Chapter 7
Surgical Anatomy of the Female Pelvis

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DEFINITIONS

Endopelvic fascia—The endopelvic fascias are those tissues outside of the muscularis of the pelvic organs that attach these organs to the pelvic sidewall. There is also some extension of loose areolar tissue over the surfaces of the organ. The surgical fascia used by gynecologists during pelvic reconstructive surgery, however, is primarily composed of the muscularis of the vaginal wall.

Pelvic diaphragm—The term *pelvic diaphragm* refers to the levator ani muscle and its covering fasciae, both the superior fascia and the inferior fascia. The term *pelvic floor* refers to all of the supportive structures that are involved with pelvic organ support. Sometimes the term *pelvic floor* and *pelvic diaphragm* can be used interchangeably, especially in the British literature.

Pelvic spaces—The space between the bladder and the anterior portion of the pelvic walls is the perivesical space or space of Retzius. The space between the lower urinary tract and the genital tract is the vesicovaginal or vesicocervical space. This is bounded laterally by the "bladder pillars," which is the region in which the tissues that go to the vagina separate from those that go to the bladder base. The rectovaginal space lies between the posterior vaginal wall and the anterior surface of the rectum, and lies primarily above the top of the perineal body.

Urethra and vesicle neck—The urethra is that portion of the lower urinary tract outside of the bladder that the urethral lumen traverses. That portion of the urethra lumen that is surrounded by the bladder vasculature is referred to as the vesicle neck.

Urinary trigone—The urinary trigone is a triangular visible area in the bladder, the apices of which are the ureteral orifices and the internal urinary meatus. This is a layer of smooth muscle connecting the ureters and the urethra, the edges of which are visible cystoscopically and when the bladder is open.

VULVA AND ERECTILE STRUCTURES

The bony pelvic outlet is bordered by the ischiopubic rami anteriorly and the coccyx and sacrotuberous ligaments posteriorly. It can be divided into anterior and posterior triangles, which share a common base along a line between the ischial tuberosities. The tissues filling the anterior triangle have a layered structure similar to that of the abdominal wall (**Table 7.1**). There is a skin and adipose layer (vulva) overlying a fascial layer (perineal membrane) that lies superficial to a muscular layer (levator ani muscles).

Subcutaneous Tissues of the Vulva

The structures of the vulva lie on the pubic bones and extend caudally under the pubic arch (**Fig. 7.1**). They consist of the mons, labia, clitoris, vestibule, and associated erectile structures and their muscles. The mons consists of hair-bearing skin over a cushion of adipose tissue that lies on the pubic bones. Extending posteriorly from the mons, the labia majora are composed of similar hair-bearing skin and adipose tissue, which contain the termination of the round ligaments of the uterus and the obliterated processus vaginalis (canal of Nuck). The round ligament can give rise to leiomyomas in this region, and the obliterated processus vaginalis can be a dilated embryonic remnant in the adult.

The labia minora, vestibule, and glans clitoris can be seen between the two labia majora. The labia minora are hairless skin folds, each of which splits anteriorly to run over, and under, the glans of the clitoris. The more anterior folds unite to form the hood-shaped prepuce of the clitoris, whereas the posterior folds insert into the underside of the glans as the frenulum.

Unlike the skin of the labia majora, the cutaneous structures of the labia minora and vestibule do not lie on an adipose layer but on a connective tissue stratum that is loosely organized and permits mobility of the skin during intercourse. This loose attachment of the skin to underlying tissues allows the skin to be easily dissected off the underlying fascia during skinning vulvectomy in the area of the labia minora and vestibule.

In the posterior lateral aspect of the vestibule, the duct of the major vestibular gland can be seen 3 to 4 mm outside

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the hymenal ring. The minor vestibular gland openings are found along a line extending anteriorly from this point, parallel to the hymenal ring and extending toward the urethral orifice. The urethra bulges slightly around the surrounding vestibular skin anterior to the vagina and posterior to the clitoris. Its orifice is flanked on either side by two small labia. Skene ducts open into the inner aspect of these labia and can be seen as small, punctate openings when the urethral labia are separated.

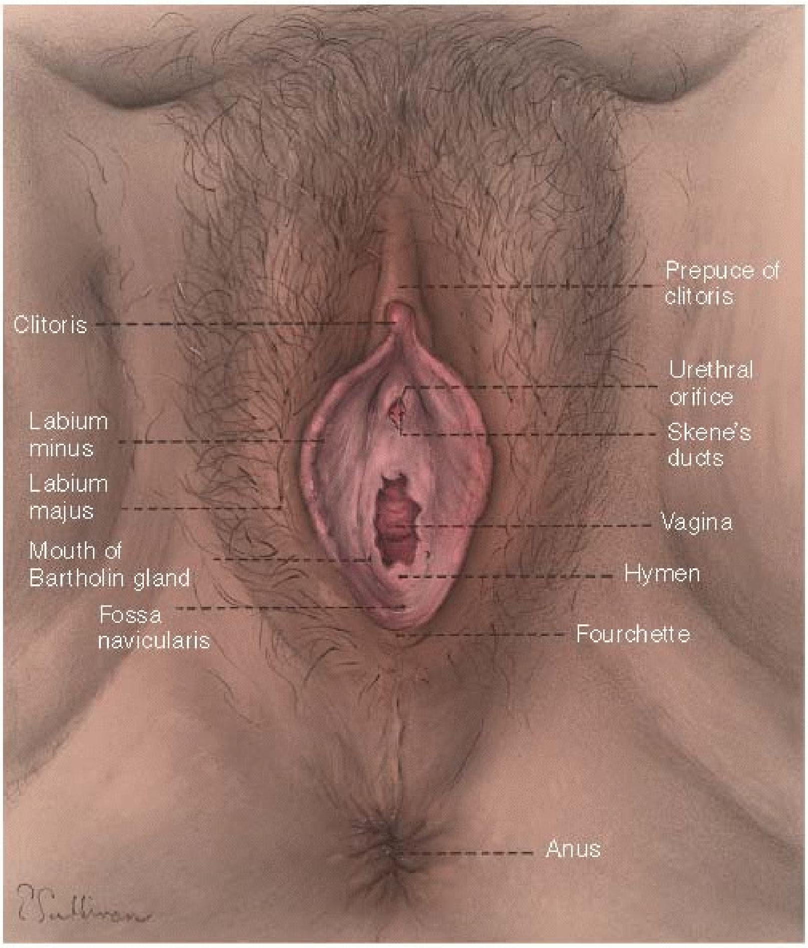

FIGURE 7.1 External genitalia.

TABLE 7.1 Layers of the Anterior Triangle of the Perineum
Skin

- Subcutaneous tissue
    - Camper fascia
    - Colles fascia
- Superficial space
    - Clitoris and its crura
    - Ischiocavernous muscle
    - Vestibular bulb
    - Bulbocavernous muscle
    - Greater vestibular gland
    - Superficial transverse perineal muscle
- Deep space-perineal membrane
    - Compressor urethrae
    - Urethrovaginal sphincter

Within the skin of the vulva are specialized glands that can become enlarged and thereby require surgical removal. The holocrine sebaceous glands in the labia majora are associated with hair shafts, and in the labia minora, they are freestanding. They lie close to the surface, which explains their easy recognition with minimal enlargement. In addition, lateral to the introitus and anus, there are numerous apocrine sweat glands, along with the normal eccrine sweat glands. The former structures undergo change with the menstrual cycle, having increased secretory activity in the premenstrual period. They can become chronically infected, as in hidradenitis suppurativa, or neoplastically enlarged, as in hidradenomas, both of which may require surgical therapy. The eccrine sweat glands in the vulvar skin rarely present abnormalities, but on occasion form palpable masses as syringomas.

The subcutaneous tissue of the labia majora is similar in composition to that of the abdominal wall. It consists of lobules of fat interlaced with connective tissue septa. Although there are no well-defined layers in the subcutaneous tissue, regional variations in the relative quantity of fat and fibrous tissue exist. The superficial region of this tissue, where fat predominates, has been called Camper fascia, as it is on the abdomen. In this region, there is a continuation of fat from the anterior abdominal wall, called the digital process of fat.

In the deeper layers of the vulva, there is less fat, and the interlacing fibrous connective tissue septa are much more evident than those in Camper fascia. This more fibrous layer is called Colles fascia and is similar to Scarpa fascia on the abdomen. Its interlacing fibrous septa of the subcutaneous tissue attach laterally to the ischiopubic rami and fuse posteriorly with the posterior edge of the perineal membrane (i.e., urogenital diaphragm).

Anteriorly, however, there is no connection to the pubic rami, and this permits communication between the area deep to this layer and the abdominal wall. These fibrous attachments to the ischiopubic rami and the posterior aspect of the perineal membrane limit the spread of hematomas or infection in this compartment posterolaterally but allow spread into the abdomen. This clinical observation has led to the consideration of Colles fascia as a separate entity from the superficial Camper fascia, which lacks these connections.

Superficial Compartment

The space between the subcutaneous tissues and perineal membrane, which contains the clitoris, crura, vestibular bulbs, and ischiocavernous and bulbocavernosus muscles, is called the superficial compartment of the perineum (**Fig. 7.2**). The deep compartment is the region just above the perineal membrane; it is discussed later.

The erectile bodies and their associated muscles within the superficial compartment lie on the caudal surface of the perineal membrane. The clitoris is composed of a midline shaft (body) capped with the glans. This shaft lies on, and is suspended from, the pubic bones by a subcutaneous suspensory ligament. The paired crura of the clitoris bend downward from the shaft and are firmly attached to the pubic bones, continuing dorsally to lie on the inferior aspects of the pubic rami. The ischiocavernous muscles originate at the ischial tuberosities and the free surfaces of the crura to insert on the upper crura and body of the clitoris. A few muscle fibers, called the superficial transverse perineal muscles, originate in common with the ischiocavernous muscle from the ischial tuberosity and lie medial to the perineal body.

The paired vestibular bulbs lie immediately under the vestibular skin and are composed of erectile tissue. They are covered by the bulbocavernosus muscles, which originate in the perineal body and lie over their lateral surfaces. These muscles, along with the ischiocavernous muscles, insert into the body of the clitoris and act to pull it downward.

The Bartholin greater vestibular gland is found at the tail end of the bulb of the vestibule and is connected to the vestibular mucosa by a duct lined with squamous epithelium. The gland lies on the perineal membrane and beneath the bulbocavernosus muscle. The intimate relation between the enormously vascular erectile tissue of the vestibular bulb and the Bartholin gland is responsible for the hemorrhage associated with removal of this latter structure.

The perineal membrane and perineal body are important to the support of the pelvic organs. They are discussed in the section on the pelvic floor.

Pudendal Nerve and Vessels

The pudendal nerve is the sensory and motor nerve of the perineum. Its course and distribution in the perineum parallel the pudendal artery and veins that connect with the internal iliac vessels (**Fig. 7.3**). The course and division of the nerve are described with the understanding that the vascular channels parallel them.

The pudendal nerve arises from the sacral plexus (S2-S4), and the vessels originate from the anterior division of the internal iliac artery. They leave the pelvis through the greater sciatic foramen by hooking around the ischial spine and sacrospinous ligament to enter the pudendal (Alcock) canal through the lesser sciatic foramen.

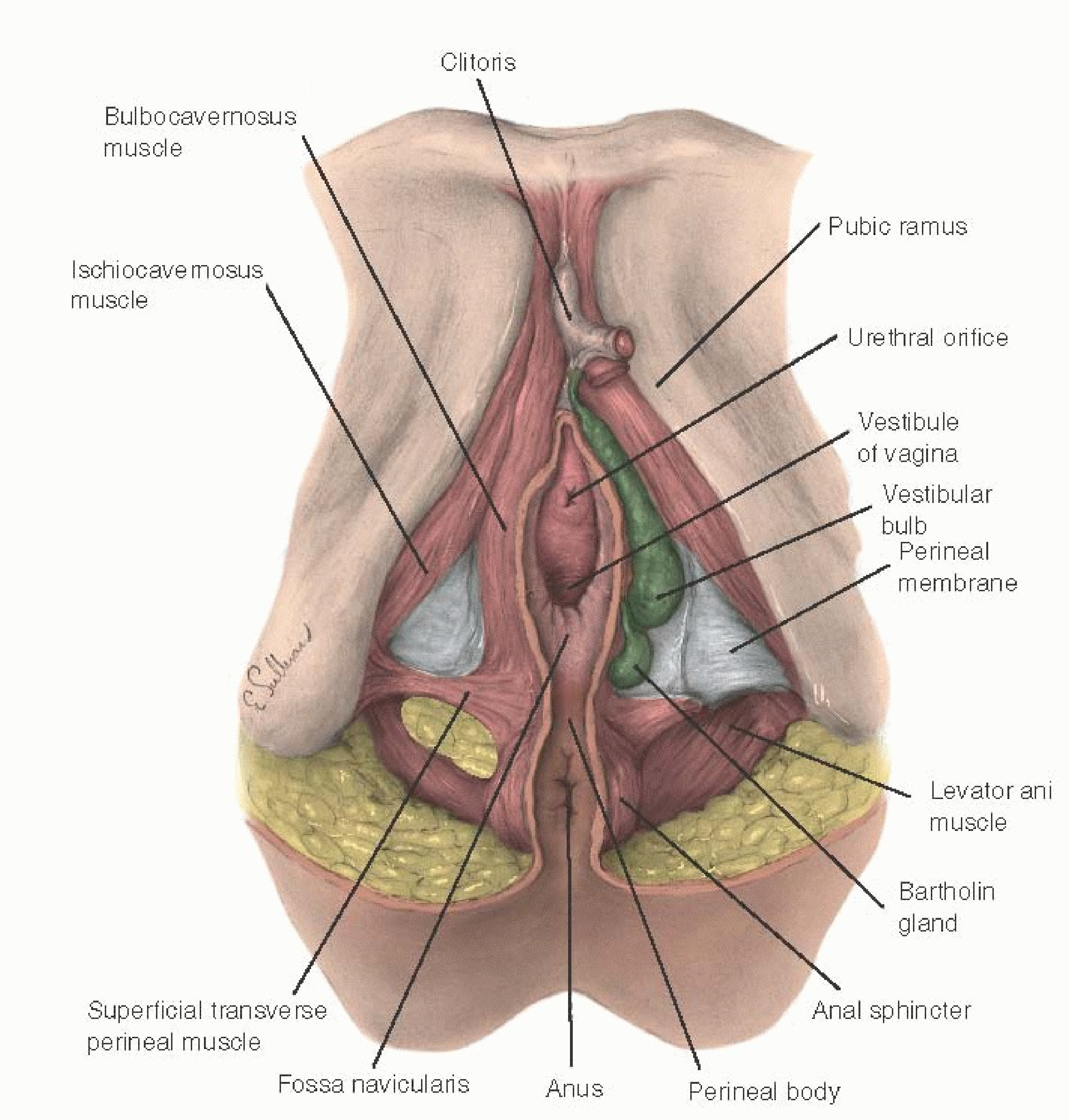

FIGURE 7.2 Superficial compartment and perineal membrane.

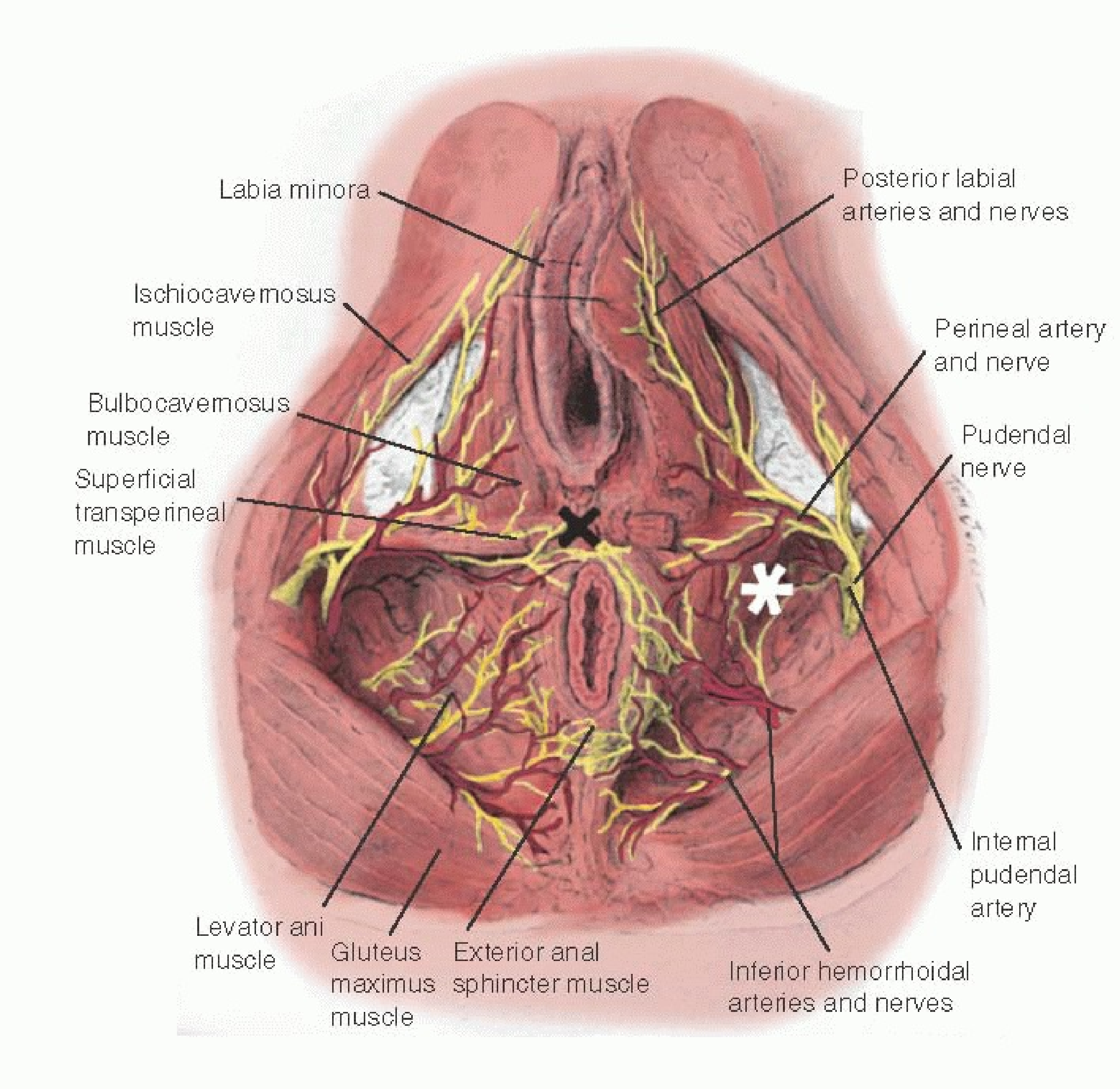

FIGURE 7.3 Pudendal nerve and vessels, with the position of the ischiorectal fossa (*asterisk*) and the perineal body (×) indicated. (From Anson BJ. *An atlas of human anatomy*. Philadelphia, PA: WB Saunders, 1950, with permission.)

The nerve and vessels have three branches: the clitoral, perineal, and inferior hemorrhoidal. The clitoral branch lies on the perineal membrane along its path to supply the clitoris. The perineal branch (the largest of the three branches) enters the subcutaneous tissues of the vulva behind the perineal membrane. Here, it supplies the bulbocavernosus, ischiocavernous, and transverse perineal muscles. It also supplies the skin of the inner portions of the labia majora, labia minora, and vestibule. The inferior hemorrhoidal branch goes to the external anal sphincter and perianal skin.

Lymphatic Drainage

The pattern of the vulvar lymphatic vessels and drainage into the superficial inguinal group of lymph nodes has been established by both injection studies and clinical observation. It is important to the treatment of vulvar malignancies; an overview of this system is provided here. This area is described and illustrated in more detail in Chapter 33.

Tissues external to the hymenal ring are supplied by an anastomotic series of vessels in the superficial tissues that coalesce to a few trunks lateral to the clitoris and proceed laterally to the superficial inguinal nodes (**Fig. 7.4**). The vessels draining the labia majora also run in an anterior direction, lateral to those of the labia minora and vestibule. These lymphatic channels lie medial to the labiocrural fold, establishing it as the lateral border of surgical resection.

Injection studies of the urethral lymphatics have shown that lymphatic drainage of this region terminates in either the right or left inguinal nodes. The clitoris has been said to have some direct drainage to deep pelvic lymph nodes, bypassing the usual superficial nodes, but the clinical significance of this appears to be minimal.

The inguinal lymph nodes are divided into two groups— the superficial and the deep nodes. There are 12 to 20 superficial nodes, and they lie in a T-shaped distribution parallel to and 1 cm below the inguinal ligament, with the stem extending down along the saphenous vein. The nodes are often divided into four quadrants, with the center of the division at the saphenous opening. The vulvar drainage goes primarily to the medial nodes of the upper quadrant. These nodes lie deep in the adipose layer of the subcutaneous tissues, in the membranous layer, just superficial to the fascia lata.

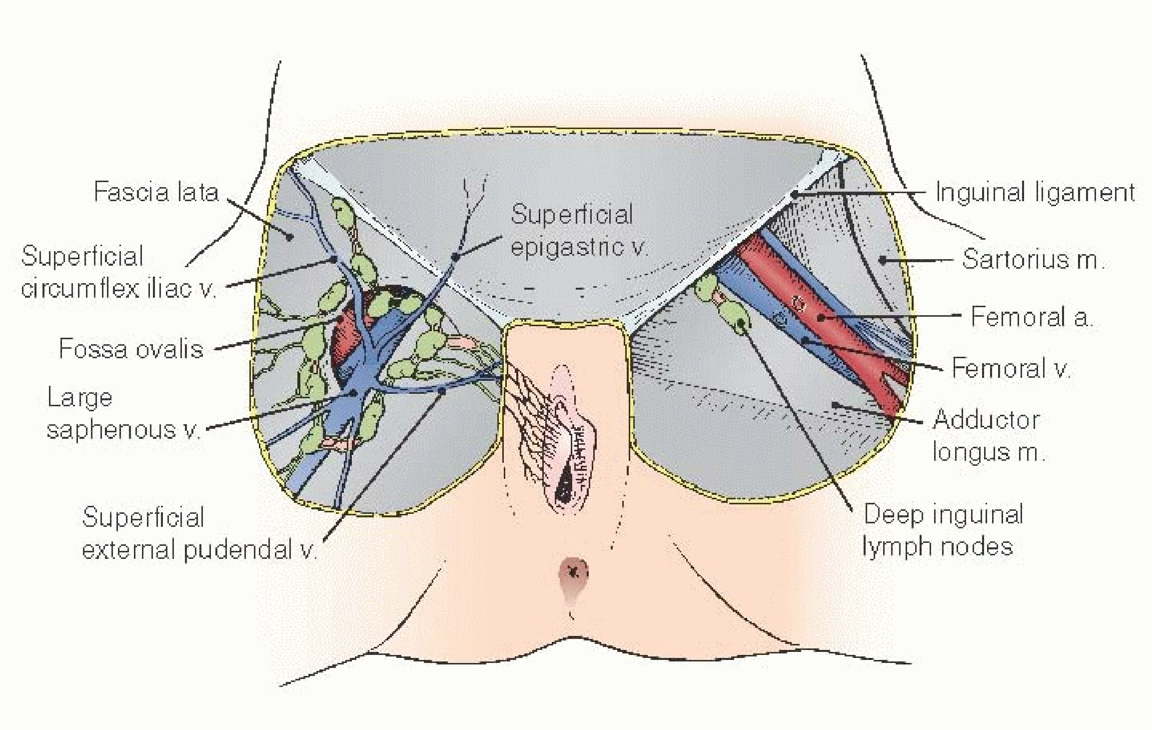

FIGURE 7.4 Lymphatic drainage of the vulva and femoral triangle. Superficial inguinal nodes are shown in the right thigh, and deep inguinal nodes are shown in the left thigh. Fascia lata has been removed on the left.

