Reproductive Systems

TREATING ERECTILE DYSFUNCTION. Erectile dysfunction (impotence), in which the penis cannot become erect or sustain an erection, was until recently not often talked about. Then, in the spring of 1998, Viagra® (sildenafil) became available, a drug that enables about half of all men who take it to produce and maintain erections. The drug was originally developed to treat chest pain. Its effects on the penis were noted when participants in the clinical trials reported improved sex lives and refused to return extra pills! In most cases, Viagra appears to be safe and effective for men.

Viagra works by interfering with certain signals to the penis. The process of erection depends upon a very small molecule, nitric oxide (NO). The penis consists of two chambers of spongy tissue that surround blood vessels. When the vessels fill with blood, as they do following sexual stimulation, the organ engorges and stiffens. The stimulation causes neurons as well as the endothelial cells that line the interiors of the blood vessels to release NO. The NO then enters the muscle cells that form the middle layers of the blood vessels, relaxing them by activating a series of other chemicals. The vessels dilate and fill with blood, and the penis becomes erect. One of the chemicals, cGMP, must be present for awhile for an erection to persist. Viagra blocks the enzyme that normally breaks down cGMP, thereby sustaining the erection.

Photo:
Even with normal penile function, having too many abnormally shaped sperm cells can impair a man's fertility.

e. Hydrolysis of phosphoproteins and nucleic acids produces phosphoric acid.

2. Strengths of acids and bases
   a. Acids vary in ionization extent.
      (1) Strong acids, such as hydrochloric acid, ionize more completely.
      (2) Weak acids, such as carbonic acid, ionize less completely.
   b. Bases vary in strength also.
3. Regulation of hydrogen ion concentration
   a. Acid-base buffer systems
      (1) Buffer systems convert strong acids into weaker acids or strong bases into weaker bases.
      (2) They include the bicarbonate buffer system, phosphate buffer system, and protein buffer system.
      (3) Buffer systems minimize pH changes.
   b. The respiratory center controls the rate and depth of breathing to regulate pH.
   c. Kidney nephrons secrete hydrogen ions to regulate pH.
   d. Chemical buffers act more rapidly. Physiological buffers act less rapidly.

18.6 Acid-Base Imbalances (p. 491)

1. Acidosis
   a. Respiratory acidosis results from increases in concentration of carbon dioxide and carbonic acid.
   b. Metabolic acidosis results from accumulation of other acids or loss of bases.
2. Alkalosis
   a. Respiratory alkalosis results from loss of carbon dioxide and carbonic acid.
   b. Metabolic alkalosis results from loss of hydrogen ions or gain of bases.

REVIEW EXERCISES

1. Explain how water balance and electrolyte balance are interdependent. (p. 482)
2. Name the body fluid compartments, and describe their locations. (p. 482)
3. Explain how extracellular and intracellular fluids differ in composition. (p. 482)
4. Describe the control of fluid movements between body fluid compartments. (p. 483)
5. Prepare a list of sources of normal water gain and loss to illustrate how water intake equals water output. (p. 484)
6. Define *water of metabolism.* (p. 484)
7. Explain how water intake is regulated. (p. 484)
8. Explain how nephrons regulate water output. (p. 486)
9. List the most important electrolytes in body fluids. (p. 487)
10. Explain how electrolyte intake is regulated. (p. 487)
11. List the routes by which electrolytes leave the body. (p. 487)
12. Explain how the adrenal cortex regulates electrolyte output. (p. 487)
13. Describe the role of the parathyroid glands in regulating electrolyte balance. (p. 487)
14. Distinguish between an acid and a base. (p. 488)
15. List five sources of hydrogen ions in body fluids, and name an acid that originates from each source. (p. 489)
16. Distinguish between a strong acid and a weak acid, and name an example of each. (p. 489)
17. Distinguish between a strong base and a weak base, and name an example of each. (p. 489)
18. Explain how an acid-base buffer system functions. (p. 489)
19. Describe how the bicarbonate buffer system resists changes in pH. (p. 489)
20. Explain why a protein has acidic as well as basic properties. (p. 490)
21. Explain how the respiratory center functions in the regulation of the acid-base balance. (p. 490)
22. Explain how the kidneys function in the regulation of the acid-base balance. (p. 491)
23. Distinguish between a chemical buffer system and a physiological buffer system. (p. 491)
24. Distinguish between respiratory and metabolic acid-base disturbances. (p. 492)
25. Describe how the body compensates for acid-base disturbances. (p. 492)

CRITICAL THINKING

1. After eating an undercooked hamburger, a twenty-five-year-old male developed diarrhea due to infection with a strain of *Escherichia coli* that produces a shigatoxin. How would this affect his blood pH, urine pH, and respiratory rate?
2. A student hyperventilates and is disoriented just before an exam. Is this student likely to be experiencing acidosis or alkalosis? How will the body compensate in an effort to maintain homeostasis?
3. A ten-year-old female is rescued from a swimming pool after several minutes of floundering in the water. What is (are) the cause(s) of the girl's acidosis? What treatment(s) will bring the body back to homeostasis?
4. A thirty-eight-year-old woman contracted *Mycoplasma* pneumonia and ran a temperature of 104°F for five days. Even though the woman drank copious amounts of liquid, her blood pressure dropped to 70/50, indicating dehydration. Should the woman receive intravenous hypertonic glucose or normal saline? Why?
5. Some time ago, several newborn infants died due to an error in which sodium chloride was substituted for sugar in their formula. What symptoms would this produce? Why are infants more prone to the hazard of excess salt intake than adults?
6. An elderly, semiconscious patient is tentatively diagnosed as having acidosis. What components of the arterial blood will be most valuable in determining if the acidosis is of respiratory origin?
7. Radiation therapy may damage the mucosa of the stomach and intestines. What effect might this have on the patient's electrolyte balance?
8. If the right ventricle of a patient's heart is failing so that venous pressure is increased, what changes might occur in the patient's extracellular fluid compartments?

WEB CONNECTIONS

Visit the website for additional study questions and more information about this chapter at:

http://www.mhhe.com/shieress8

Chapter Objectives

After studying this chapter, you should be able to do the following:

19.1 Introduction

1. State the general functions of the male and female reproductive systems. (p. 498)

19.2 Organs of the Male Reproductive System

2. Name the parts of the male reproductive system, and describe the general functions of each part. (p. 498)
3. Outline the process of spermatogenesis. (p. 500)
4. Trace the path of sperm cells from their site of formation to the outside. (p. 500)

19.3 Hormonal Control of Male Reproductive Functions

5. Explain how hormones control the activities of male reproductive organs and the development of male secondary sex characteristics. (p. 505)

19.4 Organs of the Female Reproductive System

6. Name the parts of the female reproductive system, and describe the general functions of each part. (p. 507)
7. Outline the process of oogenesis. (p. 508)

19.5 Hormonal Control of Female Reproductive Functions

8. Describe how hormones control the activities of female reproductive organs and the development of female secondary sex characteristics. (p. 513)
9. Describe the major events that occur during a menstrual cycle. (p. 513)

19.6 Mammary Glands

10. Review the structure of the mammary glands. (p. 515)

19.7 Birth Control

11. List several methods of birth control, and describe the relative effectiveness of each method. (p. 516)

19.8 Sexually Transmitted Diseases

12. List the general symptoms of sexually transmitted diseases. (p. 520)

Aids to Understanding Words

andr- [man] *andr*ogens: Male sex hormones.
ejacul- [to shoot forth] *ejacul*ation: Process of expelling semen from the male reproductive tract.
fimb- [fringe] *fimb*riae: Irregular extensions on the margin of the infundibulum of the uterine tube.
follic- [small bag] *follic*le: Ovarian structure that contains an egg.
genesis- [origin] spermato*genesis*: Process by which sperm cells are formed.
germ- [to bud or sprout] *germ*inal epithelium: Tissue that gives rise to sex cells by special cell division.
labi- [lip] *labi*a minora: Flattened, longitudinal folds that extend along the margins of the female vestibule.
mens- [month] *mens*trual cycle: Monthly female reproductive cycle.
mons- [an eminence] *mons* pubis: Rounded elevation overlying the pubic symphysis in a female.
puber- [adult] *puber*ty: Time when a person becomes able to reproduce.

Key Terms

androgen (an´dro-jen)
contraception (kon´´trah-sep´shun)
ejaculation (e-jak´´u-la´shun)
emission (e-mish´un)
estrogen (es´tro-jen)
gonadotropin (go-nad´´o-trōp´in)
meiosis (mi-o´sis)
menopause (men´o-pawz)
menstrual cycle (men´stroo-al si´kl)
oogenesis (ō´´o-jen´ĕ-sis)
orgasm (or´gazm)
ovulation (o´´vu-la´shun)
primary follicle (pri´ma-re fol´ĭ-kl)
progesterone (pro-jes´tĕ-rōn)
puberty (pu´ber-te)
semen (se´men)
spermatogenesis (sper´´mah-to-jen´ĕ-sis)
testosterone (tes-tos´tĕ-rōn)
zygote (zi´gōt)

19.1 Introduction

The male and female reproductive systems are a connected series of organs and glands that produce and nurture sex cells and transport them to sites of fertilization. Sex cells have one set of genetic instructions, compared to two in other cells, so that when sex cells join at fertilization, the right amount of genetic information, held in 46 chromosomes, is restored. Some of the reproductive organs secrete hormones vital in the development and maintenance of secondary sex characteristics and the regulation of reproductive physiology.

19.2 Organs of the Male Reproductive System

Organs of the male reproductive system produce and maintain male sex cells, or *sperm cells;* transport these cells and supporting fluids to the outside; and secrete male sex hormones. A male's *primary sex organs* (gonads) are the two testes in which sperm cells and male sex hormones form. The *accessory sex organs* of the male reproductive system are the internal and external reproductive organs (fig. 19.1; reference plates 3 and 4, pp. 24–25).

Testes

The **testes** (singular, *testis*) are ovoid structures about 5 centimeters in length and 3 centimeters in diameter. Both testes are within the cavity of the saclike *scrotum.*

Structure of the Testes

A tough, white, fibrous capsule encloses each testis. Along the capsule's posterior border, the connective tissue thickens and extends into the testis, forming thin septa that subdivide the testis into about 250 *lobules.*

Each lobule contains one to four highly coiled, convoluted **seminiferous tubules,** each approximately 70 centimeters long uncoiled. These tubules course posteriorly and unite to form a complex network of channels. These channels give rise to several ducts that join a tube called the *epididymis.* The epididymis coils on the outer

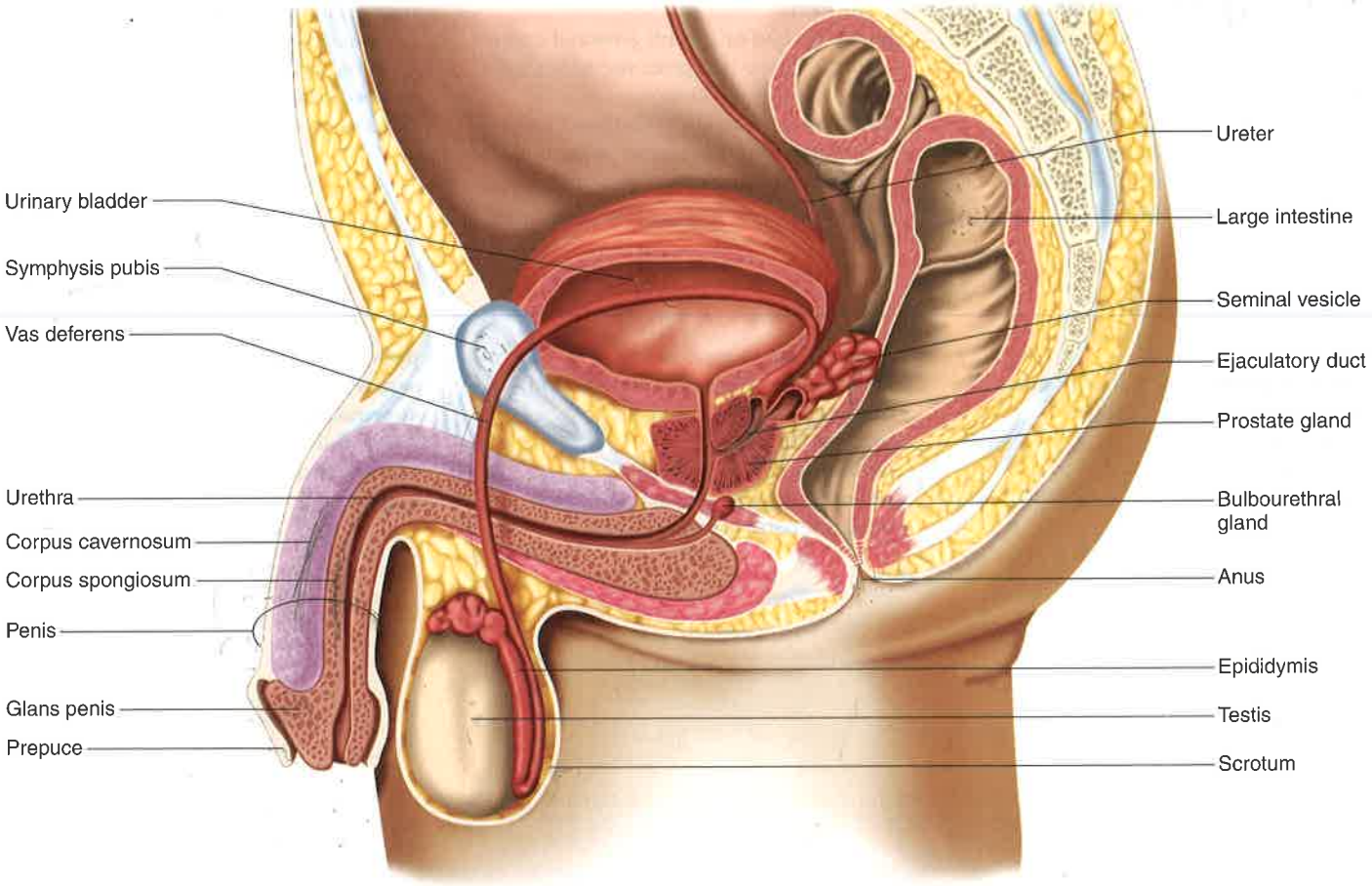


Figure 19.1
Male reproductive organs (sagittal view). The paired testes are the primary sex organs, and the other structures, both internal and external, are accessory sex organs.

surface of the testis and continues to become the *vas deferens* (fig. 19.2*A*).

A specialized stratified epithelium with **spermatogenic cells,** which give rise to sperm cells, lines the seminiferous tubules. Other specialized cells, called **interstitial cells** (cells of Leydig), lie in the spaces between the seminiferous tubules (fig. 19.2*B, C*). Interstitial cells produce and secrete male sex hormones.

The epithelial cells of the seminiferous tubules can give rise to *testicular cancer,* a common cancer in young men. In most cases, the first sign is a painless testis enlargement or a scrotal mass that attaches to a testis.

If a biopsy (tissue sample) reveals cancer cells, surgery can remove the affected testis (orchiectomy). Radiation and/or chemotherapy often prevent(s) the cancer from recurring.

