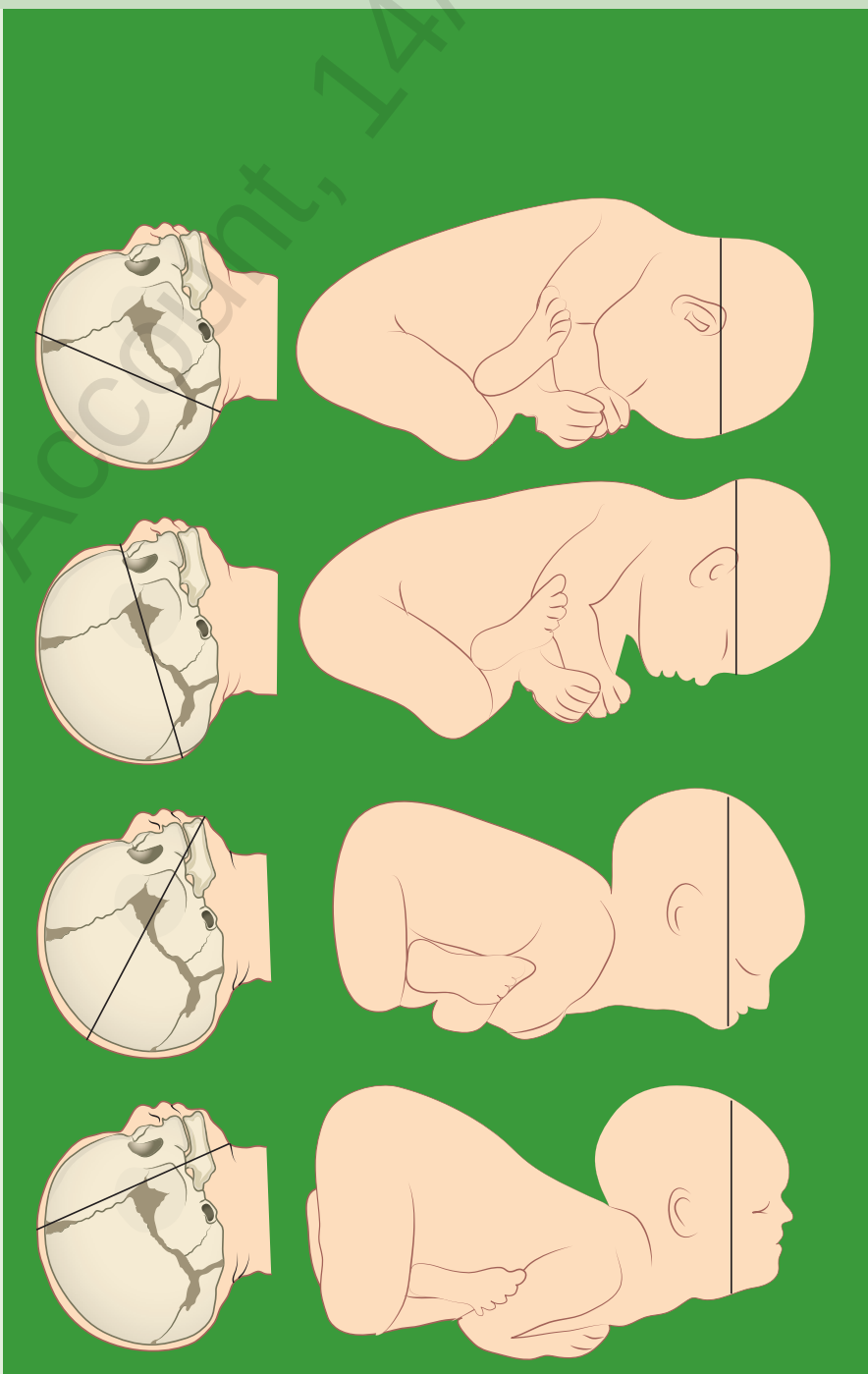
Section I

Anatomy and Physiology



1 Anatomy of Female Genital System

Introduction

The female reproductive system consists of organs concerned with menstruation, coitus, fertilization, pregnancy, and parturition. They can be divided into the following categories:

- *External genitalia*: Vulva
- *Internal genitalia*: Vagina, uterus, cervix, fallopian tubes, ovaries
- *Accessory reproductive organs*: Mammary glands

The female reproductive system can also be divided into the lower genital tract (vulva and vagina) and the upper tract (cervix, uterus, fallopian tubes, and ovaries).

Embryology

Soon after the delivery, everybody wants to know the sex of the baby. If the external genitalia of the newborn are ambiguous, the obstetrician faces a profound dilemma and constitutes a true medical emergency. Gender identity disorders have grave psychological and social problems. The gender of individual depends on chromosomes, hormones, and social environment. Sex differentiation is a complex phenomenon. It is classified into the following categories:

- Differentiation of gonads
- Differentiation of internal genital organs
- Differentiation of external genital organs

Genital system development begins in embryonic period and ends at puberty. The gonads do not acquire male or female morphologic characteristics until the seventh week of development. Testis-determining factor (TDF) gene is the key to sexual dimorphism that is situated on the short arm of Y chromosome. The gonads are formed by proliferation of the celomic epithelium and condensation of the underlying mesenchyme on the medial aspect of intermediate cell mass. The gonads appear initially as a pair of longitudinal ridges known as *gonadal* or *genital ridges*. The primordial germ cells appear among the endoderm cells in the wall of the yolk sac close to allantois. They migrate by ameboid movement along the dorsal mesentery of the hindgut and invade the genital ridges in the sixth week of development. Here they form primitive sex cords. In the absence of TDF, medullary cords disappear and get replaced by a vascular stroma (ovarian medulla). Cortical cords develop and surround one or more primitive germ cells. The germ cells subsequently develop into oogonia, while the surrounding epithelial cells form the follicular cells. This differentiates undifferentiated gonads into ovaries. Stroma of ovary develops from basal mesenchyme. Granulosa and theca cells develop from celomic epithelium.

Development of Genital Ducts

Development of genital duct system and the external genitalia occurs under the influence of hormones circulating in the fetus. Sertoli cells in the fetal testes produce a nonsteroidal substance known as *Müllerian-inhibiting substance* (MIS) that causes regression of Müllerian ducts. Androgen from the fetal testes causes masculinization of external genitalia. In the absence of MIS, Müllerian ducts develop and mesonephric duct system regresses. In the absence of androgen, external genitalia differentiate into female phenotype. The Müllerian duct develops between the fifth and sixth weeks lateral to intermediate cell mass and Wolffian duct. The Müllerian duct has the following three parts:

- Cranial vertical portion that opens into celomic cavity. Later it differentiates into fallopian tubes.
- Horizontal part crosses the mesonephric duct.
- Caudal vertical part that fuses with its partner from opposite side. This fused part later differentiates into uterus, cervix, and upper one-third of the vagina.

The dorsal celomic epithelium (which forms Müllerian duct) remains open at its site of origin and ultimately forms the fimbriated ends of the fallopian tubes. At their point of origin, each of the Müllerian ducts forms a solid bud. Each bud penetrates the mesenchyme lateral and parallel to the Wolffian duct. As the solid buds elongate, a lumen appears in the cranial part, beginning at each celomic opening. The caudal end of each Müllerian duct crosses the ventral

aspect of the Wolffian duct. The most cranial parts of the Müllerian ducts form the fallopian tubes (**Fig. 1.1**).

The caudal segments of the Müllerian ducts fuse to form the uterus and part of the vagina. The congenital absence of the uterus, the vagina with normal ovarian function, and 46,XX karyotype is the characteristic of women with Müllerian agenesis. The small rudimentary uterine bulbs are usually present with rudimentary fallopian tubes in Müllerian agenesis. This is frequently associated with skeletal, urologic, and especially renal anomalies. The ovarian and broad ligaments develop from the genital ligament. The vagina has dual origin. Upper part derives from the Müllerian duct, while the lower portion develops from the sinovaginal bulb from the urogenital sinus. By the fifth month of development, vaginal outgrowth is entirely canalized. If there is any anomaly in the development of the Müllerian ducts at any time between their origin from the celomic epithelium at 5 week of embryonic age and their fusion with the urogenital sinus at 8 weeks, the sinovaginal bulb will fail to proliferate from the urogenital sinus and the uterus and vagina will fail to develop. Congenital absence of the vagina is known as *Mayer-Rokitansky-Küster-Hauser* (MRKH) syndrome. The MRKH syndrome is associated with heterogenous group of disorders that have a variety of genetic, endocrine, and metabolic manifestation and associated anomalies of other organs. The lumen of the vagina is separated from the urogenital sinus by a thin tissue transverse septum, known as the *hymen*. The remnants of mesonephric ducts (epoophoron, paroophoron) are occasionally found in mesovarium and vagina wall.

