Perineum and True Pelvis

THE PELVIC REGION OF THE BODY

You will recall that **the pelvic region of the body is subdivided into greater (false) and lesser (true) portions**. The boundary between these subdivisions is identified by reference to landmarks on the bony pelvis[22]. On the inner aspect of this structure, the iliac fossa and superior surface of the pubis are demarcated from the lower portions of these bones by a prominent ridge that runs from the auricular surface of the ilium all the way round the front to the pubic tubercle (see Fig. 6-1*B*). This is the **iliopectineal (terminal) line**. Along with the pubic crests, ventral rims of the sacral alae, and the sacral promontory, the iliopectineal line contributes to a "circle" of bone (see Fig. 6-1*A*) that lies halfway between a transverse and a coronal plane. It is this circle, called the **pelvic brim**, that divides the pelvis into a greater portion anterosuperiorly and a lesser portion postero-inferiorly. **The part of the trunk below the pelvic brim is called the true pelvis, or often simply the pelvis.**

Inferiorly, the abdominopelvic cavity is bounded by the pelvic diaphragm, another flat muscle with holes that allow structures to pass out of it into a region of the pelvis called the **perineum, which by definition is that part of the trunk below the pelvic diaphragm.**

The part of the abdominopelvic cavity within the pelvic region of the trunk is called the **pelvic cavity**, which in turn has greater and lesser portions, according to whether it is above or below the pelvic brim. The lesser pelvic cavity is easily distinguished by its much smaller diameter and its position below and behind the abdominal cavity (Fig. 6-2). Thus, the **lesser pelvic cavity** is spoken of as being the true pelvic cavity or, even more frequently, simply as the **pelvic cavity**. It is in this sense that I will use the word. The pelvic cavity is much smaller than the abdominal cavity but is in open communication with it at the pelvic brim.

By virtue of the fact that the lower wall of the peritoneal sac coincides with a transverse plane between the end of the sacrum and the pubic crests (Fig. 6-2), the peritoneal cavity extends downward into the pelvic cavity. Since the pelvic diaphragm is inferior to the lower boundary of the peritoneum by a significant amount, there is an extraperitoneal space between the peritoneal sac and pelvic diaphragm. This space is occupied by connective tissue and by certain organs that will develop within it. If we can call the extraperitoneal space posterior to the peritoneal cavity the "retroperitoneal" space, then the extraperitoneal space below the peritoneal cavity is the **"subperitoneal"** space.

WALLS OF THE PELVIC CAVITY

Posterior, Anterolateral, and Anterior Walls

The pelvic cavity has no superior wall; it opens into the abdominal cavity. The posterior wall of the pelvic cavity is formed by the sacrum and by the piriformis muscle, which arises from the ventral surface of the sacrum. The anterolateral walls of the pelvic cavity are formed by the portion of each os coxae below its terminal line, and by a muscle (the obturator internus) that arises from the inner surface of the os coxae in the vicinity of the obturator foramen. The front wall of the pelvic cavity is formed by the bodies of the two pubic bones and the intervening pubic symphysis.

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[22] If the reader is unfamiliar with the basic structure of the innominate bone, he or she should refer to Chapter 12, p. 514.
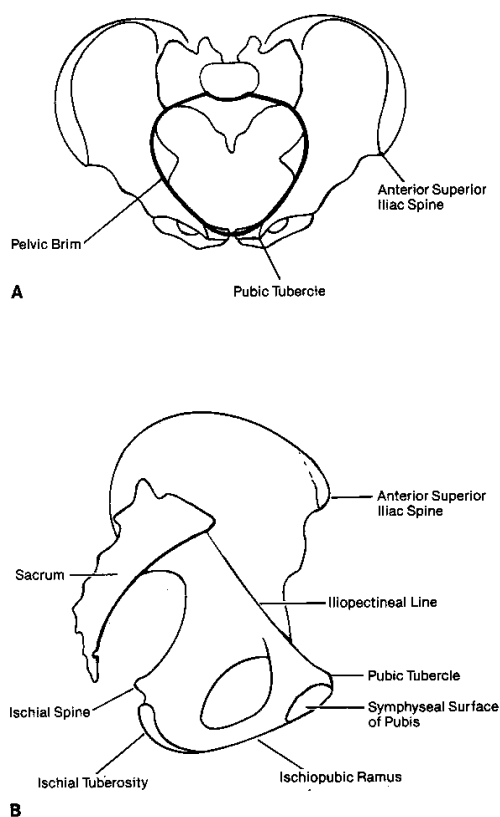
Figure 6-1. *A,* Superior view of bony pelvis. *B,* Medial view of left os coxae and sacrum. The iliopectineal line represents the os coxae's contribution to the pelvic brim.
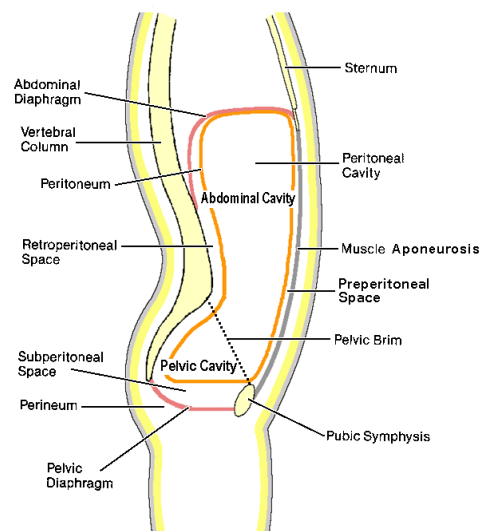
Figure 6–2. Schematic median sagittal section of abdominopelvic cavity. Postero-inferior to the pelvic brim is the lesser (true) pelvis with its cavity. Immediately anterosuperior to the pelvic brim is the greater (false) pelvis, the cavity of which merges without demarcation into that of the abdomen. The peritoneal sac abuts the abdominal diaphragm but stops short of the pelvic diaphragm.

Inferior Wall--The Pelvic Diaphragm

The inferior wall of the pelvic cavity is the pelvic diaphragm. Like its abdominal counterpart, the pelvic diaphragm is a thin muscle that stretches completely from side to side and from front to back. Unlike its abdominal counterpart, the pelvic diaphragm is convex downward, not upward (Fig. 6-3*A*). It is markedly curved from side to side (see Fig. 6-7). The pelvic diaphragm has holes in it for passage of structures from the pelvic cavity into the perineum, or vice versa (Fig. 6-3*B*). Whereas the fascia on the upper surface of the abdominal diaphragm is called endothoracic fascia, and that on its lower surface is called transversalis fascia, the comparable fascial layers on the upper and lower surfaces of the pelvic diaphragm are simply called the **superior and inferior fascias of the pelvic diaphragm**. The superior fascia is continuous with the transversalis fascia.

The pelvic diaphragm differs from the abdominal diaphragm in a few ways. First, as already mentioned, it is convex downward, not upward. Second, the pelvic diaphragm, though being a single sheet, is composed of two distinct muscles (Fig. 6-4*B*). One is the **levator ani**, the other is the **coccygeus**. The levator ani, like the abdominal diaphragm, has a central tendon. However, this central tendon is not a broad structure on which muscle fibers converge from all sides (see Fig. 6-4*A*). Rather, it is a short and narrow linear band running anteroposteriorly and receiving muscle fibers from either side (see Fig. 6-4*B*). The coccygeus was a muscle of the tail in our distant ancestors. In humans, the tail bones have been consolidated into the sacrum and coccyx. The coccygeus loses its function as a mover of the tail and, instead, joins the levator ani to form the pelvic diaphragm. The levator ani and coccygeus are derived from the hypaxial parts of the 3rd and 4th sacral dermomyotomes. Thus, they are innervated by the third
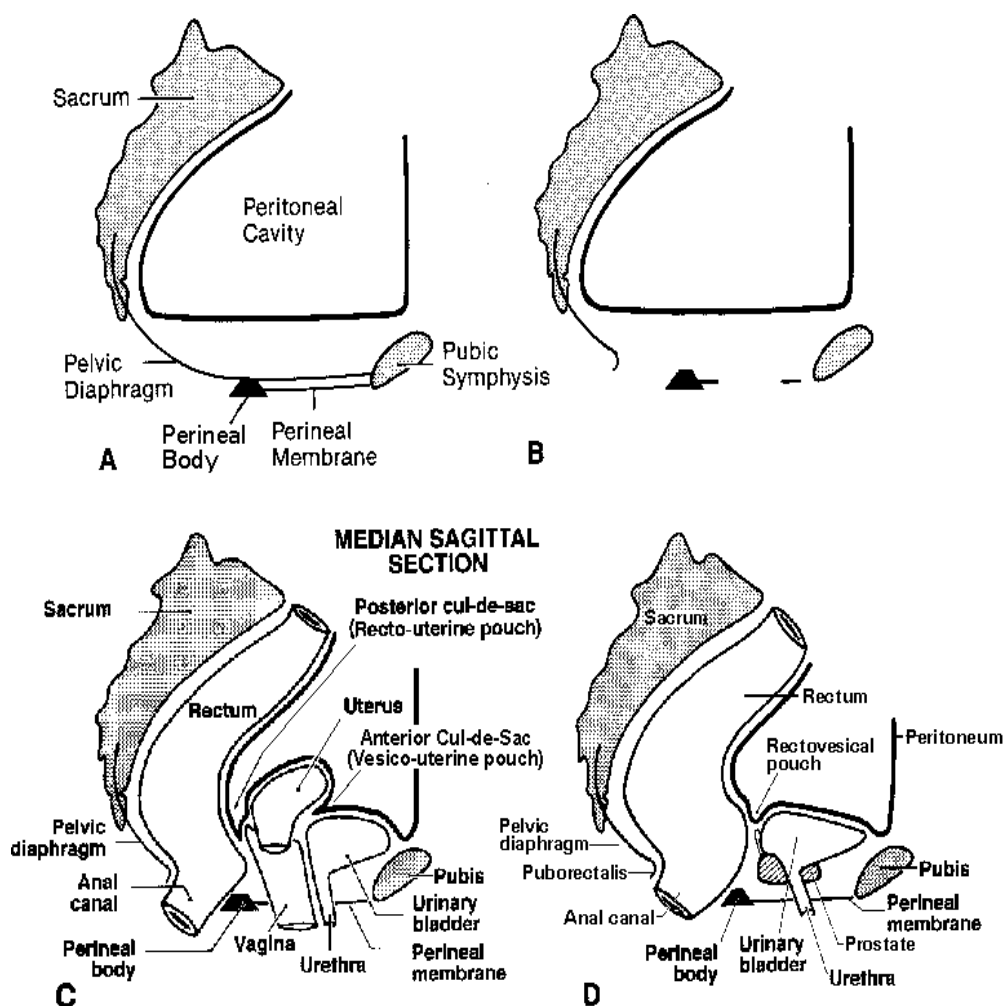
Figure 6-3. Schematic median sagittal sections of the pelvic cavity. A, Pelvic diaphragm and perineal membrane (urogenital diaphragm), drawn as if they had no holes. B, Pelvic diaphragm and perineal membrane with the midline holes actually found within them. C, Pelvic organs of a female passing through holes in the pelvic diaphragm and perineal membrane. D, Pelvic organs of a male passing through holes in the pelvic diaphragm and perineal membrane.

and fourth sacral ventral rami. The pelvic diaphragm functions primarily to enable increase in intra-abdominal pressure by resisting downward displacement.