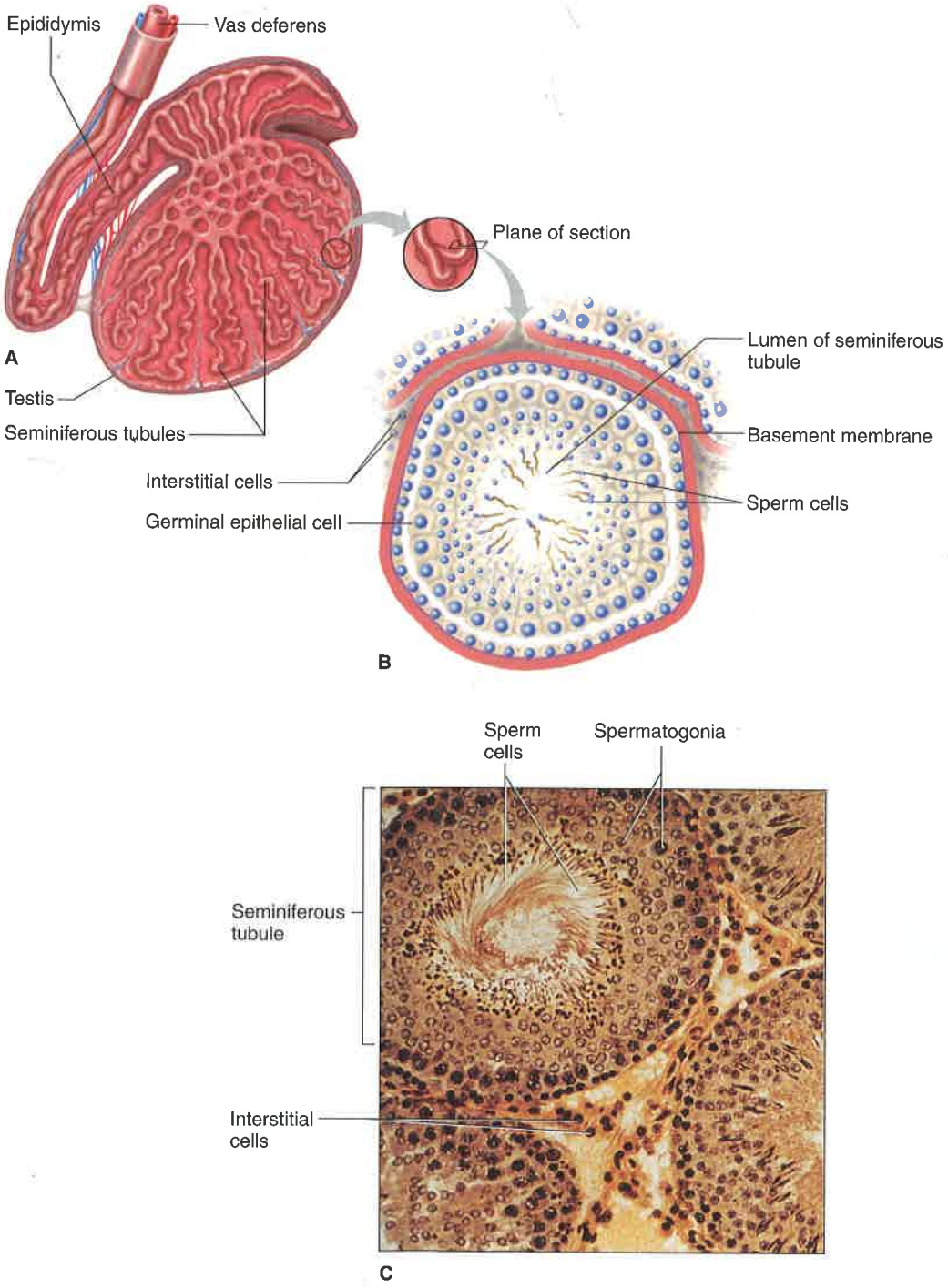


Figure 19.2
Structure of the testis. (*A*) Sagittal section of a testis. (*B*) Cross section of a seminiferous tubule. (*C*) Light micrograph of a seminiferous tubule (200×).

CHECK YOUR RECALL

1. Describe the structure of a testis.
2. Where are the sperm cells produced within the testes?
3. Which cells produce male sex hormones?

Formation of Sperm Cells

The epithelium of the seminiferous tubules consists of supporting cells and spermatogenic cells. Supporting cells provide a scaffolding for the spermatogenic cells, and also nourish and regulate them.

Males produce sperm cells continually throughout their reproductive lives. Sperm cells collect in the lumen of each seminiferous tubule, then pass to the epididymis, where they accumulate and mature.

A mature sperm cell is a tiny, tadpole-shaped structure about 0.06 millimeters long. It consists of a flattened head, a cylindrical midpiece (body), and an elongated tail (fig. 19.3; see fig. 3.9*B*, p. 57).

The oval *head* of a sperm cell is composed primarily of a nucleus and contains highly compacted chromatin consisting of 23 chromosomes. A small protrusion at its anterior end, called the *acrosome,* contains enzymes that help the sperm cell penetrate an egg cell during fertilization. (Chapter 20, p. 528, describes this process.)

The *midpiece* of a sperm cell has a central, filamentous core and many mitochondria in a spiral. The *tail* (flagellum) consists of several microtubules enclosed in an extension of the cell membrane. The mitochondria provide ATP for the tail's lashing movement, which propels the sperm cell through fluid.

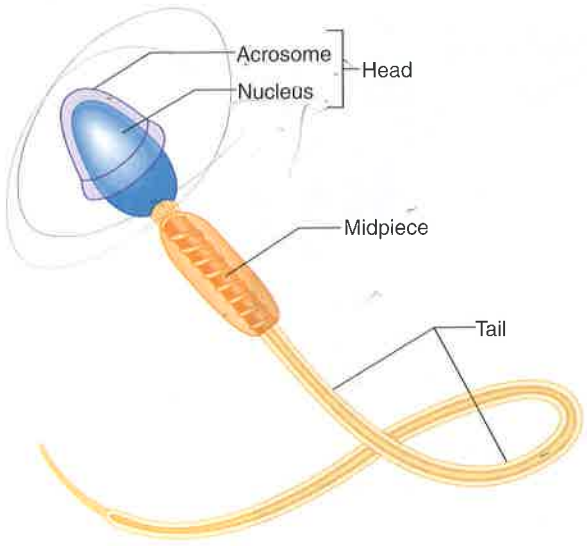


Figure 19.3
Parts of a mature sperm cell.

Spermatogenesis

Sperm cells form in a process called **spermatogenesis** (sper´´mah-to-jen´ĕ-sis). In the male embryo, spermatogenic cells are undifferentiated and are called *spermatogonia* (fig. 19.4). Each spermatogonium contains 46 chromosomes in its nucleus, the usual number for human cells. Beginning during embryonic development, hormones stimulate spermatogonia to undergo mitosis (see chapter 3, p. 65), and some of them enlarge to become *primary spermatocytes. Supporting cells* help sustain the developing sperm cells.

At puberty, the primary spermatocytes then reproduce by a special type of cell division called **meiosis** (mi-o´sis). Each primary spermatocyte divides to form two *secondary spermatocytes*. Each of these cells, in turn, divides to form two *spermatids,* which mature into sperm cells. Meiosis also reduces the number of chromosomes in each cell by one-half. Consequently, for each primary spermatocyte that undergoes meiosis, four sperm cells, with 23 chromosomes in each of their nuclei, form. Figure 19.5 depicts spermatogenesis.

CHECK YOUR RECALL

1. Explain the function of supporting cells in the seminiferous tubules.
2. Describe the structure of a sperm cell.
3. Review the events of spermatogenesis.

Male Internal Accessory Organs

The internal accessory organs of the male reproductive system are specialized to nurture and transport sperm cells. These structures include the epididymides, vasa deferentia, ejaculatory ducts, and urethra, as well as the seminal vesicles, prostate gland, and bulbourethral glands.

Epididymis

Each **epididymis** (ep´´ĭ-did´ĭ-mis; plural, *epididymides*) is a tightly coiled, threadlike tube about 6 meters long (see figs. 19.1 and 19.2). The epididymis is connected to ducts within a testis. It emerges from the top of the testis, descends along the posterior surface of the testis, and then courses upward to become the vas deferens.

Immature sperm cells reaching the epididymis are nonmotile. However, as rhythmic peristaltic contractions help move these cells through the epididymis, they mature. Following this aging process, sperm cells have the potential to move independently and fertilize egg cells. But they usually do not "swim" until after ejaculation.

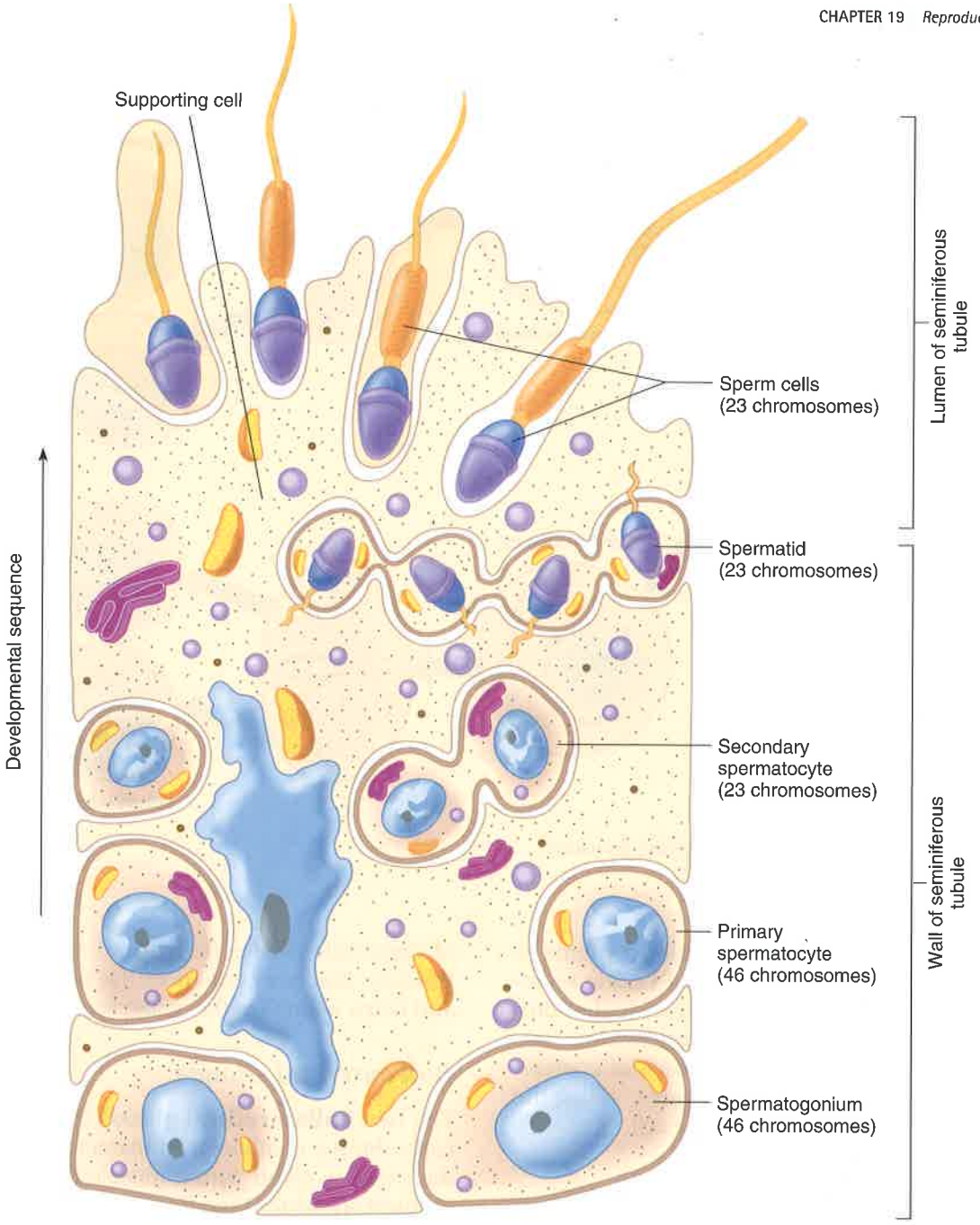


Figure 19.4
Spermatogonia give rise to primary spermatocytes by mitosis. The spermatocytes, in turn, give rise to sperm cells by meiosis. Note that as the cells approach the lumen, they mature.

Vas Deferens

Each **vas deferens** (vas def´er-enz; plural, *vasa deferentia*), also called a ductus deferens, is a muscular tube about 45 centimeters long (see fig. 19.1). It passes upward along the medial side of a testis and through a passage in the lower abdominal wall (inguinal canal), enters the abdominal cavity, and ends behind the urinary bladder. Just outside the prostate gland, the vas deferens unites with the duct of a seminal vesicle to form an **ejaculatory duct,** which passes through the prostate gland and empties into the urethra.

Seminal Vesicle

A **seminal vesicle** is a convoluted, saclike structure about 5 centimeters long that is attached to the vas deferens near the base of the urinary bladder (see fig. 19.1). The glandular tissue lining the inner wall of a seminal vesicle secretes a slightly alkaline fluid. This

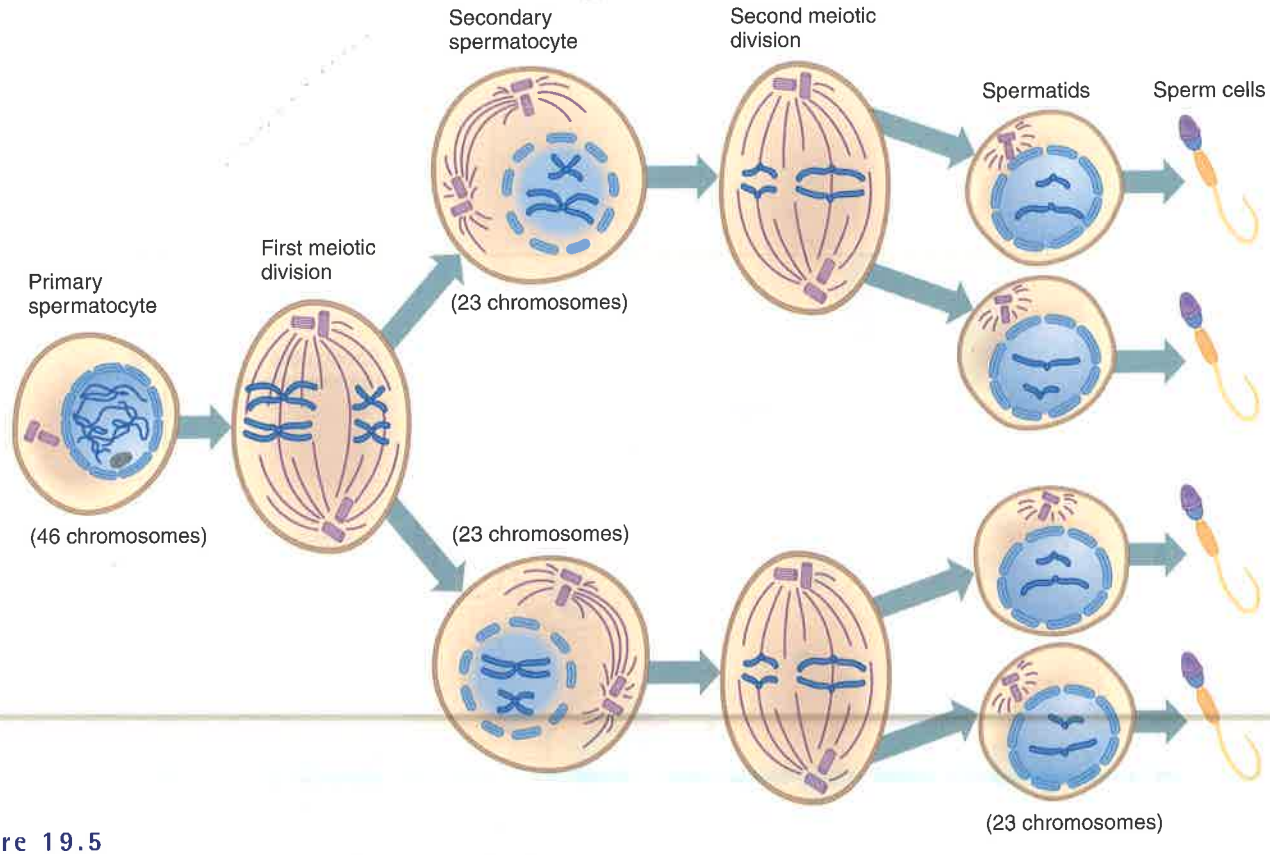


Figure 19.5
Spermatogenesis involves two successive meiotic divisions.

fluid helps regulate the pH of the tubular contents as sperm cells travel to the outside. Seminal vesicle secretions also contain *fructose,* a monosaccharide that provides energy to sperm cells, and *prostaglandins* (see chapter 11, p. 284), which stimulate muscular contractions within the female reproductive organs, aiding the movement of sperm cells toward the egg cell.

CHECK YOUR RECALL

1. Describe the structure of the epididymis.
2. Trace the path of the vas deferens.
3. What is the function of a seminal vesicle?

Prostate Gland

The **prostate gland** is a chestnut-shaped structure about 4 centimeters across and 3 centimeters thick that surrounds the proximal portion of the urethra, just inferior to the urinary bladder (see fig. 19.1). It is enclosed in connective tissue and composed of many branched tubular glands, whose ducts open into the urethra.

The prostate gland secretes a thin, milky fluid with an alkaline pH. This secretion neutralizes the fluid containing sperm cells, which is acidic due to the presence of metabolic wastes that stored sperm cells produce. Prostatic fluid also enhances the motility of sperm cells and helps neutralize the acidic secretions of the vagina.

