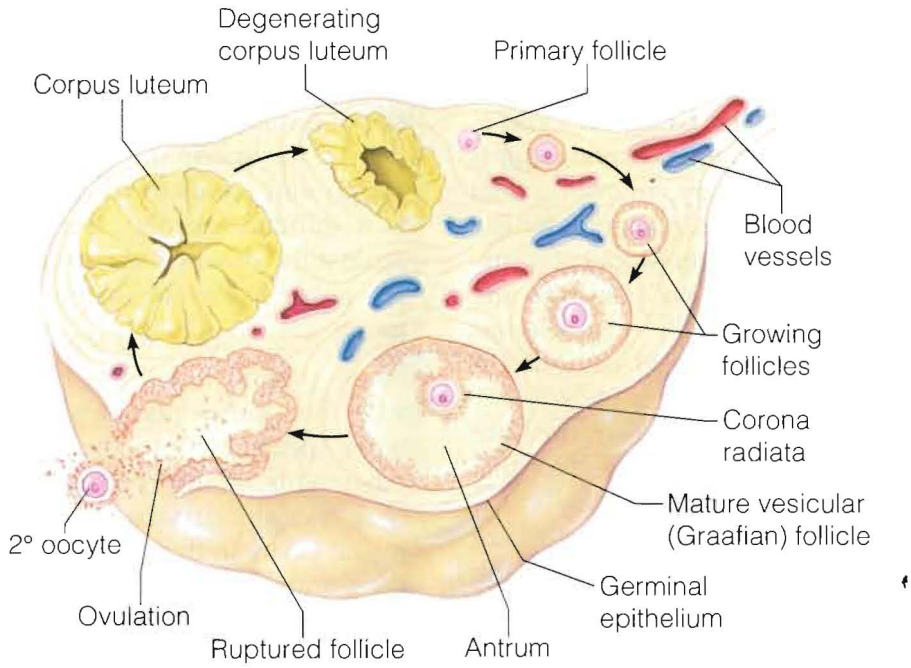


Figure 16.7 **Diagrammatic view of a human ovary.**

appear. **Secondary sex characteristics** typical of males include:

- Deepening of the voice due to enlargement of the larynx
- Increased hair growth all over the body, and particularly in the axillary and pubic regions and the face (the beard)
- Enlargement of skeletal muscles to produce the heavier muscle mass typical of the male physique
- Increased heaviness of the skeleton due to thickening of the bones

Because testosterone is responsible for the appearance of these typical masculine characteristics, it is often referred to as the "masculinizing" hormone.

HOMEOSTATIC IMBALANCE If testosterone is not produced, the secondary sex characteristics never appear in the young man, and his other reproductive organs remain childlike. This is *sexual infantilism*. Castration of the adult male (or the inability of his interstitial cells to produce testosterone) results in a decrease in the size and function of his reproductive organs as well as a decrease in his sex drive. Sterility also occurs because testosterone is necessary for the final stages of sperm production. ▲

Anatomy of the Female Reproductive System

The reproductive role of the female is much more complex than that of the male. Not only must she produce the female gametes (ova), but her body must also nurture and protect a developing fetus during 9 months of pregnancy. **Ovaries** are the primary reproductive organs of a female. Like the testes of a male, ovaries produce both an exocrine product (eggs, or *ova*) and endocrine products (estrogens and progesterone). The other organs of the female reproductive system serve as accessory structures to transport, nurture, or otherwise serve the needs of the reproductive cells and/or the developing fetus.

Ovaries

The paired *ovaries* (o′vah-rēz) are pretty much the size and shape of almonds. An internal view of an ovary reveals many tiny saclike structures called **ovarian follicles** (Figure 16.7). Each follicle consists of an immature egg, called an **oocyte** (o′o-sīt), surrounded by one or more layers of very different cells called **follicle cells.** As a developing

egg within a follicle begins to ripen or mature, the follicle enlarges and develops a fluid-filled central region called an *antrum*. At this stage, the follicle, called a **vesicular,** or **Graafian** (graf'e-an), **follicle,** is mature, and the developing egg is ready to be ejected from the ovary, an event called **ovulation.** After ovulation, the ruptured follicle is transformed into a very different-looking structure called a **corpus luteum** (kor'pus lu'te-um; "yellow body"), which eventually degenerates. Ovulation generally occurs every 28 days, but it can occur more or less frequently in some women. In older women, the surfaces of the ovaries are scarred and pitted, which attests to the fact that many eggs have been released.

The ovaries are secured to the lateral walls of the pelvis by the *suspensory ligaments*. They flank the uterus laterally and anchor to it medially by the *ovarian ligaments* (Figure 16.8). In between, they are enclosed and held in place by a fold of peritoneum, the *broad ligament*.

Duct System

The uterine tubes, uterus, and vagina form the duct system of the female reproductive tract (Figure 16.8).