The large saphenous vein joins the femoral vein through the saphenous opening. Within 2 cm of the inguinal ligament, several superficial blood vessels branch from the saphenous vein and femoral artery. They include the superficial epigastric vessels that supply the subcutaneous tissues of the lower abdomen; the superficial circumflex iliac vessels that course laterally to the region of the iliac crest; and the superficial external pudendal vessels that supply the mons, labia majora, and clitoral hood.

Lymphatics from the superficial nodes enter the fossa ovalis and drain into one to three deep inguinal nodes, which lie in the femoral canal of the femoral triangle. They pass through the fossa ovalis (saphenous opening) in the fascia lata, which lies approximately 3 cm below the inguinal ligament, lateral to the pubic tubercle, along with the saphenous vein on its way to the femoral vein. The membranous layer of the subcutaneous tissues spans this opening as a trabeculate layer called a fascia cribrosa, pierced by lymphatics. The deep nodes are found under this fascia in the femoral triangle.

The femoral triangle is the subfascial space of the upper one third of the thigh. It is bounded by the inguinal ligament, sartorius muscle, and adductor longus muscle. Its floor is formed by the pectineal, adductor longus, and iliopsoas muscles. The femoral artery bisects it vertically between the anterosuperior iliac spine and pubic tubercle. The femoral vein lies medial to the artery; the femoral nerve is lateral to it.

As these vessels pass under the inguinal ligament, they carry with them an extension of the transversalis fascia, which is the extraperitoneal connective tissue deep to the rectus abdominis muscle called the femoral sheath. These sheaths extend about 2 to 3 cm below the inguinal ligament before fusing with the vascular adventitia. Besides the two parts of the femoral sheath that accompany these vessels, a third portion—the femoral canal—can be found in the space medial to the vein. The abdominal opening of this is the femoral ring. The femoral canal contains the deep inguinal lymph nodes. Lymph channels from these nodes pierce the membrane, filling the femoral ring to communicate with the external iliac nodes. Also within this region, the femoral vessels give rise to the deep external pudendal vessels. The external pudendal vessels run deep to the femoral vein over the pectineal muscle to pierce the fascia lata. Here, they become subcutaneous and form anastomoses

with branches of the internal pudendal vessels as well as the deep femoral and lateral circumflex femoral arteries.

THE PELVIC FLOOR

When humans assumed the upright posture, the opening in the bony pelvis came to lie at the bottom of the abdominopelvic cavity. This required the evolution of a supportive system to prevent the pelvic organs from being pushed downward through this opening. In the woman, this system must withstand these downward forces but allow for the passage of the large and cranially dominant human fetus. The supportive system that has evolved to meet these needs consists of a fibromuscular floor that forms a shelf spanning the pelvic outlet and that contains a cleft for the birth canal and excretory drainage. A series of visceral ligaments and fasciae tethers the organs and maintains their position over the closed portions of the floor. The floor consists of the levator ani muscles and perineal membrane. The openings in these structures for parturition and elimination have required the development of ancillary fibrous elements that are concentrated over open areas in the muscular floor to support the viscera in these weak areas. This section discusses the structures of the pelvic floor; the fibrous supportive system is described in the section on the pelvic viscera and cleavage planes and fascia.

Perineal Membrane (Urogenital Diaphragm)

The perineal membrane forms the inferior portion of the anterior pelvic floor. It is a triangular sheet of dense, fibromuscular tissue that spans the anterior half of the pelvic outlet (**Fig. 7.2**). It was previously called the urogenital diaphragm, and this change in name reflects the appreciation that it is not a two-layered structure with muscle in between, as was previously thought. It lies just caudal to the skeletal muscle of the striated urogenital sphincter (formerly the deep transverse perineal muscle). Because of the presence of the vagina, the perineal membrane cannot form a continuous sheet to close off the anterior pelvis in the woman, as it does in the man. It does provide support for the posterior vaginal wall by attaching the perineal body and vagina and perineal body to the ischiopubic rami, thereby limiting their downward descent. This layer of the floor arises from the inner aspect of the inferior ischiopubic rami above the ischiocavernous muscles and the crura of the clitoris. The medial attachments of the perineal membrane are to the urethra, walls of the vagina, and perineal body.

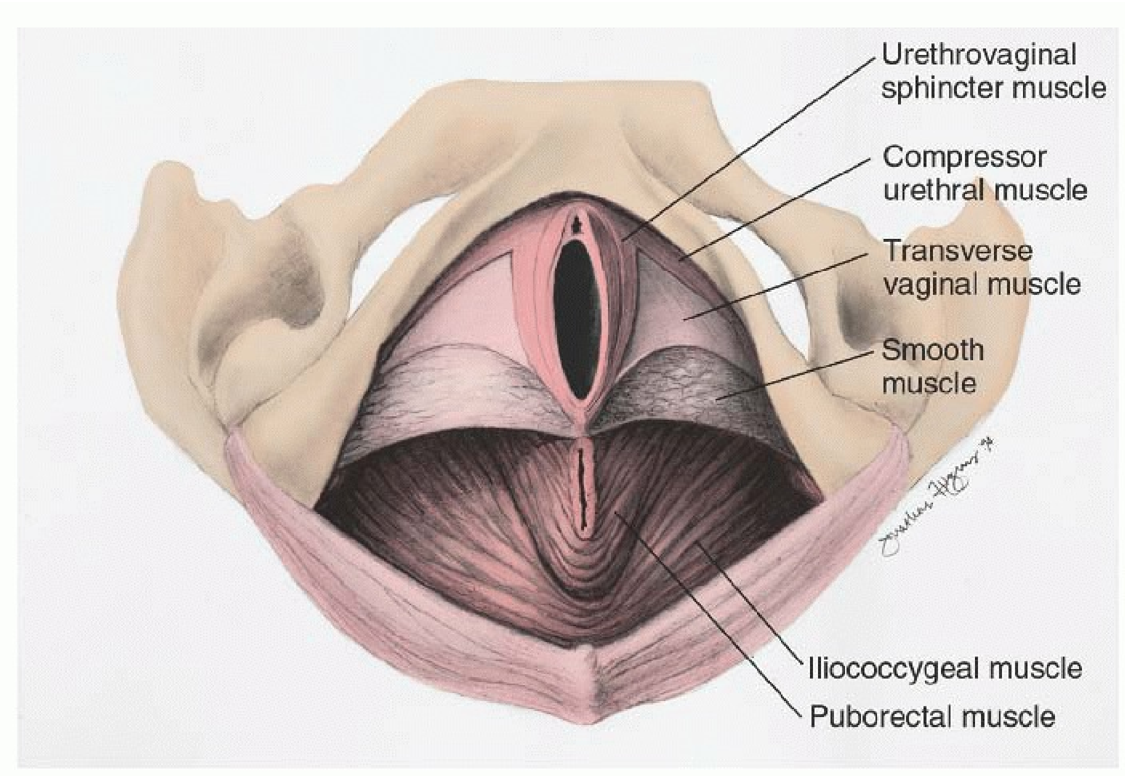

FIGURE 7.5 Structures visible after removal of the perineal membrane and superficial perineal muscles. (Copyright 1995 John O. L. DeLancey, with permission.)

Just cephalad to the perineal membrane lie two archshaped muscles that begin posteriorly to arch over the urethra (**Fig. 7.5**). These are the compressor urethral and the urethrovaginal sphincters. They are a part of the striated urogenital sphincter muscle in the woman and are continuous with the sphincter urethrae muscle. They act to compress the distal urethra. Posteriorly, intermingled within the membrane are skeletal muscle fibers of the transverse vaginal muscle and some smooth muscle fibers. The dorsal and deep nerve and vessels of the clitoris are also found within this membrane and are described later.

The primary function of the perineal membrane is related to its attachment to the vagina and perineal body. By attaching these structures to the bony pelvic outlet, the perineal membrane supports the pelvic floor against the effects of increases in intra-abdominal pressure and against the effects of gravity. The pubococcygeal and puborectal portions of the levator ani muscles lie just at the upper margin of the perineal membrane contacting its cranial surface. Contraction of these muscles elevates the medial margin of the perineal membrane along with the vagina and relaxation allows for its caudal movement. The amount of downward descent that is permitted by the connections of the perineal membrane to the midline structures can be assessed during an examination under anesthesia by placing a finger in the rectum, hooking it forward, and gently pulling the perineal body downward. If the perineal membrane has been torn during parturition, then an abnormal amount of descent is detectable, and the pelvic floor sags and the introitus gapes.

Perineal Body

Within the area bounded by the lower vagina, perineal skin, and anus is a mass of connective tissue called the perineal body (**Fig. 7.3**). The term *central tendon of the perineum* has also been applied to this structure and is descriptive, suggesting its role as a central point into which many muscles insert.

The perineal body is attached to the inferior pubic rami and ischial tuberosities through the perineal membrane and

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superficial transverse perineal muscles. Anterolaterally, it receives the insertion of the bulbocavernosus muscles.

On its lateral margins, the upper portions of the perineal body are connected with some fibers of the pelvic diaphragm. Posteriorly, the perineal body is indirectly attached to the coccyx by the external anal sphincter that is embedded in the perineal body, and it is attached at its other end to the coccyx. These connections anchor the perineal body and its surrounding structures to the bony pelvis and help to keep it in place.

Posterior Triangle: Ischiorectal Fossa

In the posterior triangle of the pelvis, the ischiorectal fossa lies between the pelvic walls and the levator ani muscles (**Fig. 7.3**). It has an anterior recess that lies above the perineal membrane. It is bounded medially by the levator ani muscles and anterolaterally by the obturator internus muscle. The main portion of the fossa is lateral to the levator ani and external anal sphincter, and it has a posterior portion that extends above the gluteus maximus. Traversing this region is the pudendal neurovascular trunk.

Anal Sphincters

The external sphincter lies in the posterior triangle of the perineum (**Fig. 7.6**). It is a single mass of muscle that has traditionally been divided into superficial and deep portions. The subcutaneous portion lies attached to the perianal skin and forms an encircling ring around the anal canal. It is responsible for the characteristic radially oriented folds in the perianal skin. The superficial part attaches to the coccyx posteriorly and sends a few fibers into the perineal body anteriorly and forms the bulk of the anal sphincter seen separated in third-degree midline obstetric tears. The fibers of the deep part generally encircle the rectum and blend indistinguishably with the puborectalis, which forms a loop under the dorsal surface of the anorectum and which is attached anteriorly to the pubic bone (**Fig. 7.6**).

The internal anal sphincter is a thickening in the circular smooth muscle of the anal wall. It lies just inside the external anal sphincter and is separated from it by a visible intersphincteric groove. It extends downward inside the external anal sphincter to within a few millimeters of the external sphincter's caudal extent. The internal sphincter can be identified just beneath the anal submucosa in repair of a chronic fourthdegree laceration of the perineum as a rubbery white layer that is often erroneously been referred to as fascia during obstetrical repair of fourth-degree laceration. The longitudinal smooth muscle layer of the bowel, along with some fibers of the levator ani, separates the external and internal sphincters as they descend in the intersphincteric groove.

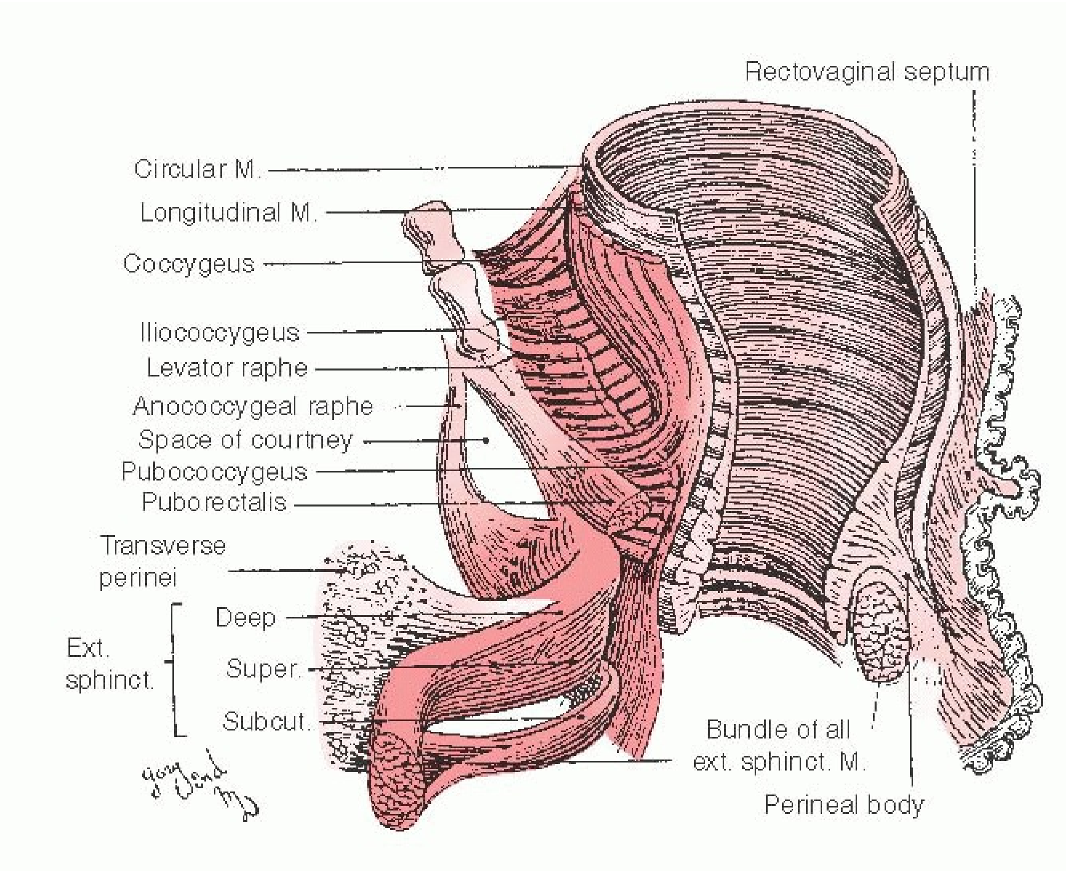

FIGURE 7.6 Semidiagrammatic dissection of the anorectal region in the woman with the external sphincter cut in the anterior midsagittal plane and reflected posteriorly (mucosa removed). The origin of the anterior muscle bundle is clarified, and the remaining anterolateral portions of the external sphincters are interdigitated into the transverse perinei. (From Oh C, Kark AE. Anatomy of the external anal sphincter. *Br J Surg* 1972;59:717, with permission.)

Levator Ani and Pelvic Wall

The typical depiction of the levator ani muscles in anatomy textbooks is unfortunately distorted by the extreme abdominal pressures generated during embalming that forces them downward. Many of these illustrations therefore fail to give a true picture of the horizontal nature of this strong supportive shelf of muscle. Examination of the normal standing patient is the best way to appreciate the nature of this closure mechanism, because the lithotomy position causes some relaxation of the musculature. During routine pelvic examination of the nullipara, the effectiveness of this closure can be appreciated, because it is often difficult to insert a speculum if the muscles are contracted and not relaxed.

The pelvic canal is spanned by the muscles of the pelvic diaphragm. This diaphragm consists of two components: (a) a thin horizontal shelf-like layer formed by the iliococcygeal muscle and (b) a thicker "U"-shaped sling of muscles that surround the levator hiatus that include the medial pubococcygeal and lateral puborectal muscles (**Fig. 7.7**). The open area within the U through which the urethra, vagina, and rectum pass is called the levator hiatus, and the portion of the hiatus anterior to the perineal body is called the urogenital hiatus.

The pubococcygeal muscle arises from a thin aponeurotic attachment to the inner surface of the pubic bone and inserts to the distal lateral vagina, perineal body, and anus. Some fibers also attach to the superior surface of the coccyx; hence the name pubococcygeus. Because the majority of the attachments, however, are to the vagina and anus, the term pubovisceral muscle is replacing this older term. The puborectal muscle is distinct from the pubococcygeal muscle and lies lateral to it. Its fibers originate from the lower pubis and some from the top of the perineal membrane. The muscle fibers pass beside the rectum forming a sling behind the anorectal junction.

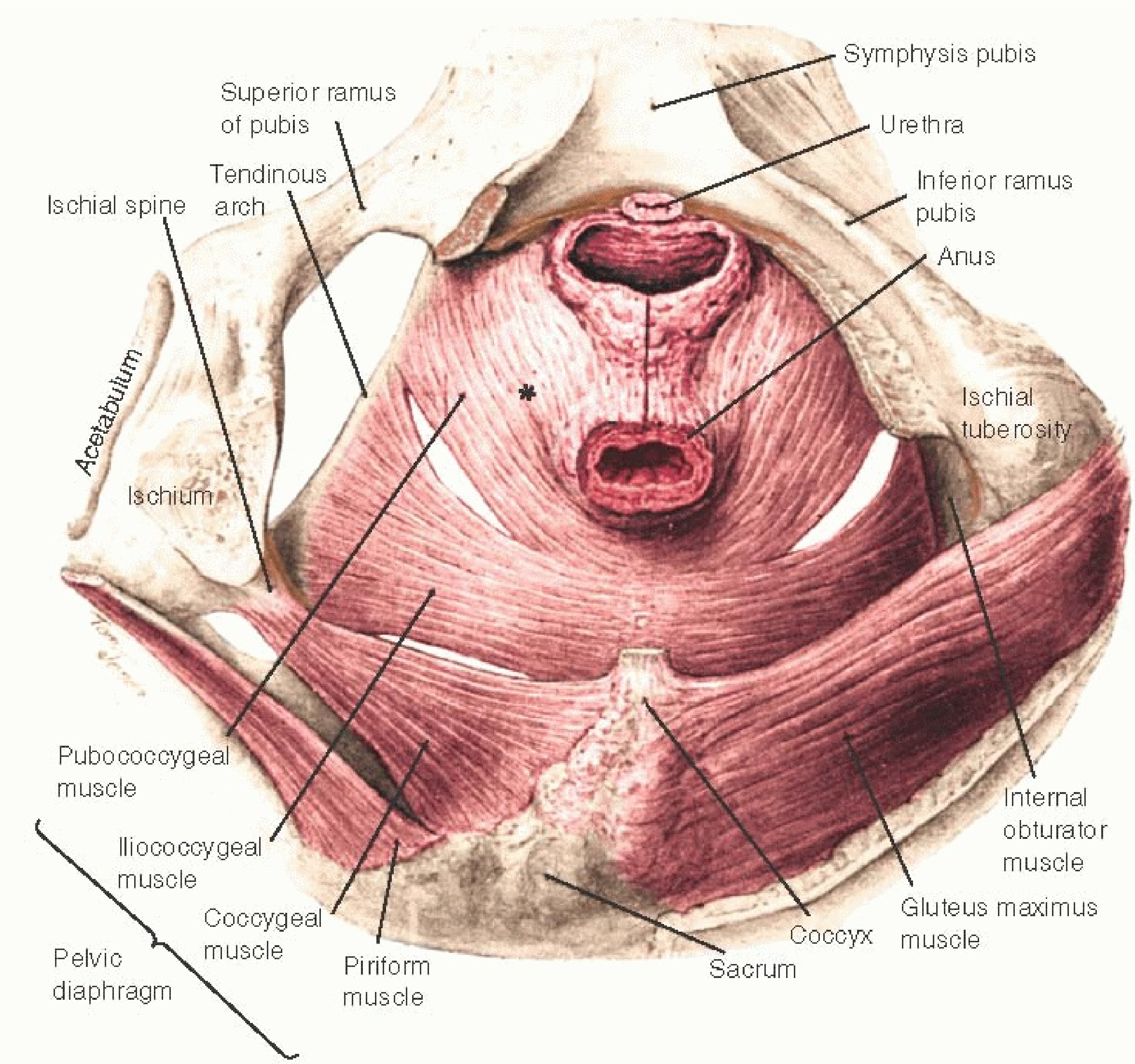

FIGURE 7.7 Anatomy of the pelvic floor. The *asterisk* indicates the puborectalis portion of the levator ani muscle. (From Anson BJ. *An atlas of human anatomy*. Philadelphia, PA: WB Saunders, 1950, with permission.)

The iliococcygeal muscle arises from a fibrous band overlying the obturator internus called the arcus tendineus levatoris ani. From these broad origins, the fibers of the iliococcygeal muscle pass behind the rectum and insert into the midline anococcygeal raphe and the coccyx. The coccygeal muscle arises from the ischial spine and sacrospinous ligament to insert into the borders of the coccyx and the lowest segment of the sacrum.

These muscles are covered on their superior and inferior surfaces by superior and inferior fasciae. When the levator ani muscles and their fasciae are considered together, they are called the pelvic diaphragm, not to be confused with the urogenital diaphragm (perineal membrane).

The normal tone of the muscles of the pelvic diaphragm keep the base of the U pressed against the backs of the pubic bones, keeping the vagina and rectum closed. The region of the levator ani between the anus and coccyx formed by the anococcygeal raphe (see previous discussion) is clinically called the levator plate. It forms a supportive shelf on which the rectum, upper vagina, and uterus can rest. The relatively horizontal position of this shelf is determined by the anterior traction on the fibrous levator plane by the pubococcygeal and puborectal muscles and is important to vaginal and uterine support.

The levator ani muscles receive their innervation from an anterior branch of the ventral ramus of the third and fourth sacral nerves called, appropriately, the nerve to the levator ani. Some aspects of the puborectal muscle may also receive a small contribution to the inferior hemorrhoidal branch of the pudendal nerve.

This section on the pelvic viscera discusses the structure of the individual pelvic organs and considers specific aspects of their interrelations (**Fig. 7.8**). Those aspects of blood supply, innervation, and lymphatic drainage that are idiosyncratic to the specific pelvic viscera are covered here. However, the section on the retroperitoneum, where the overall description of these systems is given, provides the general consideration of these latter three topics.

Genital Structures

Vagina

The vagina is a pliable hollow viscus with a shape that is determined by the structures surrounding it and by its attachments to the pelvic wall. These attachments are to the lateral margins of the vagina, so that its lumen is a transverse slit, with the anterior and posterior walls in contact with one another. The lower portion of the vagina is constricted as it passes through the urogenital hiatus in the levator ani. The upper part is much more capacious. The vagina is bent at an angle of 120 degrees by the anterior traction of the levator ani muscles at the junction of the lower one third and upper two thirds of the vagina (**Fig. 7.9**). The cervix typically lies within the anterior vaginal wall, making it shorter than the posterior wall by about 3 cm. The former is about 7 to 9 cm in length, although there is great variability in this dimension.

When the lumen of the vagina is inspected through the introitus, many landmarks can be seen. The anterior and posterior walls have a midline ridge, called the anterior and posterior columns, respectively. These are caused by the impression of the urethra and bladder and the rectum on the vaginal lumen. The caudal portion of the anterior column is distinct and is called the urethral carina. The recesses in front of and behind the cervix are commonly called the anterior and posterior fornices of the vagina, and the creases along the side of the vagina, where the anterior and posterior walls meet, are called the lateral vaginal sulci.

