Female Reproductive System

21

Clinical Case Study

A 28-year-old female was brought to the emergency room following a 4-day history of moderate right-sided pelvic pain. On the morning of the fifth day the pain had become more severe, prompting her to seek medical attention. She complained of weakness and light-headedness, and stated that she hadn't had a period for about 8 weeks. A urine pregnancy test was positive. The consulting gynecologist said that a ruptured ectopic pregnancy was likely. He ordered a blood test, the results of which suggested that the patient had suffered a slight amount of hemorrhage. A *culdocentesis* (needle sampling of the peritoneal cavity via the posterior vaginal wall) was positive for pooled blood. The patient was prepared for surgery.

What is an ectopic pregnancy? Where is it most likely to occur? Briefly explain the sequence of events leading up to the rupture of the ectopic pregnancy beginning with ovulation. Differentiate normal from abnormal events. Explain how blood from a ruptured ectopic pregnancy can be aspirated through the vagina.

Hints: Carefully study the position of the uterus and uterine tubes with respect to the ovaries within the peritoneal cavity. Read about ectopic pregnancies in the clinical sections of this chapter and refer to figure 22.34 in chapter 22.

FIGURE: Examining fetal structures for congenital problems, sampling fetal tissues for metabolic disorders, and conducting *in utero* surgeries are possible using fetoscopy. Unfortunately, ectopic pregnancies cannot be corrected using this technique.

INTRODUCTION TO THE FEMALE REPRODUCTIVE SYSTEM

The female reproductive system produces ova, secretes sex hormones, receives spermatozoa from the male, and provides sites for fertilization of an ovum and implantation of the blastocyst. Parturition follows gestation, and secretion from the mammary glands provides nourishment for the baby.

Objective 1 Explain the functional differences between the male and female reproductive systems.

Objective 2 Define *ovulation, menstruation,* and *menopause.*

Objective 3 Identify the primary and secondary sex organs in a female, and describe the female secondary sex characteristics.

The reproductive systems of the male and female have some basic similarities and some specialized differences. The two systems are similar in that (1) most of the reproductive organs of both sexes develop from similar embryonic tissues and are therefore *homologous;* (2) both systems have gonads that produce gametes and sex hormones; and (3) both systems experience latent development of the reproductive organs, which mature and become functional during puberty as a result of the influence of sex hormones secreted by the gonads.

The differences between the reproductive systems of the female and male are based on the specific functions of each in sexual reproduction and on the cyclic events that are characteristic of the female. The reproductive organs of a sexually mature, healthy male continuously produce male gametes, or spermatozoa, and transfer them to the female during *coitus (ko′ĭ-tus) (sexual intercourse).* A male does not produce any spermatozoa until puberty (at about age 13), but is then capable of producing viable spermatozoa throughout his life if he remains healthy. The gametes, or ova, of a female are completely formed, but not totally matured, during fetal development of the ovaries. The ova are generally discharged, or *ovulated,* one at a time in a cyclic pattern throughout the reproductive period of the female, which extends from puberty to menopause. *Menstruation (men″stroo-a′shun)* is the discharge of *menses* (blood and solid tissue) from the uterus at the end of each menstrual cycle. *Menopause* is the period marked by the termination of ovulation and menstruation. The reproductive period in females generally extends from about age 12 to about age 50. The cyclic reproductive pattern of ovulation and the age span of fertility are determined by hormones.

The functions of the female reproductive system are (1) to produce ova; (2) to secrete sex hormones; (3) to receive the spermatozoa from the male during coitus; (4) to provide sites for fertilization, implantation of the blastocyst (see chapter 22), and embryonic and fetal development; (5) to facilitate *parturition,* or delivery of the baby; and (6) to provide nourishment for the baby through the secretion of milk from the mammary glands in the breasts.

The organs of the female reproductive system, like those of the male, are categorized on a functional basis as follows:

- **Primary sex organs.** The primary sex organs are called *gonads,* and in the female are known more specifically as the *ovaries.* Ovaries produce the gametes (ova), or eggs, and produce and secrete sex steroid hormones. Secretion of the female sex hormones at puberty contributes to the development of secondary sex characteristics and causes cyclic changes in the secondary sex organs that are required for reproductive function.
- **Secondary sex organs.** Secondary sex organs (fig. 21.1 and table 21.1) are those structures that are essential for successful fertilization of the ovum, implantation of the blastocyst, development of the embryo and fetus, and parturition. The secondary sex organs include the *vagina,* which receives the penis and ejaculated semen during coitus and through which the baby passes during delivery; the external genitalia, which protect the vaginal orifice (opening); the *uterine* (fallopian) *tubes,* through which ovulated eggs are transported toward the uterus and where fertilization takes place; and the *uterus* (womb), where implantation and development occur. The muscular walls of the uterus play an active role in parturition. *Mammary glands* are also considered secondary sex organs because the milk they secrete after parturition provides nourishment to the child.
- **Secondary sex characteristics.** Secondary sex characteristics are features that are not essential for the reproductive process but are generally considered to be sexual attractants. Distribution of fat to the breasts, abdomen, mons pubis, and hips; body hair pattern; and broad pelvis are examples of female secondary sex characteristics. Although the breasts contain the mammary glands, large breasts are not essential for nursing the young. In fact, all female mammals have mammary glands, but only human females have protruding breasts that function as a sexual attractant.

The onset of puberty in females generally occurs between the ages of 12 and 14 (average, 12.6 years) in accordance with the nutritional condition, genetic background, and even sexual exposure of the individual. Generally, girls attain puberty 6 months to 1 year earlier than boys, accompanied by an earlier growth spurt (fig. 21.2). Puberty in girls is heralded by the onset of menstruation, or *menarche (mĕ-nar′ke).* Puberty results from the increased secretion of gonadotropic hormones from the anterior pituitary, which stimulates the ovaries to establish their ovarian cycles and sex steroid secretion.

The average age of menarche is later (age 15) in girls who are very active physically than in the general population. This appears to be due to a requirement for a minimum percentage of body fat for menstruation to begin, and may represent a mechanism favored by natural selection to ensure the ability to successfully complete a pregnancy and nurse the baby.

CHAPTER 21

coitus: L. *coitio,* a coming together

menopause: Gk. *men,* month; *pausis,* cessation

ovaries: L. *ovum,* egg

vagina: L. *vagina,* sheath or scabbard

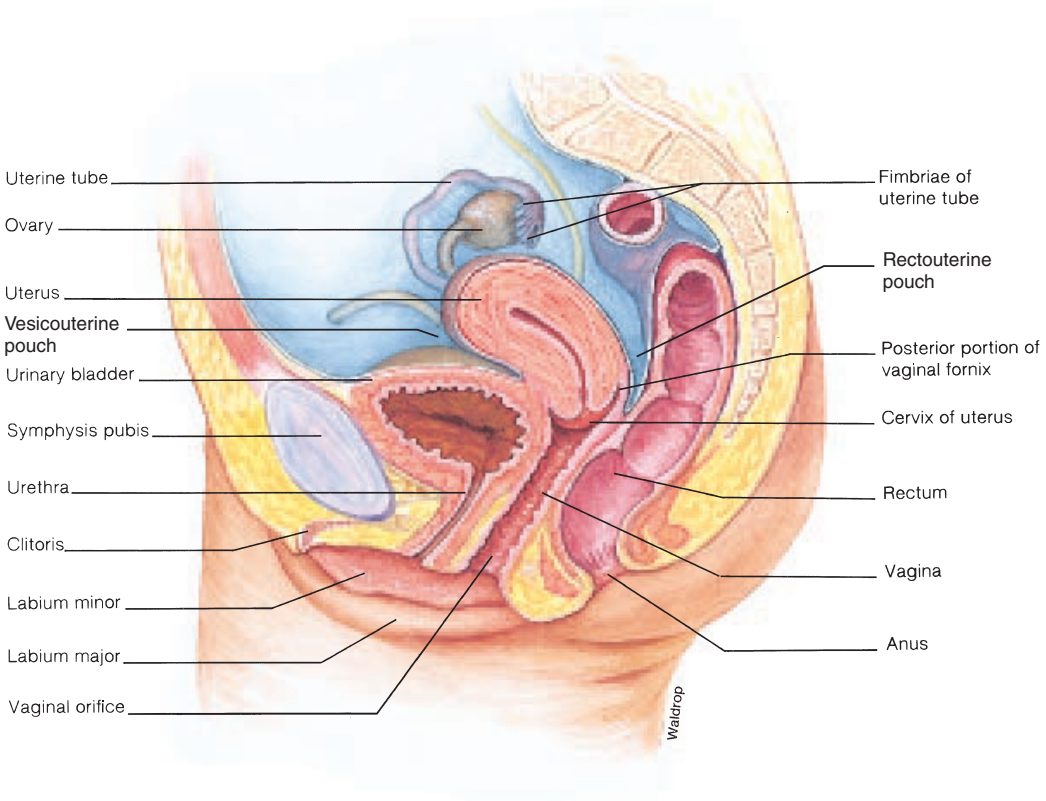

FIGURE 21.1 Organs of the female reproductive system seen in sagittal section.

TABLE 21.1 Reproductive Organs of the Female

Organ	Function/Description
Ovaries	Produce female gameres (oocytes) and female sex hormones
Uterine tubes	Convey oocytes toward uterus; site of fertilization; convey developing embryo to uterus
Uterus	Site of implantation; protects and sustains embryo and fetus during pregnancy, plays active role in parturition (childbirth)
Vagina	Conveys uterine secretions to outside of body; receives erect penis and semen during coitus and ejaculation; serves as passageway for fetus during parturition
Labia majora	Form margins of pudendal cleft; enclose and protect labia minora
Labia minora	Form margins of vaginal vestibule; protect openings of vagina and urethra
Clitoris	Glans of the clitoris is richly supplied with sensory nerve endings associated with feeling of pleasure during sexual stimulation
Pudendal cleft	Cleft between labia majora within which labia minora and clitoris are located
Vaginal vestibule	Cleft between labia minora within which vaginal and urethral openings are located
Vestibular glands	Secrete fluid that moistens and lubricates the vaginal vestibule and vaginal opening during sexual arousal and coitus
Mammary glands	Produce and secrete milk for nourishment of an infant

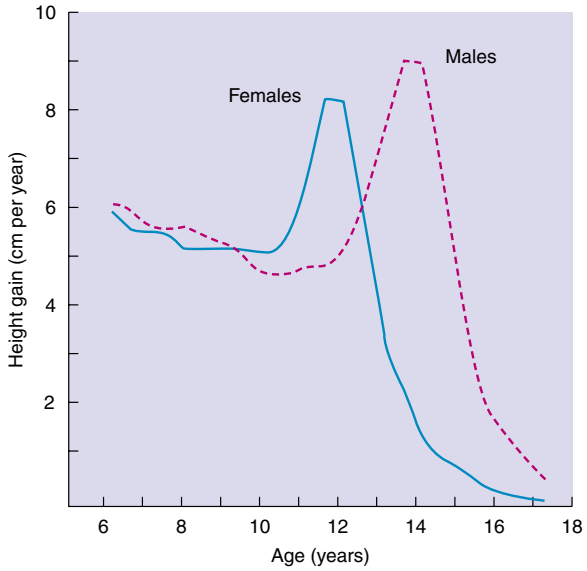

FIGURE 21.2 A comparison of male and female rates of growth in height.

Knowledge Check

1. List the functions of the female reproductive system.
2. Explain the process by which puberty occurs. Define *menstruation* and *ovulation*. What is the usual span of a woman's reproductive years? Define *menses* and *menopause*.
3. Distinguish between the primary sex organs, secondary sex organs, and secondary sex characteristics.

STRUCTURE AND FUNCTION OF THE OVARIES

The ovary contains a large number of follicles, each of which encloses an ovum. Some of these follicles mature during the ovarian cycle, and the ova they contain progress to the secondary oocyte stage of meiosis. During ovulation, the largest follicle ruptures and releases its secondary oocyte. The ruptured follicle becomes a corpus luteum and regresses to become a corpus albicans. These cyclic changes in follicular development are accompanied by changes in hormone levels.

Objective 4 Describe the position of the ovaries and the ligaments supporting the ovaries and genital ducts.

Objective 5 Describe the structural changes in the ovaries that lead to and follow ovulation.

Objective 6 Describe oogenesis and explain why meiosis of one primary oocyte results in the formation of only one mature ovum.

Objective 7 Discuss the hormonal secretions of the ovaries during an ovarian cycle.

Position and Structure of the Ovaries

Ovaries (*o′vă-rēz*) are the paired primary sex organs of the female that produce *gametes*, or *ova*, and the sex hormones, *estrogens* and *progesterone*. The ovaries of a sexually mature female are solid, ovoid structures about 3.5 cm (1.4 in.) long, 2 cm (0.8 in.) wide, and 1 cm (0.4 in.) thick. The color and texture of the ovaries vary according to the age and reproductive stage of the female. The ovaries of a young girl are smooth and pinkish. Following puberty, the ovaries are pinkish-gray and have an irregular surface because of the scarring caused by ovulation. On the medial portion of each ovary is a **hilum** (*hi′lum*), which is the point of entrance for ovarian vessels and nerves. The lateral portion of the ovary is positioned near the open end of the uterine tube (fig. 21.3).

The paired ovaries are positioned in the upper pelvic cavity, one on each lateral side of the uterus. Each ovary is situated in a shallow depression of the posterior body wall, the **ovarian fossa,** and secured by several membranous attachments. The principal supporting membrane of the female reproductive tract is the **broad ligament.** The broad ligament is the parietal peritoneum that supports the uterine tubes and uterus. The **mesovarium** (*mes′′ŏ-va′re′-um*) is a specialized posterior extension of the broad ligament that attaches to an ovary. Each ovary is additionally supported by an **ovarian ligament,** which is anchored to the uterus, and a **suspensory ligament,** which is attached to the pelvic wall (fig. 21.3).

Each ovary consists of four layers. The **germinal epithelium** is the thin outermost layer composed of cuboidal epithelial cells (see fig. 21.6). A collagenous connective tissue layer called the **tunica albuginea** (*al′′byoo-jin′e-ă*) is located immediately below the germinal epithelium. The principal substance of the ovary is divided into an outer **ovarian cortex** and a vascular inner **ovarian medulla,** although the boundary between these layers is not distinct. The **stroma**—the material of the ovary in which follicles and blood vessels are embedded—lies in both the cortical and medullary layers.

Blood Supply and Innervation

Blood is supplied by ovarian arteries that arise from the lateral sides of the abdominal aorta, just below the origin of the renal arteries. An additional supply comes from the ovarian branches of the uterine arteries. Venous return is through the ovarian veins. The right ovarian vein empties into the inferior vena cava, whereas the left ovarian vein drains into the left renal vein.

stroma: Gk. *stroma*, a couch or bed

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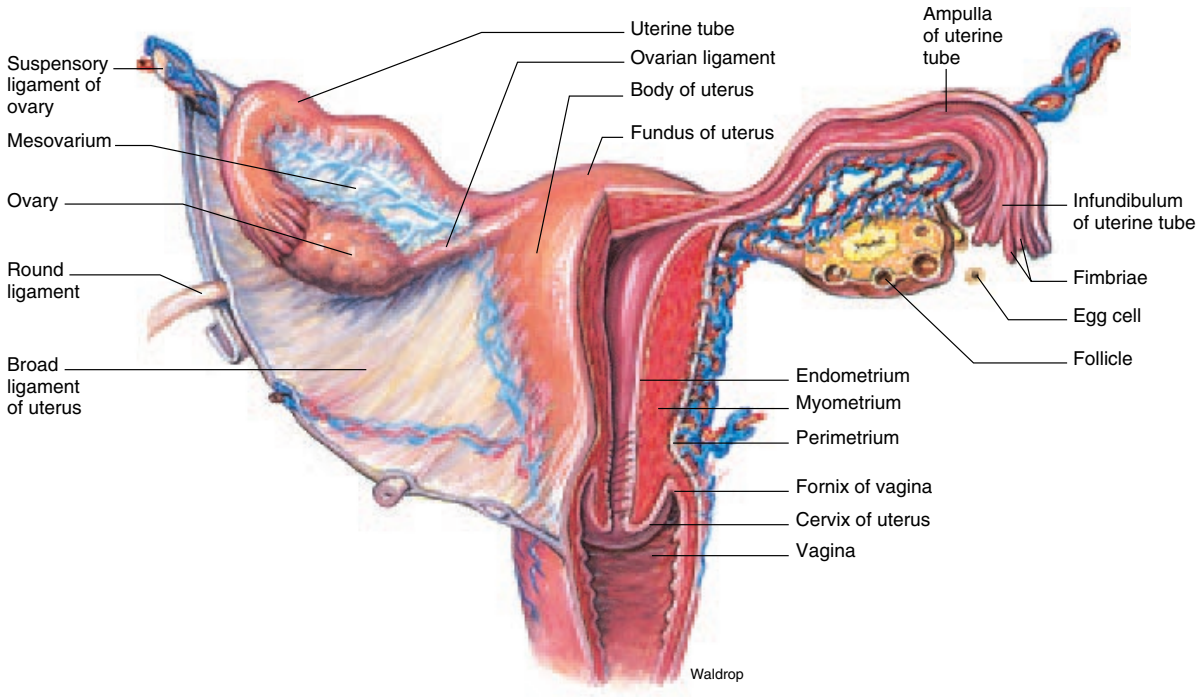

FIGURE 21.3 An anterior view of the internal female reproductive organs showing their positional relationships.