Bulbourethral Glands

The two **bulbourethral glands** (Cowper's glands) are each about a centimeter in diameter and are inferior to the prostate gland within muscle fibers of the external urethral sphincter (see fig. 19.1). Bulbourethral glands have many tubes whose epithelial linings secrete a mucuslike fluid in response to sexual stimulation. This fluid lubricates the end of the penis in preparation for sexual intercourse. However, females secrete most of the lubricating fluid for sexual intercourse.

Semen

Semen (se´men) is the fluid the male urethra conveys to the outside during ejaculation. It consists of sperm cells from the testes and secretions of the seminal vesicles, prostate gland, and bulbourethral glands. Semen is slightly alkaline (pH about 7.5), and its contents include prostaglandins and nutrients.

The volume of semen released at one time varies from 2 to 5 milliliters. The average number of sperm cells in the fluid is about 120 million per milliliter.

Topic of Interest PROSTATE ENLARGEMENT

The prostate gland is relatively small in boys, begins to grow in early adolescence, and reaches adult size several years later. Usually, the gland does not grow again until age fifty, when in about half of all men, it enlarges enough to press on the urethra. This produces a feeling of pressure because the bladder cannot empty completely and the man feels the need to urinate frequently. Retained urine can lead to infection and inflammation, bladder stones, or kidney disease.

Medical researchers do not know what causes prostate enlargement. Risk factors include a fatty diet, having had a vasectomy, and possibly occupational exposure to batteries or to the metal cadmium. The enlargement may be benign or cancerous. Because prostate cancer is highly treatable if detected early, men should have their prostates examined regularly.

Diagnostic tests include a rectal exam as well as a blood test to detect prostate-specific antigen (PSA), a cell surface protein normally found on prostate cells. Elevated PSA levels can indicate an enlarged prostate, possibly from a benign or cancerous growth. Ultrasound may provide further information. Table 19A summarizes the treatments for an enlarged prostate.

TABLE 19A MEDICAL TREATMENTS FOR AN ENLARGED PROSTATE GLAND

Surgical removal of prostate
Radiation
Drugs to block testosterone's growth-stimulating effect on prostate
Microwave energy delivered through a probe inserted into urethra or rectum
Balloon inserted into urethra and inflated with liquid
Tumor frozen with liquid nitrogen delivered by probe through skin
Device (stent) inserted between lobes of the prostate to relieve pressure on the urethra

Sperm cells are nonmotile while in the ducts of the testis and epididymis, but begin to swim as they mix with accessory gland secretions. Sperm cells cannot naturally fertilize an egg cell, however, until they enter the female reproductive tract. Acquiring the ability to fertilize an egg cell is called *capacitation,* and it reflects weakening of the sperm cells' acrosomal membranes.

CHECK YOUR RECALL

1. Where is the prostate gland located?
2. What are the functions of the prostate gland's secretion?
3. What are the components of semen?

Male External Reproductive Organs

The male external reproductive organs are the scrotum, which encloses the testes, and the penis. The urethra passes through the penis.

Scrotum

The **scrotum** is a pouch of skin and subcutaneous tissue that hangs from the lower abdominal region posterior to the penis (see fig. 19.1). A medial septum subdivides the scrotum into two chambers, each of which encloses a testis. Each chamber also contains a serous membrane, which covers the testis and helps ensure that it moves smoothly within the scrotum. The scrotum protects and aids in temperature regulation of the testes, important to sex cell production.

Penis

The **penis** is a cylindrical organ that conveys urine and semen through the urethra to the outside (see fig. 19.1). During erection, it enlarges and stiffens so that it can be inserted into the vagina during sexual intercourse.

The *body,* or shaft, of the penis has three columns of erectile tissue—a pair of dorsally located *corpora cavernosa* and a single, ventral *corpus spongiosum.* A tough capsule of dense connective tissue surrounds each column. Skin, a thin layer of subcutaneous tissue, and a layer of connective tissue enclose the penis.

The corpus spongiosum, through which the urethra extends, enlarges at its distal end to form a sensitive, cone-shaped **glans penis.** The glans covers the ends of the corpora cavernosa and bears the urethral opening (external urethral orifice). The skin of the glans is very thin and hairless, and contains sensory receptors for sexual stimulation. A loose fold of skin called the *prepuce* (foreskin) begins just posterior to the glans and extends anteriorly to cover the glans as a sheath. The prepuce is sometimes removed by a surgical procedure called *circumcision.*

CHECK YOUR RECALL

1. Describe the structure of the penis.
2. What is circumcision?

Topic of Interest MALE INFERTILITY

Male infertility—the inability of sperm cells to fertilize an egg cell—has several causes. If, during fetal development, the testes do not descend into the scrotum, the higher temperature of the abdominal cavity or inguinal canal destroys any sperm cells developing in the seminiferous tubules. Certain diseases, such as mumps, may inflame the testes (orchitis) and cause infertility by destroying cells in the seminiferous tubules.

Both the quality and quantity of sperm cells are essential factors in a man's ability to father a child. If a sperm head is misshapen, if a sperm cell cannot swim, or if sperm cells are too few, completing the journey to the egg cell may be impossible.

Computer-aided sperm analysis (CASA) uses criteria for normalcy in human male seminal fluid and the sperm cells it contains. For this analysis, a man abstains from intercourse for two to three days and then provides a sperm sample, which must be examined within the hour. The man also provides information about his reproductive history and possible exposure to toxins. The sperm sample is placed on a slide under a microscope, and a video camera sends an image to a videocassette recorder, which projects a live or digitized image. The camera also sends the image to a computer, which traces sperm cell trajectories and displays them on a monitor. Figure 19A shows a CASA of normal sperm cells, depicting different swimming patterns as they travel. Table 19B lists the components of a semen analysis.

TABLE 19B SEMEN ANALYSIS

CHARACTERISTIC	NORMAL VALUE
Volume	2–5 milliliters/ejaculate
Sperm cell density	120 million cells/milliliter
Percent motile	> 40%
Motile sperm cell density	> 8 million/milliliter
Average velocity	> 20 micrometers/second
Motility	> 8 micrometers/second
Percent abnormal morphology	< 40%
White blood cells	> 5 million/milliliter

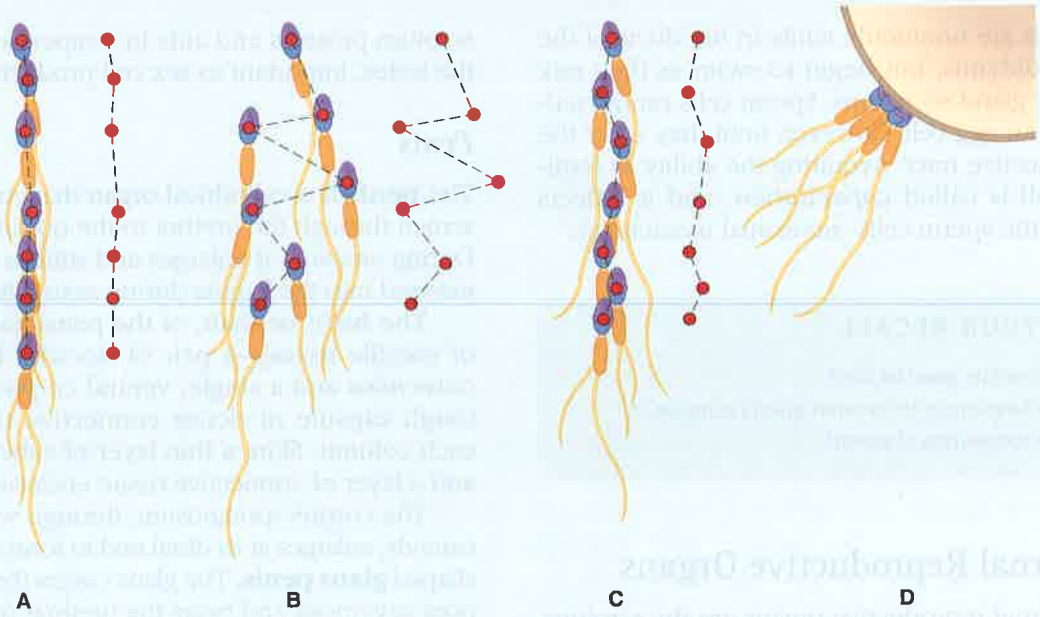


Figure 19A

A computer tracks sperm cell movements. In semen, sperm cells swim in a straight line (A), but as they are activated by biochemicals normally found in the woman's body, their trajectories widen (B). The sperm cells in (C) are in the mucus of a woman's cervix, and the sperm cells in (D) are attempting to digest through the structures surrounding an egg cell.

Erection, Orgasm, and Ejaculation

During sexual stimulation, parasympathetic nerve impulses from the sacral portion of the spinal cord release the vasodilator nitric oxide, causing the arteries leading into the penis to dilate. At the same time, the increasing pressure of arterial blood entering the vascular spaces of erectile tissue compresses the veins of the penis, reducing the flow of venous blood away from

the penis. Consequently, blood accumulates in erectile tissues, and the penis swells and elongates, producing an **erection.**

The culmination of sexual stimulation is **orgasm** (or´gazm), a pleasurable feeling of physiological and psychological release. Emission and ejaculation accompany male orgasm.

Emission (e-mish´un) is the movement of sperm cells from the testes and secretions from the prostate gland and seminal vesicles into the urethra, where they mix to form semen. Emission occurs in response to sympathetic nerve impulses from the spinal cord, which stimulate peristaltic contractions in smooth muscle within the walls of the testicular ducts, epididymides, vasa deferentia, and ejaculatory ducts. At the same time, other sympathetic impulses stimulate rhythmic contractions of the seminal vesicles and prostate gland.

As the urethra fills with semen, sensory impulses are stimulated and pass into the sacral portion of the spinal cord. In response, motor impulses are transmitted from the cord to certain skeletal muscles at the base of the penile erectile columns, causing them to contract rhythmically. This increases the pressure within the erectile tissues and helps force semen through the urethra to the outside, a process called **ejaculation** (e-jak´´u-la´shun).

The sequence of events during emission and ejaculation is coordinated so that fluid from the bulbourethral glands is expelled first. This is followed by the release of fluid from the prostate gland, the passage of sperm cells, and finally the ejection of fluid from the seminal vesicles.

Immediately after ejaculation, sympathetic impulses constrict the arteries that supply the erectile tissue, reducing blood inflow. Smooth muscles within the walls of the vascular spaces partially contract again, and the veins of the penis carry excess blood out of these spaces. The penis gradually returns to its flaccid state.

Table 19.1 summarizes the functions of the male reproductive organs.

Spontaneous emissions and ejaculations commonly occur in adolescent males during sleep and thus are called *nocturnal emissions.* Changes in hormonal concentrations that accompany adolescent development and sexual maturation cause these emissions.

CHECK YOUR RECALL

1. What controls blood flow into penile erectile tissues?
2. Distinguish among orgasm, emission, and ejaculation.
3. Review the events associated with emission and ejaculation.

19.3 Hormonal Control of Male Reproductive Functions

The hypothalamus, anterior pituitary gland, and testes secrete hormones that control male reproductive functions. These hormones initiate and maintain sperm cell production and oversee the development and maintenance of male secondary sex characteristics.

Hypothalamic and Pituitary Hormones

Prior to ten years of age, the male body is reproductively immature. It is childlike, with spermatogenic cells undifferentiated. Then, a series of changes leads to development of a reproductively functional adult. The hypothalamus controls many of these changes.

Recall from chapter 11 (p. 286) that the hypothalamus secretes gonadotropin-releasing hormone (GnRH), which enters blood vessels leading to the anterior pituitary gland. In response, the anterior pituitary secretes the **gonadotropins** (go-nad´´o-trōp´inz), called *luteinizing hormone (LH)* and *follicle-stimulating hormone (FSH).* LH, which in males is also called interstitial cell-stimulating hormone (ICSH), promotes development of testicular interstitial cells, and they in turn secrete male sex hormones. FSH stimulates the supporting cells of the seminiferous tubules to respond to the effects of the

TABLE 19.1 FUNCTIONS OF THE MALE REPRODUCTIVE ORGANS

ORGAN	FUNCTION
Testis	
Seminiferous tubules	Produce sperm cells
Interstitial cells	Produce and secrete male sex hormones
Epididymis	Stores sperm cells undergoing maturation; conveys sperm cells to vas deferens
Vas deferens	Conveys sperm cells to ejaculatory duct
Seminal vesicle	Secretes an alkaline fluid containing nutrients and prostaglandins that helps neutralize the acidic components of semen
Prostate gland	Secretes an alkaline fluid that helps neutralize semen's acidity and enhances sperm cell motility
Bulbourethral gland	Secretes fluid that lubricates end of penis
Scrotum	Encloses, protects, and regulates temperature of testes
Penis	Conveys urine and semen to outside of body; inserted into vagina during sexual intercourse; glans penis is richly supplied with sensory nerve endings associated with feelings of pleasure during sexual stimulation

male sex hormone *testosterone*. Then, in the presence of FSH and testosterone, these supporting cells stimulate spermatogenic cells to undergo spermatogenesis, giving rise to sperm cells (fig. 19.6). The supporting cells also secrete a hormone called *inhibin,* which inhibits the anterior pituitary gland by negative feedback, and thus prevents oversecretion of FSH.

Male Sex Hormones

Male sex hormones are termed **androgens** (an´dro-jenz). Testicular interstitial cells produce most of them, but the adrenal cortex synthesizes small amounts (see chapter 11, p. 295). **Testosterone** (tes-tos´te-rōn) is the most abundant androgen. It loosely attaches to plasma proteins for secretion and transport in blood.

Testosterone secretion begins during fetal development and continues for several weeks following birth; then it nearly ceases during childhood. Between the ages of thirteen and fifteen, a young man's androgen production usually increases rapidly. This phase in development, when an individual becomes reproductively functional, is **puberty** (pu´ber-te). After puberty, testosterone secretion continues throughout the life of a male.

Actions of Testosterone

During puberty, testosterone stimulates enlargement of the testes (the *male primary sex organs*) and accessory organs of the reproductive system, as well as development of *male secondary sex characteristics,* which are special features associated with the adult male body. Secondary sex characteristics in the male include:

1. Increased growth of body hair, particularly on the face, chest, axillary region, and pubic region. Sometimes, hair growth on the scalp slows.
2. Enlargement of the larynx and thickening of the vocal folds, with lowering of the pitch of the voice.
3. Thickening of the skin.
4. Increased muscular growth, broadening of the shoulders, and narrowing of the waist.
5. Thickening and strengthening of the bones.

Testosterone also increases the rate of cellular metabolism and red blood cell production, so that the average number of red blood cells in a cubic millimeter of blood is usually greater in males than in females. Testosterone stimulates sexual activity by affecting certain portions of the brain.

Regulation of Male Sex Hormones

The extent to which male secondary sex characteristics develop is directly related to the amount of testosterone that interstitial cells secrete. A negative feedback system involving the hypothalamus regulates testosterone output (see fig. 19.6).

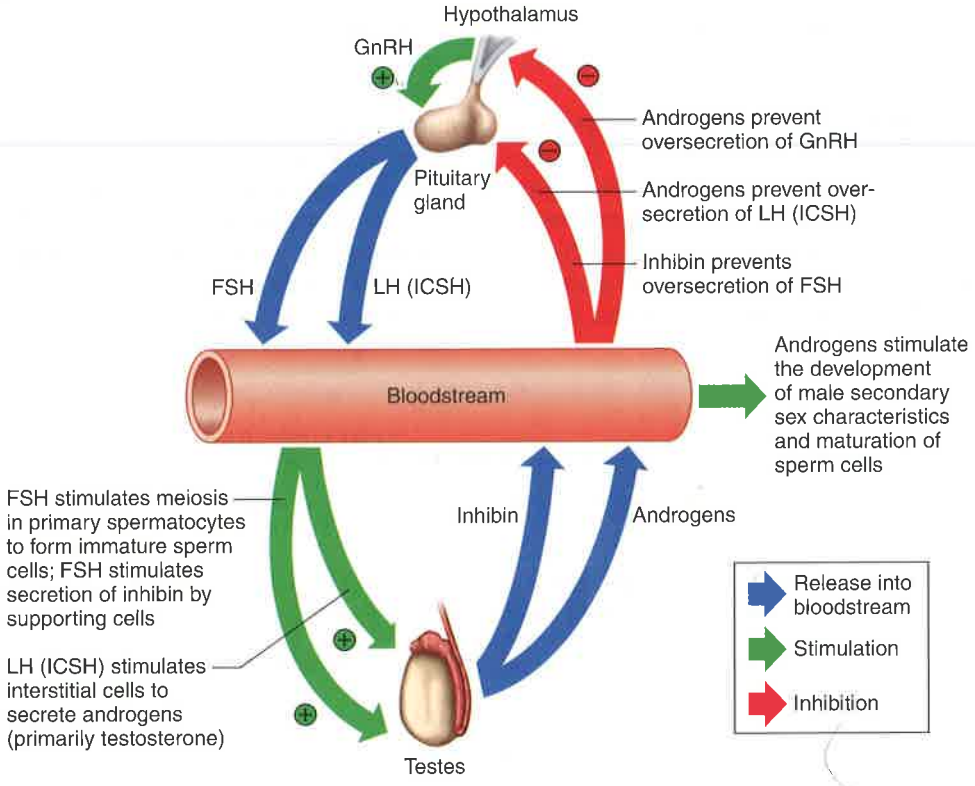


Figure 19.6
The hypothalamus controls maturation of sperm cells and development of male secondary sex characteristics. A negative feedback mechanism operating between the hypothalamus, the anterior lobe of the pituitary gland, and the testes controls the concentration of testosterone.