*Levator Ani (see Fig. 6-4*B*)*

The levator ani of each side begins its origin from the inner surface of the pubic body next to the lower margin of the symphysis. The origin then passes posterolaterally from the pubic bone onto the fascia covering the obturator internus muscle, extending along this fascia all the way back to the spine of the ischium. The obturator fascia is thickened where it gives origin to the levator ani (just as the fascias of the psoas major and quadratus lumborum were thickened where they gave origin to the abdominal diaphragm). This thickened ridge of obturator fascia is called the **arcus tendineus** (tendinous arch). The fibers of each levator ani pass from their origin to insert on a median linear **anococcygeal raphe** that starts just behind the anal canal (the part of the rectum below the pelvic diaphragm) and runs back to the
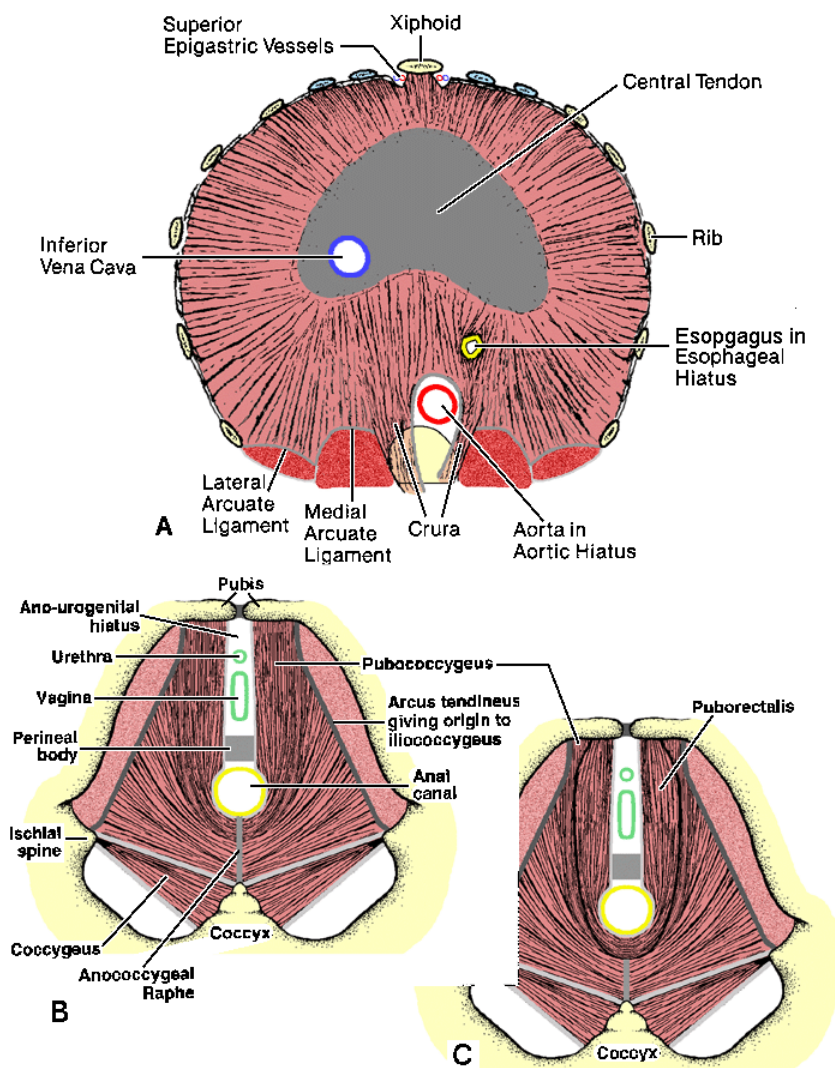
Figure 6-4. *A,* Inferior view of a flattened-out abdominal diaphragm showing major holes for passage of structures between the thoracic and abdominal cavities. *B,* Inferior view of a flattened-out pelvic diaphragm showing its named muscular components and the major holes for passage of structures from the pelvic cavity to the perineum. The pubococcygeus and iliococcygeus together constitute the levator ani. The other muscle of the pelvic diaphragm is the coccygeus. The gap between the left and right pubococcygei is called the ano-urogenital hiatus. *C,* The puborectalis is applied to the undersurface of the puborectalis and considered by some authors to be a part of the levator ani and pelvic diaphragm.

coccyx. For a substantial distance posterior to the pubic symphysis is a gap between the left and right levators ani. The muscle fibers that arise from the pubis and insert onto the anococcygeal raphe form the margins of this gap, just as the crura of the abdominal diaphragm form the margins of the gap for the aorta (see Fig. 6-4*A*). The gap at the back of the abdominal diaphragm is called the aortic hiatus. The gap at the front of the pelvic diaphragm is for passage of the urethra, vagina (if you have one), and anal canal; it is called the **ano-urogenital hiatus**. In front of the anal canal, bridging across the hiatus between the inner edges of the left and right levators ani is a pyramidal chunk of connective tissue called the **perineal body** (or, **central tendon of the perineum)** (fig. 6-4B).

The levator ani is commonly divided by anatomists into separate regions. The fibers that arise from the pubis, pass around the ano-urogenital hiatus, and insert onto the anterior part of the anococcygeal raphe are said to constitute a **pubococcygeus muscle**. Fibers that arise a bit more laterally from the pubis, and from the anterior limit of the arcus tendineus, insert into the rest of the anococcygeal raphe and constitute the **iliococcygeus muscle**. This is the thinnest portion of the levator ani, sometimes appearing to be as much fibrous as muscular.

Coccygeus (Ischiococcygeus) (see Fig. 6-4B)

The coccygeus arises from the spine of the ischium (at the posterior end of the arcus tendineus) and passes medially, fanning out, to insert onto the coccyx and end of the sacrum. It is the most posterior part of the pelvic diaphragm and lies on a coronal plane (see Fig. 6-3).

Since the coccygeus runs between two essentially immobile structures, it could serve its role as a component of the pelvic diaphragm just as well if it were a ligament rather than a muscle. In fact, the superficial fibers of the coccygeus have regressed to become ligamentous. They form the **sacrospinous ligament**. Sometimes it is even difficult to identify muscle fibers on the deep surface of the sacrospinous ligament.

Puborectalis (Considered by Some Persons to be a Third Part of Levator Ani) (see Fig. 6-4C)

Applied to the inferior edge of each pubococcygeus muscle, and not clearly separable from it, are muscle fibers that arise from the pubic body and sweep posteriorly to meet their contralateral partners behind the anal canal. Because they don't insert on the anococcygeal raphe, I adopt the view (espoused by others) that they deserve to be given a separate name - **puborectalis** - and are not strictly part of the pelvic diaphragm   The right and left puborectalis muscles form a **puborectal sling**, which is constantly active to pull the back wall of the anal canal forward and thereby assist in fecal continence. The puborectal sling is relaxed during defecation.

Another Hole in the Pelvic Diaphragm--The Greater Sciatic Foramen

The ano-urogenital hiatus has already been described. Superior to the sacrospinous ligament (on each side) is the other major gap in the pelvic diaphragm. This is the **greater sciatic foramen** (see Fig. 12-11, p. 519). The sacrospinous ligament is its inferior border. Laterally and superiorly it is bounded by the greater sciatic notch of the ilium. The medial boundary would be the sacrum if it were not for the fact that a powerful ligament, the sacrotuberous ligament, attaches to the sacrum here and closes off the most medial part of the foramen. Thus, the lateral edge of the sacrotuberous ligament is considered to be the medial boundary of the greater sciatic foramen.

Through the greater sciatic foramen passes the piriformis muscle on its way from its origin on the sacrum to its insertion on the greater trochanter of the femur. But, although the piriformis is the largest structure passing through the greater sciatic foramen, it is not the most important. It is accompanied by nerves and vessels destined for either the lower limb (the sciatic nerve, the superior gluteal vessels and nerve, the inferior gluteal vessels and nerve, the posterior cutaneous nerve of the thigh, the nerve to the obturator internus, and the nerve to the quadratus femoris) or the perineum (the internal pudendal vessels and pudendal nerve). Once these nerves and vessels leave the pelvic cavity, they never return.

PERINEUM

The perineum is that part of the trunk inferior to the pelvic diaphragm. Its lateral boundaries make the shape of a diamond (Fig. 6-5A), but it is better to view it as two triangles, an anterior and a posterior, joined at their bases (Fig. 6-5B). The anterior, or urogenital triangle, lies in a transverse plane; the posterior, or anal triangle, lies between a transverse and a coronal plane. Their conjoined base runs from side to side between the anterior limits of the ischial tuberosities (see Fig. 6-5B).
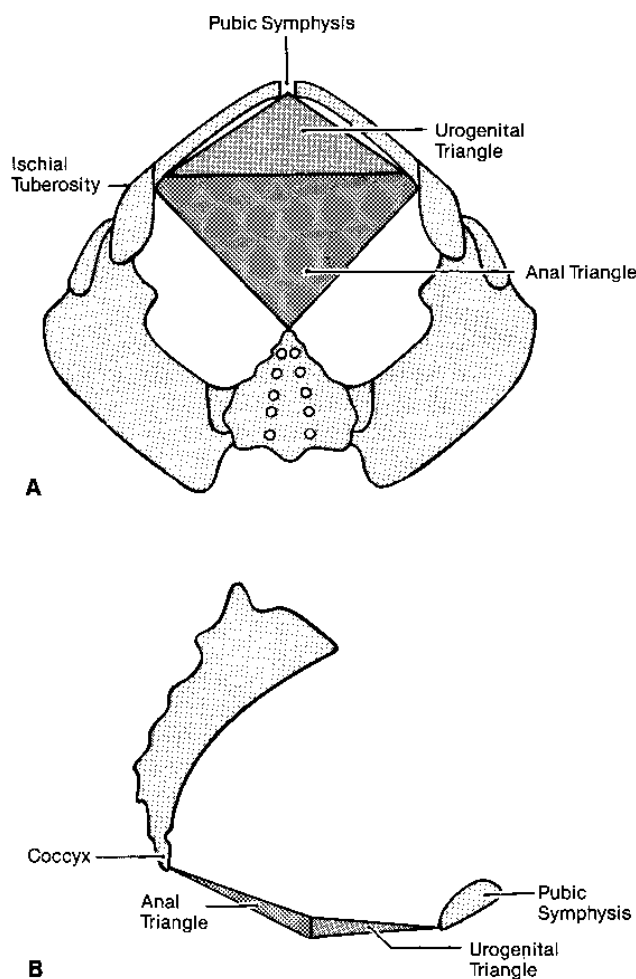
Figure 6-5. A, Inferior view of the bony pelvis showing the diamond-shaped boundary of the perineum and the regions defined as urogenital and anal triangles. B, Median sagittal section of bony pelvis illustrating positions of urogenital and anal triangles.

Urogenital Triangle

The lateral walls of the urogenital triangle are formed by the ischiopubic rami and that part of each obturator internus that lies below the arcus tendineus. The apex of the urogenital triangle is formed by the **arcuate ligament of the pubis**, which runs from one pubic bone to the other along the inferior edge of the pubic symphysis.

Contents of the Urogenital Triangle

Perineal (Triangular) Membrane. A major structure within the urogenital triangle is the perineal membrane. It is a flat fibrous sheet that stretches between the right and left ischiopubic rami (Fig. 6-6; see Fig. 6-3). It is as if the periosteum of one ischiopubic ramus bridges across to merge with the periosteum of the other ramus. The old view of the perineal membrane was that it was merely the thickened inferior fascia of a muscular urogenital diaphragm. This is incorrect[23]. No muscular urogenital diaphragm exists. If one wishes to retain the term **urogenital diaphragm**, it becomes synonymous with perineal membrane.