The ovaries have both sympathetic and parasympathetic innervation from the ovarian plexus. Innervation to the ovaries, however, is only to the vascular networks and not to the follicular substance within the stroma. All of the vessels and nerves to an ovary enter by way of the hilum, which is supported by the ovarian ligament.

Normal, healthy ovaries usually cannot be palpated either by vaginal or abdominal examination. If the ovaries become swollen or displaced, however, they are palpable through the vagina. There are many types of nonmalignant tumors of the ovaries, most of which cause swelling and some localized tenderness. The ovaries atrophy during menopause, and ovarian enlargement in postmenopausal women is usually cause for concern.

Ovarian Cycle

The germ cells that migrate into the ovaries during early embryonic development multiply, so that by about 5 months of gestation the ovaries contain approximately 6 to 7 million primordial oocytes, called *oogonia* (*o″ŏ-go′ne-ă*) The production of new oogonia stops at this point and never resumes. Toward the end of gestation, the oogonia begin meiosis, at which time they are called **primary oocytes** (*o′ŏ-sitz*). Meiosis is arrested at prophase I of the first meiotic division, and therefore the primary oocytes are still diploid (have 46 chromosomes). Although the ovaries of a newborn girl contain about 2 million oocytes, this number declines to 300,000 to 400,000 by the time she enters puberty. On average, 400 oocytes are ovulated during a woman's reproductive lifetime.

Follicle Formation

Primary oocytes that are not stimulated to complete the first meiotic division are contained within tiny follicles called **primordial follicles.** In response to stimulation by gonadotropic hormones, some of these oocytes and follicles get larger, and the follicular cells divide to produce the **follicular epithelium** that surrounds the oocyte and fills the follicle. A follicle at this stage in development is called a **primary follicle.**

Some primary follicles are stimulated to grow still bigger and develop a fluid-filled cavity called an *antrum* (*an′trum*). At this point, they are called **secondary follicles** (fig. 21.4). The follicular epithelium of secondary follicles forms a ring around the circumference of the follicle, called the *corona radiata*, and a mound that supports the oocyte. The mound is called the *cumulus oophorus* (*o-of′ŏ-rus*). Between the oocyte and the corona radiata is a thin gel-like layer of proteins and polysaccharides called the *zona pellucida* (*pĕ-loo′sĭ-dă*). Under stimulation of follicle-stimulating

oogonium: Gk. *oion*, egg; *gonos*, generation

corona radiata: Gk. *korone*, crown: L. *radiata*, radiate

cumulus oophorus: L. *cumulus*, a mound; Gk. *oophoros*, egg-bearing

zona pellucida: L. *zone*, girdle; L. *pellis*, skin

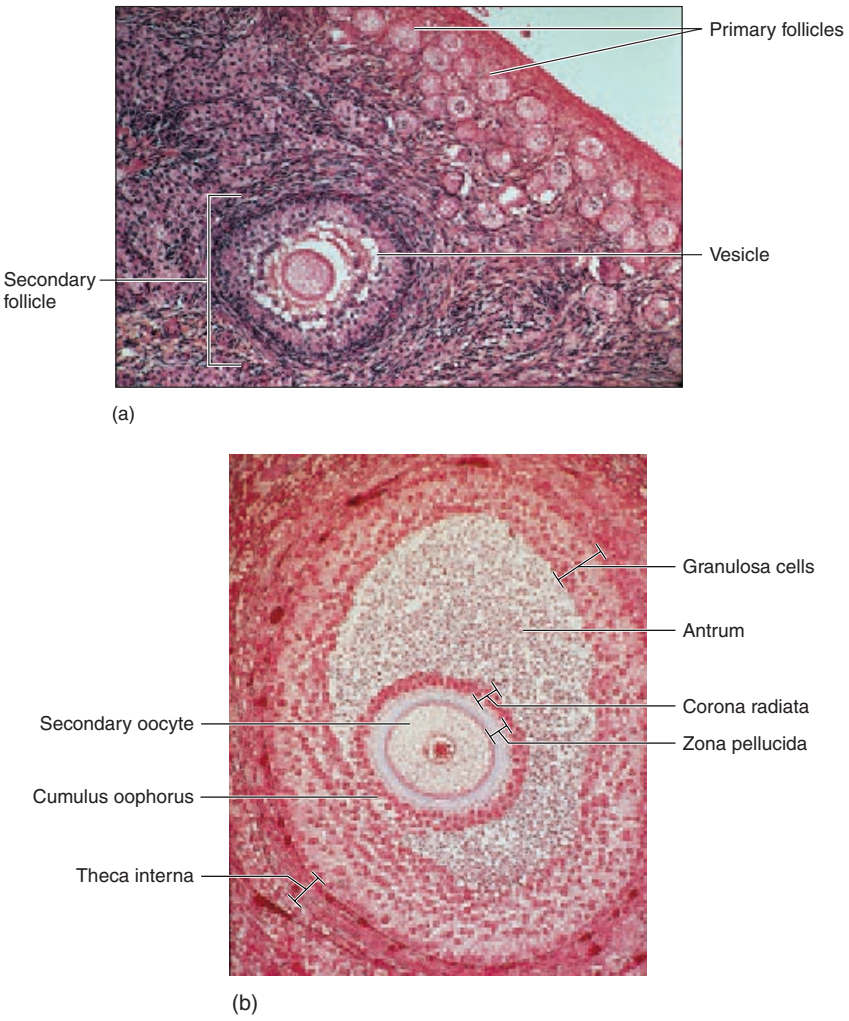

FIGURE 21.4 Photomicrographs of (*a*) primordial and primary follicles and (*b*) a mature vesicular ovarian follicle.

hormone (FSH) from the anterior pituitary, the follicular cells secrete increasing amounts of estrogen as the follicles grow. Interestingly, the follicular cells produce estrogen from its precursor testosterone, which is supplied by a layer of cells immediately outside the follicle called the *theca interna* (fig. 21.4*b*).

As the follicle develops, the primary oocyte completes its first meiotic division. This does not form two complete cells, however, because only one cell—the **secondary oocyte**—gets almost all of the cytoplasm. The other cell formed at this time becomes a small *polar body* (fig. 21.5), which eventually fragments and disappears. The secondary oocyte enters the second meiotic division, but meiosis is arrested at metaphase II and is never completed unless fertilization occurs.

theca interna: Gk. *theke*, a box; L. *internus*, interior

Ovulation

By about the tenth to the fourteenth day following day 1 of a menstrual period, usually just one follicle has matured fully to become a **vesicular ovarian** (graafian) **follicle** (fig. 21.6). Other secondary follicles regress during that menstrual cycle and become *atretic* (*ă-tret'ik*). The vesicular ovarian follicle is so large that it forms a bulge on the surface of the ovary. Under proper hormonal stimulation (a sudden burst of luteinizing hormone from the anterior pituitary, triggered by a peak level of estrogen), this follicle will rupture—much like the popping of a blister—and extrude its secondary oocyte into the peritoneal cavity near the opening of the uterine tube in the process of *ovulation* (*ov-yŭ-la-shun*) (fig. 21.7).

graafian follicle: from Regnier de Graaf, Dutch anatomist and physician, 1641–73
atretic: Gk. *atretos*, not perforated

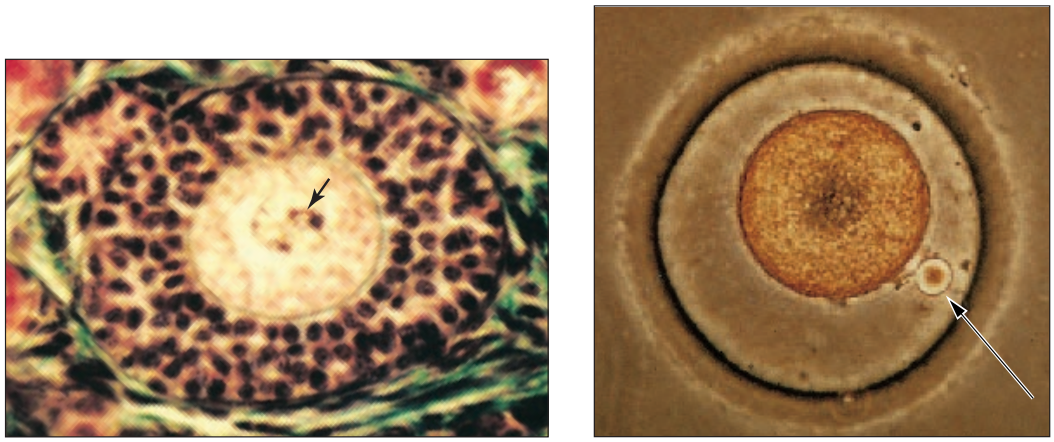

FIGURE 21.5 (*a*) A primary oocyte at metaphase I of meiosis. (Note the alignment of chromosomes [arrow]). (*b*) A mammalian secondary oocyte formed at the end of the first meiotic division and the first polar body (arrow).

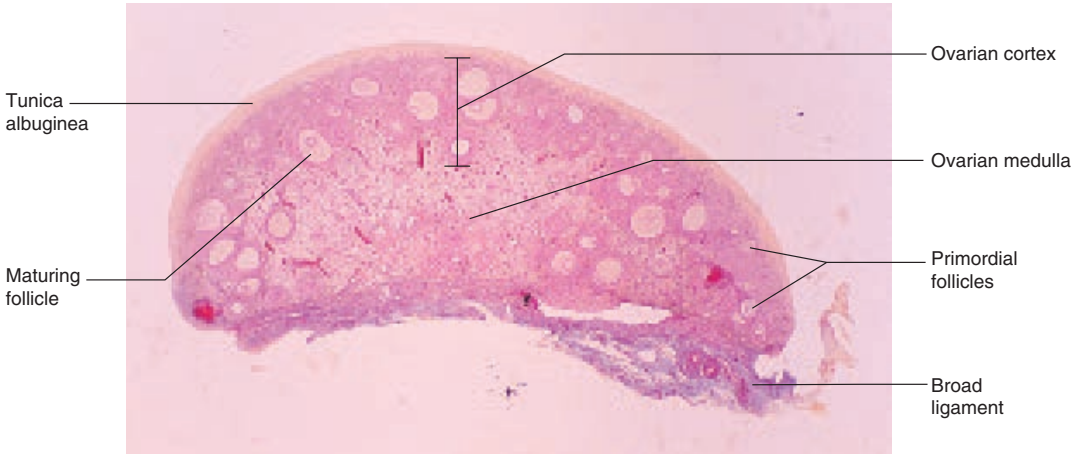

FIGURE 21.6 The histology of a mature ovary (12×).

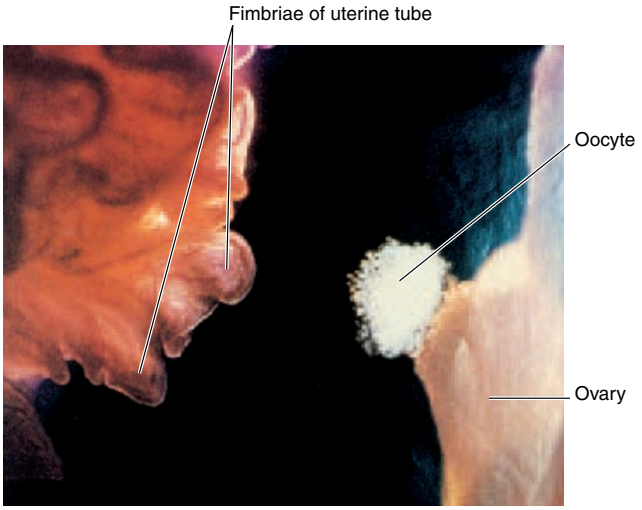

FIGURE 21.7 The release of the secondary oocyte from a human ovary. An ovulated oocyte is free in the peritoneal cavity until it is swept into the lumen of the uterine tube.

Most women are quite unaware that one follicle, approximately 2.5 cm (1 in.) in diameter, has ruptured and released its solitary egg. A substantial number of women, however (approximately 30%), experience a sharp, cramplike pain at the time of ovulation that may be confused with appendicitis when it happens on the right side.

The released secondary oocyte is surrounded by the zona pellucida and corona radiata. If it is not fertilized, it disintegrates in a couple of days. If a spermatozoon passes through the corona radiata and zona pellucida and enters the cytoplasm of the secondary oocyte, the oocyte completes the second meiotic division, becoming a mature ovum. In this process, the cytoplasm is again not divided equally; most of it remains in the *zygote* (fertilized egg), leaving another polar body, which like the first, disintegrates (fig. 21.8).

Corpus Luteum Formation

Changes continue in the ovary following ovulation. The empty follicle, under the influence of luteinizing hormone, undergoes structural and biochemical changes to become a **corpus luteum** (*loo'te-um*). Unlike the ovarian follicles, which secrete only estrogen, the corpus luteum secretes two sex steroid hormones: estrogen and progesterone. Toward the end of a nonfertile cycle, the corpus luteum regresses and is changed into a nonfunctional **corpus albicans** (*al'bĭ-kans*). These cyclic changes in the ovary are summarized in figure 21.9.

corpus luteum: L. *corpus*, body; *luteum*, yellow
albicans: L. *albicare*, to whiten

Knowledge Check

4. Describe the position of the ovaries relative to the uterine tubes and describe the position and functions of the broad ligament and mesovarium.
5. Compare the structure of a primordial follicle, primary follicle, secondary follicle, and vesicular ovarian follicle.
6. Define *ovulation* and describe the changes that occur in the ovary following ovulation in a nonfertile cycle.
7. Describe oogenesis and explain why only one mature ovum is produced by this process.
8. Compare the hormonal secretions of the vesicular ovarian follicle with those of a corpus luteum.

SECONDARY SEX ORGANS

The uterine tube conducts the zygote to the uterus, where implantation in the endometrium of the uterine wall typically occurs. The muscular layer of the uterus wall, or myometrium, is functional in labor and delivery. Sperm cells enter the female reproductive tract through the vagina, which also serves as the birth canal during parturition.

Objective 8 Describe how an ovum is moved through a uterine tube to the uterus.

Objective 9 Describe the structure and function of each of the three layers of the uterine wall.

Objective 10 Describe the structure and functions of the vulva and vagina.

Objective 11 Discuss the changes that occur in the female reproductive system during sexual excitement and coitus.

The secondary sex organs described in this section include the *uterine tubes*, *uterus*, *vagina*, and the *external genitalia (vulva)*. The *mammary glands*, which are also considered secondary sex organs, are described in a separate section.