The vagina's relations to other parts of the body can be understood by dividing it into thirds. In the lower third, the

vagina is fused anteriorly with the urethra, posteriorly with the perineal body, and laterally to each levator ani by the “fibers of Luschka.” In the middle third are the vesical neck and trigone anteriorly, the rectum posteriorly, and the levators laterally. In the upper third, the anterior vagina is adjacent to the bladder and ureters (which allow these latter structures to be palpated on pelvic examination), posterior to the cul-de-sac, and lateral to the cardinal ligaments of the vagina.

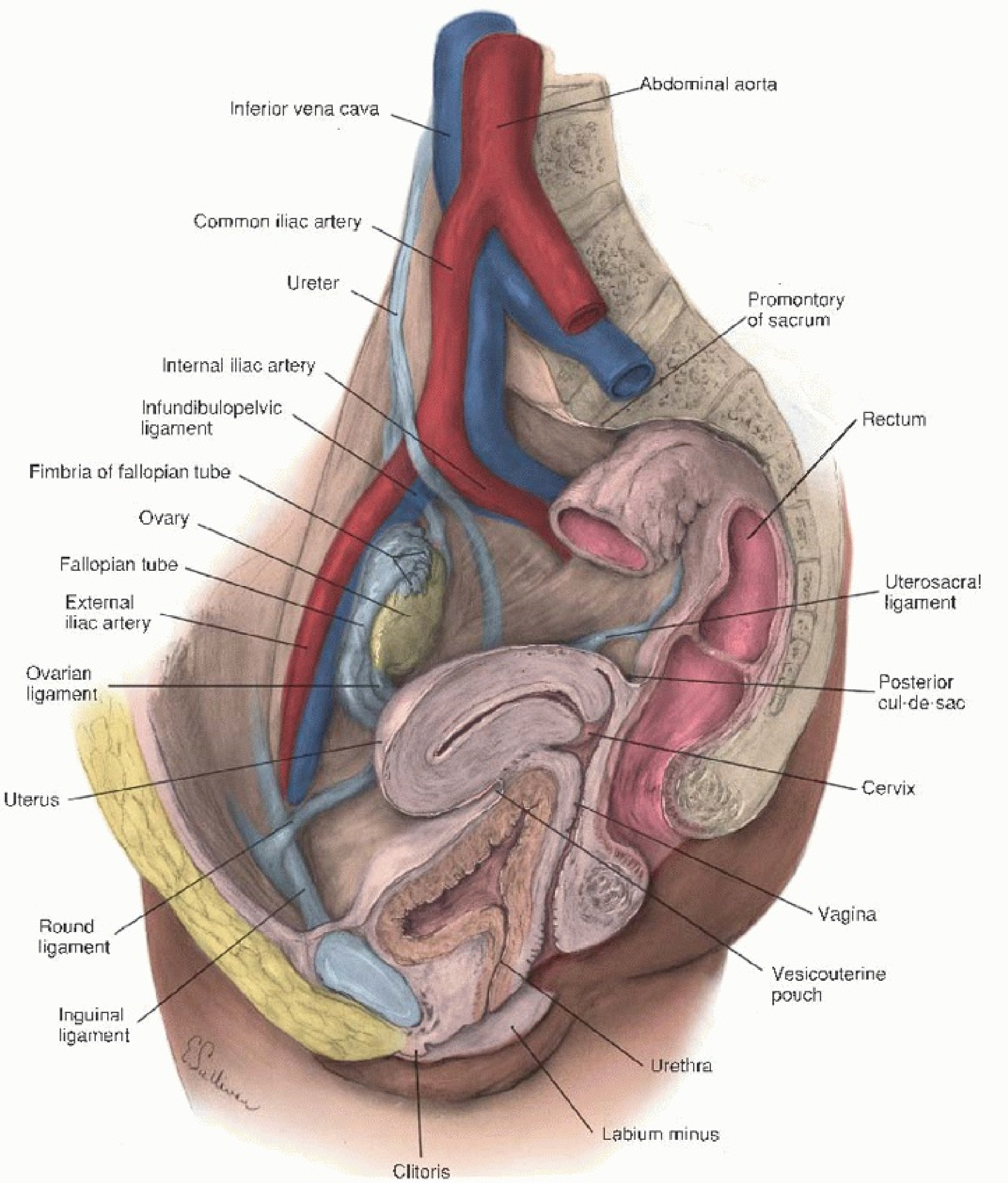

FIGURE 7.8 The pelvic viscera.

The vaginal wall contains the same layers as all hollow viscera (i.e., mucosa, submucosa, muscularis, and adventitia). Except for the area covered by the cul-de-sac, it has no serosal covering. The mucosa is of the nonkeratinized stratified squamous type and lies on a dense, dermislike submucosa. The similarity of these layers to dermis and epidermis has resulted in their being called the “vaginal skin.”

The vaginal muscularis is fused with the submucosa, and the pattern of the muscularis is a bihelical arrangement. Outside the muscularis, there is an adventitia that has varying degrees of development in different areas of the vagina. This layer is a portion of the connective tissue in the pelvis called the endopelvic fascia and has been given a separate name because of its unusual development. When it is dissected in the operating room, the muscularis is usually adherent to it, and this combination of specialized adventitia and muscularis is the surgeon's “fascia,” which might better be called the fibromuscular layer of the vagina, as Nichols and Randall suggested in *Vaginal Surgery*.

Uterus

The uterus is a fibromuscular organ with shape, weight, and dimensions that vary considerably, depending on both estrogenic stimulation and previous parturition. It has two portions: an upper muscular corpus and a lower fibrous cervix. In a woman of reproductive age, the corpus is considerably larger than the cervix, but before menarche, and after the menopause, their sizes are similar. Within the corpus, there is a triangularly shaped endometrial cavity surrounded by a thick muscular wall. That portion of the corpus that extends above the top of the endometrial cavity (i.e., above the insertions of the fallopian tubes) is called the fundus.

The muscle fibers that make up most of the uterine corpus are not arranged in a simple layered manner, as is true

in the gastrointestinal tract, but are arranged in a more complex pattern. This pattern reflects the origin of the uterus from paired paramesonephric primordia, with the fibers from each half crisscrossing diagonally with those of the opposite side.

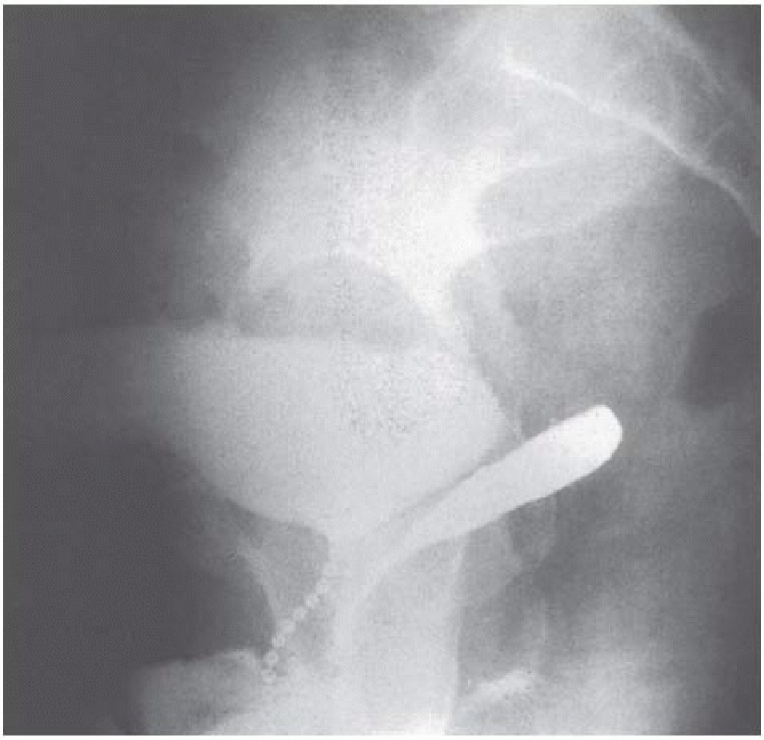

FIGURE 7.9 Bead chain cystourethrogram with barium in the vagina showing normal vaginal axis in a patient in the standing position.

The uterus is lined by a unique mucosa, the endometrium. It has both a columnar epithelium that forms glands and a specialized stroma. The superficial portion of this layer undergoes cyclic change with the menstrual cycle. Spasm of hormonally sensitive spiral arterioles that lie within the endometrium causes shedding of this layer after each cycle, but a deeper basal layer of the endometrium remains to regenerate a new lining. Separate arteries supply the basal endometrium, explaining its preservation at the time of menses.

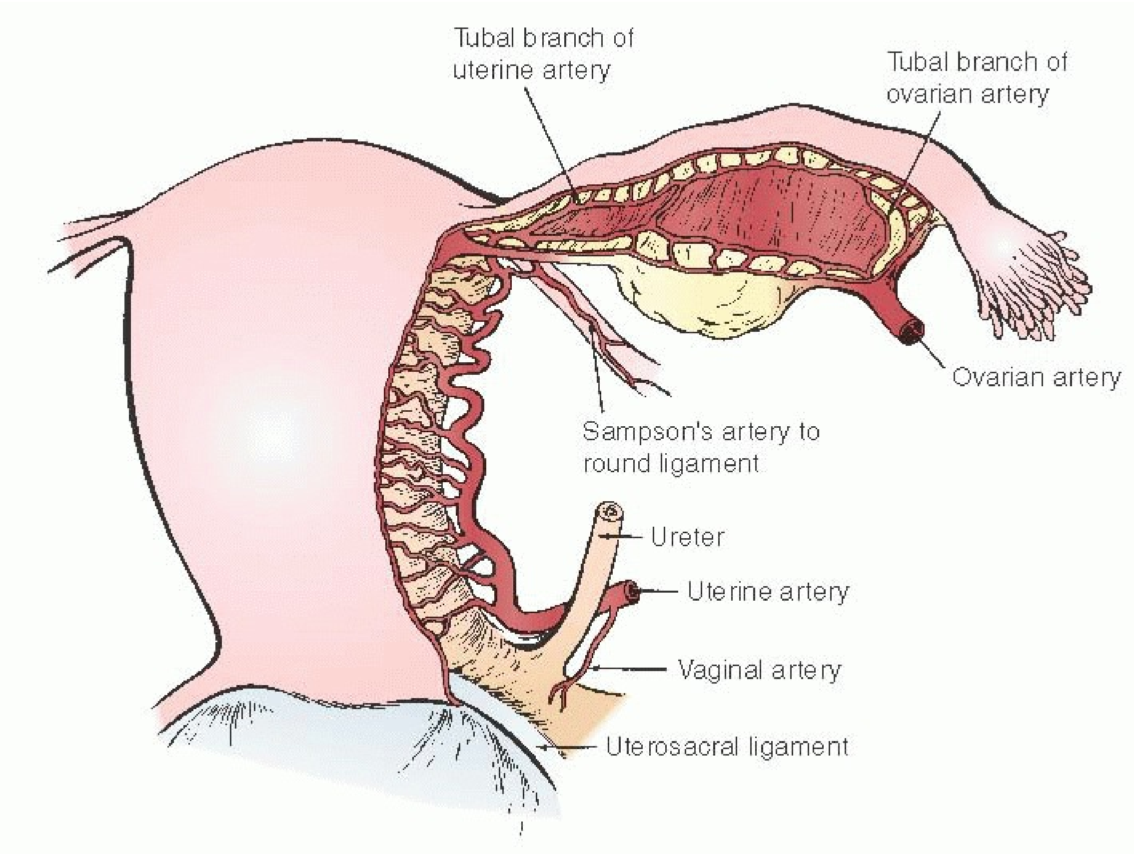

FIGURE 7.10 Uterine adnexa and collateral circulation of uterine and ovarian arteries. The uterine artery crosses over the ureter in the cardinal ligament and gives off cervical and vaginal branches before ascending adjacent to the wall of the uterus and anastomosing with the medial end of the ovarian artery. Note the small branch of the uterine or ovarian artery that nourishes the round ligament (Sampson's artery).

The cervix is divided into two portions: the portio vaginalis, which is that part protruding into the vagina; and the portio supravaginalis, which lies above the vagina and below the corpus.

The substance of the cervical wall is made up of dense fibrous connective tissue with only a small (about 10%) amount of smooth muscle. What smooth muscle is there lies on the periphery of the cervix, connecting the myometrium with the muscle of the vaginal wall. This smooth muscle and accompanying fibrous tissue are easily dissected off the fibrous cervix and form the layer reflected during intrafascial hysterectomy. It is circularly arranged around the fibrous cervix and is the tissue into which the cardinal and uterosacral ligaments and pubocervical fascia insert.

The portio vaginalis is covered by nonkeratinizing squamous epithelium. Its canal is lined by a columnar mucus-secreting epithelium that is thrown into a series of V-shaped folds that appear like the leaves of a palm and are therefore called plicae palmatae. These form compound clefts in the endocervical canal, not tubular racemose glands, as formerly thought.

The upper border of the cervical canal is marked by the internal os, where the narrow cervical canal widens out into the endometrial cavity. The lower border of the canal, the external os, contains the transition from squamous epithelium of the portio vaginalis to the columnar epithelium of the endocervical canal. This occurs at a variable level relative to the os and changes with hormonal variations that occur during a woman's life. It is in this active area of cellular transition that the cervix is most susceptible to malignant transformation.

There is little adventitia in the uterus, with the peritoneal serosa being directly attached to most of the corpus. The anterior portion of the uterine cervix is covered by the bladder; therefore, it has no serosa. Similarly, as discussed in the following, the broad ligament envelops the lateral aspects of the cervix and corpus; therefore, it has no serosal covering there. The posterior cervix does have a serosal covering.

Adnexal Structures and Broad Ligament

The fallopian tubes are paired tubular structures 7 to 12 cm in length (**Fig. 7.10**). Each has four recognizable portions. At the uterus, the tube passes through the cornu as an interstitial

portion. On emerging from the corpus, a narrow isthmic portion begins with a narrow lumen and thick muscular wall. Proceeding toward the abdominal end, next is the ampulla, which has an expanding lumen and more convoluted mucosa. The fimbriated end of the tube has many frondlike projections to provide a wide surface for ovum pickup. The distal end of the fallopian tube is attached to the ovary by the fimbria ovarica, which is a smooth muscle band responsible for bringing the fimbria and ovary close to one another at the time of ovulation. The outer layer of the tube's muscularis is composed of longitudinal fibers; the inner layer has a circular orientation.

The lateral pole of the ovary is attached to the pelvic wall by the infundibulopelvic ligament and the ovarian artery and vein contained therein. Medially, it is connected to the uterus through the utero-ovarian ligament. During reproductive life, it measures about 2.5 to 5 cm long, 1.5 to 3 cm thick, and 0.7 to 1.5 cm wide, varying with its state of activity or suppression, as with oral contraceptive medications. Its surface is mostly free but has an attachment to the broad ligament through the mesovarium, as discussed in the following.

The ovary has a cuboidal to columnar covering and consists of a cortex and medulla. The medullary portion is primarily fibromuscular, with many blood vessels and much connective tissue. The cortex is composed of a more specialized stroma, punctuated with follicles, corpora lutea, and corpora albicantia.

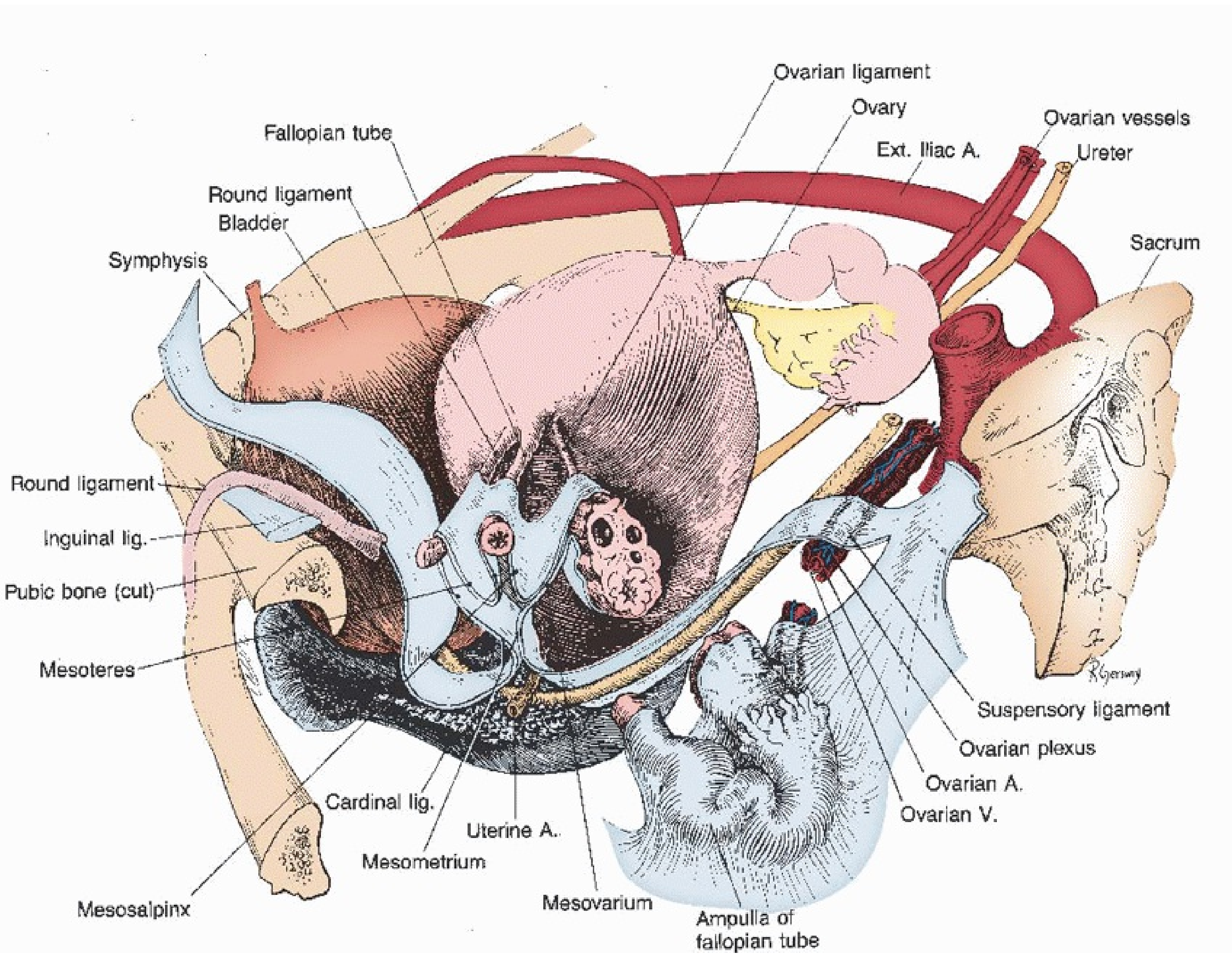

FIGURE 7.11 Composition of the broad ligament.

The round ligaments are extensions of the uterine musculature and represent the homolog of the gubernaculum testis. They begin as broad bands that arise on each lateral aspect of the anterior corpus. They assume a more rounded shape before they enter the retroperitoneal tissue, where they pass lateral to the deep inferior epigastric vessels and enter each internal inguinal ring. After traversing the inguinal canal, they exit the external ring and enter the subcutaneous tissue of the labia majora. They have little to do with uterine support.

The ovaries and tubes constitute the uterine adnexa. They are covered by a specialized series of peritoneal folds called the broad ligament. During embryonic development, the paired müllerian ducts and ovaries arise from the lateral abdominopelvic walls. As they migrate toward the midline, a mesentery of peritoneum is pulled out from the pelvic wall from the cervix on up. This leaves the midline uterus connected on either side to the pelvic wall by a double layer of peritoneum.

Within the upper layers of these two folds, called the broad ligament, lie the fallopian tubes, round ligaments, and ovaries (**Fig. 7.11**). The cardinal and uterosacral ligaments are at the lower margin of the broad ligament. These structures are visceral ligaments; therefore, they are composed of varying amounts of smooth muscle, vessels, connective tissue, and other structures. They are not the pure ligaments associated with joints in the skeleton.

The ovary, tube, and round ligament each have their own separate mesentery, called the mesovarium, mesosalpinx,

and mesoteres, respectively. These are arranged in a constant pattern, with the round ligament placed ventrally, where it exits the pelvis through the inguinal ligament, and the ovary placed dorsally. The tube is in the middle and is the most cephalic of the three structures. At the lateral end of the fallopian tube and ovary, the broad ligament ends where the infundibulopelvic ligament blends with the pelvic wall. The cardinal ligaments lie at the base of the broad ligament and are described under the section on supportive tissues and cleavage planes.

Blood Supply and Lymphatics of the Genital Tract

The blood supply to the genital organs comes from the ovarian arteries and uterine and vaginal branches of the internal iliac arteries. A continuous arterial arcade connects these vessels on the lateral border of the adnexa, uterus, and vagina (**Fig. 7.10**).

The blood supply of the upper adnexal structures comes from the ovarian arteries that arise from the anterior surface of the aorta just below the level of the renal arteries. The accompanying plexus of veins drains into the vena cava on the right and the renal vein on the left. The arteries and veins follow a long, retroperitoneal course before reaching the cephalic end of the ovary. They pass along the mesenteric surface of the ovary to connect with the upper end of the marginal artery of the uterus. Because the ovarian artery runs along the hilum of the ovary, it not only supplies the gonad but also sends many small vessels through the mesosalpinx to supply the fallopian tube, including a prominent fimbrial branch at the lateral end of the tube.

The uterine artery originates from the internal iliac artery. It usually arises independently from this source but can have a common origin with either the internal pudendal or vaginal artery. It joins the uterus near the junction of the corpus and cervix, but this position varies considerably, both with the individual and the amount of upward or downward traction placed on the uterus. Accompanying each uterine artery are several large uterine veins that drain the corpus and cervix.

On arriving at the lateral border of the uterus (after passing over the ureter and giving off a small branch to this structure), the uterine artery flows into the side of the marginal artery that runs along the side of the uterus. Through this connection, it sends blood both upward toward the corpus and downward to the cervix. Because the marginal artery continues along the lateral aspect of the cervix, it eventually crosses over the cervicovaginal junction and lies on the side of the vagina.

The vagina receives its blood supply from a downward extension of the uterine artery along the lateral sulci of the vagina and from a vaginal branch of the internal iliac artery. These form an anastomotic arcade along the lateral aspect of the vagina at the 3- and 9-o'clock positions. Branches from these vessels also merge along the anterior and posterior vaginal walls. The distal vagina also receives a supply from the pudendal vessels, and the posterior wall has a contribution from the middle and inferior hemorrhoidal vessels.

Lymphatic drainage of the upper two thirds of the vagina and uterus is primarily to the obturator and internal and external iliac nodes, and the distal-most vagina drains with the vulvar lymphatics to the inguinal nodes. In addition, some lymphatic channels from the uterine corpus extend along the round ligament to the superficial inguinal nodes, and some nodes extend posteriorly along the uterosacral ligaments to the lateral sacral nodes. These routes of drainage are discussed more fully in the discussion of the retroperitoneal space.

The lymphatic drainage of the ovary follows the ovarian vessels to the region of the lower abdominal aorta, where they drain into the lumbar chain of nodes (paraaortic nodes).

The uterus receives its nerve supply from the uterovaginal plexus (Frankenhäuser ganglion) that lies in the connective tissue of the cardinal ligament. Details of the organization of the pelvic innervation are contained in the section on retroperitoneal structures.