Development of External Genitalia

In the third week of development, mesenchyme cells migrate around the cloacal membrane to form a pair of slightly elevated cloacal folds (**Fig. 1.2**).

Anterior to cloacal membrane, cloacal folds unite to form the genital tubercle by the fourth to fifth week of gestation. Caudally, the folds are subdivided into urethral folds anteriorly and anal folds posteriorly. The genital tubercle elongates only slightly and forms the clitoris and urethral folds do not fuse, as in the male, but develop into the labia minora. Genital swellings enlarge and form the labia majora. Urogenital membrane breaks in between to expose the lower part of urogenital sinus or groove. The urogenital groove opens centrally and forms the vestibule, urethra, and lower one-third of the vagina.

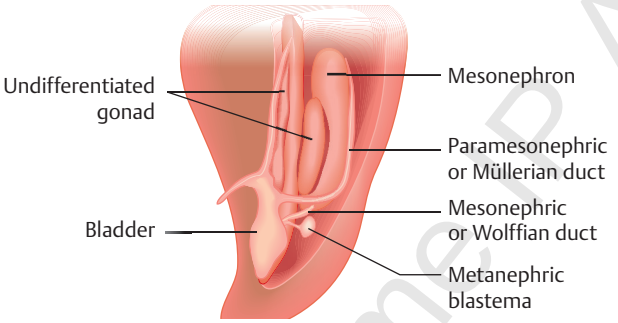


Fig. 1.1 Six-week-old human embryo.

Anatomy

Perineum

The arrangement of the superficial and deep fasciae in the urogenital region results in the formation of two triangular spaces, the superficial and deep perineal spaces.

Superficial Perineal Space

This space is situated superficial to the perineal membrane (urogenital diaphragm) and is also known as the *superficial compartment of the perineum*. The

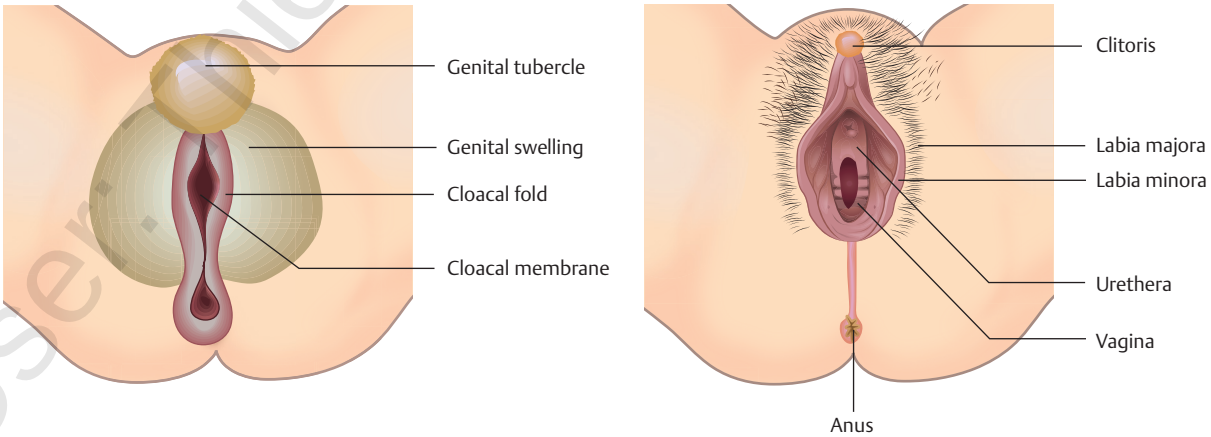


Fig. 1.2 Diagrammatic representation of external genitalia.

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. This space contains the following structures:

- Colles fascia
- The clitoris and its crura
- Ischiocavernosus muscle
- Bulbocavernosus muscle
- Greater vestibular glands
- Superficial transverse perineal muscles (**Fig. 1.3**)

Deep Perineal Space

This is the space deep to the perineal membrane. It contains deep perineal muscle, compressor urethrae, and uretherovaginal sphincter.

Perineal Body

Within the area bounded by the lower vagina, perineal skin and anus is a mass of connective tissue called the *perineal body* or the *central tendon* of the perineum. It is attached to the inferior pubic rami and ischial tuberosities through the perineal membrane and superficial transverse perineal 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 (**Fig. 1.4**). Constituent elements of endopelvic fascia are listed in **Box 1.1**.

Box 1.1 Components of the endopelvic fascia

- Parietal fascia
  - ➢ Obturator fascia
  - ➢ Levator ani fascia
  - ➢ Coccygeus fascia (sacrospinous ligament)
  - ➢ Piriform fascia
- Visceral fascia
  - ➢ Covering the uterus, vagina, bladder, rectum
- Deep endopelvic connective tissue
  - ➢ Contains six pericervical ligaments: Two pubocervical, two cardinal, and two uterosacral ligaments
  - ➢ Septae
    1. Pubocervical, rectovaginal septum
  - ➢ Pericervical ring

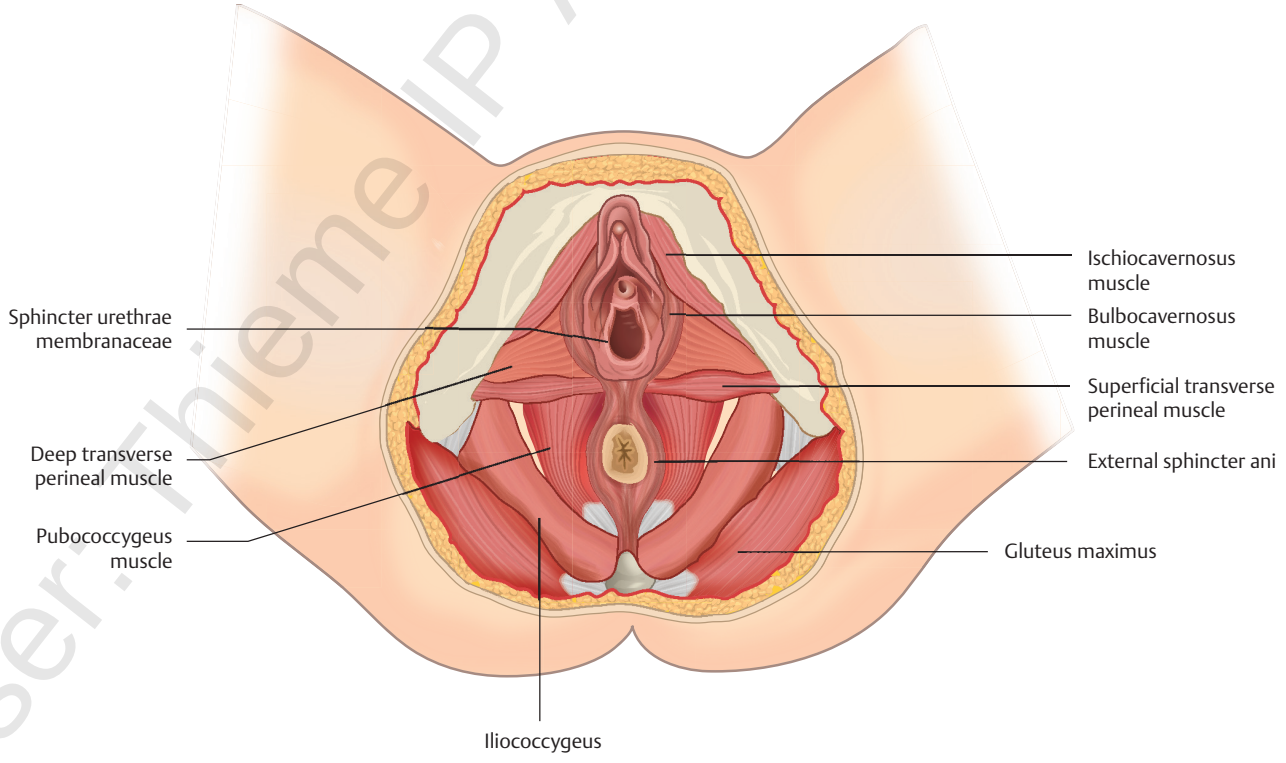


Fig. 1.3 Diagrammatic representation of perineal muscles.

