

The Reproductive System

FUNCTION PREVIEW

- The reproductive system ensures continuation of the species by producing offspring.

- ✓ Discuss the common purpose of the reproductive system organs.

Most organ systems of the body function almost continuously to maintain the well-being of the individual. The reproductive system, however, appears to “slumber” until puberty. The **gonads** (go’ nadz; “seeds”), or **primary sex organs**, are the *testes* in men and the *ovaries* in women. The gonads produce sex cells, or **gametes** (gam’ èts; “spouses”), and secrete sex hormones. The remaining reproductive system structures are **accessory reproductive organs**. Although male and female **reproductive systems** are quite different, their joint purpose is to produce offspring.

The reproductive role of the man is to manufacture male gametes called **sperm** and deliver them to the woman’s reproductive tract. The woman, in turn, produces female gametes, called **ova** (sin-

gular *ovum*), or *eggs*. If the time is suitable, a sperm and egg fuse to produce a fertilized egg, which is the first cell of a new individual. Once fertilization has occurred, the female uterus provides a protective environment in which the *embryo*, later called the *fetus*, develops until birth.

The sex hormones play vital roles both in the development and function of the reproductive organs and in sexual behavior and drives. These gonadal hormones also influence the growth and development of many other organs and tissues of the body.

Anatomy of the Male Reproductive System

- ✓ When provided with a model or diagram, identify the organs of the male reproductive system, and discuss the general function of each.

- ✓ Name the endocrine and exocrine products of the testes.
- ✓ Discuss the composition of semen, and name the glands that produce it.
- ✓ Trace the pathway followed by a sperm from the testis to the body exterior.
- ✓ Define *erection*, *ejaculation*, and *circumcision*.

As already noted, the primary reproductive organs of the male are the **testes** (tes' tēz), or *male gonads*, which have both an exocrine (sperm-producing) function and an endocrine (testosterone-producing) function. The accessory reproductive structures are ducts or glands that aid in the delivery of sperm to the body exterior or to the female reproductive tract.

Testes

Each plum-sized testis is approximately 4 cm (1½ inches) long and 2.5 cm (1 inch) wide. A fibrous connective tissue capsule, the *tunica albuginea* (tu' nī-kah al' bu-jin' e-ah; “white coat”) surrounds each testis. Extensions of this capsule (*septa*) plunge into the testis and divide it into a large number of wedge-shaped *lobules*. Each lobule contains one to four tightly coiled **seminiferous tubules**, the actual “sperm-forming factories” (Figure 16.1). Seminiferous tubules of each lobe empty sperm into another set of tubules, the *rete* (re'te) *testis*, located at one side of the testis. Sperm travel through the rete testis to enter the first part of the duct system, the *epididymis* (ep' ī-did' ī-mis), which hugs the external surface of the testis.

Lying in the soft connective tissue surrounding the seminiferous tubules are the *interstitial* (in' ter-stish' al) *cells*, functionally distinct cells that produce androgens—the most important of which is *testosterone*. Thus, the sperm-producing and hormone-producing functions of the testes are carried out by completely different cell populations.

Duct System

The accessory organs forming the male duct system, which transports sperm from the body, are the *epididymis*, *ductus deferens*, and *urethra* (Figure 16.2).

Epididymis

The cup-shaped **epididymis** is a highly coiled tube about 6 m (20 feet) long that caps the superior part

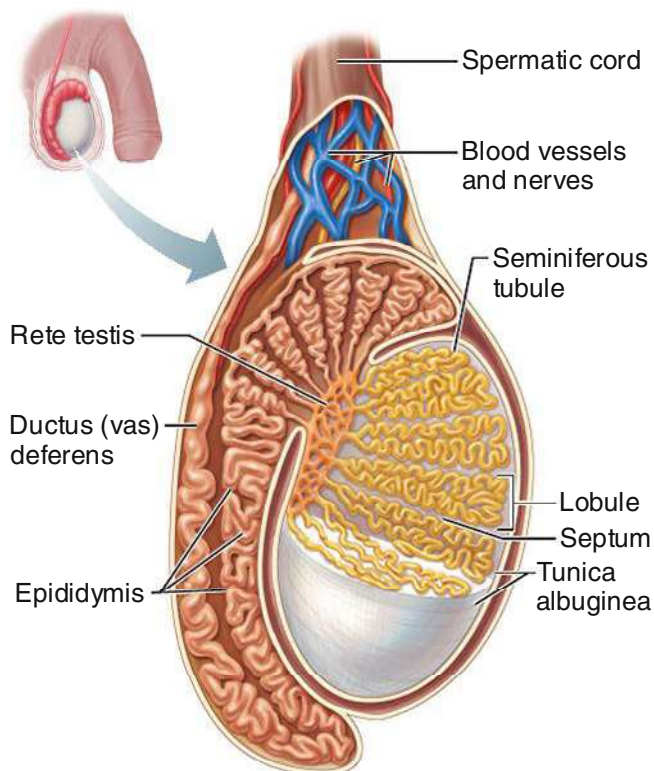


Figure 16.1 Sagittal section of the testis and associated epididymis.

of the testis and then runs down its posterolateral side (see Figure 16.1). The epididymis is the first part of the male duct system and provides a temporary storage site for the immature sperm that enter it from the testis. While the sperm make their way along the tortuous course of the epididymis (a trip that takes about 20 days), they mature, gaining the ability to swim. When a man is sexually stimulated and ejaculates, the walls of the epididymis contract to expel the sperm into the next part of the duct system, the ductus deferens.