Uterine Tubes

The paired **uterine tubes,** also known as the *fallopian* (*fă-lo'pe-an*) *tubes*, or *oviducts*, transport oocytes from the ovaries to the uterus. Each uterine tube is approximately 10 cm (4 in.) long and 0.7 cm (0.3 in.) in diameter and is positioned between the folds of the broad ligament of the uterus (see fig. 21.3). The funnel-shaped, open-ended portion of the uterine tube, the **infundibulum** (see fig. 21.3), lies close to the ovary but is not attached.

fallopian tubes: from Gabriele Fallopius, Italian anatomist, 1523–62
oviduct: L. *ovum*, egg; *ductus*, a leading

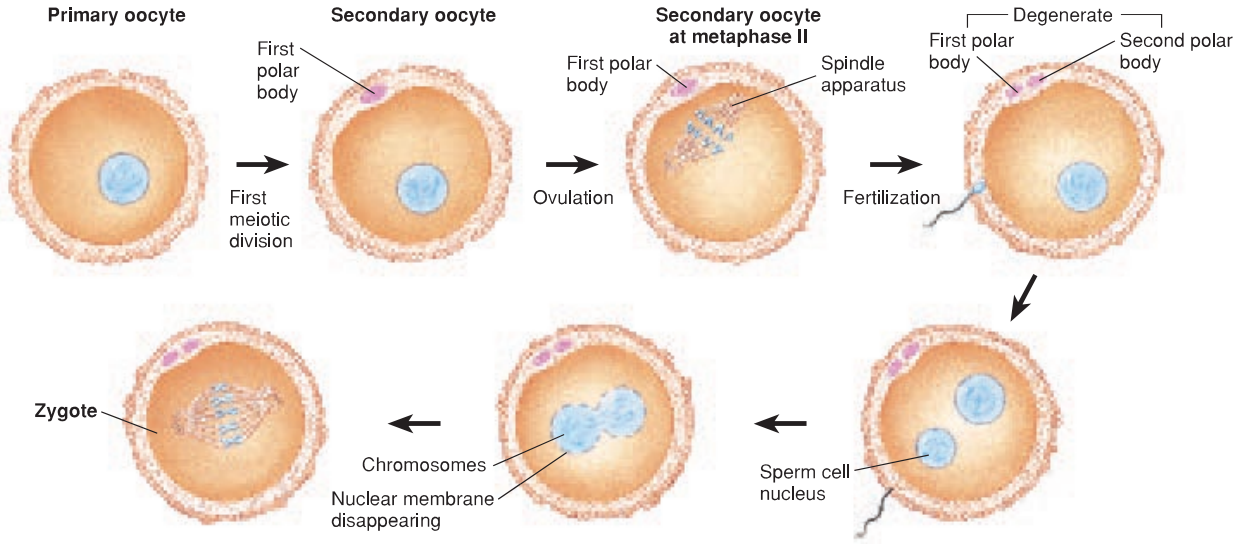

FIGURE 21.8 A schematic diagram of the process of oogenesis. During meiosis, each primary oocyte produces a single haploid gamete. If the secondary oocyte is fertilized, it forms a second polar body and its nucleus fuses with that of the sperm cell to become a zygote.

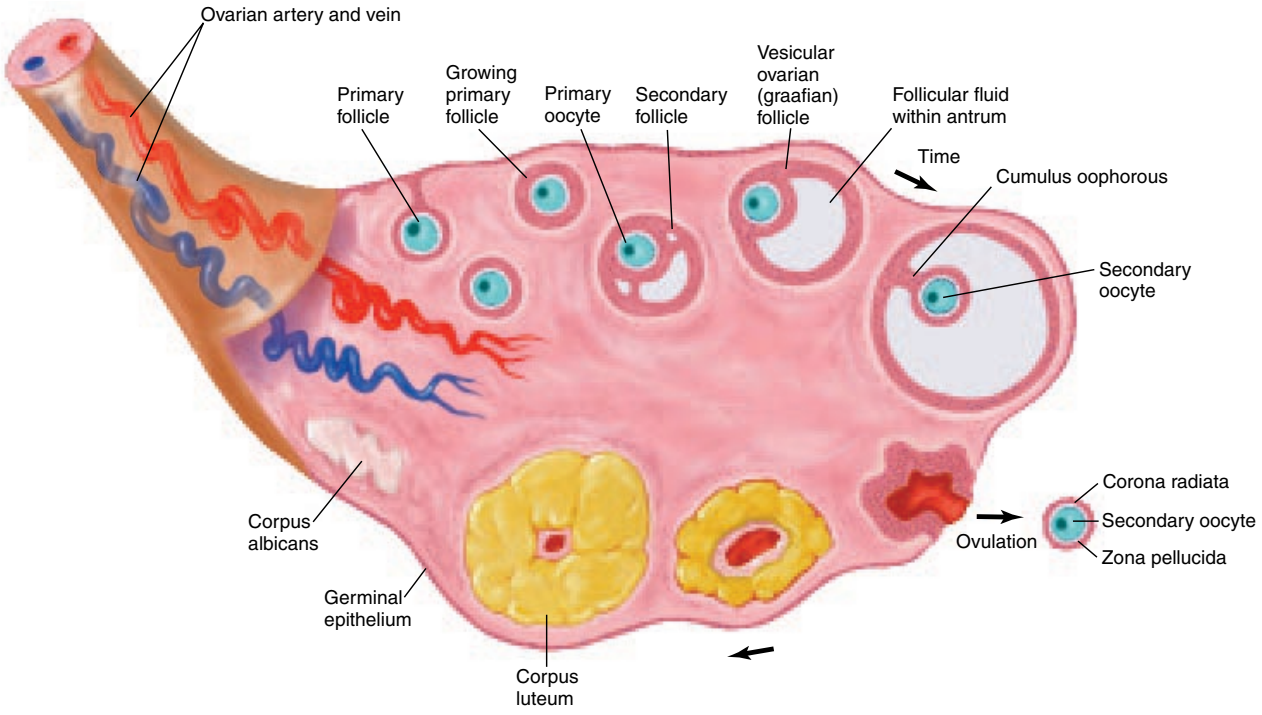

FIGURE 21.9 A schematic diagram of an ovary showing the various stages of ovum and follicle development. The arrows indicate changes with time.

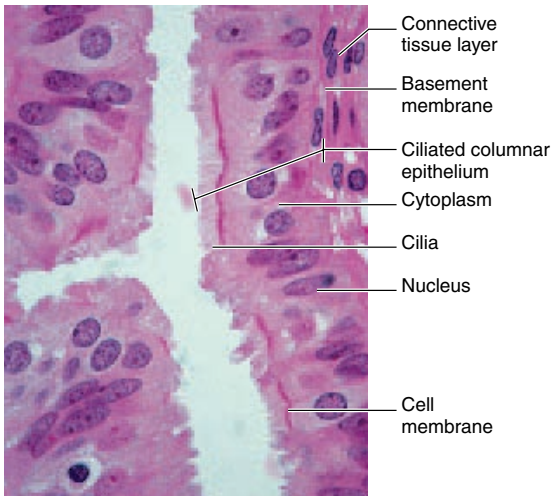

FIGURE 21.10 The histology of the uterine tube.

A number of fringed, fingerlike processes called **fimbriae** (*fim'bre-e*) project from the margins of the infundibulum over the lateral surface of the ovary. Wavelike movements of the fimbriae sweep an ovulated oocyte into the lumen of the uterine tube. From the infundibulum, the uterine tube extends medially and inferiorly to open into the cavity of the uterus. The *ampulla of the uterine tube* is its longest and widest portion (see fig. 21.3).

The wall of the uterine tube consists of three histological layers. The internal **mucosa** lines the lumen and is composed of ciliated columnar epithelium (fig. 21.10) drawn into numerous folds. The **muscularis** is the middle layer, composed of a thick inner circular layer of smooth muscle and a thin outer longitudinal layer of smooth muscle. Peristaltic contractions of the muscularis and ciliary action of the mucosa move the oocyte through the lumen of the uterine tube. The outer **serous layer** of the uterine tube is part of the visceral peritoneum.

The term *salpinx* is occasionally used to refer to the uterine tubes. It is a Greek word meaning "trumpet" or "tube," and is the root of such clinical terms as *salpingitis (sal''pin-ji''tis)* or inflammation of the uterine tubes; *salpingography* (radiography of the uterine tubes); and *salpingolysis* (the breaking up of adhesions of the uterine tube to correct female infertility).

The oocyte takes 4 to 5 days to move through the uterine tube. If enough viable sperm are ejaculated into the vagina during coitus, and if there is an oocyte in the uterine tube, fertilization will occur within hours after discharge of the semen. The zygote will move toward the uterus where implantation occurs. If the developing embryo (called a *blastocyst*) implants into the uterine tube instead of the uterus, the pregnancy is termed an *ectopic (ek-top'ik) pregnancy*, meaning an implantation of a blastocyst in a site other than the uterus (see fig. 22.34).

ectopic: Gk. *ex*, out; *topos*, place

Because the infundibulum of the uterine tube is unattached, it provides a pathway for pathogens to enter the peritoneal cavity. The mucosa of the uterine tube is continuous with that of the uterus and vagina, and it is possible for infectious agents to enter the vagina and cause infections that may ultimately spread to the peritoneal linings, resulting in *pelvic inflammatory disease (PID)*. There is no opening into the peritoneal cavity other than through the uterine tubes. The peritoneal cavity of a male is totally sealed from external contamination.

The uterine tubes are supplied with blood through the ovarian and uterine arteries. Venous drainage is through uterine veins that parallel the arteries. Both the uterine artery and vein can be observed in the broad ligament that supports the uterine tube (see fig. 21.3).

The uterine tubes have both sympathetic and parasympathetic innervation from the hypogastric plexus and pelvic splanchnic nerves. The nerve supply to the uterine tubes regulates the activity of the smooth muscles and blood vessels.

Uterus

The **uterus** (*yoo'ter-us*) receives the blastocyst that develops from a fertilized oocyte and provides a site for implantation. Prenatal development continues within the uterus until gestation is completed, at which time the uterus plays an active role in the delivery of the baby.

Structure of the Uterus

The uterus is a hollow, thick-walled, muscular organ with the shape of an inverted pear. It is located near the floor of the pelvic cavity, anterior to the rectum and posterosuperior to the urinary bladder. Although the shape and position of the uterus changes dramatically during pregnancy (fig. 21.11), in its nonpregnant state it is about 7 cm (2.8 in.) long, 5 cm (2 in.) wide (through its broadest region), and 2.5 cm (1 in.) in diameter. The anatomical regions of the uterus include the uppermost dome-shaped portion superior to the entrance of the uterine tubes, called the **fundus of the uterus;** the enlarged main portion, called the **body of the uterus;** and the inferior constricted portion opening into the vagina, called the **cervix of the uterus** (fig. 21.12). The cervix projects posteriorly and inferiorly, joining the vagina at nearly a right angle.

The **uterine cavity** is the space within the fundus and body regions of the uterus. The narrow **cervical canal** extends through the cervix and opens into the lumen of the vagina (fig. 21.12). The junction of the uterine cavity with the cervical canal is called the **isthmus of uterus,** and the opening of the cervical canal into the vagina is called the **uterine ostium.**

fundus: L. *fundus*, bottom
cervix: L. *cervix*, neck

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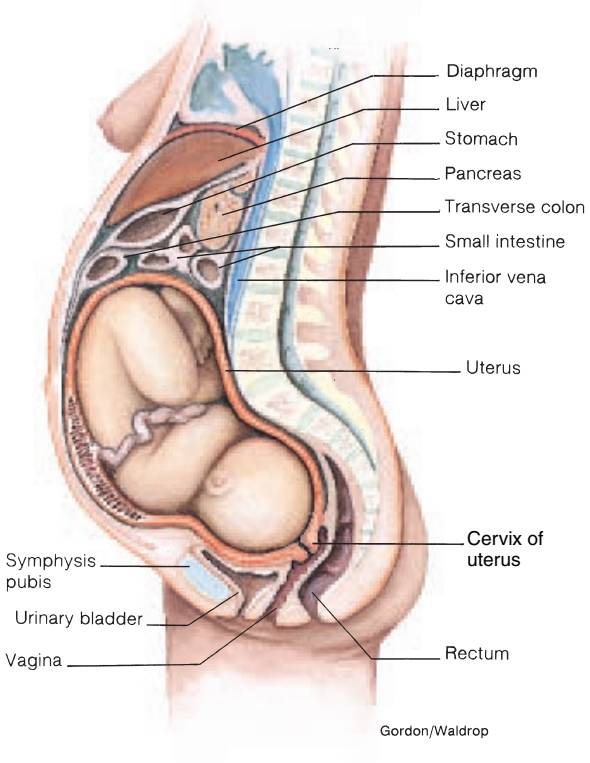


FIGURE 21.11 The size and position of the uterus in a full-term pregnant woman in sagittal section.

Support of the Uterus

The uterus is maintained in position by the muscles of the pelvic floor and by ligaments that extend to it from the pelvic girdle or body wall. The pelvic diaphragm, especially the levator ani muscle (see fig. 9.24), provides the principal muscular support to the vagina and uterus. The ligaments that support the uterus undergo marked hypertrophy during pregnancy and regress in size following parturition. They atrophy after menopause, which may contribute to a condition called *uterine prolapse*, or downward displacement of the uterus.

Four paired ligaments support the uterus in position within the pelvic cavity. The paired **broad ligaments** are folds of the peritoneum that extend from the pelvic walls and floor to the lateral walls of the uterus (see fig. 21.3). The ovaries and uterine tubes are also supported by the broad ligaments. The paired **rectouterine** (*rek''to-yoo'ter-in*) **folds** (not illustrated), which are also continuations of peritoneum, curve along the lateral pelvic wall on both sides of the rectum to connect the uterus to the sacrum. The **cardinal** (lateral cervical) **ligaments** (not illustrated) are fibrous bands within the broad ligament that extend laterally from the cervix and vagina across the pelvic floor, where they attach to the wall of the pelvis. The cardinal ligaments contain some smooth muscle as well as vessels and nerves that serve the cervix and vagina. The fourth paired ligaments are

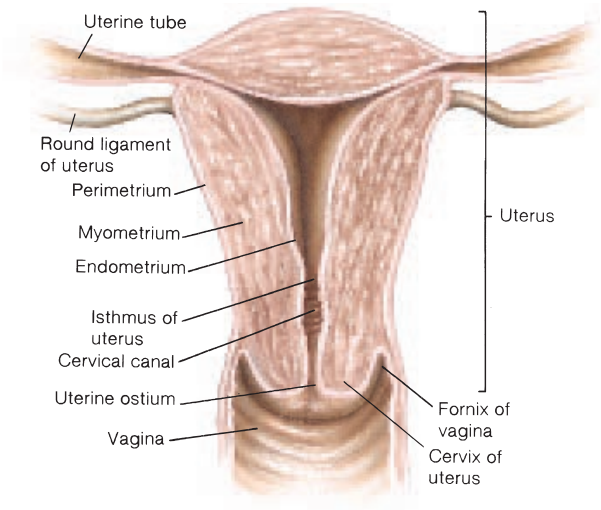


FIGURE 21.12 Layers of the uterine wall.

the **round ligaments** (see fig. 21.3). The round ligaments are actually continuations of the ovarian ligaments that support the ovaries. Each round ligament extends from the lateral border of the uterus just below the point where the uterine tube attaches to the lateral pelvic wall. Similar to the course taken by the ductus deferens in the male, each round ligament continues through the inguinal canal of the abdominal wall, where it attaches to the deep tissues of the labium majus.

Although the uterus has extensive support, considerable movement is possible. The uterus tilts slightly posteriorly as the urinary bladder fills, and it moves anteriorly during defecation. In some women, the uterus may become displaced and interfere with the normal progress of pregnancy. A posterior tilting of the uterus is called *retroflexion*, whereas an anterior tilting is called *anteflexion*.

Uterine Wall

The wall of the uterus is composed of three layers: the *perimetrium*, *myometrium*, and *endometrium* (fig. 21.12). The **perimetrium,** the outermost serosal layer, consists of the thin visceral peritoneum. The lateral portion of the perimetrium is continuous with the broad ligament. A shallow pouch called the **vesicouterine** (*ves''ĭ-ko-yoo'ter-in*) **pouch** is formed as the peritoneum is reflected over the urinary bladder (see fig. 21.1). The **rectouterine pouch** (pouch of Douglas) is formed as the peritoneum is reflected onto the rectum. The rectouterine pouch is the lowest point in the pelvic cavity and provides a site for surgical entry into the peritoneal cavity.

perimetrium: Gk. *peri*, around; *metra*, uterus

vesicouterine: L. *vesico*, bladder; *uterus*, womb

pouch of Douglas: from James Douglas, English anatomist and physician, 1675–1742

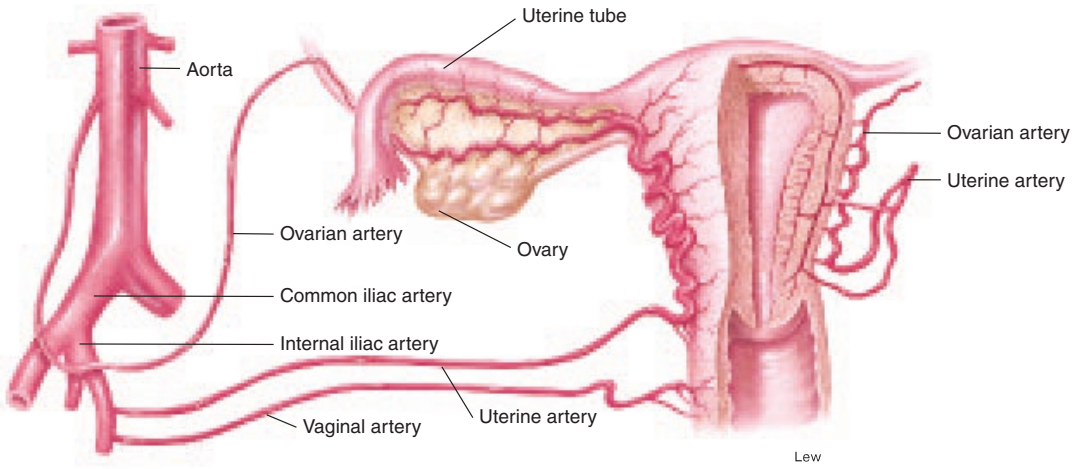


FIGURE 21.13 Arteries serving the internal female reproductive organs.