An increasing blood testosterone concentration inhibits the hypothalamus, and its stimulation of the anterior pituitary gland by GnRH decreases. As the pituitary's secretion of LH (ICSH) falls in response, the amount of testosterone the interstitial cells release decreases.

As the blood testosterone concentration drops, the hypothalamus becomes less inhibited, and it once again stimulates the anterior pituitary to release LH. Increasing LH secretion then causes interstitial cells to release more testosterone, and the blood testosterone concentration increases.

Testosterone level decreases somewhat during and after the *male climacteric,* a decline in sexual function associated with aging. At any given age, the testosterone concentration in the male body is regulated to remain relatively constant.

CHECK YOUR RECALL

1. Which hormone initiates the changes associated with male sexual maturity?
2. Describe several male secondary sex characteristics.
3. List the functions of testosterone.
4. Explain how the secretion of male sex hormones is regulated.

19.4 Organs of the Female Reproductive System

The organs of the female reproductive system produce and maintain the female sex cells, or egg cells (ova); transport these cells to the site of fertilization; provide a favorable environment for a developing offspring; move the offspring to the outside; and produce female sex hormones. A female's *primary sex organs* (gonads) are the two ovaries, which produce the female sex cells and sex hormones. The *accessory sex organs* of the female reproductive system are the internal and external reproductive organs (fig. 19.7; reference plates 5 and 6, pp. 26–27).

Ovaries

The two **ovaries** are solid, ovoid structures, each about 3.5 centimeters long, 2 centimeters wide, and 1 centimeter thick. The ovaries lie in shallow depressions in the lateral wall of the pelvic cavity (fig. 19.7).

Ovary Structure

Ovarian tissues are subdivided into two indistinct regions—an inner *medulla* and an outer *cortex*. The ovarian medulla is composed of loose connective tissue

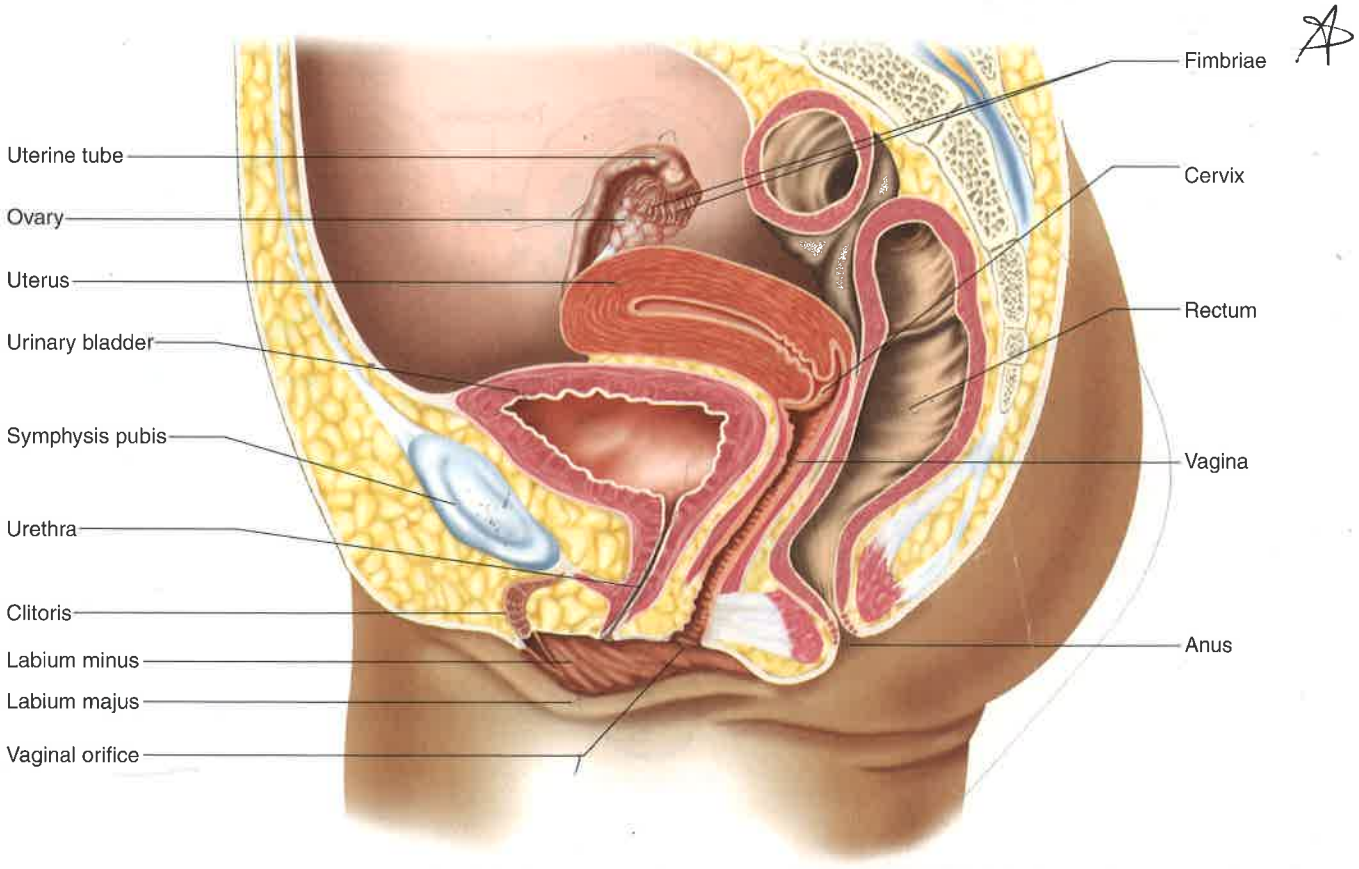


Figure 19.7
Female reproductive organs (sagittal view). The paired ovaries are the primary sex organs, and the other structures, both internal and external, are accessory sex organs.

and contains many blood vessels, lymphatic vessels, and nerve fibers. The ovarian cortex consists of more compact tissue and has a granular appearance due to tiny masses of cells called *ovarian follicles.*

A layer of cuboidal epithelium covers the ovary's free surface. Just beneath this epithelium is a layer of dense connective tissue.

CHECK YOUR RECALL

1. What are the primary sex organs of the female?
2. Describe the structure of an ovary.

Primordial Follicles

During prenatal (before birth) development of a human female, small groups of cells in the outer region of the ovarian cortex form several million **primordial follicles.** Each of these structures consists of a single, large cell, called a *primary oocyte,* which is closely surrounded by epithelial cells called *follicular cells.*

Early in development, primary oocytes begin to undergo meiosis, but the process soon halts and does not continue until the individual reaches puberty. Once the primordial follicles appear, no new ones form. Instead, the number of oocytes in the ovary steadily declines as many of the oocytes degenerate. Of the several million oocytes formed originally, only a million or so remain at birth, and perhaps 400,000 are present at puberty. The ovary releases fewer than 400 or 500 oocytes during a female's reproductive life.

Oogenesis

Oogenesis (o´´o-jen´ĕ-sis) is the process of egg cell formation. Beginning at puberty, some primary oocytes are stimulated to continue meiosis. As in the case of sperm cells, the resulting cells have one-half as many chromosomes (23) in their nuclei as their parent cells.

When a primary oocyte divides, the distribution of the cytoplasm is unequal. One of the resulting cells, called a *secondary oocyte,* is large, and the other, called the *first polar body,* is small (fig. 19.8).

The large secondary oocyte can be fertilized by a sperm cell, at which point it is considered an egg. Upon fertilization, the oocyte divides unequally to produce a tiny *second polar body* and a large fertilized egg cell, or **zygote** (zi´gōt).

The polar bodies have no further function and soon degenerate. Their role in reproduction is to allow the egg cell to accumulate the large amount of cytoplasm necessary to nurture a zygote and early embryo.

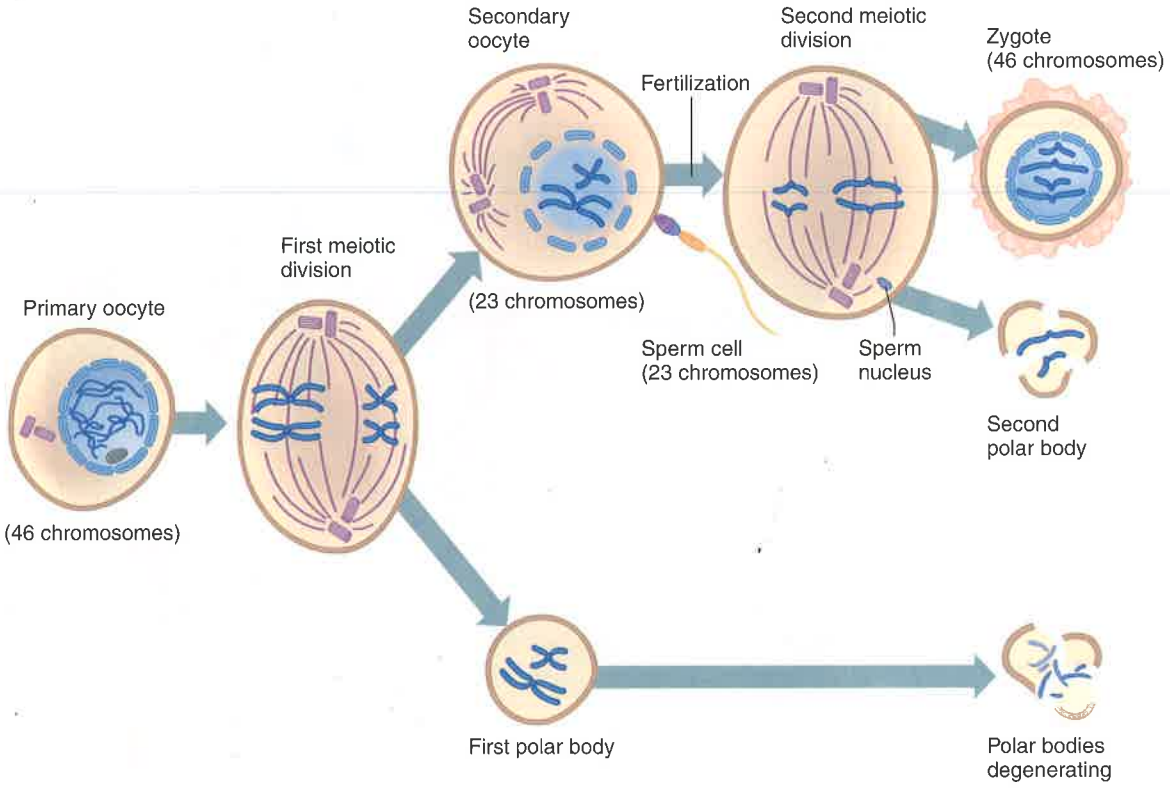


Figure 19.8
During oogenesis, a single egg cell (secondary oocyte) results from meiosis in a primary oocyte. If the egg cell is fertilized, it generates a second polar body and becomes a zygote. (Note: The second meiotic division does not occur in the egg cell if it is not fertilized by a sperm cell.)

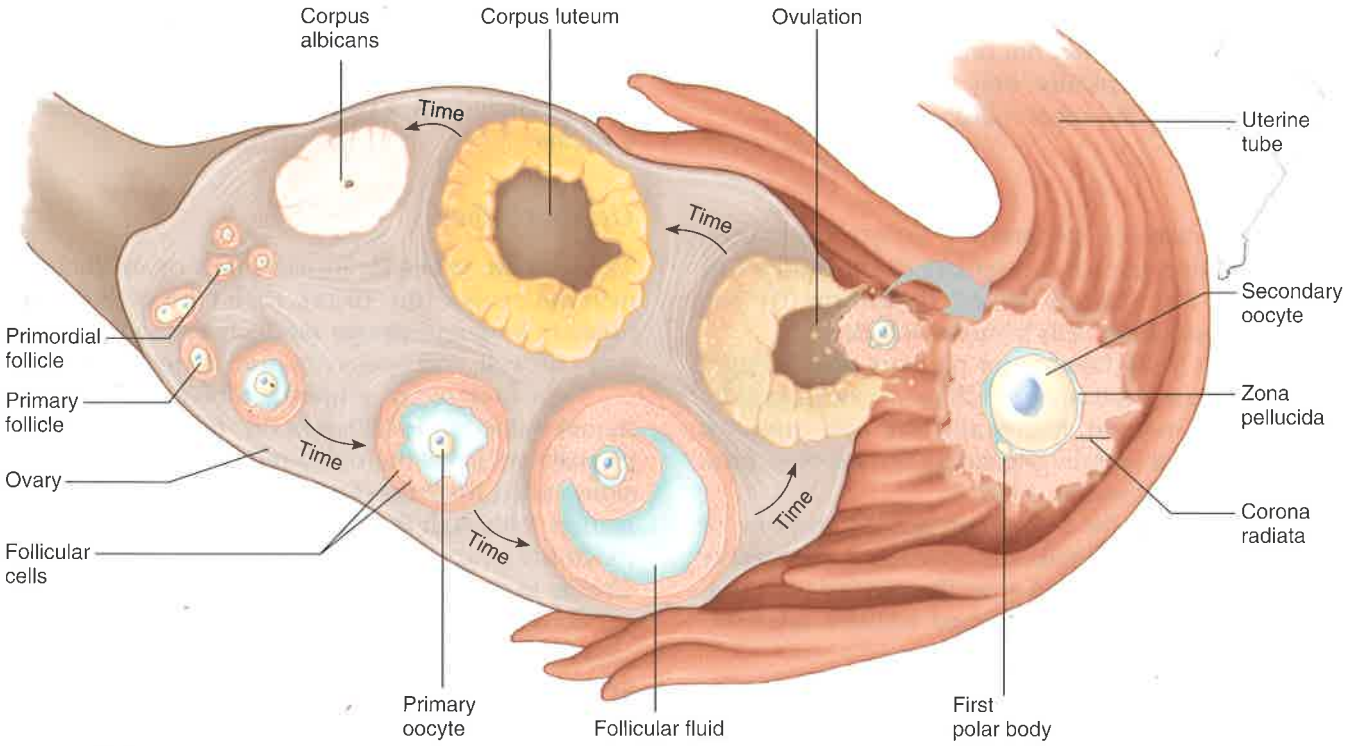


Figure 19.9
Within an ovary, as a follicle matures, a developing oocyte enlarges and becomes surrounded by follicular cells and fluid. Eventually, the mature follicle ruptures, releasing the secondary oocyte.

The largest cell in the human body is the ovum. The smallest cell is the sperm.

CHECK YOUR RECALL

1. How does the timing of egg cell production differ from that of sperm cells?
2. Describe the major events of oogenesis.

Follicle Maturation

At puberty, the anterior pituitary gland secretes increased amounts of FSH, and the ovaries enlarge in response. At the same time, some of the primordial follicles mature into **primary follicles** (pri´ma-re fol´i-klz). Figure 19.9 traces the maturation of a follicle within an ovary.

During maturation, a primary oocyte enlarges, and surrounding follicular cells proliferate by mitosis. These follicular cells become organized into layers, and soon a cavity (*antrum*) appears in the cellular mass. A clear *follicular fluid* fills the cavity and bathes the oocyte. The enlarging fluid-filled cavity presses the oocyte to one side. In time, the follicle reaches a diameter of 10 millimeters or more and bulges outward on the ovary surface like a blister.