Uterine (Fallopian) Tubes

The **uterine** (u'ter-in), or **fallopian** (fal-lo'pe-an), **tubes** form the initial part of the duct system. They receive the ovulated oocyte and provide a site where fertilization can occur. Each of the uterine tubes is about 10 cm (4 inches) long and extends medially from an ovary to empty into the superior region of the uterus. Like the ovaries, the uterine tubes are enclosed and supported by the broad ligament. Unlike in the male duct system, which is continuous with the tubule system of the testes, there is little or no actual contact between the uterine tubes and the ovaries. The distal end of each uterine tube expands as the funnel-shaped *infundibulum,* which has fingerlike projections called **fimbriae** (fim'bre-e) that partially surround the ovary. As an oocyte is expelled from an ovary during ovulation, the waving fimbriae create fluid currents that act to carry the oocyte into the uterine tube, where it begins its journey toward the uterus. (Obviously, however, many potential eggs are lost in the peritoneal cavity.) The oocyte is carried toward the uterus by a combination of peristalsis and the rhythmic beating of *cilia*. Because the journey to the uterus takes 3 to 4 days and the oocyte is viable for up to 24 hours after ovulation, the usual site of fertilization is the uterine tube. To reach the oocyte, the sperm must swim upward through the vagina and uterus to reach the uterine tubes. This is a difficult journey. Because they must swim against the downward current created by the cilia, it is rather like swimming against the tide!

HOMEOSTATIC IMBALANCE The fact that the uterine tubes are not continuous distally with the ovaries places women at risk for infections spreading into the peritoneal cavity from other parts of the reproductive tract. *Gonorrhea* (gon"o-re'ah) bacteria sometimes infect the peritoneal cavity in this way, causing an extremely severe inflammation called *pelvic inflammatory disease (PID)*. Unless treated promptly, PID can cause scarring and closure of the narrow uterine tubes, which is one of the major causes of female infertility. ▲

Uterus

The **uterus** (u'ter-us; "womb"), located in the pelvis between the urinary bladder and rectum, is a hollow organ that functions to receive, retain, and nourish a fertilized egg. In a woman who has never been pregnant, it is about the size and shape of a pear. (During pregnancy, the uterus increases tremendously in size to accommodate the growing fetus and can be felt well above the umbilicus during the latter part of pregnancy.) The uterus is suspended in the pelvis by the broad ligament and anchored anteriorly and posteriorly by the *round* and *uterosacral ligaments,* respectively (see Figure 16.8).

The major portion of the uterus is referred to as the **body.** Its superior rounded region above the entrance of the uterine tubes is the **fundus,** and its narrow outlet, which protrudes into the vagina below, is the **cervix.**

The wall of the uterus is thick and composed of three layers. The inner layer or mucosa is the **endometrium** (en-do-me'tre-um). If fertilization occurs, the fertilized egg (actually the young embryo by the time it reaches the uterus) burrows into the endometrium of the uterus (this process is called **implantation**) and resides there for the rest of its development. When a woman is not pregnant, the endometrial lining sloughs off periodically, usually about every 28 days, in response to