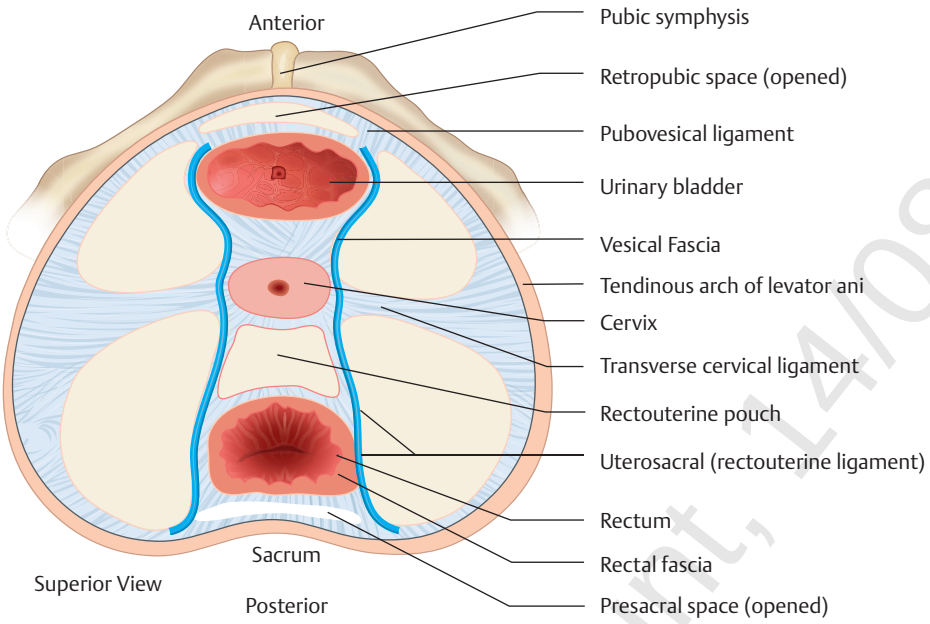


Fig. 1.4 Transverse section of the pelvic fascia.

Lower Genital Tract

External Genitalia

Vulva (Pudendum)

The female external genitalia or vulvae include the mons pubis, labia majora, labia minora, clitoris, vestibule, vestibular bulb, and the greater vestibular glands (**Fig. 1.5**).

Mons Pubis

The mons pubis is the rounded area of the skin over the pubic symphysis and the adjacent pubic bone. It bears hair over it. Before puberty, the mons pubis is relatively flat and the labia minora are poorly formed. During adolescence, coarse hair forms over the mons and labia majora and the labia minora become more prominent and flap-like. In adult females, the mons is covered by coarse hair that is limited above by a horizontal boundary. After the menopause, pubic hair thins and labial tissue atrophies slightly.

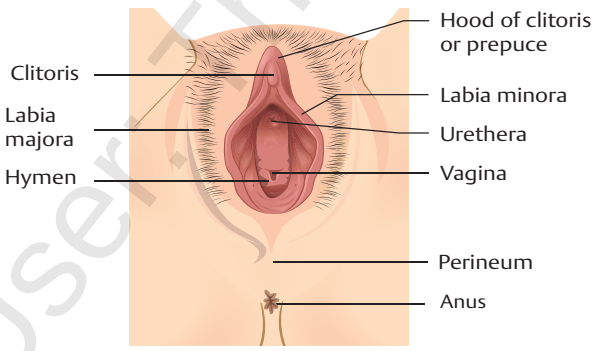


Fig. 1.5 Parts of the vulva.

Labia Majora

The labia majora are two prominent, longitudinal folds of the skin that extend back from the mons pubis to the perineum. They form the lateral boundaries of the vulva. Each labium has an external pigmented surface covered with hairs and a smooth, pink internal surface with large sebaceous follicles.

Labia Minora

The labia minora are two small cutaneous folds, devoid of fat, that lie between the labia majora. These are lined by nonkeratinized squamous epithelium and contain elastic tissues, veins, a few smooth muscles, and abundant nerve endings. These extend from the clitoris obliquely down, laterally, and back flanking the vaginal orifice. Anteriorly, each labium minus bifurcates. The upper layer of each side passes above the clitoris to form a fold, the hood or prepuce, which overhangs the glans of the clitoris. The lower layer of each side passes below the clitoris to form the frenulum of the clitoris. Posteriorly, the labia minora unite in the midline to form a thin ridge of skin called *fourchette*.

Vestibule

The vestibule is the cavity that lies between the labia minora. It contains the vaginal and external urethral orifice and the openings of the two greater vestibular (Bartholin's) glands and of numerous mucous, lesser vestibular glands.

Urethra

The urethra opens into the vestibule about 2.5 cm below the clitoris and above the vaginal opening via a short, sagittal cleft with slightly raised margins, the urethral meatus. The ducts of the paraurethral glands (Skene's glands) open on each side of the lateral margins of the urethra.

Vaginal Orifice

The vaginal orifice lies in the posterior end of the vestibule posterior to the urethral opening. It is incompletely guarded by a septum of mucous membrane called the *hymen*.

Greater Vestibular Glands (Bartholin's Glands)

The greater vestibular glands are homologues of the male bulbourethral glands. They consist of two small, round or oval, reddish-yellow bodies that flank the vaginal orifice at about the 4 and 8 o' clock position under the bulbospongiosus muscle. Each opens into the posterolateral (junction of anterior two-thirds and posterior one-third) part of the vestibule by a 2-cm duct, situated in the groove between the hymen and the labium minus (3–4 mm outside the hymenal ring). The glands are composed of tubuloacinar tissue. The secreting cells are columnar and secrete alkaline clear or whitish mucus with lubricant properties. They are stimulated by sexual arousal. The duct is lined by columnar epithelium but near its opening by stratified squamous epithelium. When the Bartholin's gland is blocked and the gland becomes enlarged filled with secretions, this condition is known as *Bartholin's gland cyst* and if this gets infected and inflammed, the condition is called *Bartholin's abscess*, which is painful (**Fig. 1.6**).

Bulbs of the Vestibule

The bulbs of the vestibule lie on each side of the vestibule. They are two elongated masses of erectile tissue, 3 cm long, which flank the vaginal orifice and unite anterior to it by a narrow commissural bulborum (pars intermedia). They are homologous to the bulb of the penis in the male. However, it is split to be bilateral. Posterior ends of vestibular bulbs if torn in labor, may cause severe hemorrhage.

Clitoris

The clitoris is an erectile structure partially enclosed by the anterior bifurcated ends of the labia minora. It has a root, a body, and a glans. The body can be palpated through the skin. It contains two corpora cavernosa, composed of erectile tissue, and enclosed in dense fibrous tissue. The glans clitoris is a small round tubercle of spongy erectile tissue at the end of the body and connected to the bulbs of the vestibule by thin bands of erectile tissue. It is exposed between the anterior ends of the labia minora. Its epithelium has high cutaneous sensitivity important in sexual responses.

Vascular Supply and Lymphatic Drainage of the Vulva

Arterial Supply

The arterial blood supply of the female external genitalia is derived from the superficial and deep external pudendal branches of the femoral artery and the internal pudendal artery, a branch of internal iliac artery on each side.

Venous Drainage

Venous drainage of the vulval skin is via external pudendal veins to the long saphenous vein. Venous drainage of the clitoris is via deep dorsal veins to the internal pudendal vein and superficial dorsal veins to the external pudendal and long saphenous veins. The veins form plexuses and drain into pudendal and saphenous veins along with vesical or vaginal venous plexus. In rare circumstances, varicosities of vulva develop that can cause severe bleeding.

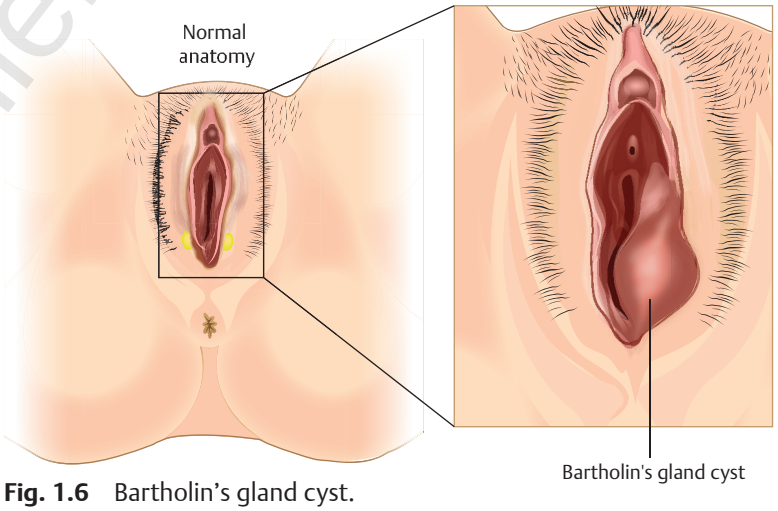


Fig. 1.6 Bartholin's gland cyst.

Lymphatic Drainage
The lymphatics drain into superficial and deep inguinal lymph nodes. There are 12 to 20 superficial lymph nodes that are spread parallel to and 1 cm below the inguinal ligament and extending down along the saphenous vein.

Innervations
The anterior third of the labium majus is supplied by the ilioinguinal nerve (L1), the posterior two-thirds are supplied by the labial branches of the perineal nerve (S3), and the lateral aspect is also innervated by the perineal branch of the posterior cutaneous nerve of the thigh (S2).