The perineal membrane, viewed inferiorly, is itself triangular (see Fig. 6-6). The long posterior edge of the perineal membrane stretches between the anterior limits of the ischial tuberosities. Its apex has been cut off so that the perineal membrane does not reach the pubic symphysis. Its short anterior edge runs between the ischiopubic rami just behind the pubic symphysis. This edge is also called the
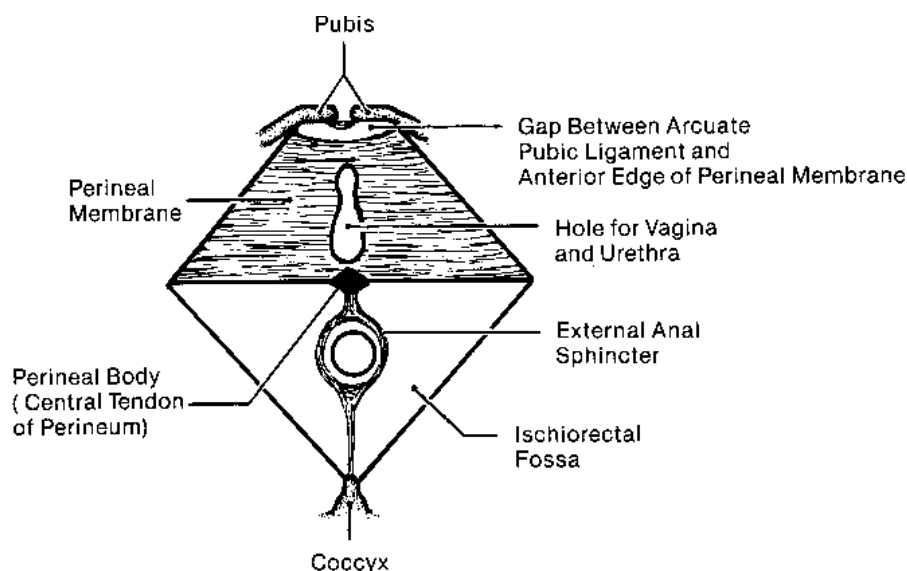
Figure 6-6. Inferior view of perineal membrane and anal triangle.

transverse ligament of the pelvis, and there is a gap between it and the arcuate pubic ligament.

The ano-urogenital hiatus of the pelvic diaphragm overlies the middle of the perineal membrane (Fig. 6-7). The urethra and vagina, which pass through the ano-urogenital hiatus, would be stopped by the perineal membrane if the latter did not contain a hole for their passage. It does (see Fig. 6-6), and thus the urethra and vagina eventually are able to reach the skin. The perineal body is fused to the middle of the posterior edge of the perineal membrane.

Perineal Muscles Superior to the Perineal Membrane--Sphincter Urethrae (Both Sexes), Deep Transverse Perineus (Males), Sphincter Urethrovaginalis (Females), Compressor Urethrae (Females). In both sexes, the part of the urethra above the pelvic diaphragm and passing through the ano-urogenital hiatus is surrounded by a circular **sphincter urethrae muscle**. In the male, this muscle

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[23] Oelrich, TM: The urethral sphincter muscle in the male. Am J Anat 158:229 - 264, 1980. Oelrich, TM: The striated urogenital sphincter muscle in the female. Anat Rec 205:223 - 232, 1983.
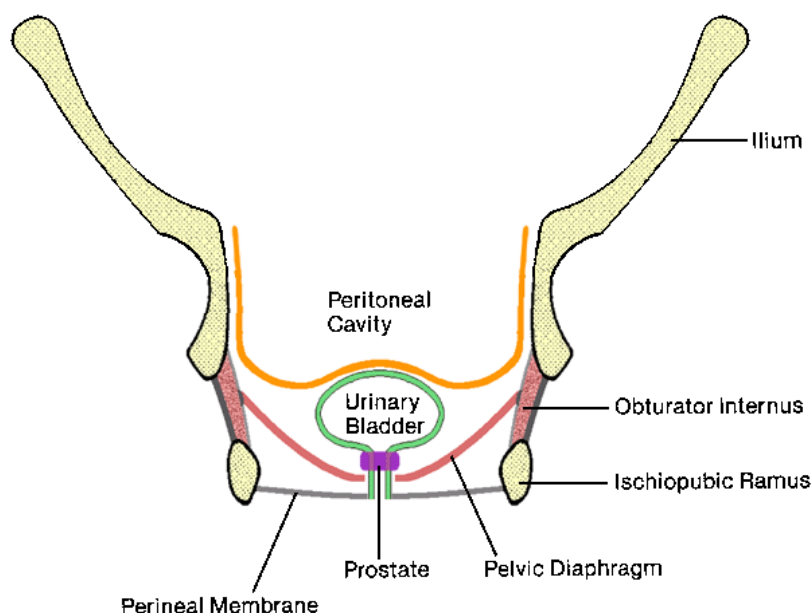
Figure 6-7. Schematic coronal section through bony pelvis and urogenital triangle in a male, showing relationship of pelvic diaphragm to urinary bladder, prostate, and perineal membrane.

becomes thicker below the ano-urogenital hiatus, as it lies on the superior surface of the perineal membrane (Fig. 6-8*A*). Embedded in the muscle here are the **bulbo-urethral glands**, which send their ducts through the perineal membrane eventually to join up with the urethra. Additionally, on the superior surface of the perineal membrane in males are some muscle fibers that arise on each side from the anterior limit of the ischial tuberosity and pass directly medially to insert on the perineal body (with some fibers interdigitating with the back of the sphincter urethrae). These fibers compose the **deep transverse perineus** muscles.

In females, once the sphincter urethrae has passed through the ano-urogenital hiatus, but while it is still above the perineal membrane, it enlarges to encircle both the urethra and vagina. Thus, at this site it is called the **sphincter urethrovaginalis**. The existence in females of deep transverse perineus muscles is debatable. However, there are apparently muscles that arise from the same sites but, rather than passing posterior to the sphincter urethrovaginalis to reach the perineal body, instead proceed to blend with the most anterior fibers of that muscle. The fibers on the right, together with those on the left, form an arch that, upon contraction, compresses the anterior urethral wall against the posterior urethral wall. Thus, the muscle is called the **compressor urethrae**. The thickness of the sphincter urethrae in males may make such a muscle unnecessary.

Genital Structures Opposed to the Inferior Surface of the Perineal Membrane -- Crura of Phallus, Bulb of Penis (Males), Bulb of Vestibule (Females) (see Fig. 6-8*A*). Attached to the inner surface of each ischiopubic ramus, just inferior to the lateral margin of the perineal membrane, is a highly vascular erectile tube surrounded by a tough fibrous envelope. This is the **crus of the phallus (penis or clitoris)** with its fibrous **tunica albuginea**. Of course, there are two crura, one on either side.

The crura of the penis meet one another at the anterior border of the perineal membrane and together pass forward into the free shaft of the penis. Within the penile shaft they are called the **corpora cavernosa**, and where their tunicae albugineae contact each other, they fuse to form the **septum of the**
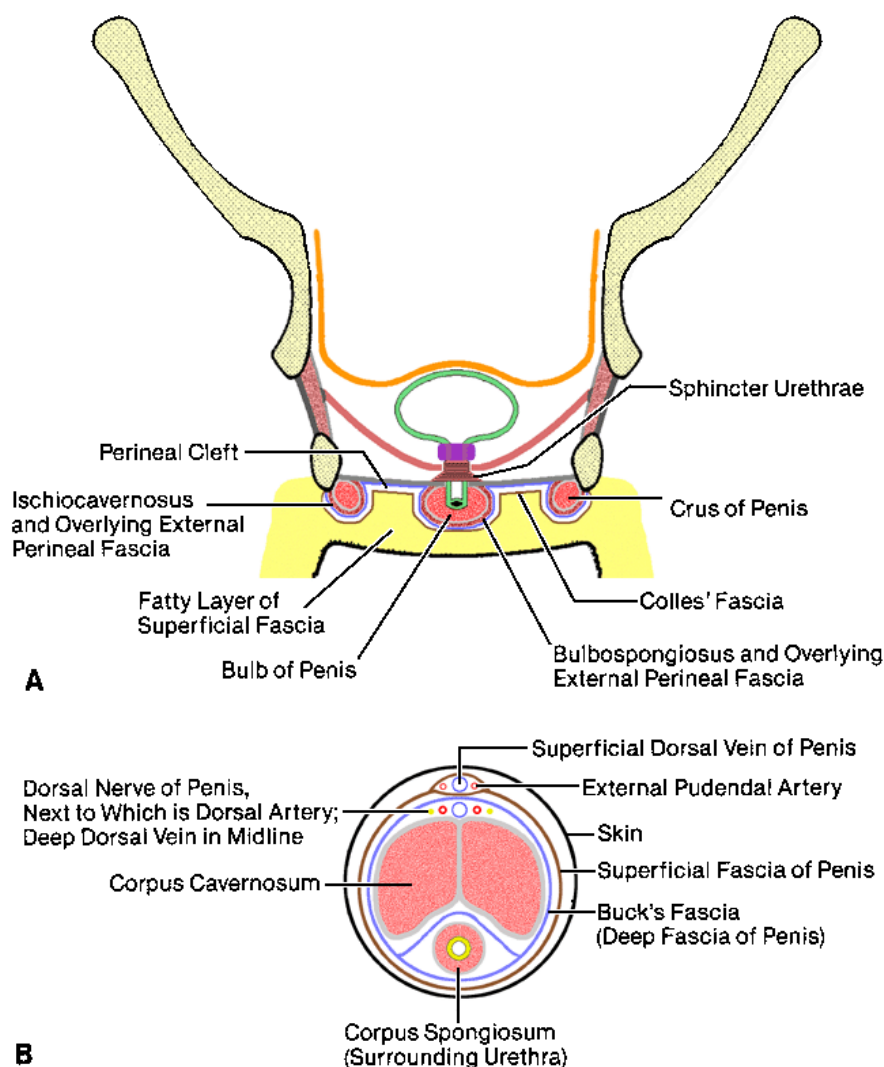
Figure 6-8. A, Schematic coronal section through bony pelvis and urogenital triangle of a male (as in Fig. 5–41), to which has been added the sphincter urethrae and the structures that lie inferior to the perineal membrane. B, Transverse section of the shaft of the penis.

penis. At certain sites the septum is perforated, allowing the vascular spaces of one side to communicate with those of the other. The existence of these communications causes some authors to view the corpora cavernosa as constituting a single **corpus cavernosum**.

The crura of the clitoris differ from those of the penis only in size. They are of smaller diameter and the shaft of the clitoris is comparatively short. Within the clitoral shaft the adherent crura are said to constitute a **corpus clitoridis**.

In males, there is another highly vascular erectile organ, with its own fibrous tunica albuginea, located on the undersurface of the perineal membrane in the midline. This is the **bulb of the penis**. As the bulb of the penis nears the anterior border of perineal membrane, it narrows into a cylindrical structure that passes into the free shaft of the penis ventral to the septum penis. This cylindrical erectile structure is called the **corpus spongiosum** of the penis. It is longer than the corpus cavernosum, and

when it reaches their distal ends, the corpus spongiosum expands dorsally to form a cap over them. This cap is the **glans penis**.

The bulb of the penis lies on the inferior surface of the perineal membrane right where the urethra pierces this membrane. The urethra passes through the tunica albuginea of the bulb to become surrounded by erectile tissue. Immediately after it enters the bulb, the urethra undergoes a small dilatation and then, after narrowing again, makes a right angle turn to run through the middle of the corpus spongiosum up to the tip of the glans. Here it opens on the skin by means of a small dilatation called the **fossa navicularis**.

The reader will recall that the part of the urethra surrounded by the prostate gland is called the **prostatic urethra**. The part of the urethra within the bulb is called the **bulbar urethra**; the part within the corpus spongiosum is called the **penile urethra**. Between the prostatic urethra and the penile urethra is the segment that actually passes through the ano-urogenital hiatus and perineal membrane; this is the **membranous urethra**.

There is no single bulb of the clitoris. After the vagina and urethra pierce the perineal membrane they immediately open up onto the skin between the labia minora. This space between the labia minora is called the **vestibule of the vagina**. At the root of each minor labium, on the inferior surface of the perineal membrane, is a flattened oval erectile body called the **bulb of the vestibule**. From the anterior pole of each bulb comes a slender extension onto the ventral surface of the corpus clitoridis. The two slender extensions from each side meet and then expand to form a small **glans clitoris**.