The thick **myometrium** is composed of three thick poorly defined layers of smooth muscle, arranged in longitudinal, circular, and spiral patterns. The myometrium is thickest in the fundus and thinnest in the cervix. During parturition, the muscles of this layer are stimulated to contract forcefully.

The **endometrium,** the inner mucosal lining of the uterus, is composed of two distinct layers. The superficial **stratum functionale,** composed of columnar epithelium and containing secretory glands, is shed as *menses* during menstruation and built up again under the stimulation of ovarian steroid hormones. The deeper **stratum basale** is highly vascular and serves to regenerate the stratum functionale after each menstruation.

The extent to which the uterus enlarges during pregnancy is nothing short of remarkable. From a fist-sized organ within the pelvis, it grows to occupy the bulk of the abdominal cavity, becoming about 16 times heavier than it was before conception. After parturition (childbirth), the uterus rapidly shrinks, but it may remain somewhat enlarged until menopause, at which time there is marked atrophy.

Uterine Blood Supply and Innervation

The uterus is supplied with blood through the uterine arteries, which arise from the internal iliac arteries, and by the uterine branches of the ovarian arteries (fig. 21.13). Each of these paired vessels anastomose on the upper lateral margin of the uterus. The blood from the uterus returns through uterine veins that parallel the pattern of the arteries.

The uterus has both sympathetic and parasympathetic innervation from the pelvic and hypogastric plexuses. Both autonomic innervations serve the arteries of the uterus, whereas the smooth muscle of the myometrium receives only sympathetic innervation.

Vagina

The **vagina** (*vă-ji′nă*) is the tubular, fibromuscular organ that receives sperm through the urethra of the erect penis during coitus. It also serves as the birth canal during parturition and provides for the passage of menses to the outside of the body. The vagina is about 9 cm (3.6 in.) long and extends from the cervix of the uterus to the vaginal vestibule. It is situated between the urinary bladder and the rectum, and is continuous with the cervical canal of the uterus. The cervix attaches to the vagina at a nearly 90 degree angle. The deep recess surrounding the protrusion of the cervix into the vagina is called the **fornix** (see fig. 21.3).

The fornix is of clinical importance because it permits palpation of the cervix during a gynecological examination. Occasionally, the deep posterior portion of the fornix provides surgical access to the pelvic cavity through the vagina. In addition, the fornix is important in the placement of two birth control devices—the cervical cap and the diaphragm (see fig. 21.26).

The exterior opening of the vagina, at its lower end, is called the **vaginal orifice.** A thin fold of mucous membrane called the **hymen** (*hi′men*) may partially cover the vaginal orifice.

The vaginal wall is composed of three layers: an inner mucosal layer, a middle muscularis layer, and an outer fibrous layer. The **mucosal layer** (fig. 21.14) consists of nonkeratinized stratified squamous epithelium that forms a series of transverse folds called **vaginal rugae** (*roo′je*). The vaginal rugae permit consider-

myometrium: Gk. *mys,* muscle; *metra,* uterus
endometrium: Gk. *endon,* within; *metra,* uterus
menses: L. *menses,* plural of *mensis,* monthly

CHAPTER 21

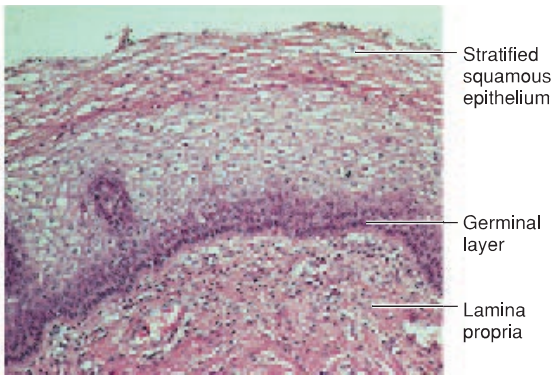


FIGURE 21.14 The histology of the vagina.

able distension of the vagina for penetration of the erect penis. They also provide friction ridges for stimulation of the penis during coitus. The mucosal layer contains few glands; the acidic mucus that is present in the vagina comes primarily from glands within the uterus. With a pH of 4.0, the acidic environment of the vagina retards microbial growth. The additives within semen, however, temporarily neutralize the acidity of the vagina to assist the survival of the spermatozoa deposited within the vagina.

The **muscularis layer** consists of longitudinal and circular bands of smooth muscle interlaced with distensible connective tissue. The distension of this layer is especially important during parturition. Skeletal muscle strands near the vaginal orifice, including the levator ani muscle, partially constrict this opening.

The **fibrous layer** covers the vagina and attaches it to surrounding pelvic organs. This layer consists of dense regular connective tissue interlaced with strands of elastic fibers.

The blood supply to the highly vascular vagina comes primarily from the vaginal branches of the internal iliac artery. Blood is also supplied to the vagina through branches of the uterine, middle rectal, and internal pudendal arteries. Blood draining from the vagina returns through vaginal veins that parallel the course of the arteries.

The vagina has sympathetic innervation from the hypogastric plexus and parasympathetic innervation from the second and third sacral nerves. Sensory innervation is through the pudendal plexus and is especially well developed near the vaginal orifice.

Vulva

The external genitalia of the female are referred to collectively as the **vulva** (*vul′vă*) (fig. 21.15). The structures of the vulva surround the vaginal orifice and include the *mons pubis*, *labia majora*, *labia minora*, *clitoris*, *vaginal vestibule*, *vestibular bulbs*, and *vestibular glands*.

vulva: L. *volvere*, to roll, wrapper

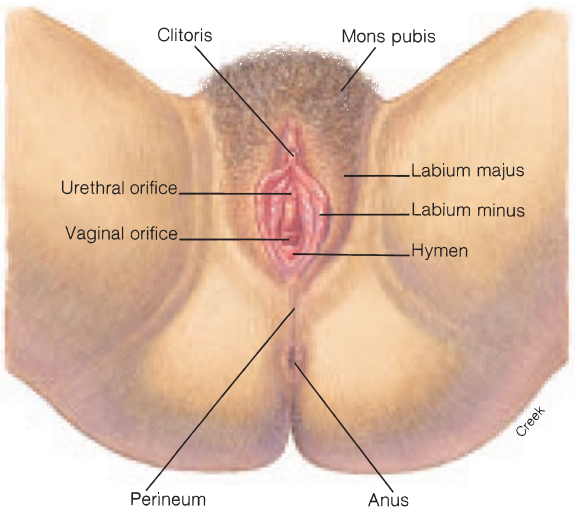


FIGURE 21.15 The external female genitalia.

The **mons pubis** is the subcutaneous pad of adipose connective tissue covering the symphysis pubis. At puberty, the mons pubis becomes covered with coarse pubic hair in a somewhat triangular pattern, usually with a horizontal upper border. The elevated and padded mons pubis cushions the symphysis pubis and vulva during coitus.

The **labia majora** (*la′be-ă mă-jor′ă*—singular *labium majus*) are two thickened longitudinal folds of skin that contain loose connective tissue and adipose tissue, as well as some smooth muscle. After puberty, their lateral surfaces are covered by pubic hair. The labia majora are continuous anteriorly with the mons pubis. They are separated longitudinally by the **pudendal** (*pyoo-den′dal*) **cleft** and converge again posteriorly on the **perineum** (*per″ĭ-ne′um*). The labia majora contain numerous sebaceous and sweat glands. They are homologous to the scrotum of the male and function to enclose and protect the other organs of the vulva.

An *episiotomy* (*ĕ-pe′ze-ot″ŏ-me*) is a surgical incision, for obstetrical purposes, of the vaginal orifice that extends into the perineum. An episiotomy may be done during parturition to facilitate delivery and accommodate the head of an emerging fetus when laceration seems imminent. After delivery the cut is sutured.

Medial to the labia majora are two smaller longitudinal folds called the **labia minora** (singular, *labium minus*). The labia minora are hairless but do contain sebaceous glands. Anteriorly, the labia minora unite to form the **prepuce** (*pre′pyoos*), a hoodlike fold that partly covers the clitoris. The labia minora further protect the vaginal and urethral openings.

mons pubis: L. *mons*, mountain; *pubis*, genital area

The **clitoris** (*klit'or-is, kli-tor'is*) is a small rounded projection at the upper portion of the pudendal cleft, at the anterior junction of the labia minora. The clitoris corresponds in structure and origin to the penis in the male; it is, however, much smaller and without a urethra. Although most of the clitoris is embedded in the tissues of the vulva, it does have an exposed **glans clitoris** of erectile tissue that is richly innervated with sensory endings. The clitoris is about 2 cm (0.8 in.) long and 0.5 cm (0.2 in.) in diameter. The unexposed portion of the clitoris is composed of two columns of erectile tissue called the **corpora cavernosa** that diverge posteriorly to form the **crura** and attach to the sides of the pubic arch.

The **vaginal vestibule** is the longitudinal cleft enclosed by the labia minora. The openings for the urethra and vagina are located in the vaginal vestibule. The **urethral orifice** (see fig. 21.15) is about 2.5 cm (1 in.) behind the glans of the clitoris and immediately in front of the vaginal orifice. The **vaginal orifice** is lubricated during sexual excitement by secretions from paired **major** and **minor vestibular glands** (Bartholin's glands) located within the wall of the region immediately inside the vaginal orifice. The ducts from these glands open into the vaginal vestibule near the lateral margins of the vaginal orifice. Bodies of vascular erectile tissue, called **vestibular bulbs,** are located immediately below the skin forming the lateral walls of the vaginal vestibule. The vestibular bulbs are separated from each other by the vagina and urethra, and extend from the level of the vaginal orifice to the clitoris.

The vulva is highly vascular and is supplied with arterial blood from internal pudendal branches of the internal iliac arteries and external pudendal branches from the femoral arteries. Extensive vascular networks are found within most of the organs of the vulva. The venous return is through vessels that correspond in name and position to the arteries.

During pregnancy, the vulva becomes swollen and bluish—especially the labia minora—because of increased vascularity and venous congestion. This discoloration is an important indicator of pregnancy. It appears at about the eighth to the twelfth week and becomes more apparent as pregnancy progresses.

The vulva has both sympathetic and parasympathetic innervation, as well as extensive somatic neurons that respond to sensory stimulation. Parasympathetic stimulation causes a response similar to that of the male: dilation of the arterioles of the genital erectile tissue and constriction of the venous return.

Mechanism of Erection and Orgasm

The homologous structures of the male and female reproductive systems (see table 21.3) respond to sexual stimulation in a similar fashion. The erectile tissues of a female, like those of a male, become engorged with blood and swollen during sexual arousal. During sexual excitement, the hypothalamus of the brain sends parasympathetic nerve impulses through the sacral segments of the spinal cord, which cause dilation of the arteries serving the clitoris and vestibular bulbs. This increased blood flow causes the erectile tissues to swell. In addition, the erectile tissues in the areola of the breasts become engorged.

Simultaneous with the erection of the clitoris and vestibular bulbs, the vagina expands and elongates to accommodate the erect penis of the male, and parasympathetic impulses cause the vestibular glands to secrete mucus near the vaginal orifice. The vestibular secretion moistens and lubricates the tissues of the vaginal vestibule, thus facilitating the penetration of the erect penis into the vagina. Mucus continues to be secreted during coitus so that the male and female genitalia do not become irritated, as they would if the vagina became dry.

The position of the sensitive clitoris usually allows it to be stimulated during coitus. If stimulation of the clitoris is of sufficient intensity and duration, a woman will usually experience a culmination of pleasurable psychological and physiological release called *orgasm*.

Associated with orgasm is a rhythmic contraction of the muscles of the perineum and the muscular walls of the uterus and uterine tubes. These reflexive muscular actions are thought to aid the movement of spermatozoa through the female reproductive tract toward the upper end of a uterine tube, where an ovum might be located.

Following orgasm or completion of the sexual act, sympathetic impulses cause a reduction in arterial flow to the erectile tissues, and their size diminishes to that prior to sexual stimulation.

Knowledge Check

9. Describe the structure and position of the uterine tubes and explain how an ovum is transported through a uterine tube to the uterus.
10. Describe the histological structure of the uterine wall and explain why the endometrium is subdivided into a stratum functionale and a stratum basale.
11. Describe the structures of the vagina and the vulva. What changes do these structures undergo during sexual excitement and coitus?

MAMMARY GLANDS

Mammary glands are modified sweat glands composed of secretory mammary alveoli and ducts. The glands develop in the female breasts at puberty and function in lactation.

Objective 12 Distinguish between the mammary glands and the breast and describe the structure of the mammary glands.

CHAPTER 21

vestibule: L. *vestibule*, an entrance, court

Bartholin's glands: from Casper Bartholin Jr., Danish anatomist, 1655–1738

orgasm: Gk. *orgasmos*, to swell; to become excited

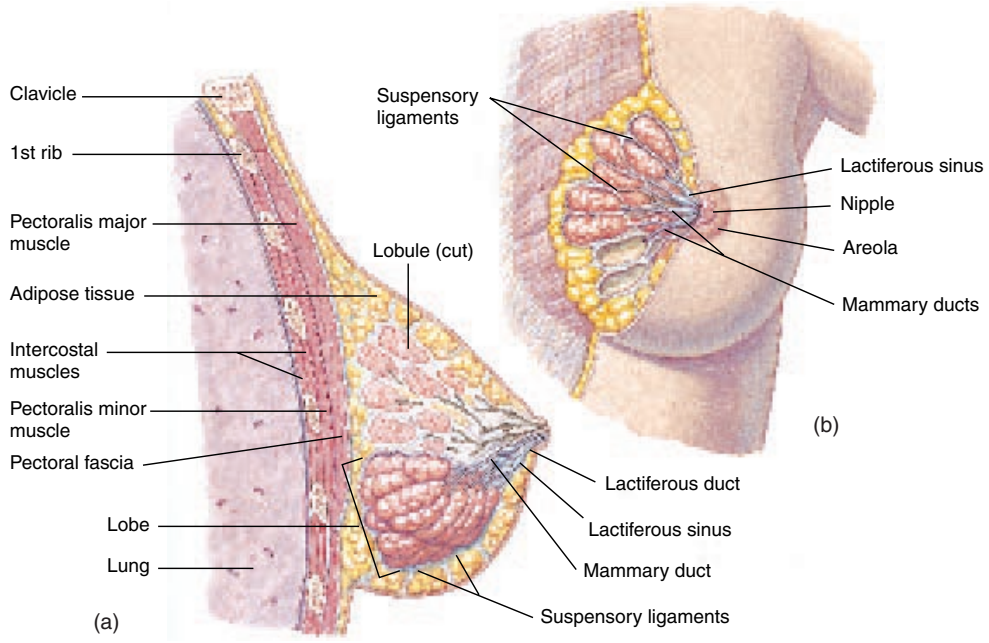


FIGURE 21.16 The structure of the breast and mammary glands. (*a*) A sagittal section and (*b*) an anterior view partially sectioned.

In structure, the **mammary glands,** located in the **breasts,** are modified sweat glands and are a part of the integumentary system. In function, however, these glands are associated with the reproductive system because they secrete milk for the nourishment of the young. The size and shape of the breasts vary considerably from person to person in accordance with genetic differences, age, percentage of body fat, or pregnancy. At puberty, estrogen from the ovaries stimulates growth of the mammary glands and the deposition of adipose tissue within the breasts. Mammary glands hypertrophy in pregnant and lactating women and usually atrophy somewhat after menopause.

Structure of the Breast and the Mammary Glands

Each breast is positioned over ribs 2 through 6 and overlies the pectoralis major muscle, the pectoralis minor muscle, and portions of the serratus anterior and external abdominal oblique muscles (see figs. 9.22 and 21.16). The medial boundary of the breast overlies the lateral margin of the sternum, and the lateral margin of the breast follows the anterior border of the axilla. The *axillary process of the breast* extends upward and laterally toward the axilla, where it comes into close relationship with the axillary vessels. This region of the breast is clinically significant because of the high incidence of breast cancer within the lymphatic drainage of the axillary process.