Internal Genitalia

Vagina

The vagina is a fibromuscular distensible tube lined by nonkeratinized stratified squamous epithelium. It extends from the vestibule (the opening between the labia minora) to the cervix. The upper end of the vagina surrounds the vaginal projection of the uterine cervix. The annular recess between the cervix and the vagina is the fornix. The different parts of this recess are given separate names, that is, anterior, posterior, and lateral (right and left side) fornices, but they are continuous.

The vagina ascends posterior and upward. It forms an angle of 45 degrees with the horizontal in the erect posture. The width of the vagina increases as it ascends. The vaginal mucosa is attached to the uterine cervix on all sides. The anterior wall is approximately 7.5 cm long and the posterior wall is approximately 9 cm long. The anterior wall of the vagina is related to the base of the bladder. The posterior wall is separated from the rectum by the rectouterine pouch superiorly, and by Denonvilliers' fascia in its middle half. Laterally are levator ani and pelvic fascia. As the ureters pass anteromedially to reach the fundus of the bladder, they pass close to the lateral fornices and at this point each ureter is crossed transversely by a uterine artery.

The vagina opens externally through introitus. The size of the introitus varies; it is capable of great distension during childbirth and to a lesser degree during sexual intercourse. The hymen is a thin fold of mucous membrane situated just within the vaginal orifice. The internal surfaces of the folds are normally in contact with each other and the vaginal opening appears as a cleft between them.

Vascular Supply and Lymphatic Drainage of the Vagina

Arterial Supply
The arterial supply of the vagina is derived from the internal iliac arteries. Two azygos arteries descend on the vagina and supply the mucous membrane. The uterine, internal pudendal, and middle rectal branches of the internal iliac artery also contribute to the blood supply.

Venous Drainage
The vaginal veins drain into the internal iliac and internal pudendal veins.

Lymphatic Drainage
Upper lymphatic vessels drain in the internal and external iliac nodes; intermediate vessels drain in the internal iliac nodes, and the lower vessels drain the vagina below the hymen in the superficial inguinal nodes.

Innervations
The lower vagina is supplied by the pudendal nerves (S2, S3, and S4). The upper vagina is supplied by the splanchnic nerves (S2, S3, and sometimes S4).

Functions of the Vagina

- Excretory duct for the menstrual fluid
- Coital canal for sexual pleasure, it brings vaginal lubrication
- Receptacle for semen to supply sperms to cervical canal, helps in capacitation of sperm
- Protective function—acidic vaginal pH prevents infection
- Absorptive function—seminal prostaglandin is absorbed to cause contraction of the myometrium and the fallopian tube
- Birth canal for delivery of the baby

Vaginal Secretion
The newborn has influence of maternal estrogen on the genital tract. Doderlein's bacilli appear by the third or fourth day and the vaginal pH is same as of an adult. By 10 to 14 days the estrogen stimulus is lost and the vaginal epithelium becomes atrophic and devoid of glycogen. The pH then rises to 7 and remains same till the puberty. The vaginal pH from the puberty to the menopause is acidic because of the presence of Doderlein's bacilli that produce lactic acid from glycogen present in exfoliated cells. The pH varies with estrogenic activity and ranges from 4 to 5. During pregnancy the glycogen is increased to maximum and the pH is high (3.5–4.5).

Upper Genital Tract

Uterus

The uterus is a thick-walled, fibromuscular organ situated in the pelvis. It lies posterior to the bladder and uterovesical space and anterior to the rectum and rectouterine pouch (**Fig. 1.7**). It is mobile, which means its position varies with distension of the bladder and

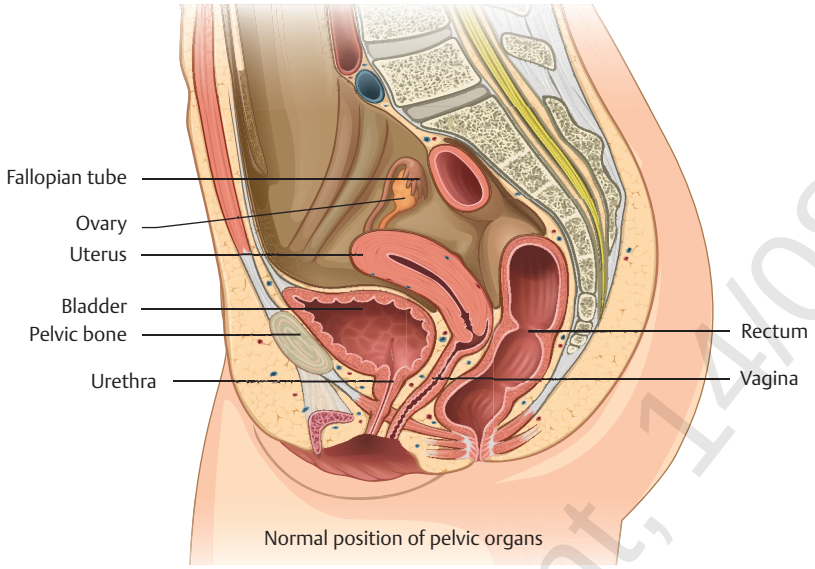


Fig. 1.7 Sagittal section of the female pelvis.

rectum. The uterus is divided into two main regions: the body of the uterus (corpus uteri) forms the upper two-thirds, and the cervix (cervix uteri) forms the lower third. In the adult nulliparous state the cervix tilts forward relative to the axis of the vagina (anteversion), and the body of the uterus tilts forward relative to the cervix (anteflexion). In 10 to 15% of women the whole uterus leans backward at an angle to the vagina and is said to be retroverted. A uterus that angles backward on the cervix is described as retroflexed.

Body

The body of the uterus is pear shaped and extends from the fundus superiorly to the cervix inferiorly. Near its upper end, the uterine tubes enter the uterus on both sides at the uterine cornua. Inferoanterior to each cornu is the round ligament and inferoposterior is the ovarian ligament. The dome-like fundus is superior to the entry points of the uterine tubes and covered by peritoneum that is continuous with that of neighboring surfaces. The fundus is in contact with small intestine and distended sigmoid colon. The lateral margins of the body are convex, and on each side their peritoneum is reflected laterally to form the broad ligament, which extends as a flat sheet to the pelvic wall. The anterior surface of the uterine body is covered by densely adherent peritoneum that is reflected onto the bladder as the uterovesical fold. This normally occurs at the level of the internal os. The posterior surface of the uterus is covered with densely adherent peritoneum till the cervix and upper vagina and is then reflected back to the rectum along the surface of the rectouterine pouch (Douglas'), which lies posterior to the uterus. The cavity of the uterine body usually measures 6 cm from the external os of the cervix to the fundus and is flat in its anteroposterior plane. The ratio of the cervix and the uterus is 2:1 in childhood. After puberty, the corpus grows faster than the cervix. The same ratio becomes 1:3 or 1:4 in reproductive age. After climacteric, the uterus shrinks and becomes fibrotic due to atrophy.

Uterus has serosal layer outside derived from visceral peritoneum. Myometrium is middle layer which contains muscular layer arranged in outer longitudinal layer, middle criss cross fibers and inner circular layer. It is lined internally by endometrium which is lined by columnar epithelium which extends below the anatomical internal os of cervix and that level is known as histological os. Mesenchymal stroma below columnar epithelium contains stromal cells, endometrial glands, vessels, and nerves.

Vascular Supply and Lymphatic Drainage of Uterus

Arterial Supply

The arterial supply to the uterus comes from the uterine artery. This arises as branch of the anterior division of the internal iliac artery. From its origin, the uterine artery crosses the ureter anteriorly in the broad ligament before branching as it reaches the uterus at the level of the cervicouterine junction (internal os). One major branch ascends the uterus tortuously within the broad ligament until it reaches the region of the ovarian hilum, where it anastomoses with the branches of the ovarian artery. Another branch descends to supply the cervix and anastomoses with branches of the vaginal artery to form two median longitudinal vessels, the azygos arteries of the vagina, which descend

anterior and posterior to the vagina. Although there are anastomoses between the ovarian and vaginal arteries, the dominance of the uterine artery is indicated by its marked hypertrophy during pregnancy.

The tortuosity of the vessels as they ascend in the broad ligaments is repeated in their branches within the uterine wall. Each uterine artery gives off numerous branches. These enter the uterine wall, divide and run circumferentially as groups of anterior and posterior arcuate arteries. They ramify and narrow as they approach the anterior and posterior midline so that no large vessels are present in these regions. However, the left and right arterial trees anastomose across the midline and unilateral ligation of the uterine artery can be done without serious effects. Terminal branches in the uterine muscle are tortuous and are called *helical arterioles*. They provide a series of dense capillary plexuses in the myometrium and endometrium. From the arcuate arteries many helical arteriolar rami pass into the endometrium. Their detailed appearance changes during the menstrual cycle. In the proliferative phase helical arterioles are less prominent, whereas they grow in length and caliber, becoming even more tortuous in the secretory phase.