Lower Urinary Tract

Ureter

The ureter is a tubular viscus about 25 cm long, divided into abdominal and pelvic portions of equal length. Its small lumen is surrounded by an inner longitudinal and outer circular muscle layer. In the abdomen, it lies in the extraperitoneal connective tissue on the posterior abdominal wall, crossed anteriorly by the left and right colic vessels. Its course and blood supply are described in the section on the retroperitoneum.

Bladder

The bladder can be divided into two portions: the dome and base (**Fig. 7.12**). The musculature of the spherical bladder does not lie in simple layers, as do the muscular walls of tubular viscera, such as the gut and ureter. It is best described as a meshwork of intertwining muscle bundles. The musculature of the dome is relatively thin when the bladder is distended. The base of the bladder, which is thicker and varies less with distention of the dome, consists of the urinary trigone and a thickening of the detrusor, called the detrusor loop. This is a U-shaped band of musculature, open posteriorly, that forms the bladder base anterior to the intramural portion of the ureter. The trigone is made of smooth muscle that arises from the ureters that occupy two of its three corners. It continues as the muscle of the vesical neck and urethra. There it rests on the upper vagina. The shape of the bladder depends on its state of filling. When empty, it is a somewhat flattened disk, slightly concave upward. As it fills, the dome rises off the base, eventually assuming a more spherical shape.

The distinction between the base and dome has functional importance, because they have differing innervations. The bladder base has α-adrenergic receptors that contract when stimulated and thereby favor continence. The dome is responsive to *β* or cholinergic stimulation, with contraction that causes bladder emptying.

Anteriorly, the bladder lies against the lower abdominal wall. It lies against the pubic bones laterally and inferiorly and abuts the obturator internus and levator ani. Posteriorly, it rests against the vagina and cervix. These relations are discussed further in consideration of the pelvic planes and spaces.

The blood supply of the bladder comes from the superior vesical artery, which comes off the obliterated umbilical artery and inferior vesical artery, which is either an independent branch of the internal pudendal artery or arises from the vaginal artery.

Urethra

The urethral lumen begins at the internal urinary meatus and has a series of regional differences in its structure. It passes through the bladder base in an intramural portion for a little less than a centimeter. This region of the bladder, where the urethral lumen traverses the bladder base, is called the vesical neck.

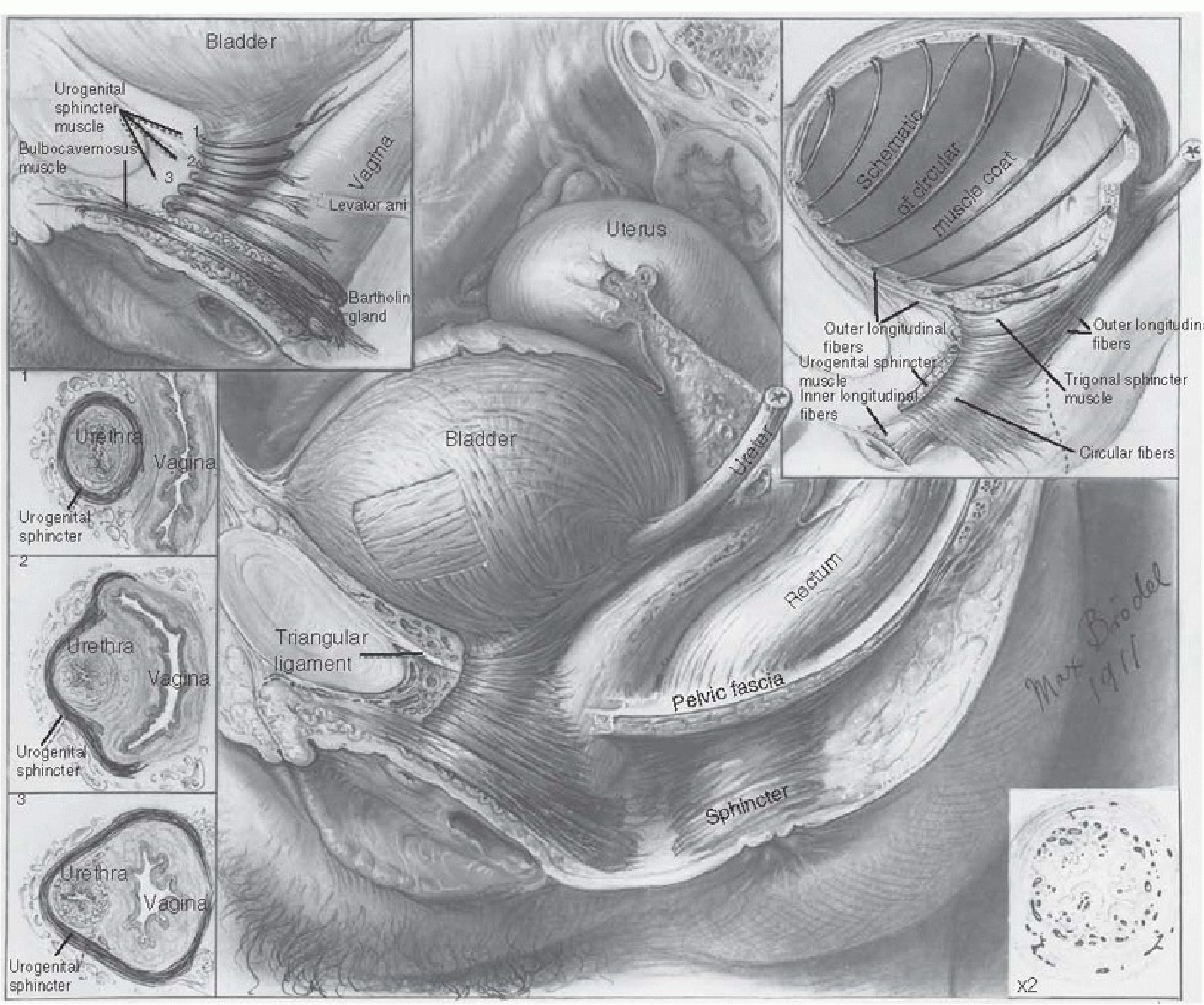

FIGURE 7.12 Lateral view of the pelvic organs showing the urethra and bladder. **Inset 3:** Two portions of the striated urogenital sphincter muscle, namely, the urethrovaginal sphincter and the urethral sphincter. The compressor urethra is not seen. (The original illustration is in the Max Brödel Archives in the Department of Art as Applied to Medicine, The Johns Hopkins University School of Medicine, Baltimore, MD, USA, with permission.)

The urethra itself begins outside the bladder wall. In its distal two thirds, it is fused with the vagina (**Fig. 7.12**), with which it shares a common embryologic derivation. From the vesical neck to the perineal membrane, which starts at the junction of the middle and distal thirds of the bladder, the urethra has several layers. An outer, circularly oriented skeletal muscle layer (urogenital sphincter) mingles with some circularly oriented smooth muscle fibers. Inside this layer is a longitudinal layer of smooth muscle that surrounds a remarkably vascular submucosa and nonkeratinized squamous epithelium that responds to estrogenic stimulation.

Within the submucosa is a group of tubular glands that lie on the vaginal surface of the urethra. These paraurethral (or Skene's) glands empty into the lumen at several points on the dorsal surface of the urethra, but two prominent openings on the inner aspects of the external urethral orifice can be seen when the orifice is opened. Chronic infection of these glands can lead to urethral diverticula, and obstruction of their terminal duct can result in cyst formation. Their location on the dorsal surface of the urethra reflects the distribution of the structures from which they arise.

At the level of the perineal membrane, the distal portion of the urogenital sphincter begins. Here the skeletal muscle of the urethra leaves the urethral wall to form the urethrovaginal sphincter (**Fig. 7.5**) and compressor urethrae (formerly called the deep transverse perineal muscle). Distal to this portion, the urethral wall is fibrous and forms a nozzle for aiming the urinary stream. The mechanical support of the vesical neck and urethra, which are so important to urinary continence, is discussed in the section of this chapter devoted to the supportive tissues of the urogenital system.

The urethra receives its blood supply both from an inferior extension of the vesical vessels and from the pudendal vessels.

Sigmoid Colon and Rectum

The sigmoid colon begins its S-shaped curve at the pelvic brim. It has the characteristic structure of the colon, with three tenia coli lying over a circular smooth muscle layer. Unlike much of the colon, which is retroperitoneal, the sigmoid has a definite mesentery in its midportion. The length of the mesentery and the pattern of the sigmoid's curvature vary considerably. It receives its blood supply from the lowermost portion of the inferior mesenteric artery: the branches called the sigmoid arteries.

As it enters the pelvis, the colon straightens its course and becomes the rectum. This portion extends from the pelvic brim

until it loses its final anterior peritoneal investment below the cul-de-sac. It has two bands of smooth muscle (anterior and posterior). Its lumen has three transverse rectal folds that contain the mucosa, submucosa, and circular layers of the bowel wall. The most prominent fold, the middle one, lies anteriorly on the right about 8 cm above the anus, and it must be negotiated during high rectal examination or sigmoidoscopy.

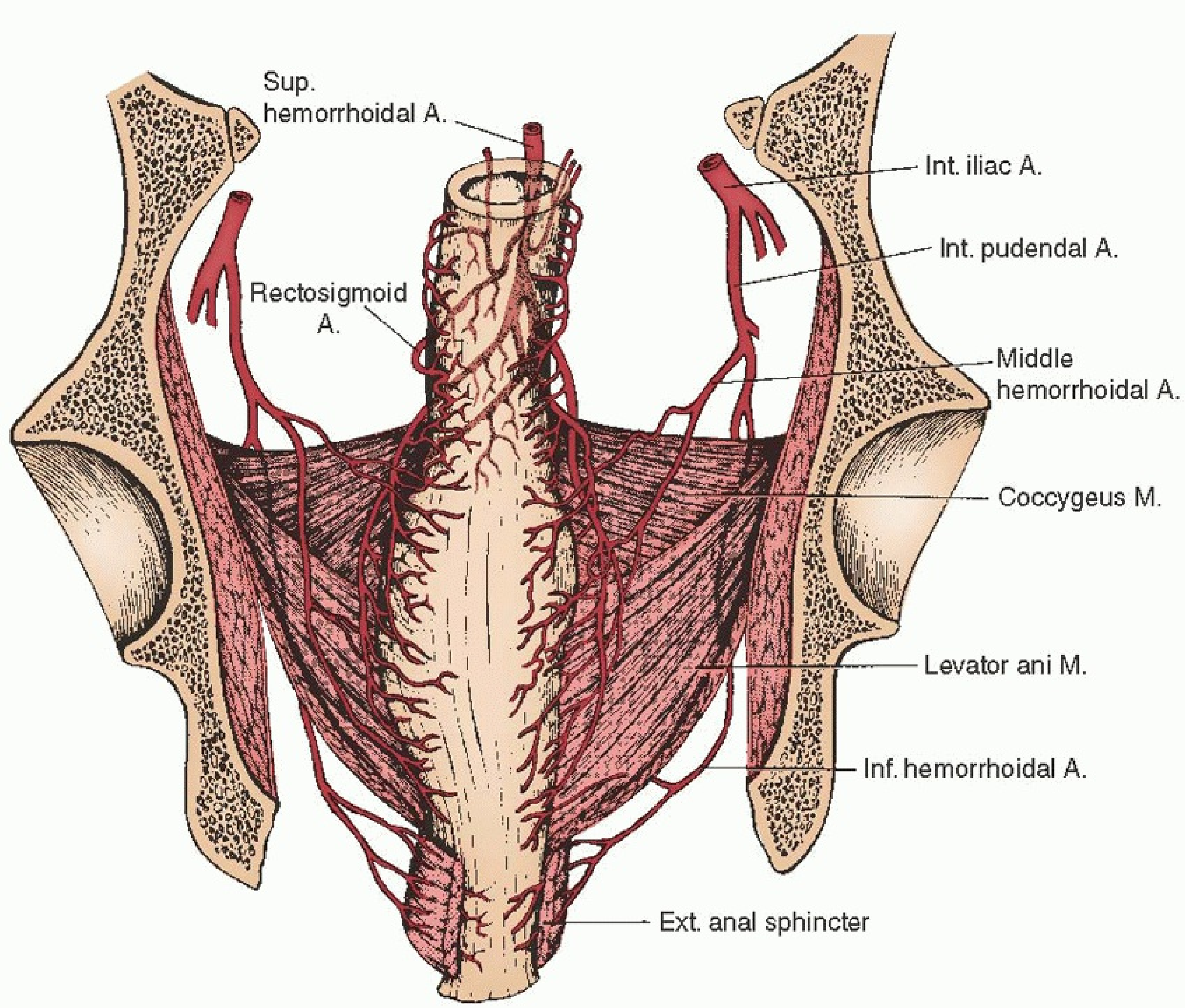

FIGURE 7.13 Rectosigmoid colon and anal canal showing collateral arterial circulation from superior hemorrhoidal (inferior mesenteric), middle hemorrhoidal (hypogastric or internal iliac), and inferior hemorrhoidal (internal pudendal) arteries.

As the rectum passes posterior to the vagina, it expands into the rectal ampulla. This portion of the bowel begins under the cul-de-sac peritoneum and fills the posterior pelvis from the side. At the distal end of the rectum, the anorectal junction is bent at an angle of 90 degrees where it is pulled ventrally by the puborectalis fibers' attachment to the pubes and posteriorly by the external anal sphincter's dorsal attachment to the coccyx.

Below this level, the gut is called the anus. It has many distinguishing features. There is a thickening of the circular involuntary muscle called the internal sphincter. The canal has a series of anal valves to assist in closure, and at their lower border, the mucosa of the colon gives way to a transitional layer of non-hair-bearing squamous epithelium before becoming the hair-bearing perineal skin.

The relations of the rectum and anus can be inferred from their course. They lie against the sacrum and levator plate posteriorly and against the vagina anteriorly. Inferiorly, each half of the levator ani abuts its lateral wall and sends fibers to mingle with the longitudinal involuntary fibers between the internal and external sphincters. Its distal terminus is surrounded by the external anal sphincter.

The anorectum receives its blood supply from a number of sources (Fig. 7.13). From above, the superior rectal (hemorrhoidal) branch of the inferior mesenteric artery lies within the layers of the sigmoid mesocolon. As it reaches the beginning of the rectum, it divides into two branches and ends in the wall of the gut. A direct branch from the internal iliac artery arises from the pelvic wall on either side and supplies the rectum and ampulla above the pelvic floor. The anus and external sphincter receive their blood supply from the inferior rectal (hemorrhoidal) branch of the internal pudendal artery, which reaches the terminus of the gastrointestinal tract through the ischiorectal fossa.

PELVIC CONNECTIVE TISSUE AND CLEAVAGE PLANES

The pelvic viscera are connected to the lateral pelvic wall by their adventitial layers and thickenings of the connective tissue that lie over the pelvic wall muscles (**Fig. 7.14**). These attachments, as well as the attachments of one organ to another, separate the different surgical cleavage planes from one another. These condensations of the adventitial layers of the pelvic organs have assumed supportive roles, connecting the viscera to the pelvic walls, in addition to their role in transmitting

the organs' neurovascular supply from the pelvic wall. They are somewhat like a mesentery that connects the bowel, for example, to the body wall. They have a supportive function as well as a role in carrying vessels and nerves to the organ. An understanding of their disposition is important to both vaginal and abdominal surgery.

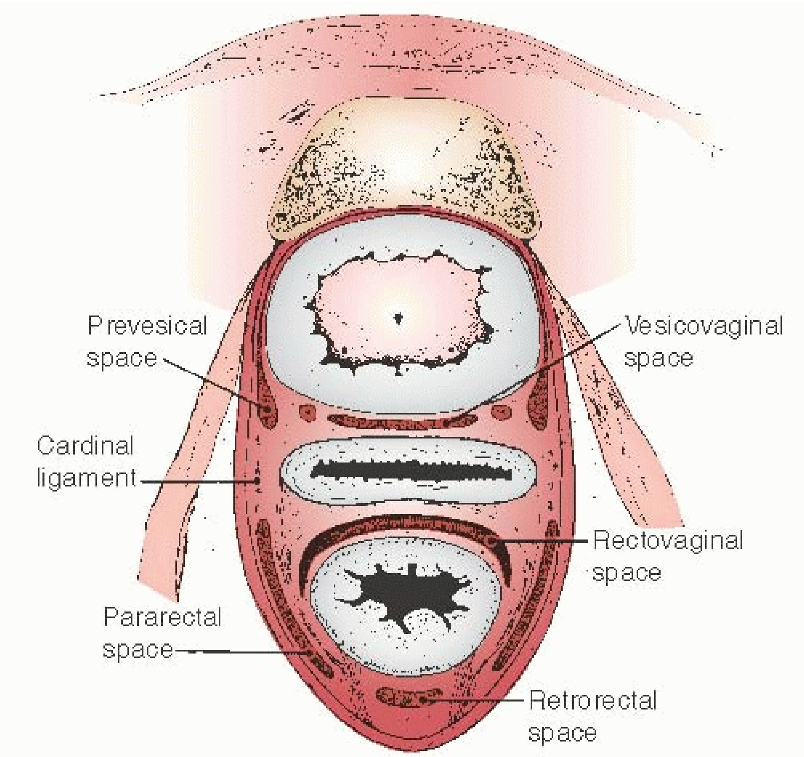

FIGURE 7.14 Cross section of the pelvis showing cleavage planes.

The tissue that connects the organs to the pelvic wall has been given the special designation of *endopelvic fascia*. It is not a layer similar to the layer encountered during abdominal incisions (rectus abdominis "fascia"). It is composed of blood vessels and nerves, interspersed with a supportive meshwork of irregular connective tissue containing collagen and elastin. These structures connect the muscularis of the visceral organs to pelvic wall muscles. In some areas, there is considerable smooth muscle within this tissue, as is true in the area of the uterosacral ligaments. Although surgical texts often speak of this fascia as a specific structure separate from the viscera, this is not strictly true. These layers can be separated from the viscera, just as the superficial layers of the bowel wall can be artificially separated from the deeper layers, but they are not themselves separate structures.

Pelvic Connective Tissue

The term *ligament* is most familiar when it describes a dense connective tissue band that links two bones, but it also describes ridges in the peritoneum or thickenings of the endopelvic fascia. The ligaments of the genital tract are diverse. Although they share a common designation (i.e., ligament), they are composed of many types of tissue and have many different functions.

Uterine Ligaments

The broad ligament comprises peritoneal folds that extend laterally from the uterus and cover the adnexal structures. They have no supportive function and were discussed in the section on the pelvic viscera.

At the base of the broad ligament, beginning just caudal to the uterine arteries, there is a thickening in the endopelvic fascia that attaches the cervix and upper vagina to the pelvic side walls (**Fig. 7.15**), consisting of the cardinal and uterosacral ligaments (parametrium). Use of the term *ligament* has caused confusion over the years because it implies a separate structure that connects two structures. In fact, they are mesenteries that transmit vessels and nerves to the genital tract.

The term *uterosacral ligament* refers to that portion of this tissue that forms the medial margin of the parametrium and that borders the cul-de-sac of Douglas. The term *cardinal ligament* is used to refer to that portion that attaches the lateral margins of the cervix and vagina to the pelvic walls. The course of the ureter as it forms a tunnel between the cardinal and uterosacral ligament forms a point of division between these two structures. The term *parametrium* refers to all of the tissue that attaches to the uterus (both cardinal and uterosacral ligaments), and the term *paracolpium* refers to the portion that attaches to the vagina (cardinal ligament of the vagina).

The uterosacral ligament portion of the parametrium is composed predominantly of smooth muscle, the autonomic nerves of the pelvic organs, and some intermixed connective tissue and blood vessels, whereas the cardinal ligament portion consists primarily of perivascular connective tissue and the pelvic vessels. Although they are often described as extending laterally from the cervix to the pelvic wall, in the standing position, they are almost vertical as one would expect for a suspensory tissue. Near the cervix, they are discrete, but they fan out in the retroperitoneal layer to have a broad, if somewhat ill-defined, area of attachment over the second, third, and fourth segments of the sacrum. These ligaments hold the cervix posteriorly in the pelvis over the levator plate of the pelvic diaphragm.

The cardinal ligaments lie at the lower edge of the broad ligament, between their peritoneal leaves, beginning just caudal to the uterine arteries. They attach to the cervix below the isthmus and fan out to attach to the pelvic walls over the piriformis muscle in the area of the greater sciatic foramen. Although when placed under tension they feel like ligamentous bands, they are composed simply of perivascular connective tissue and nerves that surround the uterine artery and veins. Nevertheless, these structures have considerable strength, and the lack of a separate “ligamentous band” in this area does not detract from their supportive role. They provide support not only to the cervix and uterus but also to the upper portion of the vagina (paracolpium) to keep these structures positioned posteriorly over the levator plate of the pelvic diaphragm and away from the urogenital hiatus.

Vaginal Fasciae and Attachments

The attachments of the vagina to the pelvic walls are important in maintaining the pelvic organs in their normal positions. Failure of these attachments, along with damage to the levator ani muscles, result in the clinical conditions of uterine prolapse, cystocele, rectocele, and enterocele.

The term fascia has many meanings. The layer that is dissected during anterior or posterior colporrhaphy and referred to as the vaginal fascia is the muscularis of the vagina. Histologically, it has an abundance of connective tissue interspersed between the smooth muscle. It is not a layer that is separate from the vagina. Laterally, the mesenteric structures of the cardinal and uterosacral ligaments connect the vagina and uterus to the muscles and connective tissues that cover the lateral walls of the pelvis. They suspended these structures within the pelvis by the downward extension on the lateral margins of the genital track (Fig. 7.15). Between the vagina and bladder is the vesicovaginal space; posterior to it is the cul-de-sac and rectovaginal space. In the midvagina, the vagina is attached laterally to the arcus tendineus fasciae pelvis. The arcus tendineus fasciae pelvis is a fibrous band that extends from its ventral attachment at the pubic bone to its dorsal attachment to the ischial spine. These

lateral attachments suspend the anterior vaginal wall across the pelvis and prevent its downward descent with increases in abdominal pressure. The structural layer formed by the vaginal wall and its lateral attachments to the arcus tendineus is clinically referred to as the pubocervical fascia.