Adjacent to the posterior ends of each vestibular bulb is a **greater vestibular gland (of Bartholin)** that sends its duct to open into the vestibule lateral to the posterior half of the vaginal orifice. (Gynecologists refer to the openings of Bartholin ducts as being at the 5 o'clock and 7 o'clock position relative to the vaginal orifice.)

Muscles Associated with the Crura and Bulbs - Ischiocavernosus and Bulbospongiosus (see Fig. 6-8*A*). Arising from the ischiopubic ramus, covering the inferior and medial surfaces of each crus, and inserting onto the tunica albuginea of the crus just before it turns to join the penis or clitoris is an **ischiocavernosus muscle**. The ischiocavernosi of the two sexes differ only in size. By contraction, these muscles elevate pressure within the relevant erectile tissues to a level substantially above the systolic blood pressure.

Arising from the perineal membrane and nearby fibrous tissues are muscle fibers that sweep around the sides of the bulb and proximal corpus spongiosum to insert on a midline raphe that runs from the perineal body forward along the inferior surface of the bulb and the proximal corpus spongiosum. This is the **bulbospongiosus muscle**. It seems to be involved as a sphincter acting on the urethra to assist in ejaculation and urination.

In females, a bulbospongiosus muscle lies on the lateral surface of each bulb of the vestibule. The fibers arise from the perineal body and run forward. The function of the bulbospongiosus in females is unknown. It would seem to have the ability to narrow the vestibule.

In both males and females there is yet another muscle on the inferior surface of the perineal membrane, but this muscle is unrelated to the erectile bodies. It is called the **superficial transverse perineus**. On each side it arises from the anterior limit of the ischial tuberosity and passes medially to insert on the perineal body.

Fascia of the Urogenital Triangle (see Fig. 6-8). The description that follows applies to the condition in males, for which a knowledge of urogenital fascia is of considerable clinical significance.

The epimysium on the external surfaces of the ischiocavernosus and bulbospongiosus is bilaminar. The thicker outer layer is called the **deep (external) perineal fascia**. It is continuous anteriorly with a deep fascial sleeve around the erectile bodies of the of the penis. This sleeve is called **Buck's fascia**. Not only does Buck's fascia encircle the entire shaft of the penis just external to the tunicae albugineae of the corpora, but it also sends a septum from side to side between the corpus spongiosum and the corpus cavernosum. It ends anteriorly by blending with the tunica albuginea of the glans. At the root of the penile shaft, Buck's fascia sends a connection from the dorsal surface of penis to the anterior surface of the symphysis pubis. This connecting band constitutes the **suspensory ligament of the penis**.

As elsewhere in the body, superficial to the most external layer of deep fascia is the subcutaneous layer. The subcutaneous layer of the urogenital triangle is special in the same way as is that of the lower abdominal wall. It has a deep fibrous lamina overlain by a more fatty loose connective tissue. The deep fibrous layer in the abdomen was called Scarpa's fascia; the fatty layer was called Camper's fascia. In the urogenital triangle the deep fibrous lamina is called **Colle's fascia**. The fatty layer has no name. Colle's fascia is continuous anteriorly with Scarpa's fascia, the tunica dartos of the scrotum, and the superficial fascia of the penis. However, Colle's fascia ends laterally by attaching to the periosteum of the ischiopubic rami, and it ends posteriorly by attaching to the back edge of the perineal membrane. It also has a midline attachment to the raphe of the bulbospongiosus, which attachment is continuous anteriorly with the attachment of the scrotal septum (a derivative of the tunica dartos) to this raphe. The fatty layer of the superficial fascia of the perineum is continuous with Camper's fascia, the tunica dartos of the scrotum, the superficial fascia of the penis, the subcutaneous layer of the medial thigh, and the subcutaneous layer of the anal triangle.

Perineal Pouches and the Perineal Cleft (see Fig. 6-8). When anatomists believed that there was a true muscular urogenital diaphragm with its own superior and inferior fascias, they decided to call the space between these "fascial layers" the "deep perineal pouch." It was said to be occupied by the muscle fibers of the "urogenital diaphragm," the bulbourethral glands, and some vessels and nerves that run on the superior surface of the perineal membrane. We now know that there is no "deep perineal pouch", although there certainly are structures that lie on the upper surface of the perineal membrane.

One may say that between the perineal membrane and the deep perineal fascia there is a trilobular space occupied laterally by the crura and ischiocavernosi, and in the midline by the bulb and bulbospongiosus. Some authors, including myself, choose to refer to this trilobular space as constituting a **superficial perineal pouch**. It is continuous with the space deep to Buck's fascia in the penis.

Between the deep perineal fascia and Colle's fascia is a thin fluid-filled space that many authors, including myself, choose to call the **perineal cleft**. It lies between deep and superficial fascia. It is continuous with the space between deep and superficial fascia in other regions of the body: (1) the space within the scrotum between the external spermatic fascia and the tunica dartos (2) the space between Buck's fascia and the superficial fascia of the penis, and (3) the space between the deep fascia on the outer surface of the external abdominal oblique and Scarpa's fascia. The attachment of Colle's fascia to the back of the perineal membrane and to the ischiopubic rami prevents the perineal cleft from having continuity with the space between deep and superficial fascias of the anal triangle or the medial side of the thigh.

The perineal cleft has considerable clinical significance. This is so because trauma to the perineum in males, or an improperly performed urethral catheterization, can lead to tearing of the urethra and deep fascia just below the perineal membrane. As a result, urine (often mixed with blood) gains access to the perineal cleft. Once within the perineal cleft, urine spreads anteriorly into (1) the scrotum between external spermatic fascia and tunica dartos, (2) the shaft of the penis between Buck's fascia and the superficial fascia of the penis, and (3) the anterior abdominal wall between the deep fascia of the external abdominal oblique and Scarpa's fascia. If the rupture into the cleft is unilateral, urine will first fill one side of the perineum and one scrotal sac. However, because the anterosuperior edge of the scrotal septum is free, urine always passes to the other scrotal sac. In the abdomen and penis also, the plane between deep and superficial fascias is continuous across the midline. You might think that any urine that has reached the anterior abdominal wall could travel downward into the thigh, or posteriorly into the back. Such spread is in fact prevented by attachment of Scarpa's fascia to (1) the fascia lata just below the inguinal ligament, (2) the iliac crest, and (3) the thoracolumbar fascia.

There are also cases in which bloody urine can get into the space between the tunica albuginea of the bulb of the penis and the deep perineal fascia. (Ordinarily this space is occupied only by the bulbospongiosus muscle.) As a consequence of a careless catheterization of the male urethra, the tip of the catheter may be driven through the wall of the urethra at the site of the bulbar dilatation. If the rupture goes no further, urine will simply spread throughout the blood-filled sinuses of the bulb and corpus spongiosum. If the catheter also pierces the tunica albuginea of the bulb, bloody urine will enter the space between deep perineal fascia and the tunica albuginea but will still be confined to the middle of the perineum and ventral surface of the penis. Subsequent infection may then cause breakdown of the external perineal fascia and entry of urine into the perineal cleft. This entire process may also result from primary untreated infection of the penile urethra.

Because the female urethra is straight and opens onto the surface almost immediately after it pierces the perineal membrane, it is not subject to the same trauma as may occur in the male.

Anal Triangle

Each lateral boundary of the anal triangle is formed anteriorly by the inner surface of the ischial tuberosity and the portion of the obturator internus arising from it (see Fig. 6-5*A*). Behind the ischial tuberosities, the lateral wall of the anal triangle is formed by the sacrotuberous ligament, which runs from the inner edge of the tuberosity upward and backward to the coccyx, sacrum, and posterior ilium (see Fig. 12-11, p. 519). External to the sacrotuberous ligament is the gluteus maximus muscle, which, therefore, also contributes to the lateral wall of the anal triangle. The apex of the anal triangle is the tip of the coccyx.

Contents of the Anal Triangle

The contents of the anal triangle are far less numerous than those of the urogenital triangle. Its major occupant is the **anal canal**, which is that portion of the rectum below the pelvic diaphragm. The anal canal passes just posterior to the perineal membrane on its way to the anus (see Figs. 6-3*C,D*, 6-6). It is surrounded by a striated muscle that arises from the central tendon of the perineum, then sends fibers

around the sides of the anal canal to converge on a tendon that goes to the coccyx (see Fig. 6-6). This is the voluntary **external anal sphincter** that constricts the anal canal and enables us to be continent. Within the wall of the anal canal is a smooth muscle sphincter (the **internal anal sphincter**), which relaxes reflexly upon parasympathetic stimulation when the rectum fills with fecal matter.

The anal canal is surrounded on all sides by fatty connective tissue, which allows it to expand easily as fecal matter enters it. This fatty tissue fills up the perineum in the region of the anal triangle. On each side, the space occupied by this fat is called the **ischiorectal fossa**, because part of it is bounded laterally by the ischial tuberosities and medially by the rectum. The two ischiorectal fossae are continuous with one another both in front of and behind the anal canal. The fat within each ischiorectal fossa also extends forward between the upper surface of the perineal membrane and lower surface of the pelvic diaphragm on the lateral sides of the sphincter urethrae. These spaces are said to comprise anterior recesses of the ischiorectal fossa.

EPISIOTOMY

During childbirth it used to be very common for the physician to incise the posterior wall of the vagina, and the skin adjacent to it, in order to prevent ragged tearing of these tissues. Most obstetricians prefer to make the incision in the midline, through the fourchette of minor labia (i.e., where they meet posterior to the vagina) and then through the perineal body. The greatest risk of this approach is carrying the incision too far, into the external anal sphincter or even anal canal. In order to avoid this risk, some obstetricians start the incision to one side of the perineal body, and attempt to direct it posterolaterally. Although entailing less risk to the rectum, such an incision produces more bleeding and is slower to heal. Episiotomy is losing favor with the obstetricians I know.

Arteries of the Perineum

The artery for perineal structures is the **internal pudendal** branch of the internal iliac artery. After crossing the tip of the ischial spine just lateral to the pudendal nerve, the internal pudendal artery enters Alcock's canal (see next page) along with the nerve. The artery has three main branches (**inferior rectal, perineal, and the artery to the clitoris or penis**) that run with the three main branches of the pudendal nerve (inferior rectal, perineal, and dorsal nerve of the clitoris or penis). Each artery supplies blood to the same tissues that the nerves innervate. The only difference is that its the artery to the phallus has two additional named branches above and beyond the dorsal artery to the phallus.

The two other branches of the artery of the phallus arise during its path superior to the perineal membrane. They are the **artery to the bulb**, which pierces the perineal membrane and feeds the bulb of the penis or vestibule, then a bit further along its course a **deep artery of the penis or clitoris**, which pierces the perineal membrane and runs within the crus and corpus cavernosum or corpus clitoridis for their whole lengths. After the deep artery of the phallus is given off, the continuation of the parent vessel is the **dorsal artery of the penis or clitoris**, which travels with the dorsal nerve, but more toward the midline (see Fig. 6-8*B*).

Why, you may ask, is the artery that accompanies the pudendal nerve not simply called the pudendal artery, instead of the more specific name of internal pudendal artery? The answer is that there is

an additional artery that goes to the labia and clitoris or scrotum and penis that is distinguished as the **external pudendal artery**. This is a branch of the common femoral artery just below the inguinal ligament. It travels medially within the superficial fascia of the thigh and crosses the round ligament or spermatic cord to feed the skin of the anterior labia or scrotum, and then continues in the superficial fascia on the dorsal surface of the phallus toward its glans (see Fig. 6-8*B*).