Ductus Deferens

The **ductus deferens** (duk' tus def'er-enz; “carrying away”), or **vas deferens**, runs upward from the epididymis through the inguinal canal into the pelvic cavity and arches over the superior aspect of the urinary bladder. This tube is enclosed, along with blood vessels and nerves, in a connective tissue sheath called the **spermatic cord** (see Figure 16.1), which travels upward through the inguinal canal. The ductus deferens then loops medially over the ureter and descends along the posterior bladder wall. The end of the ductus deferens

Q: Looking at this diagram, it is easy to see how hypertrophy of the prostate gland might lead to urinary system problems. How so?

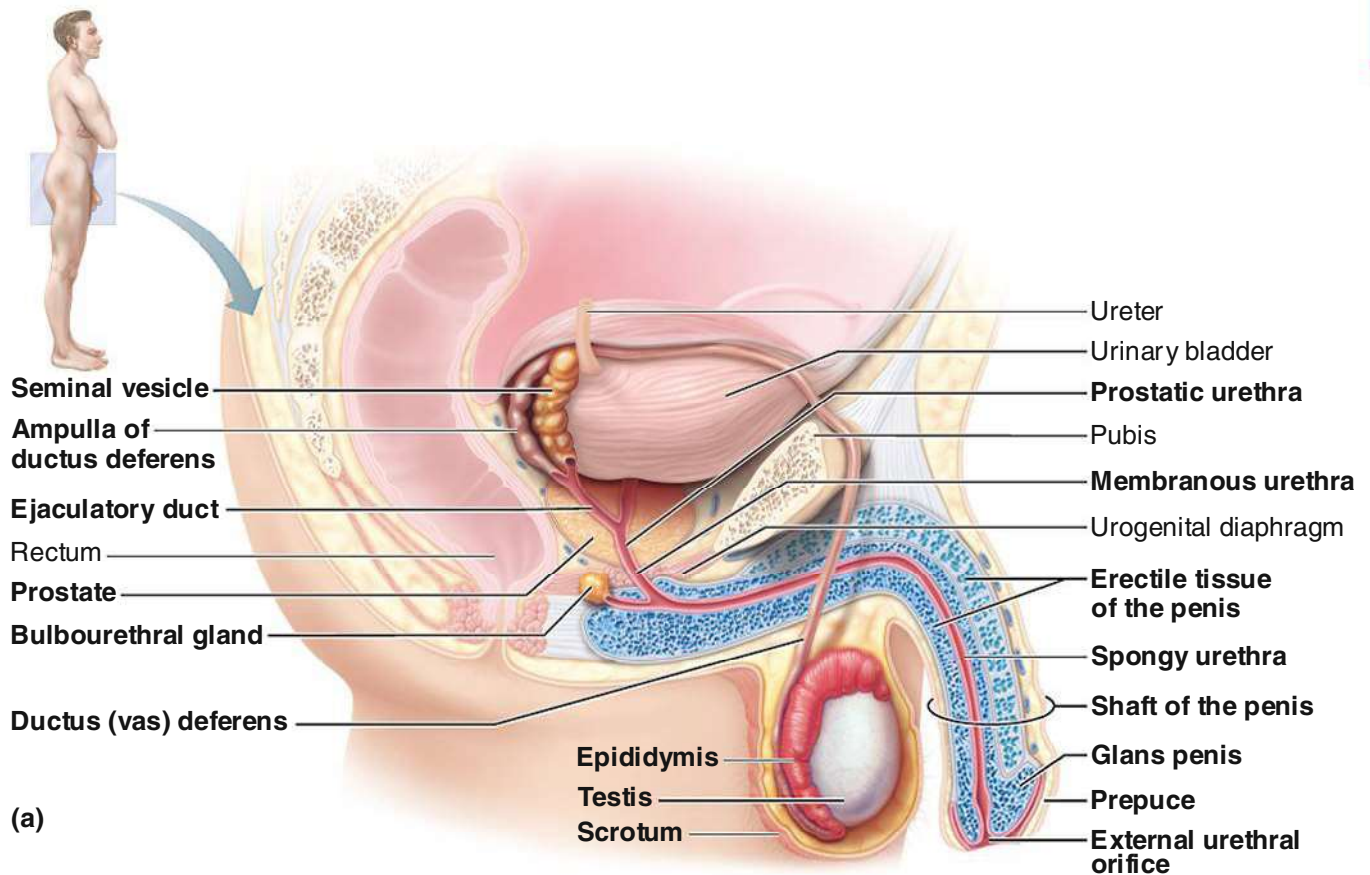


Figure 16.2 Male reproductive organs. (a) Sagittal view.

expands as the **ampulla** and then empties into the **ejaculatory** (e-jak' u-lah-to"re) **duct**, which passes through the prostate gland to merge with the urethra. The main function of the ductus deferens is to propel live sperm from their storage sites, the epididymis and distal part of the ductus deferens, into the urethra. At the moment of **ejaculation** (e-jac = to shoot forth), the thick layers of smooth muscle in its walls create peristaltic waves that rapidly squeeze the sperm forward.