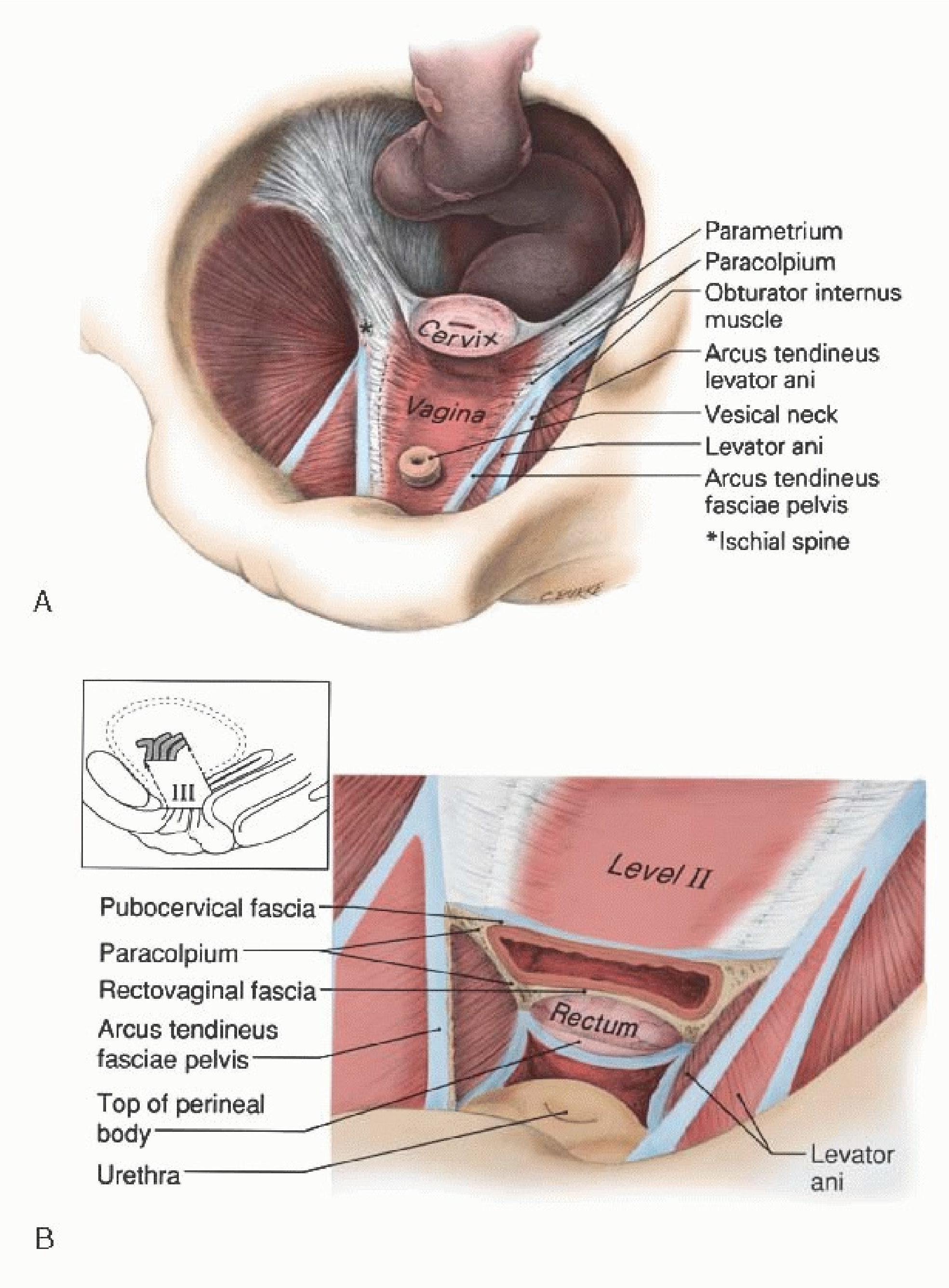

FIGURE 7.15 A: Suspensory ligaments of the female genital tract seen with the bladder removed. **B:** Close-up of the lower portion of the middle vagina (level II) shows how the lateral attachments of the vagina result in an anterior layer under the bladder (pubocervical fascia) and a posterior layer in front of the rectum (rectovaginal fascia). The cephalic surfaces of the transected distal urethra and vagina (level III) are shown. (From DeLancey JOL. Anatomic aspects of vaginal eversion after hysterectomy. *Am J Obstet Gynecol* 1992;166:1717, with permission. Copyright © 1992, Elsevier.)

Support of the posterior vaginal wall prevents the rectum from bulging forward in the clinical condition known as rectocele. This support varies in different levels of the vagina. In the distal 2 or 3 cm of the posterior vaginal wall, attachments of the perineal body to the ischiopubic rami hold the perineal body in place and prevent protrusion of the distal rectum (**Fig. 7.16**). In the midvagina above this, the vagina is attached laterally to the fascia covering the inside of the levator ani muscles (**Fig. 7.17**). This connection prevents the middle of the posterior vaginal wall from moving forward and downward during increases in abdominal pressure. The adventitial tissues between the vaginal wall and rectum contain a thickened layer called the *fascia of Denonvilliers* that extends from the bottom of the cul-de-sac of Douglas to the top of the perineal body. It is relatively thin and whether or not it provides significant support is a matter of controversy.

Urethral Supports

The support of the proximal urethra plays a role in the maintenance of urinary continence during times of increased abdominal pressure. Although it is now known that stress incontinence is primarily caused by a weak urethral sphincter mechanism (low urethral closure pressure), urethral support does play an important, if secondary, role. Therefore, considering the normal mechanisms of urethral support is appropriate.

The distal portion of the urethra is inseparable from the vagina because of their common embryologic derivation from the urogenital sinus. These tissues are fixed firmly in position by connections of the periurethral tissues and vagina to the pubic bones through the perineal membrane (**Fig. 7.18**). Cranial to this, beginning in the mid-urethra, a hammocklike layer composed of the endopelvic fascia, and anterior vaginal wall provides the support of the proximal urethra. This layer is stabilized by its lateral attachments both to the arcus tendineus fasciae pelvis and the medial margin of the levator ani muscles. The arcus tendineus fasciae pelvis is a fibrous band stretched from a ventral attachment at the lower portion of the pubic bones about 1 cm above the lower margin of the pubic bones and 1 cm from the midline to the ischial spine. The muscular attachment of the endopelvic fascia allows contraction and relaxation of the levator ani muscles to elevate the urethra and to let it descend.

It had previously been thought that the status of the urethral support system was the primary factor determining whether a woman had stress incontinence of urine. Recent studies have, however, shown that the strength of the urethral sphincter is the primary determining factor with urethral support playing a secondary role. The way in which urethral support plays a role in continence can be understood as follows. During increases in abdominal pressure, the downward force caused by increased abdominal pressure on the ventral surface of the urethra compresses the urethra closed against the hammocklike supportive layer, thereby closing the urethral lumen against the increases in intravesical pressure. The stability of the fascial layer determines the effectiveness of this closure mechanism. If the layer is unyielding, it forms a firm backstop against which the urethra can be compressed closed; however, if it is unstable, the effectiveness of this closure is compromised. Therefore, the integrity of the attachment to the arcus tendineus and the levator ani is critical to the stress continence mechanism.

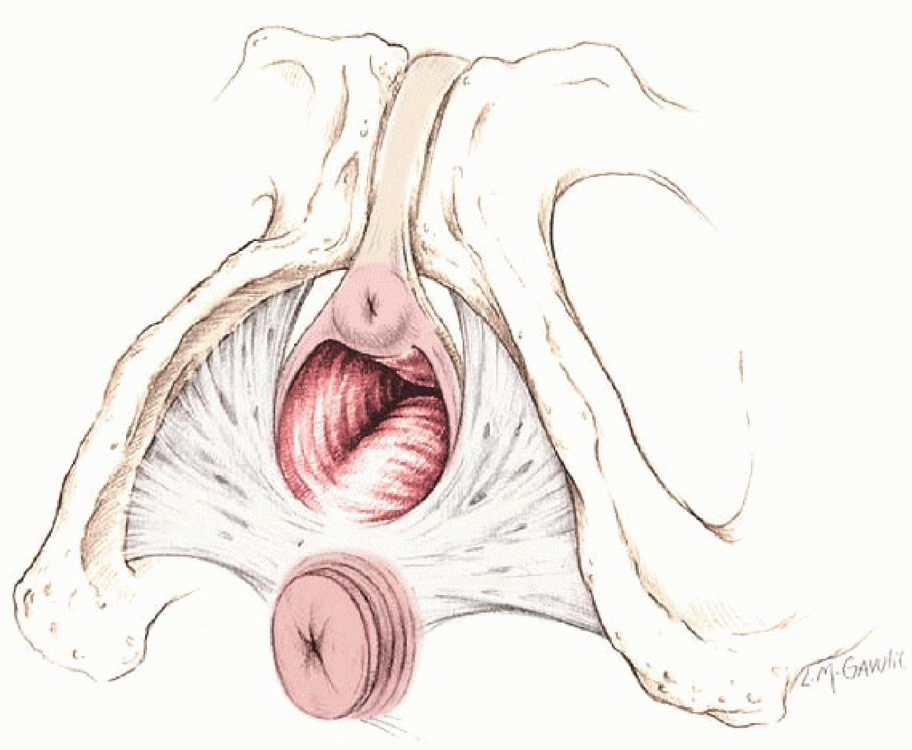

FIGURE 7.16 The peripheral attachments of the perineal membrane to the ischiopubic rami and direction of tension on fibers uniting through the perineal body. (From DeLancey JOL. Structural anatomy of the posterior compartment as it relates to rectocele. *Am J Obstet Gynecol* 1999;180:815, with permission. Copyright © 1999, Elsevier.)

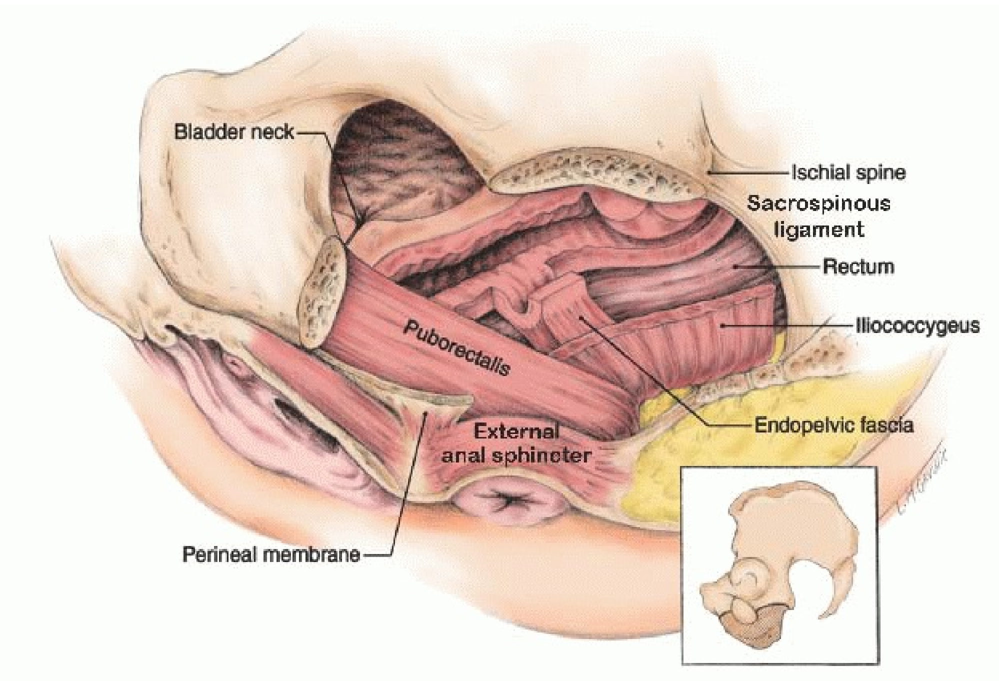

FIGURE 7.17 Lateral view of the pelvic organs after removal of the left ischial bone and ischial tuberosity. The bladder, vagina, and cervix have been cut in the sagittal plane to reveal their lumens. The rectum has been left intact. A strip of the posterior/lateral vaginal wall with its attached endopelvic fascia are shown, indicating their position relative to the levator ani muscle and this fascia's course and attachment. The two portions of the levator ani muscle (puborectalis and iliococcygeus) are visible. The ischial spine and the intact sacrospinous ligament are above the level of the removed ischial tuberosity. The left half of the perineal membrane (urogenital diaphragm) is shown just caudal to the puborectalis portion of the levator ani muscle after its detachment from the inferior pubic ramus that has been removed. (From DeLancey JOL. Structural anatomy of the posterior

compartment as it relates to rectocele. *Am J Obstet Gynecol* 1999;180:815, with permission. Copyright © 1999, Elsevier.)

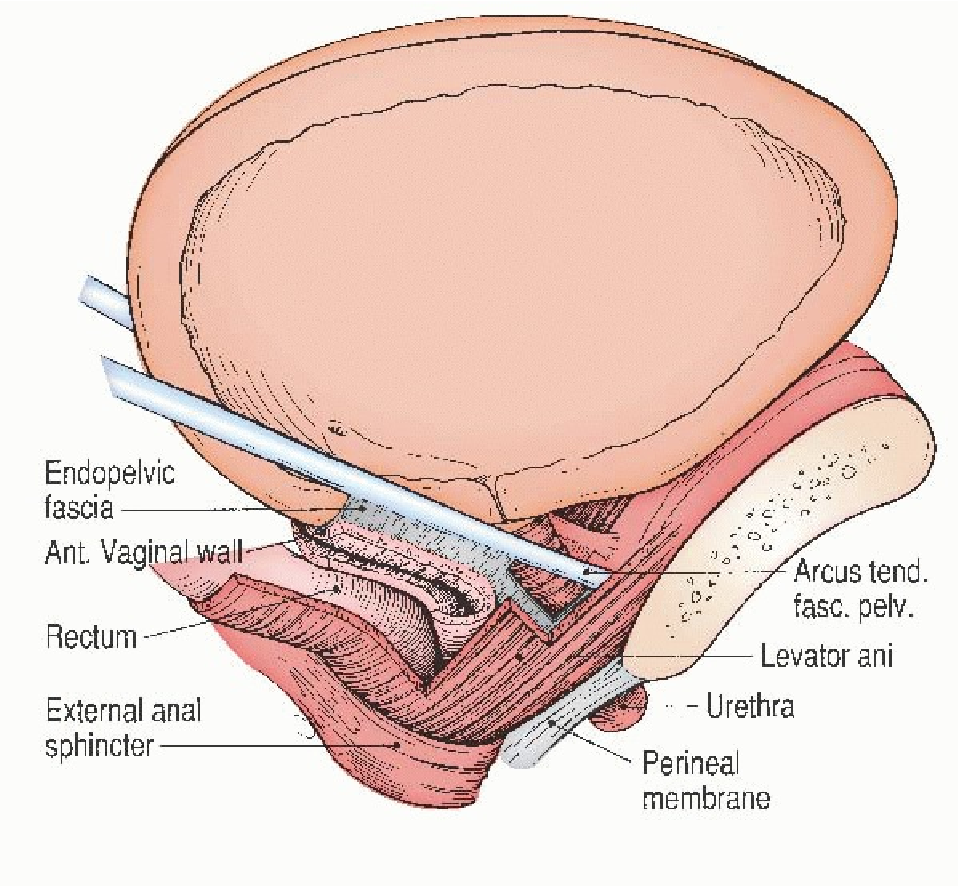

FIGURE 7.18 Lateral view of the urethral supportive mechanism transected just lateral to the midline. The lateral wall of the vagina and a portion of the endopelvic fascia have been removed so that one can see the deeper structures. (Redrawn from DeLancey JOL. Structural support of the urethra as it relates to stress urinary incontinence: the hammock hypothesis. *Am J Obstet Gynecol* 1994;170:1713, with permission. Copyright © 1994, Elsevier.)

The muscular attachment is responsible for the voluntary control of vesical neck position visible during vaginal examination or fluoroscopy when the pelvic muscles are contracted and relaxed. Relaxation of these muscles with descent of the vesical neck is associated with the initiation of urination and contraction with arrest of the urinary stream. The limit of downward vesical neck motion is determined by the connective tissue elasticity in the attachments to the arcus tendineus fasciae pelvis.

Cul-de-sacs, Cleavage Planes, and Spaces

Each of the pelvic viscera can expand somewhat independently of its neighboring organs. The ability to do this comes from their relatively loose attachment to one another, which permits the bladder, for example, to expand without equally elongating the adjacent cervix. This allows the viscera to be easily separated from one another along these lines of cleavage. These surgical cleavage planes are called spaces, although they are not empty but rather are filled with fatty or areolar connective tissue. The pelvic spaces are separated from one another by the connections of the viscera to one another and to the pelvic walls.

Anterior and Posterior Cul-de-sacs

Properly termed the *vesicouterine and rectouterine pouches*, the anterior and posterior cul-de-sac separate the uterus from the bladder and rectum.

The anterior cul-de-sac is a recess between the dome of the bladder and the anterior surface of the uterus (**Fig. 7.19**). The peritoneum is loosely applied in the region of the anterior culde-sac, unlike its dense attachment to the upper portions of the uterine corpus. This allows the bladder to expand without stretching its overlying peritoneum. This loose peritoneum forms the vesicouterine fold, which can easily be lifted and incised to create a bladder flap during abdominal hysterectomy or cesarean section. It is the point at which the vesicocervical space is normally accessed during abdominal surgery.

The posterior cul-de-sac is bordered ventrally by the vagina anteriorly, the rectosigmoid posteriorly, and the uterosacral ligaments laterally. Its peritoneum extends for approximately 4 cm along the posterior vaginal wall below the posterior vaginal fornix where the vaginal wall attaches to the cervix. This allows direct entry into the peritoneum from the vagina when performing a vaginal hysterectomy, culdocentesis, or colpotomy. The anatomy here contrasts with the anterior cul-de-sac. Anteriorly, the peritoneum lies several centimeters above the vagina whereas posteriorly, the peritoneum covers the vagina. Keeping this anatomic difference in mind facilitates entering both the anterior and the posterior cul-de-sacs during vaginal hysterectomy.

FIGURE 7.19 Sagittal section from the cadaver of a 28-year-old woman showing the anterior cul-de-sac (aCDS) and the posterior culde-sac (pCDS). Note how the posterior cul-de-sac peritoneum lies on the vaginal wall, whereas the anterior cul-de-sac lies several centimeters from the depth of the peritoneum in this area. (Peritoneum digitally enhanced in photograph to aid visibility.) (Copyright 2001 John O. L. DeLancey, with permission.)

Prevesical Space

The prevesical space of Retzius (**Fig. 7.14**) is separated from the undersurface of the rectus abdominis muscles by the transversalis fascia and can be entered by perforating this layer. Ventrolaterally, it is bounded by the bony pelvis and the muscles of the pelvic wall; cranially, it is bounded by the abdominal wall. The proximal urethra and bladder lie in a dorsal position. The dorsolateral limit to this space is the attachment of the bladder to the cardinal ligament and the attachment of the pubocervical fascia to the arcus tendineus fasciae pelvis. These separate this space from the vesicovaginocervical space. This lateral attachment is to the arcus tendineus fasciae pelvis, which lies on the inner surface of the obturator internus and pubococcygeal and puborectal muscles.

Important structures lying within this space include the dorsal clitoral vessels under the symphysis at its lower border and the obturator nerve and vessels as they enter the obturator canal. A branch to the obturator canal often comes off the external iliac artery and lies on the pubic bone; therefore, dissection in this area should be performed with care (**Fig. 7.20**). Lateral to the bladder and vesical neck is a dense plexus of vessels that lie at the border of the lower urinary tract. They are deep to the pubovesical muscle, and although they bleed when sutures are placed here, this venous ooze usually stops when the sutures are tied. Also within this tissue, lateral to the bladder and urethra, lie the nerves of the lower urinary tract. The upper border of the pubic bones that form the anterior surface of this region has a ridgelike fold of periosteum called the iliopectineal line. This is sometimes used to anchor sutures during urethral suspension operations.

Vesicovaginal and Vesicocervical Space

The space between the lower urinary tract and the genital tract is separated into the vesicovaginal and vesicocervical spaces

(**Fig. 7.14**). The lower extent of the space is the junction of the proximal one third and distal two thirds of the urethra, where it fuses with the vagina, and it extends to lie under the peritoneum at the vesicocervical peritoneal reflection. It extends laterally to the pelvic side walls, separating the vesical and genital aspects of the cardinal ligaments.

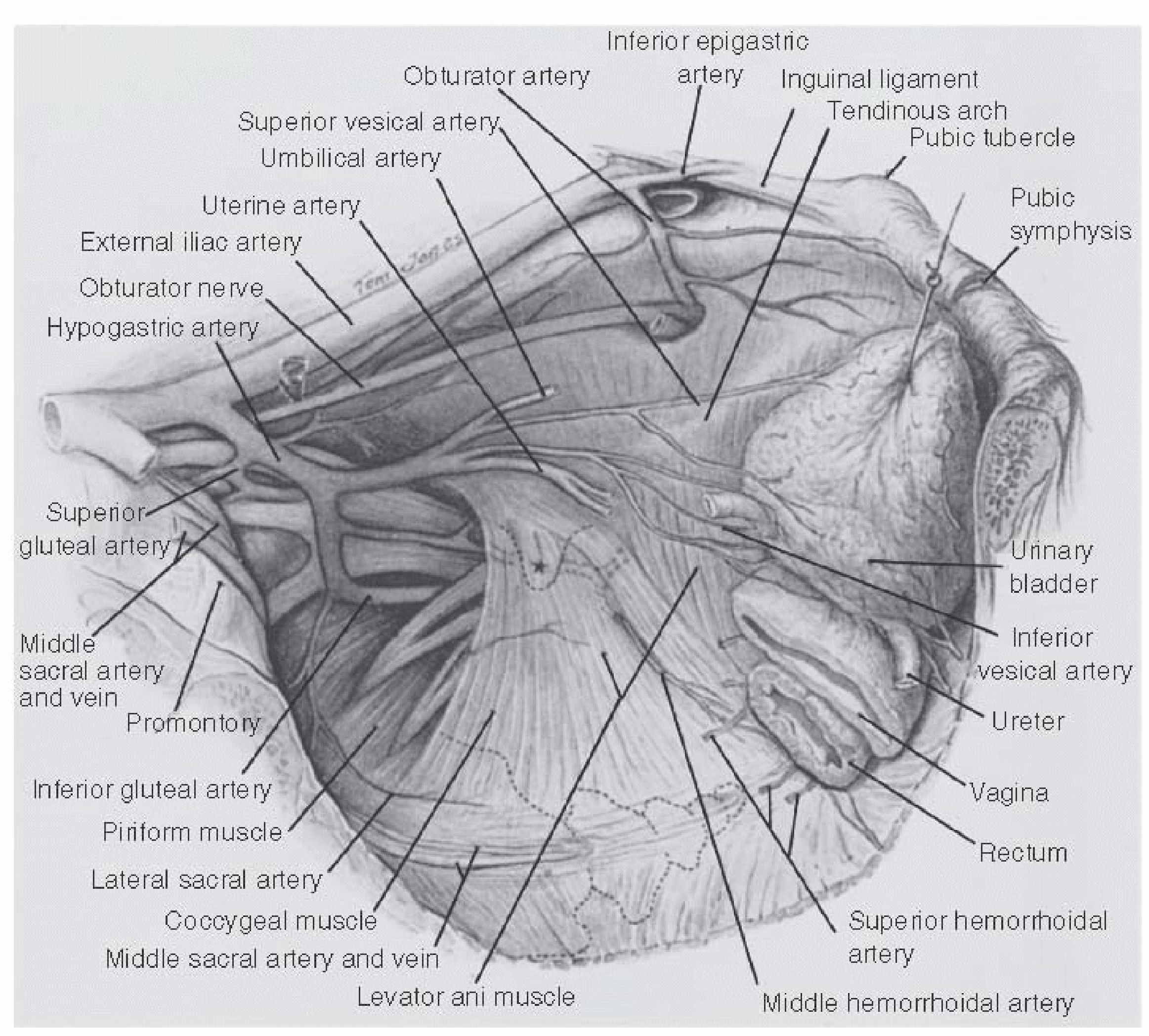

FIGURE 7.20 Structures of the pelvic wall. (From Anson BJ. *An atlas of human anatomy*. Philadelphia, PA: WB

Saunders, 1950, with permission.)