Veins of the Perineum

Accompanying most of the branches of the internal pudendal artery are veins draining to an internal pudendal vein, which runs through Alcock's canal to exit the perineum through the lesser sciatic foramen and enter the pelvis through the greater sciatic foramen, finally emptying into the internal iliac vein.

The venous drainage of the penis and clitoris deserve special mention. Instead of there being paired dorsal veins of the phallus accompanying the dorsal arteries, there is a single **deep dorsal vein** that lies in the midline between these arteries beneath Buck's fascia (see Fig. 6-8*B*). This deep dorsal vein passes backward along the dorsal surface of the phallus toward the perineal membrane. When it gets there, it passes through the gap between the perineal membrane and arcuate pubic ligament to reach the ano-urogenital hiatus of the pelvic diaphragm. Passing through this hiatus, the deep dorsal vein reaches the prostatic or uterovaginal plexus of veins. Additionally, there is a **superficial dorsal vein of the phallus** that lies within the superficial fascia of the penis or clitoris along its dorsal midline, bracketed by the external pudendal arteries (see Fig. 6-8*B*). This vein also passes toward the root of the phallus, and when it gets there it bifurcates into two vessels which are the right and left **external pudendal veins**. These receive the anterior scrotal or labial veins and pass to the great saphenous vein of the thigh.

Nerves of the Perineum

The perineum, including the phallus and the back of the scrotum or posterior regions of the labia, is innervated by the **pudendal nerve** (S2, S3, and S4). It will be recalled that this nerve, after crossing the external surface of the sacrospinous ligament, enters the perineum through the lesser sciatic foramen. It comes immediately into contact with the fascia on the medial surface of the obturator internus below the arcus tendineus. The nerve embeds itself within this fascia and runs inferiorly toward the posterolateral corner of the perineal membrane (which is at the anterior limit of the ischial tuberosity). The space within the obturator fascia occupied by the pudendal nerve is called **Alcock's canal (pudendal canal)**.

Shortly before entering Alcock's canal, the pudendal nerve gives off the **inferior rectal nerve**. This nerve passes medially through the fat of the ischiorectal fossa toward the anal canal. It supplies the external anal sphincter and the skin around the anus.

While the pudendal nerve is within Alcock's canal, it bifurcates into its two terminal branches: the **perineal nerve** and the **dorsal nerve of the phallus** (**clitoris** or **penis**, as the case may be). The perineal nerve passes superficial to the perineal membrane and gives off branches for supply of the structures within the superficial pouch, the skin of the perineum, and the skin on the back surface of the scrotum or posterior regions of the labia. The dorsal nerve of the phallus passes on the superior surface of the perineal membrane, supplying whatever perineal muscles are found there (variously sphincter urethrovaginalis, sphincter urethra, compressor urethrae, deep transverse perineus), and then pierces the perineal membrane near its anterior edge to enter the phallus. It runs on the dorsal surface of the phallus (see Fig. 6-8*B*), beneath its deep fascia, supplying the skin and fascia of the phallus. (Some skin at the root of the phallus is innervated by the anterior scrotal or anterior labial branches of the ilioinguinal

nerve.) The erectile bodies of the phallus are not supplied by its dorsal nerve, but by branches of the pelvic plexus (see further on) that pierce the pelvic diaphragm and perineal membrane.

INTERNAL ORGANS OF THE PELVIS

Of the internal organs that lie within the pelvic cavity, two--the rectum and urinary bladder--occur in both sexes. The vagina, uterus, oviducts, and ovaries are found only in females; the vas deferens, seminal vesicles, and prostate gland occur only in males.

Urinary Bladder, Urethra, and Prostate

The urinary bladder is a subperitoneal organ immediately posterior to the pubic symphysis (see Fig. 6-3*C,D*). During embryonic life, the anterosuperior edge of the bladder was joined to a tubular duct that ran upward in the anterior extraperitoneal space to reach the umbilical cord. This duct, called the urachus, degenerates into a ligament called the **median umbilical ligament**. It can be seen running from the bladder toward the umbilicus in the anterior extraperitoneal space deep to the linea alba. It raises a fold of peritoneum called the **median umbilical fold**.

In females the urinary bladder rests on the anterior part of the pelvic diaphragm and its ano-urogenital hiatus (see Fig. 6-3*C*). The female urethra exits the pelvic cavity by passing through the hiatus. In males, the beginning of the urethra is surrounded by the prostate gland, which, therefore, lies just superior to the ano-urogenital hiatus and overlaps laterally onto the pubococcygeus (see Fig. 6-3*D*). The part of the male urethra surrounded by prostate gland is called the **prostatic urethra**. Its back wall is pushed forward into the urethral lumen by a lobule of the prostate gland. The ridge produced on the back wall of the prostatic urethra is called the **urethral crest**. It is widest in the middle of its course, to produce the so-called **seminal colliculus**. The prostate adds its secretion to seminal fluid via numerous tiny ducts that open into the urethra on either side of the seminal colliculus. From the peak of the colliculus itself, the epithelium of the urethra evaginates into the prostate gland to form a small tubular pouch called the **prostatic utricle**. Many authors believe that the prostatic utricle is the male homologue of the vagina. Thus, the entire urethra of the female would represent an elongated version of the proximal half of the male prostatic urethra.

Ductus Deferens and Seminal Vesicles

The **ductus deferens (vas deferens)** enters the abdominal cavity at the deep inguinal ring (a finger's breadth above the midpoint of the inguinal ligament). In the abdominal cavity, the ductus deferens takes a postero-inferior course across the medial surfaces of the external iliac vessels and pelvic brim to enter the lateral extraperitoneal space of the pelvic cavity. Here it runs toward the posterolateral corner of the urinary bladder (crossing medial to the obturator nerve and obturator vessels on the inner surface of the obturator internus muscle). When the ductus deferens nears the back of the bladder, it turns medially into the subperitoneal space and runs along the superior border of the back wall of the bladder (crossing superior to the ureter) toward the midline. The two ducti deferentes meet in the midline of the posterior wall of the bladder and then turn downward toward the prostate gland. Each ductus expands to form the **ampulla of the ductus deferens**. Just lateral to each ampulla, on the back wall of the bladder is a **seminal vesicle**. On the upper surface of the prostate, the seminal vesicle joins the ampulla of the vas deferens to form the **ejaculatory duct**. The two ejaculatory ducts pierce the prostate and runs obliquely through it to open up on the seminal colliculus to either side of the prostatic utricle.

Rectum

The rectum is said to begin where the taeniae coli of the sigmoid mesocolon end, on the front of the third sacral vertebra. The rectum lies retroperitoneally as far as the end of the sacrum and then gently turns forward, subperitoneally, along the upper surface of the pelvic diaphragm (see Fig. 6-3*C,D*). Because the rectum is usually filled with fecal matter, its retroperitoneal portion creates a bulge in the parietal peritoneum covering its anterior surface. On either side of this midline bulge the peritoneal cavity is said to form a **pararectal fossa**.

In the male, the subperitoneal portion of the rectum runs forward to contact the back of the urinary bladder (see Fig. 6-3*D*), with the seminal vesicles and ampullae of the vasa deferentes interposed. The rectum then makes a gentle turn inferiorly to pass through the ano-urogenital hiatus of the pelvic diaphragm. That part of the rectum below the pelvic diaphragm is named the **anal canal**. It heads downward and backward to open up onto the skin, at the anus, well below the tip of the coccyx. As the inferior wall of peritoneal sac reflects from the front surface of the rectum onto the upper surface of the bladder, it tends to dip down a bit between these two organs. The small extension of the peritoneal cavity between the front of the rectum and back of the bladder is called the **rectovesical fossa** (see Fig. 6-3*D*).

Vagina, Uterus, and Uterine (Fallopian) Tubes (Fig. 6-9)

Of course, females have no prostate glands, ducti deferentes, or seminal vesicles. But absence of these structures is not the crucial difference between the pelvic contents of men and women. In women, interposed between the urinary bladder in front and the rectum behind is the upper end of the **vagina** and the **uterus**.

The uterus is a hollow organ with thick fibromuscular walls. Its inferior portion, or **cervix**, is narrower than its superior part, called the **body**. The site where the body joins the cervix is called the **uterine isthmus**. There is a bend at the isthmus so that the body lies more anterior than the cervix (see Fig. 6-3*C*). This is called uterine **anteflexion**, and its degree varies from woman to woman. The cavity of the uterine body is triangular (with its base superiorly and its apex pointing downward) and is continuous at the isthmus with the narrow cavity of the cervix. The upper end of the cervical lumen is called the **internal uterine os**. The lumen of the cervix opens inferiorly, at what is called the **external uterine os**, into the vagina. The lower end of the cervix is invaginated into the upper end of the vagina, so that the vaginal lumen not only lies below the cervix but also surrounds its lower end. The part of the vaginal lumen that envelops the cervix is called the **fornix**; it is circular in shape but may be arbitrarily divided into an anterior, two lateral, and a posterior fornix.

From the superolateral corners of the uterine body emerge the **uterine (Fallopian) tubes (oviducts)**. Between the origins of the uterine tubes, the upper wall of the uterus is rounded to form the so-called **fundus** (the actual uterine cavity has a more or less straight upper border, thus, the fundus is due entirely to the shape of the wall).

Each uterine tube can be divided into four regions. The lumen of the tube passes through the thick uterine wall to connect up with the uterine cavity. This segment is referred to as the **interstitial** part of the uterine tube. Of that portion outside the uterus, the medial half has a very narrow cavity and is thus called the **isthmus**. Lateral to its midpoint, the uterine tube gets gradually wider as it moves away from the uterus, and is called the **ampulla**. A more dramatic widening just before the lumen of the tube opens up into the peritoneal cavity is called the **infundibulum**. The opening itself is known (somewhat erroneously) as the **abdominal ostium** of the uterine tube. Numerous feather-like projects of
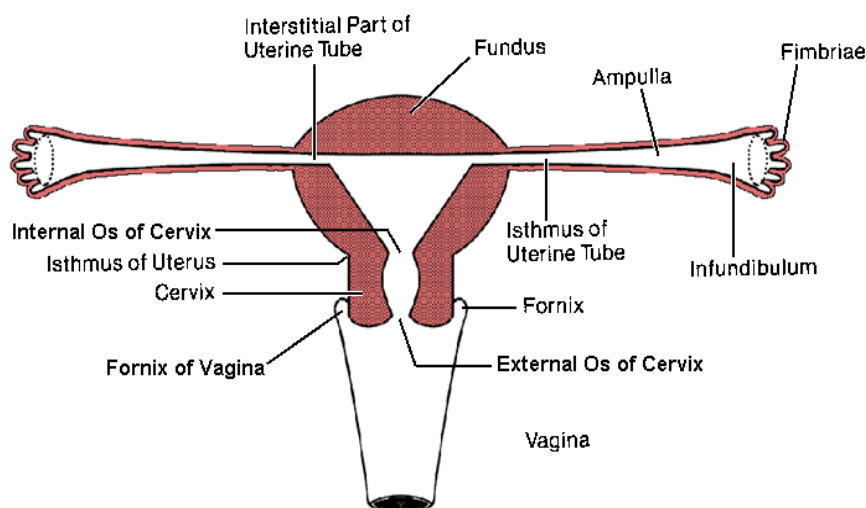
Figure 6-9. . Schematic coronal section of vagina, uterus, and oviducts.

infundibular wall surround the margin of the ostium and are called **fimbriae**. These are partly erectile and sort of "grasp" the ovary at the time of ovulation.