Venous Drainage

The uterine veins extend laterally in the broad ligaments, running adjacent to the arteries and passing behind the ureters. They drain into the internal iliac veins. The uterine venous plexus anastomoses with the vaginal, ovarian, and cervical venous plexuses.

Lymphatic Drainage

Uterine lymphatics exist in the superficial (subperitoneal) and deep parts of uterine wall. Collecting vessels from the body of the uterus and cervix pass laterally in the parametrium to three main groups of lymph nodes: the external iliac, internal iliac, and the obturator nodes. The external nodes surround their corresponding arteries. The obturator nodes lie in the obturator fossa between the external and internal iliac vessels. The obturator nerve passes through the lower part of this group of lymph nodes.

Lymph vessels from the fundus of the uterus and the uterine tubes may accompany the lymph drainage of the ovaries to para-aortic nodes. The region surrounding the isthmus of the uterine tube may drain along the round ligament to the superficial inguinal nodes.

Innervation

The nerve supply to the uterus is predominantly from the inferior hypogastric plexus. Some branches ascend with, or near, the uterine arteries in the broad ligament. They supply the uterine body and tubes, and connect with the tubal nerves from the inferior hypogastric plexus and with the ovarian plexus. The uterine nerves terminate in the myometrium and endometrium, and usually accompany the vessels. Nerves to the cervix form a plexus that contains small paracervical ganglia. Sometimes one ganglion is larger and is termed the *uterine cervical ganglion*. Branches may pass directly to the cervix uteri or may be distributed along the vaginal arteries.

Efferent preganglionic sympathetic fibers are derived from neurons in the last thoracic and first lumbar spinal segment. The sites where they synapse on their postganglionic neurons are unknown. Preganglionic parasympathetic fibers arise from neurons in the second to fourth sacral spinal segments and relay in the paracervical ganglia. Sympathetic activity may produce uterine inhibition and vasodilatation, but these activities are complicated by hormonal control of uterine functions.

Cervix

The adult, nonpregnant cervix is narrower and more cylindrical than the body of the uterus and is typically 2.5 cm long. The upper end opens into the uterine body via the internal os while the lower end opens into the vagina at the external os. In nulliparous women, the external os is usually a circular aperture, whereas after childbirth, it is a transverse slit (like the appearance of a fish mouth). The narrower isthmus forms the upper third of the cervix. Although unaffected in the first months of pregnancy, it gradually merges with the uterine body to form "lower uterine segment." The supravaginal part is separated anteriorly from the bladder by cellular connective tissue, the parametrium, which also passes to the sides of the cervix and laterally between the two layers of the broad ligaments.

Endocevix is lined by mucin secreting columnar epithelium. Part of cervix outside external os is ectocervix which is lined by nonkeratinizing stratified squamous epithelium which meets columnar epithelium at external os. Zone of transition is called the transformation zone.

Fallopian Tubes

The uterine tubes are attached to the upper part of the body of the uterus and their ostia open into the uterine cavity. The medial opening of the tube (the uterine os) is located at the superior angle of the uterine cavity. The tube passes laterally and superiorly and consists of four main parts: intramural, isthmus, ampulla, and fimbria. The intramural part is 0.7 mm wide, 1 cm long, and lies within the myometrium. It is continuous laterally with the isthmus, which is 1 to 5 mm wide and 3 cm long and is rounded, muscular, and firm. The isthmus is continuous laterally with the ampulla, the widest portion of the tube with a maximum luminal diameter of 1 cm. The ampulla is 5 cm long and has a thin wall and a tortuously folded luminal surface. Typically,

fertilization takes place in its lumen. The ampulla opens into the trumpet-shaped infundibulum at the abdominal os. Fimbriae, numerous mucosal finger-like folds, 1 mm wide, are attached to the ends of the infundibulum and extend from its inner circumference beyond the muscular wall of the tube. One of these, the ovarian fimbria, is longer and more deeply grooved than the others, and is typically applied to the tubal pole of the ovary. At the time of ovulation, the fimbriae swell and extend as a result of engorgement of the vessels in the lamina propria, which aids capture of the released oocyte. All fimbriae are covered, such as the mucosal lining throughout the tube, by a ciliated epithelium whose cilia beat toward the ampulla.

Fallopian tubes have three layers. They are serosa, muscle layer, and mucus membrane thrown into folds. It is lined by tall columnar ciliated secretory cells, ciliated columnar cells, and peg cells.

Vascular Supply and Lymphatic Drainage of Fallopian Tubes

Arterial Supply

The blood supply to the uterine tubes is derived from the ovarian and uterine arteries. The lateral third of the tube is supplied by the ovarian artery, which continues in the mesosalpinx to anastomose with branches from the uterine artery. The medial two-thirds of the tube is supplied by the uterine artery.

Venous Drainage

Venous drainage is similar to the arterial supply. The venous drainage of the lateral one-thirds of the uterine tube is via the pampiniform plexus to the ovarian veins that open into the inferior vena cava on the right side and the renal vein on the left side. The medial two-thirds of the tube drain via the uterine plexus to the internal iliac vein.

Lymphatic Drainage

Lymph drainage is via ovarian vessels to the para-aortic nodes and uterine vessels to the internal iliac chain. It is possible for lymph to reach the inguinal nodes via the round ligament.

Innervation

The uterine tube is innervated by autonomic fibers that are distributed mainly with the ovarian and uterine arteries. Most of the tube has a dual sympathetic and parasympathetic supply. Preganglionic parasympathetic fibers are derived from the vagus for the lateral half of the tube and the pelvic splanchnic nerves for the medial half. Sympathetic supply is derived from neurons in the tenth thoracic to the second lumbar spinal segments. Visceral afferent fibers travel with the sympathetic nerves and enter the cord through the corresponding dorsal roots. They may also travel via parasympathetic fibers. The ampullary submucosa contains modified Pacinian corpuscles.

Ovaries

In the adult nonpregnant state, the ovaries lay on each side of the uterus close to the lateral pelvic wall, suspended in the pelvic cavity by a double fold of peritoneum, the mesovarium, which is attached to the upper limit of the posterior aspect of the broad uterine ligament. They are dull white in color and consist of dense fibrous tissue in which ova are embedded. Before regular ovulation begins, they have a smooth surface, but thereafter their surfaces are distorted by scarring that follows the degeneration of successive corpora lutea. Prior to the first menstrual period (menarche), the ovaries are about a third of the normal reproductive adult size; they gradually increase in size with body growth. After the menopause, the average size of the ovary reduces to 2 × 1.5 × 0.5 cm and further to 1.5 × 0.75 × 0.5 cm in late menopause.

The lateral surface of the ovary contacts parietal peritoneum in the ovarian fossa. Behind the ovarian fossa are retroperitoneal structures, including the ureter, internal iliac vessels, obturator vessels and nerves, and the origin of the uterine artery. The medial surface faces the uterus, uterine vessels in the broad ligament, and the peritoneal recess here is termed the ovarian bursa. Above the superior extremity are the fimbria and distal section of the uterine tube. The inferior extremity points downward toward the pelvic floor. The anterior border faces the posterior leaf of the broad ligament and contains the mesovarium. The posterior border is free and faces the peritoneum, which overlies the upper part of the internal iliac artery and vein, and the ureter. On the right side, superior and lateral to the ovary, are the ileocecal junction, cecum and appendix. On the left side, the sigmoid colon passes over the superior pole of the ovary and joins the rectum, which lies between the medial of both the ovaries. In embryonic and early fetal life, the ovaries are situated in the lumbar region near the kidneys. They gradually descend along the gubernaculum, stopping at the lesser pelvis. Accessory ovarian tissue may occur in the mesovarium or along the course of the gubernacula. Rarely, the ovaries may descend along the whole course of the gubernacula and are found in the labia majora. During pregnancy, the ovaries are lifted high in the pelvis and, by 14 weeks of gestation, become partly abdominal structures. By the third trimester, they are totally abdominal structures and lie vertically behind and lateral to the parous uterus.

Vascular Supply and Lymphatic Drainage of Ovaries

Arterial Supply

The ovarian arteries are branches of the abdominal aorta and originate below the renal arteries.

Each descends behind the peritoneum, and at the brim of the pelvis crosses the external iliac artery and vein to enter the true pelvic cavity. Here the artery turns medially in the ovarian suspensory ligament and splits into a branch to the mesovarium of that ligament, below the uterine tube, and supplies the tube. There are variations in the site of the division to the ovary and tube. On each side, a branch accompanies the round ligaments through the inguinal canal to the skin of the labium majus and the inguinal region. Early in intrauterine life the ovaries flank the vertebral column inferior to the kidneys, and so the ovarian arteries are relatively short; they gradually lengthen as the ovaries descend into the pelvis.