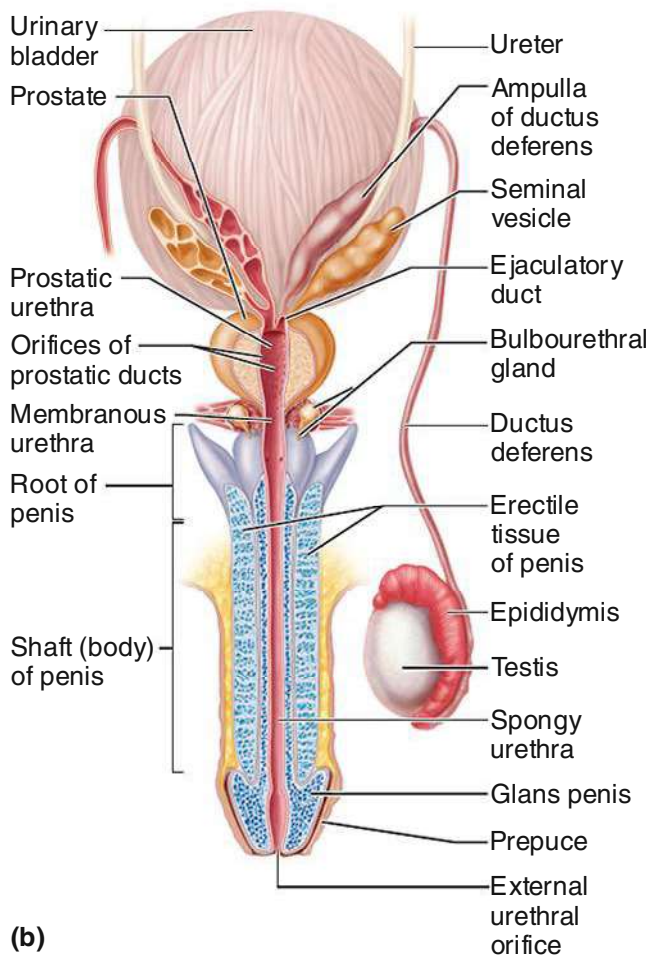
As Figure 16.2 illustrates, part of the ductus deferens lies in the scrotum, a skin sac that hangs outside the body cavity and holds the testes. Some men voluntarily opt to take full responsibility for birth control by having a *vasectomy* (vah-sek' to-me; "cutting the vas"). In this relatively minor oper-

ation, the surgeon makes a small incision into the scrotum and then cuts through and ligates (ties off) the ductus deferens. Sperm are still produced, but they can no longer reach the body exterior, and eventually they deteriorate and are phagocytized. A man is sterile after this procedure, but because testosterone is still produced, he retains his sex drive and secondary sex characteristics.

Urethra

The **urethra**, which extends from the base of the urinary bladder to the tip of the penis, is the terminal part of the male duct system. It has three named regions: (1) the **prostatic urethra**, surrounded by the prostate gland; (2) the **membranous urethra**, spanning the distance from the prostatic urethra to

A: Because the prostate gland encircles the superior part of the urethra, prostate hypertrophy would constrict the urethra in that region, impairing urination.



(b)

Figure 16.2 (continued) Male reproductive organs. (b) Frontal view; posterior aspect of penis.

the penis; and (3) the **spongy (penile) urethra**, running within the length of the penis and opening to the body exterior via the *external urethral orifice*. As mentioned in Chapter 15, the male urethra carries both urine and sperm to the body exterior; thus, it serves two masters, the urinary and reproductive systems. However, urine and sperm never pass at the same time. When ejaculation occurs and sperm enter the prostatic urethra from the ejaculatory ducts, the bladder sphincter (internal urethral sphincter) constricts. This event not only prevents the passage of urine into the urethra but also prevents sperm from entering the urinary bladder.

DID YOU GET IT ?

1. What are the two major functions of the testes?
2. What is the role of the seminiferous tubules?

3. Name the organs of the male duct system, in order, from the scrotum to the body exterior.

For answers, see Appendix D.

Accessory Glands and Semen

The accessory glands include the paired *seminal vesicles*, the single *prostate*, and the *bulbourethral (bul-bo-u-re'thral) glands* (see Figure 16.2). These glands produce the bulk of *semen* (se'men), the sperm-containing fluid that is propelled out of the male's reproductive tract during ejaculation.

Seminal Vesicles

The **seminal** (sem'ī-nul) **vesicles**, located at the base of the bladder, produce about 60 percent of *seminal fluid*, the fluid volume of semen. Their thick, yellowish secretion is rich in sugar (fructose), vitamin C, prostaglandins, and other substances, which nourish and activate the sperm passing through the tract. The duct of each seminal vesicle joins that of the ductus deferens on the same side to form the *ejaculatory duct* (see Figure 16.2). Thus, sperm and seminal fluid enter the urethra together during ejaculation.

Prostate

The **prostate** is a single doughnut-shaped gland about the size of a peach pit (see Figure 16.2). It encircles the upper (prostatic) part of the urethra just below the urinary bladder. Prostate gland secretion is a milky fluid that plays a role in activating sperm. During ejaculation, the fluid enters the urethra through several small ducts. Because the prostate is located immediately anterior to the rectum, its size and texture can be palpated (felt) by digital (finger) examination through the anterior rectal wall.