The secondary oocyte is a large, spherical cell, surrounded by a membrane (zona pellucida) and attached to a mantle of follicular cells (corona radiata) (fig. 19.10). Processes from the follicular cells extend through the zona pellucida and supply the oocyte with nutrients.

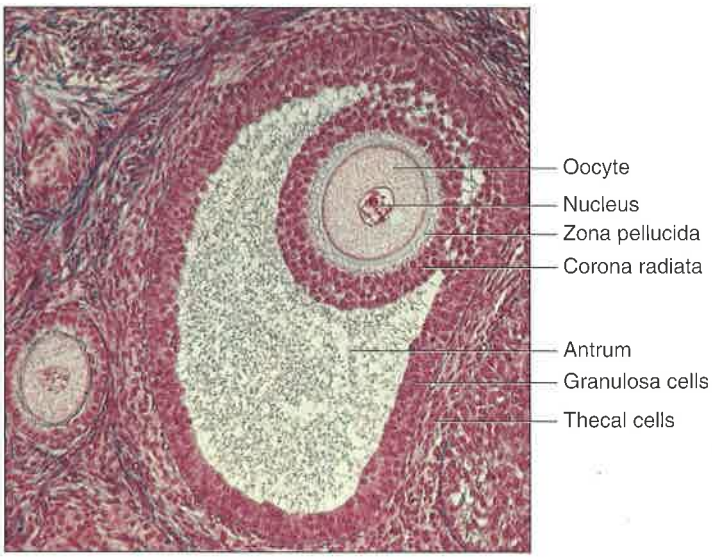


Figure 19.10
Light micrograph of a maturing follicle (200×).

As many as twenty primary follicles may begin maturing at any one time, but one follicle usually outgrows the others. Typically, only the dominant follicle fully develops, and the other follicles degenerate.

Ovulation

As a follicle matures, its primary oocyte undergoes oogenesis, giving rise to a secondary oocyte and a first polar body. The process called **ovulation** (o´´vu-la´shun) releases these cells from the follicle.

Hormones from the anterior pituitary gland trigger ovulation, causing the mature follicle to swell rapidly and its wall to weaken. Eventually, the wall ruptures, and follicular fluid and the secondary oocyte ooze from the ovary's surface (see fig. 19.9).

After ovulation, the secondary oocyte and one or two layers of follicular cells surrounding it are usually propelled to the opening of a nearby uterine tube (fig. 19.11). If the oocyte is not fertilized within a relatively short time, it degenerates.

CHECK YOUR RECALL

1. What changes occur in a follicle and its oocyte during maturation?
2. What causes ovulation?
3. What happens to an oocyte following ovulation?

Female Internal Accessory Organs

The internal accessory organs of the female reproductive system include a pair of uterine tubes, a uterus, and a vagina.

Uterine Tubes

The **uterine tubes** (fallopian tubes or oviducts) open near the ovaries (fig. 19.11). Each tube is about 10 centimeters long and passes medially to the uterus, penetrates its wall, and opens into the uterine cavity.

Near each ovary, a uterine tube expands to form a funnel-shaped *infundibulum* (in´´fun-dib´u-lum), which partially encircles the ovary medially. Fingerlike extensions called *fimbriae* (fim´bre) fringe the infundibulum margin. Although the infundibulum generally does not touch the ovary, one of the larger extensions connects directly to the ovary.

Simple columnar epithelial cells, some of which are *ciliated,* line the uterine tube. The epithelium secretes mucus, and the cilia beat toward the uterus. These actions help draw the secondary oocyte and expelled follicular fluid into the infundibulum following ovulation. Ciliary action and peristaltic contractions of the uterine tube's muscular layer help transport the secondary oocyte down the uterine tube.

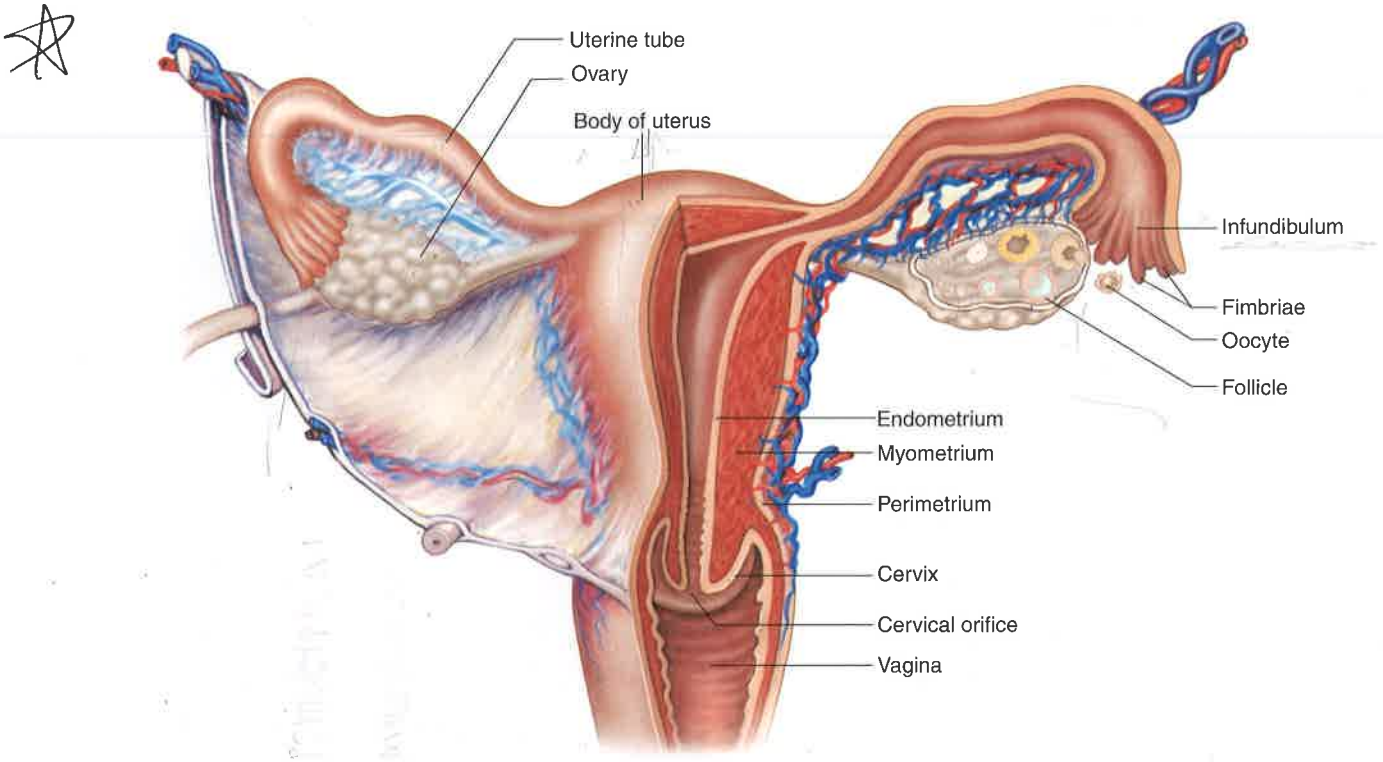


Figure 19.11
The funnel-shaped infundibulum of the uterine tube partially encircles the ovary (posterior view).

Uterus

If the secondary oocyte is fertilized in the uterine tube, becoming an ovum or egg cell, the **uterus** receives the embryo and sustains its development. The uterus is a hollow, muscular organ shaped somewhat like an inverted pear.

The size of the uterus changes greatly during pregnancy. In its nonpregnant, adult state, the uterus is about 7 centimeters long, 5 centimeters wide (at its broadest point), and 2.5 centimeters in diameter. It is located medially within the anterior portion of the pelvic cavity, superior to the vagina, and usually bends forward over the urinary bladder.

The upper two-thirds, or *body,* of the uterus has a dome-shaped top (fig. 19.11). The uterine tubes enter the top of the uterus at its broadest part. The lower third of the uterus is called the **cervix.** This tubular part extends downward into the upper portion of the vagina. The cervix surrounds the opening called the *cervical orifice,* through which the uterus opens to the **vagina.**

The uterine wall is thick and has three layers (fig. 19.12). The **endometrium,** the inner mucosal layer, is covered with columnar epithelium and contains abundant tubular glands. The **myometrium,** a thick, middle, muscular layer, consists largely of bundles of smooth muscle fibers. During the monthly female reproductive cycles and during pregnancy, the endometrium and myometrium change extensively. The **perimetrium** is an outer serosal layer that covers the body of the uterus and part of the cervix.

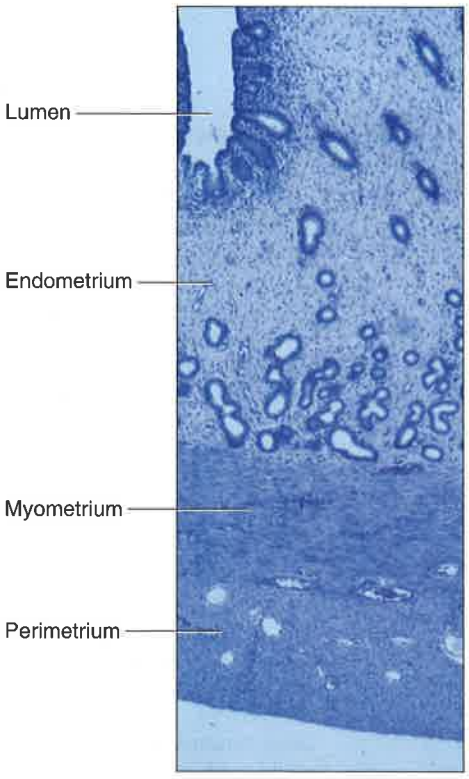


Figure 19.12
Light micrograph of the uterine wall (10.5×).

During pregnancy, the uterus expands to 500 times its normal size.

A procedure called the *Pap (Papanicolaou) smear test* can usually detect cancer of the cervix. A sample of cervical tissue is smeared on a glass slide, stained, and sent to a laboratory, where computer image recognition software is used to identify cancer cells. Cervical cancer detected and treated early has a high cure rate.

Vagina

The vagina is a fibromuscular tube, about 9 centimeters long, extending from the uterus to the outside (see fig. 19.7). It conveys uterine secretions, receives the erect penis during sexual intercourse, and provides an open channel for offspring during birth.

The vagina extends upward and back into the pelvic cavity. It is posterior to the urinary bladder and urethra, anterior to the rectum, and attached to these structures by connective tissues.

A thin membrane of connective tissue and stratified squamous epithelium called the **hymen** partially closes the *vaginal orifice.* A central opening of varying size allows uterine and vaginal secretions to pass to the outside.

The vaginal wall has three layers. The inner *mucosal layer* is stratified squamous epithelium. This layer lacks mucous glands; the mucus in the lumen of the vagina comes from uterine glands and from vestibular glands at the mouth of the vagina.

The middle *muscular layer* consists mainly of smooth muscle fibers. A thin band of striated muscle at the lower end of the vagina helps close the vaginal opening. However, a voluntary muscle (bulbospongiosus) is primarily responsible for closing this orifice.

The outer *fibrous layer* consists of dense connective tissue interlaced with elastic fibers. It attaches the vagina to surrounding organs.

CHECK YOUR RECALL

1. How is a secondary oocyte moved along a uterine tube?
2. Describe the structure of the uterus.
3. Describe the structure of the vagina.

Female External Reproductive Organs

The external accessory organs of the female reproductive system include the labia majora, labia minora, clitoris, and vestibular glands. These structures surround

the openings of the urethra and vagina, and compose the **vulva** (see fig. 19.7).

Labia Majora

The **labia majora** (singular, *labium majus*) enclose and protect the other external reproductive organs. They correspond to the scrotum in males and are composed of rounded folds of adipose tissue and a thin layer of smooth muscle, covered by skin.

The labia majora lie close together. A cleft that includes the urethral and vaginal openings separates the labia longitudinally. At their anterior ends, the labia merge to form a medial, rounded elevation of adipose tissue called the *mons pubis,* which overlies the symphysis pubis (see fig. 19.7).

Labia Minora

The **labia minora** (singular, *labium minus*) are flattened, longitudinal folds between the labia majora (see fig. 19.7). They are composed of connective tissue richly supplied with blood vessels, giving a pinkish appearance. Posteriorly, the labia minora merge with the labia majora, while anteriorly, they converge to form a hoodlike covering around the clitoris.

Clitoris

The **clitoris** (klit´o-ris) is a small projection at the anterior end of the vulva between the labia minora (see fig. 19.7). It is usually about 2 centimeters long and 0.5 centimeters in diameter, including a portion embedded in surrounding tissues. The clitoris corresponds to the penis in males and has a similar structure. It is composed of two columns of erectile tissue called *corpora cavernosa.* At its anterior end, a small mass of erectile tissue forms a **glans,** which is richly supplied with sensory nerve fibers.

Vestibule

The labia minora enclose a space called the **vestibule.** The vagina opens into the posterior portion of the vestibule, and the urethra opens in the midline, just anterior to the vagina and about 2.5 centimeters posterior to the glans of the clitoris.

A pair of **vestibular glands,** corresponding to the bulbourethral glands in males, lie one on either side of the vaginal opening. Beneath the mucosa of the vestibule on either side is a mass of vascular erectile tissue called the **vestibular bulb.**

CHECK YOUR RECALL

1. What is the male counterpart of the labia majora? Of the clitoris?
2. Which structures are within the vestibule?

Erection, Lubrication, and Orgasm

Erectile tissues in the clitoris and around the vaginal entrance respond to sexual stimulation. Following such stimulation, parasympathetic nerve impulses from the sacral portion of the spinal cord release the vasodilator nitric oxide, causing the arteries associated with the erectile tissues to dilate. As a result, blood inflow increases, and the erectile tissues swell. At the same time, the vagina expands and elongates.

If sexual stimulation is sufficiently intense, parasympathetic impulses stimulate the vestibular glands to secrete mucus into the vestibule. This moistens and lubricates the tissues surrounding the vestibule and the lower end of the vagina, facilitating insertion of the penis into the vagina.

The clitoris is abundantly supplied with sensory nerve fibers, which are especially sensitive to local stimulation. The culmination of such stimulation is orgasm.

Just prior to orgasm, the tissues of the outer third of the vagina engorge with blood and swell. This increases the friction on the penis during intercourse. Orgasm initiates a series of reflexes involving the sacral and lumbar portions of the spinal cord. In response to these reflexes, the muscles of the perineum and the walls of the uterus and uterine tubes contract rhythmically. These contractions help transport sperm cells through the female reproductive tract toward the upper ends of the uterine tubes. Table 19.2 summarizes the functions of the female reproductive organs.

TABLE 19.2 FUNCTIONS OF THE FEMALE REPRODUCTIVE ORGANS

ORGAN	FUNCTION
Ovary	Produces oocytes and female sex hormones
Uterine tube	Conveys secondary oocyte toward uterus; site of fertilization; conveys developing embryo to uterus
Uterus	Protects and sustains embryo during pregnancy
Vagina	Conveys uterine secretions to outside of body; receives erect penis during sexual intercourse; provides open channel for offspring during birth process
Labia majora	Enclose and protect other external reproductive organs
Labia minora	Form margins of vestibule; protect openings of vagina and urethra
Clitoris	Produces feelings of pleasure during sexual stimulation due to abundant sensory nerve endings in glans
Vestibule	Space between labia minora that contains vaginal and urethral openings
Vestibular glands	Secrete fluid that moistens and lubricates vestibule

The clitoris contains nearly 8,000 nerve fibers, the densest collection of any body part. The corresponding part of the penis has only 4,000 nerve fibers.

CHECK YOUR RECALL

1. What events result from parasympathetic stimulation of the female reproductive organs?
2. What changes occur in the vagina just prior to and during orgasm?

19.5 Hormonal Control of Female Reproductive Functions

The hypothalamus, anterior pituitary gland, and ovaries secrete hormones that control the development and maintenance of female secondary sex characteristics, maturation of female sex cells, and changes that occur during the monthly reproductive cycle.

Female Sex Hormones

The female body is reproductively immature until about age ten. Then the hypothalamus begins to secrete increasing amounts of GnRH. GnRH, in turn, stimulates the anterior pituitary to release the gonadotropins FSH and LH. These hormones play primary roles in controlling female sex cell maturation and in producing female sex hormones.