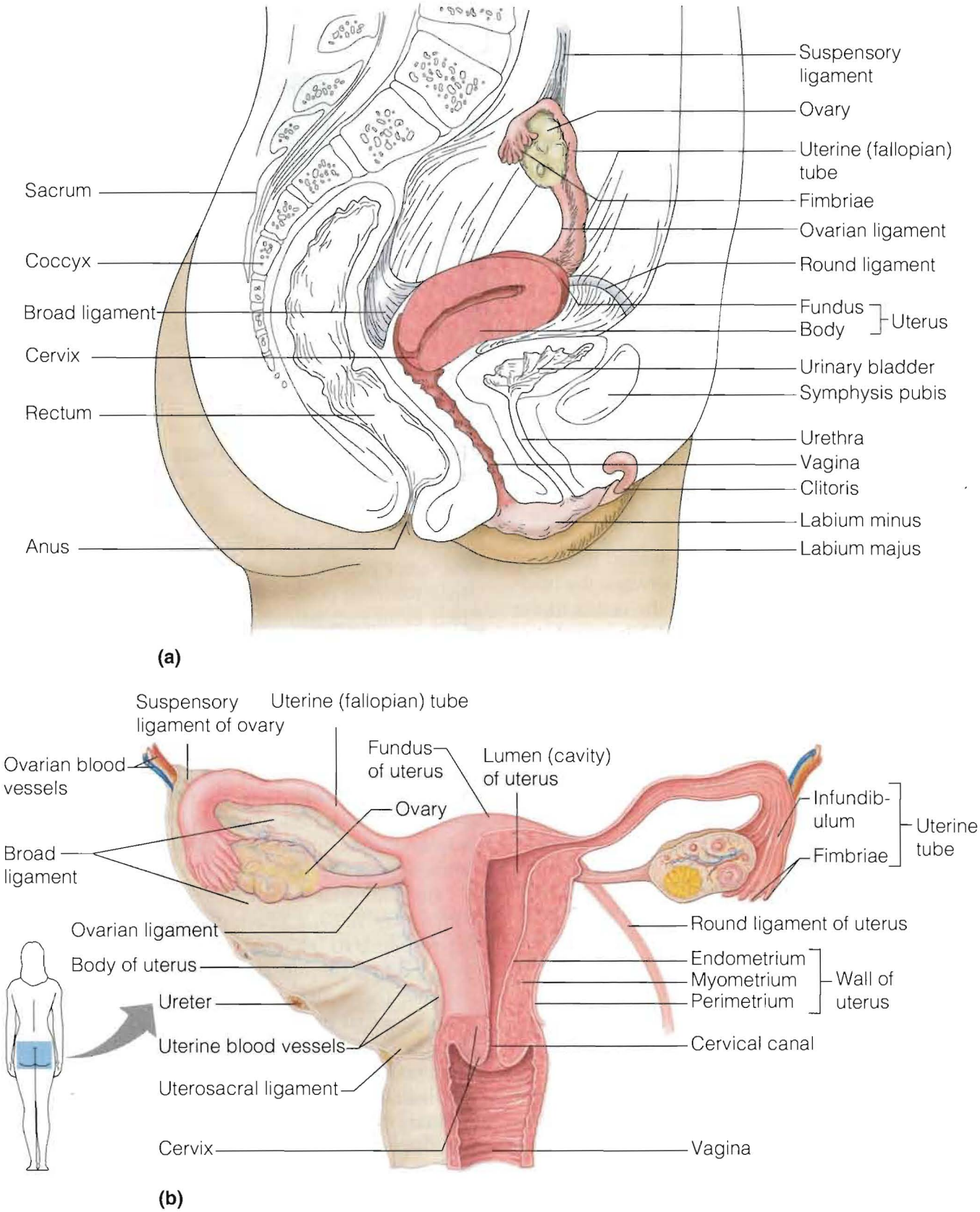


Figure 16.8 **The human female reproductive organs. (a)** Sagittal section. (The plural of *labium minus* and *majus* is *labia minora* and *majora* respectively.) **(b)** Posterior view. The posterior organ walls have been removed on the right side to reveal the shape of the lumen of the uterine tube, uterus, and vagina.

changes in the levels of ovarian hormones in the blood. This process, called *menses,* is discussed on pp. 518–520.

HOMEOSTATIC IMBALANCE Cancer of the cervix is common among women between the ages of 30 and 50. Risk factors include frequent cervical inflammation, sexually transmitted diseases, multiple pregnancies, and an active sex life with many partners. A yearly *Pap smear* is the single most important diagnostic test for detecting this slow-growing cancer. ▲

The **myometrium** (mi-o-me′tre-um) is the bulky middle layer of the uterus (see Figure 16.8b). It is composed of interlacing bundles of smooth muscle. The myometrium plays an active role during the delivery of a baby, when it contracts rhythmically to force the baby out of the mother's body. The outermost serous layer of the uterus is the perimetrium (per-ĭ-me′tre-um), or the visceral peritoneum.

Vagina

The **vagina** (vah-ji′nah) is a thin-walled tube 8 to 10 cm (3 to 4 inches) long. It lies between the bladder and rectum and extends from the cervix to the body exterior. Often called the *birth canal,* the vagina provides a passageway for the delivery of an infant and for the menstrual flow to leave the body. Since it receives the penis (and semen) during sexual intercourse, it is the female organ of copulation.

The distal end of the vagina is partially closed by a thin fold of the mucosa called the **hymen** (hi′men). The hymen is very vascular and tends to bleed when it is ruptured during the first sexual intercourse. However, its durability varies. In some females, it is torn during a sports activity, tampon insertion, or pelvic examination. Occasionally, it is so tough that it must be ruptured surgically if intercourse is to occur.

External Genitalia

The female reproductive structures that are located external to the vagina are the **external genitalia** (Figure 16.9). The external genitalia, also called the **vulva,** include the mons pubis, labia, clitoris, urethral and vaginal orifices, and greater vestibular glands.

The **mons pubis** ("mountain on the pubis") is a fatty, rounded area overlying the pubic symphysis. After puberty, this area is covered with pubic hair. Running posteriorly from the mons pubis are two elongated hair-covered skin folds, the **labia majora** (la′be-ah ma-jo′ra), which enclose two delicate hair-free folds, the **labia minora.** The labia majora enclose a region called the **vestibule,** which contains the external openings of the urethra,* followed posteriorly by that of the vagina. A pair of mucus-producing glands, the **greater vestibular glands,** flank the vagina, one on each side. Their secretion lubricates the distal end of the vagina during intercourse. (These glands are not shown in Figure 16.9.)

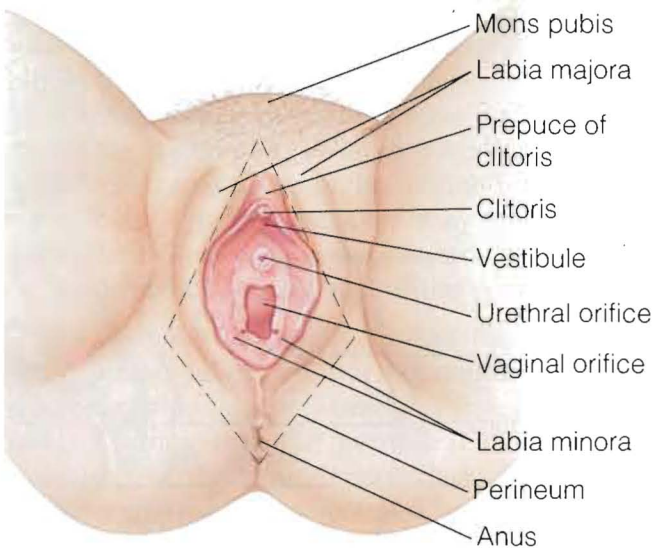


Figure 16.9 External genitalia of the human female.

Just anterior to the vestibule is the **clitoris** (kli′to-ris; "hill"), a small, protruding structure that corresponds to the male penis. Like the penis, it is hooded by a prepuce and is composed of sensitive erectile tissue that becomes swollen with blood during sexual excitement. The clitoris differs from the penis in that it lacks a reproductive duct. The diamond-shaped region between the anterior end of the labial folds, the anus posteriorly, and the ischial tuberosities laterally is the **perineum** (per″ĭ-ne′um).

*The male urethra carries both urine and semen, but the female urethra has no reproductive function; it is strictly a passageway for urine.