Rectovaginal Space

On the dorsal surface of the vagina lies the rectovaginal space (**Fig. 7.14**). It begins at the apex of the perineal body, about 2 to 3 cm above the hymenal ring. It extends upward to the cul-de-sac and laterally around the sides of the rectum to the attachment of the rectovaginal septum to the parietal endopelvic fascia. It contains loose areolar tissue and is easily opened with finger dissection.

At the level of the cervix, some fibers of the cardinal-uterosacral ligament complex extend downward behind the vagina, connecting it to the lateral walls of the rectum and then to the sacrum. These are called the rectal pillars. They separate the midline rectovaginal space in this region from the lateral pararectal spaces. These pararectal spaces allow access to the sacrospinous ligament (mentioned later). They also form the lateral boundaries of the retrorectal space between the rectum and sacrum.

Region of the Sacrospinous Ligament

The area around the sacrospinous ligament is another region that has become more important to the gynecologist operating for problems of vaginal support. The sacrospinous ligament lies on the dorsal aspect of the coccygeal muscle (**Fig. 7.20**). The rectal pillar separates it from the rectovaginal space.

As its name implies, the sacrospinous ligament courses from the lateral aspect of the sacrum to the ischial spine. In its medial portion, it fuses with the sacrotuberous ligament and is a distinct structure only laterally. It can be reached from the rectovaginal space by perforation of the rectal pillar to enter the pararectal space or by dissection directly under the enterocele peritoneum. This area is covered in more detail in Chapter 35.

Many structures are near the sacrospinous ligament, and their location must be remembered during surgery in this region. The sacral plexus lies immediately to the ligament on the inner surface of the piriformis muscle. Just before its exit through the greater sciatic foramen, the plexus gives off the pudendal nerve, which, with its accompanying vessels, passes lateral to the sacrospinous ligament at its attachment to the ischial spine. The nerve to the levator ani muscles lies on the inner surface of the coccygeal muscle in its midportion. In developing this space, the tissues that are reflected medially and cranially to gain access contain the pelvic venous plexus of the internal iliac vein, as well as the middle rectal vessels. If they are mobilized too vigorously, they can cause considerable hemorrhage.

RETROPERITONEAL SPACES AND LATERAL PELVIC WALL

The retroperitoneal space of the posterior abdomen, presacral space, and pelvic retroperitoneum contain the major neural, vascular, and lymphatic supply to the pelvic viscera. These areas are explored during operations to identify the ureter, interrupt the pelvic nerve supply, arrest serious pelvic hemorrhage, and remove potentially malignant lymph nodes. Because this area is free of the adhesions from serious pelvic infection or endometriosis, it can be used as a plane of dissection when the peritoneal cavity has become obliterated.

The structures found in these spaces are discussed in a regional context, because that is the way they are usually approached in the operating room.

Retroperitoneal Structures of the Lower Abdomen

The aorta lies on the lumbar spine slightly to the left of the vena cava, which it overlies. The portion of this vessel below the renal vessels is encountered during retroperitoneal dissection to identify the paraaortic lymph nodes (**Fig. 7.21**). The renal blood vessels arise at the second lumbar vertebra. The ovarian vessels also arise from the anterior surface of the aorta in this region. In general, the branches of the vena cava follow those of the aorta, except for the vessels of the intestine, which flow into the portal vein, and the left ovarian vein, which empties into the renal vein on that side.

Below the level of the renal vessels and just below the third portion of the duodenum, the inferior mesenteric artery arises from the anterior aorta. It gives off ascending branches of the left colic artery and continues caudally to supply the sigmoid through the three or four sigmoid arteries that lie in the sigmoid mesentery. These vessels follow the bowel as it is pulled from side to side, so that their position can vary, depending on retraction.

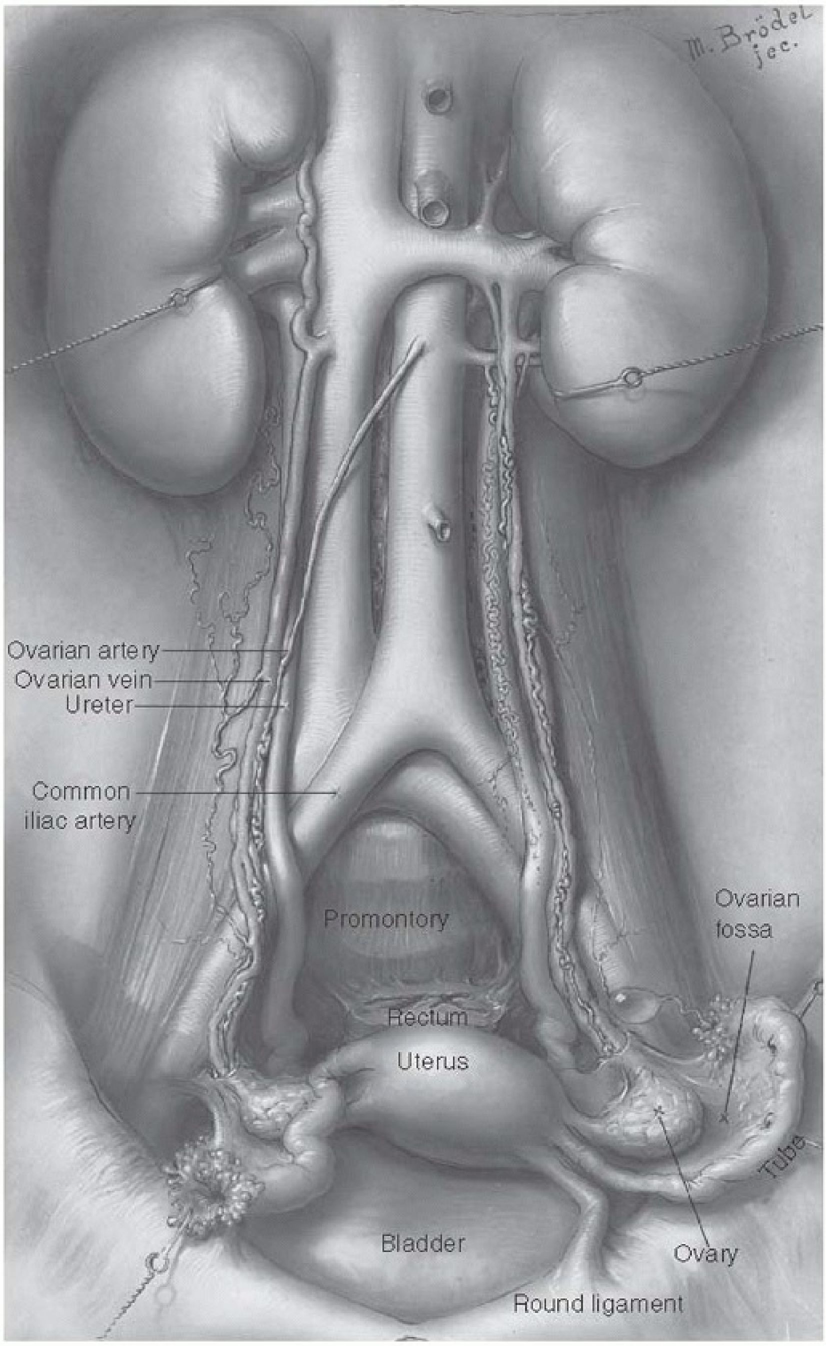

FIGURE 7.21 Structures of the retroperitoneum. Note the anomalous origin of the left ovarian artery from the left renal artery rather than from the aorta. (The original illustration is in the Max Brödel Archives in the Department of Art as Applied to Medicine, The Johns Hopkins University School of Medicine, Baltimore, MD, USA, with permission.)

Inferiorly, a continuation of the inferior mesenteric artery forms the superior rectal artery. This vessel crosses over the external iliac vessels to lie on the dorsum of the lower sigmoid. It supplies the rectum, as described in the section concerning that viscus.

The aorta and vena cava have segmental branches that arise at each lumbar level and are called the lumbar arteries and veins. They are situated somewhat posteriorly to the aorta and vena cava and are not visible from the front. When the vessels are mobilized, as is done in excising the lymphatic tissue in this area, they come into view.

At the level of the fourth lumbar vertebra (just below the umbilicus), the aorta bifurcates into the left and right common iliac arteries. After about 5 cm, the common iliac arteries (and the medially placed veins) give off the internal iliac vessels from their medial side and continue toward the inguinal ligament as the external iliac arteries. These internal iliac vessels lie within the pelvic retroperitoneal region and are discussed later.

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The aorta and vena cava in this region are surrounded by lymph nodes on all sides. Surgeons usually refer to this lumbar chain of nodes as the paraaortic nodes, reflecting their position. They receive the drainage from the common iliac nodes and are the final drainage of the pelvic viscera. In addition, they collect the lymphatic drainage from the ovaries that follows the ovarian vessels and does not pass through the iliac nodes. The nodes of the lumbar chain extend from the right side of the vena cava to the left of the aorta and can be found both anterior and posterior to the vessels.

The ureters are attached loosely to the posterior abdominal wall in this region, and when the overlying colon is mobilized, they remain on the body wall. They are crossed anteriorly by the ovarian vessels, which contribute a branch to supply the ureter. Additional blood supply to the abdominal portion comes from the renal vessels at the kidney and the common iliac artery.

This region can be exposed either by a midline peritoneal incision to the left of the small bowel mesentery or, retroperitoneally, by reflection of the colon. During embryonic development, the colon and its mesentery fuse with the abdominal wall. A cleavage plane exists here that allows the colon and its vessels to be elevated to expose the structures of the posterior abdominal wall. Because the ureter and ovarian vessels originally arise in this area, they are not elevated with the colon.

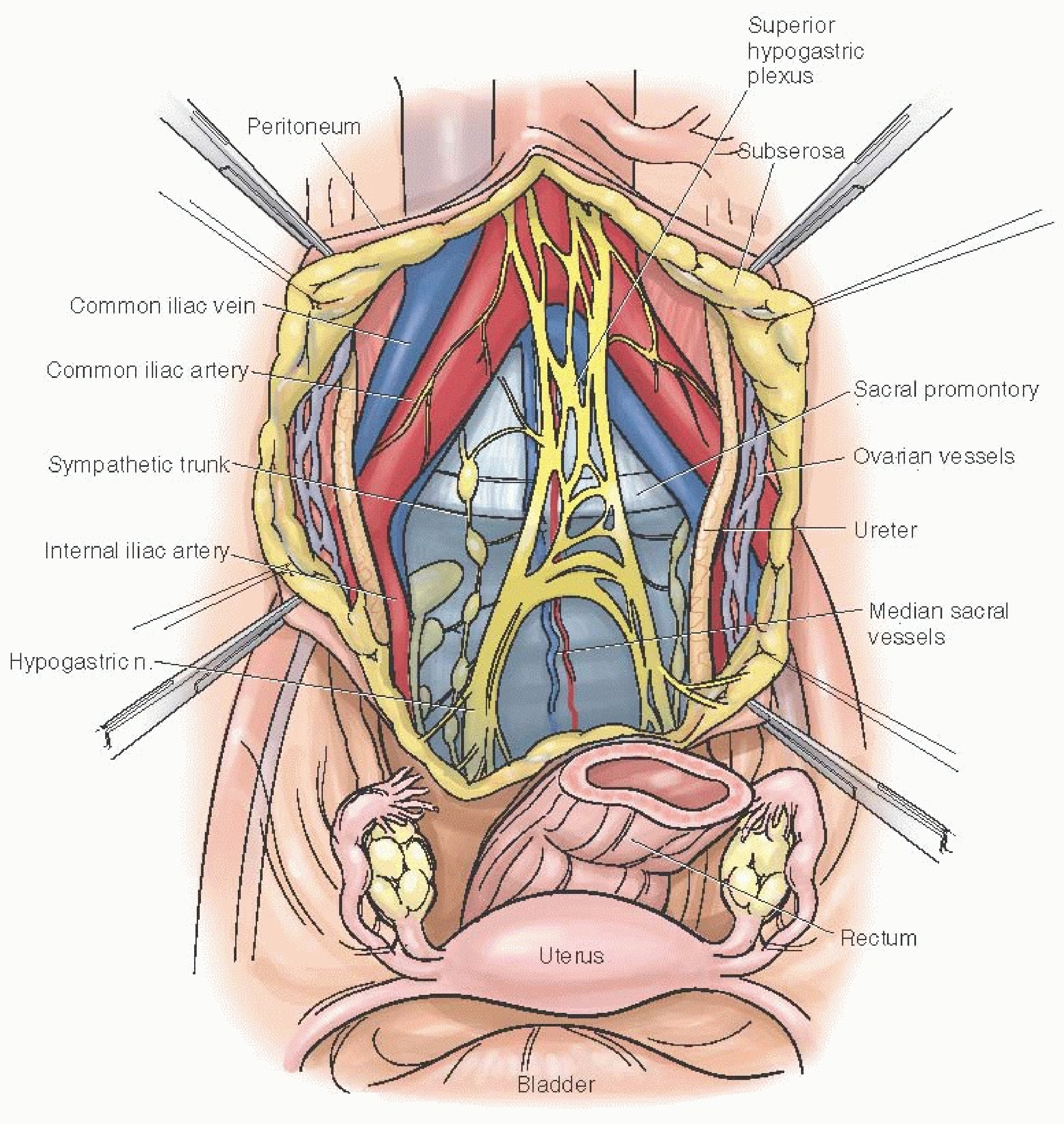

FIGURE 7.22 Presacral nerve plexus, showing passage of sympathetic trunk over bifurcation of aorta. Observe the division of the trunk into left and right presacral nerves. (Redrawn from Curtis AH, Anson BJ, Ashley FL, et al. The anatomy of the pelvic autonomic nerves in relation to gynecology. *Surg Gynecol Obstet* 1942;75:743, with permission.)

Presacral Space

The presacral space begins below the bifurcation of the aorta and is bounded laterally by the internal iliac arteries (**Figs. 7.22** and **7.23**). Lying directly on the sacrum are the middle sacral artery and vein, which originate from the dorsal aspect of the aorta and vena cava (and not from the point of bifurcation, as sometimes shown). Caudal and lateral to this are the lateral sacral vessels. The venous plexus of these vessels can be extensive, and bleeding from it can be considerable.

Within this area lies the most familiar part of the pelvic autonomic nervous system, the presacral nerve (superior hypogastric plexus). The autonomic nerves of the pelvic viscera can be divided into a sympathetic (thoracolumbar) and parasympathetic (craniosacral) system. The former is also called the adrenergic system, and the latter is called the cholinergic system, according to their neurotransmitters. α-Adrenergic stimulation causes increased urethral and vesical neck tone, and cholinergic stimulation increases contractility of the detrusor muscle. Similarly, adrenergic stimulation in the colon and rectum favors storage, and cholinergic stimulation favors evacuation. β-Adrenergic agonists, which are used for tocolysis, suggest that these influence contractility of the uterus. As is true in the man, damage to the autonomic nerves during

pelvic lymphadenectomy can have a significant influence on orgasmic function in the woman.

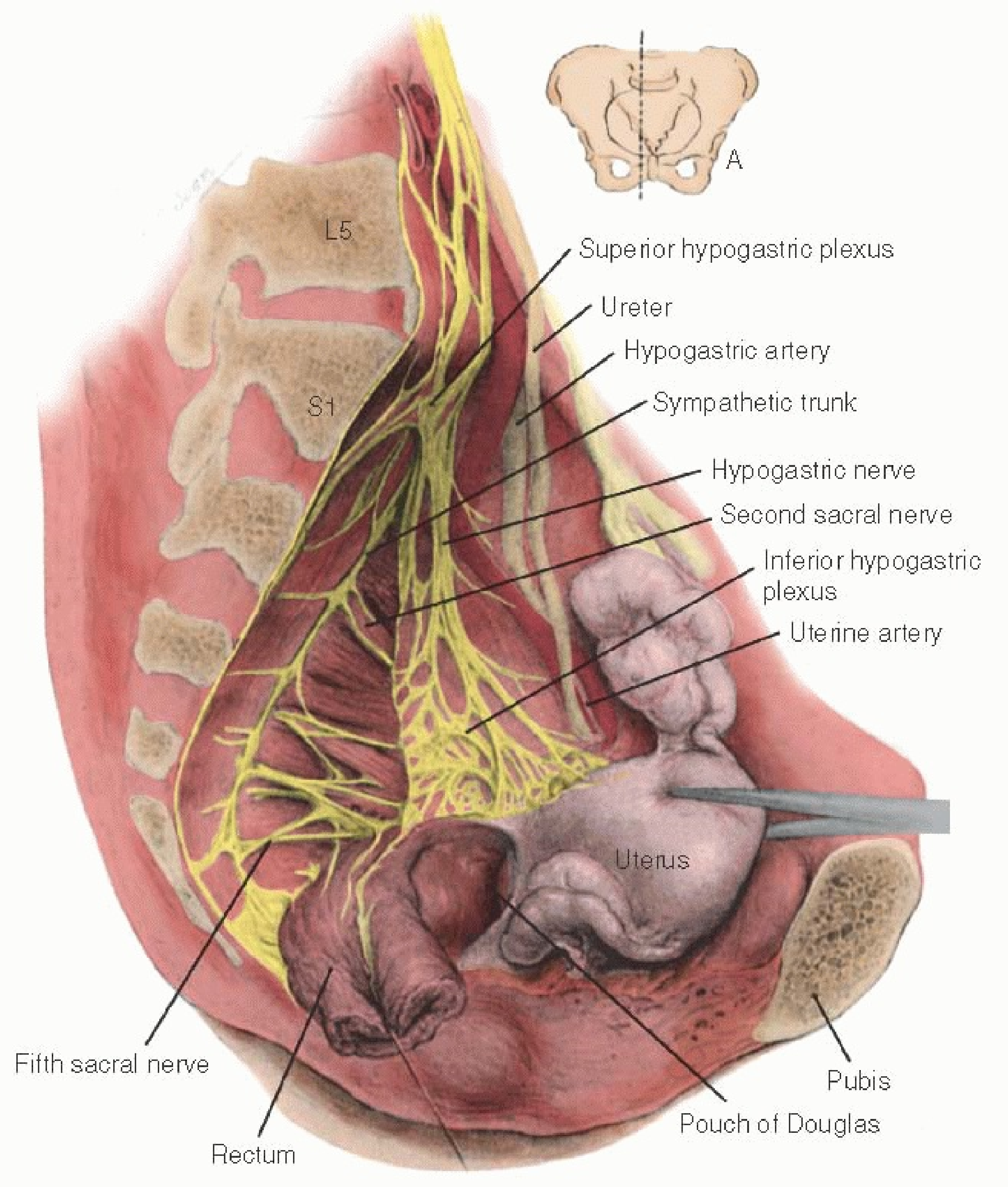

FIGURE 7.23 Nerves of the female pelvis. (From Anson BJ. *An atlas of human anatomy*. Philadelphia, PA: WB Saunders, 1950, with permission.)

How these autonomic nerves reach the organs that they innervate has surgical importance. The terminology of this area is somewhat confusing, because many authors use idiosyncratic terms. However, the structure is simple: It consists of a single ganglionic midline plexus overlying the lower aorta (superior hypogastric plexus) that splits into two trunks without ganglia (hypogastric nerves), each of which connects with a plexus of nerves and ganglia lateral to the pelvic viscera (inferior hypogastric plexus).

The superior hypogastric plexus lies in the retroperitoneal connective tissue on the ventral surface of the lower aorta and receives input from the sympathetic chain ganglia through the thoracic and lumbar splanchnic nerves. It also contains important afferent pain fibers from the pelvic viscera, which makes its transection effective in primary dysmenorrhea. It passes over the bifurcation of the aorta and extends over the proximal sacrum before splitting into two hypogastric nerves that descend into the pelvis in the region of the internal iliac vessels. The hypogastric nerves end in the inferior hypogastric plexus. The hypogastric plexuses are broad expansions of the hypogastric nerves. Their sympathetic fibers come from the downward extensions of the superior hypogastric plexus and pelvic splanchnic nerves from the continuation of the sympathetic chain into the pelvis. Parasympathetic fibers come from sacral segments two through four by way of the pelvic splanchnic nerves (nervi erigentes) to join these ganglia. They lie in the pelvic connective tissue of the lateral pelvic wall, lateral to the uterus and vagina.

The inferior hypogastric plexus (sometimes called the pelvic plexus) is divided into three portions: the vesical plexus anteriorly, uterovaginal plexus (Frankenhäuser ganglion), and the middle rectal plexus. The uterovaginal plexus contains fibers that derive from two sources. It receives sympathetic and sensory fibers from the tenth thoracic through the first lumbar spinal cord segments. The second input comes from the second, third, and fourth sacral segments and consists primarily of parasympathetic nerves that reach the inferior hypogastric plexus through the pelvic splanchnic nerves. The uterovaginal plexus lies on the dorsal (medial) surface of the uterine vessels, lateral to the sacrouterine ligaments' insertion into the uterus. It has continuations cranially along the uterus and caudally along the vagina. This latter extension contains the fibers that innervate the vestibular bulbs and clitoris. These nerves lie in the tissue just lateral to the area where the uterine artery, cardinal ligament, and uterosacral ligament pedicles are made during a hysterectomy for benign disease, and within the tissue removed during a radical hysterectomy.

The location of the sensory fibers from the uterine corpus in the superior hypogastric nerve (the presacral nerve) allows the surgeon to alleviate visceral pain from the corpus by transecting this structure. It does not provide sensory innervation to the adnexal structures or to the peritoneum and is therefore

not useful for alleviating pain in those sites. Another important way in which the autonomic nervous system is involved is through damage to the inferior hypogastric plexus during radical hysterectomy. The extension of the surgical field lateral to the viscera interrupts the connection of the bladder and sometimes the rectum to their central attachments.

The ovary and uterine tube receive their neural supply from the plexus of nerves that accompany the ovarian vessels and that originate in the renal plexus. These fibers originate from the tenth thoracic segment, and the parasympathetic fibers come from extensions of the vagus.

As the lumbar and sacral nerves exit from the intervertebral and sacral foramina, they form the lumbar and sacral plexuses. The lumbar nerves and plexus lie deep within the psoas muscle on either side of the spine. The sacral plexus lies on the piriformis muscle, and its major branch, the sciatic nerve, leaves the pelvis through the lower part of the greater sciatic foramen. The sacral plexus supplies nerves to the muscles of the hip, pelvic diaphragm, and perineum, as well as to the lower leg (through the sciatic nerve). The femoral nerve from the lumbar plexus is primarily involved in supplying the muscles of the thigh.

Pelvic Retroperitoneal Space

Division of the internal and external iliac vessels occurs in the area of the sacroiliac joint. Just before passing under the inguinal ligament to become the femoral vessels, the external iliac vessels contribute the deep inferior epigastric and deep circumflex iliac arteries. There are no other major branches of the external iliac artery in this region.

Internal Iliac Vessels

Unlike the external iliac artery, which is constant and relatively simple in its morphology, the branching pattern of the internal iliac arteries and veins is extremely variable (**Figs. 7.24** and **7.25**). A description of a common variant is included here. The internal iliac artery supplies the viscera of the pelvis and many muscles of the pelvic wall and gluteal region. It usually divides into an anterior and posterior division about 3 to 4 cm after leaving the common iliac artery (**Table 7.2**). The vessels of the posterior division (the iliolumbar, lateral sacral, and superior gluteal) leave the internal iliac artery from its lateral surface to provide some of the blood supply to the pelvic wall and gluteal muscles. Trauma to these hidden vessels should be avoided during internal iliac artery ligation as the suture is passed around behind vessels.