Each mammary gland is composed of 15 to 20 **lobes,** each with its own drainage pathway to the outside. The lobes are separated by varying amounts of adipose tissue. The amount of adipose tissue determines the size and shape of the breast but has nothing to do with the ability of a woman to nurse. Each lobe is subdivided into **lobules** that contain the glandular **mammary alveoli** (fig. 21.17). The mammary alveoli are the structures that produce the milk of a lactating female. **Suspensory ligaments** between the lobules extend from the skin to the deep fascia overlying the pectoralis major muscle and support the breasts. The clustered mammary alveoli secrete milk into a series of **mammary ducts** that converge to form **lactiferous** (*lak-tif'er-us*) **ducts** (fig. 21.16). The lumen of each lactiferous duct expands near the nipple to form a **lactiferous sinus.** Milk is stored in the lactiferous sinuses before draining at the tip of the nipple.

The **nipple** is a cylindrical projection from the breast that contains some erectile tissue. A circular pigmented **areola** (*ă-re-o'lă*) surrounds the nipple. The surface of the areola may appear bumpy because of the sebaceous **areolar glands** close to the surface. The secretions of these glands keep the nipple pliable. The color of the areola and nipple varies with the complexion of the woman. During pregnancy, the areola becomes darker in most women, and enlarges somewhat, presumably to become more conspicuous to a nursing infant.

Blood is supplied to the mammary gland through the perforating branches of the internal thoracic artery, which enter the breast through the second, third, and fourth intercostal spaces just

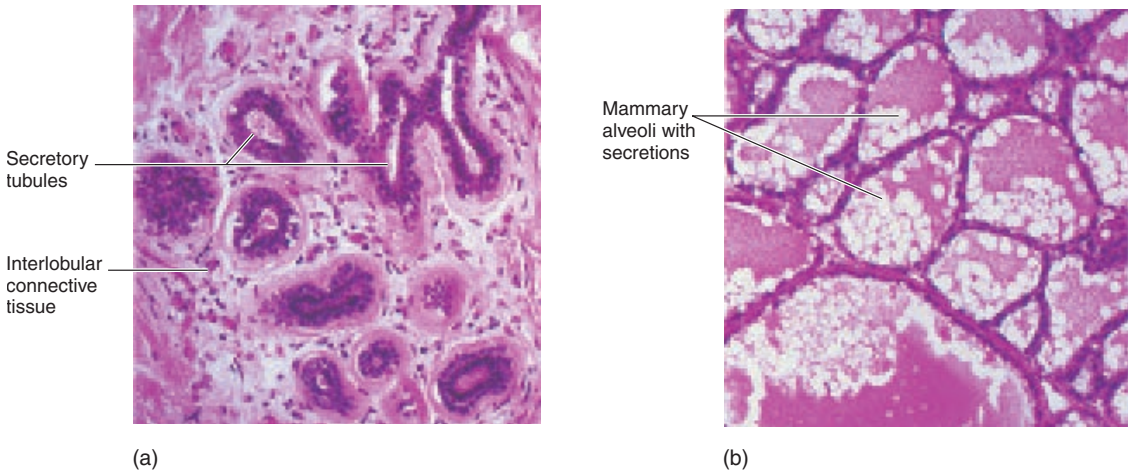


FIGURE 21.17 The histology of the mammary gland. (*a*) Nonlactating (63×) and (*b*) lactating (63×).

lateral to the sternum, and through the more superficial mammary artery, which branches from the lateral thoracic artery. Venous return is through a series of veins that parallel the pattern of the arteries. A superficial venous plexus may be apparent through the skin of the breast, especially during pregnancy and lactation.

The breast is innervated primarily through sensory somatic neurons that are derived from the anterior and lateral cutaneous branches of the fourth, fifth, and sixth thoracic nerves. Sensory nerve endings in the nipple and areola are especially important in stimulating the release of milk from the mammary glands to a suckling infant (see chapter 14).

Lymphatic drainage and the location of lymph nodes within the breast are of considerable clinical importance because of the frequency of *breast cancer* and the high incidence of metastases. About 75% of the lymph drains through the axillary process of the breast into the pectoral lymph nodes (fig. 21.18). Some 20% of the lymph passes toward the sternum to the internal thoracic lymph nodes. The remaining 5% of the lymph is subcutaneous and follows the lymph drainage pathway in the skin toward the back, where it reaches the intercostal nodes near the neck of the ribs.

The ovaries, uterus, and mammary glands in females are especially susceptible to cancer, as are the testes and prostate in males. The commonalities of the tissues making up these organs are that they are composed of highly metabolically active cells that continuously divide. In addition, these cells are sensitive to chemicals—they have to be because they are hormonally regulated—and thus, are also sensitive to carcinogens (cancer-causing agents).

Knowledge Check

12. Describe the structure of the breasts and mammary glands and explain why variations in breast size do not affect the ability to lactate.
13. List in order the parts of the mammary glands through which milk passes during lactation.

OVULATION AND MENSTRUATION

Ovulation and menstruation are reproductive cyclic events that are regulated by follicle-stimulating hormone (FSH) and luteinizing hormone (LH), secreted by the anterior pituitary, and by estrogen and progesterone, secreted by structures of the ovaries.

Objective 13 Describe the hormonal changes that result in ovulation and menstruation.

Objective 14 Describe the structural changes that occur in the endometrium during a menstrual cycle and explain how these changes are controlled by hormones.

Both ovulation and menstruation are reproductive functions of sexually mature females and are largely regulated by hormones from the anterior pituitary and the ovaries. Both occur approximately every 28 days, as menstruation follows ovulation and is regulated by the hormonal activity of the ovaries.

At ovulation, the wall of a follicle ruptures releasing a secondary oocyte that passes into the uterine tube. Ovulation typically occurs from alternate ovaries. If fertilization occurs, mitotic divisions are initiated and the blastocyst implants on the uterine wall (see chapter 22).

If the egg is not fertilized, the menstrual cycle is initiated usually 14 days after ovulation. The cycle is divided into three phases (fig. 21.19):

1. **Menstrual phase.** The menstrual phase, or *menstruation* (*men''stroo'a-shun*), is characterized by a bloody discharge of endometrial tissue from the uterus during the first 3 to 5 days of the cycle. The menstrual flow passes from the uterine cavity to the cervical canal and through the vagina to the outside of the body.

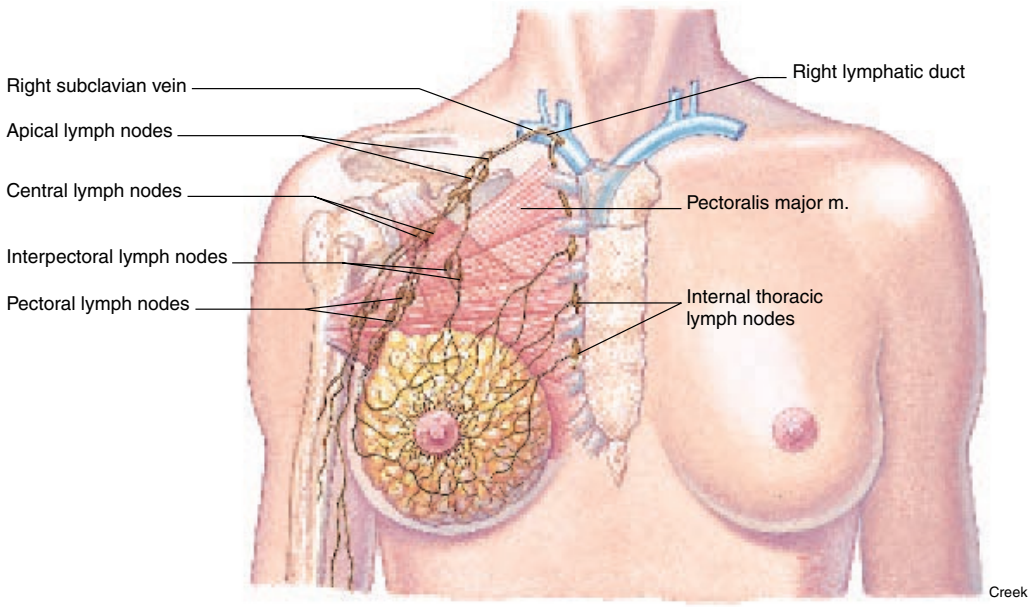


FIGURE 21.18 Lymphatic drainage of the mammary gland.

2. **Proliferative phase.** During the proliferative phase, days 5 to 14 of the cycle, endometrial tissue regrows.
3. **Secretory phase.** The secretory phase, lasting from day 14 to day 28, is characterized by an increase in glandular secretions and blood to the endometrium in preparation for nourishing a blastocyst. The last 2 or 3 days of the secretory phase may be characterized by cramping and external spotting of blood. This period of the cycle is sometimes referred to as the *premenstrual phase* (not shown in figure 21.19) and involves the initial breakdown of the endometrial lining.

The controlling center for ovulation and menstruation is the hypothalamus. On a regular cycle, the hypothalamus releases *gonadotropin-releasing hormone (GnRH)*, which in turn stimulates the anterior pituitary gland to release *follicle-stimulating hormone (FSH)* and *luteinizing hormone (LH)* at the appropriate time. The FSH stimulates the maturation of a follicle within an ovary. During the middle of the menstrual cycle, the anterior pituitary releases a large quantity of LH, in what is called an *LH surge*, and an increased amount of FSH. This surge in LH causes the mature follicle to swell rapidly and rupture. Ovulation occurs as the oocyte is discharged, along with its follicular fluid, toward the uterine tube.

Although there are several different female sex hormones, they all belong to two major groups that are referred to as *estrogen* and *progesterone*. The principal source of estrogen (in a nonpregnant female) is the ovaries. Estrogen, as associated with the menstrual cycle, causes the stratum functionale of the endometrium to thicken. It also plays an important role in the development and maintenance of the secondary sex organs and secondary sex characteristics. Progesterone is also secreted by the ovaries (in a nonpregnant female) and helps estrogen maintain the endometrium.

The principal events of ovulation and menstruation are outlined in table 21.2.

Knowledge Check

14. Define *ovulation* and *menstruation*.
15. Explain the role of GnRH in regulating female reproductive functions.
16. Diagram the relative thickness of the endometrium during the three phases of the menstrual cycle.
17. Summarize the hormonal changes that regulate ovulation and menstruation.

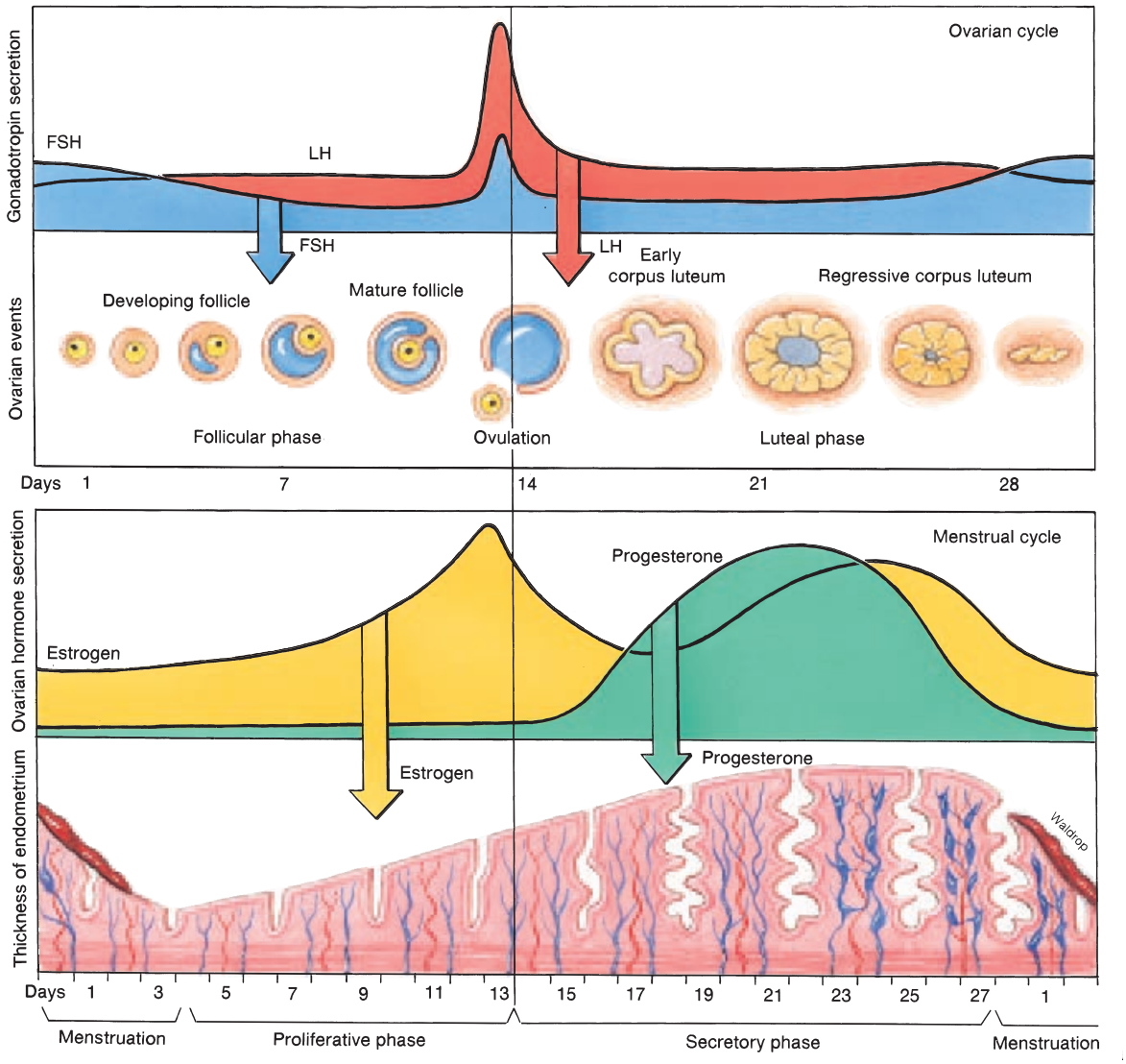


FIGURE 21.19 The cycle of ovulation and menstruation.

TABLE 21.2 Principal Events Surrounding Ovulation and Menstruation

1. The hypothalamus releases GnRH, which stimulates the anterior pituitary.
2. The anterior pituitary releases small amounts of FSH and LH.
3. FSH stimulates the maturation of a follicle.
4. Follicular cells produce and secrete estrogen.
   (a) Estrogen maintains secondary sexual traits.
   (b) Estrogen causes the uterine lining to thicken.
5. Toward the middle of the cycle, a surge in the release of LH from the anterior pituitary causes ovulation.
6. Follicular cells become corpus luteum cells, which secrete estrogen and progesterone.
   (a) Estrogen continues to stimulate the development of the endometrium.
   (b) Progesterone stimulates the endometrium to become more glandular and vascular.
   (c) Estrogen and progesterone inhibit the secretion of FSH and LH from the anterior pituitary.
7. If the oocyte is not fertilized, the corpus luteum degenerates.
8. As concentrations of estrogen and progesterone decline, blood vessels in the stratum basale of the endometrium constrict.
9. The stratum functionale of the endometrium disintegrates and sloughs away as menstrual flow.
10. The anterior pituitary, which is no longer inhibited, again secretes FSH and LH.
11. The cycle is repeated.

Developmental Exposition

The Female Reproductive System

EXPLANATION

Although genetic sex is determined at fertilization, both sexes develop similarly through the indifferent stage of the eighth week. The gonads of both sexes develop from the **gonadal ridges** medial to the mesonephros. **Primary sex cords** form within the gonadal ridges during the sixth week. The **genital tubercle** also develops during the sixth week as an external swelling cephalic to the cloacal membranes.

The ovaries develop more slowly than do the testes. Ovarian development begins at about the tenth week when **primordial follicles** begin to form within the ovarian medulla. Each of the primordial follicles consists of an **oogonium** (*o″ŏ-go′ne-um*) surrounded by a layer of **follicular cells.** Mitosis of the oogonia occurs during fetal development, so that thousands of germ cells are formed. Unlike the male reproductive system, in which spermatogonia are formed by mitosis throughout life, all oogonia are formed prenatally and their number continuously decreases after birth.