Venous Drainage

The ovarian veins emerge from the ovary as a plexus (pampiniform plexus) in the mesovarium and suspensory ligament. Two veins emerge from the plexus and ascend with the ovarian artery; they usually merge into a single vessel before entering either the inferior vena cava on the right side, or the renal vein on the left side.

Lymphatic Drainage

The main lymphatic drainage of the ovaries is along the vessels that follow the ovarian veins to para-aortic nodes situated near the origin of the renal arteries. Drainage may also occur via pelvic nodes into lower para-aortic nodes, and rarely may follow the round ligament to the inguinal nodes.

Innervation

The ovarian innervation is derived from autonomic plexuses. The upper part of the ovarian plexus is formed from branches of the renal and aortic plexuses, and the lower part is reinforced from the superior and inferior hypogastric plexuses. These plexuses consist of postganglionic sympathetic, parasympathetic, and visceral afferent fibers. The efferent sympathetic fibers are derived from the 10th and 11th thoracic spinal segments and are probable vasoconstrictor, whereas the parasympathetic fibers, from the inferior hypogastric plexuses, are probably vasodilator.

Broad Ligament

The ovaries and tubes form the uterine adnexa. They are covered by a specialized series of peritoneal folds called the *broad ligament*. During the embryonic development, the paired Müllerian ducts and ovaries arise from the lateral abdominopelvic wall. As they migrate medially and fuse, the peritoneum is pulled out of the pelvic wall from the cervix upward. This leaves the midline uterus connected on either side to the pelvic wall by a double layer of peritoneum. This peritoneal fold on either side is called the *broad ligament*. In the upper part of it, lies fallopian tube, round ligament, and ovarian ligament. The cardinal and uterosacral ligaments are at the lower margin of the broad ligament. They are not "pure ligament" but condensed fibromuscular connective tissue. The ovary, tube, and round ligament have peritoneal fold similar to mesentery, called *mesovarium*, *mesosalpinx*, and *mesoteres*, respectively. The mesosalpinx contains vascular anastomoses between the uterine and ovarian vessels, the epoophoron, the paroophoron. The mesovarium projects from the posterior aspect of the broad ligament, of which it is the smaller part, is attached to the hilum of the ovary and carries vessels and nerves to the ovary. At the lateral end of the fallopian tube and ovary, the broad ligament ends where the infundibulopelvic ligament blends with the pelvic wall.

Mesometrium

The mesometrium is the largest part of the broad ligament, and extends from the pelvic floor to the ovarian ligament and uterine body. The uterine artery passes between its two peritoneal layers typically 1.5 cm lateral to the cervix; it crosses the ureter shortly after its origin from the internal iliac artery and gives off a branch that passes superiorly to the uterine tube, where it anastomoses with the ovarian artery. This ligament continues laterally over the external iliac vessels as a distinct fold.

Infundibulopelvic (Suspensory) Ligament

The suspensory or infundibulopelvic ligament of the ovary is a peritoneal fold, which is attached to the upper part of the lateral surface of the ovary. It contains the ovarian vessels and nerves. On the right side the infundibulopelvic ligament is attached to a fold of peritoneum that is posterior and inferior to the cecum and appendix. On the left side, the peritoneal attachment is higher than on the right side and lateral to the junction of the descending and sigmoid colon. As it joins the peritoneum that covers the psoas major, it passes superiorly over the genitofemoral nerve, external iliac vessels, and the ureter.

Ligaments of the Pelvis

The ligaments of the pelvis consist of the round, uterosacral, transverse cervical, and pubocervical ligaments.

Round Ligament

The round ligaments are narrow, somewhat flattened bands, 10 to 12 cm long. Each is attached medially to the upper part of the uterus just below and anterior to the lateral cornua. From here, each passes laterally within the upper part of the broad ligament to the pelvic side wall. At the start of the inferior epigastric artery, the round ligament enters the deep inguinal ring. It traverses the inguinal canal and splits into strands that merge with the surrounding connective

tissue before terminating in the mons pubis above the labium majus. Near the uterus, the round ligament contains a considerable amount of smooth muscle, but this gradually diminishes and the terminal portion is purely fibrous. The round ligament contains blood vessels, nerves, and lymphatics. The lymphatics drain the uterine region around the entry of the uterine tube to the superficial inguinal lymph nodes.

In the fetus a projection of peritoneum (processus vaginalis) is carried with the round ligament for a short distance into the inguinal canal. This is generally obliterated in adults, although it is sometimes patent even in old age. In the canal the ligament receives the same coverings as the spermatic cord, although they are thinner and blend with the ligament itself, which may not reach the mons pubis. The round and ovarian ligaments both are developed from the gubernaculum and are continuous.

Uterosacral, Transverse Cervical, and Pubocervical Ligaments

The uterosacral ligaments contain fibrous tissue and smooth muscle. They pass back from the supravaginal cervix and uterine body on both sides of the rectum, and they are attached to the front of the sacrum. The ligaments can be palpated on rectal examination. On vaginal examination, these can be felt as thick bands of tissue passing downward on both sides of the posterior fornix. The transverse cervical ligaments (cardinal ligaments, Mackenrodt's ligaments) extend from the side of the supravaginal cervix and lateral fornix of the vagina to attach extensively on the pelvic wall. At the level of the cervix some fibers interdigitate with fibers of the uterosacral ligaments. They are continuous with the fibrous tissue around the lower parts of the ureters and pelvic blood vessels. Fibers of the pubocervical ligament pass forward from the anterior aspect of the cervix and upper vagina to diverge around the urethra. These fibers are attached to the posterior aspect of the pubic bones.

Peritoneal Folds

The parietal peritoneum is reflected over the upper genital tract to produce anterior (uterovesical), posterior (rectovaginal), and lateral peritoneal folds. The anterior cul-de-sac is a recess between the dome of the bladder and the anterior surface of the uterus. The peritoneum is loosely applied in the region of uterovesical fold. This allows the bladder expansion without stretching its overlying peritoneum. The peritoneal fold here can be lifted and incised easily. The rectovaginal pouch (pouch of Douglas) extends approximately 4 cm along the posterior vaginal wall. It has important clinical significance, collections such as blood or pus may be aspirated through vagina as culdocentesis. The pouch may enlarge due to traction or pulsion to form enterocele.

Pelvic Spaces

The space between the bladder and pubis bone is space of Retzius. Behind the bladder and urethra is vesicovaginal or vasicocervical space. Vesicovaginal space is bounded laterally by "bladder pillars." The space between the rectum and vagina is called *rectovaginal space*.

Pregnancy and Parturition

During pregnancy many morphologic changes occur in the female reproductive system and associated abdominal structures. The uterus enlarges to accommodate the developing fetus and the placenta, and various alterations take place in the pelvic walls, floor, and contents which allow for this expansion, and which anticipate parturition. At the end of gestation, dramatic changes occur that facilitate the passage of the baby through the birth canal and subsequently allow the pelvic organs to return to the nonpregnant state (involution).

Uterus in Pregnancy

The function of the uterus in pregnancy is to retain the developing fetus and to provide a protected environment until a stage at which the fetus is capable of serving independently. The uterus must grow, participate in the delivery of the fetus, and then involute. At the same time smooth muscle cells must be stretched by the growing fetus without producing abortion or preterm labor.

The uterus grows dramatically during pregnancy, increasing in weight from about 50 g at the beginning of the pregnancy to up to 1 kg at the term. Most of the weight gain is the result of increased vascularity and fluid retention in the myometrium. The increased growth of the uterine mass is driven by a combination of mechanical stretching and endocrine stimulation. The mechanical load that the growing fetus puts on the uterine wall induces hypertrophy of the uterine smooth muscle cells, and is the major stimulus that increases smooth muscle mass. Some hyperplasia occurs early in the pregnancy, mainly from the growth of the media of the myometrial arteries and veins. The myometrium is relatively unresponsive to additional endocrine stimulation during most of pregnancy, a relative quiescence that is in part attributed to progesterone. However, a number of growth factors, for example, insulin-like growth factor 1 (IGF1), have been

identified that interact with estrogen in promoting uterine growth. The myometrium thins with advancing gestation from 2 to 3 cm thick in early pregnancy to 1 to 2 cm at term.

The upper third of cervix (isthmus) is gradually taken up into the uterine body during the second month to form the lower segment. The isthmus hypertrophies like the uterine body during the first trimester and triples in length to about 3 cm. From the second trimester the wall of the isthmus and that of the body are of the same thickness and their junction is no longer visible externally. This condition persists until the middle of the third trimester when the junction between the body and the isthmus can sometimes be recognized as a transverse linear depression; the musculature above the depression is thicker than that below. The depression forms just below the vesicouterine pouch and is thought to correspond to the level of the anatomic internal os (upper margin of lower segment). It is the anatomic landmark used at the time of a lower segment cesarean section to ensure that the uterine incision is not in the body of the uterus. The lower segment is less vascular than the upper part of the uterus. Moreover, the risk of rupture of a lower segment uterine scar in subsequent pregnancies is significantly reduced compared to rupture of a scar in the body of the uterus (classical cesarean section).