Several tissues, including the ovaries, the adrenal cortices, and the placenta (during pregnancy), secrete female sex hormones belonging to two major groups—**estrogens** (es´tro-jenz) and **progesterone** (pro-jes´tĭ-rōn). *Estradiol* is the most abundant of the estrogens, which also include *estrone* and *estriol.*

The ovaries are the primary source of estrogens (in a nonpregnant female). At puberty, under the influence of the anterior pituitary, the ovaries secrete increasing amounts of estrogens. Estrogens stimulate enlargement of accessory organs, including the vagina, uterus, uterine tubes, ovaries, and external reproductive structures. Estrogens also develop and maintain the *female secondary sex characteristics,* special features associated with the adult female body, which include:

1. Development of the breasts and the ductile system of the mammary glands within the breasts.
2. Increased deposition of adipose tissue in the subcutaneous layer generally and in the breasts, thighs, and buttocks particularly.
3. Increased vascularization of the skin.

The ovaries are also the primary source of progesterone (in a nonpregnant female). This hormone promotes changes in the uterus during the female reproductive cycle, affects the mammary glands, and helps regulate the secretion of gonadotropins from the anterior pituitary.

Androgen (male sex hormone) concentrations produce certain other changes in females at puberty. For example, increased hair growth in the pubic and axillary regions is due to androgen secreted by the adrenal cortices. Conversely, development of the female skeletal configuration, which includes narrow shoulders and broad hips, is a response to a low androgen concentration.

CHECK YOUR RECALL

1. What stimulates sexual maturation in a female?
2. What is the function of estrogens?
3. What is the function of androgen in a female?

Female Reproductive Cycle

The female reproductive cycle, or **menstrual cycle** (men´stroo-al si´kl), consists of regular, recurring changes in the uterine lining, which culminate in menstrual bleeding (menses). At the same time, changes in the ovary constitute the **ovarian cycle.** Such cycles usually begin around age thirteen and continue into middle age, then cease.

Women athletes may have disturbed menstrual cycles, ranging from diminished menstrual flow (oligomenorrhea) to complete stoppage (amenorrhea). The more active an athlete, the more likely it is that she will have menstrual problems. This effect results from a loss of adipose tissue and a consequent decline in estrogens, which adipose tissue synthesizes from adrenal androgen.

A female's first menstrual cycle, called **menarche** (mĕ-nar´ke), occurs after the ovaries and other organs of the reproductive control system have matured and begun responding to certain hormones. Then, hypothalamic secretion of GnRH stimulates the anterior pituitary to release threshold levels of FSH and LH. FSH stimulates maturation of an ovarian follicle. The follicular cells produce increasing amounts of estrogens and some progesterone. LH stimulates certain ovarian cells to secrete precursor molecules (testosterone), which are also used to produce estrogens.

In a young female, estrogens stimulate the development of secondary sex characteristics. Estrogens secreted during subsequent menstrual cycles continue the development and maintenance of these characteristics.

As shown in the diagram of the menstrual cycles in figure 19.13, increasing concentration of estrogens during the first week or so of a menstrual cycle changes the uterine lining, thickening the glandular endometrium

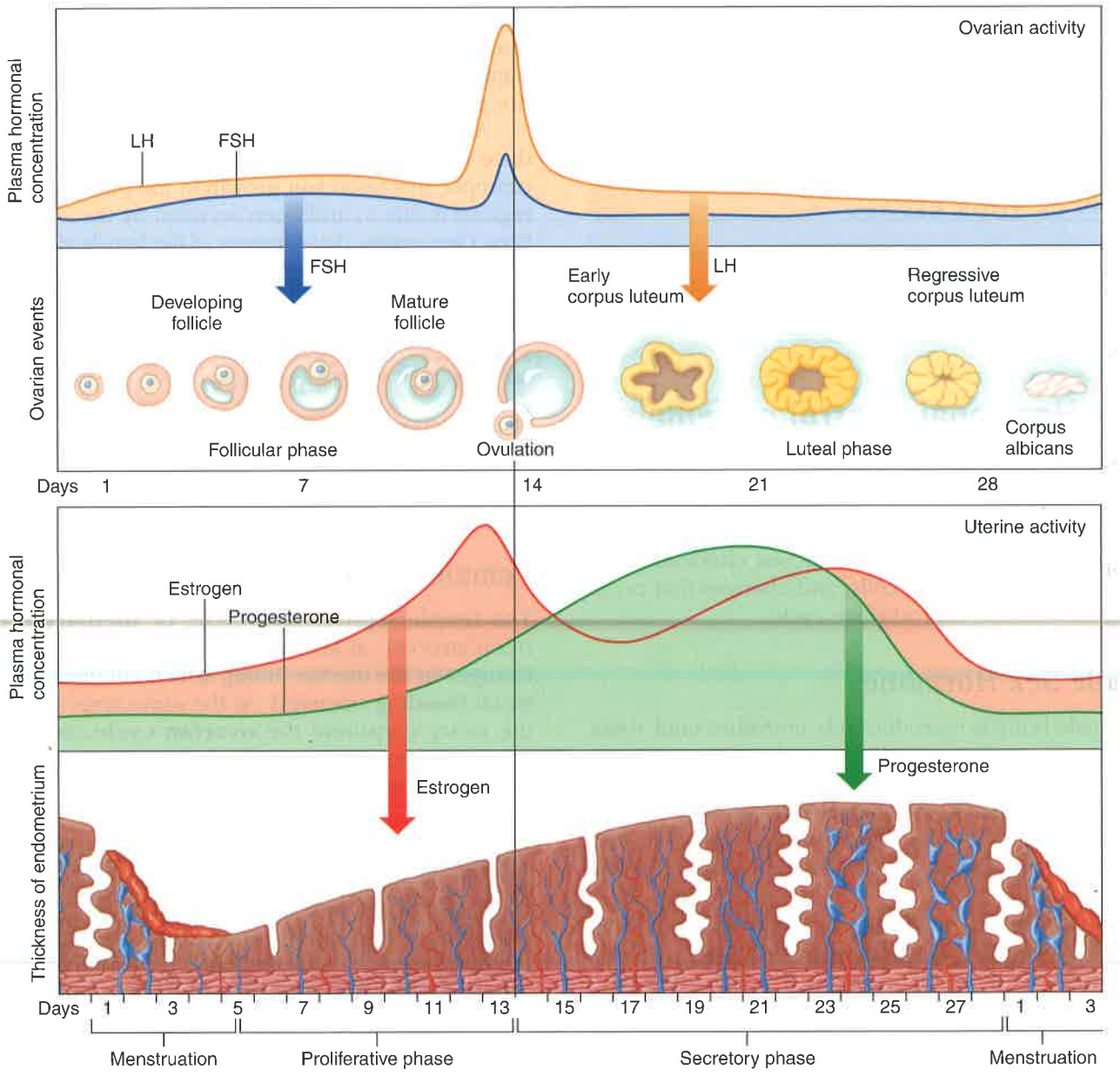


Figure 19.13
Major events in the female menstrual cycle.

(proliferative phase). Meanwhile, the developing follicle completes maturation, and by the fourteenth day of the cycle, the follicle appears on the ovary surface as a blisterlike bulge. Within the follicle, the follicular cells, which surround and connect the oocyte to the inner wall, loosen. Follicular fluid accumulates rapidly.

While the follicle matured, estrogens that it secreted inhibited the anterior pituitary's release of LH, but allowed LH to be stored in the gland. Estrogens also made anterior pituitary cells more sensitive to the action of GnRH, which the hypothalamus released in rhythmic pulses about 90 minutes apart.

Near the fourteenth day of follicular development, anterior pituitary cells finally release the stored LH in response to the GnRH pulses. The resulting surge in LH concentration, which lasts about 36 hours, weakens and ruptures the bulging follicular wall, which sends the oocyte and follicular fluid from the ovary (ovulation).

Following ovulation, the remnants of the follicle within the ovary change rapidly. The space that the follicular fluid occupied fills with blood, which soon clots, and under the influence of LH, follicular cells enlarge to form a temporary glandular structure called a **corpus luteum** ("yellow body").

Follicular cells secrete progesterone during the first part of the menstrual cycle. Corpus luteum cells secrete abundant progesterone and estrogens during the last half of the cycle. Consequently, as a corpus luteum

forms, blood progesterone concentration increases sharply.

Progesterone causes the endometrium to become more vascular and glandular. It also stimulates uterine glands to secrete more glycogen and lipids (secretory phase). As a result, endometrial tissues fill with fluids containing nutrients and electrolytes, providing a favorable environment for embryo development.

Estrogens and progesterone inhibit the anterior pituitary's release of LH and FSH. Consequently, no other follicles are stimulated to develop when the corpus luteum is active. However, if a sperm cell does not fertilize the oocyte released at ovulation, the corpus luteum begins to degenerate on about the twenty-fourth day of the cycle. Eventually, connective tissue replaces it. The remnant of such a corpus luteum is called a *corpus albicans.*

When the corpus luteum ceases to function, concentrations of estrogens and progesterone decline rapidly, and blood vessels in the endometrium constrict in response. This reduces the supply of oxygen and nutrients to the thickened uterine lining, and these lining tissues soon disintegrate and slough off. At the same time, blood escapes from damaged capillaries, creating a flow of blood and cellular debris that passes through the vagina as the *menstrual flow* (menses). This flow usually begins about the twenty-eighth day of the cycle and continues for three to five days while the concentrations of estrogens are relatively low. The menstrual flow marks the end of a menstrual cycle and the beginning of a new cycle. Table 19.3 summarizes the menstrual cycle.

Low blood concentrations of estrogens and progesterone at the beginning of the menstrual cycle mean that the hypothalamus and anterior pituitary are no longer inhibited. Consequently, FSH and LH concentrations soon increase, stimulating a new follicle to mature. As this follicle secretes estrogens, the uterine lining undergoes repair, and the endometrium begins to thicken again.

Menopause

After puberty, menstrual cycles continue at regular intervals into the late forties or early fifties, when they become increasingly irregular. Then, in a few months or years, the cycles cease altogether. This period in life is called **menopause** (men´o-pawz), or the female climacteric.

Aging of the ovaries causes menopause. After about thirty-five years of cycling, few primary follicles remain to respond to pituitary gonadotropins. Consequently, the follicles no longer mature, ovulation does not occur, and blood concentration of estrogens plummets.

Reduced concentrations of estrogens and lack of progesterone may change the female secondary sex characteristics. The breasts, vagina, uterus, and uterine tubes may shrink, and the pubic and axillary hair may thin.

CHECK YOUR RECALL

1. Trace the events of the menstrual cycle.
2. What causes menstrual flow?
3. What are some changes that may occur at menopause?

19.6 Mammary Glands

The **mammary glands** are accessory organs of the female reproductive system that are specialized to secrete milk following pregnancy (fig. 19.14; reference plate 1, p. 22). They are in the subcutaneous tissue of the anterior thorax within elevations called *breasts.* The breasts overlie the *pectoralis major* muscles and extend from the second to the sixth ribs and from the sternum to the axillae.

A *nipple* is located near the tip of each breast at about the level of the fourth intercostal space. A circular area of pigmented skin, called the *areola,* surrounds each nipple.

TABLE 19.3 MAJOR EVENTS IN A MENSTRUAL CYCLE

1. Anterior pituitary gland secretes follicle-stimulating hormone (FSH) and luteinizing hormone (LH).
2. FSH stimulates maturation of a follicle.
3. Follicular cells produce and secrete estrogens.
   a. Estrogens maintain secondary sex traits.
   b. Estrogens cause uterine lining to thicken.
4. Anterior pituitary releases a surge of LH, which stimulates ovulation.
5. Follicular cells become corpus luteum cells, which secrete estrogens and progesterone.
   a. Estrogens continue to stimulate uterine wall development.
   b. Progesterone stimulates the uterine lining to become more glandular and vascular.
   c. Estrogens and progesterone inhibit anterior pituitary from secreting LH and FSH.
6. If the egg cell is not fertilized, the corpus luteum degenerates and no longer secretes estrogens and progesterone.
7. As concentrations of estrogens and progesterone decline, blood vessels in the uterine lining constrict.
8. Uterine lining disintegrates and sloughs off, producing menstrual flow.
9. Anterior pituitary is no longer inhibited and again secretes FSH and LH.
10. The menstrual cycle repeats.

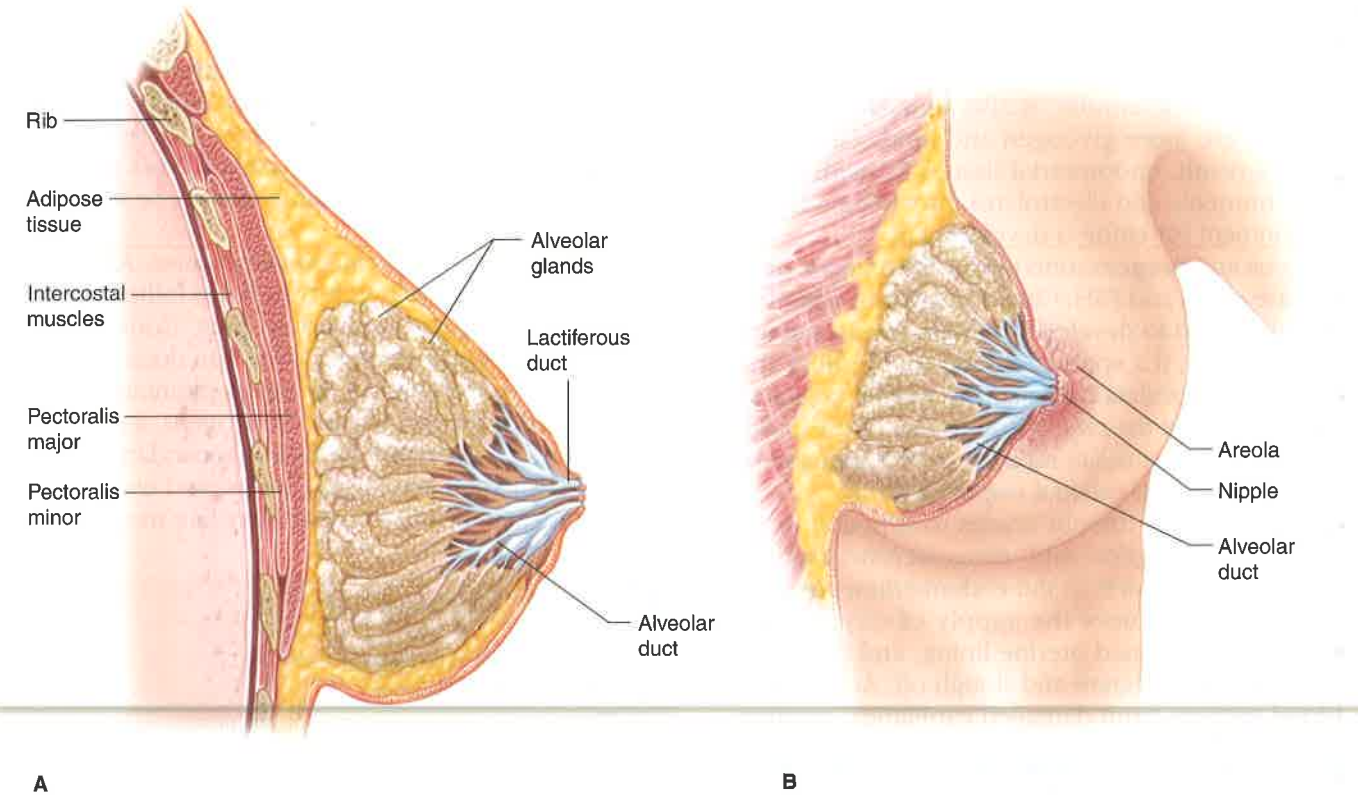


Figure 19.14
Structure of the female breast and mammary glands. (*A*) Sagittal section. (*B*) Anterior view.

A mammary gland is composed of fifteen to twenty lobes. Each lobe contains glands (alveolar glands) and an alveolar duct that leads to a lactiferous duct that leads to the nipple and opens to the outside. Dense connective and adipose tissues separate the lobes. These tissues also support the glands and attach them to the fascia of the underlying pectoral muscles. Other connective tissue, which forms dense strands called *suspensory ligaments,* extends inward from the dermis of the breast to the fascia, helping to support the breast's weight.

The mammary glands of males and females are similar. As children reach puberty, the glands in males do not develop, whereas in females, ovarian hormones stimulate development of the glands. As a result, the alveolar glands and ducts enlarge, and fat forms deposits around and within the breasts. Chapter 20 (p. 532) describes the hormonal mechanism that stimulates mammary glands to produce and secrete milk.