Ligaments of the Uterus and Ovaries (Fig. 6-10)

Although the embryonic formation of the uterus and uterine tubes is rather complex, the final result is as if these structures developed in the subperitoneal space between the urinary bladder and rectum, then grew upward, pushing parietal peritoneum ahead of them. If one views the development of the uterus and uterine tubes in this way (although it is not true), it is easy to visualize how upward protrusion of the uterus and its two laterally projecting uterine tubes would cause them to be covered on their front, top, and back surfaces by an adherent layer of peritoneum that is quite analogous to the visceral peritoneum that came to cover the bowel as it pushed into the abdominal cavity from the back. Thus, the uterine tubes and the body of the uterus are covered by visceral peritoneum. The visceral peritoneum on their posterior surface meets the visceral peritoneum on their anterior surface along the inferior borders of the uterine tubes and lateral borders of the uterine body. From these borders, a peritoneal bilayer extends downward to the parietal peritoneum at the floor of the peritoneal cavity, and outward to the parietal peritoneum along the lateral pelvic wall. This bilayer is just like a mesentery (but a bit thicker) and the sites where it merges with parietal peritoneum is just like the root of a mesentery. The bilayer is called the **broad ligament of the uterus**, and its root is called its **root**.

As the uterus grows it encroaches on the path that the gubernaculum takes to reach the future ovary. The developing uterus breaks across the gubernaculum, dividing it into two segments. One of these runs from the skin of the labium majus to the uterine body just inferior to the origin of the uterine tubes. It is called the **round ligament of the uterus**. It follows a path rather similar to that of the vas deferens, but after entering the pelvic cavity it passes through the root of the broad ligament and runs between its layers to reach the uterus. As it travels within the broad ligament, the round ligament raises a fold in its anterior layer.

The second segment of the gubernaculum also attaches to the uterus just below the origin of the uterine tube. It runs laterally between the two layers of broad ligament, parallel but inferior to the uterine tube. In the embryo, this segment of the gubernaculum passes into the lateral extraperitoneal space of the pelvis and then up to the ovary. When it contracts, this segment of the gubernaculum pulls the ovary downward into the lateral extraperitoneal space of the pelvis and then through lateral the root of the
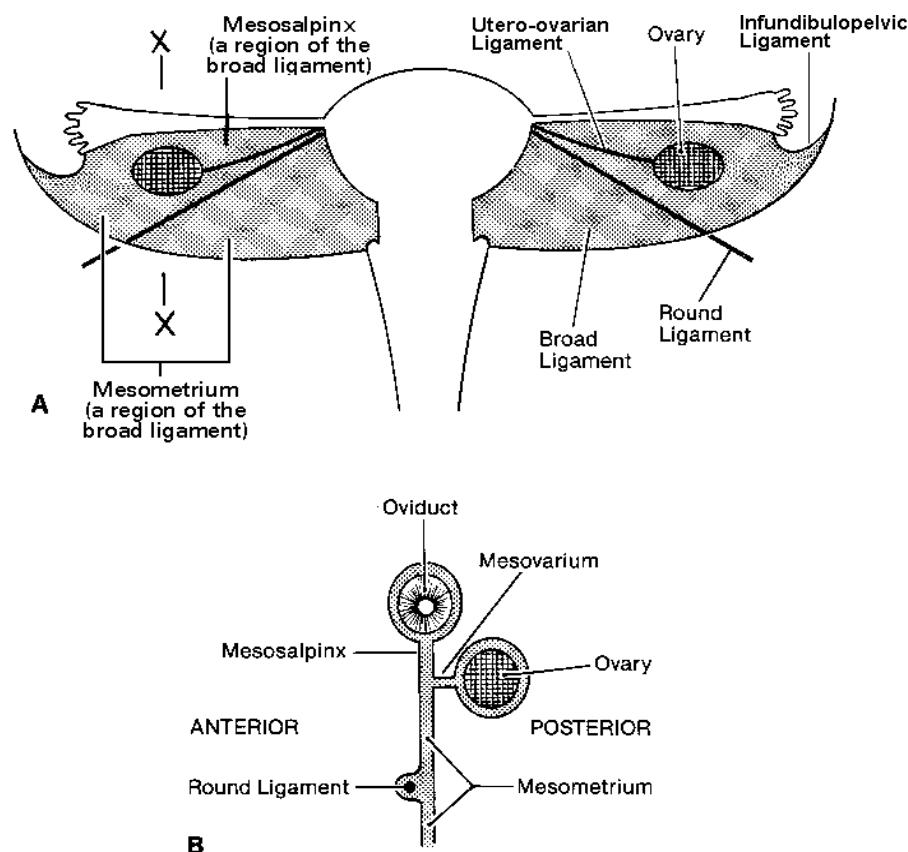
Figure 6-10. *A*, Schematic anterior view of uterus, broad ligament, and the ligaments passing between the layers of the broad ligament. *B*, Schematic sagittal section of the broad ligament through the plane X-X indicated in *A*.

broad ligament into a position between its layers just inferior to the ampulla of the uterine tube. Henceforth, this part of the gubernaculum will be known as the **utero-ovarian ligament (proper ligament of the ovary)**. It raises a ridge in the posterior layer of the broad ligament.

Once in position between the layers of the broad ligament, the ovary grows and bulges out the posterior layer of the broad ligament, thus creating a visceral peritoneum of the ovary. This protrusion is so complete that, along the anterior border of the ovary, visceral peritoneum on its superior surface meets visceral peritoneum from its inferior surface to form a bilayer which runs a short course anteriorly to merge with the posterior layer of the broad ligament. This bilayer is the **mesovarium**.

All these changes allow anatomists to assign two new names to parts of the broad ligament. The part that runs from the uterine tube down to the root of the mesovarium and the proper ovarian ligament is called the **mesosalpinx**. The part inferior to the root of the mesovarium and the proper ovarian ligament is called the **mesometrium**.

On either side, the connective tissue at the root of the broad ligament is said by some gynecologists to form a thickened **cardinal (= transverse cervical) ligament** that connects the uterus to the lateral wall of the pelvic cavity. The uterine artery is said to run in the cardinal ligament, and the ureter is said to pierce it. I am cautious about describing this structure because careful anatomical studies have not revealed its distinct presence, and I know some gynecologic surgeons who also doubt its existence. On the other hand, no-one doubts the existence of the **uterosacral ligaments** (right and left),

which run from the uterus (at the site of the internal os of the cervix) to the sacrum at S2 or S3. Each uterosacral ligament courses lateral to the rectum and raises a visible ridge in the parietal peritoneum.

Anterior and Posterior Cul-de-Sacs (Vesico-uterine and Recto-uterine Pouches) (see Fig. 6-3C)

At the site of the uterine isthmus, the visceral peritoneum on the anterior surface of the uterine body turns forward to become the parietal peritoneum over the upper surface of the bladder. It dips down a little between the two organs and thereby is created a small extension of the peritoneal cavity called the **anterior cul-de-sac (vesico-uterine pouch)**. Nonetheless, most of the anterior surface of the uterine cervix is not covered by peritoneum and is separated from the back of the bladder only by subperitoneal connective tissue.

The visceral peritoneum on the posterior surface of the uterus continues further downward; it covers the back of the cervix and even the posterior fornix of the vagina before turning backward as parietal peritoneum on the anterior surface of the rectum. Thus, a substantial pouch of peritoneal cavity extends downward between the rectum, in back, and the uterus and vagina, in front. This is the **posterior cul-de-sac** (**recto-uterine pouch of Douglas**).

Being the both the most inferior and posterior point of the peritoneal cavity in females, the posterior cul-de-sac is the repository for any free-floating abnormal contents of the peritoneal cavity. Examples of such abnormal peritoneal contents are blood, pus, and desquamated cancer cells. This takes on special significance, because a physician may easily sample the contents of the posterior cul-de-sac by passing a hypodermic needle through the posterior fornix of the vagina and the peritoneum on its surface. Such a procedure is called a **culdecentesis**. There is no comparably easy way to enter the rectovesical pouch of males.

Path of the Ovum

By giving a false embryology of the female reproductive system, I have failed to explain how it is that the lumen of the uterine tube opens into the peritoneal cavity of the pelvis. The reader may want to refer to an embryology text for the true cause of this connection, but the simple fact of the matter is that the visceral peritoneum on the outer surface of the uterine tube is continuous with the epithelial lining of the uterine tube lumen. As a result it is possible for things to pass from the peritoneal cavity into the uterine tube lumen and then to the uterine cavity. Just what sort of things are we talking about? After all, the peritoneal cavity is normally filled only with a thin layer of fluid. But this is not precisely true in females. The outer layer of the ovary is its visceral peritoneum. When the Graafian follicle ruptures through the outer layer of the ovary, it spills its contents through a hole in the visceral peritoneum and, thus, into the peritoneal cavity. To prevent the ovum from aimlessly floating throughout the peritoneal cavity and eventually degenerating, the fimbriae of the uterine tube "clasp" the ovary, sequestering a tiny portion of the peritoneal cavity between the abdominal ostium of the uterine tube and the ovarian surface. Thus, the journey of the ovum is through this tiny sequestered part of the peritoneal cavity directly into the uterine tube.

Of course, if something can pass from the peritoneal cavity into the uterine tube, and thence to the uterus, so may the opposite route be followed. Infections of the uterus may travel out the uterine tubes into the peritoneal cavity. An ovum fertilized normally in the

uterine tube may (rarely) turn around and exit the uterine tube to enter the peritoneal cavity. Once within the peritoneal cavity, the blastocyst may implant on the ovary, broad ligament, uterus, mesentery, bowel, and so on. Finally, the physician, realizing that it should be possible for something to pass from the uterus to the peritoneal cavity, may inject radio-opaque dye or radiolucent gas into the uterus, with the full expectation that if uterine tubes are normal the injected material will reach the peritoneal cavity. If it does not, there is an obstruction in the lumen of the uterine tube.

Ureter (see Fig. 5-31)

The ureter crosses the medial surface of the bifurcation of the common iliac artery and then follows the internal iliac artery into the pelvis. Upon reaching the lower limit of the peritoneal sac, the ureter turns forward and takes an anteromedial course to the bladder. In females, the ureter passes inferior to the uterine artery, one fingerbreadth lateral to the vaginocervical junction. In males the ureter passes inferior to the vas deferens.

ARTERIES OF THE PELVIC CAVITY

The superior rectal artery, median sacral artery, ovarian artery, and the pubic branch of the inferior epigastric artery (all previously described) originate outside the pelvis but enter it to supply pelvic organs. The other arteries in the pelvis are branches of the internal iliac artery.

Internal Iliac Artery

The internal iliac artery arises as a branch of the common iliac on the medial surface of the psoas major opposite the L5/S1 intervertebral disc (see Fig. 5-29). The internal iliac artery immediately crosses the pelvic brim into the lateral extraperitoneal space of the pelvis. Although the internal iliac artery gives off several constant named branches, the sequence in which they are given off is notoriously variable. It or its branches also give off tiny unnamed arteries to the pelvic part of the ureter. These participate in a linear anastomosis with ureteric branches from the renal artery. Often, the first thing the internal iliac artery does is to bifurcate into **posterior and anterior trunks**.

Posterior Trunk of the Internal Iliac Artery - Its Iliolumbar, Lateral Sacral, and Superior Gluteal Branches

Very soon after its origin, the posterior trunk gives off the **iliolumbar artery**, which is destined to supply the posterior abdominal wall. To do this, it travels superiorly across the pelvic brim out of the pelvis and into the abdominal cavity. Upon reaching the psoas major, the iliolumbar artery bifurcates into its iliac and lumbar branches. The former travels laterally behind the psoas to reach the iliacus, which it supplies. The lumbar branch travels superiorly behind the psoas, supplying it and the quadratus lumborum. It also sends a branch through the intervertebral foramen between L5 and S1 for supply of the spinal cord.

After giving off the iliolumbar artery, the posterior trunk of the internal iliac heads toward the greater sciatic foramen. Along the way it gives off the **lateral sacral artery**, which courses *medially* toward the sacrum. The lateral sacral artery gives off a branch that enters the 1st ventral sacral foramen[24]

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[24] This branch may arise independently from the posterior division of the internal iliac artery.

and then turns inferiorly to run on the pelvic surface of the sacrum just medial to the lower ventral foramina. During its descent, the lateral sacral artery gives off branches that enter these foramina. All the branches that enter ventral sacral foramina give off spinal branches, and then exit via the dorsal sacral foramina to supply the epaxial region of the trunk.