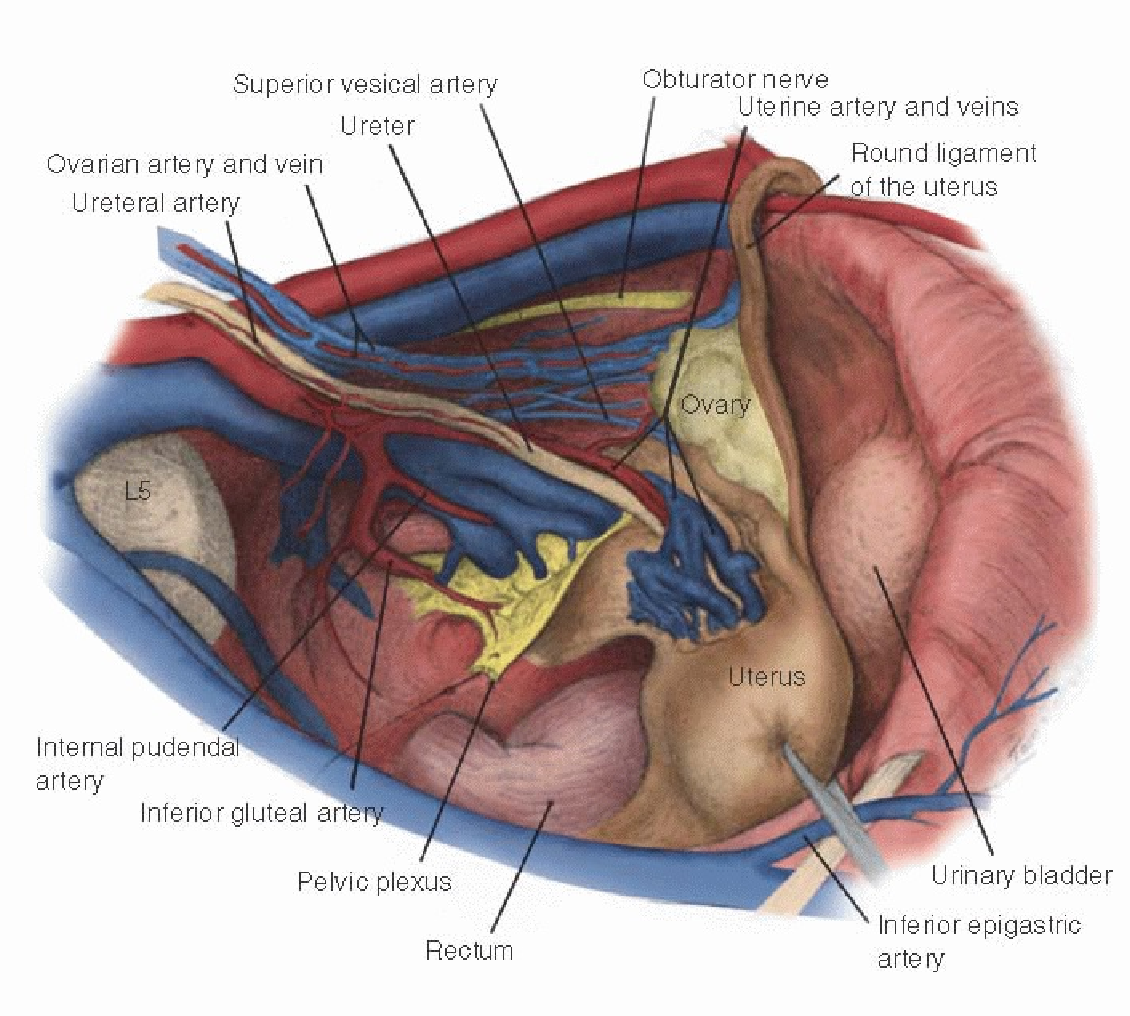

FIGURE 7.24 Arteries and veins of the pelvis. (From Anson BJ. *An atlas of human anatomy*. Philadelphia, PA: WB Saunders, 1950, with permission.)

The anterior division has both parietal and visceral branches. The obturator, internal pudendal, and inferior gluteal vessels primarily supply muscles, whereas the uterine, superior vesical, vaginal (inferior vesical), and middle rectal vessels supply the pelvic organs. The internal iliac veins begin lateral and posterior to the arteries. These veins form a large and complex plexus within the pelvis, rather than having single branches, as do the arteries. They tend to be deeper in this area than the arteries, and their pattern is highly variable.

Ligation of the internal iliac artery has proved helpful in the management of postpartum hemorrhage. Burchell's arteriographic studies showed that physiologically active anastomoses between the systemic and pelvic arterial supplies were immediately patent after ligation of the internal iliac artery (**Fig. 7.25**). These anastomoses, shown in **Table 7.2**, connected the arteries of the internal iliac system with systemic blood vessels either directly from the aorta, as is true for the lumbar and middle sacral artery, or indirectly through the inferior mesenteric artery, as with the superior hemorrhoidal vessels. These in vivo pathways were quite different from the anastomoses that had previously been hypothesized on purely anatomic grounds.

Pelvic Ureter

The course of the ureter within the pelvis is important to gynecologic surgeons and is fully considered in Chapter 37. A few of the important anatomic landmarks are considered here (**Fig. 7.24**). After passing over the bifurcation of the

internal and external iliac arteries, just medial to the ovarian vessels, the ureter descends within the pelvis. Here, it lies in a special connective tissue sheath that is attached to the peritoneum of the lateral pelvic wall and medial leaf of the broad ligament. This explains why the ureter still adheres to the peritoneum and does not remain laterally with the vessels when the peritoneal space is entered.

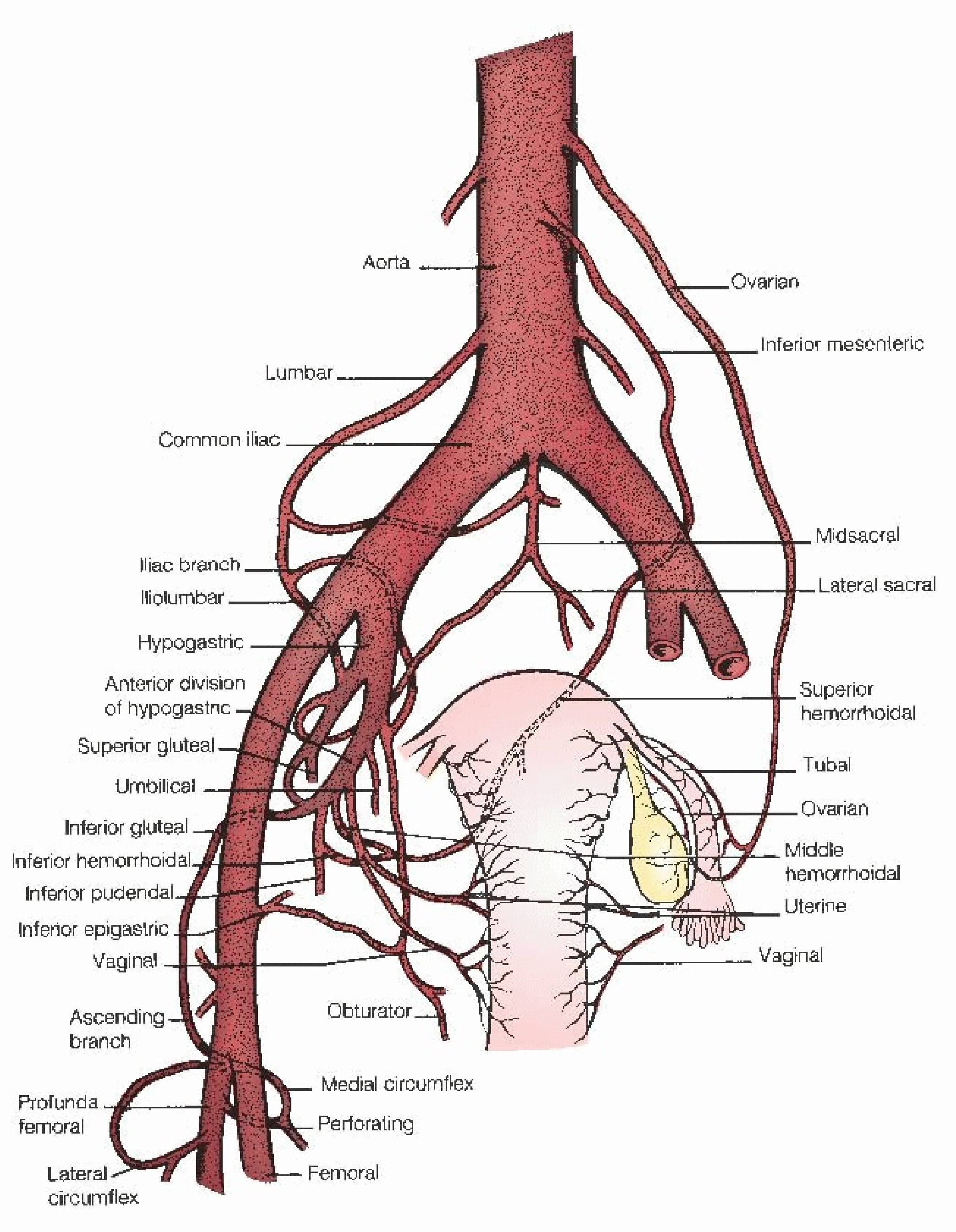

FIGURE 7.25 Collateral circulation of the pelvis.

The ureter crosses under the uterine artery ("water flows under the bridge") in its course through the cardinal ligament. There is a loose areolar plane around it to allow for its peristalsis here. At this point, it lies along the anterolateral surface of the cervix, usually about 1 cm from it. From there, it comes to lie on the anterior vaginal wall and then proceeds for a distance of about 1.5 cm through the wall of the bladder.

TABLE 7.2 Collateral Circulation after Internal Iliac Artery Ligation

INTERNAL ILIAC SYSTEMIC
Iliolumbar
Lateral sacral
Middle hemorrhoidal
Lumbar
Middle sacral
Superior hemorrhoidal

During its pelvic course, the ureter receives blood from the vessels that it passes, specifically the common iliac, internal iliac, uterine, and vesical arteries. Within the wall of the ureter, these vessels are connected to one another by a convoluted vessel that can be seen running longitudinally along its outer surface.

Lymphatics

The lymph nodes and lymphatic vessels that drain the pelvic viscera vary in their number and distribution, but they can be organized into coherent groups. Because of the extensive interconnection of the lymph nodes, spread of lymph flow, and thus malignancy, is somewhat unpredictable. Therefore, some important generalizations about the distribution and drainage of these tissues are still helpful. Distribution of the pelvic lymph nodes is discussed further in Chapter 46 on invasive carcinoma of the cervix. Figures 46.22 through 46.25 show this anatomy.

The nodes of the pelvis can be divided into the external iliac, internal iliac, common iliac, medial sacral, and pararectal nodes. The medial sacral nodes are few and follow the middle sacral artery. The pararectal nodes drain the part of the rectosigmoid above the peritoneal reflection that is supplied by

the superior hemorrhoidal artery. The medial and pararectal nodes are seldom involved in gynecologic disease.

The internal and external iliac nodes lie next to their respective blood vessels, and both end in the common iliac chain of nodes, which then drain into the nodes along the aorta. The external iliac nodes receive the drainage from the leg through the inguinal nodes. Nodes in the external iliac group can be found lateral to the artery, between the artery and vein, and on the medial aspect of the vein. These groups are called the anterosuperior, intermediate, and posteromedial groups, respectively. They can be separated from the underlying muscular fascia and periosteum of the pelvic wall along with the vessels, thereby defining their lateral extent. Some nodes at the distal end of this chain lie in direct relation to the deep inferior epigastric vessels and are named according to these adjacent vessels. Similarly, nodes that lie at the point where the obturator nerve and vessels enter the obturator canal are called obturator nodes.

The internal iliac nodes drain the pelvic viscera and receive some drainage from the gluteal region along the posterior division of the internal iliac vessels as well. These nodes lie within the adipose tissue that is interspersed among the many branches of the vessels. The largest and most numerous nodes lie on the lateral pelvic wall, but many smaller nodes lie next to the viscera themselves. These nodes are named for the organ by which they are found (e.g., parauterine).

Not only is it difficult in the operating room to make some of the fine distinctions mentioned in this anatomic discussion, but also there is little clinical importance in doing so. Surgeons generally refer to those nodes that are adjacent to the external iliac artery as the external iliac group of nodes and to those next to the internal iliac artery as the internal iliac nodes. This leaves those nodes that lie between the external iliac vein and internal artery, which are called interiliac nodes.

The direction of lymph flow from the uterus tends to follow its attachments, draining along the cardinal, uterosacral, and even round ligaments. This latter connection can lead to metastasis from the uterus to the superficial inguinal nodes, whereas the former connections are to the internal iliac nodes, with free communication to the external iliac nodes and sometimes to the lateral sacral nodes. The anastomotic connection of the uterine and ovarian vessels makes lymphatic connections between these two drainage systems likely and metastasis in this direction possible.

The vagina and lower urinary tract have a divided drainage. Superiorly (upper two thirds of the vagina and the bladder), drainage occurs along with the uterine lymphatics to the internal iliac nodes, whereas the lower one third of the vagina and distal urethra drain to the inguinal nodes. However, this demarcation is far from precise.

The common iliac nodes can be found from the medial to the lateral border of the vessels of the same name. They continue above the pelvic vessels and occur around the aorta and the vena cava. These nodes can lie anterior, lateral, or posterior to the vessels.

THE ABDOMINAL WALL

Knowledge of the layered structure of the abdominal wall allows the surgeon to enter the abdominal cavity with maximum efficiency and safety. A general summary of these layers is provided in **Table 7.3**. The abdomen's superior border is the lower edge of the rib cage (ribs 7 through 12). Inferiorly, it ends at the iliac crests, inguinal ligaments, and pubic bones. It ends posterolaterally at the lumbar spine and its adjacent muscles.

TABLE 7.3 Table of Abdominal Wall Layers

Skin
Subcutaneous layer
Camper fascia
Scarpa fascia
Musculoaponeurotic layer
Rectus sheath—formed by conjoined aponeuroses of the external oblique muscle
Internal oblique muscle: fused in lower abdomen
Transverse abdominal muscle

Transversalis fascia

Peritoneum

Skin and Subcutaneous Tissue

The fibers in the dermal layer of the abdominal skin are oriented in a predominantly transverse direction following a gently curving concave upward line. This predominance of transversely oriented fibers results in more tension on the skin of a vertical incision and in a wider scar.

Between the skin and musculoaponeurotic layer of the abdominal wall lie the subcutaneous tissues. It is made of globules of fat held in place and supported by a series of branching fibrous septa. In the more superficial portion of the subcutaneous layer, called Camper fascia, the fat predominates, and the fibrous tissue is less apparent. Closer to the rectus sheath, the fibrous tissue predominates relative to the fat in the region known as Scarpa fascia. Camper and Scarpa fasciae are not discrete or well-defined layers but represent regions of the subcutaneum. Scarpa fascia is best developed laterally and is not seen as a well-defined layer during vertical incisions.

Musculoaponeurotic Layer

Deep to the subcutaneous tissue is a layer of muscle and fibrous tissue that holds the abdominal viscera in place and controls movement of the lower torso (**Figs. 7.26** and **7.27**). Within this area are two groups of muscles: vertical muscles in the anterior abdominal wall and oblique flank muscles. The rectus abdominis muscle is found on either side of the midline, and the pyramidalis muscle is located just above the pubes. Lateral to these are the flank muscles: the external oblique, internal oblique, and transverse abdominal. The broad, sheetlike tendons of these muscles form aponeuroses that unite with their corresponding member of the other side, forming a dense white covering of the rectus abdominis muscle properly called the rectus sheath (rectus “fascia”).

Rectus Abdominis and Pyramidal Muscles

Each paired rectus abdominis muscle originates from the sternum and cartilages of ribs 5 through 7 and inserts into the anterior surface of the pubic bone. Each muscle has three tendinous inscriptions. These are fibrous interruptions within the muscle that firmly attach it to the rectus abdominis sheath. In general, they are confined to the region above the umbilicus, but they can be found below it. When this happens, the rectus sheath is attached to the rectus muscle there, and these two structures become difficult to separate during a Pfannenstiel incision.

The pyramidal muscles arise from the pubic bones and insert into the linea alba in an area several centimeters above the symphysis. Their development varies considerably among individuals. Their strong attachment to the midline makes separation of their attachment here difficult by blunt dissection.

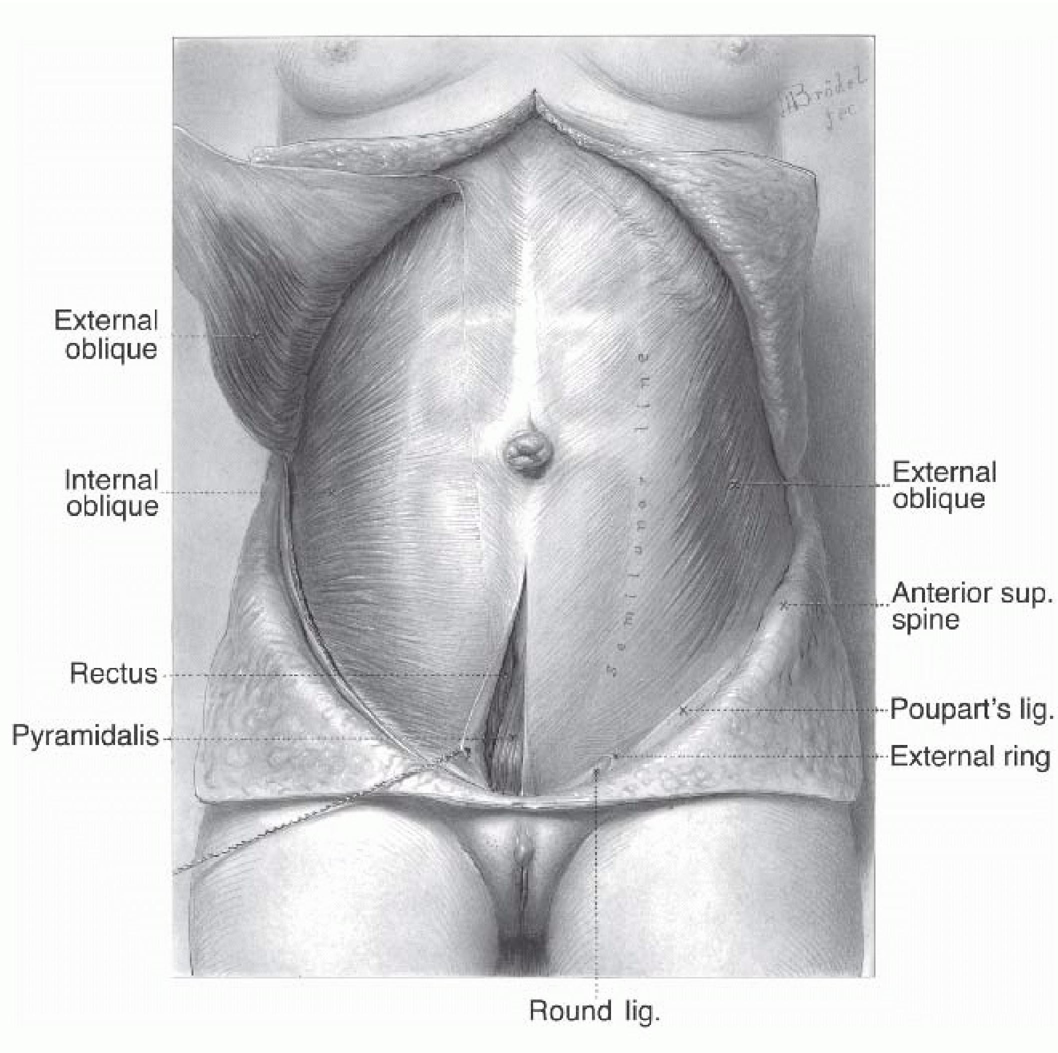

FIGURE 7.26 External oblique, internal oblique, and pyramidal muscles. (The original illustration is in the Max Brödel Archives in the Department of Art as Applied to Medicine, The Johns Hopkins University School of Medicine, Baltimore, MD, USA, with permission.)

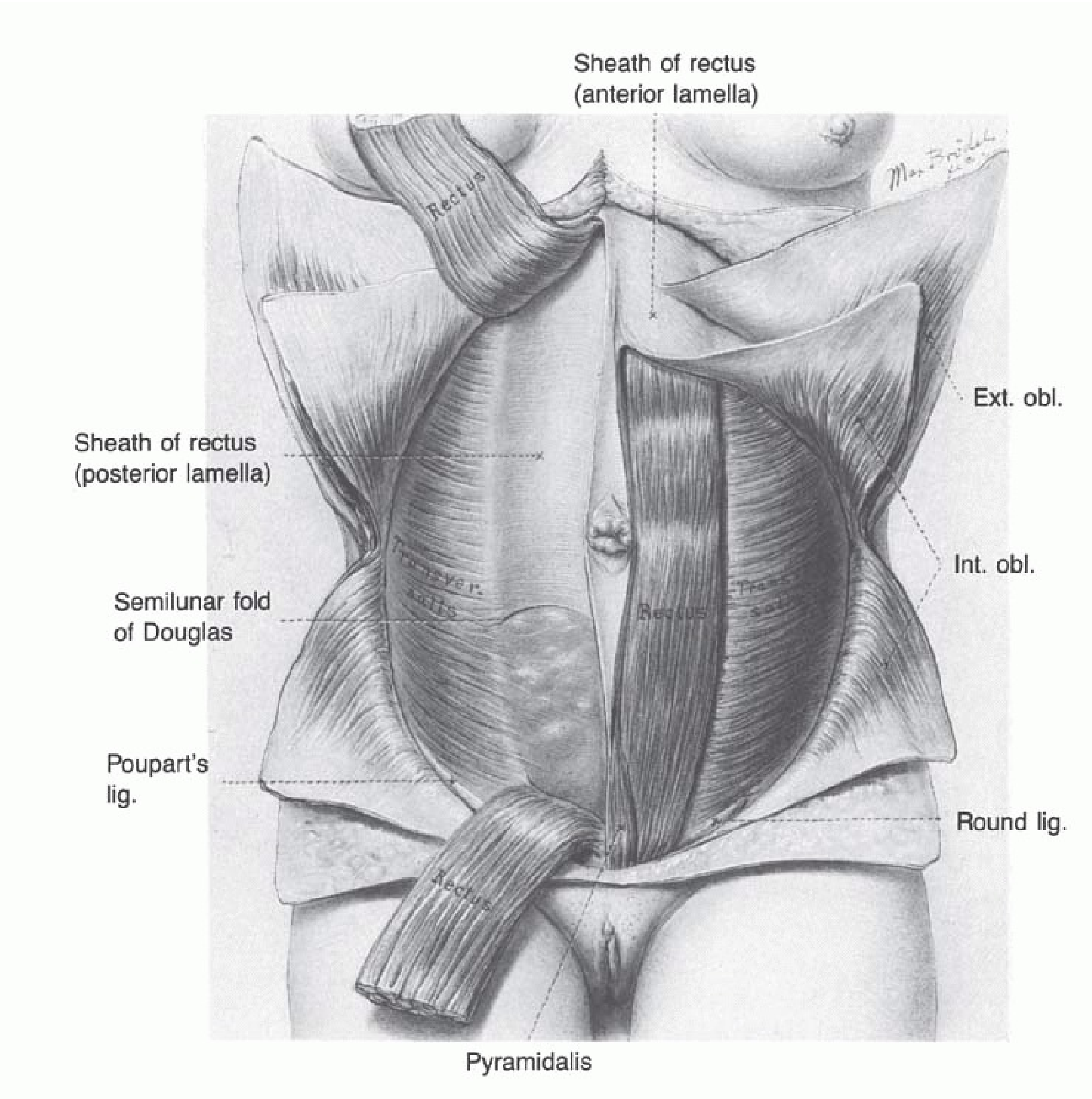

FIGURE 7.27 Transverse abdominal and rectoabdominal muscles. (The original illustration is in the Max Brödel Archives in the Department of Art as Applied to Medicine, The Johns Hopkins University School of Medicine, Baltimore, MD, USA, with permission.)