CHECK YOUR RECALL

1. Describe the structure of a mammary gland.
2. What changes do ovarian hormones cause in mammary glands?

19.7 Birth Control

Birth control is the voluntary regulation of the number of offspring produced and the time at which they are conceived. This control requires a method of **contraception** (kon´´trah-sep´shun) to avoid fertilization of a secondary oocyte following sexual intercourse (coitus) or to prevent the hollow ball of cells (a blastocyst) that will develop into an embryo from implanting in the uterine wall.

Coitus Interruptus

Coitus interruptus is withdrawal of the penis from the vagina before ejaculation, which prevents entry of sperm cells into the female reproductive tract. This method can still result in pregnancy because a male may find it difficult to withdraw just prior to ejaculation. Also, small quantities of semen containing sperm cells may reach the vagina before ejaculation occurs.

Rhythm Method

The *rhythm method* (also called timed coitus or natural family planning) requires abstinence from sexual intercourse a few days before and a few days after ovulation. The rhythm method results in a relatively high rate

of pregnancy because accurately identifying infertile times to have intercourse is difficult. Another disadvantage of the rhythm method is that it restricts spontaneity in sexual activity.

Mechanical Barriers

Mechanical barrier contraceptives prevent sperm cells from entering the female reproductive tract during sexual intercourse.

The *male condom* consists of a thin latex or natural membrane sheath placed over the erect penis before intercourse to prevent semen from entering the vagina upon ejaculation (fig. 19.15*A*). A *female condom* resembles a small plastic bag. A woman inserts it into her vagina prior to intercourse. The device blocks sperm cells from reaching the cervix.

Some men feel that a condom decreases the sensitivity of the penis during intercourse, and its use may interrupt spontaneity of the sex act. However, condoms are inexpensive and may also protect against sexually transmitted diseases.

Another mechanical barrier is the *diaphragm,* a cup-shaped device with a flexible ring forming the rim. A woman inserts the diaphragm into the vagina so that it covers the cervix, preventing entry of sperm cells into the uterus (fig. 19.15*B*). To be effective, a diaphragm must be fitted for size by a physician, inserted properly, and used with a chemical spermicide applied to the surface adjacent to the cervix and to the rim of the diaphragm. The device must be left in position for several hours following sexual intercourse. A diaphragm can be inserted up to 6 hours prior to sexual contact.

Similar to but smaller than the diaphragm is the *cervical cap,* which adheres to the cervix by suction. A woman inserts it with her fingers before intercourse. For centuries, different societies have used cervical caps made of such varied substances as beeswax, lemon halves, paper, and opium poppy fibers.

Chemical Barriers

Chemical barrier contraceptives include creams, foams, and jellies with spermicidal properties (fig. 19.15*C*).

A

B

C

D

E

Figure 19.15
Devices and substances used for birth control. (*A*) Male condom. (*B*) Diaphragm and spermicide. (*C*) Spermicidal gel. (*D*) Oral contraceptives. (*E*) IUD. (Photographs are not to scale.)

Topic of Interest TREATING BREAST CANCER

One in eight women will develop breast cancer at some point in her life (table 19C). Breast cancer is really several illnesses. As medical research reveals the cellular and molecular characteristics that distinguish subtypes of the disease, treatments old and new are being increasingly tailored to individuals. This "rational" approach may delay progression of the disease and increase the survival rate.

Warning Signs

Changes that could signal breast cancer include a small area of thickened tissue, a dimple, a change in contour, or a nipple that is flattened, points in an unusual direction, or produces a discharge. A woman can note these changes by performing a monthly "breast self-exam," in which she lies flat on her back with one arm raised behind her head and systematically feels all parts of each breast. But sometimes breast cancer gives no warning at all—early signs of fatigue and feeling ill may not occur until the disease has spread beyond the breast.

After finding a lump, the next step is a physical exam, in which a health-care provider palpates the breast and does a mammogram, an X-ray scan that can pinpoint the location and approximate extent of abnormal tissue (fig. 19B). An ultrasound scan can distinguish between a cyst (a fluid-filled sac of glandular tissue) and a tumor (a solid mass). If an area is suspicious, a thin needle is used to take a biopsy (sample) of the tissue, whose cells will be scrutinized for the telltale characteristics of cancer.

Eighty percent of the time, a breast lump is a sign of fibrocystic breast disease, which is benign (noncancer-

TABLE 19C BREAST CANCER RISK

BY AGE	ODDS	BY AGE	ODDS
25	1 in 19,608	60	1 in 24
30	1 in 2,525	65	1 in 17
35	1 in 622	70	1 in 14
40	1 in 217	75	1 in 11
45	1 in 93	80	1 in 10
50	1 in 50	85	1 in 9
55	1 in 33	95 or older	1 in 8

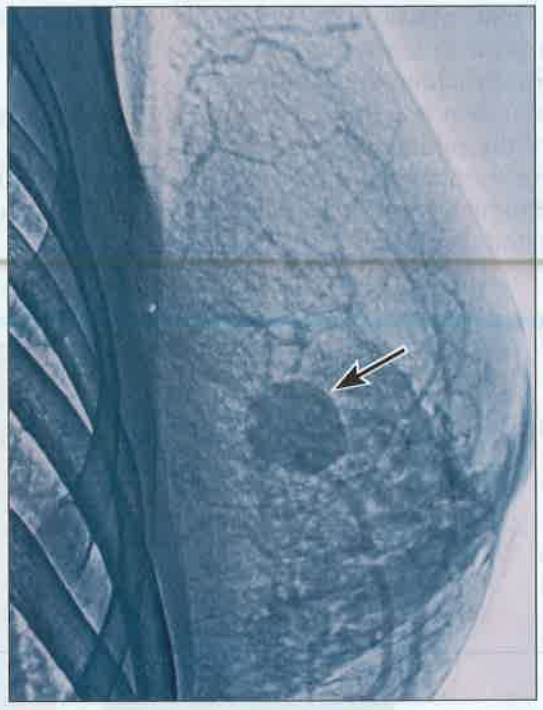


Figure 19B
Mammogram of a breast with a tumor (arrow).

Within the vagina, such chemicals create an unfavorable environment for sperm cells.

Chemical barrier contraceptives are fairly easy to use but have a high failure rate when used alone. They are most effective when used with a condom or diaphragm.

Oral Contraceptives

An *oral contraceptive,* or birth control pill, contains synthetic estrogen-like and progesterone-like chemicals (fig. 19.15*D*). In women, these drugs disrupt the normal pattern of gonadotropin secretion and prevent the LH surge that triggers ovulation. They also interfere with buildup of the uterine lining necessary for implantation.

Oral contraceptives, if used correctly, prevent pregnancy nearly 100% of the time. However, they may cause nausea, retention of body fluids, increased skin pigmentation, and breast tenderness. Also, some women, particularly those over age thirty-five who smoke, may develop intravascular blood clots, liver disorders, or high blood pressure when using certain types of oral contraceptives.

Injectable Contraception

An intramuscular injection of Depo-Provera (medroxyprogesterone acetate) protects against pregnancy for three months by preventing the maturation and release of a secondary oocyte. It also alters the uterine lining,

ous). The lump may be a cyst or a solid, fibrous mass of connective tissue called a fibroadenoma. Treatment for fibrocystic breast disease includes taking vitamin E or synthetic androgens under a doctor's care, lowering caffeine intake, and examining unusual lumps further.

Surgery, Radiation, and Chemotherapies

If biopsied breast cells are cancerous, treatment usually begins with surgery. A lumpectomy removes a small tumor and some surrounding tissue; a simple mastectomy removes a breast; and a modified radical mastectomy removes the breast and surrounding lymph nodes, but preserves the pectoral muscles. Radical mastectomies, which remove the muscles too, are rarely done anymore. In addition, a few lymph nodes are typically examined, which allows a physician to identify the ones that are affected and must be removed.

Most breast cancers are then treated with radiation and combinations of chemotherapeutic drugs, plus newer drugs that are sometimes targeted to certain types of breast cancer. Standard chemotherapies kill all rapidly dividing cells, and those used for breast cancer include fluorouracil, doxorubicin, cyclophosphamide, and methotrexate. A newer chemotherapeutic agent is paclitaxol, which was originally derived from the bark of yew trees.

Drugs called selective estrogen receptor modulators (SERMs) are used for women whose cancer cells have receptors for estrogens. These drugs include tamoxifen, which has been used for more than 20 years, and a newer drug called raloxifene. SERMs block the receptors so that estrogens cannot bind and trigger division of cancer cells. In contrast to standard chemotherapies, which are given for weeks or months, SERMs are taken for many years. Tamoxifen may also be able to prevent cancer in certain women who are at very high risk due to family history.

Another new breast cancer drug, Herceptin, can help women whose cancer cells bear many receptors that bind a particular growth factor. Herceptin is a type of immune system biochemical called a monoclonal antibody. It prevents the growth factor from stimulating cell division.

Prevention Strategies

Many health-care providers advise women to have baseline mammograms by the age of forty and yearly mammograms after that, or beginning at age fifty, depending upon individual medical and family histories. Although a mammogram can detect a tumor up to two years before it can be felt, it can also miss some tumors. Thus, breast self-exam is also important in early detection.

Genetic tests are becoming available that can identify women who have inherited certain variants of genes—such as BRCA1, BRCA2, p53, and her-2/neu—that place them at very high risk for developing breast cancer. Women at high risk can be tested more frequently, and some have even had their breasts removed because they have inherited a gene variant that, in their families, predicts a very high risk of developing breast cancer. In one family, a genetic test told a woman whose two sisters and mother had inherited breast cancer that she had escaped their fate, and she canceled the scheduled surgery. Yet her young cousin, who thought she was free of the gene because it was inherited through her father, found by genetic testing that she would likely develop breast cancer. A subsequent mammogram revealed that the disease had already begun.

Only 5 to 10% of all breast cancers arise from an inherited tendency. Much current research seeks to identify the environmental triggers that cause the majority of cases.

making it less hospitable for a blastocyst. Use of Depo-Provera requires a doctor's care because potential side effects make it risky for women with certain medical conditions.

Contraceptive Implants

A *contraceptive implant* is a set of small progesterone-containing capsules or rods inserted surgically under the skin of a woman's arm or scapular region. The progesterone, which the implant releases slowly, prevents ovulation in much the same way as do oral contraceptives. A contraceptive implant is effective for up to five years, and removal of the implant reverses its contraceptive action.

Intrauterine Devices

An *intrauterine device (IUD)* is a small, solid object that a physician places within the uterine cavity (fig. 19.15*E*). An IUD interferes with implantation of a blastocyst, perhaps by inflaming the uterine tissues.

The uterus may spontaneously expel the IUD, or the IUD may produce abdominal pain or excessive menstrual bleeding. It may also injure the uterus or produce other serious health problems. A physician should regularly check IUD placement.

Surgical Methods

Surgical methods of contraception sterilize the male or female. In the male, a physician performs a *vasectomy,*

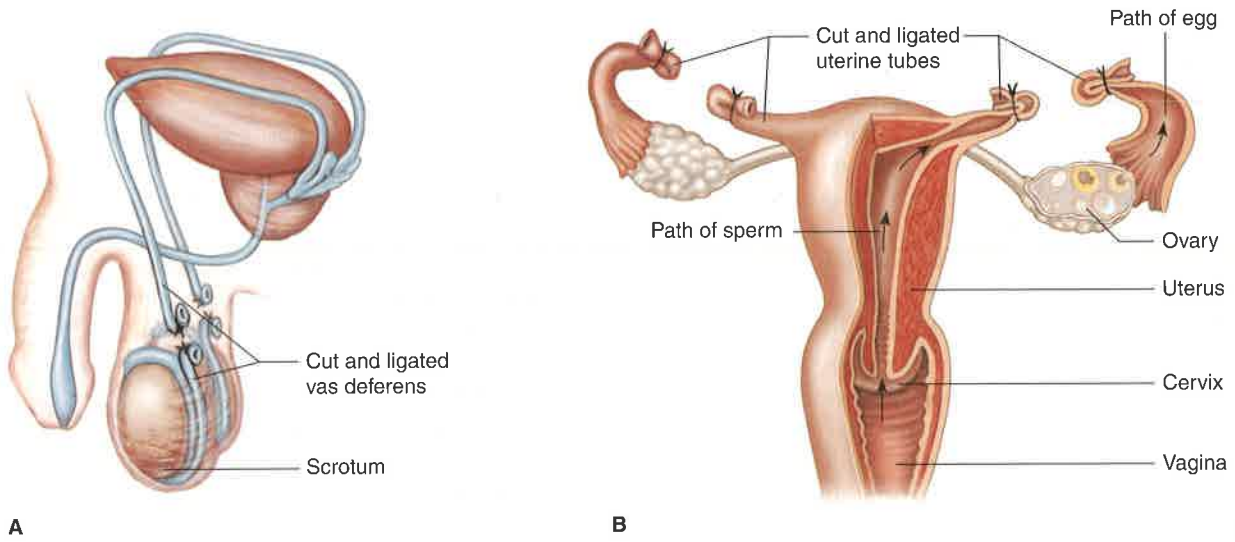


Figure 19.16
Surgical methods of birth control. (*A*) In a vasectomy, each vas deferens is cut and ligated. (*B*) In a tubal ligation, each uterine tube is cut and ligated.

removing a small section of each vas deferens near the epididymis and tying (ligating) the cut ends of the ducts. A vasectomy is a simple operation with few side effects, although it may cause some pain for a week or two.

After a vasectomy, sperm cells cannot leave the epididymis; thus, they are not included in the semen. However, sperm cells may already be present in portions of the ducts distal to the cuts. Consequently, the sperm count may not reach zero for several weeks.

The corresponding procedure in the female is *tubal ligation*. The uterine tubes are cut and ligated so that sperm cells cannot reach an egg cell.

Neither a vasectomy nor a tubal ligation changes hormonal concentrations or sex drives. These procedures, shown in figure 19.16, are the most reliable forms of contraception. Reversing them requires microsurgery.

CHECK YOUR RECALL

1. What factors make the rhythm method less reliable than some other methods of contraception?
2. Describe two methods of contraception that use mechanical barriers.
3. How do oral contraceptives, injectable contraceptives, and contraceptive implants prevent pregnancy?

19.8 Sexually Transmitted Diseases

The twenty recognized **sexually transmitted diseases (STDs)** are often called "silent infections" because the early stages may not produce symptoms, especially in women. Table 19.4 describes the six most prevalent STDs. By the time symptoms appear, it is often too late to prevent complications or spread of the infection to sex-

TABLE 19.4 SOME SEXUALLY TRANSMITTED DISEASES

DISEASE	CAUSE	SYMPTOMS	TREATMENT
Acquired immune deficiency syndrome	Human immunodeficiency virus	Fever, weakness, infections, cancer	Drugs to treat or delay symptoms; no cure
Chlamydia infection	Bacteria of genus *Chlamydia*	Painful urination and intercourse, mucous discharge from penis or vagina	Antibiotics
Genital herpes	Herpes virus 2	Genital sores, fever	Antiviral drug (acyclovir)
Genital warts	Human papilloma virus	Warts on genitals	Chemical or surgical removal
Gonorrhea	*Neisseria gonorrhoeae* bacteria	In women, usually none; in men, painful urination	Antibiotics
Syphilis	*Treponema pallidum* bacteria	Initial chancre sore usually on genitals or mouth; rash 6 months later; several years with no symptoms as infection spreads; finally damage to heart, liver, nerves, brain	Antibiotics

ual partners. Many STDs have similar symptoms, some of which are also seen in diseases or allergies that are not sexually related. A physician should be consulted if one or a combination of the following symptoms appears:

1. Burning sensation during urination.
2. Pain in the lower abdomen.
3. Fever or swollen glands in the neck.
4. Discharge from the vagina or penis.
5. Pain, itching, or inflammation in the genital or anal area.
6. Pain during intercourse.
7. Sores, blisters, bumps, or a rash anywhere on the body, particularly the mouth or genitals.
8. Itchy, runny eyes.

One possible complication of the STDs gonorrhea and chlamydia is **pelvic inflammatory disease,** in which bacteria enter the vagina and spread throughout the reproductive organs. The disease begins with intermittent cramps, followed by sudden fever, chills, weakness, and severe cramps. Hospitalization and intravenous antibiotics can stop the infection. The uterus and uterine tubes are often scarred.

Acquired immune deficiency syndrome (AIDS) is an STD that destroys the immune system. Infections and often cancer, diseases that the immune system usually conquers, overrun the body. The AIDS virus (human immunodeficiency virus, or HIV) passes from one person to another in body fluids such as semen and blood. Unprotected intercourse and using a needle containing contaminated blood are the most frequent routes of transmission in the U.S.