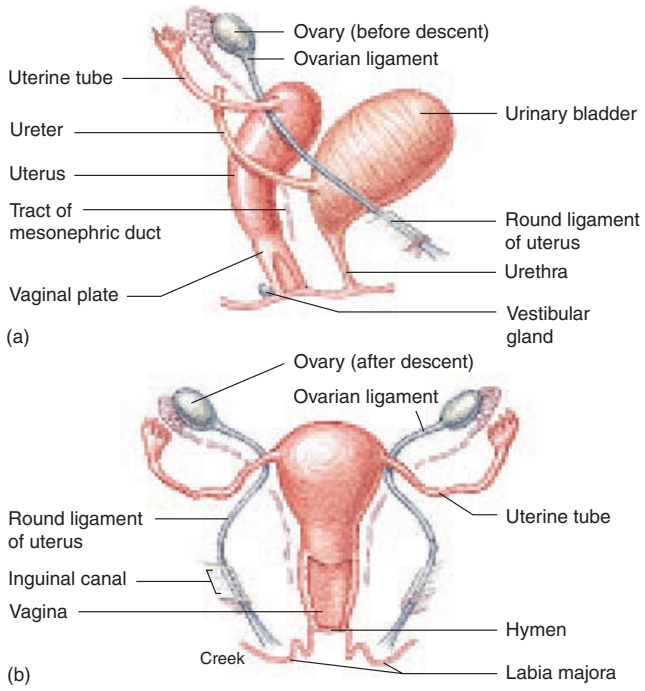


EXHIBIT I The development of the female genital tract. (*a*) A lateral view and (*b*) an anterior view.

primordial: L. *prima*, first; *ordior*, to begin
follicle: L. diminutive of *follis*, bag

The **genital tract** includes the uterus and the uterine tubes. These organs develop from a pair of embryonic tubes called the **paramesonephric** (müllerian) **ducts.** The paramesonephric ducts form to the sides of the mesonephric ducts that give rise to the kidneys. As the mesonephric ducts regress, the paramesonephric ducts develop into the female genital tract (exhibit I). The lower portions of the ducts fuse to form the uterus. The upper portions remain unfused and give rise to the uterine tubes.

The epithelial lining of the vagina develops from the endoderm of the urogenital sinus. The formation of a thin membrane called the **hymen** (see page 718) separates the lumen of the vagina from the urethral sinus. The hymen is usually perforated during later fetal development.

The external genitalia of both sexes appear the same during the indifferent stage of the eighth week (see page 718). A prominent **phallus** (*fal′us*) forms from the genital tubercle, and a **urethral groove** forms on the ventral side of the phallus. Paired **urethral folds** surround the urethral groove on the lateral sides. In the male embryo, these indifferent structures become masculinized by testosterone secreted by the testes. In the female embryo, in the absence of testosterone, feminization occurs.

In the process of feminization, growth of the phallus is inhibited, and the relatively small **clitoris** is formed. The urethral folds remain unfused to form an inner **labia minora,** and the labioscrotal swellings remain unfused to form the prominent **labia majora** (table 21.3). The external genitalia of a female are completely formed by the end of the twelfth week.

The structure of the hymen is characterized by tremendous individual variation. The hymen of a baby girl may be absent, or it may partially (or occasionally completely) cover the vaginal orifice, in which case it is called an *imperforate hymen.* An imperforate hymen is usually not detected until the first menstruation (menarche), when the discharge cannot be expelled. If the hymen is present, it may be ruptured during childhood in the course of normal exercise. On the other hand, a hymen may be so elastic that it persists even after coitus. Therefore, the presence of a hymen is not a reliable sign of virginity.

TABLE 21.3 Summary of Homologous Structures

Indifferent Stage	Male	Female
Gonads	Testes	Ovaries
Urethral groove	Membranous urethra	Vaginal vestibule
Genital tubercle	Glans penis	Clitoris
Urethral folds	Spongy urethra	Labia minora
Labioscrotal swellings	Scrotum	Labia majora
	Bulbourethral glands	Vestibular glands

müllerian ducts: from Johannes P. Müller, German physician, 1801–58
hymen: Gk. (mythology) Hymen was god of marriage; *hymen*, thin skin or membrane

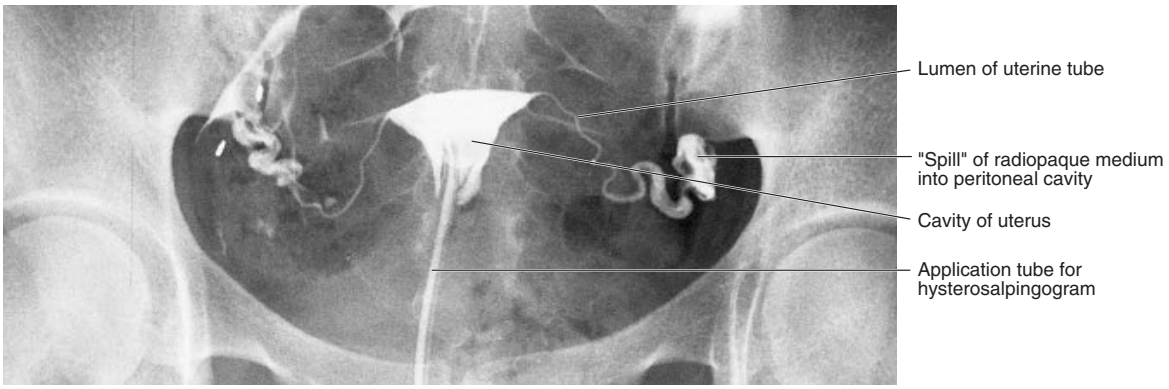


FIGURE 21.20 A contrast radiograph of the uterine cavity and lumina of the uterine tubes (hysterosalpingogram).

CLINICAL CONSIDERATIONS

Females are more prone to dysfunctions and diseases of the reproductive organs than are males because of cyclic changes in reproductive events, problems associated with pregnancy, and the susceptibility of the female breasts to infections and neoplasms. The termination of reproductive capabilities at menopause can also cause complications as a result of hormonal changes. *Gynecology (gi''nĕ-kol'ŏ-je)* is the specialty of medicine concerned with dysfunction and diseases of the female reproductive system. *Obstetrics* is the specialty dealing with pregnancy and childbirth. Frequently a physician will specialize in both obstetrics and gynecology (OBGYN).

A comprehensive discussion of the numerous clinical aspects of the female reproductive system is beyond the scope of this text; thus, only the most important conditions will be addressed in the following sections. Coverage includes diagnostic procedures, developmental abnormalities, problems involving the ovaries and uterine tubes, problems involving the uterus, diseases of the vagina and vulva, and diseases of the breasts and mammary glands. In addition, the more popular methods of birth control are described.

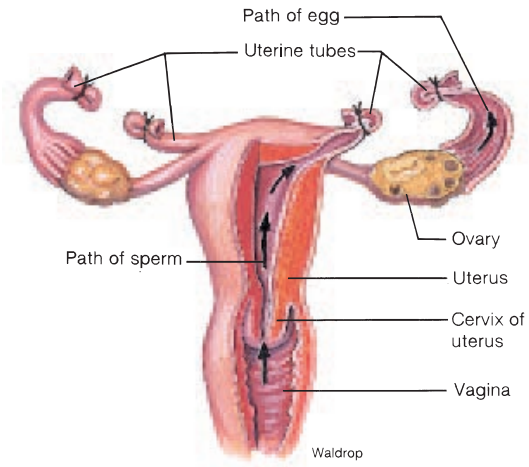


FIGURE 21.21 A tubal ligation involves the removal of a portion of each uterine tube. In actual practice, cautery, clips, or rings are used for tubal closure more often than ligation with suture thread.

CHAPTER 21

Diagnostic Procedures

A gynecological, or pelvic, examination is generally included in a thorough physical examination of an adult female, especially prior to marriage, during pregnancy, or if problems involving the reproductive organs are suspected. In a gynecological examination, the physician inspects the vulva for irritations, lesions, or abnormal vaginal discharge and palpates the vulva and internal organs. Most of the internal organs can be palpated through the vagina, especially if they are enlarged or tender. Inserting a lubricated *speculum* into the vagina allows visual examination of the cervix and vaginal walls. A speculum is an instrument for opening or distending a body opening to permit visual inspection.

In special cases, it may be necessary to examine the cavities of the uterus and uterine tubes by *hysterosalpingography (his''ter-o-sal''ping-gog'ră-fe)* (fig. 21.20). This technique involves injecting a radiopaque dye into the reproductive tract. The patency of the uterine tubes, irregular pregnancies, and various types of tumors may be detected using this technique. A *laparoscopy (lap''ă-ros'kŏ-pe)* permits visualization of the internal reproductive organs. The entrance for the laparoscope may be through the umbilicus, through a small incision in the lower abdominal wall, or through the posterior fornix of the vagina into the rectouterine pouch. Although a laparoscope is used primarily in diagnosis, it can be used when performing a **tubal ligation** (fig. 21.21), a method of sterilizing a female by tying off the uterine tubes.

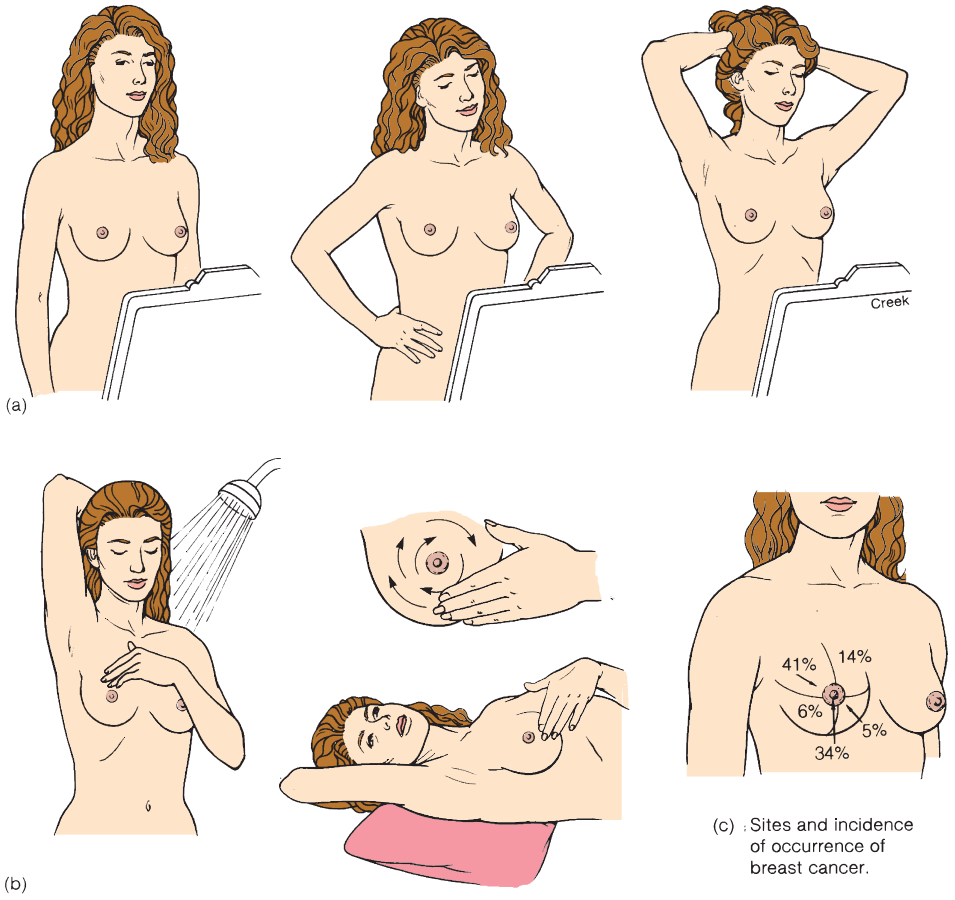


FIGURE 21.22 The technique of conducting a breast self-examination (BSE) involves (*a*) visual inspection and (*b*) palpation. The sites and incidence of occurrence of breast cancer are shown in (*c*).

One diagnostic procedure that should be routinely performed by a woman is a *breast self-examination (BSE)*. The importance of a BSE is not to prevent diseases of the breast but to detect any problems before they become life-threatening. One in nine women will develop breast cancer during her lifetime. Early detection of breast cancer and follow-up medical treatment minimizes the necessary surgical treatment and improves the patient's prognosis. Breast cancer is curable if it is caught early.

A woman should examine her breasts monthly. If she has not yet reached menopause, the ideal time for a BSE is 1 week after her period ends because the breasts are less likely to be swollen and tender at that time. A woman no longer menstruating should just pick any day of the month and do a BSE on that same day on a monthly basis. Visual inspection and palpation (Fig. 21.22) are equally important in doing a BSE. The steps involved in this procedure are the following:

1. **Observation in front of a mirror.** Inspect the breasts with the arms at the sides. Next, raise the arms high overhead. Look for any changes in the contour of each breast—a swelling, dimpling of skin or changes in the nipple. The left and right breast will not match exactly—few women's breasts do. Finally, squeeze the nipple of each breast gently between the thumb and index finger to check for discharge. Any discharge from the nipple should be reported to a physician.
2. **Palpation during bathing.** Examine the breasts during a bath or shower when the hands will glide easily over wet skin. With the fingers flat, move gently over every part of each breast. Use the right hand to examine the left breast, and the left hand for the right breast. Palpate for any lump, hard knot, or thickening. If the breasts are normally fibrous or lumpy (fibrocystic tissue), the locations of these lumps should be noted and checked each month for changes in size and location.
3. **Palpation while lying down.** To examine the right breast, put a pillow or folded towel under the right shoulder. Place the right hand behind the head—this distributes the breast tissue more evenly on the rib cage. With the fingers of the left hand held flat, press gently in small circular motions around an imaginary clock face. Begin at outermost top of

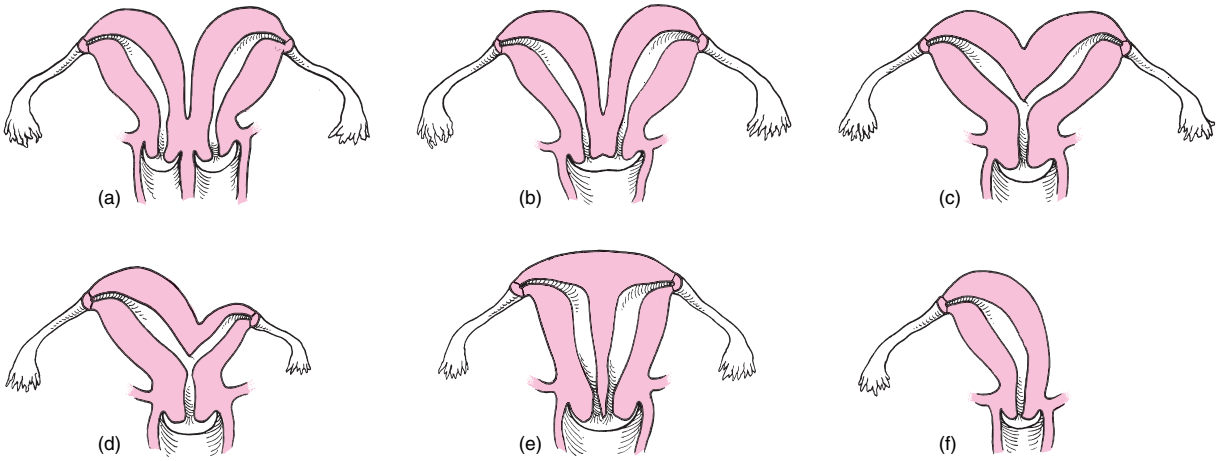


FIGURE 21.23 Congenital uterine abnormalities. (*a*) A double uterus and double vagina, (*b*) a double uterus with a single vagina, (*c*) a bicornuate uterus, (*d*) a bicornuate uterus with a rudimentary left horn, (*e*) a septate uterus, and (*f*) a unicornuate uterus.

the right breast for 12 o'clock, then move to 1 o'clock, and so on around the circle back to 12 o'clock. A ridge of firm tissue in the lower curve of each breast is normal. Then move in an inch, toward the nipple, and keep circling to examine every part of the breast, including the nipple. Also examine the armpit carefully for enlarged lymph nodes. Repeat the procedure on the left breast.

Another important diagnostic procedure is a *Papanicolaou (Pap) smear*. The Pap smear permits a microscopic examination of cells covering the tip of the cervix. Samples of cells are obtained by gently scraping the surface of the cervix with a specially designed wooden spatula. Women should have periodic Pap smears for the early detection of cervical cancer.

Developmental Problems of the Female Reproductive System

Many of the developmental problems of the female reproductive system also occur in the reproductive system of the male and were discussed in the previous chapter. Hermaphroditism and irregularities of the sex chromosomes, for example, are developmental conditions that cause a person to develop both male and female characteristics.