HOMEOSTATIC IMBALANCE

The prostate has a reputation as a health destroyer. **Hypertrophy** of the gland, an increase in its size independent of the body's growth, affects nearly every older man, and strangles the urethra. This troublesome condition makes urination difficult and enhances the risk of bladder infections (**cystitis**) and kidney damage. Traditional treatment has been surgery, but some newer options are becoming more popular. These include the following:

- Using drugs (finasteride) or microwaves to shrink the prostate

- Inserting a small inflatable balloon to compress the prostate tissue away from the prostatic urethra
- Inserting a tiny needle that emits bursts of radiofrequency radiation, which incinerate excess prostate tissue

Prostatitis, inflammation of the prostate, is the single most common reason for a man to consult a urologist, and **prostatic cancer** is the third most prevalent cancer in men. As a rule, prostatic cancer is a slow-growing, hidden condition, but it can also be a swift and deadly killer. ▶

Bulbourethral Glands

The **bulbourethral glands** are tiny, pea-sized glands inferior to the prostate gland. They produce a thick, clear mucus that drains into the penile urethra. This secretion is the first to pass down the urethra when a man becomes sexually excited. It cleanses the urethra of traces of acidic urine prior to ejaculation, and it serves as a lubricant during sexual intercourse.

Semen

Semen is a milky white, somewhat sticky mixture of sperm and accessory gland secretions. The liquid portion acts as a transport medium for nutrients and chemicals that protect the sperm and aid their movement. Mature sperm cells are streamlined cellular “missiles” containing little cytoplasm or stored nutrients. The fructose in the seminal vesicle secretion provides essentially all of their energy fuel. The relative alkalinity of semen as a whole (pH 7.2–7.6) helps neutralize the acidic environment (pH 3.5–4) of the female’s vagina, protecting the delicate sperm. Sperm are very sluggish under acidic conditions (below pH 6). Semen also contains antibiotic chemicals that destroy certain bacteria, the hormone relaxin, certain enzymes that enhance sperm motility, and substances that inhibit an immune response in the female reproductive tract.

Semen also dilutes sperm; without such dilution, sperm motility is severely impaired. The amount of semen propelled out of the male duct system during ejaculation is relatively small, only 2 to 5 ml (about a teaspoonful), but there are between 50 and 150 million sperm in each milliliter.



HOMEOSTATIC IMBALANCE

Male infertility may be caused by obstructions of the duct system, hormonal imbalances, environmental estrogens, pesticides, excessive alcohol, and many other factors. One of the first series of tests done when a couple has been unable to conceive is *semen analysis*. Factors analyzed include sperm count, motility and morphology (shape and maturity), and semen volume, pH, and fructose content. A sperm count lower than 20 million per milliliter makes impregnation improbable. ▶

External Genitalia

The male **external genitalia** (jen"i-tal'e-ah) include the *scrotum* and the *penis* (see Figure 16.2). The **scrotum** (skro'tum; “pouch”) is a divided sac of skin with sparse hairs that hangs outside the abdominal cavity, between the legs and at the root of the penis. Under normal conditions, the scrotum hangs loosely from its attachments, providing the testes with a temperature that is below body temperature. This is a rather exposed location for a man’s testes, which contain his entire genetic heritage, but apparently viable sperm cannot be produced at normal body temperature. The scrotum, which provides a temperature about 3°C (5.4°F) lower, is necessary for the production of healthy sperm. When the external temperature is very cold, the scrotum becomes heavily wrinkled as it pulls the testes closer to the warmth of the body wall. Thus, changes in scrotal surface area can maintain a temperature that favors viable sperm production.

The **penis** (pe'nis; “tail”) is designed to deliver sperm into the female reproductive tract. The skin-covered penis consists of a **shaft**, which ends in an enlarged tip, the **glans penis**. The skin covering the penis is loose, and it folds downward to form a cuff of skin, the **prepuce** (pre'pus), or **foreskin**, around the proximal end of the glans. Frequently, the foreskin is surgically removed shortly after birth, by a procedure called **circumcision**.

Internally, the spongy urethra (see Figure 16.2) is surrounded by three elongated areas of **erectile tissue**, a spongy tissue that fills with blood during sexual excitement. This causes the penis to enlarge and become rigid. This event, called **erection**, helps the penis serve as a penetrating organ to deliver the semen into the female’s reproductive tract.