CHECK YOUR RECALL

1. Why are sexually transmitted diseases often called "silent infections"?
2. What are some common symptoms of sexually transmitted diseases?

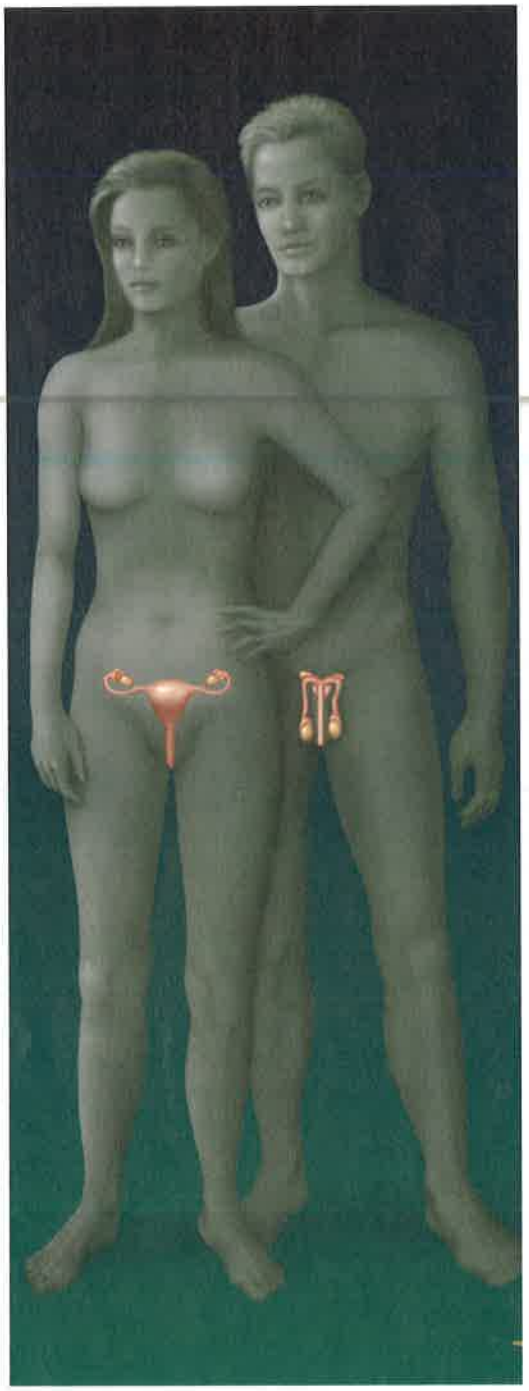
Clinical Terms Related to the Reproductive Systems

amenorrhea (a-men´´o-re´ah) Absence of menstrual flow, usually due to a disturbance in hormonal concentrations.
conization (ko´´nĭ-za´shun) Surgical removal of a cone of tissue from the cervix for examination.
curettage (ku´´rĕ-tahzh´) Surgical procedure in which the cervix is dilated and the endometrium of the uterus is scraped (commonly called D and C, for dilation and curettage).
dysmenorrhea (dis´´men-ŏ-re´ah) Painful menstruation.
endometriosis (en´´do-me´´tre-o´sis) Tissue similar to the inner lining of the uterus occurring within the pelvic cavity.
endometritis (en´´do-mĕ-tri´tis) Inflammation of the uterine lining.
epididymitis (ep´´ĭ-did´´ĭ-mi´tis) Inflammation of the epididymis.
hematometra (hem´´ah-to-me´trah) Accumulation of menstrual blood within the uterine cavity.
hysterectomy (his´´tĕ-rek´to-me) Surgical removal of the uterus.
mastitis (mas´´ti´tis) Inflammation of a mammary gland.
oophorectomy (o´´of-o-rek´to-me) Surgical removal of an ovary.
oophoritis (o´´of-o-ri´tis) Inflammation of an ovary.
orchiectomy (or´´ke-ĕk´to-me) Surgical removal of a testis.
orchitis (or-ki´tis) Inflammation of a testis.
prostatectomy (pros´´tah-tek´to-me) Surgical removal of a portion or all of the prostate gland.
prostatitis (pros´´tah-ti´tis) Inflammation of the prostate gland.
salpingectomy (sal´´pin-jek´to-me) Surgical removal of a uterine tube.
vaginitis (vaj´´ĭ-ni´tis) Inflammation of the vaginal lining.
varicocele (var´ĭ-ko-sēl´´) Distension of the veins within the spermatic cord.

Clinical Connection

Bruce Reimer was born in 1965. At age 8 months, most of his penis was accidentally burned off during a circumcision procedure. Physicians and psychologists advised the parents to "reassign" the child's gender as female. At 22 months of age, corrective surgery created Brenda from Bruce. But Brenda continually fought attempts to raise her as a girl and at age 14, threatened suicide unless allowed to live as a male. He took the name David Reimer, and eventually married, adopted his wife's children, and is now a young grandfather. Apparently, surgery could not silence David's XY chromosome constitution—that of a male. Since then, several studies of infants born with very small penises and reared as girls overwhelmingly confirm Reimer's experience that nature has a greater effect on gender identity than nurture. In the past, physicians based the decision to remove a small or damaged penis and reassign sex as female on a yardstick of sorts. If a newborn's stretched organ exceeded an inch, he was deemed a he. If the protrusion was under 3/8 of an inch, she was deemed a she. Organs that fell in between were shortened into a clitoris during the first week of life, and girlhood officially began. Today, such decisions rest more on an individual's chromosomal sex, and in some cases, surgery is delayed until a person can decide for him- or herself.

Organization



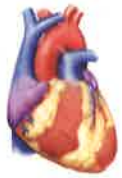
Reproductive Systems

Gamete production, fertilization, fetal development, and childbirth are essential for survival of the species.

Integumentary System

Skin sensory receptors play a role in sexual pleasure.

Cardiovascular System



Blood pressure is necessary for the normal function of erectile tissue in the male and female.

Skeletal System

Bones can be a temporary source of calcium during lactation.

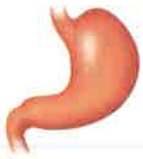
Lymphatic System

Special mechanisms inhibit the female immune system from attacking sperm as foreign invaders.

Muscular System

Skeletal, cardiac, and smooth muscles all play a role in reproductive processes and sexual activity.

Digestive System



Proper nutrition is essential for the formation of normal gametes and for normal fetal development during pregnancy.

Nervous System

The nervous system plays a major role in sexual activity and sexual pleasure.

Respiratory System

During pregnancy, the placenta provides oxygen to the fetus and removes carbon dioxide.

Endocrine System

Hormones control the production of ova in the female and sperm in the male.

Urinary System

Male urinary and reproductive systems share common structures. Kidneys compensate for fluid loss from the reproductive systems. Pregnancy may cause fluid retention.

SUMMARY OUTLINE

19.1 Introduction (p. 498)

Reproductive organs produce sex cells and sex hormones, sustain these cells, or transport them from place to place.

19.2 Organs of the Male Reproductive System (p. 498)

The primary male sex organs are the testes, which produce sperm cells and male sex hormones. Accessory organs include the internal and external reproductive organs.

1. Testes
   a. Structure of the testes
      (1) The testes are composed of lobules separated by connective tissue and filled with seminiferous tubules.
      (2) The epithelium lining the seminiferous tubules produces sperm cells.
      (3) The interstitial cells produce male sex hormones.
   b. Formation of sperm cells
      (1) The epithelium lining the seminiferous tubules includes supporting cells and spermatogenic cells.
         (a) Supporting cells support and nourish spermatogenic cells.
         (b) Spermatogenic cells give rise to sperm cells.
      (2) A sperm cell consists of a head, midpiece, and tail.
   c. Spermatogenesis
      (1) Spermatogonia give rise to sperm cells.
      (2) Meiosis reduces the number of chromosomes in sperm cells by one-half (from 46 to 23).
      (3) Spermatogenesis produces four sperm cells from each primary spermatocyte.
2. Male internal accessory organs
   a. Epididymis
      (1) The epididymis is a tightly coiled tube that leads into the vas deferens.
      (2) It stores and nourishes immature sperm cells and promotes their maturation.
   b. Vas deferens
      (1) The vas deferens is a muscular tube.
      (2) It passes through the inguinal canal, enters the abdominal cavity, courses medially into the pelvic cavity, and ends behind the urinary bladder.
      (3) It fuses with the duct from the seminal vesicle to form the ejaculatory duct.
   c. Seminal vesicle
      (1) The seminal vesicle is a saclike structure attached to the vas deferens.
      (2) It secretes an alkaline fluid that contains nutrients, such as fructose, and prostaglandins.
   d. Prostate gland
      (1) The prostate gland surrounds the urethra just inferior to the urinary bladder.
      (2) It secretes a thin, milky fluid that neutralizes the pH of semen and the acidic secretions of the vagina.
   e. Bulbourethral glands
      (1) The bulbourethral glands are two small structures inferior to the prostate gland.
      (2) They secrete a fluid that lubricates the penis in preparation for sexual intercourse.
   f. Semen
      (1) Semen consists of sperm cells and secretions of the seminal vesicles, prostate gland, and bulbourethral glands.
      (2) This fluid is slightly alkaline and contains nutrients and prostaglandins.
      (3) Sperm cells in semen begin to swim, but these sperm cells are unable to fertilize egg cells until they enter the female reproductive tract.
3. Male external reproductive organs
   a. Scrotum
      The scrotum is a pouch of skin and subcutaneous tissue that encloses the testes for protection and temperature regulation.
   b. Penis
      (1) The penis is specialized to become erect for insertion into the vagina during sexual intercourse.
      (2) Its body is composed of three columns of erectile tissue.
4. Erection, orgasm, and ejaculation
   a. During erection, the vascular spaces within the erectile tissue engorge with blood.
   b. Orgasm is the culmination of sexual stimulation. Emission and ejaculation accompany male orgasm.
   c. Semen moves along the reproductive tract as smooth muscle in the walls of the tubular structures contracts by reflex.

19.3 Hormonal Control of Male Reproductive Functions (p. 505)

1. Hypothalamic and pituitary hormones
   a. The male body remains reproductively immature until the hypothalamus releases gonadotropin-releasing hormone (GnRH), which stimulates the anterior pituitary gland to release gonadotropins.
   b. Follicle-stimulating hormone (FSH) stimulates spermatogenesis.
   c. Luteinizing hormone (LH), known in males as interstitial cell-stimulating hormone (ICSH), stimulates interstitial cells to produce male sex hormones.
2. Male sex hormones
   a. Male sex hormones are called androgens, with testosterone the most important.
   b. Androgen production increases rapidly at puberty.
   c. Actions of testosterone
      (1) Testosterone stimulates development of the male reproductive organs.
      (2) It also develops and maintains male secondary sex characteristics.
   d. Regulation of male sex hormones
      (1) A negative feedback mechanism regulates testosterone concentration.
         (a) A rising testosterone concentration inhibits the hypothalamus and reduces the anterior pituitary's secretion of gonadotropins.
         (b) As testosterone concentration falls, the hypothalamus signals the anterior pituitary to secrete gonadotropins.
      (2) The testosterone concentration remains relatively stable from day to day.

19.4 Organs of the Female Reproductive System (p. 507)

The primary female sex organs are the ovaries, which produce female sex cells and sex hormones. Accessory organs are internal and external.

1. Ovaries
   a. Ovary structure
      (1) Each ovary is subdivided into a medulla and a cortex.
      (2) The medulla is composed of connective tissue, blood vessels, lymphatic vessels, and nerves.
      (3) The cortex contains ovarian follicles and is covered by cuboidal epithelium.
   b. Primordial follicles
      (1) During prenatal development, groups of cells in the ovarian cortex form millions of primordial follicles.

(2) Each primordial follicle contains a primary oocyte and a layer of follicular cells.
(3) The primary oocyte begins meiosis, but the process halts until puberty.
(4) The number of oocytes steadily declines throughout a female's life.

c. Oogenesis
(1) Beginning at puberty, some oocytes are stimulated to continue meiosis.
(2) When a primary oocyte undergoes oogenesis, it gives rise to a secondary oocyte in which the original chromosome number is reduced by one-half (from 46 to 23).
(3) Fertilization of a secondary oocyte produces a zygote.

d. Follicle maturation
(1) At puberty, FSH initiates follicle maturation.
(2) During maturation, the oocyte enlarges, the follicular cells multiply, and a fluid-filled cavity forms.
(3) Usually, only one follicle at a time fully develops.

e. Ovulation
(1) Ovulation is the release of an oocyte from an ovary.
(2) A rupturing follicle releases the oocyte.
(3) After ovulation, the oocyte is drawn into the opening of the uterine tube.

2. Female internal accessory organs
a. Uterine tubes
(1) The end of each uterine tube expands, and its margin bears irregular extensions.
(2) Ciliated cells that line the tube and peristaltic contractions in the wall of the tube help transport the oocyte down the uterine tube. Fertilization may occur.

b. Uterus
(1) The uterus receives the embryo and sustains it during development.
(2) The uterine wall includes the endometrium, myometrium, and perimetrium.

c. Vagina
(1) The vagina receives the erect penis, conveys uterine secretions to the outside, and provides an open channel for the fetus during birth.
(2) Its wall consists of mucosal, muscular, and fibrous layers.

3. Female external reproductive organs
a. Labia majora
(1) The labia majora are rounded folds of adipose tissue and skin.
(2) The upper ends form a rounded elevation over the symphysis pubis.

b. Labia minora
(1) The labia minora are flattened, longitudinal folds between the labia majora.
(2) They are well supplied with blood vessels.

c. Clitoris
(1) The clitoris is a small projection at the anterior end of the vulva. It corresponds to the male penis.
(2) It is composed of two columns of erectile tissue.

d. Vestibule
(1) The vestibule is the space between the labia minora.
(2) The vestibular glands secrete mucus into the vestibule during sexual stimulation.

4. Erection, lubrication, and orgasm
a. During periods of sexual stimulation, the erectile tissues of the clitoris and vestibular bulbs engorge with blood and swell.
b. The vestibular glands secrete mucus into the vestibule and vagina.
c. During orgasm, the muscles of the perineum, uterine wall, and uterine tubes contract rhythmically.

19.5 Hormonal Control of Female Reproductive Functions (p. 513)

The hypothalamus, anterior pituitary gland, and ovaries secrete hormones that control sex cell maturation and the development and maintenance of female secondary sex characteristics.

1. Female sex hormones
a. A female body remains reproductively immature until about ten years of age, when gonadotropin secretion increases.
b. The most important female sex hormones are estrogens and progesterone.
(1) Estrogens develop and maintain most female secondary sex characteristics.
(2) Progesterone changes the uterus.

2. Female reproductive cycle
a. FSH initiates a menstrual cycle by stimulating follicle maturation.
b. Maturing follicular cells secrete estrogens, which maintain the secondary sex traits and thicken the uterine lining.
c. Secretion of a relatively large amount of LH by the anterior pituitary triggers ovulation.
d. Following ovulation, follicular cells give rise to the corpus luteum.
(1) The corpus luteum secretes progesterone, which causes the uterine lining to become more vascular and glandular.
(2) If an oocyte is not fertilized, the corpus luteum begins to degenerate.
(3) As concentrations of estrogens and progesterone decline, the uterine lining disintegrates, causing menstrual flow.
e. During this cycle, estrogens and progesterone inhibit the release of LH and FSH. As concentrations of estrogens and progesterone decline, the anterior pituitary secretes FSH and LH again, stimulating a new menstrual cycle.

3. Menopause
a. Menopause is termination of the menstrual cycle due to aging of the ovaries.
b. Reduced concentrations of estrogens and lack of progesterone may cause regressive changes in female secondary sex characteristics.

19.6 Mammary Glands (p. 515)

1. The mammary glands are in the subcutaneous tissue of the anterior thorax.
2. They are composed of lobes that contain glands and a duct.
3. Dense connective and adipose tissues separate the lobes.
4. Ovarian hormones stimulate female breast development.
a. Alveolar glands and ducts enlarge.
b. Fat is deposited around and within the breasts.

19.7 Birth Control (p. 516)

Birth control is voluntary regulation of how many children are produced and when they are conceived. It usually involves some method of contraception.

1. Coitus interruptus is withdrawal of the penis from the vagina before ejaculation.
2. Rhythm method is abstinence from sexual intercourse for several days before and after ovulation.
3. Mechanical barriers
a. Males and females can use condoms.
b. Females can also use diaphragms and cervical caps.