Female Reproductive Functions and Cycles

Oogenesis and the Ovarian Cycle

As described earlier, sperm production in males begins at puberty and generally continues throughout life. The situation is quite different in females. The total supply of eggs that a female can release is already determined by the time she is born. In addition, a female's reproductive ability (that is, her ability to release eggs) usually begins during puberty and ends in her 50s or before. The period in which a woman's reproductive capability gradually declines and then finally ends is called *menopause.* (Menopause is described in more detail on p. 532.)

Meiosis, the special kind of cell division that occurs in the male testes to produce sperm, also occurs in the female ovaries. But in this case, female gametes, or sex cells, are produced, and the process is called **oogenesis** (o″o-jen′ĕ-sis; "the beginning of an egg"). This process is shown in Figure 16.10 and described in more detail next.

In the developing female fetus, **oogonia** (o″o-go′ne-ah), the female stem cells, multiply rapidly to increase their number, and then their daughter cells, **primary oocytes,** push into the ovary connective tissue, where they become surrounded by a single layer of cells to form the primary follicles. By birth, the oogonia no longer exist, and a female's lifetime supply of primary oocytes (approximately 2 million of them) is already in place in the ovarian follicles, awaiting the chance to undergo meiosis to produce functional eggs. Since the primary oocytes remain in this state of suspended animation all through childhood, their wait is a long one—10 to 14 years at the very least.

At puberty, the anterior pituitary gland begins to release *follicle-stimulating hormone (FSH),* which stimulates a small number of primary follicles to grow and mature each month, and ovulation begins to occur each month. These cyclic changes that occur monthly in the ovary constitute the **ovarian cycle.** At puberty, perhaps 400,000 oocytes remain and beginning at this time a small number of oocytes are activated each month. Since the reproductive life of a female is at best about 40 years (from the age of 11 to approximately 51) and there is typically only one ovulation per month, fewer than 500 ova out of her potential of 400,000 are released during a woman's lifetime. Again, nature has provided us with a generous oversupply of sex cells.

As a follicle prodded by FSH grows larger, it accumulates fluid in the central chamber called the *antrum,* and the primary oocyte it contains begins meiosis and undergoes the first meiotic division to produce two cells that are very dissimilar in size (see Figure 16.10). The larger cell is a **secondary oocyte** and the other, very tiny cell is a **polar body.** By the time a follicle has ripened to the mature (vesicular follicle) stage, it contains a secondary oocyte and protrudes like an angry boil from the external surface of the ovary. Follicle development to this stage takes about 14 days, and ovulation (of a secondary oocyte) occurs at just about that time in response to the burstlike release of a second anterior pituitary hormone, *luteinizing hormone (LH).* As shown in Figures 16.10 and 16.11, the ovulated secondary oocyte is still surrounded by its follicle-cell capsule, now called the *corona radiata* ("radiating crown"). Some women experience a twinge of abdominal pain in the lower abdomen when ovulation occurs. This phenomenon, called *mittelschmerz* (mit′el-shmārts; German for "middle pain"), is caused by the intense stretching of the ovarian wall during ovulation.

Generally speaking, one of the developing follicles outstrips the others each month to become the dominant follicle. Just how this follicle is selected or selects itself is not understood, but the follicle that is at the proper stage of maturity when the LH stimulus occurs will rupture and release its oocyte into the peritoneal cavity. The mature follicles that are not ovulated soon become overripe and deteriorate. In addition to triggering ovulation, LH also causes the ruptured follicle to change into a very different glandular structure, the *corpus luteum.* (Both the maturing follicles and the corpus luteum produce hormones, as will be described later.)

If the ovulated secondary oocyte is penetrated by a sperm, its nucleus undergoes the second meiotic division that produces another polar body and the **ovum nucleus.** Once the ovum nucleus has been formed, its 23 chromosomes are combined