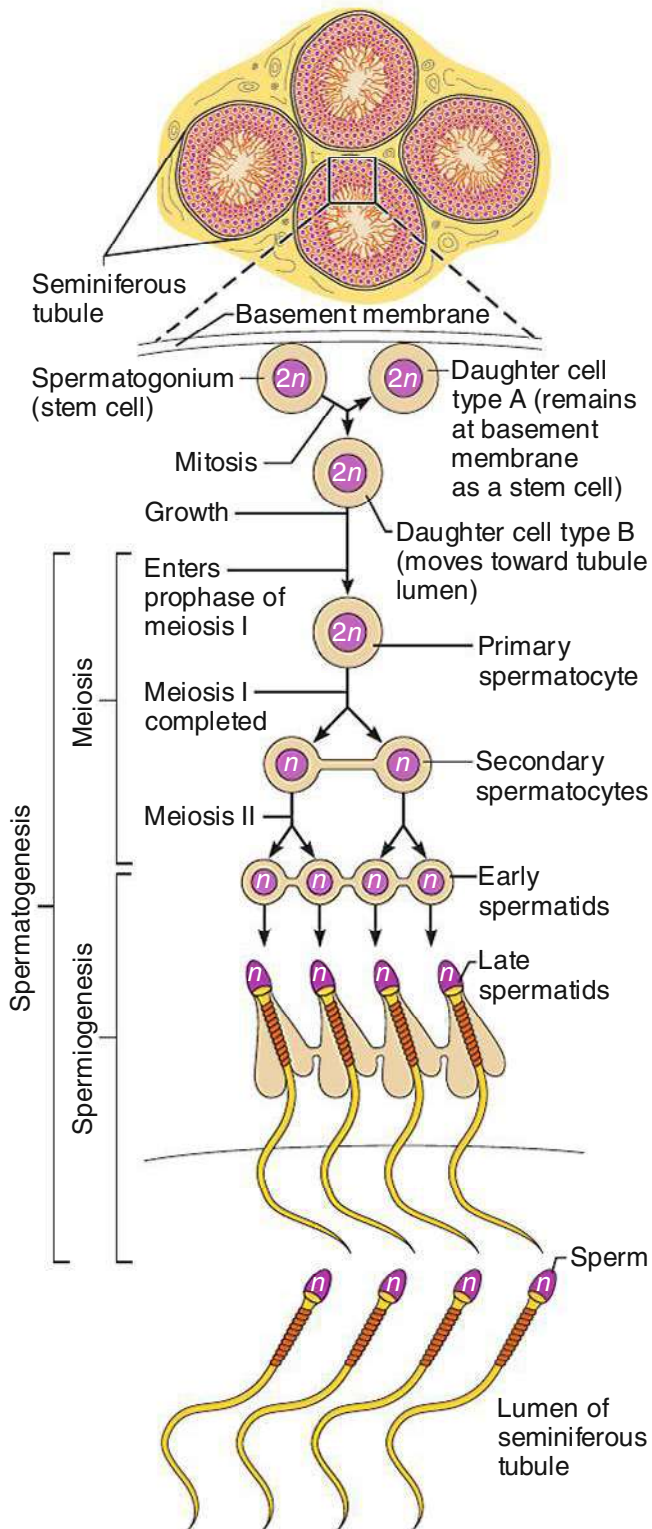


Figure 16.3 Spermatogenesis. Flowchart showing the relative position of the spermatogenic cells in the wall of the seminiferous tubule. Although the stem cells and the primary spermatocytes have the same number of chromosomes (46, designated as $2n$) as other body cells, the products of meiosis (spermatids and sperm) have only half as many (23, designated as n).

DID YOU GET IT ?

4. What is the function of the erectile tissue of the penis?
5. What is an important function of each of the two components of semen—sperm and seminal fluid?
6. Adolph, a 68-year-old gentleman, has trouble urinating and is given a rectal exam. What is his most probable condition, and what is the purpose of the rectal exam?

For answers, see Appendix D.

Male Reproductive Functions

- ✓ Define *spermatogenesis* and *meiosis*.
- ✓ Describe the structure of a sperm, and relate its structure to its function.
- ✓ Describe the effect of FSH and LH on testis functioning.

The chief role of the male in the reproductive process is to produce sperm and the hormone testosterone. These processes are described next.

Spermatogenesis

Sperm production, or **spermatogenesis** (sper"mah-to-jen'ě-sis), begins during puberty and continues throughout life. Every day a man makes millions of sperm. Only one sperm fertilizes an egg, so it seems that nature has made sure that the human species will not be endangered for lack of sperm.

Sperm are formed in the seminiferous tubules of the testis, as noted earlier. As shown in **Figure 16.3**, the process is begun by primitive stem cells called **spermatogonia** (sper"mah-to-go'ne-ah), found in the outer edge, or periphery, of each tubule. Spermatogonia go through rapid mitotic divisions to build up the stem cell line. From birth until puberty, all such divisions simply produce more stem cells. During puberty, however, *follicle-stimulating hormone (FSH)* is secreted in increasing amounts by the anterior pituitary gland, and, from this time on, each division of a spermatogonium produces one stem cell, called a *type A daughter cell*, and another cell, called a *type B daughter cell*. The type A cell remains at the tubule periphery to maintain the stem cell population. The type B cell gets pushed toward the tubule lumen, where it becomes a **primary spermatocyte**, destined to undergo *meiosis* (mi-o' sis) and form four sperm.

Meiosis is a special type of nuclear division that occurs for the most part only in the gonads (testes and ovaries). It differs from *mitosis* (described in Chapter 3) in two major ways. Meiosis consists of two successive divisions of the nucleus (called meiosis I and II), instead of only one division. It results in four (instead of two) daughter cells, or more precisely, four *gametes*.