Lower Uterine Segment

In the nonpregnant uterus two narrow zones situated on either side of the internal os require special consideration. For about 1 cm above the internal os, the peritoneum covering the front of the uterus is quite mobile and is only loosely connected by areolar tissue with the underlying muscle. Everywhere else the peritoneum is firmly blended with the myometrium. Below the internal os, the isthmus of the uterus is a zone 4 to 5 mm in depth that differs from the cervix proper in that it is lined by somewhat atrophic endometrium with sparsely distributed rather inactive looking simple tubular glands. During pregnancy these two narrow zones develop to a remarkable degree and form the lower portion of the uterus or the lower uterine segment. It is approximately the shape of a hemisphere and reaches upward from the level of the cervix for a variable distance averaging about 4 in (10 cm). In this part of the uterus the muscular wall is thinner than elsewhere and contains a preponderance of longitudinal muscle fibers moreover, the decidua is less well developed and the fetal membranes are very loosely attached. These features are noticeable by the fourth month of pregnancy and become more pronounced as term is approached. At term, the lower uterine segment comprises about one-fourth of the uterus. Anteriorly, the lower uterine segment corresponds to that part of the uterus over which the peritoneum is loosely attached. During labor the upper uterine segment actively contracts and shortens (retraction), while the lower uterine segment passively dilates and lengthens. The contraction of the interlacing muscle fibers in the upper segment is primarily responsible for control of postpartum hemorrhage (PPH) by occluding the intervening vessels. Retraction not only creates a shearing force to separate the placenta but also occludes the vessels. Both these mechanisms are responsible for controlling PPH.

Cervix in Pregnancy

The uterine cervix is required to serve two functions in relation to pregnancy and parturition. During pregnancy it is a relatively rigid fibromuscular structure that retains the developing fetus within the uterus. During active labor the cervix dilates to allow the fetus to descend through the birth canal. Considerable softening and shortening of the cervix occurs in the weeks before the onset of labor; a corresponding increase in uterine activity is usually apparent during this prelabor period. The rigidity of the cervix appears to be related to the orientation of its collagen fibers within a regular connective tissue matrix. The exact processes that allow softening, effacement, and dilatation of the cervix are unclear, but are believed to include remodeling of the connective tissue matrix, probably mediated by an increase in the activity of enzymes such as matrix metalloproteinase 1, a reduction in collagen concentration, a significant increase in the water content in the cervix, an infiltration of macrophages and neutrophils, and an increased level of apoptosis.

The cervix can be viewed during pregnancy by transvaginal ultrasound examination. The cervical length, dilation of the internal os, and bulging of the membranes into the canal can be assessed. Measurement of cervical length, on ultrasound, appears to be a strong predictor of preterm labor; the shorter the cervix, the greater the risk of premature delivery. In clinical practice cervical length has been used to screen women at high risk of preterm labor or to screen symptomatic women in threatened preterm labor to plan appropriate management.

Relations of Uterus in Pregnancy

With uterine expansion, the ovaries and uterine tubes are displaced upward and laterally. The round ligaments become more vertical. The broad ligament tends to open out to accommodate the massive increase in the sizes of the uterine and ovarian vessels. The uterine veins in particular can reach about 1 cm in diameter and they appear to act as a significant reservoir for blood during uterine contractions. Lymphatics and

nerves expand their territories (the significance of this increased innervation is not clear, because paraplegic women are able to labor normally, albeit painlessly). Later in pregnancy the increase in intra-abdominal pressure produced by the gravid uterus may produce eversion of the umbilicus. On skin over the abdomen, a combination of stretching and hormonal changes may produce stretch marks (striae gravidarum). In multiparous patients, separation (deverification) of right and left rectus abdominis muscle may occur allowing the uterine fundus to fall forward to some extent. In the supine position, the pregnant woman in late pregnancy is vulnerable to aortocaval compression as the gravid uterus presses on, and reduces blood flow in the great vessels. Aortocaval compression can cause symptoms of nausea and faintness; these symptoms are minimized if the woman lies on her left side thereby reducing the compression of the inferior vena cava.

The jejunum, ileum, and transverse colon tend to be displaced upward by the enlarging uterus, whereas the cecum and appendix are displaced to the right and the sigmoid colon posteriorly and to the left, upward, and lateral displacement of the appendix in later pregnancy can cause difficulties in the diagnosis of appendicitis. The ureters are pushed laterally by the enlarging uterus and in late pregnancy can be compressed at the level of the pelvic brim, resulting in hydronephrosis and loin pain. However, mild ureteric dilatation is considered normal during pregnancy. The axis of the uterus is shifted or dextrorotated by the presence of the sigmoid colon that may lead to inadvertent incision into large uterine vessels at the time of lower segment cesarean section unless the operator is aware of any such rotation.

Pelvic Changes in Pregnancy

The presence of a pregnant uterus results in a change in the center of gravity of the body, especially in late pregnancy. In order to compensate for this, the mother tends to straighten her cervical and thoracic spine, and throw her shoulders back, resulting in a compensatory lumbar lordosis. There is also a softening of the pubic symphysis and sacroiliac joints, caused by production of relaxin and other pregnancy hormones. This increased mobility produces a form of pelvic instability, so that the pregnant woman tends to walk with a waddling gait. Softening also produces an increase in pelvic diameter, which is of benefit during the time of labor; significant joint relaxation can be associated with pain, called *symphysis pubis diastasis*; in severe cases radiographs show that when a woman stands on one leg, the two halves of the symphysis are at different levels.

Breast

Embryology

The mammary line is a bandlike thickening of the epidermis and appears in a 7 weeks embryo. It extends on each side from the armpits to the inguinal region on both sides (**Fig. 1.8**). Majority of it disappears except a small portion in the thoracic region that penetrates the underlying mesenchyme. It forms 16 to 24 sprouts that form small solid buds. These epithelial sprouts canalize to form lactiferous ducts, and the buds form small ducts and alveoli of the gland at term. These lactiferous glands open in the epithelial pits that transform into nipple shortly after birth (**Fig. 1.9**).

After delivery, the breast secretes colostrums up to 5 days with gradual conversion to mature milk. Colostrum contains minerals and proteins (more of globulins).

Anatomy

The mammary gland is made up of two components, the parenchyma, and the surrounding stroma. The stroma provides a frame of support as well as the

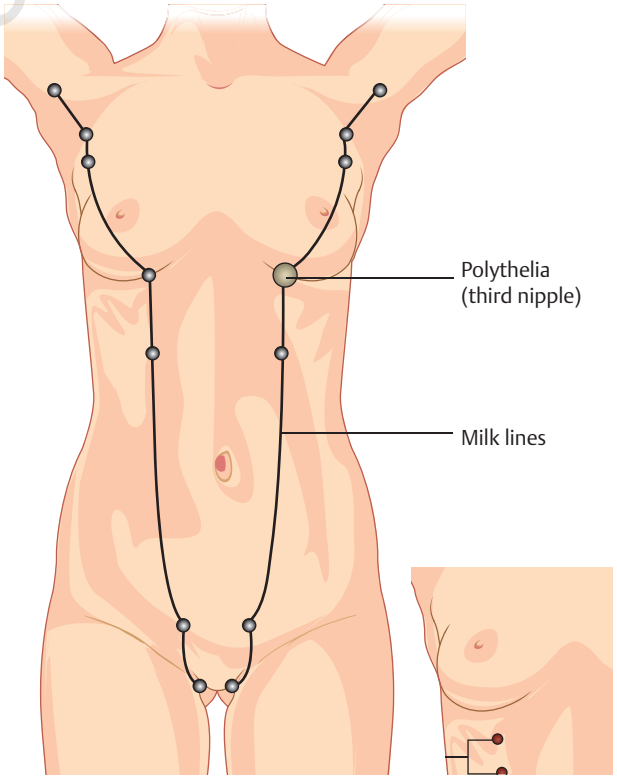


Fig. 1.8 Mammary lines from axilla to inguinal region.