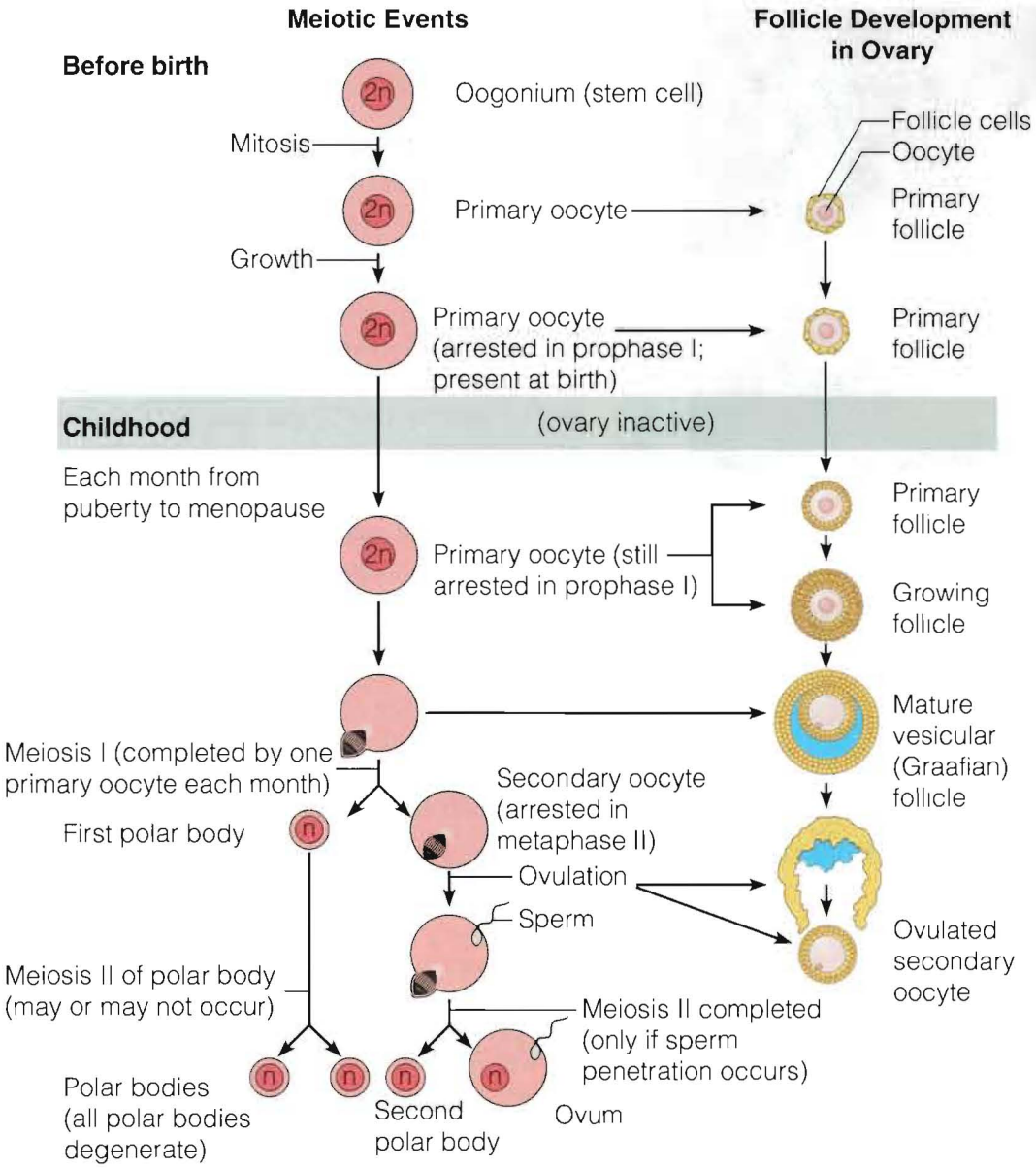


Figure 16.10 **Events of oogenesis.** Left, flowchart of meiotic events. Right, correlation with follicle development and ovulation in the ovary.

with those of the sperm to form the fertilized egg, which is the first cell of the yet-to-be offspring. However, if the secondary oocyte is not penetrated by a sperm, it simply deteriorates without ever completing meiosis to form a functional egg. Although meiosis in males results in four functional sperm, meiosis in females yields only one functional ovum and three tiny polar bodies. Since the polar bodies have essentially no cy deteriorate and die quickly.

Another major difference betwe females concerns the size and structu cells. Sperm are tiny and equipped locomotion. They have little nutri cytoplasm; thus, the nutrients in ser vital to their survival. In contrast, the

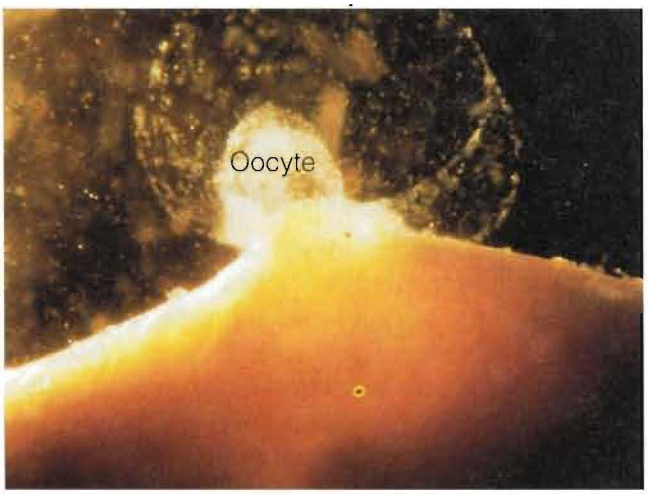


Figure 16.11 Ovulation. A secondary oocyte is released from a follicle at the surface of the ovary. The orange mass below the ejected oocyte is part of the ovary. The "halo" of follicle cells around the secondary oocyte is the *corona radiata*.

nonmotile cell, well stocked with nutrient reserves that nourish the developing embryo until it can take up residence in the uterus.

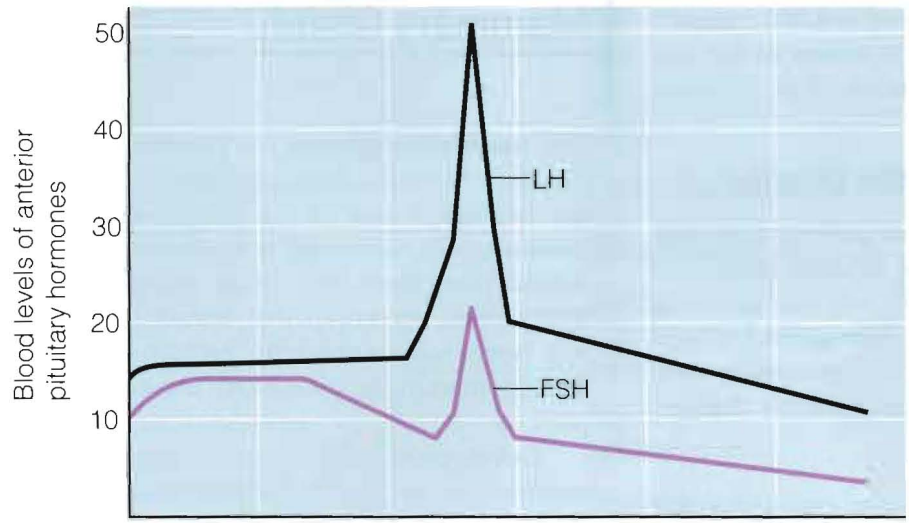
Menstrual Cycle

Although the uterus is the receptacle in which the young embryo implants and develops, it is receptive to implantation only for a very short period each month. Not surprisingly, this brief interval coincides exactly with the time when a fertilized egg would begin to implant, approximately 7 days after ovulation. The events of the **menstrual, uterine, cycle** are the cyclic changes that the endometrium, or mucosa of the uterus, goes through month after month as it responds to changes in the levels of ovarian hormones in the blood.