In spermatogenesis, the gametes are called **spermatids** (sper'mah-tidz). Spermatids have only half as much genetic material as other body cells. In humans, this is 23 chromosomes (or the so-called n number of chromosomes) rather than the usual 46 ($2n$). Then, when the sperm and the egg (which also has 23 chromosomes) unite, forming the fertilized egg, or *zygote*, the normal $2n$ number of 46 chromosomes is reestablished and is maintained in subsequent body cells by the process of mitosis (**Figure 16.4**).

As meiosis occurs, the dividing cells (primary and then secondary spermatocytes) are pushed toward the lumen of the tubule. Thus, we can follow the progress of meiosis from the tubule periphery to the lumen. The spermatids, produced by meiosis, are *not* functional sperm. They are nonmotile and have too much excess baggage to function well in reproduction. They must undergo further changes, in which their excess cytoplasm is stripped away and a tail is formed (see Figure 16.3). In this last stage of sperm development, called **spermiogenesis** (sper'me-o-gen'ē-sis), all the excess cytoplasm is sloughed off, and what remains is compacted into the three regions of the mature sperm—the *head*, *midpiece*, and *tail* (**Figure 16.5**). The mature sperm is a greatly streamlined cell equipped with a high rate of metabolism and a means of propelling itself, enabling it to move long distances in a short time to get to the egg. It is a prime example of the fit between form and function.

Sperm “pack” light. The sperm *head* contains compacted DNA, the genetic material. Essentially, it *is* the nucleus of the spermatid. Anterior to the nucleus is the helmetlike **acrosome** (ak'ro-sōm), which is produced by the Golgi apparatus and is similar to a large lysosome. When a sperm comes into close contact with an egg (or more precisely, an *oocyte*), the acrosomal membrane breaks down and releases

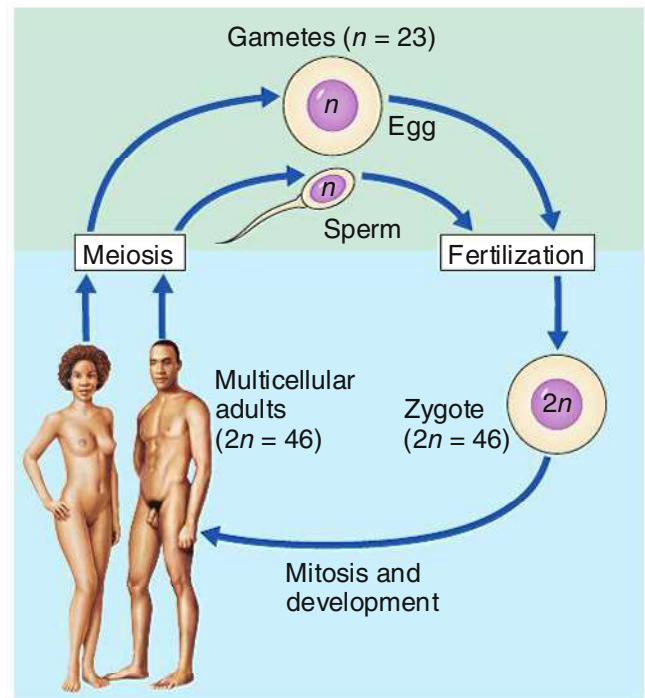


Figure 16.4 The human life cycle.

enzymes that help the sperm penetrate through the capsule of follicle cells that surround the egg. *Filaments*, which form the long tail, arise from centrioles in the midpiece. *Mitochondria* wrapped tightly around these filaments provide the ATP needed for the whiplike movements of the tail that propel the sperm along its way in the female reproductive tract.

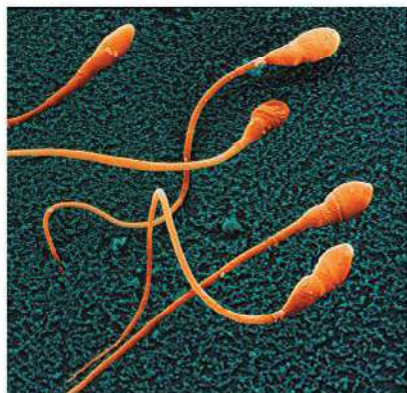
The entire process from the formation of a primary spermatocyte to release of immature sperm in the tubule lumen takes 64 to 72 days. But sperm in the lumen are still unable to “swim” and are incapable of fertilizing an egg. They are moved by peristalsis through the tubules of the testes into the epididymis. There they undergo further maturation, which results in increased motility and fertilizing power.