Other developmental abnormalities of the female reproductive system may occur during the formation of the uterus and vagina. Failure of the paramesonephric ducts to fuse normally can result in a **double uterus,** a **bicornuate** (*bi-kor'nyoo-āt*) **uterus,** or a **unicornuate uterus.** These types of uterine abnormalities and others are diagrammed in figure 21.23. In about 1 in 4,000 females, the vagina is absent. This is usually accompanied by an absence of the uterus as well.

Problems Involving the Ovaries and Uterine Tubes

Nonmalignant **ovarian cysts** are lined by cuboidal epithelium and filled with a serous albuminous fluid. These abnormal growths often can be palpated during a gynecological examination and may require surgical removal if they exceed about 4 cm in diameter. They are generally removed as a precaution because it is impossible to determine by palpation whether the mass is malignant or benign.

Ovarian tumors, which occur most often in women over the age of 60, can grow to be massive. Ovarian tumors as heavy as 5 kg (14 lb) are not uncommon, and some weighing as much as 110 kg (300 lb) have been reported. Some ovarian tumors produce estrogen and thus cause feminization in elderly women, including the resumption of menstrual periods. The prognosis for women with ovarian tumors varies depending on the type of tumor, whether or not it is malignant, and if it is, the stage of the cancer.

Two frequent problems involving the uterine tubes are salpingitis and ectopic pregnancies. **Salpingitis** (*sal-pin-gi-tis*) is an inflammation of one or both uterine tubes. Infection of the uterine tubes is generally caused by a sexually transmitted disease, although secondary bacterial infections from the vagina may also cause salpingitis. Salpingitis may cause sterility if the uterine tubes become occluded.

Ectopic pregnancy results from implantation of the blastocyst in a location other than the body or fundus of the uterus. The most frequent ectopic site is in the uterine tube, where an

Pap smear: from George N. Papanicolaou, American anatomist and physician, 1883–1962

bicornuate: L. *bi,* two; *cornu,* horn

implanted blastocyst causes what is commonly called a **tubal pregnancy.** One danger of a tubal pregnancy is the enlargement, rupture, and subsequent hemorrhage of the uterine tube where implantation has occurred. A tubal pregnancy is frequently treated by removing the affected tube.

Infertility, or the inability to conceive, is a clinical problem that may involve the male or female reproductive system. On the basis of number of people who seek help for this problem, it is estimated that 10% to 15% of couples have impaired fertility. Generally, when a male is infertile, it is because of inadequate sperm counts. Female infertility is frequently caused by an obstruction of the uterine tubes or abnormal ovulation.

Problems Involving the Uterus

Abnormal menstruations are among the most common disorders of the female reproductive system. Abnormal menstruations may be directly related to problems of the reproductive organs and pituitary gland or associated with emotional and psychological stress.

Amenorrhea (*a-men''ŏ-re-ă*) is the absence of menstruation and may be categorized as normal, primary, or secondary. *Normal amenorrhea* follows menopause, occurs during pregnancy, and in some women may occur during lactation. *Primary amenorrhea* is the failure to have menstruated by the age when menstruation normally begins. Primary amenorrhea is generally accompanied by lack of development of the secondary sex characteristics. Endocrine disorders may cause primary amenorrhea and abnormal development of the ovaries or uterus.

Secondary amenorrhea is the cessation of menstruation in women who previously have had normal menstrual periods and who are not pregnant and have not gone through menopause. Various endocrine disturbances and psychological factors may cause secondary amenorrhea. It is not uncommon, for example, for young women who are in the process of making major changes or adjustments in their lives to miss menstrual periods. Secondary amenorrhea is also frequent in women athletes during periods of intense training. A low percentage of body fat may be a contributing factor. Sickness, fatigue, poor nutrition, or emotional stress also may cause secondary amenorrhea.

Dysmenorrhea is painful or difficult menstruation accompanied by severe menstrual cramps. The causes of dysmenorrhea are not totally understood but may include endocrine disturbances (inadequate progesterone levels), a faulty position of the uterus, emotional stress, or some type of obstruction that prohibits menstrual discharge.

Abnormal uterine bleeding includes **menorrhagia** (*men''ŏ-ra'je-ă*), or excessive bleeding during the menstrual period, and **metrorrhagia,** or spotting between menstrual periods. Other types of abnormal uterine bleeding are menstruations of excessive duration, too-frequent menstruations, and postmenopausal bleeding. These abnormalities may be caused by hormonal irregularities, emotional factors, or various diseases and physical conditions.

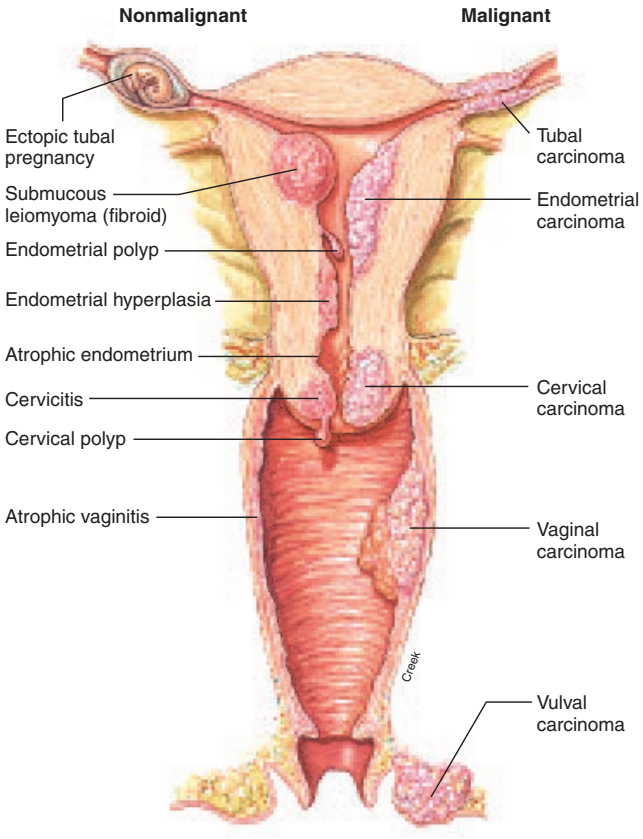


FIGURE 21.24 Sites of various conditions and diseases of the female reproductive tract, all of which could cause an abnormal discharge of blood.

Uterine neoplasms are an extremely common problem of the female reproductive tract. They include cysts, polyps, and smooth muscle tumors (leiomyomas), and most of them are benign. Any of these conditions may provoke irregular menstruations and may cause infertility if the neoplasms are massive.

Cancer of the uterus is the most common malignancy of the female reproductive tract. The most common site of uterine cancer is the cervix (fig. 21.24). Cervical cancer, which is second only to cancer of the breast in frequency of occurrence, is a disease of relatively young women (ages 30 through 50), especially those who have had frequent sexual intercourse with multiple partners during their teens and onward. If detected early through regular Pap smears, the disease can be cured before it metastasizes. The treatment of cervical cancer depends on the stage of the malignancy and the age and health of the woman. In the case of women for whom fertility is not an issue, a **hysterectomy** (*his''tĕ-rek'tŏ-me*) (surgical removal of the uterus) is usually performed.

neoplasm: Gk. *neos*, new; *plasma*, something formed

Endometriosis (*en''do-me''tre-o'sis*) is a condition characterized by the presence of endometrial tissues at sites other than the inner lining of the uterus. Frequent sites of ectopic endometrial cells are on the ovaries, on the outer layer of the uterus, on the abdominal wall, and on the urinary bladder. Although it is not certain how endometrial cells become established outside the uterus, it is speculated that some discharged endometrial tissue might be flushed backward from the uterus and through the uterine tubes during menstruation. Women with endometriosis will bleed internally with each menstrual period because the ectopic endometrial cells are stimulated along with the normal endometrium by ovarian hormones. The most common symptoms of endometriosis are extreme dysmenorrhea and a feeling of fullness during each menstrual period. Endometriosis can cause infertility. It is treated by suppressing the endometrial tissues with oral contraceptive pills or by surgery. An oophorectomy, or removal of the ovaries, may be necessary in extreme cases.

Uterine displacements are relatively common in elderly women. When uterine displacements occur in younger women, they are important because they may cause dysmenorrhea, infertility, or problems with childbirth. **Retroversion,** or **retroflexion,** is a displacement backward; **anteversion,** or **anteflexion,** is displacement forward. **Prolapse of the uterus** is a marked downward displacement of the uterus into the vagina.

An **abortion** is defined as the termination of a pregnancy before the twenty-eighth week of gestation. A **spontaneous abortion,** or **miscarriage,** occurs without mechanical aid or medicinal intervention and may occur in as many as 10% of all pregnancies. Spontaneous abortions usually occur when there is abnormal development of the fetus or disease of the maternal reproductive system. An **induced abortion** is removal of the fetus from the uterus by mechanical means or drugs. Induced abortions are a major issue of controversy because of questions regarding individual rights (those of the mother and those of the fetus), the definition of life, and morality.

Diseases of the Vagina and Vulva

Pelvic inflammatory disease (PID) is a general term for inflammation of the female reproductive organs within the pelvis. The infection may be confined to a single organ, or it may involve all of the internal reproductive organs. The pathogens generally enter through the vagina during coitus, induced abortion, or childbirth. Inflammation of the ovaries is called **oophoritis** (*o''of-ŏ-ri'tis*) and inflammation of the uterine tube is **salpingitis** (*sal''pin-ji'tis*).

The vagina and vulva are generally resistant to infection because of the acidity of the vaginal secretions. Occasionally, however, localized infections and inflammations do occur. These are termed **vaginitis,** if confined to the vagina, or **vulvovaginitis,** if both the vagina and external genitalia are affected. The symptoms of vaginitis are a discharge of pus (*leukorrhea*) and itching (*pruritus*). The two most common organisms that cause vaginitis are the protozoan *Trichomonas vaginalis* and the fungus *Candida albicans*.

Diseases of the Breasts and Mammary Glands

The breasts and mammary glands of females are highly susceptible to infections, cysts, and tumors. Infections involving the mammary glands usually follow the development of a dry and cracked nipple during lactation. Bacteria enter the wound and establish an infection within the lobules of the gland. During an infection of the mammary gland, a blocked duct frequently causes a lobe to become engorged with milk. This localized swelling is usually accompanied by redness, pain, and an elevation of temperature. Administering specific antibiotics and applying heat are the usual treatments.

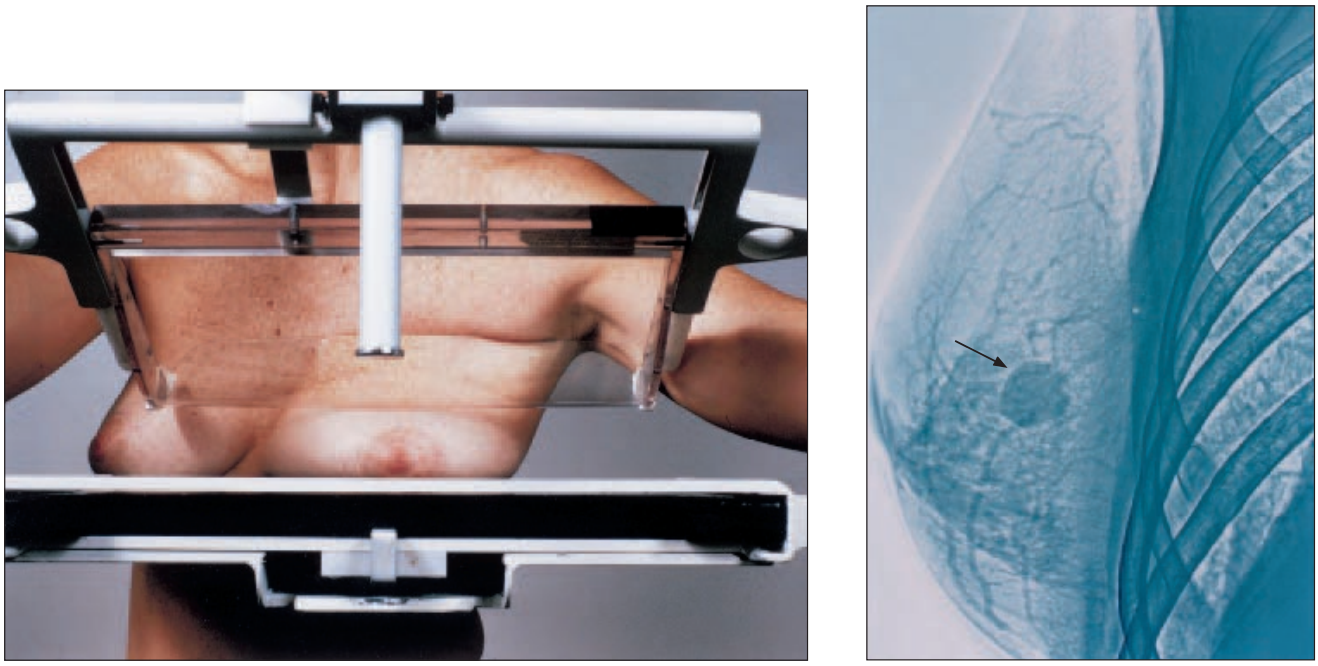
Nonmalignant cysts are the most frequent diseases of the breast. These masses are generally of two types, neither of which is life-threatening. **Dysplasia** (fibrocystic disease) is a broad condition involving several nonmalignant diseases of the breast. All dysplasias are benign neoplasms of various sizes that may become painful during or prior to menstruation. Most of the masses are small and remain undetected. Dysplasia affects nearly 50% of women over the age of 30 prior to menopause.

A **fibroadenoma** (*fi''bro-ad''ĕ-no'mă*) is a benign tumor of the breast that frequently occurs in women under the age of 35. Fibroadenomas are nontender rubbery masses that are easily moved about in the mammary tissue. A fibroadenoma can be excised in a physician's office under local anesthetic.

Carcinoma of the breast is the most common malignancy in women. One in nine women will develop breast cancer and one-third of these will die from the disease. Breast cancer is the leading cause of death in women between 40 and 50 years of age. Men are also susceptible to breast cancer, but it is 100 times more frequent in women. Breast cancer in men is usually fatal.

The causes of breast cancer are not known, but women who are most susceptible are those who are over age 35, who have a family history of breast cancer, and who are nulliparous (never having given birth). The early detection of breast cancer is important because the prognosis worsens as the disease progresses.

Confirming suspected breast cancer generally requires *mammography* (fig. 21.25). If the mammogram suggests breast cancer, a biopsy (tissue sample) is obtained and the tumor assessed. If the tumor is found to be malignant, surgery is performed, the extent of which depends on the size of the tumor and whether metastasis has occurred. The surgical treatment for breast cancer is generally some degree of *mastectomy* (*mas-tek'tŏ-me*). A *simple mastectomy* is removal of the entire breast but not the underlying lymph nodes. A *modified radical mastectomy* is the complete removal of the breast, the lymphatic drainage, and perhaps the pectoralis major muscle. A *radical mastectomy* is similar to a modified except that the pectoralis major muscle is always removed, as well as the pectoral lymph nodes and adjacent connective tissue.



(a) (b)

FIGURE 21.25 (*a*) In mammography, the breast is placed alternately on a metal plate and radiographed from above and from the side. (*b*) A mammogram of a patient with carcinoma of the breast. (Note the presence of a neoplasm indicated with an arrow.)