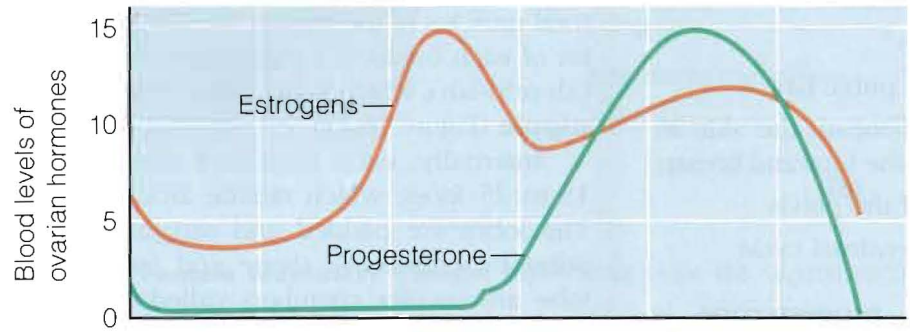
Since the cyclic production of estrogens and progesterone by the ovaries is, in turn, regulated by the anterior pituitary gonadotropic hormones, FSH and LH, it is important to understand how these "hormonal pieces" fit together. Generally speaking, both female cycles are about 28 days long (a period commonly called a *lunar month*), with ovulation typically occurring midway in the cycles, on or about day 14. Figure 16.12 illustrates the events occurring both in the ovary (the ovarian cycle) and in the uterus (menstrual cycle) at the same time. The three stages of the menstrual cycle are described next.

- **Days 1–5: Menses.** During this interval, the *functional layer* of the thick endometrial lining of the uterus is sloughing off, or becoming detached, from the uterine wall. This is accompanied by bleeding for 3 to 5 days. The detached tissues and blood pass through the vagina as the menstrual flow. The average blood loss during this period is 50 to 150 ml (or about ¼ to ½ cup). By day 5, growing ovarian follicles are beginning to produce more estrogen.
- **Days 6–14: Proliferative stage.** Stimulated by rising estrogen levels produced by the growing follicles of the ovaries, the basal layer of the endometrium regenerates the functional layer, glands are formed in it, and the endometrial blood supply is increased. The endometrium once again becomes velvety, thick, and well vascularized. (Ovulation occurs in the ovary at the end of this stage, in response to the sudden surge of LH in the blood.)
- **Days 15–28: Secretory stage.** Rising levels of progesterone production by the corpus luteum of the ovary act on the estrogen-primed endometrium and increase its blood supply even more. Progesterone also causes the endometrial glands to increase in size and to begin secreting nutrients into the uterine cavity. These nutrients will sustain a developing embryo (if one is present) until it has implanted. If fertilization does occur, the embryo produces a hormone very similar to LH, which causes the corpus luteum to continue producing its hormones. If fertilization does not occur, the corpus luteum begins to degenerate toward the end of this period as LH blood levels decline. Lack of ovarian hormones in the blood causes the blood vessels supplying the functional layer of the endometrium to go into spasms and kink. When deprived of oxygen and nutrients, those endometrial cells begin to die, which sets the stage for menses to begin again on day 28.

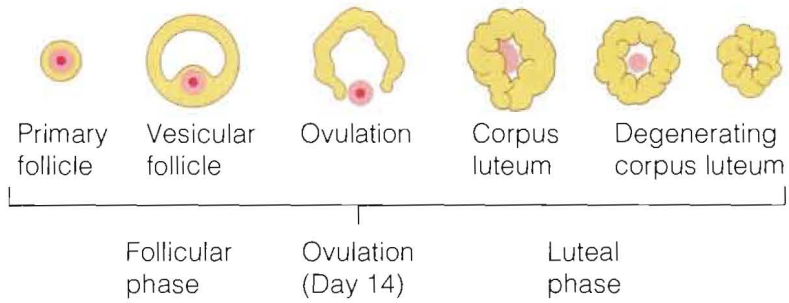
Although this explanation assumes a classic 28-day cycle, the length of the menstrual cycle is quite variable. It can be as short as 21 days or as