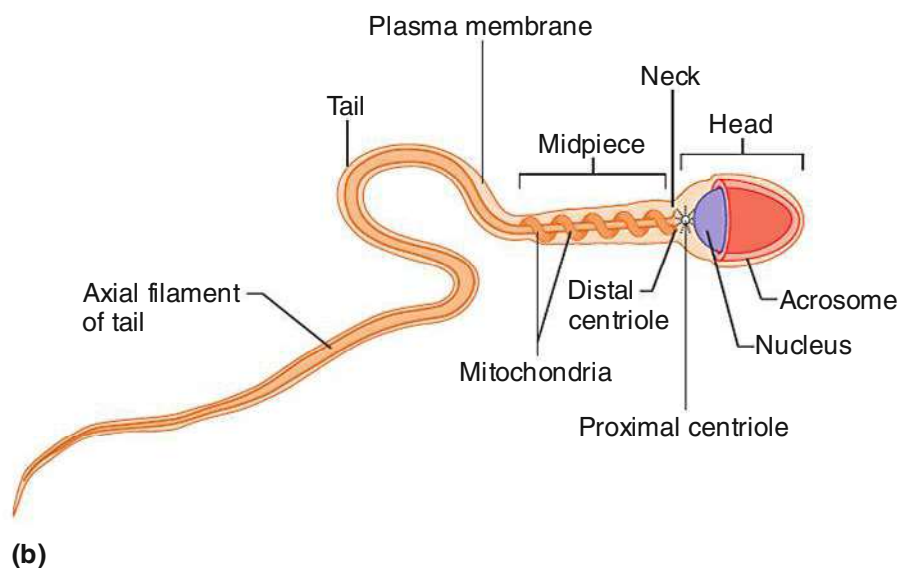
HOMEOSTATIC IMBALANCE

Environmental threats can alter the normal process of sperm formation. For example, some common antibiotics, such as penicillin and tetracycline, may suppress sperm formation. Radiation, lead, certain pesticides, marijuana, tobacco, and excessive alcohol can cause production of abnormal sperm (two-headed, multiple-tailed, and so on). ▀

Q: What is the importance of the mitochondria in the sperm midpiece?



(a)



(b)

Figure 16.5 Structure of sperm. (a) Scanning electron micrograph of mature sperm (1125 \times). (b) Diagrammatic view of a sperm.

Testosterone Production

As noted earlier, the interstitial cells produce **testosterone** (tes-tos'tē-rōn), the most important hormonal product of the testes. During puberty, as the seminiferous tubules are being prodded by FSH to produce sperm, the interstitial cells are being activated by **luteinizing hormone (LH)**, which is also released by the anterior pituitary gland (**Figure 16.6**). From this time on, testosterone is produced continuously (more or less) for the rest of a man's life. The rising blood level of testosterone in the young man stimulates the adolescent growth spurt, prompts his reproductive organs to develop to their adult size, underlies the sex drive, and causes the secondary male sex characteristics to appear. **Secondary sex characteristics** are features induced in *nonreproductive organs* by sex hormones. Male secondary sex characteristics include the following:

- Deepening of the voice as the larynx enlarges
- Increased hair growth all over the body, and particularly in the axillary and pubic regions and on the face (the beard and mustache)
- Enlargement of skeletal muscles to produce the heavier muscle mass typical of the male physique
- Increased heaviness of the skeleton due to bone growth and increase in density

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



HOMEOSTATIC IMBALANCE

If testosterone is not produced, the secondary sex characteristics never appear in the young man, and his other reproductive organs remain childlike. This is **sexual infantilism**. Castration of the adult male (or the inability of

A: They provide the energy to the tail to make the sperm motile.

Q: What is the effect of negative feedback of testosterone on anterior pituitary and hypothalamic cells?