Flank Muscles

Lateral to the rectus abdominis muscles lie the broad, flat muscles of the flank. The aponeurotic insertions of these muscles join to form the conjoined tendon, or rectus sheath, which covers the rectus abdominis. Because of its importance, the rectus sheath is further discussed below.

The most superficial of these muscles is the external oblique. Its fibers run obliquely anteriorly and inferiorly from their origin on the lower eight ribs and iliac crest. Unlike the external oblique muscle's fibers, which run obliquely downward, the fibers of the internal oblique muscle fan out from their origin in the anterior two thirds of the iliac crest, the lateral part of the inguinal ligament, and the thoracolumbar fascia in the lower posterior flank. In most areas, they are perpendicular to the fibers of the external oblique muscle, but in the lower abdomen, their fibers arch somewhat more caudally and run in a direction similar to those of the external oblique muscle.

As the name *transversus abdominis* implies, the fibers of the deepest of the three layers have a primarily transverse orientation. They arise from the lower six costal cartilages, the thoracolumbar fascia, the anterior three fourths of the iliac crest, and the lateral inguinal ligament. The caudal portion of the transverse abdominal muscle is fused with the internal oblique muscle. This explains why, during transverse incisions of the lower abdomen, only two layers are discernible at the lateral portion of the incision.

Although the fibers of the flank muscles are not strictly parallel to one another, their primarily transverse orientation and the transverse pull of their attached muscular fibers place vertical suture lines in the rectus sheath under more tension than transverse ones. For this reason, vertical incisions are more prone to dehiscence.

Rectus Sheath (Conjoined Tendon)

The line of demarcation between the muscular and aponeurotic portions of the external oblique muscle in the lower abdomen occurs along a vertical line through the anterosuperior iliac spine (**Fig. 7.28**). The internal oblique and transverse abdominal muscles extend farther toward the midline, coming closest at their inferior margin, at the pubic tubercle. Because of this, fibers of the internal oblique muscle are found underneath the aponeurotic portion of the external oblique muscle during a transverse incision. In addition, it is between the internal oblique and transverse abdominal muscles that the nerves and blood vessels of the flank are found and their injury avoided.

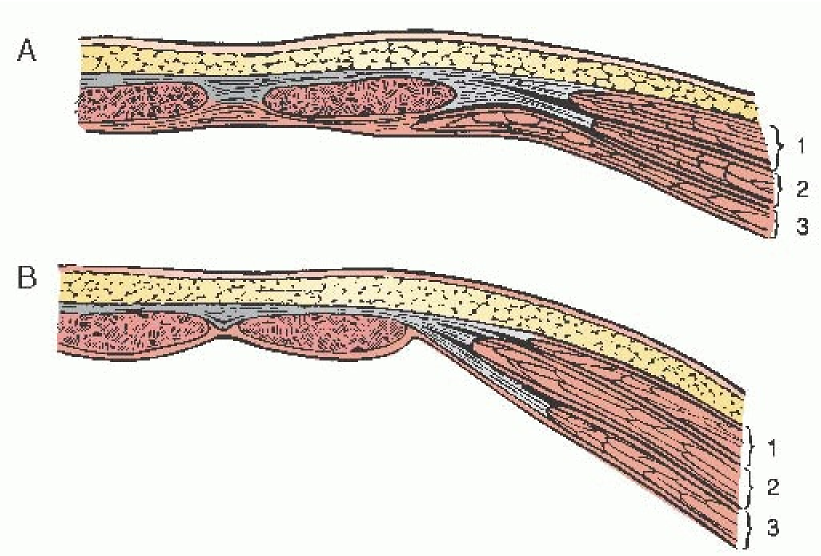

FIGURE 7.28 Cross section of lower abdominal wall. **A:** The anterior fascial sheath of the rectus muscle from external oblique (*1*) and split aponeurosis of internal oblique (*2*) muscles. The posterior sheath is formed by aponeurosis of the transverse abdominal muscle (*3*) and split aponeurosis of the internal oblique muscle. **B:** Lower portion of the abdominal wall below arcuate line (linea semicircularis) with absence of a posterior fascial sheath of the rectus muscle and all of the fascial aponeuroses (*1,2,3*) forming the anterior rectus muscle sheath.

In forming the rectus sheath, the conjoined aponeuroses of the flank are separable lateral to the rectus muscles but fuse near the midline. As they reach the midline, these layers lose their separate directions and fuse. Many specialized aspects of the rectus sheath are important to the surgeon. In its lower one fourth, the sheath lies entirely anterior to the rectus muscle. Above that point, it splits to lie both ventral and dorsal to it. The transition between these two arrangements occurs midway between the umbilicus and the pubes and is called the arcuate line. Cranial to this line, the midline ridge of the rectus sheath, the linea alba, unites these two layers. Sharp dissection is usually required to separate these layers during a Pfannenstiel incision. A vertical peritoneal incision cuts the posterior sheath.

The lateral border of the rectus muscle is marked by the semilunar line of the rectus sheath. Above the arcuate line, this is the level at which the anterior and posterior layers of the sheath split. Below it the transversalis fascia fuses with the sheath. The semilunar line is not always where the three layers of flank muscles join. During a transverse lower abdominal incision, the external and internal oblique aponeuroses are often separable near the midline.

The inguinal canal lies at the lower edge of the musculofascial layer of the abdominal wall. Through the inguinal canal, in the woman, the round ligament extends to its termination in the labium majus. In addition, the ilioinguinal nerve and the genital branch of the genitofemoral nerve pass through the canal.

Transversalis Fascia, Peritoneum, and Bladder Reflection

Inside the muscular layers, and outside the peritoneum, lies the transversalis fascia, a layer of fibrous tissue that lines the abdominopelvic cavity. It is visible during abdominal incisions as the layer just underneath the rectus abdominis muscles suprapubically. It is separated from the peritoneum by a variable layer of adipose tissue. It is frequently incised or bluntly dissected off the bladder to take the tissues in this region “down by layers.”

The peritoneum is a single layer of serosa. It is thrown into five vertical folds by underlying ligaments or vessels that converge toward the umbilicus. The single median umbilical fold is caused by the presence of the urachus (median umbilical ligament). Lateral to this are paired medial umbilical folds that are raised by the obliterated umbilical arteries that connected the internal iliac vessels to the umbilical cord in fetal life, and the corresponding lateral umbilical folds caused by the inferior epigastric arteries and veins.

The reflection of the bladder onto the abdominal wall is triangular in shape, with its apex blending into the medial umbilical ligament. Because the apex is highest in the midline, incision in the peritoneum lateral to the midline is less likely to result in bladder injury.

Neurovascular Supply of the Abdominal Wall

Vessels of the Abdominal Wall

Knowing the location and course of the abdominal wall blood vessels helps the surgeon anticipate their location during abdominal incisions and during the insertion of laparoscopic

trocars (**Fig. 7.29**). The blood vessels that supply the abdominal wall can be separated into those that supply the skin and subcutaneous tissues and those that supply the musculofascial layer. Although there is only one set of epigastric vessels in the subcutaneous tissues (superficial epigastric), there are both superior and inferior epigastric vessels in the musculofascial layer, so care must be taken in using these terms to avoid confusion.

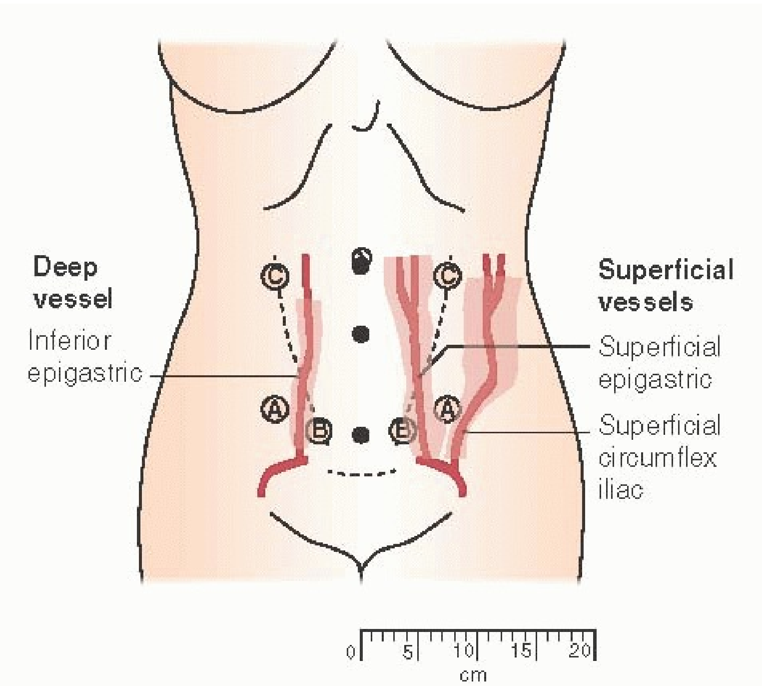

FIGURE 7.29 Normal variation in epigastric vessels. *A, B*, and *C* designate safe spots for laparoscopic trocar insertion. *Dotted lines* indicate lateral border of rectus muscle. (From Hurd WW, Bude RO, DeLancey JOL, et al. The location of abdominal wall blood vessels in relationship to abdominal landmarks apparent at laparoscopy. *Am J Obstet Gynecol* 1994;171:642, with permission. Copyright © 1994, Elsevier.)

The superficial epigastric vessels run a diagonal course in the subcutaneum from the femoral vessels toward the umbilicus, beginning as a single artery that branches extensively as it nears the umbilicus. Its position can be anticipated midway between the skin and musculofascial layer, in a line between the palpable femoral pulse and the umbilicus. The external pudendal artery runs a diagonal course from the femoral artery medially to supply the region of the mons pubis. It has many midline branches, and bleeding in its territory of distribution is heavier than that from the abdominal subcutaneous tissues. The superficial circumflex iliac vessels proceed laterally from the femoral vessels toward the flank.

The blood supply to the lower abdominal wall's musculofascial layer parallels the subcutaneous vessels. The branches of the external iliac, the inferior epigastric, and the deep circumflex iliac arteries parallel their superficial counterparts (**Fig. 7.29**). The circumflex iliac artery lies between the internal oblique and transverse abdominal muscle. The inferior epigastric artery and its two veins originate lateral to the rectus muscle. They run diagonally toward the umbilicus and intersect the muscle's lateral border midway between the pubis and umbilicus. Below the point at which the vessels pass under the rectus, they are found lateral to the muscle deep to the transversalis fascia. After crossing the lateral border of the muscle, they lie on the muscle's dorsal surface, between it and the posterior rectus sheath. As the vessels enter the rectus sheath, they branch extensively, so that they no longer represent a single trunk. The angle between the vessel and the border of the rectus muscle forms the apex of the Hesselbach triangle (inguinal triangle), the base of which is the inguinal ligament.

Lateral laparoscopic trocars are placed in a region of the lower abdomen where injury to the inferior epigastric and superficial epigastric vessels can occur easily. The inferior epigastric arteries and the superficial epigastric arteries run similar courses toward the umbilicus. Knowing the average location of these blood vessels helps in choosing insertion sites that will minimize their injury and the potential hemorrhage and hematomas that this injury can cause. Just above the pubic symphysis, the vessels lie approximately 5.5 cm from the midline, whereas at the level of the umbilicus, they are 4.5 cm from the midline (**Fig. 7.30**). Therefore, placement either lateral or medial to the line connecting these points minimizes potential vascular injury. In addition, the location of the inferior epigastric vessel can often be seen (**Fig. 7.31**) by following the round ligament to its point of entry into the inguinal ring, recognizing that the vessel lies just lateral to this point.

Nerves of the Abdominal Wall

The innervation of the abdominal wall (**Fig. 7.30**) comes from the abdominal extension of intercostal nerves 7 through 11, subcostal nerve (T12), and iliohypogastric and ilioinguinal nerves (both L1). Dermatome T10 lies at the umbilicus.

After giving off a lateral cutaneous branch, each intercostal nerve pierces the lateral border of the rectus sheath. There it provides a lateral branch that ends in the rectus muscle. The anterior branch then passes through the muscle and perforates the rectus sheath to supply the subcutaneous tissues and skin as the anterior cutaneous branches. Incisions along the lateral border of the rectus lead to denervation of the muscle, which can render it atrophic and weaken the abdominal wall. Elevation of the rectus sheath off the muscle during the Pfannenstiel incision stretches the perforating nerve, which is sometimes ligated to provide hemostasis from the accompanying artery. This may leave an area of cutaneous anesthesia.

The iliohypogastric and ilioinguinal nerves pass medial to the anterosuperior iliac spine in the abdominal wall. The former supplies the skin of the suprapubic area. The latter supplies the lower abdominal wall, and by sending a branch through the inguinal canal, it supplies the upper portions of the labia majora and medial portions of the thigh. These nerves can be entrapped in the lateral closure of a transverse incision and may lead to chronic pain syndromes.

The genitofemoral (L1 and L2) and femorocutaneous (L2 and L3) nerves can be injured during gynecologic surgery. The genitofemoral nerve lies on the psoas muscle (**Fig. 7.31**), where pressure from a retractor can damage it and lead to anesthesia in the medial thigh and lateral labia. The femoral cutaneous nerve can be compressed either by a retractor blade lateral to the psoas or by too much flexion of the hip in the lithotomy position, causing anesthesia over the anterior thigh.

BEST SURGICAL PRACTICES

- Important anatomic relationships of the ureter include the following:
  - The ureter lies medial to the ovarian vessels at the bifurcation of the internal and external iliac arteries entering the pelvic brim.
  - The ureter courses under the uterine artery approximately at 1.5 cm lateral to the cervix.
  - The ureter lies directly on the anterior vaginal wall very near the place where the vagina is detached from the cervix during the hysterectomy.
- Branches of the ilioinguinal and iliohypogastric nerves run in the region of the abdominal wall involved in lower abdominal transverse incision and can be involved with nerve entrapment syndromes after these incisions.

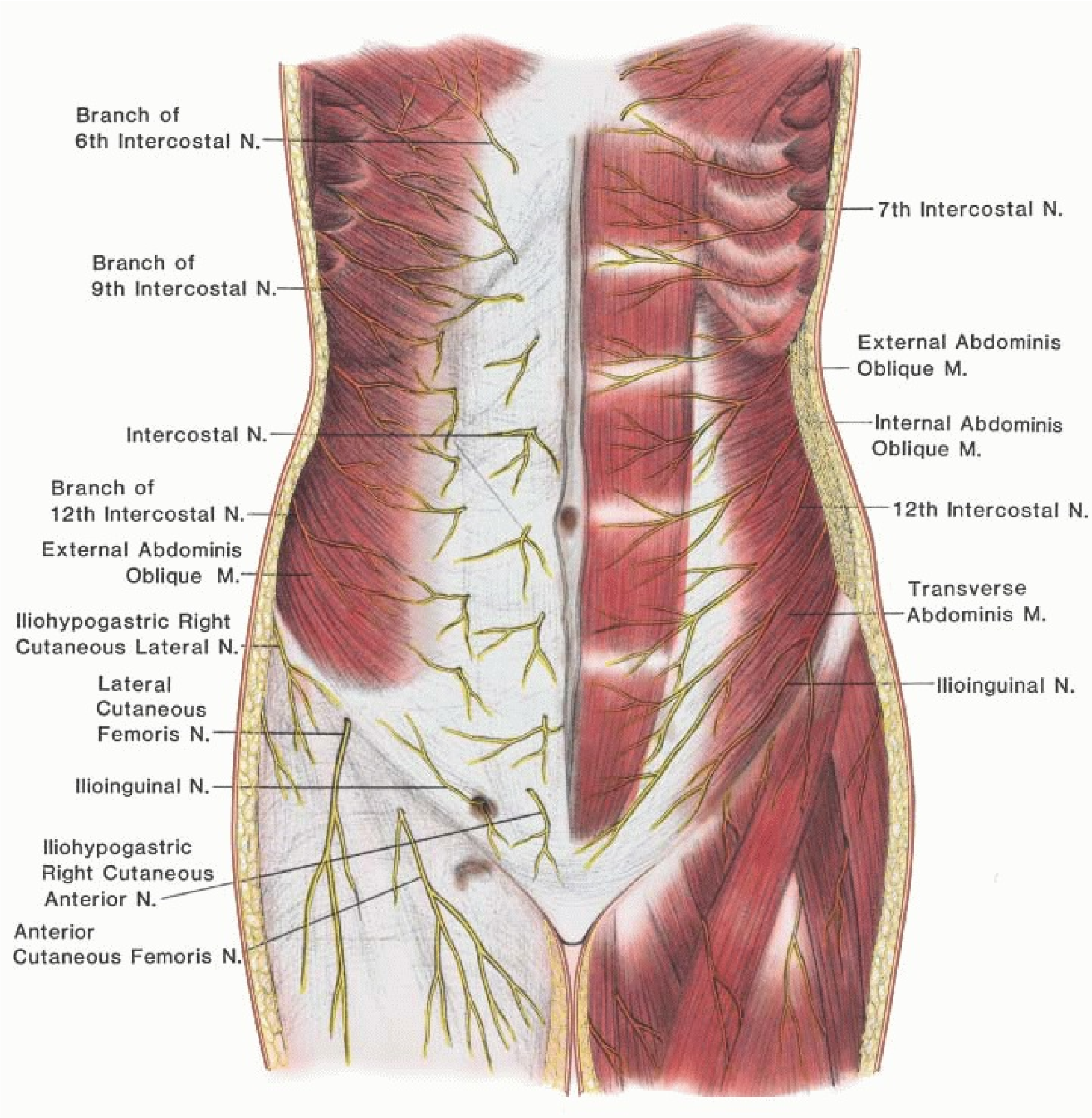

FIGURE 7.30 Nerve supply to the abdomen. **Right:** Deep innervation of T6BT12 to the transverse abdominal, internal oblique, and rectal muscles. **Left:** Superficial distribution, including cutaneous nerves, after penetration and innervation of the external oblique muscle and fascia. Innervation of the groin and thigh also is shown.

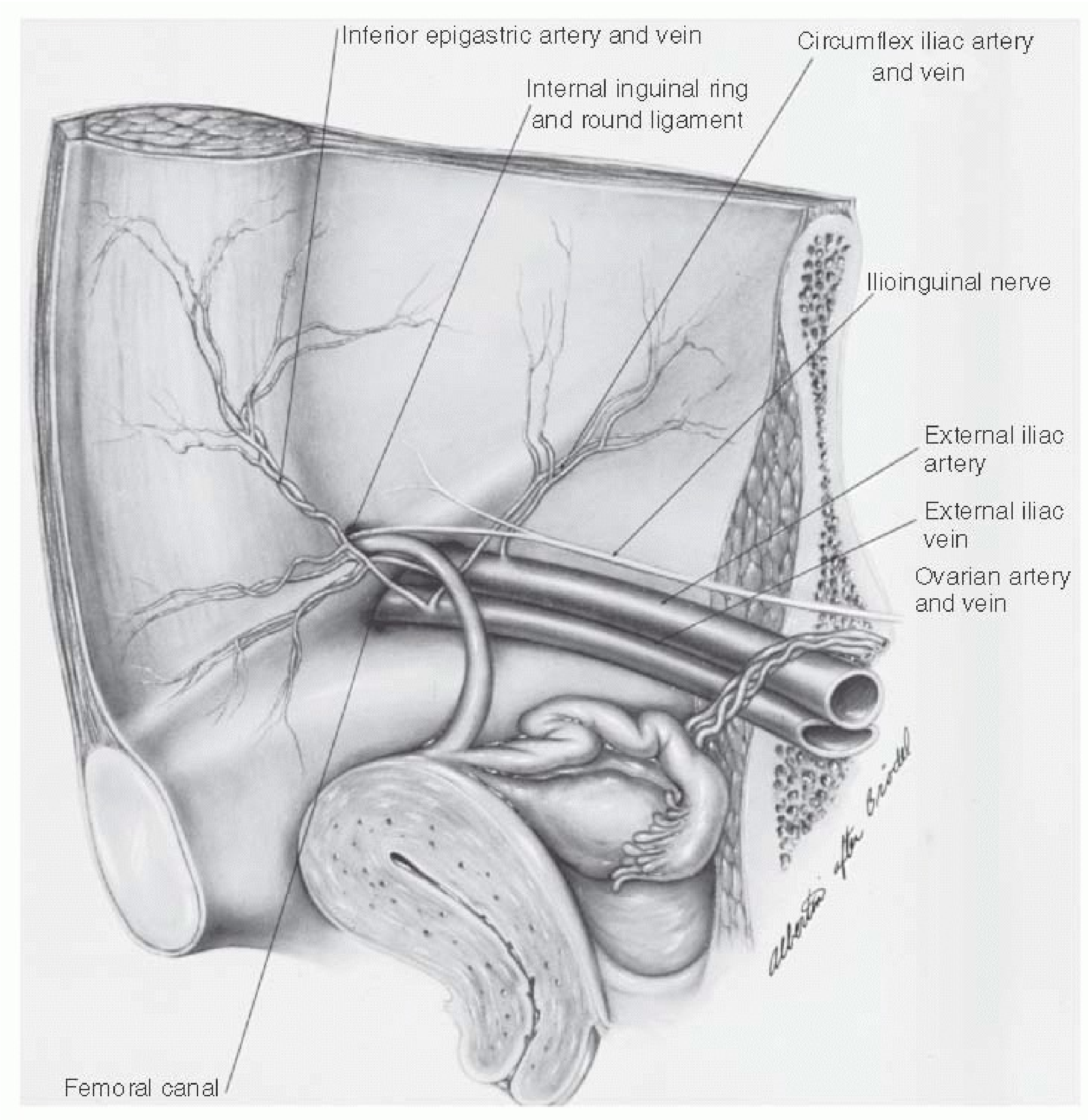

FIGURE 7.31 Sagittal view of female pelvis, showing inguinal and femoral anatomy. (The original illustration is in the Max Brödel Archives in the Department of Art as Applied to Medicine, The Johns Hopkins University School of Medicine, Baltimore, MD, USA, with permission.)

- Support of the pelvic organs comes from the combined action of the levator ani muscles that close the genital hiatus and provide a supportive layer on which the organs can rest and by the attachment of the vagina and uterus to the pelvic sidewalls.
- The internal iliac vessels supply the pelvic organs and pelvic wall and gluteal regions. The complexity of these multiple branches varies from individual to individual, but the key feature is the multiple areas of collateral circulation that come into play immediately after internal iliac artery ligation so that blood supply to the pelvic organs has diminished pulse pressure but continues to have flow even after the ligation.
- The blood supply to the female genital tract is an arcade that begins at the top with input from the ovarian vessels, lateral supply by the uterine vessels, and distal supply by the vaginal artery. There is an anastigmatic artery that runs along the entire length of the genital tract. For this reason, ligation of any single one of these arteries does not diminish flow to the uterus itself.

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