After the lateral sacral is given off, the continuation of the posterior trunk of the internal iliac is called the **superior gluteal artery**. This large vessel first passes between the lumbosacral trunk and 1st sacral ventral ramus (usually), and then goes out the greater sciatic foramen above the upper border of piriformis. It is an artery of the lower limb whose further course will be described in Chapter 12 (p. 546).

Anterior Trunk of the Internal Iliac Artery - Its Umbilical, Obturator, Inferior Gluteal, Internal Pudendal, Middle Rectal, and Sex-Dependent Branches

Very shortly after it arises, the anterior trunk of the internal iliac gives off an **umbilical artery**. The umbilical artery runs toward the anterior abdominal wall along the superior surface of the urinary bladder near its lateral edge. Along the way, the vessel gives off **superior vesical** branches to the bladder and then loses its lumen to take on the name of **lateral umbilical ligament**. The lateral umbilical ligament turns upward in the anterior extraperitoneal space and takes an oblique course toward the umbilicus. It raises a longitudinal fold--the **lateral umbilical fold** of parietal peritoneum--that lies between the fold raised by the median umbilical ligament (obliterated urachus) and that raised by the inferior epigastric artery.

After the origin of the umbilical artery, the branches of the anterior trunk of the internal iliac can come off in almost any imaginable sequence and must be traced to find out what they are. These branches consist, in both sexes, of obturator, internal pudendal, inferior gluteal, and (it is said) middle rectal arteries.

The **obturator artery** runs on the inner surface of the obturator internus toward the obturator groove, where it meets the obturator nerve and exits the pelvic cavity to enter the thigh. Within the pelvis, the obturator artery supplies the obturator internus. It anastomoses with the pubic branch of the inferior epigastric artery. In fact, sometimes the internal iliac artery does not give off an obturator branch. In such cases, the obturator artery that goes to the lower limb is merely a continuation of the pubic branch of the inferior epigastric artery. This vessel and its continuation are then said to constitute an **aberrant obturator artery**.

Within the pelvis, the **internal pudendal and inferior gluteal arteries** run fairly close to one another; they often have a common stem. Where they are separate, the inferior gluteal is more posterior of the two. Both vessels head toward the greater sciatic foramen, through they pass inferior to piriformis. The inferior gluteal artery is a vessel of the lower limb and will be described further in Chapter 12 (p. 547). The internal pudendal artery crosses the tip of the ischial spine and passes with the pudendal nerve through the lesser sciatic foramen to take up a position on the inner surface of the obturator internus below the arcus tendineus, thus in the perineum. Its course and branches within the perineum are discussed later in this chapter.

Most texts describe a **middle rectal artery** that simply goes to the rectum. I've only seen such a structure once or twice. My surgeon friends say they never look for it.

Sex-Dependent Branches of the Anterior Trunk - Inferior Vesical Artery in Males and Uterine Artery in Females. In males, the anterior trunk of the internal iliac artery (or one of its branches already mentioned) gives off an **inferior vesical artery** that runs toward the inferior part of the posterior

surface of the bladder. Upon reaching this location it gives off a branch to the ductus deferens (the **deferential artery**) and then ramifies on the bladder, seminal vesicles, and prostate. The deferential artery supplies the ductus deferens and travels with it through the spermatic cord into the scrotum.

In females, the artery corresponding to the inferior vesical is the **uterine**. It is much larger than its male counterpart. It runs in the root of the broad ligament toward the uterine cervix. During its path the uterine artery crosses anterosuperior to the ureter ("bridge over water"), which is following a subperitoneal course toward the bladder. Upon reaching the cervix just above the lateral fornix of the vagina, the uterine artery gives off a **vaginal artery** that descends along the vagina, supplying it and the inferior part of the urinary bladder[25]. The uterine artery itself turns superiorly to run within the broad ligament near the lateral border of the uterine cervix and body, suppling the uterus along the way. At the site of attachment of the utero-ovarian ligament, the uterine artery trifurcates, sending a tubal branch out along the lower border of the uterine tube, an ovarian branch out along the utero-ovarian ligament, and a ligamentous branch out along the round ligament. It is estimated that 25% of the blood supply to the ovary derives from the ovarian branch of the uterine artery.

Anastomotic Connections of the Internal Iliac Artery

Now that all the arteries of the abdomen and pelvis have been described, it is possible to consider the clinically relevant fact that there are extensive anastomotic connections between branches of the internal iliac artery and other vessels of the region. Such anastomoses, as elsewhere in the body, occur wherever the region of supply of one vessel overlaps or abuts that of another. **Therefore, a consideration of anastomoses is also a review of arterial distribution.** In the pelvis, they are particularly relevant because surgery for cancer of pelvic organs may require such extensive removal of structures that the internal iliac artery, or its anterior trunk, must be ligated. The pelvic structures that remain, and which are ordinarily supplied by this artery, are forced to rely for their blood supply on anastomoses between smaller branches of the internal iliac and branches of some other artery:

1. The lateral sacral artery from the internal iliac anastomoses with the median sacral from the aorta.
2. The iliolumbar artery from the internal iliac anastomoses with the lumbar arteries from the aorta and the deep circumflex iliac artery from the external iliac.
3. The obturator artery from the internal iliac anastomoses with the pubic branch of the inferior epigastric artery from the external iliac.
4. The internal pudendal artery from the internal iliac anastomoses through (a) its inferior rectal branches with the superior rectal artery from the IMA, and (b) through its perineal and phallic branches with the external pudendal artery from the common femoral.
6. The uterine artery from the internal iliac anastomoses with the ovarian artery from the aorta
7. The deferential branch of the inferior vesical artery anastomoses with the cremasteric branch of the inferior epigastric artery and with the testicular artery from the aorta. A comparable anastomosis between the ligamentous branch of the uterine and the artery to the round ligament occurs in women.
8. Outside the pelvis, the inferior gluteal and obturator branches of the internal iliac anastomoses with branches of the common femoral artery (these will be described in Chapter 12, p. 547).

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[25] The vaginal artery may arise independently from the anterior division of the internal iliac.

VEINS OF THE PELVIC CAVITY

All the branches of the internal iliac artery are accompanied by veins that run along side them and, quite logically, drain to the internal iliac vein.

The vesical, uterine, vaginal, and rectal veins each form by the coalescence of smaller, freely anastomosing vessels that lie in the outer connective coverings of their respective organs. Thus, in the male there is a **prostatic plexus of veins** all around the prostate gland and lower part of the bladder that gives rise to the inferior vesical vein. In the female there is a **uterovaginal plexus** draining to the uterine vein. In both sexes there is a **vesical plexus of veins** around the upper part of the bladder that gives rise to the superior vesical vein, and a **rectal plexus** draining to rectal veins. Each plexus anastomoses with nearby ones.

Three intrapelvic veins do not drain to the internal iliac. The **ovarian vein** runs with the ovarian artery into the abdominal cavity. The right ovarian vein empties into the inferior vena cava; the left ovarian vein empties into the left renal vein. The **median sacral vein** runs out of the pelvis (with its artery) to drain to the left common iliac vein. The superior rectal veins run up out of the pelvis alongside the superior rectal artery. The **superior rectal veins** contribute to the formation of the inferior mesenteric vein.

VENTRAL RAMI WITHIN THE PELVIC CAVITY

Obturator Nerve

We have already seen how one branch of the lumbar plexus, the obturator nerve (L2, 3, 4), enters the pelvic cavity to reach the obturator groove, which leads into the medial part of the thigh. During its intrapelvic course in the lateral extraperitoneal space, the obturator nerve lies on the inner surface of the obturator internus just below the pelvic brim. Interestingly, the obturator nerve does not supply the obturator internus, nor any other structure within the pelvic cavity.

Sacral Plexus (see Fig. 12-6)

The lumbar plexus gives rise to a few nerves for the lower limb, however, these are not nearly sufficient to innervate the entire lower limb, which contains cells not only from lumbar dermomyotomes 2-4, but also from the 5th lumbar through the 3rd sacral hypaxial dermomyotomes. The 5th lumbar ventral ramus (joined by a small twig from L4) joins with the 1st-3rd sacral ventral rami to form a sacral plexus of nerves, the terminal branches of which are also destined for the lower limb.

As just mentioned, a nerve bundle called the lumbosacral trunk is formed by a small branch of the 4th lumbar ventral ramus joining the 5th lumbar ventral ramus just superior to the pelvic brim on the cranial surface of the sacral ala (see Fig. 5-34). This **lumbosacral trunk** crosses the sacral part of the pelvic brim to enter the retroperitoneal space of the pelvic cavity. Here it joins the 1st sacral ventral ramus, which has entered the pelvic cavity through the 1st ventral sacral foramen. Together they cross onto the ventral surface of the piriformis, where they form a plexus with the 2nd and 3rd sacral ventral rami. From the interweaving of nerve fibers on the ventral surface of the piriformis emerge a series of nerves that exit the greater sciatic foramen with the piriformis and distribute to the lower limb structures not innervated by the lumbar plexus. Exiting above the upper border of the piriformis is the **superior gluteal nerve**. Exiting below the lower border of the piriformis are the **sciatic nerve, inferior gluteal nerve, nerve to the obturator internus, nerve to the quadratus femoris, and the posterior cutaneous**

nerve of the thigh. These nerves are discussed in Chapter 12 (pp. 548-550). The piriformis itself gets a branch from the sacral plexus that is composed of axons from S1 and S2.

Other Branches of Sacral Ventral Rami

Not all the cells from the hypaxial portions of the 2nd and 3rd sacral hypaxial dermomyotomes enter the lower limb. Some join with cells from the 4th sacral hypaxial dermomyotomes to form the pelvic diaphragm and muscles of the perineum. Thus, very soon after their emergence from the ventral sacral foramina, the 2nd-4th sacral ventral rami give off branches destined for these structures.

Nerves to the Pelvic Diaphragm and Puborectalis

The 3rd and 4th sacral ventral rami give off branches to the pelvic diaphragm and puborectalis. These branches have no occasion to leave the pelvic cavity.

Pudendal Nerve (for Muscles of the Perineum and Most of Its Skin)

The 2nd-4th sacral ventral rami give off early branches that join together to form the **pudendal nerve**, destined to supply muscles and skin of the perineum. Since the perineum is below the pelvic diaphragm, the pudendal nerve must somehow exit the pelvic cavity. It does this by leaving through the greater sciatic foramen below the lower border of piriformis, but rather more medially than any of the other nerves with this relationship. The pudendal nerve immediately crosses onto the dorsal surface of the sacrospinous ligament and, upon reaching its lower border, passes downward through the lesser sciatic foramen (see Fig. 12-11, p. 519) to reach the inner surface of obturator internus inferior to the arcus tendineus. At this point it is in the perineum. Its further course will be discussed subsequently.

Pelvic Splanchnic Nerves (Parasympathetic Preganglionic From S3 and S4)

The 3rd-4th (and occasionally also either the 2nd or 5th) sacral ventral rami give off early branches that contain the parasympathetic preganglionic axons whose cell bodies lie in the sacral segments of the spinal cord. These branches comprise the pelvic splanchnic nerves. They provide the preganglionic parasympathetic innervation for the smooth muscle and glands of the hindgut (from approximately the left colic flexure downward). They also provide the preganglionic parasympathetic innervation to smooth muscle and glands for all the internal organs of the pelvis. (Even abdominal parts of the ureters may receive some innervation originating in the pelvic splanchnic nerves.)

Coccygeal Plexus

The ventral rami of S5 and Co (joined by a small twig from S4) unite to form a coccygeal plexus. Since the 5th sacral and 1st coccygeal somites do not give rise to muscle, the coccygeal plexus is just for supply of the skin near the coccyx.