Methods of Contraception

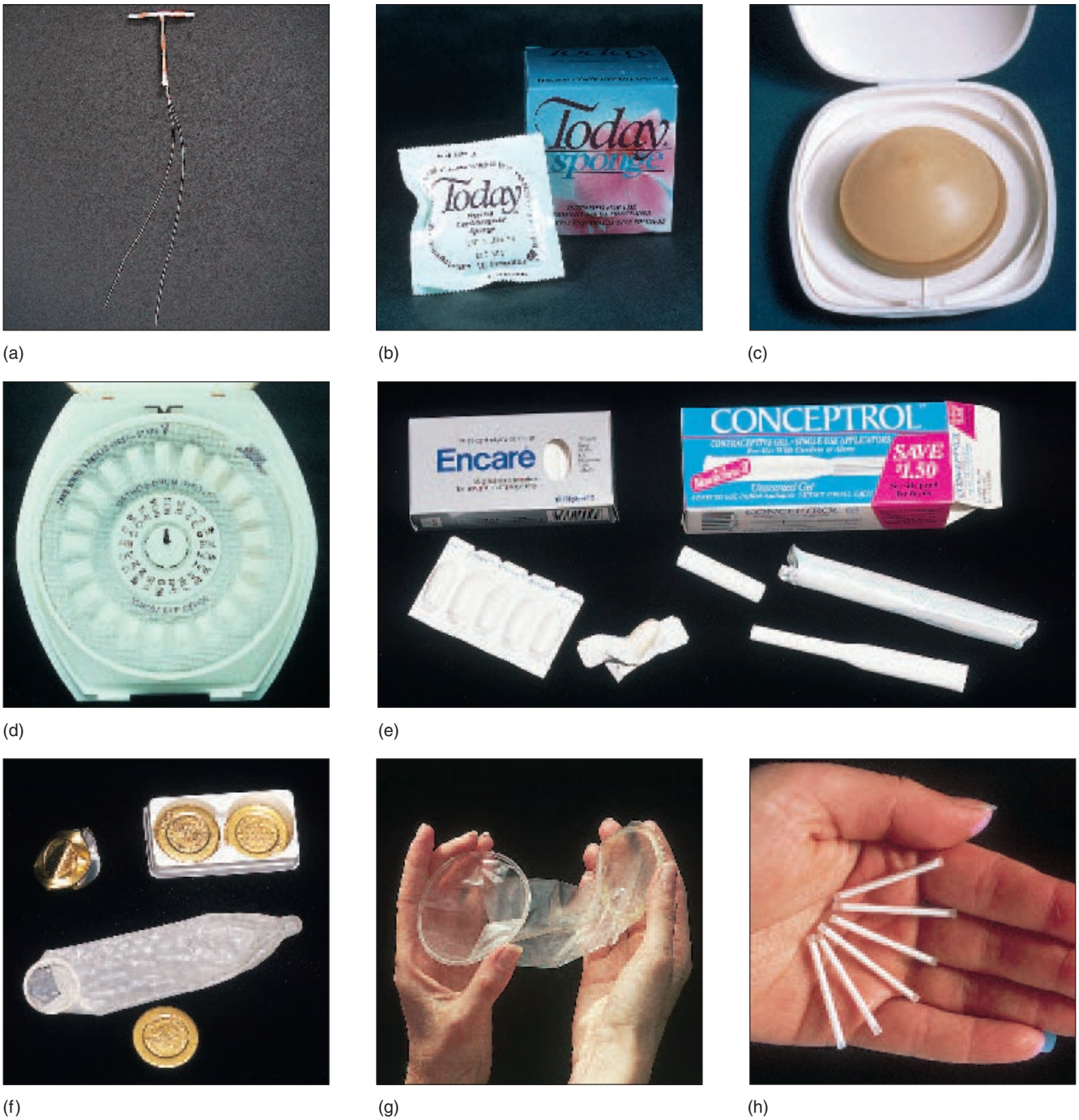
The *rhythm method* of birth control continues to be used by many people, but the popularity of this technique has declined as more successful methods of contraception have been introduced (fig. 21.26). In the rhythm method, an attempt is made to predict the day of the woman's ovulation and restrict coitus to safe times of the cycle that allow no chance for fertilization to occur. The day of ovulation can be determined by a rise in basal body temperature or by a change in mucous discharge from the vagina. This technique has one of the highest failure rates of any of the widely used birth control methods, largely because women's cycles are often irregular.

More popular methods of birth control include *sterilization*, *oral contraceptives*, *intrauterine devices (IUDs)*, and *barrier methods*—including condoms for the male and female and diaphragms for the female. All of these techniques are effective, but they vary with respect to safety, side effects, and degree of efficacy.

Sterilization techniques include *vasectomy* for the male and *tubal ligation* for the female. In the latter technique (which accounts for over 60% of sterilization procedures performed in the United States), the uterine tubes are cut and tied. This is analogous to the procedure performed on the ductus deferentia in a vasectomy. It prevents fertilization of the ovulated ovum.

About 10 million women in the United States and 60 million women in the world are currently using **oral steroid contraceptives** ("the Pill"). These contraceptives usually consist of a synthetic estrogen combined with a synthetic progesterone in the form of pills that are taken once each day for 3 weeks after the last day of a menstrual period. This procedure causes an immediate increase in blood levels of ovarian steroids (from the pill), which is maintained for the normal duration of a monthly cycle. As a result of *negative feedback inhibition* of gonadotrophin secretion, *ovulation never occurs*. The entire cycle is like a false luteal phase, with high levels of progesterone and estrogen and low levels of gonadotrophins.

Because the contraceptive pills contain ovarian steroid hormones, the endometrium proliferates and becomes secretory, just as it does during a normal cycle. In order to prevent an abnormal growth of the endometrium, women stop taking the pill after 3 weeks. This causes estrogen and progesterone levels to fall, and permits menstruation to occur. The contraceptive pill is an extremely effective method of birth control, but it does have potentially serious side effects—including an increased incidence of thromboembolism and cardiovascular disorders. It has been pointed out, however, that the mortality risk associated with contraceptive pills is still much lower than the risk of death from complications of pregnancy—or from automobile accidents.



(a) (b) (c)

(d) (e)

(f) (g) (h)

FIGURE 21.26 Various types of birth control devices. (*a*) IUD, (*b*) contraceptive sponge, (*c*) diaphragm, (*d*) birth control pills, (*e*) vaginal spermicides, (*f*) condom, (*g*) female condom, and (*h*) Norplant.

Another way in which to deliver hormonal contraceptives to a woman's body is by means of a **subdermal implant.** Implants are 2-in. rods filled with a hormonal contraceptive drug. They are implanted just under the skin, usually on the upper arm, through a tiny incision. The contraceptive hormone gradually leaches out through the walls of the rods and enters the bloodstream, preventing pregnancy for at least 5 years.

Intrauterine devices (IUDs) do not prevent ovulation, but instead prevent implantation of the blastocyst in the uterine wall in the event that fertilization occurs. The mechanisms by which their contraceptive effects are produced are not well understood but appear to involve their ability to cause inflammatory reactions in the uterus. Uterine perforations are the foremost complication associated with the use of IUDs. Because of the potential problems with IUDs, their use has diminished.

Barrier contraceptives—condoms, diaphragms, and cervical caps—are only slightly less effective than hormonal contraceptives or IUDs, but they do not have serious side effects. Barrier contraceptives are most effective when they are used in conjunction with spermicidal (sperm-killing) foams and gels. Many couples avoid them, however, because they detract from the spontaneity of sexual intercourse. Latex condoms offer an additional benefit; they provide some protection against sexually transmitted diseases, including AIDS.

Several new chemical contraceptives are being developed that should be soon available. These include hormonal patches, hormonal IUDs, and injectible contraceptives. A *hormonal patch* is intended to be placed on the skin directly over an ovary. Designed to resist moisture, the patch releases a week's worth of estrogen and progestin. A *hormonal IUD* is a T-shaped structure that fits into the uterine cavity where it slowly releases progestin up to a five-year period. Improved monthly *injectible contraceptives* have fewer side effects than Depro-Provera, which has been available since 1992.

Clinical Case Study Answer

An ectopic pregnancy is any pregnancy that implants outside the uterine cavity. This is most likely to occur in the uterine tube (see fig. 21.24). The events leading up to our patient's problem are as follows: An oocyte is extruded from the ovary during ovulation and received into the uterine tube. Soon after it enters the tube, the oocyte is fertilized, creating a zygote. Up to this point, the events are no different from those that occur in a normal pregnancy. In the case of tubal pregnancy, however, the transporting ability of the uterine tube fails, causing the conceptus to be retained in the tube. Implantation then occurs within tissues that are not well suited for that purpose. For example, the uterine tube does not expand well to accommodate a growing embryo, nor does it possess the necessary epithelium and glandular structures as does the endometrium of the uterus. The result is overexpansion and erosion of the tubal wall, leading to rupture and hemorrhage. Because the uterine tube is basically exposed to the peritoneal cavity, blood from the site of rupture can flow into and collect in the rectouterine pouch (pouch of Douglas or Douglas' cul-de-sac), which lies posterior to the vaginal fornix. There, it is easily aspirated by a needle placed through the vaginal wall.

CLINICAL PRACTICUM 21.1

A 32-year-old female comes to you because she and her husband have been unsuccessfully attempting to become pregnant for more than a year. In questioning her, you find that she has been suffering from vague pelvic pain during her periods for many years. She also reports occasional pain during intercourse over that same time. On pelvic exam, you find bilateral tender adnexal masses, flanking a normal-sized uterus. An MRI of the pelvis confirms these findings. [uterus (U), adnexal masses (A)]

QUESTIONS

1. These adnexal masses are consistent with endometriomas, foci of endometrial tissue outside the uterus on the ovaries. How would these masses cause the patient's symptoms?
2. How does endometrial tissue get to the ovaries?
3. Endometrial implants can be found throughout the peritoneal space from direct spread and have even been reported in the pleural space. Remembering that these implants cause irritation of, as well as, scarring around the organs on which they are implanted, what symptoms would the patient have if implants were found on the following organs: (a) rectum, (b) urinary bladder, (c) stomach, or (d) diaphragm?

Chapter Summary

Introduction to the Female Reproductive System (pp. 726–728)

1. The reproductive period of a female is the period between puberty (about age 12) and menopause (about age 50). In the course of this age span, cyclic ovulation and menstruation patterns occur in nonpregnant females.
2. The functions of the female reproductive system are to produce ova; secrete sex hormones; receive sperm from the male; provide sites for fertilization, implantation, and development of the embryo and fetus; facilitate parturition; and secrete milk from the mammary glands.
3. The female reproductive system consists of (a) primary sex organs—the ovaries; (b) secondary sex organs—those that are essential for sexual reproduction, characterized by latent development; and (c) secondary sex characteristics—features that are sexual attractants, expressed after puberty.

Structure and Function of the Ovaries (pp. 728–732)

1. The ovaries are supported by the mesovarium, which extends from the broad ligament, and by the ovarian and suspensory ligaments.
2. The ovarian follicles within the ovarian cortex undergo cyclic changes.
   (a) Primary oocytes, arrested at prophase I of meiosis, are contained within primordial follicles.
   (b) Upon stimulation by gonadotropic hormones, some of the primordial follicles enlarge to become primary follicles.
   (c) When a follicle develops a fluid-filled antrum, it is called a secondary follicle.
   (d) Generally only one follicle continues to grow to become a vesicular ovarian follicle.
   (e) The vesicular ovarian follicle contains a secondary oocyte, arrested at metaphase II of meiosis.
   (f) In the process of ovulation, the vesicular ovarian follicle ruptures and releases its secondary oocyte, which becomes a zygote upon fertilization.
   (g) After ovulation, the empty follicle becomes a corpus luteum.

Secondary Sex Organs (pp. 732–738)

1. The uterine tube, which conveys ova from the ovary to the uterus, provides a site for fertilization.
   (a) The open-ended portion of each uterine tube is expanded; its margin bears fimbriae that extend over the lateral surface of the ovary.
   (b) Movement of an ovum is aided by ciliated cells that line the lumen and by peristaltic contractions in the wall of the uterine tube.
2. The uterus is supported by the broad ligaments, uterosacral ligaments, cardinal ligaments, and round ligaments. The regions of uterus are the fundus, body, and cervix. The cervical canal opens into the vagina at the uterine ostium.
   (a) The endometrium consists of a stratum basale and a stratum functionale; the superficial stratum functionale is shed during menstruation.
   (b) The myometrium produces the muscular contractions needed for labor and parturition.
3. The vagina serves to receive the erect penis during coitus, to convey menses to the outside during menstruation, and to transport the fetus during parturition.
   (a) The vaginal wall is composed of an inner mucosa, a middle muscularis, and an outer fibrous layer.
   (b) The vaginal orifice may be partially covered by a thin membranous hymen.
4. The external genitalia, or vulva, include the mons pubis, labia majora and minora, clitoris, vaginal vestibule, vestibular bulbs, and vestibular glands.
5. Impulses through parasympathetic nerves stimulate erectile tissues in the clitoris and vestibular bulbs; in orgasm, muscular contraction occurs in the perineum, uterus, and uterine tubes.

Mammary Glands (pp. 738–740)

1. Mammary glands, located within the breasts, are modified sweat glands.
   (a) Each mammary gland is composed of 15 to 20 lobes; the lobes are subdivided into lobules that contain mammary alveoli.
   (b) During lactation, the mammary alveoli secrete milk. The milk passes through mammary ducts, lactiferous ducts, and lactiferous sinuses and is discharged through the nipple.
2. The nipple is a cylindrical projection near the center of the breast, surrounded by the circular pigmented areola.

Ovulation and Menstruation (pp. 740–742)

1. Ovulation and menstruation are reproductive cyclic events that are regulated by hormones secreted by the hypothalamus, the anterior pituitary, and the ovaries.
2. The menstrual cycle is divided into menstrual, proliferative, and secretory phases.
3. The principal hormones that regulate ovulation and menstruation are estrogen, progesterone, follicle-stimulating hormone (FSH), and luteinizing hormone (LH).

Review Activities

Objective Questions

1. The cervix is a portion of
   (a) the vulva.
   (b) the vagina.
   (c) the uterus.
   (d) the uterine tubes.
2. Fertilization normally occurs in
   (a) the ovary.
   (b) the uterine tube.
   (c) the uterus.
   (d) the vagina.
3. The secretory phase of the endometrium corresponds to which of the following ovarian phases?
   (a) the follicular phase
   (b) ovulation

(c) the luteal phase
(d) the menstrual phase

4. Which of the following statements about oogenesis is *true?*
   (a) Oogonia, like spermatogonia, form continuously during postnatal life.
   (b) Primary oocytes are haploid.
   (c) Meiosis is completed prior to ovulation.
   (d) During ovulation, a secondary oocyte is released from a vesicular ovarian follicle.
5. The function of the mesovarium is
   (a) movement of the sperm to the ova.
   (b) nourishment of the ovarian walls.
   (c) muscular contraction of the uterus.
   (d) suspension of the ovary.
6. Which of the following layers is shed as menses?
   (a) the perimetrial layer
   (b) the fibrous layer
   (c) the functionalis layer
   (d) the menstrual layer
7. The transverse folds in the mucosal layer of the vagina are called
   (a) perineal folds. (c) fornices.
   (b) vaginal rugae. (d) labia gyri.
8. Which of the following is *not* a part of the vulva?
   (a) the mons pubis
   (b) the clitoris
   (c) the vaginal vestibule
   (d) the vagina
   (e) the labia minora
9. The paramesonephric (müllerian) ducts give rise to
   (a) the uterine tubes.
   (b) the uterus.
   (c) the pudendum.
   (d) both a and b.
   (e) both b and c.
10. In a female, the homologue of the male scrotum is/are
    (a) the labia majora.
    (b) the labia minora.
    (c) the clitoris.
    (d) the vestibule.

Essay Questions

1. Define *puberty*, *ovulation*, *menstruation*, and *menopause*.
2. Describe the follicular changes within the ovarian cortex during the events that precede and follow ovulation.
3. Define *oogenesis*. When is the process initiated and when is it completed?
4. Describe the gross and histologic structure of the uterus and comment on the significance of the two endometrial layers.
5. Identify the secondary sex organs and explain their functions.
6. Summarize the events of a menstrual cycle and explain the roles of estrogen and progesterone.
7. List the functions of the vagina and describe its structure.
8. Distinguish between the labia majora and labia minora, between the pudendal cleft and vaginal vestibule, and between the vestibular bulbs and vestibular glands.
9. List the events that cause an erection of the female genitalia, and explain the process of orgasm.
10. Describe the structure and position of the mammary glands in the breasts.
11. List the homologous reproductive organs of the male and female reproductive systems and note the undifferentiated structures from which they develop.
12. Define *gynecology*, *obstetrics*, *speculum*, *laparoscopy*, *breast self-examination*, and *Pap smear*.
13. Distinguish between normal, primary, and secondary amenorrhea. What causes each?
14. List the various kinds of uterine neoplasms. How is cancer of the uterus generally detected?
15. Distinguish between dysplasia, fibroadenoma, and carcinoma of the breast.

Critical-Thinking Questions

1. Why is the hormonal regulation of the reproductive system much more complex in females than it is in males?
2. Your 14-year-old daughter is serious about her gymnastics lessons and exercises rigorously for at least 2 hours every day. She has not yet had her first menstrual period and is beginning to get worried. How would you reassure her?
3. A wide variety of commercial douche preparations and scented aerosols can be purchased in drug stores and supermarkets as "feminine hygiene products." Why should women avoid using them?
4. Both sterility and impotence are sexual dysfunctions in men. Only one of these is associated with women, however. Explain.
5. "Contraceptive pills trick the brain into thinking you're pregnant." Explain what is meant by this statement.
6. With respect to homologous structures, explain why men have nipples? Why do mammary glands normally function only in females?
7. If a woman is on estrogen replacement therapy following menopause, why is it important to monitor her uterine lining?

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