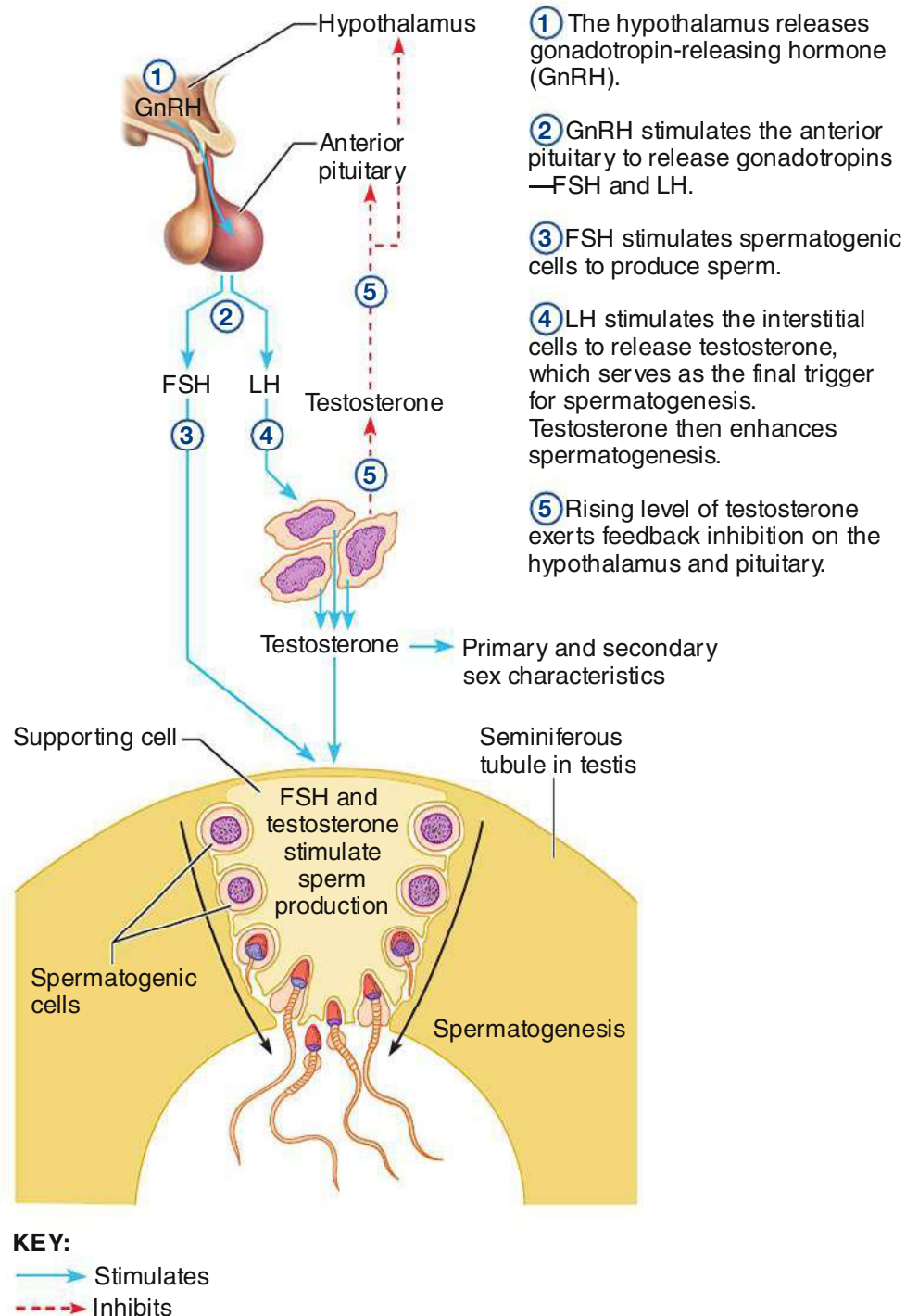


Figure 16.6 Hormonal control of the testis.

A: It "turns off" the hypothalamic releasing factor that prompts FSH and LH secretion; hence, FSH and LH secretion also fall.

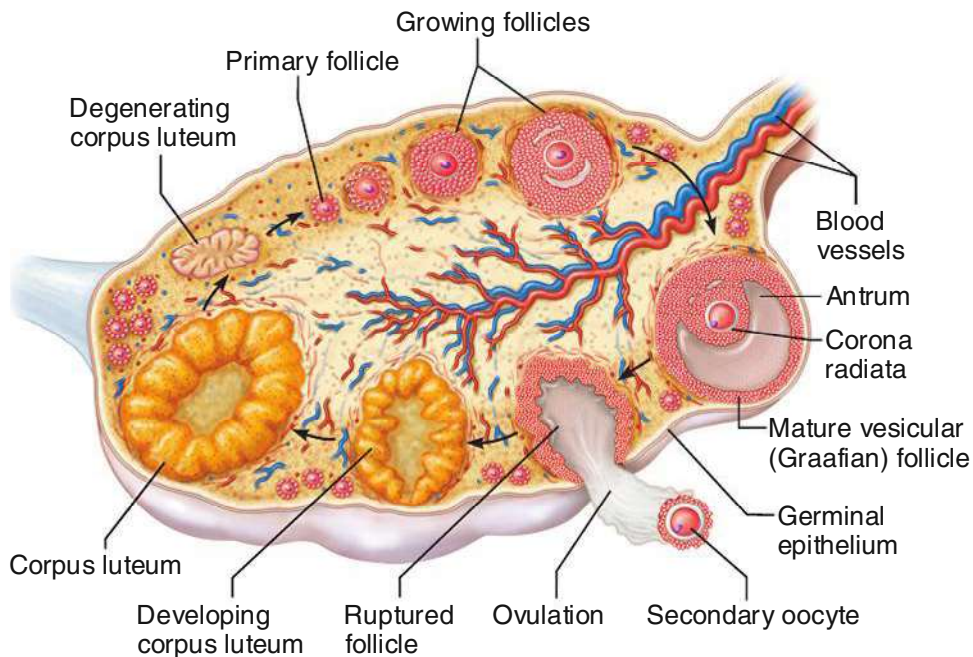


Figure 16.7 Sagittal view of a human ovary showing the developmental stages of an ovarian follicle.

his interstitial cells to produce testosterone) results in a decrease in the size and function of his reproductive organs, as well as a decrease in his sex drive. **Sterility** also occurs because testosterone is necessary for the final stages of sperm production. ▶

DID YOU GET IT ?

7. Which pituitary hormone stimulates spermatogenesis?
8. How does the final product of meiosis differ from the final product of mitosis?
9. How are nonmotile spermatids converted to functional sperm?
10. Which pituitary hormone prompts testosterone production?

For answers, see Appendix D.

Anatomy of the Female Reproductive System

- ✓ When provided with an appropriate model or diagram, identify the organs of the female reproductive system, and discuss the general function of each.
- ✓ Describe the functions of the vesicular follicle and corpus luteum of the ovary.

- ✓ Define *endometrium*, *myometrium*, and *ovulation*.
- ✓ Indicate the location of the following regions of the female uterus: *cervix*, *fundus*, *body*.

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

Ovaries

The paired *ovaries* (o' vah-rēz) are pretty much the shape of almonds but are nearly twice as large. An internal view of an ovary reveals many tiny saclike structures called **ovarian follicles** (Figure 16.7). Each follicle consists of an immature egg, called an **oocyte** (o'o-sīt; oo = egg), surrounded by one or more layers of very different cells called