PELVIC PORTION OF THE SYMPATHETIC TRUNK

The sympathetic trunk passes into the pelvis on the ventral surface of the sacrum medial to the ventral sacral foramina (see Fig. 5-34). From the ganglia arise gray rami communicantes for the sacral and coccygeal spinal nerves. It has been reported that women possess sacral splanchnic nerves that carry preganglionic sympathetic axons for the uterus and vagina.

INNERVATION OF THE INTERNAL ORGANS OF THE PELVIS

Sympathetic Innervation

The Subdiaphragmatic Sympathetic Ganglia

In the pelvis the representatives of subdiaphragmatic sympathetic ganglia are the minute **pelvic sympathetic ganglia** that lie on either side of the rectum posterior to the seminal vesicles (in men) or uterus (in women). From the pelvic sympathetic ganglia emanate postganglionic fibers that supply the lower part of the rectum and the more anteriorly lying pelvic organs (e.g., uterus, prostate, urinary bladder).

Preganglionic Sympathetic Input to Pelvic Sympathetic Ganglia

The preganglionic axons to the pelvic sympathetic ganglia pass in **lumbar splanchnic nerves**. These axons have come from cells in the lower region of the intermediolateral column, predominantly T12 - L2. It has been reported that in females some preganglionic sympathetic axons originating in spinal segments L1 and L2 actually descend within the sympathetic chain all the way down to the sacral sympathetic trunk and leave it as **sacral splanchnic nerves**. These are not found in males.

The minute pelvic sympathetic ganglia are interconnected by preganglionic sympathetic axons passing through one ganglion to get to another. These sympathetic nerve bundles are joined by preganglionic parasympathetic axons of the pelvic splanchnic nerves (see below) to form a **pelvic plexus**. The pelvic nerve plexus is connected to the inferior hypogastric plexus on each side by preganglionic sympathetic axons that have passed through it to get to pelvic sympathetic ganglia.

Parasympathetic Supply to Pelvic Organs

All pelvic organs receive their parasympathetic preganglionic input via the **pelvic splanchnic nerves**. These are early branches primarily of the 3rd and 4th sacral ventral rami. The pelvic splanchnic nerves carry preganglionic parasympathetic axons that have traveled from cell bodies in spinal cord segments S3-S4 out the ventral roots into the spinal nerves and thence to ventral rami. **The pelvic plexuses (right and left) are identified as those portions of the subdiaphragmatic plexus joined by pelvic splanchnic nerves**. They lie below the inferior hypogastric plexuses on either side of the rectum, posterior to the seminal vesicles in males or the uterus in females. As you already know, pelvic splanchnic nerves carry, among other things, parasympathetic preganglionic axons for the descending colon, sigmoid colon, and rectum. Some of these pass directly from the pelvic plexus to the colon or rectum, where they synapse on postganglionic cell bodies within its wall. Others travel up to the inferior hypogastric plexus and thence to the colon.

Pelvic organs anterior to the rectum (e.g., bladder, uterus, prostate) receive preganglionic parasympathetic axons that pass through the pelvic plexus to synapse on postganglionic parasympathetic cell bodies within the walls of these organs. However, in the pelvic plexus itself are not only small sympathetic ganglia but also tiny parasympathetic ganglia. Some of the parasympathetic innervation to pelvic organs is via postganglionic axons from these ganglia.

The pelvic splanchnic nerves are often called **nervi erigentes** (L. *erigo*, to raise), because they carry the preganglionic parasympathetic axons that, upon stimulation, cause the phallus to erect. These particular axons probably synapse in ganglia within the pelvic plexuses. In males, the relevant postganglionic fibers emerge from the pelvic plexus and descend inferiorly along the posterolateral aspect of the prostate gland. They run next to a prostatic artery and vein, forming a neurovascular bundle. At the apex of the prostate the nerves pass onto the posterolateral aspect of the membranous urethra, which they follow through the pelvic diaphragm and perineal membrane to reach the corpora cavernosa. Operations on the rectum put the pelvic plexus at risk. Operations on the prostate put the neurovascular bundle at risk. Damage to either may lead to impotence.

Visceral Pain From Internal Organs of the Pelvic Cavity

Visceral pain from all organs pelvic cavity travel back to the spinal cord along precisely the reverse of the pathway that brought sympathetic supply to these organs. Thus, if one knows the nerve bundles that carry sympathetic axons from the spinal cord to such an organ, one also knows the nerve bundles that carry pain from the organ back to the cord. In general, the pain returns to the same segments wherein lie the preganglionic sympathetic neurons for the organ.

An exception to the rule just stated concerns visceral sensation arising as the result of distension of pelvic organs. The axons carrying this sensation do not travel centrally with bundles carrying sympathetic outflow. Instead they travel centrally with bundles carrying parasympathetic outflow. Thus, all such pain fibers reach the S3-S4 (and occasionally either S2 or S5) levels of the cord.

The most severe labor pain arises from sustained contractions of the uterine body. This pain is carried centrally along the same nerves that bring sympathetic supply to the organ. You should deduce that spinal cord levels T12 - L2 are the source of sympathetic innervation to the uterus, but this is a case where the facts supercede deduction. In truth, the uterus receives it sympathetic supply from the T10 - L1 levels of the spinal cord and it is to these levels that the pain of uterine contraction returns.

As a second example of visceral pain pathways, we may trace pain produced by distension of the uterine cervix, as occurs during the first stage of labor. The sensory axons leave this organ to join the pelvic plexuses and then leave them via the pelvic splanchnic nerves. Thus, the sensory axons are carried to the S3 and S4 ventral rami, spinal nerves, and dorsal roots. The sensory cell bodies lie in the dorsal root ganglia and send their central process into the spinal cord segments S3 and S4. Referred pain from the uterine cervical distension is felt chiefly over the back of the sacrum.

The pain of delivery is a somatic pain due to perineal stretching and, if performed, episiotomy. This pain is carried by the pudendal nerve (S2-4).

It is possible to eliminate all labor and delivery pain by anesthetizing spinal nerves T10 - S4. Nowadays, the most popular means of producing anesthesia of T10 - S4 is via a lumbar epidural block. One determines if the proper levels have been anesthetized by testing the skin for its ability to respond to touch. The level of insensibility must rise as high as the umbilicus (T10) and as low as the perineum.

LYMPHATICS OF THE PERINEUM AND PELVIS

Nodes That Lie Along Vessels

In general, throughout the body, lymph nodes are gathered into groups that lie along major blood vessels. The lymph nodes of the abdomen, pelvis, and perineum follow this rule. More often than not, groups of nodes take the name of the vessels they lie near to.

Inguinal Nodes

In the subcutaneous tissue on the front of the thigh, immediately below the inguinal ligament, is a collection of lymph nodes called the **superficial inguinal nodes**. (Sometimes an upper group, lying along the origins of the superficial epigastric and superficial circumflex iliac vessels, and a lower group, lying along the terminal part of the great saphenous vein, are distinguished.) The nodes of the superficial inguinal group are very large. They are palpable even in the absence of disease. The efferents of all these nodes pass through the deep fascia of the thigh either to reach the so-called **deep inguinal nodes** that lie around the upper few inches of the common femoral vein, or to run past these to reach the external iliac nodes.

Iliac Nodes

Along the external iliac, internal iliac, and common iliac vessels are nodes that are called **external iliac, internal iliac (pelvic), and common iliac nodes**, respectively. A subgroup of internal iliac nodes near the obturator vessels and nerve are called obturator nodes. Lower iliac nodes drain to the higher ones. The common iliac nodes drain to para-aortic nodes.

Lymphatic Drainage of Specific Structures

Skin and Subcutaneous Tissue

The skin and subcutaneous tissue of the perineum and pelvis, being below a transverse plane through the umbilicus drain into the superficial inguinal nodes.

Muscles and Deep Fascia

The deep structures of the body wall send lymphatic vessels centrally alongside the vasculature that supplies blood to these structures. Hence, lymphatics from deep structures of the perineum follow branches of the internal pudendal vessels back to internal iliac nodes.

Internal Organs

The internal organs of the body send lymphatic vessels centrally alongside the vasculature that supplies blood to these structures. Lymphatics follow blood vessels centrally toward the nodes at their origins. Pelvic organs drain to internal iliac (pelvic) nodes. The ovary gets most of its blood supply from vessels that arise from the abdominal aorta; hence, most of its lymph flows to para-aortic nodes. About 25% of the arterial blood to the ovary comes from the uterine artery; hence, some lymph from ovary flows to internal iliac nodes. the fundus of the uterus may also drain to para-aortic nodes. As would be expected, most of the uterine lymph flows to internal iliac (pelvic) nodes. That from the fundus may also go to para-aortic nodes. If these normal routes of lymphatic drainage are blocked by tumor, the uterus may drain to superficial inguinal nodes. Once tumor is found here, it is generally a sign of advanced disease.

SURFACE ANATOMY OF PELVIC ORGANS

Bony Landmarks on the Pelvis

The **anterior superior iliac spines** and the **posterior superior iliac spines** are palpable. Also, there is usually a dimple in the skin over each posterior superior iliac spine. A transverse plane at the level of the superior iliac spines is called the **interspinous plane**. It crosses the **2nd sacral vertebra**. It will be recalled that S2 marks the end of the dural sac.

The sacral hiatus, formerly an important landmark for epidural anesthesia, is usually palpable, as is the coccyx.

In the anterior midline the top of pubic symphysis can be felt. Extending laterally are the palpable pubic crests, which end in the pubic tubercles.

The ischiopubic rami, ending posteriorly at the ischial tuberosities, can be palpated from below. A finger placed in the vagina can feel the ischial spines through its wall. A finger placed through the anus can feel the ischial spines through of the wall of the rectum.

Positions of Organs and Structures

Surface anatomy of pelvic organs is not of much relevance, since they are generally accessible to examination only by palpation through the rectum or vagina. The one major exception is the uterus. By placing two fingers into the vagina up to the uterine cervix, and then pushing the uterus upward, a second hand on the abdomen above the pubis can palpate the uterine fundus. Masses associated with the uterine tubes or ovaries can also be felt.

The close relationship of the urinary bladder to the anterior pelvic brim (see Fig. 6-3*C,D*) is also of significance. When empty, the bladder does not rise out of the pelvis, but when full it may do so. As the bladder roof rises, it takes parietal peritoneum with it. Thus, with the patient's bladder full, one may make a surgical incision above the pubic symphysis and enter the subperitoneal area of the pelvic cavity. If this is desired, the bladder is artificially inflated at the time of surgery by means of a urethral catheter.

Most routine examination of pelvic organs involves placement of a finger (or fingers) in the rectum and, in women, also in the vagina.

In men, a rectal examination enables assessment of the posterior surface of the prostate gland, which is anterior to the rectum. An attempt can be made to feel the seminal vesicles on the back of the bladder (see Fig. 6-3*D*), but this is not often possible.

In women, the rectal examination enables assessment of the organs anterior to the rectum. These are the posterior wall of the vagina (separated from the rectum by the connective tissue of the rectovaginal septum) and the lower uterus (separated from the rectum by the posterior cul-de-sac) (see Fig. 6-3*C*). Normally the posterior wall of the vagina is examined intravaginally. However, if a vaginal examination cannot be performed (such as in a child) a rectal examination can give some information about the

back wall of the vagina. Rectal examination in adult women is done primarily to provide information about the posterior cul-de-sac, uterine cervix, and lower uterine body.

A vaginal examination enables assessment not only of the vagina, its fornices, and the lowest part of the cervix, but also of the urethra and base of the bladder, both of which lie anterior to the vagina (Fig. 6-3*C*). Placing one finger in the vagina and the adjacent finger in the rectum allows examination of the rectovaginal septum