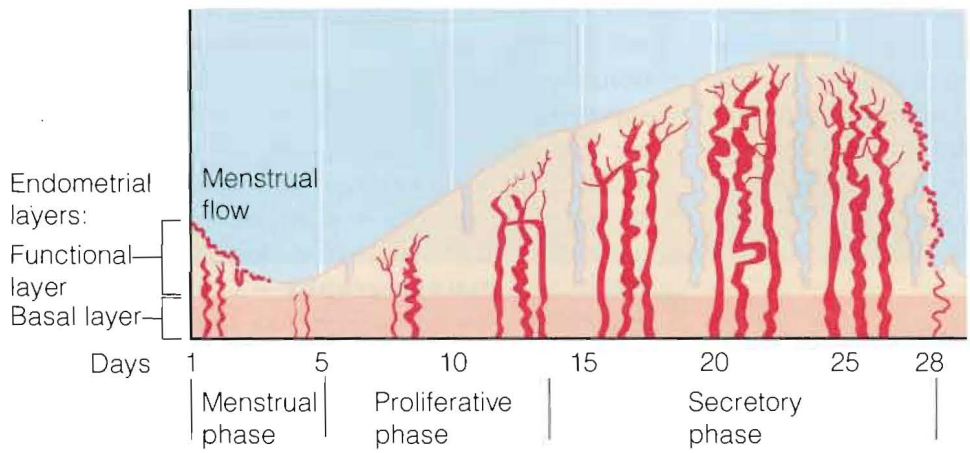
(a) Fluctuation of gonadotropin levels



(b) Fluctuation of ovarian hormone levels



(c) Ovarian cycle



(d) Uterine cycle

Figure 16.12 Hormonal interactions of the female cycles. Relative levels of anterior pituitary gonadotropins correlated with hormonal and follicular changes of the ovary and with the menstrual cycle.

long as 40 days. Only one interval is fairly constant in all females; the time from ovulation to the beginning of menses is almost always 14 or 15 days.

Hormone Production by the Ovaries

As the ovaries become active at puberty and start to produce ova, production of ovarian hormones also begins. The follicle cells of the growing and mature follicles produce **estrogens,*** which cause the appearance of the *secondary sex characteristics* in the young woman. Such changes include

- Enlargement of the accessory organs of the female reproductive system (uterine tubes, uterus, vagina, external genitals)
- Development of the breasts
- Appearance of axillary and pubic hair
- Increased deposits of fat beneath the skin in general, and particularly in the hips and breasts
- Widening and lightening of the pelvis
- Onset of menses, or the menstrual cycle

The second ovarian hormone, **progesterone,** is produced by a special glandular structure of the ovaries, the *corpus luteum* (see Figure 16.7). As mentioned earlier, after ovulation occurs the ruptured follicle is converted to the corpus luteum, which looks and acts completely different from the growing and mature follicle. Once formed, the corpus luteum produces progesterone (and some estrogen) as long as LH is still present in the blood. Generally speaking, the corpus luteum has stopped producing hormones by 10 to 14 days after ovulation. Except for working with estrogen to establish the menstrual cycle, progesterone does not contribute to the appearance of the secondary sex characteristics. Its other major effects are exerted during pregnancy, when it helps maintain the pregnancy and prepare the breasts for milk production. (However, the source of progesterone during pregnancy is the placenta, not the ovaries.)

*Although the ovaries produce several different estrogens, the most important are *estradiol, estrone,* and *estriol.* Of these, estradiol is the most abundant and is most responsible for mediating estrogenic effects.

Mammary Glands

The **mammary glands** are present in both sexes, but they normally function only in females. Since the biological role of the mammary glands is to produce milk to nourish a newborn baby, they are actually important only when reproduction has already been accomplished. Stimulation by female sex hormones, especially estrogens, causes the female mammary glands to increase in size at puberty.

Developmentally, the mammary glands are modified *sweat glands* that are actually part of the skin. Each mammary gland is contained within a rounded skin-covered breast anterior to the pectoral muscles of the thorax. Slightly below the center of each breast is a pigmented area, the **areola** (ah-re′o-lah), which surrounds a central protruding **nipple** (Figure 16.13).

Internally, each mammary gland consists of 15 to 25 *lobes,* which radiate around the nipple. The lobes are padded and separated from each other by connective tissue and fat. Within each lobe are smaller chambers called *lobules,* which contain clusters of **alveolar glands** that produce the milk when a woman is *lactating* (producing milk). The alveolar glands of each lobule pass the milk into the **lactiferous** (lak-tif′er-us) **ducts,** which open to the outside at the nipple.

HOMEOSTATIC IMBALANCE Cancer of the breast is a leading cause of death in American women. One woman in eight will develop this condition. Breast cancer is often signaled by a change in skin texture, puckering, or leakage from the nipple. Early detection by breast self-examination and mammography is unquestionably the best way to increase one's chances of surviving breast cancer. Since most breast lumps are discovered by women themselves in routine monthly breast exams, this simple examination should be a priority in every woman's life. Currently the American Cancer Society recommends scheduling **mammography**—X-ray examination that detects breast cancers too small to feel (less than 1 cm)—every 2 years for women between 40 and 49 years old and yearly thereafter (Figure 16.14). ▲