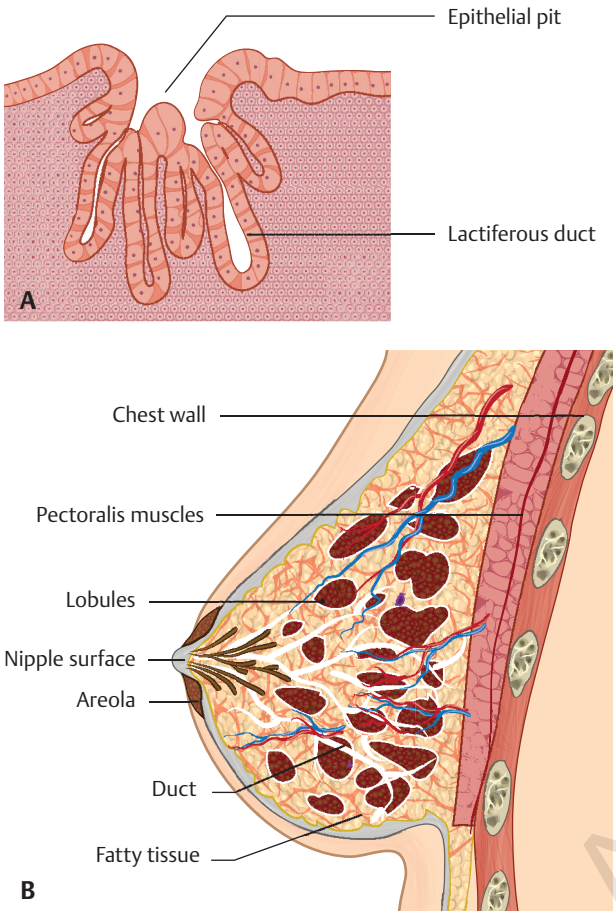


Fig. 1.9 **(A)** Structure of single unit of mammary gland. **(B)** Structure of adult mammary gland.

material within which the parenchyma can grow and function. The parenchyma consists of the alveoli (**Fig. 1.10**), grape-like clusters where milk is stored, and 10 to 15 branching ducts, which are tubular canals carrying glandular secretions. Each duct serves a particular lobule. The branching ducts are comprised of two types of cells: inner epithelial cells, which produce milk, and an outer layer of myoepithelial cells. Myoepithelial cells are usually large, contractile cells that operate at the base of the secretory cells of glands. The branching, or lactiferous ducts themselves merge into a primary duct, which drains into the openings of the nipple. This draining is actually the responsibility of the myoepithelial cells, which, when they contract, shorten and widen the ducts, pushing milk through the lactiferous ducts, into the primary duct, and toward the nipple where it collects in the widenings of the ducts, the sinuses. A suckling baby essentially squeezes the milk out of these sinuses. Finally, the nipple is surrounded by an area of pigmented skin, the areola, which contains sebaceous glands (which secrete fat) and sweat glands. The areola is the termination point for the fourth intercostal nerve, which sends sensory information about sucking to the spinal cord and the brain.

The breast tissues remain rudimentary until puberty when, in response to ovarian hormones, they begin to develop in the female. Estrogen promotes formation, while testosterone inhibits it. Estrogen stimulates proliferation of the ductal system within the stroma and elongation of the ducts into spherical masses of cells that will become secretory alveoli during pregnancy. Milk secretion is repressed by high concentrations of circulating sex steroids, primarily progesterone. Lactation, the manufacturing and secretion of milk, is induced by a decrease in estrogen and progesterone levels. Mammary epithelial proliferation carries on until early lactation, contributing to about 20% of total mammary growth that occurs during the beginning of lactation. During lactation, milk is secreted more or less continuously into the alveolar spaces and stored there until the baby's suckling brings about the contraction of the myoepithelial cells. The hormones involved in the maintenance of lactation are prolactin, insulin, and glucocorticoid (**Fig. 1.11, Flowchart 1.1**). After weaning, when the baby is no longer in need of nourishment through suckling, lactation ceases, and the mammary gland involutes. During involution, gene expression of the milk-manufacturing protein is suspended, mammary alveolar structures collapse, and secretory epithelial cells are removed through apoptosis and phagocytosis.

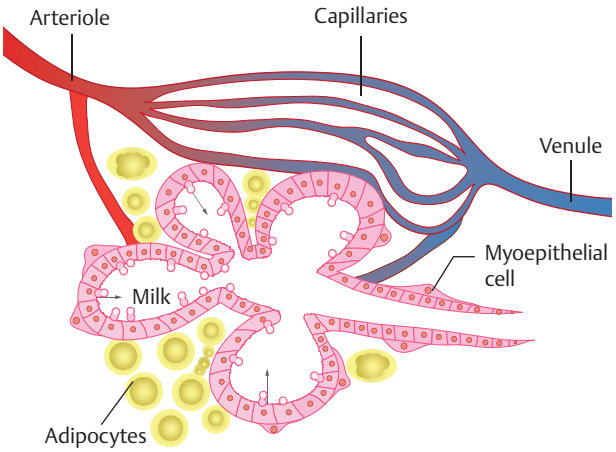
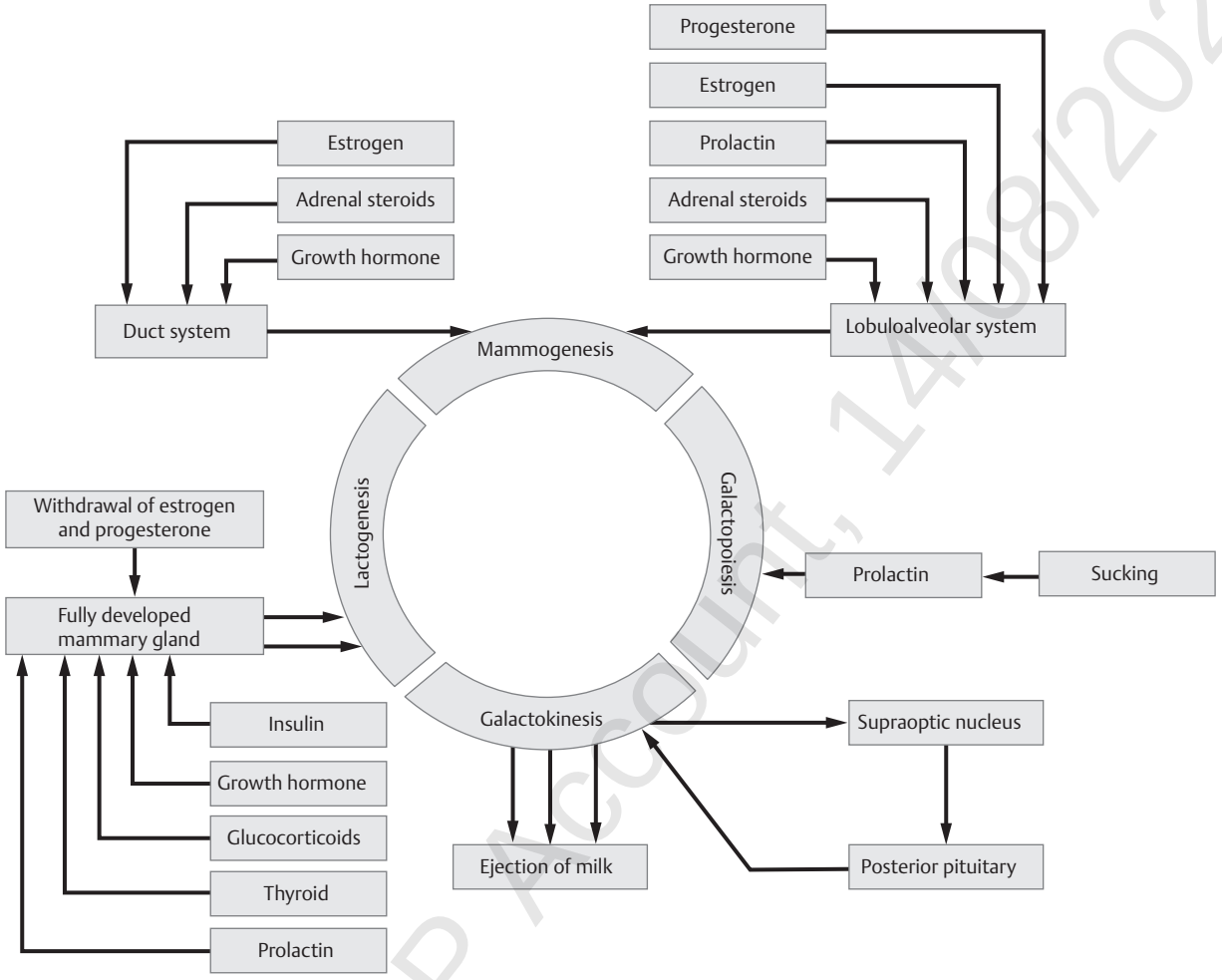


Fig. 1.10 Mammary alveolus.



Flowchart 1.1 Endocrine glands in relation to lactation.

Fig. 1.11 Process of lactation simplified.

Questions

1. Describe the lymphatic drainage of the vulva and its clinical importance.
2. Describe the course of the uterine artery in the pelvis. Identify the points where it is most likely to be injured during pelvic surgery.
3. Describe lymphatic drainage of the uterus and the cervix. What are its clinical implications?
4. Describe the anatomy of the Bartholin's gland. What is the management of Bartholin's abcess? What precautions should one take to prevent recurrence?