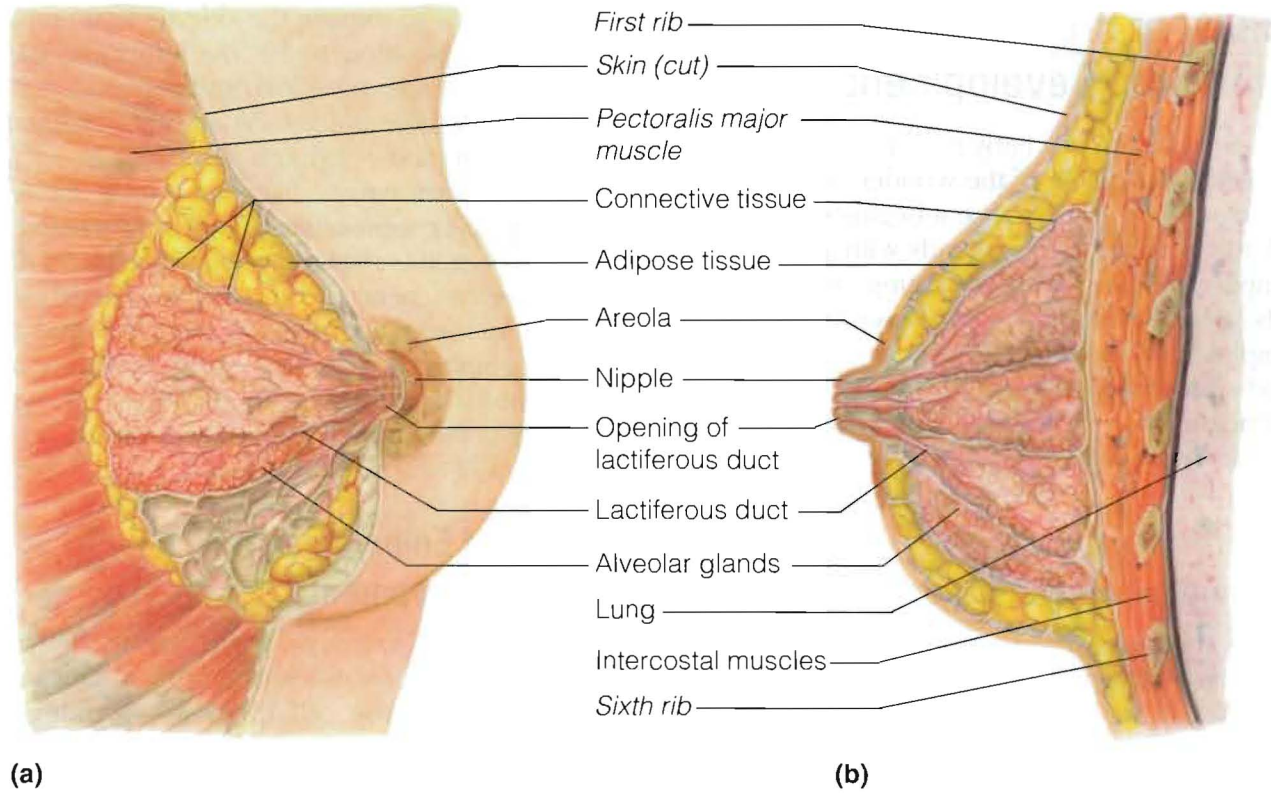


Figure 16.13 **Female mammary glands. (a)** Anterior view. **(b)** Sagittal section.

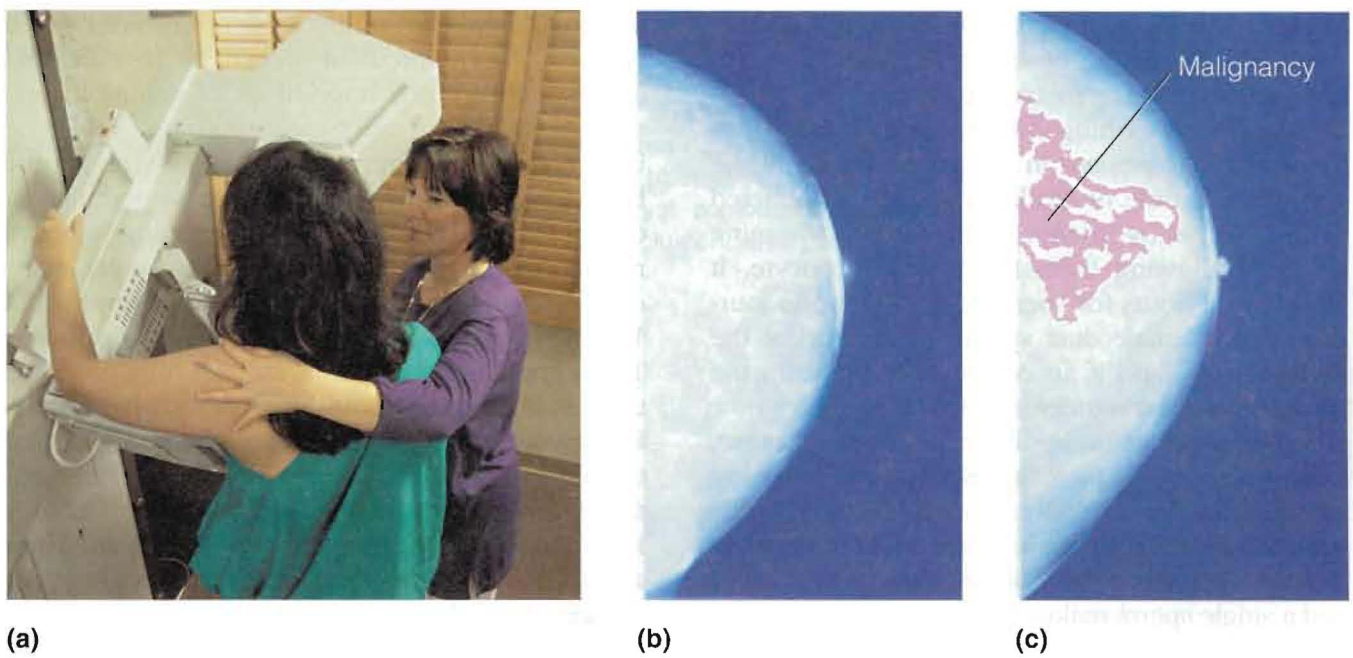


Figure 16.14 **Mammograms. (a)** Photograph of woman undergoing mammography. **(b)** Normal breast. **(c)** Breast with tumor.